sustainablySMART

Sustainable Smart Mobile Devices Lifecycles through Advanced Re-design, Reliability, and Re-use and Remanufacturing Technologies

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Lead Author:	**Karsten Schischke**
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Coordinator contact: Karsten Schischke
Fraunhofer IZM
phone +49.30.46403-156
e-mail schischke@izm.fhg.de

Contributing Partners

TU Vienna, Austria

iFixit, Germany

Disclaimer

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Content

1 Introduction

sustainablySMART is implemented in a policy environment, which is currently under rapid development, including the European Commission's Circular Economy policy and the Eco-design Directive. Environmental labelling schemes struggle to reflect latest technology developments. Under these conditions one of the exploitation routes of the project is to inform policy developments with scientific data.

2 Policy Briefs

The research plan of sustainablySMART assumed the need to develop policy recommendations in the following fields: common interfaces supporting the idea modules fit in products from different companies, put reuse components on the market in new products, warranty issues.

As the discussion on material efficiency criteria for ICT equipment gained significant momentum over time it was deemed more successful to focus on those policy initiatives, where sustainablySMART can directly provide input to ongoing discussions. These are the eco-design discussions under the European eco-design legislation and the pending harmonisation of chargers under the Radio Equipment Directive. The policy briefs published by sustainablySMART are documented below.

2.1 Eco-design policy conclusion

The technology research of sustainablySMART is closely linked with the ongoing policy discussions on strengthening a Circular Economy. Some of the project findings could be mirrored by product specific requirements under the Ecodesign Directive. In a first Policy Brief research findings on modular design, critical raw materials and battery ageing are correlated with potential policy measures.

The policy brief is posted at https://www.sustainably-smart.eu/our-results/complementary-research/ and was presented at the eceee conference on January 24-25, 2018, in Brussels.

Brussels, January 25, 2018

Policy Brief No. 1

Eco-design of Mobile Devices

Project sustainablySMART

1 Introduction

The EU funded Horizon2020 project sustainablySMART will change the lifecycle of mobile information and communication technology devices by developing new product design approaches. This includes enhanced end-of-life performance, re-use and remanufacturing aspects implemented on the product and printed circuit board level, as well as new re-/de-manufacturing processes with improved resource efficiency.
Some research results require a favorable policy environment to lead to intended positive effects. This policy brief is meant to contribute to ongoing policy discussions based on research findings resulting from sustainablySMART.

2 Findings

Modularity of Smartphones

The Lifecycle Assessment of the Fairphone 2 indicated that modularity initially comes at an additional environmental impact of roughly 10% compared to conventional, non-modular designs. This added environmental burden is mainly due to connectors, module housings and additional printed circuit board area, but is easily compensated, if modularity leads to better reparability and thus longer product lifetimes. On the example of the Fairphone 2 an overall carbon footprint reduction through extending product lifetimes from 3 to 5 years has been demonstrated. The calculated effect is a reduction of approximately 30% of greenhouse gas emissions per year of product use. Similarly high savings are not achievable with any other single eco-design strategy.
In a recyclability analysis [1] the positive effect of modularity on material recovery rates has been demonstrated: A separation of plastics (shell), display (to light metal recycling for magnesium recovery from the display back plate), battery and electronics (modules to smelter) allows to channel these four fractions to distinct recycling processes.

Critical Resources

Further separation of individual target components from either modular or conventional smartphones to recover indium, rare earth elements, tungsten, gallium, or tantalum seems not to be economically viable unless these materials are separated in processes targeting at reusable components of higher value. Among the aforementioned elements neodymium-iron-boron magnets in loudspeakers, microphones and motors of vibration alarms are those with the highest material value in smartphones and tablet devices and thus are from an economic perspective candidates with the highest potential, that separate extraction and recycling might become economically viable. For separated tantalum capacitors there are also economically viable recycling processes in place, but the extraction of individual capacitors from used devices is the economic challenge.

Battery Ageing

Research on smartphone battery ageing by the sustainablySMART project confirms some essential factors for obsolescence of batteries and devices with embedded batteries:

- Charging and discharging batteries under significantly elevated temperatures contributes to a rapid ageing of batteries
- Similarly charging batteries at below 0°C damages the battery
- Storing batteries at low temperatures (but above 0° C) and with a moderate state of charge minimizes the effect of calendaric ageing
- Keeping the state-of-charge in a mid-range between 20 and 80% or even narrower to 50% increases battery lifespans (number of full charging cycle equivalents) drastically

3 Policy Conclusions

Modularity is favorable as long as the modular concept clearly targets at better **reparability**, hardware **upgradeability** and / or better **material separation at end-of-life**. In particular the lifetime extension effect of modularity will yield a better environmental life cycle performance. The approach to measure such a performance in EU policy are **Product Environmental Footprints** (PEFs) [2]. It is not yet defined, how PEFs will be implemented in any legislation, but to set the right incentives for modularization it is important, that the PEF methodology, including related product category rules (PCRs), allows for a differentiation of product lifetimes depending on design features such as modularity. Under the **Ecodesign Directive** [3] the modular approach needs to be addressed through some new criteria, such as

- a declarable **reparability score**[1],
- a **requirement for removable batteries** (as long as the manufacturer does not provide evidence that battery lifetime is not a limiting factor for an acceptable product lifetime),
- a **disassembly time threshold for some key components** (such as the display unit) with standard tools.

Modularity as such cannot be translated into an unambiguous eco-design criterion as the level of modularity and the way the modularity concept supports a sustainable product use has to be considered. Modular product designs however can serve as a Best-Available-Technology (BAT) benchmark being referenced in the product specific regulation.

As recovery of some **critical raw materials** from waste devices is currently not economically viable due to very low concentrations and a complex material matrix, stimulating substitution or recycling requires policy incentives. The EU **Conflict Minerals Regulation** [4] could contribute to a politically motivated tantalum or tungsten recycling to secure these potential conflict minerals from recycling as a non-conflict source. Apart from the EU conflict minerals policy the ongoing developments under the **Ecodesign Directive** might have an effect on reducing the use of certain, not yet readily recoverable materials: Some draft product regulations propose a declaration of the content of some of the aforementioned elements in a product. This kind of transparency might lead to additional substitution efforts to reduce the amount of these declarable elements.

Policy measures on battery ageing actually are of two flavors: Requirements regarding the **internal battery management** to charge the battery under conditions, which are favorable for a long battery lifespan and **information requirements** targeting at the consumer to inform him about the most appropriate charging patterns. The latter could be a mandatory feature to charge only up to a certain SoC limit at 80 or 90% unless this feature is intentionally disabled by the user. Alternatively there could be a technical requirement to foster innovation towards lower electrolyte degradation at high SoC (exact requirement still to be defined). An

[1] research on a robust and verifiable reparability assessment is work in progress a spart oft he project sustainablySMART

information requirement about the battery lifespan under a defined set of charging regimes (fast charging, normal charging between 0 and 100% SoC, and between 20 and 80% SoC) would increase transparency for the consumer regarding the effect of charging patterns. Such requirements can be implemented through the **Ecodesign Directive** but appropriate test standards still need to be defined.

4 References

[1] Fairphone's Report on Recyclability: Does modularity contribute to better recovery of materials? February 2017

[2] Simone Manfredi, Karen Allacker, Kirana Chomkhamsri, Nathan Pelletier, Danielle Maia de Souza: Product Environmental Footprint Guide, European Commission Joint Research Centre, Ispra, 2012, Ref. Ares(2012)873782 - 17/07/2012

[3] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related product

[4] Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas

5 Contact

https://www.sustainably-smart.eu/

Karsten Schischke
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM
Gustav-Meyer-Allee 25
13355 Berlin
Germany
karsten.schischke@izm.fraunhofer.de
phone: +49.30.46403-156

6 Funding

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2.2 Policy initiative on standard chargers for mobile phones

The European Commission launched an initiative to harmonise common chargers for mobile phones and similar compatible devices.

Life Cycle Assessment results of sustainablySMART indicate, that the environmental impacts of chargers is much more related to the AC adapter than to the power and data cable. It is therefore of much higher importance to standardize the interface on the secondary side of the adapter than to standardize also the interface between the power / data cable and the end device. This approach requires logically a detachable cable.

The environmental benefit of harmonized common chargers however materializes only, if smartphones thereafter are sold without AC adapters (or without AC adapters and power / data cable), which is done only by very few small players in the market, such as Fairphone and SHIFT. Given that the interface of the adapters is already broadly harmonised by USB Types A and C the main policy challenge is to require or incentivize not to sell new adapters with every new smartphone.

The policy brief is posted at https://www.sustainably-smart.eu/our-results/complementary-research/ and was submitted to the European Commission in the stakeholder consultation (https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2018-6427186/feedback/F18050_en?p_id=342389).

SUSTAINABLY SMART

Brussels, January 30, 2019

Policy Brief No. 2

Regulation of Common Chargers for Smartphones and other Compatible Devices: Screening Life Cycle Assessment

Project sustainablySMART

1 Introduction: Harmonisation of Mobile Phone Chargers

The European Commission launched an initiative to regulate mobile phone chargers and those of compatible devices in December 2018 outlining a plan to adopt a regulation in late 2019 [1]. Interoperability of chargers between mobile phones is supposed to reduce the e-waste problem as chargers can be reused when a user upgrades to a new phone.
The European Commission will consider at least the technical scenarios listed in Figure 1.

1. Plug charger with detachable cable.
   a. USB Type A socket on plug charger and
      i. Cable from USB Type A to USB 2.0 Micro B;
      ii. Cable from USB Type A to USB Type C;
      iii. Cable from USB Type A to proprietary socket (e.g. Apple Lightning);
      iv. Cable of the previously defined types plus external adaptor.
2. Plug charger with detachable cable
   b. USB Type C socket on plug charger and
      i. Cable from USB Type C to USB 2.0 Micro B;
      ii. Cable from USB Type C to USB Type C;
      iii. Cable from USB Type C to proprietary socket (e.g. Apple Lightning);
      iv. Cable of the previously defined types plus external adaptor.
3. Plug charger with non-detachable cable
      i. Cable terminating with USB 2.0 Micro B;
      ii. Cable terminating with USB Type C;
      iii. Cable terminating with proprietary socket (e.g. Apple Lightning);
      iv. Cable of the previously defined types plus external adaptor.

Figure 1 – Plug charger and cable combinations [1]

In the course of the Horizon 2020 project sustainablySMART substantial life cycle data has been generated to assess various aspects of modularity of smartphones [2] and of upcoming technology trends, such as wireless charging [3]. Selected LCA results can serve as input to the current discussion about harmonization of chargers.

2 Life Cycle Analysis of a Smartphone and Charging System

2.1 Goal and scope

2.1.1 Goal

By using life cycle assessment tools, this report aims to give some insights into distinct life cycle relevancy of smartphones, chargers and charging cables. An overview of the related impacts of three sub-devices is provided: a smartphone, a charging cable and an AC adapter. With this focus the environmental relevancy of the charge and the cable can be quantified, compared to the smartphone. The technological scenarios reflected by this analysis are (see [1]):

1. Plug charger with detachable cable.
   a. USB Type A socket on plug charger and:
      i. Cable from USB Type A to USB 2.0 Micro B;
      ii. Cable from USB Type A to USB Type C

The scenarios with USB Type C sockets on the plug charger and with proprietary sockets (e.g. Apple Lightning) on the smartphone side are assumed to yield very similar results.

2.1.2 Scope

For the study only the production and end of life phases are considered. Use phase is neglected and considered not relevant for this study, although energy efficiency of the charger is relevant when discussing lifetime extension versus upgrading to a new charger. Transport is also excluded.
For the impact assessment the CML methodology is chosen, in its 2016 updated version [4]. Five impact categories have been considered, taking into account their relevance in electronic products: abiotic depletion of elements, abiotic depletion of fossil fuels, global warming potential, human toxicity potential and terrestrial eco-toxicity potential.

2.2 Approach

2.2.1 Product models

Three devices are under study: a smartphone, an AC adapter and a cable to connect both.
The smartphone model is based on a pre-existing model of a Fairphone 2 [2] assessed by Fraunhofer. Since the Fairphone 2 is a modular smartphone and implies therefore some extra impacts in the production phase, the version used for this report includes some modifications to make it more similar to a conventional smartphone.
The AC adapter has been modelled following an actual device disassembled in order to identify the different parts and components and their dimensions and weights. The model information can be found in Table 1. It has been modelled in two main parts: the printed circuit board with the electronics components for energy conversion and management and the plastic body that contains it.
The cable has been modelled as two parts: the cable itself and the USB plug, type A [5]. For that, different sources have been used. Standards documentation has been consulted for the dimensions [6], while material information has been extracted from manufacturer information [7]. The weight of some parts was estimated using an actual cable.

Table 1 - Device list

Device	Specs [8] [9]
AC adapter	EP-TA20EWE model (Samsung) Fast charging (1,67 A and 9 V output)
Cable	EP-TA20EWE model (Samsung) Micro USB cable 113 cm long
Smartphone	Modified version of a Fairphone 2 smartphone Display size: 5 inch Battery 2420 mAh at 3,8 V Memory 32 GB Weight 148 g

2.2.2 Assumptions

Following assumptions and limitations have to be considered when interpreting the results:

- The micro USB port of the cable (the end that is connected to the smartphone) has been modelled as a C type micro USB plug. There are however, various standards for different phones, so this part is not broadly representative.
- Following our reference [2] for the smartphone modelling, the EoL phase has been built for the metals recovery only, as the most representative approach for WEEE treatment. The modelled recycling process is a state-of-the-art metals smelter [10]. Recovery of other materials, additional treatments that might be needed or existing different pathways for the waste have been left out.
- Allocation of the recovered materials has been done by avoided burden approach.
- The production phases have been mainly (but not exclusively) modelled using generic datasets of the GaBi software. EoL phases, on the contrary, have been modelled using Ecoinvent and other external datasets.

2.2 Results

Figure 2 shows the relative impacts of each of the devices. Not surprisingly, the smartphone represents most of the impacts share (always 90% or higher except from ADP elements). The second is always the AC adapter and the least impactful of the group is the cable with an impact share of around 1 %.

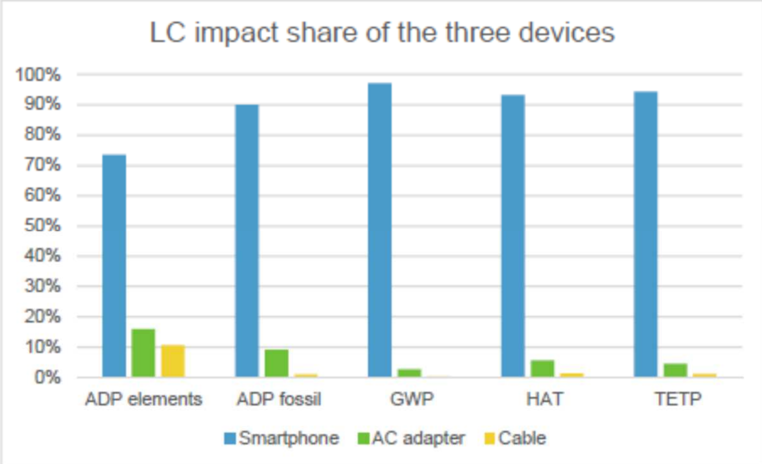

Figure 2 - Share of environmental impacts per device

Whereas the smartphone impacts are depicted only for comparison purposes to get the overall correlations right, it is evident, that among the adapter-cable-assembly the adapter is the critical part. Impacts of the cable connecting the adapter with the smartphone are much lower than those of the adapter, except for the impact category abiotic depletion

Relative impact values for the life cycle phases of the cable only are shown in Figure 3: In all impact categories production is the main driver taking up more than 90 % of the environmental impacts. In some of the impact categories the end of life phase shows environmental benefits, in particular for abiotic resource depletion. For the fossil abiotic depletion and the global warming potential, however, the impact of the end of life phase is environmentally detrimental.

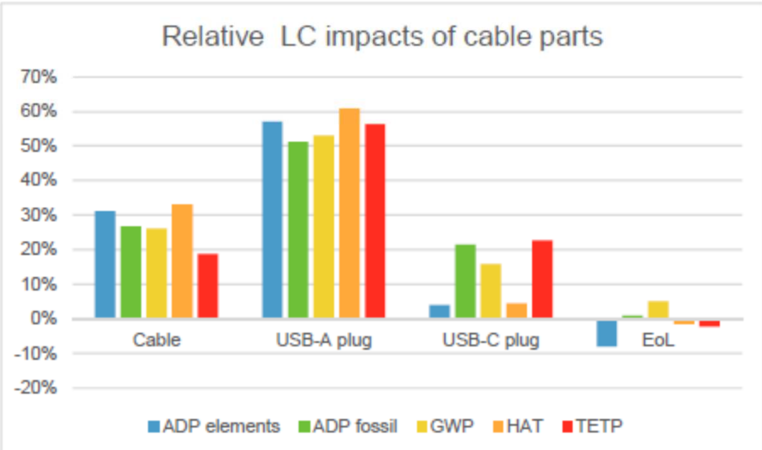

Figure 3 - Impact share (cable)

Performing the same analysis for the adapter and smartphone, a trend can be seen. In the case of the adapter (Figure 4), the end of life phase shows a greater relevance in some of the impacts and more benefits compared to the cable.

Table 2 shows the absolute values for the five impact categories for the three devices under study.

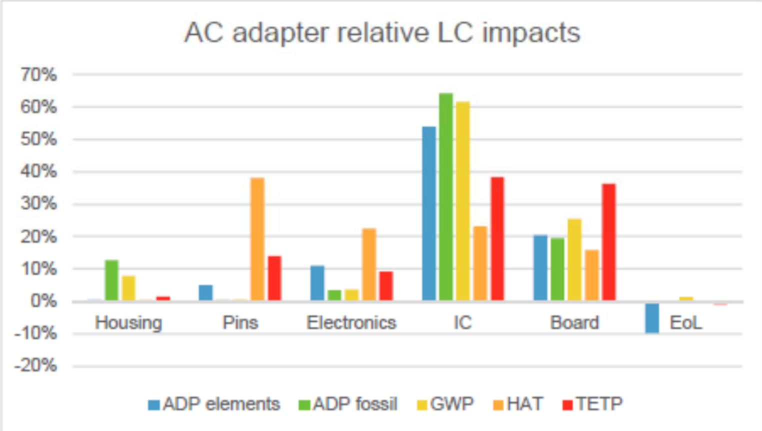

Figure 4 - Impact share (AC adapter)

Table 2 - Absolute values of impact categories under study

Impact categories		Smartphone		AC adapter		Cable	
	Unit	Production	EoL	Production	EoL	Production	EoL
ADP elements	kg Sb eq.	6,29E-04	-3,34E-04	7,15E-05	-7,74E-06	4,66E-05	-4,404E-06
ADP fossil	MJ	123	-4,9	11,8	2,94E-02	1,3	1,10E-02
GWP	kg CO_2 eq.	33,6	-0,407	0,898	1,11E-02	9,58E-02	5,08E-03
HAT	kg DCB eq.	8,44	-0,296	0,485	-1,67E-03	1,14E-01	-1,77E-03
TETP	Kg DCB eq.	0,097	-2,69E-03	4,56E-03	-4,43E-05	1,21E-03	-2,77E-05

2.3 Interpretation

Cables are the least impactful part of the system.

The considerable difference in terms of environmental impacts between the AC adapter and the cable suggests that it is much more important to keep in use the adapter and not necessarily the cable. However, also keeping the cable in use and avoiding the production of a new cable yields environmental benefits according to this screening study.

The life cycle impacts of complex electronics products are dominated by the manufacturing phase and proper end-of-life treatment results only in minor credits, if at all. Thus, the environmental argument for harmonizing chargers is rather with avoiding production of not necessarily needed chargers and the effect of avoided e-waste is only the "tip of the iceberg".

3 Consequences for harmonising "common chargers" by regulation

The trend of modularity in chargers (the AC adapter and the cable being separated pieces connected via a USB Type A or C plug) seems to be beneficial since the failure of one element does not necessarily lead to the replacement of both.

The environmental impacts of chargers is much more related to the AC adapter than to the power and data cable. It is therefore of much higher importance to **standardize the interface on the secondary side of the adapter** than to standardize also the interface between the power / data cable and the end device.

This approach requires logically a **detachable cable**.

Proprietary interfaces between power / data cable and smartphone provide some other benefits, such as reliability and robustness aspects, which are better fulfilled by some proprietary designs. Investigating these benefits is not part of this study.

The **environmental benefit** of harmonized common chargers however **materializes only**, if smartphones thereafter are sold **without AC adapters** (or without AC adapters and power / data cable), which is done only by very few small players in the market, such as Fairphone and SHIFT. Given that the interface of the adapters is already broadly harmonised by USB Types A and C the main policy challenge is to **require** or **incentivize not to sell new adapters with every new smartphone**.

4 References

[1] European Commission, DG GROW, *Common chargers for mobile telephones and other compatible devices, Inception Impact Assessment,* Brussels, Belgium, 2018.

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5 Contact

https://www.sustainably-smart.eu/

Karsten Schischke
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM
Gustav-Meyer-Allee 25
13355 Berlin
Germany
karsten.schischke@izm.fraunhofer.de
phone: +49.30.46403-156

6 Funding

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3 Input to Standardisation and Labelling

Research findings of sustainablySMART informed some of the leading labelling schemes such as EPEAT and the German Blue Angel. Input to policy studies shapes eco-design legislation and standardisation.

3.1 EPEAT Environmental Benefits Calculator

The EPEAT Benefits calculator*, developed by the Green Electronics Council (GEC), allows purchasers to assess the environmental benefits associated with purchasing IT products that meet the sustainability criteria of GEC's EPEAT ecolabel—the leading global ecolabel for the IT sector. By purchasing and using EPEAT-labeled IT products, organizations lessen their impact on the environment, including reducing greenhouse gas emissions, energy use, and generation of toxic substances and solid waste. GEC's calculator enables purchasers to quantify these and other environmental benefits associated with their purchase of sustainable IT products. This benefits calculator covers three product categories -mobile phones, servers, and computers and displays(for criteria updated in 2018).*

Fraunhofer IZM was invited to act as reviewer in the technical review panel of this calculator.

Input was provided based on LCA methodology findings from sustainablySMART. Major contributions included latest data on smartphone composition, such as statistical data on display sizes, battery weights, and bill of materials.

Since 2018 the calculator in its improved and revised version is available at:

https://greenelectronicscouncil.org/epeat-benefits-calculator/#procurement

3.1.1 Battery statistics

For several smartphones and some feature phones Fraunhofer IZM compiled battery weight data from publicly available information. This analysis has been compiled in November 2016 and covers products launched up to late 2016. The research covered data from 91 cell phone models of following brands:

- Apple
- Samsung Galaxy
- Sony Xperia
- Sony Ericsson
- HTC
- Acer
- LG
- Nokia
- Blackberry
- Palm

The following figure depicts weight shares per model compared to the total handset weight: Among iPhones the weight share of the battery is in the 20% range. For most other devices the weight share oft he battery is between 20 and 30%. The average battery weight of Samsung devices is 26% of the total handset weight. For some individual devices the battery weight share reaches up to 35%, for example in the case of the popular Samsung Galaxy S4.

On average the weight share of the battery in relation to the total handset weight of a smartphone or feature phone is 23%.

An average smartphone or feature phone weighs 125 g with a battery weight of 29 g. 29 g is also the average weight of an iPhone battery, at a higher total weight of iPhones of 144 g on average.

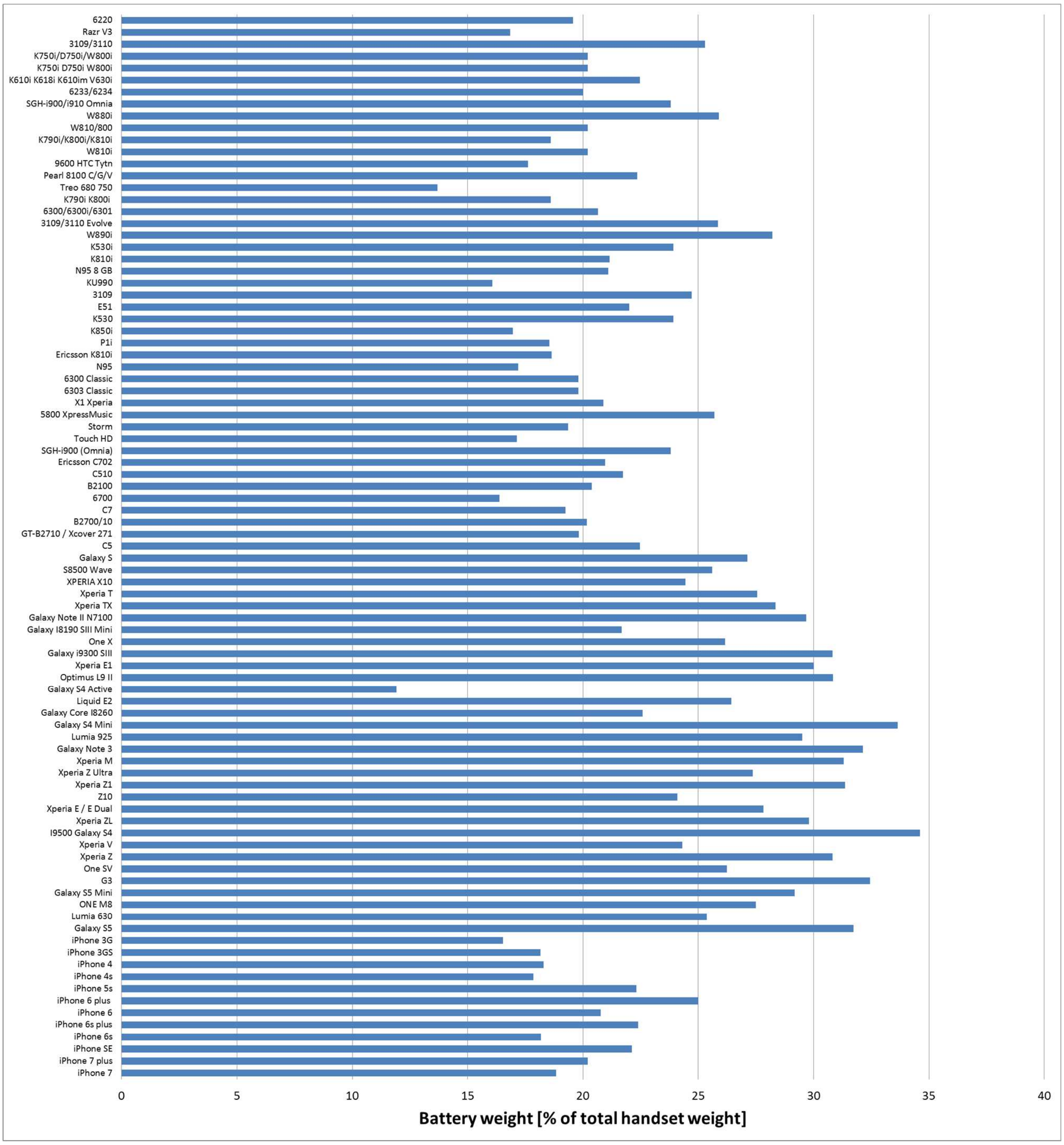


Figure 1: Share of battery weight compared to total handset weight of individual smartphones and feature phones

3.1.2 Proposal revised Bill of Materials

Following changes have been proposed to the weight of a standard mobile phone unit:

	Component	Proposed corrected value, weight (g)	Rationale
	Printed Circuit Board:		
1	Mainboard	5,28	
2	Daughterboard	1,15	
	LCD Screen:		
3	Flexible Printed Circuit	0,58	
4	Flexible Printed Circuit	0,31	
5	LCD Screen	33,92	
6	Plastic	0,68	
7	Shell	9,75	
8	LEDs Light emitting diode,	0,41	
9	IC Integrated circuit,	0,01	
	Housing		
10	Shell	20,16	A smartphone with a non-removable battery does not have a separate steel cover, but as there is a mix of plastic and steel / aluminium housing devices in the market this housing mix of the Fairphone accidently represents well the current smartphone market mix. No data revision needed.
11	Front Housing	3,5	
12	Back Housing	7,62	
	Battery		
13	Li-ion Battery	**29**	see attached report, avrg. battery weight is 29 g; non-removable batteries (= state of the art) have no rigid housing, thus are more light-weight than the removable Fairphone battery with housing
	Capacitors, Diodes, Varistors & Transistors:		
14	Diodes	0,15	
15	Varistors	0,37	
16	Transistors	0,02	
17	Capacitor	0,46	
18	Tantalum Capacitor	0,02	
19	SAW	0,04	
	Integrated Circuits:		
20	IC	0,65	
21	IC	0,41	
	Camera, Speaker, Earpiece & Vibrator:		
22	Front Camera	0,16	
23	Vibration Motor	0,72	
24	Earpiece	0,51	
25	Camera	0,92	
26	Speaker	1,33	
	Others		
27	Battery Cap	**0**	separate battery tray due to the fact, that the Fairphone came with a removable battery, which is not the case for the majority of latest smartphones
28	PCB Covers	3,94	
29	Simcard Holder	1,29	
30	Ctioils	0,06	
31	Magnetic bead	0,02	
32	Unspecified	0,37	
33	Cable	0,19	
34	Screws	0,22	
35	Copper coil	0,03	
36	Brass screw	0,14	
37	Connectors	1,91	
38	Thin film	0,31	
39	Plastic tape	0,24	
40	Net	0,78	
41	Plastic pieces	1,34	
	Total	**128,97**	Comes close to the target value of 125 g according to attached data on 91 cell phone models

3.1.3 Display statistics

Display size is an important characteristics of mobile phones and constantly changing. The current market (as of 2018) is analysed with the following data:

Display Sizes of Cell Phones listed on the German price comparison platform www.idealo.de, July 11, 2018		
Criteria:	On the market since 2017 or 2018	
	Android phones and/or LTE phones (to rule out feature phones and simple cell phones)	
Size (Diagonal, inch)	number of units	
2,4	3	
4	6	
4,5	28	
4,7	16	
5	622	
5,5	593	
6 (and above)	170	
Aspect-ratio		
3:2	5	
16:9	976	
18:9	321	
18,5:9	78	
19:9	45	
19,5:9	4	
Conclusion: 16:9 is by far the dominating display aspect-ratio		
Assuming this as the standard aspect-ratio for smartphones, display area is calculated as follows:		
Size (Diagonal, inch)	A (cm²)	number of units
2,4	15,88	3
4	44,11	6
4,5	55,82	28
4,7	60,90	16
5	68,92	622
5,5	83,39	593
6	99,24	170
Weighted Size	**77,91**	

3.2 Blue Angel Smartphones

In 2016 a revision of the Blue Angel criteria for smartphones have been discussed. At this time sustainablySMART could provide in particular insights on data deletion derived from Blancco’s research findings. The following input was discussed in the course of the revision. At the experts meeting in Berlin Fraunhofer IZM and Circular Devices have been present.

3.4.3 Data Deletion

To allow a second use of a mobile phone the device shall be designed so as to allow the user to completely and safely delete all personal data on his own without the help of pay software. This can be achieved by either physically removing the memory card or with the help of software provided by the manufacturer free of charge. When using a software the deletion process shall at least include an overwrite of all the data stored with a random pattern or in case of Flash Storage with zero values.

Compliance Verification

The applicant shall declare compliance with the requirements in Annex 1 to the Contract and submit the relevant pages of the product manual.

Background Information: *(Short introduction in meeting: Karsten Schischke, Fraunhofer-Institut, IZM)*

The criteria on data deletion are over simplified and don't take into account many important factors. We are therefore of the opinion that data deletion processes are much more complex, multivariate, and should consider more scenarios than the ones proposed by the Blue Angel requirements.

Nowadays used eMMC (embedded Multimedia Card) technology is characterised by a multi-chip package, where the flash memory package includes the flash memory chips and the microcontroller managing the access to the data. Consequently, access to the memory chips is always controlled by the microcontroller and so is the data erasure process, if triggered by a software provided by the manufacturer and installed on the phone, e.g. through the operating system. Verification of complete data erasure in case of eMMCs can be done only with either full documentation of the algorithms applied by the microcontroller to provide access to the memory chip (and related erasure processes) or by physically accessing the memory chips directly and verifying completeness of the applied erasure process (forensic methods). Chip-off requires a physical reengineering of the chip package to access directly the memory chip. JTAG refers to a universally accepted specification of ports for testing ICs on the board and requires knowledge about these JTAG connectors on the motherboard. These ports, besides chip testing, allow also access to memory data.

Such forensic tests are very costly and therefore might constitute a significant barrier for being awarded the Blue Angel.

Suggestion on criteria:

Version 1

To allow second use of a mobile phone the device shall be designed so as to allow the user to completely and safely delete all personal data on his own without the help of pay software. This can be achieved by either physically removing the memory card or with the help of software provided by the manufacturer free of charge.
This criterion might also be met, if memory components are used, for which independent third parties verified already through appropriate forensic methods, that data erasure is possible[15] and appropriate tools are provided by the manufacturer for free.

Compliance Verification

The applicant shall declare compliance with the requirements in Annex 1 to the Contract and submit the relevant pages of the product manual. When using a software the success of the erasure process has to be verified by a qualified third party, interrogating the memory chips directly (either through a chip-off approach or JTAG technology), effectively bypassing the operating system, and issuing a test report, documenting that no personal data can be restored. In case memory components are used, for which a third party verified the feasibility of data erasure a reference to this third party verification has to be provided.

A weaker criterion might read like this:

Version 2

To allow second use of a mobile phone the device shall be designed so as to allow the user to completely and safely delete all personal data on his own without the help of pay software. This can be achieved by either physically removing the memory card or with the help of software provided by the manufacturer free of charge (which can be a factory reset feature). The success of the data erasure process shall be verified with state-of-the-art data recovery tools[, such as Dr. Fone iPhone Data Recovery / Android Data Recovery by Wondershare, Smartphone Recovery Pro by Infinity Wireless Ltd., or 7- Data Recovery by SharpNight LLC]. No personal data shall be restorable with such tools.
This criterion might also be met, if memory components are used, for which independent third parties verified already through appropriate forensic methods, that

[15] No such third party verification process is in place currently, but the project sustainablySMART is researching this option and a process might be in place before the next revision of the Blue Angel criteria

data erasure is possible[16] and appropriate tools are provided by the manufacturer for free.

Compliance Verification

The applicant shall declare compliance with the requirements in Annex 1 to the Contract, document the failed data restoration process after erasure and submit the relevant pages of the product manual. In case memory components are used, for which a third party verified the feasibility of data erasure a reference to this third party verification has to be provided.

***Remark:** The 2nd version of the criterion at least provides a certain level of confidence, that data cannot be restored from an intact mobile phone with freely available tools. Only the 1st version of the criterion also provides a certain level of confidence, that even with a certain level of technological effort data cannot be restored.*

The Blue Angel criteria published later on[1] read as follows and reflect properly the input provided by sustainablySMART:

3.4.4 Data Deletion

To allow reuse of the device it shall be designed so as to enable the user to completely and securely delete all personal data without the help of pay software. This can be accomplished by either physically removing the memory card or the use of free manufacturer-provided software. As an alternative to removing the data, it shall also be possible to encode the personal data on the data medium by means of software provided, thus allowing a secure deletion of the key.
In addition, the device shall include a software function that resets the device to its factory settings.
The product documents shall include detailed instructions on how to securely delete data and how to reset the device to its factory settings.

Note: It shall not be possible to restore the personal data by means of commercially available recovery software tools that are used on the intact mobile phone or, where necessary, with the help of another computer.

Compliance Verification

The applicant shall declare compliance with the requirements in Annex 1 to the Contract, highlight the relevant passages in the product documents that make reference to data deletion and the function to reset the device to its factory settings and present the relevant pages of the product documents in Annex 2 to the Contract.

[1] BLUE ANGEL - The German Ecolabel, Mobile Phones, DE-UZ 106, Basic Award Criteria Edition July 2017 Version

3.3 Product Category Rules

In the project definition phase it was assumed that the development of specific Product Category Rules for mobile ICT devices might be needed to foster a harmonised approach for related LCAs. It was intended to propose a PCR development process to the EPD ® scheme, in case a PCR is deemed necessary. Contacts were made with the EPD ® secretariat.

3.3.1 Existing PCRs

Following PCRs relevant for the sustainablySMART product range have been developed in the past and analysed by TU Wien and Fraunhofer IZM, but all of them expired in the meantime:

- EDF, Taiwan (PCR on smartphones expired Dec 31, 2013)
- KEITI Environmental Declaration of Product (PCR for mobile phones released in 2004, before smartphones have been introduced to the market)
- JEMAI EcoLeaf (PCR for Telephones released in 2004)
- JEMAI CFP (PCR for Portable electronic communication devices released in 2012 expired 2017)

Although not called PCR there is a sector solution on LCA in place, which is the ETSI standard ETSI ES 203 199. Any new PCR would have to reflect on ETSI ES 203 199, or even more developing a distinct PCR might be obsolete, if this ETSI standard is considered appropriate for all aspects identified in the course of the sustainablySMART project.

3.3.2 Analysis ETSI ES 203 199 (2015)

Fraunhofer IZM analysed ETSI ES 203 199 (2015) Environmental Engineering (EE): Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services, which is the most comprehensive standard on LCAs for mobile IT equipment. The goal of this analysis is to check, if innovations in particular on the product and service level developed by sustainablySMART can assessed with this standard in a comprehensive and fair manner, or if certain beneficial aspects are “overlooked” when applying the standard. This analöysis could inform future review cycles of this ETSI standard.

“Typical lifetimes” are not defined in this standard --> good from LCA perspective as it should be defined individually based on best knowledge about realistic operational time and goal and scope of the study, difficult for comparison and when standard is seen as an “PCR”, especially because results are presented per year of use, the underlined lifetime for the calculation is very important

Specific procedures how to model modular products with e.g. different lifetimes per module or reused parts are not given (Re-use is defined to be part of EoLT)

Lifetime definitions include:
commercial lifetime*: length of time that a good is owned for before a new one is bought to replace it (often used to estimate the lifetime for consumer products)*

***extended operating lifetime**: aggregated duration of the actual use periods of the first user and consecutive use periods associated with reuse*

***operating lifetime**: duration of the actual use period (consisting of both active and non-active periods) for the first user NOTE: Storage time is not included in operating lifetime.*

***lifetime**: duration which may correspond to commercial lifetime, operating lifetime, extended operating lifetime or depreciation lifetime*

It is not clarified which one should be used, but this distinction at least allows for considering lifetime extending strategies properly.

For allocation of recycled materials at either input flows or at end-of-life following methods are defined:

***the 100/0 method**: allocation method that allocates the primary Raw Material Acquisition processes fully to the studied product system, i.e. no recycled Raw Material is assumed as input to the studied life cycle*

NOTE: No recycling is assumed to occur at End-of-Life.

***the 0/100 method**: allocation method that allocates 0 % of the primary Raw Material Acquisition processes to the studied product system, i.e. 100 % recycled Raw Material is assumed as input to the studied life cycle*

***the 50/50 method**: allocation method that allocates the primary Raw Material Acquisition processes equally to the introducer (initial life cycle that introduces the primary Raw Material) and the "depleter" (the last lifecycle in which the Raw Material is not recycled) i.e. the recycling of Raw Materials is allocated equally to the studied life cycle and the product system losing/introducing the material*

- ➔ None of these methods is usable to display the impacts of an individual recycling/recycled content scenario as it assumes either zero or 100% recycled content/recycling
- ➔ The 50/50 method can be individualized to the amount used, however also the impact of primary material is shared which is not consistent with other standard and leads to a very low manufacturing impact
- ➔ Calculation example in Annex R: for 50/50 it is also not consistent, if impact also of primary material has to be shared by 50%, than the impact of the recycled content would have to be increased by that amount (only when last life cycle is assumed)
- ➔ Calculation results in the same life cycle figure as calculation from Product Environmental Footprint, but it is neither transparent nor easily communicable that credits for recycled content are included in the EoL phase
- ➔ “Share of material recycled in the EoLT stage” has to be the amount of recycled material produced from the recycling process that the calculation is reasonable, howeverthe term is not defined in the text

The 100/0 allocation method should be used for calculating primary Raw Material Acquisition impact.

The 50/50 allocation method should be applied when possible to allocate both the use of recycled input material in the raw material acquisition stage and the recycling of materials in the EoLT stage. USGS yearly mineral report can be used to estimate the ratio of recycled material content for input material if primary data are not accessible.

If available input LCI data does not distinguish between primary Raw Material Acquisition and Raw Material Recycling, the 100/0 method can be used as a fall-back alternative (see examples in annex R).

➔ The allocation of the impacts and benefits to the life cycle stages are neither easy to understand nor to communicate

The standard requires that *“in case of comparative assessment between ICT goods LCAs, the operating lifetime shall be set to equal. Differences in lifetime could only be accepted if they reflect differences in actual characteristics.”*

➔ Difficult wording, of course comparison should be fair (no different operating lifetime without reason), so differences in lifetime are always connected to product characteristics?
➔ This would mean that lifetime extension because of different marketing strategy, business model, spare part availability, etc. cannot be stated?

By arranging parts in descending order of mass and by calculating the cumulative mass of each part, a basis is given for a cut-off of insignificant parts from the product system. Note however that other cut-off criteria shall apply as well.

➔ This is very misleading in the context of ICT goods because especially ICs have a high environmental impact and a very low mass

In general ETSI ES 203 199 provides a good framework to address the life cycle specifics of e.g. modular smartphones. Further clarification would help to apply the standard in such cases properly.

The requirements regarding recycling allocation are presented confusingly in the standards an need, to our understanding, a revision.

ETSI ES 203 199 equals a PCR for the ICT sector and despite its limitations it was decided instead of pursuing a distinct PCR development rather to support the ETSI standard and to get involved potentially in any future revision cycle.

3.4 JRC Study on Material Efficiency of Smartphones

The Circular Economy & Industrial Leadership unit of JRC (DG JRC-B.5) is conducting research activities related to the assessment of material efficiency aspects of Energy-related Products (ErP) and the analysis and development of methods supporting the definition of product-specific requirements. This includes an analysis of material efficiency aspects of smartphones.

Following input has been shared with the study authors:

- Poster about modular smartphones and the Fairphone 2 in particular, presented at LCM 2017: Download at https://www.sustainably-smart.eu/our-results/make-products-for-a-circular-economy/

- Results on recycling viability of certain metals from smartphones: https://www.sustainably-smart.eu/our-results/keep-products-in-a-circular-economy/

- Policy recommendations from the sustainablySMART project: Download at https://www.sustainably-smart.eu/our-results/complementary-research/

- Disassembly study of several smartphones: Download at https://www.sustainably-smart.eu/our-results/complementary-research/

- Modular products: Smartphone design from a circular economy perspective, Karsten Schischke; Marina Proske; Nils F. Nissen; Klaus-Dieter Lang, 2016 Electronics Goes Green 2016+ (EGG)

- Life Cycle Assessment of the Fairphone 2: https://www.fairphone.com/wp-content/uploads/2016/11/Fairphone_2_LCA_Final_20161122.pdf

- Product design features of mobile devices for extended product life – modularity as an approach for better reparability, upgradeability and customization, Karsten Schischke, recorded presentation and slides: https://www.eceee.org/events/eceee-seminars-and-workshops/the-ecodesign-directive-in-a-changing-policy-climate-challenges-and-opportunities/

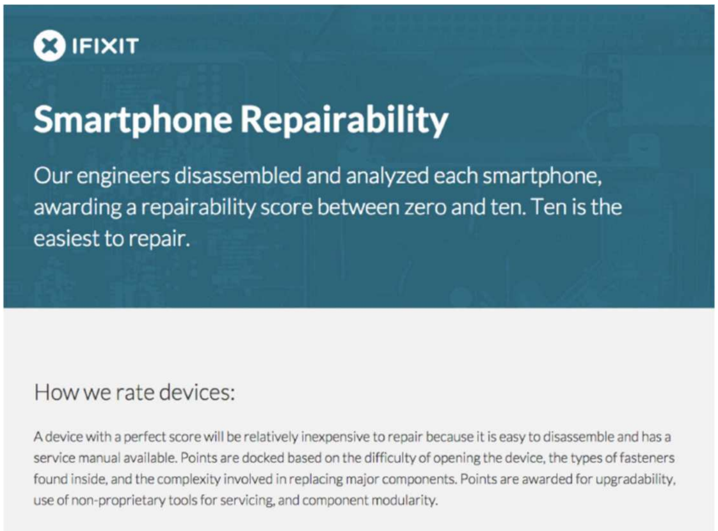
The draft JRC report[2] published on May 6, 2019, refers six times to various findings from the sustainablySMART project indicating the importance of our research as background information for policy making.

At a face-to-face meeting at LCM 2019 in Poznan methodological issues of the baseline Life Cycle Assessment undertaken by JRC has been discussed bilaterally between DG JRC and Fraunhofer IZM.

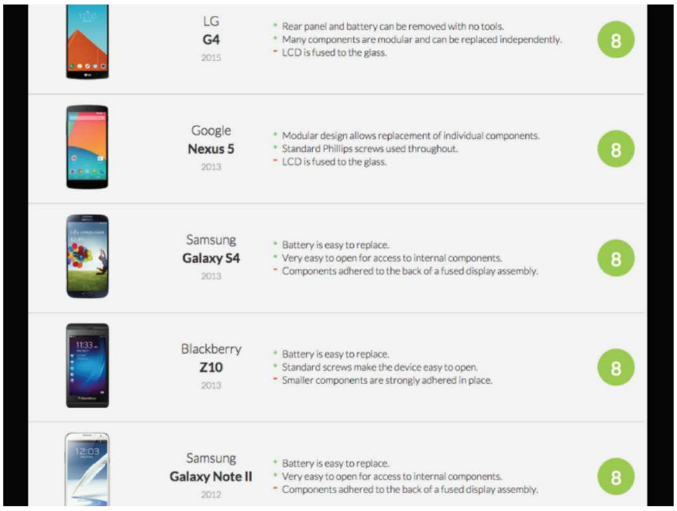
3.5 Reparability Assessment

iFixit presented the concept and methodology of the developed reparability scoring metrics at the 2018 International Conference of the Blue Angel and the Global Ecolabelling Network (GEN) in Berlin.

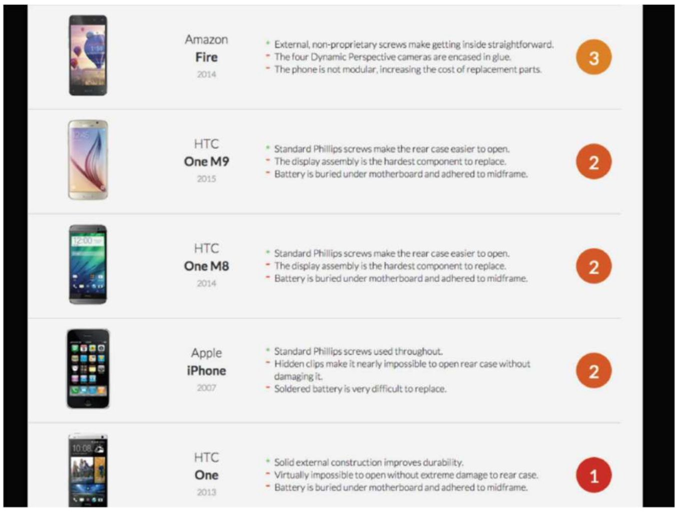
The following slides have been presented by iFixit at this occasion to summarise and discuss the reparability scoring approach developed in sustainablySMART.



[2] https://susproc.jrc.ec.europa.eu/E4C/docs/JRC_report_smartph_v2.11_clean.pdf



LG **G4** 2015	• Rear panel and battery can be removed with no tools. • Many components are modular and can be replaced independently. • LCD is fused to the glass.	8
Google **Nexus 5** 2013	• Modular design allows replacement of individual components. • Standard Phillips screws used throughout. • LCD is fused to the glass.	8
Samsung **Galaxy S4** 2013	• Battery is easy to replace. • Very easy to open for access to internal components. • Components adhered to the back of a fused display assembly.	8
Blackberry **Z10** 2013	• Battery is easy to replace. • Standard screws make the device easy to open. • Smaller components are strongly adhered in place.	8
Samsung **Galaxy Note II** 2012	• Battery is easy to replace. • Very easy to open for access to internal components. • Components adhered to the back of a fused display assembly.	8



Amazon **Fire** 2014	• External, non-proprietary screws make getting inside straightforward. • The four Dynamic Perspective cameras are encased in glue. • The phone is not modular, increasing the cost of replacement parts.	3
HTC **One M9** 2015	• Standard Phillips screws make the rear case easier to open. • The display assembly is the hardest component to replace. • Battery is buried under motherboard and adhered to midframe.	2
HTC **One M8** 2014	• Standard Phillips screws make the rear case easier to open. • The display assembly is the hardest component to replace. • Battery is buried under motherboard and adhered to midframe.	2
Apple **iPhone** 2007	• Standard Phillips screws used throughout. • Hidden clips make it nearly impossible to open rear case without damaging it. • Soldered battery is very difficult to replace.	2
HTC **One** 2013	• Solid external construction improves durability. • Virtually impossible to open without extreme damage to rear case. • Battery is buried under motherboard and adhered to midframe.	1

sustainablySMART

Sets out to demonstrate the feasibility of a »design for circular economy« approach for mobile IT designs, which includes the implementation of environmental design criteria:

- Long lifetime: reliability of target parts and components for second life / cascade reuse
- Reparability
- Design for manual and automated disassembly
- Accomplishment of verified data erasure compatibility

Project Objectives

SUSTAINABLY SMART

Our task: Develop a scientifically validated reparability scoring system

- Repair, reuse and remanufacturing require basically the same design features
- SustainablySMART will incentivize and advocate for design for repair / reuse / remanufacturing
- We'll develop a system of algorithms to allow for a reproducible ranking of mobile devices in relation to these objectives
- The results will be communicated to policy makers and are intended to be reflected in eco-labelling

This project has recieved funding from the European Union's Horizon 2020 research & innovation programme under grant agreement No 680640 and 730308

IFIXIT EUROPE

Selection Principles for Criteria

SUSTAINABLY SMART

Relevance (does the criterion address an essential aspect influencing the likelihood of repair in scenarios considered? Is the criterion the only/best one to address said aspect i.e. if we dropped this criterion, would we miss this essential aspect?)

Feasibility / objectivity / repeatability of verification (can we define the criterion in such a way that it can be assessed in a reliable and consistent way regardless of the person conducting the assessment?)

Potential for differentiation between products ('minimal pair': is there a series of relevant products i.e. smartphones or tablets currently on the market or expected to hit the market in max. 2 years, whose varying levels of reparability can (only) be distinguished by this criterion?)

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IFIXIT EUROPE

Selected Criteria / Rationale

1 — Availability of information (Q)
Repair guides or service manuals ensure reliable ways of repairing the product for all potential repair actors. Having access to repair information reduces the risk of repair failures and thereby also increases the likelihood of the repair being undertaken, since fear of breaking a product decreases when a manual is available.

2 — Deterrent Messaging (Q)
Voiding warranty or other issues that disincentivise opening up a product stand in the way of actually repairing and thus extending the product life.

3 — Path of Entry (EoD)
Before initializing a repair process, the repairer should be confident that it is possible to finish the repair successfully. Whether the product itself encourages or discourages the repairer to open the casing (how daunting is it to open up the product) is therefore a determining factor for the likelihood of repair. The assessment focuses on the ease of opening up the exterior (the amount of force) and the tools needed to do so (from fingers only to the use of uncommon tools).

4 — Visual Cues (Q)
Visual mapping and identification of the components (e.g. battery), its fasteners (e.g. screws) and cable connectors (e.g. ZIF) by means of codes, icons or colour could help the repairer to initiate and run through the process of disassembly with more confidence. It also reduces the chance of overlooking fasteners or connectors and therefore improves tha chances of success.

5 —Spare part availability (Q)
Without critical spare parts, it is impossible to repair a product and bring it back to working functionality. Critical components can be made available to the general public for DIY repair, only to authorized repair workshops, or not be made available at all. Acquiring a critical spare part for a reasonable price, in an easy and quick way, contributes to a successful repair.

6 — Type of tools needed (EoD)
The number of tools needed to replace critical components, as well as their precise type and their availability, strongly influence the chance of initializing and successfully finishing the repair. We have divided the specific tools that can be needed for smartphone or tablet repair into classes corresponding to those defined in PrEN54445, from class A (Common Tools), class B (Product specific tools), class C (Commercially available tools) to class D (Proprietary tools).

7 — Accessibility for repair (EoD)
The accessibility of critical components, which fail most often, is a crucial factor for repair success. The accessibility of a component depends on the minimum number of steps to reach the component and the number of "difficult fasteners" needed to overcome to reach the component.

8 — Difficulty to repair (EoD)
The need for high force, difficult positioning of tools or additional activities adversely affect the accessibility of critical components. "Difficult fasteners" are connecting technologies which negatively influence the time-to-access the component and the overall repair experience and can be defined when the connecting technology 1) requires the use of specialized tools like secured screwdrivers, 2) is difficult to separate like glue or one-way screws, or 3) is difficult to reach like recessed or hidden screws.

9 — Health and safety risk (Q + EoD)
Any risk of injury leads to a lower chance of actually initializing and successfully finishing the repair. We evaluate three aspects influencing safety: 1) type of battery (risk of puncture), 2) need for the use of heat during the process and 3) use of high force for prying (increased risk of injuring the repairer).

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Repair Scenario Considered

- Target audience: self-repair / laypeople
- Part replacement, not part repair
- Diagnosis is out of scope (it is assumed the problem is sufficiently clear)
- Critical components (screen assembly, battery)

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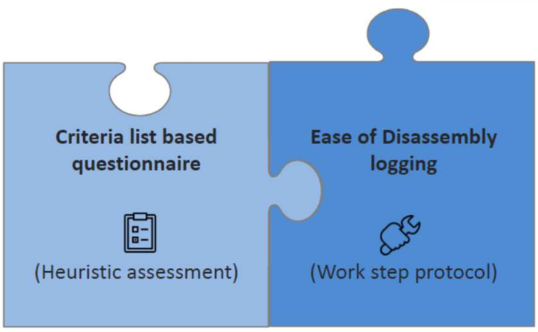
Basic Scoring Modules



This project has recieved funding from the European Union's Horizon 2020 research & innovation programme under grant agreement No 680640 and 730308

Finding a Balance

SUSTAINABLY SMART

Questionnaire Module

Easier to teach
Higher statistical variance

Qualitative Focus
Context-centered

EoD Assessment Module

Harder to teach
More exact & repeatable

Quantitative Focus
Product-centered

This project has recieved funding from the European Union's Horizon 2020 research & innovation programme under grant agreement No 680640 and 730308

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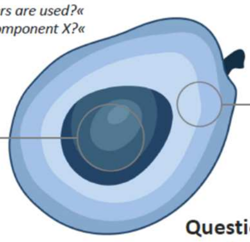
The Product & its Context

SUSTAINABLY SMART

EoD Assessment

Capture of product characteristics, like...
»How many different fasteners are used?«
»How many steps to reach component X?«



Questionnaire Assessment

Capture of product context, like...
»Are spare parts available?«
»Service manual on manufacturer's website?«

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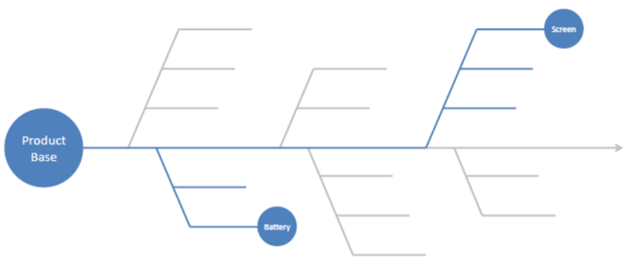
Identifiying Critical Components

SUSTAINABLY SMART



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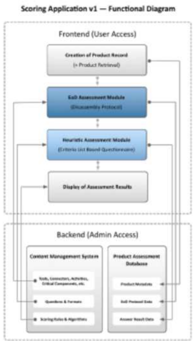
IFIXIT EUROPE

Scoring Software: Functional Overview



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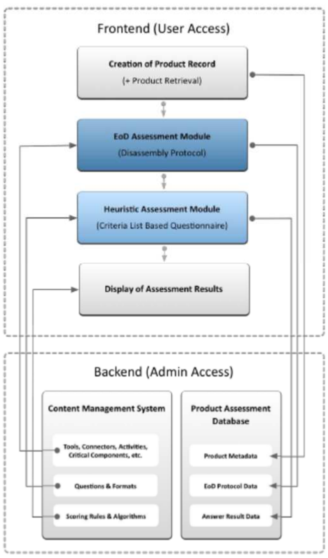
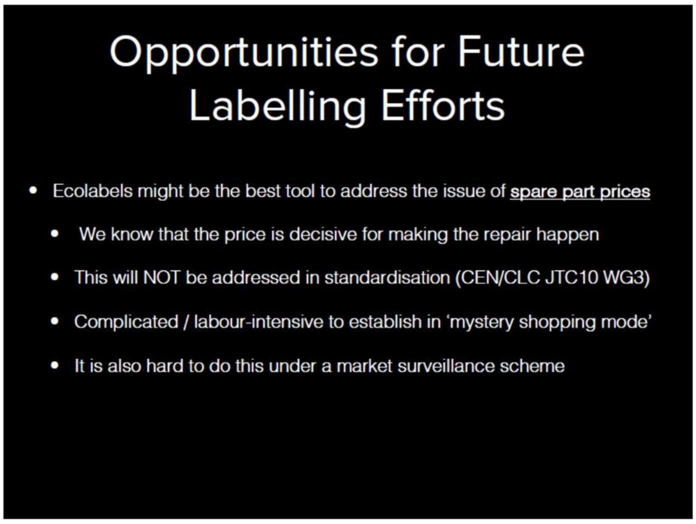
Scoring Application v1 — Functional Diagram



Challenges for a Better Electronics Industry

- Contribute to a circular economy by supporting local repair
- Integrate design for disassembly & repair into product design
- Make consumables user replaceable
- Empower citizens by making it easy to repair their products
- Discourage adhesives and difficult to disassemble designs
- Make service manuals, parts, & diagnostic software available in a standard format, under open licensing



3.6 Analysis prEN45554

3.6.1 Material efficiency standards

sustainablySMART researches innovative modularity approaches for mobile ICT devices while standardisation to assess material efficiency, more precisely a broad range of circular design aspects, is well underway: The European eco-design legislation allows for setting product related material efficiency criteria and minimum standards [1]. Several related standards are under development by the European standardization bodies CEN and CENELEC. One of these standards is explicitly on defining methods for the assessment of the ability to repair, reuse and upgrade energy-related products (prEN 45554 [2]), others are inter alia on durability [3], re-manufacturability [4] and recyclability [5]. As modularity concepts frequently target at enhanced reparability, (module) reuse and upgradeability a comparison of identified design features with the upcoming scoring criteria under prEN 45554 helps to figure out, whether modularity will be favorably assessed under a potential future product regulation for smartphones. It is important to keep in mind, that modularity will also have an effect on product assessments under the other material efficiency standards: Modularity is likely to have an effect on durability, which includes in the sense of prEN 45552 aging, fatigue and wear-out due to environmental and operating conditions [3]. Additional interfaces for modularity and a good ingress protection being in conflict with easy access to components are indicators that durability of modular smartphones is worse than for conventional designs, but a detailed scientific assessment of this correlation remains to be done. Recyclability is rather improved by modular design, as has been shown for the Fairphone 2 in a comprehensive recyclability assessment [6]. Similarly, a positive correlation between the criteria on re-manufacturability according to prEN 45553 and modular designs, which enable exchange of functional modules can be expected, but verification of this assumption is pending.

3.6.2 RRU assessment of modularity types

The repair, reuse and upgrade criteria listed in Table 2 are those defined by prEN 45554 and related to the product design as such. There are further support-related criteria, which are of a management and organizational nature, such as availability of spare parts, types and availability of information, return options, data management and password and factory reset for reuse. As these are not directly related to a product design they are not included in the screening assessment in Table 2. A key term for the RRU scoring are “priority parts”, which are those with a high average occurrence of failure, containing personal data, and those subject to rapid technological changes or changes in use profiles [2]. With this generic definition there is no unambiguous clarity what are priority parts of smartphones. Cordella, Alfieri and Sanfélix [7] suggest as priority parts for smartphones a rather short list:

- Screen
- Back cover
- Battery
- Operating System

Given the “rapid technological changes” in storage density and also due to the personal data issue memory might also qualify as priority part (for reuse and upgrade) and theoretically also the processor (CPU), but upgrading a CPU is extremely complex as this has effects on the whole system. It might be arguable, that the continuing innovations in imaging technology and settings also make cameras a priority part for smartphones. With this range of priority parts in mind, the RRU screening of modularity types in Table 1 provides a first screening, if a positive correlation between RRU criteria and the modularity types identified in Schischke et al. [8] exists.

Table 1: RRU screening of modularity types

	Repair-Reuse-Upgrade criteria				
Matrix legend: o : no relevant correlation + : favorable scoring ++ : very favorable scoring	Disassembly depth	Fasteners and connectors	Tools	Working environment	Skill level
MO **Material modularity**	+	+	+	++	++
Internal modularity for serviceability	o	+	+	+	+
Repair modularity on board level	o	+	+	+	+
Platform modularity	+	+	+	++	++
DIY repair modularity	++	++	++	++	++
Upgrade modularity	+	+	+	++	++
Mix & match modularity	++	++	++	++	++
Add-on modularity	+	+	+	+	+
Repurposing and system modularity	o	o	o	o	o

Internal modularity and repair modularity on board level are not likely to reduce the number of disassembly steps, resulting in a neutral assessment. However, the fasteners and connectors in internal modules and on board level are favorable and the assessment in the related column for internal modularity and repair modularity on the board level is favorable – if any of the relevant internal modules are defined as priority parts in the end. DIY repair and mix & match modularity scores high for all criteria, but again only if the priority parts are individual modules. The definition of the back cover as a priority part in case of the fragmented designs of the PuzzlePhone and the Google ARA concepts is problematic as the modules each feature an external surface. Add-on modularity typically targets at modules, which are features, which are not essential for the core function of the smartphone, and as such this modularity concept is only weakly linked to the proposed RRU criteria. Repurposing and system modularity seems not to be linked to the existing RRU criteria (applied to defined priority parts) at all, which unveils a weakness of the proposed material efficiency assessment framework: Positive side effects through repurposing of the whole device are not properly addressed although the environmental potential is significant, if other devices can be replaced by a reused device or a device serving multiple other computing purposes.

3.6.3 References

[1] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products, OJ L 285, 31.10.2009, p. 10–35

[2] prEN 45554:2018. General methods for the assessment of the ability to repair, reuse and upgrade energy-related products

[3] prEN 45552. General method for the assessment of the durability of energy-related products

[4] prEN 45553. General method for the assessment of the ability to re-manufacture energy-related products

[5] prEN 45555. General methods for assessing the recyclability and recoverability of energy-related products

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