Dell Asset Recovery Services

Life Cycle Assessment

On behalf of Dell Technologies

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On behalf of Sphera Solutions, Inc. and its subsidiaries

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List of Acronyms

ADP	Abiotic Depletion Potential
AP	Acidification Potential
ARS	Asset Recovery Service
CML	Centre of Environmental Science at Leiden
EF	Environmental Footprint
ELCD	European Life Cycle Database
EoL	End-of-Life
EP	Eutrophication Potential
EDPs	Electronics Disposition Partners
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
ILCD	International Cycle Data System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCA FE	Life Cycle Assessment for Experts
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MLC	Managed LCA Content
NMVOC	Non-Methane Volatile Organic Compound
ODP	Ozone Depletion Potential
PCBA	Printed Circuit Board Assembly
POCP	Photochemical Ozone Creation Potential
SFP	Smog Formation Potential
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
VOC	Volatile Organic Compound

Glossary

Life Cycle

A view of a product system as "consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal" (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

"Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle" (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

"Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 14040:2006, section 3.4)

Life Cycle Interpretation

"Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations" (ISO 14040:2006, section 3.5)

Functional Unit

"Quantified performance of a product system for use as a reference unit" (ISO 14040:2006, section 3.20)

Allocation

"Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006, section 3.17)

Closed-loop and Open-loop Allocation of Recycled Material

"An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties."

"A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials."

(ISO 14044:2006, section 4.3.4.3.3)

Foreground System

"Those processes of the system that are specific to it … and/or directly affected by decisions analyzed in the study." (JRC 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background System

"Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good…." (JRC 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Critical Review

"Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment" (ISO 14044:2006, section 3.45).

Data Sanitization

The certified data cleansing process which consists of a functional and properly seated hard drive within an asset aligning to National Institute of Standards and Technology (NIST) requirements pursuant to the Return Stream Data Security Policy (Dell Inc. 2019).

Executive Summary

Introduction

Dell's Asset Recovery Services (ARS) helps enterprise users securely and responsibly retire IT equipment no longer in use. ARS aims to optimize recovery, reuse, and recycling to minimize the environmental impacts of electronics while promoting circularity and reducing resource use. Life Cycle Assessment (LCA) is used to evaluate the potential impacts and benefits in the value chain of Dell products considering different ARS treatment options. The study was conducted in accordance with ISO 14040/44.

Methodology

The goal of the study was to evaluate the potential environmental impacts and benefits of using Dell's ARS for four representative devices (laptop, desktop, monitor, and server) considering the entire life cycle of the equipment (cradle-to-grave). For each device, the study considered a baseline scenario for the end-of-life (EoL) and four ARS scenarios (Figure 1-1). In the baseline scenario, 40% of the devices were collected and sent to a typical mechanical recycling scenario without ARS and the rest is sent to landfill. ARS scenarios consisted of Refurbishment, Refurbishment with part replacement, Part harvesting and 100% Recycling. To evaluate the impact that ARS can have on the life cycle of devices, the functional unit was defined as 1 year of use for 100 devices. Since ARS scenarios of Refurbishment and Refurbishment with part replacement led to lifetime extensions, the impacts were calculated considering a longer lifetime than other scenarios. The impacts were evaluated through substitution (credits) with selected EF 3.0 impact categories.

Inventory data was obtained from previous cradle-to-gate studies performed on Dell devices and ARS inventory is sourced from Dell's Electronics Disposition Partners (EDPs). Sphera's Managed LCA Content (MLC) was the source of secondary LCI data (formerly GaBi databases), and the modeling was done in LCA FE (formerly GaBi Professional).

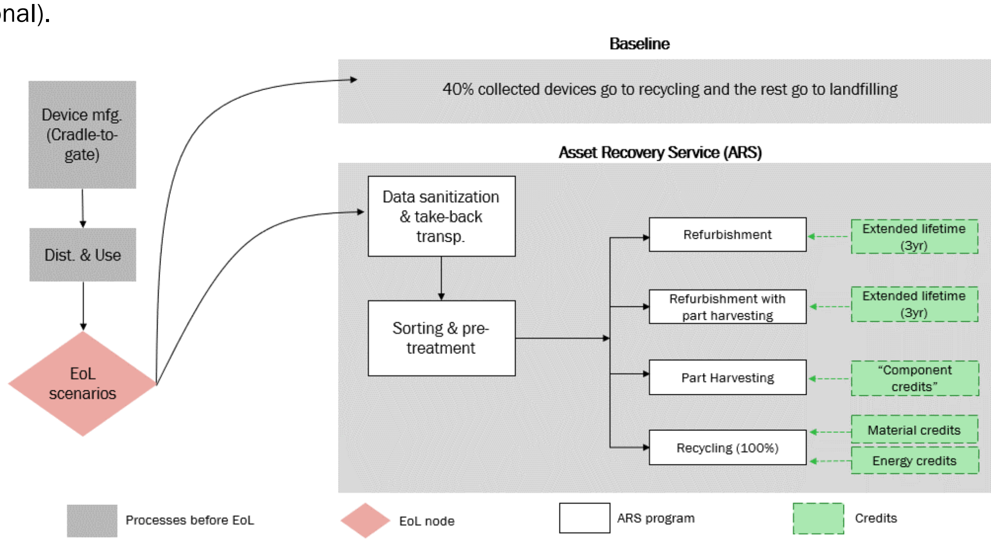


Figure 1-1: Life cycle schematic of baseline and four ARS scenarios

Results and conclusions

Figure 1-2 shows the global warming impact potential (GWP) savings per year for each end-of-life scenario as compared to the baseline scenario and breakdown of life cycle stages. For all devices, the impact is driven by the use phase and manufacturing regardless of the EoL scenario. In terms of EoL management of devices, it can be observed how the most GWP savings were those enabling life extension – Refurbishment (16% to 28%) and Refurbishment with part replacement (13% to 23%), followed by recovery scenarios – Part harvesting (6% to 18%) and Recycling (1% to 2%). This trend in results demonstrates that the potential GWP savings per year align with the salvage value of each end-of-life scenario. The trends observed in GWP also apply to the other impact categories where Refurbishment is the most favorable EoL scenario followed by Refurbishment with part replacement, Part harvesting, Recycling and Baseline. Focusing on the life cycle stages, manufacturing and use phase are two highest contributors across four devices, while distribution and ARS relevant processes are negligible.

Impact of Refurbishment with part replacement mostly came from the manufacturing of new parts defined by the replacement rate. The higher the replacement rate, the larger the environmental impact. Part harvesting generally followed Refurbishment with part replacement and here the impacts are lowest as the parts are harvested. The more parts can be harvested, the larger the avoided impact, and the larger the savings. While Refurbishment with part replacement generally led to greater savings than Part harvesting for the laptop, monitor, and desktop, for the server parts can be harvested at a higher rate and Refurbishment with part replacement requires too many new parts (high replacement rate). For this reason, one can observe slightly higher impacts in Refurbishing than Part harvesting for the server. A lesson here is that if replacement rate is too high, it is possible that the most effective EoL management strategy is Part harvesting even if this means missing out on device lifetime extension.

Compared to the Baseline scenario, Recycling scenario reduced life-cycle GWP of devices by only 2% or less, meaning that material recovery provides the least amount of savings per functional unit. Recycling is still important for closing material loops, but it resulted in a minimal advantage in terms of carbon footprint if used as the only intervention. ARS scenarios maximize device and component lifetime and ensure recycling at end-of-life.

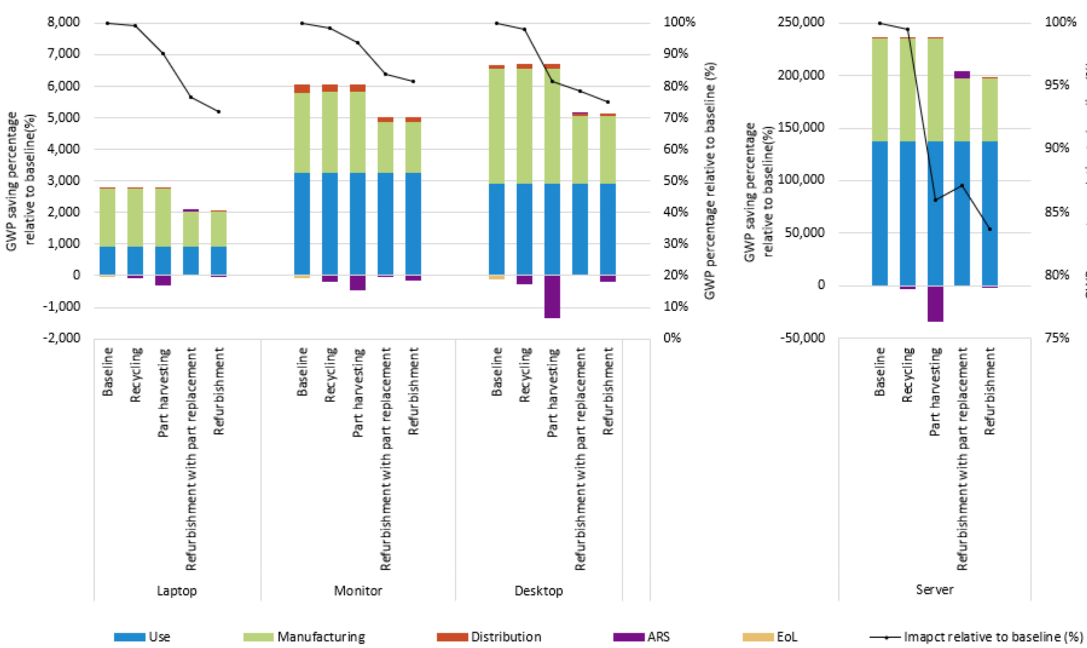


Figure 1-2: Life cycle GWP results per functional unit of five EoL scenarios of four devices and GWP percentage relative to baseline scenario

Limitations

There are two main limitations to this study. The first is around data collection for key parameters, lifetime extension, replacement and harvesting rates – where only a fraction of Environmental Disposition Partners (EDPs) provided data. Therefore, the model is representing a limited share of operating conditions where data was available. Nonetheless, the study can help understand overall trends and provide recommendations for the ARS program as a whole.

The second limitation is that the calculation procedure accounts for one single refurbishment cycle, when in reality devices could possibly be refurbished more than once – thus enhancing potential savings. As the ARS program matures, a future iteration of this study may need to account for a higher number of cycles.

Recommendations

The life cycle GWP results indicated that the use phase is one of the key hotspots for all scenarios across all devices. For Dell, this means that energy efficiency continues to be a priority for reducing GWP as long as electricity grids do not achieve a significant reduction in carbon intensity. Focusing on end-of-life management, results showed that the greatest opportunity for ARS is in enabling device lifetime extension. Global warming potential impact from ARS pre-treatment processes is minimal (less than 1%), but with the potential for reducing cradle-to-grave device GWP impacts of up to around 28% as compared to business as usual.

Therefore, key recommendations for the ARS program consist of actions that maximize device lifetime such as optimizing the sorting and grading step to increase product refurbishment rates. Lifetime extension is an effort that starts at the early design stages and continues through every phase of the product. With a long-term strategy in mind, the ARS program can work with the design teams to understand and address the limitations to higher levels of circularity. Some factors hindering device Refurbishment/Refurbishment with part replacement may stem from user behavior, so the ARS team could provide recommendations for consumers and work with marketing to possibly reward certain consumer practices. The ARS program has a great opportunity to engage other areas of Dell (design, marketing, consumer outreach) to evolve the program and increase its effectiveness. For Dell this would represent real life cycle management where end-of-life and product design work together.

Considering the ARS program will continue to mature, another recommendation is to analyze the breakeven point (environmental and economic) of the Refurbishment scenario because this ARS scenario is dependent on newly manufactured parts which carry certain environmental burdens and costs. Part harvesting can also bring certain environmental benefits as compared to the baseline. However, the credits received are dependent on the parts harvested. Further analysis of this scenario will enable prioritization of parts to harvest.

1. Goal of the Study

The goal of the study is to evaluate the potential environmental impacts and benefits of using Dell's Asset Recovery Services (ARS) for four devices. These devices include a laptop, a monitor, a desktop PC, and a server. Impacts across the life cycle for these devices will be compared with a baseline scenario that represents the absence of Dell's ARS offerings. The objectives of this study include identifying hotspots across the value chain to inform stakeholders of potential areas for improvement. The audience for this report includes Dell's internal stakeholders as well as customers.

The study and reporting follow the requirements of the international standards ISO 14044 and has undergone a critical review by an external expert in accordance to ISO/TS 14071.

2. Scope of the Study

The following sections describe the general scope of the project to achieve the stated goals. This includes, but is not limited to, the identification of specific product systems to be assessed, the product function(s), functional unit and reference flows, the system boundary, allocation procedures, and cut-off criteria of the study.

2.1. Product Systems

The following four products were chosen as representation of the respective product groups:

1. Desktop computer (Optiplex 7090 Desktop)
2. Notebook computer (Latitude 5430)
3. Monitor (U2720Q)
4. Server (Poweredge 740 rack server)

This study is based on previous cradle to gate LCI models adhering to 14040/44 performed by Sphera on behalf of Dell (Sphera 2022a) (Sphera 2019) (Sphera 2022b) (Sphera 2023a). This study maintains the cradle-to-gate and use phase portions of the previous studies and modifies the gate-to-grave EoL life cycle stages to allow for exploration of ARS scenarios. Dell ARS program typically applies to the enterprise user. A summary of cradle-to-gate product systems is included in Section 3, and the complete documentation of cradle-to-grave device LCAs can be found in each of the reports. This study focuses on end-of-life modeling and how this affects life cycle impacts of each device.

There are five end-of-life scenarios evaluated for each device, consisting of Baseline, Refurbishment, Parts harvesting and 100% Recycling (Figure 2-1). All scenarios share the same cradle-to-gate and use phase impacts. What differs is the end-of-life treatment and how this may impact the devices lifetime and the potential credits stemming from part or material recovery. The baseline scenario consists of an illustrative business-as-usual case without ARS informed by EPA statistics on electronic disposal where 40% of devices are sent to recycling facilities and the remaining 60% are landfilled (Refer to Section 3.3 for further recycling information). All ARS scenarios start with the onsite data sanitization (applied to laptop, server and desktop), take-back transport and packaging, second data sanitization and verification (applied to laptop, server and desktop), sorting and grading. Depending on the grading assessment, the devices are directed towards one of four options: Refurbishment, Refurbishment with part replacement, Parts harvesting, and Recycling.

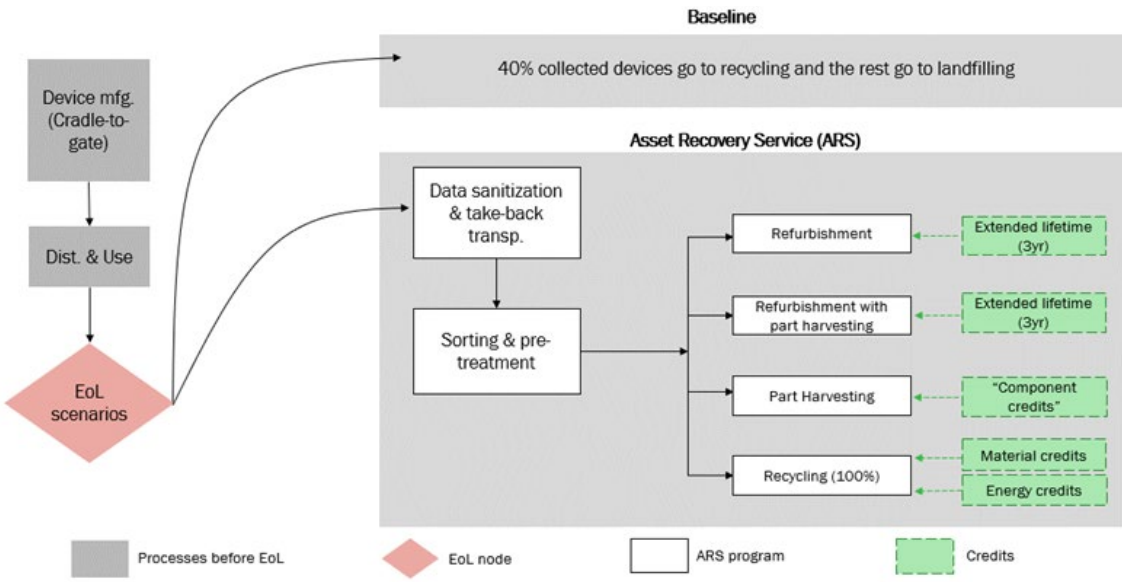


Figure 2-1: Life cycle schematic of baseline and four ARS scenarios

2.2. Product Functions and Functional Unit

Since the goal of the study is to evaluate the impact of end-of-life management over the life cycle of electronic devices, the functional unit is defined as 1 year for 100 devices each. This functional unit will enable assessment of the potential impact across all life cycle stages (cradle-to-grave), but also enables evaluation of the impacts of possible device lifetime extensions and resource recovery (Part harvesting and Recycling).

The main function of ARS is to enable the best possible end-of-life management either resulting in lifetime extension of the device (Refurbishment and Refurbishment with part replacement) and/or maximizing material and component recovery at the end-of-life (Part harvesting and Recycling). In the ARS scenarios of Refurbishment and Refurbishment with part replacement, where there is lifetime extension, impacts on an annual basis are scaled to the total lifetime and since this is higher in ARS Refurbishment and Refurbishment with part replacement, there is a reduction in the annual manufacturing impact. The scenarios of Parts harvesting and Recycling have no lifetime extension, but these result in avoided impacts due to the recovery of parts and/or material. Overall, there is recycling (and corresponding credits) to different extents in all end-of-life scenarios (Section 2.4).

Table 2-1 shows the total lifetime of four devices. The calculation process can be found in Section 3.5.

Table 2-1 Total lifetime used in scaling reference flow to functional unit.

Total lifetime of 100 devices (yr)	Baseline, Part Harvesting and Recycling	Refurbishment	Refurbishment with part replacement
Laptop	4	6.69	6.69
Monitor	5	8	8
Server	4	6.5	6.5
Desktop	4	6.84	6.84

2.3. System Boundary

The system boundary of the study is cradle-to-grave. All life cycle stages, including manufacturing, transports/logistics, use phase, and end-of-life are included in this analysis. Table 2-2 shows the activities included and excluded from the product systems.

Table 2-2: System boundaries

Included	Excluded
✓ Upstream raw material supply ✓ Product manufacturing ✓ Transport to customers ✓ Use phase, including original use phase, packaging disposal and extended use phase ✓ Data sanitization ✓ Transport to ARS processing site ✓ ARS treatment ✓ Transport to recycling	× Capital goods × Infrastructure × Employee commute and manual activities

2.3.1. Time Coverage

The intended time reference for the study is the 2022 calendar year. Cradle-to-gate LCA data pertains to previous studies and data collected in 2022 for laptop, 2017 for server, 2021 for desktop and 2021 for monitor. The manufacturing of devices has not incurred any significant changes since the time of data collection. Use phase assumes 2018 average grid data for use, and ARS data pertains to 2022.

2.3.2. Technology Coverage

This study assesses the cradle-to-grave impacts of the products based on the global production and technology mix. Manufacturing data was used from previous published reports, which collected the data by using physical teardown of the products. End-of-life is based on EPA statistics for municipal waste management, and ARS scenarios are informed by EDPs. Plans for landfill, incineration, recycling from the Managed LCA Content (former GaBi Databases) are representative of the technologies. The landfill dataset is based on U.S. EPA, while the incineration is based on the treatment of average municipal solid waste (MSW) in the USA. The recycling plan is based on Sphera's end-of-life plan for ICT, based on industry practices.

2.3.3. Geographical Coverage

The geographical coverage of this study considers device use in the United States. EDP data corresponds to operation in Texas, Massachusetts and Georgia, US.

2.4. Allocation

2.4.1. Multi-output Allocation

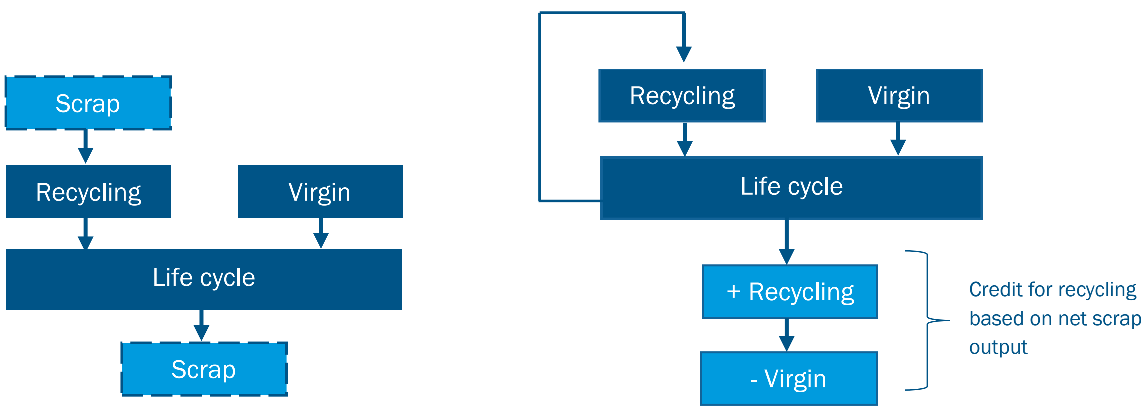
Multi-output allocation follows the requirements of ISO 14044, section 4.3.4.2. Multi-output allocation did not apply to any of the foreground data of the product systems evaluated in the study. Allocation in the background data are documented accordingly in the Sphera MLC documentation (Sphera 2023b).

2.4.2. End-of-Life Allocation

End-of-Life allocation follows the requirements of ISO 14044, section 4.3.4.3. Such allocation approaches address the question of how to assign impacts from virgin production processes to material that is recycled and used in future product systems.

Two main approaches are commonly used in LCA studies to account for end-of-life recycling and recycled content.

- Substitution approach (also known as 0:100, closed-loop approximation, recyclability substitution or end-of-life approach) – this approach is based on the perspective that material that is recycled into secondary material at end-of-life is technically able to substitute an equivalent amount of virgin material. Hence, a credit is given to account for this substitutability. To avoid double-counting the benefits of recycled content, waste materials collected for recycling at end-of-life are first used to satisfy the scrap demand of the manufacturing phase before being sent to recycling and crediting in end-of-life. This 'net scrap' approach rewards both end-of-life recycling as well as the use of recycled content.
- Cut-off approach (also known as 100:0 or recycled content approach) – burdens or credits associated with material from previous or subsequent life cycles are not considered i.e., are "cut-off". Therefore, scrap input to the production process is considered to be free of upstream virgin material burdens but, equally, no credit is received for scrap available for recycling at end-of-life. This approach rewards the use of recycled content but does not reward end-of-life recycling.



(i) Cut-off approach (scrap inputs and outputs are not considered) (ii) Substitution approach (credit given for net scrap arising)

Figure 2-2: Schematic representations of the cut-off and substitution approaches

For the end-of-life allocation approach used in each of the product systems, preference is given to the substitution approach with a net scrap calculation because it allows reflection of efforts and credits at end-of-life in more detail. Furthermore, when comparing two product systems, the equivalence of the functional unit is vital. With the cut-off approach, the function and lifetime of second life of the product would have to be equivalent to the first. This is seldom true in case of electronic products, and it is also not applicable in the devices considered.

This study applies the substitution approach to evaluate the impacts of the instances of multifunctionality at the end-of-life across devices. Multifunctionality in this study occurs in:

- **Recycling:** Recycling provides two functions: it provides a waste treatment function and a material production function that has the potential to substitute equivalent virgin material. To account for the waste treatment function, the potential material substitution is considered via material credits. Recycling occurs for devices and components that cannot be refurbished.

- **Incineration with energy recovery:** Incineration is a multifunctional process where there is waste treatment and energy production that displaces grid electricity and thermal energy from natural gas. Plastic and packaging that is not recycled undergoes incineration with energy recovery. Electronic waste that is not suitable for landfill nor recycling also undergoes incineration with energy recovery.
- **Extended lifetime:** If a device is deemed suitable for Refurbishment or Refurbishment with part replacement, it undergoes cleaning and other treatment processes, and it is put back into service for an extended time. This means that the device that is refurbished under the ARS program can serve longer than the Baseline device, and this reduces the manufacturing impacts associated with one year of use.
- **Part harvesting:** If a device is deemed suitable for Part harvesting, it undergoes disassembly, cleaning, and the harvested parts are put back into service for an extended time. This means that the harvested parts will substitute virgin parts. The substitution rate is assumed to be 1:1, which means the harvested parts have the same performance as the newly manufactured parts.

Specific aspects of the different EoL scenarios are described in more detail in Section 3.4 and 3.5.

2.5. Cut-off Criteria

As summarized in section 2.3, the system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts. The model and inventories of this study is harmonized and comparable with the applied quality and homogeneity of the four referenced and used LCA studies of the devices in order to ensure same approach across all sources and studies.

Across the devices, some data for upstream production chains, e.g., the packaging of electronic components that are populated onto the printed wiring boards (tape-and-reel packaging), were not considered in this study due to a lack of available data and high probability of very low environmental relevance.

The choice of proxy data is documented in Chapter 3. The influence of these proxy data on the results of the assessment has been carefully analyzed and is discussed in Chapter 5.

2.6. Selection of LCIA Methodology and Impact Categories

Life cycle impacts are evaluated according to the latest life cycle impact assessment method under the European Product Environmental Footprint (PEF) program in its version EF 3.0, together with IPCC AR6 factors for global warming. Due to the large number of indicators, each with different levels of recommendation (JRC 2018), this study selects eight impacts categories to be included in the body of the report (Table 2-3). To evaluate the robustness of results, a second LCIA method, CML-IA (v4.8 - Aug 2016) is applied and included in

Annex B. Although relatively outdated, CML-IA is a legacy LCIA method within Dell.

In addition, of special interest to the ARS program are three inventory metrics: non-hazardous waste, blue water consumption, and primary energy demand (Table 2-4) and as these are inventory categories, results are reported in Annex B.

Table 2-3: EF 3.0 impact category descriptions

Impact Category	Description	Unit	Reference
Climate change (global warming potential) excluding biogenic CO2	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health and material welfare.	kg CO_2 equivalent	(IPCC 2021)
Acidification Potential	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline and the deterioration of building materials.	moles H^+ equivalent	(Seppälä J. 2006, Posch 2008)
Eutrophication (freshwater)	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.	kg P equivalent	(Seppälä J. 2006, Posch 2008, Struijs 2009)
Ozone Depletion	A measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface with detrimental effects on humans and plants.	kg CFC-11 equivalent	(Guinée, et al. 2002)
Photochemical Ozone Formation	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.	kg C_2H_4 equivalent	(Van Zelm R. 441-453)
Resource use, minerals and metals	The consumption of non-renewable resources leads to a decrease in the future availability of the functions supplied by these resources. Depletion	kg Sb equivalent, MJ (net calorific value)	(Guinée, et al. 2002)

Impact Category	Description	Unit	Reference
	of mineral resources and non-renewable energy resources are reported separately. Depletion of mineral resources is assessed based on ultimate reserves.		
Resource use, energy carriers	A measure of the total amount of non-renewable primary energy extracted from the earth. Resource use is expressed in energy demand from non-renewable resources including both fossil sources (e.g. petroleum, natural gas, etc.) and uranium for nuclear fuel. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.	MJ	(Guinée, et al. 2002, van Oers, et al. 2002)
Water Use	An assessment of water scarcity accounting for the net intake and release of fresh water across the life of the product system considering the availability of water in different regions.	Litres of water equivalent (H_2Oe)	(AWARE 2017)

Table 2-4: Other environmental indicators

Indicator	Description	Unit	Reference
Non-renewable Primary Energy Demand (PED)	A measure of the total amount of non-renewable primary energy extracted from the earth(e.g., petroleum, natural gas, etc.) Efficiencies in energy conversion (e.g., power, heat, steam, etc.) are taken into account.	MJ (lower heating value)	(Guinée, et al. 2002)
Non-hazardous Waste	Non-hazardous waste is non-toxic and similar to household waste. It consists of inert waste and ordinary household waste.	kg	(CEN 2019)
Blue Water Consumption	A measure of the net intake and release of fresh water across the life of the product system. This is not an indicator of environmental impact without the addition of information about regional water availability.	Liters of water	(Sphera 2020)

It shall be noted that the above impact categories represent impact *potentials*, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) actually follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

2.7. Interpretation to be Used

The results of the LCI and LCIA were interpreted according to the Goal and Scope. The interpretation addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results

- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations and recommendations

2.8. Data Quality Requirements

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are considered to be of the highest precision, followed by calculated data, literature data, and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modeling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modeling choices, data sources, emission factors, or other artefacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data were not available (e.g., no industry-average data available for a certain country), best-available proxy data were employed.

An evaluation of the data quality with regard to these requirements is provided in section 5 of this report.

2.9. Type and Format of the Report

In accordance with the ISO requirements (ISO 2006) this document aims to report the results and conclusions of the LCA completely, accurately and without bias to the intended audience. The results, data, methods, assumptions and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the LCA to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

2.10. Software and Database

The LCA model was created using the LCA for Experts software for life cycle engineering, developed by Sphera Solutions, Inc. Sphera's Managed LCA Content (CUP 2022.2) provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

2.11. Critical Review

A single expert review according to ISO 14044 was performed by Dr. Colin Fitzpatrick, the Head of Department and Associate Professor in the Department of Electronic & Computer Engineering at the University of Limerick, Ireland.

3. Life Cycle Inventory Analysis

3.1. Data Collection Procedure

In this LCA study, the cradle-to-gate and annual electricity consumption data were collected from the previous LCA reports for four devices. The primary data for Dell ARS were collected using customized data collection templates, which were sent out by email to EDPs. The data collection templates request inputs and outputs for all treatment process involved in end-of-life management as well as key performance parameters such as data sanitization success rate, replacement rate and harvesting rate of each major component inside a device, transportation information and reported extended lifetime. Upon receipt, each questionnaire was cross-checked for completeness and plausibility. If gaps, outliers, or other inconsistencies occurred, Sphera engaged with the data provider to resolve any open issues. In the end, out of 6 EDPs supplied information, but only 5 EDPs supplied information with sufficient quality to be incorporated (EDPs included are located in Texas, Massachusetts and Georgia, US). For the purposes of illustrating a general case and building the model, averages were used for data sanitization success rate, replacement rate and part harvesting rate.

3.2. Device Cradle-to-Gate Inventory Analysis

3.2.1. Monitor

3.2.1.1. Overview of Monitor

Sphera performed LCAs for two of Dell's monitors including a 24" and a 27" in 2022 (Sphera 2022a) using 2021 data provided by Dell. The 27" monitor (U2720Q) was chosen for this LCA. The system boundary from cradle to gate includes raw material extraction, manufacturing and transport to customers. The product composition includes mechanical, electronic, and electromechanical components in addition to the panel and peripherals. Packaging is also included in the product composition, with all the components summing up to a total mass of 9.37 kg.

3.2.1.2. Material Composition

Figure 3-1 shows the material composition of the monitor as it reaches the end-of-life. Metals shown in the figure are recycled at the end, while the plastic and packaging are incinerated. More detail information can be found in Annex B1.

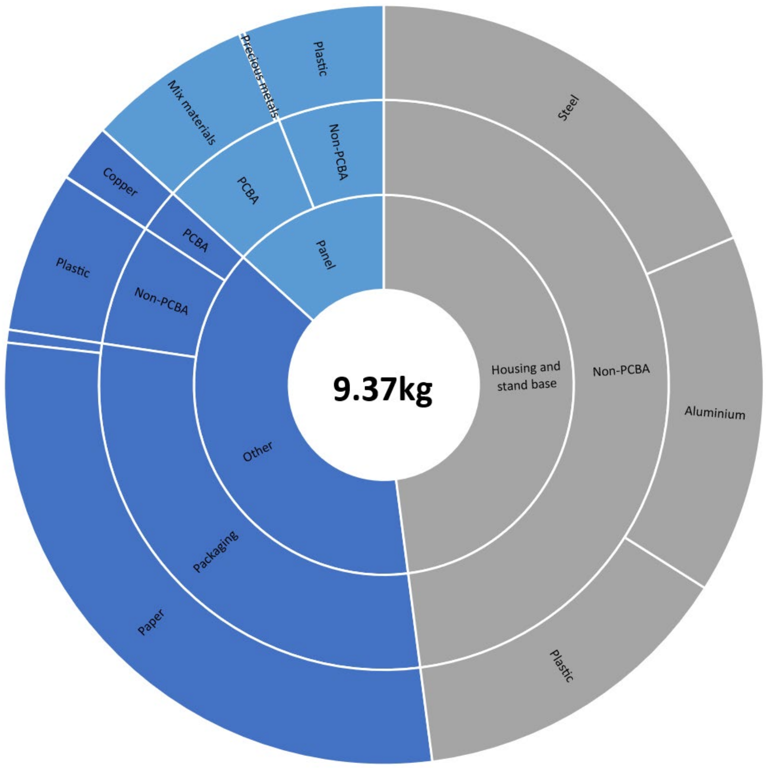


Figure 3-1: Material composition of the monitor

3.2.2. Server

3.2.2.1. Overview of Server

The LCA for the server Power Edge 740 (Sphera 2019) was performed by Sphera in 2019 with 2017 data collected from Dell. The system boundary from cradle to gate includes raw material extraction, manufacture of parts, transport to assembly, assembly and transport to customers. The part composition for the server includes electronic, mechanical, and electromechanical components, as well as packaging. The total mass of the product sums up to 29.47 kg.

3.2.2.2. Material Composition

Figure 3-2 shows the material composition of the server as it reaches the end-of-life. Metals shown in the figure are recycled at the end, while the plastic and packaging are incinerated. More detail information can be found in Annex B1.

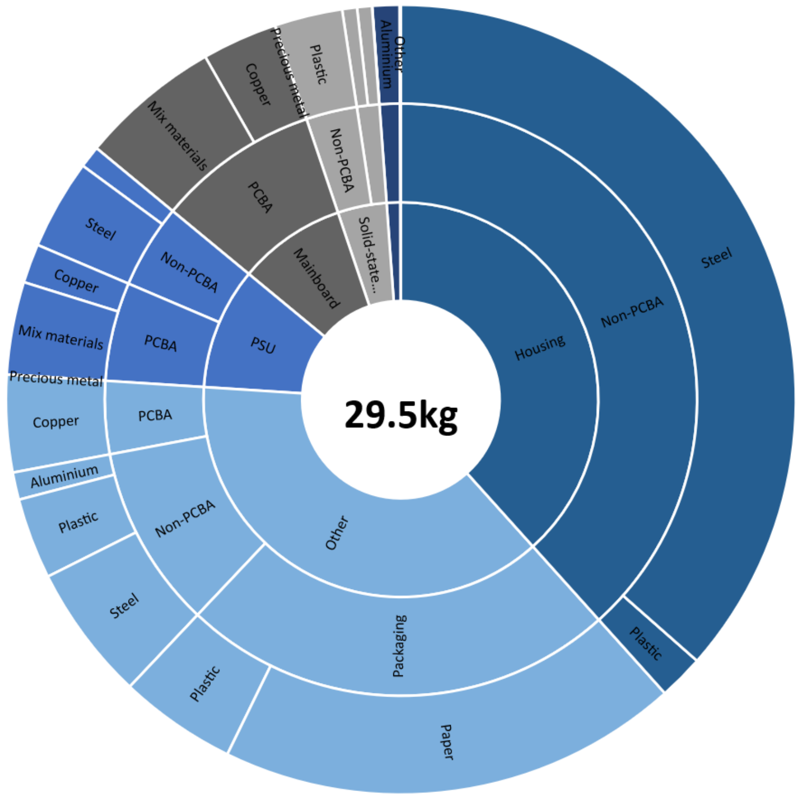


Figure 3-2: Material composition of the server

3.2.3. Desktop

3.2.3.1. Overview of Desktop

The Dell Optiplex 7090 Small Form Factor (SFF) desktop's LCA was performed by Sphera in 2022 (Sphera 2022b) using 2021 data collected from Dell. The system boundary from cradle to gate includes raw materials, manufacturing and transportation to customers. The product composition used in the LCA includes electronics, mechanical and electromechanical components in addition to mouse and keyboard. The packaging was also covered in the study with the total mass of the product summing up to 6.51 kg.

3.2.3.2. Material Composition

Figure 3-3 shows the material composition of the desktop as it reaches the end-of-life. Metals shown in the figure are recycled at the end, while the plastic and packaging are incinerated. More detail information can be found in Annex B1.

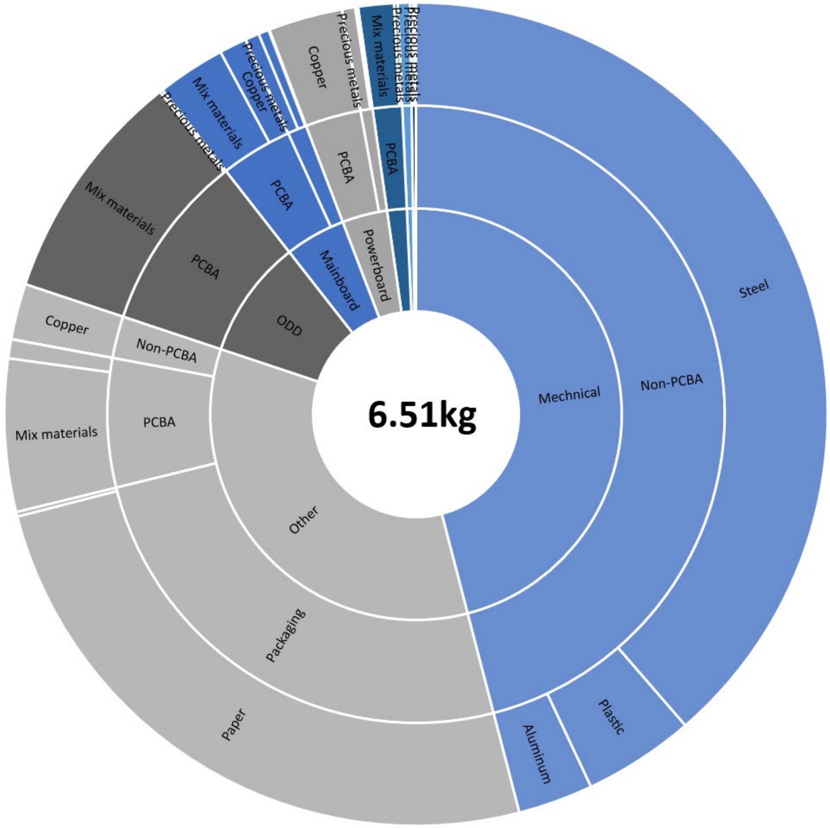


Figure 3-3: Material composition of the desktop

3.2.4. Laptop

3.2.4.1. Overview of Laptop

The Dell Latitude 5430 laptop's LCA was performed by Sphera in 2023 (Sphera 2023a) using 2022 data collected from Dell. The system boundary from cradle to gate includes raw materials, manufacturing and transportation to customers. The product composition used in the LCA includes electronics, mechanical and electromechanical components. The packaging was also covered in the study with the total mass of the product summing up to 2.22 kg.

3.2.4.2. Material Composition

Figure 3-4 shows the material composition of the laptop as it reaches the end-of-life scenarios. Metals shown in the figure are recycled at the end, while the plastic and packaging are incinerated. More detail information can be found in Annex B1.

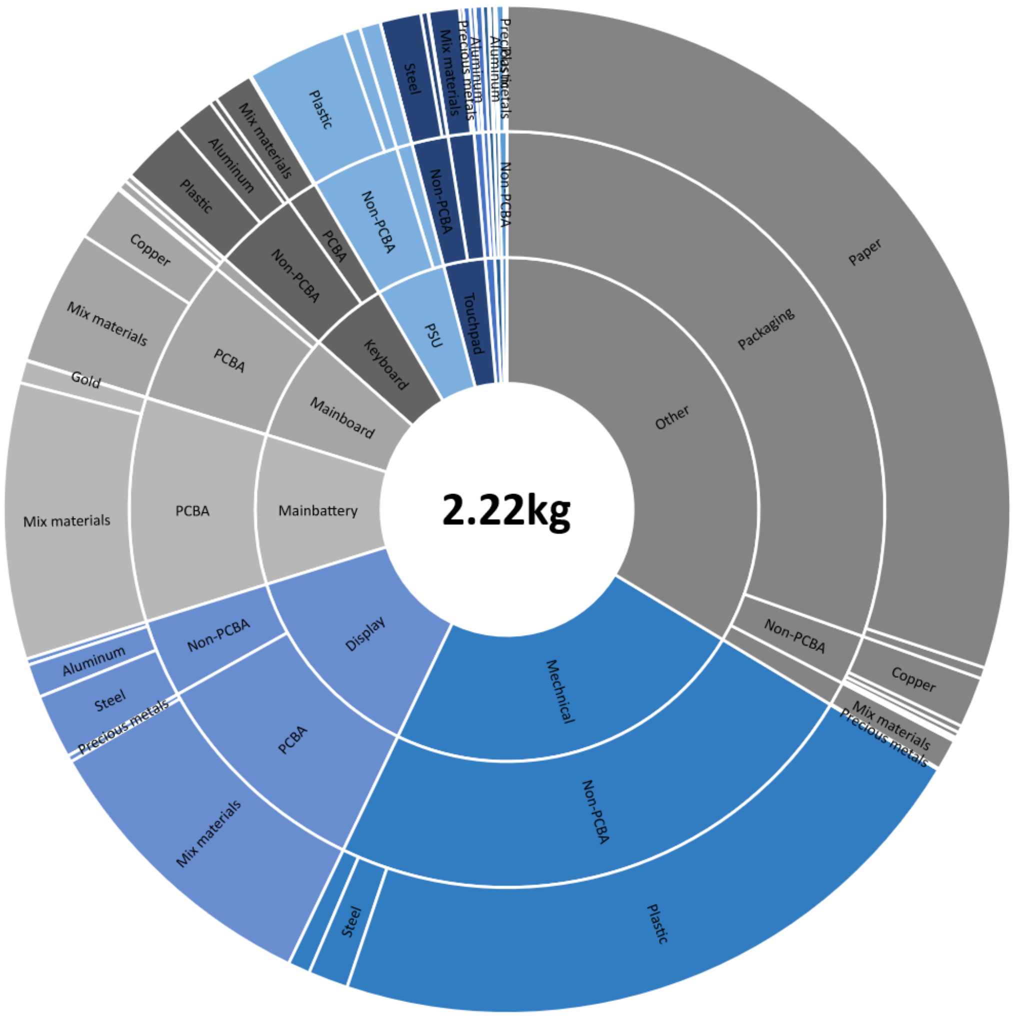


Figure 3-4: Material composition of the laptop

3.3. Use Phase

The use phase consists of electricity use and packaging disposal. The use phase is assumed to occur in the US for all of the devices' lifetime, and the packaging of each device is assumed to be landfilled during use phase. The weight of packaging for each device can be found in Annex B1, and the landfill dataset used in this study can be found in section 3.6.2.

The electricity consumption data is provided by Dell in the previous LCA reports and calculated based on the different power settings. It is assumed that refurbished devices maintain the same power ratings as new ones.

Table 3-1 shows the lifetime and electricity consumption per year of each device.

Table 3-1: Electricity consumption during use phase

Device	Baseline Lifetime (yr)	Daily power setting	Grid	kWh/yr of use per device
Monitor	5	17 hrs off (0.0005kw), 2 hrs idle mode (0.0005kw), 5hrs power mode(0.033kw)	US electricity grid mix	64.17
Server	4	6 hrs idle mode (0.201kw), 7.2hrs 10% load mode (0.261kw), 2.4hrs 100% load mode(0.51kw), 8.4 hrs 50% load mode (0.369kw)	US electricity grid mix	2,704.21
Desktop	4	3.6 hrs off (0.0004kw), 10.8 hrs sleep mode (0.00176kw), 2.4 hrs long idle mode (0.01469kw), 7.2 hrs short idle mode (0.01263kw)	US electricity grid mix	57.13
Laptop	4	1.2hrs long idle mode (0.0012kw), 6hrs short idle mode (0.0052kw), 6hrs off (0.0005kw), 10.8hrs sleep mode (0.0012)	US electricity grid mix	17.74

3.4. Baseline Waste Management

The Baseline scenario system boundary includes cradle-to-grave life cycle stages (Figure 3-5). In this study, product manufacturing, use, end-of-life, and transport are obtained from the pre-existing models developed by Sphera. In the Baseline scenario, when the devices reach the end of life, 60% of the devices are landfilled and the remaining 40% are recycled (EPA 2018).

Devices undergoing recycling are disassembled to separate mono-material, mix-material fractions and PCBA. Depending on the material, a recycling treatment is identified. Mono-material fractions of metals (steel, aluminum, and copper) are recycled as secondary materials. Mix-materials and polymers are sent to incineration with energy recovery. Only inert materials (like glass) are landfilled for laptop (Figure 3-6).

The PCBA fraction is sent to shredding where materials can be separated according to the composition: mono-material and mix-material fraction where the same treatment is applied: either recycling of secondary materials or incineration The composition of the PCBA fraction per device is documented in Annex B1. The transportation distance from use phase to end-of-life is assumed to be 100km.

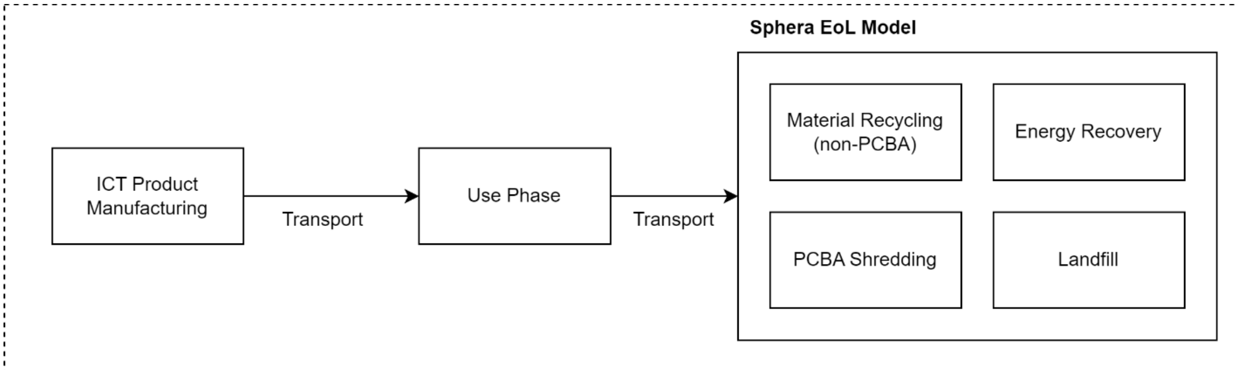


Figure 3-5: Schematic representing system boundary for the Baseline scenario

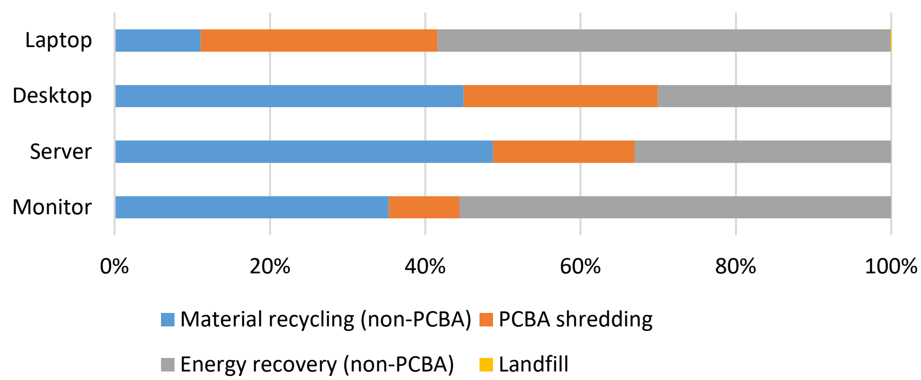


Figure 3-6: EoL pathways of the four devices

3.5. ARS Scenarios

When a device enters the ARS program, it undergoes a series of steps that sort and assess the most suitable end-of-life treatment for each device given its condition. Figure 3-7 outlines the ARS processing steps for the selected devices.

Once the device is received by ARS and the packaging is disposed. The devices undergo a series of steps that determine the suitability for each EoL treatment (Table 3-3). For the laptop, desktop and server, the product goes through the onsite data sanitization process. If the onsite data sanitization fails, the device goes through shredding and recycling. If the on-site sanitization is successful, then the device goes through distribution after which the onsite data sanitization is verified. If the product passes this verification, it moves on to the testing and sorting phase, otherwise another round of data sanitization (at the factory) is performed (2nd data sanitization). If successful, the devices move to testing and sorting, otherwise it goes to shredding. If at the start (at EDP location) the onsite data sanitization fails, the device goes through shredding, recycling, and energy recovery/material credit processes.

In the case of the monitor, there are no data sanitization processes since the monitor does not store user data. The monitor goes through distribution, and then directly to testing and sorting process. The original packaging of the devices has been landfilled during use phase.

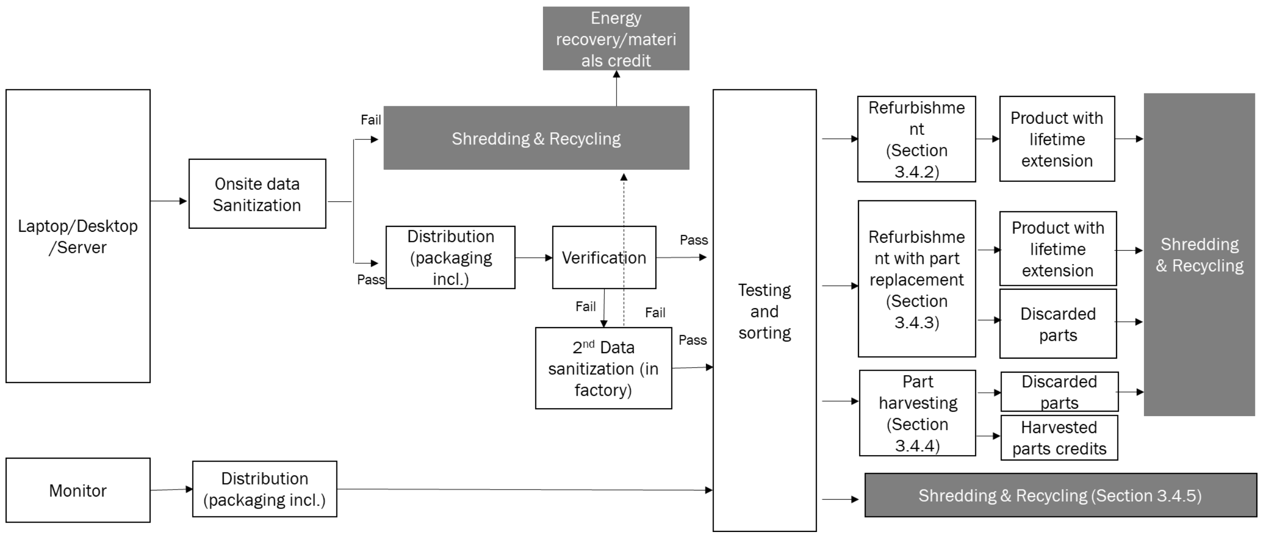


Figure 3-7: ARS flow diagram

Table 3-2 reports the reception of devices to the ARS program where the device is sent to the ARS pre-treatment and the packaging is disposed. Table 3-3 reports the electricity consumption and waste output for four pre-treatment processes. After sorting, the ARS program assesses the most suitable treatment option. Section 3.4.2 to 3.4.5 describe in detail each of the treatment options and corresponding unit processes.

Table 3-2: Weight of incoming device and packaging

Device	Returned device [kg/device]	Return packaging [kg]		
		Cardboard	Pallet	Shrink wrap
Laptop	1.54	0.44	0.047	0.05
Monitor	6.65	0.56	0.4	0.04
Server	22.36	0.11	0.38	0.08
Desktop	4.77	0.20	0.10	0.09
EoL fate	Devices are sent to ARS pre-treatment as shown in Figure 3-7	Recycling	Reuse 5 times then recycled	Incineration with energy recovery

Table 3-3: Electricity consumption and waste output for four pre-treatment processes

Device	Parameter	1st sanitization	Verification	2nd sanitization	Testing/sorting
Laptop	Electricity consumption [Wh]	10.0	12.0	10.0	26.6
	Pass rate [mass %]	90.0	90.0	95.0	n/a
	Waste for shredding and recycling[kg]	0.15	n/a	0.007	n/a
Monitor	Electricity consumption [Wh]	n/a	n/a	n/a	13.9
	Pass rate [mass %]	n/a	n/a	n/a	n/a
	Waste for shredding and recycling[kg]	n/a	n/a	n/a	n/a
Server	Electricity consumption [Wh]	2,500.0	250.0	200.0	276.5
	Pass rate [mass %]	85.0	80.0	90.0	n/a

Device	Parameter	1st sanitization	Verification	2nd sanitization	Testing/sorting
	Waste for shredding and re-cycling[kg]	3.35	n/a	0.38	n/a
Desktop	Electricity consumption [Wh]	400.0	30.0	20.0	107.1
	Pass rate [mass %]	95.0	90.0	95.0	n/a
	Waste for shredding and re-cycling[kg]	0.24	n/a	0.02	n/a

3.5.1. Total Lifetime Calculation

As mentioned in Section 2.2, impacts on an annual basis are scaled to the total lifetime in this study (Eq. 1). In ARS Refurbishment and Refurbishment with part replacement, there is a reduction in the annual manufacturing impact. The total lifetime of devices is a function of the Baseline lifetime plus the lifetime extension due to ARS process (Eq. 2). When devices go through ARS, except for monitor, they undergo a series of data sanitization and verification process. Only those devices that pass the testing series are deemed suitable for ARS scenarios, so that not all devices undergo an extension. Impacts on a per functional unit basis considering that a portion of devices is subjected to life extension is defined in Eq. 3 and it depends on Eq. 2 for the total lifetime.

$$Impacts\ per\ FU\ (1\ year\ of\ use\ for\ 100\ devices) = \frac{n*(Cradle\ to\ grave\ impacts)_d}{Total\ lifetime\ of\ device_d} \qquad \text{Eq. 1}$$

$$Total\ lifetime\ of\ device = L_{baseline,d} + (ARS_{pr,d} * L_{ext,d}) \qquad \text{Eq. 2}$$

$$ARS_{pr,d} = Onsite\ Sanitization_{r,d} * (Verification_{r,d} + (1 - Verification_{r,d}) * 2nd\ Sanitization_{r,d}) \qquad \text{Eq. 3}$$

Where,

n: Refers to the number of devices, in this case set at 100 units.

$Cradle\ to\ grave\ \mathrm{impacts}_d$: Refers to the cradle-to-grave impacts for device *d*

$Total\ lifetime\ of\ device$: Total lifetime of device in (yrs) per device *d*. Resulting values shown in (Table 2-1).

$L_{baseline,d}$: Device lifetime (yrs) under a Baseline case in the absence of ARS for device, d. The study assumes a lifetime of 4 years for laptop, server and desktop, 5 years for monitor.

$L_{ext,d}$: Device lifetime extension (yrs) as a result of the ARS Refurbishment or Refurbishment with part replacement program. The study considers a 3-year life extension.

$ARS_{pr,d}$: Overall pass rate per device, d (Table 3-4). This represents the portion of incoming devices that pass the required qualification sets including onsite data sanitization, verification and 2nd data sanitization.

$Onsite\ Sanitization_{r,d}$: Sanitation pass rate for device, d. This is the fraction of devices that make it through this step. Note that this process doesn't apply to monitors because there is no data stored in the device.

$Verification_{r,d}$: First verification pass rate for device, d. This is the fraction of devices that make it through this step. Note that this process doesn't apply to monitors because there is no data stored in the device.

$2nd\ Sanitization_{r,d}$: Second sanitation pass rate for device, d. This is the fraction of devices that make it through this step. Note that this process doesn't apply to monitors because there is no data stored in the device.

Table 3-4 ARS recovery rates per qualification step for Refurbishment and Refurbishment with part replacement.

Pass rates	$ARS_{pr,d}$	$Onsite\ Sanitation_{r,d}$	$Verification_{r,d}$	$2nd\ Sanitization_{r,d}$
Laptop	89.55%	90.00%	90.00%	95.00%
Monitor	N/A	N/A	N/A	N/A
Server	83.30%	85.00%	80.00%	90.00%
Desktop	94.5%	95%	90%	95%

3.5.2. Refurbishment

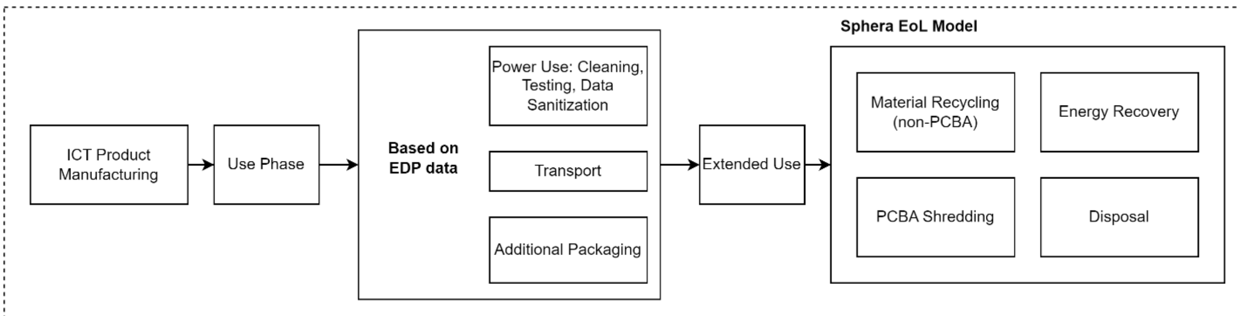


Figure 3-8: Flow chart representing system boundary for the ARS Refurbishment scenario.

The system boundary for product refurbishment alternative for the ARS scenario is shown in Figure 3-8. Refurbishing the product extends the lifetime of the product. This extended lifetime is included in the system boundary. The value is considered 3 years and is obtained from data collected through Dell's EDPs and discussion with the Dell team. Burden from data sanitization, equipment cleaning, testing, transport, and packaging is added to the system based on data provided by EDPs. It's assumed that the refurbished product has the same energy efficiency as the new product with the same annual electricity consumption shown in Section 3.3. At the end of the extended life, the device is sent to recycling (100% collection rate) because it is handled by Dell's ARS. Table 3-5 shows the related input and output of the refurbishment treatment process.

Table 3-5: Input and output of Refurbishment treatment process

Device	Inputs/Outputs	Material/ Process	Amount	Units
Monitor	Inputs	Monitor	6.65	kg
		Isopropyl Alcohol 99%	2.00	g
		Ethylene glycol surface cleaner (Windex)	2.00	g
		New sale packaging	2.72	kg
		Electricity	240.00	Wh
	Outputs	Monitor (New sale packaging incl.)	9.37	kg
Laptop	Inputs	Laptop	1.54	kg

Device	Inputs/Outputs	Material/ Process	Amount	Units
		Isopropyl Alcohol 99%	3	g
		Ethylene glycol surface cleaner (Windex)	2.00	g
		New sale packaging	0.68	kg
		Electricity	180.00	Wh
	Outputs	Laptop (New sale packaging incl.)	2.22	kg
Server	**Inputs**	Server	22.36	kg
		New sale packaging	7.11	kg
		Isopropyl Alcohol 99%	2.00	g
	Outputs	Server (New sale packaging incl.)	29.47	kg
Desktop	**Inputs**	Desktop	4.77	kg
		Isopropyl Alcohol 99%	2.00	g
		Ethylene glycol surface cleaner (Windex)	2.00	g
		New sale packaging	1.74	kg
		Electricity	24.00	Wh
	Outputs	Desktop (New sale packaging incl.)	6.51	kg

3.5.3. Refurbishment with part replacement

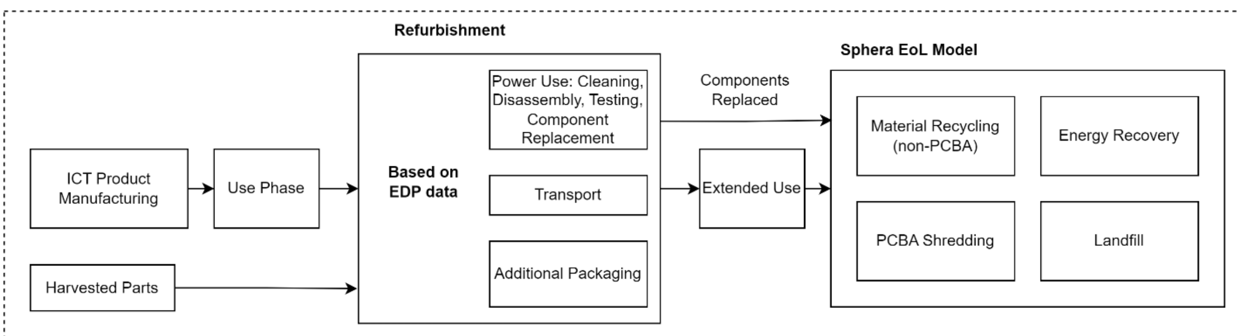


Figure 3-9: Flow chart representing system boundary for ARS Refurbishment with part replacement scenario.

Refurbishment with part replacement is the process of repairing or upgrading components in an electronic product to a seemingly new condition which is then made available for use. Flow chart representing the system boundary for refurbished products is shown in Figure 3-9.

Refurbishment with part replacement also results in extended life for the product. However, the amount of effort (material and energy use) required to ready the product for resale is higher. The environmental burdens of these activities shown in the figure are added to the product system along with the extended life of 3 years. In the part replacement process, some components are replaced either with harvested or new parts. These components are sent directly to end-of-life treatment immediately after the first use. If harvested parts are used, these carry the environmental burdens of the new part. This is consistent with the closed-loop approximation allocation approach used in the end-of-life.

Table 3-6 shows the replacement rate of parts per device. For example, for the monitor, 40% of the mechanical parts and 8.3% of the panels need replacement. This means that lifetime extension via Refurbishment with part replacement is only possible under the re-manufacturing of these parts. The higher the replacement rate, the higher the impact of this scenario.

Table 3-7 shows the inputs and outputs of the part replacement process in terms of mass and including part replacement energy and cleaning.

At the end of the extended life, the device is sent to recycling (100% collection rate) because it is handled by Dell's ARS.

Table 3-6: Replacement rate of four devices

<table>
<tr><td rowspan="2">Monitor</td><td colspan="5">Mechanical</td><td colspan="5">Panel</td></tr>
<tr><td colspan="5">40.00%</td><td colspan="5">8.33%</td></tr>
<tr><td rowspan="2">Server</td><td colspan="2">Memory (DDR)</td><td colspan="2">Solid-state drive</td><td colspan="2">PSU</td><td colspan="2">Housing</td><td colspan="2">Heat Sink</td></tr>
<tr><td colspan="2">63.33%</td><td colspan="2">33.33%</td><td colspan="2">36.67%</td><td colspan="2">0.33%</td><td colspan="2">36.67%</td></tr>
<tr><td rowspan="2">Desktop</td><td colspan="2">Memory (DDR)</td><td colspan="2">Solid-state drive</td><td colspan="2">PSU</td><td colspan="2">Housing</td><td>optical drive</td><td>HDD</td></tr>
<tr><td colspan="2">33.41%</td><td colspan="2">23.76%</td><td colspan="2">19.98%</td><td colspan="2">1.00%</td><td>2.00%</td><td>14.77%</td></tr>
<tr><td rowspan="2">Laptop</td><td>DDR</td><td>Mainbord</td><td>Speaker</td><td>SSD</td><td>Keyboard</td><td>Touchpad</td><td>PSU</td><td>Main battery</td><td colspan="2">Display</td></tr>
<tr><td>20.20%</td><td>16.60%</td><td>2.00%</td><td>17.53%</td><td>11.40%</td><td>11.40%</td><td>12.60%</td><td>24.96%</td><td colspan="2">10.00%</td></tr>
</table>

Table 3-7: Input and output of Refurbishment with part replacement treatment process

Device	Inputs/Outputs	Material/ Process	Amount	Units
Monitor	**Inputs**	Monitor	9.37	kg
		Mechanical	1.78	kg
		Panel	0.10	kg
		Isopropyl Alcohol 99%	3.00	g
		Electricity	1.53	kWh
	Outputs	Monitor	9.37	kg
		Discarded parts	1.88	kg
Laptop	**Inputs**	Laptop	2.22	kg
		DDR	0.002	kg
		Mainboard	0.02	kg
		Speaker	0.0003	kg
		SSD	0.002	kg
		Keyboard	0.01	kg
		Touchpad	0.01	kg

Device	Inputs/Outputs	Material/ Process	Amount	Units
		PSU	0.01	kg
		Mainbattery	0.05	kg
		Display	0.03	kg
		Isopropyl Alcohol 99%	3.00	g
		Ethylene glycol surface cleaner (Windex)	2.00	g
		Electricity	2.70	kWh
	Outputs	Laptop	2.22	kg
		Discarded parts	0.140	kg
Server	**Inputs**	Server	29.47	kg
		Memory (DDR)	0.011	kg
		Solid-state drive	4.00E-01	kg
		PSU	1.096	kg
		Housing	3.80E-02	kg
		Heat Sink	0.121	kg
		Electricity	15.26	kWh
		Isopropyl Alcohol 99%	1.00	g
	Outputs	Server	29.47	kg
		Discarded parts	1.67	kg
Desktop	**Inputs**	Desktop	6.74	kg
		Memory (DDR)	0.01	kg
		Solid-state drive	0.004	kg
		PSU	0.05	kg
		Housing	0.03	kg
		optical drive	0.01	kg
		HDD	0.01	g
		Isopropyl Alcohol 99%	1.00	g
		Electricity	2.56	kWh
	Outputs	Desktop	6.74	kg
		Discarded parts	0.12	kg

3.5.4. Parts Harvesting

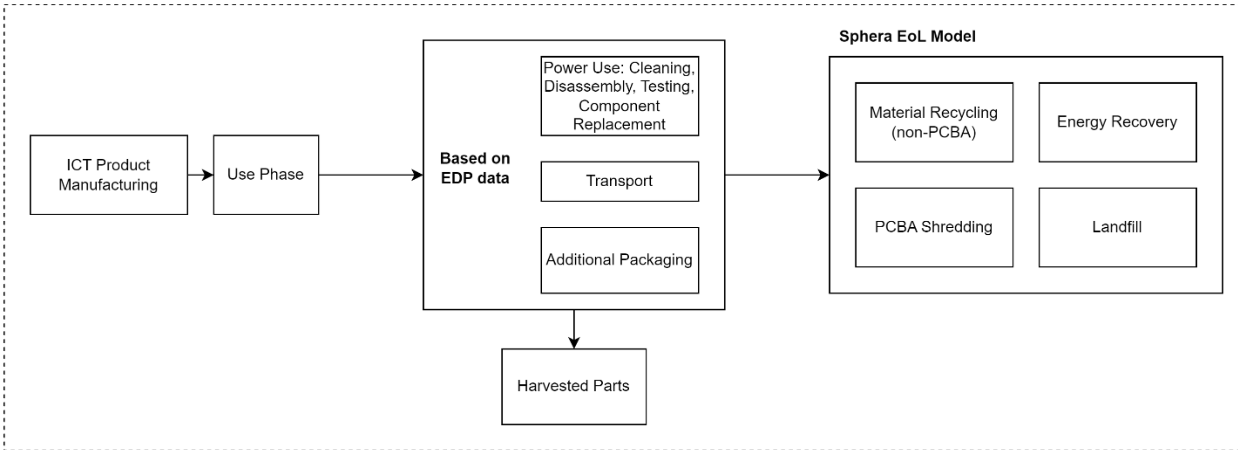


Figure 3-10: Flow chart representing system boundary for ARS Parts harvesting scenario.

Parts harvesting scenario is applied to products that are not in working condition and cannot be refurbished. The products are separated into components and parts. Amongst these parts and components, the ones in working condition are sent for Refurbishment and Refurbishment with part replacement of other products or are resold directly. The system boundary for parts harvesting in the ARS scenario is shown in the Figure 3-10.

Components that are refurbished also have an extended life in different devices. However, due to the number of different possibilities of harvested parts, applications for reuse, and range of lifetime extension, these parts are not modeled independently. Instead, being consistent with the closed-loop approximation end-of-life approach applied in other scenarios, the product system is given a credit for the harvested part equivalent to the environmental impacts of a newly manufactured part.

Table 3-8 shows the harvesting rate of parts per device. For example, for the monitor, 40% of the mechanical parts is harvested. The higher the harvesting rate, the higher the received credits. Table 3-9 shows the inputs and outputs of the harvesting process in terms of mass and including part harvesting energy and cleaning.

Table 3-8: Harvesting rate of four devices

Monitor	Mechanical									
	40.00%									
Server	Memory (DDR)		Solid-state drive		PSU		Housing		Mainbord	
	95.00%		76.25%		65.00%		1.25%		25.00%	
Desktop	Memory (DDR)		Solid-state drive		PSU		Mainboard		optical drive	HDD
	58.73%		57.50%		22.50%		23.50%		20.00%	76.00%
Laptop	DDR	Mechanical	Speaker	SSD	Keyboard	Touchpad	PSU	Main battery	Display	
	20.20%	10.00%	16.60%	2.00%	17.53%	11.40%	11.40%	12.60%	24.96%	

Table 3-9: Other related inputs of part harvesting treatment process

Device	Inputs/Outputs	Material/ Process	Amount	Units
	Inputs	Monitor	9.37	kg

Device	Inputs/Outputs	Material/ Process	Amount	Units
Monitor		Petroleum distillate based cleaner (Goo gone)	1	g
		Isopropyl Alcohol 99%	1.00	g
		Electricity	0.39	kWh
	Outputs	Discarded parts	7.59	kg
		Mechanical	1.78	kg
Laptop	Inputs	Laptop	2.22	kg
		Isopropyl Alcohol 99%	1.00	g
		Petroleum distillate based cleaner (Goo gone)	1.00	g
		Electricity	2.70	kWh
	Outputs	Discarded parts	2.03	kg
		DDR	0.002	kg
		Speaker	0.002	kg
		SSD	0.0002	kg
		Keyboard	0.02	kg
		Touchpad	0.01	kg
		PSU	0.01	kg
		Main battery	0.03	kg
		Display	0.07	kg
		Mechanical	0.05	kg
Server	Inputs	Server	29.47	kg
		Electricity	12.10	kWh
		Isopropyl Alcohol 99%	1.00	g
	Outputs	Discarded parts	25.79	kg
		Memory (DDR)	0.02	kg
		Solid-state drive	0.92	kg
		PSU	1.94	kg
		Housing	0.14	kg
		Mainboard	0.66	kg
Desktop	Inputs	Desktop	6.74	kg
		Isopropyl Alcohol 99%	1.00	g
		Electricity	0.83	kWh

De-vice	Inputs/Outputs	Material/ Process	Amount	Units
	Outputs	Discarded parts	6.39	kg
		Mainboard	0.07	kg
		Memory (DDR)	0.02	kg
		Solid-state drive	0.01	kg
		PSU	0.05	kg
		optical drive	0.12	kg
		HDD	0.08	kg

3.5.5. Recycling

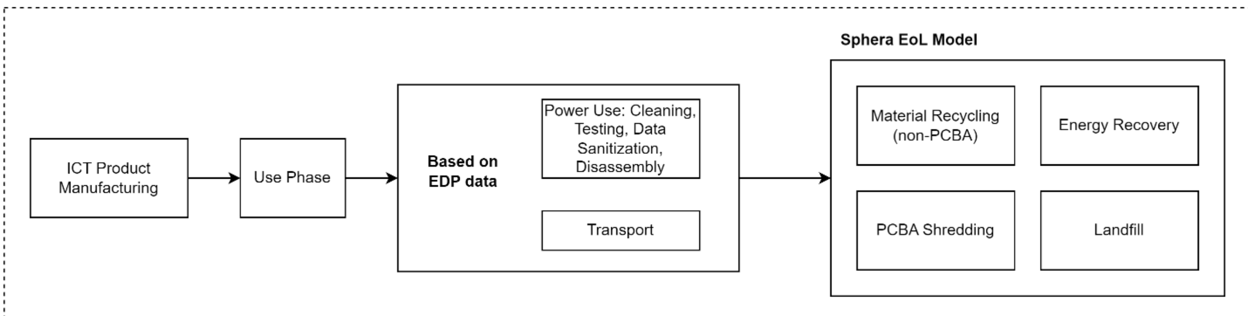


Figure 3-11: Flow chart representing system boundary for ARS Recycling scenario.

The system boundary for Recycling scenario is shown in Figure 3-11. Any product in the ARS that cannot be refurbished, or harvested for usable components is sent to recycling (represented by the Sphera end-of-life model).

Material recovery via recycling results in material credits modelled as shown in Table 3-10. For each gram of material recovered a virgin equivalent is credited on a one-to-one basis. The substitute rate for steel is 0.8 because of the scrap loss during the transformation between steel scrap and steel billet.

Table 3-10: Material credits of recycled materials

Recycled Materials	Material Credit
Aluminium	DE: Aluminium ingot mix
Steel	DE: BF Steel billet / slab / bloom
Copper	GLO: Copper mix (99,999% from electrolysis)
Gold	GLO: Gold (primary)
Palladium	GLO: Palladium mix
Platinum	GLO: Platinum mix
Silver	GLO: Silver mix

3.6. Background Data

3.6.1. Fuels and Energy

National averages for fuel inputs and electricity grid mixes were obtained from the MLC 2022 databases. Table 3-11 shows the most relevant LCI datasets used in modeling the ARS program systems. Electricity consumption was modeled using national grid mixes that account for imports from neighboring countries. Other LCI datasets used in cradle to gate can be found in the background report.

Documentation for all MLC datasets can be found at https://sphera.com/life-cycle-assessment-lca-database/.

Table 3-11: Fuels and energy background data used in ARS processes

Energy	Location	Dataset	Data Provider	Reference Year	Proxy?
Electricity	US	US: Electricity grid mix - Sphera	Sphera	2018	No
Diesel	US	US: Diesel mix at refinery Sphera	Sphera	2018	No

3.6.2. Raw Materials and Processes

Data for upstream and downstream raw materials and unit processes were obtained from the MLC 2022.2 database. in the Sphera MLC documentation (Sphera 2023b).

Table 3-12 shows the most relevant LCI datasets used in modeling the ARS program systems. Other LCI datasets used in cradle to gate and new manufacturing parts used in Refurbishment with part replacement and Part harvesting scenarios can be found in the background report. All MLC datasets can be found in the Sphera MLC documentation (Sphera 2023b).

Table 3-12: Key material and process datasets used in inventory analysis

Material / Process	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Corrugated cardboard	US	GLO: Corrugated cardboard box [for ICT]	Sphera	2021	Yes
Wooden Pallet	US	EU-28: Wooden pallets (EURO, 120x80x14 cm, 22% moisture, 18% H2O content)	Sphera	2021	Yes
Ethylene glycol surface cleaner (Windex)	US	DE: Tile and stone cleaner (approximation)	Sphera	2021	Yes
Petroleum distillate based cleaner (Goo gone)	US	DE: Tile and stone cleaner (approximation)	Sphera	2021	Yes
Packaging landfilling	US	US: Municipal Solid Waste on landfill	Sphera	2021	No

Material / Process	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Packaging incineration	US	US: Plastic wastes in waste incineration plant	Sphera	2021	No
Isopropanol	US	US: Isopropanol	Sphera	2021	No

3.6.3. Transportation

Average transportation distances and modes of transport are included for the transport of take-back devices to processing facilities, which is shown in Annex B1.

The MLC 2022 database was used to model transportation. The vehicle types, fuel usage, and emissions for these transportation processes were developed using a MLC model based on the most recent US Census Bureau Vehicle Inventory and Use Survey (2002) and US EPA emissions standards for heavy trucks in 2007. The 2002 VIUS survey is the latest available data source describing truck fleet fuel consumption and utilization ratios in the US based on field data (Langer 2013), and the 2007 EPA emissions standards are considered to be the appropriate data available for describing current US truck emissions. Fuels were modeled using the geographically appropriate datasets.

Table 3-13 shows the most relevant transportation datasets used in modeling the ARS program systems.

Table 3-13: Transportation and road fuel datasets

Mode / fuels	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Truck	US	GLO: Truck, Euro 3, more than 32t gross weight / 24.7t payload capacity	Sphera	2021	Yes
Diesel	US	US: Diesel mix at refinery Sphera	Sphera	2018	No

3.7. Life Cycle Inventory Analysis Results

ISO 14044 defines the Life Cycle Inventory (LCI) analysis result as the “outcome of a life cycle inventory analysis that catalogues the flows crossing the system boundary and provides the starting point for life cycle impact assessment”. The Life Cycle Inventory (LCI) analysis results for four devices can be found in Annex B2.

4. LCIA Results

This chapter contains the results for the impact categories and additional metrics defined in section 2.6. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

4.1. Overall Results

This section presents the results according to the selected EF 3.0 impact categories. Results according to CML-IA and the three selected inventory metrics can be found in Annex B4 and Annex B5. Overall, it was found that results are consistent across indicators as well as across impact assessment methods as the same hotspots are highlighted and scenarios enabling lifetime extension are preferred.

Given that results across impact categories align, results are first shown and discussed for GWP given its relevance to decarbonization and as an illustration of overall trends. Figure 4-1 shows the GWP life cycle results of the four products for 1 year of use of 100 devices. From a life cycle perspective, results illustrate how the use phase and manufacturing are the two largest hotspots and distribution and EoL play a minor role. When comparing end-of-life scenarios, Refurbishment and Refurbishment with part replacement tend to have the highest savings across devices because these minimize manufacturing impacts as the life of the product increases by 3 years, for a total of up to 8 years depending on the device (in average between 6.5 and 8 years as shown in Table 2-1).

End-of-life scenarios limited to material or component recovery (Part harvesting and Recycling) result in lower GWP reductions as the benefit is limited to substitution credits, which are far smaller in magnitude than upstream manufacturing and use phase (negative portion of graphs). The range of GWP reductions across devices relative to the Baseline are: Refurbishment (16% to 28%), Refurbishment with part replacement (13% to 23%), followed by recovery scenarios – Part harvesting (6% to 18%) and Recycling (1% to 2%).

A slight deviation from the trend is observed for the server where Part harvesting has lower impacts than Refurbishment with part replacement. Here, the Part harvesting rate and the replacement rate is high, and this makes Part harvesting particularly advantageous. Refurbishment with part replacement is especially high here because even though device lifetime is extended, it also requires a higher number of parts to be manufactured. A lesson here is that if replacement rate is high and potential for Part harvesting is also high, it is possible that the most suitable EoL is Part harvesting even if this means missing on device lifetime extension. In other words, there is a limit to how many parts should be refurbished to extend lifetime.

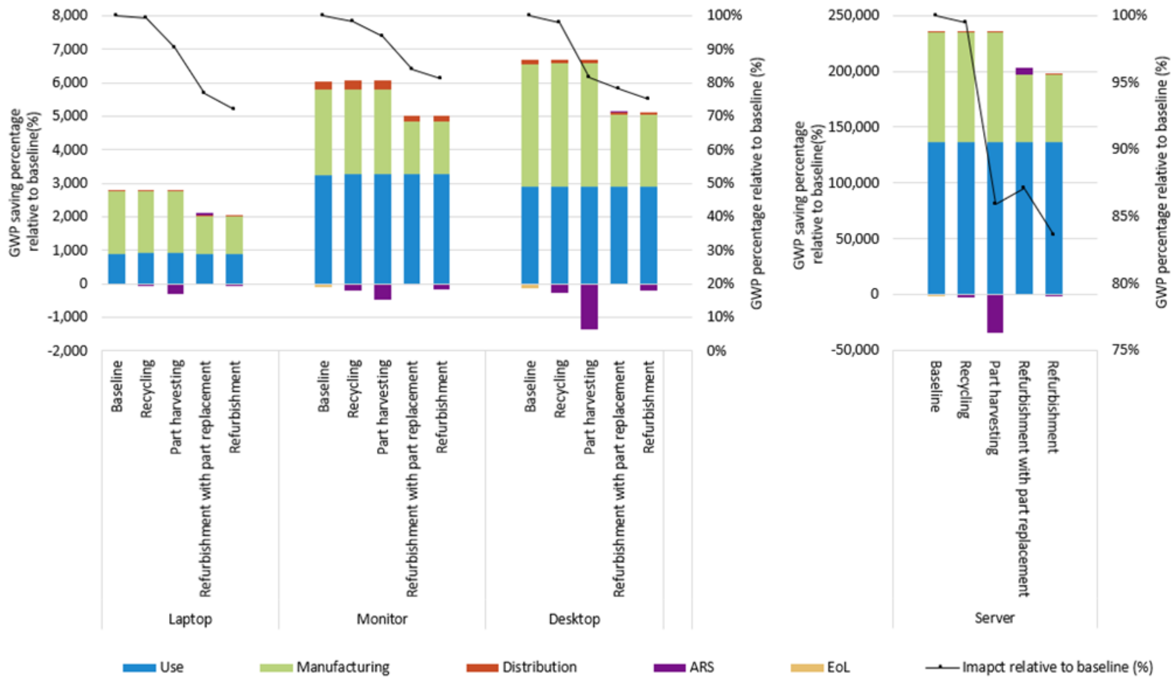


Figure 4-1: Life cycle GWP results per functional unit of five EoL scenarios of four devices and GWP percentage relative to Baseline scenario

Results of end-of-life scenarios across the other life cycle impact categories follow the same trend as with GWP where Refurbishment and Refurbishment with part replacement lead to the largest savings, followed by Part harvesting and Recycling.

Table 4-1 to Table 4-4 show the results of GWP and the remaining seven impact categories in terms of the absolute amounts. To ease interpretation of the data tables, magnitudes are color coded on a per row basis so that the largest value in the impact category is colored red and the lowest value is white. With this color code it is evident how manufacturing and use are the main hotspot across impact categories and devices.

Within the life cycle stages of manufacturing and use, the most significant driver of impact is energy. In the use phase this is tied directly to the electricity required to operate the device and the impact of the grid. In manufacturing the largest driver of impact lies within the manufacturing of specific resource-intensive components. For the monitor, the LCD panel and the PWB inside the mainboard are the main drivers. For the desktop, the mainboard and RAM, and in particular the PWB within each of them is the main hotspot. For the server, the SSD, in particular the semiconductor within it. For the laptop, the mainboard and display are the main drivers for all impact categories except ODP, which is dominated by the battery.

For the category of resource use, mineral and metals, the impact is dominated almost entirely (95% at least) by the elementary flow of gold even if it represents less than 1% of devices' mass. The impact of gold in the resource use, mineral and metals appears in manufacturing (as a burden) and in the ARS (as a credit from Part harvesting or Recycling). The gold content is a function of the gold amount present in the hundreds of electronic components and for the upstream burden, is modelled per component, each following various allocations in the gold dataset representing distinct regional and technical conditions. On the EoL side which evaluates the recycling credit, one gold dataset is used for credit calculation as a function of the total mass derived by the material declarations of the LCA datasets. While the model achieves a mass balance in the flow of gold, there is a discrepancy in the impact calculation that yields results where the credits of the small fraction of gold exceed or compensate a disproportionate fraction of the manufacturing. Given the dominance in this category by a single elementary flow where multiple technical and regional conditions are at play for the upstream versus the downstream and where characterization factors are still debated, robust conclusions cannot and should not be derived.

What can be learned from the resource use, mineral and metals is that gold recovery is important and that overall, product systems should strive to close material loops.

Table 4-1: LCIA results of monitor for GWP and other impact categories per functional unit (red color represents largest impact per row)

Scenario	Impact categories	Manufacturing	Distribution	Use	ARS	Total
Refurbishment	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.59E+03	1.62E+02	3.27E+03	-1.66E+02	4.85E+03
	EF 3.0 Acidification [Mole of H+ eq.]	8.71E+00	6.28E-01	4.93E+00	-2.24E+00	1.20E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	7.74E-03	2.86E-05	3.76E-03	8.53E-04	1.24E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.67E-07	7.22E-12	1.27E-08	8.99E-10	1.81E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	4.85E+00	7.83E-01	3.03E+00	-5.72E-01	8.09E+00
	EF 3.0 Resource use, fossils [MJ]	1.75E+04	2.21E+03	5.16E+04	-3.02E+03	6.82E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	8.81E-02	6.68E-06	6.01E-04	-6.85E-02	2.02E-02
	EF 3.0 Water use [m³ world equiv.]	1.35E+02	2.53E-01	6.98E+02	-3.01E+01	8.03E+02
Refurbishment with part replacement	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.59E+03	1.62E+02	3.27E+03	-1.39E+01	5.00E+03
	EF 3.0 Acidification [Mole of H+ eq.]	8.71E+00	6.28E-01	4.93E+00	-1.42E+00	1.29E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	7.74E-03	2.86E-05	3.76E-03	1.33E-03	1.29E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.67E-07	7.22E-12	1.27E-08	2.61E-08	2.06E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	4.85E+00	7.83E-01	3.03E+00	-1.41E-01	8.52E+00
	EF 3.0 Resource use, fossils [MJ]	1.75E+04	2.21E+03	5.16E+04	-1.28E+03	7.00E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	8.81E-02	6.68E-06	6.01E-04	-6.44E-02	2.44E-02
	EF 3.0 Water use [m³ world equiv.]	1.35E+02	2.53E-01	6.98E+02	-7.10E+00	8.26E+02
Part harvesting	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	2.54E+03	2.59E+02	3.28E+03	-4.71E+02	5.60E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.39E+01	1.00E+00	4.95E+00	-4.82E+00	1.51E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.24E-02	4.58E-05	4.90E-03	-1.24E-04	1.72E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	2.67E-07	1.16E-11	1.27E-08	-3.21E-08	2.48E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	7.75E+00	1.25E+00	3.05E+00	-1.48E+00	1.06E+01
	EF 3.0 Resource use, fossils [MJ]	2.80E+04	3.53E+03	5.16E+04	-7.68E+03	7.54E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.41E-01	1.07E-05	6.01E-04	-1.15E-01	2.63E-02
	EF 3.0 Water use [m³ world equiv.]	2.16E+02	4.05E-01	6.98E+02	-1.09E+02	8.06E+02
Recycling	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	2.54E+03	2.59E+02	3.28E+03	-2.05E+02	5.87E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.39E+01	1.00E+00	4.95E+00	-2.66E+00	1.72E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.24E-02	4.58E-05	4.90E-03	1.08E-04	1.74E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	2.67E-07	1.16E-11	1.27E-08	-1.08E-10	2.80E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	7.75E+00	1.25E+00	3.05E+00	-1.48E+00	1.06E+01
	EF 3.0 Resource use, fossils [MJ]	2.80E+04	3.53E+03	5.16E+04	-7.68E+03	7.54E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.41E-01	1.07E-05	6.01E-04	-1.15E-01	2.63E-02
	EF 3.0 Water use [m³ world equiv.]	2.16E+02	4.05E-01	6.98E+02	-1.09E+02	8.06E+02

Table 4-2: LCIA results of laptop for GWP and other impact categories per functional unit (red color represents largest impact per row)

Scenario	Impact categories	Manufacturing	Distribution	Use	ARS	Total
Refurbishment	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.12E+03	1.49E+01	9.05E+02	-5.77E+01	1.98E+03
	EF 3.0 Acidification [Mole of H+ eq.]	7.23E+00	4.19E-01	1.37E+00	-2.26E+00	6.75E+00
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.33E-02	3.25E-05	1.08E-03	2.70E-04	1.46E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	6.86E-07	9.53E-13	3.52E-09	6.97E-10	6.90E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	3.18E+00	3.18E-01	8.40E-01	-4.89E-01	3.85E+00
	EF 3.0 Resource use, fossils [MJ]	1.46E+04	1.87E+02	1.43E+04	-1.01E+03	2.80E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	6.39E-02	1.92E-06	1.66E-04	-8.57E-02	-2.17E-02
	EF 3.0 Water use [m³ world equiv.]	1.97E+02	3.81E-01	1.93E+02	-3.54E+01	3.56E+02
Refurbishment with part replacement	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.12E+03	1.49E+01	9.05E+02	7.47E+01	2.11E+03
	EF 3.0 Acidification [Mole of H+ eq.]	7.23E+00	4.19E-01	1.37E+00	-1.60E+00	7.41E+00
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.33E-02	3.25E-05	1.08E-03	2.69E-03	1.71E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	6.86E-07	9.53E-13	3.52E-09	1.47E-07	8.36E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	3.18E+00	3.18E-01	8.40E-01	-1.63E-01	4.17E+00
	EF 3.0 Resource use, fossils [MJ]	1.46E+04	1.87E+02	1.43E+04	7.09E+02	2.97E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	6.39E-02	1.92E-06	1.66E-04	-8.98E-02	-2.57E-02
	EF 3.0 Water use [m³ world equiv.]	1.97E+02	3.81E-01	1.93E+02	-1.89E+01	3.72E+02
Part harvesting	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.87E+03	2.50E+01	9.07E+02	-3.16E+02	2.48E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.21E+01	7.01E-01	1.37E+00	-4.77E+00	9.39E+00
	EF 3.0 Eutrophication, freshwater [kg P eq.]	2.22E-02	5.43E-05	1.46E-03	-1.23E-03	2.25E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.15E-06	1.59E-12	3.52E-09	-5.68E-08	1.09E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	5.31E+00	5.31E-01	8.44E-01	-1.40E+00	5.28E+00
	EF 3.0 Resource use, fossils [MJ]	2.44E+04	3.13E+02	1.43E+04	-4.47E+03	3.45E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.07E-01	3.21E-06	1.66E-04	-1.37E-01	-3.04E-02
	EF 3.0 Water use [m³ world equiv.]	3.30E+02	6.37E-01	1.93E+02	-8.17E+01	4.42E+02
Recycling	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.87E+03	2.50E+01	9.07E+02	-7.08E+01	2.73E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.21E+01	7.01E-01	1.37E+00	-2.69E+00	1.15E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	2.22E-02	5.43E-05	1.46E-03	1.28E-04	2.38E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.15E-06	1.59E-12	3.52E-09	-4.06E-11	1.15E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	5.31E+00	5.31E-01	8.44E-01	-1.40E+00	5.28E+00
	EF 3.0 Resource use, fossils [MJ]	2.44E+04	3.13E+02	1.43E+04	-4.47E+03	3.45E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.07E-01	3.21E-06	1.66E-04	-1.37E-01	-3.04E-02
	EF 3.0 Water use [m³ world equiv.]	3.30E+02	6.37E-01	1.93E+02	-8.17E+01	4.42E+02

Table 4-3: LCIA results of server for GWP and other impact categories per functional unit (red color represents largest impact per row)

Scenario	Impact categories	Manufacturing	Distribution	Use	ARS	Total
Refurbishment	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	6.02E+04	7.34E+01	1.37E+05	-1.89E+03	1.95E+05
	EF 3.0 Acidification [Mole of H+ eq.]	2.19E+02	3.99E-01	2.06E+02	-1.67E+01	4.09E+02
	EF 3.0 Eutrophication, freshwater [kg P eq.]	9.13E-02	1.77E-04	8.39E-02	-2.41E-03	1.73E-01
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	7.12E-07	4.97E-12	5.36E-07	-2.55E-09	1.25E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	1.29E+02	4.43E-01	1.27E+02	-1.01E+01	2.46E+02
	EF 3.0 Resource use, fossils [MJ]	8.72E+05	9.70E+02	2.17E+06	-2.15E+04	3.02E+06
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	3.02E+00	2.40E-05	2.53E-02	-3.48E+00	-4.37E-01
	EF 3.0 Water use [m³ world equiv.]	8.01E+03	2.22E+00	2.94E+04	-1.33E+03	3.61E+04
Refurbishment with part replacement	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	6.02E+04	7.34E+01	1.37E+05	6.26E+03	2.04E+05
	EF 3.0 Acidification [Mole of H+ eq.]	2.19E+02	3.99E-01	2.06E+02	6.68E+00	4.32E+02
	EF 3.0 Eutrophication, freshwater [kg P eq.]	9.13E-02	1.77E-04	8.39E-02	6.81E-03	1.82E-01
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	7.12E-07	4.97E-12	5.36E-07	6.79E-08	1.32E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	1.29E+02	4.43E-01	1.27E+02	4.09E+00	2.60E+02
	EF 3.0 Resource use, fossils [MJ]	8.72E+05	9.70E+02	2.17E+06	9.95E+04	3.14E+06
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	3.02E+00	2.40E-05	2.53E-02	-4.08E+00	-1.04E+00
	EF 3.0 Water use [m³ world equiv.]	8.01E+03	2.22E+00	2.94E+04	-5.77E+02	3.68E+04
Part harvesting	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	9.79E+04	1.19E+02	1.37E+05	-3.42E+04	2.01E+05
	EF 3.0 Acidification [Mole of H+ eq.]	3.56E+02	6.48E-01	2.06E+02	-1.19E+02	4.43E+02
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.48E-01	2.87E-04	8.77E-02	-4.65E-02	1.90E-01
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.16E-06	8.08E-12	5.36E-07	-3.20E-07	1.37E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	2.09E+02	7.20E-01	1.27E+02	-7.23E+01	2.64E+02
	EF 3.0 Resource use, fossils [MJ]	1.42E+06	1.58E+03	2.17E+06	-4.96E+05	3.09E+06
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	4.90E+00	3.90E-05	2.53E-02	-3.52E+00	1.41E+00
	EF 3.0 Water use [m³ world equiv.]	1.30E+04	3.60E+00	2.94E+04	-5.11E+03	3.73E+04
Recycling	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	9.79E+04	1.19E+02	1.37E+05	-2.58E+03	2.32E+05
	EF 3.0 Acidification [Mole of H+ eq.]	3.56E+02	6.48E-01	2.06E+02	-2.28E+01	5.40E+02
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.48E-01	2.87E-04	8.77E-02	-5.45E-03	2.31E-01
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.16E-06	8.08E-12	5.36E-07	-4.48E-09	1.69E-06
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	2.09E+02	7.20E-01	1.27E+02	-7.23E+01	2.64E+02
	EF 3.0 Resource use, fossils [MJ]	1.42E+06	1.58E+03	2.17E+06	-4.96E+05	3.09E+06
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	4.90E+00	3.90E-05	2.53E-02	-3.52E+00	1.41E+00
	EF 3.0 Water use [m³ world equiv.]	1.30E+04	3.60E+00	2.94E+04	-5.11E+03	3.73E+04

Table 4-4: LCIA results of desktop for GWP and other impact categories per functional unit (red color represents largest impact per row)

Scenario	Impact categories	Manufacturing	Distribution	Use	ARS	Total
Refurbishment	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	2.14E+03	7.29E+01	2.91E+03	-2.06E+02	4.92E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.09E+01	2.18E-01	4.39E+00	-1.92E+00	1.36E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	9.18E-03	7.34E-05	3.07E-03	2.57E-04	1.26E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.21E-07	4.22E-12	1.13E-08	8.02E-10	1.33E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	5.39E+00	2.74E-01	2.70E+00	-9.64E-01	7.40E+00
	EF 3.0 Resource use, fossils [MJ]	2.80E+04	9.89E+02	4.59E+04	-2.30E+03	7.26E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	2.91E-01	4.09E-06	5.35E-04	-2.95E-01	-4.13E-03
	EF 3.0 Water use [m³ world equiv.]	4.77E+02	2.86E-01	6.22E+02	-1.10E+02	9.89E+02
Refurbishment with part replacement	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	2.14E+03	7.29E+01	2.91E+03	1.21E+01	5.13E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.09E+01	2.18E-01	4.39E+00	-8.41E-01	1.46E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	9.18E-03	7.34E-05	3.07E-03	1.03E-03	1.34E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.21E-07	4.22E-12	1.13E-08	1.05E-08	1.43E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	5.39E+00	2.74E-01	2.70E+00	-4.55E-01	7.91E+00
	EF 3.0 Resource use, fossils [MJ]	2.80E+04	9.89E+02	4.59E+04	5.95E+02	7.55E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	2.91E-01	4.09E-06	5.35E-04	-2.87E-01	3.62E-03
	EF 3.0 Water use [m³ world equiv.]	4.77E+02	2.86E-01	6.22E+02	-7.24E+01	1.03E+03
Part harvesting	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	3.66E+03	1.25E+02	2.92E+03	-1.35E+03	5.35E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.86E+01	3.73E-01	4.41E+00	-8.39E+00	1.50E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.57E-02	1.26E-04	4.09E-03	-4.24E-03	1.57E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	2.07E-07	7.22E-12	1.13E-08	-5.10E-08	1.68E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	9.22E+00	4.69E-01	2.71E+00	-4.11E+00	8.29E+00
	EF 3.0 Resource use, fossils [MJ]	4.79E+04	1.69E+03	4.59E+04	-1.70E+04	7.85E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	4.97E-01	6.99E-06	5.35E-04	-5.44E-01	-4.65E-02
	EF 3.0 Water use [m³ world equiv.]	8.15E+02	4.89E-01	6.22E+02	-3.82E+02	1.06E+03
Recycling	IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	3.66E+03	1.25E+02	2.92E+03	-2.75E+02	6.43E+03
	EF 3.0 Acidification [Mole of H+ eq.]	1.86E+01	3.73E-01	4.41E+00	-2.53E+00	2.09E+01
	EF 3.0 Eutrophication, freshwater [kg P eq.]	1.57E-02	1.26E-04	4.09E-03	-3.63E-04	1.95E-02
	EF 3.0 Ozone depletion [kg CFC-11 eq.]	2.07E-07	7.22E-12	1.13E-08	-1.92E-10	2.18E-07
	EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	9.22E+00	4.69E-01	2.71E+00	-4.11E+00	8.29E+00
	EF 3.0 Resource use, fossils [MJ]	4.79E+04	1.69E+03	4.59E+04	-1.70E+04	7.85E+04
	EF 3.0 Resource use, mineral and metals [kg Sb eq.]	4.97E-01	6.99E-06	5.35E-04	-5.44E-01	-4.65E-02
	EF 3.0 Water use [m³ world equiv.]	8.15E+02	4.89E-01	6.22E+02	-3.82E+02	1.06E+03

The breakdown results of ARS can be found in Annex B6.

4.2. A Closer look at the Manufacturing Impact

Impact of the Refurbishment with part replacement and Part harvesting highly depends on individual replaced or harvested component in addition to the replacement/harvesting rate. A component with larger manufacturing burdens will lead to higher environmental burdens in the ARS processing process. Therefore, it's worthy to analyze the manufacturing impact of the major components for four devices. Table 4-5 summarizes the components with highest impact per device. This information can be useful as a way to prioritize components to salvage in ARS. Also, this information can be used to feed into product design as a way to enable lifetime extension on a component basis. Across devices, the mainboard and SSD tend to represent a significant share of impact and could be prioritized by ARS and product design. A detailed result of each component can be found in Annex B8.

In addition, it is worth noting that data wiping avoiding physical shredding of the component is of course more conducive to the goals of the ARS program.

Table 4-5: Components with higher environmental impact for four devices

Device	Components with higher impact
Monitor	Mainboard, Panel and Mechanical parts
Laptop	Mainboard and Battery
Desktop	SSD and PWB
Server	Mainboard, RAM and SSD

4.3. Sensitivity Analyses

4.3.1. Collection Rate in the Baseline Scenario

Sensitivity analyses were performed to test the variability of results to key assumptions. In this study, the baseline scenario with 40% collection rate is used as the benchmark for ARS scenarios. Considering the collection rate might have high variability and also that collection rates may increase in the future as a result of new policies, this sensitivity analysis varies the recycling rate between 0% and 100% to illustrate the full range of recycling. Figure 4-2 shows the change for the selected EF 3.0 impact categories for the monitor as a representation.

These results show that when changing the Baseline conditions to 100% collection rate, so that 100% of the device is sent to recycling as in an optimistic scenario, GWP is only reduced by 4%. Global Warming shows little sensitivity to the recycling rate because most of its impact is driven by energy consumption during manufacturing and use phase – two stages that remain the same regardless of the recycling rate at the EoL. However, other categories such as Eutrophication and Acidification show a greater sensitivity to recycling. Here, the impact can be reduced by 32% and 13% respectively when recycling rates increase. Increasing collection rate reduces Eutrophication and Acidification burden because of recycling credits associated with gold, silver, palladium and aluminum depending on the device. Therefore, these improvements should be interpreted with care as it is the result of substitution and thereby dependent on the specific previous metals datasets and technical/geographical conditions.

Similar patterns can be observed in the other 3 devices which can be found in Annex B7 where GWP shows little sensitivity to increased collection rate. The main lesson from this sensitivity analysis is that while improvements in municipal waste collection practices are important as in material circularity, this is not an immediate opportunity for decarbonization. Nevertheless, as material loops are closed, a greater share of secondary material is available, and this may lead to decarbonization upstream. However, only if post-secondary material is incorporated in manufacturing.

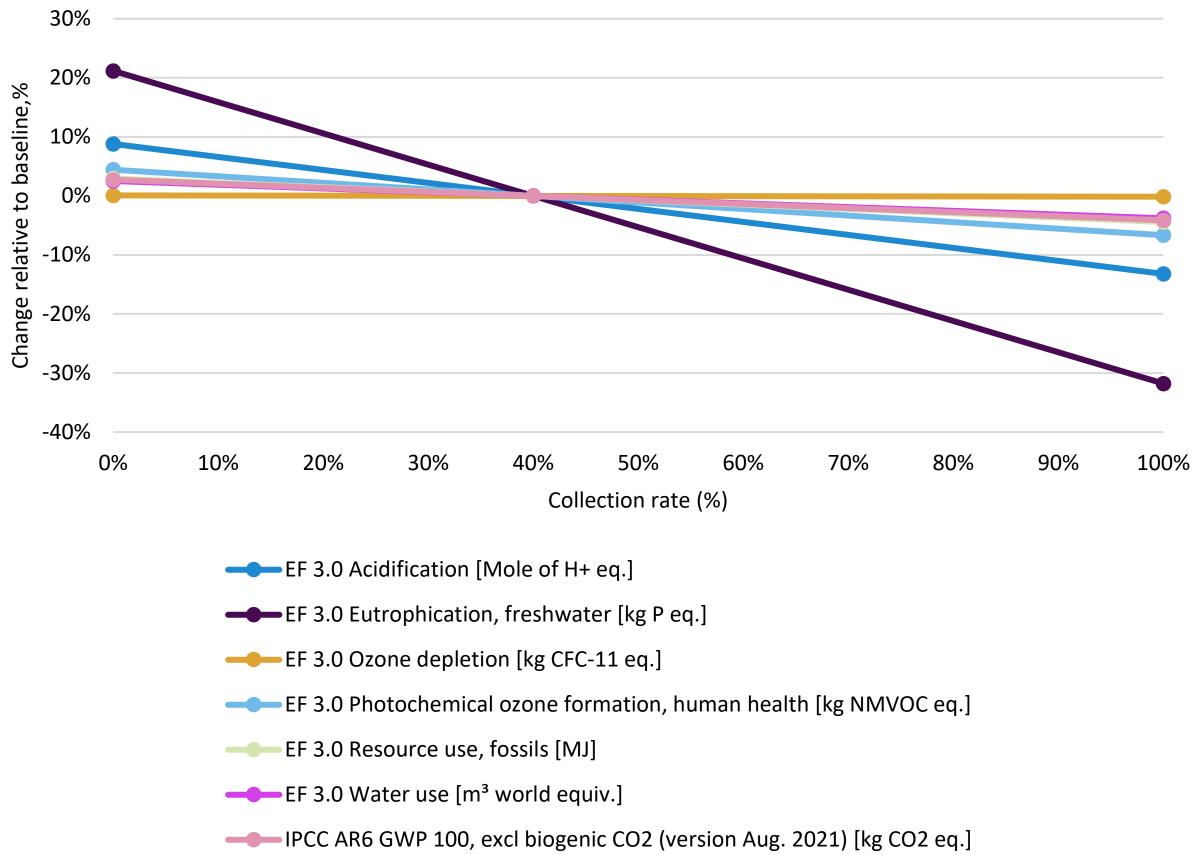


Figure 4-2 : Parameter sensitivity: collection rate in Baseline EoL scenario of monitor – collection rate

This study uses EPA statistics to define the baseline collection rate (40% recycling and 60% landfill), but in the case of enterprise EoL electronic devices, waste handlers can possibly direct all materials for recycling although there is no data to confirm this. If the baseline consisted of 100% recycling, the relative improvement of ARS would decrease slightly.

For GWP, the savings of refurbishment go between 16%-28% for baseline collection rate to 15%-26% considering 100% recycling across devices. For refurbishment with part replacement baseline savings for GWP range between 13% and 23%, but when the baseline is 100% recycling these are 12% to 21%. For part harvesting, GWP savings relative to the baseline case (between 6% to 18%) go down to 2% to 15%. Lastly, if the baseline consists of 100% recycling, the performance is very similar to ARS recycling (within 3%).

For other impact categories, the change pattern aligns with the sensitivity analysis of collection rate (Figure 4-2). For example, ODP has the lowest sensitivity in terms of collection rate, and therefore experiences negligible changes (less than 1%).

4.3.2. Lifetime Extension in ARS Refurbishment Scenarios

Results show that lifetime extension in the Refurbishment ARS scenario leads to the greatest impact reductions. The lifetime extension amount is based on the survey to EDPs and these show high variability. The 3-year lifetime extension across devices is chosen as a conservative assumption and this sensitivity analysis is included to illustrate how the environmental performance of Refurbishment in ARS scenarios changes with this assumption. Here, two additional lifetime extensions are modeled, namely 2 years and 4 years. Figure 4-3 displays the change in different impact categories taking the monitor as a reference. Results show that an even more conservative estimate of 2-year extension still leads to 15% savings in GWP and between 11%-32% in the other categories.

This sensitivity analysis also shows that as life extension increases, the improvement in impact (y-axis) is marginal. That is, while life extension may double – from 2 to 4 years – the reduction in impact does not. The ratio of improvement (impact reduction divided by the years) between a 2 year and 4 year life extension ranges between 1.3 (in Acidification) and 1.5 (in Eutrophication) which means that each unit of additional lifetime results in marginal improvements to different rates (for Global Warming the rate of improvement is 1.4). The reason for the marginal improvements as a function of lifetime extension is the fact that the use phase which makes up a large fraction of the total impact remains (Figure 4-1) unchanged on an annual basis. In fact, in the categories where use phase plays a bigger role, the sensitivity analysis results show less improvements compared to the Baseline EoL. The improvements from lifetime extension shown in Figure 4-3 also apply to lifetime extension in the first life. The study considers 3-4 years baseline lifetime depending on the device, but if the first life is extended it will show improvement as the impacts are evaluated relative to “total lifetime” (Eq. 2 in Section 3.5.1). The impact of the first life duration and how this affects the second life is not evaluated in this study. Overall, this scenario demonstrates how lifetime can be one of the greatest opportunities of improvement and it is the first few additional years that make the most difference.

Similar patterns can be observed in the other 3 devices for both Refurbishment and Refurbishment with part replacement scenarios which can be found in Annex B.

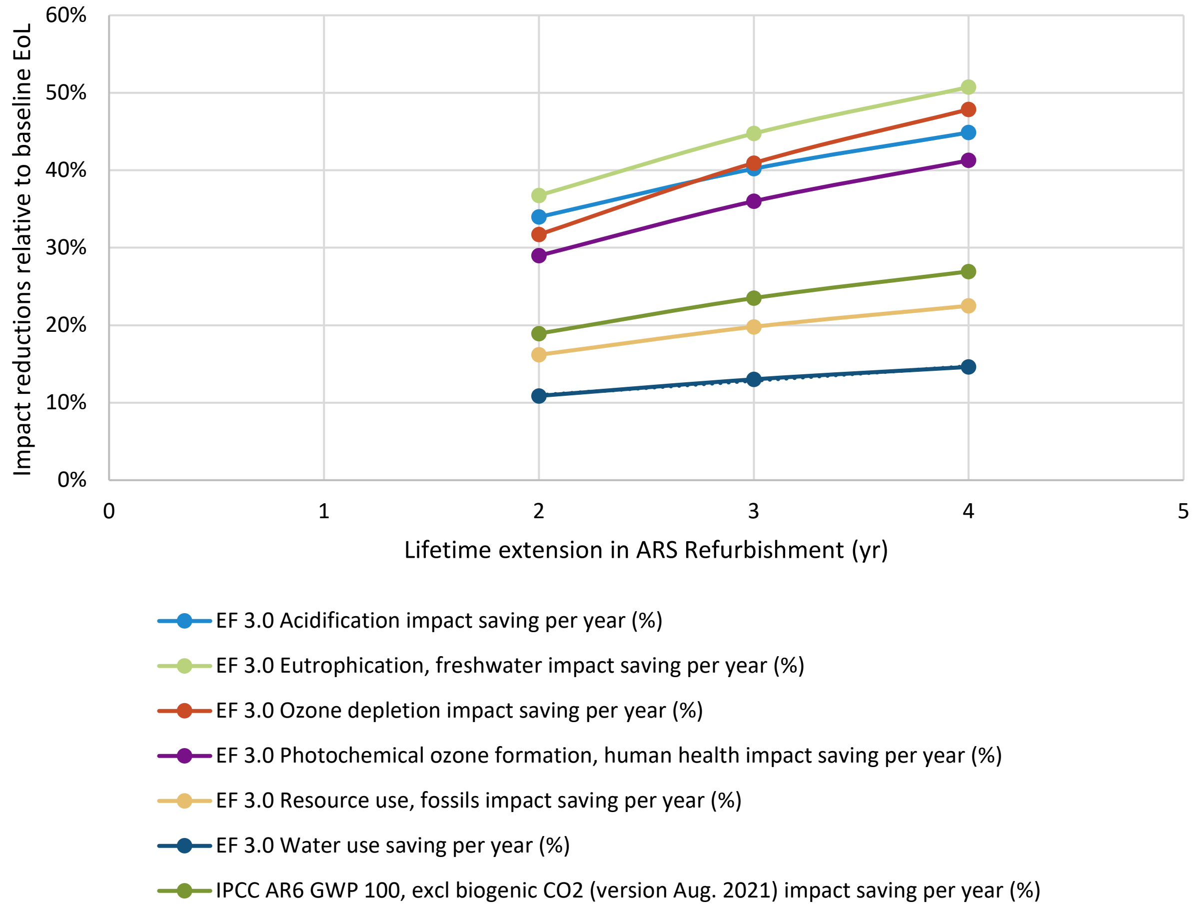


Figure 4-3: Parameter sensitivity of Refurbishment scenario of Monitor- lifetime extension

4.4. Scenario Analyses

Use phase shows significant impact to the LCA results for all EoL scenarios across four devices. The primary source of these impacts stem from the electricity used for the device's operation, which was modelled as US electricity grid mix. To explore the performance of ARS given a cleaner grid, this scenario analysis evaluates results using a mix of 50% solar energy and 50% US electricity grid. Figure 4-4 shows the GWP results across four devices and ARS scenarios and the same trend as with 100% US grid is observed: the greatest improvement occurs when devices undergo refurbishment and the main impacts in the life cycle of devices corresponds to manufacturing and use phase energy. That said, the GWP reduction is slightly greater given the condition of a cleaner grid because the use phase impacts are reduced and thus any savings in manufacturing are slightly amplified. Here the total GWP reduction from refurbishment scenarios (with and without part replacement) ranges between 16% and 33% - a couple percentages greater than before. This scenario analysis shows how ARS performance can improve slightly as the grid decarbonizes. That said, the difference is still within 10%, so that the main driver continues to be manufacturing impacts.

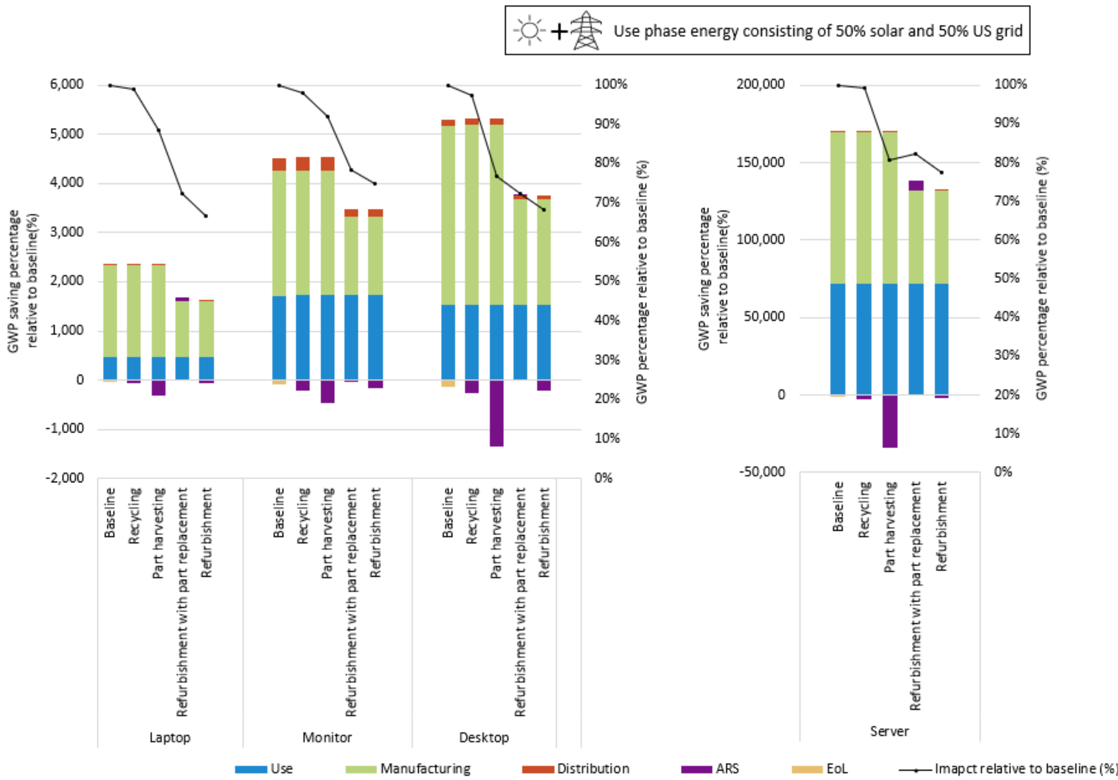


Figure 4-4: Life cycle GWP results per functional unit of five EoL scenarios of four devices and GWP percentage relative to baseline scenario using renewable energy in use phase

While adding solar energy to the grid does result in improvements most noticeably in GWP but other impact categories too. The study finds that ozone depletion impacts can increase due to emissions from solar panel manufacturing. However, ozone depletion is still reduced compared to a baseline case with no ARS. Figure 4-5 illustrates this tradeoff focusing on the monitor. Here, the savings are always positive, meaning that there is an advantage over the baseline case across the board. Also, the savings increase from the baseline grid to the grid with 50% solar – which is preferable. Only for ozone depletion, there is an opposite trend where a grid with increased solar power, results in less savings in ozone depletion (in red). The impact category of ozone depletion has a high degree of uncertainty, but this result is still useful as a way to pinpoint specific emissions of concern in manufacturing processes.

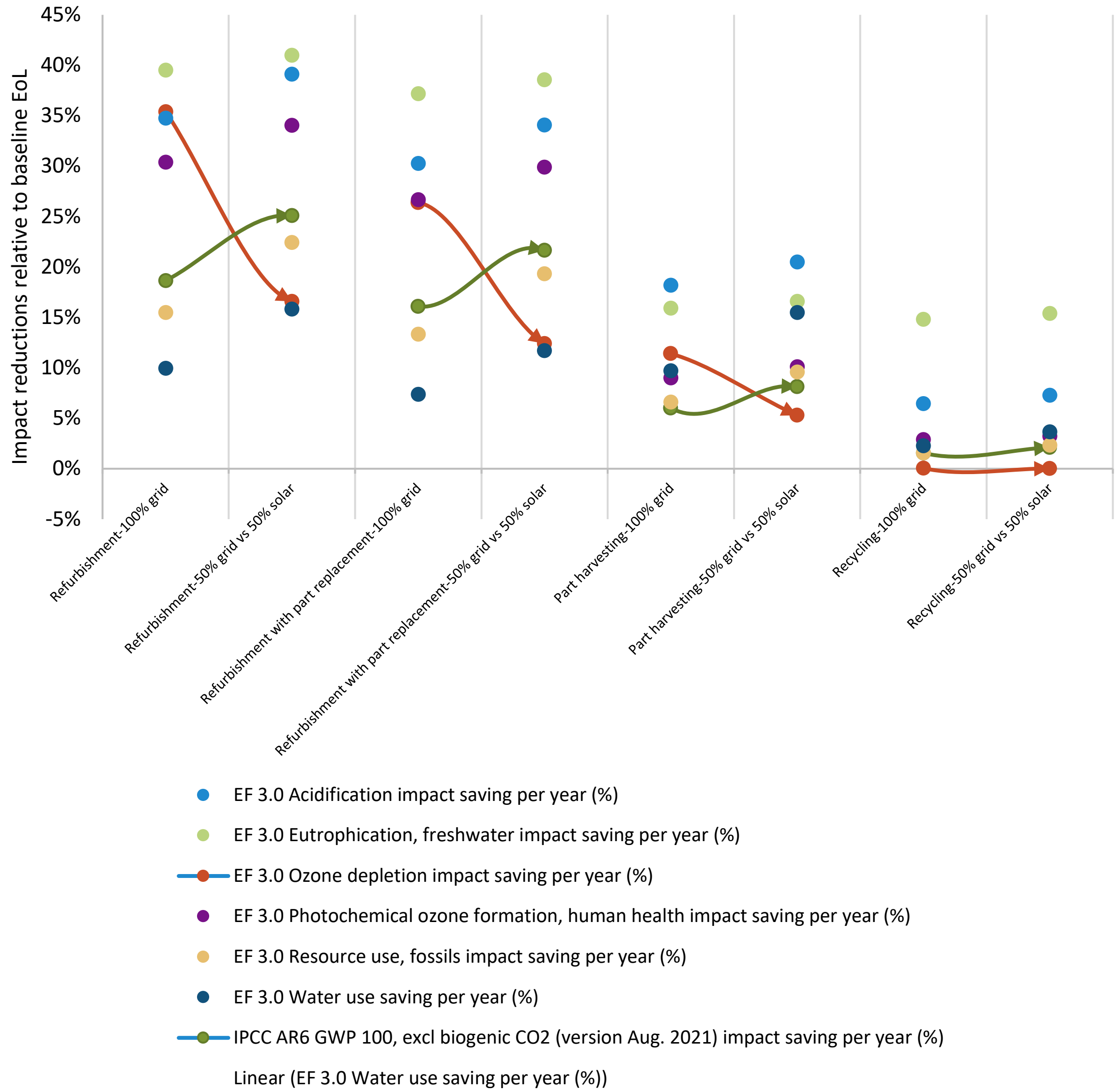


Figure 4-5: Impact reduction relative to baseline for all ARS scenarios -Monitor

5. Interpretation

5.1. Identification of Relevant Findings

All ARS scenarios show reductions to various extents compared to the Baseline scenario across all environmental indicators. The study finds that the greatest opportunity for environmental impact reduction lies in device lifetime extension. As a highlight, the ARS Refurbishment scenario can reduce between 16% to 28% of the cradle-to-grave GWP of the devices assessed in this study – this is a significant reduction given that it is an intervention at the end of life. The ARS Refurbishment with part replacement scenario leads to GWP reductions between 13% and 23%. In third place, the ARS Part harvesting scenario achieves a 6% to 18% GWP reduction. Recycling on its own leads to minimal GWP reductions (2% at most), but this action is highly relevant for closing material loops.

Given the fact that devices in better condition will be sent to Refurbishment followed by Refurbishment with part replacement, Part harvesting and Recycling, results show that environmental performance aligns with the salvage value of the devices in most of the cases. However, the environmental impact of Refurbishment with part replacement and Part harvesting scenarios highly depends on the replaced components and replacement rate, harvested components and Part harvesting rate, respectively, which might cause higher savings for Part harvesting than Refurbishment with part replacement, as was observed for the server.

5.2. Assumptions and Limitations

A key assumption and limitation of this study is that the calculation procedure makes the implicit assumption that the devices are only refurbished once. This represents a conservative starting point which calculates the minimum achievable reduction in environmental impacts. Every additional iteration of refurbishment will further increase these benefits. Expected benefits will come from a reduction in manufacturing on an annual basis and these would be marginal with each additional year as observed in the lifetime extension sensitivity analysis (Figure 4-3). As this program matures, future iterations of this study may need to account for multiple use cycles.

The data source for ARS is limited to five environmental disposition partners (EDP). The study excludes EDPs that either did not respond to the data collection survey or where data quality was low. The stages of data sanitization and verification processes are based on a single partner (DRC), because out of the five EDP's that provided quality data, only one provided these services. However, ARS processing steps including data sanitation and verification process represent a negligible contribution to life cycle impacts. The most influential parameters from EDPs is device lifetime extension, replacement and part harvesting rates. As such, future iterations in data collection would benefit from targeting these data points across a larger sample.

5.3. Results of Sensitivity Analyses and Scenario Analyses

Sensitivity analyses were performed to test the sensitivity of the results towards changes in parameter values that are based on assumptions or otherwise uncertain. The first sensitivity analysis evaluates the change in impact as a result of increased collection rates in the Baseline EoL scenario (Figure 4-2). This helps to show how the impact of the Baseline EoL scenario may change in the future with improved waste management practices (i.e. increased recycling).

The main lesson from this sensitivity analysis is that while improvements in municipal waste collection practices are important as in material circularity, it was not found to be an immediate opportunity for decarbonization. Impact categories that showed greater sensitivity to increased recycling rates was due to credits in recovered metals. Nevertheless, as material loops are closed, a greater share of secondary material is made available, and this may lead to decarbonization upstream. However, only if post-secondary material is incorporated in manufacturing.

The second sensitivity analysis takes a closer look at the potential improvements from ARS Refurbishment given different lifetime extension assumptions (from 2 to 4 years) (Figure 4-3). Results show improvements across the board because lifetime extension reduces manufacturing impacts per functional unit, but these improvements occur at a marginal rate with each additional year because use phase impacts remain unchanged. Overall, lifetime extension is the single most effective action for impact reduction.

The scenario analysis evaluates the potential savings of using renewable energy (50% solar energy) in the product use phase (Figure 4-4 and Figure 4-5). It was found that using renewable energy in use phase can bring more savings for all ARS scenarios.

5.4. Data Quality Assessment

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the MLC 2022 database were used. The LCI datasets from the MLC 2022 database are widely distributed and used with the LCA FE 10 Software. The datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

The assessment of the results is based on ISO 14044, Annex B where "very high" is defined as having significant influence (most important); "high" as having relevant influence (very important); "moderate" as having some influence (fairly important); and "low" as having minor to negligible influence (little and not important).

5.4.1. Precision and Completeness

- ✓ **Precision:** Precision is considered very high because relevant foreground data are measured or calculated based on primary information sources of the owner of the technology. Variations across different suppliers were balanced out by using average. All background data are sourced from MLC databases with documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. No data was knowingly omitted. Completeness of foreground unit process data is very high. All background data are sourced from MLC databases with the documented completeness.

5.4.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the MLC databases. Therefore consistency is rated to be very high

- ✓ **Reproducibility:** Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modeling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modeling approaches. Reproducibility is rated high as long as reports are made available.

5.4.3. Representativeness

- ✓ **Temporal:** All primary data were collected for the year 2022. All secondary data come from the MLC 2022 databases and are representative of the years from 2018 to 2022. As the study intended to compare the product systems for the reference year 2022, temporal representativeness is considered to be high.
- ✓ **Geographical:** All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Geographical representativeness is considered high.
- ✓ **Technological:** All primary and secondary data were modeled to be specific to the technologies or technology mixes under study. Where technology-specific data was unavailable, proxy data was used. Technological representativeness is considered high.

5.5. Model Completeness and Consistency

5.5.1. Completeness

All relevant process steps for each product system were considered and modeled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regard to the goal and scope of this study.

5.5.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimized by using LCI data from the MLC 2022 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.6. Conclusions, Limitations, and Recommendations

5.6.1. Conclusions

Overall, results show that on a life cycle basis, the impact of the four devices is driven by manufacturing and use. When focusing on end-of-life management interventions, results showed that all of the ARS scenarios represent an improvement relative to the Baseline case. Within the ARS scenarios, the greatest opportunity for ARS is in enabling device lifetime extension which occurs with Refurbishment and Refurbishment with part replacement. The general rank of ARS scenarios is Refurbishment, Refurbishment with part replacement, Part harvesting and Recycling. Life extension represents a direct reduction of manufacturing impacts with minimal efforts (Refurbishment has less inputs, while Refurbishment with part replacement still requires re manufacturing of some components). Part harvesting and Recycling reductions as compared to the Baseline EoL scenario are a result of credits – and these tend to be lower in magnitude.

5.6.2. Limitations

The main limitation of this study is that it is based on a limited number of EDPs and that the end-of-life of devices is highly variable (device condition, replacement and part harvesting rates, consumer behaviors and device lifetime extension). Nonetheless, the scenarios presented in this study identify the main parameters and are capable of presenting an illustrative case study based on field data that can help identify preferred scenarios and improvement avenues.

The second limitation is that the calculation procedure accounts for one single refurbishment cycle, when in reality devices could possibly be refurbished more than once – thus enhancing potential savings. As the ARS program matures, a future iteration of this study may need to account for a higher number of cycles.

5.6.3. Recommendations

Recommendations for the ARS program consist of actions that maximize device lifetime such as optimizing the sorting and grading step to increase product refurbishment rates. Lifetime extension is an effort that starts at the early design stages and continues through every phase of the product. With a long-term strategy in mind, the ARS program can work with the design teams to understand and address the limitations to higher levels of circularity. Some factors hindering device Refurbishment/Refurbishment with part replacement may stem from user behavior and so the ARS team in this case, can provide recommendations for consumers and work with marketing to possibly reward certain consumer practices. The ARS program has a great opportunity to engage other areas of Dell (design, marketing, consumer outreach), to evolve the program and increase its effectiveness. For Dell this would represent real life cycle management where end-of-life and product design work together.

Considering the ARS program will continue to mature, there are some dynamics that would be beneficial to understand, and this would require additions to the methodology. The first recommendation is to analyze the break-even point (environmental and economic) of the Refurbishment with part replacement and Part harvesting and this way understand the components to target for Refurbishment with part replacement versus Part harvesting. Components that have higher manufacturing burdens shall be targeted for part harvesting and avoid being replaced. Annex B8 provides the manufacturing impact of each component for four devices for future reference. Another possibility is to evaluate combined interventions where parts harvested can be used in Refurbishment with part replacement and a third layer to the study would be that of evaluating multiple ARS cycles.

References

André, Harpus, Maria Ljunggren Söderman, and Anders Nordelöf. 2019. "Resource and environmental impacts of using second-hand laptop computers: A case study of commercial reuse." *Waste Management* 268-279.

AWARE. 2017. "The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE)." *The International Journal of Life Cycle Assessment.*

Bare, Jane. 2012. *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) - Software Name and Version Number: TRACI version 2.1 - User's Manual.* Washington, D.C.: U.S. EPA.

Boulay, A.-M., J. Bare, L. Benini, M. Berger, M. J. Lathuillière, A. Manzardo, M. Margni, M. Motoshita, M. Núñez, A. V. Pastor, B. Ridoutt, T. Oki, S. Worbe and S. Pfister. 2017. "The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE)." *The International Journal of Life Cycle Assessment.*

BSI. 2012. *PAS 2050-1:2012: Assessment of life cycle greenhouse gas emissions from horticultural products.* London: British Standards Institute.

CEN. 2019. *EN15804:2012+A2 2019, Sustainability of construction works -Environmental product declarations -Core rules for the product category of construction products.*

Dell Inc. 2019. "Partner Standard Operating Procedures for Asset Recovery Services Standard Offer PSOW."

Drielsmaa, JA, AJ Russell-Vacari, T Drnek, T Brady, P Weihed, M Mistry, and L Perez Simbor. 2016. "Mineral resources in life cycle impact assessment—defining the path forward." *International Journal of Life Cycle Assessment* 85-105.

EPA. 2018. *Facts and Figures about Materials, Waste and Recycling, Durable Goods: Product-Specific Data.* https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/durable-goods-product-specific-data.

EPA. 2012. *Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) – User's Manual.* Washington, D.C.: U.S. EPA.

Eurostat. 2018. *Product Datasets (Recycling of e-waste).* https://ec.europa.eu/eurostat/web/products-datasets/-/cei_wm050.

Fantke, P, Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., McKone, T. 2016. "Health Impacts of Fine Particulate Matter." In *Global Guidance for Life Cycle Impact Assessment Indicators Volume 1*, by UNEP-SEATC Life Cycle Initiative. UNEP.

Graedel, TE, and BK Reck. 2015. "Six Years of Criticality Assessments - What Have We Learned So Far?" *Journal of Industrial Ecology.* doi:10.1111/jiec.12305.

Guinée, J. B., M. Gorrée, R. Heijungs, G. Huppes, R. Kleijn, A. de Koning, L. van Oers, et al. 2002. *Handbook on life cycle assessment. Operational guide to the ISO standards.* Dordrecht: Kluwer.

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 - Agriculture, Forestry, and Other Land Use.* Geneva, Switzerland: IPCC.

IPCC. 2013. *Climate Change 2013: The Physical Science Basis.* Genf, Schweiz: IPCC.

IPCC. 2013. *Climate Change 2013: The Physical Science Basis.* Geneva, Switzerland: IPCC.

IPCC. 2021. "Climate Change 2021: The Physical Science Basis. Intergovernmental Panel on Climate Change (IPCC)."

ISO. 2006. *ISO 14040: Environmental management – Life cycle assessment – Principles and framework.* Geneva: International Organization for Standardization.

ISO. 2006. *ISO 14044: Environmental management – Life cycle assessment – Requirements and guidelines.* Geneva: International Organization for Standardization.

JRC. 2010. *ILCD Handbook: General guide for Life Cycle Assessment – Detailed guidance. EUR 24708 EN.* 1st. Luxembourg: Joint Research Centre.

JRC. 2018. "Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment methods, Version 2, from ILCD to EF 3.0."

Nassar, NT, R Barr, M Browning, Z Diao, E Friedlander, EM Harper, C Henly, et al. 2012. "Criticality of the Geological Copper Family." *Environmental Science & Technology* 1071-1078.

Pfister, Stephan, Annette Koehler, and Stefanie Hellweg. 2009. "Assessing the Environmental Impacts of Freshwater Consumption in LCA." *Environ. Sci. Technol., 43(11)* 4098–4104.

Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O. 2008. "The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA." *International Journal of Life Cycle Assessment* 13: 477-486.

Rosenbaum, R. K., T. M. Bachmann, L. Swirsky Gold, M. Huijbregts, O. Jolliet, R. Juraske, A. Koehler, et al. 2008. "USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment." *Int J Life Cycle Assess, 13(7)* 532–546.

Seppälä J., Posch M., Johansson M. and Hettelingh J.P. 2006. "Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicato." *International Journal of Life Cycle Assessment* 11 (6): 403-416.

Sphera. 2020. *GaBi LCA Database Documentation.* http://www.gabi-software.com/america/support/gabi/.

Sphera. 2023a. "LCA of 4 Laptops, Latitude 5430 , Chromebook 3110, Precision 7670, and Alienware Horizon 15 MLK PLT C1." Slide deck.

Sphera. 2022b. "LCA of Dell OptiPlex 7090 SFF."

Sphera. 2022a. "LCA of two Dell Display products."

—. 2023b. *Life Cycle Assessment Datasets.* https://sphera.com/product-sustainability-gabi-data-search/.

Sphera. 2019. "Life Cycle Assessment of Dell R740."

Struijs, J., Beusen, A., van Jaarsveld, H. and Huijbregts, M.A.J. 2009. "Aquatic Eutrophication. Chapter 6 in: ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. ."

van Oers, L., A. de Koning, J. B. Guinée, and G. Huppes. 2002. *Abiotic resource depletion in LCA.* The Hague: Ministry of Transport, Public Works and Water Management.

Van Zelm R., Huijbregts M.A.J., Den Hollander H.A., Van Jaarsveld H.A., Sauter F.J., Struijs J., Van. 441-453. "European characterisation factors for human health." *Atmospheric Environment* 42.

WRI. 2011. *GHG Protocol Product Life Cycle Accounting and Reporting Standard.* Washington D.C.: World Resource Institute.

Annex A: Critical Review Statement

Critical Review Statement

Dell Asset Recovery Services (ARS) Life Cycle Assessment

Commissioned by: Dell Technologies

Conducted by: Sphera

Reviewed by: Prof. Colin Fitzpatrick, University of Limerick, Ireland

Reference: ISO 14040 (2006): Environmental Management – Life Cycle Assessment- Principles and Framework

ISO 14044 (2006): Environmental Management – Life Cycle Assessment – Requirements and Guidelines

ISO 14067 (2018): Greenhouse gases – Carbon footprint of products – requirements and guidelines for quantification

ISO/TS 14071 (2014): Environmental Management – Life Cycle Assessment- Critical Review Processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

Scope of the critical review

The reviewer had the task to assess whether

- The methods used to carry out the LCA are consistent with the international standards ISO 14040, ISO 14044 & ISO 14067
- The methods used to carry out the LCA are scientifically and technically valid
- The data used are appropriate and reasonable in relation to the goal of the study
- The interpretations reflect the limitations identified and the goal of the study
- The study report is transparent and consistent

The analysis and verification of individual datasets is outside the scope of this review.

The review process

The review process was co-ordinated by Sphera and was performed subsequent to the study with feedback from the reviewer incorporated into the final report by the LCA team.

The first complete draft of the report was made available on August 24th 2023.

This was followed by a video call on August 30th 2023 where the project was discussed thoroughly including approaches to assumptions and queries based on the first reading of the report.

A series of comments on the draft report was returned on August 31st. These comments were all addressed in the final report which was sent through on October 16th 2023.

General Evaluation

This evaluation is based on the draft final report received on October 16th 2023.

The goal of the study is clear and well expressed.

It aims to evaluate the environmental impacts and benefits of using Dell Asset Recovery Services (ARS) for laptops, desktops, monitors and servers. ARS scenarios include refurbishment, refurbishment with part replacement, part harvesting and recycling which are typical processes that take place at end of use in this situation.

The functional unit is clearly defined. The assumptions about lifetimes extension are reasonable and based on input from Dell ARS partners.

The study serves to identify hotpots across the value chain and to inform customers and internal stakeholders of potential areas for improvement.

The system boundary appropriately includes all major life cycle stages from manufacture through to end-of-life and includes ARS treatment processes and packaging during reverse logistics. The geographical scope considers device use and ARS in the United States and transportation distance & modes are appropriate.

It includes a very thorough sensitivity analysis which is highly appropriate considering the level of variability in devices with present at ARS sites. These include collection rates and extent of lifetime extension.

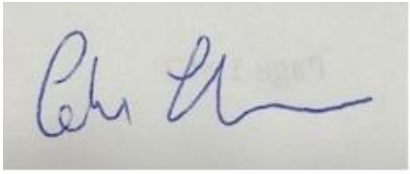
It also adopts a prospective approach and considers how ARS would perform with a future cleaner electricity grid in the US.

The data supports the recommendations that actions that maximise device lifetimes be encouraged. These include both at the ARS site, with Dell design teams and with Dell customers.

The team was at all times very open and receptive to my comments and all were addressed to my full satisfaction. They were also very open in demonstrating all aspects of the models employed as part of the calculations.

Conclusion

The study has been carried out in full conformity with ISO 14040, ISO 14044 and ISO 14067. The critical reviewer found the overall quality and rigour of the methodology and its execution to be very adequate for the purposes of this study. The study is reported in a comprehensive manner and is transparent in its scope and methodologically choice.



Colin Fitzpatrick

22nd October 2023

<u>Reviewer Credentials</u>

Colin Fitzpatrick is an Associate Professor in the Department of Electronic & Computer Engineering at the University of Limerick, Ireland. He has been active in research in the area of electronics and the environment for more than 20 years and has published widely in this field. His most prominent work in LCA has been in the area of evaluation of environmental impacts of repurposing of IT equipment and in the reuse of large household appliances. He has taught LCA as part of courses at the University of Limerick since 2004.

For further information see: https://www.linkedin.com/in/colin-fitzpatrick-b522222a/

Annex B: Detailed Results

Annex B1

Annex B2 shows some foreground data of this study. Table B 1 to Table B 4 presents the material composition of four devices and their corresponding end-of-life fate. Table B 5 shows input and output data of recycling processes. Table B 6 shows the transportation distance of the ARS take-back program.

Table B 1 Material composition of the monitor

Component	Material	Material content [kg]				
		Housing and stand base	Panel	Other	Total	EoL fate
Non-PCBA	Plastic	1.30E+00	5.57E-01	6.38E-01	**2.49E+00**	Incineration with energy recovery
	Aluminum	1.42E+00	-	-	**1.42E+00**	Recycling with material credit
	Steel	1.73E+00	-	2.00E-03	**1.73E+00**	Recycling with material credit
	Copper	-	-	-	**1.59E-01**	Recycling with material credit
PCBA	Copper	-	2.02E-02	2.30E-01	**2.50E-01**	Recycling with material credit
	Gold	-	3.49E-06	5.37E-05	**5.72E-05**	Recycling with material credit
	Palladium	-	1.64E-06	7.71E-05	**7.87E-05**	Recycling with material credit
	Platinum	-	9.01E-08	2.46E-06	**2.55E-06**	Recycling with material credit
	Silver	-	1.61E-05	1.01E-03	**1.03E-03**	Recycling with material credit
	Other	-	6.53E-01	-	**6.53E-01**	Incineration with energy recovery
Packaging	Paper (in packaging)	-	-	2.67E+00	**2.67E+00**	Incineration with energy recovery
	Plastic (in packaging)	-	-	5.07E-02	**5.07E-02**	Incineration with energy recovery

Component	Material	Material content [kg]			
Total weight	Total component	4.44E+00	1.23E+00	3.70E+00	**9.37E+00**

Table B 2 Material composition of the server

Component	Material	Material content [kg]								
		Memory (DDR)	**Solid-state drive**	**PSU**	**Housing**	**Mainboard**	**Heat Sink**	**Other**	**Total**	**EoL fate**
Non-PCBA	Plastic	-	8.35E-01	2.70E-01	5.52E-01	-	-	9.94E-01	**2.65E+00**	Incineration with energy recovery
	Aluminum	-	-			-	3.30E-01	3.36E-01	**6.66E-01**	Recycling with material credit
	Steel	-	-	1.10E+00	1.09E+01	-	-	1.67E+00	**1.37E+01**	Recycling with material credit
PCBA	Copper	4.74E-03	1.82E-01	4.80E-01		9.23E-01	-	1.19E+00	**2.78E+00**	Recycling with material credit
	Gold	1.88E-04	2.72E-03	-	-	2.22E-05	-	3.68E-04	**3.29E-03**	Recycling with material credit
	Palladium	2.17E-06	4.19E-05	-	-	1.43E-05	-	5.54E-05	**1.14E-04**	Recycling with material credit
	Platinum	9.71E-08	0.00E+00	-	-		-	2.87E-06	**2.97E-06**	Recycling with material credit
	Silver	2.86E-05	1.02E-03	-	-	1.80E-03	-	1.49E-03	**4.34E-03**	Recycling with material credit
	Other	1.20E-02	1.82E-01	1.14E+00	4.90E-03	1.73E+00	-	-	**2.58E+00**	Incineration with energy recovery
Packaging	Paper (in packaging)	-	-	-	-	-	-	5.67E+00	**5.67E+00**	Incineration with energy recovery
	Plastic (in packaging)	-	-	-	-	-	-	1.44E+00	**1.44E+00**	Incineration with energy recovery
Total weight	Total component	1.70E-02	1.20E+00	2.99E+00	1.15E+01	2.65E+00	3.30E-01	1.08E+01	**2.95E+01**	

Table B 3 Material composition of the desktop

Component	Material	Material content [kg]									
		Mainboard	Powerboard	Memory	SSD	ODD	HDD	Mechanical	Other	Total	EoL fate
Non-PCBA	Plastic	2.66E-02	3.07E-03	-	-	-	-	2.84E-01	-	3.14E-01	Incineration with energy recovery
	Aluminum	2.40E-03	3.36E-02	-	-	-	-	1.92E-01	-	2.28E-01	Recycling with material credit
	Steel	3.60E-02	4.57E-03	-	-	-	-	2.52E+00	-	2.56E+00	Recycling with material credit
	Copper	-	-	-	-	-	-	-	1.43E-01	1.43E-01	Recycling with material credit
PCBA	Copper	7.02E-02	1.90E-01	-	7.30E-03	7.66E-03	9.11E-03	-	4.86E-02	3.33E-01	Recycling with material credit
	Gold	6.10E-05	2.00E-06	4.36E-05	2.29E-05	2.34E-05	4.10E-06	-	1.05E-04	2.62E-04	Recycling with material credit
	Palladium	5.30E-06	3.00E-06	1.27E-08	2.72E-08	1.33E-08	6.20E-09	-	3.14E-06	1.15E-05	Recycling with material credit
	Platinum	-	-	-	-	-	2.00E-06	-	7.00E-08	2.07E-06	Recycling with material credit
	Silver	2.50E-04	1.67E-04	2.02E-05	5.39E-05	7.27E-05	7.50E-06	-	3.21E-04	8.92E-04	Recycling with material credit
	Other	1.75E-01	-1.42E-04	3.14E-02	7.62E-03	5.99E-01	9.09E-02	-	3.92E-01	1.29E+00	Incineration with energy recovery
Packaging	Paper (in packaging)	-	-	-	-	-	-	-	1.63E+00	1.63E+00	Incineration with energy recovery
	Plastic (in packaging)	-	-	-	-	-	-	-	1.19E-02	1.19E-02	Incineration with energy recovery
Total weight	Total component	3.10E-01	2.31E-01	3.15E-02	1.50E-02	6.07E-01	1.00E-01	2.99E+00	2.23E+00	6.51E+00	

Table B 4 Material composition breakdown of Laptop

Compo-nent	Material	Material content [kg]												
		Memory (DDR)	Main-board	Speaker	SSD	Keyboard	Touch-pad	PSU	Main bat-tery	Display	Mechani-cal	Other	Total	EoL fate
Non-PCBA	Plastic	8.00E-05	4.78E-03	4.84E-03	1.80E-04	4.72E-02	5.06E-03	7.20E-02	-	4.38E-03	4.77E-01	3.98E-03	6.20E-01	Incinera-tion with energy recovery
	Aluminum	-	6.20E-04	2.00E-06	1.10E-04	2.85E-02	3.90E-04	1.17E-02	-	2.37E-02	1.57E-02	4.88E-03	8.56E-02	Recycling with ma-terial credit
	Steel	-	6.46E-03	3.18E-03	9.60E-04	5.14E-03	2.91E-02	-	4.20E-04	4.60E-02	2.85E-02	1.30E-03	1.21E-01	Recycling with ma-terial credit
	Copper	-	-	2.80E-04	3.09E-03	-	-	-	-	-	-	3.61E-02	3.95E-02	Recycling with ma-terial credit
	Other	-	-	-	-	-	-	-	-	-	-	1.50E-03	1.50E-03	Landfill
PCBA	Copper	2.02E-03	4.04E-02	-	8.27E-04	9.51E-04	2.52E-03	1.47E-02	1.60E-02	4.47E-03	-	7.92E-04	8.27E-02	Recycling with ma-terial credit
	Gold	3.57E-06	5.02E-05	-	9.05E-06	2.25E-07	1.84E-06	6.99E-06	3.77E-08	4.08E-06	-	1.25E-07	7.61E-05	Recycling with ma-terial credit
	Palladium	8.16E-06	5.98E-05	-	2.43E-06	2.67E-06	1.93E-06	2.38E-05	-	7.45E-06	-	1.65E-07	1.06E-04	Recycling with ma-terial credit
	Platinum	1.70E-07	2.98E-06	-	1.28E-07	0.00E+00	1.64E-08	5.76E-07	-	2.84E-07	-	6.00E-10	4.15E-06	Recycling with ma-terial credit
	Silver	1.17E-04	1.12E-03	-	1.50E-04	1.64E-04	5.28E-05	1.18E-04	-	9.34E-05	-	9.44E-07	1.82E-03	Recycling with ma-terial credit
	Other	5.55E-03	9.65E-02	5.40E-03	4.25E-03	2.80E-02	2.19E-02	-	1.97E-01	2.11E-01	-	3.78E-02	5.92E-01	Incinera-tion with

Compo-nent	Material	Material content [kg]												
														energy recovery
Packaging	Paper (in packaging)	-	-	-	-	-	-	-	-	-	-	6.68E-01	6.68E-01	Incinera-tion with energy recovery
	Plastic (in packaging)	-	-	-	-	-	-	-	-	-	-	8.00E-03	8.00E-03	Incinera-tion with energy recovery
Total weight	Total compo-nent	7.78E-03	1.50E-01	1.37E-02	9.58E-03	1.10E-01	5.90E-02	8.36E-02	2.13E-01	2.90E-01	5.21E-01	7.62E-01	2.22E+00	

Table B 5 Input and output of Sphera end-of-life recycling process

Device	Inputs/Outputs	Material/ Process	Units	Amount
Monitor	**Inputs**	Monitor (packaging incl.)	kg	9.37
	Outputs	Material recycling (non-PCBA)	kg	3.31
		PCBA shredding	kg	0.85
		Energy recovery	kg	5.21
		Landfill	kg	-
Laptop	**Inputs**	Laptop (packaging incl.)	kg	2.22
	Outputs	Material recycling (non-PCBA)	kg	0.25
		PCBA shredding	kg	0.68
		Energy recovery	kg	1.30
		Landfill	kg	0.0015
Server	**Inputs**	Server (packaging incl.)	kg	29.47

Device	Inputs/Outputs	Material/ Process	Units	Amount
	Outputs	Material recycling (non-PCBA)	kg	14.38
		PCBA shredding	kg	5.36
		Energy recovery	kg	9.76
		Landfill	kg	-
Desktop	**Inputs**	Desktop (packaging incl.)	kg	6.74
	Outputs	Material recycling (non-PCBA)	kg	2.93
		PCBA shredding	kg	1.63
		Energy recovery	kg	1.96
		Landfill	kg	-

Table B 6 Transportation distance of Dell EoL take-back program

Device	Transportation	Mode	Distance	Unit	Data Source
Monitor	Customer site to processing site	Truck	235.00	km	EDP
	Discarded parts to EoL (Refurbishment with part replacement)	Truck	833.00	km	EDP
	Discarded parts to EoL (Part harvesting)	Truck	465.00	km	EDP
Laptop	On-site data sanitization to EoL	Truck	40.00	km	EDP
	Customer site to processing site	Truck	240.20	km	EDP
	2nd data sanitization to EoL	Truck	671.00	km	EDP

Device	Transportation	Mode	Distance	Unit	Data Source
	Discarded parts to EoL (Refurbishment with part replacement)	Truck	309.00	km	EDP
	Discarded parts to EoL (Part harvesting)	Truck	309.00	km	EDP
Server	On-site data sanitization to EoL	Truck	40.00	km	EDP
	Customer site to processing site	Truck	240.20	km	EDP
	2nd data sanitization to EoL	Truck	763.00	km	EDP
	Discarded parts to EoL (Refurbishment with part replacement)	Truck	516.50	km	EDP
	Discarded parts to EoL (Part harvesting)	Truck	516.50	km	EDP
Desktop	On-site data sanitization to EoL	Truck	40.00	km	EDP
	Customer site to processing site	Truck	235.00	km	EDP
	2nd data sanitization to EoL	Truck	663.75	km	EDP
	Discarded parts to EoL (Refurbishment with part replacement)	Truck	299.33	km	EDP
	Discarded parts to EoL (Part harvesting)	Truck	431.67	km	EDP

Annex B2

Annex B2 shows the LCI results of four devices. As the complete inventory comprises hundreds of flows, Table B 7 to Table B 10 only display a selection of flows based on their relevance to the subsequent impact assessment in order to provide a transparent link between the inventory and impact assessment results.

Table B 7 LCI results of Monitor (in kg)

Type	Flow	Baseline	ARS Refurbishment	ARS Refurbishment with part replacement	ARS Part harvesting	ARS recycling
Resources	Water use	3.27E+07	3.36E+07	3.60E+07	2.23E+07	2.89E+07
	Wood	2.15E-11	3.64E-11	3.64E-11	2.21E-11	2.18E-11
	Crude oil	1.13E+03	1.18E+03	1.28E+03	9.56E+02	1.09E+03
	Hard coal	5.40E+03	7.33E+03	7.45E+03	5.07E+03	5.28E+03
	Natural gas	2.91E+03	4.04E+03	4.16E+03	2.73E+03	2.89E+03
	Uranium	1.43E-01	2.10E-01	2.11E-01	1.39E-01	1.41E-01
Emissions to air	CO_2	2.53E+04	3.38E+04	3.48E+04	2.38E+04	2.50E+04
	CH_4	6.54E+01	8.57E+01	8.83E+01	6.25E+01	6.48E+01
	N_2O	5.12E-01	6.33E-01	6.64E-01	4.67E-01	5.05E-01
	NO_x	4.66E+01	5.23E+01	5.48E+01	4.26E+01	4.53E+01
	SO_2	4.22E+01	4.18E+01	4.52E+01	3.19E+01	3.85E+01
	NMVOC	4.68E+00	5.37E+00	5.67E+00	4.18E+00	4.53E+00
	CO	8.73E+01	8.94E+01	9.54E+01	8.57E+01	8.64E+01
	PM10	4.68E-02	2.81E-02	2.69E-02	1.64E-02	3.20E-02
	PM2.5	2.15E+00	2.36E+00	2.58E+00	1.85E+00	2.11E+00
	Heavy metals	1.25E-01	1.11E-01	1.37E-01	7.54E-02	1.14E-01
Emissions to water	NH_3	4.66E-02	6.94E-02	6.98E-02	4.55E-02	4.62E-02

Type	Flow	Baseline	ARS Refurbishment	ARS Refurbishment with part replacement	ARS Part harvesting	ARS recycling
	NO^{3-}	2.18E+00	2.83E+00	2.92E+00	2.07E+00	2.16E+00
	PO_4^{3-}	6.57E-02	8.97E-02	9.33E-02	6.48E-02	6.70E-02
	Heavy metals	1.46E+01	2.12E+01	2.14E+01	1.45E+01	1.46E+01
Emissions to soil	PAH	2.74E-04	1.71E-04	1.89E-04	1.60E-04	2.21E-04
	Heavy metals	5.40E-02	4.89E-02	5.14E-02	4.76E-02	4.87E-02

Table B 8 LCI results of Server (in kg)

Type	Flow	Baseline	ARS Refurbishment	ARS Refurbshment	ARS Part harvesting	ARS recycling
Resources	Water use	9.17E+08	1.21E+09	1.27E+09	7.63E+08	9.13E+08
	Wood	7.48E-10	1.26E-09	1.25E-09	7.51E-10	7.49E-10
	Crude oil	2.05E+04	2.32E+04	2.44E+04	1.63E+04	1.97E+04
	Hard coal	2.07E+05	2.82E+05	2.94E+05	1.78E+05	2.07E+05
	Natural gas	1.05E+05	1.46E+05	1.52E+05	9.16E+04	1.05E+05
	Uranium	5.83E+00	8.30E+00	8.59E+00	5.16E+00	5.83E+00
Emissions to air	CO_2	8.58E+05	1.17E+06	1.22E+06	7.39E+05	8.54E+05
	CH_4	1.92E+03	2.66E+03	2.76E+03	1.67E+03	1.91E+03
	N_2O	1.51E+01	1.95E+01	2.06E+01	1.25E+01	1.50E+01
	NO_x	1.09E+03	1.33E+03	1.40E+03	8.81E+02	1.07E+03
	SO_2	1.02E+03	1.22E+03	1.29E+03	8.19E+02	1.00E+03
	NMVOC	1.57E+02	1.84E+02	2.00E+02	1.19E+02	1.56E+02
	CO	5.68E+02	6.73E+02	7.18E+02	4.38E+02	5.54E+02
	PM10	6.67E-01	5.96E-01	6.13E-01	3.96E-01	5.22E-01

Type	Flow	Baseline	ARS Refur-bishment	ARS Re-furbshment	ARS Part harvesting	ARS recy-cling
	PM2.5	5.65E+01	6.55E+01	7.05E+01	4.35E+01	5.57E+01
	Heavy metals	1.20E+00	1.28E+00	1.36E+00	8.56E-01	1.10E+00
Emissions to water	NH_3	1.85E+00	2.68E+00	2.75E+00	1.68E+00	1.85E+00
	NO^{3-}	6.93E+01	9.15E+01	9.59E+01	5.81E+01	6.89E+01
	PO_4^{3-}	1.80E+00	2.28E+00	2.41E+00	1.46E+00	1.77E+00
	Heavy metals	5.12E+02	7.42E+02	7.61E+02	4.67E+02	5.12E+02
Emissions to soil	PAH	1.06E-03	5.09E-04	5.17E-04	4.16E-04	7.16E-04
	Heavy metals	2.14E-01	2.07E-01	2.09E-01	1.69E-01	1.94E-01

Table B 9 LCI results of Desktop (in kg)

Type	Flow	Baseline	ARS Refur-bishment	ARS Re-furbshment	ARS Part harvesting	ARS recy-cling
Resources	Water use	3.04E+07	3.61E+07	3.80E+07	2.41E+07	2.97E+07
	Wood	1.07E-11	2.33E-11	2.18E-11	1.47E-11	1.10E-11
	Crude oil	9.24E+02	9.09E+02	9.60E+02	6.78E+02	8.53E+02
	Hard coal	5.83E+03	7.50E+03	7.85E+03	4.71E+03	5.74E+03
	Natural gas	2.48E+03	3.47E+03	3.58E+03	2.17E+03	2.47E+03
	Uranium	1.20E-01	1.79E-01	1.84E-01	1.08E-01	1.20E-01
Emissions to air	CO_2	2.39E+04	3.08E+04	3.22E+04	1.95E+04	2.35E+04
	CH_4	5.14E+01	6.87E+01	7.15E+01	4.33E+01	5.10E+01
	N_2O	4.88E-01	5.82E-01	6.12E-01	3.86E-01	4.76E-01
	NO_x	3.80E+01	4.11E+01	4.40E+01	2.66E+01	3.59E+01
	SO_2	4.37E+01	4.52E+01	4.91E+01	2.91E+01	4.14E+01
	NMVOC	5.16E+00	5.69E+00	6.08E+00	3.89E+00	4.99E+00
	CO	2.39E+01	2.39E+01	2.54E+01	1.70E+01	2.20E+01

Type	Flow	Baseline	ARS Refur-bishment	ARS Re-furbshment	ARS Part harvesting	ARS recy-cling
	PM10	1.38E-01	9.96E-02	1.02E-01	8.14E-02	1.12E-01
	PM2.5	2.11E+00	2.24E+00	2.44E+00	1.44E+00	2.04E+00
	Heavy metals	1.01E-01	8.17E-02	8.90E-02	5.65E-02	8.62E-02
Emissions to water	NH_3	5.34E-02	7.33E-02	7.48E-02	4.81E-02	5.34E-02
	NO^{3-}	2.38E+00	2.89E+00	3.05E+00	1.88E+00	2.35E+00
	PO_4^{3-}	5.91E-02	7.33E-02	7.67E-02	4.71E-02	5.74E-02
	Heavy metals	1.26E+01	1.81E+01	1.88E+01	1.07E+01	1.26E+01
Emissions to soil	PAH	2.56E-04	1.44E-04	1.68E-04	9.04E-05	1.91E-04
	Heavy metals	5.53E-02	5.18E-02	5.60E-02	3.89E-02	5.14E-02

Table B 10 LCI results of Laptop (in kg)

Type	Flow	Baseline	ARS Refur-bishment	ARS Re-furbshment	ARS Part harvesting	ARS recy-cling
Resources	Water use	1.86E+07	1.99E+07	2.14E+07	1.69E+07	1.82E+07
	Wood	3.94E+00	3.94E+00	4.82E+00	3.76E+00	3.94E+00
	Crude oil	3.80E+02	3.83E+02	4.15E+02	3.30E+02	3.69E+02
	Hard coal	2.13E+03	2.59E+03	2.77E+03	1.92E+03	2.09E+03
	Natural gas	1.09E+03	1.37E+03	1.45E+03	9.90E+02	1.09E+03
	Uranium	5.29E-02	6.99E-02	7.30E-02	4.85E-02	5.26E-02
Emissions to air	CO_2	9.85E+03	1.19E+04	1.27E+04	8.91E+03	9.75E+03
	CH_4	2.35E+01	2.85E+01	3.04E+01	2.13E+01	2.34E+01
	N_2O	2.00E-01	2.27E-01	2.45E-01	1.78E-01	1.97E-01
	NO_x	1.97E+01	2.03E+01	2.19E+01	1.65E+01	1.90E+01
	SO_2	2.60E+01	2.18E+01	2.40E+01	1.82E+01	2.31E+01
	NMVOC	2.38E+00	2.54E+00	2.79E+00	2.10E+00	2.35E+00

Type	Flow	Baseline	ARS Refur-bishment	ARS Re-furbshment	ARS Part harvesting	ARS recy-cling
	CO	2.92E+01	2.97E+01	3.25E+01	2.46E+01	2.90E+01
	PM10	2.31E-02	2.44E-02	2.75E-02	2.08E-02	2.28E-02
	PM2.5	1.26E+00	1.24E+00	1.37E+00	1.05E+00	1.22E+00
	Heavy metals	5.26E-02	4.54E-02	5.15E-02	4.05E-02	4.82E-02
Emissions to water	NH_3	7.47E-02	8.04E-02	9.40E-02	7.11E-02	7.46E-02
	NO^{3-}	1.01E+00	1.17E+00	1.27E+00	9.21E-01	1.01E+00
	PO_4^{3-}	2.02E-01	2.08E-01	2.48E-01	1.92E-01	2.03E-01
	Heavy metals	6.20E+00	7.79E+00	8.32E+00	5.55E+00	6.17E+00
Emissions to soil	PAH	1.57E-04	9.42E-05	1.04E-04	8.69E-05	1.26E-04
	Heavy metals	2.95E-02	2.76E-02	3.13E-02	2.56E-02	2.80E-02

Annex B3

Annex B3 presents the results for the remaining 7 EF impact categories. Figure B 1to Figure B 27 demonstrate life cycle results of the four products for 1 year of use of 100 devices and the overall trend.

Monitor EF Indicators

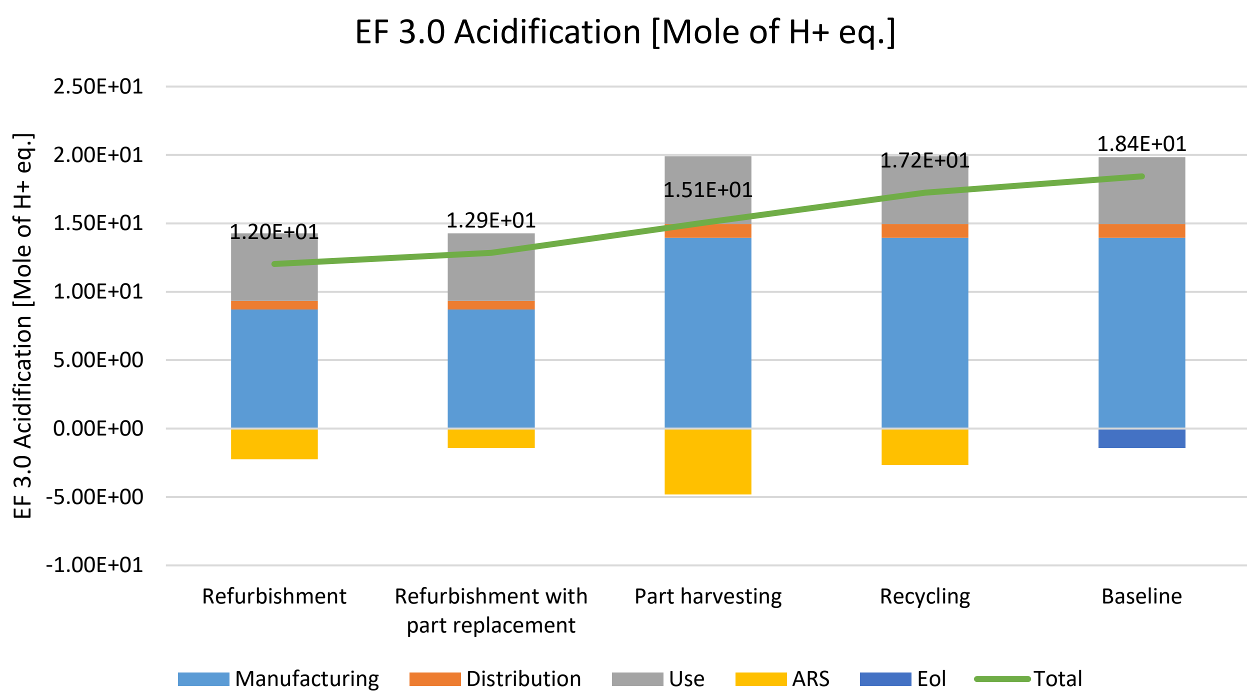


Figure B 1: EF Acidification impact of monitor across different end-of-life scenarios per functional unit

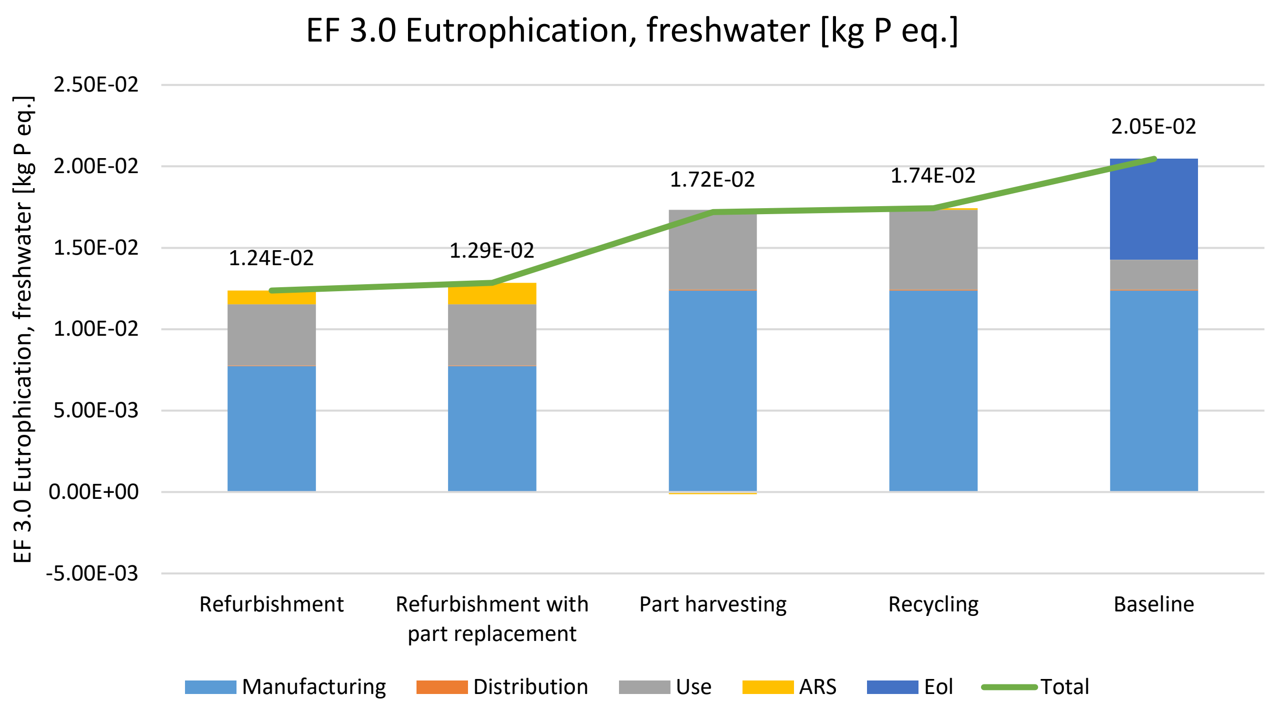


Figure B 1: EF Eutrophication impact of monitor across different end-of-life scenarios per functional unit

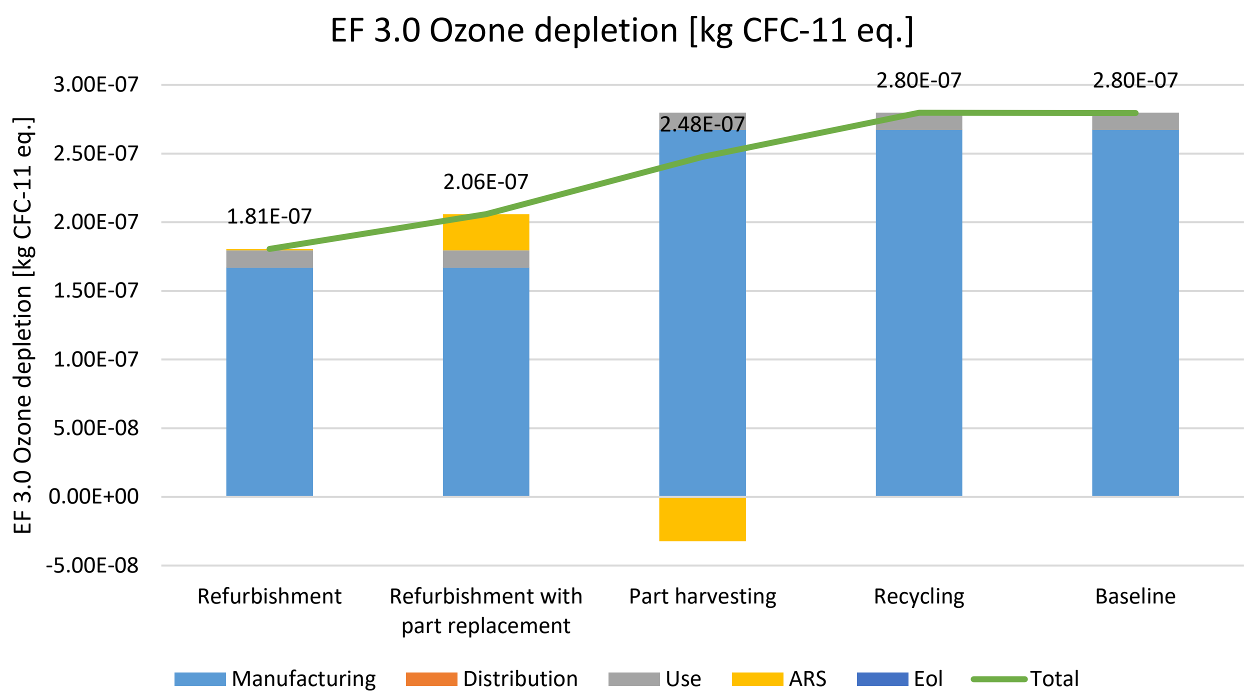


Figure B 2: EF Ozone depletion impact of monitor across different end-of-life scenarios per functional unit

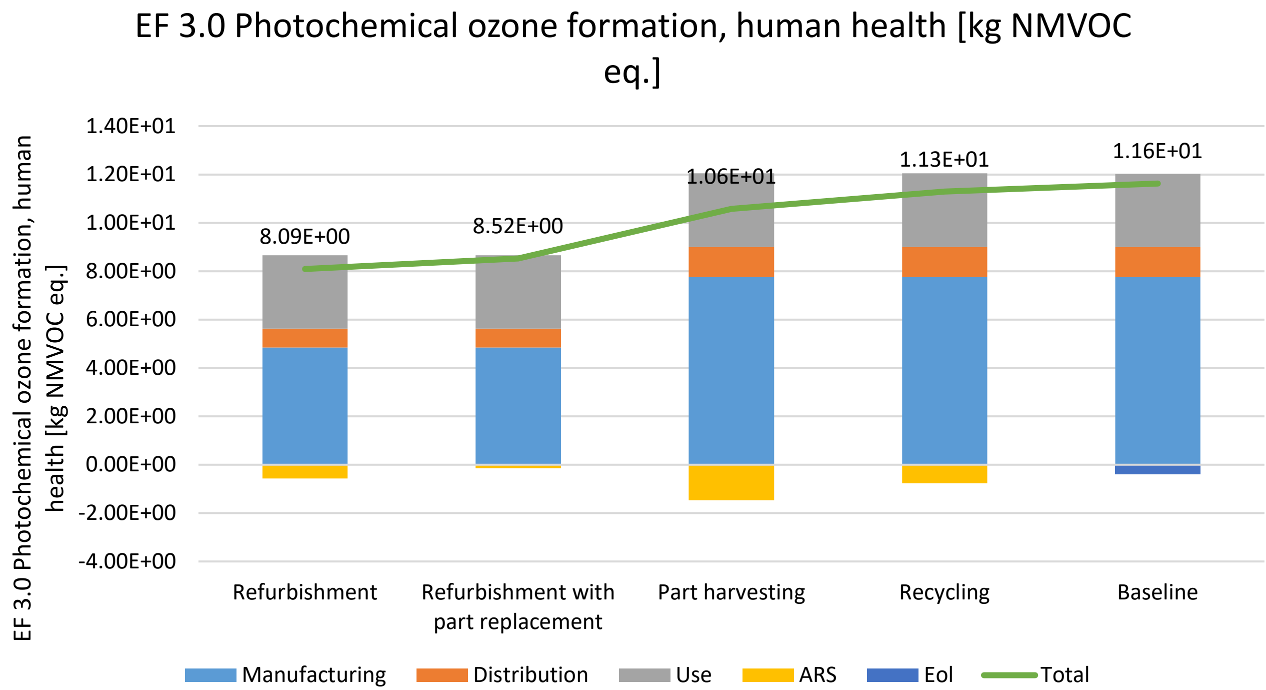


Figure B 3: EF Photochemical ozone formation impact of monitor across different end-of-life scenarios per functional unit

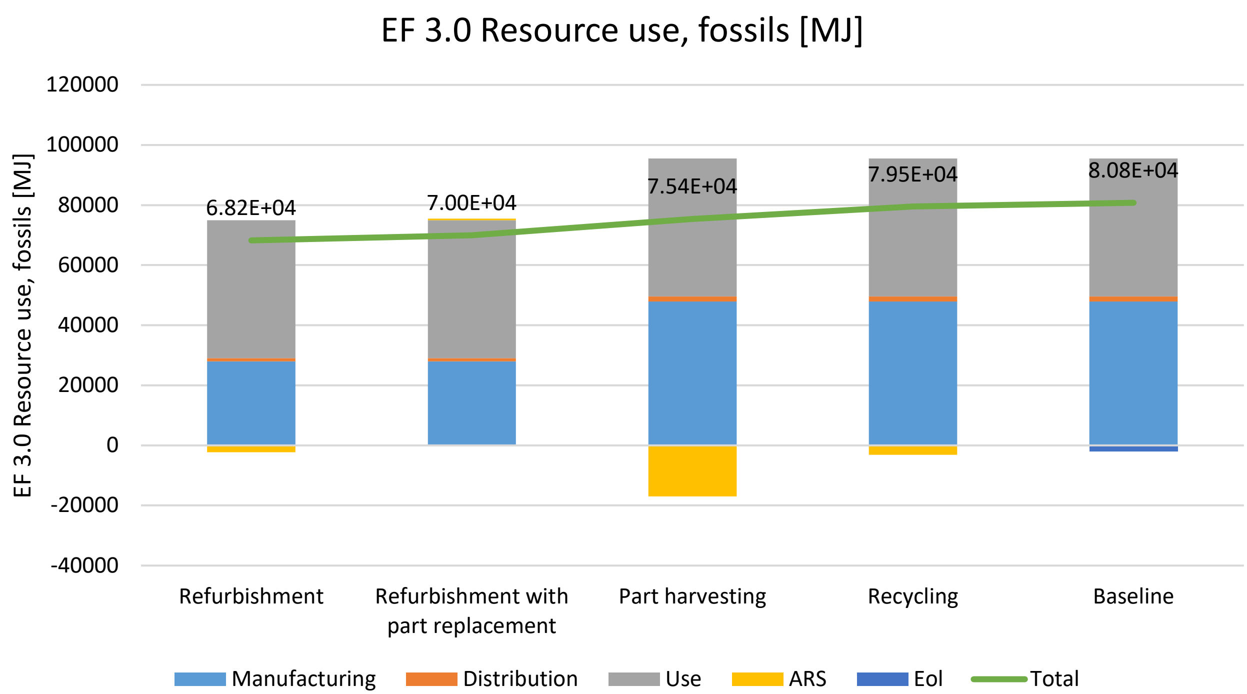


Figure B 4: EF Resource use, fossil impact of monitor across different end-of-life scenarios per functional unit

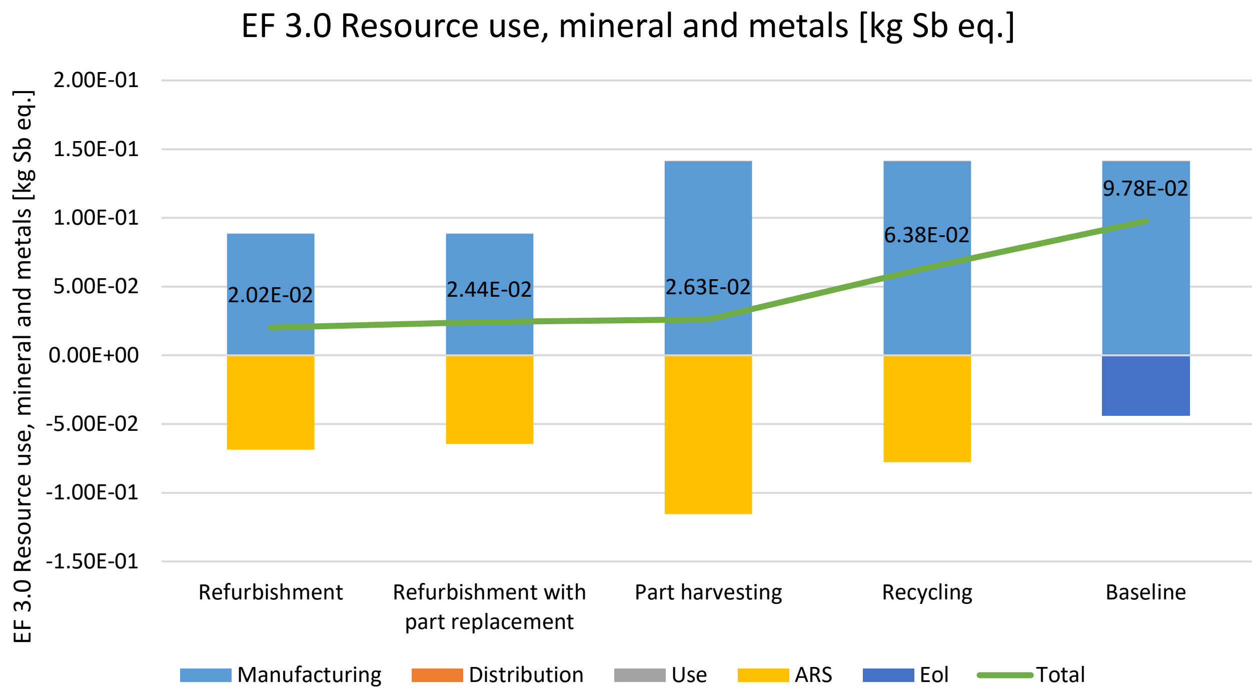


Figure B 5: EF Resource use, mineral and metals impact of monitor across different end-of-life scenarios per functional unit

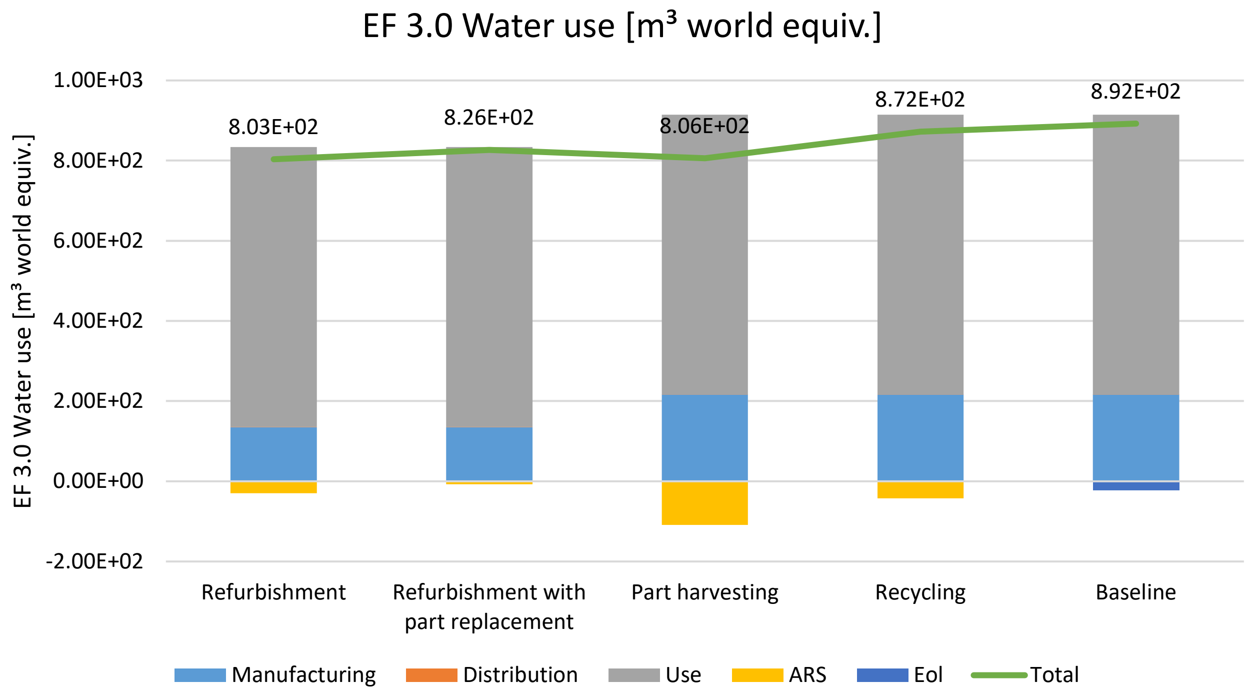


Figure B 6: EF Water use of monitor across different end-of-life scenarios per functional unit

Server EF Indicators

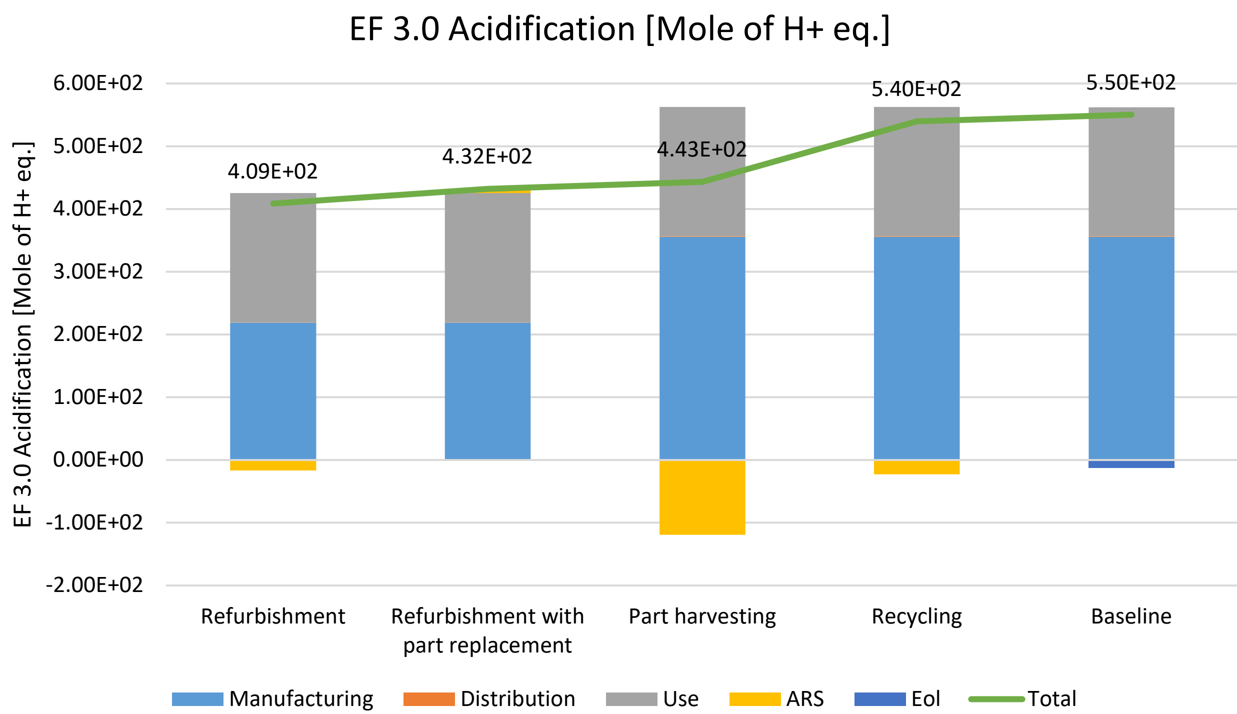


Figure B 7: EF Acidification impact of server across different end-of-life scenarios per functional unit

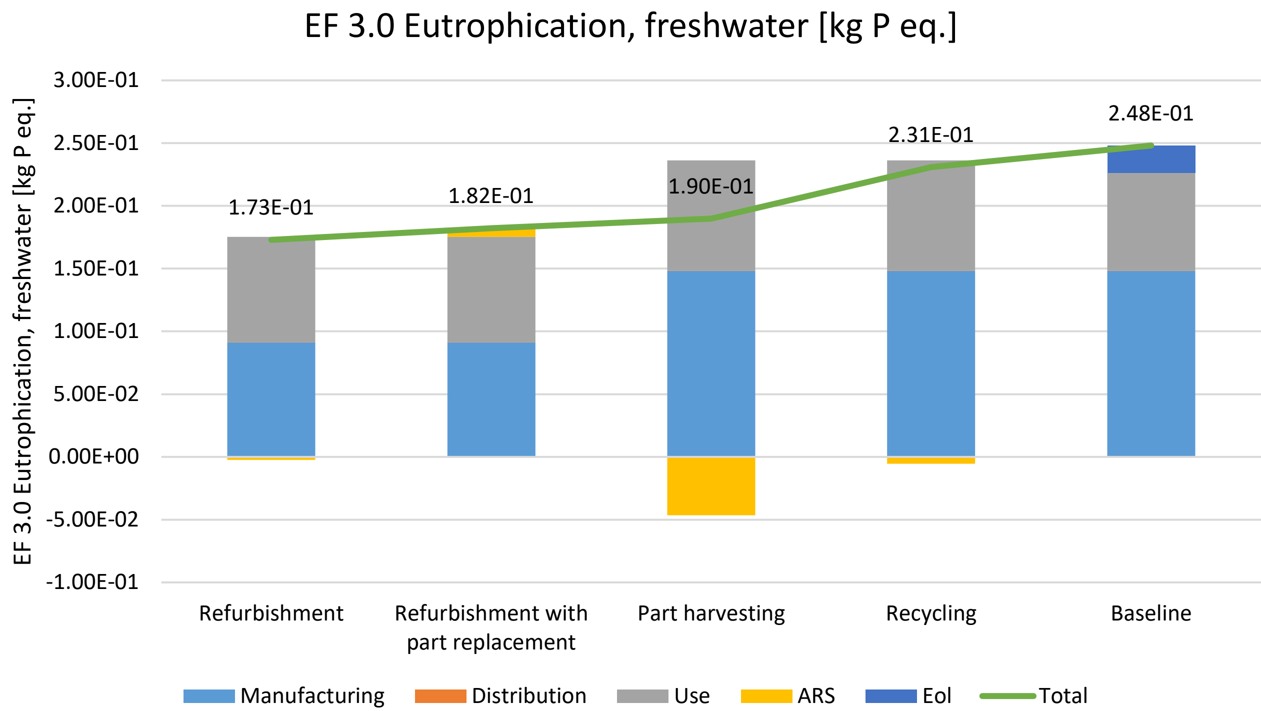


Figure B 8: EF Eutrophication impact of server across different end-of-life scenarios per functional unit

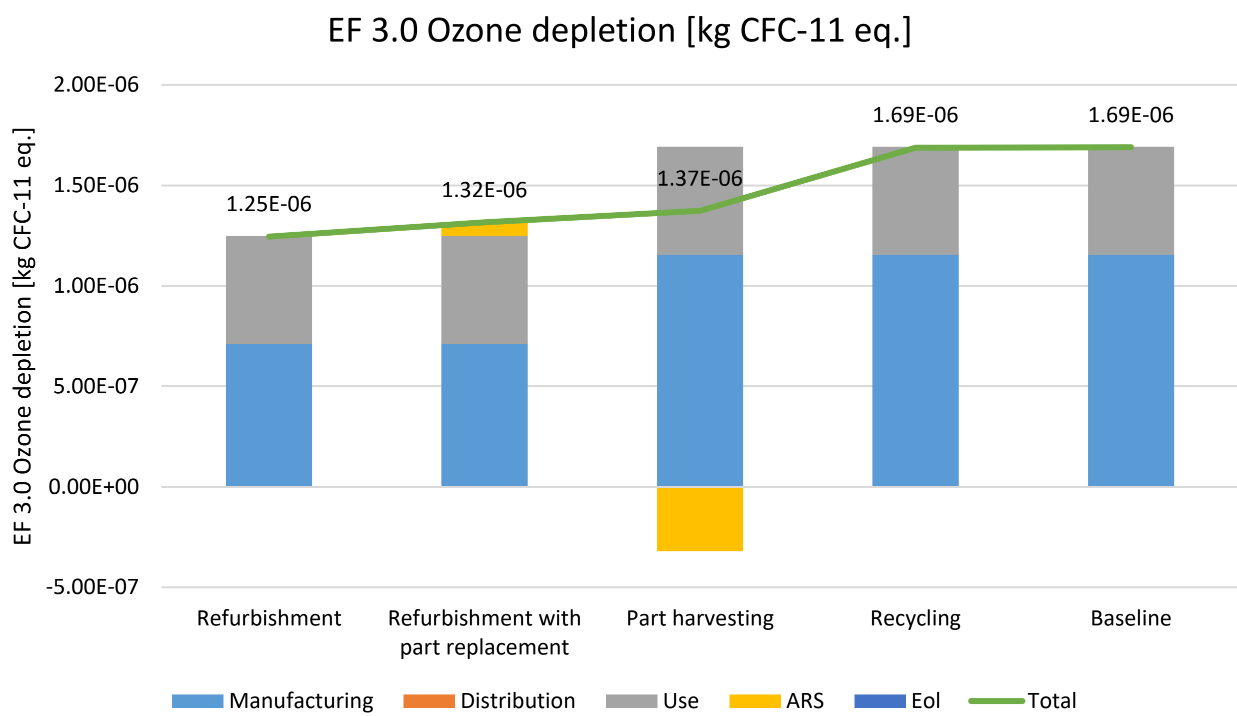


Figure B 9: EF Ozone depletion impact of server across different end-of-life scenarios per functional unit

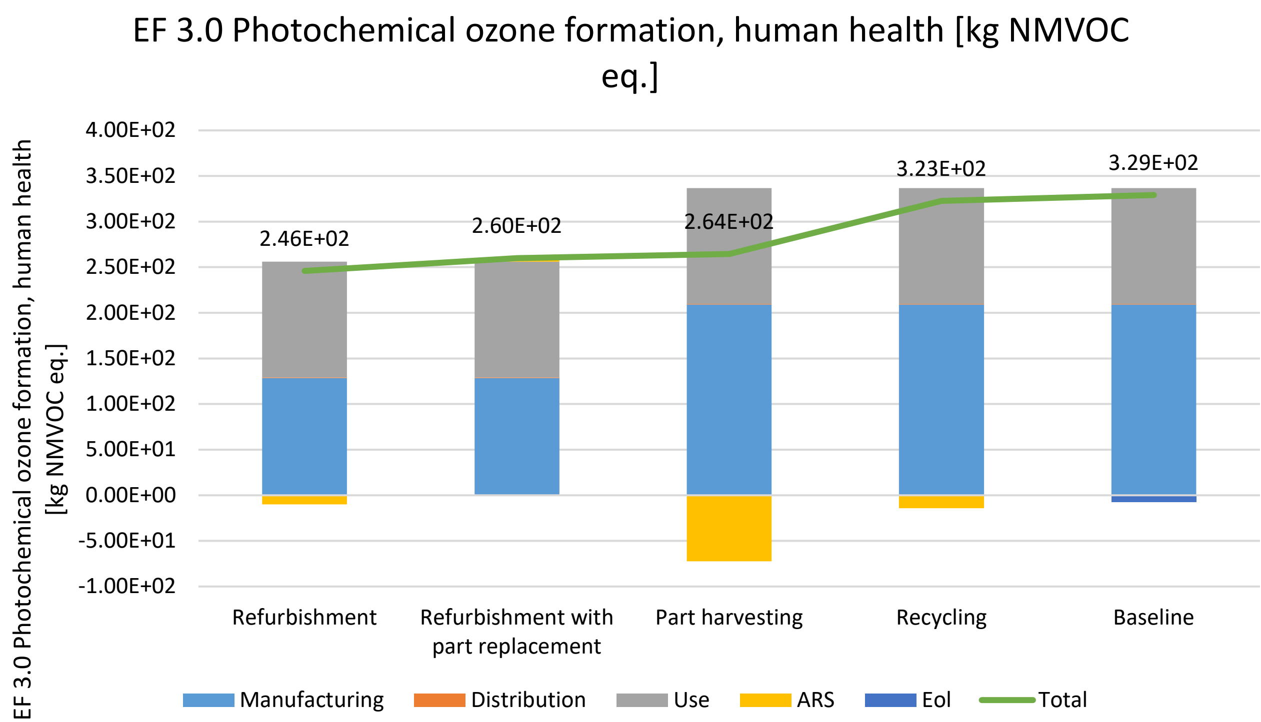


Figure B 10: EF Photochemical ozone formation impact of server across different end-of-life scenarios per functional unit

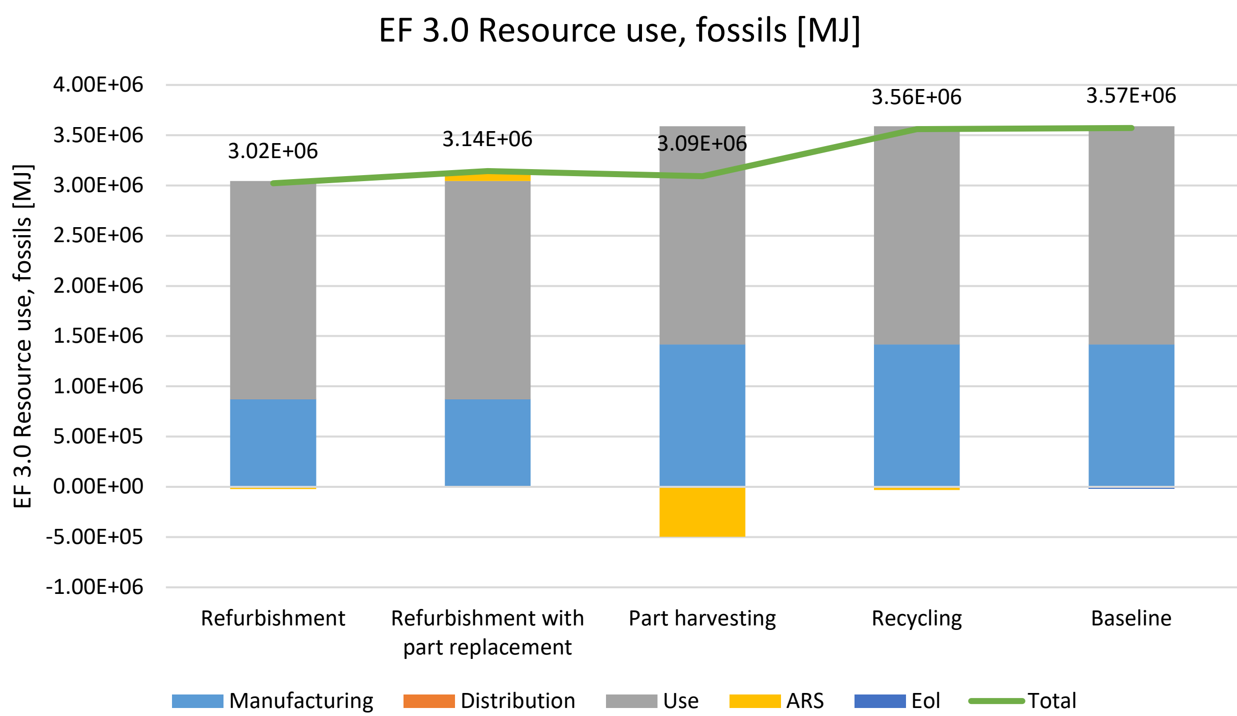


Figure B 11: EF Resource use, fossil impact of server across different end-of-life scenarios per functional unit

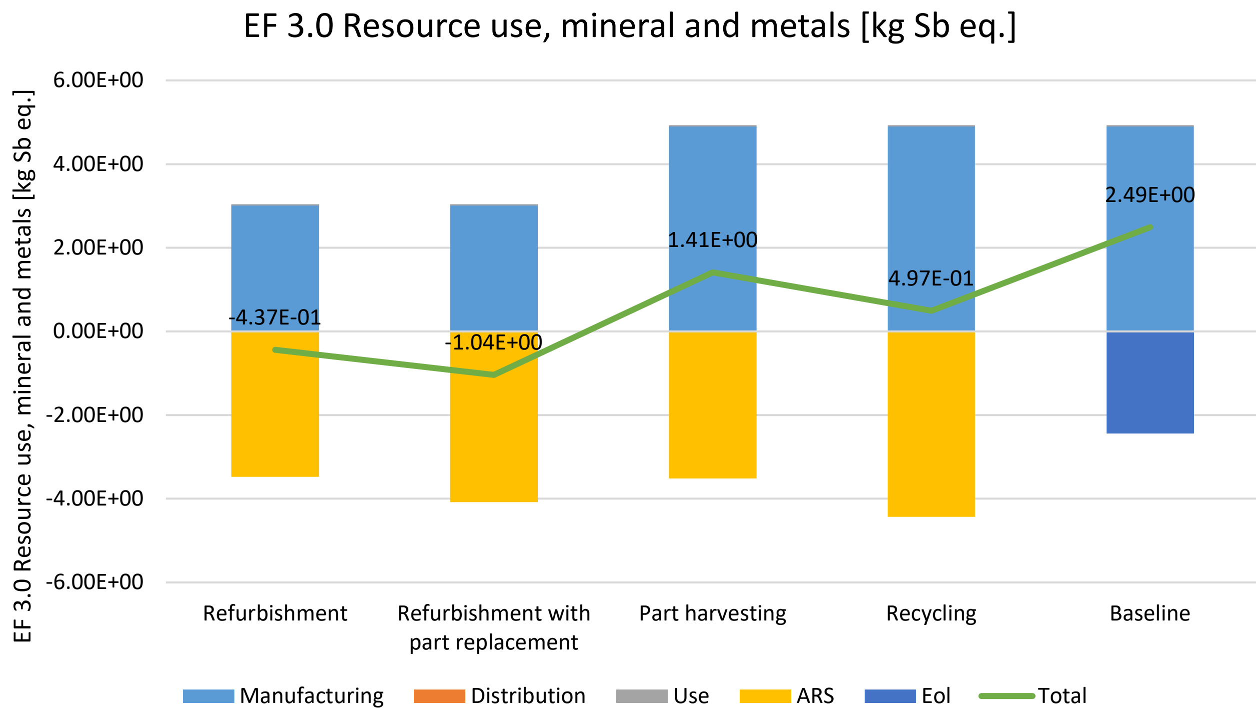


Figure B 12: EF Resource use, mineral and metals impact of server across different end-of-life scenarios per functional unit

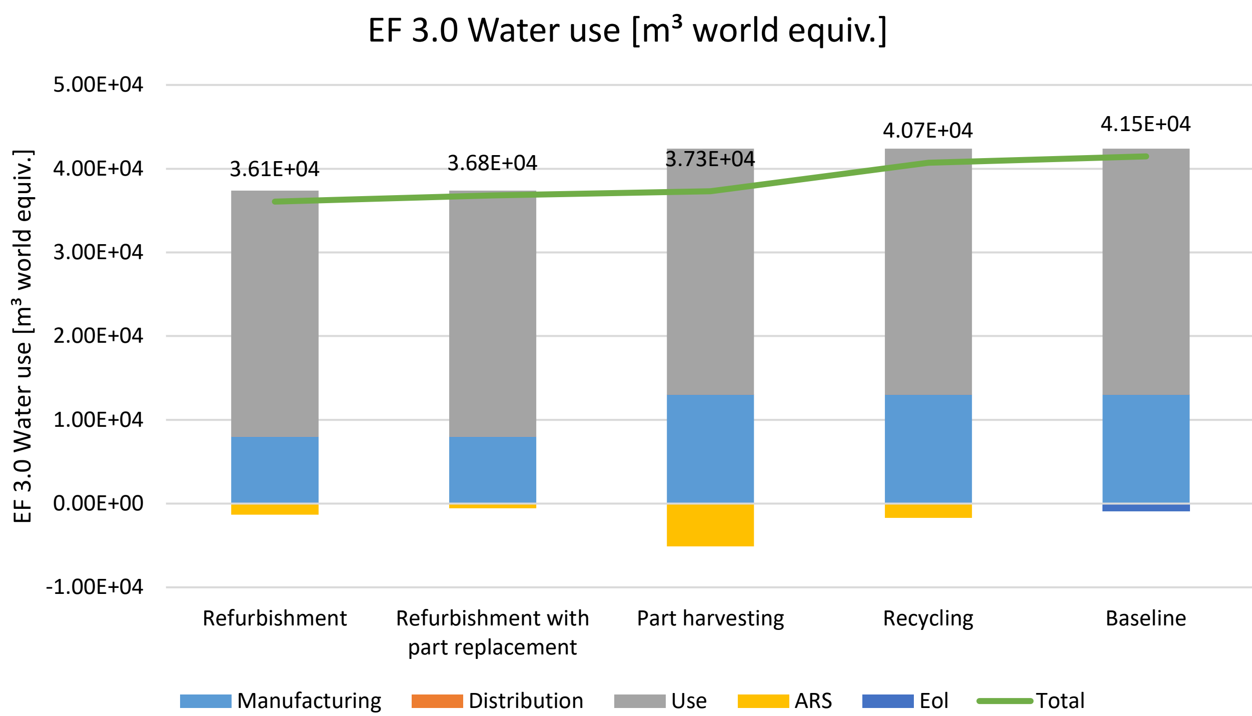


Figure B 13: EF Water use impact of server across different end-of-life scenarios per functional unit

Desktop EF 3.0 indicators

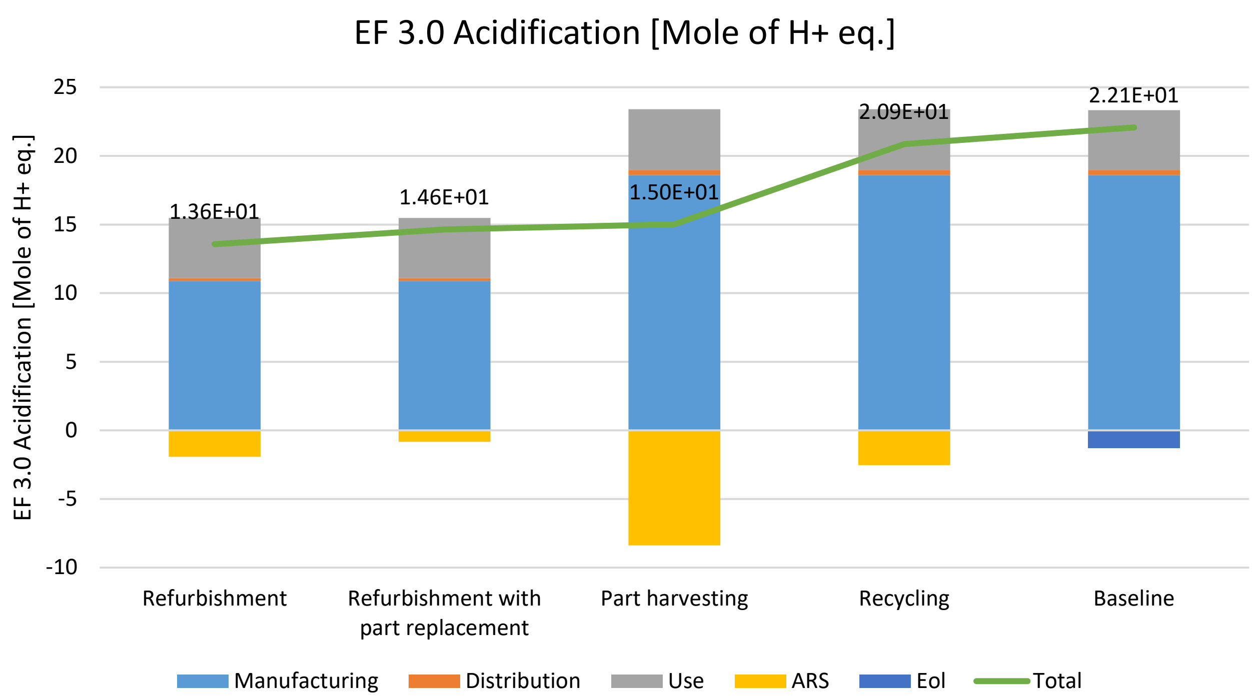


Figure B 14: EF Acidification impact of desktop across different end-of-life scenarios per functional unit

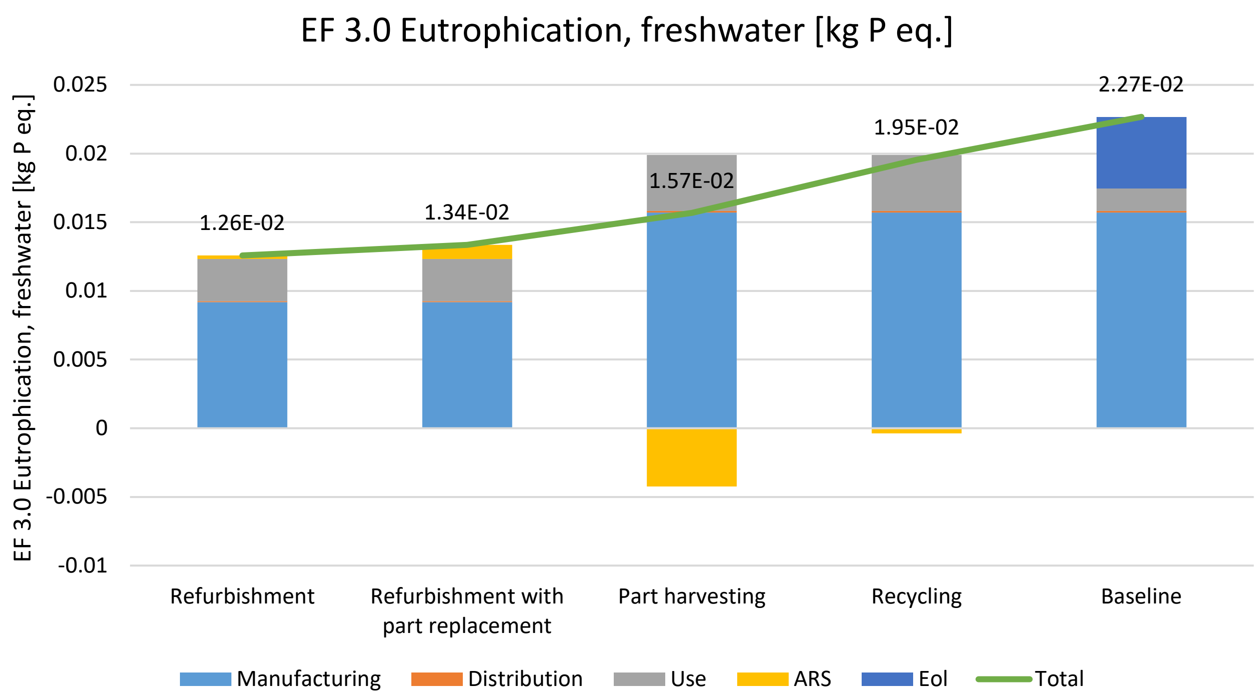


Figure B 15: EF Eutrophication impact of desktop across different end-of-life scenarios per functional unit

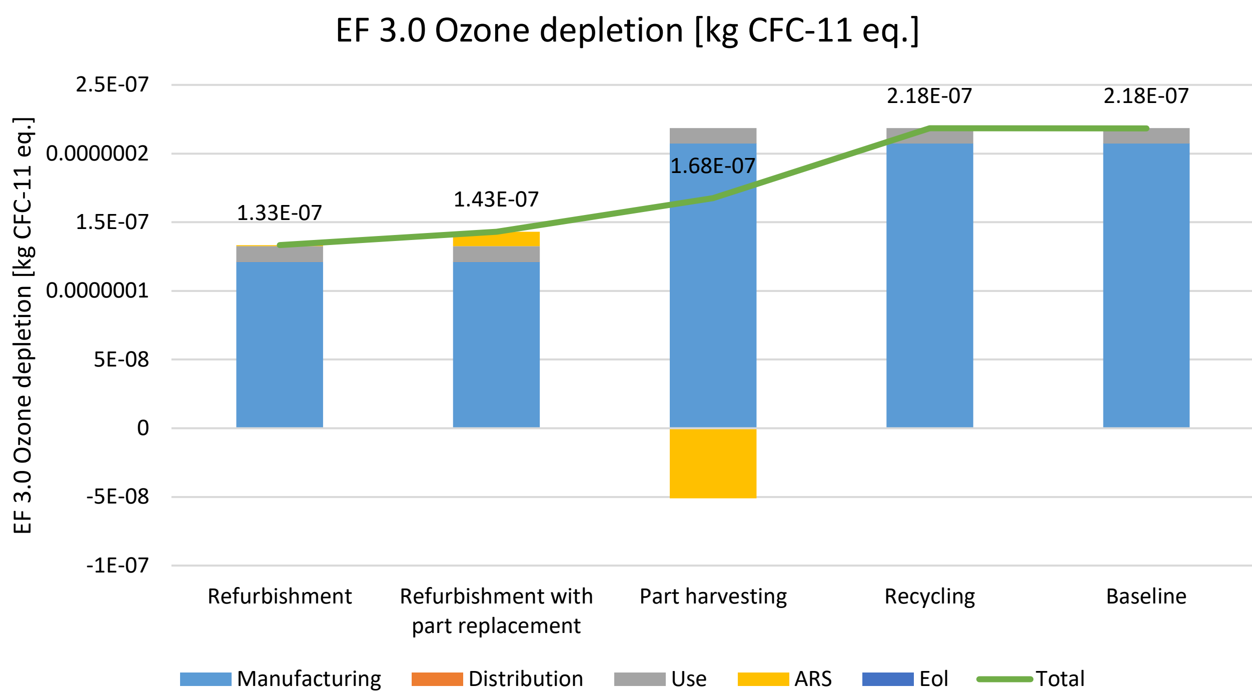


Figure B 16: EF Ozone depletion impact of desktop across different end-of-life scenarios per functional unit

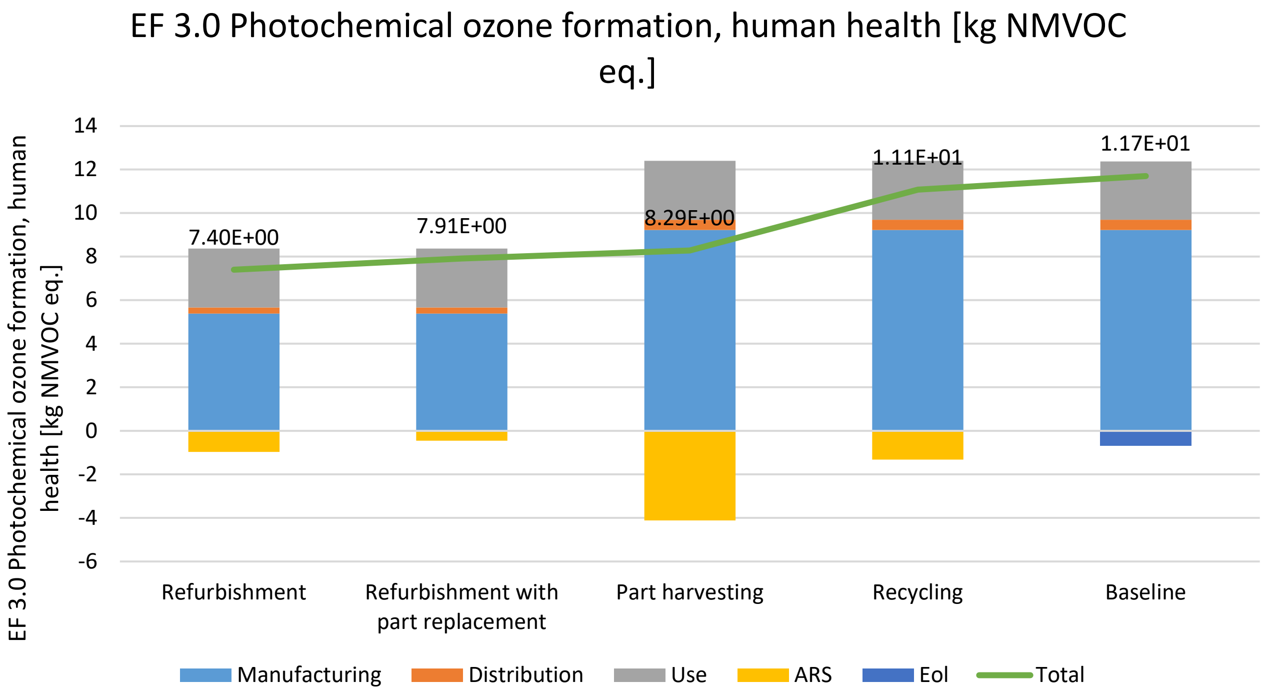


Figure B 17: EF Photochemical ozone formation impact of desktop across different end-of-life scenarios per functional unit

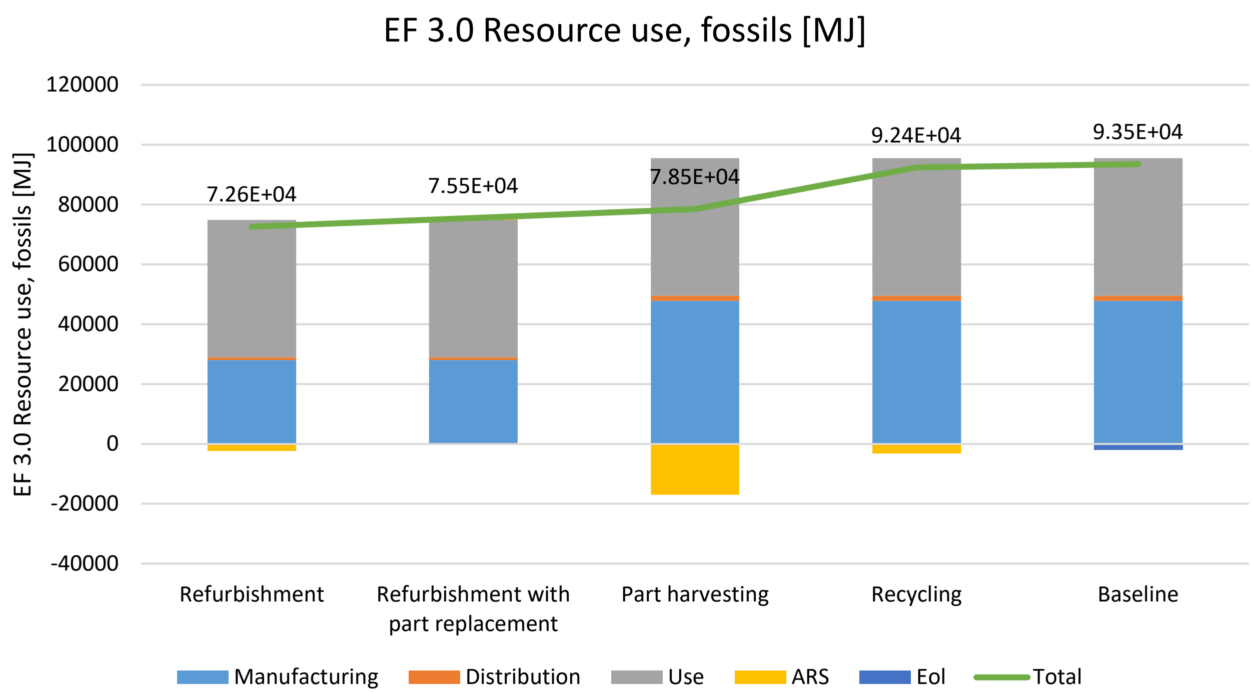


Figure B 18: EF Resource use, fossils impact of desktop across different end-of-life scenarios per functional unit

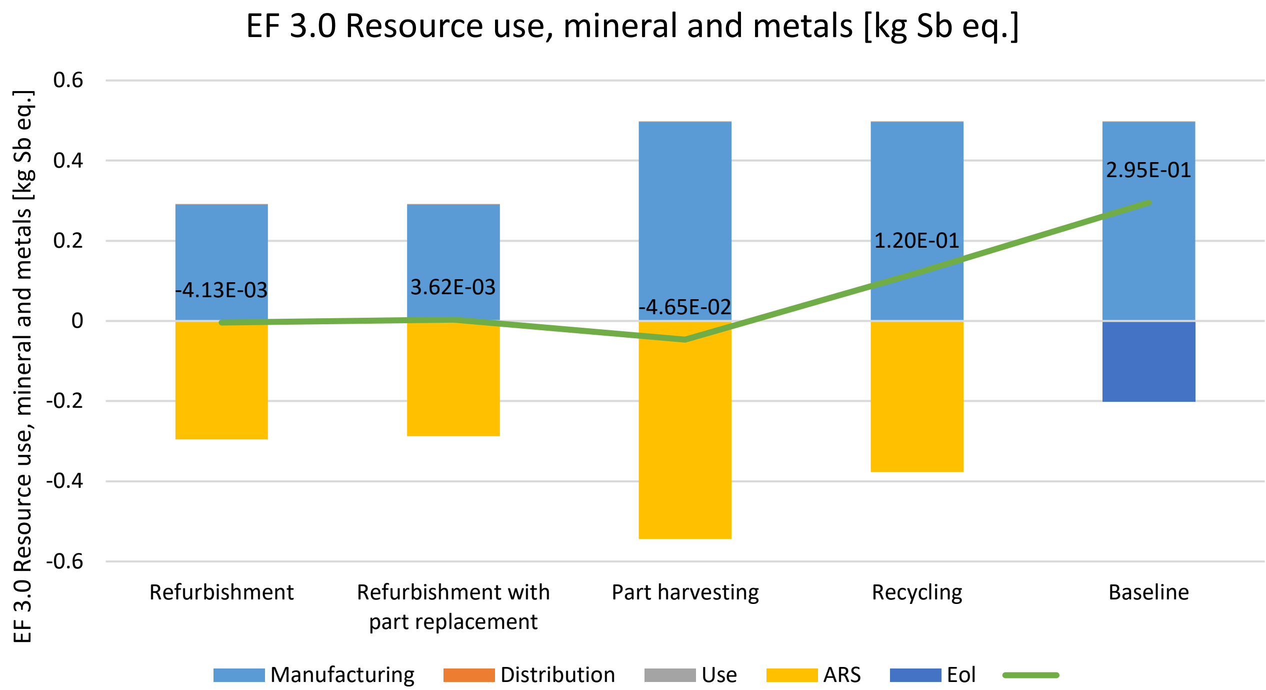


Figure B 19: EF Resource use, mineral and metals impact of desktop across different end-of-life scenarios per functional unit

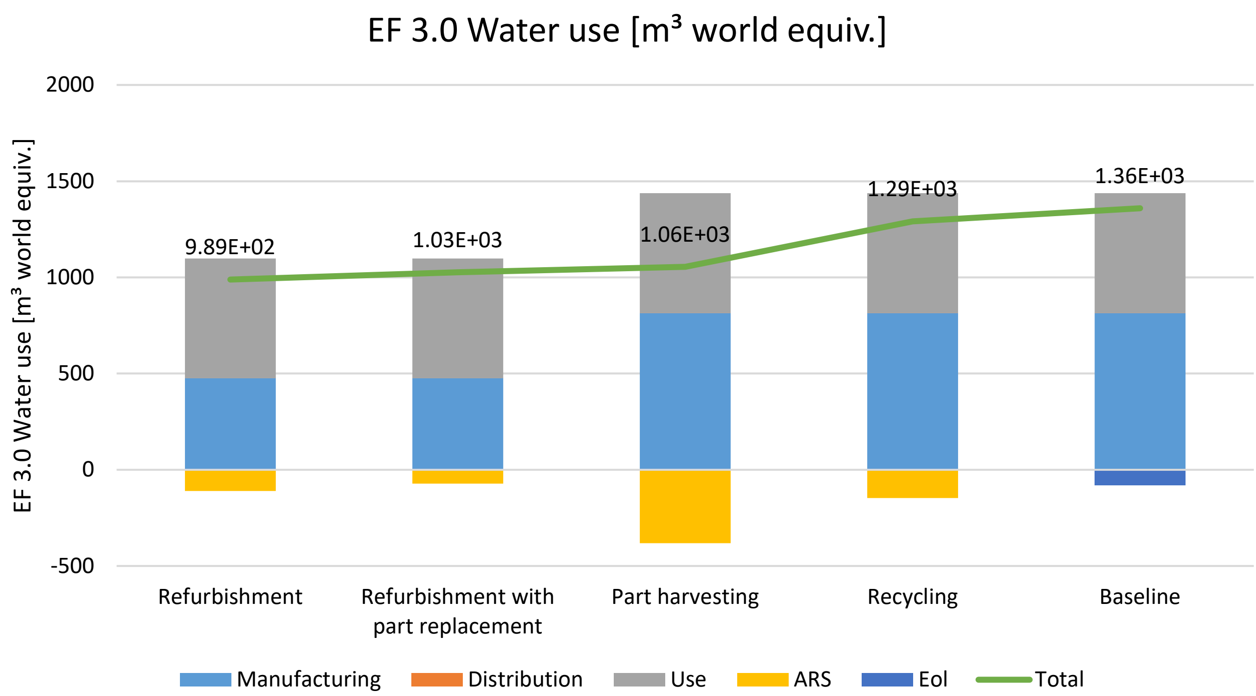


Figure B 20: EF Water use impact of desktop across different end-of-life scenarios per functional unit

Laptop EF 3.0 Indicators

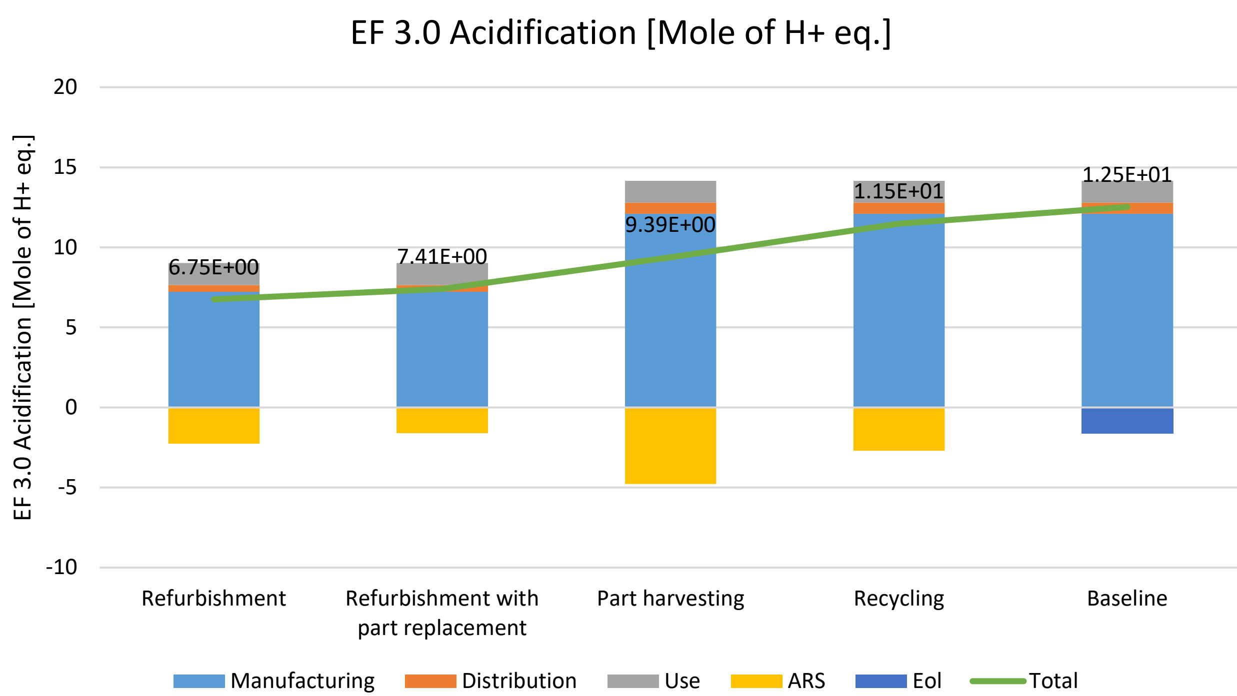


Figure B 21: EF Acidification impact of laptop across different end-of-life scenarios per functional unit

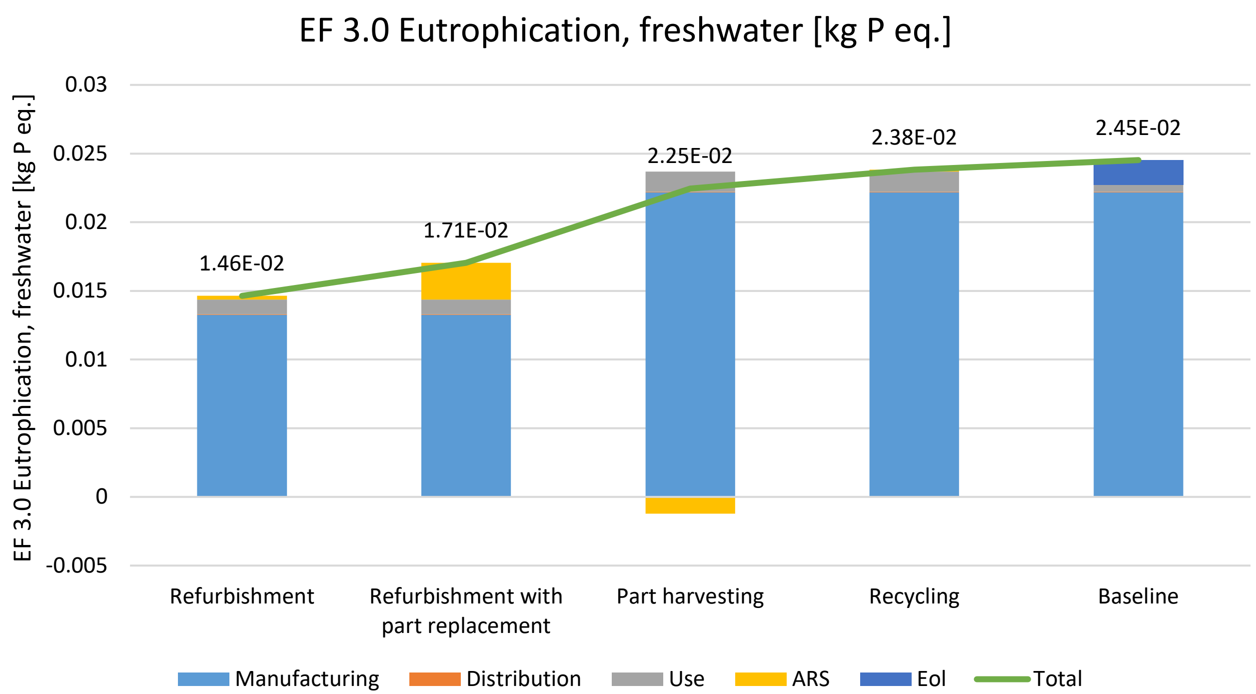


Figure B 22: EF Eutrophication impact of laptop across different end-of-life scenarios per functional unit

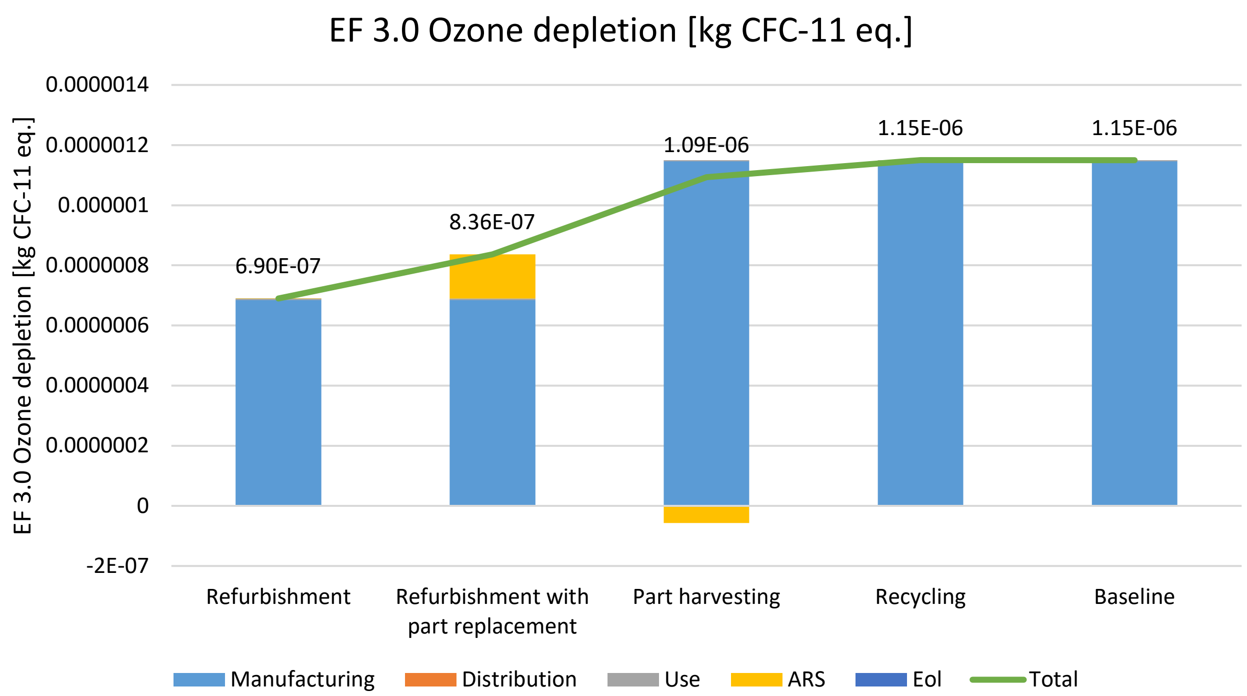


Figure B 23: EF Ozone depletion impact of laptop across different end-of-life scenarios per functional unit

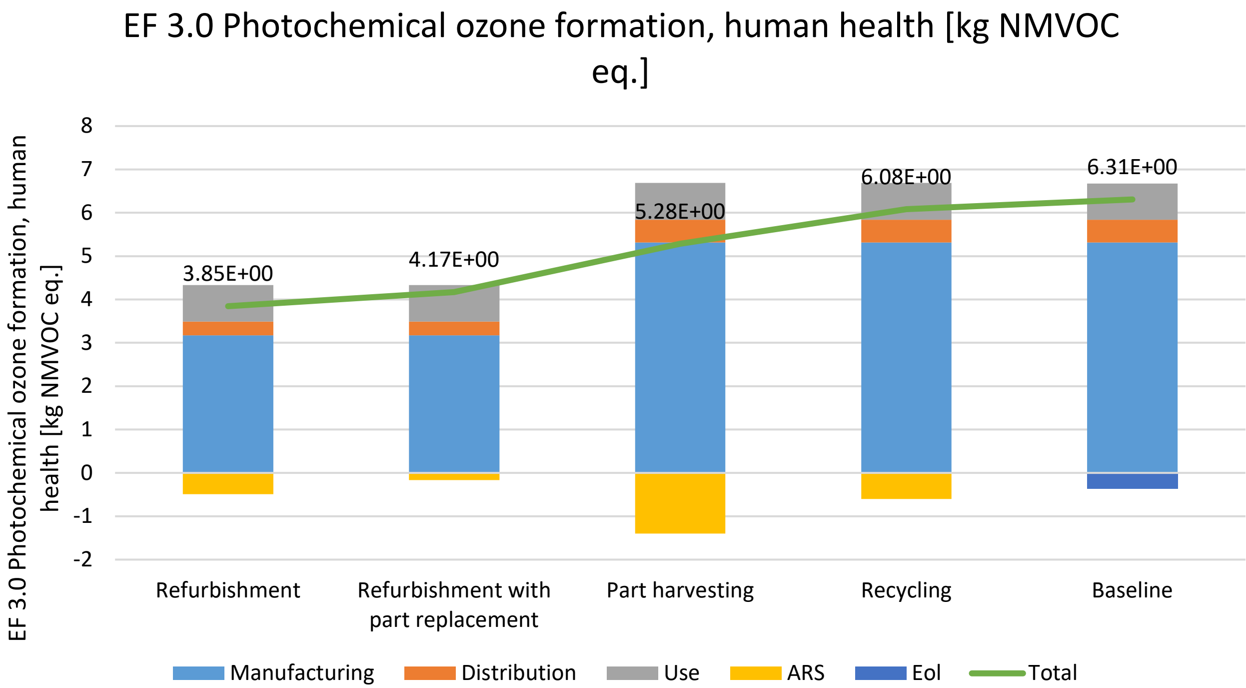


Figure B 24: EF Photochemical ozone formation impact of laptop across different end-of-life scenarios per functional unit

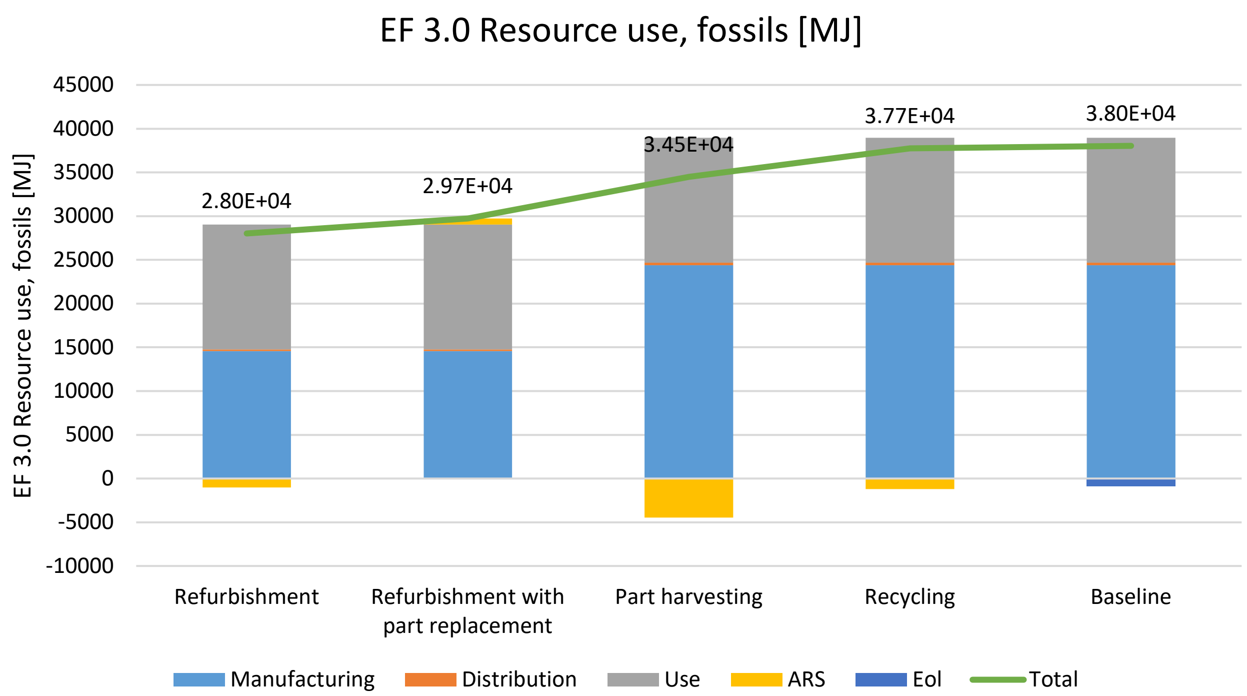


Figure B 25: EF Resource use, fossil impact of laptop across different end-of-life scenarios per functional unit

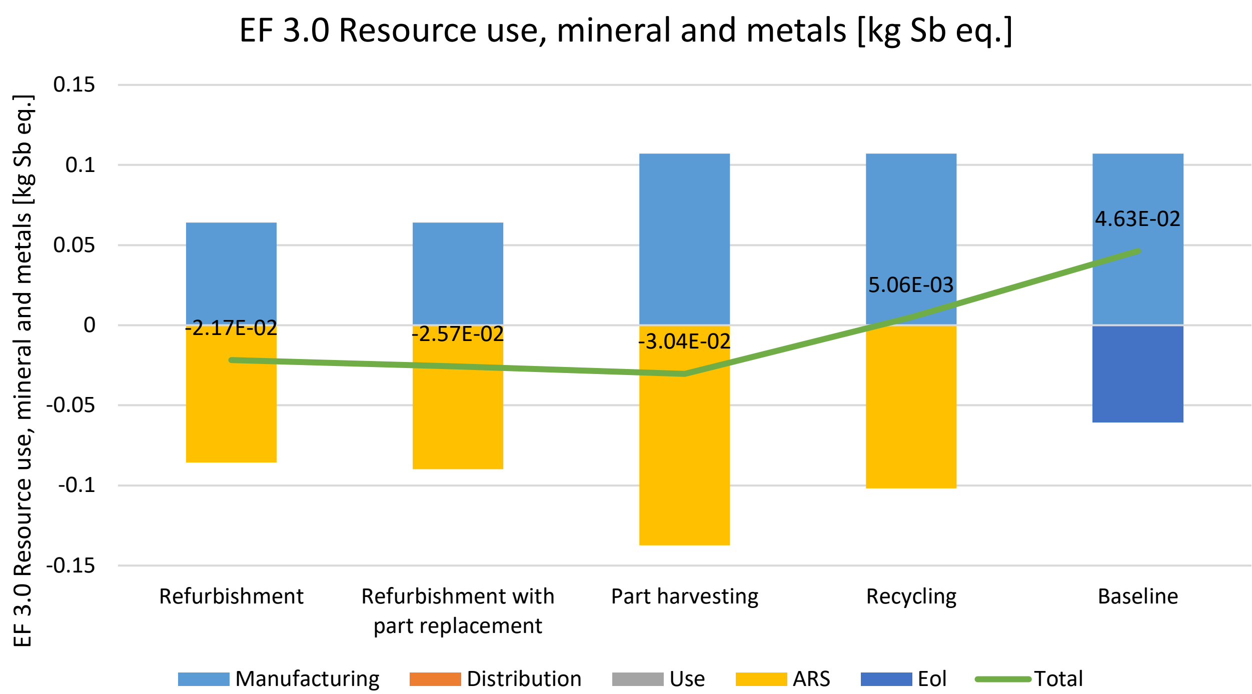


Figure B 26: EF Resource use, mineral and metals impact of laptop across different end-of-life scenarios per functional unit

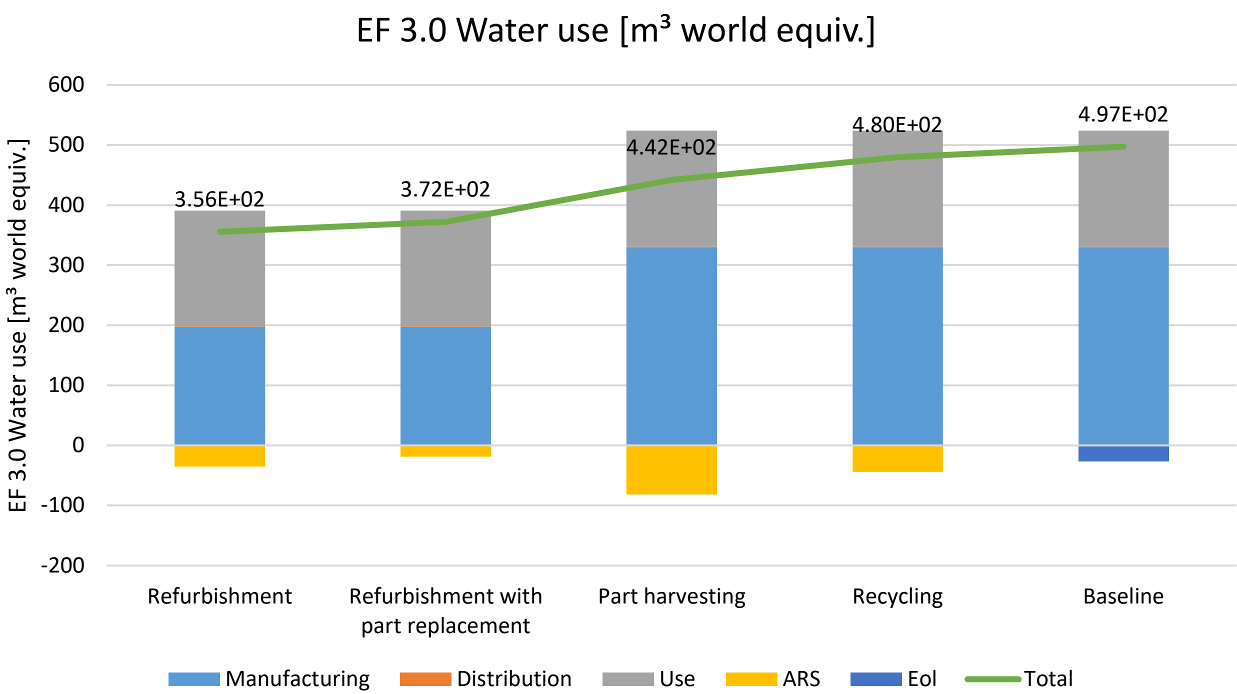


Figure B 27: EF Water use impact of laptop across different end-of-life scenarios per functional unit

Annex B4

Annex B4 presents the results for other inventory metrics mentioned in Section2.6. Table B 11 to Table B 14 show life cycle results of four ARS scenarios for four products for 1 year of use of 100 devices.

Table B 11: Results of Refurbishment scenario for other inventory metrics across four devices (1 year use of 100 devices)

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Monitor					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.04E+02	2.05E-01	4.69E+01	-3.37E+01	1.17E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	2.17E+04	2.22E+03	6.28E+04	-2.91E+03	8.38E+04
Blue water consumption [kg]	8.26E+03	1.11E+01	2.12E+04	-2.41E+03	2.71E+04
Server					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	8.25E+02	6.21E-02	8.27E+02	-2.75E+01	1.62E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.05E+06	1.06E+03	2.64E+06	-2.73E+04	3.67E+06
Blue water consumption [kg]	3.35E+05	7.38E+01	8.94E+05	-8.93E+04	1.14E+06
Desktop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	7.89E+01	1.08E-01	3.76E+01	-9.44E+00	1.07E+02

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.46E+04	1.01E+03	5.60E+04	-2.39E+03	8.92E+04
Blue water consumption [kg]	1.61E+04	2.25E+01	1.89E+04	-7.30E+03	2.77E+04
Laptop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	4.43E+01	1.72E-02	1.30E+01	-6.28E+00	5.10E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.86E+04	1.95E+02	1.74E+04	-9.50E+02	3.52E+04
Blue water consumption [kg]	7.22E+03	1.24E+01	5.88E+03	-2.16E+03	1.10E+04

Table B 12: Results of Refurbishment with part replacement scenario for other inventory metrics across four devices (1 year use of 100 devices)

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Monitor					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.04E+02	2.05E-01	4.69E+01	-1.99E+01	1.31E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	2.17E+04	2.22E+03	6.28E+04	-8.21E+02	8.59E+04
Blue water consumption [kg]	8.26E+03	1.11E+01	2.12E+04	-1.40E+03	2.81E+04
Server					

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	8.25E+02	6.21E-02	8.27E+02	8.23E+01	1.73E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.05E+06	1.06E+03	2.64E+06	1.18E+05	3.81E+06
Blue water consumption [kg]	3.35E+05	7.38E+01	8.94E+05	-6.42E+04	1.16E+06
Desktop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	7.89E+01	1.08E-01	3.76E+01	-3.21E+00	1.13E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.46E+04	1.01E+03	5.60E+04	1.10E+03	9.27E+04
Blue water consumption [kg]	1.61E+04	2.25E+01	1.89E+04	-6.35E+03	2.87E+04
Laptop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	4.43E+01	1.72E-02	1.30E+01	-2.11E+00	5.52E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.86E+04	1.95E+02	1.74E+04	1.22E+03	3.74E+04
Blue water consumption [kg]	7.22E+03	1.24E+01	5.88E+03	-1.75E+03	1.14E+04

Table B 13: Results of Part harvesting scenario for other inventory metrics across four devices (1 year use of 100 devices)

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Monitor					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.66E+02	3.28E-01	6.47E+01	-8.16E+01	1.49E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.47E+04	3.55E+03	6.29E+04	-9.19E+03	9.19E+04
Blue water consumption [kg]	1.32E+04	1.78E+01	2.12E+04	-6.29E+03	2.82E+04
Server					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.34E+03	1.01E-01	8.86E+02	-4.90E+02	1.74E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.71E+06	1.73E+03	2.65E+06	-5.99E+05	3.76E+06
Blue water consumption [kg]	5.44E+05	1.20E+02	8.94E+05	-2.45E+05	1.19E+06
Desktop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.35E+02	1.85E-01	5.33E+01	-4.67E+01	1.42E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	5.91E+04	1.73E+03	5.60E+04	-2.07E+04	9.61E+04
Blue water consumption [kg]	2.75E+04	3.85E+01	1.89E+04	-1.75E+04	2.89E+04
Laptop					

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	7.40E+01	3.00E-02	1.95E+01	-1.75E+01	7.61E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.10E+04	3.26E+02	1.74E+04	-5.31E+03	4.34E+04
Blue water consumption [kg]	1.21E+04	2.08E+01	5.87E+03	-4.56E+03	1.34E+04

Table B 14: Results of recycling scenario for other inventory metrics across four devices (1 year use of 100 devices)

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Monitor					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.66E+02	3.28E-01	6.47E+01	-4.11E+01	1.90E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.47E+04	3.55E+03	6.29E+04	-4.21E+03	9.69E+04
Blue water consumption [kg]	1.32E+04	1.78E+01	2.12E+04	-3.24E+03	3.12E+04
Server					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.34E+03	1.01E-01	8.86E+02	-4.61E+01	2.18E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	1.71E+06	1.73E+03	2.65E+06	-3.93E+04	4.32E+06

Inventory Metrics	Manufacturing	Distribution	Use	ARS	Total
Blue water consumption [kg]	5.44E+05	1.20E+02	8.94E+05	-1.15E+05	1.32E+06
Desktop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.35E+02	1.85E-01	5.33E+01	-1.44E+01	1.74E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	5.91E+04	1.73E+03	5.60E+04	-3.84E+03	1.13E+05
Blue water consumption [kg]	2.75E+04	3.85E+01	1.89E+04	-9.72E+03	3.67E+04
Laptop					
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	7.40E+01	3.00E-02	1.95E+01	-8.45E+00	8.51E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	3.10E+04	3.26E+02	1.74E+04	-1.30E+03	4.74E+04
Blue water consumption [kg]	1.21E+04	2.08E+01	5.87E+03	-2.69E+03	1.53E+04

Annex B5

Annex B5 presents the results for CML mentioned in Section2.6. Table B 15 to Table B 18 show life cycle results of four ARS scenarios for four products for 1 year of use of 100 devices.

Table B 15: CML results of Refurbishment scenario for four devices (1 year use of 100 devices)

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
Monitor					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	8.98E-02	6.88E-06	6.59E-04	-6.85E-02	2.20E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.56E+04	2.21E+03	3.88E+04	-2.57E+03	5.40E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	7.44E+00	4.47E-01	4.40E+00	-2.00E+00	1.03E+01
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	6.18E-01	9.73E-02	5.14E-01	-5.10E-02	1.18E+00
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.45E+01	7.33E-01	6.29E+00	-2.09E+00	1.94E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.51E+03	1.61E+02	3.26E+03	-1.98E+02	4.73E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.58E+03	1.61E+02	3.25E+03	-1.65E+02	4.82E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	4.50E+03	3.29E+00	1.65E+02	-2.82E+02	4.38E+03
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	7.43E+05	2.46E+03	1.66E+05	-2.90E+05	6.22E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.81E-07	8.50E-12	1.50E-08	1.24E-09	1.98E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.86E-01	4.11E-02	3.30E-01	-1.10E-01	9.47E-01

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.06E+00	1.36E-01	2.20E+00	-7.70E-01	6.63E+00
Server					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	3.05E+00	2.45E-05	2.77E-02	-3.48E+00	-4.11E-01
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	7.18E+05	1.04E+03	1.63E+06	-2.15E+04	2.32E+06
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	1.94E+02	2.74E-01	1.85E+02	-1.43E+01	3.63E+02
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	1.75E+01	7.48E-02	2.00E+01	-1.32E+00	3.63E+01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.35E+02	3.75E-01	2.18E+02	-2.48E+01	3.29E+02
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	5.97E+04	7.34E+01	1.36E+05	-1.91E+03	1.94E+05
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	5.98E+04	7.32E+01	1.36E+05	-1.88E+03	1.94E+05
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8.71E+03	3.35E+00	6.91E+03	-8.82E+02	1.47E+04
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	3.83E+07	2.83E+03	6.98E+06	-7.26E+05	4.45E+07
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.98E-07	5.86E-12	6.31E-07	-2.85E-09	1.53E-06
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	1.47E+01	-5.49E-02	1.36E+01	-9.57E-01	2.72E+01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	7.02E+01	2.54E-02	8.83E+01	-1.23E+01	1.46E+02
Desktop					

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	2.92E-01	4.37E-06	5.88E-04	-2.95E-01	-2.37E-03
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	2.51E+04	9.90E+02	3.45E+04	-2.27E+03	5.83E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	9.82E+00	1.56E-01	3.92E+00	-1.67E+00	1.22E+01
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	7.51E-01	3.38E-02	4.52E-01	-1.16E-01	1.12E+00
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	8.54E+00	3.44E-01	5.44E+00	-2.53E+00	1.18E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.09E+03	7.25E+01	2.89E+03	-2.21E+02	4.84E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.13E+03	7.27E+01	2.89E+03	-2.05E+02	4.90E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6.20E+02	1.46E+00	1.46E+02	-1.37E+02	6.32E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	9.56E+05	1.15E+03	1.48E+05	-1.08E+05	9.97E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.61E-07	4.97E-12	1.33E-08	1.10E-09	1.75E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.70E-01	1.67E-02	2.92E-01	-1.10E-01	8.68E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.73E+00	8.93E-02	1.94E+00	-1.15E+00	6.61E+00
Laptop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	6.52E-02	1.97E-06	1.82E-04	-8.58E-02	-2.05E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.24E+04	1.91E+02	1.07E+04	-9.67E+02	2.24E+04

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	6.55E+00	3.29E-01	1.22E+00	-2.02E+00	6.07E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	4.50E-01	4.13E-02	1.43E-01	-4.60E-02	5.87E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2.09E+01	6.88E-02	1.76E+00	-1.49E+00	2.12E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.09E+03	1.49E+01	9.01E+02	-7.25E+01	1.93E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.11E+03	1.49E+01	9.01E+02	-5.75E+01	1.97E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3.02E+02	7.55E-01	4.57E+01	-8.15E+01	2.68E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	6.86E+05	3.26E+02	4.60E+04	-3.93E+04	6.94E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.03E-07	1.12E-12	4.16E-09	9.55E-10	8.09E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	4.68E-01	4.16E-03	9.13E-02	-9.33E-02	4.71E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.20E+00	1.09E-02	6.11E-01	-6.74E-01	5.16E+00

Table B 16: CML results of Refurbishment with part replacement scenario for four devices (1 year use of 100 devices)

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
Monitor					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	8.98E-02	6.88E-06	6.59E-04	-6.42E-02	2.63E-02

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.56E+04	2.21E+03	3.88E+04	-9.24E+02	5.57E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	7.43E+00	4.47E-01	4.40E+00	-1.29E+00	1.10E+01
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	6.17E-01	9.73E-02	5.14E-01	4.56E-03	1.23E+00
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.45E+01	7.33E-01	6.29E+00	1.83E+00	2.33E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.51E+03	1.61E+02	3.26E+03	-4.70E+01	4.88E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.57E+03	1.61E+02	3.25E+03	-1.42E+01	4.97E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	4.49E+03	3.29E+00	1.65E+02	1.35E+03	6.01E+03
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	7.43E+05	2.46E+03	1.66E+05	-2.31E+05	6.80E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.81E-07	8.50E-12	1.50E-08	3.15E-08	2.28E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.86E-01	4.11E-02	3.30E-01	-5.99E-02	9.97E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.07E+00	1.36E-01	2.20E+00	1.16E-01	7.52E+00
Server					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	3.04E+00	2.44E-05	2.77E-02	-4.08E+00	-1.01E+00
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	7.18E+05	1.04E+03	1.63E+06	7.53E+04	2.43E+06
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	1.94E+02	2.74E-01	1.84E+02	6.68E+00	3.85E+02

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	1.75E+01	7.47E-02	2.00E+01	6.16E-01	3.82E+01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.35E+02	3.75E-01	2.19E+02	-1.19E+01	3.42E+02
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	5.97E+04	7.34E+01	1.36E+05	6.20E+03	2.02E+05
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	5.99E+04	7.32E+01	1.36E+05	6.23E+03	2.03E+05
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8.71E+03	3.35E+00	6.91E+03	4.20E+02	1.60E+04
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	3.83E+07	2.83E+03	6.98E+06	4.99E+06	5.02E+07
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.99E-07	5.86E-12	6.31E-07	8.41E-08	1.61E-06
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	1.47E+01	-5.49E-02	1.36E+01	7.66E-01	2.89E+01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	7.01E+01	2.54E-02	8.83E+01	-6.43E+00	1.52E+02
Desktop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	2.92E-01	4.37E-06	5.88E-04	-2.88E-01	5.57E-03
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	2.51E+04	9.90E+02	3.45E+04	2.54E+02	6.10E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	9.82E+00	1.56E-01	3.92E+00	-7.08E-01	1.32E+01
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	7.51E-01	3.38E-02	4.52E-01	-4.55E-02	1.19E+00
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	8.54E+00	3.44E-01	5.44E+00	-1.92E+00	1.24E+01

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.09E+03	7.25E+01	2.89E+03	-3.87E+00	5.06E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.13E+03	7.27E+01	2.89E+03	1.16E+01	5.12E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6.20E+02	1.46E+00	1.46E+02	-9.17E+01	6.77E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	9.56E+05	1.15E+03	1.48E+05	2.49E+04	1.13E+06
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.61E-07	4.97E-12	1.33E-08	1.39E-08	1.87E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.70E-01	1.67E-02	2.92E-01	-4.40E-02	9.34E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.73E+00	8.93E-02	1.94E+00	-7.35E-01	7.03E+00
Laptop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	6.52E-02	1.97E-06	1.82E-04	-8.97E-02	-2.44E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.24E+04	1.91E+02	1.07E+04	5.07E+02	2.39E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	6.55E+00	3.29E-01	1.22E+00	-1.45E+00	6.65E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	4.50E-01	4.13E-02	1.43E-01	6.38E-03	6.41E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2.09E+01	6.88E-02	1.76E+00	2.44E+00	2.53E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.09E+03	1.49E+01	9.01E+02	5.90E+01	2.06E+03

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.11E+03	1.49E+01	9.01E+02	7.40E+01	2.09E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3.02E+02	7.55E-01	4.57E+01	-5.22E+01	2.96E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	6.86E+05	3.26E+02	4.60E+04	5.52E+04	7.88E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.03E-07	1.12E-12	4.16E-09	1.73E-07	9.81E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	4.68E-01	4.16E-03	9.13E-02	-4.66E-02	5.17E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.20E+00	1.09E-02	6.11E-01	7.59E-02	5.90E+00

Table B 17: CML results of Part harvesting scenario for four devices (1 year use of 100 devices)

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
Monitor					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	8.98E-02	6.88E-06	4.12E-04	-7.21E-02	1.81E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.56E+04	2.21E+03	2.43E+04	-4.30E+03	3.77E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	7.43E+00	4.47E-01	2.76E+00	-2.67E+00	7.97E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	6.17E-01	9.73E-02	3.37E-01	-1.04E-01	9.47E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.45E+01	7.33E-01	4.38E+00	-6.49E+00	1.31E+01

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.51E+03	1.61E+02	2.04E+03	-3.16E+02	3.40E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.57E+03	1.61E+02	2.04E+03	-2.92E+02	3.48E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	4.49E+03	3.29E+00	1.04E+02	-2.08E+03	2.52E+03
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	7.43E+05	2.46E+03	1.04E+05	-3.55E+05	4.94E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.81E-07	8.50E-12	9.37E-09	-2.67E-08	1.64E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.86E-01	4.11E-02	2.09E-01	-1.43E-01	7.93E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.07E+00	1.36E-01	1.42E+00	-1.75E+00	4.88E+00
Server					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	3.05E+00	2.45E-05	1.71E-02	-2.17E+00	8.88E-01
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	7.18E+05	1.04E+03	1.00E+06	-2.49E+05	1.47E+06
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	1.94E+02	2.74E-01	1.13E+02	-6.51E+01	2.43E+02
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	1.75E+01	7.48E-02	1.23E+01	-6.02E+00	2.38E+01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.35E+02	3.75E-01	1.36E+02	-5.55E+01	2.15E+02
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	5.97E+04	7.34E+01	8.40E+04	-2.09E+04	1.23E+05

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	5.98E+04	7.32E+01	8.40E+04	-2.09E+04	1.23E+05
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8.71E+03	3.35E+00	4.26E+03	-3.69E+03	9.28E+03
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	3.83E+07	2.83E+03	4.29E+06	-1.40E+07	2.85E+07
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.98E-07	5.86E-12	3.88E-07	-2.45E-07	1.04E-06
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	1.47E+01	-5.49E-02	8.35E+00	-5.09E+00	1.78E+01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	7.02E+01	2.54E-02	5.45E+01	-2.74E+01	9.72E+01
Desktop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	2.92E-01	4.37E-06	3.44E-04	-3.19E-01	-2.60E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	2.51E+04	9.90E+02	2.02E+04	-9.01E+03	3.73E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	9.82E+00	1.56E-01	2.30E+00	-4.36E+00	7.92E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	7.51E-01	3.38E-02	2.78E-01	-3.20E-01	7.41E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	8.54E+00	3.44E-01	3.55E+00	-4.30E+00	8.14E+00
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.09E+03	7.25E+01	1.70E+03	-7.94E+02	3.07E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.13E+03	7.27E+01	1.70E+03	-7.87E+02	3.11E+03

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6.20E+02	1.46E+00	8.61E+01	-2.66E+02	4.42E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	9.56E+05	1.15E+03	8.67E+04	-4.09E+05	6.33E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.61E-07	4.97E-12	7.81E-09	-3.93E-08	1.29E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.70E-01	1.67E-02	1.74E-01	-2.94E-01	5.64E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.73E+00	8.93E-02	1.17E+00	-2.34E+00	4.65E+00
Laptop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	6.52E-02	1.97E-06	1.09E-04	-8.22E-02	-1.70E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.24E+04	1.91E+02	6.41E+03	-2.32E+03	1.67E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	6.55E+00	3.29E-01	7.31E-01	-2.54E+00	5.07E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	4.50E-01	4.13E-02	9.06E-02	-9.51E-02	4.87E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2.09E+01	6.88E-02	1.20E+00	-2.53E+00	1.97E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.09E+03	1.49E+01	5.41E+02	-1.99E+02	1.45E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.11E+03	1.49E+01	5.40E+02	-1.87E+02	1.48E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3.02E+02	7.55E-01	2.74E+01	-1.03E+02	2.27E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	6.86E+05	3.26E+02	2.75E+04	-1.48E+05	5.65E+05

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.03E-07	1.12E-12	2.48E-09	-3.87E-08	7.67E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	4.68E-01	4.16E-03	5.56E-02	-1.42E-01	3.86E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.20E+00	1.09E-02	3.80E-01	-1.02E+00	4.57E+00

Table B 18: CML results of recycling scenario for four devices (1 year use of 100 devices)

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
Monitor					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	8.98E-02	6.88E-06	4.12E-04	-4.86E-02	4.16E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.56E+04	2.21E+03	2.43E+04	-1.95E+03	4.01E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	7.43E+00	4.47E-01	2.76E+00	-1.47E+00	9.17E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	6.17E-01	9.73E-02	3.37E-01	-5.08E-02	1.00E+00
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.45E+01	7.33E-01	4.38E+00	-1.60E+00	1.80E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.51E+03	1.61E+02	2.04E+03	-1.47E+02	3.57E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.57E+03	1.61E+02	2.04E+03	-1.27E+02	3.64E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	4.49E+03	3.29E+00	1.04E+02	-2.02E+02	4.40E+03

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	7.43E+05	2.46E+03	1.04E+05	-2.06E+05	6.43E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.81E-07	8.50E-12	9.37E-09	-6.38E-11	1.91E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.86E-01	4.11E-02	2.09E-01	-8.07E-02	8.56E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.07E+00	1.36E-01	1.42E+00	-5.99E-01	6.02E+00
Server					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	3.05E+00	2.45E-05	1.71E-02	-2.72E+00	3.31E-01
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	7.18E+05	1.04E+03	1.00E+06	-1.86E+04	1.71E+06
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	1.94E+02	2.74E-01	1.13E+02	-1.19E+01	2.95E+02
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	1.75E+01	7.48E-02	1.23E+01	-1.14E+00	2.88E+01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1.35E+02	3.75E-01	1.36E+02	-2.00E+01	2.51E+02
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	5.97E+04	7.34E+01	8.40E+04	-1.58E+03	1.42E+05
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	5.98E+04	7.32E+01	8.40E+04	-1.58E+03	1.42E+05
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8.71E+03	3.35E+00	4.26E+03	-6.97E+02	1.23E+04
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	3.83E+07	2.83E+03	4.29E+06	-5.71E+05	4.20E+07
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.98E-07	5.86E-12	3.88E-07	-3.25E-09	1.28E-06

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	1.47E+01	-5.49E-02	8.35E+00	-7.77E-01	2.22E+01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	7.02E+01	2.54E-02	5.45E+01	-9.89E+00	1.15E+02
Desktop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	2.92E-01	4.37E-06	3.44E-04	-2.21E-01	7.21E-02
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	2.51E+04	9.90E+02	2.02E+04	-1.83E+03	4.44E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	9.82E+00	1.56E-01	2.30E+00	-1.28E+00	1.10E+01
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	7.51E-01	3.38E-02	2.78E-01	-9.75E-02	9.65E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	8.54E+00	3.44E-01	3.55E+00	-1.97E+00	1.05E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.09E+03	7.25E+01	1.70E+03	-1.67E+02	3.70E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	2.13E+03	7.27E+01	1.70E+03	-1.61E+02	3.74E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6.20E+02	1.46E+00	8.61E+01	-1.03E+02	6.04E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	9.56E+05	1.15E+03	8.67E+04	-8.06E+04	9.63E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	1.61E-07	4.97E-12	7.81E-09	-1.26E-10	1.68E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	6.70E-01	1.67E-02	1.74E-01	-8.39E-02	7.75E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.73E+00	8.93E-02	1.17E+00	-8.99E-01	6.10E+00

EF 3.0 Eutrophication, freshwater [kg P eq.]	Manufacturing	Distribution	Use	ARS	Total
Laptop					
CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]	6.52E-02	1.97E-06	1.09E-04	-6.10E-02	4.29E-03
CML2001 - Aug. 2016, Abiotic Depletion (ADP fossil) [MJ]	1.24E+04	1.91E+02	6.41E+03	-6.97E+02	1.84E+04
CML2001 - Aug. 2016, Acidification Potential (AP) [kg SO2 eq.]	6.55E+00	3.29E-01	7.31E-01	-1.44E+00	6.17E+00
CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	4.50E-01	4.13E-02	9.06E-02	-3.56E-02	5.46E-01
CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2.09E+01	6.88E-02	1.20E+00	-1.07E+00	2.11E+01
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.09E+03	1.49E+01	5.41E+02	-5.37E+01	1.58E+03
CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	1.11E+03	1.49E+01	5.40E+02	-4.22E+01	1.61E+03
CML2001 - Aug. 2016, Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3.02E+02	7.55E-01	2.74E+01	-5.78E+01	2.72E+02
CML2001 - Aug. 2016, Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB eq.]	6.86E+05	3.26E+02	2.75E+04	-2.78E+04	6.86E+05
CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8.03E-07	1.12E-12	2.48E-09	-1.54E-11	8.06E-07
CML2001 - Aug. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	4.68E-01	4.16E-03	5.56E-02	-6.65E-02	4.62E-01
CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]	5.20E+00	1.09E-02	3.80E-01	-4.93E-01	5.11E+00

Annex B6

Annex B6 presents the breakdown LCA results of ARS for four scenarios for EF 3.0 indicators and other inventory metrics across four devices.

Table B 19: Breakdown of ARS Refurbishment scenario for EF 3.0 indicators and other inventory metrics across four devices (1 year use of 100 devices)

EF 3.0 Eutrophication, freshwater [kg P eq.]	4. On-site data sanitization	5. Distri-butiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.1.0. Refurbishment	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
Monitor										
EF 3.0 Acidification [Mole of H+ eq.]	-	4.03E-02	-3.88E-04	-	-	1.32E-04	1.16E-01	6.65E-03	-2.40E+00	-2.24E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-	1.09E+01	7.74E-01	-	-	8.95E-02	3.28E+01	8.11E-01	-2.13E+02	-1.68E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-	1.95E-04	-1.98E-07	-	-	5.00E-08	8.53E-04	5.18E-06	-2.00E-04	8.53E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-	1.27E-10	-1.41E-12	-	-	3.44E-13	1.15E-09	6.14E-14	-3.79E-10	8.99E-10
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-	4.38E-02	-2.71E-04	-	-	8.16E-05	1.16E-01	6.30E-03	-7.38E-01	-5.72E-01
EF 3.0 Resource use, fossils [MJ]	-	1.72E+02	-6.49E+00	-	-	1.39E+00	4.85E+02	1.06E+01	-3.68E+03	-3.02E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-	4.27E-06	-8.80E-08	-	-	1.62E-08	1.22E-05	2.64E-07	-6.86E-02	-6.85E-02
EF 3.0 Water use [m³ world equiv.]	-	1.13E+00	1.64E-02	-	-	1.89E-02	3.79E+00	6.22E-02	-3.51E+01	-3.01E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-	2.79E-01	1.06E-01	-	-	4.70E-04	1.20E+00	1.06E-03	-3.53E+01	-3.37E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-	1.07E+01	7.80E-01	-	-	8.80E-02	3.22E+01	8.01E-01	-2.11E+02	-1.66E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-	4.37E+02	-7.74E+00	-	-	1.70E+00	1.30E+03	1.19E+01	-4.65E+03	-2.91E+03
Blue water consumption [kg]	-	1.00E+02	-1.71E-01	-	-	5.74E-01	4.11E+02	2.00E+00	-2.92E+03	-2.41E+03
Server										
EF 3.0 Acidification [Mole of H+ eq.]	-1.68E+00	5.22E-02	-7.53E-04	2.31E-03	-3.11E-02	2.51E-03	1.10E+00	1.99E-02	-1.50E+01	-1.55E+01

EF 3.0 Eutrophication, freshwater [kg P eq.]	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.1.0. Refurbishment	9.2.2. Transport to EoI	9.2.3. Recycling	ARS Total
EF 3.0 Climate Change - total [kg CO2 eq.]	-1.93E+02	1.04E+01	1.50E+00	1.56E+00	-3.45E+00	1.69E+00	1.41E+02	2.43E+00	-1.74E+03	-1.78E+03
EF 3.0 Eutrophication, freshwater [kg P eq.]	-4.09E-04	7.00E-05	-3.85E-07	8.73E-07	-4.86E-06	9.46E-07	1.81E-03	1.55E-05	-3.72E-03	-2.24E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-2.80E-10	3.73E-11	-2.74E-12	6.02E-12	-3.04E-12	6.52E-12	1.24E-09	1.84E-13	-3.38E-09	-2.37E-09
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.04E+00	5.19E-02	-5.26E-04	1.42E-03	-1.57E-02	1.54E-03	8.97E-01	1.89E-02	-9.28E+00	-9.36E+00
EF 3.0 Resource use, fossils [MJ]	-2.11E+03	1.85E+02	-1.26E+01	2.44E+01	-3.85E+01	2.64E+01	2.75E+03	3.18E+01	-2.08E+04	-2.00E+04
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-3.27E-01	4.17E-06	-1.71E-07	2.84E-07	-4.90E-03	3.08E-07	3.57E-05	7.92E-07	-2.90E+00	-3.23E+00
EF 3.0 Water use [m³ world equiv.]	-1.22E+02	1.13E+00	3.18E-02	3.30E-01	-1.88E+00	3.58E-01	3.76E+00	1.86E-01	-1.11E+03	-1.23E+03
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.35E+00	9.18E-02	2.05E-01	8.22E-03	-1.95E-01	8.91E-03	3.26E+00	3.17E-03	-3.02E+01	-2.55E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-1.90E+02	1.02E+01	1.51E+00	1.54E+00	-3.40E+00	1.67E+00	1.38E+02	2.40E+00	-1.71E+03	-1.75E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-2.78E+03	3.15E+02	-1.50E+01	2.97E+01	-4.90E+01	3.22E+01	4.44E+03	3.56E+01	-2.73E+04	-2.53E+04
Blue water consumption [kg]	-8.40E+03	4.90E+01	-3.31E-01	1.00E+01	-1.26E+02	1.09E+01	9.90E+02	5.99E+00	-7.55E+04	-8.29E+04
Desktop										
EF 3.0 Acidification [Mole of H+ eq.]	-9.44E-02	2.57E-02	-9.49E-04	3.10E-04	-9.24E-03	1.10E-03	6.59E-02	4.99E-03	-1.87E+00	-1.88E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-8.68E+00	8.03E+00	1.89E+00	2.10E-01	-1.08E+00	7.46E-01	2.24E+01	6.09E-01	-2.28E+02	-2.04E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-1.77E-05	8.10E-05	-4.84E-07	1.17E-07	-1.74E-06	4.16E-07	5.66E-04	3.89E-06	-3.80E-04	2.51E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-4.93E-13	5.31E-11	-3.45E-12	8.08E-13	-1.07E-12	2.87E-12	1.02E-09	4.61E-14	-2.88E-10	7.84E-10
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-4.99E-02	2.68E-02	-6.63E-04	1.91E-04	-4.87E-03	6.80E-04	7.64E-02	4.73E-03	-9.96E-01	-9.42E-01
EF 3.0 Resource use, fossils [MJ]	-8.85E+01	1.67E+02	-1.59E+01	3.27E+00	-1.24E+01	1.16E+01	3.86E+02	7.98E+00	-2.71E+03	-2.25E+03

EF 3.0 Eutrophication, freshwater [kg P eq.]	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.1.0. Refurbishment	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-1.44E-02	3.81E-06	-2.15E-07	3.81E-08	-1.37E-03	1.35E-07	8.38E-06	1.98E-07	-2.73E-01	-2.89E-01
EF 3.0 Water use [m³ world equiv.]	-5.13E+00	1.09E+00	4.00E-02	4.43E-02	-5.42E-01	1.57E-01	2.30E+00	4.67E-02	-1.06E+02	-1.08E+02
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-5.64E-01	1.28E-01	2.58E-01	1.10E-03	-5.50E-02	3.92E-03	8.08E-01	7.95E-04	-9.81E+00	-9.22E+00
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-8.55E+00	7.84E+00	1.91E+00	2.07E-01	-1.06E+00	7.34E-01	2.20E+01	6.02E-01	-2.25E+02	-2.01E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-1.13E+02	2.67E+02	-1.89E+01	3.99E+00	-1.56E+01	1.42E+01	9.17E+02	8.92E+00	-3.40E+03	-2.34E+03
Blue water consumption [kg]	-3.59E+02	5.82E+01	-4.17E-01	1.35E+00	-3.57E+01	4.79E+00	2.73E+02	1.50E+00	-7.08E+03	-7.14E+03
Laptop										
EF 3.0 Acidification [Mole of H+ eq.]	-7.65E-02	2.42E-02	-5.01E-04	1.18E-04	-8.88E-03	2.60E-04	2.61E-02	1.62E-03	-2.13E+00	-2.16E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-2.42E+00	7.84E+00	9.98E-01	7.98E-02	-1.04E+00	1.76E-01	8.98E+00	1.97E-01	-7.07E+01	-5.59E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	-3.75E-06	1.52E-04	-2.56E-07	4.46E-08	-1.72E-06	9.84E-08	2.21E-04	1.26E-06	-1.10E-04	2.58E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-5.87E-12	9.73E-11	-1.82E-12	3.07E-13	-1.04E-12	6.78E-13	7.66E-10	1.49E-14	-1.89E-10	6.66E-10
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.80E-02	2.66E-02	-3.50E-04	7.27E-05	-4.71E-03	1.61E-04	2.94E-02	1.53E-03	-5.02E-01	-4.67E-01
EF 3.0 Resource use, fossils [MJ]	-4.03E+01	1.39E+02	-8.37E+00	1.24E+00	-1.20E+01	2.75E+00	1.32E+02	2.59E+00	-1.19E+03	-9.70E+02
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-2.80E-03	3.49E-06	-1.14E-07	1.45E-08	-1.30E-03	3.20E-08	3.32E-06	6.43E-08	-7.78E-02	-8.19E-02
EF 3.0 Water use [m³ world equiv.]	-1.27E+00	9.49E-01	2.11E-02	1.68E-02	-5.18E-01	3.72E-02	1.04E+00	1.51E-02	-3.41E+01	-3.38E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-2.54E-01	2.19E-01	1.36E-01	4.20E-04	-5.23E-02	9.26E-04	3.16E-01	2.58E-04	-6.65E+00	-6.28E+00
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-2.39E+00	7.67E+00	1.01E+00	7.85E-02	-1.02E+00	1.73E-01	8.81E+00	1.95E-01	-6.97E+01	-5.52E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-5.01E+01	2.92E+02	-9.99E+00	1.52E+00	-1.51E+01	3.35E+00	3.44E+02	2.89E+00	-1.48E+03	-9.08E+02

EF 3.0 Eutrophication, freshwater [kg P eq.]	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.1.0. Refurbishment	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
Blue water consumption [kg]	- 7.80E+01	8.10E+01	-2.20E-01	5.12E-01	- 3.40E+01	1.13E+00	1.09E+02	4.87E-01	- 2.15E+03	- 2.07E+03

Table B 20: Breakdown of ARS Refurbishment with part replacement scenario for EF 3.0 indicators and other inventory metrics across four devices (1 year use of 100 devices)

Impact categories	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.2.0.Refurbishment with part replacement	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
Monitor										
EF 3.0 Acidification [Mole of H+ eq.]	-	4.03E-02	-3.88E-04	-	-	1.32E-04	9.38E-01	6.65E-03	- 2.40E+00	- 1.42E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-	1.09E+01	7.74E-01	-	-	8.95E-02	1.89E+02	8.11E-01	- 2.13E+02	- 1.13E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	-	1.95E-04	-1.98E-07	-	-	5.00E-08	1.33E-03	5.18E-06	-2.00E-04	1.33E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-	1.27E-10	-1.41E-12	-	-	3.44E-13	2.64E-08	6.14E-14	-3.79E-10	2.61E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-	4.38E-02	-2.71E-04	-	-	8.16E-05	5.48E-01	6.30E-03	-7.38E-01	-1.41E-01
EF 3.0 Resource use, fossils [MJ]	-	1.72E+02	- 6.49E+00	-	-	1.39E+00	2.22E+03	1.06E+01	- 3.68E+03	- 1.28E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-	4.27E-06	-8.80E-08	-	-	1.62E-08	4.20E-03	2.64E-07	-6.86E-02	-6.44E-02
EF 3.0 Water use [m³ world equiv.]	-	1.13E+00	1.64E-02	-	-	1.89E-02	2.68E+01	6.22E-02	- 3.51E+01	- 7.10E+00
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-	2.79E-01	1.06E-01	-	-	4.70E-04	1.50E+01	1.06E-03	- 3.53E+01	- 1.99E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-	1.07E+01	7.80E-01	-	-	8.80E-02	1.84E+02	8.01E-01	- 2.11E+02	- 1.39E+01

Impact categories	4. On-site data sanitization	5. Distribution to ARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.2.0.Refurbishment with part replacement	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-	4.37E+02	-7.74E+00	-	-	1.70E+00	3.39E+03	1.19E+01	-4.65E+03	-8.21E+02
Blue water consumption [kg]	-	1.00E+02	-1.71E-01	-	-	5.74E-01	1.42E+03	2.00E+00	-2.92E+03	-1.40E+03
Server										
EF 3.0 Acidification [Mole of H+ eq.]	-1.81E+00	5.62E-02	-8.11E-04	2.49E-03	-3.35E-02	2.70E-03	2.46E+01	2.15E-02	-1.61E+01	6.68E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-2.08E+02	1.13E+01	1.62E+00	1.68E+00	-3.72E+00	1.82E+00	8.43E+03	2.62E+00	-1.88E+03	6.36E+03
EF 3.0 Eutrophication, freshwater [kg P eq.]	-4.41E-04	7.54E-05	-4.14E-07	9.40E-07	-5.24E-06	1.02E-06	1.12E-02	1.67E-05	-4.00E-03	6.81E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-3.01E-10	4.01E-11	-2.95E-12	6.48E-12	-3.27E-12	7.02E-12	7.18E-08	1.98E-13	-3.64E-09	6.79E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.12E+00	5.59E-02	-5.67E-04	1.53E-03	-1.69E-02	1.66E-03	1.51E+01	2.03E-02	-9.99E+00	4.09E+00
EF 3.0 Resource use, fossils [MJ]	-2.27E+03	1.99E+02	-1.36E+01	2.62E+01	-4.15E+01	2.84E+01	1.24E+05	3.43E+01	-2.24E+04	9.95E+04
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-3.52E-01	4.49E-06	-1.84E-07	3.06E-07	-5.28E-03	3.31E-07	-6.03E-01	8.52E-07	-3.12E+00	-4.08E+00
EF 3.0 Water use [m³ world equiv.]	-1.31E+02	1.22E+00	3.42E-02	3.55E-01	-2.03E+00	3.85E-01	7.54E+02	2.01E-01	-1.20E+03	-5.77E+02
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	1.45E+00	9.89E-02	2.21E-01	8.85E-03	-2.10E-01	9.59E-03	1.13E+02	3.41E-03	-3.26E+01	8.23E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-2.05E+02	1.10E+01	1.63E+00	1.66E+00	-3.66E+00	1.80E+00	8.30E+03	2.58E+00	-1.85E+03	6.26E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-2.99E+03	3.39E+02	-1.62E+01	3.20E+01	-5.28E+01	3.47E+01	1.50E+05	3.83E+01	-2.95E+04	1.18E+05

Impact categories	4. On-site data sanitization	5. Distri-bu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.2.0.Refurbishment with part replacement	9.2.2. Transport to EoI	9.2.3. Recycling	ARS Total
Blue water consumption [kg]	-9.05E+03	5.28E+01	-3.57E-01	1.08E+01	-1.36E+02	1.17E+01	2.62E+04	6.45E+00	-8.13E+04	-6.42E+04
Desktop										
EF 3.0 Acidification [Mole of H+ eq.]	-9.44E-02	2.57E-02	-9.49E-04	3.10E-04	-9.24E-03	1.10E-03	1.12E+00	4.99E-03	-1.87E+00	-8.22E-01
EF 3.0 Climate Change - total [kg CO2 eq.]	-8.68E+00	8.03E+00	1.89E+00	2.10E-01	-1.08E+00	7.46E-01	2.38E+02	6.09E-01	-2.28E+02	1.22E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	-1.77E-05	8.10E-05	-4.84E-07	1.17E-07	-1.74E-06	4.16E-07	1.32E-03	3.89E-06	-3.80E-04	1.01E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-4.93E-13	5.31E-11	-3.45E-12	8.08E-13	-1.07E-12	2.87E-12	1.05E-08	4.61E-14	-2.88E-10	1.02E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-4.99E-02	2.68E-02	-6.63E-04	1.91E-04	-4.87E-03	6.80E-04	5.74E-01	4.73E-03	-9.96E-01	-4.44E-01
EF 3.0 Resource use, fossils [MJ]	-8.85E+01	1.67E+02	-1.59E+01	3.27E+00	-1.24E+01	1.16E+01	3.21E+03	7.98E+00	-2.71E+03	5.82E+02
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-1.44E-02	3.81E-06	-2.15E-07	3.81E-08	-1.37E-03	1.35E-07	7.58E-03	1.98E-07	-2.73E-01	-2.81E-01
EF 3.0 Water use [m³ world equiv.]	-5.13E+00	1.09E+00	4.00E-02	4.43E-02	-5.42E-01	1.57E-01	3.92E+01	4.67E-02	-1.06E+02	-7.07E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-5.64E-01	1.28E-01	2.58E-01	1.10E-03	-5.50E-02	3.92E-03	6.90E+00	7.95E-04	-9.81E+00	-3.13E+00
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-8.55E+00	7.84E+00	1.91E+00	2.07E-01	-1.06E+00	7.34E-01	2.35E+02	6.02E-01	-2.25E+02	1.18E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-1.13E+02	2.67E+02	-1.89E+01	3.99E+00	-1.56E+01	1.42E+01	4.33E+03	8.92E+00	-3.40E+03	1.08E+03
Blue water consumption [kg]	-3.59E+02	5.82E+01	-4.17E-01	1.35E+00	-3.57E+01	4.79E+00	1.21E+03	1.50E+00	-7.08E+03	-6.20E+03
Laptop										

Impact categories	4. On-site data sanitization	5. Distri-bu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.2.0.Refurbishment with part replacement	9.2.2. Transport to Eol	9.2.3. Recycling	ARS Total
EF 3.0 Acidification [Mole of H+ eq.]	-7.65E-02	2.42E-02	-5.01E-04	1.18E-04	-8.88E-03	2.60E-04	6.53E-01	1.62E-03	-2.13E+00	-1.53E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-2.42E+00	7.84E+00	9.98E-01	7.98E-02	-1.04E+00	1.76E-01	1.38E+02	1.97E-01	-7.07E+01	7.36E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	-3.75E-06	1.52E-04	-2.56E-07	4.46E-08	-1.72E-06	9.84E-08	2.53E-03	1.26E-06	-1.10E-04	2.57E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-5.87E-12	9.73E-11	-1.82E-12	3.07E-13	-1.04E-12	6.78E-13	1.41E-07	1.49E-14	-1.89E-10	1.41E-07
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.80E-02	2.66E-02	-3.50E-04	7.27E-05	-4.71E-03	1.61E-04	3.41E-01	1.53E-03	-5.02E-01	-1.56E-01
EF 3.0 Resource use, fossils [MJ]	-4.03E+01	1.39E+02	-8.37E+00	1.24E+00	-1.20E+01	2.75E+00	1.78E+03	2.59E+00	-1.19E+03	6.78E+02
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-2.80E-03	3.49E-06	-1.14E-07	1.45E-08	-1.30E-03	3.20E-08	-3.86E-03	6.43E-08	-7.78E-02	-8.58E-02
EF 3.0 Water use [m³ world equiv.]	-1.27E+00	9.49E-01	2.11E-02	1.68E-02	-5.18E-01	3.72E-02	1.68E+01	1.51E-02	-3.41E+01	-1.81E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-2.54E-01	2.19E-01	1.36E-01	4.20E-04	-5.23E-02	9.26E-04	4.49E+00	2.58E-04	-6.65E+00	-2.11E+00
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-2.39E+00	7.67E+00	1.01E+00	7.85E-02	-1.02E+00	1.73E-01	1.35E+02	1.95E-01	-6.97E+01	7.14E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-5.01E+01	2.92E+02	-9.99E+00	1.52E+00	-1.51E+01	3.35E+00	2.41E+03	2.89E+00	-1.48E+03	1.16E+03
Blue water consumption [kg]	-7.80E+01	8.10E+01	-2.20E-01	5.12E-01	-3.40E+01	1.13E+00	5.03E+02	4.87E-01	-2.15E+03	-1.67E+03

Table B 21: Breakdown of ARS Part harvesting scenario for EF 3.0 indicators and other inventory metrics across four devices (1 year use of 100 devices)

Impact categories	4. On-site data sanitization	5. DistributiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.3.0. Part harvesting	ARS Total
Monitor								
EF 3.0 Acidification [Mole of H+ eq.]	-	6.45E-02	-6.21E-04	-	-	2.12E-04	-4.88E+00	-4.82E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-	1.74E+01	1.24E+00	-	-	1.43E-01	-4.95E+02	-4.76E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-	3.12E-04	-3.17E-07	-	-	8.00E-08	-4.35E-04	-1.24E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-	2.04E-10	-2.26E-12	-	-	5.51E-13	-3.23E-08	-3.21E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-	7.01E-02	-4.34E-04	-	-	1.30E-04	-1.55E+00	-1.48E+00
EF 3.0 Resource use, fossils [MJ]	-	2.75E+02	-1.04E+01	-	-	2.23E+00	-7.95E+03	-7.68E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-	6.83E-06	-1.41E-07	-	-	2.60E-08	-1.15E-01	-1.15E-01
EF 3.0 Water use [m³ world equiv.]	-	1.80E+00	2.62E-02	-	-	3.02E-02	-1.11E+02	-1.09E+02
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-	4.47E-01	1.69E-01	-	-	7.53E-04	-8.22E+01	-8.16E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-	1.71E+01	1.25E+00	-	-	1.41E-01	-4.89E+02	-4.71E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-	6.99E+02	-1.24E+01	-	-	2.72E+00	-9.88E+03	-9.19E+03
Blue water consumption [kg]	-	1.60E+02	-2.73E-01	-	-	9.19E-01	-6.45E+03	-6.29E+03
Server								
EF 3.0 Acidification [Mole of H+ eq.]	-2.95E+00	9.14E-02	-1.32E-03	4.05E-03	-5.45E-02	4.39E-03	-1.16E+02	-1.19E+02
EF 3.0 Climate Change - total [kg CO2 eq.]	-3.38E+02	1.83E+01	2.63E+00	2.74E+00	-6.04E+00	2.97E+00	-3.45E+04	-3.48E+04
EF 3.0 Eutrophication, freshwater [kg P eq.]	-7.17E-04	1.22E-04	-6.73E-07	1.53E-06	-8.51E-06	1.66E-06	-4.59E-02	-4.65E-02
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-4.89E-10	6.52E-11	-4.79E-12	1.05E-11	-5.31E-12	1.14E-11	-3.19E-07	-3.20E-07
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.82E+00	9.09E-02	-9.21E-04	2.49E-03	-2.75E-02	2.70E-03	-7.05E+01	-7.23E+01
EF 3.0 Resource use, fossils [MJ]	-3.70E+03	3.24E+02	-2.20E+01	4.26E+01	-6.74E+01	4.62E+01	-4.92E+05	-4.96E+05

Impact categories	4. On-site data sanitization	5. Distribu-tiontoARS	6. packag-ing disposal	7. Verifica-tion	8. 2nd data sanitization	9. Testing and sorting	9.3.0. Part harvesting	ARS Total
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-5.71E-01	7.29E-06	-2.99E-07	4.97E-07	-8.57E-03	5.38E-07	-2.94E+00	-3.52E+00
EF 3.0 Water use [m³ world equiv.]	-2.13E+02	1.98E+00	5.56E-02	5.77E-01	-3.29E+00	6.26E-01	-4.90E+03	-5.11E+03
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	2.36E+00	1.61E-01	3.59E-01	1.44E-02	-3.42E-01	1.56E-02	-4.93E+02	-4.90E+02
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-3.33E+02	1.79E+01	2.65E+00	2.69E+00	-5.95E+00	2.92E+00	-3.39E+04	-3.42E+04
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-4.86E+03	5.51E+02	-2.63E+01	5.20E+01	-8.58E+01	5.63E+01	-5.95E+05	-5.99E+05
Blue water consumption [kg]	-1.47E+04	8.58E+01	-5.80E-01	1.76E+01	-2.20E+02	1.90E+01	-2.31E+05	-2.45E+05
Desktop								
EF 3.0 Acidification [Mole of H+ eq.]	-1.65E-01	4.49E-02	-1.66E-03	5.43E-04	-1.62E-02	1.93E-03	-8.25E+00	-8.39E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-1.52E+01	1.41E+01	3.31E+00	3.67E-01	-1.88E+00	1.30E+00	-1.37E+03	-1.37E+03
EF 3.0 Eutrophication, freshwater [kg P eq.]	-3.10E-05	1.42E-04	-8.48E-07	2.05E-07	-3.05E-06	7.29E-07	-4.34E-03	-4.24E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-8.62E-13	9.29E-11	-6.03E-12	1.41E-12	-1.87E-12	5.02E-12	-5.11E-08	-5.10E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-8.73E-02	4.69E-02	-1.16E-03	3.35E-04	-8.52E-03	1.19E-03	-4.06E+00	-4.11E+00
EF 3.0 Resource use, fossils [MJ]	-1.55E+02	2.93E+02	-2.77E+01	5.73E+00	-2.16E+01	2.03E+01	-1.71E+04	-1.70E+04
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-2.52E-02	6.67E-06	-3.76E-07	6.67E-08	-2.40E-03	2.37E-07	-5.16E-01	-5.44E-01
EF 3.0 Water use [m³ world equiv.]	-8.98E+00	1.90E+00	7.00E-02	7.75E-02	-9.49E-01	2.75E-01	-3.74E+02	-3.82E+02
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-9.87E-01	2.25E-01	4.52E-01	1.93E-03	-9.62E-02	6.86E-03	-4.63E+01	-4.67E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-1.50E+01	1.37E+01	3.34E+00	3.61E-01	-1.86E+00	1.28E+00	-1.35E+03	-1.35E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-1.98E+02	4.67E+02	-3.31E+01	6.98E+00	-2.73E+01	2.48E+01	-2.09E+04	-2.07E+04
Blue water consumption [kg]	-6.27E+02	1.02E+02	-7.30E-01	2.36E+00	-6.25E+01	8.38E+00	-1.69E+04	-1.75E+04
Laptop								
EF 3.0 Acidification [Mole of H+ eq.]	-1.34E-01	4.23E-02	-8.77E-04	2.07E-04	-1.55E-02	4.56E-04	-4.67E+00	-4.77E+00

Impact categories	4. On-site data sanitization	5. DistributiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.3.0. Part harvesting	ARS Total
EF 3.0 Climate Change - total [kg CO2 eq.]	-4.23E+00	1.37E+01	1.75E+00	1.40E-01	-1.82E+00	3.08E-01	-3.32E+02	-3.22E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-6.57E-06	2.66E-04	-4.48E-07	7.80E-08	-3.01E-06	1.72E-07	-1.49E-03	-1.23E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-1.03E-11	1.70E-10	-3.18E-12	5.38E-13	-1.82E-12	1.19E-12	-5.69E-08	-5.68E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-3.15E-02	4.66E-02	-6.12E-04	1.27E-04	-8.24E-03	2.81E-04	-1.41E+00	-1.40E+00
EF 3.0 Resource use, fossils [MJ]	-7.05E+01	2.43E+02	-1.47E+01	2.18E+00	-2.10E+01	4.80E+00	-4.61E+03	-4.47E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-4.91E-03	6.10E-06	-1.99E-07	2.54E-08	-2.28E-03	5.60E-08	-1.30E-01	-1.37E-01
EF 3.0 Water use [m³ world equiv.]	-2.22E+00	1.66E+00	3.70E-02	2.95E-02	-9.06E-01	6.51E-02	-8.03E+01	-8.17E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-4.45E-01	3.83E-01	2.39E-01	7.34E-04	-9.15E-02	1.62E-03	-1.76E+01	-1.75E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-4.18E+00	1.34E+01	1.76E+00	1.37E-01	-1.79E+00	3.03E-01	-3.25E+02	-3.16E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-8.77E+01	5.12E+02	-1.75E+01	2.65E+00	-2.64E+01	5.85E+00	-5.70E+03	-5.31E+03
Blue water consumption [kg]	-1.37E+02	1.42E+02	-3.86E-01	8.97E-01	-5.96E+01	1.98E+00	-4.51E+03	-4.56E+03

Table B 22: Breakdown of ARS recycling scenario for EF 3.0 indicators and other inventory metrics across four devices (1 year use of 100 devices)

Impact categories	4. On-site data sanitization	5. DistributiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.4.0 Recycling	ARS Total
Monitor								
EF 3.0 Acidification [Mole of H+ eq.]	-	6.45E-02	-6.21E-04	-	-	2.12E-04	-2.72E+00	-2.66E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-	1.74E+01	1.24E+00	-	-	1.43E-01	-2.26E+02	-2.07E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-	3.12E-04	-3.17E-07	-	-	8.00E-08	-2.03E-04	1.08E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-	2.04E-10	-2.26E-12	-	-	5.51E-13	-3.10E-10	-1.08E-10
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-	7.01E-02	-4.34E-04	-	-	1.30E-04	-8.34E-01	-7.64E-01

Impact categories	4. On-site data sanitization	5. Distribu-tiontoARS	6. packag-ing disposal	7. Verifica-tion	8. 2nd data sanitization	9. Testing and sorting	9.4.0 Recy-cling	ARS Total
EF 3.0 Resource use, fossils [MJ]	-	2.75E+02	-1.04E+01	-	-	2.23E+00	-3.88E+03	-3.61E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-	6.83E-06	-1.41E-07	-	-	2.60E-08	-7.78E-02	-7.78E-02
EF 3.0 Water use [m³ world equiv.]	-	1.80E+00	2.62E-02	-	-	3.02E-02	-4.47E+01	-4.28E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-	4.47E-01	1.69E-01	-	-	7.53E-04	-4.18E+01	-4.11E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-	1.71E+01	1.25E+00	-	-	1.41E-01	-2.23E+02	-2.05E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-	6.99E+02	-1.24E+01	-	-	2.72E+00	-4.90E+03	-4.21E+03
Blue water consumption [kg]	-	1.60E+02	-2.73E-01	-	-	9.19E-01	-3.40E+03	-3.24E+03
Server								
EF 3.0 Acidification [Mole of H+ eq.]	-2.95E+00	9.14E-02	-1.32E-03	4.05E-03	-5.45E-02	4.39E-03	-1.99E+01	-2.28E+01
EF 3.0 Climate Change - total [kg CO2 eq.]	-3.38E+02	1.83E+01	2.63E+00	2.74E+00	-6.04E+00	2.97E+00	-2.31E+03	-2.63E+03
EF 3.0 Eutrophication, freshwater [kg P eq.]	-7.17E-04	1.22E-04	-6.73E-07	1.53E-06	-8.51E-06	1.66E-06	-4.85E-03	-5.45E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-4.89E-10	6.52E-11	-4.79E-12	1.05E-11	-5.31E-12	1.14E-11	-4.07E-09	-4.48E-09
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-1.82E+00	9.09E-02	-9.21E-04	2.49E-03	-2.75E-02	2.70E-03	-1.23E+01	-1.41E+01
EF 3.0 Resource use, fossils [MJ]	-3.70E+03	3.24E+02	-2.20E+01	4.26E+01	-6.74E+01	4.62E+01	-2.66E+04	-3.00E+04
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-5.71E-01	7.29E-06	-2.99E-07	4.97E-07	-8.57E-03	5.38E-07	-3.85E+00	-4.43E+00
EF 3.0 Water use [m³ world equiv.]	-2.13E+02	1.98E+00	5.56E-02	5.77E-01	-3.29E+00	6.26E-01	-1.49E+03	-1.71E+03
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	2.36E+00	1.61E-01	3.59E-01	1.44E-02	-3.42E-01	1.56E-02	-4.86E+01	-4.61E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-3.33E+02	1.79E+01	2.65E+00	2.69E+00	-5.95E+00	2.92E+00	-2.27E+03	-2.58E+03
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-4.86E+03	5.51E+02	-2.63E+01	5.20E+01	-8.58E+01	5.63E+01	-3.50E+04	-3.93E+04
Blue water consumption [kg]	-1.47E+04	8.58E+01	-5.80E-01	1.76E+01	-2.20E+02	1.90E+01	-1.00E+05	-1.15E+05
Desktop								

Impact categories	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.4.0 Recycling	ARS Total
Impact categories	4. On-site data sanitization	5. Distribu-tiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.4.0 Recycling	ARS Total
EF 3.0 Acidification [Mole of H+ eq.]	-1.65E-01	4.49E-02	-1.66E-03	5.43E-04	-1.62E-02	1.93E-03	-2.39E+00	-2.53E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-1.52E+01	1.41E+01	3.31E+00	3.67E-01	-1.88E+00	1.30E+00	-2.81E+02	-2.79E+02
EF 3.0 Eutrophication, freshwater [kg P eq.]	-3.10E-05	1.42E-04	-8.48E-07	2.05E-07	-3.05E-06	7.29E-07	-4.70E-04	-3.63E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-8.62E-13	9.29E-11	-6.03E-12	1.41E-12	-1.87E-12	5.02E-12	-2.82E-10	-1.92E-10
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-8.73E-02	4.69E-02	-1.16E-03	3.35E-04	-8.52E-03	1.19E-03	-1.27E+00	-1.32E+00
EF 3.0 Resource use, fossils [MJ]	-1.55E+02	2.93E+02	-2.77E+01	5.73E+00	-2.16E+01	2.03E+01	-3.24E+03	-3.13E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-2.52E-02	6.67E-06	-3.76E-07	6.67E-08	-2.40E-03	2.37E-07	-3.50E-01	-3.77E-01
EF 3.0 Water use [m³ world equiv.]	-8.98E+00	1.90E+00	7.00E-02	7.75E-02	-9.49E-01	2.75E-01	-1.39E+02	-1.47E+02
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-9.87E-01	2.25E-01	4.52E-01	1.93E-03	-9.62E-02	6.86E-03	-1.40E+01	-1.44E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-1.50E+01	1.37E+01	3.34E+00	3.61E-01	-1.86E+00	1.28E+00	-2.77E+02	-2.75E+02
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-1.98E+02	4.67E+02	-3.31E+01	6.98E+00	-2.73E+01	2.48E+01	-4.08E+03	-3.84E+03
Blue water consumption [kg]	-6.27E+02	1.02E+02	-7.30E-01	2.36E+00	-6.25E+01	8.38E+00	-9.14E+03	-9.72E+03
Laptop								
EF 3.0 Acidification [Mole of H+ eq.]	-1.34E-01	4.23E-02	-8.77E-04	2.07E-04	-1.55E-02	4.56E-04	-2.59E+00	-2.69E+00
EF 3.0 Climate Change - total [kg CO2 eq.]	-4.23E+00	1.37E+01	1.75E+00	1.40E-01	-1.82E+00	3.08E-01	-8.15E+01	-7.17E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	-6.57E-06	2.66E-04	-4.48E-07	7.80E-08	-3.01E-06	1.72E-07	-1.28E-04	1.28E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	-1.03E-11	1.70E-10	-3.18E-12	5.38E-13	-1.82E-12	1.19E-12	-1.97E-10	-4.06E-11
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	-3.15E-02	4.66E-02	-6.12E-04	1.27E-04	-8.24E-03	2.81E-04	-6.10E-01	-6.03E-01
EF 3.0 Resource use, fossils [MJ]	-7.05E+01	2.43E+02	-1.47E+01	2.18E+00	-2.10E+01	4.80E+00	-1.36E+03	-1.22E+03

Impact categories	4. On-site data sanitization	5. DistributiontoARS	6. packaging disposal	7. Verification	8. 2nd data sanitization	9. Testing and sorting	9.4.0 Recycling	ARS Total
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	-4.91E-03	6.10E-06	-1.99E-07	2.54E-08	-2.28E-03	5.60E-08	-9.47E-02	-1.02E-01
EF 3.0 Water use [m³ world equiv.]	-2.22E+00	1.66E+00	3.70E-02	2.95E-02	-9.06E-01	6.51E-02	-4.29E+01	-4.42E+01
02 EN15804+A2 Non-hazardous waste disposed (NHWD) [kg]	-4.45E-01	3.83E-01	2.39E-01	7.34E-04	-9.15E-02	1.62E-03	-8.54E+00	-8.45E+00
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	-4.18E+00	1.34E+01	1.76E+00	1.37E-01	-1.79E+00	3.03E-01	-8.04E+01	-7.08E+01
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-8.77E+01	5.12E+02	-1.75E+01	2.65E+00	-2.64E+01	5.85E+00	-1.69E+03	-1.30E+03
Blue water consumption [kg]	-1.37E+02	1.42E+02	-3.86E-01	8.97E-01	-5.96E+01	1.98E+00	-2.63E+03	-2.69E+03

Annex B7

Annex B7 presents the sensitivity results mentioned in Section4.2 4.3. Figure B 28 to Figure B 30 show the sensitivity results of collection rate for the remaining three products. Figure B 31 to Figure B 37 show the sensitivity results of lifetime extension for the Refurbishment with part replacement scenario of monitor and both Refurbishment and Refurbishment with part replacement scenarios for the rest three products.

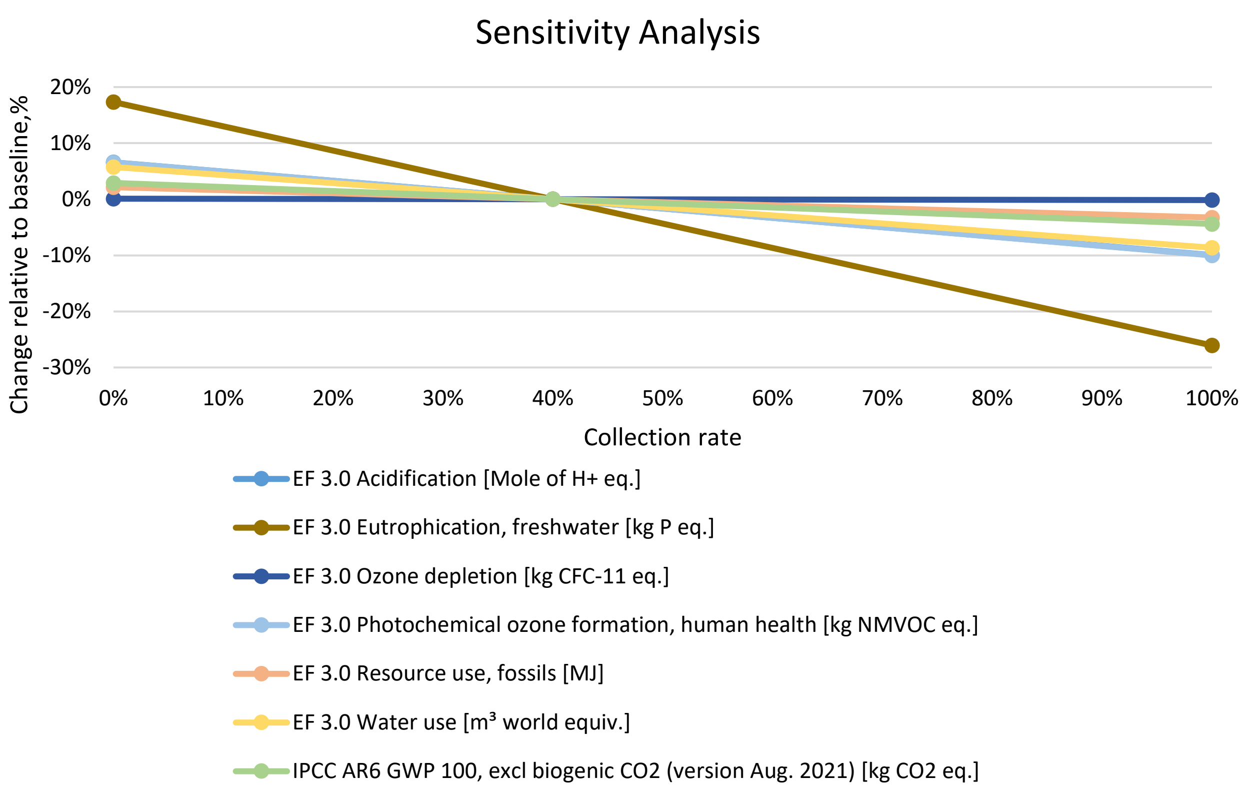


Figure B 28: Parameter sensitivity of Desktop- collection rate

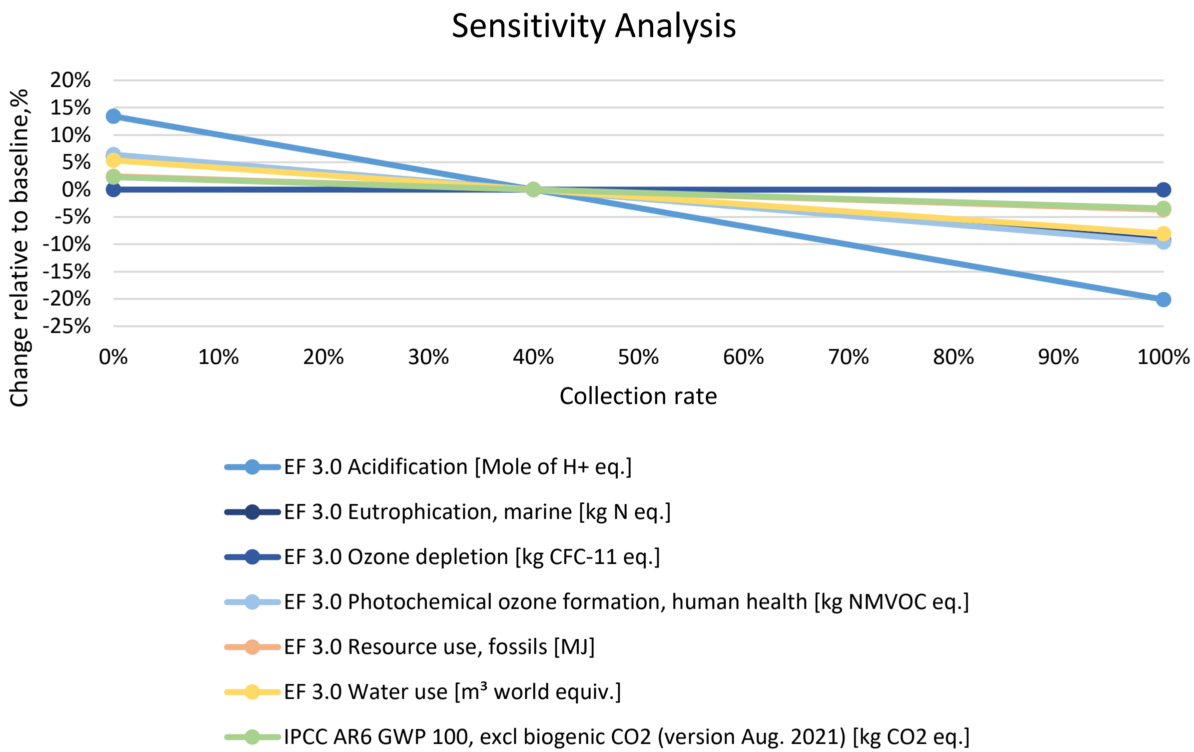


Figure B 29: Parameter sensitivity of Laptop- collection rate

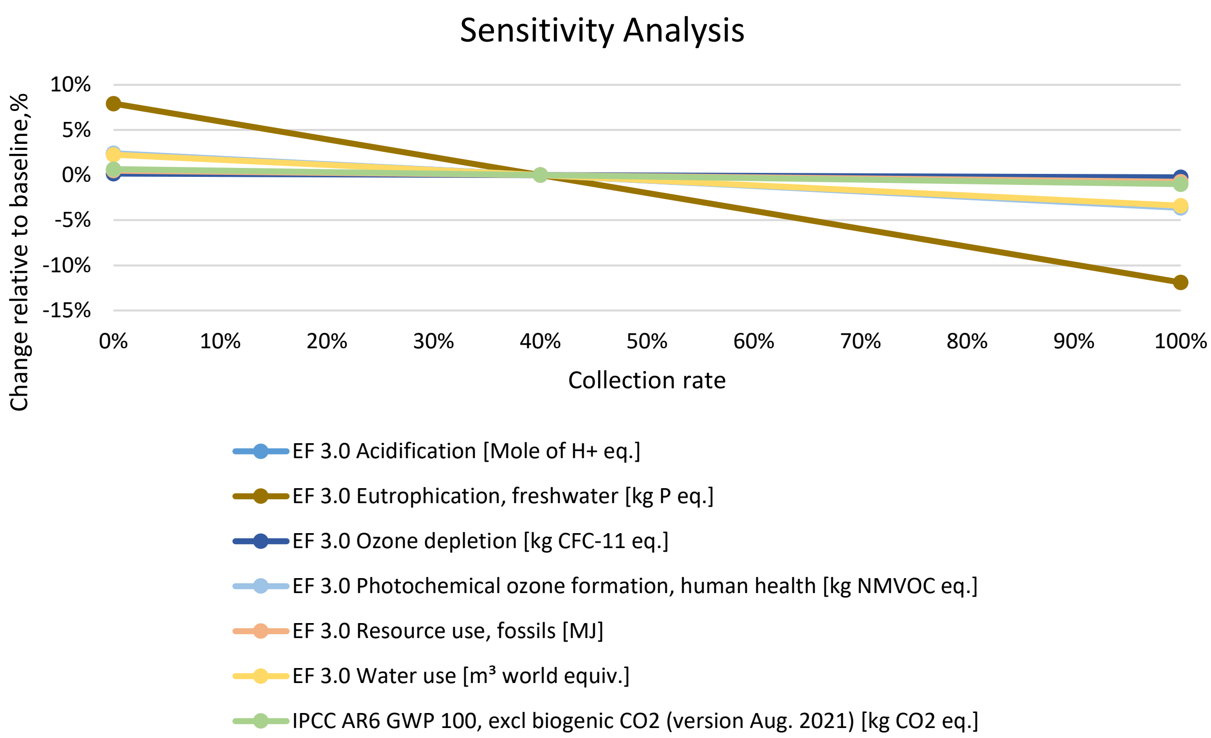


Figure B 30: Parameter sensitivity of Server- collection rate

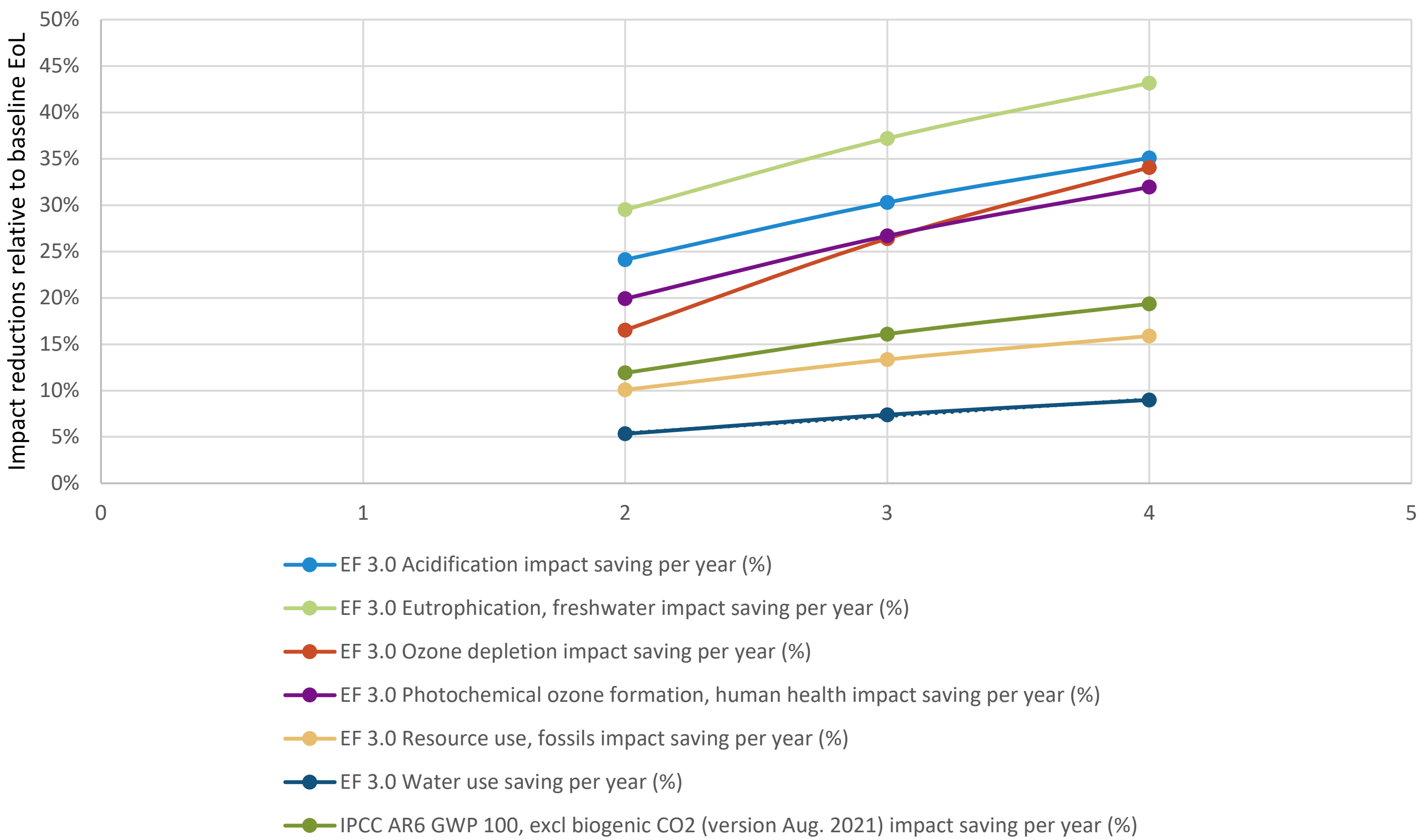


Figure B 31: Parameter sensitivity of Refurbishment with part replacement scenario of Monitor- lifetime extension

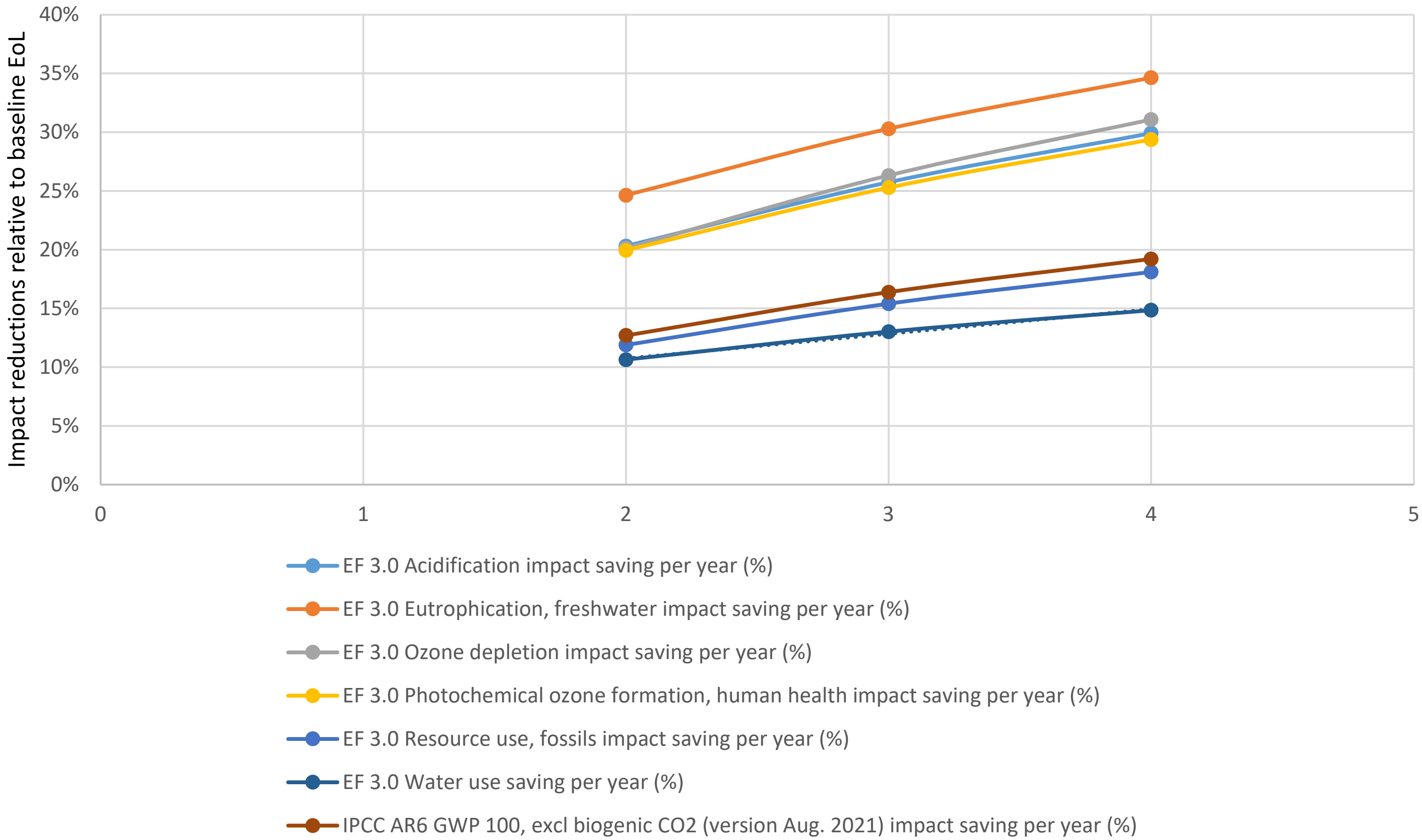


Figure B 32: Parameter sensitivity of Refurbishment scenario of Server- lifetime extension

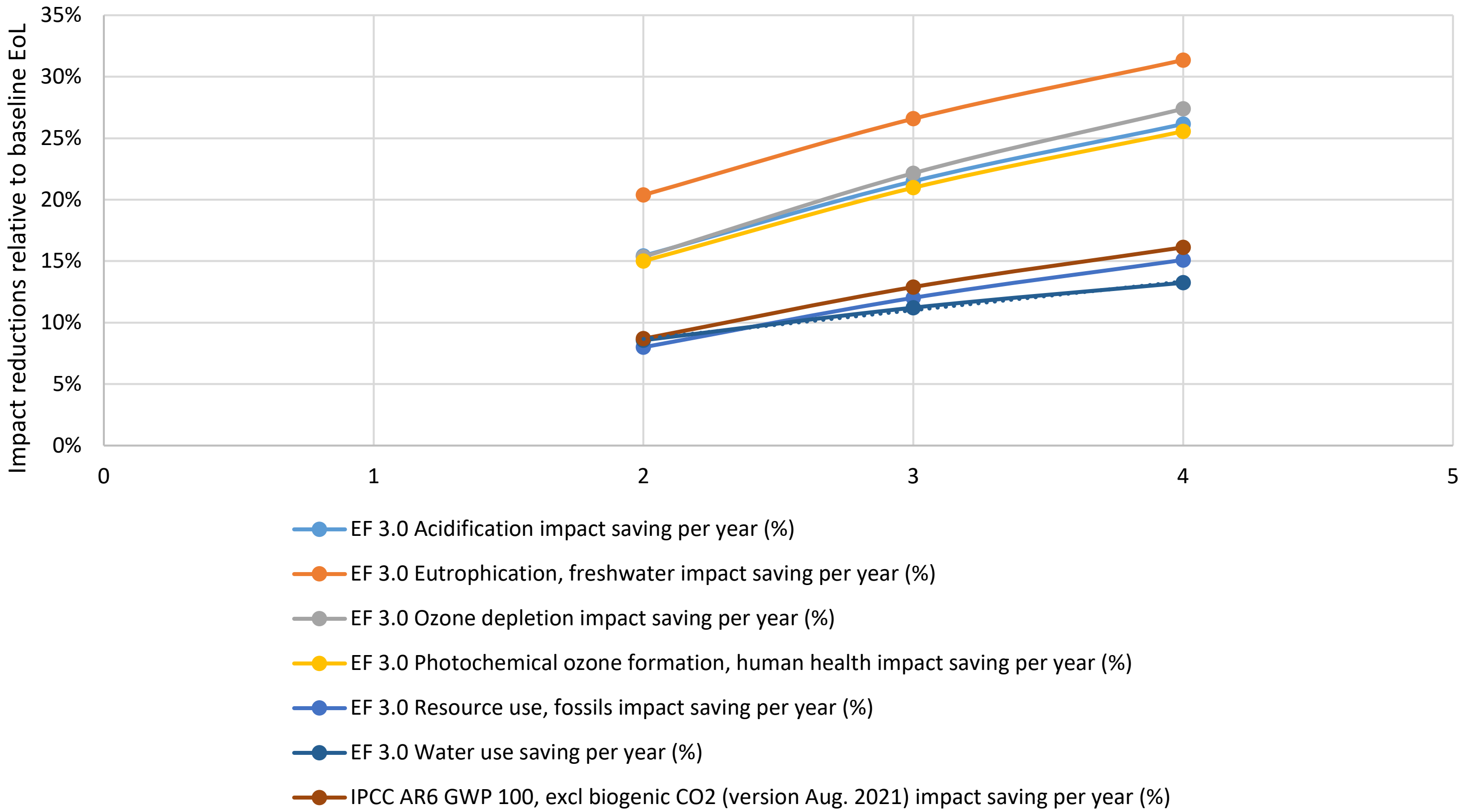


Figure B 33: Parameter sensitivity of Refurbishment with part replacement scenario of Server- lifetime extension

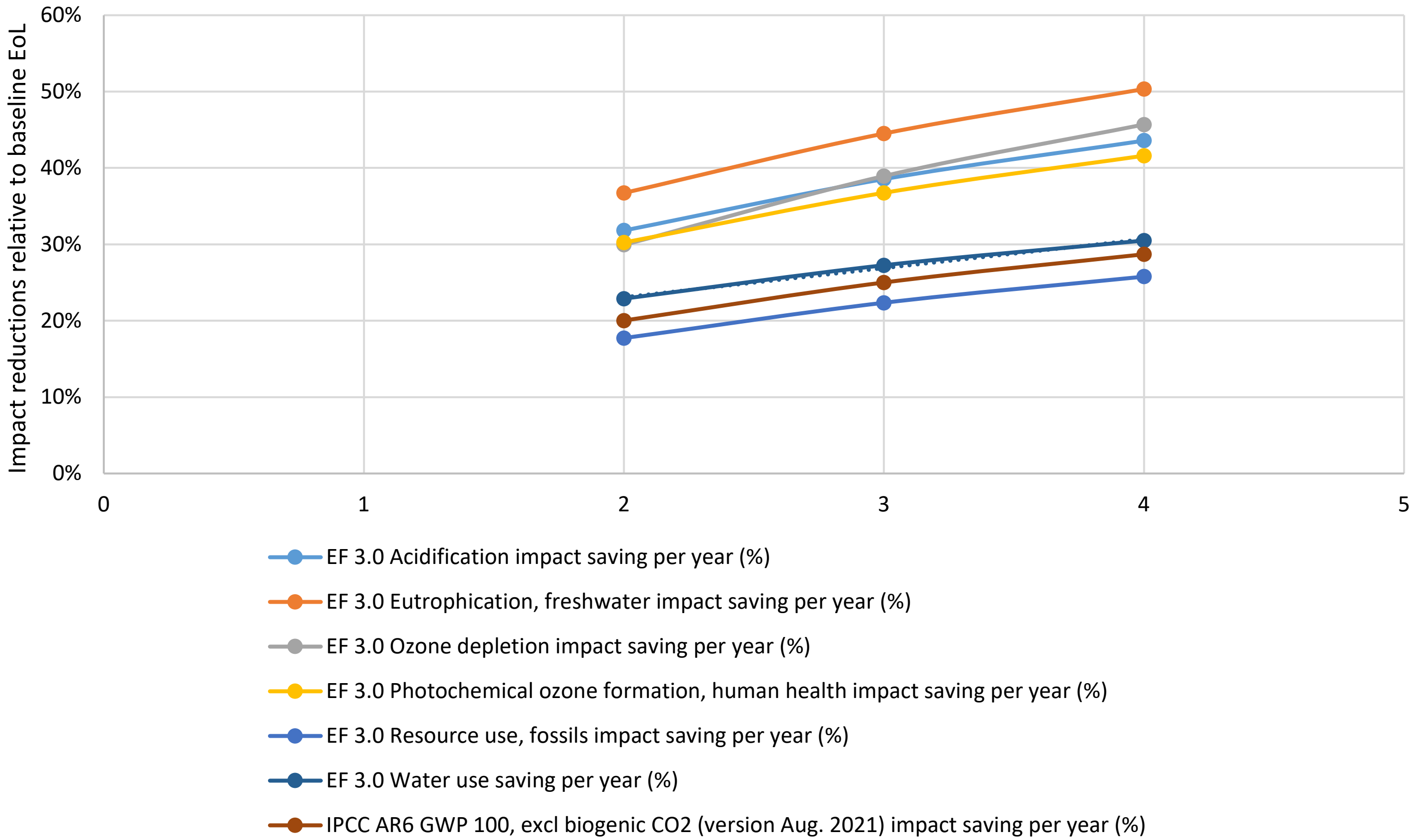


Figure B 34: Parameter sensitivity of Refurbishment scenario of Desktop- lifetime extension

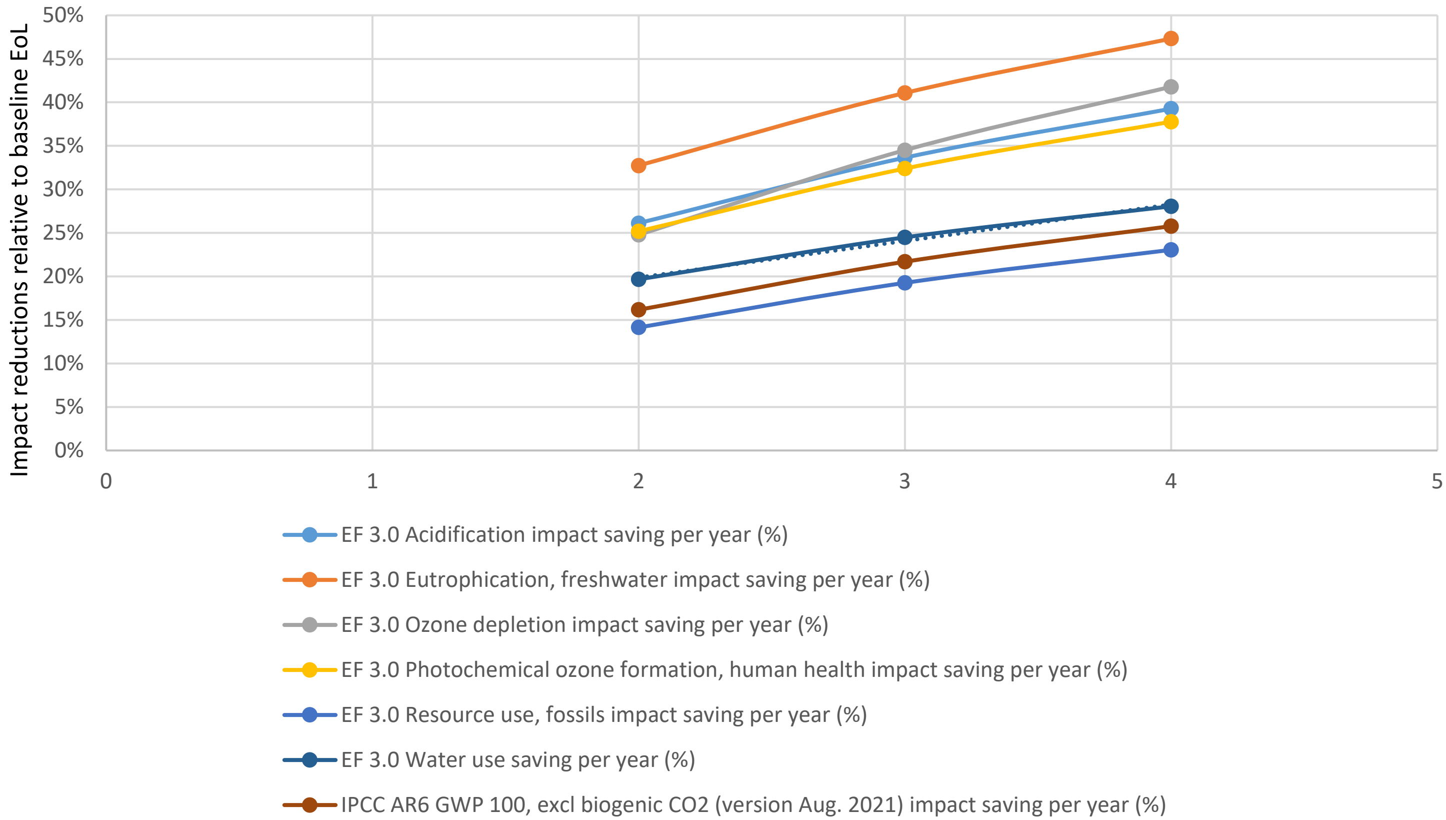


Figure B 35: Parameter sensitivity of Refurbishment with part replacement scenario of Desktop- lifetime extension

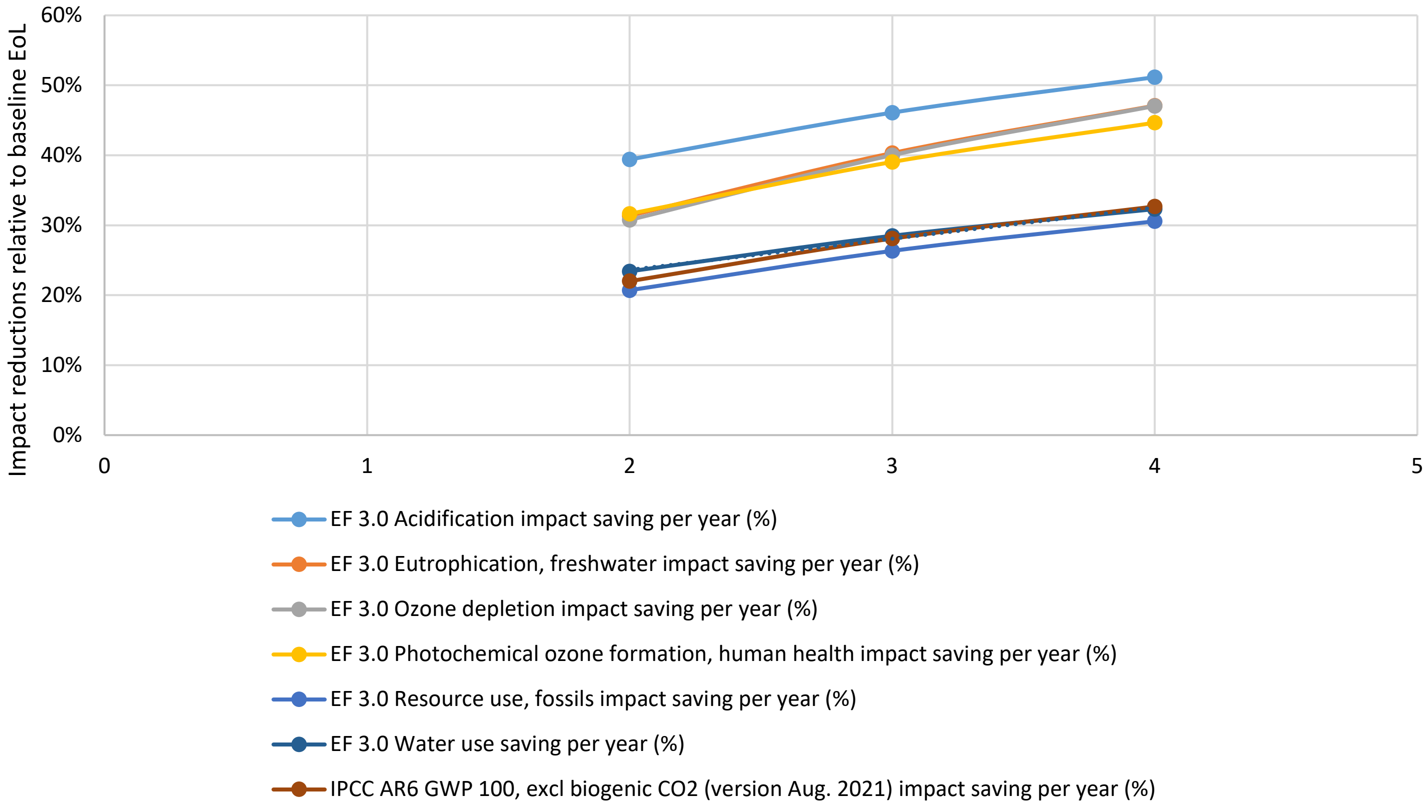


Figure B 36: Parameter sensitivity of Refurbishment scenario of Laptop- lifetime extension

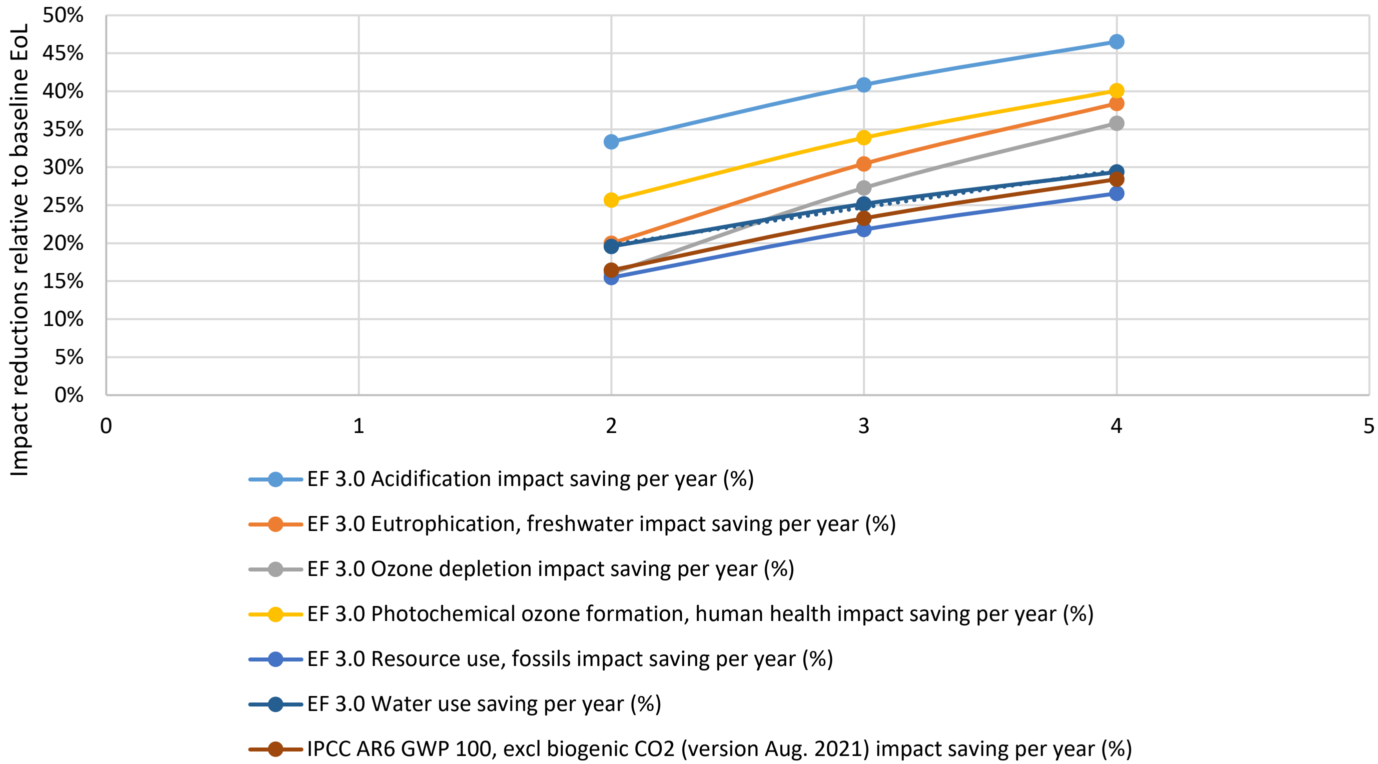


Figure B 37: Parameter sensitivity of Refurbishment with part replacement scenario of Laptop- lifetime extension

Annex B8

Annex B8 presents the breakdown of manufacturing impact mentioned in Section4.2.

Figure B 38: Manufacturing impact of one monitor for GWP and other impact categories (red color represents largest impact per row)

	Key board	Long board	Main board	Panel plus peripherals	Power supply board	Small board	Electromechanical	Mechanical components	Total
EF 3.0 Acidification [Mole of H+ eq.]	5.65E-03	4.90E-02	1.72E-01	2.19E-01	4.38E-02	2.41E-03	2.53E-02	1.70E-01	6.87E-01
EF 3.0 Eutrophication, freshwater [kg P eq.]	1.32E-05	1.55E-05	1.09E-04	3.14E-04	5.99E-05	3.53E-07	4.36E-06	3.46E-05	5.51E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.44E-10	1.61E-10	1.55E-09	7.17E-09	5.85E-10	2.12E-12	8.95E-12	3.69E-09	1.33E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	2.88E-03	1.22E-02	6.63E-02	1.98E-01	1.84E-02	1.05E-03	9.21E-03	7.03E-02	3.78E-01
EF 3.0 Resource use, fossils [MJ]	1.31E+01	3.97E+01	3.27E+02	3.67E+02	9.73E+01	4.65E+00	4.71E+01	4.67E+02	1.36E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.51E-04	5.46E-04	2.19E-03	1.29E-03	8.84E-04	8.85E-05	1.27E-03	6.36E-04	7.06E-03
EF 3.0 Water use [m³ world equiv.]	3.27E-01	7.27E-01	4.85E+00	-4.12E+00	1.95E+00	4.83E-02	8.29E-01	5.93E+00	1.05E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.12E+00	3.16E+00	2.52E+01	5.21E+01	7.59E+00	3.30E-01	3.04E+00	3.20E+01	1.25E+02

Figure B 39: Manufacturing impact of one laptop for GWP and other impact categories (red color represents largest impact per row)

	Mainboards	Touchpad	Display	Camera	PSU	Housing	Battery	RAM Board	SSD Board	Thermal solution	Speaker	Keyboard	Total
EF 3.0 Acidification [Mole of H+ eq.]	2.09E-01	1.16E-02	7.07E-02	2.25E-03	4.79E-02	6.20E-03	4.45E-02	2.18E-02	4.76E-02	9.46E-03	4.02E-03	6.66E-03	4.82E-01
EF 3.0 Eutrophication, freshwater [kg P eq.]	1.21E-04	1.31E-05	8.74E-05	9.92E-07	1.65E-05	2.32E-05	5.75E-04	1.12E-05	1.44E-05	3.80E-06	4.03E-07	2.68E-06	8.70E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	1.54E-09	1.39E-10	2.03E-09	8.51E-12	1.69E-10	1.89E-10	4.16E-08	1.06E-10	7.37E-11	8.20E-12	4.73E-12	2.24E-11	4.59E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	7.70E-02	5.03E-03	5.68E-02	1.04E-03	1.32E-02	5.16E-03	1.46E-02	8.72E-03	2.12E-02	3.78E-03	1.65E-03	2.21E-03	2.10E-01
EF 3.0 Resource use, fossils [MJ]	3.81E+02	2.51E+01	1.07E+02	6.42E+00	5.87E+01	7.84E+01	7.33E+01	5.51E+01	1.40E+02	2.18E+01	7.01E+00	1.28E+01	9.67E+02
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	2.52E-03	1.52E-04	2.23E-04	1.27E-05	5.29E-04	2.29E-06	1.93E-04	1.04E-04	3.20E-04	1.85E-04	6.38E-06	2.71E-05	4.27E-03
EF 3.0 Water use [m³ world equiv.]	5.54E+00	4.20E-01	-9.64E-01	7.26E-02	1.02E+00	3.25E-01	8.96E-01	6.16E-01	1.52E+00	2.06E+00	1.51E+00	1.30E-01	1.31E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	2.84E+01	1.99E+00	1.51E+01	4.65E-01	4.19E+00	3.11E+00	5.06E+00	3.90E+00	8.93E+00	1.53E+00	5.99E-01	8.30E-01	7.41E+01

Figure B 40: Manufacturing impact of one server for GWP and other impact categories (red color represents largest impact per row)

	Chassis	Fan	Mainboard	PSU	PWB Mixed	SSD	Total
EF 3.0 Acidification [Mole of H+ eq.]	2.25E-01	6.86E-02	8.66E-01	1.62E-01	3.27E+00	9.45E+00	1.40E+01
EF 3.0 Eutrophication, freshwater [kg P eq.]	2.85E-05	2.37E-05	1.08E-03	3.92E-05	1.04E-03	3.56E-03	5.77E-03
EF 3.0 Ozone depletion [kg CFC-11 eq.]	8.08E-10	1.16E-10	1.06E-08	1.62E-10	1.13E-08	2.33E-08	4.63E-08
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	1.60E-01	3.64E-02	4.30E-01	1.15E-01	1.51E+00	5.88E+00	8.13E+00
EF 3.0 Resource use, fossils [MJ]	3.46E+02	1.52E+02	1.98E+03	4.25E+02	7.58E+03	4.54E+04	5.59E+04
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	8.51E-06	7.36E-04	1.27E-02	2.30E-03	7.90E-02	1.01E-01	1.96E-01
EF 3.0 Water use [m³ world equiv.]	1.66E+00	1.18E+01	3.27E+01	4.73E+00	8.14E+01	3.87E+02	5.19E+02
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	3.34E+01	1.08E+01	1.56E+02	3.15E+01	5.54E+02	3.08E+03	3.86E+03

Figure B 41: Manufacturing impact of one desktop for GWP and other impact categories (red color represents largest impact per row)

	Others	Ethernet Board	Graphic Card	Mainboard	Mechanicals	Powerboard	RAM	Small Board Connector	SSD Board	Video Board	WLAN Board	ODD PC	Total
EF 3.0 Acidification [Mole of H+ eq.]	7.95E-02	1.98E-02	6.77E-02	1.80E-01	5.39E-02	5.85E-02	1.18E-01	4.62E-03	1.03E-01	2.38E-03	4.81E-03	4.75E-02	7.40E-01
EF 3.0 Eutrophication, freshwater [kg P eq.]	4.23E-05	2.45E-05	5.16E-05	1.99E-04	1.48E-05	9.52E-05	7.17E-05	5.47E-06	4.10E-05	4.66E-06	3.44E-06	3.18E-05	5.85E-04
EF 3.0 Ozone depletion [kg CFC-11 eq.]	3.60E-10	2.97E-10	6.13E-10	2.81E-09	5.85E-10	1.33E-09	9.28E-10	8.43E-11	4.45E-10	7.13E-11	4.59E-11	6.89E-10	8.26E-09
EF 3.0 Photochemical ozone formation, human health [kg NMVOC eq.]	3.57E-02	1.14E-02	3.39E-02	8.62E-02	3.47E-02	2.70E-02	5.89E-02	1.55E-03	4.86E-02	1.18E-03	2.43E-03	2.17E-02	3.63E-01
EF 3.0 Resource use, fossils [MJ]	1.81E+02	6.30E+01	1.86E+02	3.87E+02	1.90E+02	1.53E+02	2.93E+02	6.90E+00	2.77E+02	6.08E+00	1.20E+01	1.31E+02	1.89E+03
EF 3.0 Resource use, mineral and metals [kg Sb eq.]	1.48E-03	1.08E-03	2.09E-03	7.31E-03	7.40E-06	8.92E-04	4.01E-03	3.78E-05	1.75E-03	3.87E-05	1.75E-04	9.95E-04	1.99E-02
EF 3.0 Water use [m³ world equiv.]	6.20E+00	1.21E+00	3.98E+00	7.64E+00	7.05E-01	3.09E+00	4.24E+00	1.57E-01	3.00E+00	1.34E-01	1.87E-01	1.89E+00	3.24E+01
IPCC AR6 GWP 100, excl biogenic CO2 (version Aug. 2021) [kg CO2 eq.]	1.36E+01	4.68E+00	1.37E+01	3.07E+01	1.69E+01	1.21E+01	2.22E+01	5.76E-01	2.00E+01	5.04E-01	9.16E-01	8.92E+00	1.45E+02