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

# Computers and Computer Servers

*Task 7 report*

*Policy measures and scenario analyses*

*Final version*

July 2018

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, 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

**Specific contract no.: ENER/C3/2012-418 LOT1/11/FV 2015-543**
**Implements Framework Contract: ENER/C3/2012-418 LOT N° 1**

This study was ordered and paid for by the European Commission, Directorate-General for Energy.

# 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 |
| BAU | Business as Usual |
| BFR | Brominated Flame Retardants |
| 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 |
| EEE | Electrical and Electronic Equipment |
| EEI | Energy Efficiency Index |
| EERA | European Electronics Recyclers Association |
| 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 |
| ETEC | Annual total energy consumption |
| EU | European Union |
| FCC | Full Charge Capacity |
| FR | Flame Retardants |
| GHG | Greenhouse Gases |
| GPU | Graphics Processing Unit |
| HDD | Hard Disk Drives |
| ICT | Information and communications technology |
| iGfx | integrated Graphics processing unit |
| IPS | Internal power supply |
| JRC | Joint Research Centre |
| LAN | Local Area Network |
| LCD | Liquid Crystal Display |
| LED | Light Emitting Diode |
| Li-ion | Lithium-ion (battery) |
| MSA | Market Surveillance Authorities |

| | |
|---|---|
| NiCad | Nickel-Cadmium (battery) |
| NiMH | Nickel-Metal Hydride (battery) |
| NIR | Near Infrared Analysis |
| ODD | Optical Disk Drive |
| OEM | Original Equipment Manufacturer |
| OS | Operating System |
| PCB | Printed Circuit Board |
| PMMA | Polymethyl Methacrylate |
| PRO | Producer Responsibility Organisation |
| PSR | Panel Self-Refresh |
| PSU | Power Supply Unit |
| RAM | Random Access Memory |
| SME | Small and Medium-sized Enterprise |
| SoC | State of Charge (of a battery) |
| SoH | State of Health (of a battery) |
| SRAM | Static RAM |
| SSD | Solid State Drives |
| SSHD | Solid State Hybrid Drive |
| TEC | Typical Energy Consumption |
| VR | Virtual Reality |
| WEEE | Waste Electrical and Electronic Equipment |
| WoL | Wake on Lan |
| XRF | X-Ray Fluorescence |

# Introduction to the task reports

The draft final report has been split into seven tasks, following the structure of the MEErP methodology. Each task report has been uploaded individually in the project's website. These task reports present both the technical basis and present and assess recommendations for future ecodesign and 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 (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.

Task 2 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 is used on the assessment of life cycle consumer costs.

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 presents 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 presents standardised methods to quantify energy consumption in the different power modes, including active mode, and 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 key components and materials of current average and Best Available Technologies placed on the European market.

Simplified tasks 5 & 6 report presents the base cases, which are used to define the current and future impact of the current computer regulation if no action is taken (i.e. Business as Usual, BAU). The report shows the base cases energy consumption at product category level and their life cycle costs. It also provides a review 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 are used to define reviewed ecodesign requirements.

Task 7 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 resource efficiency policy options. This information is used to calculate the estimated energy and material savings potentials by implementing these policy options, in comparison to no action (i.e. BAU).

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

# 7. Task 7 report

## 7.1 Introduction to task 7 report

### 7.1.1 Overall outcomes of study

This is the concluding task report from the Preparatory study on the Review of Regulation 617/2013 (Lot 3) Computers and Computer Servers.

An overview of the outcomes required by Article 9 of the existing Regulation (EU) No 617/2013 is presented below:

- *Review in light of technological progress*, assessed throughout all seven task reports by looking at current and future technologies when proposing product categorisation (task 1), establishing market volumes and trends (task 2), identifying use patterns (task 3) and technologies (task 4), defining base cases and design options (tasks 5 and 6) and proposing ecodesign and energy labelling requirements (task 7).
- *Developments in the Energy Star programme*, assessed also throughout all task reports, in particular in tasks 1 (to consider for product categorisation and definitions), 3 (to establish use patterns), 5 (to define base cases) and 7 (to propose requirements). The developments include up to draft 2 of Version 7.0 specification.
- *Opportunities to tighten ecodesign requirements*, assessed and presented in task 7 and based on analyses in previous task reports, especially technologies (task 4), concluding requirements shall be tightened due to technological progress.
- *Significantly reduce or eliminate the energy allowances*, in particular for discrete graphics cards (dGfx), concluding that this was not possible at this point in time after an assessment of the possibilities to include a single performance metric. The results of this assessment are presented in task 7 report.
- *Update definitions and scope*, done in task 1 report and presented also in task 7 report.
- *Consider the potential to address energy consumption of integrated displays*, addressed by introducing an integrated display energy allowance to non-mobile personal computers.
- *Consider different life-cycle phases*, assessed in task 3 report (end-of-life practices), task 4 (use of materials for average technologies) and task 5 (review of LCA studies), complemented by a study performed by JRC[1] which altogether presented the basis to develop the proposed resource efficiency requirements.
- *Consider the feasibility and applying the Ecodesign requirements on other significant environmental aspects such as:*
    - *Noise*, assessed in task 3 where reported noise level requirements were collected from the manufacturers' environmental declarations of computers manufactured during the period 2012 – 2016 and compared with requirements in the Nordic Swan and the Blue Angel (considered to be relatively strict), showing that 96% of the computers fulfil the current Blue Angel noise requirements, and 81% fulfil the Nordic Swan noise

[1] Analysis of material efficiency aspects of personal computers product group. Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA. Tecchio et al. (2017). Draft version.

requirements; thus concluding there is no need to propose noise requirements.

  - *Material use efficiency, including requirements on:*
    - *Durability*, analysed and resulting in one proposed requirement on product durability and two on repairability and reusability (which indirectly influence product durability).
    - *Dismantlability*, analysed and resulting in one proposed information requirement on dismantlability.
    - *Recyclability*, analysed and resulting in three proposed requirements to increase recyclability.
    - *Standardised interfaces for rechargers*, analysed and resulting in one proposed information requirement on availability of external power supplies.
    - *Information requirements on the content of certain Critical Raw Materials*, assessed and concluded that this was not as crucial as the other requirements, thus excluded from the final proposals.
    - *Information requirements on minimum number of loading cycles and battery replacement issues*, analysed and resulting in one information requirement on battery lifetime which addresses full charge capacity and informs the end user about state of health of the battery for replacement.

Furthermore, the draft final report addresses additional aspects requested by the European Commission:

- *Assess the appropriateness of the scope of the Regulation and analyse options for including products currently not in scope (e.g. DC powered products) and for excluding part of requirements of the existing ones,* assessed in task 1 and throughout the study resulting in the product scope and categorisation presented in tasks 1 and 7. The product scope was reviewed by considering other products, but only those representing significant sales, stock and savings potential have been proposed as to be part of the scope of a future reviewed regulation. The product categorisation was reviewed with the aim of simplifying current product types and product categories and reducing ambiguities. This was assessed in task 1 report and the conclusions are presented in task 7 report.
- *Assess whether the levels of ambition for off, standby and networked standby modes are still appropriate,* assessed and requirements proposed to be made more stringent, presented in task 7 report.
- *Consider the introduction of standardised software tests, benchmarks or other ways to measure energy efficiency in realistic usage conditions and setting maximum energy use requirements as function of the processing performance,* assessed from eight personal computer benchmarks and attributes and resulting in two being tested in thirteen personal computers. Furthermore, possibilities of adapting an existing performance methodology for servers and of using a software currently under development by the Standards Council of Canada were considered. The results of the benchmark tests on personal computers are presented in task 3 report and a summary of the recommendations is presented in task 7 report. It was concluded that a standard methodology to measure performance in active mode could be included at the time of implementation of a

reviewed regulation, with the condition that such a methodology shall be developed.

- *Assess the appropriateness of current definitions and categories and the opportunity to dramatically simplify them*, assessed and concluded that a simplification beyond product categories was not feasible due to the wide range of product functionalities and configurations. This was presented in task 1 report and summarised in task 7 report.
- *Compare definitions and requirements with Energy Star, in light of enhanced convergence, reducing burden for industry but possibly replacing the EU Energy Star voluntary labelling programme with a mandatory Energy labelling regulation under Directive 2010/30/EU*, assessed through a comparison of definitions and requirements with Energy Star as mentioned previously. An Energy Labelling regulation has been proposed as one of the policy options, presented in task 7 report. This requires that a standard methodology to measure performance in active mode has been developed.

### 7.1.2 Outcomes and main conclusions from task 7

Task 7 report summarizes the outcomes from the review carried out in previous tasks, and the policy options covering energy efficiency and resource efficiency requirements.

The topics assessed and main conclusions are presented below:

1. Overview of the barriers and opportunities for the suggested policy measures, focusing on ecodesign energy requirements and energy labelling, which are summarized below:
   a. Due to fast development of computer technologies, product classification and ecodesign requirements can quickly become obsolete. This review has proposed revised product classifications based on current and future legislative and voluntary schemes. **The complexity on product classification would be avoided if a performance-based metric is developed as the product categories would be removed.**
   b. Idle mode energy consumption has been greatly optimized and it is no longer a sufficiently good proxy for the active mode. Therefore, the active mode energy consumption should directly be used in a metric, using the experience from enterprise server metrics and from other initiatives targeting active mode consumption in personal computers.
   c. The fast development would also affect an energy label. However, energy efficiency requirements can be defined assuming a future development of energy classes. A proposal of the energy classes up to 2030 is presented in the report, where A and B classes will start empty and would remain with no more than 30% in class A or no more than 50% in A and B classes up to 2030. An issue of testing for energy labelling considering the many different computer configurations can be solved by always using the worst/best performing configuration.
   d. An energy label for computers would provide consumers with useful information on energy and non-energy related parameters at the time of purchase and would help to follow product performance through registration in the product database as from Regulation 2017/1369.

2. Outcomes from assessment of methodologies to include performance in a metric for an energy efficiency requirement, concluding that:

a. Three benchmark tools (i.e. Novabench, Computer Efficiency Rating Tool (CERT)[2] and light active use power measurement[3]) have been assessed as viable solutions for including active mode in a reviewed computer regulation.
b. Novabench is already widely used on the market, however, it is a proprietary tool without control of an independent organization. However, a possibility could exist to develop a separate software specifically designed for the European Commission (not explored during this review study).
c. CERT seems promising due to its potential to deliver one single value efficiency figure – based on the experience of developing a similar metric for servers. If possible to develop this metric, it would bring coherence between the two product groups, facilitating implementation and enforcement of the regulation.
d. The light active use power measurement covers only power measurements and not performance, which is a crucial element when measuring efficiency of computers.

3. Definition of proposed scope for ecodesign and energy labelling requirements, which was defined both for energy and resource efficiency measures (with some exemptions concerning specific requirements). The main outcomes are summarized below:
   a. Assessment at an overall level, i.e. the two overarching product sub-groups of mobile and non-mobile personal computers were deemed sufficiently detailed for the application of the resource efficiency requirements.
   b. Concerning energy efficiency requirements, their applicability requires a classification at a product category level for one of the policy options investigated. In this case, the categories have been simplified based on current categorization presented in ENERGY STAR v6.1.
   c. Setting energy efficiency requirements is assessed not suitable for some types of higher performance computers at this stage, such as workstations (except IPS efficiency and information requirements).
   d. All personal computers having a short idle state power demand less than 6 W should be excluded from energy efficiency requirements.

4. Definition of policy measures for energy requirements, including timing and target levels, and their potential for energy savings, $CO^2$ emissions, monetary costs and impact on employment, which is summarized below:
   a. Three policy options (PO) were defined, including PO0 which is Business as Usual (BAU). PO1 is self-regulation, PO2 is reviewing ecodesign requirements and PO3 is reviewing ecodesign requirements and developing an energy label, both including active mode.
   b. The results of the scenario analysis show that overall computer energy use could increase about 10%, from an estimated 60.0 TWh/year in 2016 to 66.5 TWh/year by 2030 without policy intervention. The increase stems mostly from increasing sales.
   c. None of the stakeholders expressed interest in PO1 i.e. self-regulation, so far, nor is it likely that in today's global market the conditions for self-regulation, e.g. regarding minimum market coverage, will be met because the risk of 'free-riders' and thus unfair competition is too big. Consequently, self-regulation has not been considered as a policy option.

[2] Not yet developed, but inspired on Server Efficiency Rating Tool (SERT), which is already available. SERT is developed under on SPEC (Standard Performance Evaluation Corporation).
[3] Developed by the Standards Council of Canada (CSA)

d. Concerning PO2 (ecodesign), ETEC requirements for mobile and non-mobile computers at a product category level have been updated, including base allowances and functional adders. It has been estimated that approximately 11.3 TWh/year of energy can be saved by 2025 rising to 16.2 TWh/year by 2030, compared to a BaU scenario. This corresponds to 6.6 million tonnes of $CO_2$ emissions and 1.67 billion Euros savings by 2030. The net employment impact would be of 47,552 employed persons (i.e. additional jobs) during the years from 2018 to 2030.
e. Concerning PO3 (ecodesign and energy labelling), an Energy Efficiency Index (EEI) approach has been proposed both for energy label classes and for ecodesign (considering active mode and potentially as an energy/performance single score). A measured score would then be compared and an EEI value would be derived. It has been estimated that approximately 14.1 TWh/year of energy can be saved by 2025 rising to 29.9 TWh/year by 2030, compared to a no further action. This corresponds to 12.2 million tonnes of $CO_2$ emissions and 3.05 billion Euros savings by 2030. The net employment impact would be of 42,722 employed persons during the years from 2018 to 2030.

5. Definition of resource efficiency requirements, including the rationale for defining these requirements and an initial assessment of benefits quantifying material savings, which is summarized below:
   a. Thirteen potential requirements for mobile personal computers have been defined, and seven for non-mobile personal computers. Three requirements are related to product durability, one to product dismantlability, three to product recyclability, one is related to standardized rechargers and one to battery lifetime.
   b. A preliminary assessment of the benefits from implementing requirements on recyclability was done. Assumptions and different scenarios have been considered for estimating the amount of materials saved per year, ranging from 1000 to 20000 tonnes of materials saved per year by 2030.
   c. Benefits from requirements on product durability were not possible to assess as currently available information on their potential effect is not available. This is proposed to be investigated as part of future work (e.g. Impact Assessment)

## 7.2 Overview of barriers and opportunities for energy efficiency policy measures

### 7.2.1 Barriers and opportunities for reviewing existing ecodesign energy requirements

The task 2 and task 4 reports identified how technological change occurs quickly in computers. This fast change has both advantages and disadvantages from an energy saving policy perspective. On the positive side, ambitious energy efficiency targets can be met quickly as shown in task 4 and tasks 5-6 reports. On the negative side, this means that the requirements need to be regularly revised.

Additional complications can occur as unforeseen **new types of products come to market** (as shown in task 1 and task 2 reports), bringing difficulties to fit them into established energy efficiency initiatives. This is more problematic with mandatory measures like ecodesign, where **products could be completely excluded from entering the market or be out of scope** and with high sales.

Task 4 report clearly shows that the current EU ecodesign requirements on energy efficiency of computers are outdated. The data presented clearly show that **energy use of average computer models in the EU market is much lower than the energy consumption levels in the current regulation**.

The requirements in the current ecodesign regulation on computers are based on the ENERGY STAR v5.2 specification (incl. associated test procedure developed in 2008[4]). Since then, ENERGY STAR specification (v6.1) including test procedure, has been developed and implemented. This includes requirements on more power modes (e.g. the separation of idle mode into short and long idle modes currently not addressed in the ecodesign regulation). At the time of writing, ENERGY STAR specification v7.0 is under development since the requirements in ENERGY STAR v6.1 no longer reflect best energy efficiency practice[5].

In addition, based on the ENERGY STAR v6.1 test procedure, new mandatory regulations on computer energy efficiency have been developed by the California Energy Commission (details are available in the task 1 report) and finalized in December 2016. This sets relatively ambitious targets due to be enforced in two tiers[6] which will be implemented in 2019 and 2021 respectively. Computers unable to meet these requirements may find their way into other markets with less stringent regulation.

Concerns have been raised about the **difficulties identifying the right category** and the total ETEC[7] allowance for a certain product in the current ecodesign regulation. To overcome this complexity, software for classifying the computer to the correct category and showing the ETEC allowances could be developed by e.g. MSAs (Market Surveillance Authorities).

---

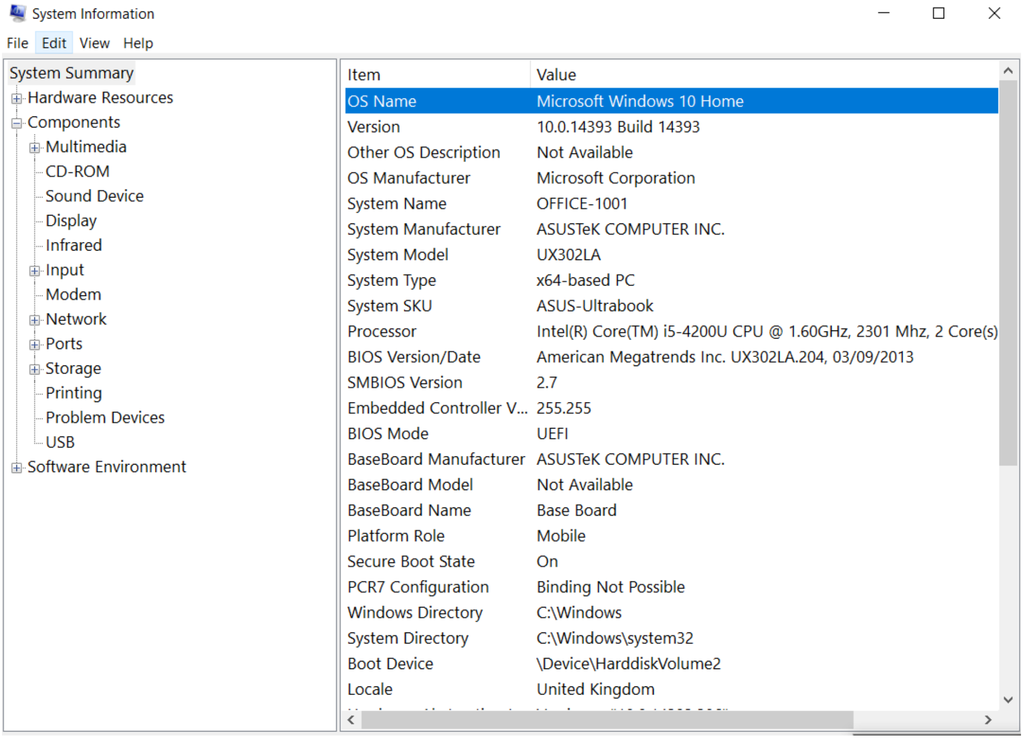
[4] US EPA, ENERGY STAR Computer Specification Archive, available from https://www.energystar.gov/index.cfm?c=archives.computer_spec_version_5_0

[5] ENERGY STAR specifications aim at setting requirements allowing about 25 % of the products on the market to qualify at the time of setting the requirements

[6] 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

[7] ETEC (annual total energy consumption) is the electricity consumed by a product over specified periods of time across defined power modes and states.

All the necessary configuration and hardware information to identify a computer’s category and ETEC allowance is readily available through built in OS features and available software tools. Figure 1 and Figure 2 show examples, for Windows and Mac, of outputs from these tools that collect and communicates information about the components within a computer. Similar possibilities exist for Linux and Chromebook.



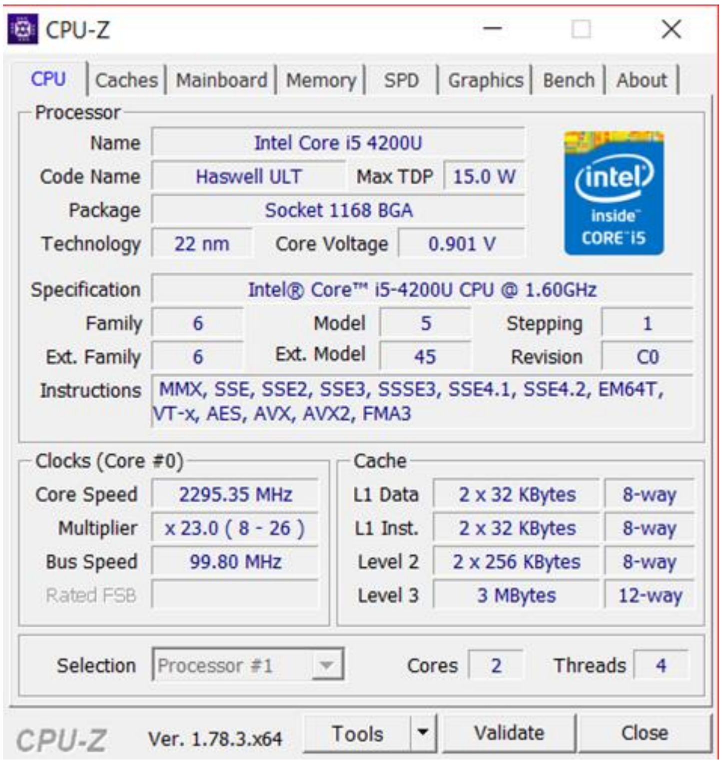




*Figure 1. Hardware reports for Windows based on built in System Information and downloadable software example, CPU-Z[8]).*

Figure 2 shows the output from pre-installed "System Information" applications (i.e. system profilers) in Apple MacOS.

[8] CPU-Z available from http://www.cpuid.com/softwares/cpu-z.html

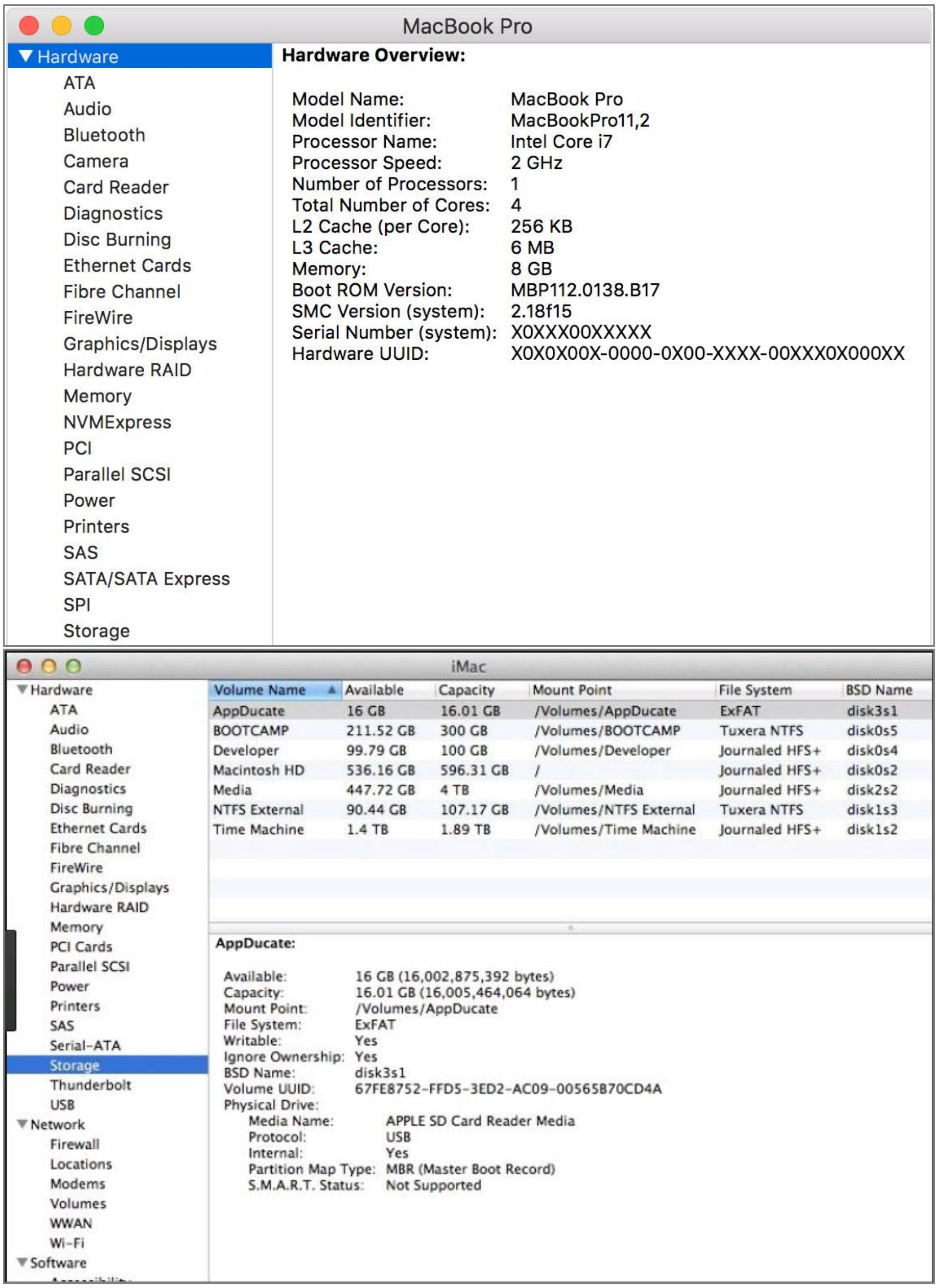



*Figure 2. Operating system software example: Hardware report (CPU detail) (Apple)[9].*

### 7.2.2 Barriers and opportunities for energy labelling

The EU Energy Label allows purchasers to distinguish products with the highest levels of energy efficiency from products that just meet the mandatory minimum ecodesign requirements.

Whilst the EU Energy Label generally provides an additional incentive for manufacturers to enhance the energy efficiency levels of products, there are some potential barriers to its adoption in the case of computers:

[9] https://support.apple.com/en-us/HT203001

1. The most important of these potential **barriers** stems from the fact that **computers can be highly configurable**. This means that small changes to the internal components of computers results in different configurations of the same computer model. Requiring the testing of each configuration of a computer would likely be overly burdensome for manufacturers due to the time and financial costs involved. The ENERGY STAR v6.1 specification addresses this issue by considering product configurations that represent the worst-case energy consumption for each product category within a product family (i.e. a single model with multiple configurations) as "representative models". Manufacturers can then test a single "representative model" to achieve ENERGY STAR compliance for all other suitable configurations within that product family.
    a. A possible EU Energy Label for computers could follow the ENERGY STAR approach in which allows the testing of the worst-case energy consuming configuration within a product family. This would result in all product configurations within a product family to receive the same EU Energy Label rating (i.e. A to G) as the worst performing configuration within that product family.
    b. An alternative approach for the EU Energy Label would be to require testing of the most efficient configuration within a product family. This would result in all configurations within the product family to receive the same EU Energy Label rating (i.e. A to G) as the most efficient configuration. Additional testing or approximations of energy use of different configurations may be required to improve the accuracy of the EU Energy Label classifications.
2. A potential **challenge** using the EU Energy Label for computers stems from the **fast-technological development in the product group**, which could result in a very quick shift to higher classes of efficiency. This challenge is common to other fast-developing electronic products (e.g. servers and storage units, complex settop boxes, networked equipment). However, a differentiation of energy efficiency in up to seven different classes, as done in the EU energy label, compensates for more dynamic programmes, such as the Energy Star label where a rescaling is done about every 3 years for the "single class". The differentiation in classes, moreover, provides more transparency to the customer.

The EU Energy Label also provides potential opportunities such as:

1. **An opportunity** that the energy label would provide to consumers consists of the additional information on potentially relevant selection criteria for purchase, such as on battery lifetime and other resource saving aspects such as the provision or absence of external power supplies.
2. Finally, from the perspective of the legislator, an **additional opportunity** of using the EU Energy Label is that data have to be reported by the suppliers in a **product** database before placing the product on the market. This would streamline future reviews of the requirements since relevant and reliable data are readily available from simple queries.

### 7.2.3 Barriers and opportunities for including active mode power demand in ecodesign and energy labelling

As discussed in the task 3 report, ecodesign and EU energy labelling also offer the potential to address inefficiencies in the way computers use electricity beyond the framework laid out under the ENERGY STAR test procedures i.e. by including the active mode. The most important opportunity for including active mode power demand in ecodesign and energy labelling is that it provides a much more realistic metric for the product efficiency compared to only including low power modes.

**The active mode power demand of computers has not been addressed by any energy efficiency initiative widely applied on the main worldwide market** despite the fact that significant savings are achievable.

Due to the development and penetration of mobile devices, the manufacturers (of chipsets, components and computers) have started developing power savings techniques for mainly mobile devices to reduce idle power demand which aims at extending the battery lifetime. This has resulted in reduced idle power demand and has created a situation where **the idle mode is no longer a sufficiently good proxy for active mode**. These power saving techniques have also come into the desktop computers.

The active power demand of a typical desktop computer can be an order of magnitude higher than idle mode power demand, particularly when performing compute intensive operations like gaming and video editing.

This situation is worsened by the computer industry adopting “modern standby”, which allows computers to reduce power to very low levels when idling. This makes the current test procedures which are based on a weighted average of low power modes including idle obsolete, because it means that real-use scenarios are not reflected. See further in task 3 report.

The lack of a standardized test procedure to measure active mode energy efficiency in personal computers is however a major obstacle. Opportunities for overcome this obstacle has been assessed by the study team – described in the following.

Figure 3 illustrates these basic requirement development steps in assessing the policy options for setting revised ecodesign requirements. The figure shows the process for the development of policy options in case there is a lack of suitable test procedures or product measurement data.

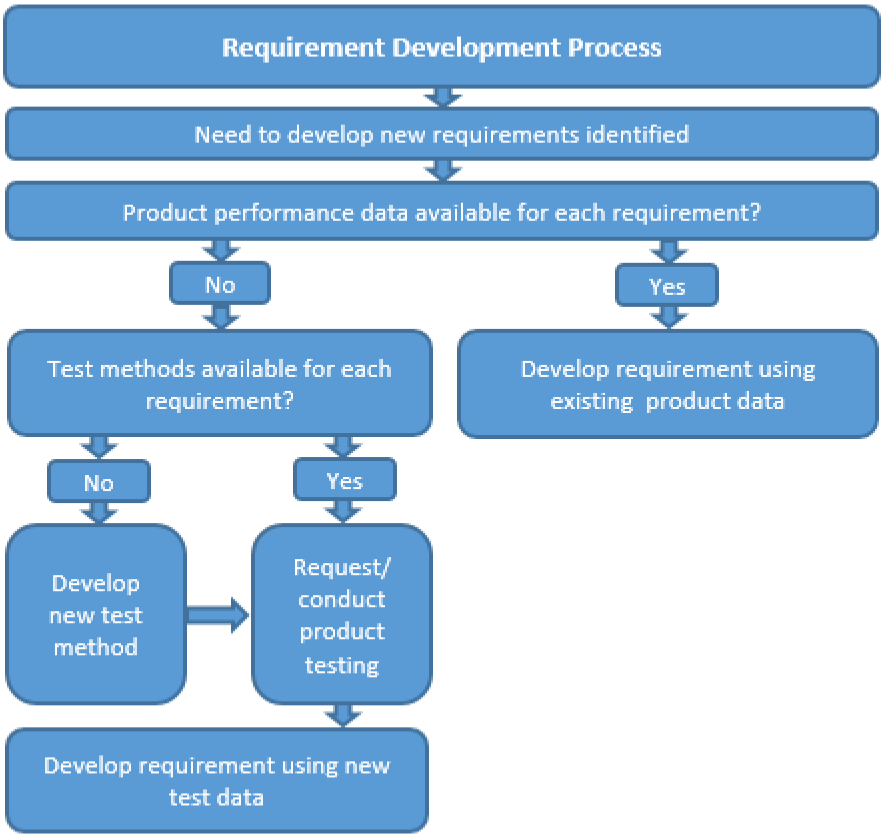



*Figure 3. General requirement development process with and without product available data.*

To start addressing this knowledge gap, the Standards Council of Canada has issued a mandate[10] for development of a standard for a test method and benchmark tool targeting energy consumption of computing appliances. The development of a simple active mode test procedure for computers was initially planned between 17[11] months and 24[12] months. This work has been initiated and it is targeted to be completed by mid-2018 though it is still not fully funded.

Based on this experience, it can be said that development work would be between 1.5-2 years, followed by a sufficiently high number of computers to be tested to provide data for setting the levels for ecodesign and energy label.

More complex active mode test procedures that include consideration of performance would likely take longer (e.g. ENERGY STAR v5.0 for computers using EEcoMark[13]).

A possible example to follow is an EU Technical Assistance Study carried out for the European Commission, which identified how the active mode power demands of servers can be accurately and effectively addressed within EU policy measures by developing a metric based on an existing test method with reported test results[14,15]. Similar work may be conducted to assess on-mode energy use of computers and possibly part of the methods could be used, duly adapted.

[10] https://www.scc.ca/en/standards/work-programs/csa/energy-performance-computing-appliances
[11] base project with no media streaming
[12] enhanced test including media streaming
[13] https://bapco.com/products/eecomark-v2/
[14] http://www.server-standards.eu/
[15] https://www.spec.org/sert/

The development of test procedures to measure performance including active mode would thus take a long time, so an early start for development is recommended alongside the review process to give sufficient time for inclusion in an amendment to the current ecodesign regulation as well in a potential energy label delegated regulation.

## 7.3 Outcomes from assessment of standardised test performance methodologies

A standardised test performance methodology for energy efficiency of personal computers does not currently exist. Existing methodologies on the market under development or used for servers have been reviewed by the study team in order to reveal if one of these could be used for a future regulation, which includes active mode.

There is no clear agreed definition of active mode with relevant stakeholders. Based on the review of different proposals from stakeholders and various sources, a proposed definition is presented below:

*'Active mode' is the state in which a computer is carrying out useful work in response to (a) prior or concurrent user input or (b) a prior or concurrent instruction over the network, (c) a prior schedule of operations to be automatically launched under given conditions. This state includes active processing, seeking or writing data from or to memory, cache and local or remote storage, including idle state time while awaiting further user input and before entering low power modes.*

Two currently available test performance methodologies used to benchmark personal computers performance (i.e. PCMark8[16] and Novabench[17]) were considered and tested.

However, since PCMark8 is both a proprietary tool and its results during performed tests gave similar correlations as those performed using Novabench (see more details in task 3 report), no further assessment using PCMark8 is carried out. On the contrary, Novabench is further assessed, since it fits all of the criteria below:

- Known and used by industry
- Include elements that reflect realistic usage conditions
- Can be used with Windows, macOS and Linux
- Available for a low price (49 USD for a commercial license)

Additionally, two other opportunities for future standardised test performance methodologies are briefly described and assessed:

- The Server Efficiency Rating Tool (SERT) benchmark used for the ENERGY STAR specification for computer servers v2.0[18], which may be a basis in terms of using the methodology and part of the benchmark components for developing a Computer Efficiency Rating Tool (CERT).
- An initiative under the Standards Council of Canada (CSA) for developing a benchmark tool targeting energy performance of computing appliances.

Additional details about the benchmark tools and testing results can be found in task 3 report.

### 7.3.1 Novabench

The active mode in personal computers' performance can be quantified by establishing the average of measured power demand of personal computers when performing certain tasks (excluding energy consumption in idle modes). These tasks are started up

[16] https://www.futuremark.com/benchmarks/pcmark8
[17] https://novabench.com/
[18] COMMISSION DECISION of 20 March 2014 on adding specifications for computer servers to Annex C to the Agreement, available from http://www.eu-energystar.org/specifications.htm

automatically by a benchmark tool (in the current case, Novabench), when it establishes a score representing computer performance.

Novabench is developed by Novawave Inc., a Canadian private company.

Tests were carried out using Novabench for 13 personal computers and high correlations were found between computer performance score and average power demand, and thus the average power demand, incl. consumption during idle modes, can be used to define active mode. Tests were performed only for desktop computers (incl. all-in-one non-mobile computers) and notebook computers. See details in task 3 report.

Despite the strong correlation between performance and measured power demand under test, there was some variability in the results. This variability is consistent with the assumption that some computers are more efficient than others when performing work (i.e. the work that is undertaken as part of the benchmark test). In order to incorporate power consumption during active mode into the ETEC formula, percentiles of performances per watt were identified by dividing the benchmark performance score by average measured power demand under test. These are shown in Table 1.

*Table 1. Percentiles of efficiency based on benchmark performance score divided by mean power demand during benchmark run.*

| | Percentile: Efficiency (Score/Mean Power) (Performance per Watt) | | |
|---|---|---|---|
| **Computer Type** | **25th** | **50th** | **75th** |
| Desktop | 18.46 | 14.91 | 12.85 |
| Integrated Desktop | 13.06 | 11.25 | 11.10 |
| Notebook | 20.32 | 18.36 | 17.30 |

Taking the 50$^{th}$ percentile values (i.e. the value representing the top 50% of efficiency performance) it is possible to include consideration of benchmark performance in a ETEC allowance formula (see section 7.5.2). The formulae use the assumption that personal computers spend a conservative 15% of their time actively conducting work (i.e. work which is reflected in the benchmark).

### 7.3.2 Computer Efficiency Rating Tool based on SPEC

A possibility exists of developing a computer benchmark tool based on a server benchmark tool called SERT (Server Efficiency Rating Tool) developed by the organisation SPEC (Standard Performance Evaluation Corporation).

SPEC is a non-profit corporation formed to establish, maintain and endorse standardized benchmarks and tools to evaluate performance and energy efficiency for computing systems. SPEC publishes submitted results from the member organizations and other benchmark licensees. Any company and organisation can be member.

SPEC has developed SERT 1.0 for the ENERGY STAR for servers v2.0 specification used in both USA and EU and it was launched in February 2013. SERT 1.1.1 is the most current SERT version supported by the ENERGY STAR server v2.0 specification (current specification).

The SERT principle is to test servers as shipped reporting energy and performance data to government energy programmes. SERT uses synthetic worklets that test discrete system components such as memory and storage, providing detailed power consumption data at different load levels. It has an automatic collection of system configuration data and automatic validation of results. It can be used on various computing platforms.

SERT has recently been further developed into SERT 2.0 – which targets ENERGY STAR for Servers v3.0 specification (currently under development). This adjusted the way the memory performance is calculated, optimised the testing which reduced the test time from 4 to 2.5 hours and added single-value metric. The metric is based on the work initiated by the European Commission for a server test standard, see Section 7.2.3. Test results cannot be compared with test results from SERT 1.1.1 due to differences in test method.

Either of the two SERT versions can be purchased for 2800 USD (non-profit price 950 USD).

The opportunity seen in developing a computer benchmark tool based on SERT is to have a testing method which is simple to use and virtually agnostic of internal architecture i.e. to be used for several types of personal computing systems (notebooks, desktop and workstations) and independently of specific operating systems e.g. Windows, Linux, MacOS and Chrome OS. Another advantage is that this same framework and overall method can also be used for computers and for servers.

This opportunity has been discussed with the chair of SPECpower Committee [19]. SPEC believes it should be possible to develop a computer efficiency rating tool using the same approach and methodology as SERT i.e. by using synthetic worklets to test the system components. Specific worklets for personal computer systems need to be developed. Some of the worklets already developed for servers, duly adapted, may be re-used.

The development would require resources in the form of a team of experts, computer hardware and test equipment. This could be provided by SPEC member companies if they see a purpose in having such a benchmark tool.

A tentative time frame for the tool development and testing of a number of products is 18 months. This excludes lead time for the computer companies to sign up to activity and to allocate resources.

### 7.3.3 Light active use power measurement developed by Standards Council of Canada

The Standards Council of Canada (CSA) has issued a mandate for development of a standard for a test method and benchmark tool targeting energy performance of computing appliances. CSA has launched the development work and is currently carrying out a first phase for proof of concept, which is foreseen to be completed by 10 January 2018. The next phase, which is the fully-featured benchmark system, is targeted to be completed by mid-2018 though still not fully funded.

The aim is to develop a new test procedure and measurement infrastructure to assess the real-world energy consumption of computing appliances with an initial focus on computers.

The approach is to include active mode as a "light active" mode, where the computer device is doing simple computational work such as that of web browsing and video

[19] Klaus Dieter-Lange, Director of the Board of SPEC and Chairman of the SPECpower Committee

streaming. The content will be based on a sample of popular websites and media content, representing a typical computer usage.

It includes also a real-world idle sequence that measures power drawn when the computer is not actively used but with browser tabs open.

For the initial phase of the development high-intensity active tasks such as gaming are not covered.

The test methodology is to execute the content-driven tasks through the default browser and video playing and measure the energy consumption during the execution. By doing this, the benchmark can be used on every computing system delivered with a browser and video player and it is not needed to compile codes for each operating system or CPU architecture used by the computing devices under test.

The drawback is that the tool is measuring the active mode energy consumption for a given workload, but it does not currently measure the performance and cannot report the efficiency level (i.e. performance vs energy consumption). This is however less important when the benchmark targets a “light active” mode of a typical computer user not playing games or doing other high-intensive computer tasks.

### 7.3.4 Conclusion

The three benchmark tools seem all to be viable solutions for including the active mode in a reviewed computer regulation, each with advantages and disadvantages.

Novabench is a tool already on the market and has the advantage of having been used for testing of more than 1 million computer systems with test results publicly available on Novabench’s web site. The study team has furthermore tested the tool by measuring a number of computers with positive results. A disadvantage is that it is developed by a private company without control by the European Commission or an independent organisation.

A Computer Efficiency Rating Tool based on SPEC seems also an option forward because with SPEC it has a solid organisation behind and the methodology seems promising because it gives a single value efficiency figure and there are good experiences for using it with servers. The server tool, SERT, has been chosen as the benchmarking tool in a proposed ecodesign regulation for enterprise servers. A standardisation mandate to ESOs has been devised[20]. Additionally, using the same methodology for the two product groups, computers and servers, would better assure coherence.

The light active use power measurement developed by Standards Council of Canada (CSA) seems also promising, however, it covers currently only power measurements and not the performance. Furthermore, it is developed by consultants for CSA and might lack sufficient involvement of the industry.

For both Novabench and the CSA tool, there might be a possibility of developing a separate software version specifically for the EU ecodesign compliance with an independent organisation behind it e.g. comprising both the European Commission and the industry. This possibility has not been further assessed during the current study.

[20] ETSI EN 303 470 " Measurement Process for Energy Efficiency KPI for Servers ". See also standardisation mandate 462 in the field of ICT.

## 7.4 Scope for energy and resource efficiency policy measures

The scope has been defined for both policy measures (i.e. a reviewed ecodesign regulation and a possible energy labelling regulation), valid for reviewed energy efficiency requirements and possible resource efficiency requirements.

For energy efficiency requirements, the scope goes in more detail than product type, including product categories (valid for one of the policy options (PO2) – see section 7.6). For resource efficiency requirements, the scope was deemed enough to be defined at product sub-group level (mobile and non-mobile personal computers). See Table 2.

Overall, the computers covered by the scope of a reviewed regulation are those intended for use by a single user at a time, therefore this product group is defined as "personal computers".

Small scale servers have been excluded from the proposed scope due to low sales (only 190000 estimated sold units in 2016) and low growth rate after 2017. They have a predicted stock of 1.84 million units in 2030 (only 0.3 % of total stock of personal computers in 2030).

Two overarching product sub-groups have been defined in the reviewed regulation, called "Mobile Personal Computers" and "Non-mobile Personal Computers". Because of differences in the technological characteristics they have two separate sets of requirements. The definitions are presented in the next section. More details of this assessment can be found in task 1 report.

The proposed requirements will be applicable to all mobile personal computers and non-mobile personal computers that fulfil the definitions shown in Table 3. Concerning exemptions, it is envisaged that energy efficiency requirements would not be suitable for some types of higher performance computers at this stage. As such, it is recommended that workstations should be exempted from energy efficiency requirements (except IPS efficiency and information requirements), as in the current regulation.

It is, however, recommended to include in the reviewed regulation the updated definitions of the most important product types that can be covered under non-mobile and mobile computer definitions, in order to provide continuity in the structure of the current regulation. This shall not be interpreted as the requirements are exclusive to these product types, but rather as examples. An overview of the proposed scope and classification is shown in Table 2. Definitions and exemptions to scope are shown in Table 3.

*Table 2. Overview of scope for energy and resource efficiency requirements.*

| Product group | Product sub-group | Examples of product types |
|---|---|---|
| Personal computer | Non-mobile computer | Desktop computer |
| | | Desktop workstation |
| | | Desktop thin client computer |
| | Mobile computer | Notebook/laptop computer |
| | | Tablet/slate computer |
| | | Portable all in one computer |
| | | Mobile workstation |
| | | Mobile thin client computer |

*Table 3. Definitions relevant for scope.*

| Term | Definition |
|---|---|
| Computer | A device which performs logical operations and processes data and is capable of using input devices and outputting information to other devices. Computers include a central processing unit (CPU) to perform their operations. |
| Personal computer | A computer designed to be used by a single user at a time with input devices such as, but not limited to, a keyboard (which can be an on-screen keyboard), a mouse, a trackpad or other pointing device, and with output devices such as, but not limited to, a graphical display or a printer. Other input sources and output destinations are possible either via specific physical ports for specific uses or via universal ports[21]. Personal computers require power supplies for converting AC current into DC current that can be either internal or external. For the purposes of this regulation personal computers are subdivided into two main types; 'Non-mobile personal computers' and 'Mobile personal computers'. |
| Non-mobile personal computer | A computer designed to be used in a permanent location with constant connection to the electricity mains. |
| Desktop computer | A non-mobile personal computer designed to be placed on a desk, on the floor or on a stand. This product type includes all-in-one non-mobile computers that have an integrated display as main output media. |
| Desktop workstation computer | A non-mobile personal computer for computationally intensive tasks excluding game play. A workstation is intended as high performance personal computer that meets all of the following:<br>a) does not support altering frequency or voltage beyond the CPU and GPU manufacturers' operating specifications,<br>b) has system hardware that supports error-correcting code (ECC) that detects and corrects errors with dedicated circuitry on and across the CPU, interconnect, and system memory;<br>c) provides support for one or more graphic or compute accelerators;<br>d) supports connection of at least 4 displays with at least UHD-4k resolution;<br>e) provides at least 4 slots for fault-tolerant error checking and correcting (ECC) memory and is placed on the market with at least 12 GB ECC memory;<br>f) is wired for > x4 PCI-E on the motherboard in addition to the graphic slot and/or PCIX support;<br>g) contains five or more logical expansion ports (PCI, PCI-Express, PCI-X, Thunderbolt, > USB3.1, or equivalent); and<br>h) has received certification for at least three independent software vendor (ISV) products. These certifications can be in process, but shall be completed within 3 months of qualification. |
| Desktop thin client computer | A non-mobile personal computer that relies on a connection to remote computing resources (e.g. computer server, remote workstation, or cloud-based resources) to provide primary functionality. The category includes integrated desktop thin clients that have an integrated display as main output media. |
| Mobile personal computer | A computer designed for portability, which is capable of operating on an integrated source of power, without requiring a permanent connection to an external power source. |
| Notebook/laptop computer | A mobile personal computer that has an integrated display and an integrated physical keyboard and a pointing device. |
| Tablet/slate computer | A mobile personal computer that meets the two following criteria:<br>(a) includes an integrated touch-sensitive display as main input and output media and relies on users' activation of the touch-sensitive display for inputs; |

[21] e.g USB 3.1 with type C connector and Thunderbolt 3.0

| Term | Definition |
|---|---|
| | (b) does not have an integrated physical keyboard, although a detached keyboard may be used as separated input device. |
| Portable all-in-one computer | A mobile personal computer that meets all of the following criteria:<br>(a) includes an integrated touch-sensitive display as main input and output media and relies on users' activation of the touch-sensitive display for inputs;<br>(b) does not have an integrated physical keyboard, although a detachable keyboard may be used as separated input device;<br>(c) includes an internal battery , but is primarily powered by connection to the ac<br>(d) includes an integrated display with a diagonal size greater than or equal to 17.4 inches |
| Mobile workstation computer | A mobile workstation that meets all of the following criteria:<br>(a) has a mean time between failures (MTBF) of at least 13,000 hours;<br>(b) has at least one discrete graphics card (dGfx) meeting the G3 (with FB Data Width > 128-bit), G4, G5, G6 or G7 classification;<br>(c) supports the inclusion of three or more internal storage devices;<br>(d) supports at least 32 GB of system memory. |
| Mobile thin client computer | A mobile personal computer that relies on a connection to remote computing resources (e.g. computer server, remote workstation, or cloud-based resources) to obtain primary functionality. |

Exemptions to the scope are:

- All personal computers that have short idle state power demand of less than 6 W are excluded from energy efficiency requirements. In the current Computer Regulation 617/2013 notebook computers having an idle state power demand of less than 6 W are already excluded. It is proposed to extend this to all personal computers to establish a level playing field for all personal computers independently of the technology and form-factor.
- Notebook/laptop computers with an integrated display with a viewable diagonal screen size of less than 22.86 cm (9 inches) are excluded from the scope of a proposed reviewed regulation. Notebook computers on this size are already excluded from Computer Regulation 617/2013 and no reason to remove this exemption was identified during this study. Products under this size limit are typically those having short idle state power demand of less than 6 W.

## 7.5 Proposed energy efficiency policy measures

### 7.5.1 Definition of 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 summarised in Table 4 below.

*Table 4. Suggested policy options addressing energy efficiency of computers, including BAU.*

| Policy option | Description of policy option |
| --- | --- |
| **Option 0 (PO0) – BAU** | No action ('Business-as-Usual', BAU) |
| **Option 1 (PO1) – Self-regulation** | Industry formulates voluntary agreements or other self-regulation measure on their own initiative which they are responsible for enforcing. |
| **Option 2 (PO2) - Ecodesign** | Reviewed **ecodesign requirements** for personal computers[22]:<br>a. ETEC limits, incl. capability adjustments[23].<br>b. Low power mode requirements[24].<br>c. Power management requirements.<br>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 Gold registered IPS (with separate requirement at the 10% loading level).<br>A review clause would be part of the reviewed regulation to assess the potential inclusion of active mode as part of ecodesign requirements in a future regulation. |
| **Option 3 (PO3) – Ecodesign and energy label incl. active mode** | A **combination of ecodesign and energy labelling policy measures incl. active mode**:<br><br>Reviewed **ecodesign requirements** for personal computers where products shall comply with a minimum EEI level, which will be equivalent to the bottom threshold of class G, including active mode requirements. A method is to be developed for the European Commission to ensure measurement of the ratio between personal computer performance and energy use is standardised (see section 7.4 for details). It is expected that this method including the threshold level will be fully developed at the time of adoption of the regulation, which will be described as part of the verification.<br><br>New **energy labelling requirements** for personal computers. The energy labelling requirements will be based on the same standardised test performance scores including active mode power demand[25] as for ecodesign requirements. Thresholds will have to be established to rate energy efficiency into 7 classes, A-G. |

[22] 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

[23] As defined in the Commission Regulation (EU) 617/2013

[24] 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.

[25] As described in section 7.4

Policy option 0, Business as Usual (BAU), involves 'no action', considering no amendments to the computer regulation take place. This establishes the baseline reference for comparison with the other policy options. PO0 (BAU) assumes only developments in technology, markets, etc. that would take place without any further regulatory actions.

Policy option 1, 'self-regulation', includes voluntary agreements offered as unilateral commitments by industry. Self-regulation shall be given priority to alternative courses of action[26] where it is likely to deliver the policy objectives faster or in a less costly manner than mandatory requirements. However, this is subject to certain conditions stipulated in Article 17 and Annex VIII to the Directive (e.g. market coverage by signatories, ambition level, etc.). These conditions are not fulfilled: none of the industry stakeholders expressed interest in self-regulation nor is it likely that in today's global market the conditions for self-regulation, e.g. regarding minimum market coverage, will be met because the risk of 'free-riders' and thus unfair competition is too big. Consequently, self-regulation has not been considered as a possible policy option.

Elements of policy options 2 and 3 will be detailed and assessed in the following sections.

The potential energy savings of policy options 2 and 3 have been evaluated and presented later in this task report. The results from the scenario analyses will be one of the main elements to select the most adequate policy option.

#### 7.5.1.1 *Timeline for implementation*

A preliminary timeline has been drafted based on assumed implementation dates for each policy option (see Table 5). Although it is foreseen that the timeline of implementation for PO2 will shift to 2021, the scenario analyses presented in section 7.5.2 remain considering 2020 as the effective date. The most appropriate timeline should be discussed during further consultation with stakeholders and a potential alignment with PO3 during the Impact Assessment.

*Table 5. Suggested timeline for implementation of suggested policy options[27].*

| Option 2 (PO2) | Option 3 (PO3) |
|---|---|
| Ecodesign | Ecodesign & Energy label incl. active mode |
| 1 January 2020 | 1 January 2022 |

#### 7.5.1.2 *PO2: Potential ecodesign requirements on energy efficiency*

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

The current ecodesign regulation on computers covers only energy efficiency requirements, and it utilizes computer categories that were adopted from the ENERGY STAR v5.1 specification from 2008. However, since these have become largely outdated it has been recommended (in task 1 report) to use the ENERGY STAR v6.1 categorization (or version 7 if available at the time of preparing the regulation proposal).

It would not be possible to have a single product category of "computer" as this would result in a single allowance. A single allowance for all types of computer may not, currently, be a viable option due to the wide range of computer functionalities and

[26] According to Ecodesign Framework Directive
[27] The letters (a-d) refer to Table 2.

subsequently CPU configurations to deliver those functions. However, product categories can be simplified as done in ENERGY STAR v6.1.

When performing the analysis of the energy performance data for products within the EU ENERGY STAR database[28], it was found that the number of product categories could be reduced without impacting the compliance rates to suggested measures.

Established test procedures are available to support measurement of all measurable proposed reviewed ecodesign requirements. Most the requirements are based on the test procedure behind the ENERGY STAR v6.1 specification and are well established in the market.

Table 6 shows the base requirements and additional allowances for key components used for the proposed ecodesign requirements under the policy option 2. The overall level of ambition has been designed to closely match the level of ambition laid down in the Californian regulation (Tier II) 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 within the proposed timelines. 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 recently been heavily discussed with industry, government and NGO stakeholders.

In case of the integrated display allowance, an alternative to what is shown in Table 6 has been discussed, which is a single requirement for both mobile and non-mobile personal computers e.g. using the allowances proposed in the display regulation. Since there are technical differences between a single display and a computer-integrated display it is however not advisable to copy the allowances from this proposal.

A single metric could then be developed based on measurement of integrated mobile and non-mobile computers. No test method exists currently, but a simple method has been discussed with stakeholders consisting of isolating the power required for backlighting which is approximately 80% of overall display power demand.

This approach may result in better estimations of display power demand. However, this would require tests of a number of computers. Since this is not available at the time of this review, separate allowances have been developed which are backed-up with test data available from other measures[29].

The allowances have been developed to ensure that market surveillance authorities, and other interested parties, can identify which allowances should be applied to a product from basic publicly available technical documentation.

[28] As explained in task report 3, the quality of the data provided by manufacturers in compliance to the current Regulation was insufficient, so the US Energy Star database was used instead – for details see task 3 report
[29] ENERGY STAR v6.1 and the Californian Regulation

*Table 6. Potential reviewed ecodesign requirement levels (Policy option 2).*

| Product Type | Category (Old) | Category (New) | Base Allowance (kWh/year) |
|---|---|---|---|
| Non-Mobile | 0 | Category 1 | 40 |
| Non-Mobile | I1 | Category 2 | 65 |
| Non-Mobile | I2 | Category 3 | 70 |
| Non-Mobile | I3 | Category 3 | 70 |
| Non-Mobile | D1 | Category 3 | 70 |
| Non-Mobile | D2 | Category 3 | 70 |
| Mobile | 0 | Category 1 | 10 |
| Mobile | I1 | Category 1 | 10 |
| Mobile | I2 | Category 1 | 10 |
| Mobile | I3 | Category 2 | 15 |
| Mobile | D1 | Category 2 | 15 |
| Mobile | D2 | Category 3 | 30 |

| Functional Adder Allowances | | Non-Mobile and Mobile Computers |
|---|---|---|
| Random Access Memory (RAM) (kWh/year)<br><br>Where "C" is the total amount of installed RAM in GB | | 4 + 0.15 * C |
| Additional storage device allowance beyond the main storage device (kWh/year) | 3.5" HDD | 16.5 |
| Additional storage device allowance beyond the main storage device (kWh/year) | 2.5" HDD | 2.6 |
| Additional storage device allowance beyond the main storage device (kWh/year) | All other storage devices | 0.5 |

| Additional Functional Adder Allowances | Non-Mobile Computers | Mobile Computers |
|---|---|---|
| First discrete graphics card (dGfx) (kWh/year)<br><br>Where "B" is the dGfx frame buffer bandwidth measured in GB/s | 58.6*tanh(0.0038*B-0.137)+26.8 | 29.3*tanh(0.0038*B-0.137)+13.4 |
| Integrated Display allowance (kWh/year)<br><br>Where:<br>"A" is the display area measured in $dm^2$<br>"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 colors) | 8.76 * 0.35 * (1 + EP) * ((21 * tanh(0.02 + 0.06 * (A-15)) + 5.5) + 10) | 8.76 * 0.3 * (1 + EP) * ((10 * tanh(0.02 + 0.075 * (A-11)) + 2.5) + 4.5) |

#### 7.5.1.3 ***PO3: EEI approach including active mode***

The proposed efficiency index (EEI) approach for ecodesign and a future EU energy label in policy option 3 is detailed below. This follows a proposed approach by Siderius, H.P.[30], adapted to incorporate active mode as explained in section 7.4. The proposed formula establishes an energy efficiency index based on a potential CERT (Computer Efficiency Rating Tool) methodology (see section 7.4.2). However, the formula may change in case another of the three methodologies described in section 7.4 is selected at the end of the development process. The proposed formula is shown below:

$EEI = CERT_{measured}/CERT_{allowed}$

[30] Slashing the Hydra: reducing allowances in MEPS for complex settop boxes. Hans-Paul Siderius. Electronics Goes Green 2016+. Berlin, September 7 – 9, 2016.

CERT is the proposed metric for calculating the efficiency of the product groups and types under scope of the reviewed regulation and based on specific worklets (as described in section 7.3.2). $CERT_{measured}$ is calculated based on the measured efficiency based on the methodology to be developed (including active state). $CERT_{allowed}$ is the minimum allowed efficiency threshold to be established based on test measurements during the development of the methodology.

A product just meeting the EU ecodesign regulatory requirements would be equal to achieving an EEI of 1.0. Given that products need to meet the ecodesign limits in order to be legally placed on the EU market, an EEI score of 1.0 would be the bottom of the "G Class".

The same EEI score could be used for both "Mobile Personal Computers" and "Non-Mobile Personal Computers" when departing from the same lowest score (i.e. 1.0, corresponding to the bottom of class G). This is possible even if different efficiency thresholds, i.e. $CERT_{allowed}$, would be set because the EEI approach is based on the divergence of a product from the minimum energy use requirements[31].

The final thresholds will be developed when the test method and sufficient test data are available. It is foreseen that thresholds for mobile and non-mobile computers need to be different due to large differences in energy consumption between mobile and non-mobile personal computers (see Task 3 report, Figures 11 to 13 and Tables 23 and 24 showing that average desktops consume more than five times the consumption of average notebooks) and therefore it is not possible to have an EEI scale for mobiles and non-mobile computers based on one common threshold level.

This may be different when the threshold level is based on efficiency (performance vs consumption) because mobiles and non-mobiles would then show less differences (see Task 3 report, Figure 16 for some examples). However, it is too early to conclude on this since only few data points exist showing a correlation between performance and energy consumption and no data exists showing differences between mobile and non-mobile computers. This will have to be investigated further once a methodology to measure efficiency including active mode is developed.

In respect to setting the limits into energy classes, Article 11 point 8 of the new Labelling Framework Regulation[32] , *repealing Directive 2010/30/EU,* reads:

*'Where a label is introduced or rescaled, the Commission shall ensure that no products are expected to fall into energy class A at the moment of the introduction of the label and the estimated time within which a majority of models falls into that class is at least 10 years later.'*

[31] Setting different thresholds and using this value in the EEI index, anyhow, would make impossible the comparison, in terms of efficiency, between a mobile computer and a non-mobile one.
[32] EUROPEAN COMMISSION Brussels, 15.7.2015 COM(2015) 341 final 2015/0149 (COD) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL setting a framework for energy efficiency labelling and repealing Directive 2010/30/EU, available from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015PC0341

Point 9 in addition reads:

*'By way of derogation from paragraph 8, where technology is expected to develop more rapidly, requirements shall be laid down so that no products are expected to fall into energy classes A and B at the moment of the introduction of the label.'*

Given that technological development occurs very quickly in computers, there would be a need to set very stringent Class A and B EEI values to ensure that large numbers of computers will not fall into these classes within a time frame shorter than 10 years or so.

Some complications could arise due to the large number of configurations that are found within individual models of computers. Many configurations of the same computer model may exist due to small changes in the internal components of a computer. This issue is recognised in the current ecodesign regulation on computers which states that if a product model is placed on the market in multiple configurations, then the product information required may be reported once per product category for the highest power-demanding configuration available within that product category. This allows manufacturers to provide the documentation on a single configuration of a computer model (per category) rather than all different configurations. An EU energy label on computers would therefore be based on the same criteria.

Table 7 illustrates potential requirements for an EU energy label on computers based on an Energy Efficiency Index (EEI) approach. The bottom limit of class G level, i.e. with a range of values between 0.9 and 1.0, presents at the bottom level (i.e. 1.0) the corresponding minimal value under the ecodesign regulation on computers[33]. The A and B classes are set with the aim that no more than 30% of products fall in the top energy class or no more than 50% in the two top classes before 10 years to avoid the need for rescaling (article 11 of reg 2017/1369). Technological progress and market incentives may accelerate the population of the top classes for mobile and/or non-mobile computers in comparison to the market distribution used to calculate the potential impacts of this policy option (see Table 8). Since these assumptions are rather uncertain at the time of this study. they should be assessed in more detail during the Impact Assessment.

In any case, these levels should be revised once the active mode methodology is fully developed.

[33] As condition to enter the EU market.

*Table 7. Potential EU Energy Label EEI requirements.*

| EU Energy Label Energy Efficiency Index (EEI) | |
|---|---|
| **EU Energy Label Class** | **EEI Value** |
| A | EEI < 0.10 |
| B | 0.10 ≤ EEI < 0.30 |
| C | 0.30 ≤ EEI < 0.50 |
| D | 0.50 ≤ EEI < 0.70 |
| E | 0.70 ≤ EEI < 0.80 |
| F | 0.80 ≤ EEI < 0.90 |
| G | 0.90 ≤ EEI < 1.0 |

Table 8 illustrates the estimated penetration rate for three main types of personal computer within each of the EU energy label classes. These levels have been defined with the expectation that no products would fall into the A and B classes, with the highest penetration in Class G. However, these levels may be revised once the active mode methodology is fully developed.

*Table 8. EU energy label classes and computer distributions.*

| | | Distribution of label classes | | |
|---|---|---|---|---|
| **Product Type** | **Energy Label Class** | **2022** | **2025** | **2030** |
| Desktop | A | 0% | 3% | 5% |
| | B | 0% | 5% | 10% |
| | C | 22% | 26% | 30% |
| | D | 22% | 26% | 30% |
| | E | 13% | 14% | 15% |
| | F | 18% | 14% | 10% |
| | G | 25% | 12% | 0% |
| Integrated Desktop | A | 0% | 2% | 5% |
| | B | 0% | 5% | 10% |
| | C | 15% | 22% | 30% |
| | D | 27% | 28% | 30% |
| | E | 19% | 17% | 15% |
| | F | 20% | 15% | 10% |
| | G | 19% | 10% | 0% |
| Notebook | A | 0% | 8% | 15% |
| | B | 0% | 11% | 20% |
| | C | 13% | 17% | 20% |
| | D | 25% | 25% | 25% |
| | E | 20% | 17% | 15% |
| | F | 22% | 13% | 5% |
| | G | 21% | 9% | 0% |

#### 7.5.1.4 *Additional requirements for PO2 and PO3*

Table 9 details the power management requirements that could be included in a reviewed ecodesign requirement on computers (Policy options 2 and 3). 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 recognize that technologies such as “Modern Standby” utilize alternative low power modes. The suggested requirements assume that where alternatives to sleep mode are used they function correctly. Should an alternative approach not work as intended then savings would be lost.

*Table 9. Potential reviewed ecodesign requirements for power management functionalities (Policy options 2 and 3).*

| 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 the sleep mode requirement. |
| | 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 the 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, the response to ‘wake events’ from that alternative low power condition should happen with a latency of ≤ 2 second from the initiation of the 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 WoL function for sleep and off mode, if WoL from off mode is supported. WoL should be disabled as default. |
| | 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 by default. |
| | Where an alternative low power mode, other than sleep, deep sleep, hibernation 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 by default. |
| | 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 when wireless network connection(s) are active. |

A set of proposed reporting ecodesign and energy labelling requirements reviewing existing ones are available in Table 10 and Table 11. These are a simplification in respect to the current reporting requirements which are currently not fulfilled by most of manufacturers (see details in task 3 report). The reporting requirements are split into those publicly available for consumers (in product information sheet), and those not publicly available (in technical documentation).

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.

*Table 10. Potential reviewed ecodesign and energy labelling reporting requirements in technical documentation.*

| Reporting Requirements |
|---|
| 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 |
| 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. |

*Table 11. Potential reviewed ecodesign and energy labelling reporting requirements in information sheet.*

| Reporting Requirements |
|---|
| 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 |
| Date of first placing on the market |
| Maximum power demand (Watts) |
| Short idle state power demand (Watts) |
| Long idle state power demand (Watts) |
| Alternative low power mode 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) |
| Any internal dGfxs can be automatically disabled (Yes/No) |
| Internal power supply efficiency at 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 mode and no load efficiency |
| Minimum number of loading cycles that the batteries can withstand (applies only to mobile personal computers) |
| The duration of idle state condition before the computer automatically reaches sleep mode [minutes], 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 [minutes] in which the computer automatically reaches a power mode that has a power demand requirement lower than sleep mode |
| The length of time [minutes] 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 |

Table 12 illustrates suggested low power mode requirements that could be used under the Policy options 2 and 3. The requirements can be met by approximately 64% of products in the EU ENERGY STAR database[34] which refers to version 6.1 of US EPA specifications[35]. Furthermore, off-mode requirements are aligned with current

[34] EU ENERGY STAR database as of 18th December 2017
[35] In the US, ENERGY STAR market penetration for computers was 56% of the shipped products in 2016. It is anticipated that this has increased for 2017 (data will be available around August 2018 according to US EPA sources). For more details see:

requirements in Standby Regulation (1275/2008) (though not covering desktop computers, integrated desktop computers, and notebook computers) and Wake on Lan (WoL) allowance for non-mobile computers shows alignment with the US ENERGY STAR requirements for small-scale servers in specification v6.1[36].

*Table 12. Suggested low power mode requirements (Policy options 2 and 3).*

| Low power mode requirements | Sleep mode (W) | Off mode (W) | Off mode WoL additional allowance (W) |
|---|---|---|---|
| Non-Mobile Personal Computers | 2.0 | 0.5 | 0.2 |
| Mobile Personal Computers | 2.0 | 0.5 | - |

Table 13 identifies the IPS requirements under Policy options 2 and 3. The requirements are based on the 80Plus Gold level requirements[37] with the addition of an efficiency requirements at the 10% loading level. The 10% loading level requirement is important to account for real world low loading levels typically observed on computers during idle states or even simple on-mode operation (e.g. typing text). The draft ENERGY STAR v7.0 specification for computers includes IPS efficiency requirements reflecting the 80Plus Gold level. These were included after extensive US EPA investigations into market availability of Gold level IPS.

*Table 13. Potential ecodesign requirements for IPS (Policy options 2 and 3).*

| Desktop computers, integrated desktop computers, notebook computers, workstations, small-scale servers, external graphics adapters and docking stations | Internal Power Supply Efficiency | | | | |
|---|---|---|---|---|---|
| | Tier I | | | | |
| | Rated Power Output (W) | 10% Load | 20% Load | 50% Load | 100% Load |
| | All | 86% | 90% | 92% | 89% |
| | 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. | | | | |

### 7.5.2 Scenario analyses of energy efficiency policy measures

In order to assess the effectiveness of the policy options listed in Table 4, it is necessary to model expected energy use under each policy scenario. As such a modelling exercise was undertaken to evaluate the expected energy use resulting from computers under the different policy options.

A number of scenarios have been developed, at the category level for desktops, integrated desktops and notebooks. The notebook modelling includes "Portable all-in-ones" as these are treated as notebook computers under the current ecodesign regulation. Separate models were developed for thin clients and integrated thin clients. The energy use associated with workstation computers was not modelled as there are no direct policy measures on these computer types apart from requirements on IPS

https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2016_USD_Summary_Report.pdf?0233-a164

[36] Considering v6.1 has 0.4 W allowance for small-scale server

[37] As detailed in the task 3 report: Table 13. 80 PLUS Certification IPS Efficiency Requirements.

efficiency. The IPS efficiency could not be modelled for workstation computers due to a lack of data on IPS loading.

All of the modelling is based on the stock model from the task 2 report, which was modified to include all products types mentioned above. The sales and stock levels for each type of computer can be seen in Table 14 and Table 15 respectively. Modelling results are only shown from 2016 to 2030, to show the effect of the policy options compared to current energy consumption levels (BAU).

*Table 14. Computer Sales Volumes (all policy options).*

| | Sales Per Year ('000s) | | | | |
|---|---|---|---|---|---|
| Computer Type | 2010 | 2015 | 2020 | 2025 | 2030 |
| Notebook | 33,563 | 27,671 | 27,602 | 36,422 | 45,934 |
| Desktop | 8,397 | 3,468 | 3,879 | 5,353 | 5,706 |
| All-In-One | 654 | 322 | 360 | 497 | 606 |
| Thin client | - | - | - | - | - |
| Integrated Thin client | - | - | - | - | - |
| Workstation[38] | 32 | 40 | 45 | 54 | 65 |
| | | | | | |
| Non-mobile | 9,083 | 3,830 | 4,284 | 5,904 | 6,377 |
| Mobile[39] | 33,563 | 27,671 | 27,602 | 36,422 | 45,934 |
| **All computers[39]** | **42,646** | **31,501** | **31,886** | **42,326** | **52,311** |

*Table 15. Computer Stock Volumes (all policy options).*

| | Stock Year ('000s) | | | | |
|---|---|---|---|---|---|
| Computer Type | 2010 | 2015 | 2020 | 2025 | 2030 |
| Notebook | 124,322 | 172,955 | 151,085 | 177,559 | 227,771 |
| Desktop | 69,504 | 46,519 | 27,533 | 34,110 | 40,102 |
| All-In-One | 5,410 | 3,921 | 2,528 | 3,166 | 3,799 |
| Thin client | - | - | - | - | - |
| Integrated Thin client | - | - | - | - | - |
| Workstation[38] | 225 | 264 | 309 | 363 | 434 |
| | | | | | |
| Non-mobile | 75,139 | 50,704 | 30,370 | 37,639 | 44,335 |
| Mobile[39] | 124,322 | 172,955 | 151,085 | 177,559 | 227,771 |
| **All computers** | **199,461** | **223,659** | **181,455** | **215,198** | **272,106** |

General assumptions regarding the market development were added to the modelling. This included changes in the distribution of products failing into each category over time, as shown in Table 16. The category change distribution was included to account for the fact that computer performance increases over time and with that comes a general move towards products in higher computer performance categories (e.g. products move from category I1 to category I3 as performance improves). This was conducted for the BAU

[38] Assumed to be part of non-mobile computers
[39] Excluding sales for tablet computers

and PO2 scenarios. The PO3 scenario was calculated based on distributions of products falling into the different product classes as described later.

*Table 16. Distribution of computer categories over time.*

| Computer Type | Category | Distribution of Products | | | |
|---|---|---|---|---|---|
| | | **2017** | **2020** | **2025** | **2030** |
| Desktop | 0 | 2% | 3% | 4% | 5% |
| | I1 | 17% | 14% | 10% | 5% |
| | I2 | 17% | 14% | 10% | 5% |
| | I3 | 29% | 35% | 46% | 57% |
| | D1 | 15% | 12% | 6% | 0% |
| | D2 | 20% | 22% | 25% | 28% |
| All-In-One | 0 | 8% | 6% | 3% | 0% |
| | I1 | 25% | 19% | 10% | 0% |
| | I2 | 12% | 12% | 11% | 10% |
| | I3 | 39% | 45% | 55% | 65% |
| | D1 | 0% | 0% | 0% | 0% |
| | D2 | 15% | 17% | 21% | 25% |
| Notebook | 0 | 0% | 0% | 0% | 0% |
| | I1 | 47% | 36% | 18% | 0% |
| | I2 | 25% | 19% | 10% | 0% |
| | I3 | 26% | 43% | 70% | 98% |
| | D1 | 2% | 1% | 1% | 0% |
| | D2 | 1% | 1% | 1% | 2% |

All scenarios are calculated using ETEC levels as calculated under the proposed ecodesign regulation approach, with the addition of 20% of time assumed to be spent in active mode. Requirements on active mode energy efficiency are only included in the policy option PO3. However, active mode energy use was included within all policy options to allow for direct comparisons and because of the potential impact on removing products with high active mode consumption when removing products with high idle mode consumption by setting requirement on idle mode. Power mode data is not provided as the ETEC values allow for comparison across all power modes under a single metric.

#### 7.5.2.1 *Policy Option 0: BAU scenario*

The BAU scenario was modelled under the assumption that the EU ecodesign regulation is not updated from the currently implemented version and no other policy measures impacting computers' energy use are implemented during the period 2016 to 2030.

The historic ETEC values were modelled back to 2009, to take into account the energy consumption from computers sold before 2016, which are still in use and therefore part of the stock.

The 2009 ETEC values were derived based on the base case developed in the computer ecodesign Impact Assessment study from 2009. The resulting ETEC values are shown in Table 17. It is important to note that active mode energy use is not considered in the ETEC values shown in Table 17 but is included in the actual modelling of total energy use. Active mode energy use has been omitted at this point so that the ETEC values can be compared to previous studies.

*Table 17. ETEC values for 2009 from the previous computer Impact Assessment.*

| Product types and categories | 2009 ETEC values |
|---|---|
| **Desktop TOTAL** | **134.6** |
| Desktop cat 0 | 78.7 |
| Desktop category I1 | 100.4 |
| Desktop category I2 | 110.3 |
| Desktop cat I3 | 126.0 |
| Desktop cat D1 | 165.6 |
| Desktop cat D2 | 184.4 |
| | |
| **Integrated desktop TOTAL** | **160.4** |
| Integrated Desktop cat 0 | 118.4 |
| Integrated Desktop category I1 | 144.9 |
| Integrated Desktop category I2 | 151.4 |
| Integrated Desktop cat I3 | 174.2 |
| Integrated Desktop cat D1 | 195.9 |
| Integrated Desktop cat D2 | 240.8 |
| | |
| **Notebook TOTAL** | **39.9** |
| Notebook Cat 0 | 30.2 |
| Notebook category I1 | 34.5 |
| Notebook category I2 | 42.8 |
| Notebook category I3 | 48.0 |
| Notebook category D1 | 53.0 |
| Notebook category D2 | 111.1 |
| | |
| **Thin client** | **80.6** |
| | |
| **Integrated Thin client** | **181.7** |
| | |
| **Workstation** | **348.2** |
| | |

The 2016 ETEC values (average and BAT) are those presented in the base case definition in task 5. Linear interpolation in between the future development of ETEC under the BAU scenario was based on the BAT market penetration and ETEC levels, also identified for each product type in task 5. It was assumed that the market penetration of BAT products today is 5%, which will increase linearly up to 20% in 2030. The assumption is based on the fact that computer energy efficiency generally improves over time but that only a small percentage of products (e.g. up to 20%) will reach the BAT levels and based on experiences from the ENERGY STAR specification developments for computers, where the market penetrations have been followed.

The BAT approach is used as a proxy for expected continuing energy efficiency seen in personal computers overtime. In reality there are many factors that affect personal computer energy efficiency levels. The Task 4 report included a description of the Best Available Technology at a component level found in computers currently on the market. The task 4 report also addressed some of the future Best Not Available Technology that may also drive further energy efficiency in computers. The main efficiency improvements in the BAT and BNAT technologies list included:

- **CPU Efficiency**: reductions in process size are likely to continue (i.e. down to 7nm and 5nm) bringing additional levels of energy efficiency. As the process size of CPUs and other components continues to reduce, leakage current will become an increasing concern for energy efficiency. New materials and architecture designs will be required to reduce leakage. This may include the development of improved node processes using new materials such as carbon nanofibers.

- **CPU power management opportunities**: likely to improve with the advent of better and wider implementation of SI0x states across CPUs and SoC designs. With the support of software based solutions such as Modern Standby computers could act much more like smart phones, in terms of power management functionality, and become significantly more efficient.

- **Software Efficiency**: Modern Standby may be supported across more computer products. This holds the potential to significantly reduce energy usage in products that support this functionality.

- **Graphics Processing Unit Efficiency**: The energy efficiency levels found in both iGfx and dGfx is likely to continue to increase in future, mirroring the improvements in CPUs and OS. Usage of high band width memories (HBM) in future iGfX and dGfx will likely lead to significant improvements in performance whilst also offering reduced energy consumption.

- **IPS Efficiency:** likely to further increase in future with the advent of two stage IPS which tackle inefficiencies at low load levels: the delta between active state power demand and idle power demand is growing, hence the load on the IPS is decreasing in idle mode which then results in further inefficiencies. Two stage IPSs will include a smaller IPS that provides power to computers at low loading levels and allowing the power management of the larger IPS. This new technology is currently being developed in the market and is likely to become more important going forward as loading levels on higher performance computers continue to fall.

- **Integrated Display Efficiency**: Improvements in integrated display efficiencies will mirror improvements found in the external display and television products. This will likely include the development of quantum dot based integrated displays which hold the potential to significantly reduce the power needed for panel backlighting.

- **Memory Efficiency**: Further power demand savings are expected from DDR4 memory as production moves to a 10nm process. It is estimated that a further power demand saving of between 10% to 20% per DIMM could be realised as a result of this shift to a smaller manufacturing process. HBM may also be used in RAM modules going forward, offering much greater performances with lower power demand levels.

- **Storage Technologies**: New types of storage products are due to start finding their way to market in the near future.  These products which provide non-volatile memory (NVM) will offer much faster retrieval of stored data, at RAM retrieval performance levels, whilst also purportedly offering improvements in energy efficiency.

- **Enhanced power management**: It is expected that innovations such as Microsoft Modern Standby will continue to be adopted by manufacturers going forward and that this type of functionality will be supported in other OS available on the market.

The extent to which these technologies, and others, that will be implemented within future personal computers, is very uncertain, unless market incentives or other regulatory measures are put in place. In addition, the extent of energy efficiency improvements provided by any of the future technologies is also uncertain. Given these uncertainties it is difficult to include definitive uptake rates for the technologies within the modelling. For this reason, an expected uptake of products meeting current BAT levels of performance was used in the modelling.

The BAT ETEC level was calculated for each product category within each product type based on the percentage difference between the average ETEC and BAT ETEC of the category the identified base case product (in task 5) belonged to. I.e. the percentage difference for the base case product was used for all other product categories of same product type assuming same % level of efficiency improvement opportunities within same product type.

For example, the difference between BAT in category I1 desktop computer and average performances in that type of computer is 72.9% whereas the difference for all-in-one computers is 46.7%. The values for all categories are shown in Table 18.

For some product types such as thin clients, there are less models available on the market and less variation in terms of BAT ETEC values compared to other product types such as desktops and all-in-ones. Furthermore, the BAT models are primarily business models with high capabilities and few power management technologies. Therefore, BAT ETEC for thin clients and integrated thin client are higher than BAT ETEC for some desktop and all-in-one categories. However, the BAT levels presented in Table 18 still present a significant reduction when compared to average ETEC levels presented also in Table 18.

*Table 18. Estimated BAT ETEC per category for 2016 calculated based on reduction % between average and BAT ETEC values for the Task 5 base cases for each product type[40].*

| Product types and categories | BAT ETEC base cases KWh/year | Average ETEC base cases KWh/year | BAT reduction from average ETEC | Estimated BAT ETEC KWh/year |
|---|---|---|---|---|
| Desktop Total avg. | | 103.6 | 72.9% | 28.1 |
| Desktop cat 0 | | 60.6 | 72.9% | 16.4 |
| Desktop category I1 | 20.9 | 77.3 | 72.9% | 20.9 |
| Desktop category I2 | | 84.9 | 72.9% | 23.0 |
| Desktop cat I3 | | 97.0 | 72.9% | 26.3 |
| Desktop cat D1 | | 127.5 | 72.9% | 34.5 |
| Desktop cat D2 | | 142.0 | 72.9% | 38.5 |
| | | | | |
| All-In-One Total avg. | | 123.5 | 46.7% | 65.9 |
| All-In-One cat 0 | | 91.1 | 46.7% | 48.6 |
| All-In-One category I1 | 59.5 | 111.6 | 46.7% | 59.5 |
| All-In-One category I2 | | 116.6 | 46.7% | 62.2 |
| All-In-One cat I3 | | 134.1 | 46.7% | 71.5 |
| All-In-One cat D1 | | 150.8 | 46.7% | 80.4 |
| All-In-One cat D2 | | 185.4 | 46.7% | 98.9 |
| | | | | |
| Notebook Total avg. | | 27.7 | 62.7% | 10.3 |
| Notebook cat 0 | | 21.0 | 62.7% | 7.8 |
| Notebook category I1 | 8.9 | 23.9 | 62.7% | 8.9 |
| Notebook category I2 | | 29.7 | 62.7% | 11.1 |
| Notebook cat I3 | | 33.3 | 62.7% | 12.4 |
| Notebook cat D1 | | 36.8 | 62.7% | 13.7 |
| Notebook cat D2 | | 77.2 | 62.7% | 28.8 |
| | | | | |
| Thin Client | 22.3 | 42.3 | 47.3% | 22.3 |
| | | | | |
| Integrated Thin Client | 50.2 | 95.4 | 47.3% | 50.2 |
| | | | | |
| Workstation | 41.8 | 268.1 | 84.4% | 41.8 |

The overall 2016 to 2030 ETEC values calculated based on the above assumptions are shown in Table 19. To clarify, the ETEC values were calculated using an array of BAT and average ETEC values. The array is based on the percentage of products assumed to be meeting the BAT and average ETEC values per product category and per product type. The overall average ETEC value for each product type was then calculated using a sales weighted average across each category.

[40] The reduction % for each base case is copied to the remaining product categories under same product type.

*Table 19. Overall ETEC values (excluding active mode energy use) for 2016 to 2030 used in the BAU scenario.*

| Product types and categories | Average ETEC | | | |
|---|---|---|---|---|
| | 2016 | 2020 | 2025 | 2030 |
| Desktop TOTAL | 115.3 | 98.7 | 94.7 | 90.7 |
| Desktop cat 0 | 60.6 | 56.9 | 54.3 | 51.8 |
| Desktop category I1 | 86.9 | 72.5 | 69.3 | 66.0 |
| Desktop category I2 | 96.2 | 79.7 | 76.1 | 72.5 |
| Desktop cat I3 | 108.6 | 91.0 | 86.9 | 82.8 |
| Desktop cat D1 | 140.2 | 119.6 | 114.3 | 108.9 |
| Desktop cat D2 | 155.5 | 133.2 | 127.3 | 121.3 |
| | | | | |
| All-In-One TOTAL | 123.5 | 128.5 | 130.2 | 131.6 |
| All-In-One cat 0 | 91.1 | 87.5 | 85.1 | 82.6 |
| All-In-One category I1 | 111.6 | 107.2 | 104.2 | 101.2 |
| All-In-One category I2 | 116.6 | 112.0 | 108.9 | 105.7 |
| All-In-One cat I3 | 134.1 | 128.8 | 125.2 | 121.6 |
| All-In-One cat D1 | 150.8 | 144.8 | 140.8 | 136.7 |
| All-In-One cat D2 | 185.4 | 178.1 | 173.1 | 168.1 |
| | | | | |
| Notebook TOTAL | 34.6 | 28.1 | 29.0 | 29.9 |
| Notebook Cat 0 | 24.1 | 19.9 | 19.1 | 18.3 |
| Notebook category I1 | 28.8 | 22.7 | 21.8 | 20.9 |
| Notebook category I2 | 29.7 | 28.1 | 27.1 | 26.0 |
| Notebook category I3 | 42.3 | 31.5 | 30.3 | 29.1 |
| Notebook category D1 | 36.8 | 34.8 | 33.5 | 32.2 |
| Notebook category D2 | 98.2 | 73.1 | 70.3 | 67.5 |
| | | | | |
| Thin client | 42.3 | 40.6 | 39.5 | 38.3 |
| | | | | |
| Integrated Thin client | 95.4 | 91.6 | 89.0 | 86.4 |
| | | | | |
| Workstation | 268.1 | 249.0 | 235.9 | 222.9 |

The overall 2016 to 2030 ETEC values calculated based on the above assumptions with active mode energy use included are shown in Table 20. Active mode power demand has been included to allow direct energy use comparisons with other policy options that include requirements on active mode efficiency. Active mode power demand, for all products in the background dataset, is estimated by multiplying short idle values by a pre-defined percentage increase. The pre-defined percentage increase is based on the difference between the measured average active mode and ENERGY STAR short idle power demands in computers tested using the Novabench benchmark. Active mode energy use is calculated by assuming computers spend 20% of their on-time in active modes.

*Table 20. Overall ETEC values (including active mode energy use) for 2016 to 2030 used in the policy option BAU scenario.*

| Product types and categories | Average ETEC | | | |
|---|---|---|---|---|
| | 2016 | 2020 | 2025 | 2030 |
| Desktop TOTAL | 187.7 | 177.8 | 170.2 | 162.5 |
| Desktop cat 0 | 98.7 | 92.4 | 88.0 | 83.7 |
| Desktop category I1 | 141.1 | 132.1 | 125.9 | 119.7 |
| Desktop category I2 | 156.2 | 146.2 | 139.3 | 132.5 |
| Desktop cat I3 | 176.9 | 165.5 | 157.8 | 150.1 |
| Desktop cat D1 | 228.7 | 214.0 | 204.0 | 194.0 |
| Desktop cat D2 | 253.4 | 237.2 | 226.1 | 215.0 |
| | | | | |
| All-In-One TOTAL | 165.1 | 167.3 | 169.2 | 170.8 |
| All-In-One cat 0 | 114.7 | 110.2 | 107.1 | 104.0 |
| All-In-One category I1 | 147.8 | 141.9 | 138.0 | 134.0 |
| All-In-One category I2 | 155.0 | 148.8 | 144.7 | 140.5 |
| All-In-One cat I3 | 176.2 | 169.2 | 164.5 | 159.8 |
| All-In-One cat D1 | 196.5 | 188.8 | 183.5 | 178.2 |
| All-In-One cat D2 | 233.6 | 224.4 | 218.1 | 211.8 |
| | | | | |
| Notebook TOTAL | 79.6 | 77.3 | 82.6 | 87.2 |
| Notebook Cat 0 | 56.3 | 53.0 | 50.8 | 48.5 |
| Notebook category I1 | 66.4 | 62.6 | 59.9 | 57.3 |
| Notebook category I2 | 68.4 | 64.4 | 61.7 | 58.9 |
| Notebook category I3 | 98.7 | 93.0 | 89.0 | 85.1 |
| Notebook category D1 | 83.1 | 78.2 | 74.9 | 71.6 |
| Notebook category D2 | 221.2 | 208.3 | 199.5 | 190.7 |
| | | | | |
| Thin client | 42.3 | 40.6 | 39.5 | 38.3 |
| | | | | |
| Integrated Thin client | 95.4 | 91.6 | 89.0 | 86.4 |
| | | | | |
| Workstation | 268.1 | 249.0 | 235.9 | 222.9 |

The ETEC values shown in Table 20 combined with the stock, gives the total energy consumption of each computer type and category in BAU from 2016 to 2030. The resulting energy use values for each type of computer can be seen in Figure 4 to Figure 8.

As shown in Figure 4, desktop computer future energy use is expected to increase due to increasing sales and a move towards higher specification products (i.e. a shift to I3 and D2 categories). The increased sales refer to the increased demand for Virtual Reality support by game consoles and desktop computers rather than by smart phones and other devices. The annual sales are assumed to only partially recover (from about 12 to 20 million from 2016 to 2026) after a sharp drop of sales from 2011 to 2016[41].

In the other hand, the sharp rise in energy use post 2020 is expected as the current slump in desktop sales abates and returns to growth. This growth is expected, according

[41] See task 2 report, section 2.2.1.2 for further explanations.

to published sources, to be driven by the uptake of new functionalities such as high specification virtual and augmented realities.

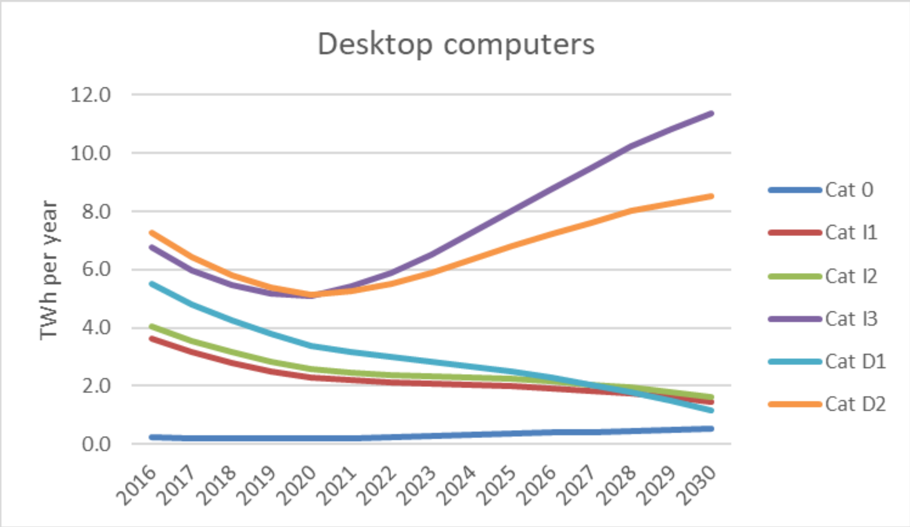


*Figure 4. Energy consumption for EU stock of desktop computers under BAU scenario.*

As illustrated in Figure 5, the future energy use of all-in-one computers is expected to follow a similar pattern as desktop computers. This similarity stems from the assumption that more integrated computers will be sold due to increased demand for Virtual Reality support and that 4% of the desktop market sales are from all-in-ones[42]. The integrated displays used in all-in-one computers will also become more sophisticated in terms of resolution, graphics, etc. in future models. These higher performance displays may also result in increased energy use of all-in-one computers.

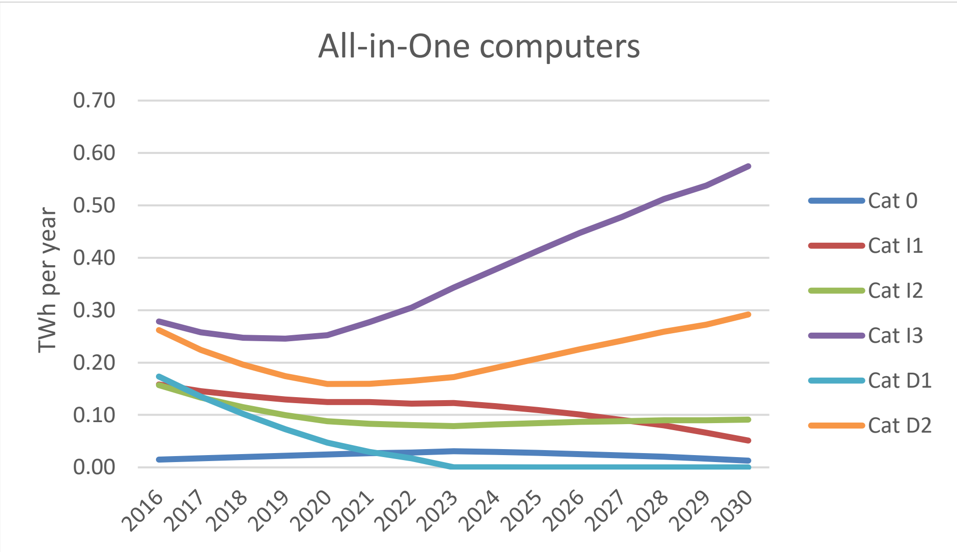


*Figure 5. Energy consumption for EU stock of all-in-one computers under BAU scenario.*

Notebook computer energy use is also expected to increase in the future due to a shift towards higher specification products and increased sales. Figure 6 shows that sales of notebooks meeting the I3 category are expected to dominate in the future as manufacturers move away from lower specification products and products with discrete graphics processing units. The I3 category is used as a proxy for future product types

[42] See Task 2 report, section 2.2.1.3 for further details

and is not intended to reflect the exact technical specification that will be present in future notebook computers.

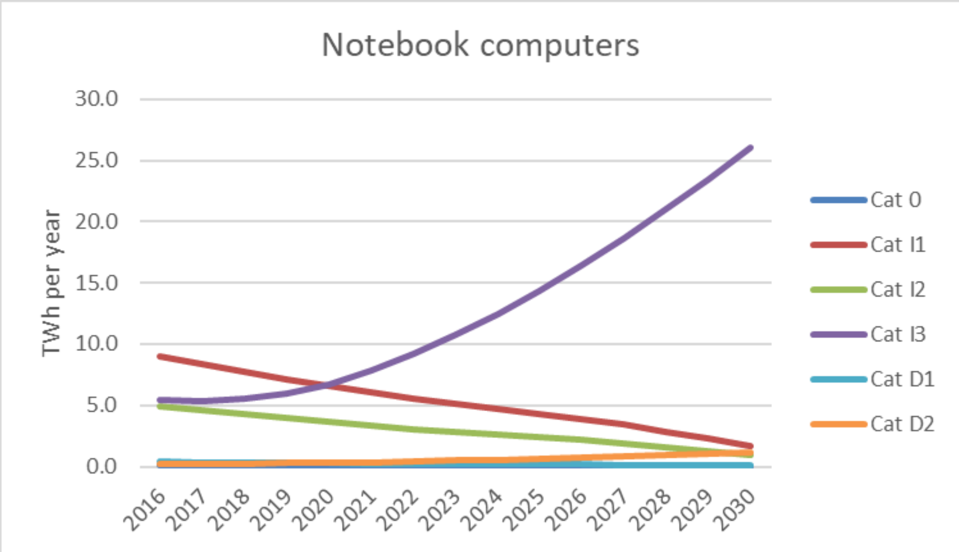



*Figure 6. Energy consumption for EU stock of notebook computers under BAU scenario.*

As shown in Figure 7, thin client energy use is expected to slightly decrease in the future. This is due to a combination of small sales increases coupled with small increases in levels of energy efficiency.

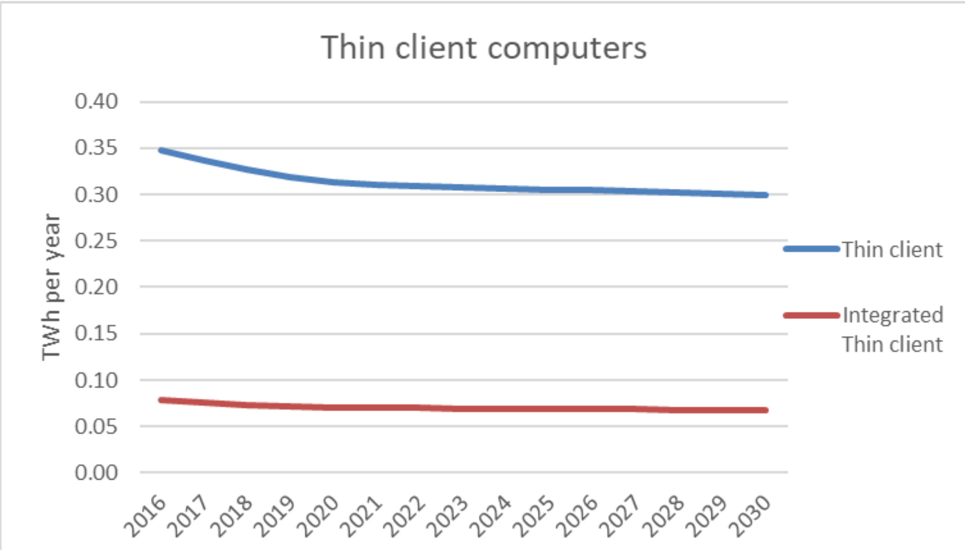



*Figure 7. Energy consumption for EU stock of thin client computers under BAU scenario.*

The future energy use of workstation computers is expected to increase into the future due to increasing sales overcoming increasing efficiency levels.

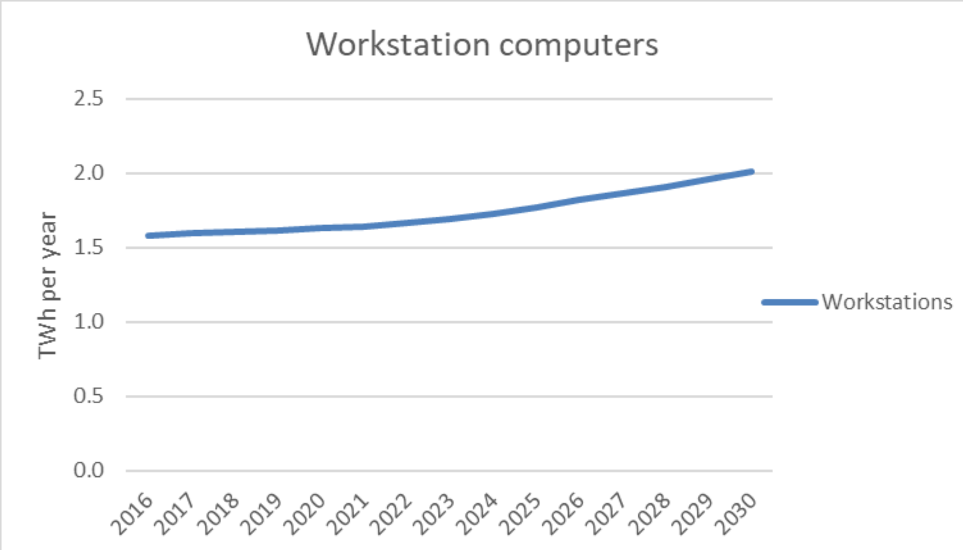



*Figure 8. Energy consumption for EU stock of workstation computers under BAU scenario.*

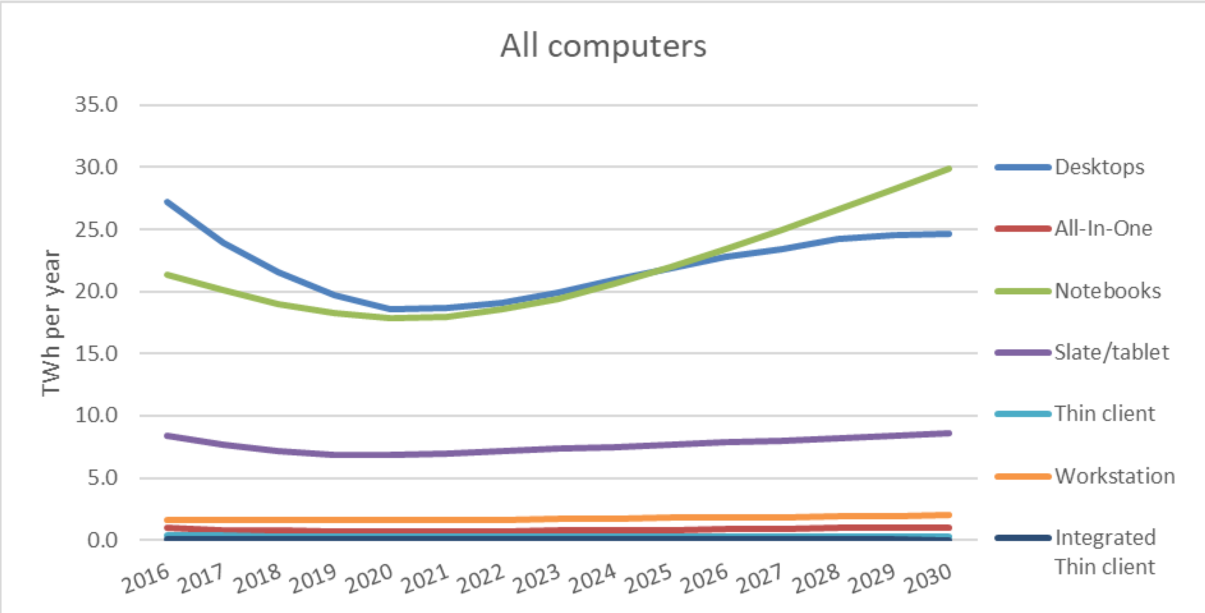



*Figure 9. Energy consumption for EU stock of personal computers under BAU scenario[43].*

The results in Figure 9 show that total energy use varies over time for the different types of computers. The changes are most pronounced for notebooks and desktops which show a decrease in energy use followed by an increase. This rise and fall is primarily due to varying stock levels, brought about by changes in sales, and increases in computational performances over time which cause an increase in active and idle power demands. The changes in sales values are likely to have the overall largest impact on the increase in energy use. The Task 2 report provides additional detail about assumed future sales of personal computers. The sales of desktop type computers were assumed to grow in future as a direct result of new technologies, such as virtual reality, spurring growth. Notebook computer sales are expected to increase due to EU population growth and

[43] Slates/tablets are included for providing overall energy consumption figures though there are no energy efficiency requirements to them.

notebook ownership per capita across the EU raising to similar levels as seen in the United Kingdom[44], where notebook ownership levels are high.

The overall energy use for notebook computers is likely to exceed that of desktop computers by around 2025. This is due to notebook sales being significantly higher than desktop computers, rather than a result of increasing energy use per individual notebook computer. The sales levels of other computers (i.e. other than desktop and notebook computers) are also expected to change overtime which will impact overall energy use. These changes are not as evident in Figure 9 due to the scale of the Y-axis.

In combining the values for the individual types of computer overall computer energy use values for Policy Option 1 were obtained as shown in Figure 10.

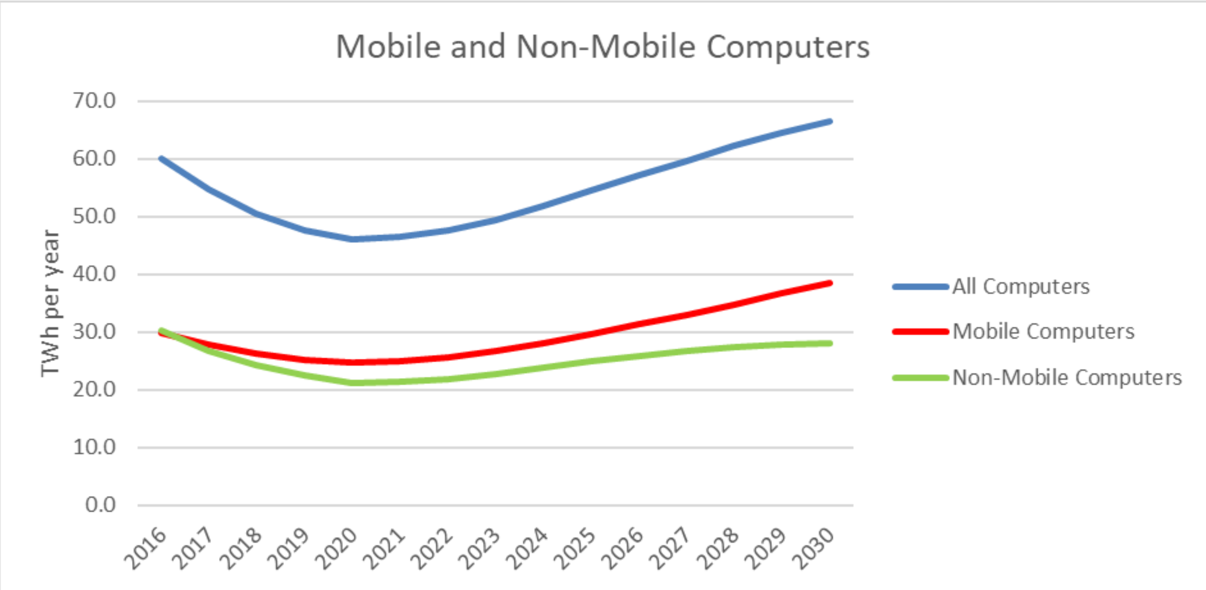



*Figure 10. Energy consumption for EU stock of mobile and non-mobile computers under BAU scenario.*

The overall energy usage from computers under the BAU scenario is shown to increase. It is clear from the results that overall computer energy use is first expected to reduce and then increase into the future. This fluctuation is almost entirely due to a slump in current sales volumes of computers which, according to published sources, is not expected to continue into the future. Despite the fact that the energy efficiency of non-mobile computers is likely to increase over time much of this increased efficiency is driven by environmental initiatives rather than market incentives. It is recognised that energy efficiencies within the mobile computer group will also be driven by concerns over battery lifetime. Despite increases in energy efficiency, energy use is likely to continue to climb due to increasing levels of computational performance and increasing sales. Increased usage of computers could also result in further increases in energy use, but this could be tempered by improvements in power management functionalities. Future work on computer energy use could consider changing usage patterns in more detail in order to refine projections.

[44] Mintel Report, Digital Trends Spring – UK, March 2016 – available for purchase at: http://store.mintel.com/digital-trends-spring-uk-march-2016

#### 7.5.2.2 *Policy Option 2: Ecodesign scenario*

The ecodesign scenario was modelled under the assumption of full implementation in 2020, meaning the average ETEC level for each product category, would reach the requirement levels in 2020 (with improvements being made from 2018 in anticipation of the 2020 implementation date). The average ETEC values were estimated for each product category by considering both the new requirement base allowances and adder allowances. It was assumed that the number of adders applied to products overall would be the same as seen in ENERGY STAR registered computers.

After implementation of the ecodesign regulations, (i.e. from 2020 in the model), the same yearly reduction rate ETEC as in the BAU scenario was assumed but departing from requirement levels, which was around 0.5-1% per year for all product types.

The Total ETEC (per product type) is based on the ETEC values and market share for each category, calculated on an annual basis.

The calculated ETEC values used in the ecodesign scenario (PO2), can be seen in Table 21.

*Table 21. Overall ETEC values for 2016 to 2030 used in the policy option 2 scenario.*

| Product types and categories | Average ETEC | | | |
|---|---|---|---|---|
| | 2016 | 2020 | 2025 | 2030 |
| Desktop TOTAL | 187.7 | 134.6 | 128.3 | 122.1 |
| Desktop cat 0 | 98.7 | 49.1 | 47.5 | 45.9 |
| Desktop category I1 | 141.1 | 97.0 | 93.1 | 89.1 |
| Desktop category I2 | 156.2 | 113.4 | 108.6 | 103.8 |
| Desktop cat I3 | 176.9 | 118.1 | 113.3 | 108.6 |
| Desktop cat D1 | 228.7 | 171.0 | 163.7 | 156.4 |
| Desktop cat D2 | 253.4 | 188.6 | 180.5 | 172.5 |
| | | | | |
| All-in-One TOTAL | 165.1 | 141.4 | 144.6 | 147.4 |
| All-in-One cat 0 | 114.7 | 86.5 | 84.9 | 83.3 |
| All-in-One category I1 | 147.8 | 117.4 | 115.0 | 112.6 |
| All-in-One category I2 | 155.0 | 128.9 | 126.0 | 123.0 |
| All-in-One cat I3 | 176.2 | 139.3 | 136.5 | 133.6 |
| All-in-One cat D1 | 196.5 | 173.2 | 168.9 | 164.6 |
| All-in-One cat D2 | 233.6 | 203.0 | 198.0 | 193.1 |
| | | | | |
| Notebook TOTAL | 79.6 | 56.8 | 56.8 | 57.0 |
| Notebook Cat 0 | 56.3 | 43.7 | 42.1 | 40.4 |
| Notebook category I1 | 66.4 | 53.9 | 51.8 | 49.7 |
| Notebook category I2 | 68.4 | 52.4 | 50.5 | 48.5 |
| Notebook category I3 | 98.7 | 59.0 | 57.2 | 55.4 |
| Notebook category D1 | 83.1 | 78.2 | 74.9 | 71.6 |
| Notebook category D2 | 221.2 | 143.8 | 139.1 | 134.3 |
| | | | | |
| Thin client | 42.3 | 40.6 | 39.5 | 38.3 |
| | | | | |
| Integrated Thin client | 95.4 | 91.6 | 89.0 | 86.4 |
| | | | | |

Combined with the same stock model as the BAU scenario, the ETEC values in PO2 (average energy use from a single model within each product type) gives the total energy consumption for each product type and category as shown in Figure 11 to Figure 13.

Figure 11 shows that overall energy consumption from each type of desktop computer under the PO2 scenario. Even under the PO2 scenario desktop computer energy use is expected to increase due to increasing sales and a move towards higher specification products (i.e. a shift to I3 and D2 categories). The rise in energy use post 2020 is expected as the current slump in desktop sales abates and returns to growth. This growth is expected, according to published sources, to be driven by the uptake of new functionalities such as high specification virtual and augmented realities.

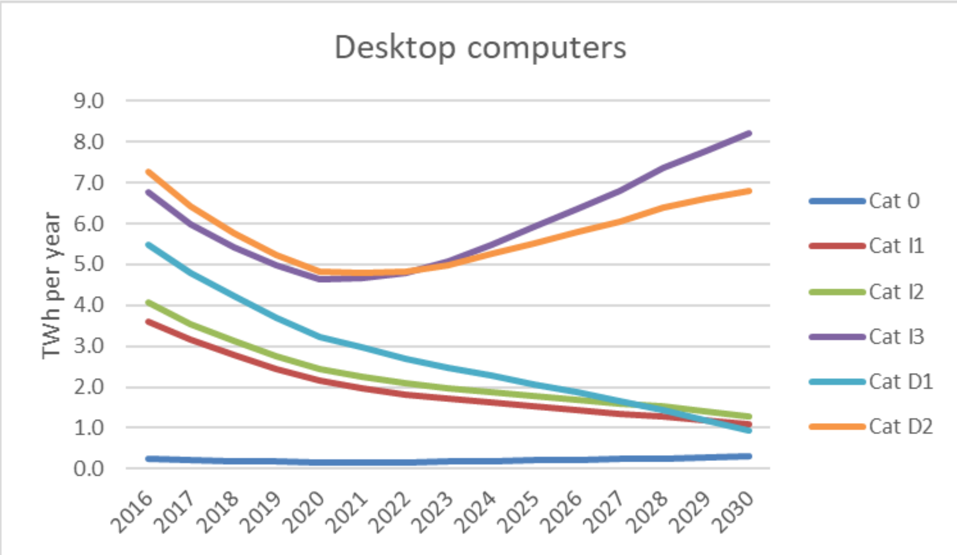



*Figure 11. Energy consumption for EU stock of desktop computers under PO2 scenario.*

As illustrated in Figure 12, all-in-one computer energy use is expected to follow a similar pattern as desktop computers under the PO2 scenario, with increasing energy use coming from increased sales and moves towards higher specification products.

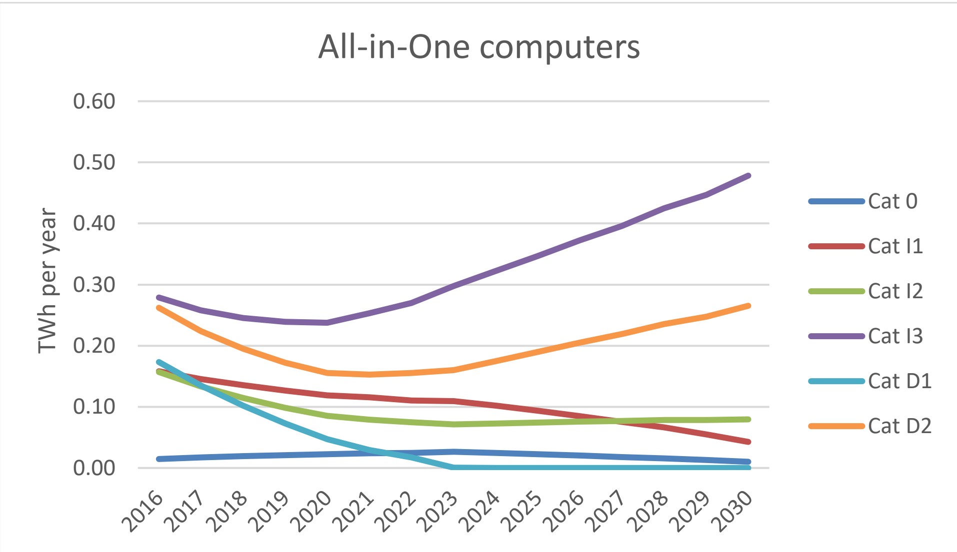



*Figure 12. Energy consumption for EU stock of all-in-one computers under PO2 scenario.*

Under the PO2 scenario, notebook computer energy use is expected to increase in the future due to a shift towards higher specification products and increased sales. Figure 13 shows that sales of notebooks meeting the I3 category are expected to dominate in the future as manufacturers move away from lower specification products and products with discrete graphics processing units. The I3 category is used as a proxy for future product types and is not intended to reflect the exact technical specification that will be present in future notebook computers.

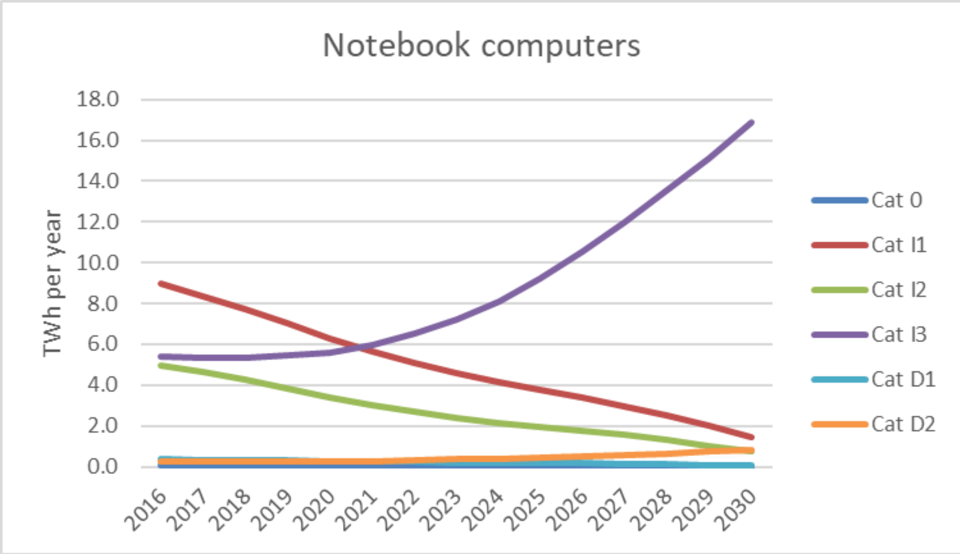



*Figure 13. Energy consumption for EU stock of notebook computers under PO2 scenario.*

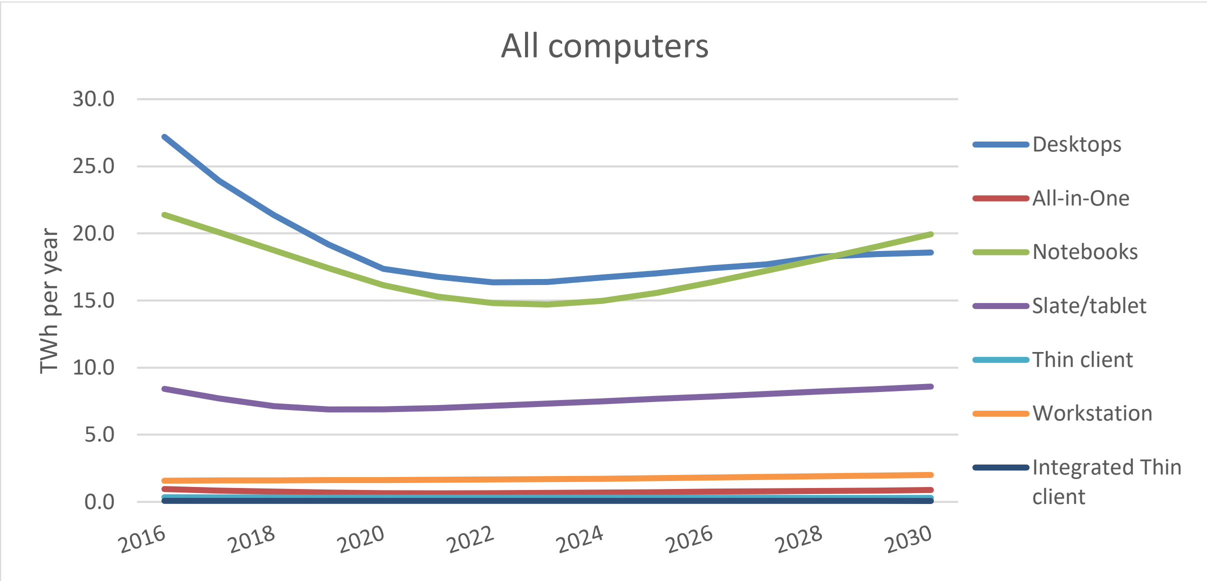



*Figure 14. Energy consumption for EU stock of personal computers under PO2 scenario.*

The results in Figure 14 show that total energy use varies over time for the different types of computers. Figure 14 shows that desktop and notebook computer energy use dominate overall computer energy use under the PO2 scenario. Again, under the PO2 scenario the changes are most pronounced for notebooks and desktops which show a decrease in energy use followed by an increase. This rise and fall is primarily due to varying stock levels, brought about by changes in sales, and increases in computational performances over time, which cause an increase in active and idle power demands. The total sales values are expected to stay the same under the PO2 scenario compared to the BAU scenario.

In combining the values for the individual types of computer overall computer energy use results for Policy Option 2 were obtained as shown in Figure 15.

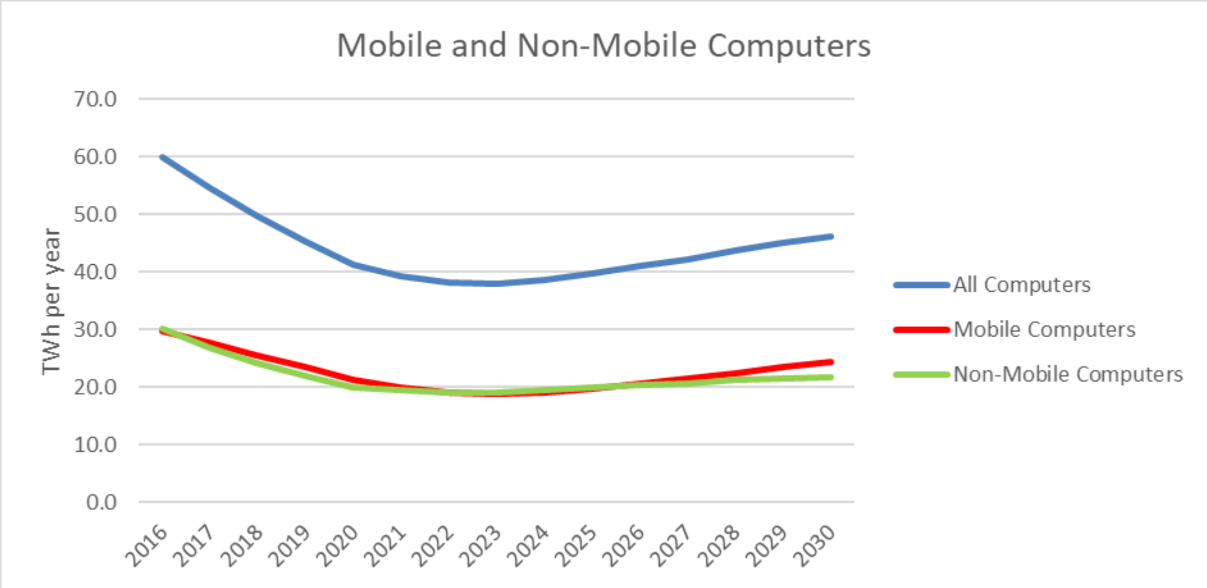



*Figure 15. Energy consumption for EU stock of mobile and non-mobile computers under* PO2 *scenario.*

When comparing the results shown in Figure 15 with those in Figure 10, the growth in energy use appears much reduced from that seen in the BAU scenario (illustrated in Figure 10). This suggests that the introduction of the proposed ecodesign regulation requirements will likely help to significantly reduce the overall increase in computers energy use. However, overall energy use is still expected to continue its rise notwithstanding the mitigation provided by the revised ecodesign regulations, and the consequent average increase in efficiency at the individual product level, because of increased sales and higher average computational performance.

#### 7.5.2.3 *Policy Option 3: Ecodesign and energy label scenario (including active mode considerations)*

The ecodesign and energy label scenario was modelled under the assumption that revised ecodesign regulations would be implemented in conjunction with the Energy Label coming into force during 2022. As such, the average ETEC level for each product type and category remains the same as in the Policy Option 1 model until 2020 after which it diverges as manufacturers alter products in anticipation of the ecodesign and Energy Label implementation in 2022.

The average ETEC level for each product type and category have been amended from the BAU scenario and Policy Option 2 scenario to include consideration of energy labelling including requirements on active mode energy efficiency.

A baseline was derived by assessing product distributions of Energy Label classes within a recent version of the ENERGY STAR database. The distribution of products amongst the Energy labelling classes is expected to change over time reflecting increased energy efficiency in all covered computers. The implementation of the Energy Label is expected to be accompanied by a fast increase in product energy efficiency as manufacturers attempt to ensure products are not labelled at the lower end of the Energy Label classes (i.e. Classes E-G). The move towards higher energy classes is expected to continue to 2030 as manufacturers continue to compete to have products labelled in the higher end of the Energy Label classes (i.e. A to C).

The assumed distributions can be seen in Table 22. The distribution of Energy Label classes between the 2016 benchmark data and 2030 is based on a straight-line interpolation.

The distribution of the classes is proposed to be further assessed and revised in the forthcoming impact assessment on computers aiming at having a rescaling approximately 10 years after the effective date of the label requirements.

*Table 22. Computer energy label class distribution by 2030 under Policy Option 3.*

| | | Distribution of label classes | | |
|---|---|---|---|---|
| Product Type | Energy Label Class | 2022 | 2025 | 2030 |
| Desktop | A | 0% | 3% | 5% |
| | B | 0% | 5% | 10% |
| | C | 22% | 26% | 30% |
| | D | 22% | 26% | 30% |
| | E | 13% | 14% | 15% |
| | F | 18% | 14% | 10% |
| | G | 25% | 12% | 0% |
| All-in-One | A | 0% | 2% | 5% |
| | B | 0% | 5% | 10% |
| | C | 15% | 22% | 30% |
| | D | 27% | 28% | 30% |
| | E | 19% | 17% | 15% |
| | F | 20% | 15% | 10% |
| | G | 19% | 10% | 0% |
| Notebook | A | 0% | 8% | 15% |
| | B | 0% | 11% | 20% |
| | C | 13% | 17% | 20% |
| | D | 25% | 25% | 25% |
| | E | 20% | 17% | 15% |
| | F | 22% | 13% | 5% |
| | G | 21% | 9% | 0% |

The Total ETEC (per product type) is based on the ETEC values and market share for each Energy Label class, calculated on an annual basis. The calculated ETEC values used in the ecodesign scenario (PO3), can be seen in Table 23. The "Fail" category represents products that do not meet the proposed ecodesign requirements.

*Table 23. Overall ETEC values for 2016 to 2030 used in the Policy Option 3 scenario.*

| **Product types and categories** | **Average ETEC** | | | |
|---|---|---|---|---|
| | **2016** | **2020** | **2025** | **2030** |
| Desktop TOTAL | 187.7 | 168.2 | 93.2 | 77.2 |
| Class A | 16.5 | 16.5 | 16.5 | 16.5 |
| Class B | 35.2 | 35.2 | 35.2 | 35.2 |
| Class C | 50.5 | 50.5 | 50.5 | 50.5 |
| Class D | 94.0 | 94.0 | 94.0 | 94.0 |

| Product types and categories | Average ETEC | | | |
|---|---|---|---|---|
| | 2016 | 2020 | 2025 | 2030 |
| Class E | 110.1 | 110.1 | 110.1 | 110.1 |
| Class F | 129.9 | 129.9 | 129.9 | 129.9 |
| Class G | 165.3 | 165.3 | 165.3 | 165.3 |
| Fail | 226.1 | 226.1 | n/a | n/a |
| All-in-One TOTAL | 165.1 | 149.6 | 103.7 | 86.2 |
| Class A | 17.7 | 17.7 | 17.7 | 17.7 |
| Class B | 35.5 | 35.5 | 35.5 | 35.5 |
| Class C | 63.5 | 63.5 | 63.5 | 63.5 |
| Class D | 99.0 | 99.0 | 99.0 | 99.0 |
| Class E | 125.1 | 125.1 | 125.1 | 125.1 |
| Class F | 142.0 | 142.0 | 142.0 | 142.0 |
| Class G | 161.4 | 161.4 | 161.4 | 161.4 |
| Fail | 208.6 | 208.6 | n/a | n/a |
| Notebook TOTAL | 79.6 | 78.1 | 40.3 | 31.2 |
| Class A | 7.4 | 7.4 | 7.4 | 7.4 |
| Class B | 14.8 | 14.8 | 14.8 | 14.8 |
| Class C | 25.6 | 25.6 | 25.6 | 25.6 |
| Class D | 46.1 | 46.1 | 46.1 | 46.1 |
| Class E | 50.9 | 50.9 | 50.9 | 50.9 |
| Class F | 58.3 | 58.3 | 58.3 | 58.3 |
| Class G | 65.4 | 65.4 | 65.4 | 65.4 |
| Fail | 108.2 | 108.2 | n/a | n/a |
| Thin client | 42.3 | 40.6 | 39.5 | 38.3 |
| Integrated Thin client | 95.4 | 91.6 | 89.0 | 86.4 |
| Workstation | 268.1 | 249.0 | 235.9 | 222.9 |

Combined with the same stock model as the BAU scenario, the ETEC values (average energy use per single model of each product type) in PO3 gives the total energy consumption for each product type and category as shown in Figure 16 to Figure 18.

Figure 16 illustrates that, under the PO3 scenario, total energy use of notebook and desktop computers will reduce significantly into the future. This reduction is entirely due to increased product efficiency stemming from the PO3 proposed requirements.

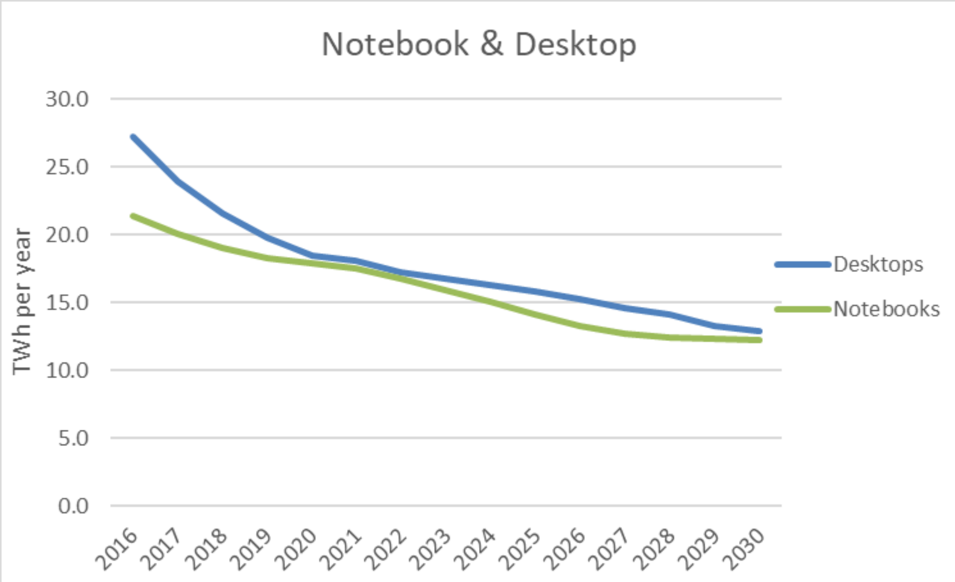



*Figure 16. Energy consumption for EU stock of desktop and notebook computers under* PO3 *scenario.*

Figure 17 provides confirmation of the reduced energy use of notebook and desktop computers under the PO3 scenario. The figure also shows that energy use from slates/tablets may increase as a result of increasing sales and increased technical functionality.

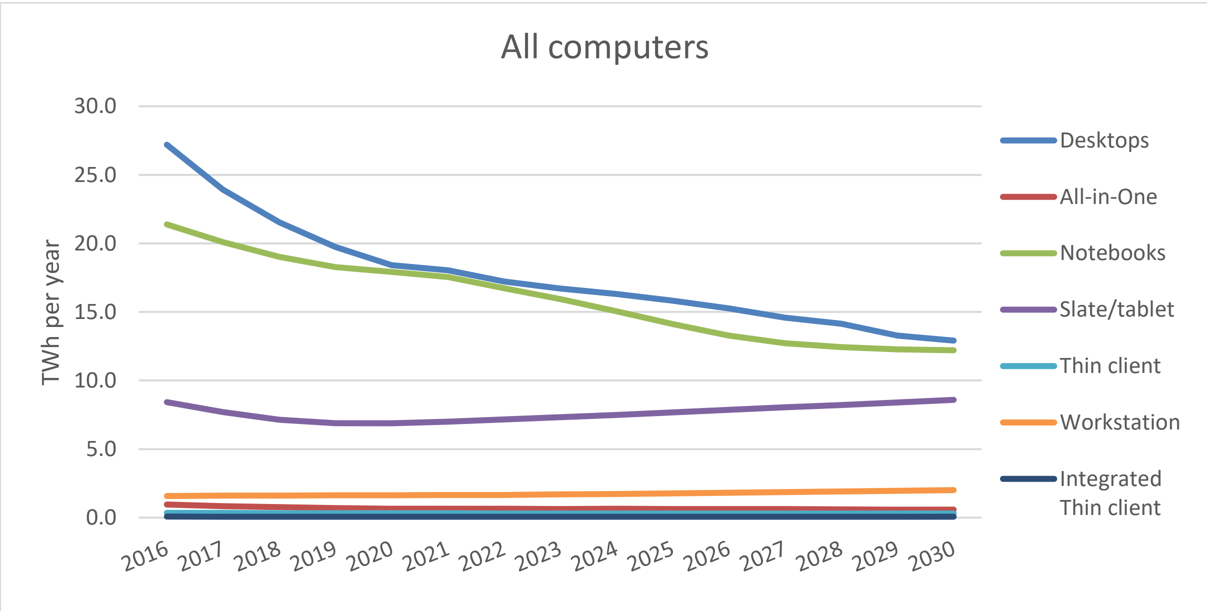



*Figure 17. Energy consumption for EU stock of personal computers under* PO3 *scenario*[45].

Figure 18 illustrates that, under the PO3 scenario, total computer energy use will reduce significantly into the future. This reduction is almost entirely attributable to the proposed PO3 efficiency requirements.

[45] Slates/tablets are included for providing overall energy consumption figures though there are no energy efficiency requirements to them.

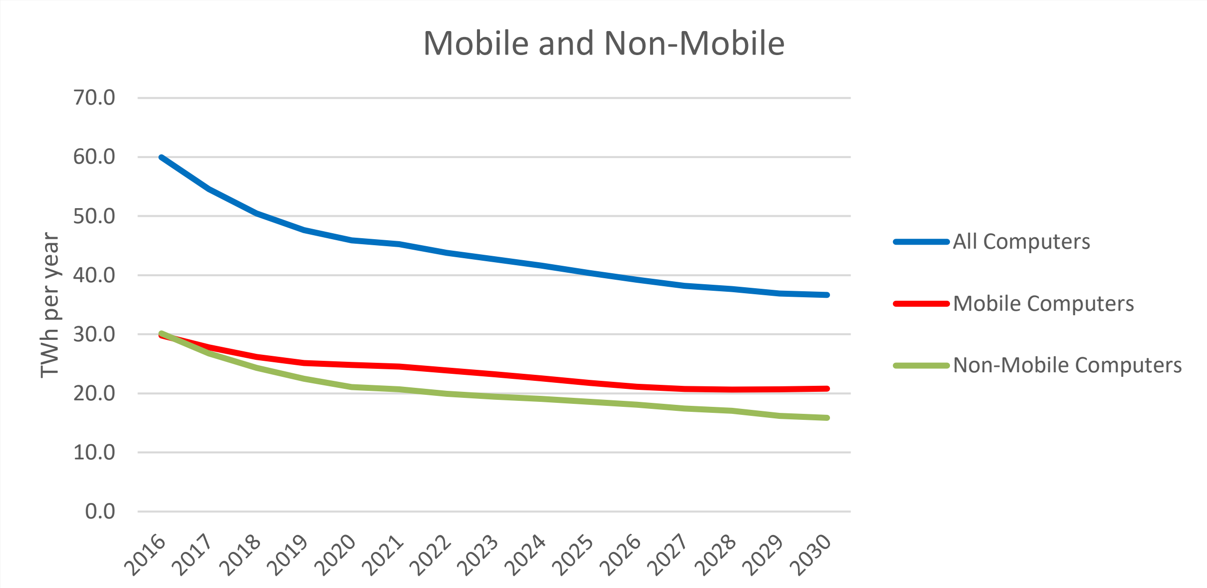



*Figure 18. Total energy use by mobile and non-mobile computers under Policy Option 3.*

#### 7.5.2.4 ***Overview of policy options: energy consumption and potential energy savings***

In comparing the three policy options, Figure 19,

Figure *20* and

Figure 21 show the overall computer energy consumptions under each of the three scenarios. It is clear that Policy Option 2 (i.e. implementation of revised ecodesign requirements) will provide significant savings but energy use will resume climbing. Under Policy Option 3 it is clear that energy use continues to fall until 2030. The estimated savings from the energy label (as included in Policy Option 3) are expected to increase into the future driven primarily by manufacturers attempting to meet ambitious top Energy label classes.

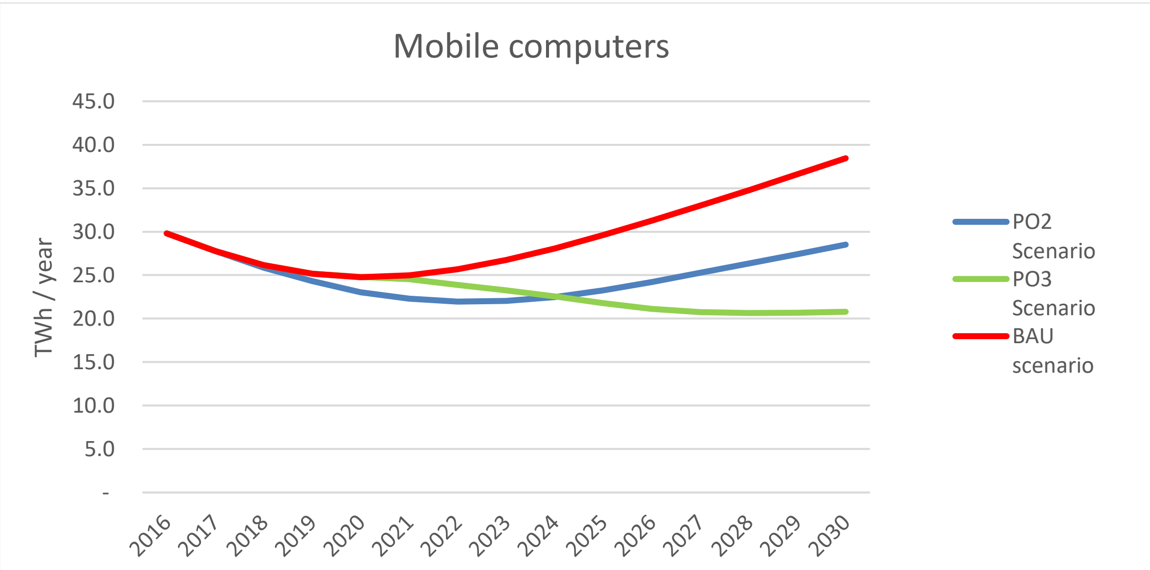



*Figure 19. Energy consumption for EU stock of mobile computers under all policy options.*

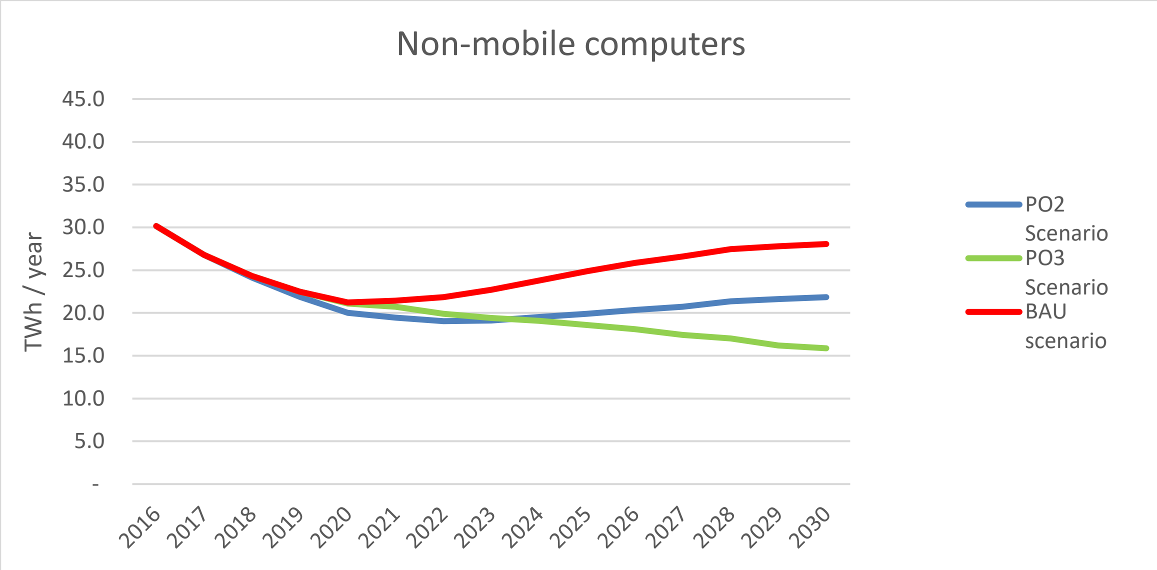



*Figure 20. Energy consumption for EU stock of non-mobile computers under all policy options.*

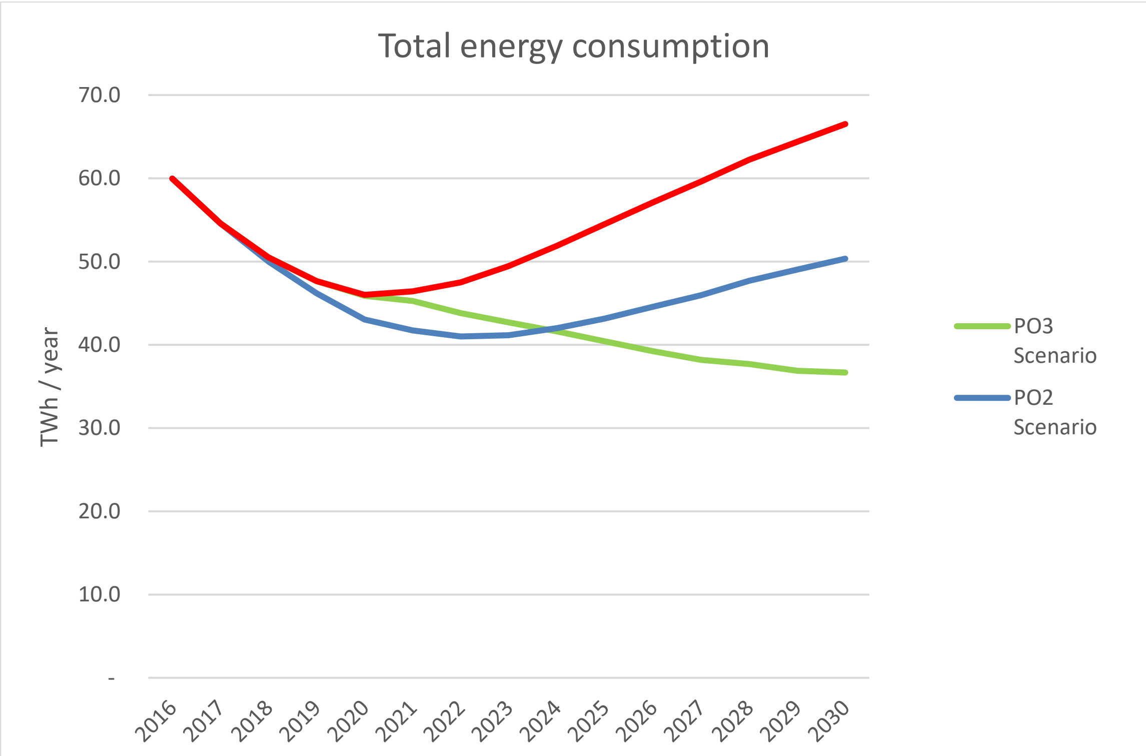



*Figure 21. Energy consumption for EU stock of personal computers under all policy options.*

Figure 21 and Table 24 shows the expected overall computer energy use associated with each policy option for selected years. The results show that adoption of either the Policy Option 2 or Policy Option 3 would result in significant savings. Savings from Policy Option 2 would be achieved more quickly than under Policy Option 3 due to the earlier implementation of the Ecodesign measures. However, the combination of Ecodesign and EU Energy labelling under Policy Option 3 would result in greater overall savings.

*Table 24. Total Computer Energy Use under each policy scenario (selected years).*

| Scenario | Total Computer Energy Use (TWh/year) 2016 | 2020 | 2025 | 2030 |
|---|---|---|---|---|
| BAU | 60.0 | 46.0 | 54.5 | 66.5 |
| PO2 | 60.0 | 43.0 | 43.2 | 50.4 |
| PO3 | 60.0 | 45.9 | 40.4 | 36.7 |

#### 7.5.2.5 *Conclusions*

The task 7 scenario analyses report the estimated impacts from amending the ecodesign requirements and implementing energy labelling requirements which are the overall potential energy savings. The results of the scenario analysis show that overall computer energy use could increase from an estimated 60.0 TWh/year in 2016 to 66.5 TWh/year by 2030 without policy intervention.

The development of an EU energy label on computers is likely to drive greater savings and for a longer period of time as the A to G class system drives manufacturer competition and results in enhanced computer energy efficiency.

A revised ecodesign regulation on computers alone would have the potential to save approximately 11.3 TWh/year by 2025 rising to 16.2 TWh/year by 2030 compared to a no further action.

A combination of a revised ecodesign regulation along with the development of an EU Energy Label on computers could result in savings of 14.1TWh/year by 2025 rising to 29.9 TWh/year by 2030 compared to no further action.

Table 25 shows the potential annual energy savings up to 2030 for the two policy options that present policy action (PO2 and PO3), in relation to that with no action (BAU).

*Table 25. Total savings for each policy scenario (selected years).*

| Scenario | Energy Use Savings (TWh/year) 2020 | 2025 | 2030 |
|---|---|---|---|
| PO2 | 2.9 | 11.3 | 16.2 |
| PO3 | 0.1 | 14.1 | 29.9 |

### 7.5.3 $CO_2$ emissions from energy efficiency policy measures

The $CO_2$ emissions derived from the energy efficiency policy measures have been quantified, and potential savings from the implementation of the two energy efficiency policy measures have been identified. This has been done for each computer type under each policy scenario.

The energy consumption under Policy Option 1 (BAU), PO2 (Ecodesign) and PO3 (Ecodesign and Energy Label) presented in previous section (7.5.2) have been the basis to calculate the $CO_2$ emissions. A $CO_2$ emission factor was taken from a recent study from Moro and Lonza, 2017[46]. This is the most up-to-date study doing a thorough

[46] Moro, A., Transp4ortation Research Part D (2017), http://dx.doi.org/10.1016/j.trd.2017.07.012

analysis of the electricity production in each Member State of the EU28 including upstream emissions from fuel production and combustion emissions.

The EU-28 $CO_2$ emissions for electricity production was 407 grams $CO_2$ per kWh based on the electricity production in 2013 from data published by the International Energy Agency[47]. The European Commission completed a study in 2013 to predict $CO_2$ emissions from electricity in the EU28 to 2050 and a value of similar magnitude was calculated in that study[48].

For each scenario, including BAU, this $CO_2$ emission factor was applied to the energy consumption values for each year from 2016 to 2030 for each computer type.

The calculated $CO_2$ emission values for the different computer types for each scenario can be seen in Table 26.

*Table 26. CO2 emissions for each computer type in each scenario for different years.*

| **Computer type** | **$CO_2$ emissions per year (million tonnes)** | | | |
|---|---|---|---|---|
| | | **2020** | **2025** | **2030** |
| Desktop computers | BAU | 7.5 | 8.9 | 10.0 |
| | PO2 | 7.1 | 6.9 | 7.6 |
| | PO3 | 7.5 | 6.4 | 5.3 |
| All-in-One computers | BAU | 0.3 | 0.3 | 0.4 |
| | PO2 | 0.3 | 0.3 | 0.4 |
| | PO3 | 0.3 | 0.3 | 0.2 |
| Notebook computers | BAU | 7.3 | 8.9 | 12.2 |
| | PO2 | 6.6 | 6.3 | 8.1 |
| | PO3 | 7.3 | 5.7 | 5.0 |
| Thin client computers | BAU | 0.1 | 0.1 | 0.1 |
| | PO2 | 0.1 | 0.1 | 0.1 |
| | PO3 | 0.1 | 0.1 | 0.1 |
| Integrated thin client computers | BAU | 0.03 | 0.03 | 0.03 |
| | PO2 | 0.03 | 0.03 | 0.03 |
| | PO3 | 0.03 | 0.03 | 0.03 |
| Workstation computers | BAU | 0.66 | 0.72 | 0.82 |
| | PO2 | 0.66 | 0.72 | 0.82 |
| | PO3 | 0.66 | 0.72 | 0.82 |
| **Total** | **BAU** | **18.7** | **22.2** | **27.1** |
| | **PO2** | **17.5** | **17.6** | **20.5** |
| | **PO3** | **18.7** | **16.4** | **14.9** |

Desktop and notebook computers show the highest current and expected $CO_2$ emissions up to 2030 due to high energy consumption (desktop) and large sales (notebook). Following the trend of energy consumption, policy option 2 presents earlier reductions as

[47] https://www.iea.org/
[48] European Commission (2014) EU Energy, Transport and GHG Emissions, Trends to 2050, reference scenario 2013. http://www.ehpa.org/media/studies-reports/eu-studies-and-reports/?eID=dam_frontend_push&docID=1762

it is implemented before, but in 2030 it is policy option 3 which gives the highest reductions.

The calculated $CO_2$ emission savings for scenarios PO2 and PO3 from the BAU scenario can be seen in Table 27.

Desktop and notebook computers show the highest $CO_2$ savings. Policy option 2 provides earlier savings but it is policy option 3 which shows the largest emissions savings.

*Table 27. $CO_2$ emission savings for each computer type in each scenario for selected years.*

| Computer type | $CO_2$ emission savings per year (million tonnes) | | | |
|---|---|---|---|---|
| | | 2020 | 2025 | 2030 |
| Desktop computers | PO2 | 0.5 | 2.0 | 2.5 |
| | PO3 | 0.1 | 2.5 | 4.8 |
| All-in-One computers | PO2 | 0.0 | 0.0 | 0.1 |
| | PO3 | 0.0 | 0.1 | 0.2 |
| Notebook computers | PO2 | 0.7 | 2.6 | 4.0 |
| | PO3 | 0.0 | 3.2 | 7.2 |
| **TOTAL** | **PO2** | **1.2** | **4.6** | **6.6** |
| | **PO3** | **0.0** | **5.7** | **12.2** |

### 7.5.4 Monetary costs from energy efficiency policy measures

The total consumer expenses are related to the purchasing, operation, repair and maintenance, upgrades and disposal of the personal computers in the scope of the study. Repair, maintenance, upgrades and disposal costs are assumed to be the same for the three policy measures (BAU, PO2 and PO3). Installation costs are assumed to be negligible for all computer types in scope.

#### 7.5.4.1 *Purchase costs*

The purchase costs for each type of computer in scope, shown in Table 28, were based on product price data collected via online research. Average prices were established by expert interpolation of the low-end and high-end products.

The purchase prices of domestic and non-domestic computers were assumed to be the same. This is due to the fact that many models of computers are used in both domestic and non-domestic premises.

No changes were assumed for purchase prices over the years 2016 to 2030. This was due to the complexities surrounding computer purchase prices. Computer prices fall overtime for a given level of computational performance, but as performance levels increase prices may still fall, remain static or increase.

*Table 28. Personal computer purchase prices.*

| Computer Purchase Costs | |
|---|---|
| **Computer Type** | **All Years** |
| Desktop | €739 |
| All-In-One | €790 |
| Notebook | €1,019 |
| Thin client | €601 |
| Integrated Thin client | €470 |
| Workstation | €2,661 |

Additional costs were added to products in the Policy Option 2 and Policy Option 3 analysis to account for costs required to improve energy efficiency.

Under the Policy option 2 analysis the additional costs were added to the percentage of products that were expected to be non-compliant with the Ecodesign requirements. The costs were added from 2018 through to 2022. The costs were added from 2018 to reflect a situation where manufacturers make changes two years ahead of the Ecodesign regulation coming into force. The adaptation costs were assumed to end by 2022 as more efficient components quickly reach price parity due to increased demand. The estimated average adaptation costs under Policy Option 2 can be seen in Table 29.

*Table 29. Average Adaptation Costs under Policy Option 2.*

| Average Adaptation Costs: Policy Option 2 | | | | | |
|---|---|---|---|---|---|
| **Computer Type** | **2018** | **2019** | **2020** | **2021** | **2022** |
| Desktop | € 4.68 | € 9.35 | € 14.03 | € 9.35 | € 4.68 |
| All-In-One | € 3.11 | € 6.22 | € 9.33 | € 6.22 | € 3.11 |
| Notebook | € 0.54 | € 1.09 | € 1.63 | € 1.09 | € 0.54 |
| Thin client | € - | € - | € - | € - | € - |
| Integrated Thin client | € - | € - | € - | € - | € - |
| Workstation | € - | € - | € - | € - | € - |

A similar approach was used to assess costs from the Policy Option 3 option. Additional costs were first added to the percentage of products that were expected to be non-compliant with the Ecodesign requirements. These costs were again assumed to commence two years ahead of the Ecodesign requirements being implemented (2020). Further costs were added to reflect continued product changes due to manufacturer efforts to meet the EU Energy Label classes A, B or C. The estimated average adaptation costs under Policy Option 3 can be seen in Table 30.

*Table 30. Average Adaptation Costs under Policy Option 3.*

| Average Adaptation Costs (€): Policy Option 3 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Computer Type** | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Desktop | 4.68 | 9.35 | 14.03 | 9.72 | 5.05 | 1.11 | 0.95 | 0.82 | 0.72 | 0.63 | 0.56 |
| All-In-One | 3.11 | 6.22 | 9.33 | 6.55 | 3.44 | 0.99 | 0.85 | 0.73 | 0.64 | 0.56 | 0.50 |
| Notebook | 0.54 | 1.09 | 1.63 | 1.10 | 0.56 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.02 |
| Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Integrated Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Workstation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

#### 7.5.4.2 *Upgrade costs*

Whilst most personal computers are not upgraded during their lifetimes, the abundance of retailers selling upgradable components suggests that at least some upgrading does take place.

The costs for upgrading, as shown in Table 31, are based on sales prices (N.B. identified through web-based research) of commonly upgradable components and assumed upgrade rates for each. The most commonly upgraded components were assumed to be:

- RAM
- Storage
- GPU
- Battery replacement
- CPU

Upgrade costs were assumed to be consistent across the domestic and non-domestic markets for all computer types apart from notebook computers. It was assumed that non-domestic notebook computers would be upgraded more often due to restrictions on purchasing new products.

*Table 31. Personal computer upgrade costs.*

| Computer Upgrade Costs | | |
|---|---|---|
| **Computer Type** | **Domestic** | **Non-Domestic** |
| | **All Years** | **All Years** |
| Desktop | € 96.75 | € 96.75 |
| All-In-One | € - | € - |
| Notebook | € 37.88 | € 63.13 |
| Thin client | € - | € - |
| Integrated Thin client | € - | € - |
| Workstation | € - | € 195.30 |

#### 7.5.4.3 *Repair and Maintenance costs*

Personal computers may require both physical and software repairs during their lifetimes. The figures in Table 32 show significant variation between costs for personal computers used in domestic and non-domestic premises. This variation occurs due to the fact that many personal computers used in non-domestic premises are managed by third parties, which involves additional costs.

The costs for domestic personal computers are based on published data covering:

- Extended warranty costs
- Purchase rates of extended warranties
- Costs for repairing key components
- Repair rates of key components

The costs for non-domestic personal computers are based on published computer maintenance contract costs over the expected lifetime of each type of computer.

*Table 32. Personal computer Repair and Maintenance Costs.*

| Computer Repair and Maintenance Costs | | |
|---|---|---|
| Computer Type | Domestic | Non-Domestic |
| | All Years | All Years |
| Desktop | € 160.36 | € 760.53 |
| All-In-One | € 162.35 | € 760.53 |
| Notebook | € 152.88 | € 633.78 |
| Thin client | € 130.44 | € 633.78 |
| Integrated Thin client | € 130.44 | € 633.78 |
| Workstation | € - | € 887.29 |

#### 7.5.4.4 *End of life costs*

It is assumed that, due to requirements placed on manufacturers and suppliers under the WEEE Directive, there are no end of life costs for domestic computers. End of life costs for non-domestic computers are shown in Table 33.

*Table 33. Personal computer End of life costs.*

| Computer End of Life Costs | |
|---|---|
| Computer Type | Non-Domestic |
| | All Years |
| Desktop | € 21.00 |
| All-In-One | € 21.00 |
| Notebook | € 14.70 |
| Thin client | € 21.00 |
| Integrated Thin client | € 21.00 |
| Workstation | € 21.00 |

#### 7.5.4.5 *Electricity Running Costs*

The electricity running costs of personal computers are calculated by multiplying the expected energy use under each policy scenario by average EU electricity prices. Electricity running costs are calculated separately for domestic and non-domestic computers due to different kilowatt hour costs.

The electricity running costs of personal computers in stock within domestic and non-domestic premises are shown in Table 34 (domestic) and Table 35 (non-domestic). The results in Table 36 show the total combined electricity running costs for all computers in stock (domestic and non-domestic) for each of the three policy options.

*Table 34. Personal computer Electricity Running Costs (Domestic).*

| Domestic Computer Electricity Running Costs (All products in stock) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Computer Type | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 1.7 | 1.1 | 1.2 | 1.4 | 1.7 | 1.0 | 0.9 | 1.0 | 1.7 | 1.0 | 0.9 | 0.7 |
| All-In-One | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Notebook | 2.9 | 2.4 | 2.9 | 4.0 | 2.9 | 2.1 | 2.1 | 2.6 | 2.9 | 2.4 | 1.9 | 1.6 |
| Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Integrated Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | | | | | |
| All | 6.2 | 4.8 | 5.5 | 7.0 | 6.2 | 4.4 | 4.4 | 5.2 | 6.2 | 4.7 | 4.2 | 3.9 |

*Table 35. Personal computer Electricity Running Costs (Non-Domestic).*

| Non-Domestic Computer Electricity Running Costs (All products in stock) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Computer Type | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 2.2 | 1.5 | 1.8 | 2.0 | 2.2 | 1.4 | 1.4 | 1.5 | 2.2 | 1.5 | 1.3 | 1.1 |
| All-In-One | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Notebook | 0.8 | 0.7 | 0.9 | 1.2 | 0.8 | 0.6 | 0.6 | 0.8 | 0.8 | 0.7 | 0.6 | 0.5 |
| Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Integrated Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Workstation | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| All | 3.4 | 2.6 | 3.1 | 3.7 | 3.4 | 2.4 | 2.4 | 2.8 | 3.4 | 2.6 | 2.3 | 2.0 |

*Table 36. Personal computer Electricity Running Costs.*

| Computer Electricity Running Costs (All products in stock) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Computer Type | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 3.9 | 2.6 | 3.0 | 3.4 | 3.9 | 2.4 | 2.4 | 2.6 | 3.9 | 2.6 | 2.2 | 1.8 |
| All-In-One | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| Notebook | 3.7 | 3.1 | 3.8 | 5.2 | 3.7 | 2.8 | 2.7 | 3.4 | 3.7 | 3.1 | 2.4 | 2.1 |
| Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Integrated Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Workstation | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| All | 9.6 | 7.3 | 8.7 | 10.7 | 9.6 | 6.9 | 6.9 | 8.1 | 9.6 | 7.3 | 6.5 | 5.9 |

The total expected electricity running cost savings can be seen in Table 37. The results show that by 2030 electricity cost savings from the PO3 scenario are almost double those under the PO2 scenario.

*Table 37. Personal computer Electricity Cost Savings.*

| Computer Electricity Running Costs (All products in stock) (Billion Euros) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Type** | PO2 | | | | PO3 | | | |
| | 2018 | 2020 | 2025 | 2030 | 2018 | 2020 | 2025 | 2030 |
| Desktop | 0.01 | 0.07 | 0.27 | 0.34 | 0.00 | 0.01 | 0.34 | 0.65 |
| All-In-One | 0.00 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.03 | 0.06 |
| Notebook | 0.04 | 0.23 | 0.84 | 1.32 | 0.00 | 0.00 | 1.04 | 2.34 |
| Thin client | - | - | - | - | - | - | - | - |
| Integrated Thin client | - | - | - | - | - | - | - | - |
| Workstation | - | - | - | - | - | - | - | - |
| All | 0.05 | 0.30 | 1.13 | 1.67 | 0.00 | 0.00 | 1.40 | 3.05 |

#### 7.5.4.6 *Typical lifetime*

The typical lifetime for the different product types has been determined based on findings from the preparatory study, the impact assessment, information collected during desktop research and expert assumptions. Different sources may describe different lifetimes, and it was thus assessed to stick to official sources and evaluate whether these typical lifetimes are nowadays shorter due to technological replacement[49].

Table 38 shows the typical lifetimes used to establish the stock and the energy use. No differences are assumed between the domestic and the non-domestic uses.

*Table 38. Average typical lifetime (in years) for product types in scope.*

| Computer Type | Domestic | Non-domestic |
|---|---|---|
| Desktop | 6 | 6 |
| All-In-One | 6 | 6 |
| Notebook | 5 | 5 |
| Tablet/slate | 3 | 3 |
| Thin client | 5 | 5 |
| Integrated Thin client | 5 | 5 |
| Workstation | 7 | 7 |

#### 7.5.4.7 *Costs to Industry*

As illustrated in Table 29 and Table 30 it is expected that industry will face adaptation costs for products under the PO2 and PO3 scenarios. Applying these adaptation costs to all products in stock gives the estimated industry adaptation costs shown in Table 39. The values suggest that adaptation costs will be higher in PO3 due to the continued drive towards the higher efficiency classes (e.g. Class A, B and C). It is expected that all of these costs will be passed to purchasers through increased product purchase costs for the highest energy classes.

[49] See Task 2 report section 2.2.2 for more details

*Table 39. Industry Adaptation Costs under Policy Option 2 and Policy Option 3 (all stock).*

| **Industry Adaptation Costs (All products in stock) (Billion Euros)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Type** | PO2 | | | | PO3 | | | |
| | 2018 | 2020 | 2025 | 2030 | 2018 | 2020 | 2025 | 2030 |
| Desktop | 0.06 | 0.40 | 0.83 | 0.88 | 0.00 | 0.07 | 0.86 | 1.00 |
| All-In-One | 0.00 | 0.01 | 0.02 | 0.03 | 0.00 | 0.00 | 0.02 | 0.03 |
| Notebook | 0.02 | 0.14 | 0.27 | 0.35 | 0.00 | 0.02 | 0.28 | 0.36 |
| Thin client | - | - | - | - | - | - | - | - |
| Integrated Thin client | - | - | - | - | - | - | - | - |
| Workstation | - | - | - | - | - | - | - | - |
| All | 0.08 | 0.55 | 1.12 | 1.25 | 0.00 | 0.09 | 1.17 | 1.39 |

### 7.5.4.8 *Costs to Purchasers*

Whilst product adaptation costs are likely to be passed to purchasers, these extra costs will be offset by savings in electricity running costs (as shown in Table 40, Table 41 and Table 42).

*Table 40. Domestic Purchaser Costs under Policy Option 2 and Policy Option 3 (all stock).*

| **Domestic Purchaser Costs (All products in stock) (Billion Euros)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Type** | PO2 | | | | PO3 | | | |
| | 2018 | 2020 | 2025 | 2030 | 2018 | 2020 | 2025 | 2030 |
| Desktop | -0.05 | - 0.29 | - 1.40 | - 1.79 | 0.00 | - 0.03 | -1.79 | -3.65 |
| All-In-One | -0.01 | - 0.03 | - 0.09 | - 0.11 | 0.00 | - 0.01 | -0.18 | -0.38 |
| Notebook | -0.18 | - 1.06 | - 4.05 | - 6.36 | 0.00 | 0.04 | -5.01 | -11.47 |
| Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Integrated Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Workstation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| All | -0.23 | - 1.37 | - 5.53 | - 8.26 | 0.00 | 0.00 | -6.98 | -15.50 |

*Table 41. Non-Domestic Purchaser Costs under Policy Option 2 and Policy Option 3 (all stock).*

| **Non-Domestic Purchaser Costs (All products in stock) (Billion Euros)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Type** | PO2 | | | | PO3 | | | |
| | 2018 | 2020 | 2025 | 2030 | 2018 | 2020 | 2025 | 2030 |
| Desktop | -0.12 | -0.77 | -3.73 | -4.79 | 0.00 | -0.07 | -4.79 | -9.76 |
| All-In-One | 0.00 | -0.02 | -0.05 | -0.07 | 0.00 | -0.01 | -0.11 | -0.22 |
| Notebook | -0.09 | -0.57 | -2.18 | -3.42 | 0.00 | -0.02 | -2.70 | -6.18 |
| Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Integrated Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Workstation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| All | -0.22 | -1.35 | -5.96 | -8.28 | 0.00 | -0.06 | -7.59 | -16.16 |

*Table 42. All Purchaser Costs under Policy Option 2 and Policy Option 3 (all stock).*

| **All Purchaser Costs (All products in stock) (Billion Euros)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Computer Type** | PO2 | | | | PO3 | | | |
| | 2018 | 2020 | 2025 | 2030 | 2018 | 2020 | 2025 | 2030 |
| Desktop | -0.17 | -1.06 | -5.13 | -6.58 | 0.00 | -0.10 | -6.57 | -13.41 |
| All-In-One | -0.01 | -0.04 | -0.14 | -0.18 | 0.00 | -0.02 | -0.29 | -0.60 |
| Notebook | -0.27 | -1.63 | -6.22 | -9.78 | 0.00 | -0.06 | -7.70 | -17.65 |
| Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Integrated Thin client | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Workstation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| All | -0.45 | -2.73 | -11.49 | -16.54 | 0.00 | -0.06 | -14.57 | -31.66 |

#### 7.5.4.9 ***Overview of all costs***

The total life cycle costs for all new products sold are shown in Table 43 (domestic) and Table 44 (non-domestic). The results show that adoption of policy option 2 or policy option 3 will result in financial savings each year as a result of reductions in electricity consumption outweighing any increases in product costs.

*Table 43. Personal computer Annual Life Cycle Costs New Sales (Domestic).*

| Domestic Computer Total Costs (based on sales per year) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Computer Type** | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 4.0 | 4.7 | 6.4 | 6.8 | 4.0 | 4.6 | 6.4 | 6.8 | 4.0 | 4.7 | 6.2 | 6.5 |
| All-In-One | 0.4 | 0.4 | 0.6 | 0.7 | 0.4 | 0.4 | 0.6 | 0.7 | 0.4 | 0.4 | 0.6 | 0.7 |
| Notebook | 35.1 | 35.6 | 47.1 | 59.7 | 35.1 | 35.1 | 46.4 | 58.5 | 35.1 | 35.6 | 45.8 | 57.3 |
| Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Integrated Thin client | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Workstation | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 |
| All | 51.8 | 53.3 | 68.0 | 82.2 | 51.8 | 52.4 | 66.8 | 80.5 | 52.4 | 53.9 | 66.2 | 79.1 |

*Table 44. Personal computer Annual Life Cycle Costs New Sales (Non-Domestic).*

| Non-Domestic Computer Total Costs (based on sales per year) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Computer Type** | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 16.2 | 19.0 | 26.1 | 27.7 | 16.2 | 18.8 | 26.0 | 27.6 | 16.2 | 19.0 | 25.4 | 26.9 |
| All-In-One | 0.3 | 0.4 | 0.5 | 0.6 | 0.3 | 0.4 | 0.5 | 0.6 | 0.3 | 0.4 | 0.5 | 0.6 |
| Notebook | 26.5 | 26.9 | 35.6 | 45.0 | 26.5 | 26.6 | 35.2 | 44.4 | 26.5 | 26.9 | 34.9 | 43.7 |
| Thin client | 1.9 | 1.9 | 2.0 | 2.0 | 1.9 | 1.9 | 2.0 | 2.0 | 1.9 | 1.9 | 2.0 | 2.0 |
| Integrated Thin client | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Workstation | 3.1 | 3.5 | 4.2 | 5.0 | 3.1 | 3.5 | 4.2 | 5.0 | 3.1 | 3.5 | 4.2 | 5.0 |
| All | 51.8 | 55.6 | 72.6 | 84.8 | 51.8 | 55.0 | 71.9 | 84.0 | 51.9 | 55.6 | 71.1 | 82.6 |

The total lifecycle costs for all products in stock are shown in Table 45. The results show that adoption of policy option 2 or policy option 3 will result in financial savings each year as a result of reductions in electricity consumption outweighing any increases in product costs.

*Table 45. Personal computer Total Life Cycle Costs (All Stock).*

| Computer Total Costs (based on all stock) (Billion Euros) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Computer Type** | BAU | | | | PO2 | | | | PO3 | | | |
| | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 | 2016 | 2020 | 2025 | 2030 |
| Desktop | 54.8 | 45.0 | 56.2 | 63.1 | 54.8 | 43.9 | 51.0 | 56.6 | 54.8 | 50.8 | 48.1 | 46.1 |
| All-In-One | 2.1 | 1.9 | 2.5 | 3.0 | 2.1 | 1.8 | 2.3 | 2.8 | 2.1 | 2.0 | 1.9 | 1.9 |
| Notebook | 82.8 | 78.9 | 99.9 | 128.7 | 82.8 | 77.3 | 93.7 | 118.9 | 82.8 | 81.1 | 80.0 | 79.2 |
| Thin client | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Integrated Thin client | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Workstation | 5.1 | 5.7 | 6.5 | 7.7 | 5.1 | 5.7 | 6.5 | 7.7 | 5.1 | 5.2 | 5.4 | 5.6 |
| All | 168.7 | 154.3 | 189.6 | 229.0 | 168.7 | 151.5 | 178.1 | 212.5 | 168.7 | 162.7 | 158.3 | 155.4 |

#### 7.5.4.10 *Conclusions*

The results displayed in this section show that the energy efficiency requirements behind PO2 and PO3 will increase product purchase costs, but that these costs will be offset by savings in running costs.

### 7.5.5 Employment impact

The adaption of products under the PO2 and PO3 scenarios will result in an employment impact i.e. an increase in number of staff used primarily to re-design product and component technologies, to establish new production lines and to test new products and components.

The net impact in person-years is calculated based on the total industry adaptation costs under Policy Option 2 and Policy Option 3 (Table 39) divided by an average annual employee cost (i.e. turnover per full-time employee) for this industry sector, which is 254,000 euro/employee.[50] See Table 46 below.

*Table 46. Industry net employment impact based on industry adaptation costs for selected years and total.*

| **Net employment impact Person-years per year** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **All computer types** | **PO2** | | | | | **PO3** | | | | |
| | **2018** | **2020** | **2025** | **2030** | **Total 2018-2030** | **2018** | **2020** | **2025** | **2030** | **Total 2020-2030** |
| | 333 | 2,161 | 4,424 | 4,940 | 47,552 | 0 | 360 | 4,591 | 5,483 | 42,722 |

[50] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Key_indicators,_manufacture_of_computer,_electronic_and_optical_products_(NACE_Division_26),_EU-27,_2010.png

## 7.6 Proposed resource efficiency policy measures

### 7.6.1 Definition of requirements

The development of resource efficiency requirements has been based on scientific literature and discussion with stakeholders. In particular this assessment largely used technical evidences provided in the report on "Analysis of material efficiency aspects of personal computers" performed by the Joint Research Centre (JRC)[51], and on input from stakeholders during the consultation process of this review study. Following the same framework as for the suggested energy efficiency requirements, the resource efficiency requirements are to be included as ecodesign requirements as part of Policy Option 2 and some as energy labelling requirements as part of Policy Option 3 (see Table 4). An overview of the proposed requirements is presented in Table 47 and Table 48.

*Table 47. Overview of potential resource efficiency requirements for policy option 2 (only ecodesign).*

| Potential requirement | Product sub-group | | Type of requirement | Focus area |
|---|---|---|---|---|
| | Mobile | Non-mobile | | |
| External Power Supplies (EPS) | ✓ | ✓ | Information in *user manual and on packaging* | Resource savings and waste prevention |
| Battery lifetime | ✓ | | Battery lifetime optimisation functionality installed and information in *user documentation* | Resource savings, product durability and waste prevention |
| Liquid spill protection | ✓ | | Information in *user documentation* and *publicly available websites* | Product durability |
| Computer disassembly | ✓ | ✓ | Disassembly features for key components available and described in *technical documentation* | Reparability and reusability |
| Personal data deletion | ✓ | ✓ | Implemented data deletion functionality | |
| Computer dismantling | ✓ | ✓ | Dismantlability features for key components available and described in *technical documentation* | Recyclability |
| Plastic parts | ✓ | ✓ | Marking of plastic components > 50 g | |
| Plastic parts containing flame retardants | ✓ | ✓ | Declaration of flame retardants in *technical documentation* | |
| Batteries | ✓ | | Marking of battery chemistry by a *standardised logo* | |

[51] JRC (DRAFT). Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA. EUR 28394 EN; doi 10.2788/89220.

*Table 48. Overview of additional[52] potential resource efficiency requirements for policy option 3 (only those relevant for energy label[53]).*

| Potential requirement | Product sub-group | | Type of requirement | Focus area |
|---|---|---|---|---|
| | Mobile | Non-mobile | | |
| External Power Supplies (EPS) | ✓ | ✓ | Logo on the energy label and information in product information sheet | Resource savings and waste prevention |
| Battery lifetime | ✓ | | Remaining full charge capacity[54] in logo on the Energy Label and information in product information sheet | Resource savings, product durability and waste prevention |
| Liquid protection | ✓ | | Logo on the Energy Label and information in product information sheet | Product durability and reparability |
| Possibility of replacing the battery | ✓ | | Logo on the Energy Label and information in product information sheet | Reparability and Reusability |

Table 47 and Table 48 show the proposed requirements, applicable either to all personal computers or to mobile personal computers. Furthermore, based on the target group (i.e. consumer, recyclers, professional operators and/or market surveillance authorities), the applicable policy measures to use for such requirements are shown.

The requirements are described in detail in the next sections and in order to ensure their applicability, specific definitions are needed, which should be stated in the ecodesign and/or energy labelling regulation(s). These are listed next:

- Built-in functionality: functionality that does not require the user to install additional software or hardware components.
- Disassembly: reversible operation for taking apart of an assembled product into constituent components.
- Dismantling: taking apart of an assembled product into constituent materials and/or components[55].
- Secure data deletion: the effective erasure of all traces of existing data from storage media so access to it becomes not feasible.
- User documentation: documentation made available by manufacturers for end-users in websites and in user manuals.

### 7.6.1.1 *Provision of information on availability and specifications of External Power Supplies (EPS)*

#### 7.6.1.1.1 Rationale and potential benefits

The function carried out by an external power supply (EPS) is to transfer power from a source (e.g. the grid) to the device by converting voltage and current characteristics to the desired load levels. EPS are frequently sold together with end-use appliances. For notebooks and tablets, they are usually personalized so they are only used with the end-

[52] Additional to those presented in Table 47
[53] Ecodesign requirements are the same as for policy option 2
[54] After 500 cycles following test procedure in EN 61960 standard
[55] adapted from the definition of disassembly from standard BS 8887-2:2009

appliance they are sold with[56]. However, re-use of EPS is possible, when the voltage, power output and the connector are compatible with multiple ICT devices[57].

Even though the general tendency is to manufacture smaller and lighter EPSs (e.g. power supplies with an output power of 65 W and a total weight of 85 g are available on the market[58]), EPSs represent a very significant percentage of the whole weight and materials used for ICT mobile products (estimated to be in the range 10 % - 20 %). Thus it is important to set specifications to minimize their impact on the environment[59]. The box containing a new mobile phone can be up to 25% lighter when an EPS is not included and similar figures can be found for small portables or even small form-factors of desktops[60].

As reported by Cucchietti et al. (2011)[61], the use of common EPSs would bring benefits to manufacturers, vendors and end-users, thanks to their interoperability:

- End-users would be able to share the same EPS for different devices (in the same power range), saving in purchase costs;
- Manufacturers and vendors would be able to ship and sell their devices without the EPS included in the packaging (with consequent transport savings).

In a more general perspective, common EPSs, thanks to their interoperability and re-use of EPS, have the potential to result in a significant reduction of resource consumption for the production of unnecessary power supplies and for the treatment of electronic waste (see section 7.6.2). Recent standardisation work[62,63,64] represents relevant sources to define common charging capabilities and interface requirements for EPSs, as in the case of IEC 62684: 2011 developed for data enabled mobile telephones.

The rationale for this section, thus, is to promote the reuse of EPSs by means of:

- the adoption of common EPSs, which can be used by different electronic products, making the service life of an EPS independent from the product's useful life and promoting the use of standardized EPSs without setting any obligation on suppliers;
- the progressively *decoupling* of personal computers from EPSs, to promote the reuse of working and suitable EPSs when replacing the computer or purchasing a new device using the same kind of EPS.

---

[56] Dimitrova, G., 2012. Impact of innovations in electronic equipment and components on their reuse and recycling. University of Natural Resources and Life Sciences, Vienna.
[57] EPS may be compliant with IEC/TS 62700:2014 or ITU-T L.1002:2016 and compatible with other devices with the same power needs
[58] FINsix®, 2016. DARTTM The World's Smallest Laptop Charger® [WWW Document]. URL https://finsix.com/shop/dart/ (accessed 9.12.16)
[59] ITU-T L.1002, 2016. Recommendations for external universal power adapter solutions for portable information and communication technology devices.
[60] E.g. Mac Mini, HP Stream Mini, Intel NUC, Gigabite Brix, Asus Chromebox, etc.: some of them, or some versions of them are sold with an EPS.
[61] 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.
[62] IEC/TS 62700, 2014. IEC/TS 62700:2014 DC power supply for notebook computers
[63] IEEE Std 1823, 2015. IEEE Standard for Universal Power Adapter for Mobile Devices.
[64] ITU-T L.1002, 2016. Recommendation ITU-T L.1002 External universal power adapter solutions for portable information and communication technology devices

#### 7.6.1.1.2 Background for requirements

Information about standardized EPSs, such as the required power supply specifications, namely voltage, current and rated output power, can be conveyed to end-users through the user's manual and a logo on the energy label of personal computers that use an EPS, and on the packaging.

The main goal of the logo could be to indicate the presence or absence of the common EPS, while the user's manual or additional documentation can inform about the type of connector used as interface between the EPS and the devices. If computer and EPS are sold separately, the user's manual can inform the end-users about the possibility to use a suitable EPS.

The information requirements in the regulation should cover:

- the recommended types of personal computer that can be connected to the EPS;
- input voltage type, input voltage range, frequency range and maximum input current of the EPS;
- output voltage, current and power ranges, with efficiency of power conversion of the EPS.
- the type of connector used to interface the EPS with the devices.

#### 7.6.1.1.3 Proposed requirements

With these considerations, the proposed requirements would be both a logo (energy label) and the provision of information in the user manual and product information sheet.

*Ecodesign*

- From 1 January 2020  manufacturers shall inform users in the user manual and publicly available websites on the required power supply specifications (voltage, current and rated output power) of personal computers that use an external power supply.
- **If an external power supply is provided with the personal computer**, the user manual shall inform the end-users about the possibility to use the contained external power supply with other devices as well as its compatibly according to the external power supply specifications. The user manual shall also notify the type of connector(s) used as interface between the external power supply and the devices.

*If **the external power supply is not provided**, the user manual shall inform the end-users about the possibility to use an alternative suitable external power supply, its specifications and type of connector(s) required to interface the external power supply with the device. Energy label*

- From 1 January 2022, a logo shall indicate the presence or absence of the external power supply. The logo shall be included in the energy label and visibly shown on the product information sheet of the personal computer. The same logo and information may be replicated on the packaging.

### 7.6.1.2 *Provision of information on battery lifetime*

#### 7.6.1.2.1 Rationale and potential benefits

Prakash et al. (2016)[65] surveyed the influence of information provided by OEMs about the availability of spare parts, repair services, exchangeable parts and lifetime on the purchase decision for personal computers. Information about the lifetime resulted as important or very important by 45% of the interviewees.

Battery durability represents a key feature, both for product lifetime and for users. In a survey conducted by IDC (2010)[66], 68 % of respondents confirmed that the battery lifetime on their notebook computers was not sufficient for their business needs, 22% of notebook computers required the purchase of a replacement battery during their lifetime, and over a half of respondents stated that battery failures caused problems for their business.

Battery durability is determined by the cycle life and calendar life. Cycle life is the number of charge/discharge cycles a battery can withstand before losing a certain portion of its initial capacity. Batteries used in mobile computers (e.g. Li-ion batteries), lose a fraction of their full charge capacity with every charge/discharge cycle they go through, due to a number of physical and chemical processes[67]. Calendar life is described by the portion of capacity a battery inevitably loses over time, even though it is not in use, for example while in storage.

Manufacturers tend to integrate batteries to improve the robustness/sturdiness of the whole device, to make devices thinner and to protect against dust, thus abandoning the previously widespread slide-lock removal mechanisms. End-users face potential difficulties in replacing an exhausted battery by themselves. Increased battery durability, therefore, becomes important.

Battery cycle tests may be used to determine the number of charging cycles a battery can withstand before its capacity fades below a certain threshold.

Current legislation requires manufacturers to provide data on the expected cycle life of batteries in notebooks (Commission Regulation (EU) No 617/2013)[68]. However, in a non-exhaustive survey of the websites of computer manufacturers, it was found that only two manufacturers were compliant by providing such information. Only one of them is fully compliant and refers to specific notebook models. Furthermore, without a set of complementing information regarding the methodology applied to determine the number of charging cycles a battery can withstand without degradation below a specific threshold, data cannot be considered comparable. The following information should be communicated to end-users:

- The definition of a charging cycle;
- The capacity threshold at which the battery is considered wasted (e.g. SoH below 80%);
- The measurement methodology (e.g. a testing standard).

---

[65] Prakash, S., Dehoust, G., Gsell, M., Schleicher, T., Stamminger, R., 2016c. Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz" (unpublished annex).

[66] IDC, 2010. White paper - The Business Case for Ruggedized PCs.

[67] On top of other factors, such as calendar aging, temperature, speed of recharge, etc.

[68] Annex II, information reguirement 7.1.1 (o)

A charging cycle is often described as discharging a device battery (possibly in several partial discharge events) and consequently recharging it to 100% SoC. This information is essential for comparability of projected life cycle of batteries from different computer 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, 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% which, as described in previous task reports, accelerates the aging of Li-Ion batteries. A study[69] 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 less than 30 times per year. Despite the low charging frequency, a large share of the batteries had lost significant portions of their initial capacity. 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. In conclusion, the user should have the means to increase the durability of its device batteries by preventing a constantly high SoC when the notebook is constantly connected to the mains.

Software tools can easily limit the SoC to which a battery of a mobile personal computer is charged when plugged into a power outlet. One of the features of this software is battery optimizing modes. A software button (on/off switch) allows the user to enable and disable a mode in which the battery is charged up to a pre-defined or user-defined SoC, commonly in the range of 50-70%. Thus, high SoC is prevented while using the notebook in grid operation, expectedly increasing battery durability at negligible cost to the manufacturer.

When battery optimizing mode is not enabled and if the device is used in grid operation for a predefined period (e.g. 2 hours), the software tool should alert the user (e.g. via a pop up message) suggesting to enable battery conservation mode. The user should be able to disable the battery conservation mode and fully charge the battery if needed, e.g. before using the device in mobile, (battery-powered) mode. The battery conservation mode is recommended also when the device is not going not be used for a period of time, to decrease calendar aging of the battery.

Some notebook manufacturers already ship their devices with such software pre-installed[70].

##### 7.6.1.2.2 Background for requirements

Declaring the State of Health (SoH) of the battery, which is the ratio of full charge capacity after a predefined number of charging cycles compared to the initial charge

[69] 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.

[70] Examples are the Lenovo Battery Conservation Mode, Dell Battery Meter, Sony Battery Care

capacity, appears as a practical indicator for identifying battery durability[71]. This information would help end-users to get an indication on how long the battery in a specific device may last. Information about aging may be complemented with the manufacturing date of the battery.

Moreover, such a declaration on the cycle stability of the battery allows the comparability among products of different manufacturers, potentially pushing the market towards higher quality of battery cells (see an example already on the market in Figure 22). Batteries could be tested in accordance with the most recent version of the standard EN 61960[72], communicating the remaining full charge capacity of the battery compared to the initial charge capacity after a predefined number of charge/discharge cycles (e.g. 100, 300, 500).

It is reasonable to consider a range of 100 to 500 cycles to declare battery durability. A remaining charge capacity of 80% of the initial charge capacity is typically reached between 300-500 charge/discharge cycles for consumer products. In addition, declarations of batteries that can be considered consumed after 1000 cycles are available[73].

Battery manufacturers have a number of possible tests to evaluate battery cycle life following the standard EN 61960 which can be applied either at the battery cell level or at battery pack level. Furthermore, non-accelerated or accelerated test procedures are available. Tests conducted at the battery pack level are closer to reality, considering that notebook batteries are often composed of four 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.

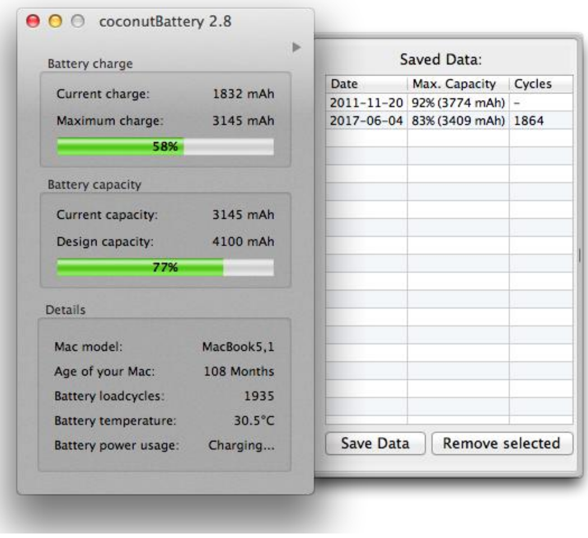



*Figure 22. Example of battery information provided by software.*

[71] State of health (SOH) is a figure of merit of the condition of a battery, compared to battery's specifications. The units of SOH are percent points (100% = the battery's initial charge capacity)
[72] IEC 61960:2011 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications
[73] https://support.apple.com/en-us/HT201585

Battery durability of mobile personal computers could further be improved by implementing a pre-installed functionality which prevents battery cell capacity to fade because of very high SoC. This may occur when the device is used stationary (i.e. in grid operation).

Manufacturers may install legacy solutions and the effectiveness of such a lifetime optimization function can be guaranteed if:

a. manufacturers take action to inform the users of its existence and the benefits, and,
b. end-users have an option to disable the pre-defined limit on SoC (e.g. until next restart).

Information about battery durability could be provided via the pre-installed software such as:

1. battery manufacturer
2. date of manufacture
3. design capacity
4. voltage
5. the capacity threshold at which the battery is considered exhausted
6. the definition of charge/discharge cycle and the measurement methodology used for testing
7. explanation on how ambient temperature and battery SoC can impact the battery lifetime
8. current SoC
9. current SoH (as the current full charge capacity compared to the design capacity)
10. number of charge/discharge cycles the battery already went through;
11. battery temperature
12. battery chemistry

#### 7.6.1.2.3 Proposed requirements

*Ecodesign*

The proposed requirements would include both testing, provision of information in user's manual and the availability of battery lifetime optimization built-in functionality as follows:

- **Provision of information on battery lifetime**: From 1 January 2020, manufacturers shall test the batteries of mobile personal computers in accordance with the most recent version of the standard EN 61960 and communicate in the user documentation the remaining full charge capacity of the battery compared to the initial charge capacity, after 300 and 500 charge/discharge cycles.
- **Battery optimization built-in functionality**: From 1 January 2020, manufacturers shall provide pre-installed software to enable a limit on the battery state of charge (SoC) when the computer is used systematically in grid operation. Such a functionality shall prevent the battery to be loaded at full charge. The manufacturer shall inform the user of the existence and the benefits of using such a functionality.

*Energy label*

- From 1 January 2022, the remaining full charge capacity of the battery compared to the initial charge capacity after 500 charge/discharge cycles shall be indicated in the product information sheet and in the energy label.

### 7.6.1.3 *Provision of information on liquid protection class for mobile personal computers*

#### 7.6.1.3.1 Rationale and potential benefits

According to JRC[74], the two most recurring accidents for mobile personal computers are:

- The computer drops while being carried or falls off the desk or the table.
- Liquids spill on the computer

Possible options to improve the durability performance of mobile personal computers may be related to the product resistance to drops (or other mechanical shocks) and resistance to water. This proposed requirement focuses on the resistance to water and the rationale and background for requirements are presented in this and the next section.

The LCD panel, the display casing (including frame joints) and the casing of mobile personal computers are the components most prone to crack due to drops. Whilst liquid spillage on detached keyboard (of desktops) results in relatively inexpensive replacements. In notebook/laptops the liquids penetrate and damage internal expensive parts, including the mother board and storage controllers: the repair is so expensive that generally the computer is disposed of.

Waterproof solutions for computers are possible, with increasing rates of protection of internal components. As a minimum, sealing can be implemented, so that just the relatively cheap notebook keyboard is replaced. Standard IEC 60529[75] classifies and rates the degree of Ingress Protection (IP) provided against, dust, water, accidental contact, and intrusion through mechanical casings and electrical enclosures. The IP code consists of two digits, indicating the solid particle protection class and the liquid ingress protection class[76]. An overview of the tests defined by IEC 60529 is provided in Table 49.

[74] JRC (DRAFT). Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA. EUR 28394 EN; doi 10.2788/89220. Section 3.2.1.

[75] https://www.nema.org/Standards/ComplimentaryDocuments/ANSI-IEC-60529.pdf

[76] As an example, an electronic device classified as IP-22 is protected against insertion of objects >12 mm (Solid particle protection) and against vertically or nearly vertically dripping water (Liquid ingress protection). When no data is available to specify one of the two protection ratings, the digit is replaced with the letter X (e.g. IP-X2). Thus, the second digit defines the liquid ingress protection that the enclosure provides against harmful ingress of water, and ranges from 0 to 9.

*Table 49. IEC 60529 test levels and descriptions.*

| Level[77] | Protection against | Test description |
|---|---|---|
| 0 | none | - |
| 1 | Dripping water | Vertically falling drops. Test duration: 10 minutes. Water equivalent to 1 mm rainfall per minute |
| 2 | Dripping water when tilted at 15° | Vertically falling drops and object tilted at an angle of 15° from its normal position. Test duration: 2.5 minutes for every direction of tilt (10 minutes total) Water equivalent to 3 mm rainfall per minute |
| 3 | Spraying water | Water falling as a spray at any angle up to 60° from the vertical, using either a spray nozzle or an oscillating fixture.<br>Spray nozzle. Test duration: 5 minutes minimum. Water volume: 10 litres per minute, 50-150 kPa.<br>Oscillating tube. Test duration: 10 minutes minimum. Water volume: 0.07 l/min per hole |
| 4 | Splashing water | Water splashing against the enclosure from any direction, using either a spray nozzle or an oscillating fixture.<br>Spray nozzle with no shield. Test duration: 5 minutes minimum. Water volume: 10 litres per minute, 50-150 kPa.<br>Oscillating tube. Test duration: 10 minutes minimum. Water volume: 0.07 l/min per hole |
| 5 | Water jets | Water projected by a nozzle (6.3 mm) against enclosure from any direction.<br>Test duration: 1 minute per square meter for at least 3 minutes.<br>Water volume: 12.5 litres per minute. Pressure: 30 kPa at distance of 3 m |
| 6 | Powerful water jets | Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction. Test duration: 1 minute per square meter for at least 3 minutes. Water volume: 100 litres per minute. Pressure: 100 kPa at distance of 3 m |
| 7 | Immersion, up to 1 m depth | The enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion). Test duration: 30 minutes |
| 8 | Immersion, 1 m or more depth | The enclosure is immersed in water under defined conditions of pressure and time (depth specified by manufacturer). Test duration: by agreement |
| 9 | Powerful high temperature water jets | Water projected by a fan jet nozzle against the enclosure from any direction. Test duration: 30 seconds in each position for a minimum of 3 minutes. Water flow rate 14-16 l/min. |

Another durability test, introduced by the Decision on EU Ecolabel criteria for notebook computers[78], is focused on water spill ingress. The test is performed as follows:

- The test shall be carried out two times
- A minimum of 30 ml of liquid shall be poured evenly over the keyboard of the notebook or onto three specific, separated locations, then actively drained away after a maximum of 5 seconds, and the computer is then tested for functionality after 3 minutes
- The test shall be carried for a hot and a cold liquid
- The notebook shall remain switched on during and after the test

[77] Refers to the second digit of the IP code
[78] European Commission, 2016. Commission Decision (EU) 2016/1371 of 10 August 2016 establishing the ecological criteria for the award of the EU Ecolabel for personal, notebook and tablet computers.

The notebook shall then be dismantled and visually inspected so as to ensure it passes the IEC 60529 acceptance conditions for water ingress.

##### 7.6.1.3.2 Background for requirements

The provision of information regarding the liquid ingress protection class for personal computers (in particular mobile computers) could be provided to final users in order to inform about the product characteristics. This allows a better informed purchase decision, thus contributing to reduce the amount of personal computers disposed of because of liquid spillage.

Such an information can be reported through the technical documentation, and conveyed to end-users through the user documentation and through dedicated pictograms. The main goal of the pictograms would be to indicate the level of protection against dripping, spraying or splashing of water and water jets.

##### 7.6.1.3.3 Proposed requirements

The proposed requirements are listed below, taking into account the considerations mentioned in the previous section.

*Ecodesign*

- From 1 January 2020, manufacturers shall inform consumers in user documentation and publicly available websites on the liquid protection class for mobile personal computers, assessed in accordance with the most recent version of the standard EN 60529.

*Energy label*

- From 1 January 2022, a logo shall indicate the liquid protection class in accordance with the most recent version of the standard IEC 60529. The logo shall be included on the label and the product information sheet of the mobile personal computers with keyboard not detached.

#### 7.6.1.4 *Provision of information to facilitate computer disassembly of key components*

##### 7.6.1.4.1 Rationale and potential benefits

Display panels, batteries, keyboards and data storage are the components most prone to fail or to be damaged in mobile personal computers[79,80]. Manufacturers claim that the need for repair is minimized through the selection of high quality materials and components, as well as through a durable, reliable and structural design[81]. However, both the average annual failure rates of computers[82] (18% for notebooks and 15.7% for tablets) and the reparability rates (about 6% of the products shipped for repair or remanufacturing to OEMs turns out not to be repairable at an acceptable cost[83]) are not negligible. For end-users, the availability of repair options to fix day-to-day problems by

---

[79] IDC, 2010. White paper - The Business Case for Ruggedized PCs.
[80] Prakash, S., Dehoust, G., Gsell, M., Schleicher, T., Stamminger, R., 2016b. Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz", Öko-Institut e.V. doi:10.1017/CBO9781107415324.004
[81] Digitaleurope, 2017. The contribution of the Digital Industry to repair, refurbishment and remanufacturing in a Circular Economy.
[82] IDC, 2016. Pay Now, Save Later: The Business Case for Rugged Devices.
[83] Digitaleurope, 2014. Trans-Boundary Movements of Waste Vs Used Goods 4.

reasonable costs is an important factor for a substantial prolongation of the lifetime[84]. However, the trend towards more integrated devices such as subnotebooks or tablets makes an easy repair or upgrade more and more challenging. Although a repair might be feasible, the discomfort for long repair time and the costs leads a certain share of users to rather purchase a new device.

Overall, the ease of repair or upgrade becomes more and more important in prolonging the operational life of personal computers because:

- it brings higher economic savings for the consumer
- it reduces electronic waste by enhancing reuse and delaying the moment the product will be disposed of as WEEE)
- it reduces the environmental impacts from the manufacturing of new devices (both energy and material use)

##### 7.6.1.4.2 Background for requirements

The reversible disassembly of relevant components (such as batteries, internal power supply units, displays, mass storage, memory, keyboard, track pad, network interface and active cooling assemblies) plays a key role to enhance reuse of personal computers.

Possible actions to enhance repair and refurbishing promoting extended lifetime and the reuse of personal computers can be drawn considering different target groups:

- Professional repair operators should be better provided with information about the disassembly, replacement and re-assembly operations needed for relevant components.
- Users can be provided with clear and easy accessible information about the disassembly and replacement of at least batteries.

Studies[85,86,87] have highlighted the importance of having repair and upgrade services offered by others than manufacturer's authorised service providers during the warranty period. According to these studies, end-users or non-professionals should be allowed to replace components which are easy exchangeable, and in case that this is not possible, a range of repair service providers shall be available to end-users to avoid lack of competition and to help to reduce repair costs.

Documentation on the sequence of disassembly, replacement and re-assembly operations for key components of personal computers could be provided for batteries, internal power supply units, display panels, data storage (HDD, SSD and eMMC), memories, keyboard and track pad, whilst for tablets/slates this could be done for batteries and displays. Repair operators cited also network interface board and cooling fan assemblies as key components.

In a survey in Germany[88], half of the respondents thought it is important that computers can be upgraded with higher energy-efficiency components or with higher performance.

---

[84] Dodd, N., Vidal-Abarca Garrido, C., Wolf, O., Graulich, K., Bunke, D., Groß, R., Liu, R., Manhart, A., Prakash, S., 2015. Revision of the European Ecolabel Criteria for Personal, Notebook and Tablet Computers. doi:10.2791/780423

[85] BIO by Deloitte, 2015. Study on Socioeconomic impacts of increased reparability.

[86] RREUSE, 2013. Investigation into the repairability of Domestic Washing Machines, Dishwashers and Fridges.

[87] Dodd, N., Vidal-Abarca Garrido, C., Gama Caldas, M., Graulich, K., Bunke, D., Groß, R., Liu, R., Manhart, A., Prakash, S., 2016. Revision of the EU Green Public Procurement (GPP) Criteria for Computers and Monitors - Technical report - Final Criteria. doi:10.2791/027791

[88] Forsa, 2013. Meinungen zu Umweltaspekten bei Computern.

In the same survey, 61% of the interviewed people stated that they would continue to use a notebook or tablet with a built-in battery in case the battery breaks or loses capacity if they can bring it to an electronic shop and the battery is replaced there directly on-site.

Relevant information for professional repair operators can include: exploded diagrams of the product showing the location of components, disassembly sequences, type and number of fastening technique(s) to be unlocked, tool(s) required and warnings if delicate disassembly operations are involved (risk of damage). Diagrams, photos or videos visualizing the disassembly steps could accompany and better communicate this information. Information should also include safety requirements and risks (if any) related to the disassembly, replacement and re-assembly operations. Such documentation could be available to professional repairers and to users (for repair operations that they can safely perform).

The Open Manual Format (oManual) is an open XML-based standard for semantic, multimedia-rich procedural manuals; it appears a suitable format for the above-mentioned information. It can be used to store and present e.g. service manuals, "how to" guides, assembly instruction and user documentation[89]. 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 European standardisation work could elaborate on this standardised format and could help to specify more precisely the information to be provided.

#### 7.6.1.4.3 Proposed requirements

The proposed requirements would include a logo for mobile computers (energy label and packaging), and a requirement of a design feature to make key components of all personal computers available for replacement, including the provision of information (ecodesign).

*Ecodesign*

- From 1 January 2020, manufacturers shall ensure that the joining or sealing assembly techniques do not prevent the disassembly of the product, making key components available for replacement. The key components are batteries[90], keyboard, trackpad or other pointing devices, data storage, memory, internal power supply units and display panels.

*From 1 January 2020, disassembly of computers shall be ensured by including in the technical documentation, available for professional repairers, the exploded diagram of the computer with the location of the key components and the sequence of disassembly operations needed to access and remove them. The diagrams shall include for each of these operations: type of operation, type and number of fastening technique(s) to be unlocked, tool(s) required, warnings if delicate disassembly operations are involved (with the risk of damage of the components), and safety requirements and risks (if any) related to the disassembly operations. Energy label*

From 1 January 2022, a logo shall be included in the label, the packaging, retailers' websites and product data sheets for all personal computers using battery packs. Three alternative logos should indicate:

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

[90] Including stand-by button cells on motherboards

- Logo 1: the batteries of the portable computer can be disassembled and replaced by the user, with or without the use of tools. Instructions on how to disassemble and replace the battery shall be provided in the product information sheet
- Logo 2: batteries must be replaced by assistance qualified service. The user documentation shall mention "The battery contained in this product can only be replaced by professionals". Instructions on how to contact the customer service shall be provided in the product information sheet.
- Logo 3: batteries cannot be replaced at all.

### 7.6.1.5 *Securing personal data deletion*

#### 7.6.1.5.1 Rationale and potential benefits

One possible barrier to the reuse, repair and recycling of computers is data privacy. Desktop computers, notebooks and tablets store sensitive and confidential data on users and organizations, including but not limited to documents, photos, videos, data on locations and contacts. The major operating systems usually include an option to "factory reset" the device[91]. However, this does not necessarily guarantee that all personal data of the user are deleted comprehensively and permanently, as the user would expect. Hence, it is believed that data privacy is an important factor that discourages users from making their obsolete but functional devices available to the reuse market or to appropriate recycling paths in case of dysfunctional devices.

Data sanitization is the process of deliberately, permanently and irreversibly destroying the data stored on a memory device[92] (prEN 50614, 2016). Other techniques of data eradication do not allow the reuse of the device (e.g. degaussing magnetic media, drilling HDD platters). Alternatively, 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.

#### 7.6.1.5.2 Background for requirements

Personal computers could have available (or pre-installed) tools to permanently delete personal data contained in data storage systems, without compromising the functionality of the whole device for further reuse[93]. Secure data deletion could be ensured by means of a dedicated functionality or software. If data deletion cannot be ensured, personal computers could have available tools to encrypt personal data in storage systems and to permanently delete the key required for decryption.

While the user-addressable storage in desktop tower computers can often be disassembled with reasonable effort, storage solutions in more integrated devices such as mini-desktops, notebooks and tablets are less easily accessed. This emphasizes the importance of tools that allow the users to delete their data, without having to rely on third parties, before the devices are passed on for reuse or recycling.

---

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

[92] prEN 50614, 2016. Draft standard for comments (general, techncial, editorial) - draft developed by CLC/TC 111X-WK07 - Requirements for the preparation for re-use of waste electrical and electronic equipment.

[93] JRC provides an overview of methods to secure data deletion assuring this condition in their report (JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220).

#### 7.6.1.5.3 Proposed requirement

*Ecodesign*

From 1 January 2020 a built-in secure data deletion functionality or software shall be made available to support the deletion of data contained in data storage components (e.g. hard drives and solid state drives) in function of the risks faced and in order to grant the security of personal data and to facilitate the reuse.

### 7.6.1.6 *Provision of information to facilitate computer dismantling*

#### 7.6.1.6.1 Rationale and potential benefits

Considerations about the lack of free-of-charge provision of information on EEE raised by the WEEE Directive have been confirmed by interviews with recyclers[94]. They reiterated that for the safe and efficient recycling of computers, products should be designed so that the access and dismantling of batteries[95] (including button batteries contained in the mainboard), display panels and PCBs (contained in several components, including motherboard, memory RAM, CPUs, graphic cards, and mass storage systems) is facilitated.

JRC[96] presents a list of information on disassembly processes and location of key components that could inform recyclers for achieving higher levels of recycled materials:

- extra information on materials that are recyclable if certain technology is used (for example for certain plastic parts containing additives)
- 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 for opening
- how to recognize special models and specific dismantling instructions for them
- information on batteries which cannot be removed without (advanced) tools (providing then information on what tools should be used and where to find them)
- personal protection equipment needed for handling
- risks for workers when the waste is not properly dismantled
- advice on available treatment techniques
- information on hazardous components and substances.

---

[94] JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220.

[95] Measures to improve the design for disassembly of batteries are also in lines with the principles of the Batteries Directive 2006/66/EC, which state in article 11 that appliances should be designed in such a way "that waste batteries and accumulators can be readily removed. Appliances into which batteries and accumulators are incorporated shall be accompanied by instructions showing how they can be removed safely and, where appropriate, informing the end-user of the type of the incorporated batteries and accumulators".

[96] JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220.

### 7.6.1.6.2 Background for requirements

In order to facilitate the ease of dismantling of key components (such as batteries, PCB assemblies larger than 0.1 $dm^2$[97], display panels larger than 1 $dm^2$[98], any mercury containing component, capacitors containing electrolyte) specific joining or sealing techniques can be used. In particular, large number of different fastenings and/or certain types of fastening difficult to be dismantled can represent an obstacle for recyclers for the efficient recovery of key components. According to JRC[99], in order to improve the recycling, it is absolutely useful that components of different material composition (like plastics and metals or batteries and printed circuit boards) are not permanently fixed together, e.g. by using non-removable joining and sealing techniques. Recyclers experience many difficulties when these material group are fixed together, resulting in higher material losses. The consequence is that, if this is not regulated in some way, recycling and recovery rates as given in Annex V of the WEEE Directive cannot be met (EERA, 2016).

Ease of dismantling can be proved and enhanced thanks to a comprehensive documentation on the sequence of operations needed to access the key components, describing the type and number of fastening technique(s) to be unlocked, and tool(s) required. As for the disassembly, the exploded diagram of the product showing the location of the components to be dismantled can also be useful. Furthermore, information relevant for dismantling should be made accessible to recyclers[100] and market surveillance authorities. Ideally this information is made available through dedicated digital platforms[101], as for paper documentation there is the risk that it is static and becomes outdated if not revised in time.

A standardised format for the documentation to support the verification of the requirement has to be defined. The format published by the Austrian Ministry of Environment[102] may represent a basis for standardization (e.g. as a transitional method which can be referenced ahead of formal development of a harmonized standard). Moreover, this format should be based on horizontal standardisation work under the European Mandate M/543 on resource efficiency aspects of energy related products[103]. This mandate requires the development of “documentation and/or marking regarding information relating to resource efficiency of the product taking into account the intended audience (consumers, professionals or market surveillance authorities)”.

---

[97] Threshold set in WEEE Directive Annex 7
[98] ibid
[99] Referring to EERA, 2016. EERA Position Paper. The Netherlands.
[100] EERA, 2016. EERA Position Paper. The Netherlands.
[101] There are on-going projects about how to develop and communicate relevant information for recyclers. For example, the EU Horizon 2020 project ‘CloseWEEE’ (http://closeweee.eu/) aims at developing process for separation and recovery of materials (including plastics, CRMs, and other valuable metals) from WEEE streams, and to improve the flow of information to recyclers through a dedicated digital platform (named ‘Recycler Information Center’ - http://www.werecycle.eu/) in order to make recycling procedures quicker and safer.

[103] European Commission, 2015b. M/543 C(2015) 9096 Commission implementing decision of 17.12.2015 on a standardisation request to the European standardisation organisations as regards ecodesign requirements on material efficiency aspects for energy-related products in support of the imp. doi:10.1017/CBO9781107415324.004

#### 7.6.1.6.3 Proposed requirement

*Ecodesign*

From 1 January 2020 manufacturers shall ensure that joining or sealing techniques do not prevent the dismantling of components listed in point 1 of Annex VII of Directive 2012/19/EU, when present. Dismantling of these components shall be ensured by making an exploded diagram of the computer with the location of the components available in technical documentation, and the sequence of dismantling operations needed to access and remove the components, including: type of operation, type and number of fastening technique(s) to be unlocked, tool(s) required, safety requirements and risks (if any) related to the dismantling operations.

Exemptions apply where non-removable joining and sealing techniques are required to assure safety. When exemptions apply, these should be described in the technical documentation.

### 7.6.1.7 *Marking of plastic components104*

#### 7.6.1.7.1 Rationale and potential benefits

The European Commission in 2013[105] observed that only a small fraction of plastic waste is at present recycled. Appropriate measures to enhance the recycling of plastics could improve competitiveness and create new economic activities and jobs, avoiding incineration as only way to "valorize" plastics waste.

According to some studies reviewed by JRC[106], plastic recycling poses various problems:

- The lack of process capable of performing plastic sorting and separation
- Plastic can be recycled a limited number of times, then quality dramatically decreases
- Complexity of the plastic mix, which makes difficult to separate plastics from each other
- Plastics can contain several additives which compromise recyclability
- Plastic can be reinforced or mixed with metals and other non-plastics, which degrade the plastic when recycled. Composite materials are a further obstacle
- Most plastic types are only present in relatively small amounts, which makes it difficult to achieve the required economies of scale for advanced recycling operations. A limitation on the number of possible different polymers, as done in the packaging sector, may help.

The marking of plastic parts, as said, should follow a standardised approach with specific exemptions as for example:

- PCB assemblies
- PMMAs, and other optical plastic components
- wiring and cables
- packaging, tape and stretch wraps, labels

[104] According to EN 50625-1:2014, a component is a constituent part of a device which cannot be physically divided into smaller parts without losing its particular function

[105] European Commision, 2013. COM(2013) 123 final - Green paper on a European strategy on plastic waste in the environment. doi:COM(2013) 123 final

[106] JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220.

- electrostatic discharge components and, electromagnetic interference components
- acoustics modules
- and in general plastics where marking is not possible because of the shape or size of the part, or when the marking would impact on the performance or functionality of the part, or where marking is technically not possible because of the molding method.

Moreover, it should be noted that requirements for computers are very similar to those for electronic displays. Since electronic displays are integrated in desktops All-in-One, in portable All-in-One, in notebooks/laptops and in tablets/slates, alignment with the Regulation on electronic displays is desirable.

#### 7.6.1.7.2 Background for requirements

Density sorting of plastic (via sink-float techniques) is currently the easiest and still most adopted sorting system for shredded plastics[107]. Different plastics are separated according to their different density thanks to floating in water or air. 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 plastics used in EEE, including computers and electronic displays.

The efficiency of manual sorting of plastics is, however, dependent on the properness of plastic marking, values of recyclates and labor cost. Marking of plastic should follow a standardised approach, as the approach proposed by ISO 11469 (i.e. ISO 11469, 2000), and standards of the series ISO 1043 (i.e. EN ISO 1043-1, 2002; EN ISO 1043-4+A1:2016, 1999). Nevertheless, the European Electronics Recyclers Association (EERA) observed[108] that markings on plastics in use nowadays are not fully reliable in some cases. Tests carried out at premises of an EERA member showed that markings on the back-covers of flat panel displays were not reliable, and the polymer-type often did not match with the marking. Recyclers who follow the markings can therefore end up separating materials incorrectly and potentially this could lead to have contaminants (such as BFR in materials where BFR is not required ). Controls should be enforced to ensure that the marking and the plastic type match.

Associations of WEEE recyclers suggested that the proper marking of plastics (and their additives and flame retardants) would be beneficial for recycling companies, especially for recyclers that dismantle plastic parts and components manually. In order to improve the manual separation of valuable plastic parts, the marking of plastic parts above a certain weight (e.g. 50 g) could be systematically applied.

[107] Peeters, J.R., Vanegas, P., Tange, L., Van Houwelingen, J., Duflou, J.R., 2014. Closed loop recycling of plastics containing Flame Retardants. Resour. Conserv. Recycl. 84, 35–43. doi:10.1016/j.resconrec.2013.12.006
[108] EERA, 2016. EERA Position Paper. The Netherlands.

#### 7.6.1.7.3 Proposed requirement

*Ecodesign*

From 1 January 2020, manufacturers shall mark plastic components heavier than 50 g by specifying the type of plastic and flame retardant(s) using symbols and abbreviations in line with standard series EN ISO 11469 and EN ISO 1043.

For the following plastic components, no marking is required:

- packaging, tape and stretch wraps
- labels, wiring and cables
- PCB assemblies, PMMA board and optical plastics, electrostatic discharge components; electromagnetic interference components, acoustic modules.

In addition, plastic components in the following circumstances are exempted from marking requirements:

- the marking is not possible because of the shape or size
- the marking would impact on the performance or functionality of the plastic component
- marking is technically not possible because of the molding method.

For exempted plastic parts, manufacturer shall provide a justification in the technical documentation.

### 7.6.1.8 *Provision of information on plastic components containing flame retardants (FRs)*

#### 7.6.1.8.1 Rationale and potential benefits

According to all the recyclers interviewed, FRs are the major barrier to plastic recycling. Current mechanical sorting processes of plastics with additives are characterised by a low efficiency, while innovative sorting systems are still at the pilot stage and revealed to be effective only in specific cases[109]. The IEC/TR 62635[110] suggests 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 brominated flame retardants (BFR) have high toxicity and for this reason they have been regulated (e.g. 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 on waste electrical and electronic equipment (WEEE) states in Annex VII that plastic containing BFR have to be removed from any separately collected WEEE.

#### 7.6.1.8.2 Background for requirements

The provision of information on the FRs content could be structured and communicated in a systematized way through specific indexes. These indexes could support recyclers to check the use of flame retardants in the computers and to develop in future processes

[109] Ardente, F., Mathieux, F., Talens Peiró, L., 2016. Revision of methods to assess material efficiency of energy related products and potential requirements. doi:10.2788/517101

[110] IEC/TR 62635, 2015. IEC/TR 62635:2015 Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment.

and technologies suitable for plastic recycling. Moreover, these indexes could allow policy makers to monitor the use of flame retardants in the products and, in the medium-long term, to promote products that use less quantities of FRs.

As an example, the "Flame retardant in plastic parts" index[111] aims at:

- detailing plastic parts that contain flame retardants (including mass and type of plastic parts; mass and type of flame retardants)
- providing, in a very synthetic way, an overview of the content of flame retardants.

To simplify the calculation and communication of this index, the scope of the index could be restricted only to plastic parts larger than a certain mass (e.g. larger than 50 g). In addition, some plastic parts could be excluded from this calculation (as e.g. PCBs assemblies and cables, which always contain FRs). Exemptions could also be foreseen for information that are confidential (e.g. the type of certain FRs). In this case, it could be sufficient to declare that a certain part contains FRs, without specifying the type of FRs.

An example of calculation table for the "Flame retardant in plastic parts" index is provided in Figure 23[112]. All masses are approximated at gram level.

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

* standard abbreviated term of the polymer, according to EN ISO 1043 series

** standard code number of the flame retardant, according to EN ISO 1043 series

*** Plastic components excluded: plastic parts smaller than 50g; plastics in PCB assemblies and cables.

*Figure 23. Table for the calculation of the index on "Flame retardant in plastic parts" for computers.*

[111] Ardente, F., Mathieux, F., Talens Peiró, L., 2016. Revision of methods to assess material efficiency of energy related products and potential requirements. doi:10.2788/517101

[112] JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220.

#### 7.6.1.8.3 Proposed requirement

*Ecodesign*
From 1 January 2020, plastic components larger than 50 g (other than PCB assemblies and cables) containing flame retardants are used, manufacturers shall provide details in a specific format[113] in the technical documentation.

### 7.6.1.9 *Marking of batteries*

#### 7.6.1.9.1 Rationale and potential benefits

The market for recycling Li-ion is growing rapidly, accelerated through the demand increase for portable electronics, such as tablet and notebook computers and through the explosion of the production for Battery Electric Vehicles, some of which use computer batteries. 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 logo placed on the battery packaging/casing. In practice, however, when the batteries reach the recycling facility, the logos are sometimes missing, making identification and sorting difficult. In order to release manual labor force, raise the sorting speed as well as accuracy, better marking/identification with improved readability is required in order to realize efficient identification and sorting.

According to interviews with German battery recyclers[114], batteries marked by, e.g., the Battery Recycle Mark 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 logo indicating the sub-chemistry system would be beneficial for more precise sorting and dedicated batch-wise treatment.

#### 7.6.1.9.2 Background for requirements

According to EERA[115], coloring on component level is good for recyclers to create awareness and traceability of these components and/or materials and substances that need to be removed. This principle can be specifically applied to batteries to identify the battery chemistry.

Battery packs and cells (including those incorporated into battery packs) can be identified with the "Battery Recycle Mark" or a similar marking symbol. Indeed, the "Battery Recycle Mark" and the IEC draft standard represents an excellent basis for color-based logos, even though additional standardization activities should be initiated to adapt it to the EU legislation. The battery logo would reduce the limits of current marking practices if properly applied (visible, durable, legible and indelible). The identifiability of battery chemistry would be enhanced by the use of different colors.

Standardization activities are currently ongoing to approve a draft international standard titled "Secondary batteries": Marking symbols for identification of their chemistry (IEC 62902 draft, 2017). The draft document specifies methods for the clear identification of secondary cells, batteries, battery modules and monoblocs according to their chemistry (electrochemical storage technology), by using the Battery Recycle Mark. The draft

[113] According to Figure 23.
[114] Done by JRC for: JRC Sustainable Resources (2017). (DRAFT) Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA; EUR 28394 EN; doi 10.2788/89220.
[115] EERA, 2016. EERA Position Paper. The Netherlands.

standard concerns secondary cells, batteries, battery modules and monoblocs with a volume of more than 900 cm³. The marking is applicable for secondary cell and batteries of following chemistries only:

- lead acid (Pb) (color: grey)
- nickel cadmium (Ni-Cd) (color: green)
- nickel metal-hydride (Ni-MH) (color: orange)
- lithium-ion (Li ion) (color: blue)
- secondary lithium metal (Li metal) (color: blue).

The draft standard also specifies dimensions of the marking symbols (with and without the recycling symbol), how the markings can be fixed on the battery (either by printing or labelling) and which procedure can be performed to test durability of marking to chemical agents. If approved, this draft document may be the starting point for batteries with a volume of less than 900 cm³, as in the case of personal computers.

Beside the content of the draft IEC standard, a two-digit code may be added to indicate the content of specific metals as well as substances hindering recycling for lithium-ion batteries.

To improve automated battery sorting solutions, future schemes could go beyond the proposed color-coded "Battery Recycling Mark". One option 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 earth elements as well as a link to material safety sheets. Access to the information can be limited only to dedicated treatment operators part of the official compliance schemes to mitigate concerns over innovations in battery technologies[116].

##### 7.6.1.9.3 Proposed requirement

*Ecodesign*
From 1 January 2020 battery packs and cells (including those incorporated into battery packs) shall be marked with marking symbols[117] for the correct identification of their chemistry. The marking symbol shall be durable and legible.

### 7.6.2 Assessment of benefits from resource efficiency requirements enhancing recyclability

This section aims at presenting the quantification of benefits and impacts associated to the below resource efficiency requirements (see Table 47 and Table 48 for reference):

1. Provision of information on availability and specifications of External Power Supplies (EPS): Information on availability and logo, both for PO2 (only ecodesign) and PO3 (ecodesign and energy labelling)
2. Provision of information on battery lifetime: Information and logo, both for PO2 (only ecodesign) and PO3 (ecodesign and energy labelling)
3. Provision of information to facilitate computer disassembly of key components: Computer disassembly features, information for PO2 (only ecodesign)

[116] However, competitors can anyhow obtain the info on content by simply examining the batteries as soon as placed on the market.
[117] Standardization activities are needed to define useable marking symbols and their correlation with battery types. The draft standard IEC 62902 can be used as a reference, or may be adapted, to mark batteries with volume equal or smaller than 900 cm³.

4. All requirements enhancing recyclability (computer dismantling, marking of plastic parts, information of plastic parts containing flame retardants and marking batteries chemistry).

The requirements on liquid protection class, securing personal data deletion and the logo for battery replacement in the energy label have not been assessed as currently available information on the potential effect of these requirements in the future are not available. These shall be investigated as part of future work (e.g. Impact Assessment).

The quantification of the benefits of the other requirements represents a high-level assessment of the material savings (in some cases also resource savings) including many assumptions that shall be further discussed with stakeholders. Overall aggregated benefits from the implementation of both policy measures (PO2 and PO3) have not been established yet, as at the moment the quantification of the benefits is only about the amount of materials saved, which varies widely according to the specific requirement. Furthermore, this does not provide an indication of the environmental benefits. It is recommended to also investigate this as part of future work. The presentation of the results is thus discussed at a requirement level, and not at policy option level.

#### 7.6.2.1 *Provision of information on availability and specifications of External Power Supplies (EPS)*

The assessment was based on future scenarios established by JRC[106] in which mobile personal computers (i.e. only notebooks and tablets) and EPS are gradually decoupled, so a certain percentage of products put on the market will not include an EPS in the packaging.

Two scenarios have been developed, one related to EPS in notebooks and another for EPS in tablets, and do not take into account that harmonisation of power specifications could imply the common use of the same EPS for tablets and notebooks. These personal computers previously had different power requirements (lower for tablets and higher for notebooks), and assessment concerning these products have been considered separately also in previous studies[118]. However, currently many notebooks can work with a power requirement of less than 100 W, and the USB type C specifications allow scalable power up to 100 W[119]. However, due to the lack of input data, it was not possible to estimate the number of notebooks and tablets potentially sharing the same EPS. Thus, the possibility of using the same EPS for both notebooks and tablets has been excluded and assumes that the technology of the common EPS would be based on micro-USB connectors, although notebooks and tablets could also rely on standard-USB connectors. The average compositions for the EPS of notebooks and tablets were based on the average composition shown in task 4 report (section 4.2.2) scaled to two capacities (i.e. 60W for tablets/slates and 90W for notebooks).

Different levels of decoupling have been modelled for 2020, 2025 and 2030, in order to estimate the material savings projections according to the corresponding mass of EPS not manufactured nor shipped. The levels of decoupling have been adapted to what was

[118] 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.

[119] the USB Power Delivery is capable of delivering up to 100 W with the standard USB connector and up to 60 W with the micro-USB connector.

assessed by Risk & Policy Analysts (2014)[118]. For more details on the scenarios, see JRC report[120].

Table 50 and Table 51 show the material savings from the different decoupling rates in years 2020, 2025 and 2030. Only slight differences are observed throughout the years, since shipment and sales[121] will be stable for the two product categories, over the considered time horizon. The estimated material savings for notebooks are in the range 365 to 9182 t/year by 2030 and 92 to 2294 t/year for tablets/slates. These results are 4-6 times higher than the associated reduction in the consumption of raw materials calculated by Risk & Policy Analysts Limited (2014) for the decoupling of EPS from mobile phones. The greatest differences come from the different decoupling rates, ranging from 2% as the current observed trend for mobile phones, and 50% as the highest possible decoupling rate. The 50% decoupling considers that the European Commission proposes legislation requiring that devices use a common EPS considering the current levels of ownership of personal computers and expected changing behavior of consumers.

*Table 50. Material savings for notebooks shown by material categories (plastics, ferrous metals, non-ferrous metals and electronics) in tonnes/year.*

| **Year** | **2020** | | | | **2030** | | | |
|---|---|---|---|---|---|---|---|---|
| **Decoupling scenario** | **2%** | **10%** | **30%** | **50%** | **2%** | **10%** | **30%** | **50%** |
| Plastics | 115 | 574 | 1722 | 2870 | 115 | 575 | 1725 | 2875 |
| Ferrous metals | 3 | 14 | 42 | 70 | 3 | 14 | 42 | 70 |
| Non-ferrous metals | 86 | 430 | 1291 | 2152 | 86 | 431 | 1294 | 2156 |
| Electronics | 163 | 815 | 2444 | 4073 | 163 | 816 | 2449 | 4081 |
| **TOTAL** | **367** | **1833** | **5499** | **9165** | **365** | **1836** | **5510** | **9182** |

*Table 51. Material savings for tablets/slates shown by material categories (plastics, ferrous metals, non-ferrous metals and electronics) in tonnes/year.*

| **Year** | **2020** | | | | **2030** | | | |
|---|---|---|---|---|---|---|---|---|
| **Decoupling scenario** | **2%** | **10%** | **30%** | **50%** | **2%** | **10%** | **30%** | **50%** |
| Plastics | 30 | 148 | 443 | 738 | 30 | 148 | 445 | 742 |
| Ferrous metals | 1 | 3 | 10 | 17 | 1 | 3 | 10 | 17 |
| Non-ferrous metals | 28 | 139 | 417 | 695 | 28 | 140 | 419 | 698 |
| Electronics | 33 | 167 | 500 | 834 | 33 | 167 | 502 | 837 |
| **TOTAL** | **92** | **457** | **1370** | **2284** | **92** | **458** | **1376** | **2294** |

#### 7.6.2.2 *Provision of information on battery lifetime*

Increased battery durability potentially increases the time the battery is used in a personal computer, by delaying the loss of capacity and delaying its end-of-life. The lower the State of Charge (SoC) of the battery when in storage (i.e. without cycling), the higher its durability. Depending on SoC, the capacity of the tested cells fades to 80 % full charge capacity after varying times:

- SoC of 95 % after less than 300 days
- SoC of 80 % after around 300 days

[120] Section 5.2.3, to be published in January 2018, according to information provided by JRC
[121] Sales and stock shown in task 2 report

- SoC of 70 % after around 400 days
- SoC of 50 % after more than 500 days

Testing performed by Schmalstieg et al. (2014)[122] under elevated temperature (i.e. 50° C) shows the effect of calendar aging at varying SoC. By deriving a factor from this effect, it is possible to establish how much capacity fade is prevented by capping the SoC and deriving the following simplified scenarios:

A. Scenario A: A notebook computer is permanently used in grid operation. Assuming that a software to limit the SoC in grid operation limits the SoC the battery durability may be increased as follows:
    a. SoC limit at 70 % may increase battery durability by factor [400 days/300 days = 1.34]
    b. SoC limit at 50 % may increase battery durability by factor [500 days/300 days = 1.67]
B. Scenario B: A notebook computer is used 75% of the time in grid operation and 25 % mobile on battery power. The effect of SoC limit would only account for the share of grid operation. Hence, if the SoC is capped at 70% during grid operation, the durability is increased by factor 1.26. If SoC is capped at 50 %, the factor is 1.50:
    a. SoC limit at 70 % may increase battery durability by factor [(0.75 * 1.34) + (0.25 * 1) = 1.26]
    b. SoC limit at 50 % may increase battery durability by factor [(0.75 * 1.67) + (0.25 * 1) = 1.50]
C. Scenario C: A notebook computer is used 50 % in grid operation and 50 % mobile on battery power. The effect of SoC limit will only account for the share of grid operation. Hence, if the SoC is capped at 70 % during grid operation, the durability is increased by factor 1.17. If SoC is capped at 50 %, the factor is 1.34:
    a. SoC limit at 70 % may increase battery durability by factor [(0.5 * 1.34) + (0.5 * 1) =] 1.17
    b. SoC limit at 50 % may increase battery durability by factor [(0.5 * 1.67) + (0.5 * 1) =] 1.34

Prakash et al. (2016c)[123] investigated the effect of extending the lifetime of notebooks used in the public administration, for a total useful life of six years instead of three years. In their assumptions, the authors estimated that a battery replacement is necessary in 50% of notebook computers, to allow such a lifetime extension. This assumption can be converted in a value of 1.5 batteries/mobile computer, and was here adopted to build a BAU scenario considering the average lifetime of notebooks (5 years), the average mass of notebook computers (see task 4 report) and the present and future sales (see task 2 report).

---

[122] Schmalstieg, J., Käbitz, S., Ecker, M., Sauer, D.U., 2014. A holistic aging model for Li(NiMnCo)O2 based 18650 lithium-ion batteries. J. Power Sources 257, 325–334. doi:10.1016/j.jpowsour.2014.02.012

[123] Prakash, S., Köhler, A., Liu, R., Stobbe, L., Proske, M., Schischke, K., 2016c. Paradigm Shift in Green IT – Extending the Life - Times of Computers in the Public Authorities in Germany, in: Electronics Goes Green 2016+. Berlin, Germany, pp. 1–7.

The benefit of a battery optimization software was established using the following parameters:

- BAU: no use of battery optimization software and need of batteries for each notebook computer set to 1.5 batteries
- Scenario B: notebooks working in grid operation 75% of the time, SoC limits 70% and 50%
- Scenario C: notebooks working in grid operation 50% of the time, SoC limits 70% and 50%

Scenario A (notebooks working in grid operation 100% of the time) was not considered realistic.

Table 52 shows the amount of batteries saved per year, as well as the corresponding resource savings (listed by resource element) from scenarios B and C in comparison to the BAU.

*Table 52. Resource savings for notebooks when a battery built-in functionality is implemented in notebook computers.*

| Material and resource savings | Scenario B | | Scenario C | |
|---|---|---|---|---|
| | Cap 70% | Cap 50% | Cap 70% | Cap 50% |
| Notebook batteries (million units/year) | 12.9 | 20.8 | 9.1 | 15.9 |
| Co (t/year) | 281 | 454 | 198 | 346 |
| Li (t/year) | 60 | 97 | 42 | 74 |
| Ni (t/year) | 131 | 211 | 92 | 161 |
| Cu (t/year) | 452 | 730 | 318 | 556 |
| Other (t/year) | 2424 | 3915 | 1707 | 2980 |
| **TOTAL RESOURCES (t/year)** | **3347** | **5407** | **2357** | **4116** |

#### 7.6.2.3 *Provision of information to facilitate computer disassembly of key components*

The analysis of material savings for this requirement was done at a product type level (i.e. number of units per year and corresponding tonnes per year). It focused on possible scenarios with improved reparability only, focusing on notebook and tablet computers that risk being discarded because repair is not feasible. Possible improvements in terms of reparability aim at reducing discarded units because of damage or reported malfunctions, and on extending their lifetime.

Based on notebook and tablet/slate computers failure rates reported by JRC[124], a number of computers expected to report failures in years 2020, 2025 and 2030 were estimated (see Table 53).

[124] See JRC report, section 6.1.3 pages 102 and 103: JRC (DRAFT). Analysis of material efficiency aspects of personal computers product group - Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA. EUR 28394 EN; doi 10.2788/89220.

*Table 53. Number of computers expected to report failures in million units per year (taken from JRC[124]).*

| Product type | 2020 | 2025 | 2030 |
|---|---|---|---|
| Notebooks | 7.7 | 7.7 | 7.7 |
| Tablets | 5.6 | 5.6 | 5.6 |
| **TOTAL** | **13.3** | **13.3** | **13.3** |

Based on these numbers, it was considered that a part of the computers reporting failure are not repaired and thus discarded as WEEE:

- Notebooks and tablets/slates in the first 2 years of use, with warranty plans. Repair rate would be 80%.
- Notebooks and tablets/slates older than 2 years, with no warranty plans. Repair rate would be 20%.

When implementing the proposed requirements, repairability would be enhanced to 81-84% in the first 2 years covered by warranty, and to 24-36% after 2 years not covered by warranty.

Considering the first 2 years of use, between 0.13 and 0.53 million of units are expected to be discarded as WEEE, and are now considered as potentially repaired devices. With this hypothesis, between 150t and 615t of material can be saved every year to 2030 (see Table 54)

*Table 54. Material savings in the first 2 years of use covered by warranty plans by implementing requirement.*

| Product type | 2020 | 2025 | 2030 |
|---|---|---|---|
| Notebooks (million units/year) | 0.08-0.31 | 0.08-0.31 | 0.08-0.31 |
| Tablets (million units/year) | 0.06-0.22 | 0.06-0.22 | 0.06-0.22 |
| **TOTAL (million units/year)** | **0.14-0.53** | **0.14-0.53** | **0.14-0.53** |
| **TOTAL tonnes/year)** | **153-613** | **153-612** | **154-615** |

When notebook and tablet/slate computers older than 2 years, without warranty plans, are considered, repair rates and therefore resource savings can potentially increase, with material savings ranging from 610t to 2460t per year to 2030 (see Table 55).

*Table 55. Material savings after 2 years of use not covered by warranty plans by implementing requirement.*

| Product type | 2020 | 2025 | 2030 |
|---|---|---|---|
| Notebooks (million units/year) | 0.31-1.23 | 0.31-1.23 | 0.31-1.24 |
| Tablets (million units/year) | 0.22-0.89 | 0.22-0.89 | 0.22-0.89 |
| **TOTAL (million units/year)** | **0.53-2.12** | **0.53-2.12** | **0.53-2.13** |
| **TOTAL tonnes/year)** | **613-2453** | **612-2448** | **615-2459** |

The values in Table 54 and Table 55 take into consideration the amount of materials required to produce spare parts necessary for the repair.

The assessment of the potential benefits related to enhanced reparability of desktop computers is characterized by higher degrees of uncertainty. Because there is no statistical analysis that reports figures for yearly failure rates of desktop computers, a hypothetical failure rate of 16.5 % was assumed (as an average of 18.5 % for notebooks and 14.5 % for tablets).

In the case of desktop computers, however, a very high repair rate of 90% was assumed (the percentage of devices which reported a failure and were repaired), independent from the age of the desktop computer. It was also assumed that enhanced reparability strategies would bring smaller benefits in terms of repair rate increase (in the range of 0.5 – 1 %).

With these hypothesis, and considering market data of years 2020, 2025 and 2030, between 2 to 2.24 million desktop computers will report failures. Without enhanced reparability strategies 0.20 – 0.22 million computers would be discarded. Based on the hypothesis on enhanced reparability strategies between 96 to 216 t of materials could be saved every year. However, future work is needed to collect data about repair services of desktop computers, in order to strengthen the estimations.

#### 7.6.2.4 ***Requirements enhancing recyclability***

Requirements that enhance recyclability are synergic in promoting more resource efficient treatments and the potential benefits and impacts are therefore assessed together. However, this assessment is presented in two sections, first for notebooks and second for other product types. This is because the assessment of the potential benefits related to design for dismantling strategies is more difficult and uncertain for other personal computers than notebooks.

##### 7.6.2.4.1 Notebooks

The potential benefits have been assessed based on the comparison of some reference scenarios. In particular, it is assumed that without any specific policy measure on recyclability, waste notebook computers will be treated in the future according to the current situation (defined as BAU).

*Business as Usual (BAU) scenario for disposal of notebooks*

The definition of BAU has been done according to a detailed analysis of the current end of life practices of notebook computers, which is summarised in task 3 report and explained in further detail in the material efficiency analysis report published by JRC[125].

Current practices combine different mechanical and manual dismantling and separation methods, depending on which components they target and whether they have acceptors for special parts that are difficult to process such as storage drives. These practices can be characterised by two main BAU scenarios:

1. Mechanical crushing and sorting: After the removal of the battery and display panel, the entire device is treated in a medium shredder for further separation of the different fractions (named BAU1).
2. Manual medium-depth dismantling: After the removal of the battery and display panel, certain high value components are manually recovered from the notebook, such as printed circuit boards (PCBs) which are directly forwarded to the copper smelter and storage drives (when accessible) are forwarded to a medium

[125] Report to be publicly available in January 2018, according to information provided by JRC

shredder for further separation of iron, aluminium, magnets and circuit board fractions (named BAU2).

The rest of the notebook's body goes then to a medium shredder for further separation of fractions.

It is assumed that these BAU scenarios are equally representative of EU treatments, with 50% of the notebook stock reaching its end of life and being processed with mechanical crushing and sorting (BAU1). While another 50% is processed according to medium-depth dismantling and subsequent mechanical crushing and sorting (BAU2). Compared to the BAU1, the BAU2 scenario is characterised by higher recycling rates of batteries, PCB and storage systems, due to the more careful manual dismantling and the following dedicated recycling. An overview of BAU can be seen in Figure 24.

Current stock and future trends for notebook computers have been calculated and presented in task 2 report, and assumptions on Bill of Materials (BOM) for average notebook computers have been presented in task 4 and 5-6 reports. Furthermore, it has been assumed that 50% of the notebook computers will have HDD as storage device up to 2020, while the rest will have SSD.

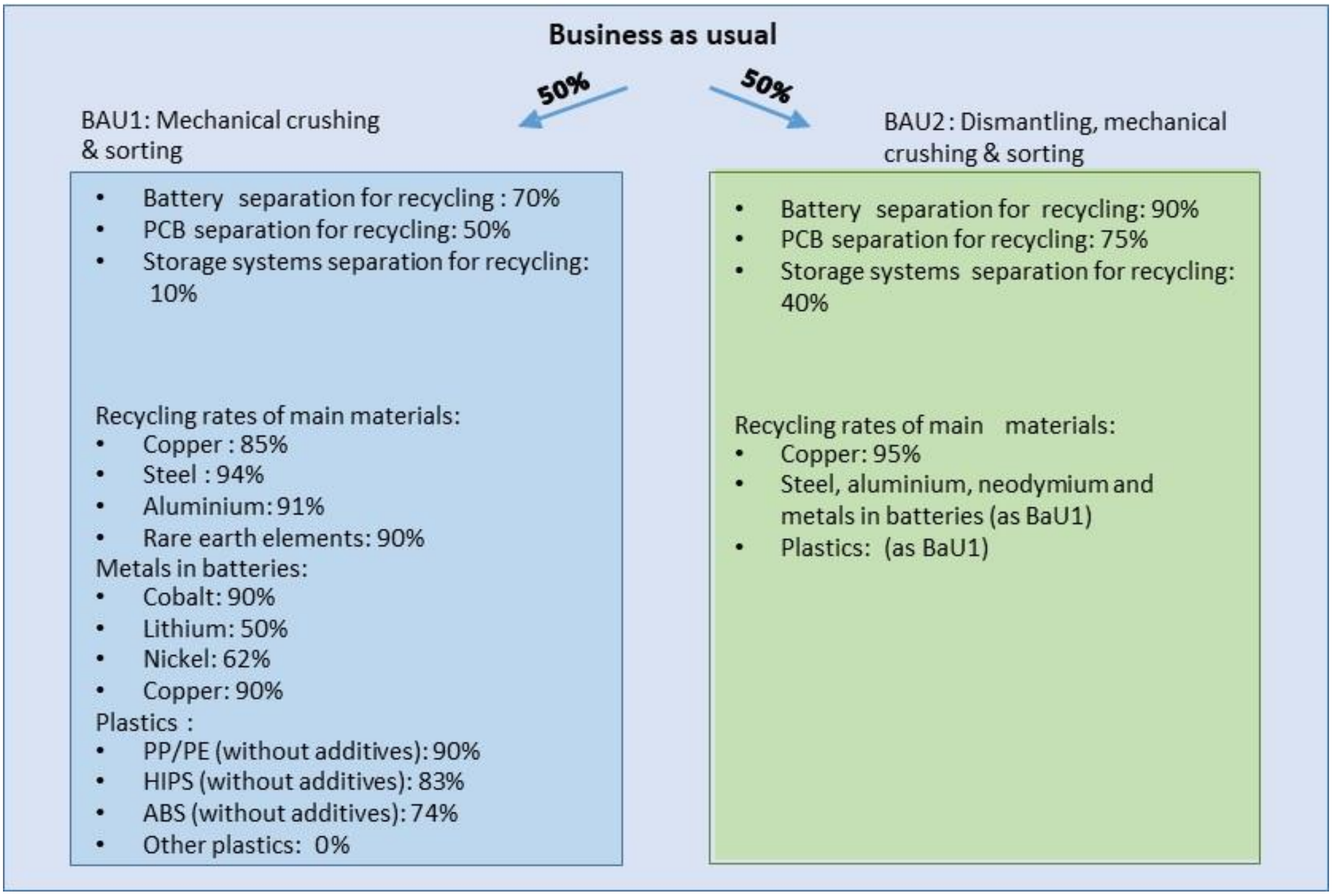



*Figure 24. BAU scenario for notebook computers.*

The average recycling rates of different metals present in printed circuit boards (PCBs), when PCBs are separated for dedicated treatments is shown in Table 56. The same recycling rates are assumed for SSD[126].

*Table 56. Average recycling rates of different materials found in PCBs[127].*

| Material | Recycling rate (%) | Material | Recycling rate (%) |
|---|---|---|---|
| Ag | 95% | Pb | 80% |
| Al | 0% | Pd | 95% |
| As | 0% | Sn | 75% |
| Au | 95% | Sr | 0% |
| Ba | 0% | Ta | 0% |
| Be | 0% | Zn | 50% |
| Bi | 80% | SiO2 | 0% |
| Cd | 0% | B2O3 | 0% |
| Cl | 0% | K2O | 0% |
| Co | 0% | CaO | 0% |
| Cr | 0% | MgO | 0% |
| Cu | 95% | NaO | 0% |
| Fe | 0% | C | 0% |
| Ga | 0% | Br | 50% |
| Mn | 0% | Sb | 80% |
| Ni | 90% | | |

The recycling rate of rare earths (neodymium and dysprosium) from HDD magnets extracted and separately treated is assumed to be 90%[128]. The assumed recycling rates of metals from batteries extracted and separately treated are cobalt 90%[127], nickel 62% and copper 90%[129] while lithium is 50%[130]. Recycling rates of other components materials are derived from IEC (2012)[131].

*Benefits from implementing resource efficiency requirements enhancing recyclability*

It is assumed that the proposed requirements enhancing recyclability will improve the economic viability of treatments more focused on medium-depth manual dismantling (BAU2) compared to treatments based only on the 'Mechanical crushing and sorting' after depollution (BAU1). Moreover, a better design for recycling of the notebook could increase the separation of valuable components and the recycling rates of materials. These two parameters (i.e. the flow of waste treated in the different scenarios and the efficiency of the different recycling treatments) are assumed to be affected by the recycling improvements and this is reflected in the quantification of benefits from implementing these resource efficiency requirements.

[126] SSD have a structure similar to that of PCB and are assumed to be collected together with PCBs and recycled in the same facilities.

[127] Chancerel, P., Marwede, M., 2016. Feasibility study for setting-up reference values to support the calculation of recyclability / recoverability rates of electr(on)ic products. doi:10.2788/901715.

[128] 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.

[129] Wang, X., Gaustad, G., Babbitt, C.W., Richa, K., 2014. Economies of scale for future lithium-ion battery recycling infrastructure. Resour. Conserv. Recycl. 83, 53–62. doi:10.1016/j.resconrec.2013.11.009.

[130] The recycling of lithium, although technically feasible with high efficiency (50 - 90 %) is still not largely developed in the EU. Currently, a plant for the recycling of lithium has been established in France. Similar plants could be set in the EU, especially assuming in the next future a large growth of the amount of waste batteries sorted for recycling.

[131] IEC/TR 62635, 2015. IEC/TR 62635:2015 Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment.

The recycling improvements have been defined in two main improvement scenarios, which have been modelled accordingly to quantify the corresponding benefits:

1. Moderate improvement (scenario I.1): this scenario assumes that, thanks to the enforcement of the resource efficiency requirements, the flow of waste notebooks processed through the medium-depth manual dismantling and mechanical crushing would increase compared to the BAU scenarios. This can be justified with the reduction of efforts to locate and dismantle relevant components and the consequent reduction of labour costs. The investigated actions would grant a higher extraction rates of batteries and also a moderate increase of the separation rate and recycling rate of PCBs, storage systems and large plastics parts in both the scenarios (i.e. medium-depth manual dismantling and mechanical crushing and mechanical crushing & sorting scenario).
2. High improvement (scenario I.2): this scenario is analogous to the previous one (I.1) with the difference that material efficiency actions are supposed to produce higher benefits, in terms of both higher flows of waste treated with medium-depth manual dismantling and higher separation and recycling rates of components and materials. Also in this case, it is supposed that the scenario based on the mechanical crushing & sorting would achieve a higher extraction rate of the batteries.

An overview of the improvement scenarios is shown in Figure 25.

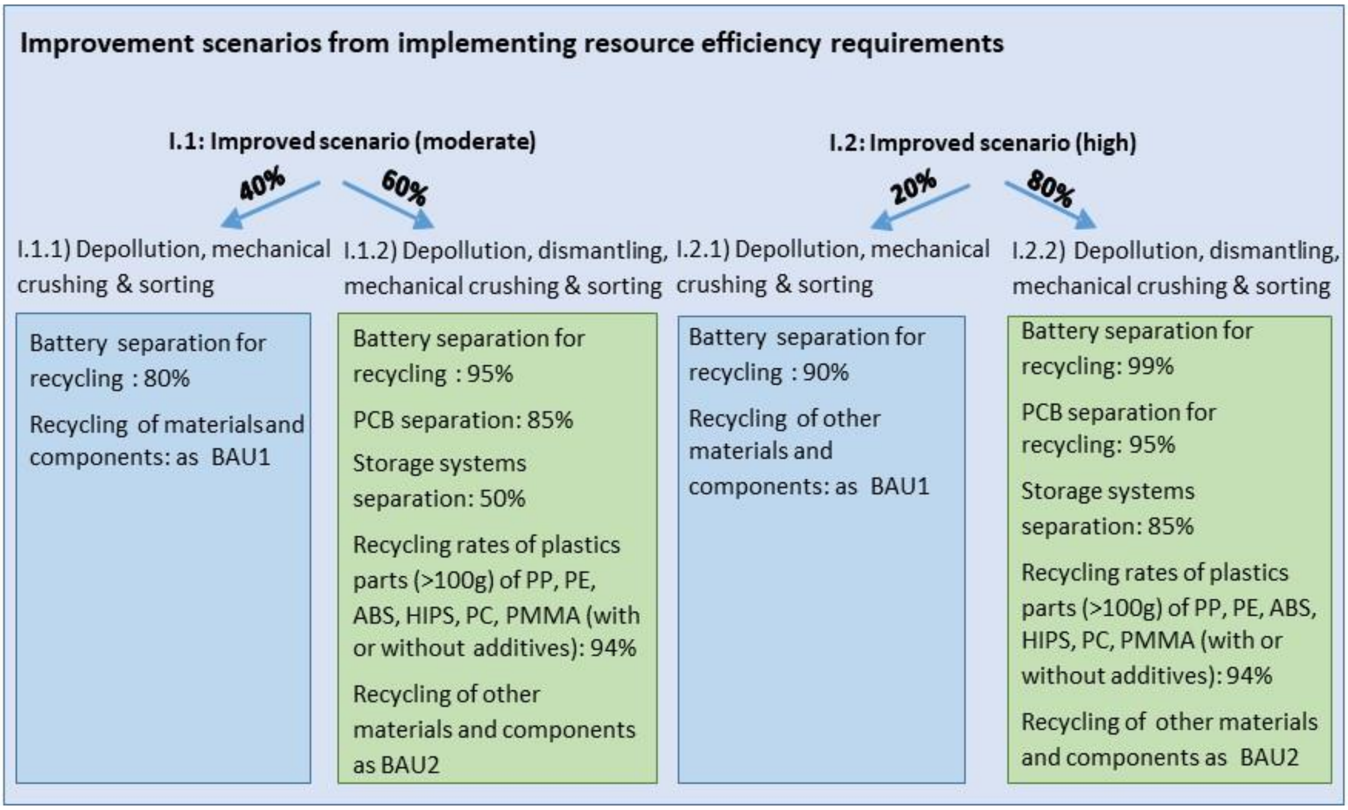



*Figure 25. Improvement scenarios from implementing proposed resource efficiency requirements on notebook computers.*

The benefits have been estimated in terms of additional recycled materials obtained by moving from BAU towards the improvement scenarios (both moderate I.1 and high I.2). See Table 57 for the amount of additional recycled materials available in the material stream.

*Table 57. Estimated benefits measured in terms of additional recycled materials after recycling from moderate and high improvement scenarios.*

| Material | Amount of additional recycled material (ton) | |
|---|---|---|
| | Moderate improvement scenario (I.1) | High improvement scenario (I.2) |
| Plastics (from various components) | 8067 | 10756 |
| Copper (from various components) | 318 | 763 |
| Silver (from PCBs) | 2.6 | 8.5 |
| Gold (from PCBs) | 0.2 | 0.5 |
| Bismuth (from PCBs) | 0.1 | 0.3 |
| Nickel (from PCBs) | 9.7 | 22.2 |
| Lead (from PCBs) | 8.0 | 21.1 |
| Palladium (from PCBs) | 0.2 | 0.5 |
| Tin (from PCBs) | 12.3 | 32.3 |
| Zinc (from PCBs) | 8.5 | 22.6 |
| Bromine (from PCBs) | 18.0 | 47.2 |
| Antimony (from PCBs) | 2.5 | 6.5 |
| Neodymium (from HDDs magnets) | 1.9 | 7.0 |
| Cobalt (from batteries) | 74.8 | 144.5 |
| Lithium (from batteries) | 8.7 | 16.8 |
| Nickel (from batteries) | 23.8 | 46.0 |

This additional pool of recycled materials can be compared to historical pools of important recycled materials in the EU, which are:

- In 2012, 10.9t of palladium were recycled in the EU28[132]. The implemented requirements would generate an additional recycling of about 0.2 t - 0.6 t of palladium in the future, equivalent to 1.8% – 4.7% of the current recycling amount.
- In 2012, 6.3 kt of cobalt were recycled in the EU28[132]. The implemented requirements would generate an additional recycling of about 74.8 t - 144.5 t of cobalt in the future, equivalent to 1.2% - 2.3% of the current recycling amount.
- In 2013, 14 t of neodymium were recycled in the EU28[132]. This implies that a large share of neodymium in WEEE is currently lost. The implemented requirements would generate an additional recycling of about 1.9 t – 7 t of neodymium in the future, equivalent to 13.5% - 49.7% of the current recycling amount.
- Lithium from batteries is mostly not recycled. According to BIO by Deloitte[132], the lithium currently recycled amounts to 16 t. The implemented requirements would improve the batteries extraction in the future, and would promote the recovery of lithium as well. The amount of additional lithium potentially recycled ranges from 8.7 t to 16.8 t. These amounts are equivalent to around 50%-100% of the current recycled masses.
- Compared to the current recycling of antimony in the EU (9.7 kt[132]) the implemented requirements would also allow moderate minor benefit in terms of additional antimony recycled (up to 6.5 t, equivalent to 0.1% of the current recycling).

[132] BIO by Deloitte, 2015. Study on Socioeconomic impacts of increased reparability.

The previous estimated benefits are based on the assumption that all the waste notebooks will be properly collected and treated in the EU at their end of life. However, there are evidences of large amounts of waste electronics that are illegally exported or improperly collected and treated (e.g. disposed into trash bins)[133]. Assuming a loss of 26% of the flow of waste notebooks, potential benefits related to the proposed requirements have been estimated and are shown in Table 58.

*Table 58. Revised benefits considering a 26% share of waste notebooks being exported outside the EU from moderate and high improvement scenarios.*

| Material | Amount of additional recycled material (ton) | |
|---|---|---|
| | Moderate improvement scenario (I.1) | High improvement scenario (I.2) |
| Plastics (from various components) | 5970 | 7959 |
| Copper (from various components) | 240 | 609 |
| Silver (from PCBs) | 2.0 | 6.6 |
| Gold (from PCBs) | 0.1 | 0.4 |
| Bismuth (from PCBs) | 0.1 | 0.2 |
| Nickel (from PCBs) | 7.3 | 17.7 |
| Lead (from PCBs) | 6.1 | 17.5 |
| Palladium (from PCBs) | 0.1 | 0.4 |
| Tin (from PCBs) | 9.4 | 26.8 |
| Zinc (from PCBs) | 6.5 | 18.6 |
| Bromine (from PCBs) | 13.7 | 39.1 |
| Antimony (from PCBs) | 1.9 | 5.4 |
| Neodymium (from HDDs magnets) | 1.4 | 5.1 |
| Cobalt (from batteries) | 55.6 | 107.8 |
| Lithium (from batteries) | 6.5 | 12.5 |
| Nickel (from batteries) | 17.7 | 34.3 |

#### 7.6.2.4.2 Other computer product types

The assessment of the potential benefits related to design for dismantling strategies is more difficult and uncertain for other personal computer types other than notebooks.

In the case of tablets, a small amount of waste currently reach recycling facilities. However, the dismantling process of tablets is still under development and being currently refined by recyclers. However, in task 3 report some criticalities during the processing of waste tablets are discussed, mainly related to the extraction of the batteries and PCBs. Design for recycling strategies as proposed in this chapter could contribute to simplify the pre-processing of tablets and overall increase the resource efficiency of the recycling processes, in terms of higher quantity/quality of materials separated for recycling.

For the assessment of the benefits of design for dismantling strategies for tablets it is roughly assumed to achieve similar improvements as discussed for notebooks. This implies that the efficiency of sorting and processing of PCBs and batteries could increase by around 10% - 20%. Considering the average BoM of tablet presented in task 4 report, as well as the average composition of batteries (same as notebooks) and assuming the

[133] 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.

same recycling rates as in Figure 25, it is roughly estimated that the additional amounts of recycled materials are: 30-60 tonnes of cobalt, 4-7 tonnes of lithium, 80-170 tonnes of copper and 0.2-0.6 of various precious metals.

The process of dismantling and depolluting traditional desktop computers (in tower design) is instead well established and no criticalities have been identified in our analysis. However, the market of traditional desktop computers is estimated to continue declining, while the market shares of new types of desktops (e.g. mini-desktops) are expected to grow in the next future. These new desktops can pose some problems during the recycling, especially due to the very compact structure and the difficulties to extract PCBs and batteries potentially contained in the computer. Design for recycling strategies as proposed could contribute to keep the attention of manufacturers on end of life aspects high for these desktops and to promote design for recycling solutions that facilitate their processing. However, due to the lack of information about the flows of mini-desktops sold and their average BoM, it is not possible to quantify such benefits.