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Life Cycle Assessment of The Fairphone (Gen. 6)

Legal notice

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Declaration

This report is a deliverable from a study carried out by Fraunhofer IZM and commissioned by Fairphone B.V. The study was commissioned to reach objective and unbiased conclusions. Fraunhofer IZM declares no conflict of interest.

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Abbreviations

ADPe	Abiotic Depletion Potential (elements)
AP	Acidification Potential
ASM	Artisanal and Small Mining
BOM	Bill of Materials
CMOS	Complementary Metal Oxide Semiconductor
CO2e	Carbon Dioxide equivalents
DCB	1,4-Dichlorobenzene
DRAM	Dynamic Random Access Memory
EF	Environmental Footprint
EoL	End of Life
eSIM	Embedded SIM
FAETP	Freshwater Aquatic Ecotoxicity Potential
FMD	Full Material Declaration
FPC	Flexible Printed Circuit
GB	Giga Bite
GEC	Green Energy Certificate
GW	Global Warming
HTP	Human Toxicity Potential
HWD	Hazardous Waste Disposal
IC	Integrated Circuit
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
kg	kilogram
LANCA	LANd use indicator value CAlculation
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LPDDR	Low-Power Double Data Rate
LSM	Large Scale Mining
MPU	Main Processing Unit
NAND	Not-AND
OLED	Organic Light-Emitting Diode
PC	Polycarbonate
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
PCF	Product Carbon Footrpint
Pt	Points
RE	Renewable Energy
REC	Renewable Energy Certificate
RM	Recycled Materials
RSL	Reference Service Life
SIM	Single Identity Module

SMT	Surface Mounted Technology
SO2	Sulfur Oxide
Sphera LCA FE	Sphera Life Cycle Assessment For Experts
TCDD	2,3,7,8-Tetrachlorodibenzodioxine
TPU	Thermal Polyurethane
USB	Universal Serial Bus
USES	Uniform System for the Evaluation of Substances
YTMC	Yangtze Memory Technologies

1 Executive Summary

Goal, scope and methodology overview

This report shows the life cycle assessment study of The Fairphone (Gen. 6), a modular smartphone by Fairphone B.V. and a selection of its accessories. This life cycle assessment (LCA), is a cradle-to-grave analysis, covering the life cycle stages of the production, transport, use phase as well as end of life of the products and meeting ISO 14040, 14044 and 14067 standards. The specific goals of this study are:

- Estimating the environmental impacts of The Fairphone (Gen.6) and its accessories.
- Identifying environmental hotspots and main drivers. Additionally, providing further insights as to how these drivers affect the impacts i.e. which supply chain steps or aspects are most relevant and thus are to be prioritized when engaging with suppliers.
- Analysing the benefits of a series of eco-design approaches that Fairphone B.V. has been applying in its latest models e.g. decarbonisation of the supply chain, use of recycled materials, etc.
- Analysing the environmental performance of repair, both in a general scale (as practised by its users) as well as on a module-per-module basis.
- Considering Fairphone B.V.'s efforts on improving the environmental and social impacts of Artisanal and Small Mining (ASM) for key minerals, estimating the potential effect in the final results of different sourcing routes for gold in the device.

In accordance with ISO 14067, the environmental footprint of the device is divided into two footprints, representing two allocation approaches for the electricity related emissions:

- **Footprint (w/o reduction measures)**: which considers no eco-design measures implement i.e. all material in the device is primary material and all electricity use is modelled based on the regional mix in the production location.
- **Footprint (RM):** which considers the recycled content in the device but allocates the electricity geographically (i.e. via regional grid mixes of the production locations)
- **Footprint (RM + RE)**: which considers both recycled content and the intentional use of renewable energies in certain steps of the supply chain. In all cases however, the functional unit is *the use of The Fairphone (Gen. 6) device for 3 years*.

The following impact categories are assessed in this study:

- Abiotic depletion, both elements and fossil, according to the CML methodology.
- Acidification potential, according to the CML methodology.
- Freshwater ecotoxicity, according to the CML methodology.
- Human toxicity, according to the CML methodology.
- Land use, according to the EF3.1 methodology.
- Hazardous waste disposal, according to the EN15804 methodology.
- Climate change, according to the ISO 14067 methodology (which is based on the IPCC AR6 characterization factors).
- Blue water use, as calculated by Sphera LCA FE software (Version 10.9.1.10).

The foreground LCI data for the modelling of the device has been retrieved from various sources, depending on data availability. Whenever possible, primary data from Fairphone B.V. and its suppliers was used and when the data was not available or the activities covered were not in direct control of Fairphone, secondary data was used. Background data was retrieved from the Sphera database (commercial database and Electronics Extension) and the Ecoinvent database.

Key findings

The Fairphone (Gen. 6)

The total global warming impact for the entire life cycle of The Fairphone (Gen. 6) is of 41,8 kg CO2e for the Footprint (RM) and of 29,3 kg CO2e for the Footprint (RM + RE). Table 1-2 and Table 1-3 show the full impacts.

For the Footprint (RM + RE) the production phase contributes between 69 to 100% of the total impact, depending on the indicator. Transport and use follow with contirbutions that range from close to 0% to 18% in the case of the transport and up to 36% for the use phase. Lastly, EoL has a negligible contribution for all indicators.

Table 1-1 - Environmental impacts of the The Fairphone (Gen. 6), divided by life cycle phase, Footprint (w/o reduction measures)

	Total	**Production**	**Transport**	**Use phase**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,41E-03	1,40E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,68E-01	1,53E-01	1,01E-02	4,40E-03	1,87E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	6,05E-01	5,09E-01	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,24E+00	6,60E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	1,31E+02	9,80E+01	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	5,71E-07	4,69E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	4,23E+01	3,81E+01	1,94E+00	2,19E+00	3,68E-02
Blue water use [kg]	6,74E+04	4,26E+04	7,66E+02	2,39E+04	8,81E+01

Table 1-2 - Environmental impacts of The Fairphone (Gen6), divided by life cycle phase, Footprint (RM)

	Total	**Production**	**Transport**	**Use phase**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,35E-03	1,35E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,65E-01	1,50E-01	1,01E-02	4,40E-03	1,87E-04

Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,78E-01	4,84E-01	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,20E+00	6,56E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	1,30E+02	9,74E+01	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	6,17E-07	5,20E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon	4,18E+01	3,76E+01	1,94E+00	2,19E+00	3,68E-02
Blue water use [kg]	6,70E+04	4,22E+04	7,66E+02	2,39E+04	8,81E+01

Table 1-3 - Environmental impacts of The Fairphone (Gen. 6), divided by life cycle phase, Footprint (RM + RE)

	Total	**Production**	**Transport**	**Use phase**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,40E-03	1,40E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,38E-01	1,23E-01	1,01E-02	4,40E-03	1,87E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	3,04E+00	2,95E+00	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,01E+01	8,46E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	3,00E+02	2,68E+02	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	5,11E-07	4,14E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon	2,93E+01	2,51E+01	1,94E+00	2,19E+00	3,68E-02
Blue water use [kg]	7,88E+04	5,40E+04	7,66E+02	2,39E+04	8,81E+01

As Figure 1-1 shows, production phase of The Fairphone (Gen. 6) drives all impact categories, ranging from a contribution of around 60% (blue water use) to almost 100% (mineral and resource use, ADPe). Transport and use phase also show a significant contribution in some impacts such as toxicity for transport (both ecological and human) and land and water use for the use phase. End of Life shows a comparatively negligible contribution for all indicators. This picture is consistent with LCAs of small consumer electronic devices where the production of the semiconductors and boards causes the highest impacts of the entire life cycle, while the contribution of the rest of the life cycle phases is comparatively lower.

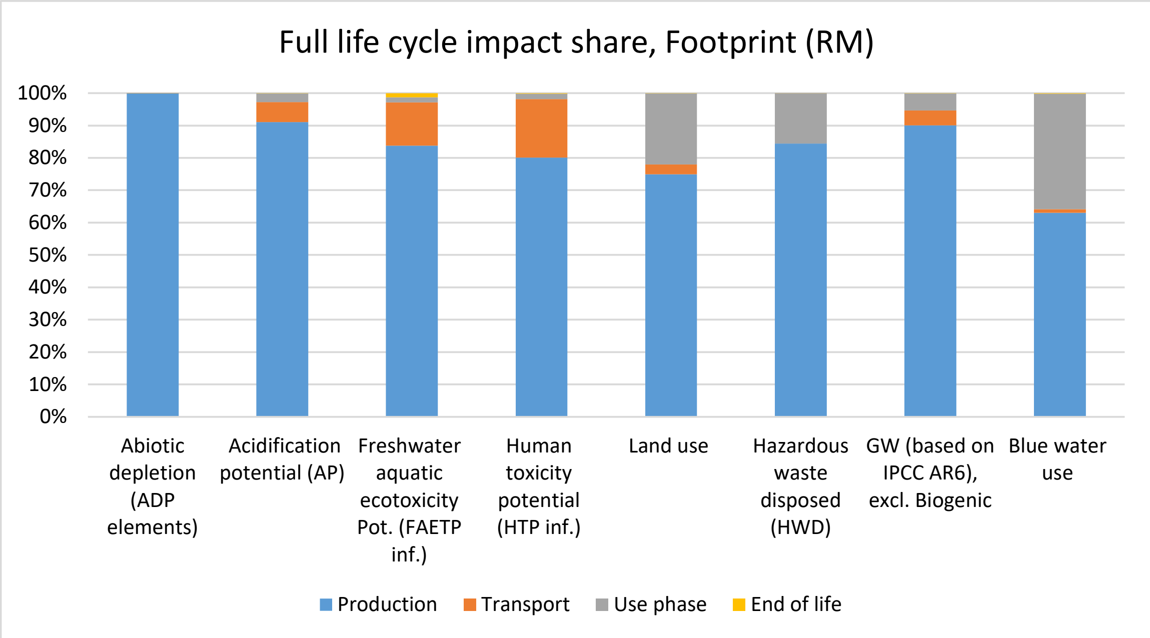

Figure 1-1- Full life cycle impacts distribution for The Fairphone (Gen. 6), Footprint (RM)

Figure 1-2 shows the impact distribution for the production phase for Footprint (RM), divided by module. The main contributor is clearly the main PCBA that takes up roughly half of the production impacts depending on the indicator. The display module follows with a contribution of 5 to 20% depending on the impact category. The Main Camera and the battery also show a significant contribution. Some spikes for land use in the package or toxicity in mechanical elements like the loudspeaker and mid frame can also be seen.

The primary PCBA's impacts are mostly driven by the manufacturing of the ICs. Their manufacturing is a very energy intensive process, in particular the production of the silicon die, which involves many process steps and, in many cases, additionally intensive use of chemicals. In this case the memory chip has the highest impact, due to its multi-die architecture and advanced technology node. Similarly, the various camera modules contribute to the environmental impacts mainly due to their image sensors, which are silicon wafers. Some of them include a double layer of logic and sensing, which increase their impacts further. Finally, the display module shows significant impacts mostly related to the manufacturing energy, which impact is reduced significantly in the Footprint (RM + RE).

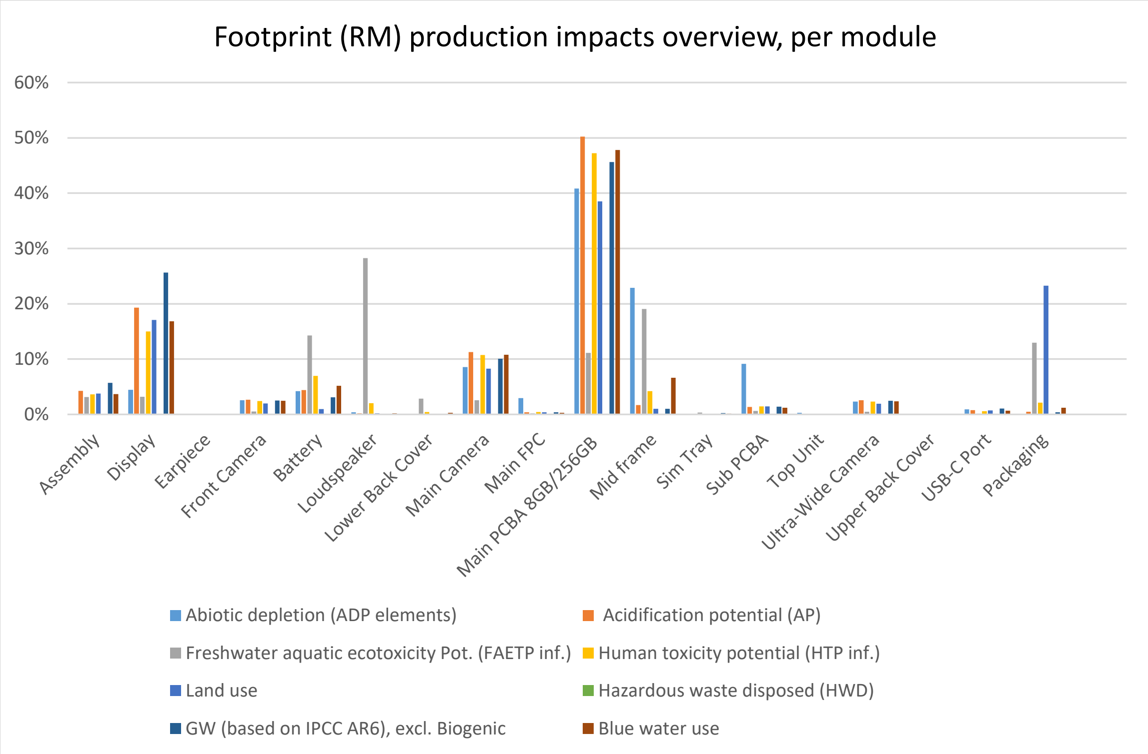

Figure 1-2 - Production impacts distribution for selected indicators for Footprint (RM), per module

The benefits of extending the device's lifespan can be better visualized when normalising the total impacts to the years of use, see Figure 1-3. As production is the main driver of the emissions, a lifetime extension to 10 years can achieve up to 61% of reduction of the *yearly* emissions. Due to improvements in the battery lifetime, this can be achieved with minimal overhead (i.e. battery replacement as maintenance).

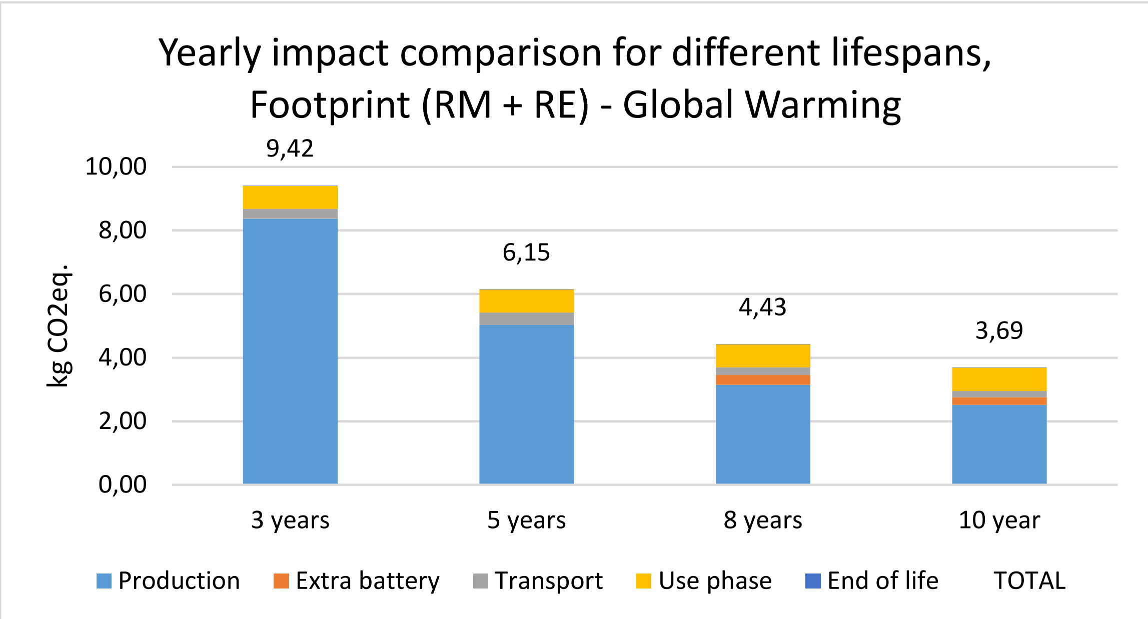

Figure 1-3 - Global warming comparison for different phone lifespan scenarios, Footprint (RM + RE)

Repair

The modular design of all Fairphone devices is intended to make repair easier for the users and thus allows for increasing the lifespan of devices and/or parts. In order to estimate its benefits, two repair scenarios have been built: a reference scenario where, after failure, the full phone is replaced and a mixed repair scenario where both warranty repairs and failure-related repairs are considered. Based on data provided by Fairphone B.V., the total lifetime for both scenarios is set to 6 years. Figure 1-4 shows the comparison, where it is clear that the repair scenario has roughly half of the impact of the reference, suggesting that the repair overhead (i.e. the additional effort needed for repair) is very limited.

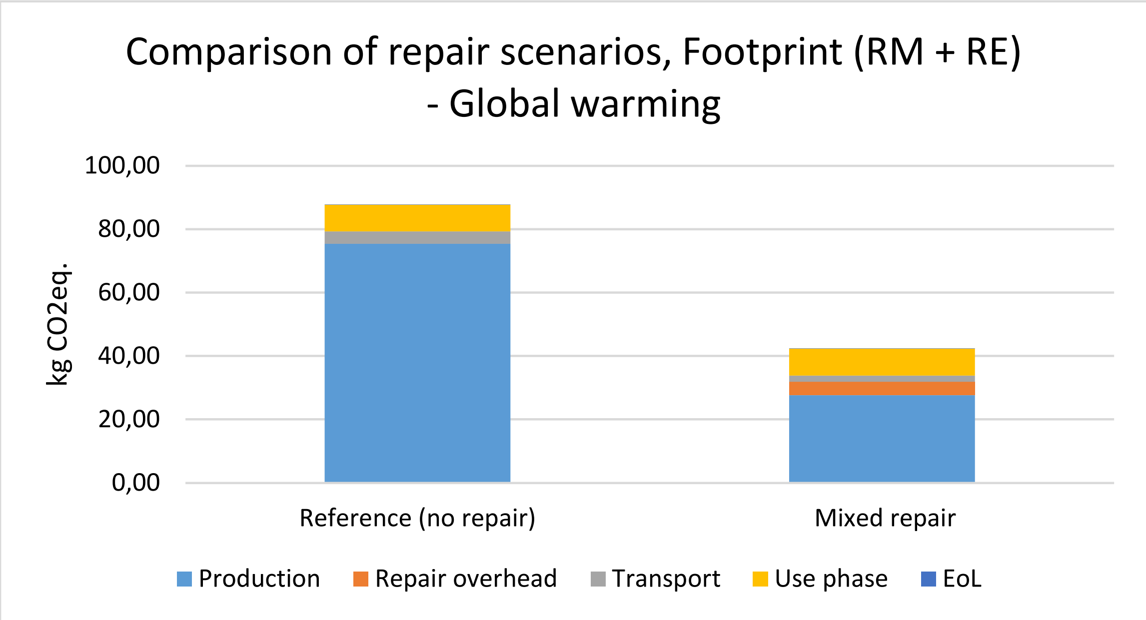

Figure 1-4 - Comparison of repair scenarios, global warming. This comparison uses Footprint (RM + RE) as reference.

Accessories

The analysis of the full life cycle of the accessories reveals that, for the most part, the transport phase is dominant in all impact categories. This is because, in most cases, the accessories are simple products with low manufacturing impacts but with the package the total weight to be transport even doubles, making the distribution impacts the highest comparatively.

Sensitivity analysis

A series of sensitivity analysis have been made in order to estimate the impacts of varying certain parameters of modelling approaches. Since there is some uncertainty in the battery modelling, different existing models and tools have been compared as to assess the potential uncertainty range, which has been observed to fall between 3 and 6 kg CO2e (representing 7 and 14% of the total Footprint (FM)). Another aspect analysed has been the gold supply chain, comparing large and small scale mining. Data is scarce and spread in this topic so no reliable answer has been produced but artisanally mined gold shows a range of close to 0% to a little below 5% of the total Footprint (RM) emissions while gold from large scale mines shows a range of also close to 0% up to 6% of the total. Finally, a series of design choices have also been analysed in terms of their effect in the total emissions of the device. The highest impact has been observed in the camera choice, where having all three cameras being high resolution could potentially lead to a 14% increase in the total emissions and reducing the resolution of all three to a reduction of 7%. After that the display size shows also a significant effect with an effect range between -3% and +4%. On a more modest scale, battery capacity only represents between 0% and 2% variation of the impact. Finally, different approaches to PCB design, varying the layer counts in favour of more compact designs (or vice versa) also do not show a big impact, with a range between -1% and +2%.

Comparison with Fairphone 5

Figure 6-17 shows a comparison of global warming for the entire life cycle for both devices. For the entire life cycle, the impacts of both seem to be almost the same. For The Fairphone (Gen. 6) both transport and the use phase are lower. In the case of the transport, the lower use of air transport has contributed to the reduction of its impacts. In the case of the use phase, the longer battery life (53h as per test results provided by Fairphone B.V.) reduces the required annual charging cycles, which in turn reduces the overall energy need. In the production phase, The Fairphone (Gen. 6) shows a higher impact, although this is mostly due to methodological and modelling changes rather than significant changes in the device itself.

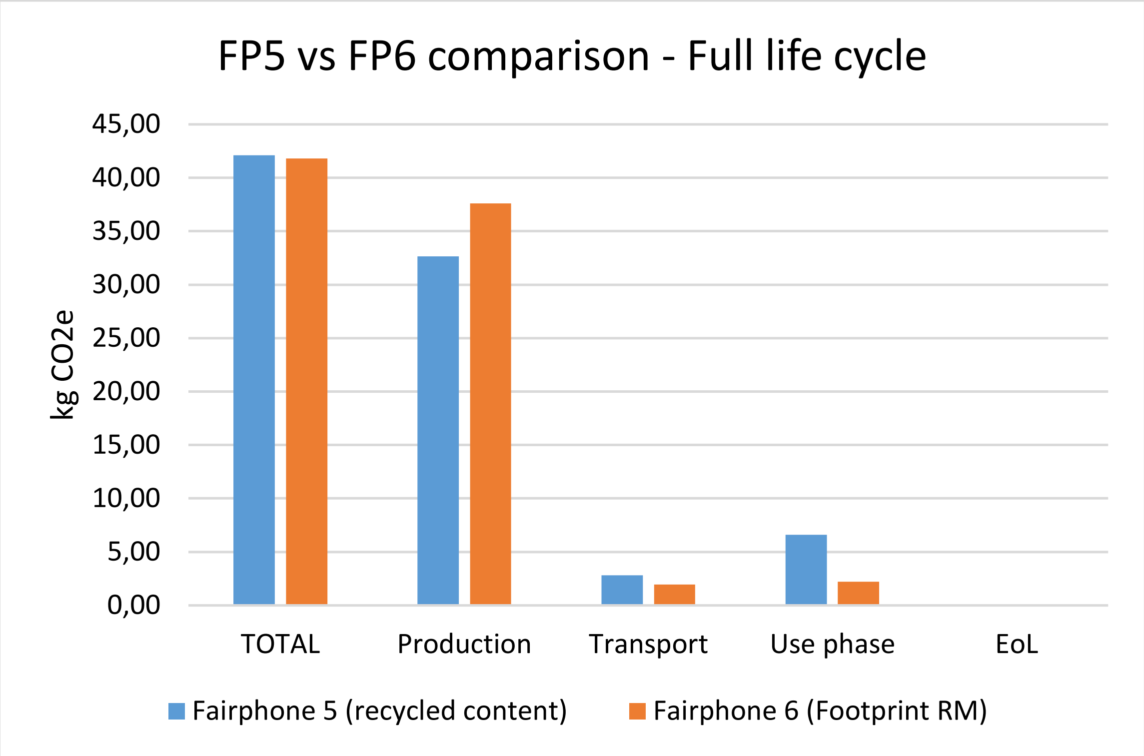

Figure 1-5 - GW comparison for The Fairphone (Gen.6) and Fairphone 5, at the full life cycle level

Conclusions

The results of the LCA of The Fairphone (Gen. 6) show a slight improvement over its predecessor mostly driven by an even less air-dependent distribution and a longer battery lifetime that potentially reduces the necessary charging cycles per year. The production impacts show to be slightly higher mostly due to a more comprehensive modelling and some methodological changes, the device itself having likely a similar impact to the previous iteration.

The production of the electronic components in the mainboard and more importantly of the integrated circuits is the dominant activity from an environmental perspective. Other modules like the display and the battery also show to be of significance across impact categories.

The use of recycled materials in The Fairphone (Gen. 6) has more modest impacts. Smartphones are electronics-dense devices with small form factors. The energy required to extract and refine the materials is smaller than the energy required to turn the materials into electronic components.

In general, most of the indicators analyzed continue to be heavily influenced by the burning of fossil fuels and thus by the energy consumption. Indicators like land use, hazardous waste or ADPe however reveal other important aspects like potential trade-off effects of increased use of renewables. Furthermore, ADPe also serves as a better display of the benefits of recycling, particularly of metals.

Regarding repair, the LCA shows the benefits of repair and extended use against premature disposal of the device. Following the trend observed from studies of earlier Fairphone models, additional efforts for single-component replacement do not seem to clearly translate into benefits over replacing the full module, except for the display (which comes with great uncertainty due to data quality).

2 Goal of the study

This report presents the life cycle assessment of The Fairphone (Gen. 6), a modular smartphone by Fairphone B.V. and related accessories.

This document adheres to principles, requirements and guidance from existing international standards on life cycle assessment (LCA), covering the life cycle stages of the production, transport, use phase and end of life of the product.

The project report and life cycle assessment (LCA) were prepared in conformity with the following standards:

- ISO 14040:2006-07 – Life Cycle Assessment principles and framework
- ISO 14044:2021-02 – General principles and requirements for LCA
- ISO 14067:2019-02 – Requirement and guidelines for carbon footprints of products.

This report gives a detailed analysis on the following impact categories (for a more detailed explanation of the categories and the rationale behind their selection, please refer to Section 5.1).

- Abiotic depletion, both elements and fossil, according to the CML methodology.
- Acidification potential, according to the CML methodology.
- Freshwater ecotoxicity, according to the CML methodology.
- Human toxicity, according to the CML methodology.
- Land use, according to the EF3.1 methodology.
- Hazardous waste disposal, according to the EN15804 methodology.
- Climate change, according to the ISO 14067 methodology (which is based on the IPCC AR6 characterization factors).
- Blue water use, as calculated by Sphera LCA FE software (Version 10.9.1.10).

The study was carried out without the critical review of an independent party.

The more specific goals of this study are:

- Estimating the environmental impacts of The Fairphone (Gen.6) and its accessories.
- Identifying environmental hotspots and main drivers. Additionally, providing further insights as to how these drivers affect the impacts i.e. which supply chain steps or aspects are most relevant and thus are to be prioritized when engaging with suppliers.
- Analyzing the potential benefits of a series of eco-design approaches that Fairphone B.V. has been applying in its latest models e.g. decarbonisation of the supply chain, use of recycled materials, etc.
- Analyzing the environmental performance of repair, both in a general scale (as practiced by its users) as well as on a module-per-module basis.
- Considering Fairphone B.V.'s efforts on improving the environmental and social impacts of ASM mining for key minerals, estimating the potential effect in the final results of different sourcing routes for gold in the device.
- Analyzing the potential effects of different design choices, i.e. display size, battery capacity, PCB size and camera resolutions.

3 Scope of the study

3.1 Functional Unit

The Life Cycle Assessment is a cradle-to-grave analysis that is, covering all relevant processes from raw material acquisition to the product's end of life. Following the guidelines of ISO 14067 for accounting of electricity supply, the environmental footprint of the device in this LCA is divided into three footprints. For the purposes of this report, footprints are understood as different configurations on the device based on the impact work considered. They are the following:

- **Footprint (w/o reduction measures)**: environmental footprint of the device not considering recycled content nor renewable energy use in its manufacturing. Acts as a reference scenario to analyze the potential benefits of the undertaken measures to reduce the environmental impact of the device.
- **Footprint (RM)**: environmental footprint of the devices that includes recycled content. Energy supply during manufacturing here is allocated on a purely geographical basis i.e. it does not take into account supplier-specific sourcing of energy such as the use of Renewable Energy Certificates (RECs).
- **Footprint (RM + RE)**: environmental footprint of the device as sold to the user, which includes both recycled content and usage of RE throughout the supply chain, whenever it could be documented. For the manufacturing of the rest of the device, geographical allocation still applies (more on this in Section 3.3.2).

The functional unit for all footprints is *the use of The Fairphone (Gen. 6) device for 3 years*.

Additionally, other accessories were also assessed within the study:

The Fairphone (Gen. 6) specific:

- Cut-out case
- Flip case
- Lanyard cord
- Finger loop
- Card holder
- Screen protectors

Generic:

- Screwdriver
- SIM card pin
- USB cables
- 30W and 65W charger

Further scenarios were analyzed as described in the following section.

3.2 Reference Service Life (RSL)

The reference service life for all footprints in this study is the use of one The Fairphone (Gen. 6) for 3 years. The baseline was set to 3 years for two reasons: on the one hand, the study aims to keep continuity with previous LCAs for earlier Fairphone iterations and on the other hand, it reflects the estimated average lifespan of smartphones nowadays[1].The amount of additional batteries needed in the extended lifespan scenarios are based on the assumption that a smartphone battery shall endure at least 500 charging cycles (Clemm, et al., 2016). Internal tests performed by Fairphone B.V. confirm that the current model's battery can withstand above 1000 charging cycles without a capacity drop below 80%. Considering a battery life of 53h (see Section 4.4.1.2), it is estimated that the battery needs replacement every 6 years. For more information on the user profile, see Section 4.4.1.2. The following scenarios were analyzed:

- 3 years (baseline)
- 5 years (due to: EU Eco-design Requirements for Smartphone and Tablets; min. software support period).
- 8 years (due to: target lifespan, based on Fairphone's minimum software support) assuming one battery replacement for maintenance.
- 10 years (due to: Fairphone's vision) assuming one battery replacement for maintenance.

3.3 Footprints and scenarios analyzed

In Section 3.1 above the three footprints under consideration have been outlined. Besides that and in order to observe the effects of certain features and approaches in different areas, a set of scenarios was analyzed in this LCA. For the purposes of this report, scenario is understood as varying cases we look at in order to assess hypothetical versions of the device environmentally.

This sub-section gives an overview of the different footprints and scenarios modelled for further analysis.

3.3.1 Recycled content

The use of recycled materials is treated differently in the various footprints under analysis. A description of these when it comes to recycled content can be found below:

- Footprint (w/o reduction measures) – without recycled materials. As a benchmark to allow comparison, a hypothetical situation of fully primary materials is modelled to identify and quantify the benefits and/or drawbacks of recycled material.
- Footprint (RM) and Footprint (RM + RE). The Fairphone (Gen. 6) device with secondary material content. The specific list of materials and verifiable amounts were provided by Fairphone B.V.
    - Aluminum 88% (in the mid-frame)
    - Copper 48% (26% in the shielding on the PCB and 22% in the PCB itself)
    - Indium 98% (in the display and touch panel)
    - Iron 39% (in the battery pack stee sheet and 0,3% in the SIM tray)
    - Magnesium 96% (in the display frame)
    - Nickel 39% (in the shielding on the PCB)
    - Plastics 94% (in the structural plastic casing)
    - Rare Earth Elements 40% (35% in the loudspeaker and 5% in the linear vibrator)
    - Tin 56% (46% in the PCB solder paste and 10% in the battery solder paste)
    - Zinc 71% (in the shielding on the PCB)
    - Gold 2.6% (in various parts and pieces)

In order to properly account for the recycled content, the recovery routes for the secondary materials in the device were considered. Most of these were modelled based on literature and in some cases, using generic datasets. A more detailed description of the modelling can be found in Section 4.3.1.

[1] See https://www.statista.com/statistics/786876/replacement-cycle-length-of-smartphones-worldwide/ and https://www.statista.com/statistics/619788/average-smartphone-life/

Fairphone (Gen. 6) also includes certain amount of recycled glass but due to lack of data at the time of reporting it has not been included in the analysis.

3.3.2 Renewable energy use

Fairphone B.V. works alongside its suppliers in an effort to decarbonize its supply chain. In order to estimate the savings of such an approach, a separate footprint is calculated with all the certified uses of 100% renewable energy in the device's manufacturing, which are the following:

- Final device assembly.
- Memory chips (NAND and DRAM) manufacturing
- All three cameras (front, main, ultra-wide camera).
- Display assembly
- Battery assembly

Also in the accessories, renewable energies are employed in the assembly of the following:

- Charger assembly
- Cables assembly

As explained in Section 3.1, the footprint is divided into three models with different energy sources. This follows the requirements of ISO 14067 in which a clear differentiation between geographical and market allocation for sourced energy emissions needs to be made. In Footprint (RM) the emissions allocation for used energy throughout the supply chain is purely geographical: the energy emissions are modelled per the energy mix of the geographical area where the activity takes place. In the Footprint (RM + RE), the allocation is mixed: wherever supplier specific data was available (i.e. GEC, RECs) the respective type of energy was used (market allocation). For the rest of activities, due to a lack of data on residual mixes, the appropriate regional mix (geographical allocation) was used.

3.3.3 Repair

The modular design of all Fairphone devices enables user repair and thus allows increasing the lifespan of devices and/or parts. In order to analyze the potential benefits of the repairs that the design of the Fairphone (Gen. 6) allows for, the following scenarios were considered. Both scenarios below are based on the Footprint (RM + RE).

- **Reference scenario**: In order to serve as the benchmark, the reference scenario depicts a situation where, during an extended lifetime of 6 years, 2 entire devices are purchased, used and discarded. No repair nor maintenance activity takes place.
- **Mixed repair scenario**: In this scenario, repair and maintenance activities are undertaken in order to keep the first device in use for 6 years. This includes the replacement of a faulty module (the associated impact of which is modelled as an average of spare parts) and a full battery replacement.

The modules assumed to fail for the repair scenarios are based on actual module sales data and warranty repair data for the Fairphone 5 via the official website and matched with the modules of this device. The life span for the repair scenarios was calculated based on user surveys performed by Fairphone B.V. reflecting expected lifetime extension by the users.

3.3.4 Sensitivity analysis

The sensitivity analysis in an LCA covers all aspects in which known uncertainty exists, offering variation on key parameters to study their effect on the final results. In this study, the following scenarios are included in the sensitivity analysis:

- **Memory chip modelling**: The memory chip is the most important component from an environmental perspective and its impacts greatly depend on its architecture. Since the specific die structure within the package and the specific technology node are unknown, some different assumptions are compared.
- **Gold supply chain modelling**: Across different programs like *Fairminded credits*[2] or *Fairtrade gold*[3], Fairphone B.V. has been supporting Artisanal and Small-scale Mining (ASM) for gold. In order to try to estimate how this translates into environmental impacts, the following scenarios are built:
  - Baseline scenario: gold modelling as it is done in the Footprint (w/o reduction measures), using generic datasets that reflect an average of global production. It shall serve as the reference for comparison.
  - Large Scale Mining (LSM) scenario: gold modelling reflecting exclusively large mining operations, using data from literature and mining companies' own environmental declarations.
  - ASM scenario: gold modelling reflecting exclusively ASM production, using data retrieved from literature.
- **Design options**: In order to identify not only the current environmental impacts of the device but also the effects of potential design differences, alternative scenarios have been built to quantify the changes in environmental impacts for design variations of key components i.e. battery, display, cameras and PCB.

3.4 Product description

The Fairphone (Gen. 6) is a modular smartphone with an OLED display, exchangeable battery and dual SIM (one physical and one eSIM). The size of the phone is 6.3'' and it has a weight of 191g. It contains 8 GB RAM and 256 GB internal storage. The smartphone storage can be extended by a microSD card, which is not part of the covered system boundaries. The Fairphone (Gen. 6) consists of the following modules:

- Battery
- Display
- Top Unit
- Main camera
- Ultra-Wide Camera
- Front Camera
- Upper Back Cover
- Lower Back Cover
- USB-C port
- Loudspeaker
- Earpiece
- Main PCBA
- Sub PCBA
- Mid frame

Plus, the packaging.

[2] https://www.fairphone.com/de/2024/11/22/what-are-fairmined-credits/

[3] https://www.fairphone.com/de/2021/11/30/fairtrade-hirose/

3.5 System boundaries

This LCA covers a cradle-to-grave study. The modelling thus covers the following phases:

- Production phase, including:
    - Raw material acquisition
    - Production transport
    - Intermediate product manufacturing
    - Device assembly
- Transport
- Use phase
- End of Life

A more detailed description of the modelling for each life cycle phase can be found in Section 4.

3.6 Geographical coverage

Fairphone B.V. provided a list of suppliers, thus whenever possible, dataset choice has followed the actual location of the production activities. For generic datasets it was sometimes possible to pick a geographically representative dataset while in other cases (mainly electronics) the geographical coverage was more general (representing average energy mixes from global manufacturers).

For more considerations on the geographical coverage of the energy use during production, please see Section 3.3.2.

For the use phase, the energy mix selected has been based on the sales split as provided by Fairphone B.V.

3.7 Reference Year

The foreground system was modelled based on data for the reference year 2025. The temporal coverage of the background data varies, although the used databases are in their latest versions (2025). More insight on that will be given in Section 4.

3.8 Criteria for the exclusion of inputs and outputs

In principle the only exclusion criteria considered was the lack of available data: either because no suitable dataset was found in the available databases or because no external data could be found to build a new dataset. Otherwise, no quantitative or qualitative criteria have been used to pre-emptively exclude processes.

4 Life cycle inventory

4.1 Data collection and calculation procedures

The data for this LCA has been retrieved from various sources, ranging from primary data provided by Fairphone B.V. (e.g. Bill of Materials, Full Material Declaration) to secondary data from literature (e.g. display manufacturing inventory data, inventory data for secondary material production). Furthermore, ready-made datasets from Sphera (V2025.1) and Ecoinvent (3.9.1) databases were used.

4.2 Background data and data quality

For the LCA modeling the software Sphera LCA for Experts was used in combination with the Sphera LCA Database (including extensions on precious metals and electronics) and Ecoinvent 3.9 database.

Whenever possible, background datasets were further adjusted to specific components and processes from the foreground system. All unit processes are documented in the annex table in Section 9.

In the annex table an overview of the data quality can also be found. The table below presents the criteria and grading system used to assess and communicate the data quality.

Table 4-1 – Data Quality Requirements (DQR) criteria followed for the data quality assessment, with explanation of the different quality levels (as recommended by the Environmental Footprint (EF) framework) (S., L., A., O., & Diaconu, 2019). The table shows the precission (P), time representativeness (TiR), technological representativeness (TeR) and the geographical representativeness (Gr).

Quality rating	P_{EF} and P_{AD}	$Ti_{R\text{-}EF}$ and $Ti_{R\text{-}AD}$	$Ti_{R\text{-}SD}$	$Te_{R\text{-}EF}$ and $Te_{R\text{-}SD}$	$G_{R\text{-}EF}$ and $G_{R\text{-}SD}$
1	Measured/calculated and verified	The data (collection date) can be maximum 2 years old with respect to the "reference year" of the data set.	The "reference year" of the data set falls within the time validity of the secondary data set	Technology aspects have been modelled exactly as described in the title and metadata, without any significant need for improvement	The processes included in the data set are fully representative for the geography stated in the "location" indicated in the metadata
2	Measured/calculated/literature and plausibility checked by reviewer	The data (collection date) can be maximum 4 years old with respect to the "reference year" of the data set.	The "reference year" of the data set is maximum 2 years beyond the time validity of the secondary data set	Technology aspects are very similar to what described in the title and metadata with need for limited improvements. For example: use of generic technologies' data instead of modelling all the single plants.	The processes included in the data set are well representative for the geography stated in the "location" indicated in the metadata
3	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data (collection date) can be maximum 6 years old with respect to the "reference year" of the data set.	The "reference year" of the data set is maximum 3 years beyond the time validity of the secondary data set	Technology aspects are similar to what described in the title and metadata but merits improvements. Some of the relevant processes are not modelled with specific data but using proxies.	The processes included in the data set are sufficiently representative for the geography stated in the ""location" indicated in the metadata. E.g. the represented country differs but has a very similar electricity grid mix profile,
4	Qualified estimate based on calculations, plausibility not checked by reviewer	The data (collection date) can be maximum 8 years old with respect to the "reference year" of the data set.	The "reference year" of the data set is maximum 4 years beyond the time validity of the secondary data set	Technology aspects are different from what described in the title and metadata. Requires major improvements.	The processes included in the data set are only partly representative for the geography stated in the "location" indicated in the metadata. E.g. the represented country differs and has a substantially different electricity grid mix profile
5	Rough estimate with known deficits	The data (collection date) is older than 8 years with respect to the "reference year" of the data set.	The "reference year" of the data set is more than 4 years beyond the time validity of the secondary data set	Technology aspects are completely different from what described in the title and metadata. Substantial improvement is necessary	The processes included in the data set are not representative for the geography stated in the ""location" indicated in the metadata.

$Ti_{R\text{-}EF}$: time representativeness for the elementary flow
$Ti_{R\text{-}AD}$: time representativeness for the activity data
$Ti_{R\text{-}SD}$: time representativeness for the secondary data set

4.3 Allocations

This product needed no co-product allocations since no co-products are produced. However, allocation for recycling was needed and is presented in the following sub-sections.

4.3.1 Use of secondary materials

In the manufacturing of The Fairphone (Gen. 6) and accessories, several secondary materials are used. In both Footprint (RM) and Footprint (RM + RE), the amount of secondary material is reflected as integrated in The Fairphone (Gen. 6) at market introduction.

Aluminum (88% recycled)

Secondary aluminum production was modelled using a generic dataset for remelting of aluminium ingots from scrap. The dataset includes data by European Aluminium from 2015, covering the EU-28 region. Dataset owned by Sphera.

Copper (48% recycled)

Secondary copper production was modelled using Ecoinvent datasets for copper smelting and electrolytic refining from electronics scrap. The geographical coverage of the dataset is RoW (Rest of the World), meaning that the data has been adapted from the original, which covered a different region.

Indium (98% recycled)

Secondary indium production was modelled using inventory data from (Amato, Rocchetti, Fonti, Ruello, & Beolchini, 2015), which describes a process of indium recovery from end-of-life LCDs. The process involves three main steps: washing, leaching and cementation. The inventory data used includes both energy and material inputs. Sorting and transport of the waste LCDs prior to the indium recovery is not included in the scope.

Magnesium (96% recycled)

Magnesium recovery inventory data was extracted from (Ehrenberger, 2013) in which magnesium recovery from vehicle waste is described. The process includes pre-treatment, preparation and secondary magnesium production. The data used in the reference study is based on a real company in Germany.

Nickel (39% recycled)

Due to the lack of better data, nickel was modelled using Ecoinvent datasets for copper smelting and electrolytic refining, following the approach of the extended EoL modelling for the Fairphone 5 itself (see Section 4.4.1.3).

Rare Earth Elements (40% recycled)

Rare Earths include Neodymium, praseodymium and dysprosium. However, due to lack of data available, only neodymium has been considered. Secondary neodymium production is modelled using inventory data extracted from (Wang, Sun, Gao, Chen, & Nie, 2022), in which an LCA was performed for NdFeB magnetic material recovery on a representative recycling company in China. The modelling includes the pre-treatment of the waste magnets, milling and sintering. It includes both energy and material inputs to the process.

Zinc (71% recycled)

The inventory data for secondary zinc production was extracted from (Genderen, Wildnauer, Santero, & Sidi, 2016) in which data for primary zinc production is provided. The paper divides the main processes into two big steps: mining/beneficiation and smelting. It is assumed that the smelting is needed for producing zinc from waste, while mining is left out of scope. Data used in the paper is from 2012 and based on primary data from 18 smelters operating in Africa, Australia, Europe and North America. In our modelling energy input and direct emissions were considered.

Polycarbonate (PC) (94% recycled)

Secondary PC production was modelled using generic datasets, in particular:

- A generic dataset for plastic injection molding as the main processing step, owned by Sphera.
- A dataset for secondary plastic granulate with low metal contamination, owned by Sphera.

Thermal Polyurethane (TPU) – (90% recycled in soft case)

The secondary TPU was modelled using the same approach as for the secondary PC.

Tin (56% recycled in Fairphone 5 at launch)

Data on tin recycling is relatively scarce and less detailed compared to copper. Due to the limited availability of comprehensive tin recycling data and supported by several sources[4] indicating that tin is often recovered through the same refining and recycling routes as copper (e.g., anode sludge processing in copper refining), we modeled tin recycling flows and emission factors similarly to copper. This approach allows for a reasonable estimation while acknowledging the current data gaps in tin-specific recycling processes.

Paper and cardboard

Some data sources exist on the environmental benefits of recycled paper and cardboard. The only source found with full LCI data (Simamora, Wiloso, & Yani, 2023) reflects a plant that sources its process steam and electricity from internal co-generation, rendering its environmental impacts higher than the virgin paper datasets used in our model. This source and others however (Hong & Xiangzhi, 2012) suggest that at least for carbon footprint, the impact reduction through use of recycled paper is between 15% and 43%. Other sources[5] seem to confirm this range.

Unfortunately, no suitable source was found that allowed a full integration of recycled paper and carboard in the model and thus the package manufacturing in all footprints does not consider the recycled fraction in it.

4.3.2 Allocation for reuse, recycling and recovery

In this LCA a 100/0 approach has been used for the allocation of recycling. All activities related to the recovery of the recycled content of The Fairphone (Gen. 6) from their previous useful life is allocated to this device. In order to avoid double counting, the efforts related to the recovery of materials at the end of life of The Fairphone (Gen. 6) are thus allocated to its next use. This means that all recycling activities after the pre-treatment of the electronics scrap are out of scope. Thus, the EoL modelling includes only transport to recovery site, depollution and shredding.

4.4 Life Cycle Inventory (LCI) analysis

4.4.1 Fairphone (Gen. 6)

4.4.1.1 Production

The manufacturing and raw material acquisition phase was modelled based on the bill-of-materials (BOM) accompanied with material data by the suppliers and a tear-down of the device carried out by Fraunhofer IZM. This is described on module level in the following sub-section.

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[4] https://www.internationaltin.org/aurubis-to-recover-tin-from-new-copper-waste-processing-plant-in-belgium and https://www.mdpi.com/2075-4701/11/1/22

[5] Carbon Footprint of a Cardboard Box - Consumer Ecology

4.4.1.1.1 Intermediary products and components

Extraction of all raw materials is included in the generic datasets used for the modelling, retrieved from the databases of Sphera and Ecoinvent. For most intermediary products (e.g. components and parts), generic datasets have been used as well.

For some intermediary products, where suitable datasets were not found, the modelling has been done using primary data for their material composition and for their manufacturing either primary data or secondary data from literature, depending on availability.

4.4.1.1.2 Cross module approaches

Several component types are found in several modules and modelled following the same approach in the LCA.

Printed circuit boards

Printed circuit boards were modelled according to the number of layers and the area. For the main and the sub PCB, production layouts were available to account for the cut-offs. Furthermore, flex-boards are modelled on the basis of the smallest rectangular area and assuming 1 layer. The main parameters are listed below

- Main PCB: 10 layers, 37.8 cm^2
- Sub PCB: 6 layers, 12.8 cm^2
- Battery flex-board: 1 layer, 1.23 cm^2
- Main flex-board (display): 1 layer, 12.4 cm^2
- Ultra-wide camera flex-board: 1 layer, 2.5 cm^2
- Front camera flex-board: 1 layer, 0.96 cm^2
- Main camera flex-board: 1 layer, 2.5 cm^2
- USB-C port flex-board: 1 layer, 1.08 cm^2

The model also includes other minor flex-boards (e.g. button-kit) which are part of the model but are not listed above.

Electronic components

Electronic components like capacitors, resistors, etc. were modelled based on generic data sets scaled by weight, as provided by Fairphone B.V. within the Full Material Declaration (FMD).

The environmental impact of integrated circuits was determined by the processed die area within the package. The die size of the majority of ICs was identified by a third party and provided by Fairphone B.V. For the modelling of ICs, a parametric dataset by Sphera has been used where several key parameters can be adjusted individually, including (but not limited to):

- Type of die (e.g. NAND, DRAM, CMOS, MPU…).
- Technology node.
- Packaging mass.
- Gold mass (in contacts).
- Substrate area.

For each IC the relevant data was extracted from both the BoM and the FMD. All non-memory and non-processor chips were assumed as CMOS.

For the small ICs, the die size was not determined and, in many cases further data was not available (e.g. material composition). For these, the modelling was done using generic datasets chosen based on IC type and packaging format. The die size is therefore assumed within the dataset itself.

Connectors

Connectors were modelled based on their material composition adding electricity and water use extracted from the inventory of Ecoinvent datasets[6] and rescaled by mass. Energy mix is selected based on the production location in China.

4.4.1.1.3 Battery

The Fairphone (Gen. 6) contains a removable and rechargeable lithium-ion battery with the following specifications:

- Weight: 63.1 g
- Capacity: 4415 mAh

The modelling has been done using material data provided by Fairphone B.V. within the FMD and primary data from the supplier for the energy required for manufacturing. The energy mix has been chosen considering the manufacturing location in China for the Footprint (RM) and considering the allocated RECs for the Footprint (RM + RE). Energy data covers only the assembly of the battery pack.

4.4.1.1.4 Display

The Fairphone (Gen. 6) has a 6.3-inch OLED display.

The display was modelled according to the material composition as described in the FMD provided by Fairphone B.V. Furthermore, the energy consumption for manufacturing was based on primary data provided by the manufacturer. Manufacturing takes place in China and electricity use is modelled based on the Chinese grid mix for the Footprint (RM) and considering the contractual REC use for the Footprint (RM + RE).

The display PCBA is modelled according to the BOM and visual inspection.

4.4.1.1.5 Top Unit

The top unit includes mainly housing elements and a flex cable with the camera flash. The main modelling approaches and assumptions used were:

- Housing elements have been modelled based on material composition, including a generic dataset for plastic injection molding to account for the manufacturing of the part.
- The flex cable has been modelled as a one-layer flexible PCB, scaled based on area.
- The connectors have been modelled on a material basis, following the FMD provided by Fairphone B.V.

4.4.1.1.6 Cameras

The Fairphone (Gen. 6) contains three cameras which comprise architecturally three separate modules:

- Main Camera
- Ultra-Wide Camera
- Front Camera

[6] https://ecoquery.ecoinvent.org/3.10/cutoff/dataset/8825/documentation

All three cameras were modelled following the same approach:

- Injection-molded polyethylene housing, using generic datasets for both the material and the manufacturing process. The material composition follows the data provided by the suppliers in the FMD.
- Flex boards plus electronic components according to the BOM, using generic datasets.
- The supplier has also provided data on the die size of the sensors and the amount of layers, since current smartphone cameras tend to have CMOS and logic dies in their image sensors (YOLE Intelligence, 2023). According to this data, both the main and ultra-wide cameras do have stacked dies while the front camera uses a single die. All have been modelled as logic dies.
- In the Footprint (RM + RE), renewable energy has been considered for the assembly of all three cameras, following the RECs presented by the supplier.

4.4.1.1.7 Back cover (upper and lower)

In The Fairphone (Gen. 6) the back cover is split into two parts: the upper and the lower back covers. They weigh 4.7g and 9.8g respectively and have been modelled on a material basis following the FMD.

4.4.1.1.8 USB-C Port

The USB-C connector weighs 0.77 g and is modelled according to the material composition plus a one-layer flexible PCB. The connector has been modelled following the approach outlined above (Section 4.4.1.1.2).

4.4.1.1.9 Loudspeaker

The loudspeaker consists of the bottom speaker box (3.7 g) and the vibration motor (1.1 g) and is modelled according to the material composition plus a one layered flexible printed circuit board.

4.4.1.1.10 Earpiece

The earpiece weighs 1 g and is modelled according to the material composition.

4.4.1.1.11 Main PCBA 8GB/256GB

The Main PCBA is comprised by the following elements:

- PCB, modelled following the approach presented in Section 4.4.1.1.2).
- Passive components (e.g. resistor, capacitors, inductors…), modelled following the approach presented in Section 4.4.1.1.2).
- Non-IC active components (diodes, transistors) modelled based on package area and using generic datasets.
- Integrated circuits, were modelled following the approach presented in Section 4.4.1.1.2. The processor and the memory (DRAM + flash) chips are the most relevant from an environmental perspective and special attention has been given to these. The model assumes that the memory package contains 4 flash dies and 4 DRAM dies, their area being estimated based on X-ray images provided by Fairphone B.V. For a more detailed discussion on the topic see sensitivity analysis in Section 6.5.1.

As for the shielding, the modelling was performed following the material composition as detailed by the FMD provided by Fairphone B.V.

For the use of renewable energy in the memory chip production, the used dataset could not be adapted to different energy mixes. Therefore, based on several sources[7][8][9], the contribution of energy had to be estimated and remodeled. Furthermore, since the data availability was limited to carbon emissions, the RE use could not be integrated into other indicators.

4.4.1.1.12 Sub PCBA

The sub PCBA has been modelled following the same approach as with the primary PCBA.

4.4.1.1.13 Mid Frame

The middle frame weighs 36.5 g and is modelled according to the material composition. This includes the mid frame as such, as well as several mechanical elements like nuts, button seals etc. The button kit and fingerprint sensor are modelled as a single-layer flexible printed circuit (FPC) including some passive components, identified visually and modelled based on size using generic datasets.

4.4.1.1.14 Packaging

Packaging has been modelled following primary data provided by Fairphone B.V. The packaging modelling includes:

- Phone box.
- Carton (for 20 pcs).
- Pallet (for 1200 pcs).

All items were scaled by weight and the respective share allocated to a single piece.

Although research exists on the environmental impacts of recycled paper, no suitable source has been found in order to fully integrate secondary paper in the model. Thus, the modelling for all footprints is done without considering recycling. This applies to every package including accessories.

4.4.1.1.15 Final assembly

The final assembly was modelled based on primary data from Fairphone B.V. and includes electricity use of 2.85 kWh for the Surface Mounted Technology (SMT) process, display module glue dispensing, final assembly and testing, packing and nano coating. Additionally, the use of nitrogen gas (0.7 kg) and cleaning agents (1.32 mL) and cloth (0.15 g) was also considered.

In the Footprint (RM + RE) the use of renewable energy in the assembly process has been considered.

4.4.1.2 Transport and use phase

Two tiers of transport are considered. Tier 1 refers to transport from the final assembly to Europe whereas transport during the manufacturing phase, meaning transport from suppliers to final assembly, is referred to as tier 2 transport.

These transports result in the following (all per The Fairphone (Gen. 6) unit):

[7] https://www.greenpeace.org/static/planet4-eastasia-stateless/2023/04/620390b7-greenpeace_energy_consumption_report.pdf

[8] https://www.interface-eu.org/publications/semiconductor-emission-explorer

[9] https://www.mckinsey.com/industries/semiconductors/our-insights/keeping-the-semiconductor-industry-on-the-path-to-net-zero.

- Tier 1 transport is modelled as 4080 kgkm of sea transport (85%) and 268 kgkm of air transport (15%), with an additional 24 kgkm of land transport. The model is based on a prognosis done by Fairphone B.V. for distribution to customers from 2025 onwards. The transported weight includes the devices and the associated package as per data provided by Fairphone B.V.
- Tier 2 transport assumes 75% land transport within China and 40% land transport outside China, the rest being equally divided between air and sea. That totals 40 kgkm land transport, and 10 kgkm for sea and for air transport. Distances are calculated based on supplier lists. Transported weights are based on component weight plus a packaging overhead of 10% of components above 1 g and 90% below 1 g.

All three footprints for The Fairphone (Gen. 6) use phase was based on the following pattern:

- 3 years of use
- A battery life estimation of 53h based on testing performed by Fairphone B.V. measuring battery duration during active use. This results in a full charging cycle every 2 days.
- One charging cycle consumes 20,31 Wh on average as per tests performed by Fairphone B.V., resulting in 3.36 kWh/a.

The energy per charging cycle was based on measurements provided by Fairphone B.V. The energy mix assumed as a mix of different country mixes and was based on the sales split for Fairphone 5 during 2024. In order to reflect the most up to date data, the emissions factors per country have been taken from EEA[10] representing the year 2023. For the rest of the impact categories, Sphera datasets have been used.

Additionally, three further scenarios were modelled:

- 5 years of use, no replacement battery
- 8 years of use, one replacement battery
- 10 years of use, one replacement battery

More specific description on the battery replacement assumptions is presented in Section 3.2 above.

4.4.1.3 End of Life

The End-of-Life modelling follows mostly the modelling performed for previous iterations of the Fairphone LCAs (Proske, Sanchez, Clemm, & Baur, 2020). Figures for e-waste collection rates are uncertain and vary depending on the source, ranging from rather low (~33%)[11] to higher values up to ~54%[12]. Recycling rates for the collected fraction are nonetheless reportedly high[13]. However, more specifically for mobile phones and smartphones, it seems that, according to (Buchert, Manhart, Bleher, & Pingel, 2012), *mobile phones are normally fed into pyro-metallurgical plants such as e.g. a Umicore facility in Belgium*. Furthermore, the same report states that it can be assumed that most of the non-

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[10] https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1

[11] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_electrical_and_electronic_equipment&oldid=556612#Electrical_and_electronic_equipment_.28EEE.29_put_on_the_market_and_WEEE_processed_in_the_EU (Figure 1)

[12] https://www.scycle.info/new-study-update-of-weee-collection-rates-targets-flows-and-hoarding/

[13] https://www.interregeurope.eu/find-policy-solutions/webinar/collection-and-recycling-of-weee-key-learnings

collected mobile phones are likely stored by the users and thus a late end-of-life treatment can be expected.

The same assumptions for End-of-Life transport were applied as they were in previous Fairphone model LCAs. Likewise, the plastic fraction of the device is assumed to be small enough to burn in the smelting process alongside the rest of the device.

Considering that the recycling efforts for the secondary materials integrated in the device are considered in scope, the recycling efforts at the end of the device's life are considered out of scope. Therefore, the system boundaries reach only until pre-treatment. No credits for recycling are considered.

The following steps were considered for the EoL:

- EoL transport: mix of train and truck transport, assumed distance of 1,500 km.
- Depollution: the removal of the battery is assumed to be manual and thus has no additional impacts associated with it.
- Shredding: considered as a pre-treatment for the depolluted smartphone.

4.4.2 Accessories

For all accessories, the entire life cycle was considered. For the finger loop, lanyard, screen protector, cut-out case, flip case, card holder, cables and chargers no use phase is included since no direct impacts have been identified during this phase. The following sub-sections give further detail on the main modelling assumptions.

4.4.2.1 The Fairphone (Gen. 6) screen protector

Although Fairphone B.V. offers two different screen protectors (privacy filter and blue light filter), these two are practically identical in terms of material composition and were thus modelled as a single, generic screen protector.

The product consists of:

- Screen protector
- Packaging (cardboard, paper)
- Cleaning kit (cloth, wet wipe)

All parts have been modelled using generic datasets by Sphera. The protector has been modelled as a flat glass. The weight is based on primary data provided by Fairphone B.V.

4.4.2.2 The Fairphone (Gen. 6) cut-out case.

The cut-out case is a protective case for the The Fairphone (Gen. 6). As its name indicates, it features a cut-out on the back through which it is possible to use other accessories such as a finger loop, a card holder, or a lanyard. It is made from 100% recycled PC and TPU. It also contains 2 small volume buttons made from recycled TPU.

4.4.2.3 The Fairphone (Gen. 6) flip case

The flip case is a protective case for the The Fairphone (Gen. 6), which is compatible with other accessories such as a finger loop, a card holder, or a lanyard, which are described in the following sections.

Like the cut-out case, the main part of the flip case has been modelled as recycled PC and TPU, and the buttons as recycled TPU.

4.4.2.4 The Fairphone (Gen. 6) finger loop

The finger loop accessory is an alternative back cover for The Fairphone (Gen. 6) with a small strap to help hold the phone securely. The back cover is made of 100% recycled PC. The finger loop material is silicone rubber, and the metal part with the logo has been modelled as a 74% recycled aluminum alloy.

The product includes:

- Back cover finger loop
- Screwdriver
- Screws

4.4.2.5 The Fairphone (Gen. 6) card holder

Like the finger loop, the card holder accessory is an alternative back cover for The Fairphone (Gen. 6) with a case for bank cards. The materials of both the back cover and the card holder are the same as those used for the finger loop back cover and the finger loop, respectively.

The product includes:

- Back cover card holder
- Screwdriver
- Screws

4.4.2.6 The Fairphone (Gen. 6) lanyard

This accessory has a different shape compared to the previous two. It is mainly modeled as 100% recycled polymer, including the rope, regulating rings, and other parts made from some type of PC or PET. It also includes fasteners made of 75% recycled aluminum.

The product includes:

- Lanyard
- Screwdriver
- Screws

4.4.2.7 Cables (generic accessory)

Within the scope of this analysis, three different cables have been modeled:

- USB3.1 (1m)
- USB2.0 (1m)
- USB2.0 (2,5 m)

All three elements have been modelled based on the bill of materials provided by Fairphone B.V. as well as the weight obtained through on-site teardown of units in Fraunhofer IZM.

According to the provided BOM, the three cables are made from the same materials and include recycled materials such as TPE, which is part of the housing and the inner jacket, PET for the braided jacket, and copper for the wires and shielding nets. Each is used in proportion to each cable, which varies in size (1 or 2.5 m) or USB type (2.0 or 3.1).

4.4.2.8 Charges (generic accessory)

Within the scope of this analysis, two different chargers have been modeled:

- 30W charger
- 65W charger

For the modelling of the chargers, the provided BOM was carefully considered once again. Concerning the recycled materials used in both chargers, polycarbonate (PC) is utilized for the plastic shells, and copper is used for the copper pins.

5 Life Cycle Impact Assessment (LCIA)

In this section the results of the Life Cycle Impact Assessment will be presented in a tabular form for all impact categories under analysis. The hot spot analysis and interpretation of the results is outlined and explained in the next chapter.

5.1 Definition of impact categories

This LCA calculates environmental impacts in the following impact categories, for which then the results are given and interpreted in the following sections.

- Acidification: Acidification potential refers to the contribution of several gases to the occurrence of acid rain, which in turn is the major contributor in increased acidity in soil. The most common contributors to this effect are ammonia, sulphur dioxide and nitrogen oxide. The CML methodology normalizes these gases to be expressed in kg SO_2 eq. Agriculture is the main emitter of ammonia, mainly through decomposition of manure and organic matter. Other lesser contributors in this sector are fertilizers and aerosols (von Schneidemesser, et al., 2016). The main sources of sulphur dioxide in contrast are burning of fossil fuels and smelting activities (mostly for mineral ores). Likewise, fossil fuel burning in its different applications is also the main responsible for nitrogen oxide emissions.
- Global Warming (GW): "Global warming is considered as a global effect. Global warming - or the "greenhouse effect" - is the effect of increasing temperature in the lower atmosphere. The lower atmosphere is normally heated by incoming radiation from the outer atmosphere (from the sun). A part of the radiation is normally reflected from the surface of the earth (land or oceans). The content of carbon dioxide (CO_2) and other "greenhouse" gasses (e.g. methane (CH_4), nitrogen dioxide (NO_2), chlorofluorocarbons etc.) in the atmosphere reflect the infrared (IR)-radiation, resulting in the greenhouse effect i.e. an increase of temperature in the lower atmosphere to a level above normal. […] The GW for greenhouse gases is expressed as CO_2-equivalents, i.e. the effects are expressed relatively to the effect of CO_2." (Stranddorf, Hoffman, & Schmidt, 2005).
- Resource depletion: "The model of abiotic resource depletion […] is a function of the annual extraction rate and geological reserve of a resource. In the model as presently defined, the ultimate reserve is considered the best estimate of the ultimately extractable reserve and also the most stable parameter for the reserve parameter. However, data for this parameter will by definition never be available. As a proxy, we suggest the ultimate reserve (crustal content)." (van Oers & Guinée, The Abiotic Depletion Potential: Background, Updates and Future, 2016). "The impact category for elements is a heterogeneous group, consisting of elements and compounds with a variety of functions (all functions being considered of equal importance)." Although ADPe measures generally mineral and metal depletion, it does so by weighting the different minerals on the basis of their relative scarcity (i.e. both considering the extraction rate and the known reserves). According to the latest update of the ADPe model (van Oers, Guinée, & Heijungs, 2020), currently the main contributors to the indicator are gold, copper and silver. Therefore, ADPe tends to be heavily influenced by these, particularly gold. The indicator is expressed in kg Sb equivalents, since antimony was selected as the reference material.
- Ecotoxicity: CML uses the USES-LCA (Huijbregts, et al., 2000) method to estimate both ecotoxicity and human toxicity, which is in turn a development of the previously built USES 2.0 toxicity model but adapted to the needs of LCA. USES 2.0 was developed for quantitative assessment of the risks on the local and regional scale via emissions of certain substances. The model accounts for substance emissions channels, distribution through containers, exposure types and effects after exposure; all feeding into the risk assessment. Amongst other changes, the USES-LCA version removes the regional aspects of the model and limits itself to a global

scale, since usually LCI data is not traceable to regions. The metric eventually calculates toxicity potentials based on the relationship between the predicted environmental concentration of a given substance in a given compartment (e.g. aquatic, terrestrial) over the known no-danger concentration of said material in said compartment. Each substance then is normalized and aggregated to be expressed in kg 1,4-dichlorobenzene equivalents. The most relevant substances for ecotoxicity are 2,3,7,8-TCDD (i.e. dioxins) and benzopyrene, amongst others. Dioxins used to be emitted during thermic processes (e.g. metal mining) and waste incineration, although the latter has been curved via legislation. The main sources of benzopyrene are mostly organic and fuel combustion.

- Human toxicity: Based on the same models than the ecotoxicity indicators in CML (Huijbregts, et al., 2000) the human toxicity potential measures the relationship between the predicted daily intake of a given substance via a given exposure route over the know Human Limit Value (HLV) for that substance and exposure path. After aggregation, all the substance-specific potentials are normalized to be expressed in kg 1,4-DB eq. The most relevant substances for human toxicity are benzene and derivatives. Common benzene exposure routes include (Wallace, 1989): smoking, transport related activities, some consumer products like adhesives or paints and petrochemical and refining operations.
- Land Use: The land use indicator used in the Environmental Footprint 3.1 method is based on the LANCA model (REF), but aggregating into a single index i.e. the Soil Quality Index (SQI). This indicator was developed and defined by (De Laurentiis, et al., 2019). This index takes the CFs for all five soil impact categories defined by LANCA and selects and weights the most relevant. On the basis of this selection, the final index is built. This aggregation includes: erosion resistance, mechanical filtration, groundwater regeneration and biotic production. The impact is expressed in points, which are dimensionless units after normalizing the original impacts via country-specific references. Typical sources for land use are usually land-intensive activities like mining, crop growth, forestry, land transport or some renewable energies (e.g. solar and wind parks).
- Hazardous waste disposed: Hazardous and non-hazardous wastes are intermediate flows in the model that are then gathered into their respective indicators. Therefore, the classification of a waste stream into hazardous or non-hazardous is dependent on the Ecoinvent and Sphera databases categorizations (EuGeos, 2020). As for the usual drivers of this indicator i.e. common sources of hazardous waste, the EPA lists the following sources: lab waste, CRTs, household hazardous waste (e.g. cleaning products), radiological waste, pharmaceutical waste, industrial solvent and used oil.
- Blue water use[14]: This indicator is an inventory value calculated by Sphera LCA For Experts and it represents the *total amount of water withdrawn from its source*. Blue water use is measured in terms of mass (kg).

These indicators have been chosen in order to be translatable to the Science Based Target Network methodology [15] for company environmental footprint calculations. Moreover, they also have been chosen based on relevance as characterized by (Mikosch, Dettmer, Plaga, Gernuks, & Finkbeiner, 2022). Some changes have been made with respect to the previous LCA (Sánchez, Baur, & Eguren,

[14] https://www.wri.org/insights/whats-difference-between-water-use-and-water-consumption

[15] https://sciencebasedtargetsnetwork.org/how-it-works/the-first-science-based-targets-for-nature/

Life Cycle Assessment of the Fairphone 5, 2024), mostly modifying the land use indicator and adding human toxicity and waste generation indicators.

5.2 Life Cycle Impact Assessment results for The Fairphone (Gen. 6)

5.2.1 Full life cycle

Table 5-1 - Environmental impacts of the The Fairphone (Gen. 6), divided by life cycle phase, Footprint (w/o reduction measures)

	Total	**Production**	**Transport**	**Use phase**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,41E-03	1,40E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,68E-01	1,53E-01	1,01E-02	4,40E-03	1,87E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	6,05E-01	5,09E-01	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,24E+00	6,60E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	1,31E+02	9,80E+01	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	5,71E-07	4,69E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	4,23E+01	3,81E+01	1,94E+00	2,19E+00	3,68E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	8,38E-02	0,00E+00	1,39E-06	2,05E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	3,62E+00	2,50E+00	3,24E-03	1,12E+00	5,09E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-3,78E+00	-2,69E+00	-2,73E-03	-1,09E+00	-5,13E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	6,38E-02	5,67E-02	2,27E-04	6,82E-03	1,58E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	4,31E+01	3,80E+01	1,94E+00	3,17E+00	3,68E-02
Blue water use [kg]	6,74E+04	4,26E+04	7,66E+02	2,39E+04	8,81E+01

Table 5-2 - Environmental impacts of The Fairphone (Gen. 6), divided by life cycle phase , Footprint (RM)

	Total	Production	Transport	Use phase	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,35E-03	1,35E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,65E-01	1,50E-01	1,01E-02	4,40E-03	1,87E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,78E-01	4,84E-01	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,20E+00	6,56E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	1,30E+02	9,74E+01	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	6,17E-07	5,20E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	4,18E+01	3,76E+01	1,94E+00	2,19E+00	3,68E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	8,38E-02	0,00E+00	1,39E-06	2,05E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	3,61E+00	2,49E+00	3,24E-03	1,12E+00	5,09E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-3,77E+00	-2,68E+00	-2,73E-03	-1,09E+00	-5,13E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	6,36E-02	5,65E-02	2,27E-04	6,82E-03	1,58E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	4,26E+01	3,75E+01	1,94E+00	3,17E+00	3,68E-02
Blue water use [kg]	6,70E+04	4,22E+04	7,66E+02	2,39E+04	8,81E+01

Table 5-3 - Environmental impacts of The Fairphone (Gen. 6), divided by life cycle phase, Footprint (RM + RE)

	Total	Production	Transport	Use phase	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,40E-03	1,40E-03	5,17E-07	1,06E-06	1,31E-07
Acidification Potential (AP) [kg SO2 eq.]	1,38E-01	1,23E-01	1,01E-02	4,40E-03	1,87E-04

Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	3,04E+00	2,95E+00	7,74E-02	9,26E-03	7,15E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,01E+01	8,46E+00	1,48E+00	1,34E-01	1,53E-02
Land Use [Pt]	3,00E+02	2,68E+02	3,96E+00	2,85E+01	1,26E-01
Hazardous waste disposed (HWD) [kg]	5,11E-07	4,14E-07	0,00E+00	9,59E-08	1,95E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	2,93E+01	2,51E+01	1,94E+00	2,19E+00	3,68E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	8,38E-02	0,00E+00	1,39E-06	2,05E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	3,13E+00	2,01E+00	3,24E-03	1,12E+00	5,09E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-3,29E+00	-2,20E+00	-2,73E-03	-1,09E+00	-5,13E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,88E-02	2,18E-02	2,27E-04	6,82E-03	1,58E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,19E+01	2,67E+01	1,94E+00	3,17E+00	3,68E-02
Blue water use [kg]	7,88E+04	5,40E+04	7,66E+02	2,39E+04	8,81E+01

5.2.2 Production

Table 5-4 - Environmental impacts of The Fairphone (Gen. 6) production, Footprint (w/o reduction measures)

	Total	Assembly	Display	Earpiece	Front Camera	Battery	Loudspeaker	Lower Back Cover	Main Camera	Main FPC
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,41E-03	1,38E-06	6,11E-05	1,27E-06	3,46E-05	5,65E-05	5,35E-06	5,87E-07	1,16E-04	3,98E-05
Acidification Potential (AP) [kg SO2 eq.]	1,53E-01	6,39E-03	2,92E-02	1,55E-04	3,99E-03	6,62E-03	2,83E-04	7,93E-05	1,70E-02	5,73E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,11E-01	1,52E-02	4,79E-02	3,92E-04	2,65E-03	6,45E-02	1,37E-01	1,37E-02	1,25E-02	1,00E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6,61E+00	2,40E-01	1,05E+00	5,25E-03	1,60E-01	4,47E-01	1,35E-01	2,84E-02	7,05E-01	3,04E-02
Land Use [Pt]	9,81E+01	3,66E+00	1,67E+01	3,38E-02	1,96E+00	9,70E-01	2,03E-01	6,22E-02	8,06E+00	3,88E-01
Hazardous waste disposed (HWD) [kg]	4,75E-07	1,88E-08	1,26E-07	3,97E-11	2,19E-09	1,87E-09	5,29E-09	1,36E-09	2,73E-09	1,26E-09
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	3,81E+01	2,15E+00	9,69E+00	8,03E-03	9,56E-01	1,17E+00	2,41E-02	2,19E-02	3,79E+00	1,48E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	8,88E-08	4,92E-07	5,46E-10	2,26E-07	2,18E-04	3,77E-08	1,82E-09	1,08E-06	9,22E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,50E+00	9,52E-02	4,42E-01	4,53E-04	6,46E-02	2,02E-02	1,16E-03	1,63E-03	2,75E-01	1,13E-02
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,69E+00	-9,39E-02	-4,34E-01	-4,17E-04	-6,38E-02	-1,95E-02	-1,12E-03	-1,54E-03	-2,72E-01	-9,88E-03
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,67E-02	6,69E-03	2,89E-02	1,04E-05	8,65E-04	6,33E-04	5,79E-05	4,22E-05	1,43E-03	3,91E-04
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,80E+01	2,15E+00	9,66E+00	8,02E-03	9,55E-01	1,17E+00	2,40E-02	2,19E-02	3,79E+00	1,48E-01
Blue water use [kg]	4,26E+04	1,55E+03	7,37E+03	3,17E+01	1,05E+03	2,19E+03	9,18E+01	1,19E+02	4,56E+03	1,25E+02

	Main PCBA	Mid Frame	Sim Tray	Sub PCBA	Top Unit	Ultra-Wide camera	Upper Back Cover	USB-C Port	Packaging
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,03E-04	3,09E-04	7,53E-07	1,23E-04	1,21E-05	3,15E-05	1,13E-08	1,25E-05	8,53E-07
Acidification Potential (AP) [kg SO2 eq.]	7,64E-02	4,13E-03	9,91E-05	2,08E-03	1,81E-04	3,85E-03	1,94E-05	1,21E-03	7,51E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,00E-02	9,33E-02	1,61E-03	3,01E-03	2,88E-03	2,48E-03	3,28E-05	7,44E-04	6,27E-02
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,93E+00	4,25E-01	5,86E-03	9,58E-02	1,40E-02	1,54E-01	6,87E-04	4,02E-02	1,40E-01
Land Use [Pt]	3,77E+01	1,30E+00	9,58E-02	1,40E+00	1,95E-01	1,92E+00	2,59E-02	6,97E-01	2,27E+01
Hazardous waste disposed (HWD) [kg]	2,92E-07	3,31E-09	3,11E-10	5,57E-09	6,79E-09	2,58E-09	6,63E-10	3,53E-09	1,02E-10

GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	1,71E+01	8,33E-01	8,73E-02	5,32E-01	4,70E-02	9,32E-01	9,96E-03	4,01E-01	1,49E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,02E-02	2,55E-08	4,62E-09	3,41E-03	3,96E-09	2,16E-07	1,07E-09	1,68E-08	1,09E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,22E+00	3,30E-02	3,54E-03	3,91E-02	4,87E-03	6,27E-02	8,97E-04	1,85E-02	2,04E-01
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,20E+00	-3,18E-02	-3,09E-03	-3,67E-02	-4,50E-03	-6,18E-02	-8,44E-04	-1,81E-02	-4,40E-01
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,13E-02	8,34E-04	3,08E-05	1,78E-03	7,09E-05	9,00E-04	1,86E-05	1,23E-03	1,64E-03
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,70E+01	8,32E-01	8,73E-02	5,27E-01	4,70E-02	9,31E-01	9,95E-03	4,00E-01	1,48E-01
Blue water use [kg]	2,02E+04	2,91E+03	6,31E+01	5,04E+02	4,36E+01	1,00E+03	1,29E+01	2,90E+02	5,10E+02

Table 5-5 - Environmental impacts of The Fairphone (Gen. 6) production, Footprint (RM)

	Total	Assembly	Display	Earpiece	Front Camera	Battery	Loudspeaker	Lower Back Cover	Main Camera	Main FPC
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,35E-03	1,38E-06	6,01E-05	1,27E-06	3,46E-05	5,67E-05	5,35E-06	5,87E-07	1,16E-04	3,98E-05
Acidification Potential (AP) [kg SO2 eq.]	1,50E-01	6,39E-03	2,90E-02	1,55E-04	3,99E-03	6,63E-03	2,79E-04	7,93E-05	1,70E-02	5,73E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	4,84E-01	1,52E-02	1,54E-02	3,92E-04	2,65E-03	6,92E-02	1,37E-01	1,37E-02	1,25E-02	1,00E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	6,56E+00	2,40E-01	9,86E-01	5,25E-03	1,60E-01	4,57E-01	1,35E-01	2,84E-02	7,05E-01	3,04E-02
Land Use [Pt]	9,74E+01	3,66E+00	1,67E+01	3,38E-02	1,96E+00	9,52E-01	2,03E-01	6,22E-02	8,06E+00	3,88E-01
Hazardous waste disposed (HWD) [kg]	5,21E-07	1,88E-08	1,26E-07	3,97E-11	2,19E-09	5,24E-08	5,28E-09	1,36E-09	2,73E-09	1,26E-09
GW (based on IPCC AR6), excl. Biogenic carbon	3,76E+01	2,15E+00	9,65E+00	8,03E-03	9,56E-01	1,17E+00	2,32E-02	2,19E-02	3,79E+00	1,48E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	8,88E-08	4,92E-07	5,46E-10	2,26E-07	2,18E-04	3,77E-08	1,82E-09	1,08E-06	9,22E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,49E+00	9,52E-02	4,42E-01	4,53E-04	6,46E-02	1,92E-02	1,13E-03	1,63E-03	2,75E-01	1,13E-02
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,68E+00	-9,39E-02	-4,34E-01	-4,17E-04	-6,38E-02	-1,87E-02	-1,10E-03	-1,54E-03	-2,72E-01	-9,88E-03
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,65E-02	6,69E-03	2,88E-02	1,04E-05	8,65E-04	6,33E-04	5,67E-05	4,22E-05	1,43E-03	3,91E-04
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,75E+01	2,15E+00	9,62E+00	8,02E-03	9,55E-01	1,17E+00	2,32E-02	2,19E-02	3,79E+00	1,48E-01
Blue water use [kg]	4,22E+04	1,55E+03	7,12E+03	3,17E+01	1,05E+03	2,18E+03	9,14E+01	1,19E+02	4,56E+03	1,25E+02

	Main PCBA	Mid Frame	Sim Tray	Sub PCBA	Top Unit	Ultra-Wide camera	Upper Back Cover	USB-C Port	Packaging
Abiotic Depletion (ADP elements) [kg Sb eq.]	5,50E-04	3,09E-04	7,54E-07	1,23E-04	4,16E-06	3,15E-05	1,13E-08	1,25E-05	8,53E-07
Acidification Potential (AP) [kg SO2 eq.]	7,55E-02	2,57E-03	9,99E-05	2,08E-03	1,24E-04	3,85E-03	1,94E-05	1,21E-03	7,51E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,39E-02	9,23E-02	1,63E-03	3,01E-03	2,02E-04	2,48E-03	3,28E-05	7,44E-04	6,27E-02
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3,10E+00	2,76E-01	5,88E-03	9,58E-02	5,16E-03	1,54E-01	6,87E-04	4,02E-02	1,40E-01
Land Use [Pt]	3,75E+01	9,88E-01	9,65E-02	1,40E+00	1,11E-01	1,92E+00	2,59E-02	6,97E-01	2,27E+01
Hazardous waste disposed (HWD) [kg]	2,93E-07	2,89E-09	7,26E-10	5,57E-09	1,00E-09	2,58E-09	6,63E-10	3,53E-09	1,02E-10
GW (based on IPCC AR6), excl. Biogenic carbon	1,72E+01	3,89E-01	8,77E-02	5,32E-01	3,13E-02	9,32E-01	9,96E-03	4,01E-01	1,49E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,02E-02	3,71E-08	4,65E-09	3,41E-03	2,35E-09	2,16E-07	1,07E-09	1,68E-08	1,09E-09

ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,22E+00	3,03E-02	3,57E-03	3,91E-02	2,84E-03	6,27E-02	8,97E-04	1,85E-02	2,04E-01
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,19E+00	-2,82E-02	-3,11E-03	-3,67E-02	-2,62E-03	-6,18E-02	-8,44E-04	-1,81E-02	-4,40E-01
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,13E-02	6,18E-04	3,15E-05	1,78E-03	7,30E-05	9,00E-04	1,86E-05	1,23E-03	1,64E-03
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,71E+01	3,88E-01	8,76E-02	5,27E-01	3,12E-02	9,31E-01	9,95E-03	4,00E-01	1,48E-01
Blue water use [kg]	2,02E+04	2,79E+03	6,35E+01	5,04E+02	3,25E+01	1,00E+03	1,29E+01	2,90E+02	5,10E+02

Table 5-6 - Environmental impacts of The Fairphone (Gen. 6) production, Footprint (RM + RE)

	Total	Assembly	Display	Earpiece	Front Camera	Battery	Loudspeaker	Lower Back Cover	Main Camera	Main FPC
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,40E-03	1,08E-05	1,00E-04	1,27E-06	3,56E-05	5,69E-05	5,35E-06	5,87E-07	1,17E-04	3,98E-05
Acidification Potential (AP) [kg SO2 eq.]	1,23E-01	1,43E-03	7,92E-03	1,55E-04	3,47E-03	6,50E-03	2,79E-04	7,93E-05	1,65E-02	5,73E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,95E+00	4,56E-01	1,89E+00	3,92E-04	4,85E-02	8,08E-02	1,37E-01	1,37E-02	5,83E-02	1,00E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,46E+00	6,10E-01	2,56E+00	5,25E-03	1,98E-01	4,66E-01	1,35E-01	2,84E-02	7,43E-01	3,04E-02
Land Use [Pt]	2,68E+02	3,41E+01	1,46E+02	3,38E-02	5,12E+00	1,75E+00	2,03E-01	6,22E-02	1,12E+01	3,88E-01
Hazardous waste disposed (HWD) [kg]	4,15E-07	7,23E-11	4,68E-08	3,97E-11	3,33E-10	5,19E-08	5,28E-09	1,36E-09	7,83E-10	1,26E-09
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	2,51E+01	2,37E-01	1,50E+00	8,03E-03	7,57E-01	1,12E+00	2,32E-02	2,19E-02	3,60E+00	1,48E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,38E-02	3,98E-10	1,16E-07	5,46E-10	2,17E-07	2,18E-04	3,77E-08	1,82E-09	1,07E-06	9,22E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,01E+00	9,70E-03	7,82E-02	4,53E-04	5,57E-02	1,70E-02	1,13E-03	1,63E-03	2,66E-01	1,13E-02
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,20E+00	-9,04E-03	-7,28E-02	-4,17E-04	-5,50E-02	-1,64E-02	-1,10E-03	-1,54E-03	-2,64E-01	-9,88E-03
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,18E-02	4,94E-04	2,48E-03	1,04E-05	2,21E-04	4,71E-04	5,67E-05	4,22E-05	7,82E-04	3,91E-04
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	2,67E+01	2,37E-01	1,50E+00	8,02E-03	7,56E-01	1,12E+00	2,32E-02	2,19E-02	3,59E+00	1,48E-01
Blue water use [kg]	5,40E+04	3,66E+03	1,61E+04	3,17E+01	1,26E+03	2,24E+03	9,14E+01	1,19E+02	4,78E+03	1,25E+02

	Main PCBA	Mid Frame	Sim Tray	Sub PCBA	Top Unit	Ultra-Wide Camera	Upper Back Cover	USB-C Port	Packaging
Abiotic Depletion (ADP elements) [kg Sb eq.]	5,49E-04	3,09E-04	7,54E-07	1,23E-04	4,16E-06	3,24E-05	1,13E-08	1,25E-05	8,53E-07
Acidification Potential (AP) [kg SO2 eq.]	7,62E-02	2,57E-03	9,99E-05	2,08E-03	1,24E-04	3,33E-03	1,94E-05	1,21E-03	7,51E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,41E-02	9,23E-02	1,63E-03	3,01E-03	2,02E-04	4,84E-02	3,28E-05	7,44E-04	6,27E-02
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,93E+00	2,76E-01	5,88E-03	9,58E-02	5,16E-03	1,93E-01	6,87E-04	4,02E-02	1,40E-01
Land Use [Pt]	3,79E+01	9,88E-01	9,65E-02	1,40E+00	1,11E-01	5,08E+00	2,59E-02	6,97E-01	2,27E+01
Hazardous waste disposed (HWD) [kg]	2,92E-07	2,89E-09	7,26E-10	5,57E-09	1,00E-09	6,46E-10	6,63E-10	3,53E-09	1,02E-10
GW (based on IPCC AR6), excl. Biogenic carbon	1,54E+01	3,89E-01	8,77E-02	5,32E-01	3,13E-02	7,33E-01	9,96E-03	4,01E-01	1,49E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,02E-02	3,71E-08	4,65E-09	3,41E-03	2,35E-09	2,07E-07	1,07E-09	1,68E-08	1,09E-09

ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,21E+00	3,03E-02	3,57E-03	3,91E-02	2,84E-03	5,38E-02	8,97E-04	1,85E-02	2,04E-01
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,19E+00	-2,82E-02	-3,11E-03	-3,67E-02	-2,62E-03	-5,30E-02	-8,44E-04	-1,81E-02	-4,40E-01
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,12E-02	6,18E-04	3,15E-05	1,78E-03	7,30E-05	2,56E-04	1,86E-05	1,23E-03	1,64E-03
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,70E+01	3,88E-01	8,76E-02	5,27E-01	3,12E-02	7,33E-01	9,95E-03	4,00E-01	1,48E-01
Blue water use [kg]	2,02E+04	2,79E+03	6,35E+01	5,04E+02	3,25E+01	1,22E+03	1,29E+01	2,90E+02	5,10E+02

6 Life cycle interpretation and sensitivity analysis

6.1 The Fairphone (Gen. 6) general results

This section interprets the results of The Fairphone (Gen. 6) LCA. All sub-sections focus primarily on the Footprint (RM), except when signaled otherwise. A brief overview of what the different footprints entail can be found in Section 3.1.

Figure 6-1, Figure 6-2 and Figure 6-3 below show the full life cycle impacts distribution for all three footprints. The graphics include all indicators under analysis.

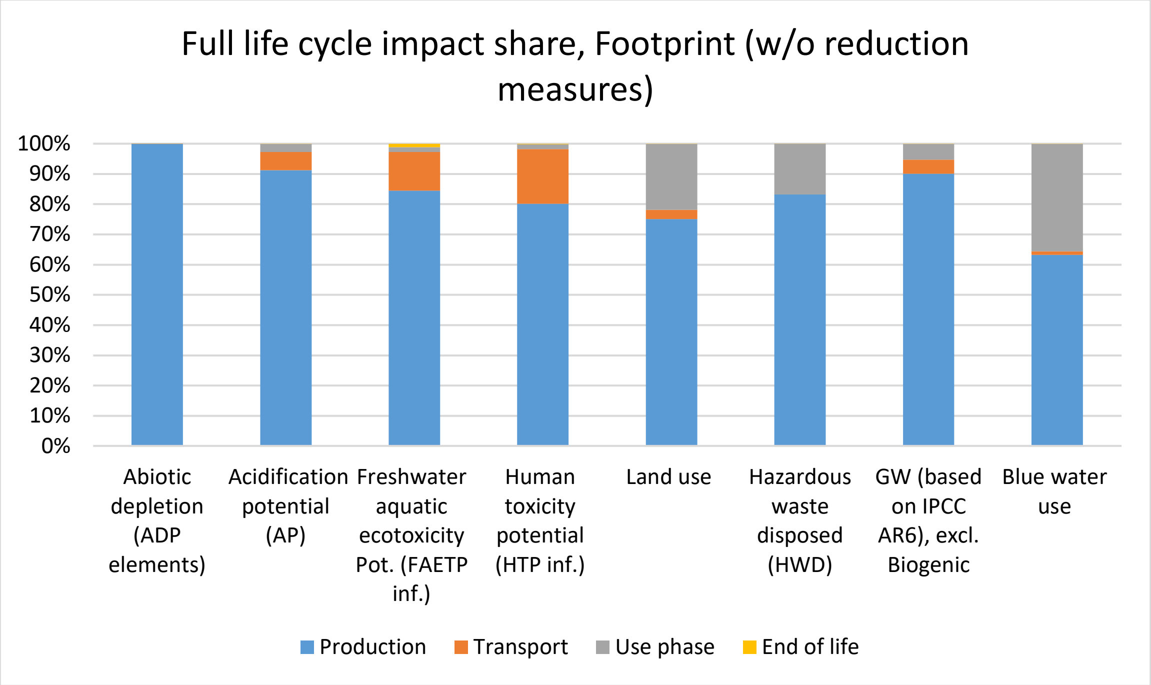

Figure 6-1 - Full life cycle impacts distribution for The Fairphone (Gen. 6), Footprint (w/o reduction measures)

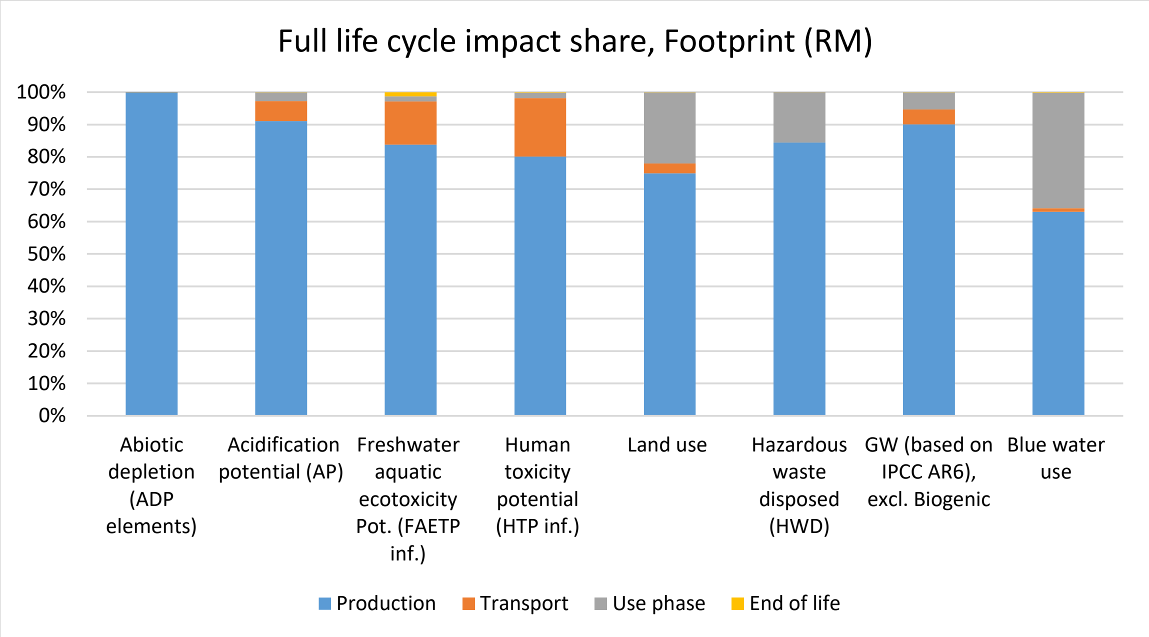

Figure 6-2 - Full life cycle impacts distribution for The Fairphone (Gen. 6), Footprint (RM)

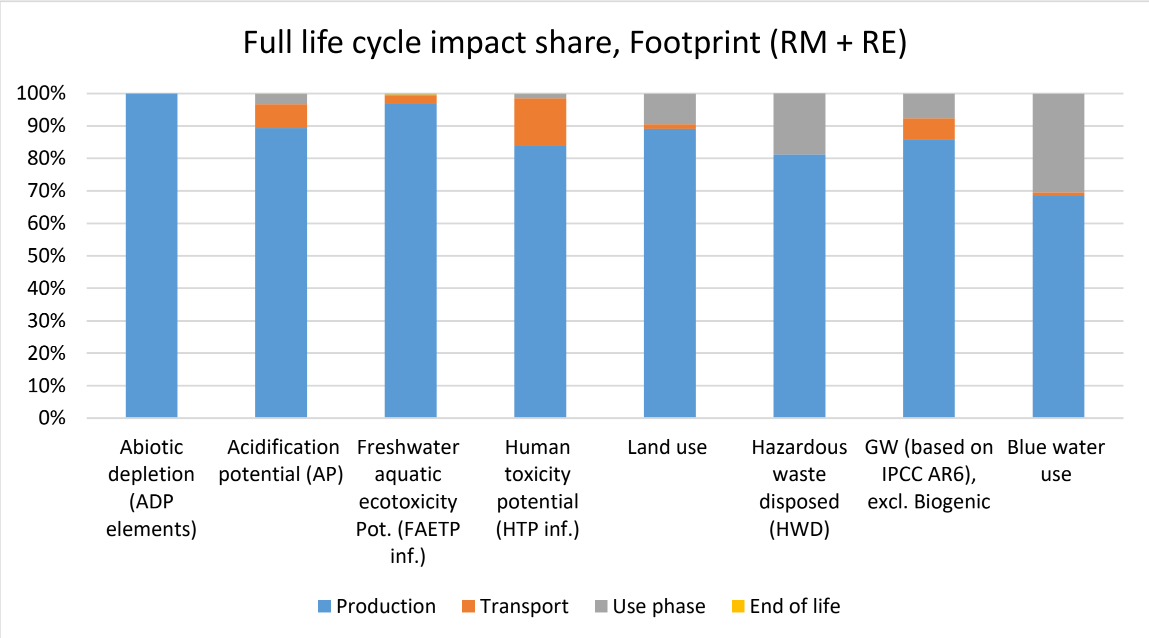

Figure 6-3 - Full life cycle impacts distribution for The Fairphone (Gen. 6), Footprint (RM + RE)

Across all analyzed categories, the production of the device is the main contributor, ranging from 60% to almost 100% (in particular for mineral and resource depletion). The use phase is, for some indicators, the second main contributor: above 20% for land use, 15% for hazardous waste generation and almost 40% for water use. In the case of hazardous waste, the main causes are both the generation of hazardous waste during oil and coal burning but also renewable energies like wind energy, since currently the blades of wind turbines cannot be recycled[16] due to their material composition (Rathore & Panwar, 2022). Similarly, for the indicator land use, renewable energies also play a role since they are usually land intensive (e.g. PV, wind, hydro). Transport shows its biggest contribution in both eco- and human toxicity, with around 10% contribution, while being mostly negligible in the rest of the indicators. Lastly, EoL does not show a significant contribution in any indicator.

In order to estimate the benefits of increased lifespan, the comparison of the yearly impacts for different usage periods is displayed in Figure Figure 6-4. Extending the life of the device to 5 years results in a reduction of 35% in the emissions, while an extension to 10 years reaches a 61% reduction of the yearly emissions. It shall be noted that these yearly emissions are theoretical, since in actuality the impacts do not occur yearly.

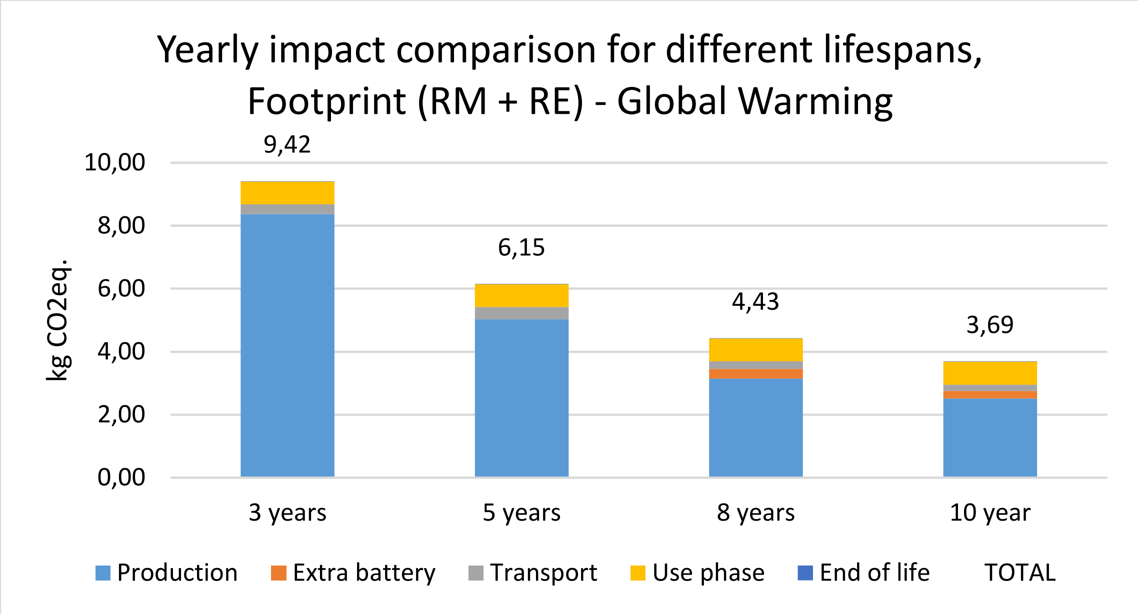

Figure 6-4 - Global warming comparison for different phone lifespan scenarios, Footprint (RM + RE)

The following sub-sections dive deeper in the LCA results.

6.1.1 Production Phase

Figure 6-5 below shows the production impact distribution for all indicators per module.

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[16] https://edition.cnn.com/2023/05/28/world/wind-turbine-recycling-climate-intl

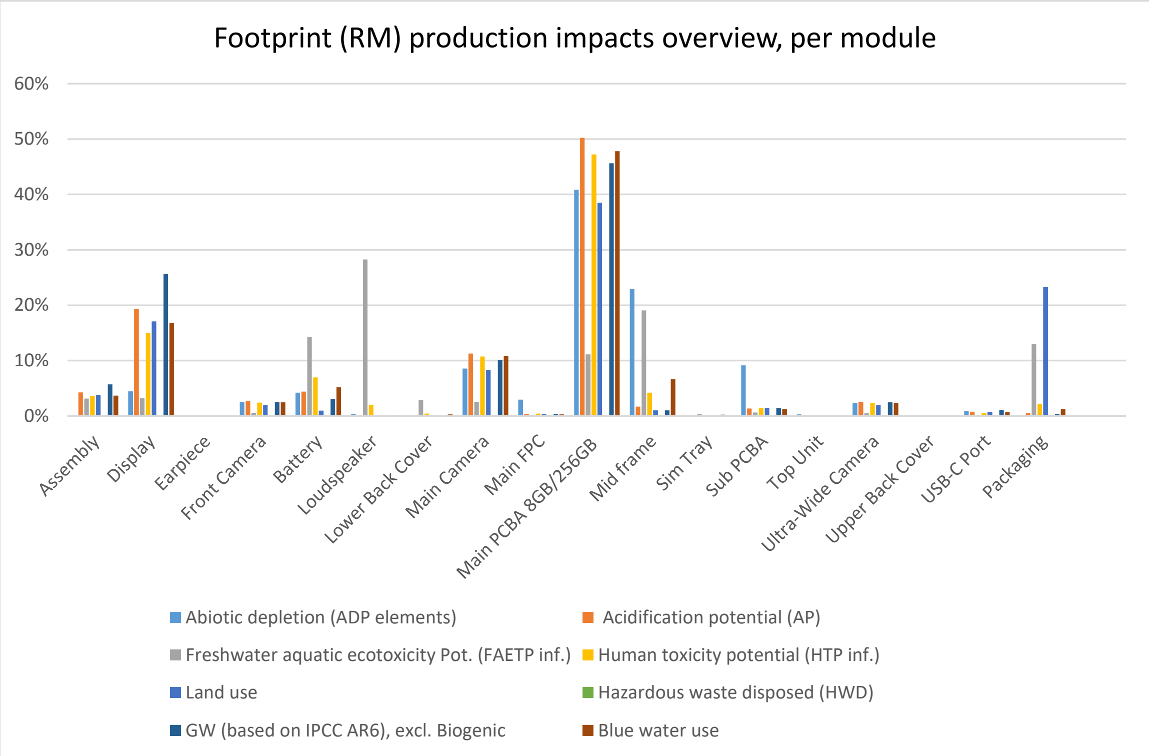


Figure 6-5 - Production impacts distribution for selected indicators for Footprint (RM), per module

The main PCBA, where all the device's electronics are contained, is the main contributor (except for ecotoxicity) and contributes around 50% for most indicators. The display's share of impact lays between 3% and 26%, being the most relevant in acidification, hazardous waste, global warming and water use. The main camera also shows a contribution of up to 10% for most of the analyzed indicators. The battery has comparatively a more modest contribution but stands out in ecotoxicity and hazardous waste generation with a contribution of around 10%.

For the ecotoxicity indicator the most relevant modules are the loudspeaker, the mid frame and the packaging. In the case of the loudspeaker the impact is related mostly to the tungsten and in the case of the midframe it is mostly driven by the molybdenum. In both cases Ecoinvent datasets were used (in the absence of more appropriate ones from Sphera), which very likely overestimate the toxicity effects of the background energy datasets used for the mining activities. Therefore, the actual impact of these modules for this indicator are likely lower and thus their contribution less relevant.

Although the discrepancies between databases are known, their specific causes are still not fully clear. In (Pauer, Wohner, & Tacker, 2020), a literature review on the topic reveals that while consistently observed, the causes and direction of the differences between Sphera and Ecoinvent databases are mixed. In their own analysis comparing the environmental impacts of several packaging options however, they observe similar dissonances as the ones observed in this study i.e. the modelling of energy mixes drives many of the more pronounced differences. As examples the paper mentions higher SO2 emissions during coal-fired power plants in the background datasets and higher phosphates release during treatment of coal mining overburden, which triggers eutrophication. Furthermore, human toxicity is also identified as an indicator affected by these differences.

In the following sub-sections, a closer look into the modules identified as relevant is taken.

6.1.1.1 Main PCBA

The impact distribution for the main PCBA can be seen in Figure 6-6 below. For all impact categories under study, the IC manufacturing is the most relevant activity with a contribution ranging from 70-90%. The PCB is the second contributor with a comparatively lower contribution of around 10-20% of the impacts. For ADPe, the connectors are also relevant (due to the gold plating they use).

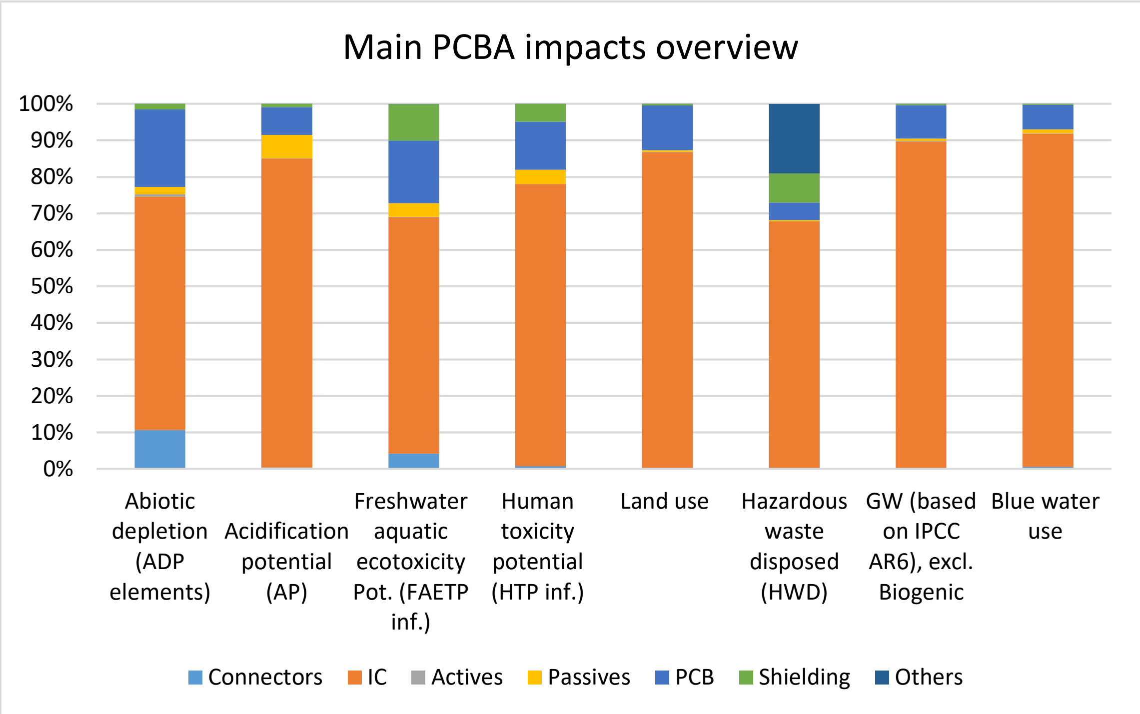


Figure 6-6 - Main PCBA impact distribution for selected indicators

The share of impacts for the ICs is displayed in Figure 6-7 below. For ADPe, once again, the gold used is the most relevant aspect. As such the storage chip and the accumulation of other miscellaneous chips are driving the impact. For all other indicators, the distribution is relatively similar: the storage and processor stand out as the single chips with the biggest contribution. Besides, the amplifier chips together also add up to a significant contribution for most indicators. Other types of chips show lower impacts which vary in proportion of the amount mounted on the PCB.

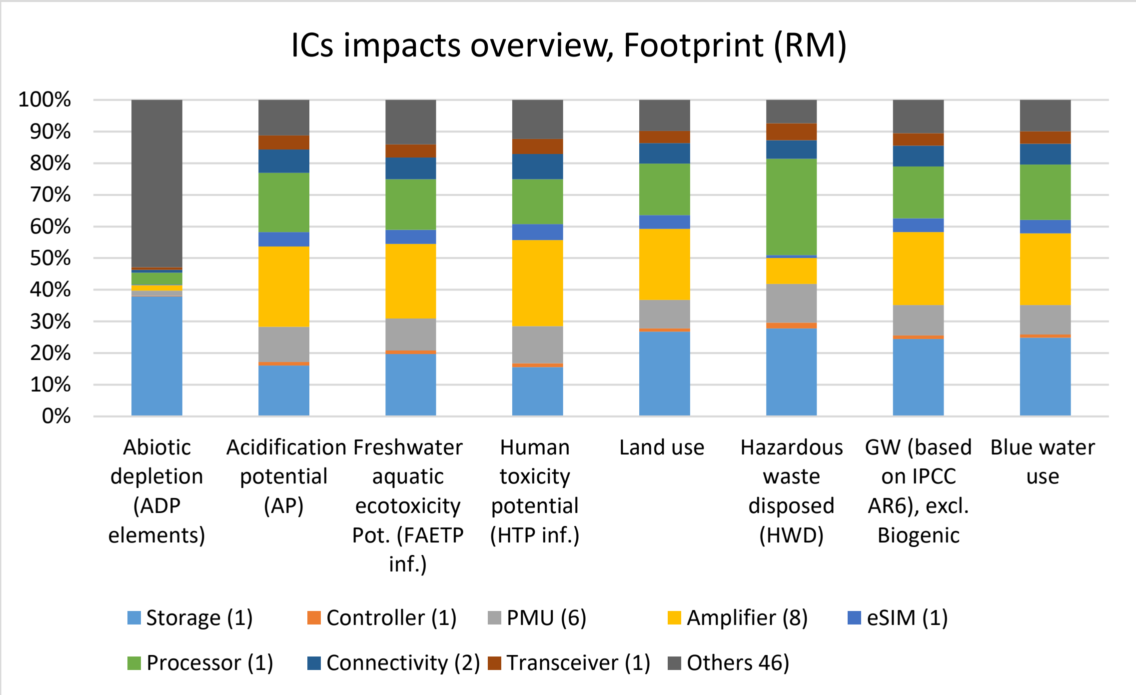


Figure 6-7 - Impacts distribution for the ICs in The Fairphone (Gen. 6), grouped per IC type. The value in brackets represents the amount of chips per category.

When zooming into the memory component as an example (see Figure 6-8), it is a multi-chip package (MCP) combining DRAM and NAND memory dies within a single package. we can see that the front-end manufacturing dominates the impacts. According to the product's datasheet the package contains 4 DRAM dies of 16 Gb each, plus an undefined number of dies comprising the flash memory (NAND). According to an analysis performed in 2022 by TechInsights[17], where they look into YMTC 232L NAND dies from different manufacturers, the number of dies could vary depending on the capacity per die. 232L dies in the analysis show a total capacity of around 1 Tb per die, which would require 2 flash dies to provide The Fairphone (Gen. 6) memory capacity. However, in the same analysis, the Micron 128L and 176L memory dies have half of that capacity, meaning 4 NAND dies. Based on x-ray images provided by Fairphone B.V., the latter option seems to fit the die distribution of the memory component under investigation and has been chosen for the modelling. According to these images, the flash die area is significantly bigger than the DRAM die area and thus shows a higher relevance in the environmental impacts. The impacts here are, for all indicators, mostly related to the energy used in the front-end manufacturing processes. Furthermore, the main countries (Taiwan, Japan, China) manufacturing ICs still heavily rely on fossil fuels.

[17] https://www.techinsights.com/blog/comparison-latest-3d-nand-products-ymtc-samsung-sk-hynix-and-micron

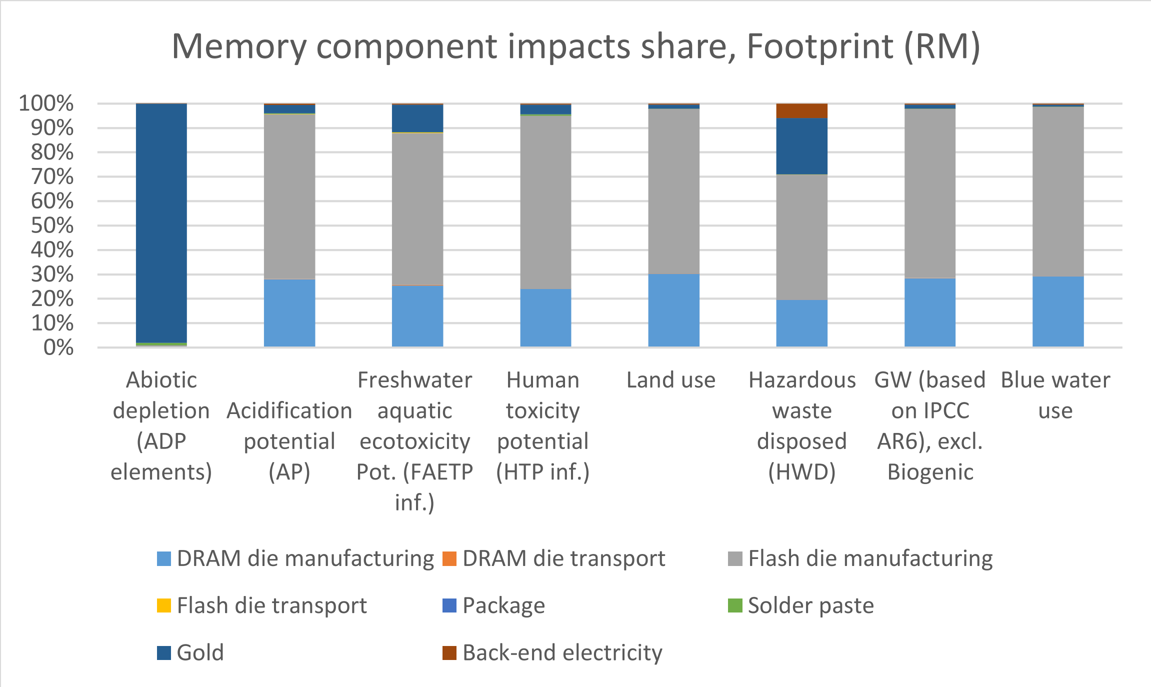


Figure 6-8 - Impacts distribution for the memory component

Due to the relevance of the storage and the uncertainties regarding the available data, Section 6.5 presents a sensitivity analysis of its environmental footprint.

6.1.1.2 Display

Figure 6-9 below shows the impacts distribution of the display. For most indicators, the manufacturing energy is the most relevant aspect. It shall be reminded that the Footprint (RM) model does not yet include the renewable energy employed for the production of some modules such as the display. To see the effect of this measure, please refer to 6.1.2.

For the Footprint (RM), the manufacturing energy is the main environmental hotspot and it takes up above 60% of impacts for all categories other than ADPe and hazardous waste generation.

ADPe is driven by the gold usage in both the FPC and the controller ICs.

Freshwater ecotoxicity is driven by the process of indium tin oxide sputtering in the display manufacturing process. Following the hotspots of the Ecoinvent dataset used for the process, it involves binding the ITO into a copper plate and the production of such equipment involves copper ion emissions during copper tailing treatment.

HWD is driven also significantly from energy use but also by the production of 2-Ethylhexyl Acrylate for the IC cover tapes used in the display. While the causes are not directly accessible in the dataset, tracking the full documentation by EBAM (EBAM, 2024) hints that the usage of stabilizer for acrylic acid during production can end up in relevant amounts in wastewater.

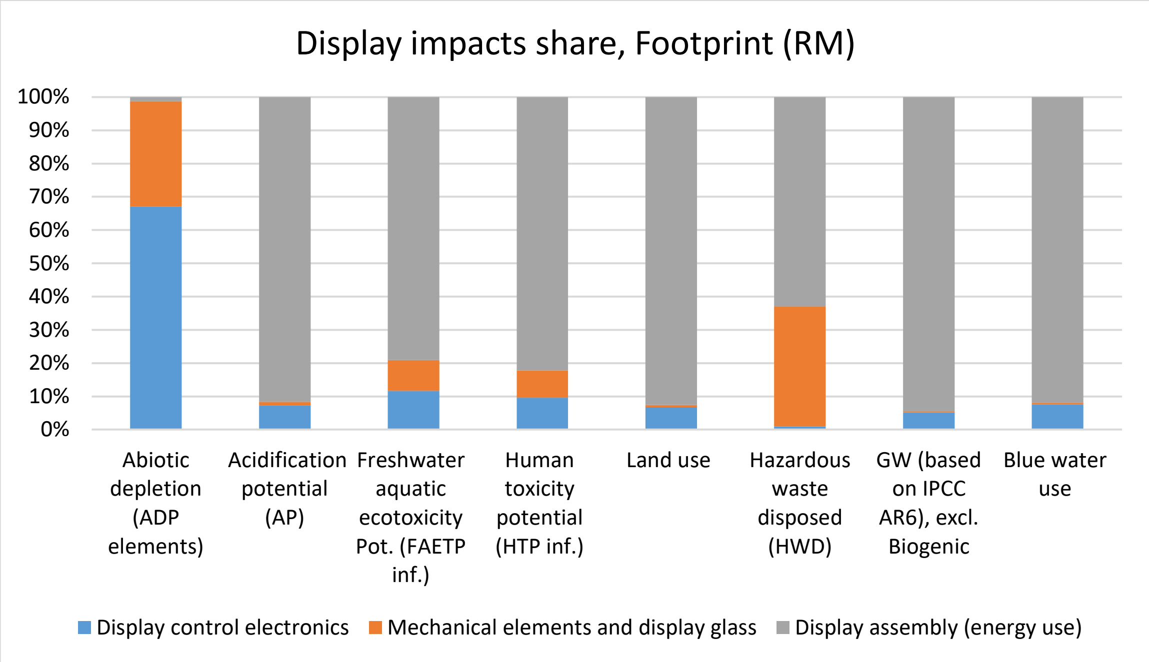


Figure 6-9 - Impacts distribution for the production of the display of The Fairphone (Gen. 6)

6.1.1.3 Main Camera

Figure 6-10 shows the impact share for the main camera, the one with the highest environmental impacts of the three cameras in the device. For most impact indicators, the sensor die (modelled as a bare die i.e. no packaging) is the highest contributor, representing 90% for acidification, human toxicity, land use, global warming and water use. In the case of ADPe, the camera component shows the biggest contribution due to its gold content. In hazardous waste generation, the manufacturing energy shows the biggest contribution with 70%. The manufacturing impact is calculated using primary data provided by the manufacturer and is based on the Chinese electricity mix. The Chinese mix is still heavily reliant on coal and oil[18] combustion, which generates several hazardous residuals[19]. In the indicator of ecotoxicity, the contribution of the camera component is also relevant (around 30%), mostly related to various metals in the component (e.g. chromium, iron). According to the dataset hotspot analysis from Ecoinvent, the impact mainly originates from the mining step, specifically during treatment of bauxite waste (red mud). This mostly involves emissions of metallic ions into the environment. The camera uses chromium in several alloys across different parts and pieces.

[18] https://www.iea.org/countries/china

[19] https://www.epa.gov/coal-combustion-residuals/coal-combustion-residuals-ccr-basics

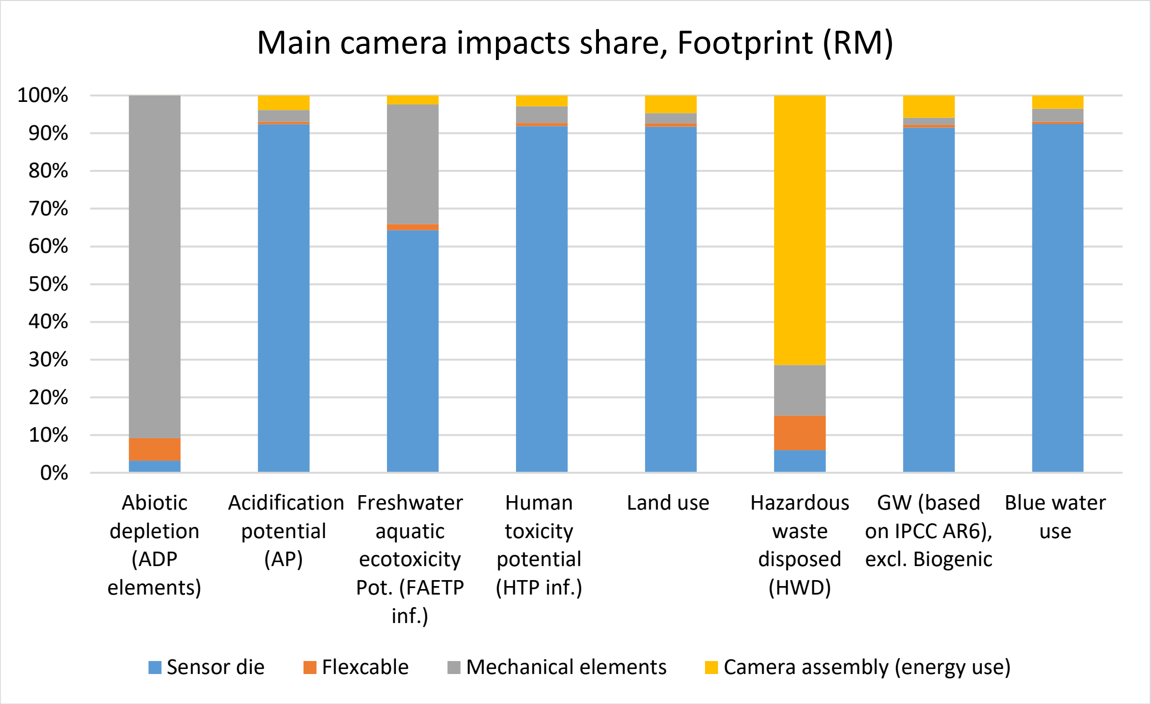


Figure 6-10 - Impacts distribution of the main camera module

The same impact distribution can be observed in the front camera and the ultra-wide camera as well.

6.1.1.4 Battery

The figure below shows the impact distribution for the battery. The energy use during the battery cell manufacturing shows the biggest contribution across the indicators (except ADPe where the electronics are more relevant). It is relevant to note that the electricity needed to manufacture the cell is not included in the modelling (i.e. it is modelled on a material basis). However, Fairphone B.V. did facilitate Product Carbon Footprint (PCF) data from the battery supplier and, for global warming, the current modelling shows a slight underestimation of around 17% for the battery cell, which results in an underestimation of 2% at the full battery level.

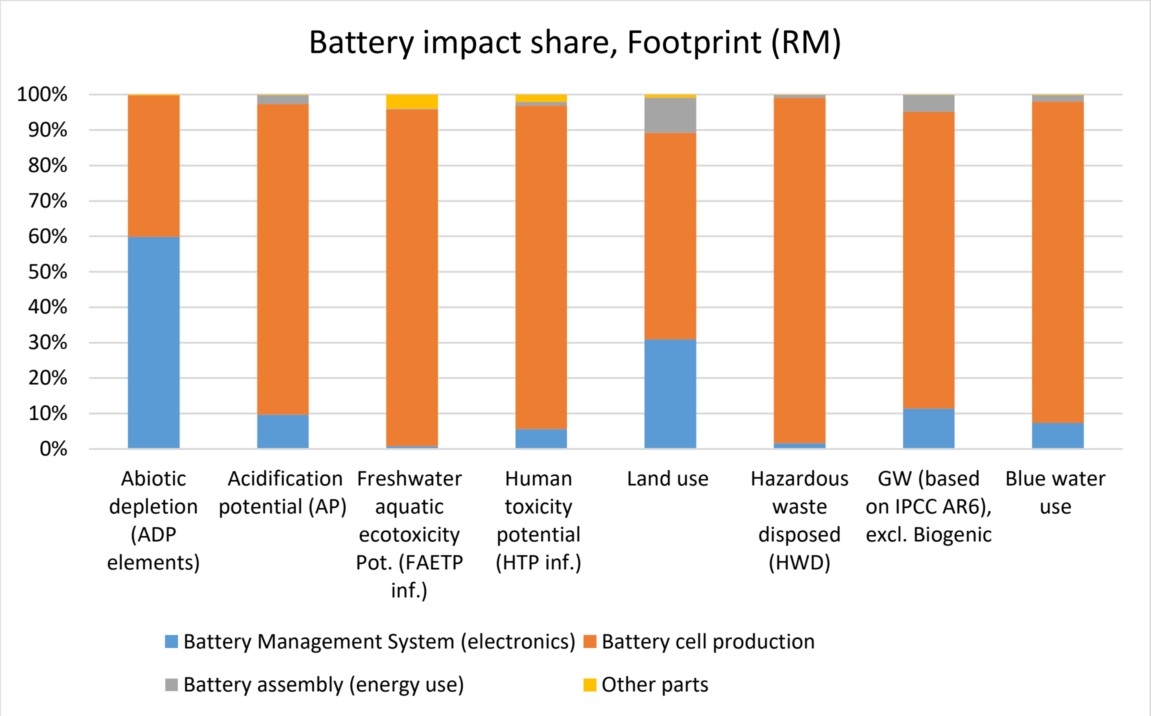


Figure 6-11 - Impacts distribution of the battery of the Fairphone (Gen. 6)

6.1.1.5 Transport and EoL

Figure Figure 6-12 below shows the impacts for the device transport, divided by distribution section. For all indicators, the transport to the distribution hub is the highest since it's the only part that includes air transport, which has comparatively a massive impact as opposed to sea and land transport. In the broader context, the transport phase is most relevant for both eco- and human toxicity, mostly due to fumes and direct emissions of burned fuel (see Section 5.1).

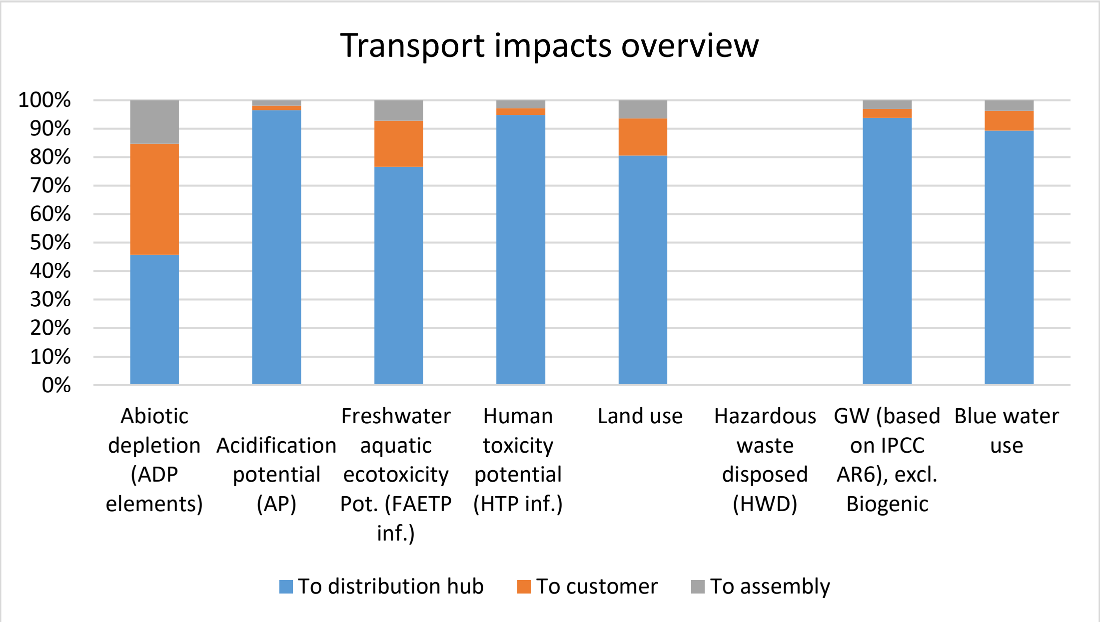
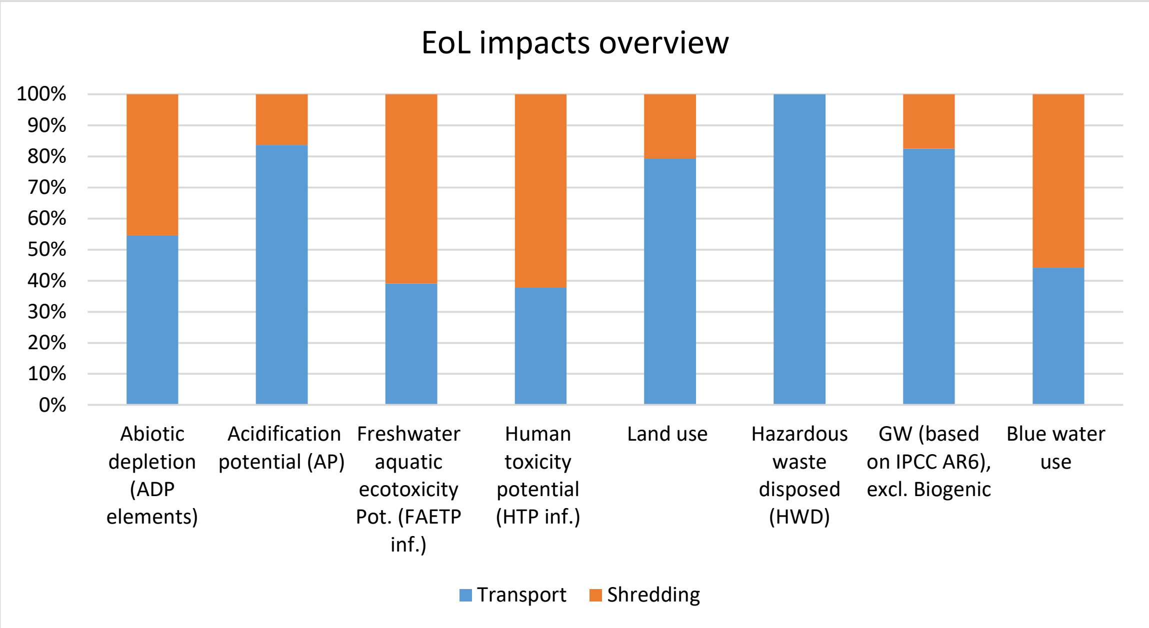


Figure 6-12 - Impacts distribution of the different transport sections during distribution

Lastly, Figure 6-12 shows the impact distribution for the EoL. For most impact categories, the transport to the disposal site is the main contributor to the EoL impacts except for eco- and human toxicity, where the shredding step shows an almost equal contribution. As explained in our previous LCA (Sánchez, Baur, & Eguren, 2024), this is connected in the model to release of particles during shredding although it is very likely that the Ecoinvent dataset used is no longer representative of current shredding practices. As mentioned in the scope section, the rest of the EoL process after pre-treatment is not considered in this study.



6.1.2 Eco-design measures

In this section, a closer look will be taken into the eco-design measures that Fairphone has been applying to its devices. The focus will be in two main actions: the use of recycled materials and the use of renewable energies. For that, the impacts are divided into three different footprints:

- Footprint (w/o reduction measures): footprint with no eco-design measures whatsoever. It uses only primary materials and no renewable energies.
- Footprint (RM): this footprint includes the recycled content used in the device but no renewable energy.
- Footprint (RM + RE): full eco-design footprint, with The Fairphone (Gen. 6) as sold to consumers. Wherever Fairphone B.V. and its suppliers could provide certificates for the use of renewable energy, it was included in the model.

Figure 6-13 shows the comparison for global warming for the three footprints at the full life cycle level and Figure 6-14 shows the same comparison for production only. At a life cycle level, the use of recycled materials achieve a 1% reduction of emissions, while adding the decarbonization of the supply chain achieves a further reduction of 31% of the emissions.

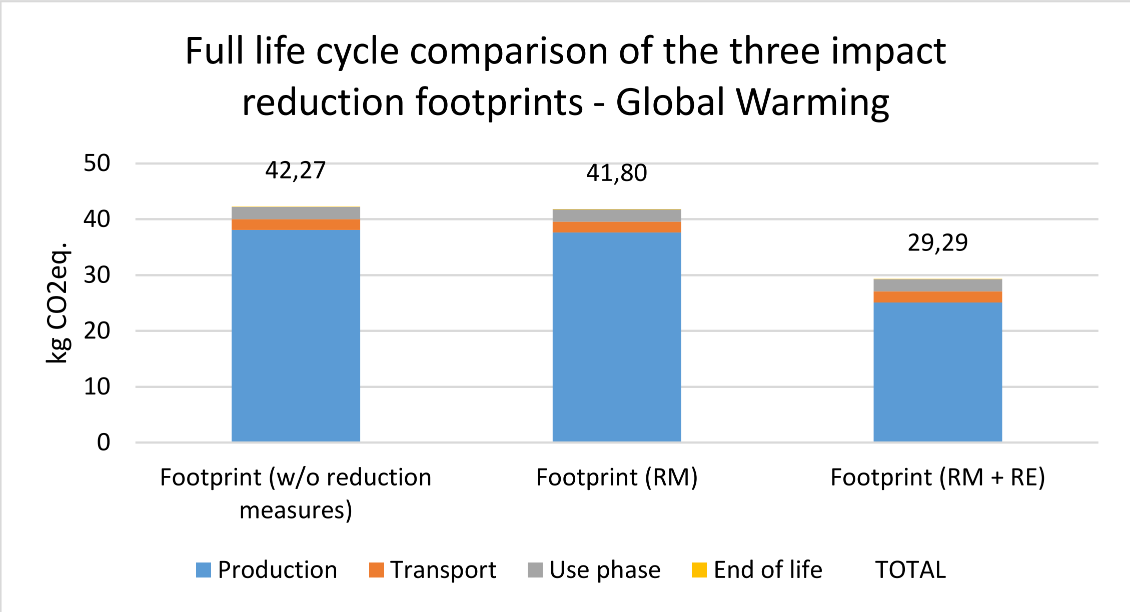


Figure 6-13 - Comparison of environmental impact reduction measures for global warming, full life cycle

The environmental impact reduction measures reflected in the different footprints are all addressing impacts at the level of production. The use of recycled material shows a low reduction. This is because the main driver for most impacts analyzed is the energy use during the manufacturing of the electronics, which is not affected by the use of recycled material. This can also be seen when comparing with the Footprint (RM + RE), where the use of renewable energy in memory chip production shows a reduction of the main PCBA impacts but more importantly, the use of RE in the display production shows a massive reduction due to its high energy requirement.

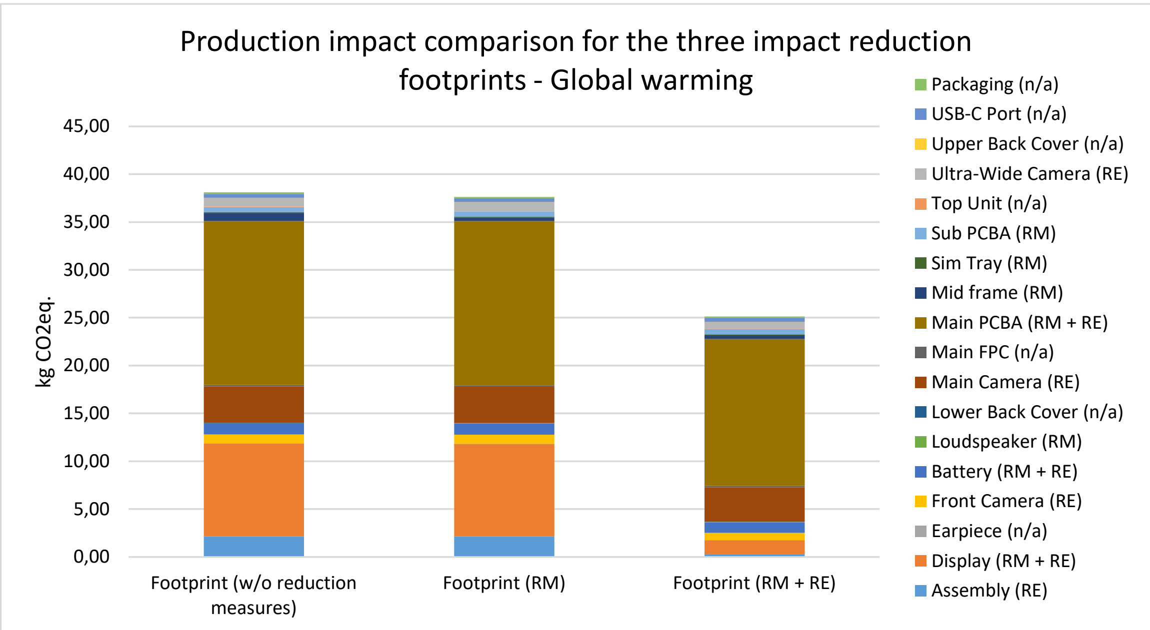


Figure 6-14 - Comparison of environmental impact reduction measures for global warming, production phase

Table 6-1 shows the changes in the total life cycle impacts for all indicators:

Table 6-1 - Full life cycle impacts for different environmental impact reduction measures. Values marked with an asterisk (*) are affected by mixing different databases and therefore do not necessarily represent an actual increase.

	Footprint (w/o reduction measures)	Footprint (RM)		Footprint (RM + RE)	
ADPe	1,41E-03	1,35E-03	-4%	1,40E-03	-1%
AP	1,68E-01	1,65E-01	-2%	1,38E-01	-18%
FAETP	6,05E-01	5,78E-01	-5%	3,04E+00	+403%*
HTTP	8,24E+00	8,20E+00	-1%	1,01E+01	+23%*
LU	1,31E+02	1,30E+02	-1%	3,00E+02	+130%
HWD	5,71E-07	6,17E-07	+8%	5,11E-07	-11%
GW	4,23E+01	4,18E+01	-1%	2,93E+01	-31%
WU	6,74E+04	6,70E+04	-1%	7,88E+04	+17%

The Footprint (RM) shows its biggest reduction in ADPe, 4% less compared to the Footprint (w/o reduction measures). As a counterpart, the use of recycled content shows a 9% increase on HWD, connected to the use of quicklime in order to produce recycled iron. This is however compensated in the Footprint (RM + RE) by replacing the Chinese national grid by renewable energies in many modules, resulting in a 9% reduction compared to the Footprint (w/o reduction measures). The biggest reductions for the Footprint (RM + RE) are for acidification and global warming. A significant increase however can be seen for both eco- and human toxicity in RE as opposed to the Footprint (w/o measures), although in this case the results are probably distorted by known issues with the background data used in Ecoinvent datasets (Chinese PV could not be modelled with Sphera datasets and an Ecoinvent dataset was used). The increase in land use for the Footprint (RM + RE) however is probably accurate (+132%) and responds to PV being a relatively land-intensive energy generation method. Likewise, water use also increases 17% from Footprint (RM) due to the high water use in the production of the silicon and also in the processing of the wafers necessary for the PV panels. ~~for similar reasonseco.~~

6.2 Repair

In this section, the repair scenarios will be discussed and their environmental implications explained. These scenarios have been built using the Footprint (RM + RE), which includes all implemented measures to reduce environmental impact through recycled materials and renewable energy (see above).

6.2.1 General

In order to estimate the potential benefits of repair, two scenarios have been built, and their results for global warming are presented in Figure 6-15 below.

- Reference (no repair). For a total lifespan of 6 years and an average lifespan of 3 years per device, this scenario assumes the usage of 2 phones by replacing the faulty one every 3 years.

- Mixed repair. In this scenario one single phone is used for 6 years by repairing it once and having one battery replacement. The repair is modelled based on actual data provided by Fairphone B.V. on spare parts sales and warranty repairs. Then the production efforts of the new parts and the associated transport and EoL efforts are aggregated into a weighted average to create the repair overhead.

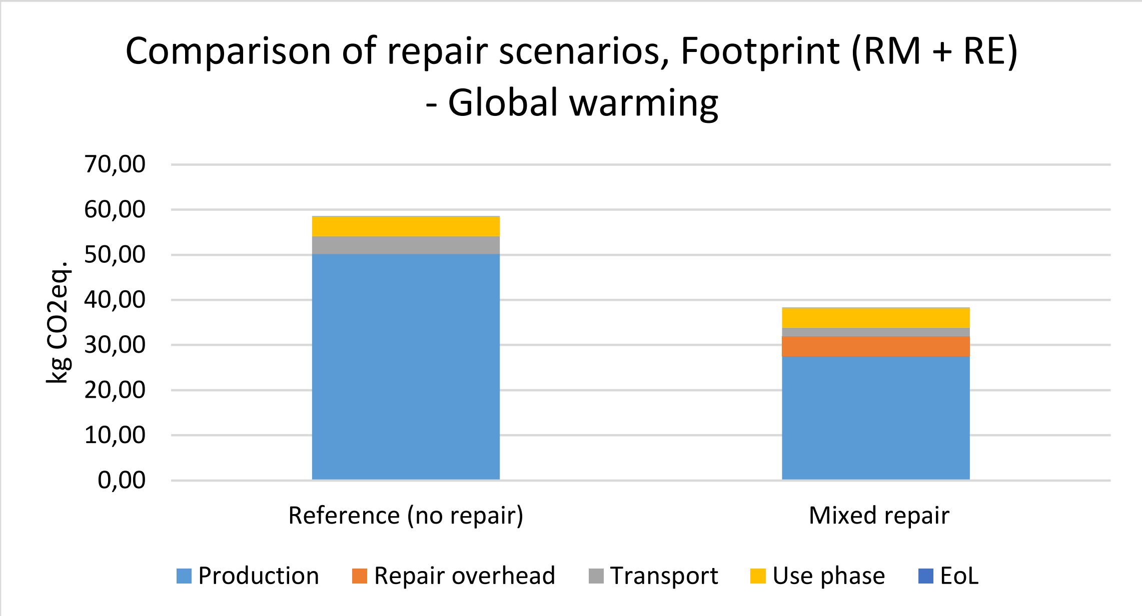


Figure 6-15 - Comparison of repair scenarios, global warming. This comparison uses Footprint (RM + RE) as reference.

The graphic shows clearly that by avoiding the need of producing a new device by instead producing only spare parts to replace faulty parts, repair shows a significant benefit. The total impacts for the mixed repair scenario are 34% lower than these of the reference scenario. Furthermore, by using renewable energy in the production of certain modules (e.g. display), the absolute repair overhead is minimized further.

6.2.2 Module level

Figure 6-16 below shows a spread of the module replacement and module repair scenarios for selected modules. In the module replacement scenario it is assumed that the module, when faulty, is fully replaced by a new one. In the module repair scenario, only the faulty part is replaced. The following parts are selected for repair:

- Display: glass
- Camera modules: camera component
- USB-C Port: USB-C connector component
- Loudspeaker: loudspeaker component
- Main PCBA: memory chip

The scenarios include all relevant repair overheads i.e. additional production efforts, transport, package and for the module repair also the soldering/desoldering energy use.

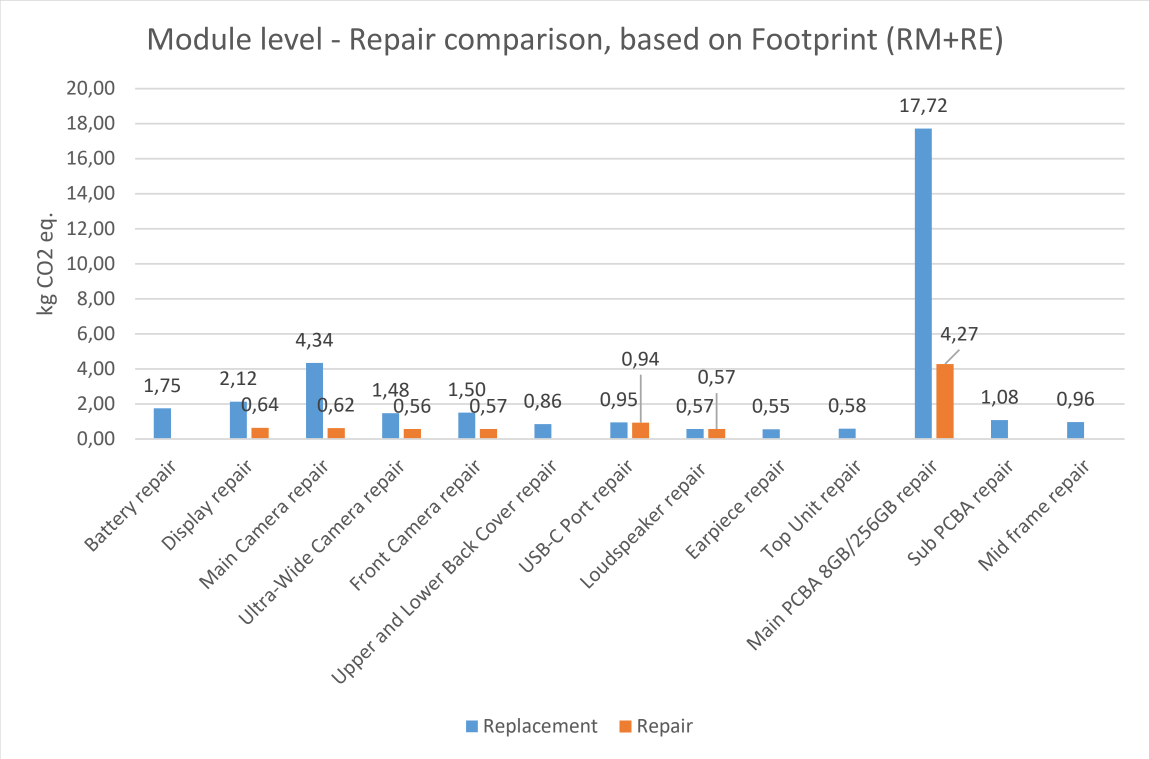


Figure 6-16 - Comparison of module level repair scenarios: full module replacement vs module repair. These models use Footprint (RM + RE) as a basis. Please note that the module level repair does not apply for all modules, since there is not always individual parts that can be replaced e.g. back cover, mid frame.

The graph shows, as also seen in previous LCAs (Sánchez, Baur, & Eguren, 2024), that from an environmental perspective module repair tends to pay off. This is not quite the case for smaller modules with lower impacts e.g. the USB-C module or the loudspeaker. In the case of bigger modules, the payoff is significant. This is particularly true for the main PCBA and the main camera. By using renewable energy in the display manufacturing and thus lowering its carbon footprint, the potential saving is also reduced. For other indicators like ADPe and blue water use, the opposite is true: since the impacts increase through the use of renewables in production, the quantifiable benefit of repair increases.

6.2.3 Payback

Another way to visualize the additional effort of repair is through an estimation of the theoretical environmental payback time needed after repair. When a module fails, repair activities entail certain effort and related environmental impacts (the repair overhead). These include the manufacturing of the new modules, their transport, their disposal and, if applicable, the repair activity itself (soldering and desoldering). If, as conceptualized in Section 6.1, the *yearly impact* can be understood to drop with extended use; then the payback time can be defined as the additional time a device has to be kept in use until the yearly impacts drop to the level prior to repair.

Table 6-2 shows the payback times in days for all modules. The graphic compares the replacement of the whole module versus the module-level repair, for those modules in which it is applicable. The model is based on global warming as the indicator and takes Footprint (RM + RE) as the basis.

Table 6-2 - Environmental payback time for the replacement and repair of the modules of The Fairphone (Gen. 6)

	Replacement	**Repair**
Phone replacement	929 days	n/a
Battery	29 days	n/a
Upper and Lower Back Cover	17 days	n/a
Display	34 days	14 days
Loudspeaker	13 days	13 days
Main camera	65 days	14 days
Ultra-Wide Camera	25 days	13 days
Front Camera	25 days	13 days
USB-C Port	18 days	18 days
Earpiece	12 days	n/a
Main PCBA 8GB/256GB	310 days	64 days
Mid frame	18 days	n/a
Sub PCBA	20 days	n/a

As a reference, replacing the full device has an estimated payback time of 3 years (900 days). The figure above shows that any repair entails an environmental benefit over a full replacement and always a significant one. The longest payback time is the main PCBA replacement which takes 10 months of use extension. The rest of the modules show a payback time of between 13 and 34 days only. The figure also shows that in general module level repairs pays off, especially in the case of high impact modules like the main PCBA where the payback time can be lowered to 2 months (64 days).

6.3 Modularity overhead

Modularity is a design feature that is, at least to some extent, exclusive to Fairphone. In order to make the phone discretely repairable, it has to be design to be modular and easy to dismantle. In previous iterations of the LCA (Sánchez, Baur, & Eguren, 2024) the additional components required to achieve this modularity have been named *modularity overhead* and have been assessed separately, in order to better identify the additional production footprint of modularity.

In recent years, the typical design of smartphones and the design of the Fairphone itself has changed. In order to assess what the modularity overhead is this generation, a comparative analysis has been performed. 12 devices from top brands released in 2024 and 2025 have been analyzed based on the teardown documentation in iFixit[20]. The aim of this comparative analysis was to see which design features, both external and internal, were exclusive to The Fairphone (Gen. 6) to make it modular. The analysis focused in for criteria: housing fasteners, internal modularity, internal connections and internal housing. The conclusions reached are the following:

- Housing fasteners. This is the main observed difference. The norm seems to be to glue the housing to provide ingress protection, while The Fairphone (Gen. 6) provides a less tight connection to allow for easy access to the interior.
- Internal modularity. Although there seems to be some small variation in the analyzed devices and one of them presented a more monolithic structure, in general all devices show to have a rather similar internal design to The Fairphone (Gen. 6).
- Internal connections. For the most part the internal connections are done very similarly as The Fairphone (Gen. 6), using board-to-board connections to bring together the different modules (e.g. cameras, display, battery, etc.). Some of the analyzed devices used glue for elements like the battery, while The Fairphone (Gen. 6) uses screws.
- Internal housing. The current version of the Fairphone already shows minimal internal housing when compared to previous iterations and this has also been observed in some of the analyzed devices.

Based on the above, it has been concluded that in this case there is no clear modularity overhead. The main difference observed has to do with how the main housing and some components like the display or the battery are attached together, but this does not represent so much an overhead i.e. additional pieces but rather a different piece (screws instead of glue).

6.4 Comparison with Fairphone 5

In order to assess the evolution of the device from an environmental perspective, this section provides a brief comparison of both devices. It shall be noted that this comparison is for indicative purposes, since there is methodological differences that influence the results. For this comparison, the baseline footprint for the Fairphone 5 has been used (which contains already the recycled content) (Sánchez, Baur, & Eguren, 2024) and for The Fairphone (Gen. 6) the Footprint (RM) has been used.

Figure 6-17 shows a comparison of global warming for the entire life cycle for both devices. For the entire life cycle, the impacts of both seem to be almost the same. For The Fairphone (Gen. 6) both transport and the use phase are lower. In the case of the transport, the lower use of air transport has contributed to the reduction of its impacts. In the case of the use phase, the longer battery life (53h as per test results provided by Fairphone B.V.) reduces the required annual charging cycles, which in turn reduces the overall energy need.

[20] https://de.ifixit.com/

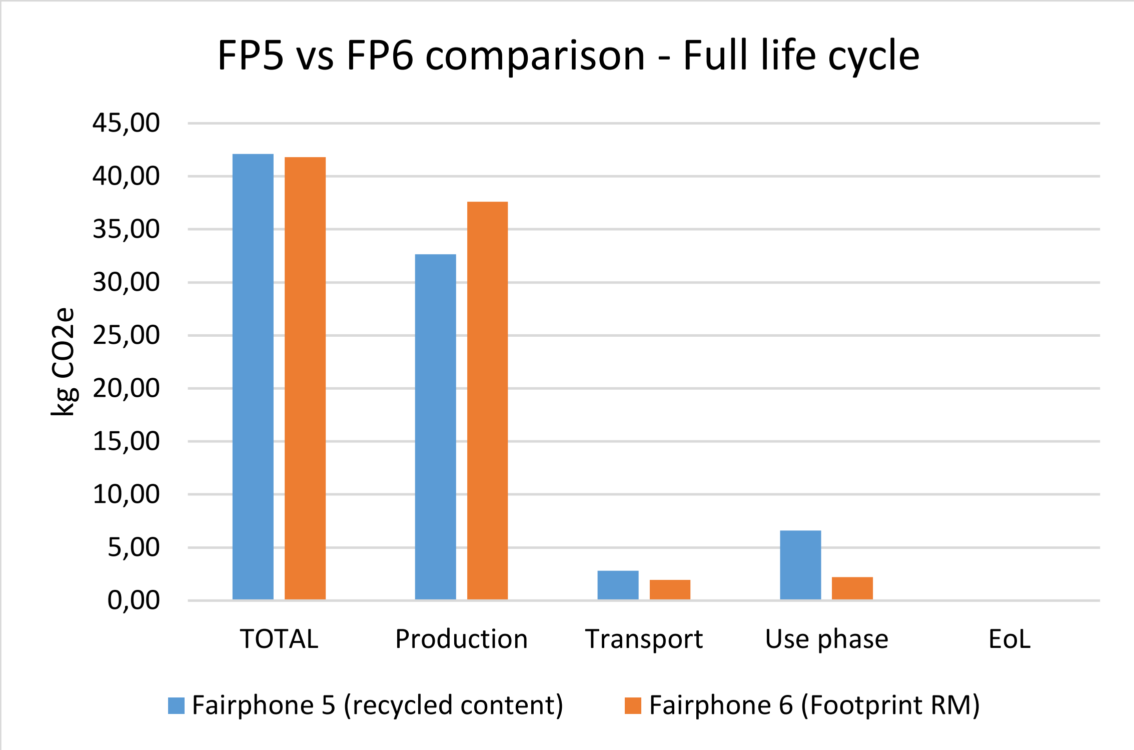


Figure 6-17 - GW comparison for The Fairphone (Gen.6) and Fairphone 5, at the full life cycle level

In the production phase, The Fairphone (Gen. 6) shows a higher impact. Figure 6-18 below shows the comparison per module. The assembly impacts are different mostly because the baseline footprint in Fairphone 5 already included the renewable energy use. For the battery, the cell modelling in Fairphone 5 did not include one of the active elements due to lack of suitable proxies in the used databases. In the current model however, this gap has been filled so the higher impact reflects rather a more comprehensive model. For all three cameras, the differences have to do with the differences on the sensor die size. Furthermore, the ultra-wide camera in this model is known to only have one layered die in the sensor, while for the Fairphone 5 since this data point was not known, a double layer was assumed. The display modelling difference is directly influenced by the manufacturing energy, which was based on literature for the Fairphone 5 and is now based on primary data provided by the supplier. Finally, the differences in the electronics modelling go in different directions: the processor chip, for example, shows higher impact in this version while the memory chip shows a lower one.

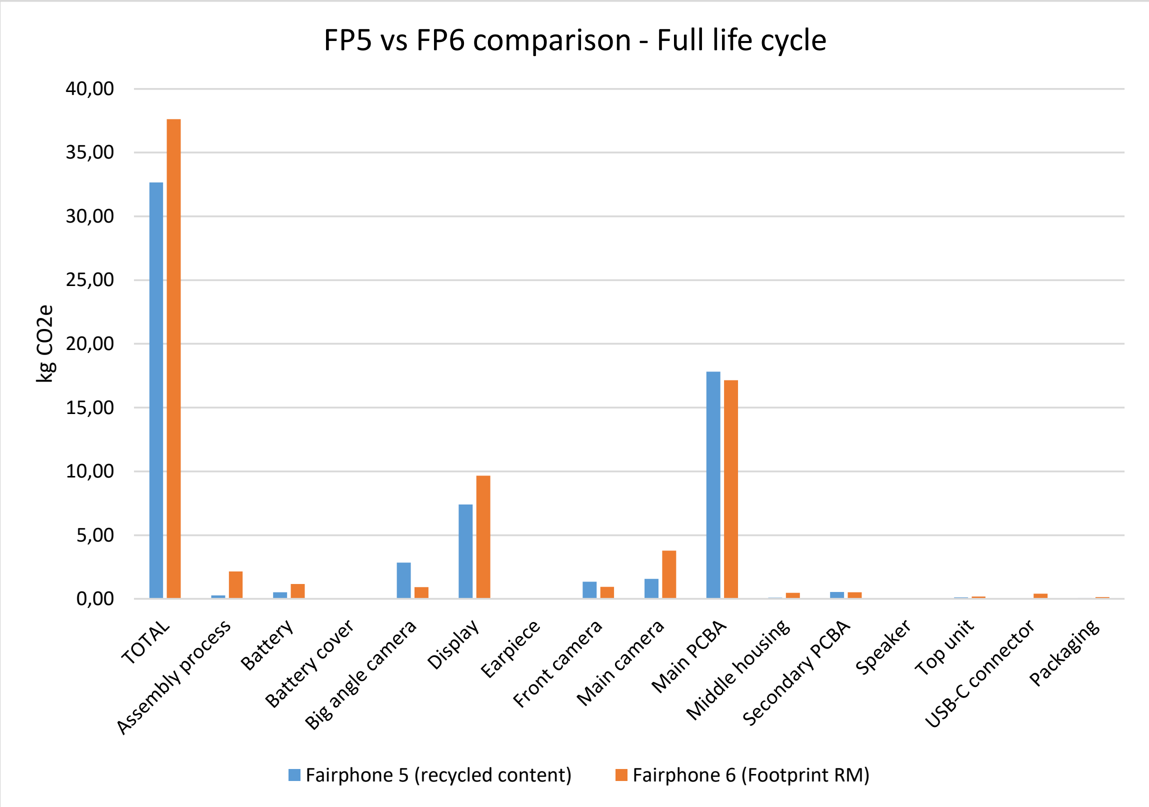


Figure 6-18 - GW comparison for the production phase of The Fairphone (Gen.6) and Fairphone 5

In conclusion, the methodological differences make it difficult to identify a strong trend but the overall production phase results seem to be very similar. When looking into the full life cycle, the longer battery life and a lower aircraft shipment use have a positive effect in the total emissions.

6.5 Sensitivity analysis

In this section, the sensitivity analysis will be presented. In this case the focus lays on the following points:

- Modelling of the memory chips.
- Modelling of the mining types of the gold in the device.
- Smartphone design alternatives.

6.5.1 IC modeling

As mentioned in Section 6.1.1.1 the exact die architecture of the memory component is not known. Furthermore, the current dataset being used, while offering a fair deal of flexibility, does not cover memory dies of more modern generations and the LPDDR5X chips such as the memory in The Fairphone (Gen. 6) are already part of the 14 nm generation[21]. In order to estimate the potential variability of the memory impacts, data from different sources has been gathered and compared. This exercise has only been performed for global warming since it's the only for which alternative data was

[21] https://en.wikipedia.org/wiki/LPDDR

available. It has to be stressed that this exercise does not aim to compare the tools and data sources used as such but rather to quantify the potential underestimation of the current model.

From the work of (Jones, 2023) emissions factors per wafer have been extracted for the technology nodes deemed most representative for both NAND and DRAM wafers. Then the emissions per die have been estimated based on the die size. Lastly, (Nagapurkar & Das, 2022) show that the back-end emissions can represent between 2 to 17% of the total chip manufacturing impacts, so an overhead of 10% has been added. Another model has been created using the imec.netzero tool[22]. A yield of 60% has been estimated for the DRAM[23] die and one of 50% for the NAND[24]. Since the imec tool only allows for logic die modelling, that has been taken as a proxy for the memory die. In one calculation, the node has been set to 14N and in another one to 65N, as a control model to get closer to our current model (which represent older nodes). The comparison can be seen below.

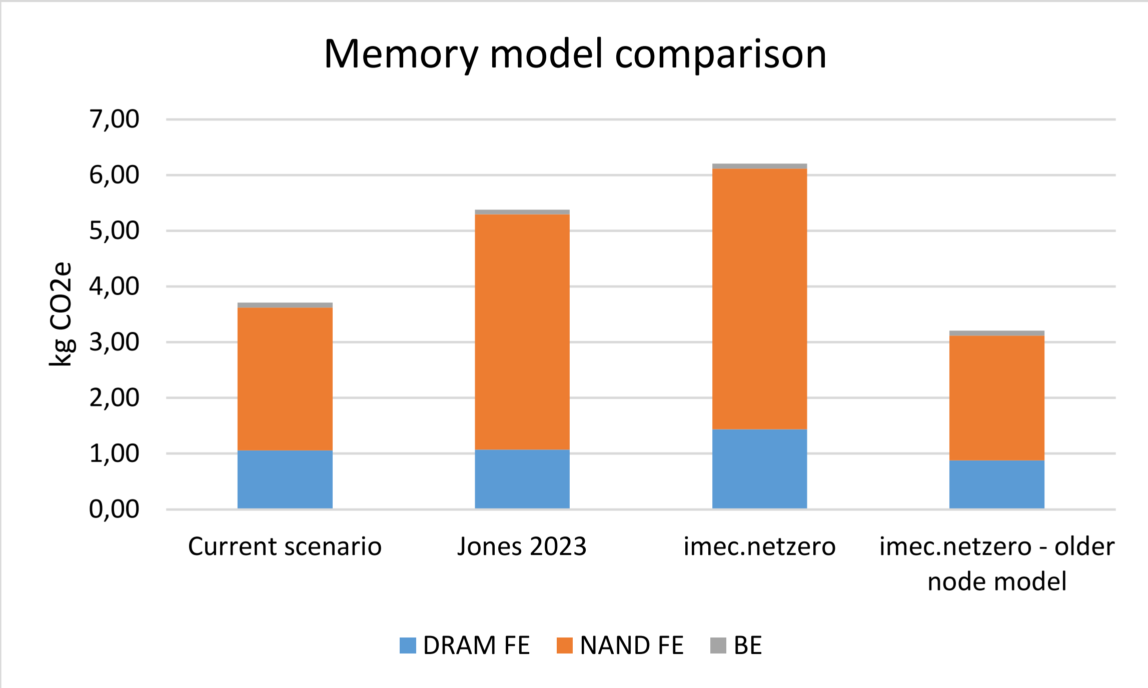


Figure 6-19 - Comparison of chip modelling approaches, global warming

The figure illustrates that using data representing newer technology nodes shows higher impacts, as per (Jones, 2023). The Jones data is not location specific and therefore, like the currently used dataset used in this study, represents an industry average. However, it did allow for newer technology nodes data for both NAND and DRAM dies. The imec data, as mentioned, only covers logic chips and it's thus not technologically very accurate in our case. However, the control scenario does provide very similar values to our baseline, suggesting that in reality the memory impact is probably higher than our current model reflects. This increase would however only represent between 4% and 7% of the production impacts. In general, smaller (newer) technology nodes involve more complex designs and more

[22] https://netzero.imec-int.com/

[23] https://www.tweaktown.com/news/108316/samsung-1c-dram-for-hbm4-yields-rumored-to-hit-around-50-percent-to-battle-sk-hynix-and-micron/index.html

[24] https://www.digitimes.com/news/a20210824PD210.html

processing steps which in turn translate in a higher energy input per wafer. Newer technology nodes also tend to have lower yields (although these improve as the manufacturing process matures) but in turn, due to the achieved smaller die size they allow for higher die output per wafer. This means that while the wafer manufacturing impacts tend to increase over time, the impact per die can vary significantly.

6.5.2 Mineral supply chain analysis

In this section, the effects in the environmental impacts of different mining routes is analyzed. Data on this topic is however scarce and therefore, although the differences between large and small scale mining apply to many minerals, including several used in the device, this analysis is limited to gold, because due to its high value and versatility it is also the mineral for which the most data is generated. The analysis also focuses on global warming, since this is by far the indicator where the most data could be found.

According to the FMD provided by the suppliers of the various The Fairphone (Gen. 6) parts and components, the total amount of gold is on the milligram scale. Gold is mainly used in electronic components such as connectors (for the contact plating) and integrated circuits (for bonding the dies into the package contacts). Despite the small amount used, it is still environmentally relevant. Although estimates vary, a single gram of gold can be responsible of between 15 kg CO2e (Aurubis, 2024) to 29 kg CO2e (Norgate & Haque, 2012). In the current and past Fairphone LCAs, we have modelled gold using the generic Sphera dataset for primary gold production[25]. This dataset represents a geographic industry average of mostly large-scale underground mining sources. Although the specific sources of the gold in the Fairphone device is still hard to track, Fairphone B.V. has been involved in several activities in the recent years that support small-scale mining (through programs like Fairmined Credits[26] and Fairtrade gold[27]). Although the main goal of said activities responds to social concerns (working conditions, economic growth of certain areas), the question remains: what are the environmental aspects of such initiatives?

In order to analyze this question further, this section will present a sensitivity analysis of the gold in The Fairphone (Gen. 6) attempting to quantify the environmental impact variation of different kinds of gold sourcing (both in terms of geographic location and scale of operations). To do so, first a literature review has been undertaken. Then relevant data points have been gathered and adapted (which involved normalizing the emissions to kg gold produced, removing outliers and where several minerals were extracted, allocate emissions to gold via price). Finally, the data has been adapted to The Fairphone (Gen. 6) gold amount. The result is a range of values for gold sourced from large scale mining.

This analysis will be drawing heavily on the comprehensive work by Sam Ulrich and colleagues. In (Ulrich, Trench, & Hagemann, Gold mining greenhouse gas emissions, abatement measures and imapct of carbon price, 2022) a more granular characterization of the emissions of gold mining is built by compiling data from companies mining in 35 countries, comprising 177 operations and 5 company aggregated totals. The study comes to a weighted average of 23.300 kg CO2e / kg Au. This value is, as reported in the same source, higher than previous estimates e.g. (Mudd, 2010) but in line with what the World Gold Council had reported in 2019 (World Gold Council, 2019). The paper further breaks

[25] https://lcadatabase.sphera.com/2025/xml-data/processes/21b5f6eb-4dbf-425b-a186-08f3fcae254e.xml

[26] What are Fairmined credits? - Fairphone

[27] https://www.fairphone.com/de/2021/11/30/fairtrade-hirose/

down the values geographically. A divide between developed and developing countries is found, with an average of around 19.200 kg CO2e / kg Au for developed countries and one of 30.300 kg CO2e / kg Au for developing countries. When dividing per country, the lowest emissions were estimated in Canada (8.133 kg CO2e / kg Au) and the highest in South Africa (91.800 kg CO2e / kg Au). The paper identifies several factors that contribute to the emissions per kg. The main aspect is the kind of energy employed. Interestingly, the paper also finds that off-grid mines have a slightly lower emissions intensity than on-grid mines. Furthermore, the gold grade produced is important, as well as the type of operation. In this sense, (Ulrich, Trench, & Hagemann, 2020) estimates that underground mines have 40% lower emissions than open-pit mines.

In order to complete the regionalized data provided by (Ulrich, Trench, & Hagemann, 2022), a series of mining company environmental reports have been gathered in order to explore the impact range of LSM gold. Likewise, LCA data for ASM mining has also been gathered to represent small-scale mining impacts.

For LSM data, the environmental reports of 18 companies have been reviewed, selected based on data provided by Fairphone B.V. representing the top gold suppliers worldwide. The list covers companies from China, Australia, South Africa, Russia, US and Canada (and more countries in terms of operation locations). The carbon intensity per kg gold has been estimated top-down i.e. dividing the company emissions over their respective year’s production volume. This was not necessary for companies reporting the normalized value directly. The result of this exercise shows first and foremost a very wide spread of values, ranging from very low values of 8.462 kg CO2e / kg Au, to maximum values of around 140.000 kg CO2e. The average value was calculated at 37.532 kg CO2e. The variation causes are hard to pinpoint and can range from the aforementioned differences in mining (Ulrich, Trench, & Hagemann, Gold mining greenhouse gas emissions, abatement measures and imapct of carbon price, 2022), differences in the methodological decisions and data sources used for the carbon emission accounting to our own allocation issues i.e. in order to estimate the emissions per produced gold kg from the companies’ environmental declarations, data points such as total gold output or price were retrieved from third sources, which further increases uncertainty.

With regards to ASM, the data is scarcer. The main sources we build from are (Valdivia & Ugaya, 2011) and (South Pole, 2022). (Valdivia & Ugaya, 2011) presents the LCA of two small-scale mines in Perú: one alluvial gold mine and one artisanal underground gold mine. (South Pole, 2022) provides carbon emissions data for 5 small-scale mines in South America: an underground and an open pit mine in Perú and three more gold mines in Colombia, also mixing open and underground types. Another data point for ASM was found in a Springer Nature publication[28] on small-scale gold mining. Once again, the results show a considerable spread ranging from a minimum of 5.344 kg CO2e / kg Au to a maximum figure of 106.853 kg CO2e / kg Au. Here again, it is difficult to pinpoint what is driving the differences. Although most open pit mines are found at the higher end of the range, the highest value is for an artisan underground mine. All the studied mines are off-grid mines. No strong correlation was found with the gold grade nor the throughput either.

Based on this data, a sensitivity analysis has been performed on the gold present in The Fairphone (Gen. 6) device for different sourcing options, summarized in Figure 6-20 below. Although the spread is too wide to draw solid conclusions, a number of observations can be made. ASM shows a slightly lower average end-impact with 0,63 kg CO2 eq. as opposed to the average of 0,68 kg CO2 eq. from the LSM data. Furthermore, both the LSM minimum and maximum are higher than in the ASM case, although a very significant overlap exists between both, suggesting a very high variability and not clear-cut environmental benefits/drawbacks from any mining model.

[28] https://communities.springernature.com/posts/artisanal-gold-mining-is-a-magnifying-glass-for-sustainability

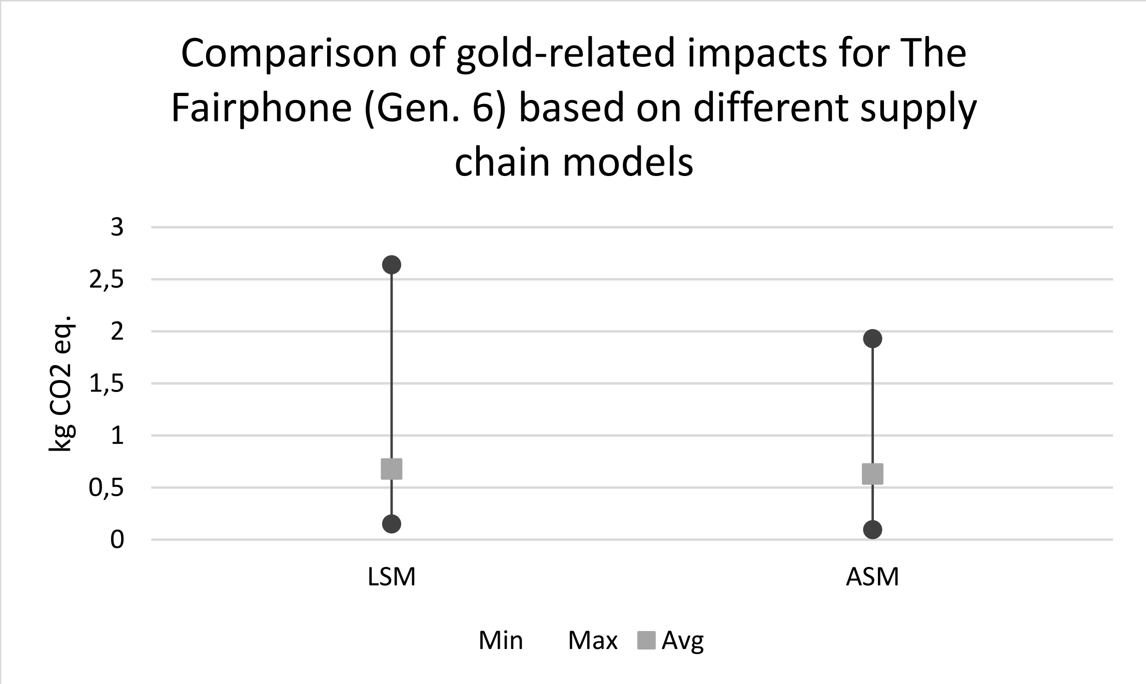


Figure 6-20 - Comparison of different mining routes, showing full value variation range

Both the LSM and ASM average values are higher than the value used in the current modelling approach in this study (0,62 kg CO2e) on The Fairphone (Gen. 6). Table 6-3 below shows the maximum and minimum values for the different options.

Table 6-3 - Full results for all mining routes

	Min	Max
LSM version	0,15 kg CO2e	2,64 kg CO2e
ASM version	0,09 kg CO2e	1,93 kg CO2e
Current gold GW impact in The Fairphone (Gen. 6)	0,62 kg CO2e	

As mentioned above, the data spread is too wide to draw any definitive conclusions. This suggests that the actual emissions related to gold production are very tightly tied with the specific operations of the different mines, which for now are very difficult to track starting from an end-product as complex as a smartphone. Furthermore, although the data timidly points to slightly lower impacts related to ASM gold production, there is a very big overlap suggesting no clear-cut advantage (from a strictly environmental point of view) when compared to LSM, and also no significant downside. As the decarbonization of electricity generation, both on- and off-grid progresses, further research on the environmental aspects of mining and the current supply chain structure may result in more clear-cut differences between different sourcing options.

6.5.3 Design choices

In Section 6.1.1 the contribution of the different modules to the environmental impacts has been analyzed. However, a relevant question is how these impacts would change if other design choices are taken. In this section of the sensitivity analysis, different design options for key modules are studied in order to visualize what changes in functionality may affect the environmental impacts. It shall be kept in mind that the scaling factors chosen for the scenarios described below are very sensitive to the specific design of the key components e.g. two single-cell batteries with the same active materials can have different weights and capacities. Thus the scenarios below shall be taken as an estimation based on available data.

6.5.3.1 Battery

Li-ion batteries are composed by several cells, which are connected in series in order to achieve the desired voltage and in parallel to reach certain capacity/power (Preger, Torres-Castro, & McDowall, 2021). Furthermore, energy density can also be changed via cathode/anode material selection.

Lithium-ion cells can deliver up to 3,6V and 330 Wh/kg[29]. The Fairphone (Gen. 6) battery has a maximum voltage of 4,5V and a related capacity of 4,3 Ah. Its total weight is 63g. Thus, its energy density should be around 323 Wh/kg, which suggests a single cell architecture. This is consistent with existing reports of single-cell batteries being common in smartphones[30]. The same sources point out however, that dual-cell batteries do exist mostly for higher power (with similar capacity).

Table 6-4 below shows the evolution of the Fairohone batteries throughout the different generations. From the table it can be seen that the total battery weight does not directly correlate with the power. All batteries have used the same architecture and just a single cell. The biggest leap in energy density was achieved from Fairphone 3 to Fairphone 4 by changing the electrode and electrolyte materials, allowing for increased capacity in lower mass. From there, the capacity differences are small and likely due to specific design improvements (especially in the case of the transition from Fairphone 5 to The Fairphone (Gen 6).

Table 6-4 - Evolution of the battery through Fairphone generations

Model	Battery weight	Battery capacity and voltage	Active materials
The Fairphone (Gen. 6)	63g	4,4 Ah (4,5V)	Lithium hexafluorophosphate
Fairphone 5	67g	4,08 Ah (4,45V)	Graphite
Fairphone 4	41g	3,9 Ah (?V)	Lithium hexafluorophosphate
Fairphone 3	52g	3,1 Ah (3,85V)	Graphite

Therefore, for the sensitivity analysis, the following scenarios can be considered:

- **Small battery**: Fairphone 4 battery, with 20g less mass and 0,4 Ah less capacity. That also affects the lifespan i.e. lower duration, more charging cycles, less longevity. No changes in manufacturing due to lack of data.
- **Fast charge battery**: assuming same battery as The Fairphone (Gen 6.) but with two cells instead of one, effectively doubling the voltage (same capacity). This should have no effect in lifespan. No changes in manufacturing due to lack of data (just double the cell).

Figure 6-21 below shows the comparison in global warming for the different battery scenarios. At the component level the differences are significant: lowering the battery capacity and thus size shows an

[29] https://www.cei.washington.edu/research/energy-storage/lithium-ion-battery/

[30] https://www.chargerlab.com/single-cell-vs-dual-cell-batteries-whats-the-difference/

emissions reduction of 29%, whereas adding an extra cell to allow fast charging would mean an increase of 84% of the battery production emissions. At the full life cycle however, the differences are much more limited. The reduction scenario ends up with a change of almost 0%. Since the battery now lasts less, it requires more charging cycles per year, ending up consuming more energy in total. In the fast charging scenario, the total lifecycle impact is 2% higher than the current design.

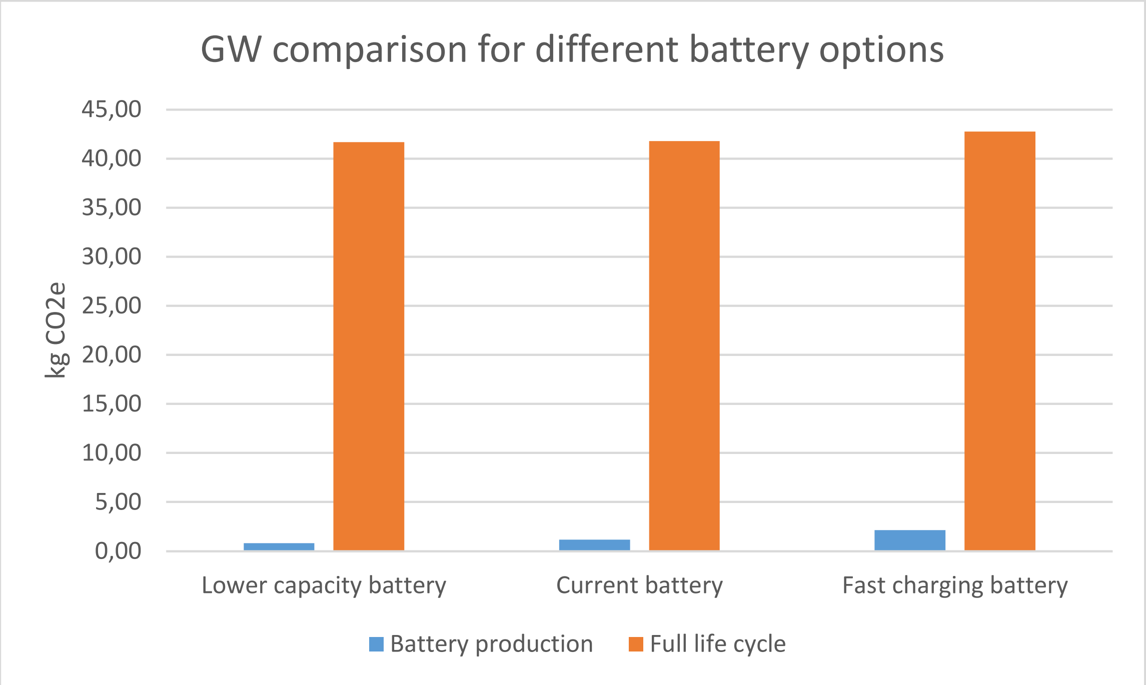


Figure 6-21 - Comparison of global warming for different battery choices, at component and full life cycle level

6.5.3.2 Display

Varying the display size has a direct effect the amount of materials needed and therefore on its weight. Regarding manufacturing energy, the relationship is unclear, but since many manufacturing steps are comparable to semiconductor manufacturing (e.g. photolithography)[31], a fair assumption is that manufacturing effort at least partially scales with area.

Table 6-5 below shows the evolution of the different displays by Fairphone. Historically the data on display manufacturing has been scarce and this is the only time in which primary data was available, so it will serve as the basis. The mass of the display also seems to not have changed according to size, probably due to different architectures (e.g. the FairPhone 5 display had an AMOLED display).

Table 6-5 - Evolution of the display through Fairphone generations

Model	Display size	Display mass	Display manufacturing energy
The Fairphone (Gen. 6)	6,3" (96 cm2)	28g	12,11 kWh (primary data)

[31] https://oriwhiz.com/blogs/cellphone-repair-parts-gudie/lcd-screen-making-process?shpxid=1e1305ae-1145-4d7f-949d-9a9bb5e6c86b

Fairphone 5	6.5" (101,2 cm2)	28g	8 kWh (literature, AMOLED)
Fairphone 4	6.3" (97,4 cm2)	34g	0,45 kWh (AUO)

Regarding energy consumption, the sources are varied. Informal sources[32] leave the consumption range between 200 mW and 400 mW. Another source[33] relates the pixel count with the energy use, estimating around 1000 mW for a 5" display and up to 1500 mW for a 2560x1440 Quad-HD display (The Fairphone (Gen 6.) display has a 2848 x 1116 pixel count). Yet another source[34] stresses the importance of brightness although this is more relevant for OLED displays than for LCDs. Brightness use is however highly dependent on user behavior and therefore, the main assumption on the power will be correlated with the pixel count.

Therefore, the assumptions will be the following:

- Smaller display: Display of 5,65" like the Fairphone 3 had. Both mass and manufacturing energy are scaled based on area. Energy use decreases with the pixel count.
- Bigger display: 6.9" display like the Samsung Galaxy S25 Ultra or iPhone 16 Pro Max. Materials and manufacturing energy increase with area, energy use increases with pixel count.

Figure 6-22 below shows the comparison for global warming for the different display options. At a module level, reducing display size leads to a 13% reduction of emissions and to a total life cycle impacts reduction of 3%. On the other hand, a bigger display corresponds to a 16% impact increase at module level and a general increase of 4%. It's to be noted that these scenarios use the Footprint (RM) as the basis of calculation and thus for the Footprint (RM + RE) the margins are likely to be lower, since the main driver of the impacts is manufacturing energy.

[32] See https://petewarden.com/2015/10/08/smartphone-energy-consumption/ and https://www.quora.com/What-percentage-of-battery-is-consumed-by-the-display-of-an-average-smartphone

[33] https://www.qnovo.com/blogs/understanding-power-usage-in-a-smartphone

[34] https://www.productscience.ai/blog/battery-consumption-in-smartphones#:~:text=look%20at%20displays.-,Displays,-There%20are%20lots

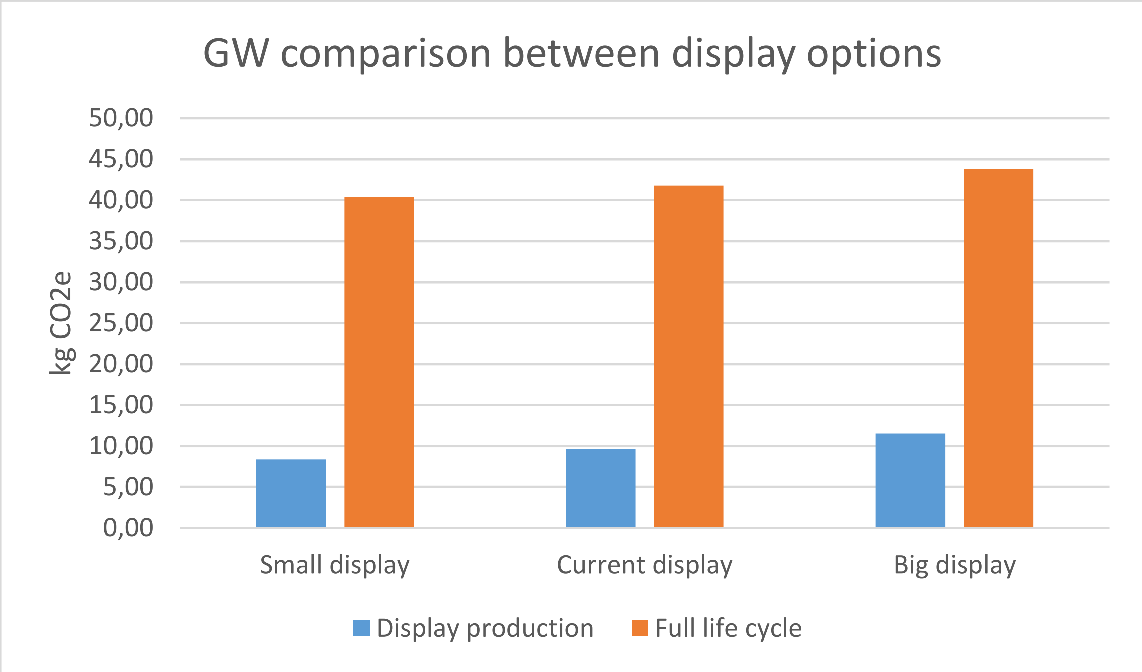


Figure 6-22 - Comparison of global warming for different display choices, at component and full life cycle level

6.5.3.3 Cameras

The key element that determines the quality of the image is the CMOS sensor: the larger the size, the better the performance[35]. Table 6-6 below represents the change in camera resolutions and the die sizes for Fairphone. It can be seen that in general, higher resolutions do correlate with higher sensor areas, even if the different cameras still show different sensor areas.

Table 6-6 - Camera characteristics in The Fairphone (Gen. 6) and Fairphone 5

Model	Camera	Resolution	Sensor die size
The Fairphone (Gen. 6)	Main camera	50M	2-layer 9,2mm x 7,2 mm
The Fairphone (Gen. 6)	Ultra-Wide camera	13M	1-layer 5,41mm x 4,84mm
The Fairphone (Gen. 6)	Front camera	32M	2-layer 4,2mm x 3,16mm
Fairphone 5	Main camera	50M	2-layer (assumption) 9mm x 7mm
Fairphone 5	Ultra-Wide camera	50M	2-layer (assumption) 5mm x 7mm
Fairphone 5	Front camera	50M	2-layer (assumption) 6mm x 5mm

Since The Fairphone (Gen.6) already has three cameras with three different resolutions, these will be taken as the proxy, so as to build the following scenarios:

[35] https://www.utmel.com/blog/categories/optoelectronics/structure-and-imaging-principle-of-smartphone-camera

- **Three low resolution cameras**: all three cameras are assumed to be like the ultra-wide camera (13M).
- **Three medium resolution cameras**: all three cameras are assumed to be like the front camera (32M).
- **Three high resolution cameras**: all three cameras are assumed to be like the main camera (50M).

Figure 6-23 below shows the comparison between the different camera scenarios and the current design. The environmental impact of the main camera (the highest resolution, 50M) is significantly higher than the other two. Thus, the full high-res camera scenario shows 14% higher full life cycle impact as the current scenarios, while both lower res scenarios (32M and 13M) both show a 7% reduction potential of the total.

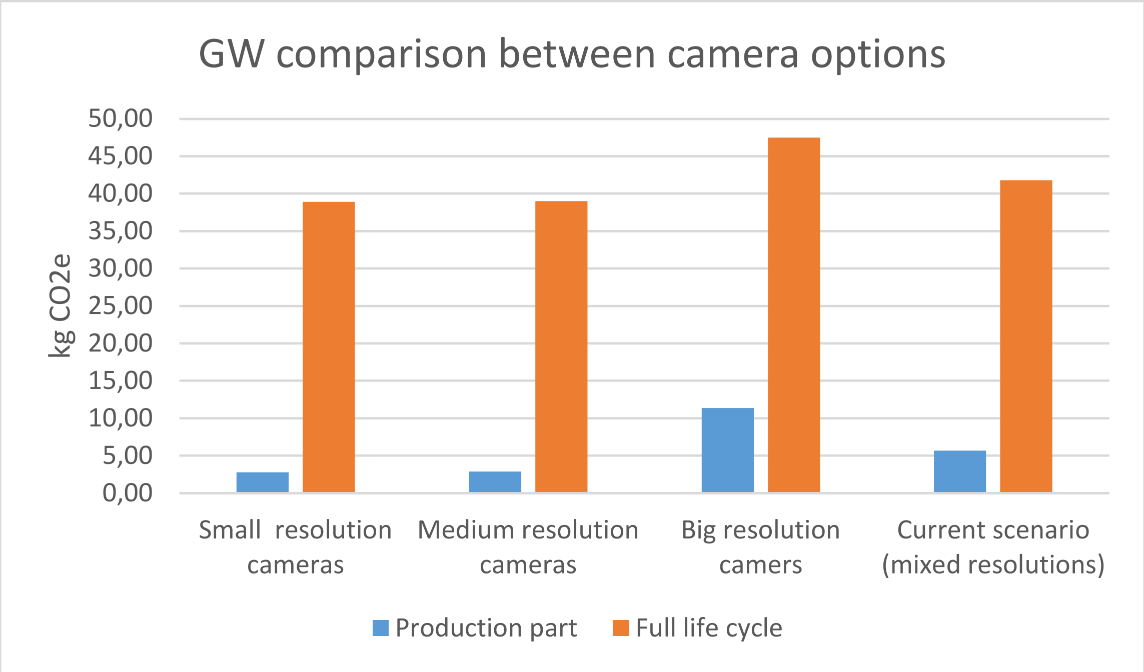


Figure 6-23 - Comparison of global warming for different camera choices, at component and full life cycle level

6.5.3.4 Printed Circuit Boards (PCBs)

The current PCB in the device has 10 layers and an area of 66,32 x 57 mm^2. It is known that the PCB impact rises with size and layer count (even though the specific scale of the change is still unclear), but what are the effects of these design changes and what is the actual wiggle room?

Determining the necessary layer count for a PCB is complex and depends on numerous factors[36], most importantly for our inquiry:

- Pin density. Refers to the amount of pins per squared inch (which in turn correlates with the amount of components on the board and thus its functionality). Devices like smartphones tend to be small form factor but very densely populated which in turn requires more layers.

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[36] See https://www.pcbcart.com/article/content/factors-determining-PCB-layers.html and https://www.protoexpress.com/blog/the-importance-of-pcb-layer-count-estimation/

- Operational frequency. High speed, high frequency boards need several layers, since they allow for controlling impedance and reducing interference[37].
- Heat dissipation. More layers mean more copper, which in turn offers more ways of dissipating heat. Thus, smaller boards also benefit for having more layers in terms of heat management.

In short, reducing the amount of layers in the device's PCB would require increasing its size and vice-versa. Given the form factor of a smartphone and the high functionality requirements, there is very likely a limit (both up- and downwards) as to how much smaller or thinner the board can get. Unfortunately, no generic estimate could be found on the quantitative correlation between size and layer count, so assumptions need to be made (for all scenarios the phone size will remain constant):

- **Small PCB, more layers**. The total PCB area used is around two thirds of the current main PCB area. In this scenario pin density would be up by around 100%, so an increment to 16L could be expected.
- **Bigger PCB, less layers**. The total PCB area would more than double, causing a density drop of around 43%, which we assume to mean a layer count drop to 6L.

Figure 6-24 below shows a representation of the assumptions made.

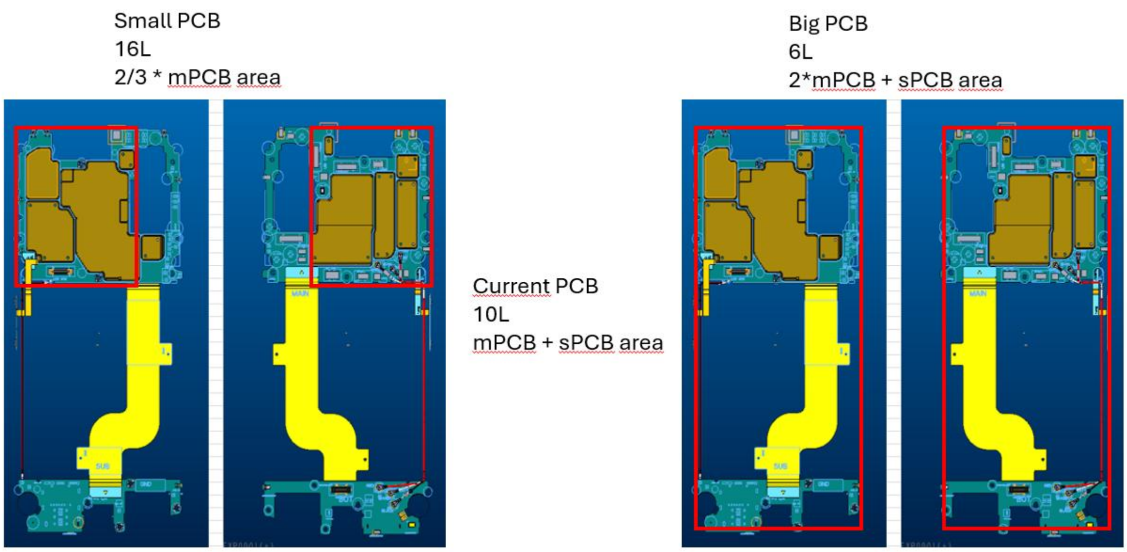

Figure 6-24 - Visualization of the assumed PCB scenarios

Figure 6-25 below shows the comparison for GW. As the results suggest, lowering the size of the PCB seems preferrable to reducing its layer count. The smaller PCB with more layers shows a 22% reduction over the current PCB design, while the bigger and thinner PCB shows a 34% increase. This translates however only to a 1% reduction to full lifetime emissions and a 2% increase for the bigger PCB. It shall be reminded however, that the specific relationship between PCB size and needed layers is heavily based on assumptions and that, as previously mentioned, the functionality requirements of the device likely set limits as to how small or low on layers the PCB can technically be, which the selected scenarios may not properly reflect.

[37] https://www.quantum-controls.com/how-many-layers-does-your-pcb-need/

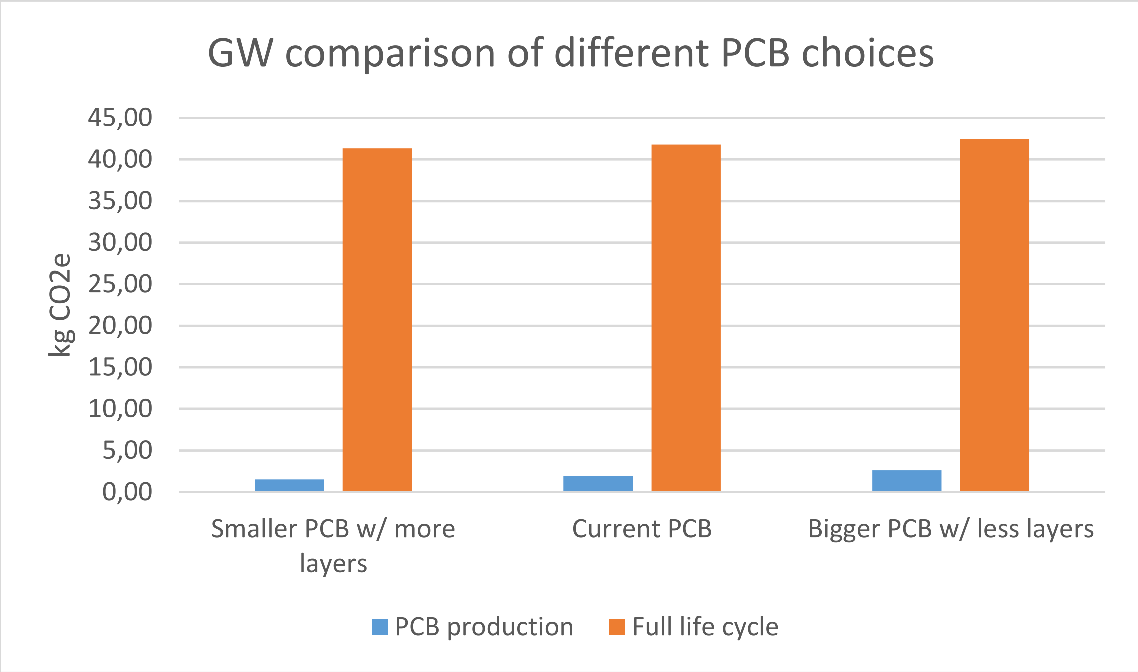

Figure 6-25 - Comparison of global warming for different PCB choices, at component and full life cycle level

6.6 Accessories

In this section the environmental impacts of The Fairphone (Gen. 6) accessories as well as generic accessories are presented separately. In the following sub-sections, a closer look to the environmental hot spots for each accessory is presented. The full results of LCA (w/o reduction measures) are given in the annex, section 9.3 to 9.10.2.

6.6.1 Screen protector

Table 6-7 - Environmental impacts of the screen protector, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	5,84E-07	3,23E-07	2,56E-07	5,03E-09
Acidification Potential (AP) [kg SO2 eq.]	6,33E-03	7,60E-04	5,56E-03	1,59E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	6,73E-02	2,63E-02	4,08E-02	1,77E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	9,32E-01	1,23E-01	8,09E-01	4,08E-04
Land Use [Pt]	1,17E+01	9,64E+00	2,10E+00	8,25E-03
Hazardous waste disposed (HWD) [kg]	2,93E-09	2,92E-09	0,00E+00	4,65E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,19E+00	1,16E-01	1,06E+00	1,71E-02

ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,21E-09	2,15E-09	0,00E+00	5,79E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	9,04E-02	8,86E-02	1,72E-03	6,34E-05
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,09E-01	-2,08E-01	-1,45E-03	-6,22E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	9,49E-04	8,26E-04	1,21E-04	1,68E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,19E+00	1,15E-01	1,06E+00	1,71E-02
Blue water use [kg]	6,49E+02	2,31E+02	4,15E+02	3,11E+00

The next figure below shows graphically the impact distribution across its life cycle. All impact categories are primarily driven by transportation, followed by production. The package weight in this case is higher than the product itself, which causes the higher transport-related impacts.

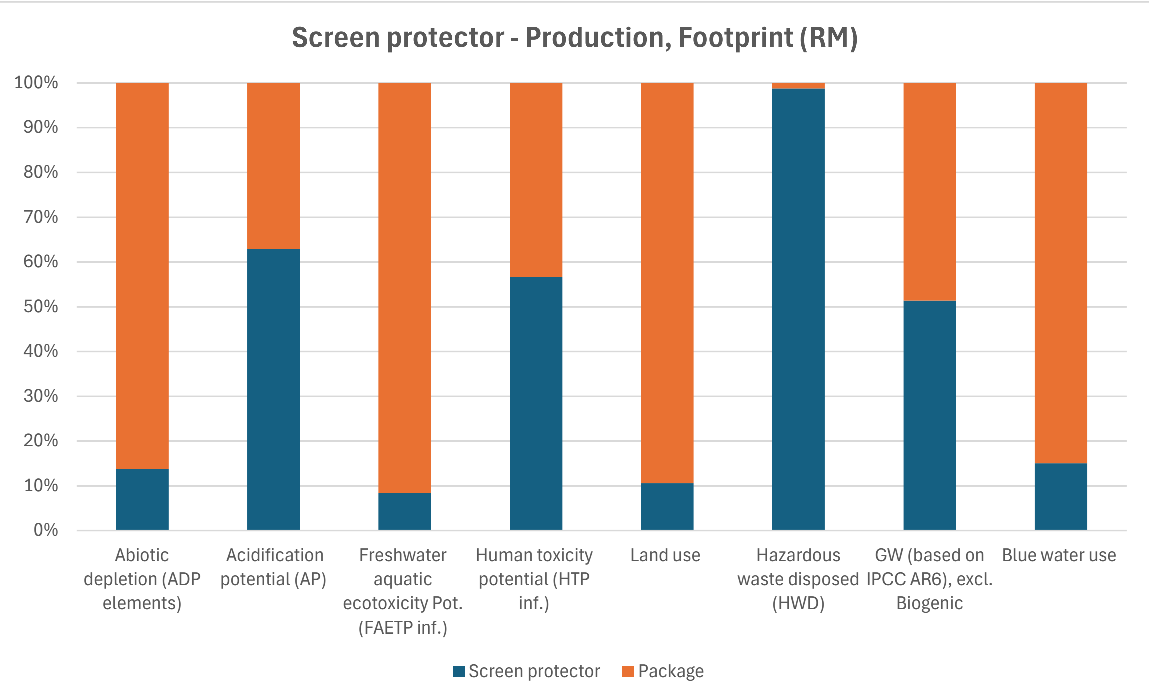

Figure 6-26 - Environmental impacts of screen protector, per life cycle phase. Presented as % of the total life impacts.

The figure 6-2 zooms in on the production phase, where the contributions of the different components can be distinguished, in this case, the screen protector itself and its packaging. As can be seen for most of the indicators, the greatest impact comes from the packaging, except for HTP and AP, where the impact of the screen protector is a bit higher.

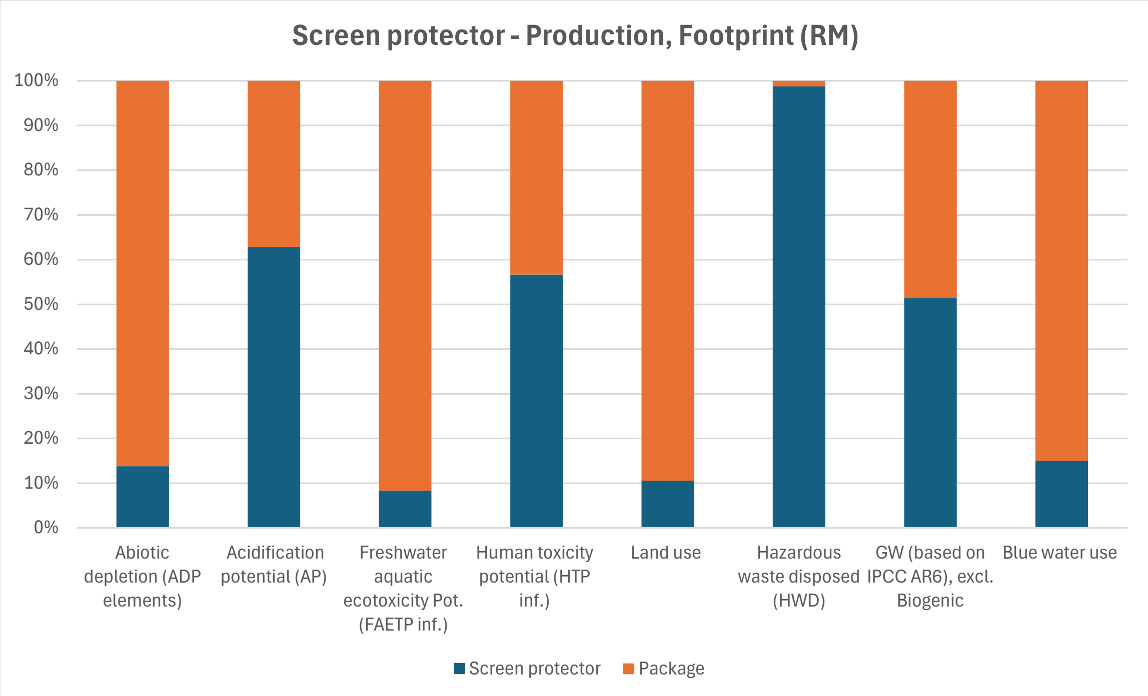

Figure 6-27 - Environmental impacts of the screen protector production. Presented as % of the total life impacts.

6.6.2 Cut-out case

Table 6-8 - Environmental impacts of the cut-out case, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	5,45E-07	2,25E-07	3,13E-07	7,30E-09
Acidification Potential (AP) [kg SO2 eq.]	6,95E-03	2,76E-04	6,65E-03	2,30E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	6,88E-02	1,93E-02	4,93E-02	2,57E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,02E+00	4,39E-02	9,71E-01	5,92E-04
Land Use [Pt]	9,71E+00	7,16E+00	2,53E+00	1,20E-02
Hazardous waste disposed (HWD) [kg]	2,75E-09	2,74E-09	0,00E+00	6,75E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,36E+00	6,62E-02	1,27E+00	2,48E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,09E-09	2,01E-09	0,00E+00	8,39E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	6,61E-02	6,39E-02	2,07E-03	9,19E-05

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,40E-01	-1,38E-01	-1,74E-03	-9,02E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	6,91E-04	5,43E-04	1,46E-04	2,43E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,36E+00	6,57E-02	1,27E+00	2,48E-02
Blue water use [kg]	6,90E+02	1,88E+02	4,98E+02	4,51E+00

In the following graph, the impact of the three main phases in the life cycle of the cut-out case is shown. Transport shows the highest impact for most indicators, driven by the total transported mass (including the package). Production follows, with a significant contribution in ADPe and ecotox. Production is the main driver for land use and HWD.

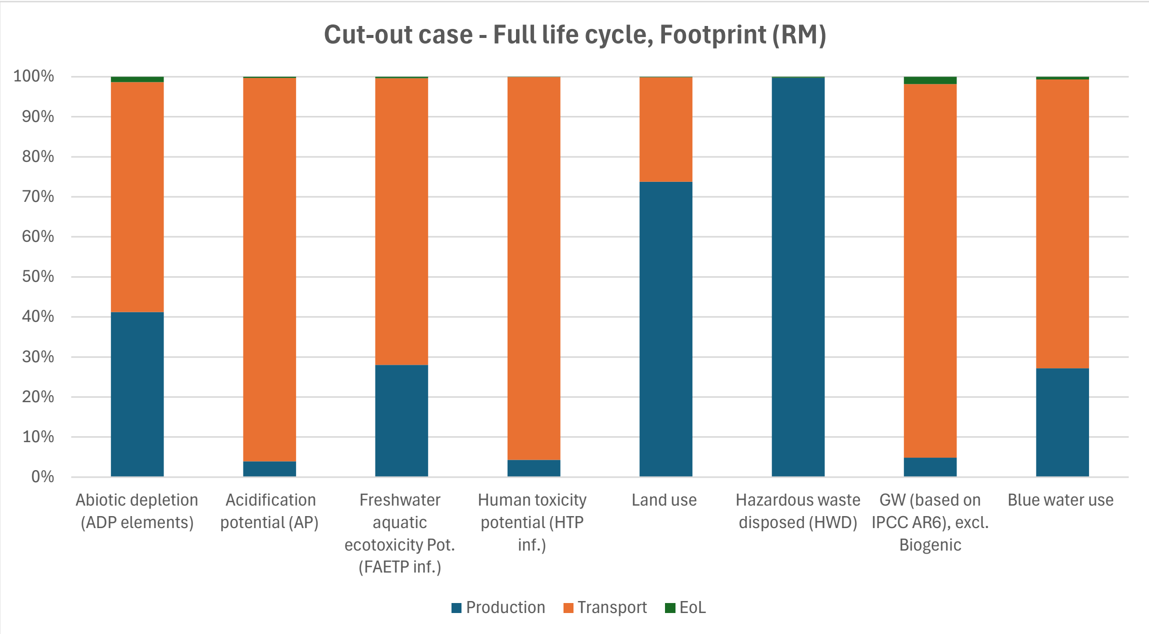

Figure 6-28 - Environmental impacts of cut-out case, per life cycle phase. Presented as % of the total life cycle impacts.

The cut-out case itself has the highest impact only for hazardous waste disposal, but for the other indicators, it is the packaging that has the greatest impact, particularly for ADP, FAETP, and land use where it constitutes more than 95%.

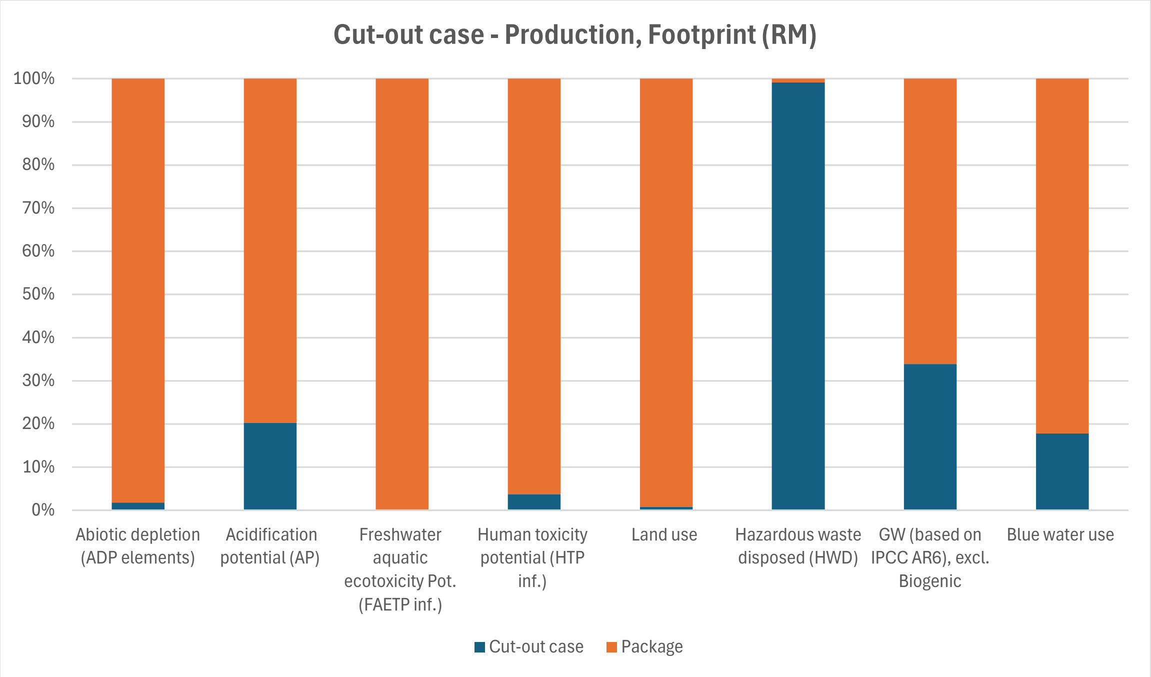

Figure 6-29 - Environmental impacts of the cut-out case production. Presented as % of the total life impacts.

For the cut-out case, the difference between the two footprints is primarily based on the use of recycled TPU, which has significantly less impact compared to virgin TPU. No renewable energy has been used for this accessory.

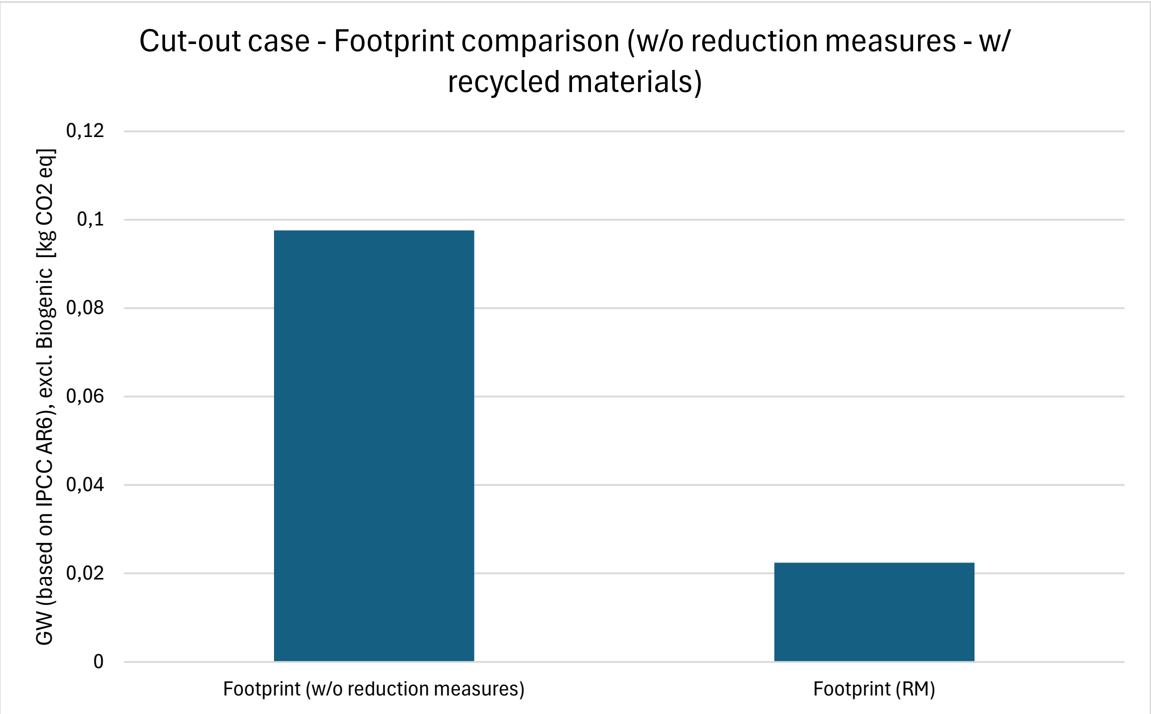

Figure 6-30 – Cut-out case global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.3 Flip case

Table 6-9 - Environmental impacts of the flip case, divided by life cycle phase, Footprint (RM)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	8,54E-07	4,88E-07	3,40E-07	2,58E-08
Acidification Potential (AP) [kg SO2 eq.]	7,80E-03	4,55E-04	7,26E-03	8,14E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	7,48E-02	2,03E-02	5,37E-02	9,08E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,12E+00	5,45E-02	1,06E+00	2,09E-03
Land Use [Pt]	1,01E+01	7,30E+00	2,76E+00	4,23E-02
Hazardous waste disposed (HWD) [kg]	3,72E-09	3,70E-09	0,00E+00	2,39E-11
GW (based on IPCC AR6), excl. Biogenic carbon	1,68E+00	2,04E-01	1,38E+00	8,76E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,09E-09	2,01E-09	0,00E+00	8,39E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	6,61E-02	6,39E-02	2,07E-03	9,19E-05
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,40E-01	-1,38E-01	-1,74E-03	-9,02E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	6,91E-04	5,43E-04	1,46E-04	2,43E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,36E+00	6,57E-02	1,27E+00	2,48E-02
Blue water use [kg]	8,04E+02	2,44E+02	5,43E+02	1,60E+01

The graph shows that for the flip case, transport is the main contributor for most indicators except ADPe, land use and HWD, where production drives the impacts. For this accessory, similarly to the accessories in previous sub-sections, the transport efforts of the total packaged weight are the main cause of impact.

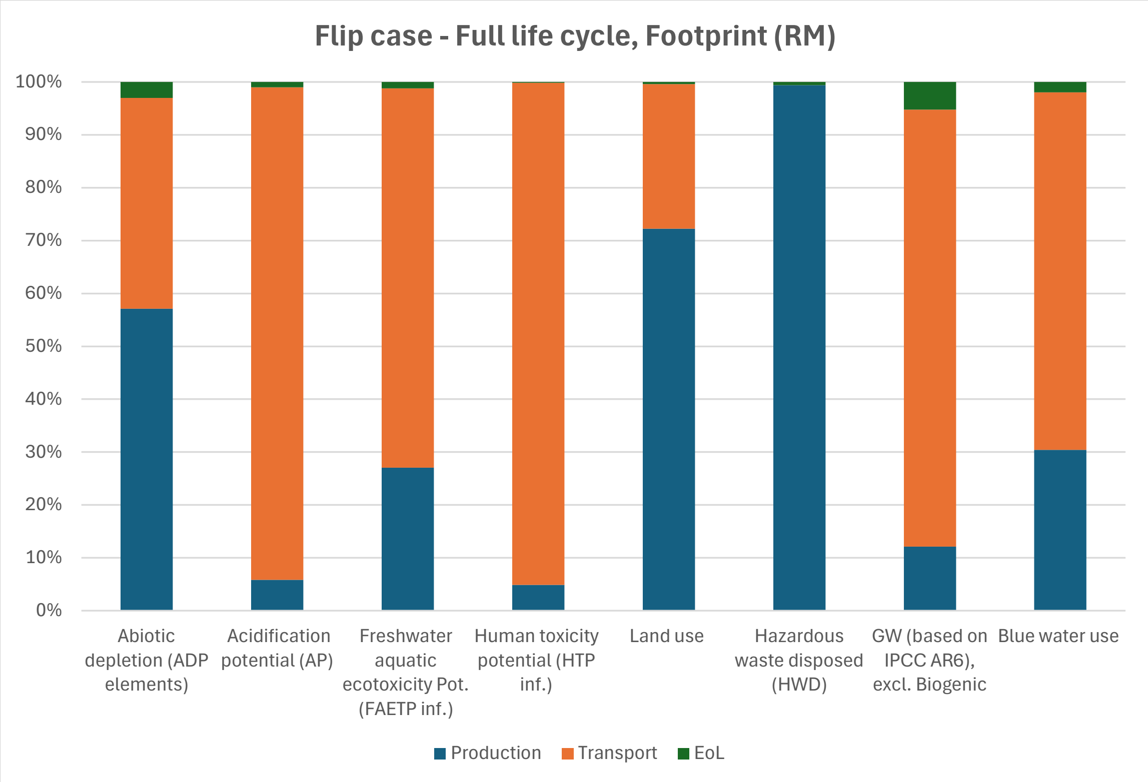

Figure 6-31 - Environmental impacts of flip case, per life cycle phase. Presented as % of the total life impacts.

The next graph shows that Hazardous Waste Disposal (HWD) and Global Warming (GW) impacts mainly come from the accessory itself, whereas for Freshwater Aquatic Ecotoxicity Potential (FAETP), Human Toxicity Potential (HTP), and land use, the main impact originates from the packaging.

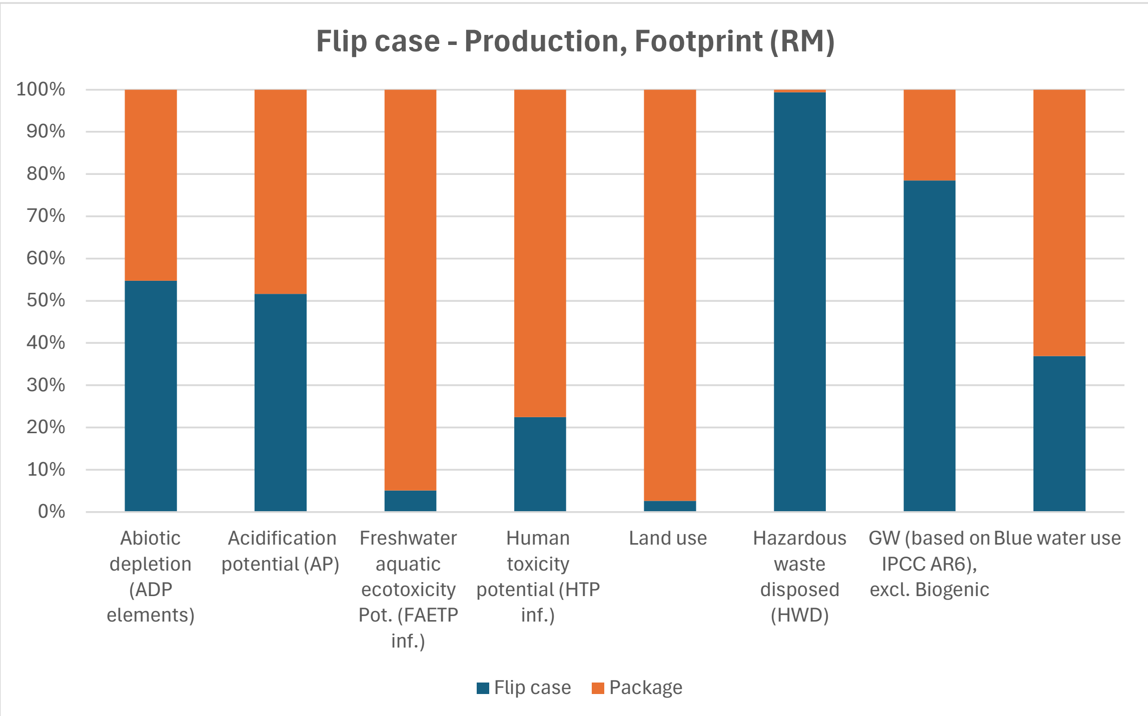

Figure 6-32 - Environmental impacts of the flip case production. Presented as % of the total life impacts.

For this case, the lower proportion of recycled material results in a smaller difference in GW, as shown in the following graph. However, a decrease is still observed.

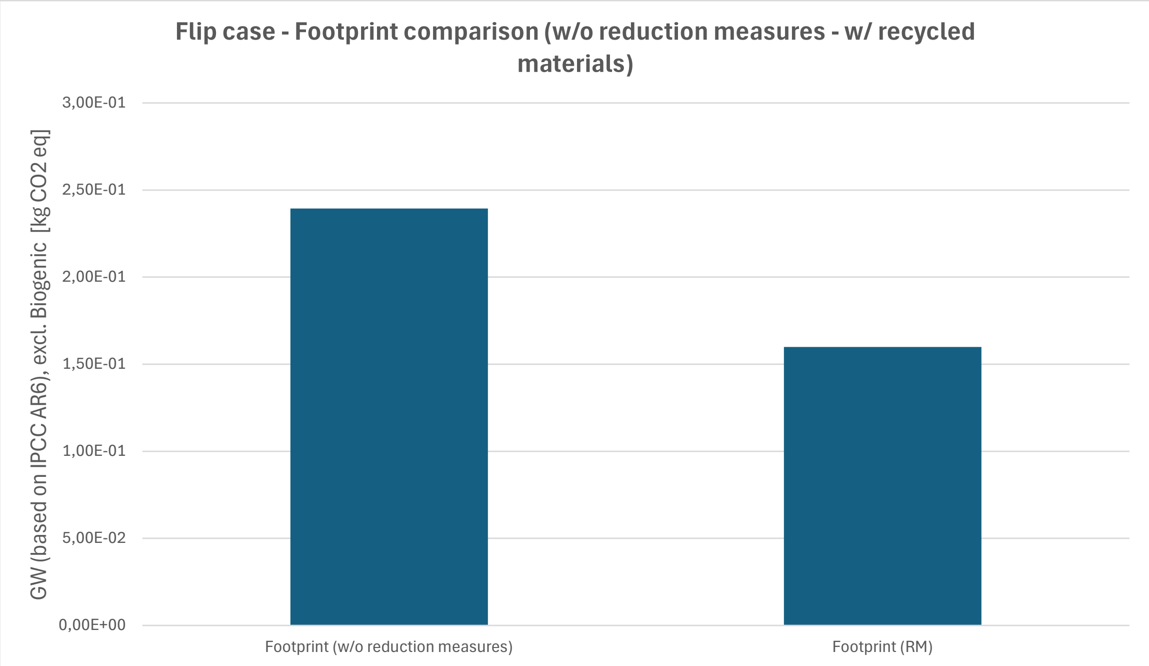

Figure 6-33 – Flip case global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.4 Finger loop

Table 6-10 - Environmental impacts of the finger loop, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,46E-04	3,24E-04	2,14E-07	2,18E-05
Acidification Potential (AP) [kg SO2 eq.]	2,03E-03	1,54E-04	1,87E-03	5,68E-06
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	3,76E-02	1,60E-02	2,13E-02	2,43E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,54E-01	4,90E-02	2,04E-01	5,61E-04
Land Use [Pt]	7,75E+00	6,85E+00	8,85E-01	1,13E-02
Hazardous waste disposed (HWD) [kg]	1,84E-09	1,84E-09	0,00E+00	6,40E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	4,05E-01	9,18E-02	2,90E-01	2,35E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	7,19E-09	7,11E-09	0,00E+00	7,95E-11

ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	6,88E-02	6,78E-02	8,63E-04	8,72E-05
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,29E-01	-1,28E-01	-7,39E-04	-8,56E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,77E-04	5,11E-04	6,32E-05	2,30E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	4,03E-01	9,13E-02	2,89E-01	2,35E-02
Blue water use [kg]	3,81E+02	2,00E+02	1,77E+02	4,27E+00

Figure 6-24 shows that, for the finger loop, production has the greatest overall impact across some indicators like ADPe, land use and HWD. Transportation is the most significant for AP, ecotox, human tox and global warming.

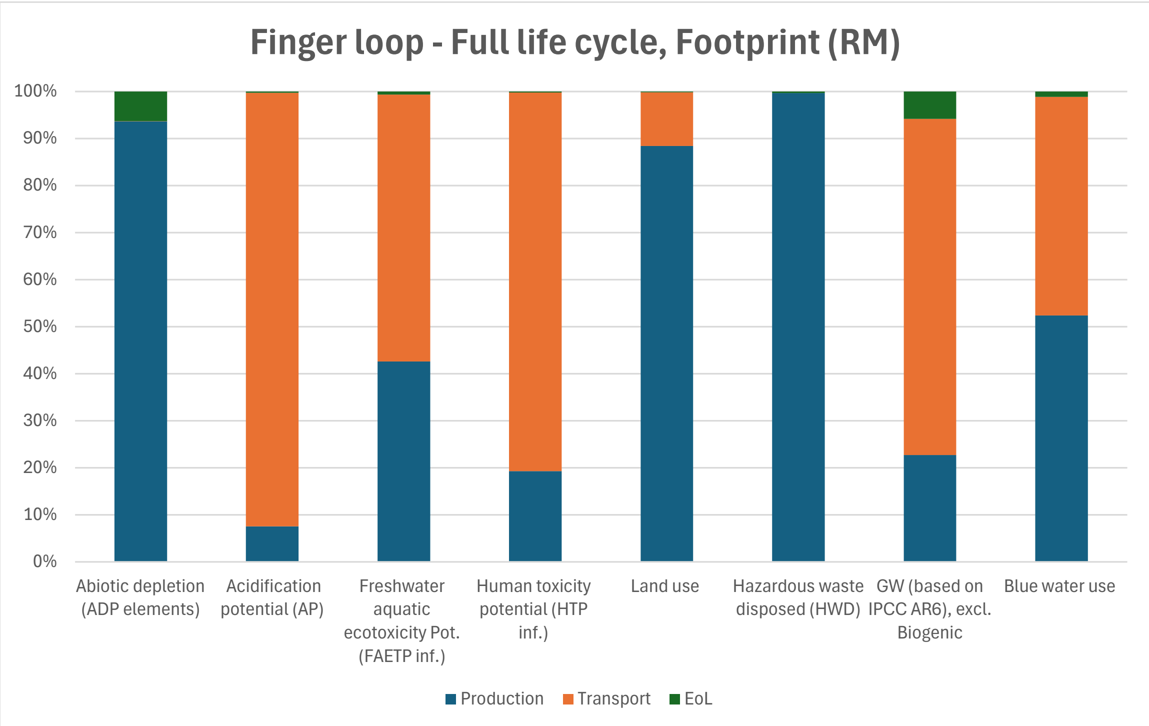

Figure 6-34 - Environmental impacts of finger loop, per life cycle phase. Presented as % of the total life impacts

The production graph for Footprint (RM) clearly demonstrates that the packaging contributes the most impact across the majority of indicators. However, for Hazardous Waste Disposal (HWD), the plastic case exhibits a greater impact.

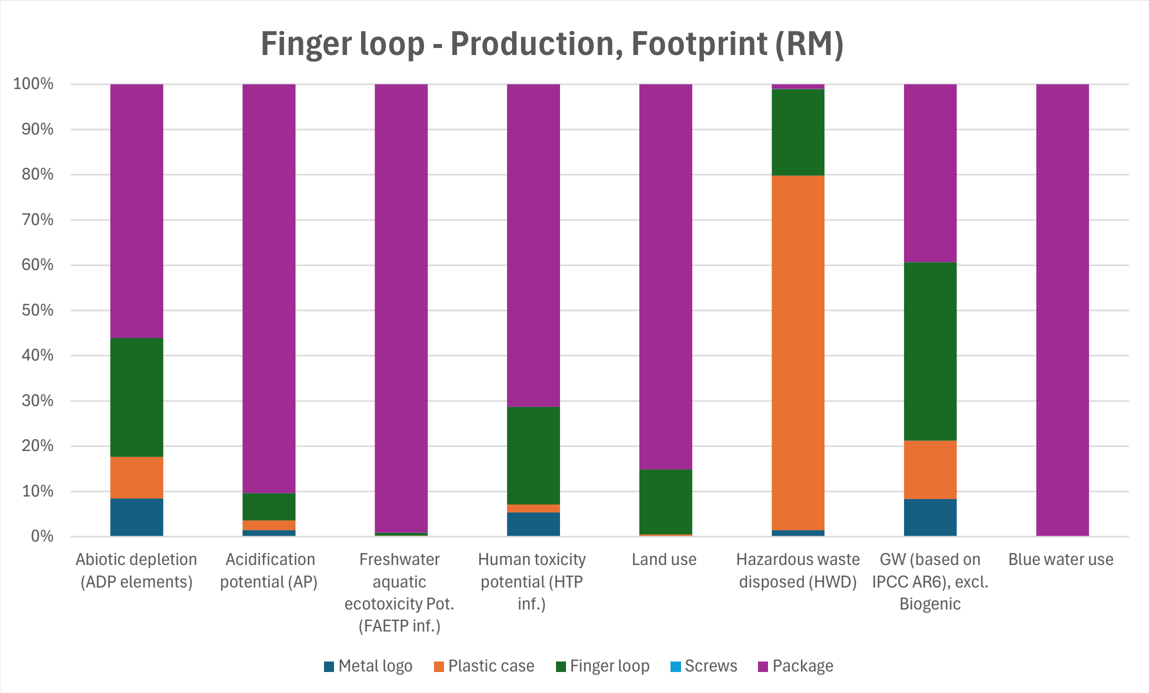

Figure 6-35 - Environmental impacts of the finger loop production. Presented as % of the total life impacts

In the comparison of the two footprints applicable to this accessory, it can be seen that when using recycled materials the finger loop has the highest GW in the Footprint (RM). However, without the usage of recycled materials, the plastic case would be the main contributor to GW.

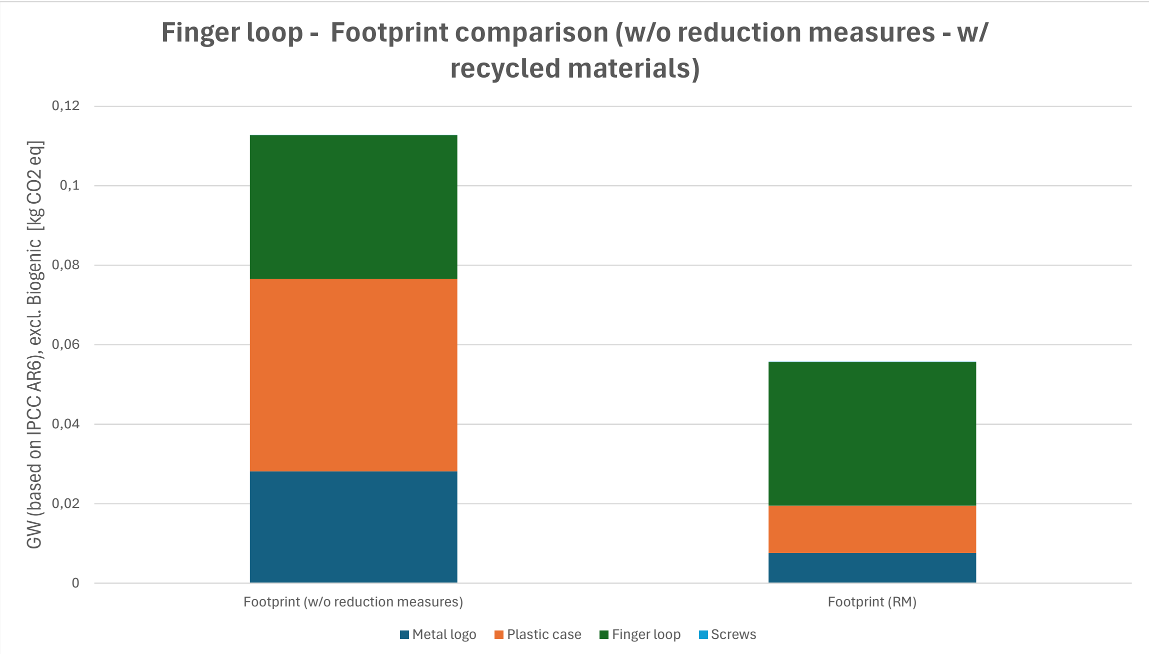

Figure 6-36 – Finger loop global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.5 Card holder

Table 6-11 - Environmental impacts of the card holder, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,99E-06	1,83E-06	1,47E-07	1,15E-08
Acidification Potential (AP) [kg SO2 eq.]	3,52E-03	4,45E-04	3,04E-03	3,62E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	3,93E-02	1,62E-02	2,27E-02	4,04E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	5,07E-01	6,40E-02	4,42E-01	9,32E-04
Land Use [Pt]	9,66E+00	8,48E+00	1,16E+00	1,88E-02
Hazardous waste disposed (HWD) [kg]	2,43E-09	2,42E-09	0,00E+00	1,06E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	7,69E-01	1,51E-01	5,79E-01	3,90E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,00E+00	1,35E-08	1,00E+00	2,00E+00
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	9,49E-02	9,38E-02	9,56E-04	1,45E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,54E-01	-1,53E-01	-8,04E-04	-1,42E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	7,13E-04	6,42E-04	6,71E-05	3,83E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	7,67E-01	1,50E-01	5,78E-01	3,90E-02
Blue water use [kg]	5,25E+02	2,89E+02	2,29E+02	7,10E+00

In the following figure can be observed, that production is the main contributor to the indicators, especially for ADPe, land use, HWD, and blue water use, while transportation also has a considerable impact on AP. FAETP. HTP and GW.

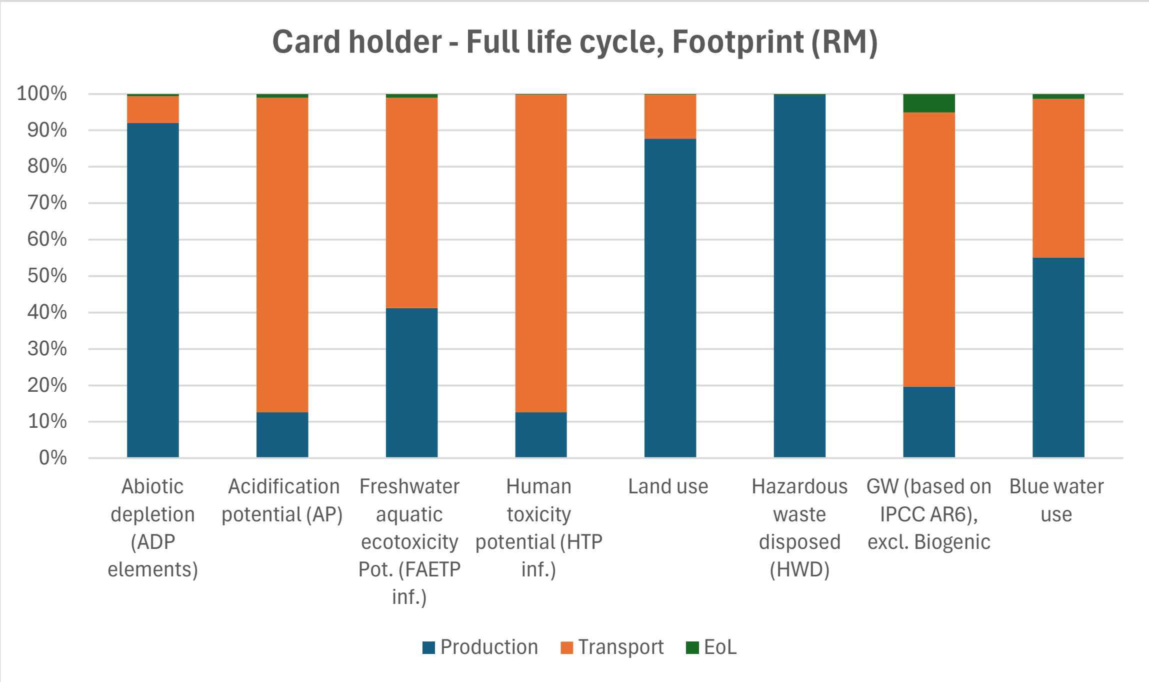

Figure 6-37 - Environmental impacts of card holder, per life cycle phase. Presented as % of the total life impacts.

Regarding production, it is important to note that packaging and the card case have the highest overall contributions, except for HWD, where the plastic case has the greatest impact. The other parts, such as the heat releasing film, screws, or glue, have less impact as they are present in smaller quantities.

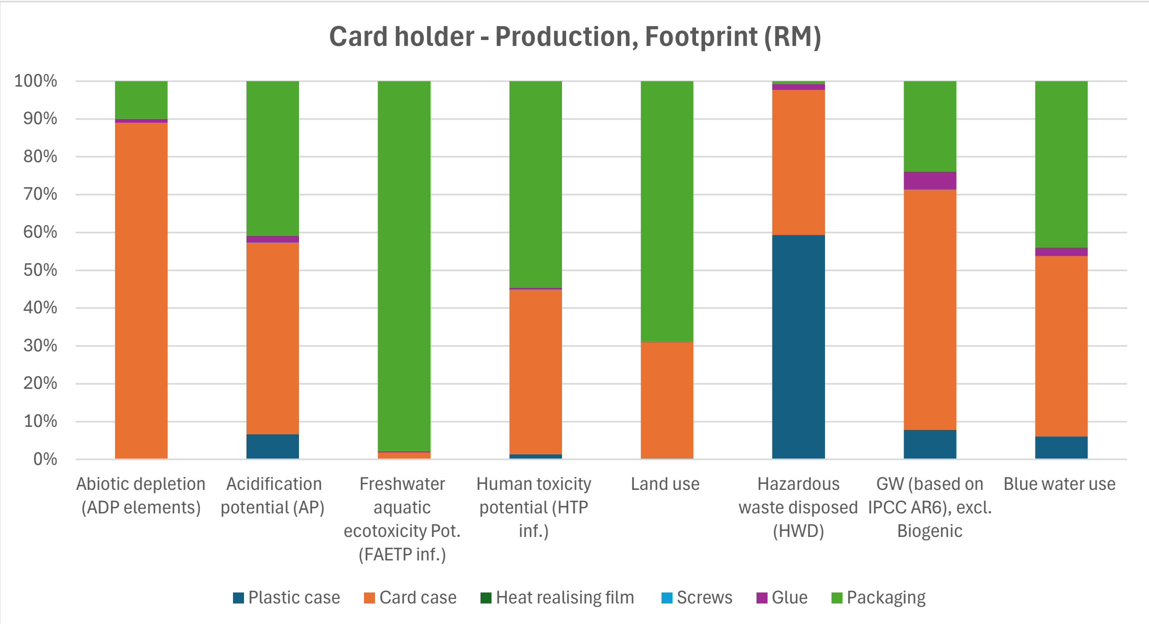

Figure 6-38 - Environmental impacts of the card holder production. Presented as % of the total life impacts.

Regarding the comparison of the two footprints, it can be seen that the plastic case´s GW would triple from Footprint (RM) to the Footprint (w/o reduction measures), if no recycled plastics was used.

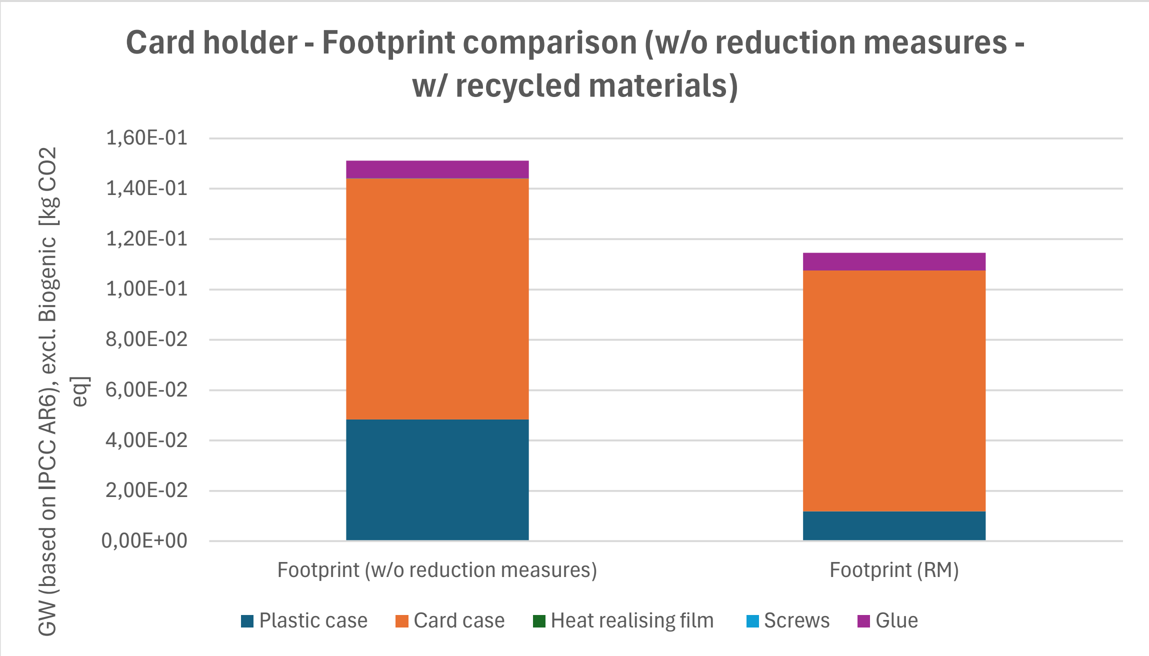

Figure 6-39 – Card holder global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.6 Lanyard

Table 6-12 - Environmental impacts of the lanyard, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,06E-07	2,64E-07	3,27E-07	1,57E-08
Acidification Potential (AP) [kg SO2 eq.]	7,52E-03	5,24E-04	6,94E-03	4,94E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	7,32E-02	2,13E-02	5,14E-02	5,52E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,07E+00	5,88E-02	1,01E+00	1,27E-03
Land Use [Pt]	1,00E+01	7,32E+00	2,65E+00	2,57E-02
Hazardous waste disposed (HWD) [kg]	1,08E-08	1,08E-08	0,00E+00	1,45E-11
GW (based on IPCC AR6), excl. Biogenic carbon	1,53E+00	1,53E-01	1,33E+00	5,32E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	5,51E-09	5,33E-09	0,00E+00	1,80E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	7,80E-02	7,56E-02	2,17E-03	1,98E-04

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,62E-01	-1,60E-01	-1,82E-03	-1,94E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	8,48E-04	6,91E-04	1,52E-04	5,22E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,48E+00	1,02E-01	1,32E+00	5,32E-02
Blue water use [kg]	5,29E+02	2,40E+00	5,20E+02	6,89E+00

In Figure Figure 6-40, transport is seen as the dominant life cycle phase in all indicators except land use and HWD, where the manufacturing phase drives the impact.

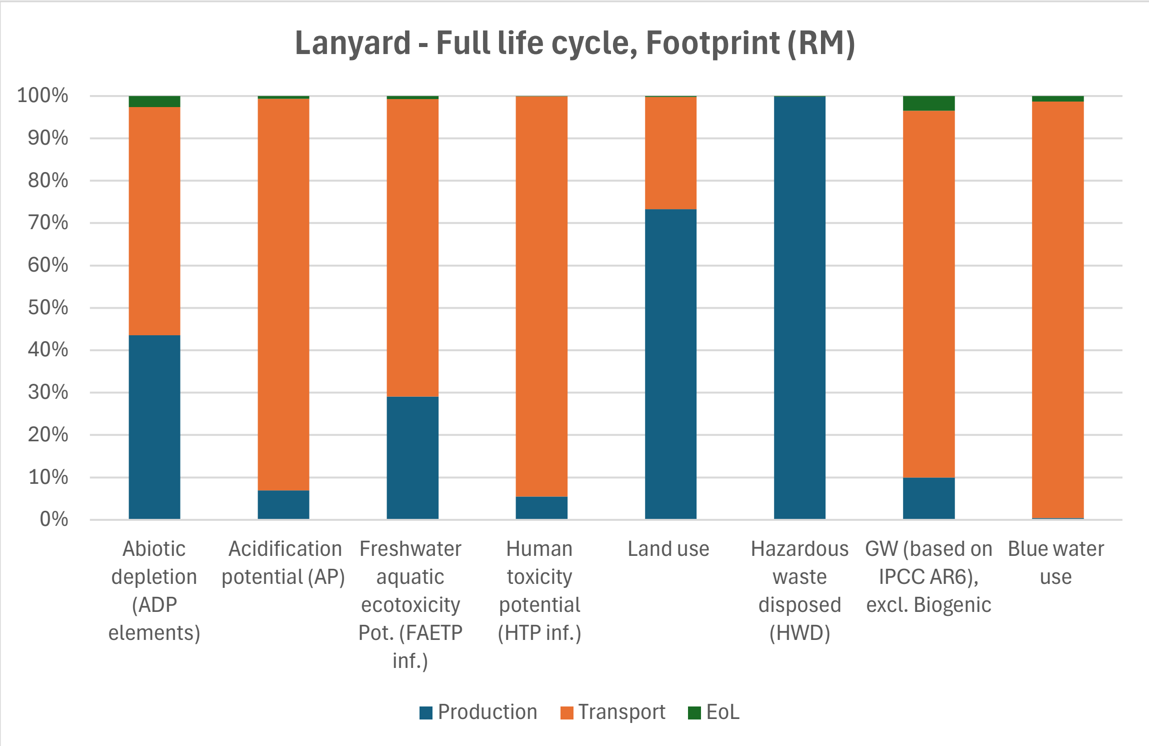

Figure 6-40 - Environmental impacts of lanyard, per life cycle phase. Presented as % of the total life impacts.

Packaging is the part that has the biggest production impact for the lanyard production for ADP, AP, FAETP, HTP, land use and to a lesser extent for GW. Following that the rope is the element that has the greatest impact on blue water use.

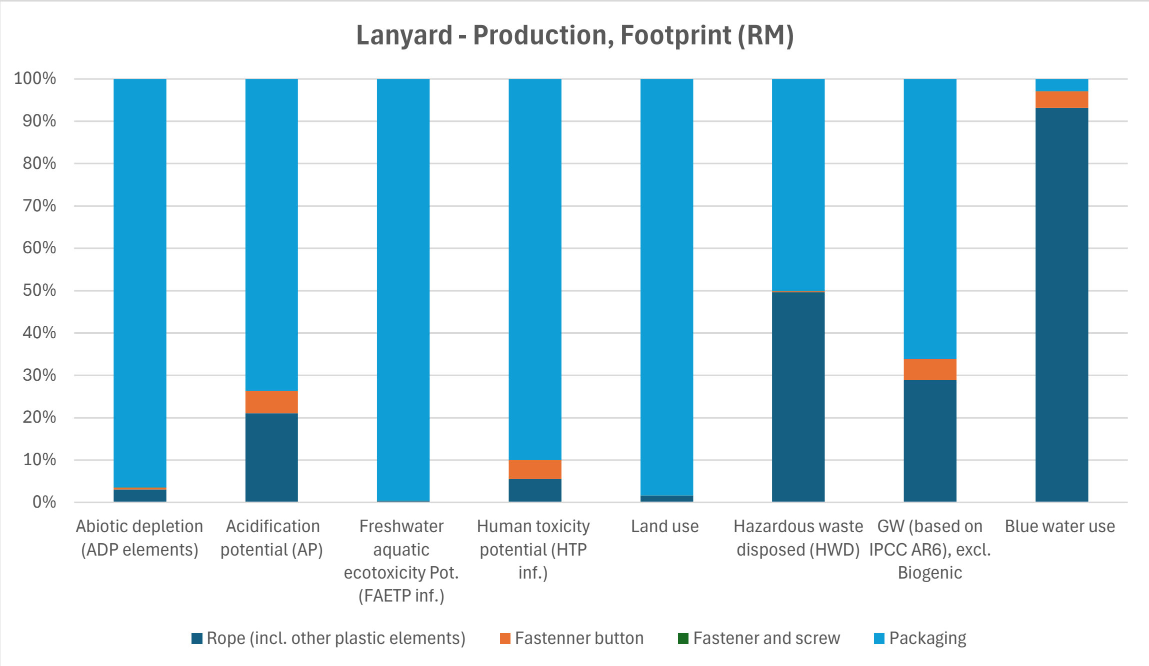

Figure 6-41 - Environmental impacts of the lanyard production. Presented as % of the total life impacts.

Due to the recycled materials used for the rope and the fastener button, the GW is much lower for the Footprint (RM). Elements such as fasteners and screws do not contribute to any reduction as they do not contain recycled material.

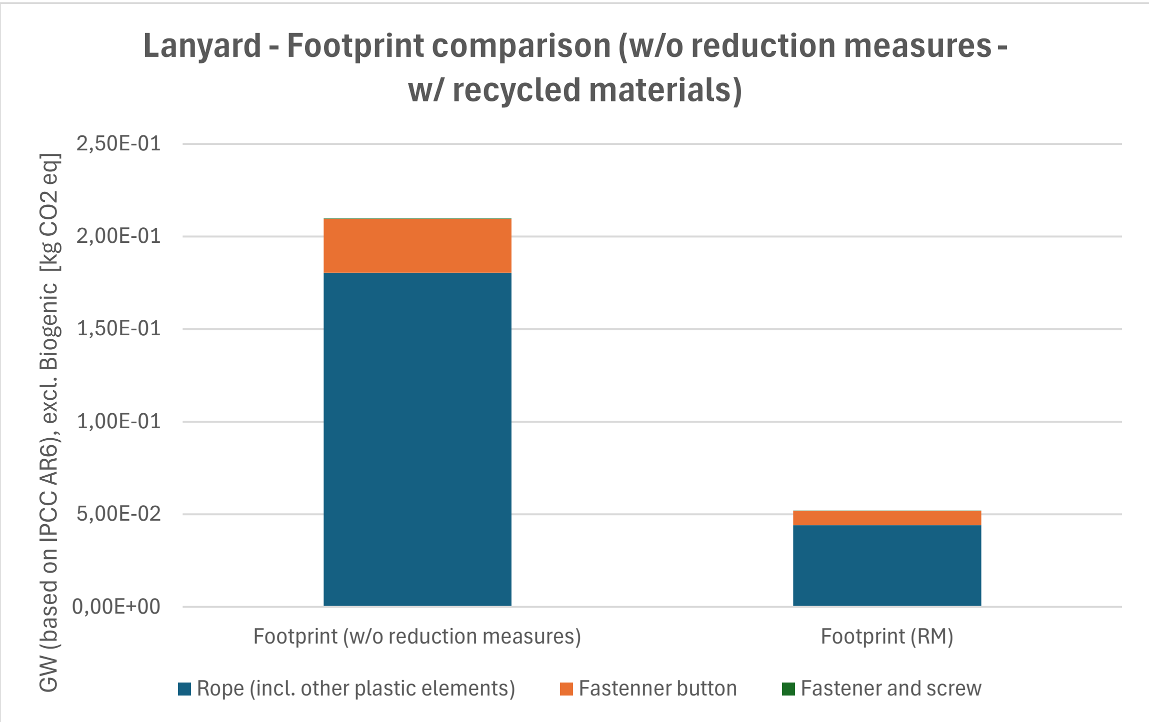

Figure 6-42 – Lanyard global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.7 SIM-Card pin

Table 6-13 - Environmental impacts of the SIM Card, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,35E-07	1,30E-07	3,71E-10	4,50E-09
Acidification Potential (AP) [kg SO2 eq.]	3,41E-05	1,64E-05	7,55E-06	1,01E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,78E-04	4,58E-05	5,68E-05	1,75E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	3,51E-03	1,98E-03	1,16E-03	3,64E-04
Land Use [Pt]	1,35E-02	4,10E-03	3,01E-03	6,35E-03
Hazardous waste disposed (HWD) [kg]	8,75E-12	7,36E-12	0,00E+00	1,39E-12
GW (based on IPCC AR6), excl. Biogenic carbon	6,08E-03	1,92E-03	1,51E-03	2,65E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,28E-10	1,13E-10	0,00E+00	1,51E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,04E-03	7,73E-05	1,94E-03	2,14E-05
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,73E-03	-7,55E-05	-1,63E-03	-2,15E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,40E-04	3,06E-06	1,37E-04	2,44E-07
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,17E+00	1,92E-03	1,16E+00	2,65E-03
Blue water use [kg]	5,41E+00	2,38E+00	5,60E-01	2,47E+00

For the SIM card, only the full life cycle Footprint (RM) will be analyzed, as it does not contain packaging per se; it is part of the phone set, which already has its own packaging analyzed accordingly. It is also not made from any recycled materials, nor does it use renewable energy.

For this accessory, production has the greatest impact on ADP and HWD, while for FAETP, land use, GW, and blue water, the EoL has a greater impact. A slightly higher impact from transportation could be noted for HTP, but it is not the most significant factor.

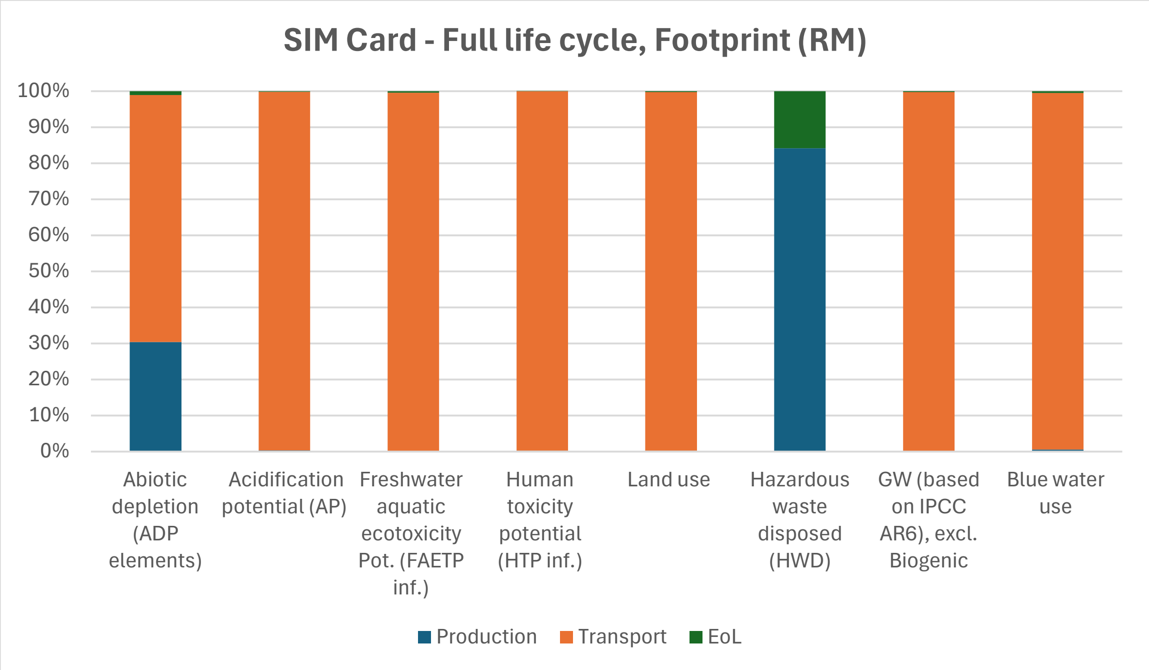

Figure 6-43 - Environmental impacts of SIM Card, per life cycle phase. Presented as % of the total life impacts.

6.6.8 Screwdriver

Table 6-14 - Environmental impacts of the screwdriver, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,31E-09	4,64E-10	3,83E-09	2,01E-09
Acidification Potential (AP) [kg SO2 eq.]	1,13E-04	1,86E-05	8,78E-05	6,34E-06
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	7,15E-04	1,32E-05	6,31E-04	7,08E-05
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,53E-02	8,19E-04	1,43E-02	1,63E-04
Land Use [Pt]	4,81E-02	9,67E-03	3,51E-02	3,30E-03
Hazardous waste disposed (HWD) [kg]	2,91E-10	2,89E-10	0,00E+00	1,86E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	3,45E-02	9,32E-03	1,84E-02	6,83E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,02E-10	2,78E-10	0,00E+00	2,31E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,62E-03	2,68E-04	2,33E-03	2,54E-05

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,23E-03	-2,52E-04	-1,96E-03	-2,49E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,74E-04	1,05E-05	1,63E-04	6,70E-07
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,44E+00	9,31E-03	1,42E+00	6,83E-03
Blue water use [kg]	3,46E+03	3,45E+03	6,31E+00	1,24E+00

For most impact categories, transportation is the main contributor, as can be seen in the following graph, except for HWD and blue water use, where higher impact is caused by production.

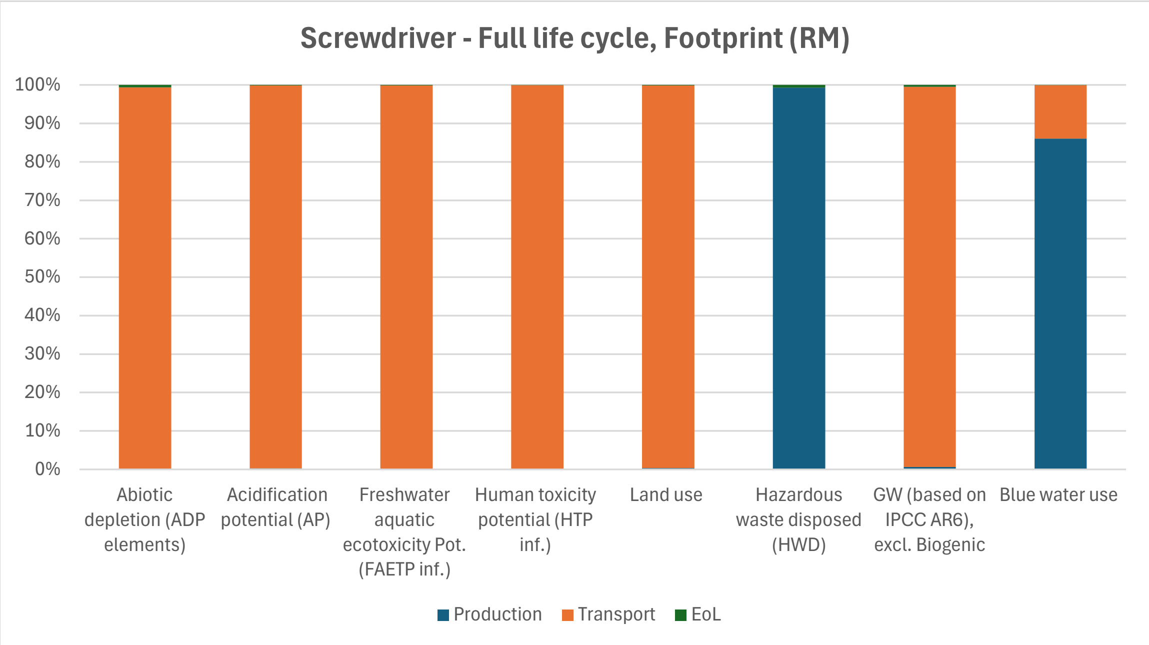

Figure 6-44 - Environmental impacts of screwdriver, per life cycle phase. Presented as % of the total life impacts.

The next figure shows that the steel shaft has the bigger impact for AP, FAETP, HTP and GW. The handle made from recycled PC for ADP, land use, HWD and Blue water use.

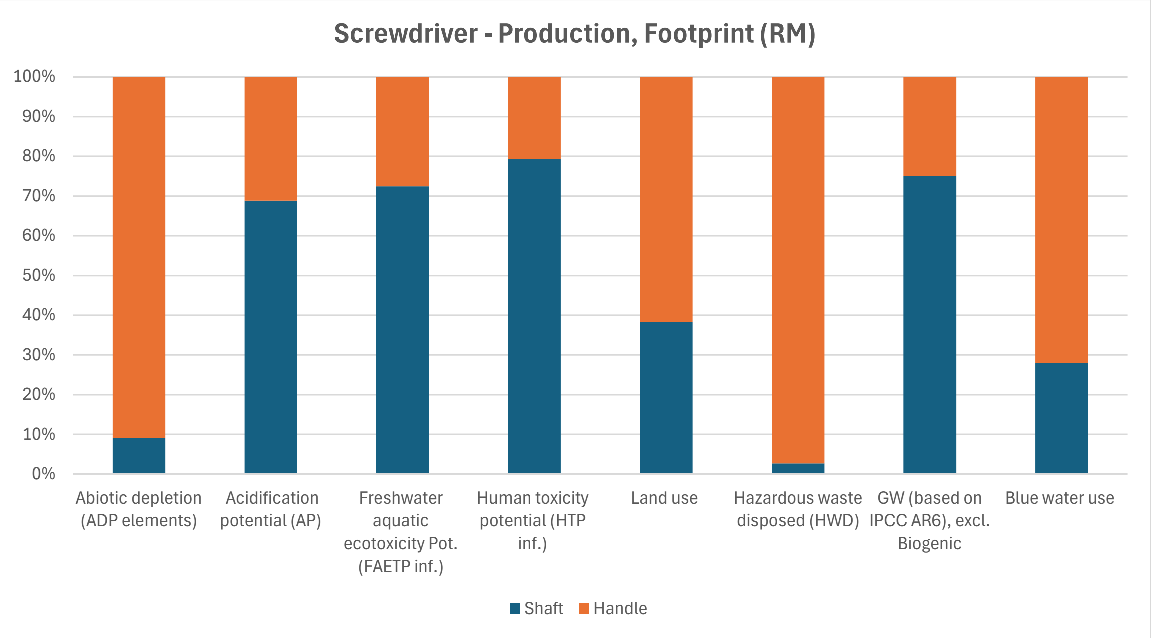

Figure 6-45 - Environmental impacts of the screwdriver production. Presented as % of the total life impacts.

As previously mentioned, the handle is made of recycled plastic; therefore, the impact for the Footprint (RM) is much lower than for the Footprint (w/o reduction measures), where virgin material is used.

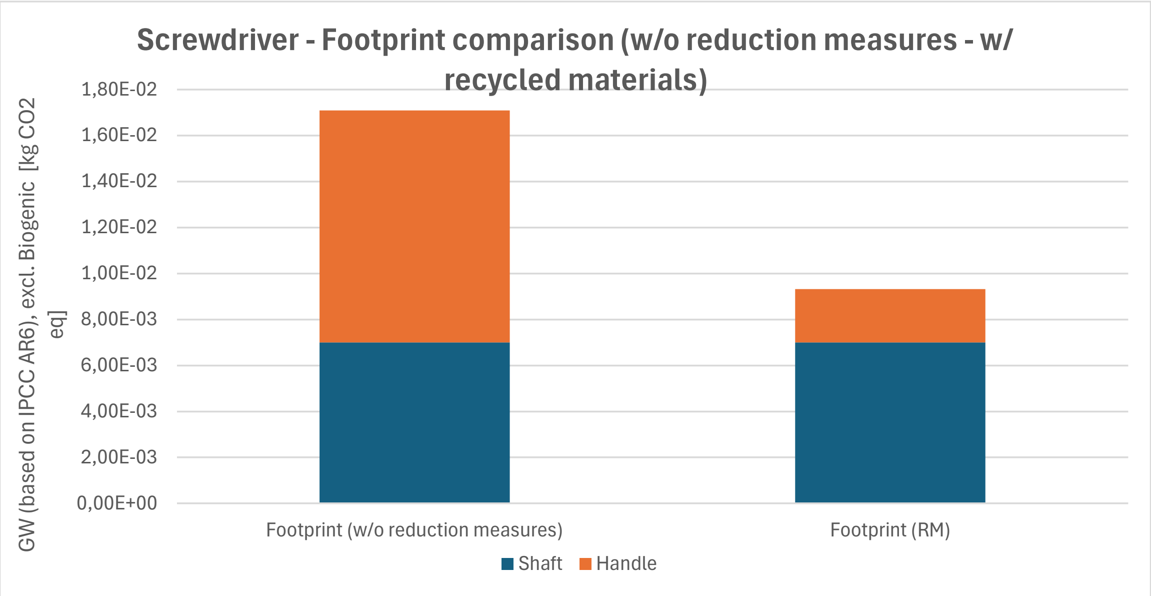

Figure 6-46 – Screwdriver global warming comparison between footprints (w/o reduction measures - w/ recycled materials).

6.6.9 Cables

The composition of the cables is very similar; they are made of the same materials and components but in different quantities. For USB 2.0, the difference lies in the length, and for USB 3.1, what changes compared to USB 2.0 is the amount of recycled material, especially the copper, which is higher for the USB 3.1 cable. Therefore, the results of the three cable options will be interpreted altogether.

For acidification, global warming and human tox; transport is the main impact driver. In the case of the 2,5 m cable, production drives these impacts as more cable (and thus more metal and more plastic) needs to be produced. For the rest of indicators, production is the environmental hotspot.

Regarding production, it is worth noting that for ADP, the adapter PCB contributes the most in all three cable types. The cables themselves also have a significant impact on the AP, HWD, GW, and blue water use indicators, while the packaging is significant in land use. Finally, it should be mentioned that the wire + contacts largely contribute to the FAETP and HTP indicators.

The comparison between the different footprints highlights that using recycled materials and renewable energy results in 50% less impact on global warming. Furthermore, it can be stated that the energy used for manufacturing the cables the main contributor to the impact.

6.6.9.1 USB 2.0 (1m)

Table 6-15 - Environmental impacts of the USB 2.0 (1m), divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,52E-05	3,49E-05	2,44E-07	3,87E-08
Acidification Potential (AP) [kg SO2 eq.]	7,72E-03	2,57E-03	5,09E-03	4,89E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,81E-01	1,41E-01	3,80E-02	2,25E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,07E+00	3,25E-01	7,38E-01	4,82E-03
Land Use [Pt]	8,46E+00	6,48E+00	1,94E+00	3,35E-02
Hazardous waste disposed (HWD) [kg]	7,58E-09	7,57E-09	0,00E+00	4,69E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,79E+00	8,14E-01	9,66E-01	9,65E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,77E-08	3,77E-08	0,00E+00	4,96E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	8,89E-02	8,72E-02	1,60E-03	1,47E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,38E-01	-1,36E-01	-1,35E-03	-1,48E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,57E-03	2,45E-03	1,13E-04	5,39E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,85E+00	8,75E-01	9,65E-01	9,64E-03
Blue water use [kg]	1,24E+03	8,27E+02	3,83E+02	2,72E+01

Table 6-16 - Environmental impacts of the USB 2.0 (1m), divided by life cycle phase, Footprint (RM + RE)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,75E-05	3,72E-05	2,44E-07	3,87E-08
Acidification Potential (AP) [kg SO2 eq.]	6,53E-03	1,39E-03	5,09E-03	4,89E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,87E-01	2,47E-01	3,80E-02	2,25E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,16E+00	4,14E-01	7,38E-01	4,82E-03
Land Use [Pt]	1,58E+01	1,38E+01	1,94E+00	3,35E-02
Hazardous waste disposed (HWD) [kg]	3,10E-09	3,10E-09	0,00E+00	4,69E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,17E+00	1,96E-01	9,66E-01	9,65E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,66E-08	1,65E-08	0,00E+00	4,96E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	6,85E-02	6,68E-02	1,60E-03	1,47E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,17E-01	-1,16E-01	-1,35E-03	-1,48E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,09E-03	9,68E-04	1,13E-04	5,39E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,39E+00	4,18E-01	9,65E-01	9,64E-03
Blue water use [kg]	1,74E+03	1,33E+03	3,83E+02	2,72E+01

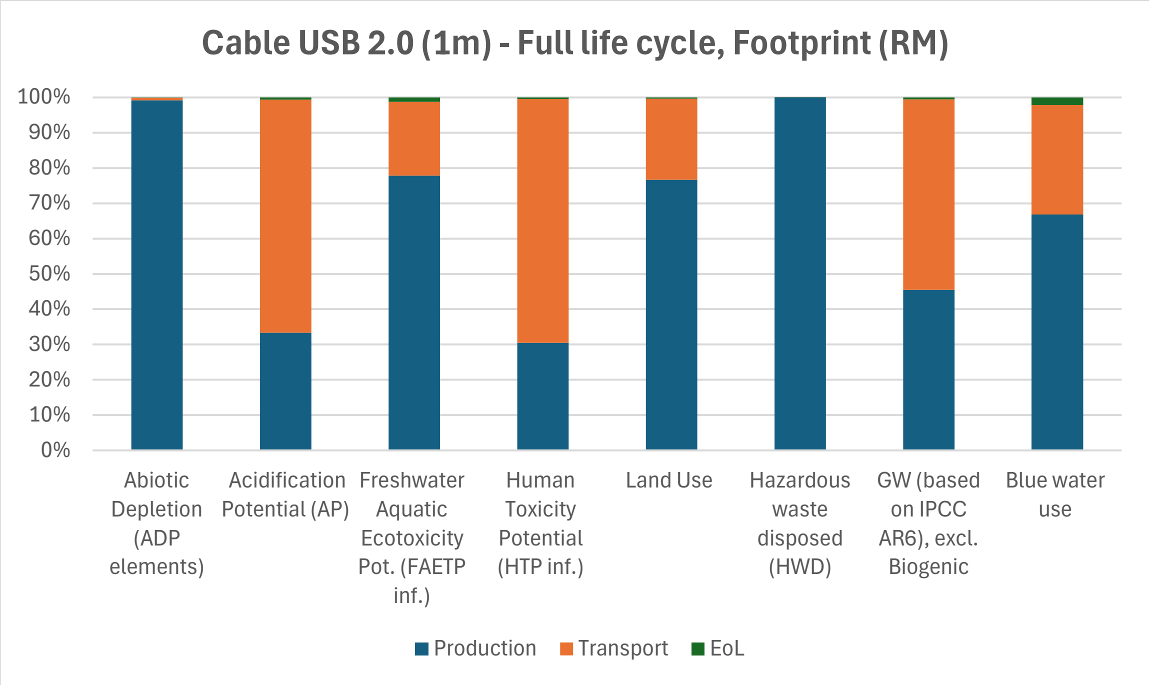

Figure 6-47 - Environmental impacts of USB 2.0 (1m), per life cycle phase. Presented as % of the total life impacts.

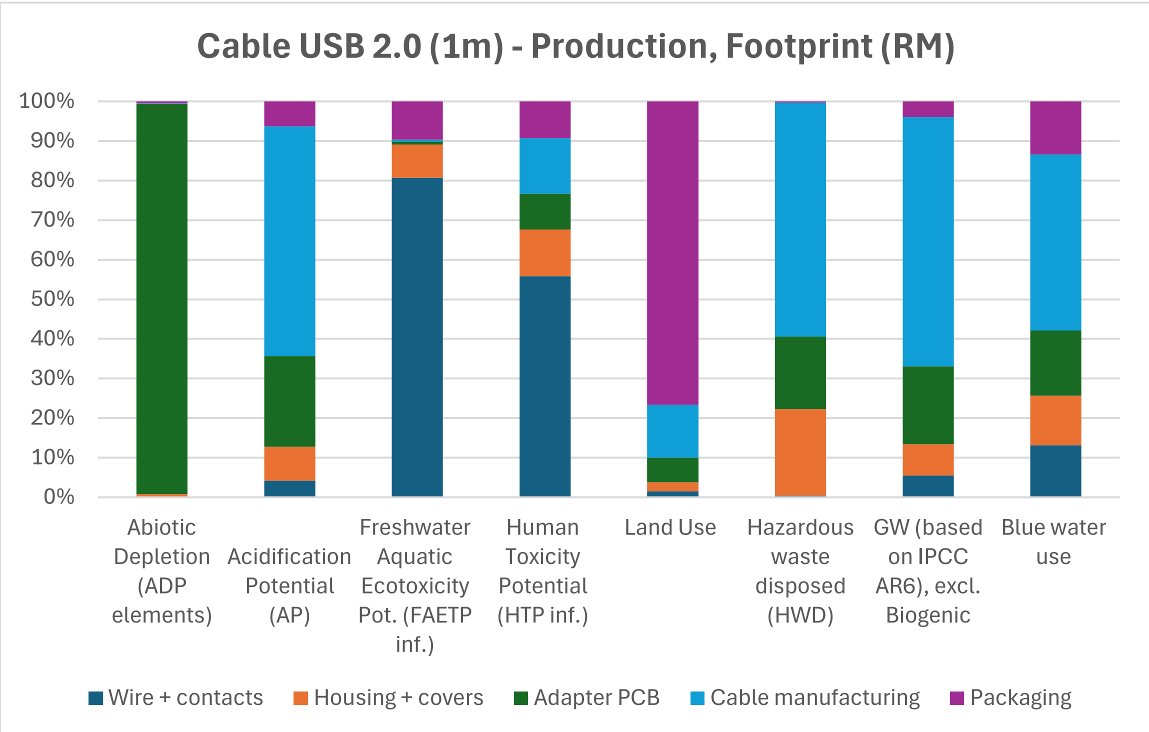

Figure 6-48 - Environmental impacts of the USB 2.0 (1m) production. Presented as % of the total life impacts.

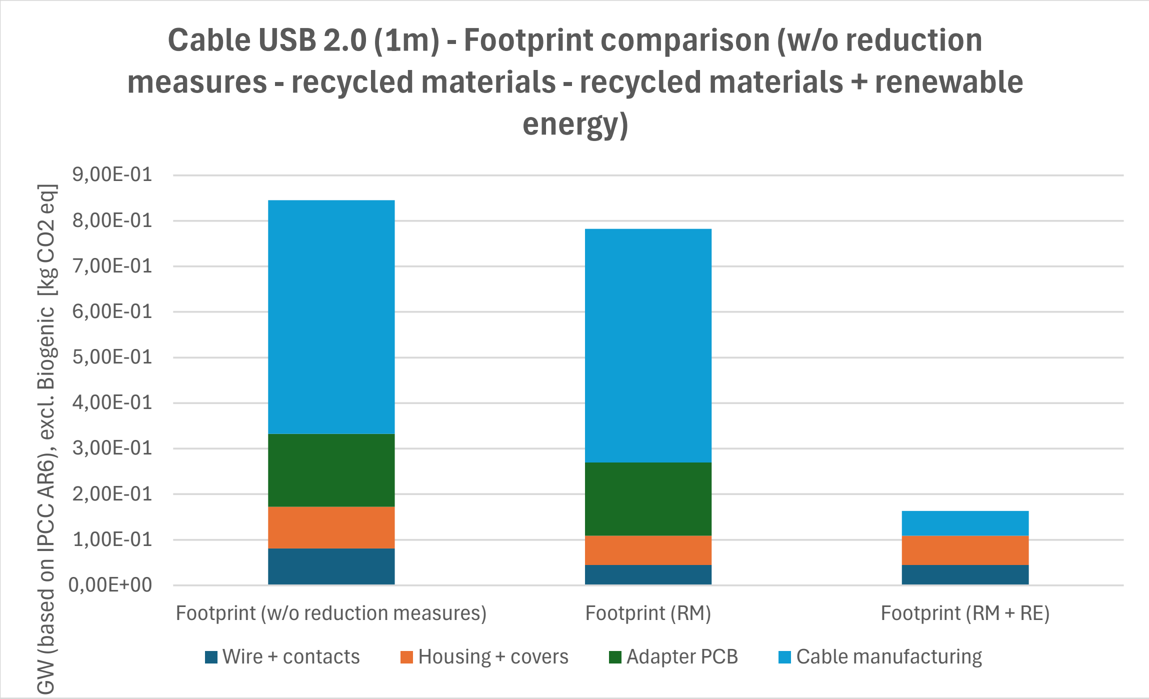

Figure 6-49 – USB 2.0 (1m) global warming comparison between *footprints (w/o reduction measures - w/ recycled materials – w/ recycled materials and renewable energy).*

6.6.9.2 USB 2.0 (2,5m)

Table 6-17 - Environmental impacts of the USB 2.0 (2,5m), divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,56E-05	3,51E-05	4,28E-07	8,01E-08
Acidification Potential (AP) [kg SO2 eq.]	6,77E-03	2,90E-03	3,76E-03	1,01E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	3,87E-01	3,40E-01	4,27E-02	4,66E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,08E+00	6,64E-01	4,09E-01	9,99E-03
Land Use [Pt]	7,78E+00	5,94E+00	1,77E+00	6,94E-02
Hazardous waste disposed (HWD) [kg]	9,48E-09	9,47E-09	0,00E+00	9,72E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,53E+00	9,32E-01	5,80E-01	2,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,63E-08	3,62E-08	0,00E+00	1,03E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	4,28E-02	4,07E-02	1,73E-03	3,05E-04

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-3,99E-02	-3,81E-02	-1,48E-03	-3,07E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,41E-03	2,27E-03	1,27E-04	1,12E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,50E+00	9,00E-01	5,78E-01	2,00E-02
Blue water use [kg]	4,13E+02	0,00E+00	3,56E+02	5,63E+01

Table 6-18 - Environmental impacts of the USB 2.0 (2,5m), divided by life cycle phase, Footprint (RM + RE)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,79E-05	3,74E-05	4,28E-07	8,01E-08
Acidification Potential (AP) [kg SO2 eq.]	5,58E-03	1,72E-03	3,76E-03	1,01E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	4,92E-01	4,45E-01	4,27E-02	4,66E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,17E+00	7,53E-01	4,09E-01	9,99E-03
Land Use [Pt]	1,50E+01	1,32E+01	1,77E+00	6,94E-02
Hazardous waste disposed (HWD) [kg]	5,00E-09	4,99E-09	0,00E+00	9,72E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,07E+00	4,74E-01	5,80E-01	2,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,52E-08	1,51E-08	0,00E+00	1,03E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,23E-02	2,03E-02	1,73E-03	3,05E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,96E-02	-1,78E-02	-1,48E-03	-3,07E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	9,31E-04	7,93E-04	1,27E-04	1,12E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,04E+00	4,43E-01	5,78E-01	2,00E-02
Blue water use [kg]	4,13E+02	0,00E+00	3,56E+02	5,63E+01

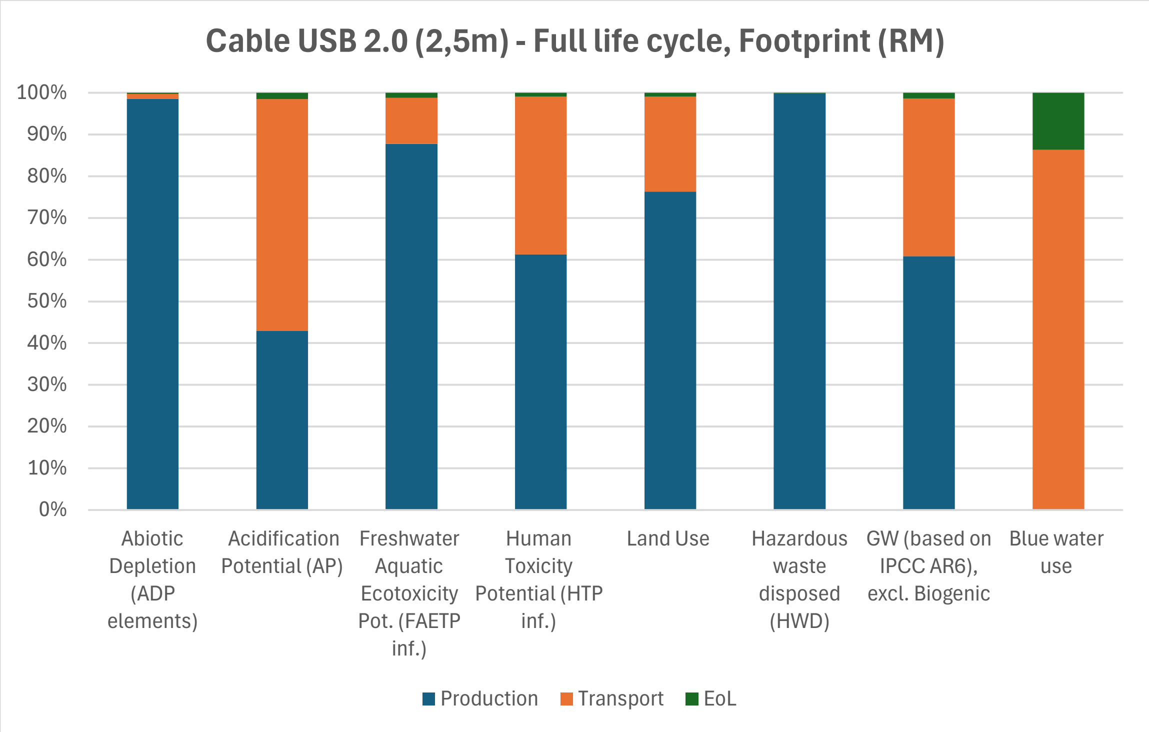

Figure 6-50 - Environmental impacts of USB 2.0 (2,5m), per life cycle phase. Presented as % of the total life impacts.

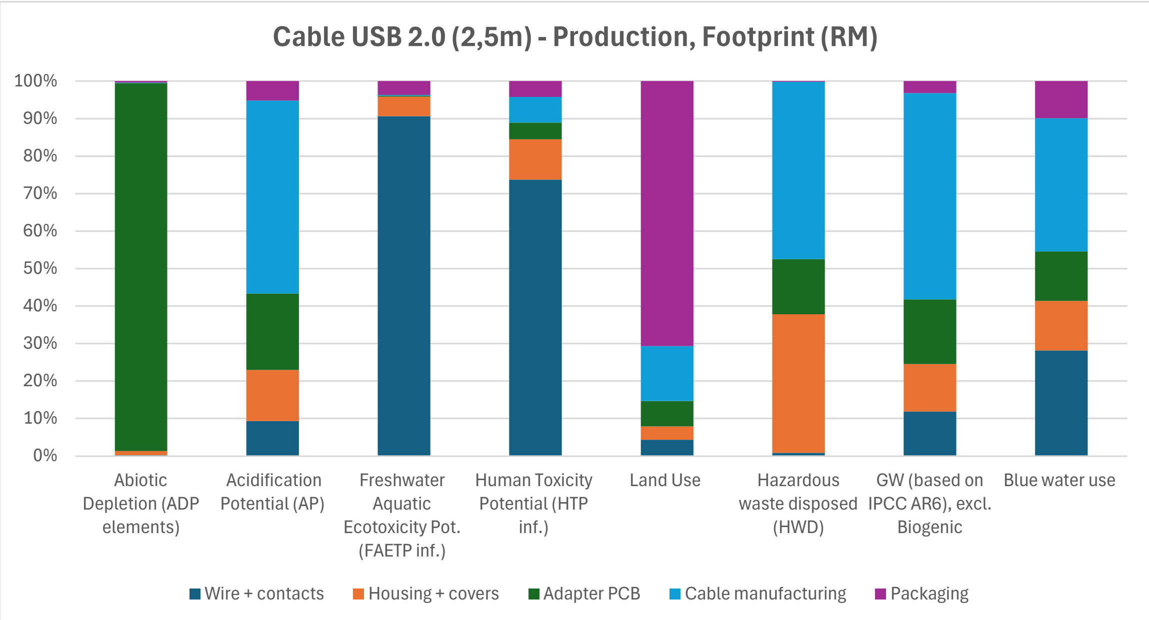

Figure 6-51 - Environmental impacts of the USB 2.0 (2,5m) production. Presented as % of the total life impacts.

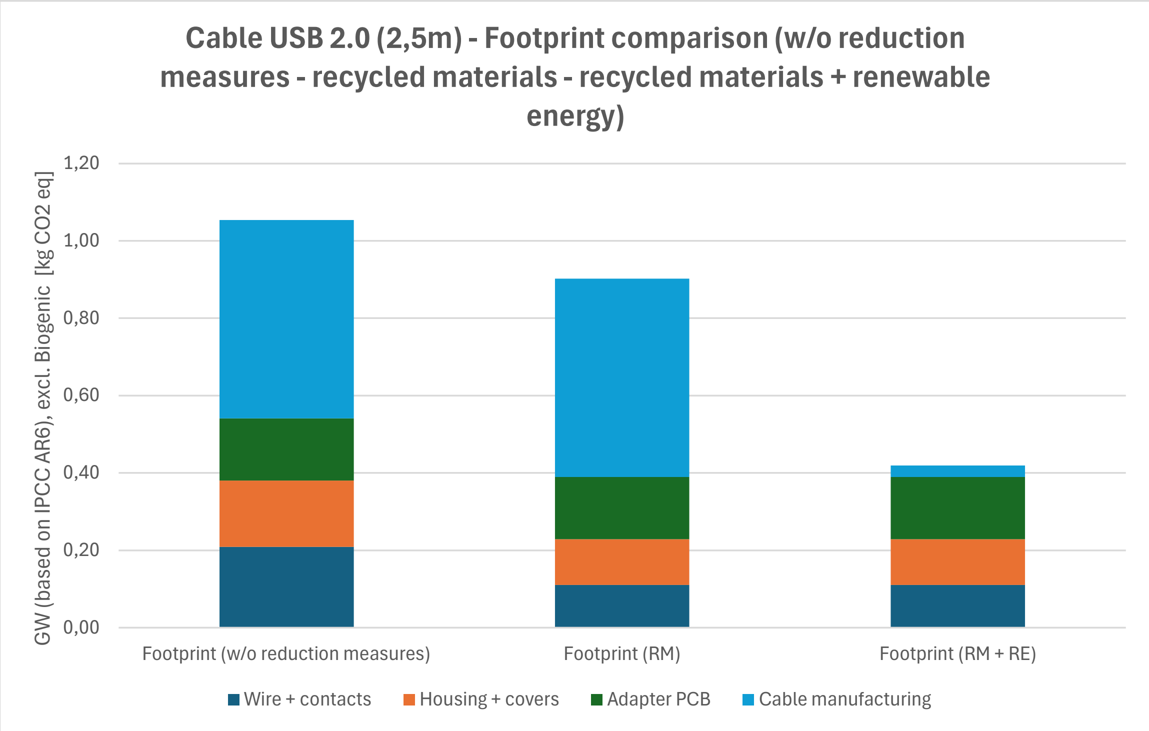

Figure 6-52 – USB 2.0 (2,5m) global warming comparison between footprints (w/o reduction measures - w/ recycled materials – w/ recycled materials and renewable energy).

6.6.9.3 USB 3.1

Table 6-19 - Environmental impacts of the USB 3.1, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,52E-05	3,49E-05	2,51E-07	4,90E-08
Acidification Potential (AP) [kg SO2 eq.]	7,96E-03	2,55E-03	5,34E-03	6,20E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,85E-01	1,43E-01	3,95E-02	2,85E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,11E+00	3,28E-01	7,80E-01	6,11E-03
Land Use [Pt]	8,54E+00	6,46E+00	2,03E+00	4,25E-02
Hazardous waste disposed (HWD) [kg]	6,59E-09	6,58E-09	0,00E+00	5,95E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,84E+00	8,07E-01	1,02E+00	1,22E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,35E-08	3,35E-08	0,00E+00	6,28E-11

ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	8,40E-02	8,22E-02	1,67E-03	1,86E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,33E-01	-1,31E-01	-1,40E-03	-1,88E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,59E-03	2,47E-03	1,17E-04	6,83E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,83E+00	8,04E-01	1,02E+00	1,22E-02
Blue water use [kg]	1,25E+03	8,17E+02	4,00E+02	3,44E+01

Table 6-20 - Environmental impacts of the USB 3.1, divided by life cycle phase, Footprint (RM + RE)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	3,75E-05	3,72E-05	2,51E-07	4,90E-08
Acidification Potential (AP) [kg SO2 eq.]	6,78E-03	1,37E-03	5,34E-03	6,20E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,91E-01	2,49E-01	3,95E-02	2,85E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,20E+00	4,16E-01	7,80E-01	6,11E-03
Land Use [Pt]	7,45E+00	5,37E+00	2,03E+00	4,25E-02
Hazardous waste disposed (HWD) [kg]	2,21E-03	2,21E-03	0,00E+00	5,95E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,38E+00	3,49E-01	1,02E+00	1,22E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,24E-08	1,23E-08	0,00E+00	6,28E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	6,36E-02	6,17E-02	1,67E-03	1,86E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,13E-01	-1,11E-01	-1,40E-03	-1,88E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,11E-03	9,87E-04	1,17E-04	6,83E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,38E+00	3,47E-01	1,02E+00	1,22E-02

Blue water use [kg]	9,20E+02	4,86E+02	4,00E+02	3,44E+01

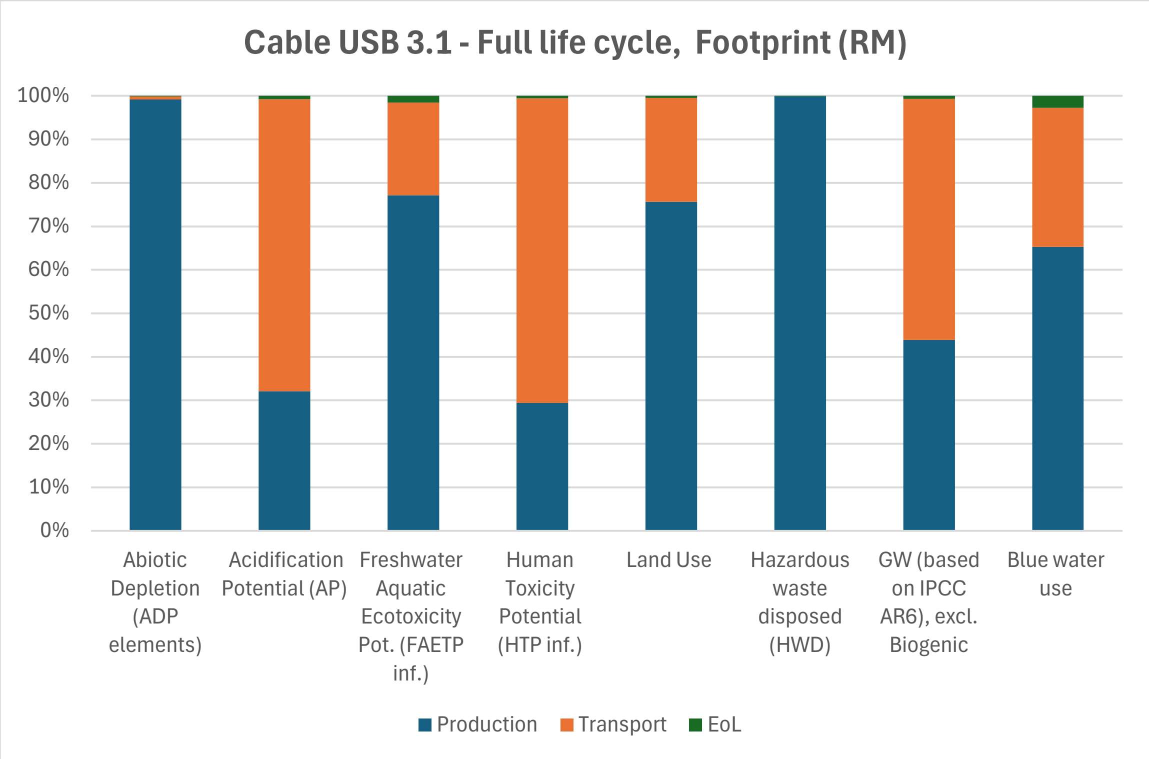

Figure 6-53 - Environmental impacts of USB 3.1, per life cycle phase. Presented as % of the total life impacts.

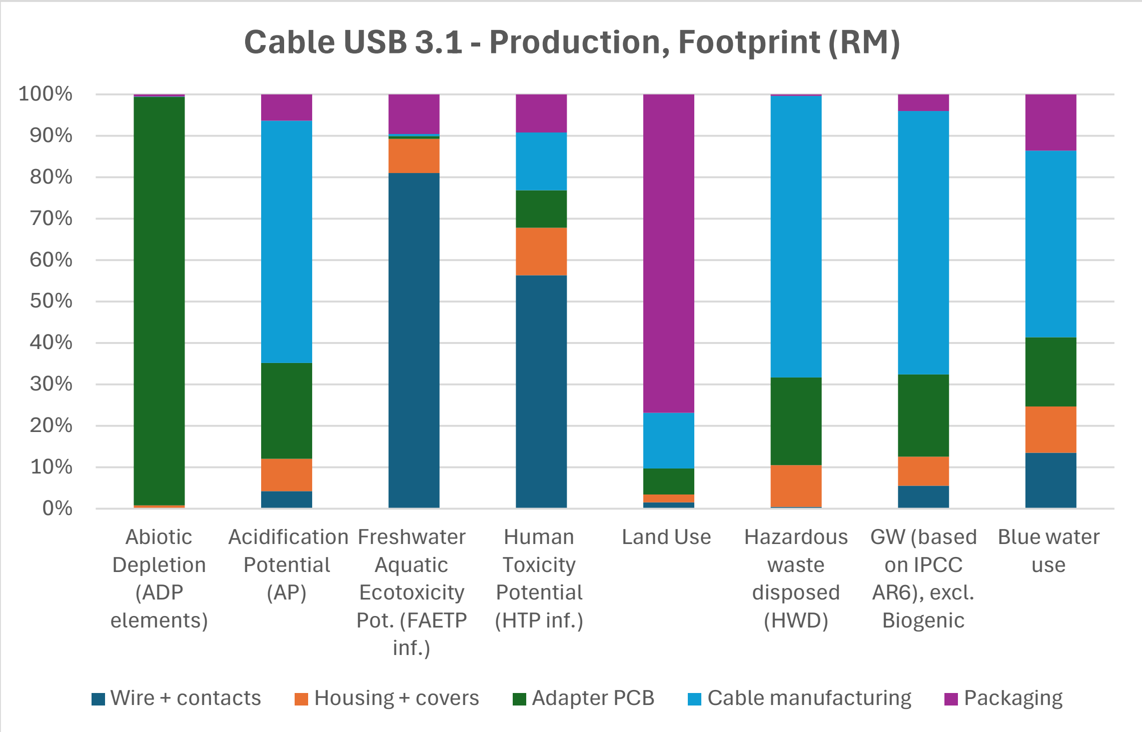

Figure 6-54 - Environmental impacts of the USB 3.1 production. Presented as % of the total life impacts.

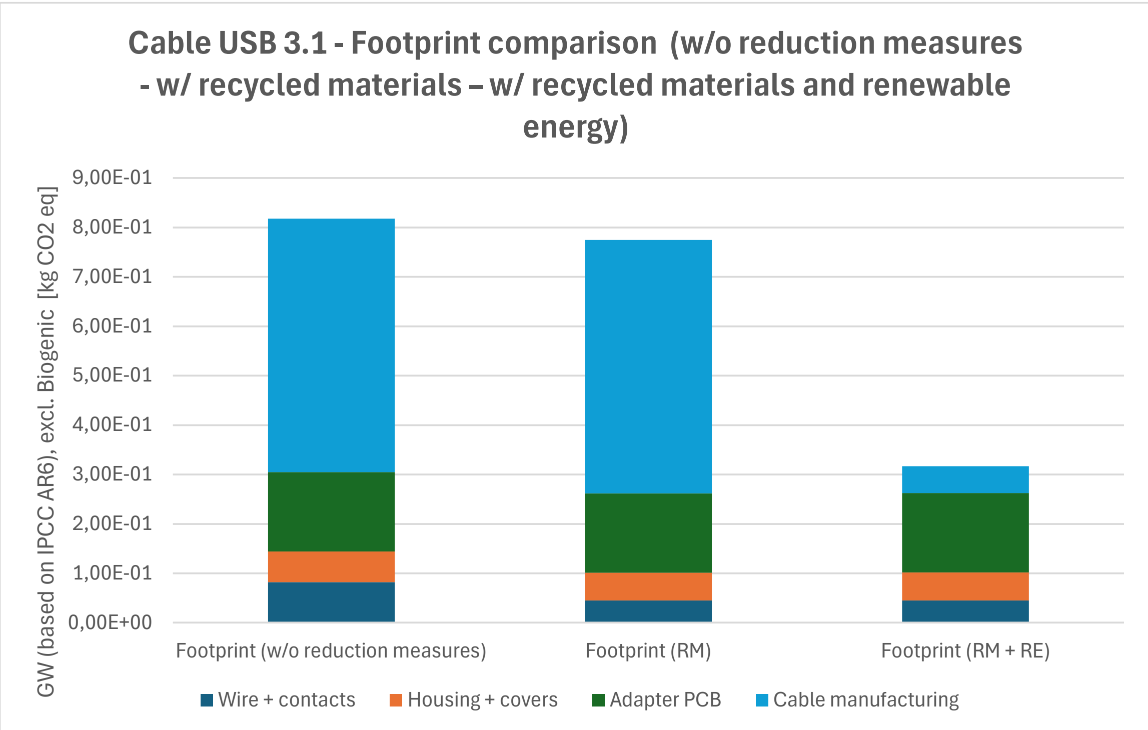

Figure 6-55 – USB 2.0 (2,5m) global warming comparison between footprints (w/o reduction measures - w/ recycled materials – w/ recycled materials and renewable energy).

6.6.10 Chargers

6.6.10.1 30W Charger

Table 6-21 - Environmental impacts of the 30W Charger, divided by life cycle phase, Footprint (RM)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	2,61E-04	2,61E-04	3,27E-07	4,02E-08
Acidification Potential (AP) [kg SO2 eq.]	3,51E-02	2,81E-02	6,95E-03	5,08E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,15E-01	6,09E-02	5,14E-02	2,34E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,84E+00	8,24E-01	1,02E+00	5,01E-03
Land Use [Pt]	1,39E+01	1,12E+01	2,65E+00	3,48E-02
Hazardous waste disposed (HWD) [kg]	1,99E-08	1,99E-08	0,00E+00	4,88E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	3,69E+00	2,36E+00	1,33E+00	1,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,77E-03	1,77E-03	0,00E+00	5,15E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,90E-01	1,88E-01	2,17E-03	1,53E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,44E-01	-2,42E-01	-1,82E-03	-1,54E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,39E-03	5,23E-03	1,52E-04	5,60E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,68E+00	2,35E+00	1,32E+00	1,00E-02
Blue water use [kg]	3,56E+03	3,01E+03	5,20E+02	2,82E+01

Table 6-22 - Environmental impacts of the 30W Charger, divided by life cycle phase, Footprint (RM + RE)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	2,62E-04	2,62E-04	3,27E-07	4,02E-08
Acidification Potential (AP) [kg SO2 eq.]	3,46E-02	2,76E-02	6,95E-03	5,08E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,59E-01	1,05E-01	5,14E-02	2,34E-03

Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,88E+00	8,61E-01	1,02E+00	5,01E-03
Land Use [Pt]	1,70E+01	1,43E+01	2,65E+00	3,48E-02
Hazardous waste disposed (HWD) [kg]	1,80E-08	1,80E-08	0,00E+00	4,88E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	3,50E+00	2,16E+00	1,33E+00	1,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,77E-03	1,77E-03	0,00E+00	5,15E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,81E-01	1,79E-01	2,17E-03	1,53E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,36E-01	-2,34E-01	-1,82E-03	-1,54E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	4,77E-03	4,61E-03	1,52E-04	5,60E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,49E+00	2,16E+00	1,32E+00	1,00E-02
Blue water use [kg]	3,78E+03	3,23E+03	5,20E+02	2,82E+01

The charger has a high overall impact stemming from production, as it is an accessory with a greater number of components, especially electronic ones, which significantly increases the impact. Transport remains the driver in human toxicity, however, as the total weight to be transported remains significant.

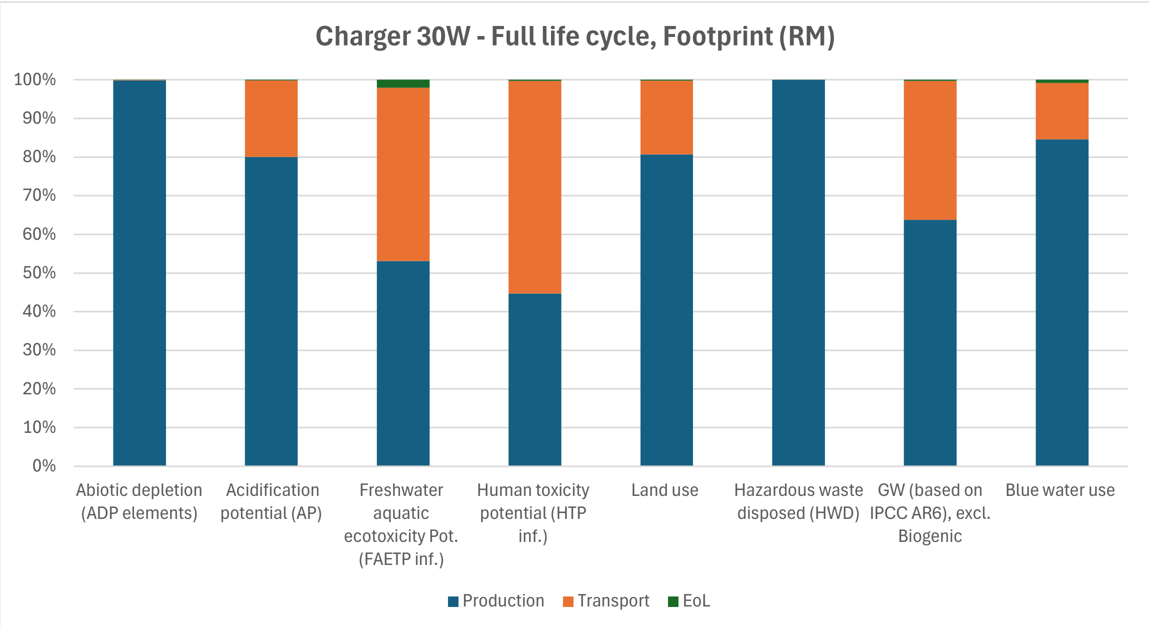

Figure 6-56 - Environmental impacts of 30W Charger, per life cycle phase. Presented as % of the total life impacts.

The next graph shows that the connector board has a significant impact on ADP and AP. On the other hand, the packaging highly contributes to the land use while the plastic shell contributes notably to the FAETP.

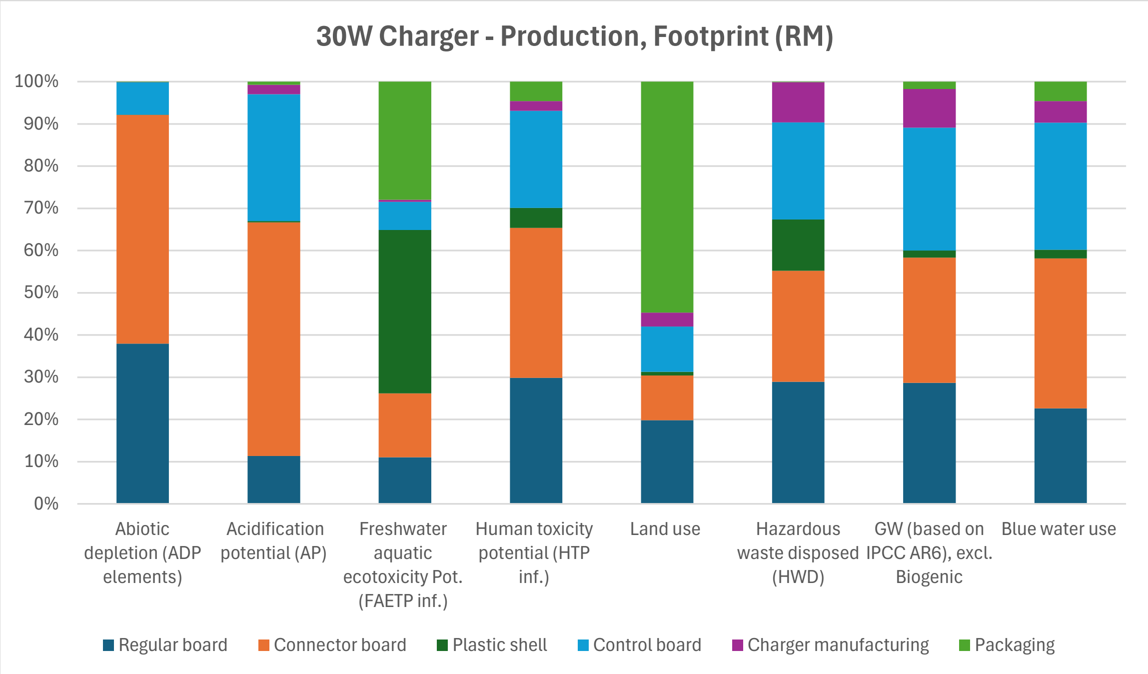

Figure 6-57 - Environmental impacts of the 30W Charger production. Presented as % of the total life impacts.

In the comparison of the impact reduction footprints, a decreased impact on GW is observed due to the use of recycled material for the plastic shell and renewable energy for the manufacturing of the charger.

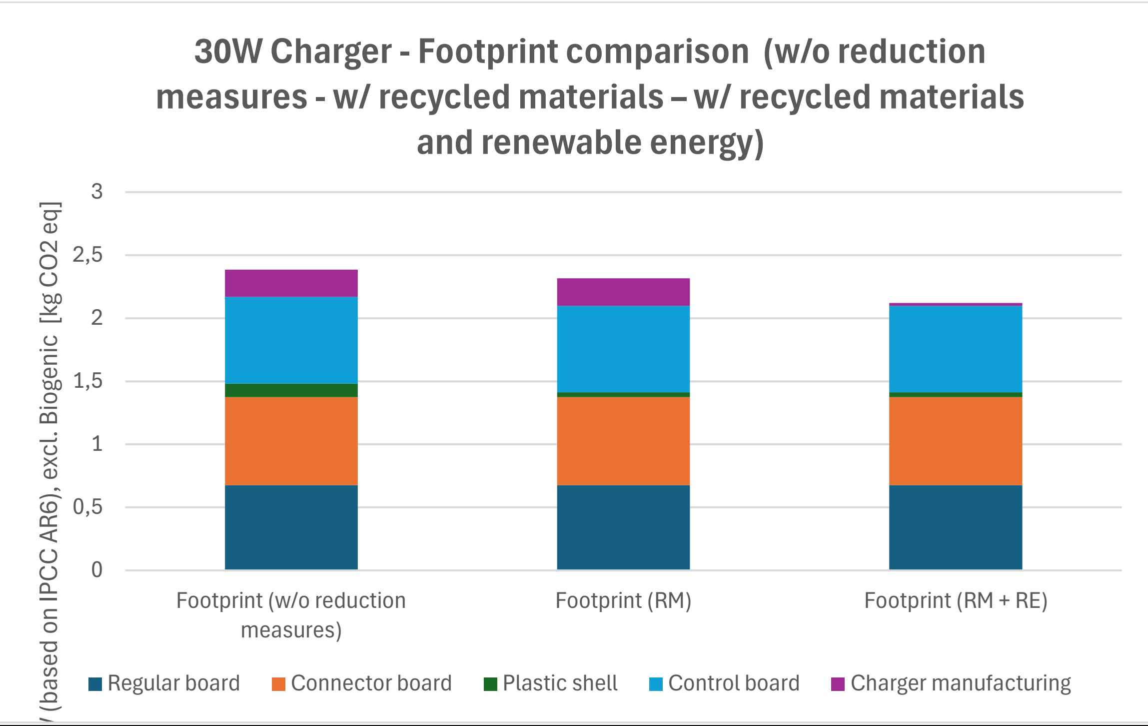

Figure 6-58 – 30W Charger global warming comparison between footprints (w/o reduction measures - w/ recycled materials – w/ recycled materials and renewable energy).

6.6.10.2 65W Charger

Table 6-23 - Environmental impacts of the 65W Charger, divided by life cycle phase Footprint (RM)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	4,70E-04	4,70E-04	3,51E-07	9,88E-08
Acidification Potential (AP) [kg SO2 eq.]	4,30E-02	3,54E-02	7,49E-03	1,25E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,31E-01	6,96E-02	5,54E-02	5,74E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,36E+00	1,26E+00	1,09E+00	1,23E-02
Land Use [Pt]	2,47E+01	2,18E+01	2,84E+00	8,55E-02
Hazardous waste disposed (HWD) [kg]	4,65E-08	4,65E-08	0,00E+00	1,20E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	6,33E+00	4,88E+00	1,43E+00	2,46E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,23E-03	1,23E-03	0,00E+00	1,27E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	4,58E-01	4,56E-01	2,33E-03	3,76E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-5,10E-01	-5,08E-01	-1,96E-03	-3,79E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,20E-02	1,19E-02	1,64E-04	1,38E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	6,31E+00	4,87E+00	1,42E+00	2,46E-02
Blue water use [kg]	8,64E+03	8,01E+03	5,61E+02	6,94E+01

Table 6-24 - Environmental impacts of the 65W Charger, divided by life cycle phase, Footprint (RM + RE)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	4,71E-04	4,71E-04	3,51E-07	9,88E-08
Acidification Potential (AP) [kg SO2 eq.]	4,25E-02	3,49E-02	7,49E-03	1,25E-04

Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,75E-01	1,14E-01	5,54E-02	5,74E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,40E+00	1,30E+00	1,09E+00	1,23E-02
Land Use [Pt]	2,77E+01	2,48E+01	2,84E+00	8,55E-02
Hazardous waste disposed (HWD) [kg]	4,46E-08	4,46E-08	0,00E+00	1,20E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	6,14E+00	4,69E+00	1,43E+00	2,46E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,23E-03	1,23E-03	0,00E+00	1,27E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	4,50E-01	4,47E-01	2,33E-03	3,76E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-5,01E-01	-4,99E-01	-1,96E-03	-3,79E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,14E-02	1,12E-02	1,64E-04	1,38E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	6,12E+00	4,67E+00	1,42E+00	2,46E-02
Blue water use [kg]	8,85E+03	8,22E+03	5,61E+02	6,94E+01

The 65W charger, like the 30W charger, has a significant impact during the production phase due to the large amount of electronics present in this accessory. Similarly to the 30W charger, human toxicity is driven by the transportation effort.

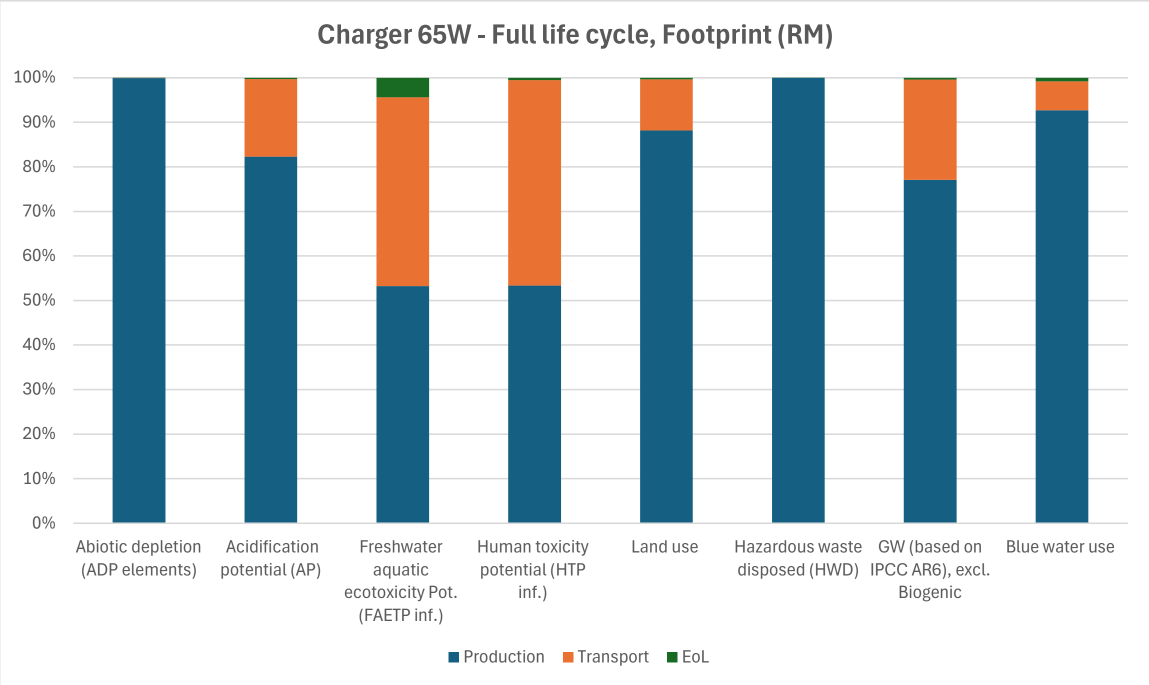

Figure 6-59 - Environmental impacts of 65W Charger, per life cycle phase. Presented as % of the total life impacts.

The PD protocol board is the charger component that has the greatest impact on most indicators due to all the electronic components it comprises. The housing has a significant impact on the FAETP.

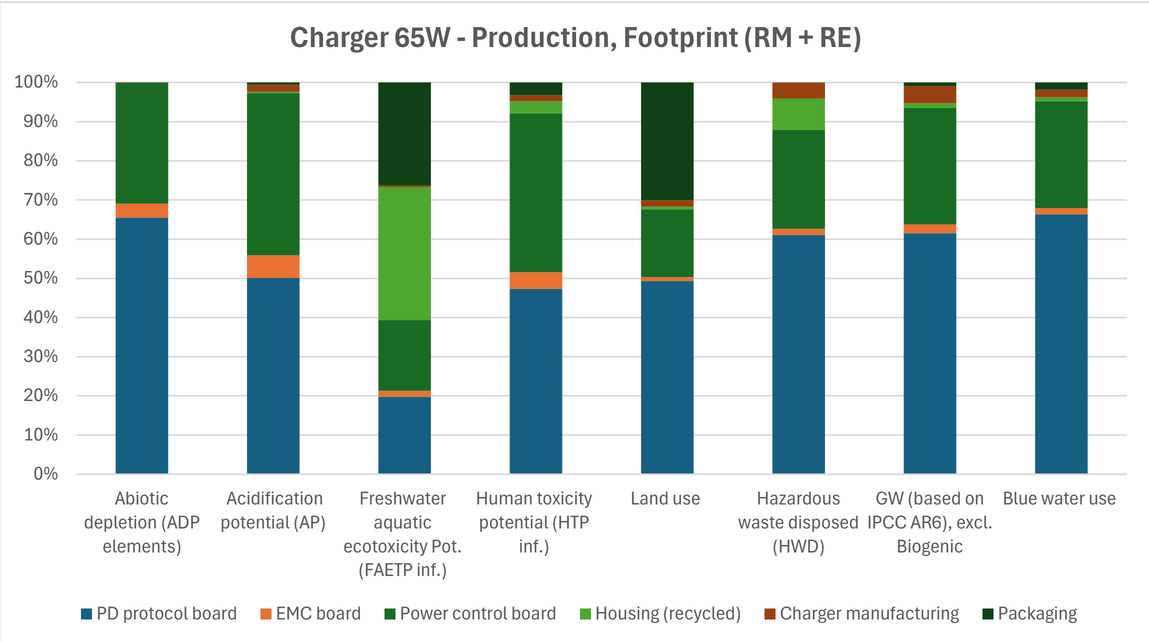

Figure 6-60 - Environmental impacts of the 65W Charger production. Presented as % of the total life impacts.

The recycled materials in the housing and the renewable energy used for the manufacturing reduces the impact on global warming (Footprint (RM + RE)) compared to the Footprint (w/o reduction measures) where none are used.

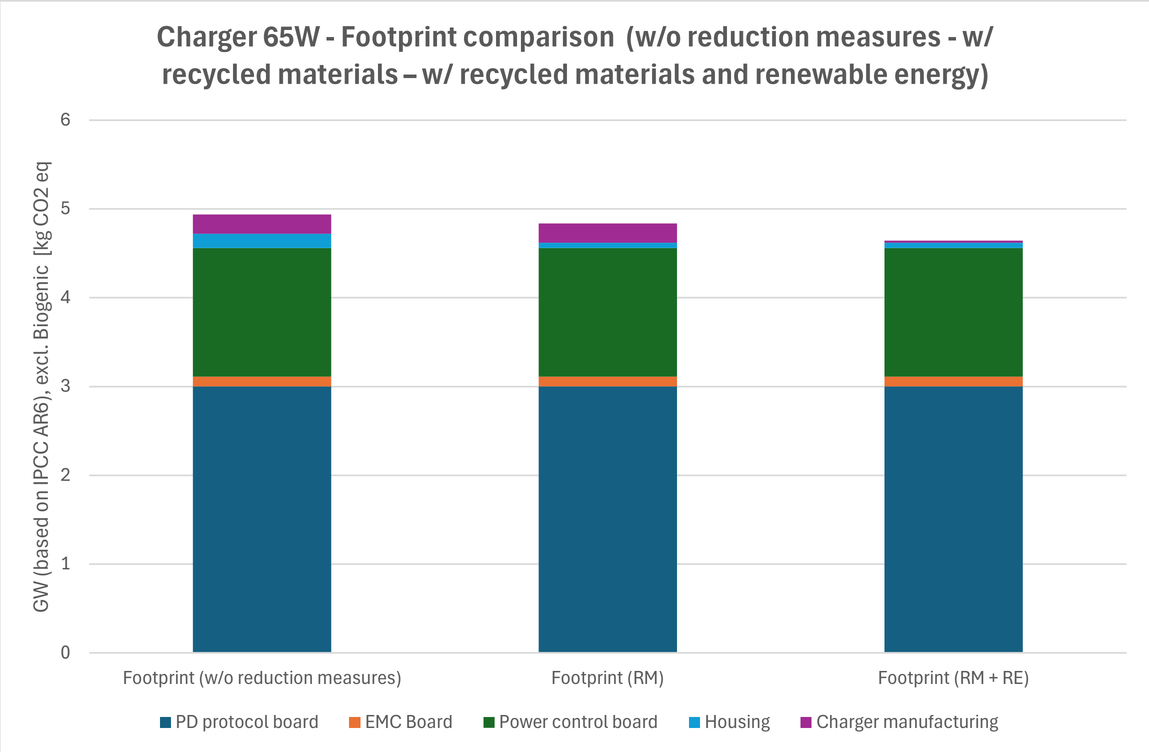

Figure 6-61 – 65W Charger global warming comparison between footprints (w/o reduction measures - w/ recycled materials – w/ recycled materials and renewable energy).

7 Conclusions and recommendations

In this section, the overall findings and main conclusions will be outlined. Furthermore, recommendations for future LCAs and future activities will be made. These conclusions are divided into two sub-sections: one concerning The Fairphone (Gen. 6) and one concerning the accessories.

7.1 The Fairphone (Gen. 6)

The results of the LCA of The Fairphone (Gen. 6) show an impact distribution similar to the one already seen in previous iterations of smartphone LCAs for Fairphone. The production of the electronic components on the mainboard and more importantly of the integrated circuits is the dominant activity from an environmental perspective. Other modules like the display and the battery also show to be of significance across impact categories.

Among the IC-related impacts, the memory component clearly stands out as an environmental hotspot. The modelling of the memory chips however shows that data availability is key for a proper assessment: On one hand, information on memory-chips configurations and technology nodes is needed to better quantify the manufacturing efforts involved. On the other hand, suitable LCA datasets that reflects both the relevant technologies and the latest technology nodes are required to accurately capture an industry that evolves rapidly. Based on the modelling of the three footprints and the sensitivity analysis, we estimated a range of potential impact values. Nevertheless, improved data quality in the future would help reduce uncertainty for this key component.

Regarding the eco-design measures undertaken by Fairphone B.V. once again the use of renewable energies throughout the supply chain proves the most impactful. The environmental footprint of components like the memory or the display can be drastically reduced by decarbonizing its manufacturing process. This is however not an exclusively Fairphone-related endeavor, since a generalization of this practice requires further introduction of renewable energies in the electricity mixes of the countries where these components are produced.

The use of recycled materials in The Fairphone (Gen. 6) has more modest impacts. Smartphones are, compared to other electronic devices, electronics-dense devices with small form factors. This means that the contribution to the environmental footprint of the materials in the device is comparatively small to that of the energy required to turn these into the intermediate products that populate its motherboard.

In general, most of the indicators analyzed continue to be heavily influenced by the energy consumption and the related burning of fossil fuels. Indicators like land use, hazardous waste or ADPe however reveal other important aspects like potential trade-off effects of increased use of renewables. Furthermore, ADPe also serves as a better display of the benefits of recycling, particularly of metals. However, as the increase in the generated hazardous waste seems to suggest, keeping products (rather than materials) in use is important. This connects well with the circular economy principle of prioritizing *the smaller circles* over the *larger*.

Other indicators, especially the toxicity-related ones, reveal the challenges of using several databases. As the list of focus indicators increases (when compared to previous LCAs), the combination of the Sphera and Ecoinvent databases introduces distortion in the form of outlying hotspots that make it difficult to reliably read certain results. Furthermore, some relevant aspects like national electricity grid or the aforementioned IC manufacturing, evolve faster than the available tools reflect at the moment. Therefore, in future LCA activities, data availability and compatibility aspects shall be taken into consideration from the conception phase in order to ensure more reliable results, even if the scope may need to be shrunk.

Lastly, this LCA also performed a sensitivity analysis on mining routes. Although the data quality is limited, ASM shows a slight potential for environmental impacts reduction. Through this exercise also the high impact of mining activities is highlighted, which could be relevant to be followed in the future as emissions reductions strategies are applied by both big and small actors alike. Furthermore, if the energy related emissions of electronic devices continue decreasing via implementation of renewable energies, the environmental impact of the mining of various metals may become more relevant at the product level.

7.2 Accessories

As seen in previous iterations, the accessories show comparably lower impact than the phone. This time, Fairphone B.V. has provided extensive data on the packaging with which the accessories are shipped. The inclusion of this in the model has revealed that in many cases, the package is heavier than the accessory itself. Combined with the fact that many of these are relatively simple products (cases, screen protectors, pins, etc.) results in the distribution phase being the major contributor for most of the accessories. The possibility of a simplification of packaging or bundle-shipping that could potentially contain several accessories in one package could be interesting cases to look at in search of reduction pathways.

Given that most of the accessories do not have electronics in them, the use of recycled material does show significant reduction potential across indicators and items. In most cases the emissions are reduced to less than half by using secondary material. In more complex accessories like the cables or chargers, the most effective eco-design measure remains the use of RE energies in the assembly process. The combination of recycled content and a further inclusion of renewable energies through the supply chain would help bring this even further down.

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9 Annex

9.1 LCA results per module for Footprint (w/o reduction measurements)

Table 9-1 - LCA results for the display production, Footprint (w/o reduction measures)

	Total	Display control electronics	Mechanical elements and display glass	Display assembly (energy use)
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,11E-05	4,03E-05	2,01E-05	7,34E-07
Acidification Potential (AP) [kg SO2 eq.]	2,92E-02	2,13E-03	4,84E-04	2,66E-02
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	4,79E-02	1,80E-03	3,39E-02	1,22E-02
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,05E+00	9,46E-02	1,43E-01	8,11E-01
Land Use [Pt]	1,67E+01	1,12E+00	1,90E-01	1,54E+01
Hazardous waste disposed (HWD) [kg]	1,26E-07	1,28E-09	4,56E-08	7,96E-08
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	9,69E+00	4,93E-01	7,76E-02	9,12E+00
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	4,92E-07	1,15E-07	1,39E-09	3,76E-07
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	4,42E-01	3,66E-02	3,25E-03	4,03E-01
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-4,34E-01	-3,51E-02	-2,98E-03	-3,96E-01
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,89E-02	4,43E-04	1,17E-04	2,83E-02
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	9,66E+00	4,92E-01	7,78E-02	9,09E+00
Blue water use [kg]	7,37E+03	5,44E+02	2,84E+02	6,54E+03

Table 9-2 - LCA results for the main camera production, Footprint (w/o reduction measures)

	Total	Sensor die	Flexcable	Mechanical elements	Camera assembly (energy use)

Abiotic Depletion (ADP elements) [kg Sb eq.]	1,16E-04	3,73E-06	6,92E-06	1,05E-04	1,80E-08
Acidification Potential (AP) [kg SO2 eq.]	1,70E-02	1,57E-02	1,12E-04	5,31E-04	6,51E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,25E-02	8,02E-03	1,98E-04	3,95E-03	2,98E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	7,05E-01	6,48E-01	5,96E-03	3,14E-02	1,98E-02
Land Use [Pt]	8,06E+00	7,39E+00	7,66E-02	2,14E-01	3,78E-01
Hazardous waste disposed (HWD) [kg]	2,73E-09	1,63E-10	2,52E-10	3,65E-10	1,95E-09
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	4,07E+00	3,73E+00	3,14E-02	7,72E-02	2,32E-01
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,08E-06	1,07E-06	1,82E-09	1,92E-09	9,21E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,75E-01	2,56E-01	2,20E-03	7,21E-03	9,85E-03
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,72E-01	-2,54E-01	-1,92E-03	-6,78E-03	-9,70E-03
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,43E-03	5,30E-04	7,79E-05	1,26E-04	6,93E-04
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,79E+00	3,47E+00	2,92E-02	7,00E-02	2,22E-01
Blue water use [kg]	4,56E+03	4,22E+03	2,49E+01	1,58E+02	1,60E+02

Table 9-3 - LCA results for the battery production, Footprint (w/o reduction measures)

	Total	**Battery Management System (electronics)**	**Battery cell production**	**Battery assembly (energy use)**	**Other parts**
Abiotic Depletion (ADP elements) [kg Sb eq.]	5,65E-05	3,39E-05	2,26E-05	4,52E-09	1,85E-10
Acidification Potential (AP) [kg SO2 eq.]	6,62E-03	6,39E-04	5,82E-03	1,64E-04	1,13E-06

Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	6,45E-02	5,42E-04	6,39E-02	7,50E-05	4,33E-06
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	4,47E-01	2,54E-02	4,17E-01	4,99E-03	1,45E-04
Land Use [Pt]	9,70E-01	2,94E-01	5,77E-01	9,51E-02	3,88E-03
Hazardous waste disposed (HWD) [kg]	1,87E-09	8,65E-10	5,03E-10	4,90E-10	1,26E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	1,19E+00	1,44E-01	9,90E-01	5,85E-02	9,53E-04
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,18E-04	2,18E-04	6,87E-09	2,32E-09	2,12E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	2,02E-02	1,07E-02	6,88E-03	2,48E-03	1,48E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,95E-02	-1,02E-02	-6,72E-03	-2,44E-03	-1,34E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	6,33E-04	2,24E-04	2,33E-04	1,74E-04	5,25E-07
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,17E+00	1,33E-01	9,84E-01	5,60E-02	8,05E-04
Blue water use [kg]	2,19E+03	1,59E+02	1,99E+03	4,03E+01	1,58E+00

Table 9-4 - LCA results for the main PCBA production, Footprint (w/o reduction measures)

	Total	**Connectors**	**IC**	**Actives**	**Passives**	**PCB**	**Shielding**	**Others**
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,03E-04	5,85E-05	3,52E-04	3,84E-06	1,08E-05	1,07E-04	1,72E-05	5,34E-05
Acidification Potential (AP) [kg SO2 eq.]	7,64E-02	2,90E-04	6,39E-02	6,72E-05	4,82E-03	5,69E-03	1,46E-03	1,88E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP	5,00E-02	2,27E-03	3,49E-02	5,09E-05	1,98E-03	8,90E-03	1,51E-03	3,62E-04

inf.) [kg DCB eq.]								
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,93E+00	2,26E-02	2,40E+00	1,93E-03	1,18E-01	3,23E-01	6,12E-02	8,04E-03
Land Use [Pt]	3,77E+01	1,21E-01	3,24E+01	3,03E-02	1,59E-01	4,62E+00	2,57E-01	8,14E-02
Hazardous waste disposed (HWD) [kg]	2,92E-07	2,84E-10	1,98E-07	9,28E-11	1,01E-09	1,38E-08	2,29E-08	5,60E-08
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.] [kg CO2 eq.]	1,71E+01	4,11E-02	1,54E+01	1,65E-02	1,08E-01	1,54E+00	4,19E-02	3,21E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	8,02E-02	1,20E-09	8,02E-02	1,12E-09	4,51E-09	1,05E-07	2,84E-09	2,94E-09
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,21E+00	4,14E-03	1,09E+00	1,11E-03	4,39E-03	1,08E-01	2,10E-03	5,96E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,19E+00	-3,96E-03	-1,08E+00	-1,08E-03	-3,60E-03	-9,88E-02	-2,16E-03	-5,78E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,12E-02	8,85E-05	4,99E-03	2,96E-05	2,55E-04	5,69E-03	1,41E-04	1,31E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,70E+01	4,10E-02	1,53E+01	1,65E-02	1,08E-01	1,53E+00	4,18E-02	7,07E-03
Blue water use [kg]	2,02E+04	1,14E+02	1,84E+04	1,78E+01	2,02E+02	1,33E+03	6,30E+01	3,18E+01

9.2 Module-level repair

Table 9-5 - GW results for the module repair for both full module replacement and module-level repair

	GW for module replacement ($kg CO_2$ eq.)	GW for module level repair (kg CO2 eq.)
Battery repair	1,75	n/a
Display repair	2,12	0,64
Main Camera repair	4,34	0,62
Ultra-Wide Camera repair	1,48	0,56
Front Camera repair	1,50	0,57
Upper and Lower Back Cover repair	0,86	n/a
USB-C Port repair	0,95	0,94
Loudspeaker repair	0,57	0,57
Earpiece repair	0,55	n/a
Top Unit repair	0,58	n/a
Main PCBA 8GB/256GB repair	17,72	4,27
Sub PCBA repair	1,08	n/a
Mid frame repair	0,96	n/a

9.3 Cut-out case

Table 9-6 - Environmental impacts of the cut-out case, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	4,14E-07	3,96E-07	1,12E-08	7,30E-09
Acidification Potential (AP) [kg SO2 eq.]	5,94E-04	3,53E-04	2,18E-04	2,30E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,16E-02	1,97E-02	1,67E-03	2,57E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,04E-02	4,97E-02	3,01E-02	5,92E-04
Land Use [Pt]	7,40E+00	7,31E+00	8,23E-02	1,20E-02
Hazardous waste disposed (HWD) [kg]	7,03E-10	6,97E-10	0,00E+00	6,75E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	2,06E-01	1,41E-01	3,96E-02	2,48E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	9,61E-09	9,53E-09	0,00E+00	8,39E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	7,11E-02	6,90E-02	2,07E-03	9,19E-05

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,44E-01	-1,42E-01	-1,74E-03	-9,02E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	7,25E-04	5,77E-04	1,46E-04	2,43E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,43E+00	1,41E-01	1,27E+00	2,48E-02
Blue water use [kg]	2,53E+02	2,32E+02	1,68E+01	4,51E+00

9.4 Flip case

Table 9-7 - Environmental impacts of the flip case, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	7,34E-07	6,69E-07	4,00E-08	2,58E-08
Acidification Potential (AP) [kg SO2 eq.]	1,51E-03	5,36E-04	8,91E-04	8,14E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,81E-02	2,07E-02	6,48E-03	9,08E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,94E-01	6,07E-02	1,32E-01	2,09E-03
Land Use [Pt]	7,83E+00	7,45E+00	3,38E-01	4,23E-02
Hazardous waste disposed (HWD) [kg]	1,56E-09	1,53E-09	0,00E+00	2,39E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	5,42E-01	2,83E-01	1,71E-01	8,76E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,47E-07	2,47E-07	0,00E+00	2,97E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	7,74E-02	7,48E-02	2,26E-03	3,25E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,50E-01	-1,47E-01	-1,90E-03	-3,19E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	7,93E-04	6,25E-04	1,59E-04	8,60E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,75E+00	2,83E-01	1,38E+00	8,76E-02

Blue water use [kg]	3,73E+02	2,91E+02	6,61E+01	1,60E+01

9.5 Finger loop

Table 9-8 - Environmental impacts of the flip case, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	9,46E-07	9,28E-07	1,11E-08	6,92E-09
Acidification Potential (AP) [kg SO2 eq.]	6,73E-04	4,38E-04	2,14E-04	2,18E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,82E-02	1,63E-02	1,65E-03	2,43E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,79E-02	5,74E-02	3,00E-02	5,61E-04
Land Use [Pt]	7,03E+00	6,93E+00	8,18E-02	1,13E-02
Hazardous waste disposed (HWD) [kg]	8,44E-10	8,38E-10	0,00E+00	6,40E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	2,12E-01	1,49E-01	3,94E-02	2,35E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,07E-08	1,07E-08	0,00E+00	7,95E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	7,16E-02	7,07E-02	8,63E-04	8,72E-05
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,31E-01	-1,30E-01	-7,39E-04	-8,56E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,96E-04	5,30E-04	6,32E-05	2,30E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	4,60E-01	1,48E-01	2,89E-01	2,35E-02
Blue water use [kg]	2,51E+02	2,31E+02	1,64E+01	4,27E+00

9.6 Card holder

Table 9-9 - Environmental impacts of the card holder, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,98E-06	1,96E-06	1,57E-08	1,15E-08

Acidification Potential (AP) [kg SO2 eq.]	9,13E-04	4,83E-04	3,94E-04	3,62E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,96E-02	1,65E-02	2,75E-03	4,04E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,24E-01	6,50E-02	5,81E-02	9,32E-04
Land Use [Pt]	8,71E+00	8,54E+00	1,45E-01	1,88E-02
Hazardous waste disposed (HWD) [kg]	1,36E-09	1,35E-09	0,00E+00	1,06E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	3,02E-01	1,87E-01	7,56E-02	3,90E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,00E+00	1,76E-08	1,00E+00	2,00E+00
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	9,76E-02	9,65E-02	9,56E-04	1,45E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,56E-01	-1,55E-01	-8,04E-04	-1,42E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	7,24E-04	6,53E-04	6,71E-05	3,83E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	8,04E-01	1,87E-01	5,78E-01	3,90E-02
Blue water use [kg]	3,49E+02	3,14E+02	2,88E+01	7,10E+00

9.7 Lanyard

Table 9-10 - Environmental impacts of the lanyard, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	7,63E-07	7,23E-07	2,45E-08	1,57E-08
Acidification Potential (AP) [kg SO2 eq.]	1,31E-03	7,47E-04	5,14E-04	4,94E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	2,66E-02	2,22E-02	3,82E-03	5,52E-04
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,45E-01	7,02E-02	7,39E-02	1,27E-03
Land Use [Pt]	7,82E+00	7,60E+00	1,95E-01	2,57E-02
Hazardous waste disposed (HWD) [kg]	6,91E-09	6,90E-09	0,00E+00	1,45E-11

GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	4,61E-01	3,11E-01	9,67E-02	5,32E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	2,05E-08	2,03E-08	0,00E+00	1,80E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	8,82E-02	8,58E-02	2,17E-03	1,98E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,71E-01	-1,69E-01	-1,82E-03	-1,94E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	8,98E-04	7,41E-04	1,52E-04	5,22E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,64E+00	2,60E-01	1,32E+00	5,32E-02
Blue water use [kg]	4,56E+02	4,08E+02	3,87E+01	9,69E+00

9.8 Screwdriver

Table 9-11 - Environmental impacts of the screwdriver, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	**Production**	**Transport**	**EoL**
Abiotic Depletion (ADP elements) [kg Sb eq.]	2,41E-08	1,82E-08	3,83E-09	2,01E-09
Acidification Potential (AP) [kg SO2 eq.]	1,34E-04	3,94E-05	8,78E-05	6,34E-06
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	7,67E-04	6,47E-05	6,31E-04	7,08E-05
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,65E-02	2,07E-03	1,43E-02	1,63E-04
Land Use [Pt]	6,67E-02	2,83E-02	3,51E-02	3,30E-03
Hazardous waste disposed (HWD) [kg]	8,70E-11	8,51E-11	0,00E+00	1,86E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,45E+00	1,72E-02	1,42E+00	6,83E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,08E-09	1,06E-09	0,00E+00	2,31E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	3,15E-03	7,94E-04	2,33E-03	2,54E-05

ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,71E-03	-7,33E-04	-1,96E-03	-2,49E-05
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,78E-04	1,40E-05	1,63E-04	6,70E-07
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,45E+00	1,71E-02	1,42E+00	6,83E-03
Blue water use [kg]	1,83E+01	1,07E+01	6,31E+00	1,24E+00

9.9 Cables

9.9.1 USB 2.0 (1 m)

Table 9-12 - Environmental impacts of the USB 2.0 (1m), divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	6,96E-05	6,96E-05	2,70E-08	3,87E-08
Acidification Potential (AP) [kg SO2 eq.]	3,73E-03	3,06E-03	6,20E-04	4,89E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,50E+00	1,50E+00	4,46E-03	2,25E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	8,92E+01	8,91E+01	8,84E-02	4,82E-03
Land Use [Pt]	6,75E+00	6,49E+00	2,28E-01	3,35E-02
Hazardous waste disposed (HWD) [kg]	-1,02E-08	-1,02E-08	0,00E+00	4,69E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,00E+00	8,78E-01	1,16E-01	9,65E-03
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,77E-08	3,77E-08	0,00E+00	4,96E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	8,89E-02	8,72E-02	1,60E-03	1,47E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,38E-01	-1,36E-01	-1,35E-03	-1,48E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,57E-03	2,45E-03	1,13E-04	5,39E-06

ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,85E+00	8,75E-01	9,65E-01	9,64E-03
Blue water use [kg]	8,67E+02	7,94E+02	4,62E+01	2,72E+01

9.9.2 USB 2.0 (2,5 m)

Table 9-13 - Environmental impacts of the USB 2.0 (2,5 m), divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	1,29E-04	1,29E-04	6,24E-08	8,01E-08
Acidification Potential (AP) [kg SO2 eq.]	5,64E-03	4,22E-03	1,33E-03	1,01E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	4,02E+00	4,00E+00	9,82E-03	4,66E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	2,41E+02	2,40E+02	1,92E-01	9,99E-03
Land Use [Pt]	5,24E+00	4,66E+00	5,02E-01	6,94E-02
Hazardous waste disposed (HWD) [kg]	2,10E-01	2,10E-01	0,00E+00	9,72E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	3,01E-01	3,01E-02	2,51E-01	2,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	4,38E-08	4,37E-08	0,00E+00	1,03E-10
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	9,57E-02	9,37E-02	1,73E-03	3,05E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,42E-01	-1,40E-01	-1,48E-03	-3,07E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,64E-03	2,51E-03	1,27E-04	1,12E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,68E+00	1,08E+00	5,78E-01	2,00E-02
Blue water use [kg]	1,56E+02	0,00E+00	9,95E+01	5,63E+01

9.9.3 USB 3.1

Table 9-14 - Environmental impacts of the USB 3.1, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL

Abiotic Depletion (ADP elements) [kg Sb eq.]	1,05E-04	1,05E-04	3,79E-08	4,90E-08
Acidification Potential (AP) [kg SO2 eq.]	4,81E-03	3,94E-03	8,14E-04	6,20E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	1,66E+00	1,65E+00	6,00E-03	2,85E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	9,10E+01	9,09E+01	1,18E-01	6,11E-03
Land Use [Pt]	3,50E-01	7,27E-08	3,07E-01	4,25E-02
Hazardous waste disposed (HWD) [kg]	2,63E-02	2,63E-02	0,00E+00	5,95E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	1,24E+00	1,07E+00	1,54E-01	1,22E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	3,47E-08	3,46E-08	0,00E+00	6,28E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	8,69E-02	8,50E-02	1,67E-03	1,86E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-1,36E-01	-1,34E-01	-1,40E-03	-1,88E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	2,56E-03	2,43E-03	1,17E-04	6,83E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	1,88E+00	8,48E-01	1,02E+00	1,22E-02
Blue water use [kg]	9,54E+01	0,00E+00	6,10E+01	3,44E+01

9.10 Chargers

9.10.1 30W Charger

Table 9-15 - Environmental impacts of the 30W Charger, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	2,73E-04	2,73E-04	7,58E-08	4,02E-08
Acidification Potential (AP) [kg SO2 eq.]	3,00E-02	2,83E-02	1,63E-03	5,08E-05
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,27E-02	3,83E-02	1,20E-02	2,34E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,06E+00	8,16E-01	2,36E-01	5,01E-03

Land Use [Pt]	1,21E+01	1,15E+01	6,15E-01	3,48E-02
Hazardous waste disposed (HWD) [kg]	1,82E-08	1,82E-08	0,00E+00	4,88E-12
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	2,74E+00	2,42E+00	3,08E-01	1,00E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,77E-03	1,77E-03	0,00E+00	5,15E-11
ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	1,95E-01	1,93E-01	2,17E-03	1,53E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-2,50E-01	-2,48E-01	-1,82E-03	-1,54E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	5,46E-03	5,30E-03	1,52E-04	5,60E-06
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	3,75E+00	2,42E+00	1,32E+00	1,00E-02
Blue water use [kg]	3,19E+03	3,04E+03	1,22E+02	2,82E+01

9.10.2 65W Charger

Table 9-16 - Environmental impacts of the 65W Charger, divided by life cycle phase, Footprint (w/o reduction measurements)

	Total	Production	Transport	EoL
Abiotic Depletion (ADP elements) [kg Sb eq.]	4,82E-04	4,82E-04	3,53E-08	9,88E-08
Acidification Potential (AP) [kg SO2 eq.]	3,66E-02	3,57E-02	6,97E-04	1,25E-04
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]	5,83E-02	4,72E-02	5,30E-03	5,74E-03
Human Toxicity Potential (HTP inf.) [kg DCB eq.]	1,37E+00	1,25E+00	1,03E-01	1,23E-02
Land Use [Pt]	2,25E+01	2,21E+01	2,73E-01	8,55E-02
Hazardous waste disposed (HWD) [kg]	4,40E-08	4,39E-08	0,00E+00	1,20E-11
GW (based on IPCC AR6), excl. Biogenic carbon [kg CO2 eq.]	5,14E+00	4,98E+00	1,35E-01	2,46E-02
ISO14067 GW100, Air craft emissions [kg CO2 eq.]	1,23E-03	1,23E-03	0,00E+00	1,27E-10

ISO14067 GW100, Biogenic GHG emissions [kg CO2 eq.]	4,66E-01	4,63E-01	2,33E-03	3,76E-04
ISO14067 GW100, Biogenic GHG removal [kg CO2 eq.]	-5,17E-01	-5,15E-01	-1,96E-03	-3,79E-04
ISO14067 GW100, Emissions from land use change (dLUC) [kg CO2 eq.]	1,21E-02	1,19E-02	1,64E-04	1,38E-05
ISO14067 GW100, Fossil GHG emissions [kg CO2 eq.]	6,41E+00	4,97E+00	1,42E+00	2,46E-02
Blue water use [kg]	8,17E+03	8,05E+03	5,25E+01	6,94E+01