Ecodesign preparatory study on mobile phones, smartphones and tablets

Final Task 3 Report

Users (product demand side)

Written by Fraunhofer IZM, Fraunhofer ISI, VITO
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Authors:

Karsten Schischke (Fraunhofer IZM)
Christian Clemm (Fraunhofer IZM)
Anton Berwald (Fraunhofer IZM)
Marina Proske (Fraunhofer IZM)
Gergana Dimitrova (Fraunhofer IZM)
Julia Reinhold (Fraunhofer IZM)
Carolin Prewitz (Fraunhofer IZM)
Antoine Durand (Fraunhofer ISI)
Bernd Beckert (Fraunhofer ISI)

Contributors:

Clemens Rohde (Quality control, Fraunhofer ISI)
Simon Hirzel (Quality control, Fraunhofer ISI)
Mihaela Thuring (Quality control, contract management, VITO)

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Contact: Davide Polverini

E-mail: davide.polverini@ec.europa.eu

European Commission
B-1049 Brussels

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1. GLOSSARY

Term	Definition
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
5G	5th Generation
ADSL	Asymmetric Digital Subscriber Line
AEC	Acoustic Echo Cancellation
ANSI	American National Standards Institute
BAT	Best Available Technologies
BB	Broadband
BE	Belgium
BNAT	Best Not yet Available Technologies
CP-OFDM	Cyclic Prefix - Orthogonal Frequency-Division Multiplexing
DECT	Digital Enhanced Cordless Telecommunications
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
ES	Spain
ETNO	European Telecommunications Network Operators
ETR	Effective Tax Rate
ETSI	European Telecommunications Standards Institute
EU	European Union
EUR	Euro
FAMGA	Facebook, Apple, Microsoft, Google and Amazon
FTTB	Fibre-to-the-Building
FTTC	Fibre-To-The-Curb
FTTH	Fibre-to-the-Home
FTTP	Fibre to the Premises
GB	Gigabyte
GHG	Greenhouse Gas
GmbH	Gesellschaft mit beschränkter Haftung
GSM	Global System for Mobile Communications
GSMA	Groupe Speciale Mobile Association
HD	High Definition
HFC	Hybrid Fibre-Coaxial
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
ICT	Information and Communications Technology
IDC	International Data Corporation
IEEE	Institute of Electrical and Electronic Engineers
IMT	Intima-Media Thickness
IoT	Internet Of Things
IP	Internet Protocol

ISI	Institut für System- und Innovationsforschung
IT	Italy
IZM	Institut für Zuverlässigkeit und Mikrointegration
kWh	Kilowatt Hour
LCC	Life Cycle Cost
LLCC	Least Life Cycle Cost
LTE	Long Term Evolution
Mbps.	Megabyte per Second
MEErP	Methodology for the Ecodesign of Energy-related Products
MP3	MPEG Audio Layer 3
MS	Member State
NIS	Network and information systems
OEM	Original Equipment Manufacturer
OHA	Obsoleszenz als Herausforderung für Nachhaltigkeit
OS	Operating System
PT	Portugal
SIM	Subscriber Identity Module
SOH	State Of Health
TV	Television
TWh	Terawatt Hour
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
US	United States
USD	US-Dollar
VDSL	Very High Speed Digital Subscriber Line
VITO	Vlaamse Instelling voor Technologisch Onderzoek
W	Watt
WCDMA	Wideband Code Division Multiple Access
WIFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

2. INTRODUCTION

According to the Ecodesign Working plan 2016-19, "Given their specificity, a separate track is proposed for ICT products..., that will also fully take into account their circular economy potential, which is particularly relevant in the case of mobile / smart phones". Within this context, DG GROW launched this preparatory study on mobile phones, smartphones and tablets in order to assess the feasibility of proposing Ecodesign and/or Energy Labelling requirements for these product groups. Preparatory studies aim to assess and specify generic or specific ecodesign measures for improving the environmental performance of a defined product group, sometimes in combination with energy label criteria. The ecodesign preparatory studies therefore provide the scientific foundation for defining these generic and/or specific ecodesign requirements as well as energy labelling criteria. The overall objective is to clearly define the product scope, analyse the current environmental impacts of these products and related systems (extended product scope) and assess the existing improvement potential of any measures. In particular, aspects relevant to the circular economy, are in the scope. The central element of the MEErP, being the underlying assessment methodology, is to prioritise today's possible improvement options from a Least Life Cycle Cost (LLCC) perspective. Identification of the improvement options are based on possible design innovations, Best Available Technologies (BAT) for the short term and Best Not yet Available Technologies (BNAT) for long term, which can help in mitigating the impacts of these products. Policy options are assessed through a scenario analysis and the different outcomes have to be evaluated from the perspective of the EU targets, taking into account potential impacts on the competitiveness of enterprises in the EU and on the consumers.

The overall objective of Task 3 is to **analyse such consumer behaviour and local infrastructure aspects which may influence the environmental performance of products in scope**. To some extent, product-design can be used to influence a consumer's behaviour so as to modify the environmental impacts associated with the product use. Vice versa, specific use of a particular product can influence its environmental impact. Identified use cases may help to improve LCC calculations and will inform the definition of base-cases in subsequent tasks. Furthermore, "real-life" usage scenarios might build the basis for changes in existing standard measurement and testing methods.

Where appropriate the distinction of private and professional user and respective user behaviour will influence the definition of the use pattern and lifetime assumptions. Smartphones are multifunctional devices that have many different and still increasing application options (app store). The utilisation intensity may vary significantly depending on the actual product configurations (e.g. installed applications, functional accessories, dual sim cards and extended storage). All these aspects are relevant for the following analysis.

3. SUBTASK 3.1 – SYSTEMS ASPECTS OF THE USE PHASE FOR ERPS WITH DIRECT IMPACT

The use phase analysis comprises reasons for buying (or rarely leasing) a new or used device, typical use patterns, including use of applications and device functions, charging patterns and frequency, and accidental drops, spillage and similar events which eventually leads to product malfunctions or damages and the decision to repair, not to repair or to replace a device.

3.1. Purchase decisions and contracts

When purchasing a new smartphone, some features are more important than others for consumers. Figure 1 shows the results of a survey conducted in 2015 in Germany highlighting the most important purchasing criteria. The interviewed persons were 14 years and older. The most important criteria cited were a long battery life (almost 70%) and good internet and Wi-Fi access. For 40% of respondents a high-quality finish was a major purchase criteria.

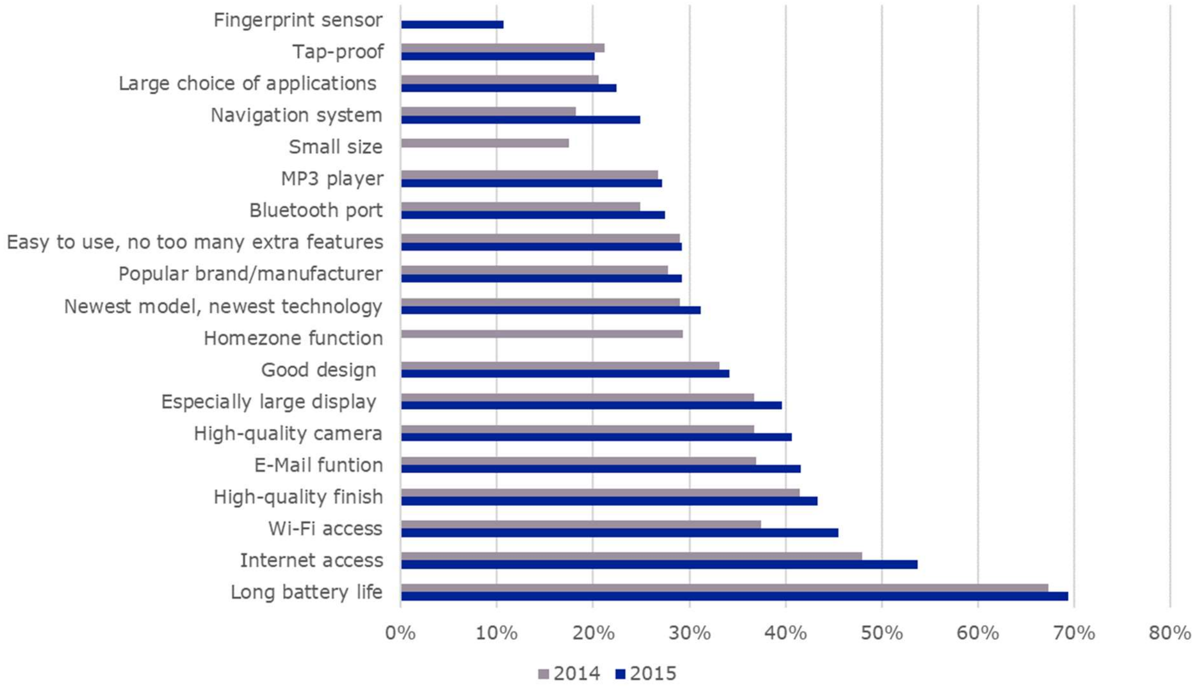


Figure 1: Most important criteria for buying a new mobile phone or smartphone in Germany[1]

A later online survey among German consumers (n=1813) in 2017 focussed again on purchase criteria for smartphones. On the question, which aspects played an important role for selecting a smartphone, long-lasting battery and robustness and durability were the most important criteria, see the following Figure. These factors are closely linked to characteristics of long-lasting smartphones.

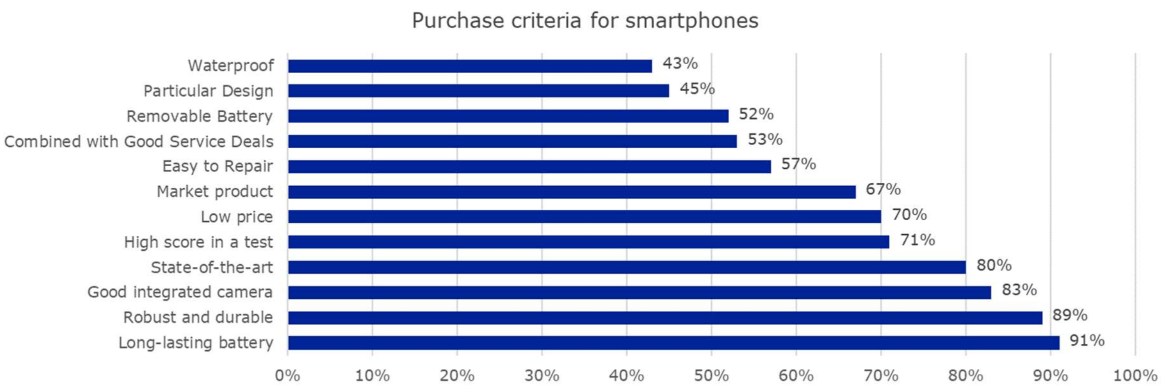


Figure 2: What role did the following aspects play in selecting the current smartphone? Percentages represent the sums for the answers "a rather large" / "a large role" (n = 1813) (Jaeger-Erben and Hipp 2018)

[1] https://www.statista.com/statistics/463196/mobile-and-smartphones-purchase-criteria-germany/

Most recent representative data from Bitkom[2] published in February 2020 confirms in general the interest in (more) robust devices (Figure 3). A robust display is much more important than 5G. Battery life per charge is also of high importance – and at the same time fast charging is appreciated. High water resistance is another important purchase criterion, and large storage capability.

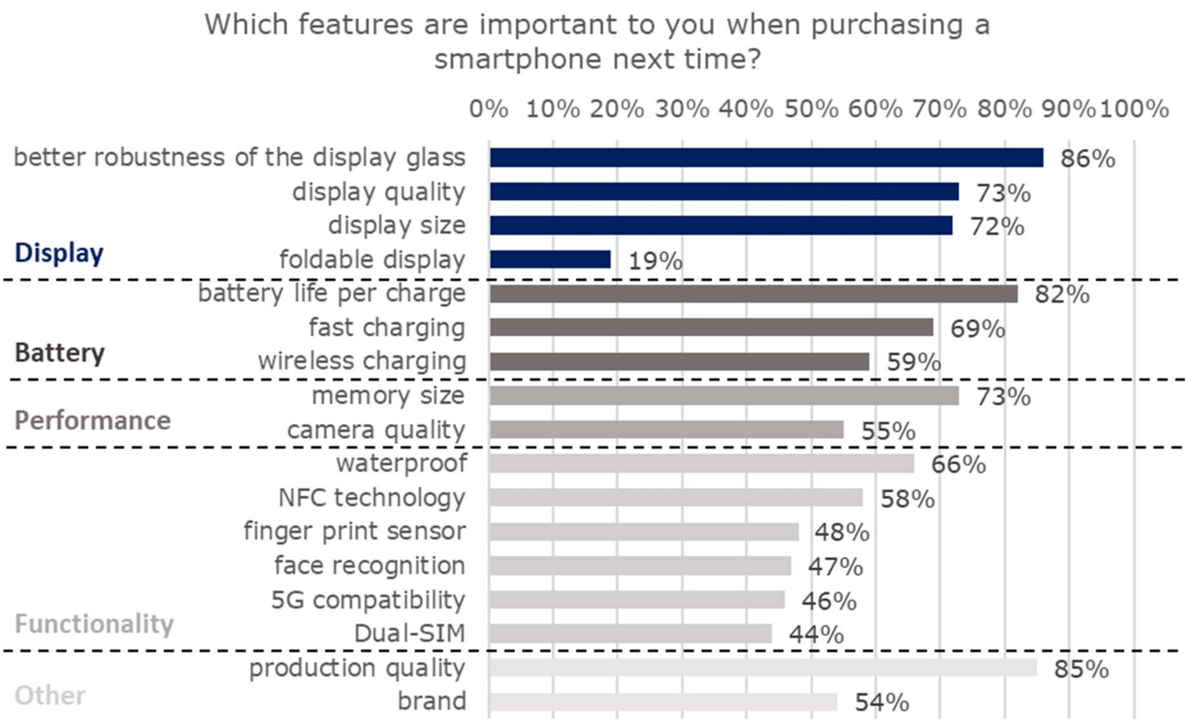


Figure 3: Survey on purchase criteria for the next smartphone, Germany, 2020

In a recent Eurobarometer survey (European Commission 2020b) the reasons for purchasing a new digital device respondents replied to

- 37% old device **broke**
- 30% the **performance** of the old device had significantly deteriorated
- 19% certain applications or **software** stopped working on the old device

In the same survey a majority of 64% of the respondents would like to keep using their current digital devices for at least 5 years.

A survey back in 2016 initiated by Greenpeace led to similar findings (Stuart Smedley 2016): 37% of the users (multiple answers allowed) wanted to get a more up-to-date device, 26% stated the former device was broken. 14% received a new phone as a gift, 12% upgraded due to functions, which the replaced device didn't offer.

[2] https://www.bitkom.org/Presse/Presseinformation/Markt-rund-um-Smartphones-waechst-auf-36-Milliarden-Euro

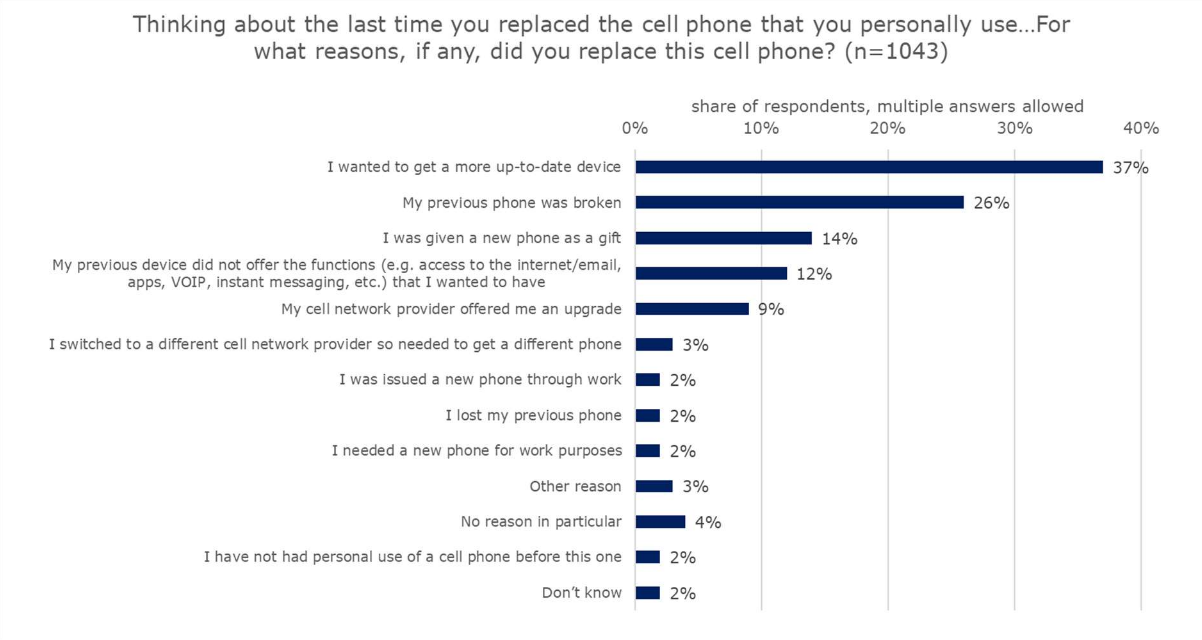


Figure 4: Reasons mobile phone replacement, Germany, 2020

In a study on circular economy aspects seen from a consumer perspective (Cerulli-Harms et al. 2018) the product group smartphones has been investigated among few other product groups. Key findings from focus group interviews on durability are:

Focus group participants in the four countries Czech Republic, Sweden, Germany, and Ireland considered **durability** to be highly important and were very interested in purchasing products that lasted longer: "This was particularly the case for products that participants considered to be "important investments", such as dishwashers and washing machines." In our understanding some high-end smartphones (and tablets) can also be considered "important investments", so this durability statement might hold true for this market segment as well. Cerulli-Harms et al. however distinguish only between product groups: Compared with the unanimous importance of durability for white goods "opinions with regard to the importance of durability varied more when talking about other types of products. Some participants felt that durability was just as important for products such as televisions and smartphones, while for others, technological progress was a factor influencing them to purchase this type of products more frequently, and therefore their expectations with regard to these products' lifetime were lower."

Participants were asked in this representative EU-wide consumer survey (12 EU countries covered) for their preference for new gadgets compared to second hand (Cerulli-Harms et al. 2018). In contrast to other product groups, new electronic goods and gadgets seemed to be particularly important to participants. Overall, 45% agreed to always buy new gadgets including 8% who even strongly agreed. These results could indicate, that measures for lifetime extension targeting at repair, reuse, refurbishment will not be embraced by half of the consumers. On the other hand, this half of the market might tend to give devices away for a second use.

Leasing could be a product-service approach to increase sustainability of smartphones and research by Rousseau sheds some light on this issue: Support for leasing smartphones cannot be taken for granted. A majority of respondents in a survey among millennials in Flanders, Belgium, were not open to leasing smartphones. The main barriers were the uncertainty regarding the consequences of entering into a lease contract, financial considerations and the role smartphones play in determining the self-identity of young consumers. Environmental concerns, financial considerations and a desire to own the latest model were stated as possible drivers of adopting such a product-service system. (Rousseau 2020; Sabbaghi and Behdad 2018)

Cerulli-Harms et al. also asked for the perception of **purchasing refurbished electronics,** including explicitly smartphones, and observed different reactions depending on the country: In Ireland, some of the focus group participants were more willing to purchase refurbished products, "as long as they felt that the price-quality ratio was good, or that there was a large price difference between refurbished (or second hand) products and new ones. Others were concerned with the fact that products bought refurbished or second hand would break down more easily." In the Czech Republic, purchasing refurbished electronics was not very common for the focus group participants, and some participants even had bad experiences with such purchases. This latter aspect is important, as it points at the need for quality assured refurbished products for a better perception of second hand electronics, thus likely better acceptance.

The Impact Assessment study on a common charger found out that only 9% are willing to buy a phone without a charger, given the device is sold at the same price. 36% expect a price discount for a phone without charger, thereof 7% are willing to accept a compensation of 10 Euros, which is roughly the cost of a separately sold charger. 30% are willing to accept a phone without a charger, but only at a compensation, which significantly exceeds the price of a stand-alone charger (Figure 5).

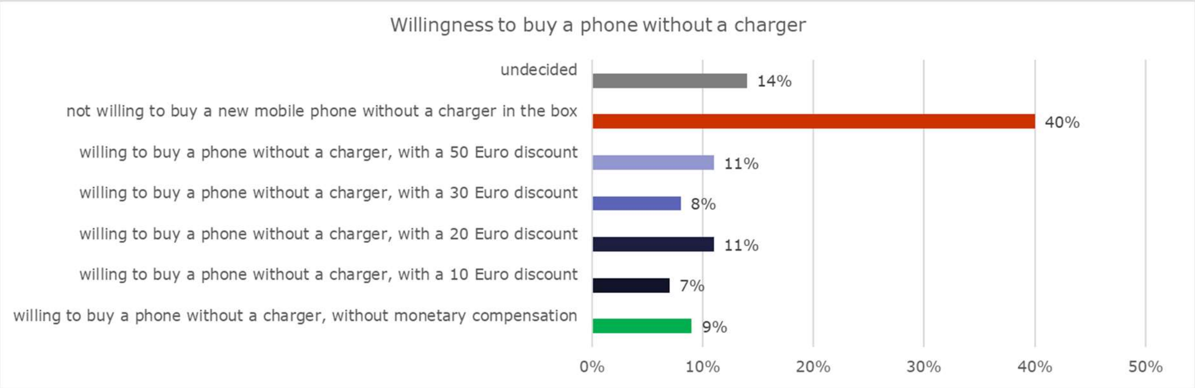


Figure 5: Willingness to buy a mobile phone without a charger (Ipsos, Trinomics, Fraunhofer FOKUS, Economisti Associati 2019)

"Among those who were unwilling to consider buying a phone without a charger, 68% indicated that the charger provided with the new phone saved the trouble of finding the right charger. The bundle was also perceived as an assurance that the charger would work properly (38%), that it was safe because from the same brand as the phone (35%), and that it would charge the mobile phone efficiently (23%). 55% of those that would consider buying a phone without a charger would do so for environmental reasons, as they indicated that it would help them to save resources and reduce e-waste." (Ipsos, Trinomics, Fraunhofer FOKUS, Economisti Associati 2019)

In an unpublished survey in May and June 2020 a telecommunications provider asked their customers to state relevance of a range of aspects when buying a smartphone from a telecommunications provider. Respondents in all 5 EU countries where this survey was undertaken mentioned "device quality" as the most important aspect (roughly 90% of respondents in all countries). "Sustainability of the device" is important to 50% of the respondents in Germany and to 75 – 90% of the respondents in other EU countries. Except for Germany sustainability is more important than the smartphone brand (60 – 75%) and close to price (80 – 90%). These recent results confirm the recognised trend towards increasing importance of sustainability as purchase criterion. It is however worthwhile noticing, that price and brand are obvious characteristics of a smartphone, whereas "sustainability" is a less transparent feature, thus might not be taken into account in purchasing decisions to the same degree than other transparent criteria.

There are basically two types of **mobile phone contracts** (Bisping and Dodsworth 2019):

- prepaid or monthly rolling contracts, where the customer either pre-pays or post-pays for a service on a monthly basis without commitment beyond one month
- contracts with a pre-determined initial commitment period of over one month, where the customer will pay a set fee for at least the number of months set out in the contract term. These contracts can include the provision of a handset, or they can be SIM-only, i.e., limited to the provision of telephony services. Providing the handsets with the contract is frequently factored-in with the subscription price

Frequently consumers do not have a separate mobile phone or landline or broadband contract, but a bundled contract. 68% of all EU citizens have their telco services bundled in one contract, with lower rates in Poland and Sweden (Ipsos 2017).

In a recent paper studying Asian consumers' acceptance towards refurbished smartphones, Chun et al. found that consumers' intentions to purchase a refurbished smartphone are strongly influenced by the perceived risk of a refurbished device (Chun et al. 2020). Since many consumers still don't trust the quality of refurbished products, one recommendation of the authors is to take direct measures to enhance this trust.

3.2. Active use lifetime

3.2.1. Actual use

Mobile Device users in the UK where asked in a survey by YouGov about product upgrades[3]. Being asked how long they use a device before buying a new one, the survey results show shorter upgrade cycles for smartphones than for tablets: Almost 70% of all respondents upgrade to the next smartphone within 1 to 4 years, whereas only 30% of tablet users upgrade within the first 4 years. 5-6 years is the upgrade cycle of smartphones for a significant share of 15% of the respondents. One third of the respondents upgrade tablets in year 5 or 6. These findings roughly correspond to the market data presented in the task 2 report.

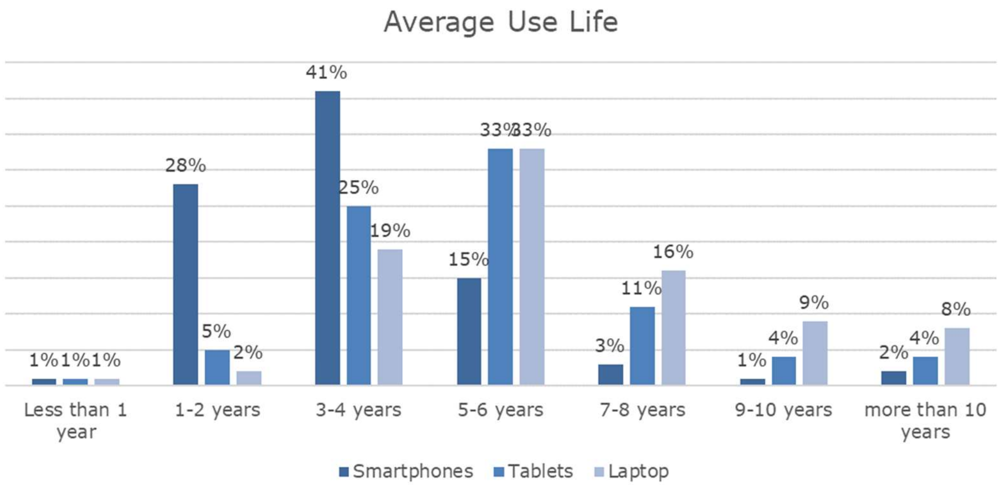


Figure 6: On average, how long do you tend to own the following devices before buying a new one? (source : YouGov Research, 2020)

[3] https://yougov.co.uk/topics/technology/articles-reports/2020/05/07/45-smartphone-owners-would-rather-upgrade-repair

In conjunction with the Impact Assessment of a common charger solution a user survey also asked how frequently users buy a new mobile phone. One third state to acquire a new mobile phone every 2 years, almost 60% acquire a new phone less frequently (Figure 7). This data also indicates an average replacement cycle of 3,2 – 3,4 years for mobile phones (i.e, actual product lifetime is longer due to reuse of some of the devices, see Task 2 report).

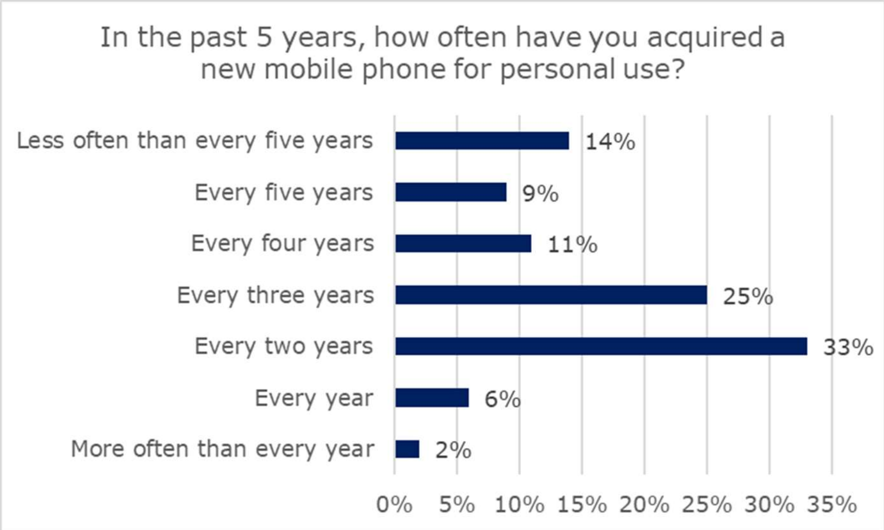


Figure 7: Frequency of acquiring a new mobile phone (Ipsos, Trinomics, Fraunhofer FOKUS, Economisti Associati 2019)

In general users tend to use their smartphones increasingly longer (Figure 8) and market experts state this is due to the maturity of the devices, less issues with the owned handsets, because users have found their preferred model or brand, and as the prices of high-end devices are on the rise (Ng 2019).

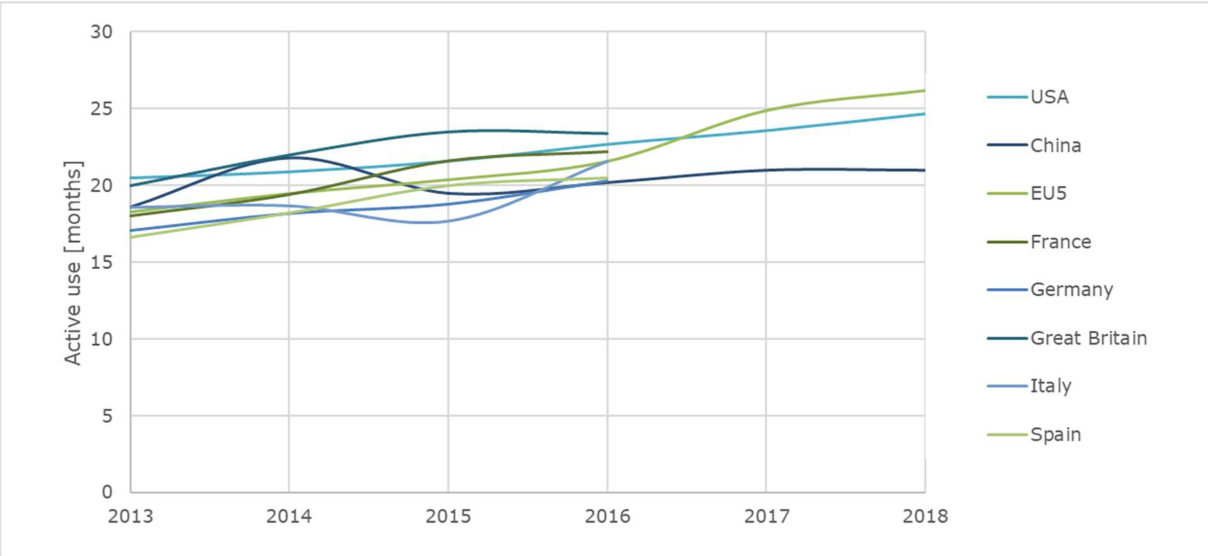


Figure 8: Active use in months according to (Kantar Worldpanel 2017) and (Ng 2019)

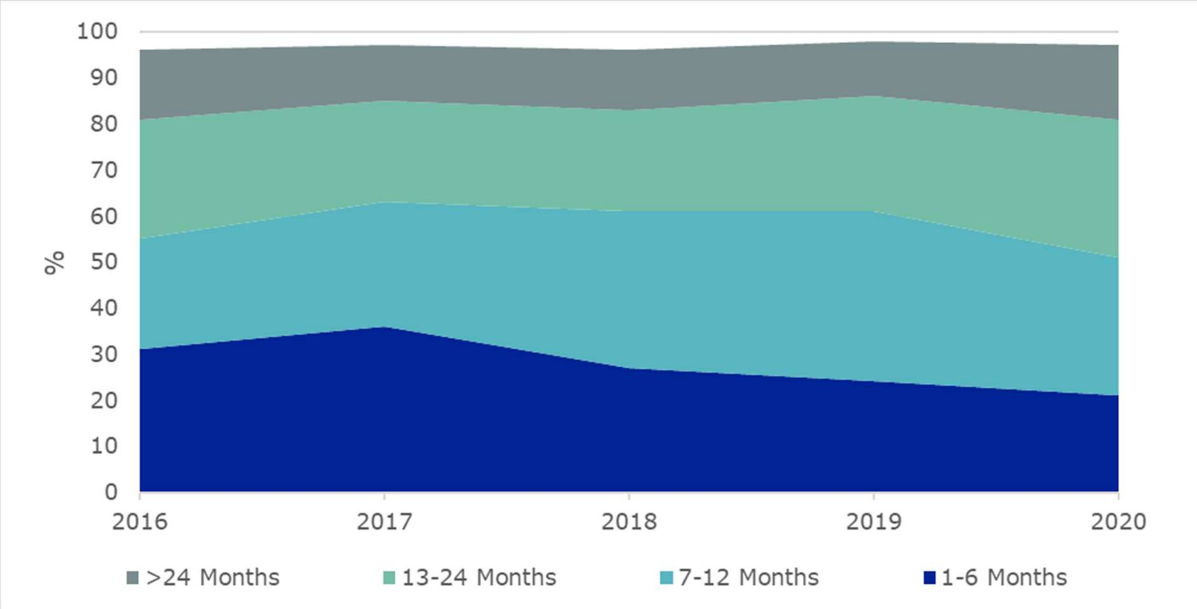


Figure 9: « When was the currently used smartphone bought », survey by Bitkom in Germany (Ametsreiter 2016, 2017, 2019, 2020; Haas 2018)

Use time of devices can also be roughly estimated through the release date of the devices and the correlated data traffic. According to (DeviceAtlas 2019), the majority of devices used in the first quarter of 2019 are from 2016 and 2017, but about 10% of the devices are from 2013 and 2014. The age of the devices is linked to the release date. Active use might have started significantly later.

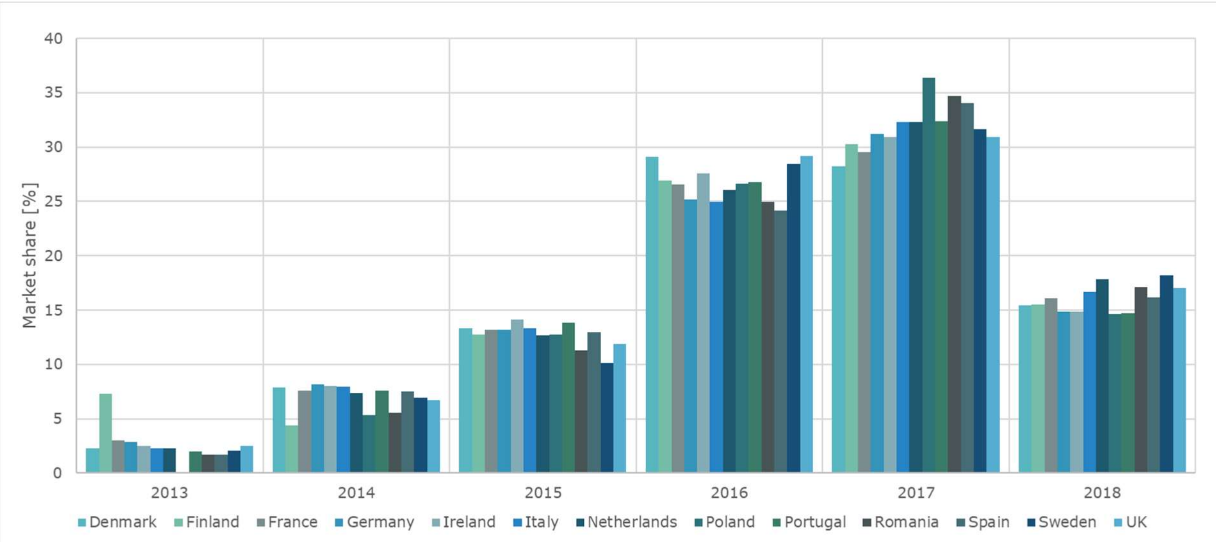


Figure 10: Release year of devices used in the 1st quarter 2019 according to (DeviceAtlas 2019)

3.2.2. Lifetime expectation

Numerous surveys have been conducted in the last years on the expected lifetime of smartphones in different countries.

A survey of Austrian consumers on expected and actual product lifetimes of mobile phones (Wieser et al. 2015) shows that consumers seem to expect a mobile phone to perform its function significantly longer than they will actually use their own device (Table 1).

Table 1: Results from the survey study about 'expected' and 'actual' lifetime of mobile phones (Wieser et al 2015).

	Question	Answer (average)
Expected Lifetime	'How long do you expect a mobile phone to last or flawlessly function under normal intensity of use' (n=996)	5.2 years
Actual Lifetime	'How long would you normally use a mobile phone before storing, disposing or discarding?' (n=842)	2.7 years

A survey among German consumers in 2017 also asked for the expected lifetime of smartphones (Jaeger-Erben and Hipp 2018): The average expected lifetime is roughly 4 years with a share of 9% expecting a long lifetime of more than 8 years (Figure 11). The researchers noted that this outlier might be rather a general wish for long lasting smartphones instead of experience-based expectations.

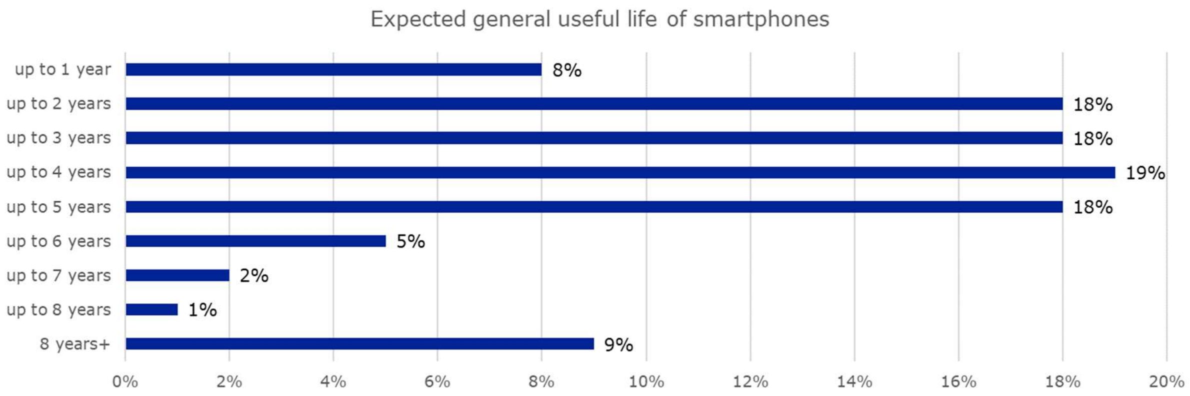


Figure 11 : How long should a smartphone hold in your view? (n = 1813)

A third survey conducted with students in the U.S. comes to the conclusion that the expected lifetime of a smartphone is 2.8 years (Sabbaghi and Behdad 2018).

These figures correspond roughly to the analysis presented in Task 2 regarding actual lifetimes.

3.3. General device use

There is a multitude of statistics available, what in particular smartphones are used for. Multi-functionality as such is an interesting feature for eco-design as it might lead to replacement effects elsewhere (e.g., digital still cameras replaced by smartphones). For the analysis in this study, emphasis is put on those use characteristics, which are likely to have an effect on use lifetime. These are mainly trends, which require more powerful computing and better connectivity. Such performance requirements might make devices obsolete for the user.

Figure 12 shows results of a global survey on the amount of time spent on daily smartphone usage in 2017. As of that time, almost half of the respondents spent five or more hours on their smartphones daily. More than 25% spent even more than seven hours every day using their device.

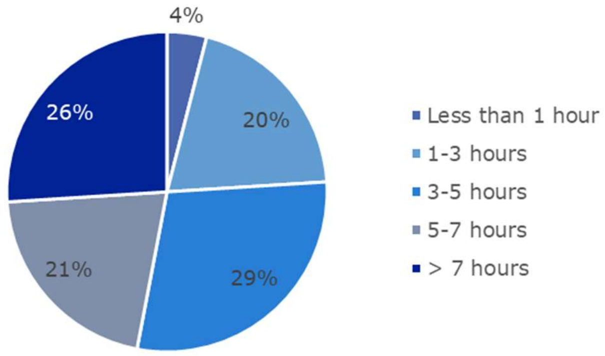


Figure 12: Average hours spent on smartphone/day[4]

Very intensive use of mobile devices can become a health issue (addiction), but also stresses the device, due to more frequent charging of the battery. Such use patterns however hardly can be influenced by measures, such as pop-up notifications on the screen regarding use times, as research suggests (Loid et al. 2020) : In an experiment notifications regarding excessive smartphone use did not lower self-reported problematic smartphone use, nor participants' screen time or the frequency of phone-checking behaviour.

According to a 2017 survey in the UK less demanding functionalities where dominating, such as texting, e-mails, social media usage (Figure 13). Camera usage was next. Only 41% made or received phone calls on a daily basis, similar to watching videos on YouTube (42%). The high use share of social media apps however points at the need, that these apps need to be compatible with the OS version running on a device.

Discontinuing the app support for an older operating system can trigger obsolescence of otherwise still properly working phones: An example is WhatsApp. Support for iOS 7 and Android 2.3.7 was discontinued early 2020, affecting iPhones sold until 2013 and Android phones until 2011[5]. As the data on wished smartphone lifetime indicates, this is against the smartphone lifetime expectancy of slightly more than 10% of all smartphone users (Figure 11) but actually a potential issue for less than 5% of all smartphone users who still use such old phones (Figure 6 and Figure 10).

[4] https://www.statista.com/statistics/781692/worldwide-daily-time-spent-on-smartphone/

[5] https://metro.co.uk/2020/01/20/whatsapp-users-urged-buy-new-phones-millions-set-become-obsolete-12087872/

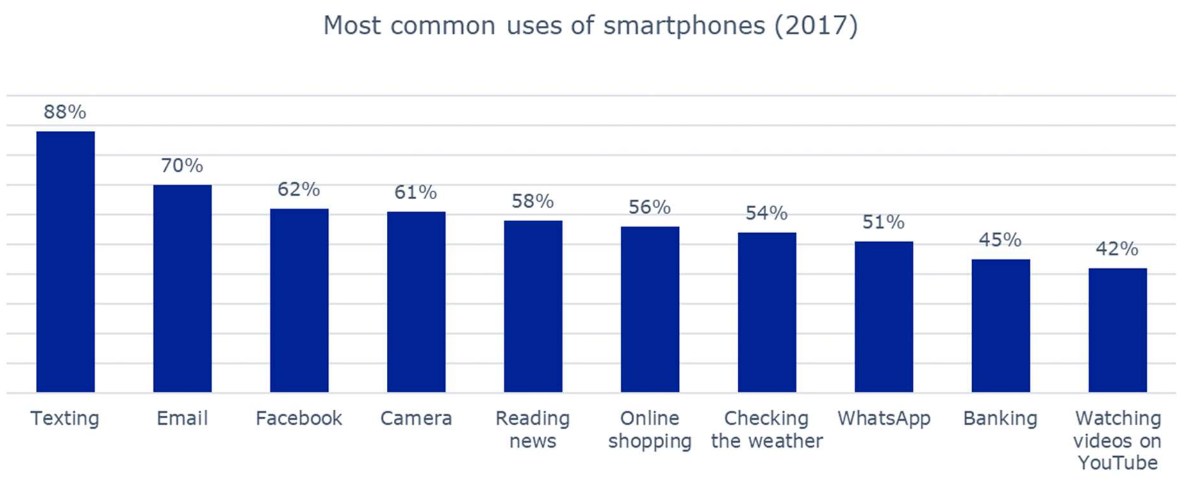


Figure 13: Most common uses of smartphones, UK, 2017[6]

The share of people watching videos on mobile phones is steadily increasing: In Europe this figure is forecasted to grow from 330 million users in 2019 to 370 million users in 2023 (eMarketer 2019).

Video streaming on smartphones increased steadily over time, reflecting also the increasingly larger displays. In 2019 83% of all smartphone users in Germany watched streamed videos on these devices (Bitkom Research GmbH 2019). The figure for tablets is even higher, but went down in 2019 for the first time. Compared to these devices laptops throughout the years were very popular for video streaming at a constant high value of 90% or slightly below of all laptops (Figure 14).

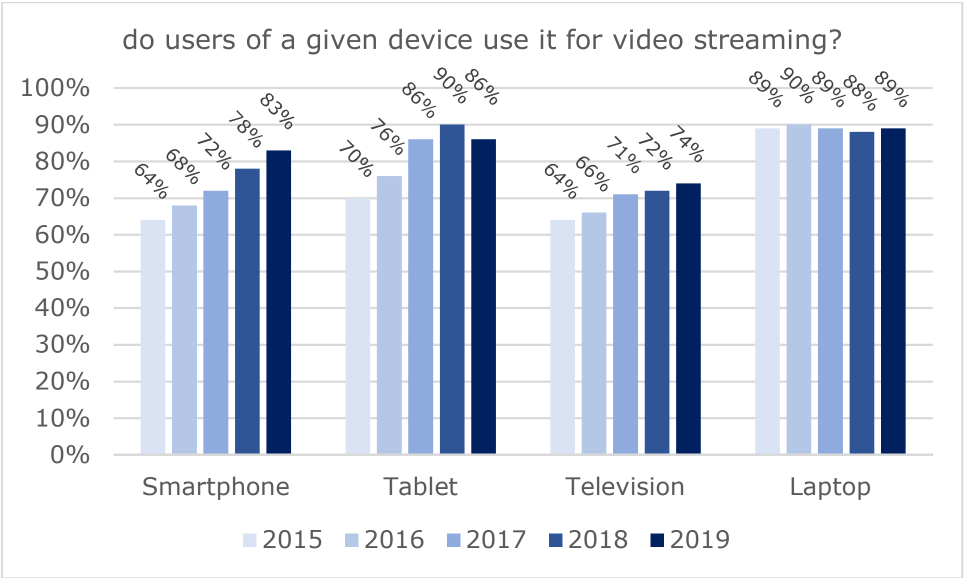


Figure 14: Use of smartphones and tablets compared to TV sets and laptops for video streaming, Germany, 2015-2019

As of 2019 63% of global mobile data traffic is related to videos. The data traffic due to social networking applications is next, but much lower. In the range of few percent each are web browsing, audio, and software downloads and updates. (Ericsson 2020)

Users of smartphones in Germany spent on average 152 minutes on the internet on weekdays, and 202 minutes on the weekend (Saturday and Sunday combined) in 2018.

6 https://www.gadget-cover.com/blog/what-are-the-most-popular-reasons-why-people-use-their-smartphones-every-day

Tablets are used less frequently, but still 96 minutes in average for internet access on weekdays and 123 minutes on weekends (DCORE GmbH 2018).

Data traffic is constantly increasing in terms of GB per smartphone. These dynamics are not the same in all global regions. According to data by Ericsson in Western Europe data traffic per device will triple in the next five years (Ericsson 2020). For Central and Eastern Europe the same factor applies, but on a lower overall level, mirroring almost exactly the global average dynamics. Data traffic per smartphone in Western Europe will exceed 35 GB by 2025 and in Central and Eastern Europe 20 GB (Figure 15).

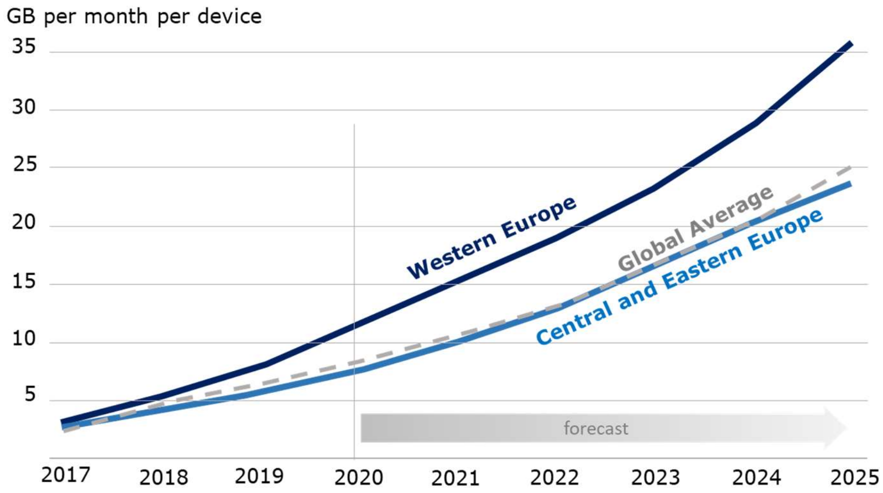


Figure 15: Mobile data traffic per smartphone (GB per month), Europe, 2017-2025

This trend is correlated with the adoption of 5G: In Central and Eastern Europe, LTE became the dominant technology in 2019, and now accounts for 43% of all subscriptions. In 2025, LTE is forecasted to account for even 66% of mobile subscriptions, while 5G subscriptions are forecast to make up 27% by then. Correspondingly, there will continue to be a significant decline in WCDMA/HSPA, from 38% as of 2020 to 3% of all subscriptions. In Western European countries, currently LTE is by far the dominant access technology, accounting for 68% of all subscriptions, but will decline to 43% and WCDMA/HSPA to only 2% of subscriptions by 2025. The 5G subscription penetration is projected to reach 55% in Western Europe by the end of 2025, which is a faster uptake than for 4G in the past. (Ericsson 2020)

3.4. Battery charging patterns

Battery charging behaviour has an impact on real-life ageing of the battery and thus battery lifetime. A study (Ferreira et al. 2011) from the early days of smartphones analysed battery charging behaviour with 4035 participants over a period of four weeks, during which anonymous battery information was collected from Android devices running Android 1.6 or higher (at that time).

The visualization in Figure 16 shows the average battery available at different hours of the day, across all the users, and how frequently the percentage was observed, when the battery was not being charged. Each bubble represents a different day of the study, for a given hour (size and colour correspond with how frequently the percentage was observed at a given hour of the day).

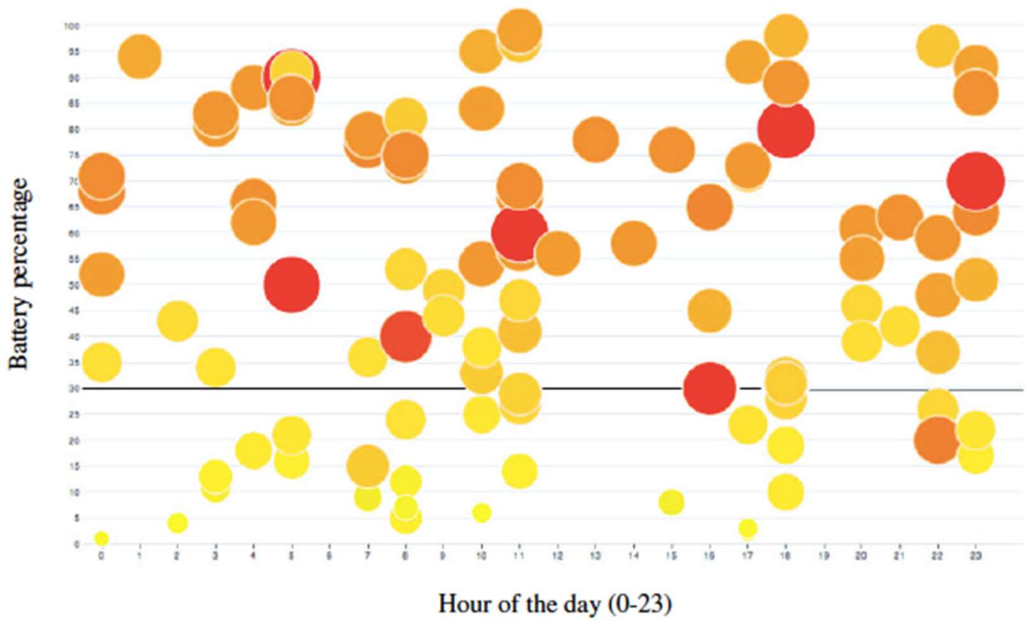


Figure 16: Average battery levels during the day (when not charging) (Ferreira et al. 2011)

These results and findings on charging durations (Figure 16) indicate the following charging patterns:

- Most users avoided battery levels below 30 %
- On average the lowest average battery level was 65% at midnight, while the highest was 74% at 5 am.
- Most people charge their phone for a small period (0-30 min), but there is also a significant share of users with devices plugged in for extended periods of time (above 14 hours)

Battery charging behavior has an impact on real-life ageing of the battery overall performance and battery lifespan. In July 2020 a smartphone OEM[7] analyzed smartphone users charging behaviour in their daily life, which was based on 345 anonymous participants in EU.

The findings on the scenarios of charging smartphone across all the users (Figure 17):

- Most (79%) of users charge their phone overnight
- 35% charge their phone frequently during their daily spare time
- 20% of users charge their phone during the day when they are working or studying.

The findings of this survey seem to indicate that a majority of the users charges phones overnight, which is likely to mean charging up to 100% charging level and then the device is likely to remain in trickle charge mode for several more hours. A stakeholder indicated that most smartphones and tablets do not use trickle charge, but charge up to a certain level, typically 100%, after which charging is terminated and only until the charge level has fallen to below a certain threshold, e.g. 95%, charging is initiated again. Statistical data to underpin this statement is missing, though. A substantial share of users also charges for very short times only as conditions permit. Such a use pattern actually could

[7] Results have been shared with the study team under the condition to anonymise the source

help to keep the battery in a mid-charge range instead of very low and very high states of charge, as these extremes typically have an adverse effect on battery health.

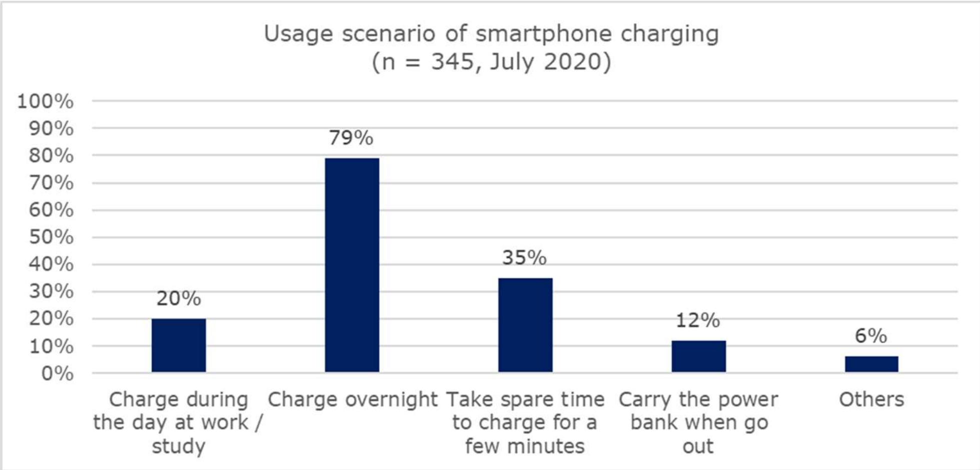


Figure 17: Smartphone charging patterns – at which times smartphones are charged (EU, anonymous OEM)

In the same survey smartphone users where asked at which charging level they consider re-charging the battery. The results on user charging behaviors indicate the following charging patterns:

- Most users (78%) will charge their phones when the battery is below 20%
- Only 2% of users always keep the phone charged when the phone is not in use

Coupling both findings that a vast majority charges overnight and also close to 80% typically consider charging when the battery level is below 20% gives cause for the assumption that a typical charge cycle is from below 20% charging level up to full charge with following trickle charge for several hours more.

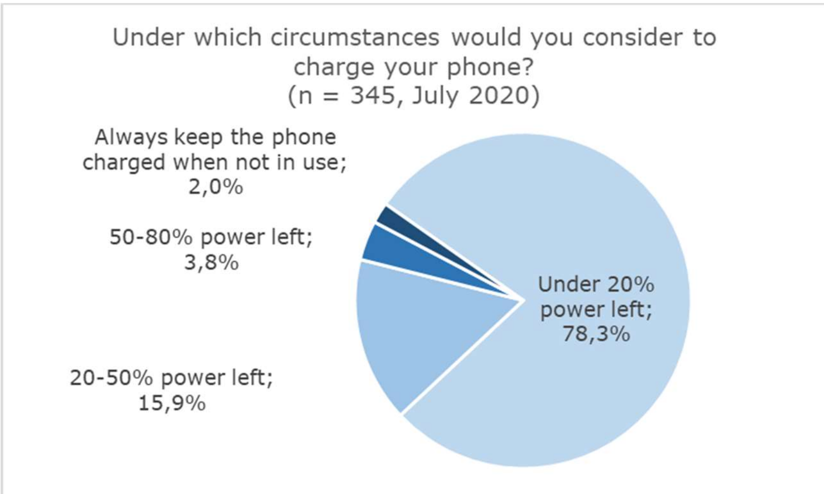


Figure 18: Smartphone charging patterns – at which charge level smartphones are charged (EU, anonymous OEM)

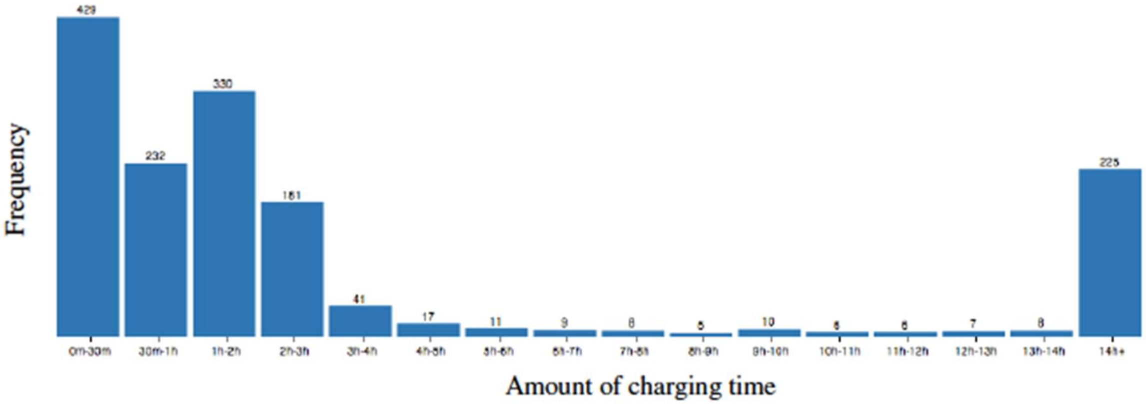


Figure 19: Charging duration (amount of time the phone remains plugged in)

According to the findings of Ferreira et al. throughout the day there is no clear preference when to charge the smartphone, with slightly higher shares in the late afternoon. Times with least charging are the early morning hours (Figure 20). Overnight charging seems to be done by a significant share of the users, but this is definitely not the majority of the users, according to these findings.

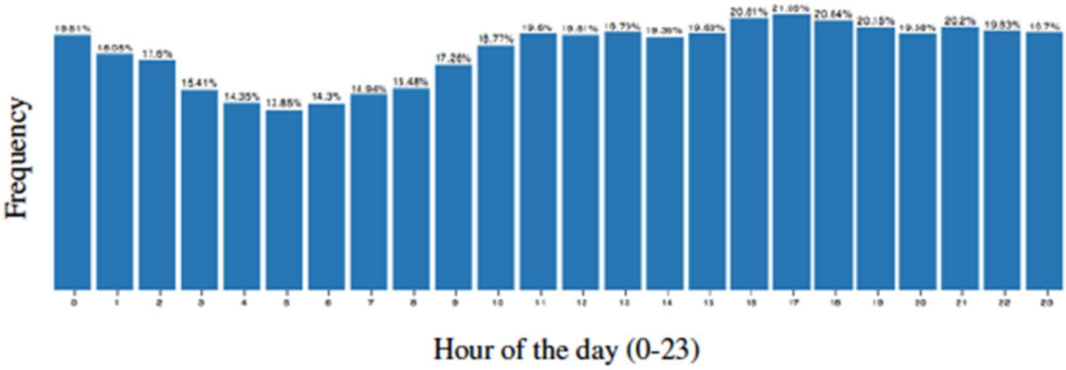


Figure 20: Charging schedule (times when users have their phones plugged in)

coconutBattery[8] is a software tool that displays the state of health and other data on batteries in Apple devices, including iPads and iPhones: the battery's build date, cycle count, design capacity, full charge capacity (the current maximum capacity the battery can retain), state of charge, battery temperature and current consumption. The software also displays the battery state of health (SOH) in percent, calculated as the quotient of the full charge capacity, which steadily decreases over time and use, and the design capacity. Users of the software can choose to actively transmit data from their batteries to a central database.

An analysis of the coconutBattery database in 2016 revealed the cycle frequency of smartphones and tablets (i.e. aggregated data for a range of iPhone and iPad models), estimated via the age of the battery and the number of full charge/discharge cycles (Clemm et al. 2016). In the case of smartphones, based on data from 4,844 individual devices, the distribution of annual charging cycles approximately follows a normal distribution (Figure 21). The average and median value are 218 and 219 cycles per year, respectively, equivalent to around 0.6 charging cycles per day, 4.2 per week or 18.2 per month. This

[8] https://www.coconut-flavour.com/coconutbattery/

data suggests that a smartphone is only charged with approximately 60 % of its design capacity daily on average.

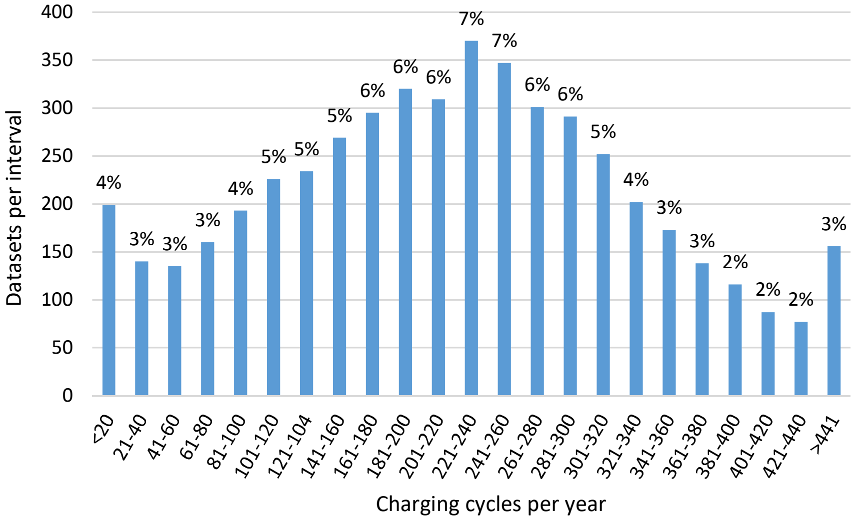


Figure 21: Distribution of the cycle frequency of smartphone batteries (Clemm et al. 2016)

The cycle frequency of tablets, based on data from 776 individual devices, is skewed towards lower cycle count per year when compared to smartphones (Figure 22). This reflects the different use pattern in the case of tablets, with less intense daily use. The average and median value are 79 and 68 cycles per year, respectively, equivalent to around 1.5 and 1.3 charging cycles per week or 6.6 and 5.7 cycles per months. Consequently, it may be assumed that tablets at the time were only charged with up to 22 % of their design capacity daily on average.

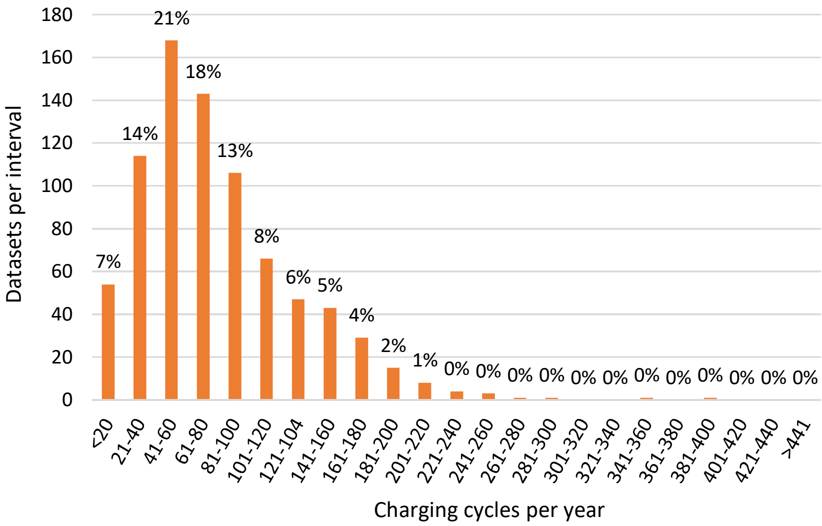


Figure 22: Distribution of the cycle frequency of tablet batteries (Clemm et al. 2016)

Fast charging is a feature, in which consumers are interested and they are even willing to pay more for this option: The survey results among smartphone users provided to the study team through the stakeholder consultation shows that 48% of the users are willing to pay more to have a fast charging smartphone support function and better charging experience in the future.

3.5. Device protection, defects and repairs

Main limiting states of technical nature for smartphones, mobile phones and tablets are summarised in Table 2, with a description of possible failure mechanisms (Cordella et al. 2020).

Table 2: Main failures for smartphones, mobile phones and tablets

Part	Main failures	Failure mechanism
Screen: - Glass cover	Screen cracked, scratched, splintered	Accidental drops or other mechanical stresses (shocks, vibrations)
- Touch screen layer	Screen cracked, scratched, splintered	Accidental drops or other mechanical stresses (shocks, vibrations)
- Display	Black screen, broken/dead pixels (spots, stripes or similar), no background light	Accidental drops or other mechanical stresses (shocks, vibrations)
Back cover	Breakage	Accidental drops or other mechanical stresses (shocks, vibrations)
Battery	Loss of performance in terms of duration of battery cycles	Aging of the battery due to quality issues or use under stress conditions or regular longterm use
	Battery not charging	EPS / battery connection failure
	Overheating	
Connectors	Disconnected connector assemblies	Mechanical stress, particle ingress
Operating System	Malfunctioning/ loss of security and performance (e.g. device not switching on, error codes, apps crashes)	OS and/or security updates not provided by the manufacturer
Whole Product	Short circuits, disconnection of main parts (including buttons and connectors)	Stress conditions (e.g. exposure dust and water, shocks, vibration).

There are many more failures observed among smartphones, mobile phones and tablets, but these are the dominating ones. Further statistics on occurring defects and failures are provided in 3.5.2.

3.5.1. Use of protective shells and covers

The use of protective covers or shells is a measure to reduce the risk of product defects in case of accidental drops. 2017 data from the U.S. suggests that 79% of all smartphone users use a protective case[9]. According to a 2015 survey by Bitkom in Germany, 91 % of smartphone owners are protecting their smartphone with a cover[10].

In a 2019 survey in Germany (clickrepair 2019) smartphone users stated whether they use a device with a protective case or a protective foil. The share of protective cover usage is highest among users of Apple devices (86,1%), and for none of the brands this share is below 70%.

Table 3: Use of protective foils and covers for smartphones, Germany, 2019 (clickrepair 2019)

[9] https://www.statista.com/statistics/368627/us-protective-case-usage-among-smartphone-owners/
[10] https://t3n.de/news/91-prozent-smartphone-besitzer-636523/

Brand	Share of users using the devices…	
	…with a protective foil	…with a protective cover
Apple	50,8%	86,1%
Huawei	49,1%	83,7%
Samsung	40,6%	83,1%
Xiaomi	57,1%	82,1%
Sony	45,4%	80,2%
LG	35,7%	78,3%
HTC	43,3%	76,8%
Nokia	31,3%	70,1%

3.5.2. Defects and repairs

Almost 8 in 10 Europeans think manufacturers should be required to make it easier to repair digital devices or replace their individual parts. 24% still think this even if it meant that devices cost more (European Commission 2020b).

3.5.2.1. Defects

A survey among students at a Polish university and evaluation of social media content provides some indications on typical **defects** of smartphones (Kostek and Samek 2018). According to these findings, most frequent damages were found to be freezing phones, scratched backs and not working touch screens. A weak battery was mentioned as a shortcoming by one third of the surveyed students, and one third of complaints mentioned on social media where related to the weakness of the battery.

A defect does not necessarily lead to a repair. Device use might continue (for a while) without getting the device fixed.

Being asked, which incident lead to a smartphone damage, survey respondents in the U.S. in 2018 replied as depicted in Figure 23: 74% of respondents reported to dropping their phones on the ground. Phones falling from pockets was ranked second at a 49% occurrence rate. This survey obviously allowed for multiple answers, and stated percentages suggest that in average every respondent experienced more than two incidents leading to a damage of a device.

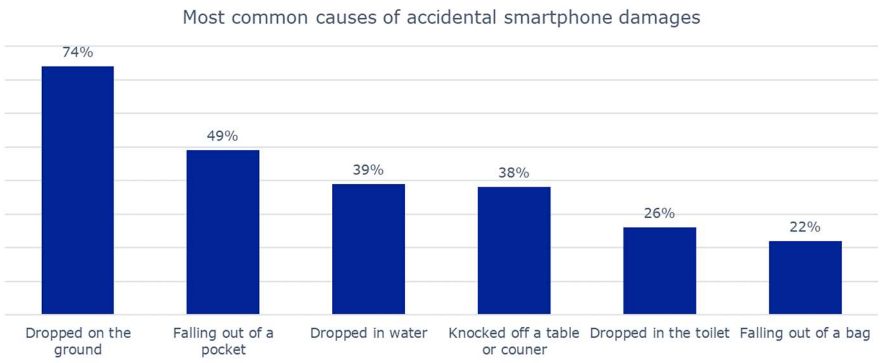


Figure 23: Causes of accidental smartphone damages, United States, 2018[11]

2017 research by CCS Insight indicates that one in three European consumers have experienced a broken smartphone screen in the three years before (Cat Phones 2019).

[11] https://www.statista.com/statistics/959492/us-top-common-smartphone-damage-cause/

Data from a 2019 survey among smartphone users in Germany (clickrepair 2019) gives insights in most frequent defects of smartphones. Table 4 shows that more than two-third of the defects were related to display damages, followed by casing and battery issues.

Table 4: Defects in smartphones, Germany, 2019 (clickrepair 2019)

Defects	Share
Display	67,4%
Casing	50,0%
Battery	33,9%
Connectors	16,1%
Camera	7,9%

Another survey investigated care and maintenance practices for smartphones, indicating widespread use of protection measures against soiling. One out of five users state a careful use of the battery as main measure (Figure 24).

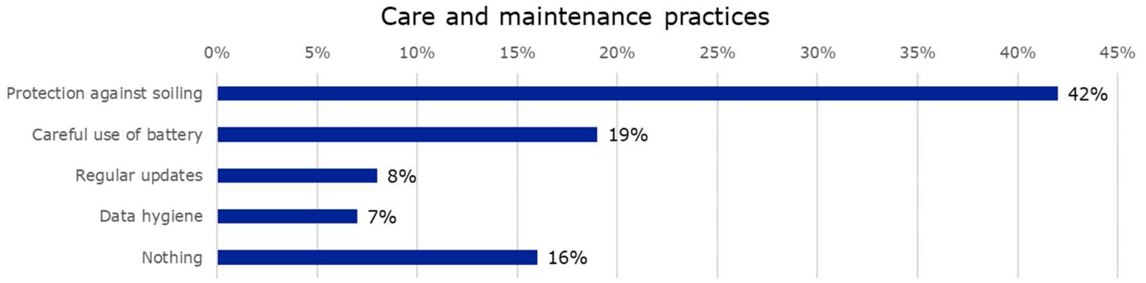


Figure 24: Smartphones - Care and maintenance practices according to a survey in Germany (Jaeger-Erben and Hipp 2018)

Not yet published research by the TU Berlin / Fraunhofer IZM young researchers group "Obsolescence as a challenge for sustainability!" suggests that a majority of users at least on an annual basis delete non-used apps and/or data files a free some storage space. Only slightly above 20% delete such data never or less frequently than on an annual basis. One in four users expose their device to humidity at least once a year, very few even once per month. More than half of the respondents stated to expose the device at least once a year to heat. 7 out of 10 users state that their phone is subject to shocks or drops at least once a year, and slightly below 20% state this to happen monthly or even weekly.

Based on the stated frequency of drops or shocks a correlation can be derived as depicted in Figure 25: Roughly 5% of all devices experience at least 50 drops or shocks per year, 10% of all devices experience at least 15 drops or shocks and roughly 70% of the devices experience 5 or less drops and shocks.

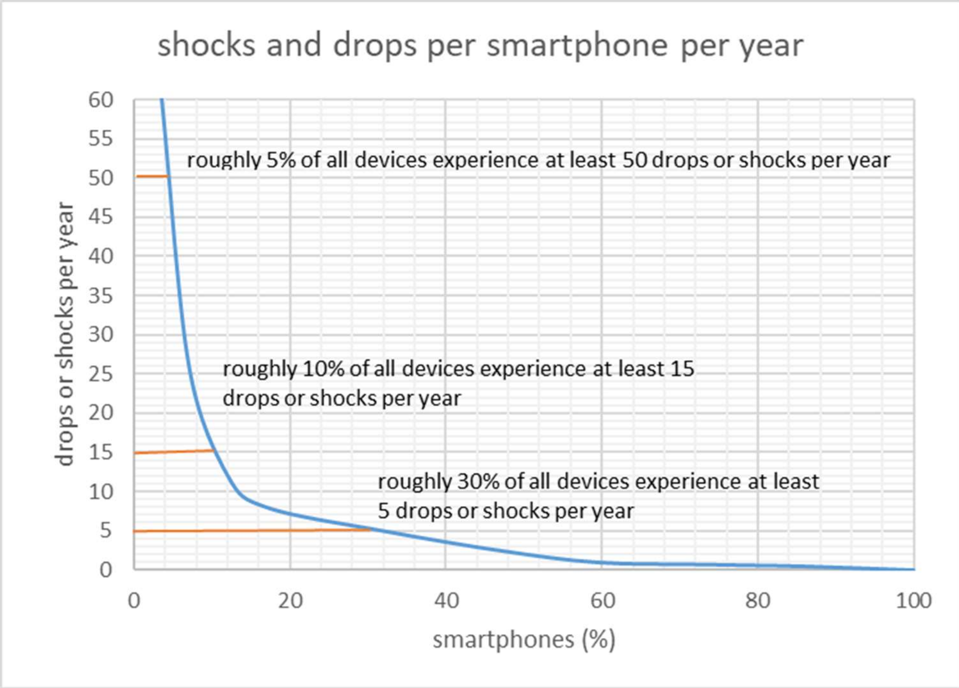


Figure 25: Smartphones – Shock and drop occurrence

Another survey in 2018 investigated defects and repairs of tablets (WERTGARANTIE 2018). In 64.1% of the cases of damaged tablets due to a drop the display is defect, the casing is affected in 47.1% of the cases.

Table 5: Kind of damages of dropped tablets, Germany, 2018 (WERTGARANTIE 2018)

Defects	Share
Display	64.1%
Casing	47.1%
Camera	18.1%
Blemish to the appearance	17.5%
Ports	13.6%

The same study stated as a finding, that up to 25% of some tablet models face technical issues and for several models this rate is in the range of 10-20%. Among the technical issues the battery is by far dominating (52,8%).

3.5.2.2. Repairs

Most common **repairs** for smartphones are (Agrawal 2017): Broken screen (50-55%), water-caused damage (15-20%), damage of the charging connection (5-10%), phone locked (5-10%), connectivity (7%), audio output, which includes a faulty or malfunctioning sound system, speaker, loudspeaker, microphone, or ringer (5%), phone crush (<5%). One stakeholder group questions these figures as batteries are not listed at all.

Another source states as most common repairs (Verduzco 2021):

- Cracked Screen
- Dead Battery
- Charge Port Repair
- Broken Power Button / Home Button

- Broken Headphone Jack
- Water Damage

with cracked screen being the "single most common type of smartphone damage", but not stating any percentages.

3.5.2.3. Repair attitudes

In 2019 Euroconsumers (Euroconsumers 2019a, 2019b, 2019c, 2019d) conducted a study amongst members of consumer organisations in four countries (Belgium, Italy, Portugal and Spain) asking whether they repaired their smartphones when they became defect. In most of the countries, around half of the interrogated persons did (see Table 6).

Table 6: Repair of smartphones; Base: respondents who acquired a new smartphone and had a problem with it (van den Berge and Thysen 2020)

Smartphones	BE (n=281)	IT (n=721)	PT (n=236)	ES (n=333)	Total (n=1571)
Did you repair it? (Yes)	37%	53%	54%	46%	50%

When it comes to reasons for not repairing smartphones, economic reasons (cost, value) were usually the main driver in all countries. Between 17%-20% stated that repair was not possible (Table 7).

Table 7: Reasons for not repairing smartphones; Base: respondents who acquired a new smartphone, had a problem with it (van den Berge and Thysen 2020)

If not, why? (multiple responses were possible)	BE (n=175)	IT (n=332)	PT (n=127)	ES (n=153)	**Total (n=787)**
The repair costs were too high	34%	39%	32%	27%	**34%**
The device wasn't worth the repair cost anymore	26%	33%	33%	32%	**31%**
Repair was not possible	19%	18%	17%	20%	**18%**
The device could still be used	18%	13%	17%	12%	**15%**
Other reason	17%	7%	13%	16%	**12%**
It would have given a lot of work (time/effort)	13%	14%	6%	11%	**12%**
No spare parts available	4%	5%	3%	3%	**4%**

These numbers are in line with a UK survey that queried the following question: "if each of the following devices stopped working, do you think you would usually try to get it repaired, or would you just buy a new one?"[12]:

- Tablet: 48% state to buy a new one, 40% to get it repaired
- Smartphone: 45% state to buy a new one, 47% to get it repaired

In a follow-up question of the same 2020 UK survey respondents were asked to state, why they would rather buy a new device if their device would stop working (Figure 26): More than 50% stated the costs of repair to be an issue, 27% the general inconvenience of repair. 53% stated the age of the broken device as a major reason.

[12] https://yougov.co.uk/topics/technology/articles-reports/2020/05/07/45-smartphone-owners-would-rather-upgrade-repair

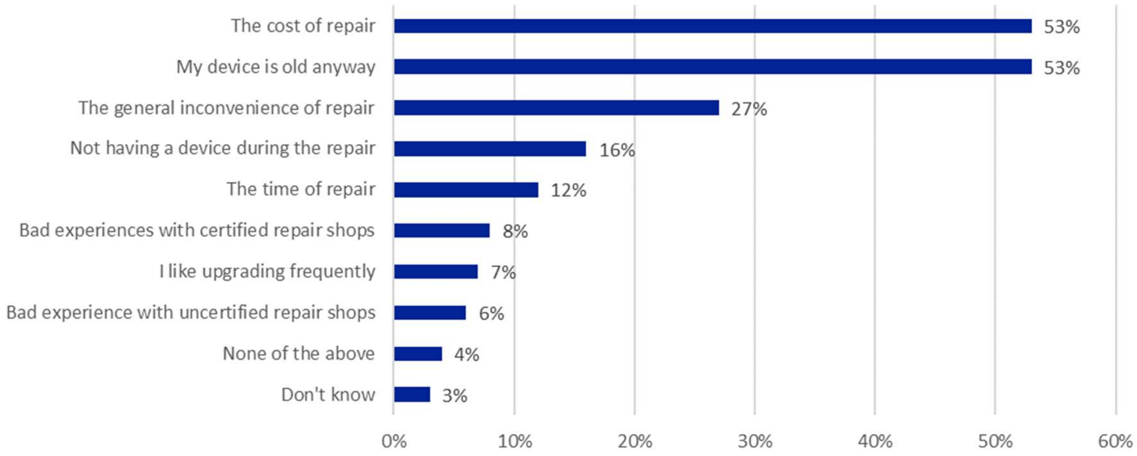


Figure 26: Barriers for repair according to a recent UK survey by YouGov

Users tend to hold the lack of robustness responsible for defects, not insufficient care (Table 8). In a survey where users with a broken smartphone were asked to state what they consider the reason for the defect, only very few considered insufficient care to be the reason, much more frequently inappropriate handling and the most frequently stated reason is insufficient robustness of the phone. A high ranking answer is also "expectable wear and tear", which indicates, that many users are not surprised by the experienced defects.

Table 8: Allocation of responsibility for a broken device: « In your opinion, what are the reasons for the defect? » (N = 1,752 cases where an electrical device break) (Jaeger-Erben and Hipp 2018)

Device	Technical failures	Insufficient robustness	Expectable wear and tear	Insufficient care	Inappropriate handling
Smartphone	56	106	77	16	66

A broken smartphone frequently is the trigger to purchase a new device (Figure 27). Actually, this is much less frequently the case for laptops, where repair or using someone else's / a second-hand / a hoarded device is more common. Only 11% go for a repair, when the smartphone breaks. For the respondents to this survey in Germany the root-cause not to consider a repair are likely to be similar to those stated by the YouGov results shown in Figure 26 above.

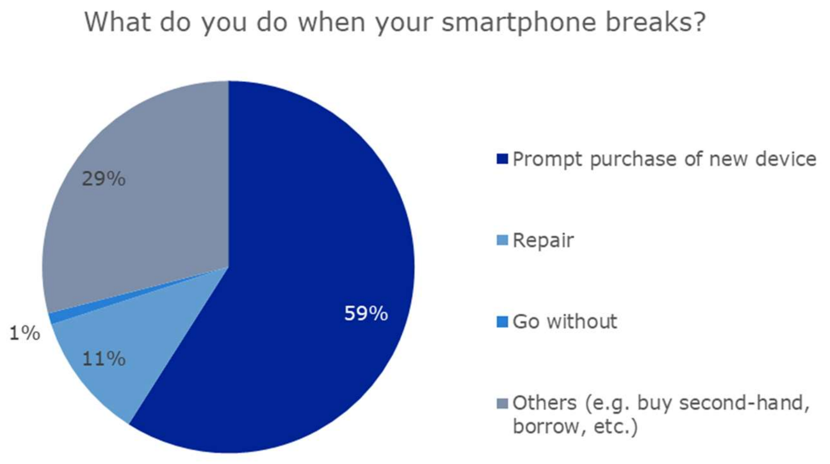


Figure 27: « What do you do when your smartphone breaks ? » results from a German survey (OHA - Obsoleszenz als Herausforderung für Nachhaltigkeit 2019)

A recent paper exploring smartphone life expectancy and maximum lifespans showed that that consumers' mental depreciation plays a critical role in determining a smartphone's lifespan (Fitzpatrick and Makov 2020). Examining visitor traffic to free smartphone repair manuals available on iFixit.com (22 million visits), the authors measured consumers' interest in repair over time and analysed mental depreciation. They found that the interest in repair declines as time goes by, regardless of how easy or hard the devices are to repair. Furthermore, the authors compared the interest for repair between the Samsung Galaxy S5 (user-replaceable battery) and the Samsung Galaxy S6 (integrated battery) and have not found any evidence that this change in objective reparability made any difference to the interest in repair (Figure 28).

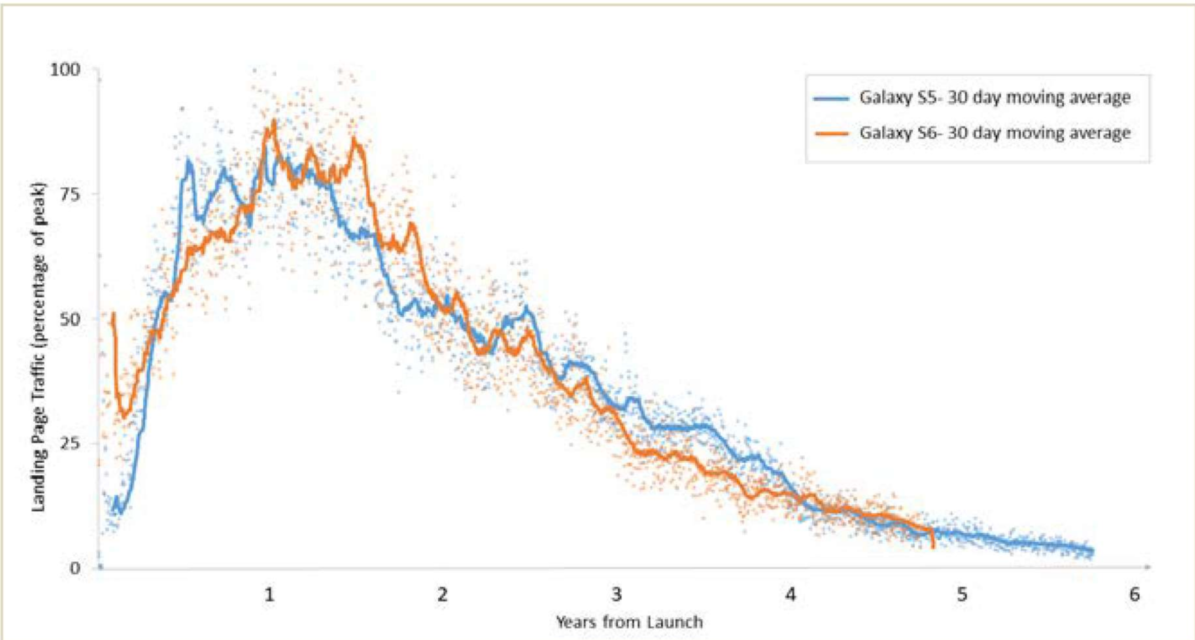


Figure 28: Comparison of Repair Interest for Samsung Galaxy S5 & Samsung Galaxy S6 (Fitzpatrick and Makov 2020)

With this analysis the authors want to highlight that besides technical aspects, psychological obsolescence and mental depreciation have to be taken into account in the discussion around prolonging the lifespan of products and postponing the obsolescence of smartphones. Some stakeholders objected these conclusions with the following argumentation: "While a product's objective reparability may not affect the owner's wish to repair a product or have it repaired, it is very likely to affect their decision to actually do so. One can expect that out of those wishing to repair their product and therefore consulting repair guides on the iFixit website, a significantly smaller number of people will actually undertake the repair of a product that is hard to repair, compared to a product that is easy to repair. As Makov and Fitzpatrick fail to acknowledge this gap in their paper, they come to false conclusion about the influence of reparability on product lifetimes."

Regarding having products **repaired** once these were no longer under warranty, various factors play a role, as mentioned by focus group participants in the aforementioned study (Cerulli-Harms et al. 2018). These factors – for smartphones and other devices - are:

- Price of repair vs. price of a new product[13]
- The price of the product itself (the lower the price, the more likely participants were to prefer a replacement – which mirrors also our assumed distinction regarding importance of durability as stated above -)
- The time it would take to have a product repaired
- Technological progress
- Trust towards the quality of the repair

In the specific case of smartphones an additional factor is mentioned: "Some would prefer buying a new one because technology for smartphones progresses fast. Others flagged the fact that smartphones carry a lot of personal data (such as pictures). This factor adds emotional value to them; moreover, transferring this type of information from one device to another was perceived as difficult. As such, having a smartphone repaired was sometimes seen as preferable." It is an interesting finding, that data privacy concerns and complexity of data transfer between devices is rather motivating longer product lifetimes through repairs. The study states as main motivations for repairs "saving money" and "being able to keep a product". Environmentally motivated reasons were mentioned as well, but to a lesser extent.

3.5.2.4. Insurances

The market for device insurances is steadily growing. The global mobile phone insurance market was valued at US$ 22,6 Billion in 2018[14], but this does not only include coverage of accidental damages – which is said to be the largest market -, but also virus protection, data protection and theft protection.

3.5.3. Encryption

Encryption of data is essential to restrict unauthorised access to data in case of a stolen device, but also to make data retrieval at end of life almost impossible, if the encryption key is inaccessible or deleted once the device becomes a candidate for a second use.

In a global survey (with focus on the United States and South Korea) smartphone users where asked, if their data is encrypted (Breitinger et al. 2020).

[13] Remark by a stakeholder : « In markets where operators subsidize devices the real price is not transparent and the competition between repair and new purchase becomes distorted. »

[14] https://www.businesswire.com/news/home/20190416005458/en/Mobile-Phone-Insurance-Market-Reach-38.1-Billion

Table 9: Smartphone, survey results on data encryption (Breitinger et al. 2020)

Encryption	Smartphone users
Yes, I changed it	15,7%
Yes, by default	20,8%
No	15,7%
I don't know, I use the default settings	47,7%

Almost half of the respondents stated not to know, if data is encrypted and default settings have not been checked or changed. Slightly above one third knowingly encrypt data on their smartphones.

4. SUBTASK 3.2 – SYSTEMS ASPECTS OF THE USE PHASE FOR ERPS WITH INDIRECT IMPACT

The aim of this subtask is to report on any indirect consumption effects during the use phase that affect the environment and resources.

Several studies and papers are dedicated to the ICT sector, including the indirect impact of the use phase of user equipment like smartphones and tablets. One of the most recent sources is Malmodin (2020) that analyses the power and energy consumptions of networks (mobile and fixed line) and data centres. The main results are presented in this chapter.

4.1. Affected energy systems

The products covered in this study are connected to network in order to communicate with data centres. The use phase of smartphones and tablets have therefore an impact on:

- the access networks: mobile access networks or fixed broadband access networks[15]
- the data centres, providing the services and processing data of the used applications

As a consequence, using a tablet or a smartphone does not only affect the energy consumption of the product itself. The access network has to be operated and the corresponding energy consumption depends mainly on the type of network used and to a lower extend on the amount of data transferred. In addition, data centres consume energy and their consumption depends on the application and the amount of data transferred.

Mobile devices are used for various purposes such as gaming, social-media, video, shopping, etc. An overview of the most popular apps globally is provided in Table 10[16].

[15] more information on access network is provided in the chapter 4.2.1

[16] https://www.businessofapps.com/data/app-statistics/, based on App Annie. (accessed on 11.08.2020)

Table 10: Most-popular apps globally in 2019

Rank	App	Company
1	Facebook	Facebook
2	WhatsApp Messenger	Facebook
3	Facebook Messenger	Facebook
4	WeChat	Tencent
5	Instagram	Facebook
6	QQ	Tencent
7	Alipay	Ant Financiual Services Group
8	Taobao	Alibaba Group
9	WiFi Master Key	Linksure
10	Baidu	Baidu

Data for smartphones in Spain (see Figure 29) shows also that social-media applications are the most popular ones, which indicates that a similar trend might be assumed for EU27.

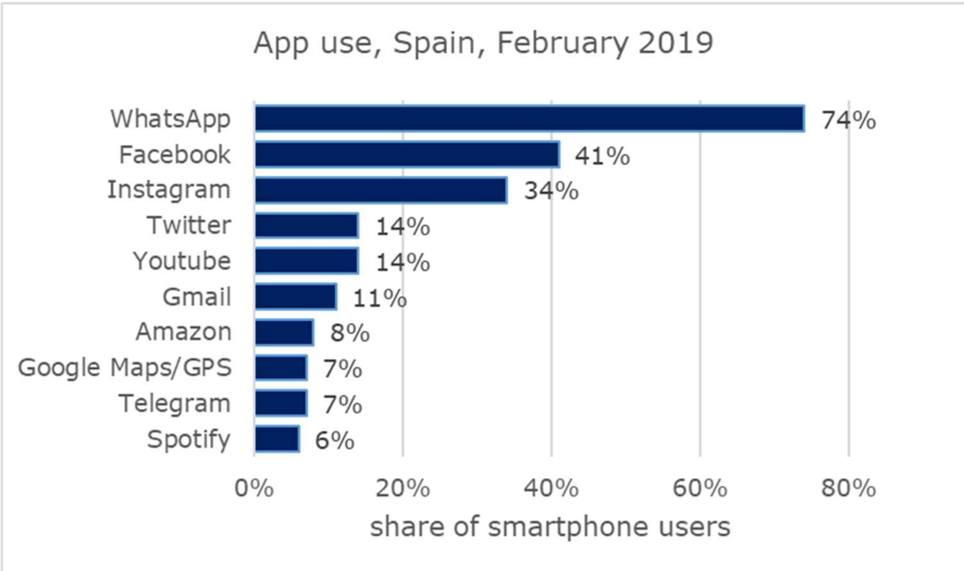


Figure 29: Most used apps by smartphone owners in Spain as of February 2019[17]

4.2. Energy consumptions of the affected system

One of the findings of Malmodin is that the power of such equipment is not proportional to the data volume even if the data volume has an impact on it.

4.2.1. Mobile and fixed broadband access networks

As access networks have to be operated 24/7 the whole year, there is an idle power. The data volume has a rather low impact on the energy consumption, which could be verified for networks during the lockdowns due to the Corona outbreak, as stated by GSMA:

17 https://www.statista.com/statistics/746955/most-downloaded-and-used-smartphone-apps-in-spain/ (accessed on 11.08.2020)

"network electricity usage has remained flat, even as voice and data traffic has spiked by 50% or more"[18].

In his paper, Malmodin presents figures for mobile access networks (see Figure 30), where the power of a 4G radio unit ranges from 200 W (in idle mode) to 350 W by the highest data traffic (100 Mbps). Power for fixed access line (see Figure 31) is less sensitive to traffic: between 19 W in idle mode and 23 W at 100 Mbps.

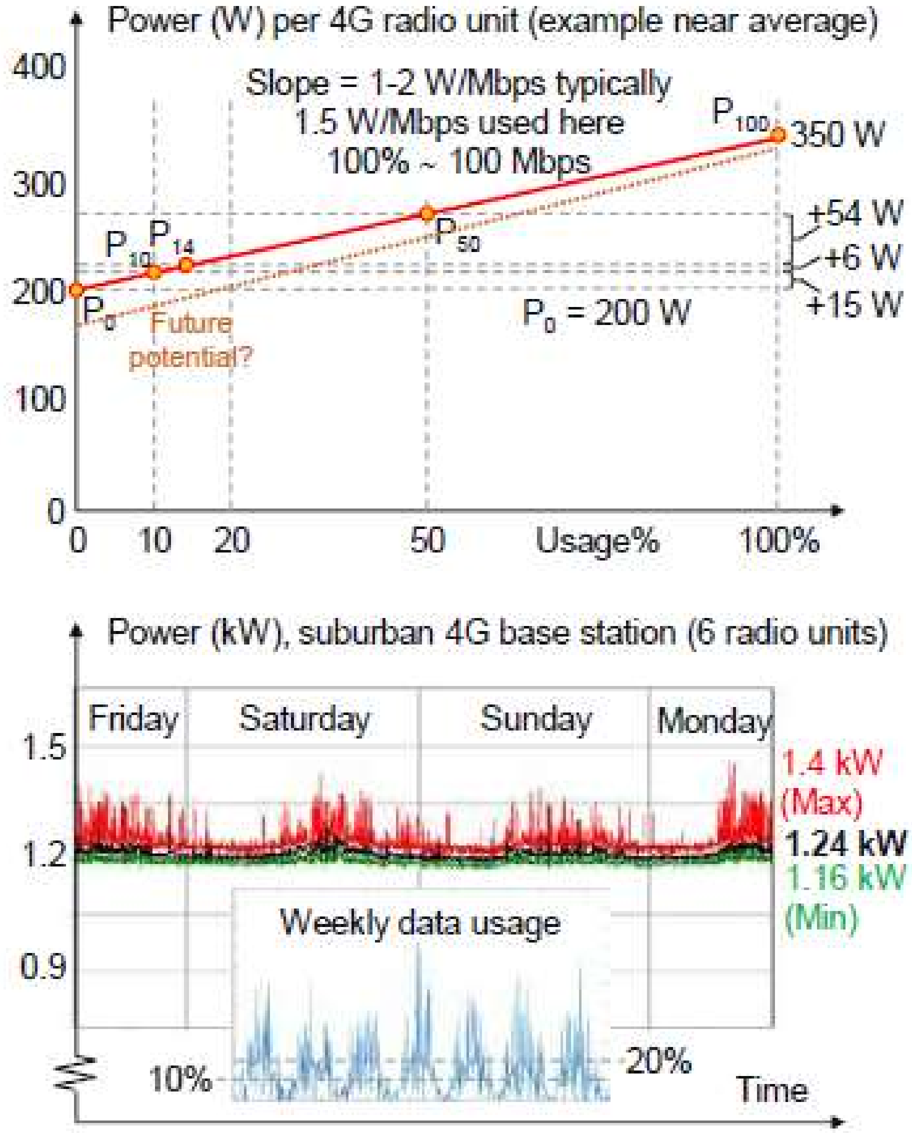


Figure 30: Power and data model for suburban 4G radio unit / base station (based on real data) (Malmodin 2020)

18 https://www.gsma.com/gsmaeurope/latest-news-2/covid-19-network-traffic-surge-isnt-impacting-environment-confirm-telecom-operators/ (accessed on 11.08.2020)

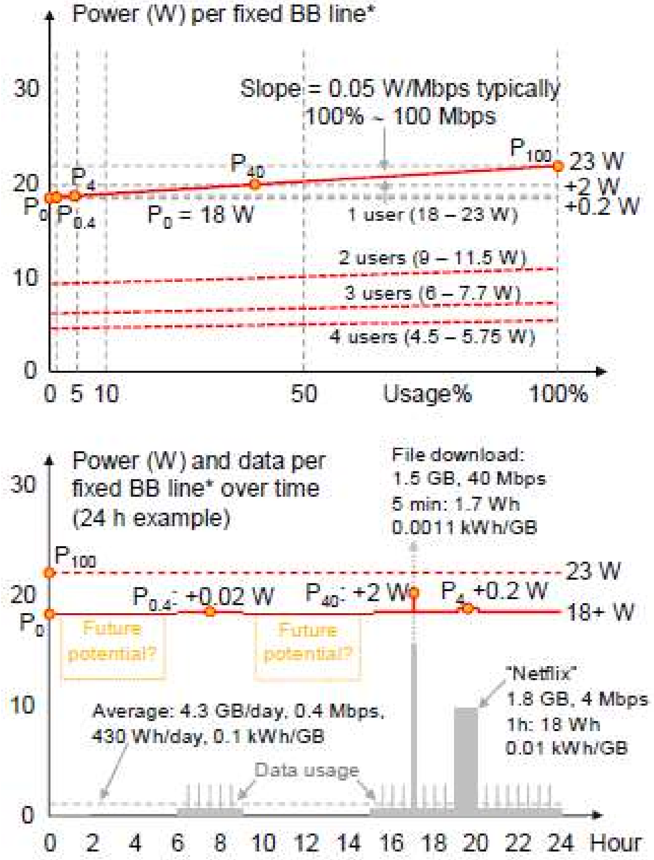


Figure 31: Power/data and power/time (24 h) model for a fixed BB access line (household)[19] (Malmodin 2020)

4.2.2. Data centres

The performance and energy consumption of data centres is specific to each application. Figures related to the data centre of some of major applications are provided by Malmodin (Malmodin 2020) in Table 11: Examples of data centre / services power/energy figures and use statistics (Malmodin 2020). The average power / user for applications from Netflix and the FAMGA[20] is estimated to be 1.1 W, which corresponds to a yearly energy consumption of 9.4 kWh/user.

Table 11: Examples of data centre / services power/energy figures and use statistics (Malmodin 2020)

Year 2018 unless stated	AEC TWh	Users million	Use time (h/day)	Average W*/W*/kWh
FAMGA+N	33	3.500	na	1,1/na/9,4
Netflix	0,3	125	1 h 11 m	0,27/5/2,4
Netflix 2019	0,45	155	1 h 11 m	0,34/7/3
Facebook	3,4	2.400	40 m	0,16/6/1,4
Google	10,1	3.500	1 h	0,3/8/3
YouTube	1	2.000	11 m	0,1/2,7/0,5

[19] including home router and all components of a fixed BB access network per line
[20] FAMGA: Facebook, Apple, Microsoft, Google and Amazon

* Energy split on 24/7 all year round, next W-figure: energy split only on use time

4.3. Interaction between the products covered by the study and the energy system

Mobile phones and smartphones, and home tablets, interact with a cellular radio network. This interaction is important with respect to the overall energy consumption. With increasing mobile data communication, the required radio spectrum increases tremendously. Only if the existing radio capacities (available frequencies) are used effectively, performance and the energy efficiency of the access network will increase. The telecom operators have a strong interest in reducing energy consumption of their networks (mainly the base transceiver station) by utilizing latest technologies (e.g. multi input multi output antennas). This means that the end-user terminals (smartphones) need to be capable to operate effectively in conjunction with the network equipment.

4.4. The energy use and the energy-related resources & environmental impacts

As a combination of the data traffic generated by smartphones, tablets and DECT phones and of the power of the different access network components, energy use of networks per subscription and year can be estimated. According to the analysis of Malmodin (Malmodin 2020) (see Figure 32) the global average power per mobile subscription decreased from 5 W in 1995 to 1.7 W in 2005 and slightly increased to up to 2 W by 2020, while the data traffic increased by a factor of 10,000.

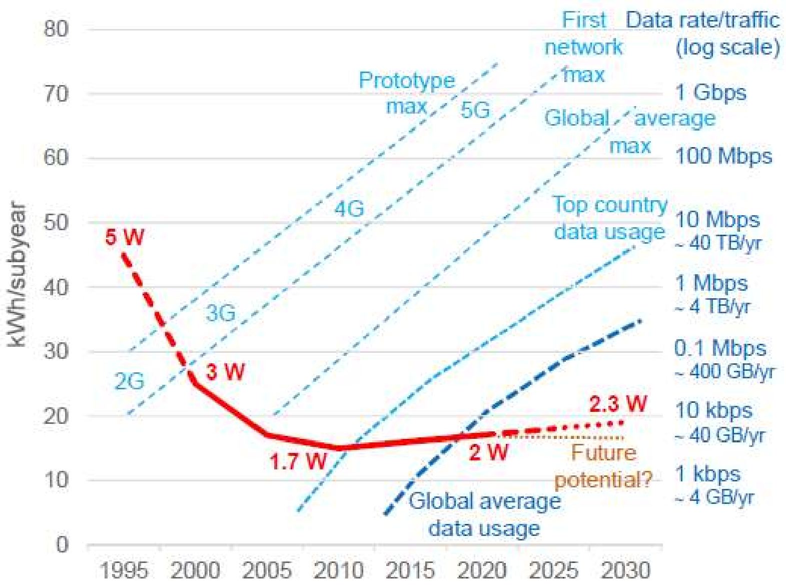


Figure 32: Average power, electricity use and data per mobile subscription over time for mobile access networks (Malmodin 2020)

Regarding the fixed broadband access network, the average power decreased from 25 W in 2000 to 18 W in 2020 while the average data traffic per line was multiplied by more than 100 over the same period (see Figure 33).

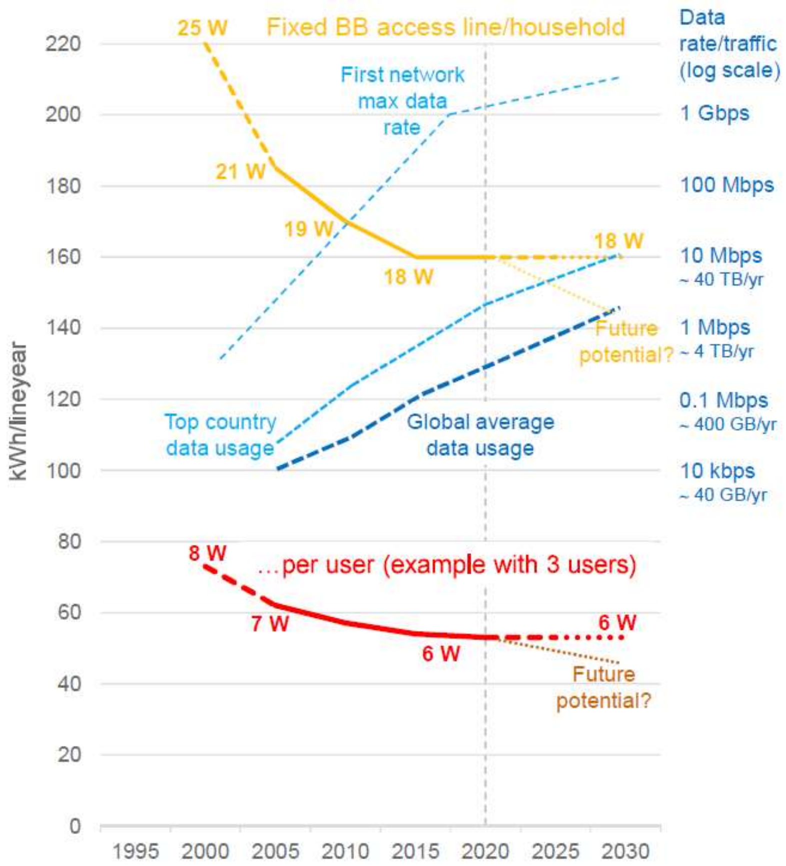


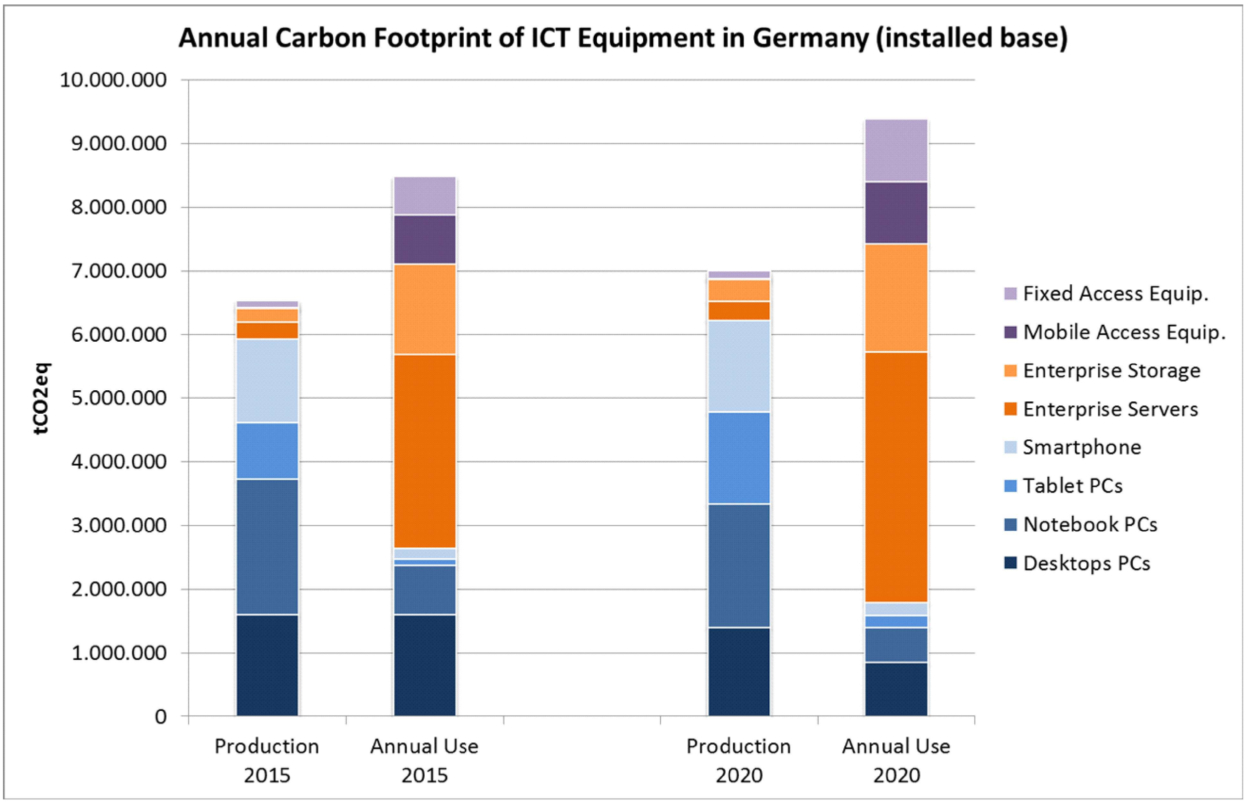
Figure 33: Average power, electricity use and data per fixed BB line (Malmodin 2020)

At present, it seems feasible to argue that the modernisation of the radio networks in conjunction with modern end-user devices is improving energy efficiency. But there is a conflict of goals. Looking at the overall resource consumption, the use phase related environmental aspects shift between the end-user terminal (smartphone) and the network equipment. Figure 34 shows the annual (normalised to one year) carbon footprint assessment for various product groups and ICT equipment. Due to the large number of smartphones in use, the normalised annual GHG emissions for the production strongly outweighs the GHG emissions related to the annual use. The GHG emissions from the mobile access equipment (network) are considerable only in the use phase.

The data indicates that the telecom operator would prefer the customers to have the latest technology (latest smartphone generation) in use. This would ensure more energy efficient interactions with the network equipment (the operator saves energy on an extended system level). However the environmental benefit for the smartphone user is minimal. On the contrary, the overall environmental impact would increase with very short product cycles and fast product turnover in the market.

Although the ICT sector makes efforts to reduce its carbon footprint, the overall tendency still is an increase of GHG emissions by the sector. As stated by European Telecommunications Network Operators, "European telecom companies are radically changing the way they work. By 2019, almost 50% of the energy used by ETNO companies came from renewable resources. This reflects positively on the green performance of the sector, which in 2019 reduced its overall emissions by 8.5% with respect to the previous year. Also carbon intensity is decreasing, with ETNO companies reducing emissions from 32 grams per EUR earned in 2018 to about 29 grams in 2019." (European Telecommunications Network Operators' Association 2020).

Figure 34: Annual carbon footprint of ICT equipment stock in Germany (Source: Fraunhofer IZM)



In addition, companies operating data centres purchase massive amounts of renewable energy in order to improve their carbon footprint (see Figure 35).

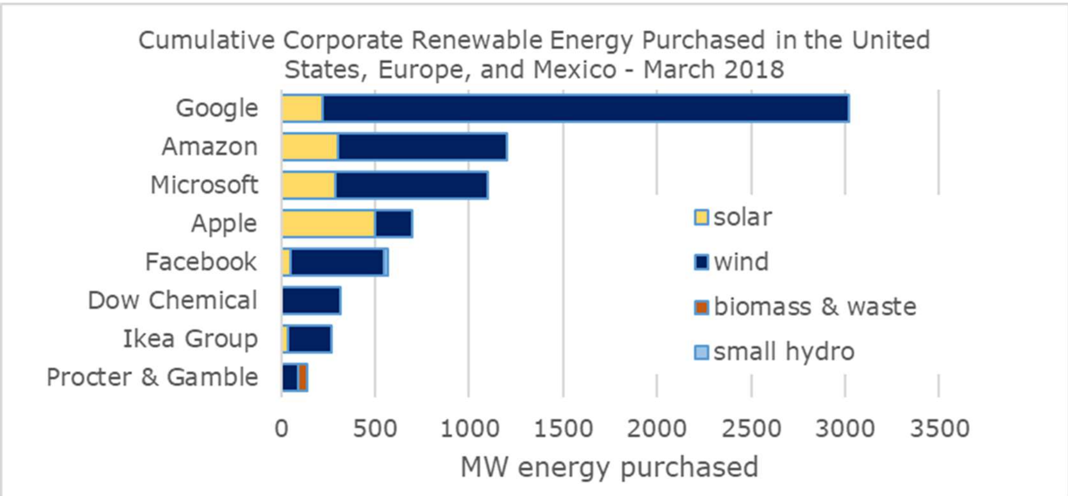


Figure 35: Cumulative Corporate Renewable Energy purchased in the US, Europe and Mexico - March 2018 (source Forbes 2019[21])

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21 https://www.forbes.com/sites/energyinnovation/2018/04/12/google-and-apple-lead-the-corporate-charge-toward-100-renewable-energy/#20d38bb91b23 (accessed on 11.08.2020)

5. SUBTASK 3.3 –END-OF-LIFE BEHAVIOUR

The end-of-life analysis covers "actual" end-of-life in the sense of disposal and recycling, but before that a potential second or third life through reuse plays a significant role for the devices under study. Also the phenomenon of hibernating devices (see Task 2 report), which are not used any further but kept at home, is addressed as this effect hinders a second use of devices and / or delays the potential recovery of resources through recycling.

5.1. Reuse

For data on consumers selling used devices through second hand platforms, such as ebay, see the market analysis in Task 2.

Analysing 500.000 used Apple and Samsung smartphones sold in 2015 and 2016 via eBay, the product properties which affect how long smartphones retain market value and facilitate market-based reuse were examined (Makov et al. 2019): Contrary to expectations, reparability and large memory size have limited impact on the current economic life span of smartphones and their market-based reuse. On the other hand, the brand as an intangible product property, can extend smartphones' economic life span by 12,5 months.

Mugge et al. investigated the potential of selling refurbished smartphones using a quantitative study. An online survey was conducted questioning 250 respondents to study the impact of various incentives that companies can employ to improve consumers' purchase intention of refurbished phones (Mugge et al. 2017). Or in other words: How can the reuse pull market be stimulated? Results are given for 6 different user groups in Table 12. An upgraded, i.e. exchanged battery ranks highest as an incentive, followed by guaranteed software issues and upgraded performance. This in turn confirms the findings by others, why devices are barriers to reuse: a weak battery, limited software support and overall performance issues. Upgraded internal storage, display and camera are also incentives, which could convince users to buy reused smartphones. The "sustainability enthusiast" is much easier to convince, as the product related incentives matter less. It is fair to say that "sustainability enthusiasts" come with an intrinsic motivation to make use of reuse options. For the "proud power user" product and information incentives are much more important. It is apparently more difficult to meet the expectations of this consumer group.

This survey also demonstrates that information on the refurbishing process, a classification system and quality certification are very important for refurbished smartphone appeal.

Table 12: An overview of how the six customer groups differ regarding the impact of the 16 incentives for enhancing their purchase intention of refurbished smartphones (Mugge et al. 2017)

Incentive	Category	Consumer group						Total
		1	2	3	4	5	6	
		Casual supporter	Sustainability enthusiast	Conservative critic	Susceptible follower	Proud power-user	Expert techie	
Upgraded battery	Product	6,65	6,00	5,97	6,33	6,55	6,70	6,44
Guaranteed software updates	Product	6,37	6,16	5,62	6,07	6,57	6,36	6,25
Upgraded performance	Product	5,91	5,32	5,31	5,84	6,43	6,00	5,91
Classification system	Information	5,76	5,28	5,52	5,58	6,07	5,60	5,69
Info on refurbishing process	Information	5,76	5,56	5,1	5,84	5,81	5,53	5,65
Quality certification	Information	5,46	5,52	5,07	5,47	5,76	5,51	5,5
Upgraded internal storage	Product	5,41	4,52	4,79	5,33	5,79	5,77	5,39
Upgraded screen	Product	5,33	4,2	5,03	5,29	5,86	5,55	5,34
Unbiased testimonials	Information	5,37	4,76	4,79	4,98	5,52	5,13	5,16
Upgraded camera	Product	5,04	3,84	4,83	5,27	5,74	5,21	5,13
Extendable protection period	Service	4,85	4,52	4,72	4,93	5,24	5,28	4,99
More innovative features	Product	4,50	4,20	4,07	4,96	5,48	5,06	4,84
Extended trial period	Service	4,89	4,00	4,03	4,36	4,86	4,72	4,57
Extendable protection coverage	Service	4,20	3,80	3,97	4,29	4,64	4,26	4,26
Updated appearance	Product	3,48	3,20	3,83	4,42	4,47	3,85	3,96
Leasing option	Service	3,96	3,56	3,55	4,00	3,69	3,00	3,64

Question: Would this incentive increase the chance of you purchasing a refurbished smartphone?

Scale from 1 (not at all) to 7 (very much)

5.2. Upgrade to new device

A 2014 survey (Wieser and Tröger 2018) with residents from Austria shows that around one third of total respondents replaced their mobile phone because of a defect or restricted functionality (see Figure 36). Better performance of a new device was the sole motivation for 6% of the respondents to upgrade to a new phone and in total for almost 23% of the respondents the better performance played a role in this decision. Release of a new model triggered for almost 10% of the respondents the upgrade decision. In addition, the telecom provider plays a significant role here: Almost 14% were influenced in their upgrade decision by the operator offering a new device (see 3.1). For 8% this even was the only reason to replace an existing phone.

Some of the answers also echo the findings on repair attitudes (see 3.5.2.3), e.g. where "the device was too old to got it repaired" can be seen here again as a reason for an upgrade.

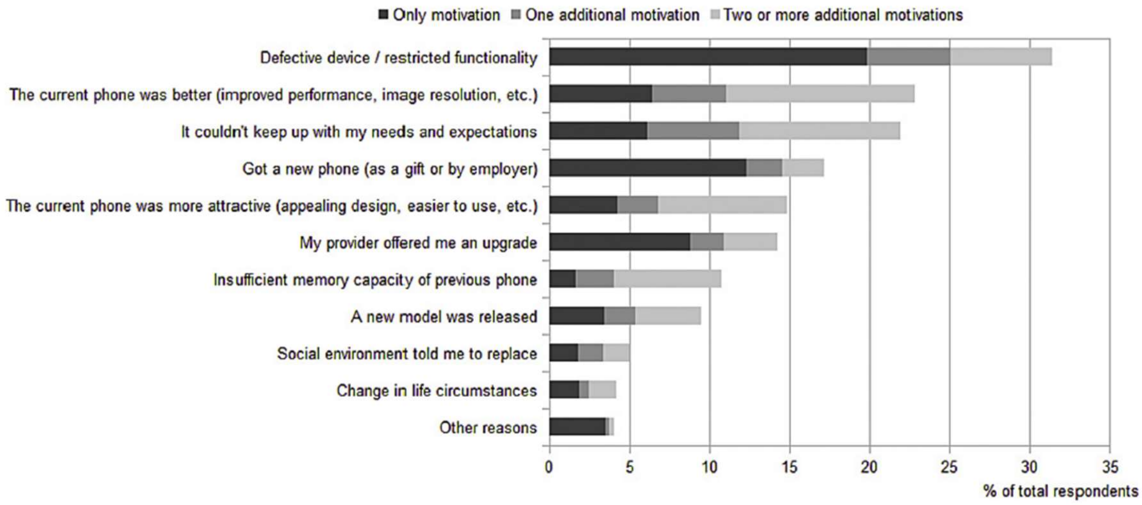

Figure 36: Reasons for mobile phone replacement by Austrian residents, 2014 (Wieser and Tröger 2018)

A survey conducted among UK students in 2015 (Wilson et al 2017) shows that technological and quality obsolescence are the main reasons to replace smartphones. When questioned what the reason for replacing their previous mobile phone with their current mobile phone was, 37% responded "the technology was outdated", another 28,7% replied "it didn't have the specific function that I wanted" and 26,5% stated "the technology was worn out". Broken beyond repair and repair costs where less an issue for replacements (Figure 37).

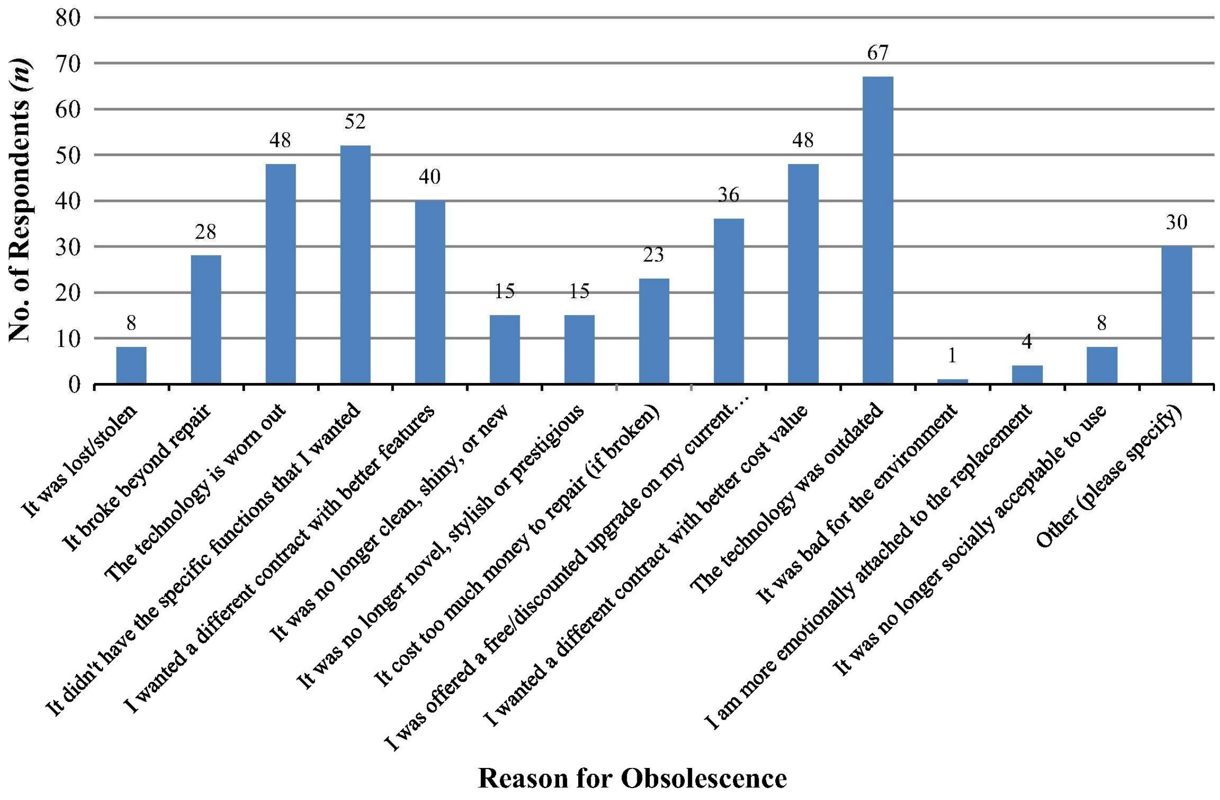

Figure 37: Reasons for mobile phone replacement by UK students, 2015 (Wilson et al 2017)

When it comes to repair, recent research shows that the willingness to pay for repair services seems to decrease at an annual rate of 6.7% during the use phase (Sabbaghi and Behdad 2018). This study also suggests that expensive repair services and a lacking access to a functioning repair infrastructure are a main barrier for mobile phone users. Because of high repair costs and the belief that phones cannot be repaired, 66% did not attempt to repair their defective phones.

The survey by Wieser and Tröger (2018) in Austria unveiled that of all consumers with a defective phone 34% actually did attempt to repair it. From that share, 43% were broken beyond repair, 31% were reparable and 26% did not know how to repair after the first attempt (Wieser and Tröger 2018), see Figure 38. According to these figures roughly 10% of all defective phones are repaired in the end.

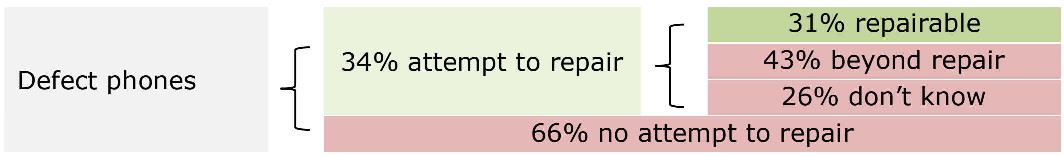

Figure 38: Defective phone, attempts to repair yes/no, percentage of phones that were repairable (2014) (Wieser and Tröger 2018)

5.3. Disposal and recycling

Focus group participants in the circular economy behavioral study (Cerulli-Harms et al. 2018) were generally willing to recycle electronics products: “Willingness to recycle was somewhat lower in the Czech Republic [compared to Sweden, Germany, and Ireland]. In this country, recycling was seen as time consuming, as well as too much of an effort. Participants felt that recycling should be motivated by a financial bonus, for example a discount on the next purchase.”

In a recent Eurobarometer survey (European Commission 2020b) asking about the willingness to recycle old devices most important is a nearby recycling point (43%). Next, 40% responded to be willing to recycle, if they were sure that it did not pose any potential privacy risks.

The survey among UK students by Wilson et al. (2017), see above, also asked for the whereabouts of mobile phones, which have been replaced by a new one: More than 50% kept the old device (Figure 39).

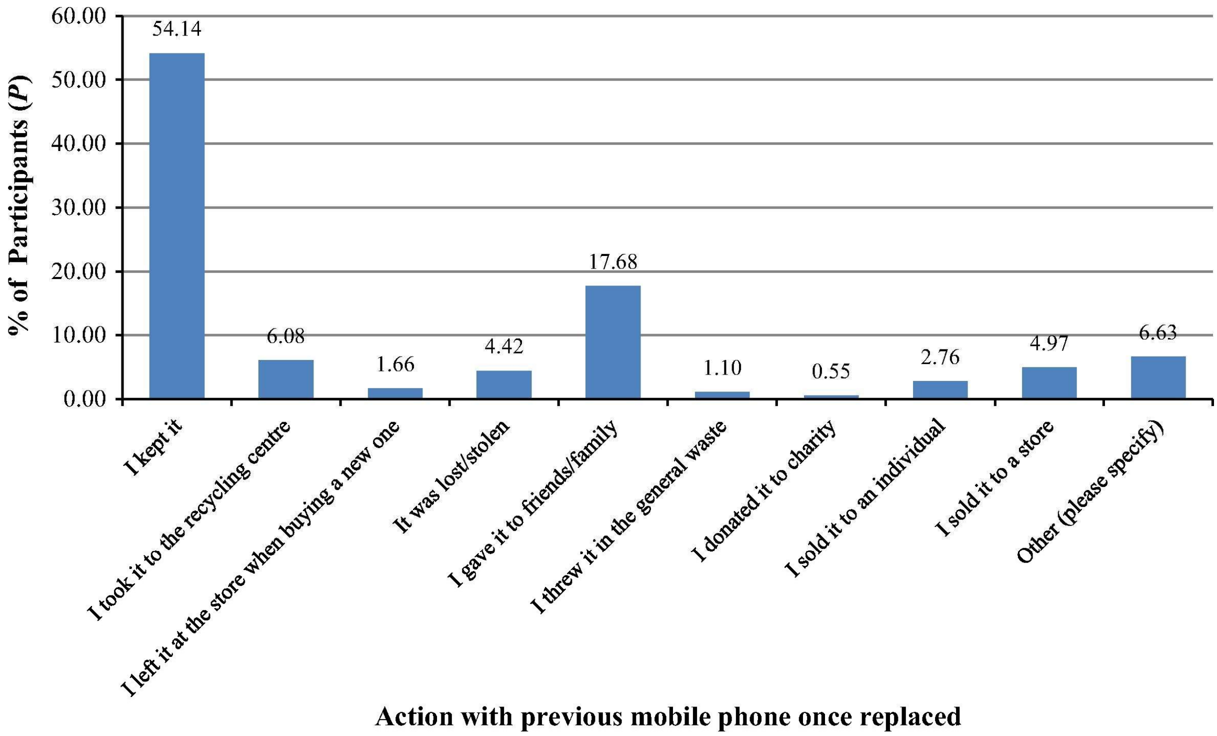

Figure 39: Action with previous mobile phone once replaced among UK students, 2015 (Wilson et al 2017)

Being asked, why they kept replaced phones the reason for most respondents was to keep it as spare device (Figure 40). Information stored on the device is another, although much less frequently mentioned reason – leaving it open, whether trust in data deletion is the underlying reason or the intention to keep the phone as storage device.

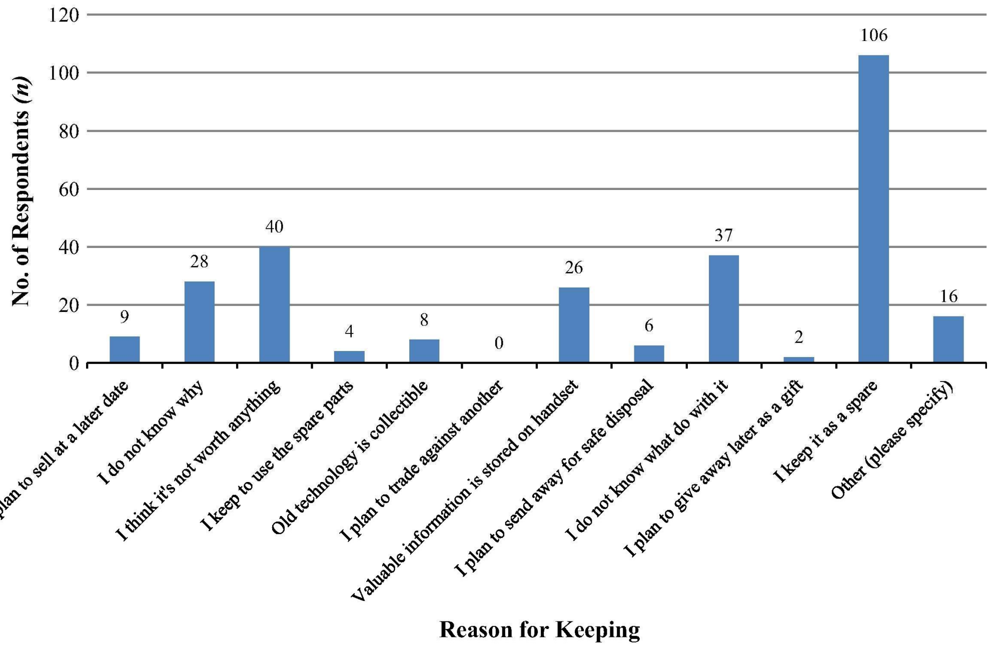

Figure 40: Reasons for keeping replaced phones among UK students, 2015 (Wilson et al 2017)

Although collection programmes for mobile phones are in place in many countries, consumers often store their phones after use, leading to a hibernating stock of old devices. In a recent paper, Poppelaars et al. reviewed user experiences of commercial collection programmes for mobile phones and provided recommendations on how to improve them (Poppelaars et al. 2020). Using a divestment model, the authors concluded that smoothing the return procedure with more guidance and feedback could significantly improve the user experience of collection programmes. Since the devices are kept in drawers for various reasons (e.g. data safety, back-up solution, etc.), the collection programmes need to propose interesting alternatives for users to mitigate expected risks. Uncertainties with respect to privacy concerns and data loss could be reduced by taking the user step by step through the back-up, transfer and removal of data when preparing the phone for shipping. A certificate that data was safely deleted could be provided to the user. Furthermore, to trigger a feeling of satisfaction at the end of the divestment processes, the authors suggest that a confirmation could be provided to the consumer upon the safe reception of the device. As an example, some outcomes could be communicated by confirming the positive environmental contribution made by the user.

In a 2015 survey in Portugal (Martinho et al. 2017) respondents stated concerning smartphones and tablets not in use, that the most significant destination was potential reuse by keeping them in the home (45% and 23%, respectively), followed by giving them to a friend or relative (19% and 8%, respectively) or selling them (7% and 0%, respectively). Recycling destinations implemented by extended producer responsibility (EPR) schemes were mentioned by only 4% of respondents for smartphones and 1% for tablets, with other destinations being reported by 0% and 3% of respondents, respectively. The low delivery rate of devices to recycling programs and schemes was justified by various reasons: Most respondents revealed not knowing where they should deliver the devices (24% and 25% for smartphones and tablets, respectively) or preferred to give them to family member or friend (21% and 24%, respectively). Concerning other reasons, smartphones were used as an alternative device (15%), whereas some tablet respondents gave no motive (21%).

According to a recent survey (Bitkom e.V. 2020) in Germany 64% of all citizens stated to have disposed or sold a mobile phone in the past. 21% keep (all) their used phones. 50% of those who are hoarding mobile phones do so to have a replacement device in case their current phone has a defect. 37% are afraid, that data might be extracted from disposed phones. For 36% lazyness is apparently the main barrier: Disposing or selling the old phone is not worth the effort for them. 24% consider data transfer too complicated and 19% do not know how to dispose old phones properly.

Half of those who discontinued the use of an old phone sold it directly to another user. 9% sold it to a professional re-commerce trader. 41% at least brought their phone to an e-waste collection point – many more than in other EU member states (see above). 25% at least once gave it away, 5% donated a device. Only 1% stated to have disposed a mobile phone with household waste, which is a rather low value.

9 out of 10 who already disposed or sold an old phone did so after taking data protection measures: 80% removed the SIM card, 57% transferred data to another storage medium, but only 29% made use of factory reset. 14% got data deleted by a professional service provider, and 9% used data erasure software.

6. SUBTASK 3.4 – LOCAL INFRASTRUCTURE (BARRIERS AND OPPORTUNITIES)

Mobile and cordless phones and tablets as defined in Task 1 rely on a network infrastructure, which is essential for the functionality, but also direct and indirect environmental impacts of this product group.

6.1. Fixed networks

The products covered in this study exchange data through the communication infrastructure. Table 13 provides an overview of the current telecommunications and internet connectivity in Europe for fixed networks.

Table 13: Fixed networks and communication infrastructures (own compilation)

Network	Protocols	Average data rates	Telephone	Internet	Usage in Europe	Additional info	When was it introduced on the market	Until when is the connection available?
Telecom networks	ADSL (ANSI T1.413 Issue 2)[22], VDSL (ETSI TM6)	ADSL: Downstream 9 Mbit/s Upstream 1 Mbit/s VDSL: Downstream 50 Mbit/s Upstream 10 Mbit/s	Yes	Yes	Homes passed: 215 million (mid 2018) Actual usage: 116,553,748 or 52.8% of all broadband HHs (2017).		ADSL: 1998 VDSL: 2001	
Cable-TV-networks	Docsis 3.0, 3.1 (ITU-T Recommendation J.112)	Docsis 3.0: Downstream 300 Mbit/s Upstream 100 Mbit/s Docsis 3.1[23] Downstream 10 Gbit/s Upstream 1 Gbit/s	Yes	Yes	Homes passed: 96,8 million (mid 2018) Actual usage: 45,702,115 or 20.7% of all broadband HHs (2017).		DOCSIS 3.0: 2006 DOCSIS 3.1: 2013	Continued roll-out
Fibre networks	FTTH, FTTB, FTTP	1 Gbit/s-500 Gbit/s	Yes	Yes	Homes passed: 26,6 million (mid 2018) Actual usage: 52,496,296 or 23.8% of all broadband HHs (2017).	With strong differences between different countries in the EU. In Germany, FTTP-coverage is below 10%, in Spain almost 80%.	Expansion in Europe since 2006	
DECT	DECT 6.0 (ETR-178 technical report. Subsequent standards have been published)	32 kbit/s (available in both directions)	Yes	No	1.3 million units sold in 2017 (no aggregate data found)	ECO-DECT and DECT ULE (Ultra Low Energy) are labels for low energy and low radiation devices.	1993	In Germany, approval extended until 2025
WiFi	IEEE 802.11 family renamed to WiFi 4 (11n), 2009, WiFi 5 (11ac), 2014, WiFi 6 (11ax), 2019.	Half of max. data rate in available on the consumer side[24]: 36-300 Mbit/s, 115 Mbit/s-3,5 Gbit/s, 300 Mbit/s -6 Gbit/s.	Some Voice over IP	Yes	Private use: all fixed networks because termination boxes include WiFi routers (214,7 Mio routers) plus enterprise use and public Hotspots.		1998	

[22] https://webstore.ansi.org/standards/atis/ansit14131998
[23] https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/213/NEWS_213_DOCSIS_english.pdf
[24] https://www.intel.de/content/www/de/de/support/articles/000005725/network-and-i-o/wireless.html

According to the latest EU-Report on Broadband Coverage, there were 215 million homes passed by fixed broadband networks in mid-2018 in the EU 28 (European Commission 2019).

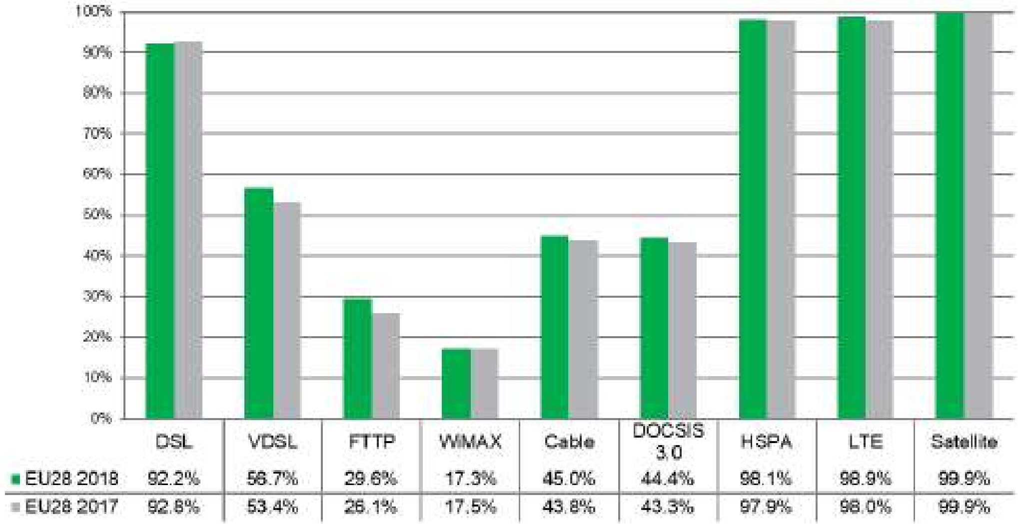

Figure 41: Broadband coverage by technology in the EU (European Commission 2019)

Other figures are provided by international telecommunications market research and consulting firm TeleGeography. According to this company,[25] there were 222 million broadband subscribers in Europe in 2017, including mobile broadband subscribers (see Table 14).

Table 14: European Broadband Subscriptions by Technology in 2017 (TeleGeography 2018) [26]

Technology	European Broadband Subscriptions (Mio)	Share (%)
DSL	116.5	52.8%
Cable	45.7	20.7%
Fibre	52.5	23.8%
Fixed-wireless	3.3	1.5%
Other	2.7	1.2%
Total	220.8	100%

The fixed broadband coverage level is above 95% in the EU-28, however few Member States are still below 90%.

[25] TeleGeography 2018, "DSL" includes ADSL, VDSL and VDSL2, "Fibre" includes Vectoring

[26] ibid.

Figure 42: Overall fixed broadband coverage by country, 2018 (European Commission 2019)

6.1.1. Data consumption

In Europe, the overall average broadband Internet usage for all households was 168.2 GB/household in 2018, according to London-based consulting firm OpenVault[27]. In 2017, the respective value was 126.2 GB/ household.

6.1.2. Telecom networks (ADSL, VDSL)

Internet connectivity over the telephone network is offered via the transmission protocol family DSL (Digital Subscriber Line). The DSL provides internet connectivity over the telephone network. Depending on different upstream and downstream speeds, a distinction is made between Asymmetric Digital Subscriber Line (ADSL) and Very High Speed Digital Subscriber Line (VDSL), with download speeds from 1 Mbit/s (ADSL) to 100 Mbit/s (VDSL).

The DSL system uses twisted copper pairs originating from the central office of the provider to the customer premises equipment (DSL modem).

The broadband Internet connections are realized over the traditional telephone network, which uses twisted pair copper wire cables on the last mile to the customer premises. Backbone networks are completely based on fibre-optical networks, however the signal is being converted to electrical signals for the copper network at the so called DSLAMs (Digital Subscriber Line Access Multiplexer).

Households need a termination box in their homes which receives data and phone signals and distributes signals via LAN cables or WiFi (wireless) within the house. Most DSL termination boxes thus include a WiFi-router.

6.1.2.1. Possible follower technologies

Vectoring or VDSL2 is an improved version of VDSL which still uses copper wires on the last mile. However, for Vectoring-connections, the actual distances of the "last mile" are

[27] Broadband usage accelerates in Europe and the US. January 22, www.broadbandtvnews.com/2019/01/22/broadband-usage-accelerates-in-europe-and-the-us/ (accessed on 11.08.2020)

being shortened, so that fibre cables come closer to the respective households. This requires new termination stations at the curbside, thus this version is also called Fibre-To-The-Curb (FTTC). Vectoring or FTTC is being rolled-out in various countries in Europe, mostly by former telecom incumbents like Deutsche Telekom or Orange. It enables download speeds of up to 100 Mbit/s depending on the length of the "last mile". The signal gets weaker with line length, a phenomenon called attenuation.

FTTB/H (Fibre-To-The-Building/ -Home) replaces the copper lines on the last mile with fibre cables and converts the optical signal directly at the premises (building or home). This increases download and upload speeds considerably (see section fibre networks). Also, the attenuation problem does not apply to fibre-optical lines.

6.1.2.2. Current usage

DSL-broadband connections are the most popular ones in Europe with over 50 percent of all broadband technologies. According to TeleGeography, there were 116.5 million DSL subscribers in Europe in 2017.[28]

Also, the coverage of DSL connections in Europe is high with over 90 percent (see EU 2019).

6.1.2.3. Data rates and protocols

DSL data rates for download range between 9 and 100 Mbit/s according to the protocol. The real rates depend on the length of the "last mile" and other factors (see above). Table 15 provides an overview of the data rates according to the DSL protocol.

Table 15: Data rates and protocols for DSL[29]

	Download	Upload
ADSL	Up to 9 Mbit/s	Up to 1 Mbit/s
VDSL	Up to 50 Mbit/s	Up to 10 Mbit/s
VDSL2	Up to 100 Mbit/s	Up to 40 Mbit/s

6.1.3. Cable-TV-networks

Cable-TV networks not only deliver broadcast services like TV and radio but also deliver two-way telecommunication services like Internet connectivity and telephony. Cable Internet is delivered over a fixed cable TV network using coaxial cable according to cable broadband standards family DOCSIS, providing download speeds of 300 Mbit/ and above. Cable Internet requires a cable modem which is plugged into the cable-TV-outlet and can directly be connected to a desktop or laptop computer or to a WiFi-router to transmit Internet wirelessly in every room.

DOCSIS (Data Over Cable Service Interface Specification) uses the TV cable network to transfer bidirectional data transmission. The last part of the connection to a customer's home is made of optical fibre and coaxial cables, amplifiers and electrical/optical converters (hybrid fibre-coaxial (HFC) network). DOCSIS 3.1 allows (in comparison to

[28] TeleGeography 2018, "DSL" includes ADSL, VDSL and VDSL2, "Fibre" includes Vectoring

[29] https://www.dslvertrag.de/wie-unterscheiden-sich-eigentlich-dsl-adsl-sdsl-und-vdsl/ and https://www.inside-digital.de/ratgeber/dsl-vdsl-vectoring-kabel-glasfaser-unterschiede (accessed on 11.08.2020)

DOCSIS 3.0) the maximization of downstream and upstream rates without expensive changes in the infrastructure.[30]

6.1.3.1. Possible follower technologies

DOCSIS 3.1: The new protocol introduced by European cable-TV providers from 2018 is capable of an even higher downstream data throughput of up to 10 Gbit/s, depending on the number of users using the connection at the same time (shared medium). DOCSIS 4.0 will provide higher upload speeds in the future.
DOCSIS 4.0 allows for higher upstream speeds as well as having a higher frequency spectrum (and therefore allowing higher bandwidths).[31] Comparable performance can then only be expected through FTTH or FTTB (or through 5G as a mobile solution at gigabit speeds).[32]

FTTH: Whereas DOCSIS already requires replacing coax cable by fibre optical cables to a certain point near the end-user, FTTH (Fibre-to-The-Home) will provide fibre cables directly to the homes, increasing download and upload speeds up to 10 Gbit/s and more in both directions.

6.1.3.2. Current usage

Most cable Internet-connections today use DOCSIS 3.0. The total number of homes passed with cable Internet according to the European Broadband Survey in mid-2018 is 96.8 million in Europe (45% of 215 million EU homes passed by fixed broadband networks)[33]. This figure relates to the homes which can principally be reached by the network and not the actual number of users.

Actual usage in 2017 is estimated to be 45,702,115 or 20.7% of all broadband households (see TeleGeography 2018).

6.1.3.3. Data rates and protocols

Data Over Cable Service Interface Specification (DOCSIS) is the relevant protocol for Internet and Voice over IP over the cable TV-network. An overview is provided in Table 16.

Table 16: DOCSIS versions and broadband capacities[34]

DOCSIS Version	Introduction	Max Downstream	Max Upstream	Features
3.0	2009/2010	1 Gbit/s	300 Mbit/s	Increased down-/up-stream rate
3.1	2017	10 Gbit/s	2,5 Gbit/s	Increased down-/up-stream rate
4.0	T.b.d.	10 Gbit/s	6 Gbit/s	Increased upstream rate

[30] https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/213/NEWS_213_DOCSIS_english.pdf
[31] https://www.teltarif.de/internet/tv-kabel/docsis.html (accessed on 11.08.2020)
[32] http://anga.de/media/file/965.BR-DOCSIS_3.1-final_online.pdf (accessed on 11.08.2020)
[33] See European Commission 2019, page 7
[34] http://anga.de/media/file/965.BR-DOCSIS_3.1-final_online.pdf, https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/213/NEWS_213_DOCSIS_english.pdf, https://www.golem.de/news/technetix-docsis-4-0-mit-10g-im-kabelnetz-wird-wirklichkeit-2001-146400.html and https://www.teltarif.de/internet/tv-kabel/docsis.html (accessed on 11.08.2020)

6.1.4. Fibre networks

Internet access via fibre-optical networks is considered to be the ideal, technically most advanced and future-proof Internet access technology because fibre networks achieve the highest data speeds (up to 100 Gbit/s). Since connections are stable they provide the same high download and upload speeds (symmetrical data transmission).

Internet over fibre networks is called FTTB/H/P (Fibre-To-The-Building/ Home/ Premises) because the fibre optic cables are going all the way to the buildings or homes. Currently, only a small fraction of broadband subscribers can actually use FTTB/H because telecom companies still need to lay fibre cables on the "last mile". This requires roadside work and negotiations with every home and apartment owner. FTTB/H subscribers need to install a fibre network termination box in their homes. The box converts the optical signal into an electrical signal so that the in-house cable network can be used. Similar to DSL-boxes, fibre boxes also have a WiFi router included so that all rooms in the house can use wireless Internet as well.

6.1.4.1. Possible follower technologies

In the fixed network, fibre technology is considered the ideal broadband technology. One way to further increase bandwidth capacity is to lay more than one fibre into homes. On the other hand, new technologies to use the light spectrum within one fibre more efficiently and to increase the pulse repetition rate can also result in even higher transmission rates in the future.

6.1.4.2. Current Usage

According to telecom research firm TeleGeography (2018), there were 52.5 million fibre Internet users in Europe in 2017. This makes up for 23.8% of all broadband Internet users in Europe. However, the availability of fibre networks (which the EU calls Fibre-To-The-Premises, FTTP) in Europe is very different: Whereas in Germany, less than 10 percent of the population can use fibre networks, in Spain it concerns almost 80 percent of the households (Figure 43).

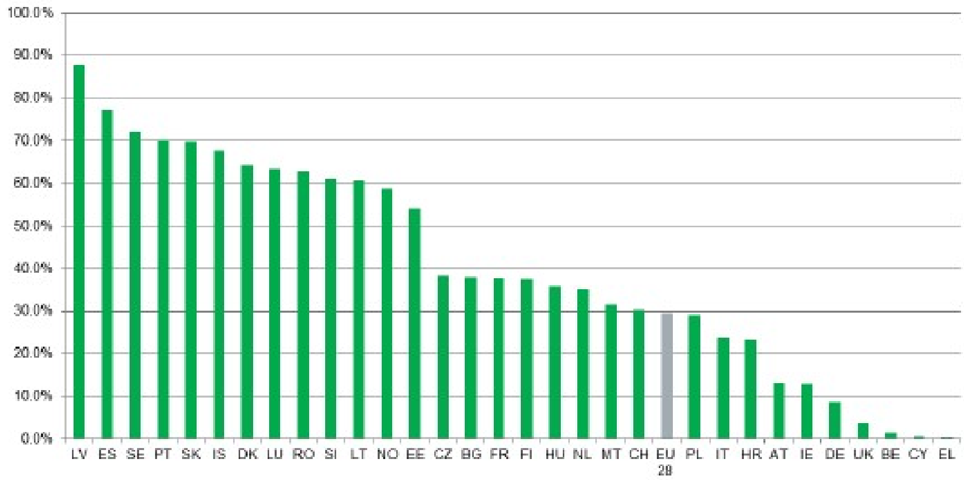

Figure 43: FTTP coverage by country, 2018 (European Commission 2019)

6.1.4.3. Data rates and protocols

Although fibre networks can transmit hundreds of Gbit/s and in experimental settings Terrabits/s and even Pentabits/s have been demonstrated, current telecom operators usually offer transmission speeds of 1-10 Gbit/s to their end customers.

6.1.5. DECT (Digital Enhanced Cordless Telecommunications)

DECT telephones are cordless telephones which use the DECT wireless standard to transfer speech from the headset to the base station. Up to six handsets can be used in the home of users. The handsets are wirelessly connected to a base station which is connected via a cable to the main telephone line. The base station acts as both a radio transmitter and receiver, sending the connection to the handset's speaker and receiving input from the handset's microphone, which is sent along the land line like a normal connection. DECT phone handsets need batteries which are recharged at the base station.

6.1.5.1. Possible follower technologies

There are 3 main approaches:

- DECT-modules are integrated in modern WiFi-Boxes
- IP-telephony via WLAN (voice over wireless LAN)
- Bluetooth-Technology (currently with a shorter range)

6.1.5.2. Current Usage

European market in 2017: approximately 1.3 million consumer devices were sold, forecasts expect the market volume to decrease to around 1.1 million devices per year by 2021.[35]

6.1.5.3. Data rates and protocols

The standard data rate for the wireless communication between handset and the base station is 32 kbit/s in both directions. Most devices use the DECT 6.0 protocol but older versions of the protocol are still being used.

6.1.6. WiFi

WiFi stand for "Wireless Fidelity" and is a family of wireless networking technologies, based on the IEEE 802.11 standards family, now termed Wi-Fi 4, Wi-Fi 5 and Wi-Fi 6. WiFi is used for local area networking of devices and Internet access. The base stations sending out the Internet data is called a WiFi router. WiFi routers are integrated in termination boxes of telecom-, cable-TV- and fibre-networks (see sections above). Devices receiving WiFi signals are laptops, smartphones, tablets, computers, smart TVs, printers, digital audio players, digital cameras, etc. Wi-Fi is also called WLAN (Wireless Local Area Network) in parts of Europe, for example in Germany.

[35] Gigaset Report for the 2nd Quarter 2017, p. 3, https://gse.gigaset.com/fileadmin/gigaset/images/AG/Publications/Quarterly-Reports/EN/Gigaset_Q2_2017_EN.pdf (accessed on 11.08.2020)

6.1.6.1. Possible follower technologies

WiFi 6 (11ax) which was certified in 2019 can transmit between 300 Mbit/s -6 Gbit/s. In 2020, first WiFi 6-routers and devices are available on the market, however, there will be a transition phase of at least 5 years to the new standard.

6.1.6.2. Current Usage

Private use: all fixed networks because termination boxes include WiFi routers. The figures report up to 214.7 Million WiFi-routers in private households in Europe. Not included in this figure are end devices like laptops or smartphone which have WiFi sending and receiving capabilities.

In addition, enterprises use Wi-Fi on premises to connect their employees to company intranets and the Internet. Also, there are commercial and public WiFi Hotspots in many places in European cities.

6.1.6.3. Data rates and protocols

Currently, most WiFi-routers and devices use WiFi 4. Until 2023. Cisco estimates that 66% will use WiFi 5.[36]

Table 17: Standards and actual transmission speeds of WiFi[37]

IEEE 802.11	Theoretical (in Mbit/s)	Actual (in Mbit/s)
WiFi 4 (802.11n)	600	100
WiFi 5 (802.11ac)	1300	200
WiFi 6 (802.11ax)	10000	2000

6.2. Mobile networks

6.2.1. Overview

Table 18 provides an overview of the current telecommunications and internet connectivity in Europe for mobile networks.

[36] Cisco Annual Internet Report (2018–2023) White Paper, March 9, www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html (accessed on 11.08.2020)

[37] see: https://www.lifewire.com/how-fast-is-a-wifi-network-816543 (accessed on 11.08.2020)

Table 18: Mobile networks (own compilation)

	Protocols	Average data rates	Telephone	Internet	Usage in Europe	Additional info	When was it introduced on the market	Until when is the connection available?
3G	IMT-2000	3G UMTS: 384 Kbit/s 3G HSDPA: 7,2 Mbit/s 3G HSPA+: 42 Mbit/s	Yes	No	465 million people in Europe subscribed to mobile services in 2018. (GSM Association). 2G: 18% 3G: 40%		2001	Bundesnetzagentur requires network operators to provide at least 98 percent of German households with up to 50 Mbit/s fast connections by the end of 2019. UMTS cannot achieve this → Focus on LTE and 5G[38]
4G (LTE)		4G LTE: 500 Mbit/s 4G LTE-A: 1 Gbit/s	Yes	Yes	4G: 42%		2009 (in Stockholm and Oslo) 2010 in Germany	
5G	Further development of 4G protocol, called CP-OFDM (Cyclic Prefix OFDM).	up to 10 Gbit/s, depending on distance to the next mobile radio station and on simultaneous use of other users. In pilots, data speeds below 1 Gbit/s were achieved	Yes	Yes	Only a few early adopter users in 2020. Plans in Germany are to provide 5G to 99% of the population by 2025.	Many more mobile radio stations (antennas) are needed. Also, a dense fixed fibre network to connect mobile radio stations is required.	Action plan to start launching 5G services in all EU member states by end 2020 (source)	

[38] https://www.techbook.de/mobile/3g-nutzern-droht-die-abschaltung-des-netzes (accessed on 11.08.2020)

Most smart phones use the 3G (UMTS) or the 4G (LTE)-standard. 3G is still heavily used, but at the end of 2017, there were already 285 million 4G connections in Europe, accounting for 42% of total connections.

The GSM Association expects 4G to be the dominant mobile technology in 2025 (Figure 44).

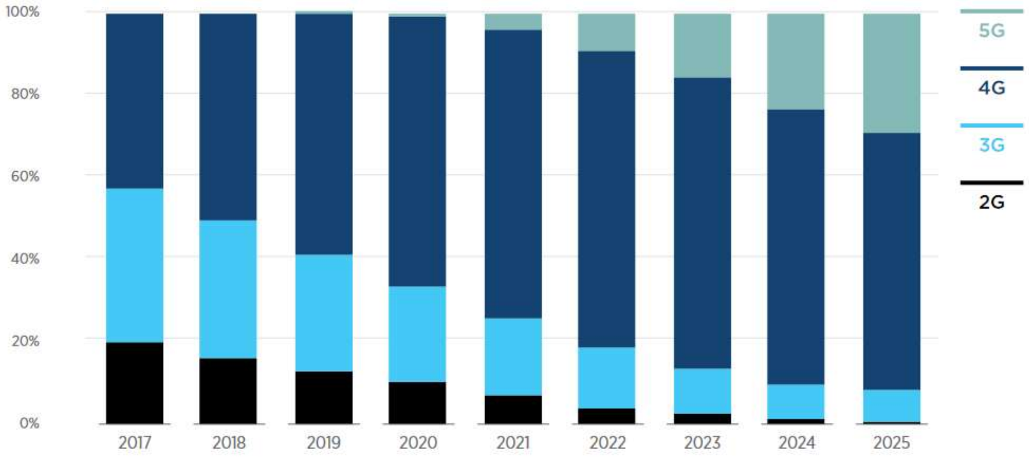

Figure 44: Shares of European connections by technology

The use of Internet over smartphones is very unevenly distributed over Europe but growing everywhere.

6.2.1.1. Possible follower technologies

The fifth generation (5G) is the follow-up technology for 4G/LTE. 5G will have higher transmission capacities (up to 10 Gbit/s), depending on the distance to the next mobile radio station the simultaneous use of other users. In 2020 the 5G rollout has just started. The new technology is only available in a few areas (see Figure 45) and there are only a few devices available.

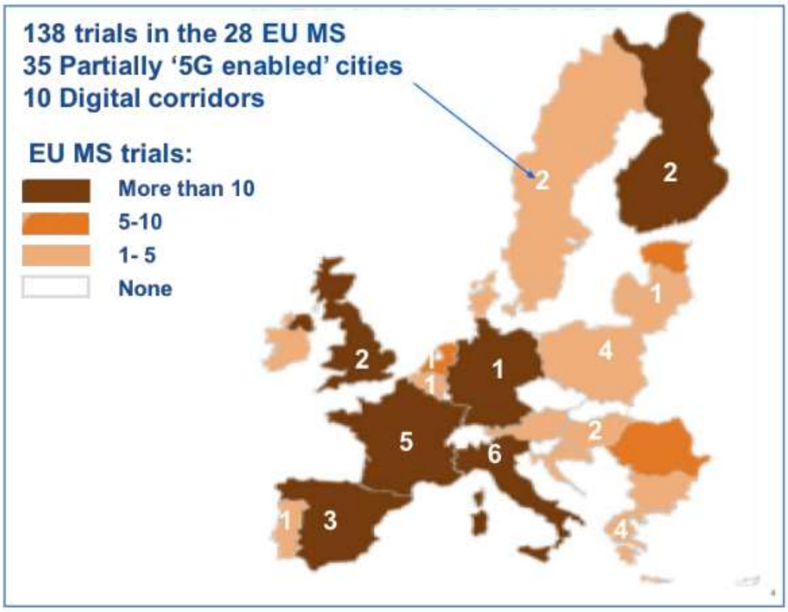

Figure 45: 5G trials and initial city pilot rollouts (European Commission 2019)

The fifth generation of mobile Internet will bring radical changes for European society as well as economy. In addition to economic opportunities, a wide range of areas such as transport, energy and agriculture will be digitally and ecologically transformed by the launch of 5G networks. As 5G will be the basis for future technologies and developments, the introduction of 5G especially in urban areas and along major transport routes is essential for European economic viability and the primary objective of the EU's 5G Action Plan. Europe is one of the most advanced regions in the expansion of 5G networks. In their report, the EU Commission states that 5G services will be available in 138 European cities by the end of 2020. Initially, these services will mainly be available to the public for faster and more powerful connections (European Commission 2020a).

The Commission created a toolbox that provides the Member States with important (security) measures and the progress made by the countries. For the roll-out, the EU decided not to exclude any provider from building 5G mobile networks in Europe. The providers (such as Telekom, Vodafone, etc.) have the possibility to develop strategies together with the governments and industry (NIS Cooperation Group 2020).

In Germany, telecom operator Vodafone started the commercial launch of 5G in July 2019.[39] Providers of 5G do not have any influence regarding the decision of 5G compatible products. But, depending on the chosen bandwidth, 5G providers could influence compatible products.[40] In total, 5 billion euros have been allocated to the 5G expansion until 2025.[41]

6.2.1.2. Data rates and protocols

Data rates for the various network generations is as follows:

- 3G UMTS: 384 Kbit/s
- 3G HSDPA: 7,2 Mbit/s
- 3G HSPA+: 42 Mbit/s
- 4G LTE: 500 Mbit/s
- 4G LTE-A (for Advanced, also called LTE+ or 4G+): 1 Gbit/s
- 5G: up to 10 Gbit/s

6.2.2. For which applications is 5G required?

The big terms that are frequently used in connection with the 5G expansion are "Internet of Things" (IoT), vehicle-to-vehicle communication or industry 4.0. It already indicates that the vision of the 5G network is intended for more than private customers only. In (almost) all industrial and service sectors a rethinking has to take place with the introduction of the 5G network especially as its applications are only partially known today. 5G provides three basic services to enable stable and quick data transfer that will fundamentally change society and technology. Therefore, 5G offers:[42]

- enhanced mobile broadband
- massive machine type communication
- ultra-reliable and low-latency communication

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[39] https://www.onlinekosten.de/news/vodafone-startet-5g-fuer-private-kunden-5g-option-fuer-5-euro-pro-monat_220227.html (accessed on 11.08.2020)

[40] https://www.teltarif.de/telekom-5g-probleme/news/81287.html (accessed on 11.08.2020)

[41] https://www.computerbase.de/2020-06/corona-konjunkturpaket-bund-glaser-5g-ausbau/ (accessed on 11.08.2020)

[42] https://www.5g-anbieter.info/5g-anwendungen.html (accessed on 11.08.2020)

The following areas of use are already apparent today. Each of them can be divided into further subgroups:[43]

- Constant availability of a minimum of performance (100 Mbit+)
- Performance even at high data volumes (e.g. during mass events)
- Undisturbed data connection even with mobility at high speed (e.g. train, airspace)
- Technical basis for the IoT, E-Health, Industry 4.0, Logistics, Smart City or Smart Farming
- New broadcast technologies (e.g. live TV for mobile devices in Ultra-HD)
- Augmented Reality Maintenance
- Basis for autonomous vehicles / autonomous train control
- Improved mobile telephony (Voice over 5G)

With its low latency and the data transmission almost in real time, 5G creates the perfect basis for the deployment of Virtual Reality (computer-generated reality) and Augmented Reality (mixed reality: reality merges with a virtual world) even on smartphones or tablets. The applications are mostly not yet market-ready nor ready for large-scale use. A potential future application for private customers is virtual showrooms where manufacturers can present their products virtually and users can remotely configure them according to their needs.[44]

In addition to these new applications, already known applications will become significantly more powerful for end users. Video streaming (apps like Netflix or amazon prime) or instant downloads benefit from the faster data connection. The 5G network also promotes the attractiveness of cloud services. In addition to cloud storage, cloud gaming is becoming more attractive for the end user: Data is stored on a cloud while images only are transmitted to the user in quasi real time. Hence, 5G reduces the demands on the device's hardware, but requires fast internet connections.[45]

According to IDC, the market share of 5-G Smartphones will increase from 9% (126 Million pieces) in 2020 to 28% in 2023.

In Europe, the sales of 5G smartphones had a share of 4% of the overall smartphone sales in the first quarter of 2020[46]. The European 5G market is anticipated to grow as fast as 153.7% per year until 2027. This immense growth rate can be related to the quick adoption of 5G networks in Europe.[47] The expansion of 5G network is mainly driven by the Chinese manufacturer Huawei which is responsible for the highest market share of base stations in Europe[48].

6.3. Repair shops

Repair shops are also part of the local infrastructure relevant for the smartphones and tablets. Key information and figures have already been provided in Task 2.

[43] ibid.
[44] https://www.telekom.de/unterwegs/was-ist-5g/5g-ar-vr
[45] https://www.chip.de/news/Die-besten-Apps-fuer-das-schnelle-5G-Internet_170621499.html
[46] https://www.counterpointresearch.com/covid-19-weighs-european-smartphone-market-q1-2020/
[47] https://www.grandviewresearch.com/industry-analysis/5g-smartphone-market
[48] https://newseu.cgtn.com/news/2020-07-15/How-Huawei-s-European-growth-started-in-the-UK-S9uyuAsAiQ/index.html

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