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Development of European Ecolabel and Green Public Procurement Criteria for Personal Computers & Notebook Computers

TECHNICAL REPORT, TASK 4

Improvement potential

(Draft) Working Document

Nicholas Dodd, Oliver Wolf (JRC-IPTS)

Kathrin Graulich, Rita Groß, Ran Liu, Andreas Manhart, Siddharth Prakash (Öko-Institut e.V. – Institute for Applied Ecology)

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Institute for Prospective Technological Studies (IPTS)

Contact information
Nicholas Dodd
Address: Joint Research Centre, Edificion EXPO, Calle Inca Garcilaso 3, E-41092 Sevilla, Spain
E-mail: nicholas.dodd@ec.europa.eu
Tel.: +34 954 488 486

http://ipts.jrc.ec.europa.eu/

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Table of Contents

List of Tables

List of Figures

INTRODUCTION

This draft Task report is intended to provide the background information for the revision of the EU Ecolabel criteria for Desktop PCs and Notebook PCs. The study has been carried out by the Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) with technical support from the Öko-Institut e.V. (OEKO). The work is being developed for the European Commission's Directorate General for the Environment.

The draft Task 4 report addresses the requirements of the Ecolabel Regulation No 66/2010 for technical evidence to inform criteria revision. It consists of background information regarding the improvement potential for computers. Together with the description of the scope and legal framework (Task 1), the market analysis (Task 2), and the technical analysis (Task 3) as well as input from stakeholders, the information will be used to determine the focus for the revision process and present an initial set of criteria proposals (Task 5).

4. IMPROVEMENT POTENTIAL

4.1 Background – Key environmental issues of desktop and notebook PCs

The technical analysis of LCA studies on desktop and notebook computers (cf. Task 3 report) revealed that especially for computer products with a short life time, such as notebook PCs or tablet PCs, the manufacturing phase has more significant environmental impacts compared to the use phase.

Within the manufacturing phase of desktop PCs, the motherboard and other Printed Wiring Boards of the desktop unit, the power supply, CD ROM and the hard disk drive (HDD) are mainly responsible for the environmental impacts (see Figure 1). Further, the LCD panel and PWB of the display are the main contributors at component level (see Figure 2).

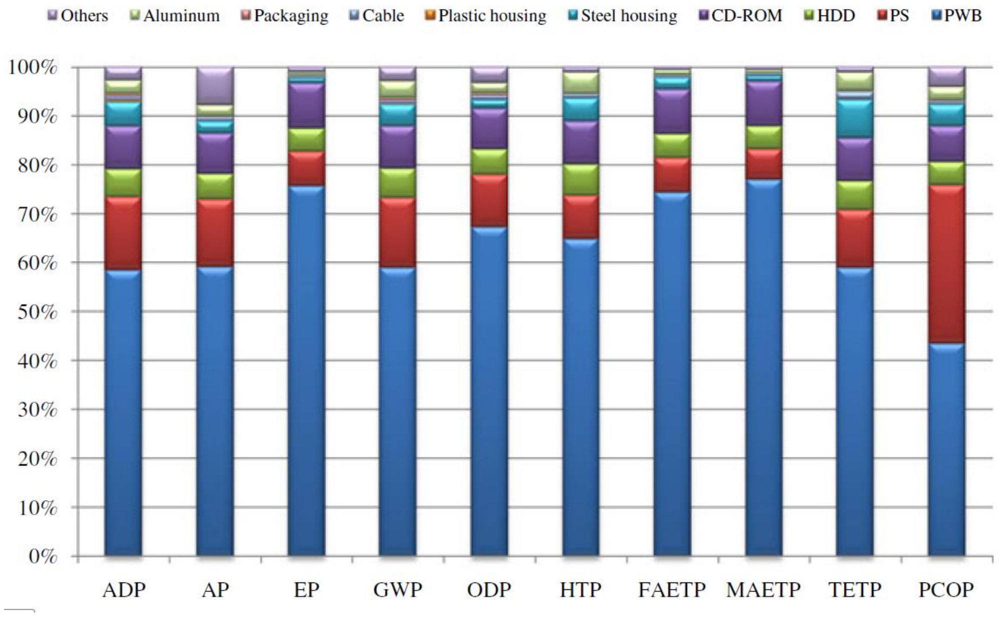

Figure 1: Desktop unit: Main contributors to environmental impacts of the manufacturing phase at component level (Source: Song et al 2013)

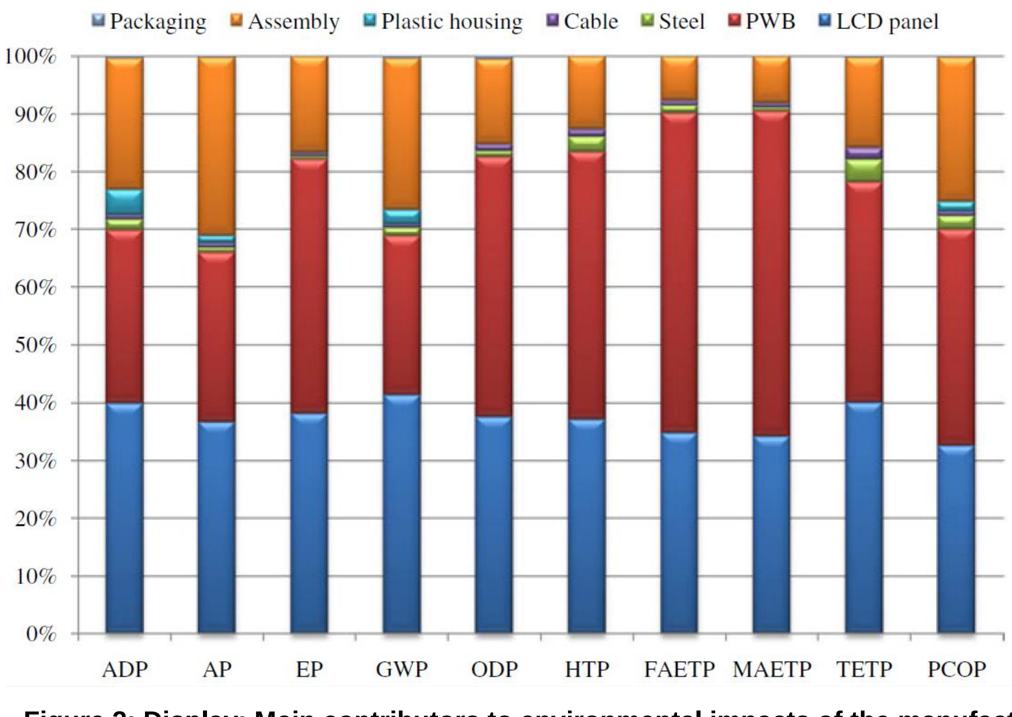

Figure 2: Display: Main contributors to environmental impacts of the manufacturing phase at component level (Source: Song et al 2013)

In relation to the manufacturing of notebooks, the production of the display and mainboard are the main contributors to environmental impacts, followed by battery production (see Table 1).

Table 1: Notebook: Main contributors to environmental impacts of the manufacturing phase at component level (Source: Ciroth & Franze 2011)

Environmental impacts	Major contributors		
	LCD display production	**Mainboard production**	**Battery production**
Climate change human health	√ (45%)	√ (23%)	Not relevant
Climate change ecosystem	√ (45%)	√ (23%)	Not relevant
Human Toxicity	√ (27%)	√ (52%)	√ (6%)
Particulate matter formation	√ (43%)	√ (27%)	Not relevant
Fossil Depletion	√ (45%)	√ (22%)	√ (3%)
Metal Depletion	√ (36%)	√ (37%)	√ (16%)

Many present debates on the environmental impacts attributable to ICT still focus strongly on the use phase of devices and infrastructures. Often insufficient attention is given to the environmental impacts arising during the production phase. This is partly due to the poor availability of data on production processes.

ICT devices contain a great number of important metals such as gold, silver, platinum group metals, indium, tantalum, gallium etc. Most of these critical raw materials are concentrated in the following components of computers (cf. Table 15 and Table 16): Motherboard and other Printed Circuit Boards (silver, gold, palladium), display and background illumination (indium, gallium, etc.), and batteries (cobalt) which also correspond to the main contributing components of computers revealed from the LCA analyses as stated above. The availability and impacts relating to critical raw materials is the subject of policy analysis by the European Commission [1].

While the amounts of these metals are very low in a single computer product (cf. Table 14) the overall content for desktop and notebook computers sold worldwide sums up to approximately 225 t silver, 50 t gold, 18 t palladium, 113,000 t copper and 4,900 t cobalt (Hagelüken and Buchert 2008). Furthermore, as a result of performance improvements in microelectronics, the diversity and purity of the

[1] European Commission, *Defining critical raw materials*, http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

necessary elements has increased greatly. For instance, while in 1980 around 11 elements were required to produce a computer chip, this number has risen to more than 45 – most of which are “rare metals” (UBA 2009; Graedel 2008).

The extraction and processing of these metals is associated with major material requirements, appropriation of land and consumption of energy, and it causes severe environmental impacts. For instance, in many places around the world the mining of gold and silver incurs high ecological and social costs. Broad-scale excavation of rock, energy-intensive comminution, cyanide leaching and amalgamation with mercury are just a few typical causes of the far-reaching impacts on people and the environment (Prakash et al. 2011a). Prakash and Manhart (2010) have found that the primary production of the quantities of gold, silver, palladium, copper and iron used for a single desktop PC generates emissions of around 23 kg CO_{2e}. Recovery techniques for these metals, such as the use of mercury to recover gold from electroscrap, also generate major adverse effects for people and the environment (Prakash & Manhart 2010).

The technical analysis of LCA studies (see Task 3) also reveals that the environmental impacts of the manufacturing phase of computer products can be reduced, if the end-of-life (EoL) treatment is managed more resource efficiently, since the secondary resources from recycling contribute to the avoidance of primary production. Within the EoL, sound management of toxic substances during recycling processes has been modelled to result in a ca. 75% reduction of impacts.

The scope for the direct influence of ecolabel criteria on the production of single computer components appears to be rather limited. However, the impacts of the manufacturing phase can be reduced by improving design (e.g. robustness, design for disassembly) or indirectly by extending a product’s lifetime or by reusing parts.

The following table provides an overview how the key environmental issues identified in relation to desktop and notebook computers will be addressed by the proposed areas for improvement and the ecolabel criteria proposals which will be further elaborated in the following sections of this report.

Table 2: Key environmental issues of desktop and notebook PCs and corresponding areas of improvement / ecolabel criteria

Hot spots	Areas of improvement / ecolabel criteria	
Production phase / End-of-life phase		
Motherboard	• Upgradeability of components; • Hazardous substances; • Design for disassembly.	**Lifetime extension** • Expansion capability; • User repairability; • Service (availability of spare parts); • Second-hand usage; • User instructions.
Power supply	• Design for disassembly.	
CD ROM	• Design for durability; • Design for disassembly.	
Display	• Design for disassembly; • Hazardous substances.	
Chassis	• Recycled content; • Hazardous substances; • Design for disassembly; • Material recovery	
Battery	• Prolongation of batteries' lifetime; • Removability of batteries; • User instructions.	
HDD	• Design for durability.	
Use-phase		
	Energy requirements • Energy efficiency; • Power management; • Power supplies; • User instructions.	

<u>Initial stakeholder feedback on key environmental issues</u>

- The main technical focus should be on the following areas: Energy efficiency (to include power demand in all power modes); hazardous material content; upgradability/repairability; material selection (e.g. minimising use of different materials in casings etc.); recyclability (including pigments that can impact recycling processes); recycled content; closed loop manufacturing
- There are some additional environmental impact areas that should be investigated. These include: Reporting on hazardous material content; declaration of recycled content; declaration of reusability/recycling rates using existing technologies; declaration of post-consumer recycled content; declaration of all major materials and amounts; declaration of overall product weight; durability of batteries; user replacement of batteries; inclusion of all power cables in the scope.

4.2 Improvement Potential

The aim of the Task 4 report is to evaluate and prioritise improvement options which could inform the revision of the existing criteria by using the findings of the market and technical analysis (Task 2 and 3 reports).

Based on the environmental hot spots identified in the previous tasks, in this task the environmental improvement potential of the product group is analysed and prioritised. This includes best available standards or technologies (BAT) already available on the market, a comparison of requirements on certain issues as specified in other ecolabels, as well as challenges linked to some of the proposed criteria revisions.

Furthermore, during the course of the revision process two questionnaires were sent out to selected stakeholders. The target groups were industry, Member States, NGOs and research institutions. The specific suggestions arising from stakeholders about certain criteria are reflected at the end of each improvement section. Further detailed feedback is expected from the two Ad-Hoc Working Groups (AHWG') that will take place during the criteria revision process.

In the following "Technical Report" the results of this task will be compared with the current two criteria sets in a way that will discuss and indicate how the improvement potential can be integrated into the revised set of criteria which will be proposed for discussion.

4.2.1 Energy requirements for computers

4.2.1.1 Energy efficiency

The Energy Star Program Requirements for Computers (Version 5.2)[2] is currently the most established benchmark for the energy requirements of computers. For example, in 2011 on average 54 % of all new computers sold in the US market were certified according to this specification (see Table 3).

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[2] See http://www.energystar.gov/ia/partners/product_specs/program_reqs/Computers_Program_Requirements.pdf?51a7-ce51

However, in detail this percentage differs between product categories: For notebook PCs, the market penetration with Energy Star products is already 75%, whereas for desktop PCs and workstations, only 17% and 20% fulfil the Energy Star criteria. In addition, product tests tend to show that a significant percentage of non-Energy Star products also meet existing Energy Star criteria (Carroll et al. 2009).

Table 3: Sales volumes and market-penetration of computers certified according to Energy Star 5.2 criteria in the USA in 2011

Product Category	Units shipped in the USA in 2011 [thousand devices]	Estimated market penetration of Energy Star 5.2 in the USA in 2011
Computers	50.870	54 %
Desktops	6.391	17 %
Notebooks	42.930	75 %
Small-Scale servers	475	N/A
Thin Clients	925	N/A
Workstations	150	20 %

Source: Energy Star 2012

In general, the experience shows that approximately two years after a new Energy Star version becoming effective, a large proportion of devices fulfil the energy requirements, as they build also the basis for Green Public Procurement.
However, for the EU27 the implementation rate of Energy Star, version 5.0 rated computer products and monitors is lower according to a study commissioned by the European Commission, DG ENERGY (IDC 2013)[3].

Table 4: Energy Star vs. Non-Energy Star Models

Product Category	Models sold	Models installed base
PCs	24%	21%
Notebook	33%	21%
Desktop	6%	20%
Integrated PC	34%	18%
Workstation	3%	12%

[3] The time period for the data analysed in this report is 6 months from September 2011 to March 2012 for products sold. The ENERGY STAR products and models represented in the report were drawn from the EU ENERGY STAR database in June 2012. The time periods for the various calculations are as follows: Sales analysis – the preceding six month period (from January 2012); installed base calculations – snapshot of the given time (June 2012).

Product Category	Models sold	Models installed base
Monitors	72%	72%
15"-17"	80%	44%
18"-22"	77%	34%
23"-30"	63%	52%
>31"	2%	2%

Particularly for computers IDC (2013) stated that it was often very difficult to find products listed on the Energy Star database that were actually available in the current market place. This was due to complexity of the product specifications on the market and a lack of standardisation in the definitions of a "model" (in many cases, for example, model numbers are altered depending on the various installations of a processor, OS, and memory).

The Energy Star Program Requirements for computers were used to define the binding implementing measure under the Ecodesign Directive. While the definitions of the draft Commission Regulation with regard to ecodesign requirements for computers and computer servers are widely identical with those of Energy Star v5.2, the Tier 1 efficiency requirements use the same benchmarks and TEC-calculation formulas. These Tier 1 requirements will enter into force on 1 July 2014.

Tier 2 (entering into force on 1 January 2016) also uses the same calculation formulas but sets stricter requirements.

New Energy Star Program Requirements for Computers are currently under development (Draft Version 6.0) [4] and shall take effect April 28, 2014. The available draft version differs from Energy Star version 5.2 in terms of definitions (see section Task 1 report) and energy efficiency requirements. These requirements aim to target the top 25% of models currently on the market (Energy Star 2011). Given the relatively greater significance of the manufacturing phase for tablets identified by Task 3, and that they are not included within the scope of Energy Star, it is not proposed to have overall energy criteria for tablets (see also section 4.1.1.3).

[4] See https://energystar.gov/products/specs/node/143

Considering the general desire for harmonised approaches and coherent product policy, there are two possibilities for setting energy related criteria under the revised European Ecolabel:

- Aligning with Tier 2 requirements of the Ecodesign Regulation for computers and computer servers based on Energy Star v5.2
- Aligning with Energy Star Program Requirements v6.0

Both, the Ecodesign Regulation and Energy Star for computers are part of the European product policy mix. Nevertheless, the two systems have different aims: While the Ecodesign Regulation aims at pushing worst-performing products from the market, Energy Star aims at qualifying the best-performing products (same approach as the European Ecolabel).

Proposed approach

Taking into account the fact that Energy Star Version 6.0 definitions are more up-to-date regarding current technological developments (see Task 1 and Task 2), it is recommended to use these efficiency requirements for the European Ecolabel.

In the current Ecolabel criteria set, there is a variation from Energy Star (no additional allowances for discrete graphics processing units (GPUs)); it is recommended to remove this variation for the purpose of reducing the complexity of verification (also, none of the other ecolabels has a comparable criterion).

In the case of faster market penetration of Energy Star rated products during the validity period of the EU Ecolabel, and following the precedent set by Imaging Equipment, it should be discussed to include a dynamic approach in the Ecolabel criteria to better react to market developments with regard to energy efficiency gains, e.g. a bi-annual review of the Energy Star market share.

It is proposed to separately focus attention on the performance of specific components, such as the internal power supply for desktops, in order to make additional efficiency gains based on improvements available in the market (see section 4.2.1.3).

4.2.1.2 Power management

Power management enables users to save energy by automatically switching a device into a mode with lower power consumption after a certain period of user inactivity has elapsed.

Generally, all analysed eco- and energy labels for computers have criteria on power management (see Task 1). Also the draft Commission Regulation with regard to ecodesign requirements for computers and computer servers has power management criteria. It is also noteworthy that the criteria on power management (System Sleep Mode, Display Sleep Mode, WOL and Wake Management) between Energy Star Draft Version 6.0 and the current version of the EU ecolabel criteria are mostly the same. The only difference in Energy Star Version 6.0 is a reference to System Sleep Mode, where "the speed of any active 1 Gb/s Ethernet network links shall be reduced when transitioning to Sleep Mode or Off Mode".[5]

Proposed approach *It is recommended to align the revision of the power management criterion for all products (with the exception of tablets) with the Energy Star v6.0 approach. This also applies to the network requirements for Wake-on-LAN (WoL) and wake management for computers with Ethernet capability.*

4.2.1.3 Power supplies

<u>Efficiency of power supplies</u>

Power supplies have a significant impact on the total device efficiency.

External power supplies (EPS): The efficiency of external power supplies (i.e. where there is an external power pack with transformer) is covered by the horizontal Ecodesign Regulation (EC) 278/2009. The requirements of Tier 2, being valid since April 2011, are harmonised to Level V requirements of the *International Efficiency Marking Protocol* (see Table 5).

[5] This criterion is also included in Energy Star Version 5.2 and the current Blue Angel criteria for personal computers and notebook computers (RAL UZ 78a and 78d).

Also current TCO Criteria for Desktops, All-in-One PCs, Notebooks and Tablets (each from 2012) set these requirements for Level V.[6] According to Schnabel (2012), today the Level V requirements are the strictest and most ambitious ones. The European Union is currently the only governing body to enforce compliance with the Level V standard, and most EPS manufacturers are adjusting their product portfolios to meet these requirements.

Table 5: Current standards of the International Efficiency Marking Protocol for no-load power and efficiency of external power supplies (Source: ElectronicDesign 2012)

Level	No-load power* requirement	Average efficiency requirement
I	None of the cases below fit	
II	No criteria were ever established	
III	≤ 1 W	≥ power x 0.49
	≤ 10 W: ≤ 0.5 W of no-load power	1 to 49 W: ≥ [0.09 x Ln(power)]+0.49
	10 to 250 W: ≤ 0.75 W of no-load power	49 to 250 W: ≥ 84%
IV	0 to 250 W: ≤ 0.5 W of no-load power	≤ 1 W: ≥ power x 0.50
		1 to 51 W: ≥ [0.09 x Ln(power)]+0.5
		51 to 250 W: ≥ 85%
V	0 to 49 W: ≤ 0.3 W of no-load power	Standard voltage ac-dc models (>6 V_{out})
	50 to 250 W: ≤ 0.5 W of no-load power	≤ 1 W: 0.48 x power + 0.140
	50 to 250 W: ≥ 87%	1 to 49 W: [0.0626 x Ln(power)]+0.622
		Standard voltage ac-dc models (<6 V_{out})
	0 to 49 W: ≤ 0.3 W of no-load power	≤ 1 W: 0.497 x power + 0.067
	50 to 250 W: ≤ 0.5 W of no-load power	1 to 49 W: [0.0750 x Ln(power)]+0.561
	50 to 250 W: ≥ 86%	

* i.e. the power designated on the label of the power supply

Furthermore, there exists an EU Code of Conduct (CoC) on the energy efficiency of external power supplies. The CoC run by the JRC is a voluntary initiative aimed at developing ambitious standards and references for voluntary industry adoption. Currently, the CoC is under revision, the draft Version 5 has been published in September 2012, and contains rather tightened requirements compared to the above listed Level V requirements (EU Draft CoC EPS 2012).

[6] The Nordic Ecolabelling requirements for Computers (version 6.4 from 2009) set efficiency requirements for external power supplies which have to fulfil the requirements of the Energy Star specification for single voltage external power supplies, version 2.0. However, these Energy Star specifications were sunset on December 31, 2010 and the label is not valid any more.

The Ecodesign Regulation (EC) 278/2009 on External Power Supplies is currently under regular revision due to being 4 years in force. In this context, a review study was launched to explore the additional saving potential as well as the appropriateness of the scope, the definitions and the requirements in view of technological progress. According to this review study it is estimated that 52% of the 2012 EPS models would need to be redesigned to meet tier 1 (effective from January 2014) and 93% redesigned to meet tier 2 (effective from January 2016) of the draft EU Code of Conduct (EU Staff WD EPS 2013).

Proposed approach

The Commission has proposed to tighten the existing ecodesign requirements for EPS along the lines of the draft Code of Conduct, version 5 (EU Staff WD EPS 2013). Against this background, it is recommended not to additionally develop specific EU Ecolabel criteria on external power supplies.

Internal power supplies (IPS): Internal power supplies (e.g. in desktop computers) do not fall under a horizontal ecodesign-measure like the external power supplies. However, the draft Commission regulation with regard to ecodesign requirements for computers and computer servers (EU Ecodesign PCs Draft 2013) contains requirements for the efficiency of internal power supplies in desktop PCs, integrated desktop PCs, desktop thin-clients, workstations and small-scale servers. Additionally, there is the so called 80plus-label[7] specifically for the certification of internal power supplies, both for 115 V (power supplies for desktop, workstations and non-redundant server applications) and for 230 V (power supplies for redundant data centre applications). This label is available in five classes (bronze, silver, gold, platinum, titanium) with different efficiency requirements. Currently (as of June 2013) there are 4,169 models of around 250 producers certified for 115 V applications, and 487 models of 49 producers certified for 230 V applications (see Table 6).

[7] www.plugloadsolutions.com/80PlusPowerSupplies.aspx

Table 6: Number of 80plus certified power supplies for 115 and 230 V applications

80plus class / Number of certified models	Standard	Bronze	Silver	Gold	Platinum	Titanium	Total
115 V Internal	1,266	1,625	319	759	200	---	**4,169**
230 V Internal	---	34	104	175	166	8	**468**

The Energy Star Program requirements for computers (both, version 5.2 and draft version 6.0) incorporate efficiency-requirements both for internal power supplies and external power supplies with integral cooling fans. For 115 V applications, the Energy Star requirements are identical with those of 80plus-bronze, for 230 V applications, the Energy Star benchmark is slightly above those of 80plus bronze (see Table 7). The current Blue Angel Ecolabel criteria[8] set requirements for internal power supplies that are aligned with the Energy Star requirements.

Table 7: Efficiency requirements for internal power-supplies by 80plus, Energy Star, Blue Angel and EU Ecodesign

	115 V Input power			230 V Input power			
Minimum efficiency at:	20 % of rated output	50 % of rated output	100 % of rated output	10 % of rated output	20 % of rated output	50 % of rated output	100 % of rated output
80plus bronze	82 %	85 %	82 %	-	81 %	85 %	81 %
80plus silver	85 %	88 %	85 %	-	85 %	89 %	85 %
80plus gold	87 %	90 %	87 %	-	88 %	92 %	88 %
80plus platinum	90 %	92 %	89 %	-	90 %	94 %	91 %
80plus titanium	-	-	-	90 %	94 %	96 %	91 %
Energy Star v5.2 / v6.0	82 %	85 %	82 %	-	82 %	85 %	82 %
Blue Angel	82 %	85 %	82 %		82 %	85 %	82 %
Ecodesign for Computers	82 %	85 %	82 %	90 %	82 %	85 %	82 %

[8] RAL-UZ 78a for Personal Computers (Desktop Computers, Integrated Desktop Computers, Workstations, Thin Clients), Ed. March 2012; RAL-UZ 78d for Notebook Computers, Ed. January 2011; RAL-UZ 135 for Netbooks (Small Portable Computers), Ed. July 2011

Proposed approach

As it appears that there is an adequate market supply for internal power supplies rated with the label "80plus silver" and "80plus gold", it is recommended to align the revision of the internal power supply criterion with the minimum efficiency according to one of these levels, being 3-5% stricter than Energy Star v6.0.

Universal power supplies

Following an initiative of the European Commission, in 2009 leading producers of mobile-phones signed a Memorandum of Understanding regarding the harmonisation of charging capability for mobile phones[9]. This initiative is based on the vision that in the future, power supplies will be marketed and sold independently from end-devices such as smartphones or tablet PCs.

Such developments would not only favour consumer-demands for universal charging-solutions, but could also yield environmental benefits like reduced impacts in production and end-of-life caused by reduced production volumes, as power-supplies could be used long time-periods and for various devices (EC 2009). This initiative led to the publication of the Standard *EN 62684 – Interoperability specifications of common external power supply (EPS) for use with data-enabled mobile telephones*, which is specifically tailored to the requirements of smartphones (CENELEC 2011).

Although these initiatives focus on mobile phones and smart phones, tablet PCs are quite similar from a technological perspective so this standard might also be applied to tablet computers. Despite the above presented efforts, most smartphones and tablet computers today are, however, still sold together with an individual external power supply. Furthermore, many tablet computers are equipped with charging interfaces that are not suitable for the use of universal power supplies.

Finally, it has to be considered that in case standardised power supplies lead to a separate marketing of tablet PCs and power supplies in the future, this might also result into rebound-effects caused by increased USB-charging at computers. In

[9] http://ec.europa.eu/enterprise/sectors/rtte/files/chargers/chargers_mou_en.pdf

particular charging via notebook PCs can cause higher electricity consumption in cases where they are exclusively used to charge tablet PCs, see below (Manhart et al. 2012).

Proposed approach

Regarding these potential rebound effects, no final conclusions can be drawn about the overall effect and environmental benefit of requiring universal power supplies for tablet PCs at the moment. For this reason it is recommended not to include a universal power supply as a requirement for the EU Ecolabel.

Charging tablet computers

Tablet computers are devices that are designed to be operated non-stationary, battery powered throughout their use phase. Thus, the energy consumption is not only determined by the device itself, but also by the charger and the way consumers charge their tablet PCs.

These aspects were analysed more detailed by Manhart et al. 2011a: With an average use-time of 2 hours per day, tablet computers usually require charging every 4 days (Quanta 2010), which results into 91 charging cycles per year. Charging of a typical tablet PC by Apple (iPaD) requires between 5 W and 10 W over 2.5 to 7.6 hours – depending on the applied charging-system (Buchanan & Kaufmann 2010). Generally, shorter charging-times require higher charging-currents, resulting into an average electricity demand of 25 Wh to 38 Wh per charging-cycle.

In addition, there are efficiency-losses during the charging itself, which result from losses in the charger and no-load losses after the end of charging (in case the charger is still connected to the mains).

The efficiency-levels of external power supplies are regulated by the Regulation (EC) 278/2009 (EU Ecodesign EPS 2009). According to this Regulation, external power supplies with a rated output power of 7.5 W have to achieve a minimum efficiency of around 75 %. This means that efficiency-losses for one charging-cycle are around 8.3 to 12.7 Wh.

In addition, no-load power losses have to be considered. It is assumed that a certain share of users leave the tablet computers connected to the mains after completion of the charging-cycle. This appears particularly in case of overnight-charging, which usually exceeds the required charging-time. The EuP Preparatory Study for battery chargers and external power supplies assumes that chargers of mobile-phones are connected to the mains for 10 hours per day (EuP 2007). Although this time-span appears quite long, it has to be considered that some users leave chargers plugged-in 24 hours a day, a trend which might also be supported by modern charger designs, which allow unplugging the USB charging cable without removing the charger from the mains-socket.

Thus, an assumption could be made that on average chargers are connected to the mains for additionally 10 hours after the end of each charging-cycle. As no-load losses are limited by Regulation (EC) 278/2009 to 0.3 W, this results into no-load losses of around 3 Wh per charging-cycle. In total, these effects result into an annual power consumption of tablet PCs of around 4 kWh per year (see Table 8).

Table 8: Annual energy consumption of tablet computers

Charging cycles per years	Power-demand	Efficiency-losses	No-load losses	Annual energy consumption
	per charging-cycle			
91	31 Wh	10 Wh	3 Wh	4 kWh

In comparison, the annual typical energy consumption (TEC) of desktop PCs and notebook PCs is significantly higher (see Table 9).

Table 9: Maximum TEC allowances for desktop PCs and notebook PCs according to Energy Star Version 5.2

Energy Star Product Category	TEC_{BASE} Desktop PCs (kWh)	TEC_{BASE} Notebook PCs (kWh)
A	148	40
B	175	53
C	209	88.5
D	234	n.a.

Proposed approach

Although the functional use of tablet PCs differs from that of desktop and notebook PCs, it is recommended that tablet PCs are exempted from specific energy efficiency requirements due to their low total energy consumption.

Alternatively to an external power supply connected to the mains, tablet computers can also be charged via USB-interface by another computer. While this has the advantage of higher power-supply efficiencies[10], it might also be possible that consumers leave the computer in idle-mode for the sole reason of charging the tablet computer. Although many desktop PCs are able to supply the USB-ports with power in off-mode, this is not the case for most notebook PCs. As the idle-mode power consumption of notebooks ranges between 10 W – 50 W (compared to 7.5 W for charging with an external power supply), this type of charging is very inefficient.

Proposed approach

It is recommended to add inefficient charging via USB-port of notebook computers to the criterion "user instructions".

4.2.1.4 Stakeholder feedback on energy criteria

- Energy Star minus 10 (or 20%) is proposed i.e. stricter requirements.
- The use of dynamic criteria is proposed, e.g. 201X (X watt energy use), 201Y (X watt minus 5 or 10%), 201Z (X watt minus 10 or 20%) and so on, to secure a progressive update of energy requirements.

4.2.2 Environmentally hazardous substances

Hazardous substances and the related requirements of Article 6(6) and 6(7) of the Ecolabel Regulation (EC) 66/2010 are analysed and discussed in a separate Task report.

[10] For example: Internal power supplies of desktop PCs reach efficiencies above 80%, external power supplies of notebook PCs typically have efficiencies around 87%

4.2.3 Life time extension

The high rate of innovation in the sector and falling prices for new units are causing the actual lifetime of ICT products to become ever shorter. Reasons cited for the replacement of computers are for example that current technologies are out of date, hard drives become more unreliable within 3-4 years, a reduced performance with updates and new software, increasing user expectation and standard warranties being 3 years (cf. Task 2). For notebooks, there is empirical evidence that they often have a useful lifetime of less than 3 years (cf. Task 2); reasons for their replacement are inter alia that due to their mobile use, laptops are more susceptible to wear and tear (cf. section 4.2.3.3) and are also more expensive to repair.

The technical analysis and literature review of LCA studies (see Task 3) shows that the ever shorter product life cycles is likely to have an influence on environmental impacts in the following way: the manufacturing phase of computers becomes more relevant compared to the use phase, especially for those products entailing a shorter life time and an energy efficient use phase, such as notebook PCs with their power drain having being optimised for mobile use.

A study by Prakash et al. (2011) revealed that the environmental impact (and associated energy use) of producing a notebook is such that it cannot be compensated in a realistic period of time by savings through improved energy efficiency during the use phase. Assuming a realistic energy efficiency improvement of 10% between two notebook generations, the energy amortisation periods would be between 33 and 88 years, while if energy efficiency improves by 20% the period would be between 17 and 44 years, depending upon the data source used to analyse notebook production.

The study suggested that from an environmental perspective (with regard to global warming potential) it is not reasonable to purchase a new notebook after a usage period of only a few years, even if the assumed energy efficiency of the new device exploits the full scope of cutting-edge technology.

Computer products contain a number of valuable and scarce raw materials such as gold, tantalum, indium, and rare earths. Many of these metals are required in future technologies such as wind power, photovoltaic and electric mobility.

However, their primary extraction entails substantial environmental and social impacts. For example, the production of one tonne of gold generates emissions of approximately 18,000 t CO_{2e} and has a cumulative resource requirement of almost 740,000 t (IFEU 2011). Prakash & Manhart (2010) have found that the primary production of the quantities of gold, silver, palladium, copper and iron used for a single desktop PC generates emissions of around 23 kg CO_{2e}. Regarding social impacts, cobalt, for instance, is largely mined today in the Democratic Republic of Congo under dangerous conditions, often without sufficient worker safety, and in some cases partly by children (Tsurukawa et al. 2011). Furthermore, recovery techniques for these rare metals, such as the use of mercury to recover gold from electro scrap, generate major adverse effects for people and the environment (Prakash & Manhart 2010).

Even with the onset of the WEEE Directive most of these raw materials are, on the basis of evidence to date, largely irretrievably lost from the industrial cycle because of existing inefficiencies in the recycling infrastructure, particularly as regards collection and pre-treatment (see Table 10). Ever shorter lifecycles and continual manufacturing of new computer products increases the pressure on primary extraction (Prakash et al. 2011, Tsurukawa et al. 2011, and Buchert et al. 2012). Based on these findings, it is considered that high attention should be given to the extension of the lifetime of computers. For example, Ospina et al. (2012) revealed that implementing Design for Reuse (DfR) and Design for Disassembly (DfD) measures could facilitate the extension of the lifetime for a notebook PC to 10 years, being 2.5 times higher compared to the lifetime of the notebook PC used as a baseline in their study.

Table 10: Losses of rare metals during collection, pre-treatment and final treatment of notebooks in Germany (Source: Öko-Institut)

Metal		Content in all notebooks sold in Germany in 2010 [t]	Losses during collection	Losses during pre-treatment	Losses during final treatment	Recovery in Germany [t]
Cobalt	Co	461.31	50%	20%	4%	177
Neodymium	Nd	15.16		100%	100%	0
Tantalum	Ta	12.06		100%	5%	0
Silver	Ag	3.11		70%	5%	0.443
Praseodymium	Pr	1.94		100%	100%	0
Gold	Au	0.74		70%	5%	0.105
Dysprosium	Dy	0.43		100%	100%	0
Indium	In	0.29		20%	100%	0
Palladium	Pd	0.28		70%	5%	0.040
Platinum	Pt	0.028		100%	5%	0
Yttrium	Y	0.012		40%	100%	0
Gallium	Ga	0.010		40%	100%	0
Gadolinium	Gd	0.0048		40%	100%	0
Cerium	Ce	0.00069		40%	100%	0
Europium	Eu	0.00028		40%	100%	0
Lanthanum	La	0.00008		40%	100%	0
Terbium	Tb	0.00003		40%	100%	0

In the following sections, different measures which aim at increasing the longevity of computers have been collated and analysed.

4.2.3.1 Expansion capability

Products should be equipped with a minimum number of interfaces to ensure a certain expandability of the products external connection capabilities for consumers. Various ecolabel criteria implement this requirement as follows:

Table 11: Existing expansion capability requirements in ecolabel criteria

	EU Ecolabel	Blue Angel	Nordic Swan
Desktop PCs / Integrated Desktop PCs / Workstations / Thin Clients	At least 4 USB interfaces	At least 4 USB interfaces	At least one additional interface for external storage media and other peripheral devices
Notebook PCs	At least 3 USB interfaces as well as a connection for an external monitor.	At least 3 USB interfaces as well as a connection for an external monitor.	• Port for external monitor • Port for external keyboard and mouse • At least one additional interface for external storage media and other peripheral devices.
Tablet PCs			• Minimum 1 expansion port / contact following industry standard for accessories. • Support for external monitor, keyboard and mouse.
Netbooks	---	Existence of at least 2 UBS ports as well as ports for an external monitor	---

Proposed approach

It is recommended that in addition to the existing EU ecolabel criteria, for mobile computers the possibility for an additional battery slot should be required due to several reasons: the possibility to increase battery capacity; making it easier to replace a battery in case of defect; an additional slot might also be used for other devices (e.g. CD ROM drive).

4.2.3.2 Upgradeability

Technology advances of single hardware components like working memory, hard drives for storage, or CD / DVD drives combined with changing consumer needs (e.g. rising amount of data to be stored due to digital audio, video and pictures, or switch to HD, Blu-ray or 3D-technology etc.) often urge consumers to replace the whole product in case these components cannot be exchanged individually.

Modular designed computer products facilitate the replacement of single modules and thus an upgrade and prolonged lifetime of the existing product. However, a precondition for upgrading relevant components of the computer by the end-user is that the modules are accessible and can be easily replaced without the use of special tools. Various ecolabel criteria implement the requirement for upgradeability (also called capacity enhancement or capability enhancement) as follows:

Table 12: Existing upgradeability requirements in ecolabel criteria

	EU Ecolabel	**Blue Angel**	**Nordic Swan**
Desktop PCs / Integrated Desktop PCs / Workstations / Thin Clients	Personal computers shall have facilities that enable exchangeable and upgradeable memory and graphic cards. The computer shall also be designed so that major components (including memory drives, CPUs and cards) can be exchanged and/or upgraded easily by the end-user. For example using snap, slide in / slide out or cartridge-style housing for components.	Personal computers shall provide the following upgrade options: • Memory expansion compared to the standard configuration according to Energy Star 5.0 (applies to thin clients only if they are equipped with a processor) • Installation, exchange and expansion of storage capacity (not applicable to thin clients) • Installation and / or exchange of optical drive (not applicable to thin clients)	The user shall be able to replace the modules without the use of special tools and it shall be possible to upgrade the computer by • Working memory expansion • Installation, exchange and expansion of mass storage • Installation and/or exchange of CD ROM, DVD and hard disk drive.
Notebook PCs	Notebook computers shall have facilities that enable exchangeable and upgradeable memory. The computer shall also be designed so that major components (including memory drives, CPUs and cards) can be exchanged and/or upgraded easily by the end-user. For example using snap, slide in / slide out or cartridge-style housing for components.	Notebook PCs shall provide the following expansion option: The memory shall be exchangeable or expandable compared to the standard configuration according to Energy Star 5.0	The design of notebook PCs must permit performance expansions (upgrades). At a minimum, the following expansion of the working memory must be possible
Tablet PCs	Same requirement as for notebook PCs	Same requirement as for notebook PCs	The design of tablet PCs must permit performance expansions (upgrades). • Working memory (RAM) capacity shall

	EU Ecolabel	Blue Angel	Nordic Swan
			be minimum 1 GB • Storage capacity shall be minimum 16 GB • Storage expansion slot (example SDHC slot)

Compared to the Blue Angel and Nordic Swan criteria, the EU ecolabel is stricter and additionally requires graphic cards and CPUs to be exchangeable and upgradeable. As these components are, however, often soldered the overall feasibility of this criterion is to be discussed.

Proposed approach

It is recommended to include the following components in a criterion on upgrade-ability: Memory, storage capacity, optical drives, graphic cards and CPUs. For the latter, it could be discussed to make an exemption for notebook PCs and tablet PCs.

4.2.3.3 Repairability / Warranty / Service

Products shall be repairable, if certain components break down. A case study by WRAP (2011) of a certain notebook and reference to the findings of a survey of 30,000 notebooks by a US computer warranty company (Square Trade 2009), serve to illustrate and encourage the durability and repair of laptop computers. The WRAP study highlights the following most common faults and issues associated with notebooks:

- LCD (liquid crystal display) screens - difficult to remove from case lids and can break;
- hard drive and motherboard (main printed circuit board) faults
- overheating due to insufficient ventilation (often fewer fans are used due to space restrictions and ventilation slots become blocked) affecting electronic components such as hard-drives and printed circuit board components;
- keyboard damage - particularly individual keys that are not available to purchase;

- lid hinge and bracket damage - due to fatigue by constant use;
- DC (direct current) damage to sockets - often plastic connectors where the power lead is exposed.

In case of defective individual hardware components, different approaches might be effective in order to avoid replacement of the whole product:

- (User) repairability: The end-user might either exchange a defective component (e.g. battery in mobile computer products) or engage professional repair services. In this context, provision of service agreement and/or consumer information on technical support or professional repair possibilities can contribute to extend the product life.
- Prolonged warranty: According to the European Directive 1999/44/EC on Sale of Consumer Goods and Guarantees[11], the seller has to guarantee the conformity of the goods with the contract for a period of two years after the delivery of the goods. If the goods are not delivered in conformity with the sales contract, consumers can ask for the goods to be repaired, replaced, reduced in price, or for the contract to be rescinded (legal guarantee, warranty). Commercial guarantees are made voluntarily by the trader and can only be in addition to the legal warranties. A warranty going beyond the minimum legal requirements of two years might facilitate the extension of the lifetime of products as it could be interpreted, but it could also lead to replacement with a new product. A pre-condition for a *real* extension of lifetime is therefore that sellers ensure returned products are repaired and not only replaced in case of defect within the warranty times. For example, Ospina et al. 2012 describes the possibility of accessible upgrade services and guaranteed take-back for re-use.
- Suggested pre-conditions for the above described repairability approaches comprise:
  - Design for repair: Components have to be easily accessible and exchangeable (see section 0).

11 http://ec.europa.eu/consumers/cons_int/safe_shop/guarantees/

– Availability of replacement parts: Spare parts have to be available for a certain time, also after the end of the product's production. From the perspective of lifetime extension, this time period should not be too short.
– Reasonable repair costs: The costs for spare parts and repair should be appropriate related to the purchase costs for a new device.

The following table provides an overview how the various ecolabel criteria implement the different requirements for repairability / warranty and service.

Table 13: Existing repairability, warranty and service requirements in ecolabel criteria

EU Ecolabel	Blue Angel	Nordic Swan	TCO	EPEAT
• User repairability: The applicant shall provide clear instructions to the end-user in form of a manual (in hard or soft copy) to enable basic repairs to be undertaken. • Consumer information: Information should be included in the user instructions or the manufacturer's website to let the user know where to go to obtain professional repairs and servicing of the product, including contact details as appropriate. • Availability of replacement parts: The applicant shall ensure that spare parts are available for at least five years from the end of the product's production	• Availability of replacement parts: Provision of spare parts for appliance repair is guaranteed for at least 5 years from the time that production ceases. Rechargeable batteries, in particular, shall be available for a period of five years from the end of production (if provided). • Consumer information: The product information shall include information on the above requirements.	• Quality of the product: The licensee must guarantee that the quality in the production of the ecolabelled product is maintained throughout the validity period of the license. Verification: Procedures for collating and where necessary, dealing with claims and complaints regarding the quality of the ecolabelled product. • User information: Information on the guarantee and the availability of spare parts. Information on how the consumer can use the service and support function.	• Warranty: The brand owner shall provide a warranty for a period of at least one year. • Availability of spare parts: The brand owner shall guarantee the availability of spare parts for at least 3 years from the time that production ceases.	• Availability of additional three year warranty or service agreement • Availability of replacement parts

Proposed approach

It is recommended to keep the existing EU Ecolabel criteria. They could be complemented by criteria on "design for repair" and "Reasonable repair costs". The time period for the availability of replacement parts should not be shortened. Adding a criterion on prolonged warranty appears not to be targeted against the background that it does not guarantee defect taken-back products being repaired instead of being replaced by a new one.

4.2.3.4 Life-time of individual components

Prolongation of battery lifetime

One of the expendable parts that might lead to an overall reduced lifetime of especially mobile computer products is the battery. The lifetime and capacity of batteries used in mobile computer devices depends on different factors[12]:

- Level of charge and discharge: A partial charge up to 90% and discharge not below 10% prolongs battery life. When not in use, the battery should be stored not fully charged, allowing some self-discharge while retaining sufficient charge to keep the protection circuit active
- Elevated temperature, high currents and raising the charge voltage hasten the capacity loss. For example, heat build-up can occur when operating the notebook PC in bed or on a pillow, thus restricting the airflow. Further, the device should not be left e.g. in a heated up car in summer. When not in use, the battery should be stored in a cool place.
- System configurations: for example, the general energy configuration, the brightness of the display, as well as wireless communication, programmes or peripheral devices not being in use can influence the overall life time of batteries.

[12] http://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries

- A further way to extend battery life is to remove it from the notebook PC when it is connected to the mains. However, it has to be noted that in case of power failure unsaved work could be lost.

For Li Ion batteries, a range of 500 to 1,000 and for LiPo batteries, 300 to 500 charging cycles are indicated as maximum lifetime. A number of manufacturers can be seen to make claims for extended battery life [13] as this is a key marketing tool given the importance of battery life to notebook users.

To date, however, it had not been possible to require and verify a certain minimum number of charging cycles for batteries, as there appears to be no standardised measurement to analyse and compare the overall lifetime of batteries (number of charging cycles) of different products. In Germany, the Federal Environmental Agency has commissioned a study to quantify the environmental impacts of batteries in mobile computer products, to research the factors influencing the lifetime of batteries and to derive possible measures to extend their lifetime[14]. Published results are expected in summer 2014.

However, in the interim, and as part of the process of revising the Blue Angel ecolabel criteria for mobile phones in Germany, the following test procedure has been applied to derive minimum requirements regarding the lifetime of rechargeable batteries, inter alia for mobile computers:

Four different batteries per size and type shall be tested. All four tested batteries shall meet the requirements of the following test method.

<u>Test Method</u>:

C is the rated capacity given on the battery in ampere hours (Ah) as maximum capacity. The test starts (quasi the “zeroth“ cycle) with a discharge at 0.2 C until the cut-off voltage is reached (according to IEC/EN 61960: specified voltage under load where the discharge of one cell or battery is completed). The subsequent repeated charge and discharge shall be done in accordance with the specifications listed in the following tables. Different requirements are set for different applications.

<u>Test Specifications for Rechargeable Lithium Batteries</u>:

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[13] For example: Acer, *Green design*, http://www.acer-group.com/public/Sustainability/environment/products-4.htm

[14] UFOPLAN FKZ 3713 95 316; inter alia following research aspects: How can the lifetime of batteries be determined? How can a longer lifetime of Li-batteries be achieved? Which obstacles exist?

Cycle No.	Charge	Rest period after charge	Discharge	Rest period after discharge
1-399	Manufacturer specification	30 minutes	1.0 C to cut-off voltage	30 minutes
400	Manufacturer specification	1 hour	0.2 C to cut-off voltage	

The minimum discharge time for cycle 400 shall be 3.5 hours and the capacity delivered during cycle 400 shall be equal to 70 % of the rated capacity.

Applied Test Specification for Rechargeable Lithium Batteries in Blue Angel ecolabel requirements for Mobile Phones:

Cycle No.	Charge	Rest period after charge	Discharge	Rest period after discharge
1-149	Manufacturer specification	30 minutes	1.0 C to cut-off voltage	30 minutes
150	Manufacturer specification	1 hour	0.2 C to cut-off voltage	

The minimum discharge time for cycle 150 shall be 3.5 hours and the capacity delivered during cycle 150 shall be equal to 90 % of the rated capacity.

Proposed approach

For the EU Ecolabel, it is recommended to add advice for the prolongation of batteries' lifetime in the criterion "user instructions".

Further, it shall be discussed if a performance standard and test specifications for rechargeable Lithium Batteries could also be required by the EU Ecolabel for notebook PCs and tablet PCs.

<u>Advantages and disadvantages of "readily removable" batteries</u>

In Europe, Article 11 of the Batteries Directive 2006/66/EC requires manufacturers to design electrical and electronic equipment 'in such a way that waste batteries and accumulators can be readily removed'. However, the definition "readily removable" is a discussion point regarding the question 'who should be able to remove the battery from the device (also end-users or only professionals like appliance service centres or waste treatment facilities?)'.

Furthermore, it is not specified in the Directive that the battery and/or waste electrical and electronic equipment shall remain intact during the removal process causing problems in terms of waste avoidance or re-use strategies.

Especially tablet PCs or slim notebook PCs increasingly appear to contain fixed embedded or glued batteries that, e.g. in case of defect, are not “readily removable” and exchangeable by end-users any-more and might lead to an early replacement of the whole computer device instead. For example, the German Federal Environmental Agency analysed the recent product tests of the German consumer test magazine Stiftung Warentest regarding exchangeability of batteries and found out that most batteries of the examined tablet PCs and ultrabooks were not exchangeable any more (UBA 2013).[15]

Manufacturers argue (Digital Europe et al. 2013) that

- A strict “end-user removability” requirement will lead to either bulkier products with increased battery and appliance volume and weight (i.e. increased material effort and impacts in production and transport), or to a reduced battery capacity:
  - End-user removal requires the battery to be externally accessible, compartmented and designed to incorporate additional safety requirements for international regulatory compliance, including battery enclosure.
- On the other hand, “professional service removability” ensures from the viewpoint of manufacturers that performance and reliability requirements are met, minimising (premature) product failures:
  - It ensures adequate mechanical protection of the battery, being specifically important for products which are exposed to high shock or vibration levels and/ or used in a humid environment.
  - It reduces the likelihood of the mistreatment of products during the battery removability process (e.g. static discharge, short circuits or mechanical damage) and of harm to untrained persons (e.g. consumers) from direct contact with a charged battery cell is prevented.
  - It prevents the use of non-approved and low-quality replacement batteries that could render the product unsafe.

[15] Stiftung Warentest, test 12/2011: only 2 out of 14 tested tablet PCs had exchangeable batteries; test 7/2012: none out of 6 analysed ultrabooks had the possibility to exchange the battery.

From an environmental perspective (e.g. Smolaks 2012; Wölbert 2013, c't 2013), the removability of batteries as expendable parts is, in some cases, hampered considerably for end-users, as

- Special tools are available to change the battery;
- In some cases, the claim under guarantee expires in case of own repairs;
- The battery exchange by professional services
  - Means that products are not available for the end-users during a certain period of time;
  - Is expensive and often includes additional delivery costs;
  - Often requires a backup of all data, in case that the whole computer product is simply exchanged (which would not lead to an increased lifetime).

This combination of issues would prevent an extended lifetime or reusability, the main factors to reduce the overall impacts of computer products, as many end-users will simply purchase a new product. Furthermore, for the recycling of electronic waste, glued-in batteries are problematic (see excursus in section 4.2.4.2)

Proposed approach

From an environmental perspective with a focus on lifetime extension it is recommended to add a criterion on safe and easy removability of batteries for notebook PCs and tablet PCs. Special attention, however, should be given to the exact interpretation, formulation and verification of the term "easily" removable.

HDD reliability

Hard disk drives (HDD) are one of the computer components where according to WRAP (2011)[16] most common faults are reported by several studies and it is also understood that there may be significant variations in the reliability of HDD products. Several HDD manufacturers, as well as OEM procurement procedures for HDD, specify the reliability of HDD with certain indicators like

[16] See http://www.wrap.org.uk/sites/files/wrap/Laptop%20case%20study%20AG.pdf

- “Mean time between failures (MTBF)”: MTBF is the probable average number of service hours between failures. It is a statistical term relating to reliability as expressed in power on hours (POH). It is common to see MTBF ratings between 300,000 and 1,200,000 hours for HDD mechanisms[17].
- “Annualised failure rate (AFR)”: indicates the estimated probability that a component will fail during a full year of use (probable percent of failures per year, based on the manufacturer’s total number of installed units of similar type). It is a relation between the mean time between failure (MTBF) and the hours that a number of components are run per year[18].

However, both specifications are based on a large number of drives running continuously at a test site with data extrapolated. Both, MTBF and AFR are representative of the relative reliability of a family of products and cannot predict the behaviour of a single individual drive. “Real-life” reliability of hard drives is closely related to individual user behaviour, such as ambient temperatures, excessive shock failure or handling damage[17]. Some of these factors such as 'operating shock' reliability are understood to be the subject of product testing by HDD manufacturers to meet the requirements of OEM's [19] and this can be seen in example product specifications [20].

Proposed approach

It is recommended to discuss the feasibility of an Ecolabel criterion requiring a standardised test method being applied comparably indicating the potential reliability of HDD, for example using the indicator “Mean time between failures (MTBF)”, “Annualised Failure Rate (AFR)” or others relating to simulated environmental stresses.

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[17] Source: http://knowledge.seagate.com/articles/en_US/FAQ/174791en?language=de_DE

[18] Source: http://enterprise.media.seagate.com/2010/04/inside-it-storage/diving-into-mtbf-and-afr-storage-reliability-specs-explained/

[19] see Hewlett Packard, *HDD quality system*, ftp://ftp.hp.com/pub/c-products/servers/proliantstorage/drivers-enclosures/scsi-hdd-quality-sys.pdf

[20] see HGST, Notebook HDD specifications, http://www.hgst.com/hard-drives/mobile-drives

4.2.3.5 Second hand usage / secure data deletion

As described in Task 2, second usage of computers can prolong the use time of computers for some years. Especially in the business sector it is a usual practice that leased devices are refurbished after a first usage and are resold as second hand IT. Manhart et al. (2012), however, discussed that a hindrance to the giving of IT devices to a second hand usage could be the end-users' concern on misuse of data stored in the devices. People want to securely erase their private data before they forward products to second hand use. Due to this uncertainness, users might prefer to store their devices at home instead of providing them to a second hand usage.

For security reasons, it must be possible for end users to delete data without the use of tools. For example, a hard reset could be provided along with the factory setting to facilitate the permanent deletion of data. Special companies provide a data wiping service, e.g. Kroll Ontrack (2012) providing either a software based process or a demagnetizing process of data erasure as a solution for removing files from storage media permanently.

For comparison: The most current German Blue Angel ecolabel for mobile phones (2013) contains the following criterion on data deletion:

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

Proposed approach
It is recommended to discuss with the stakeholders the possibility for a product-related EU Ecolabel criterion on secure data deletion.

Supporting case study: Second-hand usage in non-European countries

A large number of European Waste Electrical and Electronic Equipment (WEEE) is exported to non-European countries, for example to West-Africa which developed to a primary destination (Pucket et al. 2005; Greenpeace 2008). Within West-Africa, the megacity Lagos (Nigeria) serves as a major hub for imported second-hand goods. For used computers, the Alaba International Market and Ikeja Computer Village are the major clusters where 15,000 people in 5,500 workshops repair used equipment, mainly imported from overseas. The repaired and functioning computers and monitors are sold to the domestic market as well as to other West-African countries (Manhart et al. 2011b). Amoyaw-Osei et al. (2011) found out that the market-share of used computers reaches 51% for desktop PCs and 38% for notebook PCs in Ghana, which illustrates the importance of used information and communication technologies to bridge the digital divide.

At first sight, the export and reuse of European worn-out computer products seems advantageous regarding the extension of the use-phase which is known to be a decisive factor for reducing the overall environmental burden of these products (see Task 3). However, the end-of-life treatment of these products can change for the worse when they are exported from Europe, as in most West-African countries no environmentally sound end-of-life management of waste electronic equipment is established (see section 4.2.4.2).

4.2.3.6 Avoiding software-induced replacement

Swan (cited in St-Laurent et al. 2012) argues that software design practices and marketing strategies worsen the problem of e-wastes. For example, St-Laurent et al. (2012) described that a common reason for computer replacement is that they cannot run recent software at a reasonable speed.

As the EU Ecolabel is focused on the product’s hardware, no direct criteria for life-prolonging software can be required. Nevertheless, to avoid software-induced early replacement of the whole product, it should be designed in a modular way so that relevant components are exchangeable and upgradeable in case the hardware becomes outdated due to new software requirements (see section 0)

4.2.3.7 *Universality in design*

Ospina et al. (2012) describe the advantages of universality in the design and connections, e.g. in the housing, chassis or in other parts and components, so that the same parts can be re-used in different models. This aspect, however, feeds rather indirectly into the criteria on upgradeability and repairability or on end-of life management, with both requiring components to be easily accessible and removable.

Proposed approach

It is recommended not to develop an own criterion on universality in design but to define exact conditions for the structure and joining techniques enabling a quick and safe separation of components for a separate reuse/recycle or a treatment of components containing harmful substances.

4.2.3.8 *Stakeholder feedback on lifetime criteria*

- **Quality of components**: Obligation for notebook manufacturers to provide batteries with longer than 4-hour capacity (with 85% load) is proposed.
- **Upgradeability**: The criteria development should take into account that many of the “new” products, e.g. tablets, are very hard to upgrade with regards to e.g. memory, disk space, and replacement of the battery.
- **Warranty/guarantee**:
  - It is proposed to include a guarantee being issued to specific parts of the product (e.g. non-exchangeable batteries in a 3-year period).
  - A consumer guarantee (of 1-2 year) besides the general warranty period of two years is proposed as a guarantee is a more safe instrument than a warranty for the consumer if they want to complain, and should have the effect that manufacturers produce products that work for a longer period.
- **Spare parts**:
  - Obligation for notebook manufacturers to release spare parts **at lower prices** is proposed (total price of individual parts cannot exceed 20% of the actual price of the notebook, possibly using remanufactured parts to

facilitate recycling companies).

– A **shorter time** to oblige manufacturers **to maintain spare parts for up to 3 years** after the production ceases is proposed.

- Focus in the revision must be development of requirements that **avoiding software-induced replacement**.

4.2.4 Resources and end-of-life management

End-of-life management of computers and monitors is widely determined and regulated on the basis of the content of resources as well as hazardous substances. While hazardous substances are described in detail in section 4.2.1.4 of this report, the following sections provide an overview of the material composition as well as European and non-European end-of-life management paths.

4.2.4.1 Material composition of computers and computer monitors

Based on data from Gmünder (2007) and own investigations, Manhart et al. (2011b) provide a detailed material breakdown of a desktop PC without monitor and peripheral (see Table 14).

Table 14: Mean material composition of a desktop PC (without monitor and peripherals)

	Amount contained in a desktop computer	
	[g/unit]	**[%]**
Steel	6,737.50	69.2 %
Plastics	1,579.55	16.2 %
Aluminium	550.21	5.7 %
Copper	413.225	4.2 %
Zinc	25.94	0.3 %
Tin	19.57	0.2 %
Antimony	18.58	0.2 %
Nickel	12.70	0.1 %
Lead	6.59	0.1 %
Neodymium	5.87	0.1 %
Silver	1.70	0.0 %
Gold	0.26	0.0 %
Palladium	0.12	0.0 %
Chromium	0.02	0.0 %
Ceramics & others	366.04	3.8 %
Sum	**9737.87**	**100 %**

Source: Gmünder 2007 & Manhart et al. 2011b

Although the data still reflect a pre-RoHS computer (high lead content), the principal material composition is comparable to many other computers. The following variations are likely to be observed with other types of computers:

- Different product weight (mostly less than 9.7 kg);
- Reduced concentration of steel and increased concentration of plastics in devices with plastic casing;
- Significantly reduced concentration of lead on post-RoHS devices;
- Reduced concentration of neodymium in devices without Hard Disk Drive,
- Higher concentration of other materials in mobile electronic devices (caused by the materials of the rechargeable battery such as lithium, cobalt and nickel).

Computers – as well as many other electronic devices – contain various materials regarded as critical in the EU (e.g. antimony, palladium, rare earths such as neodymium) and metals with high intrinsic material value (gold, silver, palladium). Thus, the metal content and in particular the content of precious and critical metals is one of the key drivers of e-waste recycling. However, the general bill of materials such as those presented in Table 14 mostly do not account for all trace-elements and thus might mislead.

In the course of the debate on critical metals in the EU, which was stimulated by the *Report of the Ad-hoc Working Group on defining critical raw materials* (EU 2010), detailed surveys were conducted in order to quantify the contents of critical and precious metals in electronic products. Table 15 and Table 16 present data compiled by Buchert et al. 2012 on critical and precious metal concentration in notebooks and computer monitors.

Table 15: Mean content of critical raw materials in notebooks (incl. LCD monitors)

Metal		Content per note-book (CCFL) [mg]	Content per notebook (LED) [mg]	Occurrence
Cobalt	Co	65,000	65,000	Lithium-ion batteries (100%)
Neodymium	Nd	2,100	2,100	Spindle motors (37%), voice coil accelerators (34%), loudspeakers (30%)
Tantalum	Ta	1,700	1,700	Capacitors on the motherboard (90%), capacitors on other PCBs (10%)

Metal		Content per note-book (CCFL) [mg]	Content per notebook (LED) [mg]	Occurrence
Silver	Ag	440	440	Motherboard (57%), other PCBs (43%)
Praseodymium	Pr	270	270	Voice coil accelerators (53%), loudspeakers (47%)
Gold	Au	100	100	Motherboard (54%), other PCBs (46%)
Dysprosium	Dy	60	60	Voice coil accelerators (100%)
Indium	In	40	40	Display & background illumination (100%)
Palladium	Pd	40	40	Motherboard (64%), other PCBs (36%)
Platinum	Pt	4	4	Hard disk drive platters (100%)
Yttrium	Y	1.80	1.60	Background illumination (100%)
Gallium	Ga	0.00	1.60	LED background illumination (100%)
Gadolinium	Gd	0.01	0.75	Background illumination (100%)
Cerium	Ce	0.08	0.10	Background illumination (100%)
Europium	Eu	0.13	0.03	Background illumination (100%)
Lanthanum	La	0.11	0.00	CCFL background illumination (100%)
Terbium	Tb	0.04	0.00	CCFL background illumination (100%)

Source: Buchert et al. 2012

Table 16: Mean weight of critical raw materials in LCD PC monitors

Metal		Content per LCD monitor (CCFL) [mg]	Content per LCD monitor (LED) [mg]	Occurrence
Silver	Ag	520	520	PCB and contacts (100%)
Gold	Au	200	200	PCB and contacts (100%)
Indium	In	79	82	Internal coating on display
Palladium	Pd	40	40	PCB and contacts (100%)
Yttrium	Y	16	3.20	Background illumination
Gallium	Ga	0.000	3.30	LED background
Europium	Eu	1.200	0.06	Background illumination
Lanthanum	La	1.000	0.00	CCFL background
Cerium	Ce	0.680	0.20	Background illumination
Gadolinium	Gd	0.096	1.50	Background illumination
Terbium	Tb	0.340	0.00	CCFL background
Praseodymium	Pr	< 0.019	0.00	CCFL background

Source: Buchert et al. 2012

The data provided in Table 15 and Table 16 indicate the high potential for secondary resources from these product groups, which was also confirmed by other studies (Hagelüken 2006, Salhofer & Spitzbart 2009, Schluep et al. 2009). Nevertheless, not all of these materials can currently be recycled. As illustrated by Buchert et al. (2012), only some of the contained silver, gold, palladium and cobalt are recycled in the established management paths in the EU (see sections 4.2.3 and 4.2.4.2).

4.2.4.2 End-of-life management of computer products

End-of life management in the EU

Computers and computer monitors are classified under category 3 “IT and telecommunication equipment” of the WEEE-Directive. This means that special collection and management systems for end-of-life computers and computer monitors are in place within the EU. However, the 2008 review of the WEEE-Directive 2002/96/EC revealed that less than half of the arising waste of this product-category was collected within the formal system in the EU in 2005 (see Table 17).

Table 17: Collection rates for IT and telecommunication equipment in the EU in 2005

Category		% collected of WEEE arising in 2005
3A	IT and Telecom excl. CRTs	27.8 %
3B	CRT monitors	35.3 %
3C	LCD monitors	40.5 %

Source: Huisman et al. 2007

According to Digital Europe et al. (2013a), currently in most Member States the collection rate based on official data of WEEE separately collected by systems set up by producers is on average 1/3 of electronic and electrical equipment sold. However, recent research in several Member States has revealed that there are large flows of WEEE beyond the producer take back systems which are collected and recycled for a profit. In addition to this 1/3 managed by producer take-back systems, on average, a further 1/3 is also collected and treated by treatment operators. So in fact 2/3 of the WEEE is being treated by treatment operators.

The fate of devices not collected cannot be exactly quantified. Nevertheless, the following pathways are believed to be responsible for the majority of the items not collected:

- Prolonged storage in households and offices;
- Disposal via the municipal waste stream;
- Export as used or end-of-life equipment to non-European destinations.

While exports to non-European destinations and their implications are analysed in more detail in section 4.2.3, disposal via municipal waste stream is not regarded as appropriate disposal. Prolonged storage in households and offices represents a delay of the end-of-life management and is typically not associated with significant negative environmental impacts[21].

The devices collected within the formal WEEE-System in the EU undergo recycling activities, which can be classified into the following steps:

- Preparation for reuse;
- Pre-processing / dismantling (including detoxification);
- End-processing and final disposal.

While reuse is mostly conducted with devices handed in from corporate consumers[22], the majority of end-of-life computers and computer monitors are passed-on to the pre-processing stage, which involves detoxification (taking out batteries, displays across 100 cm^2 and CFL-backlight-units…) followed by dismantling and/or shredding and sorting.

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[21] Although the impacts of prolonged storage have not yet been quantified, it is sometimes argued that storage on large scale leads to significant secondary resource-stocks that cannot yet be utilised by industry/society. On the other side, it is argued that such storage could also benefit recycling as end-of-life management will take place several years in the future when – probably – recycling systems are better prepared to recover critical raw materials. Another factor to be considered is the fact that reuse activities depend on high quality used equipment of moderate age. Thus, devices entering WEEE collection after prolonged storage are typically less attractive for the reuse market.

[22] Computers and monitors collected from corporate consumers typically come in large batches of identical models, which facilitates repair and reuse activities.

Many European recycling enterprises focussing on IT and telecommunication equipment utilise mechanical pre-treatment technologies such as shredders, QS[23] and smashers (Martens 2011). These technologies enable the handling of large quantities with little labour input. On the other side, various studies showed that manual dismantling of IT and telecommunication equipment leads to significantly higher recovery rates for precious metals (Hagelüken 2006, Chancerel & Rotter 2009; Chancerel 2010; Salhofer & Spitzbart 2009). This relates to the fact that mechanical pre-processing technologies are not capable of liberating and separating all precious metals bearing components into one homogenous output fraction. As an example, many printed circuit boards (with high concentrations of precious metals) are mounted with aluminium or steel parts. In the mechanical processes, the printed circuit board parts with steel and aluminium are often sorted into the steel- and aluminium-fraction. In the subsequent end-processing facilities for steel and aluminium, all precious metals are lost.

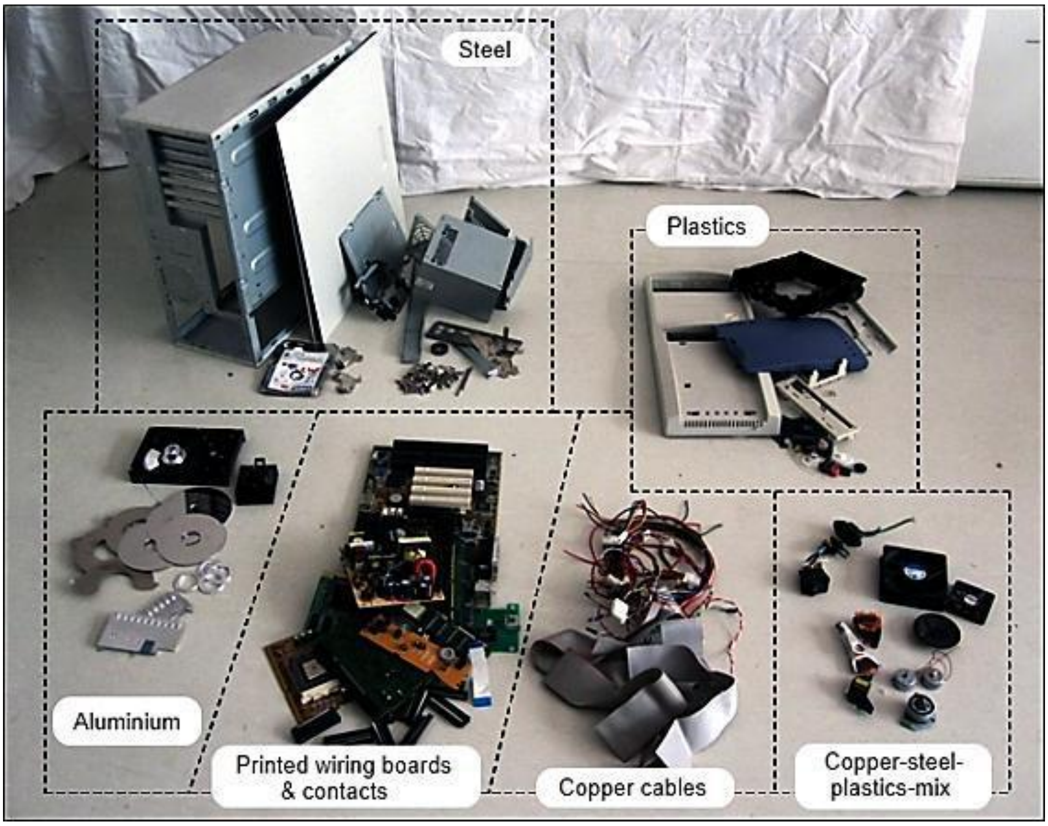
Manual pre-processing is often applied in the recycling of LCD-monitors (Ardente & Mathieux 2012) as well as in some enterprises with other IT-equipment.

Pre-processing (mechanical and manual) of computers typically yields the following output fractions (see Figure 3):

- Steel
- Aluminium
- Copper (insulated or liberated)
- Printed circuit boards
- Plastics
- Copper-steel-plastics-mix
- Rechargeable batteries (from mobile devices)

[23] QS stands for "Querstromzerspanner" and describes a rotating massive metal-chain that breaks incoming devices into pieces.

Figure 3: Manually dismantled and sorted desktop PC



Source: Öko-Institut e.V.

Flat-screen computer displays also yield steel, copper, aluminium, plastics and printed circuit boards. In addition, they contain the display itself as well as backlights which both constitute separate recycling fractions.

While some of the above mentioned fractions can undergo further pre-treatment and/or sorting[24], the outputs are generally fed into end-processing units, which can be described as follows:

- Steel is fed into secondary steel plants;
- Aluminium is fed into secondary aluminium smelters;
- Copper is fed into copper-refineries;

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24 Examples: Liberation of insulated copper-cables, sorting of aluminium in different grades, further processing of copper-steel-plastic-mix, further sorting of plastics according to colour and polymer-types.

- Printed circuit boards and IC-contacts are fed into integrated smelters to recover copper, precious metals and other metals as by-products (e.g. lead, tin, indium);
- Plastics are either recycled (material recovery of thermoplastics) or incinerated (energy recovery);
- Rechargeable batteries (Li-Ion, NiMH) are fed into battery recycling facilities to recover cobalt, nickel, copper and rare-earths[25];
- Display units are incinerated (energy recovery, no material recovery)[26];
- CFL-backlights are treated as hazardous waste (mercury recovery, disposal).[27]

Supporting case study: Recycling of plastics

While most of the above listed end-processing steps are well developed and can lead to high recycling rates, the field of plastics recycling requires special attention. According to MBA-Polymers (2012), less than 10% of higher value plastics from complex waste streams such as durable goods are currently recycled. In comparison, over 90% of the metals, such as steel, copper and aluminium, are recycled from these same complex waste streams.

While downstream markets for material recovery of thermoplastics (e.g. ABS) were a major problem due to the risks of cross-contamination, this situation is undergoing significant changes stimulated by new sorting technologies (see Ardente & Mathieux 2012) as well as high resource prices.

Furthermore, Ardente & Mathieux (2012) in seeking to facilitate high rates of plastics recycling they highlight, based on feedback from the recycling industry, the importance of plastics marking in line with ISO 11469 and the provision of information

[25] There is one facility recycling these metals from waste Li-Ion and NiMH-batteries located in Hoboken, Belgium. The facility is operated by Umicore and started operation mid 2011 (Umicore 2013).

[26] Recycling of metals from display units such as indium is currently not established on an industrial scale. As indium is widely regarded as critical metal, some recyclers and policy-makers consider temporal storage of display-units anticipating future recycling options (Böni & Widmer 2011).

[27] Although the company Rhodia (part of the Solvay-Group) started as first company the recovery of rare earth elements from CFLs on an industrial scale in beginning 2012 in France (Grafenstein 2013), these operations are more addressing CFL with bigger form-factors (e.g. energy-efficient lamps).

in line with ISO 1043-2/4 about plastics' content of functional additives such as flame retardants.

Amongst others MBA-polymers is an example of a company recycling mixed plastics from WEEE. Plastics-sorting is carried out fully automatically within the facilities of MBA-polymers located in Austria and China. These facilities produce secondary-plastics of high quality which can be used in the production of new products. According to MBA-Polymers (2012), their processes to recycle plastics use less than 20% of the energy needed to produce virgin plastics from petrochemicals, saving between 1-3 tons of CO_2 for every ton of virgin plastics that are replaced.

The following table provides an overview how the various ecolabel criteria implement different requirements for recycling of plastics.

Table 18: Existing requirements for recycled content and material recovery of plastics in ecolabel criteria

EU Ecolabel	Blue Angel	Nordic Swan	TCO	EPEAT
Recycled content: The external plastic case of the system unit, monitor and keyboard shall have a post-consumer recycled content of not less than 10% by mass. Material recovery: ---	Recycled content: The (post-consumer) recyclate material may be used in case parts and chassis on a percentage basis. Material recovery: 90% of the mass of plastics and metals of the case parts and of the chassis must be recyclable as a material (this does not mean the recovery of thermal energy by incineration).	Recycled content: --- Material recovery: 90% by weight of plastics and metals in the enclosure and chassis must be technically suitable for material recovery. This does not include the recovery of thermal energy through incineration.	Recycled content: --- Material recovery: ---	Recycled content: --- Material recovery: Required: minimum 65% reusable / recyclable Optional: minimum 90% reusable / recyclable Required: Easy disassembly of external enclosure Optional: Manual separation of plastics

Several computer manufacturers use post-consumer recycled plastic in certain of their product lines. For example:

- Dell used recycled-content plastic in flat-panel monitors and certain desktops by six percent.

- In some of HP's notebook and convertible tablet PCs post-consumer recycled plastic resin is used for a minimum 12% of the total plastic (by weight) in the manufacturing of each of the products.
- Lenovo self-declares to be an industry leader in using post-consumer recycled content (PCC) plastics in the manufacture of new computer and monitor products. A certain Lenovo ThinkPad model contains 18% net PCC, making it the industry's highest amount of PCC in a notebook; a certain workstation model reaches 14% of PCC and certain Desktop models even plus 30%.[28] Depending on the final application requirements, the plastic resins of Lenovo's certain products contain between 10% and 65% PCC. Some plastic resins also contain up to 20% post-industrial recycled content (PIC), meaning material that is diverted from the waste stream during a manufacturing process.

Generally, however, using PCC in IT products presents significant challenges due to the unique structural, performance, and cosmetic requirements associated with these applications.

Table 19: Existing design for disassembly requirements of plastics in ecolabel criteria

Variety of plastics	
EU Ecolabel	• Plastic parts shall be of one polymer or be of compatible polymers for recycling
Blue Angel	• Plastic parts with a mass greater than 25 grams shall consist of a single polymer or a polymer blend compatible with recycling. A maximum of 4 types of plastic may be used for these parts. • Plastic cases may consist of two separable polymers or polymer blends at the most.
Nordic Swan	• Plastic parts heavier than 25g must compose of one polymer or compatible polymers, except for the enclosure, which shall consist of no more than two types of polymers that are separable.
TCO	• No more than two different types of plastic materials are accepted for parts weighing more than 100 grams in the product (notebook / desktop PCs), or more than 25 grams (tablet PCs) respectively. • All-in-one PCs: Each product unit shall have no more than two different types of plastic materials for parts weighing more than 100 grams. The light guide in FPD panels and PWB laminates are exempted
EPEAT	• Optional: reduced number of plastic material types
Metal inlays in plastic parts	
EU Ecolabel	• Metal inlays that cannot be separated shall not be used.
Blue Angel	• ---
Nordic Swan	• Plastic parts (>25g) may contain metallic inlays provided that these can easily be separated without the use of special tools.

[28] http://www.lenovo.com/social_responsibility/nl/en/materials.html

TCO	• Only for Desktop / All-in-one PCs: In-Mould Insert Moulding or glued metal parts are not accepted
EPEAT	• Optional: Molded/glued in metal eliminated or removable
Surface coating	
EU Ecolabel	• All plastic materials in covers/housings shall have no surface coatings incompatible with recycling or reuse.
Blue Angel	• Desktop PCs: It shall NOT be allowed to apply a metallic coating to plastic case parts • Notebook PCs: It shall be allowed to apply a metallic coating to plastic case parts if such coating is technically required. However, no electroplating shall be allowed.
Nordic Swan	• All plastic materials in covers/housings shall have no surface coatings incompatible with recycling or reuse.
TCO	• Only for Desktop / All-in-one PCs: There shall be no internal or external metallization of the desktop computer / All-in-one PC outer plastic casing.
EPEAT	• Required: Elimination of paints or coatings that are not compatible with recycling or reuse
Material coding	
EU Ecolabel	• Plastic parts shall have the relevant ISO 11469 marking if greater than 25 g in mass.
Blue Angel	• Plastic components greater than 25 grams in mass shall be marked in accordance with ISO 11469.
Nordic Swan	• Plastic parts heavier than 25g must carry permanent labeling specifying the material in accordance with latest versions of ISO 11469 and ISO 1043, sect. 1-4. • This criterion does not apply to extruded plastics or the light conductors in flat panel displays. • Plastic parts covering a flat surface of less than 200mm² are also exempted from this requirement.
TCO	• Plastic parts weighing more than 25 grams shall be material coded in accordance with ISO 11469 and ISO 1043, sections 1-4. • Exempted are PWB laminates.
EPEAT	• Required: Marking of plastic components • Required: Identification and removal of components containing hazardous materials • Optional: Marking of plastics

Proposed approach:

Design for disassembly requirements should be retained and improved, where possible, in the revised EU ecolabel criteria. Options for improvement of the existing criteria are discussed in the Technical Report.

The general approach should address the recovery and recycling of specific components identified as being important because they are LCA hot spots, as they contain critical raw materials and/or hazardous substances e.g. batteries, specific main components such as motherboards, CD ROM drives and accumulators, or require easy removal in order to maximise the recovery rate e.g. motherboards, specific plastic sub-components such as display PMMA filters.

Supporting case study: Recycling of rechargeable batteries

According to Kang et al. (2013) rechargeable lithium-ion (Li-ion) and lithium-polymer (Li-poly) batteries have recently become dominant in consumer electronic products because of advantages associated with energy density and product longevity. However, due to the small size of these batteries and the high rate of disposal of consumer products in which they are used, lithium batteries may contribute substantially to environmental pollution and adverse human health impacts due to potentially toxic materials. Kang et al. (2013) demonstrated with their research based on standardised leaching tests, life-cycle impact assessment and hazard assessment models, that the environmental impacts associated with resource depletion, human toxicity and ecotoxicity are mainly related to cobalt, copper, nickel, thallium, and silver. Thus, collection, sorting and professional recycling of portable rechargeable batteries is crucial in order to minimise these impacts.

In Europe, Article 11 of the Batteries Directive 2006/66/EC requires manufacturers to design electrical and electronic equipment "in such a way that waste batteries and accumulators can be readily removed". Furthermore, the appliance "shall be accompanied by instructions showing how the battery can be removed safely and, where appropriate, informing the end-user of the type of the incorporated batteries and accumulators." [29] Finally, Article 12 §3 of the Batteries Directive legally requires the removal of batteries or accumulators from collected waste electrical and electronic equipment on the basis of Directive 2002/96/EC. According to the recast WEEE Directive 2012/19/EU, Article 8.2 and Annex VII, Member States shall ensure that all separately collected WEEE undergoes proper treatment which includes the removal and selective treatment of batteries inter alia.

However, the term "readily removable" is not defined clearly. For example, the duration of the removal process and the tools to be used are not specified.

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[29] These provisions shall not apply where, for safety, performance, medical or data integrity reasons, continuity of power supply is necessary and requires a permanent connection between the appliance and the battery or accumulator.

Furthermore, it is not specified that the battery and/or waste electrical and electronic equipment shall remain intact during the removal process, potentially causing problems in terms of waste avoidance and/or re-use strategies (see section 4.2.3.4). According to c't 2013, electronics recyclers report that

- There is often no information available showing how the battery can be removed safely,
- Batteries of tablet PCs are often only removable with heat guns and special screwdrivers, and
- The removal of fix embedded batteries means too much effort and time for recyclers, thus becoming uneconomic.

This might lead to a recycling praxis of fixed embedded batteries not being removed from the WEEE due to the high effort for recyclers. In that case, valuable scarce resources like cobalt or nickel would be lost and at the same time, the batteries would interfere with the recycling potential of other precious metals e.g. from the printed circuit boards. Furthermore, embedded batteries constitute a safety risk for the recycling operations when they go partially charged to the shredding machines.

Proposed approach

From an environmental perspective with a focus on resource recycling it is recommended to add a criterion on safe and easy removability of batteries for notebook PCs and tablet PCs. Special attention, however, should be given to the exact interpretation, formulation and verification of the term "easily" removable.

Supporting case study: End-of-life management in selected non-European countries

Regarding the exports of WEEE to non-European countries, West-Africa has developed into a primary destination. However, in most West-African countries no environmentally sound end-of-life management of waste electronic equipment is established[30]. In turn, e-waste is commonly handled and recycled by the informal sector with adverse impacts on human health and the environment. In addition, it is

[30] There is currently only one registered and operating e-waste recycler in West-Africa. This is City Waste Recycling Ltd. located in Accra, Ghana.

known that working conditions in this informal recycling sector are below international standards (Manhart et al. 2011b; Prakash & Manhart 2010). While the sources of pollution are numerous, the following processes have been identified as major concerns related to devices such as computers and computer monitors:

- Open burning of cables to retrieve copper;
- Breaking and uncontrolled disposal of CRTs;
- Dismantling of flat screen monitors with CFL-backlights;
- Uncontrolled disposal / burning of plastics;
- Hydrochemical leaching of printed circuit boards (not observed in West-Africa).

Amoyaw-Osei et al. (2011) quantified the total dioxin emissions from open cable fires in five West-African countries (Liberia, Côte d'Ivoire, Ghana, Benin, and Nigeria) based on field studies in the greater Accra Region (Ghana). This quantification suggests that open cable fires caused, as a comparative proportion, 3 to 7 % of the total European dioxin emissions in 2005 (EU15). According to the authors, around 10 to 20% of these emissions can be attributed to cables from waste electrical and electronic equipment (WEEE), the remaining 80 to 90% mainly to cables from waste vehicles.

Reports from these informal recycling practices in West-Africa stimulated policy action in the EU resulting in Annex VI of the new WEEE-Directive (2012/19/EU), which lays out minimum requirements for shipments. This Annex – amongst others – contains the requirement that exporters claiming to export used equipment (*not* waste) have to provide evidence of evaluation or testing, which states that the devices for export are fully functional. Compared to the previous legal situation (where the burden of proof was on the side of customs and inspection authorities), this represents a major policy shift, which is likely to significantly reduce the export of non-functional equipment (e-waste). Nevertheless, exports of functional used equipment remain legal.

4.2.4.3 Stakeholder feedback on end-of-life criteria

- **Design for disassembly**:
  - Focus in the revision must be development of requirements that regulates the time that it takes to dismantle the printed circuit boards.
  - Criteria for an easy and effective disassembly should be tested and verified by independent dismantling and E-waste companies.
- **Re-used parts**:
  - Use of secondary material should be encouraged (if relevant), but, in general, must meet the same requirements as other material.
  - Surface coating can be positive when increasing the volume of recycled plastic.
  - Due to underperformance of used components in the use phase, computers made from re-used parts and components do not fit into the current scope. It is proposed to create a separate category with lesser performance requirements for computers using re-used parts and components, in recognition of their lesser environmental impact over the life-cycle of the product.
- **Packaging**: The economic benefit of packaging bag's recycling is lower, thus a revision of the criterion on packaging bag is needed.

4.2.5 Corporate production / supply chain management

4.2.5.1 General CSR criteria: Challenges for the implementation into ecolabels

Many product groups, including computer products, are associated with both, environmental and social impacts in their life-cycle. Within this context, it is to be discussed whether the EU Ecolabel should, for some product groups where hot spots for social impacts are identifiable, introduce social requirements into their criteria documents.

A main reference point during the revision process will be the EU Ecolabel's Social Task Force, which to date has had two meetings. Any proposals arising from this revision will need to be checked against and should align with the recommendations emerging from the Task Force and the EUEB. Early findings include reference to ILO Core Labour Standards and the need for clear communication to license holders that non-compliance could lead to license revocation.

To inform this discussion, Manhart and Prakash (2012) elaborated some specific recommendations regarding the integration of social criteria into the EU Ecolabel. It is proposed that some of these are reflected in the the revision of the EU Ecolabel criteria for desktop and notebook PCs.

- When integrating social criteria in the EU Ecolabel, in general two different (or as recommended: combined) approaches are conceivable: product or on company related criteria[31].
  - While some product-specific environmental standards directly influence social standards (e.g. elimination of the use of hazardous substances in a product leads to safer working conditions for the employees), it has to be understood that compliance with social standards is generally a process-based approach, and has to be formulated at the company level. Thus, it is important to also consider criteria which address the improvement of social standards in a process-oriented manner in a company.
- As social concerns vary from product group to product group, also varying approaches and criteria must be chosen to best address the issues of concern. It is believed that a copy-paste paragraph on social aspects to be used in all criteria documents of different product categories will fail to have a desired positive impact on sustainable production and consumption. A three-step approach is suggested:

[31] While some social aspects are tightly bound to the product level (e.g. health impacts of products on end consumers), others are bound to production processes and cannot be assessed by analysing a product itself. In the latter case, criteria and verification mechanisms need to go beyond products and ask for conditions in and/or around a certain production facility. Thus, the Ecolabel will in any case have to envisage a mix of product- and facility/company-related criteria.

- In a first analytical step, social hot spots of a product life-cycle should be identified using a standard methodology[32].
- In a second step, it should be attempted to derive specific criteria for each of the identified hot spots. Or alternatively, to concentrate on the most important hotspots and define few (1-2), but most relevant social criteria. As the EU Ecolabel is primarily an *eco*label, there is no general obligation to fully integrate all social hot spots (as is the case e.g. with fair-trade-labels).
- In a third step, existing approaches and initiatives to resolve the identified hot spots and corresponding verification mechanisms should be collected and evaluated.

▪ If the methodology as proposed above is to be applied, verification mechanisms will vary and could include – depending on the type of hotspot, the level of the supply chain and the existence of approaches and initiatives – the following:
  - Self-declaration,
  - Industry code of conduct (CoC), e.g. Electronic Industry Citizenship Coalition EICC[33]
  - International code of conduct (CoC), e.g. UN Global Compact, OECD guidelines for multi-national enterprises
  - Membership of industry initiatives, addressing certain global environmental and social issues for improvement[34]
  - Membership of multi-stakeholder initiatives (e.g. Fair Labor Association)[35],
  - Third-party verified certifications, e.g. SA8000 for manufacturing processes[36],

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[32] This could be done for example by applying aspects of Social Life Cycle Assessment (s-LCA) or Product Sustainability Assessment (PROSA). See: UNEP-SETAC Guidelines for Social Life Cycle Assessment of Products, Paris, 2010 and PROSA – Product Sustainability Assessment – Guideline (http://www.prosa.org/fileadmin/user_upload/pdf/leitfaden_eng_final_310507.pdf).
[33] www.eicc.info
[34] See for example: www.eicc.info/initiatives.shtml
[35] See for example www.fairlabor.org
[36] www.sa-intl.org/sa8000

– Commissioning and carrying out of self-audits.

- Depending upon the identified hotspot and corresponding social criteria, one or more of the above mentioned mechanisms could be selected. Each verification mechanism has its strengths and weaknesses, which have to be kept in mind and communicated transparently in order to avoid any misunderstanding in product marketing. For example, although a criterion requiring membership of a certain industry initiative could lead to increased membership numbers, it may not necessarily boost the effectiveness of the initiative.

So far, Nordic Swan, EPEAT as well as the TCO ecolabel contain corporate social responsibility criteria (see Table 20).

Table 20: Existing requirements for CSR in ecolabel criteria

TCO	Nordic Swan	EPEAT
The Brand owner shall demonstrate the TCO Certified product is manufactured under working practices that promote good labour relations and working conditions by proving accordance with the following: • ILOs eight core conventions 29, 87, 98, 100, 105, 111, 138, and 182. • UN Convention on the Rights of the Child, Article 32. • the health and safety legislation in force in the country of manufacture, and • the labour law, including rules on minimum wage and the social security protection in the manufacturing country. In situations where the right to freedom of association and collective bargaining are restricted under law, workers shall be permitted to freely elect their own representatives. Reasonable effort shall be made to ensure that the requirements of this standard are being met by suppliers and subcontractors throughout the supply chain. The brand owner accepts that TCO Development may conduct/commission on-site inspections and receive full audit reports as part of the application to verify that the Brand owner is fulfilling its obligations according to this Mandate. For the social audit reports and on-site-inspections, the requirement is limited to the 1st tier production facility. The following information shall be submitted to an approved verifier: 1. The requirement is fulfilled by one of the following options (a-d): a) The Brand owner is a member of EICC and provides documented proof of third party audits conducted at production facilities of TCO certified products. b) The Brand owner is SA8000 certified or carrying out the production at SA8000 certified facilities and provides documented proof of third party audits conducted at production facilities of TCO certified products. c) The Brand owner shall complete the Self-documentation	The licensee must have a code of conduct that required adherence to the ten principles of the UN Global Compact. (Including description of how suppliers and manufacturers are informed of this code of conduct.)	Required: Corporate report consistent with Performance Track or GRI Optional: Corporate report based on GRI

TCO	Nordic Swan	EPEAT
according to a questionnaire provided by TCO Development and provide documented proof of third party audits conducted at production facilities of TCO certified products. d) The Brand owner applies for a 12 month grace period by submitting a signed declaration stating which option above (a, b or c) shall be implemented by them and an estimation of when all the necessary documented proof will be available. 2. A written guarantee that the above mandate is fulfilled. The guarantee shall be signed by the responsible person at the Brand owner company.		

The most recent TCO Development criteria from 2012 introduced a comprehensive mandate regarding supply chain responsibility, inter alia focusing on working conditions in the production of TCO certified products (see above). However, in awarding its first "Sustainability Certification" to a leading smartphone manufacturer, TCO has been strongly criticised by occupational and environmental health and justice and workers' rights groups throughout the world following disclosure of the poor occupational safety and health conditions at the manufacturer's production sites[37].

Proposed approach

It is recommended not to require general social criteria for desktop and notebook PCs at this point of time as guaranteeing compliance throughout the supply chain is very difficult and it would lead to a general image problem for the whole ecolabel if a licensed product was found to be produced under poor social conditions.

Social criteria might be proposed as an option for those licensees that are able to guarantee compliance by third-party verified certification. Alternatively, process-oriented criteria could be drafted requiring that applicants shall be members of an initiative addressing certain specific hotspots of the product group and that is working with their suppliers on continuous improvement (see examples below).

[3737] See: http://www.amrc.org.hk/system/files/Global%20health%20and%20justice%20groups%20demand%20that%20TCO%20withdraw%20Samsung%20certification.pdf

4.2.5.2 Examples: Industry initiatives on hotspots in the electronics industry

4.2.5.2.1 Minimizing the risk of using “conflict metals” in electronics

Computer products contain a whole range of scarce resources which are largely mined in the Democratic Republic of Congo, a conflict region, under dangerous conditions, without sufficient maintenance of health and safety standards and often by children.

The Nordic Ecolabelling for Displays has discussed the inclusion of a criterion to minimise the risk from the use of “conflict metals” in electronics within the next revision round of the criteria set. For example, there are two voluntary industry initiatives that have started to implement conflict-free sourcing programs.

Solutions for hope initiative

The ‘Solutions for Hope Project’[38] was launched in 2011 as a pilot initiative to source conflict-free tantalum from the Democratic Republic of Congo (DRC). Tantalum is a metal used in capacitors for electronic products and is derived from the mineral coltan, which is in rich supply in the DRC. Section 1502 of the so called US Dodd-Frank Act[39] requires that companies publicly traded in the U.S. disclose the use of certain conflict metals, including tantalum, in their products and describe the process used to ensure that the purchase of these minerals does not fund the illegal armed groups operating in the DRC. Some have raised concerns that without a recognised industry standard for verification of mineral sourcing, there is the potential for a de facto embargo of minerals from the region. Thousands of people in the DRC, many operating outside of the conflict regions, depend on artisanal mining of coltan and other minerals. Through the Solutions for Hope Project, a program of responsible sourcing of coltan from the DRC has been created and tested to promote economic stability of the area.

[38] http://solutions-network.org/site-solutionsforhope/

[39] http://www.sec.gov/about/laws/wallstreetreform-cpa.pdf

Conflict-free tin initiative

To support responsible sourcing and economic development in the Democratic Republic of Congo (DRC), industry partners convened by the Dutch government have started a conflict-free tin sourcing program in the province of South Kivu in October 2012[40]. Since the beginning of the initiative, the situation at the mine site has changed substantially; employment rates have increased, the income of miners has more than doubled, being reliant on the quality of the tin and the world price. Due to the increased cash flow in the region, women networks have started saving to buy products which they can sell to the miners in order to support their families. Furthermore, working conditions and the security situation at the mine site has improved since local cooperatives buy equipment such as helmets, boots and water pumps for the miners and stabilize mineshafts with wooden piles in order to prevent accidents. Finally, an interesting side effect of the project is the formalisation of the sector, allowing the Congolese government to tax the materials sourced due to the improved transparency.

4.2.5.2.2 Minimizing the use of F-gases in production

Fluorinated gases (F-gases), such as Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6), or Nitrogen trifluoride (NF_3), are a family of man-made gases used in a range of industrial applications. Because they do not damage the atmospheric ozone layer, they are often used as substitutes for ozone-depleting substances. However, F-gases are powerful greenhouse gases, with a global warming effect up to 23 000 times greater than carbon dioxide (CO_2), and their emissions are rising significantly [41].

SF_6 and NF_3 emissions occur during the manufacture of LCD screens for use in monitors and televisions. LCD manufacturers use F-GHGs to clean chemical vapour deposition chambers and plasma etch silicon containing materials.

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[40] http://solutions-network.org/site-cfti/

[41] Source: http://ec.europa.eu/clima/policies/f-gas/index_en.htm

NF_3 is used in the production of thin-film-transistor flat panel displays (LCDs). For a long time the global warming potential of NF_3 had been considered tolerable compared to that of SF_6 which is also widely used in the manufacture of LCDs. However, the global warming potential of NF_3 (17,200) comes close to that of SF_6 (22,200), so that the gas shows the second highest GWP value of all known greenhouse gases[42].

Following the introduction of NF_3 into the production of flat panel displays (TFT-LCD), and the rapid expansion of the sector after 2000 in Korea, Japan, and Taiwan, the demand for NF_3 rapidly increased and caused quadrupling of the production capacities for NF_3 in the USA and East Asia. The gas replaced step by step SF_6 which had initially been used as main cleaning agent in this sector. NF_3 emissions from the East Asian LCD production were considered the main cause of the steep increase in measured atmospheric concentrations NF_3 production is estimated to range around at least 6,000 t/y. Almost 5,000 t are used in LCD manufacturing in Korea, Taiwan and Japan.

In summary, fluorinated greenhouse gases (F-GHGs) are among the most potent and persistent greenhouse gases (GHGs) contributing to global climate change. These gases are relevant in the manufacture of semiconductors, light emitting diodes, and liquid crystal display (LCD) flat panel displays, inter alia for televisions, computer monitors or tablet PCs.

Over the last decade, major flat panel suppliers as well as the semiconductor industry have taken voluntary steps to reduce their F-GHG emissions.

In 2003, LCD manufacturers in Taiwan, Japan and Korea launched a voluntary initiative through the WLICC to set aggressive F-GHG emission reduction goals for 2010. These countries produce roughly 96% of the world's LCDs [43]. LCD manufacturers have started implementing control technologies that reduce the emissions of greenhouse gases by 90%.

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42 Source: http://ec.europa.eu/clima/policies/f-gas/docs/2011_study_en.pdf

43 Source: http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/monitors/Addressing%20Greenhouse%20Gas%20Emissions%20from%20LCD%20Manufacture.pdf

Voluntary industry initiatives

- *Semiconductor industry*: In April 1999, members of the World Semiconductor Council (WSC) announced a goal of reducing PFC emissions by at least 10 percent below the 1995 baseline level by year-end 2010[44]. This target has been reached; for example, the European semiconductor industry[45] has met and surpassed the voluntary reduction goal by reducing absolute emissions by 41% from the 1995 baseline to 2010. A new voluntary agreement for the post-2010 period is currently being elaborated
- *LCD industry*: According to US EPA (2013), in 2001 the World LCD Industry Cooperation Committee (WLICC) agreed to voluntary reduction activities and set a goal to reduce F-GHG emissions to at least 0.82 million tons CO_{2eq} by 2010. This goal had not been achieved due to a rise in emissions resulting from a rapid increase in production for LCD flat panels. As their worldwide demand continues to increase, also by new emerging suppliers with growing market share, F-GHG emissions are also projected to rise.

The goals and results of these initiatives are published at sectoral not at manufacturers' or product level so that it is not possible to propose, for example, a certain limit value as criterion for the EU ecolabel.

As it is currently difficult to compare panel suppliers' F-GHG emissions due to a lack of consistency in estimating emissions, estimating emissions reductions, and monitoring the efficacy of installed abatement systems, the US EPA has developed sets of questions that are intended to be a starting point to help panel purchasers and retailers to understand how their suppliers are reducing their F-GHG emissions and identify opportunities for discussions to target and implement further mitigation efforts[46]. For ICT products, indirect emissions as F-gases occurring in the supply chain (so called "scope 3 emissions") are most relevant; thus they should be recorded and reported according to a defined standard (e.g. GHG Protocol Scope 3 Standard), e.g. within the annual environment report.

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44 www.epa.gov/semiconductor-pfc/resources/indx.html
45 https://www.eeca.eu/esh_pfc/
46 http://www.epa.gov/climateleadership/documents/questions_for_suppliers.pdf

F-gases addressed in current ecolabel criteria

For computers and computer displays, no current ecolabel criteria address F-gases. However, for televisions, EPEAT as well as within the Nordic Ecolabelling revision process, criteria for reducing F-gases in the production are implemented or discussed:

- *EPEAT*: The Television Criteria contain the following optional criterion: "Reduce fluorinated gas emissions resulting from flat panel display manufacturing" (however, not defining a certain baseline or target for the reductions).
- *Nordic Ecolabelling*: According to Nordic Ecolabelling (2013), it is planned to introduce a requirement on usage of abatement system for NF_3 and SF_6 when/if these gases are involved in the production of LCD panels that are used in TVs that will be licensed for Nordic Ecolabelling. As Nordic Ecolabelling is the first environmental labelling organisation suggesting such a requirement from the producer of the LCD/TFT-cell, a declaration of how much kg of the gas is purchased per annum in relation to how many m^2 of displays are produced shall be required so that Nordic Ecolabelling can then in the next revision have a relevant picture of where to aim a potential limit value. Nordic Ecolabelling is aware that this requirement may raise some difficulties regarding the sub suppliers declaring data and understands that the requirement is not formulated as an absolute requirement with limit values.
  - Proposed criterion: "*Nitrogen trifluoride (NF_3) and sulphur hexafluoride (SF_6) emission during LCD production*: The LCD panel must be produced in such a way that the Greenhouse gases NF_3 and SF_6, if part of the production process, are abated by a system that is an integrated part of the production process. It is the responsibility of the manufacturing company to ensure that the abatement system is installed, operated and maintained in accordance with the manufacturers (of the abatement system) specifications. The manufacturer of the LCD shall declare the amount of NF_3 and SF_6 purchased in relation to amount of LCD (m^2) produced over one year.

In general, it can be seen that product assemblers/brands have the potential to play an important role in reducing the climate impacts of the products they sell by sourcing from suppliers with a demonstrated commitment to reducing F-GHG emissions.

Proposed approach

The potential to introduce such a criterion into the EU Ecolabel and how requirements and their verification could be approached are to be discussed.

4.2.5.3 Stakeholder feedback on production criteria

The EU ecolabel criteria should address NF_3 in order to either disregards its potential danger, or to include measures to reduce emissions of NF_3 during the production of ecolabelled IT products

4.2.6 Further stakeholder feedback

- Revision of **audio test** is suggested to allow some "family" certification. So far, for each configuration an official test report is required as verification. It is suggested to test and verify only the maximum configuration without changing any of the elements involved in the certification process, to be able to declare conformity also with lower configurations.
- The **cost of relevant testing / verification** is seen as dis-incentive especially for SMEs.
- **Harmonisation with** the current and recently revised criteria from **TCO** for computers and monitors is suggested.

4.3 Focus for the revision

Based on the technical analysis of LCA literature of desktop and notebook computers, which revealed environmental hotspots during the lifecycle (see Task 3 report and summary in section 4.1 of this report), and the improvement potential derived from this Task Report (see section 4.2), a framework is proposed for the criteria revision. It is suggested to re-allocate the current structure and approach of the existing criteria document to better align the criteria to the identified hotspots. The revision of criteria and new criteria proposals will focus in particular on those issues highlighted as environmental hotspots. For other relevant issues, not listed as hotspots, relevant criteria would be set but based more on an industry average. It is also to be considered whether all the criteria should be retained.

The following tables give an overview on the existing criteria within the EU Ecolabel for computers and notebooks (see Table 21) and a proposal for a new schematic to cluster and allocate the single criteria to certain thematic fields and/or environmental hotspots (see Table 22:).

Table 21: Current EU ecolabel criteria for desktop and notebook computers

Current EU ecolabel criteria
Criterion 1 – Energy savings
Criterion 2 – Power management
Criterion 3 – Internal power supplies
Criterion 4 – Mercury in fluorescent lamps
Criterion 5 – Hazardous substances and mixtures
Criterion 6 – Substances listed in accordance with Article 59(1) of Regulation (EC) No 1907/2006
Criterion 7 – Plastic parts
Criterion 8 – Noise
Criterion 9 – Recycled content
Criterion 10 – User instructions
Criterion 11 – User repairability
Criterion 12 – Design for disassembly
Criterion 13 – Lifetime extension
Criterion 14 – Packaging
Criterion 15 – Information appearing on the Ecolabel

Table 22: New proposed criteria cluster and allocation of sub-criteria for the revision of the Ecolabel criteria for computers

New proposed criteria cluster	Proposed allocation of sub-criteria
1 Energy consumption	Criterion 1.1 – Energy savings
	Criterion 1.2 – Power management
	Criterion 1.3 – Internal power supplies
2 Environmentally hazardous substances	Will be presented in a separate document
3 Life time extension	Criterion 3.1 – Capability enhancement / upgradeability
	Criterion 3.2 – Lifetime of batteries
	Criterion 3.3 – HDD reliability
	Criterion 3.4 – Repairability
	Criterion 3.5 – Data deletion enabling second-hand usage
4 End-of-life management: Design and material selection	Criterion 4.1 – Material selection and material information
	Criterion 4.2 – Design for disassembly and recycling
	Criterion 4.3 – Packaging
5 Corporate production / supply chain management	Criterion 5.1 – Social labour conditions during manufacture
	Criterion 5.2 – Emission of fluorinated GHG during LCD production
	Criterion 5.3 – Use of “conflict-free minerals” during production
6 Further criteria	Criterion 6.1 – Noise
	Criterion 6.2 – Ergonomics
7 Information	Criterion 7.1 – User instructions
	Criterion 7.2 – Information appearing on the Ecolabel

Finally, the introduction of a modular, dynamic and flexible criteria set is proposed for discussion, e.g.:

- Blue Angel divides the requirements into “M”-requirements, which must be fulfilled, and “S”-requirements, which should be fulfilled.
- EPEAT differs between “R” (required) and “O” (optional) criteria, the latter being more advanced.
- EU Ecodesign uses different “Tiers” to secure a progressive update, especially of energy requirements, e.g. 201X (X watt energy use), 201Y (X watt minus 5 or 10%), 201Z (X watt minus 10 or 20%) and so on.

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