



Ecodesign preparatory study on mobile phones, smartphones and tablets

Draft Task 3 Report
Users (product demand side)



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1 1. INTRODUCTION

2 According to the Ecodesign Working plan 2016-19, "Given their specificity, a separate
3 track is proposed for ICT products..., that will also fully take into account their circular
4 economy potential, which is particularly relevant in the case of mobile / smart phones".
5 Within this context, DG GROW launched this preparatory study on mobile phones,
6 smartphones and tablets in order to assess the feasibility of proposing Ecodesign and/or
7 Energy Labelling requirements for these product groups. Preparatory studies aim to
8 assess and specify generic or specific ecodesign measures for improving the
9 environmental performance of a defined product group, sometimes in combination with
10 energy label criteria. The ecodesign preparatory studies therefore provide the scientific
11 foundation for defining these generic and/or specific ecodesign requirements as well as
12 energy labelling criteria. The overall objective is to clearly define the product scope,
13 analyse the current environmental impacts of these products and related systems
14 (extended product scope) and assess the existing improvement potential of any
15 measures. In particular, aspects relevant to the circular economy, are in the scope. The
16 central element of the MEErP (Kemna 2011; Mudgal et al. 2013), being the underlying
17 assessment methodology, is to prioritise today's possible improvement options from a
18 Least Life Cycle Cost (LLCC) perspective. Identification of the improvement options are
19 based on possible design innovations, Best Available Technologies (BAT) for the short
20 term and Best Not yet Available Technologies (BNAT) for long term, which can help in
21 mitigating the impacts of these products. Policy options are assessed through a scenario
22 analysis and the different outcomes have to be evaluated from the perspective of the EU
23 targets, taking into account potential impacts on the competitiveness of enterprises in
24 the EU and on the consumers.

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

34 Where appropriate the distinction of private and professional user and respective user
35 behaviour will influence the definition of the use pattern and lifetime assumptions.
36 Smartphones are multifunctional devices that have many different and still increasing
37 application options (app store). The utilisation intensity may vary significantly depending
38 on the actual product configurations (e.g. installed applications, functional accessories,
39 dual sim cards and extended storage). All these aspects are relevant for the following
40 analysis.
41

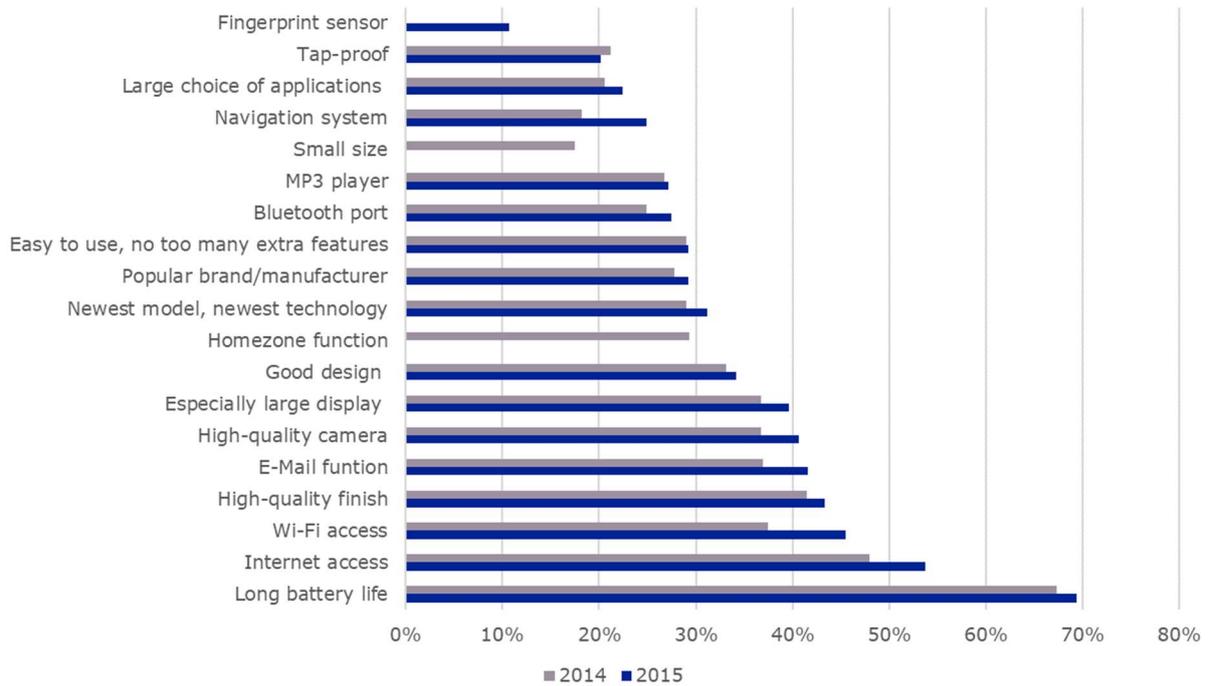
42 2. SUBTASK 3.1 – SYSTEMS ASPECTS OF THE USE PHASE FOR ERPS WITH 43 DIRECT IMPACT

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

49 **2.1. Purchase decisions and contracts**

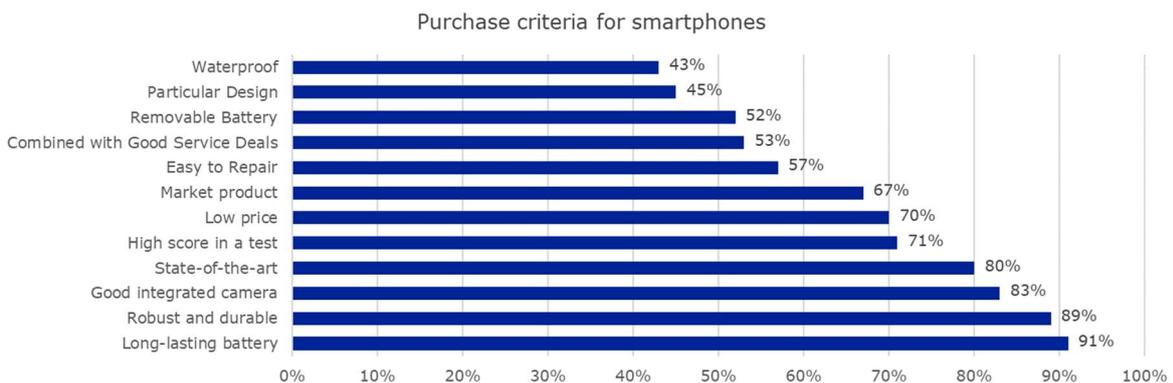
50 When purchasing a new smartphone, some features are more important than others for
51 consumers. Figure 1 shows the results of a survey conducted in 2015 in Germany
52 highlighting the most important purchasing criteria. The interviewed persons were 14

1 years and older. The most important criteria cited were a long battery life (almost 70%)
 2 and good internet and Wi-Fi access. For 40% of respondents a high-quality finish was a
 3 major purchase criteria.



4
 5 **Figure 1: Most important criteria for buying a new mobile phone or smartphone**
 6 **in Germany¹**

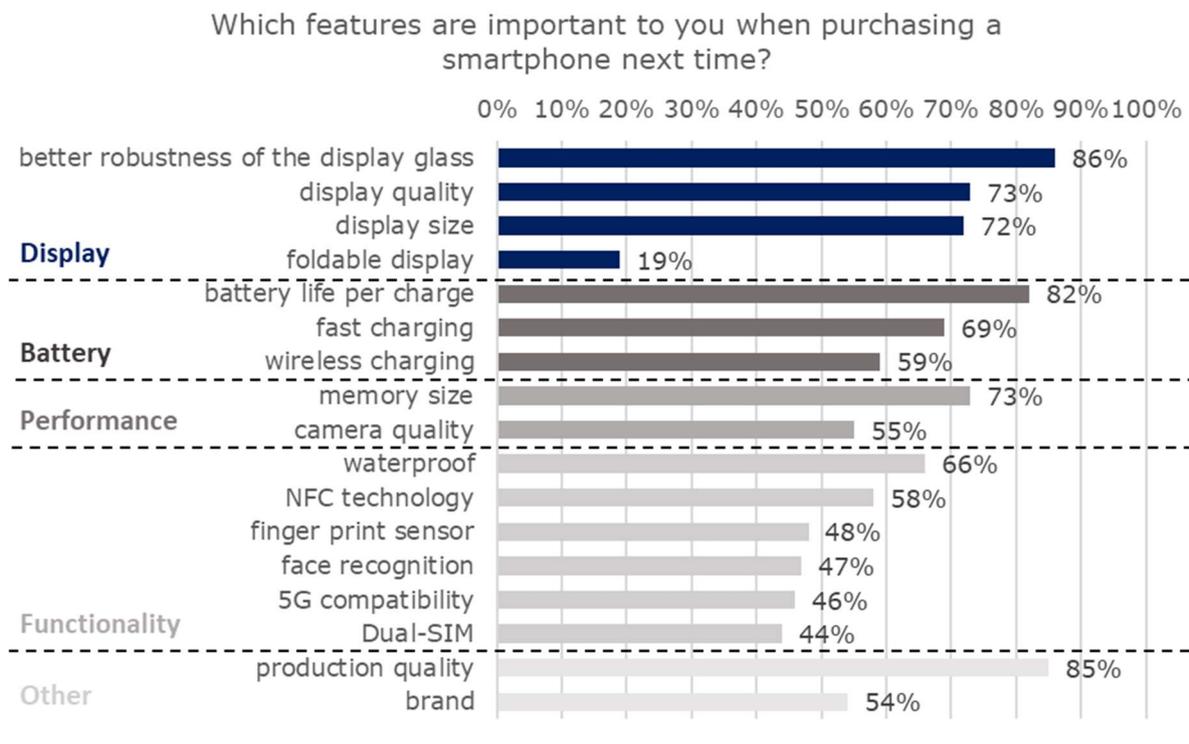
7 A later online survey among German consumers (n=1813) in 2017 focussed again on
 8 purchase criteria for smartphones. On the question, which aspects played an important
 9 role for selecting a smartphone, long-lasting battery and robustness and durability were
 10 the most important criteria, see the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



12
 13 **Figure 2: What role did the following aspects play in selecting the current**
 14 **smartphone? Percentages represent the sums for the answers "a rather large" /**
 15 **"a large role" (n = 1813) (Jaeger-Erben and Hipp 2018)**

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

1 Most recent representative data from Bitkom² published in February 2020 confirms in
 2 general the interest in (more) robust devices (Figure 3). A robust display is much more
 3 important than 5G. Battery life per charge is also of high importance – and at the same
 4 time fast charging is appreciated. High water resistance is another important purchase
 5 criterion, and large storage capability.



6

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

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

- 10 • 37% old device **broke**
- 11 • 30% the **performance** of the old device had significantly deteriorated
- 12 • 19% certain applications or **software** stopped working on the old device

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

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

18 Focus group participants in the four countries Czech Republic, Sweden, Germany, and
 19 Ireland considered **durability** to be highly important and were very interested in
 20 purchasing products that lasted longer: "This was particularly the case for products that
 21 participants considered to be "important investments", such as dishwashers and washing
 22 machines." In our understanding some high-end smartphones (and tablets) can also be
 23 considered "important investments", so this durability statement might hold true for this
 24 market segment as well. Cerulli-Harms et al. however distinguish only between product
 25 groups: Compared with the unanimous importance of durability for white goods "opinions

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

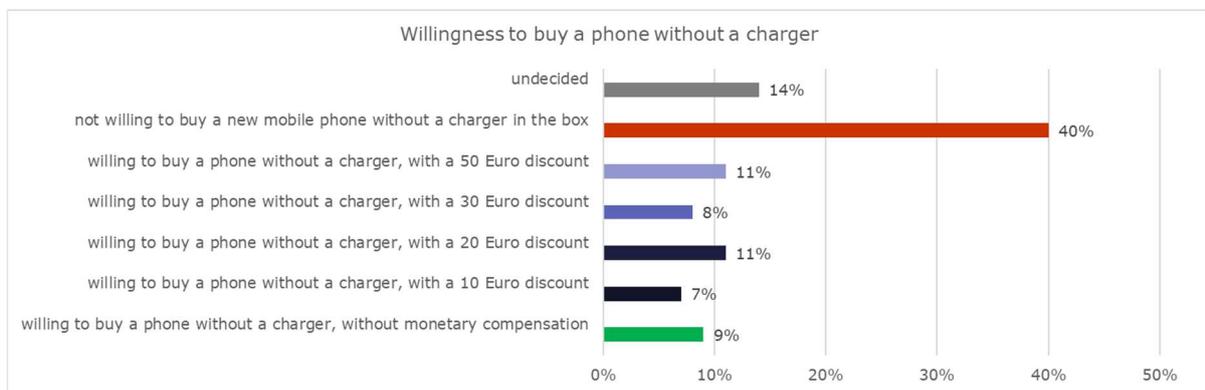
1 with regard to the importance of durability varied more when talking about other types of
2 products. Some participants felt that durability was just as important for products such
3 as televisions and smartphones, while for others, technological progress was a factor
4 influencing them to purchase this type of products more frequently, and therefore their
5 expectations with regard to these products' lifetime were lower."

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

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

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

34 The Impact Assessment study on a common charger found out that only 9% are willing
35 to buy a phone without a charger, given the device is sold at the same price. 36% expect
36 a price discount for a phone without charger, thereof 7% are willing to accept a
37 compensation of 10 Euros, which is roughly the cost of a separately sold charger. 30%
38 are willing to accept a phone without a charger, but only at a compensation, which
39 significantly exceeds the price of a stand-alone charger (Figure 4).



40

41 **Figure 4: Willingness to buy a mobile phone without a charger (Ipsos, Trinomics,**
42 **Fraunhofer FOKUS, Economisti Associati 2019)**

1
2 "Among those who were unwilling to consider buying a phone without a charger, 68%
3 indicated that the charger provided with the new phone saved the trouble of finding the
4 right charger. The bundle was also perceived as an assurance that the charger would
5 work properly (38%), that it was safe because from the same brand as the phone (35%),
6 and that it would charge the mobile phone efficiently (23%). 55% of those that would
7 consider buying a phone without a charger would do so for environmental reasons, as
8 they indicated that it would help them to save resources and reduce e-waste." (Ipsos,
9 Trinomics, Fraunhofer FOKUS, Economisti Associati 2019)

10 In an unpublished survey in May and June 2020 a telecommunications provider asked
11 their customers to state relevance of a range of aspects when buying a smartphone from
12 a telecommunications provider. Respondents in all 5 EU countries where this survey was
13 undertaken mentioned "device quality" as the most important aspect (roughly 90% of
14 respondents in all countries). "Sustainability of the device" is important to 50% of the
15 respondents in Germany and to 75 – 90% of the respondents in other EU countries.
16 Except for Germany sustainability is more important than the smartphone brand (60 –
17 75%) and close to price (80 – 90%). These recent results confirm the recognised trend
18 towards increasing importance of sustainability as purchase criterion. It is however
19 worthwhile noticing, that price and brand are obvious characteristics of a smartphone,
20 whereas "sustainability" is a less transparent feature, thus might not be taken into
21 account in purchasing decisions to the same degree than other transparent criteria.

22 There are basically two types of **mobile phone contracts** (Bisping and Dodsworth
23 2019):

- 24
- 25 • prepaid or monthly rolling contracts, where the customer either pre-pays or post-
26 pays for a service on a monthly basis without commitment beyond one month
 - 27 • contracts with a pre-determined initial commitment period of over one month,
28 where the customer will pay a set fee for at least the number of months set out in
29 the contract term. These contracts can include the provision of a handset, or they
30 can be SIM-only, i.e., limited to the provision of telephony services. Providing the
31 handsets with the contract is frequently factored-in with the subscription price

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

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

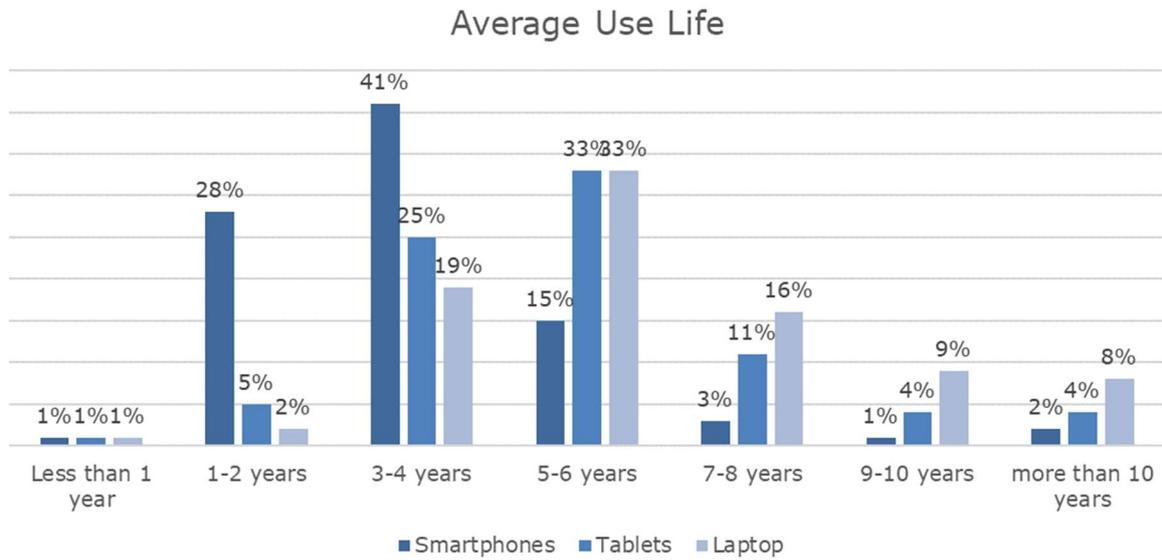
40 **2.2. Active use lifetime**

41 **2.2.1. Actual use**

42 Mobile Device users in the UK were asked in a survey by YouGov about product
43 upgrades³. Being asked how long they use a device before buying a new one, the survey
44 results show shorter upgrade cycles for smartphones than for tablets: Almost 70% of all
45 respondents upgrade to the next smartphone within 1 to 4 years, whereas only 30% of
46 tablet users upgrade within the first 4 years. 5-6 years is the upgrade cycle of

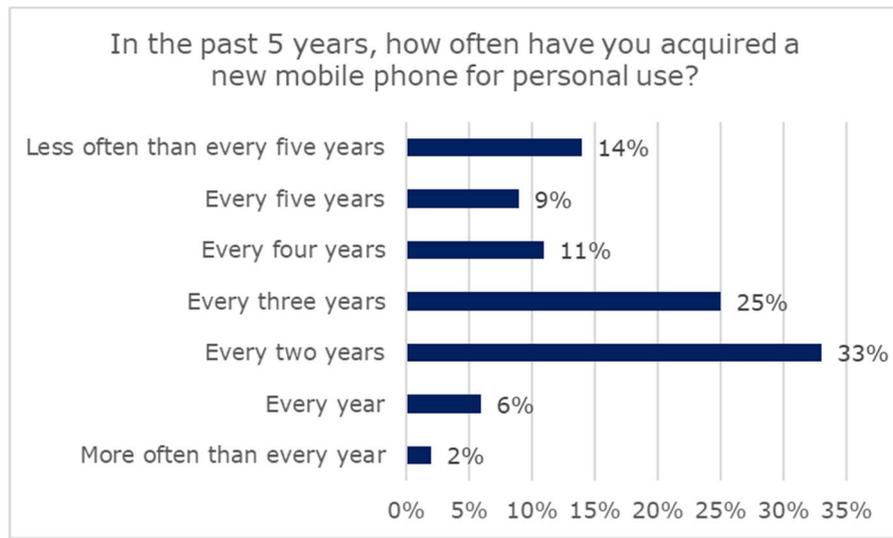
³ <https://yougov.co.uk/topics/technology/articles-reports/2020/05/07/45-smartphone-owners-would-rather-upgrade-repair>

1 smartphones for a significant share of 15% of the respondents. One third of the
 2 respondents upgrade tablets in year 5 or 6. These findings roughly correspond to the
 3 market data presented in the task 2 report.



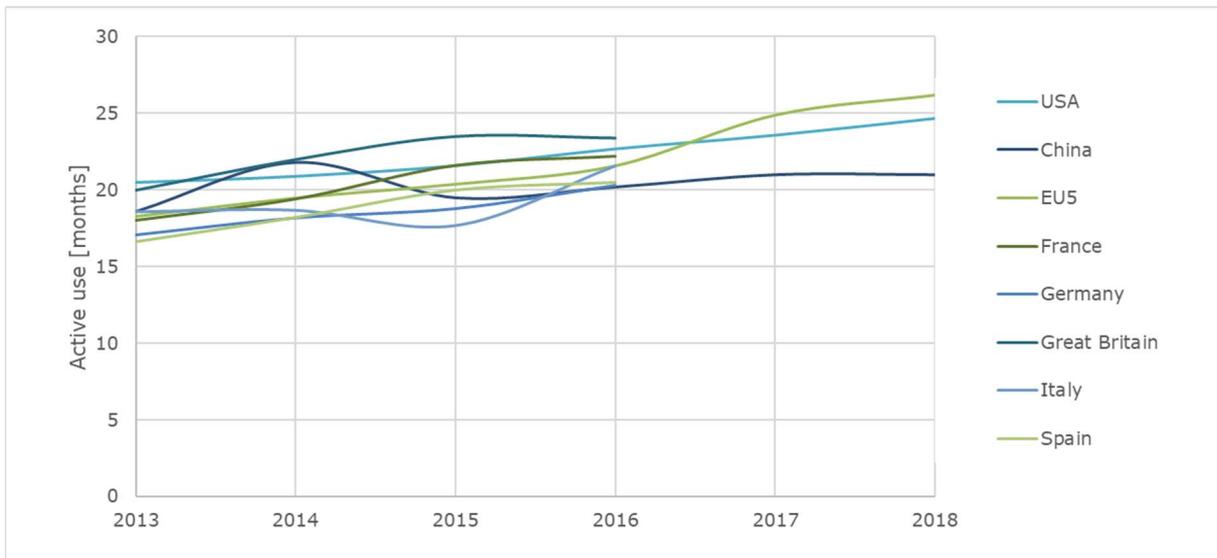
4
 5 **Figure 5: On average, how long do you tend to own the following devices before**
 6 **buying a new one? (source : YouGov Research, 2020)**

7 In conjunction with the Impact Assessment of a common charger solution a user survey
 8 also asked how frequently users buy a new mobile phone. One third state to acquire a
 9 new mobile phone every 2 years, almost 60% acquire a new phone less frequently
 10 (Figure 6). This data also indicates an average replacement cycle of 3,2 – 3,4 years for
 11 mobile phones (i.e, actual product lifetime is longer due to reuse of some of the devices,
 12 see Task 2 report).



13
 14 **Figure 6: Frequency of acquiring a new mobile phone (Ipsos, Trinomics,**
 15 **Fraunhofer FOKUS, Economisti Associati 2019)**

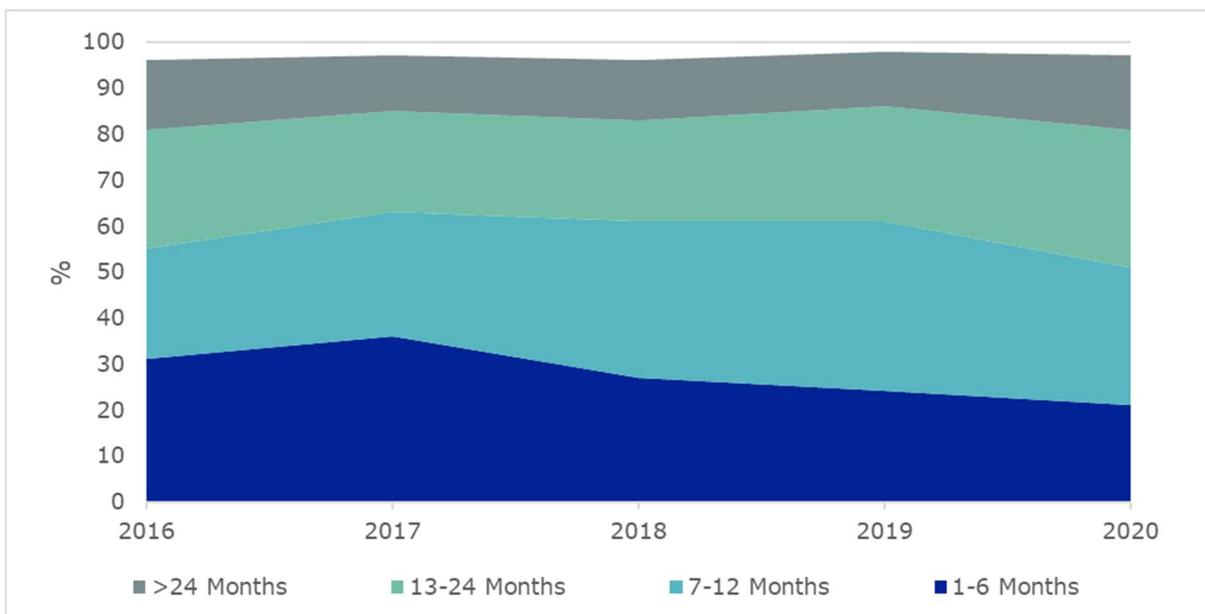
16 In general users tend to use their smartphones increasingly longer (Figure 7) and market
 17 experts state this is due to the maturity of the devices, less issues with the owned
 18 handsets, because users have found their preferred model or brand, and as the prices of
 19 high-end devices are on the rise (Ng 2019).



1

2 **Figure 7: Active use in month according to (Kantar Worldpanel 2017) and (Ng**
 3 **2019)**

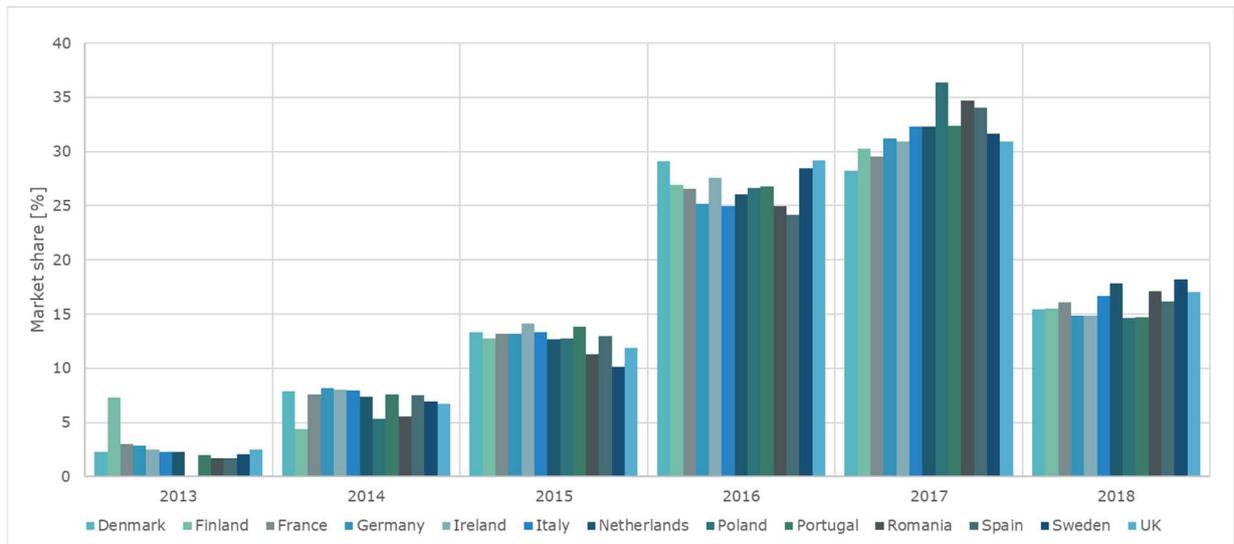
4



5

6 **Figure 8: « When was the currently used smartphone bought », survey by Bitkom**
 7 **in Germany (Ametsreiter 2016, 2017, 2019, 2020; Haas 2018)**

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



1

2 **Figure 9: release year of devices used in the 1st quarter 2019 according to**
 3 **(DeviceAtlas 2019)**

4

5 **2.2.2. Lifetime expectation**

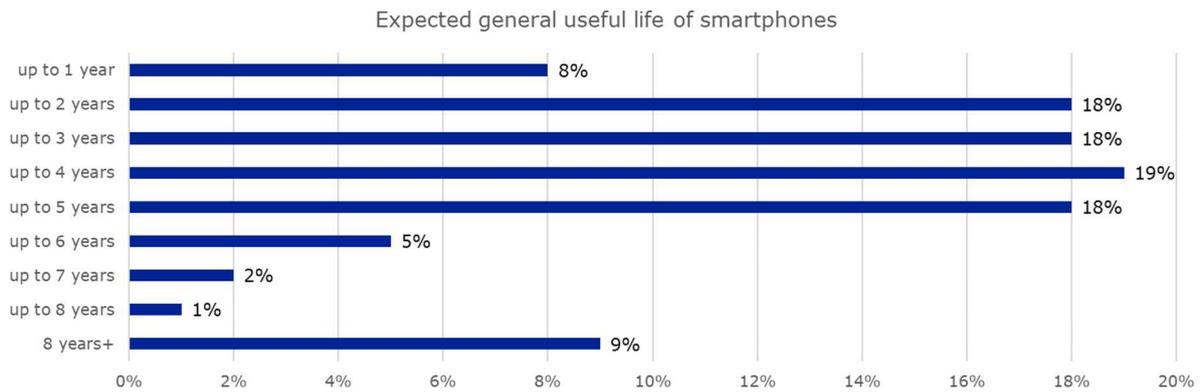
6 Numerous surveys have been conducted in the last years on the expected lifetime of
 7 smartphones in different countries.

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

11 **Table 1: Results from the survey study about 'expected' and 'actual' lifetime of**
 12 **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

13 A survey among German consumers in 2017 also asked for the expected lifetime of
 14 smartphones (Jaeger-Erben and Hipp 2018): The average expected lifetime is roughly 4
 15 years with a share of 9% expecting a long lifetime of more than 8 years (Figure 10). The
 16 researchers noted that this outlier might be rather a general wish for long lasting
 17 smartphones instead of experience-based expectations.



1
2 **Figure 10 : How long should a smartphone hold in your view? (n = 1813)**

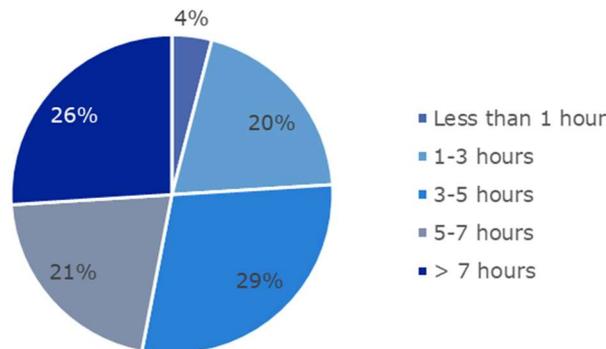
3 A third survey conducted with students in the U.S. comes to the conclusion that the
4 expected lifetime of a smartphone is 2.8 years (Sabbaghi and Behdad 2018).

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

7 **2.3. General device use**

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

15 Figure 11 shows results of a global survey on the amount of time spent on daily
16 smartphone usage in 2017. As of that time, almost half of the respondents spent five or
17 more hours on their smartphones daily. More than 25% spent even more than seven
18 hours every day using their device.



19
20 **Figure 11: Average hours spent on smartphone/day⁴**

21 Very intensive use of mobile devices can become a health issue (addiction), but also
22 stresses the device, due to more frequent charging of the battery. Such use patterns
23 however hardly can be influenced by measures, such as pop-up notifications on the
24 screen regarding use times, as research suggests (Loid et al. 2020) : In an experiment

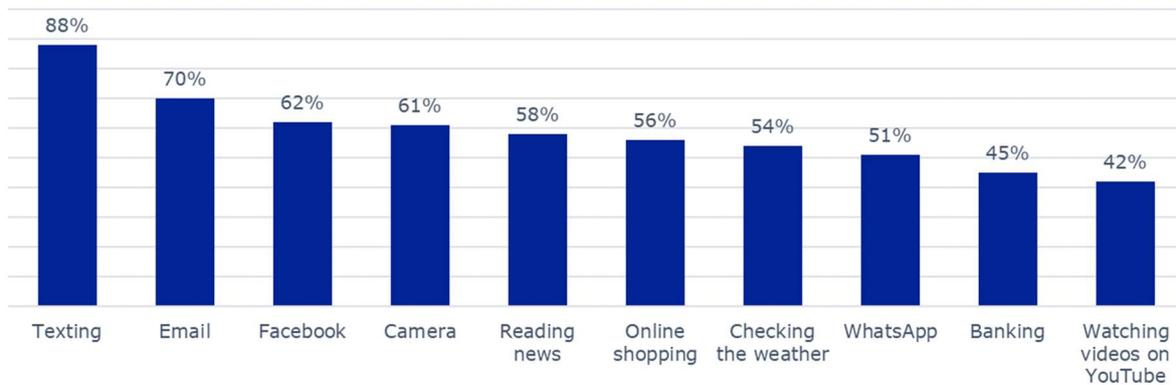
⁴ <https://www.statista.com/statistics/781692/worldwide-daily-time-spent-on-smartphone/>

1 notifications regarding excessive smartphone use did not lower self-reported problematic
2 smartphone use, nor participants' screen time or the frequency of phone-checking
3 behaviour.

4 According to a 2017 survey in the UK less demanding functionalities were dominating,
5 such as texting, e-mails, social media usage (Figure 12). Camera usage was next. Only
6 41% made or received phone calls on a daily basis, similar to watching videos on
7 YouTube (42%). The high use share of social media apps however points at the need,
8 that these apps need to be compatible with the OS version running on a device.

9 Discontinuing the app support for an older operating system can trigger obsolescence of
10 otherwise still properly working phones: An example is WhatsApp. Support for iOS 7 and
11 Android 2.3.7 was discontinued early 2020, affecting iPhones sold until 2013 and Android
12 phones until 2011⁵. As the data on wished smartphone lifetime indicates, this is against
13 the smartphone lifetime expectancy of slightly more than 10% of all smartphone users
14 (Figure 10) but actually a potential issue for less than 5% of all smartphone users who
15 still use such old phones (Figure 5 and Figure 9).

Most common uses of smartphones (2017)



16

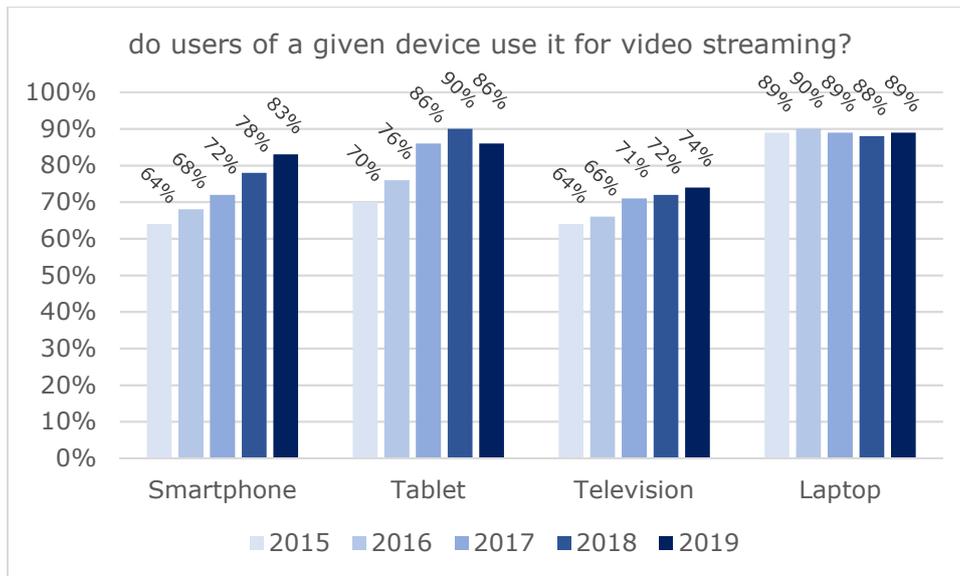
17 **Figure 12: Most common uses of smartphones, UK, 2017⁶**

18 The share of people watching videos on mobile phones is steadily increasing: In Europe
19 this figure is forecasted to grow from 330 million users in 2019 to 370 million users in
20 2023 (eMarketer 2019).

21 Video streaming on smartphones increased steadily over time, reflecting also the
22 increasingly larger displays. In 2019 83% of all smartphone users in Germany watched
23 streamed videos on these devices (Bitkom Research GmbH 2019). The figure for tablets
24 is even higher, but went down in 2019 for the first time. Compared to these devices
25 laptops throughout the years were very popular for video streaming at a constant high
26 value of 90% or slightly below of all laptops (Figure 13).

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

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

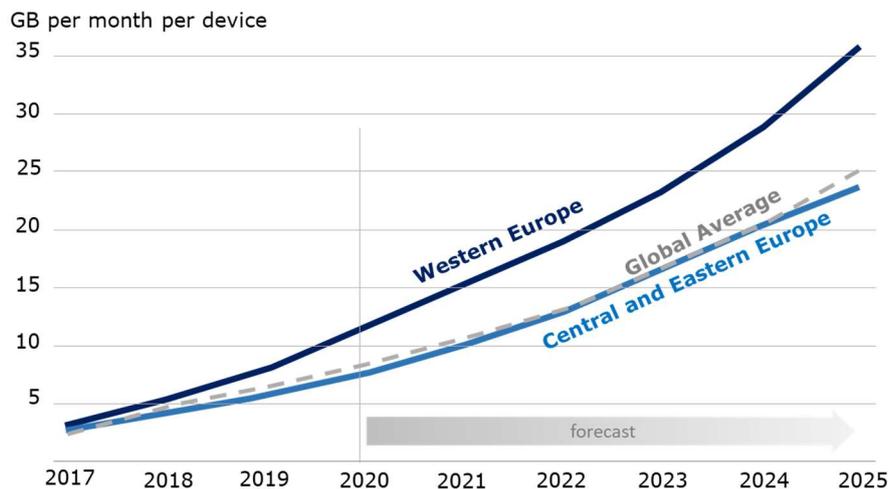


1

2 **Figure 13: Use of smartphones and tablets compared to TV sets and laptops for**
 3 **video streaming, Germany, 2015-2019**

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

7 Data traffic is constantly increasing in terms of GB per smartphone. These dynamics are
 8 not the same in all global regions. According to data by Ericsson in Western Europe data
 9 traffic per device will triple in the next five years (Ericsson 2020). For Central and
 10 Eastern Europe the same factor applies, but on a lower overall level, mirroring almost
 11 exactly the global average dynamics. Data traffic per smartphone in Western Europe will
 12 exceed 35 GB by 2025 and in Central and Eastern Europe 20 GB (Figure 14).



13

14 **Figure 14: Mobile data traffic per smartphone (GB per month), Europe, 2017-**
 15 **2025**

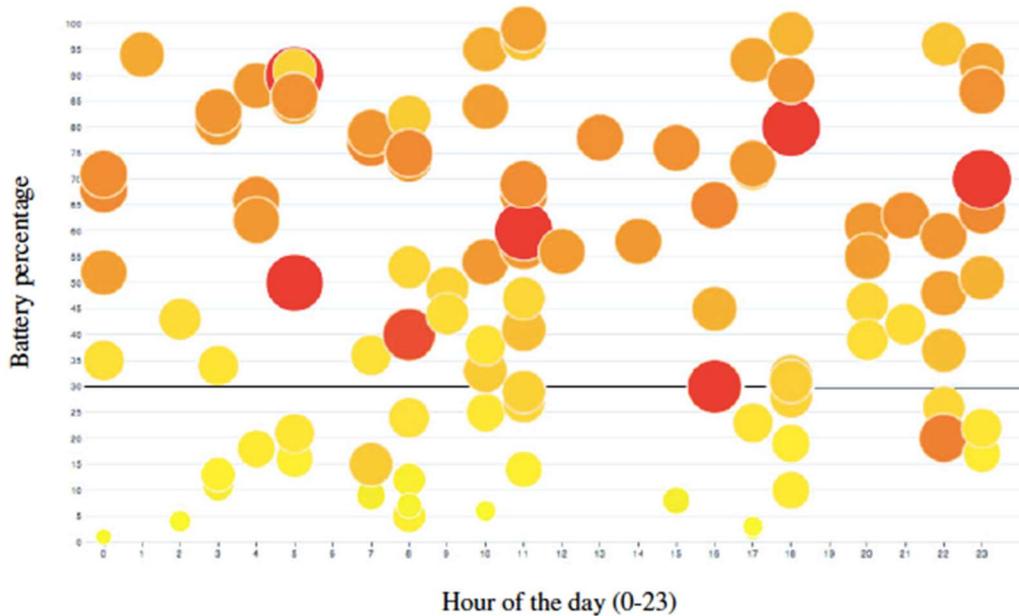
16 This trend is correlated with the adoption of 5G: In Central and Eastern Europe, LTE
 17 became the dominant technology in 2019, and now accounts for 43% of all subscriptions.
 18 In 2025, LTE is forecasted to account for even 66% of mobile subscriptions, while 5G
 19 subscriptions are forecast to make up 27% by then. Correspondingly, there will continue
 20 to be a significant decline in WCDMA/HSPA, from 38% as of 2020 to 3% of all
 21 subscriptions. In Western European countries, currently LTE is by far the dominant
 22 access technology, accounting for 68% of all subscriptions, but will decline to 43% and

1 WCDMA/HSPA to only 2% of subscriptions by 2025. The 5G subscription penetration is
2 projected to reach 55% in Western Europe by the end of 2025, which is a faster uptake
3 than for 4G in the past. (Ericsson 2020)

4 **2.4. Battery charging patterns**

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

10 The visualization in Figure 15 shows the average battery available at different hours of
11 the day, across all the users, and how frequently the percentage was observed, when the
12 battery was not being charged. Each bubble represents a different day of the study, for a
13 given hour (size and colour correspond with how frequently the percentage was observed
14 at a given hour of the day).



15

16 **Figure 15: Average battery levels during the day (when not charging) (Ferreira**
17 **et al. 2011)**

18 These results and findings on charging durations (Figure 15) indicate the following charging
19 patterns:

- 20
- 21 • Most users avoided battery levels below 30 %
 - 22 • On average the lowest average battery level was 65% at midnight, while the
23 highest was 74% at 5 am.
 - 24 • Most people charge their phone for a small period (0-30 min), but there is also a
25 significant share of users with devices plugged in for extended periods of time
26 (above 14 hours)

27 Battery charging behavior has an impact on real-life ageing of the battery overall
28 performance and battery lifespan. In July 2020 a smartphone OEM⁷ analyzed smartphone

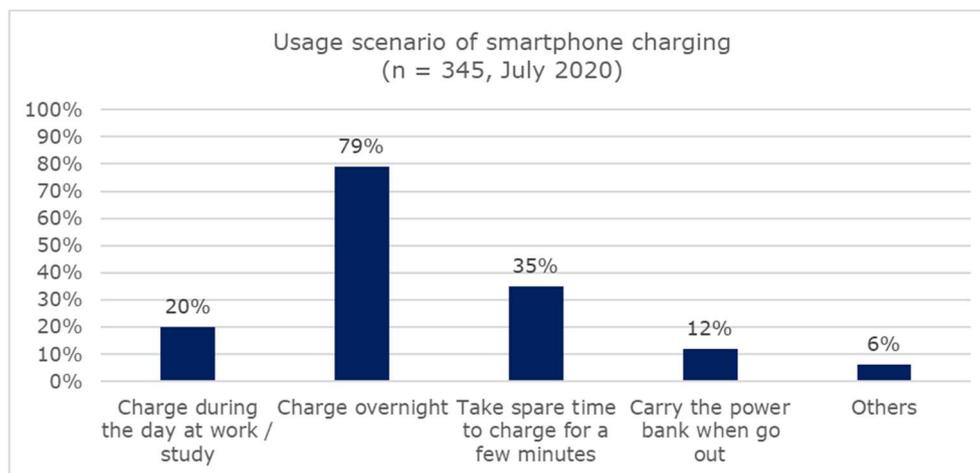
⁷ Results have been shared with the study team under the condition to anonymise the source

1 users charging behaviour in their daily life, which was based on 345 anonymous
2 participants in EU.

3 The findings on the scenarios of charging smartphone across all the users (Figure 16):

- 4
- 5 • Most (79%) of users charge their phone overnight
 - 6 • 35% charge their phone frequently during their daily spare time
 - 7 • 20% of users charge their phone during the day when they are working or
 - 8 studying.

9 The findings of this survey seem to indicate that a majority of the users charges phones
10 overnight, which is likely to mean charging up to 100% charging level and then the device
11 is likely to remain in trickle charge mode for several more hours. A substantial share of
12 users also charges for very short times only as conditions permit. Such a use pattern
13 actually could help to keep the battery in a mid-charge range instead of very low and very
14 high states of charge, as these extremes typically have an adverse effect on battery health.



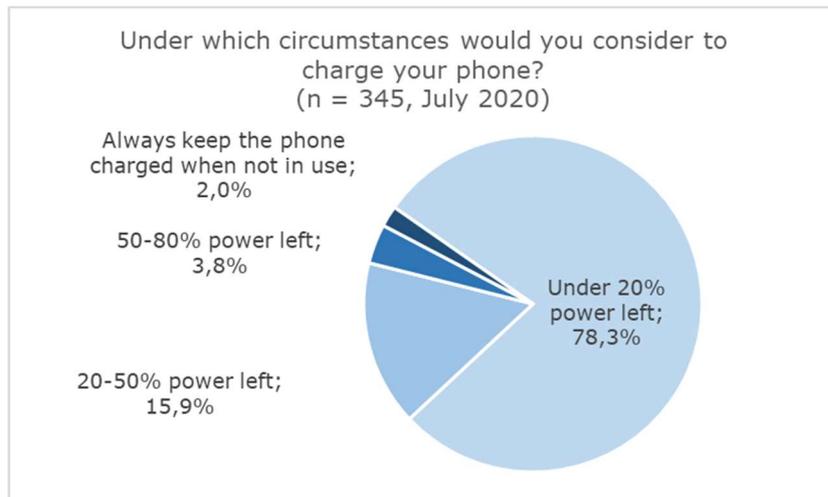
15

16 **Figure 16: Smartphone charging patterns – at which times smartphones are**
17 **charged (EU, anonymous OEM)**

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

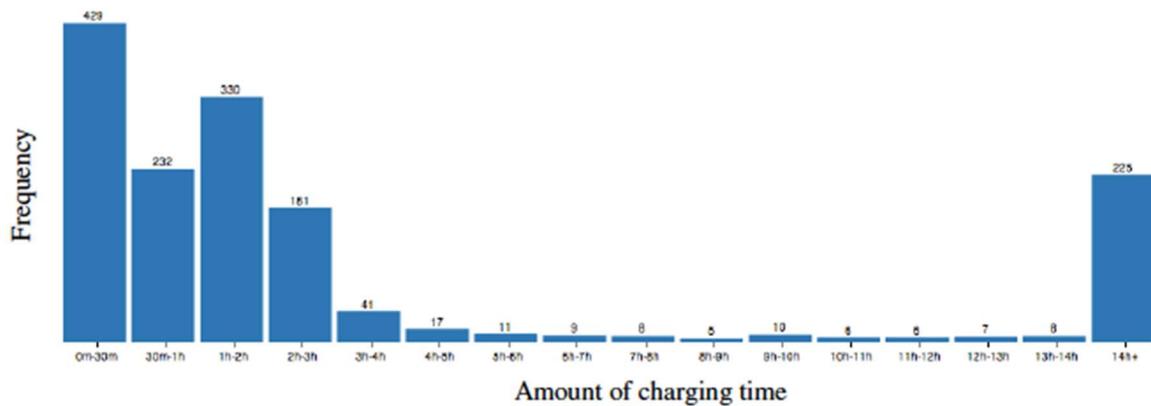
- 21
- 22 • Most users (78%) will charge their phones when the battery is below 20%
 - 23 • Only 2% of users always keep the phone charged when the phone is not in use

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



1
2
3
4

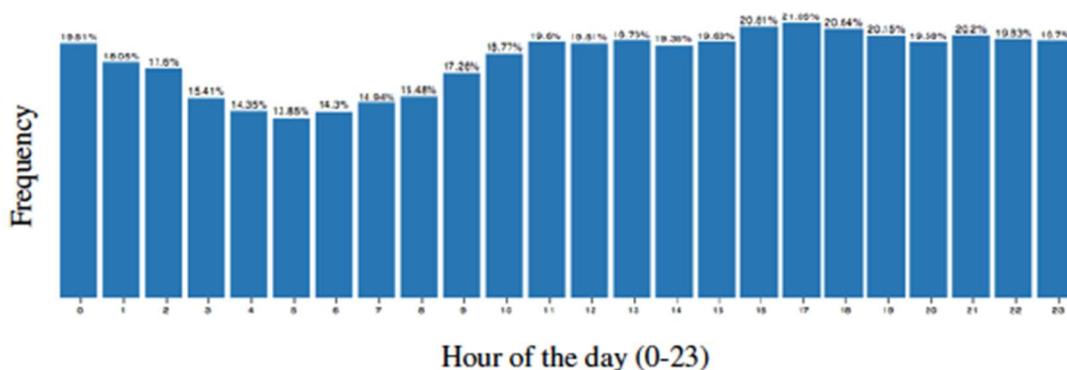
Figure 17: Smartphone charging patterns – at which charge level smartphones are charged (EU, anonymous OEM)



5

Figure 18: Charging duration (amount of time the phone remains plugged in)

6
7 According to the findings of Ferreira et al. throughout the day there is no clear preference
8 when to charge the smartphone, with slightly higher shares in the late afternoon. Times
9 with least charging are the early morning hours (Figure 19). Overnight charging seems to
10 be done by a significant share of the users, but this is definitely not the majority of the
11 users, according to these findings.

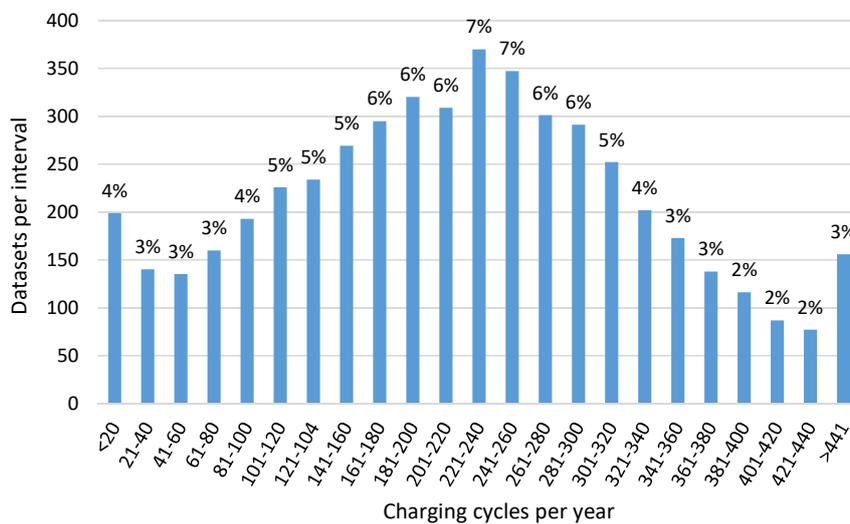


12

Figure 19: Charging schedule (times when users have their phones plugged in)

1 coconutBattery⁸ is a software tool that displays the state of health and other data on
 2 batteries in Apple devices, including iPads and iPhones: the battery's build date, cycle
 3 count, design capacity, full charge capacity (the current maximum capacity the battery can
 4 retain), state of charge, battery temperature and current consumption. The software also
 5 displays the battery state of health (SOH) in percent, calculated as the quotient of the full
 6 charge capacity, which steadily decreases over time and use, and the design capacity.
 7 Users of the software can choose to actively transmit data from their batteries to a central
 8 database.

9 An analysis of the coconutBattery database in 2016 revealed the cycle frequency of
 10 smartphones and tablets (i.e. aggregated data for a range of iPhone and iPad models),
 11 estimated via the age of the battery and the number of full charge/discharge cycles (Clemm
 12 et al. 2016). In the case of smartphones, based on data from 4,844 individual devices, the
 13 distribution of annual charging cycles approximately follows a normal distribution (Figure
 14 20). The average and median value are 218 and 219 cycles per year, respectively,
 15 equivalent to around 0.6 charging cycles per day, 4.2 per week or 18.2 per month. This
 16 data suggests that a smartphone is only charged with approximately 60 % of its design
 17 capacity daily on average.

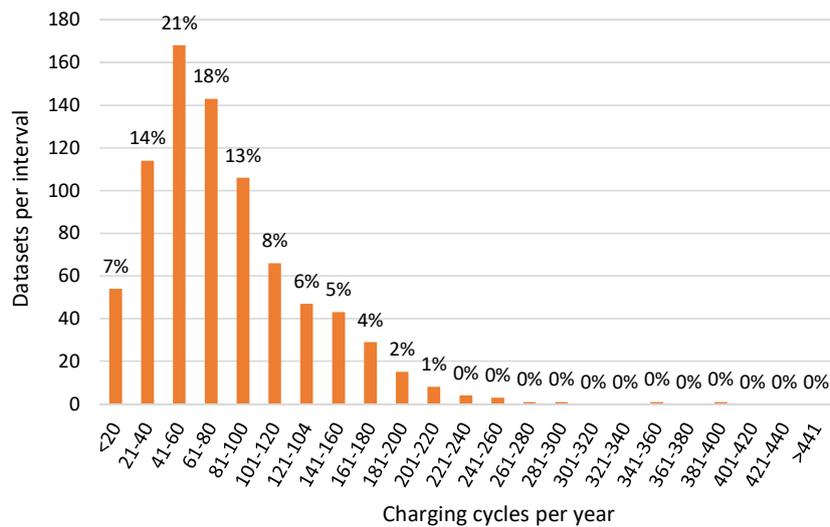


18

19 **Figure 20: Distribution of the cycle frequency of smartphone batteries (Clemm et**
 20 **al. 2016)**

21 The cycle frequency of tablets, based on data from 776 individual devices, is skewed
 22 towards lower cycle count per year when compared to smartphones (Figure 21). This
 23 reflects the different use pattern in the case of tablets, with less intense daily use. The
 24 average and median value are 79 and 68 cycles per year, respectively, equivalent to
 25 around 1.5 and 1.3 charging cycles per week or 6.6 and 5.7 cycles per months.
 26 Consequently, it may be assumed that tablets at the time were only charged with up to
 27 22 % of their design capacity daily on average.

⁸ <https://www.coconut-flavour.com/coconutbattery/>



1

2 **Figure 21: Distribution of the cycle frequency of tablet batteries (Clemm et al.**
 3 **2016)**

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

9 **2.5. Device protection, defects and repairs**

10 Main limiting states of technical nature for smartphones, mobile phones and tablets are
 11 summarised in Table 2, with a description of possible failure mechanisms (Cordella et al.
 12 2020).

13 **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

Part	Main failures	Failure mechanism
Whole Product	Short circuits, disconnection of main parts (including buttons and connectors)	Stress conditions (e.g. exposure dust and water, shocks, vibration).

1

2 There are many more failures observed among smartphones, mobile phones and tablets,
3 but these are the dominating ones. Further statistics on occurring defects and failures are
4 provided in 2.5.2.

5

2.5.1. Use of protective shells and covers

6 The use of protective covers or shells is a measure to reduce the risk of product defects
7 in case of accidental drops. 2017 data from the U.S. suggests that 79% of all
8 smartphone users use a protective case⁹. According to a 2015 survey by Bitkom in
9 Germany, 91 % of smartphone owners are protecting their smartphone with a cover¹⁰.

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

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

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%

16

17

2.5.2. Defects and repairs

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

21 2.5.2.1. Defects

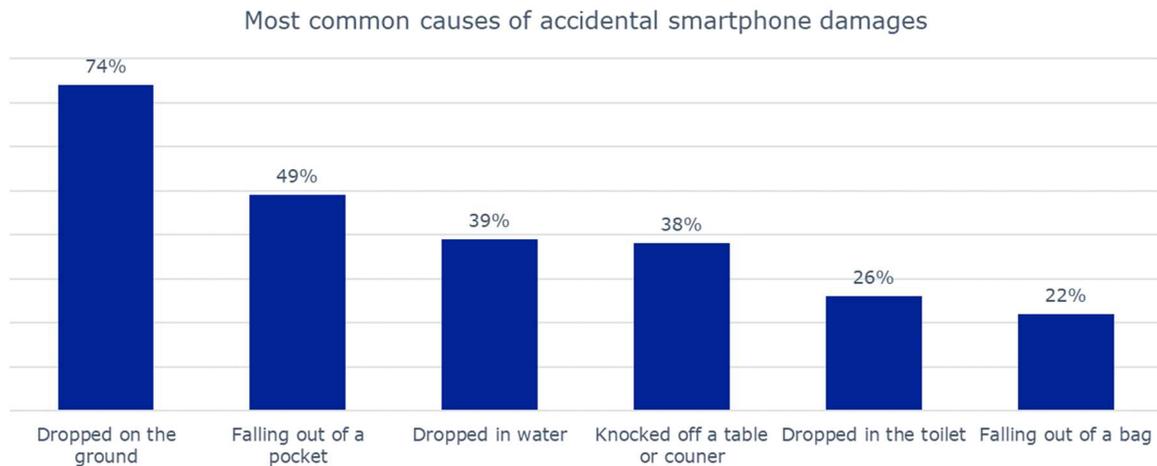
22 A survey among students at a Polish university and evaluation of social media content
23 provides some indications on typical **defects** of smartphones (Kostek and Samek 2018).
24 According to these findings, most frequent damages were found to be freezing phones,
25 scratched backs and not working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

⁹ <https://www.statista.com/statistics/368627/us-protective-case-usage-among-smartphone-owners/>

¹⁰ <https://t3n.de/news/91-prozent-smartphone-besitzer-636523/>

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

3 Being asked, which incident lead to a smartphone damage, survey respondents in the
4 U.S. in 2018 replied as depicted in Figure 22: 74% of respondents reported to dropping
5 their phones on the ground. Phones falling from pockets was ranked second at a 49%
6 occurrence rate. This survey obviously allowed for multiple answers, and stated
7 percentages suggest that in average every respondent experienced more than two
8 incidents leading to a damage of a device.



9

10 **Figure 22: Causes of accidental smartphone damages, United States, 2018¹¹**

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

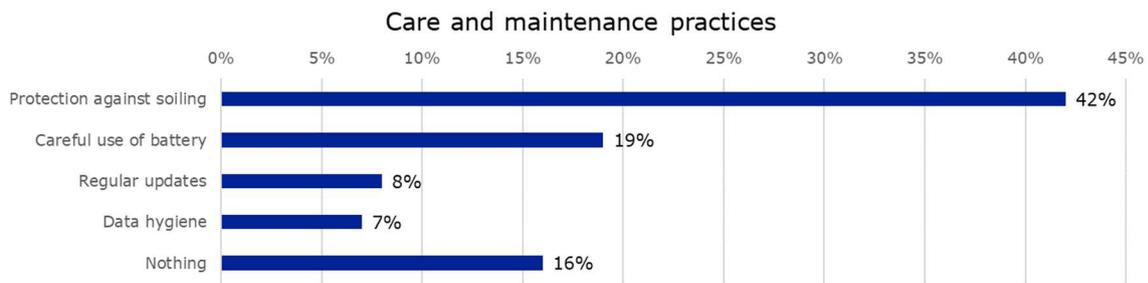
15 **Table 4: Defects in smartphones, Germany, 2019 (clickrepair 2019)**

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

16

17 Another survey investigated care and maintenance practices for smartphones, indicating
18 widespread use of protection measures against soiling. One out of five users state a
19 careful use of the battery as main measure (Figure 23).

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

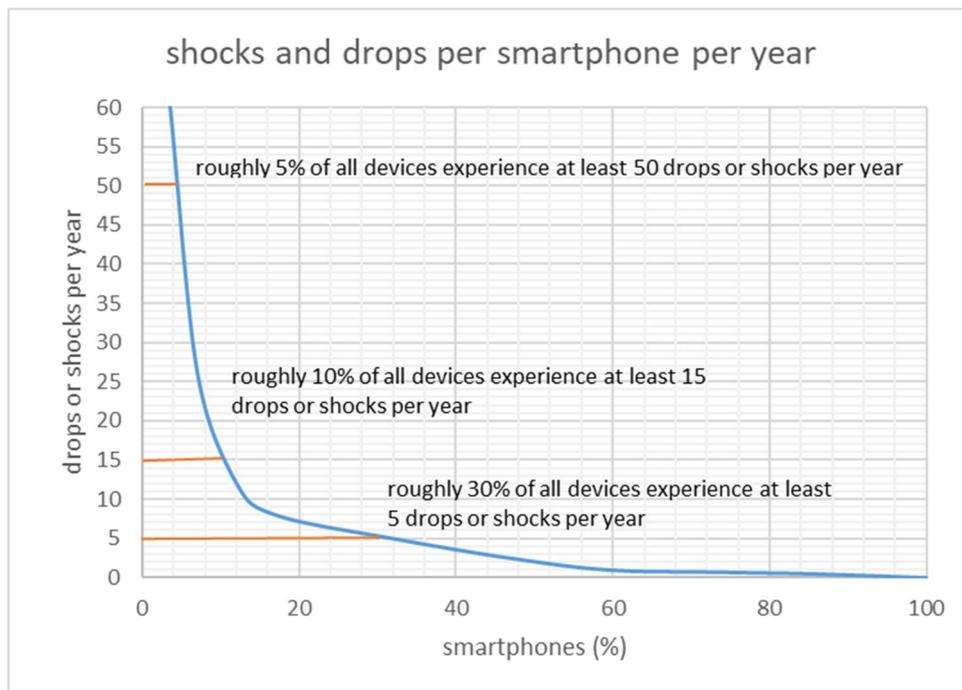


1

2 **Figure 23: Smartphones - Care and maintenance practices according to a survey**
 3 **in Germany (Jaeger-Erben and Hipp 2018)**

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

13 Based on the stated frequency of drops or shocks a correlation can be derived as
 14 depicted in Figure 24: Roughly 5% of all devices experience at least 50 drops or shocks
 15 per year, 10% of all devices experience at least 15 drops or shocks and roughly 70% of
 16 the devices experience 5 or less drops and shocks.



17

18 **Figure 24: Smartphones – Shock and drop occurrence**

19 Another survey in 2018 investigated defects and repairs of tablets (WERTGARANTIE
 20 2018). In 64.1% of the cases of damaged tablets due to a drop the display is defect, the
 21 casing is affected in 47.1% of the cases.

1 **Table 5: Kind of damages of dropped tablets, Germany, 2018 (WERTGARANTIE**
 2 **2018)**

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

3

4 *2.5.2.2. Repairs*

5 Most common **repairs** for smartphones are (Agrawal 2017): Broken screen (50-55%),
 6 water-caused damage (15-20%), damage of the charging connection (5-10%), phone
 7 locked (5-10%), connectivity (7%), audio output, which includes a faulty or
 8 malfunctioning sound system, speaker, loudspeaker, microphone, or ringer (5%), phone
 9 crush (<5%).

10 *2.5.2.3. Repair attitudes*

11 In 2019 Euroconsumers (Euroconsumers 2019a, 2019b, 2019c, 2019d) conducted a
 12 study amongst members of consumer organisations in four countries (Belgium, Italy,
 13 Portugal and Spain) asking whether they repaired their smartphones when they became
 14 defect. In most of the countries, around half of the interrogated persons did (see Table
 15 6).

16 **Table 6: Repair of smartphones; Base: respondents who acquired a new**
 17 **smartphone and had a problem with it (van den Berge and Thyssen 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%

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

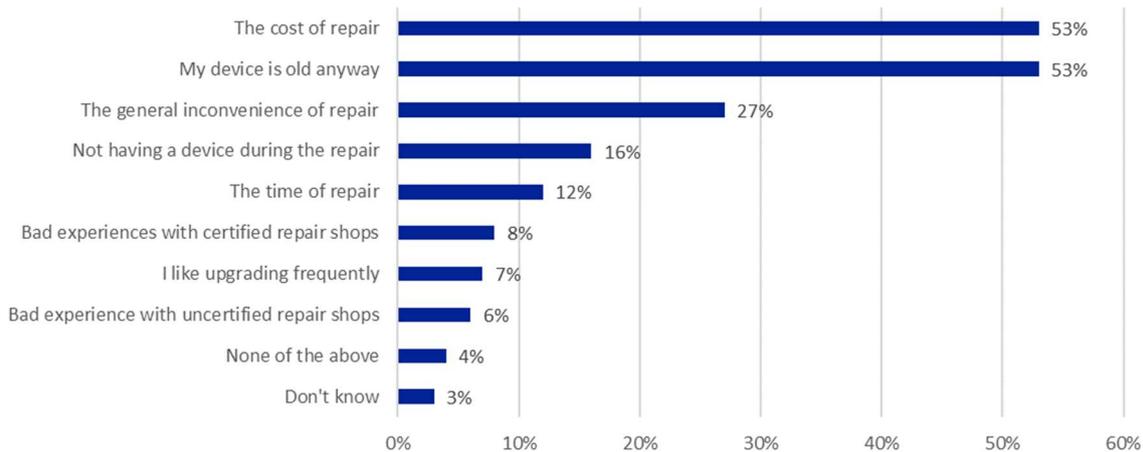
21 **Table 7: Reasons for not repairing smartphones; Base: respondents who acquired**
 22 **a new smartphone, had a problem with it (van den Berge and Thyssen 2020)**

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%

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

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

6
 7 In a follow-up question of the same 2020 UK survey respondents were asked to state,
 8 why they would rather buy a new device if their device would stop working (Figure 25):
 9 More than 50% stated the costs of repair to be an issue, 27% the general inconvenience
 10 of repair. 53% stated the age of the broken device as a major reason.



11
 12 **Figure 25: Barriers for repair according to a recent UK survey by YouGov**

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

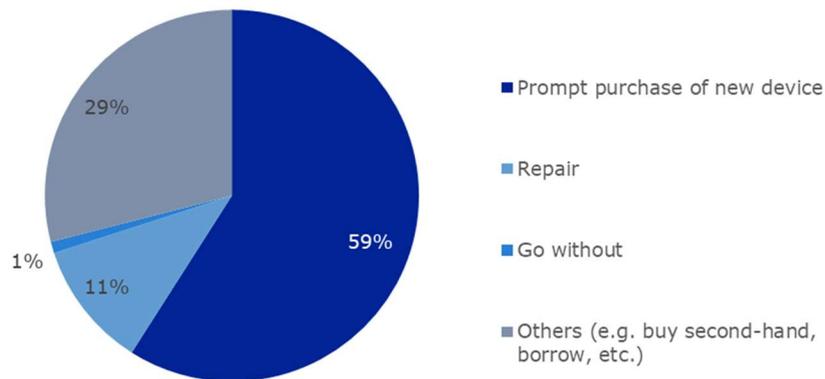
20 **Table 8: Allocation of responsibility for a broken device: « In your opinion, what
 21 are the reasons for the defect? » (N = 1,752 cases where an electrical device
 22 break) (Jaeger-Erben and Hipp 2018)**

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

23
 24 A broken smartphone frequently is the trigger to purchase a new device (Figure 26).
 25 Actually, this is much less frequently the case for laptops, where repair or using someone
 26 else's / a second-hand / a hoarded device is more common. Only 11% go for a repair,
 27 when the smartphone breaks. For the respondents to this survey in Germany the root-
 28 cause not to consider a repair are likely to be similar to those stated by the YouGov
 29 results shown in Figure 25 above.
 30

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

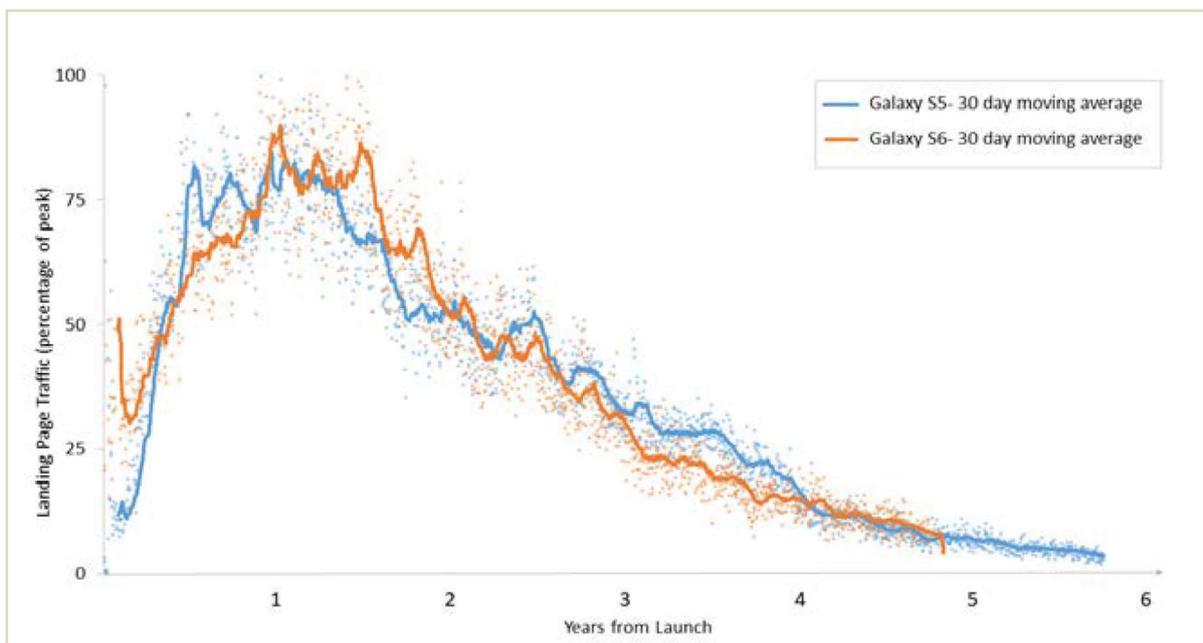
What do you do when your smartphone breaks?



1

2 **Figure 26: « What do you do when your smartphone breaks ? » results from a**
3 **German survey (OHA - Obsoleszenz als Herausforderung für Nachhaltigkeit 2019)**

4 A recent paper exploring smartphone life expectancy and maximum lifespans showed
5 that that consumers' mental depreciation plays a critical role in determining a
6 smartphone's lifespan (Fitzpatrick and Makov 2020). Examining visitor traffic to free
7 smartphone repair manuals available on iFixit.com (22 million visits), the authors
8 measured consumers' interest in repair over time and analysed mental depreciation.
9 They found that the interest in repair declines as time goes by, regardless of how easy or
10 hard the devices are to repair. Furthermore, the authors compared the interest for repair
11 between the Samsung Galaxy S5 (user-replaceable battery) and the Samsung Galaxy S6
12 (integrated battery) and have not found any evidence that this change in objective
13 reparability made any difference to the interest in repair (Figure 27).



14

15 **Figure 27: Comparison of Repair Interest for Samsung Galaxy S5 & Samsung**
16 **Galaxy S6 (Fitzpatrick and Makov 2020)**

17 With this analysis the authors want to highlight that besides technical aspects,
18 psychological obsolescence and mental depreciation have to be taken into account in the
19 discussion around prolonging the lifespan of products and postponing the obsolescence of
20 smartphones.

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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
- 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.

2.5.2.4. Insurances

The market for device insurances is steadily growing. The global mobile phone insurance market was valued at US\$ 22,6 Billion in 2018¹³, 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.

2.5.3. 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).

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%

¹³ <https://www.businesswire.com/news/home/20190416005458/en/Mobile-Phone-Insurance-Market-Reach-38.1-Billion>

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

4

5 **3. SUBTASK 3.2 – SYSTEMS ASPECTS OF THE USE PHASE FOR ERPS WITH** 6 **INDIRECT IMPACT**

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

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

14 **3.1. Affected energy systems**

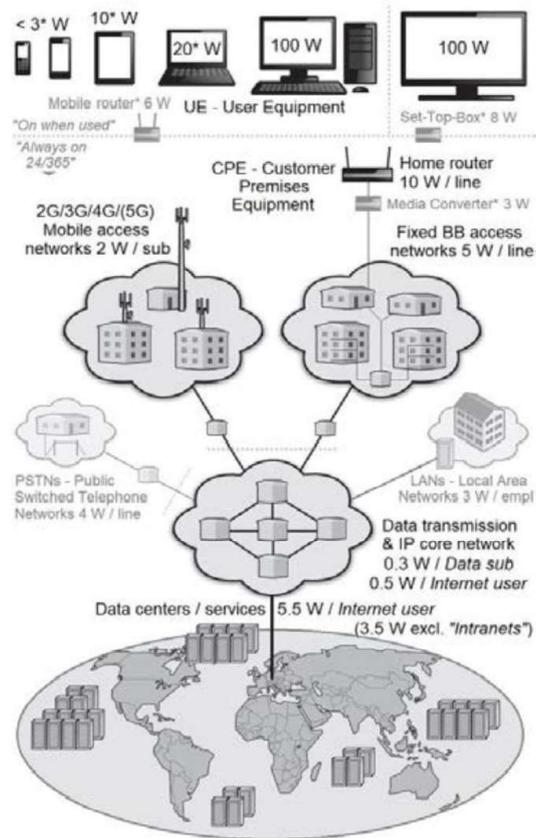
15 The products covered in this study are connected to network in order to communicate
16 with data centres. The use phase of smartphones and tablets have therefore an impact
17 on:

- 18 • the access networks: mobile access networks or fixed broadband access
19 networks¹⁴
 - 20 • the data centres, providing the services and processing data of the used
21 applications
- 22

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

29 Malmodin (Malmodin 2020) provides an overview of the ICT sector (see Figure 28).

¹⁴ more information on access network is provided in the chapter 3.2.1



1

2 **Figure 28: Global ICT sector average power values per subscription, line, user**
 3 **device or similar (Malmodin 2020)**

4 Mobile devices are used for various purposes such as gaming, social-media, video,
 5 shopping, etc. An overview of the most popular apps globally is provided in Figure 29.

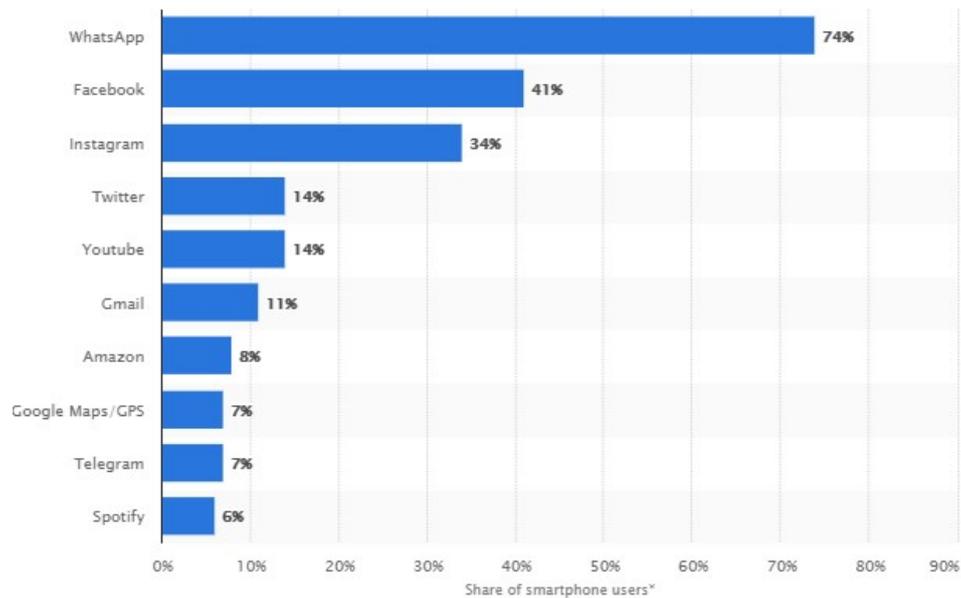
Rank	App	Company
1	 Facebook	Facebook
2	 WhatsApp Messenger	Facebook
3	 Facebook Messenger	Facebook
4	 WeChat	Tencent
5	 Instagram	Facebook
6	 QQ	Tencent
7	 Alipay	Ant Financial Services Group
8	 Taobao	Alibaba Group
9	 WiFi Master Key	LINKSURE
10	 Baidu	Baidu

6

7 **Figure 29: Most-popular apps globally in 2019¹⁵**

¹⁵ <https://www.businessofapps.com/data/app-statistics/>, based on App Annie. (accessed on 11.08.2020)

1 Data for smartphones in Spain (see Figure 30) shows also that social-media applications
2 are the most popular ones, which indicates that a similar trend might be assumed for
3 EU27.



4

5 **Figure 30: Most used apps by smartphone owners in Spain as of February 2019¹⁶**

6

7 **3.2. Energy consumptions of the affected system**

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

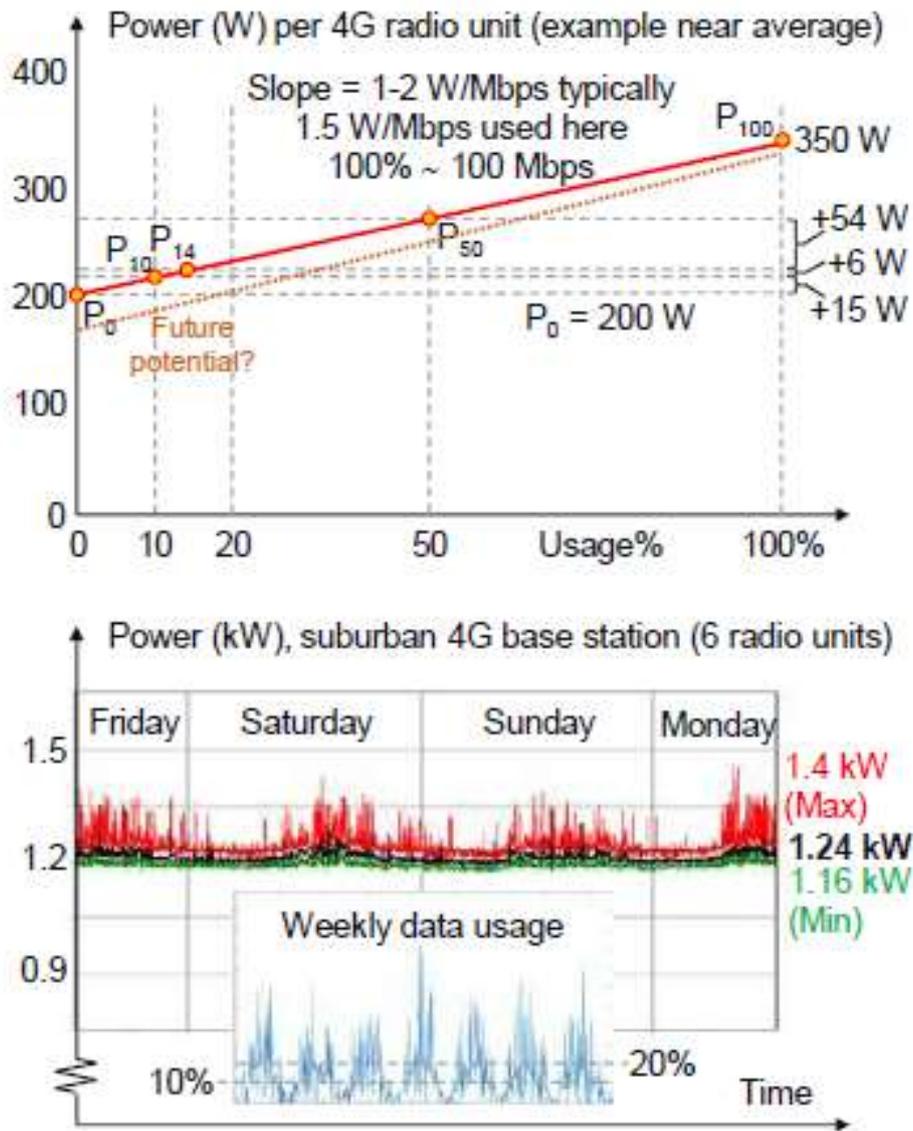
10 **3.2.1. Mobile and fixed broadband access networks**

11 As access networks have to be operated 24/7 the whole year, there is an idle power. The
12 data volume has a rather low impact on the energy consumption, which could be verified
13 for networks during the lockdowns due to the Corona outbreak, as stated by GSMA:
14 "network electricity usage has remained flat, even as voice and data traffic has spiked by
15 50% or more"¹⁷.

16 In his paper, Malmodin presents figures for mobile access networks (see Figure 31),
17 where the power of a 4G radio unit ranges from 200 W (in idle mode) to 350 W by the
18 highest data traffic (100 Mbps). Power for fixed access line (see Figure 32) is less
19 sensitive to traffic: between 19 W in idle mode and 23 W at 100 Mbps.

¹⁶ <https://www.statista.com/statistics/746955/most-downloaded-and-used-smartphone-apps-in-spain/> (accessed on 11.08.2020)

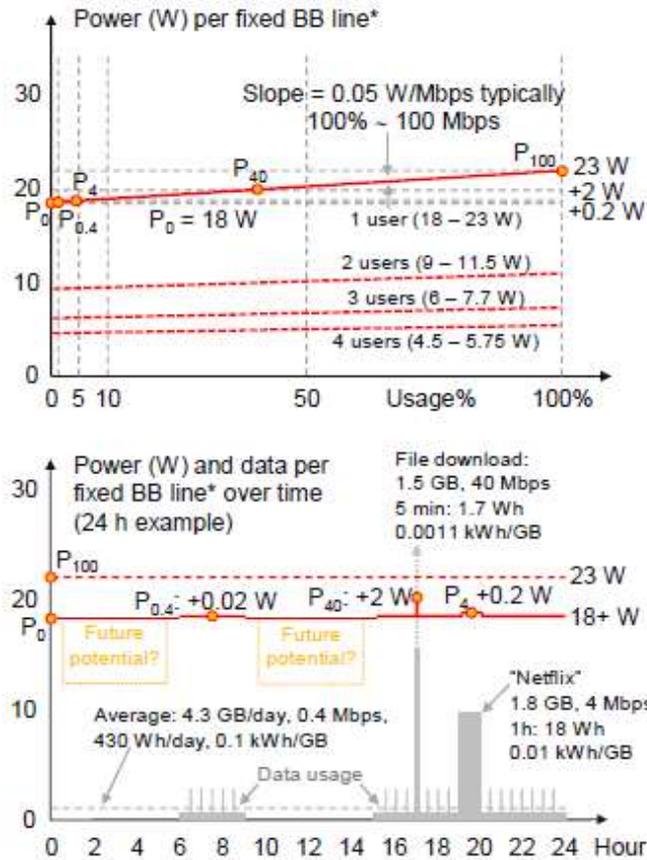
¹⁷ <https://www.gsma.com/gsmadeurope/latest-news-2/covid-19-network-traffic-surge-isnt-impacting-environment-confirm-telecom-operators/> (accessed on 11.08.2020)



1

2 **Figure 31: Power and data model for suburban 4G radio unit / base station (based**
 3 **on real data) (Malmodin 2020)**

4



1
2 **Figure 32: Power/data and power/time (24 h) model for a fixed BB access line**
3 **(household)¹⁸ (Malmodin 2020)**

4
5 **3.2.2. Data centres**

6 The performance and energy consumption of data centres is specific to each application.
7 Figures related to the data centre of some of major applications are provided by
8 Malmodin (Malmodin 2020) in Table 10: Examples of data centre / services power/energy
9 figures and use statistics (Malmodin 2020). The average power / user for applications
10 from Netflix and the FAMGA¹⁹ is estimated to be 1.1 W, which corresponds to a yearly
11 energy consumption of 9.4 kWh/user.

12 **Table 10: Examples of data centre / services power/energy figures and use**
13 **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

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

¹⁸ including home router and all components of a fixed BB access network per line

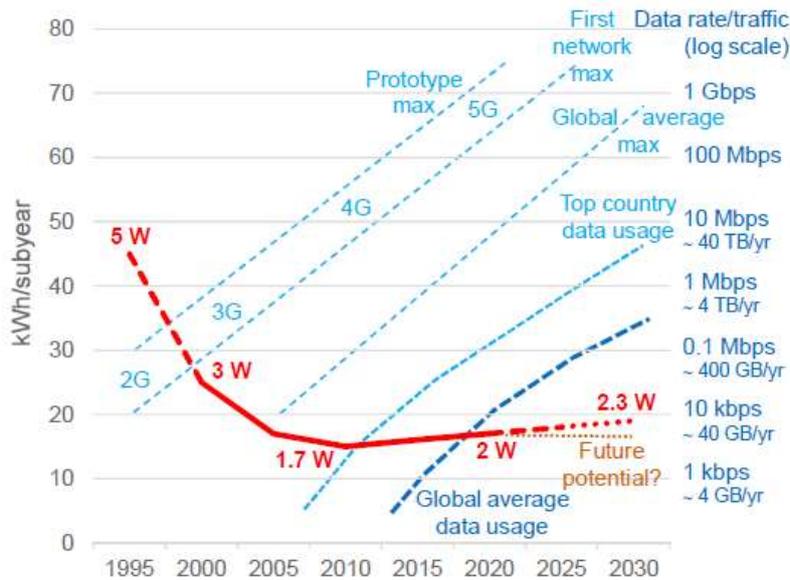
¹⁹ FAMGA: Facebook, Apple, Microsoft, Google and Amazon

3.3. 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.

3.4. 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 33) 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.

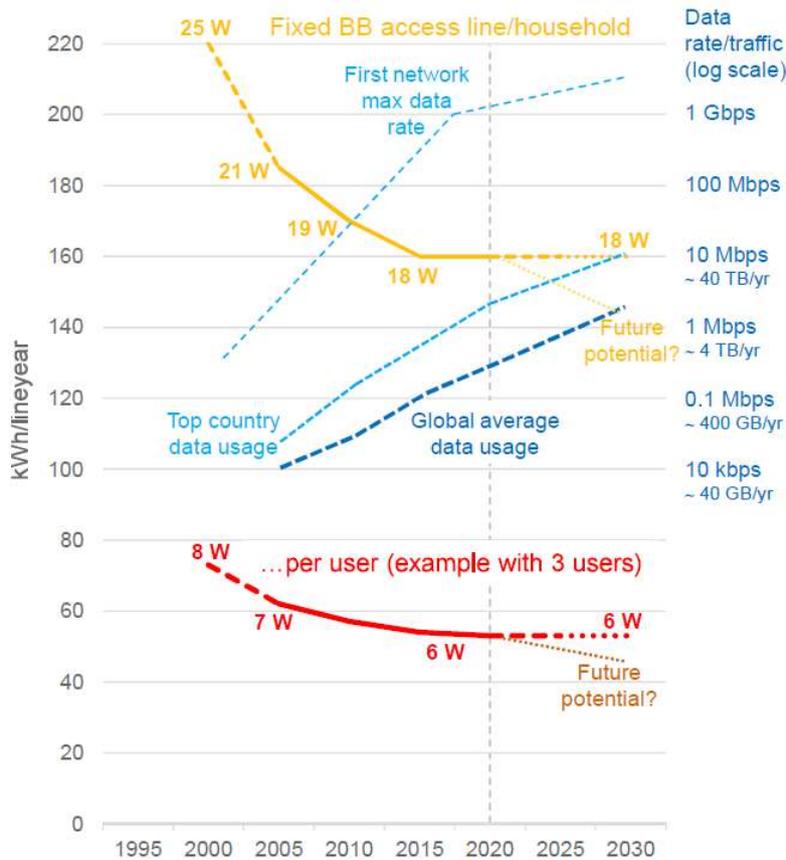


20

Figure 33: 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 34).

25



1
2 **Figure 34: Average power, electricity use and data per fixed BB line (Malmö 2020)**
3

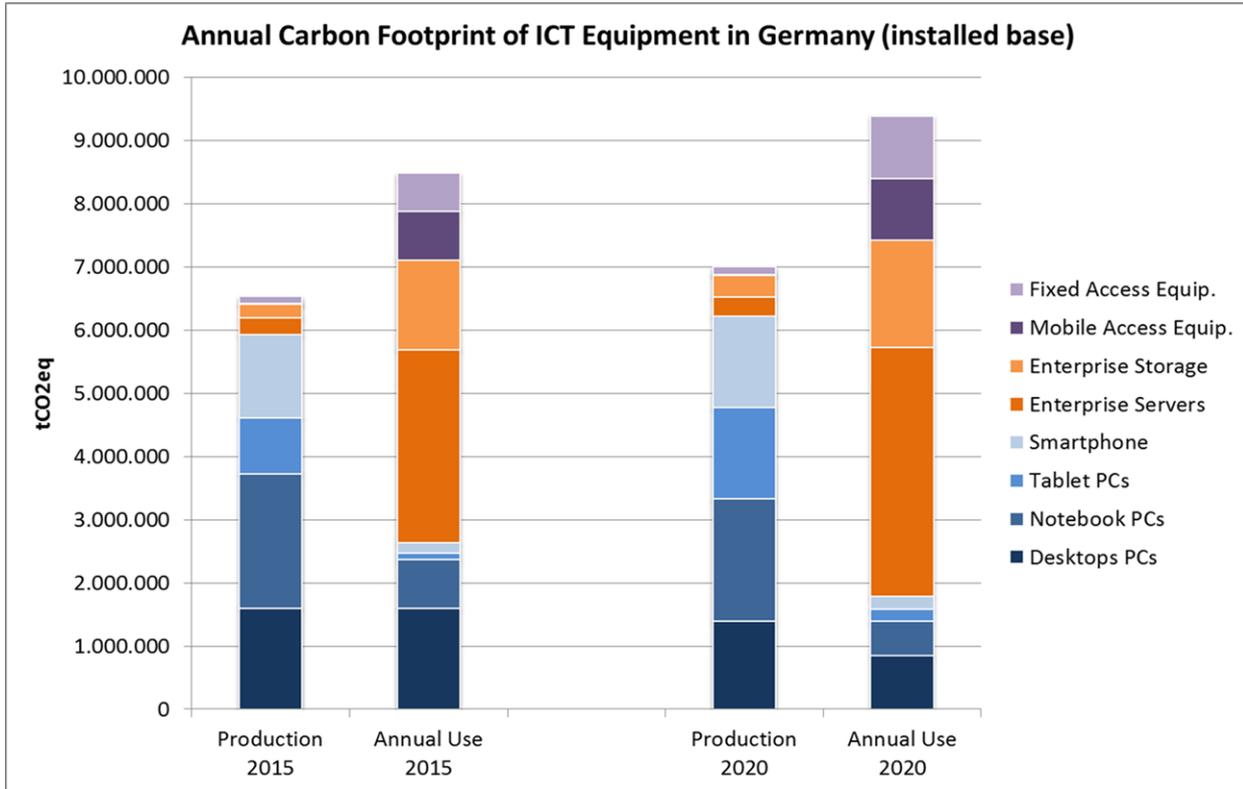
4 At present, it seems feasible to argue that the modernisation of the radio networks in
5 conjunction with modern end-user devices is improving energy efficiency. But there is a
6 conflict of goals. Looking at the overall resource consumption, the use phase related
7 environmental aspects shift between the end-user terminal (smartphone) and the
8 network equipment. Figure 35 shows the annual (normalised to one year) carbon
9 footprint assessment for various product groups and ICT equipment. Due to the large
10 number of smartphones in use, the normalised annual GHG emissions for the production
11 strongly outweighs the GHG emissions related to the annual use. The GHG emissions
12 from the mobile access equipment (network) are considerable only in the use phase.

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

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

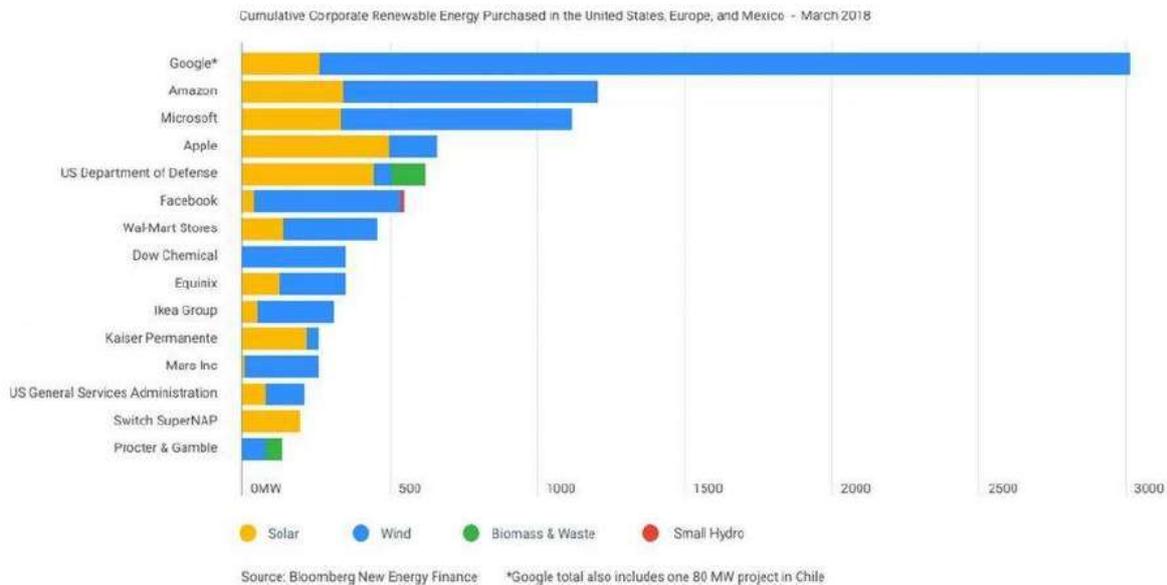
27

1 **Figure 35: Annual carbon footprint of ICT equipment stock in Germany (Source:**
 2 **Fraunhofer IZM)**



3
 4 In addition, companies operating data centres purchase massive amounts of renewable
 5 energy in order to improve their carbon footprint (see Figure 36).

6 **Figure 36: Cumulative Corporate Renewable Energy purchased in the US, Europe**
 7 **and Mexico - March 2018 (source Forbes 2019²⁰)**



8
 20 <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)

1 **4. SUBTASK 3.3 –END-OF-LIFE BEHAVIOUR**

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

8 **4.1. Reuse**

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

11 Analysing 500.000 used Apple and Samsung smartphones sold in 2015 and 2016 via
12 eBay, the product properties which affect how long smartphones retain market value and
13 facilitate market-based reuse were examined (Makov et al. 2019): Contrary to
14 expectations, reparability and large memory size have limited impact on the current
15 economic life span of smartphones and their market-based reuse. On the other hand, the
16 brand as an intangible product property, can extend smartphones’ economic life span by
17 12,5 months.

18 Mugge et al. investigated the potential of selling refurbished smartphones using a
19 quantitative study. An online survey was conducted questioning 250 respondents to
20 study the impact of various incentives that companies can employ to improve consumers’
21 purchase intention of refurbished phones (Mugge et al. 2017). Or in other words: How
22 can the reuse pull market be stimulated? Results are given for 6 different user groups in
23 Table 11. An upgraded, i.e. exchanged battery ranks highest as an incentive, followed by
24 guaranteed software issues and upgraded performance. This in turn confirms the findings
25 by others, why devices are barriers to reuse: a weak battery, limited software support
26 and overall performance issues. Upgraded internal storage, display and camera are also
27 incentives, which could convince users to buy reused smartphones. The “sustainability
28 enthusiast” is much easier to convince, as the product related incentives matter less. It is
29 fair to say that “sustainability enthusiasts” come with an intrinsic motivation to make use
30 of reuse options. For the “proud power user” product and information incentives are
31 much more important. It is apparently more difficult to meet the expectations of this
32 consumer group.

Table 11: 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

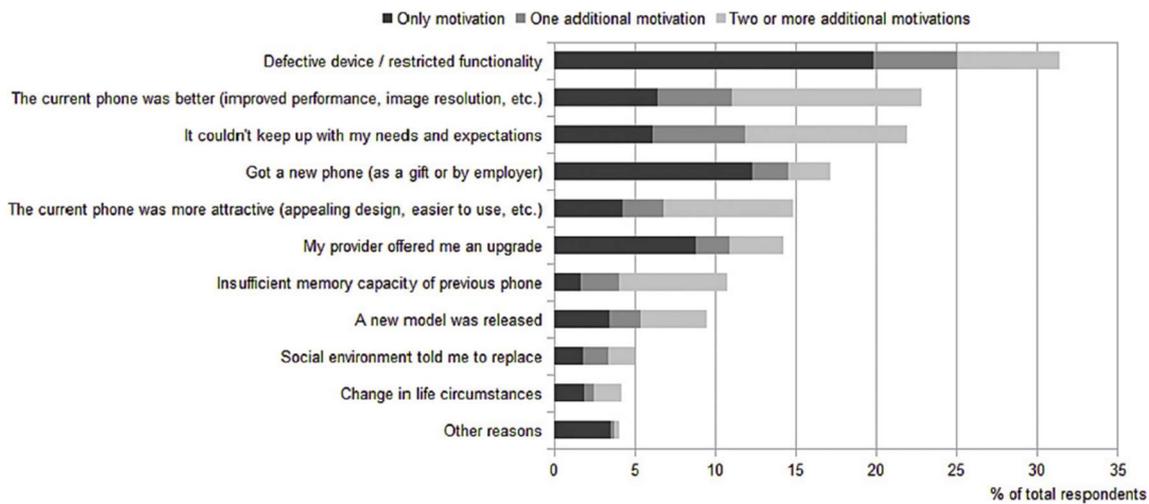
Question: Would this incentive increase the chance of you purchasing a refurbished smartphone?

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

1

2 **4.2. Upgrade to new device**

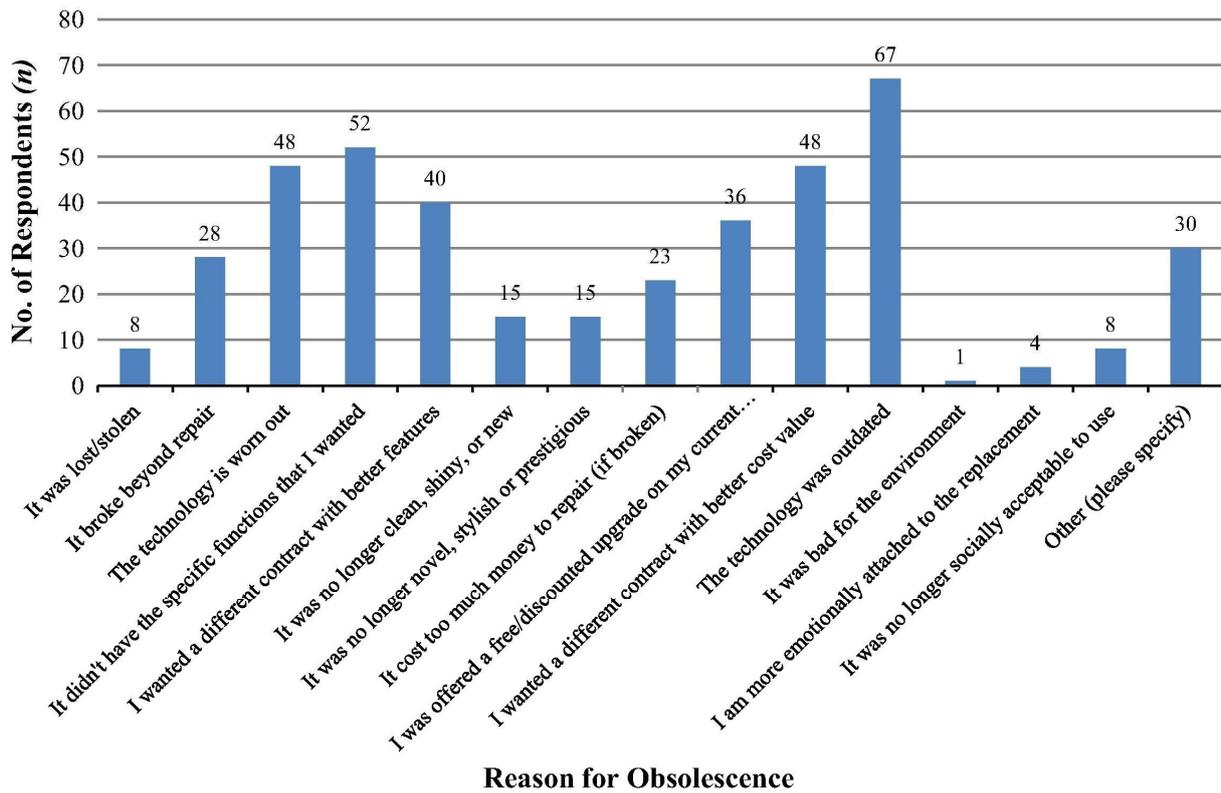
3 A 2014 survey (Wieser and Tröger 2018) with residents from Austria shows that around
 4 one third of total respondents replaced their mobile phone because of a defect or
 5 restricted functionality (see Figure 37). Better performance of a new device was the sole
 6 motivation for 6% of the respondents to upgrade to a new phone and in total for almost
 7 23% of the respondents the better performance played a role in this decision. Release of
 8 a new model triggered for almost 10% of the respondents the upgrade decision. In
 9 addition, the telecom provider plays a significant role here: Almost 14% were influenced
 10 in their upgrade decision by the operator offering a new device (see 2.1). For 8% this
 11 even was the only reason to replace an existing phone.



12

13 **Figure 37: Reasons for mobile phone replacement by Austrian residents, 2014**
 14 **(Wieser and Tröger 2018)**

15 A survey conducted among UK students in 2015 (Wilson et al 2017) shows that
 16 technological and quality obsolescence are the main reasons to replace smartphones.
 17 When questioned what the reason for replacing their previous mobile phone with their
 18 current mobile phone was, 37% responded "the technology was outdated", another
 19 28,7% replied "it didn't have the specific function that I wanted" and 26,5% stated "the
 20 technology was worn out". Broken beyond repair and repair costs were less an issue for
 21 replacements (Figure 38).

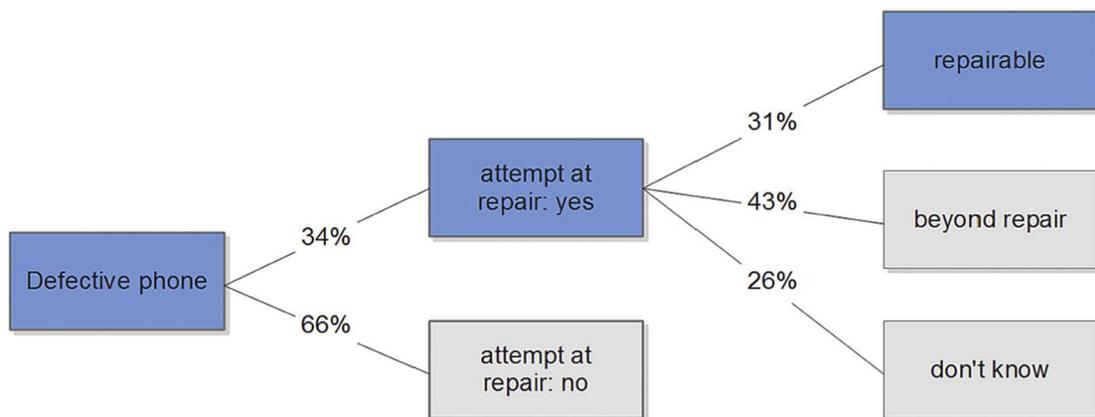


1

2 **Figure 38: Reasons for mobile phone replacement by UK students, 2015 (Wilson**
 3 **et al 2017)**

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

10 The survey by Wieser and Tröger (2018) in Austria unveiled that of all consumers with a
 11 defective phone 34% actually did attempt to repair it. From that share, 43% were broken
 12 beyond repair, 31% were repairable and 26% did not know how to repair after the first
 13 attempt (Wieser and Tröger 2018), see Figure 39. According to these figures roughly
 14 10% of all defective phones are repaired in the end.



15

16 **Figure 39: Defective phone, attempts to repair yes/no, percentage of phones that**
 17 **were repairable (2014) (Wieser and Tröger 2018)**

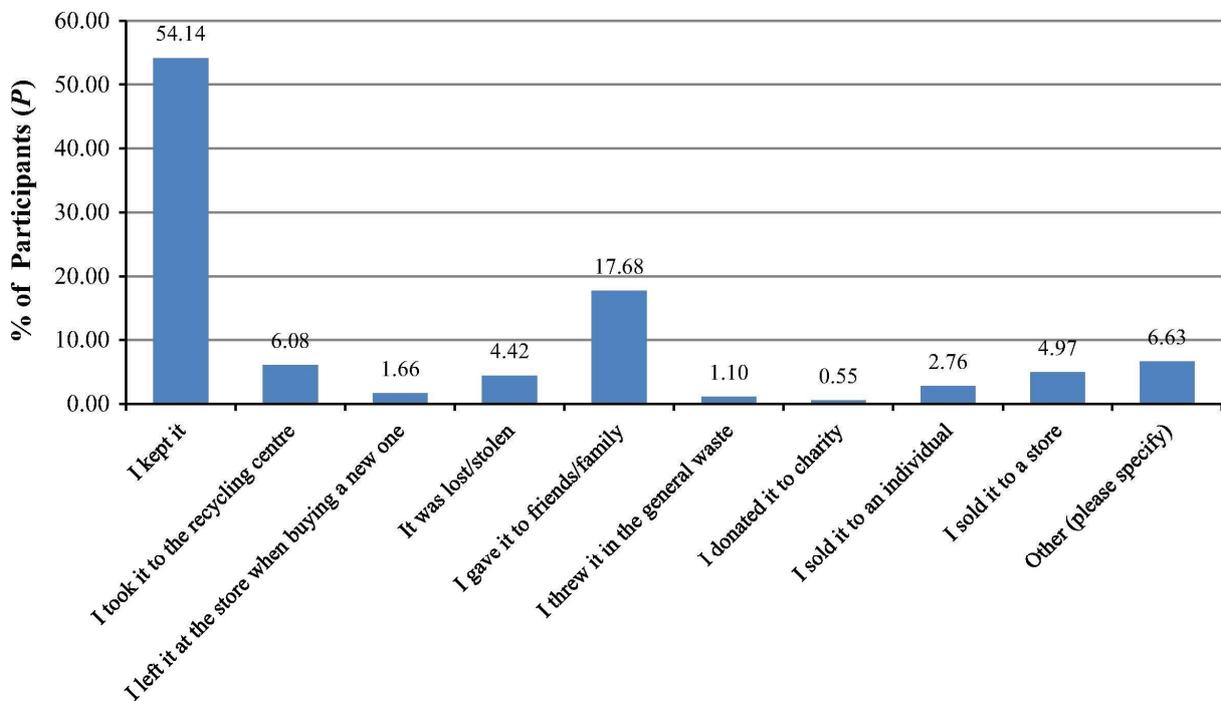
1

2 **4.3. Disposal and recycling**

3 Focus group participants in the circular economy behavioral study (Cerulli-Harms et al.
4 2018) were generally willing to recycle electronics products: "Willingness to recycle was
5 somewhat lower in the Czech Republic [compared to Sweden, Germany, and Ireland]. In
6 this country, recycling was seen as time consuming, as well as too much of an effort.
7 Participants felt that recycling should be motivated by a financial bonus, for example a
8 discount on the next purchase."

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

13 The survey among UK students by Wilson et al. (2017), see above, also asked for the
14 whereabouts of mobile phones, which have been replaced by a new one: More than 50%
15 kept the old device (Figure 40).

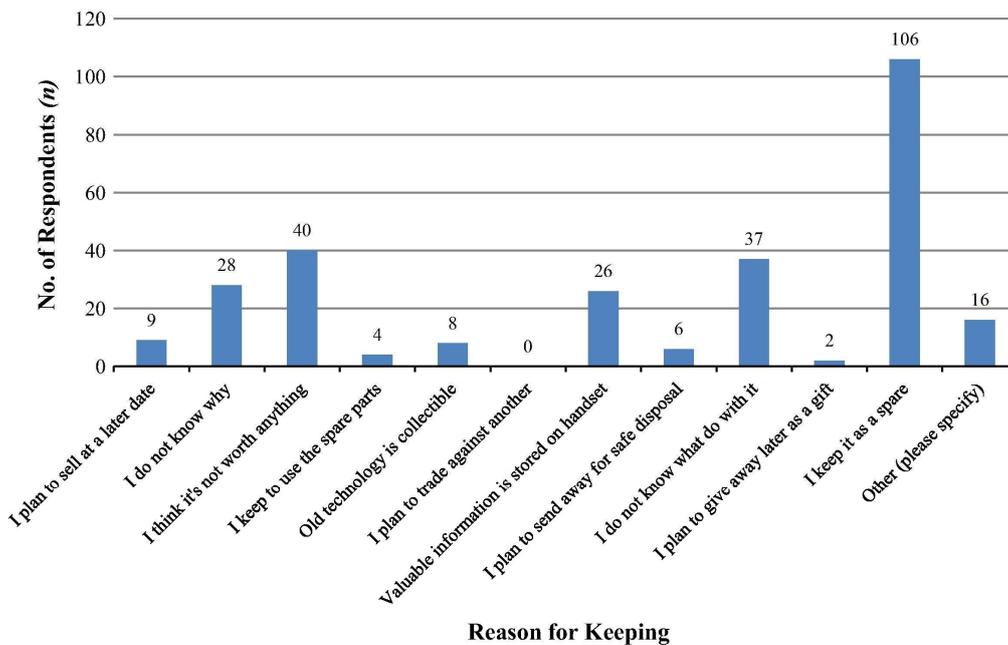


16

Action with previous mobile phone once replaced

17 **Figure 40: Action with previous mobile phone once replaced among UK students,**
18 **2015 (Wilson et al 2017)**

19 Being asked, why they kept replaced phones the reason for most respondents was to
20 keep it as spare device (Figure 41). Information stored on the device is another,
21 although much less frequently mentioned reason – leaving it open, whether trust in data
22 deletion is the underlying reason or the intention to keep the phone as storage device.



1
2 **Figure 41: Reasons for keeping replaced phones among UK students, 2015**
3 **(Wilson et al 2017)**

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

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

33 According to a recent survey (Bitkom e.V. 2020) in Germany 64% of all citizens stated to
34 have disposed or sold a mobile phone in the past. 21% keep (all) their used phones.
35 50% of those who are hoarding mobile phones do so to have a replacement device in
36 case their current phone has a defect. 37% are afraid, that data might be extracted from

1 disposed phones. For 36% lazyness is apparently the main barrier: Disposing or selling
2 the old phone is not worth the effort for them. 24% consider data transfer to complicated
3 and 19% do not know how to dispose old phones properly.

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

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

13 **5. SUBTASK 3.4 – LOCAL INFRASTRUCTURE (BARRIERS AND OPPORTUNITIES)**

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

17 **5.1. Fixed networks**

18 The products covered in this study exchange data through the communication
19 infrastructure. Table 12 provides an overview of the current telecommunications and
20 internet connectivity in Europe for fixed networks.

Table 12: Fixed networks and communication infrastructures (own compilation)

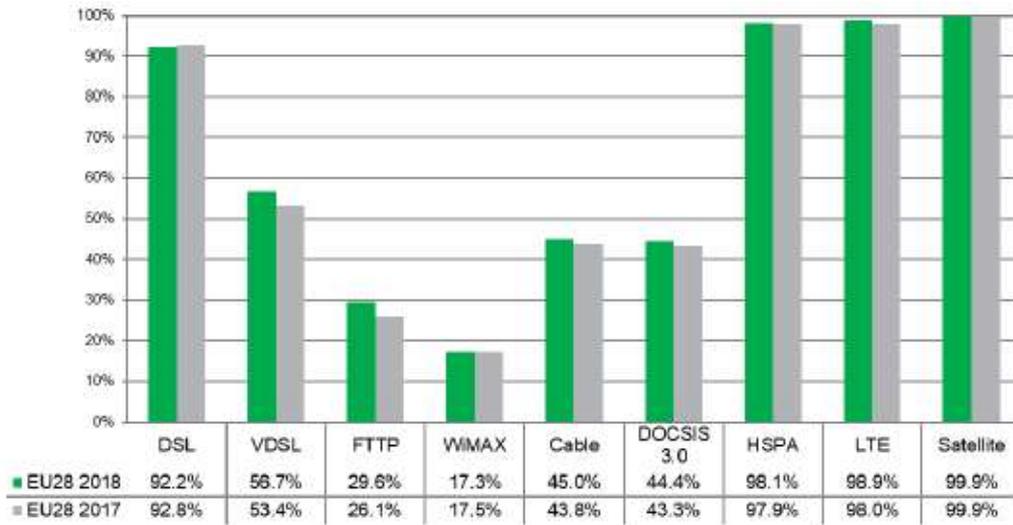
Network	Protocols	Average data rates	Telephone	Internet	Usage in Europe	Additional info	When was it introduced on the market	Until when is the connection available?
Telecom networks	ADSL (ANSI T1.413 Issue 2) ²¹ , VDSL (ETSI TM6)	ADSL: Downstream 9 Mbit/s Upstream 1 Mbit/s VDSL: Downstream 50 Mbit/s 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 ²² 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 ²³ : 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	

²¹ <https://webstore.ansi.org/standards/atis/ansit14131998>

²² https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/213/NEWS_213_DOCSIS_english.pdf

²³ <https://www.intel.de/content/www/de/de/support/articles/000005725/network-and-i-o/wireless.html>

1 According to the latest EU-Report on Broadband Coverage, there were 215 million homes
 2 passed by fixed broadband networks in mid-2018 in the EU 28 (European Commission
 3 2019).



4
 5 **Figure 5-1: Broadband coverage by technology in the EU (European Commission**
 6 **2019)**

7 Other figures are provided by international telecommunications market research and
 8 consulting firm TeleGeography. According to this company,²⁴ there were 222 million
 9 broadband subscribers in Europe in 2017, including mobile broadband subscribers (see
 10 Table 13).

11 **Table 13: European Broadband Subscriptions by Technology in 2017**
 12 **(TeleGeography 2018)**²⁵

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%

13
 14 The fixed broadband coverage level is above 95% in the EU-28, however few Member
 15 States are still below 90%.

²⁴ TeleGeography 2018, “DSL” includes ADSL, VDSL and VDSL2, “Fibre” includes Vectoring

²⁵ *ibid.*



1

2 **Figure 2: Overall fixed broadband coverage by country, 2018 (European**
 3 **Commission 2019)**

4 **5.1.1. Data consumption**

5 In Europe, the overall average broadband Internet usage for all households was 168.2
 6 GB/household in 2018, according to London-based consulting firm OpenVault²⁶. In 2017,
 7 the respective value was 126.2 GB/ household.

8 **5.1.2. Telecom networks (ADSL, VDSL)**

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

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

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

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

²⁶ 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)

1 *5.1.2.1. Possible follower technologies*

2 Vectoring or VDSL2 is an improved version of VDSL which still uses copper wires on the
3 last mile. However, for Vectoring-connections, the actual distances of the “last mile” are
4 being shortened, so that fibre cables come closer to the respective households. This
5 requires new termination stations at the curbside, thus this version is also called Fibre-
6 To-The-Curb (FTTC). Vectoring or FTTC is being rolled-out in various countries in Europe,
7 mostly by former telecom incumbents like Deutsche Telekom or Orange. It enables
8 download speeds of up to 100 Mbit/s depending on the length of the “last mile”. The
9 signal gets weaker with line length, a phenomenon called attenuation.

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

14 *5.1.2.2. Current usage*

15 DSL-broadband connections are the most popular ones in Europe with over 50 percent of
16 all broadband technologies. According to TeleGeography, there were 116.5 million DSL
17 subscribers in Europe in 2017.²⁷

18 Also, the coverage of DSL connections in Europe is high with over 90 percent (see EU
19 2019).

20 *5.1.2.3. Data rates and protocols*

21 DSL data rates for download range between 9 and 100 Mbit/s according to the protocol.
22 The real rates depend on the length of the “last mile” and other factors (see above).
23 Table 14 provides an overview of the data rates according to the DSL protocol.

24 **Table 14: Data rates and protocols for DSL²⁸**

	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

25

26 **5.1.3. Cable-TV-networks**

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

34 DOCSIS (Data Over Cable Service Interface Specification) uses the TV cable network to
35 transfer bidirectional data transmission. The last part of the connection to a customer’s
36 home is made of optical fibre and coaxial cables, amplifiers and electrical/optical

²⁷ TeleGeography 2018, “DSL” includes ADSL, VDSL and VDSL2, “Fibre” includes Vectoring

²⁸ <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)

1 converters (hybrid fibre-coaxial (HFC) network). DOCSIS 3.1 allows (in comparison to
2 DOCSIS 3.0) the maximization of downstream and upstream rates without expensive
3 changes in the infrastructure.²⁹

4 *5.1.3.1. Possible follower technologies*

5 DOCSIS 3.1: The new protocol introduced by European cable-TV providers from 2018 is
6 capable of an even higher downstream data throughput of up to 10 Gbit/s, depending on
7 the number of users using the connection at the same time (shared medium). DOCSIS
8 4.0 will provide higher upload speeds in the future.
9 DOCSIS 4.0 allows for higher upstream speeds as well as having a higher frequency
10 spectrum (and therefore allowing higher bandwidths).³⁰ Comparable performance can
11 then only be expected through FTTH or FTTB (or through 5G as a mobile solution at
12 gigabit speeds).³¹

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

17 *5.1.3.2. Current usage*

18 Most cable Internet-connections today use DOCSIS 3.0. The total number of homes
19 passed with cable Internet according to the European Broadband Survey in mid-2018 is
20 96.8 million in Europe (45% of 215 million EU homes passed by fixed broadband
21 networks)³². This figure relates to the homes which can principally be reached by the
22 network and not the actual number of users.

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

25 *5.1.3.3. Data rates and protocols*

26 Data Over Cable Service Interface Specification (DOCSIS) is the relevant protocol for
27 Internet and Voice over IP over the cable TV-network. An overview is provided in Table
28 15.

29 **Table 15: DOCSIS versions and broadband capacities³³**

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

²⁹ https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/213/NEWS_213_DOCSIS_english.pdf

³⁰ <https://www.teltarif.de/internet/tv-kabel/docsis.html> (accessed on 11.08.2020)

³¹ http://anga.de/media/file/965.BR-DOCSIS_3.1-final_online.pdf (accessed on 11.08.2020)

³² See European Commission 2019, page 7

³³ 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)

4.0	T.b.d.	10 Gbit/s	6 Gbit/s	Increased upstream rate
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5.1.4. Fibre networks

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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).

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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.

16

5.1.4.1. Possible follower technologies

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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.

22

5.1.4.2. Current Usage

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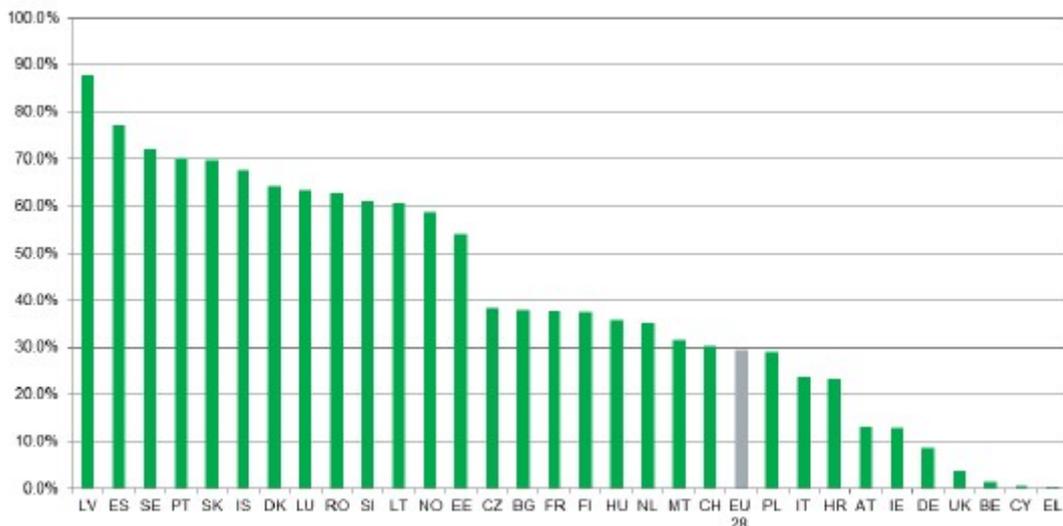
25

26

27

28

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 3).



29

30

31

Figure 3: FTTP coverage by country, 2018 (European Commission 2019)

1 *5.1.4.3. Data rates and protocols*

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

5 **5.1.5. DECT (Digital Enhanced Cordless Telecommunications)**

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

14 *5.1.5.1. Possible follower technologies*

15 There are 3 main approaches:

- 16
 - DECT-modules are integrated in modern WiFi-Boxes
 - IP-telephony via WLAN (voice over wireless LAN)
 - Bluetooth-Technology (currently with a shorter range)
- 17
18
19

20 *5.1.5.2. Current Usage*

21 European market in 2017: approximately 1.3 million consumer devices were sold,
22 forecasts expect the market volume to decrease to around 1.1 million devices per year
23 by 2021.³⁴

24 *5.1.5.3. Data rates and protocols*

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

28 **5.1.6. WiFi**

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

³⁴ 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)

1 *5.1.6.1. Possible follower technologies*

2 WiFi 6 (11ax) which was certified in 2019 can transmit between 300 Mbit/s -6 Gbit/s. In
3 2020, first WiFi 6-routers and devices are available on the market, however, there will be
4 a transition phase of at least 5 years to the new standard.

5 *5.1.6.2. Current Usage*

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

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

13 *5.1.6.3. Data rates and protocols*

14 Currently, most WiFi-routers and devices use WiFi 4. Until 2023. Cisco estimates that
15 66% will use WiFi 5.³⁵

16 **Table 16: Standards and actual transmission speeds of WiFi³⁶**

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

17

18 **5.2. Mobile networks**

19 **5.2.1. Overview**

20 Table 17 provides an overview of the current telecommunications and internet
21 connectivity in Europe for mobile networks.

³⁵ 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)

³⁶ see: <https://www.lifewire.com/how-fast-is-a-wifi-network-816543> (accessed on 11.08.2020)

Table 17: 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 ³⁷
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)	

³⁷ <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 (see Figure 4).

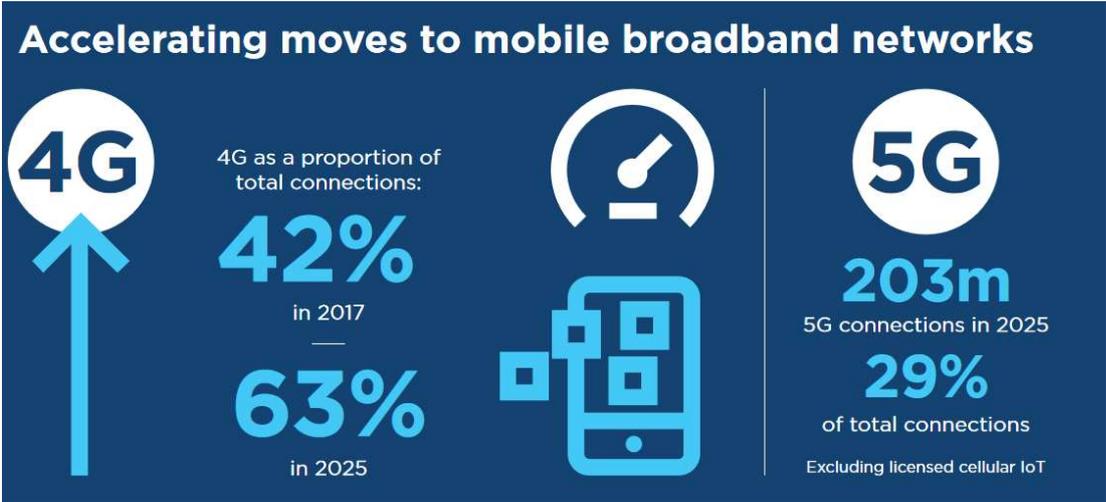


Figure 4: Estimated future use of mobile technologies (GSM Association 2018)

The GSM Association expects 4G to be the dominant mobile technology in 2025 (Figure 5).

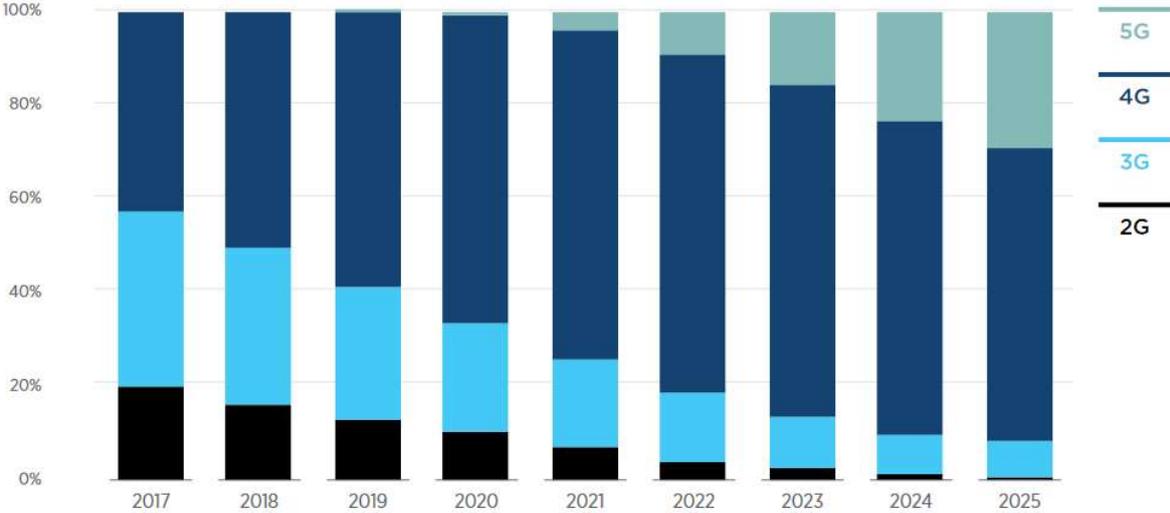


Figure 5: Shares of European connections by technology

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

5.2.1.1. 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 6) and there are only a few devices available.

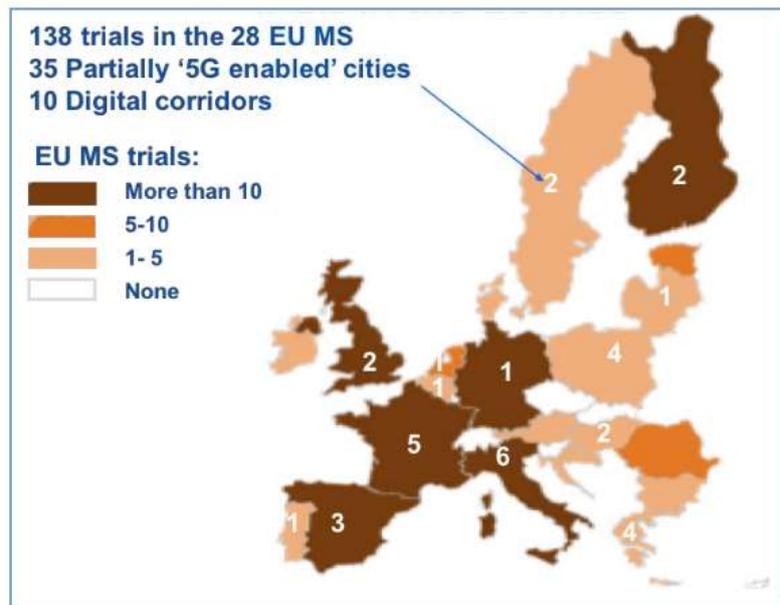


Figure 6: 5G trials and initial city pilot rollouts (European Commission 2019)

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 2019.³⁸ 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.³⁹ In total, 5 billion euros have been allocated to the 5G expansion until 2025.⁴⁰

³⁸ 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)

³⁹ <https://www.teltarif.de/telekom-5g-probleme/news/81287.html> (accessed on 11.08.2020)

⁴⁰ <https://www.computerbase.de/2020-06/corona-konjunkturpaket-bund-glaser-5g-ausbau/> (accessed on 11.08.2020)

5.2.1.2. 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

5.2.2. 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:⁴¹

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

The following areas of use are already apparent today. Each of them can be divided into further subgroups:⁴²

- 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.⁴³

In addition to these new applications, already known applications will become significantly more powerful for end users. Video streaming (apps like Netflix or amazon

⁴¹ <https://www.5g-anbieter.info/5g-anwendungen.html> (accessed on 11.08.2020)

⁴² *ibid.*

⁴³ <https://www.telekom.de/unterwegs/was-ist-5g/5g-ar-vr>

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.⁴⁴

According to IDC in Figure 7, the market share of 5-G Smartphones will increase from 9% (126 Million pieces) in 2020 to 28% in 2023.

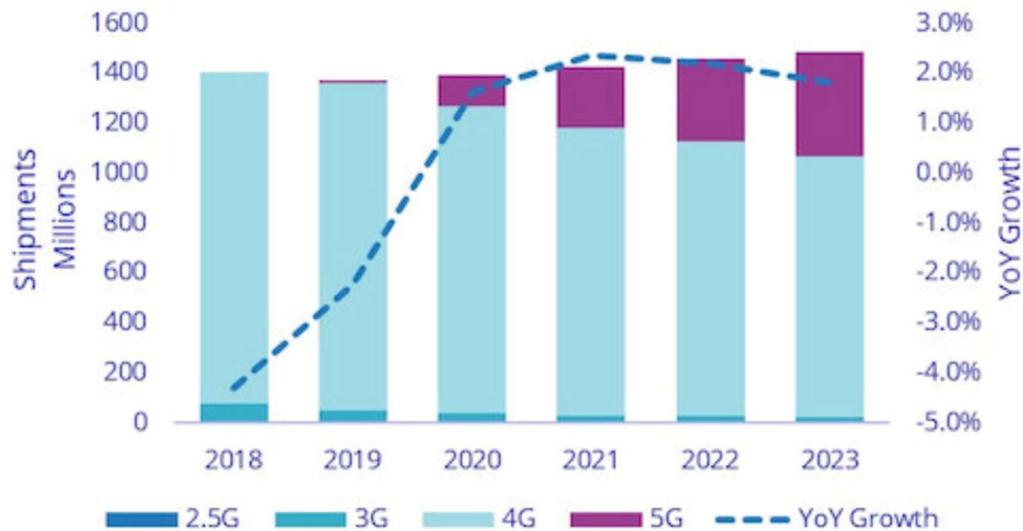


Figure 7: Worldwide Smartphone Forecast by Generation, 2019/Q2 (IDC 2019).

In Europe, the sales of 5G smartphones had a share of 4% of the overall smartphone sales in the first quarter of 2020⁴⁵. 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.⁴⁶ 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 Europe⁴⁷.

5.3. 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.

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⁴⁴ https://www.chip.de/news/Die-besten-Apps-fuer-das-schnelle-5G-Internet_170621499.html

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