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European Commission

Impact Assessment Study to Assess Unbundling of Chargers

Annexes to the draft final report

Economisti Associati, Ipsos, Trinomics, Fraunhofer, Yeny Vazquez
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Annexes

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Annex A: Glossary

Terms	Definitions
Alternating Current (AC)	Alternate current (AC) is the electrical current which periodically reverses direction. This is the way in which electricity arrives to households and certain electrical components like coils or capacitors can only function with such a current.
Charger	A device used to charge the battery of a mobile phone (or other electronic device), typically consisting of an external power supply (charging block) and a cable to connect the power supply to the mobile phone (also sometimes called cable assembly)
Counterfeit charger	Counterfeit chargers (external power supplies and/or connector cables) are chargers infringing intellectual property right(s), such as trademark, patent and design. They have a reputation for being lower quality (e.g. they can damage batteries). They frequently do not fulfil safety requirements, thus posing risks to consumer safety (e.g. risk of causing electrocution, starting a fire).
Decoupling	See “unbundling” below.
Direct Current (DC)	Direct current (DC) is the electrical current that always flows in the same direction. Usually batteries from portable electronic devices are charged with such a current.
External Power Supply (EPS)	Device which converts alternating current (AC) power from the mains into lower voltage direct current (DC). It is sometimes also referred to as an (external) power adapter, charging block, or power brick.
High-end phones	Phones that are the most expensive or advanced in the context of a company’s offer or in the market as a whole.
Interoperability	The ability of a system or product to work with other products or systems. A charger is considered interoperable with a device if it is able to charge its battery correctly.
Low Voltage Directive (LVD)	Directive of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment. The LVD focuses on health and safety risks, and applies to a wide range of equipment designed for use within certain voltage limits, including power supply units.
Memorandum of Understanding (MoU)	Non-binding agreement between two or more parties outlining the terms and details of an understanding, including each parties' requirements and responsibilities. It expresses a convergence of will between the parties, indicating an intended common line of action.
Mobile Phone	Battery-powered handheld communication device of which the primary purpose is voice telephony, which operates on public cellular networks, which potentially supports other services and which is designed to be hand-portable.
Proprietary Charging Solution	Charging solution owned by a single organization or individual. Ownership by a single organization gives the owner the ability to place restrictions on the use of the solution and to change it unilaterally. Specifications for proprietary solutions may or may not be published, and implementations are not freely distributed.
Quick Charge	Quick Charge is a Qualcomm's proprietary technology which allows for the charging of battery powered devices, primarily mobile phones, at levels above and beyond the typical 5 volts and 2 amps for which most USB

Terms	Definitions
	standards allow. To take advantage of Qualcomm Quick Charge, both the external power supply and the device must support it.
Radio Equipment Directive (RED)	The Radio Equipment Directive 2014/53/EU (RED) establishes a regulatory framework for placing radio equipment on the market. It ensures a Single Market for radio equipment by setting essential requirements for safety and health, electromagnetic compatibility, and the efficient use of the radio spectrum. It also provides the basis for further regulation governing some additional aspects. These include technical features for the protection of privacy, personal data and against fraud. Furthermore, additional aspects cover interoperability, access to emergency services, and compliance regarding the combination of radio equipment and software.
Stand-alone charger	Chargers (usually external power supplies) sold on their own, without being part of a full package including a phone (or another device) and the charger.
System on a Chip (SoC)	A system on a chip (SoC) is an integrated circuit (also known as a "chip") that integrates all or most components of a computer or other electronic system. These components almost always include a central processing unit (CPU), memory, input/output ports and secondary storage, often alongside other components such as radio modems and a GPU – all on a single substrate or microchip.
Unbundling	Unbundling (frequently also referred to as “decoupling”) is the practice of marketing or charging for products or services separately, rather than as part of a package. In the context of this study, it refers to the selling of mobile phones or other electronic devices without a charger.
Universal serial bus (USB)	USB is an industry standard that establishes specifications for cables, connectors and protocols for connection, communication and power supply between personal computers and their peripheral devices, or between a device and the external power supply. Released in 1996, the USB standard is currently maintained by the USB Implementers Forum (USB IF).
USB 3.1	USB 3.1, released in July 2013, is the successor standard that replaces the USB 3.0 standard. USB 3.1 preserves the existing SuperSpeed transfer rate, giving it the new label USB 3.1 Gen 1, while defining a new SuperSpeed+ transfer mode, called USB 3.1 Gen 2 which can transfer data at up to 10 Gbit/s over the existing USB-type-A and USB-C connectors (1250 MB/s, twice the rate of USB 3.0)
USB 3.2	USB 3.2, released in September 2017, replaces the USB 3.1 standard. It preserves existing USB 3.1 SuperSpeed and SuperSpeed+ data modes and introduces two new SuperSpeed+ transfer modes over the USB-C connector using two-lane operation, with data rates of 10 and 20 Gbit/s (1250 and 2500 MB/s).
USB 4	The USB 4 specification, released in August 2019, is a major update to deliver the next-generation USB architecture that complements and builds upon the existing USB 3.2 and USB 2.0 architectures. It doubles the maximum aggregate bandwidth of USB and enables multiple simultaneous data and display protocols. In contrast to prior USB protocol standards, USB4 requires USB-C connectors, and for power delivery it requires support of USB PD.
USB micro-B	Connector (B-Plug and B-Receptacle) which can be used for charging support and additional functions, whose reference specification is “Universal Serial Bus Cables and Connector Class Document” Revision 2.0 August 2007, by the USB Implementers Forum.
USB Power Delivery	In July 2012, USB-IF announced the finalization of the USB Power Delivery (PD) specification (USB PD rev. 1), an extension that specifies using certified PD aware USB cables with standard USB Type-A and Type-B connectors to

Terms	Definitions
	deliver increased power (more than 7.5 W) to devices with larger power demand. The USB Power Delivery specification revision 2.0 (USB PD rev. 2) was released as part of the USB 3.1 suite. It covers the Type-C cable and connector with four power/ground pairs and a separate configuration channel. Revision 3.0 was released in 2017.
USB Type-C	24-pin USB connector system, which is distinguished by its two-fold rotationally-symmetrical connector. A device with a Type-C connector does not necessarily implement USB 3.1, USB Power Delivery, or any Alternate Mode: The Type-C connector is common to several technologies while mandating only a few of them.
WEEE	Waste of electrical and electronic equipment (WEEE) such as computers, TV-sets, fridges and cell phones, which is the subject of Directive 2012/19/EU.
Wireless Charging	Inductive charging (also known as wireless charging or cordless charging) uses an electromagnetic field to transfer energy between two objects through electromagnetic induction. This is usually done with a charging pad and is logically equivalent to a contactless connector. The charging pads are generally connectable to a EPS via a cable and connector, such as USB. Energy is sent through an inductive coupling to an electrical device, which can then use that energy to charge batteries.

Annex B: Technical Analysis

A charging solution is formed by three main elements: the external power supply (EPS), the cable assembly connecting the EPS to the device, and the device itself, including its battery and its System on a Chip (SoC). For a device to charge, these three elements need to be interoperable. Charging solutions are normally designed ad-hoc to meet the devices' requirements, defined as "charging profile". The charging profile describes the variation of the current and the voltage during the charge and depends on the type of battery and the recharge time. Interoperability, in summary, relies on the following:

- EPS providing the current and voltage that the device accepts, determined by the battery's demand profile and the device's SoC;
- A cable connecting the EPS to the device supporting the power being transmitted, with plugs (connectors) at both ends that are compatible with the EPS and the device.

Interoperability of the External Power Supply (EPS)

Traditionally, the EPS sold to charge mobile phones and other portable devices followed the standard IEC 62684, published in 2011 and updated in 2018. This standard specifies the interoperability of common EPS for use with data-enabled mobile telephones. It defines the common charging capability and specifies interface requirements for the EPS. The maximum power allowed by this standard is 7.5W (5V at 1.5A). This standard nowadays would be insufficient to power certain devices (e.g. high-end mobile phones and tablets) or would charge them at a very low speed.

Since then, new technologies using higher current and/or voltage have emerged. Table 1 offers a summary of standard solutions, and Table 2 of proprietary charging solutions. Battery charging protocols are discussed more in depth in sections 4.1.1 and 4.2.2.

Table 1: Standard battery charging protocols

Charging technology	Battery charging specifications applicable	Applicable receptacle connectors[1]	Voltage	Current	Power
Common EPS, as defined in 2009 MoU[2]	IEC 62684	USB Standard-A (source), USB Micro-B (sink), USB Type-C (source or sink)	5V	Up to 1.5A	Up to 7.5W
USB Battery Charging 1.2	EN-IEC 62680-1-1				
USB Type-C	EN-IEC 62680-1-3	USB Type-C (source or sink)	5V	1.5A, 3A	7.5W or 15W
USB PD 2.0 (superseded)	EN-IEC 62680-1-2	USB Standard-A (source), USB Type-C (source or sink)	5V, 9V, 15V, 20V	Configurable up to 5A[3]	Up to 100W[4]

[1] Source refers to the EPS, and sink to the device that is charged. It should be noted that devices can be both source and sink (e.g. when a laptop is charged it would be a sink, and when it is used to charge other devices it would be a source).

[2] Following the MoU signed in 2009, CENELEC received a mandate from the European Commission to develop a harmonised standard for mobile phone chargers. In response, CENELEC created a task force to develop the interoperability specifications of a common EPS, and work was transferred into the IEC. The IEC published the standard IEC 62684 in 2011 and updated it in 2018.

[3] Power transfer over 3A requires use of an electronically marked 5A cable

[4] Power over 60W requires the use of USB Type-C at the source

USB PD 3.0	EN-IEC 62680-1-2	USB Type-C (source or sink)	5V, 9V, 15V, 20V	Configurable up to 5A	Up to 100W
USB PD 3.0 + PPS (Programmable Power Supply)	EN-IEC 62680-1-2	USB Type-C (source or sink)	5V Prog, 9V Prog, 15V Prog and 20V. PPS adds 3V to 21 V in 20mV increments	Configurable up to 5A	Up to 100W

Table 2 : Main proprietary battery charging protocols[5]

Charging technology	Battery charging specifications applicable	Receptacle connectors	Voltage	Current	Power
Quick Charge 1.0	None	USB Standard-A (source), USB Micro-B (sink)	5V	2A	10W
Quick Charge 2.0	None	USB Standard-A (source), USB Micro-B (sink)	5V, 9V, 12V	3A	18W
Quick Charge 3.0	None	USB Standard-A (source), USB Micro-B (sink), USB Type-C (sink)	3.6-20V (200mV increments)	2.5A, 4.6A	18W
Quick Charge 4 and 4+	None (QC mode)	USB Type-C (source or sink)	3.6-20V (200mV increments)	2.5A, 4.6A	100W
	USB PD mode		5V, 9V	3A	27W
	USB PD 3.0 PPS mode		3 V - 21 V (20 mV steps increments)	3A	27W
Quick Charge 5	N/A	USB Type-C (source or sink)	N/A	N/A	+100W
Huawei SuperCharge	None	USB Standard-A (source), USB Type-C (sink)	10V, 5V, 4.5V	2.25A, 4.5A, 5A	20W
			10V, 5V, 20V	4A, 8A, 3.25A	40W
			11V	6A	66W
VOOC	None	USB Standard-A (source), USB Type-C (sink), USB micro-B (sink)	5V	4A	20W
			5V	5A	25W
			10V	5A	50W
			5V	6A	30W
			10V	6.5A	65W

Ipsos MORI, based on multiple sources: literature review (e.g. technical standards and other technical documentation), interviews with manufacturers, mapping of portable electronic devices.

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[5] Only proprietary charging protocols that are relevant for the EU market are listed. The table does not aim to be comprehensive of all existing proprietary charging protocols.

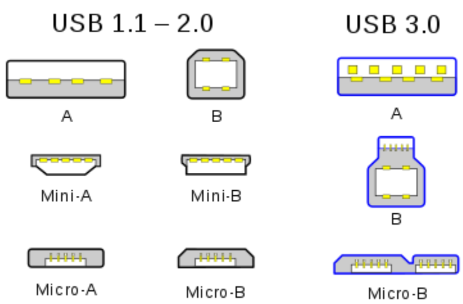
Standard charging solutions for EPS

Evolution of USB charging protocols

Universal Serial Bus (USB) is a set of specifications developed for serial data transmission by the USB Implementers Forum (USB-IF). The objective of the first specification developed, USB 1.0, was to allow an easy and high speed connection between PC and peripherals. The speed of data transmission of USB 1.0 was between 1.5 and 12 Mbits/s, the voltage was 5V, and the maximum current was 100 mA (0.5 W). Several connectors' shapes were adopted to implement this protocol, see Figure 5.

USB 2.0 was released in 2001, increasing the speed of data transmission to 480 Mbits/s, and the current to 500mA (2.5W). USB 3.0, released in 2008, increased the data transfer rate to 5 Gbits/s and the current to 0.9 A (delivering up to 4.5W of power). These protocols, however, were not oriented to charging devices, and interoperability was not guaranteed as there were no clear specifications or standards for USB-based charging products.

Figure 1. USB connectors used for USB 1.1, USB 2.0 and USB 3.0 data transfer



Source: https://es.wikipedia.org/wiki/Universal_Serial_Bus

In order to facilitate interoperability, the USB-IF created a specification for battery charge and/or power delivery: "Battery Charging Specification – BC 1.0, BC 1.1, and BC 1.2", released in 2007, 2009 and 2010, respectively (IEC 62680-1-1). The latest revision of BC 1.2 was published in 2015. The power flow of the USB BC is unidirectional, from the EPS to the connected device, and limited to 7.5W. This protocol has a wider scope than IEC 62684, which is specific to mobile phones.

USB Type-C is a standard designed to increment the amount of power flowing from the the EPS to the device, hencereducing duration of the charge. The standard extended the power capabilities to 15 W, with current being dinamically managed in the interval of 0.5A to 3A. The connectors are symetric and reversable. With this standard, data transmision speed was also increased to 10 Gbits

USB Power Delivery 1.0, released in 2012, allowed power delivery of up to 100W over a single USB. In 2014 an updated version, USB PD 2.0, was released together with the specification for the USB Type-C connector (IEC 62680-1-3). In 2015, a third version of the protocol, USB PD 3.0, was published (reviewed in 2019). The protocol defines all the elements of a USB system: hosts, devices, hubs, chargers and cable assemblies, as well as the architecture, protocols, power supply behaviour, connectors and cabling required when using USB PD.

USB PD 2.0 can be used with USB Type-A, Type-B and Type-C connectors. USB PD 3.0, however, can only be used with USB Type-C connectors.

USB Type-C main characteristics are:

- Power delivery up to 100W.

- Symmetry (it can connect both the EPS and the device).
- Simultaneous data transmission and power delivery.

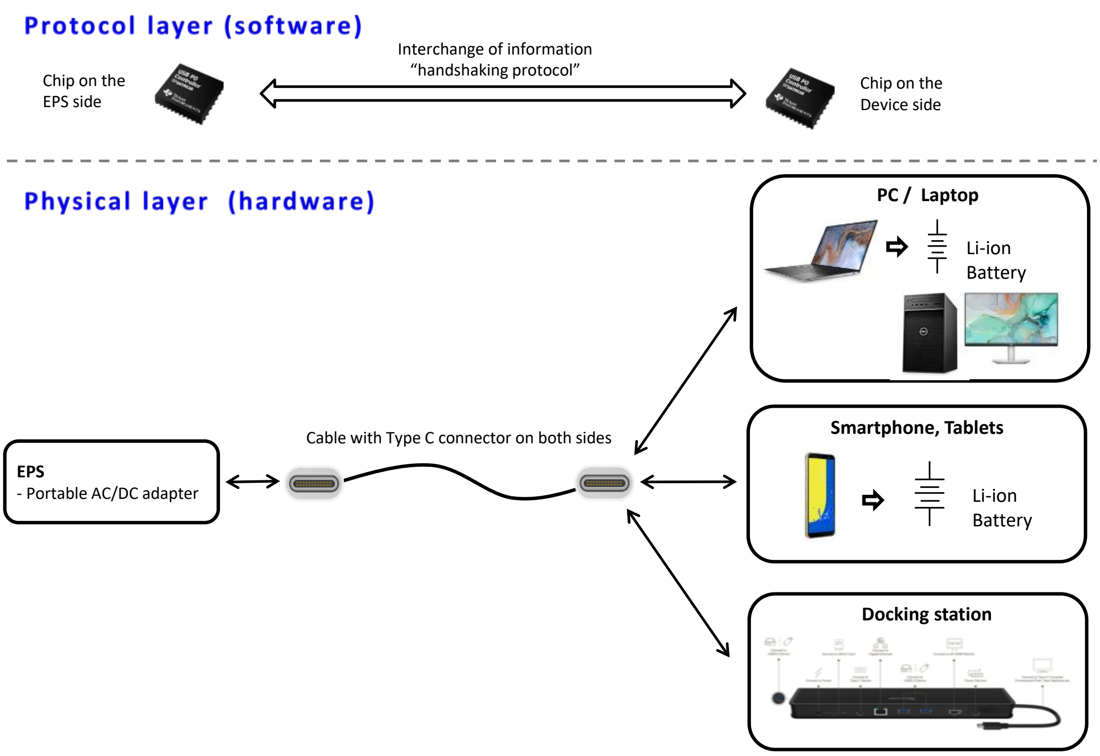
USB Power Delivery (USB PD)

The Universal Serial Bus Power Delivery (USB PD) is a technical specification (EN-IEC 62680-1-2) that, combined with a Type-C connector (EN-IEC 62680-1-3), allows an increment of the power that can be delivered to electrical devices.

USB PD can be divided into physical and protocol layers, see Figure 2. The physical layer (i.e. the hardware) is composed by the EPS, the cable or cord with a USB Type-C connector and the downstream unit. The protocol layer (i.e. the software) defines the communication protocol and the content of the communication. Devoted chips (SoC), USB compliant, are required for the implementation of the communication protocol.

Downstream devices can be divided into those that can store energy, such as smartphones, tablets, or laptops; and those that cannot store energy, such as desktop computers, docking stations and monitors.

Figure 2. Characteristics of the USB PD



The power transmission can be implemented in two different modes, following the standard IEC 62680-1-2:

- Fixed Supply Operation. The EPS identifies a set of fixed voltages (5 V, 9 V, 15 V and 20 V) and current (maximum of 5 A).

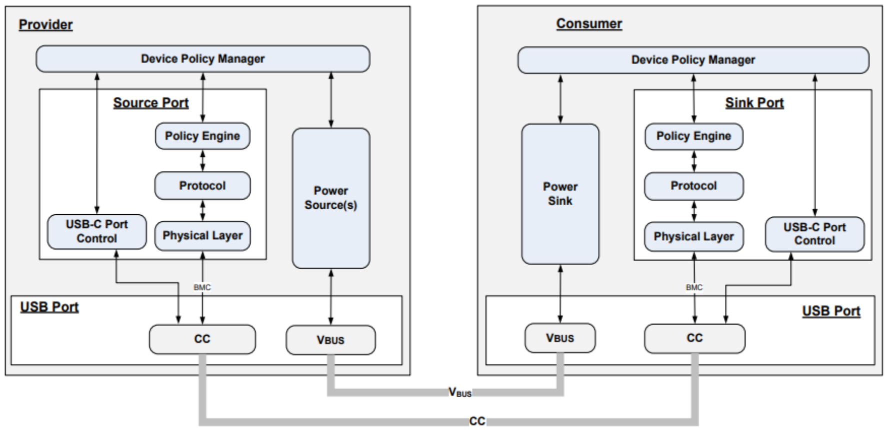
- Programmable Power Supply Operation (PPS). The voltage and the current can be individually controlled. The voltage varies between 3.3V and 21 V while the current can increase up to 5 A. This power topology allows a better control of the thermal rise of the battery during a high power charge.

How downstream devices are charged

The downstream component of the electrical device is the battery. Batteries provide the energy required by portable electrical devices. There are many types of battery technologies: Nickel-cadmium (Ni-Cd), Nickel-metal hydride (NiMH), lithium polymer (Li-polymer) and Lithium ion (Li-ion). Nowadays, the Li-ion is a widely spread technology due to its very high energy density, good cycling capability, and competitive cost. However, its lifespan is highly dependent of the cell temperature, and therefore the charging profile must be correctly applied in order not to damage it.

The USB PD standard defines the architecture for communication between the EPS and the downstream device. In Figure 3, the “provider” (box on the left) refers to the EPS, and the “consumer” (box on the right) to the downstream device. Both the provider and the consumer use a “USB port”, i.e. the Type-C receptacle, with connector pins devoted for communication (represented as CC) and pins for power delivery (represented as VBUS).

Figure 3. High Level Architecture View



Source: UNE - EN IEC 62680-1-2:2020, page 60

The power delivery bus (VBUS) connects the power source (e.g. the EPS) with the power sink (the battery of the device being charged) to provide power. In addition, each device has a chip for communication and control.

The output power for EPS that are compliant with the USB PD specification varies between 0.5 W and 100 W. Output voltages are standardized, as well as minimum currents for each power interval, see Figure 4.

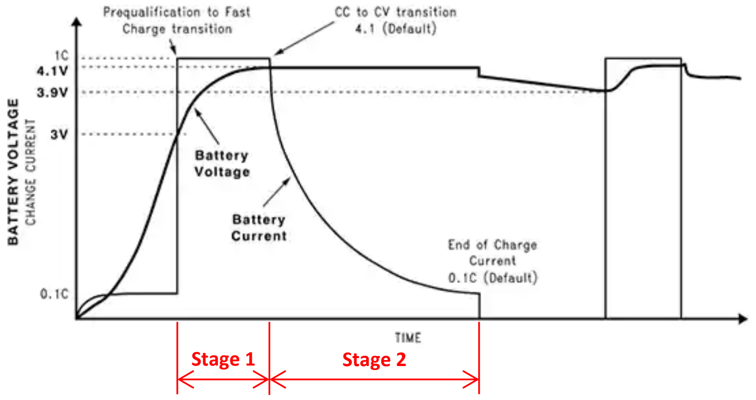
Figure 4. Normative Voltages and Minimum Currents.

PDP Rating (W)	Current at 5V (A)	Current at 9V (A)	Current at 15V (A)	Current at 20V (A)
0.5 ≤ x ≤ 15	x ÷ 5			
15 < x ≤ 27	3	x ÷ 9		
27 < x ≤ 45	3	3	x ÷ 15	
45 < x ≤ 60	3	3	3	x ÷ 20
60 < x ≤ 100	3	3	3	x ÷ 20[1]
[1] Requires a 5A cable.				

Source: UNE - EN IEC 62680-1-2:2020, page 491.

The battery charges in two stages, as depicted in Figure 5. Stage 1 occurs at constant current (CC) and while the voltage increases. The current applied to the battery defines the charging speed; each battery requires a specific current to be charged in a certain amount of time. As explained above, current flows increase the temperature and exciding the safety temperature damages the battery permanently. Fast charging occurs mainly during stage 1. In stage 2, the voltage applied to the battery remains constant and the current reduces. The second stage of the charge is named constant voltage stage (CV).

Figure 5. Li-ion battery charge profile.



Source: A designer´s Guide to Lithium (Li-ion) battery charging. Contributed by Digi-Key´s North America Editors6.

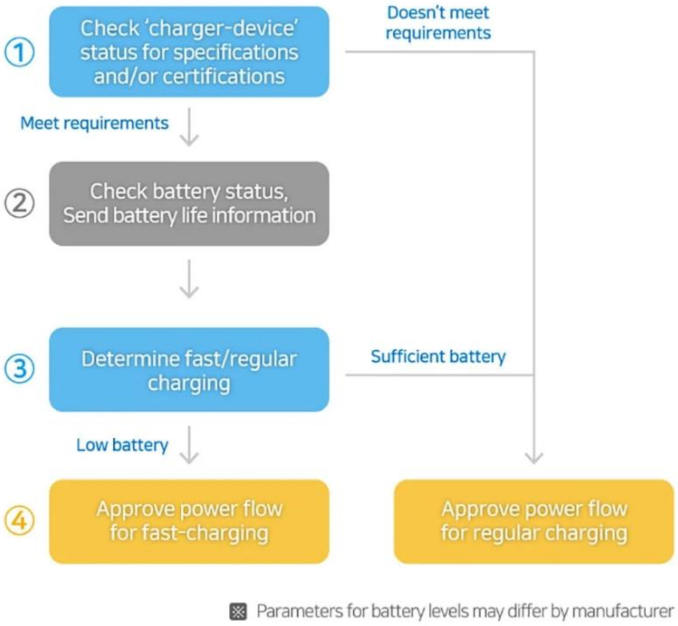
The term "C" in Figure 5 refers to the C-rate. The C-rate defines the time duration of the battery charge once a certain amount of current is applied. For instance, if a battery with a charging rate current of 1Ah is charged at 2C, then the charge lasts 30 minutes approximately. Conversely, if the battery is charged at 0.2C, the charge lasts approximately two hours.

How does the EPS "know" how much power it should deliver?

When an EPS and a downstream device are connected, they exchange information. The standard IEC 62680-1-2 states that USB PD compliant EPS shall be able to charge non-compliant devices. During the smart talk, or handshake, the EPS identifies if the device downstream is a USB PD type, as shown in Figure 9, and determines whether it should apply fast, or regular charge. It also provides information about device protections (overcurrent, overtemperature, overvoltage, etc.) during information exchange.

[6] https://www.digikey.com/en/articles/a-designer-guide-fast-lithium-ion-battery-charging

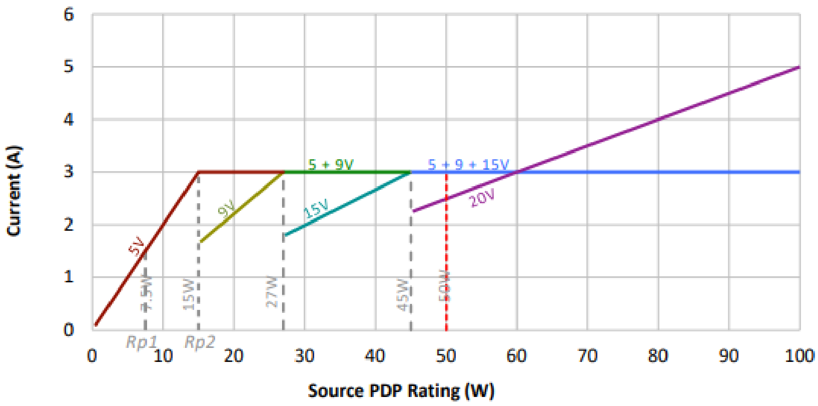
Figure 6. Simplified flowchart of the interchanged information before charging.



Source: 100W USB-C PD 3.0 Controllers for Fast Charging. By Scott McMahan. Available at: https://eepower.com/new-industry-products/100w-usb-c-pd-3-0-controllers-for-fast-charging/# .

The standard also defines five basic power levels and requires that each power level shall be able to deliver previous lower levels. This means that if an EPS can deliver up to 100W (20V/5A), it should also be able to safely charge other devices that require less power (e.g. 27W or 15W).

Figure 7. Power Rule Illustration for a Fixed Supply operation.



Source: UNE - EN IEC 62680-1-2:2020, page 492

USB PD 3.0 introduced the PPS (Programmable Power Supply) protocol. With PPS, the EPS and the downstream device exchange data every 10 seconds, so that the EPS can dynamically adjust the output voltage and current.

USB PD Certification

On 8 January 2018, USB-IF announced the "Certified USB Fast Charger" which certifies chargers that use the feature "Programmable Power Supply" (PPS) of the USB PD specification. The certification allows manufacturers to use the USB-IF logo in their products, which are also included in the USB-IF website (https://www.usb.org/products).[7]

According to interviewees, many manufacturers decide not to certify their products, even if they are compliant with the USB PD specification, due to a variety of reasons, e.g.: certification costs, administrative burden, low perception of advantages of certification, or the need to test the products in external laboratories (which can give rise to concerns about IP leakage).

On the other hand, products that include add-ons beyond USB PD (e.g. EPS providing power via USB PD or a proprietary solution, depending on the device that the user connects) cannot be certified.

Proprietary charging solutions for EPS

In the smartphone ecosystem, many models use in-house technologies rather than the more ubiquitous USB PD standard or Quick Charge. However, only a few of these technologies are truly proprietary. Many are just USB PD or Quick Charge repackaged under a different brand name, such as MediaTek's PumpExpress, which uses USB PD.

This sub-section explores the main fast charging technologies that are truly proprietary: Qualcomm's Quick Charge, Huawei SuperCharge, and Oppo VOOC.

Quick Charge

Quick Charge (QC) is a proprietary Qualcomm battery charging protocol used for managing power delivered over USB cables and connectors, mainly by communicating to the EPS and negotiating a voltage. QC is an optional feature available with Qualcomm's Snapdragon SoC.

The first fast charging technology available on the market was Qualcomm's Quick Charge 1.0, released in 2013 and providing up to 10W. In 2014, Qualcomm released Quick Charge 2.0, which provided maximum power of 18W.

Quick Charge 3.0, released in 2016, introduced the feature INOV (Intelligent Negotiation for Optimum Voltage), which allowed for a fined tuned power output and a more optimized charging cycle.[8] Instead of providing a fixed voltage, Quick Charge 3.0's INOV communicated with the device to request any voltage between 3.2V and 20V at 200mV increments, allowing for a wider selection of voltages.

INOV is able to dynamically adjust the charging voltage over the battery charging cycle. As a battery charges up, it slowly draws less and less current, slowing down the charging speed. Qualcomm stated that INOV allows the phone to request just enough voltage to reach the desired charge current, thereby maximising efficiency.

Quick Charge 4 was announced in December 2016 alongside the Snapdragon 835 SoC. Quick Charge 4 introduces two charging modes: QC and USB PD. This means that the device would charge with USB PD if either the device or the EPS are not QC compatible. It also featured additional safety measures to protect against over-voltage, over-current and overheating, as well as cable quality detection. QC 4.0 was not compatible with previous QC versions. Qualcomm announced Quick Charge 4+ in 2017, including some additional safety features, as well as compatibility with QC 2.0 and QC 3.0 devices.

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[7] The USB-IF website (https://www.usb.org/products) includes a list of products that have passed the USB-IF compliance programme.

[8] Source: https://www.androidauthority.com/quick-charge-3-0-explained-643053/

Quick Charge 5 was announced in July 2020. Qualcomm states that this standard is compatible with USB PD PPS (although it could not be certified as it includes add-ons beyond USB PD).

Quick Charge comes as an option with Snapdragon SoC and it has been adopted by a large number of mobile phone manufacturers, such as Samsung, BQ, Lenovo, LG, Redmi, Xiaomi, HTC, Nokia, or Sony. As of November 2020, no devices featured QC 5 yet.[9] It should be noted that not all devices that include Snapdragon SoC use QC. For instance, Google Pixel phones use Snapdragon chips, but their battery charging protocol is USB PD. Other manufacturers that were early adopters of Quick Charge, such as Samsung, continue using Snapdragon chips but have moved to USB PD.

According to interviewees, QC has also been adopted by manufacturers of other devices, including tablets, drones, wireless speakers, powerbanks, and mobile 4G routers. EPS that use QC bring USB Type-A or USB Type-C sockets, or both if they are multi-port.

Huawei SuperCharge

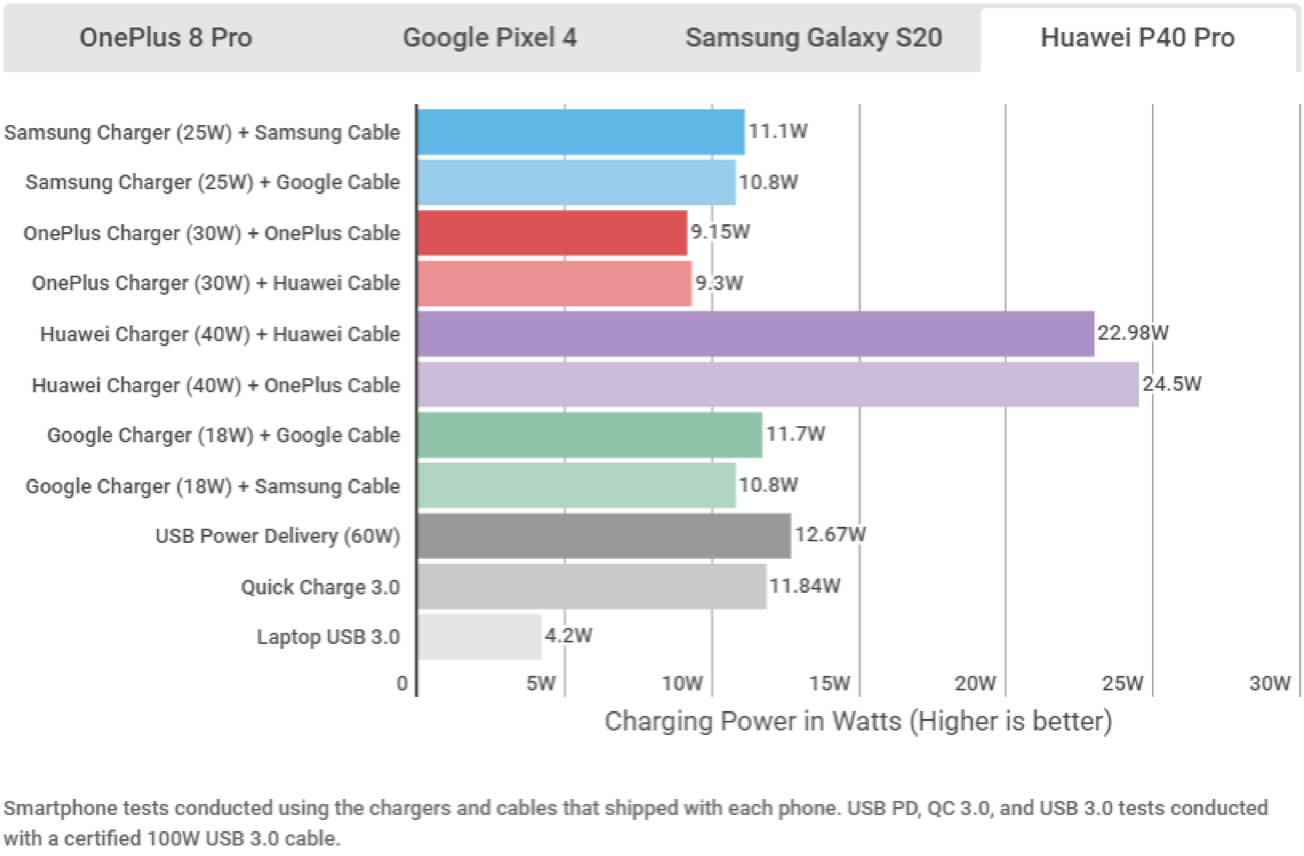
Huawei, through its affiliated company HiSilicon, produces their own SoC, known as Kirin. This SoC incorporates Huawei's proprietary charging solution, SuperCharge. There are two main versions of SuperCharge: 20W and 40W, and Huawei also manufacturers EPS that are able to deliver over 60W. HiSilicon does not produce SoC for other OEMs, and therefore only Huawei devices use Huawei SuperCharge.

Huawei's devices adjust the charging voltage and current automatically depending on the type of charger and cable that the consumer uses. The devices also disable SuperCharge automatically when plugging in a cable that does not support SuperCharge.

A test conducted by Android Authority revealed that Huawei P40 Pro, a SuperCharge-enabled device, can only be charged at the maximum speed that the device accepts when using a Huawei EPS. According to interviewees (and confirmed by Android Authority's test), Huawei devices can also be charged with USB PD-enabled EPS, although the wattage accepted is generally lower (10-15W).

[9] See list of devices featuring QC, as reported by Qualcomm, here: https://www.qualcomm.com/media/documents/files/quick-charge-device-list.pdf (updated November 2020)

Figure 8. Huawei interoperability



Source: https://infogram.com/2020-usb-fast-charging-tests-1h8n6mdkqjxm6xo

Huawei SuperCharge delivers fast charging by increasing the current (up to 8A), and therefore it needs a cable that can transmit high current. Android Authority conducted the test using a OnePlus cable, which also delivers fast charging by increasing the current. Had Android Authority used a different third-party cable, it would have probably failed to deliver 20W.

Huawei's EPS use the proprietary SuperCharge protocol and can also charge devices via the USB Battery Charge protocol (EN-IEC 62680-1-1). However, unlike the devices, the EPS do not support USB PD.

According to information provided by interviewees, all Huawei EPS use USB Type-A sockets and they have no plans yet to move to USB Type-C at the EPS end.

Oppo VOOC

Oppo VOOC (Voltage Open Loop Multi-step Constant-Current Charging), also known as Dash Charge (20W), Warp Charge (30W) or Dart Charge (65W), is a proprietary technology created by BBK Electronics. BBK Electronics Corporation markets smartphones under the Oppo, Vivo, OnePlus, Realme and iQOO (a sub-brand of Vivo) brands. In contrast to other fast charging technologies (e.g. USB PD), which increase the voltage during fast charging, VOOC uses low voltage and a higher current than the "common" charger.

As of 2020, VOOC comes in five variations: [10]

- VOOC 2.0, which operates at 5 V/4 A.

[10] Source: Wikipedia (https://en.wikipedia.org/wiki/VOOC#cite_note-vooc3-8)

- VOOC 3.0 (2019), which appears to operate at 5 V/5 A.
- SuperVOOC (2018), a successor of VOOC 2.0 with 10 V/5 A (50W).
- VOOC 4.0 (2020), a successor of VOOC 3.0, which operates at 5 V/6 A (30 W).
- SuperVOOC 2.0 (2020), a successor of Super VOOC with 10 V/6.5 A (65 W).

All versions of VOOC require a proprietary cable to work. In addition to electrical requirements like thickness (low electrical resistance) to handle the high currents without overheating, the VOOC 2.0 protocol requires a fifth pin on the (USB-A to USB-C) cable to communicate through. Without such communication, the charger runs at a limit of 5 V/1.5 A. **Mobile devices using VOOC cannot be charged at a fast speed using non-proprietary EPS**. A Fast Charging Accessory test conducted by Android Authority revealed that One Plus and Realme devices charged at around 7W-13W when using Quick Charge or USB PD EPS, compared to 26W of power when charging with the original EPS and cable.[11]

According to IDC data, sales of VOOC-enabled smartphones in 2018 represented less than 1% of total sales of smartphones in the EU.

Our mapping of devices suggests that the sockets of Oppo VOOC EPS are USB Type-A.

Summary of interoperability between EPS and device

In summary, most devices can be charged with a USB PD EPS (provided the right cables are connected) at a reasonable speed. This includes USB PD EPS, as well as QC 4+ and QC 5 EPS, since they can provide power using the USB PD mode in addition to their proprietary charging protocol.

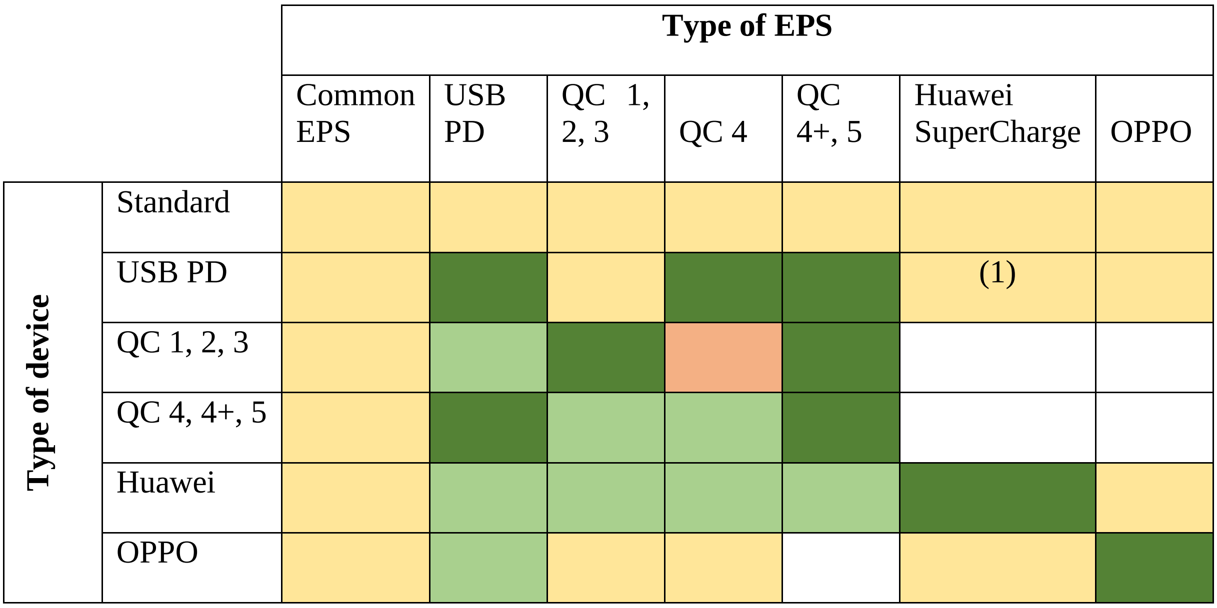
Phone manufacturers are including either (a) USB PD as the only battery charging protocol in their devices, or (b) USB PD in combination with another proprietary solution. This makes these devices interoperable with any USB PD compliant EPS. Oppo devices (e.g. OnePlus, Realme) are the least interoperable, and they can only be charged at high speed when using proprietary accessories (though tests show that USB PD can charge these phones at around 13W).

As shown in Figure 12, in some instances (e.g. Huawei and Oppo devices) the power provided by USB PD EPS is lower than their proprietary charging solution. This may be because the USB PD protocol included in these devices use a low voltage (e.g. 5V or 9V at 3A), whereas the proprietary solutions can accept higher wattage.

USB PD is backwards compatible, which means that low-end devices which still use the standard BC protocol (EN-IEC 62680-1-1) can be charged safely (up to 7.5W).

[11] Source: https://docs.google.com/spreadsheets/d/e/2PACX-1vSjHsJNBiBByEQixvUB4wpPqmJLlmUEjqODs79WkJZ99MpXPSGuFWag1Y0nXvv8HY7MlwkOr4vl1eyU/pubhtml?gid=0&single=true

Figure 9. Summary of interoperability between the most common types of EPS and devices



Legend:

	Interoperability is not guaranteed
	Standard charge (up to 7.5W) guaranteed
	Fast charge (10-15W, but below maximum capability of device)
	Fast charge (optimum charge)
	No information available

Source: Ipsos MORI, based on Android Authority tests (https://docs.google.com/spreadsheets/d/e/2PACX-1vSjHsJNBiBByEQixvUB4wpPqmJLlmUEjqODs79WkJZ99MpXPSGuFWag1Y0nXvv8HY7MlwkOr4vl1eyU/pubhtml?gid=0&single=true) and (https://infogram.com/2020-usb-fast-charging-tests-1h8n6mdkqjxm6xo) and information provided by interviewees.

(1) According to information provided by interviewees, Huawei EPS and cables can charge other mobile phones at 10W. However, tests conducted by Android Authority showed that the proprietary cable is not interoperable with Google Pixel 4. This is most probably because Google Pixel 4 blocks any cables that do not fully comply with the USB Type-C specification, or that have some add-ons.

Connectors at the EPS end

In addition to the software, the hardware – in this case, shape of the USB socket and the cable – also affects interoperability. The study conducted in 2019 concluded that manufacturers of mobile phones (and some other devices) provide EPS with detachable cables with either USB Type-A or USB Type-C sockets.

Table 3: Summary of specifications for USB A and USB C receptacles

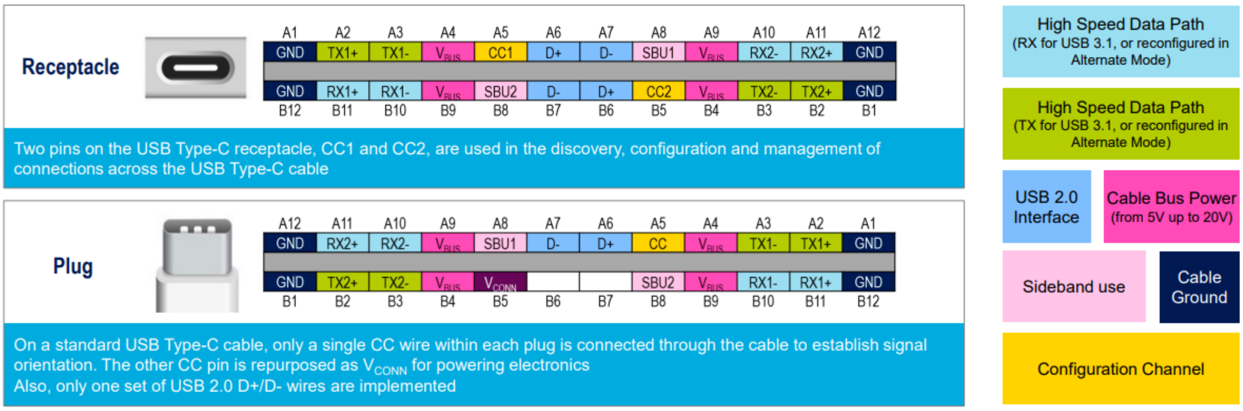
Type of connector	**Latest specification connector**	**Latest specification it supports (power)**	**Latest specification it supports (data transfer)**	**Max Power**	**Max data transfer**
USB Type-A	USB 3.1 Standard-A	USB PD (IEC 62680-1-2)	USB 3.2	100W	20 Gbps
USC Type-C	IEC 62680-1-3	USB PD (IEC 62680-1-2)	USB 4	100W	40 Gbps

**Maximum data transfer of USB A may be increased up to 40 Gbps with Thunderbolt (Intel's proprietary solution)*

Both USB Type-A and USB Type-C are interoperable with legacy charging technologies (i.e. defined by IEC 62684) and with USB PD.

The Type-C connector can handle the maximum power (100W corresponding to 5 A and 20V) and, as explained in section 4.1.1, is formed by pinouts for power and communication (see Figure 10).

Figure 10. USB Type C Pinout description



Source: Presentation of STMicroelectronics for APEC 2018.

The amount of current that the cable can transfer is determined by its diameter, or American Wire Gauge (AWG).[12] For instance, for a USB 3.0 cable, the section varies from 20 AWG for 5 A (with diameter of 0.812 mm) to 28 AWG for 830 mA (with diameter of 0.321 mm). Although a 20 AWG cable can withstand all power range up to 100 W, using this cable for small power applications can be expensive.

Figure 11. Example of USB 3.0 cable composition

Source: https://www.l-com.com/frequently-asked-questions/what-is-a-usb-cable

Interoperability of connectors at the device end

Finally, the cables connecting the device and the EPS also affect the interoperability. At the device end, the most common connectors are USB micro-B and USB Type-C. The latter is gradually superseding the former in smartphones and tablets; however, USB micro-B continues to be the mainstream solution for devices that require less power (e.g. e-Readers, hearing devices). For more information on the connectors used by different types of devices, see section 2.3.1.

[12] American Wire Gauge (AWG) is a logarithmic stepped standardized wire gauge system used since 1857 for the diameters of round, solid, nonferrous, electrically conducting wire.

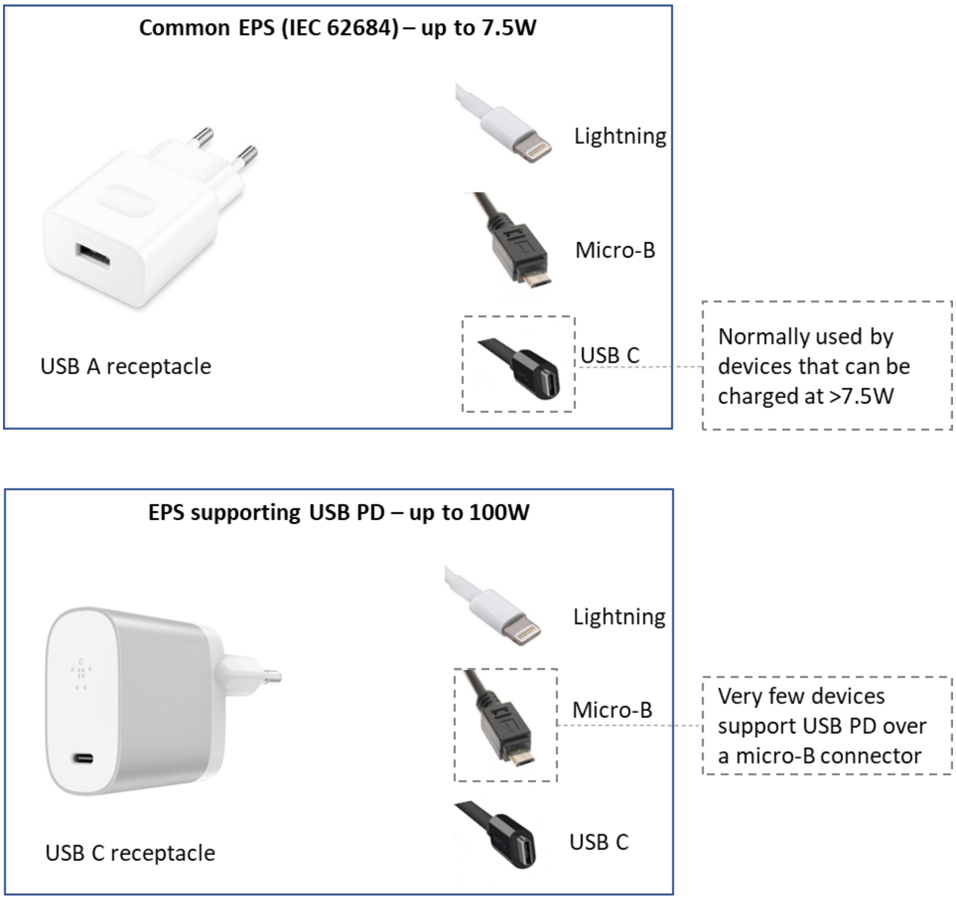
Table 4. Maximum power and speed for data transfer supported by USB connectors

Type of connector	Latest specification connector	Latest specification it supports (power)	Latest specification it supports (data transfer)	Max Power	Max data transfer
USB micro-B	USB 3.1 Micro-B	IEC 62684	USB 2.0	7.5 W	480 Mbps
USC Type-C	IEC 62680-1-3	USB PD (IEC 62680-1-2)	USB 4	100W	40 Gbps

Apple has a proprietary connector, Lightning, which has been incorporated in all iPhones and some other Apple products since 2012 and continues to be used in the last generation of iPhones launched in 2020. Recent iPads and MacBookhave USB Type-C. Apple has not published the Lightning specifications; however, it should be able to carry, at least, up to 20W, which is the power accepted by iPhone 12. Apple devices (smartphones, tablets and laptops) are USB PD enabled and can be charged with any EPS that supports USB PD.

In summary, interoperability is determined by the EPS and the cable *separately*. This means, the same EPS could be used to charge several devices even if the devices use different cables/connectors, and the same cable could be used for several devices, even if they use different EPS (e.g. because they have different charging requirements). The figure below summarises the most common charging solutions available in the market.

Figure 12. Summary of charging solutions



Source: Ipsos MORI

Future evolution of the different charging technologies

The study team has explored in interviews with manufacturers the future evolution of charging technologies. It seems unlikely that chip (SoC) and phone manufacturers will abandon fast charging proprietary solutions in the near future. However, they are increasingly making their devices and EPS interoperable with USB PD; the standard solution is frequently included in devices and EPS along with other proprietary solutions. Qualcomm, for instance, has included a USB PD mode in their chips since QC 4 was released in 2017; One Plus also includes a USB PD mode in their latest EPS; and Huawei includes USB PD in their devices (although it does not include USB PD in their EPS). In addition, some phone manufacturers that used proprietary solutions in the past, have moved towards USB PD exclusively (e.g. Samsung).

Basically, this means that most mobile phones sold nowadays can be charged with an USB PD EPS. The speed of charge may not be as fast in all cases as if the original EPS was used, but it would nonetheless be charged at a relatively fast speed (10-15W). The EPS included in the box with mobile phones, however, are not so versatile and in some cases only include the proprietary solution, making them unsuitable to charge other devices at fast speed (i.e. the maximum wattage they would provide is in the range of 5W-7.5W).

The EPS included in the box with mobile phones have sockets for USB Type-A or USB Type-C connectors, and some industry manufacturers have confirmed that they will continue using USB Type-A for the foreseeable future. Our stock model currently assumes that USB Type-A will be phased out in 2024, and this assumption may need to be revisited.

The connectors at the device end are fragmented between USB Type-C, USB micro-B, and proprietary solutions (mainly Lightning). The stock model used in the first IA study assumed that USB micro-B would be superseded by USB Type-C in 2022. This assumption may need to be revisited, especially for smaller devices, as the transition appears to be happening slower than originally expected.

Annex C: Survey results

This annex contains the results of the two surveys that were carried out as part of this study – the first of a representative sample of consumers, the second of a non-representative sample of stakeholders.

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1. Consumer survey

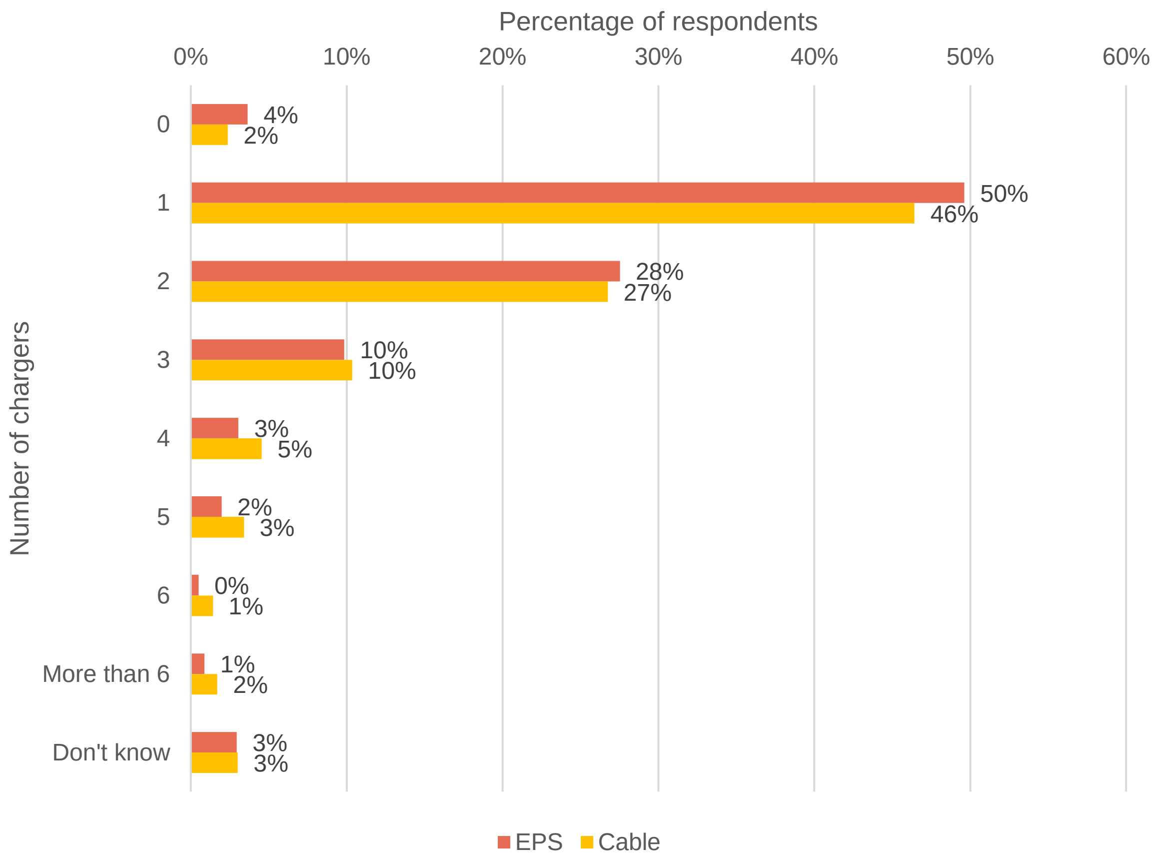
The consumer survey (CS) was carried out using Ipsos Online Panels in January 2021 and collected responses from a representative sample of 5,010 respondents split evenly across the six largest EU Member States: France, Germany, Italy, Poland, Romania, Spain. The survey collected information about the type of mobile phones and chargers in use by consumers, as well as their experiences with and preferences towards unbundling. Furthermore, the survey also investigated consumers' awareness by providing information about environmental impacts, interoperability, charging speed, and counterfeit chargers and then explored the effect of this type of information on consumer preferences. The section below provides an overview of the responses to the main survey questions.

How many chargers do consumers use?

Consumers participating in the survey were asked to indicate the number of mobile phone chargers (EPS and cable separately) that they were using at the time of the survey. As shown in Figure 1, around half of respondents used only one charger (50% used only one EPS and 46% used only one cable). Slightly over a quarter of respondents used two chargers (28% two EPS, and 27% two cables). Ten percent of respondents had three chargers in use (both EPS and cable). On average, each respondent used 1.8 EPS and 2.1 cables. The average was slightly higher for younger and/or male than for older and/or female respondents. Also, respondents whose main phone was from Apple reported using slightly more chargers than users of other brands: 2.1 EPS (vs. 1.7 for other brands) and 2.5 cables (vs. 2.0 for other brands).

Figure 13: Number of chargers in use by consumers

Question: How many different mobile phone chargers (EPS and cables) do you currently use? Please include all chargers that you use to charge a mobile phone - irrespectively of whether or not you also use them to charge other devices. If you're unsure of the exact number, please provide your best estimate.



Source: Ipsos (2021), consumer survey. N=5,010.

How frequently do consumers use different types of chargers to charge their mobile phones?

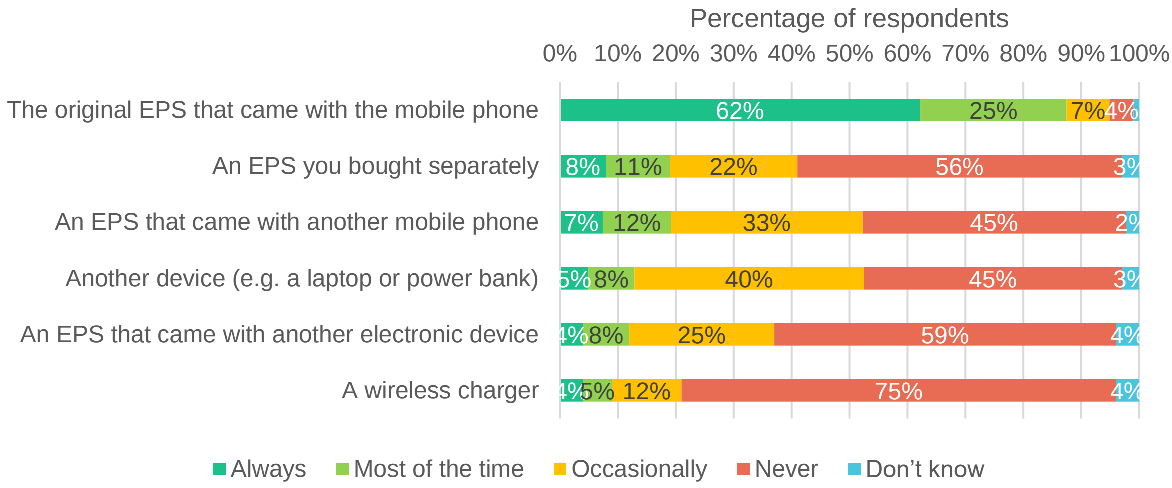
Figure 14 illustrates the types of EPS used by the respondents. Consumers generally tend to use the EPS that came with their phone when they acquired it – 62% indicated that they always use the EPS that was provided with the mobile phone, and 25% indicated that they use it most of the time.

Only 4% never used the charger provided with the mobile phone at the time of purchase, and 7% used it only occasionally. Using an EPS bought separately does not seem to be very common. Over half of respondents (56%) reported that they did not use an EPS bought separately from a mobile phone, and 22% said that they used it only on an occasional basis. The figures in the case of an EPS that came with another phone are similar: a little less than half of respondents (45%) never uses an EPS of a phone that came with another mobile phone to charge the mobile phones they use, and 33% reported that they did so only occasionally.

Respondents also indicated that it was rare for them to use another device (such as a laptop or a power bank) to charge their phones (45% never did this, and 40% did so occasionally). Even fewer respondents used an EPS that came with a different electronic device or a wireless charger to charge their phones (59% and 75% respectively never did).

Figure 14: Types of EPS used

Question: How frequently do you use the following types of external power supplies (EPS) to charge your mobile phone(s)?



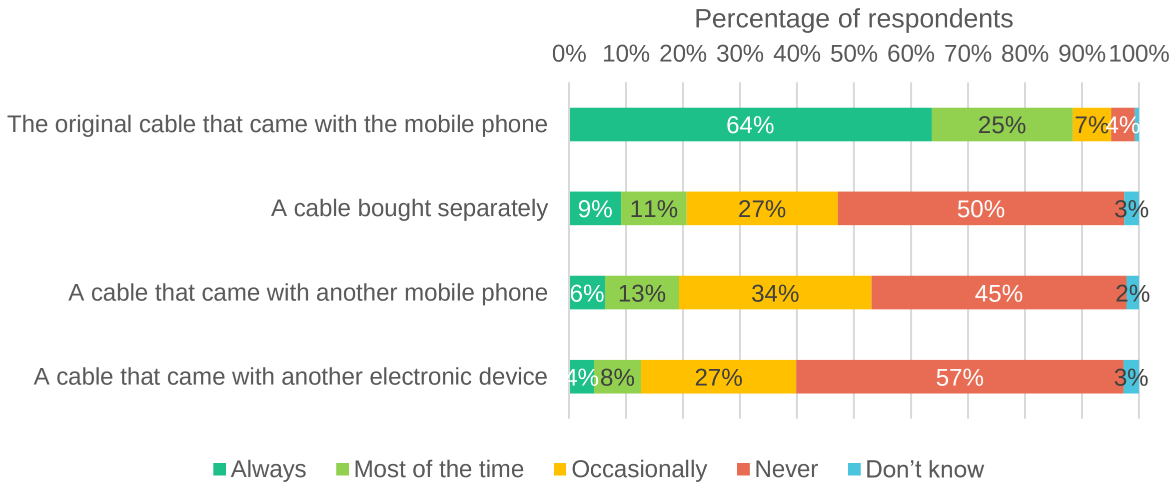
Source: Ipsos (2021), consumer survey. N=5,010.

A similar question was asked about the cable part of the charger, and responses were broadly similar. Results are reported in Figure 3. A majority of respondents (64%) reported that they always used the cable provided with their mobile phones to charge their phones, and one quarter used it most of the time.

Using any other cables (provided with another phone, with another device, or bought separately) appeared to be considerably less common. Half of the respondents never used a cable bought separately to charge their phones, and 27% did so only occasionally. Respondents were also unlikely to use a cable that came with another mobile phone to charge the phones they normally use (45% indicated 'never' and 34% 'occasionally). Cables of other electronic devices were never used by 57% of consumers, and used only occasionally by 27%.

Figure 15: Types of cables used

Question: How frequently do you use the following types of cables to charge your mobile phone(s)?



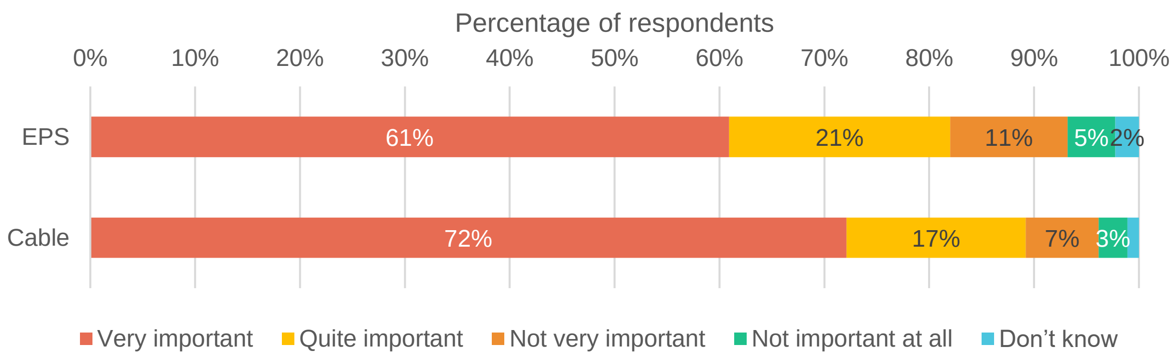
Source: Ipsos (2021), consumer survey. N=5,010.

How important is it to find a charger in the box?

Consumers appear to believe that it is important to have a charger in the box when purchasing a new mobile phone (Figure 4). Asked about the importance of an EPS being provided along with the phone, 82% said the inclusion of the EPS is important for them (including 61% who said that it is *very* important). Figures were even higher in response to a similar question on the importance of finding a cable in the box: 89% consider finding a cable in the box important (including 72% saying it is *very* important).

Figure 16: Importance of finding a charger in the box

Question: When purchasing a new mobile phone, how important is it for you that the following elements are provided along with the phone?



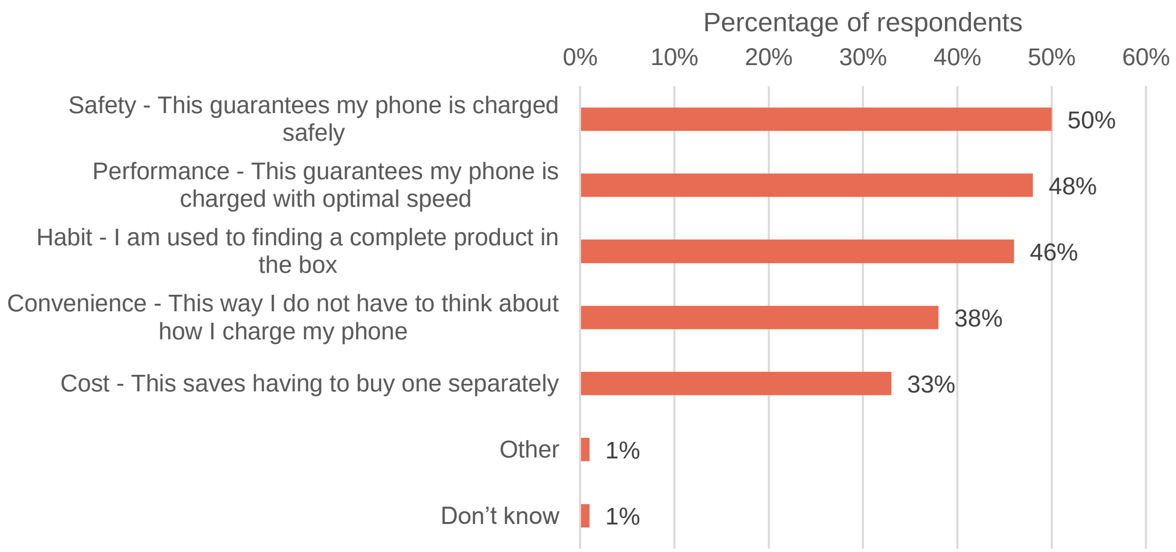
Source: Ipsos (2021), consumer survey. N=5,010.

The survey also sought to understand the reasons why respondents believed that it was important (or not important) that charging accessories were provided along with a new mobile phone.

Among the respondents who were of the opinion that having an EPS provided with a new phone is important (i.e. responded *very* important or *quite* important), half indicated that this was out of safety considerations (Figure 5). Performance was indicated as a reason for having the EPS provided a long with the phone by 48% of respondents. Habit (i.e. finding a complete product in the box) was indicated by 46% of respondents. Convenience in terms of not having to think about how to change the phone was used as an explanation by 38% of respondents. Cost factors were mentioned by one respondent in three. 'Don't know' was chosen by 1%.

Figure 17: Why the EPS is important

Question: Why is it important for you that the EPS is provided along with the phone?

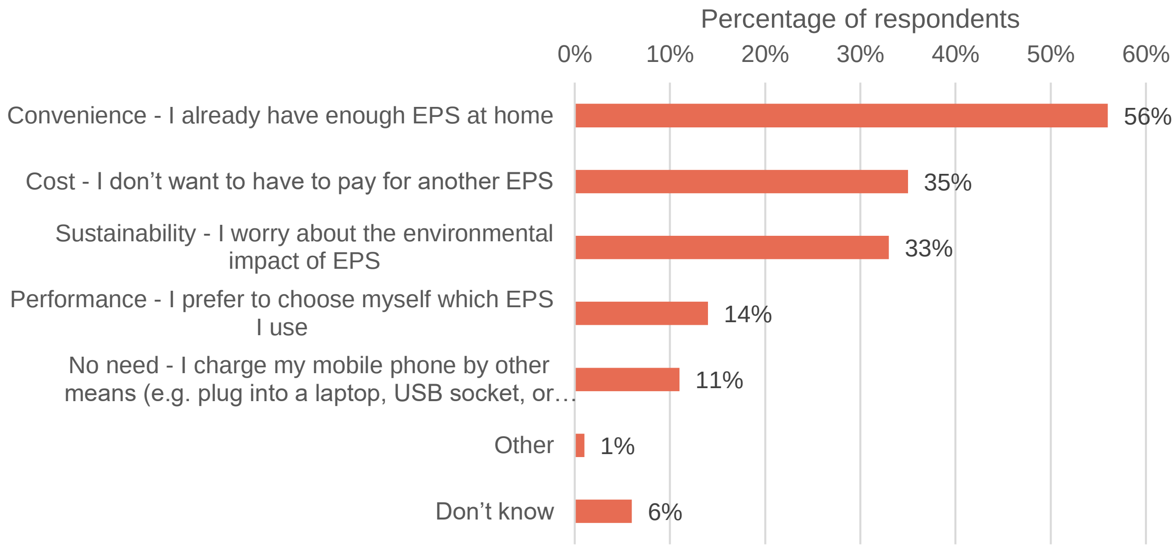


Source: Ipsos (2021), consumer survey. N=4,109.

However, among the respondents who were of the opinion that finding an EPS in the box with a new phone was *not very* important or not important *at all* (Figure 6), over half (56%) indicated considerations around convenience (i.e. having already enough EPS at home). Not wanting to pay for the EPS was selected as a response by 35% of respondents, whilst 33% mentioned environmental concerns. In addition to this, 14% indicated that, for performance reasons, they would prefer continuing using the EPS they have, and 11% did not feel the need of a new EPS because they are used to charging their phone by other means. Six percent selected 'don't know'.

Figure 18: Why the EPS is not important

Question: Why is it not important for you that the EPS provided along with the phone?

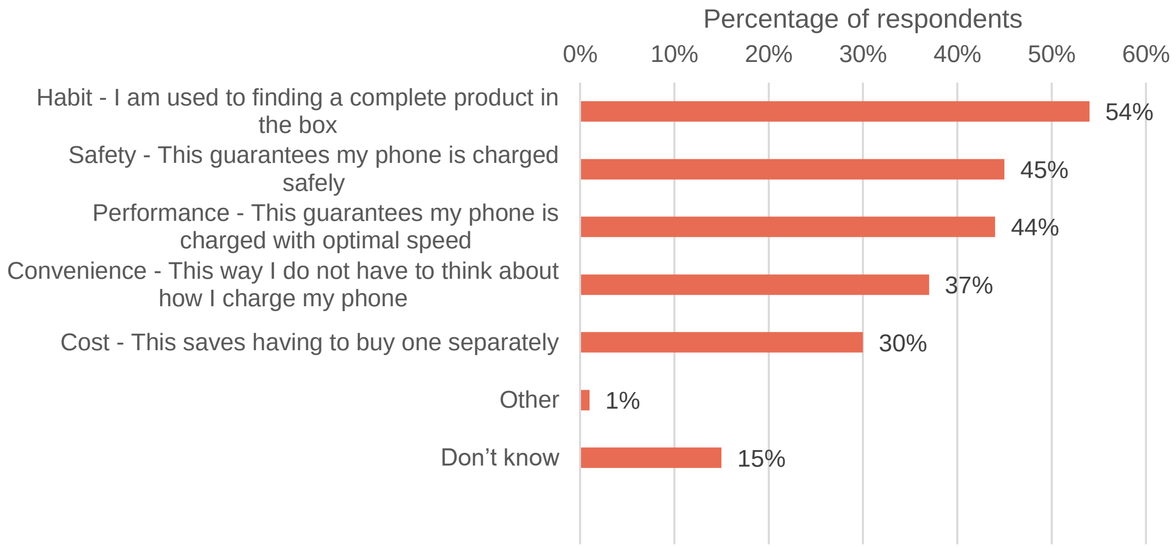


Source: Ipsos (2021), consumer survey. N=789.

A very similar question was also asked about the cable assembly. Figure 7 reports the responses to the question that asked why it was important that a cable was provided along with a phone. The habit of finding a complete product in the box when purchasing a new phone was the most common reason (54%), followed by safety (45%) and optimal charging performance (44%). Thirty-seven percent of respondents also indicated that having a cable in the box meant that they did not have to think about how to charge their phone. Cost savings mattered for 30% of respondents. Whilst 1% indicated 'other' as the reason, 15% did not know how to justify that they believed that finding a cable in the box with a new phone was important.

Figure 19: Why the cable is important

Question: Why is it important for you that the cable is provided along with the phone?

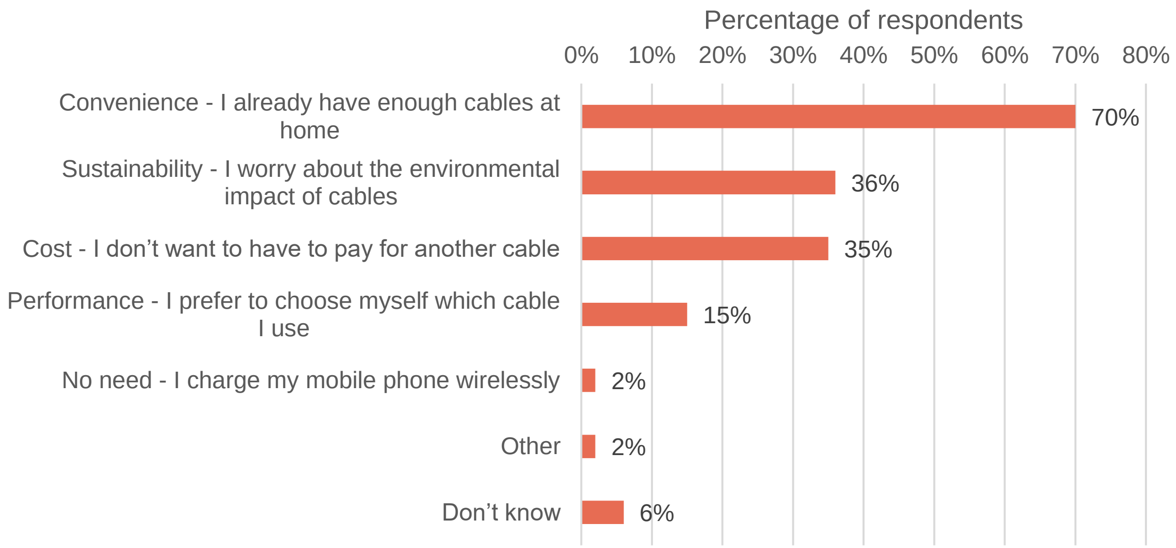


Source: Ipsos (2021), consumer survey. N=4,469.

Lastly, respondents that indicated that the cable was not important as an accessory in the box were asked to justify their answer (Figure 8). Convenience was the reason for 70% of them, followed by environmental impact concerns (36%) and cost considerations (35%). Fifteen percent indicated that, for performance reasons, they would rather be free to choose a cable. Two percent reported not needing one as they charged their phone via wireless. 'Other' was selected by 2%, and 6% did not know how to answer.

Figure 20: Why the cable is not important

Question: Why is it not important for you that the cable is provided along with the phone?



Source: Ipsos (2021), consumer survey. N=486.

Does the provision of information affect consumer preferences?

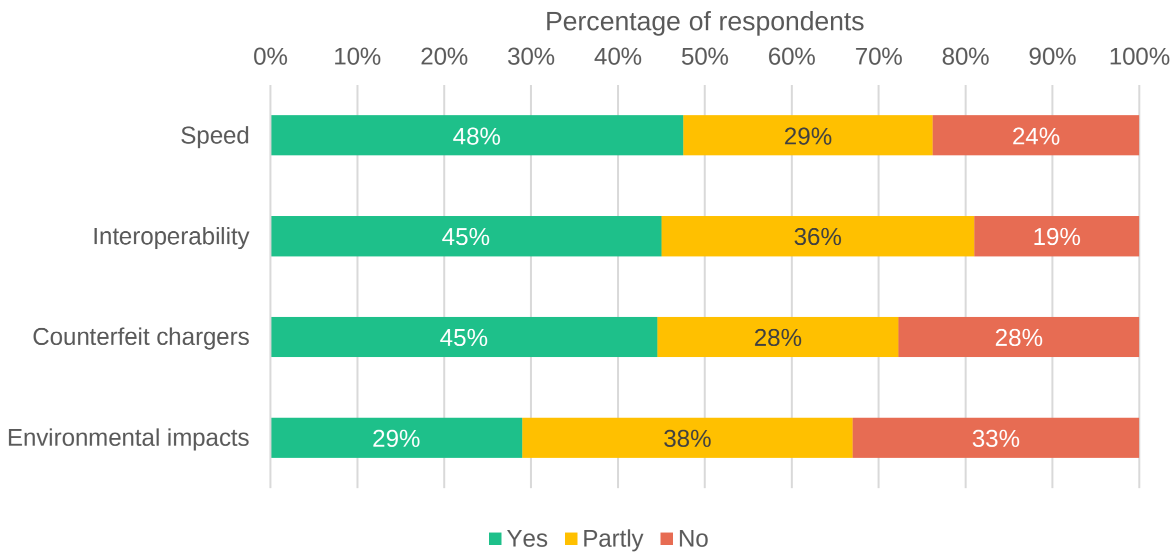
Respondents were then provided with information on four different aspects related to chargers, namely:

- **Environment:** "Mobile phone chargers have negative **environmental impacts**: their production requires raw materials and generates CO_2 emissions, and when chargers are no longer used, they generate electronic waste (approx. 12,000 tonnes per year in the EU)."
- **Interoperability**: "The vast majority of chargers from all major mobile phone manufacturers are **interoperable**, i.e. can be used to charge all modern phones irrespective of the brand. This is because cables are detachable from the external power supply (EPS), and large parts of the market have adopted technologies based on common specifications and standards."
- **Speed:** "The **speed** with which a phone is charged depends primarily on the amount of power provided by the EPS. This can vary, resulting in faster or slower charging speeds. In other words, even though most modern EPS can be used to charge nearly all mobile phones on the market, they may not do so at the same speed."
- **Counterfeit chargers:** "Some mobile phone chargers that are sold on their own are **counterfeit**, i.e. they claim to be from a well-known brand (e.g. Samsung or Apple), but are actually fake. Such chargers can give rise to serious safety issues, in particular electric shock, electrocution and fire risks."

Questions were firslty asked to understand the extent to which consumers already knew about the information they were provided with (Figure 21). Respondents seemed to be generally aware of the fact that EPS can generally be used to charge nearly all mobile phones but they might do so at different speeds: 48% knew about this, and 29% knew about this at least in part. As regards interoperability, 45% of respondents said they had previous knowledge, and 36% had some previous knowledge. A similar share (45%) knew that there exist counterfeit chargers on the market and that they can give rise to serious safety, while 28% of respondents knew about this in part. Less known where the environmental impacts of chargers: 29% of respondents knew that chargers can cause negative environmental impacts, whereas 38% partly knew about this.

Figure 21: Knowledge of information related to chargers

Question: Did you know this?



Source: Ipsos (2021), consumer survey. N=5,010.

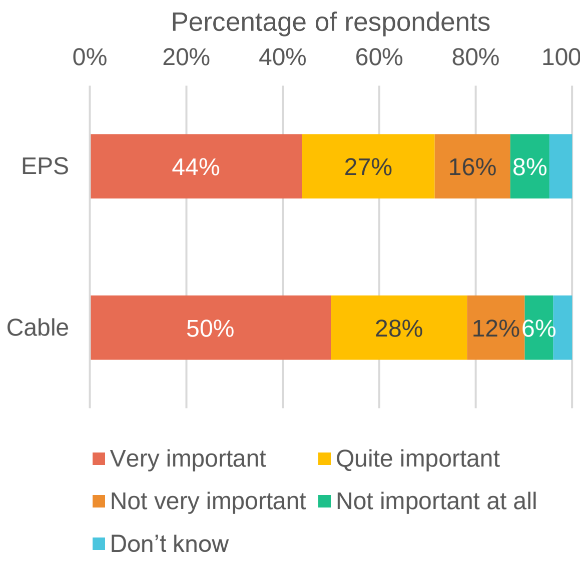
Figure 22 shows that, once consumers are informed about some of the negative environmental consequences of chargers, the share of those who believe that having EPS and cable is very important falls in both cases by over 15 percentage points. After providing respondents with this information, the share of those who think that having an EPS in the box is important (or very important) decreases from 82% to 71%, whilst for the cable the percentage goes from 89% to 78%.

Giving information about interoperability of chargers seems to yield a similar change in consumer attitudes towards unbundling, as illustrated in Figure 23. Those who indicated that they would still consider important that EPS and cable were provided along with a mobile phone dropped to 72% and to 78% respectively (comprising those who indicated 'very important').

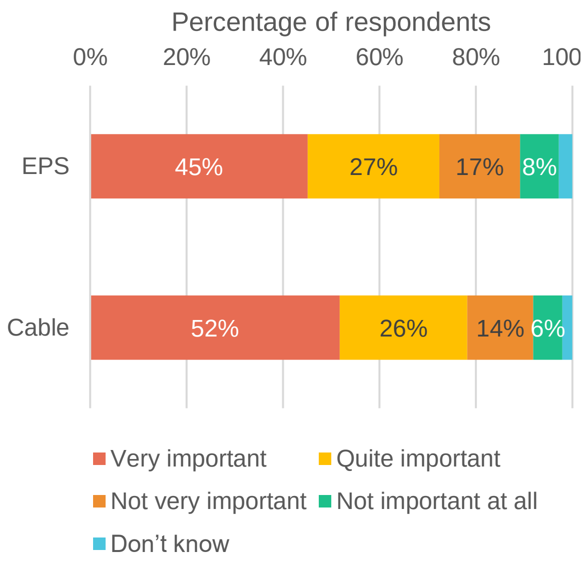
Figure 22: Environment

Figure 23: Interoperability

Question: In light of this, how important is it for you that the following elements are provided along with the phone?



Source: Ipsos (2021), consumer survey. N=5,010.



Source: Ipsos (2021), consumer survey. N=5,010.

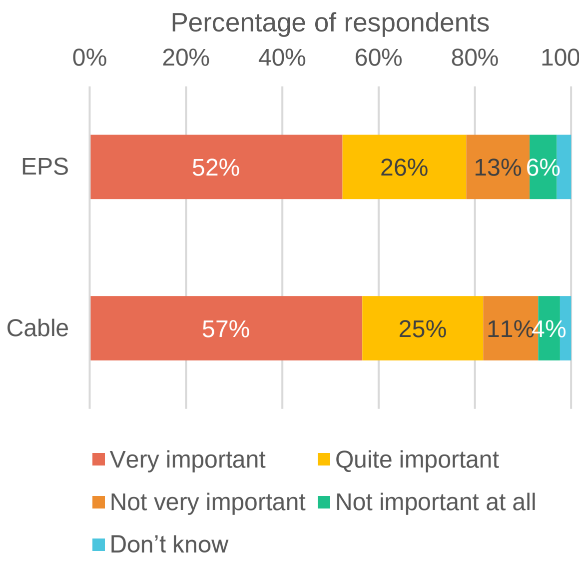
Consumer reaction to information about charging speed (i.e. the fact that, even though most modern EPS can be used to charge nearly all mobile phones on the market, they may not do so at the same speed) and the presence of counterfeit chargers (i.e. that some mobile phone chargers that are sold on their own claim to be from a well-known brand, but are actually fake, which can give rise to serious safety issues) does not appear to cause marked shifts in preferences compared to when the question was asked before any complementary information was provided. Results are shown in Figure 24 (speed) and Figure 25 (counterfeit chargers).

The change is modest overall. When provided with information about the speeds that different chargers can achieve, the combined proportion of people indicating that they consider it very important and important to find charging accessories in the box with a new phone decreased by four percentage points for the EPS and by seven percentage points for the cable. Information around the issue of counterfeit chargers did not seem to cause clear changes in consumer preferences.

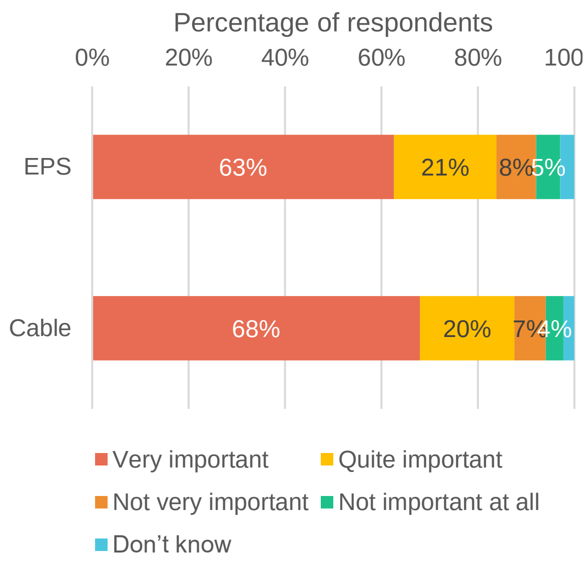
Figure 24: Speed

Figure 25: Counterfeit chargers

Question: In light of this, how important is it for you that the following elements are provided along with the phone?



Source: Ipsos (2021), consumer survey. N=5,010.

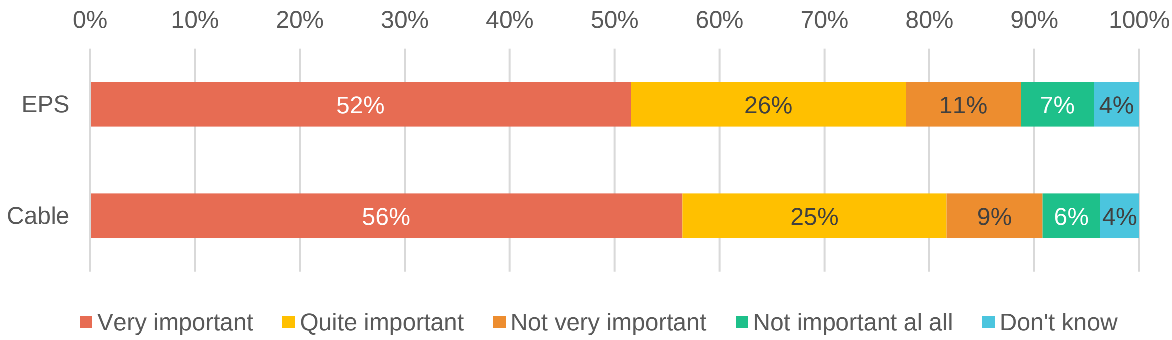


Source: Ipsos (2021), consumer survey. N=5,010.

After all four pieces of information had been provided, 78% of respondents stated that the inclusion of an EPS was (*very* or *quite*) important for them (see Figure 26). This is only 4% lower than before any information had been provided (see Figure 16), although it should be noted that the proportion of those for whom the inclusion of an EPS was *very* important fell more strongly (by 9%). The proportion of respondents who considered the inclusion of a cable (*very* or *quite*) important fell by 8% (to 81%), including a 16% drop of those who responded *very* important.

Figure 26: Importance of finding a charger in the box <u>after information had been provided</u>

Question: When purchasing a new mobile phone, how important is it for you that the following elements are provided along with the phone?



Source: Ipsos (2021), consumer survey. N=5,010.

Informed views on chargers and de-coupling

After having provided respondents with all the information referred to above, the survey went on to test their views on a series of different options in relation to unbundling of chargers.

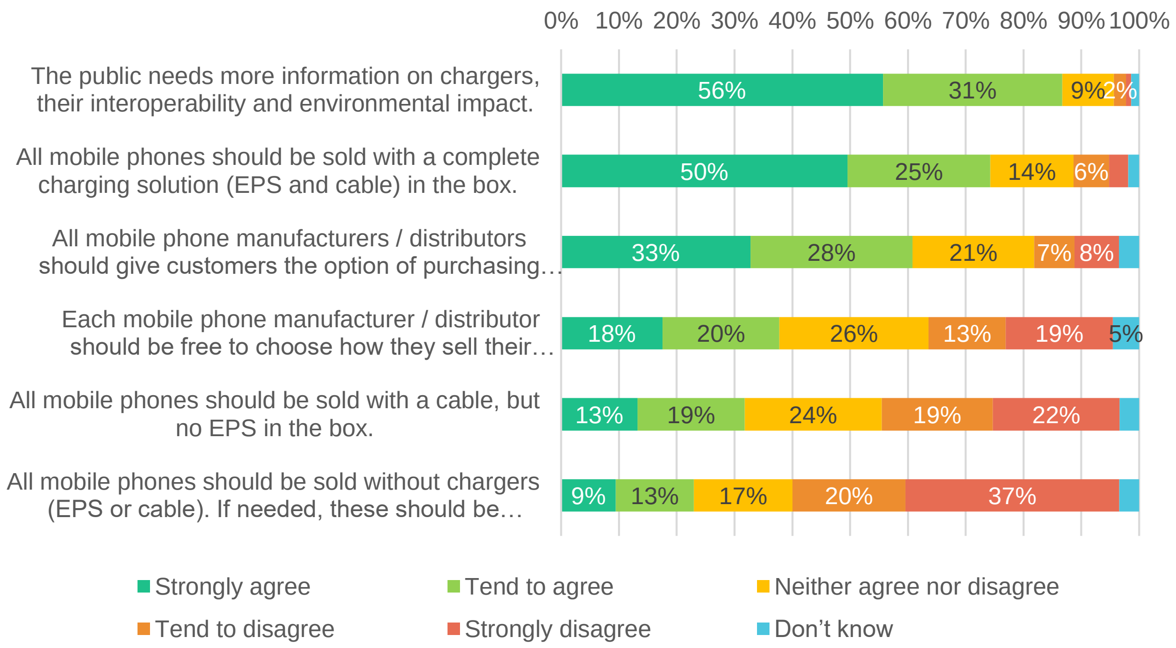
There seemed to be consensus among consumers on the need for more information on chargers, especially on interoperability and environmental impact. Overall, as reported in Figure 15, 87% agreed (56% of which strongly) about this.

Figure 27 also shows that 75% of consumers were of the opinion that all mobile phones should be sold along with a charger in the box (half of consumers strongly agreed and one quarter tended to agree with this statement). 14% had a neutral opinion on this, and around nine percent disagreed or strongly disagreed. Only 32% agreed (13% strongly agreed) that all phones should be sold with cables but no EPS (though it is worth noting that 41% disagreed with this, 22% of which strongly disagreed, with 24% neutral). Even less support is expressed by consumers for complete unbundling of EPS and cable from the mobile phone (20% disagreed with this statement, and 37% strongly disagreed), and 17% had a neutral opinion.

On the other hand, the majority of consumers were in favour of mobile manufacturers and distributors having to give them the choice, when buying a new phone, to also purchase a cable and/or EPS (61%, including 33% strongly agree). On the question of whether the choice of how to sell their phones and chargers (i.e. what to include in the box) should be left to manufacturers and distributors, opinions were split fairly evenly between those in favour (38%), those against (32%), and those neutral or unsure (31%).

Figure 27: Informed views on chargers and de-coupling

Question: Overall, considering all the information you have been provided with: Do you agree or disagree with the following statements?



Source: Ipsos (2021), consumer survey. N=5,010.

What choices would consumers make if phones were sold unbundled from their chargers?

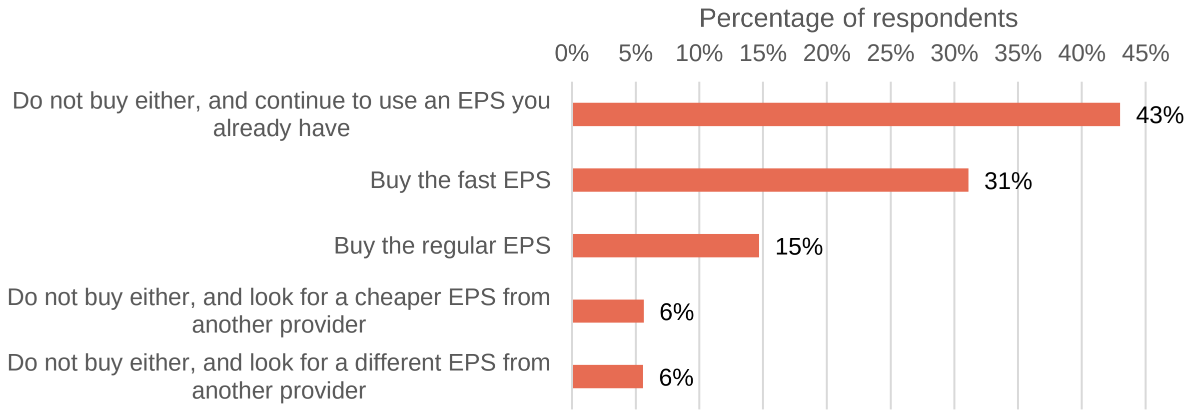
The survey also tested consumers' reactions to two potential scenarios, one in which only the EPS is removed from the bundle, and one where devices are sold without both EPS and cable.

One half of the respondents were presented with the former scenario, and the other half with the latter (Figure 28 and Figure 29).

Despite previous indications that respondents placed some value in purchasing mobile phones with charging accessories included in the box, if unbundling of the EPS happened and EPS (both at 5W and 18W) were sold at an additional cost separately, 43% of consumers would choose not to buy any and use an EPS that they already have, as it appears from Figure 11. Around a third (31%) would opt for the fast (and more expensive) EPS. The regular EPS would be the preferred option of 15% of consumers. A cheaper charger or one made by a different manufacturer were chosen by 6% of respondents each.

Figure 28: Mobile phones without EPS

Question: Imagine a scenario where phones are no longer routinely sold with chargers in the box. You have decided to purchase a new mobile phone. By default, this comes with a cable, but no EPS. The manufacturer (or distributor) is offering the following as optional accessories: (1) a "regular" (5W) EPS for €14.90; or (2) a "fast charging" (18W) EPS for €19.90. Which of the following would you be most likely to choose?

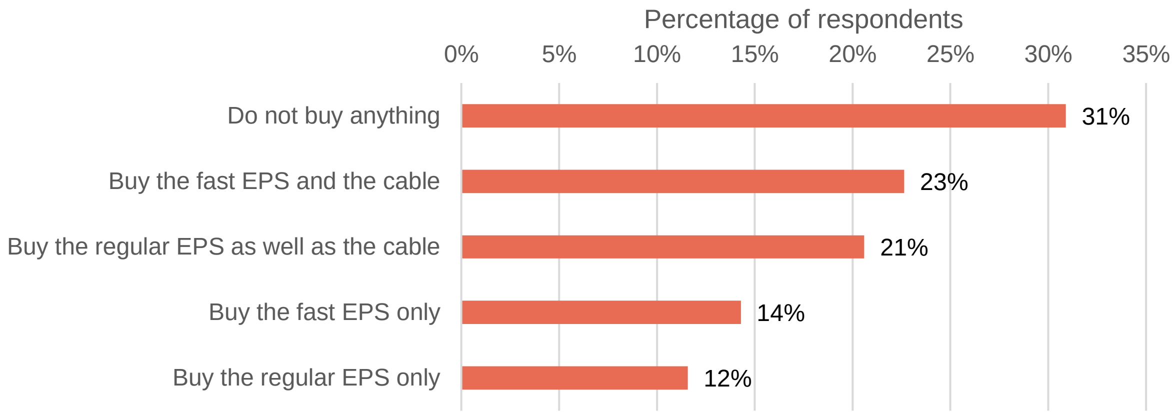


Source: Ipsos (2021), consumer survey. N=2,505.

If the phone was sold without EPS and without cable (Figure 17), consumers would be less likely compared to the previous case not to buy any charging accessories (31%). Almost one quarter (23%) would buy both the fast EPS and the cable, whist a similar percentage (21%) would buy the normal 5W charger and the cable. A group of consumers would then only buy the fast EPS (14%) and the regular EPS only (12%).

Figure 29: Mobile phones without any charging accessory

Question: Imagine a scenario where phones are no longer routinely sold with chargers in the box. You have decided to purchase a new mobile phone. By default, this comes without any accessories (neither EPS nor cable). The manufacturer (or distributor) is offering the following as optional accessories: (1) a "regular" (5W) EPS for €14.90; or (2) a "fast charging" (18W) EPS for €19.90. A compatible 1m USB cable can be purchased for €9.90. Which of the following would you be most likely to choose?

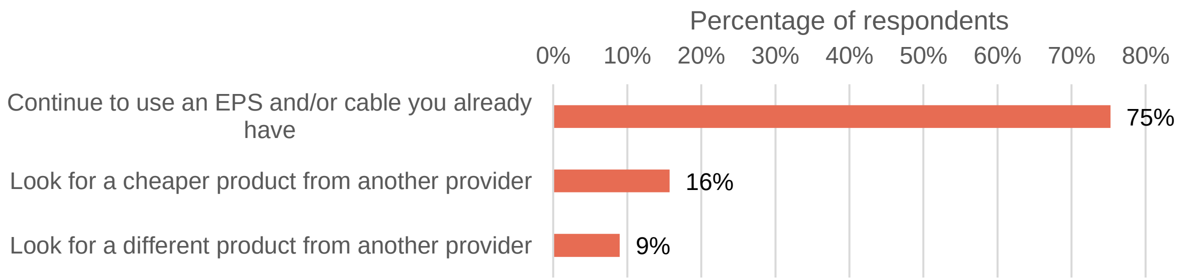


Source: Ipsos (2021), consumer survey. N=2,505.

Figure 30 shows what the respondents that would not buy both an EPS and a cable would do. Three quarters would continue to use an EPS that they already have, whilst only 25% would look to purchase an alternative (16% a cheaper option, and 9% a different EPS).

Figure 30: Choices instead of buying the manufacturer's charging accessories

Question: Regarding the product(s) (EPS and/or cable) that you would choose not to buy, would you:



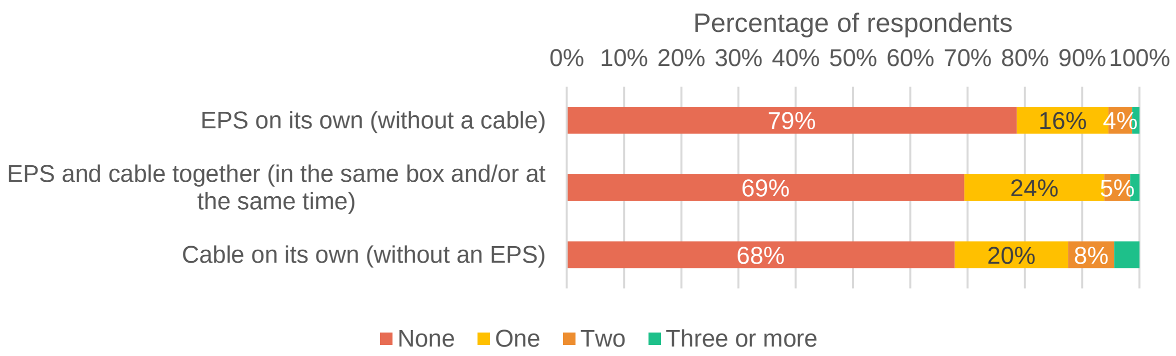
Source: Ipsos (2021), consumer survey. N=1,423.

Stand-alone charger purchases

All respondents were asked how many wired chargers (EPS and/or cables) they had bought in the previous 24 months separately (i.e. they did not come with a new phone), as reported in Figure 31. Most respondents had not bought any accessories. EPS were purchased separately by 20% of respondents (including 4% that had bought two in the past 24 months), but 79% did not buy any. EPS and cable at the same time were bought by 29% of respondents (5% of these bought two) and 28% had bought only a cable.

Figure 31: Charging accessories bought separately in the past 24 months

Question: In the last 24 months, how many new wired mobile phone chargers (external power supplies and/or cables) have you purchased separately from a mobile phone? Please include all chargers that you have purchased to charge a mobile phone - irrespectively of whether or not you also use them to charge other devices. Please do not include any wireless chargers you may have bought. If you are unsure, please include your best estimate.

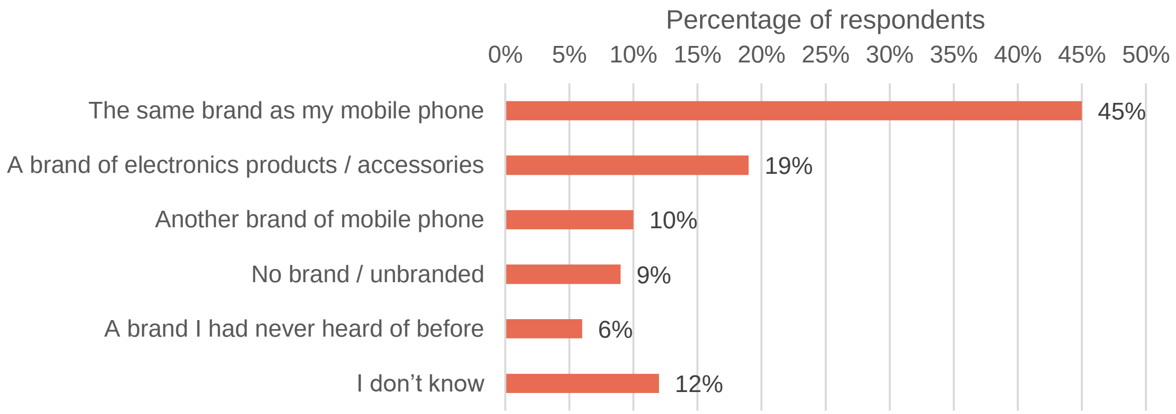


Source: Ipsos (2021), consumer survey. N=5,010.

Those respondents that had previosly stated that they had purchased at least one EPS (whether with a cable or not) in the two years before the survey were asked about the brand of the charger(s) they purchased separately. As Figure 32 shows, the most common choice among the respondents was to buy a charger of the same make as the mobile phone (45%), followed by the choice of a charger of a known brand of electronic products or accessories (19%). One in ten purchased a charger of another mobile phone manufacturer. Sligthly less (9%) bought a charger with no brand, and around 6% decided to purchase a charger of a brand they had never heard of before. Twelve percent did not know.

Figure 32: Stand-alone charger brands

Thinking of the last time you bought a mobile phone charger (EPS) separately from a mobile phone: What brand was this? Filter: Respondents who have purchased at least one EPS – whether with a cable or not

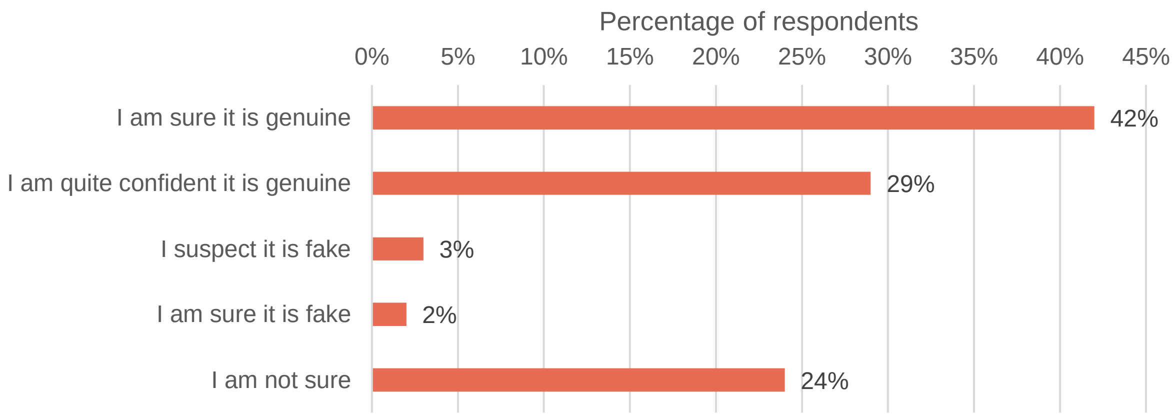


Source: Ipsos (2021), consumer survey. N=1,841.

The respondents who reported having bought a branded charger were asked a follow-up question to determine whether they knew if the EPS they bought separately was genuine. Responses are presented in Figure 33. Overall, consumers seem confident that the chargers they bought are not fake (42% are sure, whilst 29% are *quite* confident). Respondents that believe that the chargers they bought separately are fake are few: 3% suspect the charger that they bought may be fake, 2% are certain. However, those that were not sure are almost one in four (24%).

Figure 33: Counterfeit chargers

Question: How confident are you that the charger (EPS) is genuine (i.e. not fake)?

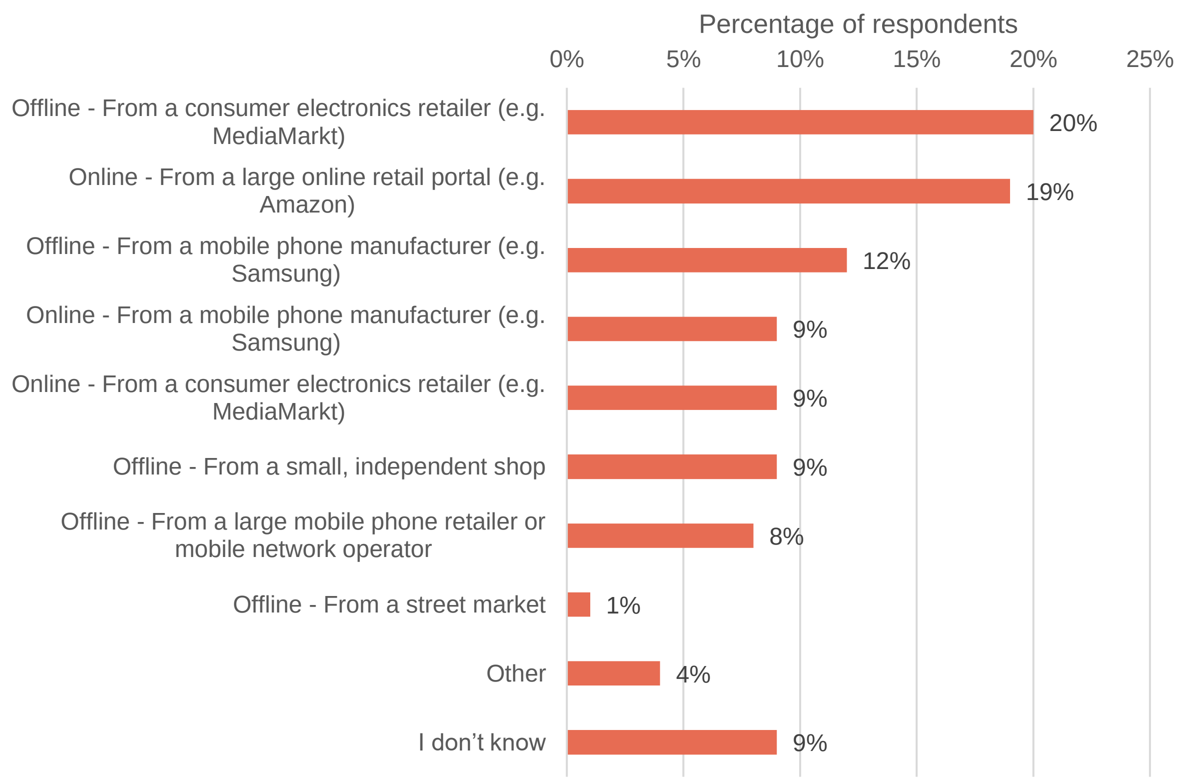


Source: Ipsos (2021), consumer survey. N=1,469.

Respondents who had previously said that they bought a stand-alone EPS were also asked about the type of retailer that they bought their EPS from. As it appears from the results in Figure 22, one in five consumers bought their EPS from a physical shop in a consumer electronics retailer. Large online retail portals such as Amazon had been chosen by 19% of respondents. While 12% bought the EPS directly in a mobile phone manufacturer's shop, 9% bought from the manufacturer's website. A similar share (9%) used the website of a consumer electronics retailer. Independent shops had been chosen by 9% of respondents. Some consumers (8%) bought their EPS from a mobile phone retailrer or network provider's shop, and just 1% from street markets. 'Other' as an option was selected by 4% of respondents, while those that did not know where they bought their EPS from accounted for 9% of all respondents to this question.

Figure 34: EPS seller

Question: Thinking of the last time you bought a mobile phone charger (EPS): where did you buy this?

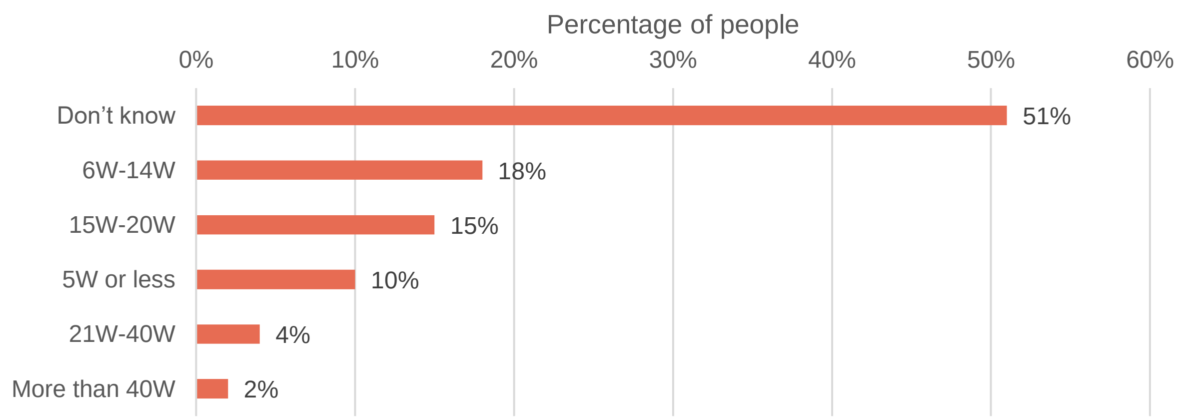


Source: Ipsos (2021), consumer survey. N=1,841.

Respondents that had bought an EPS separately were also prompted to describe the technical features of the EPS bought separately, as shown in Figure 23. More than half of consumers (51%) reported not knowing the technical specifications of the EPS they bought, as illustrated in Figure 18. However, 18% reported having purchased an EPS delivering 6W-14W, 15% a charger delivering 15W-20W, and 10% a charger delivering at most 5W. EPS delivering more than 40W had been purchased only by 2% of respondents.

Figure 35: Power characteristics of stand-alone EPS

Question: How many Watts (W) of power can the last charger (EPS) you bought deliver? This is usually specified on the EPS itself, in a format more or less as in this example: OUTPUT: 5.0 V, 1.55 A, 7.8 W.

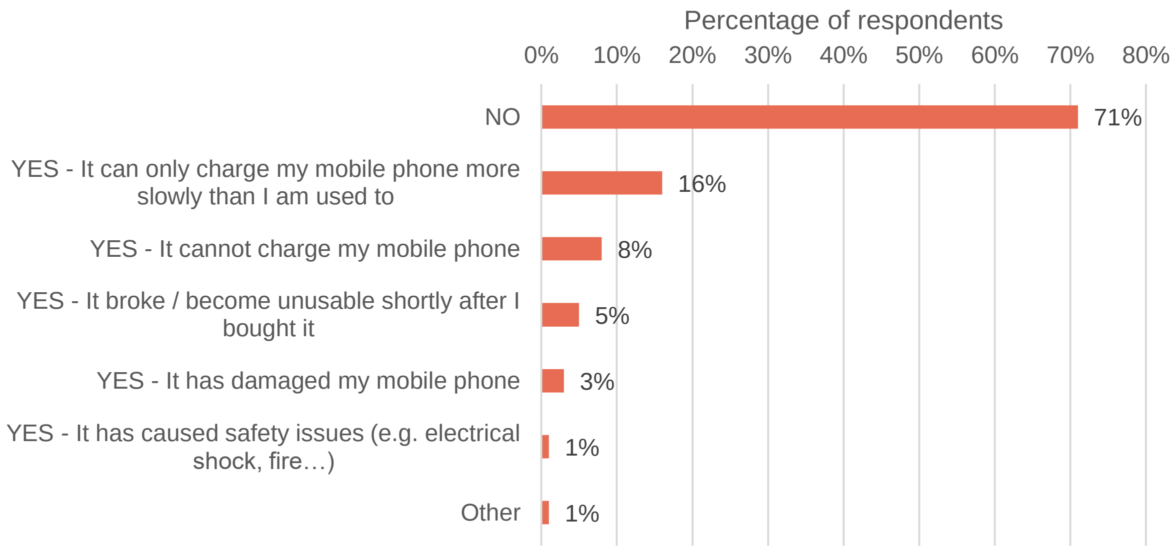


Source: Ipsos (2021), consumer survey. N=1,841.

An additional question tried to understand whether the consumers who had bought a stand-alone charger had also experienced problems with the EPS. As shown in Figure 24, 71% of respondents reported no problems or difficulties with the EPS. However, 16% reported that the new stand-alone EPS charged their phone more slowly than normal, 8% found that it could not charge their phone at all, 5% that it broke or became unusable shortly after purchase, and 3% that it caused damage to their mobile phone. Only 1% reported having had safety issues as a result of using their sand-alone charger. Another 1% indicated that it caused 'other' issues.

Figure 36: Problems with stand-alone EPS

Question: Thinking of the last mobile phone charger (EPS) you bought: have you encountered any problems or difficulties with this?

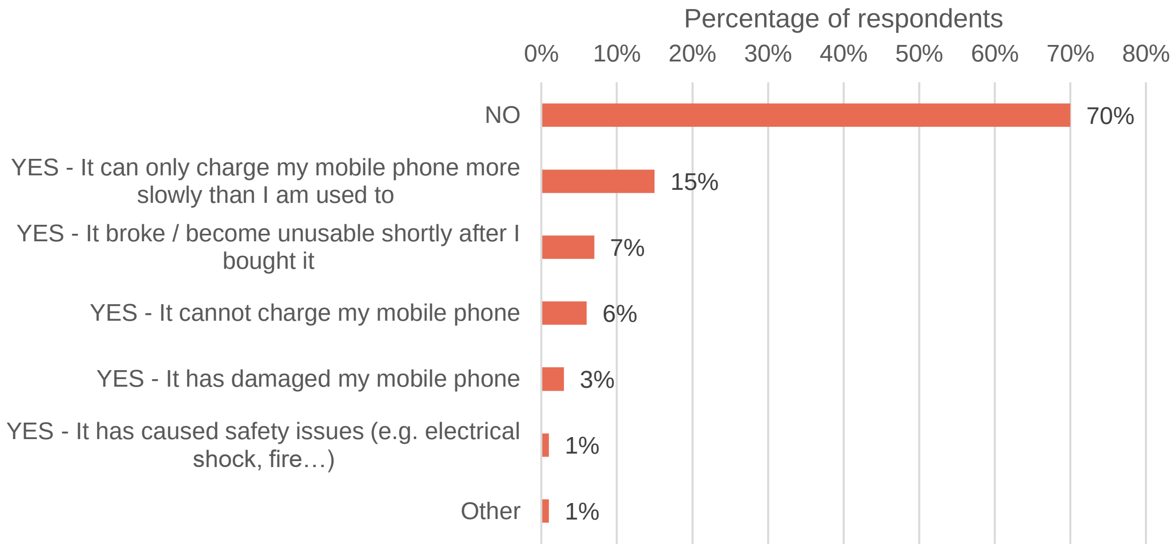


Source: Ipsos (2021), consumer survey. N=1,841.

The same question was asked about the cable assembly, and the responses are presented in Figure 25. Overall, 70% of respondents did not experience any problems or difficulties with the cable they bought separately. Nevertheless, 15% reported experiencing slower charging compared to usual, 7% that the cable broke or became unusable quickly, and 6% reported not being able to use the cable to charge their phone. As in the case of Figure 19, 1% experienced safety issues with the cable and 1% 'other' issues.

Figure 37: Problems with stand-alone cables

Question: Thinking of the last mobile phone charging cable you bought separately: have you encountered any problems or difficulties with this?



Source: Ipsos (2021), consumer survey. N=1,841.

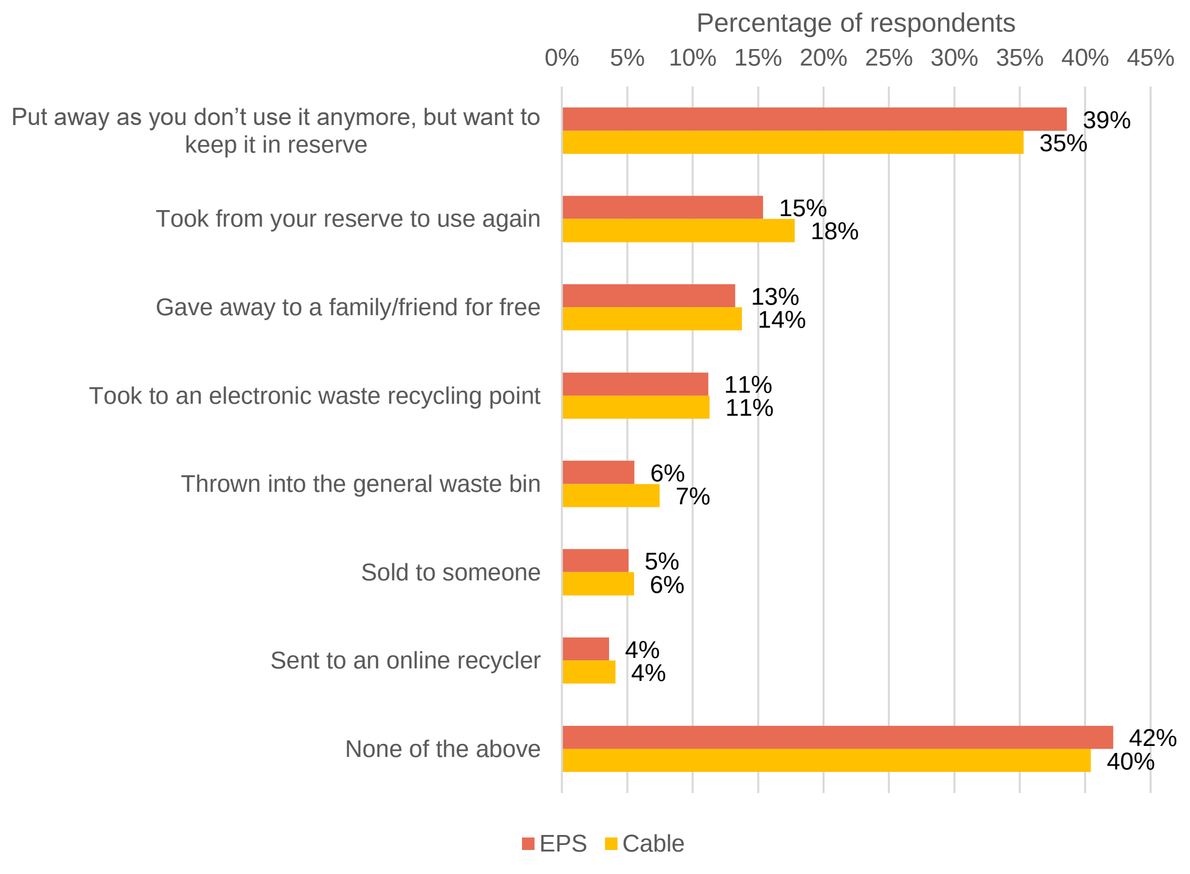
Do consumers re-use or dispose of old chargers?

The survey also explored consumers' behaviours when it comes to having multiple (old) chargers at home, and the results are illustrated in Figure 38.

Responses do not vary considerably between EPS and cable. When responses have spare chargers, they tend to keep them in storage (39% for EPS, 35% for cables). Some have started re-using old charging accessories, especially cables (18%), but also EPS (15%). Respondents also gave their old chargers to relatives or friends for free (13% for the EPS, 14% for the cable). When disposing of them, 11% correctly recycled both EPS and cable and 4% sent them to an online recycler (both cable and EPS), whilst a slightly smaller share threw them in the general waste bin (6% for the EPS, 7% for the cable component). Selling old chargers was not overly common (5% sold their EPS, 6% their cables). However, around 40% did not do any of these.

Figure 38: Use of old chargers

Question: In the last 24 months have you retired, discarded or re-used any mobile phone chargers? For EPS and cables separately.



Source: Ipsos (2021), consumer survey. N=5,010.

2. Stakeholder survey

The following section presents the findings from the stakeholder survey conducted via EU Survey to explore stakeholders' views on the common charger and unbundling initiatives, as well as understanding the perceived benefits, risks, and anticipated market reactions to unbundling. A total 121 stakeholders responded the survey from the 9 December 2020 until the 25 January of 2021.

Stakeholders' profile

Out of all stakeholders who contributed to the survey, 84% of these were based in the EU, with the remainder based in Asia (8%), North America (4%) or elsewhere in Europe (4%). Respondents included private citizens (31%), private companies (23%), public authorities (23%), and civil society organisations (18%). The private company respondents were approximately evenly split between representatives of manufacturers of mobile phones and similar devices on the one hand, and representatives of other sectors (including manufacturers of other products, retailers and wholesalers) on the other.

Stakeholders' views on the Common Charger Initiative

Survey results reveal stakeholders' support towards the implementation of a common charger legislation for mobile phones; as shown in Figure 27, over four in five respondents (85%) strongly agreed or tended to agree with the idea of making all EPS interoperable with all mobile phones. Figure 33 shows that support was higher among public authorities (96% supporting it) and civil society organisations (86%) compared to private companies (61%) and private citizens (75%).

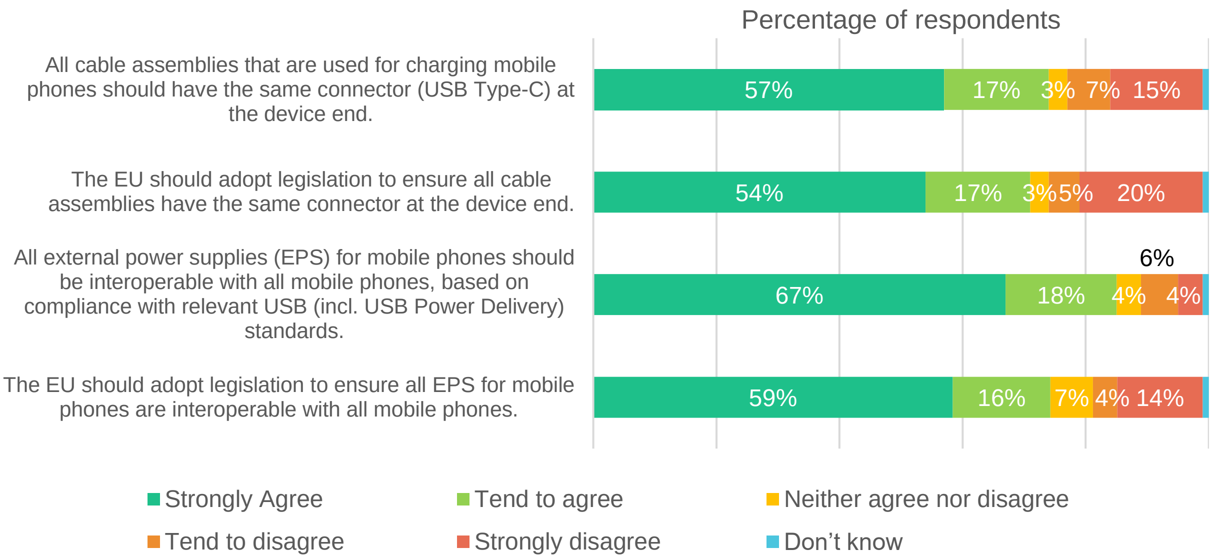
Almost three in four respondents (74%) also agreed with the initiative of harmonising the connectors at the device end of all cable assemblies used for charging mobile phones. Similarly, support was higher among public authorities (86% support), civil society organisations (73%) and private citizens (74%), compared to private companies (61%).

As shown in Figure 39, most stakeholders also agreed that EU legislation should be adopted to achieve this harmonisation of connectors (71% of respondents strongly agreeing or tending to agree with this), and interoperability of EPS, an initiative supported by 75% of respondents.

When asked about the product scope of a potential common charger initiative – hence, the products to which this should be applied – 53% of respondents agreed with the idea of adopting both a common connector and EPS for mobile phones, tablets and e-readers. At least 40% of respondents also suggested applying the initiative to other portable electronic devices such as wireless headphones, digital cameras, portable speakers, laptops or videogames.

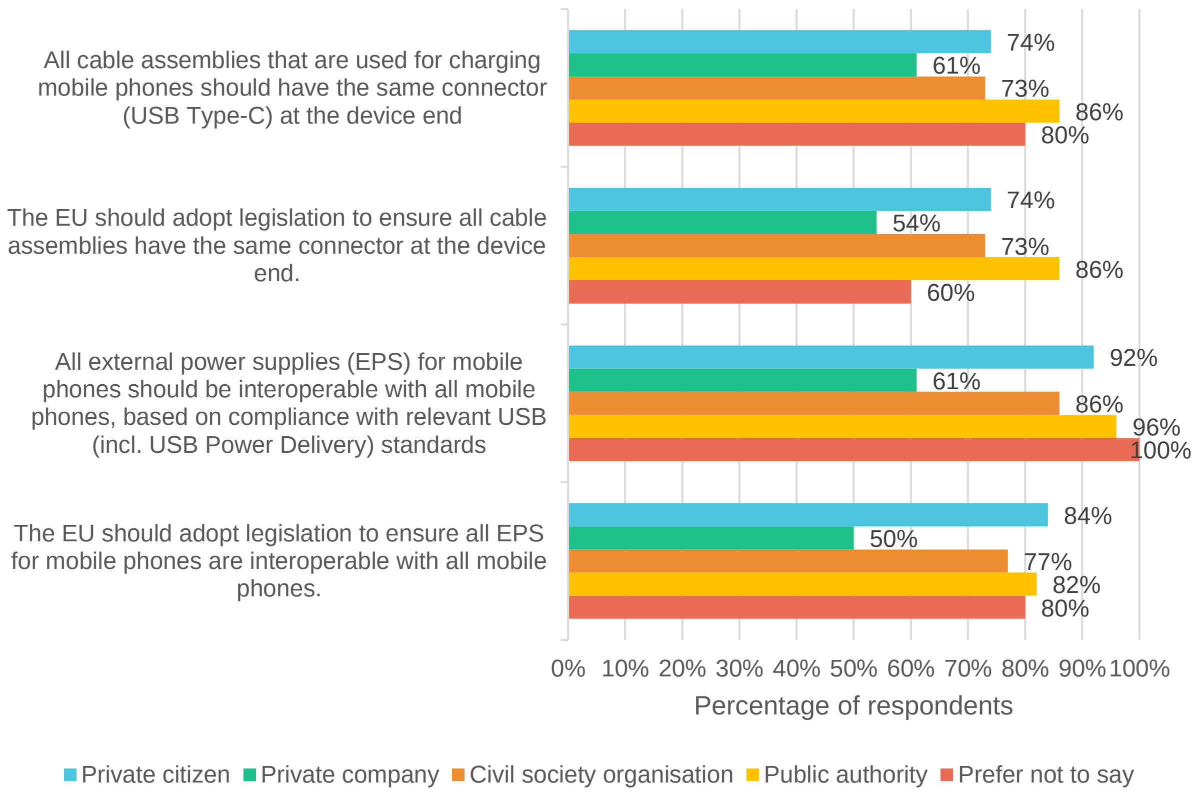
Figure 39: Stakeholders' views on the Common Charger Initiative

Question: The European Commission is considering adopting legislation to facilitate a "common charger" for all mobile phones. Do you agree or disagree with the following statements?



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

Figure 40: Percentage of agreement (strongly agree and tend to agree) towards the Common Charger Initiative per stakeholder group



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

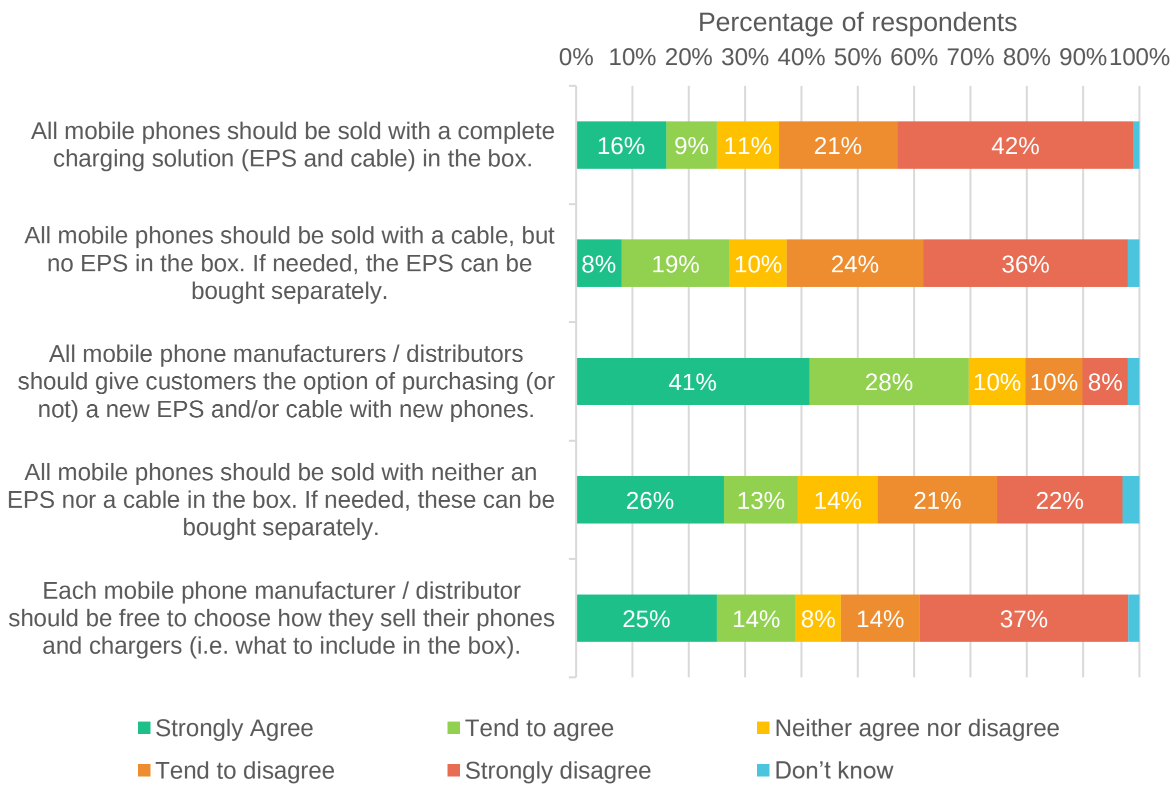
Stakeholders' attitudes towards unbundling

The survey responses reveal stakeholders' support towards decoupling initiatives. As shown in Figure 41, 63% of respondents were opposed to the idea of all mobile phones being sold with a complete charging solution (EPS and cable) in the box. Opposition was higher among civil society organisations (82% opposed) compared to private companies (61%), private citizens (58%) and public authorities (57%). At the same time, approximately three in four respondents agreed that unbundling measures should be applied to mobile phones (76% supporting this view), tablets (75%), e-readers (72%), portable speakers (63%), wireless headphones (62%) and digital cameras (60%). Over half of respondents considered that these measures could also be applied to laptops (58%), smartwatches and fitness trackers (55%), radio-controlled toys (55%) and videogame devices (55%).

Results also show that stakeholders support the idea of mobile phone manufacturers and distributors allowing customers to decide whether to purchase (or not) an EPS or cable with their phones, with 69% of respondents agreeing with this approach. As shown in Figure 42, this idea was strongly supported by 82% of civil society organisations, 76% of private citizens, and 71% of public authorities, yet only by 50% of private companies.

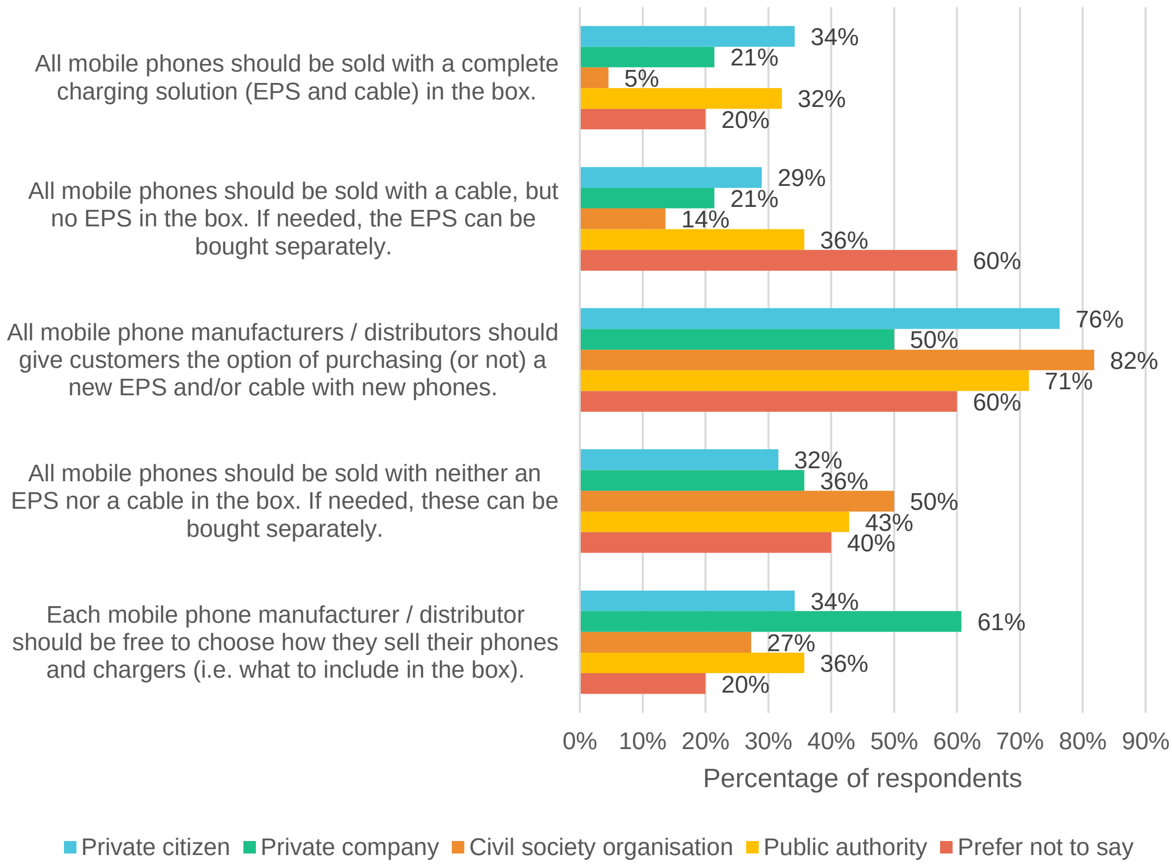
Figure 41: Stakeholders' views on mobile phone unbundling

Question: The European Commission is also considering a possible initiative to foster "de-coupling" or "unbundling", so that mobile phones are no longer routinely sold with a charger in the box. Do you agree or disagree with the following statements?



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

Figure 42: Percentage of agreement (strongly agree and tend to agree) towards unbundling of chargers from mobile phones per stakeholder group



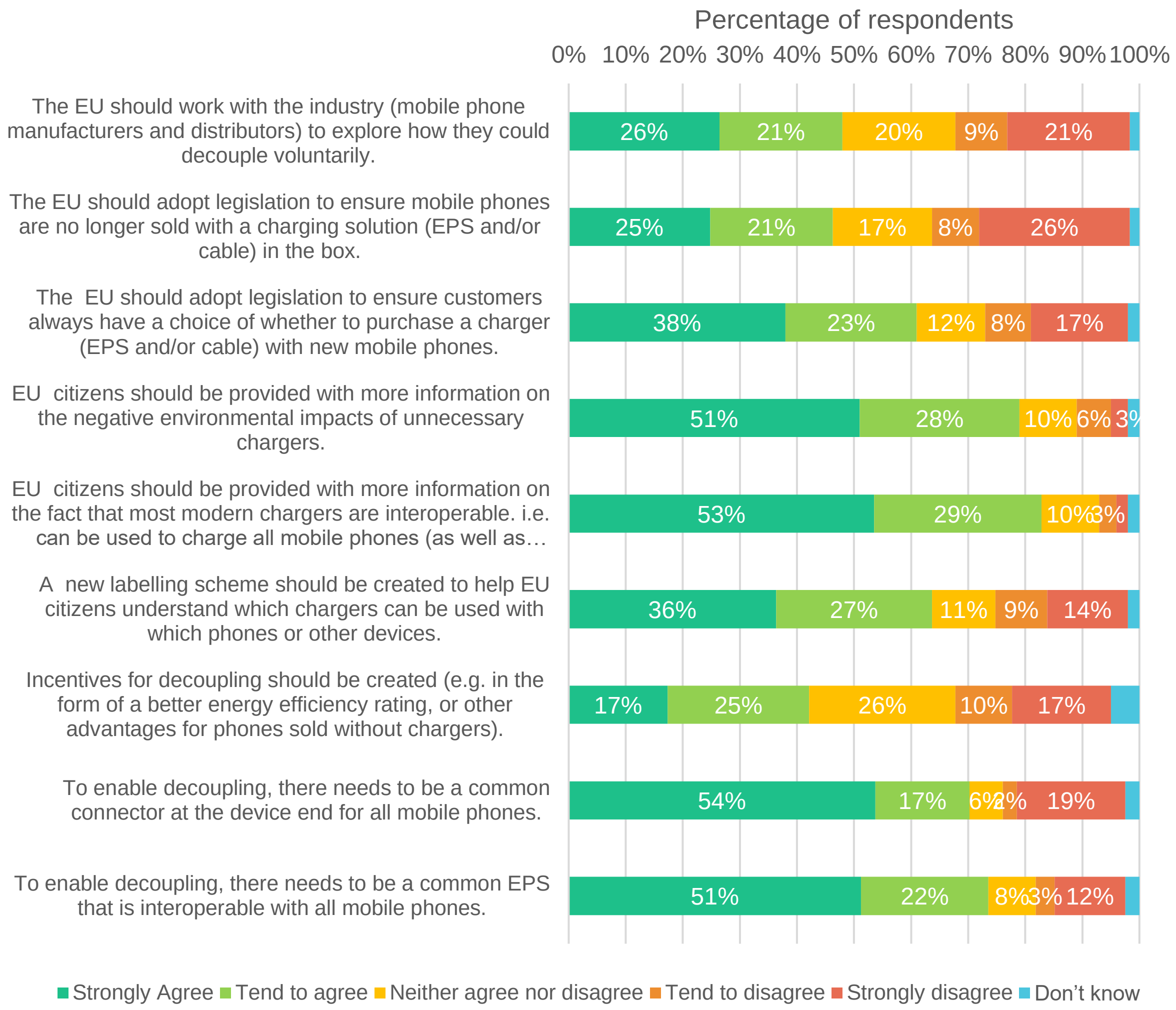
Source: Ipsos (2021), stakeholder survey. N=121, all respondents

Regarding stakeholders' views on how to facilitate unbundling, Figure 43 shows that 82% of respondents agreed with providing EU citizens with more information on chargers' interoperability, and 79% agreed with providing more information on the negative environmental impacts of unnecessary chargers. Other initiatives supported by over half of respondents include adopting a new labelling scheme to help citizens understand which chargers can be used with their devices (63% support) or adopting EU legislation to ensure customers have the opportunity to choose whether they want to purchase EPS and/or cable with their new phones (61% support). As shown in Figure 32, this last initiative was supported by 77% of civil society organisations and 74% of private citizens but only by 43% of private companies.

Finally, while almost half of respondents (46%) supported the idea of implementing EU legislation to ensure EPS and/or cables are not included in mobile phones' boxes, Figure 32 shows that this initiative was only supported by 32% of private companies and 47% of private citizens.

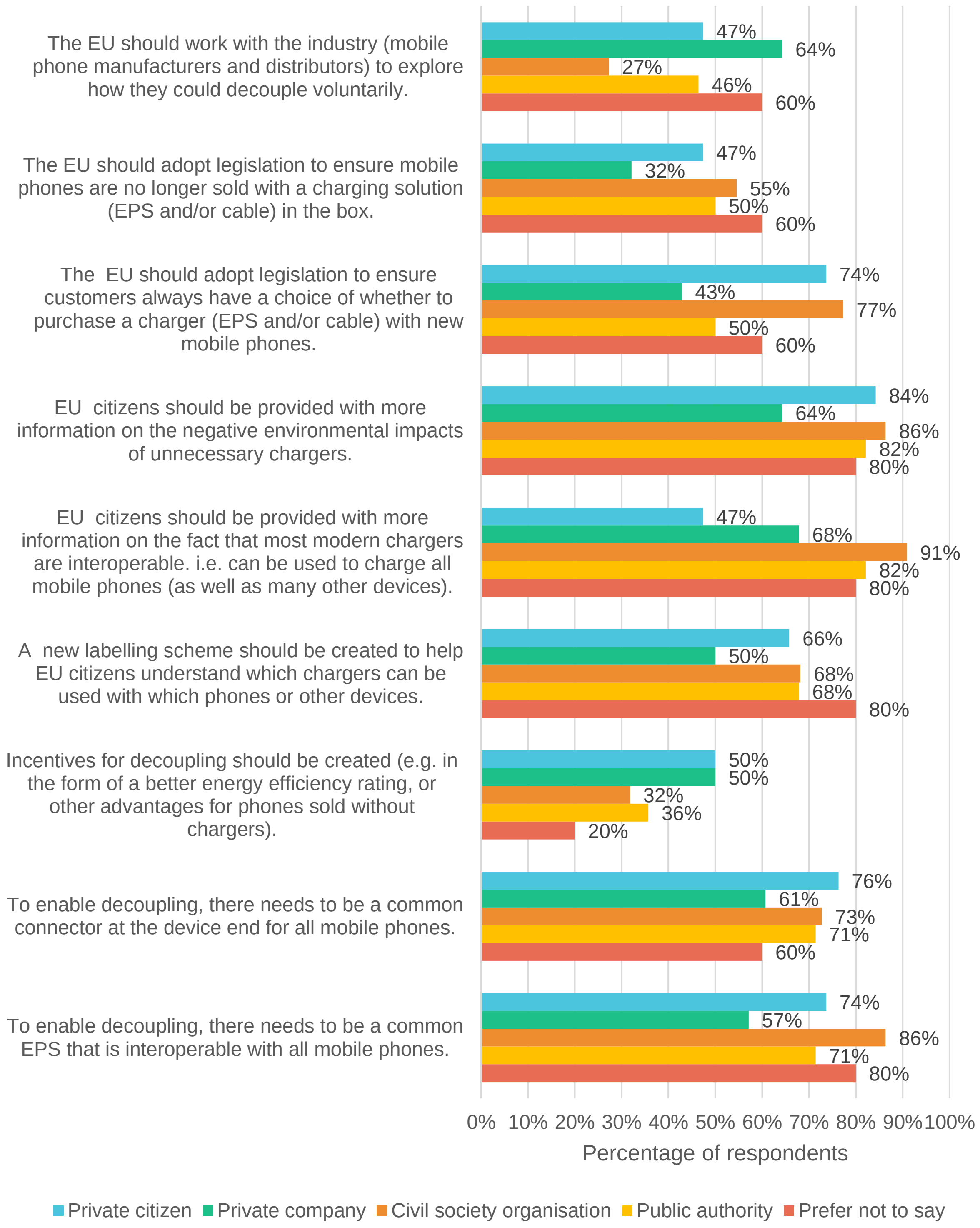
Figure 43: Stakeholders' views on how to facilitate unbundling of chargers from mobile phones

Question: A range of options to facilitate the decoupling of chargers from mobile phones could potentially be considered. Do you agree or disagree with the following statements regarding such measures?



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

Figure 44: Percentage of agreement (strongly agree and tend to agree) towards how to facilitate unbundling per stakeholder type



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

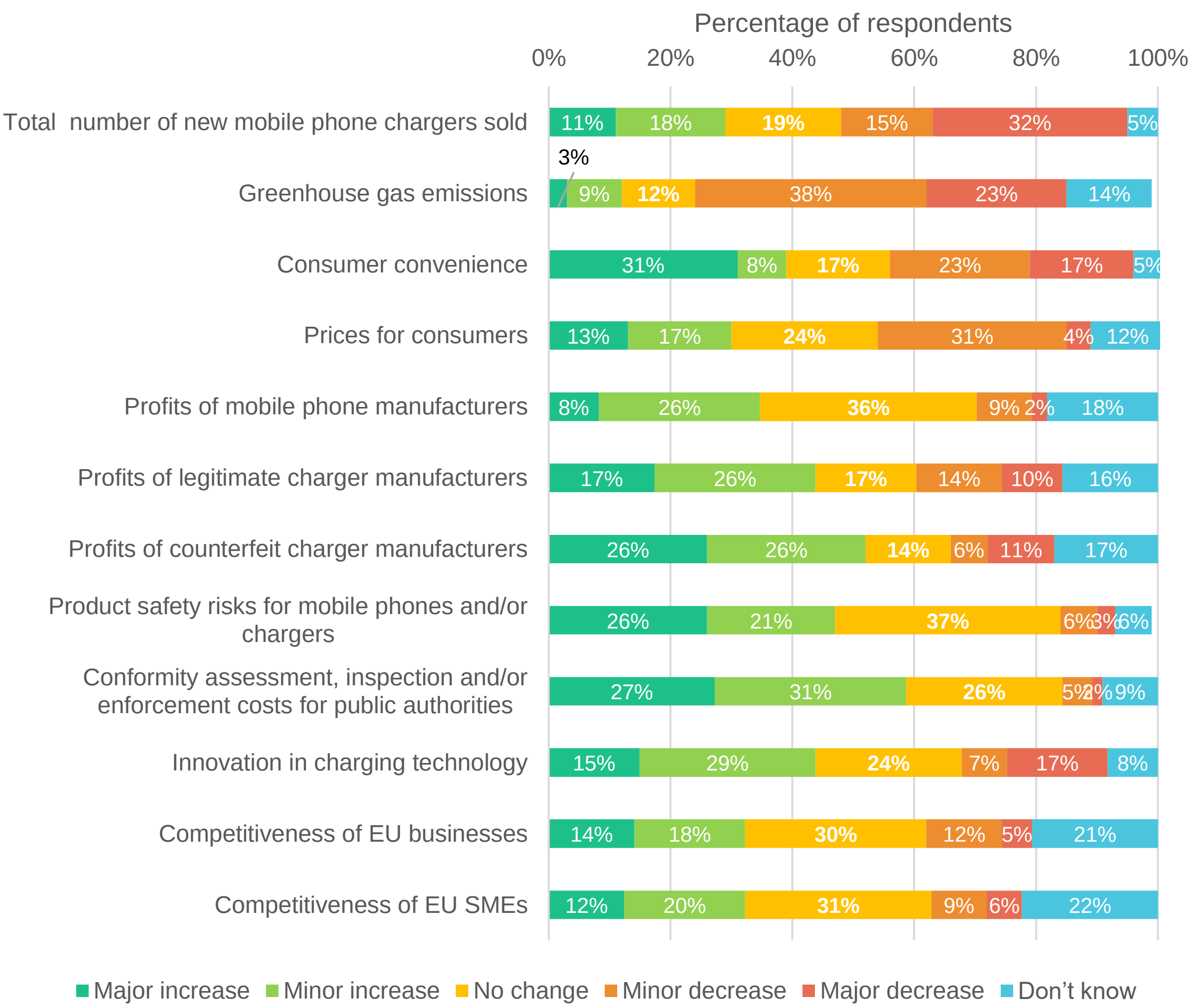
Perceived benefits and risks of unbundling

Respondents anticipated different benefits and risks from the widespread unbundling of chargers from phones in the EU. As shown in Figure 45, the most common changes include:

- Decrease in greenhouse gas emissions (61% of respondents anticipate a net decrease);
- Increase in conformity assessment, inspection and/or enforcement costs for public authorities (58% of respondents anticipate a net increase);
- Increase in profits of counterfeit charger manufacturers (52% of respondents anticipate a net increase);
- Increase in product safety risks for mobile phones and/or chargers (47% of respondents anticipate a net increase);
- Decrease in the total number of new mobile phone chargers sold (47% of respondents anticipate a net decrease).

Figure 45: Anticipated changes of widespread unbundling of chargers from mobile phones

Question: What impacts do you expect would follow from widespread decoupling of chargers from phones in the EU (i.e. a situation where most mobile phones are sold without a charger 'in the box')? Would you expect each of the following aspects to increase, decrease, or remain broadly unchanged?



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

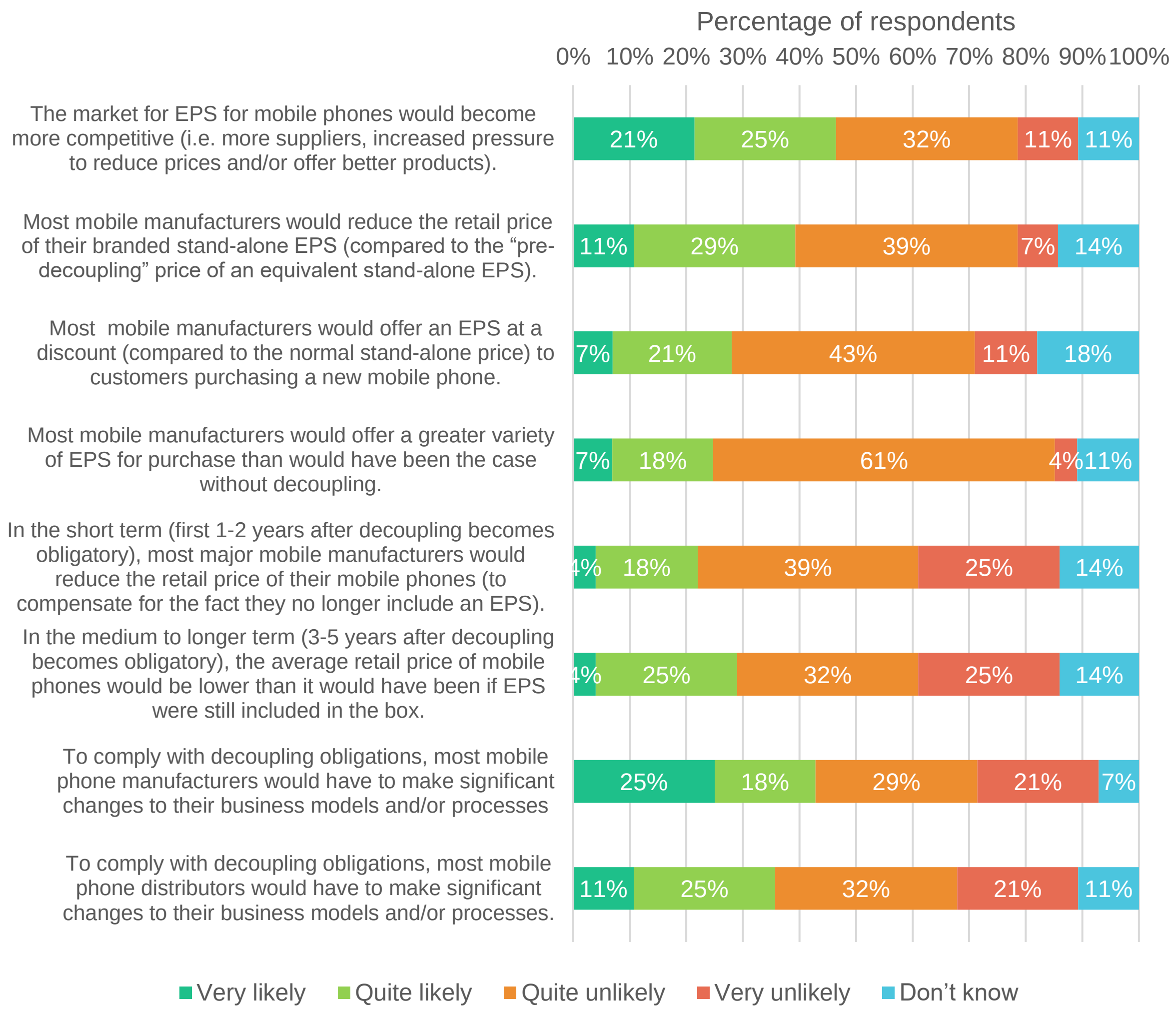
Anticipated market reactions to unbundling

Finally, private companies were asked to provide their views on the likelihood of different market reactions to making the unbundling of EPS from phones mandatory. As shown in Figure 46, over half of respondents stated that, if unbundling is made mandatory in the EU:

- Unlikely changes in EPS variety - It is unlikely that mobile manufacturers will offer a greater variety of EPS for purchase than would have been the case without unbundling (65% of respondents thought it is quite/very unlikely)
- Unlikely changes in mobile phones or EPS prices - It is unlikely that in the short, medium or longer term the retail price of mobile phones will be reduced (64% of respondents thought it is quite/very unlikely for this to happen in the short term; 57% of respondents thought it is quite/very unlikely to happen in the long term) or that that EPS are offered at a discount to customers purchasing a new mobile phone (54% of respondents thought it is quite/very unlikely)
- Unlikely changes to business models - It is unlikely that, to comply with unbundling obligations, most mobile phone manufacturers or distributors will have to make significant changes to their business models and/or processes (53% of respondents thought it is quite/very unlikely that phone distributors will change their business models; 50% thought it is quite/very unlikely that this applies to phone manufacturers)

Figure 46: Anticipated impacts of mandatory unbundling as perceived by industry stakeholders

Question: If mobile phone manufacturers and distributors were obliged (be it via a voluntary industry commitment or via regulation) to decouple the EPS from the phone (i.e. to no longer include an EPS in the box, but rather offer this as an optional accessory), how do you think the market would react? How likely would the following be to occur?



Source: Ipsos (2021), stakeholder survey. N=121, all respondents

Annex D: List of interviewees

Stakeholder type	Organisations interviewed	Number of organisations interviewed
Public authorities (standardisation bodies and national authorities)	• French Market Surveillance Authority • CEN-CENELEC • ITU-T Study Group 20	3
Industry associations	• Airfuel Alliance • Digital Europe • Eurocommerce • GSMA • Information Technology Industry Council • The App Association • USB Implementers Forum	7
Private companies (representing manufacturers of electronic devices and manufacturers of chargers)	• Anker • Apple • Fairphone • Google • HMD / Nokia • HP Inc • Huawei • Jabra • JBL/Harman • Lenovo • Olympus / OM Digital Solutions • Oppo • Portway • Power Integrations • Qualcomm • Samsung • Xiaomi	17
Consumer organisations	• ANEC • European Disability Forum	2
Environmental and recycling organisations	• ECOS • EuRIC • Landbell Group • Viegand Maagøe	4
Total stakeholders interviewed		**33**

Annex E: Mapping of environmental schemes

This chapter maps existing and foreseen environmental schemes for electronic devices that aim to increase energy efficiency or reduce e-waste and could be potentially implemented for decoupling of mobile phones and other electronic devices. Identifying and mapping such relevant schemes allows us to identify those that could facilitate the decoupling of mobile phones and other electronic devices and explore how these could be designed and implemented.

Accordingly, we first present in subsection *First Impact Screening*, an initial assessment of a selection of instruments and environmental schemes addressing the reduction of (e-)waste (WEEE: Waste Electrical and Electronic Equipment) and/or increasing energy efficiency. Building upon the results of this first screening, we present in subsection *3.2. In-depth analysis of selected schemes* an expanded analysis of the schemes identified as highly relevant. These results informed the identification of potential policy options (see section 6).

First impact screening

The table overleaf presents a selection of instruments and environmental schemes addressing the reduction of (e-)waste and/or increasing energy efficiency. For each of the instruments, we provide illustrative examples within the WEEE sector (when available) and from other sectors in the EU and outside. Further, our assessment classified the different policy options into three main categories as follows (some of the schemes were placed under more than one):

- **Regulatory:** This includes mandatory tools that ban or limit certain products or behaviours. In principle, this could include an outright ban on the sale of chargers with phones, or a legal obligation for distributors to offer consumers the option of acquiring a phone either with or without a charger.
- **Economic:** This category includes market-based instruments that influence purchasing decisions through taxes, fiscal incentives, subsidies, penalties, or grants for green enterprises or products. Softer economic incentives could include demand-side measures, such as enhancing demand via public procurement.
- **Information and behavioural:** This category entails information campaigns to stimulate demand for unbundled solutions or to 'nudge' consumer behaviour, inter alia by raising awareness of the environmental benefits of reducing their numbers, pledges to adopt certain behaviours, or making pro-environmental alternatives the default. It can also include new/enhanced labelling and/or certification requirements.

Finally, the last column of the table includes an assessment of the relevance, using a 3-point scale (Low, Medium, High) to describe the potential application of each of the schemes for the decoupling of mobile phones and other electronic devices. We assessed the relevance by taking into account the level of potential environmental impact that such a policy action may have, the window of opportunity of the EC to move such an instrument/scheme forward based on the current regulatory framework and initiatives in place (e.g. Green Public Procurement, Eco-design Regulation, EU Circular Action Plan), and the appropriateness of the instrument/scheme to be applied to the mobile phone and charger markets considering the experience with other products categories (e.g. PET bottles recycling industry).

Moreover, we have considered the views of external experts to include further schemes or policies that offer useful insights. Also, as part of the stakeholder survey and interviews, we have invited stakeholders to identify and point us to potentially relevant schemes. We have used these inputs to expand the list of schemes and identify the most relevant to the task.

Table 5: Selection of environmental schemes and their relevance for electronic devices management [13]

Instrument / Schemes	**Type**	**Examples**	**Assessment of relevance**
Subsidies or tax credits for services supporting circularity	Economic	**Alteration to taxes on circular economy-based products**, such as the UK Plastic packaging tax. This is a new tax that applies to plastic packaging produced in or imported into the UK that does not contain at least 30% recycled plastic. Imported plastic packaging will be liable to the tax, whether the packaging is unfilled or filled. The tax will take effect from April 2022.	**Low** – does not address e-waste generation or volumes, although reduces the impact of e-waste. EU has no/limited influence on fiscal measures
		Alteration of taxes to facilitate the development of circular trading platforms, such as (the now-defunct) Circle Market Platform developed in the Netherlands, connecting post-industrial, pre-consumer, and post-consumer excess to reuse and recycling markets. This can include VAT exceptions for products and resources sold through such platforms, or governmental support for the private sector to launch such circular trading platforms.	**Low** – does not address e-waste generation or volumes, although reduces the impact of e-waste. EU has no/limited influence on fiscal measures
		Alteration of taxes to foster repair of products. In 2016, in Sweden, the VAT for repair dropped from 25 % to 12 %, to incentivise shifts to repair services for a wide range of products in Sweden so that they last longer. In 2019, the Korean government drew up a plan to amend the act on the promotion of saving and recycling of resources, under which the Korean ministry of environment will classify containers into four grades — the best, good, fair and bad. The best grade will receive incentives, and the bad grade should pay 30% extra.	**Medium** – improved durability has a role in reducing e-waste. EU has no/limited influence on fiscal measures
Innovation funding to develop durable and/or recyclable materials and promote the creation of related start-ups or associations	Information and behavioural/ Economic	An example is the **Versnellingshuis Nederland Circulair (Acceleration House Netherlands Circular)**. In 2019, the Dutch government and various partners set up the *Versnellingshuis Nederland Circulair* to assist entrepreneurs in scaling up circular business models. Entrepreneurs can ask questions about knowledge, financing and legislation and regulations. The Versnellingshuis also helps CE by giving entrepreneurs access to an extensive network of cooperation partners.[14]	**Medium** – improved durability has a role in reducing e-waste. Innovation funding is within EU scope, though impact on waste is indirect and direct benefit would be to (mainly) non-EU manufacturers.

[13] The information in the table is based on various sources, including: Kautto, Petrus, and David Lazarevic. "Between a policy mix and a policy mess: Policy instruments and instrumentation for the circular economy." *Brandão, M., D. Lazarevic, G. Finnveden, G.(Eds.), Handbook of the Circular Economy. Edward Edgar Publishing* (2020). Available at: https://www.researchgate.net/publication/340861379_Between_a_policy_mix_and_a_policy_mess_Policy_instruments_and_instrumentation_for_the_circular_economy; and Hartley, Kris, Ralf van Santen, and Julian Kirchherr. "Policies for transitioning towards a circular economy: Expectations from the European Union (EU)." *Resources, Conservation and Recycling* 155 (2020): 104634. Available at: https://www.sciencedirect.com/science/article/pii/S0921344919305403

[14] Versnellingshuis CE https://versnellingshuisce.nl/. Accessed on 18.11.20

Instrument / Schemes	Type	Examples	Assessment of relevance
Using public procurement to create demand for circular products and services.	Regulatory	**The EU Green Public Procurement** criteria were developed to facilitate the inclusion of green requirements in public tender documents. In 2020, the *Revision of the EU GPP criteria for computers and monitors (and extension to smartphones)*[15] aimed at helping public authorities to ensure that ICT equipment and services deliver environmental improvements that contribute to European policy objectives. The 2020 revision includes new criteria related to both the durability and interoperability of chargers. For instance, public tenders would be required to ensure that joining or sealing techniques applied to the EPS for tablets, notebooks and desktops do not prevent the replacement of the parts. Moreover, tenders would be awarded additional if EPS are provided with detachable cables and if the offered equipment is available without EPS (unbundled). At the national level, the **Green Deal Circular Purchases (GDCA) (Belgium)** is a voluntary agreement between (private) partners and the Flemish government, aiming to decrease the uncertainty about CE products and help buyers to change their procurement proceedings. Over 150 participating organisations have committed to collectively applying or facilitating this procurement method.[16]	**Medium** – efforts to expand related policies to the use of EPS are already in place.
Deposit – Return Schemes (A surcharge is paid when purchasing and repaid once the used product is returned)	Economic	One of the key actions related to electronics included in the EU Circular Action Plan (CEAP)[17] is the improvement of the collection and treatment of electronic waste by "*exploring options for an EU-wide take-back scheme to return or sell back old mobile phones, tablets and chargers*". According to the CEAP Implementation tracking table prepared by the EC[18], the action related to *reward systems to return old devices* is planned for 2021. Examples of similar schemes include the programme Denver Recycles, which offers Denver residents an "E-cycle Coupon" for recycling televisions, monitors, and other electronic items.[19] Besides, Deposit-Return schemes have proved to be very successful in other sectors, such as plastics recycling. In	**Medium** – returned chargers likely to be obsolete or approaching end-of-life, cost-benefit may be too small.

[15] JRC (2020). EU Green Public Procurement Criteria revision for Computers and Monitors. Technical report v2.0.Draft criteria. Retrieved from: https://susproc.jrc.ec.europa.eu/product-bureau//sites/default/files/2020-07/200616_Technical_Report_GPP_Computers_v2.pdf

[16] https://vlaanderen-circulair.be/en/retrospect

[17] European Commission (2020) Circular Economy Action Plan – For a cleaner and more competitive Europe. Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

[18] Quick Reference on CEAP Implementation (2020). Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/implementation_tracking_table.pdf

[19] City and County of Denver (2020) E-cycle Coupon Program. Retrieved from: https://www.denvergov.org/content/denvergov/en/trash-and-recycling/recycling/electronics-recycling.html

Instrument / Schemes	Type	Examples	Assessment of relevance
		Germany, a successful deposit-return scheme collects approximately 98% of all PET bottles.[20] Similarly, in China, between 2012 and 2015, the Incom recycling company collected around 18 million empty PET bottles with over 2,200 RVM in the Beijing.[21]	
Promote the establishment of WEEE Donation Centres for recycling and refurbishment	Information and behavioural	The European initiative Right to repair[22] brings together repair groups and cafés aiming to inform citizens and consumers about the opportunities and barriers to their right to repair and involving them in campaigning activities. For instance, in Paranduskohvik[23], a repair café in Tartu (Estonia) volunteers repair and 'upclycle' broken household items. To support the grow of repair cafés in Europe, the EU-project Interreg Europe presented in January 2021 a guide for entities wanting to open a Repair Café.[24] According to the 2019 annual report by Repair Café International, 2,000 repair cafés worldwide prevented an estimated of 420,000 kilos of waste in 2019.[25] In the US, the Goodwill Industries in the US receive electronics donated through Donation Centers[26] for recycling and refurbishment. The company is able to employ and train people with disabilities and disadvantages in the recycling and refurbishment of computers and other electronics. Revenue from these operations is reinvested within the communities the organization serves.	**Medium-** improved collection rates for refurbishment have a role in reducing e-waste but role for policy is unclear.
Sustainable Product Service Systems (SPSS)[27] The core concept of these models is that businesses retain ownership on the product and rather sell a	Economic, Information and behavioural	In the Netherlands, Signify (formerly Philips Lighting) sells lighting as a service, and in the UK, Rolls Royce sells aeroplane engine time rather than jet engines. Dell in the US already has "PC as a Service".[28] In the US, A2C Services is an example of a SPSS scheme that has effectively increased the life cycle of its products. The company processed 700,000 desktops	**Medium** – may be potential in expanded producer responsibility but it is unlikely that a product leasing type business model be relevant for chargers. The role of policy is not clear.

[20] EPA Network (2018) Deposit - Return Schemes Data and figures from 16 member countries of the EPA Network https://plonesaas.devel4cph.eea.europa.eu/epanet/reports-letters/reports-and-letters/ig-plastics_working-paper_deposit-return-schemes.pdf

[21] Ecobusiness (2016). Press release. Two innovators helping to improve recycling in China. Retrieved from: https://www.eco-business.com/news/two-innovators-helping-to-improve-recycling-in-china/

[22] https://repair.eu/privacy-policy/

[23] European Commission (2020) Repair Café from MTÜ SPARK Makerlab https://ec.europa.eu/clima/sites/clima/files/eu-climate-action/pact/esc_repair_cafe_en.pdf

[24] InterregEU (2021) Guide to opening a Repair Café. Retrieved from: https://www.interregeurope.eu/2lifes/news/news-article/10876/guide-to-opening-a-repair-cafe/

[25] Repaircafe.org (2019) Jaarverslag 2019. Retrieved from: https://www.repaircafe.org/repair-cafes-voorkomen-420-000-kilo-afval-in-2019/

[26] https://www.goodwillsew.com/good-to-know-newsletter/electronics-recycling-q-a-with-goodwill-e-cycle

[27] JRC (2020) Guidance for the Assessment of Material Efficiency: Application to Smartphones

[28] World Economic Forum (2019) A New Circular Vision for Electronics. Time for a Global Reboot. Platform for Accelerating the Circular Economy (PACE). http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf

Instrument / Schemes	Type	Examples	Assessment of relevance
service to consumers		and laptops from 2013 to 2015 to remanufacture 99% of compliant end of-lease ICT, extending the useful life of 3- to 5-year-old PCs.[29]	
Improve labelling to assess the energy efficiency of bundled/unbundled products	Information and behavioural	Under the EU Energy Labelling Directive an implicit incentive to manufacturers for unbundling of the external EPS from the display was provided in the methodology for calculating the energy efficiency of the display[30]. This provides that if a (necessary) external EPS was not supplied with the display that the product could be assessed without the EPS (and its consequent energy losses), and the label would indicate the unbundling. This is hoped to incentivize the diffusion of standardised external power supplies which would have a multi-fold relevance in terms of reparability, durability, health, and recyclability.	**Medium** –energy efficiency labelling unlikely to be a major issue for chargers as energy use is only a few kWh per year. The labelling mechanism can be interesting. To be addressed through the Energy Labelling Directive (and Ecodesign) rather than this initiative
Minimum Energy Performance Standards (MEPS)	Regulatory	Since 2019, the Ecodesign Regulation[31] sets the (minimum) energy efficiency requirements for external power supplies. In accordance, the EC Communication on the Ecodesign requirements for EPS presents an indicative target on energy saving for EPS: about 4.3 TWh electricity can be saved by 2030, corresponding to 1.45 million tonnes of CO_2 Equivalent.[32] In Australia and New Zealand, EPS are covered by energy efficiency regulations based on MEPS.[33]	**Medium,** more stringent energy efficient requirements have a role in reducing energy consumption, but current regulation already addresses this issue. Future Ecodesign revisions could address the material efficiency aspects of EPS, to be addressed under Ecodesign.
Development of a digital "Product Passport" for EPS	Information and behavioural	The Ecodesign and Energy Labelling Working Plan (EELWP 2020-2024)[34] introduces the development of a digital "Product Passport" to provide information on a product's origin, composition, repair and dismantling possibilities, and end of life handling, as well as interlinkages to other product information systems.	**Medium,** if included under existing certification schemes.
Ban on selling bundled certain electronic devices and services	Regulatory	In the past, the European Union has pursued unbundling of broadband services, as most EU countries were served by a monopoly telephone	**Medium** – directly addressed unbundling, although focus was service offerings and competition. Direct regulatory action could

[29] UK Government Office of Science (2017). From waste to resource productivity. Evidence and case studies

[30] https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/televisions/tv-energylabelling-mars2019.pdf

[31] European Commission (2019) Commission Regulation (Eu) 2019/178 of 1 October 2019 laying Down Ecodesign Requirements For External Power Supplies Pursuant To Directive 2009/125/Ec of The European Parliament And Of The Council And Repealing Commission Regulation (Ec) No 278/2009

[32] Ibid.

[33] https://www.energyrating.gov.au/products/external-power-supplies

[34] Euroepan Commission (2020) Draft report. Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 (Task 3, preliminary analysis of product groups and horizontal initiatives) Retrieved from: https://www.ecodesignworkingplan20-24.eu/documents

Instrument / Schemes	Type	Examples	Assessment of relevance
		company.[35] In fact, the European Commission decided in 2002 to open infringement proceedings against Germany, France, Ireland, the Netherlands, and Portugal concerning the Regulation on Unbundling of the Local Loop.[36] The Regulation made compulsory the unbundling of and shared access to the local copper loop controlled by the incumbent operators.[37]	be possible through a horizontal Ecodesign measure.
Create a pictogram providing instant information on compatibility between chargers, cables and product	Information and behavioural	In the days when wireless local network protocols were coming to market and standardisation of IEEE 802.11 was on-going, The Wi-Fi term (as a play on words with Hi-Fi) and also a Wi-Fi pictogram was created indicating the certification of a product for interoperability. This labelling proved successful.	**High** – if unbundling would be mandatory, the consumer has to know if the product can work with a third-party or other OEM cable and changer.
Create an electronic label providing instant information on compatibility between chargers, cables and product	Information and behavioural	The EU Energy Label already includes a QR code which when scanned links to the product information sheet published in the EPREL database. Australia, Singapore, and the US have on average e-labels on 78-90% of smartphones, 82-86% of PCs and 81% of tables (in Australia)[38]. In India, the Ministry of Electronics and Information Technology (MeitY) in 2017 published a guideline for e-labelling.[39] Similarly, Russia has announced the introduction of electronic labelling of consumer electronics.[40]	**High –** if unbundling would be mandatory, the consumer has to know if the product can work with a third-party or other OEM cable and changer.
Create an Environmental labelling and information scheme (ELIS) to provide information on sustainability of chargers and cables	Information and behavioural	In Europe, the **EU Ecolabel** covers a wide range of product groups and since 1992 is awarded to products and services meeting high environmental standards throughout their life cycle: from raw material extraction to production, distribution, and disposal.[41] An example from the public sector can be seen in South Korea, where since 2010, the government started to grant Green Certificates to qualified industries, projects and technologies (with green technology	**High,** if included under existing certification schemes (e.g. EU-Eco label), but need to consider the impact on consumers, could be 'too much information' and confuse rather than aid consumers

[35] Wallsten (2014) The Incentive Effects of Wholesale Unbundling Regulation on Investment. Available at: https://services.crtc.gc.ca/pub/docwebbroker/opendocument.aspx?dmid=2068486

[36] European Commission (2002), Telecommunications: Commission Takes Further Action on Unbundling Infringement Proceedings Against Five Member States, Press Release (Brussels, March 20, 2002), http://europa.eu/rapid/pressrelease_IP-02-445_en.htm.

[37] Regulation (EC) No 2887/2000 of the European Parliament and of the Council of 18 December 2000 on unbundled access to the local loop.

[38] VVA (2018) Study for the introduction of an e-labelling scheme in Europe. Research into e-labelling schemes outside the EU.

[39] https://www.meity.gov.in/esdm/standards

[40] Noerr (2019) Russia: New developments in regulation of labelling and conformity assessments of goods. Retrieved from: https://www.noerr.com//en/newsroom/news/russia-new-developments-in-regulation-of-labelling-and-conformity-assessments-of-goods

[41] https://ec.europa.eu/environment/ecolabel/index_en.htm

Instrument / Schemes	Type	Examples	Assessment of relevance
		sales that account for more than 30% of its total sales).[42] In the US, **EPEAT[43]** is the leading global ecolabel for the IT sector, which provides independent verification of manufacturers' claims and lists sustainable products on an online registry. Several smartphone manufacturers are included in the EPEAT Registry[44], including Apple, Google and Samsung.	
Put forward specific (non-binding) recovery targets for EPS and cables	Regulatory	In the new EU Circular Action Plan (CEAP)[45], electronics and ICT are included among the products that will be given priority in the context of their value chains. According to the plan, the Commission will put forward waste reduction targets for specific streams as part of a broader set of measures on waste prevention. Today, the WEEE Directive[46] set collection, recycling, reuse, and recovery targets for 10 different groups of e-waste; however, there is no specific mention of EPS (see Article V, Annexes II and V). Outside the EU, examples of countries establishing recovery rates include Taiwan, where their Environmental Protection Agency (EPA) has published a new strategy based on the goals of "source reduction". Current plans include targets for use of recyclable or renewable materials in the production and consumption of waste.[47] In China, in 2019 the State Council of China issued the Work Plan for the Pilot Programme of "Zero Waste Cities", which includes promoting green mining, and solid waste recycling (key sectors: battery, electronics, automobile).[48]	**Medium –** as targets have shown to gain public attention and interest from other sectors.
Establish a colour-code in EPS' ports or/and cables to provide	Regulatory, Information and behavioural	USB connectors are often coloured-coded to tell what specification it is, as follows[49]: · Black USB connector: - USB 2.x. It was labeled 'Hi-Speed' because it had	**Low,** if unbundling would be mandatory, the consumer has to know if the product can work with a third-party

[42] Renault, J. et al (2019) Report on experiences with the implementation of Circular Economy outside Europe. CICERONE Project. Retrieved from: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c894509e&appId=PPGMS

[43] Green Electronics Council (n.d.) EPEAT Overview. https://greenelectronicscouncil.org/epeat/epeat-overview/

[44] EPEAT Registry. https://www.epeat.net/search-mobile-phones

[45] European Commission (2020) Circular Economy Action Plan – For a cleaner and more competitive Europe. Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

[46] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) Text with EEA relevance. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019

[47] Renault, J. et al (2019) Report on experiences with the implementation of Circular Economy outside Europe. CICERONE Project. Retrieved from: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c894509e&appId=PPGMS

[48] Ibid.

[49] Geeks in Phoenix (2014) How to tell what type of USB connector you have by color. https://www.geeksinphoenix.com/blog/post/2014/01/12/How-to-tell-what-type-of-USB-connector-you-have-by-color.aspx

Instrument / Schemes	Type	Examples	Assessment of relevance
information about interoperability		a maximum transfer rate of 480 Mbps (megabit per second) · Blue USB connector: USB 3.x It defines a new SuperSpeed mode, with transfer speeds up to 5 Gbps (gigabit per second). · Red or Yellow USB connector - Sleep and Charge, This color indicates that the connector does not power off during sleep or standby mode. This was applied, with mixed success for USB Type-A only, an equivalent for USB Type C is not in place.	or other OEM cable and changer. Lack of success of Type-A measures, suggests it would be challenging to implement.
Establish a durability index for EPS	Regulatory, Information and behavioural	From January 2021, electronics sold in France are required to have a repairability index (*l'indice de réparabilité)*, which is expected to set an example for other European countries. The score (grade out of 10) takes into consideration the ease of disassembly, price, and availability of spare parts, and access to repair information reports.[50] The index, which will be first added to the labels of washing machines, laptops, smartphones, TVs, and lawn-mowers, aims to be extended to more categories of products after 2021.[51]	**Medium** – if unbundling would be mandatory, the consumer would be able to choose the charger with the highest repairability/durability index, but low value of charger and difficulty to open EPS or cable means it is unlikely to be useful from a reparability perspective.

In-depth analysis of selected schemes

Below we present a detailed analysis of the environmental instruments and schemes identified as "highly" relevant during the impact screening.

1. Create a pictogram providing instant information on compatibility
Description: There have been numerous studies to investigate the effectiveness of the use of pictograms as a strategy to convey information for users, concluding that a *pictogram is better than a label, and recognizing an*

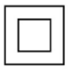
[50] L'indice de réparabilité. https://www.indicereparabilite.fr/.

[51] RepairEU(2020). French repairability index: what to expect in January?. Press release. Retrieved from: https://repair.eu/es/news/french-repairability-index-what-to-expect-in-january/

image is easier than reading text.[52] Among their advantages are that they can be interpreted more accurately and more quickly than words, they improve understanding of warnings for those with visual or literacy difficulties, and make warnings more noticeable, and are more easily processed at a distance compared to textual information.[53] An example of a pictogram created to indicate interoperability certification is the Wi-Fi logo (and term). As stated on the WiFi-Alliance website[54], “interoperability is the foundation of Wi-Fi’s success story”, and the logo now appears on consumer products worldwide that deliver interoperability, industry-standard security protections. The Wi-Fi term (as a play on words with Hi-Fi) is a trademark of the Wi-Fi Alliance and the brand name for products using the IEEE 802.11 family of standards, which today is used by over 700 million people around the world and used in about 800 million new Wi-Fi devices every year.[55]

Current related regulatory framework: The new Regulation (EU) 2019/1782[56] on eco-design (Annex II) presents the information requirements for the nameplate for an EPS. According to the regulation, the label shall include output power, voltage, and current, while instruction manuals for end-users (where applicable) shall include other information (e.g. average active efficiency, efficiency at low load, no load-power consumption). However, the regulation does not specify the use of pictograms or symbols. The table below presents some examples of the pictograms used currently on EPS.

Examples of pictograms currently used for EPS

Pictogram	Meaning
	WEEE label (established by the EU directive on waste electrical and electronic equipment). The symbol indicates that the product should not be discarded as unsorted waste but must be sent to separate collection facilities for recovery and recycling.[57]
	‘CE’ appears on many products traded on the extended Single Market in the European Economic Area (EEA). It means that the products have been assessed to meet high safety, health, and environmental protection requirements.[58]
	Appliances marked with this symbol are ensured by double insulation and do not require a safety connection to electrical earth (ground).[59]
	Established by the ISO 7000 / IEC 60417 to identify electrical equipment designed primarily for indoor use.

As such, there is evidence that pictograms that are not immediately recognized may be learned rapidly, after which the role of the pictogram is to stimulate recall of that information.[60] Although making more information available does not necessarily lead to more sustainable consumer choices, environmental labelling has been proven to be a popular policy instrument over the last decades, promoted by multiple actors both public and private.[61] Therefore, the introduction of a new pictogram can be an effective way to communicate the compatibility of EPS and cables.

[52] Tijus, C., Barcenilla, J., de Lavalette, B. C., & Meunier, J. (2007). Chapter 2: The Design, Understanding and Usage of Pictograms. In *Written Documents in the Workplace*. Leiden, The Netherlands: Brill https://doi.org/10.1163/9789004253254_003

[53] Ibid.

[54] WiFi Alliance (2019) https://www.wi-fi.org/news-events/newsroom/wi-fi-alliance-celebrates-20-years-of-wi-fi

[55] ICTEA (n.d.) Knowledgebase-WiFi. Retrieved from: https://www.ictea.com/cs/index.php?rp=%2Fknowledgebase%2F274%2FiQue-es-Wi-Fi.html&language=english

[56] European Commission (2019) Commission Regulation (Eu) 2019/178 of 1 October 2019 laying Down Ecodesign Requirements For External Power Supplies Pursuant To Directive 2009/125/Ec of The European Parliament And Of The Council And Repealing Commission Regulation (Ec) No 278/2009.

[57] WEEE label. Retrieved from: https://europa.eu/youreurope/business/product-requirements/labels-markings/weee-label/index_en.htm

[58] https://ec.europa.eu/growth/single-market/ce-marking_en

[59] DaikinEurope (n.d) Retrieved from: https://www.daikin.eu/en_us/faq/my-device-has-a-double-square-on-the-label-what-does-it-mean.html

[60] Tijus, C., Barcenilla, J., de Lavalette, B. C., & Meunier, J. (2007). Chapter 2: The Design, Understanding and Usage of Pictograms. In *Written Documents in the Workplace*. Leiden, The Netherlands:Brill. https://doi.org/10.1163/9789004253254_003

[61] Gåvertsson, I. & Milios, Leonidas & Dalhammar, Carl. (2020). Quality Labelling for Re-used ICT Equipment to Support Consumer Choice in the Circular Economy. Journal of Consumer Policy. 43. 10.1007/s10603-018-9397-9.

2. Create an electronic label providing instant information on compatibility

Description: Traditionally, manufacturers have had to use physical labels on ICT products to convey the compliance information; however, these may increase costs and potentially limit design options, and may only ineffectively convey information to consumers.[62] As a result, e-labels are gaining attention as a way to convey information to consumers and regulators more effectively and efficiently. E-labelling includes a machine-readable code (e.g. QR code) that allows a scanning device (such as a smartphone) to retrieve the labels and access the relevant product information, including safety, electromagnetic interference, energy, materials, and/or recycling. As a previous study showed[63], ICT products are becoming smaller in size, and thus it is becoming harder for manufacturers to find space on the device to apply the required physical label. This, coupled with growing smartphone ownership (i.e. more consumers having the possibility to easily access information electronically) makes e-labelling very attractive. According to the study, e-labelling now covers the majority of consumer electronics in Australia, Singapore, and the US (with an average of 78-90% smartphones using e-labelling, 82-86% of PCs, and 81% of tables in Australia). In India, the Ministry of Electronics and Information Technology (MeitY), in 2017 published a guideline for e-labelling.[64] Similarly, Russia has announced the introduction of electronic labelling of consumer electronics to have all types of consumer goods electronically labeled starting from 2024.[65]

Current related regulatory framework: In 2019, the European Commission adopted new energy efficiency labels for some product groups (incl. dishwashers, washing machines and washer-driers, refrigerators, lamps, and electronic displays).[66] A new element in these labels is a QR code with which consumers are able to get additional information by scanning the code with a common smartphone. The information is then inserted by manufacturers into the EPREL EU database, which will be starting to be available from March 2021 onwards.[67] Including an electronic-label in devices such as EPS could have the following advantages[68] of an e-label:

- **Include all relevant information (also compatibility):** Besides showing traditional product information such as safety, electromagnetic interference, energy, materials, the e-label for EPS could include interoperability information to help users solve their frequent questions related to the compatibility of different models of chargers, cables, and phones.
  Moreover, previous research[69] involving Danish and Norwegian electric and electronic (EE) equipment manufacturers showed that product labelling is currently regarded as challenging due to the fact that it had to be different from country to country. As QR codes can store a lot more information than traditional barcodes (i.e. where a barcode has a 20 character capacity, a QR code can store over 7,000 characters[70]), e-labels can incorporate information in different languages and adjust to local specificities, if required.
- **Easier enforcement and improved compliance**: The EC indicated that it was estimated that 10-25% of products on the market do not fully comply with energy efficiency labelling regulations and that around 10% of potential energy savings are lost due to non-compliance; and it is expected that the e-labelling and will make compliance control more efficient and effective since manufacturers and importers have to register their products and all detailed technical documentation into EPREL.[71]
- **Reduced environmental impact**: E-labels not only allow manufacturers to reduce the material they use in labels but also and can provide details to consumers on how to environmentally dispose of the product. When identifying barriers for reuse and recovery, EU manufacturers have recommended the inclusion of the manufacturing year in labels, since the product's lifetime can help in making the reuse decision.[72]
- **Reduced Impact on product innovation**, such that physical labelling requirements may become a constraint on product design as manufacturers reach a point where they need to alter the optimal design of a product just to satisfy labelling requirements.

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[62] Cory, Nigel. (2017). How E-Labels Can Support Trade and Innovation in ICT. http://www2.itif.org/2017-e-label-support-ict.pdf

[63] VVA(2018) Study for the introduction of an e-labelling scheme in Europe. Research into e-labelling schemes outside the EU.

[64] https://www.meity.gov.in/esdm/standards

[65] https://www.noerr.com/en/newsroom/news/russia-new-developments-in-regulation-of-labelling-and-conformity-assessments-of-goods

[66] European Commission (2019). Press release. New energy efficiency labels explained. Retrieved (20.01.2021) from: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_19_1596

[67] https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/product-database/qr-code-new-energy-label_en

[68] Based on Cory, Nigel. (2017). How E-Labels Can Support Trade and Innovation in ICT. http://www2.itif.org/2017-e-label-support-ict.pdf

[69] Andersen, Terje & Jæger, Bjørn & Mishra, Alok. (2020). Circularity in Waste Electrical and Electronic Equipment (WEEE) Directive. Comparison of a Manufacturer's Danish and Norwegian Operations. Sustainability. 12. 10.3390/su12135236.

[70] https://www.labelsandlabelling.com/features/smart-and-intelligent-labels

[71] European Commission (2019). Press release. New energy efficiency labels explained. Retrieved (20.01.2021) from: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_19_1596

¿[72] Andersen, Terje & Jæger, Bjørn & Mishra, Alok. (2020). Circularity in Waste Electrical and Electronic Equipment (WEEE) Directive. Comparison of a Manufacturer's Danish and Norwegian Operations. Sustainability. 12. 10.3390/su12135236.

3. Create an Environmental labelling and information scheme (ELIS) to provide information on the sustainability of EPS and/or cables

Description: A recent report[73] by the OECD showed how environmental labelling and information schemes (ELIS) have substantially grown in the last years, covering an increasingly wide set of policies and initiatives providing information to external users about one or more aspects of the environmental performance of a product or service. In general, ELIS may rely on a) environmental seals based on certification, b) reporting methods (e.g., comprehensive reports or foot-printing), and c) intermediate schemes that provide simplified semiquantitative information (e.g., a multi-tier rating).

As of January 2021, the Ecolabel Index[74] (i.e., the largest global directory of ecolabels) includes 456 ecolabels in 199 countries and 25 industry sectors. For the (non-exclusive) category 'electronics', the index includes over 72 ecolabels worldwide (e.g., *Blue Angel, B corporation, China Environmental Labelling*), and on 'waste management & recycling' 37 ecolabels (e.g. *Eco-leaf, BEST standard, e-Stewards Certification*). For reference, Fair-phone (one of the renowned companies manufacturing smartphones with 'less environmental impact'), for instance, is certified by the ELIS *Fairtrade-gold, Ecovadis* and *B corporation.*

Current related regulatory framework: Within the ELIS, the EU Ecolabel covers a wide range of product groups and since 1992 is awarded to products and services meeting high environmental standards throughout their life cycle: from raw material extraction to production, distribution, and disposal [75] As such, the label aims to promote the circular economy among consumers and encourage companies to develop products that are durable, easy to repair and recycle.

The groups of electronic equipment currently covered by the EU-Eco label includes a) televisions and b) electronic displays. For each of the groups, the EU ecolabel defines key environmental hot-spots and solutions provided by the EU-Eco labeled products. In November 2020, the EU Eco-label established the criteria for electronic displays[76], which aim to cover "*the best electronic displays on the market, in terms of environmental performance"*, targeting products that are energy-efficient, repairable, easy to dismantle, have a minimum recycled content and which may only contain a limited number of hazardous substances. For instance, according to the criteria, products shall contain on average a minimum of 10 % post-consumer recycled plastic (in case the recycled content is greater than 25% a declaration may be made in the text box accompanying the Ecolabel) (see Criterion 4-End of life management). In the case of these electronic displays, external cables (specified as AC and DC power cords, modem cable and LAN cable if applicable, HDMI cable and RCA cable), as well as printed circuit boards included in power supply units, are explicitly covered by restrictions on the presence of specific substances (i.e., hazard components). However, there is no further reference to cables or power supply units is made.

4. Establish a repairability/ durability index for EPS and cables

Description: Reducing the global material consumption and associated environmental footprint can be achieved by increasing the durability of electrical and electronics products by means of repair[77]. Therefore, two main methods have recently been developed for evaluating product repairability based on available state-of-the-art literature and calculate a "repairability score" through the characterization and rating of product-specific criteria and parameters[78] : the Assessment Matrix for ease of Repair (AsMeR) developed by the KU Leuven[79], and the Repair Scoring System developed by the JRC within the study *Analysis and development of a scoring system for repair and upgrade of products[80],* which we explain in detail under '*current related regulatory framework'*.

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[73] OECD (2016) Environmental Labelling and Information Schemes- Synthesis Report. Retrieved from: https://www.oecd.org/env/labelling-and-information-schemes.htm

[74] http://www.ecolabelindex.com/

[75] https://ec.europa.eu/environment/ecolabel/index_en.htm

[76] European Commission (2020) Commission Decision (EU) 2020/1804 of 27 November 2020 establishing the EU Ecolabel criteria for electronic displays (notified under document C(2020) 8156) (Text with EEA relevance). https://eur-lex.europa.eu/eli/dec/2020/1804/oj

[77] Bracquene, E., et al. (2021) Analysis of evaluation systems for product repairability: A case study for washing machines, Journal of Cleaner Production,https://doi.org/10.1016/j.jclepro.2020.125122.

[78] Ibid.

[79] Bracquene, E., et al., Repairability criteria for energy related products - study in the BeNeLux context to evaluate the options to extend the product life time - final Report [Online]. Available. http://www.benelux.int/files/7915/2896/0920/FINAL_Report_Benelux.pdf

[80] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission. Retrieved from:

France has taken a step forward towards the implementation of a reparability index that aims to inform the consumer about the possibility to repair a product.[81] Already from January 2021, electronics sold in the country are required to have a repairability index (*l'indice de réparabilité)*, which is expected to set an example for other European countries. The score (grade out of 10) takes into consideration the ease of disassembly, price, and availability of spare parts, and access to repair information reports.[82] For smartphones, the calculation of the *l'indice de réparabilité* for smartphones considers the availability of EPS (in the *Reparability index calculation worksheet for smartphones*[83] presented as 'chargers'). The score considers the availability over time of chargers (i.e., years after planning the last unit of a model in the market), and the delivery time of chargers (i.e., in working days). Regarding disassembly, the index considers the 'removability' and 'reusability' of the charging connector but does not include the 'ease of disassembly' of the charger, unlike for other parts (e.g., battery, camera, display).

Current related regulatory framework: Empowering consumers and providing them with cost-saving opportunities is a key building block of the EU sustainable product policy framework, as highlighted in the EU Circular Action Plan (CEAP)[84]. Specifically, the CEAP mentions the EC proposal related to the revision of the EU consumer law to ensure that consumers receive relevant information on products, including on the availability of repair services, spare parts, and repair manuals.

Accordingly, the *Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 (draft)*[85] confirms that the Commission is currently studying the possibility of a scoring system on the reparability of products, which would consider the Repair Scoring System and findings presented in JRC 2019 study[86]. A limited number of technical parameters were selected by the JRC study which covers design characteristics for disassembly (including e.g., the number of stages required to remove a part of a product, necessary tools and skills to repair, and disassembly time), and relevant operational aspects related to the repair/upgrade of products (e.g., diagnosis support and interfaces, type and availability of information and spare parts, and commercial guarantee). Based on a total of twelve technical paraments, an assessment composed of 'scoring criteria' and 'pass/fail' criteria would provide technical guidance to inform about the ability to repair and upgrade products. One of the specific product groups the study refers to is laptops, and thus, includes EPS as one of the priority parts which manufacturers have to ensure are available. As such, the score would consider if the EPS follows the technical specifications for a common EPS designed for use with portable ICT devices, as outlined in the ITU-T L.1002 standard[87] (i.e., EPS with a detachable input cable and a detachable output cable to the ICT device plus a USB Type-C connector to support broad reusability and interoperability).[88]

As next steps, in the *Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024*[89] it is indicated that in the Commission services have discussed previously with stakeholders the potential implementation of such reparability scoring system and contracted a study to assess how reparability information can be presented to consumers.

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https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair _scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020

[81] Repair.eu (2020) French repairability index: what to expect in January?

[82] L'indice de réparabilité. https://www.indicereparabilite.fr/.

[83] Reparability Index Worksheet for Smartphones. Retrieved from: https://www.indicereparabilite.fr/grilles-de-calcul/

[84] European Commission (2020) Circular Economy Action Plan – For a cleaner and more competitive Europe. Retrieved from: https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

[85] Euroepan Commission (2020) Draft report. Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 (Task 3, preliminary analysis of product groups and horizontal initiatives) Retrieved from: https://www.ecodesignworkingplan20-24.eu/documents

[86] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission. Retrieved from: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair _scoring_system_final_report_v3.2_pubsy_clean.pdf, last accessed on 24 May 2020

[87] ITU-T (2016) ITU-T L.1002 (10/16) External universal power adapter solutions for portable information and communication technology devices

[88] Cordella, M.; Alfieri, F.; Sanfelix, J. (2019): Analysis and development of a scoring system for repair and upgrade of products, Final report. European Commission. Retrieved from: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair

[89] Euroepan Commission (2020) Draft report. Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 (Task 3, preliminary analysis of product groups and horizontal initiatives) Retrieved from: https://www.ecodesignworkingplan20-24.eu/documents

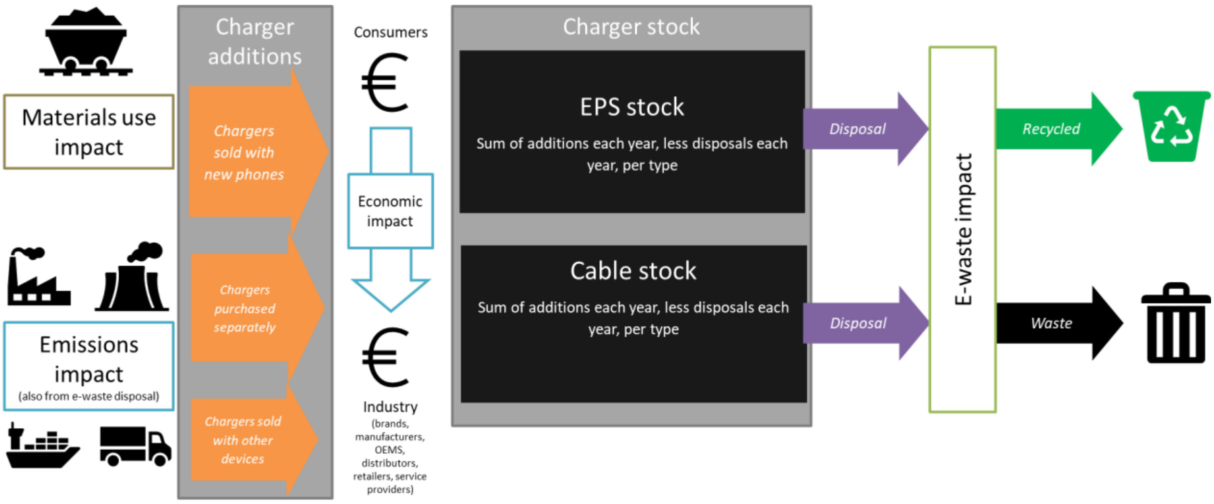
Annex F: Summary description of the stock model

One of the primary instruments applied in this impact assessment is the stock model. This is used to simulate the additions and disposals of chargers each year. A summary of the stocks and flows modelled is provided by Figure 47 below. The model was developed as part of the 2019 IA study and has been updated, expanded and refined for this impact assessment.

It models inflows to the stock of chargers from those supplied with smartphones, those sold in the standalone market and those supplied with other devices. It models outflows based on assumptions of consumer disposal behaviour.

The flows are multiplied by assumptions on material content, emissions impact, costs, prices, weight, material content, waste treatment and recycling to calculate the impacts reported in the impact assessment. Full details on these assumptions are provided in Annex G.

Figure 47: Summary schematic of the stock model



The stock model, distinguishes in Table 6 the following charger components (EPS, Cable) and types (by Wattage and connectors/receptacles) within the model.

Table 6: Stock model – charger components and types modelled

No EPS	
EPS < 7.5 W	USB Type-A receptacle
EPS < 7.5 W	USB Type-C receptacle
EPS < 7.5 W	USB Type-A and Type-C receptacles (multi-port)
7.5W <= EPS <=27W	USB Type-A receptacle
7.5W <= EPS <=27W	USB Type-C receptacle
7.5W <= EPS <=27W	USB Type-A and Type-C receptacles (multi-port)
EPS > 27W	USB Type-A receptacle
EPS > 27W	USB Type-C receptacle
EPS > 27W	USB Type-A and Type-C receptacles (multi-port)
EPS > 27W	Captive cable
No cable	
Cable	USB Type-A - USB Micro B plugs
Cable	USB Type-A - USB Type-C plugs
Cable	USB Type-A - proprietary (Lightning) plugs
Cable	USB Type -A - proprietary (Other device) plugs
Cable	USB Type-C - USB Type-C plugs
Cable	USB Type-C - proprietary (Lightning) plugs
Cable	USB Type-C - proprietary (Other device) plugs
Cable	Captive cable

Annex G: Modelling assumptions and policy option characteristics

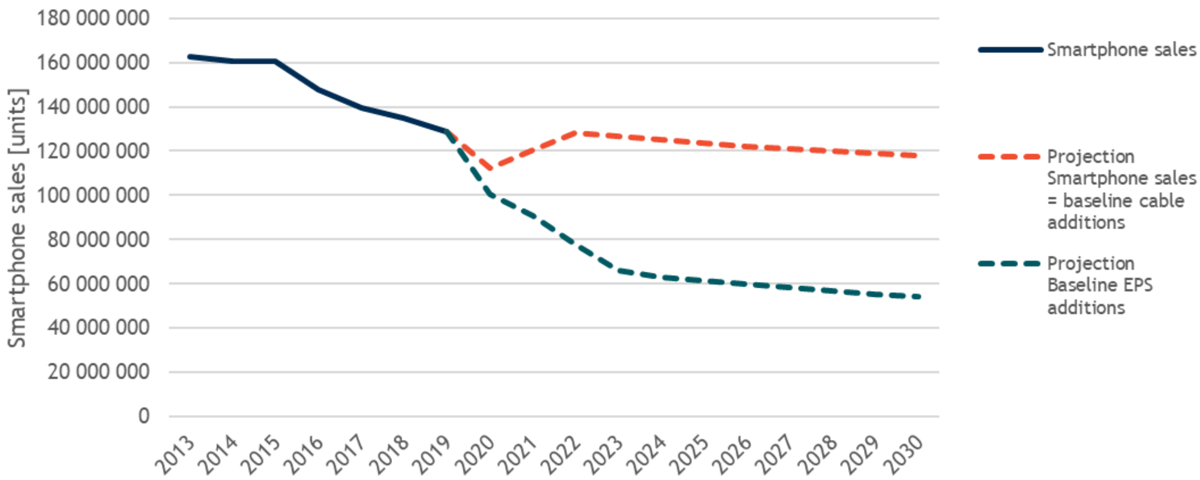
The stock model is used to model the charger stock based on annual additions (with phones and other devices, and as standalone sales) and disposals (to general waste or recycling).

Model assumptions – baseline

Baseline additions – with smartphones

A **Smartphone sales projection** was produced (see Figure 0-1), as a basis for estimating chargers supplied with phones. Total smartphone sales were assumed to remain the same across all policy options. Sales up to 2019 were included on the basis of purchased market data from IDC and show a declining trend in sales. Projections from 2020 onwards were made on the basis of a logarithmic trendline based on the 2013-2019 data, and then extrapolated forward to 2030. Values for 2020 and 2021 have been reduced by 15% and 7.5% respectively to reflect estimated sales reductions caused by COVID[90]. The projection represents the smartphone sales, and, as all phones are assumed to be supplied with cables, then the projection can also be understood to represent baseline cable additions with smartphones. The figure also presents a projection of baseline EPS additions with smartphones which represents the unbundling that is already taking place and how this is projected to continue in future.

Figure 48: Smartphone sales, baseline cable and EPS additions projections 2013-2030 [units]



Source: Own calculations

In terms of the types of chargers. For chargers provided with smartphones, we assumed market shares are held at 2017-2019 or 2018-2019 averages, with 4 brands modelled, Samsung (29.7%), Apple (17.8%), Huawei (21.8%) and Other (30.7%).

The key evolutions projected include:

- Samsung began unbundling of EPS from its phones with the launch of the S21 in 2021, we assume this will be the case for new models launched from now on, meaning their

[90] Market data for the full year 2020 is scarce, but suggests a significant impact from COVID and reductions in sales of 10-20% in Europe. For example: https://www.counterpointresearch.com/european-smartphone-market-2020/#:~:text=and%20Samsung%20Lose-,European%20Smartphone%20Market%20Down%2014%25%20YoY%20in%202020%3B%20Xiaomi%20Gains,While%20Huawei%20and%20Samsung%20Lose&text=2020%20was%20a%20rollercoaster%20year,supply%20and%20demand%20side%20issues.

entire range is unbundled by 2024. Since 2020 the S10+, S20, A71 phones were supplied with 25W USB Type-C EPS. Prior to this the standard was USB Type-A 15W. All Samsung phones adopted USB Type-C since 2019, completing the switch begun in 2017.

- Apple unbundled EPS from all their phones from 2021, and began to provide USB-Type-C – Lightning cables with some new phones since 2019, and for all phones since 2021.
- Huawei have not unbundled and given their SuperCharge is seen as an important selling point for their phones are not expected to in future. High power EPS (>27W) were introduced since 2019 on premium models, and are projected to be rolled out to 80% of their range by 2024. We assume that their EPS will remain USB Type-A. USB-C on phones (and cables) has been adopted since 2016 for some phones, with the switch from Micro-B assumed to be completed across all phones by 2024.
- Other – High end phones (10% of Other, brands such as Sony, LG, Google, some Nokia), have already, or are assumed to follow Samsung and unbundle EPS. In this high-end segment, we assume OnePlus/Oppo (3.3% of Other total), which have proprietary chargers, will not unbundle, instead adopting >27W EPS and moving to EPS with USB Type-C by 2024. The Mid (30%) and Low (60%) parts of the 'Other' range are assumed to migrate away from USB Micro-B by 2026, moving to USB Type-C. 12% of all EPS still supplied with phones in the 'Other' category are USB Type-C by 2024, increasing to 29% by 2030.

Baseline additions – standalone market

Standalone charger sales projections were produced to estimate chargers bought separately from phones. This market is especially expected to be influenced by the policy options.

In the baseline ***standalone EPS sales*** are estimated as there is little reliable data on this market from public or commercial sources. The closest match in available statistical data is from PRODCOM with code '27904140 - Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof' matching closest to what would be the standalone charger market and where data is available for 2016-2019. Calculation of sales based on the PRODCOM data is presented below in Table 7. The table shows the calculated sales, and these sales divided by the 18-79 year old EU population[91], to calculate an average ratio of purchases of EPS per person per year of 0.31. This value was validated by the consumer survey equivalent value of 0.33[92] to give confidence that the value is broadly accurate.

Table 7: PRODCOM 27904140 EU27 (exc. UK) estimated sales (PRODQNT less EXPQNT plus IMPQNT) 2016-2019

	2016	2017	2018	2019	Average
PRODCOM 27904140	129 904 091	110 096 823	100 368 624	80 276 263	**105 161 450**
Per EU population 18-79 years [unit/person]	0.38	0.33	0.30	0.24	**0.31**

Source: Own calculations based on PRODCOM

[91] This age range was selected on the basis that those outside this age range would rarely purchase a charger. EU population is the EU27 after the UK exit.

[92] Consumers were asked 3 questions, if they purchased a standalone EPS, cable or both in the last 24 months, and from which an average of 0.33 EPS per person per year was calculated.

To estimate annual sales of EPS across the full period the average value of 0.31 EPS was multiplied by the 18-79 year old population of the EU. EU population projections from Eurostat were used for years 2020-2030[93]. Table 0-2 summarises the baseline sales and projected differences in total sales per policy option. As policy options are projected to only enter force in 2024 then the variations only become evident from this point.

For all EPS **projections to 2030** a ***'rebound effect'*** was also calculated in addition to the 0.31 per person value. This rebound effect addresses the impact of unbundling in the baseline. As unbundling removes EPS from the box, consumers may choose to purchase an EPS separately when buying a phone. The consumer survey suggested 57% of consumers would still purchase a new EPS with a new phone. This value was also corroborated by stakeholders that have piloted unbundling previously, e.g. one manufacturer piloted unbundling and found approximately 60% of consumers still bought a charger with the new phone. A further adjustment to this 0.57 rebound is made to reflect that consumers that purchase a standalone EPS in this way would be unlikely to then purchase an additional standalone EPS, so the 57% value is reduced by 31% (reflecting the average 0.31 of these consumers that would have normally purchased a standalone EPS). **The net impact of these two effects is that in the stock model for every smartphone supplied without an EPS, 0.39 standalone EPS sales are added.** This accounts for the great majority of the observed increase in standalone EPS sales in the baseline 2021-2030.

For standalone EPS sales we assume, based on the consumer survey, that approximately 8% of standalone EPS purchases are multiport devices. Low power EPS (<7.5W) reduce to 5% by 2026 from 24% in 2020. EPS begin to switch from USB Type-A to USB Type-C in 2019, by 2030 75% of standalone EPS are USB Type-C. Around 32% of EPS are assumed to be high power (>27W) EPS, predominantly EPS USB Type-C.

Table 8: Standalone EPS sales projections [million units]

Policy option	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline	104.8	104.9	**105.0**	109.8	116.9	125.1	129.2	129.8	130.0	130.2	130.3	130.5	130.6	130.2

Source: Own calculations

In the baseline ***standalone cable sales*** are estimated based on the EPS estimations as there is no data on this market from public nor commercial sources. The closest PRODCOM category '27904400 - Appliance cords, extension cords, and other electrical cord sets, for a voltage ≤ 1 kV, with insulated wire and connectors' covers too many other cables to be useful[94]. Therefore the standalone sales of cables are based upon the ratio of cable to EPS purchases reported by consumers in the consumer survey. The consumer survey found that consumers reported purchasing 0.44 cables per person per year, compared to 0.33 for EPS, approximately 32% more cables than EPS. This is consistent with cables tending to be less durable than EPS and requiring more frequent replacement. Adjusting the ratio used for EPS by 32% we approximate gross standalone cable purchases of 0.41 per person per year.

A rebound effect is also added for cables to account for the fact that, as highlighted above, many people will purchase an EPS with which a cable is bundled when purchasing a 'rebound effect' EPS. The consumer survey results were used to calculate that 62% of standalone EPS purchases included purchase of a cable. Therefore rebound EPS additions are multiplied by 62% to calculate cable additions. Similar to the EPS rebound effect a further correction was made to account that this rebound would include people that would have normally bought a standalone cable in any case, therefore the rebound was reduced by 0.41 per person. **The net**

[93] Eurostat [TSP00001]

[94] The PRODCOM data for this code suggests EU sales of >500 million each year, considerably higher than what is likely for the specific cables relevant for this work.

result of this is that for every EPS unbundled an additional 0.21 cables are purchased standalone.

As no cables are unbundled in the baseline then no additional rebound effect of this type is modelled.

For the **projection of the Baseline to 2030** the 0.41 value was applied and to which the 0.21 EPS-linked rebound was added. **The net additions per person taking these two effects into account sees the base 0.41 cables per person value increase to 0.45 by 2024.** The projected sales are presented in Table 0-3.

For standalone cable sales we assume a reduction in USB Type A – Micro B cables from 30% in 2020 to 1% by 2030. Lightning cables fully migrate from USB Type-A to USB Type-C by 2026. By 2030 half of all cables are USB Type-C – Type-C, the remainder (around 25%) Type-A – Type-C.

Table 9: Standalone cable sales projections [million units]

Policy option	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline	138.0	138.1	138.2	138.3	138.5	138.6	138.7	138.9	139.0	139.0	139.1	139.1	139.1	138.4

Source: Own calculations

Baseline outputs summary

The following, Table 10 Baseline scenario evolution 2017-2030, presents a summary of the baseline scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone, based on the assumptions presented above.

Baseline additions total

The table shows total additions of around 207 million EPS in 2021, declining to 184 million by 2030 as further unbundling of EPS from smartphone sales takes place. It also highlights the aprx. 60 million EPS unbundled from 2023 onwards.

The table shows total additions of around 265 million cables in 2021, with this total remaining broadly similar to 2030.

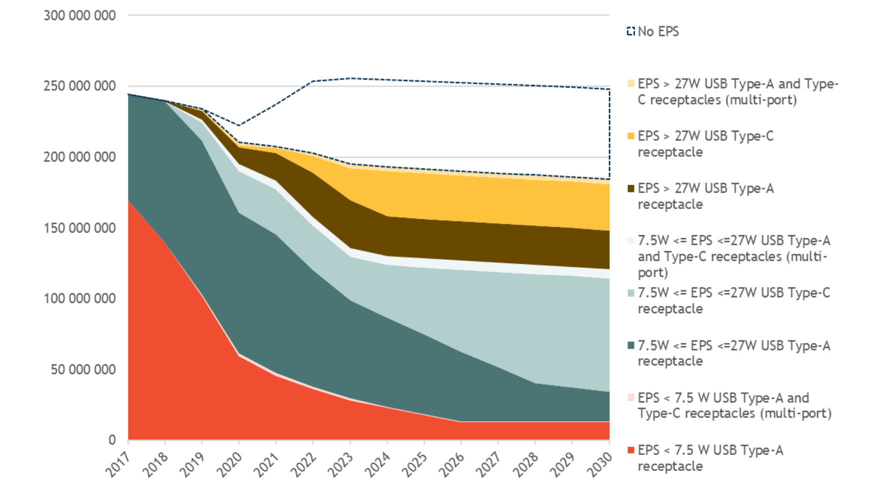
Baseline stock

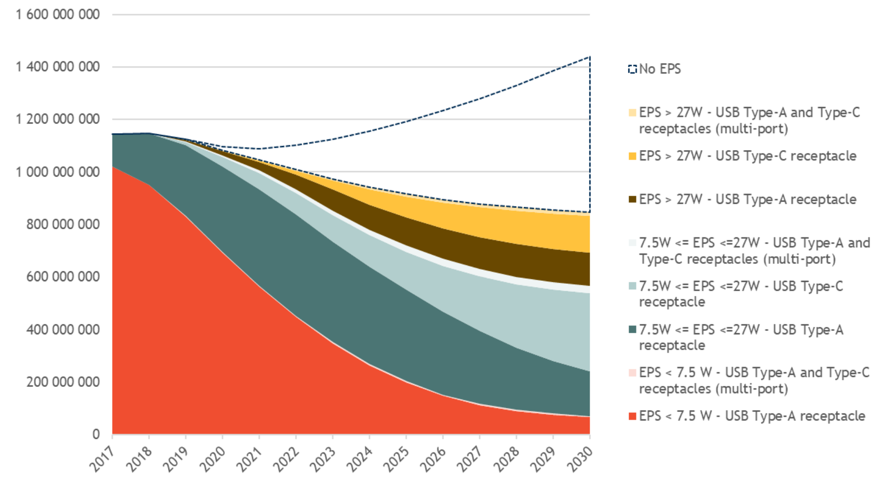
The stock evolution is calculated by summing the additions over time, less the disposals over time. The assumptions for disposals are presented in the following sections, but in summary is based on the assumption that for the chargers sold in a particular year 10% are disposed of each year until after 10 years all chargers sold in that year have been disposed.

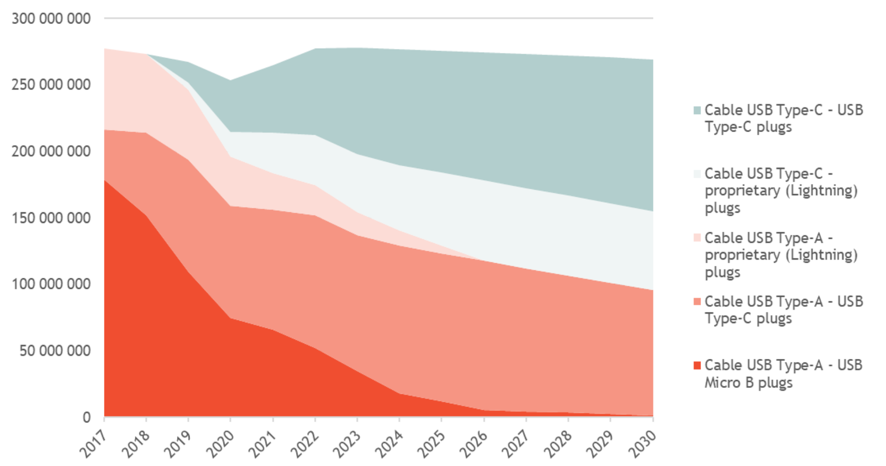
The inputs from sales combined with disposals result in a baseline stock of approximately 1.1 billion EPS in 2020, these are modelled to decline to around 850 million (-22%) by 2030. This shows the source of the projected impact of the unbundling already taking place. The 1.1 billion value is the equivalent of 3.2 EPS per 18-79 year old person in the EU. This is broadly consistent with self-reporting by consumers in the consumer survey where on average 1.75 EPS were in use per person and 1.32 EPS were kept in 'reserve', i.e. functioning but stored. An average of 3.07 EPS per person in total.

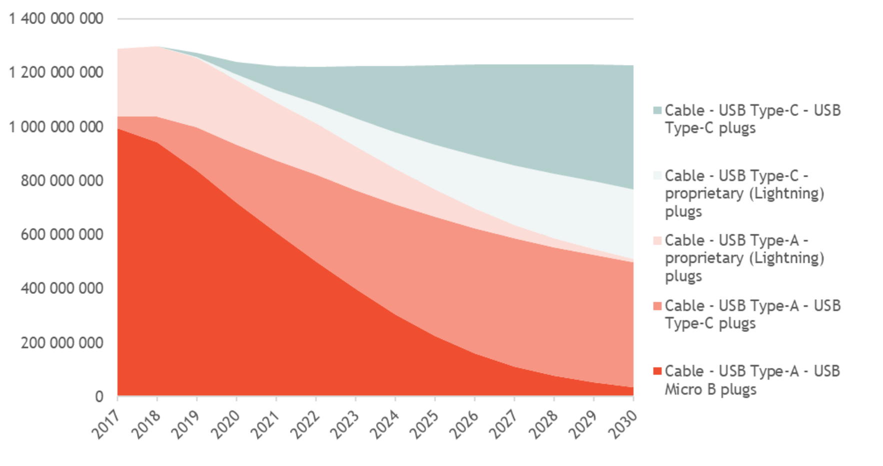
For cables the totals are a baseline stock of approximately 1.24 billion cables in 2020, these are modelled to decline a little to around 1.23 billion (-1%) by 2030. The small reduction in smartphone purchases (and cables) over time, being offset by cables being bought with EPS as EPS unbundling increases. The 1.24 billion value is the equivalent of 3.7 cables per 18-79 year old person in the EU. This is consistent with self-reporting by consumers in the consumer survey where on average 2.05 cables were in use per person and 1.57 cables were kept in 'reserve', i.e. functioning but stored. An average of 3.62 cables per person in total.

Table 10 Baseline scenario evolution 2017-2030

<table>
<tr><th></th><th>Annual sales (with Smartphones + standalone) [units]</th><th>Stock [units]</th></tr>
<tr><td>EPS</td><td>


</td><td>


</td></tr>
<tr><td>Cables</td><td>


</td><td>


</td></tr>
</table>

Source: Own stock model calculations.

Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason

Model assumptions – policy options

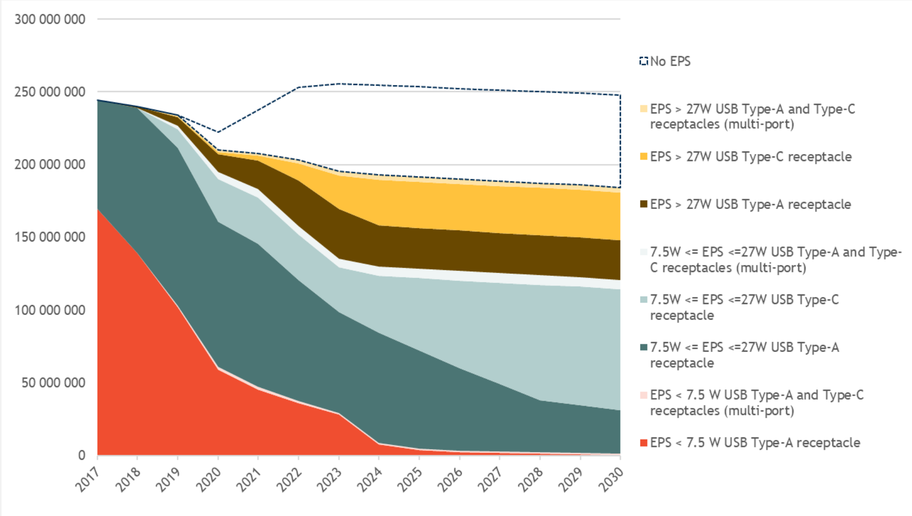
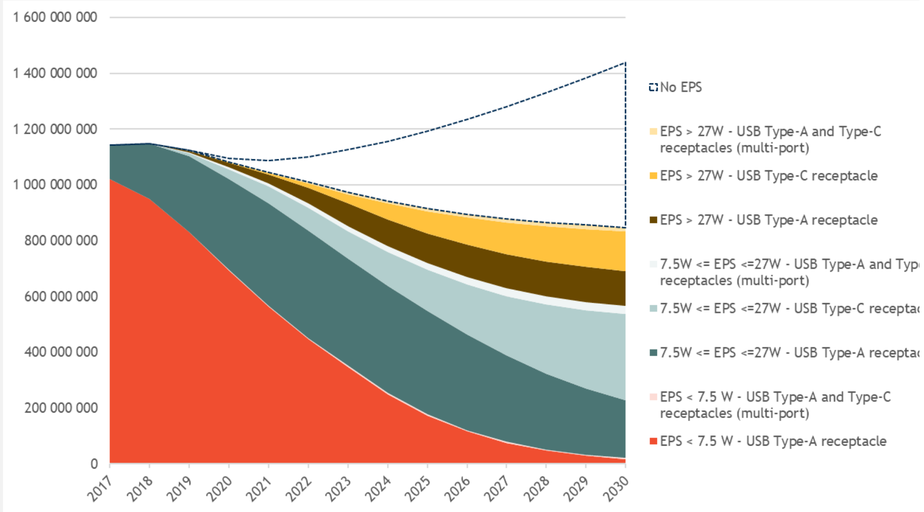
Policy Option 1: Harmonise device-end connectors

The following table presents an aggregate summary of the Policy option 1 scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key impact of this option is that all smartphones must have USB Type-C connection ports, cables supplied with phones would alter to align with this change. In summary, the assumptions underlying this scenario are the same as the baseline except for the following variations:

- **With smartphones** there is no variation in total additions of EPS or cables compared to the baseline as these are directly linked to smartphone sales which remain unchanged across policy options. Changes in EPS and cables types supplied with smartphones do occur with the main variations from the baseline including:
    - **EPS – types:** The option requires a switch to USB Type-C on the phone, and the change to cables with USB Type-A to Type-C cables (see below), is expected to also indirectly lead to an increase in wattage of EPS to the 7.5W <= EPS <=27W bracket as manufacturers take advantage of the faster charging possibilities of USB Type-C compared to USB Micro-B. This is modelled by a reduction of the baseline share of EPS USB Type-A <7.5W to zero, with this share being redistributed to the EPS USB Type-A 7.5W <= EPS <=27W category from 2024 onwards.
    - **Cables - types:** both USB micro-B and Lightning (all Type-C in the baseline from 2021) cables are modelled to be reduced to zero in 2024 on introduction of the policy. In 2023 these cable types are already reduced by half compared to the baseline as manufacturers begin to adjust. The displaced market shares are allocated, first the Lightning cable share is all reallocated to USB Type-C – Type-C cables. Whilst the USB Type-A to Micro-B cable share is redistributed to USB Type-A – Type-C, and USB Type-C – Type-C cables, but predominantly the former given the configuration of the EPS still also supplied with smartphones, and the likelihood that for cost reasons manufacturers still producing USB Micro-B in 2024 will revert to USB Type-A – Type-C cables as the cheapest alternative. The C:C share of this displacement is around 12% in 2024, increasing to 29% by 2030.
- **Standalone charger** sales are modelled on the basis described above, and with variations in types compared to the baseline including:
    - **EPS - sales:** no change in totals compared to baseline.
    - **EPS – types:** Similar to the with smartphone sales, the move to USB Type-C connectors also leads to a faster reduction in <7.5W EPS than in the baseline, reducing from 6% of the total in 2024 (baseline 9%) to 0.5% by 2030 (baseline 5%). These displaced sales are split between EPS USB Type-A and USB Type-C on the basis of their share of cable sales with smartphones in the same year.
    - **Cables – sales:** the requirement for harmonised device-end connectors, will particularly impact the purchase of cables with proprietary connectors, namely the Lightning connectors of Apple. An impact on total cable sales is assumed due to the results of the consumer survey which show that Apple users have a higher propensity than average to purchase standalone cables, which would no longer be necessary under this policy option. A reduction of 27% is applied to the share of the market of Apple (17.8%) to model this effect, this effectively reduces the 0.41 cables per person per year ratio to 0.39, which represents a 4.8% reduction in sales compared to the baseline.
    - **Cables - types:** Significant reduction in all non USB Type-C cables from 2024 although some residual sales for older phones remain. USB Micro-B cables declining to 1% market share by 2027 (by 2030 in baseline). Lightning cables are reduced to 2% of the total by 2027. Displaced sales split in proportion to the smartphone market, i.e. 47:53 between

Type-A-C and Type-C-C cables in 2024, increasing to 45:55 to C-C cables by 2030. In total by 2030 USB Type-A – Type-C cables account for 34% of the market, whilst USB Type-C – Type-C cables 63%, legacy Lightning and Micro-B cables the small remainder.

Table 11: Policy Option 1 scenario evolution 2017-2030

<table>
<tr><th></th><th>Annual sales (with Smartphones + standalone) [units]</th><th>Stock [units]</th></tr>
<tr><td>EPS</td><td>
</td><td>
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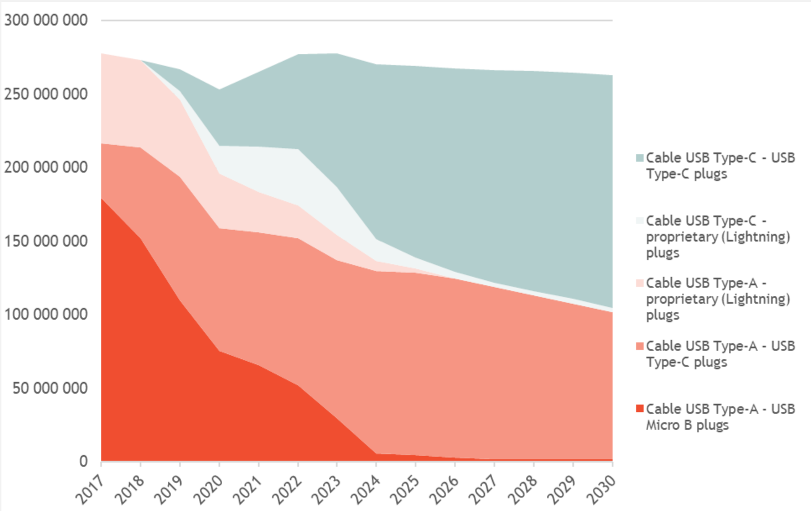
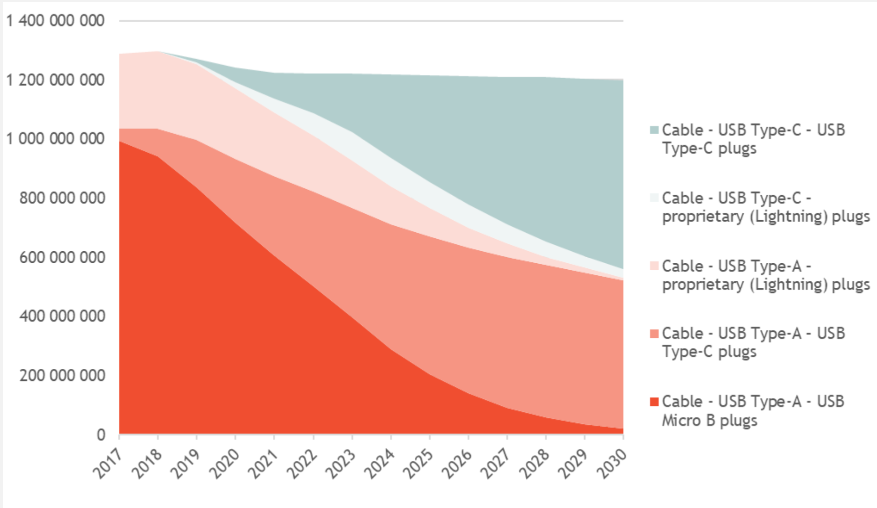
<tr><td>Cables</td><td>
</td><td>
</td></tr>
</table>

Source: Own stock model calculations.

Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Policy Option 2: Require mobile phones to be compatible with USB PD or USB Type-C

The following table presents an aggregate summary of the Policy option 2 scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key assumptions underlying this scenario are the same as the baseline except for the following variations:

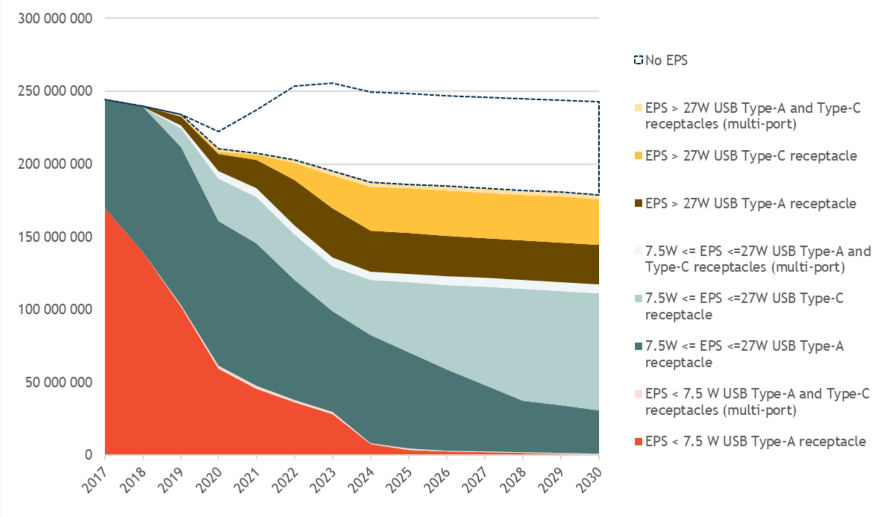
- **With smartphones** there is no variation in total additions of EPS or cables compared to the baseline as these are directly linked to smartphone sales which remain unchanged across policy options. Changes in EPS and cables types supplied with smartphones do occur with the main variations from the baseline including:
    - **EPS - types:** The same as for option 1, a requirement for USB-PD compatibility leads to a move away from low power (<7.5W) EPS, with these reduced to zero from 2024 as EPS are made more powerful to take advantage of the required USB Type-C charging.
    - **Cables - types:** The requirement for USB-PD compatibility results in all non-Apple phones that were still using USB Micro-B in the baseline (8.6% in 2024) switch to USB Type-C to ensure compatibility. In 2023 USB Micro-B cables are already reduced by half compared to the baseline as manufacturers begin to adjust. The displaced market share is allocated in the same way as Option 1 between USB Type-A–Type-C, and USB Type-C–Type-C cables.
- **Standalone charger** sales are modelled on the basis described above in Table 0-3, and with variations in types compared to the baseline including:
    - **EPS – sales:** are reduced by the policy measure (-4% by 2030) compared to the baseline. This results from an assumed reduction in standalone sales to consumers that purchased a new EPS to acquire a faster charger, as the requirement for USB-PD compatibility, as described above, is expected to lead to a higher proportion of fast chargers supplied as standard with smartphones and/or that other standalone chargers are more likely to be able to fast-charge any phone. It is applied in the model through a reduction in the ratio of people assumed to purchase an EPS (0.31 per person/per year in the baseline), with a reduction of 5% applied to this ratio, reflecting the proportion of those in the consumer survey for the 2019 study that reported buying a standalone charger for the purpose of fast charging capabilities.
    - **EPS – types:** This options affects EPS types in exactly the same way as option 1, with a faster reduction in <7.5W EPS than baseline, reducing to 0.5% by 2030. Displaced sales split between EPS USB Type-A and USB Type-C.
    - **Cables – sales:** this option is not expected to directly influence standalone cable sales. However, as described above, they are expected to result in a reduction in standalone EPS sales of approximately 5%. This is also assumed to have an impact on cable sales as a share of EPS sales will be for EPS and cables bundled together. The consumer survey provided information to estimate that 62% of EPS purchased standalone were purchased with cables. This ratio is applied to the 5% assumption on EPS reductions, resulting in a 3.1% reduction in cable sales compared to the baseline.
    - **Cables - types:** Significant reduction in remaining USB Micro B cables from 2024. Some residual sales for older phones remain. USB Micro-B cables declining to 1% by 2027 (by 2030 in baseline). Micro-B displaced sales split in proportion to the smartphone market 47:53 between A-C and C-C cables in 2024, increasing to 45:55 to C-C cables by 2030. In total by 2030 USB Type-A – Type-C cables account for 24% of the standalone market by 2030, whilst USB Type-C – Type-C cables 50%.

Table 12 Policy Option 2 scenario evolution 2017-2030

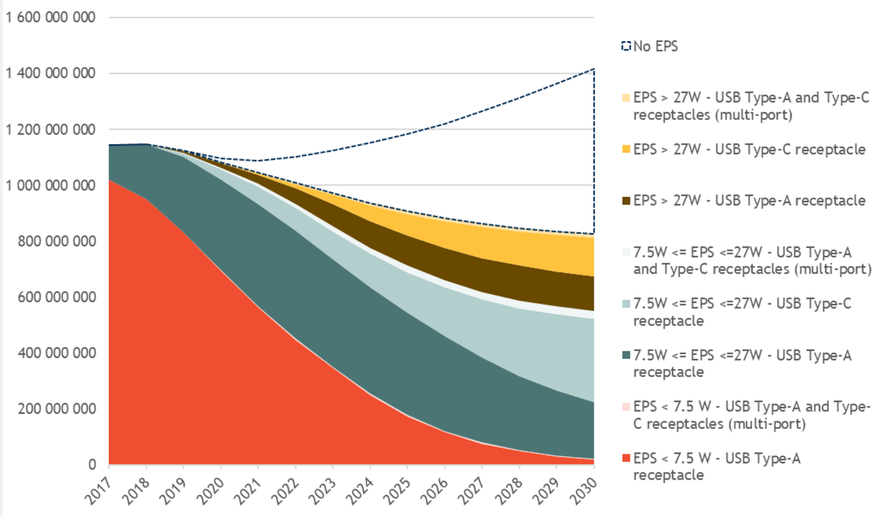
Annual sales (with Smartphones + standalone) [units] | **Stock [units]**

EPS

Annual sales (with Smartphones + standalone) [units]

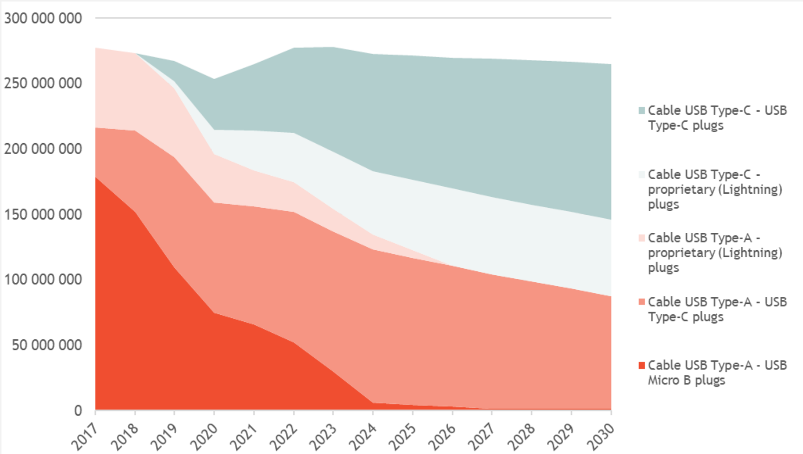


Stock [units]

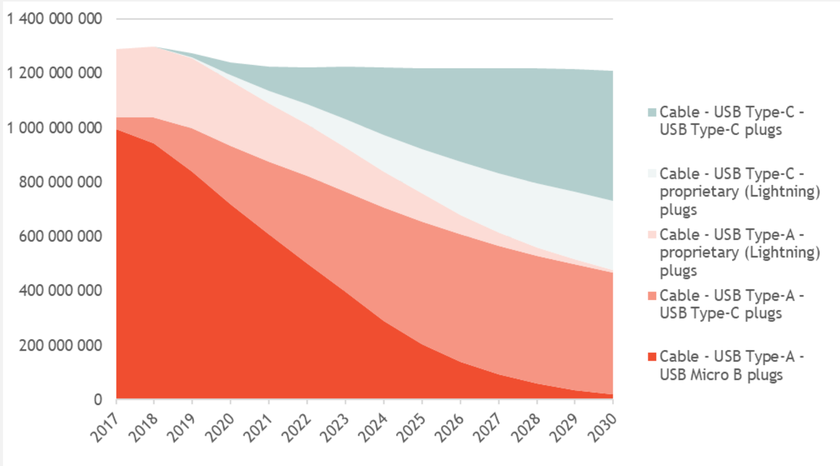


Cables

Annual sales (with Smartphones + standalone) [units]



Stock [units]



Source: Own stock model calculations.

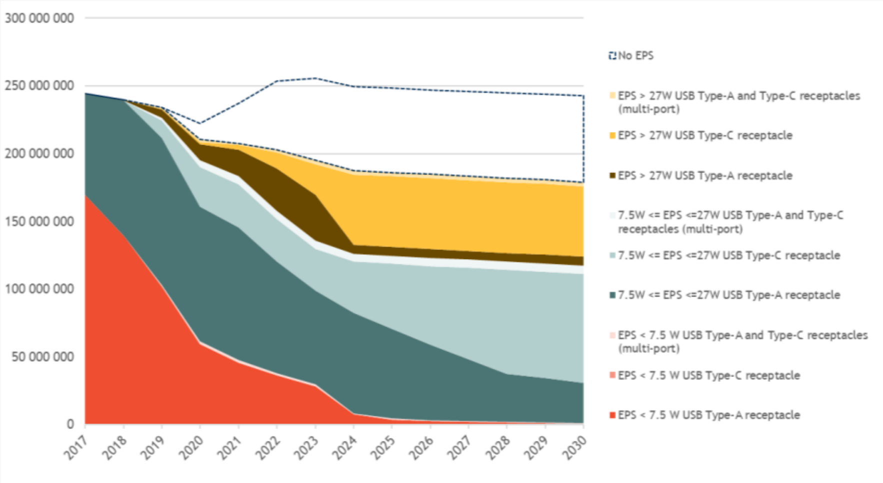
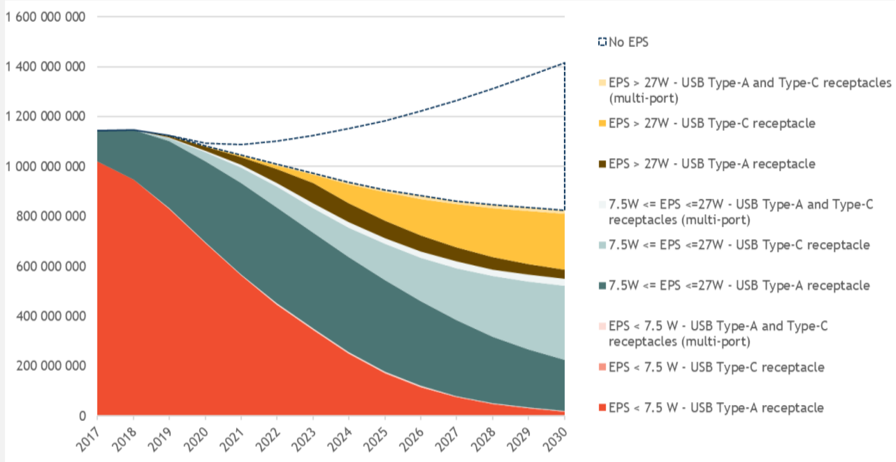
Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Policy Option 3: 'Common' EPS for mobile phones

The following table presents an aggregate summary of the Policy option 3 scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key assumptions underlying this scenario are the same as the baseline except for the following variations:

- **With smartphones** there is no variation in total additions of EPS or cables compared to the baseline as these are directly linked to smartphone sales which remain unchanged across policy options. Changes in EPS and cables types supplied with smartphones do occur with the main variations from the baseline including:
    - **EPS – types:** the option works the same as option 1 and 2 in assuming that the remaining share of <7.5W EPS are removed from 2024 as the policy is implemented as requiring USB Type-C or PD compatibility meaning a minimum 15W charging. Additionally, proprietary EPS, such as those provided by Huawei and Oppo/OnePlus would need to comply with the appropriate standard, this results in a transition of these EPS from USB Type-A to Type-C, but remaining in the high (>27W) power category.
    - **Cables – types:** The changes would be identical to Option 2, with USB Micro-B cables being eliminated by 2024.
- **Standalone charger** sales are modelled on the basis described above in Table 0-3, and with variations in types compared to the baseline including:
    - **EPS – sales:** are adjusted in the same way as policy option 2 with an equivalent small displacement of sales for the purposes of fast charging.
    - **EPS – types:** This option is modelled with the same assumptions as Option 1, with with a faster reduction in <7.5W EPS than baseline, reducing to 0.5% by 2030.
    - **Cable – sales:** are adjusted in the same way as policy option 2 with an equivalent small reduction of sales from cables normally purchased indirectly with EPS.
    - **Cable – types:** The changes are identical to Option 2, with USB Micro-B cables being eliminated by 2024.

Table 13 Policy Option 3 scenario evolution 2017-2030

<table>
<tr><th></th><th>Annual sales (with Smartphones + standalone) [units]</th><th>Stock [units]</th></tr>
<tr><td>EPS</td><td>
</td><td>
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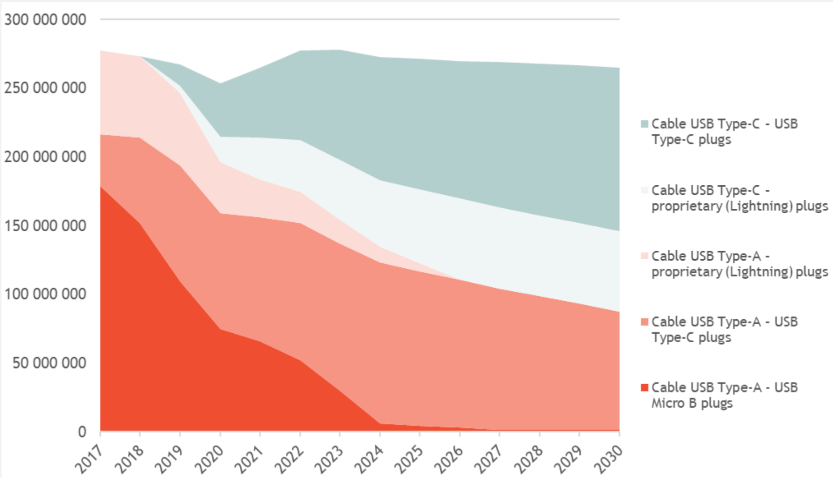
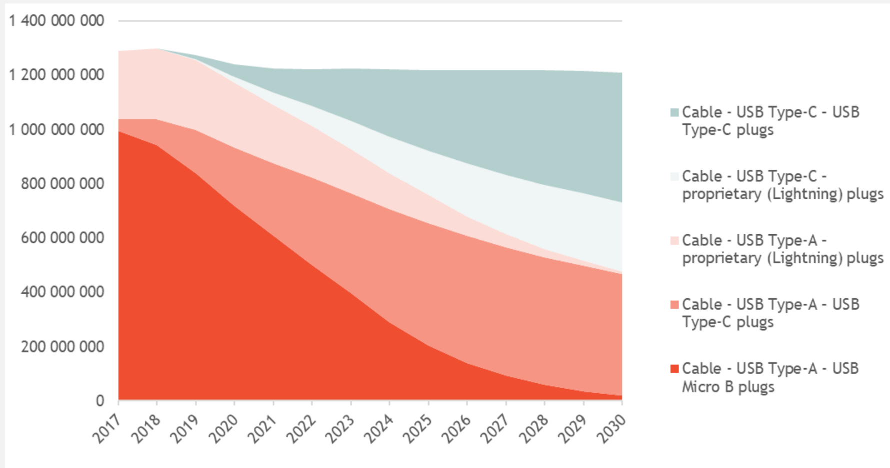
<tr><td>Cables</td><td>
</td><td>
</td></tr>
</table>

Source: Own stock model calculations.

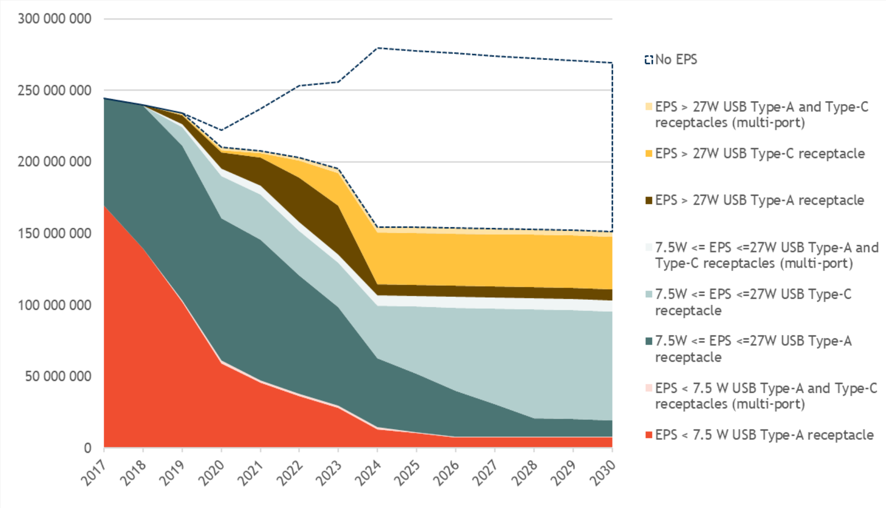
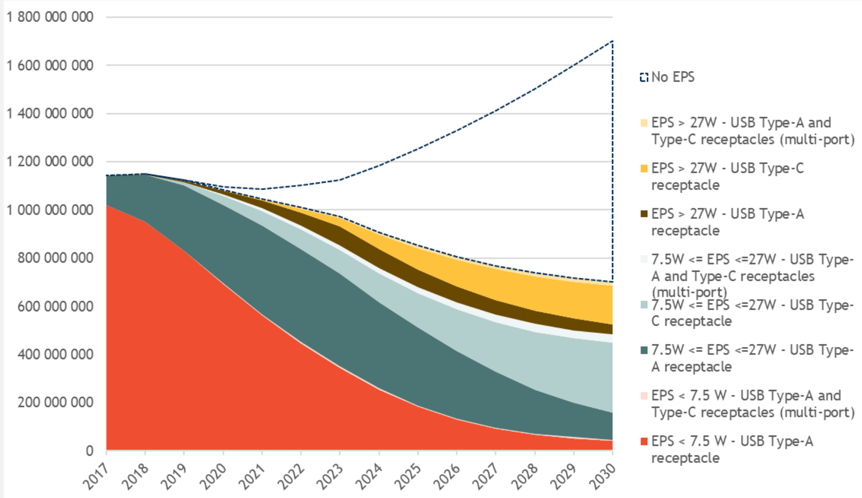
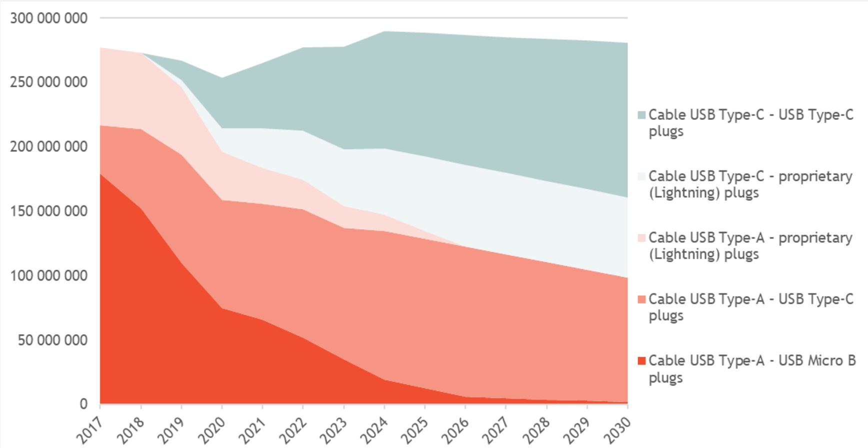
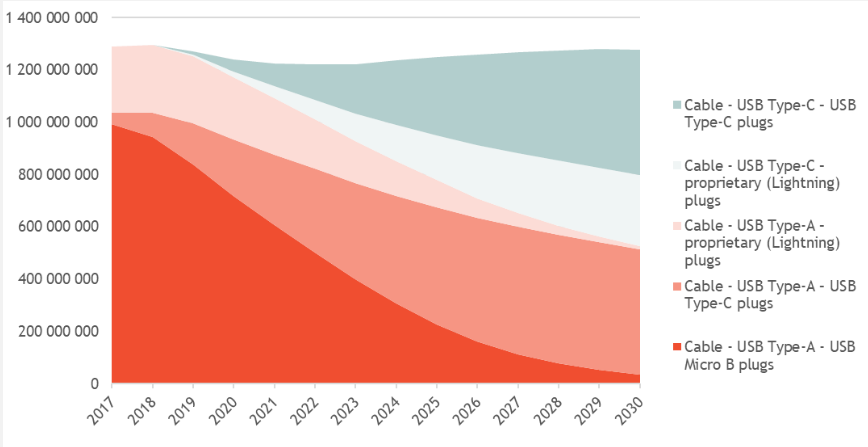
Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Policy Option 4a: Mandatory unbundling of EPS

The following table presents an aggregate summary of the Policy option 4a scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key assumptions underlying this scenario are the same as the baseline except for the following variations:

- **With smartphones** there is a key variation in total additions of EPS or cables compared to the baseline, with EPS additions reduced to zero by this policy option. Purchases of EPS at the same time as a phone are added to standalone sales. No variations in cables additions are expected. For EPS and cable types:
    - **EPS – types:** All EPS unbundled from 2024 onwards, this results in around 60 million fewer EPS being supplied with smartphones each year.
    - **Cables – types:** No variation from baseline types.
- **Standalone charger** sales are modelled on the basis described above in Table 0-3, and with variations in types compared to the baseline including:
    - **EPS - sales:** show a significant increase in this option of +16% or around 22 million per year by 2030. This is solely due to the mandatory unbundling of all smartphones, which creates a larger number of 'rebound' standalone purchases, added at the net ratio of 0.39 per unbundled phone as described previously for the baseline.
    - **EPS – types:** No changes compared to the baseline, EPS type splits remain the same, only the numbers of EPS are significantly increased.
    - **Cable – sales:** show an increase in this option of +7% by 2030. This is due to the indirect purchase of cables with EPS purchased as part of the rebound effect of unbundling. These are added at the net ratio of 0.21 per phone with unbundled EPS as described previously for the baseline.
    - **Cable – types:** No changes compared to the baseline.

Table 14 Policy Option 4a scenario evolution 2017-2030

	Annual sales (with Smartphones + standalone) [units]	Stock [units]
EPS		
Cables		

Source: Own stock model calculations.

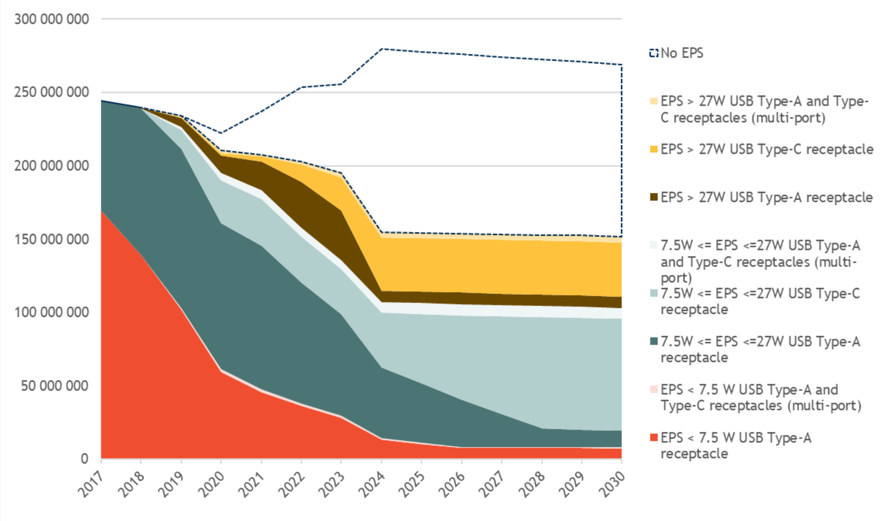
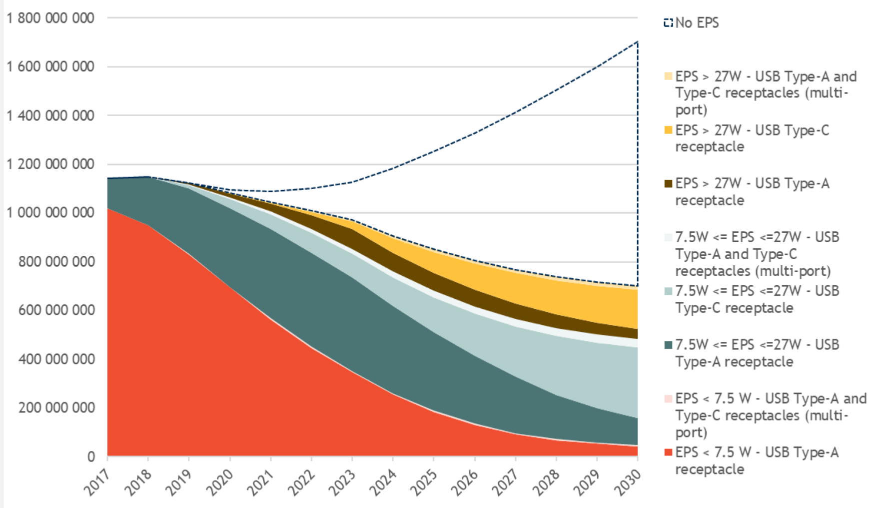
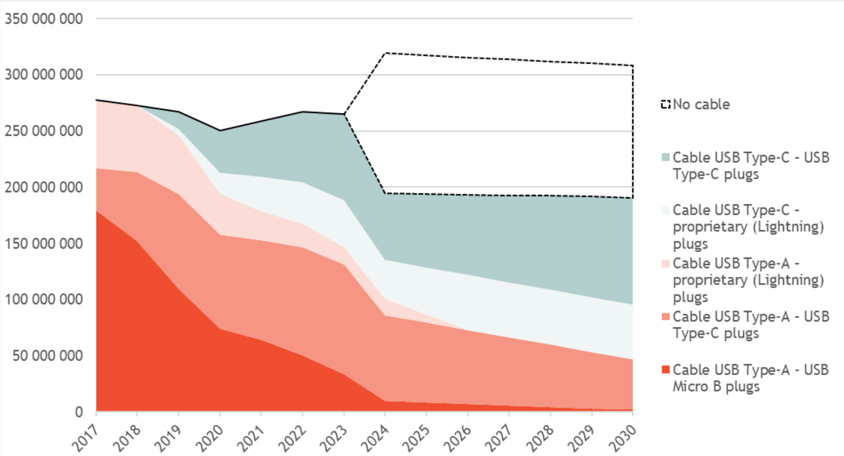
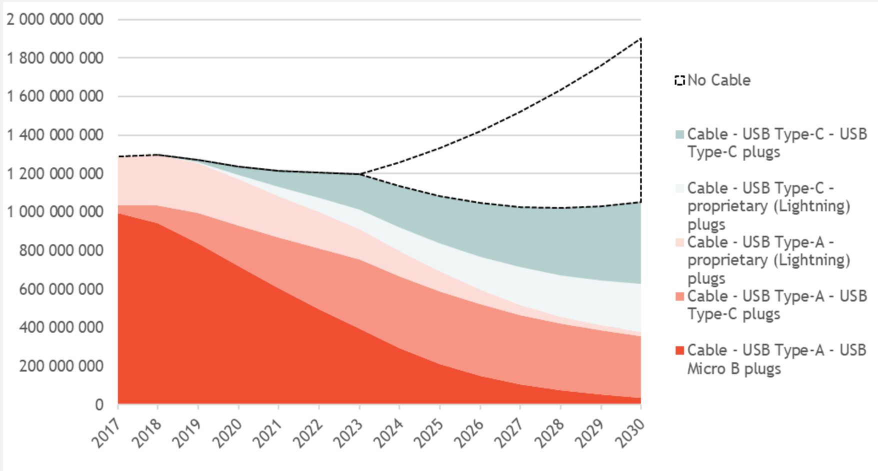
Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Policy Option 4b: Mandatory unbundling of EPS + Cable

The following table presents an aggregate summary of the Policy option 4b scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key assumptions underlying this scenario are the same as the baseline except for the following variations:

- **With smartphones** there are two key variation in total additions of EPS and cables compared to the baseline, with both EPS and cable additions reduced to zero by this policy option. Purchases of EPS and/or cable at the same time as purchasing a phone are accounted under standalone sales. For EPS and cable types:
  - **EPS – types:** All EPS unbundled from 2024 onwards.
  - **Cable – types:** All cables unbundled from 2024 onwards.
- **Standalone charger** sales are modelled on the basis described above in Table 0-3, and with variations in types compared to the baseline including:
  - **EPS – sales:** these increase the same as Option 4a.
  - **EPS – types:** No changes compared to the baseline, EPS splits remain the same, only the numbers of EPS purchased standalone are significantly increased.
  - **Cable – sales:** show a significant increase of +26% by 2030, or approximately 40 million cables per year. This is due to the mandatory unbundling of cables from all smartphones, which leads to a rebound in standalone cable purchases. These are modelled in the same way as the rebound for EPS (see baseline description), although the effect is different. The consumer survey did not provide a sound basis to directly estimate this effect but did provide a clear indication of how many additional cables are purchased standalone compared to EPS, +32% more. This adjustment was therefore applied to the 0.57 rebound value for EPS, to result in a 0.75 rebound effect, but this was reduced on the basis that 0.41 of these 0.75 would have purchased a standalone cable normally in any case. The net result of these effects is that we estimate that for every phone supplied unbundled without a cable that approximately 0.44 are bought standalone. This 0.44 ratio applied to the projected smartphone sales results in total standalone cable sales 26% higher than the baseline in 2030.
  - **Cable – types:** No changes compared to the baseline, cable splits remain the same, only the numbers of cables purchased standalone are significantly increased.

Table 15 Policy Option 4b scenario evolution 2017-2030

	Annual sales (with Smartphones + standalone) [units]	Stock [units]
EPS		
Cables		

Source: Own stock model calculations.

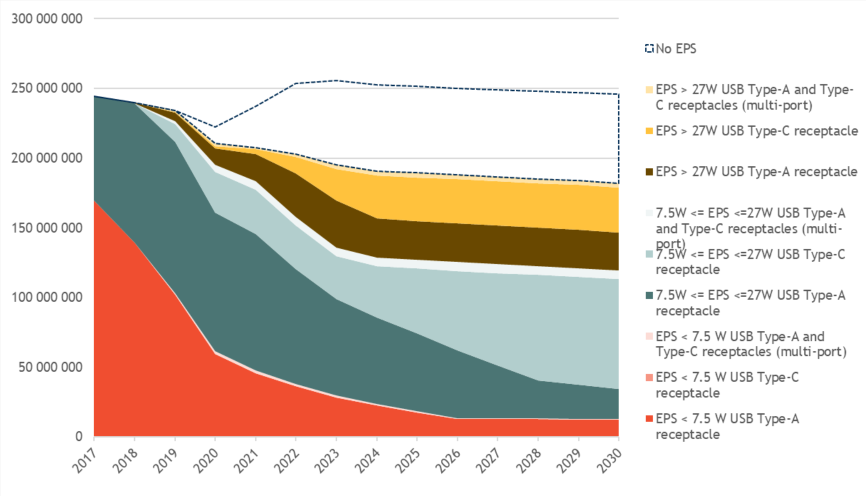
Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Policy Option 5: Interoperability labelling / information scheme

The following table presents an aggregate summary of the Policy option 5 scenario evolution of chargers split by EPS and cables. This shows the annual additions to the charger stock based on chargers provided with smartphones and chargers purchased standalone. The key assumptions underlying this scenario are the same as the baseline except for the following variations:

- **With smartphones** there is no variation in total additions of EPS or cables compared to the baseline as these are directly linked to smartphone sales which remain unchanged across policy options. Changes in EPS and cables types supplied with smartphones do occur with the main variations from the baseline including:
  - **EPS – types:** No change in EPS types compared to baseline.
  - **Cables – types:** No change in cable types compared to baseline.
- **Standalone charger** sales are modelled on the basis described above in Table 0-3, and with variations in types compared to the baseline including:
  - **EPS – sales:** is modelled with a small decrease (-1 percentage point applied to the 0.31 per person ratio) in standalone purchases resulting from the interoperability labelling / scheme as this is assumed to lead to a small but positive impact on EPS compatibility and consumer understanding. The size of any such effect is highly uncertain with little evidence on how effective it might be. The small size of any anticipated impact from this information measure is reflected in the small impact on sales (-2%) compared to the baseline.
  - **EPS – types:** No changes compared to the baseline, EPS splits remain the same, only that the numbers of EPS purchased standalone are slightly decreased.
  - **Cable – sales:** reduce a little due to the indirect purchase of cables with EPS, this effect is applied in the same way as for the earlier options. Resulting cable sales are around 1% lower than the baseline.
  - **Cable – types**: No changes compared to the baseline, cable splits remain the same, only that the numbers of cables purchased standalone are slightly decreased.

Table 16 Policy Option 5 scenario evolution 2017-2030

<table>
<tr><th></th><th>Annual sales (with Smartphones + standalone) [units]</th><th>Stock [units]</th></tr>
<tr><td>EPS</td><td>


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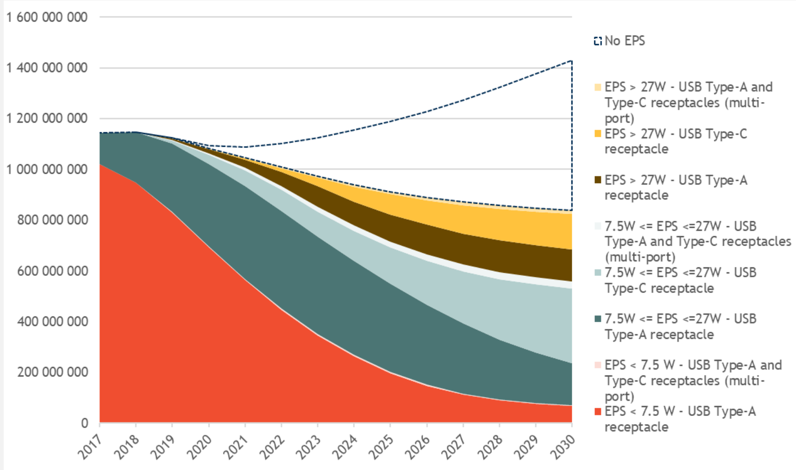
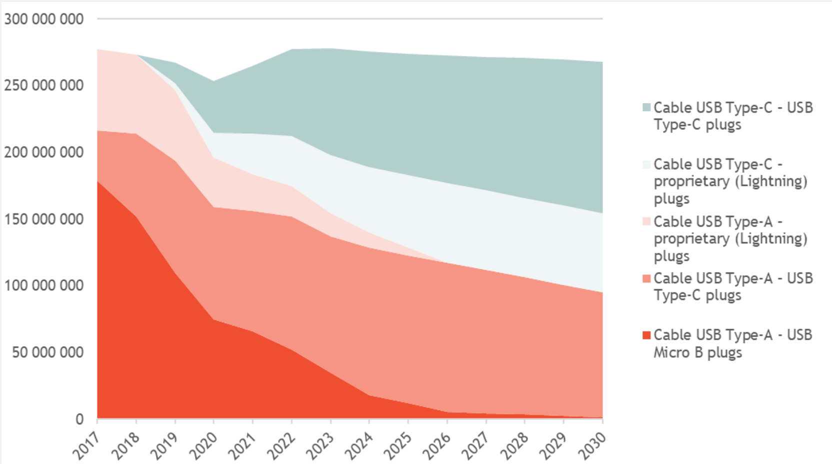


</td></tr>
<tr><td>Cables</td><td>


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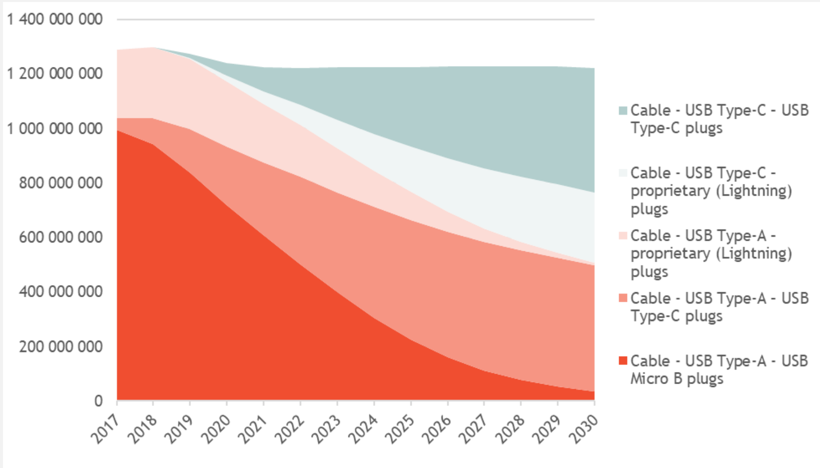


</td></tr>
</table>

Source: Own stock model calculations.

Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Table 20 Standalone EPS sales projections [million units]

Policy option	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2030 difference with baseline
Baseline	104.8	104.9	105.0	109.8	116.9	125.1	129.2	129.8	130.0	130.2	130.3	130.5	130.6	130.2	
PO1							129.2	129.8	130.0	130.2	130.3	130.5	130.6	130.2	0%
PO2							129.2	124.6	124.8	124.9	125.0	125.2	125.3	125.0	-4%
PO3							129.2	124.6	124.8	124.9	125.0	125.2	125.3	125.0	-4%
PO4a							129.2	154.7	154.2	153.7	153.3	152.8	152.4	151.5	16%
PO4b							129.2	154.7	154.2	153.7	153.3	152.8	152.4	151.5	16%
PO5							129.2	127.7	127.9	128.0	128.1	128.3	128.5	128.1	-2%

Source: Own calculations

Table 21 Standalone cable sales projections [million units]

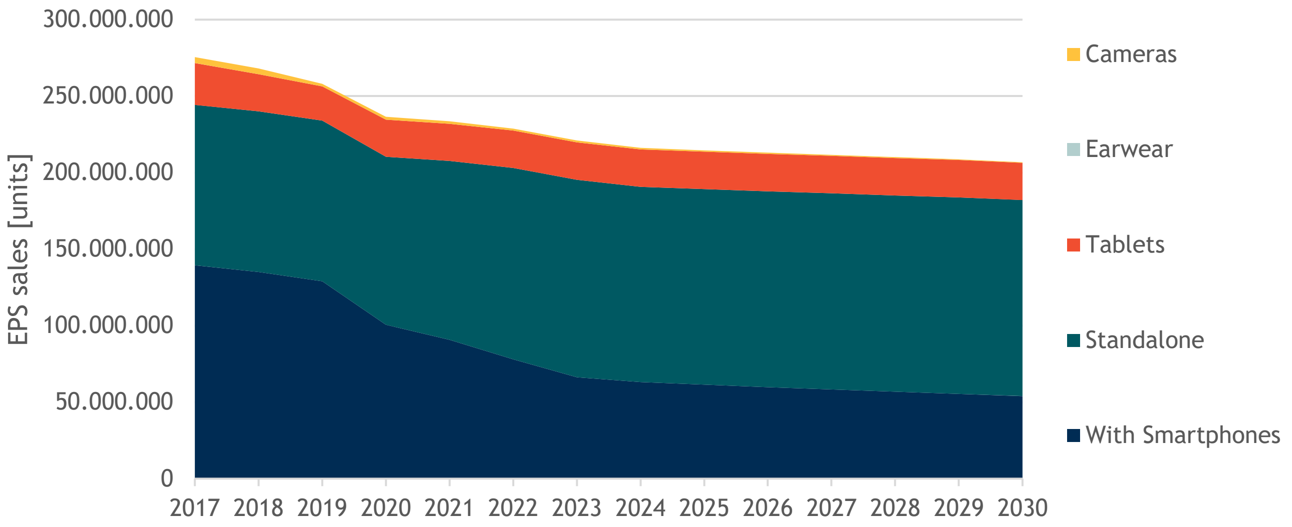
Policy option	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2030 difference with baseline
Baseline	138.0	138.1	138.2	140.7	144.3	148.4	150.5	150.9	151.1	151.2	151.3	151.4	151.5	150.8	
PO1							150.5	144.3	144.5	144.6	144.6	144.7	144.8	144.2	-4%
PO2							150.5	146.9	147.1	147.2	147.3	147.4	147.5	146.8	-3%
PO3							150.5	146.9	147.1	147.2	147.3	147.4	147.5	146.8	-3%
PO4a							150.5	163.2	163.1	162.8	162.6	162.4	162.3	161.4	7%
PO4b							150.5	194.4	193.9	193.4	192.8	192.4	191.9	190.7	26%
PO5							150.5	150.1	150.3	150.4	150.5	150.6	150.7	150.0	-1%

Source: Own calculations

Baseline additions – other devices

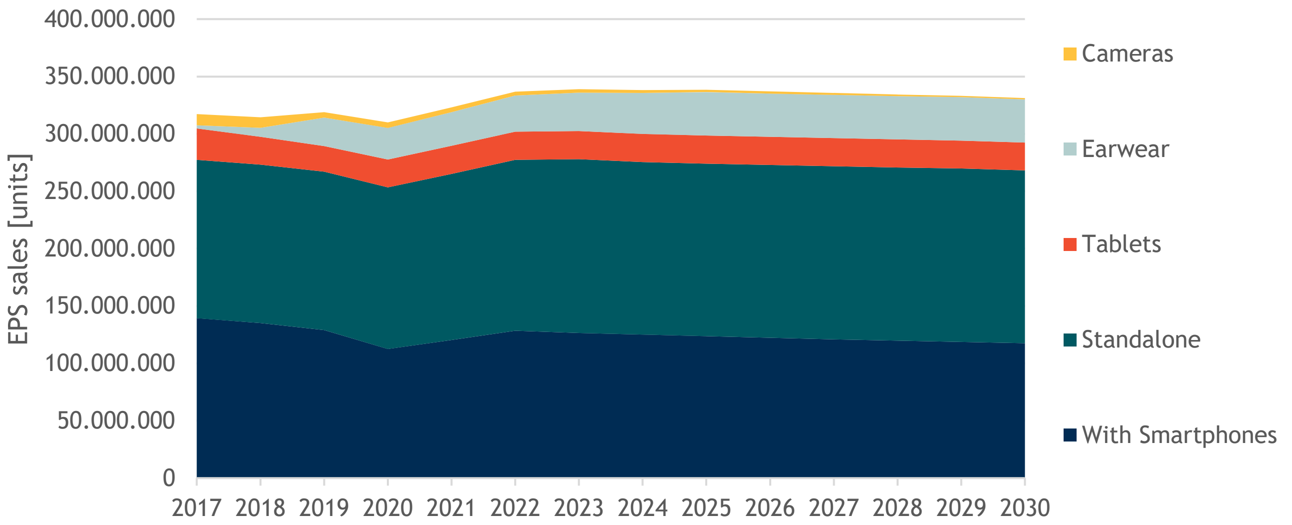
Overall, other devices tend to be much smaller markets for EPS and cables than those supplied with smartphones or standalone sales. The Figures below present the total additions of EPS and cables for the baseline, split by market/device. These show that for EPS cameras are a negligible share of the total, whilst tablets contribute around 11-12% of all EPS added each year, the remainder are covered by the 'with smartphone' and standalone market sales. For cables the other devices take a greater share, around 18-19% of the total, as the cables supplied with earwear have an impact. Nevertheless, it remains the case that the with smartphone and standalone market segments still contribute more than 80% of the annual cable additions. This gives some clear context to the importance of other devices in the wider chargers discussion, that they are relatively minor contributors to the issue, particularly cameras.

Figure 49 Annual EPS sales totals per market/device 2017-2030, units



Source: Own stock model calculations.

Figure 50 Annual cable sales totals per market/device 2017-2030, units



Source: Own stock model calculations.

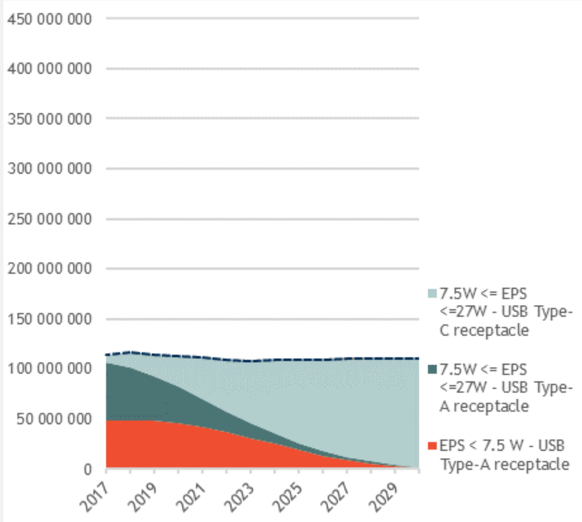
The following table presents the baseline development in the stock of chargers supplied with other devices. Important to recognise are the following:

- **Tablets –** sales of tablets average 23-24 million units per year from 2016 onwards. All tablets are supplied with EPS. Around 40% are low power (<7.5W) USB Type-A types, with USB Micro-B cables. The rest of the EPS are higher power (7.5W <= EPS <=27W) and are transitioning from USB Type-A to USB Type-C receptacles. By 2025 we expect all tablet EPS will be USB Type-C. Lightning cables for tablets are expected to be phased out by 2023, and all cables move to USB Type-C – Type-C by 2025.
- **Earwear -** sales of (relevant Bluetooth/wireless) earwear increased from zero in 2015 to around 25 million units per year by 2019 displacing traditional wired headphones, this trend is expected to continue in future, with sales of earwear increasing to around 38 million units per year by 2025. Earwear, whilst often supplied with a proprietary charging case / dock are never supplied with an EPS. Earwear are almost always supplied with cables, only 0.5% were not in our market mapping.

In 2019 it was estimated that approximately 48% of the market was for Apple earwear which are supplied with Lightning connectors and a mix of USB Type-A and USB Type-C cables, with a transition to USB Type-C – Lightning cables taking place. It is modelled that these market shares remain constant and that Apple does not change from USB Type-C – Lightning cables. For the remaining 52% market share, around 41% are USB Type-A cables, 11% USB Type-C cables, over time the share of USB Type-C is expected to grow from 11% to 31% by 2030. Similarly, the share of USB Micro-B cables reduce from 40% in 2019 to 0% by 2030.

- **Cameras** - sales of cameras have significantly declined over the last decade, from 30 million in 2010 to 5 million in 2020, with the increasing quality of smartphone cameras displacing compact digital camera sales. This trend is projected to continue with remaining camera sales being addressed to professional and hobby users, with a projected decline to around 1.2 million annual sales by 2030. Around 66% of cameras are supplied without EPS, although many are supplied with their own battery charging cradle, and others with a non-USB charging cable to the cradle or direct to the camera itself. Of the EPS that are supplied, all are low (<7.5W) power, and the majority have USB Type-A receptacles, although USB Type-C is being introduced and is expected to be adopted on half of EPS supplied with cameras by 2030. For cables, around 13% of cameras are already supplied without cables, and around 23% are estimated to be supplied with non-USB cables for charging. Of the remainder, the largest share (43%) are supplied with USB Type-A to USB Micro-B cables, and although a move to USB Type-A or USB Type-C to USB Type-C cables is expected going forward the share of USB Micro-B is only reduced to zero by 2028 as cameras do not require higher power charging and are a smaller, slower moving market.

Table 19 Policy Option 5 scenario evolution 2017-2030

<table>
<tr><th></th><th>Tablets stock [units]</th><th>Earwear stock [units]</th><th>Cameras stock [units]</th></tr>
<tr><td>EPS</td>
<td>
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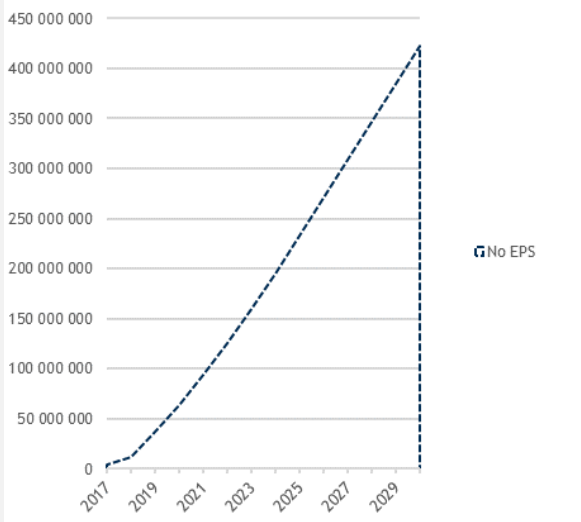
<td>
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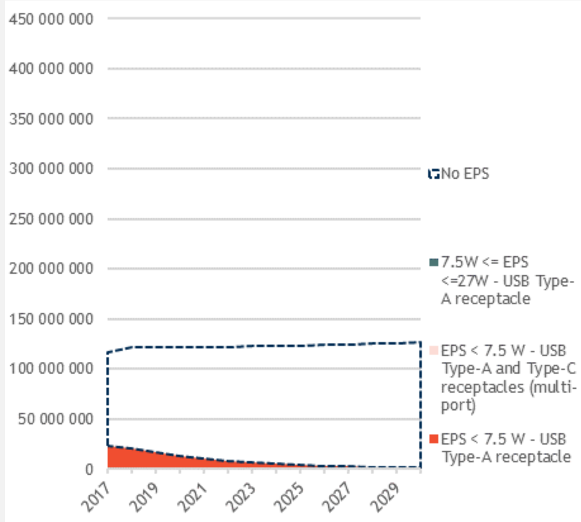
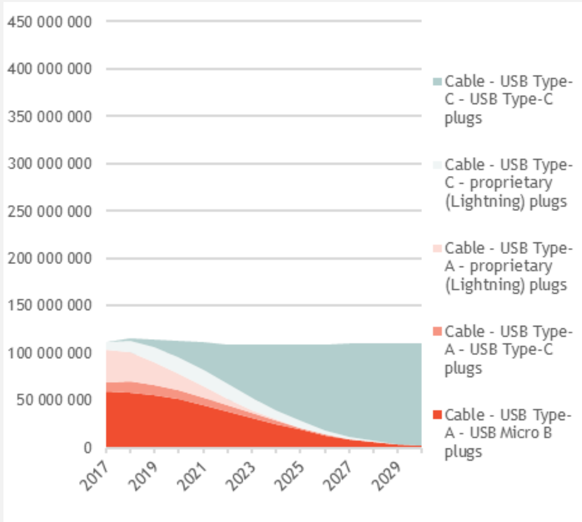
<td>
</td></tr>
<tr><td>Cables</td>
<td>
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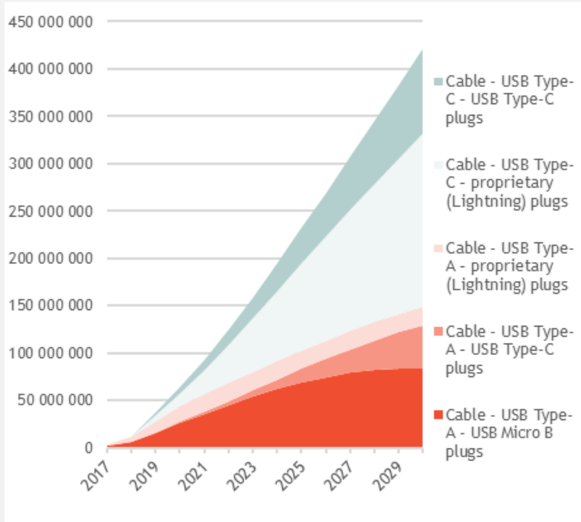
<td>
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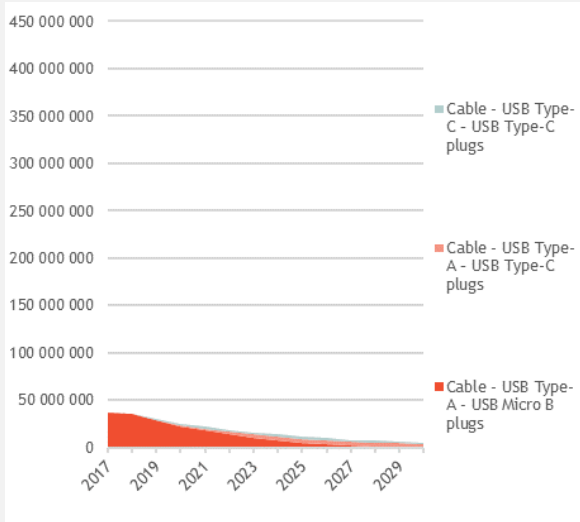
<td>
</td></tr>
</table>

Source: Own stock model calculations.

Note: The No EPS area in the stock graph does not decline as there are no disposals assumed (unlike other EPS), the total accumulates for this reason.

Model assumptions – other devices

The table below summarises the main assumptions that we have built into the stock model for each policy option and other device. It also includes the assumptions for the policy packages (see following section also). In all policy options, the rebound effects (i.e. the percentage of consumers who would buy a standandalone EPS when acquiring a new unbundled phone) work in the same way as for smartphones.

Option	Tablets	Earwear	Cameras
PO1	EPS – moved forward transition to 7.5W <= EPS <=27W by 1 year to 2024 Cable – USB Micro-B eliminated one year earlier than in the baseline, in 2024	EPS – not relevant Cables – all USB Micro-B and Lightning connectors are eliminated by 2024. Instead, cables use USB Type-C to C connectors, USB Type-A to C connectors, or USB Type-C to Lightning connectors.	EPS – no changes Cables – USB Micro-B and proprietary connectors are substituted by USB Type C. As a result, all cables sold are either USB Type A to C, or USB Type-C to C.
PO2	EPS – same as PO1 Cable – USB Micro-B eliminated one year earlier than in the baseline, in 2024	This policy option does not apply to earwear.	The option has been modelled for cameras (although section 6.1 of the report recommends not to apply it in full). EPS – assume share with proprietary cables move to provide EPS and cables compatible with USB battery charging protocols. The splits between EPS with USB Type-A and C receptacles follows the same split as for mobile phones. Cables – Eliminate USB Micro-B cables 2 years earlier.
PO3	EPS – same as PO2 Cable – same as PO1	This policy option does not apply to earwear.	EPS – same as PO2 Cables – same as PO2
PO4.a	EPS – all unbundled from 2024, already half in 2023 Cables – no change	EPS – already 100% unbundled Cables – no change	EPS – all unbundled from 2024, already half in 2023 Cables – no change
PO4.b	EPS – all unbundled from 2024, already half in 2023 Cables – all unbundled from 2024, already half in 2023	EPS – not relevant Cables – all unbundled from 2024, already half in 2023	EPS – all unbundled from 2024, already half in 2023 Cables – all unbundled from 2024, already half in 2023
PO5	No change compared to baseline – information only affects standalone market	No change compared to baseline – information only affect standalone market	No change compared to baseline – information only affect standalone market
Package 1	Same as PO1	Same as PO1	Same as PO1
Package 2	EPS – same as PO3 Cables – same as PO1	EPS – same as PO3 Cables – same as PO1	EPS – same as PO3 Cables – same as PO1
Package 3	EPS – same as PO4a Cables – same as PO1	EPS – same as PO4a Cables – same as PO1	EPS – same as PO4a Cables – same as PO1
Package 4	EPS – same as PO2 2020-2022, same as PO4a from 2023 Cables – same as PO2	EPS – same as PO2 2020-2022, same as PO4a from 2023 Cables – same as PO2	EPS – same as PO2 2020-2022, same as PO4a from 2023 Cables – same as PO2
Package 5	EPS – same as PO1 2020-2022, same as PO4a from 2023 Cables – same as PO1	EPS – same as PO1 2020-2022, same as PO4a from 2023 Cables – same as PO1	EPS – same as PO1 2020-2022, same as PO4a from 2023 Cables – same as PO1

Model assumptions – packages and synergy effects

The policy packages are modelled as the combined effect of the individual policy options. The underlying assumptions for the packages of options remain the same as the policy options but with the following adjustments to account for how the policy options interact with each other:

- Package 1 (options 1 and 2): The impacts of this package are slightly smaller than the sum of the impacts of options 1 and 2 individually. This is because both of these options entail the replacement of all remaining USB micro-B receptacles in phones with USB Type-C receptacles, and therefore this effect only accrues once if the options are combined.
- Package 2 (options 1 and 3): The exact same considerations apply as for package 1 – namely, the fact that both option 1 and option 3 individually would lead to the elimination of USB micro-B connectors and receptacles, and therefore, this effect must not be counted twice when these options are combined into a package.
- Package 3 (options 1 and 4.a): The impact of this package is slightly higher than the sum of the impacts of options 1 and 4.a individually. These options target different aspects of the charger (connector at the device end, and unbundling), and therefore there are no duplications of impacts. It is sensible to assume that harmonised receptacles in phones (and hence connectors on cables) could enhance the success of unbundling, in the sense that they would reduce the need for additional stand-alone cables to be bought. Therefore it is assumed that there is a synergy effect that affects the sale of unbundled cables, and that the proportion of consumers who choose to buy a cable when they buy a standalone EPS reduces from 62% to 56%.
- Package 4 (options 2 and 4.a): As in package 3, the effects of options 2 and 4.a are complementary. In addition, there is a synergy effect that enhances the effectiveness of unbundling (i.e. the addition of option 2 reduces the number of consumers who decide to acquire an EPS when they buy a phone that is unbundled). We have assumed that the combination of measures in this package will reduce the proportion of consumers who choose to purchase an EPS along with an unbundled new phone by 10%, i.e. from 57% under the baseline scenario (and all the options individually) to 51%.
- Package 5 (options 1, 2 and 4.a): In this case, options 1 and 2 have overlapping impacts (as explained in package 1), and option 4 complements the effects of 1 and 2. In addition, in there is a synergy effect similar to package 4, i.e. the proportion of consumers who choose to purchase an EPS along with an unbundled new phone falls from 57% to 51%.

Model assumptions – disposals and treatment

There is no new relevant data from the literature that is additional to that presented in the IA 2019 study on how and when chargers are disposed of. Therefore, to estimate the number of EPS and cables disposed of every year, average values based on the responses to the consumer survey were considered. These suggested that approximately 10% of the EPS and cables in stock are being disposed of each year. This assumption was applied in the model such that after 10 years all chargers purchased 10 years previously would be removed from the stock, with 10% removed each year.

Analysis of WEEE disposal and treatment[95] notes that there are many data gaps and issues, but studies chart increasing recycling rates over time. Based on analysis of the data for WEEE of small equipment and treatment in 2010 and 2018 we derive an assumption for waste disposal. This estimates for 2010 a rate of 41% of e-waste being sent for treatment, increasing to 65% by 2018. An annual increment of 1.5% improvement in this rate is applied per year based on this historic trend and an assumption that improvements will tail off somewhat over time as the 'low hanging fruit' in increasing rates is used. By 2030, this increment sees 84% of charger disposals assumed to be collected for waste treatment.

Concerning the EPS and cables treatment, the recycling rates assumed in the stock model are mainly based on the input provided during the interviews with recycling experts. As explained during these interviews, the standard recycling process for EPS and cables waste follows four main steps: 1) collecting and transporting 2) sorting 3) disassembly and shredding 4) post-treatment. As EPS and cables are usually collected in larger containers with other small electronics (including different types of IT equipment, household electronics, but also toys, etc.), the first step during the recycling process is sorting the waste and removing all devices (including those that contain batteries). This is then followed by the disassembly and shredding stage, during which the EPS main groups of components are separated (i.e., metals, plastics, and others). After the separation, the metals are prepared to be sold to smelters for post-treatment. In the case of the plastics obtained from the EPS, these are usually transported to plastic recycling facilities where density separation is a major step for classifying, among other separation methods such as optical and XR sorting. The aim of this step is to identify the plastics that can be potentially reused in new products (mainly based on plastic type and colour). The plastics that cannot be recycled and other components such as rubber are usually incinerated. As such, it was mentioned during the interviews that 40-50% of the plastic contained in the EPS can be separated to reuse, and around 50% of the plastic is usually discarded and incinerated (the main reason being the high content of flame retardants, which prevent recycling). Regarding the cables, it was indicated that the plastics are very difficult to recycle as the thin layer is not easily removed by the shredder.

In addition, as regards EPS and cables recycling, it was pointed out during the interviews that the costs associated with the recycling process as well as the legislation on extended producer responsibility (EPR) currently provide an incentive to manufacturers to reduce the volumes of EPS and cables put on the market. First, the value of the waste contained in the EPS and cables is relatively low compared to e.g., mobile phones, and thus the recycling treatment costs are higher (i.e. mobile phones have a higher material value due to a high content of precious metals, and thus the treatment costs are compensated by the revenue from the metals recycling). Further, as part of their EPR responsibilities, manufacturers are required to fund the WEEE treatment based on their share of devices sold each year. This means that any reduction in the weight of their products directly translates into cost savings for them, as Producer Responsibility Organizations (PRO) typically charge an EPR fee in €/kg. Finally, the compulsory registration process in place for WEEE manufacturers and importers may differ across EU Member States, and in some countries, two separate registration processes (and required paperwork) are needed (one for the mobile phone and one for the EPS, as these are classified under different WEEE categories).

Against this background, our main assumptions include:

- 40% of plastics contained in the EPS and cable are recycled in 2020, a rate that increases 1 percentage point annually until 2030.
- 90% of copper, aluminium and stainless steel contained in the EPS and cables are recycled in 2020, which increases 0.25 percentage points each year until 2030. The high content of copper makes its extraction and reuse very attractive, but the recovery rate is already very high and will unlikely change significantly.

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[95] Key studies used as sources for this estimation, are Balde et al (UNITAR) (2020) In-depth review of the WEEE collection rates and targets in the EU-28, Norway, Switzerland and Iceland; and Balde et al (UNITAR) (2020) The Dutch WEEE flows 2020, what happened between 2010 and 2018?

- For other materials, the stock model assumes that 40% are recycled, increasing 1 percentage point annually. The small size coupled with the high complexity of small components included in the EPS (e.g., resistors, rectifiers, capacitors) makes them very difficult and unattractive to recycle, as explained during the interviews.

Model assumptions – Charger types and profiles

Material content

To estimate the material content of EPS and cables, the stock model relies on a refined bill of materials (BoM) that includes all the components contained in a standard EPS[96] and cable. Based on this refined BoM, the heaviest and largest components and the materials used were identified. We note that the information about the materials used for most components is limited, as manufacturers generally do not include these details in the datasheets of the components. The detailed BoM is presented below.

Table 20. Detailed BoM of a mobile charger (heavier items are highlighted)[97]

Quantity	Component	Dimensions					Total weight	Main components [98]
		ø	L	W	H	mm^3	mg	
		mm						
1	Ceramic capacitor	2.0	2	1.25	1.25	3	6	Ceramic, Sn, Ni, Cu
1	Ceramic capacitor	6.2	3.2	1.6	0.85	4	27	Ceramic, Sn, Ni, Cu
1	Ceramic capacitor	15	2	1.25	1	3	6	Ceramic, Sn, Ni, Cu
2	Ceramic capacitor		2	1.25	1	5	12	Ceramic, Sn, Ni, Cu
1	Y1 Capacitor						10	Ceramic, Sn, Ni, Cu
1	Diodes Bridge rectifier		2.8	1.78	0.98	5	10	Plastic, "Green" Molding Compound (Case); Tin
1	Schottky rectifier		6.29	5.35	1	34	95	Plastic, "Green" Molding Compound (Case); Tin
1	Standard rectifier		2.8	1.78	0.98	5	10	Plastic, "Green" Molding Compound (Case); Tin
1	Switching diode		1.7	1.25	0.9	2	33	Metal, Silicon
1	MOSFET		9	2.4	16.1	348	4 000	Silicon (min 90%), others (10%)
1	NTC Thermistors		1.6	0.8	0.8	1	5	Copper, Ni plating and Sn Plating
1	Fixed Inductor	6	8.5	-	-	240	562	Copper (min 50%), others (50%)
1	Transformer		16.9	18.8	13	4130	10 000	Copper (30%), ferrite, insulating tape
8	Resistors	1.8	3			61	40	Metal connector, ceramic (insulating case), carbon granulates
6	Resistors	2.5	6			177	30	Metal connector, ceramic (insulating case), carbon granulates
2	Resistors	2.5	6			59	10	Metal connector, ceramic (insulating case), carbon granulates
2	Electrolytic capacitor	10	12.5			1963	6 000	Aluminium (50%), others (50%)
1	Electrolytic capacitor	6.3	8			249	1000	Aluminium (50%), others (50%)
1	Electrolytic capacitor	6.3	9			281	1000	Aluminium (50%), others (50%)
1	PSR Controller		4	5	1.75	35	254	Various
1	USB Connector		14.5	19.3	7.15	1996	6 000	Steel (60%), Copper (10%) , Others (30%)
1	Plastic cabinet						20 000	Plastic (100%)
1	Printed circuit board		37	31	1.4		2971	Fiberglass (95%) , copper (5%)
1	Plugs						3 400	Copper (100%)
	Solder						500	

[96] Based on the 5.3V 2A Mobile Phone Charger Reference Design developed by TexasInstruments. See: https://www.ti.com/tool/PMP4432

[97] As presented by Texas Instruments in https://www.ti.com/lit/pdf/tidrbx2

[98] The components listed are based on the datasheets presented in the databases of Mouser.co.uk, Digikey.es.

The refined BoM considers all the components contained in a mobile phone charger[99], which allowed us to identify the heaviest and largest components (e.g., transformer, electrolytic capacitors, and transistors), based on the datasheets published by the manufacturers. Once the key components of the charger (in terms of mg and cm^3) were identified, we conducted desk research to determine the materials used in each of the components of the charger. As a result of this analysis, we updated the materials considered in the stock model, to include for the EPS, besides 'plastic' and 'copper' (which were included in the 2019 IA study), the categories, 'stainless steel' and 'aluminium' and the category 'other' include the materials contained in the smallest components (e.g., resistors, diodes), as well as the ferrite, silicon, solder, and other insulation materials contained in the charger. We do not distinguish between different types of plastics, since it was indicated during the interviews with stakeholders that there is little difference in the recyclability potential of different types of plastics used in chargers. Regarding the cables, the updated stock model also adds the subcategory 'stainless steel' (present in the USB connector), in addition to copper, plastics and others.

In addition, in the previous 2019 IA study, we indicated that there is a trend towards heavier chargers as fast charging EPS technologies were assessed to have more complex and heavier components and would gradually become the new standard. However, our literature research and the interviews also highlighted that technological developments may change this trend. According to a supplier of high-performance electronic components, it is estimated that the new technologies (e.g., Gallium Nitride [GaN] diodes, super-junction) would enable 40% less volume and 30% less weight for EPS (a full switchover of the market towards these technologies is anticipated to happen within a decade), through improved energy efficiency and reduction in heat, and therefore a reduction in insulation and other materials. Therefore, it is expected that the high-power and high-quality devices will become lighter than current models per nominal power in the future.

Against this background, the key assumptions considered by the stock model are:

- There are differences in the material content of EPS of different nominal power (wattage). Therefore, the stock model considers an adjustment of the standard composition of EPS>27 W. The main difference, as experts suggested, is a higher content of copper and aluminium due to a higher current capacity. Owing to a high variability of material content profiles between manufacturers and based on expert's judgement, the model assumes for higher power EPS (EPS>27 W) an average of 10% more copper (an increase mainly due to a higher power transformer) and 20% more aluminium (mainly contained in the EPS electronic components). Moreover, the introduction of new components such as GaN diodes is assumed to decrease the amount of silicon (contained in the EPS transistor) by 90%. The input values used in the model are presented in Table 12.
- The material content of cables varies for USB-C cables (i.e. with at least one connector to be of type C). Compared to the 'standard composition', the amount of copper contained in USB-C cables is assumed to be higher than for USB Type-A and/or Micro B cables.[100] The stock model assumes that the wires inside a USB-C cable are thicker (24-gauge) compared to standard-sized (28-gauge wires).[101] Based on this diameter difference of the copper wires, it is estimated that the USB-C cables have 55 % more copper content. This significant increase in copper content was confirmed during the interviews with a recycling company and a manufacturer of electronic components. The input values used in the model are presented in Table 12.

[99] Based on the 5.3V 2A Mobile Phone Charger Reference Design developed by Texas Instruments. See: https://www.ti.com/tool/PMP4432

[100] Copenhagen Economics (2019) United in Diversity- EU consumers' evidence on the innovation and environmental impacts from possible common charger regulation forcing a single device-end connector type

[101] DELTA-OPTI- Technical Dictonary - AWG. https://shopdelta.eu/awg_l2_aid938.html

In addition to the materials included in Table 21, some manufacturers mentioned during the interviews the use of other materials in the chargers and cables such as bioplastics. For example, a manufacturer of mobile phones pointed out that the TPU (thermoplastic polyurethanes) contained in the cable will be 42% biobased plastic in the future. Other cables available in the market today include stainless steel braiding and aluminium hosing[102]. As these changes are not yet observed as a general trend in the market, the stock model does not distinguish between different types of plastics (including bioplastics) nor consider other types of materials besides those listed in the table below.

Table 21. Standard material composition of a mobile charger and cable[103]

Component	% of total weight	
EPS	*Standard composition*	*Adjustment, EPS >27W*
Plastic	36%	37%
Copper and copper alloys	13%	15%
Stainless steel (USB connectors)	6%	7%
Aluminium	7%	9%
Others	35%	33%
Cable	*Standard composition*	*Adjustment, USB C-Cables*
Plastic	30%	23%
Copper and copper alloys	30%	46%
Stainless steel (USB connectors)	24%	24%
Others	16%	7%

- The weight of higher power EPS (>27W) will decrease with technological developments in the next decade. The model assumes that new components would enable 30% less weight in more powerful (>27W) EPS by 2030, based on figures provided by suppliers of high-performance electronic components. In contrast, for EPS<27W the model assumes a 20% weight decrease by 2030 driven by an increasing market trend toward smaller EPS. In both cases, the gradual weight decrease is assumed to be constant between 2020 and 2030.

Model assumptions – GHG Emissions

The GHG emissions impacts of chargers are a factor of the weight of the chargers and the global warming potential (GWP). Only a limited number of relevant assessments can be identified for the GHG emissions impact of chargers. Therefore, to refine the GWP values considered in the 2019 IA study, the updated stock model considers in addition the data presented in the framework of the Eco-design preparatory study on mobile phones, smartphones and tablets- Task 5. Table 12 presents the input values used by the updated stock model.

[102] See for example MyEpico Metal Cable (https://www.myepico.com/product/pd-metal-cable/) and Verbatim USB-C to USB-A Sync & Charge Cable (https://www.verbatim-europe.co.uk/)

[103] Based on the 5.3V 2A Mobile Phone Charger Reference Design by Texas Instruments. https://www.ti.com/tool/PMP4432

Table 22. Average GWP per g of weight of component and per unit of EPS and cable Average GWP per g of weight of component and per unit of EPS and cable[104]

Life-Cycle Phase	Average GWP (kg CO_{2e} per g of weight of component)		Estimated average GWP (kg CO_2e per unit of EPS and cable[105]).	
	EPS	Cable	EPS	Cable
Raw material and manufacturing	0.035	0.012	1.73	0.36
Transport	0.031	0.023	1.54	0.69
End of life	0.0003	0.0002	0.01	0.01
Total	**0.066**	**0.035**	**3.29**	**1.06**

Impact of lighter packaging and online/in-store purchase

Manufacturers have highlighted the positive impact on reducing emissions that unbundling has due to the use of fewer **materials** for the packaging and higher transport efficiency. Apple, for instance, has indicated that with the removal of inbox accessories, they have reduced the packaging weight by 39 per cent and with it, the carbon footprint.[106] Similarly, Nokia has reported its efforts to maximise transport efficiency by reducing packaging materials.[107] However, other stakeholders have argued that unbundling will lead to a higher amount of packaging material and associated emissions (as users will potentially buy separately a charger and cable)[108]. Furthermore, a retail association during an interview indicated that while the packaging of phones is normally cardboard, when EPS are sold separately, they are packaged in plastic.

To analyse qualitatively the impact of lighter packaging in transport, we have distinguished between *upstream transport* and *last-mile transport*. Upstream transport includes transport from the factory to the manufacturer's warehouse, and then further transport to the parcel distribution centre or retail shop. Last-mile transport refers to the distance between a store or distribution centre to the customer. In this analysis, we have also differentiated upstream transport packaging (i.e., the packaging used during the upstream transport) and delivery packaging (i.e., used for the last-mile transport). The values included in Table 12 for the transport phase include the transport packaging but exclude last-mile transport. Furthermore, we could consider four possible purchase options affecting transport emissions and materials used: 1) sale of a total phone+charger (bundled); 2) sale of a phone with no-EPS (and/or cable) (unbundled), 3) sale of standalone EPS and cable and no phone, 4) sale of standalone EPS, cable and unbundled phone as three separate items.

Table 23. Comparison of upstream transport GHG emissions

Purchased option	Weight (g)			Estimated GHG emissions ($kgCO_2eq/g$)	GHG difference with option 1 ($kgCO_2eq/g$)
	Item	Packaging	Total		
(1) Total phone + EPS (and or cable) (bundled)	270	68	338	9.1	-
(2) Phone with no-EPS (and/or cable) (unbundled)	150	38	188	5.1	-4.1

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[104] Based on SustainablySMART (2019) Regulation of Common Chargers for Smartphones and other Compatible Devices: Screening Life Cycle Assessment. Policy Brief No. 2; Ercan, M. (2013), Global Warming Potential of a Smartphone Using Life Cycle Assessment Methodology; Charles River Associates (2015) Harmonising chargers for mobile telephones Impact assessment of options to achieve the harmonisation of chargers for mobile phones; Schischke, K et al (2021) Eco-design preparatory study on mobile phones, smartphones and tablets- Task 5.

[105] Based on the baseline, weighted average weight of an EPS (50g), and cable (30g) in 2020.

[106] Apple (2020) Product Environmental Report. iPhone 12 Pro.

[107] Nokia (2019) People and Planet Report 2019.

[108] See for example: https://www.youtube.com/watch?v=WVPM6D-3aZo&t=286s&ab_channel=Mrwhosetheboss

(3) Standalone EPS and no phone and/or cable	52 (EPS)	21	73	2.3	-6.2
	20 (Cable)	8	28	0.64	
(4) Sale of standalone EPS, cable and unbundled phone as separate items.	52 (EPS)	21	73	2.3	-1.1
	20 (Cable)	8	28	0.64	
	150 (Phone)	38	188	5.1	

The change in GHG emissions of upstream transport between the different purchase options depends largely on the weight difference determined by the upstream transport packaging (assuming that the main transport mode is the same). A previous LCA has suggested a transport packaging factor of 1.25 for the total phone-kit (i.e., including charger and cable).[109] As shown in Table 13, this means that if a consumer purchases an unbundled smartphone (option 2, 150+38g packaging) instead of a total-phone kit (option 1, 270+68 packaging), the GHG emissions of 151g per item will be saved (or 4.1kg of $CO_{2,eq}$ considering the average values of Table 12). In contrast, recent purchases of Samsung accessories shows that a standalone purchase of an EPS weighed 73g, of which 21g was the transport packaging material (i.e., a packaging factor of 1.4). If a consumer purchases not only the unbundled smartphone but also a standalone EPS and a cable (option 4)[110], the GHG difference compared to a total-phone kit will be around 1.1 kg of $CO_{2,eq}$. These estimations are only indicative, and we note that the weight of packaging materials may vary considerably between manufacturers (and with time). As expected, more GHG emissions from transport will be saved as fewer items need to be transported (options 2 and 3). According to our analysis, it seems reasonable to conclude that even if a consumer purchases the EPS, cable, and smartphone as separate items (option 4), this will not result in a significant change in upstream transport emissions compared to the purchase of a total-phone+charger package (option 1). This has been also suggested by other analysts, who have concluded that smaller packaging does not necessarily lead to lower shipping emissions.[111]

In the case of the GHG emissions of last-mile transport between the different options, these depend not only on the weight difference determined by the delivery packaging but also on other factors, including whether the purchase is online or in-store. Depending, among others, on the distance traveled, the items purchased and the mode of transportation, the emissions will differ. Similarly, the distance of the distribution centres and the mode of transport used by the delivery companies (e.g., vans, cargo bikes) influences the impact of the delivery.[112] All these factors result in large variability of GHG and materials footprints. For the different combinations of purchase options of EPS, cables and phones analysed here, the distances of last-mile transport are considerably lower compared to the upstream transport (from Asia to Europe) and, therefore, we expect the last-mile transport to have little impact on the overall GHG emissions. Furthermore, we do not expect the GHG emissions to vary significantly across the different purchase options, given that the passenger cars and delivery vans are often not full when they are used and that the weight or volume of the item is often not a limitation that affects the number of trips/deliveries.[113]

In the case of the delivery packaging material, we note that the values reported by the studies included in Table 12 for the life-cycle phase *raw material and manufacturing* exclude the

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[109] Ercan (2013). "Global warming potential of a smartphone: Using life cycle assessment methodology.". https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A677729&dswid=_new

[110] Weight of packaging estimated using a packaging factor of 1.4.

[111] As University of Florida Professor Sara Behdad suggested, according to https://www.theverge.com/2020/10/16/21519466/apple-iphone-12-chargers-airpods-greenhouse-gas-emissions-e-waste

[112] Shahmohammadi, Sadegh, et al. "Comparative Greenhouse Gas Footprinting of Online versus Traditional Shopping for Fast-Moving Consumer Goods: A Stochastic Approach." *Environmental science & technology* 54.6 (2020): 3499-3509. https://pubs.acs.org/doi/abs/10.1021/acs.est.9b06252

[113] Ibid.

packaging materials. Based on our analysis, we expect that the difference of the impact on emissions of the (additional) packaging used for delivery would negligible (compared to the emissions of the other materials used). According to a previous study, the GWP of the packing emissions accounts for 0.47 kg CO_{2eq} /kg of packaging material used[114]. Taking these values into account, the share of the GHG emitted during the raw material and manufacturing phase related to packaging (including a packaging cardboard box, plastic wrappings, and phone manual) would be less than 0.3 % (approx., 0.01 kg CO_2eq) for an average EPS and cable set. This means that even if the material used for the packing was three times higher, then the share attributed to it will be less than 2% of the total GHG emissions. Therefore, the impact of packaging on GHG emissions of the raw material and manufacturing phase is negligible and not considered relevant for the overall results.

As a result of the low expected impact and the high number of variables required for a more detailed analysis as explained above, our updated stock model will not assess quantitatively the impact of lighter packaging and delivery in GHG emissions and materials used.

Model assumptions – sensitivity check

There are various uncertainties when projecting forward and assuming market and technological developments into the future, and also for the other assumptions that underpin the market model. Whilst some assumptions such as charger profiles, e.g. weight, price, etc; will see scaling effects proportional to the changes made, others can have more complex effects. The model was examined for variables for which sensitivity checks would be possible and where variance in the variable/assumption could have an important impact on the results. Also we considered triangulation of data to validate model results, for example in terms of quantities of charger units, we have good confidence that the model overall settings are robust as the number of EPS and cables in the stock, compared to the survey reported EPS and cables owned by consumers correspond closely.

One of the key sets of assumptions identified for checks was the rebound rates for EPS and cables, i.e. the proportion of consumers that would purchase these standalone in the case they were unbundled. In the model the rebound rates are:

- **EPS:** 57% of consumers buying an EPS standalone if this was unbundled, reduced by the 31% of those that would normally have purchased a standalone EPS in any case, a net rebound effect of 0.39 EPS purchased standalone for every EPS unbundled. This also has an indirect impact on cable purchases as 62% of standalone EPS purchases are bundled with a cable.
- **Cables:** a similar adjustment was made, on the basis of 75% of consumers purchasing a cable standalone if this was unbundled, reduced by the 41% that would have purchased a standalone cable anyway, for a net effect of 0.44 cable purchases for every cable unbundled.

Naturally, these assumptions are especially relevant for policy options 4a and 4b where unbundling is mandated.

Using a 35% rather than 57% assumption for consumers purchasing an EPS standalone in the case of unbundling results in a net effect of 0.24 EPS purchased for every EPS unbundled. Using 70% rather than 57% results in a net effect of 0.48. The impact of these changes is minimal on all policy options except PO4a and PO4b. The following table compares these low and high assumptions for PO4a and PO4b compared to the central 57% assumption used in the work. As expected, a lower rebound assumption results in greater environmental benefits compared to the baseline (i.e. higher reductions in emissions, etc), and vice-versa for a higher assumption. The overall impact of the assumption is quite significant in the results, so that if in

[114] See Figure 23 in Ercan (2013). "Global warming potential of a smartphone: Using life cycle assessment methodology.". https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A677729&dswid=_new.

reality the rebound effect is lower, then the beneficial impact of these policy options would also be higher.

Table 24 Results of sensitivity check of rebound effect assumption on PO4a and PO4b

	PO4a average annual difference with baseline			PO4b average annual difference with baseline		
	LOW	CENTRAL	HIGH	LOW	CENTRAL	HIGH
CO_2 emissions	-13.4%	-9.0%	-6.6%	-26.2%	-19.9%	-16.4%
Material use	-9.8%	-6.1%	-4.1%	-28.3%	-21.8%	-18.3%
E-waste	-4.4%	-2.7%	-1.8%	-12.8%	-10.0%	-8.4%
Untreated	-4.1%	-2.6%	-1.7%	-11.9%	-9.4%	-7.9%
Recycled	-3.9%	-2.3%	-1.4%	-13.6%	-10.7%	-9.1%
Cost to consumers	-0.1%	4.2%	6.6%	-4.9%	2.4%	6.4%
Benefit for manufacturers and wholesalers [NPV million EUR]	-10.6%	-6.8%	-4.7%	-27.4%	-20.9%	-17.3%

Annex H: Categorisation of portable electronic devices

During the inception phase, the study team developed a mapping of 186 mobile phones and 192 other devices,[115] tracking the following characteristics:

- Descriptive elements: type of device, brand, model, and year it was released;
- Charging profile: current, voltage, power and type of battery (Li-ion, Li-polymer, etc.);
- Type of chargers used: connector, fast charging (indicating whether USB PD / proprietary);
- Unbundling: whether EPS included in the box, and whether cable included in the box.

Based on the information gathered in the mapping, as well as the devices' market trends (using information from the first IA study), the team proposed the scope of devices for the remainder of the study, as well as a categorisation of devices to help prioritise the market data to be acquired.

As a result of the scoping and prioritisation work, laptops and radio-controlled toys were excluded from further analysis, and it was decided that the study would focus on: smartphones, tablets, cameras, handheld videogame consoles, hearing devices (headphones/earbuds), e-readers, portable speakers, and smartwatches / fitness trackers.

Laptops were excluded because they use significantly higher wattage than mobile phones, and therefore it would not be possible to extrapolate data and assumptions from smartphones to laptops (different impacts on safety and the environment). Radio-controlled toys were excluded because their charging characteristics also differ from mobile phones; they generally use lower current (0.1-1A vs 1-2A used in mobile phones) and, most importantly, use different types of batteries (Ni-MH / Ni-Cd, instead of Li-Ion or Li-Polymer used in mobile phones).

The prioritisation of other devices was conducted using the following criteria:

1. The extent to which unbundling already exists, de-prioritising those that are already sold unbundled;

2. The trend of sales of the products, de-prioritising those devices with a decreasing trend.

As a result, we categorised each device as high, medium, or low priority, as shown in the table below.

Table 24: Summary of the rationale to prioritise portable electronic devices

Device	Sales trend	Potential to reduce fragmen-tation	Additional unbundling potential	Priority	Rationale
Tablets	Decreasing	High	High	High	Closest device to smartphones in terms of battery and charging characteristics

[115] The sample includes: 29 cameras (including action cameras), 10 handheld videogame consoles, 9 e-readers, 11 smartwatches / fitness trackers, 30 headphones/earbuds, 14 laptops, 15 radio-controlled toys, 2 smartglasses, 26 portable speakers, 45 tablets.

Device	Sales trend	Potential to reduce fragmen-tation	Additional unbundling potential	Priority	Rationale
Cameras	Decreasing	High	High	High	High potential to reduce fragmentation and likely high impact of unbundling. However, the technical feasibility of charging all types of cameras with USB C connector and USB-PD enabled ESP needs to be further investigated.
Hearing devices	Increasing	High	Medium	Medium	Very fragmented market (type of connector) and growing market. All products analysed include a cable and half of them include also an EPS. This category has 2 subproducts: headphones and earbuds. Some earbuds are charged via wireless in their box, and the box connects to an EPS via USB/Lightning. We will treat the earbuds' box as part of the product, and look at the connector in the box.
Hand-held video game consoles	Constant	Low	High	Medium	A priori, it seems feasible technically that consoles share cable and EPS with smartphones (but this needs further investigation during data collection). All devices analysed in the mapping are sold with cable and EPS, therefore impact of unbundling may be significant.
Portable speakers	Increasing	Medium	Low	Low	Most of the devices use USB-C or USB micro-B, and only 5/26 are sold with an EPS, which would make the impact of unbundling somewhat limited. The trend towards USB-C and towards de-coupling has been confirmed in interviews with manufacturers.
E-readers	Constant	Low	Low	Low	Impact likely to be low as EPS not included in the box and connectors already standardised
Smartwatches and	Constant	High	Low	Low	Most devices are charged via wireless. These wearables are often

Device	Sales trend	Potential to reduce fragmen-tation	Additional unbundling potential	Priority	Rationale
fitness trackers					designed to be water resistant and support hard conditions, therefore USB connectors may not offer the best solution.

This categorisation informed the acquisition of commercial data. Devices categorised as high or medium priority were prioritised over those classified as low.

Market trends

This section briefly presents the charging characteristics, market trends, and current extent of unbundling in the market for other portable devices.

Commercial data was acquired from IDC for two categories of electronic devices, in addition to mobile phones – tablets and hearing devices. Market trends for other devices have been obtained from public sources; mainly, PRODCOM for digital cameras, and the United Nation's Comtrade database for the remaining devices.

Table 25: Estimated sales of other portable electronic devices

Type of device	**Latest available year**	**Estimated sales in the EU (thousand units), latest available year**	**Sales trend, latest three years available**	**Source**
Tablets	2019	22,350	-18%	IDC (2020)[116]
Hearables	2019	23,612	+857%	IDC (2020) [117]
Digital cameras	2019	5,428	-52%	PRODCOM (2021)
Handheld video games	2018	52,100	+5%	Comtrade (2019)
E-readers	2019	20,943	+2%	Comtrade (2021)
Smartwatches and fitness trackers	2019	12,764	-2%	Comtrade (2021)
Portable speakers	2019	3,400	+27%	Comtrade (2021)
TOTAL		**140,597**		

In total, it is estimated that in 2019 around 137.7 million devices were sold in Europe.[118] However, product sales show varied trends. The sample includes hearables, whose sales between 2016 and 2019 have grown considerably (+857%), and also other products, such as digital cameras, whose sales have decreased (-52%).

[116] Source: IDC Quarterly Personal Computing Device Tracker, Q3 2020 Final Historical, November 18, 2020

[117] Source: IDC Quarterly Wearable Device Tracker, Q3 2020 Final Historical Release, November 27, 2020

[118] Data from IDC covers a variable sample of Member States depending on the type of device. Data from Comtrade refers to EU-28 (including UK). Additional details on sources and methodology are provided in the annexes.

Charging profile of other devices

Table 13 provides an overview of the main charging characteristics (current, voltage, and power) of the portable devices within the scope of this study (as per section 2.1).

Table 26: Typical charging characteristics of portable electronic devices

Device	Current	Voltage	Power	Connectors used	Unbundling
Group 1 (High priority)					
Smartphones	1A – 3A	5V – 12V	5W – 20W	Around ¾ of the devices analysed use USB Type-C (57/77), although some use USB Micro-B or Lightning.	Most phones are sold with an EPS (17/19), and only two are sold without; however, none are sold without a cable.
Tablets[119]	1A – 3.25A	2.5V – 20V	7.5W – 45W (although most devices use 10-15W)	There is considerable fragmentation in the connectors used in tablets. Half of the devices mapped (23/45) use USB micro-B, some use USB Type-C (15/45), Lightning is used by 4/45 models, and proprietary connectors are used by 3/45 models.	All the devices in the sample for which information was available (41) have both cable and EPS in the box.
Digital cameras (including action cameras)	0.2A – 1.89A	3.6V – 8.4V	1W – 10W	Digital cameras seem to use a wide range of charging connectors. Most of the camera models analysed have a USB micro-B connector (17/29), followed by USB Type-C (8/29). There are also few that use proprietary connectors (3/29) or mini-B (1/29). The fragmentation between USB Type-C and USB micro-B is similar both across digital cameras (11 with USB micro-B, 3 with USB Type-C) and action cameras (6 with USB micro-B, 5 with USB Type-C).	Some devices are sold unbundled.9/29 cameras are sold without an EPS, and only 1/29 is sold without a cable.
Group 2 (Medium priority)					
Hearing devices (earbuds and headphones)	0.1A – 2A	3.7V – 9V	0.3W – 10W	There is some fragmentation in the market for hearing devices. 16/30 devices use USB micro-B, 11/30 use USB Type-C, and 3/30 use proprietary solutions.	All the devices mapped (30) without an EPS, but none of the devices is sold without a cable.
Handheld videogame consoles	0.9A – 6A	3.7V – 15V	4.1W – 39W	The market for portable videogame consoles appears to be fragmented. Some consoles have USB micro-B (5/11), some USB	One device is sold without a cable, but they all include an EPS in the box.

[119] The sample analysed includes small notebooks.

Device	Current	Voltage	Power	Connectors used	Unbundling
				Type-C (4/11), 1 has USB mini-B and 1 has a proprietary solution.	
Group 3 (Low priority)					
E-readers	0.5A – 2.5A	3.7V – 5.35V	2.6W – 12.5W	Out of a sample of e-readers, a majority (7/9) are fitted with USB micro-B, and only few (2/9) have USB Type-C.	All devices include a cable, but only 1/9 include an EPS.
Smartwatches and fitness trackers	0.15A – 2A	5V	0.75W – 10W	There is some fragmentation. Some devices analysed use wireless or magnetic charging (5/11), others use propietary (6/11).	In the sample, 5/11 devices are sold without an EPS, and all include a cable. Smartwatches that are charged via wireless/magnetic charging include a wireless pad that can be connected via USB to an EPS.
Portable speakers	0.5A-7.5A	3.6V-20V	2.5W-45W	A total of 26 portable speakers were analysed. More than half (15/26) use USB micro-B, 10 use USB Type-C, and 1 uses a proprietary connector.	Most speakers in the sample are sold without an EPS (21/26), but all of them include a cable in the box.

Source: Ipsos's own research (2021) based on a sample of 387 products.

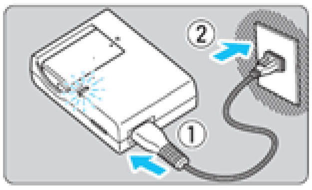
The devices included in Table 26 broadly share the same charging profile; however, there are some exceptions. Some tablets and portable speakers require considerably more power than other devices (up to 45W), however most of devices analysed are within the range 5-18W.

Connectors

The main connectors used by portable electronic devices are USB Type-C and USB micro-B, in conjunction with some proprietary connectors. It is worth noting the peculiarities of two devices: (a) reflex and mirrorless cameras, and (b) earbuds.

Reflex and mirrorless cameras generally offer consumers two options to charge the battery: a cable (normally with USB connectors) connected to the camera, or an additional power supply to charge the battery out of the camera. These cameras bring removable batteries, so that consumers may continue using their camera (with an additional battery) while charging their original battery. These chargers and batteries are frequently proprietary.

Figure 51: Example of proprietary solution included in a camera



Earbuds normally charge via wireless, and the wireless charger is the box where they are stored. This box, or wireless charger, connects to an EPS via a USB cable (Type-C or micro-B). For the purpose of this study, we have treated the box as part of the product.

Figure 52. Example or earbuds charged in the box

Across all types of devices, USB Type-C tends to be limited to more high-end products (i.e. those that are the most expensive). However, as illustrated in Table 13, there are some categories of devices where the trend towards USB Type-C seems to be clearer. Among smartphones, around three quarters of all the models considered in the mapping exercise were fitted with USB Type-C connectors.[120] Similarly, convergence towards USB Type-C can be seen also in earwear.

The trend towards USB Type-C appears to be slower in a set of other devices – namely, portable speakers, tablets, videogame consoles, and digital cameras. One potential reason for the low uptake of USB Type-C technology has been provided by industry stakeholders in the course of consultations. Several stakeholders noted how the decision to introduce USB Type-C connectors is often dictated by cost factors, as USB Type-C connectors are normally more expensive than other USB standards. Interviewees explained that these types of considerations are relevant particularly in the case of low-end devices, where each cost saving is important.

Two manufacturers of devices such as hearing devices and cameras also seemed to agree on the fact that the market was converging towards the USB Type-C standard, and that it would reach a high level of harmonisation within one to five years.

Battery charging protocols

Most devices among those selected for the purpose of this study do not require high power and have relatively small-capacity batteries, which allows for the use of the common USB BC protocol.

Different types of fast charging technologies seem to be very common in smartphones (128/186). Tablets followed in terms of fast charging solutions, with 10/53 models supporting fast charging.

Unbundling

Overall, EPS de-coupling appears to be very common in categories of products such as e-readers and hearables (around 9 in 10 models sold without an EPS), portable speakers (8 in 10), and smartwatches/fitness trackers (a little over half). Notably, among the tablets and hand-held videogame consoles in the sample, none was sold without the EPS in the box, regardless of their connector types.

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[120] The models included in the mapping were released between 2017 and 2020

Table 27: Unbundling of EPS and cables

Device	Without EPS	Without cable	Total sample
Hearables	100%	0%	30
E-readers	89%	0%	9
Portable speakers	81%	0%	26
Fitness trackers/Smartwatches	55%	0%	11
Digital cameras	31%	3%	29
Hand-held videogame consoles	0%	0%	7
Tablets	0%	0%	43

Source: Ipsos's own research (2021) based on a sample of 142 products.

Annex I: Market data for portable electronic devices

Tablets

Product description

Tablets are electronic devices that are normally larger in size than a smartphone, but smaller than a laptop. Tablets often run an operating system that allows them to perform computer-like functions and have different types of connectivity: Bluetooth, Wi-Fi, or 4G, or any of the previous types combined, depending on the product.

There are essentially two types of tablets:

Slate tablets: Tablets that do not have a permanently attached keyboard but may support an external one (optical or removable). They primarily receive inputs via a touch screen (LCD or OLED) which is normally equal to or larger than 7 inches, but smaller than 16 inches. They run operating systems similar to those of PCs or mobile devices, such as iOS, Android, BlackBerry OS, Windows, or Mac OS.

Detachable tablets: Tablets that can work as standalone device, but can also work with an external physical keyboard made specifically for these devices (required for their functioning, or optional). The additional keyboard is normally connected to the tablet via a physical connector.

Charging characteristics

In a sample of 53 tablets reviewed for this study[121], it was found that there is a certain degree of fragmentation in the market. Table 1 shows that the current of the tablets in the sample ranges between a minimum of 1A to a maximum of 8A. Voltage is bound between 2.5V and 20V. The power required is between 5W and 45W.

Table 28: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Tablets	1	8	2.5	20	5	45

Source: Ipsos' own research (2021), based on a sample of 53 tablets.
Note: Information not available for all products in the sample.

Decoupling

Among the sample of tablets reviewed as part of the mapping exercise, micro-B connectors accounted for half (23 devices) of all the devices for which information was available, as illustrated in Table 16. One third (15 devices) used USB Type-C, whilst the remaining 8 devices used proprietary connectors.

Although information on battery types was not always readily available, eight tablets in the sample used a Li-Polymer battery, whilst the remaining three tablets used a Li-Ion battery.

[121] The sample in question may not entirely match the sample in the modelling, as the sample analysed here is the result of a selection of models included in the IDC dataset and other tablet models.

There does not seem to be any de-coupling in the market for tablets. All the devices in the sample are sold with both the cable and the EPS in the box.

Table 29: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	**Micro-B**	**Type-C**	**Proprietary**	**Wireless**	**Li-Polymer**	**Li-Ion**	**Other**	**Without EPS**	**Without cable**
Tablets	0	23	15	8	0	8	3	0	0	0
		50%	33%	18%		73%	27%			

Source: Ipsos' own research (2021), based on a sample of 53 tablets.
Note: Information not available for all products in the sample.

Market trends

The first tablet launched to the market was Apple's iPad in April 2010, with a 9.7-inch display and a battery that could last up to 10 hours. Unlike the iPad 2 that followed suit in 2011[122], the iPad 1 did not incorporate a camera. The first Android tablet, Samsung's Galaxy 7.0, was released in 2010, and in 2011 Samsung launched its Galaxy Tab 8.9. However, tablet sales in EMEA[123] declined from 2013 until 2019, when they rebounded and started performing more positively, especially in the consumer segment, driven by sales performance in Western Europe[124]. Sales may have picked up partly as a result of shortages in the laptop segment of the market due to increased demand for home-schooling or home-working[125].

Location of manufacturers

Tablet manufacturers are mainly based in Asia or in the United States. In the EU, Alcatel (French-Chinese manufacturer) and Archos are headquartered in France.

Market data

The analysis of market trends for tablets for this study relies on commercial data acquired from IDC. According to IDC data, over 22 million tablets were sold in the EU-27 in 2019. Samsung and Apple devices represented half of the market.

[122] Techradar (2016), 15 memorable milestones in tablet history, available at: https://www.techradar.com/news/mobile-computing/10-memorable-milestones-in-tablet-history-924916, last accessed 25 January 2021.

[123] Europe, the Middle East and Africa

[124] IDC (2020), EMEA Tablet Market Posts Strongest Performance Since 2013, Says IDC, available at: https://www.idc.com/getdoc.jsp?containerId=prEUR146830220, last accessed 25 January 2021.

[125] IDC (2020), EMEA Tablet Market Posts Strongest Performance Since 2013, Says IDC, available at: https://www.idc.com/getdoc.jsp?containerId=prEUR146830220, last accessed 25 January 2021.

Table 30: Top 10 Vendor Tablet (Slate and Detachable) Shipments in 2019 in the EU-27 (data also includes shipments to Iceland)

Vendor	Units in 2019 (thousands)
Apple	6,057
Samsung	5,643
Huawei	2,215
Lenovo	2,119
Microsoft	881
Amazon.com	786
TCL	388
Archos	204
Denver	103
ASUS	99
Others	3,855
TOTAL	**22,350**

Source: IDC Quarterly Personal Computing Device Tracker, Q3 2020 Final Historical, November 18, 2020

Digital cameras

Product description

Digital cameras are devices for making digital recordings of images. They were first introduced on the consumer market in the first half of 1990s[126]. They generally allow the recording of both photos and videos. When the photosensitive receptors (i.e. pixels) placed on the semiconductor within the camera are struck by light through the camera lenses, the light is transformed into electric current which is then converted into binary digits for storage on a memory device (e.g. a memory card). Typically, cameras have a liquid crystal display (LCD) which allows to preview the photos and videos taken.

There are different types of digital cameras based on their use and their automatic or manual focus features.

- **Compact digital cameras:** Also called point-and-shoot cameras, they are the most common types of consumer digital cameras and come with automatic settings for less experienced users. They tend to be more economical than other models.
- **Digital single-lens reflex (DSLR):** These cameras use a system that reflects the light captured by the camera into a mirror inside the camera body, which in turn shows the picture into a viewfinder. When a photo is taken, the mirror opens and lets the light hit

[126] Encyclopedia Britannica (2020), Digital camera, available at: https://www.britannica.com/technology/digital-camera, last accessed 14 January 2021.

the internal digital sensor and is then processed onto the memory card. They support different types of lenses.

- **Mirrorless cameras:** Contrary to DSLR cameras, mirrorless cameras have a screen instead of a viewfinder, but allow users to change lenses as required.
- **Sport cameras:** Often also called ‘action cameras’, sports cameras are small devices that can be attached to a person’s body or to sport equipment (e.g. to a bike, a motorbike, or a helmet), allowing to film or take photos hands-free by using automatic settings. Certain action cameras can be used also in extreme conditions (e.g. underwater).

Charging characteristics

A total of 29 digital cameras were included in the analysis of charging characteristics. Across the sample, as shown in Table 31, the current needed to charge the devices is as low as 0.2A and as high as 1.89A. Voltage ranges between a minimum of 3.6V to a maximum of 8.4V. The minimum power generated is 1W, although one model requires 10W.

Table 31: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Digital cameras	0.2	1.89	3.6	8.4	1	10
Compact	0.2	0.7	3.6	7.2	1	7.4
Mirrorless	-	1.89	3.6	7.6	1.1	8.7
Reflex	0.7	1.5	5	8.4	1.1	10
Action cameras	1	2	3.6	5	1.3	10

Source: Ipsos’ own research (2021), based on a sample of 29 digital cameras.
Note: Information not available for all products in the sample.

De-coupling

A majority of cameras (17, or 59%) relies on USB micro-B connectors, as reported in Table 5. A few cameras also come with USB Type-C technology (8, or 28%), whereas receptacles for proprietary connectors are fitted on 3 cameras in the sample (10%). One action camera (3% of the sample) is fitted with USB mini-B.

Twenty-three out of the 29 cameras in the sample (92%) have a Li-Ion battery, with only one (4%) having a Li-Polymer battery and one having a Lithium battery.

Where the information was available, it was found that 9 cameras are sold without an EPS (31%), but only one (3%) was sold without a cable.

Table 32: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	**Micro-B**	**Type-C**	**Proprietary**	**Wireless**	**Li-Po**	**Li-Ion**	**Other**	**Without EPS**	**Without cable**
Digital cameras	1	17	9	2	0	1	23	1	9	1
	3%	59%	31%	7%		4%	92%	4%	31%	3%
Compact		7					7		1	
Mirrorless		3	2				5			1
Reflex		1	2	2			5			
Action cameras	1	6	5			1	6	1	8	

Source: Ipsos' own research (2021), based on a sample of 29 digital cameras.
Note: Information not available for all products in the sample.

Market trends

Digital cameras were pioneered by Eastman Kodak in the 1970s[127], but it was only towards the end of the 1980s that the first consumer digital cameras started to appear. However, the upward sales trend started to flatten with the introduction of smartphones with in-built cameras on the market around 2007[128]. Worldwide, the decline in units shipped between 2007 and 2018 was in the region of 80%, from 100 million to 19 million[129]. Historic manufacturers gradually sought to diversify and extend their expertise of digital imaging solutions to other, more technical fields – such as the medical device industry; nevertheless, manufacturers seem to believe that the demand for digital cameras may somehow stabilise[130].

Location of manufacturers

Most manufacturers of digital cameras have their headquarters in Asia (China, Japan, South Korea, Taiwan) and in the United States. Three digital camera manufacturers (Leica, Medion, Praktica) are based in Germany. Two other manufacturers of digital medium-format cameras are based in Denmark (Phase One), Sweden (Hasselblad).

Market data

Publicly available data released annually by Camera & Imaging Products Association (CIPA), representing the major manufacturers of imaging devices, is available up to November 2020 and shows both number of units shipped and value in JPY. CIPA's data can be considered as well representative of the total shipments of digital cameras to Europe, as it includes figures for shipments from all their members – the largest and most established players in the

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[127] Financial Times (2012), Kodak to shut digital camera unit, available at: https://www.ft.com/content/1226ed52-534c-11e1-950d-00144feabdc0, last accessed 14 January 2021.

[128] CNBC (2019), How Canon, Nikon and other Japanese camera companies are fighting for survival in the Smartphone era, available at: https://www.cnbc.com/2019/07/26/japanese-camera-companies-fight-for-survival-in-the-smartphone-era.html, last accessed 14 January 2021.

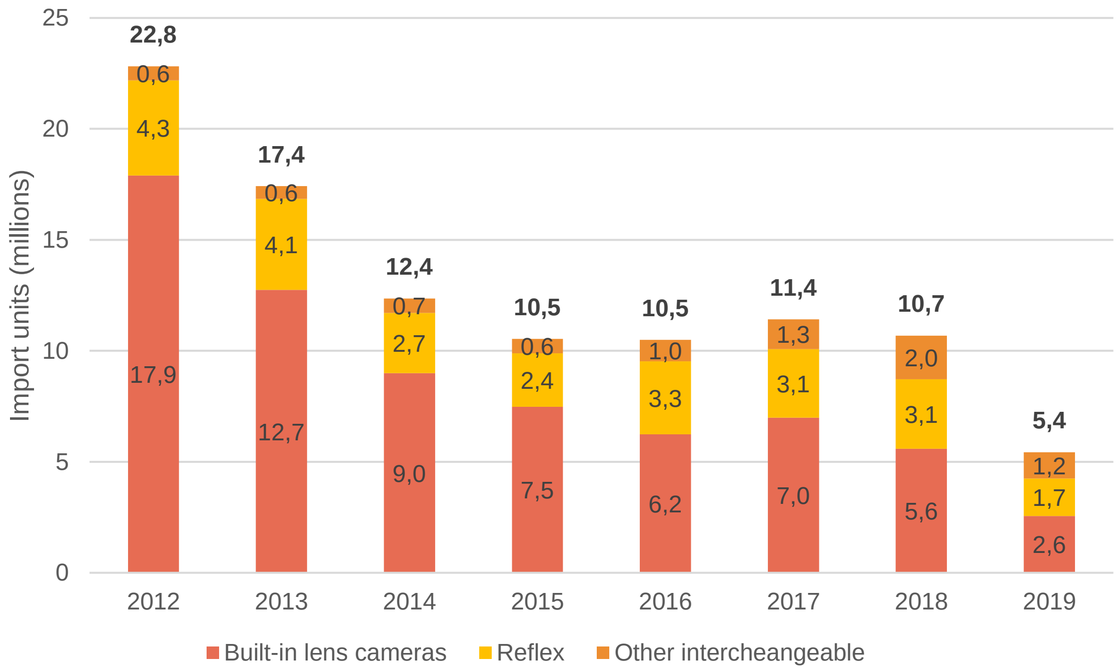
[129] *Ibid.*

[130] *Ibid.*

market[131], including: Canon, OM Digital Solutions (Olympus), Ricoh, Sigma Corporation, Fujifilm, Nikon, Panasonic, Epson, Sony. However, although the data refers to Europe, it may include countries outside of the European Union.

Firstly, data on CIPA shipments to Europe was used to obtain market shares for the different camera models (built-in lens, reflex, and other interchangeable) by year. These shares were then applied to Eurostat's Prodcom data (the sum of units produced in the EU-27and units imported, minus units exported) to produce an estimation of digital camera sales by type in the EU-27. An overview of the results for the years 2012-2019 is provided in Figure 51.

Figure 53: Sales of digital cameras to the EU-27



Source: Authors' calculations based on CIPA (2021), Digital Cameras and Prodcom 26701300 - Digital cameras (PRODQNT + IMPQNT – EXPQNT).

Figure 51 shows that the total number of digital cameras sold in the EU-27 declined over time, from 22.8 million in 2012 to 5.4 million in 2019. Sales of built-in lens cameras, which remained the most popular throughout the period, decreased from 17.9 million in 2019 to 2.6 million in 2019.

Hearables

Product description

The category of hearables comprises wireless devices that can be worn inside (earbuds) or over the ear (headphones) and that are connected wirelessly to an external device for the reproduction and sometimes capturing of sounds.

Earbuds: A type of device that rest inside the ear or that are inserted slightly into the ear canal. They can be completely wireless and independent of each other and charge or they can have a cable or band behind the neck connecting them one another. Completely wireless earbuds charge by being placed inside a charging case which is in turn charged by connecting to the

[131] A list of current members of the Association is available at: http://www.cipa.jp/stats/documents/e/list_e.pdf (last accessed 14 January 2021).

electricity generally via an USB Type-C cable or another proprietary solution, or via a wireless charging mat.

Headphones: Headphones, which are bigger in size than earbuds, are heald over the head by a rigid band. Unlike earbuds, they generally charge by being plugged into the mains though an EPS and a cable.

Charging characteristics

The mapping analysis carried out for this study identified a set of 34 devices – 29 earbuds and 5 headphones, shown in Table 33[132].

Earbuds' current ranges between 0.15A and 2A depending on the model, whilst voltage is between 3.7V and 5V. The power they use for charging goes from 0.32W for the less power-intensive models up to 12W.

Headphones have 0.1A as minimum current required and can take up to 2A. The voltage they use is bound between 3.7V at the lower end and 9V at the higher end. Power for these devices ranges between 0.7W and 10W.

Table 33: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Earbuds	0.15	2	3.7	5	0.32	12
Headphones	0.1	2	3.7	9	0.7	10

Source: Ipsos' own research (2021), based on a sample of 34 hearables.
Note: Information not available for all products in the sample.

De-coupling

Table 34 shows the types of connectors used by the devices analysed and their level of de-coupling.

Earbuds – including their charging cases – mainly have USB micro-B connectors (15, or 60%). Ten earbuds models have USB Type-C (34%) and four have proprietary connectors (14%). For headphones, 3 have USB micro-B, one USB Type-C, and one a proprietary connector.

Four earbuds models had Li-Ion batteries and one had a Li-Po battery. Two models of headphones had Li-Ion batteries and one a Li-Po battery.

There are signs of de-coupling, with 25 out of 28 earbuds models being sold without EPS, and one being sold without cable. Three out of five headphones models were also sold without EPS, but all came with a cable.

132 The sample in question may not entirely match the sample in the modelling, as the sample analysed here is the result of a selection of models included in the IDC dataset and other earwear models.

Table 34: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	**Micro-B**	**Type-C**	**Proprietary**	**Wireless**	**Li-Polymer**	**Li-Ion**	**Other**	**Without EPS**	**Without cable**
Earbuds	0	15	10	4	0	1	4	0	25	1
		52%	34%	14%		20%	80%		89%	4%
Headphones	0	3	1	1	0	1	2	0	3	0
		60%	20%	20%		33%	67%		60%	

Source: Ipsos' own research (2021), based on a sample of 34 hearables.
Note: Information not available for all products in the sample.

Market trends

The growth of the music industry, as well as mobile technology and internet penetration rates, seem to be driving sales of these type of devices globally[133]. Apple introduced its AirPods along with its iPhone 7 in 2016, and in the same year Jabra released its Elite Sport earbuds model.

Location of manufacturers

While many manufacturers of earbuds and headphones are located in Asia and in the United States, one manufacturer is located in Austria (AKG Acoustics, now owned by Harman International), one in Denmark (Jabra, part of GN Group), and one in Germany (Sennheiser).

Market data

Market data for hearing devices was purchased from IDC. IDC has provided data on shipments in 20 EU countries for top end earwear (a high-level overview is presented Table 22). It provides very detailed data per model (hence, type of connector used) and, although it does not represent the full earwear market as it does not include the basic earwear segment, it is a good source for the stock model, and can potentially be complemented with other sources.

Over 32 million headphones/earbuds were sold in 20 EU countries in 2019.

[133] Grand View Research (2020), Earphones & Headphones Market Size, Share & Trends Analysis Report By Product (Earphones, Headphones), By Price, By Technology, By Application, By Region, And Segment Forecasts, 2020 – 2027, available at: https://www.grandviewresearch.com/industry-analysis/earphone-and-headphone-market, last accessed 25 January 2021.

Table 35:Top 10 Vendor Earwear Shipments in 20 EU Member States in 2019

Vendor	Units in 2019 (thousands)
Apple	12,372
Samsung	4,355
GN Group	1,729
Sony	1,663
Bose	1,198
Skullcandy	733
JLAB	488
Huawei	450
Xiaomi	160
MyKronoz	46
Others	419
Total	**23,612**

Source: IDC Quarterly Wearable Device Tracker, Q3 2020 Final Historical Release, November 27, 2020

Handheld videogame consoles

Product description

Handheld videogame consoles are entirely portable, self-contained devices with an in-built screen which are specifically designed to play video games. Whilst older consoles used removable memory cartridges to play games, the most recent consoles allow for the direct download of games from the internet. Some portable consoles (like Nintendo Switch) can also be docked to play games on a larger screen[134].

Charging characteristics

Eleven portable videogame consoles were selected as part of a mapping exercise that built on the findings of the previous IA study[135], as reported in Table 36, which includes 9 consoles. The analysis revealed that the current used by these devices ranges between 0.9A to 3A, whilst their voltage can vary between a minimum of 3.7V and a maximum of 15V. The lowest power required by the devices in the sample is 4.1W and the highest 39W.

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[134] Tom's Guide (2021), The best handheld gaming consoles in 2021, available at: https://www.tomsguide.com/uk/round-up/best-handheld-gaming-consoles, last accessed 14 January 2021.

[135] European Commission (2020), Impact assessment study on common chargers of portable devices, available at: https://op.europa.eu/en/publication-detail/-/publication/c6fadfea-4641-11ea-b81b-01aa75ed71a1, last accessed 14 January 2021.

Table 36: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Handheld videogame consoles	0.9	3	3.7	15	4.1	39

Source: Ipsos' own research (2021), based on a sample of 9 handheld videogame consoles.
Note: Information not available for all products in the sample.

De-coupling

As shown in Table 37, there is no clear prevalence of any of the different connector types, but this may be due to the fact that some devices were released prior to 2015, as innovation in the market has been modest in recent times. USB micro-B is the most common charger (44% of all devices analysed), followed by USB Type-C (33%), which is normally found only on newer models. Proprietary and USB mini B connectors are installed on 11% of devices each.

Eighty-six percent of the devices for which information was available had Li-Ion batteries, and one (14%) had Li-Polymer batteries.

Details on de-coupling are available for eight of the 9 devices in the sample. Among these, none was sold without charging accessories.

Table 37: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	Micro-B	Type-C	Proprietary	Wireless	Li-Po	Li-Ion	Other	Without EPS	Without cable
Handheld videogame consoles	1	4	3	1	0	1	6	0	0	0
	11%	44%	33%	11%	-	14%	86%	-		

Source: Ipsos' own research (2021), based on a sample of 9 handheld videogame consoles.
Note: Information not available for all products in the sample.

Market trends

Portable videogame consoles started to be commercialised in the 1980s, when Nintendo launched a series of affordable Game & Watch portable consoles[136]. Nintendo's success was largely due to the introduction on the market of a more advanced device, the Game Boy, which, together with its upgraded version, the Advance, sold more than 100 million units worldwide between 1989 and 2007 and dominated sales[137]. However, the introduction of smartphones seems to have led to a slump in sales of consoles, which prompted manufacturers like Nintendo and Sony to discontinue some of their products[138].

Location of manufacturers

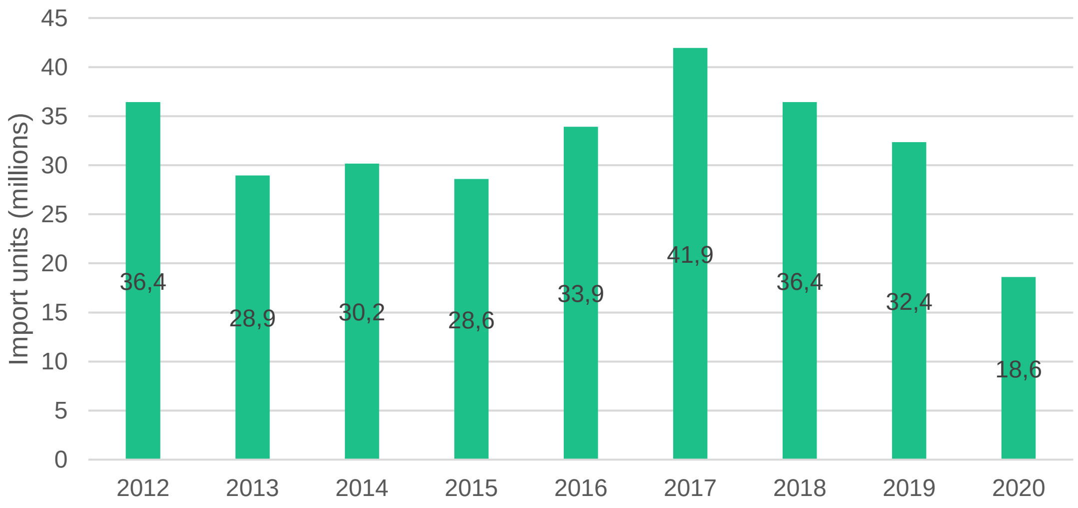
Most manufacturers are based in China, Japan, or in the United States. One manufacturer of a specific model of handheld console, Evercade, is based in the United Kingdom. There do not appear to be any manufacturers of handheld consoles in the European Union.

Market data

Public data on videogame consoles is generally unfit for the scope of our study as it tends to focus on home videogame consoles (i.e. non-portable) or on the videogame software industry; moreover, market data tends to have a worldwide focus.

UN Comtrade data could be used to overcome the lack of public data. Comtrade code for videogame consoles[139], represented in Figure 54, includes both portable and non-portable consoles. The chart shows a sudden increase in 2017, possibly coinciding with the launch of Nintendo Switch.

Figure 54: UN Comtrade imports of videogame consoles into the EU-27 from the world



Source: UN Comtrade (2019).
Note: HS code: 950450, reporter: (EU28-UK), partner: World.

However, the lack of granularity of this data implies that it cannot be used in the stock model. A set of assumption would be required to determine the share of battery-powered devices among all the videogame consoles imported in the EU. According to a report published by Goldstein Research[140], in 2016, 91% of revenue from videogame consoles came from TV gaming consoles. The relatively small proportion of handheld consoles seems to be indirectly confirmed by the revenue split of the videogame software industry – only 2% is driven by games for handheld devices[141].

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[139] HS code: 950450.

[140] Goldstein Research (2020), Europe Gaming Console Market Overview, available at: https://www.goldsteinresearch.com/report/europe-gaming-console-market-share-analysis, last accessed 14 January 2021.

[141] ISFE Europe's Video Games Industry (2019), Key Facts 2018 trends & data, available at: https://www.isfe.eu/wp-content/uploads/2019/08/ISFE-Key-Facts-Brochure-FINAL.pdf, last accessed 14 January 2021.

Applying an assumption that 9% of all imports of consoles are handheld would mean that in 2020 there were around 1.7 million handheld devices. This, however, does not provide any insight into the different types of chargers used by these devices. It would thus be possible to use the results of the device mapping exercise to estimate the share of different types of connectors in the market, under the assumption that the devices identified in the mapping are representative of the overall market distribution in 2018. Based on the shares reported in Table 8, and assuming that 9% of all imports are handheld consoles, it would appear that in 2020 around 187 thousand devices used a USB mini connector and a similar amount used proprietary chargers, whilst around 561 thousand fitted with USB Type-C, and the remaining 748 thousand units used USB micro-B.

Further to this, the results from the mapping exercise reported in Table 24 also suggest that there was no unbundling.

E-readers

Product description

An e-reader is a portable, handheld device which is used to read digital books, newspapers, periodicals, or other suitable text-based documents. E-readers have a display made of electronic paper, i.e. screens that look like normal paper to facilitate reading. Screens are formed by millions of capsules containing positively and negatively charged pigments, enveloped between two see-through layers of electrodes. When electric fields are applied to the electrodes, the pigments move either towards the surface or towards the bottom of the capsule, allowing the electronic paper to display text.

Charging characteristics

Eight e-reader models were examined as part of the mapping exercise, and their main characteristics are reported in Table 25. Among the devices for which information was available, current ranged between 0.5A to 1A, voltage between 3.7V and 5.35V, and power was between 2.6W and 12.5W.

Table 38: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
E-readers	0.5	1	3.7	5.35	2.6	5

Source: Ipsos' own research (2021), based on a sample of 8 e-readers.
Note: Information not available for all products in the sample.

De-coupling

As reported in Table 39, the devices analysed mainly came with micro-B connectors (75%), whereas only two (25%) had a USB Type-C port. Information on batteries was not available in most cases; however, two e-readers used Li-Polymerbatteries.

Although all the devices in the sample were sold with a charging lead, none was sold with an EPS.

Table 39: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	**Micro-B**	**Type-C**	**Proprietary**	**Wireless**	**Li-Po**	**Li-Ion**	**Other**	**Without EPS**	**Without cable**
E-readers	0	6	2	0	0	2	0	0	8	0
		75%	25%			100%			100%	

Source: Ipsos' own research (2021), based on a sample of 8 e-readers.
Note: Information not available for all products in the sample.

Market trends

E-readers became popular around 2007-2010, with the launch of the first models in South Korea, followed by Amazon Kindle DX in 2009. Other manufacturers soon entered the market for e-readers (among these, Kobo and Onyx)[142]. The introduction of e-ink's Carta and Mobius (co-developed by Sony) in 2013[143] respectively improved screen responsiveness to gestures and page-turning and expanded the size of screens[144]. Currently, coloured e-ink e-readers seem to be one of the main recent innovations in the market, but take-up of the new technology seems to have been slow, with many large manufacturers not releasing new e-reader models in 2020[145].

Location of manufacturers

Manufacturers of e-readers are mainly headquartered in Asia, Canada, and the United States. Booken, an e-book reader manufacturer, is based in France. Another manufacturer, reMarkable, is based in Norway.

Market data

Public data on e-readers is fragmented and does not provide enough level of detail on the EU market. Press releases from market intelligence firms seem to suggest that the global market for e-readers will become considerably smaller in future[146], as its global value is projected to drop to USD 160 million in 2025 from USD 460 million in 2020[147].

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142 Good E-reader (2017), A Short History of E-Paper and the eReader Revolution, available at: https://goodereader.com/blog/electronic-readers/a-short-history-of-e-ink-and-the-ereader-revolution, last accessed 25 January 2021.

143 For further information: https://www.eink.com/reading-writing.html?type=application&id=1 (last accessed 25 January 2021).

144 Good E-reader (2017), A Short History of E-Paper and the eReader Revolution, available at: https://goodereader.com/blog/electronic-readers/a-short-history-of-e-ink-and-the-ereader-revolution, last accessed 25 January 2021.

145 Good E-reader (2020), What is next for e-readers and e-notes in 2021?, available at: https://goodereader.com/blog/electronic-readers/what-is-next-for-e-readers-and-e-notes-in-2021, last accessed 25 January 2021.

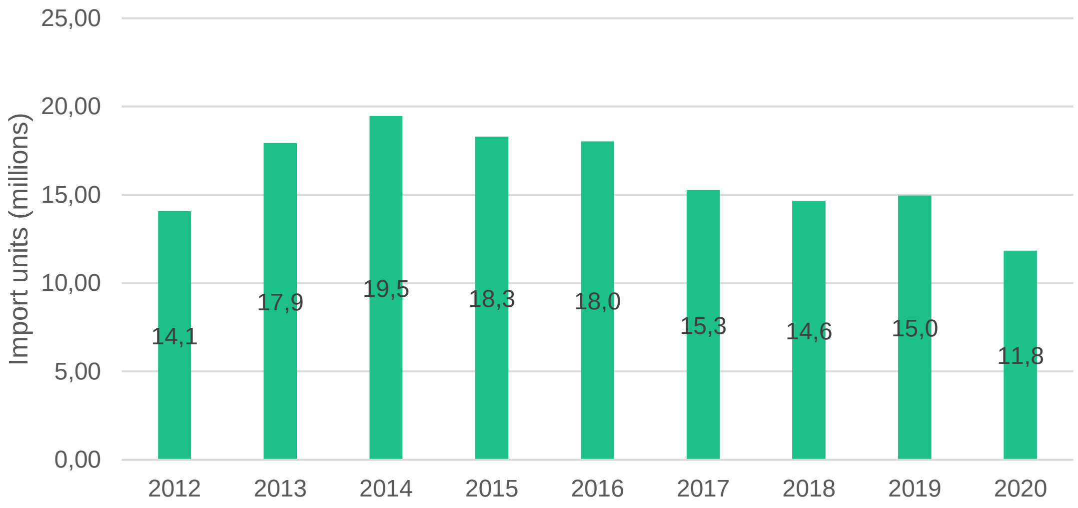
146 WFMJ (2020), Global eReader Market Size Worth Around USD 200 Million by 2024, from USD 460 Million in 2020, at a CAGR of -12.7% During 2020-2024 with Top Countries Data, available at: https://www.wfmj.com/story/43004268/global-ereader-market-size-worth-around-usd-200-million-by-2024-from-usd-460-million-in-2020-at-a-cagr-of-127-during-2020-2024-with-top-countries-data, last accessed 25 January 2021.

147 Statista (2020), E-reader market size worldwide 2018 and 2025, available at: https://www.statista.com/statistics/1061333/market-revenue-e-reader-worldwide/#:~:text=E%2Dreader%20market%20size%20worldwide%202018%20and%202025&text=The%20global%20e%2Dreader%20market,rate%20of%20minus%2012.6%20percent., last accessed 25 January 2021.

Comtrade data does not offer details about the number of units shipped to the EU-27. Similar to what was done for the first Impact Assessment[148], units imported are estimated by taking the overall value in USD provided by Comtrade, divided by an average price (in EUR, converted to USD) of the top 10 devices sold in early 2021 on Amazon France.

As illustrated in Figure 55, sales of e-readers peaked in 2014 at 19.5 million units, and declined slightly afterwards, standing between 18 and 15 millions a year in the following years until 2019. In 2020, shipments to the EU were slightly less than 12 million.

Figure 55: Comtrade imports of e-readers into the EU-27 from the world



Source: UN Comtrade (2021).
Note: HS code: 854370, reporter: (EU28-UK), partner: World. Units imported are obtained by using USD values from Comtrade divided by an average price of the 10 top e-readers sold on Amazon France on 25 January 2021 (ordered by: 'recommended by Amazon'). The exchange rate used is EUR/USD 1.22 on 25 January 2021.

Based on the findings of the mapping, it is possible to assume that 75% of all devices sold in 2020 (8.9 million units) had a USB micro-B connector, while the remaining 3.0 million unit had an USB Type-C connector. In addition to this, whilst all 11.8 million units shipped came with a cable, none included an EPS in the box.

Smartwatches and fitness trackers

Product description

Smartwatches and fitness trackers are types of wearable technology that can be worn either as an accessory or as part of clothes.

Smartwatches have similar functionalities to smartphones but are worn as traditional watches around the wrist. They rely on the functions of operating systems similar to those used by smartphones and through a screen they allow users to make calls, send messages, use apps such as maps, calculators, and calendars, and track physical and physiological activity. They are generally charged via wireless docking stations.

Fitness trackers are a specialised type of wearable, normally in the shape of a bracelet to wear around the wrist, that measures physical activity such as distance walked or run through in-built sensors. Fitness tracker also come with additional functions, such as altitude or atmospheric pressure measurement, or allow to convert data on steps and runs into calories

[148] European Commission (2020), Impact assessment study on common chargers of portable devices, available at: https://op.europa.eu/en/publication-detail/-/publication/c6fadfea-4641-11ea-b81b-01aa75ed71a1, last accessed 14 January 2021.

consumed. More advanced models also provide information on heart rate and body temperature. However, more high-end devices tend to have more precise measurements – for example, they are more likely to tell a brisk wrist movement from a step. They can be charged via wireless chargers or via cable.

It is important to note that smartwatches and fitness trackers are often designed to withstand particular weather and atmospheric conditions – for instance, they often need to be waterproof.

Charging characteristics

The mapping exercise covered 11 devices between smartwatches and fitness trackers, as illustrated in Table 40. Where information was available, it was found that the minimum current they require is 0.15A and the maximum is 2A. The six devices for which information on voltage was available all used 5V. Power in the sample ranged between 0.75W to 10W.

Table 40: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Smartwatches and fitness trackers	0.15	2	5	5	0.75	10

Source: Ipsos' own research (2021), based on a sample of 11 smartwatches and fitness trackers.
Note: Information not available for all products in the sample.

De-coupling

The devices analysed had either a proprietary connector (55%) or a wireless charging system (45%), as reported in Table 41. Half of the six devices for which information on batteries was fond were fitted with Li-Polymerbatteries, and the other half with Li-Ion batteries.

More than half (55%) of the smartphones and fitness trackers reviewed were sold without an EPS in the box, but none was sold without a cable.

Table 41: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	Micro-B	Type-C	Proprietary	Wireless	Li-Po	Li-Ion	Other	Without EPS	Without cable
Smartwatches and fitness trackers	0	0	0	6	5	3	3	0	6	0
				55%	45%	50%	50%		55%	

Source: Ipsos' own research (2021), based on a sample of 11 smartwatches and fitness trackers.
Note: Information not available for all products in the sample.

Market trends

Although some models of smartwatches were commercialised in the 1990s and early 2000s[149], smartwatches had a short-lived moment of popularity around 2013, and then became increasingly popular after 2015, with the launch of Apple Watch[150], which joined a market where Pebble (then acquired by FitBit) and Samsung were already present with other models[151]. With the launch of Apple Watch, worldwide sales went up from 4.2 million pieces in 2014 to 19.4 million pieces the following year[152].

Smart Fitness Tracker were launched around 2008, when FitBit released its Tracker and in 2014 FitBit had a 67% market share globally; however, competition from smartwatches seems to have hindered the market for fitness trackers[153].

Location of manufacturers

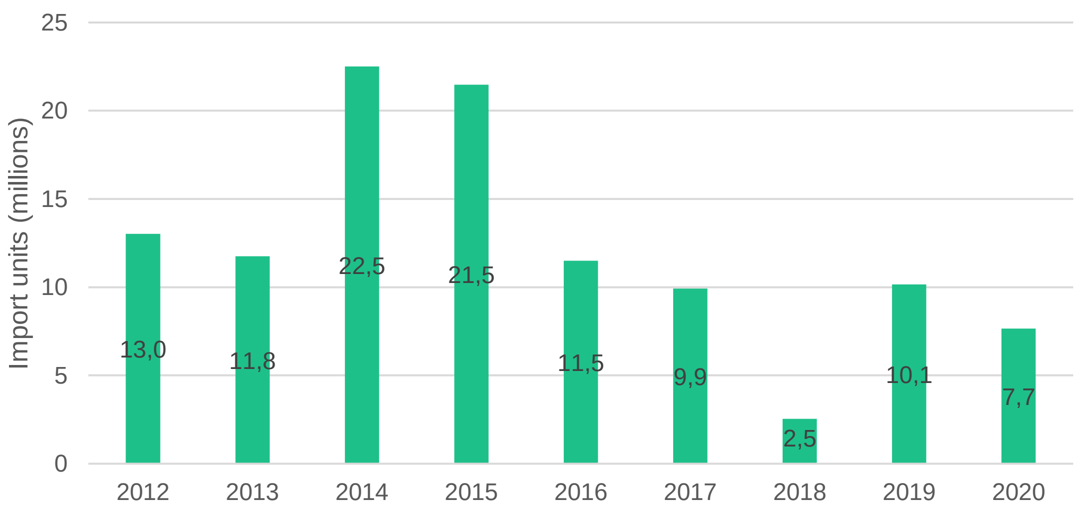
Manufacturers of smartwatches and fitness trackers are mainly based in Asia or in the United States[154]. One manufacturer of fitness trackers, Polar Electro, is based in Finland.

Market data

No granular data on fitness trackers and smartwatches sales volumes seems to be available publicly. However, Comtrade can provide data for the EU-27 for a category comprising wrist watches with a display[155], in which smartwatches are classified.

It appears from Figure 56 that the number of smartwatches imported into the EU-27 has peaked in 2014 – coinciding with the launch in 2014 of Apple Watch and Samsung Gear S, followed by Samsung Gear S2 in 2014, and by the Samsung Gear S3 in 2016.

Figure 56: Comtrade imports of smartwatches into the EU-27 from the world



[149] Encyclopedia Britannica (2020), Smartwatch, available at: https://www.britannica.com/technology/smartwatch, last accessed 25 January 2021.

[150] Bloomberg (2018), A Concise History of the Smartwatch, available at: https://www.bloomberg.com/news/articles/2018-01-08/a-concise-history-of-the-smartwatch, last accessed 25 January 2021.

[151] Wearable (2015), Smartwatch timeline: The devices that paved the way for the Apple Watch, available at: https://www.wareable.com/smartwatches/smartwatch-timeline-history-watches, last accessed 25 January 2021.

[152] Bloomberg (2018), A Concise History of the Smartwatch, available at: https://www.bloomberg.com/news/articles/2018-01-08/a-concise-history-of-the-smartwatch, last accessed 25 January 2021.

[153] Wired (2018), How Fitbit Started the Wearables Craze That Got Us All Moving, available at: https://www.wired.com/story/how-fitbit-got-us-all-moving/, last accessed 25 January 2021.

[154] Technavio (2017), Top 10 Smartwatch Manufacturers : Riding the Popularity Wave for these Multidisciplinary Gadgets, available at: https://blog.technavio.com/blog/top-ten-global-smartwatch-manufacturers, last accessed 25 January 2021.

[155] HS code: 910212.

Source: UN Comtrade (2021).
Note: HS code: 910212, reporter: (EU28-UK), partner: World.

Based on the mapping exercise, it can be assumed that 55% of all the devices sold in 2020 was fitted with a proprietary receptacle for the charger (4.2 million devices) and the remaining 45% (3.5 million devices) was shipped with a wireless charger. The mapping also suggests that around 4.2 million devices were shipped without EPS, but none without a cable.

Portable speakers

Product description

Portable speakers are small devices that reproduce sound when connected to an external peripheral by a cable or Bluetooth. Their batteries have very different storage capacity and can last from around 6-10 hours to up to 24 hours[156]. Some of the high-end portable speakers have smart features which allow them to be compatible with otther technologies.

Charging characteristics

The charging profile of the 26 portable speakers taken into consideration in the analysis is varied and is reported in Table 14. Current characteristics across the sample range between 0.5A and 3A. The voltage of the speakers in the sample varies between 3.6 at the lower end and 20 at the higher end. The wattage is between 2.5W and 45W for the most powerful speaker.

Table 42: Charging characteristics

	Current (A)		Voltage (V)		Power (W)	
	Min	Max	Min	Max	Min	Max
Portable speakers	0.5	3	3.6	20	2.5	45

Source: Ipsos' own research (2021), based on a sample of 26 portable speakers.
Note: Information not available for all products in the sample.

De-coupling

Table 43 shows that most of the portable speakers analysed (58%) had a USB micro-B connector, whilst 42% had a USB-C connector. The speaker that requires the highest voltage in the sample (15V/20V) supports the USB PD protocol. The most common battery type was Li-Ion (85%), and only 8% had a Li-Polymer battery.

Most of the portable speakers examined are already sold without EPS. Among the 26 devices in the sample, 21 (81%) is sold without a charging block. However, all the devices analysed include a cable in the box.

[156] What HiFi (2020), 7 things to consider before buying a Bluetooth speaker, available at: https://www.whathifi.com/advice/7-things-to-consider-before-buying-a-bluetooth-speaker, last accessed 25 January 2021.

Table 43: Connectors and de-coupling

	Connector					Battery			Decoupling	
	Mini-B	Micro-B	Type-C	Proprietary	Wireless	Li-Po	Li-Ion	Other	Without EPS	Without cable
Portable speakers	0	15	11	0	0	2	22	0	21	0
		58%	42%			8%	85%		81%	

Source: Ipsos' own research (2021), based on a sample of 26 portable speakers.
Note: Information not available for all products in the sample.

Market trends

The overall demand for wireless speakers (e.g. speakers that receive signal from an external device via Bluetooth or Wi-Fi) has been driven, in recent years, by consumer preference for smart portable speakers . US-based Bose launched its portable speaker model in September 2019, whilst in May 2020 Sony presented one of its newest portable speakers, the SRS-XB.

Location of manufacturers

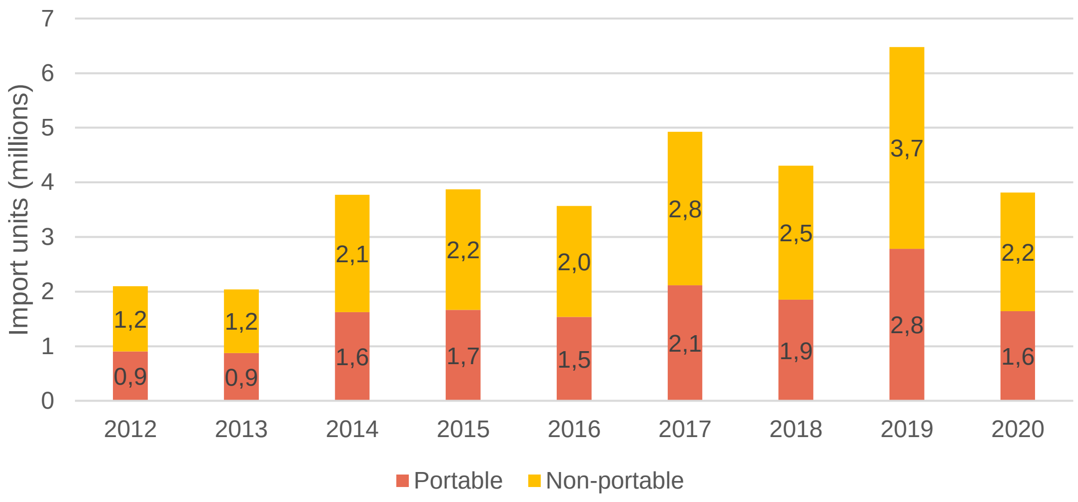
Manufacturers are mainly based in Asia or in the United States. One manufacturer of high-end speakers, Bang & Olufsen, is based in Denmark, another, Philips, is based in the Netherlands, and a third, Urbanista, is based in Sweden.

Market data

Commercial data tends to focus largely on wireless speakers, a category that comprises any type of sound reproduction equipment that is connected to an external device by means of technologies such as Bluetooth or Wi-Fi. Thus, this type of data often includes home entertainment devices or vehicle components that are not portable.

By using import data from Comtrade for the category of sound recording or reproducing apparatus , and assuming that Statista's estimation for the United States of a 43% market share of portable speakers out of all wireless speakers holds true for the EU, Figure 6 shows that in 2020 around 1.6 million portable speakers were imported into the EU-28. However, there are strong limitations to this approach given by the fact that the tariff category used is not limited to wireless devices; hence, the share of portable speakers could be considerably smaller.

Figure 57: Comtrade imports of portable speakers into the EU-27 from the world



Source: UN Comtrade (2021).
Note: HS code: 851989, reporter: (EU28-UK), partner: World. The share of portable speakers is obtained under the assumption that the HS code includes only wireless speakers and that 43% of those devices are portable, providing the assumption in Statista (2021) on the US market for wireless speakers holds true for the EU-28 market.

Assuming that the figures from Table 41 are a good representation of the market for portable speakers, the results of the mapping exercise suggest that out of the 1.6 million portable speakers imported into the EU-27 in 2020, 928 thousand units were fitted with USB micro-B and 672 thousand had USB Type-C. Just under 1.3 million devices were sold without EPS in the box, but all had a cable.

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