OUT OF USE

CO_2 - CALCULATOR

Intro

Thank you for your interest in our new CO_2 tool. This document provides you with the calculations on which our tool operates.

Our CO_2 - Calculator calculates the emissions saved through re-use or recycling of various IT materials. It offers companies a simple and quick way to display, with just a few clicks, their potential impact on CO_2 emissions when reusing or recycling their equipment.

By giving the material a second life, you avoid the unnecessary mining of new raw materials and the production of new products. The recycling of appliances also has a positive effect, as the materials can be recovered and converted into secondary raw materials.

Avoided emissions are expressed in kilograms of CO_2. A comparison is also made with the annual operation of X m^2 of forest.

The results of our calculator are based on 2 scientific studies:

- A study of CO_2 logic commissioned by Out of Use.
- A literature study by the Swedish independent and non-profit research institute IVL Svenska Miljöinstitutet.

Both studies can be found attached in this information document.

The following overview lists the values on which the calculator is built:

Sub category	Reuse : Avoided total (sum) (kg CO2-eq)	Recycling : Avoided (kg CO2-eq)/kg
Desktop: All-in-one desktop)	**470**	**3,65**
Desktop: SFF (Small Form Factor)	**380**	**3,65**
Desktop: Tower	**750**	**3,65**
Desktop: USDT (Ultra Small DeskTop)	**290**	**3,65**
Handheld: Smartphone	**55**	**9,55**
Handheld: Tablet-big	**140**	**1,44**
Handheld: Tablet-Small	**95**	**1,44**
Laptop: Screen 14+ inch	**300**	**5,00**
Laptop: Screen below 14 inch	**250**	**5,00**
Monitor: Screen 33+ inch	**620**	**1,76**
Monitor: Screen below 33 inch	**440**	**1,76**
Network equipment: Rack mounted (blade)	**200**	**1,44**
Network equipment: Rack mounted (large)	**800**	**1,44**
Network equipment: Small	**8,7**	**1,44**
Other Components: Docking station	**8,4**	**1,44**
Other Components: HDD	**71**	**1,44**
Other Components: Keyboard	**3,7**	**1,44**
Other Components: Power adaptor, laptop	**3,5**	**1,44**
Other Components: Smartphone/tablet charger	**1,3**	**1,44**
Other Components: SSD	**94**	**1,44**
Printer: Desk	**180**	**2,03**
Server: Tower	**750**	**1,44**
Server: Rack mounted	**400**	**1,44**

Attachments:

1. Literature study: Avoided impact of reuse and recycling of WEEE (CO2 Logic – Out of Use)
2. The climate benefits of reusing IT products and the method for creating data bases (IVL Svenska Miljöinstitutet)

1. Literature study: Avoided impact of reuse and recycling of WEEE (CO2 Logic – Out of Use)

CO2logic

Literature study: Avoided impact of reuseand recycling of WEEE

OUT OF USE GIVING PURPOSE

Research question

Out of use offers companies and organisations a complete solution to recycle all their ICT, electrical and electronic waste (WEEE) in a sustainable way. The collection and recycling or reuse of e-waste willhave an avoided climate impact comparing it with other types of waste management.

In this report the avoided climate impact of recycling a device and reusing a device will be investigated. Hence, there will be explored what the answer is on the following questions: **What is the avoided climate impact of recycling a device? What is the avoided climate impact of reusing a device in termsof GHG emission?** There will be focused on five specific devices: personal computer, desktop computer, mobile phone, printer and LCD monitors. In order to answer these questions, a literature study was carried out.

Context

E-waste is often referred to as Waste Electrical and Electonic Equipment (WEEE). The WEEE directive 2002/96/EC of the European Commission describes WEEE as "waste, …, including all components, subassemblies and consumables which are part of the product at the time of discarding". It includes a wide range of products – almost any household or business item with circuitry or electrical components with power or battery supply (Baldé et al., 2017). Hence, the definition of e-waste is verybroad, therefore it can be subdivided in six waste categories:

1. Temperature exchange equipment
2. **Screens & monitors**
3. Lamps
4. Large equipment
5. Small equipment
6. **Small IT and telecommunication**

The collection and logistical processes and recycling technology differ for each category, in the same way as the consumers' attitudes when disposing of the EEE also vary. In this research the focus will mainly be on the second and sixth category (screens, mobile phones, personal computers and printers).

The global quantity of e-waste generation in 2016 was around 44.7 million metric tonnes (Mt) or 6.1 kg per inhabitant. This amount is expected to grow to 52.2 Mt in 2021, with an annual growth rate of 3 to 4%. In Europe the amount of e-waste per inhabitant is 16.6kg/inhabitant, but it also shows the highest regional collection rate of 35% compared to e-waste generated (Baldé et al., 2017). Accordingto the Baldé et al. (2017), Belgians are estimated to produce around 20-25kg per capita per year.

WEEE contains a large variety of different substances including valuable materials and plastics with each a different impact on the environment and human health. Up to 60 elements from the periodic table can be found in complex electronics, and many of them are technically recoverable (Baldé et al.,2017). This includes heavy metals but also persistent organic pollutants. Besides it contains also precious metals including gold, silver, copper, platinum and palladium. It is extremely important to treat e-waste adequately in order to prevent the health and environmental risks that the hazardous substances contained in e-waste can pose. An amount of 0.1% of the world's CO2 emissions can be attributed to these important metals in WEEE products (UNEP, 2013). Reuse and recycling of e-waste should prevent waste of these valuable materials and rare elements. The graph below gives a generaloverview of the material composition of e-waste.

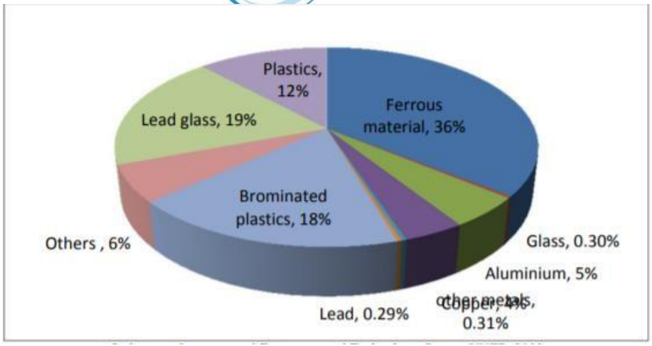


Figure 1: material composition e-waste (UNEP, 2013)

In general, electrical and electronic equipment generate GHG emission from three stages. There are principally several ways to reduce GHG emission such as:

- Replace some amount of the virgin material for production with material recovered from **recycle process**; by replacing virgin material, some amount of GHG emission contributed from raw material extraction can be avoided.
- **Extend the lifetime of a product**, it can reduce the amount of electrical and electronic equipment produced, thus reducing GHG emissions from manufacturing and raw material extraction
- **Innovation in technology**, replace the older technology with low energy consumption product which could potentially reduce the energy consumption during usage time

In the following paragraphs there is focussed on the first two ways (recycle and reuse) of reducing GHG emissions.

Recycling

When a material is recycled, it is used in place of virgin inputs in the manufacturing process, rather than being disposed of and managed as waste. GHG emissions reductions associated with remanufacture using recycled inputs are calculated taking the difference between (1) the GHG emissions from manufacturing a material form 100% recycled inputs, and (2) the GHG emissions frommanufacturing an equivalent amount of the material from 100% virgin inputs. Hence emissions associated with virgin material, extraction, procession, transportation and manufacturing are compared with recycling, collection, sorting, processing and transportation. The recycling scenario is also often benchmarked with a landfilling and/or combustion scenario in some studies. Landfilling avoids CH_4 emissions and when waste is combusted, energy recovery displaces electricity generated by utilities by burning fossil fuels (thus reducing GHG emissions from the utility sector).

Recycling e-waste not only avoids CO_2 emissions but also ensures that no harmful substances end up in the environment. Life Cycle Assessment (LCA) studies not only look at the impact on global warming,but at an overall impact on the environment. A frequently used impact assessment method is the Eco-indicator '99 method, an endpoint approach. Endpoints are elements of an environmental mechanism that are in themselves of value to society – e.g. human health, damage to plant or animal species and depletion of natural resources such as fossil fuels and mineral ores (Wäger et al., 2011). The Eco-indicator ’99 method aggregates all damages related to human health, ecosystem quality as well as resource consumption into one single indicator on the endpoint level, expressed in Eco-indicator points (EIP).

The study of Huisman et al. (2008) was launched by the European Commission to do a review of the WEEE Directive to analyse the impact and implementation of the WEEE directive and potential changes that might be required. There was focussed on the total environmental, economic and social impacts. WEEE was subdivided in different categories. For each category they investigated what these impacts were. Here we will just focus on the result of category 3A, IT and Telecom excl. CRT's, which includes following types of appliances:

- Computers (desktops and laptop)
- Printers
- Copying equipment
- Fax equipment
- Telephones (fixed and mobile), including answering equipment
- Calculators

Endpoint indicators and GWP were calculated for a default treatment (Table 1), which was for this category a recycling scenario where shredding and separation of the appliances is assumed. Besides that, the same indicators were also calculated for a worst case scenario with MSW (uncontrolled landfill and incineration without energy recovery). The default method gives an avoided impact of **475 kgCO2e/ton of material**. Taking into account the impact of MSW, the avoided impact equals 1391 kgCO2e/ton of material.

Table 1: Overview of the results of the LCA analysis for category 3A

Category 3A	Default	MSW	Unit
Weight	4.19	4.19	kg
Eco-indicator 99 H/A v203	-0.73	0.11	Pt
Idem, Human health	-0.55	0.05	Pt
Idem, Ecosystem quality	-0.042	0.045	Pt
Idem, Resource depletion	-0.13	0.01	Pt
Global warming (GWP100)	-2.01	3.82	kg CO2 eq

A second case study is from Switzerland (Wäger et al., 2011), where the aim was to calculate the overall environmental impacts of collection, pre-processing and end-processing for the existing Swiss WEEE collection and recovery systems. This was benchmarked with two baseline scenarios, incineration and landfilling, in which the same amount of WEEE is either incinerated in an MSWI plant or landfilled. Both mid- (CML-method) and endpoints (Eco-indicator '99) were calculated. The results of the three Eco-indicator '99 damage categories are shown in Figure 2. The functional unit corresponds to the total amount of resources recovered from 1 ton of WEEE, plus all the energy produced in the case of complete incineration of the same amount of WEEE.

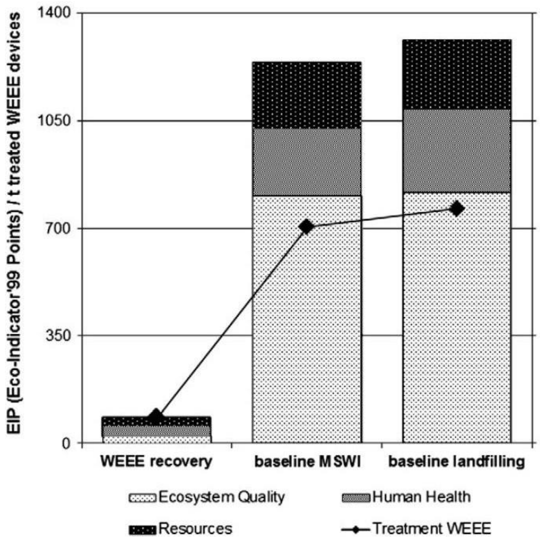


Figure 2: Environmental impact of the Swiss WEEE recovery scenario 2009 compared to the environmental impacts of the baseline scenario 'Incineration in an MSWI plant' and 'Landfilling' according to the Eco-indicator '99 (H/A) method (Wäger et al., 2011)

The ecosystem quality dominates the environmental impacts for both baseline scenarios. In both cases this is due to the direct metal emissions to air and/or water of the incineration and landfilling of the WEEE amount, respectively. The Global Warming Potential (GWP), a mid-point indicator, was also calculated (Table 2). Comparing it the two baseline scenarios MSWI and landfilling, there is an avoided impact of **2750 and 2100 kgCO2e per ton of WEEE**, respectively

Table 2: GWP (kgCO2e) of the Swiss WEEE recoverysystem compared to baseline scenarios 'MSWI' and 'Landfilling'

GWP (kgCO2e)	
WEEE recovery	900
Baseline MSWI	3650
Baseline landfilling	3000

The third case study is a Belgian study (Van Eygen et al., 2015) which investigated the impact on natural resources of the recycling scheme of a desktop and a laptop, benchmarked with a landfill scenario. The analysis was performed in four steps. First, the recycling chain was analysed through material flow analysis (MFA) at the level of specific materials. Second, an indicator was calculated, which quantifies the effectively recycled weight ratios of the specific materials. Third, a second indicator expresses the recycling efficiency of so-called critical raw materials. Finally, the natural resource consumption of the recycling scheme in a life cycle perspective is calculated using the Cumulative Exergy Extraction form the Natural environment (CEENE) method, and is benchmarked with a landfill scenario.

The result of the last step (Figure 3) shows that the natural resource consumption of the recycling scenario is lower/smaller than in case of landfilling the WEEE: **80% and 87% less resource consumption**is achieved for desktops and laptops respectively, hence saving significant primary raw materials.

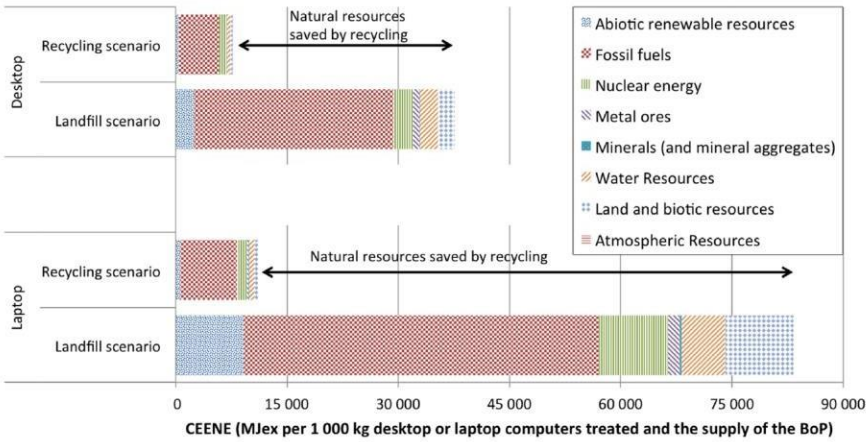


Figure 3: Comparison of the CEENE analysis for the recycling and landfill scenario (Van Eygen et al., 2015)

In the last study case from the US EPA (2006), again different options of waste management, recycling, combustion and landfilling, were compared in term of GHG impact. The report did not include emissions from the use phase of a product's life, since use does not have an effect on the waste management emissions of a product. In Table 3, emissions for 1 ton of a given material are presentedacross different management options. For a personal computer of 1.5 kg, the recycling scenario has abenefit of 4.06 and 4.37 kgCO2e compared to the combustion and landfilling scenario, respectively.

Table 3: GWP for three different waste management scenarios

kgCO2e/ton of material recovered	Recycling	Combustion	Landfilling
Personal computer	-2510	-200	400

Finally, for six types of devices, an own estimation of the reduced impact due to recycling was made. This was based on the one hand on the material composition of these devices and on the other hand on the savings in terms of GHG emissions for each type of material (Table 4). The material compositionfor the desktop and laptop were based on Van Eygen et al. (2015). For the other devices, this was based on HP Product material content information (2019). An overview of the detailed material composition for each device can be found in Annex 2. The result for each device can be found in Table 5. There can be noticed that per kg of material, the biggest savings are for a mobile phone. However, there needs to be remarked that the material composition was based on an early mobile phone, hence less representative for smartphones.

Table 4: Savings due to the use of recycled material insteadof virgin material in kgCO2e/ton of material

Material	Benefit/savings
Metal/iron	1,739
Copper	2,805
Aluminium	9,957
Gold	17,044,350
Lead	1,610
Nickel	1,900
Zinc	1,800
Palladium	8,846,730
Silver	106,515
Tin	2,150
Plastics (ABS, HDPE, PP, PS, PUR)	2,483
Glass	400

Table 5: Savings (kgCO2e) due to use of recycled inputs instead of virgin material

Device	Savings (kgCO2e)	Savings (kgCO2e/kg)
Desktop (5 kg)	18.3	3.65
Laptop (1.5 kg)	7.5	5.0
Display (3 kg)	5.3	1.76
LaserJet Printer (2.5 kg)	4.4	1.76
Inkjet Printer (2.5 kg)	5.1	2.03
Mobile phone (200g)	1.9	9.55

Reuse

When a device is reused, e.g. when its lifetime is extended, it avoids GHG emissions due to reducing the amount of electronical equipment used. Three case studies that investigated the impact of life time extension of an electronic device (notebook, laptop and cell phone) are discussed below.

1) Case study: lifetime extension of a notebook (Germany)

In the study of Prakash et al. (2016), based on a life cycle assessment (including manufacturing, distribution, usage and disposal), it was investigated what the effect would be if a notebook was used for six years instead of three years in a computer workplace (CW). This CW includes: notebook + external monitor + docking station + external keyboard + mouse.

In the model, the service life was extended by making some improvements. The internal memory was upgraded from 4 gigabytes to 8 gigabytes, the battery was replaced and the original HDD was exchanged with SSD on 50% of the notebooks.

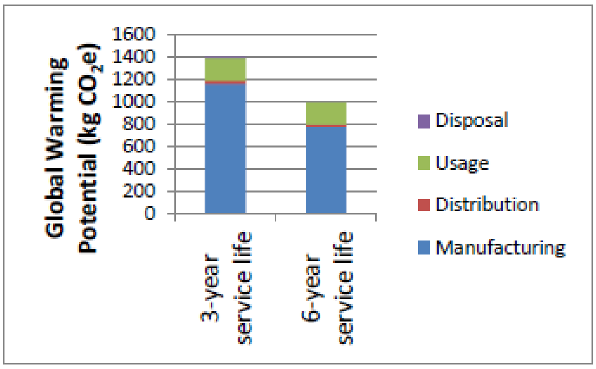


Figure 4:GWP (kgCO2e) for a computer workplace with a notebookover a period of 10 years of service (Prakash et al., 2016)

The findings (Figure 4) show that the extension of the service life of a notebook reduces the greenhouse gas potential by approximately 390 kg CO2e per computer workplace over a period of tenyears (Table 6).

Table 6: GWP (kgCO2e) for a computer workplace with a notebook

GWP (kgCO2e) over a period of 10 years of service	
3-year service life	1,390
6-year service life	1,000
Per year of use	39

2) Case study: reuse of laptop computers (Sweden)

Andre et al. (2019) did a study on the environmental impact of using second-hand laptops, mediated by commercial reuse operation, instead of new ones. The life cycle assessment included the manufacturing of all components from assembly to the end of life treatment. The results for the impactof the different components of the laptop and the net impact on climate change are presented in thegraph below. From this graph, it can be deducted that the GHG emission are reduced by approximately**22 kgCO2 per year of access to laptop use**.

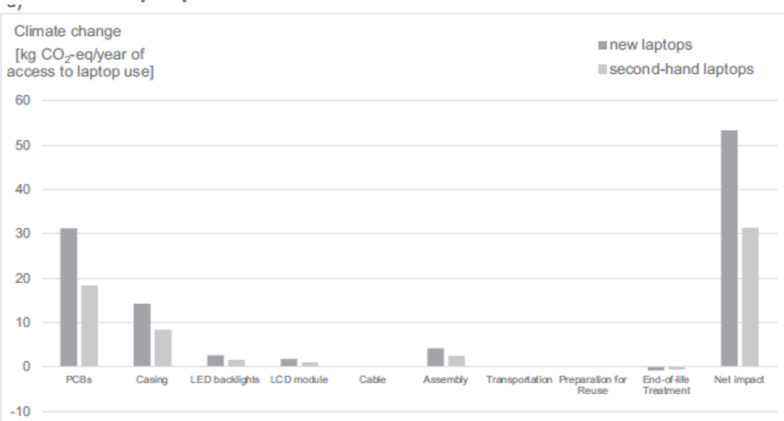


Figure 5: Climate change (kgCO2e) per year of access to laptop use fornew laptops and second-hand laptops (Andre et al., 2019)

3) Case study: smartphone reuse (Germany)

The third case study (Zink et al.,2014), again from Germany, has compared three reuse options for end-of-life (EoL) scenario of a smartphone, including traditional refurbishment. In their calculation, they take into account a displacement rate of 0.05, which is the amount of primary production and useprevented by the production and use of a unit of secondary product. The net impact is presented in the table below.

Table 7: GWP impact of refurbished smartphone

Displacement rate			GWP (kgCO2e)
Refurbished smartphone			7.03
-	Primary cell phone	0.05	-0.78
Net impacts			6.25

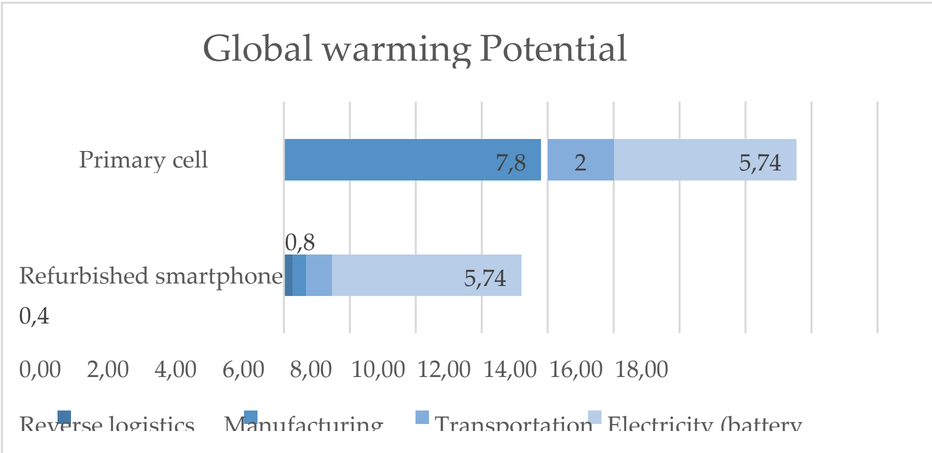
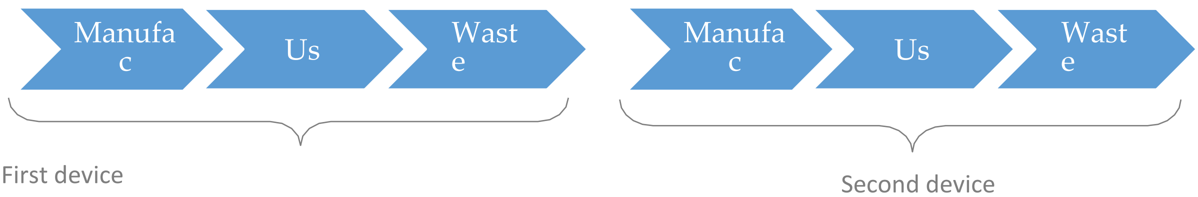


Figure 6: The global warming potential (kgCO2e) of a refurbished smartphone compared to a primary cell phone

LCA studies

Besides the research that already existed regarding reuse of electronic appliances, two scenarios for several appliances (laptop, smartphone, printer and desktop) were compared based on LCA studies for each appliance. A LCA study of an appliance from cradle to grave takes into account the manufacturing (extraction of raw material inputs and the associated processing required to manufacture), the use of the device, the transport and the end of life scenario. In some cases also the packaging of the item was taken into account. Based on the main three steps: manufacturing, Use and end-of-life scenario, following two scenarios were compared:

(1) Use of new device



(2) Reuse of device

If we subtract the second scenario from the first scenario, the difference in impact will depend on following two extra steps in the first scenario:

Transport and packaging was not included because not all the studies communicated about this impact. Table 8 gives an overview of the impact of the three main stages for several devices, while table 9 summarizes the total impact of an extra manufacturing and EoL stage, i.e. the savings due to the reuse for each device. There needs to be remarked that regarding the end-of-life (EoL) treatment,there a several uncertainties due to lack of knowledge about the different pathways. Hence, the EoL model is probably different in each study and therefore can have a higher impact for the one device (due to lower collection rate in model) than another. Nevertheless, they have a low impact when comparing it to the impact of the manufacturing process.

Table 8: Overview of the findings of different LCA studies - GWP (kgCO2e) during its lifetime

Device	Manufacturing	Use	EoL treatment	Country	Source
Iphone 8	45.6	9.12	1.14	U.S.	Apple Inc (2017)
Smartphone	49.8	7.2	-0.3	Sweden	Malmodin & Kimfalk (2016)
Cell phone	7.8	5.74	Not included	Germany	Zink et al (2014)
Printer *estimations*	*5 - 28*	*7 - 41*	*0.2 - 1.5*	Poland	Grzesik (2012)
LCD monitor	90.6	114	6.94	India	Bhakar (2015)
CRT monitor	200	537	14.3	India	Bhakar (2015)
LED monitor	97.7	41	6.98	India	Bhakar (2015)
Desktop Apple	253	300	5.9	U.S.	Apple Inc (2019)
Personal computer	1805.5	1207.3	2.16	Western Australia	Sirait (2012)
Notebook *estimation*	*1160*	*180*	*20*	Germany	Prakash (2016)
Macbook Pro	162	12.5	2	U.S.	Apple Inc (2019)

The estimation for the notebook comes from the study of Prakash that was already mentioned above. The estimated savings in table 9 for the notebook are much bigger than the modelled savings when extending the lifetime from three to six years in their investigation. This difference can be explained by the fact that in the estimation below there was not taking into account the material and processing emissions of upgrading the computer (e.g. replacing the internal memory and battery), which they do bring into account in their model. Emissions as a result of upgrading your device hasn't been taking into account into the savings for the other devices either. The actual savings are thus more likely to bea little lower than the presented values in table 9.

Table 9: Savings due to the reuse of a EEE device (kgCO2e)

Device	Savings due to reuse of device (= EoL + Manufacturing impact)
Iphone 8	47
Smartphone	50
Cell phone	7.8 (but Eol was not included)
Printer *estimation*	*17*
LCD monitor	98

CRT monitor	214
LED monitor	105
Desktop Apple	259
Personal computer	1808
Notebook	1180
Macbook Pro	164

Summary

A first conclusion that can be made, when looking at the summary of the savings due to recycling and reuse of WEEE devices, is that the reuse of a devices has a bigger benefit on GHG emissions than recycling. This is quite logic as the process of recycling includes more different steps (disassembly of the device, processing and refinement of the different materials etc.), while reuse only includes some upgrading. However, there are some remarks that can be made for the reuse of a device:

A first aspect of reusing a device, that was not included in this literature research is the effect of technological development in the use phase, mainly in terms of energy-efficiency and functionality. New products can be more energy-efficient, however they are also more likely to consume more energy in total (André et al., 2019). Consequently, this can lead to conclusions of both increased or decreased environmental impact. However, André et al. (2016) brings the argument that for an LCA ofreuse of computers, functional equivalence between computer generations over a period of six yearsjustifiable as this is more matter of individual preferences and that many applications do not require the latest functionality improvements.

Another aspect that is important for the environmental impact of reuse are the lifetimes of both first and second use. An extended lifetime, can increase significantly the benefits of reusing a device.

On device level, there can be noticed that biggest savings comes from reusing a notebook or laptop, however there is a big variation on the results. Note also, that the different devices have different sizes and weights. In table 5, the relative savings are also showed (per kg of material). This is the highest fora mobile phone, followed by a laptop. The main explanation is possibly the high content of precious metals in mobile phones and laptops in comparison to the other devices.

Table 10: Summary of savings (kgCO2e) due to recycling and reuse of different devices

Device	Recycle (kgCO2e)	Reuse (kgCO2e)
Smartphone	-	47 - 50
Cell phone	1.9	6.25 - 7.8
Printer	4.4 - 5.1	*17*
Display monitor	5.3	98 - 105 - 214
Notebook / PC / Laptop	4.3 - 7.5	22 - 39 – 164 - 1180 -1808
Desktop	18.3	259

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Annexes

Annex 1: Estimation of avoided emissions due to recycling

Annex Table 1: Estimation of avoided emissions from literature review

material	virgin material	recycling	savings	source	scope	used
	(kgCO2e/ton)					
metal/iron	3.190	1.100	2.090	Ademe, 2012 (Europe)	LCA	x
			1487	AEA Technology, 2001 (EU 25)	LCA	x
			1570	Ademe, 2007 (Europe)	scope 1 & 2	
			1000	Prognos, 2008 (EU 27)	scope 3	
	1670	700	970	BIR 2008 (international)	scope 1 & 2	
			1.970	EPA 2006 (USA)	LCA	
iron			818	TNO Rapport, 2011 (Netherlands)	unclear	
metal			3.414	TNO Rapport, 2011 (Netherlands)	unclear	
			1.421	World Steel Association, 2011 (int.)	unclear	
	2.040	400	1.640	EcoInvent 2009 (Europe)	LCA	x
			1.739	**average used**		
copper	2.933			Ademe, 2012 (Europe)	LCA	x
			1.180	Prognos, 2008 (EU 27)	scope 3	
	1250	440	810	BIR 2008 (international)	scope 1 & 2	
			350	TNO Rapport, 2011 (Netherlands)	unclear	
	3.000	100	2.900	UNEP, 2013 (international)	LCA	x
	2.810	100	2.710	EcoInvent 2009 (Europe)	LCA	x
			2.805	**average used**		
aluminium	9.827	513	9.314	Ademe, 2012 (Europe)	LCA	x
			6.010	TNO Rapport, 2011 (Netherlands)	unclear	
	3.830	290	3.540	BIR 2008 (international)	scope 1 & 2	
	10.200	1.320	8.880	EcoInvent 2009 (Europe)	LCA	
			9.097	**average used**		
gold			11.048.180	TNO Rapport, 2011 (Netherlands)	unclear	
	16.991.000			UNEP, 2013 (international)	LCA	
	17.879.750	835.400	17.044.350	EcoInvent 2009 (Europe)	LCA	
			17.044.350	**average used**		
lead	1.630	20	**1.610**	BIR 2008 (international)	scope 1 & 2	x
nickel	2.120	220	**1.900**	BIR 2008 (international)	scope 1 & 2	x
zinc	2.360	560	**1.800**	BIR 2008 (international)	scope 1 & 2	x
platinum	13.954.000			UNEP, 2013 (international)	LCA	
ruthenium	13.954.000			UNEP, 2013 (international)	LCA	
palladium	9.380.000			UNEP, 2013 (international)	LCA	
	9.284.300	437.570	**8.846.730**	EcoInvent 2009 (Europe)	LCA	x

silver	144.000			UNEP, 2013 (international)	LCA	
		-1/5->1/10	115.200	http://www.panac.jp/eng/co2/index.html	x	
	112.140	14.310	97.830	EcoInvent 2009 (Europe)	x	
			106.515	**average used**		
indium	142.000			UNEP, 2013 (international)	LCA	
tin	16.000			UNEP, 2013 (international)	LCA	
	2.180	30	**2.150**	BIR 2008 (international)	scope 1 & 2	
cobalt	8.000			UNEP, 2013 (international)	LCA	
plastics	2.383	202	2.181	Ademe, 2012 (Europe)	LCA	
			3.265	TNO Rapport, 2011 (Netherlands)	unclear	
ABS			3.265	TNO Rapport, 2011 (Netherlands)	unclear	
HDPE			1.125	TNO Rapport, 2011 (Netherlands)	unclear	
PP			1.185	TNO Rapport, 2011 (Netherlands)	unclear	
PS			2.464	TNO Rapport, 2011 (Netherlands)	unclear	
PUR			3.183	TNO Rapport, 2011 (Netherlands)	unclear	
			2.483	**weighted average based on UNEP,2013**	LCA	x
Glass	200	20	180	Prognos 2008 (EU 27)	Scope 3	
	500	900	**400**	Hilmann et al. (2015)		x

Annex 2: Material composition devices

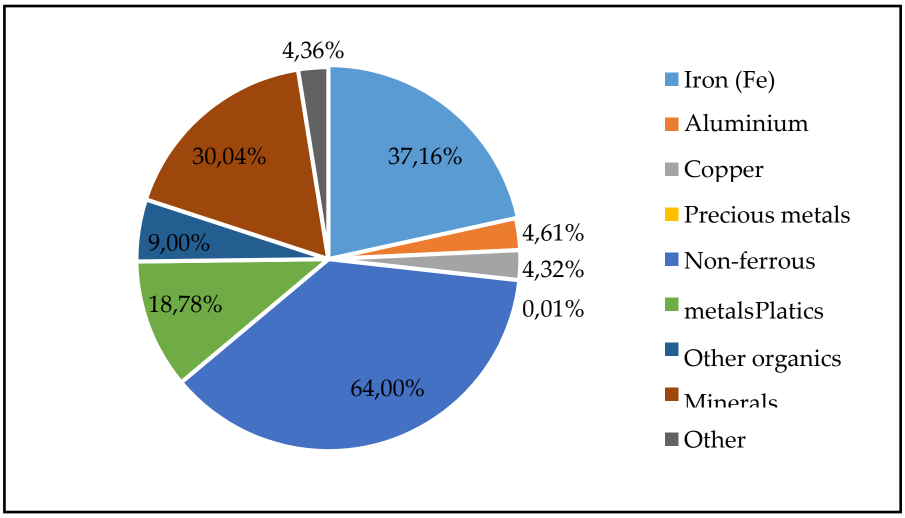

Figure 1: Material composition of a desktop

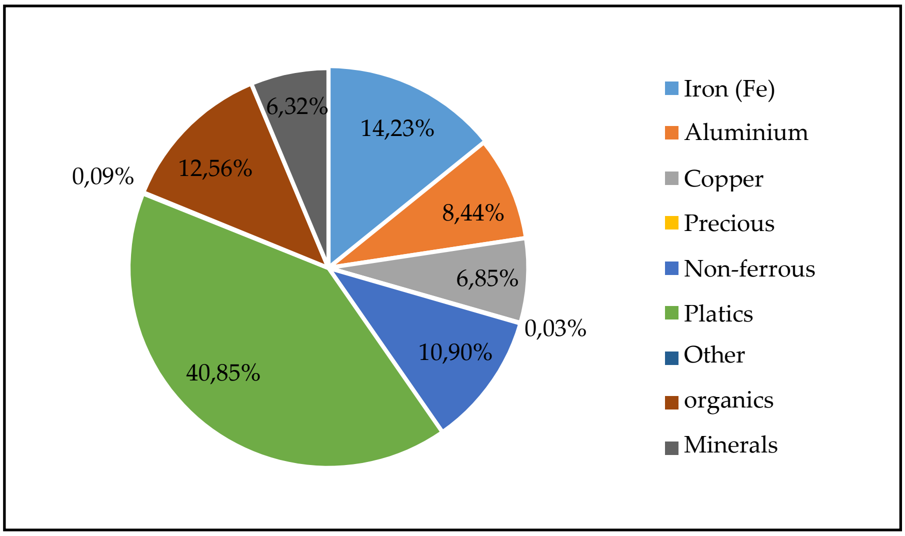

Figure 2: Material composition of a laptop

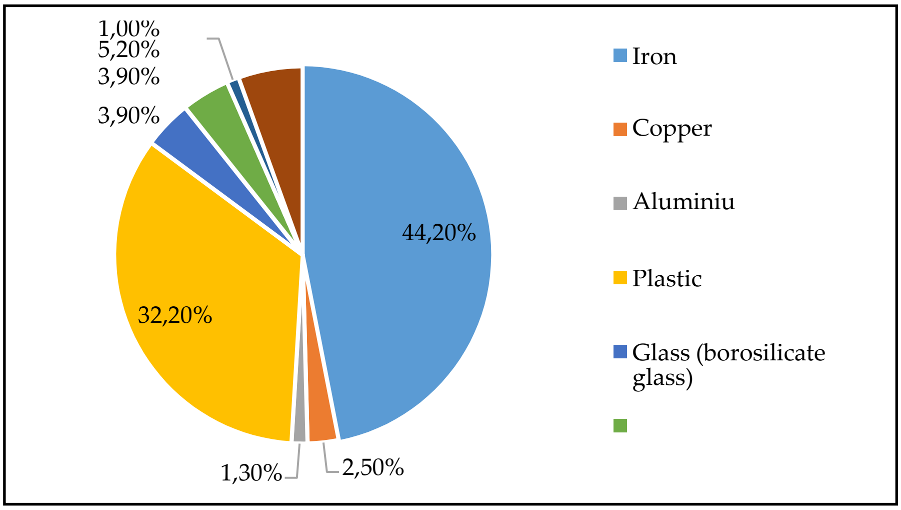

Figure 3: Material composition of a display

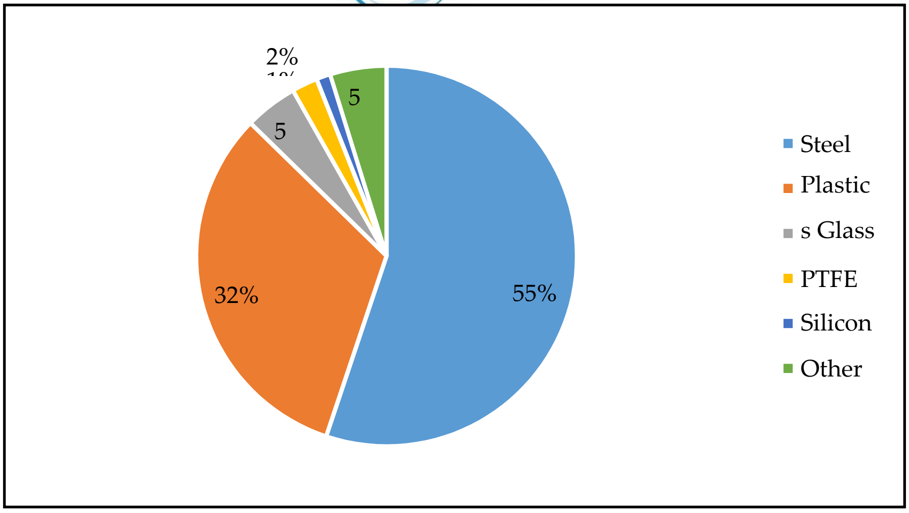

Figure 4: Material composition of a LaserJet Printer

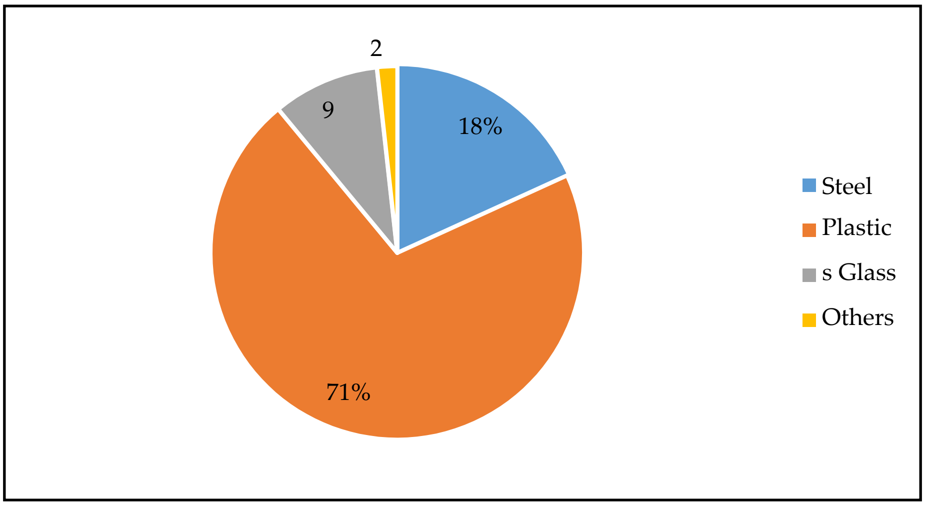

Figure 5:Material composition of a Inkjet printer

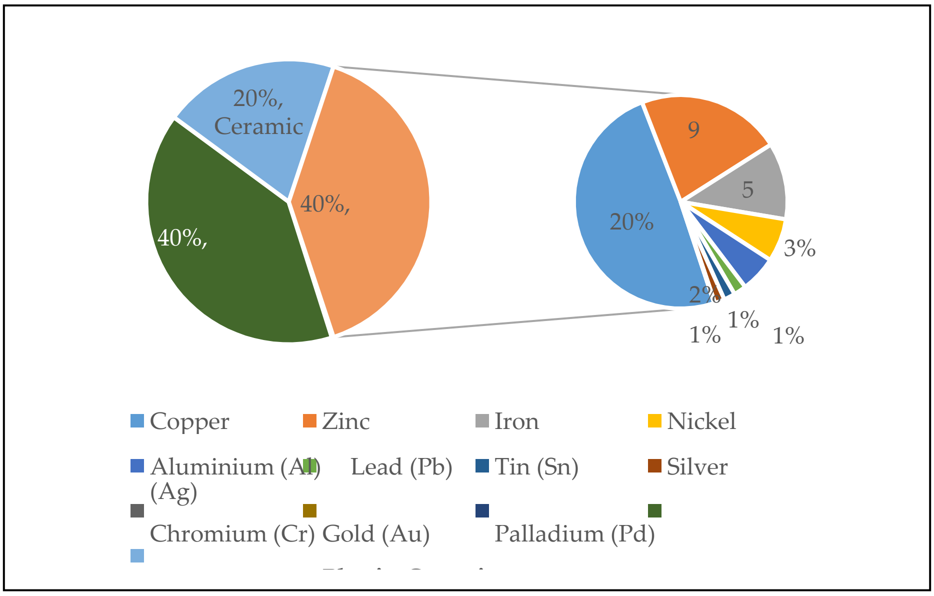

Figure 7: Material composition of a mobile phone

2. The climate benefits of reusing IT products and the method for creating data bases (IVL Svenska Miljöinstitutet)

No. B 2372
January 2020

Product databases: the environmental benefits of reuse

The climate benefits of reusing IT products and the method for creating data bases

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IVL SVENSKA MILJÖINSTITUTET

In collaboration with Inrego AB

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The report has been reviewed and approved in accordance with IVL's management system

Preface

This report is divided into two sections.

The first section explains a method for the creation of databases showing the environmental benefits from reuse, which covers a limited number of product groups. The idea is that this section of the report could be followed to create a useful database for any specific product group, or several product groups within a common field of work.

Databases that are created are intended to operate within a well-defined area, with a specific purpose. Examples are the climate benefits from reusing products that are part of ventilation systems in an office environment, or the climate benefits from reusing IT products.

The second section is a case study and describes a database for the climate benefits of reusing IT products, produced according to the method in part 1. The database contains a number of different categories and sub-categories of IT products, as well as calculated data on the climate benefit of reusing them in Sweden. The idea is that this database could be used by companies that work with the reuse of IT products, to calculate the climate benefits of reusing for their customers, or by organisations that want to investigate the potential climate benefit of their current or future internal reuse of IT products.

The advantage of producing distinct databases is that they are relatively simple to create, and they can be adapted to the purpose and made quite easy to work with, which increases the likelihood that they are actually used to their full potential. The disadvantage is that it is generally not possible to compare results between different databases without first analysing the differences between the databases and assumptions.

The case study in this report only looks at "climate benefits", but it is quite possible to develop a database that looks at another, or several other, environmental aspect(s). It is up to the person who creates each database to investigate and choose which environmental benefits to include, depending on what is relevant in the context and what is possible given the availability of data.

The words "environmental benefit" and "climate benefit" are often used in this report when perhaps using "environmental impact" and "climate impact" would be more accurate. This is because reusing is not always a "benefit", given the impact of the whole system. For example, reusing a product that travels a long way to its new user can cause such a lot of emissions that the "climate benefit" of reuse becomes negative, making it a "negative climate impact". However, the choice of words is intentional, as these databases are often about quantifying the benefits. Another reason for the choice of words is that "environmental impact" is normally seen as "negative" and therefore must be defined as "negative" or "positive", but it is not clear what these words mean when we talk about savings in general. In contrast, "environmental benefit" and "climate benefit" are positive words by nature, and we therefore assume that they are easier for a non-expert to assimilate.

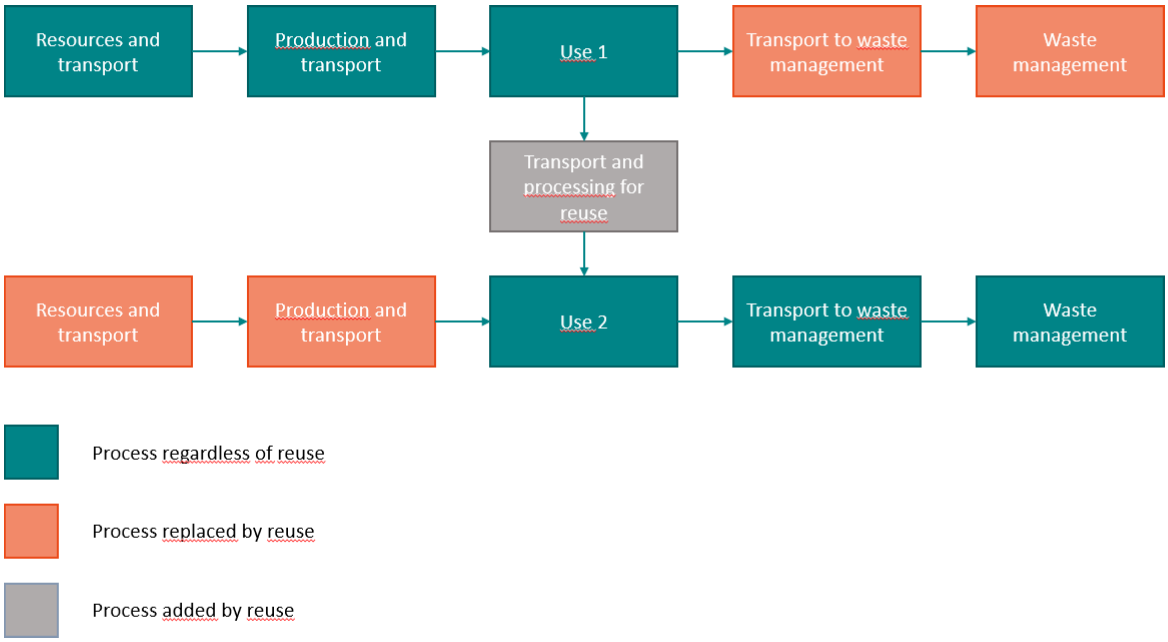
The author would like to thank their partner Inrego AB for its commitment and constructive cooperation throughout the project leading up to this report.

Table of Contents

Summary

This report contains two sections. The first section contains a method for the creation of databases for the environmental benefits from reuse, customised for a specific stakeholder and application. The second section is an implementation of the method from section one and it contains a database of the climate benefits of the reuse of IT equipment, created for use by a company facilitating the reuse of IT equipment. This database can be found on page 21.

The impact of "environmental benefits from reuse" is, in this report, defined as the difference between a product being reused or a similar product being bought new. This means that the production of one new product is avoided, along with its transport to the customer, waste handling, and the transport to waste handling. However, the process of reconditioning the reused product is added, as well as the transport to, and from, the reconditioning.



A "database for the environmental benefits of reuse" created using this method is a table of product categories that are reused in some specific context and that contains data on the potential environmental savings for different parts of the life cycle. All databases created following this method has the same basic equation defining the included parts of the life cycle, but they can be calculated in different ways for different databases, which means that the results should generally not be used outside their specific context. The various included parts of the life cycle are shown in the equation below.

$$Environmental\ benefits = PROD_u + TRP_{up} + AVF_u + TRP_{ua} - TRP_{re} - RECOND \qquad (1)$$

$PROD_a$ = Environmental impact from the avoided new production; TRP_{ap} = Environmental impact from the avoided transport from production; $WASTE_a$ = Environmental impact from the avoided waste handling (of the product that was not produced); TRP_{aw} = Environmental impact from the avoided transport to waste handling; TRP_{re} = Environmental impact from the added transport to and from reconditioning; RECOND = Environmental impact from the reconditioning of the product.

Included with the database is documentation meant to help a user to understand where the data comes from and how the calculations are made. It also contains details of what conditions need to be met for the results to be applicable, and if any limited conclusions can be drawn if they are only partially met.

The first section of the report describes how to create a database, how it should be designed and what the documentation should include. The description is meant to be able to be used to create databases, for environmental benefits from reuse, within all sorts of different product ranges.

Every database that is produced following this description is meant to have a specific purpose, e.g. to be used to measure the environmental benefit of reuse at one or several reuse processes within a specific industrial branch. The user group of such a database is thought to be within industry, where there is a need of a credible, easy-to-use database that has been made for the purpose, and that can be commonly used within the community.

The second section of the report contains a database of the “climate benefits of reuse of IT products”. This database is primarily made to be used by a reconditioning company, within Sweden, to help its clients calculate the climate benefit of their reuse of IT products. The database can be found again on page 21 and is preceded by documentation describing aspects including usability and data sources.

The database is mostly composed of publicly available material from some of the large computer companies: HP; DELL; Lenovo; and Apple. The results are presented for different categories, e.g. ”laptops”, “desktops”, “monitors”, “mobile phones”, “tablets”, “servers” and “printers”. Some of the categories also have subcategories, and there are also a few not mentioned here.

The results in the database have a few conditions that need to be met for them to be applicable. The most important of these is the condition: ”acquiring a reused product leads to not acquiring a similar newly produced product”. If this condition is not met, then the results are not valid.

The results in the database are dominated, almost completely, by the avoided impact from the production. This production data is taken from the producers’ PCF-files (Product Carbon Footprint) and they are regarded as having high credibility. Most categories use data that is no older than three years (2016-2018).

A reused IT product is here assumed to have the same potential performance as a new product in the same category. The use phase is not included since the reused product is assumed to be used in the same way as a new product would have been used, and the energy use is assumed to be the same. The assumption of equal energy use of newer and older products could potentially be incorrect, and for products that use a lot of energy when used, this could potentially lead to incorrect conclusions, but the project has not studied this.

1 Methods for creating the database

1.1 Reuse

The term "reuse" here refers to when a product that's no longer needed by its owner ("user 1") is taken over by a new user ("user 2") who has a need for it, instead of it becoming waste.

Reusing is the second most desirable way to reduce our waste, right after "avoid production", according to the EU Waste Framework Directive (directive 2008/98/EC)[1]. Reuse is thus the most desirable option for a product that has already been manufactured, rather than material or energy recycling or disposing of it to landfill.

Individuals, organisations and companies reuse products by buying, selling, exchanging, donating and receiving used products.

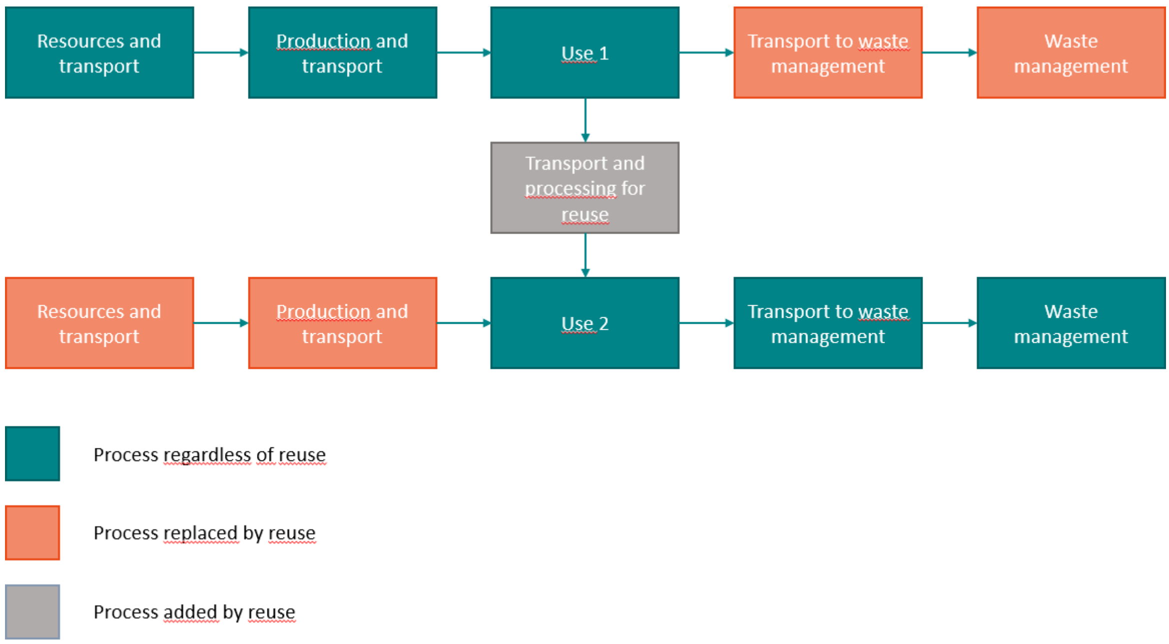


Image 1: Schematic diagram of reuse, as calculated in this report

1.2 Database

One way to promote reuse is to emphasise the environmental benefits of it, but it is also useful to be able to compare the environmental benefits across various products in order to know which products provide the most benefits when reused. As there are lots of stakeholders in the same industry, everyone is required to use similar results for the same things if credibility is to be maintained. In the absence of a compulsory calculation standard, the different calculations run the risk of arriving at different results, and expert knowledge is usually required to understand the differences.

One solution to this is to develop a database containing the products of interest to the stakeholder in question, as well as values showing the environmental benefits associated with their reuse and make that database available to all of the stakeholders in the industry. In order to suit an industry stakeholder, the database needs to be useful even for people who do not have in-depth expert knowledge, while also being credible. Exactly what this means can differ from case to case, and it is also one of the reasons why different databases, produced according to this method, may need to be constructed in different ways. For example, they may have different types of data and focus on different types of environmental problems.

By creating a customised database, tailored to the industry and the stakeholder in question, it is possible to make the results for the various products in the database more comparable than would have been possible in a more general database. But this also has the consequence of the comparability between two different databases possibly being so poor that comparisons of results from different databases should generally be avoided, unless an in-depth review is made of how the calculations are done in each database.

As comparisons between different databases should be avoided, it is important to think about which additional stakeholders may be interested in using it, so that their interests can be safeguarded in the database. This is to avoid the creation of multiple databases with more or less the same products in them, which are calculated in different ways.

1.2.1 Designation and naming of databases

A database that takes a holistic approach to the environmental impact of the products in question should be called a “product database for the environmental benefits of reuse”, or similar. If the database focuses on a specific environmental impact category, such as climate impact, then it should not use the word “environmental benefits”, in this case the word “climate benefits” should be used instead.

1.3 The environmental benefits of reuse

When a buyer chooses to buy a reused product instead of a new one, it means that a new product of this kind does not need to be manufactured, which is generally an environmental benefit since in principle all production uses materials and energy, which in turn always has an environmental impact. When a new product does not need to be manufactured, all transportation that would otherwise have occurred to transport the product to the customer, as well as waste handling including transport, are also avoided.

However, there are generally a number of extra processes that occur when reusing a product which have an additional environmental impact. These include the transport that occurs to move the product from user 1 to user 2, and the reconditioning of the product where it may be stored, repaired or refreshed, and these processes have an impact that encumbers the actual reuse.

These parts are described in detail in the next section.

1.3.1 Equation

The equation for calculating the environmental benefit of recycling a product is as follows:

$$Environmental\ benefits = PROD_u + TRP_{up} + AVF_u + TRP_{ua} - TRP_{re} - RECOND \quad (1)$$

- $PROD_a$ = Environmental impact from the avoided new production
- TRP_{ap} = Environmental impact from the avoided transport from production
- $WASTE_a$ = Environmental impact from the avoided waste handling (of the product that was not produced)
- TRP_{aw} = Environmental impact from the avoided transport to waste handling
- TRP_{re} = Environmental impact from the added transport to and from reconditioning, or more generally: all transport between user 1 and user 2
- RECOND = Environmental impact from the reconditioning of the product

It is entirely possible that TRP_{re} and RECOND, which contribute negatively to the calculation, can be larger overall than the other four, normally positive, parts. In this case, the environmental benefit becomes negative, and is therefore more of a negative environmental impact. If this occurs for any of the products in a database, then the database needs to be extra clear about what positive and negative values mean, and in some cases it may be better to use the word "environmental impact" instead of "environmental benefit". This needs to be determined for each specific database where the problem occurs. The goal is to reduce the risk of misunderstandings for all of the likely users.

It is also possible that one or more of the other four ($PROD_a$, TRP_{ap}, $WASTE_a$ and TRP_{aw}) may be negative, which means that this part is counted as contributing to the equation as a negative environmental impact. This can also contribute to the environmental benefit becoming a negative environmental impact and is also managed by using the word "environmental impact" instead of "environmental benefit" consistently in that database.

1.3.2 Calculating the various parts of the equation

The way in which the six parts included in the calculation of the environmental benefit are calculated is described in detail in each individual database. There are no specific limitations on how they can be calculated, but it is of course important to include all aspects that are considered important for the products in the specific database.

It should be possible to understand from the description how the calculation is done; what important assumptions have been made; which parts are included and excluded; and a description and references for all of the data used.

It is important that the products' environmental benefits are calculated in the same way, and that data of the same quality and origin are used, in one and the same database. In cases where this is not possible, for example due to a lack of data, this needs to be noted and justified. Potential problems with comparisons that may arise from different methods of calculation or data should also be analysed and discussed.

1.3.3 Data quality and traceability

All of the data used must be listed and described with the description of the calculation, for each part of the calculation where that data is used. The more important a piece of data is for the end result, the more important it is that it is well described. It should be possible to read where important data is taken from or exactly how it is calculated, and it should be shown how less important data was produced.

It is not necessary for all information to be available to accurately reproduce the whole, or parts of, the calculation. The goal is for a reader to be able to understand how the calculation is done, so that if they have thorough subject knowledge, they should be able to determine whether it is a reasonable calculation method.

There are no specific data quality requirements, as in some cases high quality data is not available. However, the quality of the data should always be discussed in the documentation, partly in general terms based on the purpose of the database, and partly for all data that is considered important, so that the user can make their own assessment of the credibility.

1.3.4 Allocation of the environmental benefits between users 1 and 2

Several stakeholders are often involved in reuse, and since potentially all of them are interested in knowing exactly how much of the calculated environmental benefit they can count as their own, sometimes the environmental benefit needs to be allocated between them. This is done to avoid counting the same benefit twice. However, it is not clear how the division should then be made between these stakeholders. The obvious stakeholders are users 1 and 2, but any intermediaries can also be seen as stakeholders.

The equation calculates the total environmental benefit from the entire reuse and that is the perspective that should be used primarily, whenever possible. This is because allocation between stakeholders can often be managed in a variety of ways, based on different motivations, leading to different results. All stakeholders have also contributed to the total environmental benefit, and in general contexts where the total benefit of reuse is presented, the total figure should be used.

How allocation is managed is decided and described in each individual database, but the recommendation is to use the 50/50 method [2], where the environmental benefit is shared equally between users 1 and 2 (meaning any intermediaries do not get their own cut of the environmental benefit). The reason for this recommendation is that the 50/50 method is easy to understand, and that it provides a benefit for both users 1 and 2, on the assumption that both of these must make direct choices for reuse to occur. If more complex allocation methods are used, they should be well motivated in the database documentation, under the allocation section.

The total environmental benefit should always be reported in the database. The database documentation should also always describe how the environmental benefit should be allocated between different stakeholders, where this is needed.

1.4 Method for producing a database

The checklist below outlines the things that need to be done to create a product database showing the environmental benefits of reuse.

1.4.1 Checklist, producing the database

1. Identify the need for the database – who will use it and why?
2. Identify additional stakeholders – are there additional stakeholders who may be affected, and whose perspectives should be taken into account?
3. Complete an inventory of the products – what products, or product categories, should be included?
4. Analyse the products – which environmental aspects are important to capture?
5. Complete an inventory of the data – what data is available?
6. Create a calculation model – develop a calculation that works for the products/product categories, for all the components of equation 1.
7. Create a database for the products and their environmental benefits (see the list of requirements below).
8. Create the documentation for the database (see the list of requirements below).

1.4.2 Requirements list, database and documentation

For each product or product category a database should contain:

- The product name or product category name (unique)
- A defining description of the product or category (this may be included in the name)
- Possibly multiple levels of categories
- The product unit for which the result applies (for example "piece" or "kg" or "m^2") (if the same unit is used for all products/product categories then it is sufficient to specify the unit somewhere next to the calculated result, for example in the result heading together with environmental impact unit).
- Estimated results for each included environmental benefit/impact, for each part of the equation and the total sum, including units for these
- Any other data that is considered relevant for usability, such as product weight.

The database documentation shall contain the following sections, with the content described, in the following order:

- General information about the database
  - Contents
    - The name of the database
    - Who produced it
    - Who funded its production
    - When it was produced
    - Which environmental impact categories are included
  - (Other information of a general nature may be included here).
- The aim and use of the database
  - Text that clearly states how the database is intended to be used, by whom and why

- A presentation of the product categories
  - A description of the group of product categories
  - A description of each product category
- The calculation and equation
  - A presentation of the equation used, and an explanation of what this means in the current database
- Conditions
  - A description of which conditions need to be met for the database results to be applicable. Discuss how well the results can be assumed to work if the various conditions are not met.
- Allocation indications
  - A description of how the result should be allocated between the various stakeholders involved in the reuse, when allocation is desirable.
- The general data quality of the database
  - A discussion of the general quality of the database, with regard to how fair the results are considered to be, based on the data and calculations that they are based on.
- Review of the calculation and data
  - A comprehensive review of the calculation/equation, where the important aspects in relation to size are identified, and important data sources are presented.
  - A review of all of the important exceptions, such as from the overall description of the calculation/equation and common data sources, as well as comments on how each exception may conceivably affect comparability to other results.
  - A detailed review of each part of the equation, with a description of the calculation and each input data. For important data and important parts of the calculation, data quality and any data gaps should be described.
- (Any) Other documentation

2 The climate benefits of reusing IT products

2.1 Documentation, database

2.1.1 General information about the database

Name: Product database to show the climate benefits of reusing IT products

Produced by: IVL Swedish Environmental Research Institute in 2019

Produced on behalf of: Inrego AB

Produced with funding from: Inrego AB and the Foundation for IVL (SIVL)

Environmental impact categories included: Climate impact (GWP100)

2.1.2 The aim and use of the database

Please note that the results in this database are produced for a specific purpose and are designed to ensure good comparability within the database. It is not possible to assume that comparability is good when comparing these results with other results outside the database, regardless of the context.

The purpose of the database is to enable a stakeholder dealing with the reuse of IT products to calculate the climate benefit of reuse.

The stakeholder is primarily intended to be a reuse company, which acts as an intermediary and collects IT products that are no longer used, checks that they work and then sells them to companies or private individuals. Alternatively, the stakeholder may be a company that reuses its IT products within its company, or a private person who buys used IT gadgets or sells their own used IT gadgets.

In addition to common IT products, the database also contains a number of components or peripherals, such as RAM memory, keyboards and power adapters. A reuse company that uses the database may want to use the data for components in order to partly attribute the benefit of saving components from products that would otherwise have to be disposed of. The company can also use the component data to calculate, at a highly detailed level, the impact of reconditioning a product where a certain part has to be replaced. For components, the impact of reconditioning and their transport has been set to zero, as they are normally counted as part of the more complete products (all other categories in the database) and they weigh relatively little.

A company that reuses its own IT products, or a private person who purchases used goods, can completely disregard the effects of reconditioning (RECOND), and also disregard the transport to and from reconditioning (TRP_{re}), unless the products in question have been transported across countries. The RECOND value in the database corresponds to the impact of energy required for the operating and heating of the reuse company's premises which is emitted per recycled product, and the TRP_{re}value corresponds to two transports within Sweden for the product in question. Both of these impacts are small in this context for all of the IT products in the database.

2.1.3 A presentation of the product categories

The group of product categories is “IT products”, and the aim was to include the categories that create large flows for the companies that manage IT waste, focusing on the categories that are widely reused.

List of the product categories included:

- Notebook (average all subcategories)
- Notebook: Screen below 14 inches
- Notebook: Screen 14+ inch
- Notebook: Hybrid
- AIO: (average all subcategories) (All-in-one desktop)

- AIO: Screen below 24 inches
- AIO: Screen 24+ inch
- Desktop (average all subcategories)
- Desktop: USDT (Ultra Small Desktop)
- Desktop: SFF (Small Form Factor)
- Desktop: Tower
- Monitor (average all subcategories)
- Monitor: Screen below 33 inches
- Monitor: Screen 33+ inch
- Printer: Desk
- Server: Rack
- Handheld (average all subcategories)
- Handheld: Tablet-big
- Handheld: Smartphone
- Handheld: Tablet-Small
- Projectors: mid-size
- Network equipment (average all subcategories)
- Network equipment: Small
- Network equipment: Rack mounted (blade)
- Network equipment: Rack mounted (large)
- Components (average all subcategories)
- Components: SSD
- Components: HDD
- Components: RAM memory
- Components: Processor
- Components: Laptop battery
- Components: Laptop screen
- Components: Tablet screen
- Components: Smartphone screen
- Components: Keyboard
- Components: Power adaptor, laptop
- Components: Docking station
- Components: Network card
- Components: Fan
- Components: DVD
- Components: Mouse pad
- Components: Smartphone/tablet charger

2.1.4 The calculation and equation

The equation for calculating the environmental benefit of recycling a product is as follows:

$$Environmental\ benefits = PROD_u + TRP_{up} + AVF_u + TRP_{ua} - TRP_{re} - RECOND \qquad (1)$$

- $PROD_a$ = Climate impact from the avoided new production
- TRP_{ap} = Climate impact from the avoided transport linked to new production
- $WASTE_a$ = Climate impact from the avoided waste handling (of the product that was not produced)
- TRP_{aw} = Climate impact from the avoided transport to waste handling

- TRP_{re} = Climate impact from the added transport to and from reconditioning, or more generally: all transport between user 1 and user 2
- RECOND = Climate from the reconditioning of the product

The climate benefit here is defined as the consequence of someone buying a used IT product, instead of a new one. It is then assumed that a similar product does not need to be manufactured ($PROD_a$), and since it is not manufactured, it does not need to be transported to buyers (TRP_{ap}), nor to waste disposal ($WASTE_a$) or waste handling (TRP_{aw}). However, it is assumed that the used product will pass through a reuse company, which transports the product (TRP_{re}) and reconditions it (RECOND), thereby contributing to added impact that reduces the climate benefit.

2.1.5 Conditions

The results in this database are produced for a specific purpose and are designed to ensure good comparability within the database. It is not possible to assume that comparability is good when comparing these results with other results outside the database, regardless of the context.

The following conditions must be met for the results in the database to be valid:

1. The reuse occurs in Sweden.
2. The buyers of the used product would have bought a new product, within the same category, if they had not bought the used one.
3. The new product is assumed to have been manufactured in Asia.
4. Reuse occurs within three years of the last update to the database.

If all or part of the reuse does not occur in Sweden, the calculation could potentially be wrong in all parts except for $PROD_a$. However, since $PROD_a$ is generally the dominant part of the equation, it is still possible to draw conclusions based on the value of the total climate savings.

If condition 2 is not met, the database results are not applicable. This is because the result is dominated by the impact of manufacturing a new product being avoided.

If condition 3 is not met, $PROD_a$ is not correct, and as $PROD_a$ is generally the dominant part of the equation, it is possible that no conclusions can be drawn based on the results of the database.

If condition 4 is not met, the results may still be applicable depending, however, on how quickly technology has developed, both in terms of the product in question and the production methods used by the manufacturer.

2.1.5.1 Alternative uses of the database results

Alternative uses are not recommended. For example, if the database is to be used to extract values for the manufacture and/or use of IT products, it is recommended that the user goes straight to the background data instead (see references 3–7) to gain a better understanding that conforms with what they are looking for.

2.1.6 Allocation indications

The results in the database apply to the total reuse. If the climate benefits need to be divided among different stakeholders, they should be divided equally between user 1 and user 2. In this case user 1 is the organisation or person who sold/donated the product for reuse, and user 2 is the organisation or person who bought or received the product for the purpose of reusing it.

2.1.7 The general data quality of the database

The data quality of the database is considered to be relatively high, given that it is largely based on calculations performed by the product producers where they have used a common calculation method, and that many of the major producers, such as HP, Dell, Lenovo and Apple, are included in the data. It is worth noting that Apple does not use exactly the same calculation method as the others, but our assessment is that the results are sufficiently comparable.

The documentation of this database does not include an in-depth analysis of the calculation method used by producers to calculate the climate impact of their products. This method is called the Product Attribute to Impact Algorithm (PAIA) and is a tool for calculating life cycle analysis (LCA) results, developed by the Materials System Laboratory at the Massachusetts Institute of Technology (MIT) in the USA. The general assessment is that the method is reliable, and that the producers use it correctly. This assessment is based on studies of the results used in this database as well as experience with similar calculations.

2.1.8 Calculations and data

Overview, important aspects

The equation for calculating the environmental benefit of recycling a product is as follows:

$$Environmental\ benefits = PROD_u + TRP_{up} + AVF_u + TRP_{ua} - TRP_{re} - RECOND \qquad (1)$$

$PROD_a$, the influence of the avoided new production, completely dominates the calculated climate benefit. The data for $PROD_a$ is largely taken from the producers' (HP, DELL, Lenovo and Apple) own calculated results, which are published for individual products. The result presented in the database is the average of a number of products. See the detailed description below for more info.

Overview, important exceptions

The data set for the following categories is of poorer quality for $PROD_a$ – i.e. the influence of the avoided new production – which is the dominant part in the calculation of the database result.

- Printer
- Server
- Projectors
- Network equipment
- Components

As a consequence of this poor data quality, users should be extra cautious when drawing conclusions that are largely influenced by results from these categories.

Detailed review of data and calculations

Below is a description of the data used for the different parts of the calculation.

- $PROD_a$ = Climate impact from the avoided new production

  - Data: Results are generally taken directly from the producers' “Product Carbon Footprint” (PCF) files, which are published for a variety of products in most of the categories included in this database. Sub-totals, in the files, from the use, transport and waste handling phases have been calculated. These results are then averaged, for each product category, for the results published over the last three years (2016–2018). All of the published PCF files are not included in the background data to this database, but in some cases a selection has been made, with the goal of getting a good representation in all categories and from all producers. The number of data sets (PCF files) behind the results for each category are presented below.
    - Desktop: USDT (Ultra Small DeskTop): 15 data sets (PCF files)
    - Desktop: SFF (Small Form Factor): 16 data sets (PCF files)
    - Desktop: Tower: 10 data sets (PCF files)
    - AIO: Screen below 24 inches (All-in-one desktop): 11 data sets (PCF files)
    - AIO: Screen 24+ inch (All-in-one desktop): 12 data sets (PCF files)
    - Monitor: Screen below 33 inches: 41 data sets (PCF files)
    - Monitor: Screen 33+ inch: 4 data sets (PCF files)
    - Notebook: Screen below 14 inches: 22 data sets (PCF files)
    - Notebook: Screen 14+ inch: 37 data sets (PCF files)
    - Notebook: Hybrid: 8 data sets (PCF files)
    - Handheld: Tablet-big: 7 data sets (PCF files)
    - Handheld: Smartphone: 11 data sets (PCF files)
    - Handheld: Tablet-Small: 5 data sets (PCF files)
  - Exception 1: For the Printer and Server categories, there was only isolated carbon footprint data from the producers, and it was also more than three years old. These results are therefore considered to be of lower quality, yet comparable within the database.
  - Exception 2: For the Network components and Projector categories, data from the producers is missing, so the result is calculated from specially developed models based on material and component content. These results are therefore considered to be of lower quality, yet comparable within the database.
  - Exception 3: For the Components category, the result is partly calculated based on disaggregated information from the producers’ PCF files, and partly from specially developed models based on material and component content. These results are therefore considered to be of lower quality, yet comparable within the database.
- TRP_{ap} = Climate impact from the avoided transport linked to new production
  - Data: These results are calculated based on the general impact of transport, using data from the EcoInvent database (v3.5), based on the weight of the product, plus one (1) kg for packaging, and the assumption that transport is via container vessels from Asia, and then via lorries within Sweden. For the Components category and its subcategories, the packaging is assumed to weigh 50 g. The quality of these results is considered to be relatively low, but they are still considered to be acceptable since they generally account for a relatively small part of the total impact.
  - Comments: In many cases, this data could instead be taken directly from the producers’ PCF files. But the potential risk considered was that the impact of transport differed between the products in a way that was difficult to understand and justify, as there is no information in the PCF files on all of the assumptions on transport modes and transport distance.
- $WASTE_a$ = Climate impact from the avoided waste handling (of the product that was not produced)

  - Data. These results are taken directly from the producers' PCF files, where they are included as a percentage of the total impact. The product categories, where impact is not based on information from PCF files, have been assumed to have the same percentage as the average of the product categories with this information. The quality of the data is generally considered to be high because it comes directly from the producers, but these figures should be used with great caution as it is unclear exactly what they include.
  - Comments: It is unclear exactly how this section is calculated in the PCF files, and, in general, the impact of waste handling can vary greatly depending on the assumptions made. The contribution of waste handling in the PCF files does not vary much and is not very large, relatively speaking. This, coupled with the fact that it is difficult to calculate such data, led to the assessment that this was the best way to include the impact of waste handling in this model/database.
- TRP_{aw} = Climate impact from the avoided transport to waste handling
  - Data: These results are calculated based on standard transport within Sweden, with an estimated distance based on the product weight in each product category. Background data for the impact of truck transport is taken from Ecoinvent [8].
- TRP_{re} = Climate impact from the added transport to and from reconditioning, or more generally: all transport between user 1 and user 2
  - Data: These results are calculated based on two standard transportations within Sweden, one from user 1 to the reuse company, and one from the reuse company to user 2. The calculation uses an estimated distance corresponding to transport within southern Sweden, as well as the product weight in each product category. Background data for the impact of truck transport is taken from Ecoinvent [8].
- RECOND = Climate from the reconditioning of the product
  - Data: The RECOND value in the database corresponds to the impact of energy required for the operating and heating of the reuse company's premises which is emitted per recycled product. The energy usage data per recycled product is taken from reuse company Inrego AB [9], who work with the reuse of IT products, and the impact of fuel and (Swedish) electricity is taken from the LCA database Ecoinvent [8].

2.2 Database

Produktdatabas för klimatfördelar med återbruk av IT-produkter, version 1.0 (2019)								
This database needs to be used together with its documentation! (All numbers rounded to two significant digits)								
Sub category	**Avoided total (sum) (kg CO2-eq)**	**New production**	**Transport from new production**	**Refurbishment**	**Transport to and from refurbishment**	**Waste handling**	**Transport to waste handling**	**Weight (kg)**
Notebook (average all sub categories)	**280**	*280*	*1,2*	*-0,4*	*-0,5*	*1,6*	*0,1*	1,6
Notebook: Screen below 14 inch	**250**	*250*	*1,1*	*-0,4*	*-0,4*	*1,5*	*0,1*	1,4
Notebook: Screen 14+ inch	**300**	*300*	*1,5*	*-0,4*	*-0,6*	*1,6*	*0,1*	2,1
Notebook: Hybrid	**280**	*280*	*1,0*	*-0,4*	*-0,4*	*1,6*	*0,1*	1,2
AIO (average all sub categories) (All-in-one desktop)	**470**	*460*	*4,4*	*-0,4*	*-1,7*	*10,0*	*0,4*	8,4
AIO: Screen below 24 inch	**420**	*410*	*3,8*	*-0,4*	*-1,4*	*7,3*	*0,3*	7,0
AIO: Screen 24+ inch	**520**	*500*	*5,1*	*-0,4*	*-1,9*	*14,0*	*0,5*	9,8
Desktop (average all sub categories)	**470**	*460*	*4,3*	*-0,4*	*-1,6*	*9,1*	*0,4*	8,2
Desktop: USDT (Ultra Small DeskTop)	**290**	*290*	*1,6*	*-0,4*	*-0,6*	*3,4*	*0,1*	2,4
Desktop: SFF (Small Form Factor)	**380**	*370*	*3,6*	*-0,4*	*-1,3*	*8,7*	*0,3*	6,7
Desktop: Tower	**750**	*730*	*7,7*	*-0,4*	*-2,9*	*15,0*	*0,7*	15,0
Monitor (average all sub categories)	**520**	*510*	*5,6*	*-0,4*	*-2,1*	*8,4*	*0,5*	11,0
Monitor: Screen below 33 inch	**440**	*430*	*3,6*	*-0,4*	*-1,3*	*6,4*	*0,3*	6,6
Monitor: Screen 33+ inch	**620**	*600*	*7,5*	*-0,4*	*-2,8*	*10,0*	*0,7*	15,0
Printer: Desk	**180**	*170*	*12,0*	*-0,4*	*-4,7*	*0,0*	*1,2*	26,0
Server: Rack	**400**	*390*	*13,0*	*-0,4*	*-4,8*	*0,0*	*1,2*	26,0
Handheld (average all sub categories)	**98**	*97*	*0,7*	*-0,4*	*-0,3*	*0,7*	*0,0*	0,4
Handheld: Tablet-big	**140**	*140*	*0,8*	*-0,4*	*-0,3*	*1,0*	*0,0*	0,7
Handheld: Smartphone	**55**	*55*	*0,5*	*-0,4*	*-0,2*	*0,5*	*0,0*	0,2
Handheld: Tablet-Small	**95**	*94*	*0,6*	*-0,4*	*-0,2*	*0,7*	*0,0*	0,3
Projectors: mid size	**21**	*20*	*1,4*	*-0,4*	*-0,5*	*0,0*	*0,1*	2,0
Network equipment (average all sub categories)	**340**	*330*	*6,8*	*-0,4*	*-2,6*	*2,6*	*0,7*	14,0
Network equipment: Small	**8,7**	*9*	*0,7*	*-0,4*	*-0,3*	*0,1*	*0,0*	0,5
Network equipment: Rack mounted (blade)	**200**	*200*	*3,2*	*-0,4*	*-1,2*	*1,6*	*0,3*	5,9
Network equipment: Rack mounted (large)	**800**	*780*	*17,0*	*-0,4*	*-6,2*	*6,3*	*1,7*	35,0
Components (average all sub categories)	**22**	*22*	*0,1*	*0,0*	*0,0*	*0,2*	*0,0*	0,2
Components: SSD	**94**	*93*	*0,0*	*0,0*	*0,0*	*0,7*	*0,0*	0,1
Components: HDD	**71**	*70*	*0,4*	*0,0*	*0,0*	*0,6*	*0,0*	0,8
Components: RAM memory	**5,1**	*5*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	0,0
Components: Processor	**50**	*50*	*0,0*	*0,0*	*0,0*	*0,4*	*0,0*	0,0
Components: Laptop battery	**7,9**	*8*	*0,2*	*0,0*	*0,0*	*0,1*	*0,0*	0,3
Components: Laptop screen	**61**	*60*	*0,1*	*0,0*	*0,0*	*0,5*	*0,0*	0,1
Components: Tablet screen	**32**	*32*	*0,1*	*0,0*	*0,0*	*0,3*	*0,0*	0,2
Components: Smartphone screen	**14**	*14*	*0,0*	*0,0*	*0,0*	*0,1*	*0,0*	0,1
Components: Keyboard	**3,7**	*3*	*0,4*	*0,0*	*0,0*	*0,0*	*0,0*	0,8
Components: Power adaptor, laptop	**3,5**	*3*	*0,1*	*0,0*	*0,0*	*0,0*	*0,0*	0,2
Components: Docking station	**8,4**	*8*	*0,4*	*0,0*	*0,0*	*0,1*	*0,0*	0,8
Components: Network card	**1,9**	*2*	*0,1*	*0,0*	*0,0*	*0,0*	*0,0*	0,2
Components: Fan	**0,3**	*0*	*0,0*	*0,0*	*0,0*	*0,0*	*0,0*	0,0
Components: DVD	**3,4**	*3*	*0,1*	*0,0*	*0,0*	*0,0*	*0,0*	0,2
Components: Mouse pad	**0,1**	*0*	*0,1*	*0,0*	*0,0*	*0,0*	*0,0*	0,1
Components: Smartphone/tablet charger	**1,3**	*1*	*0,1*	*0,0*	*0,0*	*0,0*	*0,0*	0,1

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