EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Directorate B, Growth and Innovation (Sevilla)
Unit 5, Circular Economy and Industrial Leadership

Guide for the Assessment of Material Efficiency: application to smartphones

Author(s): JRC – B.5	**Date:** 19 April 2018

Summary:

Improving the material efficiency of products has the potential of bringing added value to the environment and to the economy, by saving resources and avoiding production of waste. However, improved design of products needs to be assisted by appropriate assessment methods.

In this context, the Joint Research Centre Directorate B, Circular Economy & Industrial Leadership unit (JRC B.5), has been prepared a methodological guide for the assessment of material efficiency of products (GAME). The methodology is based on the analysis of technical and functional aspects of products, as well as on the definition of life cycle scenarios of assessment targeting environmental and economic impacts, and adheres on practical targets:

- To identify key material efficiency aspects of products;
- To propose of tangible improvement measures.

This report describe the application of the methodology to the assessment of material efficiency aspects for smartphones, with the aim of compiling a list of possible actions for improving their performance with respect aspects as durability, reparability, upgradability, use of materials and recyclability.

This draft report is structured in the following chapters:

1. Product group definition and characterisation (including: scoping, legislation and testing methods of interest, relevant information on market, user behaviour and product);
2. Identification of hot-spots for material efficiency (based on product-specific information and life cycle considerations);
3. Technical analysis and assessment of material efficiency aspects (e.g. durability, reparability, use and recycling of materials);
4. Definition of possible improvement measures;
5. Additional questions for stakeholders.

Two written consultations are planned, the first one taking place from 23 April 2018 until 21 May 2018. Please note that at this stage it has been possible to prepare only a draft and incomplete report, mainly focused on the product group definition and characterisation. The goal of the first consultation is to revise and integrate the background information gathered so far and set the basis for the development of the

other steps of the study. Depending on your interest in and familiarity with the subjects covered in the report, you may provide input either to all or some parts and questions of the report, by using the provided commenting form.

DISCLAIMER: The views expressed are purely those of the writer and may not in any circumstances be regarded as stating an official position of the European Commission. The information transmitted is intended only for the Member State or entity to which it is addressed for discussions and may contain confidential and/or privileged material.

Table of Contents

INTRODUCTION

The Communications from the Commission COM(2015) 614 'Closing the loop - An EU action plan for the Circular Economy' and COM(2016) 773 'Ecodesign Working Plan 2016-2019' point out the increased importance of improving the resource efficiency of products in order to promote a transition towards a more circular economy in the EU. This can be for instance supported through a series of measures aiming to make products more durable, easier to repair, reuse or recycle. Improving the material efficiency of products has the potential of bringing added value to the environment and to the economy, by saving resources and avoiding production of waste. However, improved design of products needs to be assisted by appropriate assessment methods. The importance of assessment and verification procedures is also confirmed by the recent creation of the CEN-CENELEC JTC10 'Energy-related products – Material Efficiency Aspects for ecodesign', which is working on the development of general standards on material efficiency aspects for Energy-related Products (ErP).

In this context, the Commission has launched a technical research study focused on the assessment of material efficiency aspects for smartphones, and aimed at compiling a list of possible actions for improving their performance with respect to circular economy aspects such as durability, reparability and upgradability, use of materials and recyclability. The study, entrusted by DG ENV to the Joint Research Centre Directorate B, Circular Economy & Industrial Leadership unit (JRC B.5), will follow the Guide for the Assessment of Material Efficiency (GAME), as described in the present document. GAME is a methodology that has been prepared by JRC B.5[1] to support the possible implementation of measures to improve the material efficiency of products. The methodology adheres on practical targets:

1. Identification of key material efficiency aspects of products;
2. Proposal of tangible improvement measures.

GAME is based on the analysis of technical and functional aspects of products, as well as on the definition of life cycle scenarios of assessment targeting environmental and economic impacts.

Final results of the study, which has a research orientation, could feed into work on actions covered under the Circular Economy Action Plan and related to product policy[2] and the Ecodesign task force for ICT products[3].

This draft report is structured in the following chapters:

1. Product group definition and characterisation (including: scoping, legislation and testing methods of interest, relevant information on market, user behaviour and product);
2. Identification of hot-spots for material efficiency (based on product-specific information and life cycle considerations);

---

[1] GAME builds on former knowledge on material efficiency analysis and product policy implementation, and is the further development of a former methodology used by JRC for the Resource Efficiency Assessment of Energy-related PROducts (REAPRO, see Ardente, F. and Mathieux, F., Identification and assessment of product's measures to improve resource efficiency: the case study of an energy using Product. Journal of Cleaner Production, 2014, 83, 126-141, https://doi.org/10.1016/j.jclepro.2014.07.058)

[2] http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF

[3] https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf

3. Technical analysis and assessment of material efficiency aspects (e.g. durability, reparability, use and recycling of materials);
4. Definition of possible improvement measures;
5. Additional questions for stakeholders.

A Technical Working Group (TWG) of experts, consisting of manufacturers, retailers, repairers, recyclers, academia, environmental and consumer NGOs, as well as experts working in relevant authorities of Member States, has been formed to provide input to the study.

Two open technical consultations are planned that will allow providing technical input and feedback along the study progress as follows:

- The first written consultation, which will take place from 23 April 2018 until 21 May 2018, will cover the first chapter of the document and questions raised along the document (see the Table of Content).
- The second consultation will cover the overall research work, and is tentatively planned to be launched in summer 2018 (tbc).

A series of boxes have been inserted along the document in order to point out specific questions of interest for the study team. We would much appreciate if you could send your feedback, on these questions and any other comments you may have, to JRC-B5-E4C@ec.europa.eu by using the provided commenting form.

Please bear in mind that at this stage you will be commenting on a draft and incomplete report mainly focused on the product group definition and characterisation. The goal of the first consultation is to revise and integrate the background information gathered so far and set the basis for the development of the other steps of the study. Depending on your interest and familiarity with the subjects covered in the report, you may provide input either to all or some parts and questions of the report.

The final study is currently planned to be published by the end of 2018. Information and reports will be made available on a dedicate website (http://susproc.jrc.ec.europa.eu/E4C/index.html).

1 PRODUCT GROUP DEFINITION AND CHARACTERIZATION

The present study focuses on the assessment of material efficiency aspects associated to the design of smartphones.

The first step is to define the scope of the analysis and gather background information supporting it, as for instance:

- Key definitions, legislative references and existing testing methods;
- Information about market and use of the product (e.g. information about prices of new and second hand products, costs of repair/refurbishment, functional lifetime, consumers expectations, market failures, circular business models).
- Technical information about product design and system aspects (e.g. product function(s), key technologies, cause of failures, repair and End-of-Life, Bill Of Materials, hazardous components of products).

The information also aims to support the definition of product design option(s), which can be considered representative for average performance conditions and alternative designs (e.g. more durable/reparable products, high-end vs. low-end products), and which will be further assessed in the course of the study.

1.1 Scoping

1.1.1 Product definitions

Some general definitions were found in a few voluntary labelling and certification schemes, as described in the table below. As apparent, no standard definition is used internationally for this fast developing product group.

Table 1: Definitions provided in different labelling and certification schemes

Reference	Scope	Definition
RAL-UZ 106 (2013) - Blue Angel Eco-Label for Mobile Phones	Mobile phones	Mobile phones include 'Handys' (as the Germans call mobile phones) and smart phones using the LTE (often also called 4G), HSDPA (3G+), UMTS (3G) or GSM standard (2G). The devices shall be primarily designed for making phone calls, text messaging and/or the mobile use of internet services. The size of the visible display is used to distinguish mobile phones from mobile computers (e.g. tablet PCs). Thus, devices with a maximum visible display size of 100 cm2 are considered as mobile phones, provided that they meet the above requirements.

TCO Certified Smartphones 2.0	Smart-phones (display sizes ≥ 3" to ≤ 6")	The intended use of a Smartphone is portable computing and mobile communication. A Smartphone is an electronic device used for long-range communication over a cellular network of specialized base stations known as cell sites. It must also have functionality similar to a wireless, portable computer that is primarily for battery mode usage and has a touch screen interface. Connection to mains via an external power supply is considered to be mainly for battery charging purposes and an onscreen virtual keyboard or a digital pen is in place of a physical keyboard.
UL Standard 110, Edition 2 - Standard for Sustainability for Mobile Phones (2017)	Mobile phones	A wireless handheld device that is designed to send and receive transmissions through a cellular radiotelephone service including only the device itself and not packaging or accessories. Slates/tablets, as defined in the most recent applicable version of Energy Star specification, are excluded from this definition.

1.1.2 Product definition proposed

For the purposes of this study, a smartphone is described as follows:

- A smartphone is an electronic device primarily designed for mobile communication (making phone calls, text messaging) and use of internet services.
- It can be used for long-range communication over a cellular network of specialized base stations known as cell sites, including LTE (often also called 4G), HSDPA (3G+), UMTS (3G) or GSM standard (2G).
- It is functionally similar to wireless, portable computers (e.g. tablet PCs), since

- designed for battery mode usage, and connection to mains via an external power supply is mainly for battery charging purposes,

- presenting an operating system (Google's Android, BlackBerry OS, Apple's iOS, Nokia's Symbian, Microsoft's Windows Phone), WiFi connectivity, web browsing capability, and ability to accept applications (Apps),

- It has a display size between 3 and 6 inches and a high-resolution touch screen interface, in place of a physical keyboard.

In particular, the following functions seem to be important for consumers:

- size of the screen, camera, quality aspects as reliability and screen resolution[4],
- longevity of battery, internet access, and high specification camera[5].

[4] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

Basic mobile phones, feature phones[6], smart-watch phones are not considered in the scope of this study.

1.1.3 Questions for stakeholders

1) Are the definitions provided for smartphones and related functionalities comprehensive and clear, or would you have any additional definitions and classifications to share?
2) Do you agree with the proposed scope of the study? How would you otherwise suggest to improve it?

[5] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[6] A feature phone is a mobile phone that incorporates features such as the ability to access the Internet and store and play music but lacks the advanced functionality of a smartphone.

1.2 Legislation and testing methods

This section describes legislative aspects that can influence material efficiency of the product (e.g. repair and/or upgrade, use of materials). Testing methods and standards which are used worldwide to assess and verify material efficiency of the product are also presented.

1.2.1 Safety

1.2.1.1 General Product Safety Directive 2001/95/EC

The General Product Safety Directive (GPSD) 2001/95/EC aims to ensure that only safe products are made available on the market.

The GPSD applies in the absence of other EU legislation, national standards, Commission recommendations or codes of practice relating to safety of products. It also complements sector specific legislation. Specific rules exist for the safety of toys, electrical and electronic goods, cosmetics, chemicals and other specific product groups[7]. The GPSD does not cover pharmaceuticals, medical devices or food, which fall under separate legislation.

The GPSD establishes obligations to both businesses and Member States' authorities:

- Businesses should place only products which are safe on the market, inform consumers of any risks associated with the products they supply. They also have to make sure any dangerous products present on the market can be traced so they can be removed to avoid any risks to consumers.
- Member States, through their appointed national authorities, are responsible for market surveillance. They check whether products available on the market are safe, ensure product safety legislation and rules are applied by manufacturers and business chains and apply sanctions when necessary. Member States should also send information about dangerous products found on the market to the Rapid Alert System for non-food dangerous products (RAPEX). This is a cooperation tool enabling rapid communication between EU, EEA authorities about dangerous products to be able to trace them everywhere on the European market. Third countries like China and international institutions are also involved.
- Market surveillance authorities cooperate closely with customs, which play a major role in protecting consumers from any imported unsafe products coming from outside the EU.

1.2.1.2 Radio Equipment Directive (2014/53/EU)

The Radio Equipment Directive (2014/53/EU) ensures a Single Market for radio equipment by setting essential requirements for safety and health, electromagnetic compatibility, and the efficient use of the radio spectrum. It applies to all products using the radio frequency spectrum, including also smartphones.

The Directive requires equipment to be constructed for efficient use of the radio spectrum, as well as electromagnetic compatibility, to avoid interference with terrestrial and orbital communications.

The Radio Equipment Directive also requires that manufacturers shall ensure that the radio equipment is accompanied by instructions and safety information in a language which can be easily understood by consumers and other end-users, as determined by the Member State concerned. Such information shall include, where applicable, a description of accessories and

[7] https://ec.europa.eu/info/business-economy-euro/product-safety-and-requirements/consumer-product-safety/standards-and-risks-specific-products_en (accessed on 21 March 2018)

components, including software, which allow the radio equipment to operate as intended. Such instructions and safety information, as well as any labelling, shall be clear, understandable and intelligible.

Another relevant requirement for the material efficiency aspects is that, within certain categories or classes, radio equipment interacts with accessories, in particular with common chargers. In the recital of the Radio Equipment Directive there is a clear reference to mobile phones and their compatibility with a common charger.

1.2.1.3 Main standards and testing methods

Main standards and testing methods on safety include:

- IEC 60065:2014 - Audio, video and similar electronic apparatus - Safety requirements.
- IEC 60950-1:2005+AMD1:2009+AMD2:2013 CSV - Information technology equipment - Safety - Part 1: General requirements.
- IEC 62209-1:2016 - Measurement procedure for the assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices. Devices used next to the ear (Frequency range of 300 MHz to 6 GHz).
- IEC 62368-1:2014 - Audio/video, information and communication technology equipment - Part 1: Safety requirements.

1.2.2 Chemicals

1.2.2.1 CLP Regulation (EC) No 1272/2008

The Classification, Labelling and Packaging (CLP) Regulation ((EC) No 1272/2008) is based on the United Nations' Globally Harmonised System (GHS) and its purpose is to ensure a high level of protection of health and the environment, as well as the free movement of substances, mixtures and articles.

The CLP Regulation amended the Dangerous Substances Directive (67/548/EEC (DSD)), the Dangerous Preparations Directive (1999/45/EC (DPD)) and Regulation (EC) No 1907/2006 (REACH), and since 1 June 2015, is the only legislation in force in the EU for classification and labelling of substances and mixtures.

CLP is legally binding across the Member States and directly applicable to all industrial sectors. It requires manufacturers, importers or downstream users of substances or mixtures to classify, label and package their hazardous chemicals appropriately before placing them on the market.

One of the main aims of CLP is to determine whether a substance or mixture has properties which lead to classify and label it as hazardous.

When relevant information (e.g. toxicological data) on a substance or mixture meets the classification criteria in CLP, the hazards of a substance or mixture are identified and communicated by assigning a certain hazard class and category. The hazard classes in CLP cover physical, health, environmental and additional hazards.

CLP is also the basis for many legislative provisions on the risk management of chemicals. In addition, the notification obligation under CLP requires manufacturers and importers to submit classification and labelling information for the substances they are placing on the market to a database (the 'C&L Inventory') held by the European Chemical Agency (ECHA).

1.2.2.2 REACH Regulation (EC) No 1907/2006

The Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) aims to improve the protection of human health and the environment from the risks that can be posed by chemicals because of their intrinsic properties. REACH establishes procedures for collecting and assessing information on the properties and hazards of substances.

The Regulation also calls for the progressive substitution of the most dangerous chemicals (referred to as 'Substances of Very High Concern') when suitable alternatives have been identified.

Companies are responsible for collecting and communicating information on the properties and uses of the substances they manufacture, import or use in their products above one tonne a year. Depending on the volume of the substance, different rules apply.

Substances with the following hazard properties may be identified as SVHCs:

1. Substances meeting the criteria for classification as carcinogenic, mutagenic or toxic for reproduction (CMR) category 1A or 1B in accordance with the CLP Regulation.
2. Substances which are persistent, bio-accumulative and toxic (PBT) or very persistent and very bio-accumulative (vPvB) according to REACH Annex XIII.
3. Substances on a case-by-case basis, which cause an equivalent level of concern as CMR or PBT/vPvB substances.

Once a substance is identified as an SVHC, it is included in the Candidate List. ECHA regularly assesses the substances from the Candidate List to determine which ones should be included in the Authorisation List (Annex XIV). Once a substance is included in an Authorisation List, this can be used/produced only if

a. The risk to human health or the environment is adequately controlled, or
b. It can be demonstrated that the socio-economic benefits compensate the impacts, also taking into account possible alternatives

A Restrictions List (Annex XVII) is also periodically revised. Once a substance is included in the Restrictions List, specific or general uses of such substance are prohibited.

Article 33 of REACH establishes the right of consumers to be able to obtain information from suppliers on substances in articles and also suppliers of articles are obliged to provide certain pieces of information on articles containing substances with irreversible effects on health or environment to industrial or professional users or distributers.

1.2.2.3 ROHS Directive 2011/65/EU

Smartphones are in the scope of the ROHS Directive, included as IT and telecommunications equipment. The legislation restricts the use of certain hazardous substances used in electrical and electronic equipment, which have to be substituted by safer alternatives. Restricted substances are listed in Annex II of the Directive and they are:

- Lead (0.1 %)

- Mercury (0.1 %)
- Cadmium (0.01 %)
- Hexavalent chromium (0.1 %)
- Polybrominated biphenyls (PBB) (0.1 %)
- Polybrominated diphenyl ethers (PBDE) (0.1 %)
- Bis(2-ethylhexyl) phthalate (DEHP) (0.1 %)
- Butyl benzyl phthalate (BBP) (0.1 %)
- Dibutyl phthalate (DBP) (0.1 %)
- Diisobutyl phthalate (DIBP) (0.1 %)

The restriction of DEHP, BBP, DBP and DIBP shall not apply to cables or spare parts for the repair, the reuse, the updating of functionalities or upgrading of capacity of EEE placed on the market before 22 July 2019. Further exemptions are provided in Annex III and Annex IV.

1.2.3 Materials

1.2.3.1 EU list of Critical Raw Materials

The Commission's communication COM(2017) 490 'on the 2017 list of Critical Raw Materials for the EU'[8] indicates 27 raw materials that can be defined as critical because risks of supply shortage and their impacts on the economy are higher than those of most of the other raw materials. The list is shown in Table 2.

Table 2. EU list of Critical Raw Materials on 13 September 2017

Raw Material		
1. Antimony	10. Germanium	19. Phosphorus
2. Baryte	11. Hafnium	20. Scandium
3. Beryllium	12. Helium	21. Silicon metal
4. Bismuth	13. Indium	22. Tantalum
5. Borate	14. Magnesium	23. Tungsten
6. Cobalt	15. Natural graphite	24. Vanadium
7. Coking coal	16. Natural rubber	25. Platinum Group Metals
8. Fluorspar	17. Niobium	26. Heavy Rare Earth Elements
9. Gallium	18. Phosphate rock	27. Light Rare Earth Elements

1.2.3.2 Import of minerals from conflict-affected and high-risk areas

The EU Regulation 2017/821 establishes a Union system for supply chain due diligence in order to curtail opportunities for armed groups and security forces to trade in tin, tantalum and tungsten, their ores, and gold. Minerals and metals covered by the EU Regulation 2017/821 are listed in Table 3.

[8] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2017:0490:FIN

Table 3: Conflict minerals and metals covered by the EU Regulation 2017/821

Description	Volume threshold (kg)
Tin ores and concentrates	5 000
Tungsten ores and concentrates	250 000
Tantalum or niobium ores and concentrates	To be adopted no later than 1 July 2020
Gold ores and concentrates	To be adopted no later than 1 July 2020
Gold, unwrought or in semi-manufactured forms, or in powder with a gold concentration lower than 99,5 % that has not passed the refining stage	100
Tungsten oxides and hydroxides	100 000
Tin oxides and hydroxides	To be adopted no later than 1 July 2020
Tin chlorides	10 000
Tungstates	100 000
Tantalates	To be adopted no later than 1 July 2020
Carbides of tungsten	10 000
Carbides of tantalum	To be adopted no later than 1 July 2020
Gold, unwrought or in semi-manufactured forms, or in powder form with a gold concentration of 99,5 % or higher that has passed the refining stage	100
Ferrotungsten and ferro-silico-tungsten	25 000
Tin, unwrought	100 000
Tin bars, rods, profiles and wires	1 400
Tin, other articles	2 100
Tungsten, powders	2 500
Tungsten, unwrought, including bars and rods obtained simply by sintering	500
Tungsten wire	250
Tungsten bars and rods, other than those obtained simply by sintering, profiles, plates, sheets, strip and foil, and other	350
Tantalum, unwrought including bars and rods, obtained simply by sintering; powders	2 500
Tantalum bars and rods, other than those obtained simply by sintering, profiles, wire, plates, sheets, strip and foil, and other	150

This Regulation is designed to provide transparency and certainty as regards the supply practices of Union importers, and of smelters and refiners sourcing from conflict-affected and high-risk areas.

Although the listed minerals hold great potential for development, can, in conflict-affected or high- risk areas, be a cause of dispute where their revenues fuel the outbreak or continuation of violent conflict, undermining endeavours towards development, good governance and the rule of law.

This Regulation lays down the supply chain due diligence obligation according to the material and the threshold for the annual import volumes. Moreover Union importers of these minerals or metals have disclosure obligations. They shall:

- Make available to Member State competent authorities the reports of any third-party audit carried out or evidence of conformity with a supply chain due diligence scheme recognised by the Commission
- Make available to their immediate downstream purchasers all information gained and maintained pursuant to their supply chain due diligence with due regard for business confidentiality and other competitive concerns.
- Publicly report as widely as possible, including on the internet, on their supply chain due diligence policies and practices for responsible sourcing

Where a Union importer can reasonably conclude that metals are derived only from recycled or scrap sources, it shall, with due regard for business confidentiality and other competitive concerns:

- Publicly disclose its conclusion; and
- Describe in reasonable detail the supply chain due diligence measures it exercised in reaching that conclusion.

With the exception of this disclosure requirement, this Regulation shall not apply to recycled metals.

1.2.3.1 Main standards and testing methods

Main standards and testing methods on materials include:

- ISO 1043-1:2011 - Plastics - Symbols and abbreviated terms - Part 1: Basic polymers and their special characteristics. The standard defines abbreviated terms for the basic polymers used in plastics, symbols for components of these terms, and symbols for special characteristics of plastics.
- ISO 1043-2:2011- Plastics - Symbols and abbreviated terms - Part 2: Fillers and reinforcing materials. The standard specifies uniform symbols for terms referring to fillers and reinforcing materials.
- ISO 1043-3:2016 - Plastics - Symbols and abbreviated terms - Part 3: Plasticizers. The standard provides uniform symbols for components of terms relating to plasticizers to form abbreviated terms.
- ISO 1043-4:1998 - Plastics - Symbols and abbreviated terms - Part 4: Flame retardants. The standard provides uniform symbols for flame retardants added to plastics materials.
- ISO 11469:2016 - Plastics - Generic identification and marking of plastics products. The standard specifies a system of uniform marking of products that have been fabricated from plastics materials. Provision for the process or processes to be used for marking is outside the scope of this International Standard.

1.2.4 Functional and performance aspects

1.2.4.1 Batteries

The Batteries Directive 2006/66/EC intends to contribute to the protection, preservation and improvement of the quality of the environment by minimising the negative impact of batteries and accumulators and waste batteries and accumulators. It also ensures the smooth functioning of the internal market by harmonising requirements as regards the placing on the market of batteries and accumulators. With some exceptions, it applies to all batteries and accumulators, no matter their chemical nature, size or design.

The Directive:

- prohibits the marketing of batteries containing some hazardous substances (Batteries and accumulators must not have a lead, mercury or cadmium content above the fixed threshold limits of 0.004% w/w, 0.0005% w/w and 0.002% w/w respectively unless labelled in accordance with the Directive. Specific labelling requirements are outlined in the directive where these thresholds are exceeded),

- defines measures to establish schemes aiming at high level of collection and recycling,
- fixes targets to Member States for collection and recycling activities (minimum collection rates of 25 % by 26 September 2012, and of 45 % by 26 September 2016).
- sets out provisions on labelling of batteries[9]. In particular all batteries shall be marked with the symbol indicating 'separate collection' (the crossed-out wheeled bin in the Figure 1).
- Sets out provision on their removability from equipment[10]: Member States shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed. Where they cannot be readily removed by the end-user, Member States shall ensure that manufacturers design appliances in such a way that waste batteries and accumulators can be readily removed by qualified professionals that are independent of the manufacturer.

Figure 1: Separate Collection symbol for batteries

It also aims to improve the environmental performance of all operators involved in the life cycle of batteries and accumulators, e.g. producers, distributors and end-users and, in particular, those operators directly involved in the treatment and recycling of waste batteries and accumulators. Producers of batteries and accumulators and producers of other products incorporating a battery or accumulator are given responsibility for the waste management of batteries and accumulators that they place on the market.

1.2.4.2 External power supply

External power supplies are subject to the EU ecodesign regulation (EC) No 278/2009. They convert power input from the mains into lower voltage output for smartphones and a large variety of other electric and electronic products.

Ecodesign requirements for External Power Supplies (EPS) are mandatory for all manufacturers and suppliers wishing to sell their products in the EU. These requirements cover both the 'active' efficiency, i.e. the average efficiency when power is supplied to, and the 'no-load' power consumption, i.e. the power that the supply still uses when connected to the power mains but not supplying electricity to any device.

An EU Code of Conduct on Energy efficiency of External Power Supplies is also available, the version 5 being released in 2013. The Code of Conduct is a voluntary initiative targeting single voltage external ac-dc and ac-ac power supplies for electronic and electrical appliances,

[9] Article 21 of the Batteries Directive 2006/66/EC

[10] Article 11 of the Batteries Directive 2006/66/EC

which also include mobile phone chargers. The initiative aims to minimise the energy consumption of external power supplies both under no-load and load conditions in the output power range 0.3W to 250W.

In June 2009, a campaign[11] for the introduction of a voluntary agreement for a common charger for mobile phones was launched. many of the world's largest mobile phone manufacturers signed an EC-sponsored memorandum of understanding (MoU), agreeing to make most new data-enabled mobile phones marketed in the European Union compatible with a to-be-specified common EPS. All signatories agreed to develop a common specification for the EPS to allow for full compatibility and safety of chargers and mobile phones. The standard was published in December 2010 as EN 62684:2010 'Interoperability specifications of common EPS for use with data-enabled mobile telephones' by CENELEC and in January 2011 by the IEC as IEC 62684:2011.

At international level, the international efficiency marking protocol for EPS was developed by the U.S. EPA. This provides a system to designate the minimum efficiency performance of an EPS, so that finished product manufacturers and government representatives can easily determine a unit's efficiency. This mark demonstrates the performance of the EPS when tested to the internationally supported test methods[12].

1.2.4.3 Packaging and Packaging Waste Directive 2004/12/EC

The Packaging and Packaging Waste Directive 2004/12/EC seeks to reduce the impact of packaging and packaging waste on the environment by introducing recovery and recycling targets for packaging waste, and by encouraging minimisation and reuse of packaging. A scheme of symbols, currently voluntary, has been prepared through Commission Decision 97/129/EC. These can be used by manufacturers on their packaging so that different materials can be identified to assist end-of-life recycling.

The latest revision of the Packaging and Packaging Waste Directive occurred on 29 April 2015 with the adoption of Directive (EU) 2015/720 of the European Parliament and of the Council amending Directive 94/62/EC as regards the consumption of lightweight plastic carrier bags.

1.2.4.4 Guarantees for consumers

The Consumer Sales Directive 1999/44/EC regulates aspects of the sale of consumer goods and associated legal guarantees. According to the 1999/44/EC Directive the term guarantee shall mean any undertaking by a seller or producer to the consumer, given without extra charge, to reimburse the price paid or to replace, repair or handle consumer goods in any way if they do not meet the specifications set out in the guarantee statement or in the relevant advertising.

The duration of the guarantee for new products must be at least 2 years. The minimum duration is applied in the majority of EU-countries. Longer durations are applied in some countries (e.g. Sweden, Ireland, the Netherlands and Finland) depending on the expected lifespan of the item sold. The duration of the guarantee for second hand goods can be lower (minimum 1 year).

The seller must deliver goods to the consumer, which are in conformity with the contract of sale, and then further specifies presumption of conformity of a number of conditions. All

[11] http://ec.europa.eu/growth/sectors/electrical-engineering/red-directive/common-charger_en

[12] https://www.regulations.gov/document?D=EERE-2008-BT-STD-0005-0218 (accessed on 18 April 2018)

Member States introduced in their national law a 'reversal of burden of proof' of at least 6-months. This is the period within which the lack of conformity is presumed to have existed at the time of delivery and the seller is thus liable to the consumer, i.e. the seller must prove that the item was not defective. After six months the burden of proof shifts to the consumer, i.e. the consumer must prove that the product was defective.

Article 3 of the Consumer Sales Directive indicates a list of remedies that should be provided to the consumer in the case of a defect (i.e. repair, replacement, reduction in price and rescission of contract). In the first place, the consumer may require the seller to repair the goods or he may require the seller to replace them.

In addition, Directive 2011/83/EU on consumer rights defines the concept of 'commercial guarantee' (also known as 'warranty'), which can be offered by sellers or producers in addition to the legal guarantee obligation. This can either be included in the price of the product or at an extra cost.

The average consumer does not seem to be aware of the provisions set by legal guarantees. At EU level, awareness of commercial guarantees lies at 67% while only 35% are also aware of the legal guarantee period in their country: the majority of consumers in half of EU Member States think that the legal guarantee period is a single year. Additional coverage over a wider range of cases (e.g. accidental damage, water damage) is increasingly being offered to consumers as a complimentary service, in sales campaigns or in return for additional payment[13].

In 2018 the European Commission plans to propose 'A New Deal for Consumers'[14]. This consists in the revision of the Injunctions Directive, with a view of fully exploiting the potential of injunctions by addressing the main problems faced by consumers in obtaining redress, and by diminishing significant disparities among Member States in the level of the use of the injunction procedure and its effectiveness. The Commission announced that the revision of the Injunction Directive would be presented as a 'New Deal for Consumers' package together with other possible legislative actions on EU consumer law directives:

- providing consumers with rights to individual remedies/redress against unfair commercial practices (by amending the Unfair Commercial Practices Directive);
- ensuring more proportionate, effective and deterrent financial penalties to tackle breaches of consumer laws (by amending the Unfair Commercial Practices Directive, Unfair Contract Terms Directive, Consumer Rights Directive and Price Indication Directive);
- introducing additional transparency requirements for online platforms, especially on whom consumers conclude contracts with when buying on online platforms (by amending the Consumer Rights Directive);
- extending some consumer rights to contracts where consumers provide data instead of paying with money (by amending the Consumer Rights Directive);

[13] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[14] http://www.europarl.europa.eu/legislative-train/theme-area-of-justice-and-fundamental-rights/file-new-deal-for-consumers (accessed on 18 April 2018)

- simplifying some rules and requirements, such as information requirements and rules on sending back goods and reimbursement (by amending the Consumer Rights Directive and/or Unfair Commercial Practices Directive).

1.2.4.5 Durability and reparability

A recent press release of the European Parliament15 informs the public about the request by MEPs of making goods and software easier to repair and update. Parliament highlights the importance of promoting a longer product lifespan, in particular by tackling programmed obsolescence for tangible goods and for software, and making spare parts affordable. More specifically, recommendations include:

- 'Minimum resistance criteria' to be established for each product category from the design stage
- Extension of the guarantee to match the repair time
- Promotion of repairs and second-hand sales
- Avoidance of technical, safety or software solutions which prevent repairs from being performed, other than by approved firms or bodies
- Ease of disassembly of essential components (such as batteries and LEDs), unless for safety reasons
- Availability of spare parts which are indispensable for the proper and safe functioning of the goods 'at a price commensurate with the nature and life-time of the product'
- Introduction of an EU-wide definition of 'planned obsolescence' and of a system that could test and detect the 'built-in obsolescence', as well as 'appropriate dissuasive measures for producers'.
- Development of an EU label to inform consumers better about product's durability, eco-design features, upgradeability in line with technical progress and reparability.

The French decree 2014-1482 published in December 201416 put new requirements on retailers to inform consumers about the durability of their products and the availability of spare parts, under the threat of fine of 15'000 EUR. Manufacturers are required to deliver the parts needed for repairs within two months. The French decree also extends the burden of proof on the seller in the case of a fault within 24 months. Planned obsolescence is also a legal offence punishable by 300'000 EUR. Planned obsolescence is defined as 'all techniques by which a producer seeks to deliberately limit product life in order to increase the replacement rate'17.

Additionally, Sweden has lowered the VAT on the repair of certain products and allowed the tax deduction of repair costs. However, ICT products are not yet covered in this legislative context. In Belgium, VAT on repair for ICT products is set at 6%18.

---

[15] http://www.europarl.europa.eu/news/en/press-room/20170629IPR78633/making-consumer-products-more-durable-and-easier-to-repair (accessed on 21 March 2018)

[16] Decree No. 2014-1482 of 9 December 2014 concerning Disclosure Requirements and Supply of Spare Parts

[17] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[18] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

Out of the legislative context, some manufactures claim to meet specific standards and certifications to ensure a more durable smartphone:

- The Galaxy S8 Active claims to be tested to achieve both MIL-STD-810G specification and IP68 certification[19]. This MIL-STD (also called MIL-SPEC, military standard, or MilSpecs) was developed by the U.S. Defense Department to test the survivability of devices that might be used by troops in the harshest conditions. Phones meet MIL-SPEC by undergoing a range of trials, among which a drop test.
- A specific test method is also proposed by CTIA Certification, with a Device Hardware Reliability Test Plan published in 2015[20].
- IEC 60529 'Degrees of protection provided by enclosures (IP Code)' (Table 4) is an important standard to classify products based on the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in electrical enclosures. The standard aims to provide users more detailed information than vague marketing terms such as waterproof. This standard defines the IP codes, which are designed as a 'system for classifying the degrees of protection provided by the enclosures of electrical equipment'. The IP Code (or International Protection Rating, sometimes also interpreted as Ingress Protection Rating) consists of the letters IP followed by two digits and an optional letter. The first number (from 0 to 6) in the rating code represents the degree of protection provided against the entry of foreign solid objects, such as fingers or dust (Table 5). The second number (from 0 to 8) represents the degree of protection against the entry of moisture (Table 6). IP67 and IP68 are the highest level of protection claimed by some manufacturers. An IP code with an 'X' in place of the first or second number means that a device has not been tested with respect to the corresponding type of protection. Devices are not required to pass every test below the claimed rating, although many companies test their smartphones at various protection levels. Examples of how some devices are rated by manufacturers:

  - The iPhone 8 and 8 Plus are rated with an IP67 rating, which means that they are fully protected from dust (6) and can also withstand being submerged in 1m of static water for up to 30 mins (7).

  - The Samsung Galaxy S8 is rated IP68. This means that, like the iPhone 8 (and 8 Plus), the Galaxy S8 can withstand being submerged in static water, but the specific depth and duration must be disclosed by the company, which in this case is 1.5 meters for up to 30 minutes.

  - The Sony Xperia XZ is rated with an IP65 and IP68 rating, meaning that it is protected from dust and against low-pressure water jets, such as a faucet, when all ports are closed. The company also specifies that the Z5 can be submerged in 1.5 meters of fresh water for up to 30 mins.

Table 4: meaning of IP codes used to claim the Smartphone's level of protection

[19] https://insights.samsung.com/2017/08/11/drop-testing-samsungs-most-durable-smartphone-2/ (accessed on 13 February 2018)

[20] Device Hardware Reliability Test Plan, Version 1.1 of August 2017. Available at: https://www.ctia.org/docs/default-source/certification/ctia-device-hardware-reliability-test-plan-ver-1-1.pdf?sfvrsn=2 (accessed on 20 March 2018)

IP codes	First Digit - SOLIDS	Second Digit - LIQUIDS
IP67	Protected from total dust ingress.	Protected from immersion between 15 centimetres and 1 meter in depth.
IP68	Protected from total dust ingress.	Protected from long term immersion up to a specified pressure.

Table 5: Solid protection levels set by the IEC 60529[21]

Level	Effective against	Description
0	-	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, slender screws, large ants etc.
5	Dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment
6	Dust tight	No ingress of dust; complete protection against contact (dust tight). A vacuum must be applied. Test duration of up to 8 hours based on air flow

Table 6: Moisture protection levels set by the IEC 60529[22]

Level	Protection against	Effective against	Details
0	None	-	-

[21] https://www.cnet.com/how-to/how-waterproof-are-the-new-iphones-heres-what-all-the-ratings-mean/ (accessed on 13 February 2018)

[22] https://www.cnet.com/how-to/how-waterproof-are-the-new-iphones-heres-what-all-the-ratings-mean/ (accessed on 13 February 2018)

1	Dripping water	Dripping water (vertically falling drops) shall have no harmful effect on the specimen when mounted in an upright position onto a turntable and rotated at 1 RPM.	Test duration: 10 minutes Water equivalent to 1 mm rainfall per minute
2	Dripping water when tilted at 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle of 15° from its normal position. A total of four positions are tested within two axes.	Test duration: 2.5 minutes for every direction of tilt (10 minutes total) Water equivalent to 3 mm rainfall per minute
3	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect, utilizing either: a) an oscillating fixture, or b) A spray nozzle with a counterbalanced shield. Test a) is conducted for 5 minutes, then repeated with the specimen rotated horizontally by 90° for the second 5-minute test. Test b) is conducted (with shield in place) for 5 minutes minimum.	For a Spray Nozzle: Test duration: 1 minute per square meter for at least 5 minutes Water volume: 10 litres per minute Pressure: 50–150 kPa For an oscillating tube: Test duration: 10 minutes Water Volume: 0.07 l/min per hole
4	Splashing of water	Water splashing against the enclosure from any direction shall have no harmful effect, utilizing either: a) an oscillating fixture, or b) A spray nozzle with no shield. Test a) is conducted for 10 minutes. Test b) is conducted (without shield) for 5 minutes minimum.	Oscillating tube: Test duration: 10 minutes, or spray nozzle (same as IPX3 spray nozzle with the shield removed)
5	Water jets	Water projected by a nozzle (6.3 mm) against enclosure from any direction shall have no harmful effects.	Test duration: 1 minute per square meter for at least 15 minutes Water volume: 12.5 litres per minute Pressure: 30 kPa at distance of 3 m

6	Powerful water jets	Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction shall have no harmful effects.	Test duration: 1 minute per square meter for at least 3 minutes Water volume: 100 litres per minute Pressure: 100 kPa at distance of 3 m
6K	Powerful water jets with increased pressure	Water projected in powerful jets (6.3 mm nozzle) against the enclosure from any direction, under elevated pressure, shall have no harmful effects. Found in DIN 40050, and not IEC 60529.	Test duration: at least 3 minutes Water volume: 75 litres per minute Pressure: 1000 kPa at distance of 3 m
7	Immersion, up to 1 m depth	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).	Test duration: 30 minutes - ref IEC 60529, table 8. Tested with the lowest point of the enclosure 1000 mm below the surface of the water, or the highest point 150 mm below the surface, whichever is deeper.
8	Immersion, 1 m or more depth	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects. The test depth and duration is expected to be greater than the requirements for IPx7, and other environmental effects may be added, such as temperature cycling before immersion.	Test duration: Agreement with Manufacturer Depth specified by manufacturer, generally up to 3 m

9K	Powerful high temperature water jets	Protected against close-range high pressure, high temperature spray downs. Smaller specimens rotate slowly on a turntable, from 4 specific angles. Larger specimens are mounted upright, no turntable required, and are tested freehand for at least 3 minutes at distance of 0.15–0.2 m. There are specific requirements for the nozzle used for the testing. This test is identified as IPx9 in IEC 60529.	Test duration: 30 seconds in each of 4 angles (2 minutes total) Water volume: 14–16 litres per minute Pressure: 8–10 MPa (80–100 bar) at distance of 0.10–0.15 m Water temperature: 80°C

Test methods are developed and used also by consumers testing organizations (Table 7) in order to test and inform consumers about different performance aspects and durability of their products (e.g. battery performance, resistance to specific stresses as rain, water submersion, shocks)

Table 7: Examples of durability tests carried out by Consumers Testing Organizations[23]

Test Type	Description
Running time test	The running time test is performed by a robot that repeats a list of common tasks until the battery is empty. This includes: voice calls, standby, playback of on-line videos, taking of pictures, scrolling on digital maps.
Rain test	The mobile phones are switched on and connected to a network. A measurement according to EN 60529 - 2000-09 is performed. A raining appliance is used to give an even rain distribution according to IPx1 (7.2 l/h). The phones lie horizontally on a rotary table and are irrigated for 5 minutes. The correct function is assessed immediately, after one day, after 2 days and after 3 days.
Water resistance submersion	Only devices that are claimed to be waterproof (IPxx) are tested. They are submerged into water tube at the stated maximum depth for 30 minutes to verify the waterproofness. The correct functioning is assessed immediately, after one day, after 2 days and after 3 days.
Shock resistance tumble test	The durability against mechanical shocks (e.g. drops) is tested with a tumbling barrel to simulate an 80 cm fall against a stone surface, as described in EN 60065. Handsets are switched on and set into operation (call) and are put into a tumbling drum (tumbling height of 80 cm) for 50 rotations (100 drops) and the damages are checked after each 25 and 50 rotations.

[23] Based on input from Consumers Testing Organisations

Scratch resistance test	The scratch resistance of the phones' displays and their bodies is examined. Therefore, a hardness test pencil (ERICHSEN, Model 318 S) is used. A rating for the display is generated depending on the maximum load that does not lead to permanent scratches on the device under test.

1.2.4.6 Other standards and testing methods

Other standards and testing methods on functional and performance include:

- IEC 61960-3:2017 - Secondary cells and batteries containing alkaline or other non-acid electrolytes. Secondary lithium cells and batteries for portable applications. Prismatic and cylindrical lithium secondary cells, and batteries made from them
- IEC 61966-2-1:1999 - Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space – sRGB.
- IEC 62133-1:2017 - Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications. Nickel systems
- IEC 62133-2:2017 - Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications. Lithium systems
- IEC 62684:2011 - Interoperability specifications of common external power supply (EPS) for use with data-enabled mobile telephones
- ISO 3664:2009 - Graphic technology and photography – Viewing conditions
- ISO 3741:2010 - Acoustics -- Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Precision methods for reverberation test rooms
- ISO 3744:2010 - Acoustics -- Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Engineering methods for an essentially free field over a reflecting plane
- ISO 3745:2003 - Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Precision methods for anechoic and hemi-anechoic rooms
- ISO 7779:2010 - Acoustics -- Measurement of airborne noise emitted by information technology and telecommunications equipment
- ISO 9241-400:2007 - Ergonomics of human--system interaction -- Part 400: Principles and requirements for physical input devices.
- ISO 9296:2017 - Acoustics -- Declared noise emission values of information technology and telecommunications equipment
- ISO 11201:2010 - Acoustics -- Noise emitted by machinery and equipment -- Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections
- ISO 12646:2015 - Graphic technology -- Displays for colour proofing -- Characteristics
- Standard ECMA-74- Measurement of Airborne Noise emitted by Information Technology and Telecommunications Equipment

1.2.5 End-of-Life of the product

1.2.5.1 Waste Directive 2008/98/EC

Directive 2008/98/EC, which is being amended, sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. Waste legislation and policy of the EU Member States shall apply as a priority order the following waste management hierarchy:

1. Prevention
2. Preparation for reuse
3. Recycling
4. Recovery
5. Disposal.

The Directive introduces the 'polluter pays principle' and the 'extended producer responsibility'. It incorporates provisions on hazardous waste and waste oils, and includes two new recycling and recovery targets to be achieved by 2020: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste. The Directive requires that Member States adopt waste management plans and waste prevention programmes. These also include measures to encourage the design of safer, more durable, re-usable and recyclable products.

Annex III of the Waste Framework Directive 2008/98/EC also provides properties of waste which render it hazardous.

1.2.5.2 Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU

Smartphones fall in the scope of the WEEE Directive as 'small IT and telecommunication equipment (no external dimension more than 50 cm)'.

According to Article 4, Member States shall encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE.

Annex VII of WEEE lists a series of materials and components to remove and collect separately for depollution at the EOL of products:

- Polychlorinated biphenyls (PCB) containing capacitors in accordance with Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT),
- Mercury containing components, such as switches or backlighting lamps,
- Batteries,
- Printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board is greater than 10 square centimetres,
- Toner cartridges, liquid and paste, as well as colour toner,

- Plastic containing brominated flame retardants,
- Asbestos waste and components which contain asbestos,
- Cathode ray tubes (the fluorescent coating has to be removed),
- Chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC). Equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 1005/2009,
- Gas discharge lamps,
- Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps,
- External electric cables (the mercury shall be removed),
- Components containing refractory ceramic fibres as described in Commission Directive 97/69/EC of 5 December 1997 adapting to technical progress for the 23rd time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances,
- Components containing radioactive substances with the exception of components that are below the exemption thresholds set in Article 3 of and Annex I to Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation,
- Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume)[24]
- These substances, mixtures and components shall be disposed of or recovered in compliance with Directive 2008/98/EC.

Article 14 allows Member States to require producers to show purchasers, at the time of sale of new products, information on collection, treatment and disposal of EEE. These can include: (a) the requirement not to dispose of WEEE as unsorted municipal waste and to collect such WEEE separately; (b) the return and collection systems available to them, encouraging the coordination of information on the available collection points irrespective of the producers or other operators which have set them up; (c) their role in contributing to re-use, recycling and other forms of recovery of WEEE; (d) the potential effects on the environment and human health as a result of the presence of hazardous substances in EEE; (e) the meaning of the symbol shown in Annex IX, which must be applied to each EEE placed on the market. Moreover, article 15 establishes that in order to facilitate the preparation for re-use and the correct and environmentally sound treatment of WEEE, including maintenance, upgrade, refurbishment and recycling, Member States shall take necessary steps to ensure that producers provide information free of charge about preparation for re-use and treatment in

[24] Substance of concern could be defined based on Annex II of RoHS Directive 2011/65EU (+ exemptions in Annex III and Annex IV); Annex XVII (restriction list) and Annex XIV (authorisation list) of REACH; Annex III of the Waste Framework Directive 2008/98/EC

respect of each type of new EEE placed for the first time on the market within one year after the equipment is placed on the market.

1.2.5.1 Extended Product Responsibility

To raise levels of high-quality recycling, improvements are needed in waste collection and sorting. Collection and sorting systems are often financed in part by extended producer responsibility (EPR) schemes, in which manufacturers contribute to product collection and treatment costs[25].

All Member States of the EU have implemented EPR schemes on the four waste streams for which EU Directives recommend the use of EPR policies: packaging, batteries, End-of-Life Vehicles (ELVs) and Electrical and Electronic Equipment (WEEE). In addition, a number of Member States have put in place additional schemes for products that are not directly addressed in EU-wide legislation (e.g. for tyres, graphic paper, oil and medical waste)[26].

1.2.6 Ecolabels and Green Public Procurement

Environmental Labelling and green public procurement criteria have been developed to help customers and public authorities to identify and purchase smartphones that meet environmental criteria. Criteria typically cover energy use, sustainable sourcing of materials, product life extension, restrictions in the use of hazardous materials and conflict minerals, as well as social aspects. However, the market uptake of ecolabelled products appears so far limited.

1.2.6.1 Blue Angel

Criteria for the award of the Blue Angel eco-Label to mobile-phones have been setup in Germany. The last version of the criteria is dated February 2013. For the time being, the label has been awarded only to Fairphone 2.

Blue Angel considers that the main environmental impacts of mobile phones are related to the manufacture stage and to the materials used in the product. As a consequence, the focus of the label is on longevity of products, limitation in the use of harmful substances, and ease of recycling, also through the implementation of efficient take-back schemes. In addition, Blue Angel eco-labelled devices meet precautionary criteria designed to minimise user exposure to radiofrequency electromagnetic fields beyond the limits recommended for protection against known risks.

The Blue Angel eco-label for mobile phones is claimed to be awarded to devices which:

- Have efficient charging;
- Have been designed as durable and recyclable;
- Avoid environmentally damaging materials;
- Comply with fundamental labour standards during production;
- Comply with precautionary health protection criteria;

---

[25] COM(2015) 614 final COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Closing the loop - An EU action plan for the Circular Economy

[26] OECD, The State of Play on Extended Producer Responsibility (EPR): Opportunities and Challenges, Global Forum on Environment: Promoting Sustainable Materials Management through Extended Producer Responsibility (EPR), 17-19 June 2014, Tokyo, Japan, available at: https://www.oecd.org/environment/waste/Global%20Forum%20Tokyo%20Issues%20Paper%2030-5-2014.pdf (accessed on 6 April 2018)

- Are manufactured in a way that supports an improved take-back and recycling scheme.

Requirements are summarised in Annex I.

1.2.6.2 TCO

TCO Certified is an international third party sustainability certification scheme for IT products. Although covering mobile phones, no model is awarded with this standard. TCO is a type-1 label certifying that products fulfil requirements along its life cycle:

- Manufacturing (social responsible manufacturing, environmental management system)
- Use phase (climate, ergonomics, health and safety, extended product life and emissions)
- End of life (reduction of hazardous content and chemicals, design for recycling)

The second and last version of criteria for smartphones is the TCO Certified Smartphones 2.0, which has been released in November 2015. Requirements needed to be met by TCO Certified Smartphones are summarised in Annex I.

1.2.6.3 EPEAT

EPEAT is a free source of environmental product ratings allowing the selection of high-performance electronics. The system began in 2003 with a stakeholder process convened by the U.S. Environmental Protection Agency and has grown to become a global environmental rating system for electronics. Managed by the Green Electronics Council, EPEAT currently tracks more than 4400 products from more than 60 manufacturers across 43 countries.

Manufacturers register products in EPEAT based on the devices' ability to meet certain required and optional criteria that address the full product lifecycle, from design and production to energy use and recycling:

- Bronze-rated products meet all of the required criteria in their category.
- Silver-rated products meet all of the required criteria and at least 50% of the optional criteria,
- Gold-rated products meet all of the required criteria and at least 75% of the optional criteria.

The U.S EPEAT registry uses a lifecycle based sustainability standard developed by UL (Underwriter Laboratories)[27] as part of its criteria for mobile phones. The requirements applied are listed in Annex I.

1.2.6.4 Green public procurement

There are examples of green public procurement requirements for smartphones in the EU and worldwide:

- The Scottish Procurement established a new suite of frameworks for the supply of ICT client devices in 2016, which included mobile phones[28].

---

[27] UL 110. Standard for Sustainability for Mobile Phones. Available at the following link: epeat.net/...round/UL%20110%20Verification%20Requirements%20-%20FINAL.pdf (accessed on 23 March 2018)

[28] http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue69_Case_Study_139_Scotland.pdf (accessed on 18 April 2018)

- In the U.S., Federal government agencies and many states, provincial, and local governments are required to buy greener electronics (including mobile phones) off of the EPEAT registry, where manufacturers register their products stating the environmental performance of their products.
- In Japan the Law on Promoting Green Purchasing sets out criteria including provisions for material efficiency and it specifically covers mobile phones.

1.2.7 Questions for stakeholders

1) Are there any other relevant legislations, testing methods and standards that you consider relevant to take into account with respect to the following aspects of smartphones?

- Functional performance parameters
- Durability, reparability and recyclability (e.g. drop and waterproof tests)
- Safety
- Use of resources (energy and materials)
- Waste and emissions
- Noise and vibrations
- Ecodesign
- Others

2) How the presented legislative references and standards could influence material efficiency aspects of smartphones, in your opinion?

For example, the General Product Safety Directive 2001/95/EC specifies specific rules for electrical and electronic goods, which could hinder reparability

3) What is the uptake for the standard EN 62684:2010 'Interoperability specifications of common EPS for use with data-enabled mobile telephones'? Can its implementation be considered satisfactory and how the market has reacted?

4) Could you please share your experience about how Extended Producer Responsibility systems have been implemented in your country for smartphones?

1.3 Market

1.3.1 Basic market data

1.3.1.1 Market sales

Smartphones came onto the consumer market in the late 90s but only gained mainstream popularity with the introduction of Apple's iPhone in 2007[29]. Smartphones have rapidly overtaken basic mobile phones and feature phones (Figure 2), as well as other small electronics as digital cameras, GPS, MP3 players, calculators, voice recorders. Every two out of three mobile phones that were shipped globally in 2014 were smartphones: the introduction of smartphones on the market has changed the behaviour of both consumers and businesses[30].

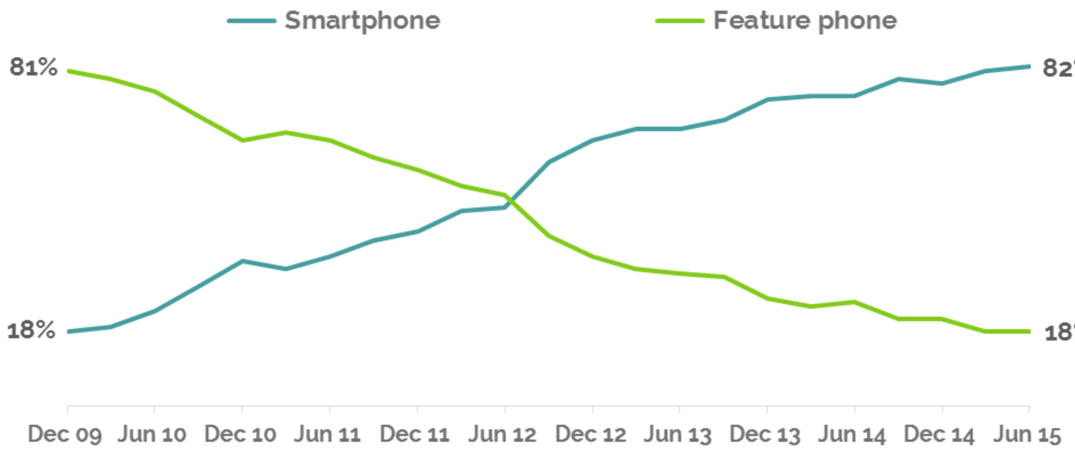

Figure 2: Smartphone and feature phone ownership in the UK (Source: Farmer31)

The smartphone industry has been steadily developing and growing, both in market size, as well as in models and suppliers. Almost 1.5 billion smartphones were sold to end users in 2016, an increase from less than 300 million units in 2010[32].

2016 was the year when the smartphone market stopped growing. Smartphone sales between 2015 and 2016 dropped by 2% in US, Great Britain, Germany, France, Italy, Spain, China, Australia, and Japan. As the smartphone industry matures, fewer consumers are moving between brands and ecosystems – and market growth has increasingly relied on replacing existing devices, rather than bringing in large numbers of new buyers[33].

[29] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[30] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[31] Farmer A, 2015, SIM-only on the march as consumers hold on to handsets for longer. 19th August 2015. Available at: https://yougov.co.uk/news/2015/08/19/sim-only-march-consumers-hold-handsets-longer/ (Accessed on 9th February 2018)

[32] https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/ (accessed on 12 February 2018)

[33] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

However, smartphone shipments worldwide are projected to add up to 1.71 billion in 2020[34], a tenfold increase from the amount of shipments in 2009.

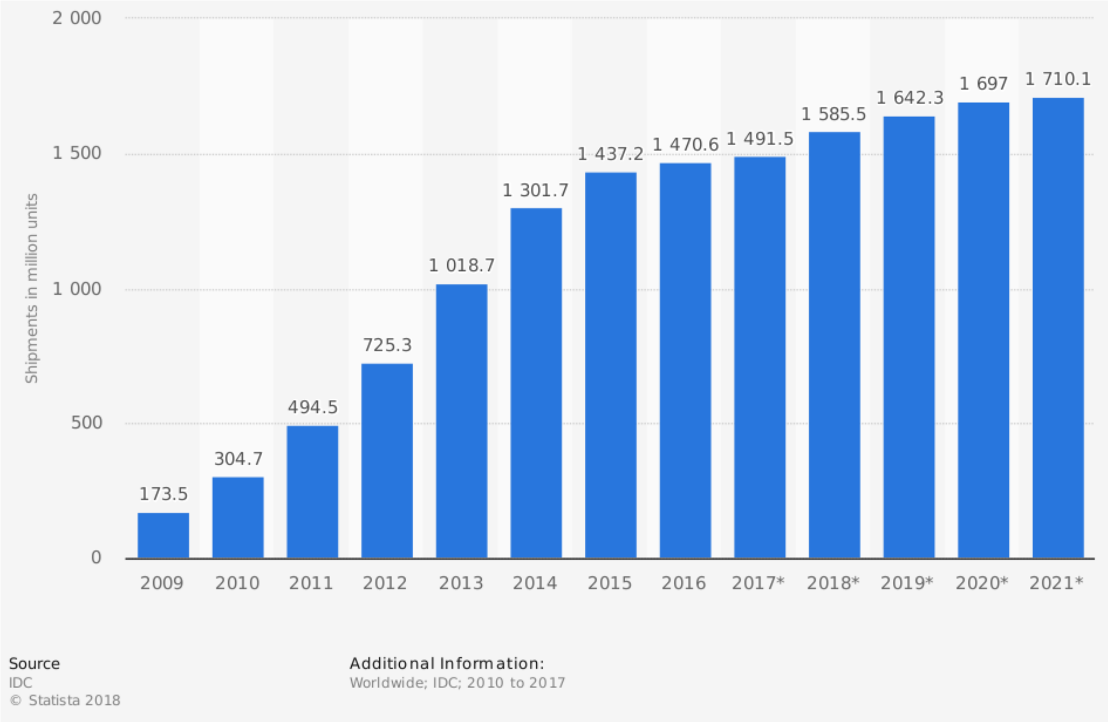

Figure 3 : Global smartphone shipment forecast from 2010 to 2021 (million units)[35]

[34] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[35] https://www.statista.com/statistics/263441/global-smartphone-shipments-forecast/ (accessed on 12 February 2018)

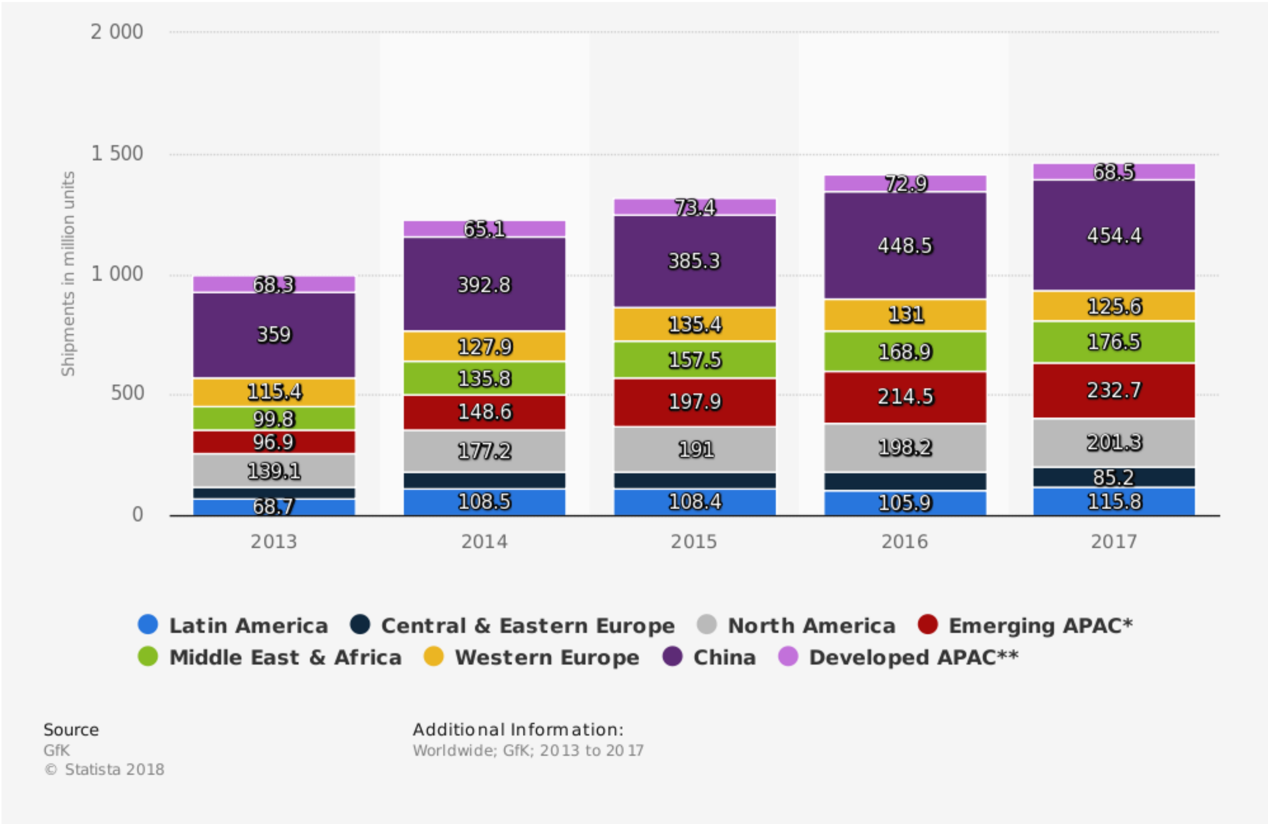

Figure 4: Smartphone unit shipments worldwide from 2013 to 2017 (in million units), by region[36]

Sales of smartphones in Western Europe increased from 115.4 million units in 2013 to 125.6 million units in 2017 (+9%). After reaching a peak of 135 million units in 2015, sales decreased by 3% and 4% in the following years[37]. Sales are instead increasing in Central and Eastern Europe, from 50.9 million units in 2013 to 85.2 million units in 2017 (+67%)[38]. The overall picture for Europe results in an increase of shipments from 166.3 million units in 2013 to 210.8 units in 2018 (+27%). Sales in Europe represent around 15% of the global sales of smartphones (Figure 4).

In terms of total value, sales of smartphones in 2017 were 56 billion U.S. dollars in Western Europe[39] and 21.2 billion U.S. dollars in Central and Eastern Europe[40], which add to 77.2 billion U.S. dollars. Total value of sales has increased since 2013, although a decrease registered in 2015.

[36] https://www.statista.com/statistics/412108/global-smartphone-shipments-global-region/

[37] https://www.statista.com/statistics/412224/global-smartphone-shipments-western-europe/ (accessed on 12 February 2018)

[38] https://www.statista.com/statistics/412204/global-smartphone-shipments-central-and-eastern-europe/ (accessed on 12 February 2018)

[39] https://www.statista.com/statistics/412280/global-smartphone-sales-value-western-europe/ (accessed on 12 February 2018)

[40] https://www.statista.com/statistics/412256/global-smartphone-sales-value-central-and-eastern-europe/ (accessed on 12 February 2018)

Values of single units in 2017 for Western Europe and for Central and Eastern Europe would correspond to 446 and 249 U.S. dollars, respectively. Compared to 2013, single unit value has decreased by 16% in Eastern Europe while it has remained almost constant in Western Europe. The European average is 366 U.S. dollars, 10% less than in 2013.

1.3.1.2 Market penetration

The number of smartphone users is forecast to grow from 2.1 billion in 2016 to around 2.5 billion in 2018 (Figure 5), with smartphone penetration rates increasing as well. Over 36% of the world's population is projected to use a smartphone by 2018, up from about 10% in 2011[41] and 21.6% in 2014[42]. Higher penetration levels are achieved in regional markets. Saturation may be reached soon in developed countries. In Japan 97% of mobile subscribers have smartphones[43].

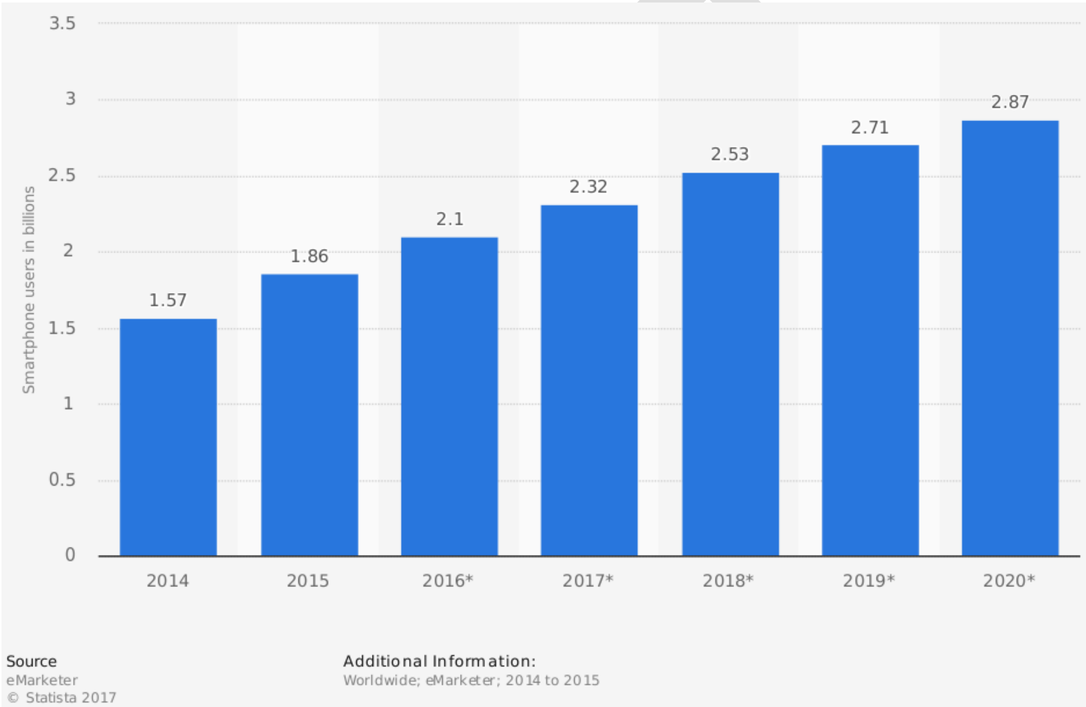

Figure 5: Number of smartphone users worldwide from 2014 to 2020 (in billions)[44]

[41] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

[42] https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/ (accessed on 12 February 2018)

[43] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[44] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

China, the most populous country in the world, leads the smartphone industry. The number of smartphone users in China is forecast to grow from around 563 million in 2016 to almost 675 million in 2019. Around half of the Chinese population is projected to use a smartphone by 2020[45]. This would correspond to about a quarter of all smartphone users in the world[46].

The United States is also an important market for the smartphone industry, with around 223 million smartphone users in 2017. By 2019, the number of smartphone users in the U.S. is expected to increase to 247.5 million[47].

The smallest regional market for smartphones is the Middle East and Africa, where smartphone penetration will stand at an estimated 13.6 percent[48]. The highest penetration rates are instead registered in Western Europe and North America. It is estimated that in 2018 about 64% of the population of those regions will own a smartphone. Market penetration has increased significantly in the last years in both regions: from 22.7% in 2011 in Western Europe, and from 51% in 2014 for North America[49, 50]. Smartphone penetration per capita in Central & Eastern Europe has been estimated to increase from 13.3% in 2011 to 58.2% in 2017.

Penetration rates in Europe appear significant in the most populated countries (Table 8):

- The number of smartphone users in France was estimated to reach 43.35 million in 2017. From 2015 to 2022 the number of smartphone users is expected to grow by 17.68 million users (+26%). Most individuals without a smartphone still own a regular mobile phone and only 7% of the population do own no type of phones[51]. In relative terms, the share of monthly active smartphone users is projected to increase from 59% of the total population in 2016 to 78.5% in 2022[52].
- The number of smartphone users in Germany was estimated to reach 55.46 million in 2017[53]. In relative terms, the share of monthly active smartphone users is projected to increase from 61% of the total population in 2016 to 78.5% in 2022[54].

[45] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

[46] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[47] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

[48] https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/ (accessed on 12 February 2018)

[49] https://www.statista.com/statistics/203734/global-smartphone-penetration-per-capita-since-2005/ (accessed on 12 February 2018)

[50] https://www.statista.com/statistics/203722/smartphone-penetration-per-capita-in-western-europe-since-2000/ (accessed on 12 February 2018)

[51] https://www.statista.com/statistics/467177/forecast-of-smartphone-users-in-france/ (last accessed on 12 February 2018)

[52] https://www.statista.com/statistics/568093/predicted-smartphone-user-penetration-rate-in-france/ (accessed on 12 February 2018)

[53] https://www.statista.com/statistics/467170/forecast-of-smartphone-users-in-germany/ (accessed on 12 February 2018)

[54] https://www.statista.com/statistics/568095/predicted-smartphone-user-penetration-rate-in-germany/ (accessed on 12 February 2018)

- The number of smartphone users in Italy was estimated to increase from 26.8 million in 2015 to 31.5 million in 2017[55]. In relative terms, the share of monthly active smartphone users is projected to increase from 46% of the population in 2014 to 65% in 2021[56].
- The number of smartphone users in Spain was estimated to reach 30.3 million in 2017. From 2015 and 2021 the number of user is expected to grow by 7.7 million to 34.3 million users (+16%)[57]. In relative terms, the share of monthly active smartphone users is projected to increase from 59% of the population in 2016 to 72% in 2022[58].
- The number of monthly active smartphone users in the United Kingdom (UK) is projected to grow steadily from 41.09 million in 2015 to 53.96 million in 2022[59]. In relative terms, the share of monthly active smartphone users is projected to increase from 62% of the population in 2014 to 78% in 2022[60]

However, ownership patterns show significant differences in take-up across age groups. For example, 88% of 16-24 year olds owned smartphones in 2014 in the UK, compared to 14% of those over 65. The pattern is similar for US consumers.[61]

Table 8: Number of smartphone users in different countries from 2015 to 2022 (in millions)[62]

Country	2015	2016	2017*	2018*	2019*	2020*	2021*	2022*
France[63]	34.7	39.4	43.3	46.5	49.0	50.9	52.4	53.6
Germany[64]	43.6	50.5	55.5	59.0	61.6	63.2	64.2	65.0

[55] https://www.statista.com/statistics/467179/forecast-of-smartphone-users-in-italy/ (accessed on 12 February)

[56] https://www.statista.com/statistics/568187/predicted-smartphone-user-penetration-rate-in-italy/ (accessed on 12 February 2018)

[57] https://www.statista.com/statistics/467185/forecast-of-smartphone-users-in-spain/ (accessed on 12 February 2018)

[58] https://www.statista.com/statistics/568268/predicted-smartphone-user-penetration-rate-in-spain/ (accessed on 12 February 2018)

[59] https://www.statista.com/statistics/553464/predicted-number-of-smartphone-users-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[60] https://www.statista.com/statistics/553707/predicted-smartphone-user-penetration-rate-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[61] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[62] https://www.statista.com/statistics/467177/forecast-of-smartphone-users-in-france/ (last accessed on 12 February 2018)

[63] https://www.statista.com/statistics/467177/forecast-of-smartphone-users-in-france/ (last accessed on 12 February 2018)

[64] https://www.statista.com/statistics/467170/forecast-of-smartphone-users-in-germany/ (accessed on 12 February 2018)

Italy[65]	26.8	29.3	31.5	33.3	34.7	35.8	36.7	N.A.

* forecast

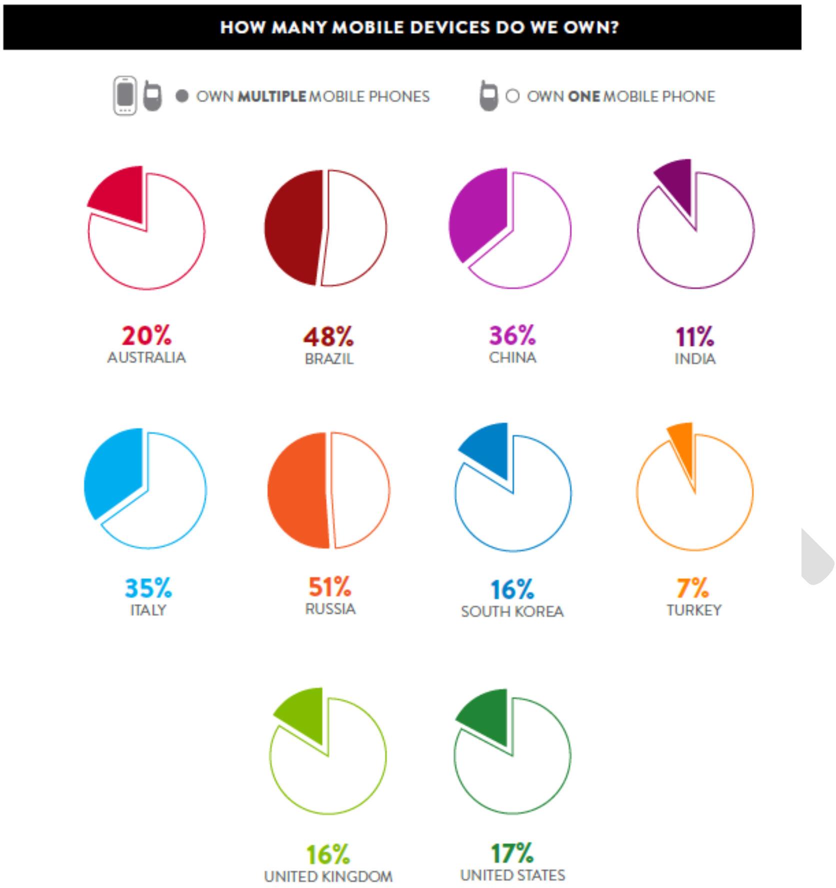

Figure 6: Ownership of devices in different countries[66]

1.3.1.3 Market shares by vendor

Until the first quarter of 2011, Nokia was the leading smartphone vendor worldwide with a 24 percent market share[67]. In 2016, the leading smartphone vendors were Samsung and Apple, with about 20-25% and 15% of the share respectively, followed by Huawei, OPPO and Vivo[68]

[65] https://www.statista.com/statistics/467179/forecast-of-smartphone-users-in-italy/ (accessed on 12 February)

[66] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

[67] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[68] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

[69] (Figure 7: Worldwide Smartphone Company Market Share from 2014 to first quarter of 2017 (Share in Unit Shipments)). Other prominent smartphone vendors include Lenovo and Xiaomi[70]. At the end of 2017, Apple had a worldwide market share of 19%, surpassing Samsung in terms of market share in that quarter[71].

China is not only home of three of the top smartphone vendors (Huawei, Lenovo and Xiaomi), but it is also the largest smartphone market in the world. Domestically, the competition amongst smartphone vendors is intense, but somewhat more balanced. In the first quarter of 2015, Apple was the most successful smartphone vendor in China[72].

However, shares vary depending on the country and the year considered. For example, in the UK the most popular mobile device vendor has been Apple since 2010, which had a total market share of 49% in the first eight months of 2017. In January 2017, the total market share of the Apple iPhone 7 Plus in terms of total smartphone sales in the UK was higher than all others[73].

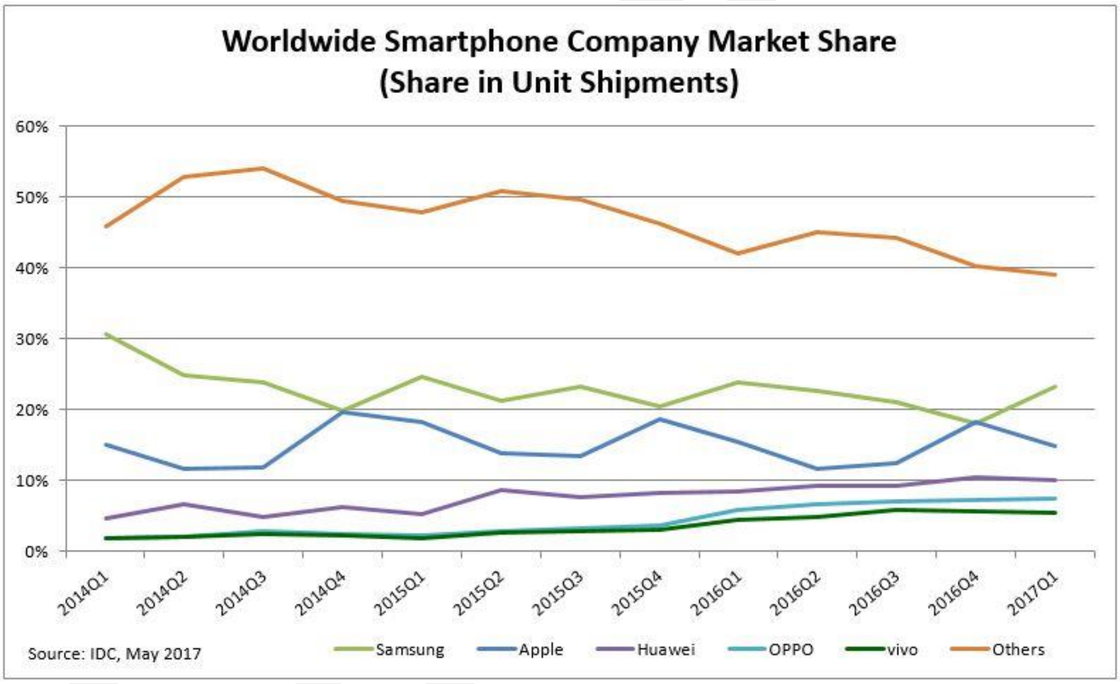

Figure 7: Worldwide Smartphone Company Market Share from 2014 to first quarter of 2017 (Share in Unit Shipments)[74]

[69] https://www.idc.com/promo/smartphone-market-share/vendor (accessed on 13 February 2018)

[70] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[71] https://www.statista.com/statistics/271490/quarterly-global-smartphone-shipments-by-vendor/ (accessed on 12 February 2018)

[72] https://www.statista.com/statistics/299121/global-market-share-held-by-lenovo-smartphones/ (accessed on 12 February 2018)

[73] https://www.statista.com/statistics/553707/predicted-smartphone-user-penetration-rate-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[74] https://www.idc.com/promo/smartphone-market-share/vendor (accessed on 13 February 2018)

1.3.1.4 Market shares by operating system

Google's Android is the clear leader among operating systems with a global market share of more than 80%. Apple's operating system iOS is its main competitor, accounting for about 15 percent of the share[75]. The two operating systems amounted to 352.67 million Android units and 77.04 million iOS units being shipped in the final quarter of 2016[76] (Figure 8 -Figure 9 - Figure 10). There are however differences between regional markets; in the United States for example, the market is almost equally divided between Android and iOS[77].

Other smartphone operating systems on the market include Microsoft's Windows Phone and Blackberry's RIM to a lesser extent. Symbian, which was used extensively on mobile phones and early generations of smartphones by leading manufacturers, such as Samsung, LG, Motorola and most notably Nokia, was a dominant player on the market in 2009 and 2010. Due to the growing popularity of Android, which most major smartphone manufacturers adopted as their OS of choice, and Nokia's partnership with Windows Phone, which began in 2011, Symbian was effectively pushed off the market in 2014[78].

Although the main producers of operating systems are based in the U.S., the Chinese smartphone industry may dominate the market in the coming years. Forecasts predict that China will control just under a third of the smartphone market in 2017, in comparison to the U.S.'s estimated share of 12.1 percent[79].

[75] https://www.statista.com/topics/840/smartphones/ (accessed on 12 February 2018)

[76] https://www.statista.com/statistics/263441/global-smartphone-shipments-forecast/ (accessed on 12 February 2018)

[77] https://www.statista.com/statistics/263453/global-market-share-held-by-smartphone-operating-systems/ (accessed on 12 February 2018)

[78] https://www.statista.com/statistics/263453/global-market-share-held-by-smartphone-operating-systems/ (accessed on 12 February 2018)

[79] https://www.statista.com/statistics/263441/global-smartphone-shipments-forecast/ (accessed on 12 February 2018)

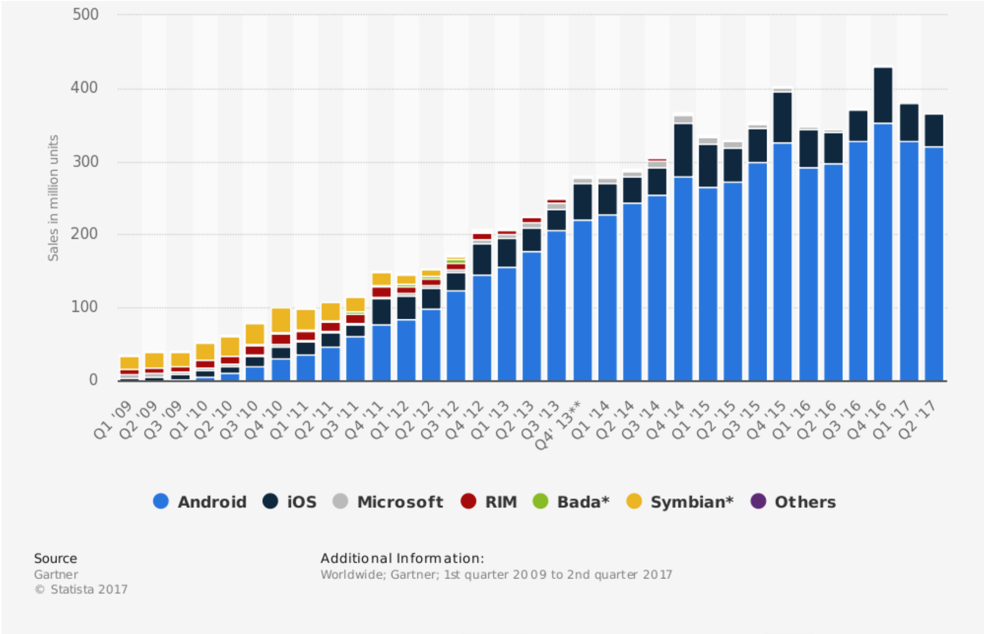

Figure 8: Global smartphone sales to end users from 1st quarter 2009 to 2nd quarter 2017, by operating system (in million units)[80]

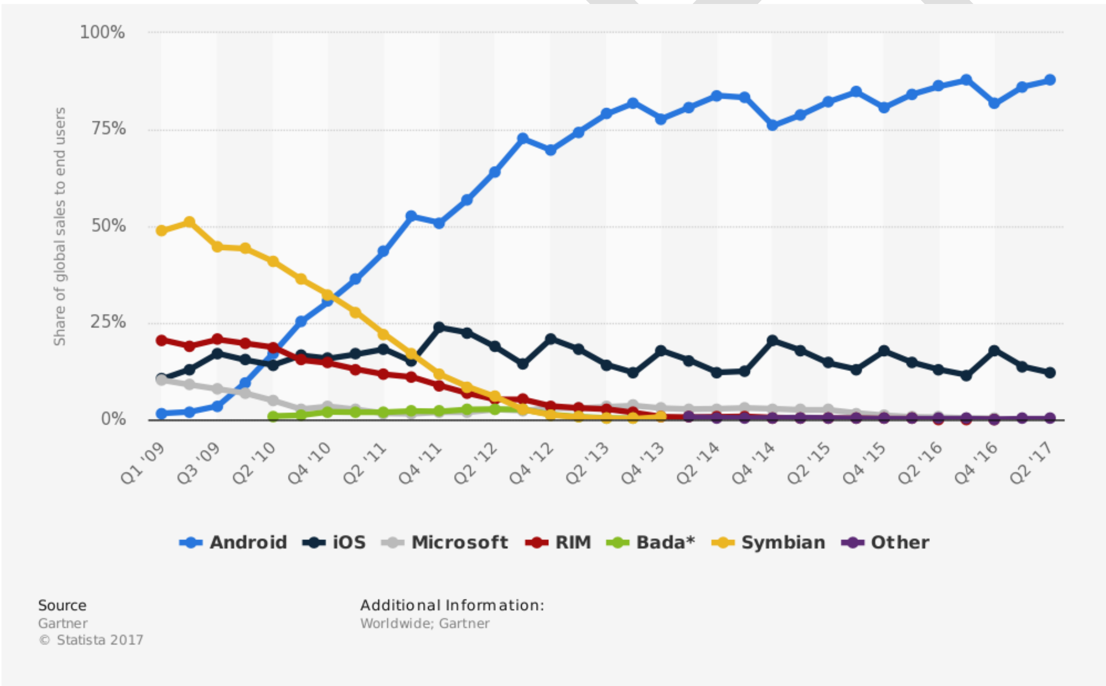

Figure 9: Global market share held by the leading smartphone operating systems in sales to end users[81]

---

80 https://www.statista.com/statistics/266219/global-smartphone-sales-since-1st-quarter-2009-by-operating-system/ (accessed on 12 February 2018)

81 https://www.statista.com/statistics/266136/global-market-share-held-by-smartphone-operating-systems/

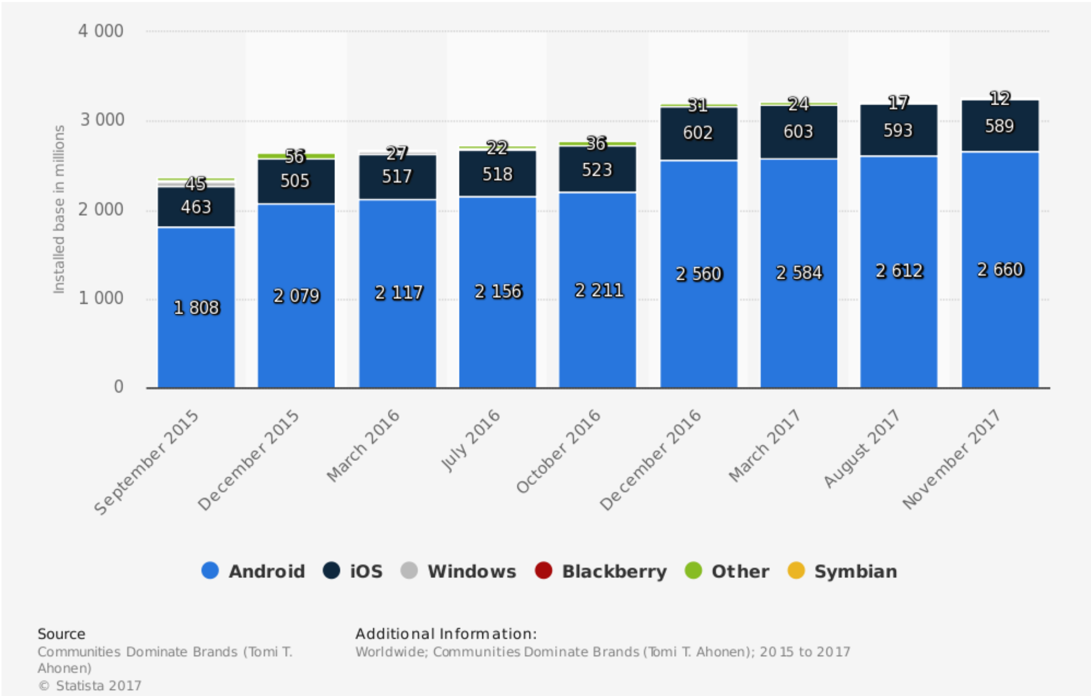

Figure 10: Installed base of smartphones by operating system from 2015 to 2017 (in million units)[82]

1.3.2 Key actors

Different actors play an important role in the smartphone business:

- Mobile phone producers[83], which have a direct influence on the design and servicing of smartphones. The landscape of producers is characterised by the large established global companies such as Apple, Samsung, Sony and Nokia[84], who are making gradual transitions towards greener models. Start-up companies, such as Fairphone and Puzzlephone, that have sustainability as a central element of their business, are gaining popularity although their production volume is still a small percentage of the market
- Software producers[85], which make business through the use of a device (e.g. Google via Android, Apple via iTunes, and other digital services and app developers), and which have interest in securing agreements with hardware providers and providing up-to-date software to customers along the lifetime

[82] https://www.statista.com/statistics/385001/smartphone-worldwide-installed-base-operating-systems/ (accessed on 12 February 2018)

[83] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[84] Nokia's mobile phone section was bought by Microsoft and ran on a Microsoft operating system, but announced that production would seize in summer 2017. Meanwhile, Finnish company HMD began production of Nokia-branded Android phones in 2014

[85] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

of smartphones, in order to avoiding the installation of a different operating system.

- Retailers[86], which are among the biggest providers of mobile phones and which can influence customers towards certain business models, and can enter second-hand markets. Many EU countries also oblige retailers under specific conditions (e.g. size of shop) to provide a collection point for WEEE[87]. For large retail chains of electronics and white goods, sales of mobile phones represent a minor element of total turnover, however these sales are growing in importance. For more specialised retailers the share of turnover represented by phone sales can be as high as 80%, with the remaining 20% represented by reparations, tablets or accessories.

- Network service providers[88], which are large sellers/providers of mobile phones which they sell via subscriptions of network services to attract and keep customers. They can have a strong influence over how often customers upgrade their telephones, but also have relevance to warranties, repair and refurbishment processes. The range of models via which network service providers are offering mobile phone upgrades have been diversifying rapidly over the past few years in global markets and now can include leasing and buy-back upgrades. Sales of phones do not directly generate profits for the service providers (some service providers even claim it is a cost). The providers' main turnover is via data and network services and subscriptions for these. The role of mobile phone sales is thus indirectly linked to profits.

- Mobile phone repairers[89], which are more and more frequent to find (on the web and on the streets). Phone producers/electronics retailers increasingly demand that repair shops are certified in order to activate product warranties. However, there is also a wide range of repairers ranging from authorised, through unauthorised but above-board repairers, to grey actors. For repair companies, repair of mobile phones is in general a large part of the business representing up to 95% of the turnover. However, even here accessories are of increasing importance. For one specialised phone repair company (MyTrendyPhone), accessories have become the major focus, representing 80% of turnover.

[86] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[87] For instance, in Spain, shops with a surface larger than 400 m^2 must accept small electronic devices (as smartphones) with no burden for customers (see https://www.ecolec.es/sociedad/que-hago-con-el-raee/, accessed on 21 March 2018)

[88] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[89] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

- Refurbishers and second-hand sellers[90], which commercialise second hand IT with warranties. These can be single shops, as well as chains (e.g. Blue City in Denmark). Market is expanding as smartphone prices increase. There is also a strong overlap between companies involved in mobile phone repair and second-hand sales.

1.3.3 Costs

1.3.3.1 Purchase price

Statistics available online[91] indicate that the average selling price for smartphones in Europe was 366 U.S. dollars in 2017 (310 U.S. dollars as worldwide average in 2014). This would correspond to about 300 EUR.

Over the last few years, mid-range smartphones accounted for about 40 to 50% of all smartphone shipments, while low-end's share varied between 26 and 34% and high-end held from 20 to 28% of the share. Smartphones that cost less than 150 U.S. dollars are considered low-end. Mid-range smartphone retail prices vary from 150 U.S. dollars to 550 U.S. dollars. Any smartphone above 550 U.S. dollars fits in the high-end category[92].

Since 2010, the average selling prices of smartphones worldwide has varied within the mid-range category. In 2010, customers paid, on average, 440 U.S. dollars for a smartphone, the highest price over the last six years. The average selling price of smartphones worldwide was 333 U.S. dollars in 2013, 310 U.S. dollars in 2013, and 305 U.S. dollars in 2015, with further reductions predicted for the future years[93] (Figure 11).

The average selling price for an Android smartphone was 231 U.S. dollars in 2015. In comparison, Blackberry smartphones costed about 348 U.S. dollars and Windows Phones had an average selling price of 247 U.S. dollars in the same year. By 2018, Windows Phones are projected to become the most affordable smartphones, with an average selling price of 195 U.S. dollars. Android smartphones are forecast to cost 202 U.S. dollars by 2018. iPhones have, by far, the highest average selling price. In 2015, an iPhone cost, on average, 652 U.S. dollars. The average selling price of iPhones is forecast to decline to 610 U.S. dollars by 2018[94].

According to Counterpoint[95], more than half of the Australian, Chinese, German and Saudi smartphone users revealed that they would be willing to spend more than US$400 to replace their current device. More than one third of German and Australian users would be willing to spend more than US$500 in their next smartphone purchase. Apple dominates the installed base in both countries, and more than 85% of the Apple users would not switch brands.

---

[90] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[91] https://www.statista.com/statistics/510668/smartphone-average-selling-price-worldwide/ (accessed on 14 February 2018)

[92] https://www.statista.com/statistics/510668/smartphone-average-selling-price-worldwide/ (accessed on 14 February 2018)

[93] https://www.statista.com/statistics/510668/smartphone-average-selling-price-worldwide/ (accessed on 14 February 2018)

[94] https://www.statista.com/statistics/510668/smartphone-average-selling-price-worldwide/ (accessed on 14 February 2018)

[95] https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 13 February 2018)

Willingness to pay more than US$400 significantly decreases in the other countries investigated (30% in Thailand, 27% in South Africa, 23% in Malaysia, 13% in Japan, 5% in India).

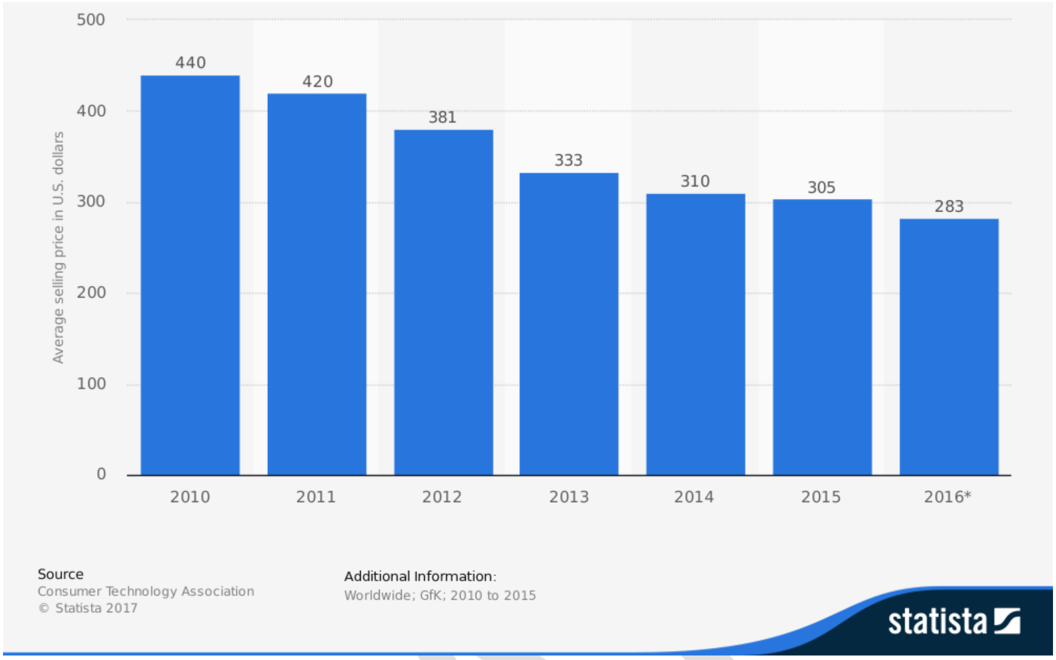

Figure 11: Average selling price of smartphones worldwide from 2010 to 2016 (in U.S. dollars)[96]

A study financed by WRAP[97] investigated the value of consumer electronics for trade-in and re-sale. Although not covering smartphones, the study analysed tablets, which can be considered, to some extent, as a proxy for smartphones. The study provides indication about the depreciation of electronic devices (Table 9). Like most new consumer items, most value is lost in the first year with depreciation slowing over subsequent years. For example, the residual value could be on average:

- 54% of the original price for 1 year old product
- 32% after 2 years
- 20% after 3 years.

Trade-in is expected to be no longer economic after 4-5 years, although as the product category is only 3 years old this is an estimate.

[96] https://www.statista.com/statistics/510668/smartphone-average-selling-price-worldwide/ (accessed on 14 February 2018)

[97] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

Table 9: Depreciation of tablets from year to year[98]

Product Types	Year			
	2010	2011	2012	2013
Kindle Fire 7"			129	60
Galaxy Tab 2 7.0			160	65
iPad Mini			279	180
Galaxy Tab 2 10.1			279	160
Ipad 4th Gen			460	275
Asus Nexus 7			160	90
Acer Icona W700			600	365
Galaxy tab 10.1			300	100
Ipad 2		499	275	150
Acer Icona tab A200		210	125	70
Kindle 4			80	40
TF101		300	170	100
Ipad 1	499	275	150	100
Average refurb, repair & logistical cost A GBP	43.22	43.22	43.22	43.22
Average refurb/repair & logistical cost B GBP	29.19	29.19	29.19	29.19

1.3.3.2 Margins

The purchase price (PP) of products is given by the manufacturing costs (MC) plus the margins added, which can be simplified as follows:

PP = MC x (1+MM) x (1 + RM) x (1+VAT)

Where:

- MC = manufacturing costs, which include the cost of components
- MM = manufacturing margin, which include additional costs and profit of manufacturers (e.g. 20-30%)
- RM = aggregated (wholesale-retailer) sales margin (e.g. 50-300%)
- VAT = value-added tax (e.g. 21.6% as average in the EU in 2015)

In the literature it is reported that PP is about 3.2 times MC[99]. Considering MM and VAT equal to 30% and 21.6%, respectively, RM would thus be around 100%. Margins for 2nd hand

[98] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

[99] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

products could instead be 1.7 times the residual value (Figure 12: Contribution of materials and parts to the total product price for new and 2nd hand phones).

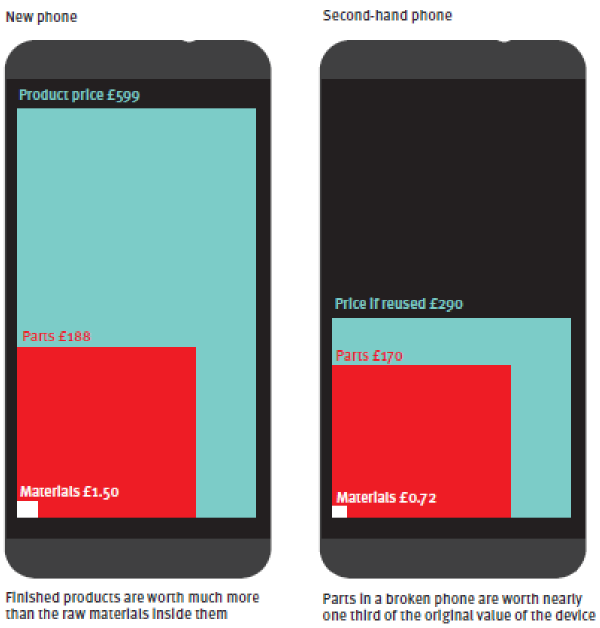

Figure 12: Contribution of materials and parts to the total product price for new and 2nd hand phones

In terms of manufacturing costs[100]:

- Display is reported to be the most important component (20% of the total manufacturing cost), followed by apps/baseband processor (17%) and mechanicals (12%). These 3 components make together up to 50% of the total manufacturing cost.
- 75% of the total manufacturing cost is reached by adding 3 components (electromechanicals (8%), radio frequency power amplifier (RF/PA) (7%) and cameras (6%)), and
- 90% of the total manufacturing cost is reached by further including 2 additional components (user interface (5%) and power management (4%)).
- Other 5 components (box contents, conversion costs, blue tooth and wireless local-area network (BT/WLAN), battery, glue logic & micro-controller units (MCU)) make the remaining 10% of the manufacturing costs.

Table X: Manufacturing costs for Google Pixel XL by component in 2016 (in U.S. dollars)[101]

Component	**Cost (US $)**	**%**

[100] https://www.statista.com/statistics/625527/manufacturing-costs-of-google-pixel-xl/ (accessed on 12 February 2018)

[101] https://www.statista.com/statistics/625527/manufacturing-costs-of-google-pixel-xl/ (accessed on 12 February 2018)

Display	58.0	20%
Apps/baseband processor	50.0	17%
Mechanicals	35.0	12%
Memory	26.5	9%
Electromechanicals	24.0	8%
RF/PA	19.5	7%
Cameras	17.5	6%
User interface	15.5	5%
Power management	11.0	4%
Box contents	10.0	3%
Conversion costs	7.8	3%
BT/WLAN	5.0	2%
Battery	4.0	1%
Glue logic & MCU	2.0	1%
Total	285.8	

1.3.3.3 Additional costs

A study financed by WRAP[102] investigated the value of consumer electronics for trade-in and re-sale. Although not covering smartphones, the study analysed tablets, which can be considered as a proxy for smartphones. The study provides indication about the impact that average refurbishment and repair costs have on the life cycle value of tablets. These costs are relatively high, especially because of the high volume of screen damage.

In terms of revenue share between an owner and an ITAM[103], higher end specification products provide the best revenue sharing arrangement and when average repair is factored in it can be seen that residual value is reduced per item - although total revenues will increase because more items have been recovered for resale. If the residual value falls to a point where it is equal to the repair cost then 'material cost neutral' arrangements should be factored in to prevent conventional recycling and cost.

[102] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

[103] Information Technology Asset disposal – an asset recovery specialist

Table 10: Breakdown of refurbishment cost for PC Tablets[104]

Product Type	Logistic cost from a single user GBP (A)	Logistic cost - regional depot GBP (B)	Standard refurb cost GBP	Cleaning, storage and dispatch cost GBP	Re-packaging cost material GBP	Recycle Cost Avg GBP	Total GBP
Kindle Fire 7"	14.5		12.11	2.5	2.75	1.52	33.38
Kindle Fire 7"		0.47	12.11	2.5	2.75	1.52	19.35
Galaxy Tab 2 7.0	14.5		12.11	2.5	2.75	1.52	33.38
Galaxy Tab 2 7.0		0.47	12.11	2.5	2.75	1.52	19.35
iPad Mini	14.5		12.11	2.5	2.75	1.52	33.38
iPad Mini		0.47	12.11	2.5	2.75	1.52	19.35
Galaxy Tab 2 10.1	14.5		12.11	2.5	2.75	1.52	33.38
Galaxy Tab 2 10.1		0.47	12.11	2.5	2.75	1.52	19.35
Ipad 4th Gen	14.5		12.11	2.5	2.75	1.52	33.38
Ipad 4th Gen		0.47	12.11	2.5	2.75	1.52	19.35
Asus Nexus 7	14.5		12.11	2.5	2.75	1.52	33.38
Asus Nexus 7		0.47	12.11	2.5	2.75	1.52	19.35
Acer Icona W700	14.5		12.11	2.5	2.75	1.52	33.38
Acer Icona W700		0.47	12.11	2.5	2.75	1.52	19.35
Galaxy tab 10.1	14.5		12.11	2.5	2.75	1.52	33.38
Galaxy tab 10.1		0.47	12.11	2.5	2.75	1.52	19.35
Ipad 2	14.5		12.11	2.5	2.75	1.52	33.38
Ipad 2		0.47	12.11	2.5	2.75	1.52	19.35
Acer Icona tab A200	14.5		12.11	2.5	2.75	1.52	33.38
Acer Icona tab A200		0.47	12.11	2.5	2.75	1.52	19.35
Kindle 4	14.5		12.11	2.5	2.75	1.52	33.38
Kindle 4		0.47	12.11	2.5	2.75	1.52	19.35
TF101	14.5		12.11	2.5	2.75	1.52	33.38
TF101		0.47	12.11	2.5	2.75	1.52	19.35
Ipad 2	14.5		12.11	2.5	2.75	1.52	33.38
Ipad 2		0.47	12.11	2.5	2.75	1.52	19.35

[104] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

Table 11: Example of revenue share between owner and ITAM[105]

Model	Manuf	Processor	Hard Drive	RAM	Screen size	Resale in GBP 2013 refurbished	Cost to refurbish GBP (volume pick up)	Value for revenue share in GBP	Client return GBP	ITAM Return GBP
Kindle Fire 7"	Amazon	n/a	0GB	8GB	7	60	19.35	40.65	28.46	12.20
Galaxy tab 10.1	Samsung	1Ghz	16GB	1GB	10.1	100	19.35	80.65	56.46	24.20
Ipad 2	Apple	A5 1Ghz	16GB	0.5GB	9.7	150	19.35	130.65	91.46	39.20
Asus Nexus 7	Asus	Tegra 3 QC	16GB	16GB	7	160	19.35	140.65	98.46	42.20
Ipad 4th Gen	Apple	A6 1.4Ghz DC	16GB	16GB	9.7	275	19.35	255.65	178.96	76.70

Table 12: Example of revenue share, with average repair cost added, between owner and ITAM[106]

Model	Manuf.	Processor	Hard Drive	RAM	Screen size	Resale in GBP (2013) refurb.	Cost to refurb GBP (volume pick up)	With average repair added	Value for revenue share in GBP	Client return GBP	**ITAM Return GBP**
Kindle Fire 7"	Amazon	n/a	0GB	8GB	7	60	19.35	9.84	30.81	21.57	9.24
Galaxy tab 10.1	Samsung	1Ghz	16GB	1GB	10.1	100	19.35	9.84	70.81	49.57	21.24
Ipad 2	Apple	A5 1Ghz	16GB	0.5GB	9.7	150	19.35	9.84	120.81	84.57	36.24
Asus Nexus 7	Asus	Tegra 3 QC	16GB	16GB	7	160	19.35	9.84	130.81	91.57	39.24
Ipad 4th Gen	Apple	A6 1.4Ghz DC	16GB	16GB	9.7	275	19.35	9.84	245.81	172.07	73.74

1.3.3.4 Overview of life cycle costs

The life cycle cost information collected for smartphones is summarised in Table 13: Summary of life cycle cost information collected for smartphones.

Table 13: Summary of life cycle cost information collected for smartphones

Cost category	**Average value** [(1) (2)]
Manufacturing cost **(EUR/product)**	
• Low-end	46.9 (= 150/3.2)
• Medium	93.7 (= 300/3.2)
• High-end	156.2 (= 500/3.2)
Purchase price **(EUR/product)**	

[105] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

[106] Kevin Culligan and Brian Menzies, 2013, The value of consumer electronics for trade-in and re-sale, WRAP's report for the project HWP200-401, available at: http://www.wrap.org.uk/sustainable-electricals/esap/resource-efficient-business-models/reports/value-consumer-electronics-trade-and-re-sale (last accessed on 15 February 2018)

• Low-end	150
• Medium	300 (range of variation: 200-375)
• High-end	500
Value of the product	54% of original price after 1 year, 32% of original price after 2 years, 20% of original price after 3 years
Installation costs **(EUR/product)**	0
Maintenance costs **(EUR/product)**	0
Repair costs **(EUR/product)** (3)	10 (as rough estimation)
Refurbishment costs **(EUR/product)** (3)	20 (as rough estimation)
Margin for resale	1.7 times the residual value
Disposal costs **(EUR/product)**	In accordance to the WEEE directive provisions, producers fulfil their responsibility of financing the costs of collection, treatment, recovery and environmentally sound disposal of domestic WEEE deposited at collection facilities. To some extent these costs are passed over to the consumer in the final purchase price. WEEE financing is a part of selling price, with relevant differences across the EU. In UK the fee is not visible, in Italy the fee is visible to trade partners, but not to consumers, in France the fee is visible also to final consumer. Costs also vary from country to country, logistic costs are a main source of variability. Manufacturers can leverage on economies of scale to ensure that collection and treatment costs are optimised.
Note: (1) VAT included (2) Costs are considered representative for 2018 (3) Where relevant	

1.3.4 Market drivers and trends

Some market trends have been pointed out:

1. There are signs indicating that after a period of growth, sales of smartphones could begin to decrease, especially in developed economies. Sales of phones in Western Europe for instance observed a fall of 6% between 2015 and 2016, which result in lower replacement rates, or longer replacement times form the other side. This could be due to the high price of new smartphones, compared to the technological

innovation brought by new models[107], but also to the increased interest in circular business models.

2. Across developed markets, the pace of upgrades for smartphones and laptops is slowing as consumers have upgraded their devices, they have opted for premium models. Businesses increasingly have to compete on price and user experience rather than impressive hardware to attract and retain customers[108]. This has become a hot area for competition and innovation, in terms of quality of material and design. Full metal and glass designs are making their way down the value chain into low and mid-range devices[109].

3. Camera performance has been an area of strong focus over the past year, with dual cameras making a return. Consumer reception to these innovations has been positive, but owners had already been happy with smartphone camera quality for some time. The leading driver of purchase across US, China, and Europe is the size of the screen, followed by the quality of the camera (Figure 13). Quality aspects as reliability and screen resolution are also important drivers[110]. Other sources instead indicate that the longevity of battery is the most important feature (for 71% of consumers), followed by internet access (57%) and a high specification camera (41%)[111].

4. Consumers have started to adjust their purchasing behaviour, increasingly looking for the best value on these premium devices. Getting a good deal on the price of a phone has a powerful influence on purchases, especially in premium-focused markets like the US and Great Britain. Huawei is successfully taking advantage of these behavioural changes, offering premium specs at mid-range prices[112]. In Japan, 97% of mobile subscribers have smartphones, which results in sharp price competition between retailers[113].

---

[107] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[108] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[109] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[110] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[111] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[112] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[113] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

5. Internet sales continue to increase in total market share, along with shopping through value-based websites like Amazon and eBay. In the US, a third of smartphone sales were made online in 2016, up from 27% in 2014, while 34% of purchases in Urban China were transacted online.

6. Early upgrade programmes were designed by retailers to convince consumers to upgrade their devices on a frequent basis – usually every 12 months – improving revenues and keeping customers locked into a specific smartphone vendor and carrier. However, these programmes did not result being attractive to consumers, also due to the fact that the market is saturated and offering no disruptive but similarity competitive technologies. Some manufacturers (e.g. Apple and Samsung) now offer branded upgrade plans directly to consumers, but sales from these channels remain a small part of the overall smartphone business[114].

7. In terms of disruptive technologies, some experts expected smartwatches to become as popular as phones. These wearable smartphones have achieved healthy levels of adoption in some regions, but barely got started in others. In the US, over 40 million Americans (16%) now wear an activity tracker or smartwatch. Penetration in Europe is far lower, at 9%. The brands experiencing significant success are those which focused on individual needs through niche products, rather than on a one-device-fits-all approach. Wearables continue to appeal to health and exercise enthusiasts, but have not gained much traction beyond that. The convenience of using a smartwatch for notifications relayed from a smartphone has not proved to be that compelling for consumers, and it may be an attempt to solve a problem that consumers were not aware they had. Ultimately, these devices have made consumers' lives more complex than more simplified. Because of this, some manufacturers (e.g. Lenovo and Microsoft) stop the production of smartwatches[115].

8. Ownership and use of fingerprint readers and other biometric identifiers (e.g. eye recognition) are expected to continue increasing rapidly. Shopping is likely to be one of the key applications to adopt fingerprint readers over the coming year. Biometric identifiers could be used to authenticate transactions instantly and supply shipping address data stored on the phone.[116]

9. In June 2016, the first 500 megabit per second (Mbit/s) mobile broadband services were launched in South Korea, with a gigabit per second (Gbit/s, equivalent to 1,000 Mbit/s) service planned for 2019. Delivering a Gbit/s connection over a mobile network is a phenomenal technological achievement yet when it goes live it may be met not only with acclaim but also with questions over the need, and commercial

---

[114] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[115] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[116] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

viability, of such high speeds. Over half of UK adults have a 4G connection, and this already offers peak headline speeds of over 300 Mbit/s across parts of the UK. This headline speed is higher than the maximum speeds available from the majority of active fixed broadband connections. A 2 Mbit/s connection is sufficient to deliver a high-definition television image to a 40 inch screen, and even a 20 Mbit/s connection is more than sufficient to download high-definition video to a five-inch smartphone screen. A large household might have dozens of bandwidth-devouring devices, such as multiple TV sets each receiving different ultra-high definition live sports streams. While this household might have an aggregate demand close to 1 Gbit/s at peak times, smartphones are owned and used by individuals, and typical usage does not necessitate a need for anything close to 1 Gbit/s. There is no single consumer application that currently requires a Gbit/s connection to a mobile phone (indeed there are not any websites today that can transfer data at 1 Gbit/s).[117]

10. Virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and virtual assistants may produce a bigger impact. Tethered VR remains out of reach for many consumers, due to the combined cost of a VR display and a processor powerful enough to run it. With its 2016 introduction of Daydream virtual reality, and Project Tango, Google is set to compete aggressively in the mobile VR and AR space against Facebook's Oculus, which currently powers Samsung Gear VR. Asus is preparing to release its Zenfone AR, the first phone to combine the power of Daydream VR and Project Tango. Microsoft's HoloLens remains in developer only mode, with hints of a consumer-ready version in 2018. HTC is planning to introduce a mobile version of its popular Vive desktop VR system, and Apple continues to articulate his company's interest in augmented reality. In Scandinavia, 3% of consumers reported owning a VR headset at the end of 2016. Considering the 5% of the population that owns a smartwatch, and 9% that own a fitness band, this relatively high penetration for a new technology like VR indicates that it could become an important category on the market.

11. As mobile VR/AR grows, screen size will remain at the top of the feature preference list, since delivering the most realistic user experience relies on devices with large AMOLED screens. This fits with the current market trend towards the sales of screens above 5" (Figure 14). However, the high-resolution requirements and AMOLED screens present a challenge to manufacturers wanting to lower their cost of production[118]. Moreover, there seems to be a tendency to all-glass, bezel-free smartphones, which would increase the area of the phone that is susceptible to cracks and breakages[119].

12. Recently, there is a trend towards storing and process information remotely in the cloud (e.g. Dropbox, Google Docs). Offloading tasks to the cloud means older

[117] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[118] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[119] https://www.theverge.com/2017/3/29/15104372/glass-screen-smartphone-design-lg-g6-samsung-galaxy-s8 (accessed on 18 April 2018)

hardware can be used, including second-hand devices. More durable hardware could be helpful, and performance diagnosis software would need to be integrated to ensure that the agreed service commitments (e.g. speed to load webpages) were met[120]

13. Services may play a more important role than hardware. Apple Music was launched in 2015 and, more recently, expanded to include video, with the company announcing it will soon introduce two original shows. LeEco found success in China by partnering with major networks and content providers to offer live streaming of television content on their phones. The company is currently working on similar partnerships and services as it expands its US footprint with LeEco Live, including MGM, Lionsgate, Sling TV and others. Partnerships may be established with content providers like Netflix, Hulu, or Amazon, or with content producers (as LeEco has done in deals with movie studios), or with telecoms providers like AT&T, Verizon, Comcast, and others[121].

14. Premium market saturation, slowing pace of technology change and a slowing upgrade cycle can also be an opportunity for the second-hand market[122] and the implementation of other circular business models (see Section 1.4.4).

15. Due to consumers' increasing dependence on smartphones, a strong demand for rapid repair services (under one hour) has developed in recent years. Fast-repairers are experiencing significant growth and require physical repair shops. Phones could be borrowed to consumers for longer repairs. This could be enabled by increasing reliance on 'cloud offloading' of a phones data and functionality to allow easy transfer to a temporary borrowed phone. More broadly, cloud offloading may be a key enabler of recirculation and leasing models for smart phones in the future. In addition to repair, refurbishment and second-hand sales both to private consumers and to businesses are also growing rapidly often in association with take-back/buy-back schemes operated by producers/retailers/network service providers. An additional contribution comes from manufacturers, which are paying more attention on designs for durability and reparability also to reduce warranty costs[123].

16. Second-hand premium devices from developed countries can compete with low-end and mid-tier devices in developing countries, where there is still only ten per cent smartphone penetration of the mobile market, and projections indicate rapid growth

[120] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[121] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[122] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[123] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

rates will continue, especially in urban areas. Penetration may be further boosted by prices falling, e.g. smartphones costing less than $100 or even less than $50[124].

17. Bundling of new mobile phones to binding subscription packages has been an important means for service providers to attract and keep hold of customers. In addition, service providers are motivated by a wish that their customers have the newest phones that can be used for new and novel services the network service providers subsequently roll-out. This is now being challenged by rising demand for SIM-only services and reluctance to accept long binding periods[125].

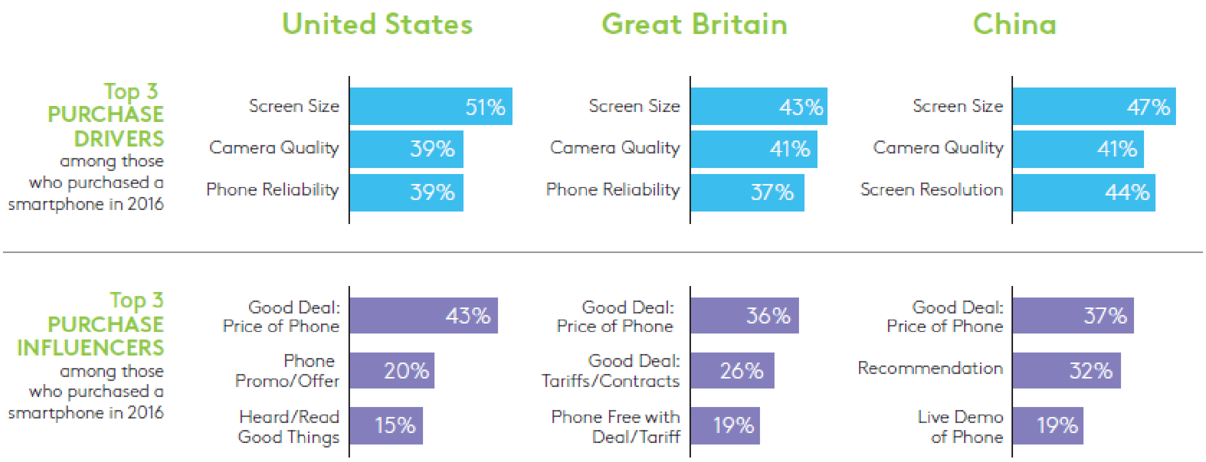

Figure 13: Purchase drivers and influencers for smartphones[126]

[124] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[125] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[126] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

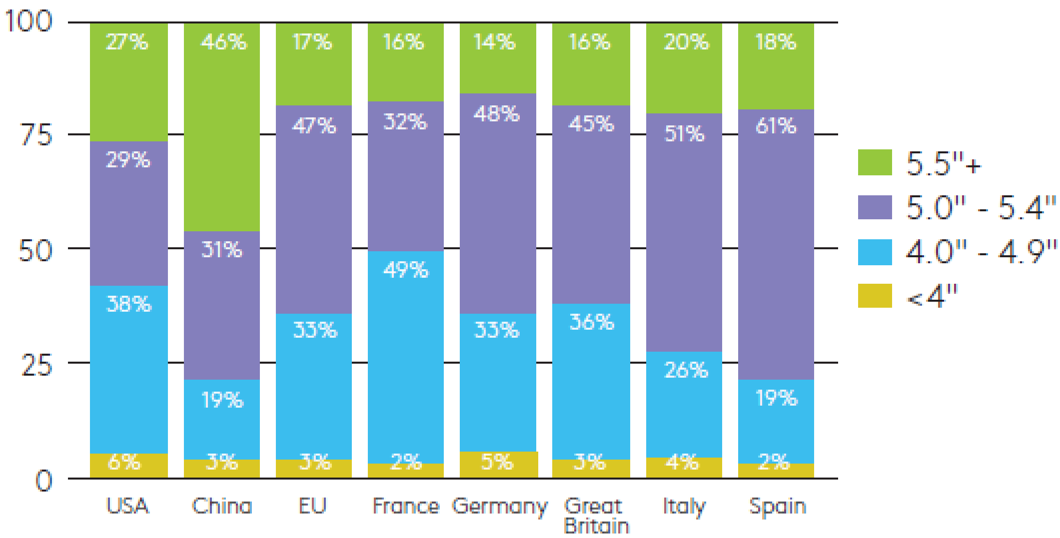

Figure 14: Screen size shares of smartphone sales in 2016[127]

1.3.5 Circular business models

High purchase price and lack of further disruptive new features has slowed down consumer replacement rates of older phones and led to increased demand for repair services and for second-hand phones[128]. Businesses are responding to these trends in different ways:

1. Some are attempting to reverse trends with research, development and marketing activities targeted on new smart phones (See section 1.4.3).
2. Others are exploiting the new opportunities by developing circular business models and services that gain value from extending the lifetime of phones, directly (via offering repair, take-back, refurbishment and resale) or indirectly (as part of CSR strategies).

Circular business models can include[129]:

- Design actions, extended support and accessories:

  - Design of phones with reduced environmental impacts of materials, and/or increased durability, reparability and upgradeability of components and software.

[127] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[128] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[129] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

- Extended support: Extending support for older phone models via continued provision of spare parts for repair services, continued software updates and online support.

- Accessories for mobile phones (e.g. new covers) can indirectly extend active lifetimes of mobiles by giving them a fresh look without the need to buy a new phone. They can also protect the mobile phone from damage when dropping.

- Repair activities: Provision of repair services for mobile phones online or via shops
- Reuse markets:

- Reuse of old phones via C2C, B2C or B2B platforms for second hand sales

- Voluntary take-back/buy-back of phones: Take-back/buy-back services are offered by service providers, retailers or producers. Used phones that are handed in, are refurbished and resold, components removed for use in repairs/refurbishments or are sent for recycling in WEEE systems established in each country.

- Refurbishment (including preparation for reuse) and resell: The business carries out a refurbishment of the used phone prior to sale to a new user. This might include repairs and will include data removal. A special case is where the phones had been discarded as waste (in such cases refurbishment is called preparation for reuse).

- Leasing: The business retains ownership and has thus an incentive to gain greatest possible value from the phone via recirculation to new users and scavenging of components when the phone is no longer fit for recirculation.

The growth in circular businesses is leading to partnerships and interactions across the value chain between sellers of phones (producers, retailers, network service providers), repairers, second-hand sellers and refurbishers. At the same time, some service providers are developing in-house refurbishment and repair services rather than working with partners, in part due to the growing demand for rapid repairs[130]. There is no model that can be universally seen as the winning, being all possible options contributing to improve the resource efficiency of the smartphones industry.

1.3.5.1 Design actions, extended support and accessories

Consumers seem more interested in saving costs through repair and second hand sales rather than purchasing smartphones made of sustainable materials and producing reduced environmental impacts. There are high expectations of reliability for electronics products which can be met with design approaches aimed at improving its ability to last, being repaired and upgraded[131].

Ease of repair, for instance, can reduce the frustrations provoked by the failure of a device, preserve loyalty of customers towards the manufacturer, and add value to the brand. Screen and battery replacements are the parts of smartphones that most frequently need repairs. Repair can be worthwhile even three to five years after sale. However, there is huge variation

[130] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[131] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst, Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

in the cost of repair since many devices do not have easily removable batteries or replaceable screens, as designers favour slimness over reparability[132].

Modular designs can allow easier replacement of components and cheaper repair costs. According to iFixit, replacing a screen on the iPhone 3GS takes 15 minutes versus 90 minutes on the HTC One. This difference has a huge impact given the frequency of these repairs and the fact that labour cost is the main constraint on repair. The trade off in thickness, at least comparing the iPad and Google Nexus 7, appears to be just one millimetre. Modular design also includes basic features as swappable covers, which can have an influence on the use behaviour allowing a stylistic refresh of older devices[133]. Some companies like Puzzlephone, Fairphone, Google and ZTE have started to introduce the concept of modular phone[134].

Important aspects for smartphones are also longevity of the battery[135] and their resistance to impacts and moisture[136]. Some companies like Samsung and Apple have advertised their smartphones showing how their products are tested and remanufactured. However, currently there are no minimum quality standards available at EU or national level.

Apart from hardware considerations, design of smartphones also concerns software issues. Apparently, anti-theft and security software installed on smartphones can be removed only by the original owner[137]. Moreover, out-of-date software implies reduced features, limited app compatibility and security vulnerabilities. 20% of consumers would replace a device when there are no more software updates for the old one. Availability of software updates and support also influence the resale value of smartphones:

- The value of a used LG G2, which has no guarantee of timely software updates, was found to be 15% less than the value of a used Google Nexus, which is almost identical but guarantees timely updates[138].
- Devices with unsupported operating systems could have limited to no resale value, which is a major barrier to reuse. Android and iPhone devices were reported to retain

[132] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst, Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[133] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[134] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[135] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[136] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst, Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[137] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst, Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[138] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

on average 42% and 53% of their value after 18 months, respectively, with the iPhone software support lasting on average 16 months longer.[139].

These problems could be solved either through[140]

- extended software support, which could also be a competitive advantage in a saturated market characterised by price drop and slower innovation;
- the installation of a second life firmware for older devices, which would be appealing for market segments interested in lower-end devices also in case of a functional downgrade.

Extended guarantee policies could stimulate the implementation of design approaches with which to improve the material efficiency of smartphones and the offer of support services for software update and hardware repair. However, these would be hindered[141] by:

- Low consumer awareness of minimum guarantee period and low likelihood of winning a claim after the first six months;
- The fact that the most common causes of failure of a phone (i.e. dropping on a hard surface and contact with water) are normally considered as misuse and not covered by legal guarantees, although phones can be designed to withstand such handling;
- Missed shift of costs from retailers to producers, which in some cases have been reported to cover only 1 year of guarantee period.

1.3.5.1 Repair activities

Repair activities are attractive for smartphones because of the relatively high price of the product[142]. In the US and UK, around 10% of customers are prepared to repair their devices[143] and in recent times, several examples of small, independent services can be found for smartphones, which offer either repair training, used devices and accessories, or repair services[144].

[139] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[140] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[141] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[142] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[143] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[144] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

Some large producers restrict the access to repair manuals, diagnostic tools, original components, and specialised repair equipment only to authorised centres. Apple is one of those companies from whom it is particularly difficult to obtain spare parts[145].

The willingness of producers to cooperate with independent repairers can be limited by factors as: safety issues, due to the lack of trust in independent repairers and related liability issues, intellectual property rights, competition in the repair market. Unwillingness of producers to provide spare parts can result in the purchase by independent repairers of second hand smartphones to cannibalise for components, or in the use of compatible but lower quality components from other sources[146].

The independent sector includes a wide spectrum of actors. This includes, at the bottom end, actors that do not follow environmental, health and safety standards and have bad working conditions for their staff. However, denying independent repairers access to original parts and tools does not prevent phone owners to approach them to undertake repair operations, especially under the increasing demand for rapid repairs. By not issuing original components readily, producers could be losing a potential source of income and undermine the quality of repairs made through independent channels[147].

Depending on the conditions of the warranty, repair operations undertaken by independent repairers could compromise the consumer's warranty. However, seen from another perspective, when performed during the terms of the warranty, they can reduce the costs faced by manufacturers and retailers to return a functional product to the consumer[148]. Warranty on repaired products would be important for the repairers to build trust and deliver a good service, especially for repairers that are not certified by manufacturers. Repair services are also challenged by the cost of work, which could be counter balanced through the implementation of lower VAT or tax breaks[149].

1.3.5.2 Reuse markets

The take-back and buy-back of used phones and their refurbishment for resale and/or revalorisation of their components seem to be the most widely implemented circular business model. Reuse of products and components avoid the costs of producing new parts[150].

---

[145] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[146] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[147] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[148] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[149] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[150] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

The majority of the value of broken devices lies in the highly engineered components, rather than raw materials, meaning that reuse and parts harvesting is a much better way of retaining value compared to recycling. Opportunities for parts use in secondary markets include redeploying screens and cameras for low cost devices, and reusing batteries to power LED lighting[151].

Second-hand devices which are still relatively new can be reused internally by manufacturers, as replacements for phones returned by customers under insurance claims or warranty. Older devices can be sold to consumers on the second-hand market[152].

The market for second-hand mobile phones has been growing since the early 2000s in developing countries. It is only more recently, with the advent of smartphones, which second hand sales have also begun to establish themselves as a significant trend in developed countries[153].

It is estimated that the world market of 2nd hand smartphones was about 120 million units generating more than USD 17 billion for their owners, at an average value of USD 140 per device. This would correspond to a 50% increase from the 80 million smartphones traded in 2015, with a value of USD 11 billion, or an average value of USD 135[154]. The global 2nd hand market of smartphones is expected to rise from 53 million to 257 million between 2013 and 2018. However, the global potential could be greater since only 12% of smartphone upgrades involved the old device being sold or traded, while projections suggest only 8% of new sales will be offset by reuse in 2018[155] (Figure 15).

[151] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[152] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[153] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[154] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[155] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

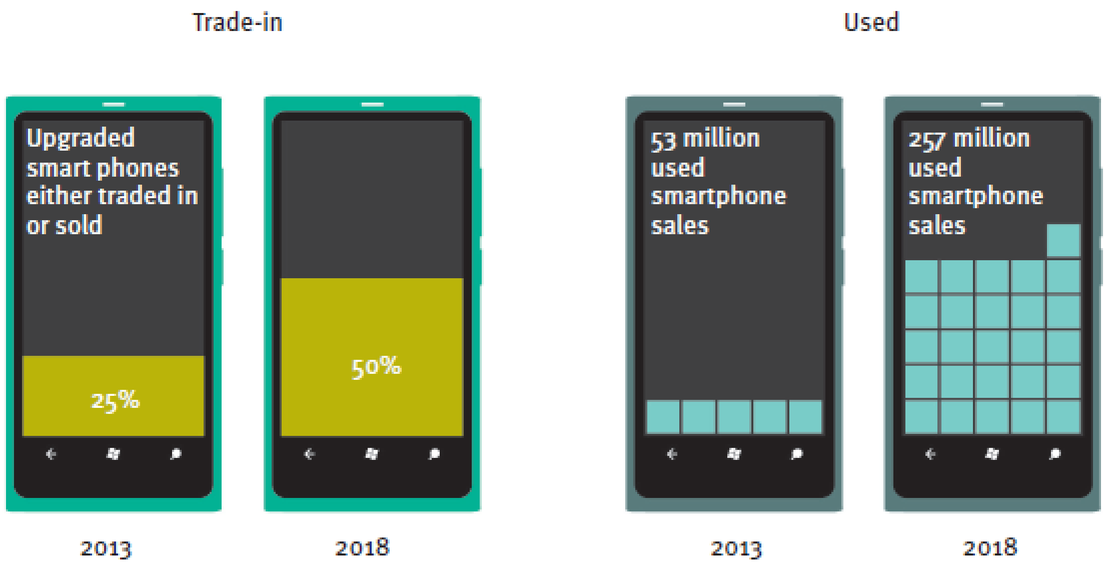

Figure 15: Market predictions for traded-in and used smartphones to 2018[156]

Surveys in Germany and the U.S. found that nearly two thirds of smart phones enjoy a second-life, either as exchange between relatives and friends, or as new sales. The growth in the second hand market is directly correlated with the higher price of new devices. When a new high-end smart phone model is introduced, previous models become available on second-hand markets. This represents a 'cascading' phenomenon also recognised in other second-hand markets, where best quality used goods are re-circulated in domestic markets, while lower quality goods go to markets with lower purchasing power[157].

Second-hand devices are competitive with mid to low tier smartphones: for instance, the Moto E has been a runaway success in 2012, in part because it was retailed for £90 ($130). But the two year older Galaxy S3 had slightly superior specifications, and sold on eBay for £70-£140[158] (Figure 16).

[156] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[157] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[158] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

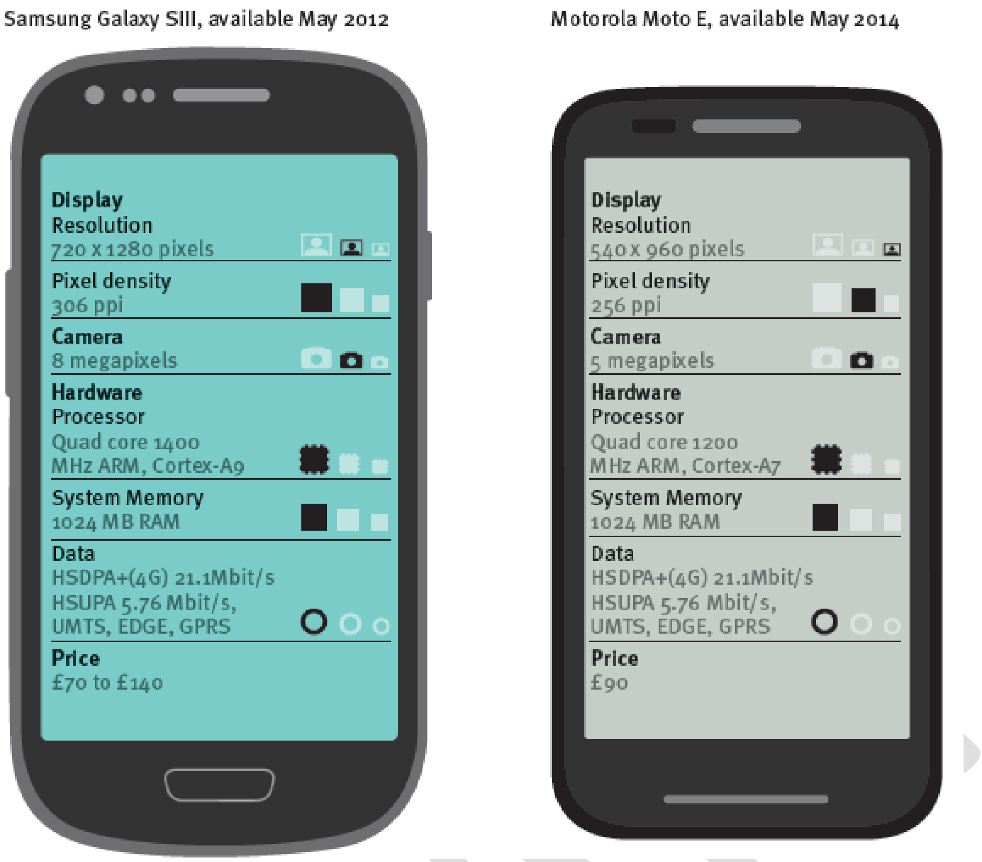

Figure 16: Specifications of two similar smartphones sold in the UK in 2012 and 2014[159]

In 2013 it was estimated that 70% of take-back phones in western economies found second-hand markets in developing countries. This share is likely to have fallen since then as second-hand markets have taken off in western economies, but nevertheless is still likely to be significant[160].

On the one hand, 2nd hand markets ensure a continuing life for products that otherwise would end as waste, thus offsetting new production and associated environmental impacts. On the other hand, older phones shipped to developing countries for resale typically end in open landfills once they are disposed, with negative consequences for human health and the environment, at least until modern e-waste recycling facilities will be deployed[161].

[159] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[160] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[161] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

An innovative concept was launched in 2010 by Dutch social enterprise Closing the Loop. Closing the Loop collects used phones from companies and organisations in the Netherlands and sells them in Africa but with the guarantee that for each phone sold there, a waste phone will be collected for transport to the Netherlands for responsible recycling[162].

While some producers are fully engaged with international refurbishment and resale companies (e.g. Apple have appointed refurbishment company Brightstar to be in charge of its take-back system in the UK) others fear that uncontrolled resale could damage the producer's profile through sale of low quality second hand versions of their phones. The problem seems to have reduced with the establishment of large, international refurbishing companies. However, some refurbishers are finding the supply of take-back phones from network service providers/retailers to be limited in volume and inconsistent in flow. They wish to work more closely with network service providers/retailers to help them develop better methods for marketing and incentivising consumers to return their phones[163].

A retailer can act both as an official WEEE collector for discarded mobile phones, and in a separate take-back-and-buy channel, where they purchase used phones from consumers (in the understanding that they are not waste since intended for reuse)[164]. Collaboration between carriers, retailers, software providers and consumers could facilitate the recovery of devices that would be otherwise scrapped or stored away[165].

Second-hand and refurbishment businesses are affected by the Consumer Sales Directive. For example, sellers of second-hand phones in Nordic Countries have the same minimum guarantee obligations as sellers of new phones. In practice, however, only a six month guarantee period is effectively applied in most cases[166]. Retailers like mobiles.co.uk already offer six month old refurbished devices on contracts that cost 15% less than normal contracts[167]. Enforcing the full guarantee period could have both negative (increase of costs) and positive (increase of consumer confidence) effects[168].

---

[162] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[163] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[164] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst, Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[165] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[166] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[167] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[168] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

Capability to reuse smartphones, either directly or after repair, refurbishment or remanufacturing, could be improved[169]:

- On the behavioural side, millions of phones sit in drawers in developed countries (e.g. US and UK, where unused devices make up to $58 billion) although there is no shortage of demand for second-hand devices. Between 27% and 36% of US consumers said they keep an old phone because they 'don't know what to do with it'; 17% were just 'too lazy' to get rid of them. Consumers could be incentivised to sell their old devices by being made aware of the value the devices still have and the availability of platforms to sell them on such as eBay and Amazon.
- On the hardware side, size, shape and connectivity of components could be standardised, and ease of disassembly of the product improved.
- On the software side, a lack of available drivers is the main challenge. Although Windows and Linux are able to dynamically load drivers, tablets and smartphones have architectures which require device specific kernels. There is no technical reason why this couldn't change, as Google's Project Ara, which uses dynamically loading drivers, shows. However, the more fundamental challenge is to extend the availability of drivers, most of which are developed by component manufacturers and are only provided under licence to original equipment manufacturers (OEMs). Moreover, diagnosis tools could be used to assess the conditions of the device.

1.3.5.3 Leasing services

Leasing services and other Sustainable Product Service Systems (SPSS) are core strategies for the circular economy. Their rationale is to replace product ownership with renting and leasing to shift 'the emphasis from selling product ownership to selling product use or its functions'. These forms have been broadly argued to fall into three main categories:

1. Product-Orientated (selling a good with additional services);
2. Use-Orientated (leasing or renting goods with attached services); and
3. Result-Orientated (providing a service rather than just material goods).

However, recent critiques suggest that this 3-fold typology fails to capture the wide variations of materials, services, and contractual relationships within potential and actual SPSS. The field of SPSS research is still in need of further development[170].

The offer of products as services provides an incentive, to the actor offering the service, to optimise their products in terms of material efficiency aspects such as their durability, reparability, upgradability, and suitability for remanufacturing. The system also enhances reuse of products by passing older products to users who have less interest, need, or capacity to buy more expensive and recent models and functionalities. Some providers offer mobile phone upgrades every 12 months. Upgrade models don't directly generate much profit for the operator, but are a new means for ensuring customer loyalty. They currently represent a little

[169] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[170] K. Hobsona,, N. Lynchb, D. Lilleyc, G. Smalleyc,(2018). Systems of practice and the Circular Economy: Transforming mobile phone product service systems. Environmental Innovation and Societal Transitions 26 (2018) 147–157

over 10% of customers while it is estimated that by 2020 they could comprise a quarter of the market[171].

1.3.5.4 Market failures and possible corrections

A list of some possible actions to correct market failures limiting the development and implementation of circular economy business models is reported in Table 14.

Table 14: Some possible actions to correct market failures (adapted from Watson et al.[172])

Obstacle	Possible Measure
Mobile phones are not designed to be durable, reparable or upgradable	Mandatory testing of durability and reliability
	Shift the burden of proof more towards the seller in case of a fault, for instance by re-interpretation of the concept of 'misuse' to no longer include common causes for faults such as dropping the smartphone or exposure to water
	Ecodesign measures on resource efficiency (e.g. design for disassembly, repair and upgrade)
	Extended legal guarantee, incentivising sale of products with longer lifespans
	Strengthen rights of retailer to pass the costs of honouring legal guarantees to the producer
Lack of consumer awareness of the length of guarantee periods	Enforcement of the requirement for sellers to inform consumers of their rights
	Mandatory labelling of warranty rights in the sales country on new phones
Lack of software support (e.g. reduced performance and data security issues)	Adjust implementation of Consumer Sales Directive such that software support is required for the full legal guarantee period
	Development and use of compatible firmware and software

[171] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[172] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

Unused smartphones are kept at home instead of being sold for reuse	Incentivise platforms for the selling of old smartphones and the purchase of 2nd hand devices
	Information campaigns about the value of used electronics
Waste regulations concerning ownership and treatment of WEEE can make it difficult for refurbishers to have access to discarded phones and prepare them for reuse	Increase cooperation along the value chain
	Allow bypassing of WEEE collection systems by certified refurbishers
Lack of repair information, tools and original components to independent repairers	Requirement on producers to make repair information, diagnosis tools, and original parts available to all parties during the expected lifetime of mobile phone
	Use of standardised parts and tools
High salaries and expensive logistics can present a problem for economic viability of repair/ take back and refurbishment	Lower VAT or other tax breaks for repair and refurbishment of electronics
Variable quality of phones delivered to take-back systems	Measures to encourage leasing models (in particular for the public sector)
Low consumer confidence in buying second-hand phones	Implement refurbishment certification standards
	Enforce guarantees for repaired and second-hand products

1.3.6 Questions for stakeholders

1) Does the basic information reported provide a satisfactory overview of the market of smartphones? Could you otherwise share any information you propose to amend/integrate for the following aspects?

- Sales and penetration of smartphones
- Key actors, main market channels, market structure and major players

2) According to your experience, which is the current ownership of new and 2nd hand smartphones in the EU? Which are the trends for the future?

3) Could you please indicate any modifications/integrations you would propose for the reported life cycle costs of smartphones? If the case, could you please explain why you would apply any modifications and provide supporting information?

Category	Average value (1) (2)		
	Low-end	**Medium**	**High-end**
Key technical characteristics of representative products			
Manufacturing cost **(EUR/product)**	46.9 (= 150/3.2)	93.7 (= 300/3.2)	156.2 (= 500/3.2)
Purchase price **(EUR/product)**	150	300 (range of variation: 200-375)	500
Variation of the value of the product over time	54% of original price after 1 year, 32% of original price after 2 years, 20% of original price after 3 years		
Installation costs **(EUR/product)**	0		
Maintenance costs **(EUR/product)**	0		
Repair costs **(EUR/product)** (3)	10 (as rough estimation)		
Refurbishment costs **(EUR/product)** (3)	20 (as rough estimation)		
Margin for resale (% of residual value)	1.7 times the residual value		
Disposal costs **(EUR/product)**	In accordance to the WEEE directive provisions, producers fulfil their responsibility of financing the costs of collection, treatment, recovery and environmentally sound disposal of domestic WEEE deposited at collection facilities. To some extent these costs are passed over to the consumer in the final purchase price. WEEE financing is a part of selling price, with relevant differences across the EU. In UK the fee is not visible, in Italy the fee is visible to trade partners, but not to consumers, in France the fee is visible also to final consumer. Costs also vary from country to country, logistic costs are a main source of variability. Manufacturers can leverage on economies of scale to ensure that collection and treatment costs are optimised.		
Note: (1) VAT included (2) Costs representative for 2018 (3) Where relevant			

4) How can price and LCC of smartphones be affected by a switch from conventional product ownership to service product systems (e.g. leasing)? Could you please describe any practical example?

5) Would you agree that the contribution of parts to the overall cost of the product can be ranked as indicated in the table below? What would be the relative price of spare part compared to the product purchase price?

Please fill in the table, and if you have any modifications to apply please explain why and provide supporting information.

Component	Contribution of the component to the overall cost of the product (%)	Relative price of the spare part compared to the product purchase price (%)
Display	20	
Apps/baseband processor	17	
Mechanicals	12	
Memory	9	
Electromechanicals	8	
RF/PA	7	
Cameras	6	
User interface	5	
Power management	4	
Box contents	3	
Conversion costs	3	
BT/WLAN	2	
Battery	1	
Glue logic & MCU	1	
Total		

6) Is the description of market drivers and trends correct and comprehensive? Do you have any further information to share, or modifications to propose?

7) Is the description of circular business models correct and comprehensive? Do you have any further information to share, or modifications to propose?

8) EU countries oblige retailers to provide a collection point for WEEE under specific conditions (e.g. size of the shop). Do you have any examples and further information to share for instance with respect the gain/cost of this activity?

9) Is the description of market failures and corrections comprehensive, or are there any amendments and integrations that you would propose? Are there any important aspects which would need to be regulated? Please explain why and how.

For example, instructions about how to prolong the lifespan of the smartphone's battery, the use of a common charger, and information about the updatability of the software used could be explicitly required in the Radio Equipment Directive (2014/53/EU).

1521

1.4 User behaviour

Smartphones have changed the world in a remarkably short time frame and they have become an essential tool and accessory for their users. Over 36% of the world's population is estimated to use a smartphone these days and penetration per capita in Central & Eastern Europe has been estimated to be almost 60% in 2017[173].

The devices are used for many different purposes, and as a result have made many other small electronic devices, such as digital cameras unnecessary[174]. Smartphones are multifunctional devices and they need mobile telecommunication (telco) networks and the internet in order to deliver all their functions. Growing popularity of smartphones also increases the overall data traffic in networks.

1.4.1 Conditions of user and behavioural aspects

Consumers use smartphones on various activities: in just a decade, smartphones have become central to people's lives from communication purposes to content consumption and other applications[175]. Information about how consumers use their smartphones is provided in the followings.

1.4.1.1 Type of phone and age of users

A majority of consumers in both developed and high-growth economies owns a mobile phone, although there are some differences in the types of mobile devices owned (Figure 17). Younger users are more likely to own a smartphone and older users are more likely to own a feature phone, although there are some exceptions (Figure 18).

[173] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (accessed on 12 February 2018)

[174] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[175] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

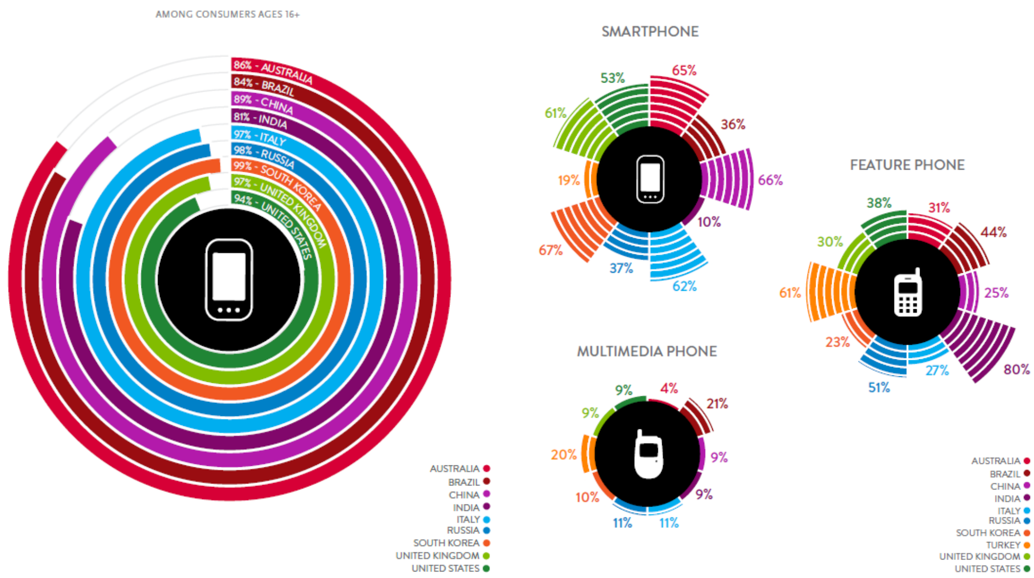

Figure 17: Use of mobile phones in different countries[176]

[176] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

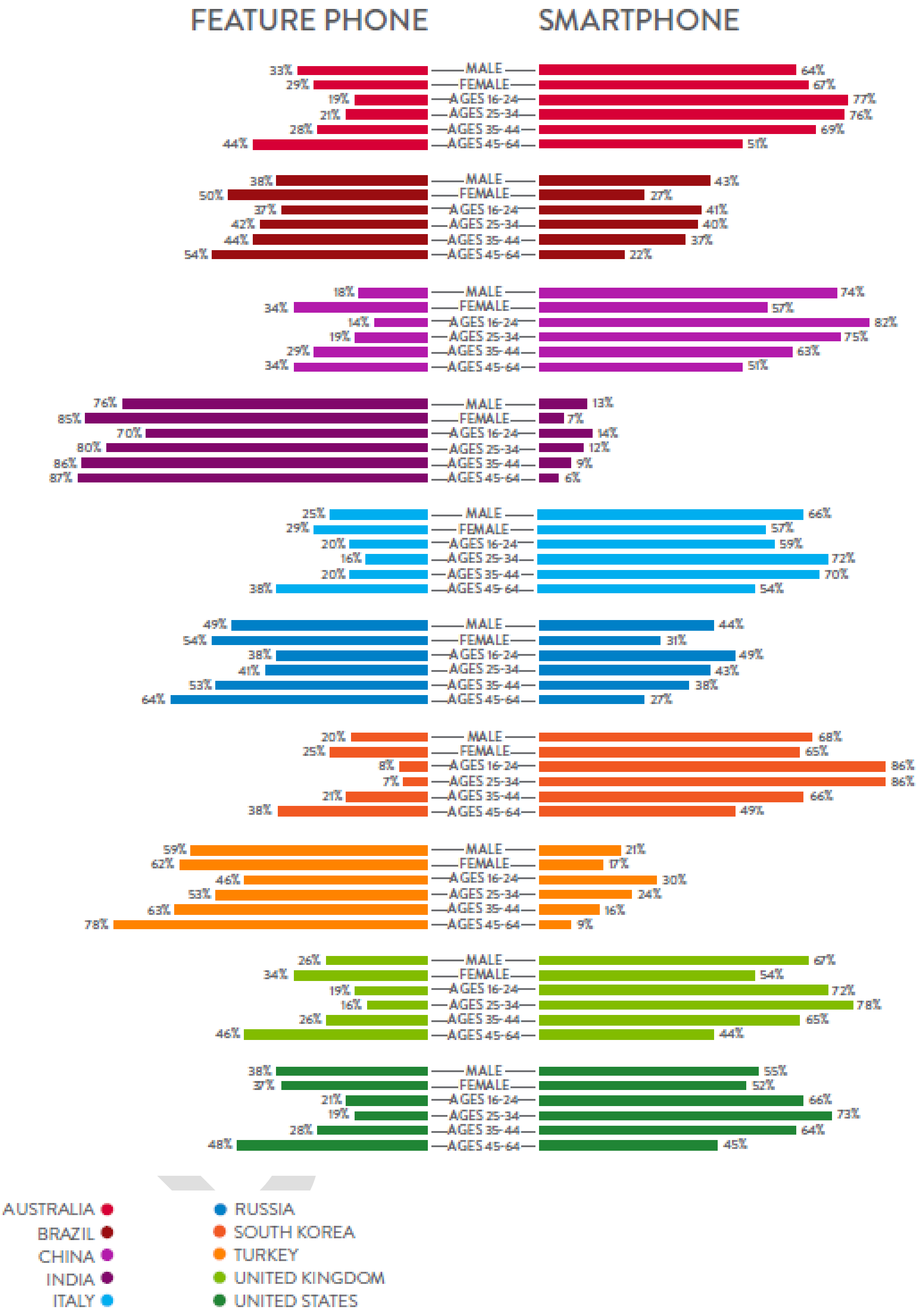

Figure 18: Users of mobile phones in different countries by age

1.4.1.2 Functionalities

Browsing the internet and gaming are amongst the most popular activities on a smartphone across different countries (Figure 19). On an average, 64% of the respondents to a global survey browse the internet on their smartphone daily, while 62%

use their smartphone for gaming. Voice calls remain as the preferred choice of communication across many markets (such as Germany and Japan) ahead of messaging compared to emerging markets in Asia and Africa, where messaging took the front seat. Watching videos and spending time on social networks are the fifth and sixth most popular activities on a smartphone[177].

It is reported that on average, a consumer in the US spends about 644 minutes per month in voice calls (164.5 voice call per month) and exchanges about 764 text messages.[178]

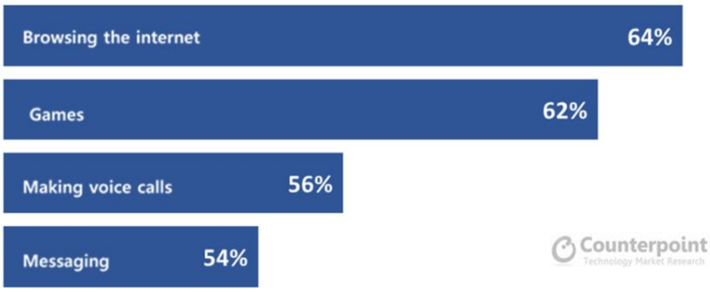

Figure 19: Global daily use behaviour[179]

The use of search engines on smartphones is one of the top activities in many European countries, as well as checking of email accounts and visiting social networks. These are the most common activities carried out weekly with a smartphone in France, Spain, and the UK[180,181, 182]. Belgian and Dutch inhabitants, however, mostly used their smartphone to check their emails in 2016, with a total of 45% and 63%, respectively having done this activity at least weekly[183]. Use of data communication services has been increasing over time[184] (Figure 20).

[177] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

[178] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

[179] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

[180] https://www.statista.com/statistics/467177/forecast-of-smartphone-users-in-france/ (last accessed on 12 February 2018)

[181] https://www.statista.com/statistics/467185/forecast-of-smartphone-users-in-spain/ (accessed on 12 February 2018)

[182] https://www.statista.com/statistics/553707/predicted-smartphone-user-penetration-rate-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[183] https://www.statista.com/topics/3341/smartphone-market-in-europe/ (accessed on 12 February 2018)

[184] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at:

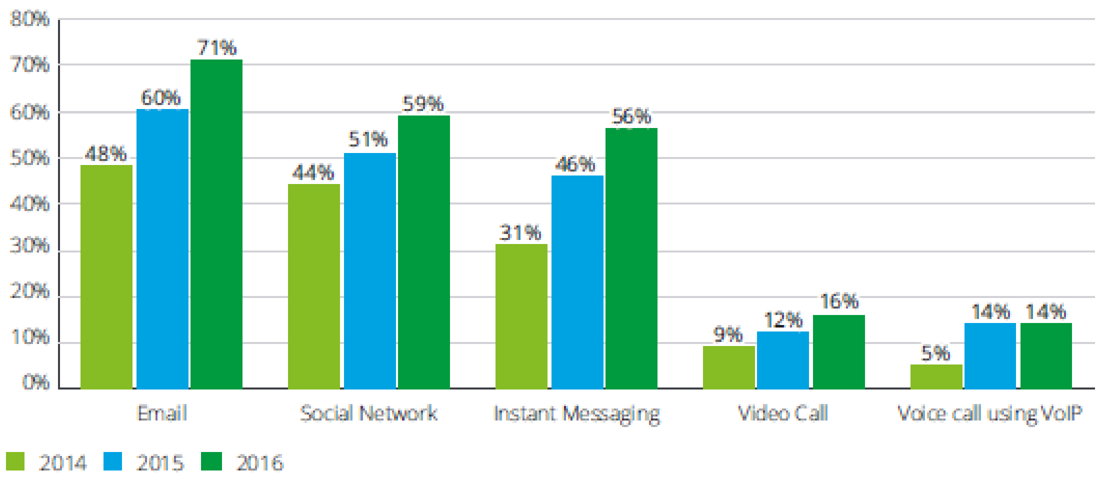

Figure 20: Smartphone users who use data communication services weekly in the UK(%)[185]

Interestingly, the use of smartphones for voice calls, which is the primary function of phones, seems to be decreasing over time. For instance, only 69% of smartphones users in the UK declared to use their device to make standard phone calls weekly in 2016, compared to 96% in 2012[186] (Figure 21).

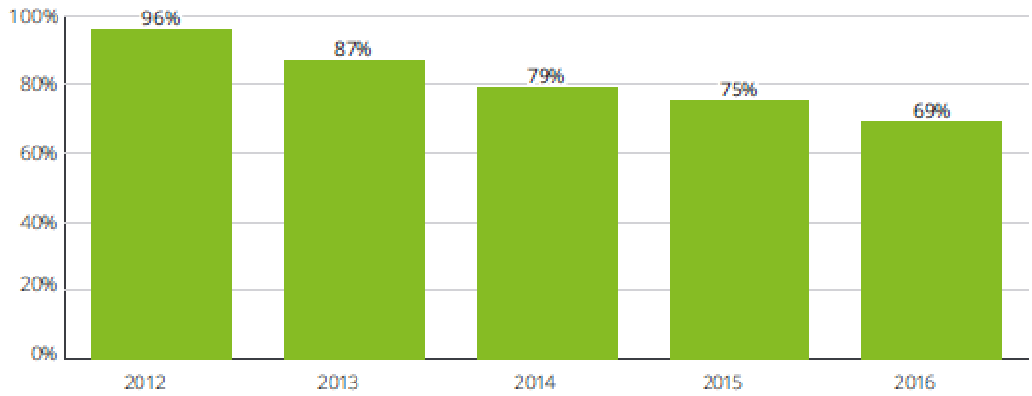

Figure 21: Use of smartphones for standard phone calls in the UK from 2012 to 2016 (%)[187]

www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[185] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[186] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[187] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at:

Applications are one of the most disruptive innovations of the last decade and have played a core role for the commercial success of smartphones (Figure 22). Smartphone users like apps for some, but not all activities. Apps tend to be most successful for processes or tasks which are completed regularly[188].

Applications installed on smartphones devices often track user's location, contributing to higher battery drain, as well as to privacy concerns, which could be limited by disabling features when not needed. However, smartphones also have a big potential to drive sustainable development through the use of sustainable apps. Applications facilitating sharing economy practices and providing information about products (e.g. environmental impacts, energy-efficiency) are becoming increasingly popular and represent the greener way of using a smartphone[189].

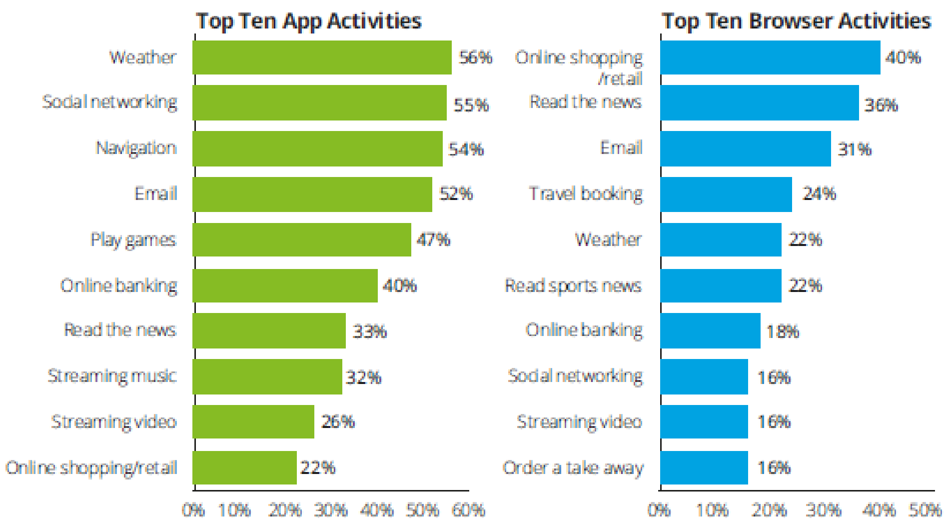

Figure 22 Top ten activities accessed in the UK when using an app or a browser (%)[190]

However, use of smartphones varies depending on the age group. For instance, 36% of 18-24 year olds and 26% for 55-64 year olds are data users[191].

---

www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[188] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[189] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[190] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[191] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at:

Another important functionality of smartphones is their ability to take pictures (Figure 23). In the UK, for instance, there has been a marked increase in the regularity of photo taking and sharing. In 2016, 27% of people took photos on a daily basis, more than double the proportion recorded in 2015 (11%). There has been a corresponding increase in daily photo posting to social media and sharing via instant messaging, from 5% to 12%. The proportion of those taking and sharing photos weekly has fallen, suggesting that some occasional weekly users have become daily users. All in all, there has been a significant increase in photo taking and sharing. Videos are also becoming increasingly more popular also because of faster connectivity speeds and the availability of sharing applications and social media platforms[192]. However, video viewing is generally not considered a replacement of TV, although it provides consumers around the world with more opportunities to view content, regardless of their location[193].

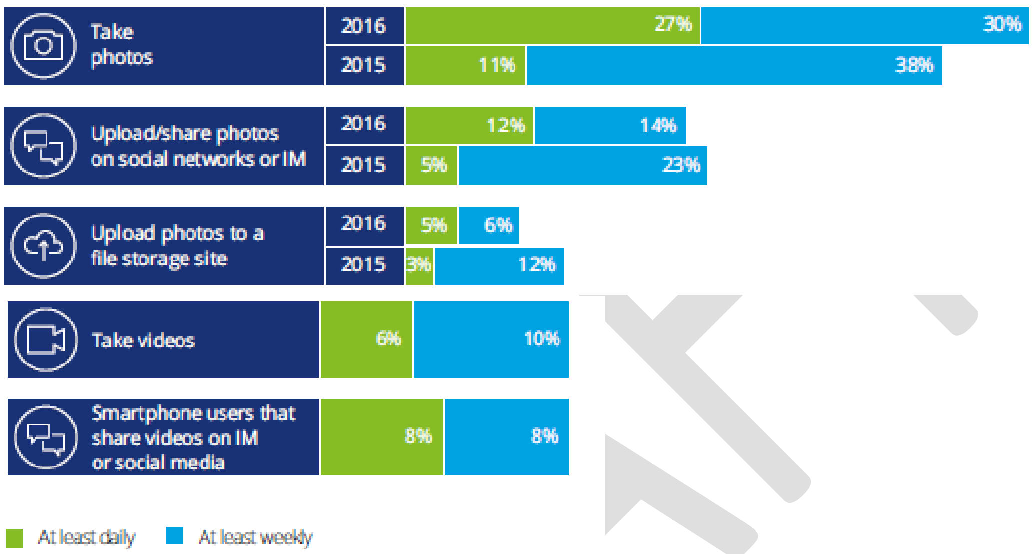

Figure 23 Photo and video taking and sharing in the UK in 2015 and 2016 (%)[194]

With respect to other features, only 12% of users were reported to use the voice assistant in the UK in 2016, and another 21% were using the fingerprint identity verification method to log into their devices[195].

---

www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[192] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[193] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

[194] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

Smartphones compete with other devices such as laptops and tablets for a range of applications (Figure 24). According to a survey conducted in the UK[196], smartphones would be the preferred device for checking social networks, calling using internet, playing games, taking photos and recording videos.

	Preferred device	Second choice
Browse shopping websites	Laptop	Tablet
Make online purchases	Laptop	Tablet
Check bank balances	Laptop	Smartphone
Check social networks	Smartphone	Laptop
Video calls	Laptop	Smartphone
Voice calls using the Internet	Smartphone	Laptop
Watch short videos	Laptop	Tablet
Stream films and/or TV series	Laptop	Tablet
Watch TV programmes via catch-up services	Laptop	Tablet
Watch live TV	Laptop	Tablet
Online search	Laptop	Tablet
Read the news	Laptop	Smartphone
Play games	Smartphone	Tablet
Take photos	Smartphone	Tablet
Record videos	Smartphone	Tablet

Figure 24: Preferred device in the UK for a range of applications (%)[197]

1.4.1.3 Time and place of use

People spend more time on their smartphones than any other device: smartphones are taking a central stage of consumer life (Figure 25). Almost half of respondents to a global survey spent more than 5 hours per day on their smartphone. Additionally, one in four users now spend

[195] https://www.statista.com/statistics/553464/predicted-number-of-smartphone-users-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[196] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[197] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

more than 7 hours every day on their smartphone, these are true power users mostly running businesses on their phones or consuming digital content for long hours[198].

Figure 25: Time Spent on Smartphones Daily199

Smartphones are personal, but their use has an impact also on surrounding persons. Smartphones can enhance social lives, but overuse can be perceived as anti-social, and cause arguments. During the day, 18-24 year olds are among the most frequent users of smartphones. A third uses their devices 'always' or 'very often' when meeting friends, shopping or watching television. Over a tenth uses their phones 'always' or 'very often' when eating at home, or eating out. As with most emerging technologies, consumers will need to find a balance between usefulness and overuse of smartphones[200].

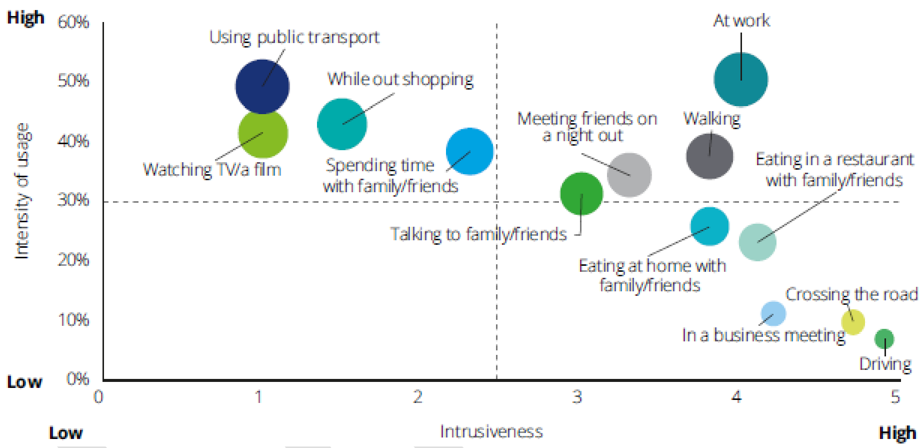

Figure 26: Usage of smartphones while doing other activities[201]

---

[198] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

[199] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

[200] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[201] Deloitte, 2016. There’s no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at:

In the UK, a tenth of smartphone owners instinctively reach for their phones as soon as they wake up – and not just to turn off their alarm. A third reaches for their phones within five minutes of waking, and half within a quarter of an hour. A similar pattern takes place at night. Two thirds of smartphone owners do not check their phones at night, however, over three quarters of smartphone owners check their phones within one hour before going to sleep; half within 30 minutes; a quarter within five minutes; and a tenth immediately before[202].

Exposure to light, including that from a screen just before going to sleep, can confuse the brain into thinking it is still day-time, and inhibit the process of falling asleep. One study of 10,000 16-19 year olds found that their quality of sleep was related to the quantity of time spent in front of a screen before going to bed. The study's authors recommended that screens be turned off at least an hour before turning out the lights. Alternatively, night-time modes make device screens show warmer, yellower tones instead of standard blue lights, which can help preparing the body for sleep[203].

1.4.1.1 Purchasing behaviour

The main factor consumers in the UK are taking into consideration when making a decision about purchasing a new smartphone is the price, while the main reason for purchasing a new smartphone is that the consumer's current device is out of date[204].

Currently, environmental concerns are not a driver for consumers to choose greener solutions according to businesses. Retailers do not report any increased interest in 'greener' phones i.e. made from materials with lower environmental impacts or phones that are modular to allow easy repair or component upgrading. A lack of consumer pull in this direction is pointed out also by some manufacturers. They experience that environmental concerns are less important to consumers than experience of the phone and value for money[205].

Getting good value for the money spent on a device matters more to consumers responsible for purchase decisions in the U.S., U.K., Italy and China. Russian consumers instead take care more about 'stylish design' when deciding which mobile device to purchase, while Chinese consumers are more concerned with having a wide choice of applications to use on their device.[206]

www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[202] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[203] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[204] https://www.statista.com/statistics/553464/predicted-number-of-smartphone-users-in-the-united-kingdom-uk/ (accessed on 12 February 2018)

[205] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[206] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

According to a global survey conducted in 2016[207], more than half of the Australian, Chinese, German and Saudi smartphone users revealed that they would be willing to spend more than US$400 to replace their current device. These would be the target markets for brands looking to promote their premium portfolio. More than one third of German and Australian users would be willing to spend more than US$500 in their next smartphone purchase. Only 13% of Japanese users were willing to spend >$400 for the purchase of their next device – even though Apple is also the dominant smartphone brand in Japan. This also explains the slowing upgrade cycles as Japanese consumers are generally more conservative than their peers in other markets.

Global trade and the rise of online retail makes it easier to buy cheaper smartphones from abroad which do not necessarily need to comply with European standards and regulations, e.g. regarding hazardous substances, potentially causing health risks to the consumers[208].

[207] Counterpoint Research survey (2016) available at https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 20 February 2018)

[208] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

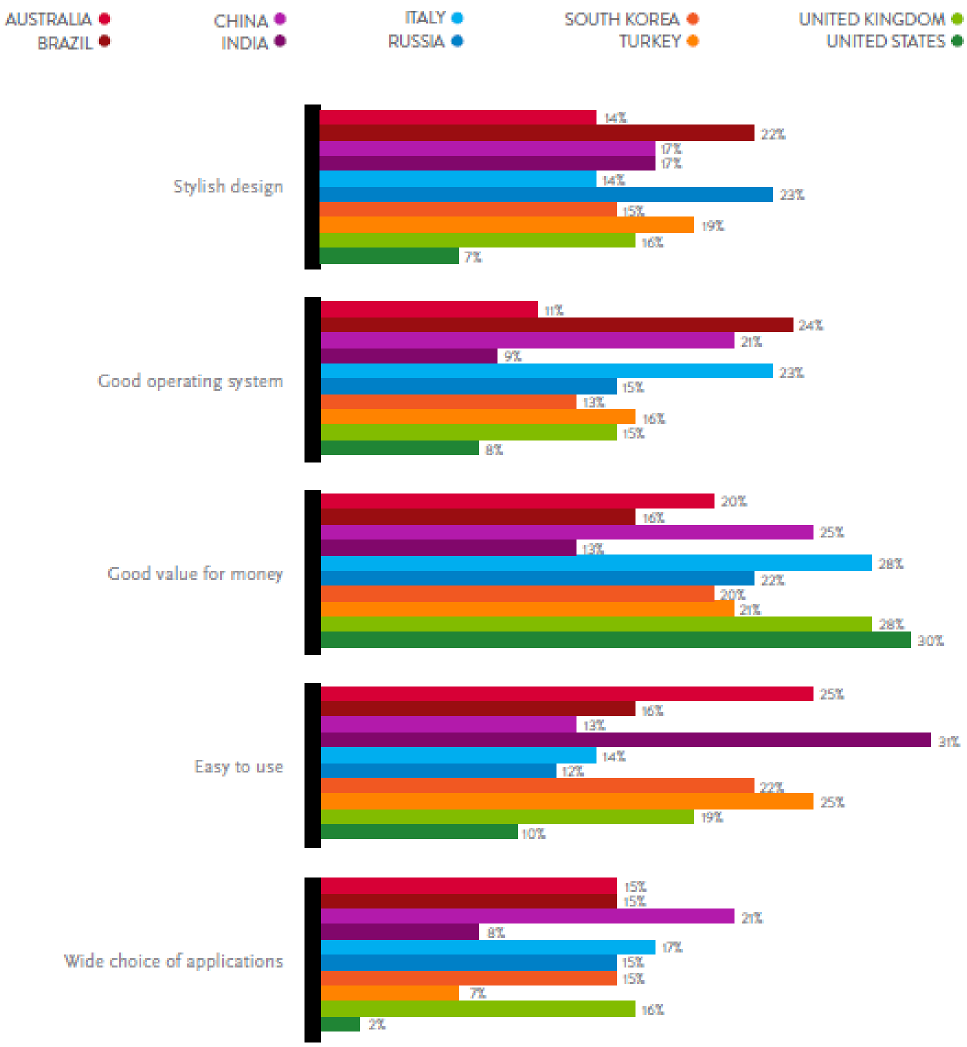

Figure 27: Top selection criteria for buying mobile devices[209]

1.4.2 Product's lifetime

The median lifespan of mobile phones was reported to decrease from 4.8 to 4.6 years (-3%) between 2000 and 2005.[210] However, according to the Ellen MacArthur Foundation, the average use time of mobile phones in mature markets in 2010 (Western Europe, North America, Japan) was less than 30 months.[211] In 2014, the average upgrade cycle for most

[209] Nielsen, 2013, THE MOBILE CONSUMER: A GLOBAL SNAPSHOT - FEBRUARY 2013, available at: http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2013%20Reports/Mobile-Consumer-Report-2013.pdf (accessed on 13 February 2013)

[210] Conny Bakker, Feng Wang, Jaco Huisman and Marcel den Hollander. Products that go round: exploring product life extension through design. Journal of Cleaner Production 69, 10-16, doi:https://doi.org/10.1016/j.jclepro.2014.01.028 (2014)

[211] https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram/in-depth-mobile-phones (accessed on 22 February 2018)

smartphone buyers was 23 months[212]. This is in line with the results of a global consumer survey conducted in 2016[213], according to which the average global smartphone replacement cycle has decreased to 21 months (Figure 28). Emerging market consumers are being more assertive in replacing their device than consumers in developed markets. This trend is the complete opposite compared to what happened with feature phones. The growth of Chinese brands offering higher specification devices at affordable prices seems to have triggered a faster upgrade cycle, as well as the rise of second hand and refurbished smartphones[214].

Figure 28: Average Smartphone Replacement Cycle in 2016[215]

According to another survey[216], the speed of smartphone innovation has slowed in the past few years and consumers of developed countries are now holding to their phones for a longer time. In the 5 most populated countries of the EU, the average life cycle of smartphones increased from 18.3 months in 2013 to 21.6 months in 2016.

[212] https://www.wsj.com/articles/your-love-of-your-old-smartphone-is-a-problem-for-apple-and-samsung-1519822801 (accessed on 1 March 2018)

[213] https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 13 February 2018)

[214] https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 13 February 2018)

[215] https://www.counterpointresearch.com/almost-half-of-smartphone-users-spend-more-than-5-hours-a-day-on-their-mobile-device/ (accessed on 13 February 2018)

[216] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

	USA	China	EU5	France	Germany	Great Britain	Italy	Spain
2016	22.7	20.2	21.6	22.2	20.3	23.4	21.6	20.5
2015	21.6	19.5	20.4	21.6	18.8	23.5	17.7	20.0
2014	20.9	21.8	19.5	19.4	18.2	22.0	18.7	18.2
2013	20.5	18.6	18.3	18.0	17.1	20.0	18.6	16.6

Figure: Smartphone life cycles by country (number of months)[217]

An average lifetime of 2 years for new mobile phones, and 2.5 years considering 2nd hand use, is reported in a review study covering Germany. This could be due to the fact that mobile phone contracts in Germany usually run over 2 years and the use period correlates strongly with the contract period. With the conclusion of a follow-up contract, a new model is often purchased and the old device taken out of service.[218] Such outcomes are aligned with those of Stiftung Warentest, according to which 42% of users in Germany exchange their mobile phone within 2 years. Around 16% of users change phones every 3 years, with another 12% every 4 years. Only about 20% of respondents exchange their mobile phone less frequently than every 5 years[219].

However, according to another source from the U.S.[220], the average upgrade cycle for most smartphone buyers could rise to 31 months in 2018 and 33 months in 2019.

[217] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[218] Siddharth Prakash, Günther Dehoust, Martin Gsell, Tobias Schleicher, Prof. Dr. Rainer Stamminger, 2015, Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz", ZWISCHENBERICHT: Analyse der Entwicklung der Lebens-, Nutzungs- und Verweildauer von ausgewählten Produktgruppen. TEXTE 10/2015, Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit Forschungskennzahl 371332315. Available at http://www.umweltbundesamt.de/publikationen/einfluss-der-nutzungs-dauer-von-produkten-auf-ihre (accessed on 22 February 2018)

[219] Siddharth Prakash, Günther Dehoust, Martin Gsell, Tobias Schleicher, Prof. Dr. Rainer Stamminger, 2015, Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz", ZWISCHENBERICHT: Analyse der Entwicklung der Lebens-, Nutzungs- und Verweildauer von ausgewählten Produktgruppen. TEXTE 10/2015, Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit Forschungskennzahl 371332315. Available at http://www.umweltbundesamt.de/publikationen/einfluss-der-nutzungs-dauer-von-produkten-auf-ihre (accessed on 22 February 2018)

[220] https://www.wsj.com/articles/your-love-of-your-old-smartphone-is-a-problem-for-apple-and-samsung-1519822801 (accessed on 1 March 2018)

1.4.3 Causes of replacement

According to a recent study[221], discarded or replaced phones are often not replaced because of malfunctions or because they are worn out or damaged. Often it would be rather because of functional obsolescence driven by launching of new models and features, and by social expectations.

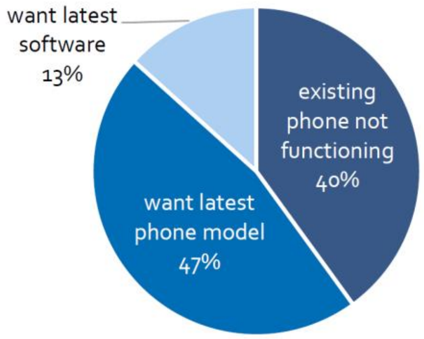

Figure: Reasons for smartphone replacement[222]

However, according to some information shared confidentially (the study is not public yet), loss of performance, failures and breakages of smartphones would be important reasons for replacing the product in Europe.

1.4.4 Questions for stakeholders

1) Could you please share any behavioural information that you propose to amend/integrate in the analysis, in particular with respect to the definition of typical modalities and conditions of use of the product?
2) Could you please point out any other relevant studies providing statistical information on smartphones' lifetime and reasons for replacement?

[221] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[222] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

1.5 Product and system aspects

1.5.1 Design and innovation

During the design of a product, important decisions are taken that can have consequences over the entire life cycle of the product. These can for instance address: functions and levels of performance to deliver, aesthetics considerations, type of components and materials to use, durability and disassemblability of parts, recyclability and inherent safety of materials. The design phase plays a key role in determining the impacts of a product.

Smartphones are changing with every subsequent generation, not only in terms of their computational power but also in the size and the materials they are made of. The Moore's law (doubling of computational power every two years) and breakthroughs in material science together with consumer preferences drive innovation at an enormous speed. This also defines the raw materials needed to produce the devices[223]. Smartphones are becoming more powerful over time. Consequently energy consumption of their components, such as chipsets and screens increases[224].

When smartphones were introduced on the market, products were innovating rapidly: the average time new models spent on the market was 6-9 months in 2010, whilst the average shelf time was about three years prior to 2007[225]. However, innovation has slowed down in the last few years, and longer upgrade cycles have been adopted[226].

1.5.2 Manufacture

Smartphones are complex products for which increasing computing power, display and device size, and use of high-grade materials are demanded. Electronics are required in a smartphone (e.g. integrated circuits (IC), printed wiring boards (PWB), batteries, or displays) which production is a very energy intensive and pollutant process[227]. Environmental concerns are also due to the high consumption of water, including ultrapure water, for the cleaning and rinsing phases required in the production of smartphones, as well as the use of hazardous materials[228].

Furthermore, the majority of smartphones are produced in Asia, mainly in China (e.g. Apple, Nokia, Xiaomi, Huawei), South Korea (Samsung), Japan (Sony), India (LG), or Taiwan (HTC). Many smartphones are produced by the same manufacturer (e.g. Foxconn, LeEco). The production deployment in some of these countries raises social concerns about the working conditions associated for instance to: exposure to harmful chemicals, child labour exploitation, work overload, low wages.[229]

This calls for the importance for manufacturers to select, monitor and work closely with suppliers to improve working conditions during the manufacture of components and the assembly of phones. For instance, Fairphone has set improving working conditions of its

---

[223] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[224] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[225] http://money.cnn.com/2011/01/31/technology/new_smartphone/index.htm (accessed on 1 March 2018)

[226] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[227] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[228] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[229] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

manufacturer suppliers as one of its core commitments. It works closely with its top-tier suppliers (case makers and final assembly partner) to assess and improve the working conditions in its supply chain. It has also set up specific programmes with ten of their suppliers that focus on improving environmental and social impacts of Fairphone manufacturing.[230]

The majority of the smartphone manufacturers have a supplier management and audit programme in place, however their efforts in this area vary. Many of the big manufacturers are part of The Responsible Business Coalition (formerly Electronic Industry Citizenship Coalition), which requires its members to adhere to its Code of Conduct that sets standards on social, ethical and environmental issues. Apple and Fairphone are also part of the Clean Electronics Production Network (CEPN) which has a goal to move toward zero exposure of workers to toxic chemicals in the electronics manufacturing process.[231]

Apple is moreover the only smartphone company which has made a 100% renewable energy commitment for both its own operations and its supply chain.[232]

1.5.3 Technological aspects

1.5.3.1 Functions

The functions of a smartphone and their relative importance can be analysed following the principles of the standard EN 12973[233].

In Section 1.1.2, a smartphone is described as follows:

- A smartphone is an electronic device primarily designed for mobile communication (making phone calls, text messaging) and use of internet services.
- It can be used for long-range communication over a cellular network of specialized base stations known as cell sites, including LTE (often also called 4G), HSDPA (3G+), UMTS (3G) or GSM standard (2G).
- It is functionally similar to wireless, portable computers (e.g. tablet PCs), since

  - designed for battery mode usage, and connection to mains via an external power supply is mainly for battery charging purposes,

  - presenting an operating system (Google's Android, BlackBerry OS, Apple's iOS, Nokia's Symbian, Microsoft's Windows Phone), WiFi connectivity, web browsing capability, and ability to accept sophisticated applications,

- It has a display size between 3 and 6 inches and a high-resolution touch screen interface, in place of a physical keyboard.

Functions of a smartphone could be classified as:

- Communication functions (phone calls making, text messaging, access to web services, keyboard, touch-screen interface);

[230] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[231] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[232] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[233] CSN EN 12793:2000 Value Management, which is based on 5 steps: 1) Identifying and listing the functions; 2) Organising the functions; 3) Characterising the functions; 4) Setting the functions in a hierarchical order; 5) Evaluating the functions

- Portable operability (rechargeable battery input, duration of battery, computational features);
- Multimedia functions (camera features, audio/video recording, audio/video reproduction, screen size and resolution).

According to the information collected in the former sections 1.3 and 1.4, the following functions seem particularly important for consumers:

- Size of the screen, camera, quality aspects as reliability and screen resolution[234]
- Longevity of battery, internet access, and high specification camera[235].

A classification of smartphone's functions is reported in Table 15: Smartphone's functions and related needs.

Table 15: Smartphone's functions and related needs

Functions	Specific needs
Communication and connectivity	Cellular Band communication Wi-Fi Networks Connections Internet Access Microphone and video Keyboard and/or touch-screen Near Field Communication (NFC) USB/cable connection Infrared/blue-tooth connection GPS connection Tethering Fingerprint sensors
Multimedia	Functional display (size and resolution) Functional camera Audio and video recording Audio and video reproduction
Portable operability	Rechargeable battery, power supply and connector working Duration of the battery Upgradable memory Updatable operating system Updatable software
Durability	Resistance to stresses Longevity of battery Reparability Upgradability

[234] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[235] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

1.5.3.2 Parts

Smartphones is composed of between 500 to 1,000 different components, many of which are extremely small[236].

Figure 29: Parts of a generic smartphone[237]

The main parts of a smartphones are listed below:

- Frame and back Cover
- Display[238]

  - Liquid Cristal Displays (LCDs): in-plane switching (IPS) technology and its variations. On an LCD-based display, there is a backlight that is shining through some polarizers, and it is shining through some filters. And by manipulating the crystal display, different colours can be seen on the other side. This means that the light is not being generated by the display itself; it is being generated by the light behind the display, and only some of it is coming from the other side. When the display is black, its crystal is being manipulated so that none of the light gets through. However, the light behind the display is still being generated meaning that the smartphone will be using a bit of battery.

  - Light-Emitting Diodes (LEDs): active-matrix organic light-emitting diode (AMOLED) or Super AMOLED and its variations. On an LED-based display, pixels are being emitted by light-emitting-diodes (also known as LEDs) which produce red,

[236] https://ifixit.org/blog/6448/smartphone-repairs/ (accessed on 1 March 2018)

[237] https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

[238] https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

green, and blue colours. The display itself is generating the different and colours so that when a pixel is off and a black colour is shown, it is not using up any battery. These displays are more efficient in delivering extended periods of battery life. However, one drawback is that AMOLED panels are more expensive than IPS ones.

- In terms of screen size, most displays sold in 2016 were larger than 5"[239] (Figure 14).

- Battery[240,241,242,243]: Batteries of phones normally use lithium-ion (Li-ion) technology and are either removable or non-removable in mobile devices. This is currently the best available technology as more secure and with higher energy density than previous types (e.g. lead-acid, nickel-metal). Li-ion batteries allow compacted and light cells, have relatively low price, and still present potential for improvement. One of the recent evolutions is the lithium polymer (LiPo) battery, which are lighter and more flexible, although they are more expensive and have higher risk of ignition. The performance of the battery over time is more and more important, since new models of smartphones have bigger screens, faster processors and demanding apps that require long lasting batteries. For example, the Zenphone 4 Max from Asus includes a 5000 mAh battery that can be used as a 'power bank' and allows charging of a connected smartphone.

- 'System-on-a-chip' or SoC (also known as an IC chip)[244]: the SoC is one the most important component and comprises the smartphone's CPU (Central Processing Unit), GPU (Graphics Processing Units), LTE (Long Term Evolution) modem, display processor, video processor, and other electronics that turn it into a functional 'system'. Most of smartphones use the same system architecture from ARM. Some companies also use architectural licenses so that they are able to make their proprietary processors for use in smartphones as long as they are compatible with ARM's system architecture.

- Memory and storage[245]: no smartphone can function without the use of RAM and memory (system storage).

  - RAM: most mobile devices are shipped with LPDDR3 or LPDDR4, while some high-end smartphones are shipped with LPDDR4X RAM. 'LP' stands for 'Low-

[239] Kantar World Panel, ComTech, 2017, AN INCREDIBLE DECADE FOR THE SMARTPHONE: WHAT'S NEXT? The Future of Mobile is in Combining Devices, Content, and Services - Rev 2017-24-Feb-0925, available at: https://www.kantarworldpanel.com/dwl.php?sn=news_downloads&id=1361 (accessed on 13 February 2018)

[240] https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

[241] https://www.tomsguide.com/us/smartphones-best-battery-life,review-2857.html (accessed on 22 March 2018)

[242] https://www.xataka.com/tecnologiazen/avances-en-baterias-moviles-cuando-llegara-el-sustituto-del-ion-litio (accessed on 22 March 2018)

[243] https://www.xatakamovil.com/varios/la-enciclopedia-de-las-baterias-para-moviles (accessed on 22 March 2018)

[244] https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

[245] https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

Power' and reduces the total voltage of these chips, making them highly efficient and giving mobile phones an extended battery life. LPDDR4 is more efficient and powerful than LPDDR3, while the LPDDR4X is the fastest, most efficient, but expensive. Newer generations of RAM are going to be introduced, such as LPDDR5.

- Internal storage: it ranges from 32GB to 256GB.

- Operating System (OS), or firmware: smartphone are run through operating systems, often referred to as mobile OS or smartphone OS. An operating system allows the device to run applications and programs, therefore, bringing advanced functions that were previously restricted to computers only[246]. The update of the OS is as important as the physical elements of a smartphone to ensure a longer life of the device and to reduce phone replacement rates. A lack of updates might indeed make smartphones obsolete while its hardware is still fully functioning[247].
- Modems[248]: these are communication components used in smartphones to receive and send information. Every SoC manufacturer has its own brand of modems. The fastest one is the Cat. 9 LTE modem. However, this can be used at its full potentiality only if the level of speed is supported in the cellular network.
- Audio Components (microphone, earpiece speakers, headset connector)
- Camera[249]: all smartphones come with a rear-facing and front-shooting camera. This comprises up of three main parts: the sensor (which detects light), the lens (the component in which light comes through), and the image processor. While the megapixels on the smartphone are still an important part of the camera, they carry less importance than in the past. Instead, the primary limiting factor is the camera sensor of the phone and how sensitive it is when light passes through the lens. Each sensor behaves differently from smartphone to smartphone. Since smartphones have small sensor sizes, they tend to perform badly in low-light areas. This is an area where camera sensor manufacturers have worked to improve.
- Sensors[250] (light/proximity sensors): there are five main sensors in a smartphone that allow its functionalities:

- Accelerometer, which is used by apps to detect the orientation of the device and its movements, as well as allows features like shaking the phone to change music.

- Gyroscope, which works with the Accelerometer to detect the rotation of the device, for features like tilting the phone to play racing games or to watch a movie.

---

246 https://www.statista.com/statistics/266136/global-market-share-held-by-smartphone-operating-systems/

247 David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

248 https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

249 https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

250 https://fossbytes.com/whats-inside-smartphone-depth-look-parts-powering-everyday-gadget/ (accessed on 2 March 2018)

- Digital Compass, which helps the device to find the North direction, for map/navigation purposes.

- Ambient Light Sensor, which is automatically able to set the screen brightness based on the surrounding light, thus helping to reduce the eyes strain and to conserve the battery life.

- Proximity Sensor, which detects the proximity of the device with the body, so that the screen is automatically locked when brought near the ears to prevent unwanted touch commands.

- Vibration Mechanism
- USB port

A smartphone includes also a set of accessories included in the sale package:

1. Headset;
2. USB Cable;
3. Charger;
4. Documentation/instruction.

Others accessories generally not sold by the smartphone manufactures but necessary for a smartphone to function and last are:

- Micro SD cards
- Micro SIM
- Protection accessories (e.g. cases and screen protections)

With respect to the carbon embodied in them, it is reported that most relevant parts of a smartphone are[251]:

- Chips (ICs) (around 35% of the overall product)
- The power supply (30%, in contrast of batteries (2%) casings (5%))
- Screens (11%, manufacturers should consider making the LCD and glass separately replaceable, as the glass has lower embodied carbon than an LCD or AMOLED display).

1.5.4 Limiting states and failures

The most common causes of breakage in 2013 have been reported to be the drop on a hard surface (43%) and the contact with water (35%). Such damages are normally considered to be under the responsibility of consumers and are not covered by legal guarantees. However mobile phones can be designed to withstand expected usage profiles and provide reasonable information on how to use them[252].

Limiting states of smartphones could be delayed through technical measures such as:

[251] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[252] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

- Design of more durable smartphones and possibility to update smartphones (see Section 2.4.5)
- Consumer's purchase of accessories protecting the device, as screen protectors and cases[253]
- Facilitation of repair operations (see Section 2.4.6)

1.5.5 Designs for durability

According to a smartphone insurance provider, a cell phone breaks in the US every two seconds. Research shows that about 26% of users have broken their screen at some point or another, and 15% are currently living with a cracked screen[254]. In the followings, a non – exhaustive list of characteristics that could make smartphones more durable is provided:

- Chassis: The phone must be well built in order to strike that fine balance between aesthetics and durability. For example, space grade and aircraft aluminium are known for being lightweight and strong[255].
- Glass Panel: Strengthened glass panels are getting more and more durable. Corning's Gorilla Glass 4, for example, offers twice the protection of its predecessor (Gorilla Glass 3). Both Gorilla Glass and Apple's ion-strengthened glass have been chemically altered via ion exchange to improve their strength. The process would involve the exchange of sodium ions in the glass material with larger potassium ions under high temperature. The end result is a material that is more impact resistant and scratch-proof than regular glass[256]. Recently, a new type of glass that can heal itself from cracks and breaks has been developed. This is made from a low weight polymer called 'polyether-thioureas' and can heal breaks when pressed together by hand without the need for high heat to melt the material[257].
- Fingerprint Sensor: The use of high-end materials on smaller components like the fingerprint sensor can improve the overall reliability of the device. A scratched or cracked sensor can for instance hinder the phone's ability to read fingerprints[258].
- Camera Lens: A scratched camera lens can affect a phone's photo quality, and a cracked lens can do the same, in addition to compromising the device's resistance to water and other contaminants. A sapphire crystal lens is harder than glass, which makes this component more durable[259].

[253] https://www.nytimes.com/2017/05/24/technology/personaltech/reality-check-what-does-and-doesnt-protect-your-smartphone.html (accessed on 9 March 2018)

[254] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[255] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[256] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[257] https://www.theguardian.com/technology/2017/dec/18/smashed-cracked-phone-screen-self-healing-glass-university-of-tokyo (accessed on 23 March 2018)

[258] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[259] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

- Water Resistance: The ingress protection, or IP rating, was a standard drawn up by the International Electrotechnical Commission to help measure the resistance of handsets to the elements. The first digit measures resistance to dirt and dust, while the second measures resistance to liquids. In a phone with an IP68 rating, for example, 6 means that it provides complete protection from dust and dirt following an eight-hour test, while 8 denotes its water resistance completely submerged at a depth of one and a half meters for up to 30 minutes (see Section 1.2.4)[260].
- Screen: The easier it is to replace a screen, the less risk there will be in breaking other components while performing the repair[261].
- Charging Port: The charging port is another major component that is likely to break due to wear and tear from the constant cycles of plugging and unplugging. Most smartphones are engineered to have modular charging ports that are easy to replace[262].
- Drop Tests: drop tests are done to determine how resistant a handset is to physical damage (see Section 1.2.4)[263].
- Water Immersion Test: water immersion tests involve leaving a handset underwater in varying depths for a set amount of time, to determine how well it is protected against liquid damage (see Section 1.2.4)[264].
- Ergonomics: Ease of use is an important feature since a phone that is easy to manipulate has fewer chances of accidental slips and falls. Key factors in determining the ergonomics of a smartphone are how easy it is to grip, and the ease with which corners of the screen and external keys can be reached with one hand[265].
- Slip Resistance: slip resistance can also be an important characteristic, to avoid that device slips off from different surfaces[266].

Resistance to common causes of failure as fall on a hard surface and immersion in water could be achieved via product testing and/or the inclusion of most common causes of damage in the legal guarantees.

In addition, the functional withstand of products could be extended by ensuring that devices can be updated. There are indeed concerns about the premature obsolescence of devices due to slowing the phone down or making new software updates unavailable for older phones,

[260] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[261] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[262] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[263] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[264] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[265] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

[266] https://smartphones.gadgethacks.com/how-to/4-most-durable-premium-smartphones-for-clumsy-people-0175454/#jump-comparisonchart (accessed on 23 March 2018)

which encourages consumers to buy a new phone.[267] The unavailability of compatible software updates (mobile operating system) is a relatively important factor for the replacement of smartphones. Some apps do not work without an updated operating system. Moreover an upgrade of the software can increase the safety and improve the functionality of the smartphone[268]. This can make smartphones obsolete even if its components are still fully functioning[269].

1.5.6 Repair and upgrade operations

Smartphone repair can be in any of three areas[270]:

- Functional symmetry of the smartphone: a smartphone connects a Logic Board and a Motherboard, both of which are then looped into the circuit board to form a unit. Faults in this symmetry may include corrupted Operating Software (OS), broken or malfunctioning touch screen, ineffective charging system, erratic keyboard, phone crush, dead USB connector, phone lock, camera etc.
- The assembly of different hardware components and their connectivity: this often mandates disassembling, and reassembly of a part or all of the entire smartphone hardware, which is unique to each brand. Faulty parts may be buttons, battery, SD card, SIM card, earpiece, loudspeaker, Internal LCD Display, speaker etc.
- Network Configuration, reception and transmission: Most common network problems include a problem with the network signal, or multifunction in Bluetooth, Wi-Fi, and LAN.

Upon troubleshooting and diagnosing a problem, the next step is initiating a repair. The most common repairs that modern smartphones require include:

1. Smashed and/or cracked Screen: Between 50 and 55% of all smartphone repairs, are caused when the screen is damaged. A broken touch screen (external) or PDA has to be replaced with a new one. Similarly, any damage to the LCD screen or Internal LCD Display calls for a replacement, although a minor damage may be repaired.

2. Water-caused damage: Between 15 and 20% of all smartphone repairs, occur are after liquid immersion or contact with either water or any other liquid. Such immersion or contact damages the circuitry and may several hardware components or the motherboard. In most cases, such repairs require the replacement or reconnection of several parts.

3. Damage or malfunction of the charging connector: Between 5 and 10% of all smartphone repairs, occur after the charging connector is damaged or malfunctioning. The cause of such damage may be after aging or electric short-circuits. Related problems may include a broken or faulty dock or USB connector.

4. Phone lock: Between 5 and 10% of all smartphone repairs, are to unlock the smartphone either after faulting security protocols or after forgetting the unlocking codes.

---

[267] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[268] OCU (2017) ESTUDIO Obsolescencia del software. Una vida demasiado corta. Compra Maestra 423 - Marzo 2017

[269] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[270] https://www.engadget.com/2017/01/04/7-most-common-repairs-with-modern-smartphones/ (accessed on 23 March 2018)

5. Connectivity: About 7% of all smartphone repairs are to address problems with the network signal. The receiver may be faulty or damages and thus in need of replacement, although most problems occur after the receiver is disconnected. Related problems that may trigger a smartphone repair include problems with the Bluetooth, Wi-Fi, and LAN connectivity to the worldwide web or other devices.
6. Audio Output: About 5% of all smartphone repairs are to address a faulty or malfunctioning sound system, speaker, loudspeaker, microphone, or ringer. There are times that the smartphone has no voice output, when the headphone socket is damaged or disconnected, or when SD card content has no audio. At other times, the volume control buttons are disconnected, damaged or lost, and thus need replacement.
7. Phone Crush: Below 5% of all smartphone repairs exclusively respond to a smartphone that has crushed, resulting in a lifeless phone that necessitates either recovery of data, or to format the system. A crushed smartphone may also be not charging if the connector is damaged or if the power button is faulty and can therefore not boot the smartphone.

Some repairs could only need a DIY solution, but in most of cases it would be recommendable to consult a specialized technician. Existing smartphones, indeed, are usually not designed to be repairable by consumers (see also Section 2.2.5.1). [271]

Design for repair and upgrade strategies are implemented by some companies. Apart from economic considerations, a key issue is the availability of spare parts and software updates, even after the device has been discontinued from production.[272]

Design for repair and upgrade includes also the concept of modular smartphone, which has received lots of attention during the past year although without being able to reach large scale mass-volume production. Modular smartphones (e.g. Fairphone and Puzzlephone) offer the possibility to replace specific modules of the device, allowing their repair and update. Modular design comes with some challenges due to the larger mass and volume needed to house different components in a way they ensure full flexibility of the device.[273]

However, smartphones do not necessarily need to be fully modular. Research suggests that in order to achieve highest efficiency in terms of material recovery and cost savings, smartphones should be designed to be partially modular, meaning that printed circuit boards (PCBs), screens, batteries and shells should be easy and rapid to separate.[274]

Repair of smartphones requires a set of tools. Since most parts inside any smartphone are very sensitive to ESD or Static Electricity, it would be recommendable to use only ESD-Safe tools and equipment. The list of tools and equipment includes[275]:

[271] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[272] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[273] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[274] http://circulatenews.org/2017/12/circular-electronic-product-must-three-features/?lipi=urn%3Ali%3Apage%3Ad_flagship3_feed%3BHD7nUnWAR0ik%2FdKTHcRqWg%3D%3D) (accessed on 9 March 2018)

[275] http://www.smartphonetrainingcourses.com/repair-tool-kits/ (accessed on 9 March 2018)

- Soldering Iron or Soldering Station, used to solder parts and components like capacitor, resistor, diode, transistor, regulator, speaker, microphone, display.
- Cleaning Sponge, used to clean tip of soldering iron while soldering.
- Hot Air Blower, also called SMD (Surface Mount Device) rework system and SMD repair system, regulating or managing temperature and flow or hot air, and used to remove and again solder ICs.
- PCB Holder / PCB Stand, used to hold the PCB of a mobile phone while soldering or repairing.
- Solder Wire and Flux, used to solder electronic components. Flux is applied before soldering to remove any oxide or contamination at the solder joints.
- Solder Paste, which is solder in melted semi-solid form looking like paste and used mainly for Reballing of ICs.
- Desoldering Wire, or Desolder wire, used to remove excess solder from track of PCB. Thinner or PCB Cleaner: Thinner or PCB cleaner is used to clean the PCB of a mobile phone. The most common PCB cleaner used in mobile phone repairing is IPA or Isopropyl Alcohol.
- Jumper Wire, which is a thin laminated or coated copper wire used to jumper from one point to another on the track of a mobile phone while repairing.
- Point Cutter, used for cutting wires.
- Precision Screwdriver, used to remove and tighten screws while assembling and dissembling a mobile phone. Precision screwdrivers of sizes T4, T5, T6 and four head are good for most mobile repairing operations.
- Tweezers, used to hold electronic components while soldering and desoldering.
- ESD-Safe Cleaning Brush, used for cleaning the PCB of a mobile phone while repairing.
- Multimeter, used to find faults, check track and components.
- Battery Booster, used to boost the power of battery of a mobile phone.
- Ultrasonic Cleaner, used to clean PCB of a mobile phone and electronic components.
- BGA (Ball Grid Array) Kit, used to Reball and repair ball-type ICs.
- Magnifying Lamp, used to see the magnified view of the PCB of a mobile phone. Most magnifying lamps also have light. Magnifying lamps are available in different magnification such as 3x, 4x, 5x, 10x, 50x.
- Mobile Opener, used to open the housing or body of a mobile phone.
- DC Power Supply, Regulated DC (Direct Current) power supply, used to supply DC current to a mobile phone to switch on a mobile phone without battery.

In the repair sector, a global support platform is provided by iFixit[276]. iFixit provides repair guidance for most smartphone brands and models[277]. Instructions for popular phones include[278]:

[276] https://www.ifixit.com/ (accessed on 9 March 2018)

[277] https://www.ifixit.com/Device/Phone (accessed on 9 March 2018)

1. Replace of iPhone Battery. iPhones do not technically feature a user-replaceable battery since Apple uses a proprietary screw. However, with a specialty pentalobe screwdriver, the battery of an iPhone can be removed in less than an hour.
2. Replace of Samsung Galaxy S Battery. Samsung is one of the few remaining smartphone makers that do not seal batteries into their phones. The battery on a Galaxy S series phone can be changed in less than five minutes without any tool (just prying off the back panel, pulling out the old battery, placing in a new one, and snapping the phone back together again).
3. Replace of iPhone Screen. Replacing a screen with a brand new display assembly is easier than replacing the battery. This can be done with a prying tool like a spudger.
4. Replace of Samsung Galaxy S Screen. Replacing the display assembly can be done with a precision screwdriver set and some specialty prying tools. However, extra care is needed with the new touchscreen since the newest generation is significantly less repairable than its predecessors.

iFixit has also published Reparability Scores for smartphones available on the market[279] (see Annex II).

1.5.7 Materials

1.5.7.1 Bill Of Materials

Compiling a precise list of materials contained in a smartphone is difficult due to tightly protected trade secrets and variations between models and manufacturers. Nevertheless, the mass of an average smartphone in general consists of around: 40% metals (predominantly copper, gold, platinum, silver and tungsten), 40% plastics, 20% ceramics, and trace materials[280].

The current trend in smartphone body design is towards the use of high-grade materials instead of, once commonly used, plastics. That poses an increased demand on the supply of especially metals, such as aluminium, stainless steel or even titanium. Also specialty ceramics and toughened glass is used increasingly. Sells made of Polycarbonate / Acrylonitrile butadiene styrene (PC/ABS) alloy and Polypropylene (PP) were found to cause up to ten times lower climate impacts compared to aluminium or titanium mainly due to the differences in energy consumption in processing[281]. Newer generations of smartphones could cause greater environmental impacts due to larger screens, more advanced chips, and the materials used.

The bill of material of a smartphone is provided in table X at elementary level. As a consequence, compounds such as PVC and flame retardants are not addressed. The materials listed are a selection of some of the most common materials used in smartphones. Actual inputs vary across models and over time.

[278] https://ifixit.org/blog/6448/smartphone-repairs/ (accessed on 9 March 2018)

[279] https://www.ifixit.com/smartphone-repairability?sort=score (accessed on 9 March)

[280] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

[281] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

Table 16 BOM of a smartphone at elementary level[282]

Material	Common Use	Content per smartphone (g)	Content in all smartphones made since 2007 (t)	CRM listed (Y/N)
Aluminium (Al)	Case	22.18	157,478	N
Copper (Cu)	Wiring	15.12	107,352	N
Plastics	Case	9.53	67,663	N
Cobalt (Co)	Battery	5.38	38,198	Y
Tungsten (W)	Vibration	0.44	3,124	Y
Silver (Ag)	Solder, PCB	0.31	2,201	N
Gold (Au)	PCB	0.03	213	N
Neodymium (Nd)	Speaker Magnet,	0.05	355	Y
Indium (In)	Display	0.01	71	Y
Palladium (Pd)	PCB	0.01	71	N
Gallium (Ga)	LED-backlights	0.0004	3	Y

1.5.7.2 Critical Raw Materials and minerals from conflict-affected and high-risk areas

Of the 83 stable and non-radioactive elements in the periodic table, at least 70 can be found in smartphones. Some metals, like iron and aluminium, are available in such large quantities that there is no problem in terms of availability. For others, there are potential supply concerns and risks. For instance, dysprosium and copper reserves might last until 2050, or even earlier, as well as for gold[283].

An average smartphone can contain 62 different types of metals[284], some of them included in the EU list of critical raw materials:

282 Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

283 http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

284 http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

- Cobalt is used in the manufacture of batteries to extend their lifetime (on average 5.38 grams per device)[285] The overall post-consumer cobalt recycling rate is considered high, yet only a small portion of the cobalt used in consumer electronics is recycled.[286]
- Tungsten is used in the vibration component (on average 0.44 grams per device)[287]. Current recycling rates of tungsten are moderate.[288]
- Indium is used in displays (on average 0.01 grams per device)[289]. It is estimated that less than 1% of Indium is currently recycled from post-consumer waste.[290]
- Gallium is used in Power Amplifiers (PAs) to amplify voice and data signals to the appropriate power level allowing their transmission to the network base-station and in LED-backlights (on average 0.0004 g per device)[291]. It is estimated that less than 1% of gallium is currently recycled from post-consumer waste. Gallium is sometimes substituted by Indium, which is however associated with similar supply problems.[292]
- Antimony is used in the electronics industry to make some semiconductor devices, such as infrared detectors and diodes. It is alloyed with lead or other metals to improve their hardness and strength. A lead-antimony alloy is used in batteries. Other uses of antimony alloys include type metal (in printing presses), bullets and cable

[285] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[286] Fairphone (2017). Smartphone Material Profiles Opportunities for improvement in ten supply chains. Available at: https://www.fairphone.com/wp-content/.../SmartphoneMaterialProfiles_May2017.pdf (accessed on 19 April 18)

[287] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[288] Fairphone (2017). Smartphone Material Profiles Opportunities for improvement in ten supply chains. Available at: https://www.fairphone.com/wp-content/.../SmartphoneMaterialProfiles_May2017.pdf (accessed on 19 April 18)

[289] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[290] Fairphone (2017). Smartphone Material Profiles Opportunities for improvement in ten supply chains. Available at: https://www.fairphone.com/wp-content/.../SmartphoneMaterialProfiles_May2017.pdf (accessed on 19 April 18)

[291] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[292] Fairphone (2017). Smartphone Material Profiles Opportunities for improvement in ten supply chains. Available at: https://www.fairphone.com/wp-content/.../SmartphoneMaterialProfiles_May2017.pdf (accessed on 19 April 18)

sheathing. Antimony compounds are used to make flame-retardant materials, paints, enamels, glass and pottery.[293]

- Beryllium is used in electronics and telecommunication equipment as an alloying element in copper to improve its mechanical properties without impairing the electric conductivity. Copper beryllium is used in electronic and electrical connectors, battery, undersea fibre optic cables, chips (consumer electronics and telecommunications infrastructure). During this manufacture step, the European industry generates a lot of scrap (around half of the beryllium input) which is totally sent back to suppliers outside Europe for recycling. The beryllium contained in the waste ends up in landfill or is down-cycled with a large magnitude material stream. However, there is no post-consumer functional recycling of beryllium in Europe and in the world.[294]
- 16 (out of 17) rare earth elements (REE) are of relevant for smartphones. Neodymium, terbium and dysprosium are used to allow smartphones to vibrate through permanent magnet motors; terbium and dysprosium are used in tiny quantities in touchscreens to produce the colours of a phone display[295]. With the majority of REE production taking place in China, supply is vulnerable, yet less than 1% of REEs are currently recycled from post-consumer waste.

These materials are spread out in small and finite reserves in different places on the planet, have no adequate replacement, and their extraction can be problematic and time-consuming. Improvements are thus needed in researching alternatives, recycling existing materials and, ultimately, opening new mines[296]. Sustainability of mining activities depends on different factors: profits, conditions of workers and environmental impacts.

Furthermore, smartphones, as any electronic devices, require the so called conflict minerals (also referred to as 3TG = Tungsten, Tantalum, Tin, and Gold). These materials come from areas where they are mined in conditions of armed conflict and human rights abuses, and sold or traded by armed groups. This is an issue particularly associated with the Democratic Republic of Congo[297].

[293] http://criticalrawmaterials.org/antimony/ (accessed on 19 April 2018)

[294] Pr. Lena SUNDQVIST OEQVIST et al. (2018). Production technologies of CRM from secondary resources. SCRREEN - D4.2 - Issued on 2018-01-31. Available at http://scrreen.eu/wp-content/uploads/2018/03/SCRREEN-D4.2-Production-technologies-of-CRM-from-secondary-resources.pdf

[295] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

[296] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

[297] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

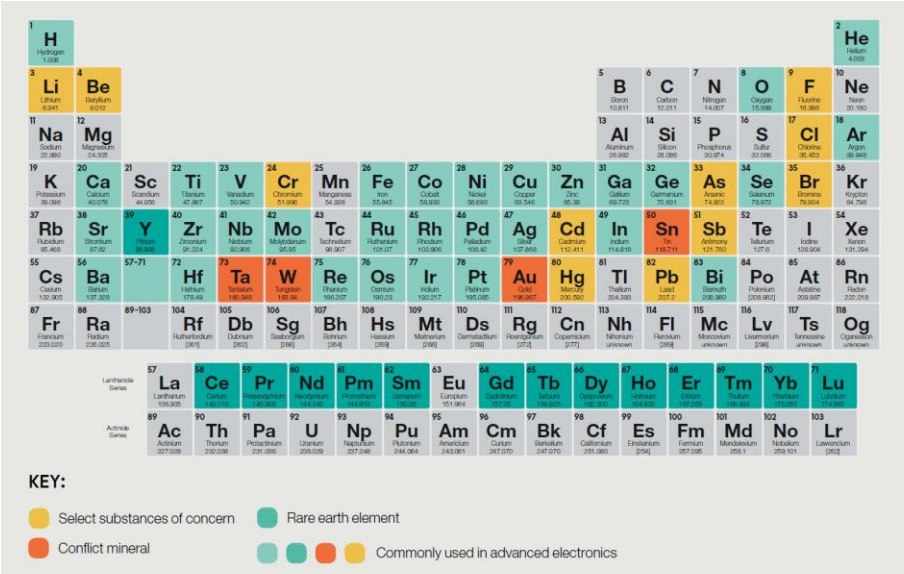

Figure 30: Substances of concern in smartphones[298]

Production of smartphones takes place in the other part of the world than sourcing of raw materials. Copper is mined in Chile, the United States, Peru, Australia, Russia, Indonesia, Canada, Zambia, Poland, Kazakhstan, Mexico and China. A lot of smartphone materials are sourced in China, via companies that have traditionally been reticent to reveal too much about their methods[299].

Materials can be responsibly sourced taking environmental and ethical issues into account. Currently 9 out of every 10 smelters in Apple's supply chain are reported to have been verified as conflict-free or are undergoing audits, and the number is intended to grow. In 99% of the countries where Apple sells goods there is also an official recycling programme. The majority of companies have made similar commitments. However, the frontrunner in this field is Fairphone, which aims to change the manufacture of smartphones in four key areas: mining, design, manufacturing and life cycle[300]. Fairphone is currently committed in supply chain transparency and due-diligence on conflict minerals. For example, Fairphone sources fairtrade certified gold for its phones and has extended its supply chain due-diligence programmes beyond 3TG to include cobalt in an effort to resolve forced child labour issues, as well as Apple did. Responsible mining initiatives also exist (e.g. Alliance for Responsible Mining, Responsible Minerals Initiative, Enough Project, Initiative for Responsible Mining Assurance, Towards Sustainable Mining Initiative, The Finnish Network for Sustainable

[298] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[299] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

[300] http://www.techradar.com/news/phone-and-communications/mobile-phones/our-smartphone-addiction-is-costing-the-earth-1299378 (accessed on 1 March 2018)

Mining); Huawei is for instance a member of the Responsible Cobalt Initiative (RCI), which is driving the supply chain's due diligence system and standards for cobalt[301].

1.5.7.1 Recycled materials

Smartphones contain a wide variety of materials, often speciality metals. End-of-life smartphones are therefore a great source of once extracted and processed high value secondary materials if designed for easy disassembly and recycling. However, once mixed with other WEEE, recovery of some of the materials becomes a greater challenge. Although phone manufacturers have started using more secondary materials in their products, the recycled content of smartphones, and particularly of high-grade materials, still remains relatively low.[302]

Many manufacturers indicate that they are moving towards more circular system in sourcing their materials by using some recycled or recovered materials in their products, however none of them do it at very large scale (i.e. less than 50%). Moreover, for most manufacturers, the secondary materials use is limited to plastic. However Fairphone also reports using recycled copper and tungsten in its devices. Apple reports to have made risk assessments across 44 elements in its products, identifying aluminium, tin, and cobalt as priority materials for developing a supply of secondary sources of materials. Despite some progress made in closing the loop on smartphone materials, all smartphone manufacturers are at least partially reliant on virgin materials.[303]

Some companies have started to pay attention on the use of recycled, safer and more sustainable materials[304].

1.5.7.2 Hazardous substances

Some of the smartphone manufacturers are eliminating 5 priority substance groups in smartphones and smartphone accessories[305]:

1. PVC: PVC is by far the most common halogen containing plastic. There are however other plastics that contain halogens in the plastic itself. Halogens are problematic from both a health and environmental perspective throughout the product life cycle. There is industry effort to reduce the PVC content in individual components. Sony, for instance, has eliminated PVC from the Xperia™ smartphone models[306].

---

[301] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[302] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[303] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[304] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[305] Elizabeth Jardim (2017): FROM SMART TO SENSELESS: The Global Impact of 10 Years of Smartphones. Greenpeace. Available at: http://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf (accessed on 1 March 2018)

[306] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

2. Brominated flame retardants (BFRs): Brominated flame retardants (BFRs) can result in the release of highly toxic dioxins, among other hazardous chemicals, when scrap is burned—threatening the health of workers and community members at rudimentary e-waste recycling operations. Plastic containing brominated flame retardants has to be separated according to the WEEE Directive. Industry is working to limit the use of components and materials containing BFRs. Sony, for instance, claims not to use polybrominated diphenyl ethers, polybrominated biphenyls, hexabromocyclododecanes, in a progressive effort of phasing out BFRs. Sony has developed a bromine-free flame retardant for the manufacture of a polycarbonate plastic flame retardant. Moreover, Sony has banned the use of tris (2-chloroethyl) phosphate, a chlorinated flame retardant identified as carrying risks similar to those associated with brominated flame retardants, as well as phosphoric acid tris (2-chloro-1-methylethyl) ester (TCPP) and tris (1,3-dichloro-2-propyl) phosphate (TDCPP)[307].

3. Beryllium (Be) and compounds: Beryllium and beryllium compounds, when released as dusts or fumes during processing and recycling, are recognized as known human carcinogens. Exposure to these chemicals, even at very low levels and for short periods of time, can cause beryllium sensitization that can lead to chronic beryllium disease (CBD), an incurable and debilitating lung disease. Industry is working to avoid the use of such substances. Sony for instance is using no beryllium oxide and no beryllium compounds in Xperia™ smartphones[308].

4. Antimony (Sb) and compounds: Antimony trioxide is recognized as a possible human carcinogen; exposure to high levels in the workplace, as dusts or fumes, can lead to severe skin problems and other health effects[309]. Sony has banned the use of LCD panels containing diarsenic trioxide and diarsenic pentoxide[310].

5. Phthalates: Phthalates, used widely as softeners for PVC, migrate out of plastics over time. Some are classified as 'toxic to reproduction' and are known to be hormone disrupters. Industry is working to eliminate specific phthalates. Sony for instance has succeeded in eliminating the phthalates DEHP, DBP, BBP, DIDP, DNOP and DINP[311] from the Xperia™ smartphones models[312].

Moreover, in terms of hazardous materials such as lead, cadmium, chromium VI, PBDEs and PBBs, Fairphone reports that they do not exceed the thresholds set in the ROHS regulation (1000 ppm - except 100 ppm for cadmium). The Fairphone 2 materials also comply with the RoHS Directive requirements set for Bromine Flame Retardants (BFR)s. In addition, other flame retardants, such as HBCDD and TBBPA have not been detected when tested in specific

[307] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

[308] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

[309] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[310] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

[311] DEHP stands for bis (2-ethylhexyl) phthalate and di (2-ethylhexyl) phthalate; DBPs for dibutyl phthalate and di-n-butyl phthalate; BBPs for benzyl butyl phthalate and butyl benzyl phthalate; DIDP for di-isodecyl phthalate; DNOP for di-n-octyl phthalate; and DINP for di-isononyl phthalate.

[312] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

components (PCBs, filters, connectors, resistors, etc.). The Fairphone 2 is Phthalates- and PVC-free and no benzene and n-Hexane are used in the production process[313].

Sony has defined a list of 'Environment-related Substances to be Controlled' (also referred to as 'Controlled Substances'), which are chemicals that have significant impact on both humans and the global environment. These also include substances that may not be controlled by laws. Sony either prohibits the use of these substances in parts or phases them out wherever a viable alternative that meets all product quality and technical requirements is available[314].

1.5.8 End of Life

1.5.8.1 Scenario description

Extended producer responsibility (EPR) is mandatory for electronic equipment producers in Europe. The producers are obliged to pay-in to WEEE recycling schemes in order to ensure that waste is recycled appropriately and does not end up in landfills[315]. However, the collection rates for small electronics are still low:

- 20% of young Norwegian adults throw small electronics in the waste bin[316]
- 89% of the mobile devices thrown away in the US in 2010 (141 million units) were disposed in landfill[317]
- 28-125 million phones languish unused in the UK, meaning that for every phone in use, up to four sit in drawers unused[318]. A similar situation occurs in Finland, where consumers typically have between two and five functioning mobile phones stored at home that are not in use[319].

Collection rates for recycling, refurbishing and/or remanufacturing smartphones in Europe) are around 15%, and the secondary (e.g., refurbished) smartphone market is only a fraction (6%) of the primary market.[320]

This scenario represents an underused bank of valuable resource including fully functioning products, components and materials and critical metals, which could be recovered more

[313] https://support.fairphone.com/hc/en-us/articles/215392683-How-about-hazardous-materials- (accessed on 19 April 18)

[314] https://www.sony.net/SonyInfo/csr_report/environment/products/replace.html (accessed on 8 March 2018)

[315] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[316] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[317] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[318] Dustin Benton, Emily Coats and Jonny Hazell, 2015, A circular economy for smart devices: Opportunities in the US, UK and India, Green Alliance, available at: https://www.green-alliance.org.uk/a_circular_economy_for_smart_devices.php (accessed on 12 February 2018)

[319] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[320] https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram/in-depth-mobile-phones (accessed on 22 February 2018)

efficiently through the implementation of circular economy approaches requiring changes in both business models and consumer behaviour[321].

There are already some signs of change: mobile replacement rates by consumers are slowing after many years of increase. Manufacturers and consumers are increasingly aware that used smartphone has a residual value that can be exploited, which is for instance boosting take-back systems, remanufacturing, shops offering repair services, and 2nd hand markets.[322] However, anti-theft and security software installed on smartphones can be problematic as they can only be removed by the original owner. Retrieving working phones from waste streams is made impossible in cases where such software is installed[323].

Most of the big manufacturers have extensive global take-back programmes in place, however the companies apart from Fairphone are not very transparent about the destination of the recycled devices and the amount of secondary materials sourced through the take-back schemes. Furthermore, Apple's has developed the innovative LIAM-robot, which is designed to be able to disassemble 1.2 million iPhone units per year. If significantly scaled up, this would make way for Apple towards greater degree of closed-loop production[324].

In Japan the recycling rates for certain materials are exceptionally high, for example as high as 98% for metals. This is mainly due to very comprehensive framework of legislation and regulations which encourage material circulation. For example, in Japan both the producer of products and the consumer pay towards the appropriate recycling of products at the end of their life, which incentivises effective recycling[325].

WEEE however can end up in countries without appropriate recycling facilities through informal routes leading to environmental pollution and health risks in these countries. For instance, the presence of polyvinyl chloride (PVC) plastic and brominated flame retardants (BFRs) can result in the release of highly toxic dioxins, among other hazardous chemicals, when scrap is burned. Other hazardous chemicals commonly used in electronics also pose a range of environmental and human health problems[326].

Closing the loop collects the client's redundant phones and reuses or recycles them. For each redundant phone a waste phone is collected from developing countries with no recycling infrastructure and brought back to developed countries to be appropriately recycled. The programme can also work in reverse – for each unit of new phones put in the market the phone producer buys an equal amount of old phones from developing countries to be transported to be recycled in countries with appropriate infrastructure[327].

---

[321] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[322] David Watson, Anja Charlotte Gylling, Naoko Tojo, Harald Throne-Holst,Bjørn Bauer and Leonidas Milios, 2017, Circular Business Models in the Mobile Phone Industry, Nordic Council of Ministers 2017, http://dx.doi.org/10.6027/TN2017-560

[323] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[324] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[325] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[326] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[327] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

1.5.8.2 Depollution considerations

Annex VII of WEEE lists a series of materials and components to remove and collect separately for depollution at the EOL of products. The following materials and components have been preliminarily identified of possible interest for smartphones:

- Batteries;
- Printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board is greater than 10 square centimetres;
- Plastic containing brominated flame retardants;
- Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps.

1.5.9 Networks, cloud offloading and data centres

The use of smartphones relies on mobile networks (voice and data) and data servers storing user (e.g. photos, videos) and provider data (e.g. music, maps, apps and their back-end data).

The monthly average consumption of mobile data has grown between 2012 and 2017 from 450 MB to up to 3.9 GB and 6.9 GB in Western Europe and North America, respectively. The monthly mobile data traffic per active smartphone in North America could reach 26 GB in 2022. These projections have even made some network operators question the future of unlimited data subscriptions. Despite the increase in energy efficiency, the higher volumes of transferred data might cause a net increase in energy consumption of networks and of data centres[328]. The proliferation of cameras in phones and the complementary availability of ever-faster fixed and mobile networks for instance resulted in a vast increase in the number of photographs taken and shared. It is estimated that two trillion photos and images were sent, posted, forwarded or backed up from smartphones globally[329].

In Europe, the data centres account for approx. 2% of the total energy consumption[330]. Furthermore, increased transmission speeds require continuous updates of the physical infrastructure that imposes higher requirements of non-renewable natural resources[331] with a continuous increase of the power needs foreseen for the next years (Figure 31: Global power demand of data centres.

[328] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

[329] Deloitte, 2016. There's no place like phone - Consumer usage patterns in the era of peak smartphone - Global Mobile Consumer Survey 2016: UK cut, available at: www.deloitte.co.uk/mobileuk2016/assets/pdf/Deloitte-Mobile-Consumer-2016-There-is-no-place-like-phone.pdf (accessed on 20 February 2018)

[330] P. Bertoldi, B. Hirl N. Labanca (2012). Energy Efficiency Status report 2012. Electricity Consumption and Efficiency Trends in the EU -27. Joint Research Centre - Institute for Energy and Transport. Available at: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/energy-efficiency-status-report-2012-electricity-consumption-and-efficiency-trends-eu-27 (accessed on 19 April 2018)

[331] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

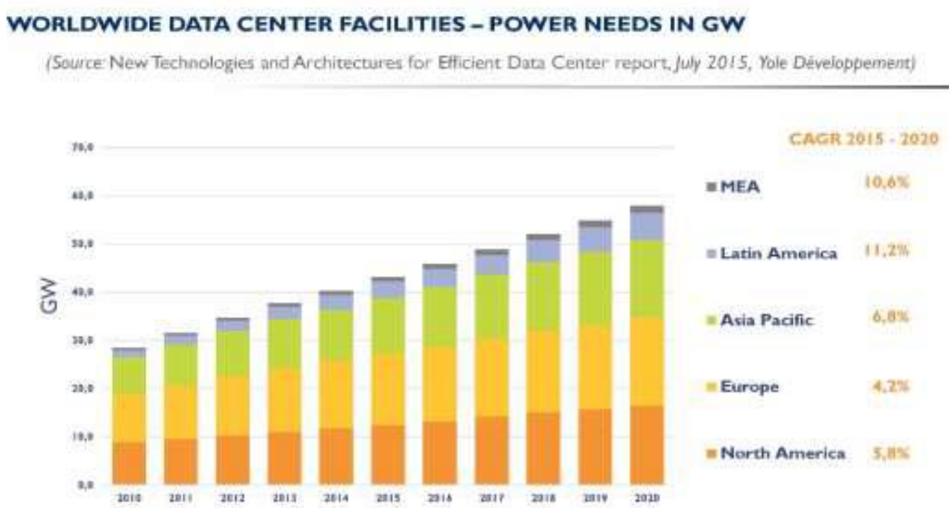

Figure 31: Global power demand of data centres.

Impacts from networks and data centres could be reduced by:

- Developing active networks adjusting their-selves based on the activity of users and building zero-emission radio access networks (RAN) to increase energy-efficiency of telco networks, which also requires greater use of renewable energy and innovative energy-efficiency solutions such as liquid cooling of base stations (BTS) connected to local or district heating[332].
- Designing apps that demand only small amounts of data in order to function.

1.5.10 Questions for stakeholders

1) Could you please share any qualitative and quantitative information to characterise penetration and market shares of smartphones on the market with respect to the following aspects? Which are the main trends for the future? • Weights and materials • Energy consumption • Specific functional characteristics (e.g. screen size) • Specific parts (e.g. type of battery) • Specific technologies (e.g. smartwatches) • Other features of relevance
2) Which are the typical innovation cycles for smartphones, and which are the main design concepts and innovative technologies/materials that could improve the material efficiency of the product?

[332] http://transform-together.weebly.com/news-3---launch-of-ss-wg.html (accessed on 1 March 2018)

3) Do you have information about the typical demand of resources (energy, water, materials) and production of waste and emissions (e.g. CO2) associated to the manufacture of a smartphone (e.g. amount of waste per unit of products)? Do you have examples to share about clean manufacturing processes?

4) Do you agree with the reported functional analysis? Could you please say which are in your opinion the main functions of a smartphone, and provide information about their specific needs, associated parts, and their relative importance/criticality (e.g. based on their probability of failure and the expected impact?

Functions	**Specific needs**	**Comment / specific points of attention**
Communication and connectivity	Cellular Band communication	
	Wi-Fi Networks Connections	
	Internet Access	
	Microphone and video	
	Keyboard and/or touch-screen	
	Near Field Communication (NFC)	
	USB/cable connection	
	Infrared/blue-tooth connection	
	GPS connection	
	Tethering	
	Fingerprint sensors	
Multimedia	Functional display (size and resolution)	
	Functional camera	
	Audio and video recording	
	Audio and video reproduction	
Portable operability	Rechargeable battery, power supply and connector working	
	Duration of the battery	
	Upgradable memory	
	Updatable operating system	
	Updatable software	
Durability	Resistance to stresses	
	Longevity of battery	
	Reparability	
	Upgradability	
OTHERS (Please add if any)		

5) Do you have any comment or information to provide with respect to the description of the parts of a smartphone? For instance,

- Which are in your opinion the most important parts from a functional and technical point of view? Why?
- Which are in your opinion the best available technologies and future innovations, especially with respect to material efficiency (e.g. for batteries, display)?
- Which are the main parameters that can be used to characterise their performance and how this can affect the material efficiency of smartphones (e.g. duration and longevity of batteries)?

Part	**Comment**
Frame and back Cover	
Display	
Battery	
System-on-a-chip	
Memory and storage	
Operating System	
Modems	
Audio Components	
Camera	
Sensors	
Vibration Mechanism	
USB port	
Headset	
USB Cable	
Charger;	
Documentation/instruction.	
Micro SD cards	
Micro SIM	
Protection accessories (e.g. cases and screen protections)	
OTHERS (Please add if any)	

6) Do you have statistics or information to share about the frequency of limiting states and failures of parts and functions of smartphones (also in terms of loss of performance), and the related failure mechanisms?

7) Which are the strategies that could be implemented to avoid/postpone such limiting states and key failures? For instance:

- How effective are protection accessories (e.g. cases and screen protections) in reducing the failure frequency?
- How the progressive slowing down of the operating system could be limited and/or avoided?
- How the progressive loss of performance of the battery could be limited and/or avoided?

8) How maintenance of smartphones and user behaviour can affect the durability of the product? Which means could be implemented to improve the use of a smartphones?

9) Which are the typical repair and upgrade operations for smartphones? How frequent and expensive they are?
10) Could you share any relevant information on disassembly steps, disassembly time, and difficulties related to the disassemble of key parts of a smartphone? How this could be improved?
11) Which are the main barriers to repair/upgrade of smartphones? How could users be facilitated to repair/upgrade their smartphones?
12) Do you have any information to share about logistics of smartphones and their raw materials (e.g. origin of materials, country of manufacturing, means of transport and packaging used)?
13) Could you please share any examples of Bills of Materials for smartphones models?
14) Which are the parts typically used in smartphones containing substance reported in the EU list of Critical Raw Materials or in the EU Regulation 2017/821 about minerals from conflict areas? Which are the main alternative materials available?
15) Do you have any examples to share about the use of recycled materials in smartphones? Which are the main potentialities, barriers and challenges? It is more a problem of market shortage of recycled materials or their technical specifications?
16) Could you please provide examples of parts typically used in smartphones that can contain hazardous substances of concern (e.g. substances listed in the Candidate and Authorisation Lists of REACH, substances listed in Annex II of ROHS)? Are there safer alternatives available?
17) Which are the main initiatives aiming to the supply of safer and more sustainable materials?
18) Do you have any examples to share about lean design for smartphones and how this can affect other material efficiency aspects? Vice versa, do you have examples of how a design focusing on other material efficiency aspects (e.g. durability, reparability, recyclability) can affect the use of materials in the product?
19) Which are the typical end-of-life scenarios for smartphones in the EU (e.g. % sent to refurbishment, recycling, landfill)?
20) Which are the typical refurbishment/remanufacturing operations for smartphones? How frequent and expensive they are? Which are the main barriers? How could these processes be facilitated?
21) Which are the 'state-of-art' technologies used for the pre-treatment of the product at the End-of-Life, and the recycling/recovery of materials? Which are typical recycling/recovery rates?
22) Which are the emerging trends for the recycling process?

23) Annex VII of WEEE lists a series of materials and components to remove and collect separately for depollution at the EOL of products. Do you have any comments about the list of materials and components of possible interest for smartphones identified in the report?

- Batteries;
- Printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board is greater than 10 square centimetres;
- Plastic containing brominated flame retardants;
- Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps.

24) Which are costs, barriers and opportunities associated to the recycling process, and more in general to End-of-Life treatments? How could the process be improved, especially with respect to product design considerations?

25) How the quality of smartphones is related to its material efficiency (e.g. durability, reparability)? What could be the impact on the final cost of a smartphone of having a more material efficient (e.g. durable, reparable) product?

2 IDENTIFICATION OF MATERIAL EFFICIENCY HOT-SPOTS

2.1 Introduction

Material efficiency of products is more and more in the spotlight. Nevertheless, relative importance of different material efficiency aspects should be assessed on a product-by-product basis in order to address improvement strategies towards relevant hotspots where tangible benefits can be produced. The aim of this section is to identify which are the most relevant material efficiency aspects.

The identification of material efficiency hotspots is related to the analysis of technical, environmental and economic information over the life cycle of products. In particular, information about environmental and economic impacts can be gathered through Life cycle assessment (LCA) and Life cycle costing (LCC). This can allow determining the main contributions to the overall impacts of products in terms of life cycle stages, processes, product components and/or specific inputs and outputs.

The scope of the assessment will be defined with respect to:

1. Functional unit (FU) and reference flow
2. Reference product or types of products, representative of current and future conditions of use (stock vs. market)
3. Key performance indicators[333]
4. System Boundary and modelling approach[334].

Depending on the quality of the available information, the assessment could be either based on the review of existing studies[335], and/or on the development of ad-hoc studies[336] being representative for products on the stock/market.

Appropriate improvement options will also be identified preliminarily based on the hotspot analysis[337]. These can be in general grouped, according to the 3R waste hierarchy, as:

---

[333] For the assessment of environmental impacts, the most ambitious level would be to use the indicators proposed in PEF, which would require carrying out a full LCA with the aid of commercially available databases (and software tools). The assessment can however be streamlined by referring to shorter lists of key indicators, and/or simplified tools. Ecoreport is a simplified LCA tool used in MEErP preparatory studies in study supporting Ecodesign/Energy Label. Although coming with a moderate assessment effort, Ecoreport lacks in terms of modelling flexibility, possibilities to harmonise with PEF, indicators addressing scarcity of resources (e.g. ADP). Reference impact categories can be identified based on the observation of EPDs and literature studies, as described by Cordella and Hidalgo (2016, see https://doi.org/10.1016/j.spc.2016.07.002).

[334] The modelling of the life cycle can include the application of assumptions and the further processing of foreground and LCI data for the calculation of the inputs and outputs associated to the key elements of the product's life cycle: Bill of Materials (BOM), expected lifetime, maintenance and repair activities, distribution and transportation processes, EoL scenarios, etc. When the uncertainty of assumptions taken is considered to be relevant a sensitivity analysis should be included.

[335] Cordella, M., and Hidalgo, C. (2016) Analysis of key environmental areas in the design and labelling of furniture products: Application of a screening approach based on a literature review of LCA studies. Sustainable Production and Consumption, 8, 64-77, https://doi.org/10.1016/j.spc.2016.07.002

[336] Cordella, M., Bauer, I., Lehmann, A., Schulz, M., Wolf, O. (2015) Evolution of disposable baby diapers in Europe: life cycle assessment of environmental impacts and identification of key areas of improvement. Journal of Cleaner Production, 95, 322-331, https://doi.org/10.1016/j.jclepro.2015.02.040

1. Reduce strategies (e.g. extension of the product's lifetime through increased durability);
2. Reuse strategies (e.g. extension of the product's lifetime through increased reparability);
3. Recycle strategies (e.g. use materials that can increase recyclability of the product).

Different hotspots are in general associated to different impact categories. Based on the results of the assessment, reference impact categories will be selected for further assessments[338].

2.2 Questions for stakeholders

1) Could you share any relevant LCA/LCC studies on smartphones which could be used to identify material efficiency hotspots?
2) In your opinion, how functional unit (FU) and reference flow should be defined to assess impacts of smartphones as much coherently as possible?
3) In your opinion, which reference product or types of products (representative of current and future conditions of use) should be assessed? Please describe also how they should be defined and if indicate if you would be able to share information to model them (e.g. BOM, energy use, EOL).
4) In your opinion, which key performance indicators should be assessed to keep the assessment pragmatic and focused on tangible impacts?
5) In your opinion, how the System Boundary of smartphones should be modelled, in particular with respect to the impacted infrastructures and EOL?
6) Which are in your opinion the most relevant material efficiency hotspots of smartphones? Please explain why.
7) Which material efficiency aspects are in your opinion <u>not</u> relevant for smartphones? Please explain why.
8) Which are in your opinion the most relevant strategies and options to improve the material efficiency of smartphones from an environmental and an economic point of view? Please explain why.

[337] Different strategies and options could be interconnected since changes in product design could affect other material efficiency aspects (e.g. lean designs might reduce product longevity and recyclability).

[338] For example: 1) an environmental indicator where contribution to the impacts due to materials is dominant (e.g. 75-100% of the overall impact); 2) an environmental indicator where contribution to the impacts due to the use phase is dominant; 3) an environmental indicator where contribution to the impacts from both materials and use phase is significant (e.g. 30-50% each); 4) Net Present Value (NPV).

3 TECHNICAL ANALYSIS AND ASSESSMENT OF MATERIAL EFFICIENCY ASPECTS

The information gathered so far should allow understanding the factors affecting the material efficiency of products and assessing the feasibility of design options aimed at improving the material efficiency of the product with respect to the identified hotspots.

3.1 Technical analysis

Technical information about key material efficiency aspects will be analysed from an eco-design perspective and summarised in the present section. The aim will be to set the basis for the identification of a preliminary list of design measures which will be further assessed in terms of economic and environmental impacts.

3.1.1 Product's longevity

Depletion of materials and production of waste tend to decrease when the lifetime of a product is increased[339]. Designing more durable products is a key strategy to save materials and reduce the amount of waste to handle at the End of Life. The durability of a product is defined in this context as the ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached. A limiting state is reached when one or more required functions/sub-functions are no longer delivered. The limiting state could either due to technical failure and/or other socio-economic conditions, so that the lifetime of a product can be differentiated between:

- Technical lifetime, which is the time span or number of usage cycles for which a product is considered to function as required, under defined conditions of use, until a first failure occurs[340].
- Functional lifetime, which is the time a product is used until the requirements of the user are no longer met, due to the economics of operation, maintenance and repair or obsolescence[341].
- Overall average lifetime, which is the average time of use of a products calculated considering the possible limiting states and the following fate of the product.

To increase the lifetime of products it is needed to identify technical problems that could cause the replacement of a product and technical measures that could prevent it:

1. The delay of technical problems over time, with consequent increase of the technical lifetime, will be the focus of a durability analysis. This aims at identifying stress conditions, design aspects and misuses that could produce failures of key parts and loss of function(s)/sub-function(s) during the normal and/or special conditions of operation of the product. Key aspects and/or correction measures to increase the longevity of products and parts must be identified.
2. Fixing a technical problem and/or extending the function lifetime is instead the focus of a reparability and reusability analysis. This aims at identifying the barriers and attributes influencing the chance of repair and reuse of products and key parts. Key

[339] This is generally the case when an increase of lifetime is not associated to design choices or repair/refurbishment operations requiring a significant addition of materials. Trade-offs among different material efficiency aspects could otherwise occur.

[340] This is typically modelled based on statistical data and accelerated tests.

[341] This can be differentiated between first and successive users.

aspects and/or correction measures to increase the reparability and reusability of products and parts have to be identified. The analysis has also to include considerations about re-manufacturability and upgradability.

The two analyses can be based on the common ground of information gathered in the former section:

1. The functional analysis of the product[342] allows defining main functions and sub-functions of the product, and understanding conditions of use of the product and interactions between product and final users;
2. The analysis of causes of replacements, frequency of failures, impacted parts, environmental impacts, and the breakdowns of repair costs allows defining priority parts and priority parts[343].

3.1.1.1 Durability

The durability analysis will focus on investigating degradation mechanisms and paths that may cause limiting states (i.e. failure modes of main functions and/or sub-functions)[344]. Maintenance needs and measures to avoid or postpone faults will be identified.

Factors producing limiting states include the stresses of product's parts and their capability to withstand these constrains and to provide a satisfactory performance level. Stress factors can be linked to environmental profile (e.g. ambient temperature and humidity, mechanical vibration due to the transportation) or to the operating profile (e.g. electrical stresses due to the function of the equipment, temperature variation during the turning on/off, shocks: vibration, drops, and mechanical impacts).

3.1.1.2 Reparability and reusability

The reparability and reusability analysis will focus on investigating frequency and temporal distribution of repair operations; repair operations requiring the replacement of components and disassembly steps/difficulty needed; typical upgrade features and frequency of upgrade; technical, market and legal barriers (e.g. functional obsolescence, difficulty to disassembly components, software updates, short innovation cycles, cost of the repair operation, unavailability of repair instructions, unavailability of spare parts). Measures that could improve the reparability and reusability of products will be identified.

3.1.2 Use of materials and recycling

Smartphones are made of a long and heterogeneous list of materials, also including critical raw materials, minerals from conflicting areas, and hazardous substances. Reducing and/or optimising the amount of materials used in the product, for instance increasing the amount of recycled materials, can potentially lead to environmental and social benefits.

Moreover, after their useful life, products are disposed in order to remove and treat properly any source of hazard and to recover value embedded in components and/or materials. This is

[342] EN 12973:2000 - Value management

[343] This can be based on 1) Analysis of the frequency of (single and multiple) failure modes and impacted parts; 2) Typical repair and upgrade operations; 3) Understanding barriers hindering the longevity and repair of products, technical solutions to overcome them, and the benefits associated from a user and a market perspective; 4) Setting of preliminary objectives. Environmental and economic considerations can also be taken into account, including quality aspects

[344] IEC 60300-3-1 - Dependability management – Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology

done in the recycling process. Recovery of materials and energy can also avoid the depletion of new resources. Designs that facilitate the recycling process, for instance improving the depollution, the dismantling, the recyclability and the recoverability of products, can have positive effects.

Measures that could improve the material efficiency of smartphones in this area will be identified.[345]

3.1.2.1 Use of materials

Sustainability of smartphones can improve if critical and hazardous materials are avoided, in favour of better ones, as recycled and safer materials. The use of recycled content can however be limited by aspects related to regulations and standards, market availability of recycled materials, technical design specifications.

3.1.2.2 Lean designs

Depletion of materials, and related impacts, can in general decrease by adopting leaner designs, as well as by excluding unnecessary accessories such as low quality cables, headsets and chargers). However, this could potentially come at the expenses of durability and recyclability of the product.

3.1.2.3 Fitness for recycling

Recyclability and recoverability of products could be limited by the presence of specific substances, and by technological and design issues. Some parts of the product should be extracted during the recycling process because of their hazardousness (e.g. components listed in Annex VII of WEEE), their reusability (e.g. a display still functioning), their value (e.g. metals) and/or other critical aspects (e.g. CRM). Design factors facilitating or limiting the recyclability of the product will be identified. In particular, a key role is played by the definition of reference EOL treatment scenarios.

3.1.3 Preliminary definition of options and measures to improve the material efficiency of the product

Design options for improving the material efficiency of the product group can be identified based on the information gathered through the technical analysis. Options could for instance include:

- Increasing the durability of whole product / key parts;
- Improving the reparability of the product (with respect to key parts);
- Improving the recyclability of whole product / key parts;
- Facilitating the recovery of components and materials;
- Increasing the recycled content of whole product / key parts;
- Product light-weighting.

Objectives embedded in each design option can be achieved through the definition of technical measures (e.g. making the product more disassemblable).

[345] The analysis can be fed by information as: Regulations and standards applicable on the product category (e.g. Annex VII of WEEE, REACH, CLP); Regulation and standards applicable on product manufacture and on Secondary Raw Materials; Market expectation in terms of product design and feedback from manufacturers and recyclers; Statistical data about EOL practices, related technologies and limitations; Data about product composition (e.g. list of components and materials, joining techniques and tools needed, quality of products); Statistical data about value of materials.

3.14 Questions for stakeholders

1) Do you have any additional comment/information about this section?

3.2 Assessment of design options

3.2.1 Introduction

The environmental relevance and the economic affordability of scenarios that integrate design options and measures with which to improve the material efficiency of products will be evaluated on the basis of LCA and LCC information. Scenarios to assess could include:

- Durability scenarios[346]
- Reparability and upgradability scenarios[347]
- Scenarios with increased recycled content, recyclability and recoverability[348]
- Lean design scenarios[349].

In order to reflect specificities of each scenario, specific design options linked to practical examples of products should be covered in the assessment. The assessment can be however simplified by referring to key indicators, as those selected during the hotspot analysis. Interpretation of the results should aim gaining further knowledge about the relative importance of the scenarios, the conditions under which they are favourable, and possible side effects.

3.2.2 Questions for stakeholders

1) Could you share information about any relevant LCA/LCC studies for smartphones that you know addressing the assessment of alternative design options with respect to specific material efficiency aspects (e.g. increased/reduced durability, reparability, recycled materials)?
2) In your opinion, which reference product or types of products (representative of current and future conditions of use) should be assessed for scenarios addressing specific material efficiency aspects? Would you be able to share information to model them (e.g. BOM, energy use)?

[346] More durable products are characterized by a longer lifetime than the base-case product(s). Design changes allowing the product to be more durable are to be taken in into account in the life cycle modelling (e.g. change of materials, increased mass of the product, reduced reparability and/or recyclability of the product). The technological progress and the availability of newer products with improved efficiency are also to be considered in the LCA/LCC modelling as far as possible.

[347] Increase reparability will also bring to products with longer lifetimes. In this case, the LCA/LCC modelling shall include, for instance, the increased consumption of spare parts and the related supply (if relevant). This scenario can also include options for reusability, re-manufacturability and upgradability of products. Also in this case, the technological progress and the availability of newer products with higher energy efficiency shall be also considered in the LCA/LCC modelling.

[348] The increased recyclability of a product/component make possible the creation of new value chains, when a market for recycling materials is already in place (e.g. metals). The recycled content of a product depends, among other factors, on the market availability of secondary materials, which can be more or less abundant (e.g. metals vs. plastics). Changes in the product design might be needed in order to reach a higher recyclability and/or recycled content (e.g. change of materials, increased mass of the product). This can also have effects on other areas, as for instance the product's durability, that have to be included in the LCA/LCC modelling. Particularly in this case, the modelling of the EOL is a key factor. Both current and future practices should be considered.

[349] Leaner product's designs allow saving materials but could have effects on other material efficiency areas (e.g. durability and recyclability) which have to be included in the LCA/LCC modelling.

3) In your opinion, which main modifications (functional unit, reference flow, key performance indicators, modelling assumptions for repair operations, EOL treatments, etc.) should be applied to the assessment methodology, compared to the baseline assessment of hotspots defined in Section 2?
4) In your opinion, which are the most important material efficiency aspects to assess? Under which conditions scenarios associated to specific material efficiency aspects can be favourable, and which are the possible side effects? Please justify your answer with appropriate supporting information.

4 DEFINITION OF POSSIBLE DESIGN MEASURES FOR IMPROVING MATERIAL EFFICIENCY

4.1 Introductions

This section will aim to sum up the information gathered in the former sections with the aim to define practical design measures that could help to improve the material efficiency of the product. Trade-offs and relative relevance of each measure will be described, as well as their technical feasibility and the availability of assessment and verification methods.

4.2 Questions for stakeholders

1) In your opinion, which could be the most relevant measures to improve the material efficiency of smartphones? Please explain why.

2) In your opinion, which could be the trade-offs associated to the measures suggested in the former question? Please explain why.

3) Which methods could be used to assess and verify the performance of smartphones with respect to the measures suggested in the first question?

6 ADDITIONAL QUESTIONS FOR STAKEHOLDERS

1) Are there any other relevant projects and initiatives about the circularity and, more in general, sustainability of smartphones that you would like to point out?
2) Do you have any other comments to make?

ANNEX I – ECOLABELLING REQUIREMENTS FOR SMARTPHONES

The following tables summarises the requirements that smartphones have to fulfil to be labelled according to Blue Angel (Table 17), TCO (

Table 18) and EPEAT (**Error! Reference source not found.**).

Table 17: Requirements for the award of the Blue Angel to mobile-phones

Aspect	Requirement
3.1 Battery State-of-Charge Indicator	The mobile phone shall have an integrated state-of-charge indicator. The latter shall optically display the current state of charge during use and during charging. Also, the device shall, upon completion of the charging process, display a clearly visible note advising the user to disconnect the charger from the mains or that the computer is no longer needed for charging.
3.2 Charging Interface	The mobile phone shall be rechargeable by means of a standardized charger complying with the EN 62684 standard 'Interoperability specifications of common external power supply (EPS) for use with data-enabled mobile telephones' and equipped with a correspondingly defined USB interface.
3.3 Longevity 3.3.1 Warranty	 The applicant undertakes to offer a free minimum 2-year warranty on the mobile phone, except for the rechargeable battery. The product manual shall include warranty details. The rechargeable batteries shall meet the technical requirement 3.8.2.
3.3.2 Software Updates	The devices shall have a function to keep the operating system up-to-date free of charge. The updates shall, above all, close security gaps and provide other software updates, if any.
3.3.3. 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 by him/her-self and without the need to pay for 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.
3.4 Take Back and Recyclable Design 3.4.1 Take Back	 The applicant shall operate its own take-back scheme for mobile phones to direct all collected devices to proper treatment (reuse, recovery and/or recycling). The applicant shall actively communicate this system to its customers. This take-back scheme can be based on collections at the branches, return campaigns, deposit systems or the like. A mere reference to the collection governed by the Elektro- and Elektronikgesetz (ElektroG) (Electrical and Electronic Equipment Act) would not be sufficient. The collection system can be organised by the applicant itself, by contracting partners and/or together with other manufacturers of mobile phones.
3.4.2 Structure and Connection Technology	The following shall apply to mobile phones: • The rechargeable batteries shall be easy to remove for recycling purposes to allow their recycling by material type separate from the rest of the device. • An efficient removal of the rechargeable batteries for recycling purposes shall be possible by using standard tools (guidance value: in no more than 5 seconds). The housing of the device may be damaged during this process but the leaking of battery chemicals must be prevented.

3.5 Material Requirements 3.5.1 Requirements for the Plastics used in Housings and Housing Parts	 The plastics must not contain as constituents any substances classified as: a. carcinogenic in category 1 or 2 according to Table 3.2 or categories 1A and 1B according to Table 3.1 of Annex VI to Regulation (EC) No 1272/200811 b. mutagenic in category 1 or 2 according to Table 3.2 or categories 1A and 1B according to Table 3.1 of Annex VI to Regulation (EC) No 1272/2008 c. toxic to reproduction in category 1 or 2 according to Table 3.2 or categories 1A and 1B according to Table 3.1 of Annex VI to Regulation (EC) No 1272/2008 d. being of very high concern for other reasons according to the criteria of Annex XIII to the REACH Regulation, provided that they have been included in the List (so-called 'Candidate List') set up in accordance with REACH, Article 59, paragraph 1. Halogenated polymers shall not be permitted. Neither may halogenated organic compounds be added as flame retardants. Moreover, no flame retardants may be added which are classified pursuant to Table 3.1 or 3.2 in Annex VI to Regulation (EC) 1272/2008 as very toxic to aquatic organisms with long-term adverse effect and assigned the Hazard Statement H 410 or Risk Statement R 50/53, respectively. The following shall be exempt from this rule: • process-related, technically unavoidable impurities; • fluoro-organic additives (as, for example, anti-dripping agents) used to improve the physical properties of plastics, provided that they do not exceed 0.5 weight percent; • plastic parts less than 10 g in mass.
3.5.2 Requirements for the Display	The components of the display shall not be classified as toxic or very toxic or carcinogenic, mutagenic or toxic to reproduction in category 1, 2 or 3 according to Table 3.2 or in category 1A, 1B, or 2 according to Table 3.1 of Annex VI to Regulation (EC) 1272/2008
3.5.3 Printed Circuit Boards	Neither PBBs (polybrominated biphenyls), nor PBDEs (polybrominated diphenyl ethers), nor chlorinated paraffins may be added to the carrier material of printed circuit boards
3.6 Use of Biocidal Silver	The use of biocidal silver on touchable surfaces shall not be permitted.
3.7 Electromagnetic Radiation	Mobile phones to be awarded the Blue Angel eco-label shall be so designed as to make sure that – when used at the ear - the specific absorption rate (SAR) induced by radio-frequency electromagnetic radiation does not exceed, under any operating condition, 0.60 watts per kg, locally averaged over 10 grams of tissue.
3.8 Requirements for the Battery 3.8.1 Replaceability	 Blue Angel eco-labelled products shall be so designed as to allow the user to replace the rechargeable batteries without any special tool.

<table>
<tr><td>3.8.2 Life and Life Cycle Test

3.8.3 Safety</td><td>Four different batteries per size and type shall be tested. All four tested batteries shall meet the requirements of the following test method.
Test Method:
C is the rated capacity given on the battery in ampere hours (Ah) as maximum capacity. The test starts (quasi the 'zeroth' cycle) with a discharge at 0.2 C until the cut-off voltage is reached (according to IEC/EN 61960: specified voltage under load where the discharge of one cell or battery is completed). The subsequent repeated charge and discharge shall be done in accordance with the specifications listed in the following tables. Different requirements are set for different applications.

Test Specifications for Rechargeable Lithium Batteries
<table>
<tr><td>Cycle Nr.</td><td>Charge</td><td>Rest period after charge</td><td>Discharge</td><td>Rest period after discharge</td></tr>
<tr><td>1-149</td><td>Manufacturer specification</td><td>30 min</td><td>1.0 C to cut-off voltage</td><td>30 min</td></tr>
<tr><td>150</td><td>Manufacturer specification</td><td>1 hour</td><td>0.2 C to cut-off voltage</td><td></td></tr>
</table>

The minimum discharge time for cycle 150 shall be 3.5 hours and the capacity delivered during cycle 150 shall be equal to 90 % of the rated capacity.
The batteries shall meet the test requirements specified in EN 62133, as amended (EN 62133:2003, Parts 3 and 4, or equivalent parts, respectively).</td></tr>
<tr><td>3.9 Audio Properties</td><td>Devices equipped with an audio player shall meet the DIN EN 60950-1 standard (Information technology equipment - Safety - Part 1: General requirements)</td></tr>
<tr><td>3.10 Labour Conditions</td><td>Fundamental principles and rights with respect to the universal human rights, as specified in the applicable core labour standards of the International Labour Organisation (ILO Core Labour Standards) shall be complied with during manufacture (assembly) of the Blue Angel eco-labelled products. Where compliance gaps due to local legal frameworks with ILO core labor standards on Collective Bargaining and Free Association are identified, the companies shall present their efforts and progress in promoting independent, freely elected and genuine worker representation, by providing documentation evidencing concrete steps towards holding elections accessible to third party observers, as well as measures to promote constructive dialogue between workers/worker representatives and management.</td></tr>
</table>

3.11 Operating Instructions	The product manual included with the devices shall include both the technical specifications and the environment and health-related user information. It shall be either installed on the mobile phone, easily accessible on the Internet or supplied as a data medium or in printed form together with the device. The product manual as well as manufacturer's website shall allow easy access to the following basic user information: 1. Information on the significance and correct interpretation of the battery state-of-charge indicator. 2. Instructions to disconnect the charger from the mains upon completion of the charging process in order to reduce no-load losses. 3. Instructions that charging on non-used PCs should be avoided in order to reduce power consumption during charging. 4. Instructions for using a proper charging unit. 5. Information on warranty period and warranty terms. 6. Instructions for safe data deletion. 7. Information on the take-back scheme. 8. Instructions to avoid high ambient temperatures that might lead to a significantly reduced battery capacity. The aim is to prevent the battery from irreversible capacity loss and, hence, a reduced battery life. 9. Instructions for 'proper' storing of the device (storage temperatures and charge state), as this is a decisive factor for battery life extension. 10. Instructions for replacing the rechargeable battery. 11. General information on environmental and resource significance of proper product disposal. 12. Information on an environmentally sound disposal at the end of use in accordance with the German Elektrogesetz (Electrical and Electronic Equipment Act). 13. Instructions that the battery should not be disposed of as normal household waste but instead should be taken to a battery collection facility. 14. Indication and explanation of the SAR data as well as information on how to reduce the exposure to radio waves when using the mobile phone. 15. Information on the audio properties and the safe use of an integrated audio player, if any.
3.12 Outlook on Possible Future Requirements	The fact that mobile phones are a valuable source of secondary raw materials and the currently very low return rate of used devices will call for an examination within the scope of the next revision of whether greater attention should be paid to the take back of mobile phones. These Basic Criteria could, for example, be extended by quantitative collection targets.

Table 18: Requirements and related background information for TCO Certified Smartphones.

Aspect	Background	Requirement
A.1.1. Information to End-Users	It is important that the purchaser of a product that has been certified in accordance with TCO Certified Smartphones receive information concerning the quality, features and capabilities of the product. This information is based on the viewpoint from the user's perspective that TCO Development represents.	An information document called 'TCO Certified Document' provided by TCO Development shall accompany the product to describe why these particular criteria have been chosen for the products within the TCO Certified program, and what is expected to be achieved by them.
A.2 Visual ergonomics	Good visual ergonomics is a very important aspect of quality that can also have a direct effect on the health, comfort and performance of the user. Good ergonomics, such as a high quality display image, can also influence our productivity and extend the usable life of a product. In this way, ergonomic design can also offer sustainability benefits.	
A.2.1 Luminance characteristics		
A.2.1.1 Luminance level	Luminance being emitted from a particular area is a measure of the luminous intensity per unit area of light travelling in a given direction and falls within a given solid angle. The unit of luminance is cd/m2. It shall be possible to set the luminance level according to the lighting conditions of the surroundings. Poor luminance can lead to low contrast and consequently affect legibility and colour discrimination and thus lead to misinterpretations. It shall be possible to set a sufficiently high luminance level with respect to the ambient lighting in order to present a comfortable viewing situation and to avoid eyestrain.	The following conditions shall be fulfilled: - The maximum white luminance shall be ≥ 200 cd/m2 at 80% image loading. - The minimum white luminance shall be ≤ 100 cd/m2 at 80% image loading

<table>
<tr><td>A.2.1.2 Luminance uniformity</td><td>Luminance uniformity is the capacity of the display to maintain the same luminance level over the whole active screen area. The luminance uniformity is defined as the ratio of maximum to minimum luminance within the fully active screen area.
Image quality is badly affected by non-uniform luminance. When poor luminance uniformity is visible, it can locally affect the contrast and consequently the legibility of information on the display. The areas of deviating luminance can have different sizes and cause varying contour sharpness.</td><td>Luminance variation across the active screen, the Lmax to Lmin ratio, shall be ≤ 1.20</td></tr>
<tr><td>A.2.1.3 Greyscale gamma curve</td><td>Greyscale gamma curve is the capability of the imaging device to maintain the original greyscale luminance of a greyscale pattern at all tested greyscale levels.
A TCO Certified Smartphone shall be delivered with a sufficiently accurate calibrated gamma curve in default pre-set since it makes it easier to distinguish between different light levels in the display image. A well-tuned greyscale is the basis for accurate detail rendering of any imaging device. The greyscale rendering is measured via a number of steps in a greyscale in the test image. Each greyscale step, regardless of grey level, shall have a relative luminance close to what is specified by common video standards sRGB and ITU Rec709 in order to give accurate rendering of the greyscale of the original image.</td><td>The different grey scale luminance levels shall be within the Max- and Min levels according to the table below, where 100% means the luminance level measured for white, RGB 255, 255, 255.
<table>
<tr><th>Grey level</th><th>L_{sRGB} %</th><th>L_{max} %</th><th>L_{min} %</th></tr>
<tr><td>255</td><td>100</td><td>100</td><td>100</td></tr>
<tr><td>225</td><td>75</td><td>80</td><td>71</td></tr>
<tr><td>195</td><td>55</td><td>62</td><td>48</td></tr>
<tr><td>165</td><td>38</td><td>47</td><td>30</td></tr>
<tr><td>135</td><td>24</td><td>33</td><td>18</td></tr>
<tr><td>105</td><td>14</td><td>22</td><td>9</td></tr>
<tr><td>75</td><td>7</td><td>13</td><td>4</td></tr>
<tr><td>45</td><td>3</td><td>6</td><td>1</td></tr>
</table></td></tr>
<tr><td>A.2.2 Screen colour characteristics</td><td></td><td></td></tr>
</table>

A.2.2.1 Correlated colour temperature, CCT variation	The correlated colour temperature (CCT) is the temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions. It is expressed in kelvin (K). The colour of a white area in nature could be neutral, warmer or colder dependent of e.g. the weather and lighting conditions. This is called the colour temperature of the white. The colour temperature of the display should be about the same as of the ambient lighting conditions. This makes it possible to more accurately evaluate the colour of an image on the display compared to real scenes or prints. Normal daylight has a correlated colour temperature in the range 5000 – 10000 K.	The default correlated colour temperature of the active display shall be in the range 5000K to 10000K.
A.2.2.2 Colour uniformity	The colour uniformity of a display is the capability to maintain the same colour in any part of the screen. The human visual system is very sensitive to changes in colour hue in white and grey areas. Since the white or grey colour hues are the background on which most colours are judged, the white or grey areas are the reference colours on the screen. Patches of colour variation on an active white or grey screen could reduce the contrast locally, be disturbing and affect the legibility, colour rendering and colour differentiation.	The maximum colour deviation between measured active areas on the screen that are intended to maintain the same colour shall be $\Delta u'v' \leq 0.012$

<table>
<tr><td>A.2.2.3 RGB settings</td><td>The RGB colour model is an additive colour model in which red, green, and blue light are added together in various ways to reproduce a broad array of colours.
Accurate colour rendering is important when realistic colour images or colour presentations are presented on the display. Poor colour rendering can lead to poor legibility and misinterpretation.
The u' and v' chromaticity co-ordinates of the primary colours red (R), green (G) and blue (B) of the screen shall aim at values given in international IEC, EBU and ITU standards. The u' and v' chromaticity co-ordinates of the primary colours R, G and B form a triangle in the CIE 1976 uniform chromaticity scale diagram. The larger the area of the triangle, the wider the range of colours the screen is capable of presenting.
The colour characteristics of a display are based on the visual appearance of the display's primary colour stimuli, the R, G, B-stimuli.</td><td>The minimum colour triangle shall have the following coordinates:
<table>
<tr><td></td><td colspan="2">Red</td><td colspan="2">Green</td><td colspan="2">Blue</td></tr>
<tr><td>Co-ordinate</td><td>u'</td><td>v'</td><td>u'</td><td>v'</td><td>u'</td><td>v'</td></tr>
<tr><td>Requirement</td><td>≥ 0.375</td><td>≥ 0.503</td><td>≤ 0.160</td><td>≥ 0.548</td><td>≥ 0.135</td><td>≤ 0.305</td></tr>
</table></td></tr>
<tr><td>A.3 Workload ergonomics</td><td></td><td></td></tr>
<tr><td>A.3.1 Material Characteristics</td><td>Normal use is considered as the operation descriptions given in the product's user manual/guides.
Skin allergies, in the form of rash or inflammation, may happen when the skin comes in contact with substances that irritate the skin. It is medically termed as 'contact dermatitis'. Nickel is a well-known contact allergen and irritant, which may cause skin reactions upon exposure, including itching, irritation, inflammation or the appearance of rashes.</td><td>The Smartphone shall not release nickel from the surfaces that come in contact with user´s skin during normal use</td></tr>
<tr><td>A.3.2 Headset</td><td>A headset is headphones combined with a microphone, or one headphone with a microphone.
A headset provides hands-free smartphone communication. This has many benefits, especially in call centers and other telephone-intensive jobs and for anybody wishing to have both hands free during a telephone conversation. It also reduces the emissions from the smartphone towards the head as it can be placed further away from the head while making a call.</td><td>The Smartphone shall be delivered with a headset to be used for audio communication over the cellular network.</td></tr>
</table>

A.5 Electrical Safety		
A.5.1 Electrical Safety	Electrical safety concerns the electrical design of apparatus with respect to its electrical insulation and other arrangements that are intended to prevent accidents resulting from contact with live components, and the risk of fire or explosion as a result of electrical flash-over due to inadequate or faulty electrical insulation.	The Smartphone and the internal or external power supply/supplies shall be certified in accordance with EN/IEC 60 950 or EN/IEC 60065 or EN 62368-1.
A.6 Environment	This section details the environmental criteria in TCO Certified, which offer a unique, integrated balance of environmental issues in the manufacturing, use and end of life phases of the product. The environmental criteria are divided into the following sections: 1. Manufacturing – criteria focusing on the manufacturing phase and environmental management 2. Climate – energy consumption, one of the most important issues in the environmental impact of IT products. 3. Hazardous Substances – heavy metals, flame retardants, plastics. 4. Material resource efficiency – factors to extend the life of the product and influence better use of material resources. 5. End of life – factors to stimulate recycling and minimize the impact of e-waste. Potential environmental effects are evident at each stage of the product life cycle. The environmental criteria TCO Development has focused on in this document are those that we consider most relevant to the product group. They have also proved to be attainable in volume manufacturing and are verifiable. Future criteria updates will likely focus on the manufacturing phase, hazardous substances and climate issues. Compliance with these criteria is verified by sending the requested information to a verifier approved by TCO Development.	

A.6.1 Product description	The aim of this product description is to provide third party verified information about the product. The information is used by TCO Development to verify that the product complies with the criteria in TCO Certified. The information is also provided on the certificate to buyers so that it helps them calculate the sustainability impact of the products and the benefit of buying products that fulfil TCO Certified. Using the declared sustainability information a buyer can, for example, implement climate compensation or other sustainability-related measures connected to the sustainability impact of the product. This data is often used by organisations in their annual sustainability report or internal programs aimed at minimizing the environmental impact of IT. Recycled plastic is post-consumer recycled plastic, which has been used in products. Plastic parts are all product parts made out of plastic except panels, electronic components, cables, connectors, PWBs, insulating mylar sheets and labels. This is primarily due to insufficient available alternatives. This also means that the weight of these items is not included when calculating the total weight of the plastic in the product in this requirement. Marking plate /Marking label is the label that contains the product's electrical rating in terms of voltage, frequency, current and the manufacturer's name, trademark or identification mark together with the manufacturer's model or type reference. The label shall be in accordance with IEC 60 950:1 clause 1.7.1.	A product declaration shall be provided for the Smartphone. The following information shall be verified by the third party facility and is printed by TCO Development on the certificate.
A.6.2 Manufacturing		

A.6.2.1 Environmental management system certification	Manufacturing plant: Manufacturing facility where the final assembly of the TCO Certified product takes place. A certified environmental management system shows that the company has chosen to work in a systematic way with constant improvement of the environmental performance of the company and its products. A certified environmental management system includes external independent reviews.	Each manufacturing plant must be certified in accordance with ISO 14001, or EMAS registered. If the product is manufactured by a third party, it is this company that shall be certified or registered.
A.6.3 Climate		
A.6.3.1 Energy consumption	Energy is the single most important topic in the issue of climate change. Energy efficient equipment is an important and effective way to fight climate change. With an ever-increasing volume of IT equipment in use, the efficiency of each product is vital. To reduce energy consumption from the Smartphone the external power supply shall comply with the International Efficiency Marking Protocol for External Power Supplies.	The external power supply shall meet at least the International Efficiency Protocol requirement for level V.
A.6.4 Hazardous substances		
A.6.4.1 Cadmium (Cd), mercury (Hg), lead (Pb) and hexavalent chromium (CrVI)	The effects of cadmium, mercury, lead and hexavalent chromium are well documented as substances that are hazardous to both our health and the environment. Electronic devices contain hazardous substances like heavy metals and brominated flame retardants. This causes problems both in the use phase (additives can leak from the plastic and accumulate in dust, harming both our health and the environment) and at end-of-life, where uncontrolled recycling can cause the release of toxins such as dioxins and furans. This criterion is harmonized with EU RoHS2 Directive (2011/65/EU), except that TCO Certified does not allow mercury in the display panel backlight. As TCO Certified is a global label this also affects products sold outside the EU.	The Smartphone shall not contain cadmium, mercury, lead and hexavalent chromium.

A.6.4.2 Halogenated substances	Halogenated flame retardants and plasticizers are often persistent, can bio-accumulate in living organisms and have been detected in both humans and the environment. These substances are problematic in the manufacturing and end of life phases where workers or the environment can be exposed. They can also migrate from the products during the use phase with unknown health effects as a result. Plastic parts are parts made mainly of plastics, e.g. the housing. Parts containing other materials in any significant amounts, e.g. cables with metal conductors, are not included in the definition. Printed wiring board laminate is a printed board that provides point-to-point connections but not printed components in a predetermined configuration on a common base. Halogens are a group of five chemically related non-metallic elements in the Periodic Table; fluorine, chlorine, bromine, iodine and astatine. Polybrominated biphenyls (PBB) and Polybrominated diphenyl ethers (PBDE) are restricted in the RoHS directive (2002/95/EC) due to the hazardous properties of these substances. Hexabromocyclododecane (HBCDD) has been identified as a Substance of Very High Concern in accordance with EU REACH criteria due to PBT (persistent, bio accumulative, toxic) properties.	1. Plastic parts weighing more than 5 grams shall not contain flame retardants or plasticizers that contain halogenated substances. Note: This applies to plastic parts in all assemblies and sub-assemblies. Exempted are printed wiring board laminates, electronic components and all kinds of cable insulation. 2. The Smartphone shall not contain PBB, PBDE and HBCDD. Note: This applies to components, parts and raw materials in all assemblies and sub-assemblies of the product e.g. batteries, paint, surface treatment, plastics and electronic components.

A.6.4.3 Non-halogenated substances	The purpose of this mandate is to increase the knowledge of substances with regards to their human and environmental impacts and to drive a shift towards less hazardous alternatives. These substances may be problematic in the manufacturing and end of life phase where workers or the environment can get exposed and can also migrate from the products during the use phase with unknown health effects as a result. The mandate uses the hazard assessment and decision logic framework called GreenScreen™ for Safer Chemicals developed by the non-profit organization Clean Production Action (CPA). The GreenScreen methodology can be used for identifying substances of high concern and safer alternatives. The GreenScreen criteria are in line with international standards and regulations including the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), OECD testing protocols and the European REACH Regulation. The U.S. EPA's Design for Environment (DfE) Alternatives Assessment is also an important influence on the GreenScreen™ for Safer Chemicals. Plastic parts are parts made mainly of plastics, e.g. the housing. Parts containing other materials in any significant amounts, e.g. cables with metal conductors, are not included in the definition. Printed wiring board laminate is a printed board that provides point-to-point connections but not printed components in a predetermined configuration on a common base. Licenced Profilers are organisations approved by CPA with the capacity to provide GreenScreen assessments. Accepted substances are considered the most sustainable alternatives which are possible for the industry to use, also taking into consideration aspects such as availability and functionality. Accepted substances are found on the TCO Development website under 'Accepted Substances list'.	Non halogenated flame retardants used in plastic parts that weigh more than 5 grams shall be on the publically available Accepted Substance List for TCO Certified. This means that the substance has been assessed by a licensed profiler according to GreenScreen™ and been assigned a benchmark score ≥ 2 The following acceptance decisions apply to substances given Benchmarks 4, 3, 2, 1 or designated U (undefined): 4: Accepted – (Few concerns) 3: Accepted – (Slight concern) 2: Accepted – (Moderate concern) 1: Not accepted - (High concern) U: Not accepted - (Unspecified) All substances of a flame retardant mixture shall be accounted for. Non-accepted components shall not exceed concentration levels of 0.1% by weight of the flame retardant. Exempted are printed wiring board laminates, electronic components and all kinds of cable insulation. A grace period for the above may be granted, see B.6.4.3 for rules TCO Development will conduct spot-checks and require full disclosure of the flame retardants, including CAS number, used in the product to verify that the obligations according to this mandate are fulfilled.

A.6.4.4 Halogenated plastics	PVC is by far the most common halogen containing plastic. There are however other plastics that contain halogens in the plastic itself. Halogens are problematic from both a health and environmental perspective throughout the product life cycle and should be phased out. Plastic parts are parts made mainly of plastics, e.g. the housing. Parts containing other materials in any significant amounts, e.g. cables with metal conductors, are not included in the definition. Printed wiring board laminate is a printed board that provides point-to-point connections but not printed components in a predetermined configuration on a common base. Halogens are a group of five chemically related non-metallic elements in the Periodic Table; fluorine, chlorine, bromine, iodine and astatine.	Plastic parts in the Smartphone weighing more than 5 grams shall not contain intentionally added halogens as a part of the polymer. Note: Printed wiring board laminates, and all kinds of internal and external cable insulation are not considered to be part of plastic parts and are therefore not included in the mandate.
A.6.4.5 Phthalates	Phthalates are substances mainly used as plasticizers. The substances restricted in the mandate are listed as Substances of Very High Concern and are included in REACH Annex XIV classified as toxic to reproduction. These substances are problematic from both a health and environmental perspective throughout the product life cycle and should be phased out.	The Smartphone shall not contain Bis (2-ethylhexyl) phthalate (DEHP), Butyl benzyl phthalate (BBP), Dibutyl phthalate (DBP), and Diisobutyl phthalate (DIBP). No parts of the product are exempted. Also diisononyl phthalate (DINP, CAS no. 28553-12-0), diisodecyl phthalate (DIDP, CAS no. 26761-40-0) and di-n-octyl phthalate (DNOP, CAS no. 117-84-0)
A.6.4.6 Hazardous substances in product packaging	Packaging constitutes a well-known environmental problem and is regulated in many countries worldwide. Packaging material has a short lifetime and generates large volumes of waste. There are three main areas of concern, content of hazardous substances, use of resources and transport volume.	The packaging material shall not contain lead (Pb), cadmium (Cd), mercury (Hg) or hexavalent chromium (Cr6). Plastic packaging material shall not contain organically bound halogens.

A.6.4.7 Batteries	The widespread use of batteries has given rise to many environmental concerns, such as toxic metal pollution, as they may contain very high amounts of lead, cadmium and mercury. Used batteries also contribute to electronic waste. In the United States, the Mercury-Containing and Rechargeable Battery Management Act of 1996 banned the sale of mercury-containing batteries, enacted uniform labeling requirements for rechargeable batteries, and required that rechargeable batteries be easily removable. The Battery Directive of the European Union has similar requirements, in addition to requiring increased recycling of batteries. Note that restrictions on hazardous substances in batteries are covered by A.6.4.1 Hazardous substances	Batteries shall be rechargeable and when necessary, replaceable by the end user or a qualified professional.
A.6.5 Material Resource Efficiency		

A.6.5.1 Lifetime extension	A longer product lifetime makes a significant positive contribution to more efficient resource use as well as the reduction of air and water pollution. A pre-condition for prolonged lifetime is that the product is of high quality, which is supported by good warranties. Another requirement is the availability of spare parts for a number of years once the product is taken out of production. During this period, products should, if possible, be repaired and not replaced. Brand owner: The company or organization owning or controlling the Brand Name. Brand Name: The name or sign, including but not limited to a trademark or company name, used to identify, amongst users and customers, the manufacturer or seller of a product. Product Warranty is a period where the Brand owner offers to repair or replace broken products during a period of time at no charge. Spare parts are those parts that have the potential to fail during normal use of the product. Product parts whose life cycle usually exceeds the average usual life of the product need not be provisioned as spare parts. When the cost for replacing a broken part (e.g. panel) exceeds the cost of replacing the whole product, then that part need not be considered as a spare part under this mandate.	1. The brand owner shall provide a product warranty for at least one year on all markets where the product is sold. 2. The brand owner shall guarantee the availability of spare parts for at least three years from the time that production ceases. Instructions on how to replace these parts shall be available to professionals upon request.
A.6.6 End of life		

A.6.6.1 Material coding of plastics	Prolonging the life of IT-products by reuse is the best way to minimize their environmental impact. But when this is no longer possible, it is important to facilitate material recycling of the products. Material coding of plastics aims at making the recycling of plastics easier so that the plastic can be used in new IT equipment. Plastic parts are parts made mainly of plastics, e.g. the housing. Parts containing other materials in any significant amounts, e.g. cables with metal conductors, are not included in the definition. Printed wiring board laminate is a printed board that provides point-to-point connections but not printed components in a predetermined configuration on a common base.	Plastic parts weighing more than 5 grams shall be material coded in accordance with ISO 11469 and ISO 1043-1, -2, -3, -4. Exempted are printed wiring board laminates.

A.6.6.2 Take back system	The amount of electronic waste in the world today is enormous and a growing environmental problem. It is important that manufacturers provide mechanisms to take back their equipment at end-of-life under the principle of individual producer responsibility wherein each manufacturer must be financially responsible for managing its own branded products at end-of-life. Currently much electronic waste is being exported to developing countries where it is managed unsustainably and disproportionately burdens those regions with this global environmental problem. The Basel Convention and its decisions govern the export of many types of electronic waste, however it is not properly implemented in all countries. With this mandate TCO Development aims to influence the expansion of better electronic waste management practices to more countries. Brand owner is the company that owns the brand name visible on the product. Take back system is a system that makes sure that the customer can return used products to be recycled. The system can be with or without a fee. Environmentally acceptable recycling methods are: • Product and component reuse • Material recycling with secured handling of hazardous chemicals and heavy metals • Pollution-controlled energy recovery of parts of the product	The brand owner (or its representative, associated company or affiliate) shall offer their customers the option to return used products for environmentally acceptable recycling methods in at least one market where the product is sold and where electronics take back regulation is not in practice at the date of application.
A.6.6.3 Preparation for recycling of product packaging material	Packaging constitutes a well-known environmental problem and is regulated in many countries worldwide. Packaging material has a short lifetime and generates large volumes of waste. There are three main areas of concern; hazardous substance content, use of resources and transport volume. Brand owner is the company that owns the brand name visible on the product.	Non-reusable packaging components weighing more than 5 grams shall be possible to separate into single material types without the use of tools. Exempted is reusable packaging.

A.7 Socially responsible manufacturing	Shorter product cycles and growing demand for new technologies put increasing pressure on industry and its complex supply chain to deliver new devices faster and at a low cost. The result is often inadequate working conditions at manufacturing facilities, long working hours, low wages and a lack of health and safety measures. TCO Development aims for greater brand engagement throughout the supply chain by setting criteria and verification routines that create strict social policies toward suppliers, as well as factory audit structures and an open dialog within the IT industry.	

A.7.1 Supply chain responsibility	It is TCO Development's opinion that codes of conduct and factory audits are currently the tools that are most practical to help the majority of brands to work with socially responsible manufacturing in a structured way. It is also TCO Development's opinion that these tools are improving the situation incrementally as long as they are used in the correct and committed way by the brand. The contribution of TCO Certified is: • TCO Certified defines a minimum level of the Brand owner's code of conduct. • TCO Certified is a control system to ensure that the brand takes the responsibility and works in a structured way in accordance with their code of conduct. • TCO Certified creates an incentive for Brand owners to work proactively. Brand owner: The company or organization owning or controlling the brand name. First tier manufacturing facility: Manufacturing plant where the final assembly of the TCO Certified product is taking place. Corrective action plan: A list of actions and an associated timetable detailing the remedial process to address a specific problem.	By signing this mandate the Brand owner agrees to the (1. Commitment) and agrees to conduct the (2. Structured work). Additionally TCO Development requires that the Brand owner show (3. Proof) of the commitment and the structured work by allowing random inspections, by sharing audit reports and corrective action plans and by providing other documented proof described below. 1. Commitment: The Brand owner shall have a code of conduct that is considered consistent with the following in the manufacturing of TCO Certified products: • ILO eight core conventions: 29, 87*, 98*, 100, 105, 111, 138 and 182. • UN Convention on the Rights of the Child, Article 32. • Relevant local and national Health & Safety and Labour laws effective in the country of manufacture. *In situations with legal restrictions on the right to freedom of association and collective bargaining, non-management workers must be permitted to freely elect their own worker representative(s) (ILO Convention 135 and Recommendation 143). 2. Structured work: • The Brand owner shall ensure that routines are in place to implement and monitor their code of conduct in the manufacturing of TCO Certified products. • In the final assembly factories the Brand owner shall ensure the implementation of their code of conduct through factory audits. • In the final assembly factories and in the rest of the supply chain the Brand owner shall ensure that a corrective action plan is developed and fulfilled within reasonable time for all violations against their code of conduct that the Brand owner is made aware of. 3. Proof: • TCO Development may conduct/commission random factory inspections (spot-checks) at any final assembly factory manufacturing TCO Certified products for the Brand owner and may require full audit reports during the certification period in order to assess social commitment and advancement. • TCO Development may also require seeing corrective action plans and auditing reports from factories further down the supply chain to ensure that corrective actions have been successfully implemented. • TCO Development additionally requires the documentation below to be verified by a third party approved verifier.

A.7.2 Senior Management Representative	It is beneficial to all parties that an open and transparent dialogue between TCO Development and the Brand owner exists for the monitoring of compliance with the criteria or when issues concerning working conditions at manufacturing facilities require clarification. A contact person responsible for the organization's efforts to enforce the socially responsible manufacturing criteria needs to be consistently available for dialogue with TCO Development throughout the validity of the certificate.	The Brand owner shall have an appointed Senior Management Representative (SMR) who, irrespective of other responsibilities, has the authority to ensure that the social criteria in the manufacturing of TCO Certified products are met and who reports directly to top management. • The contact details of the SMR shall be submitted and the SMR shall be available for dialogue in English with TCO Development throughout the validity of all the Brand owners' certificates. • To ensure that the SMR has the necessary authority and is working in a structured and proactive way implementing the code of conduct, a review of the SMR shall be done every year according to B.7.2.2.
A.7.3 Conflict minerals	The exploitation and trade of the natural resources Tantalum, Tin, Tungsten and Gold (3T+G) from conflict-affected areas is commonly regarded as a major source of conflict financing. TCO Development supports the underlying goal of the EU conflict minerals measures and those contained in the Dodd Frank Act 1502, but believe it is also vital to support in-region responsible sourcing programs in order to help suppliers meet these due diligence requirements, maintain trade and develop mining that directly benefits the people whose livelihoods depend on a legitimate trade. TCO Development now requires all Brand owners who use TCO Certified to address the issue of conflict minerals in their certified products in a progressive and proactive way. Conflict minerals: Tantalum, Tin, Tungsten and Gold = 3T+G DRC: Democratic Republic of the Congo	The Brand owner shall have a public conflict minerals policy and also indicate all the initiatives they are using/funding. It is TCO Developments opinion that the OECD Due Diligence Guidance for Responsible Supply Cain of Conflict-Affected or High-risk Areas is the most ambitious approach in the list. At least one of the following options shall be marked: • A Due Diligence process based on the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected or High-risk Areas • iTSCi (International Tin Research Institute (ITRI) Tin Supply Chain Initiative). • CFTI (Conflict-free Tin Initiative). • PPA (The Public-Private Alliance for Responsible Minerals Trade). • Other relevant DRC in-region initiative • CFSI (EICC/GeSi Conflict-Free Sourcing Initiative).

Table 19: EPEAT requirements for Mobile Phones.

Area	Requirement
7. Supply Chain Management of Materials	R 7.1.1 Compliance with the European Union REACH Regulation
	O 7.2.1 Reduction of European Union REACH Candidate SVHC Substances
	O 7.3.1 Substitutions assessment
	O 7.4.1 Requesting substance inventory
	O 7.4.2 Receiving substance inventory
8. Sustainable Materials Use	R 8.1.1 Declaration of post-consumer recycled and biobased plastics content
	O 8.1.2 Post-consumer recycled plastic and biobased plastic content in the mobile phone
	O 8.1.3 Post-consumer recycled plastic and biobased plastic content in accessories
9. Substances of Concern	R 9.1.1 Compliance with the European Union RoHS Directive
	R 9.2.1 Restrictions of extractable nickel
	O 9.2.2 Restrictions of DEHP, DBP, and BBP product
	O 9.2.3 Restriction of bromine and chlorine
	R 9.2.4 Restriction of cadmium and mercury in the mobile phone battery cell
	R 9.2.5 Restriction of substances in textile and leather
10. Energy Use Requirements	R 10.1.1 Battery charger systems
	O 10.1.2 Reduction of energy consumption of battery charging systems
	R 10.1.3 External power supply energy efficiency
	O 10.1.4 Reduced maintenance mode power
11. End of Life Management	R 11.1.1 Take-back program
	R 11.2.1 Primary recyclers third party certified
	R 11.3.1 Battery removability/replacement by qualified repair service providers or authorized repair providers
	O 11.3.2 Battery removability/replacement instructions
	O 11.3.3 Battery removability/replacement without use of tools
	R 11.4.1 Ease of disassembling mobile phone
	O 11.4.2 Further ease of disassembling mobile phone
	R 11.5.1 Feature to erase user data from mobile phone
	R 11.6.1 Repair and refurbishment
	O 11.6.2 Further repair and refurbishment
	R 11.7.1 Availability of replacement parts
	R 11.8.1 Notification regarding and the identification of materials and components requiring selective treatment
12. Packaging	O 12.1.1 Use of recyclable fiber based packaging materials

	R 12.2.1 Separability and labelling of plastics in packaging
	O 12.3.1 Use of post-consumer recycled plastic packaging
	R 12.4.1 Expanded polystyrene packaging (EPS) restriction
	R 12.5.1 Recycled content in fiber packaging
	O 12.6.1 Environmentally preferable paper/paperboard in POS packaging
	O 12.6.2 Environmentally preferable paper/paperboard for printed content
	R 12.7.1 Restriction of chlorine in packaging materials
	R 12.8.1 Heavy metal restriction in packaging
	O 12.9.1 Improve packaging efficiency
13. Corporate Sustainability	R 13.1.1 Corporate sustainability (CS) reporting
	O 13.2.1 Corporate sustainability (CS) reporting in the supply chain
	O 13.3.1 Third party assurance of corporate sustainability (CS) reporting
14. Life Cycle Assessment	O 14.1.1 Conducting a life cycle assessment
	O 14.2.1 Product LCA third-party verification of making LCA publicly available
15. Supply Chain Impacts	O 15.1.1 Supplier responsibility
	R 15.2.1 Final assembly facilities environmental management system
	O 15.2.2 Supplier production facilities environmental management system
	R 15.3.1 Conflict minerals public disclosure
	O 15.4.1 Reduce fluorinated gas emissions resulting from flat panel display manufacturing

ANNEX II – REPARABILITY SCORES FOR SMARTPHONES BY IFIXIT

Reparability Scores for smartphones available on the market as published by iFixit[350].

Table 20: Reparability Scores for smartphones available on the market[351]

Model (Year)	Characteristics	Score
Fairphone 2 2015	• Modular design allows replacing battery and screen in seconds with no tools. • Smaller modules can be removed with a standard Phillips #0 screwdriver. • Disassembly instructions are printed on the phone.	10
Motorola Droid Bionic 2011	• Battery can be removed in seconds. • Modular design allows replacement of many individual parts. • Rear camera replacement requires removing an EMI shield.	9
Motorola Atrix 4G 2011	• LCD and front glass are not fused and can be replaced individually. • Battery is easy to replace. • Many components soldered in place, which increases replacement costs.	9
LG G5 2016	• No glue and few screws make for a relatively simple opening procedure. • Many components are modular, making for easier, cheaper part replacement. • The fused display assembly will need to be replaced if the LCD or glass breaks, increasing costs.	8
Xiaomi Redmi Note 3 2015	• Many components are modular and can be replaced independently. • High-wear components are easily replaced. • Components mounted to the back of a fused display assembly.	8
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
Samsung Galaxy S III 2012	• Battery is easy to replace. • Device is easy to open. • Components adhered to the back of a fused display assembly.	8

[350] https://www.ifixit.com/smartphone-repairability?sort=score (accessed on 9 March)

[351] https://www.ifixit.com/smartphone-repairability?sort=score (accessed on 9 March)

Samsung Galaxy Note 2011	• 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
Samsung Galaxy S II 2011	• 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
Nokia N8 2010	• Battery is easy to replace. • LCD and front glass are not fused and can be replaced individually. • Removing the camera is incredibly difficult.	8
Dell Streak 2010	• Device is easy to open. • Battery is easy to replace. • LCD is fused to the glass.	8
Google Pixel 2016	• The battery is secured with removable adhesive tabs, making replacement simple. • Many components are modular and can be replaced independently. • The fused display is thin and unsupported, and must be removed to access any other component.	7
Google Pixel XL 2016	• The battery is secured with removable adhesive tabs, making replacement simple. • Many components are modular and can be replaced independently. • The fused display is thin and unsupported, and must be removed to access any other component.	7
Apple iPhone 7 Plus 2016	• The battery is straightforward to access. • The solid state home button eliminates a common point of failure. • With the addition of tri-point screws, many repairs will require up to four different types of drivers.	7
Apple iPhone 7 2016	• The battery is straightforward to access. • The solid state home button eliminates a common point of failure. • With the addition of tri-point screws, many repairs will require up to four different types of drivers.	7
Meizu MX6 2016	• Front panel is fairly easy to remove and replace. • Many components are modular and can be replaced independently. • Pentalobe screws make opening difficult.	7
Lenovo Moto Z 2016	• Many components are modular and can be replaced independently. • High-wear components are soldered to the main board, making those repairs difficult. • Manufacturer does not share repair information with repair shops or consumers.	7
Vivo X7+ 2016	• Many components are modular and can be replaced independently. • Stiff clips on the rear cover makes opening difficult. • Components mounted to the back of a fused display assembly.	7
Huawei P9 2016	• Many components are modular and can be replaced independently. • The battery is secured with removable adhesive tabs, making replacement simple. • Proprietary pentalobe driver required for opening.	7
Oppo R9m (F1+) 2016	• Many components are modular and can be replaced independently. • Stiff clips on the rear cover makes opening difficult. • Components mounted to the back of a fused display assembly.	7
Wiko Pulp 4G 2015	• Battery can be removed in seconds. • Many components are modular and can be replaced independently. • High-wear components are soldered to the main board, making those repairs difficult.	7
Google Nexus 5x 2015	• Standard Phillips screws make the phone easier to work on. • Many components are modular and can be replaced independently. • LCD is fused to the glass.	7
Apple iPhone 6s Plus 2015	• Front panel is fairly easy to remove and replace. • The battery is easy to access and replace. • Proprietary pentalobe driver required for opening.	7

Apple iPhone 6s 2015	• Front panel is fairly easy to remove and replace. • The battery is easy to access and replace. • Proprietary pentalobe driver required for opening.	7
OnePlus 2 2015	• Standard Phillips screws make the phone easier to work on. • Many components are modular and can be replaced independently. • LCD is fused to the glass.	7
Google Nexus 6 2014	• Many components are modular and can be replaced independently. • A single standard screw type makes repair simpler. • LCD is fused to the glass.	7
Apple iPhone 6 2014	• Improved fingerprint sensor cable routing from the iPhone 5s. • The battery is straightforward to access (if you have a Pentalobe screwdriver). • Apple does not share repair manuals with repair shops or consumers.	7
Apple iPhone 6 Plus 2014	• Improved cable routing, larger case makes access easier. • The relatively easy to access, longer-lasting battery may have an increased lifespan. • Apple does not share repair information with repair shops or consumers.	7
Fairphone 1.0 2014	• The battery can be replaced without any tools. • There are only 8 Phillips screws in the entire device, all standardized. • The Fairphone comes with a set of free, open source repair manuals. • The glass is fused to both the display and the display frame.	7
Motorola Moto X 2013	• Modular design allows replacing of individual components. • Only a single type of screw is used throughout. • Strong adhesive on the rear cover makes opening difficult.	7
Google Nexus 4 2012	• The back cover can be removed with common tools. • Pressure contacts throughout the phone ease disassembly. • The battery is held in place with strong adhesive.	7
Apple iPhone 5 2012	• Front panel is easy to remove and replace. • Battery is relatively easy to replace. • Proprietary pentalobe driver required for opening.	7
Google Nexus S 2010	• Battery is easy to replace. • Standard screws and connectors make the motherboard accessible. • Fused LCD and glass; the front panel is attached with adhesive.	7
Apple iPhone 3GS 2009	• LCD and front glass are not fused and can be replaced individually. • Standard Phillips screws used throughout. • Battery is buried under the logic board, making it difficult to replace.	7
Apple iPhone 3G 2008	• LCD and front glass are not fused and can be replaced individually. • Standard Phillips screws used throughout. • Battery is buried under the logic board, making it difficult to replace.	7
Apple iPhone X 2017	• The battery is straightforward to access. • Many components live on complex cable assemblies, increasing the cost of replacement parts. • Front and back glass doubles the crackability, and rear glass is very difficult to remove if damaged.	6
Google Pixel 2 2017	• Front panel is fairly easy to remove and replace. • Standard screws used throughout. • Cable placement makes battery removal more difficult than necessary.	6
Google Pixel 2 XL 2017	• Many components are modular and can be replaced independently. • Standard Phillips screws used throughout. • Battery is adhered in place and difficult to remove.	6
Apple iPhone 8 Plus 2017	• The battery is straightforward to access. • Wireless charging reduces strain on the single port. • The rear glass is extremely difficult to replace if broken.	6

Apple iPhone 8 2017	• The battery is straightforward to access. • Wireless charging reduces strain on the single port. • The rear glass is extremely difficult to replace if broken.	6
Asus ZenFone 3 Max 2016	• Many components are modular and can be replaced independently. • Stiff clips on the rear cover makes opening difficult. • Components adhered to the back of a fused display assembly.	6
Lenovo K5 Note 2016	• Many components are modular and can be replaced independently. • High-wear components are soldered to the main board, making those repairs difficult. • Components mounted to the back of a fused display assembly.	6
Vivo X7 2016	• Many components are modular and can be replaced independently. • Stiff clips on the rear cover makes opening extremely difficult. • Components mounted to the back of a fused display assembly.	6
Shift 5.1 2016	• Some manufacturer-provided repair documentation exists. • Components adhered to the back of a fused display assembly. • High-wear components are soldered to the main board, making those repairs difficult.	6
Apple iPhone SE 2016	• Battery is fairly easy to access and replace. • The placement of the Touch ID cable makes the opening procedure risky. • Proprietary pentalobe driver required for opening.	6
Xiaomi Mi 5 2016	• Most components are modular and can be replaced independently. • Components adhered to the back of a fused display assembly. • Manufacturer does not share repair information with repair shops or consumers.	6
Huawei Mate 8 2015	• Many components are modular and can be replaced independently. • Standard screws make the device easy to open. • Components mounted to the back of a fused display assembly.	6
Sony Xperia Z5 Compact 2015	• Many components are modular and can be replaced independently. • Adhesive on some components makes repairs more difficult than necessary. • Components adhered to the back of a fused display assembly.	6
Apple iPhone 5s 2013	• Front panel is fairly easy to remove and replace. • Battery is adhered in place and difficult to remove. • Proprietary pentalobe driver required for opening.	6
Apple iPhone 5c 2013	• Front panel is easy to remove and replace. • Battery is adhered in place and difficult to remove. • Proprietary pentalobe driver required for opening.	6
Samsung Galaxy Nexus 2011	• Battery is easy to replace. • Only the volume switch and vibrator motor are soldered in. • The glass is fused to both the display and the display frame.	6
Apple iPhone 4s 2011	• Screws and limited adhesive ease opening. • The back panel is easy to remove, but requires a pentalobe driver. • LCD is fused to front glass.	6
Motorola Droid 3 2011	• Battery is easy to replace. • Many components on a single cable, which increases cost of parts. • LCD replacement requires disassembly of the entire device.	6
Apple iPhone 4 2010	• Screws and limited adhesive ease opening. • Modular design allows replacement of many individual parts. • Replacing the rear camera requires removing an EMI shield.	6
Samsung Galaxy S 4G 2010	• Modular design allows replacing of individual components. • Battery is easy to replace. • LCD is fused to front glass.	6
LG G6 2017	• Many components are modular and can be replaced independently. • Components adhered to the back of a fused display assembly. • Front and back glass doubles the crackability, and strong adhesive on both makes it tough to begin any repair.	5

Samsung Galaxy Alpha 2014	• The battery is incredibly easy to remove and replace. • The glued in display requires heat and careful prying to remove without cracking the glass. • Replacing anything other than the battery requires first removing the display.	5
Samsung Galaxy S5 Mini 2014	• The battery is incredibly easy to remove and replace. • The display is the first components out, but it is glued in place. • Replacing anything other than the battery requires first removing the display.	5
OnePlus One 2014	• Many components are modular and can be replaced independently. • Battery is difficult to replace. • LCD is fused to the glass.	5
Samsung Galaxy S5 2014	• The battery is incredibly easy to remove and replace. • The glued in display requires heat and careful prying to remove without cracking the glass. • Replacing anything other than the battery requires first removing the display.	5
HTC Surround 2010	• Battery is relatively easy to replace. • Accessing the internal MicroSDHC card voids the warranty. • Very difficult to access the front panel and LCD for replacement.	5
Samsung Galaxy Note8 2017	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and strong adhesive on both makes it tough to begin any repair. • The battery is very strongly adhered to the back of the display and buried beneath the midframe.	4
Samsung Galaxy S8+ 2017	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and strong adhesive on both makes it tough to begin any repair. • The battery is very strongly adhered to the back of the display and buried beneath the midframe.	4
Samsung Galaxy S8 2017	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and strong adhesive on both makes it tough to begin any repair. • The battery is very strongly adhered to the back of the display and buried beneath the midframe.	4
Samsung Galaxy Note7 2016	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and rear glass is very difficult to remove to get into the device. • Adhesive on some components makes repairs more difficult than necessary.	4
Samsung Galaxy S6 2015	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and rear glass is very difficult to remove to get into the device. • The battery is very tightly adhered to the back of the display, and buried beneath the midframe.	4
Motorola Droid 4 2012	• LCD and front glass are not fused and can be replaced individually. • Tons of adhesive seals the phone and its components. • Replacing the front glass requires complete phone disassembly.	4
Motorola Droid RAZR 2011	• Battery is relatively easy to replace. • All plastic frames and casings are incredibly tedious to remove. • The front panel is adhered to the display.	4
Samsung Galaxy S7 Edge 2016	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and rear glass is very difficult to remove to get into the device. • Replacing the screen or battery without damaging other components is very difficult and requires special tools.	3

Samsung Galaxy S7 2016	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and rear glass is very difficult to remove to get into the device. • Replacing the screen or battery without damaging other components is very difficult and requires special tools.	3
Samsung Galaxy S6 Edge 2015	• Many components are modular and can be replaced independently. • Front and back glass doubles the crackability, and rear glass is very difficult to remove to get into the device. • The battery is very tightly adhered to the back of the display, and buried beneath the midframe and motherboard.	3
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
Google Nexus 6P 2015	• Solid external construction improves durability. • Very difficult to open without damaging the phone. • Tough adhesive on access panels and the battery.	2
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