Preparatory study on the Review of Regulation 617/2013 (Lot 3)

Computers and Computer Servers

Task 7.1 report

Presentation of policy measures

Final version for consultation

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VITO NV
Boeretang 200
2400 Mol
Belgium
vito.be

Viegand Maagøe A/S
Nr. Farimagsgade 37
1364 Copenhagen K
Denmark
viegandmaagoe.dk

Prepared by:

Viegand Maagøe and VITO
Study team: Larisa Maya-Drysdale, Michelle Peled, Jonathan Wood, Mette Rames and Jan Viegand (Viegand Maagøe)
Quality manager: Wai Chung Lam (VITO)
Website design and management: Karel Styns (VITO)
Contract manager: Karolien Peeters (VITO)

Prepared for:

European Commission
DG ENER C.3
Office: DM24 04/048
B-1049 Brussels, Belgium

Contact person: Paolo Tosoratti
E-mail: Paolo.TOSORATTI@ec.europa.eu

Project website: computerregulationreview.eu

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Table of contents

List of tables

List of figures

Abbreviations

AC	Alternate Current
AVFS	Adaptive Voltage and Frequency Scaling
B2B	Business to Business
B2C	Business to Consumers
BAT	Best Available Technology
BOM	Bill of Materials
CCFL	Cold cathode fluorescent lamp
CPU	Central processing unit
CRM	Critical Raw Materials
DBEF	Dual Brightness Enhancement Film
DC	Direct Current
dGfx	Discrete Graphic Card
DFS	Dynamic frequency scaling
DIY	Do-it-yourself
DVS	Dynamic voltage scaling
EC	European Commission
EEE	Electrical and electronic equipment
EGA	External graphics adapter
EMEA	Europe, Middle East and Africa
EoL	End-of-life
EPA	Environmental Protection Agency (USA)
EPS	External power supply
ESOs	European Standardisation Organisations
EU	European Union
FCC	Full charge capacity
FR	Flame retardants
GHG	Greenhouse Gases
GPU	Graphics processing unit
HDD	Hard disk drives
iGfx	Integrated graphics processing unit
IPS	Internal power supply
JRC	Joint Research Centre
LCD	Liquid crystal display
LED	Light emitting diode
Li-ion	Lithium-ion battery
NiCad	Nickel-Cadmium battery
NiMH	Nickel-metal hydride battery
ODD	Optical disk drive
OS	Operating System
PCB	Printed Circuit Board
PRO	Producer Responsibility Organisation
PSR	Panel self-refresh

PSU	Power Supply Unit
RAM	Random access memory
SME	Small and medium enterprise
SoC	State of charge of a battery
SRAM	Static RAM
SSD	Solid state drives
SSHD	Solid state hybrid drive
VR	Virtual Reality
WEEE	Waste Electrical and Electronic Equipment

Introduction to the task reports

This is the introduction to the interim report of the preparatory study on the Review of Regulation 617/2013 (Lot 3) for Computers and Computer Servers. The interim report has been split into five tasks, following the structure of the MEErP methodology. Each task report has been uploaded individually in the project's website. These task reports present the technical basis to define future ecodesign and/or energy labelling requirements based on the existing Regulation (EU) No 617/2013.

The task reports start with the definition of the scope for this review study (i.e. task 1), which assesses the current scope of the existing regulation in light of recent developments with relevant legislation, standardisation and voluntary agreements in the EU and abroad. The assessment results in a refined scope for this review study.

Following it is task 2, which updates the annual sales and stock of the products in scope according to recent and future market trends and estimates future stocks. Furthermore, it provides an update on these trends as well as on consumer expenditure data, which will be used on the assessment of additional life cycle consumer costs if or when setting new requirements.

Next task is task 3, which presents a detailed overview of use patterns of products in scope according to consumer use and technological developments. It also provides an analysis of other aspects that affect the energy consumption during the use of these products, such as component technologies, power supply load efficiency and user interface in particular power management practices. Furthermore, it also touches on aspects that are important for material and resource efficiency such as repair, maintenance and replacement practices, and it gives an overview of what happens to these products at their end of life. Finally, this task also touches on standardised methods to quantify energy consumption in the different power modes, touching on the active mode, and it presents an overview of the energy consumption of products in scope based on manufacturers and ENERGY STAR database information.

Task 4 presents an analysis of current average technologies at product and component level, and it identifies the Best Available Technologies both at product and component level. An overview of the technical specifications as well as their overall energy consumption is provided when data is available. Finally, the chapter concludes with an overview of the product configurations in terms of components and key materials of current average and Best Available Technologies placed on the European market.

Simplified tasks 5 & 6 report presents the base cases, which will be later used to define the current and future impact of the current computer regulation if no action is taken. The report shows the base cases energy consumption at product category level and their life cycle costs. It also provides a high-level overview of the life cycle global warming potential of desktops and notebooks giving an idea of the contribution of each life cycle stage to the overall environmental impact. Finally, it presents some identified design options which will be used to define reviewed ecodesign requirements.

Task 7.1 report presents the policy options for an amended ecodesign regulation on computers and computer servers. The options have been developed based on the work throughout this review study, dialogue with stakeholders and with the European Commission. The report presents an overview of the barriers and opportunities for the reviewed energy efficiency policy options, and the rationale for the new material efficiency policy options. This report will be the basis to calculate the estimated energy and material savings potentials by implementing these policy options, in comparison to no action (i.e. Business as Usual – BAU).

The task reports follow the MEErP methodology, with some adaptations which suit the study goals

7. Introduction to task 7.1 report

Task 7.1 presents the ecodesign requirements, both for energy efficiency and for material efficiency. The potential inclusion of extending these requirements to an Energy Label has also been assessed. The framework of setting these requirements, including the different policy options, the timeline and the standardization activities required to implement these options are described. Furthermore, a short overview to the barriers and opportunities of the policy options is also presented.

This report only focuses on the first section of task 7 (7.1, policy analysis) according to MEErP. The scenario analyses will be carried out after the stakeholder meeting and will be included in this task report in a later version.

This task report includes the following:

1. Overview of the barriers and opportunities for the suggested policy measures, focusing on ecodesign energy requirements and energy labelling.
2. Definition of policy measures for energy requirements, including timing and target levels.
3. Definition of material efficiency requirements.

7.1 Overview of barriers and opportunities for energy efficiency policy measures

Technological change occurs quickly in computers. This has both advantages and disadvantages from an energy saving policy perspective.

On the positive side, ambitious energy efficiency targets can be met quickly as witnessed by the often-rapid growth in the number of computers that meet new ENERGY STAR specifications. The rate at which computers can meet new efficiency targets necessitates the revision of specifications at regular intervals, which can cause issues for policy makers.

Short product lifetimes necessitate both the need for improved durability and useful life, but also provide the opportunity to quickly change the level of energy efficiency at the in-stock level.

Additional complications can occur as unforeseen new types of products come to market, meaning that it is often unclear how these products fit into established energy efficiency initiatives. This is more problematic with mandatory measures, such as ecodesign, where products could be completely blocked from the market or the products would be out of scope resulting in the regulation no longer covers the majority of products being sold.

Despite potential barriers, it is clear that the current EU mandatory policy approaches dealing with the energy efficiency of computers are outdated. This is evidenced by the large delta between average computer energy use and allowances provided in current mandatory initiatives.

7.1.1 Barriers and opportunities for reviewing existing ecodesign energy requirements

The current EU Commission Regulation (EU) No 617/2013 on computers and computer servers is largely out of date due to improvements in the energy efficiency of computers on the EU market. Despite these improvements, further energy efficiency opportunities for computers, especially amongst non-mobile computers such as desktops, remain.

The requirements in the current ecodesign regulation on computers are based on the ENERGY STAR v5.1 specification, and associated test procedure, that was developed in 2008 [1]. Since that time another ENERGY STAR specification (v6.1), and associated test procedure, has been developed and implemented. The ENERGY STAR v6.1 specification includes requirements on important power modes (e.g. the separation of idle mode into short and long idle modes) that are not addressed in the current ecodesign regulation on computers. At the time of writing, a new ENERGY STAR specification (v7.0) is in the process of being developed after it became clear that the requirements in the ENERGY STAR v6.1 specification no longer reflect best environmental practice in terms of energy efficient computers.

In addition to changes within the ENERGY STAR specification, new mandatory regulations on computer energy efficiency have been developed in the USA. In December 2016, the Californian Government finalised a regulation on computer energy efficiency, based on the ENERGY STAR v6.1 test procedure, which sets relatively ambitious targets which are due to be enforced in two tiers[2]. The first tier of requirements will be implemented in 2019 and the second-tier requirements in 2021. Computers that are unable to meet the regulatory energy efficiency requirements in California may find their way into other markets such as the EU. A revised EU ecodesign regulation on computers would help to ensure that sales of inefficient computers into the EU market will not increase.

Ecodesign also offers the potential to address other inefficiencies in the way computers use electricity beyond the framework laid out under the ENERGY STAR test procedures. The active state power demand of computers has not been addressed by any major energy efficiency initiative despite the fact that significant savings are achievable. Active state test methodologies have been developed for similar products, such as computer servers. EU level projects are underway to identify how the active state power demands of servers can be accurately and effectively addressed within EU policy measures. This suggests that the active state energy efficiencies of computers could also be addressed within ecodesign.

The lack of a test procedure to measure active state energy efficiency in computers is a major stumbling block. In assessing the policy options for setting revised ecodesign requirements it is important to understand the basic steps undertaken in a requirement development process. Figure 1 illustrates these basic requirement development steps, and shows how the process can be extended due to a lack of suitable test procedures or measured product data in case the test procedures or product data are required for the policy options.

[1] US EPA, ENERGY STAR Computer Specification Archive, available from https://www.energystar.gov/index.cfm?c=archives.computer_spec_version_5_0

[2] Californian Energy Commission, Appliance Efficiency Rulemaking for Computers, Computer Monitors, and Signage Displays, available from https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=16-AAER-02

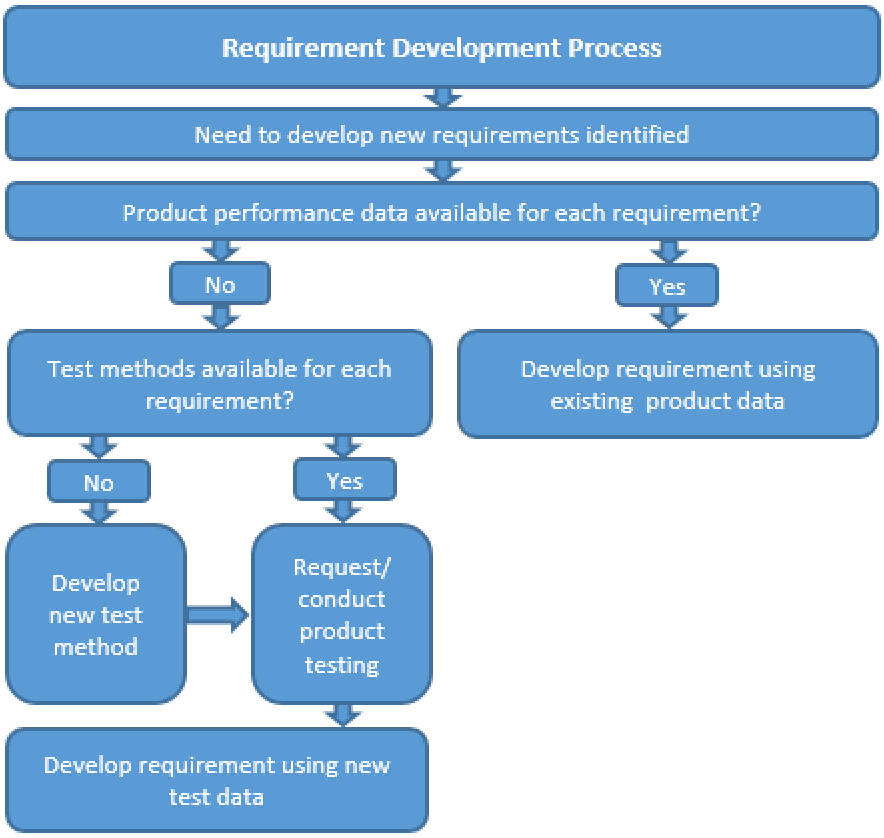

Figure 1. General requirement development process.

There is wide recognition that the active state of computers is an important consideration that should be addressed and steps are being undertaken to address this knowledge gap. However, there are likely to be delays in the development of an active state test procedure. Table 1 shows the expected duration for the development of a simple active state test procedure for computers. These values are based on an existing Canadian based initiative that is attempting to secure international support on the development of a simplistic active state test procedure which will cover a range of electronics products including computers. Even if there are no delays in the process it will still take between 17 (base project with no media streaming) and 24 (enhanced test including media streaming) months from the outset of the process to complete the test procedure. More complex active state test procedures that include consideration of performance would likely take longer. Given the complexities in developing active state test procedures for computers, and based on past projects which have failed to complete, it is likely that the process will take longer than estimated in Table 1.

Given these delays in developing a suitable test procedure, there is no potential to include active state efficiency requirements within a tier I ecodesign requirement without causing significant delays. However, there is a potential to use an ecodesign requirement to mandate reporting active state energy use whilst a suitable test procedure is being developed. Transitional methods can be published alongside new ecodesign regulations which provide a suggested interim test methodology ahead of a standardized test procedure being developed by one of the European Standardisation Organisations. Any information reported can then be used to inform the development of other policy measures.

Table 1. Example of a timeline for the development of a simple active state test procedure.

	Base Project	Remote Streaming
Task	Duration (months)	Duration (months)
Detailed Specification Dev	2.0	1.0
Execution Environment Dev	3.0	2.0
Content Definition	4.5	-
Validation Test Development	2.0	1.5
Alpha Testing	1.0	1.0
Beta 1 Updates and Testing	1.5	1.0
Beta 2 Updates and Testing	2.0	-
Public Release Updates and Testing	1	0.5
Total Time	**17**	**7.0**

7.1.2 Barriers and opportunities for combining reviewed ecodesign energy requirements with energy labelling

It is suggested that a revised ecodesign regulation could start to require mandatory reporting of computer active state energy efficiencies which could be used to inform the development of an EU Energy Label on computers. In turn, a tier II ecodesign requirement could be written which requires compliance to a defined class within a future EU Energy Label approach that includes active state energy efficiency requirements. This would allow two ecodesign tiers to be written at the same time, one that is based on established test procedures, and a second tier which also includes active state efficiency requirements, without having to revise the regulation. Figure 2 illustrates the basic process to implement this combination. A more detailed description of this option is presented in the next section.

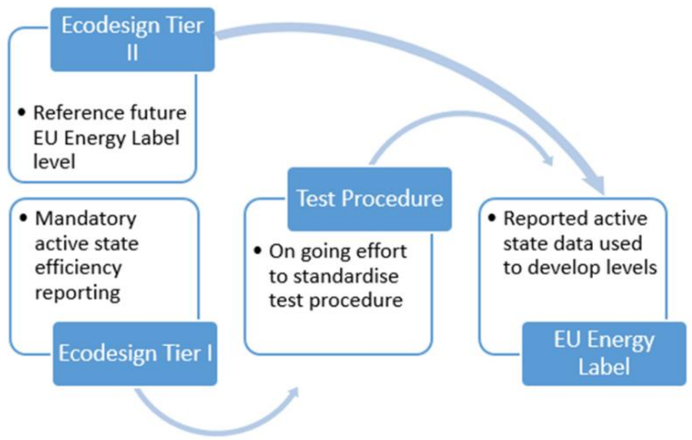

Figure 2. Combined policy measures (ecodesign & energy label) addressing energy efficiency of computers.

7.2 Definition of suggested energy efficiency policy measures

This section provides an overview of the suggested policy options on energy efficiency for computers in scope of the preparatory study. The suggested policy options are shown in Table 2 below.

Table 2. Suggested policy options addressing energy efficiency of computers.

Policy option	Description of policy option
Option 1 – BAU	No action ('Business-as-Usual', BAU)
Option 2 - Ecodesign	Reviewed **ecodesign requirements** for mobile and non-mobile personal computers: a. ETEC limits, incl. capability adjustments[3], for desktops, integrated desktops, desktop thin clients, notebooks, tablets/slates, portable all in ones, mobile thin clients and mobile workstations at product category level and based on ENERGY STAR v6.1. b. Low power mode requirements[4] for desktops, integrated desktops, desktop workstations, desktop thin clients, notebooks, tablets/slates, portable all in ones, mobile thin clients and mobile workstations based on ENERGY STAR v6.1. c. Power management requirements for desktops, integrated desktops, desktop workstations, desktop thin clients, notebooks, tablets/slates, portable all in ones, mobile thin clients and mobile workstations based on current EU Commission Regulation (EU) No 617/2013 and with new technology provisions. d. IPS efficiency requirements at 10%, 20%, 50%, 80% and 100% rated output for desktops, integrated desktops, desktop thin clients, desktop workstations, small scale servers, external graphic adapters and docking stations to be based on efficiency levels of 80Plus registered IPS.
Option 3 – Ecodesign and energy label	A **combination of ecodesign and energy labelling policy measures**: Reviewed **ecodesign requirements** for mobile and non-mobile personal computers: a to d – Same as option 2 e. Information requirements on reporting active state power demand for desktops, integrated desktops, notebooks, tablets/slates and portable all in ones. New **energy labelling requirements** for mobile and non-mobile personal computers, considering the same attributes as for ecodesign to develop energy classes as it follows, where g to j are the same as ecodesign option 2 but with varying levels according to the energy class.: f. ETEC limits g. Low power mode requirements h. Power management requirements i. IPS efficiency requirements j. A review clause will be written identifying that active state power demands will be included in a revised Energy Labelling Regulation on computers.
Option 4 – Ecodesign and energy label	A **combination of ecodesign and energy labelling policy measures**:

[3] As defined in the Commission Regulation (EU) 617/2013
[4] Low power mode requirements include off mode and sleep mode as defined in the Commission Regulation (EU) 617/2013, and will be based on current product performances seen in the ENERGY STAR database.

Policy option	Description of policy option
including active mode	Reviewed **ecodesign requirements** for mobile and non-mobile personal computers: **Tier I**: a. Option 3 (only ecodesign requirements). **Tier II:** a. Amending ecodesign requirements, for desktops, integrated desktops, notebooks, tablets/slates and portable all in ones where products shall comply with an energy label level (e.g. Class 'C') which includes active mode (see below). New **energy labelling requirements** for mobile and non-mobile personal computers: a. Energy labelling regulation based on ETEC ranges and active state power demand for desktops, integrated desktops, notebooks, tablets/slates and portable all in ones.

The suggested policy options presented here are to be evaluated according to the potential energy savings they represent in a subsequent scenario analysis[5]. According to this evaluation, revised ecodesign energy requirements are to be recommended as one of the main outcomes of this review study. The options are based on the information gathered in the present review study, and the specific wishes by the Commission.

Option 1 is Business as Usual (BAU) and it is a policy option since it is used to compare with the energy savings from the other options. Furthermore, the MEErP methodology calls this an option to give the possibility of no action as one of the political actions.

When defining the policy options above, an assessment was done of the existing policy measures and measurement methods that are needed to measure and report compliance when considering these options. When it is the case that no measurement methods exist for the suggested policy options, the study team has estimated the time it will take to have these in place considering current initiatives in the EU and elsewhere. Thus, the timeline for their development and their conjunction with the ecodesign requirements is also taken into account. A timeline has been drafted and it is shown in Table 3.

Table 3. Suggested timeline for implementation of suggested policy options. The letters (a-k) refer to Table 2.

Option 1	Option 2	Option 3	Option 4		
BAU	Ecodesign	Ecodesign & Energy label	Ecodesign & Energy label		
No action	a-d	Ecodesign: a-k Energy labelling: g-k	Ecodesign: Tier I (a)	Ecodesign: Tier II (a)	Energy label: a
2016	Aug-18	Aug-18	Aug-18	Aug-21	Jul-20

7.2.1 Potential ecodesign requirements on energy efficiency

This section lists the reviewed ecodesign requirements that could be included in option 2, option 3 and option 4 presented in Table 2.

[5] Following the MEErP methodology which is part of the contract of this review study

Established test procedures are available to support measurement of all measurable proposed reviewed ecodesign requirements, with the exception of the active state energy efficiency reporting. Most the requirements are based on the test procedure behind the ENERGY STAR v6.1 specification and so are well established in the market.

Table 4 shows the base requirements and additional allowances for key components. The overall level of ambition has been designed to closely match the level of ambition laid down in the Californian Regulation on computer energy efficiency. All coverage assessment levels are based on the performances of products registered to the US ENERGY STAR database in 2015 and 2016. Older products were removed from the coverage level assessments as it was deemed that most pre-2015 computers would no longer be available on the market.

The proposed requirements are ambitious but achievable in the time lines proposed. Many of the additional allowances have been copied directly from the recently published Californian Regulation. This process was adopted after the levels of ambitions were checked against sourced product data. Adopting some of the Californian allowances has the added advantage that they have already been recently heavily discussed with industry, government and NGO stakeholders.

The allowances have been developed to ensure that market surveillance authorities, and other interested parties, can relatively easily assess which allowances can be allocated to a product. That is, all data that is needed to identify which allowances can be applied to a product are commonly available in basic publicly available technical documentation.

Table 4. Potential reviewed ecodesign requirement levels.

<table>
<tr><th colspan="2">Product Type</th><th>Category</th><th>Base Allowance (kWh/year)</th></tr>
<tr><td colspan="2" rowspan="9">Desktop and Integrated Desktop Computer</td><td>0</td><td>40</td></tr>
<tr><td>I1</td><td>75</td></tr>
<tr><td>I2</td><td rowspan="7">85</td></tr>
<tr><td>I3</td></tr>
<tr><td>D1</td></tr>
<tr><td>D2</td></tr>
<tr><td>I3</td></tr>
<tr><td>D1</td></tr>
<tr><td>D2</td></tr>
<tr><td colspan="2" rowspan="6">Notebook [6]</td><td>0</td><td>10</td></tr>
<tr><td>I1</td><td>12</td></tr>
<tr><td>I2</td><td>15</td></tr>
<tr><td>I3</td><td rowspan="2">20</td></tr>
<tr><td>D1</td></tr>
<tr><td>D2</td><td>40</td></tr>
<tr><th colspan="2">Functional Adder Allowances</th><th colspan="2">Desktop, Integrated Desktop & Notebook</th></tr>
<tr><td colspan="2">Random Access Memory (RAM) (kWh/year)

Where "C" is the total amount of installed RAM in GB</td><td colspan="2">4 + 0.15 * C</td></tr>
<tr><td rowspan="3">Additional storage device allowance beyond the main storage device (kWh/year)</td><td>3.5" HDD</td><td colspan="2">16.5</td></tr>
<tr><td>2.5" HDD</td><td colspan="2">2.6</td></tr>
<tr><td>All other storage devices</td><td colspan="2">0.5</td></tr>
<tr><th colspan="2">Additional Functional Adder Allowances</th><th>Desktop, Integrated Desktop</th><th>Notebook</th></tr>
<tr><td colspan="2">First discrete graphics card (dGfx) (kWh/year)

Where “B” is the dGfx frame buffer bandwidth measured in GB/s</td><td>58.6*tanh(0.0038*B-0.137)+26.8</td><td>29.3*tanh(0.0038*B-0.137)+13.4</td></tr>
<tr><td colspan="2">Integrated Display allowance (kWh/year)

Where:
"A" is the display area measured in dm2
"EP" is an allowance of (0.65) for Enhanced Performance Displays with a colour gamut support of 38.4% of CIELUV or greater (99% or more of defined Adobe RGB colours)</td><td>8.76 * 0.35 * (1 + EP) * ((21 * tanh(0.02 + 0.06 * (A-15)) + 5.5) + 10)</td><td>8.76 * 0.3 * (1 + EP) * ((10 * tanh(0.02 + 0.075 * (A-11)) + 2.5) + 4.5)</td></tr>
</table>

Table 5 illustrates the percentage of products registered within the US ENERGY STAR database during 2015 and 2016 would meet the above set of proposed ecodesign requirements. Coverage rates are expected to be comparable to the coverage rates against the Californian Regulation on computer energy efficiency. It should be noted that

[6] The notebook product type entry also includes the additional mobile products "Tablet/Slate", "Mobile Thin Clients", "Portable-All-In-One" and "Mobile Workstations".

the Californian Regulation will have a significant impact on the number of products that can meet the requirements in Table 5.

Table 5. Computer types meeting the suggested ecodesign requirement levels (based on products registered in the US ENERGY STAR database).

		Categories						
Computer Type	Allowance/Compliance	0	I1	I2	I3	D1	D2	All
Desktop Computer	Base Allowance (kWh/year)	40	75	85	85	85	85	-
	Compliance Rate	50%	51%	56%	35%	43%	33%	43%
Integrated Desktop Computer	Base Allowance (kWh/year)	40	75	85	85	85	85	-
	Compliance Rate	43%	58%	68%	53%	50%	59%	58%
Notebook Computer	Base Allowance (kWh/year)	10	12	15	20	20	40	-
	Compliance Rate	60%	39%	52%	55%	100%	42%	46%

A revised approach to IPS efficiency is suggested in Table 6. Efficiency requirements are tied to the rated output of the IPS. This approach has been suggested because losses resulting from inefficiencies in higher rated output IPS are much larger than losses in lower output rated IPS. In addition, higher rated IPS tend to spend more time at low loading levels due to a larger delta between active and idle power demands. "Right sizing" of IPS (i.e. choosing an appropriately sized IPS) is a simple way to reduce energy losses in computers. Requiring higher levels of efficiencies in larger IPS encourages "right sizing" as there will be a small but noticeable price difference when purchasing a more efficient IPS.

Table 6. Potential ecodesign requirements for IPS.

<table>
<tr><td rowspan="14">Desktop computers, integrated desktop computers, notebook computers, workstations, small-scale servers, external graphics adapters and docking stations</td><td colspan="5">Tier I - Internal Power Supply Efficiency</td></tr>
<tr><td>Rated Power Output (W)</td><td>10% Load</td><td>20% Load</td><td>50% Load</td><td>100% Load</td></tr>
<tr><td><450W</td><td>80%</td><td>86%</td><td>88%</td><td>86%</td></tr>
<tr><td>450W ≤ to <600W</td><td>82%</td><td>87%</td><td>89%</td><td>87%</td></tr>
<tr><td>≥ 600W</td><td>84%</td><td>89%</td><td>90%</td><td>87%</td></tr>
<tr><td colspan="5">power factor = 0.9 at 100 % of rated output power. Internal power supplies with a maximum rated output power of less than 75 W are exempt from the power factor requirement.</td></tr>
<tr><td colspan="5">Tier II - Internal Power Supply Efficiency</td></tr>
<tr><td>Rated Power Output (W)</td><td>10% Load</td><td>20% Load</td><td>50% Load</td><td>100% Load</td></tr>
<tr><td><450W</td><td>82%</td><td>87%</td><td>90%</td><td>88%</td></tr>
<tr><td>450W ≤ to <600W</td><td>83%</td><td>88%</td><td>90%</td><td>88%</td></tr>
<tr><td>≥ 600W</td><td>86%</td><td>90%</td><td>91%</td><td>88%</td></tr>
<tr><td colspan="5">power factor = 0.9 at 100 % of rated output power. Internal power supplies with a maximum rated output power of less than 75 W are exempt from the power factor requirement.</td></tr>
</table>

Table 7 shows that there are sufficient numbers of IPS registered with the 80PLUS programme that meet the suggested efficiency levels. The coverage rates are based on IPS which were registered with the 80PLUS programme in 2016 and tested at the European voltage and frequency combination of 230v/50Hz.

Table 7. Compliance rate of IPS to the suggested ecodesign requirements (based on products registered with the 80PLUS programme).

	Tier I - Compliance Rate @				Tier II - Compliance Rate @			
Rated Output Power (W)	10%	20%	50%	100%	10%	20%	50%	100%
<450W	52.2%	47.8%	65.2%	60.9%	26.1%	30.4%	21.7%	47.8%
450W to <600W	41.7%	58.3%	41.7%	41.7%	33.3%	41.7%	41.7%	41.7%
≥ 600W	96.0%	84.0%	56.0%	40.0%	72.0%	68.0%	32.0%	32.0%

Table 8 details the power management requirements that could be included in reviewed ecodesign requirement on computers. The sentences in bold font are the additions and/or modifications to the existing requirements. Most of the proposed requirements are taken directly from the current EU computer regulation but some important changes have been made to reflect changes in products coming to the market in greater numbers. The requirements no longer dictate the use of sleep mode and recognise that technologies such as "Modern Standby" utilise other low power modes. The suggested requirements attempt to ensure that where alternatives to sleep mode are used they function correctly. This is an important consideration as sleep mode is included in products to save energy. Should an alternative approach not work as intended then savings would be lost.

Table 8. Potential reviewed ecodesign requirements for power management functionalities.

Power Management Enabling	
Desktop computers, integrated desktop computers, notebook computers, mobile workstation computers, portable-all-in-one computers and workstation computers.	Computers shall offer a power management function, or a similar function which, when the computer is not providing the main function or when other energy-using products are not dependent on its functions, automatically switches the computer into a power mode that has a lower power demand than sleep mode **or the alternative low power state used when determining measured TEC.**
	The computer shall reduce the speed of any active ≥1 Gigabit per second (Gb/s) Ethernet network links when transitioning to sleep or off-with-WOL mode.
	When in sleep mode, the response to 'wake events', such as those via network connections or user interface devices, should happen with a latency of ≤ 5 seconds from the initiation of a wake event to the system becoming fully usable including rendering of display.
	For products where an alternative low power mode condition, other than sleep, hibernate or off mode, is used when determining TEC, the response to 'wake events' from that alternative low power condition should happen with a latency of ≤ 1 second from the initiation of a wake event to the system becoming fully usable including rendering of display.
	The computer shall be placed on the market with the display sleep mode set to activate within 10 minutes of user inactivity.
	A computer with Ethernet capability shall have the ability to enable and disable a WOL function, if available, for sleep mode. A computer with Ethernet capability shall have the ability to enable and disable WOL for off mode if WOL from off mode is supported.
	Where a distinct sleep mode exists, the mode shall be set to activate within 30 minutes of user inactivity. This power management function shall be activated before placing the product on the market.

	Where an alternative low power mode, other than sleep, hibernate or off mode, is used, the mode shall be set to activate within 5 minutes of user inactivity. This power management function shall be activated before placing the product on the market.
	Users shall be able to easily activate and deactivate any wireless network connection(s) and users shall be given a clear indication with a symbol, light or equivalent, when wireless network connection(s) have been activated or deactivated.

A set of proposed reporting ecodesign requirements reviewing existing ones can be seen in Table 9. An attempt has been made to simplify some of the reporting requirements as it became clear that the current reporting requirements had caused some confusion.

Table 9. Potential reviewed ecodesign reporting requirements.

Reporting Requirements
Manufacturers shall provide in the technical documentation and make publicly available on free-access websites the following information:
Product type and category (one and only one category)
Manufacturer's name, registered trade name or registered trade mark, and the address at which they can be contacted
Product model number
Year product first placed on the market
Active state energy use under common operating conditions
Maximum power demand (Watts)
Short idle state power demand (Watts)
Long idle state power demand (Watts)
Sleep mode power demand (Watts)
Sleep mode with WOL enabled power demand (Watts) (where enabled)
Off mode power demand (Watts)
Off mode with WOL enabled power demand (Watts) (where enabled)
Identification of whether any internal dGfxs can be automatically disabled during product usage
Internal power supply efficiency at 5%, 10 %, 20 %, 50 % and 100 % of rated output power
Power factor of internal power supply efficiency at 100 % of rated output power
External power supply average active state and no load efficiency
The minimum number of loading cycles that the batteries can withstand (applies only to notebook computers)
Measurement methodology used to determine all measured attributes
Sequence of steps for achieving a stable condition with respect to power demand
Description of how sleep and/or off mode was selected or programmed
Sequence of events required to reach the mode where the equipment automatically changes to sleep and/or off mode
The duration of idle state condition before the computer automatically reaches sleep mode, or another condition which does not exceed the applicable power demand requirements for sleep mode
The length of time after a period of user inactivity in which the computer automatically reaches a power mode that has a lower power demand requirement than sleep mode
The length of time before the display sleep mode is set to activate after user inactivity
User information on the energy-saving potential of power management functionality
User information on how to enable the power management functionality
For products with an integrated display containing mercury, the total content of mercury as X,X mg
Test parameters for measurements: — test voltage in V and frequency in Hz, — total harmonic distortion of the electricity supply system, — information and documentation on the instrumentation, set-up and circuits used for electrical testing.

Reporting Requirements
If a product model is placed on the market in multiple configurations the required product information may be reported once per product category, for the highest power-demanding configuration available within that product category. A list of all model configurations that are represented by the model for which the information is reported shall be included in the information provided.

7.2.2 Potential EU energy label requirements

This section describes the potential approach for a new set of energy label requirements that could be included in option 3 presented in Table 2.

Table 10 illustrates a potential approach that does not address active state energy efficiency. This approach suggests that the requirements are based on the forthcoming ENERGY STAR v7.0 specification in order to both extend the life of the label and to take advantage of the comprehensive ENERGY STAR development process. When new ENERGY STAR specifications are first developed, they are designed so that only around the top 25% of the most efficient products on the market can meet the specification. The specifications are developed with the aid of a "dataset" which comprises product data from the ENERGY STAR database and additional relevant information provided by stakeholder. The additional information is especially necessary where a new ENERGY STAR specification aims to include new requirements for which reporting under ENERGY STAR has not been previously conducted. The ENERGY STAR specification is then typically implemented in about 9 months to 1 year after the specification has been developed. This gap between development and implementation provides industry with a chance to manufacture products that meet the ENERGY STAR requirements ahead of implementation. Whilst the numbers of products able to meet the ENERGY STAR specification increase rapidly, it is unlikely that significant numbers of products would be able to quickly match the top 10% or 5% most efficient products in the ENERGY STAR dataset.

Table 10. Potential approach for EU energy label requirements.

Desktop, Integrated Desktop & Notebook Computers		
EU Energy Label Level	Energy-in-Use Requirements (kWh/year)	Compliance Rate in the ENERGY STAR v7.0 Dataset
A	Energy requirements to reflect compliance rate at - >	5%
B		10%
C	Equivalent to ENERGY STAR v7.0 (on completion of specification development)	25%
D	Energy requirements to reflect compliance rate at - >	40%
E		55%
F		70%
G		85%

Table 11 illustrates the expected timing of the ENERGY STAR v7.0 specification. It is currently unclear whether significant changes will be made to the test procedure used under ENERGY STAR v6.1. It is therefore not possible to base requirements on ENERGY STAR v7.0 at this stage. If the ENERGY STAR v7.0 specification is finalised by the end of

June 2017 then there are unlikely to be significant delays in adjusting Tier I EU Ecodesign and first stage EU Energy label requirements as presented in Table 2 and Table 3.

Table 11. Expected timeline of the ENERGY STAR v7.0 specification.

Timeline for ENERGY STAR Version 7.0 Computer Specification Development:	
Q4 2016:	Launch and webinar, Draft 1 specification and webinar
Q1 2017:	Draft 2 specification and webinar, Draft 3 specification and webinar (if needed)
Q2 2017:	Final draft specification, Final specification
Q1 2018:	Version 7.0 effective

7.2.3 Potential approaches to policy option 4

As previously presented in the policy option 4 in Table 2, a tier II ecodesign requirement could be written in anticipation of a future EU Energy Label which addresses active mode energy efficiency. This would allow a revised ecodesign regulation to be published with two tiers without the need to conduct a new review process after just one tier.

The first stage in this process would be to include the active state energy reporting requirements as a tier I ecodesign requirement. This would require that manufacturers begin to experiment with measuring active state power demands under usage conditions.

At the same time, efforts would need to be made to develop a standardised active state test procedure. The European Commission could choose to investigate the potentials of following a similar course of action as they have undertaken when investigating the potential for SERT to support policy objectives on servers. If the Commission were not inclined to take direct action on the development of a computer active state test procedure, it would be necessary to rely on other interested parties to develop a suitable way forward on active state power demand.

7.3 Definition of material efficiency requirements

The material efficiency requirements are being developed by the Joint research Centre (JRC) in collaboration with TU Berlin. Following the same framework as for the suggested energy efficiency requirements, the material efficiency requirements are meant to be included as ecodesign requirements and/or as energy labelling requirements. Below, an overview of the suggested requirements is presented, which is based on the analysis from JRC[7].

7.3.1 Disassemblability of key components for personal computers

7.3.1.1 Rationale

Concerning mobile personal computers, displays, batteries, keyboards and hinges are the components most prone to fail or to be damaged. Furthermore, battery performance is one of the key features for consumers' choice[8], but degrades over time. Mass storage

[7] Analysis of material efficiency aspects of personal computers product group. JRC Technical Reports. 6th of December, 2016. DRAFT version, not publicly available at the time of writing this report.

[8] Dodd, N., Wolf, O., Graulich, K., Groß, R., Liu, R., Manhart, A., Prakash, S., 2014b. Development of European Ecolabel and Green Public Procurement Criteria for Personal and notebook computers, Technical Report Task 1, scope and definitions

and memory determine significantly the performance of both mobile and non-mobile personal computers, i.e. if used to capacity can limit the usability of the device and as such determine the use time of the device.

For end-users, the availability of professional repair options to fix day-to-day problems with the devices by reasonable costs is an important fact for a substantial prolongation of the use time[9]. However, the trend to build and sell more integrated devices such as subnotebooks or tablets, make an easy repair or upgrade more difficult. Although a repair might be feasible, the difficulty and the costs may lead a certain share of users to rather purchase a new device.

Overall, the ease of repair or upgrade becomes more and more important in order to prolong the operational life of the devices and to avoid environmental impacts due to the manufacturing of a new device and the disposal of electronic waste.

7.3.1.2 Proposal of requirements

The reversible disassembly of relevant components (such as batteries, internal power supply units, displays, mass storage systems, memory modules, keyboard, track-pad, network interface board and wireless LAN board) plays a key role to enhance repair and reuse of personal computers.

Requirements were therefore organised in three levels:

1. A first level to provide information about the sequence of disassembly, replacement and re-assembly operations needed for each relevant component of personal computers. This level is for end-users and professional repair operators.
2. A second level devoted to the ease of disassembly and replacement of batteries used in personal computers through a specific logo. The target for this level is the end-user.
3. A third more ambitious level focused on the ease of disassembly as a metric, to be defined according the number of disassembly steps that allows reversible and non-destructive disassembly of components of personal computers. The target for this level is repairers and recyclers.

The information mentioned in the first requirement concern exploded diagrams of the product showing the location of components, type and number of fastenings, tools required, diagnostics and testing hardware and software, safety requirements and risks. It has been recognised that repair and upgrade of components should not be limited only to manufacturer’s authorised service providers during the warranty period, but generally to professional repairers, in order reduce safety risks (e.g. due to improper repairs or incorrect components). End-users or non-professionals should be allowed to replace components, which are easy exchangeable. In case that only official repair services are available, this will limit competition and may not help to reduce repair costs[10]. Figure 3 shows the suggested requirement.

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[9] Ibid

[10] Dodd, N., Wolf, O., Graulich, K., Groß, R., Liu, R., Manhart, A., Prakash, S., 2014b. Development of European Ecolabel and Green Public Procurement Criteria for Personal and notebook computers, Technical Report Task 1, scope and definitions

Ease of repair and replacement of components of computers

From xx xx 20xx manufacturers shall ensure that the following components of computers (if present) can be disassembled, replaced and re-assembled:

i. For notebooks and desktop computers: batteries, internal power supply units, display, mass storage systems, memories, keyboard, trackkpad, network interface board, wireless LAN board;

ii. For tablets: batteries, display,

The ease of repair and replacement shall be ensured by documenting the sequence of disassembly, replacement and re-assembly operations needed for each of the components above (if present), including:

i. the exploded diagram of the product showing the location of the component(s);

ii. for each of these disassembly, replacement and re-assembly operations, documentation of the type and number of fastening technique(s) to be locked and unlocked and of the tool(s) required;

iii. information about diagnostics and testing hardware and software (if needed);

iv. information about the safety requirements and risks related to each disassembly, replacement and re-assembly operation.

Repair instructions shall be provided to professional repairers and made available in free-access website. Manufacturers shall also provide in the user's manual the contact details about servicing of the computer and authorised repairers.

Figure 3. Suggested first requirement for disassemblability of key components for personal computers.

Especially for tablets and ultrabooks, the upgrade of components such as the main memory or mass storage is currently technically limited due to the high integration and the small form factor of the device. An extension of the mass storage for example is in some devices feasible (e.g. through extra slots for SD cards), but not for all the models of computers. Technical possibilities and limits of replacement and upgrade have to be discussed with the stakeholders.

The documentation of the disassembly steps includes a description of each step to access the targeted components, including for each of these steps: type and number of fastening technique(s) to be unlocked, tool(s) required, part(s) required, warnings if delicate operations are involved (risk of damage), as well as diagrams or photos visualizing the disassembly steps. Such documentation should be publically available to professional repairers, and to users (for repair operations that they can safely perform).

The Open Manual Format (oManual) could be used to make the above mentioned information available. oManual is an open XML-based standard for semantic, multimedia-rich procedural manuals. It can be used to store and present e.g. service manuals, "how to" guides, assembly instruction and user manuals[11]. The oManual structure is suitable to describe/document steps (disassembly, dismantling) for specific products. It provides the necessary structure to describe the steps in words and pictures/videos. On-going

[11] IEEE 1874, 2013. IEEE Standard for Documentation Schema for Repair and Assembly of Electronic Devices. doi:10.1109/IEEESTD.2014.6712032

European standardisation work could elaborate on this standardised format and could help to specify more precisely the information to be provided within this proposed requirement.

More articulated requirements could focus on the limitation of the disassembly steps needed for certain repairs. A possible definition of disassembly "step" (or disassembly task) is "a basic disassembly action that cannot be further disaggregated"[12]. A simple definition is to say that one step finishes with the removal of a part or a change of a tool. The use of the "Maynard Operation Sequence Technique (MOST)" is a more elaborated way to define a step. MOST is based on fundamental activities called standard sequences, which are a set of basic motions which include horizontal actions over a distance, physical move in the vertical direction, action of gaining control, action of placement and action of loosening. A "step" can then be defined as a sequence of certain activities[13]. Vanegas et al. (2016)[14] for example identified six basic tasks (sequence of basic motions) for the disassembly of an household appliance (computer display): tool change, identifying connectors, manipulation of the product, positioning, disconnection, and removing. For each task they defined a sequence of activities. For repair activities, the reverse tasks to assemble the product also need to be defined. The application of the MOST would require the definition on how to describe/list each (dis)assembly step in a consistent and comprehensive way, for example by using a standardised structure (including the above mentioned oManual).

Battery performance represents one of the key features for consumers' choice[15]. However, it degrades over time, and replacements may be necessary to re-establish the initial performance of the whole product. The ease of access and replace the battery of a personal computer becomes therefore relevant, especially when this operation has to be done by end-users or by professional repair operators. This piece of information can be driven to end-users before the moment of the purchase, through specific logos. Figure 4 shows the suggested requirement for a potential logo for of batteries for mobile personal computers.

[12] Vanegas, P., Peeters, J., Cattrysse, D., Duflou, J., Tecchio, P., Mathieux, F., Ardente, F., 2016. Study for a method to assess the ease of disassembly of electrical and electronic equipment. Method development and application to a flat panel display case study
[13] Ibid
[14] Ibid
[15] Dodd, N., Wolf, O., Graulich, K., Groß, R., Liu, R., Manhart, A., Prakash, S., 2014b. Development of European Ecolabel and Green Public Procurement Criteria for Personal and notebook computers, Technical Report Task 1, scope and definitions

Labelling of the ease of replacing of the batteries in portable computers

From xx xx 20xx manufacturers shall label portable computers that uses one or more battery packs according to the following labels.

i. Label 1: identifies that the batteries of the portable computer can be manually disassembled and replaced by the user, without the need of tools. Instructions on how to disassemble and replace the battery is provided in the user manual;
ii. Label 2: identifies that the batteries of the portable computer can be disassembled and replaced by the user, with the use of tools. Instructions on how to disassemble and replace the battery is provided in the user manual;
iii. Label 3: identifies that the batteries of the portable computer cannot be disassembled and replaced by the user but it requires assistance. The user manual shall mention "The battery contained in this product cannot be replaced by the end-user, but by professionals". Instructions on how to contact the customer service is provided in the user manual.

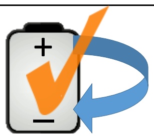
Figure 4. Suggested second requirement for disassemblability of key components for personal computers (labelling of the ease of replacing batteries).

The disassembly operations in Label 2 should be performed using manual or power-driven standard tools. The list of the tools to be considered can be drawn from Annex B of Recchioni et al. (2016)[16].

Assistance is required for disassembly operations of Label 3, because of the complexity of the disassembly, or because of the use of glues and adhesives, or because the disassembly operation may damage the product or compromise the safety of the end-user.

Possible symbols to identify Label 1, Label 2, and Label 3 are represented in Table 12. These proposals can be used to start standardisation discussions and activities to develop vertical standards for the product group, to define symbols and definitions. A specific test for user understanding of alternative options may be envisaged.

Table 12. Possible symbols and explanations to indicate replacing of batteries options.

Symbol	Meaning
	Label 1 Battery can be disassembled and replaced by the user without the need of tools. Instructions provided in the user manual
	Label 2 Battery can be disassembled and replaced by the user with the use of tools (e.g. screwdrivers). Instructions provided in the user manual

[16] Recchioni, M., Ardente, F., Mathieux, F., 2016. Environmental Footprint and Material efficiency support for product policy. Feasibility study for a standardised method to measure the time taken to extract certain parts from Electrical and Electronic Equipment. European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability, Ispra. doi:10.2788/29866

Symbol	Meaning
	Label 3 Battery replacement requires assistance. The user manual shall mention "The battery contained in this product cannot be replaced by the end-user, but by professionals ". The user manual shall contain details and information about the customer service to be contacted.

As proposed in the third requirement, in the future more ambitious requirements could be suggested. An example of this is shown in the next paragraph where quantitative parameters for disassembly are either Boolean (e.g. 'Are only reversible and non-destructive processes to open the device?' (yes/no) or integer values (e.g. number of steps X to remove the battery).

Advanced proposal on the ease of disassembly of components in personal computers

"From xx xx 20xx manufacturers shall ensure that following components of the computer can be accessed, replaced and re-assembled (if present): batteries, internal power supply units, displays, mass storage systems, memories, keyboard, track-pad, network interface board, wireless LAN board. This shall be ensured by allowing the reversible and non-destructive disassembly of the components in a minimum number "X" of disassembly steps".

Whereas reversible and non-destructive in this context means, that a) the sequence of disassembly steps can be reversed to assemble the product, b) the parts to be (dis)assembled do not break in case of professional handling and c) the device is fully functioning after the assembly. Further standardisation work might be necessary to define unambiguously what "disassembly steps" and "reversible and non-destructive disassembly " are. Moreover, further research would be needed to define the target value for the requested number of steps "X".

Standards under the development of European mandate M/543 for material efficiency aspects of energy related products[17] could serve the purpose, as those related to the development of method to assess the ability to access or remove components from products to facilitate the repair, remanufacture or reuse.

7.3.2 Dismantability of key components for notebooks and tablets/slates

7.3.2.1 Rationale

Waste notebooks and tablets, after depollution with the extraction of the battery, can follow two main processing routes: a first one based on the full mechanical crushing (shredding) and sorting of the waste; and the other including some additional pre-treatments (medium-depth manual disassembly) and subsequent shredding and mechanical sorting.

[17] European Commission, 2015. COM(2015) 614 final. Communication from the Commission to the European Parliament, the Councli, The European Economic and Social Commitee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy

Article 15 of the WEEE Directive (2012/19/EU) also calls for "Member States to take necessary measures to ensure that producers provide information free of charge about preparation for re-use and treatment in respect of each type of new EEE placed for the first time on the Union market within one year after the equipment is placed on the market". Relevant information about EEE placed on the market is crucial for WEEE treatment operators. Indeed, the rapid evolution in product design, the miniaturisation of EEE, components and materials used for their manufacturing some of which are critical make their repair and recycling increasingly challenging. However, according to association of reuse and recycling industries this article remained so far largely not implemented nor enforced.

These considerations have been also confirmed by interviewed recyclers, which reiterated that, for the safe and efficient recycling of computers, products should be designed so that the access and dismantling of the batteries and other valuable components (PCBs - including motherboard, memory RAM, CPUs, graphic cards, displays, and storage systems) is facilitated. In particular, there is the risk that certain components of computers (e.g. batteries and displays) difficult to be extracted would be shredded together with other waste, with the consequent dispersion of pollutants and contamination of other recyclable fractions[18], the risk of explosions in the shredders[19][20], and the irreversible loss of valuable resources [21]. The improper battery treatments can be associated with risks in terms of worker and facility safety, including accidental fires in the WEEE treatment plants.

For the safe and efficient recycling, information on disassembly process and location of battery and other valuable components is essential. Information could concern:

- general information on the product (including the month and year when the products were placed on the market);
- content of dangerous components/substances used (as a minimum the ones mentioned in Annex VII of the WEEE Directive, see section 3.1): provision of a short description and photo, and the place where these are usually found in the appliance;
- dismantling instructions: these could include exploded diagrams of the computer model, indicating the opening mechanism and required tools; in case of clips, this should include information related to the direction the housing should be opened;
- how to recognize special models and specific dismantling instructions for them;
- advice on collection (separate/mixed) and on logistics.

Additional relevant information could include also:

- extra information on materials that are recyclable if certain technology is used (e.g.
- poly-methyl methacrylate (PMMA) plates from displays to be dismantled manually),

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[18] DEFRA, 2006. Battery Waste Management Life Cycle Assessment, Department for Environment, Food and Rural affairs (DEFRA)
[19] Hand, C., 2013. Dealing with waste lithium batteries | Croner-i [WWW Document]. URL https://app.croneri.co.uk/feature-articles/dealing-waste-lithium-batteries-0 (accessed 9.13.16)
[20] Powel, J., 2002. Large volumes of electronics scrap are shredded before recycling, and this booming trend has many new twists and turns
[21] Van Eygen, E., De Meester, S., Tran, H.P., Dewulf, J., 2016. Resource savings by urban mining: The case of desktop and laptop computers in Belgium. Resour. Conserv. Recycl. 107, 53–64. doi:10.1016/j.resconrec.2015.10.032

- information on batteries which cannot be removed without (advanced) tools,
- (providing then information on what tools should be used and where to find them),
- description of the component/substance and its different types, as for example substances not dangerous),
- personal protection equipment needed for handling,
- risks for workers when the waste is not properly dismantled,
- advice on possibilities to sort the components or substances (when different treatment is possible for different types)
- advice on available treatment techniques

Apart from all this information (to be provided e.g. via digital platforms), recyclers stressed the importance of labelling, provided that the information fulfils the following conditions: it is uniform; it is adopted early and by all; and it is visible and easily recognisable (big logos or letters, colours. The labelling should be applied to:

- provide information on hazardous components and substances,
- give instructions for logistics and/or treatment

It is also recognised that up to one third of total WEEE produced in the EU, including computers, are not correctly disposed and treatments[22]. In particular, there is a risk that the small dimensions of IT equipment would facilitate the incorrect sorting by users into the waste bin. Economic incentives for a proper waste collection and treatment are crucial, as for example, establishing deposit/refund systems for computers, in order to incentivize users for a proper disposal of the waste and improve resources recovery[23][24].

7.3.2.2 Proposal of requirements

Computers should be designed so that components that crucial for material efficiency aspects can be easily located, extracted and addressed to specific recycling treatments. Measures to ease the dissassembly have been proposed and analysed for various EEE[25][26][27][28].

Figure 5 illustrates a proposal of requirements for the ease of dismantling of key components in notebooks and tablets.

It is highlighted that the design for dismantling requirements are not proposed for desktop computers (without integrated displays), since evidences collected so far indicate that the design of these products is generally not posing dismantling problems during

[22] Huisman, J., Botezatu, I., Herreras, L., Liddane, M., Hintsa, J., Luda di Cortemiglia, V., Leroy, P., Vermeersch, E., Mohanty, S., van den Brink, S., Ghenciu, B., Dimitrova, D., Nash, E., Shryane, T., Wieting, M., Kehoe, J., Baldé, C.P., Magalini, F., Zanasi, A., Ruini, F., Bonzio, A., 2015. Countering WEEE Illegal Trade Summary Report, Market Assessment, Legal Analysis, Crime Analysis and Recommendations Roadmap, Unu. Lyon, France. doi:978-92-808-4560-0

[23] Ibid

[24] Zhong, H., Schiller, S., 2011. Design of the expense allocation mechanism in e-waste recycling deposit system under EPR framework, in: ICSSSM11. IEEE, pp. 1–6. doi:10.1109/ICSSSM.2011.5959352

[25] Ardente, F., Mathieux, F., European_Commission, Sustainability, J.R.C.I. for E. and, 2012. Application of project's methods to three product groups. doi:10.2788/75910

[26] Ardente, F., Mathieux, F., Talens Peirò, L., 2013. Environmental Footprint and Material Efficiency Support for Product Policy - Report on benefits and impacts/costs of options for different potential material efficiency requirements for Electronic displays. doi:10.2788/28569

[27] Talens Peiró, L., Ardente, F., 2015. Environmental Footprint and Material Efficiency Support for product policy - Analysis of material efficiency requirements of enterprise servers. doi:10.2788/409022

[28] Talens Peiró, L., Ardente, F., Mathieux, F., 2016. Analysis of material efficiency aspects of Energy related Product for the development of EU Ecolabel criteria - Analysis of product groups: personal computers and electronic displays. doi:10.2788/642541

their recycling. The design of new models of desktops (e.g. 'mini-desktop') could pose some problems in the future, since their compact structure make their design more similar to that of game consoles[29]. However, these computer models did not reach their EoL yet, and therefore their EoL behaviours can be only estimated thought analogies with other similar product groups (as game consoles or notebook). However, based on very limited information available from a manufacturer, mini-desktop computers without batteries are not supposed to cause high difficulties for their recycling. Mini-desktops with batteries should be, instead, properly labelled (to highlight the presence of the battery), and should be regulated by a design for disassembly requirement similar to that of notebook and tablets.

Design for dismantling, recycling and recovery of personal computers.

1. Design for dismantling

From xx xx 20xx manufacturers shall ensure that welding or glueing (other than through the use of adhesive tape for batteries) are not used as joining or sealing techniques for the following components (if present):

- batteries;
- PCB assemblies larger than 0.1 dm^2;
- LCDs panels larger than 1 dm^2;
- any mercury containing component;
- capacitors containing electrolyte or polychlorinated biphenyls; and in addition,
- PMMA boards, storage systems (Solid state drives - SSDs – and Hard disk drives –HDDs) and optical disk drives (ODDs).

Accessing components shall be ensured by documenting the sequence of dismantling operations needed to access the targeted components, including for each of these operations, the type and number of fastening technique(s) to be unlocked, and tool(s) required.

2. Provision of information

Manufacturers shall provide recyclers with information relevant for dismantling, recycling and/or recovery at end-of-life including at least the following:

(a) a diagram of the product showing the location of the components above indicated, when present;

(b) instructions on the sequence of operations needed to remove these components, including type and number of fastening techniques to be unlocked and tool(s) required;

(c) if the product contains cadmium, lead, arsenic, mercury or their compounds: the indication of the specific substance(s), the location of all component(s) containing each, its quantity (as X,X mg), and the advised recycling techniques, if any, to be applied.

This information shall be available in a website.

[29] In the case of game consoles, industries proposed a "Self-Regulatory Initiative", addressing also some EoL aspects issues (Sony, Microsoft, Nintendo, 2015). This documents states that "to improve both recycling and reuse at end-of-life, maintenance and refurbishment is possible by non-destructive disassembly" and "To improve recycling at end-of-life, console plastics parts >25g are marked indicating their material composition (using ISO conforming marks)".

Figure 5. Suggested requirements for the ease of dismantling key components in notebooks and tablets/slates.

Concerning desktop computers with integrated displays, their EoL treatments are affected by problems similar to those of electronic displays and, therefore, should be characterised by similar requirements. Finally, desktop computers with integrated displays could be specifically labelled in order to allow recycling operators to identify them as computers already at the early stages of the recycling process. Some components, such as frames for tablets containing magnesium, although shown as relevant for dismantling in the analysis of recycling practices, have excluded from the list of targeted components above. This is due to the fact that frames could take various form and shapes and that the requirement could hence be difficult to be verified. It is however argued that ensuring an easier dismantling of the abovementioned components should also enhance a facilitated dismantling of frames.

According to a European recycler association, information relevant for dismantling should be make accessible to recyclers and market surveillance authorities, ideally trough dedicated digital platforms, as for paper documentation there is the risk that it is static and becomes outdated when not revised in time.

A standardised format for the documentation to support the verification of the requirement will have to be defined. For example the format published by the Austrian ministry of environment can represent a first example. Moreover, this standardised format should be based on the horizontal standardisation work under the European Mandate M/543 on material efficiency aspects of energy related products[30], which requires "documentation and/or marking regarding information relating to material efficiency of the product taking into account the intended audience (consumers, professionals or market surveillance authorities)" to be developed.

Additional work is also necessary to unambiguously define what is a high adhesion two side adhesive tape.

On the other hand, more ambitious and quantitative requirements could be prescribed in the future on the design for dismantling of the products (based, for example, on the development of metrics to assess the ease of dismantling[31]). Again, standardisation work under the mandate M/543[32] could serve the purpose, as those related to the development of method to assess the ability to access or remove certain components or assemblies from products to facilitate their extraction at the EoL for ease of treatment and recycling.

[30] European Commission, 2015. COM(2015) 614 final. Communication from the Commission to the European Parliament, the Councli, The European Economic and Social Commitee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy.

[31] For examples of metric to assess the ease of disassembly, see: Vanegas P., Peeters J.R., Cattrysse D., Duflou J.R., Tecchio P., Mathieux F., Ardente F., 2016. Study for a method to assess the ease of disassembly of electrical and electronic equipment - Method development and application in a flat panel display case study. EUR 27921 EN. doi:10.2788/130925 (Available: https://ec.europa.eu/jrc/en/publication/study-method-assess-ease-disassembly-electrical-and-electronic-equipment-method-development-and?search)

[32] European Commission, 2015. COM(2015) 614 final. Communication from the Commission to the European Parliament, the Councli, The European Economic and Social Commitee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy.

7.3.3 Labelling of batteries

7.3.3.1 Rationale

The rechargeable Li-ion battery market is growing rapidly, accelerated through the demand increase for portable electronics, such as tablet PCs and notebooks. After collection, batteries at the EoL mostly appear as mixtures and are subject to manual sorting according to their chemistries. The identification of the chemistry type is based on the label placed on the battery packaging/casing. In practice, however, when the batteries reach the recycling facility, the labels are sometimes is missing, making identification and sorting difficult. In order to release manual labor force, raise the sorting speed as well as accuracy, better labelling with improved readability is required in order to realize efficient identification and sorting.

According to interviews with German battery recyclers, batteries marking by, for example, the Battery Recycle Mark[33] will facilitate the separation of mixed batteries and therefore increase the recycling rates of Li-ion batteries. Furthermore, interviews revealed that cobalt content in Li-ion batteries varies between 0% and 15% based on the battery sub-chemistry. A more detailed marking indicating the sub-chemistry system will be beneficial for more precise sorting and dedicated batch-wise treatment.

7.3.3.2 Proposal of requirements

Figure 6 shows proposed requirements for the labelling of Li-ion batteries based on the rationale presented above.

Labelling of Li-ion batteries

From XX.XX.20XX battery packs and cells (including those incorporated into battery packs) shall be labelled with the “Battery Recycle Mark“.

The label shall be visible, durable, legible and indelible.

For lithium-ion batteries, a two-digit code shall be added to indicate the content of specific metals as well as substances hindering recycling.

Figure 6. Proposal of requirement for labelling of Li-ion batteries.

Although the “Battery Recycle Mark” represents an excellent basis for this labelling requirement, additional standardization activities could probably be initiated to adapt it to the EU legislation.

To improve automated battery sorting solutions, future requirements should go beyond the proposed color-coded “Battery Recycling Mark”. One solution suggested by a large German battery recycling company is to add a QR (Quick Response) code to both battery cell and pack. The QR code could provide more precise information related to the battery subtype, concentration of cobalt and other rare earths elements as well as a link to material safety sheets. Access to the information shall be limited only to dedicated treatment operators part of the official compliance schemes to mitigate concerns over innovations in battery technologies. Example of additional information to be provided through a QR code are illustrated in Figure 7. Moreover, this documentation could contain

[33] http://www.baj.or.jp/e/recycle/recycle04.html

additional information on substances that are valuable for recovery, as the content of cobalt or other valuable substances in the batteries.

QR code for Li-ion batteries

From xx xx 20xx Li-ion battery packs and cells (including those incorporated into battery packs) shall be labelled with a QR code. The code shall be visible, durable, legible and indelible.

The following information shall be accessible via the QR code

(i) main battery chemistry systems

(ii) sub-chemistry system

(iii) link to material safety data sheet

Figure 7. Proposed Quick Response (QR) code for Li-ion batteries.

7.3.4 Marking of plastic parts

7.3.4.1 Rationale

Although in theory plastics are all perfectly recyclable, in practice the recyclability of plastics is generally very low. "Products consisting mainly of plastic have a very low recyclability rate in practice and it is all the lower when different plastics are combined in the same product". Moreover, the European Commission in 2013 observed that only a small fraction of plastic waste is at present recycled. Appropriate measures to enhance the recycling of plastics could also improve competitiveness and create new economic activities and jobs.

Plastic recycling poses various problems as:

- The lack of process capable of performing plastic sorting and separation;
- Plastic can be recycled roughly a limited number of times; then the plastic is worn out and of a poor quality.
- Complexity of the plastic mix, which makes difficult to separate plastics from each other and generally expensive to recycle.
- Plastics can contain several additives which degrade the virgin plastic;
- Plastic can be reinforced or mixed with metals and other non-plastics, which degrade the plastic when recycled.
- Most plastics type are only present in relatively small flow amounts, which makes difficult to achieve the required economies of scale for advanced recycling operations.

Density sorting of plastic (via sink-float techniques) is currently the easiest and still most adopted sorting systems for shredded plastics. Different plastics are separated according to their different density thanks to water or air separators. Some advanced processes for the separation of plastics are currently under development (e.g. Near Infra-Red analysis (NIR) spectroscopy, X-Ray Fluorescence (XRF) spectroscopy, Visible light optical separation), although their efficiency of separation and their applicability to the sorting of shredded plastics are still under investigation. Sorting of different plastics is also performed based on manual disassembly. This technique can be technically and economically viable for high-quality technical plastics used in EEE, including computers. The efficiency of manual sorting of plastics is, however, dependant on the properness of plastic marking, values of recyclates and labour cost. Marking of plastic should follow standardised approach, as that proposed by ISO 11469, and standards of the series ISO 1043.

7.3.4.2 Proposal of requirements

Examples of requirements on plastic marking have been included in the proposal for implementing measures for electronic display, and could be similarly proposed for computers, in order to improve the manual separation of valuable plastic parts and, in particular, for parts heavier than 50g. Also, association of WEEE recyclers suggested that the proper marking of plastics (and their additives, especially flame retardants) would be beneficial for recycling companies.

The proposed requirement is illustrated in Figure 8.

Marking of plastic parts in computers.

Plastic parts heavier than 100 g,

1. Shall be marked by specifying the type of plastic using standardised symbols. The marking shall be legible.

Plastic parts in the following circumstances are exempted from marking requirements:

i. the marking is not possible because of the shape or size;

ii. the marking would impact on the performance or functionality of the plastic part;

iii. marking is technically not possible because of the molding method.

For the following plastic parts no marking is required:

(1) packaging, tape and stretch wraps;

(2) labels, wiring and cables;

(3) PCB assemblies, PMMAs, optical components, electrostatic discharge components, electromagnetic interference components.

2. If flame retardants are present, they shall be marked, using standardised symbols, as following:

>x-FR-y<

where:

x= plastic polymer

FR = flame retardant

y= type of the flame retardant coding

For exempted plastic parts, the market surveillance authority shall check that a justification is provided by the manufacturers in the end-of-life documentation.

Figure 8. Proposed requirements for marking of plastics of personal computers in scope.

7.3.5 Declaration of flame retardants

7.3.5.1 Rationale

Recycling of plastics can pose various problems during the recycling, especially due to the content of additives as flame retardants (FRs). FRs are chemical additives added into plastics to avoid potential internally and externally initiated ignitions.

FR are used for EEE and, in particular, computers. For example, the analysis of the bill of material of notebooks revealed the presence of two large plastic parts (mass around 50g) in polycarbonate with halogen-free phosphorous compound (code FR 40, according to ISO 1043-4).

However, FRs can reduce the recyclability of plastic parts. The presence of additives can reduce the mechanical properties of the materials, requiring additional treatments and additives to compensate for the degradation of such properties, as well as reduce the value of the materials in the market, and consequently the economic feasibility of recycling. On such purpose, the IEC/TR 62635 (2015) suggests in the Annexes that a 0% recycling rate should be considered for polymers with FRs that are not properly separated from the other materials before the shredding.

Moreover, some FRs as certain brominated flame retardants (BFR) have high toxicity and for this reason they have been regulated, for instance by the directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic products (RoHS). This Directive established that Member States shall ensure that new electrical and electronic equipment put on the market does not contain substances as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE). In addition, the directive 2012/19/EU on waste electrical and electronic equipment (WEEE) states in Annex VII that plastic containing BFR have to be removed from any separately collected WEEE.

Product’s requirements could be developed to facilitate the identification of components containing FRs and their composition.

7.3.5.2 Proposal of requirements

Requirements on the provision of information regarding the content of FRs in plastic parts (i.e. heavier than 25 g) could contribute to the separation of these plastics during the dismantling, allowing their recycling at high rates.

In particular, it is relevant to provide detailed information about products in a more systematized way, allowing also to monitor the use of certain FRs in the computer and allowing recyclers to develop processes and technologies suitable for the plastic recycling. This information could be provided by the manufacturers, based on the declaration of specific indexes on plastics as e.g. the “Flame retardant in plastic parts” index. This index aims at:

- detailing plastic parts that contains flame retardants (including mass and type of plastic parts; mass and type of flame retardants)
- calculating the percentage of plastic parts in the product that do not contain flame retardants
- promoting products that use less quantities of flame retardants

A proposal of requirement for the use of the "Flame retardant in plastic parts" index for computer is illustrated in Figure 9.

Provision of information on plastic parts in personal computers containing flame retardants.

If plastic parts (other than PCB assemblies and cables) containing flame retardants are used, manufacturers shall provide in a website documentation in the format of the following table.

Table I - 'Flame retardant in plastic parts' index.
(All masses shall be expressed in grams)

Brand name and Product family:			
Part reference	**Polymer***	**Flame retardant****	**Mass (g)**
Reference *(1)*	…	…	…
Reference *(2)*	…	…	…
…	…	…	…
Reference *(j)*	…	…	…
A) Overall mass of plastic parts*** incorporated in the computer that contain flame retardants ***(g)***			…
B) Overall mass of plastic parts*** incorporated in the computer ***(g)***			…
C) Total mass of the computer ***(g)***			…
			Index (%)
Ratio of plastic containing flame retardants to the total mass of plastic (A / B)			…
Ratio of plastic containing flame retardants to the total mass of computer (A / C)			…

* standard abbreviated term for the polymer(s)
** standard code number of the flame retardant(s)
*** PCB assemblies and cables are excluded

Figure 9. Information requirements on flame retardants in personal computers in scope.

7.3.6 Information on the content of Critical Raw Materials (CRM)

7.3.6.1 Rationale

Within the "Raw Materials Initiative", the European Commission identified a list of CRM that are crucial for the EU economy[34]. The criticality associated with these materials are in many cases compounded by low substitutability and low recycling rates. Therefore, boosting resource efficiency and increasing the recyclability of these materials has been identified as one pillar to reduce the risks associated to their supply.

Several CRM are contained in computers as cobalt in the batteries, neodymium and rare earths in the HDD magnets, indium in the displays, magnesium in some metal frames, and various CRM (including palladium, rare earth elements, antimony, beryllium, cobalt, gallium, chromium, silicon) in the PCBs.

[34] The list of CRM is provided in: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0297&from=EN

The knowledge of computer's components containing CRM (with details on the composition) would facilitate their identification by operators during the end-of-life (EoL) processing. Together with requirements on the design to ease the dismantling, this type of labelling of CRM could increase the efficiency in the sorting of relevant components, addressing them to the proper treatments and, ultimately, increase their recycling rates[35].

A detailed analysis of all the CRM used in computers is very difficult since the large number of CRM that are present in several components. This analysis focuses on two main CRM that have been identified as relevant during previous reports.

Currently computer HDD represent the main realistic source for recyclable neodymium (Nd)[36]. Compared to the total neodymium magnets (NdFeB)[37] production capacity, the recovery potential from HDDs is in the 1−3% range[38]. NdFeB magnets should be treated not far from the waste collection and treatment points, since shipping and handling large volumes of NdFeB magnets can be difficult, because of their very high magnetic strength[39].

The separation of HDD and NdFeB magnets can occur after waste shredding or manual disassembly[40]. However, recycling through shredding results in a very significant (>90%) loss of NdFeB (mainly lost in the ferrous fraction); after shredding, the neodymium must be leached out of the material and then be reprocessed in almost the same manner that virgin material is processed[41]. Neodymium liberated through shredding also contaminates other recyclable fractions[42].

On the other hand, manually dismantling of HDD proved to be much more efficient and with lower environmental impacts. Experimental measurement of the efficiency of manual extraction of HDD from waste computers under current processes resulted around 35%[43]. This percentage could be further increased thanks to an improved design of the product for the dismantling of the HDD or provision of information on the content and location of Neodymium. Neodymium from magnets can be then further recycled through hydrogen decrepitation process[44] or by raising the temperature of the material above its Curie temperature (312 °C) in order to lose its magnetics properties[45]. The efficiency of the Neodymium recycling can reach the 90%[46]. Recycling of Neodymium

[35] Ardente, F., Mathieux, F., 2014. Identification and assessment of product's measures to improve resource efficiency: the case-study of an Energy using Product. J. Clean. Prod. 83, 126–141. doi:10.1016/j.jclepro.2014.07.058
[36] Sprecher, B., Kleijn, R., Kramer, G.J., 2014a. Recycling Potential of Neodymium: The Case of Computer Hard Disk Drives. Environ. Sci. Technol. 48, 9506–9513. doi:10.1021/es501572z
[37] http://e-magnetsuk.com/neodymium_magnets/
[38] Ibid
[39] Ibid
[40] Ibid
[41] Ibid
[42] Ibid
[43] Ibid
[44] Zakotnik, M., Devlin, E., Harris, I.R., Williams, A.J., 2006. Hydrogen Decrepitation and Recycling of NdFeB-type Sintered Magnets. J. Iron Steel Res. Int. 13, 289–295. doi:10.1016/S1006-706X(08)60197-1
[45] Dupont, D., Binnemans, K., 2015. Recycling of rare earths from NdFeB magnets using a combined leaching/extraction system based on the acidity and thermomorphism of the ionic liquid [Hbet][Tf2N]. Green Chem. 17, 2150–2163. doi:10.1039/C5GC00155B
[46] Sprecher, B., Kleijn, R., Kramer, G.J., 2014a. Recycling Potential of Neodymium: The Case of Computer Hard Disk Drives. Environ. Sci. Technol. 48, 9506–9513. doi:10.1021/es501572z

from HDD magnets proved also to have significant lower environmental impacts (from 60% to 90% lower) compared to primary production[47].

7.3.6.2 Proposal of requirements

Some examples of requirements concerning the content of CRMs have been developed for other product groups. For example, measures to improve the recycling of Neodymiun and other rare earths from magnets have included the declaration of the content of rare earths (as e.g. the proposal for ecodesign requirements for fans[48]), the provision of instructions for the dismantling (as e.g. the requirement for the dismantling of magnets in ventilation units[49]), or the potential labelling/marking of the components (e.g. the proposal for a QR code on rare earth content developed by NSF (2015) for the environmental labelling enterprise servers[50]).

Relevant information on CRM in computers could regard the content of cobalt in batteries, or the content and location of components containing rare earths (e.g. neodymium, dysprosium, praseodymium in magnets), and also the content of other relevant materials (especially those in PCBs). This information could be provided in the documentation needed to support the requirement on the design for dismantling of valuable components. Alternatively, specific label (as QR codes) could also be developed in the future to detail the content of CRM and placed directly to the components or, alternatively, in the computer back-cover.

However, it is recognized that, to be effective and easily verifiable, the provision of information on the presence of CRM into computers requires a standardised format for such communication, including for example, dedicated labelling. Standards under the development within the European mandate M/543[51] could serve the purpose, as those related to the "use and recyclability of Critical Raw Materials to the EU" and the development of "documentation and/or marking regarding information relating to material efficiency of the product".

7.3.7 Battery durability for notebooks and tablets/slates

7.3.7.1 Rationale

Lithium-ion batteries inevitably lose a fraction of their full charge capacity with every charge/discharge cycle they go through. It has been shown that the capacity of some batteries fades quicker than others[52]. To guarantee a minimum of durability and hence to

[47] Sprecher, B., Xiao, Y., Walton, A., Speight, J., Harris, R., Kleijn, R., Visser, G., Kramer, G.J., 2014b. Life Cycle Inventory of the Production of Rare Earths and the Subsequent Production of NdFeB Rare Earth Permanent Magnets. Environ. Sci. Technol. 48, 3951–3958. doi:10.1021/es404596q

[48] According to the preparatory study of ventilation fans, it is proposed that manufacturers declare the weight (if any) of the permanent magnets containing rare earths, in kg with 2 digits (e.g. 'Permanent Magnets 2.12 kg'), on the nameplate and in the technical document (VHK, 2015).

[49] "The manufacturer's free access website shall make available detailed instructions, inter alia, identifying the required tools for the manual disassembly of permanent magnet motors, […] for the purpose of efficient materials recycling […]" (EU, 2014).

[50] "The manufacturer shall indicate the type of actuator/voice coil and spindle magnets in the product's hard disk drive on the external enclosure of the hard disk drive by means of a QR code. The QR code shall link directly to the magnet type and location information on a publicly available database or the manufacturer's website in at least English. The QR code shall be printed in black on a white background if one or more of the magnets contain neodymium. The QR code shall include a non-machine readable chemical symbol (Nd)" (NSF, 2015).

[51] European Commission, 2015. COM(2015) 614 final. Communication from the Commission to the European Parliament, the Councli, The European Economic and Social Commitee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy.

[52] Clemm, C., Mählitz, P., Schlösser, A., Rotter, V.S., Lang, K.-D., 2016. Umweltwirkungen von wiederaufladbaren Lithium-Batterien für den Einsatz in mobilen Endgeräten der Informations- und Kommunikationstechnik (IKT)", UBA Texte 52/2016.

prevent premature waste generation, battery cycle tests may be used to determine the number of charging cycles a battery can withstand before its capacity fades to a certain threshold.

Current legislation requires manufacturers of notebooks to provide data on the expected cycle life of batteries in notebooks (Commission Regulation (EU) No 617/2013). In a non-exhaustive survey of the websites of notebook manufacturers it was found that only two manufacturers provided such information (Apple[53] and HP[54]), only one of which refers to specific notebook models. Further, without a set of complementing information regarding the methodology applied to determine the minimum number of charging cycles, the data cannot be considered meaningful. At least the following information is required to put the number of charging cycles provided by the manufacturer in context:

- The definition of a charging cycle
- The capacity threshold at which the battery is considered wasted
- The measurement methodology (e.g. a testing standard)

A charging cycle is often defined as discharging a devices battery to an equivalent of 100 % of the battery's capacity (possibly in several partial discharge events) and consequently recharging it to 100 % SoC (e.g. Apple). This definition does not state which battery capacity a 100 % discharge (or recharge) refers to – the initial shipped capacity (roughly equivalent to the nominal capacity as provided by the manufacturer) or the full charge capacity (FCC), the latter of which decreases over time with battery aging. This information is essential for comparability of projected life cycle of device batteries of different manufacturers.

Information on the methodology and capacity threshold would allow for transparency as well as a certain degree of comparability between the different cycle numbers manufacturers provide for their devices. Ideally, a standardized methodology would be stipulated to allow for greater transparency and comparability.

A common use pattern for notebooks is stationary use, in particular in office environments. Stationary use means non-mobile use, e.g. on a desk, and in grid operation, i.e. directly plugged into a power outlet or using a docking station. As the battery is constantly connected to the grid, the battery SoC is permanently close to 100 %. High SoC is known to accelerate the aging of Li-ion batteries. A study on the lifetime of notebook batteries in the field found that 50 % of the notebooks batteries in offices of companies or public administrations were cycled up to 30 times per year. Despite the low charging frequency, a large share of the batteries had lost significant portions of their initial capacity[55]. This is partly attributed to the high SoC during notebook use in grid operation as well as other factors, such as increased temperatures when working in grid operation and using a docking station in particular, among other factors.

Increased battery durability becomes increasingly important considering the current trend towards more integrated devices, leading manufacturers to integrate batteries within devices and abandoning the previously widespread slide-lock removal

[53] https://support.apple.com/en-us/HT201585
[54] http://support.hp.com/us-en/document/c00596784
[55] Clemm, C., Mählitz, P., Schlösser, A., Rotter, V.S., Lang, K.-D., 2016. Umweltwirkungen von wiederaufladbaren Lithium-Batterien für den Einsatz in mobilen Endgeräten der Informations- und Kommunikationstechnik (IKT)", UBA Texte 52/2016.

mechanisms. Integrated batteries potentially make it difficult for users to replace an EOL battery, hence battery durability is a more meaningful factor than ever.

In conclusion, the user should have the means to increase the durability of their device batteries by preventing a constantly high SoC when using their notebook in grid operation.

State of the art

It is technically feasible to limit the state of charge to which a notebooks battery is charged when plugged into a power outlet via software tools. Currently, one of the large notebook manufacturers ships its devices with such software pre-installed. One of the features of this software is the so-called 'battery conservation mode'. A software button (on / off switch) allows the user to enable and disable a battery conservation mode, in which the battery is charged up to a state of charge of 60 % only. Thus, high SoC is prevented while using the notebook in grid operation, potentially increasing battery durability at relatively low cost to the manufacturer.

When battery conservation mode is not enabled, the software tool will recommend to the user (via a pop up message) to enable battery conservation mode, if the device is used in grid operation (and thus 100 % SoC) for a predefined period (e.g. 2 hours). The user can switch off battery conservation mode and fully charge the battery if needed, e.g. before using the device in mobile, battery-powered mode. The disabling of battery conservation mode can further be triggered at a certain time as defined by the user (e.g. with a timer of when coupled to a calendar application). Battery conservation mode is further recommended when the device will not be used for a period of time, to decrease calendar aging of the battery.

7.3.7.2 Proposal of requirements

A minimum level of battery durability can be established when manufacturers are required to publish information about battery cycle life. In a durability test for batteries, two main parameters consist of the number of charge/discharge cycles and the remaining full charge capacity compared to the initial charge capacity (state of health). Consequently, the two possible ways to identify battery durability are:

- Declaring the number of charging cycles device batteries can withstand before the capacity fades to a set threshold, or,
- Declaring the state of health of the battery (the remaining full charge capacity compared to the initial charge capacity) after a predefined number of charging cycles.

The second option was chosen for the requirement (see Figure 10) on 'Provision on information on battery cycle life', as the first option would disadvantage products with higher durability, as more charging cycles are needed to reach the desired threshold. The availability of information on battery cycle life would help users to get an indication on how long the battery in a specific device may last. Moreover, such a requirement allows the comparability between products of different manufacturers, and potentially pushing the market towards higher quality of battery cells.

Provision of information on battery life

From XX.XX.20XX manufacturers shall test the battery in accordance with the most recent version of the standard EN 61960. Manufacturers shall communicate in the user's manual and on a free-access website the remaining full charge capacity of the battery compared to the initial charge capacity, after 500 charge/discharge cycles.

Figure 10. Proposed information requirements on battery life.

A remaining charge capacity of 80% of the initial charge is typically reached between 300-500 charge/discharge cycles, for consumer products. Taking into consideration this evidence and the technological progress (declarations of batteries that can be considered consumed after 1000 cycles are available[56]), it is reasonable to consider the upper limit, 500 cycles, as a predefined parameter for the requirement.

For manufacturers to comply with the current regulation, the "Guidelines accompanying Commission Regulation (EU) No 617/2013"[57] recommends industry actors use standard EN 61960[58], in order to facilitate a consistent approach. Battery manufacturers have a number of possible tests to evaluate battery cycle life following the standard EN 61960. The test on battery life can be applied either at the battery cell level or at battery pack level. Furthermore, non-accelerated or accelerated test procedures are available. Specifically, section 7.6.3. "Endurance in cycles at a rate of 0,5 It A (accelerated test procedure)" is pointed out in order to reduce the burden of the test requirements (as compared to the regular test procedure); however, with this approach, batteries are subject to overstressed conditions and capacity may fade quicker.

Tests conducted at the battery pack level are closer to reality, considering that notebook batteries are often composed of 4 or more cells. However, OEMs may use the same battery cells in different pack combinations, so testing a specific cell would give a good indication of how all packs incorporating that cell behave. It is therefore recommended to refer to the test for cells rather than for battery packs since single cell design may be used in multiple battery pack designs.

Using the accelerated test procedure, and assuming that battery charging takes 3.5 hours, the test procedure is estimated to result in the following time investments:

- Charging: 3.5 hours
- Idle time: 0.5 hours
- Discharge: 2 hours
- Time investment per cycle (sum): 6 hours
- Time investment for 500 cycles: 125 days

However, the non-accelerated testing procedure can more realistically reproduce use patterns of notebooks and tablet PCs, as the prescribed discharge rate of 0.2 C (discharge within 5 hours) is much closer to the power consumption of such devices compared to the discharge rate of 0.5 C in the accelerated testing procedure.

[56] https://support.apple.com/en-us/HT201585
[57] https://www.energimyndigheten.se/globalassets/energieffektivisering/produkter-med-krav/datorer-och-servrar/guidelines-617-2013-computers-and-servers--cf.pdf
[58] IEC 61960:2011 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications

Furthermore, private communications with manufacturers confirmed that non-accelerated testing procedures are commonly applied to batteries at the manufacturing plant.

Under the assumption that battery charging takes 3.5 hours, the test procedure is estimated to result in the following time investments:

- Charging: 3.5 hours
- Idle time: 0.5 hours
- Discharge: 5 hours
- Time investment per cycle (sum): 9 hours
- Time investment for 500 cycles: 188 days

It can be assumed that cell testing of cycle life takes place at the cell manufacturer rather than to be carried out by the device manufacturer. It can further be assumed that cell manufacturers test their cells before mass production, in part to provide specifications to their customers. Hence, it can be assumed, that certain testing data on cell cycle life and the applied methodology is already available to the cell manufacturer and the additional burdens of a legislative requirement in this context would be limited.

Alternatively to the declaration of remaining full charge capacity after 500 charge/discharge cycles, battery manufacturers may be asked to provide the number of cycles, until state of health drops to 80 %, following EN 61960. Usually battery life is identified with the number of cycles needed to reach 80 % of original capacity. Such a requirement can be then used for labelling purposes.

Future requirements could set a minimum number of charging cycles, measured according to standardised procedure(s), before the remaining charge capacity drops below a certain threshold (e.g. 60 % or 80 %).

Battery durability of notebooks could further be improved by implementing a pre-installed software tool on notebooks, which allows the user to limit the SoC of the battery to a defined value when the device is used stationary (i.e. in grid operation). The effectiveness of such a software tool can however only be guaranteed if the manufacturer takes action to inform the users of its existence and the benefits. See a potential requirement in Figure 11.

Extension of battery pack lifetime of notebook via software tools

From XX.XX.20XX manufacturers shall make available on a free-access website and pre-installed on the notebook a battery optimisation software for users to enable a limit on the state of charge (SoC) in grid operation.

i. Such a software shall enable the user to limit the state of charge of the battery to 70 % or less compared to the available full charge capacity.

ii. The option to enable and disable the cap on SoC shall be available in the notebook and it has to be accessible to the user.

iii. The manufacturer shall inform in the user's manual of the existence and the benefits of using such a software.

iv. An automatic message shall be implemented to remind the user to activate the limit on SoC if the notebook is used in grid operation at full charge for more than two hours.

Figure 11. Potential requirement of extension of battery pack lifetime via software tools.

7.3.8 Labelling of External Power Supply (EPS)

7.3.8.1 Rationale

The rationale for this requirement is to promote the reuse of EPS by means of:

- The adoption of common EPS, which should make the service life of an EPS independent from the product's useful life.
- The progressive decoupling of products and EPS, which intends to promote the re-use of EPS already available by the final users.

Resource savings can be achieved thanks to the reduced production and delivery of new EPS and the consequent reduction of electronic waste.

An opportunity in this context comes from the mobile-phone sector, and is presented by the recently signed Memorandum of Understanding between the European Commission and fourteen electronics manufacturers. The agreement implies the harmonization for all EPS for data enabled telephones and hence enables the reusability of the EPS. As reported by Cucchietti et al. (2011) [59], a common EPS would bring benefits to manufacturers, vendors and customers; the latter category, in particular, would be able to share just one charger for more than one device. Manufacturers and vendors would be able to ship and sell their devices without the charger in the package, with potential resource savings due to the reduced use of materials and impacts for transport and distribution (about 90% of EPS are manufactured in Asia[60] and the box containing a new mobile phone can be around 25% lighter when an EPS is not included.

Back to the personal computers product group, as little as 10 years ago, it was observed that efficient EPS are more and more smaller, lighter in weight, and more convenient to store and transport[61]. PCBs used in EPS were characterized as low-grade (<200 ppm gold), the classification used for low mass of valuable materials[62][63]. Nowadays, efficient EPS operate at cooler temperatures, contain fewer parts, and are likely to result in greater product reliability[64]; it is also possible to find on the market EPS for notebooks with a weight of 85 g, and an output power of 65 W[65]. Moreover, new EPS would not have large transformers or capacitors (EPS based on the switching-mode technology do not require such components), and would be characterized by smaller size and weight, thanks to the technological innovation and to more integrated and miniaturized components[66]. The PCBs of EPS could be potentially processed by dedicated recycling

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[59] Cucchietti, F., Giacomello, L., Griffa, G., Vaccarone, P., Tecchio, P., Bolla, R., Bruschi, R., D'Agostino, L., 2011. Environmental benefits of a Universal Mobile Charger and energy-aware survey on current products, in: 2011 IEEE 33rd International Telecommunications Energy Conference (INTELEC). Ieee, pp. 1–9. doi:10.1109/INTLEC.2011.6099888

[60] Risk & Policy Analysts Limited, 2014. Study on the Impact of the MoU on Harmonisation of Chargers for Mobile Telephones and to Assess Possible Future Options.

[61] Bio Intelligence Service, 2007. Preparatory Studies for Eco-design Requirements of EuPs.

[62] Dimitrova, G., 2012. Impact of innovations in electronic equipment and components on their reuse and recycling. University of Natural Resources and Life Sciences, Vienna.

[63] Goosey, M., Kellner, R., 2002. A Scoping Study End-of-Life Printed Circuit Boards 1–44.

[64] Bio Intelligence Service, 2007. Preparatory Studies for Eco-design Requirements of EuPs.

[65] FINsix®, 2016. DARTTM The World's Smallest Laptop Charger® [WWW Document]. URL https://finsix.com/shop/dart/ (accessed 9.12.16).

[66] Dimitrova, G., 2012. Impact of innovations in electronic equipment and components on their reuse and recycling. University of Natural Resources and Life Sciences, Vienna.

processes to optimize the recycling output, but due to the complex dismantling required and the small quantity of valuable materials, this becomes economically not viable[67].

With these preconditions, it seems reasonable to promote the reuse of EPS, in order to extend the lifetime of the device and therefore to enhance resource savings. According to the study[68], the harmonization of EPS for portable electronic devices would affect manufacturers in different ways:

- there would not be significant costs on manufacturers of portable electronic devices;
- significant impacts on competition, competitiveness, trade and investment flows are not expected;
- harmonization might slow down innovation, according to some stakeholders consulted by the authors;
- manufacturers of chargers and cables, could potentially benefit from the use of more expensive components, but also are likely to incur revenue losses due to increased decoupling.

7.3.8.2 Proposal of requirements

A requirement for the labelling of notebook packaging and tablet packaging is presented in this section. The provision of information regarding the EPS specifications and the presence/absence of the EPS in the packaging of notebooks and tablets could potentially enhance the re-use of available EPS, and hence result in a significant reduction of resource consumption for the production of unnecessary power supplies and for the treatment of electronic waste. Such a requirement could promote the use of common EPS across different devices. Resource savings can be potentially achieved thanks to reductions in production, packaging, transport and distribution. See the proposed requirements in Figure 12.

Labelling of information on power supply specifications in personal computer packaging

From xx xx 20xx manufacturers shall label the packaging of personal computers that use an external power supply with the required power supply specifications (voltage, current and rated output power).

The label shall indicate the presence or absence of the external power supply within the packaging.

i. In case of presence of the external power supply, the label shall notify the users about the possibility to use the contained external power supply with other devices, compatibly with the external power supply specifications. The label shall also notify the type of connector used as interface between the external power supply and the devices.

ii. In case of absence of the external power supply, the label shall notify the users about the possibility to use an alternative suitable external power supply, which meets the external power supply specifications. The label shall also notify the type of connector required to interface the external power supply with the device.

Figure 12. Proposed EPS labelling requirement on power supply specifications for personal computers' packaging.

[67] Sarkis, J., 2001. Greener manufacturing and operations. Greenleaf Publishing.
[68] Risk & Policy Analysts Limited, 2014. Study on the Impact of the MoU on Harmonisation of Chargers for Mobile Telephones and to Assess Possible Future Options.

7.3.9 Data deletion for desktop, notebook and tablet/slate computers storage media

7.3.9.1 Rationale

One major barrier to the reuse, repair and recycling of computers is data privacy issues. Desktop computers, notebooks and tablets regularly store sensitive and confidential data on users and organizations, including but not limited to documents, photos, videos, data on locations and contacts, on various storage media such as HDD, SSD, flash, SIM and memory cards. The major operating systems usually include an option to "factory reset" the device, bringing the device into its original factory state[69]. However, this does not necessarily guarantee that all personal data of the user are deleted comprehensively and permanently. Hence, it is believed that data privacy issue is one of the major factors that discourage users from making their obsolete but functional devices available to the reuse market or to appropriate recycling paths in case of dysfunctional devices. If reliable and comprehensive data deletion would be readily available to the user, the number of devices becoming available for the reuse market or appropriate recycling may increase considerably.

Besides comprehensive data deletion, it may be viable to encrypt user data and consequently permanently delete the key required for decryption as to ensure third parties cannot access user data thereafter. This means that the data is still physically present on the storage media, but permanently inaccessible.

It should be noted that depending on the effort invested, it cannot necessarily be fully guaranteed, that user data cannot be recovered with highly sophisticated technical tools. Hence, a requirement should aim at reasonably safe data deletion without taking into account data recovery methods, which require large amount of temporal and financial investments.

7.3.9.2 Proposal of requirements

A study on computer severs[70] compiled a list of available standards by country based on data from Hintermann and Fassnacht (2008)[71] and Fisher (2015)[72].

According to the U.S. department of defense's standard 5220.22-M for clearing and sanitization for different types of media, data clearing is defined as "a method of sanitization by applying logical techniques to sanitize data in all user-addressable storage locations for protection against simple non-invasive data recovery techniques using the same interface available to the user; typically applied through the standard read and write commands to the storage device, such as by rewriting with a new value or using a menu option to reset the device to the factory state (where rewriting is not supported)".

Hence, standards on data clearing are particularly relevant to enable the reuse of devices. While the user-addressable storage in desktop computers can oftentimes be disassembled with reasonable effort, storage solutions in more integrated devices, such as notebooks and tablets, are less easily accessed. This emphasizes the importance of

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[69] At the time of writing this feature is available in some form at least on Windows 10, macOS X, Android and iOS.

[70] Talens Peiró, L., Ardente, F., 2015. Environmental Footprint and Material Efficiency Support for product policy - Analysis of material efficiency requirements of enterprise servers. doi:10.2788/409022

[71] Hintermann, R., Fassnacht, C., 2008. Leitfaden zum Sicheren Datenlöschen.

[72] Fisher, T., 2015. Data Sanitization Methods. A List of Software Based Data Sanitization Methods

tools that allows the users to delete their data, without having to rely on third parties, before the devices are passed on for reuse or recycling.

The German environment label Blue Angel has a set of criteria for mobile phone (RAL GmbH, 2013). The requirements in terms of data deletion issues can be described as:

"To allow a second use of a mobile phone the device shall be designed so as to allow the user to completely and safely delete all personal data on his own without the help of pay software. This can be achieved by either physically removing the memory card or with the help of software provided by the manufacturer free of charge. When using a software, the deletion process shall at least include an overwrite of all the data stored with a random pattern, or, in case of Flash Storage with zero values."

See the proposed requirement in Figure 13.

Permanent deletion of personal data stored on personal computers

From xx xx 20xx manufacturers shall ensure that users can permanently delete their personal data contained in the storage systems.

i. Data deletion shall be ensured by means of a function/software, either provided by manufacturers on free-access websites, or pre-installed on personal computers;

ii. Such a function/software shall permanently delete all user data without compromising the functioning of the device for further use.

Figure 13. Proposed requirements for permanent deletion of personal data stored in desktop, notebook and tablet/slate computers.