Sustainability Impact Measurement Refurbed GmbH

for:

Refurbed GmbH

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Contents

1 Refurbed GmbH

Refurbed GmbH (hereinafter referred to as Refurbed) is the fastest growing online marketplace for refurbished products in the entire DACH region. Founded in 2017 by Peter Windischhofer, Kilian Kaminski and Jürgen Riedl in Vienna, Refurbed now employs more than 290 people. The platform offers fully refurbished electronic devices up to 40 % cheaper and with at least twelve months warranty. Refurbishment significantly reduces greenhouse gas emissions compared to buying a new device. A tree is also planted for every product sold to further reduce the impact on the environment. The product range on the marketplace now includes several thousand products - from smartphones, laptops and tablets to household appliances and e-bikes.

2 Fraunhofer Austria Research GmbH

Fraunhofer Austria Research GmbH (hereinafter referred to as FhA) is a non-profit research institution that solves important socio-political tasks through research activities. The company does not pursue any self-interested goals and does not seek any entrepreneurial profit. The goal is to provide great benefits for Austrian society:

- Through active knowledge transfer of our research results, FhA contributes to information diversity and awareness building in Austrian society, especially in the core topic of sustainability in production and logistics.
- Through active innovation transfer, FhA takes measures to promote the public in the intellectual field, especially in the translation of fundamental into applied knowledge for more sustainability in production and logistics.

Within the framework of industrial projects, FhA works as an innovative partner with companies from a wide variety of fields of activity. Together with the customer, the project team solves specific problems related to production and logistics. The topic of ecological sustainability has gained in importance in recent years and is an integral part of the goals of their research partners.

FhA operates at 4 locations in Austria, with the headquarters in Vienna. Other locations are Graz, Klagenfurt and Wattens. The daily work routine takes place in the office, home office or on-site with customers.

3 Introduction

As part of the project "Sustainability Impact Measurement at Refurbed GmbH", FhA carried out an extensive accounting of ecological variables (CO_2-emissions, water consumption and electronic waste) at the product level for the year 2021. Five reference products, which are sold on Refurbeds online marketplace, were examined. These are two smartphone models, one tablet and two laptops. Models were selected based on either high sales or the availability of comparative environmental impact data. The aim of the project was to be able to make a quantitative statement on the extent to which the purchase of a refurbished electronic device has ecological advantages over the respective new device. To this end, a data survey was carried out among refurbished supplier and an individual calculation model was created to be able to allocate all emissions at product level.

Note: For better readability of the document, the notation CO_2-equivalents and use CO_2 or greenhouse gases (GHG) as a general term.

4 Terms and abbreviations

Refurbed:	Online marketplace for refurbished electronics.
DL&GTB:	Delete data, test, and evaluate device (DL&GTB): Process that aims to reset a used device to factory settings, test the device for functionality as well as evaluate it based on defined visual criteria and assign a product grading (A, B, C). This process must be completed by every device sold on Refurbeds online marketplace.
Preparation:	Reconditioning process, which aims to replace defective or visually worn components.
Refurbishment:	Entire process: DL&GTB and preparation
Refurbed-product:	Product offered on Refurbeds online marketplace.
Refurbed-supplier:	Company that performs DL&GTB and, if applicable, reprocessing and distributes Refurbed products via Refurbed.
Reseller:	Refurbed suupplier which only performs the process step DL&GTB and distributes the Refurbed products via Refurbed.
Refurbisher:	Refurbed supplier who performs all necessary process steps for a refurbishment and distributes Refurbed products via Refurbed.
CCF:	Corporate Carbon Footprint - Balance of all CO_2-emissions attributable to a facility.
PCF:	Product Carbon Footprint - Balance of all CO_2-emissions that occur along the life cycle of a defined product.
CF:	Corporate Footprint - Like CCF, but includes other ecological parameters such as water consumption.
PF:	Product Footprint - Like PCF, but includes other ecological parameters such as water consumption.
ES:	Emission source
EF:	Emission factor

5 Object of investigation

The subject of this study is electronic devices that are sold on Refurbeds online marketplace. These are devices that have already been used. The process considered here differs significantly from classic recycling. It is not the waste product electronic equipment that is recycled, but the still functional product is prepared for further use. For this purpose, the device is decoupled from its life cycle after the first phase of use and returned to it after completion of the second phase of use, when further reprocessing no longer makes sense from an economic point of view. The aim of this process is to significantly extend the service life of an electronic device and thus save valuable resources by keeping the device in use for as long as possible.

In order to implement a balance in accordance with the existing standards and to maintain comparability with the respective new unit, a clear definition of the object of investigation is necessary. The choice of the declared unit and the reference flow was therefore defined as described below.

5.1 Declared unit

This paper deals with a partial product footprint (PF). A second life cycle is considered, which does not follow on from a previous life cycle but runs parallel to it. Figure 1 illustrates this process.

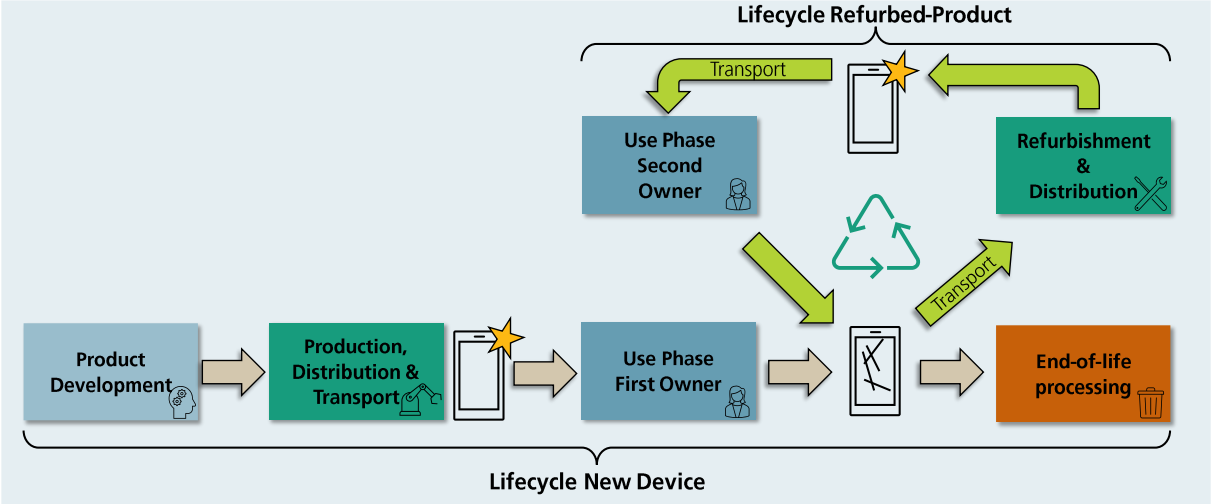

FIGURE 1: LIFE CYCLE NEW PRODUCT VS. REFURBED-RRODUCT

The aim of the refurbishment process is to be able to offer the consumer an electronic device that largely meets the same criteria as a new device. If the buyer is prepared to forego the "latest" technology, they can purchase a device that is visually flawless and technically fully functional. Due to the reduced use of resources, this has a far less negative impact on the environment compared to the respective new device.

The declared unit is therefore defined as **"acquisition of an electronic device"**.

All emissions from the first life cycle are attributed to the first owner. Those emissions caused by refurbishment are attributed to the second owner.

The devices listed in Table 1 were examined in their basic version. For example, the version with 64GB storage was chosen for the Apple iPhone 11, as well as for the calculation of the refurbed Apple iPhone 11 model.

TABLE 1: OVERVIEW OF EXAMINED DEVICES

Category	Manufacturer	Model	Variant	Year of introduction
Smartphone	Apple	iPhone	11	2019
Smartphone	Samsung	Galaxy	S20 FE	2020
Tablet	Apple	iPad	Pro 4 12,9"	2020
Laptop	Apple	Macbook	Air 13,3"	2017
Laptop	Lenovo	Thinkpad	T460 i5	2016

5.2 Reference flow

The respective reference flow includes all processes that are necessary to offer the electronic device to the customer (declared unit). Process steps such as packaging and shipping, but also the disposal of the end device or individual components are also taken into account. The process modules listed below can be collected and evaluated based on primary or secondary data. The utilization phase process module is an exception, as there is no information on the actual service life. However, the manufacturer states an expected service life which exceeds the actual duration in reality (Rainer Pamminger, 2021). To maintain comparability with existing statements regarding total emissions, the useful life specified by the manufacturer was also used for this study. Table 2 shows the reference flow for a new appliance.

TABLE 2: REFERENCE FLOW: LIFE CYCLE NEW DEVICE

	Process module	**Meaning**	**Responsible entity**
Reference flow: Life cycle new device	Product development	Activities arising from the development of the product	Manufacturer
	Raw material extraction and processing	Mining and further processing of the required raw materials into functional individual components	Component manufacturer
	Transport	Transport: Individual components→ Production	Component manufacturer
	Production	Assembly of the individual components into a final product	Manufacturer
	Transport	Transport: Finished product → Distributor	Manufacturer
	Distribution	Direct sales of the devices via online store or through an authorized supplier	Distributor
	Use phase	Emissions resulting from the use	First owner
	Transport	Transport: First owner → Disposal	Manufacturer
	Disposal	Emissions resulting from the disposal of the device that is no longer needed	Manufacturer

Table 3 shows the reference flow for a refurbed product. The "refurbishment" process step includes all activities and resources required to bring the device into the desired condition. Required spare parts, such as the display, battery or charging cable, are included in the balance sheet with their complete life cycle (cradle-to-grave).

TABLE 3: REFERENCE FLOW: REFURBED-PRODUCT

	Process module	Meaning	Responsible institution
Reference flow: Refurbed product life cycle	Transport	Transport: Used equipment → Refurbed-supplier	Refurbed-supplier
	Refurbishment	DL&GTB and if necessary preparation of used equipment spare parts, which are necessary for the refurbishment of the electronics	Refurbed-supplier
	Distribution	Distribution of the devices on an online marketplace	Refurbed
	Transport	Transport: Refurbed products → customers	Refurbed-supplier
	Use phase	Emissions resulting from the use	Second owner

6 System boundaries

The choice of system boundaries is tied to two decision-making processes. On the one hand, as few emission sources as possible should lie outside the system boundaries to obtain a representative result. Important factors here are the availability of data and how extensive an evaluation of these is. On the other hand, comparability with the respective reference product must be given. Therefore, it may be necessary to include items that are not required by standards (ISO standard 14040/67) or to temporarily exclude emission sources for a comparison.

6.1 Nature of the inputs and outputs of the system

According to ISO 14040/67, the following phases are to be taken into account for the balancing of a life cycle:

1. Raw material extraction
2. Construction (product development)
3. Production
4. Transport/delivery
5. Application (use phase)
6. End-of-life treatment (disposal)

For the present investigation, all phases/process modules were taken into account, as shown in Table 2 and 3. The standard stipulates that all items in a phase, that are directly related to the product, are to be recorded.

In order to maintain comparability with the respective new device and to comply with the approach of conservative selection of system limits, the following items were adjusted.

- **Commuting behavior**

The commuting behavior of the employees does not have to be included in the balance of a Refurbed supplier according to the standard, since this activity is not directly attributable to the remanufacturing process. However, the carbon footprint of new equipment takes this emission source into account, which is why it was also considered for Refurbed products for reasons of comparability.

- **Transport/delivery**

The transport relationships at the facility level of a new device and a refurbed product are listed below in each case.

Transport activities for new equipment:

Individual components	→	Production of new equipment	=	included
Production of new equipment	→	Wholesale	=	included
Wholesale	→	Intermediary	=	included
Wholesale	→	Specialty store	=	included
Intermediary	→	End customer	=	(not) included
Specialty store	→	End customer	=	(not) included
End customer	→	Disposal	=	included

Transport activities for Refurbed product:

Used equipment	→	Refurbed supplier	=	included
Refurbed supplier	→	End customer	=	included

It is not clear from the manufacturers' documentation whether the entire transport chain was taken into account in the balancing of the ecological variables. Specifically, it is possible that the last transport step to the end customer was excluded for new equipment. This involves the collection of new equipment from the end customer at a specialist supplier and the dispatch of new equipment from an intermediary to the end customer (Apple_Environmental_Progress_Report, 2023). The reason for this is the insufficient data available and the large number of options available to customers for purchasing a product. These include online sales (analogous to Refurbed), picking up the product in a specialty store (retail store), or even in an electronics wholesaler. Travel to stores can be by fossil fuel-based motor vehicle, but can also be low-emission by bicycle. Based on the wide range of options, balancing this step is a major challenge. Refurbed products, on the other hand, do not have such a multi-layered transport chain since the products are sold exclusively online and usually no other

intermediaries are included in the process chain. This leads to the fact that the transport can be transparent, traceable, and documented with sufficient data, so that the transport to the end customer is explicitly included in the present balance of Refurbed. The conservative approach ensures that a comparison and communication of the results to the outside world is possible without restrictions. Furthermore, it should be noted that for new equipment, emissions from the transport process module only account for between 2-5 % of total emissions. Including the final transport step to the end customer would probably increase this share by 10 %. Accordingly, the environmental footprint of a new appliance would increase by about 0.5 %, which would not result in a significant change in total emissions. However, an adjustment would be associated with the fact that the publicly available emission value at the manufacturing company does not match the one used in the report. For this reason, no adjustment is made to the emission source for new devices and a possible overestimation of the emissions of a refurbed product, compared with the respective new device, is accepted.

- **Use**

According to the manufacturer, the service life of new devices is 3 years for smartphones and tablets and 4 years for laptops. Software updates, on the other hand, are available for much longer, which ensures software security far beyond the first use phase (Apple Sicherheitsupdates, 2023). The actual useful life of electronic devices therefore strongly differs from the duration specified by the manufacturer. Consideration of the actual period in each case requires extensive analysis, which is not part of this paper. The useful life was therefore determined for the respective products as shown in Table 4. For refurbed products, the difference between the 1st usage phase and the average software availability was selected.

TABLE 4: USE (DATA IN YEARS)

Model	**New device** [years]	**Software support** [years]	**Refurbed-product** [years]
Apple iPhone 11	3	6	3
Samsung Galaxy S20 FE	3	6	3
Apple iPad Pro 4 12,9"	3	6	3
Apple Macbook Air 13,3"	4	8	4
Lenovo Thinkpad T460 i5	4	8	4

6.2 Decision criteria for process modules

This study compares the life cycle of a new product with that of a refurbished product. As can be seen in Table 2 and 3, the respective reference flows and thus the process modules differ. Even if these modules do not coincide, all items that are necessary for a comparison of the declared unit were taken into account.

6.3 Criteria for significance

The structured procedure for evaluating the potentially significant emission sources per process module was performed as shown in Figure 2. The criteria for the exclusion of an item are:

- **very low effect**

  The emission factor for this item is already known and very low compared to the others

- **negligible amounts of ES**

  The quantity of the considered position is very small

To be able to exclude an emission source, both of the above conditions must apply and the product of these variables must be expected to account for less than 1 % of total emissions. If an item is responsible for more than 50 % of total emissions, the "1 % hurdle" is applied to the remaining emissions. The basis for the materiality analysis is the British Standard PAS 2060 for climate neutrality.

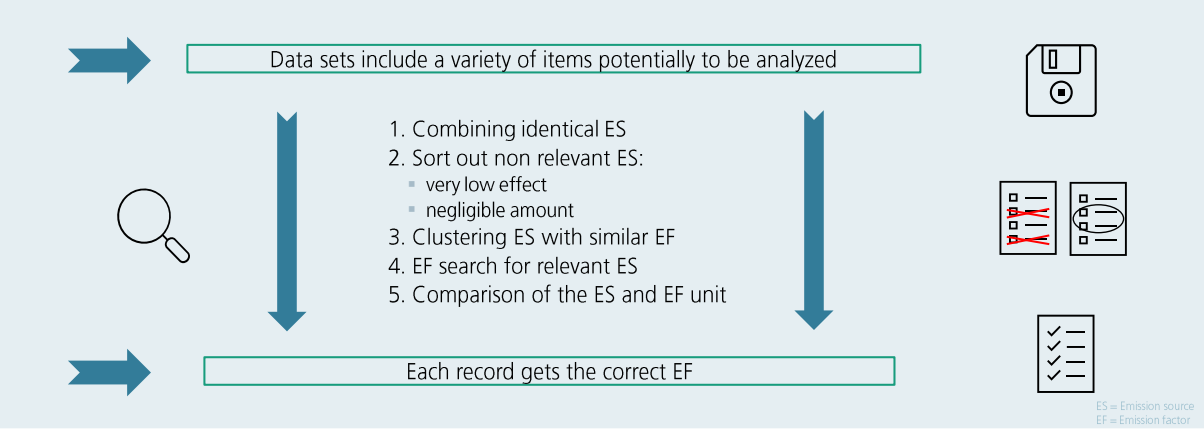

FIGURE 2: METHOD CRITERIA FOR SIGNIFICANCE

7 Emission sources

An emission source is defined as any activity that has an environmental impact, either positive or negative. The process of identifying these sources is described below.

7.1 Data sources

As part of the project, data was collected from the two main players in the provision of a Refurbed product. Refurbed as an online marketplace and Refurbed suppliers who perform the refurbishment of the electronic devices. Other stakeholders such as spare parts manufacturers, transport companies or recycling companies were not included in the individual data collection process, as sufficient information is available on this in eco-databases (e.g. Ecoinvent).

7.2 Data acquisition

The data necessary for balancing the ecological variables were collected from the main actors by means of questionnaires. This was filled out by 6 different Refurbed suppliers each, as well as by Refurbed itself. The questionnaire is divided into three categories, which are described below:

- **Corporate Carbon Footprint**

Content: Prefabricated balance sheet in accordance with ISO 14064-1, which has already been filled with the main emission sources (Scope 1 to 3).

Goal: Creation of a CCF from each participating company.

Task: Fill in the prefabricated positions with the quantities generated in the company (year: 2021) and add further significant sources.

- **General information**

Content: Company-specific questions on the processed electronic equipment as well as on the reprocessing process in general.

Goal: Adequate allocation of the emissions from the CCF that cannot be directly allocated to the reference products.

Task: Answering the defined questions.

- **Commuter behavior**

Content: Employee survey on commuting behavior in the form of an online survey.

Objective: To record the number of kilometers traveled by each defined means of transport by employees commuting to work.

Task: Answering the defined questions from as many employees as possible.

8 Emission factors

Ideally, each emission source has its own emission factor, which includes the ecological impact in relation to the basic quantity. The product of emission source and emission factor represents the total amount of the respective emissions to be accounted for in the period under consideration.

8.1 Considered ecological variables

Each ecological variable has a defined unit of its emission factor. Within the scope of the project, three ecological variables were analyzed, which are listed and described below.

8.1.1 CO_2-emissions

For standard-compliant accounting and reporting in accordance with ISO 14067, seven types of greenhouse gases must be accounted for under the Kyoto Protocol (United Nations Framework Convention on Climate Change). These are collected and weighted under the name CO_2-equivalent.

These are the following gases:

- Carbon dioxide (CO_2)
- Methane (CH_4),
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFC)
- Perfluorinated hydrocarbons (PFC)
- Sulfur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3).

The IPPC 2021 - GWP100a is used as the calculation method for the carbon footprint. Total gross emissions are expressed in kilograms of carbon dioxide equivalent [kg CO_2].

8.1.2 Water use

The "water use" category of the Developer Environmental Footprint Version 3.1 (EF v3.1) is used as the calculation method for balancing water consumption. The total gross emissions are given in liters [l]. The selected emission factors take into account the complete life cycle of the materials, i.e. from the water-intensive extraction of the raw materials to the consumption during assembly and transport.

8.1.3 Electronic waste

The unit e-waste quantifies the amount of electronic components that have to be replaced due to visual or functional defects. The total gross emissions are given in grams [g].

8.2 Sources for emission factors

As far as possible, the emission factors used were taken from the Ecoinvent database (version 3.9.1) to ensure the highest quality and comparability of the values. If no suitable factors could be found, scientific publications (Federal Environment Agency and studies by recognized institutions) were used.

8.3 Procedure model for the selection of emission factors

The selection of the emission factors was carried out using an FhA internal procedure model, which was created based on the requirements of ISO 14064-1. Figure 3 shows the four steps, which are followed by the user from top to bottom. The procedure model ensures that the most suitable emission factor is always used for an emission source, regardless of the person processing it.

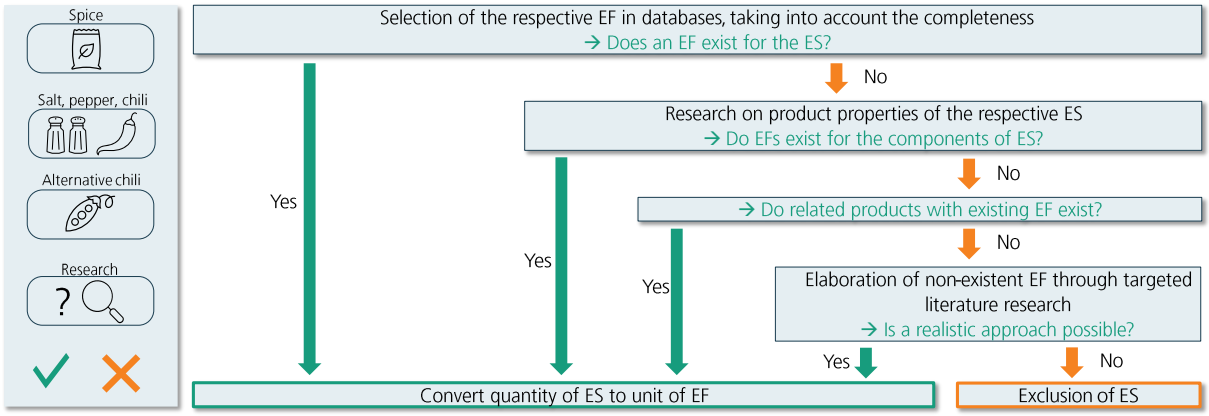

FIGURE 3: PROCEDURE MODEL FOR EF-RESEARCH

9 Allocation procedure

By means of the data collection (Chapter 7.2), it was possible to record all significant emissions associated with the reference products. These are directly attributable and non-directly attributable emissions. The former includes the spare parts required for refurbishment. The quantity of these was recorded separately for each model and averaged against the respective unit. Emissions caused by energy consumption at the respective site or by the auxiliary materials required for the refurbishment process cannot be easily allocated to the products on the basis of average values. The reason for this is that the processing time for each product category can vary greatly due to the differing complexity of a piece of equipment. Therefore, an adequate allocation of the emissions that cannot be directly assigned was carried out on the basis of the processing time of the devices. For this purpose, an Excel-based calculation model was created that transparently and comprehensibly takes into account all parameters and allocates all emissions that occur along the reprocessing process to the respective device in a more appropriate amount. Figure 4 clearly shows how the calculation model is structured and what information is processed in it.

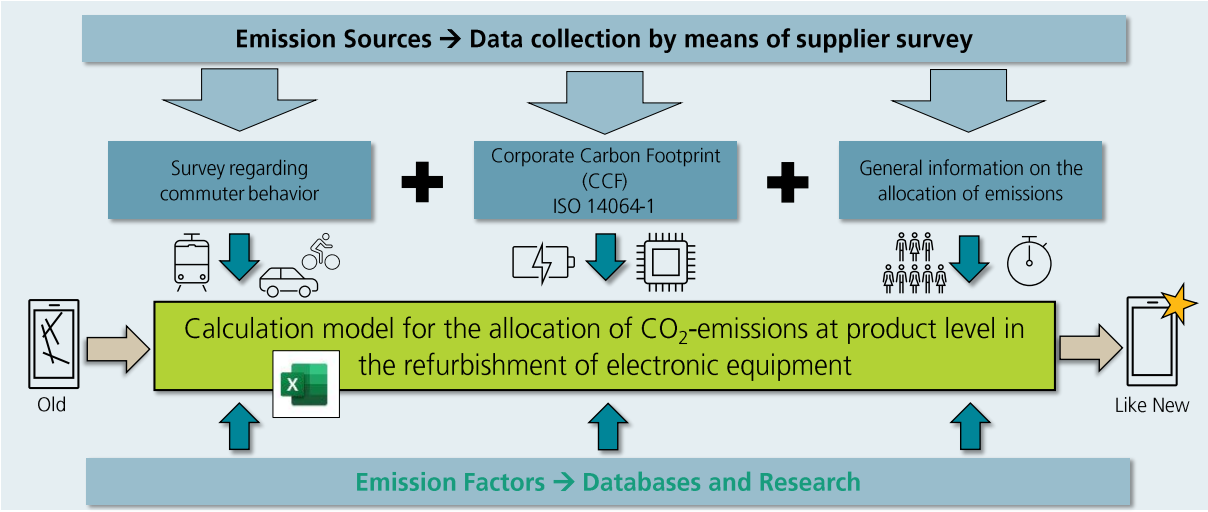

FIGURE 4: CALCULATION MODEL FOR THE ALLOCATION OF EMISSIONS AT PRODUCT LEVEL

10 Uncertainties and exclusions

The collection and evaluation of data is always associated with inaccuracies. The following section describes how this factor was taken into account in this study.

10.1 Uncertainties

The use of secondary data during data collection and evaluation is the main cause of uncertainties in the results. In order to exclude a too low ecological footprint of the company, each value, which was necessary for the calculation of the GHG emissions, was supplemented with a safety factor (percentage match in %). Below is the FhA internal guideline for identifying a suitable safety factor.

- **Emission sources**
  - Primary data: 90 - 99 %
  - Secondary data: 80 %

- **Emission factors**
  - High match: 99 %
    The EF could be found in a database such as Ecoinvent or has been addressed in relevant literature.
  - Medium match: 95 %
    The EF could be assembled from partial products into the required product.
  - Low match: 90 %
    The EF could not be researched and the EF of a related product was used.

10.2 Exclusions

To cover the emissions of all exclusions within the system boundary, the ecological footprint was increased by 5 % for Refurbed partners and by 1 % for Refurbed. In this way, 100 % of the greenhouse gas emissions caused are covered.

11 Evaluation

In the following, the results of the balancing on the basis of the functional unit are presented. The evaluation is carried out for the reference products listed in section 5.1.

At the beginning, the distribution of CO_2-emissions among the four central process modules (utilization phase, refurbishment, transport, and online marketplace) is discussed. This is only done for the ecological parameter CO_2. The reason for this is that around 99 % of the emissions from the emission category water consumption and e-waste occur in the Refurbishment process module. A visual evaluation therefore offers no added value. Subsequently, the percentage savings of the ecological variables are shown for each of the refurbished products analyzed compared with the respective new equipment.

Table 5 shows the average replacement rates of the individual components per device for the analyzed smartphone devices as well as laptops. The values refer to suppliers who carry out the refurbishment.

TABLE 5: AVERAGE REPLACEMENT RATE OF SPARE PARTS (DATA IN PIECES PER DEVICE)

Model	Display [pieces/device]	Battery [pieces/device]	Further electronic components [pieces/device]
Apple iPhone 11	0,2	0,9	0,1
Samsung Galaxy S20 FE	0,2	0,5	0,1
Apple MacBook Air 13,3"	< 0,1	0,2	1,1
Lenovo Thinkpad T460 i5	0,4	0,4	1,2

In order to be able to classify the quantities listed below with regard to their quantity, three comparisons are listed:

- CO_2-emissions:
  - One-way flight from Vienna to Berlin in economy class per person. This corresponds to around 500 flight kilometers: 150 kg CO_2 (myclimate, 2023)
- Water consumption:
  - Capacity of one bathtub: 150 liters (WEMAG, 2023)
- Electronic waste:
  - Amount of waste per capita in Austria: 13.2 kilograms (D-Statis, 2023)

11.1 Refurbished Apple iPhone 11

Figure 5 shows the distribution of CO_2-emissions based on the process modules of an Apple iPhone 11. Whereas only 17 % of the emissions of a new device are attributable to the use phase (Figure 6), this position amounts to 78 % for a refurbished device. The refurbishment process and the electronic components replaced in the process offer the greatest leverage for reduction. These are responsible for around 18 % of the emissions. Both transport (2 %) and emissions from the

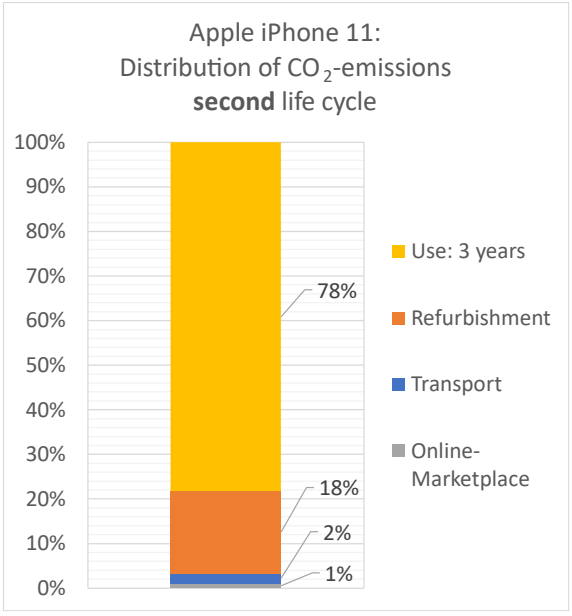

FIGURE 6: CO_2-EMISSIONS OF THE PROCESS MODULES OF A REFURBISHED APPLE IPHONE 11

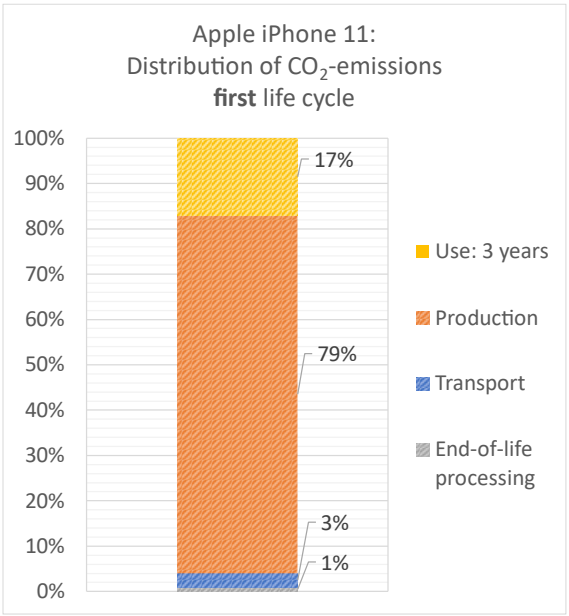

FIGURE 5: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW APPLE IPHONE 11 (APPLE IPHONE 11, 2019)

online marketplace (1 %), on the other hand, are very low and contribute little to the carbon footprint.

11.1.1 CO_2-emissions

By purchasing a refurbished Apple iPhone 11, the buyer is credited with a carbon footprint of 15.7 kg CO_2 (Figure 7). Compared to a new device, which is responsible for 72 kg of CO_2, this represents savings of 78 % (Apple iPhone 11, 2019).

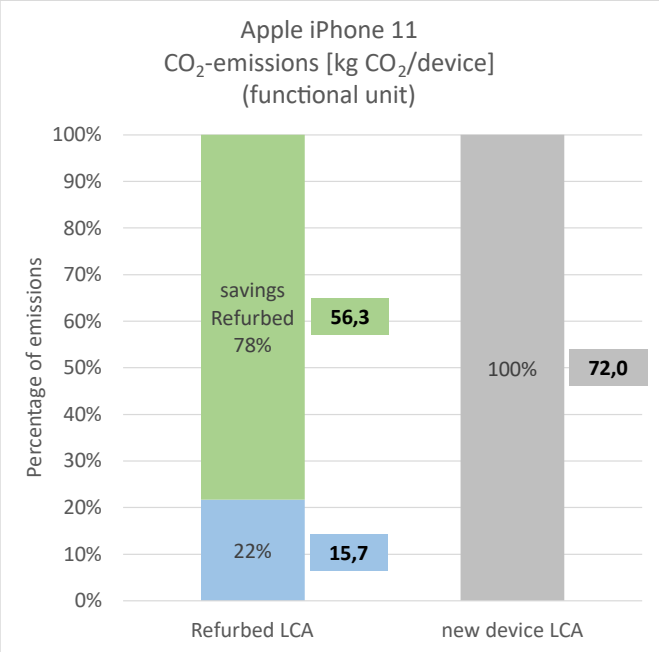

FIGURE 7: COMPARISON: CO_2-EMISSIONS APPLE IPHONE 11

11.1.2 Water use

The water consumption of a refurbished Apple iPhone 11 is around 1695 liters (Figure 8). Compared to a new device, which requires 12075 liters, this represents savings of 86 % (The Life of an iPhone, 2020).

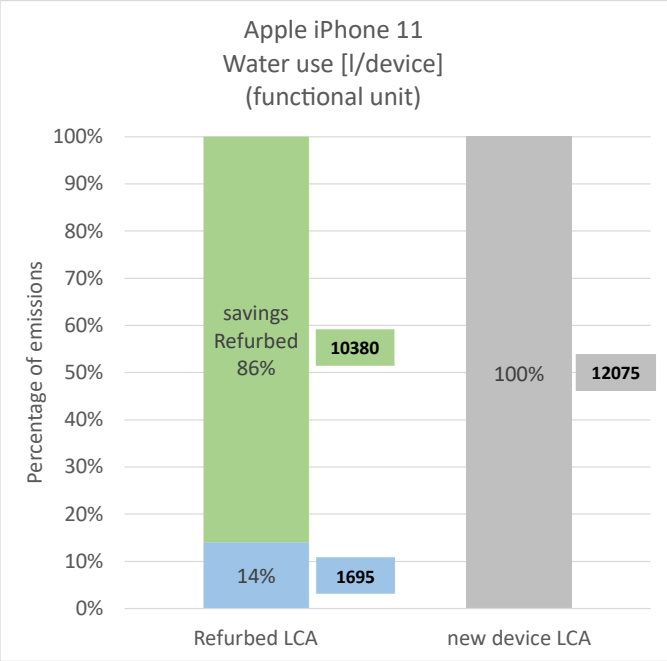

FIGURE 8: COMPARISON: WATER USE APPLE IPHONE 11

11.1.3 Electronic waste

The refurbishment of an Apple iPhone 11 results in around 70 g of electronic waste due to the replacement of defective or visually worn-out components (Figure 9). Compared to a new device, which has a total weight of 239 g, this represents savings of 71 % (weight incl. electronic accessories).

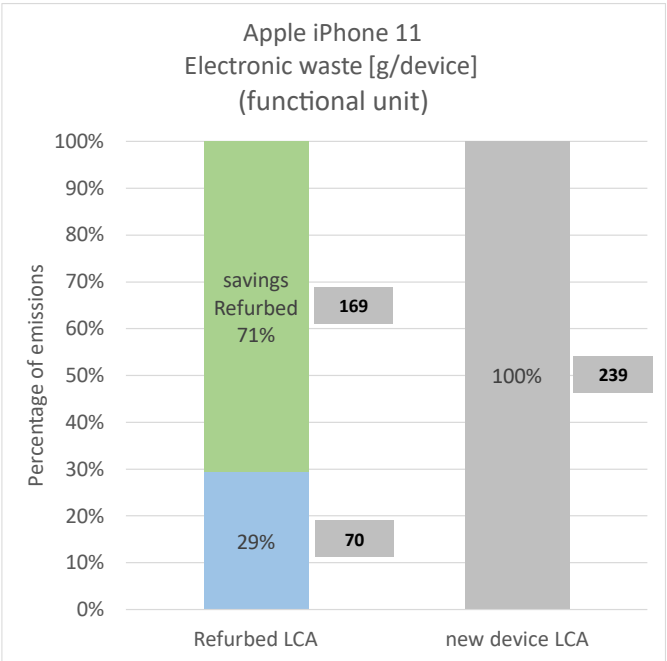

FIGURE 9: COMPARISON: ELECTRONIC WASTE APPLE IPHONE 11

11.2 Refurbished Samsung Galaxy S20 FE

Note: The data available from Samsung for evaluating the ecological sizes of their respective new devices could not be used for this elaboration (Samsung Galaxy S20 FE, 2022). The emissions reported there are far below those of comparable products (around 60 % lower). It can therefore be assumed that other system limits were used in the Samsung study, leading to an underestimation of the ecological parameters. The same data set was therefore used as for the Apple iPhone 11.

Figure 10 shows the distribution of CO_2-emissions based on the process modules of a Samsung Galaxy S20 FE. Whereas only 17 % of the emissions for a new device are attributable to the use phase, this position is 81 % for a refurbished device (Figure 11). The refurbishment process and the electronic components replaced in the process offer the greatest leverage for reduction. These account for around 16 % of emissions. Both transport (2 %) and emissions from the online marketplace (1 %), on the other hand, are very low and contribute little to the carbon footprint.

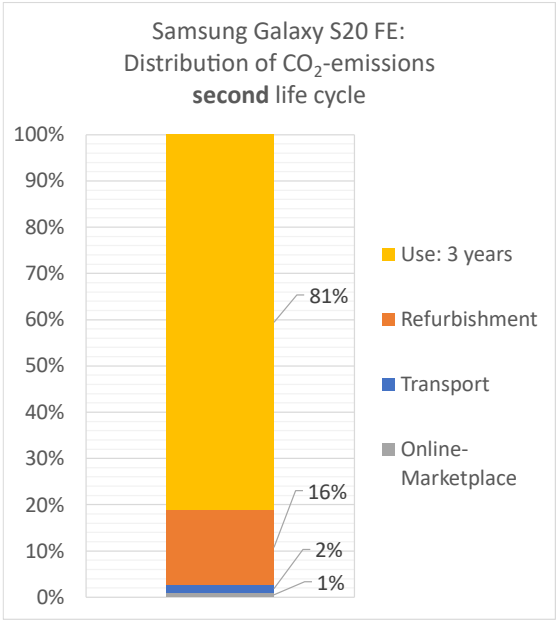

FIGURE 10: CO_2-EMISSIONS OF THE PROCESS MODULES OF A REFURBISHED SAMSUNG GALAXY S20 FE

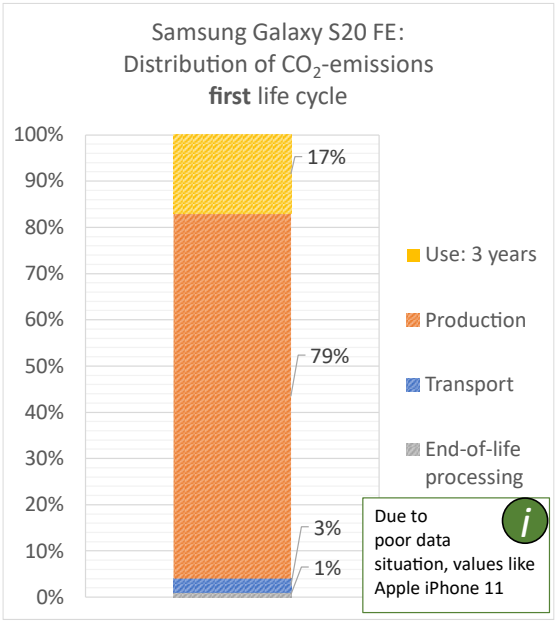

FIGURE 11: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW APPLE IPHONE 11 (APPLE IPHONE 11, 2019)

11.2.1 CO_2-emissions

By purchasing a refurbished Samsung Galaxy S20 FE, the buyer is credited with a CO_2-footprint of 15.1 kg CO_2 (Figure 12). Compared to a new device, which is responsible for 72 kg of CO_2, this represents savings of 79 %.

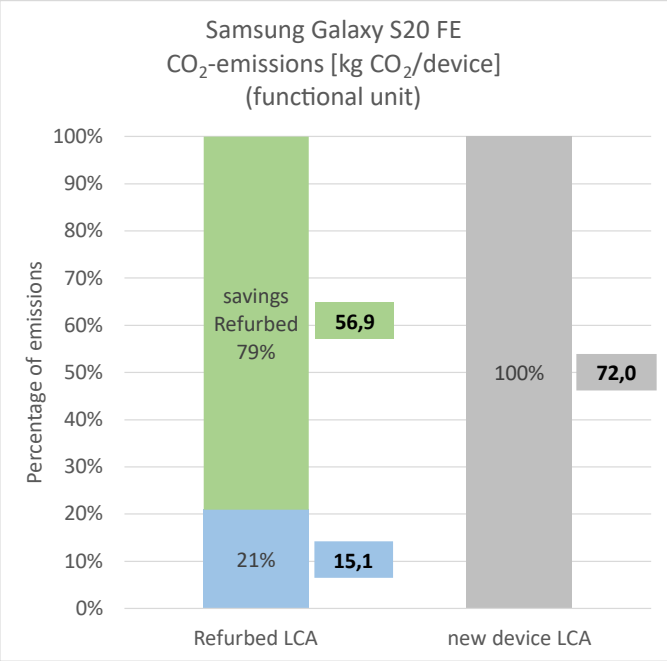

FIGURE 12: COMPARISON: CO_2-EMISSIONS SAMSUNG GALAXY S20 FE

11.2.2 Water use

The water consumption of a refuribshed Samsung Galaxy S20 FE is around 1065 liters (Figure 13). Compared to a new device, which requires 12075 liters, this represents savings of 91%.

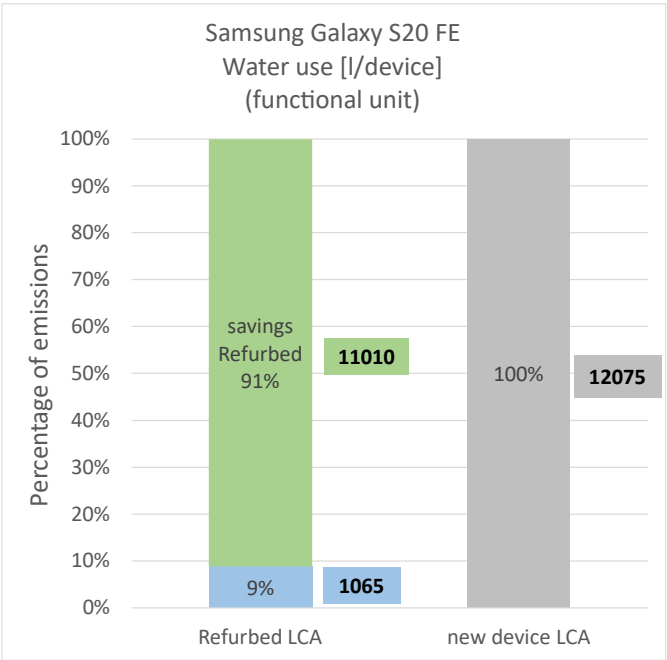

FIGURE 13: COMPARISON: WATER USE SAMSUNG GALAXY S20 FE

11.2.3 Electronic waste

The refurbishment of a Samsung Galaxy S20 FE results in around 93 g of electronic waste due to the replacement of defective or visually worn components (Figure 14). Compared to a new device, which has a total weight of 235 g, this represents savings of 60 % (weight incl. electronic accessories).

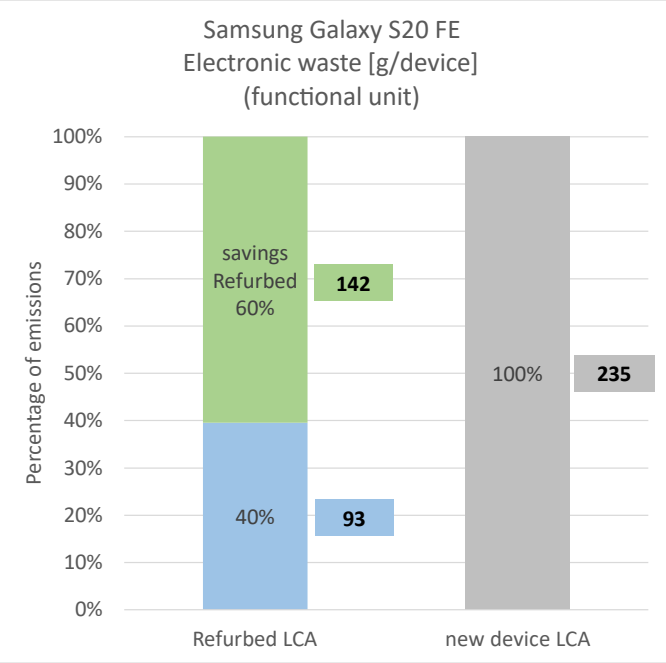

FIGURE 14: COMPARISON: ELECTRIC WASTE SAMSUNG GALAXY S20 FE

11.3 Refurbished Apple iPad Pro 4 12,9"

Note: When evaluating this model, it should be noted that the majority of the Refurbed partners who stock this product are resellers. This means that the ecological values are very low in comparison, as no spare parts are installed by this type of supplier.

Figure 15 shows the distribution of CO_2-emissions based on the process modules of an Apple iPad Pro 4 12.9". Whereas only 6 % of the emissions for a new device are attributable to the use phase, this position is 69 % for a refurbished device (Figure 16). The greatest leverage for reduction is provided by the refurbishment process (12 %) and the electronic components replaced in the process, as well as emissions from transport (18 %). The emissions caused by the online marketplace amount to around 1 % and contribute only slightly to the CO_2-footprint.

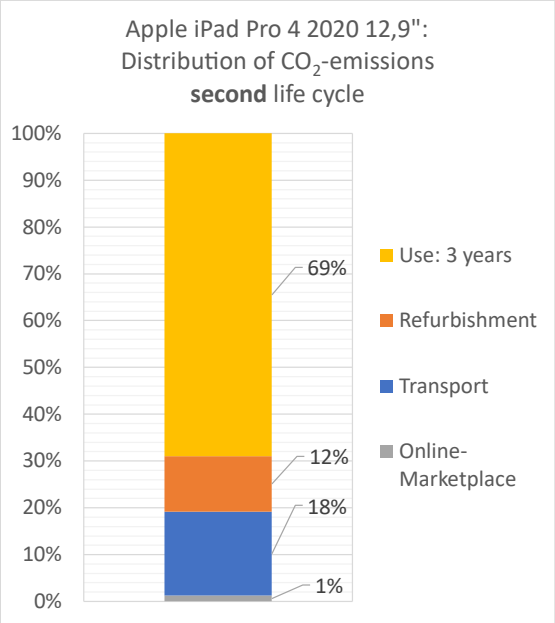

FIGURE 15: CO_2-EMISSIONS OF THE PROCESS MODULES OF A REFURBISHED APPLE IPAD PRO 4 12,9“

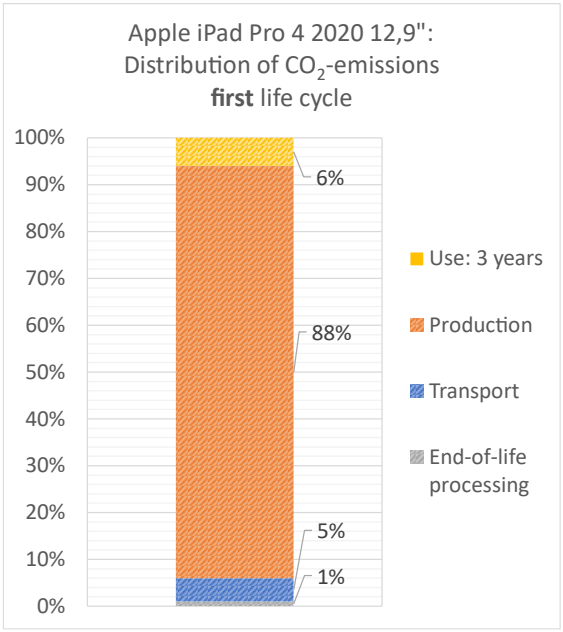

FIGURE 16: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW APPLE IPAD PRO 4 12,9“ (APPLE IPAD PRO 4 12,9", 2020)

11.3.1 CO_2-emissions

By purchasing a refurbished Apple iPad Pro 4 12.9", the buyer is credited with a carbon footprint of 12.2 kg of CO_2 (Figure 17). This represents savings of 91 % compared to a new device, which is responsible for 140 kg of CO_2.

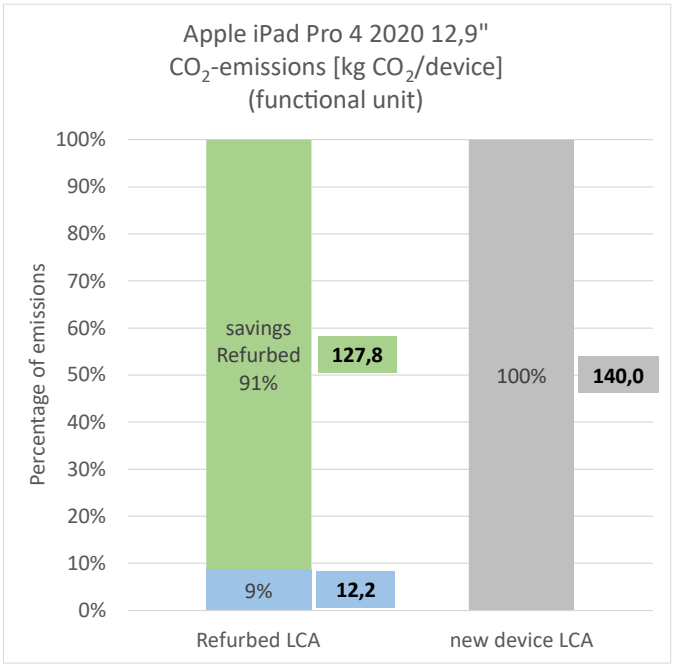

FIGURE 17: COMPARISON: CO_2-EMISSIONS APPLE IPAD 4 12,9"

11.3.2 Water use

The water consumption of a refurbished Apple iPad Pro 4 12.9" is around 622 liters (Figure 18). Compared to a new device, which requires 23479 liters, this represents savings of 97 %.

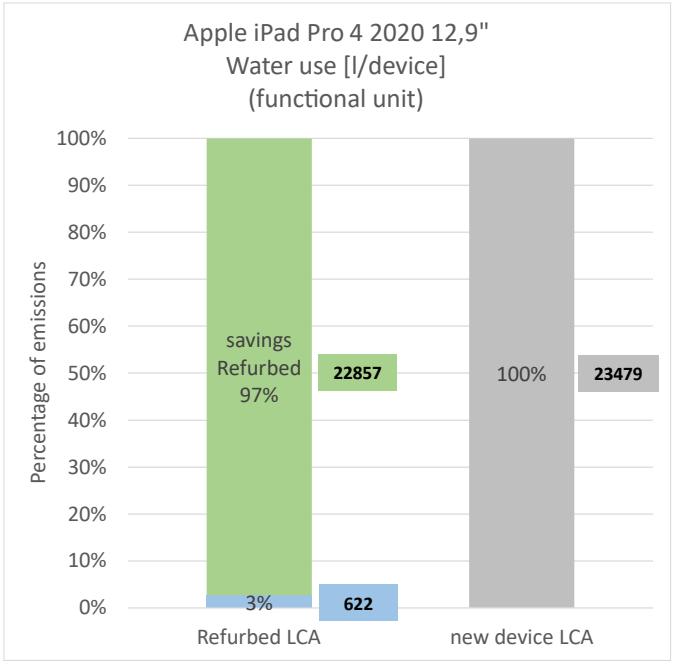

FIGURE 18: COMPARISON: WATER USE APPLE IPAD PRO 4 12,9"

11.3.3 Electronic waste

The refurbishment of an Apple iPad Pro 4 12.9" results in around 51 g of electronic waste due to the replacement of defective or visually worn components (Figure 19). Compared to a new device, which has a total weight of 688 g, this represents savings of 93 % (weight incl. electronic accessories).

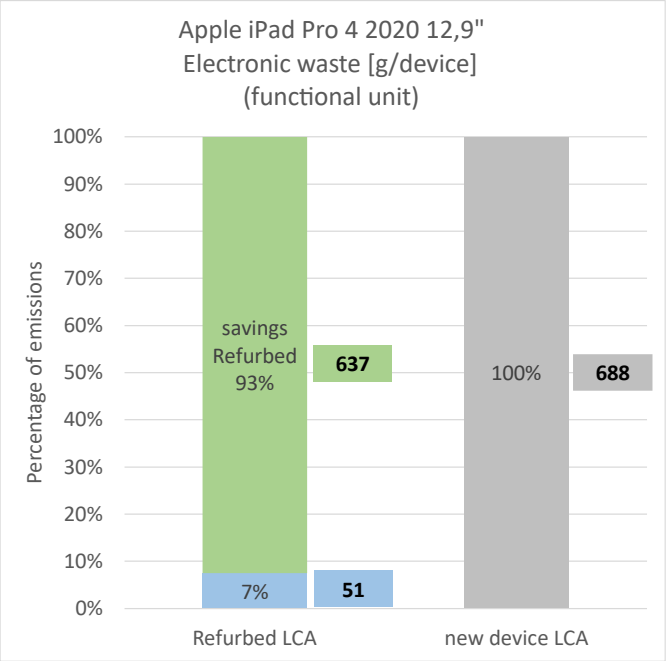

FIGURE 19: COMPARISON: ELECTRIC WASTE APPLE IPAD PRO 4 12,9"

11.4 Refurbished Apple MacBook Air 13,3“

Figure 20 shows the distribution of CO_2-emissions based on the process modules of an Apple MacBook Air 13.3". Whereas only 13 % of the emissions of a new device are attributable to the use phase, this position is 76 % for a refurbished device (Figure 21). The refurbishment process and the electronic components replaced in the process offer the greatest leverage for reduction. These account for around 19 % of emissions. Both transport (4 %) and emissions from the online marketplace (<1 %), on the other hand, are very low and contribute little to the carbon footprint.

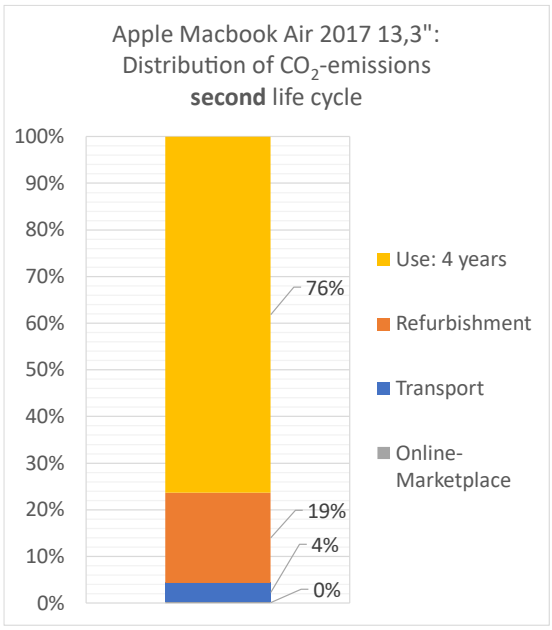

FIGURE 20: CO_2-EMISSIONS OF THE PROCESS MODULES OF A REFURBISHED APPLE MACBOOK AIR 13.3“

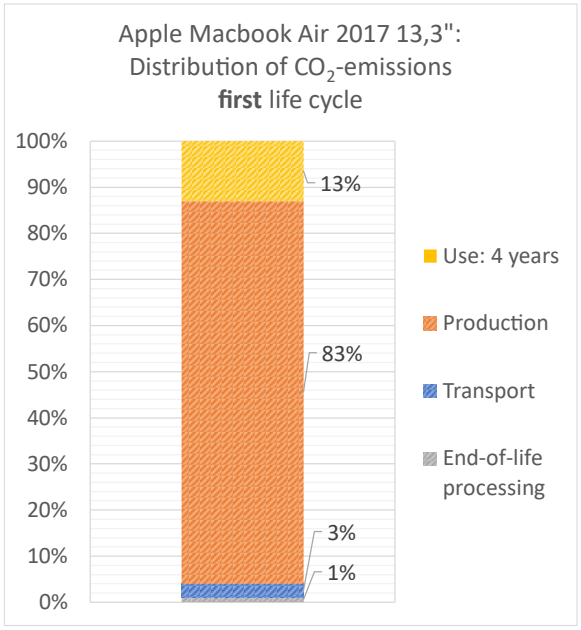

FIGURE 21: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW APPLE MACBOOK AIR 13,3“ (APPLE MACBOOK AIR 13,3", 2017)

11.4.1 CO_2-emissions

By purchasing a refurbished Apple MacBook Air 13.3", the buyer is credited with a carbon footprint of 57.7 kg CO_2 (Figure 22). Compared to a new device, which is responsible for 339 kg of CO_2, this represents savings of 83 %.

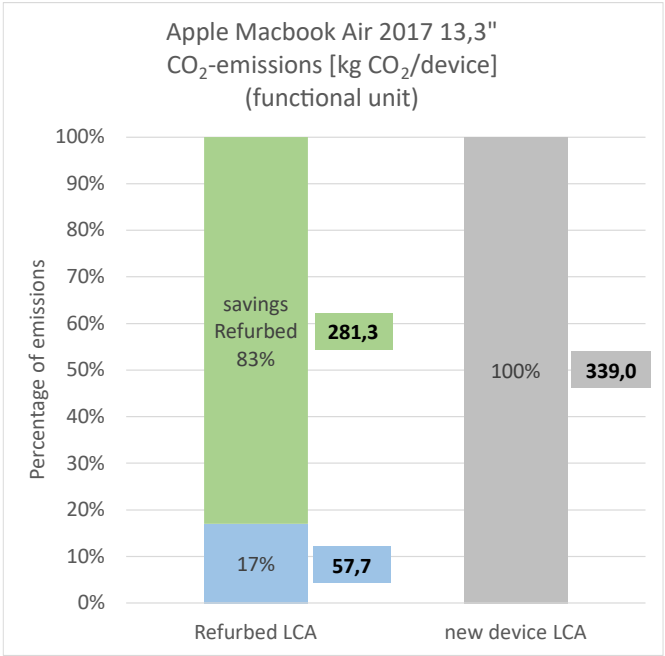

FIGURE 22: COMPARISON: CO_2-EMISSIONS APPLE MACBOOK AIR 13,3"

11.4.2 Water use

The water consumption of a refurbished Apple MacBook Air 13.3" is around 5385 liters (Figure 23). Compared to a new device, which requires 56853 liters, this represents savings of 91 %.

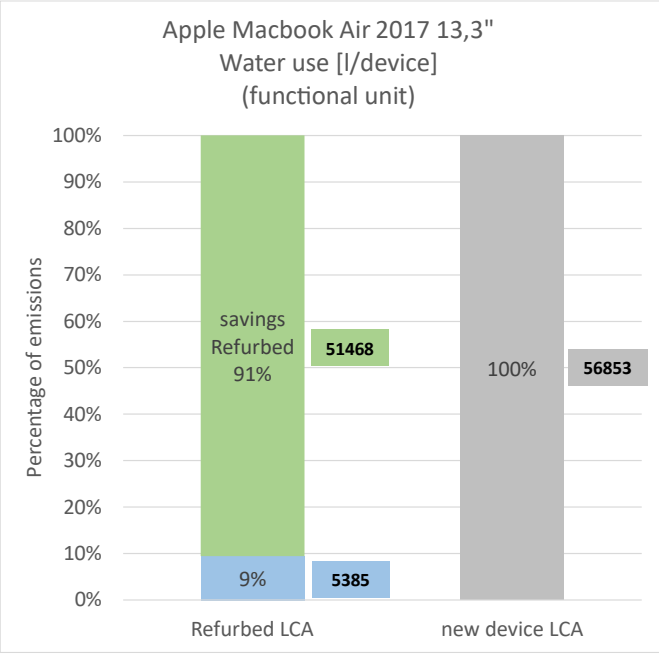

FIGURE 23: COMPARISON: WATER USE APPLE MACBOOK AIR 13,3"

11.4.3 Electronic waste

The refurbishment of an Apple MacBook Air 13.3" results in around 330 g of electronic waste due to the replacement of defective or visually worn components (Figure 24). Compared to a new device, which has a total weight of 1616 g, this represents savings of 80 % (weight incl. electronic accessories).

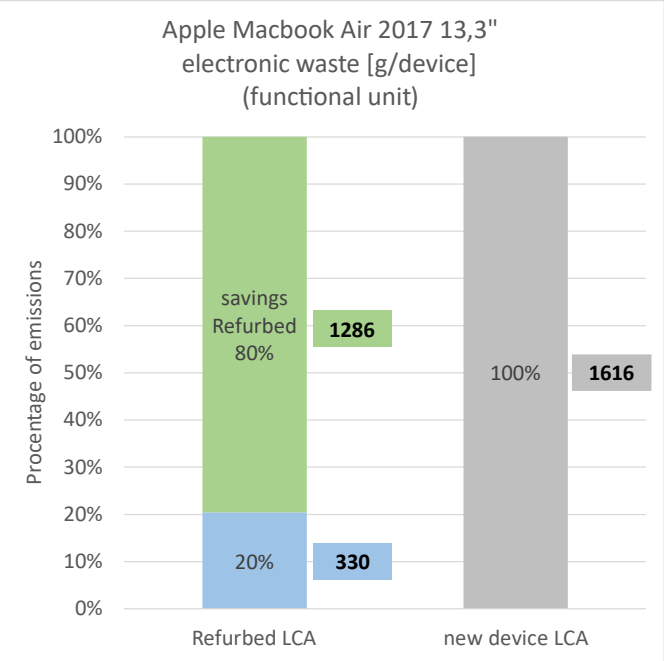

FIGURE 24: COMPARISON: ELECTRIC WASTE APPLE MACBOOK AIR 13,3"

11.5 Refurbished Lenovo Thinkpad T460 i5

Figure 25 shows the distribution of CO_2-emissions based on the process modules of a Lenovo Thinkpad T460 i5. Whereas only 26 % of the emissions of a new device are attributable to the use phase, this position is 84 % for a refurbished device (Figure 26). The refurbishment process and the electronic components replaced in the process offer the greatest leverage for reduction. These account for around 15 % of emissions. Both transport (1 %) and emissions from the online marketplace (<1 %), on the other hand, are very low and contribute little to the carbon footprint.

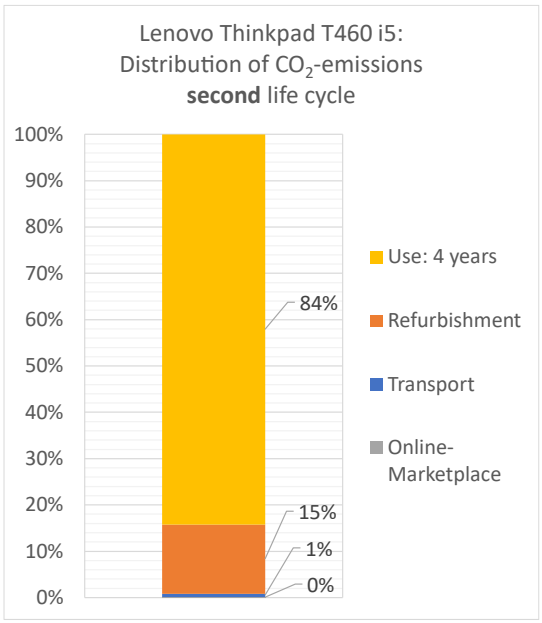

FIGURE 25: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW REFURBISHED LENOVO THINKPAD T460 I5

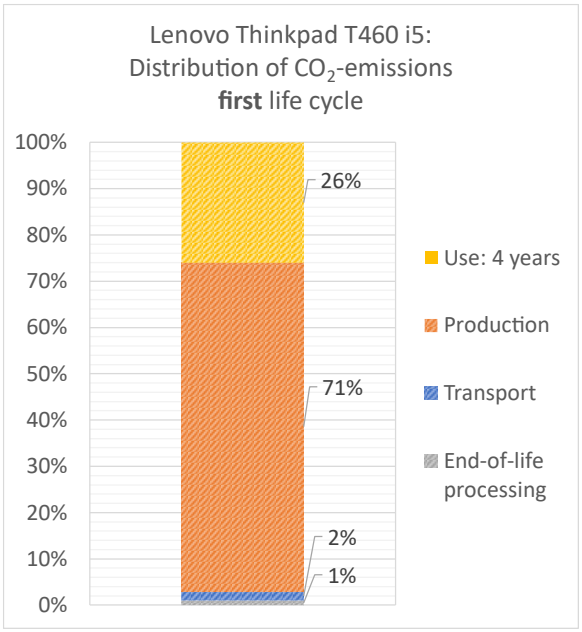

FIGURE 26: CO_2-EMISSIONS OF THE PROCESS MODULES OF A NEW LENOVO THINKPAD T460 I5 (LENOVO THINKPAD T460 I5, 2015)

11.5.1 CO_2-emissions

By purchasing a refurbished Lenovo Thinkpad T460 i5, the buyer is credited with a carbon footprint of 143.5 kg CO_2 (Figure 27). This represents savings of 69 % compared to a new device, which is responsible for 462 kg of CO_2.

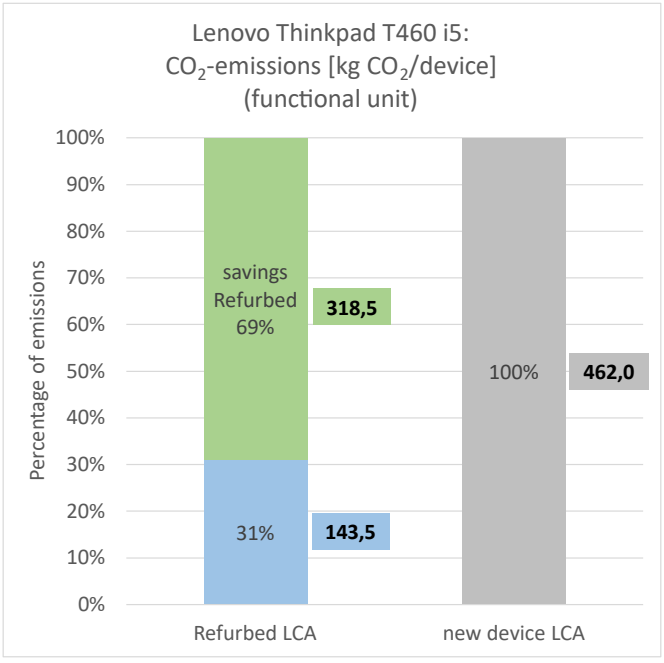

FIGURE 27: COMPARISON: CO_2-EMISSIONS LENOVO THINKPAD T460 I5

11.5.2 Water use

The water consumption of a refurbished Lenovo Thinkpad T460 i5 is around 10438 liters (Figure 28). Compared to a new device, which requires 77481 liters, this represents savings of 87 %.

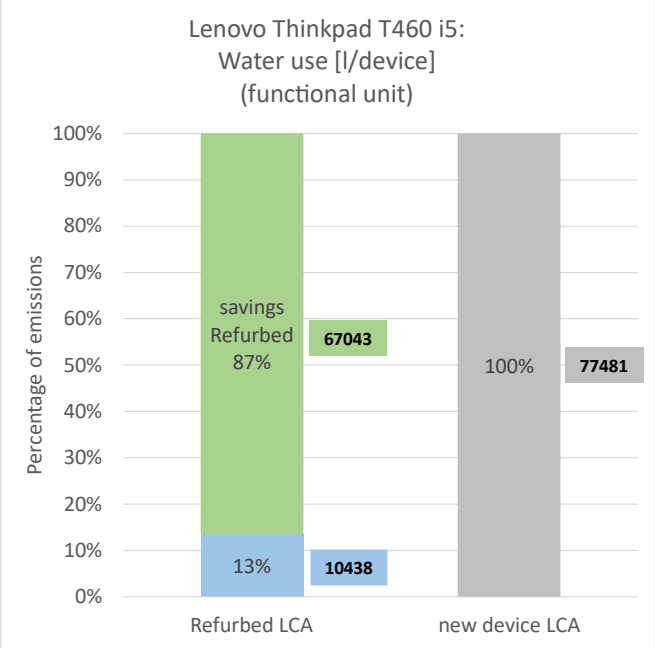

FIGURE 28: COMPARISON: WATER USE LENOVO THINKPAD T460 I5

11.5.3 Electronic waste

The refurbishment of a Lenovo Thinkpad T460 i5 results in around 617 g of electronic waste due to the replacement of defective or visually worn components (Figure 29). Compared to a new device, which has a total weight of 1697 g, this represents savings of 64% (weight incl. electronic accessories).

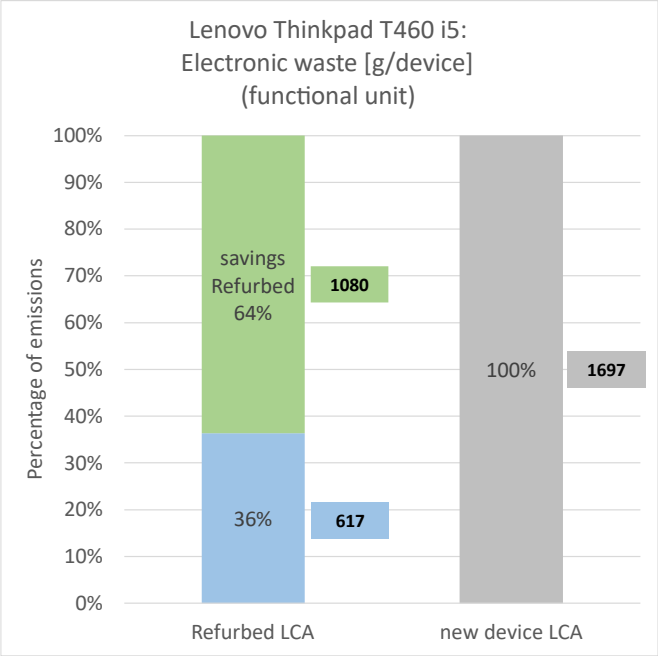

FIGURE 29: COMPARISON: ELECTRONIC WASTE LENOVO THINKPAD T460 I5

11.6 Comparison of the results with existing studies

In order to be able to compare the present results with existing studies, it must be ensured that the same system boundaries were used. Unfortunately, many companies that communicate information regarding their sustainability, currently do not provide sufficient background information. As the results strongly depend on the prevailing supplier structure, the considered devices as well as the defined useful life, this information is essential for a valid comparison. Two reports could be identified which allow a comparison.

The Internet platform "Swappie" communicates savings of 78.8 % of CO_2-emissions if one of its refurbished smartphones is preferred to a new device (Swappie, 2021). The level of savings is very much in line with the results of this study, which puts the average savings for the smartphones under consideration at 78.5 %.

Another, very detailed life cycle analysis by the French Agency for Ecological Transition (ADEME) also arrives at results of the same order of magnitude. However, it should be noted in this study that the selected useful life for refurbished smartphones was only 2 years. An extrapolation of the results to a useful life of 3 years comes to an emission value for a "refurbished mobile phone" of around 7.3 - 14.8 kg CO_2/device. This value is therefore lower than the average value calculated here of 15.6 kg CO_2/device (Apple iPhone 11 and Samsung Galaxy S20 FE). However, a direct comparison is only meaningful to a limited extent, since ADEME's study looked at smartphones in general and this study analyzed two specific models (ADEME, 2022).

In general, the above-mentioned studies and further analyses (Rainer Pamminger, 2021) show that refurbished electronics conserve valuable resources and reduce emitted CO_2-emissions compared to new devices. In order to be able to better compare the results of such analyses and

check their validity in the future, a standard should be developed within the industry for the balancing of ecological variables.

11.7 Measures for the reduction of ecological variables

By purchasing refurbished instead of new electronics, consumers can significantly reduce the negative impact of electronics on the environment. To minimize the remaining environmental impact, further measures can be taken by both suppliers and Refurbed.

The most effective way to minimize the environmental footprint of Refurbed products is to reduce the use of spare parts components. In addition to replacing defective components, some Refurbed supplier currently install a new battery as standard. Likewise, charging cables and power supply units are often replaced with new ones. Here, for example, an incentive system for end customers can be used to encourage them to choose a device that has not received a new battery. Similarly, electronic accessories that are supplied as standard are often already available to the customer and do not have to be supplied.

Furthermore, spare-part-harvesting is a topic that can also be implemented at Refurbed suppliers. By incorporating functional spare parts of defective devices into Refurbed products, the use of new separately purchased spare parts is saved. This leads to a reduction in the purchase of spare parts and to a higher recycling of defective equipment.

Another measure to reduce emissions is the packaging of the articles. Here, particularly sustainable materials can be used. In order to implement this at all Refurbed suppliers, an innovative standard system can be developed on the part of Refurbed. Refurbed, as one of the largest suppliers of refurbished electronics, has the market power to impose sustainable requirements on suppliers.

In terms of transportation emissions, the primary concern of retailers should be that electronic devices are purchased locally. Refurbed, on the other hand, has the opportunity to reduce the emissions caused by transport to Refurbed customers, e.g. by means of additional options such as climate-neutral shipping. Furthermore, the current system - the customer is offered the device with the best price/performance ratio on the platform - can be supplemented by the environmental factor. If customers in Austria are interested in a Refurbed product, a suppliers geographically close by could be preferred. This leads to a reduction of the transport route and subsequently to a reduction of emissions.

Refurbed has partners from several European countries who sell their refurbished products via the online marketplace. The supply of electricity from sustainable or renewable sources is not yet embedded in every supplier. Switching from fossil to renewable energy supply is an easy step to realize, but has a big leverage in reducing emissions.

Refurbed has the possibility to realize a reduction of emissions through the mentioned measures by creating incentive systems for Refurbed suppliers nationwide.

12 Ecological impact of Refurbed

In order to be able to assess the influence of an online marketplace on the ecological variables of refurbished electronics in detail, only those processes should be considered which can be influenced by Refurbed. Without the proportional emissions from the use phase, this can be divided into 3 categories. Refurbishment, transport, and online marketplace. The aim of the following illustrations is to show transparently how many emissions are caused by refurbishment and transport (emissions that can be reduced by measures) and how large the share of an online marketplace is (emissions that are additionally added).

As can be seen in Figure 30, the share of the online marketplace for smartphones is 5 % on average. In relation to the total amount of emissions to be influenced (an average of 3 kg CO_2/device), these are emissions of only 0.15 kg CO_2/device. The additional impact of selling products via the online marketplace is therefore very low.

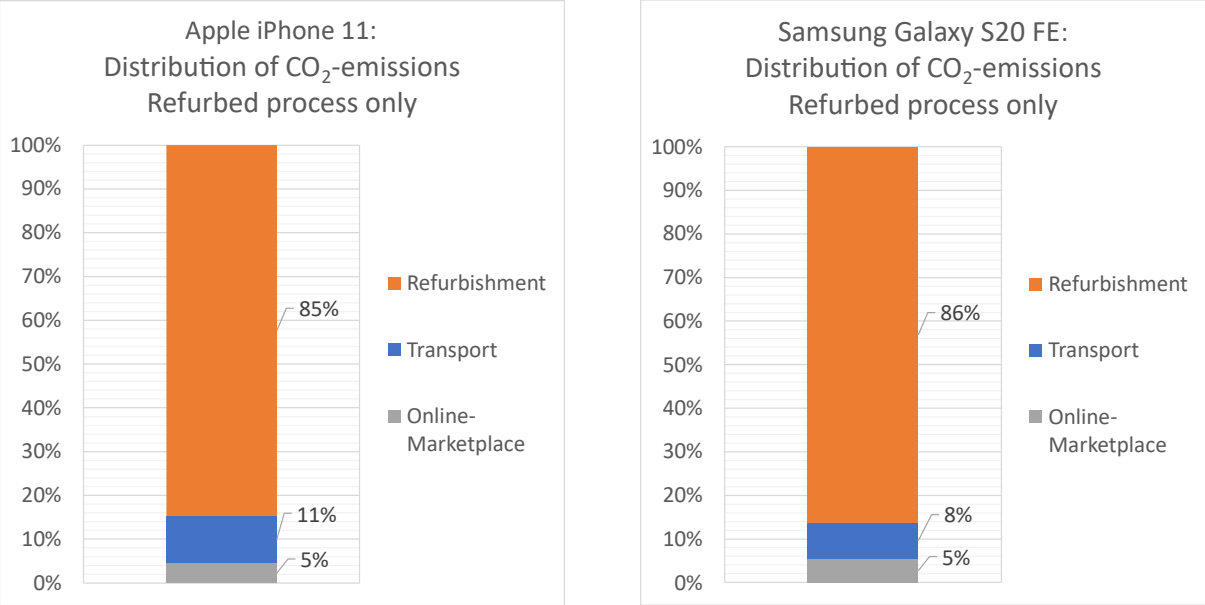

FIGURE 30: REFURBISHMENT APPLE IPHONE 11 (LEFT) AND SAMSUNG GALAXY S20 FE (RIGHT)

The additional impact of 4 % (0.15 kg CO_2/device) from Refurbed is very similar for a tablet (Figure 31). As already mentioned in Section 11.3, however, the accounting for this product is only meaningful to a limited extent, as the suppliers analyzed are primarily resellers. It is therefore to be expected that, if refurbishers are also considered, the share of emissions due to the refurbishment process will increase and that due to transport and the online marketplace will decrease. Overall, the amount of emissions to be influenced is around 3.7 kg CO_2/device.

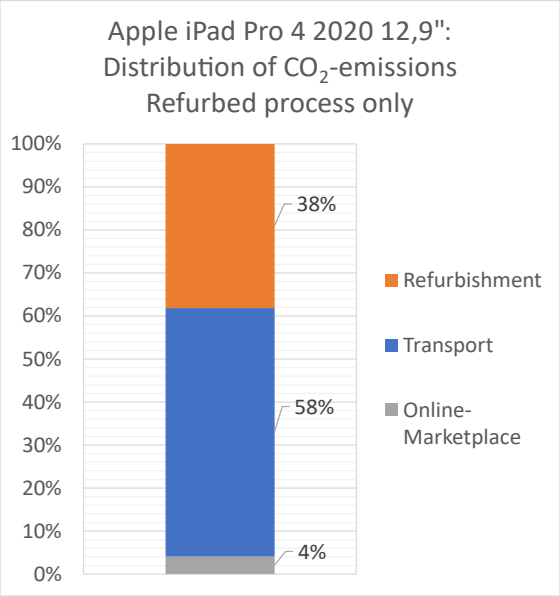

FIGURE 31: REFURBISHMENT APPLE IPAD PRO 4 13,3"

Figure 32 shows the percentage breakdown of categories for laptops. Due to the increasing total emissions with increasing size of an electronic device, the share of the online marketplace decreases. This is constant in absolute terms because the effort of selling on the platform is independent of the product. The emissions to be influenced amount to around 13 kg CO_2/device for an Apple MacBook Air 13.3" and around 23 kg CO_2/device for a Lenovo Thinkpad T460 i5.

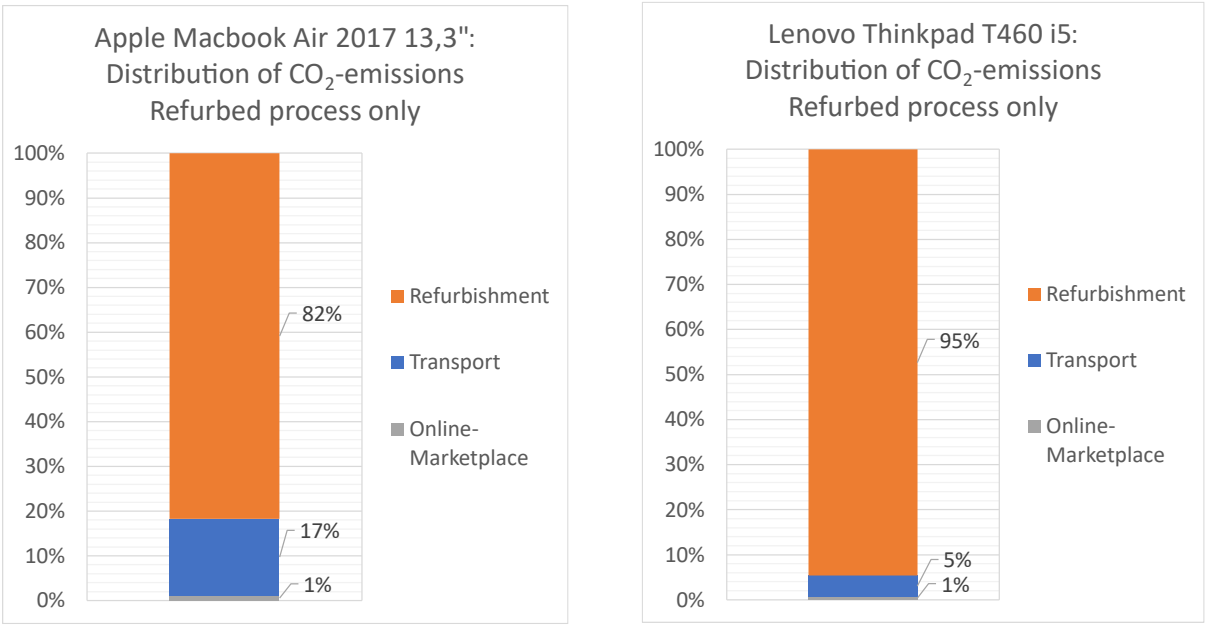

FIGURE 32: REFURBISHMENT APPLE MACBOOK AIR 13,3" (LEFT) AND LENOVO THINKPAD T460 I5 (RIGHT)

The additional ecological impact of an online marketplace can therefore be assessed as very low at an average of 1-5 % on average. This contrasts with the great benefits offered by a central platform such as Refurbed.

An analysis by the Ellen MacArthur Foundation comes to the conclusion that online marketplaces play an important role in providing customers with the necessary confidence in used electronics and guaranteeing a transparent price/performance ratio (Ellen MacArthur Foundation, 2017). These and other criteria, which an online marketplace fulfills, are of key importance when customers are deciding to buy refurbished electronic equipment. With Refurbeds far-reaching brand strength, the second-life market of electronic products is established in the public. The creation of a market for discarded electronic equipment is served by companies such as Refurbed, managing to keep the ever-growing amount of electronic waste in circulation for as long as possible (Gautam, Behera, Sinha, Gicheva, & Singh, 2022). This is highly relevant, as the current status of Sustainable Development Goal 12 (Responsible Consumption and Production) shows that Austria still has a lot of catching up to do in the category of electronic waste (Sustainable Developement Report, 2023).

A customer survey was conducted to substantiate the above findings regarding the positive impact (reduced CO_2-emissions) of Refurbed on the environment. The survey was sent out to 26,000 people. In total, 6,000 people participated. The response rate was 23 %. The aim of the survey was, among other things, to obtain the influence of Refurbed on customers' purchasing decisions. The evaluation showed that 80 % of the respondents had purchased new equipment before their first purchase of a Refurbed product. In addition, 96 % of participants indicated that they would purchase their next refurbished product again on a platform like Refurbed. The results of the survey make it clear that a central online platform like Refurbed is an important criterion for customers to purchase a refurbished product. Particularly important to the respondents is the quality of the products (32 %), which Refurbed can guarantee through its high standards and a standardized evaluation process of the devices for its supplier. Likewise, the low price on the platform is of high importance to the clientele (29 %). An online marketplace can guarantee this by means of transparent presentation of price/performance. In addition, Refurbed uses marketing measures to strengthen the presence of the topic of sustainability among consumers, which is the most important reason for purchasing refurbished electronics for around 18 % of respondents. In addition to the points mentioned above, customers also decide to buy from Refurbed and thus to buy refurbished electronics because of the trustworthiness of the platform (9 %).

In summary, Refurbed products make an important contribution to minimizing the negative environmental impact of electronics. A central online marketplace such as Refurbed plays a key role in encouraging more consumers to buy refurbished electronics instead of new ones, thereby conserving valuable resources and reducing CO_2-emissions.

13 Value attitude and temporal validity range

In making decisions during the study, preference was given to scientific knowledge (e.g., physics, chemistry, biology). When this was not possible, other scientific approaches (e.g., from social and economic sciences) or approaches from international conventions that are applicable and valid within the geographic scope of the study were used.

The temporal validity range of the data is the time frame for which the quantified values are representative. Due to continuously changing emission factors, especially in the energy and transportation sectors, it is necessary to update the values annually.

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