

Eco-design exercise: Case carbon neutrality

ECO-DESIGN FOR SMARTPHONES

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1. Introduction

The main idea for this eco-design exercise was to gather enough data on smartphones to be able to give some advice on strategies that could efficiently reduce the global impact. As one knows, the global market for smartphones is expanding increasingly and there is a real need for more sustainability in this field.

In this report, we only focus on the technical changes that are required for more sustainability. Of course, the most efficient way to cut carbon and other categories impact on the earth is to stop producing such units. This is not the subject here since we try to improve the device itself. Yet everybody should keep in mind that only a shared effort can lead to more sustainability.

The whole chain and lifetime actors must be involved in this path from designers to politics, regulators, and consumers. The suggestion we developed here should be taken as a part of this joint effort and not a providential solution to cut carbon emissions. All the suggestions here come from the team brainstorming and are supported by literature and LCA data. We tried our best to measure or estimate the potential gain provided by each of the solutions.

This report first gathers some LCA rapid overview and then all the suggestions are detailed one by one. In the end, all the results are combined in the conclusion section.

2. Published LCA (Life Cycle Assessment) data

In this section, we will discuss the various sources that we used to draw the create the different eco-conception strategies. The main sources we used were the LCA of models 2 and 3 of the Fairphone [1] & [2], it was interesting here to see the different impact they calculated on already implemented solutions such as modularity or ease of repair. Of course, we did not limit our survey to these two, we also considered the LCA of a Sony Z5 [3]. The other LCA found were old and not up to date (e.g., the LCA of a Sony Xperia T [4])

Let us start with the Fairphone case. We used the data from the third generation and the comparison with Fairphone 2 that was in there. Hereafter is a little summary of the information that we found the most interesting from an eco-design point of view.

In this study of Fairphone 3, the result is a GWP of 39.5 kg CO2e. According to the authors: "The main impact for all impact categories is caused by the production phase. Transport and use phase have a smaller impact. EoL has a negative impact value, meaning a positive potential for the environment. This is especially relevant for the impact category ADP elements. Most of this impact could potentially be recovered through recycling." In addition, we learn that an effective way to reduce the impact is to extend the lifetime: "The absolute impact increases with the length of the use phase. However, the impact per year of use decreases with longer use as the main product impact is distributed across a longer useful life (see Figure below). The figure shows a decrease of 29% for the yearly GWP impact category when extending lifetime to 5 years and one of 42% when extended to 7 years"

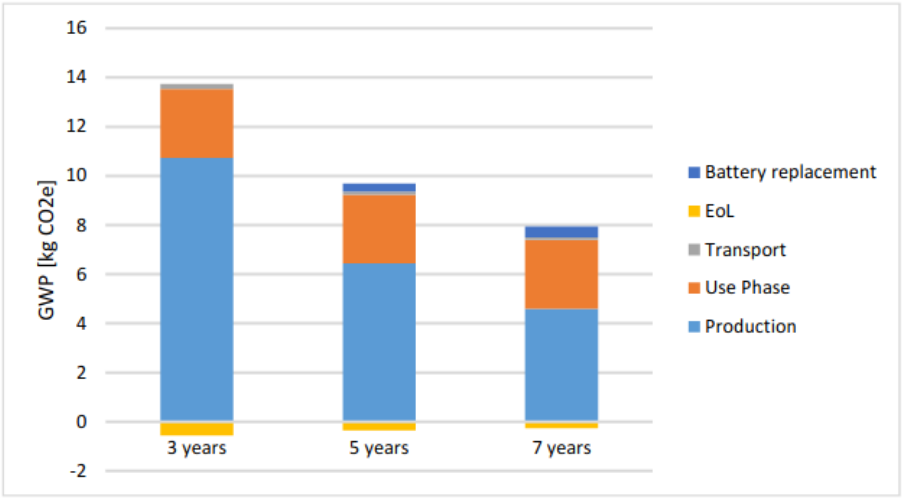


Figure 1: Impact per year of use, Fairphone 3

In this report there is a graph that presents the data by type of components (see figure below). This illustrates the major contribution of IC's production in each considered impact category. The highest contributors here are the RAM & flash and the connectors (due to the rare material used in them). There is currently no device making choices over IC. They also studied the impact of

modularity on the device, according to them it contributes as 2.3% of the total GWP and 17.2% of ADP fossils (due to the additional connectors and housing). Yet the main idea for the Fairphone is to have easy repairs, they consider different repair scenarios in which there is a clear bonus with these repairs.

The final assembly is quite emitting due to the electricity consumed per phone, yet they state an improvement since Fairphone 2. There is a need for optimization at the manufacturer level. They draw a comparison with Fairphone 2, the improvements are little but positive in various categories, except from the use phase since the phone requires more power to run. And since the core is more complex it pollutes more (more flash and more RAM).

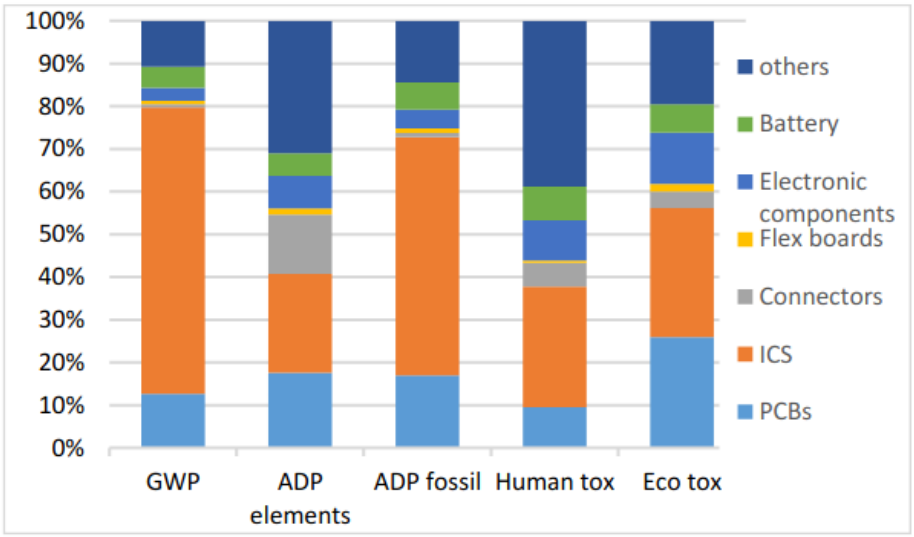


Figure 2: Relative impact per component type of the phone, Fairphone 3

Then moving to the Sony Z5, the study's main result is the Global Warming Potential (GWP) calculated to 57 kg CO_2e for an assumed operating lifetime of 3 years, excluding the network usage. Similarly, as for the Fairphone, the main contributors are Integrated Circuits. Here it is relevant to note that between two generations of smartphones (Z3 and Z5), "the total GHG emissions from IC production are about 33 kg CO_2e for the Z5 model and about 26 kg for Z3 reflecting the difference in IC chip area (9,5 vs7,5 cm2)". "A major part of the GHG emissions, 48 kg CO_2e, was related to the production processes where the IC production dominated. The use stage resulted in 7 kg CO_2e for the smartphone itself (battery charging with a global average electricity mix)".

The study also found that gold acquisition is the second most contributor to the different indicators impacts. With gold and copper being the main contributors to the toxic impact categories and resource depletion. Also, the EoL models have high uncertainty due to a profound lack of data.

3. Strategies

Before trying to diminish the environmental impact of smartphones, we should have a clear understanding of the reasons consumers desire to replace the devices they already own.

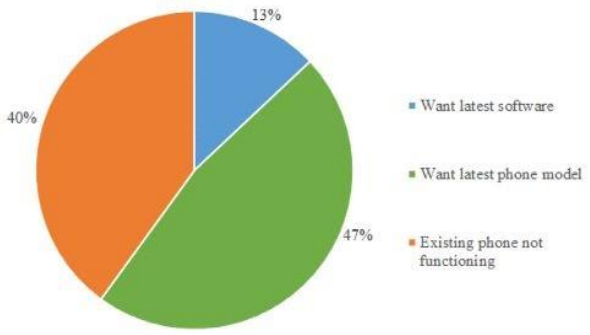


Figure 3: Reasons for purchasing a new smartphone [1]

Globally, the replacement cycle of smartphones was about 21 months in 2016. [5] As a comparison, it is calculated that the median lifespan of a (pre-smartphone era) mobile phone decreased from 4.8 to 4.6 years between 2000 and 2005. [6]

The decision to replace a smartphone is often based on a perception of functional obsolescence driven by new models on the market. Other important causes of replacement are technical issues due to loss of performance, failures, and breakages, as well as functional problems due to the lack of software support. [7]

3.1. DESIGN FOR REPAIR

The results of a consumer survey published in 2018 [8] suggest that frequency of failures in smartphones can be high compared to other products. 47% of failures were reported to occur in the first two years of use, while other 39% of failures occurred between the second and third year. The highest number of problems was related to battery (42%) and operating system (OS) (14%).

Repairing smartphones could be worthwhile even 3–5 years after the initial sale. However, there is huge variation in the cost of repair depending on involved parts, design choices, labor costs and socio-economic context. For example, repairing the display could cost up to 15–40% of the purchase price of new devices, while other repair operations could cost only 10% of the purchase price. The use of standardized interfaces (e.g., for connectors and External Power Supplies (EPS)) can make repairs easier and more beneficial. Sub-standard quality of spare parts and repair operations may undermine the functionality of the device and the reputation of the brand. Another important aspect is the sharing (e.g., via the web) of maintenance and repair information, such as the availability and cost of spare parts and repair services in different countries. [9]

The main idea is that the longer consumers can keep their device, the smaller its environmental footprint becomes. This means that a design which prioritizes longevity, easy repair, and modular

upgrades would be optimal. Few companies are yet opting for this type of design, however by analysing data from the Fairphone company, the impact of such design consideration can be determined. Since these are products already on the market, the data which shows the potential reduction of multiple environmental impacts, is valid and reasonable.

Considering a modular smartphone, the main environmental impact of the device is in the production of the core module. Modular design increases slightly the manufacturing impact, but it has the potential to reduce the GWP and other environmental impacts.

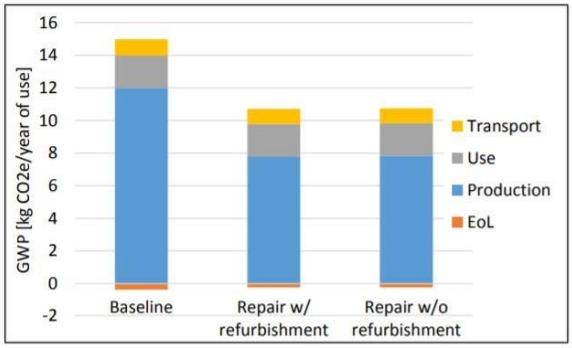


Figure 4: Results per year of use - baseline and repair scenarios [1]

To analyze the potential of the modular and therefore repairable design, a repair scenario is analyzed with an assumed use time of five years and an average number of repairs. The figure shows a comparison between Fairphone 2 and two other repair scenarios: one with refurbishment and one without. The graph indicates that a longer use time of the Fairphone 2 is beneficial even when additional modules must be produced in case of repairs. This is possible since the main environmental impact is caused by the core module which is kept over the whole life cycle in the repair scenario. The benefits through repair and longer use compared to the baseline scenario are between 20 and 35 % depending on the impact category. [10]

The results show that the manufacturing of the electronic components causes the main environmental impact and that industrial design decisions such as modularization have a minor impact. Modularization is a design choice that can strongly benefit repair scenarios, which in turn increases the use stage cycle of the device. This in turn means that by prolonging the use stage (number of years) there is a high potential to reduce the overall environmental impact of the smartphone.

3.2. DESIGN FOR RELIABILITY

Reliability of smartphones is an essential aspect to maintain the quality of the device lifetime. For smartphones, increasing the durability effects positively to reduce the environmental impacts of these electronic devices [11]. This can be done by improving the reliability of the device by reducing the probability of failures and/or its repairability by restoring the failures if occur. From the consumer's perspective there is a preference in the reliability of the devices over repairability [12]. Moreover, both the methods can bring potential benefits in the environmental impacts. The advantages for more reliable devices can be potentially higher where the effects related to the repair or replacement of the devices are prevented or at minimum prolonged. This study intends to assess limiting states impacting the durability of smartphones, identify significant design trends, and solutions to enhance the reliability and reparability of smartphones, based on information available in the literature [11].

Main failures of smartphones can come from display, back cover, battery, operating system, and electronics components used in the phone as can be seen in Table 1. Stress factors can be associated with environmental (e.g., ambient temperature and humidity) or operating conditions (e.g., electrical stresses, mechanical shocks and vibrations, dust, and water ingress), and can be influenced by a variety of factors, including the materials used and the dimensions and shape of components. The primary faults and degrading processes that might result in smartphone limiting states [13].

Part	Main failures	Failure and degradation mechanisms
Display	Display glass cracked, scratched, splintered LCD failure: black screen, broken/dead pixels, no background light The touchscreen does not respond as expected	Drops by accident or other mechanical tensions (shocks, vibrations)
Back cover	Breakdown (e.g., cracks, scratches)	Drops by accident or other mechanical tensions (shocks, vibrations)
Battery	Loss of efficiency The battery will not charge. Overheating	The battery is aging. Failure of the external power source, the charging port, and the battery connection Internal resistance is higher now.
Operating System	Security and performance are compromised due to malfunctioning.	Updates for software, operating systems, and/or security are not available. Inadequate capability (memory) or performance (low RAM, outdated SoC)
Electronics	Disconnection of parts, short circuits	Situations of stress (e.g., water and dust exposure, shocks, vibration)

Table 1: Main failures of smartphones and affected parts [13]

Smartphone limiting states may be avoided or delayed in general by:

- The development of more robust devices, the usage of high-quality components, and the use of protective accessories (such as screen protectors and external cases) by users
- Future-proofing devices by ensuring that they have enough memory capacity and performance (RAM, SoC), as well as the ability to receive software/firmware and security upgrades throughout time
- The distribution of information on the device's proper use and maintenance.

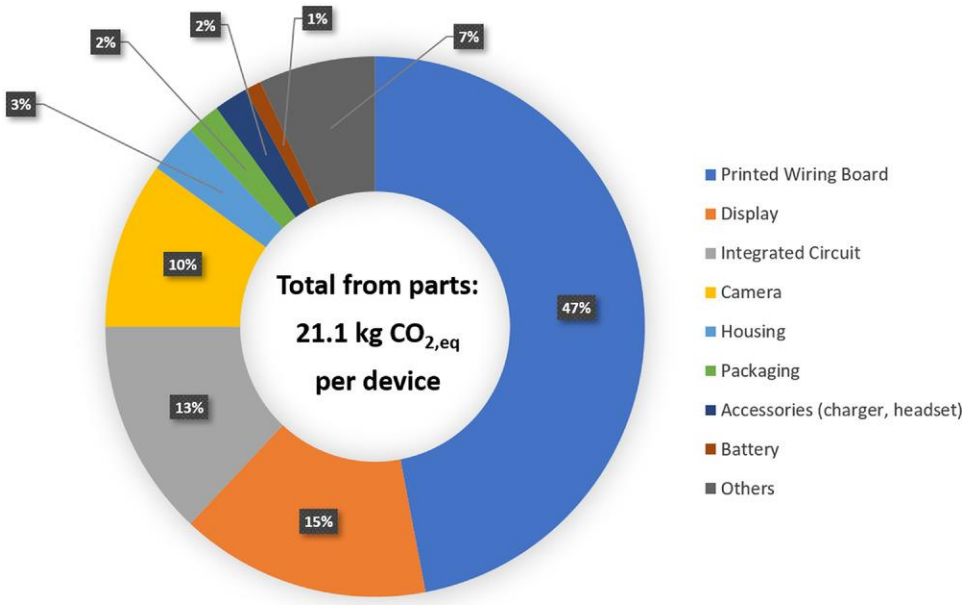


Figure 5: Carbon footprint of a single smartphone unit's Bill of Materials, as well as the contributions of several components [14]

Figure 5 illustrates the carbon footprint content of materials used in various components of cellphones. Integrated circuit (IC) printed wiring board (PWB), display, and camera all make major contributions [14]. Absolute findings may vary based on the specifics of the design, user behavior, and system, as well as the modeling technique, assumptions, and data utilized in various research. From the chart, it can be deduced that manufacturing the different components of smartphones contributes to large amount of carbon footprint which. So, reliability of smartphones plays a vital role in the longevity of smartphones by lowering re-manufacturing chances which eventually reduces the carbon footprint, thus lowering the impacts affecting the environment.

3.3. DESIGN FOR UPGRADABILITY

It is important to explore how product design can more proactively address product life extension through either longer product life, refurbishment, remanufacturing, and upgradability, before it reaches the final stage: product recycling.

Users and customers have strong wants on the functionality of the products, however reduction of environmental impacts is also required in nowadays production. To fulfill these contradictive requirements at the same time and find a good balance between the two items, eco-efficiency is an important concept. For this reason, the modularization in relation to upgradability will be analyzed. The concept of modularization is a traditional idea which seeks to avoid unnecessary production by replacing only the failed components, instead of the whole product. The concept can be applied to component upgrade when some of the product functions are in deterioration. [15]

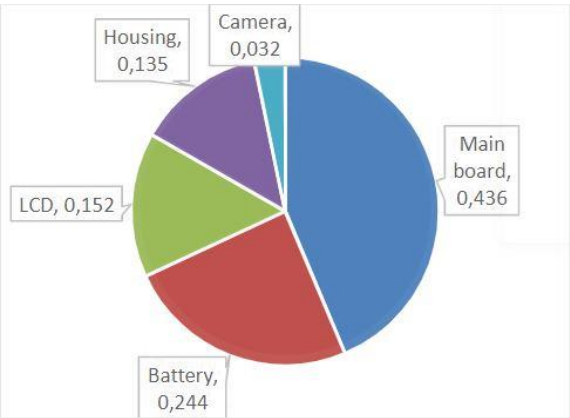


Figure 6: Relative importance of components [15]

Figure 4 shows the importance of various components in a smartphone, from the perspective of the customer. This shows which are the parts that customers and users prioritize, and which parts they would like improved and upgraded. These are also the components that usually drive them to purchase a new device. It can be determined that the mainboard is by far the most important, with the battery and display having a smaller but significant importance as well.

In the following section the case of the modular Fairphone will be analyzed since it can give us a clear picture of the Global Warming Potential of each of the modules in its Fairphone 2 smartphone.

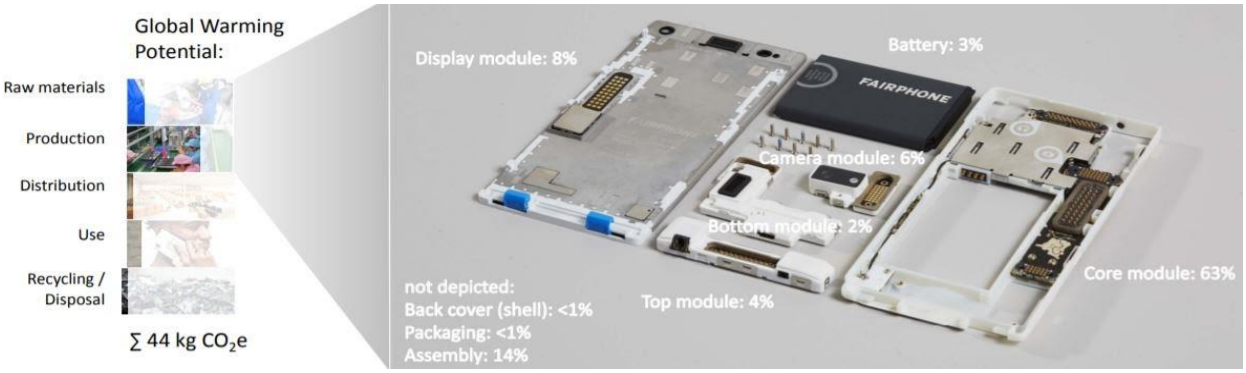


Figure 7: Fairphone 2 LCA results (GWP) over full life cycle and per module [1]

Figure 5 clearly shows that the core module contributes by far the most to the GWP of the entire device (63%), while the battery (3%) and the display (8%) have a significantly lower impact. However, analyzing this in relation to the relative importance of components, it can be determined that in more than 55% of the cases, there would be no need for an upgrade in the core module, which in turn reduces the emissions for a "new"/upgraded device by more than 60%, compared to a new device. However, in almost 44% of the situations, there is a need to upgrade the mainboard, which means the core module must be replaced. Still, in this case, the reduction of the emissions for the upgraded device is about 35% compared to a new device. Both cases clearly suggest that a design for upgradability leads to an increase in the use stage of the device, which in turn decreases the overall environmental impact of the smartphone.

3.4. DESIGN FOR MULTIFUNCTIONALITY

As the phone evolved from a simple land line to a modern smartphone, it replaced multiple devices on the way. Items that used to be owned by every household are now a rare sight. For example, radios, mp3 players, road maps, car navigators and more, have all been replaced by smartphones as is illustrated in figure 8. The way the integration process reduces the environmental impact is straight forward. Adding a GNSS chip to a smartphone increases its impact. On the other hand, it decreases the overall impact of the smartphone + navigator combo. To get an idea of the scale of the reduction, an example case is needed.



Figure 8: Devices replaced by smartphones

As an example, we chose a universal remote control. While it would require some industry level coordination, nothing prevents smartphones from being used as universal remote control. According to a 2013 life-cycle assessment (LCA) of a tv remote, its global warming potential (GWP) is 13.45 [kg CO_2 eq]. [16] By replacing the remote, the GWP of the remote + smartphone combo, will be reduced by this amount. On the other hand, one needs to consider the additional hardware and energy consumption required by the smartphone to replace the remote. The purpose of this example is to get the order of magnitude of the potential reduction. Therefore, it will be assumed that the smartphone remote uses Bluetooth and consequently does not require any additional hardware. This might not be the case if such a universal smartphone remote was developed.

The energy increase can be estimated with certain assumptions. According to the LCA mentioned above, the remote uses 36 AA batteries over its 10-year lifespan. This equates to 10.8 batteries for a 3-year usage. One Alkaline AA battery has a capacity of around 3 Wh. [17] This is estimated with a current draw slightly under 0.2 A. This approximation would lead to a total energy need of 32.4 Wh. [18] The finish energy grid produces 0.193 [kg CO_2 eq.] per kWh. [18] Consequently, the impact of the additional energy used by the smartphone would be $32.4 * \frac{0.193}{1000} = 0.0063$ [kg CO_2 eq.]. While this is an estimate, the value is so low that it can be disregarded. Since there was no significant additional impact on the smartphone side, the original reduction of 13.45 [kg CO_2 eq.] is an acceptable estimate. As was mentioned in chapter 2, the Fairphone 3 has a GWP for a 3-year usage of 39.5 [kg CO_2 eq.]. This means that replacing a remote with a smartphone remote would reduce the impact of the smartphone-remote combo by $\frac{13.45}{13.45+39.5} * 100 =$ 25.4 percent. While this is a crude estimate, it shows that multifunctionality can lead to a significant decrease in the impact of our device park.

While the reduction can be significant, it depends on a lot of factors that need to be considered. The user adoption rate would need to be considered for a realistic analysis. The Braess's paradox can also reduce the benefits of combining devices. Finally, the remote did not change the hardware of the smartphone but this is not always the case and could lead to different results.

3.5. EFFECT OF SOFTWARE ON ENERGY CONSUMPTION

The software impacts how much energy is used by the device during its lifespan. The use phase of the Fairphone 2 is 13.9%. [1] Consequently, making software more energy efficient could reduce that percentage. But how much more efficient can the software become?

To answer that question, we can look at how different applications of the same category perform. A paper from 2017 compared different media applications. Comparing three video players (VLC Player, YouTube Video, Samsung Video) we obtain a decrease in energy consumption of 54% between the worse (VLC Player) and the best (Samsung Video). [19] This shows that there can be significant differences between similar software. While this difference is impressive, it is not clear if this energy efficiency can be achieved by small developers.

To get a better idea of this, we can look at different methods to make software more energy efficient. For example, modifying a single threaded application to be multithreaded produces a 36% decrease in energy use. On the simpler side, going from an indetermined to determined progress bar results in a 12% decrease. [20] The source for these two examples is old but it shows that there is a possibility to reduce energy consumption regardless of the financial stability of the developer. It is important to keep in mind that these percentages will not result in the same reduction in the usage phase. Users use multiple applications at various times for distinct reasons. This level of variability makes it hard to predict the outcome in GWP from the energy efficiency improvements on a single application. But it does demonstrate that there is room for improvement and that the effect of software on energy consumption should not be ignored.

3.6. DESIGN FOR DISASSEMBLY

One of the crucial aspects for remanufacturing a product is the disassembly procedure. Disassembly can be defined as a systematic approach for removing a set of components or parts from a particular product to extract material or any necessary components from the product. Maintaining proper disassembly is crucial because it dictates the End of Life (EoL) or rejection of products to reduce environmental pollution [21].

Effective disassembly procedures can increase the recovery rate of electronic products like smartphones and reduce the WEEE rate, which reduces the harmful impact on the environment. In recent times, the difficulties of disassembling products (e.g., smartphones) have increased. However, being one of the crucial factors for remanufacturing, different disassembling procedures are being developed and followed for different product types. While maintaining a proper disassembly procedure is an important aspect, the disassembly time and recovery rate of the disassembled products are also important. Remanufacturing planning of smartphones must consider the customer's satisfaction and the disassembly efficiency. In contrast, before remanufacturing a certain smartphone, the reusability of each product needs to be analyzed and thus determine the most efficient method for disassembly operation for the End of Life (EoL) product [22].

The complexity of disassembly depends on the type of joining material used for smartphones, and based on that, the method of disassembly operations also changes. For example, if the smartphones'

parts are combined with joining materials like glue rather than screws, then the disassembly operation requires special tools with dissecting materials and that leaves a significant impact on the environment. The product disassembly and reassembly can be made better through utilizing modular design or removable/reusable fasteners. However, the recent trend towards more highly integrated joining techniques that use adhesives rather than fast removable joining materials like screws are increasing [23]. Figure 1 shows the trend of using such joining technique in smartphones.

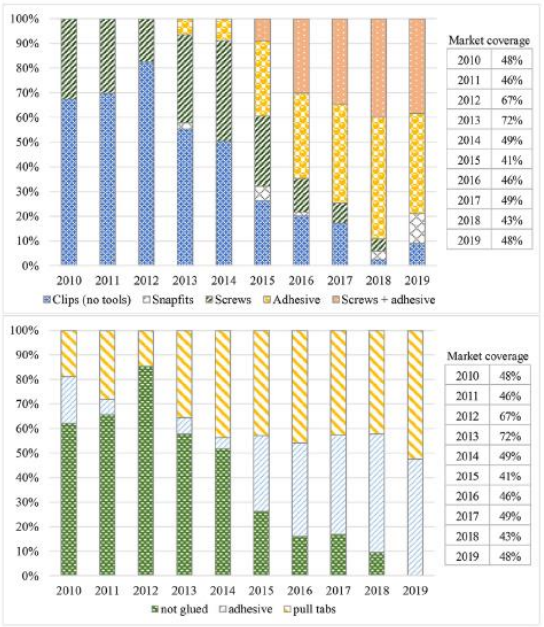


Figure 9: Evolution of trends for joining and fastening techniques in smartphones [23]

Adhesives that are hard to disassemble from smartphones can cause highly impactful parts like batteries to get damaged while being disassembled from the smartphone. Such damage might go beyond the possibility of recovering further, and that can have a significant impact on the environment. Furthermore, damaged smartphone components from wrong disassembly operation can result in dumping the component, which can also affect the environment.

To maintain a proper disassembly operation, first-hand information from the smartphone manufacturer like the Bill of Materials (BOM) can come as a significant asset. The BOM can be used in overall EoL decision modeling and determine the disassembly operation, which will not damage the impactful components in the smartphone [24]. Furthermore, it is also crucial for the disassembler to maintain the laws and regulations of a particular region regarding environmental impacts. Thus, following the right strategy of disassembling is incredibly important. While it is vital to maintain the proper procedure for disassembly to reduce the environmental impact by the damage of disassembled product, the focus is also driven by the cost effectiveness, time, and customer satisfaction [25].

3.7. MANUFACTURING OPTIMIZATIONS

The manufacturing phase has the largest contribution to the environmental impact as mentioned previously. The production of the core module, and notably the mainboard, has the most impact on all impact categories throughout the production phase. When broken down by component type, the influence of ICs on manufacturing takes the lead, followed by PCBs as can be seen from Fairphone 3 data in Figure 10. The core module causes more than half of the total production impact and is therefore analyzed in detail in the following. The mainboard's ICs cause more than 80% of the related GWP impact [2].

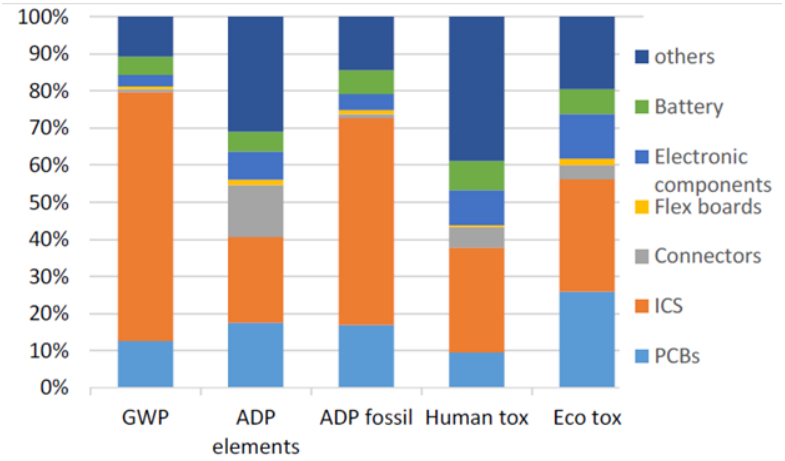


Figure 10: Relative impact per component type of the phone [2]

The influence of ICs on the final output is significant. At the same time, current life cycle data is scarce, and technology is rapidly evolving. Consequently, these findings are associated with greater levels of uncertainty than other phone features. By comparing Fairphone 3 with its earlier version Fairphone 2, overall values were consistent although the overall relative impacts of the Fairphone 3 are a bit lower. From the studies made with Fairphone 2 & 3, it has been identified clearly ICs contribute to the major impact among the other parts of smartphones [2].



Figure 11: Carbon footprint of Apple Inc. in 2020 [26]

Now, looking at a different angle i.e., the energy used in manufacturing by different industries. Industry leader such as Apple Inc. claims 100% renewable energy source for all its facilities and from its suppliers but not transparent of energy type used in manufacturing devices. Figure 11 shows that 71% of carbon emission comes from product manufacturing. Although this company has a roadmap to be carbon neutral by 2030 [26], there are hundreds of such device manufacturing companies who do not have a proper roadmap and concern for advancing towards carbon neutrality. Renewable energy will surely play a key role in the carbon emission trade-off caused by the production of different electronic components like ICs, PCB, etc.

As mentioned earlier, IC contributes to the largest GWP, and the manufacturing industry of such components should also be more concerned about using renewable energy in production. To name one such company, TSMC- the world's largest capacity provider for logic ICs among other components used in smartphones, who are a visionary in carbon neutrality not only in the roadmap but by its action too. TSMC was able to acquire more renewable energy in 2020, allowing them to achieve carbon neutrality. Also, TSMC officially joined the RE100[1] in July 2020, making it the first semiconductor firm in the world to do so. By 2050, it pledged to use 100 percent renewable energy in its worldwide operations and emit zero direct CO_2 from power usage. Figure 12 shows its 2030 sustainability targets include using 25 percent renewable energy in all fabs and 100 percent renewable energy in non-fabrication operations [27].

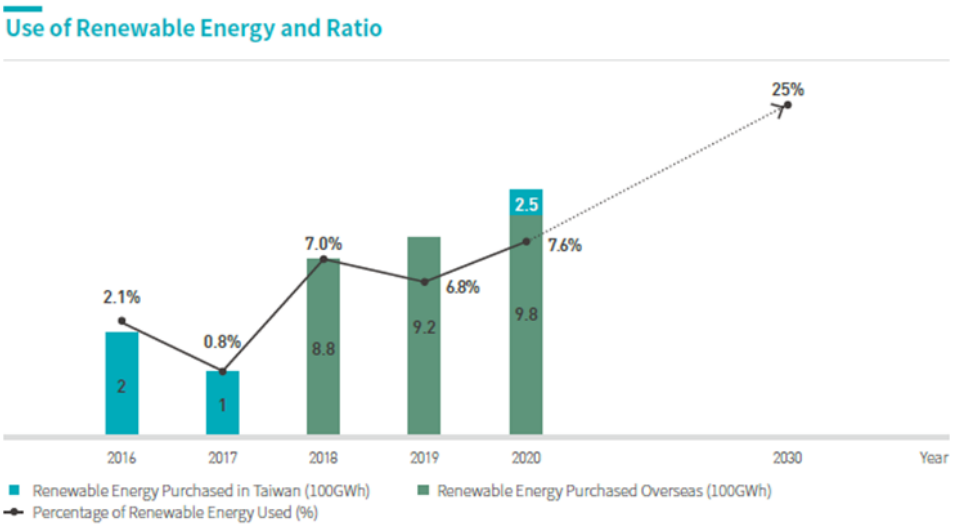


Figure 12: Trend and goal of renewable energy use by TSMC [27]

From the chart it can be seen renewable energy use in 2020 was 7.6% and in 2019 it was 6.8%. TSMC has placed solar panels in its facilities to create carbon-free renewable energy for our own fabs in addition to acquiring renewable energy. In 2020, 416 kWp of solar panel capacity was built, generating 4.63 GWh and lowering carbon emissions by 2,356 metric tons (equal to yearly carbon absorbed by 200,000 trees). In 2021, an additional 227 kWp of solar panel capacity will be added, generating up to 5.76 GWh of energy.

In 2020, TSMC implemented 460 energy-saving initiatives across eight categories, saving 500 GWh of energy and 250,000 metric tons of carbon emissions. The energy savings amounted to NT$1.25 billion (about $4 per person in the US) in actual money, with external carbon costs reduced by decreased carbon emissions equivalent to NT$380 million [27].

Figure 13 shows the total energy consumption by TSMC, and the type of energy used in the last five years. There was an increasing trend of using renewable energy from 880GWh in 2018 to 920GWh in 2019 and in 2020 it was 1230GWh which is more than 7% of the total energy used in that year. Of the non-renewable energy used in 2020, CO2 emission was 75%, F-GHG was 15% and N2O was about 8% [27]. These data again prove that GHG emission due to energy usage in product manufacturing plays a key role in the adverse environmental impact.

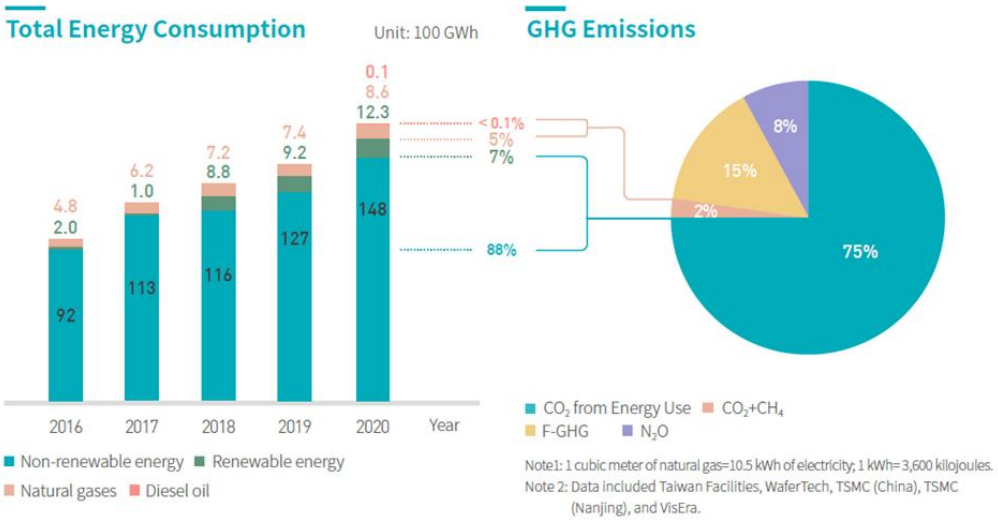


Figure 13: Total energy consumption and GHG emissions by TSMS [27]

These measures by TSMC are exemplary for other industries to use renewable energy in manufacturing. If more industries can reduce carbon emission by using renewable energy, environmental impacts will be minimized. Thus, renewable energy during manufacturing should be promoted by the industries and through adapting towards zero-carbon neutrality industries will contribute to the global climate cause set by Sustainable Development Goals for a better and greener world.

4. Results and discussion

In this report we have analyzed multiple strategies that can help reduce the environmental impact of smartphones. Firstly, we analyzed the LCA data to understand better how smartphone production contributes to global warming potential. Further on, we did research to understand the reasons consumers choose to replace their device and buy new smart phones. We then proposed certain strategies which would help the environmental impact and global warming potential.

We have determined that a significant percentage of the consumers are replacing their smart phones due to technical difficulties and errors of the device, so we analysed the impact of repairability, reliability, upgradability, and disassembly. These strategies are interconnected and would prolong the use stage of the lifetime cycle of the device, which is one sure way to significantly reduce the environmental impact. A superior design would first ensure that the device is sturdy and reliable and already offers a long use stage. This needs to be improved since smartphones in general are less reliable when compared to other electronics. A superior design would also enable the device to be easily repaired, upgraded, and disassembled.

We considered the modularization of the devices and analysed data from the Fairphone company. We could determine that a modular design increases the repairability of the device and can prolong the use stage cycle in two scenarios: repair and refurbish. In both scenarios the GWP and other environmental impacts was reduced to 20-35 %. Modularization is also a key design element when considering a different strategy, design for upgradability. Like repairability, this strategy focuses on replacing only certain modules of the smartphones with the goal of prolonging the use stage of the device. We need to mention that the Faiphone 2 is already a modular device, so these numbers might not apply to other smartphones, which are not designed in the same way. However, the data can give us an idea of the potential reduction of environmental impacts when design consideration of smartphones take into consideration the possibility of repair or upgrade.

Disassembly is a crucial stage that can reduce environmental pollution in two separate ways: by limiting the amount of electronic waste and by reusing resources for remanufacturing. This in turn reduces the energy consumption for procuring new material resources, and the environmental impact associated with producing primary materials. In recent times, the difficulties of disassembling products, especially smartphones, have increased. It is especially important to find the right methods of linking parts or modules of the device, in such a way that the disassembly procedure maximizes the recovery of elements. Usually, companies that produce smartphones have not focused on the end-of-life scenario of the device, prioritizing costs and simplicity. Lately the use of adhesives in smartphones has become the norm, since it allows for a thinner device which consumers appreciate. This, however, makes the disassembly procedure exceedingly difficult and many elements are being destroyed unnecessarily. This leads to more electronic waste and a larger environmental impact. It is important to find the proper incentive to persuade more companies to design in such a way that facilitates disassembly.

The biggest contributor to GWP and other environmental impacts is represented by far by the manufacturing stage of the smartphone, amounting to over 80% of the emissions. Switching to green energy would exponentially decrease the environmental impact. It is also one of the most difficult strategies to implement since it is difficult to influence companies and entire countries to switch their energy sources. Initially, this change can increase the cost of production, hence reduce profits. This means that proper incentive is needed to achieve the desired effect.

5. Conclusion

Smartphones being one of the most crucial and most widely used electronic devices, their impact on the environment on a large scale is massive. Since the major impact comes from the manufacturing stage of the smartphone, it is crucial that the environmental impact at the manufacturing stage is minimized as much as possible. Therefore, smartphone's efficient production and design is of the utmost importance to reduce the environmental impact of the device. Switching to green energy is one of the most promising solutions since it can reduce the environmental impact by up to 80%. However, it is also highly challenging since some of the impactful manufacturing procedures cannot yet be replaced.

In addition, another strategy analyzed focuses on having a longer lifetime and higher reliability. This is essential for smartphone devices as it can reduce the GWP with less amount of manufacturing and reduce the rate of WEEE.

Although materials in smartphones play a huge role in the lifetime of the device, the sustainability of software or applications for smartphones are being neglected. Software or applications also play a role in the longevity of smartphones since some of these software or applications can reduce the lifetime of smartphones or drain batteries at a higher rate. The adoption of more reliable software or applications mostly depend on the users, but it must be highlighted that such adoption can reduce the emission by 10%.

Furthermore, maintaining a proper disassembly procedure is incredibly important since a wrong disassembly operational method can damage the extracted parts or components from a smartphone which may make an impact on the environment and the remanufacturing process. In such a case, the use of screws instead of stronger adhesives as the joining technique of components in the smartphone should be followed to reduce the environmental impact. Effective disassembling, repairing, and remanufacturing methods can have a smaller impact on making a safer environment than the adoption of green energy in the manufacturing process, but it still can amount to a 20% to 30% reduction of the impact on the environment. Most smartphone companies have already adopted the method; therefore, it is pretty evident that the manufacturing companies of smartphones should adopt more environmentally friendly methods in the manufacturing process to reduce the harmful impact on the environment.

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7. Team

In the table below there is a detailed overview of the group's meetings. The meetings were held either in Zoom or in the group's Telegram chat.

Meeting no.	**Participants**	**Date**	**Topics discussed**
1	All members	27.11.2021	• Understand the assignment • Split the workload: each had to find information on design strategies and LCA data
2	All members	01.12.2021	• Discuss the data and information we have found so far • Analyze potential strategies
3	All members (Matthieu in group chat)	02.12.2021	• Discussion with Mervi for clarifications • Overview of scenarios and strategies • Split the workload: each had to focus on a certain topic: LCA data or eco-design strategies
4	All members	06.12.2021	• Share data and information we found • Analyze scenarios; focus on hard facts, and numbers, make assumptions and calculations
5	All members	07.12.2021	• Work on presentation
6	All members	08.12.2021	• Revision of presentation • Practice presentation delivery
7	All members in chat	13.12.2021	• Split workload: each had to write about the topics they tackled in the presentation
8	All members	14.12.2021	• Discuss the report
9	All members	15.12.2021	• Revision of report