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COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Accompanying the documents

Commission Regulation

laying down ecodesign requirements for smartphones, mobile phones other than smartphones, cordless phones and slate tablets pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) 2023/826

and

Commission Delegated Regulation

supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to the energy labelling of smartphones and slate tablets

{C(2023) 1672 final} - {C(2023) 3538 final} - {SEC(2023) 164 final} - {SWD(2023) 102 final}

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Annex 4: Analytical methods

All projections cover the years until 2030. As most of the policy options involve measures, which are intended to result in extended product lifetimes and consequently less replacement sales, the full effect of the policy options will be reached shortly before 2030 only. Any forecast and modelling beyond 2030 involves major uncertainties: Given the very short innovation cycles of mobile phones and tablets technology will have evolved in non-predictable directions in ten years from now. None of the market analysts in this industry predict product developments beyond a time forecast of more than 5 or 6 years.

LIFETIME MODELLING

Many of the considered design options[1] affect the lifetime. Therefore, estimations of the effect of design options on the lifetime of base case devices are needed. Further, products exit the active use phase and enter end-of-life distributed over time rather than all at the same point in time. Therefore, a lifetime model was set up that takes account of the identified reasons for products reaching their end of life and how this changes over time.

The assumed average lifetime is a statistical value. The products exit the active use phase and enter end-of-life distributed over time rather than all at the same point in time. The lifetime model takes account of the identified reasons for products reaching their end of life and how this changes over time. To build the lifetime model and calculate the number of products retired per year and per reason, a maximum lifetime was defined:

- Smartphones and feature phones:
  - Average lifetime: 2.5 – 3.5 years
  - Maximum lifetime: 7 years
- Cordless phones and tablets:
  - Average lifetime: 5 years
  - Maximum lifetime: 9 years

It is assumed that from a stock sold in year 0, the first products are retired in year 1 and the last products are retired in 7 / 9. For the simplified lifetime model, no product is used longer than the maximum lifetime.

Products leave the use phase due to hardware defects and non-hardware reasons:

- Hardware defects:

[1] In line with the MEErP methodology, by 'design option' a specific product architecture is meant, with technical features which make it more advanced and/or more efficient when compared to the 'base case', i.e. the average EU product defined for analysis. Typically, a design option is formulated to model a product architecture compliant with a specific requirement (or, a specific set or requirements), for instance a product with a minimum efficiency/performance level, a product with a minimum level of reparability, durability, etc.

  - Display damage
  - Damage of glass back cover
  - Battery failure and/or loss of capacity
  - Damages through water & dust ingress
  - Other defects
- Non-hardware reasons:
  - Performance-related product retirement
  - Software-related product retirement
  - Non-technical reasons (“psychological obsolescence”, context-related reasons, etc.)

For the hardware-related defects, a yearly failure rate and yearly repair rate are calculated as percentages of the remaining stock. Battery-related issues are treated differently with a failure rate of batteries increasing over time. The non-hardware reasons are then adjusted to meet the average lifetime of each product segment.

The individual design options are plotted on these lifetime models to account for e.g. additional repairs and defects in later years when options extend product lifetime. Thereby, the reduction of one failure rate (e.g. more resistant display) will reduce the number of products leaving the stock due to this specific defect, leading to the increase in absolute numbers of other defects and repairs in the following years as the number of products in the remaining stock changes and the percentaged failure rates stay the same.

Depending on the design option, the failure rate and/or the repair rate is affected.

Within the lifetime model, repair costs are calculated in parallel. Thereby, as for the failure rate, the repair regarding all defects change with each option as the percentage of failure and repair rates stay the same. As an example, the longer provision of OS updates would lead to higher absolute hardware defects and higher repair costs as less products leave the stock early for software reasons. The costs per active use time however would decrease.

The lifetime model for low-end smartphones (Base Case 1) is depicted in Figure 1: On average, the product lifetime is 2,5 years, but some units will leave the stock of products sold in a given year earlier than others, and there is a tail of products reaching much longer lifetimes. Maximum lifetime for the purpose of this modelling is assumed to be 7 years. The bars show the number of products leaving the stock (left scale) per reason. The blue line shows the remaining stock from year 0 (right scale).

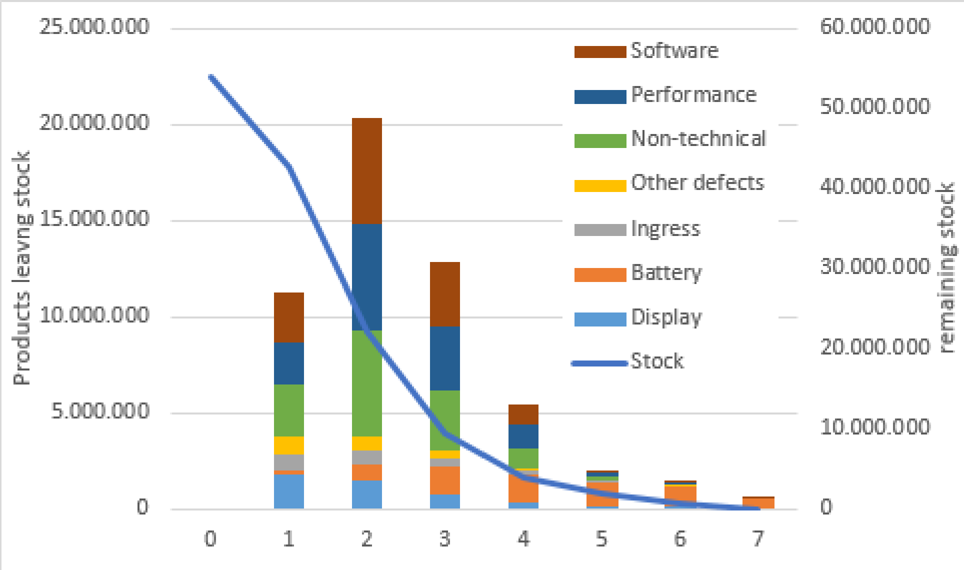

Figure 1 : Low-end smartphones (BC 1) - Lifetime model

For comparison, the lifetime models of the other Base Cases are shown below.

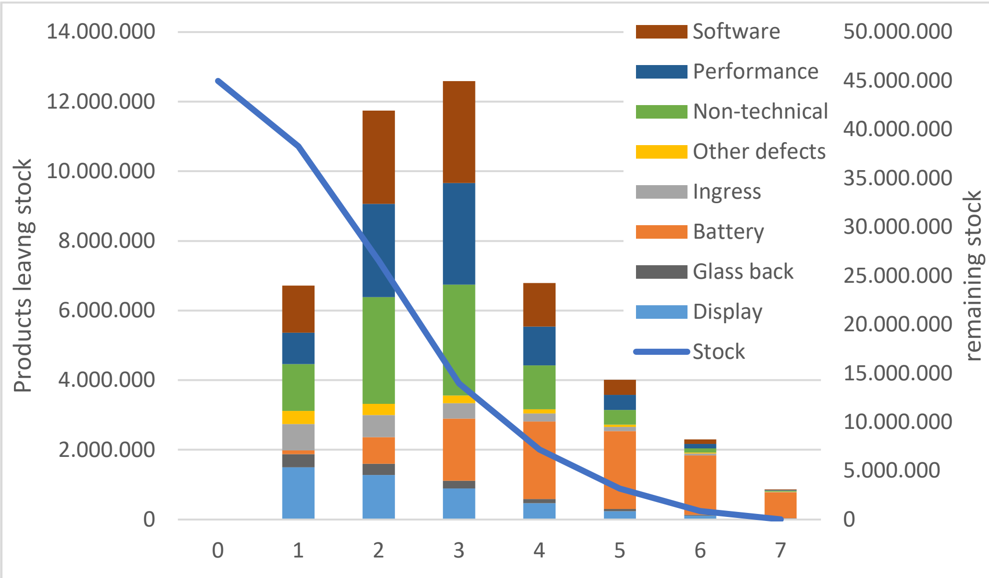

Figure 2 : Mid-range smartphones (BC 2) - Lifetime model

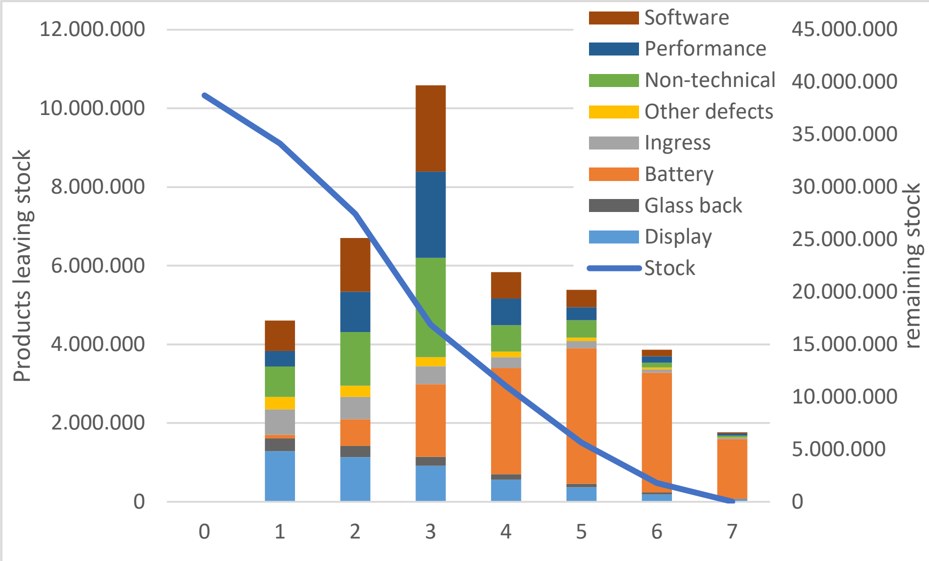

Figure 3 : High-end smartphones (BC 3) - Lifetime model

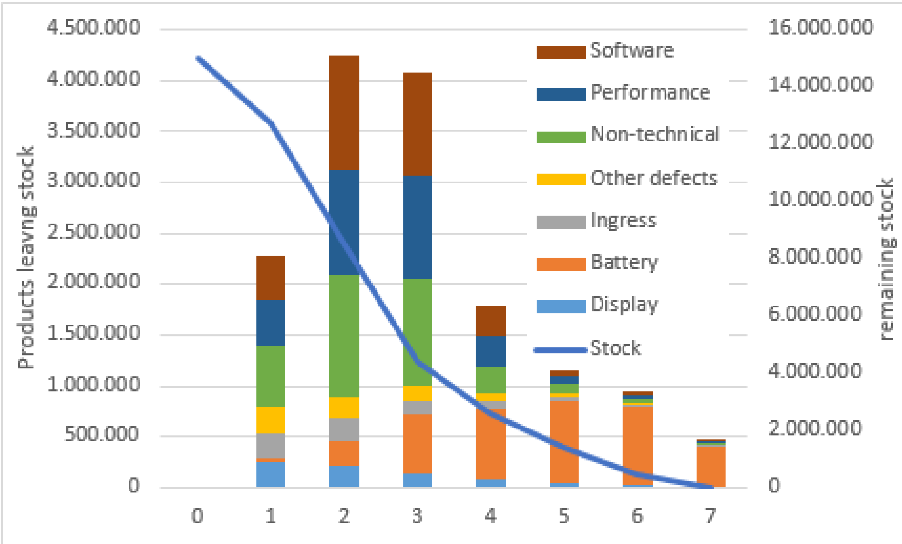

Figure 4 : Feature phones (BC 4) - Lifetime model

The lifetime model for cordless phones in Figure 5 is simpler than the other ones as there are not so many triggers for end of life than for the more complex smartphones and tablets.

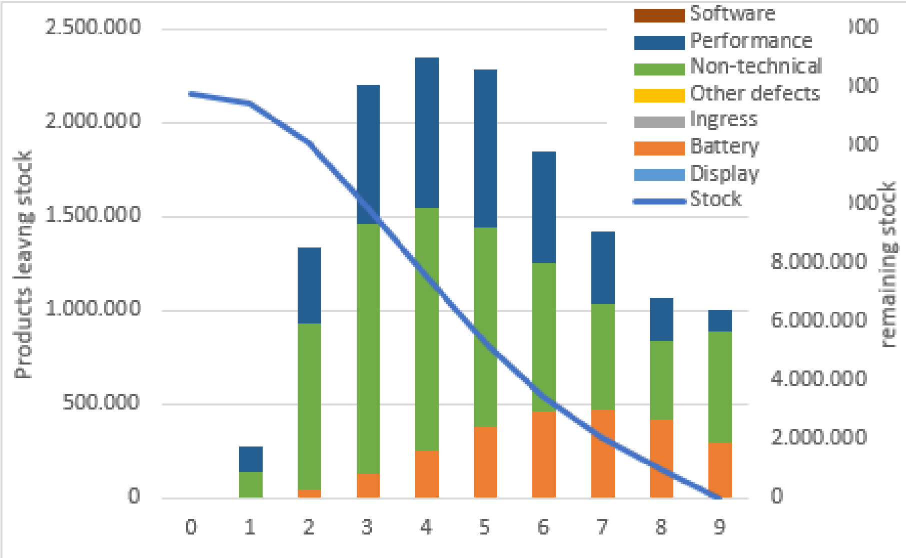

Figure 5 : Cordless phones (BC 5) - Lifetime model

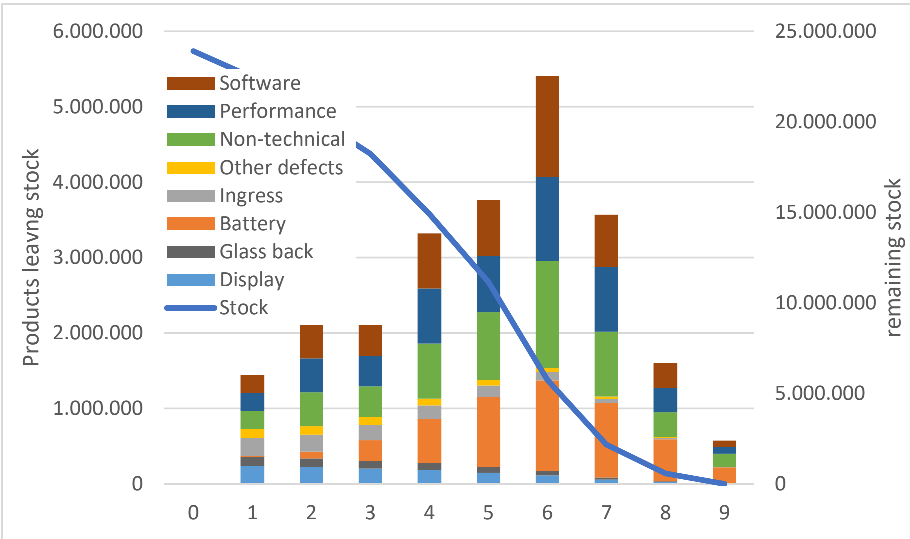

Figure 6 : Tablets (BC 6) - Lifetime model

ANALYSED DESIGN OPTIONS

A key element of the analytical approach to derive policy options is the modelling of implementing consecutively design options, which have been identified in a screening as having potentially a positive effect on overall environmental impacts and consumer costs. The design options analysed in the preparatory study comprise the following individual measures, sorted by intervention domain. Several of these options were discarded for various reasons (cost implications, negative side effects, marginal positive effects, no robust data), other underwent reformulations and revisions in the course of being translated into Ecodesign or

Energy Label requirements to reflect the findings of calculating the implementation options and due to later stakeholder intervention and new findings arising after December 2020 when these options have been presented and discussed first in a stakeholder meeting of the preparatory study.

Reliability

(1) Robustness of display and glass back-cover against accidental drops
  - The most frequent defect in smartphones and tablets are damages of the display. It can be assumed that a large share of the defects is broken glass due to drops of the device. Therefore, design measures to increase the glass withstand used to cover the display and the back of the device appear appropriate to mitigate the relatively high failure rates[2]. Another display related aspect is the way front glass and display unit are assembled: Current smartphone designs are characterised by front glass and display unit being fused or glued together by an adhesive. This has some advantages, but makes repairs more costly, as in case of a defect the whole assembly of screen glass and display unit has to be exchanged. For tablets it has been more common to keep display unit and cover glass separated, thus both being replaceable individually. This design can be considered best practice in terms of reparability. It does not relate to a design improvement, but rather represents a "design freeze" of what was common practice until few years ago. The use of display glass best-available-technology (BAT) has the potential to decrease the probability of display and back cover glass shattering when a drop of the device occurs. For instance, the reported fracture toughness of the BAT (Corning® Gorilla® Glass Victus™) is increased by more than 10 % over one of the previous iterations of hardened glass for mobile devices (Corning®Gorilla® Glass 5). Overall costs 1-3 Euros[3]. Improvements comprise: Lifetime extension through less retired devices, cost reduction through less repairs and extended lifetime, cost increase due to different cover glass

(2) Display scratch-resistance
  - Design measures to increase the withstand of the glass used to cover the display do not only prevent breaks in case of accidents, but also scratches of the display, which might lead to hard to read displays and may also weaken the glass in case of accidents. Improved scratch resistance can also contribute to reducing replacement of phones for aesthetic reasons. New display glass generations are

[2] Note: The toughness of the display can have also other influence factors than just the variety of the glass. It depends on how the display it is integrated into the device, e. g. if the display is tightly integrated under tension it is more likely to break. The alternative is to build it in a flexible way on a rubber seal or the like which dampens shock forces transmitted from other housing components to the display.

[3] https://www.forbes.com/sites/timworstall/2013/03/21/could-sapphire-replace-gorilla-glass-in-smartphones/ https://www.autonews.com/article/20150829/OEM10/308319972/will-automakers-go-for-gorilla-glass; https://www.androidauthority.com/corning-gorilla-glass-victus-1140743/

not only hardened to prevent breaks, but are also more scratch-resistant and both aspects can be addressed by the same design change. Additionally, scratches are not defined as failures in the base case. Therefore, scratch-resistance is not calculated as an individual design option, but relevance for product lifetime has to be acknowledged. Besides the scratch resistance of the display also those of others surfaces matter: Scratches make devices not desirable anymore and as such also limit the reuse value of used devices even if full functionality is still given.

(3) Provision of additional screen and glass back-cover protection

- Damages of the display and of the back cover glass through accidental drops could be reduced by smartphone covers/bumpers and display protection foils. According to clickrepair (clickrepair 2019) 20% of the smartphones without protective covers showed damages throughout their live, but only 10% of the smartphones with protective cover, see Task 3. This would mean that covers would reduce the probability of damages by 50%. The difference is even higher for tablets according to clickrepair (WERTGARANTIE 2018). Assumption: 80% already use bumpers and/or foil, more people use bumpers than foil (clickrepair 2019), half of the other users could be reached through bumpers and foil included in delivery. The additional costs will affect all 20% which were not already using a cover. From material perspective, this design option would require additional bumpers and foils for 20% of the users (of which half of them will actually use them). Bumpers and display protection foils can be made from different materials: plastics, leather, textiles for phone covers and PET or glass for the display protection. This design options assumes bumpers made of TPU / silicone and display foils made of PET. Forecasted costs are 4/5€ for bumper and display foil together, costs within smartphone package are expected to be lower than end-user prices for individual bumpers and foils. Resulting improvements are lifetime extension through less retired devices, cost reduction through less repairs and extended lifetime, but cost increase through additional screen foil and bumper.

(4) Water and dust resistance

- Close to 50 % of smartphones sold in Europe in 2019 had an IP-rating to indicate a level of ingress protection from dust and water (see Annex 5). However, as this estimation is based on market data on the 25 best-selling smartphone models in Europe, and therefore it can be assumed that the market share of phones with an IP-rating is overestimated, as the lower-end devices with a lower individual market share, but a high combined market share, are likely not to feature an IP-rating. "Dropped into water" is among the most common accidental smartphone damages in a U.S. survey in 2018 (39 % of respondents reported this damage). The assumed failure rate due to water ingress is estimated to be half of all defects not related to the dominating failing parts (display, battery, backcover), which results in an annual failure rate of 0,84 % for smartphones and feature phones, and 0,5% for tablets. It is assumed that the probability of failure due to ingress is reduced by 50 %. Ingress protection needs to be accounted for in the design phase of devices. Effort and material is needed to implement it, sealing any points of entry to the phone with gaskets and adhesives, possibly applying water-resistant coatings. This may also result in increased manufacturing costs over devices without an IP-rating. Testing and verification of ingress protection according to testing standards may also be an additional cost factor. As no data on the cost associated with the implementation of ingress protection could be identified, the preparatory study assumed that it adds 3 Euros to manufacturing costs as a proxy. It can be argued, that dust and water ingress protection also have an effect on repair costs and lead to more complex repairs. The actual parts replacement time, which is likely to increase by 2 – 3 minutes, plus the additional time for testing water tightness after repair (which is done in a vacuum chamber or similar within seconds) is only one aspect of overall repair labour costs. Thus, repair costs per individual repair case is likely to increase slightly, but this considered marginal across all devices compared to the purchase price increase for all devices.

(5) Battery endurance (cycle stability)

- Smartphones with user-replaceable batteries no longer play a major role on the market (see Annex 5), while tablets have always had embedded rather than user-replaceable batteries. As batteries can therefore not easily be replaced, the inevitable ageing of the embedded batteries will likely lead to a limiting state at some point during the use phase. On the contrary, the batteries of feature phones and DECT phones can commonly be accessed and replaced easily. Battery-related defect rates of the different product segments over their lifetime are between 8,3 % (low-end smartphone) and 50 % (cordless phone). The endurance of device batteries can be defined over time or over use. Some OEMs specify the number of charge/discharge cycles device batteries are expected to withstand before their capacity drops to 80 % relative to the nominal or initial capacity. For instance, Apple Inc. states that smartphone batteries are designed to retain up to 80 % of their initial capacity after 500 full charge cycles, and 1000 full charge cycles in case of tablets4. The endurance of batteries may either be increased by specifying a minimum state of health after a defined period of use time or after a defined number of charge/discharge cycles. Such a design option can be verified by battery endurance testing in accordance with the international standard IEC/EN 61960. The standard specifies a testing procedure to continuously charge and discharge batteries and measure the capacity fade up to a threshold to be specified or over a specified number of

[4] https://www.apple.com/batteries/service-and-recycling/

charge/discharge cycles. However, such tests can be time-consuming. Depending on the battery capacity and the charging profile defined by the OEM, one cycle may take 5 hours or more. Therefore, testing over 500 cycles may take more than 100 days. The design option to be assessed here is: Device batteries shall retain at least 90% of their initial capacity after 300 full charge/discharge cycles, measured in accordance with IEC/EN 61960. Assuming linear capacity loss as a function of the number of charge/discharge cycles, smartphone batteries may improve by 20 % (SOH 80 % after 600 cycles instead of 500 cycles). Batteries of feature phones are also assumed to be improved by 20 %. Batteries of DECT phones are not expected to improve, as their ageing is assumed to not be influenced as much by cycle withstand and more by calendar ageing. Tablet batteries may not be affected by the design option when they were designed to withstand 1000 cycles while retaining 80 % SOH. However, not all tablet batteries may be designed this way. A lithium-ion battery cell for a smartphone costs the device OEM somewhere between $2 to $4 depending on its capacity and other design attributes. It constitutes about 1 to 2% of the entire cost of the mobile device[5]. It is therefore assumed that a high-endurance battery costs the OEM $4, which is assumed to equal 4 Euros for reasons of simplicity. This results in an increase by 0 to 2 Euros, depending on the assumed quality and capacity of the base case without this design option, taking into account current penetration rates. Tablet batteries are assumed to cost double due to their higher capacity.

(6) Higher battery capacities to reduce number of charging cycles and states of very low state of charge

- Long battery life is the most important feature in smartphones for prospective buyers. Battery life denotes the time the device can be used before the battery needs to be recharged. As batteries inevitably age over time and with use, the available capacity decreases, leading to a decrease in battery life. Installing batteries with higher capacity results in increased battery life and therefore, even as the batteries age, the battery life may remain to be acceptable to the user for a longer period of time. Higher battery capacity therefore may postpone a limiting state in which the decreased battery life is insufficient to the user and results in a repair (battery replacement) or replacing the device with a new unit. It can be assumed that the same logic applies to feature phones, DECT phones and tablets. Higher battery capacity may also decrease the charging frequency and therefore the number of charging cycles is stretched out over a longer period of time, which enhances product lifetime. This design option has not been elaborated on for the following reasons: It is assumed that OEMs strive to implement high battery capacity due to the demand on user-side for longer

[5] https://www.beroeinc.com/article/lithium-ion-batteries-price-trend-cost-structure/

battery life, even without this design option. Battery life results from a combination of battery capacity and power draw from the device, i.e. the same battery life may be achieved by a smaller battery in a device with a lower power draw compared to a larger battery in a device with a higher power draw. Therefore, "higher battery capacity" is relative and cannot be specified across the board for all devices in a product group.

(7) Pre-installed battery management software

- Some manufacturers of smartphones have started implementing features that aim at extending the battery lifespan. Some of these include: Smart charging that aims to prevent the battery to remain in trickle charge mode for extended periods of time after the charging process is complete (e.g. via timed overnight charging). A high state of charge tends to accelerate battery ageing; user-selectable charging rate to prevent fast charging when it is not needed. High charging rates tend to accelerate battery ageing; dynamic performance management of the device to prevent random shutdowns in cases where an aged battery can no longer meet the required power draw from high-performance applications. Unexpected shutdowns may lead to users replacing their battery or device. It is assumed that the around half of the charging processes benefit from the functionality of this smart charging software. Therefore, the overall benefit for affected device batteries is assumed to be roughly 25 % increase lifespan (roughly half a year). Given the considerable sales data on smartphones in particular, and considering that OEMs constantly develop new software features for their handsets, it is assumed that the additional cost to develop and maintain a pre-installed battery management software is negligible on a per-device basis, with the exception of the low-end smartphone, where the profit margins are comparatively smaller.

(8) Battery status (SOH, age, cycles, peak performance) reporting

- Some ICT device batteries employ specialized hardware and software to store, estimate and report the battery status to the host device's OS. Making this information accessible to stakeholders including the user as well as the repair and refurbishment practitioners may come with a range of potential advantages, including the possibility for continued use of a battery based on specific information on its health. (Clemm et al. 2019) listed some potential benefits and drawbacks of making such data available for different stakeholders. Relevant state of health information includes: battery type, date of manufacture, nominal battery capacity, remaining battery capacity, number of charging cycles performed. Potential benefits may include, among others: Incentive for users to adopt behaviour that slows down battery degradation; consumer empowerment with regard to in-warranty battery failures; users may benefit from a "race to the top" as manufacturers are incentivized to optimize battery endurance; continued use of batteries that may otherwise be disposed of due to unknown health status; increased trust in used devices by potential buyers due to known battery health status. Clemm et al. (2019) further reported that iOS devices commonly provide such information while Android devices do not. No feature phones or DECT phones could be identified that provide such a functionality. It is assumed that a battery with advanced functionality on battery SOH estimation will increase the price to the OEM by no more than 1 Euro, in practice most likely rather in the range of a few cents. It is estimated that the lifespan of 10 % of the smartphone and tablet batteries is increased by 20 % through the potential benefits of this design option listed above, effectively reducing the failure rate caused by batteries. It is assumed that due to battery health information being available, the confidence in second-hand devices increases slightly. On the other hand, devices with relatively lower SOH may no longer sell on second-hand markets for the same reason. It can well be assumed that reliable information about the actual value of second hand smartphones will increase the average price consumers are willing to pay for them.

(9) Information provision (correct battery use; whether it is embedded and therefore not replaceable)

- An informed user who is aware of the influence of their behaviour on the lifespan of their device battery is more likely to favour behaviour that is beneficial for the lifespan. A share of 10 % of the device batteries benefits from more aware users. Their lifespan increases by 10 %. This is applicable to all base cases. This design option does not lead to increased purchase prices for the devices.

Operating system, software and firmware

(10) New models on the market should always be equipped with the most recent OS

- 20% of devices reach end-of-life due to software issues, and an OS not further supported is a major issue here. New devices on the market are always equipped with the most recent operating system (OS) version are potentially supported longer with up-to-date software. The effect could be 1 to 2 years longer product life as approximately every year a new OS version (Android and iOS) is introduced. However, hardware in the market is not always compatible with latest OS versions nor does the intended use require all latest OS features. Such an option therefore might also lead to the non-intended effect that models are discontinued earlier than needed or devices are increasingly “oversized” in terms of the specification. Due to these side effects, this option is not analyzed any further. Instead, supporting the OS, with which a model is shipped, for an extended period of time, regardless which actual OS version it is, is seen as the more effective option (see following option).

(11) Availability of update support of OS (e.g. 5 years after the placement of the last unit of the model on the market), including information on impact of updates and reversibility of updates

- Discontinued OS support is a major reason for security and performance issues. Data on OS support for individual models suggests, that low-end devices are supported much shorter than high-end devices. Support duration is roughly in the range of 2,5 to 3,5 years. An OS support of 5 years eliminates the OS as major lifetime limiting factor for another 2,5, 2 and 1,5 years for the 3 smartphone market segments. Almost 20% of users bought a new device as software or applications stopped working on their device. These 20% are at stake for a prolonged lifetime through extended OS support. Although it is not certain, that third party application providers follow suit with their maintenance strategy it is much more likely as they are at risk to lose part of their user base. As with increasing lifetime other obsolescence factors will become more important (defects, performance other than OS), continued OS support will not extend the lifetime of all 20% of the devices at stake to full 5 years. It seems plausible, that on average for these 20% the lifetime is extended by ¼ of the time span between Base Case end of life and OS support duration of 5 years. Assumption on additional costs per device is based on approximately 1000 different smartphone models being on the EU market, with on average 150.000 sold units, and updates being in the cost range of "several hundred thousand US dollars per model" (Clark 2016), i.e. calculating with 2 Euros per device for this option. For comparison: Stated software development costs for the Fairphone 2 are 4,62 € at 140.000 sold phones per year (Fairphone 2015)

(12) Possible use of open source OS or open source Virtual Machine software

- The use of open source OS or open source Virtual Machine software has been mentioned by the JRC material efficiency study (Cordella 2020) as an option. Actually, also Android is an open source project and OEMs are adapting Android according to their specific interests (features, user experience etc.). The possibility to change over from a pre-installed OS to (another) open source OS is motivated by, e.g. keeping a device running with a less phone-resource intensive operating system when the pre-installed / market-leading OS slows down the device or does not support the device anymore. Data privacy concerns are also a motivation for some users to rely on alternative open source software. The latter is not directly related to any lifetime extension. In general, deviating from a pre-installed OS or one of the market-dominating OS requires some technical skills. It is therefore questionable, how many users would really make use of alternative open source OS. Most likely the effect would be minimal, but there is no data to underpin this judgement.

(13) Security patches latest 2 months after the release of the new update

- Getting security patches rolled out rapidly is important to reduce data security risks. In case of Android, such a provision of security patches requires some time due to e.g. OEM specific OS variants, which need to be updated as well. 1 month for providing such security patches after the initial update is considered hardly feasible. 2 months delay is still ambitious but feasible (Mobile & SecurityLab 2019). While this option enhances data security for the user, there is no specific improvement potential in terms of lifetime extension. In conjunction with an overall long-term support of the OS, such timely provision of security patches is considered a relevant sub-aspect.

(14) The capacity of the device allows the installation of next OS versions and future functionalities (e.g. min. 4 GB for the RAM and 64 GB for the Flash could be considered reasonable for current models on the market)

- “Future-proof” hardware in terms of memory (RAM) and storage (Flash) has been mentioned by the JRC material efficiency study (Cordella 2020) as an option. The minimum requirement for Android 10 and 11 is 2GB of RAM and there are several smartphone models on the market with 32 GB Flash supporting Android 10. Android 11 has been released only on September 8, 2020, and there are few devices at all on the market, apparently none with 32 GB. Technically, Android 10 and 11 require 4 GB flash memory for application private data, thus a 32 GB storage capacity leaves room for additional software and data. Just providing more memory and storage does not guarantee an upwards compatibility with future OS versions, as also the SoC and other hardware components need to be compatible. An environmental assessment, confirmed by LCA data published by OEMs, indicates the high environmental impact of flash memory in particular and incentivizing an oversizing of storage capacity should be avoided. Also from a cost perspective there is a significant difference between a model with 32 and the same model with 64 GB (in the range of 20 Euros purchase price difference), which will not be compensated LCC-wise through longer product lifetime. **Due to these considerations the option of more memory and storage to support future OS versions has not considered for the further analysis.**

Reparability

(15) Battery removability/replacement: Joining techniques

- All of the 25 best-selling smartphones of 2019 had an embedded battery that cannot be easily removed and replaced without the use of tools (see Annex 5). The majority of embedded batteries are fixed in the devices using adhesives. This is a potential barrier to the removal and replacement of the battery, as frequently thermal energy, solvent, and/or prying force need to be applied in order to dissolve the joint. This may also increase the risk of physical damage to the battery and other components during the removal process. The semi-soft battery packs may be bend or punctured, leading to short circuit and thermal runaway in the worst case. These factors can be assumed to lead to a decrease in (successful) repair attempts by users. Professional repair operators are assumed to have the skills, tools and knowledge[6] to remove and replace batteries independently of the type of adhesive employed, but the use of strong adhesives may increase the time spent on the process and therefore the involved repair

[6] As already presented in the in the ‚SOCIAL IMPACTS‘ section of the main report, professional repairers typically consider the assembly and disassembly operations at component level (e.g.: battery) routinary work which can be learnt in a relatively simple way.

cost for the user. This design option avoids designs that utilize adhesive joining of the battery within devices in favour of solutions that intend to ease the process of removal and replacement of batteries and make it safer. Such designs where reversible adhesive bonds are in use, include: Batteries are mounted into the housing with double sided pressure sensitive adhesive (PSA) tapes with stretch-release-properties; PSA systems with adhesion properties that are sensitive to contact with ethanol; battery wrapping technology with a pull tab attached to the battery wrap. Accordingly, the design option aims at a device design where the battery is not fastened within the device using joining techniques that require tools, thermal energy, or chemicals to solve. Close to 50% of the best-selling smartphones sold in Europe in 2019 had a type of pull tab adhesive solution in place. It is assumed that the implementation of such joining techniques incurs negligible additional costs during the manufacturing phase that do not result in an increased purchase price for consumers. On AliExpress, an order of 500 pull tabs ranges from USD 44 to 132, equivalent to 0,07 to 0,22 Euro , depending on the smartphone model. It can be assumed that the cost for the adhesives strips does therefore not play a role in manufacturing devices when bought in much larger quantities directly from suppliers. Although the potential of such repair-friendly battery implementation is significant, it materialises only in conjunction with better overall accessibility of the battery and spare parts availability, as other barriers, such as the need to still consult professional repair services, thus still significant overall repair costs, data privacy concerns in case of third party repairs and times of non-availability of the device remain. With better removability of the battery only a small additional fraction of the devices with integrated batteries will be repaired.

(16) Battery removability/replacement: Joining battery and display unit

- Professional repair operators are assumed to have the skills, tools and knowledge to remove and replace batteries in almost any type of design with respect to all six base cases. However, the probability of damaging other components in the process may be influenced by the product design choices. One design choice that may considerably increase the likeliness of damaging other components is to adhere the device battery to the backside of the display unit. This design has been documented in at least one smartphone of a major manufacturer (Clemm and Lang 2019). This design choice is likely to increase the cost for repair due to the increased risk of damage to the display unit, as well as increasing the material consumption due to additional display units required to replace accidentally broken units during repair. An additional impact of this design choice may be that users themselves are further discouraged from DIY repairs. Therefore, this design option aims to prevent this design choice from being implemented in future devices: Batteries may not be adhered to the display unit. It is unknown whether any devices currently employ this design choice, therefore it is assumed that 1 % or less of devices is affected in the market for all base cases. Due to the uncertainty with respect to market relevance of the design choice, this design option is not evaluated further.

(17) Battery removability/replacement without use of tools and use of standardised batteries for cordless phones

- Less than 10 % of the mobile phones sold released to the market in 2019 had a user-replaceable (non-embedded) battery, and none of the best-selling smartphone models in Europe in 2019 had a user-replaceable battery. By definition, embedded batteries are integrated into devices and cannot be accessed without the use of tools. Devices are commonly sealed using adhesives and require thermal energy, hand-held tools, or machines to be opened. The design that was prevalent in smartphones previously allowed access to the battery by simply removing the back cover of the device. This design is still commonplace in feature phones and DECT phones, but not in smartphones and tablets. This design option requires all devices to adopt a design where batteries can be accessed, removed, and replaced without the use of any types of tools, thermal energy, or solvents. In case of cordless phones, user-replaceable (rechargeable) AAA batteries, or other standardized battery form factors, which are available in the market, ease not only the exchange of batteries, but also long-term availability at reasonable prices from multiple sources is given. Although most cordless phones are designed for user-replaceable AAA batteries there are some products, which feature other, non-standardized form factors and not in all cases these are user-replaceable. The exact market share of these designs is not known, but as this is a feature of some popular models, a market share of 15% is a plausible estimate. Benefits are the ease of replacing a faulty or faded battery and the opportunity to use a secondary battery. A likely side-effect is that the back cover is easily removable with such a design as well. Another side-effect may be in the material of the back cover of devices with a user-replaceable battery. A removable back cover is less likely to be made from glass, but rather from plastic or metal, to ease damage-free separation from the device. There are only very few devices on the market with high ingress protection and a readily-removable battery. The battery is accessible without any tools after removing the back cover. It has been pointed out by a stakeholder that back covers made of metal, as well as allowing batteries to be user replaceable (which means making the back cover detachable) might make it harder or impossible to integrate coils for wireless charging capabilities. In fact the very few smartphones with user replaceable battery on the market do have wireless charging capability, e.g. Gigaset GS4. This design option depends on the availability of spare batteries to unveil its full potential. The repair rate is increased as a weak battery is always a trigger point, which might lead to upgrading to another device. A user-replaceable battery would lower the barrier to get a repair done, thus is assumed to increase the repair rate significantly – in particular for already somewhat older devices -, also in comparison to an established professional repair infrastructure. The reduced battery repair costs correspond to batteries as OEM spare parts, to be acquired by the user. However, some will likely make use of the convenience of a professional battery replacement (without the need to wait for a replacement battery to be shipped), but also in these cases replacement costs are not expected to be much higher than the parts costs due to the simplicity of the process.

(18) Glass back cover removability/replacement

- Damage of a glass back cover is one of the main limiting states of technical nature for smartphones and tablets. Therefore, in addition to design measures to replace the display, the ability to detach and remove a shattered glass back cover has the potential to prevent a premature limiting state and prolong the lifetime of the device. Easily removable glass back cover needs to be accounted for in the design phase of devices. As there is no evidence of smartphone or tablet designs with easily removable glass back cover and no data on the cost associated with the implementation of easily removable glass back could be identified, we assume that it adds 2 Euros to manufacturing costs. This amount or a part thereof may be added to the sales price.

(19) Display removability/replacement

- The most frequent defect in smartphones and tablets are damages of the display. Therefore, in addition to design measures to increase the withstand of the display glass against accidental drops, the ability to detach and remove a shattered display without further damage seems appropriate to preclude a premature limiting state. Prioritizing the display in the design and making it accessible has the potential to incentivize repair, thus prolonging the lifetime of the device. For instance, there are examples that the display can be removed either without tools or just with the use of a regular Philips screwdriver. Whereas displays can be replaced by professional repair shops with some efforts, i.e. costs, a detachable display unit mainly fosters additional DIY repair, but also simplifies and speeds up the process for professional repair shops. This measure depends on the availability of display units to unfold its full potential. As long as availability for consumers is not given, the effect will be limited to those cases, where displays can be sourced from third parties or through cannibalising other defect devices.

(20) Provision of repair and maintenance information

- Provision of information (e.g. through user manuals) is necessary to support the repair/upgrade operation. Repair information should be both comprehensive and available to various target groups of repairers. Enabling a broad access to such information (e.g. to independent repair service providers) could contribute to create a level-playing field in the repair sector and to reduce repair costs and the effort to find suitable repair centres (Cordella et al. 2020). For popular devices comprehensive repair guidance is available through third parties already, and additional information through OEMs would not improve the situation for these devices much. However, OEMs are able to provide information, how a device is supposed to be repaired instead of relying on the guess-work and experience of third parties. For the broad market of low-end and mid-range devices such third party repair instructions are much less common and better OEM information can make a significant difference. Better information is of limited effect, if the repair process is still too complicated and if no spare parts are available. Therefore this option unveils its full potential only in conjunction with other measures. Due to these other barriers this option is calculated as stand-alone with a 10% increase in repairs. Provision of repair and maintenance information is not expected to result in relevant additional costs.

(21) Availability of spare parts (priority parts, e.g. battery, display) that can be used for repair without negative implications for functionality of the device

- The availability of spare parts, especially for those parts with highest failure rate, is a paramount parameter to ensure that a repair/upgrade process can take place. The lack of spare parts prevented 4% of the respondents in a study on consumer repair attitudes to repair their smartphones. Another important aspect is the provision of information on repair costs: Most of the OEM provide professional repair services in-house or through authorised independent repairers. As an example, it is possible to bring iPhones and iPads to Apple stores where they can be repaired. Samsung has launched a doorstep repair service where professional repairers come to the customer. Huawei also offers customer service centres where repairs are offered. Most of the OEMs provide information on their repair services and costs on their websites. Also, there are market platforms providing information on the costs of spare parts. Some manufacturers raised the concern of counterfeit parts/products on the market, which could undermine the functionality of the device and the brand reputation, especially in case of bad repair (Cordella et al. 2020). Ensuring spare parts availability results in additional logistics costs, but it is up to the price policy of the OEM, if this results in increased product prices or increased spare parts prices. Given the very competitive market this option is calculated with no changes to purchase prices, but higher repair costs (+5%). The availability of spare parts has a limited effect on DIY repairs as long as other reparability options are not implemented (removable and reusable fasteners; display removability), but is assumed to be more than the 4%, which stated in the survey, missing spare parts was the reason not to get the device repaired, as availability for the user also addresses the cost barrier and other causes of not getting a device repaired. Again, additional logistics costs arise, but DIY repairs cost less. Given a 5% cost increase on professional repairs due to increased parts costs and that the additional 10% of repairs are DIY, both effects compensate each other.

(22) Provision of information on maximum costs for display & battery replacement

- Another important aspect is the provision of information on repair costs. As stated above, most of the OEM provide professional repair services in-house or through authorised independent repairers and offer information on repair services and prices on their websites. The main potential effect of this option is the informed choice by consumers for products where repair is less costly. Thus the market would shift towards better reparable devices. This market shift depends on numerous factors, including the repair costs spread, once such information is available across the market, and how consumers would factor this in their purchase decisions. A positive effect on LCC and the environment is likely, but can be estimated hardly at this moment.

(23) Use of reversible and reusable fasteners (housing)

- The use of removable and reusable fasteners to join the housing together is a considerable factor influencing the reparability and dismantlability of products. Commonly used fasteners for the housing are clips that require no tools to reversibly disconnect, snap-fits that do require tools for leverage, screws, adhesives, or a combination of screws and adhesives. Adhesives commonly require the application of thermal energy or chemical solvents to be dissolved, except for pull-tab solutions (Clemm et al. 2020b). This option refers to better access to relevant parts for repair, and better re-assembly of repaired devices without the need to acquire new fasteners not provided with the spare part. The disassembly and repair can be supported through the use of reversible and reusable fasteners, assuming, that this will simplify repairs. The full repair potential however depends also on other aspects (availability of spare parts etc.). As a stand-alone option this is likely to have a limited effect, increasing repair rates by 10% (more DIY repairs, faster turnaround in repair shops etc.). Product costs might slightly increase as the use of adhesives reduces typically assembly times, BOM changes are considered marginal. Product prices are expected to increase by 0,10 Euros. On the other hand the increased number of DIY repairs reduces repair costs. DIY repairs (spare part only) is roughly 50% of the costs of professional repairs. This option is calculated with a 50% repair costs reduction for the 10% of additional repairs. It is likely that some of the repairs now done by professional repair shops will then be done as DIY, which will decrease LCC further and is not accounted for in this analysis.

Use of materials

(24) Use of recyclable materials

- Positive effect on the effectiveness and efficiency of recycling can be facilitated through appropriate product design targeting depollution, dismantling, recyclability and recoverability of products. Also, where the market of certain recycled materials needs to be stimulated, it could be more appropriate to set quantitative targets in terms of recyclability (Cordella et al. 2020). EN 45555:2019 provides guidance for the assessment of the recyclability of electronic products, taking into account the fasteners and assembly techniques, compatibility of materials with current recycling techniques as well as the ability to access and remove plastics parts containing fillers or flame retardants. In addition to positive effects on reparability, some of the other design options have the potential to facilitate design for higher recyclability. Thus, this design option is not evaluated further. In the later modelling the benefits of ease of disassembly through reparability measures is not taken into account as it is unlikely, that recyclers under current conditions would treat disposed devices in any way differently than they do today. Separation of individual fractions beyond “batteries” and “rest of the device towards a copper / precious metal smelter" is unlikely, but might change with OEMs putting in place dedicated recovery technologies (Chandler 2020).

(25) Use of post-consumer recycled plastics

- The use of post-consumer recycled (PCR) plastics in electrical and electronic equipment still poses a number of special challenges. This includes in particular diverse material-related quality requirements, e.g. the impact resistance, tensile strength, rigidity, processability or insulating properties. These requirements must also be met by recycled plastics if they are to be used within the existing device design and the established production processes. Another basic requirement for the use of plastic recyclates is compliance with defined limit values for harmful substances (e.g. RoHS, REACH). The challenges lie particularly in the reliable procurement of quality-assured raw materials that originate from appropriately optimized preparation processes. The availability and prices for such quality-assured secondary materials are decisive factors for the replacement of primary materials. Manufacturers of smartphones and DECT phones have already started using post-consumer recycled plastics. The technical feasibility of using 100% recycled ABS was demonstrated in a DECT phone. An LCA performed under the H2020 PolyCE project indicates that the potential environmental impact of a plastic component produced by injection moulding with recycled feedstock can be reduced by 24 %, compared to the use of virgin plastics.

(26) Use of bio-based plastics

- Apple reported the use of bio-based plastics in the cover glass frame of iPhone (Apple 2018a). Several phone companies such as Nokia, Samsung and NEC have launched phones using PLA in the phone housing (Shen et al. 2009). Production costs, technical challenges in the scale-up of production, short-term availability of bio-based feedstock as well as the need for the plastics converters to adapt to the new material are amongst the main reasons for the relatively low replacement rate of virgin (petrochemical) with bio-based plastics (Venkatasamy 2019). Assumption: in view of the complex processing required, the market price of bio-based plastics is substantially higher (at least 70%) than the price of virgin plastics.

(27) Provision of products without External Power Supplies (EPS) and other accessories

- The Impact Assessment Study on Common Chargers of Portable Devices (Ipsos 2019) analysed the effect of common chargers and the option to sell mobile phones without external power supplies. Unbundling of selling a mobile device and the external power supply is an option. In case all mobile phones, smartphones and tablets are sold without external power supplies by default, given that compatible units are already widely available in households, only a limited share of users would be expected to purchase a separate external power supply. Headsets are a slightly different issue, but continued use of existing ones is definitely an option. Headset cables are to a non-negligible share subject to defects, thus replacement purchases will be required more frequently than those of EPS, but many also purchase higher quality headsets than those shipped with the phone. A rough estimate is 25% more users would buy a separate headset, if phones are shipped without by default. The smaller package reduces logistics costs all the way from final assembly and packaging to the shop floor. Estimated savings on packaging material savings and more importantly logistics are in the range of 0,50 € for phones and 1 € for the larger tablets.

(28) Standardised interfaces for external connectors and EPS

- A common charger solution eases the implementation of Unbundling external power supplies from device sales, but is not essential for such an approach as shown by Apple's recent announcement to ship iPhones without external power supplies. Furthermore the widespread use of external power supplies with detachable USB Type-A to USB Type-C cables allows in many cases already a reuse of existing power supplies. As the Impact Assessment Study on Common Chargers of Portable Devices (Ipsos 2019) has demonstrated, the harmonisation of connectors as such has little effect on consumers and the environment. The benefits of harmonised connectors and chargers materialise with the unbundling of device and external power supply, see design option above. For a distinct environmental and LCC assessment of a common charger solution see the Impact Assessment Study on Common Chargers of Portable Devices (Ipsos 2019).

Readiness for second use and recycling

(29) Reliable data erasure through encryption combined with factory reset

- There are strong indications, that data privacy concerns are a major reason for the large amount of hibernating devices. Instead of hibernation, many of these devices could be made available for the reuse market, thus replacing new devices, if the user has confidence in data erasure or encryption with deletion of the encryption key. Encryption by default leads to reliable data erasure, once a factory reset is done. This requires the encryption key to be deleted in the factory reset process. Android and iOS support this feature. Alternatively third party software can be used to overwrite data before factory reset, but given the architecture of flash memory not all data might be erased this way. 65% of smartphones, feature phones, tablets are assumed to go into hibernation. 37% are hoarding devices in Germany as they are afraid, that data might be extracted from disposed phones. In UK 40% have similar concerns when being asked why not recycle used devices – and it can be assumed a similar high rate would give the same answer, if the question would have been related to "why not reuse"? This means that more than 20% of all mobile phones and tablets due to data privacy concerns are hoarded after use. A conservative estimate is, that with proper and trustworthy data erasure processes in place, 5% of low-end smartphones and feature phones (as there is a smaller reuse market for these devices) and 10% of all other mobile phones and tablets could re-enter the reuse market. Due to other limitations, second life is assumed to be shorter than first life, a plausible assumption are an additional 1,5 years. Refurbishment will likely require a battery replacement as additional material consumption. For the first user the re-sale value of the device reduces life cycle costs, the second user has to pay the higher re-sale price, if the device is traded through a recommerce company, which is frequently the case, but just selling C2C through ebay or similar is also common. Assuming at least a battery replacement and a recommerce margin for some of the devices adds additional costs throughout the significantly extended lifetime. These recommerce processing costs and margins are derived from a short analysis of leading recommerce platforms and comparing offered prices for acquiring used devices and sales prices. The found margins also indicate, that recommerce platforms can achieve better margins with flag-ship devices than with low-end devices, which likely results in less interest by the recommerce platforms to get engaged more in these market segments and reuse would need to rely rather on the C2C reuse market.

(30) Data transfer from an old to a new product is conveniently possible via installed or downloadable tools or cloud-based services

- Complicated data transfer from one device to another one is a barrier to phone and tablet reuse and recycling as devices are rather kept as a data archive: 24% of all users in Germany hoarding devices do so as they consider data transfer too complicated. Similarly, valuable information stored on the old device turned out to be a major reason for users in the UK not to recycle old phones. These findings are presented in more detail in the preparatory study. These data points indicate, that simpler data transfer could also increase the number of hoarded devices which can be made accessible for reuse, i.e. a second life. Data transfer through the cloud under the condition of an existing Google account is typically feasible for transfers from Android to Android devices with limited effort and if registering for a Google account is not seen as a barrier. Similarly such data transfer is conveniently provided for iPhones. However, users still state to consider this too complicated (or they are just not aware of the feature). Hence, this design option is rather about better transparency, how to transfer data technically than implementing new technical measures. Given the figures for Germany, the maximum potential is 15% of devices which can be reused, if this option is fully exploited. A conservative estimate is, that this in the end might materialise for 5% of the low-end smartphones and 10% of other smartphones and tablets. For feature phones this option is assumed not to be a relevant option. Similar to the data erasure option above, enhanced data transfer is assumed to yield more reuse / recommerce: Refurbishment will likely require a battery replacement as additional material consumption. For the first user the re-sale value of the device reduces life cycle costs, the second user has to pay the higher re-sale price, if the device is traded through a recommerce company, which is frequently the case, but just selling C2C through ebay or similar is also common. Assuming at least a battery replacement and a recommerce margin for some of the devices adds additional costs throughout the significantly extended lifetime. Given that this option and the data erasure option above are calculated as conservative scenarios by far not exploiting the full potential, these two options can be considered additive. The amount of devices the reuse market can absorb however is definitely limited and these two options would already have a massive push effect on the reuse market.

Ability to recycle smartphones / parts / materials

(31) Collection of products / put in place take back schemes

- Insufficient collection is particularly relevant for small devices such as smartphones and tablets. Lack of information about disposal of obsolete devices, hording effects and data security issues are amongst the main reasons for the low collection rates. Separate collection and mindful storage avoiding excessive mechanical stress also facilitates reuse. Setting up take-back schemes offers additional positive effects, for example, devices being returned via take-back schemes and transported further for refurbishment or recycling or parts harvesting. It should be noted that anti-theft and security software installed on smartphones poses potential barrier for independent organisations and professionals since this software can only be removed by the original owner or by the manufacturer (Cordella et al. 2020). An option to incentivise the collection of mobile devices is a deposit. This has been proposed in the past by various stakeholders and industry came forward with arguments against it, arguing among other points, that logistics and capital lockup would be issues. The German manufacturer Shift however introduced few years back a 22 Euros deposit on smartphones (which is more than 5% of the price of their cheapest model), demonstrating the feasibility of this approach. The option to put in place and strengthen product take-back schemes is subject to another study of the European Commission, which investigates this aspect more in detail.

(32) Identification, access and removal of specific parts

- The removal of certain parts at the EOL is necessary for the safe disposal of the device and an efficient recycling and recovery of materials. Identification, access and removal of parts of concern according to Annex VII of WEEE (batteries and PCBs) and parts containing precious/critical raw materials is of particular relevance for the effective EOL management of discarded products. Also, there is the risk that certain components (e.g. batteries and displays) difficult to be extracted would be shredded together with other waste, with the consequent dispersion of pollutants and contamination of other recyclable fractions, the risk of explosions in the shredders, and the irreversible loss of valuable resources. Design options enhancing reparability as outlined above would also correspond better with manual dismantling processes at end-of-life, although processes and tools are typically not the same (non-destructive versus destructive). As the major LCC and environmental benefits of this option are related to reparability not recyclability, no separate "Design for Recycling" options are proposed here.

(33) Provision of additional information for recyclers

- For the safe and efficient recycling, information on disassembly process and location of battery and other valuable components is essential (Maya-Drysdale et al. 2017b). Information could concern: general information on the product (including the month and year when the products were placed on the market); content of dangerous components/substances used (as a minimum the ones mentioned in Annex VII of the WEEE Directive): provision of a short description and photo, and the place where these are usually found in the appliance; dismantling instructions: these could include exploded diagrams of the device, indicating the opening mechanism and required tools; in case of clips, this should include information related to the direction the housing should be opened; how to recognize special models and specific dismantling instructions for them; advice on collection (separate/mixed) and on logistics. Apart from this information, providing uniform, visible and comprehensive marking has the potential to improve the sorting and recycling of device and targeted parts (Maya-Drysdale et al. 2017b). The marking can be applied to: Content in the product of CRM and minerals from conflict-affected and high-risk areas; marking of parts containing halogenated substances or hazardous substances/SVHC; marking of plastic parts > 25g in accordance to ISO 11469 (mainly relevant for cordless phones and a substantial share of tablets); marking of batteries (chemistries). After collection, batteries at the EoL mostly appear as mixtures and are subject mostly to manual sorting and separated according to their chemistries. The identification of the chemistry type is based on the label placed on the battery packaging/casing. In practice, however, when the batteries reach the recycling facility, the labels sometimes are missing, making identification and sorting difficult. In order to release manual labour force, raise the sorting speed as well as accuracy, better marking with improved readability is required in order to realize efficient identification and sorting (Tecchio et al. 2018a). Interviews with battery recyclers conducted within the framework of the preparatory study on the Review of Regulation 617/2013 (Lot 3) indicate that uniform battery marking will facilitate the separation of mixed batteries and therefore increase the recycling rates of Li-ion batteries (Tecchio et al. 2018a). Except for the battery marking clearly identifying chemistries, the other measures do have a very limited effect under current recycling practice, as recyclers do not have the infrastructure to access and consult such documentation easily and to integrate this information in their workflow. Research is ongoing to improve recycling through e.g. an electronic product passport, advanced automation for dismantling, and recycling of rare earth magnets from mobile devices, the latter even in conjunction with proposing a marking system for the magnets and their composition. Data and information requirements and capabilities of recyclers to make use of the data needs to be developed in parallel. Currently the effect of enhanced information provision cannot be reliably predicted, and due to these major uncertainties, this is not underpinned with a calculation. The only case where there is a clear mentioning of data needs by recyclers is the marking of batteries per distinct chemistry. By now, a better separation could lead to more efficient battery recycling and higher recovery rates, but this benefit cannot be quantified yet. Marking batteries is considered almost cost-neutral.

Packaging

(34) Use of fiber-based packaging materials

- Most of the sales packages for this product group are already made of paper and cardboard material, which typically provides good protection against rough handling and is not in conflict with an appealing appearance at the point of sales. Occasionally plastics inlays are in use, but any further improvement in materials compared to the assessment results of the Base Case seems marginal and is not further analysed here.

(35) Improvement of packaging efficiency

- Occasionally sales packages are oversized and packaging material could be used more efficiently. A significant effect in terms of reducing packaging sizes and material is related to the unbundling of devices and external power supply, or other accessories. This option and effect is linked to the unbundling discussion.

Manufacturing

(36) Renewable energy used for the manufacturing of PCBs and semiconductors

- Given that the manufacturing of semiconductors and printed circuit boards are particularly energy intensive processes, a shift towards renewable energy for these components is particularly relevant to reduce the carbon footprint of mobile phone, smartphone and tablet production. It should be noted however that a phone or tablet is made of one or more rigid PCBs but easily in the range of 50 or more integrated circuits. Such an approach therefore would require involvement of multiple players. For a more focused approach shifting to renewable energy for the production of the largest PCB (i.e. mainboard, and mainboard PCBs, which are soldered together, e.g. stacked PCBs), CPU / SoC, memory: RAM, and storage: Flash, would already cover a large portion of the GHG emissions. The expected effect are reduced carbon emissions from mainboard, SoC, RAM, Flash manufacturing (-60% to account roughly for the electricity related energy share of PCB production and chip front-end and back-end). As newly installed renewable power capacity increasingly costs less than the cheapest power generation options based on fossil fuels (IRENA 2020), increasing use of renewable power in the supply chain is feasible without increasing product costs, but this assumption might be challenged by the conditions in specific regions, available power sources, and the willingness of suppliers to change to renewable sources.

(37) Ground or cargo vessel transports only

- Avoiding air cargo reduces impacts of shipping devices to the EU significantly. This also reduces costs significantly as air cargo of smartphones roughly costs

1 € and sea transport is significantly cheaper, less than 0,10€[7]. A major drawback of this option is a delayed market introduction of new devices by several weeks and a slower reaction time, if a significant share of failures in the field are detected right after market introduction. The carbon emissions of sea transport are 1/10 or less of the GHG emissions resulting from air freight8.

(38) Area-optimised PCB design

- The design of feature phones and DECT phones frequently relies on a large PCB, which provides stability to the overall device and connects all external connectors, buttons and slots on the various edges of the device. In low-end and partly also mid-range smartphones the PCB fulfils a similar function as carrier for all connectors and button contacts, but frequently in an odd-form designed around the embedded battery, resulting in significant cut-offs and PCB losses in the manufacturing process. In high-end smartphones the size of the mainboard is typically optimized, i.e. minimized, for optimal volume use inside the device and distances are bridged by flex connector PCBs. In tablets similar odd-form PCB designs are found with significant cut-off losses. For an option with area-optimized rigid PCB design, some other design changes are required: More flex PCB to bridge distances (incl. connectors) and potentially additional plastics frame / housing material to provide required stability. Whereas additional housing material adds negligible costs in the range of few cents at maximum, flex PCBs add more costs, but on the other hand area savings of the rigid PCB in a similar range materialises. The overall design, and thus the assembly is getting more complex. In the end such design might cost 0,50 € more.

(39) Reduction of fluorinated gas emissions resulting from flat panel display manufacturing

- Reducing fluorinated gas emissions from display manufacturing can reduce the carbon footprint of LCDs by up to 10%. Reducing GHG emissions through abatement of PFCs by 5% is a substantial improvement. As various perfluorocompounds are used and for several purposes, emission reduction can be achieved through a combination of measures, including substitution, process optimisation, abatement. These measures add costs, but there is no public data on how much achieving which abatement rate costs. As a proxy this option is calculated with an additional 0,5% LCD costs.

(40) Reduction of fluorinated gas emissions resulting from IC manufacturing

- Similar to the LCD case, reducing fluorinated gas emissions from IC manufacturing can reduce the carbon footprint of semiconductor packages by

[7] https://www.worldbank.org/en/topic/transport/publication/air-freight-study#:~:text=The%20demand%20for%20air%20freight,typically%20exceeds%20%244.00%20per%20kilogram.

[8] Example : https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/gogreen/dhl-gogreen-carbon-calculator-062016.pdf

up to 10%. Reducing GHG emissions through abatement of PFCs by 5% is a substantial improvement. This is defined as an option for CPU/SoC, RAM, Flash components, but can be extended to other semiconductors as well. As various perfluorocompounds are used and for several purposes, emission reduction can be achieved through a combination of measures, including substitution, process optimisation, abatement. These measures add costs, but there is no public data on how much achieving which abatement rate costs. Given that there are multiple activities under way by the semiconductor industry, this option is calculated with an additional 0,5% semiconductors costs.

(41) Content in the product of CRM and minerals from conflict-affected and high-risk areas, and other metals

- There are significant differences in the content of critical raw materials (CRMs) found by various chemical analyses. This is largely related to deliberately made design decisions, where certain materials are state-of-the-art, but there are also cases where the exact material choice is up to a supplier. Most relevant CRMs are tantalum, cobalt, platinum group metals, indium, gallium and rare earth elements. Given the variance of concentrations found in these devices a reduction by 10 or 20% through informed design choices seems feasible. However, reducing cobalt might be in conflict with battery capacity, rare earth elements in magnets are used for affixing modules and accessories in an easily reversible way, and gallium is essential for proper radio communication and compromises here might be hardly justifiable from a performance perspective. Gold is another relevant material, but rather from an environmental perspective. Also gold content is varying widely among devices and progress is made to reduce gold layer thicknesses and to replace gold wire bonds with copper wire bonds. As the properties of gold add to the reliability of contacts - and a large number of connectors adds to the modularity of the design -, reducing gold might be in conflict with durability and other strategies targeting at extended product lifetime.

Energy

(42) Extended battery endurance per full charge

- Variations in battery endurance per full charge among smartphones can be observed. This is partly related to the battery size, but even more how energy-efficient the smartphone operates. Given the multiple functions of smartphones – and tablets -, there are numerous technical aspects, including software and hardware, which have an impact on energy efficiency of the device. Battery endurance is a major indicator for this. As the analysis shows 30% above average battery endurance is achieved by a significant share of the market, including flagship devices with a high-end specification. Therefore, an energy-efficiency related design option is a battery endurance of 30% above average for smartphones and also for tablets. The positive effect of longer battery endurance is two-fold: Energy savings through less frequent charging and longer battery lifetime in terms of cycles as the same number of charging cycles is stretched over a 30% longer period. As there is some correlation of battery capacity and battery endurance in a given system, a longer battery endurance incentivizes larger batteries, which has to be taken into account as a possible side-effect of this design option.

(43) Reduced standby power consumption (BAT: 0,4 W base station; 0,05 W charging cradle only)

- There is a spread of standby power consumption among cordless phones with base station. Several devices meet a standby power consumption of 0,4 W, even with an integrated answering machine and other typical features. These particularly power-saving units are in the same price range as other cordless phones with base station, which gives no reason to assume, that low power consumption comes at a significantly increased product cost. It is very unlikely, that this likely marginal extra component cost exceeds the achievable electricity cost savings of 1,84 € on average.

(44) Eco-DECT

- There are several measures to reduce the power consumption of DECT handsets, but more important to reduce radiation. Such features are frequently summarized with the term Eco-DECT and typically include an adaptation of radiation power of handset and/or base station depending on the distance between both and that a radio connection is actually only established once there is an incoming call or the user activates the handset. Radiation power of the handset might be switched off when the handset is placed in the base station. The power savings of the handset and base station as a combo vary and actually power consumption of the base station might be even higher, if radiation power of the handset is regulated down. Such features to reduce overall radiation are beneficial for the user, but impacts on human health cannot be quantified in the context of this study. According to Gigaset as one main manufacturer in this market, these Eco-DECT features do not lead to increased product prices9.

Other features

(45) Memory extension card option for smartphones and tablets with 32 GB on-board Flash or less

- As storage limitations can be considered a performance issue after a while of use, additional storage through providing memory extension card options is a viable way for the user to mitigate this problem. This option however is already standard and broadly available for smartphones with up to 32 GB flash storage (more than 90% of all model variants10). Flash capacities above 32 GB might still constitute a limitation for some users, but in general should suffice for most.

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[9] https://blog.gigaset.com/en/what-is-eco-dect/
[10] data for Germany, idealo.de, Nov 16, 2020

(46) Dual-SIM (SIM-card or eSIM)

- The Dual-SIM option can make a second mobile phone obsolete as the same device can e.g. be used for private and business use, with different phone contracts and numbers. In case a second device is really replaced through this feature, the impact is very relevant on a per unit basis. However, Dual-SIM, either through a second SIM card slot or an on-board eSIM chip is already implemented in the majority of devices: Among feature phones, low-end and mid-range smartphones at least 80% of all model variants feature Dual-SIM. Among high-end smartphones roughly 50% of the model variants come with a second SIM option[11]. This widespread implementation of Dual-SIM is considered to leave enough options for the user to choose a Dual-SIM option, if this feature is of interest. As there are many users for whom Dual-SIM does not matter, it is important also to have choices without Dual-SIM as either the additional SIM slot or the additional eSIM chip relates to additional environmental impacts in the production phase and additional costs for the user. Although it might be important to make a clear reference to the Dual-SIM option at the point-of-sales to ensure decision for a Dual-SIM device is made where this makes sense, this option is not further analysed.

ECONOMIC ASSUMPTIONS AND CALCULATIONS

Business revenue

Business revenue has been estimated using the **purchase price** and **sales** of each device under different options. We have applied the following formula:

$$BRj = \Sigma (PPij \times Qij)$$

Where:

- BRj = Business revenue for manufacturers under Option ‘j’
- PPij = Purchase price of device ‘i’ under Option ‘j’

Qij = Quantity of device ‘i’ sold under Option ‘j’, being ‘j’ = 1; 2; 3.1; 3.2; 3.3; 4; 5.1 and 5.2;

and ‘i’= low-end smartphones, mid-range smartphones, high-end smartphones, feature phones, cordless phones and tablets.

These values (i.e. purchase price and sales) have been taken from European Commission (2021) and have been employed to calculate Business revenue for the period 2010-2030. How we have obtained the purchase price is explained below.

Administrative costs

[11] data for Germany, idealo.de, Nov 16, 2020

Estimations about costs related to provide labels on the packaging or on the device itself (required under some of policy options considered) have been carried out.

In order to estimate the cost of *printing labels* for **suppliers** under those options including a reparability score and/or an Energy Label, we have proceeded as follows:

Labelling cost = Nº devices sold (million units) x cost of print a label (per device)

The formula has been applied to each device. About the second component (the print label cost), the value has been taken from another Impact Assessment report based on TV displays and carried out by European Commission in 201912. This value is **EUR 0.3 per device**.

Figures for the number of sales (for each device and under the different policy options) have been taken from the Ecodesign Preparatory Study (European Commission, 2021).

ENVIRONMENTAL ASSUMPTIONS AND CALCULATIONS

Figures related to energy savings, Greenhouse Gas Emissions, acidification, material consumption and external societal costs are taken from the Ecodesign Preparatory Study (2021). These values have been used for the impact assessment.

The assessment of environmental impacts in the Preparatory Study were based on the Methodology for ecodesign of energy-related products (MEErP) and the underlying EcoReport file, including generic datasets applied coherently across product group studies und the Ecodesign Directive. As these generic datasets partially do not reflect properly the specific technologies found in mobile phones, cordless phones and tablets, the authors of the Preparatory Study undertook the effort to research more recent data on semiconductor component, printed circuit boards, displays, batteries, special glass and updated the EcoReport file accordingly. Design options were assessed regarding hardware changes required and resulting material consumption changes and regarding further effects throughout the product life cycle, such as the share of failing units and the likeliness that a user fixes defects or rather decides for a device upgrade. Such considerations resulted in a complex lifetime model to analyse the consequence of combinations of design options. The basic functional unit for these assessments has been one year of use of a given device, i.e. environmental impacts of the average product life cycle are divided by the calculated averaged years of use to establish impacts per year of use for the 6 market segments separately: low-end smartphones, mid-range smartphones, high-end smartphones, feature phones, cordless phones and tablets.

Improvements achieved through policy options, which reflect a combination of design options, are then calculated as a delta of total environmental impacts of the market (distinct stock

12 Reference: SWD(2019)354

models for the six market sub-segments) in a given year versus the impacts in the baseline scenario.

Assessed environmental indicators comprise

- Material consumption
- Other Resources & Waste
  - Total Energy (GER)
  - of which, electricity (in primary MJ)
  - Water (process)
  - Water (cooling)
  - Waste, non-hazardous/ landfill
  - Waste, hazardous/ incinerated
- Emissions (Air)
  - Greenhouse Gases in GWP100
  - Acidification, emissions
  - Volatile Organic Compounds (VOC)
  - Persistent Organic Pollutants (POP)
  - Heavy Metals
  - PAHs
  - Particulate Matter (PM, dust)
- Emissions (Water)
  - Heavy Metals
  - Eutrophication

The overall analysis throughout the Preparatory Study assessed all these indicators with the main conclusion that the results in almost all cases point in the same direction for the various indicators. For this reason, taking a selection of indicators, such as greenhouse gas emissions, total energy, and acidification as guiding indicators and as indicators being of high relevance for EU climate policy, is justified.

SOCIAL ASSUMPTIONS AND CALCULATIONS

<u>Employment</u>

The methodology followed to estimate **employment effect in repair/maintenance sector** consist of two steps.

- <u>First</u>: a time series of the number of **old devices** (smartphones, feature phones, cordless phones and tablets) over the period of analysis (i.e., 2020-2030) has been estimated by linking data from European Commission (2021) on **projected annual stock** (the stock of devices in use remains the same in all policy options, see Annex 5) with data on **projected annual sales** under eight policy options (see Figure 14 and Figure 15). An old phone/tablet is defined as a device with an age of 1 year or above. The number of old phones is calculated under the assumption, that (almost) no devices leave the stock in year 1, so that "old phones" = "stock" – "new sales in a given year".

Figure 7: Smartphones, feature phones and cordless phones – Annual sales EU for various scenarios, 2010-2030

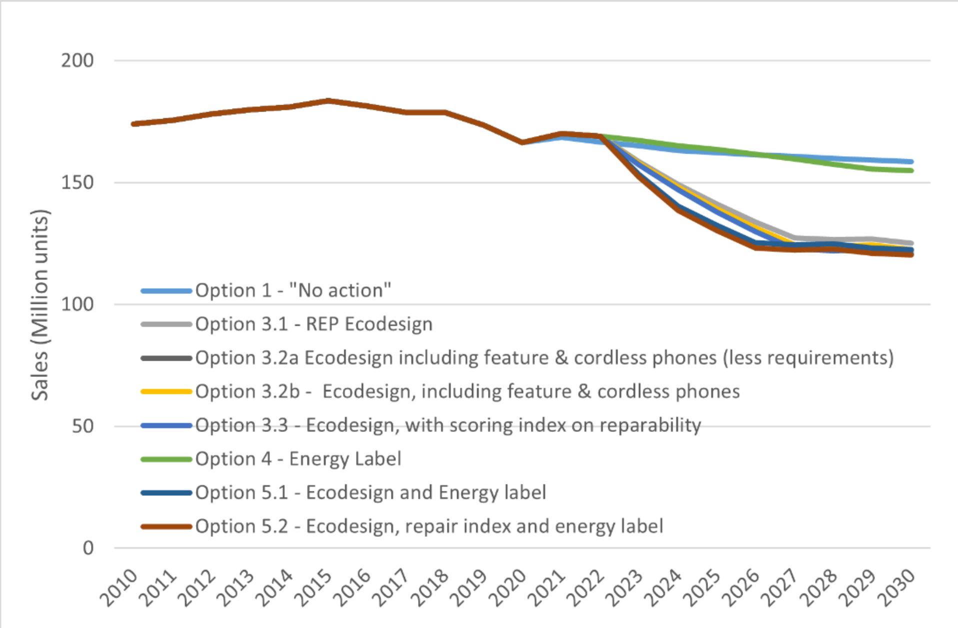

Figure 8: Tablets – Annual sales EU for various scenarios, 2010-2030

- Second: employment has been estimated by 2 methods (**Method A** and **Method B**). Based on CEPS (2019) which states that refurbished smartphones already accounted for 10% of the overall sales volume in France in 2017, **Method A** assumes a 10%

refurbishment rate of old smartphones and considers that 8 persons are employed in the repair sector per 10,000 devices being repaired or maintained (CEPS, 2019). 10% of refurbishment is also applied to tablets. However, this rate is not realistic for the two other devices: feature and cordless phones. Cordless phones are barely repaired due to its low acquisition price (about 50€) and the non-existent tendency to refurbish this type of device. Because of this, we have assumed 0% of refurbishment (no repair/maintenance sector for his device). Regarding feature phones, they also present a low acquisition price (about 80€). We have assumed that 2% are refurbished. **Method B** assumes that the increase in employment is based on the percent increase in repair expenditure projected by EC (2021) relative to Option 1. The biggest effects on employment are related to the numbers involved in the repair and maintenance sector. As the results of both methods are similar, the report only presents results from Method A.

A *sensitivity analysis* using **20%** and **30%** rates for smartphones and tablets is performed. This is supported by a behavioural experiment conducted with respondents from various EU countries, which found that 20% of consumers had a tendency to buy a second-hand mobile phone (including refurbished devices) as a replacement for their old device (Cerulli-Harms et al., 2018). An upper bound for the rate of refurbishment has been set at 30% for smartphones as in CEPS (2019). However, the lower refurbishment rate considered for features phones makes that those employed on sensitive analyse were different for this device. In this way, we have used **4%** and **6%** for feature phones.

European Commission (2018)[13] estimates that 67% of the repairs in the Information and Communication Technologies sector are done by **professionals** and 33% are undertaken by **other types of repairs** (repair cafés, self-repair, etc.). We have applied these percentages, assuming that self-repair, repair cafés, etc. do not require formal jobs.

Employment estimations are present on following tables.

[13] Socio-economic analysis of the repair sector in the EU. Study to support ecodesign measures to improve reparability of products. Final Report and Annex: Member State Reports

Table 4: Employment in the repair and maintenance sector. Nº jobs. Method A (10%):

Smartphones/ Features p./ Cordless p.	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	22.144	22.027	22.027	22.027	22.027	22.027	22.027	22.027
2022	22.256	22.062	22.062	22.062	22.062	22.062	22.062	22.062
2023	22.337	22.859	22.872	22.867	22.915	22.167	23.212	23.294
2024	22.446	23.561	23.588	23.576	23.659	22.298	24.164	24.299
2025	22.488	24.185	24.225	24.207	24.317	22.389	24.729	24.888
2026	22.532	24.745	24.797	24.774	24.904	22.507	25.239	25.418
2027	22.579	25.253	25.314	25.287	25.432	22.651	25.287	25.466
2028	22.628	25.305	25.366	25.337	25.480	22.796	25.254	25.435
2029	22.680	25.277	25.421	25.307	25.448	22.941	25.390	25.570
2030	22.734	25.415	25.478	25.446	25.583	22.996	25.446	25.626

Tablet	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	9.241	9.241	9.241	9.241	9.241	9.241	9.241	9.241
2022	8.509	8.509	8.509	8.509	8.509	8.509	8.509	8.509
2023	7.902	7.902	7.902	7.902	7.902	7.902	7.902	7.902
2024	7.532	7.663	7.664	7.663	7.674	7.534	7.722	7.737
2025	7.453	7.643	7.645	7.643	7.658	7.459	7.698	7.717
2026	7.401	7.647	7.649	7.647	7.666	7.414	7.699	7.720
2027	7.366	7.663	7.665	7.663	7.685	7.386	7.663	7.685
2028	7.347	7.644	7.646	7.644	7.666	7.375	7.628	7.650
2029	7.347	7.628	7.646	7.628	7.650	7.383	7.644	7.666
2030	7.347	7.644	7.646	7.644	7.666	7.387	7.644	7.666

Table 5: Employment in the repair and maintenance sector. Nº jobs. Method B

Smartphones/ Features p./ Cordless p.	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	22.144	21.683	21.683	21.683	21.683	21.683	21.683	21.683
2022	22.256	21.496	21.496	21.496	21.496	21.496	21.496	21.496
2023	22.337	21.855	22.052	21.997	22.341	22.100	22.617	23.276
2024	22.446	21.566	21.954	21.811	22.406	22.088	22.816	23.913
2025	22.488	22.432	23.078	22.855	23.682	22.020	23.756	25.118
2026	22.532	23.219	24.092	23.798	24.824	21.901	24.611	26.204
2027	22.579	23.943	25.012	24.657	25.856	21.734	24.657	26.256
2028	22.628	24.015	25.087	24.707	25.882	21.571	24.707	26.312
2029	22.680	24.090	25.173	24.760	25.905	21.413	24.760	26.371
2030	22.734	24.168	25.255	24.816	25.932	21.461	24.816	26.433

Tablet	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	9.241	9.241	9.241	9.241	9.241	9.241	9.241	9.241
2022	8.509	8.509	8.509	8.509	8.509	8.509	8.509	8.509
2023	7.902	8.666	8.693	8.666	8.857	7.902	9.039	9.307
2024	7.532	8.976	8.999	8.976	9.282	7.532	9.619	10.060
2025	7.453	9.496	9.560	9.496	9.954	7.433	10.099	10.668
2026	7.401	10.024	10.101	10.024	10.594	7.362	10.568	11.254
2027	7.366	10.506	10.618	10.506	11.200	7.269	10.506	11.200
2028	7.347	10.487	10.597	10.487	11.171	7.230	10.487	11.171
2029	7.347	10.487	10.605	10.487	11.171	7.191	10.487	11.171
2030	7.347	10.487	10.612	10.487	11.171	7.191	10.487	11.171

Table 6: Employment in the repair and maintenance sector. Nº jobs (rf 20%)

Smartphones/ Features p./ Cordless p.	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	22.144	22.027	22.027	22.027	22.027	22.027	22.027	22.027
2022	44.512	44.125	44.125	44.125	44.125	44.125	44.125	44.125
2023	44.674	45.719	45.744	45.734	45.830	44.334	46.425	46.589
2024	44.892	47.123	47.177	47.152	47.319	44.596	48.329	48.598
2025	44.976	48.370	48.450	48.413	48.634	44.779	49.457	49.776
2026	45.065	49.491	49.593	49.547	49.807	45.015	50.479	50.836
2027	45.158	50.507	50.627	50.574	50.864	45.302	50.574	50.932
2028	45.256	50.609	50.731	50.675	50.961	45.591	50.508	50.870
2029	45.359	50.554	50.842	50.613	50.897	45.882	50.780	51.140
2030	45.467	50.830	50.956	50.891	51.167	45.992	50.891	51.252

Tablets	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	9.241	9.241	9.241	9.241	9.241	9.241	9.241	9.241
2022	17.017	17.017	17.017	17.017	17.017	17.017	17.017	17.017
2023	15.804	15.804	15.804	15.804	15.804	15.804	15.804	15.804
2024	15.063	15.327	15.329	15.327	15.348	15.067	15.445	15.475
2025	14.905	15.287	15.289	15.287	15.317	14.918	15.397	15.434
2026	14.803	15.294	15.298	15.294	15.332	14.827	15.397	15.441
2027	14.732	15.327	15.331	15.327	15.370	14.773	15.327	15.370
2028	14.693	15.288	15.292	15.288	15.331	14.750	15.257	15.301
2029	14.693	15.257	15.293	15.257	15.301	14.766	15.288	15.331
2030	14.693	15.288	15.293	15.288	15.331	14.774	15.288	15.331

Table 7: Employment in the repair and maintenance sector. Nº jobs (rf 30%)

Smartphones/ Features p./ Cordless p.	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	22.144	22.027	22.027	22.027	22.027	22.027	22.027	22.027
2022	66.768	66.187	66.187	66.187	66.187	66.187	66.187	66.187
2023	67.011	68.578	68.615	68.601	68.745	66.501	69.637	69.883
2024	67.338	70.684	70.765	70.727	70.978	66.893	72.493	72.898
2025	67.464	72.555	72.676	72.620	72.951	67.168	74.186	74.665
2026	67.597	74.236	74.390	74.321	74.711	67.522	75.718	76.254
2027	67.737	75.760	75.941	75.861	76.296	67.953	75.861	76.398
2028	67.884	75.914	76.097	76.012	76.441	68.387	75.761	76.305
2029	68.039	75.831	76.263	75.920	76.345	68.824	76.170	76.710
2030	68.201	76.245	76.435	76.337	76.750	68.989	76.337	76.878

Tablet	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
2021	9.241	9.241	9.241	9.241	9.241	9.241	9.241	9.241
2022	25.526	25.526	25.526	25.526	25.526	25.526	25.526	25.526
2023	23.705	23.705	23.705	23.705	23.705	23.705	23.705	23.705
2024	22.595	22.990	22.993	22.990	23.023	22.601	23.167	23.212
2025	22.358	22.930	22.934	22.930	22.975	22.376	23.095	23.151
2026	22.204	22.941	22.946	22.941	22.997	22.241	23.096	23.161
2027	22.098	22.990	22.996	22.990	23.055	22.159	22.990	23.055
2028	22.040	22.932	22.938	22.932	22.997	22.125	22.885	22.951
2029	22.040	22.885	22.939	22.885	22.951	22.149	22.932	22.997
2030	22.040	22.932	22.939	22.932	22.997	22.160	22.932	22.997

Table 8: Employment on repair and maintenance sector by market players. Smartphones, feature phones and cordless phones. Nº jobs in 2030.

	Method A								Method B							
	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
Professional	15232	17028	17070	17049	17141	15407	17049	17169	15232	16193	16921	16627	17374	14379	16627	17710
Non- professionals	7502	8387	8408	8397	8442	7589	8397	8457	7502	7975	8334	8189	8558	7082	8189	8723
Producer	3865	4321	4331	4326	4349	3909	4326	4356	3865	4109	4293	4219	4408	3648	4219	4494
Retailer/distributor	7048	7879	7898	7888	7931	7129	7888	7944	7048	7492	7829	7693	8039	6653	7693	8194
Micro repairer	4774	5337	5350	5344	5372	4829	5344	5381	4774	5075	5304	5211	5446	4507	5211	5551
Small repairer	3183	3558	3567	3562	3582	3219	3562	3588	3183	3384	3536	3474	3630	3005	3474	3701
Medium size repairer	2273	2542	2548	2545	2558	2300	2545	2563	2273	2417	2526	2482	2593	2146	2482	2643
Large size repairer	1591	1779	1783	1781	1791	1610	1781	1794	1591	1692	1768	1737	1815	1502	1737	1850

	20% rf								30% rf							
	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
Professional	30463	34056	34141	34097	34282	30815	34097	34339	45695	51084	51211	51146	51423	46223	51146	51508
Non- professionals	15004	16774	16815	16794	16885	15177	16794	16913	22506	25161	25224	25191	25328	22766	25191	25370
Producer	7729	8641	8663	8651	8698	7819	8651	8713	11594	12962	12994	12977	13048	11728	12977	13069
Retailer/distributor	14095	15757	15796	15776	15862	14258	15776	15888	21142	23636	23695	23664	23793	21387	23664	23832
Micro repairer	9548	10674	10701	10687	10745	9658	10687	10763	14322	16011	16051	16031	16118	14488	16031	16144
Small repairer	6365	7116	7134	7125	7163	6439	7125	7175	9548	10674	10701	10687	10745	9658	10687	10763
Medium size repairer	4547	5083	5096	5089	5117	4599	5089	5125	6820	7625	7644	7634	7675	6899	7634	7688
Large size repairer	3183	3558	3567	3562	3582	3219	3562	3588	4774	5337	5350	5344	5373	4829	5344	5381

Table 9: Employment on repair and maintenance sector by market players. Tablets. Nº jobs in 2030.

Tablets	Method A								Method B							
	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
Professional	4922	5121	5123	5121	5136	4949	5121	5136	4922	7026	7110	7026	7485	4818	7026	7485
Non- professionals	2425	2523	2523	2523	2530	2438	2523	2530	2425	3461	3502	3461	3686	2373	3461	3686
Producer	1249	1299	1300	1299	1303	1256	1299	1303	1249	1783	1804	1783	1899	1222	1783	1899
Retailer/distributor	2278	2370	2370	2370	2376	2290	2370	2376	2278	3251	3290	3251	3463	2229	3251	3463
Micro repairer	1543	1605	1606	1605	1610	1551	1605	1610	1543	2202	2229	2202	2346	1510	2202	2346
Small repairer	1029	1070	1070	1070	1073	1034	1070	1073	1029	1468	1486	1468	1564	1007	1468	1564
Medium size repairer	735	764	765	764	767	739	764	767	735	1049	1061	1049	1117	719	1049	1117
Large size repairer	514	535	535	535	537	517	535	537	514	734	743	734	782	503	734	782

Tablets	20% rf								30% rf							
	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2	1	3.1	3.2a	3.2b	3.3	4	5.1	5.2
Professional	9844	10243	10246	10243	10272	9899	10243	10272	14767	15364	15369	15364	15408	14847	15364	#####
Non- professionals	4849	5045	5047	5045	5059	4875	5045	5059	7273	7568	7570	7568	7589	7313	7568	7589
Producer	2498	2599	2600	2599	2606	2512	2599	2606	3747	3898	3900	3898	3909	3767	3898	3909
Retailer/distributor	4555	4739	4741	4739	4753	4580	4739	4753	6832	7109	7111	7109	7129	6870	7109	7129
Micro repairer	3086	3210	3212	3210	3220	3103	3210	3220	4628	4816	4817	4816	4829	4654	4816	4829
Small repairer	2057	2140	2141	2140	2146	2068	2140	2146	3086	3210	3211	3210	3220	3102	3210	3220
Medium size repairer	1469	1529	1529	1529	1533	1477	1529	1533	2204	2293	2294	2293	2300	2216	2293	2300
Large size repairer	1029	1070	1071	1070	1073	1034	1070	1073	1543	1605	1606	1605	1610	1551	1605	1610

Consumer expenditure

Consumer expenditure is also obtained from European Commission Preparatory Study (2021). Here, three components are identified and sum up for each policy option using the following formula:

$$CE = PP + RC + EC$$

Where:

CE = Consumer expenditure

PP = Purchase price

RC = Repair cost

EC = Energy cost

Purchase price

The purchase price (PP) of products is given by the manufacturing costs (MC) plus the margins added. Following to Cordella et al. (2020), this could be simplified as follows:

$$PP = MC \times (1+MM) \times (1 + RM) \times (1+VAT)$$

Where:

MC = material costs, considered to include the cost of the phone's / tablet's parts

MM = manufacturing margins, considered to include additional costs (e.g. investment and operational costs associated with manufacturing, product design, software, Intellectual Property, certifications)

RM = aggregated sale margin

VAT = value-added tax (e.g. 21.6% as average in the EU in 2015)

In the case of smartphones, the average sales price for mobile phones is steadily increasing over the years: In 2012 mobile phones on the EU 27 market on average were sold for 290 euro. At that time feature phones still had a significant market share whereas today the market is almost completely absorbed by smartphones. As of 2020 the average price was 395 euro in EU 27, with a span from 322 euro in Bulgaria up to 495 euro in Belgium. Until 2023 a slight further increase of the average sales price is predicted. For the EU 27 on average the price for mobile phones will increase from 395 euro to 403 euro.

Following the current trend and for 2030, the purchase price of each smartphone is estimated as follows: low-end smartphone (EUR 200), mid-range smartphone (EUR 500) and high-end smartphone (EUR 1000). For feature phones it is EUR 80, and EUR 50 for cordless phones.

In the case of tablets, according to data from Statista the average tablet was sold on the consumer market in Germany for 603 euro in 2010 and for 337 euro in 2019, thus indicating a trend towards more affordable lower-end devices in this market over the past decade (European Commission, 2021).The same data source provides market shares for several device models form the leading OEMs Apple and Samsung, which combined make up 59% of the European market. In the second quarter of 2018, low-end devices with a retail price below 200 € only accounted for 6 % market share. Medium-priced devices with retail prices in the range of 200 to 400 € accounted for 17 %, devices in the range of 400 to 800 € accounted for 11 %. High-end devices with a retail price above 800 € had a major market share with 25 %. The current trend estimates a purchase price for tablets in 2030 of EUR 330.

In order to estimate prices for *Ecodesign* sub-options and for each device, different design requirements have been evaluated in terms of their saving potential along the life cycle cost. These cost calculations per design option[1] have been researched and calculated as part of the preparatory study and were subject to stakeholder consultation without major concerns being raised by manufacturers and other stakeholders regarding the accuracy of made cost statements. The average product prices resulting from individual design improvements are listed in Table 10 and take into account that there is already a significant penetration of some of the options in the market. In several cases the purchase price is forecasted to increase by up to 3 Euros per option. Many other options are cost neutral. The stated Base Case prices are the baseline.

From these cost impacts per product type and per individual design option, the overall estimated purchase price effect of the actual requirements is derived as follows:

1. The cost increase is adapted (and typically lowered), if the actual technology-neutral requirement allows also for other technical solutions than the analysed technical design options (example: Overall better drop resistance can be reached not only by a more resistant display, but also by integrating e.g. bumper features in the housing or through the design option of protective foils, which is a less costly solution)
2. The cost increase is adapted (and typically lowered), if the actual requirement is formulated less ambitious than the initially analysed design option in the preparatory study, due to identified barriers (example: OS support instead of 5 years only set requirement: 5 years security updates and 3 years functional updates)
3. Some design options despite an environmental improvement potential have been ruled out from further analysis due to unintended possible side effects (example: removable backside cover glass is seem as incompatible to current designs, thus significantly limiting design choices; similar effect achieved through defining the back cover assembly as a spare part and by introducing reliability requirements, which will lead to less repair cases) or due to parallel policy developments (example: take back schemes)
4. The remaining and adapted options are then aggregated, respecting synergies, to derive the forecasted sales price of devices under the various policy options (summarised in section 6.3.2 and detailed further below, Table 11, and in Annex 10).

Resulting purchase price changes were subject to a comprehensive sensitivity analysis, showing that even if price increase is significantly higher than forecasted, overall life cycle costs for consumers are significantly decreasing. This is due to the lifetime extending effect of several requirements combined, leading to significantly longer product replacement cycles.

Below table 10, detailed explanations are given, on how the (total) purchase price changes were calculated.

Table 10: Purchase price effects of individual design options

	low-end smartphone	mid-range smartphone	high-end smartphone	feature phone	cordless phone	tablet
	sales price [€]					
Base Case	200,00	500,00	1.000,00	80,00	50,00	330,00
Resistent Display	203,00	501,00	1.000,50	80,00	50,00	331,40
Bumper + foil	200,80	500,80	1.000,80	80,80	50,00	331,50
Water & dust ingress	203,00	503,00	1.000,00	83,00	50,00	333,00
battery endurance	202,00	500,50	1.000,00	81,00	50,00	331,00
battery management software	201,00	500,00	1.000,00	80,00	50,00	330,00
battery status	200,00	500,00	1.000,00	80,00	50,00	330,00
information	200,00	500,00	1.000,00	80,00	50,00	330,00
availability of updates	202,00	502,00	1.002,00	80,00	50,00	332,00
battery removability: joining techniques	200,00	500,00	1.000,00	80,00	50,00	330,00
Battery removability w/o tools	200,00	500,00	1.000,00	80,00	50,00	330,00
glass back cover removability	200,00	501,00	1.001,20	80,00	50,00	330,00
Display removability	200,00	500,00	1.000,00	80,00	50,00	330,00
repair & maintenance information	200,00	500,00	1.000,00	80,00	50,00	330,00
availability of spare parts (shops)	200,00	500,00	1.000,00	80,00	50,00	330,00
availability of spare parts (end user)	200,00	500,00	1.000,00	80,00	50,00	330,00
information on repair costs	200,00	500,00	1.000,00	80,00	50,00	330,00
reversible/reusable fasteners	200,05	500,05	1.000,08	80,00	50,00	330,08
un-bundling	199,20	498,50	998,50	79,20	49,20	328,00
data erasure	200,13	501,00	1.001,50	80,10	50,00	331,00
data transfer	200,13	501,00	1.001,50	80,00	50,00	331,00
take back schemes	200,50	500,50	1.000,50	80,50	50,50	330,03
Identification, access and removal of specific parts	200,00	500,00	1.000,00	80,00	50,00	330,00
provision of recycling information	200,00	500,00	1.000,00	80,00	50,00	330,00
declaration of share of new electricity	200,00	500,00	1000,00	80,00	50,00	330,00
ground or vessel cargo	199,82	499,10	999,10	79,82	50,00	329,40
area-optimised PCB design	200,50	500,50	1.000,00	80,50	50,50	330,50
reduction fluorinated gas emissions - display	200,05	500,13	1.000,25	80,03	50,02	330,10
reduction fluorinated gas emissions - IC	200,10	500,25	1.000,50	80,05	50,04	330,20
battery standby time	200,40	500,60	1.000,80	80,40	50,00	331,00
standby DECT	200,00	500,00	1.000,00	80,00	50,00	330,00

In order to model the effects (on prices, durability, repair rates, etc..) of the policy options described under this impact assessment, an iterative process (described in the table below) was used, starting from the individual design options. For each of the product subcategories under analysis (low-end smartphones, mid-range smartphones, etc..), a product architecture featuring compliance with a limited subset of three requirements (battery removability/joining techniques, repair information, availability of spare parts for professional repair shops) was first modelled. Then, further subsets[14] of two-three requirements each were integrated into the modelling in an iterative way, i.e. adding one subset per step, at each time re-evaluating the effects (on prices, durability, repair rates).

This analysis has been undertaken already in the course of the preparatory study, following the Methodology for Ecodesign of Energy-related Products (MEErP), and is presented here as a

[14] The requirements under each subset are considered in an aggregated way as it is assumed that they 'work in synergy', i.e. that the design modifications needed on the product can be similar for all the requirements of the subset.

consolidated compilation to ease the understanding of the analytical approach and underlying assumptions and data.

Table 11: Product price modelling based on consecutive implementation of technical options

	Low-end smartphone	Mid-range smartphone	High-end smartphone	Feature phone	Cordless phone	Slate tablet
Current product price (€)	200,00	500,00	1000,00	80,00	50,00	330,00
Implementing: • battery removability: joining techniques • repair & maintenance information • availability of spare parts for professional repair shops Not relevant for cordless phones. Resulting effect: Higher repair rates (new rates listed below) compared to the status quo, technical implementation without any effects on product costs (see Table 10), but logistics and documentation efforts slightly increase repair costs.						
repair rate battery (of broken devices)	50%	45%	40%	50%		45%
display repair rate (of broken devices)	50%	45%	40%	50%		45%
other repair of broken devices	50%	45%	40%	50%		45%
affected devices	100%	100%	100%	100%		100%
additional repair costs	4%	4%	4%	4%		4%

<table>
<tr><td>New product price (€)</td><td>200,00</td><td>500,00</td><td>1000,00</td><td>80,00</td><td>50,00</td><td>330,00</td></tr>
<tr><td colspan="7">Additionally, implementing:

• battery removability without tools
• glass back cover removability
• display removability
• availability of spare parts for end-users
• reversible / reusable fasteners
• repair index as information requirement (smartphones and slate tablets only)
Resulting effect: Further increased repair rates (new rates listed below) compared to the status quo, technical implementation without any effects on product costs (see Table 10), main cost effect are lower repair costs (displays specifically, for batteries current spare parts prices assumed) due to DIY repairs partly replacing professional repairs

In case of cordless phones only those products (15% of the market) are affected, which do not currently feature replaceable batteries. In these cases one battery replacement is assumed to extend product life by 2,5 years (battery lifetime).</td></tr>
<tr><td>repair rate battery (of broken devices)</td><td>80%</td><td>80%</td><td>80%</td><td>50%</td><td>+2,5 years</td><td>80%</td></tr>
<tr><td>repair price battery</td><td>30</td><td>30</td><td>30</td><td></td><td>7,50</td><td>50</td></tr>
<tr><td>display repair rate of broken devices)</td><td>70%</td><td>70%</td><td>70%</td><td>60%</td><td></td><td>70%</td></tr>
<tr><td>other repair of broken devices</td><td>60%</td><td>55%</td><td>50%</td><td>50%</td><td></td><td>55%</td></tr>
<tr><td>affected devices</td><td>100%</td><td>100%</td><td>100%</td><td>100%</td><td>15%</td><td>100%</td></tr>
</table>

reduced repair costs of displays	30%	30%	30%	20%		30%
New product price (€)	200,00	500,00	1000,00	80,00	50,00	330,00

Additionally, implementing:

- Extended battery endurance per full charge (smartphones and slate tablets)

Resulting effect: Battery endurance on average extended by 30%, which shifts the point in time where the battery reaches a critical status by approx. 0,6 years, thus overall extending product life (but by less than 0,6 years due to other lifetime limiting factors, which gain in importance). Product costs increase due to higher battery costs (better quality and/or higher capacity, see cost figures in Table 10), which scale with product price segment and battery size.

delayed critical status of the battery	+ 0,6 years	+ 0,6 years	+ 0,6 years			+ 0,6 years
affected devices	100%	100%	100%			100%
additional cost for measure (€)	0,40	0,60	0,80			1,00
reduced energy consumption [kWh/a]	1,52	2,19	3,05			2,43
New product price (€)	200,40	500,60	1000,80	80,00	50,00	331,00

Additionally, implementing:

- Extended availability of OS updates (smartphones and slate tablets)

Resulting effect: Where software obsolescence is considered the critical factor for premature device replacements (5% of devices) further OS support is forecasted to extend the product lifetime. This effect is less eminent for those product segments with already a longer product lifetime. Product costs increase for all devices (see Table 10).

prolonged lifetime (years)	+ 2,5 years	+ 2 years	+ 1,5 years			+ 1 year
affected devices	5%	5%	5%			5%
additional cost for measure (€)	2,00	2,00	2,00			2,00
New product price (€)	202,40	502,60	1002,80	80,00	50,00	333,00

Additionally, implementing:

- Enhanced battery management

Resulting effect: Battery endurance on average extended by 25%, which shifts the point in time where the battery reaches a critical status by approx. 0,55 years, thus overall extending product life (but by less than 0,55 years due to other lifetime limiting factors, which gain in importance). Product costs increase for low-end smartphones, feature phones and cordless phones (see Table 10) as they are assumed not yet to have hardware suitable for such battery management features, other products are expected to have such battery managenent hardware already integrated and the main change is to control and manage the battery properly.

improvement potential (25%)	+ 0,55 years	+ 0,55+ years	0,55+ years	0,55+ years	0,55+ years	0,55 years
affected devices	100%	75%	50%	100%	100%	50%
additional cost for measure	1,00	0	0	2,00	2,00	0
New product price (€)	203,40	502,60	1002,80	82,00	52,00	333,00

Additionally, implementing:

- Enhanced battery endurance in cycles

Resulting effect: Battery endurance on average extended by 20%, which shifts the point in time where the battery reaches a critical status by approx. 0,5 years, thus overall extending product life (but by less than 0,5 years due to other lifetime limiting factors, which gain in importance). This does not affect high-end smartphones and an assumed 50% of mid-range smartphones and tablets, which typically already feature high quality batteries, and it does not affect cordless phones due to different charging patterns. Product costs increase for all devices (see Table 10).

improvement potential (20%)	+ 0,5 years	+ 0,5 years		+ 0,5 years		+ 0,5 years
affected devices	100%	50%		100%		50%
additional cost for measure	2,00	0,75		1,00		1,20
New product price (€)	205,40	503,35	1002,80	83,00	52,00	334,20

Additionally, implementing:

- Information about charging patterns to improve battery lifetime

Resulting effect: Battery endurance on average extended by 10%, which shifts the point in time where the battery reaches a critical status by approx. 0,25 years, thus overall extending product life (but by less than 0,25 years due to other lifetime limiting factors, which gain in importance). This however is assumed to affect only those devices, where users are open to such kind of information (10%). Product costs are not affected as this is an information requirement only with no product design changes (see Table 10).

improvement potential (10%)	+ 0,25 years	+ 0,25 years	+ 0,25 years	+ 0,25 years	+ 0,25 years	+ 0,25 years
affected devices	10%	10%	10%	10%	10%	10%

additional cost for measure (€)	0	0	0	0	0	0
New product price (€)	205,40	503,35	1002,80	83,00	52,00	334,20
Additionally, implementing: • Battery status information accessible at end of first life (smartphones and slate tablets) Resulting effect: Knowledge about battery state of health enhances reusability (i.e., affect 10% of the devices, which is roughly the additional market share for reuse), but also reparability (simplifies identification of root causes for short battery lifetime). Battery state-of-health is considered relevant for 10% of the reused devices, with an assumed shift of the the point in time where the battery reaches a critical status by approx. 0,4 years, thus overall extending product life (but by less than 0,4 years due to other lifetime limiting factors, which gain in importance). Product costs are not affected as only anyway available data from the battery management system has to be made accessible for the user with no product design changes (see Table 10).						
improvement potential (10%)	0,4	0,4	0,4			0,4
affected devices	10%	10%	10%			10%
additional cost for measure (€)	0	0	0			0
New product price (€)	205,40	503,35	1002,80	83,00	52,00	334,20
Additionally, implementing: • Encryption of data and data erasure Resulting effect: Data privacy concerns as barrier for reuse of devices mitigated through better trust in data erasure, which is facilitated by data encryption. This has been identified as a relevant barrier for 5 – 10% of the devices at end of first life. Potential second life expected 1,5 years, which is further reduced by other lifetime limiting factors. Product costs increase due						

to implementation of data encryption (see Table 10), complemented by information requirements.						
additional lifetime	+ 1,5 years	+ 1,5 years	+ 1,5 years	+ 1,5 years		+ 1,5 years
affected devices	5%	10%	10%	5%		10%
additional cost for measure (€)	0,13	1,50	1,50	0,10		1,00
New product price (€)	205,53	504,85	1004,30	83,10	52,00	335,20
Additionally, implementing: • Ease of data transfer to new device Resulting effect: Lack of convenient data transfer is a reason for device hibernation and a barrier to reuse. This has been identified as a relevant barrier for 5 – 10% of the devices at end of first life. Potential second life expected 1,5 years, which is further reduced by other lifetime limiting factors. Product costs increase due to implementation of simplified data transfer, including cloud services (see Table 10), complemented by information requirements.						
additional lifetime	+ 1,5 years	+ 1,5 years	+ 1,5 years	+ 1,5 years		+ 1,5 years
affected devices	5%	10%	10%	5%		10%
additional cost for measure (€)	0,13	1,50	1,50	0,10		1,00
New product price (€)	205,65	505,85	1005,80	83,10	52,00	336,20
Additionally, implementing: • Resistent display or • Bumper and foil or • Integrated protective design measures (alternative to design options analysed in the preparatory study an listed in Table 10)						

Instead of a resistent display or extra protective cases a similar level of protection is achievable by a design, which exposes the display glass less to accidental damages, e.g. elevated rims around the display glass, frame integrated shock absorbing structures, no edge displays. This might have aesthetical implications.

Resulting effect: Less device and particular display defects, better drop resistance. Integrated design measures are significantly less costly than further improvements of the display glass (deviation from Table 10), although for aesthetical reasons OEMs might opt for the more costly option of strengthening the glass further. Integrated design measures are expected to reduce defect rates by 10 to 15% (i.e., “improvement potential“ below), in case of high-end smartphones 50% of devices are expected to already meet the robustness requirement (due to resistant display glass, i.e. no extra costs for these). The use of protective cases similarly results in less device defects, but would be relevant only for those devices not used with (third party / OEM) protective cases already (10-15%). For feature phones and cordless phones display defects are not a relevant issue.

improvement potential (integrated design measures)	15%	10%	10%		10%
affected devices	100%	100%	50%		70%
improvement potential (protective cases)	50%	50%	50%		60%
affected devices	10%	10%	10%		15%
Additional costs for integrated design measures (€)	0,15	0,10	0,05		0,07

New product price (€)	205,80	505,95	1005,85	83,10	52,00	336,27
Additionally, implementing: • Unbundling of device and external power supply unit and headsets Resulting effect: Less external power supplies to be shipped with devices due to incentivizing unbundling through an information requirement. Saved costs related to saved external power supplies is assumed to be partially reflected in reduced purchase prices, but additional costs for headsets and power supplies have to be factored in for those users, who do not have a headset or external power supply readily available. These extra costs are included in the new product price stated below (see also Table 10). For cordless phones and slate tablets (reuse of mobile phone headsets) additional headset costs are not expected.						
affected devices unbundling	100%	100%	100%	100%	100%	100%
cost savings (€)	-6,50	-8,00	-8,00	-6,50	-3,00	-5,00
affected devices headset	25%	25%	25%	25%		
additional cost headset (€, per unit)	14,00	14,00	14,00	14,00		
affected devices extra EPS	20%	20%	20%	20%	20%	20%
additional cost extra EPS (€, per unit)	11,00	15,00	15,00	11,00	11,00	15,00
New product price (€)	205,00	504,45	1004,35	82,30	51,20	332,77
Additionally, implementing:						

- Power consumption thresholds for cordless phones

Resulting effect: Reduction of power consumption in standby. Given the demonstrated feasibility to comply with threshold by products, which do not deviate in terms of price from other typical products no price change is expected (see Table 10).

Reduced energy consumption (kWh/a)					1,73	
affected devices					100%	
Additional cost (€)					0	
New product price (€)	205,00	504,45	1004,35	82,30	51,20	332,77

Additionally, implementing:

- Ground or vessel cargo, incentivized through an information requirement

Resulting effect: Less transport related emissions. Cost savings due to lower shipping costs (see Table 10), but potentially delayed market entry of products. Cost savings are expected to be reflected in product prices. Lower rate of affected devices for low-end smartphones, feature phones (20%) and slate tablets (50%), where container vessels are more common for logistics. For cordless phones this is not relevant due to significant manufacturing base in Europe and longer innovation cycles, i.e. cargo vessels being common already for EU imports.

affected devices	20%	100%	100%	20%		50%
cost savings (€, per unit)	-0,90	-0,90	-0,90	-0,90		-1,20
cost savings (€, per average device)	-0,18	-0,90	-0,90	-0,18		-0,60

New product price (€)	204,82	503,55	1003,45	82,12	51,20	332,17
Additionally, implementing: • Increased share of renewable energy use, • Reduction of fluorinated gas emissions in display production, • Reduction of fluorinated gas emissions in IC production, all incentivized through an information requirement Resulting effect: Less carbon emissions across supply chains. Cost increases due to production related measures, scales with number, complexity and size of displays and ICs respectively (see Table 10).						
affected devices	100%	100%	100%	100%	100%	100%
Additional cost displays (€)	0,05	0,125	0,25	0,03	0,02	0,10
Additional costs ICs (€)	0,10	0,25	0,50	0,05	0,04	0,20
New product price (€)	**204,97**	**503,93**	**1004,20**	**82,20**	**51,26**	**332,47**

The resulting product prices stated above correspond to the implementation of technical solutions to achieve the intended effect per design measure. The resulting product price under the various policy options then differs depending on the individual design measures required to meet the set of requirements: Reflecting the impacts of policy options on prices is done in Annex 10 (rounded product prices in Table 36, Table 47 and Table 48).

Implementing the aforementioned options in many cases is expected to increase product lifetime significantly, which in turn means, costs for consumers go down as they will hold on to their devices longer. The resulting lifetime changes per design option, again factoring in the already seen market penetration of design options, in Table 12. This takes into account also failure and repair statistics, and typical obsolescence factors, e.g. improved battery endurance is only factored in, where battery endurance is identified to be the lifetime limiting factor.

Table 12: Lifetime effects of individual design options

	low-end smartphone lifetime	mid-range smartphone	high-end smartphone	feature phone	cordless phone	tablet
Base Case	2,500	3,000	3,500	3,000	5,000	5,000
Resistent Display	2,522	3,019	3,512	3,000	5,000	5,010
Bumper + foil	2,508	3,012	3,516	3,005	5,000	5,019
Water & dust ingress	2,537	3,049	3,500	3,051	5,000	5,071
battery endurance	2,574	3,055	3,500	3,126	5,000	5,047
battery management software	2,580	3,091	3,590	3,137	5,091	5,051
battery status	2,506	3,008	3,513	3,000	5,000	5,007
information	2,504	3,005	3,509	3,006	5,004	5,005
availability of updates	2,779	3,219	3,597	3,000	5,000	5,157
battery removability: joining techniques	2,502	3,002	3,504	3,000	5,000	5,016
Battery removability w/o tools	2,530	3,049	3,582	3,000	5,338	5,054
glass back cover removability	2,500	3,009	3,519	3,000	5,000	5,000
Display removability	2,531	3,055	3,622	3,000	5,000	5,054
repair & maintenance information	2,549	3,070	3,600	3,065	5,000	5,076
availability of spare parts (shops)	2,510	3,009	3,507	3,002	5,000	5,023
availability of spare parts (end user)	2,520	3,037	3,566	3,004	5,000	5,023
information on repair costs	2,502	3,009	3,566	3,000	5,000	5,042
reversible/reusable fasteners	2,520	3,030	3,565	3,000	5,000	5,042
un-bundling	2,500	3,000	3,500	3,000	5,000	5,000
data erasure	2,669	3,046	3,587	3,043	5,000	5,084
data transfer	2,669	3,046	3,587	3,000	5,000	5,084
take back schemes	2,524	3,031	3,537	3,073	5,025	5,045
Identification, access and removal of specific parts	2,500	3,000	3,500	3,000	5,000	5,000
provision of recycling information	2,500	3,000	3,500	3,000	5,000	5,000
declaration of share of new electricity	2,50	3,00	3,50	3,00	5,00	5,00
ground or vessel cargo	2,500	3,000	3,500	3,000	5,000	5,000
area-optimised PCB design	2,500	3,000	3,500	3,000	5,000	5,000
reduction fluorinated gas emissions - display	2,500	3,000	3,500	3,000	5,000	5,000
reduction fluorinated gas emissions - IC	2,500	3,000	3,500	3,000	5,000	5,000
battery standby time	2,586	3,135	3,705	3,148	5,000	5,112
standby DECT	2,500	3,000	3,500	3,000	5,000	5,000

The resulting consumer costs per year of use, including also anticipated repair costs, are listed in Table 13. It is evident, that even in those cases where product prices are forecasted to increase, mostly the consumer costs per year of use go down. This analysis does not yet take into account the interdependencies when implementing several design options in parallel. In some cases the overall effect is synergistic the resulting savings are larger than the sum of individual options, and in some cases the opposite applies. Such complex lifetime modelling (see above) has been applied to model overall effects of implementing these options in parallel.

Table 13: Costs per year of use per individual design option

	low-end smartphone	mid-range smartphone	high-end smartphone	feature phone	cordless phone	tablet
	costs per year of use [€]					
Base Case	86,92	176,94	301,45	36,39	11,84	73,72
Resistent Display	87,15	175,90	300,33	36,39	11,84	73,78
Bumper + foil	86,92	176,38	300,15	36,60	11,84	73,63
Water & dust ingress	86,78	175,09	301,45	36,78	11,84	73,22
battery endurance	84,66	172,88	301,46	35,09	11,84	72,92
battery management software	84,02	170,12	293,37	34,63	11,48	71,99
battery status	86,68	173,02	300,24	36,39	11,84	73,42
information	86,77	173,23	300,66	36,31	11,82	73,47
availability of updates	80,09	166,64	294,45	36,39	11,84	72,30
battery removability: joining techniques	86,78	176,66	300,94	36,39	11,84	73,60
Battery removability w/o tools	85,17	172,80	291,52	36,39	11,55	71,92
glass back cover removability	86,92	176,75	300,31	36,39	11,84	73,72
Display removability	85,88	173,99	292,33	36,39	11,84	73,03
repair & maintenance information	86,09	174,16	295,14	36,26	11,84	73,42
availability of spare parts (shops)	87,06	176,99	301,68	36,55	11,84	74,01
availability of spare parts (end user)	85,10	172,53	291,45	36,25	11,84	72,32
information on repair costs	86,90	176,57	297,46	36,39	11,84	73,68
reversible/reusable fasteners	86,65	175,76	297,08	36,39	11,84	73,58
un-bundling	86,60	176,44	301,02	36,12	11,68	73,32
data erasure	82,06	174,62	294,76	35,99	11,84	72,90
data transfer	82,06	174,62	294,76	36,39	11,84	72,90
take back schemes	86,29	175,31	298,51	35,91	11,88	73,11
Identification, access and removal of specific parts	86,92	176,94	301,45	36,39	11,84	73,72
provision of recycling information	86,92	176,94	301,45	36,39	11,84	73,72
declaration of share of new electricity	86,92	176,94	301,45	36,39	11,84	73,72
ground or vessel cargo	86,85	176,64	301,20	36,33	11,837	73,60
area-optimised PCB design	87,12	177,10	301,45	36,56	11,94	73,82
reduction fluorinated gas emissions - display	86,94	176,98	301,52	36,40	11,841	73,74
reduction fluorinated gas emissions - IC	86,96	177,02	301,60	36,41	11,845	73,76
battery standby time	83,23	168,23	283,25	34,63	11,84	69,74
standby DECT	86,92	176,94	301,45	36,39	11,47	73,72

Those options that report higher benefits will be selected and their average manufacturing costs have been calculated and added, determining the new prices.

Design options with particularly high saving potential through consecutive implementation are:

- Moderate reparability option;
- Broad reparability option;
- Increased battery endurance per full charge;
- Improved battery management and information provision;
- Extended OS support;
- Improved data erasure and confidence in processes;
- Unbundling of device and accessories.

Energy Label option and those that incorporate a *reparability scoring* will establish prices based on a different criterion such as the added cost of putting labels.

Repair costs

There are different levels of repair with different implications on costs for the user. Some manufacturers encourage repairs by the end-user (“do it yourself” repairs and facilitate this through a modular product design). In these cases, only spare parts costs and shipping costs are relevant.

The costs of professional repair services include labour costs, the margin of the repair service and the replacement cost of spare parts (e.g. battery replacement costs and display replacement costs). It is important to note that the total cost of repair services can vary significantly from one country to another, since repair is a labour-intensive activity subject to regional labour costs.

Smartphones

When repair is implemented by original equipment manufacturers (OEMs), the cost for battery replacement for smartphones is shown to vary to a large extent, ranging from 10 EUR to 78 EUR. For display replacement, it varies from 65 EUR to 579 EUR. The analysis shows an average price for battery replacement of 58.60 EUR (14% of the average purchase price). Displays replacement costs show an average price of 174.30 EUR (42% of the average purchase price). The analysis of the dataset shows an average sales price of 414.80 EUR for new devices.

Tablets

The cost for battery replacement for tablets lies between 76 EUR and 119 EUR, with the average price amounting to 89.90 EUR (21% of the average purchase price). The cost for display replacement varies between 89 EUR and 280 EUR, with an average price of 154.09 EUR (37% of the average purchase price). As with smartphones, the average sales price for tablets (EUR 420.80) is significantly higher than the price of battery and display replacement.

In both cases, i.e. for smartphones and tablets, to obtain the average repair cost, the share (%) of devices being subject to such a defect and the share (%) of actual repairs undertaken (in contrast to continued used of a defective device and to end of use life) have been taken into account.

Considering all these aspects, average repair costs are added to all devices in order to calculate the consumer expenditure. This supposes to add the following figures (estimations for 2030 under the current trend): EUR 10 for low-end smartphones, EUR 19 for mid-range smartphones, EUR 32 for high-end smartphones, EUR 7 for feature phones, EUR 4 for cordless phones, EUR 17 for tablets.

Energy cost

The only relevant energy cost for smartphones and tablets are electricity prices. A first estimation of energy consumption (in kWh) per device and considering its lifetime is made on the Preparatory Study. Prices including taxes, levies and VAT for household consumers were on average 0.2126 €/kWh as of first half of 2020 (Eurostat 2020).All figures cover the period 2010-2030 applying a discount rate (interest minus inflations) and an escalation rate (project annual growth of running cost) of 0.04%.

Under the current trend and for 2030, energy cost added to purchase price and repair cost for different devices and over their lifetime is the following: EUR 4 for low-end smartphone, EUR 6 for mid-range smartphone, EUR 9 for high-end smartphone, EUR 3 for feature phones, EUR 6 for cordless phones, EUR 9 for tablets.

Purchase price, repair cost and energy cost will change under different policy options.