European Commission

ICT TASK FORCE STUDY

Task 12 Final Policy Recommendations

Final Draft

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Sensitive/EU RESTRICTED (delete as applicable)

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JRCXXXXXX

EUR XXXXX XX

PDF	ISBN XXX-XX-XX-XXXXX-X	ISSN XXXX-XXXX	doi:XX.XXXX/XXXXXX
Print	ISBN XXX-XX-XX-XXXXX-X	ISSN XXXX-XXXX	doi:XX.XXXX/XXXXXX

Luxembourg: Publications Office of the European Union, 20XX [if no identifiers, please use Brussels: European Commission, 20XX or Ispra: European Commission, 20XX or Geel: European Commission, 20XX or Karlsruhe: European Commission, 20XX or Petten: European Commission, 20XX or Seville: European Commission, 20XX depending on your unit]

How to cite this report: Author(s), *Title*, EUR (where available), Publisher, Publisher City, Year of Publication, ISBN 978-92-79-XXXXX-X (where available), doi:10.2760/XXXXX (where available), JRCXXXXXX.

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2. Product Grouping

A categorisation of the different products subsumed under the wider category of 'ICT products' is proposed in Table 1 below. Grouping of products is based on their application in the context of ICT system (e.g. data centre, telecommunication network, end-use) but also based on functional similarities (e.g. audio video devices, wearable devices, among others). This categorisation will be the basis for the definition of the scope/product applicability of the policy recommendations presented in Chapter 4.

Table 1: Product grouping

Product Groups		Sub categories
Data Centre Devices		Servers; storage, networking (Networking (switches/routers), Uninterruptible Power Supply (UPS)
Telecommunication Network Devices		Broadband communication equipment, Network in Offices (1GB/10+ GB LAN, WLAN), Mobile networks (mobile radio, aggregate/core, satellite TV, TETRA, 2G, 3G, 4G, 5G, Cable (fixed, landline) networks (i.e. PSTN/KSDN, TV-cable, ADSL, VDSL, FTTLA, FTTH/B, FTTH)
Consumer ICT devices (Consumer Electronics)	Electronic displays	Televisions, Monitors, Digital Signage Displays
	Audio/video devices	video projectors / beamers, interactive whiteboards, videoconference systems, , complex set-top boxes; cameras, virtual reality headsets video players/recorders;
	Audio Equipment	Loudspeakers, Radios, Players/recorders, Amplifiers, Receivers, Tuners, Microsets, Wireless speakers, Smart speakers, Soundbars, Network audio players MP3 players, stand-alone home audio, network connected home audio;
	Personal ICT Equipment	Desktop PCs, Workstations, Notebooks/Laptops, Slate Tablets, Smartphones, Mobile Phones, Fixed Phones, video game consoles,
	Accessories and peripherals	External power supplies (chargers), docking stations, external drives (hard drives, memory stick), and power banks, keyboards
	Wearable ICT Devices	Smartwatches, Fitness trackers, Earbuds, Headsets, Virtual Reality
	Imaging Equipment	Monochrome laser MFD (Multi-Functional Printer, Colour laser MFD, Monochrome laser printer, Colour laser printer, Colour inkjet MFD, Colour inkjet printer, Professional printer and MFD, Scanner, Copier, Facsimile (fax) machine, 3D Printers
	Home / Office Network Equipment	Home/office network equipment, IoT Cellular Gateway, IoT Home/Office Gateway, Home Network-attached storage equipment (NAS)
Other ICT Devices	ICT in public Space	ATMs, Cash Registers and POS Terminals, Ticket Machines, Public WLAN hotspots, Toll-related ICT, Security cameras
	Industrial Sensors	ICT devices for industrial monitoring & management
	Building Automation & Control	ICT devices for building monitoring & management

3. Current policy landscape

The current EU sustainable product policy is based on a combination of policy instruments at mandatory and voluntary level.

At mandatory level, the Directive 2009/125/EC established a framework for the setting of energy and material efficiency ecodesign requirements for energy-related products (ErP), including the ICT devices under the scope of this study. The Energy Labelling Regulation (EU) 2017/1369 also applies to energy-related products placed on the market or put into service. It provides a framework for the labelling of those products and the provision of standard product information regarding energy efficiency, allowing the provision of 'supplementary information' regarding the functional and environmental performance of a product.

At voluntary level the most relevant EU initiatives are the voluntary European Ecolabel scheme (according to the Regulation (EC) No 66/2010) and the Green Public Procurement (GPP) Criteria, published as Staff Working Documents of the European Commission, and developed for different product groups and services.

In this policy framework the table below provide a summary of the ICT product groups already covered (or planned to be covered) by these complementary policy initiatives.

Table 2: Current policy landscape

Product Group		Sub categories	Existing and planned EU Initiatives			
			Ecodesign Directive	Energy Labelling	EU Ecolabel	EU GPP
Data Centre Devices		Servers	Regulation (EU) 2019/424			SWD(2020)55 final
		Storage	Regulation (EU) 2019/424			
		Networking (switches/routers)	(EC) No 1275/2008			
		UPS				
Telecommunication Network		Broadband communication equipment	No specific regulation pursued for now	No specific regulation pursued for now		
		Network in Offices (1GB/10+ GB LAN, WLAN)				
		Mobile networks (mobile radio, aggregate/core, satellite TV, TETRA, 2G, 3G, 4G, 5G				
		Cable (fixed, landline) networks (i.e. PSTN/KSDN, TV-cable, ADSL, VDSL, FTTLA, FTTH/B, FTTH)				
Consum	Electronic	Televisions	Regulation (EU)	Regulatio	Commi	SWD(20

	displays	Monitors	2019/2021	n (EU) 2019/2013	ssion Decision 2020/1804/EU	21) 57 final
		Digital Signage Displays				
	Audio/video devices	video players /recorders				
		video projectors / beamers				
		video game consoles	Voluntary Agreement (VA) COM/2015/0178 and (EC) No 1275/2008			
		interactive whiteboards				
		videoconference systems				
		MP3 players				
		stand-alone home audio				
		network connected home audio				
		complex set-top boxes	standby Regulation (EC No 1275/2008)*			
		cameras				
		Headsets and virtual reality headsets;				
	Audio Equipment	Loudspeakers				
		Radios				
		Players/recorders				
		Amplifiers				
		Receivers				
		Tuners				
		Microsets				
		Wireless speakers				
		Smart speakers				
		Soundbars				
		Network audio players				

	Personal ICT Equipment	Desktop PCs,	Regulation (EU) 617/2013 (under revision)			Commission Staff Working Document SWD(2021) 57 final
		Workstations				
		Notebooks/Laptops				
		Smartphones	Under preparation	Under preparation		
		Slate Tablets				
		Mobile				
		Home/Office fixed phones	Under preparation (limted to cordless)			
	Accessories and peripherals	External Power Supplies	(EU) 2019/1782			
		docking station				
		external drive (hard drives, memory stick)				
		power bank				
		Keyboard, mouse				
	Imaging Equipment	Monochrome laser MFD (Multi-Functional Printer)	(EC) No 1275/2008 and Regulation under preparation**	Regulation Under preparation		GPP (SWD(2020) 148 final)
		Colour laser MFD				
		Monochrome laser printer				
		Colour laser printer				
		Colour inkjet MFD				
		Colour inkjet printer				
		Professional printer & MFD				
		Scanner				
		Copier				
		Facsimile (fax) machine				
		3D Printers				
	Home / Office Network Equipment	Home Network-attached storage equipment (NAS)				
		Home/office network equipment				

		IoT Cellular Gateway				
		IoT Home/Office Gateway				
Other ICT Devices	ICT in public Space	ATMs				
		Cash Registers and POS Terminals				
		Ticket Machines				
		Public WLAN hotspots devices				
		Toll-related ICT				
		Security cameras				
	Building Automation and Control					
	Industrial Sensors					
*the Voluntary Agreement for "complex set-top boxes" has been discontinued. **the Voluntary Agreement for Imaging Equipment has been discontinued						

In the existing product policy framework, there are other policy initiatives that have a more horizontal approach and can still be relevant for the ICT context. These initiatives include:

- The Regulation (EU) 1275/2008 laying down ecodesign requirements for off mode, standby mode of electrical and electronic household and office equipment (currently under revision in order to extend the scope to networked standby energy consumption)
- Radio equipment directive (Directive 2014/53/EU) with the ongoing amendment on common charger
- Directive 2006/66/EC on batteries and accumulator (currently there is a proposal for a concerning batteries and waste batteries, repealing and amending this directive)

4. Policy Recommendations

4.1. Introduction

Addressing the environmental impacts of ICT from multiple perspectives, through both supply and demand, and by deploying flexible and future-proof policy instruments reflects not only the multi-layer nature of ICT systems but also the fast pace of technological development and innovation.

Policies are recommended on the basis of two levels as depicted in Figure 1:

- the *device* level, represented by the orange area, which in turn refers to ICT hardware (dark blue shade) as well as software which is necessary for the functioning of the device, such as firmware or an operating system (light blue shade), and
- the *system* level, which crosses the boundaries of the device, and refers to application software (light orange shade), cloud services and other ICT services (dark orange shade).

Such distinction allows for the policy proposals to capture the technical complexity of ICT systems, but also facilitates policy-making by signalling potential boundaries for the "original equipment manufacturer (OEM)" of the device. In other words, policies at system level could also address areas where parties other than the OEM of the device operate.

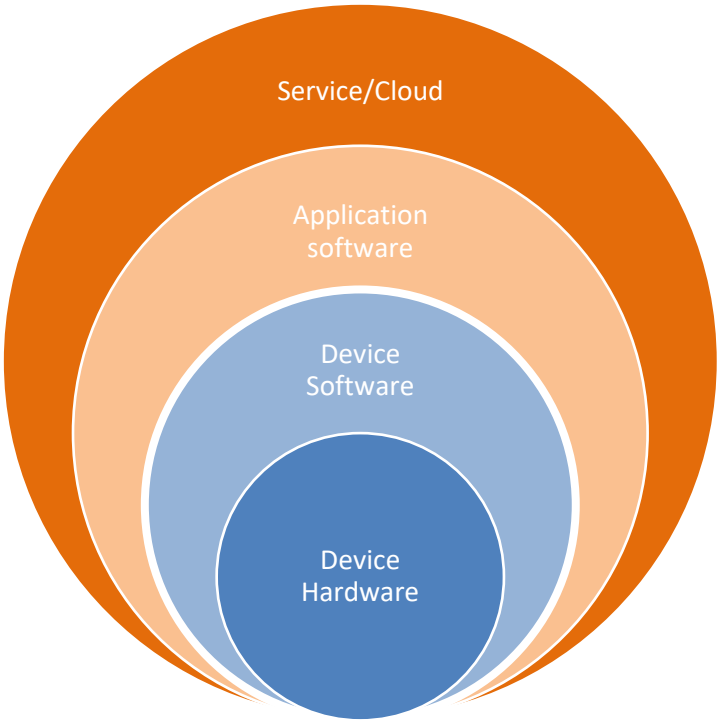

Figure 1: The multiple layers of ICT systems

Device-level policy options ensure that innovation continues at hardware level to improve energy and material efficiency. The ecodesign framework (under the Ecodesign Directive and the Energy Labelling Regulation) already establishes well-developed energy efficiency provisions, which can continue to be adjusted and updated to an ambition level that would effectively stimulate innovation, especially with regards to ICT products which remain energy intensive in the use phase. Some product group gaps can be addressed such as updated provisions for computers, the strengthening of provisions for imagining equipment and game consoles, and the introduction of policies for home and office network equipment.

The ecodesign framework as a policy instrument has also been able to accommodate a wider range of provisions focused at improving material efficiency, an aspect which is very relevant for ICT products which are contain valuable and scarce materials, are manufacture-intensive, demonstrate short and reduced lifetime and contribute to e-waste generation. With regards to ICT material efficiency provisions, such as those aimed at increasing reliability, reparability and recyclability, have already been introduced for servers and electronic displays (and are being proposed for mobile phones and tablets), but should be expanded to a

wider range of ICT products with the aforementioned characteristics. In order to enhance the role of consumers in the economic transition towards circularity, the extension of product guarantees and the provision of easy-to-understand information via circularity indices (e.g. durability or reparability scores), can be deployed and expanded. Moreover, policies that facilitate the development of the second-hand and refurbishing market, such as building consumer trust via information and labelling of the quality of refurbished products or refurbishers themselves, can also offer potential for circularity and retention of valuable materials in use.

However, policies at device level are insufficient to effectively capture the systemic nature of ICT products and the way in which environmental impacts take place. Induction effects, presented and analyse the previous Tasks of this study, leading to higher data storage, transmission and processing needs, mean that addressing efficiency alone may not be sufficient to enable energy and material savings overall. System/Cloud-based policies that target directly enablers of energy and material consumption, such as the efficiency of software applications and the settings of video streaming regardless of the medium of streaming (device, application or platform). Those can take the form of minimum requirements (e.g. in the case of software efficiency), or informational provisions such as clear communications to consumers on their data and settings usage.

The market shift towards service-based business models calls for policy design that also considers services. The current ecodesign framework maintains its focus on the product, meaning that other policy instruments may need to be deployed. Some such instruments already exist, such as the EU Green Public Procurement, which could expand their reach and impact through mandatory implementation (e.g. in the framework of the new Ecodesign for Sustainable Products Regulation (European Commission, 2022), and cover a wide range of criteria targeted at both device and service level. Other instruments may need to be considered, such as provisions that directly aim at telecommunication services. Provision of information to consumers on the environmental impact of the telecommunication services they are offered can enable them to make informed decisions and foster innovation at systemic level; both in the hardware deployed to deliver those services and the way they are marketed. Lastly, even though financial policies are not the focus of this report, tools such as pricing policies and taxation can be very effective in curbing data traffic and incentivising efficiency in data use and subsequently energy, in accordance with the polluter pays principle.

Policy recommendations are described in more detail in the sections below using the structure in Figure 1 (section 4.2. for the *device* level and section 4.3. for the *system* level).

4.2. Device Level

4.2.1. Energy Efficiency

#1 Extending the implementation of energy efficiency requirements

Energy efficiency requirements are currently enforced for a number of relevant ICT devices, namely electronic displays, servers and computers.

Public ICT and Home network equipment are the only ICT categories where energy consumption is clearly rising. According to the study by VHK and Viegand Maagøe (2020). (2020), the electricity consumption of home/office network equipment has increased from 10.28 TWh/year in year 2010 to 16.61 TWh/year in year 2020. Furthermore, it is expected to further increase to 18.49 TWh/year by year 2025, constituting approximately 7.6% of the electricity consumption of ICT devices overall. This product group can also be considered together with similar network equipment devices, such as hotspot equipment. When combined, these products are expected to consume 25 TWh/year in year 2025, which would correspond to more than 10% of the energy consumption of ICT devices.

Neither category is currently regulated, nor included in the Ecodesign and Energy Labelling Working Plan 2022-2024. Relevant aspects would include energy efficiency in active move and material efficiency aspects, while stand-by and off mode consumption are already covered by the by Regulation (EC) No 1275/2008.

#2 ***Introduction of energy efficiency requirements based on "a****ctive mode" performance*

The energy efficiency of ICT devices with high computing capacity (e.g. servers, computers, game consoles but also tablets, smartphones) is dependent on the active mode(s) the device is running on. Some active modes can require a more intensive use of CPUs and graphic cards (e.g. gaming), notably increasing the

level of energy consumption of the device. Energy efficiency requirements in ecodesign regulations are based on tests performed on a combination of modes (e.g. "active", "sleep", "off", "idle") so as to reflect variable consumer behaviour during a products lifetime. However, in the case of computers, energy consumption under Regulation (EU) No 617/2013 is considered only for the power modes of "off", "sleep" and "idle" (see Table 3). In the context of the revision of the Ecodesing and Energy Labelling Criteria for computers, the Commission, CLASP/GTD offered support to fill this gap and have developed an open-source software for testing the energy-efficiency and performance of personal computers (Test Suite) as they perform a range of common tasks[1].

The main characteristics of the Test Suite developed by GTD are:

- It is based on the open-source Phoronix Test Suite
- It runs a series of worklets[2]
- It executes native binaries in Microsoft Windows, MacOSX, and Linux (incl. ChromeOS)
- Measuring power does not alter the performance or the power demand
- All the results are fused together in a single meta-efficiency metric value

Table 3: Modes considered under Regulation (EU) No 617/2013.

Mode	Definition	Minimum Requirement
Active mode	The state in which a computer is carrying out useful work in response to (a) prior or concurrent user input or (b) a prior or concurrent instruction over the network. This state includes active processing, seeking data from storage, memory or cache, including idle state time while awaiting further user input and before entering low power modes;	No
Idle state	A state of a computer in which the operating system and other software have completed loading, a user profile has been created, the computer is not in sleep mode, and activity is limited to those basic applications that the operating system starts by default;	Energy consumption threshold based on the combination of "off", "sleep" and "idle"
Off mode	'power demand level in the low power mode which cannot be switched off (influenced) by a user, other than through the movement of a mechanical switch, and which may persist for an indefinite period of time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions. Where Advanced Configuration and Power Interface (ACPI) standards are applicable, off mode usually correlates to ACPI system level G2/S5 ('soft off') state;	Off mode and sleep mode power limits.
Sleep mode	Low power mode that a computer is capable of entering automatically after a period of inactivity or by manual selection. In this mode the computer will respond to a wake event. Where Advanced Configuration and Power Interface (ACPI) standards are applicable, sleep mode usually correlates to ACPI system level G1/S3 (suspend to RAM) state;	

Similarly, in the case of game consoles, power cap established under the voluntary agreement (VA) Self-Regulatory Initiative for Energy Efficiency of Games Consoles (4.0) are not set for the "Active Gaming Mode". The VA set requirements only for "Navigation Mode" and "Media Playback Mode" (see table below).

[1] https://www.clasp.ngo/tools/on-mode-computer-testing-tool/

[2] A worklet is a set of tasks, placed in a workflow, that is, in a sequence of activities that can be easily reproduced on a regular basis

Table 4: Modes considered in game consoles

Mode	Definition	Minimum Requirement
Active Gaming Mode	Active Gaming: Mode in which the Games Console is actively performing its primary function of game playing.	NO
Media Playback:	Mode in which there is decoding and playing of video files and codecs up to UHD content, on the Games Console's own optical discs, and streaming media players.	YES
Navigation: Mode	C. in which no other mode is engaged and the Games Console is displaying a menu of functions (the "Home Menu").	YES
Off, Standby, Networked Standby	As defined in EU Regulation (EU) No 1275/2008 (as amended by EU Regulation (EU) No 801/2013);	YES

It is suggested to:

1) Establish minimum energy requirements based on a combination of modes and/or;
2) set specific requirements for a representative active mode

4.2.2. Material efficiency

#3: Material efficiency of consumer electronics

The proposed measure includes a range of provisions (see table 5 below) related to a number of material efficiency aspects to be applied horizontally across the scope of consumer electronics (see product scope in table 1). The existence of potential trade-offs and synergies between these different strategies, make recommendable the development of a single horizontal measure covering all these aspects and potential provisions. Moreover, different provisions could be suitable/applicable to different product groups included in the scope of this proposal.

The proposed measure covers "consumer electronics" and refers to any electronic devices designed to be purchased and used by end users or consumers for non-professional purposes.

The overall aim of this measure is to increase the product durability, reusability, and recyclability, according to the waste hierarchy of priorities reduce-reuse-recycle.

Table 5: Material efficiency provisions

Aspect	Provisions
Hardware durability and reliability	• Resistance to stresses/ageing mechanisms (e.g. drop/shock/ scratch resistance, ingress protection from water/dust) • Battery endurance in cycles, battery protection software, intelligent charging, information on battery state of health • Minimum / Expected lifetime • Durability/reliability score
Software related durability	• Minimum requirements for availability of software functionality / security updates • Availability and durability of cloud based services associated to the product. • Decoupling of the electronic device from cloud services
Reparability, Upgradability and Reusability	• Introduction of a Reparability Scoring Index / Label • Availability of repair/upgrade/maintenance info to independent operators/end-users • Spare part availability and delivery time • Disassembly generally or related to Disassembly Depth, Tools, Fasteners, Working • Environment and Skill Level • Use of coding standards for identification of components and materials • Use of standard components • Reusability/Upgradability specific provisions

Ability to be refurbished and remanufactured	• Ability to be identified of products/parts • Wear and damage resistance during the remanufacturing process steps
Recyclability	• Ability to easily separate the product into different materials (e.g. metals, plastic, CRMs) • Choice of materials and restrictions on substances (e.g. choice and combination of polymers, additives) • Condition for the access to product data relevant for the recycling, • Recyclability information (incl. scores) to consumers / recyclability claims

Hardware durability and reliability

Resistance to stresses/ageing mechanisms

Proxy examples of provisions related to resistance to stresses or ageing mechanisms include:

- Drop/shock resistance
- Scratch Resistance
- Ingress protection

These elements should define how long a particular product/part function would endure, after preparing and/or using the product under recommended operational conditions and be submitted to known stresses and/or aging effects.

Battery endurance, protection software, intelligent charging, State of Health

Batteries are a key component of portable ICT devices. Provisions related to battery durability can cover design aspects (e.g. endurance), information/instructions and battery power management. In particular:

- Battery endurance in cycles: measures to ensure that the batteries used in the devices achieve at least X cycles at Y percent of the initial charge capacity.
- Instruction for battery maintenance: Measure to increase consumer awareness of impacts on battery lifetime related to exposing the device to elevated temperatures, state of charge, fast charging and other known adverse effects on battery lifetime;
- Battery Protection Software: Pre-installed battery protection software that can limit the maximum battery charge (e.g. at 80%) when the electronic device is used plugged-in mode, reducing the degradation of the battery.
- Intelligent charging software: the availability of this functionality allow to identify the user's regular charging habits/pattern, stop the charging process before it reaches 100% (e.g. at 80%), and fully charge the device only when needed by the user.
- Information on battery state of health: Pre-installed software to determine and monitor the status of the battery/accumulator and allow for the reading of the battery or accumulator's 'state of health' and 'state of charge', as well as the number of 'full charge cycles' already performed from the battery/accumulator and to display these data for the user. See the explanatory note below for the definitions. The software must also provide tips for users to maximise battery lifespan.

Minimum / Expected Lifetime

A horizontal measure would go beyond the consumer guarantees under the existing EU regulations and set the harmonised rules regarding the products life expectancy. There are various approaches that could be followed in this context, from the information requirements, labelling on the expected (technical) lifespan or lifespan guarantees that consider the durability of the product.

Regulating "durability" as a horizontal measure requires use of different parameters (e.g., number of years/hours/cycles, kilometres, Mean Time Before Failure (MTBF), etc.) and different testing methods per product group.

Also, for some ICT products, there is no standard for assessing accurately product lifespans. The definition of the lifespan of the products (in absolute terms), followed by a definition of the test methods and reporting standards would need to put in place. Alternatively, a mandatory usage of meter on specific products groups could be regulated to provide an objective information on the product lifetime throughout its use; it could

count the number of hours of use (e.g. in TVs, smartphones, laptops etc.) or the cycles of use (e.g. for batteries in portable ICT).

Durability/Reliability score

Multi-parameter circularity aspects, such as durability or reliability, often require a complex assessment process, and can be expressed via different metrics. For instance, the reliability of an electronic device can be assessed by means of its resistance to accidental drops or high temperatures, its battery endurance or the lifetime of one of its components. As such, scoring of circularity aspects can offer a tool for assessing and communicating such multi-parameter and complex product characteristics.

According to European standard EN 45552, reliability refers to the functioning of a product before any limiting event, while the concept of durability is more inclusive of limiting events that may require maintenance and repair until a limiting state is reached.

For the development of a reliability or durability scores, a distinct methodological framework can be established on the basis of identification of relevant priority parts, parameters and a scoring system. In the case of durability, the consideration of reliability, reparability and upgradeability may need to be combined. Examples of such methods can be drawn from the ongoing French initiative for the introduction of a durability index[3] , as well as the work of JRC on reparability index[4].

Such scores can offer tools for product policy, either via setting a minimum score as requirement, or via linking the results to a classification system which can be used for communicating a durability or reliability class to consumers.

Software related durability

Availability of software functionality / security updates

The lifetime of software is crucial to the lifetime of electronics. This provision aims to avoid functional obsolescence, safety and incompatibility issues of the electronic device. The provision covers security and functionality updates for the firmware and operating system.

The availability of software updates entails availability of all elements that are necessary for the normal operation of the device after the installation of an update.

Setting horizontal minimum requirements on firmware / system software for all consumer electronics can increase durability by reducing software-related hardware obsolescence.

Availability and durability of cloud based services of the product

Many electronics make use of cloud based services to provide their function. Examples include products as security cameras, smart speakers. The end of support for these cloud based services can make the electronic device cloud service should be obliged to provide longer-term support for the devices in data centers, so that the operation of the device can be maintained (e.g. for a period of at least 5 years after the last item was placed on the market model).

Decoupling of the electronic device from cloud services

An additional provision could ensure the possibility of turning off the external cloud service either through a built-in functionality or through appropriate software updates from the coupling and continue using the device independently. OEMs should ensure the availability of minimum "core functionalities" even without an activated network function; or the labelling on the product that it relies on an internet connection or external cloud services.

Repair, Reuse, Upgrade

Reparability Scoring Index / Label

[3] ADEME, In Extenso Innovation Croissance (Benoît TINETTI, Marion JOVER, Chloé DEVAUZE, Mariane, IGHILAHRIZ), Fraunhofer IZM (Anton BERWALD), 2021. Preparatory study for the introduction of a durability index.

[4] European Commission, Joint Research Centre, Cordella, M., Sanfelix, J., Alfieri, F., Methods for the assessment of the reparability and upgradability of energy-related products : application to TVs : final report, Publications Office, 2019, https://data.europa.eu/doi/10.2760/501525

A reparability score is the result of the following steps (Cordella et al. 2019; Spiliotopoulos et al. 2022):

- Identification of priority parts
- Identification of relevant parameters influencing reparability (existing for ErP/electronics)
- Scoring system and aggregation

Repair Info / maintenance instructions to independent operators/end-users

Examples of information are the following:

- a disassembly map or exploded view;
- wiring and connection diagrams, as required for failure analysis;
- electronic board diagrams, to the level of detail needed to replace parts
- list of necessary repair and test equipment;
- technical manual of instructions for repair;
- diagnostic fault and error information;
- component and diagnosis information
- instructions for software and firmware (including reset software);
- information on how to access data records of reported failure incidents stored on device;
- procedure for authorisation of part replacement, when remote notification or authorisation of serial numbers are necessary for the full functionality of a spare part and the device.
- how to access professional repair (internet webpages, addresses, contact details).

Furthermore, the process for registration of independent/professional repairers should be specified and harmonised: "the process for professional repairers to register for access to information; to accept such a request, the manufacturers, importers or authorised representatives may require the professional repairer to demonstrate that…"

Spare part availability and delivery time

The following parameters are relevant for spare part availability:

- Duration: "manufacturers, importers or authorised representatives shall make available to [end-users/independent operators] at least the following spare parts, for a minimum period from [X] month after the date of placement on the market until [Y] years after the date of end of placement on the market: [parts]"
- Method of availability: "the list of spare parts concerned and the procedure for ordering them shall be publicly available on the free access website of the manufacturer, importer or authorised representative, from [X] month after placing the first unit of a model on the market and until the end of the period of availability of these spare parts.
- Delivery Time: "manufacturers, importers or authorised representatives shall ensure the delivery of the spare parts within [X] working days after having received the order."
- Maximum price of spare parts: "manufacturers, importers or authorised representatives shall indicate an expected maximum pre-tax price at least in Euro for spare parts"
- Availability of the procedure for authorisation of part replacement, and all necessary elements that would for a normal operation of the device after a replacement of a part.

Disassembly or related to Disassembly Depth, Tools, Fasteners, Working Environment and Skill Level

The following options are proposed (based on EN 45554:2020):

- General provision (when specification is non-applicable): “manufacturers shall ensure that joining, fastening or sealing techniques do not prevent the disassembly for repair or reuse purposes (of the following components)”
- Specification based on:
- Fasteners: “fasteners shall be [removable or reusable]”
- Tools: “the process for replacement shall be feasible with [no tool, a tool or set of tools that is supplied with the product or spare part, or basic tools, or with commercially available tools]”
- Disassembly depth: the process for disassembly of a part shall be feasible within a [X] number of steps.
- Working environment: “the process for replacement shall, as a minimum, be able to be carried out in a [workshop environment or use environment]”
- Skill level: “the process for replacement shall, as a minimum, be able to be carried out by [Expert or layman or generalist].”

Use of component and material coding standards

The following specification can apply:

- Labelling of every main component with title and QR code leading to a spare part availability provider: *https://frame.work/*
- Coloured wires

Use of standard components

Examples of provisions:

- Common battery within same product family
- Port harmonisation
- Use of shared solutions, fittings, and parts
- Use of standardized materials and recommended colors
- Use of standardized components to secure interchangeability. This could either occur within a brand level (e.g., lighting port used by various apple products), across multiple (two or more) brands (eg., use of USB c connector), or even within a brand proprietary

Reusability/Upgradability specific provisions

Reusability and Upgradeability are concepts closely related to Reparability, in the sense that all design-related reparability provisions aiming at ease of disassembly are acting in a synergic manner to increase reusability and upgradeability. Nevertheless, there are still some types of provisions that are more distinctly specific to reusability and upgradeability:

- Modular design (the product is built from individually distinct functional units), transformability; detachable elements; adjustable sizing, customizing surfaces,
- functionality for secure data deletion and reset the device to its factory settings

The requirement on a functionality for secure data deletion can be implemented by means of technical solutions such as, but not limited to: 1) a functionality implemented in firmware, typically in the Basic Input/Output System (BIOS), 2) in software included in a self-contained bootable environment provided in a bootable compact disc, digital versatile disc or universal serial bus memory storage device included with the product, or 3) in software installable in the supported operating systems provided with the product.

Secure data deletion in ICT devices can be also achieved by a 'secure deletion of the encryption key', that means the effective erasure of the encryption key used to encrypt and decrypt data, by overwriting the key completely in such a way that access to the original key, or parts of it, becomes infeasible.

Remanufacturing / Refurbishment

Ability to be identified of products/parts

One of the key steps of remanufacturing/refurbishment processes is the product inspection and the determination of the condition its parts and the functionality. In this way it is possible to determine which parts need reprocessing e.g. repair, reworked, replaced or upgraded and which parts might need special care. In the product identification it is also important to identify the original legal requirements applying to the product by giving information on the applicable legislation at the time the product was placed on the market.

Example of provisions are based on typical criteria that influence the ease of identification of the product and its parts according to the standard EN45553:2020:

- Access for diagnostics (e.g. embedded or external diagnostic tools to verify condition);
- Information on how to determine its functionality (also relevant in the preparation for reuse context, see also the CENELEC standard EN 50614:2020)[5];;
- Information on the status of the functionality (e.g. if the different functions of the product are still operational);
- Information on wear-sensitive parts (e.g. if certain parts do not withstand specific cleaning methods);
- Indication of the applicable legislation at the time the original product was placed on the market;
- Indication of parts containing hazardous substances (e.g. to safeguard health and safety of operators performing remanufacturing); and
- Indication of the need for special care / handling during the testing in view of e.g. safety of the testing expert, of others, or of the equipment itself.

Wear and damage resistance during remanufacturing process

As described in the EN45553, the ability to be wear and damage resistant during the remanufacturing process steps describes the ability of a product and/or its parts to withstand all treatment necessary during the remanufacturing steps without being damaged.

Proposed criteria that influence wear and damage resistance to avoid premature deterioration due to the remanufacturing process are:

- materials and fasteners to be sufficiently strong to enable the product to be remanufactured one or more times;
- materials and markings being able to withstand cleaning agents (either chemical or mechanical)

Recyclability

Ability to easily separate the product into different materials

An example of requirements linked to this provision includes the avoidance of connections that enclose a material permanently (as inserts into plastic).

Methods such as: moulding inserts into plastic, rivets, staples, press-fit, bolts, bolt and nut, brazing, welding and clinching make harder to separate the different materials. These processes mentioned are typical for

[5] EN 50614:2020. Requirements for the preparing for re-use of waste electrical and electronic equipment

tightly enclosing one material into another and are therefore recommended to be avoided to facilitate recycling (Source: Polyce 2021[6])

Choice of materials and restrictions on substances

Examples of requirements linked to this provision include:

- Avoid the use of coatings on plastics such as painting, lacquering, since it can result in changed density of the plastic.
- Do not use plating, galvanizing, vacuum-metallization as coating on plastics, since it can result in density change of the plastic.
- Avoid moulding different material types together by 2K or xK processes (different plastic materials injected into the same mould, or over-moulding, or in mould labelling) such as moulding a thermoplastic elastomer onto PP.
- Minimise the use of unnecessary additives in plastic component as they reduce the purity of the plastic streams.
- Avoidance of hazardous substances that cause material streams not to meet the requirements to be recycled and reused in new products in the future.
- Avoidance of design choices hindering recycling (e.g. multilayers, use of carbon black)

Access to product data relevant for the recycling (including CRM)

Examples of relevant requirements include:

- marking of parts and materials, use of component and material coding standards for the identification of components and materials, indicative weight range of different materials, including Critical Raw Materials (CRM) and environmentally relevant materials; access to information, hardware and software needed for the recycling process.
- making available in the form of manuals or by means of electronic media (e.g. CD-ROM, online services) information relevant for treatment facilities as for art 15 (1) of the Directive 2012/19/EU
- making available to recyclers, on a free-access website[7], the dismantling information needed to access any of the products components referred to in point 1 of Annex VII of Directive 2012/19/EU. This dismantling information shall include the sequence of dismantling steps, tools or technologies needed to access the targeted components.

Currently only two ecodesign implementing measures adopted have addressed CRM recyclability, introducing information requirements on their presence in the product. One of these regulations refers to servers and data storage products[8], and focuses on Cobalt (in batteries) and (Neodymium) in Hard Disk Drives.

Recyclability information

Examples of requirements linked to this provision include:

- include a sentence or a pictogram in relation to product disposal[9]
- provide guidance to consumer about product dismantling (if necessary before the recycling)

[6] https://www.polyce-project.eu/wp-content/uploads/2021/04/PolyCE-E-book-Circular-Design-Guidelines-2.pdf

[7] the "Information for Recyclers" (I4R) platform was developed to share information with recyclers of WEEE and in order to comply with the requirement

[8] Regulation on ecodesign requirements for servers and data storage products (EU 2019/424). Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1553786820621&uri=CELEX%3A32019R0424

[9] Currently, mandatory marking of EEE indicating separate collection consists of the crossed-out wheeled bin - see Annex IX of the WEEE Directive

- provide information on the recyclability of the product
- Marking of plastic components (e.g. type of polymer)

Recyclability score

The recyclability-related provisions listed above can serve as parameters for the development of an overall recyclability index/score. This would allow manufacturers to form their design-for-recyclability strategies. Similarly to the reparability score, the recyclability score can comprise of standardised methodological steps:

- Identification of priority materials
- Identification of relevant parameters influencing recyclability
- Scoring system and aggregation

Summary of the material efficiency measures

Table 6: Importance of material efficiency provisions for the different product grouping identified; Rated importance/priority: (+lower, ++medium, +++higher)

	Hardware durability and reliability				Software Related Durability			Reparability, upgradability and reusability							Remanufacturing and refurbishing		Recyclability				
	Minimum lifetime and labelling Resistance to stresses/ageing mechanisms	Battery endurance in cycles…	Minimum / Expected Lifetime	Durability/Reliability score	Availability of software functionality / security updates	Availability and durability of cloud based services of the product	Decoupling of the electronic device from cloud services	Introduction of a Reparability Scoring Index / Label	Availability of repair/upgrade info	Spare parts availability and delivery time	Disassembly / Depth, Tools, Fasteners, Working Environment, Skill Level	Use of component and material coding standards	Use of standard components	Reusability/Upgradability specific provisions	Improve the ability to be identified of products/parts	Wear and damage resistance during the remanufacturing process steps	Ability to easily separate the product into different materials	Choice of materials and restrictions on substances	Access to product data relevant for the recycling	Recyclability information	Recyclability Score
Electronic displays	++	N.A.	++	++	+++	+	+	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++
Audio/video devices	++	++	++	++	+	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++
Audio Equipment	+++	+++	+++	+++	+	+++	+++	+	+	+	++	+	++	++	+	+	++	++	++	++	++
Personal ICT Equipment	+++	+++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++
Accessories and peripherals	+++	+++	+++	+++	+	+	+	+	+	+	+	+	++	+++	+	+	++	++	++	++	+
Wearable ICT Devices	+++	+++	+++	+++	+++	+++	+++	++	++		++	+	++	+	+	+	++	++	++	++	+
Imaging Equipment	++	N.A.	++	++	++	++	++	++	++	++	++	+++	+++	+	+++	+++	++	++	++	++	+
Home / Office Network Equipment	++	N.A.	++	++	+	+	+	+	+	+	++	+	+	+++	+++	+++	++	++	++	++	+
** Some provisions on reparability and recyclability for electronic displays are already included in Regulation (EU) 2019/2021*																					

As the majority of impacts associated with ICT products (especially consumer electronics) stems from material extraction and manufacturing, reliability and durability are very relevant aspects for this product family. The appropriateness of opting for a reliability, reparability and/or durability could be examined at product group level. For instance, for product groups which demonstrate variable failure rates for different parts, the development of both a reliability and reparability index can offer complementary information on the circularity of a product. By contrast, less complex product groups as audio equipment, wearable devices, accessories and peripherals (e.g. a charging cable) may benefit more from a reliability provision than repair.

Hardware durability and reliability is a relevant aspects also for mobile personal ICT devices (e.g. smartphones and tablets) that are more exposed to use and/or environmental stresses, battery aging, accidents.

Software related durability measures are high relevant for 1) ICT devices whose correct functioning and security level are high dependent from the update level of the firmware and operation system (e.g. personal ICT devices) and 2) for devices whose main functionalities are linked to cloud based applications, as it could be the case for some security cameras, loudspeakers, smartwatches

Whenever a product family is composed of some frequent failing parts/components and for which some distinct parameters influencing reparability can be identified, then a product can be proposed as relevant for reparability. This can be the cases of mobile and wearable ICT devices as smartphones, tablets, smartwatches whose display component is highly exposed to drops/shocks.

Reparability strategies tends to be more effective for devices with a longer expected lifetime and higher purchase price (or in general with cost of repair that can be kept low compared to the purchase of new devices). For this reason priority is rated higher for electronic displays, audio/video devices, and personal ICT equipment. Use of standard components as EPS, batteries, SSD modules, RAM modules among others, can benefit the reparability of different families of ICT devices, including imaging equipment.

Modular design is an important features for accessories as External Power Supplies (where the DC cable can be detachable) and in general for personal ICT equipment as computers (e.g. upgradable RAM and SSD) and it considered beneficial also for the upgradability/reusability of reliable equipment as home/office network equipment.

Similarly to repair, measures aiming to facilitate remanufacturing and refurbishment are more relevant for devices with a longer expected lifetime and higher purchase price. Moreover, a special considerations is need for printer cartridges for their nature of consumables and the importance of reducing the electric and electronic waste production associated to their use.

Recyclability measures are considered more product group neutral, due to the similarities of ICT product groups in terms of material composition. Regarding the specific proposal of a recyclability index, due to the complexity of development of such indices, it is proposed that not all products in scope are covered at the same time.

Other material efficiency aspects analysed but not proposed

Recycled content

A potential measure could be to set minimum content of post-consumer recycled material (e.g. plastic) expressed either as a fraction of the total material input (in %) or in absolute numbers (kg per unit, million tonnes Mt in aggregates)

Although such a measure could be a way to stimulate recycled plastic demand in production, the proposal was discarded for the following reasons:

- Relevance: the life cycle environmental impacts of ICT products are mainly associated with the manufacturing of electronics (e.g. PCB and ICs) and with the extraction and processing of precious metals used in these components and the environmental benefits are relatively smaller compared to other measures.
- Comparability: The use of this criterion is not appropriate to compare the environmental performance of products using plastic with products using alternative materials for casing (e.g. aluminium / magnesium alloy).
- Possible trade-offs: The increase in recycled content (w/w%) could, in some cases, come with some trade-offs, such as an increase in the use of plastic to ensure the same performance. The mere measurement of the recycled content cannot consider this trade-off.

In addition there are some concerns about Market Surveillance of such a requirement; the new standard EN 45557:2020 has introduces horizontal principles for the calculation and verification of recycled content (w/w%) in energy-related products and some voluntary certification schemes have been developed for the recycled content certification (e.g. UL ECVP 2809 (3rd edition), SCS Services Recycled Content Standard V7.070), the market surveillance of the supply chain for ICT remain very challenging.

4.2.3. Other policy recommendations

#4 Minimum Guarantee for B2B ICT sales

Currently, minimum liability conditions for goods according to Directive (EU) 2019/771, and digital content and digital services according to Directive (EU) 2019/770, are applicable only in the business-to-consumer sector. In the context of public procurement, such conditions exist as criteria in already established voluntary GPP guidance documents, which could be enforced mandatorily (see proposal #13 below).

However, sales of ICT products in a business-to-business context are currently not covered by European legislation. It is suggested to explore the establishment of such minimum guarantee for products such as consumer electronics sold in B2B transactions.

#5 Quality labelling and certification for refurbishing and second-hand markets

Quality label for refurbished products

As pointed out by the EU Parliament Study "A Longer Lifetime for Products - Benefits for Consumers and Companies"[10], a common quality labelling for refurbished products could facilitate incorporating product lifetime into purchasing decisions for second-hand products, while tackling the challenge of providing honest information to consumers without overloading them.

The information provided on a label for refurbished products should be clear and reliable in order to generate consumer confidence on the use of products for a longer time. The label could be based on self-declaration but some form of market surveillance could be foreseen.

[10] https://www.europarl.europa.eu/RegData/etudes/STUD/2016/579000/IPOL_STU(2016)579000_EN.pdf

This could be done by adopting an EU common labelling system about the quality of refurbished ICT goods.

Market places for second-hand / refurbished ICT devices are already providing information to consumers but they could use slightly different grading systems or the same class/grade can have slightly different meanings. The grade systems for consumer ICT mainly focus on cosmetic and technical conditions of the device. In the table below examples of grading systems applied by different marketplaces.

Table 7: Examples of grading systems for refurbished products

RefurbMe[11]	BackMarket[12]	Gazelle[13]
Excellent (Grade A) Devices are like new.	Excellent Appearance: Like new. The body may have very light micro-scratches, invisible at a distance of 8 inches (a bit longer than a standard-sized pencil) or more. For items with screens, the screen will have no scratches. Technical Condition: Excellent. Durability scores are high, and chances of encountering technical issues are very low.	Excellent The screen and body of these devices are in excellent condition.
Good (Grade B) Devices are in working condition but have light cosmetic issues.	Good Appearance: Light signs of wear. The body may have light micro-scratches, invisible at a distance of 20 inches (about an arm's length) or more. For items with screens, the screen will have no scratches. Technical Condition: Very Good. Durability scores are above average,	Good Very good condition, although with light aesthetic blemishes. The functionality is the same.

[11] https://www.refurb.me/blog/what-are-refurbished-grades-a-b-c
12 https://help.backmarket.com/hc/en-us/articles/360026656634-What-to-expect-from-each-product-grade
13 https://buy.gazelle.com/collections/clearance/products/ipad-7-32gb-wifi

	and chances of encountering technical issues are low.	
Fair (Grade C) Devices have light but visible scratches on the body.	Fair Appearance: Signs of wear. The body may have a few visible scratches and dents that don't affect performance. For devices with screens, they may have light scratches that are slightly visible when the device is on. Technical Condition: Good. Durability scores are average and still correspond with the quality levels required by our quality charter.	Fair A good condition with visible wear and tear.

Quality Code of Conduct or Certification for ICT refurbishers and second-hand marketplaces

An additional proposal would include the voluntary commitment to observe a European standard for quality in refurbishment and placing of second-hand ICT devices on the market. It would boost consumer trust in purchasing second hand ICT, encourage an increase in the quality of ICT refurbishment and reduce market barriers for refurbished products. The standards would be applicable to refurbishers or directly to second hand products marketplaces (and indirectly to the refurbishers and traders operating under the marketplace).

It would cover key aspects of the refurbishment process services, which are important factors for consumer decisions on buying second hand, e.g. quality control during the refurbshment process, clear length and coverage of the commercial guarantee, transparent and clear communication of the status of the refursbished devices. The commitment would set a standardised minimum level of quality on each aspect. This will increase consumer confidence, as they could trust that providers with this label address consumer concerns about refurbishment carried out in an effective manner.

Existing standards at national level can be of inspiration for a EU proposal. As example is the British Standard BS 8887-240:201114 which specifies requirements for the process of reconditioning, i.e. returning a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components.

This proposal could be implemented by:

1) a negotiated industry code of conduct, agreed by representative business associations at EU level. Consumer organisations and civil society representatives would be involved in the development process. The Commission could facilitate negotiations and help to provide publicity. The code would be open to all the operators across the

[14] BS 8887-240:2011 Design for manufacture, assembly, disassembly and end-of-life processing (MADE) Reconditioning

EU (including independent refurbishers and marketplace platforms). To ensure visibility and consumer recognition, a standardised label would be made available to all subscribers. Enforcement of the code would be monitored by the stakeholders that negotiated the code.

2) an EU standardisation process. Once a EU standard is available a quality management standard for refurbishing and marketing second hand ICT devices could be certified by accredited Certification Bodies for the audit and certification of management systems.

#6 Take Back and preparation for Reuse

According to Milios (2021) in the electronics sector there is a need for developing take-back systems exclusively for re-use, either on the side of existing systems of recycling or by completely substituting the existing systems.

The higher effectiveness of a more targeted collection has been demostrated on the field by Coughlan and Fitzpatrick (2020): trialling the preparation for reuse of consumer ICT WEEE in Ireland, targeted collections demonstrate significantly higher reuse rates than from the current collection system.

Johnson et al. (2015) also provided recommendations around removing barriers to accessing suitable equipment which included the establishment of special collections of WEEE for material suitable for preparation for reuse and also to enable approved preparation for reuse of WEEE organisations to receive WEEE from the general public specifically targeting items with potential for preparation for reuse.

According to Milos (2021), having collection systems running in parallel would unavoidably create tensions regarding the collected volumes of materials for either re-use or recycling. A viable option could be to establish integrated systems of collection for re-use and recycling, managing products and materials in a cascading manner.

The "Study on options for return schemes of mobile phones, tablets and other small electrical and electronic equipment in the EU" (Ramboll et al. 2022) identify and conceptualise policy measures for action at the EU level to incentivise the return and take-back of small used and waste EEE. Among other actions identified, this study suggests make use of door-to-door and postal services to ease the return of used and waste EEE, the development of dedicated drop-off points database for small EEE and targets for re-use at national level.

Products that have sufficient value and function could be re-used while those who are under a threshold value could be redirected to recycling.

Related to the development of appropriate channels for sourcing used equipment, another intervention required by the electronics sector is the enhanced communication through establishment of on-line platforms. Either government-sponsored or industry-managed, on-line platforms have the potential to diminish transaction costs and enable easier sourcing of used equipment between interested parties. This policy intervention also implies a wider mobilisation of actors, from public authorities to companies and civil society participation, accelerating policy transition processes.

#7 Sustainable Sourcing

The EU Regulation (EU) 2017/821 has introduced a supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas regulation requires EU companies in the supply chain to ensure they import these minerals and metals from responsible and conflict-free sources only. On first of January 2021 this new regulation came into full force across the EU. It is important to highlight that this regulation is quite limited in scope as do not apply to final product manufacturers, including ICT device manufacturers, as only EU mineral importers are obliged to perform a due diligence.

The OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas ('OECD Due Diligence Guidance') is the main reference (OECD, 2016) for the implementation of the due diligence obligations. With the exception of this specific legislative initiative on 3TG minerals, multinational

companies in the ICT field have been encouraged to take responsibility for their supply chains only a voluntary basis, despite human right violations in their mineral supply chain are evident as reported by academic research, NGOs and from the studies reported in this report.

The EU Non-financial Reporting Directive (NFRD) Directive 2014/95/EU has introduced information requirements. Large companies from 2018 onwards are requested to publish information on the policies they implement in relation to environmental protection, social responsibility and treatment of employees, respect for human rights, anti-corruption and bribery, and diversity on company boards, including on due diligence procedures throughout the supply chain with a view to addressing existing and potential negative effects. The NFRD does not impose a legal obligation on EU companies to undertake human rights due diligence; however if they do, they are required to provide information on it. It also requires them to give the reasons why they do not undertake it, if that is the case. The Directive 2014/95/EU is currently under revision.[15]

In this context the European Commission has undertaken some preliminary steps, including publishing a study[16] and conducting public consultations[17], towards a possible legislative initiative on mandatory due diligence. In particular, in 2022, the European Commission, proposed a *Directive on sustainable corporate governance* that would have a cross sectoral scope and broad range of sustainability impacts covered including human rights and environmental due diligence[18].

Regarding initiatives relevant for the ICT sector, the European Commission recently proposed a new Battery Regulation with mandatory sustainability requirements which include supply chain due diligence for minerals used in batteries[19]. According to the Commission Communication there is a fair degree of consensus among stakeholders for a mandatory due diligence. According to the proposal a mandatory supply chain due diligence is considered more effective than a voluntary in addressing the social and environmental risks related to raw material extraction, processing and trading of certain raw materials for battery manufacturing purposes.

It is proposed that mandatory due diligence is established for ICT product manufacturers. This could be explored in the context of an expansion of scope of the aforementioned EU Regulation (EU) 2017/821 to cover not only materials that are directly imported in the EU market, but also when those materials are present in imported ICT products placed in the EU market. Alternatively, it could be explored whether the aforementioned newly-proposed *Directive on sustainable corporate governance* could serve this purpose.

Summary of other device level recommendations

Table 8: Importance of system level policies for the different product grouping identified; Rate importance/priority: + , ++, +++

	Device level

[15] https://ec.europa.eu/info/business-economy-euro/company-reporting-and-auditing/company-reporting/non-financial-reporting_en#review
[16] https://op.europa.eu/en/publication-detail/-/publication/8ba0a8fd-4c83-11ea-b8b7-01aa75ed71a1/language-en
[17] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12548-Sustainable-corporate-governance
[18] Proposal for a Directive on Corporate Sustainability Due Diligence and amending Directive (EU) 2019/1937 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0071
[19] COM(2020) 798 final

	B2B Guarantees	Refurbish Quality Label	Take Back & prep Reuse	Sustainable Sourcing
Electronic displays	+++	+++	+++	++
Audio Video devices	+++	+	++	++
Audio Equipment	+++	+	++	++
Personal ICT Equip.	+++	+++	+++	++
Accessories	+	+	+	++
Wearable Devices	+++	+	+	++
Imaging Equipment	+++	+++	+++	++
Home / Office Network Equipment	++	++	++	++
DC devices	++	+++	+++	++
Telecom / network	N/A	++	++	++

4.3. System level

#8 Video streaming default settings

As demonstrated by the survey presented in Task 7 of this study, video streaming default settings are used by the majority of respondents. This is also confirmed by further evidence in Suski et al. (2020). Therefore, a requirement to set the resolution to minimum resolution settings by default alone has the potential to bring about energy savings as demonstrated by studies (Medlener et al (2022).

Video can be streamed by the hardware device using various platforms, such video sharing and social media platforms or SVOD/TVOD platforms, or dedicated applications which can be installed by user or pre-installed by the OEM before placing on the market. As such, a requirement to use minimum resolution can be addressed at device level within the ecodesign framework, or at platform/application level via another regulatory instrument.

#9 Consumer information on environmental impact of settings and data usage

Another requirement relevant provision is related to providing information to consumers about potential change in energy use when settings are changed by them. Regulation (EU) 2019/2021 on ecodesign requirements for electronic displays already contains a requirement that such warning message is displayed:

"If the user selects a configuration other than the normal configuration and this configuration results in a higher power demand than the normal configuration, a warning message about the likely increase in energy use shall appear and confirmation of the action shall be explicitly requested".

"If the user selects a setting other than those that are part of the normal configuration and this setting results in a higher energy consumption than the normal configuration, a warning message about the likely increase in energy consumption shall appear and confirmation of the action explicitly requested".

"A change by the user in a single parameter in any setting shall not trigger any change in any other energy-relevant parameter, unless unavoidable. In such a case a warning message shall appear about the change of other parameters and the confirmation of the change shall be explicitly requested".

Another source of "passive" data usage is 'unintentional' or 'background' data demand (Hazas et al 2016). High levels of communication between apps and the cloud have been found associated with automated updates or performing backup of application data and digital photos to the cloud (Hazas et al 2016). Similarly to the case of changes in settings, such operations could also be accompanied by messages to device users warning about background data usage and allowing them to opt for performing them manually rather than automatically.

The abovementioned provisions would be relevant to all ICT products that have the ability to stream and display video. Those include: computers, game consoles, smartphones and tablets.

#10 Energy Efficiency and Carbon Footprint Labelling of Telecommunication Network Services

The systemic nature of digital services and the challenge to account for their environmental impacts and attribute them to different parts of the system has been described in Tasks 3 and 4. Nevertheless, consumers making purchasing decisions for digital services (e.g. telecommunication services) respond to simple and understandable information, which can be aggregated to a single metric, score or class. Life Cycle Assessment approaches can be pursued in order to assess a range of environmental impacts, and identify the most relevant one(s) to communicate. For instance, the ITU standard L.1410[20] outlines an LCA-based methodology for ICT, which encompasses the distinction between ICT goods, ICT network, and ICT services.

According to the Commission Study on Greening Cloud Computing and Electronic Communications Services and Networks Towards Climate Neutrality by 2050 (Idea et al. 2022), two possible approaches to communicate the environmental footprint of electronic communications networks and services could be applied:

- Reporting at company level
- Reporting at level of subscription service

[20] L.1410 : Methodology for environmental life cycle assessments of information and communication technology goods, networks and services. Available at: https://www.itu.int/rec/T-REC-L.1410

Many electronic communications network providers already report at company and disclose how much energy they consume in total as a company, what is their share of renewable energies and the GHG emissions related to their services. For this purpose companies refer mainly to the Global Reporting Initiative (GRI), Greenhouse Gas Protocol (GHGP) or the results of energy management according to ISO 14001 or ISO 50001 as suitable methods of accounting. Key metrics used in reporting are:

- Annual energy consumption of the company [MWh/a]
- Share of renewable energies in annual energy consumption [%]
- Annual GHG emissions of the company [tonnes CO2-eq/a]

However reporting at level of company is not the most suitable option to enable greener end user subscription decisions. It can be argued that reporting at the level of subscription can better guide consumers. As described in Task 3 report of this study, in order to access the internet, there are several technical access options, each of which require different amounts of energy (e.g. mobile vs fixed access network, different generations). Moreover, different operators could be able to reach different level of energy efficiency of their system and different use of renewables. The customers of this service decide which provider to contract and which access technology to use.

The same Commission Study (Idea et al. 2022) suggests that, in order to reduce the complexity of calculating the energy consumption of data transmission, information could therefore (at first) only be provided on the energy consumption of the access network. This would already make it possible to distinguish between different access options (e.g. broadband cable or fibre optics) and different providers.

By using reference units, key figures can be presented in such a way that they are intuitively understood by end-users. A suitable "functional unit", which in the case of a "subscriber" could be an average user or a user with a defined data volume and online times (see Figure 2). In order to realise an appealing presentation of these numerical values for consumers, the respective watt values (power consumption of the service per subscriber) or other efficiency values (e.g. energy intensity or carbon footprint of data transmission) could be put into a colour scale, comparable to the well-known EU energy efficiency label.

Energy efficiency colour scale	E.g. Power consumption of the service per subscriber	E.g. Energy intensity of data transmission	E.g. Carbon footprint of data transmission
	< 1 Watt	< 1 Wh/GByte	< 1 g CO_2-eq/GByte
	< 2 Watt	< 2 Wh/GByte	< 2 g CO_2-eq/GByte
	< 4 Watt	< 4 Wh/GByte	< 4 g CO_2-eq/GByte
	< 8 Watt	< 8 Wh/GByte	< 8 g CO_2-eq/GByte
	< 16 Watt	< 16 Wh/GByte	< 16 g CO_2-eq/GByte
	< 32 Watt	< 32 Wh/GByte	< 32 g CO_2-eq/GByte
	≥ 32Watt	≥ 32 Wh/GByte	≥ 32 g CO_2-eq/GByte

Figure 2: Example for energy efficiency label for access network. Source: Commission Study on Greening Cloud Computing and Electronic Communications Services and Networks Towards Climate Neutrality by 2050

#11 Application software products: material and energy efficiency

The preparatory study of the Ecodesign Working Plan 2022-2024[21] recommends that, to exploit the savings potential as far as possible, future legislative implementation is pursued by:

A) Setting horizontal minimum requirements on firmware / system software for all ErPs to increase durability by reducing software-related hardware obsolescence.

B) Including and further specifying requirements on software updates horizontally or as pre-requisite in all Ecodesign and Energy Labelling regulations to reduce the risk of deteriorating energy/ resource efficiency of products after updates.

C) Conducting a feasibility study on the possibility to set energy and resource efficiency measures on application software.

While approach A) has been already applied for other aspects (i.e. stand-by efficiency) and approach B) is being addressed by Ecodesign and Energy labelling regulations, initiatives under C) are not yet applied in the Ecodesign / Energy Labelling context. Firstly, a clarification is needed to define what application software is and clarify to what extent and under which circumstances it can be regulated under the ErP context.

According to Directive 2009/125/EU, 'Energy-related product', (a 'product'), means any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently.

For instance, if the consumer downloads a game application from an app store onto a smartphone, the contract for the supply of the game application is different from the contract for the sale of the smartphone. The game application therefore would meet the aforementioned definition of energy related product, as:

- It is a product placed on the market
- is intended to be incorporated in an energy related product covered by the Ecodesign directive (e.g. smartphone or tablet)
- has an impact on the energy consumption of the device
- the environmental performance can be assessed independently

In other cases the application software is pre-installed. For example, a smartphone could come with a standardised pre-installed application provided under the sales contract, such as an alarm application or a camera application. In this case the digital content is not considered as a product placed on the market, as it is an integrated part of the smartphone.

Energy and resource efficiency measures on "application software" could be implemented in the form of minimum requirements, information requirements, and / or mandatory labelling. The Ecodesing and Energy Labelling preparatory study suggests:

[21] Preparatory study for the Ecodesign and Energy Labelling Working Plan 2020-2024 - TASK 4 COMPLEMENTARY ANALYSES AND RECOMMENDATIONS FOR THE ECODESIGN AND ENERGY LABELLING WORKING PLAN 2020-2024 – FINAL. Available at: https://www.ecodesignworkingplan20-24.eu/documents

- Minimum Ecodesign requirements on energy and resource efficiency of application software, e.g. energy demand, CPU cycles, hardware utilization, support for the energy management system, etc.).
- Energy Labelling requirements to display the energy and resource efficiency of application software products to end consumers.

Further information requirements, e.g. instructions on efficient use of the application software, support for the energy management system.

Other potential aspects relevant for minimum mandatory requirements, could cover aspects like:

- Minimum continuity of the application software product (ideally it should be comparable with the expected lifetime of the hardware)

Information requirements could cover aspects that allow the optimisation of the application software / hardware system like:

- Information on system requirements (processor performance)
- Information on local working memory required (MByte)
- Information on local permanent storage required (MByte)
- Requirements for other software (operating system, middleware and auxiliary applications: software stack) (e.g. Windows 7, .NET Framework and browser version XY)
- The required external services that are not available on the reference system (e.g. cloud services, storage services, API usage, ...)
- The required additional hardware (e.g. graphics card, peripheral devices such as a camera connected via USB).

Information on backward compatibility. Software application with longer backward compatibility can reduce the risk of technology obsolescence for hardware

A labelling system of application software could be used by consumers to evaluate the material and energy efficiency performance of the application software. From the material efficiency perspective it could include aspects that contribute to extend the lifetime of the hardware are:

- system requirements (processor performance)
- working memory required (MByte)
- Minimum local permanent storage required (MByte)
- Requirements for other software (operating system, middleware and auxiliary applications: software stack) (e.g. Windows 7, .NET Framework and browser version XY)
- The required external services that are not available on the reference system (e.g. cloud services, storage services, API usage, ...)
- The required additional hardware (e.g. graphics card, peripheral devices such as a camera connected via USB).
- % of hardware utilisation in idle and active mode (standard usage scenario)
- Interoperability

- Continuity of the software product
- Backward compatibility
- Uninstallability
- Modularity
- Offline capabilities

Energy Efficiency:

- Energy consumption in idle and active mode (standard usage scenario)
- Support for the energy management system

Ecodesing and energy labelling requirements could complement those of the supply of digital services and digital content (in which application software is included) established by the Directive (EU) 2019/770. This Directive introduces general conformity requirements on digital content or digital service, which shall:

(a) be fit for the purposes for which digital content or digital services of the same type would normally be used, taking into account, where applicable, any existing Union and national law, technical standards or, in the absence of such technical standards, applicable sector-specific industry codes of conduct;

(b) be of the quantity and possess the qualities and performance features, including in relation to functionality, compatibility, accessibility, continuity and security, normal for digital content or digital services of the same type and which the consumer may reasonably expect, given the nature of the digital content or digital service ….

(c) where applicable, be supplied along with any accessories and instructions which the consumer may reasonably expect to receive; and

(d) comply with any trial version or preview of the digital content or digital service, made available by the trader before the conclusion of the contract.

According to the same Directive 2019/770, the trader shall ensure that the consumer is informed of and supplied with updates, including security updates that are necessary to keep the digital content or digital service in conformity, for the period of time:

(a) during which the digital content or digital service is to be supplied under the contract, where the contract provides for a continuous supply over a period of time; or

(b) that the consumer may reasonably expect, given the type and purpose of the digital content or digital service and taking into account the circumstances and nature of the contract, where the contract provides for a single act of supply or a series of individual acts of supply.

#12 Mandatory Green Public Procurement

EU Green Public Procurement (GPP) criteria aim at facilitating public authorities' purchase of products, services and works with reduced environmental impacts. Even though GPP criteria for Data Centres, Server Rooms and Cloud Services are already in place (European Commission, 2020) and can contribute to meeting climate and circularity objectives, their application remains voluntary, thus a lack of knowledge and wider implementation at Member State level restrains the GPP framework from

reaching its full potential (Montevecchi et al, 2020; Bilsen et al, 2022). A mandatory application of the criteria may lead to positive impacts (Bilsen et al, 2022). A mandatory reference to GPP is included here in the proposal for Recast of Energy Efficiency Directive[22].

One particularly relevant aspect within the EU GPP framework would be extending the minimum duration of guarantee (liability for lack of conformity) to the public procurement. Currently, minimum liability conditions for goods according to Directive (EU) 2019/771, and digital content and digital services according to Directive (EU) 2019/770, are applicable only in the business-to-consumer sector.

According to these directives the seller (or the trader) shall be liable to the consumer for any lack of conformity which exists at the time when the goods/digital services were delivered and which becomes apparent within two years of that time.

No mandatory minimum liability is foreseen in business to business contracts, including for the procurement of goods and services provided under public procurement contract. Minimum level of guarantee could be implemented by making some of the voluntary EU GPP Criteria, already developed under the EU GPP Framework, mandatory for all the products.

It would be recommended to make mandatory the "core level" criteria – which are designed to allow for easy application of GPP, focusing on a product's environmental performance and aimed at keeping administrative costs for companies to a minimum.

As example, the EU GPP Criteria for computers, monitors, tablets and smartphones (SWD(2021) 57 final) include minimum manufacturer criteria for new and refurbished devices (see table below).

Table 9: Existing voluntary criteria for Computers, Monitors, Tablets and Smartphones

Core criteria on manufacturer's warranty of Computers, Monitors, Tablets and Smartphones
TS3: Manufacturer's warranty Applicable to all categories of devices except refurbished/remanufactured devices The tenderer must provide products covered by X years [*minimum 2, to be defined*] of the manufacturer's warranty. Verification: The tenderer must provide written evidence of the manufacturer's warranty. Equipment holding a Type I Ecolabel fulfilling the specified requirements will be deemed to comply.
TS24: Refurbished/remanufactured product warranty Applicable to the procurement of refurbished/remanufactured products.

[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558

The tenderer must provide products covered by X years [*at least 1 year*] warranty. Verification The tenderer must provide written evidence of the warranty

#13 Financial instruments

Certain business models, such as the offering of unlimited data plans and a fixed price regardless of the data use level, enables data use and subsequently energy use.

Financial instruments such as pricing policies can provide a powerful policy tool by incentivising efficiency in data use and subsequently energy, in accordance with the polluter pays principle[23].

Examples can be drawn from other sectors with impactful consumption, such as water, where the EU Water Framework Directive (2000/60/EC) indicates that Member States shall ensure that *"water-pricing policies provide adequate incentives for users to use water resources efficiently, and thereby contribute to the environmental objectives of this Directive"*.

Taxation can also play a role in lowering consumption. For example, reduced rates of electricity tax for Data Centres in some countries (e.g. Finland, Sweden, Norway or France) offer little incentive to save energy, and the Energy Taxation Directive currently under revision can have an impact in setting appropriate taxation minima (Banet et al, 2021).

Another policy that has been proposed is that of a "*transit fee*" which can be imposed on a certain unit of quantity of data traffic, which could address both environmental externalities and network congestion costs (Madlener et al, 2022).

Summary of the system level recommendations

Table 10: Importance of system level policies for the different product grouping identified; Rate importance/priority: +, ++, +++

	System level				
	Video default settings	**Telecom service Label**	**Application efficiency**	**Mandatory GPP**	**Financial**
Electronic displays	+++	N/A	++	+++	N/A
Audio Video devices	N/A	N/A	+	+	N/A
Audio Equipment	N/A	N/A	+	+	N/A

[23] https://environment.ec.europa.eu/economy-and-finance/ensuring-polluters-pay_en

Personal ICT Equip.	+++	N/A	+++	+++	N/A
Accessories	N/A	N/A	N/A	++	N/A
Wearable Devices	++	N/A	+++	+	N/A
Imaging Equipment	N/A	N/A	N/A	+++	N/A
Home / Office Network Equipment	N/A	N/A	N/A	+++	N/A
DC devices	N/A	N/A	N/A	+++	N/A
Telecom / network	N/A	+++	N/A	+++	+++
UPS	N/A	N/A	N/A	++	N/A

In terms of product coverage, requirements related to minimum guarantee in a B2B context are relevant for a wide range of product groups from consumer electronics to servers. A quality label for refurbished products would be most relevant for consumer electronics, while take back schemes specifically designed for preparation for reuse could initially target products with higher value, including smartphones, laptops and tablets in consumer sector or servers in the business to business sector.

Obligations related to sustainable sourcing would be linked to specific materials, including CRM, therefore affecting a wide range of ICT products.

A requirement to set low video resolution settings as default are relevant for all display and personal ICT equipment where streaming takes place, even though such requirement may be addressed to a streaming platform or app, rather than the device itself. Similarly, consumer information on environmental impact of settings and data usage would be most relevant for devices where consumer interaction takes place via a display, including displays themselves, personal ICT equipment and game consoles.

Labelling related to the energy efficiency and Carbon Footprint for Telecommunication Network Services would directly impact telecommunication providers, and indirectly devices for which such services are provided, such as personal ICT equipment. Application software efficiency would be relevant for a range of ICT devices, for which applications are used, again including personal ICT devices and displays.

Finally, mandatory EU GPP criteria could be set in the case of ICT products for which voluntary GPP criteria are already in place, including those related to the guarantee provision.

Figure 3 below provide a summary of the applicability of the policy recommendation by provision type and by ICT system level (device hardware – device software – application software – service / cloud). Table 11 provides a summary of the prioritization of the requirements / recommendations for the various ICT product groups in the scope of this analysis.

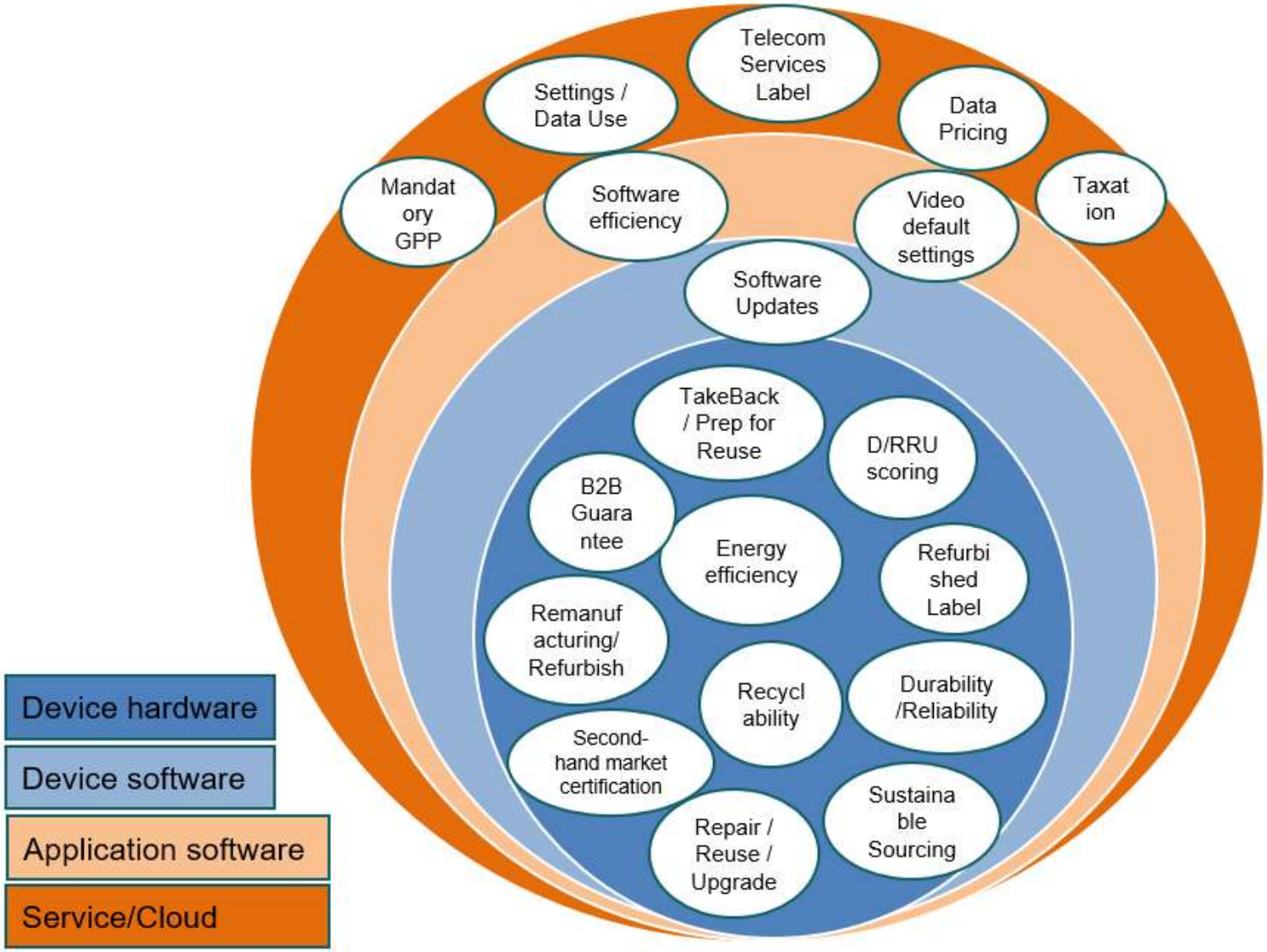

Figure 3: Policy recommendations by provision type and by ICT system level

Table 11: Prioritization of requirements for the various ICT product groups; Priority score: +, ++, +++

	Device-based																									Service-Cloud based				
		Hardware durability and reliability				Software Related Durability			Reparability, upgradability and reusability							Remanufacturing & refurbishing		Recyclability					Other device based							
	Energy Efficiency	Min lifetime & labelling Resistance to tresses/ageing	Battery endurance in cycles	Minimum/Expected Lifetime	Durability/Reliability score	Availability of software	Availability and durability of cloud based services	Decoupling of device from cloud services	Reparability Scoring Index / Label	Availability of repair/upgrade info	Spare parts availability and delivery time	Tools, Fasteners, Working	Use of component and material coding standards	Use of standard components	Reusability/Upgradability specific provisions	Improve the ability to be identified of products/parts	Wear and damage resistance during remanufacturing	Ability to separate product into different	Choice of materials and restrictions on substances	Access to product data relevant for the recycling	Recyclability information	Recyclability Score	B2B Guarantees	Refurbish Quality Label	Take Back & prep Reuse	Sustainable Sourcing	Video default settings	Telecom service Label	Application efficiency	Mandatory GPP	Financial
Electronic displays*	++	++	N/A	++	++	+++	+	+	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++	+++	+++	+++	++	+++	N/A	++	+++	N/A
Audio/video devices	++	++	++	++	++	+	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++	+++	+	++	++	N/A	N/A	+	+	N/A
Audio Equip	+	+++	+++	+++	+++	+	+++	+++	+	+	+	++	+	++	++	+	+	++	++	++	++	++	+++	+	++	++	N/A	N/A	+	+	N/A
Personal ICT Equip.	++	+++	+++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++	++	++	+++	+++	+++	++	+++	N/A	+++	+++	N/A
Accessories	+	+++	+++	+++	+++	+	+	+	+	+	+	+	+	++	+++	+	+	++	++	++	++	+	+	+	+	++	N/A	N/A	N/A	++	N/A
Wearable ICT Devices	+	+++	+++	+++	+++	+++	+++	+++	++	++		++	+	++	+	+	+	++	++	++	++	+	+++	+	+	++	++	N/A	+++	+	N/A
Imaging Equipment	+	++	N/A	++	++	++	++	++	++	++	++	++	+++	+++	+	+++	+++	++	++	++	++	+	+++	+++	+++	++	N/A	N/A	N/A	+++	N/A
Home / Office Network Equipment	++	++	N/A	++	++	+	+	+	+	+	+	++	+	+	+++	+++	+++	++	++	++	++	+	++	++	++	++	N/A	N/A	N/A	+++	N/A
DC devices*	+++																						++	+++	+++	++	N/A	N/A	N/A	+++	N/A
Telecom / network	++																						N/A	++	++	++	N/A	+++	N/A	+++	+++
UPS	++																						++				N/A	N/A	N/A	++	N/A

** Some provisions on reparability and recyclability for electronic displays are already included in Regulation (EU) 2019/2021 and Regulation (EU) 2019/424*

Conclusions

Addressing the environmental impacts of ICT product use calls not only for a wider consideration of environmental aspects beyond energy efficiency, but also for a policy approach that spans beyond the boundary of individual products as hardware. A key challenge in this context is how product policy instruments, which as a rule need several years to develop regulations for individual products and technologies, can be applied to fast moving technologies with a high turnover of new products entering the market.

This study resulted in a set of policy recommendations using a structure that starts with the device as tangible hardware with direct resource use, and expands to software and telecommunication services that enable further resource use by a range of devices in an ICT system (Figure 1 and Figure 3).

A distinction between products for which use phase energy consumption remains the most relevant aspect and those for which material extraction and manufacturing are critical is still meaningful. Therefore, a range of material efficiency provisions are proposed for consumer electronics using a horizontal approach (policy recommendation #3), as already applied for the stand-by regulation. Such horizontal solutions have the potential to address the fast innovation cycles that characterise ICT products.

Those are paired with a number of measures that aim at facilitating the development of second-hand product and component use, such as refurbishing, remanufacturing and takeback schemes.

Beyond the device boundary, video streaming and the use of application software have been demonstrated to enable energy consumption to a significant degree. These could be addressed by means of minimum efficiency requirements (in the case of application software) as well as informational requirements to raise consumer awareness on these impacts.

Lastly, wider systemic measures such as the labelling of telecommunication services, consumer information on data use and financial instruments could also contribute to curbing the induction effects of ICT system impacts by allowing consumers to make informed choices in the context of new business models and by fostering competition among providers on the basis of sustainability.

As described in the previous chapters of this report, existing EU policy instruments can provide the legal basis for the implementation of some of the policy recommendations proposed. In this context, relevant EU policy tools include the product design legislation (e.g. Ecodesign Directive and Energy Labelling Regulation) (see chapter 3), waste legislation (e.g. the WEEE Directive 2012/19/EU), legislation on consumer right (e.g. Directive 2011/83/EU) and legislation aiming to protect fundamental rights (e.g. regulation (EU) 2017/821) on supply chain due diligence obligations).

The Ecodesign Directive (2009/125/EC) and the Energy Labelling Regulation (Regulation (EU) 2017/1369) are the most relevant frameworks for the implementation of the energy efficiency requirements and the material efficiency requirements for consumer electronics (recommendations #1 on extending the implementation of energy efficiency requirements; #2 on introduction of energy efficiency requirements based on "active mode" performance and #3 on material efficiency of consumer electronics). Under specific conditions, the same tools can be also suitable for the implementation of the recommendation #8 on video streaming default settings, #9 on consumer information on environmental impact of settings and data usage and #11 on energy/material efficiency of application software (e.g. in case the application software is pre-installed in the ICT device).

The proposal for a new Ecodesign for Sustainable Products Regulation (ESPR) (European Commission, 2022) published on 30 March 2022, builds on the existing Ecodesign Directive. This new framework will allow for the setting of a wide range of requirements, including on material efficiency aspects described under policy recommendation #3. For groups of products that share sufficient common characteristics, the framework will also allow to set horizontal rules. The proposed ESPR also provides a basis for the setting of mandatory green public procurement criteria.

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ISBN XXX-XX-XX-XXXXX-X