Simplified LCA Study on HP's IT Hardware Recycling Processes

Take-Back Operations —V 4.0
November 2017
Life Cycle Assessment report – Public report

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1 Introduction

1.1 Background and justification of the study

The HP Take Back Operations (TBO) organization has developed a new web tool whose primary function is to allow HP customers, partners and HP delivery teams to request, track and obtain quotations for take back services, linking the customer to the vendor and providing to both parties all required functionalities to deliver the service. This tool is, at the moment, used for the EMEA B2B hardware recycling program operational in 42 countries, which previously were operating through a web form, and will be extended to other programs.

Among other capabilities, the tool will allow HP to gain extra visibility in front of the customer, will provide the program manager with critical information on its program and, if required, will allow TBO to incorporate new free or paid services into its service portfolio.

In the context of this new web tool, among the other offered services, a new customer reporting service has been added, a **Customer Sustainability Report** automatically generated by the web tool using actual collected weights as an input. This report is based on the results of a screening life cycle assessment of the recycling processes.

This study provides detailed and reliable data on the environmental benefits of recycling processes that then can be translated into environmental savings per asset or per weight of asset

Next points offer a brief introduction to LCA and all public information related to this study. The following points, although included in the confidential full LCA report, have been removed from this document because the information is confidential.

- IT hardware specific breakdown of materials.
- Inventory data for each IT hardware and the name of the Ecoinvent processes used in the modeling.
- Primary material recycling process results.
- IT Hardware recycling process results.
- Primary material recycling process interpretation.
- IT Hardware recycling process interpretation.

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1.2 Fundamentals of life cycle analysis

Life cycle analysis (LCA) is an environmental management methodology which has been growing over the past few years in a wide range of sectors. LCA is based on an objective and transparent methodology that shows the environmental burdens associated with a product or a system throughout its life cycle (production, distribution, use, maintenance, and end-of-life). Thus, LCA is a practical tool that can be used to make decisions in both the business and public sectors (e.g. recruitment and definition of criteria for eco-labels).

The applicability of LCA has been recognized internationally and is subject to standardization through a set of ISO and UNE-EN standards. The following standards have been used in the development of this study:

- UNE-EN ISO 14040:2006 – Environmental Management – Life cycle analysis – Principles and framework [1]
- UNE-EN ISO 14044:2006 – Environmental Management – Life cycle analysis – Requirements and guidelines [2]
- UNE-EN ISO 14025:2006 – Environmental labels and declarations – Type III environmental declarations – Principles and procedures [3]
- ISO/TR 14047: 2003 – Environmental Management – Life cycle analysis – Examples of application of LCI (Life cycle inventory) [4]
- ISO/TS 14048: 2003 – Environmental Management – Life cycle analysis – Data documentation format [5]
- ISO/TR 14049: 2000 – Environmental Management – Life cycle analysis – Examples of application of ISO14041 to goal and scope definition and inventory analysis [6]

The guideline UNE-EN ISO 14040:2006 defines the analysis of a life cycle as “the collection and evaluation of the inputs, outputs and the environmental impacts of a product throughout its life cycle”.

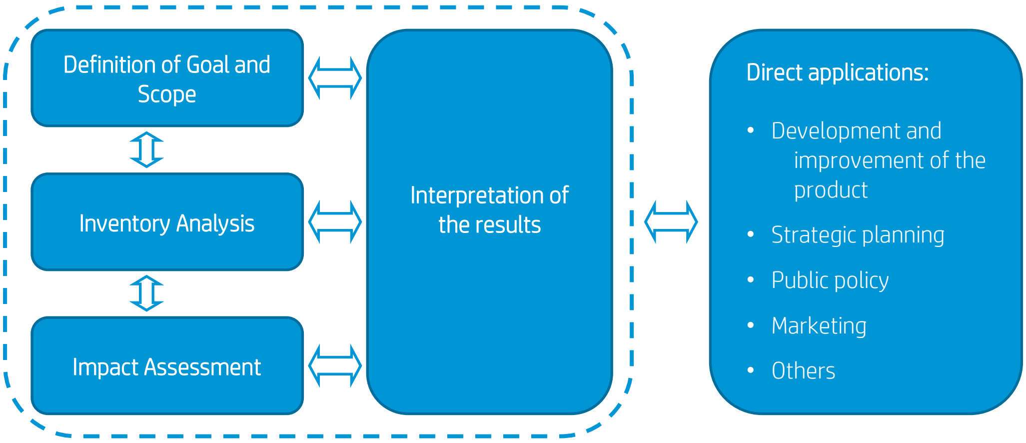

Figure 1 Framework and analysis of the life cycle stages [1]

It should be noted that the LCA is an iterative technique; each stage can be reinterpreted, redefined and completed on the basis of the results of the ongoing study.

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2 Goal and Scope Definition

This first phase of an LCA is to determine the goal and scope of the study. According to ISO 14044, the goal of the study should clearly specify the following: the intended application; reasons for performing the study; the intended audience; and whether the results are intended to be disclosed to the public.

The scope definition is performed in accordance with the stated goal of the study and should define the central aspects of the study, including: the functional unit; system boundaries; cut-off criteria; allocation; impact assessment method; assumptions; and limitations.

2.1 Goal of the study

The goal of this study is to assess the environmental benefits of recycling personal systems, printers, industrial printers, monitors and other products (accessories). Environmental benefits are quantified by comparing the environmental impacts of recycling with the environmental avoided impacts of avoiding the extraction and processing of new raw materials.

The application of this study is to provide additional value to the service provided (B2B hardware recycling program), that could help to customers differentiate HP from the competition by communication of reliable and useful information for the customer.

The HP Take Back Operations (TBO) department intents to communicate the results of this study with a customer sustainability report specifically tailored by order. As such, the LCA model and the report follows ISO 14040 and ISO 14044 requirements for LCA studies and was critically reviewed by HP's internal LCA experts.

2.2 Scope of the study

2.2.1 Analyzed products

The focus of this study are all hardware assets collected at end of life by TBO service providers. Usually, this equipment is between 4 and 6 years old and breakdown of materials can be very different within the same category.

Categories of IT hardware under study are:

- CRT Monitors,
- Desktops,
- Laptops,
- LCD Monitors,
- Keyboards,
- Mice,
- Plotters
- Printers,
- Servers,
- Tablets.

Each collected piece of IT hardware has an average breakdown of materials. The following materials have been considered in this study:

- Aluminium,
- Cable,
- Copper,
- Fibber,
- Flexible Circuit,
- Glass,
- PCBA,
- Plastics,
- Plastic foam,
- Power board,
- Stainless steel,
- Steel / Iron.

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The specific breakdown of materials cannot be disclosed for confidentiality reasons.

2.2.2 Functional Unit

A functional unit is defined as the quantified performance of a product system for use as a reference unit (ISO 14040). The functional unit provides a reference to which the all the inputs and outputs of a system are related. This reference is necessary to ensure comparability and quantification of LCA results. Essentially, the functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit. It is the common base that provides a reference to which all the input data (resources and energy required) and output data (emissions and waste) are quantitatively normalized. Thus, the functional unit must be measurable and clearly defined when considering the entire life cycle of a product or process (cradle-to-grave).

The functional unit of this study is 1 kg of hardware that goes to the recycling processes.

2.2.3 System description

HP recycling services start in a web tool (hp.com/recycle), where a user (can be a customer, a service partner, a sales partner or an HP employee) places an order for end-of-life IT hardware take back. From that, the HP service provider collects and transports the hardware to an HP authorized sorting and waste facility. IT hardware then undergoes several sorting, shredding and material recovery processes. The specific process, commonly called the recycling process, is dependent on the material content of the hardware. As a result of this recycling, several prime materials (aluminum, steel, polyethylene, polypropylene, gold, copper, silver, platinum, etc.) are collected and then sold to manufacturers to start a new life as part of a new product.

Since the recycling efficiency of those processes is not 100%, some waste is generated. Part of this waste is transported to an incineration facility to be incinerated with energy recovery, other unprofitable materials are transported to a landfill.

2.2.4 System boundaries

In the life cycle of any product, there are always multiple interdependent systems operating that should be taken into account in the study (the entire process is linked to others that have happened previously or subsequently). In a complex system, to analyze all the possible processes would result in a system of global scale, including processes that have negligible contribution to the evaluated system. Thus, it is necessary to establish system boundaries at the beginning of the LCA.

In the following figure (Figure 2), general system boundaries are shown. These boundaries include the collection and transportation of IT hardware to recycling facility, all recycling processes and management of on-site generated waste. Moreover, the output breakdown of materials from IT hardware that is recovered as environmental benefits is included. These environmental benefits are quantified as avoided environmental impacts responsible for manufacturing those materials.

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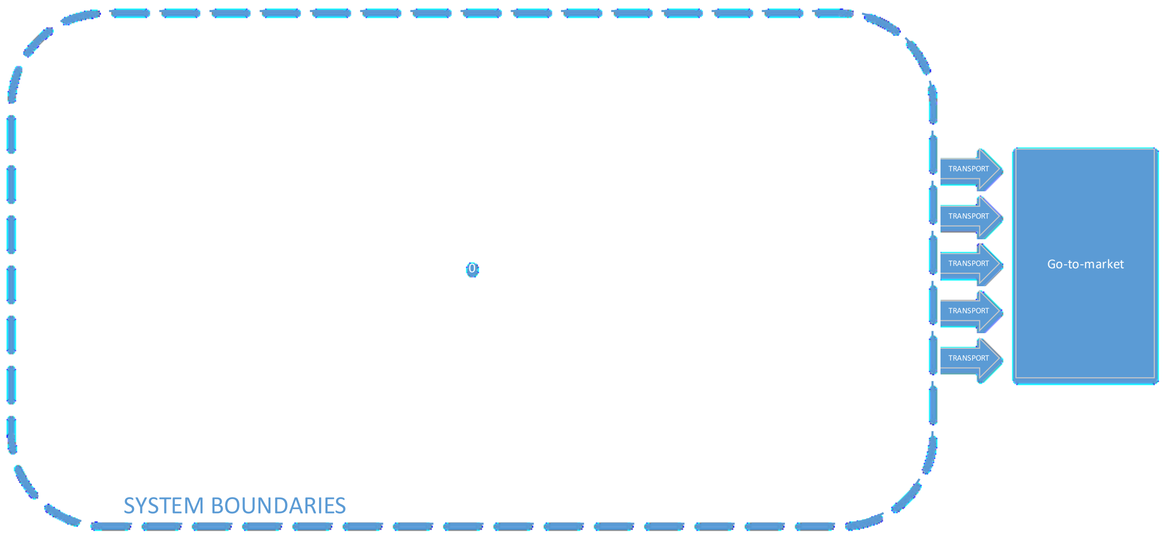

Figure 2 System boundaries

2.2.5 Assumptions

In all life cycle assessments there are data that are difficult to obtain and/or to corroborate. These data are carefully assumed to represent the real process and are necessary for the modelling and calculation of the life cycle. These assumptions are explicitly stated so that they can be easily modified (if necessary). These are the general assumptions concerning all the systems being studied:

- 95% of the material is recycled (global recycling efficiency),
- 3% of the material is incinerated,
- 2% of the material goes to landfill,
- Distance of 150 km to recycling facility (see sensitive analysis on point 5.3.1),
- Distance of 50 km to landfill facility,
- Distance of 50 km to energy recovery facility,
- Due to the lack of information, flexible circuit, PCBA and power board are considered as a mixture of plastics while considering no metal recovery,
- PC/ABS is modelled as 50 PC : 50 ABS due to the lack of more detailed data. A wide range of combination exists being the most frequent: 45 PC : 55 ABS / 65 PC : 35 ABS / 85 PC : 15 ABS [7],
- Market aluminium considers different inputs of primary and secondary aluminium according to the ecoinvent process *Aluminium, cast alloy {GLO}| market for* (see sensitive analysis on point 5.3.3),
- Market copper considers different inputs of primary and secondary copper according to the ecoinvent process *Copper {GLO}| market for* (see sensitive analysis on point 5.3.3),
- Market steel/iron considers different inputs of primary and secondary steel according to the ecoinvent process *Steel, low-alloyed {GLO}| market for;* CONVERTER (primary) 56,7% and ELECTRIC (secondary) 43,3% (see sensitive analysis on point 5.3.3),

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- Market stainless steel considers different inputs of primary and secondary stainless steel according to the ecoinvent process *Steel, chromium steel 18/8 {GLO}| market for;* CONVERTER (primary) 72,4% and ELECTRIC (secondary) 27,6% (see sensitive analysis on point 5.3.3),

- Cable recycling considers 39% of Cable (PVC/PE) and 62% copper according to the ecoinvent process *Waste electric wiring {CH}| treatment of, collection for final disposal |,*

- Treatment of shredding is a copied process for shredding of electric and electronic equipment (emissions to the air have not been accounted) of the ecoinvent process *Waste electric and electronic equipment {GLO}| treatment of, shredding |,*

- Plastic distribution on mixed plastics process has been extracted from the ecoinvent process *Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics |,*

- Battery recycling is modeled as an empty process due to lack of reliable information.

2.2.6 Critical review

Following the LCA methodology, an internal review of the study was conducted, whereby an LCA expert reviewed the progress of this assessment throughout the duration of the study.

It should be noted that neither the report nor the results that it contains are intended to be presented publicly in comparative assertions. Consequently, the study has not been reviewed by an external panel of experts.

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3 Life Cycle Inventory Analysis (LCI)

The second phase of an LCA is to collect life cycle inventory (LCI) data. LCI data contains the details of the resources flowing into a process and the emissions flowing from a process to air, soil and water. The following sections summarize the data collection process and key LCI data used in the system modeling and life cycle impact assessment.

3.1 Data collection

As is typical in LCA, the data used in this study is a combination of primary and secondary data. The primary inventory data, for IT hardware specific to this study, from 2017, were obtained from a recycling service provider.

The secondary data were extracted from the generic database Ecoinvent v3.3 [8], which is included in the internationally recognized software, SimaPro v8. In all possible cases, inventory data relative to Western Europe have been selected. It has been used for recycling processes as well as for the transport processes, waste management and other processes that the service provider does not have a direct influence on.

3.2 Process of calculation and allocation

While conducting an LCA, allocation situations occurs when the studied system is a multinational process and not all outputs (or functions) are used for the considered functional unit. According to ISO 14044, allocation of the process inputs should be avoided by using the system boundary expansion approach. If allocation cannot be avoided, an allocation method – based on physical causality (mass or energy content for example) or any relationship such as economic value – should be used.

In this study, there are no allocation situations in the foreground processes since there are no multifunctional processes delivering outputs used in recycling of the functional unit. In addition, no change in allocation was made to the secondary data.

3.3 Qualitative and quantitative description of included processes

The following is a qualitative description of each of the stages considered in this LCA study.

Stage 1 – TRANSPORTATION

This stage accounts for the transportation of the collected waste to the recycling plant. In addition, it considers the transportation to landfill and incineration of the unrecyclable fraction of materials.

Stage 2 – RECYCLYING

This stage accounts for all necessary processes to recycle a piece of hardware, such as sorting, shredding, separating, smelting, pelletizing, etc. Different processes apply to each material, so recycling is modelled by selecting each applicable and specific process in the Ecoinvent v3.3 database.

Stage 3 – WASTE MANAGEMENT

This stage accounts for all incineration and landfilling processes for all fractions of materials that are not recycled. Appropriate specific landfill and incineration processes for each type of material have been chosen from the database.

Below are the inventory data for each fraction of materials and the name of the Ecoinvent processes used for modelling them.

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Table 1 Inventory for primary materials on scope

Recycling of 1 kg of aluminium	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Secondary aluminium	0,95	kg	Aluminium, cast alloy {RER}| treatment of aluminium scrap, post-consumer, prepared for recycling, at refiner | Alloc Def, U
Aluminium to incineration	0,03	kg	Scrap aluminium {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U
Aluminium to landfill	0,02	kg	Waste aluminium {CH}| treatment of, sanitary landfill | Alloc Def, U
Avoided products			
Market aluminium	0,95	kg	Aluminium, cast alloy {GLO}| market for | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of copper	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Secondary copper	0,95	kg	Copper {SE}| treatment of metal part of electronics scrap, in blister-, by electrolytic refining | Alloc Def, U
Copper to incineration	0,03	kg	Scrap copper {Europe without Switzerland}| treatment of scrap copper, municipal incineration | Alloc Def, U
Copper to landfill	0,02	kg	PROXY: Inert waste {CH}| treatment of, sanitary landfill | Alloc Def, U
Avoided products			
Market copper	0,95	kg	Copper {GLO}| market for | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of steel/iron	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Secondary steel/iron	0,95	kg	Steel, low-alloyed {RER}| steel production, electric, low-alloyed | Alloc Def, U

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Steel/Iron to incineration	0,03	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, municipal incineration | Alloc Def, U
Steel/Iron to landfill	0,02	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Alloc Def, U
Avoided products			
Primary steel/iron	0,54	kg	Steel, low-alloyed {RER}| steel production, converter, low-alloyed | Alloc Def, U
Secondary steel/iron	0,41	kg	Steel, low-alloyed {RER}| steel production, electric, low-alloyed | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of mixed plastics	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Mixed plastics to incineration	0,03	kg	Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
Mixed plastics to landfill	0,02	kg	Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
Polyethylene	0,44	kg	Polyethylene, high density, granulate {RER}| production | Alloc Def, U
Polyvinylchloride	0,04	kg	Polyvinylchloride, emulsion polymerised {RER}| polyvinylchloride production, emulsion polymerisation | Alloc Def, U
			Polyvinylchloride, suspension polymerised {RER}| polyvinylchloride production, suspension polymerisation | Alloc Def, U
			Polyvinylchloride, bulk polymerised {RER}| polyvinylchloride production, bulk polymerisation | Alloc Def, U
Polyethylene terephthalate	0,17	kg	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Alloc Def, U
Polystyrene	0,05	kg	Polystyrene, general purpose {RER}| production | Alloc Def, U
Polypropylene	0,25	kg	Polypropylene, granulate {RER}| production | Alloc Def, U

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Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of ABS plastic	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
ABS to incineration	0,03	kg	PROXY: Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
ABS to incineration	0,02	kg	PROXY: Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
ABS plastic	0,95	kg	Acrylonitrile-butadiene-styrene copolymer {RER}| production | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of polycarbonate plastic	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Polycarbonate to incineration	0,03	kg	PROXY: Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
Polycarbonate to incineration	0,02	kg	PROXY: Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
Polycarbonate	0,95	kg	Polycarbonate {RER}| production | Alloc Def, U

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Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of HIPS	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
HIPS to incineration	0,03	kg	PROXY: Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
HIPS to incineration	0,02	kg	PROXY: Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
HIPS	0,95	kg	Polystyrene, high impact {RER}| production | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1kg of Polypropylene sulfide	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Polyphenylene sulfide to incineration	0,03	kg	PROXY: Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
Polyphenylene sulfide to incineration	0,02	kg	PROXY: Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
Polyphenylene sulfide	0,95	kg	Polyphenylene sulfide {GLO}| production | Alloc Def, U

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Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of PC/ABS	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
PC/ABS to incineration	0,03	kg	PROXY: Waste plastic, mixture {CH}| treatment of, municipal incineration | Alloc Def, U
PC/ABS to incineration	0,02	kg	PROXY: Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, sanitary landfill | Alloc Def, U
Avoided products			
ABS plastic	0,475	kg	Acrylonitrile-butadiene-styrene copolymer {RER}| production | Alloc Def, U
Polycarbonate	0,475	kg	Polycarbonate {RER}| production | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of stainless steel	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Secondary stainless steel	0,95	kg	Steel, chromium steel 18/8 {RER}| steel production, electric, chromium steel 18/8 | Alloc Def, U
Stainless Steel to incineration	0,03	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, municipal incineration | Alloc Def, U
Stainless Steel to landfill	0,02	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Alloc Def, U
Avoided products			
Primary steel/iron	0,69	kg	Steel, chromium steel 18/8 {RER}| steel production, converter, chromium steel 18/8 | Alloc Def, U

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Secondary steel/iron	0,26	kg	Steel, chromium steel 18/8 {RER}| steel production, electric, chromium steel 18/8 | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of glass	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Glass made of cullets	0,95	kg	PROXY: Packaging glass, white {GLO}| packaging glass production, white, without cullet | Alloc Def, U
Glass to incineration	0,03	kg	Waste glass {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U
Glass to landfill	0,02	kg	Waste glass {CH}| treatment of, inert material landfill | Alloc Def, U
Avoided products			
Glass made without cullet	0,95	kg	PROXY: Packaging glass, white {GLO}| packaging glass production, white, without cullet | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of plastic foam	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Plastic foam to incineration	0,03	kg	Waste polyurethane {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U
Plastic foam to incineration	0,02	kg	Waste polyurethane {CH}| treatment of, inert material landfill | Alloc Def, U
Avoided products			
Plastic foam	0,95	kg	PROXY: Polyurethane, rigid foam {RER}| production | Alloc Def, U

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Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of fiber	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Glass to incineration	0,03	kg	Waste textile, soiled {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U
Glass to landfill	0,02	kg	Inert waste {CH}| treatment of, sanitary landfill | Alloc Def, U
Avoided products			
Fibre	0,95	kg	PROXY: Viscose fibre {GLO}| viscose production | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U
Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of rubber	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Treatment of shredding	0,06	kWh	Electricity, medium voltage {GLO}| market group for | Alloc Def, U
	8,00E-10	p	Mechanical treatment facility, waste electric and electronic equipment {GLO}| market for | Alloc Def, U
Glass to incineration	0,03	kg	Waste rubber, unspecified {RoW}| treatment of, municipal incineration | Alloc Def, U
Glass to landfill	0,02	kg	Inert waste {Europe without Switzerland}| treatment of inert waste, sanitary landfill | Alloc Def, U
Avoided products			
Rubber	0,95	kg	Synthetic rubber {RER}| production | Alloc Def, U
Transport			
Transport to landfill	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

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Transport to energy recovery facility	50	kgkm	Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Def, U

Recycling of 1 kg of cable	AMOUNT	UNIT	ICV Ecoinvent v3.3
Outputs			
Copper to recycling	0,39	kg	Recycling of 1 kg of copper
PVC/PE to recycling	0,61	kg	Recycling of 1 kg of mixed plastics

Specific LCI models for IT hardware are confidential and not disclosed here.

3.4 Data quality requirements

For the development of this study, we have taken into account the data quality requirements that are stated in ISO 14044. These requirements are summarized in the table below.

Table 2 The data quality requirements in this study

INTEGRITY		Used all the relevant processes for each different product and ensured each process was accurately suited to its specific situation.
CONSISTENCY		To ensure consistency, data have been used with the same level of detail and developed under the same methodological considerations
REPRODUCIBILITY		This report does not describe all data used in such a way that the study can be reproduced by an independent professional since some models and data are confidential and not disclosed here.
REPRESENTATIVENESS	**TEMPORAL COVERAGE**	The specific dates are based on average data from the year 2017, thus, they are less than 1 year old. On the other hand, generic data from the database Ecoinvent v3.3 have been used and have been updated within the last year.
	GEOGRAPHIC COVERAGE	The specific data used in the recycling process of the materials have been extracted by generic data representative of the country (as is the case of the profile of electricity production) or more extensive territories (Europe).
	TECHNOLOGICAL COVERAGE	The specific data reflect the physical reality of the declared product, seeing as they have been supplied by leading manufacturers of this materials in Europe.

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4 Life Cycle Impact Assessment (LCIA)

The life cycle impact assessment (LCIA) consists of interpreting the inventory and analyzing and evaluating the impacts made by the identified environmental burdens. It is necessary to remember that the results of the LCIA are relative and do not predict impacts on end-point categories, exceedance of any thresholds, safety margins, or risk.

4.1 Impact assessment methodology

To calculate the environmental profile of the analyzed products, a 0:100 End of Life formula with credits for avoided virgin materials [9] has been applied. This means that in the studied system a full allocation of the recycling impact is assigned to the product generating recycled material and no burdens are allocated to the downstream products using recycled materials as an input. In addition, credits are given since it's assumed that the recycled material from the product life cycle analyzed replaces virgin material in the expanded system.

Selected Impact assessment methodologies are ReCiPe Midpoint (H) V1.12 [10] and CML-IA baseline V3.03 [11]. ReCiPe has been chosen since it is considered to be the most recent and harmonized approach among all the available methodologies, created by RIVM, CML, PRé Consultants, Radboud Universiteit Nijmegen and CE Delft. On the other hand, CML-IA has been selected to quantify energy savings; it was developed by the Institute of Environmental Sciences (CML) in Leiden University, Netherlands.

In this study, the following environmental impact categories are evaluated (Table 3). Additionally, SimaPro software has been used to carry out the corresponding calculations.

Table 3 IT Impact categories included in this study

IMPACT CATEGORY	INDICATOR (UNITS)	IA METHOD
Climate change	kg CO_2 eq	ReCipe Midpoint (H)
Abiotic resource depletion (fossil fuels)	MJ	CML-IA baseline
Water depletion	m^3	ReCipe Midpoint (H)

CLIMATE CHANGE

The impact category, climate change, takes into account to the different air emissions within the system boundaries that can potentially contribute to the increase in the average temperature of the planet. This effect occurs as a result of an increase in greenhouse polyatomic gas concentration (carbon dioxide, methane, water steam, nitrous oxide, etc.) which absorb most of the infrared radiation emitted by the Earth's surface. Thus, the energy balance and the radiation emitted by the sun is unbalanced, with a consequential impact on the climate.

The indicator for this impact category is kg of carbon dioxide (CO_2 equivalent).

ABIOTIC RESOURCE DEPLETION

This impact category refers to the depletion of abiotic resources caused by the consumption of non-renewable resources (fossil fuels) in relation to the known reserves at a global level. The exhaustion of resources is due to the consumption of total available reserves beyond the rate of replacement.

The indicator for fossil fuel depletion is MJ.

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WATER DEPLETION

The impact category water depletion refers to the contribution of the analyzed system to the depletion of water resources by linking the consumption with the scarcity of water at the local level.

The indicator for this impact category is m^3 of water.

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5 Conclusions and recommendations

This study explored the potential environmental benefits that recycling of different IT assets could bring. Regardless of which IT asset was chosen, the potential environmental benefits on the life cycle of not extracting and processing new raw materials were found to be greater than the potential impacts associated with the recycling processes of those same materials, even when transportation, landfilling and incineration of the fraction of materials that was not able to be recycled is considered.

For all kind IT assets studied, plastics recycling was found to be the main driver for greater environmental savings even though all primary materials saw environmental savings in their environmental profiles.

Metals, on the other hand, reported smaller environmental impacts since market metals were accounted as already containing secondary metals. Copper, however, reported counter-intuitive results and further study it's recommended. The rest of the materials, such as glass, fiber or rubber, also reported relevant environmental benefits however, since they represent a small percentage in weight on most of IT assets, they become less relevant on the general environmental profile.

It's also worth noting that results on energy and water savings follow similar tends since water usage is closely tied with energy use, therefore energy savings lead to water savings. Additionally, we can conclude that in this system, transportation is insignificant for the studied impact categories.

Overall, this study concludes with a quantification of the avoided carbon dioxide emissions, avoided energy and water use for each studied IT assessed, as a result of its recycling process.

The results of the study offer a number of ways the modelling of the system process can be improved. Recycling could be modelled using service providers recycling process primary data and it could be taken into account specific recycling efficiency on each material, thus, geographical and technological approach should be also improved.

To conclude, according to this study's results, printers (desktop printers and plotters) bring bigger environmental savings in all studied impact categories, followed by personal systems (laptops and desktops), computing products (servers and tablets) and finally by monitors (LCD monitors and CRT monitors). Accessories (Keyboards and mice) report grater environmental savings compared with other categories, due to its high plastic percentage in its composition however it's important to mention that there is very high uncertainty associated with just one majoritarian material/process within the scope and the level of detail considered in this study.

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