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Lot 3
Personal Computers (desktops and laptops) and Computer Monitors
Draft Final Report (Task 1-7)

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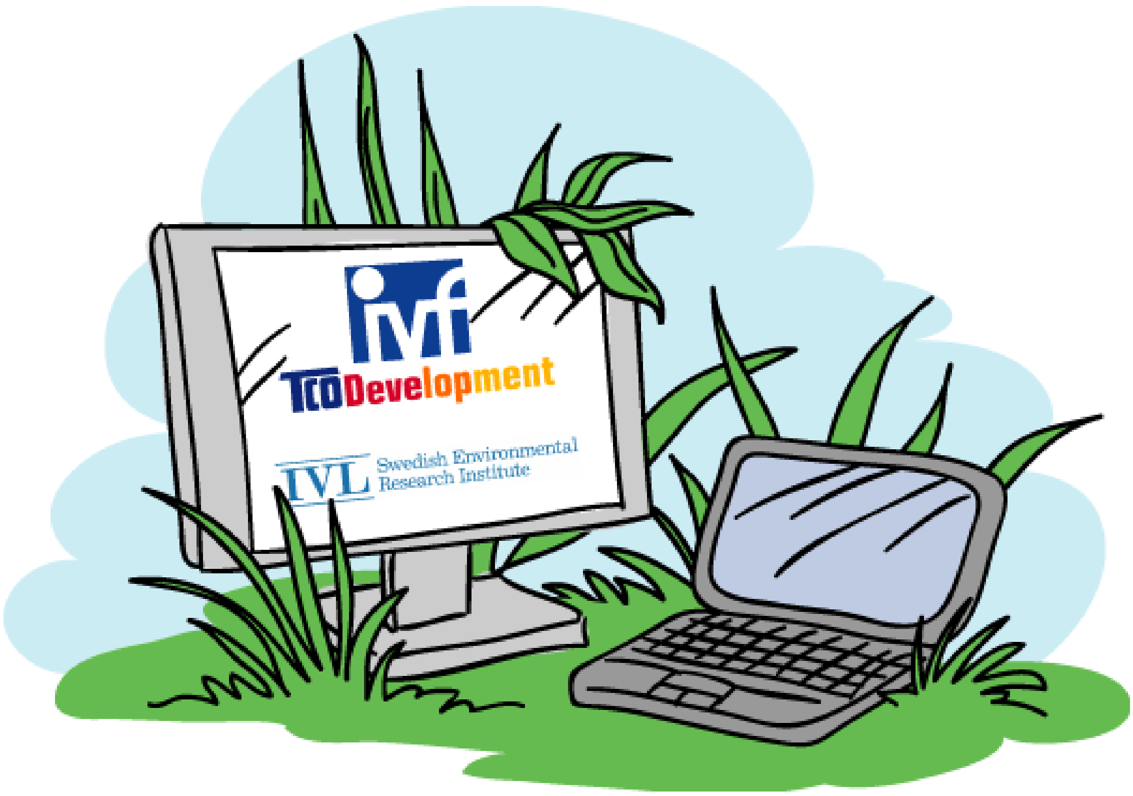

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Preface

This report refers to directive 2005/32/EC of the European parliament and of the council of 6 July 2005 with the main objective to establish a framework for the setting of eco-design requirements for energy-using products.

To get a better knowledge about energy using products, and their environmental performance, and to prepare the coming implementing measures, there was a call for tender from the commission for preparatory studies in September 2005. These studies cover different product groups. The objective of the studies is to find out whether and which eco-design requirements could improve the environmental performance throughout the life cycle of the products relevant to that study. This is the first draft final report within the EuP preparatory study, Lot 3, Personal Computers (desktops and laptops) and Computer Monitors, covering tasks 1 – 7.

The methodology developed by VHK for the European Commission (MEEUP 2005) is followed. A large corpus of information has been collected. The most important parts of it are described in this report.

The report is made available to all stakeholders, through the web-page www.ecocomputer.org . All stakeholders are invited to comment on the report, please send the comments to ecocomputer@ivf.se . All comments will be shown to and discussed with the European Commission. The comments will also be shown in the final report but with the identities of the sources of comments hidden.

The report will also be presented on a seminar in Brussels, open for all stakeholders April 20, 2007. Invitation will be published on the web site.

Some information for the reader of this report:

- Abbreviations are described at the end of the report
- The chapters are called task 1-7 in order to follow the VHK-methodology.
- References are placed at the end of each task.

Finally, we would like to use the opportunity to thank all the people and organisations contributing to this study by giving data and/or feedback comments. Thank you!

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Summary

The VHK-methodology has been the base for this report on EuP preparatory study, Lot 3, Personal Computers and Computer Monitors. Information has been gathered from research available, but also from other sources, such as industry and other stakeholders. The main results are described here, for more details, se the tasks described further in the report.

Task 1, product definition, shows that there are several labelling schemes for the product group, with Energy Star as the most important for Computers and Monitors and TCO for Monitors. The product definition chosen is based mainly on the Energy Star definition, and includes desktops, integrated computers, laptops and computer monitors. Note that workstations, desktop-derived, mid-range and large servers, game consoles, thin clients/blade PCs, hand helds and PDAs are out of the scope for this study.

Task 2, Economic and Market analysis, shows that the installed base in EU-25 of the products within this study in 2005 were approximately; 146 million Desktops, 60 million Laptops, 81 million CRT-monitors and 68 million LCD-monitors.

Task 3, Consumer behaviour and local infrastructure, shows that even if the usage pattern is of great importance for this kind of products, it is not especially well described in research. The usage patterns differ mainly between home and office use, but is also depending on other things, such as age, Internet penetration etc. The usage patterns for desktops in office are for example 37% of time in off-mode, 36 % of time in sleep mode, and 26% of time in active mode.

Task 4, Technical analysis existing products, gives the major technical information, such as the “Bill of material” for the product cases chosen. For Desktop PC the following characteristics have been used: 3 GHz processor (or correspondingly), built-in graphics card, 512 MB RAM and 80 GB HDD; Laptop, characterized by mobile 1,7 GHz processor (or correspondingly), good 3-dimensional graphic performance, 15”-screen, 512 MB RAM and 60 GB HDD; for LCD display: 17”, resolution 1280*1024; and for CRT display, 17”.

Task 5, Definition of base-case, shows the result in terms of environmental and cost impact for the base cases calculated with the Ecoreport tool. For all the product cases, energy use during the use phase is of highest importance.

Task 6, Technical analysis BAT (Best available technology) gives the major technologies of importance, to further improve the environmental performance of the product group. Improvements such as Power Management, high efficiency power supply units and improved processors are described in detail.

Task 7, Improvement potential, where the impact of the improvement options are calculated in the Ecoreport tool, shows a great potential for improvement. If the improvements giving the least life cycle cost (LLCC) were used for the products in use in EU 2005, the potential for saving global warming gases would be approximately 10 mega tones CO2eq.

1 Product definition

Introduction

In task 1 of this study the products within the study have been defined by looking at how personal computers and monitors are defined and categorized in trade statistics, relevant standards and voluntary initiatives. Also the existing legislation and its impact on the product categories have been studied.

The objective of this part of the study and the report is to describe the definitions and the background of the assessment that will be carried out in subsequent parts of the study. The methodology developed by VHK for the European Commission (MEEUP 2005) is followed.

To delimit the "playing field" of eco-design there is a need to define what is included in *personal computers and computer monitors.* The product definition that will be used in this study and is described in this section takes its starting point in the name of Lot 3, "*Personal Computers (desktops and laptops) and Computer Monitors*".

1.1 Historic perspective

Personal computers and computer monitors are quite new products in society. They first started to come out on the market in the eighties. Since the introduction of personal computers, there has been a tremendous development of the products. Moore's law, which is a prediction made by Gordon E. Moore in the sixties that the processor speed will double every 18th month, still holds true.

One reason for the rapid development of the personal computer is that a PC has always been made with standard components developed mainly by sub-suppliers and sold by retailers. This has created a very dynamic sector because there are business opportunities for many different actors.

The fast development of the product group could, from an Eco-design perspective be both a threat and an opportunity. The threat is that so much development is done in a short time, and people are so eager to find new fancy solutions, that the consequences of the development might not be enough scrutinized. The great opportunity is that the products are not yet fixed by too much tradition, thus giving product design a major playing field in functionality and implementations. Already today, personal computers are combined with mobile phones, home media centres and other kind of products. Monitors can also be a TV-set or perhaps in the future the new wall painting?

There is no universally accepted definition of the term personal computer. Most people seem to agree that a personal computer is relatively cheap, multi-purpose, based on microprocessors, designed as a single-user system and usually very flexible regarding which operating system, hardware and application platform it can be fitted with.

1.2 Market data definitions

1.2.1 Eurostat

The basic information available in Eurostat gives rough numbers for production, import and export, which then makes it possible to calculate the net numbers of new equipment brought into use by taking new = production + import - export. To calculate the installed base, the average life-time in use must be estimated (the manufacturers have been asked for estimates).

In Eurostat, there are two registers (data-sets), which basically contain similar data, PRODCOM and COMEXT. PRODCOM is the most important for this study, since COMEXT has no data on production. The data in PRODCOM is organised according to product codes. Some of the codes have changed over time, which makes it necessary to use the data as the union (sum) of data on several codes.

In the Eurostat (Prodcom/comext) statistics, computers and monitors are classified as follows:

1 30021200 Laptop PCs and palm-top organisers

2 30021300 Desktop PCs (including integrated computers)

3 30021400 Digital data processing machines: presented in the form of systems

4 32302083 Black and white or other monochrome video monitors

5 32302045 Colour video monitors with cathode-ray tube (CRT)

6 32302049 Flat panel video monitor, LCD or plasma, etc., without tuner (colour video monitors) (excl. with cathode-ray tube).

1.2.2 Market data and base cases

The VHK-methodology states that the product categories to be assessed in base cases must be possible to identify in the market figures. This complicates the study, since the VHK-methodology also point out Eurostat as the source for market information, and Eurostat has very poor categorisation and market information for this kind of products.

The main weaknesses of the data in PRODCOM are:

1 Data for the different countries are only available from their entry into EU

2 For countries with few manufacturers, the production figures are hidden due to rules within Eurostat (competitive secrecy). This means that some countries show negative values for new equipment. An application to get

hold of the hidden data was sent to Eurostat, through their Swedish representative (SCB), but it was denied.

Since there are weaknesses in the EUROSTAT information, industry has been asked to provide the project with complementary data and data sources. These sources and data will be evaluated and reported in subsequent tasks.

1.3 Energy star definitions

Energy Star is one of the most important voluntary initiatives regarding products covered by this study. It is widely used both in the USA and the EU, it is agreed upon within a wide group of stakeholders, and the definitions are well developed. More information about the Energy Star initiative will follow in the chapter called "Voluntary agreements" in this report. The definitions used by Energy Star are:

1.3.1 Computers

The Energy Star Program Requirements for Computers: version 4.0

A device, which performs logical operations and processes data. Computers are compose of, at a minimum: (1) a central processing unit (CPU) to perform operations; (2) user input devices such as a keyboard, mouse, digitizer or game controller; and (3) a display screen to output information. For the purposes of this specification, computers include both stationary and portable units, including desktop computers, gaming consoles, integrated computers, notebook computers, tablet PCs, desktop-derived servers and workstations.

The computers are in the Energy Star program divided in the following type definitions:

1 ***Desktop Computer***
A computer where the main unit is intended to be located in a permanent location, often on a desk or on the floor. Desktops are not designed for portability and utilize an external monitor, keyboard and mouse. Desktops are designed for a broad range of home and office applications including, email, web browsing, word processing, standard graphics applications, gaming, etc.

2 ***Desktop-derived server***
A desktop-derived server is a computer that typically uses desktop components in a tower form factor, but is designed explicitly to be a host for other computers or applications. For the purposes of this specification, a computer must be marketed as a server.

3 ***Game consoles***
Stand alone computers whose primary use is to play video games. For the purposes of this specification, game consoles must use a hardware architecture based on typical computer components (e.g. processors, system memory, video architecture, optical and/or hard drives etc.) The primary input from game consoles are special hand held controllers rather than the

mouse and keyboard used by conventional computer types. Game consoles are also equipped with audiovisual outputs for use with televisions as the primary display, rather than an external monitor or integrated display. These devises do not typically use a conventional operating system, but often perform a variety of multimedia functions such as DVD/CD playback, digital picture viewing, and digital music playback.

4 ***Integrated Computer***
A desktop system in which the computer and display function as a single unit, which receives its ac power through a single cable. Integrated computers come in one of two possible forms: (1) a system where the display and computer are physically combined into a single unit; or (2) a system packaged as a single system where the display is separate but is connected to the main chassis by a dc power cord and both the computer and display are powered from a single power supply. As a subset of desktop computers, integrated computers are typically designed to provide similar functionality as desktop systems.

5 ***Notebook and Tablet computers***
A computer designed specifically for portability and to be operated for extended periods of time without a direct connection to an ac power source. Notebooks and tablets must utilize an integrated monitor and be capable of operation off and integrated battery or other portable power source. In addition, most notebooks and tablets use an external power supply and have an integrated keyboard and pointing device, though tablets use touch sensitive screens. Notebook and tablet computers are typically designed to provide similar functionality to desktops except within a portable device. For the purposes of this specification, docking stations are considered accessories and therefore, the performance levels associated with notebooks do not include them.

6 ***Workstations***
For the purposes of this specification, to qualify as a workstation, a computer must:

a. Be marketed as a workstation

b. Have a mean time between failures (MTBF) of at least 15,000 hours based on Bellcore TR-NWT-000332, issue 6, 12/97; and

c. Support error-correcting code (ECC) and/or buffered memory

d. In addition, a workstation must meet three of the following six optional characteristics:

i. Have supplemental power support for high end graphics (i.e. PCI-E 6 pin 12 V supplemental power feed)

ii. System is wired for 4x or 8x PCI-E on motherboard in addition to graphics slot(s) and/or PCI-X support *iii.* Does not support Uniform Memory Access (UMA) graphics:

iv. Include 5 or more PCI, PCIe, PCI-X slots;

v. Capable of multi-processor support for two or more processors (must support physically separate processor packages/sockets, i.e, not met with support for a single multi core processor)

and/or

vi. Be qualified by at least 2 Independent Software Vendor (ISV) product certifications; these certifications can be in process, but must be completed within 3 months of qualification.

Product groups not covered by Energy Star include mid-range and large servers, thin clients/blade PCs, handhelds and palm-top organisers.

Definitions of different categories of desktops

For the ourposes of detemining Idle state levels, desktops and integrated computers must qualify under Categories A, B or C as defined below.

Category A: All desktop computers that do not meet the definition of either Category B or category C below are under Category A for Energy Star qualification

Category B: To qualify under category B desktops must have:

- Multi-core processor(s) or greater than 1 discrete processor; and
- Minimum of 1 gigabyte of system memory

Category C: To qualify under Category C desktops must have:

- Multi-core processor(s) or grater than 1 discrete processor; and
- A GPU with greater than 128 megabytes of dedicated, non-shared memory.

In addition to the requirements above, models qualifying under Category C must be configured with a minimum of two of the following three characteristics:

- Minimum of 2 gigabytes of system memory
- TV tuner and/or video capture capability with hight definition support; and/or
- Minimum of 2 hard disk drives

1.3.2 Computer monitors

Definition of computer monitors from the *Energy Star Requirements for Computer Monitors Eligibility Criteria (version 4.1).*

Computer Monitor (also referred to as "Monitor")

A commercially-available, electronic product with a display screen and its associated electronics encased in a single housing that is capable of display output information from a computer via one or more inputs, such as VGA, DVI, and/or IEEE 1394. The monitor usually relies upon a cathode-ray tube (CRT), liquid crystal display (LCD) or other display device. This definition is intended primarily to cover standard monitors designed for use with computers. To qualify, the computer monitor must have a viewable diagonal screen size greater than 12 inches and must be capable of being powered by a separate AC wall outlet or a battery unit that is sold with an AC adapter. Computer monitors with a tuner/receiver may qualify as ENERGY STAR under this specification as long as they are marketed and sold to consumers as computer monitors (i.e., focusing on computer monitor as the primary function) or as dual function computer monitors and televisions. However, products with a tuner/receiver and computer capability that are marketed and sold as televisions are not included in this specification.

1.3.3 Operational Modes, computer

The Energy Star Program Requirements for computers, draft 3 defines three computer operational modes: idle, sleep and stand-by. These are described below.

Idle State

For purposes of testing and qualifying computers under this specification, this is the state in which the operating system and other software have completed loading, the machine is not asleep, and activity is limited to those basic applications that the system starts by default. 4

Sleep mode

A low power state that the computer is capable of entering automatically after a period of inactivity or by manual selection. A computer with sleep capability can quickly "wake" in response to network connections or user interface devices. For the purposes of this specification, Sleep mode correlates to ACPI System Level S3 (suspend to RAM) state, where applicable.

Standby level (Off Mode)

The power consumption level in the lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For purposes of this specification, standby correlates to ACPI System Level S4 or S5 states, where applicable.

1.3.4 Operational modes, computer monitor

The Energy star Program requirements for Computer Monitors, Eligibility Criteria (version 4.1) defines the five operational modes for monitors described below.

On Mode/Active Power

The product is connected to a power source and produces an image. The power requirements in this mode is typically greater than the power requirement in sleep and off modes

Sleep Mode/Low Power

The reduced power state that the computer monitor enters after receiving instructions from a computer or via other function. A blank screen and reduction in power consumption characterize this mode. The computer monitor returns to On Mode with full operational capability upon sensing a request from a user/computer (e.g., user moves the mouse or presses a key on the keyboard)

Off Mode/Standby Power

The lowest power consumption mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when a computer monitor is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For purposes of this specification, Off Mode is defined as the power state when the product is connected to a power source, produces no images, and is waiting to be switched to On Mode by a direct signal from a user/computer (e.g., user pushes power switch)

Hard Off Mode

A condition where the product is still plugged into the mains, but has been disconnected from an external power source. This mode is usually engaged by the consumer via a "hard off switch". While in this mode, a product will not draw any electricity and will usually measure 0 watts when metered.

Disconnect

The product has been unplugged from the mains and therefore is disconnected from all external power sources.

1.3.5 Energy Star definitions and this study

The scope of energy star is slightly different from the scope of this study. Energy star covers “all” computers and monitors, and the Eup preparatory study is limited to “personal computers” and monitors. The definitions used by Energy Star are nevertheless very useful for this study. They are agreed upon within approximately the same stakeholder group as this study, and they do aim at a larger group of products within which the products of this study are a part, and the same kind of impact (energy and/or environment). At the stakeholder workshop for the Lot 3 study in May 2006, the Energy Star was also agreed upon as one of the most important voluntary agreements for this study.

Some of the products within the Energy Star definitions are out of the scope of this preparatory study, such as Desktop derived server, Game consoles and Work stations.

Regarding the Desktop differentiation categorisations A, B and C, they might be of interest when deciding the base cases, but there are some difficulties with their potential use. The VHK methodology requires market data and usage pattern divided to the different products, which so far was impossible to find related to the categorisations A, B and C. The base definition of base case will be done in task 5 of this study.

The operational modes defined in Energy Star will be used for the definition of operational modes when looking into the consumer behavior (task3) and test procedures, since they are applicable to our study, and are agreed upon by the stakeholders.

1.4 Proposed product definitions

For the purpose of this study, the following product definition is suggested for *personal computers:*

> A device which performs logical operations and processes data. Personal computers are composed of, at a minimum: (1) a central processing unit (CPU) to perform operations; (2) user input devices such as a keyboard, mouse, digitizer or game controller; and (3) a display screen to output information. For the purposes of this study, personal computers include both stationary and portable units, including desktop computers, integrated computers, notebook computers and tablet PCs. For further definitions of these computer categories, the Energy Star definitions are applicable.

Note that workstations, desktop-derived, mid-range and large servers, game consoles, thin clients/blade PCs, handhelds and PDAs are not included in this product definition of personal computers, and will therefore not be covered by this study.

For the purpose of this study, the following product definition is suggested for *computer monitors*:

A commercially-available, electronic product with a display screen and its associated electronics encased in a single housing that is capable of display output information from a computer via one or more inputs, such as VGA, DVI, and/or IEEE 1394. The monitor usually relies upon a cathode-ray tube (CRT), liquid crystal display (LCD) or other display device. This definition is intended primarily to cover standard monitors designed for use with computers. To qualify, the computer monitor must have a viewable diagonal screen size greater than 12 inches and must be capable of being powered by a separate AC wall outlet or a battery unit that is sold with an AC adapter. Computer monitors with a tuner/receiver may be covered by this study as long as they are marketed and sold to consumers as computer monitors (i.e., focusing on computer monitor as the primary function) or as dual function computer monitors and televisions. However, products with a tuner/receiver and computer capability that are marketed and sold as televisions are not included in the scope of this study.

1.5 Product group performance and functional Unit

There are several benchmarking methods for computers, often used by computer magazines, where they test the performance in different type of applications, often specifically games. Unfortunately they do not really work to find out the performance of a product in a broader view, since the use of computers is so differentiated!

When using life cycle assessment, LCA, to stimulate the development of environmentally superior products, the calculations should ideally yield environmental impact per some important unit of performance. This would drive development towards products with the same (or better) performance with less environmental impact during the whole life cycle of the product.

1.5.1 Functional unit for personal computers

Since personal computers are used to fulfil so many different needs, it is impossible to find one technical performance measure that could represent all these needs in a good way. This issue was also discussed during the 30 May workshop and it was concluded that personal computers are used for such a variety of reasons that there is not one technical performance parameter that stand out enough to merit being used as the functional unit in an LCA.

Most LCA of personal computers, such as EPIC-ICT (2006), (Fujitsu 2003) and Atlantic Consultings (1998) study for the Ecolabel Unit of the European Commission, use “1 computer” as the functional unit. The EIPRO study (2006) uses “Euros of computer”. Compared to “1 computer”, “Euros of computer” reflects to an extent the technical performance, since there normally is a relation between price and technical performance. Reporting environmental impact per euro computer should in theory stimulate the development of expensive computers with low environmental impact. If one could in advance determine how many years each computer will be used, “computer year” is another possibility that also to a degree reflects the technical performance.

In this study, all calculations for computers (desktops and laptops) will initially be performed on the functional unit 1 computer (desktops and laptops). The possible use of other functional units, such as “Euros of computer” or “computer years” will be further investigated and discussed. The end results can easily be recalculated. However, one should be aware of that none of these alternatives is a perfect functional unit. There use could possibly lead to conclusions that could stifle the development of more efficient computers.

1.5.2 Functional unit for computer monitors

The functional unit for a Computer monitor used by the ENERGY STAR Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1), is Environmental impact per Mpixel. Some statistics for TCO-labelled monitors, shows that the energy consumption of computer monitors are proportional to the size of the screen (cm2). This study will therefore use the environmental impact per Mpixel as the functional unit and as a secondary performance parameter use the environmental impact related to the size of the screen.

1.6 Test standards and voluntary agreements

The general objective of this task is to describe test standards and voluntary labels related to the product categories within the scope of this study.

1.6.1 Test standards

Electrical safety standards

The electrical safety standards most commonly in use are IEC 60950, (Safety of information technology equipment), EN 60950 and the American standard UL 60950. They are all very similar and can be considered harmonized.
The safety standards have demands on electrical shock prevention and fire resistance that makes the choice of materials in the design of the computer somewhat restricted.

Electromagnetic Compatibility, EMC, standards

The EMC standards most commonly in use for computers are EN 55022, (Radiated emissions), EN 55024, (Immunity), and IEC 61000-2-2 and IEC 61000-3-3, (Disturbances on the low voltage main power supply). In the US, the FCC Part 15B class B standard is in use. The EMC standards also influence what is possible to do or not when designing a computer.

EN 62018 Power consumption for information technology equipment (ITE) – Measurement methods (2004)

This standard is adapted from IEC 62018 (2003) standard of the same name. The standard specifies methods of measurement of electrical power consumption in different modes of the use phase of ITE. It specifies the following conditions:

- configuration of the tested equipment
- environment
- power supply
- supply-voltage waveform
- power measurement accuracy
- testing instrumentation
- time of measurement
- test procedure.

*Scope***:** Information Technology Equipment identified in more details in the standard IEC 60950-1 named “Information technology equipment – Safety “

Noise standards

Test standards for noise used in this study will be ISO 7779 in operator position.

Test standards within Energy Star, TCO and other voluntary agreements are described under the “Voluntary agreement” headline.

1.7 Voluntary agreements

There are many different voluntary (and mandatory) environmental performance labels and declarations. The International Organization for Standardization (ISO) has identified three broad types of voluntary labels.

- Type I (ISO 14024) a voluntary, multiple criteria-based, third party program that awards a license that authorises the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations
- Type II (ISO 14021) informative environmental self-declaration claims
- Type III (ISO/TR 14025) environmental product declaration, EPD, voluntary programs that provide "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information".

1.7.1 Type I Eco-labels

"Eco-labelling" is a voluntary method of environmental performance certification and labelling that is practised around the world. An "eco-label" is a label which identifies overall environmental preference of a product or service within a specific product/service category based on life cycle considerations. In contrast to "green" symbols or claim statements developed by manufacturers and service providers, an eco-label is awarded by an impartial third-party in relation to certain products or services that are independently determined to meet environmental leadership criteria. In Europe there are several national eco-labels, and other labelling schemes of which some are described below.

The European Union Eco-label, the Flower

http://europa.eu.int
www.eco-label.com

The European Union Eco-label, the Flower, was started in 1992 and can be found throughout the European Union as well as in Norway, Lichtenstein and Iceland. The European Union Eco-labelling Board (EUEB) develops ecological criteria for product groups in close collaboration with the Commission.

Today there are no computers or monitors labelled.

Desktops 2005/341/EC / Notebooks 2005/343/EC

Effective 2005**.**

The criterion regulates the energy consumption of Personal computers, Desktops/Notebooks in Sleep mode, Off mode, and the energy consumption of the external power supply when it is connected to the electricity supply but is not connected to the computer.

Table 1 Criteria for the European Union Eco-label, the Flower

Computer	Mode	Power Allowance
PC	Sleep	5W
	Off	2W
Note Book	Sleep	5W
	Off	2W

Power supply	Not connected to the computer	0.75W

Noise

Desktops
Measures according to ISO 7779 and declares in A-weighted sound power level (LWAd) according to ISO 9296 in dBel. (dB)
Noise levels must not exceed:
4.0 B(A) in the idle operating mode (equivalent to 40 dB(A))
4.5 B(A) when accessing a hard-disk drive (equivalent to 45 dB(A)).

Notebooks
Noise levels must not exceed:
Idling mode: 3.5 B (A).
When accessing a hard-disk drive: 4.0 B (A)

Energy star

For US: www.energystar.gov

For EU: www.eu-energystar.org

In 1992, US Environmental Protection Agency (EPA) introduced Energy Star as a voluntary labelling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. Personal computers and monitors are products within the scope of Energy star.

The European Union made an agreement with the US government to coordinate the energy-efficiency labelling programs some years ago. Described is the version now effective (version 3.0) and also the new version (4.0) which will be effective from July 20 2007.

Computer Memorandum of Understanding (Version 3.0).

Effective in 1999. Applies to computers and integrated computer systems.

The ENERGY STAR Program Requirements for computers,

The Energy Star v. 3.0, criteria regulate the energy consumption in sleep mode in relation to the power consumption rated for the computer.

Table 2 Energy Star, version 3.0, criteria for computers.

Maximum Continuous Power Rating of Power Supply	**Watts in sleep mode**
$\leq$ 200W	$\leq$ 15W
> 200W $\leq$ 300W	$\leq$ 20W
> 300W $\leq$ 350W	$\leq$ 25W
> 350W $\leq$ 400W	$\leq$ 30W
> 400W	$\leq$ 35W

Of all labelling schemes, Energy Star has by far the best market coverage for computers. The European Energy Star programme today qualifies 268 PC models (Energy Star version 3.0).

ENERGY STAR Program Requirements for Computers: version 4.0

Effective July 20, 2007
Note: This is only a summary of the content, for the full text, www.eu-energystar.org

- Tier 1 Requirements –effective July 20, 2007
    - Power supply efficiency requirements
        - Internal Power Supply: 80% minimum efficiency at 20%, 50% and 100% of rated output and Power Factor $\geq$0.9 at 100% rated output.

- External Power Supply: Must fulfil the ENERGY STAR requirements for External Power Supply (www.energystar.gov/powersupplies)

- Operational Mode Efficiency Requirements (for definitions and categories, se earlier in this report)

Table 3 Energy Star, version 4, criteria for computers.

Product Type	Tier 1 Requirements
Desktops, Integrated Computers, Desktop-Derived Servers and Gaming Consoles	Standby (Off Mode): <2.0 W Sleep Mode: ≤4.0 W Idle State: Category A: ≤ 50.0 W Category B: ≤ 65.0 W Category C: ≤ 95.0 W
Notebooks and Tablets	Standby (Off Mode): ≤ 1.0 W Sleep Mode : ≤ 1.7 W Idle State: Category A: ≤ 14.0 W Category B: ≤ 22.0 W
Capability adder for sleep and Standby	
Capability	Additional Power Allowance
Wake on LAN (WOL)	+ 0.7 W for Sleep + 0.7 W for Standby

- Power Management Requirements
  Products must be shipped with the display's Sleep mode set to activate within 15 min of user inactivity and Computer sleep mode to activate within 30 min of user inactivity

- All computers shall have the ability to enable and disable Wake on LAN

- User Information Requirement including information about the Power management, how to properly wake from sleep mode and about Energy Star

- Tier 2 Requirements –effective January 2009
  - To be decided

Energy Star Computer Test Method (version 4)

Test configuration

Power consumption of a computer shall be measured and tested from an AC source to the system.

Test conditions

Line Impedance: < 0.25 ohm
Total Harmonic Distortion: < 5%
Ambient Temperature: 25 deg. C +/- 3 deg. C
For products to be qualified in markets using 100V/120V input:

- Input AC Voltage[1]: 115 VAC RMS +/- 5V RMS
- Input AC Frequency[1]: 60 Hz +/- 3 Hz

For products to be qualified in markets using 230 V input:

- Input AC Voltage[1]: 230 VAC RMS +/- 5V RMS
- Input AC Frequency[1]: 50 Hz +/- 3 Hz

Testing equipment

A true RMS wattmeter with sufficient crest factor and frequency response, and a resolution of at least 0.1 W is needed.

Program Requirements for Computer Monitors Eligibility Criteria (version 4.1)

Effective in 2006. Applies to computers monitors.

The standard prescribes measurement of the monitor power consumption in Sleep, Off and Active mode. In Active mode particular luminance adjustments are stipulated.

Table 4 Energy Star, version 4.1, Energy criteria for computer monitors.

Sleep	2W
Off	1W
Active mode	X < 1 mega pixel, then Y = 23; if X > 1 mega pixel, then Y = 28X. Y is expressed in watts and rounded up to the nearest whole number and X is the number of mega pixels in decimal form X= Mega pixels Y= Allowed power consumption

Test Conditions:

Table 5 Energy Star, version 4.1, test conditions for computer monitors.

Supply Voltage*:	North America: Europe: Australia/New Zealand: Japan:	115 (± 1%) Volts AC, 60 Hz (± 1%) 230 (± 1%) Volts AC, 50 Hz (± 1%) 230 (± 1%) Volts AC, 50 Hz (± 1%) 100 (± 1%) Volts AC, 50 Hz (± 1%)/60 Hz (± 1%)
Total Harmonic Distortion (Voltage):	< 2% THD	
Ambient Temperature:	20°C ± 5°C	
Relative Humidity:	30 – 80 %	
Line Impedance:	< 0.25 ohm	

The measurements shall be performed with a RMS power meter

The RMS power meter shall have a crest factor of at least five.

The labelling scheme has had and has a very important impact in the reduction of power consumption on computer monitors.

TCO Development, TCO label

www.tcodevelopment.com

The TCO label is global – the certificate has no geographical limitations and the label is present in markets in many parts of the world with the strongest base in the northern part of Europe. The TCO labelling started in 1992 and does not only cover environmental issues, but also addresses other issues regarding the work environment, such as image quality, visual and work load ergonomics, noise, electromagnetic- and chemical emissions.

Today about 50 % of all computer displays in the world are TCO-labelled (about 3500 models). About 20 computers are TCO-labelled.

Standards: *TCO'05 Desktop computers, version.1.0 /*
TCO'05 Notebook computers, version 2.0
Effective 2005.

The criteria regulate the energy consumption of Personal computers, Desktops/Notebooks in Sleep mode and Off mode.

Table 6 Energy criteria for TCO 05, computers.

Computer	Mode	Power Allowance
PC	Sleep	5W
	Off	2W
Notebook	Sleep	4W
	Off	2W

Noise

Measures according to ISO 7779 and declares in A-weighted sound power level (LWAd) according to ISO 9296 in Bel. (B)

Noise levels must not exceed:

Operating mode: 3.9 B
Idling mode: 3.5B
If the product does not emit prominent discrete tones according to procedures specified in ECMA 74 Annex D a higher declared A-weighted sound power level (LWAd) is accepted butshall not exceed:
Operating mode: 4.2B
Idling mode: 3.8B

If noise emission measurement is carried out on one appliance only, the declared sound power level LWAd" shall be LWA + 0.3 B.

Standard: *TCO'03 Displays, Flat Panel Displays Ver 3.0*
Effective 2005-10-19

The standard prescribes measurement of the monitor power consumption in Sleep, Off and Active mode. In Active mode particular luminance adjustments are stipulated.

The power consumption criteria and the measurement methods is harmonised with the criteria in Energy Stars, Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1) Tier 2.

The standard and its predecessors have had a decisive impact on the power consumption for computer monitors.

Standard: *TCO'03 Displays, CRT Displays Ver. 3.0*

The standard prescribes measurement of the monitor's power consumption in Sleep and Off mode.

Table 7 Energy criteria for TCO 03, monitors.

Sleep mode	≤ 4W
Off mode	≤3 W

Test conditions
AC mains voltage* 230 VAC RMS, tolerance ± 1 %
AC mains frequency* 50 Hz, tolerance ± 0.5 Hz
Line impedance 0.25 Ω
Total harmonic distortion < 2%
Test room temperature 23±3 $_o$C [1]
Humidity 20-75 % RH (non-condensing) [2]

Refresh rate 85 Hz [3]

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* – or other voltage and frequency combination specified by the client based the market in which the VDU will be sold.

The measurements shall be performed with a RMS power meter
The RMS power meter shall have a crest factor of at least five.

Nordic Eco labelling: The Swan

www.svanen.nu
The Swan is the official Nordic eco-label, introduced by the Nordic Council of Ministers in 1989. Today about 5 computer displays and 24 computers are labelled with the Swan.

Standard: *Personal computers Ver. 4.1*
Effective 2005.

The criterion regulates the energy consumption of Personal computers, Desktops/Notebooks in Sleep mode, Off mode, and the energy consumption of the external power supply when it is connected to the electricity supply but is not connected to the computer.

Table 8 Energy criteria for the Swan, personal computers.

Computer	Mode	Power Allowance
PC	Sleep	5W
	Off	2W
Note Book	Sleep	5W
	Off	2W

Power supply	Not connected to the computer	0.75W

Noise

Measures according to ISO 7779 and declares in A-weighted sound power level (LWAd) according to ISO 9296 in Bel. (B)

Noise levels must not exceed:

Desktop computers,: Operating mode: 5,0 B (A), Idling mode: 4,5 B (A)
Deskside computers, Operating mode: 5,3 B (A) Idling mode: 4,8 B (A)
Portable computers, Operating mode: 4,5 B (A)) Idling mode: 4,0 B (A)

The Blue Angel

www.blauer-engel.de
The Blue Angel was created in 1977 on the initiative of the German Federal Minister of the Interior and approved by the Ministers of the Environment of the

national government and the federal states. Today about 7 computer displays and 63 computers are labelled with the Blue Angel.

Standards: *Computers RAL-UZ-78*
Effective 2006.

The criterion regulates the energy consumption of Personal computers, Desktops/Notebooks in Sleep mode, Off mode, and the energy consumption of the external power supply when it is connected to the electricity supply but is not connected to the computer.

Table 9 Energy criteria for the Blue Angel.

Computer	**Mode**	**Power Allowance**
PC	ON (ACPI S3)	<4,5 W
	Off without wake up	< 2,5 W
	Off with wake up function	< 3,5 W
Note Book	ON (ACPI S3)	<3,5 W
	Off	< 2 W
Monitors	ON <1 megapixels	23 W
	On >= 1 megapixels	28*pixels
	Sleep	2 W
	Off	1 W

Noise

Measures according to ISO 7779 and declares in A-weighted sound power level (LWAd) according to ISO 9296 in dBel. (dB)

Noise levels must not exceed:

Idle mode max 44 dB(A)
If noise emission measurement is carried out on one appliance only, the declared sound power level LWAd" shall be LWA +3dB.

Group for Energy Efficient Appliances

http://www.gealabel.org

Standard: *Product Sheet, Personal Computers (system units)*
Reference: IT01-280601
Effective 2006.

The criterion regulates the energy consumption of Personal computers, Desktops/Notebooks in Sleep mode, Off mode and On mode. External power supply, if any, shall comply with EU "Code of Conduct on Energy Efficiency of External Power Supplies" version 2, phase 2

Table 10 Energy criteria for the Group for energy-efficient appliances.

Computer	Mode	Power Allowance
PC	Sleep	5W
	Off	2W
	On (Idle)	70W

Power supply	Not connected to the computer	0.3 – 0.5W

The Top Runner System, Japan

http://www.eccj.or.jp/top_runner/index.html

The Top Runner System uses, as a base value, the value of the product with the highest energy consumption efficiency on the market at the time of the standard establishment process and sets standard values by considering potential technological improvements added as efficiency improvements. The target standard values are extremely high. For achievement evaluation, manufacturers can achieve target values by exceeding target values by weighted average values using shipment volume, the same as the average standard value system.

Under this system, designated machinery and equipment products are required to achieve a weighted average value by the target fiscal year right now year 2007, using each manufacturer's shipment volumes by category. Under this method, if demand is high for a product whose manufacturer emphasises other functionalities over energy consumption efficiency, the manufacturer can ship the equipment even if the energy consumption efficiency is lower than the target value. That is, the manufacturer can achieve the target value on an average basis by shipping a product with higher efficiency in the same category. The system functions well to facilitate manufacturers' voluntary activities.

Top runner Computer classifications

The top runner classification method gives several different classes based on:

1. Classifications based on product characteristics
   Computers are largely classified in terms of the nature of their usage and necessary functions into server-side computers (mainframe computers, mid-range computers, etc.) and client-side computers (workstations, desktop PCs, etc.). Client-side computers are further divided into desktop computers (non-battery-driven) and notebook PCs (battery-driven).
2. Classification based on performance characteristics such as number of I/O signal transmission paths (I/O) and memory size.

Top runner Energy consumption efficiency measurement method

Energy consumption efficiency is calculated by the following formula.
$E = [(W_1 + W_2)/2]/Q$

In this formula, E, W_1, W_2 and Q represent the following values.
E: Energy consumption efficiency (unit: watts/million calculations)
$(W_1+W_2)/2$: Power consumption (unit: watts)

W_1: Power consumption in idle state (unit: watts)

The power consumption of the idle state (hereinafter "idle state") is when operation is possible without resetting the initial programs and in the states before operating in low power mode such as standby mode and suspended mode in accordance with the ACPI standards.

W_2: Power consumption in low power mode (unit: watts)

The power consumption of low power mode is the low power mode of standby mode and suspended mode in ACPI standards (however, limited to states in which program and data are store in the main memory). Concerning server-side computers and client-side computers that do not have low power modes, the value of W_1 is used for W_2.

Q: Composite theoretical performance (CTP) (unit: millions of calculations)

W_1 is expressed in watt units for values measured by the method below.

1 Ambient temperature between 16°C and 32°C.

2 Power supply voltage in ±10% specified input voltage. However, for items with specified input voltage of 100 volts, it is ±10% of 100 volts

3 Power supply frequency at standard frequency

4 Without losing the computer's basic functionality, measurements are done with the maximum configuration on a scope that removes I/O control equipment, communications control equipment, HDDs, etc. that can be disconnected from the computer. For items to which the number of processors can be expanded, measurements shall be done with the minimum configuration of processors. For items other than battery-driven types among client-side computers, measurements can be done with the power supply to the graphic display turned off.

W_2 is expressed in watt units for values measured by the method below.

1 Ambient temperature shall be 16 to 32°C

2 The power supply voltage shall be within the range of the rated input voltage ±10%. If a computer has a rated input voltage of 100 volts, the power voltage shall be within the range of 100 volts ±10%

3 The power supply frequency shall be the rated frequency

4 The measurement shall be made using a system configuration which retains a maximum of basic computer functions while the I/O control unit, communication control unit, magnetic disk drive unit and other removable units disconnected from the computer. However, if the computer is of a type that allows more processors to be installed, the measurement shall be performed using the number of processors required for a minimum configuration.

HDDs (Hard Disk Drives)

Top runner does also have energy consumption efficiency targets and measuring methods for HDD divided in several classes, due to disk size and number of discs.

Comparison of criteria for Desktops within different eco-labelling systems

This information is just an overview and is not complete. For the detailed information please consult the criteria documents (available at the websites of the different eco-labels).

The comparison is made between:

- TCO'05 Desktops, Version 1.0 2005-06-29 www.tcodevelopment.com. International labelling
- Swan labelling of Personal computers, Version 4.1 June 2005 – 18 June 2008 www.svanen.nu. Nordic labelling
- Blue Angel. *Computers RAL-UZ-78* Effective 2006. www.blauer-engel.de. German labelling
- EU-flower. Ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to personal computers (2005/341/EC),
  11 April 2005 www.eco-label.com. European labelling
- Energy Star. Computer Memorandum of Understanding (Version 3.0). Effective in 1999.

Table 11 Comparison of the labelling criteria for desktops.

Criteria for Desktops	TCO'05	The Swan	Blue angel	EU-flower
Visual Ergonomics	X			
Work load ergonomics	X			
Electromagnetic Emissions	X	X[1]	X[1]	X[1]
Acoustic Noise	X	X	X	X
Energy [2]	X	X	X	X
Ecology	X	X	X	X

[1] The requirements in TCO'05 are stricter.

[2] See separate comparison.

Table 12 Comparison of the labelling criteria for desktops.

Criteria for Desktops	**TCO'05**	**The Swan**	**Blue angel**	**EU-flower**
Ecology				
Environmental Responsibility				
Company's environmental responsibility	X	X		
Environmental hazards				
Mercury, cadmium, and lead	X	X	X	X
Flame retardants	X	X	X	X
Chlorinated plastics	X	X	X	
Preparation for Recycling				
Material coding of plastics	X	X	X	X
Variety of plastics	X	X	X	X
Metallization of plastics	X	X	X	X
Material recovery of plastics and metals		X	X	X
Design for recycling - Mercury lamps	X	X	X	X
Easy to dismantle		X	X	X
Recycling information for customers	X	X	X	X
Guarantee and spare parts				
Guarantee		X	X	
Supply of spare parts		X	X	
Upgradebility/performance expansion		X	X	X
Packaging				
Requirements regarding packaging materials			X	X

Table 13 Comparison of the eco-labelling criteria for desktops.

Energy criteria for Desktops	**The Swan** Jun 2005	**EU-Flower** April 2005	**TCO´05** Jul 2005	**GEEA*** 2006 ?	**Blue Angel** 2006	**Energy Star** 2007 (1999)
Sleep	4W	4W	5W	5W	4,5W	4.0 W (15-35*)
Off	2W	2W	2W	2W	2,5W	2.0 W
On idle	-	-	-	70 W	-	50-95
Labelled products	20	-	- (16 TCO´99)	? latest update 2002	60	(288)

Comparison of criteria for Notebooks within different eco-labelling systems

This information is just an overview and is not complete. For the detailed information please consult the criteria documents (available at the websites of the different eco-labels).

The comparison is made between:

- TCO'05 Notebooks, Version 2.0 2005-09-21 www.tcodevelopment.com. International labelling
- Swan labelling of Personal computers, Version 4.1 June 2005 – 18 June 2008 www.svanen.nu. Nordic labelling
- Blue Angel. *Computers RAL-UZ-78* Effective 2006. www.blauer-engel.de. German labelling
- EU-flower. Ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to portable computers (2005/343/EC), 11 April 2005 www.eco-label.com. European labelling.

Table 14 Comparison of labelling criteria for notebooks.

Criteria for Notebooks	TCO’05	The Swan	Blue angel	EU-flower
Visual Ergonomics	X	X[1]	X[1]	
Work load ergonomics	X			
Electromagnetic Emissions	X	X[1]	X[1]	X[1]
Acoustic Noise	X	X	X	X
Energy [2]	X	X	X	X
Ecology	X	X	X	X

[1] The requirements in TCO’05 are stricter.

[2] See separate comparison.

Table 15 Comparison of labelling criteria for notebooks.

Criteria for Notebooks	TCO’05	The Swan	Blue angel	EU-flower
Ecology				
Environmental Responsibility				
Company’s environmental responsibility	X	X		
Environmental hazards				
Mercury, cadmium, and lead	X	X	X	X
Flame retardants	X	X	X	X
Chlorinated plastics	X	X	X	
Preparation for Recycling				
Material coding of plastics	X	X	X	X
Variety of plastics	X	X	X	X
Material recovery of plastics and metals		X	X	X
Mercury lamps	X	X	X	X
Easy to dismantle		X	X	X
Recycling information for customers	X	X	X	X
Guarantee and spare parts				
Guarantee		X	X	
Supply of spare parts		X	X	
Upgradebility/performance expansion		X	X	X
Packaging				
Requirements regarding packaging materials			X	X

Table 16 Comparison of energy criteria for notebooks.

Energy Criteria for Laptops	**The Swan** Jun 2005	**EU-flower** Apr 2005	**TCO`05** Jul 2005	**GEEA** 2006?	**Blue Angel** 2006
Sleep	3W	3W	4W	5W	3,5W
Off	2W	2W	2W	2W	2W
Power supply	0.75W	0.75W	-	-	-
Labelled products	-	-	- (4 TCO´99)	-	-

Comparison of criteria for Monitors within different eco-labelling systems

This information is just an overview and is not complete. For the detailed information please consult the criteria documents (available at the websites of the different eco-labels).

The comparison is made between:

- TCO'03 Displays FPD/CRT, Version 3.0 2005-10-19 www.tcodevelopment.com. International labelling
- Swan labelling of Personal computers, Version 4.1 10 June 2005 – 18 June 2008 www.svanen.nu. Nordic labelling
- Blue Angel. *Computers RAL-UZ-78* Effective 2006. www.blauer-engel.de. German labelling
- EU-flower. Ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to personal computers (2005/341/EC), 11 April 2005 www.eco-label.com. European labelling.

Table 17 Comparison of labelling criteria for Monitors.

Criteria for Monitors	**TCO'03**	**The Swan**	**Blue angel**	**EU-flower**
Visual Ergonomics	X	X[1]	X[1]	
Work load ergonomics	X			
Emissions	X	X[1]	X[1]	X[1]
Energy [2]	X	X	X	X
Ecology	X	X	X	X

[1] The requirements in TCO'03 are stricter.

[2] See separate comparison.

Table 18 Comparison of labelling criteria for Monitors.

Criteria for Monitors	TCO'03	The Swan	Blue angel	EU-flower
Ecology				
Environmental Responsibility				
Company's environmental responsibility	X	X		
Environmental hazards				
Mercury, cadmium, and lead	X	X	X	X
Flame retardants	X	X	X	X
Chlorinated plastics	X	X	X	
Preparation for Recycling				
Material coding of plastics	X	X	X	X
Variety of plastics	X	X	X	X
Metallization of plastics	X	X	X	X
Material recovery of plastics and metals		X	X	X
Design for recycling - Mercury lamps	X	X	X	X
Easy to dismantle		X	X	X
Recycling information for customers	X	X	X	X
Guarantee and spare parts				
Guarantee		X	X	
Supply of spare parts		X	X	
Packaging				
Requirements regarding packaging materials			X	X

Table 19 Comparison of labelling energy criteria for Monitors.

Energy criteria for Monitors	**Energy Star** Jan 2006	**GEEA** 2006	**TCO´03** Jan 2006	**The Swan** Jun 2005	**EU-flower** Apr 2005	**Blue Angel** 2006
Sleep	2W	* With USB 2.3 W	*	*	*	*
Off	1W	*	*	*	*	*
Active mode	(1)	*	*	*	*	*
Labelled products	464	?	717 (3000 TCO´99)	5	-	3

(1) X < 1 megapixel, then Y = 23; if X > 1 megapixel, then Y = 28X. Y is expressed in watts and rounded up to the nearest whole number and X is the number of megapixels in decimal form
X= Mega pixels
Y= Allowed power consumption

** Same requirement as Energy Star*

1.7.2 Type II Self-declaration

ECMA 370 THE ECO DECLARATION-TED
www.ecma-international.org

A self declaration which is a harmonisation between The Ecma Technical Report TR/70 and IT-Ecodeclaration which was launched in 1996 by IT-företagen in Sweden. It is a self declaration to be used when selling products to environmentally aware customers. There are two parts in the declaration:

The Company environmental profile covers

- Recycling system participations
- Environmental policy and environmental management systems

Environmental product attributes covers

- Hazardous substances
- Batteries
- Safety and EMC
- Consumable materials
- Packaging materials
- Treatment information

- Environmental conscious design (such as disassembly, recycling, product life time)
- Energy consumption
- Emissions
- Ergonomics
- Documentation
- **Note:** ECMA do also have a working group working on computer performance and energy consumption in order to make a standard on energy efficiency, perhaps for use within the EuP. It might become important to the outcome of the EuP regulations for products within the scope of this study. But the ECMA working group have recently started, and aim at finishing their work late 2007, and their results will therefore not be a part of this preparatory study**.** [ECMA 2006].

The IT-Ecodeclaration

www.itecodeclaration.org

Since the harmonisation with ECMA there is a possibility for manufacturers to have their eco-declaration (ECMA 370) verified by IT-Företagen.

EPEAT

www.epeat.net

EPEAT, the “Electronic Product Environmental Assessment Tool,” is a procurement tool designed to help institutional purchasers in the public and private sectors in the USA to evaluate, compare and select desktop computers, laptops and monitors based on their environmental attributes. The system will be available to manufacturers for registering their products in late May of 2006, and the product registry will be viewable and searchable by purchasers in June of 2006.

EPEAT is a system in which manufacturers declare their products’ conformance to a comprehensive set of environmental criteria in eight environmental performance categories:

- Reduction/Elimination of Environmentally Sensitive Materials
- Material Selection
- Design for End of Life
- Product Longevity/ Life Cycle Extension
- Energy Conservation
- End of Life Management
- Corporate Performance
- Packaging

EPEAT evaluates electronic products according to three tiers of environmental performance – Bronze, Silver and Gold. To achieve the bronze level, the product shall conform to all of the 23 required environmental criteria in IEEE 1680 (Standard for Environmental Assessment of Personal Computer Products, Including Laptop Personal Computers, Desktop Personal Computers, and Personal Computer Monitors). To achieve the silver level, the product shall conform to all of the required criteria plus at least 50% of the 28 optional criteria, and to achieve the gold level the product shall conform to all the required criteria and at least 75% of the optional criteria.

1.7.3 Type III declarations

The EPD®system

www.environdec.com

An environmental product declaration, EPD, is defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards on life cycle assessment, but not excluding additional environmental information". The EPD® system is a programme for Type III environmental declarations with an international applicability. EPDs, which are always based on a life cycle assessment, are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication is not precluded.

The EPD®system is operated by an independent so-called programme operator, the Swedish Environmental Management Council, SEMC. SEMC is responsible for providing general guidelines which describe the overall aim, methodological structure and elements of the EPD®system.

The EPD®system is one of other available EPD programmes, however being the only programme at present aiming at an international applicability.

There is today one make of LCD-modules but no personal computer with an EPD registered in the EPD®system.

1.7.4 Test standards and voluntary agreements and this study

There are several voluntary initiatives working on improvement of the environmental performance of the products within the scope of this study. Some of them are of more importance than others. For this study, the most important voluntary initiatives are Energy Star (for Computers and Monitors) and the TCO labelling schemes (for Monitors), since they are most widely used, and also since they are regularly updated with more tight requirements to keep stimulating improved environmental performance.

The results of energy consumption measurements are totally dependent on how the different testing standards have chosen to set up the unit under test, especially in the Active/Idle mode. It is therefore often very difficult to compare results from tests being performed according to different testing standards. Regarding test standards within this study, the ones used by most of the labelling schemes and initiatives for computers and monitors will be used. Energy consumption will be assessed in off, sleep and on (idle) modes according to the coming *ENERGY STAR Computer Test Method (Version 4.0), effective July 19, 2007* for computers and the *ENERGY STAR Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1)* for monitors. *ISO 7779* will be used for noise.

1.8 Existing legislation

The main objective with describing the existing legislation is to guarantee that suggestions and proposed activities follow the existing legislation. Since the legal documents are often very large, attempts to summarize the most important parts of them are made here. To get the full details, please look into the full documents.

1.8.1 Legislation and Agreements at EU-Level

***WEEE Directive for Waste of Electric and Electronic Equipment* 2002/96/EEC (february 2003)**

http://ec.europa.eu/environment/waste/weee_index.htm

An important conclusion from the 30 May workshop was that declarations prepared for complying with the WEEE-directive are very suitable as bill of materials. In other words, it will be relatively easy for industry to supply the LCA data needed thanks to WEEE.

Product design

Member States shall encourage the design and production of electrical and electronic equipment which take into account and facilitate dismantling and recovery, in particular the reuse and recycling of WEEE, their components and materials. In this context, Member States shall take appropriate measures so that producers do not prevent, through specific design features or manufacturing processes, WEEE from being reused, unless such specific design features or manufacturing processes present overriding advantages, for example, with regard to the protection of the environment and/or safety requirements.

Separate collection

1 Member States shall adopt appropriate measures in order to minimise the disposal of WEEE as unsorted municipal waste and to achieve a high level of separate collection of WEEE

2 For WEEE from private households, Member States shall ensure that by the 13 August 2005:

(a) systems are set up allowing final holders and distributors to return such waste at least free of charge. Member States shall ensure the availability and accessibility of the necessary collection facilities, taking into account in particular the population density;

(b) when supplying a new product, distributors shall be responsible for ensuring that such waste can be returned to the distributor at least free of charge on a one-to-one basis as long as the equipment is of equivalent type and has fulfilled the same functions as the supplied equipment. Member States may depart from this provision provided they ensure that returning the WEEE is not thereby made more difficult for the final holder and provided that these systems remain free of charge for the final holder. Member States making use of this provision shall inform the Commission thereof;

(c) without prejudice to the provisions of (a) and (b), producers are allowed to set up and operate individual and/or collective take-back systems for WEEE from private households provided that these are in line with the objectives of this Directive;

(d) having regard to national and Community health and safety standards, WEEE that presents a health and safety risk to personnel because of contamination may be refused for return under (a) and (b). Member States shall make specific arrangements for such WEEE.

Implementation of WEEE

The implementation of WEEE directive in the member states is ongoing.

RoHs Restriction of Hazardous substances

The RoHs directive, 2002/95/EC, dictates that Member States shall ensure that, from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE). National measures restricting or prohibiting the use of these substances in electrical and electronic equipment which were adopted in line with Community legislation before the adoption of this Directive may be maintained until 1 July 2006.

EMC

The EMC directive, 89/336/EEC (to be replaced by 2004/108/EC) set restrictions on the emission of electromagnetic radiation and on the immunity against electromagnetic radiation for electronic products. Countries outside the EU have similar regulations although the detailed requirements differ. In some countries there are, for instance, no restrictions on immunity.

In addition to the general EMC directive more detailed standards exists for certain products such as computers.

From the perspective of this study the EMC directive is not critical.

1.8.2 Legislation at Member State level

Since legislation at member state level follow the European directives, there appears to be no other particular legislation at member state with relevance for this study. As an example, the Swedish legislation is described below. The main differences between the European countries are the time schedules for implementing the European directives.

In Sweden *Förordning om förbud mm i vissa fall i samband med hantering, införsel och utförsel av kemiska produkter*, SFS 1998:944, contains the restrictions from the RoHS directive for use of cadmium, mercury, lead, chromium and some other chemicals in electric and electronic products. The WEEE directive is mainly implemented in *Förordningen om producentansvar för elektriska och elektroniska produkter*, SFS 2005:209. While SFS 1998:944 and SFS 2005:209, concerns the computer manufacturer, *Avfallsförordning*, SFS 2001:1063, stipulates that the computer user should separate computer waste from the normal waste stream.

Miljöbalken, the environmental framework law in Sweden, stipulates in the 5th general principle about Housekeeping and materials circulation that everybody should "5 §. Economize with resources and energy and use renewable energy as a first priority." This principle has however not yet been tried in the context of manufacturing and use of personal computers.

In short, Sweden has implemented the RoHs and WEEE directives and has, in practice, no separate national restrictions regarding the manufacturing and use of computers.

1.8.3 Third Country Legislation

The European legislation WEEE and RoHs is spreading to countries outside the EU. In most cases the national legislation is similar to the European, but there are some differences. The most important ones are described below.

China

The Chineese RoHs, called "Administrative Measures on the Control of Pollution Caused by Electronic Information Products" will start to take effect from the 1st January 2007. It is very similar to EU RoHs regarding substances. The difference is that all products have to be tested in an authorised laboratory before they can be sold in China. The legislation is not covering export from China.

California

California follows RoHs strictly. An exemption must be decided by EU, which the industry find difficult. It also sets targets for recyclability and improvement targets for recycling.

Korea

Korea follows RoHs and WEEE, with the difference that the Korean law covers both electronics and automotives in the same legislation.

1.8.4 Existing legislation and this study

The most important legislations according to our analysis are the RoHS and the WEEE directives. One important reason is that there might be conflicts between energy consumption and chemical content and/or end-of-life treatment. The VHK-methodology also prescribes a “past WEEE and RoHs-situation” for the calculations in the study. Other legislation might have an impact on this study regarding options for improvement. It is essential that the suggestions either follows the existing legislation, or point out which changes in legislation might be needed to reach the improvements suggested.

1.9 References

- MEEUP Methodology Report. Final Report. Methodology Study Eco-design of Energy-using Products. 28.11.2005. VHK for European Commission.Available at http://www.vhk.nl/
- INVITATION TO TENDER No. TREN/D1/40-2005
- ENERGY STAR® Program Requirements for Computers DRAFT 3. Version 4.0
- ENERGY STAR® Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1)
- EPIC-ICT (2006) Development of Environmental Performance Indicators for ICT Products on the example of Personal Computers. Draft January 2006. "Data needs and data collection, Generic Modules, Environmental impacts, Impact assessment and weighting, Environmental interpretation and evaluation"
- Fujitsu FMV Lifebook. Product Environmental Aspects Declaration. Ecoleaf 2003. http://www.jemai.or.jp/english/ecoleaf/
- Atlantic Consulting and IPU. LCA Study (Version 1.2), EU Ecolables for Personal Computers, March 1998.
- Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. May 2006 Technical Report EUR 22284 EN
- WEEE Directive for Waste of Electric and Electronic Equipment 2002/96/EEC (february 2003)
- RoHs Restriction of Hazardous substances 2002/95/EC
- Telephone call with Silvio Weeren ECMA September 2006
- *IVF industrial survey (2006)*
  Several stakeholders did answer the questionnaire from IVF during the summer 2006. Due to secrecy agreements, they are not named here, but they do cover the main players for both computers and monitors, and also covering companies from Europe, The USA and Asia. The number of respondents to the questionnaire was 16.

2 Economic and market analysis

Introduction

The objective of this part of the study and the report is to make an economic and market analysis to use within the subsequent tasks of this study. The methodology developed by VHK for the European Commission (MEEUP 2005) is followed. A large corpus of information has been collected. The most important parts of it are described in this report.

The main sources for information have been Eurostat, EITO and the stakeholder survey performed during 2006.

2.1 Generic Economic Data

2.1.1 Task and Procedure

To determine the volumes and values of the product categories " personal computers and monitors" within the total of EU industry and trade policy, the following generic economic data will be researched:

- EU-production
- Extra-EU trade
- Intra-EU trade
- Apparent consumption.

To present some indication of the installed base of equipment, indicative data on medium expected lifetime for the different types of equipment covered in the report are taken from the answers from industry, supplied in the survey[2006].

To make the data coherent with official EU data, the statistical information is derived from Eurostat, the official statistical office of EU.

Since the data from Eurostat has some limitations we will include, later in the report, trade-data given by the industry, as a comparison.

The most appropriate dataset in Eurostat, for our purposes, is the dataset PRODCOM, which gives production and trade data for a very large number of product-groups (more than 7000).

The following PRODCOM codes are applicable to the investigated product groups.

Table 20 PRODCOM classification applicable to PC, Laptops and Desktops

PRODCOM-Code	Code Description
30021200	Laptop PCs and palm-top organisers
30021300	Desk top PCs
30021400	Digital data processing mach//systems
32302045	Colour video monitors wit//de-ray tube
32302049	Flat panel video monitor//de-ray tube)
32302083	Black and white or other monochrome monitors

Apart from PRODCOM, Eurostat also provides a dataset on EU-25 trade statistics, (Comext). This dataset, which does not contain any production data but purely trade data, is based on CN codes (Combined Nomenclature). The relations between PRODCOM codes and CN codes for relevant equipment are presented below in Table 21. The use of CN codes for computers and monitors is highly complicated due to the fact that there have been numerous changes in the CN coding scheme during the years of interest. The table below shows these changes to the best of our ability.

Table 21 PRODCOM classifications and corresponding CN-codes applicable to PC, Laptops and Desktops

PRODCOM-Code	Code Description	Corresponding CN-code	Code Description	From	To
30021200	Laptop PCs and palm	84713000		01/01/1996	31/12/1997
30021200	Laptop PCs and palm	84713010	Laptop computers, notebooks whether or not incorporating multi media kit	01/01/1998	31/12/1999
30021200	Laptop PCs and palm	84713091	84713090 Other, portable digital automatic data processing machines, weighing not more than 10 kg Other digital automatic data processing machines, comprising in the same housing at least a central processing unit, a keyboard and a display.	01/01/1998	31/12/1999
30021200	Laptop PCs and palm	84713099		01/01/1998	31/12/1999
30021200	Laptop PCs and palm	84713000		01/01/2000	31/12/2005
30021300	Desk top PCs	84714110	Other digital automatic data processing machines, comprising in the same housing at least a central processing unit, a keyboard and a display (main frame)	01/01/1996	31/12/2005
30021300	Desk top PCs	84714130		01/01/1998	31/12/1999
30021300	Desk top PCs	84714190	Other digital authomatic data processing machines (other than main frame)	01/01/1996	31/12/1997
30021300	Desk top PCs	84714190		01/01/2000	31/12/2005
30021300	Desk top PCs	84714191		01/01/1998	31/12/1999
30021300	Desk top PCs	84714199		01/01/1998	31/12/1999
30021400	Digital automatic data processing machines presented in the form of systems	84714910	Other digital automatic data processing machines, presented in the form of systems, Pcs (personal computers) whether or not incorporating multi media kits	01/01/1996	31/12/2005
30021400	Digital automatic data processing machines presented in the form of systems	84714930		01/01/1998	31/12/1999
30021400	Digital automatic data processing machines presented in the form of systems	84714990	Other digital automatic data processing machines, presented in the form of systems	01/01/1996	31/12/1997
30021400	Digital automatic data processing machines presented in the form of systems	84714990		01/01/2000	31/12/2005
30021400	Digital automatic data processing machines presented in the form of systems	84714991		01/01/1998	31/12/1999
30021400	Digital automatic data processing machines presented in the form of systems	84714999		01/01/1998	31/12/1999
32302045	Colour video monitors with cathode-ray tube	85281031		01/01/1993	31/12/1995
32302045	Colour video monitors with cathode	85281041		01/01/1993	31/12/1995
32302045	Colour video monitors with cathode	85281043		01/01/1993	31/12/1995
32302049	Flat panel video monitor, LCD or plasma, etc., without tuner (colour video monitors) (excl. with cathode-ray tube)	85281049		01/01/1993	31/12/1995
32302083	Black and white or other monochrome video monitors	85282020		01/01/1993	31/12/1995

Since both the PRODCOM codes and the CN-coding scheme have evolved over time, neither of the datasets are distinctive and clear enough to provide ideal data for this investigation. Apart from changes in coding over the years, the product definitions are in several cases dubious in the sense that it is not clear what parts of equipment are included. This can later be seen especially in the case of Desktops, where it is not clearly stated whether a monitor is included or not, and if it is included, it is not indicated what type of monitor.

The quality of data seems to be very dependant on the distinctness of the coding, as can be seen later in the report. The data on Laptops, which is probably the most distinct code, seem to be much more “reliable” (no disruptive changes) as compared to the data on Desktops, for which the definition is less obvious. On the other hand, the code for laptops also includes palmtops, which are to be left out of the study, thus making the data from Eurostat quite inappropriate for the study. This has been solved by using data from other sources, EITO and answers from an industry survey, to compile a more correct picture of the sales figures on laptops.

2.1.2 Results

2.1.2.1 Production of Desktops, laptops and monitors in EU-25

The following Tables, 22 and 23 contain the data provided by PRODCOM for domestic production in 2004. The data have lots of empty spaces, which are either due to data not reported by the country or, due to confidentiality reasons. When data are incomplete, Eurostat does not publish an EU summery.

The Eurostat reasons for missing data are explained in Williams [2003] by the following paragraphs:

Availability of data

There are two reasons why expected data might not be found in Europroms:

The data is confidential. If only a small number of enterprises produce a product in the reporting country, there is a risk that information regarding an individual enterprise might be revealed. If the enterprise does not agree to this the reporting country declares the production figures confidential. They are transmitted to Eurostat but not published.

However if several countries declare their production for a heading to be confidential, an EU total can be published because the data for an individual country cannot be inferred.

The data is missing. There are a number of reasons why data might be missing: the reporting country does not survey the heading; the reporting country has reason to doubt the accuracy of the data and suppresses it; or the reporting country uses the wrong volume unit or the wrong production type, which means that the data is not comparable with other countries and is suppressed by Eurostat.

If data is missing for one or more Member States the corresponding EU total cannot be calculated and is also marked as missing.

Europroms stands for the combined data from PRODCOM and Comext, published in PRODCOM. In the continued text, PRODCOM will be stated as the source also for Europroms.

In the tables produced by PRODCOM, countries negotiating for EU membership are also included. Their values are not included in the EU25 totals.

Table 22 Personal computers EU25, domestic production in 2004 (PRODCOM statistics)

2004	Laptop PCs and palm-top organisers		Desktop PCs		Digital data processing systems	
	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE
	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)
France	407	392			47	
Netherlands					10	52
Germany	3332	2642	627	383	2517	1497
Italy	36	37	66	104	12	14
United Kingdom	104	135		174	665	536
Ireland						
Denmark	0	0	2	2	3	8
Greece						
Portugal			99	63		
Spain	94	99	48	30	257	140
Belgium			98	46		
Luxemburg						
Iceland						
Norway						
Sweden					25	44
Finland	0	1	40	45	2	2
Austria	262	221				
Malta						
Estonia			61	28		
Latvia			7	3		
Lituania			37	24		
Poland	67	37	176	42		
Czech Republic						
Slovakia						
Hungary					3436	1031
Romania			72	35		0
Bulgaria				3	1	1
Slovenia			25	13		0
Croatia			25	10	3	12
Cyprus						
EU15TOTALS						
EU25TOTALS				2112	13143	9593

Table 23 Monitors EU25, domestic production in 2004 (PRODCOM statistics)

2004	Colour video monitors cathode-ray tube		Flat panel video monitor		Black and white or other monochrome monitors	
	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE
	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)
France						
Netherlands						
Germany						5
Italy	1299	121	2	4	289	45
United Kingdom		20				
Ireland						
Denmark		0			3	1
Greece						
Portugal						
Spain	8	4				
Belgium						
Luxemburg						
Iceland						
Norway						
Sweden						
Finland						
Austria						
Malta						
Estonia						
Latvia						
Lituania						
Poland						
Czech Republic						
Slovakia						
Hungary						
Romania						
Bulgaria						
Slovenia						
Croatia						
Cyprus						
EU15TOTALS					468	
EU25TOTALS			36		468	

During summer 2006, PRODCOM data for 2005 were published and it was decided to include these tables too. The reliability of data seems not to have improved, since there are many empty spaces due to countries not reporting and due to the limitations mentioned earlier. For reasons not explained in Eurostat, Ireland is not yet present in the production statistics of 2005 (September 2006), neither is data for the United Kingdom.

Table 24 Personal computers EU25, domestic production in 2005 (PRODCOM statistics)

	Laptop PCs and palm-top organisers		Desktop PCs		Digital data processing mach//systems	
	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE
	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)
France	70	39	251	168	20	732
Netherlands						85
Germany	6192	4334	736	388	3125	1551
Italy	32	25	45	54	6	8
Denmark	0	0	2	4	3	7
Greece						
Portugal			82	51		
Spain	105	90	59	32	384	135
Belgium			55	45		
Luxemburg						
Iceland						
Norway						
Sweden					34	55
Finland	3	2	23	26	1	1
Austria	141	101				
Malta						
Estonia	3	3	68	27		
Latvia			4	2		
Lituania	0	0	34	16		
Poland	142	91	242	78	5	
Czech Republic						
Slovakia						
Hungary					3338	1253
Romania			98	48	0	1
Bulgaria	0	0	22	3	1	1
Slovenia			18	10		
Croatia			42	15	5	19
Cyprus						
EU15TOTALS						
EU25TOTALS			2732		14285	8838

Table 25 Monitors EU25, domestic production in 2005 (PRODCOM statistics)

2005	Colour video monitors cathode-ray tube		Flat panel video monitor		Black and white or other monochrome monitors	
	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE
	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)	(1000 Units)	(M EURO)
France						
Netherlands						
Germany			67			5
Italy	1210	110	2	2	222	38
Denmark		0			4	1
Greece						
Portugal						
Spain	8	4				
Belgium						
Luxemburg						
Iceland						
Norway						
Sweden						
Finland						
Austria						
Malta						
Estonia						
Latvia						
Lituania			0	0		
Poland						
Czech Republic						
Slovakia						
Hungary						
Romania						
Bulgaria						
Slovenia						
Croatia						
Cyprus						
EU15TOTALS					437	
EU25TOTALS	1341	154	361	190	437	

To be able to show more realistic production data, the project team applied to Eurostat to have the restrictions on confidential data lifted for the purpose of this assignment, but the request was denied. According to Williams [2003], the confidentiality policy is explained the following way:

Confidentiality in PRODCOM

Some national PRODCOM data and EU aggregates are confidential. Confidential data is suppressed and is only available for the PRODCOM staff or researchers or other officials associated with PRODCOM according to the Eurostat Rules of protection of confidential data.

Important producers like Ireland are because of these restrictions totally misrepresented in the statistics.

Later in the report, data on production taken from other sources will be introduced. Data, which are considered more correct than the production data from PRODCOM, due to less restrictions from competition issues.

2.1.2.2 Computers and monitors total EU trade (import and export)

The data on trade published in PRODCOM are derived from the database COMEXT, and are much more complete than data on production. The confidentiality issues may affect some of the national figures, according to Williams[2003], but all relevant data are included in the EU totals. For the investigation the data from COMEXT were also compiled and found to be an exact match to the data from PRODCOM. The data from PRODCOM have been chosen, to avoid the issue of changing coding-schemes in COMEXT between different years in the presentation.

Table 26 EU-25 Total trade (import-export) (PRODCOM data)

		VOLUMES (1000 UNITS)		Value (M Euro)	
Product	**PERIOD**	**EXPORTS**	**IMPORTS**	**EXPORTS**	**IMPORTS**
Laptop PCs and palm-top organisers	**2003**	1605	11401	1284	7201
	2004	2118	14413	1378	9176
	2005	3704	21325	2271	11499
Desk top PCs	**2003**	1084	2255	574	820
	2004	1995	3373	730	823
	2005	2125	4181	957	657
Digital data processing mach//systems	**2003**	1922	6066	1477	1490
	2004	3516	5578	1406	1004
	2005	3382	2405	1215	955
Colour video monitors with cathode-ray tube	**2003**	135	151	33	46
	2004	93	197	39	53
	2005	95	204	24	55
Flat panel video monitor	**2003**	242	1157	79	420
	2004	427	1718	146	652
	2005	477	5602	214	1550
Black and white or other monochrome monitors	**2003**	44	809	13	35
	2004	154	794	10	33
	2005	108	1002	18	34

The figures above show that EU is a large net importer of Laptops, a ratio of import seven times higher than export. The locations for production outside EU are not investigated in detail. Through the survey to the producers it was obvious that relocations by the multinationals to South East Asian production sites is an ongoing move. It will later be covered in more detail.

For Desktop PCs and systems, the figures are much more in balance: imports are about twice the export. Especially for systems, EU seems to have a higher added value, since the value of export and import is almost equal while the number of imported units is twice the exported units.

For monitors, EU is a growing net importer of the more modern flat panel monitors, in 2003 the relation import/export was 4 to 1, but had grown to more than 10 to 1 in 2005. It can also be noted that flat panel monitors represent a very large expansion in trade volume; the import has grown 5 times in 3 years, while the other products have had a much more moderate growth in volume.

2.1.2.3 Computers and monitors domestic trade (import and export)

In the following two tables the domestic trade data for EU-25 countries in 2004 are presented. The data say little about the net consumption in EU, since production cannot be deduced from the data, but they give information on for which countries computers and monitors are important export products.

The tables show that very few of the EU countries are net exporters of any type of computers. The only two net exporters of pure equipment are the Netherlands and Ireland. For systems, with a higher added value, the numbers are different with quite a number of net exporters, which is in line with the need for a knowledge-based industry in Europe.

(The data of Luxemburg seem to be very doubtful, probably a mistake between number of units and the value.)

For monitors, none of the EU-25 countries is a net exporter of any significance, and the huge imbalance between export and import of flat panel monitors can be noted here as well.

Table 27 Domestic trade of computers 2004 (PRODCOM data)

	Laptop PCs and palm-top organisers		Desktop PCs		Digital data processing mach//systems	
	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS
	1000 units		1000 units		1000 units	
France	510	3142	189	1645	1536	1792
Netherlands	9497	7230	747	550	1139	771
Germany	4567	6446	210	318	642	398
Italy	69	2309	114	938	37	396
United Kingdom	1183	6162	517	4106	589	796
Ireland	2420	3035	1744	382	309	34
Denmark	100	579	67	98	7	100
Greece	4	331	1	19	0	38
Portugal	20	315	17	23	3	22
Spain	187	1963	204	501	77	303
Belgium	642	1356	143	79	59	263
Luxemburg	3	3047	81	84829	8	15
Iceland	:	:	:	:	:	:
Norway	:	:	:	:	:	:
Sweden	234	771	30	83	120	125
Finland	107	433	6	23	12	41
Austria	91	474	91	121	92	140
Malta		8	0	1	1	2
Estonia	1	40	1	7	0	2
Latvia	4	33	0	7	0	43
Lithuania	35	90	11	20	2	9
Poland	7	536	13	333	4	35
Czech Republic	187	443	3079	398	2285	2097
Slovakia	13	76	6	135	1	7
Hungary	81	181	101	177	9	18
Romania	0	0	0	0	0	0
Bulgaria	0	49	3	24	5	47
Slovenia	2	62	2	15	84	9
Croatia	5	58	2	32	2	8
Cyprus	0	16	0	3	0	1
EU25TOTALS	3704	21325	2125	4181	3382	2405

Table 28 Domestic trade of monitors 2004 (PRODCOM data)

	Colour video monitors cathode-ray tube		Flat panel video monitor		Black and white or other monochrome monitors	
	EXPORTS	IMPORTS	EXPORTS	IMPORTS	EXPORTS	IMPORTS
	1000 units		1000 units		1000 units	
France	19	63	57	425	8	60
Netherlands	82	97	951	1775	49	45
Germany	38	56	186	468	46	157
Italy	28	22	157	919	113	610
United Kingdom	78	150	2379	2435	26	120
Ireland	1	3	41	59	0	1
Denmark	0	2	25	119	1	2
Greece	0	2	2	94	0	18
Portugal	10	2	30	80	6	22
Spain	4	30	149	607	38	81
Belgium	13	26	173	424	28	41
Luxemburg	0	1	1	7	0	1
Iceland	:	:	:	:	:	:
Norway	:	:	:	:	:	:
Sweden	9	4	31	127	0	13
Finland	1	2	7	30	1	3
Austria	3	6	11	31	1	5
Malta	0	1	0	2	18	1
Estonia	0	1	6	13	0	0
Latvia	0	2	4	17	0	2
Lithuania	0	1	3	3	0	1
Poland	0	4	12	92	0	8
Czech Republic	0	5	29	59		5
Slovakia	0	1	19	47	0	2
Hungary	0	4	5	19	0	2
Romania	0	1	0	5	0	1
Bulgaria	0	1	0	2	0	0
Slovenia	0	1	2	7	1	1
Croatia	1	4	1	7	0	3
Cyprus	0	0	0	1	0	1
EU25TOTALS	95	204	477	5602	108	1002

2.1.2.4 Apparent EU-consumption

Due to the unreliable data on production, the task of calculating the apparent consumption is quite difficult, introducing a high degree of uncertainty. The apparent consumption is to be calculated by taking "imports + production – export", and due to the misrepresentations in production data, quite a large number of countries are represented as having a negative consumption, which is of course unrealistic.

In the course of the task, a first try was made to plot all data of all countries, in order to find some patterns, which could help generating a complete picture. The intention was to find out if some specific figures were wrong for specific years, which could then be corrected. This proved not to be the case, no obvious patterns were found.

The next line of thought was to search for consumption of important computer parts, like CPUs in PRODCOM, and look for a statistical correlation between that consumption and the production of computers. The coding scheme proved not to be explicit enough, so no correlation could be found.

Instead other sources were contacted, to get what data were available. The first source of data was EITO (a European cooperation between the producers). Then the producers were asked to give as much information as possible on market figures in the industry survey [2006]. The producers were also asked to supply information on which data provider they would use for sales statistics. They all pointed to Gartner Group and IDC, which are commercial data providers, and far too costly to be relevant for this assignment.

Not to overburden the responders, the producers were only asked for data on EU-25 and on some of the larger countries. The subsequent answers did only provide figures of EU25.

Since both EITO and the producers, record sales data instead of data on import and export, for the countries and for EU as a total, the procedure for calculation of apparent consumption was changed, to be equal to the volume of sales. This has the advantage of reducing the impact of stock, which has to be taken into account when using the formula based on export, import and production.

In the survey was included a request for prognoses for quite a long horizon. EITO provides prognoses up to 2007, on Laptops and Desktops. The producers were quite restricted in answers on the future.

Tables 29-31 show the apparent consumption of the major countries as calculated on data from PRODCOM and EITO. This information was provided in the survey, to get comments from the respondents.

Table 29 Apparent consumption, Desktops, for major countries.
Data from PRODCOM (2000 – 2004), EITO (2005-2007)

YEAR	Ireland	Italy	France	Germany	Poland	Spain	UK
2000, desktop	-478.004	1.396.677	184.431	787.690	-	101.234	1.838.547
2001, desktop	-2.536.664	1.118.344	195.681	563.335	-	25.297	1.535.429
2002, desktop	-2.743.536	510.066	1.197.920	904.982	203.992	98.435	1099.408
2003, desktop	87.162	2.399.222	3.199.424	4.773.481	213.983	858.860	4.307.948
2004, desktop	114.792	2.490.392	3.436.181	4.673.238	428.079	893.214	4.566.424
2005, desktop	164.754	2.590.315	3.881.697	4.979.217	-	935.968	4.780.247
Prognoses							
2006, desktop	206.079	2.667.797	4.025.116	4.901.330	-	988.879	4.888.657
2007, desktop	241.811	2.765.386	4.093.822	4.755.861	-	1.004.970	4.915.409

Table 30 Apparent consumption, Laptops, for major countries.
Data from PRODCOM (2000 – 2004), EITO (2005-2007)

YEAR	Ireland	Italy	France	Germany	Poland	Spain	UK
2000, laptop	868.786	495.433	1.326.373	4.101.971	-	430.009	4.452.755
2001, laptop	549.841	568.088	1.124.608	3.412.759	-	383.801	1.439.322
2002, laptop	570.375	668.377	1.453.383	3.650.046	134.357	550.204	2.370.032
2003, laptop	87.162	1.119.686	1.454.485	2.523.278	172.269	575.320	1.987.743
2004, laptop	114.792	1.390.650	1.841.378	3.154.098	313.801	772.655	2.419.083
2005, laptop	164.754	1.844.044	2.474.567	3.832.705	-	999.558	3.075.689
Prognoses							
2006, laptop	206.079	2.216.222	2.916.323	4.451.002	-	1.166.091	3.584.735
2007, laptop	241.811	2.515.151	3.265.896	5.017.909	-	1.402.871	4.095.955

Table 31 Apparent consumption, data from PRODCOM (2000 – 2004), EITO (2005-2007), for major countries. Monitors

YEAR	Ireland	Italy	France	Germany	Poland	Spain	UK
2000, monitor	6.445	729.447	421.802	59.969	-	49.256	84.391
2001, monitor	11.965	1.003.271	520.782	88.171	-	35.957	42.923
2002, monitor	9.362	1.156.981	431.288	81.301	8.683	117.537	-3.102.706
2003, monitor	4.078	2.029.832	257.953	152.826	6.640	169.575	-1.163.988
2004, monitor	14.682	1.908.639	330.660	215.052	25.490	441.990	16.583
2005, monitor	-	-	-	-	-	-	-

The production and sales data part of the questionnaire was answered by a few of the suppliers. Not to show the exact numbers from each respondent, due confidentiality agreements, the mean values of the answers are provided as a value from the industry as a group. The deviations between the different answers were less than 5%, thus implicating that the mean value representats for the industry opinion well.

The respondents did choose to answer on EU-25, for all years, but with the indication that data from some of the former Russian countries are not included.

None of the respondents gave any answers on individual countries.

In Table 32, the mean value of the respondents` answers are presented in bold letters, while the figures in normal text represent the data calculated from official sources, PRODCOM and EITO.

Table 32 Apparent consumption of computers and monitors, survey answers compared to data from PRODCOM and EITO

	Year	Desktop		Year	Laptop		Year	Monitor
EU15	**2000, desktop**	*2.054.521*		**2000, laptop**	*5.938.319*		**2000, monitor**	*193.841*
	SURVEY	**24 100 000**		**SURVEY**	**6 100 000**		**SURVEY**	
EU15	**2001, desktop**	*1.270.287*		**2001, laptop**	*12.743.295*		**2001, monitor**	*1.097.577*
	SURVEY	**22 400 000**		**SURVEY**	**6 800 000**		**SURVEY**	
EU15	**2002, desktop**	*3.390.633*		**2002, laptop**	*11.586.060*		**2002, monitor**	*560.211*
	SURVEY	**21 700 000**		**SURVEY**	**8 000 000**		**SURVEY**	
EU25	**2003, desktop**	*19.739.653*		**2003, laptop**	*9.875.074*		**2003, monitor**	*2.403.206*
	SURVEY	**24 000 000**		**SURVEY**	**11 400 000**		**SURVEY**	
EU25	**2004, desktop**	*20.424.397*		**2004, laptop**	*12.231.536*		**2004, monitor**	*1.430.935*
	SURVEY	**26 200 000**		**SURVEY**	**15 000 000**		**SURVEY**	
EU25	**2005, desktop**	*21.898.231*		**2005, laptop**	*15.617.607*		**2005, monitor**	
	SURVEY	**28 500 000**		**SURVEY**	**19 900 000**		**SURVEY**	**37 800 000**
	Prognoses			**Prognoses**			**Prognoses**	
EU25	**2006, desktop**	*22.021.866*		**2006, laptop**	*18.135.846*		**2006, monitor**	
	SURVEY	**28 100 000**		**SURVEY**	**23 900 000**		**SURVEY**	
EU25	**2007, desktop**	*21.927.681*		**2007, laptop**	*20.507.445*		**2007, monitor**	
	SURVEY	**29 100 000**		**SURVEY**	**27 800 000**		**SURVEY**	
EU25	**2008, desktop**			**2008, laptop**			**2008, monitor**	
	SURVEY	**29 900 000**		**SURVEY**	**31 400 000**		**SURVEY**	
EU25	**2015, desktop**			**2015, laptop**			**2015, monitor**	
EU25	**2020, desktop**			**2020, laptop**			**2020, monitor**	

The table above shows that, there is a huge difference between the data found in open statistics (PRODCOM) and the data supplied by industry.

For Desktops, the error sources in official statistics have been identified (hidden data when few producers in one country) and we have choosen to trust the data from industry for the coming calculations.

For Laptops, the PRODCOM data are almost twice as high as the survey data for the years 2001 – 2002, while the data from the survey is much higher than PRODCOM for the following years. The reason for this is probably due to the fact that the code for Laptops in PRODCOM also includes Palmtops. The Laptop market has been growing four times since 2000, according to Industry, and we assume that the relation of market size between Laptops and Palmtops has changed, thus explaining the differences in numbers between the sources.

Looking into PRODCOM data when plotting graphically, Laptops/Palmtops seems to be better represented in the statistics (less Intra EU-production?) than Desktops. The figures show no disruptive changes, as is often the case for Desktops.

For Monitors, survey data are only available for 2005. The figure supplied is 35 times higher than the number extracted from statistics. The interpretation is that monitors are included in the Desktops in Eurostat data, thus giving the apparent consumption of Monitors to be the number of Desktops + the number of individually represented Monitors. There is very little indication of the type of monitors for the earlier years in the interval. For the later years we can deduce from trade volumes that Flat panel monitors are dominating (5/1) compared to the other types. The ratio is growing very fast, which gives the impression that maybe 85% of the 37 M monitors sold in 2005 are Flat panel.

The results from collecting data from the different sources have given the following approximation of apparent consumption:

Table 33 Approximation of apparent consumption in EU-25, calculated mainly from figures from the industry survey, 2000 - 2008

	Desktops	**Laptops**	**Cathode ray monitors**	**Flat panel monitors**
	(million)	(million)	(million)	(million)
2000	24	6	24	
2001	22	6,5	20	2
2002	22	8	17	5
2003	24	11	10	15
2004	26	15	6	20
2005	28	20	4	26
2006	28	23	2	32
2007	29	28		36
2008	30	31		38

The figures for monitors are very rough approximations, based on the assumptions that all Desktops included a monitor and that the type of monitor is approximately reflected by the distribution of different types of monitors in the trade data.

As can be seen from the data (prognosis), the consumption of Desktops is flattening out to what seems to be a stable level, while the market for Laptops is expanding. The market Desktops can be considered more or less as a pure replacement market.

The distribution of the market for office use and for home use is not presented in official statistics, Eurostat. The survey included questions on this, but only a few of the producers could answer, and then only on the distribution of their own sales.

A recent German study on power consumption labelling [Schlomann, 2005] has produced some information on the distribution between home use and office use of Desktops and Laptops in Germany. According to the study, 30% of the Desktops are in office use and 70% in home use. For Laptops the distribution is the opposite, 60% of Laptops are used in office and 40% at home. Later in this report, the same distribution will be assumed true for Europe as a whole and used to calculate the distribution of the installed base.

2.2 Market and stock data

2.2.1 Task and procedure

The market and stock analyses serve two purposes, first to give the rationale for the base cases which will be defined later on in the assignment, secondly to provide basic economic datasets for the assessments of environmental significance for computers.

In this section estimates of the following will be provided:

- Annual sales data of the different types of equipment covered by lot 3
- Actual stock data, or with a more appropriate term "The installed base"
- Average economic lifetimes of the products.

The data shall as far as possible give the situation in midterm horizon (past 2000) and forward (2010), as well as long term (2020), and references to the years 1990 and 1995 (Kyoto Protocol references).

Due to the unreliable quality of the official data on production, the significant data are supplied by the industry through the survey [2006].

For such a fast moving technology as computers, it is not possible to distinguish in statistics or other sources between equipment to any detail in performance. What was defined as a workstation 10 years ago could hardly be used for ordinary office purposes today. "Moore's law" is still valid, giving an astonishing development speed, making all definitions in performance terms “moving targets”.

The “moving definitions” Desktop and Laptop have therefore been used for the computers, since it is the level to which the products can be traced in the statistics. For monitors the three definitions which, can be found in Eurostat, Colour CRT, Monochrome and Flat panel monitors are used. The industry data from the survey[2006] contain very little information on monitors, thus forcing quite rough approximations to be made on the distribution of the different types. The final estimates have been reduced to approximations on CRT and Flatpanel.

For the forward looking information, the industry was asked for data and ideas on the developments in midterm horizon (2010), while other sources of “foresight character” have been used for the long term (2020) information.

2.2.2 Results

2.2.2.1 Calculation of installed base of computers and monitors

To calculate the approximate number of units in use, the average lifetime in use for the different equipments must be known. Especially for this type of equipment it must be noted that most computers are replaced, not because they are broken, but due to the fact that the performance is no longer valid. The prime driver for replacement is the software, both operating systems (OS) and application software. The specifications for new operating systems from Microsoft are very often above the performance of a large portion of the installed base.

In this situation, calculation of lifetime (economic) must be based on the producer’s experiences. Some producers have done customer surveys and some have data from take-back systems in some countries. Data on age of computers taken back are however not a very good measurement, since it has been found, that most of the equipment going to the “scrap-yard” has been lying unused for some years before thrown away.

To get some indication on lifetimes, the suppliers were asked for their opinions in the survey. The table below shows the average economic lifetime, calculated as mean values of the answers. The deviations were quite high; ranging from 3.5 years to 7 years for Desktop in home use, so the averages should only be taken as some indications. The “second life” of computer in a second hand market, is not included in the figures. There have been indications that 20% of the equipment goes to a second use, thus adding 2 to 3 years to their lifetime.

Table 34 Average economic lifetimes, opinions of the suppliers, for the first life.

Equipment	**Years**
desktop office	6,00
home	5,83
Laptop office	4,60
Laptop home	4,75
CRT	6,00
LCD	5,88
workstation	7,00

The deviation in the answers was quite high, especially on differences in lifetime for office use and for home use. Some of the respondents claimed that the lifetime was longer in office use, some the opposite. Because of the uncertainties the estimated lifetimes have been simplified to whole years, and assumed the same for office use and home use. The following table shows the lifetimes used for further calculations:

Table 35 Average economic lifetimes, for calculation of installed base.

Equipment	Average economic lifetime (years)
Desktop	6
Laptop	5
CRT	6
LCD	6

Integrating the data in Table 33 (apparent consumption), over the approximated lifetimes, the following very rough estimation of equipment in use is calculated (since the integration is to be made 6 years back, and there are no reliable data before 2000, the calculations are made from 2005 and forward). For laptops, the expected lifetime is shorter, thus making it possible to present an estimate also for 2004. For Flat panel-monitors, no sales were reported before 2001, thus allowing calculation of installed base from 2001 and forward.

Table 36 A very rough approximation over units in use in EU 25.

	Desktops	Laptops	CRT-monitors	Flat panel monitors
	(million)	(million)	(million)	(million)
2004		46,5		42
2005	146	60,5	81	68
2006	150	77	59	100
2007	157	97	42	134
2008	165	117	25	167

Applying the distribution home-office taken from [Schlomann, 2003], the following table over installed base in office and home is produced:

Table 37 Approximate installed base of computers and monitors, in office and in home use.

	Desktops		Laptops		CRT-monitors		Flat panel monitors	
	(million)		(million)		(million)		(million)	
	Office	Home	Office	Home	Office	Home	Office	Home
2004			28	18,5			13	29
2005	44	102	36,5	24	24	57	20,5	47,5
2006	45	105	46	31	18	41	30	70
2007	47	110	58	39	13	29	40	94
2008	49	116	70	47	7,7	17,5	50	117

For CRT-monitors and Flat panel- monitors, the distribution between office and home use has been assumed to be the same as the distribution for Desktops.

2.2.2.2 Estimations of market and installed base 2010

The survey did not give any estimation of sales volumes after 2008, but as will be shown later, no major changes of the format of computers are expected in that time frame.

[Schlomann, 2003] gives some estimates on predicted German installed base in 2015. For the office, the number of computers is expected to increase by 10%, the expansion completely by Laptops. For home use a German expansion of 40% is expected until 2015, with a focus on Laptops.

Comparing this with the estimates for Europe as a whole until 2008 given in the survey, the survey indicates a bigger expansion. This can be explained by the high computer maturity in Germany and other West European countries, compared to the new member states, thus giving room for a bigger expansion.

With the available information the best estimates for 2010 are probably calculated by extrapolating the trends in Table 37 for another two years, giving the following:

Table 38 Rough approximation of installed base of computers and monitors, 2009 – 2010.

	Desktops		Laptops		CRT-monitors		Flat panel monitors	
	(million)		(million)		(million)		(million)	
	Office	Home	Office	Home	Office	Home	Office	Home
2009	50	123	82	55	2	5	55	130
2010	51	130	94	63	1	1	60	140

The expansion rate of Flat panel-monitors has been reduced compared to the extrapolation, since the sales in the years preceding 2009 have consisted to a large part of replacements for old CRT-monitors. As indicated before, the major part of the expansion of the market is based on Laptops, while the Desktop market is a replacement market, except in the new member states.

2.2.2.3 Retrospect to 1995

For Kyoto references, relevant data for 1995 and 2000 are needed. The production data in Eurostat are very sparse, to such a level that it is not useful to present by nation. Laptops and flat panel monitors are not yet present in the statistics. Eurostat published data for the first time in 1995, thus not making any earlier data available, making it impossible to calculate the installed base.

In 1995, the computer was not yet a communication device to any large extent, Internet was breaking through, initiating a large expansion of the installed base.

Table 39 Production 1995, PRODCOM data.

1995	**Desktop PCs**		**Colour video monitors cathode-ray tube**	
	VOLUME (1000 units)	VALUE IN (M EURO)	VOLUME (1000 units)	VALUE IN (M EURO)
EU15TOTALS	1683	4560	64	38

Table 40 Extra EU trade 1995, PRODCOM data.

1995	Desktop PCs		Colour video monitors cathode-ray tube		Flat panel video monitor		Monochrome monitors	
	VOLUME (1000 units)	VALUE IN (M EURO)	VOLUME (1000 units)	VALUE IN (M EURO)	VOLUME (1000 units)	VALUE IN (M EURO)	VOLUME (1000 units)	VALUE IN (M EURO)
EU15-export	93077	2748	52	34	15	8	50	15
EU15-import	3857	2257	91	43	44	16	382	34

The quality of the data has obviously not yet been stabilized; the export volume is not in line with the value of the export. The best estimate possible from the figures supplied is that the market in EU15 was roughly 2 million Desktops in 1995.

2.2.2.4 Retrospect to 2000

In 2000, Eurostat was better established, giving more reliable data. Internet had made the breakthrough at least in office, thus generating a large expansion of the computer market.

Table 41 Production 2000, PRODCOM data.

2000	**Laptop PCs and palm-top organisers**		**Desktop PCs**		**Colour video monitors cathode-ray tube**		**Flat panel video monitor**	
	(1000 units)	(M EURO)	(1000 units)	(M EURO)	(1000 units)	(M EURO)	(1000 units)	(M EURO)
EU15TOTALS	6844	9311	7442	7398	736	155	10	36

Table 42 Extra EU15 trade 2000, PRODCOM data.

2000	**Laptop PCs and palm-top organisers**		**Desktop PCs**		**Digital data processing mach//systems**		**Colour video monitors cathode-ray tube**		**Flat panel video monitor**		**Monochrome monitors**	
	(1000)	(M EURO)	(1000)	(M EURO)	(1000)	(M EURO)	(1000)	(M EURO)	(1000)	(M EURO)	(1000)	(M EURO)
EU15-export	1234	1031	860	939	686	1092	59	38	59	26	57	15
EU15-import	7172	4924	2915	1009	830	939	182	76	120	75	729	46

According to the data from PRODCOM, the Desktop market was 9.6 M units, while the industry survey indicated a market of **24 M Desktops.** For Laptops, the data from PRODCOM include Palmtops, making the figures from the survey much more reliable, indicating a market of **6 M Laptops** for EU25.

The market data for monitors are obviously not yet reliable, and the survey did not give any information, thus generating the assumption that the market for **monitors** was roughly the same size as the market for Desktops, **24 M units.**

Calculations on the installed base in 2000 cannot be made on the existing data to any reasonable quality.

Comparing the data from 1995, 2000 and 2005 it can be noted that the external trade values (import + export) for Laptops have gone from 0 in 1995, to almost 14.000 M Euro in 2005. For Desktops, the trade values have gone from 5.005 M Euro to 1.614 M Euro in the same period. Apart from the very large expansion in sales volume on Laptops, a different production pattern may also explain the very large difference in the development; Desktops are often assembled close to the market thus not showing up in external trade.

Flat panel monitors have also evolved to a very large market in short time. In 1995 there was no noticeable trade and in 2005, the external trade represented a value of 1.760 M Euro.

2.3 Market trends

2.3.1 Consumer tests

2.3.1.1 Desktops and laptops

Stiftung Warentest is a German foundation that helps consumers by providing independent and objective tests of consumer products. In February 2006 they published a test of ten laptops and six Desktops where they tested the computers both within the group (Laptops/Desktops) and also between the two groups. The test is (as of 2006-10-12) available for purchase at. [Stiftung Warentest, 2006]

The tested laptops were:

- Benq Joybook R53 G16 (Best in test)
- Toshiba Satellite L20-120
- Acer Aspire 1652WLMi
- Samsung R50 WVM 1730
- Asus A6KM-Q002H
- Dell Inspiron 1300 Advanced
- Fujitsu Siemens Amilo A 1667 G
- Sony Vaio VGN-FS315M.G4
- Hewlett Packard Pavilion ze2356ea
- Maxdata NB ECO 4100IW DE

And the tested Desktops were:

- Dell Dimension 5150 Large (Best in test)
- Hewlett Packard Pavilion t3257.de (Best in test)
- Medion Multimedia PC Intel P4 640
- Acer Aspire E300
- Fujitsu Siemens Scaleo Pi
- Packard Bell iMedia 5191

When comparing Desktops vs. laptops they concluded that laptops have well enough computing capacity for "normal" use, and have the advantage of being portable. All computers tested, laptops and Desktops, were considered to be satisfying. On the other hand, if the user doesn't need the portability, a Desktop is a better choice by the following reasons:

- Desktops have better computing power, especially valid for heavy uses such as video editing or gaming
- Desktops have larger hard drives
- Desktops are better equipped, they have for example more USB ports, memory card readers

- Desktops are more flexible, it is possible to exchange and add components such as hard drives, graphic cards and so on
- Desktops have generally better ergonomics, it is easier to get good ergonomic working posture

The evaluations were based on the following criteria:

- Computing power (25% laptops, 40% Desktops)
  Using benchmark applications for office, multimedia and games
- Handling (20%)
  Evaluating documentation, recovery possibilities, day-to-day handling, laptop weight and Desktop build quality
- Screen (15% laptops)
  Evaluating the screen quality and external display possibilities
- Battery (15% laptops)
  Evaluating the battery operating time, battery drain warnings and the recharge times
- Versatility (10% laptops, 25 % Desktops)
  Evaluated the enclosed software and hardware and communication and expansion capabilities
- Environmental characteristics (15%)
  Evaluated the noise and power consumption in use, stand by and off mode

2.3.1.2 Monitors

Tom's Hardware Guide is a web site where they review and test hardware, mostly aimed for computer enthusiasts. They regularly test monitors, and in the end of March 2006 they compared eleven 19" LCD monitors.
The test is (as of 2006-10-12) available at [Tom´s Hardware]

The tested monitors are:

- BenQ FP91V+
- BenQ FP91V
- Hyundai Q90U
- NEC 1980FxiNEC 90GX2
- Samsung 960BF
- Samsung 970P
- Sony MFM-HT95
- ViewSonic VX922
- ViewSonic VP930
- Xerox Xa7-192i

All monitors share the same resolution of 1280*1024 pixels and have at least VGA and DVI connections while the specified contrast varies between 600:1 and 1000:1, the specified brightness varies between 250 and 450 nits and the specified response time varies between 2 and 18 ms.

The tested properties are design, ergonomics, connectivity, delta tracking, contrast, colour gamut, spatial uniformity, latency, overshoot and “In Use”.

They summarize the test with stating that the pace of monitor technology improvement is currently huge, as is the rate of getting new monitors to the market. One current trend is that the manufacturers design monitors for specific applications, such as office production, gaming or photo and graphic production. This makes it difficult to select a test winner since different monitors are suitable for different uses. However, they mention the ViewSonic VP930 as it is good in many respects, while the ViewSonic VX922 may be better suited for gamers and the Samsung 970P might be best among these monitors for photo retouching.

2.3.2 Production structure

In the discussions with the producers, the general characteristics of the production structure and supply chain were covered. The patterns seem to be similar for many of the producers:

The design is often a shared operation between Europe, US and South East Asia, thus getting costumer preferences from several markets.

The Integrated circuits and other components are produced mainly in South East Asia.

For Laptops and Displays (LCD) the whole production is located to South East Asia, while Desktops due to the more modular design, very often are assembled close to the market in Europe, from parts produced in South East Asia.

2.3.3 Actual markets shares by producer

Detailed data on market shares and market penetration are only available through commercial data sources, therefore the producers were each asked for their own market shares. Since not all producers have answered the survey, the picture is not complete, but gives an indication on who are the major “players” in different market segments.

During the discussions with industry, they all pointed to the fact that around **10% - 35%**, of the market for Desktops is held by so called **“White boxes”**, that is more or less temporary suppliers operating without a brand, buying surplus details on the global market to compete in the low price segment. These suppliers are by nature very hard to reach for voluntary agreements concerning environmental performances. The White boxes are more common on the private market.

Due to the sensitive nature of the figures on market shares, the observations are limited to indications on who are the major players on the different markets.

The dominating suppliers of office Desktops seem to be Dell and HP. For Desktops in home use, Packard Bell has a market share similar in size with HP and Dell. Apple, Lenovo (former IBM), Acer and NEC are also present.

For laptops, HP, Toshiba and Dell are dominating the office market, while the home market is shared between HP, Toshiba, Dell, Packard Bell and Sony. NEC has a relatively small market share.

For CRT-monitors, HP seems to dominate.

In the LCD-monitor market, Dell, Acer, Samsung and HP all have a market share above 10%. Philips, Fujitsu-Siemens and LG have market shares around 5% each.

The actual market shares are not shown in figures, since some of the suppliers opted not to give specific figures due to principle.

2.3.4 Prospect 2010, Market and features

Taking the speed of development into account, it would be possible with major changes in system format and usage pattern. Higher technological performance, like processor speed and higher memory density could lead to a very fast move towards smaller devices, and a fast integration with the mobile phone.

In the survey to industry [2006], a number of questions along different possible directions of that kind were asked.

In the answers, the general impression delivered, that for the short term future (2010), the major trend will be to use new technology to enhance the performance in existing formats. The major driver for this is the coming introduction of the next OS (operating system) from Microsoft (Vista), which will demand as much performance as can be generated in the coming years. Market impact from Vista is expected to start in 2007, and an accelerated shift out of older equipment is expected. This is mainly reflected in the estimated market figures in earlier chapters.

The industry are foreseeing a breakthrough for connectivity in several steps, in short term by network technologies like WWAN and WIMAX, in longer term on more advanced technologies. This will put increased pressure on battery operation and longer running time on battery. More energy efficiency is expected in short term through more efficient components, but also gradually better batteries.

For laptops, the move for higher efficiency will be balanced by the need to make the devices thinner and less heavy in physical respect.

A change in display technology is expected, but it seems from the answers uncertain whether the technology with LED-backlights (a development of the older LCD technology, but environmental positive due to reduction of mercury) will be ready for market before 2010. This seems to be a rather conservative judgement since several other sources have indicated that the next technology OLED may come into market before 2010. The development of monitors is also continuously driven by accelerated demands from the users for better resolution and better performance for showing moving pictures. The producers of monitors also have to balance between demands for design and demands for workplace quality.

According to “Display search”, the average prices of Flat panel computer monitors are shrinking at an exponential rate, the cost per square meter display area has gone from 10.000$ in 1999, to 2.000$ in 2005, indicating a continued move to larger and cheaper displays.

New memory technology is expected to improve the speed of hard-drives in the near future. The very fast evolution of flash memories will offer shortterm possibilities for energy reduction by partly replacing hard discs.

In the case of home entertainment, the suppliers show quite different opinions whether the computer will move into the living room and become the centre device for digital TV, DVD and so on. Several of the respondents express the view, that the market will supply specialized equipment for this type of applications, while others believe the general computer will gradually take over from the TV.

Several of the answers point to a gradual need for a home server, continuously on, to serve as communication centre. They also point to the problem of wireless LANs, which demand the computer to stay alive to keep the connection running, thus limiting the ability to go into energy saving mode.

In summary, for the short term (2010), the existing formats will prevail. A new wave of replacement sale will start around 2007. The numbers in previous sections point to a continued expansion of Laptop volume, while Desktops are levelling out to a steady volume of pure replacements. The sale of CRT-monitors is quickly declining in volume but with some indications for a continued demand in niche markets and niche applications.

2.3.5 Prospect 2020, Market and features

15 years in the future is a very long time, dealing with fast moving technology as ICT. According to the futurologist Ray Kurtzweil [2004] all Information Technologies double their power every year (price, performance, capacity and bandwidth). If this vision holds true, we are, when looking towards 2020, trying to understand how mankind will use technology 32.000 times as powerful as today´s (2 to the power of 15). It must be observed that not all experts agree on the validity of Moore law beyond 2015 and claim a slower expansion rate after that, but on the other hand many have done so before and the evolution has repeatedly proved them wrong and some are even arguing that the speed of Moore’s law is going up.

Based on such enormous developments, a fifteen-year prediction can only be in the form of a discussion on early observed trend babies and key questions around them.

2.3.5.1 Will the current computer format prevail?

We already have the technology to make very small handheld devices with the full capacity of an ordinary PC - while at the same time having functionality as cell phone, GPS and camera. With new coming communication technologies it would be possible to be connected everywhere and every time through a palmtop/mobile phone with all necessary capacity for the kind of personal computing we are used to.

The limitations of this movement seem to be the user interface, before these kinds of devices can make the PC or Laptop redundant, completely new ways of interacting with the device must be invented. Technologies like speech recognition and displays in eyeglasses are tested but have yet to prove the usability before any major change of format can take place.

Anyhow the evolution of the mobile phone into a multipurpose device has shown that more and more daily tasks are executed on such devices. The phone will for certain be a computer, but so far with a very limited user interface.

One important possibility is that new short distance wireless technology will open new possibilities to use the phone as the computer, always carried with you, but connecting to wireless interface devices in the office or at home and in public places - thereby obtaining the interface of the computer.

2.3.5.2 Will the net takeover?

Some foresights (Cisco) [2006] are indicating a long term development where the network will be the computer, meaning giving lots of users the ability to “borrow computer power from each other when needed” thus reducing the need for local capacity. They also indicate that more and more applications will be accessible over the net (a development currently pursued by Google), reducing the need for local storage and local maintenance of software.

For some applications, this may be a commercial success, but computer power does not seem to be a limitation in the future.

The network capabilities will for certain change the ways we are working and the way we share information both locally (in the company and in the community), and globally. Nearly unlimited capacity for video-meetings and other ways of remote communication will give the opportunity to work from anywhere. 0ne driver for such a development will probably also be the cost of energy and possible future limitations on travels (oil price).

2.3.5.3 Will advancements in technology be used for reducing prices instead of enlarging capacities?

For the short term, the industry has given a clear answer that the specifications for new operating systems will use all possible capacity (within reasonable price limits), but with increasing capacity per unit, it is quite possible that the market, in the future, goes more definitely for lower prices instead. Since such a development would affect the revenues of the total industry, it is likely to meet commercial interests forcing an ever increasing need for capacity and consolidation of the companies in the business.

2.3.5.4 Will TV, DVD, CD be replaced by computers, to give more interactivity?

The introduction of digital TV, streaming video, massive supply of news over the Internet and other related developments, will increase the opportunities of using a computer as a "communication centre in the living room". It is still under debate whether personal computers will be used or whether the media industry will provide other configurations of computerized equipment for such applications.

The development of network capacity and storage capacity will open for completely new services allowing much more of interactivity and personal choices.

The big question is whether the media industry and computer industry will amalgamate to one industry or if the now two industry branches will pursue different directions of development

2.3.5.5 Will voice on IP dominate, will the computer be a phone or vice versa?

Voice on IP is expanding rapidly, the direction of development on devices for connection is still under debate, IP-phones may be simple, but will not so far give the versatility of the computer for video, file interaction and so on. When voice on IP becomes the dominating tele-communication, it may become necessary or practical for every home to have a server always on, to manage the connection and the connectivity.

2.3.5.6 Will everything in the household be connected?

Some future studies see the need, desirability and possibility to make all household installation (like refrigerators, stoves, washing machines, the heating system and so on) computerized and connected. The need for such developments and the business potential are generally yet to be proven, but if there will be a market, the computing structure of the household may be effected quite a lot.

2.3.5.7 Will we have computer screens as art?

The cost of large screens is decreasing rapidly, so there might be other usage patterns than pure communication in the traditional sense. With decreased cost, we might use computer screens on the wall showing art, to fit the moment. We could even use computer screens to improve the reality, show a nice outside view instead of the boring backyard. The possibilities will be limitless, but what will the consumer's desires and preferences be?

2.3.5.8 Carried Artificial Intelligence, improving our decision capacity everywhere?

The development of AI has not quite lived up to expectation yet. Still with much increased computing power and more agile user interfaces, AI may come to a daily use by everybody, improving the ability to take daily decision in a more informed and optimal way. In 15 years time, the technology might be here, but what would be the effects? What will be the impact on the perception of knowledge and the market value of education? It would surely be revolutionary, but is it desirable?

2.3.5.9 Conclusion 2020

It is now ten years since the breakthrough of the Internet. In those times information was more or less exclusively confined to paper. There were computers but they were heavy and clumsy and very often crashed. In fifteen years´ time, the opportunities of applying and using computer technology will be huge. The speed of knowledge acquisition is exponential, most written text can be found in some form on the web, Google has effectively already copied all the world´s known books. Music and movie industry are heavily affected. The futurist Kurzweil even claims computers will disappear from our sight by 2010. The directions for applications will be dependant both on what producers choose to develop and what will be accepted by the customers. The development speed makes predictions practically useless for such a long timeframe - but we will all be affected.

This chapter was included to give indications of possible multidirectional futures. The directions of applications will naturally affect industry and industry structure immensely.

2.4 Consumer expenditure database

2.4.1 Comparison of average unit prices 2003 – 2005

Since the capacity of especially Desktops and Laptops varies a lot between individual units, and even more over the years, it is almost impossible to make any relevant price comparisons at a detailed level. It can be observed in general that the market tends to decide a generally accepted price by the consumers for one physical unit, and then supply as much performance as is possible for that price. A closer study would probably reveal a pattern with different accepted prices for different consumer segments.

This observation is in general supported by the table below, where the average unit prices have been calculated, based on import volumes and values, taken from PRODCOM, over as many years as available in the statistics.

Table 43 Average unit prices, calculated from PRODCOM import data

Year	Laptop	Desktop	System	Colour CRT	Flat panel monitor	Monochrome monitors
	EURO	EURO	EURO	EURO	EURO	EURO
1995		585		480	369	91
2000	687	346	1131	420	627	64
2003	632	364	246	306	364	44
2004	637	244	180	273	380	43
2005	539	157	397	273	277	34

From the table, it is obvious that Laptops had a very stable price from 2000 to 2004, but that the price started to drop in 2005. The prices for Desktops have been shrinking continuously thus not supporting the theory above. All other unit prices have been falling in general. The clear exception is systems, but this is probably due to the wide variety of intellectual content and value added included under this code.

It must be noted that the prices in this calculation are not based on retail prices, but on the prices when passing the customs.

From the survey [2006], the following weighted mean retail prices for the most sold version of equipments from each producer have been calculated:

Table 44 Weighted mean value of retail prices, 2005, data from survey.

Desktop Office	Desktop home	Laptop office	Laptop home	CRT	LCD
Euro/unit	Euro/unit	Euro/unit	Euro/unit	Euro/unit	Euro/unit
620	520	1242	990	73	201

The bases for the calculations are: for Desktops office 3.3 M units, for Desktop home 1.1 M units, for Laptop office 1.6 M units, for Laptop home 0.8 M units, for CRT 0.7 M units and for LCD 1.3 m units.

It must also be noted that for computers, the real cost for the consumer also depends a lot on the software. In the figures in the table it is unlikely that any major part of the cost for software is included. Most computers have the major part of software installed by the retailers or by the users.

2.4.2 Electricity rates

The electricity rates do change over time. Since the study shall cover the year 2005, the [EUROSTAT] rates from 1 July 2005 will be used in the calculations in subsequent tasks.

Table 45 Household electricity rates. (Standard Consumer Dc, Yearly consumption 3500 kWh of which 1.300 kWh by night) July 2005 incl. all taxes.

Country	Electricity rate (€/100 kWh)	Tax share of price (%)
EU- 25 average	13,6	23,8
Austria (AT)	13,91	31,8
Belgium (BE)	14,29	23,0
Cyprus (CY)	12,03	14,6
Czech Republic (CZ)	8,71	16,0
Denmark (DK)	23,20	58,5
Estonia (EE)	7,13	15,2
Finland (FI)	10,38	25,2
France (FR)	11,94	24,2
Germany (DE)	18,01	25,2
Greece (EL)	6,94	8,2
Hungary (HU)	11,24	20,0
Ireland (IE)	14,36	16,6
Italy (IT)	20,10	24,8
Latvia (LV)	8,29	15,3
Lithuania (LT)	7,18	15,2
Luxembourg (LU)	15,02	12,7
Malta (MT)	7,69	4,9
Poland (PL)	9,35	23,2
Portugal (PT)	13,80	5,1
Slovak Republic (SK)	13,30	16,1
Slovenia (SI)	10,49	16,7
Spain (ES)	10,97	18,0
Sweden (SE)	13,33	39,6
The Netherlands (NL)	19,6	43,5
United Kingdom (UK)	9,26	4,9

During 2005 the prices rose by 5% on average for households and by 16% for industrial consumers.

2.4.3 Repair and maintenance costs

Regarding the repair and maintenance cost, there are some different ways to handle this:

2.4.3.1 Service agreement

For the computer and monitor market, an often used way to handle repair and maintenance cost, is to buy a service agreement. An example of that is (from one of the companies answering our survey) if a company buys a 1000€ computer set (computer and monitor), they often pay about 200€ for a 3 year service agreement, where ALL repair and maintenance costs are included. The same kind of agreement is also available for private consumers who can pay approximately 120€/year for the same kind of service. The costs do differ from small to big customers and also depend on where the equipment is.

Quite often these service agreements are already included in the purchase prices.

2.4.3.2 Upgrading

Computers (but hardly monitors) can be upgraded to fulfil a better performance by changing processors, hard disk drives, graphics cards and other parts. This is an opportunity sometimes used by private consumers, but hardly by companies. The industry gave some figures saying approximately 2% of the customers use that opportunity. We assume that the cost for an upgrade is about 200€.

2.4.3.3 Repair

Computers

Those who do not have a service agreement do repair their computers when they break. Most computers break somehow sometime. Figures on repair cost were very difficult to find, but contacts to a couple of computer repair companies gave some information. An ordinary repair cost is about 75€ for labour for identifying and changing some broken hardware, which have different costs, but often between 50 and 150€.

Monitors

Monitors do mostly have a three-year warranty, within which time broken monitors are repaired for free. The repair cost of a monitor is often about 120€ which is far too much to pay for a monitor of older age than 3 years, since a new one does not cost much more than that.

Software

A quite common repair and maintenance cost for computers is the cost to provide the computers with new or upgraded software. A study referred to by Tim Landeck [Total Cost of Ownership] says that the initial purchase price for hardware and software is approximately 16% of the Total Cost of Ownership of a computer.

The computer repair companies say that they do very often have to reinstall software, such as operating system at a cost of approximately 75 €.

2..4.3.4 Conclusion repair and maintenance cost

We assume an extra cost of 125€ for repair and maintenance for computers in their lifetime. For computers and monitors, we assume no extra cost for repair and maintenance.

2.4.4 Disposal costs

Disposal costs for computers and monitors, come under the WEEE directive, which means that the producer has the responsibility to take care of the equipment after use. That means that in a past WEEE situation there will be no cost for the consumer related to the disposal of this equipment, except from the higher price the manufacturer might use due to their disposal costs. Today the situation differs very much from country to country, and even from region to region within the countries. The WEEE directive is working in Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Hungary, Ireland, Luxembourg, The Netherlands, Portugal, Slovakia, Spain and Sweden. On the other hand WEEE system is not yet completed in Cyprus, France, Italy, Latvia, Lithuania, Malta, Poland, Slovenia and UK.

Since Sweden has a ”producer responsibility” legislation since 2001, even before the WEEE directive, there might be of interest to highlight up some of the information from it:

2.4.4.1 Swedish example of disposal costs

“El-kretsen”, the Swedish electric and electronic waste collection company, did collect 126 millions kg electronic waste 2005 (incl. refrigerators and freezers from. 13/8-2005). Without refrigerators and freezers: 112 million kg. Approximately 12% were computers and monitors. “El-kretsen” is collecting almost all electric and electronic waste in Sweden, but some of it comes to the recycling companies from other sources, perhaps 8-10%.

Since the introduction of producer responsibility 2001, the increase has been 15-20%/year, most of it last year, probably due to the WEEE- directive.

Table 46 Total cost for disposal 2005 Sweden, assumption.

	kg	SEK/kg	M SEK	1000 Euro
Desktop computers	5,7 M	2,0	11,4	1140
Laptop computers	140 000	2,5	0,35	350
CRT monitors	10,2 M	4,0	40,8	4800
LCD monitors	96 000	3,5	0,33	330
total				**6620**

For a CRT of 17" and of 16 kg, it means a cost of approximately 6€

The costs for the manufacturers are calculated on their market shares to decide who should pay what. For example, if one company has 20% market shares of CRT, it would mean 0.2*4800 000 €, which is about 960 000 €. That is independent of if they did really provide the products, which are physically sent to the end of life treatment. So even if a manufacturer is new to the market, they have to pay for end of life for "their" share of products.

2.4.5 Interest and inflation rates

The following table shows inflation and interest rates for the EU25 as published by Eurostat and the ECB. [2005]

Table 47 Interest rate EU25, 19 Jan 2006.

Country	Inflation rates [%] (1)	Interest rates [%] (2)
Belgium (BE)	2,8	3,4
Czech Republic)CZ)	1,9	:
Denmark (DK)	2,2	3,4
Germany (DE)	2,1	3,4
Estonia (EE)	3,6	-
Greece (EL)	3,5	3,6
Spain (ES)	3,7	3,4
France (FR)	1,8	3,4
Ireland (IE)	2,2	3,3
Italy (IT)	2,1	3,6
Cyprus (CY)	1,4	5,2
Latvia (LV)	7,1	3,5
Lithuania (LT)	3,0	3,7
Luxembourg (LU)	3,4	:
Hungary (HU)	3,3	6,6
Malta (MT)	3,4	4,6
The Netherlands (NL)	2,1	3,4
Austria (AT)	1,6	3,4
Poland (PL)	0,8	5,2
Portugal (PT)	2,5	3,4
Slovenia (SI)	2,4	3,8
Slovak Republic (SK)	3,9	3,5
Finland (FI)	1,1	3,4
Sweden (SE)	1,3	3,4
United Kingdom (UK)	2,0	4,5
EU 15	2,2 (3)	3,42 (3)
EU 25	2,1	3,9

2.5 References

- Brian Williams, Eurostat Data Shop Handbook, Europroms, PRODCOM Data, 2003
- Barbara Schlomann et. al. Technical and legal application possibilities of the compulsory of the standby consumption of electrical household and office appliances. Fraunhofer ISI, 2005
- Ray Kurzweil, Keynote speech at The 1st Conference on Advanced Nanotechnology, Foresight Institute 2004
- Charles Giancarlo, Senior Vice President and Chief Development Officer, Cisco Systems, **Technology Innovation: What's Next?** a Cisco Live Webcasts replay published on Executive Thought Leadership Services Podcasts 2006
- Toms hardware:

  http://www.tomshardware.com/2006/03/27/the_spring_2006_lcd_collection/

  or in German at http://hardware.thgweb.de/2006/04/07/19_zoeller_13_lcd_monitore_im_vergleich/

  and Swedish at http://www.tomshardware.se/skarmar_och_tv/skarmar/20060322/.
- EUROSTAT (4/2006)Electricity prices for households and industry on 1st July 2005,
- Phone call to Elkretsen, Fredrik Benson, October 2006
- Tim Landeck [Total Cost of Ownership] http://www.thesnorkel.org/toolkit/articles/TCO_Final%20.pdf
- Annual Inflation (%) in Dec 2005 Eurostat "Euro-Indicators", 7/2006 - 19 January 2006
- Source: ECB long-term interest rates; 10-year government bond yields, secondary market. Annual average (%), 2005
- http://www.stiftung-warentest.de/online/computer_telefon/test/1335574/1335574/1336536.html
- *IVF industrial survey (2006)*

Several stakeholders did answer the questionnaire from IVF during the summer 2006. Due to secrecy agreements, they are not named here, but they do cover the main players for both computers and monitors, and also covering companies from Europe, The USA and Asia. The number of respondents to the questionnaire was 16.

3 Consumer behaviour and local infrastructure

Introduction

The main sources for information have been several international studies on usage patterns.

The general picture of computer usage pattern is an elusive one, in spite of the fact that several studies are available. “Computer usage pattern” is used in the meaning of how much time a computer is in the different modes: active,, idle, sleep and off. For this study, it is important to understand the usage patterns for office usage and for home usage. The usage patterns are very much influenced by the software and by Internet.

It can roughly be said that computers are in active use less than one third of the time. Regarding lower active modes, their respective usage times differ for central units and displays, but for several reasons the equipment goes into those modes much less often than could be expected.

Maintenance and repair of personal computers are often done under some kind of service agreement. The users make software repairs and changes more often than hardware changes or repairs. Regarding “End of Life behaviour”, it is very much influenced by the WEEE-directive, forcing all/most personal computers and monitors into an End of Life treatment, for which the cost was included in the original purchase.

3.1 Real life efficiency

Real life efficiency according to the VHK methodology includes many different issues. For personal computers and monitors the main issue is the frequency of use and type of use, which we hereby call the usage pattern.

3.1.1 Background

Back in 1977, DEC co-founder Ken Olsen said: "There is no reason for any individual to have a computer in his home" [Wikipedia]. Considering computer specifications by that time, he was obviously right. By 2006 the opposite seems more plausible, which shows what changes computers have undergone during the elapsed time. Their volume, weight and energy consumption have decreased by several orders of magnitude, whereas their capacity has made such quantitative increases that several qualitative changes in their usage have been made possible or even mandatory. Nothing indicates that this change rate will be slowing down anytime soon.

Currently, personal computers and monitors are used in so many different ways, that no clear-cut definition of their usage is possible. This is not a limitation of the analysis, but rather an intrinsic property of the devices: their capability and application area are intently open-ended. The use of specialised, single purpose computers for embedded systems is increasing rapidly, but it does not mean that personal computers are getting any less general-purpose. Even “home entertainment” computers keep all their generality and in no way become as specialised as TV or HiFi sets are.

Personal computers are becoming more and more communication machines: email has substituted mail to a major extent, and VoIP (voice over Internet protocol) and TV over Internet are becoming as popular as broadband. When computers are connected to broadband, there is a benefit from not switching them off, because of frequent automatic software updates, and in order to be reachable by a chat or VoIP. This makes people switch off the computers more and more seldom [Magnus Bergqvist, 2006].

Still, the communicating device is a further development of a calculating machine. A telephone or a mailbox consumes no energy while in stand by status; current personal computers do. This situation was acceptable when computers were used for limited time periods and then switched off, but using them as communication machines poses demands on access, response time and energy consumption that current personal computers do not fulfil.

This study also shows that there is a big lack of information on the issue. There doesn’t seem to be available any extensive and recent survey on computer usage pattern. Studies are perishable, since the usage pattern has changed very much due to rapid performance and functionality changes in the computers. In past studies, much more effort seems to have been put into ascertaining and calculating power requirements and possible energy consumption reduction, than into ascertaining usage patterns, and by that means understanding the origin of the power and energy consumption figures.

Nevertheless, enough information has been put together both to give a rough image of the usage pattern and to indicate clearly that, even if the truth is beyond reach and some assumptions are unavoidable, a much more detailed picture can be expected of a deeper study.

3.1.2 System’s influence on usage pattern

Some features induce and even compel more or less sustainable user behaviours. Features can be related to hardware or software, to producer or vendor, or a combination of several of them. For example

- A computer that takes a very long time (at the user’s perception) to boot, or wake up from hibernation, will be switched off as seldom as possible.
- Unstable wake up from hibernation will drastically limit the usage of this feature.

- If system updates have to be run other than office-time, the system managers will enforce an “Always on”-policy.
- Broadband connections facilitate computer applications that tend to make the users to have the computer always turned on.
- If the computer is clearly “off”, normal users will not check if it still is consuming energy.

Users in general, and home users in particular, are very conscious of the computer’s initial cost, and to a certain extent of the costs for coming software and hardware upgrades. On the other hand they are seldom aware of the total cost for ownership.

Firms may budget for system administration and help desks, but the power management built into the computers is rarely a purchasing argument.

In other words: the users mostly behave rationally to achieve their perceived needs from the computer, but this behaviour need not be optimal from a sustainability viewpoint. If sustainability is to be achieved, an optimal usage pattern should be automatically enforced by the equipment. A non-sustainable system configuration will automatically lead to a non-sustainable usage pattern.

3.1.3 Information from reports and other sources studied

The procedure within this part of the study was to gather as much information as possible regarding usage pattern. The decision was to normalise it to common units, and make a general average of it. The information and how the normalisation was done are described below. In Table 51 mean values from all sources are presented as the usage pattern that will be used in the subsequent tasks of this study.

U. S. Residential Information Technology Energy Consumption in 2005 and 2010
(prepared by TIAX LLC for U.S. Department of Energy [TIAX LLC, 2006])

The report is mainly oriented towards developing a preliminary estimate of national annual energy consumption (AEC) for the USA, at present and in three possible scenarios. Their methodology is according to the following figure.

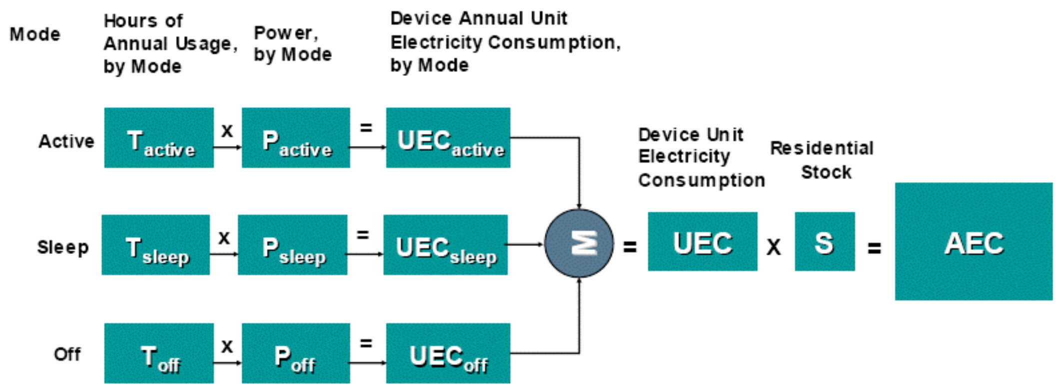

Figure 1 TIAX annual energy consumption, methodology.

However, TIAX states: " […] device usage patterns have the greatest uncertainty of any component of the AEC calculations" [p. 22]. The figures used in their calculations are based on telephone surveys. No home usage pattern is reported.

- In the USA, stationary PCs stand for 47% of the residential ICT electric consumption, laptops for 6%, and monitors for 18%. The ICT energy consumption is a small but increasing part of the total energy consumption: ~3% of the residential electricity consumption, ~1% of the national electricity consumption.
- Besides, the current estimations for ICT electric consumption have to be raised, mainly because PCs and monitors spend more time in active mode.
- Reasons named not to turn off are: "Convenience – Will or may use again", "Forget to turn it off", "Can damage the PC", "Too lazy", "No reason to turn it off".
- Access to broadband increases active mode time by approximately 25%

Table 48 TIAX 2006, Residential, hours/year in each mode.

	Active	Sleep	Off
Desktop	2954	350	5456
Laptop	2368	935	5457
Monitor	1861	881	6018

Fraunhofer report on possibilities of compulsory labelling

In the German report [Schlomann, 2005], several estimates have been presented on usage patterns, both for home use and office use of desktops, laptops and monitors. Estimates are made for 2001, 2004 and 2015, and are valid for Germany. The estimates are based on literature studies and experience. The data for 2004 are presented in Table 49.

Table 49 Estimated usage patterns, Germany 2004, [Schlomann, 2005].

Hours 2004	Normal operation	Standby	Off-mode	Off
PC-home	425	1417	4834	2084
PC-office	1540	660	5248	1312
Notebook-home	425	667	5251	2417
Notebook-office	1430	770	3280	3280
CRT-home	425	709	3813	3813
CRT-office	1540	880	5072	1268
LCD-home	425	992	3672	3672
LCD-office	1540	880	5072	1268

To make comparisons possible, the values for “Normal operation” and “Standby” are put together as “Active”. For “Monitor”, CRT and LCD are averaged.

Energy Star energy calculator, a tool presented by Energy Star

The tool suggests some standard usage patterns. [http://www.eu-energystar.org/]

- Home: Estimated average EU use 2003 (mainly web, e-mail). Derived from 'on-mode' 1.6 h/day in 2000 and 2.3h/day in 2010.
- Average office: Based on use for e-mail and occasional search/document/presentation: 3 hours per day active 'on' use, 1 hour 'on' preparing for standby. On 'standby' in other office hours (e.g. managers, sales representatives). Switched 'off' (using the PC power button, not disconnected from mains) at night. Power Users (video-editing, CAD) will probably better fit in the 'average office' profile.
- For both home and office usage, the model assumes 2 hours per day in On-mode, 9 h/d in Stand by-mode, and 13 h/d in Off-mode. [http://www.eu-energystar.org/en/index.html].

Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings
(prepared by TIAX LLC for U.S. Department of Energy [TIAX LLC, 2004])

Table 50 TIAX user patterns.

Case	Usage by Mode[27] [hours/week]		
	On	Sleep	Off
Baseline	98	7	62
Power Aware	98	7	62
Power Aware + 100% PM-enabled	19	86	62

As other reports show (see below), the condition "Power aware + 100% power management-enabled" is very seldom applicable. Thus, it is disregarded. The values from the other two lines (in fact, the same) are used for the groups Desktop Office, Laptop Office, Monitor Office and Desktop + Monitor Office.

The report also states, that for Desktop PCs, the "power management on" rate is somewhere between 6% and 25%.

Monitoring Home Computers, by MTP

In March 2006, AEA Technology made a study called "Monitoring Home Computers" for the Market Transformation Programme (MTP) and the Energy Savings Trust (EST) in Great Britain. [MTP, 2006]

Method

The MTP method is different from the other studies, in that they have recorded home computers' power consumption every minute during two weeks. Power consumption shows a number of distinct thresholds, which can be associated to different usage modes, as follows

Figure 3 Data record for one computer - identifying a Low mode

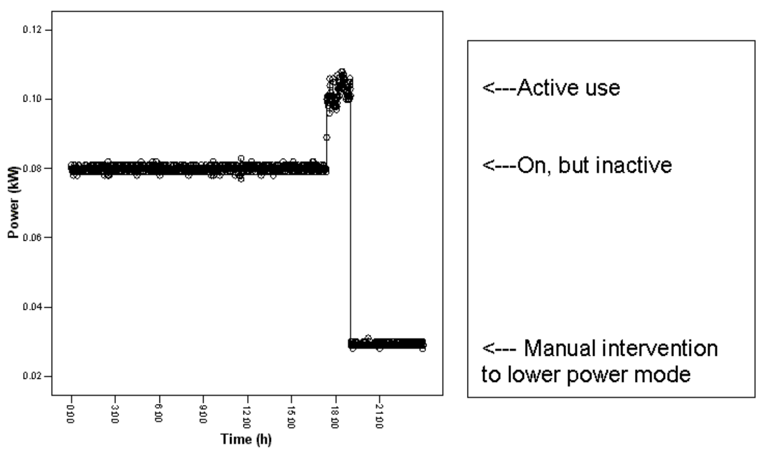

Figure 2 Data record for one computer – identifying a Low mode. [MTP, 2006, p. 13]

The measurements have been made in eighty households from ten different regions in England. In addition to the measurements, more information about the households and the computers was collected by means of questionnaires.

Results

The study came to the following conclusions

- Even where power management features are available on the computers, many computer users are not taking advantage of them.
- “Monitor off” was available on 95% of the computers where this feature was checked for availability. The most common setting (52% of the computers) was for the monitor to turn off after 20 minutes, and the average was 27 minutes. However, almost 27% of the computers with the feature had it set to “never”.
- “Disks off” was most commonly set to “Never” (78% of the computers). When activated at all, the average delay time was 40 minutes.
- “Standby” was most commonly set to “Never” (78% of the computers). When activated at all, the average delay time was 23 minutes.
- “System hibernate” was most commonly set to “Never” (97% of the computers). The only computer that had it enabled had a delay time of 45 minutes.
- Most users were unaware what different energy marking labels (e.g. Energy Star, TCO, Nordic Swan, Blue Angel, Ecolabel) stand for.

Table 51 Usage pattern from MTP’s report [Table 20], home use.

Mode	Usage time h / day]	Usage time [h / year]
Mains Off	2,7	985,5
PC Off	15	5475
Low	0,2	73
Active	6,1	2226,5
Total	24	8760

These values can be regarded as the best available figures. However, their limitations are that

- they are valid only for home usage
- they do not discriminate between desktop and laptop computers.

EEDAL'06 (International Energy Efficiency in Domestic Appliances & Lighting Conference '06 [Presentation by Kurt Roth, 2006]

A presentation based on US studies

A rather coarse usage pattern is presented. It is not quantifiable in this report's terms.

Table 6. PC on-time data from RECS and calculated average on-time

	% of Households		Weekly hours on/week	
hours/week assumed to be the midpoint of the range	All	With a PC	Each PC	Share of Average
Households with PC *On*				
less than 2 hours/week	9.7%	17.3%	1	0.2
2 to 15 hours/week	24.6%	43.8%	8	3.5
16 to 40 hours/week	11.4%	20.3%	25	5.1
41 to 167 hours/week	5.3%	9.4%	80	7.5
all the time	5.2%	9.3%	168	15.5
Totals: %, share	56.2%	100%		31.8
Hours/week over 40				
41 to 167 hours/week		9.4%	40	3.8
all the time		9.3%	128	11.8

Sources: Nordman and Meier (2004) and EIA (2001)

Figure 3 EEDAL 06, PC on-time. [Kurt Roth, 2006]

EEDAL'06, (International Energy Efficiency in Domestic Appliances & Lighting Conference '06 [Karine Thollier, Institut de Conseil et d'études en Développement Durable, Belgium, 2006]

A presentation based on a study for the Belgium authorities.

No quantifiable information regarding usage pattern. Other interesting viewpoints:

- The resource consumption, including both materials during production and energy during usage, can be reduced by moving from CRT-displays to flat ones.
- The number of people enabling display sleep is grossly double as large as those enabling CPU sleep.
- "Hard Off" is negligible as compared to "Soft Off"

[Karine Thollier, 2006]

Förbättrad energistatistik för lokaler (Improved Energy Statistics for Buildings)

An inventory of 123 office and official buildings in Sweden.

No quantifiable information regarding usage pattern.

- PCs stand for 14,2% of the energy consumption in office buildings, and 15% when electric heating is excluded.

[Statens energimyndighet, 2005] (The Swedish Energy Authority)

Vart tar watten vägen? (Where does the Watt go?)

This is a Swedish report dealing with energy consumption in University buildings. It includes qualitative but no quantifiable information regarding computer usage pattern.

- Student PCs are left "On" for no apparent reason, whereas they could hibernate during grossly 50% of the time.

[Institutionen för Värme- och Kraftteknik, 2003] (Institution for Heat and Energy Technology, Lund's University of Technology, Sweden)

Sustainable Products 2006: Policy Analysis and Projections, UK 2006

No quantifiable information regarding usage pattern. Other interesting viewpoints:

- "Non-domestic electricity use by ICT equipment has increased by nearly 70% between 2000 and 2005; domestic figures have more than doubled in the same timeframe."

[www.mtprog.com , 2006]

Residential computer usage patterns, reuse and life cycle energy consumption in Japan

The report in based on a large survey, 1033 Japanese Internet users, and deals only with home computers. It concludes that they are in

- active mode 2,35 hours per workday and 2,8 hours per nonworking day on average
- sleeping mode 25% of non active time
- off 75% of non active time.

Besides, it draws the following conclusions

- The question of what power mode the computer is in when not being used is key to reasonable estimation of electricity use.
- The survey informs that 78% of users are reporting that computers are turned off when not in use, 3,4% always on, 7,1% always on except at night, 8,5% in standby mode and 2,7% in hibernate mode.

[Eric Williams, 2005]

***EPIC-ICT: Development of Environmental Performance Indicators for ICT Products on the example of Personal Computers: "Data needs and data collection, Generic Modules, Environmental impacts, Impact assessment and weighting, Environmental interpretation and evaluation"* [2005]**

One single computer (Dell OptiPlex desktop computer GX280) is used as model to Life Cycle Analysis of personal computers. Two usage pattern models are used

- EPA's (EnergyStar, i.e. 4 hours/day at maximum level, 5.5 h/d at minimum level and 14.5 h/d at off level)
- Dell's own, which is intended for newer products.

Already at this level there are major differences; when recalculating both patterns to hours per year and assuming off mode during weekends in the EPA model, they compare as follows

Table 52 Usage patterns in EPIC.

Usage in [h/y]	Model	
Service level	EPA	Dell
Maximum	1040	250
Minimum	910	2943
Sleep	520	3223
Off	6266	2344

[EPIC, 2006]

TECHNOLOGIES DE L'INFORMATION ET ECLAIRAGE - Campagne de mesures dans 49 ensembles de bureaux de la Région PACA

This report deals with energy consumption reduction in offices. Even if it does not define any complete usage pattern, it does point out their main characteristics. Information used thereof

- Active time for stationary office computers: 3 h/workday
- Monitor sleep time: 68%
- Monitor active time: 25%

[ENERTECH, 2005]

3.1.4 IVF Survey 2006

IVF has sent a questionnaire to a number of companies and institutes, regarding the whole of Lot 3. In this report, the answers from sixteen respondents including market leading companies and a number of institutes are taken into consideration.

Power management

More or less advanced power management functionality is built into practically every new computer, but it is often partially disabled at the installation. “Display off” is more often enabled than “Hard disks off”, “Sleep” or “Hibernate”. The reasons may vary, but are probably mostly due to the capability of the operating systems.

- For office use, one reason can be system updates done overnight. Thus, for them to be effective, the computers must be “on” all the time, because waking them up from a central server is not a usual feature.
- For home use, the “wake up-time” can be experienced as bothersome, when computer usage is interspersed with other home activities. As a whole, the usage of power management functionality is well under maximum, and the reasons for it are not always clear.
- The “Wake up” from an energy saving mode can be perceived as an uncertainty factor. Many users have experienced computer instability after an incorrect wake up. Often the only cure to it has been a reboot, at the worst case causing loss of data. This could be an explanation for “Display off”-acceptance (well established and experienced as safe) and the non-acceptance for “Hard disks off”, “Sleep” and “Hibernate” functions.

Usage modes

- Normally “Off” means “Soft Off”, i.e. the operating system or the power button on the computer is used to turn it off. This does not mean that the power consumption goes down to zero [ENERTECH, 2005]. It is indeed drastically reduced, but remains around 3 W.
- Computer manufacturers often make a major difference between “Active” and “Idle”, and even some states in-between. For their purposes it is clearly motivated, but not from the user perspective. Consequently, for the current purposes, both concepts are used as equivalent and named “Active”.
- Some of the companies gave suggestions on figures for usage pattern. The data given are included in our calculations, but cannot be presented individually due to confidentiality reasons.

3.1.5 Estimation of usage pattern, based on collected data from the studies and answers presented

When calculating the usage hours, it has to be taken into account that office and home computers are used very differently during weekends.

The following summary, table 4 shows the mean values of the data from all sources presented earlier. There are some limitations to consider:

- It has not been possible to get information for all use cases from all reports and manufacturers. Even if not stated, the sample size varies for different usage modes, as not all sources consider all modes, and the accessible information forms a rather sparse matrix. When adding up all sources, this leads to usage times that most often do not add up to 8760 hours per year. Consequently, usage times are normalised to that value.
- Most information was originally produced for other purposes, only matching partially the current requirements. All information does match the same quality standards. Not being in position to weight the data for quality, a non-weighted average have been used.

Table 53 Computer usage pattern, mean values from all sources.

Computer usage pattern			Normalised time [hours/year]	Percent
Desktop	Office	Off	3285	37
		Sleep	3196	36
		Active	2279	26
	Home	Off	4305	49
		Sleep	2873	33
		Active	1582	18
Laptop	Office	Off	3153	36
		Sleep	2995	34
		Active	2613	30
	Home	Off	4468	51
		Sleep	2904	33
		Active	1388	16
Monitor	Office	Off	2375	27
		Sleep	3798	43
		Active	2586	30
	Home	Off	4835	55
		Sleep	2636	30
		Active	1289	15

”**Off**” includes soft off (computer turned off by software or power button but still connected to mains) and hard off. The latter occurs very rarely.

“**Sleep**” includes several low energy consumption states, none of them permitting interactive usage.

“**Active**” includes all power states between idle and high (maximum power usage).

3.1.6 Conclusions regarding usage pattern

Office computers are in active use during less than one third of the time. For home computers this value is less than one sixth. The rest of the time is sleep and soft off. The off time is about one third of all available time, which is less than the time out of office. Hard off time is negligible.

The active time is assumed to correspond to active usage. For the rest of the time there is a tendency towards higher processor activity levels than necessary, i.e. sleep when it could be in hibernate mode or off, or soft off when it could be hard off.

For home computers, the off time is longer than for computers in office use. In relation to the relatively limited active time, the sleep time is dominating.

Most users, both at office and home, are unaware of the difference in energy consumption between soft off and hard off.

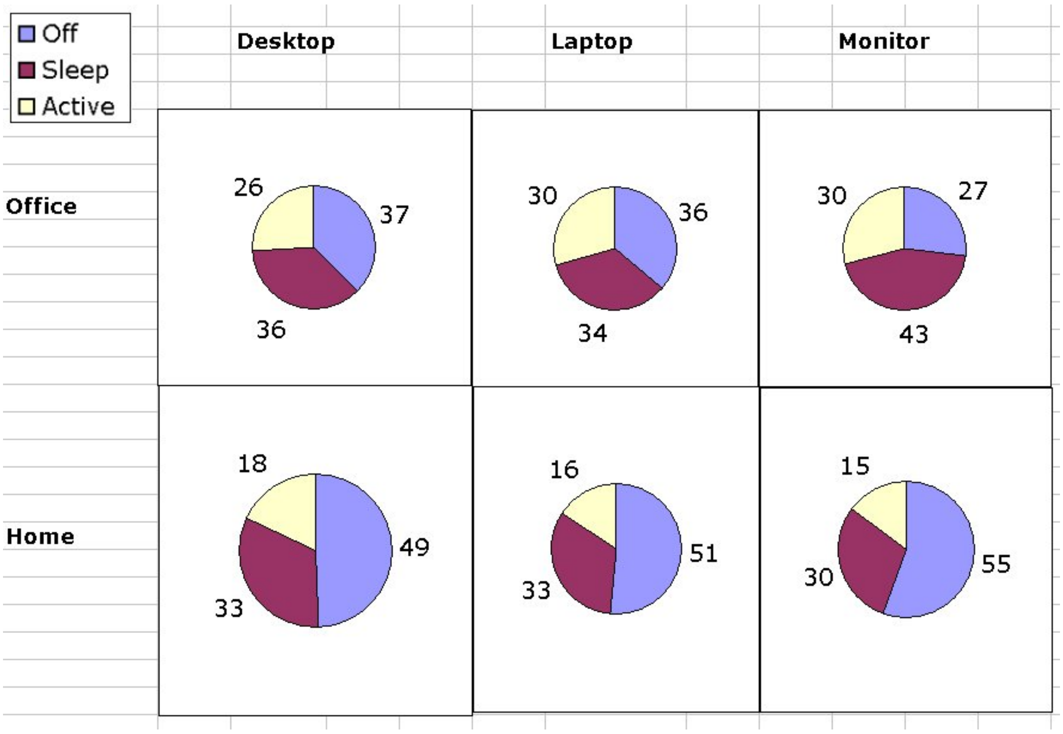

Figure 4 User patterns mean values from all sources.

3.2 End of Life behaviour

3.2.1 Economical product life

Computers and monitors are usually not replaced due to being worn out or broken, but due to increased demands for functionality, often triggered by new versions of software. In the survey, the stakeholders were asked for the expected lifetime ***in use*** for the different products within this study. It was rather amazing to find out that most products are stored, for example in the garage, for some years after use before they are sent to the End of Life treatment organisation.

The table below shows the average economic lifetime for the "first life" of equipment, calculated as mean values of the answers in the survey, the number of respondents on this issue was 6. The deviations were quite large, ranging from 3,5 years to 7 years for Desktop in home use, so the averages should only be taken as indicative.

Table 54 Average economic lifetimes, of first life, opinions of the suppliers.

Equipment	Average first life economic lifetime (years)
Desktop	6
Laptop	5
CRT	6
LCD	6

3.2.2 Repair- and maintenance practice

Service agreement

For the computer and monitor market, an often-used way to manage repair and maintenance costs, is to buy a service agreement. An example of that is (from one of the companies answering our survey) if a company buys a 1000€ computer set (computer and monitor), they often pay about 200€ for a 3 year service agreement, where ALL repair and maintenance costs are included. The same kind of agreement is also available for private consumers who can pay approximately 120€/year for the same kind of service. The costs do differ from small to big customers and also depend on where the equipment is located and used. Quite often these service agreements are included in the purchase prices.

Upgrading

Desktop computers can be upgraded to give better performance by adding more memory, by changing or adding hard disks, and by changing graphics cards. The logic for upgrading is in the first two cases basically the effects of the continuously improving price/performance relationship, while the upgrading of graphics controllers is driven by new functionality needed, especially for gamers. Upgrading is an opportunity sometimes used by private consumers, but more seldom by professional users. The survey gave some figures saying approximately 2% of the customers use that opportunity. We assume that the cost for an upgrade is about 200 €.

For Laptops, the only realistic upgrade is adding more memory, and replacement of worn out batteries, while monitors leave no opportunity for upgrades.

Repair

Computers

Also customers without service agreements do repair their computers when they break. Figures for repair costs were very difficult to find, but interviews with some computer repair companies (who wanted to be anonymous in this report) gave some indications. An ordinary repair cost is about 75€ for labour for identifying and changing broken hardware. The costs for the spare parts differ, but are often somewhere between 50 and 150€. We assume every computer need one repair at a cost of 125€ in its life time. Some repairs are also made within the warranty time.

Monitors

Monitors mostly have a three-year warranty, within which time broken monitors are repaired for free. The repair cost for a monitor is often about 120€ which is far too much to pay for repairing a monitor older than 3 years, it is often more economical to by a new instead.

Software

A quite common repair and maintenance behaviour for computers is to upgrade the software or adding on new software applications. A study referred to by Tim Landeck [Total Cost of Ownership] claims that the initial purchase price for hardware and software is approximately 16% of the Total Cost of Ownership of a computer.

The computer repair companies say that they often reinstall software, such as the operating system at a cost of approximately 75 €. The costs for software will not be included in the calculations, according to the VHK-methodology.

Conclusions regarding repair and maintenance

In the calculations in the subsequent tasks, we will use the following figures: Repair and maintenance cost, 200€ for a computer. No extra cost for a computer monitor. Maintenenance, repair and service transportation is assumed to be 40 km per product. The VHK methodology do add 1% material for spare parts, which is a good assumption for this kind of products.

3.2.3 Present fractions to recycling, re-use and disposal

The end of life behaviour regarding computers and monitors will be very much influenced by the WEEE directive. (For more information, se task 1 and 2.) The WEEE directive puts the responsibility for Waste of Electric and Electronic Equipment on the producer. That means that in a post-WEEE situation there will be no added cost for the consumers at disposal time. Today the situation differs quite a lot from country to country, and even from region to region within countries.

The producers within our survey are also handling end of life treatment differently. Some of them have made agreements with collecting and recycling companies, country by country. Some have built their own systems to gather and treat the products after life. All customers will have the opportunity to get rid of their equipment for no extra cost. Sometimes the customers have to bring the equipment to specific places to get rid of it, and sometimes they only need to make a phone call and the waste will be collected at the door. The WEEE directive is implemented in the major part of EU and is under implementation in the rest of EU25.

The WEEE directive quota at time of disposal for products covered by this study, is 75% recovery and 65% recycling.

When asking the companies about the fractions for recycling, re-use and disposal the answers differ, but the main conclusion is that almost all parts of the products are (or will be when WEEE is implemented) possible to re-use, recycle or bring to "incineration with energy recovery". Only about 2 % will be disposed. A small part of the products will go to destruction (dangerous materials need to be destroyed, for example by extra hot incineration)

According to a telephone interview with Johan Herrlin, Stena Technoworld [2006] the waste from computers and monitors collected in Sweden 2005 (according to the producer responsibility law introduced 2001) distributes to the different waste fractions as follows:

- 80 % recycling to new material
- 15 % Incineration (energy recovery)
- 1 % Destruction
- 4 % Deposition.

For the countries not yet following the WEEE directive, the estimate is that people follow the main stream of municipal waste in the countries, also when getting rid of electronics (see Figure 5).

EU-15

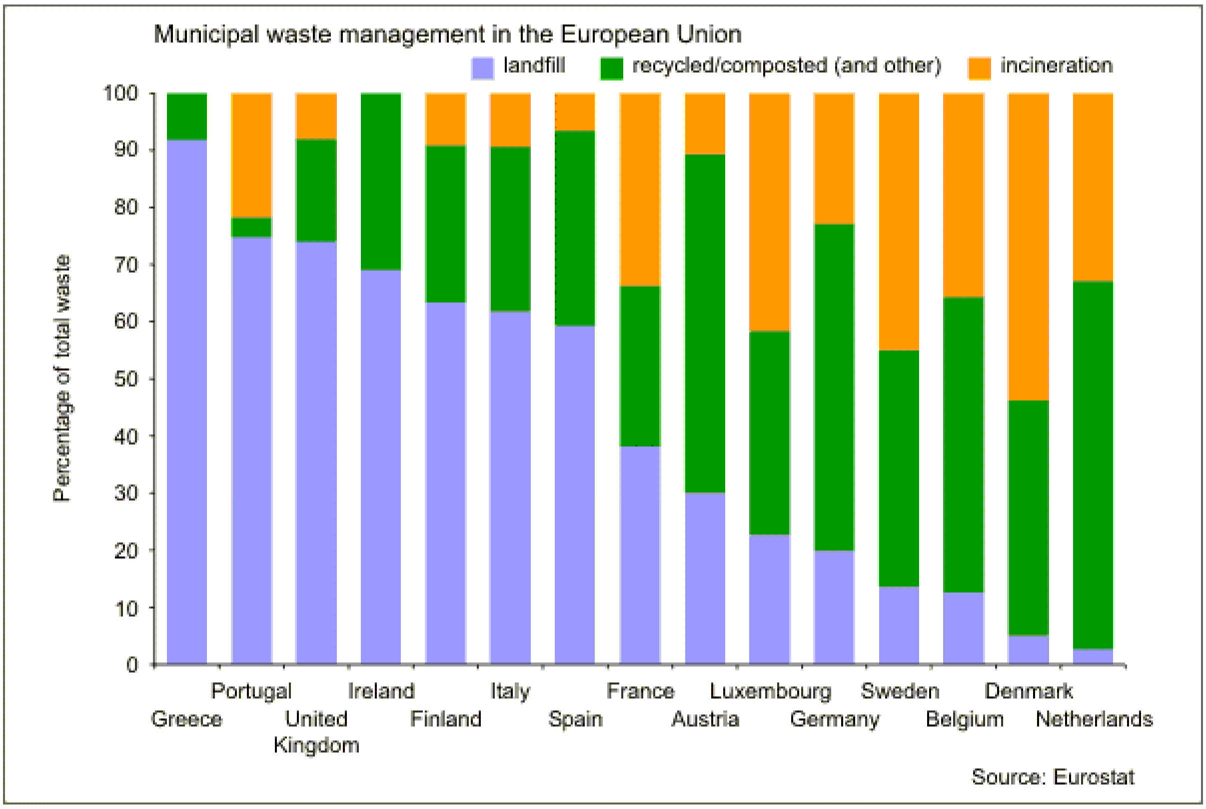

Figure 5 Municipal waste management in the European Union 2003.

It is estimated that around 580 kilograms of municipal waste was produced in average by each person in the EU-15 countries in 2003.

Greece landfills over 90% of its municipal waste, and Portugal and the United Kingdom landfill around three quarters of their municipal waste. The Netherlands and Denmark dispose of almost no municipal waste to landfill, while Belgium, Sweden, Germany and Luxembourg all landfill less than a quarter of their municipal waste.

In Denmark, Sweden and Luxembourg incineration is the single main method of disposal and over half of Denmark's municipal waste is treated in that way. The Netherlands and Austria recycle/compost around 60 per cent of their municipal waste, and Belgium and Germany recycle/compost around half of theirs.

Note 1: Only broad comparisons can be made between countries because of differences in definitions of types of waste management. The recycling category includes some other recovery options (fuel manufacture, for example), which are negligible in most countries, but account for about 10 per cent of municipal waste in Germany, and 6 per cent in Spain.

Note 2: EU-15 refers to the 15 members states of the European Union in the period prior to enlargement in 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. [Eurostat environment waste statistics]

This figures are only given to give a hint about the present situation, the study shall use a past-WEEE scenario in the calculations.

Conclusion

The recovery rate (for recycling, energy recovery, ect) in the VHK methodology is assumed to be 95% that is used as default figures in the Ecoreport tool. It is supposed to give a past-WEEE picture. This is close to the figures from the well-developed WEEE system in Sweden, and will therefore be used in the calculations in this study.

3.2.4 Estimated second hand use, fraction of total life time and estimated second product life

The answers in the survey regarding second product life also differ a lot. The main findings are though, that there are significant volumes of products used in a second life. The second life can be estimated to be about half of the first life time described above for the different product groups. The more valuable the equipment is, the more likely it is that it will have a second life. Before the second life the products are often refurbished. About 20 % of the equipment is estimated to have a second life now, but the percentage will increase to 30% within some years according to a Swedish study [Bengt-Erik Svensson and Carl-Olof Andersson 2004]. This study also shows that the products in their second life often are used in schools, given to development agencies (e.g. SIDA) or sold to developing countries.

Conclusions second second hand use

In the calculations in the subsequent tasks, we will use that 20% of the products will have a second life of 3 years, leading to the following total life:

Table 55 Average total life time.

Equipment	Average economic lifetime (years) including second life
Desktop	6,6
Laptop	5,6
CRT	6,6
LCD	6,6

3.2.5 Best practice in sustainable product use

Computers and monitors are used for a large variety of purposes and under many different usage patterns. The use of computers and monitors is highly dependant on the software. The common operating systems, like Microsoft XP, and most virus protecting softwares offer the possibility of automatic updates over the Internet. It is common to schedule such updates to times when not actively using the equipment, thus generating a tendency to leave it on, even over night.

New ways of communication, such as “chat”, voice over IP, “MSN” and other, also imply 24 hours usage. For many such applications, constant monitoring of the incoming data packages on the network is essential. An effective functionality for using energy saving modes while actively listening to the net, is becoming more and more important.

Very time consuming booting procedures, generated by more complex software and more complex linkages in networks, discourage users from turning off the equipment. In office environment it is common to add to the boot procedure an extensive virus scan, synchronising of documents, and recreating connections to network disks and printers.

To create a “smart” (sustainable and high performance) usage pattern, the functionality of software such as the operating system is central, to allow the energy saving functions to be activated much more frequently.

Some of the most important best practices in sustainable product use are collected from information from our stakeholders.

Power management

Power management is a software tool making the computer and/or monitor use less energy by going into power saving modes, when less computing activity is needed. Power saving can be implemented in several ways, like turning the fans off when less heat is generated, stopping the disks from spinning after a certain time of inactivity, reducing power to the CPU when at less activity and even turning the motherboard off for all functions except waiting for interrupts.

The most modern standard, *The Advanced Configuration and Power Interface ACPI* specification, see reference [ACPI, 2006] is an open industry standard first released in December 1996 developed by HP, Intel, Microsoft, Phoenix and Toshiba that defines common interfaces for hardware recognition, motherboard and device configuration and power management. According to its specification, "ACPI is the key element in Operating System-directed configuration and Power Management (OSPM)". The older standard APM made power management to be put under control of the BIOS (the basic built in firmware), which gave much less room for efficient energy usage.

Although modern computers are equipped with these advanced functions for power management, they are often disabled in standard installations of software, especially in office network environments. As indicated in the article above, integration of legacy software, not built for APCI can cause problems, which has generated a suspicion for problems among many IT-departments.

According to [TIAX LLC, 2004] “Network software that enables power management for networked office equipment has the greatest energy savings potential of all the measures selected for further study, i.e., applied to all relevant equipment it could reduce total annual energy consumption by 21 to 30 percent. This reflects the relatively low power management-enabled rates of office equipment as well as the large differences in power draw between active and low-power modes.” According to the same report, desktop PCs have a 6% to 25% PM-enabled rate.

Application of WOL (Wake on LAN), a functionality to allow booting triggered from the network, can be a solution for a more sustainable management of office networks, especially for the sake of software upgrades during non-working hours. In the latest Energy Star specification, WOL functionality is required or alternatively the ability to monitor the net in sleep mode.

Hard off switch

Most products use some energy even if they are switched off by the software (soft off). Most users are not aware of the difference between a soft off, putting the equipment in standby and a hard off (physically disconnecting). A best practise usage pattern could be to making hard off a habit, whenever the start-up time is not generating an inconvenience.

Customer information

Computers and monitors are very sophisticated equipment, making it difficult for people to understand how to use the products in a sustainable way. It is therefore of importance to give customers relevant information, regarding how to use power management, how to switch off the product, how to treat the equipment after use (End of Life treatment) and other important information. Some products include good information in this respect; while other producers do not supply that kind of information at all. The “white box” sector has special difficulties regarding information. “White box” products are products assembled from standard components by small local companies, sometimes with their own brand. These companies seldom provide information on how to treat the products in a sustainable way.

Change to a more sustainable product

Some techniques are more sustainable than others. One example is the LCD monitor, which uses much less energy than the CRT for the same size of screen. Another way for the customer is to choose equipment, which fulfils the requirements from voluntary labelling schemes, such as Energy Star or TCO labelling scheme.

Sustainable End of life treatment

Most manufacturers do have a good system for End of life treatment, either internally, or by an agreement with another company. It is of importance that computers and monitors do come to a WEEE-compatible end, which is also the case in many countries.

3.3 Local infra-structure

Computers and monitors are more or less dependent on two main infrastructure systems, electricity and Internet. These are described below.

3.3.1 Electricity availability

One absolute requirement is electric supply, which is available all over Europe to all households. It is also becoming even more available, for example on trains and other transports, making it possible to connect and use equipment when travelling.

For sensitive computer installations or in areas with frequent interruptions of the electrical supply, it is common to protect the equipment by installing Uninterruptible Power Supplies (UPS, "battery backup"), to allow undisturbed usage for a limited time during power failures.

In environments with other kind of disturbances in the power distribution, frequency and amplitude variations, other types of filtering devices are used to improve the conditions for computer installations.

3.3.2 Internet

Internet availability

Internet is the other infrastructure of importance for computers and monitors. Even if standalone computers still exist, the computer has become more and more a communication machine. Modems have been common for many years now, allowing low speed call up connections to the Internet. Nowadays broadband is more and more common, which makes computer communication much faster, and often to a fix cost independent of traffic volume. The increasing bandwidth opens up for new applications and new ways to use computers, making it the centre for communication.

The Internet connectivity opens up for a number of new applications, all pointing to changes in usage patterns with more active on time, especially in home environment. Such new applications are: Voice over IP, TV over broadband, downloading of music and film and so on. It is still to be seen, whether all of these new applications will be used on general purpose PCs or on special devices. The power management usage in such network dependent applications is in its turn highly dependent on the operating system, as explained in earlier chapters.

The establishment of WLANs and hotspots at public places make it even more important to allow fast start-up from off state, or very effective power management. For laptops, the customers will certainly make this a buying parameter, to gain long battery working time.

In September 2006 the Internet penetration was 239 881 917 users in EU25, with Benelux and the Nordic countries leading the way and eastern and south Eastern

Europe generally lagging behind. [Eurostat Internet penetration] In Sweden, Denmark and Finland over 80% of firms have broadband access, compared to less than 45% in Cyprus, Poland and Greece.

The level of Internet access is lower in sparsely populated rural regions (40%) than in heavily populated urban areas (52%). Students are on proportion the most regular Internet users. By contrast, 48% of unemployed persons claimed never to have accessed the Internet. Another interesting tendency is that women in Europe increased their Web usage at a faster rate than men in the past three years, according to a report published by the European Interactive Advertising Association http://www.eiaa.net

Table 56 Internet usage in Europe, data from Eurostat.

Internet Usage in Europe						
EUROPE	Population (2006 Est.)	% Pop. of World	Internet Users, Latest Data	Penetration (% Population)	% Usage of World	Use Growth (2000-2006)
European Union	462,371,237	7.1 %	**239,881,917**	51.9 %	22.1 %	157.5 %
EU Candidate Countries	110,206,019	1.7 %	**24,983,771**	22.7 %	2.3 %	622.1 %
Rest of Europe	234,711,764	3.6 %	**43,847,215**	18.7 %	4.0 %	417.5 %
TOTAL EUROPE	807,289,020	12.4 %	**308,712,903**	38.2 %	28.4 %	193.7 %
Rest of World	5,692,408,040	87.6 %	**777,538,000**	13.7 %	71.6 %	203.9 %
TOTAL WORLD	6,499,697,060	100.0 %	**1,086,250,903**	16.7 %	100.0 %	200.9 %

NOTES: (1) European Internet Statistics were updated on Sept. 18, 2006. (2) Population is based on data contained in world-gazetteer.com. (3) The usage numbers come from various qualified sources, mainly from data published by Nielsen//NetRatings , ITU , and other trustworthy sources. (4) Data may be cited, giving due credit and establishing an active link back to Internet World Stats . © Copyright 2006, Miniwatts Marketing Group. All rights reserved worldwide.

As can be seen from the tables above, the internet usage is expanding rapidly, thus also giving the indication toward more "on-time" for computers, as discussed earlier.

Internet usage

The Internet usage is also studied, which gives a hint of the computer usage pattern.

According to data released by comScore Networks's (http://www.comscore.com/) new World Metrix panel. The worldwide average number of hours spent online in the month of March 2006 was 31.3 hours a month. The top 15 countries include Israel (57.5 hours), Finland (49.3 hours), South Korea (47.2 hours), and the Netherlands (43.5 hours). The following are the top countries on broadband use:

Table 57 Average monthly online hours per unique visitor by country, March 2006.

Average Monthly Online Hours per Unique Visitor by Country, March 2006	
Country	**Avg. Hours per Visitor March 2006**
Worldwide	31,3
Israel	57,5
Finland	49,3
South Korea	47,2
Netherlands	43,5
Taiwan	43,2
Sweden	41,4
Brazil	41,2
Hong Kong	41,2
Portugal	39,8
Canada	38,4
Germany	37,2
Denmark	36,8
France	36,8
Norway	35,4
Venezuela	35,3
Note: Visitors are 15 years old or older,	
Source: comScore World Metrix, 2006	

The numbers of Internet users in Europe roughly corresponds to the number of computers in use (installed base), in previous chapters. But the usage patterns in table 4 indicate that the average computer is in active mode 2 to 4 times as much as the time connected to the Internet. This shows that there is still a lot of use for other applications than Internet access.

Experiences indicate that WLAN installations are more sensitive for computers not actively participating in the network traffic, thus contributing to the practice of disabling power management.

3.3.3 Barriers for new technologies/products

Barriers for new technologies/products are gathered, mainly through the IVF industrial survey [2006]. Some of the most important quotations on barriers for new technologies/products from the answers of the questionnaire received from stakeholders are presented below. They are divided into three levels, consumer level, company level and system level.

At the consumer level

- "Cost, value added must be clearly demonstrated"
- "Price and product weight for Laptops"
- "Consumers focus on cost and performance rather than energy efficiency"
- "Consumers typically don't know what they want beyond a 6-12 month horizon. Until an industry 'innovator' demonstrates what is possible, the consumers act within their existing experience base. The number of true industry innovators is decreasing as the market continues to commoditize"
- "Regional/economical/political directives/regulations"
- "Product understanding/use"
- "General resistance to change. Hassle/time/expense needed to upgrade associated software etc, Difficulty of being an early adopter (no software available, technology maturity problems). Cost of being first (both to the manufacturer and the consumer)"
- "Price, easiness of use, belief in the new technologies".

At a company level

- "Cost, the customer must be willing to pay. Another important barrier at our company is the level of standardization. Our company only design and markets products, which are at a high level of standardization"
- Most PC OEM's (component manufacturer) have turned into marketing focused distributors that rarely invest in technology innovation, choosing instead to focus on business model innovation."
- "Economic"
- "Lacking clear and consistent signals and awards from customers including public sector, innovative programs that would meaningfully award manufacturers, lack of aggregation of public sector purchasing power (e.g., across EU-25)"
- "Price, compatibility with existing software and network, ability for IT staff to support product"
- "Company regulations, skills shortage, funding/financing"
- "Financial cycle (amortization) "

- “Legacy architecture support”
- “Proprietary application portability”
- “Proof of reliability required”
- “Technical compatibility”
- “Risk of missing the market by being too late or too early (causes business disruption). Cost of upgrading/deployment/infrastructure changes/training. Need for stability/uniformity of installed base”.

At a system level

- “The PC market is a commodity market, which follows a 'waterfall' model. Typically new technologies come into the market at the highest price points and migrate over time to lower price points. There are some technologies (typically reserved for mobile uses) which will never meet desktop price points due to the tax of miniaturization”
- “Fear of adopting technology until a clear industry standard emerges (e.g. 802,11N, USB, Firewire, etc.). Lack of customer demand for new features/technology. Lack of infrastructure to support new technology (e.g. fiber optic networks/gigabit network equipment), Legal/licensing/patent uncertainties (e.g. duplicating music, CDs, using a competitors patented technology).”
- “Immature technologies”
- “Need for interoperability (globally) for hardware and software. Lack of standards/compatibility”.

Conclusion regarding barriers

The answers from stakeholders show that they think the main barriers for customers on new technologies/products are related to cost/performance. At the company level there are also much cost related thoughts, but also a fear of introducing new solution at the wrong time. The hardware must be able to harbour several different generations of software also old ones, thus there are certain limits for disruptive developments. At the system level, it seems that most producers feel a lack of standards. An interesting thing is that the answers were so similar and in agreement. Still it is of importance to notice that the answers are gathered from industry, and that there might be other barriers for new technologies/products within the society.

3.4 References

- Monitoring Home Computers [MTP Market Transformation Programme and the Energy Saving Trust AEA Technology, England, 2006] http://www.mtprog.com/ReferenceLibrary/RPICT01_06_Use_of_home_PCs_FINAL.pdf
- TECHNOLOGIES DE L'INFORMATION ET ECLAIRAGE - Campagne de mesures dans 49 ensembles de bureaux de la Région PACA [ENERTECH, France, 2005]
- Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings, prepared by TIAX LLC for U.S. Department of Energy [TIAX LLC, 2004]
- U. S. Residential Information Technology Energy Consumption in 2005 and 2010 [TIAX LLC for U.S. Department of Energy, USA, 2006]
- EEDAL'06 (International Energy Efficiency in Domestic Appliances & Lighting Conference '06 [Kurt Roth, TIAX LLC, USA, 2006]
- EEDAL'06 (International Energy Efficiency in Domestic Appliances & Lighting Conference '06 [Karine Thollier, Institut de Conseil et d'études en Développement Durable, Belgium, 2006]
- Förbättrad energistatistik för lokaler – "Stegvis STIL" Rapport för år 1 [Statens energimyndighet, Sweden, 2005]
- Sustainable Products 2006: Policy Analysis and Projections [www.mtprog.com , UK, 2006]
- Vart tar watten vägen? [Institutionen för Värme- och Kraftteknik, Lunds Tekniska Högskola, Sweden, 2003]
- Residential computer usage patterns, reuse and life cycle energy consumption in Japan [Eric Williams, United Nations University and Takuro Hatanaka, Mizuho Securities, Japan, 2005]
- Barbara Schlomann et. al. Technical and legal application possibilities of the compulsory labelling of the standby consumption of electrical household and office appliances. Fraunhofer ISI, 2005
- Energy Star energy calculator http://www.eu-energystar.org/calculator.htm
- Eurostat municipal waste http://www,defra,gov,uk/environment/statistics/waste/kf/wrkf08,htm
- Eurostat internet penetration: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NP-06-012/EN/KS-NP-06-012-EN.PDF
- European Interactive Advertising Association <http://www,eiaa,net> Women (EIAA)'s Mediascope Europe unit

- Tim Landeck [Total Cost of Ownership] http://www.thesnorkel.org/toolkit/articles/TCO_Final%20.pdf.
- Reuse IT-products, Perspicuous survey, [Bengt-Erik Svensson and Carl-Olof Andersson, Commission for El-Kretsen AB, October 2004]
- IVF Industrial Survey, 2006. Several stakeholders did answer the questionnaire from IVF during the summer 2006. Due to secrecy agreements, they are not named here, but the list covers the main players for both computers and monitors, also covering companies from Europe, the USA and Asia. The number of respondents to the questionnaire was 16.
- Telephone meeting October 2006 with Ph.D. Magnus Bergquist, ethnologist
Associate Professor
Dep. of Applied Information Technology
IT University, Göteborg
http://www.ituniv.se/
- Telephone meeting October 2006 with Catriona McAlister
ICT Product Manager
Market Transformation Programme
AEA Environment
Glengarnock Technology Centre
http://www.aeat.co.uk/
[AEA, 2006]
- Telephone meeting, October 2006 with Johan Herrlin at Stena Technoworld. http://www.stenametall.com
- ADVANCED CONFIGURATION AND POWER INTERFACE SPECIFICATION
Revision 3.0b, October 10, 2006
http://www.acpi.info/spec.htm

4 Technical analysis existing products

Task 4 consists of a technical analysis of personal computers existing on the EU-market. Bill of materials and resource consumption during all life cycle stages are presented for several product types. This analysis provides general inputs for the definition of base cases in Task 5. The methodology developed by VHK [MEEUP 2005] is followed.

The main computer manufacturers supplied the data presented. For further information about the data collection, se Appendix 1. Each data set is an average of data from several manufacturers for reasons of confidentiality and also to obtain data representative for the average situation in Europe. The averages cover a large share of the market since they were collected as the best-selling products from the major manufacturers. Originally, six different product types were identified. However, due to lack of data supply, averaged data for four product types are presented. These product types, henceforth referred to as the product cases are:

- Desktop PC, characterized by 3 GHz processor (or equivalent), built-in graphics card, 512 MB RAM and 80 GB HDD
- Laptop, characterized by mobile 1.7 GHz processor (or or equivalent), good 3-dimensional graphic performance, 15”-screen, 512 MB RAM and 60 GB HDD
- LCD display, 17”, resolution 1280*1024
- CRT display, 17”.

4.1 Production Phase

Preferably, production data should be modularized so that it is possible to distinguish between the contributions from major components. The EPIC report [EPIC-ICT, 2006] shows how a computer can be modularized in a way that is useful for the interpretation of data. This modularization was suggested to the stakeholders in a communication regarding the tentative choice of base cases in October [IVF, October 2006]. The feedback received from the stakeholders, showed that the manufacturers could not deliver data modularized the “EPIC” way. Nevertheless, it is to an extent possible to trace impacts from discrete components. See Task 5.2.

4.1.1 Components and materials assumptions

The production data or bill-of-material is the most difficult part to get right in any life cycle assessment. To obtain data that can be fed into the EuP EcoReport a questionnaire was devised, see questions 15-22 in Appendix 1.

For data not fitting the EcoReport format, assumptions presented in Appendix 1 have been used consistently in the study. The shakiest of these assumptions concerns the approximation of lithium ion batteries with *Large caps and coils.*

Concerning primary scrap production, the default value of 25% proposed in the EcoReport for primary scrap manufacture during sheet metal production was assumed for all products.

4.1.2 Bill of materials, BOM

4.1.2.1 Desktop PCs

Data derived from the summer survey [IVF survey, 2006], shown in Table 58 below, indicate that desktops for the home market varies more in weight, but that the average weight is roughly the same. From this we infer that there are no major differences in the BOM between desktops made for the two markets.

Table 58 Weights desktop PCs [IVF Summer survey 2006]

	Office desktop	**Home desktop**
Installed base 2005 in EU 25 (millions)	44	102
Average weight (kg)	9,7	11,7
Min – Max weight (kg)	8,89-11	8,4-14,6

The bill of materials for desktop PCs is shown in Table 59 . The entries are based on an average of all complete datasets received for office desktops. The bill of materials represents an average best-selling desktop computer in 2005. See Appendix 1 for more detailed information on data collection.

Table 59 Bill of materials for desktop PCs.

EuP Lot 3 prep study: Office desktop PC				MZ
Pos nr	**MATERIALS Extraction & Production Description of component**	**Weight in g**	**Category Click &select**	**Material or Process select Category first !**
1	LDPE	246	1-BlkPlastics	1-LDPE
2	ABS	381	1-BlkPlastics	10-ABS
3	PA 6	138	2-TecPlastics	11-PA 6
4	PC	264	2-TecPlastics	12-PC
5	Epoxy	98	2-TecPlastics	14-Epoxy
6	Flex PUR	2	2-TecPlastics	16-Flex PUR
7	Steel sheet galvanized	6312	3-Ferro	21-St sheet galv.
8	Steel tube/ profile	107	3-Ferro	22-St tube/profile
9	Cast iron	483	3-Ferro	23-Cast iron
10	Ferrite	0	3-Ferro	24-Ferrite
11	Stainless 18/8 coil	10	3-Ferro	25-Stainless 18/8 coil
12	Al sheet/ extrusion	315	4-Non-ferro	26-Al sheet/extrusion
13	Al diecast	15	4-Non-ferro	27-Al diecast
14	Cu winding wire	257	4-Non-ferro	28-Cu winding wire
15	Cu wire	334	4-Non-ferro	29-Cu wire
16	Cu tube/sheet	67	4-Non-ferro	30-Cu tube/sheet
17	Powder coating	2	5-Coating	39-powder coating
18	Big caps & coils	483	6-Electronics	44-big caps & coils
19	Slots /ext. Ports	310	6-Electronics	45-slots / ext. ports
20	Integrated Circuits, 5% Silicon, Au	69	6-Electronics	46-IC's avg., 5% Si, Au
21	Integrated Circuits, 1% Silicon	96	6-Electronics	47-IC's avg., 1% Si
22	SMD & LEDs avg	194	6-Electronics	48-SMD/ LED's avg.
23	PWB ½ lay 3.75 kg/m2	78	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
24	PWB 6 lay 4.5 kg/m2	163	6-Electronics	50-PWB 6 lay 4.5 kg/m2
25	Solder SnAg4Cu0.5	48	6-Electronics	52-Solder SnAg4Cu0.5
26	Cardboard	2287	7-Misc.	56-Cardboard

4.1.2.2 Laptops

Data derived from the summer survey [IVF survey, 2006], shown in Table 60 below, indicate that there are some differences in weight between laptops for the home market and office laptops. The laptop BOM presented below sums up to 2.8 kilogram and is therefore a good representation of both office and home laptops.

Table 60 Weights laptops [IVF Summer survey 2006].

	Office laptop	**Home laptop**
Installed base 2005 in EU 25 (millions)	36,5	24
Average weight (kg)	2,5	2,9
Min – Max weight (kg)	1,95 - 2,9	2,2-3,6

The battery charger or external power supply that comes as an accessory with every laptop computer is part of the bill of materials. Note that this is an overlap with the preparatory study of external power supplies, Lot 7.

The bill of materials for laptops is shown in Table 61. The last entry, *Glass for LCD*, is entered without subcategory. The reason is to avoid double counting of environmental impacts while still accounting for material inputs and maintaining a material balance. Entry 20, *LCD screen m2*, is using the unit 0.001 m2. The bill of materials represents an average best-selling laptop computer in 2005 fitted with a 15” LCD-screen. See 4.6 for more detailed information on data collection.

Table 61 Bill of materials for laptops.

Nr	Product name	Date	Author
	EuP Lot 3 prep study: Laptops		**MZ**

Pos nr	**MATERIALS Extraction & Production** Description of component	**Weight** in g	**Category** Click &select	**Material or Process** select Category first !
1	LDPE	43	1-BlkPlastics	**1-LDPE**
2	PP	4	1-BlkPlastics	**4-PP**
3	PS	3	1-BlkPlastics	**5-PS**
4	EPS	50	1-BlkPlastics	**6-EPS**
5	PVC	23	1-BlkPlastics	**8-PVC**
6	ABS	142	1-BlkPlastics	**10-ABS**
7	PA 6	281	2-TecPlastics	**11-PA 6**
8	PC	267	2-TecPlastics	**12-PC**
9	PMMA	36	2-TecPlastics	**13-PMMA**
10	Epoxy	3	2-TecPlastics	**14-Epoxy**
11	Steel sheet galvanized	489	3-Ferro	**21-St sheet galv.**
12	Al sheet/ extrusion	38	4-Non-ferro	**26-Al sheet/extrusion**
13				
14	Cu wire	60	4-Non-ferro	**29-Cu wire**
15	Cu tube/sheet	15	4-Non-ferro	**30-Cu tube/sheet**
16	MgZn5 cast	122	4-Non-ferro	**33-MgZn5 cast**
17	Powder coating		5-Coating	**39-powder coating**
18				
19				
20	LCD screen m2 (viewable screen size)	63	6-Electronics	**42-LCD per m2 scrn**
21	Big caps & coils	501	6-Electronics	**44-big caps & coils**
22	Slots /ext. Ports	133	6-Electronics	**45-slots / ext. ports**
23	Integrated Circuits, 5% Silicon, Au	47	6-Electronics	**46-IC's avg., 5% Si, Au**
24	Integrated Circuits, 1% Silicon	31	6-Electronics	**46-IC's avg., 5% Si, Au**
25	SMD & LEDs avg	50	6-Electronics	**47-IC's avg., 1% Si**
26	PWB ½ lay 3.75 kg/m2	5	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
27	PWB 6 lay 4.5 kg/m2	77	6-Electronics	**50-PWB 6 lay 4.5 kg/m2**
28	Solder SnAg4Cu0.5	7	6-Electronics	**52-Solder SnAg4Cu0.5**
29	Glass for lamps	1	7-Misc.	**54-Glass for lamps**
30	Cardboard	921	7-Misc.	**56-Cardboard**
31	Glass for LCD	362	7-Misc.	

4.1.2.3 LCD Displays

Industry did not express a need to divide the displays into home and office markets, ie the same displays are sold to both types of customers. However, since displays are used differently in offices compared to homes, it was necessary to collect market data for the two segments. Table 62 below, derived from Task 2 and the summer survey, shows the installed base and weight of 17" LCD-displays.

Table 62 Weights of LCD-displays [IVF Summer survey 2006].

	Office LCD-display	**Home LCD-display**
Installed base 2005 in EU 25 (millions)	20,5	47,5
Average weight 17” (kg)	6,2	
Min – Max weight 17” (kg)	4,0-7,0	

The bill of materials for LCD-displays is shown in Table 63. The last entry, *Misc glass*, is entered without subcategory. The reason is to avoid double counting of environmental impacts while still accounting for material inputs and maintaining a material balance. Entry 14, *LCD screen m2,* is using the unit 0.001 m2. The bill of materials represents an average best-selling LCD-display in 2005. See 4.6 for more detailed information on data collection.

Table 63 Bill of materials LCD displays.

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
EuP Lot 3 prep study: LCD displays				**MZ**
1	LDPE	164	1-BlkPlastics	1-LDPE
2	EPS	279	1-BlkPlastics	6-EPS
3	PVC	43	1-BlkPlastics	8-PVC
4	ABS	679	1-BlkPlastics	10-ABS
5	PA 6	422	2-TecPlastics	11-PA 6
6	PC	385	2-TecPlastics	12-PC
7	PMMA	153	2-TecPlastics	13-PMMA
8	E-glass fibre	120	2-TecPlastics	18-E-glass fibre
9	Aramid fibre	6,5	2-TecPlastics	19-Aramid fibre
10	Steel sheet galvanized	1854	3-Ferro	21-St sheet galv.
11	Al sheet/ extrusion	39	4-Non-ferro	26-Al sheet/extrusion
12	Cu wire	190	4-Non-ferro	29-Cu wire
13	Powder coating	1,0	5-Coating	39-powder coating
14	LCD screen m2 (viewable screen size)	91	6-Electronics	42-LCD per m2 scrn
15	Big caps & coils	41	6-Electronics	44-big caps & coils
16	Slots /ext. Ports	37	6-Electronics	45-slots / ext. ports
17	Integrated Circuits, 5% Silicon, Au	13	6-Electronics	46-IC's avg., 5% Si, Au
18	Integrated Circuits, 1% Silicon	20	6-Electronics	47-IC's avg., 1% Si
19	SMD & LEDs avg	11	6-Electronics	48-SMD/ LED's avg.
20	PWB ½ lay 3.75 kg/m2	30	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
21	PWB 6 lay 4.5 kg/m2	20	6-Electronics	50-PWB 6 lay 4.5 kg/m2
22	Solder SnAg4Cu0.5	7,6	6-Electronics	52-Solder SnAg4Cu0.5
23	Glass for lamps	26	7-Misc.	54-Glass for lamps
24	Cardboard	650	7-Misc.	56-Cardboard
25	Office paper	55	7-Misc.	57-Office paper
26	Misc glass	308	7-Misc.	
27	Cast iron	1165,0	3-Ferro	23-Cast iron

4.1.2.4 CRT Displays

Industry did not express a need to divide the displays into home and office markets, ie the same displays are sold to both types of customers. However, since displays are used differently in offices compared to homes, it was necessary to collect market data for the two segments. Table 64 below, derived from Task 2 and the summer survey, shows the installed base and weight of 17" CRT-displays[1].

[1] The reason for chosing CRT-screen size 17" is that it represents the most sold screen 2005. In actual view size it is smaller and not comparable to a 17" LCD-screen.

Table 64 Weight of CRT displays

	Office CRT-display	**Home CRT-display**
Installed base 2005 in EU 25 (millions)	24	57
Average weight 17” (kg)	16,2	
Min – Max weight 17” (kg)	15,0-17,5	

The bill of materials for CRT-displays is shown in Table 65. The last entry, *Misc glass*, is entered without subcategory. The reason is to avoid double counting of environmental impacts from the glass in the CRT while still accounting for material inputs and maintaining a material balance. Entry 10, *CRT screen m2,* is using the unit 0.001 m2. The bill of materials represents an average best-selling CRT-display in 2005. See 4.6 for more detailed information on data collection.

Table 65 Bill of materials CRT Displays.

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	EPS	165	1-BlkPlastics	6-EPS
2	PVC	44	1-BlkPlastics	8-PVC
3	ABS	1755	1-BlkPlastics	10-ABS
4	PA 6	447	2-TecPlastics	11-PA 6
5	PC	0,6	2-TecPlastics	12-PC
6	Steel sheet galvanized	126	3-Ferro	21-St sheet galv.
7	Al sheet/ extrusion	14	4-Non-ferro	26-Al sheet/extrusion
8	Cu wire	222	4-Non-ferro	29-Cu wire
9	Powder coating	6,0	5-Coating	39-powder coating
10	CRT screen m2 (nominal screen size)	90	6-Electronics	43-CRT per m2 scrn
11	Big caps & coils	38	6-Electronics	44-big caps & coils
12	Slots /ext. Ports	40	6-Electronics	45-slots / ext. ports
13	Integrated Circuits, 5% Silicon, Au	17	6-Electronics	46-IC's avg., 5% Si, Au
14	Integrated Circuits, 1% Silicon	14	6-Electronics	47-IC's avg., 1% Si
15	SMD & LEDs avg	13	6-Electronics	48-SMD/ LED's avg.
16	PWB ½ lay 3.75 kg/m2	96	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
17	PWB 6 lay 4.5 kg/m2	24	6-Electronics	50-PWB 6 lay 4.5 kg/m2
18	Solder SnAg4Cu0.5	11	6-Electronics	52-Solder SnAg4Cu0.5
19	Glass for lamps	6,5	7-Misc.	54-Glass for lamps
20	Cardboard	1880	7-Misc.	56-Cardboard
21	Office paper	280	7-Misc.	57-Office paper
22	Misc glass	11110	7-Misc.	

4.2 Distribution phase

The distribution phase is (in the EcoReport) assumed to be proportional to the volume of packaged final product in m^3. This volume was assessed by question 9 in Appendix 1. The entries, which are averages of all complete datasets received and used in respective product case, are shown in Table 66 below.

Distribution to Europe is also dependant on where in the world the product is manufactured. To account for a lot of smaller size electronics being manufactured in Asia, the question: *Is it an ICT or consumer electronics <15 kg?*, has to be answered in the EcoReport. This question was answered with YES for all product cases. A CRT actually weighs more than 15 kg, but most CRTs are today being produced in Asia.

Table 66 Volume of packaged product.

Product case	Volume of packaged product (m^3)[2]
Desktop	0,09
Laptop	0,02
LCD-display	0,04
CRT-display	0,1

4.3 Use phase (product)

Since there is no test standard that takes into account the use profile of personal computers, it is not possible to assess life-cycle impacts of PCs in standard conditions. Only the real-life base-cases according to the VHK-method [MEEUP 2005] can be assessed. However, the Energy Star programme requirements are used as much as possible to ensure that the input data for the calculations is representative.

4.3.1 Electricity measurements

Measuring computers' electricity use is problematic in three ways:

- The terminology is confusing
- Energy Star's idle measurement method was just recently defined
- There is no agreed method to measure when the computer is actually working

In this section is described how the study has dealt with these problems.

The terminology

The terminology used for computers' different operational modes is confusing. The EuP EcoReport states three "energy modes": On, stand-by and off. In Energy Star version 4.0, the corresponding modes are: idle, sleep and stand-by. In this study terms and definitions will as much as possible follow Energy Star version 4.0, see Table 67 below.

Table 67 Operational modes for personal computers.

Energy Star version 3.0	EuP EcoReport	Energy Star version 4.0	Terminology used in this study
Not measured	On	Idle	Idle
Sleep	Stand-by	Sleep (ACPI S3)	Sleep
Not measured	Off	Standby level (Off Mode) (ACPI S4 or S5)	Off[3]

[2] Averages of all complete datasets received and used in respective product case.

[3] So called soft off ie the pc is still plugged in.

Idle measurements

The major difference between the old (but still in use) Energy Star version 3.0 and the new 4.0 is that 4.0 requires measurement (and comparing with threshold limit values) of all the three modes: idle, sleep and off. With version 3.0, only the sleep mode was measured. Consequently, version 4.0 includes a test procedure that defines how the computer should enter the different operational modes and the duration of each measurement.

During 2005, before Energy Star 4.0 was available, it was more common to test for "Operational Mode" which has the following loose definition: "For PCs, this generally correlates with the ACPI S0 power consumption state. i.e. PC hard disk drive (HDD) operating, Operating System active with desktop displayed, but no other devices (drives) or software applications running". According to one producer ACPI S0 would "roughly" approximate idle power consumption for his PCs, although, there are slight differences in the definitions used. The E* 4.0 "Idle State" definition is as follows: "For purposes of testing and qualifying computers under this specification, this is the state in which the operating system and other software have completed loading, the machine is not asleep, and activity is limited to those basic applications that the system starts by default." So, the definitions are close to one another but are not exact. Therefore, these values should not be taken as 100% accurate for E*4.0 idle, but as approximations.

Because this study took place while the new Energy Star test method was being developed, not all data was derived using the new method. The possible error due to this is estimated to plus or minus 10% on the power values.

Measures of performance

As described above, the computer is not performing any work when in idle mode. The power use during work can be anything from the same (thinking about what to write) to a lot more (playing a sophisticated computer game with lots of graphics) than idle mode power. ECMA have a working group aiming at developing a universally accepted test method where energy consumption can be measured against computer performance. However, the working group has recently started, and aims at finishing their work late 2007. Their results can therefore not be used in this preparatory study [ECMA 2006].

In this study it is assumed that most of the time a computer is on, it is in idle mode. Of course this is not true, thus we know we have an error source. Also the time estimations for the different operational modes is a source of error, see task 3. Since the energy consumption is calculated as power multiplied by time, these two error sources can be examined together. The possible error due to these two error sources is estimated to plus or minus 50% on the energy consumption values. What this means to the robustness of the results is examined by sensitivity calculations in Task 8.

Only data about power consumption in the idle, sleep and off modes were asked from the manufacturers when requesting data, see questions 11-13 in Appendix 1. In the usage pattern study, Task 3, there is no differentiation between time spent in idle and active modes – both are referred as "active" mode in that task.

Displays

For displays, the situation is less complicated. Off, sleep and active mode is measured according to Energy Star Program Requirements Version 4.1, which already is effective. Active mode represents a working mode in which the performance is well defined. Luminance adjustments are stipulated in active mode.

4.3.2 Repair, service and maintenance

Repairs are fixed at 1% extra material over the life cycle in the EuP EcoReport. Interviews with computer repair shops and Information Technology Managers indicate that an average PC repair cost could amount to 125 Euro for computers, see Task 2. LCD-displays and CRT-displays are normally no longer repaired at all according to TCO [2007].

Assuming that repair transports are local and happens on average once for all units that needs repairing, a transport distance of 40 km has been inserted in the EcoReport for computers. Since monitors are no longer repaired, zero repair transport distance is inserted.

4.3.3 Annual electricity per product case

This section describes the data collection for deciding the electricity use in the different base cases. The figures, which are presented in Table 68, are selected to represent an average computer/monitor in 2005.

Table 68 Electricity use figure selected for the base cases.

Product cases ***Operational modes***	**Desktop**	**Laptop**	**LCD-screen**	**CRT-screen**
Idle (Watt)	78,2	32[4]	31,4	69,5
Sleep (Watt)	2,2	3	0,9	1,5
Off (Watt)	2,7	1,5	0,8	1,5

4.3.3.1 Desktop PCs

In the table below, data from the product case data sets are compared with data from the IVF summer survey and data from Energy Star. Both in the summer

[4] Screen on. The only available idle mode test standard, in EnergyStar 4.0, specifies testing with screen off. The figure 32,0 includes 10 Watt for the LCD-screen.

survey and for the product case data sets, data representing the best-selling computers in 2005 were asked for. The number of individual computers is less in the product case. The summer survey data indicate that desktops for the home market have a lower but more varied idle power than office desktops.

The Energy Star data comprises almost all desktops (more than 100 different models) on the market 2006, ie a year later. The values are adjusted to represent that all computers are equipped with a power supply unit with at least 80% efficiency. Note that the Energy Star data is not representing the best-selling computer. Approximately 10% of desktops in the Energy Star data are integrated computers. However, the market share of integrated computers is estimated to less than 2%. Including or not including the integrated computers in the Energy Star averages does not change the figure significantly.

Table 69 Desktop energy consumption

Data sources / ***Operational modes***	**IVF summer survey**		**Product case data sets[5]**	**Energy Star 2006 data**
	Office desktop	**Home desktop**		
Idle, Average (min – max) (Watt)	73,8 (70,5-78)	61 (50-79,7)	78,2	81,7 (23-221)
Sleep, Average (min – max) (Watt)	3,3 (1,2 - 4,2)	3,7 (2,61-5)	2,2	3,1 (10,1-1,4)
Off, Average (Watt)	1,4 (1 – 2,3)	1,4 (0,7-3)	2,7	2,0 (10,1-0,4)

The figures from the IVF summer survey and the Energy Star figures indicate that the product case figures 78.2 Watt, 2.2 Watt and 2.7 Watt constitute balanced estimates for the average 2005 desktop computer. These are the figures used in the calculations. The summer survey results indicate lower values (especially for home desktops), but the existence of a considerable white box market segment and also high-end computers, motivate using the Product case figures for the calculations. The possible error should be well within plus or minus 10%.

The use phase entries for desktop PCs used in offices are shown in Table 70 below. The energy entries are based *on an average of all complete datasets* received for desktops, see Product case in Table 69 above. The time related entries are based on Task 3.2.4.

[5] Average of all complete data sets received for this product case.

Table 70 Use phase entries for desktops used in offices.

Description	Value	Unit	Yearly [kWh]
Product Life in years	**6,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0782	kWh	178,2178
Idle-mode: No. Of hours, cycles, settings, etc. / year	2279	#	
Sleep-mode: Consumption per hour	0,0022	kWh	7,0312
Sleep-mode: No. Of hours / year	3196	#	
Off-mode: Consumption per hour	0,0027	kWh	8,8695
Off-mode: No. Of hours / year	3285	#	
TOTAL over Product Life	**1,28**	**MWh**	
Maintenance, Repairs, Service			
No. of km over Product-Life	40	km	
Spare parts (fixed, 1% of product materials & manuf.)	68	g	

The use phase entries for desktop PCs used in *homes* are shown in Table 71 below. The energy entries are based *on an average of all complete datasets* received for desktops, see Product case in Table 69 above. The time related entries are based on Task 3.2.4.

Table 71 Use phase entries for desktops used in homes.

Description	Value	Unit	Yearly [kWh]
Product Life in years	**6,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0782	kWh	123,7124
Idle-mode: No. Of hours, cycles, settings, etc. / year	1582	#	
Sleep-mode: Consumption per hour	0,0022	kWh	6,3206
Sleep-mode: No. Of hours / year	2873	#	
Off-mode: Consumption per hour	0,0027	kWh	11,6235
Off-mode: No. Of hours / year	4305	#	
TOTAL over Product Life	**0,93**	**MWh**	
Maintenance, Repairs, Service			
No. of km over Product-Life	40	km	
Spare parts (fixed, 1% of product materials & manuf.)	68	g	

4.3.3.2 Laptops

In the table below, data from the product case data sets are compared with data from the IVF summer survey and data from Energy Star. Both in the summer survey and for the product case data sets, data representing the best-selling computers in 2005 were asked for. The number of individual computers is less in the product case.

The Energy Star data comprises almost all laptops (just under 100 different models) on the market 2006, ie a year later. The values are adjusted to represent that all laptops are equipped with a power supply unit with at least 80%

efficiency. Note that the Energy Star data is not representing the best-selling computer.

Table 72 Laptop energy consumption.

Data sources / ***Operational modes***	**IVF summer survey**		**Product case data sets**[6]	**Energy Star 2006 data**
	Office laptop	**Home laptop**		
Idle, Average (min – max) (Watt)	25,7 (18-34,6)	22,6 (17-34,2)	22,0	19,5 (6,8-38,1)
Sleep, Average (min – max) (Watt)	3,2 (1,7-7,7)	2,3 (0,5-5,0)	4,9	1,4 (0,3-3,5)
Off, Average (Watt)	1,6 (0,3-3)	1,4 (0,28-3)	1,2	0,9 (0,1-2,4)

The figures from the IVF summer survey and the Energy Star figures indicate that the product case figures 22.0 Watt, 4.9 Watt and 1.2 Watt constitute balanced estimates for the average 2005 laptop. However, the idle value has to be adjusted because laptops are tested with the screen off[7]. Estimates from one producer stating that the screen takes 30% of the total energy consumed, would mean adding 9.4 Watts to the 22 Watts. TCO tests in 2005, gives an average of 16.4 Watts for 15" LCD-displays. The 16.4 Watt figure include power supply losses and screens in laptops are, according to TCO, more energy optimized than screens in LCD-displays, so the figures correspond well. 10 Watt is added to the 22 Watt idle power figure. The sleep and off mode values are also adjusted to better reflect the results of the summer survey, which had a larger sample.

Table 73 Laptop adjusted energy consumption.

Product case data sets adjusted	
Idle, Average (Watt)	32
Sleep, Average (Watt)	3
Off, Average (Watt)	1,5

The figures in Table 73 are used in the calculations. As stated in 4.3.1, the possible error should be well within plus or minus 10%. All the use phase entries for Laptops used in offices are shown in Table 74 below. The time related entries are based on the Task 3.

[6] Average of all complete data sets received for this product case.

[7] If possible, laptops should be tested with the battery packs removed. This means that losses due to battery charging are not included in the figures. It was not possible to quantify these losses within the framework of this study.

Table 74 Use phase entries for laptops used in offices.

Description	Value	Unit	Yearly [kWh]
Product Life in years	**5,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,032	kWh	83,616
Idle-mode: No. Of hours, cycles, settings, etc. / year	2613	#	
Sleep-mode: Consumption per hour	0,003	kWh	8,985
Sleep-mode: No. Of hours / year	2995	#	
Off-mode: Consumption per hour	0,0015	kWh	4,7295
Off-mode: No. Of hours / year	3153	#	
TOTAL over Product Life	**0,55**	**MWh**	
Maintenance, Repairs, Service			
No. of km over Product-Life	40	km	
Spare parts (fixed, 1% of product materials & manuf.)	38	g	

The use phase entries for laptops used in *homes* are shown in Table 75 below. The energy entries are based on the discussion above, see Table 73. The time related entries are based on the Task 3.

Table 75 Use phase entries for laptops used in homes.

Description	Value	Unit	Yearly [kWh]
Product Life in years	**5,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,032	kWh	44,416
Idle-mode: No. Of hours, cycles, settings, etc. / year	1388	#	
Sleep-mode: Consumption per hour	0,003	kWh	8,712
Sleep-mode: No. Of hours / year	2904	#	
Off-mode: Consumption per hour	0,0015	kWh	6,702
Off-mode: No. Of hours / year	4468	#	
TOTAL over Product Life	**0,34**	**MWh**	
Maintenance, Repairs, Service			
No. of km over Product-Life	40	km	
Spare parts (fixed, 1% of product materials & manuf.)	68	g	

It should be noted that the power losses in the battery charger or external power supply is included in the power figures for laptop computers. Battery chargers and external power supplies, relevant for laptops, are covered also by a separate study, lot 7, ie there is an overlap with the lot 7 study in this area. This is further discussed in Task 5.

4.3.3.3 LCD-displays

In the table below, data from the product case data sets are compared with data derived from the summer survey and data from TCO. Both in the summer survey and for the product case data sets, data representing the best-selling LCD-displays in 2005 were asked for. The number of individual displays is less in the product case. The TCO data, comprising around 100 different 17" LCD-display models, has no correlation to market share.

The reason for that the sleep and off values are almost identical is that for most models, this is today technically the same mode.

The reason for the TCO active mode figures being lower is probably that the TCO data represents a more coherent market segment from an energy perspective (the difference between minimum and maximum values are lower for the TCO data despite many more models).

Table 76 17" LCD-display energy consumption.

Data sources	**IVF summer survey**		**Product case data sets**[8]	**TCO 2005 data 17" LCD**
Operational modes	**Office LCD-display**	**Home LCD-display**		
Active, Average (min – max) (Watt)	39,9 (30-70)		31,4	25,9 (17,1-47,0)
Sleep, Average (min – max) (Watt)	1,2 (0,65-2)		0,9	1,1 (0,5-4,0)
Off, Average (Watt)	1,1 (0,65-2)		0,8	1,0 (0,5-3,0)

The figures from the IVF summer survey and the TCO figures indicate that the product case figures 31.4 Watt, 0.9 Watt and 0.8 Watt constitute balanced estimates for the average 2005 LCD-display. These are the figures used in the calculations. The figures indicate that the possible error is within plus or minus 20%.

The use phase entries for LCD-displays used in offices are shown in Table 77 below. The energy entries are based on the product case data, see Table 76 above. The time related entries are based on the Task 3.

Table 77 Use phase entries for LCD-displays used in offices.

Description	**Value**	**Unit**	**Yearly [kWh]**
Product Life in years	**6,6**	Years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0314	KWh	81,2004
Idle-mode: No. Of hours, cycles, settings, etc. / year	2586	#	
Sleep-mode: Consumption per hour	0,0009	KWh	3,4182
Sleep-mode: No. Of hours / year	3798	#	
Off-mode: Consumption per hour	0,0008	KWh	1,9
Off-mode: No. Of hours / year	2375	#	
TOTAL over Product Life	**0,57**	**MWh**	
Maintenance, Repairs, Service			
No. of km over Product-Life	0	Km	
Spare parts (fixed, 1% of product materials & manuf.)	68	g	

[8] Average of all complete data sets received for this product case.

The use phase entries for LCD-displays used in *homes* are shown in Table 78 below. The energy entries are based on the product case data, see Table 76 above. The time related entries are based on Task 3.

Table 78 Use phase entries for LCD-displays used in homes.

Description	**Value**	**Unit**	**Yearly [kWh]**
Product Life in years	**6,6**	Years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0314	KWh	40,4746
Idle-mode: No. Of hours, cycles, settings, etc. / year	1289	#	
Sleep-mode: Consumption per hour	0,0009	KWh	2,3724
Sleep-mode: No. Of hours / year	2636	#	
Off-mode: Consumption per hour	0,0008	KWh	3,868
Off-mode: No. Of hours / year	4835	#	
TOTAL over Product Life	**0,31**	**MWh**	
Maintenance, Repairs, Service			
No. Of km over Product-Life	0	Km	
Spare parts (fixed, 1% of product materials & manuf.)	68	g	

4.3.3.4 CRT-displays

In the table below, data from the product case data sets are compared with data derived from the summer survey and data from TCO. Both in the summer survey and for the product case data sets, data representing the best-selling CRT-displays in 2005 were asked for. The number of individual displays is small in all presented data. The TCO data has no correlation to market share.

Table 79 CRT-display energy consumption.

Data sources / ***Operational modes***	**IVF summer survey**		**Product case data sets**[9]	**TCO 2005 data 17" CRT**
	Office CRT-display	**Home CRT-display**		
Active, Average (min – max) (Watt)	75		69,5	60,4
Sleep, Average (min – max) (Watt)	9		1,5	2,6
Off, Average (Watt)	1		1,5	2,2

The figures from the IVF summer survey and the TCO figures indicate that the product case figures 69.5 Watt, 1.5 Watt and 1.5 Watt constitute balanced estimates for the average 2005 CRT-display. These are the figures used in the calculations. The figures indicate that the possible error is a bit more than plus or minus 10%.

The use phase entries for CRT-displays used in offices are shown in Table 80 below. The energy entries are based *on an average of all complete datasets*

[9] Average of all complete data sets received for this product case.

received for CRT-displays, see Table 79 above. The time related entries are based on Task 3.

Table 80 Use phase entries for CRT displays used in offices.

Description	**Value**	**Unit**	**Yearly** [kWh]
Product Life in years	**6,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0695	kWh	179,727
Idle-mode: No. Of hours, cycles, settings, etc. / year	2586	#	
Sleep-mode: Consumption per hour	0,0015	kWh	5,697
Sleep-mode: No. Of hours / year	3798	#	
Off-mode: Consumption per hour	0,0015	kWh	3,5625
Off-mode: No. Of hours / year	2375	#	
TOTAL over Product Life	**1,25**	**MWh**	65
Maintenance, Repairs, Service			
No. of km over Product-Life	0	km	
Spare parts (fixed, 1% of product materials & manuf.)	164	g	

The use phase entries for CRT-displays used in *homes* are shown in Table 81 below. The energy entries are based *on an average of all complete datasets* received for CRT-displays, see Table 79 above. The time related entries are based on the Task 3.

Table 81 Use phase entries for CRT-displays used in homes.

Description	**Value**	**Unit**	**Yearly** [kWh]
Product Life in years	**6,6**	years	
Electricity			
Idle-mode: Consumption per hour, cycle, setting, etc.	0,0695	kWh	89,5855
Idle-mode: No. Of hours, cycles, settings, etc. / year	1289	#	
Sleep-mode: Consumption per hour	0,0015	kWh	3,954
Sleep-mode: No. Of hours / year	2636	#	
Off-mode: Consumption per hour	0,0015	kWh	7,2525
Off-mode: No. Of hours / year	4835	#	
TOTAL over Product Life	**0,67**	**MWh**	65
Maintenance, Repairs, Service			
No. of km over Product-Life	0	km	
Spare parts (fixed, 1% of product materials & manuf.)	164	g	

4.4 Use phase (system)

Personal computers and monitors operate in many different systems. Below follows a discussion of the more frequent systems. *The conclusion is that a calculation of PCs' effects on systems larger than the PC itself is not relevant in the context of this study.*

To limit the systems analysis the EIPRO study [2006] is used to focus the analysis to the three areas having the greatest environmental impact according to this study. The three areas are:

- food and drink
- private transport
- housing.

Together these areas are responsible for 70 – 80% of the environmental impact of consumption, and account for some 60% of consumption expenditure. In theory, also the environmental impacts from B2B consumption are included indirectly, thus the three product areas should account for about the same percentage of the total environmental impact in society.

Below, the PCs interaction and influence on the three product areas above is described and discussed. It is concluded that environmentally significant PC system aspects in the short term is the influence on room heating, where the PC can be anything from a rather poor heating device to causing a 30% extra energy use because of cooling needs. In the longer term PCs possible influences on travel and transport patterns may well prove significant. However, it is hard to see that any of these system aspects should have an impact on the design of computers other than further accentuating the need to minimize the energy use. It may also be argued that PCs have a large potential for helping us to save energy when used for controlling different systems, for example, the heating system of a building. But that aspect is outside the scope of this study.

4.4.1 Housing

The energy used in a computer is dissipated as heat. Sometimes this heat can be utilized, for example in housing heat exchange systems. Other times the dissipated heat is just causing some extra comfort or discomfort before it is ventilated out and lost. Particularly in offices, the heat is often cooled down, thus causing extra energy losses. So, in a systems perspective including the home or the office where the computer is standing, the electricity used by the computer could during favourable conditions theoretically lead to an equivalent decrease of the energy needed to heat the house or the office. In a systems perspective the energy for the computer could then be regarded as zero. During unfavorable conditions, the waste heat from the computer needs to be cooled down. Modern air-conditioning equipment is quite efficient so only a third of the input energy is needed[10], thus in a systems perspective 1.3 times the computers energy use needs to be put into the system.

To sum up: when the building in which the computer is standing is included in the system, the extra energy for the computer could be anything between 0 to 1.3 times the computers energy requirements. Parameters influencing the size of the multiplication factor are among other:

[10] EnergyStar Energy calculator at www.eu-energystar.org

- Having a heating system is a must for factors below 1. In many European countries, central heating systems are still quite rare.
- Having a heat exchanger for the ventilation air is a must for factors close to zero. Passive heating systems have much less ability to utilize waste heat.
- Having a modern heat pump where you for every kWh in get 4-5 kWh out would also drive the factor close to 1. In such a system, the computer becomes an extremely inefficient heater.
- Having a cooling system is a must for factors above 1. Air-conditioning in private homes is still quite rare in most European countries. In offices, air-conditioning is almost standard today.
- The outdoor temperature decides if you are cooling (factor 1.3) or heating (factor 0-1) or neither (factor 1). The world average global temperature is predicted to increase 2-6 degrees during this century.

There are no studies of the utilization of dissipated heat from electrical appliances in buildings in EU-25. It is hardly relevant to guess at what the average factor for computers would be. Maybe one could conclude from the above that the computer is at best a very poor heating device. At worst the computer causes 30% more energy use than what it consumes itself.

It could be more fruitful to turn the question around. How should are cooling and heating systems be designed to best utilize/cope with the waste heat from PCs and other electrical appliances that we fill our homes and offices with? The benefit of having heat exchanging on the ventilation air is mentioned above. Providing district cooling in combination with district heating is another example of smart utilization of computer waste heat.

4.4.2 Transport

PCs with Internet connection can influence travel habits by making it easier for people to work at home, shop from home, enabling virtual meetings etc. It is true that none of the potential to decrease travelling has yet materialized[11]. However, if PCs are going to lead to increased or decreased travel depends probably more on other factors such as fuel shortage, global warming etc, than the development of PC technology and falls therefore outside the scope of this study.

A more direct influence of PCs on the environmental impacts when travelling is the weight of portable PCs like laptops. To assess this effect we assume that an extra impact will only occur when traveling by road. Rail traffic is more volume than weight dependent and for air travel it is unlikely that the laptop would contribute to any difference in the luggage weight because of so called rebound effects, ie people would carry close to maximum weight regardless if they bring their notebook or not.

[11] This far it is probably the case that globalisation and the information technology has increased our far away contacts and thus led to an increased travelling.

One model often used [Earthscan 2004] is to assume that 30% of the fuel consumption of a road vehicle relates to weight. Assuming 0.1 l/km and 2000 kg total weight this would equate to 0.3/2000*0.1=0.015 ml fuel per km and kg. Assuming that a laptop travels 50000 km during its 5.6 years of lifetime, it would mean causing 0.015*50000*2.4 kg=1.8 litres of fuel which is roughly equal to 18 kWh. This should be compared to the 550 kWh electricity consumed by an office laptop during its lifetime.

4.4.3 Food and drink

It is hard to see any systems where PCs influence what we drink and eat. But PCs could possibly mean a lot to the way we bring home our food and drink as discussed above.

4.5 End-of-life phase

Post Weee conditions means at least 75% recycling of which maximum 10% energy recycling. Data from producers and recycling companies, see Task 3, indicate that the recycling potential of PCs and monitors exceed the 75% goal by far and is in the same order as the default entries in the EcoReport, ie, 95% recycling and 5% landfill. Therefore, for disposal/recycling, the default entries of the EcoReport tool are assumed for all the product cases, see Table 82 below.

The question: PWB easy to disassemble is answered with YES in all product cases. In desktops and laptops, the motherboard, the main printed circuit assembly can be taken out and inserted even by laymen. In monitors the main printed circuit assembly can normally be taken out without tools after opening the encasement according to TCO [2007].

Table 82 Default entries for Disposal & recycling of the EcoReport tool.

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	0	5%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	0	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	0	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	0	1%	4
235	Plastics: Materials Recycling (please edit% only)	0	9%	4
236	Plastics: Thermal Recycling (please edit% only)	0	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	0		fixed

4.6 References

- Advanced Configuration and Power Interface Specification. ACPI. Hewlett-Packard Corporation, Intel Corporation, Microsoft Corporation. Phoenix Technologies Ltd. Toshiba Corporation. Revision 3.0b October 10, 2006
- Battery chargers and external power supplies. Draft final report. Task 5: Definition of base-case. November 27, 2006.
- Communication regarding tentative choice of base-cases and provision of data. 17 October 2006.
- Communications with Lars Waller at TCO in 2007.
- Computer Memorandum of Understanding (Version 3.0) between The United States Environmental Protection Agency
- Energy Star® Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1)
- Energy Star® Program Requirements for Computers: Final Draft Version 4.0.
- Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. May 2006 Technical Report EUR 22284 EN
- EPIC-ICT. Development of Environmental Performance Indicators for ICT Products on the example of Personal Computers. Draft January 2006. “Data needs and data collection, Generic Modules, Environmental impacts, Impact assessment and weighting, Environmental interpretation and evaluation”
- IVF Industrial Survey, 2006. Several stakeholders did answer the questionnaire from IVF during the summer 2006. Due to secrecy agreements, they are not named here, but the list covers the main players for both computers and monitors, also covering companies from Europe, the USA and Asia. The number of respondents to the questionnaire was 16.
- MEEUP Methodology Report. Final Report. Methodology Study Ecodesign of Energy-using Products. 28.11.2005. VHK for European Commission. Available at http://www.vhk.nl/
- Request for provision of LCA data. IVF communication to stakeholders 11 November 2006.
- Stakeholder meeting at IVF in Mölndal, Sweden 30 May 2006 .
- Telephone call with Silvio Weeren ECMA September 2006
- WEEE Directive for Waste of Electric and Electronic Equipment 2002/96/EEC (february 2003)
- Zackrisson et al. Measuring your Company´s Environmental Impact. Earthscan 2004.

5 Definition of base-case

The base-cases calculations serve dual purposes: one is to assess the total energy consumption and environmental impact in EU25 from personal computers and monitors in 2005, the other is to give knowledge about design options that could reduce the environmental impact with focus on energy consumption.

The base-cases presented are based on the product cases in Task 4. This means four products: desktops, laptops, CRT displays and LCD displays. The usage pattern has a large influence on the results and on the improvement options available. Therefore, the environmental impact from each product is calculated with two usage patterns (representing home and office use) giving in total eight different base-cases.

5.1 Product-specific inputs

The bill of materials for desktops, laptops, CRT displays and LCD displays are presented in Task 4.1.2. The bills of materials include packaging materials.

The methodology developed by VHK (MEEUP 2005) is followed, which means using the EcoReport tool. The 25% steel scrap rate during manufacturing proposed by the EcoReport tool was assumed for all base-case calculations.

The EcoReport tool calculates the impact from distribution as proportional to the volume of packaged product. The volumes in Table 83 were used for the calculations. The total weight including packaging is also presented in the table. This weight is equal to the sum of the bill of materials.

Table 83 Volumes and weights

Product case	**Desktops**	**Laptops**	**LCD displays**	**CRT displays**
Packaged volume (m3)	0,09	0,02	0,04	0,1
Weight incl. packaging (kg)	12,8	3,7	6,7	16,3
Weight excl. packaging (kg)	10,5	2,8	6,0	14,1

There are no test standards to facilitate calculation of annual resource consumption, thus a EU standard base-case is not relevant. For the real-life situation, the usage pattern and the electricity consumption during the different usage modes are crucial. Please refer to Task 4.3 for the figures used. In addition, 40 km of transport in connection to repairs and maintenance was assumed for the calculations of the use phase impacts for desktops and laptops. No repairs are assumed for monitors, hence no transports for repairs. The EcoReport tool further assumes 1% of the bill of materials as spare parts during the use phase. This is a reasonable assumption for laptops and desktops because they are repaired, see 4.3.2 for a discussion on cost of repairs. For monitors, which are normally not repaired, the assumption introduces a systematic error in the use phase. The magnitude of this error is equal to 1% of the production phase.

For the disposal/ recycling phase, the default entries of the EcoReport tool were assumed as most likely for all the product cases. See Task 4.5.

5.2 Base-case environmental impact assessment

The base-case environmental impact assessments are carried out for products sold in 2005. As described in Task 4, the base-cases are chosen to represent an average computer or monitor in 2005.

The EcoReport tool delivers the results in the form of eleven impact categories, which are not comparable with each other. This means that to be really sure about that something is "environmentally" better or not, all eleven[12] impact categories have to point in the same direction. This is rarely the case when trying to compare eg environmental aspects in different life cycle stages. The analysis will therefore be limited to discussions on individual impact categories. Note that in Appendix 1, the production phase impacts are given in more detail. Energy related impact categories, like greenhouse gases, acidifying emissions etc are referred to as energy when it is obvious that energy use is the cause, like in the use phase of PCs and monitors.

5.2.1 Desktops in offices

Table 84 show the life cycle environmental impacts of a desktop personal computer used in an office. In Appendix 2, the environmental impacts for the production phase are shown in detail.

[12] Since Persistent Organic Pollutants and Ozone Depletion emissions are always negligble, there are in reality only nine impact categories to consider.

Table 84 Environmental impacts overview for a Desktop PC used in an office.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: Office desktop PC	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**627**			564	63	**627**	**0**
2	TecPlastics	g			**501**			451	50	**501**	**0**
3	Ferro	g			**6911**			346	6565	**6911**	**0**
4	Non-ferro	g			**987**			49	937	**987**	**0**
5	Coating	g			**2**			0	2	**2**	**0**
6	Electronics	g			**1439**			767	672	**1439**	**0**
7	Misc.	g			**2287**			114	2172	**2287**	**0**
	Total weight	g			**12753**			2292	10461	**12753**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1917	341	**2259**	**368**	**13571**	158	191	**-33**	**16165**
9	of which, electricity (in primary MJ)	MJ	1090	102	**1192**	**0**	**13464**	0	78	**-78**	**14578**
10	Water (process)	ltr	749	17	**766**	**0**	**904**	0	71	**-71**	**1600**
11	Water (cooling)	ltr	309	90	399	0	35877	0	17	-17	36260
12	Waste, non-haz./ landfill	g	27328	911	**28239**	**204**	**15880**	782	227	**555**	**44877**
13	Waste, hazardous/ incinerated	g	574	6	**580**	**4**	**316**	1687	88	**1599**	**2499**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	117	21	**138**	**28**	**596**	12	13	**-1**	**761**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	1072	107	**1179**	**94**	**3483**	23	67	**-43**	**4713**
17	Volatile Organic Compounds (VOC)	g	8	4	**12**	**4**	**7**	0	1	**-1**	**22**
18	Persistent Organic Pollutants (POP)	ng i-Teq	183	18	**201**	**1**	**90**	5	1	**5**	**297**
19	Heavy Metals	mg Ni eq.	221	43	**265**	**10**	**254**	43	10	**33**	**563**
	PAHs	mg Ni eq.	139	3	**142**	**7**	**49**	0	8	**-8**	**190**
20	Particulate Matter (PM, dust)	g	81	27	**108**	**101**	**428**	203	3	**200**	**837**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	407	1	**408**	**0**	**91**	13	45	**-32**	**467**
22	Eutrophication	g PO4	7	1	**8**	**0**	**0**	1	1	**0**	**9**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Based on the figure above and Appendix 2, the following conclusions are drawn:

- In the use phase, about six times more energy is used than in any other phase. Minimizing energy use during the use phase is therefore an obvious improvement area.
- In the production phase: integrated circuits, surface mounted devices, big caps and coils, PWB manufacturing, sheet metal manufacturing and galvanized steel dominate most impact categories, see Appendix 2. This indicates that the motherboard including the processor, the power supply and the steel casing also are relevant improvement areas.

5.2.2 Desktops at home

Table 85 shows the life cycle environmental impacts of a desktop personal computer used at home. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 85 Environmental impacts overview for a Desktop PC used at home.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: Home desktop PC	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**627**			564	63	**627**	**0**
2	TecPlastics	g			**501**			451	50	**501**	**0**
3	Ferro	g			**6911**			346	6565	**6911**	**0**
4	Non-ferro	g			**987**			49	937	**987**	**0**
5	Coating	g			**2**			0	2	**2**	**0**
6	Electronics	g			**1439**			767	672	**1439**	**0**
7	Misc.	g			**2287**			114	2172	**2287**	**0**
	Total weight	g			**12753**			2292	10461	**12753**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1917	341	**2259**	**368**	**9936**	158	191	**-33**	**12529**
9	of which, electricity (in primary MJ)	MJ	1090	102	**1192**	**0**	**9829**	0	78	**-78**	**10942**
10	Water (process)	ltr	749	17	**766**	**0**	**662**	0	71	**-71**	**1357**
11	Water (cooling)	ltr	309	90	**399**	**0**	**26182**	0	17	**-17**	**26565**
12	Waste, non-haz./ landfill	g	27328	911	**28239**	**204**	**11664**	782	227	**555**	**40662**
13	Waste, hazardous/ incinerated	g	574	6	**580**	**4**	**232**	1687	88	**1599**	**2415**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	117	21	**138**	**28**	**437**	12	13	**-1**	**603**
15	Ozone Depletion, emissions	mg R-11 ec				negligible					
16	Acidification, emissions	g SO2 eq.	1072	107	**1179**	**94**	**2547**	23	67	**-43**	**3777**
17	Volatile Organic Compounds (VOC)	g	8	4	**12**	**4**	**5**	0	1	**-1**	**21**
18	Persistent Organic Pollutants (POP)	ng i-Teq	183	18	**201**	**1**	**66**	5	1	**5**	**273**
19	Heavy Metals	mg Ni eq.	221	43	**265**	**10**	**192**	43	10	**33**	**500**
	PAHs	mg Ni eq.	139	3	**142**	**7**	**42**	0	8	**-8**	**183**
20	Particulate Matter (PM, dust)	g	81	27	**108**	**101**	**408**	203	3	**200**	**817**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	407	1	**408**	**0**	**67**	13	45	**-32**	**444**
22	Eutrophication	g PO4	7	1	**8**	**0**	**0**	1	1	**0**	**9**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

The focus areas for improvements are the same as for desktops used in offices, although the use phase energy use is a bit less than in office desktops. The solutions may differ because of the different ways of using computers in homes versus offices.

5.2.3 Laptops in offices

Table 86 show the life cycle environmental impacts of a laptop personal computer used in an office. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 86 Environmental impacts overview for a laptop used in an office.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: Laptop in office	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**265**			239	27	**265**	**0**
2	TecPlastics	g			**587**			528	59	**587**	**0**
3	Ferro	g			**489**			24	465	**489**	**0**
4	Non-ferro	g			**235**			12	223	**235**	**0**
5	Coating	g			**5**			0	5	**5**	**0**
6	Electronics	g			**914**			514	400	**914**	**0**
7	Misc.	g			**1284**			64	1220	**1284**	**0**
	Total weight	g			**3779**			1381	2398	**3779**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1118	148	**1266**	**122**	**5832**	92	112	**-20**	**7200**
9	of which, electricity (in primary MJ)	MJ	630	30	**660**	**0**	**5730**	0	47	**-47**	**6343**
10	Water (process)	ltr	522	10	**532**	**0**	**387**	0	42	**-42**	**877**
11	Water (cooling)	ltr	249	41	**290**	**0**	**15264**	0	10	**-10**	**15544**
12	Waste, non-haz./ landfill	g	4231	247	**4478**	**85**	**6680**	232	136	**96**	**11340**
13	Waste, hazardous/ incinerated	g	229	3	**232**	**2**	**134**	1167	52	**1114**	**1482**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	71	9	**81**	**10**	**258**	7	8	**-1**	**348**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	445	50	**495**	**30**	**1486**	14	40	**-26**	**1985**
17	Volatile Organic Compounds (VOC)	g	6	2	**8**	**1**	**4**	0	1	**0**	**12**
18	Persistent Organic Pollutants (POP)	ng i-Teq	23	2	**24**	**0**	**38**	2	1	**1**	**64**
19	Heavy Metals	mg Ni eq.	65	4	**69**	**4**	**120**	25	6	**19**	**212**
	PAHs	mg Ni eq.	119	2	**121**	**4**	**33**	0	5	**-5**	**153**
20	Particulate Matter (PM, dust)	g	37	14	**51**	**23**	**385**	118	2	**116**	**574**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	369	0	**369**	**0**	**41**	8	27	**-19**	**391**
22	Eutrophication	g PO4	4	1	**5**	**0**	**0**	0	0	**0**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Based on the figure above and Appendix 2, the following conclusions are drawn:

- In the use phase, about five times more energy is used than in any other phase. Minimizing energy use during the use phase is therefore an obvious improvement area.
- In the production phase: integrated circuits, PWB and PWB manufacturing and big caps and coils dominate many impact categories, see Appendix 2.

This indicates that the motherboard including the processor and the battery also are relevant improvement areas. Since the lithium ion battery was approximated to big caps and coils, which was the least bad assumption available, this improvement area needs further validation.

- Care must be exercised so that increasing impacts in the production phase, eg by improving the processor, does not offset improvements in the use phase.

5.2.4 Laptops at home

Table 87 shows the life cycle environmental impacts of a laptop personal computer used at home. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 87 Environmental impacts overview for a laptop used at home.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: Laptops at home	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**265**			239	27	**265**	**0**
2	TecPlastics	g			**587**			528	59	**587**	**0**
3	Ferro	g			**489**			24	465	**489**	**0**
4	Non-ferro	g			**235**			12	223	**235**	**0**
5	Coating	g			**5**			0	5	**5**	**0**
6	Electronics	g			**914**			514	400	**914**	**0**
7	Misc.	g			**1284**			64	1220	**1284**	**0**
	Total weight	g			**3779**			1381	2398	**3779**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1118	148	**1266**	**122**	**3627**	92	112	**-20**	**4995**
9	of which, electricity (in primary MJ)	MJ	630	30	**660**	**0**	**3525**	0	47	**-47**	**4138**
10	Water (process)	ltr	522	10	**532**	**0**	**240**	0	42	**-42**	**730**
11	Water (cooling)	ltr	249	41	**290**	**0**	**9384**	0	10	**-10**	**9664**
12	Waste, non-haz./ landfill	g	4231	247	**4478**	**85**	**4124**	232	136	**96**	**8783**
13	Waste, hazardous/ incinerated	g	229	3	**232**	**2**	**83**	1167	52	**1114**	**1432**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	71	9	**81**	**10**	**162**	7	8	**-1**	**251**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	445	50	**495**	**30**	**918**	14	40	**-26**	**1418**
17	Volatile Organic Compounds (VOC)	g	6	2	**8**	**1**	**3**	0	1	**0**	**12**
18	Persistent Organic Pollutants (POP)	ng i-Teq	23	2	**24**	**0**	**23**	2	1	**1**	**49**
19	Heavy Metals	mg Ni eq.	65	4	**69**	**4**	**82**	25	6	**19**	**174**
	PAHs	mg Ni eq.	119	2	**121**	**4**	**29**	0	5	**-5**	**148**
20	Particulate Matter (PM, dust)	g	37	14	**51**	**23**	**373**	118	2	**116**	**562**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	369	0	**369**	**0**	**26**	8	27	**-19**	**377**
22	Eutrophication	g PO4	4	1	**5**	**0**	**0**	0	0	**0**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

The focus areas for improvements are the same as for laptops used in offices. However, the solutions may differ because of the different ways of using computers in homes versus offices. Note that there is less difference between use phase energy and production phase energy (a factor 3) compared to office laptops. Even more care must therefore be exercised so that increasing impacts in the production phase does not offset improvements in the use phase.

5.2.5 LCD-displays in offices

Table 88 shows the life cycle environmental impacts of a LCD-display used in an office. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 88 Environmental impacts overview for a LCD-display used in an office.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: LCD display in office	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**1165**			1048	116	**1165**	**0**
2	TecPlastics	g			**1086**			977	109	**1086**	**0**
3	Ferro	g			**3019**			151	2868	**3019**	**0**
4	Non-ferro	g			**229**			11	217	**229**	**0**
5	Coating	g			**1**			0	1	**1**	**0**
6	Electronics	g			**270**			191	79	**270**	**0**
7	Misc.	g			**1038**			52	986	**1038**	**0**
	Total weight	g			**6808**			2431	4377	**6808**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	836	149	**985**	**192**	**6006**	166	118	**48**	**7231**
9	of which, electricity (in primary MJ)	MJ	364	77	**441**	**0**	**6000**	0	10	**-10**	**6431**
10	Water (process)	ltr	151	3	**154**	**0**	**401**	0	9	**-9**	**546**
11	Water (cooling)	ltr	434	41	**475**	**0**	**15993**	0	6	**-6**	**16462**
12	Waste, non-haz./ landfill	g	8165	488	**8653**	**119**	**7038**	418	30	**388**	**16199**
13	Waste, hazardous/ incinerated	g	130	1	**130**	**2**	**139**	2105	11	**2094**	**2366**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	46	9	**55**	**15**	**262**	12	8	**4**	**336**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	235	39	**274**	**48**	**1547**	25	16	**8**	**1878**
17	Volatile Organic Compounds (VOC)	g	2	1	**2**	**2**	**2**	0	0	**0**	**6**
18	Persistent Organic Pollutants (POP)	ng i-Teq	57	5	**63**	**1**	**40**	3	0	**3**	**106**
19	Heavy Metals	mg Ni eq.	38	12	**50**	**6**	**103**	45	1	**44**	**203**
	PAHs	mg Ni eq.	33	0	**33**	**5**	**12**	0	1	**-1**	**49**
20	Particulate Matter (PM, dust)	g	37	7	**44**	**45**	**33**	215	1	**215**	**338**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	112	0	**112**	**0**	**40**	14	5	**9**	**161**
22	Eutrophication	g PO4	4	0	**4**	**0**	**0**	1	0	**1**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Based on the figure above and Appendix 2, the following conclusions are drawn:

- In the use phase, about six times more energy is used than in any other phase. Minimizing energy use during the use phase is therefore an obvious improvement area.
- In the production phase: Cu-wire, integrated circuits, galvanized steel and polyamid dominate many impact categories, see Appendix 2.

5.2.6 LCD-displays at home

Table 89 shows the life cycle environmental impacts of a LCD-display used at home. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 89 Environmental impacts overview for a LCD-display used at home.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: LCD display at home	0	MZ

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**1165**			1048	116	**1165**	**0**
2	TecPlastics	g			**1086**			977	109	**1086**	**0**
3	Ferro	g			**3019**			151	2868	**3019**	**0**
4	Non-ferro	g			**229**			11	217	**229**	**0**
5	Coating	g			**1**			0	1	**1**	**0**
6	Electronics	g			**270**			191	79	**270**	**0**
7	Misc.	g			**1038**			52	986	**1038**	**0**
	Total weight	g			**6808**			2431	4377	**6808**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	836	149	**985**	**192**	**3247**	166	118	**48**	**4473**
9	of which, electricity (in primary MJ)	MJ	364	77	**441**	**0**	**3242**	0	10	**-10**	**3672**
10	Water (process)	ltr	151	3	**154**	**0**	**217**	0	9	**-9**	**363**
11	Water (cooling)	ltr	434	41	475	0	8638	0	6	-6	9106
12	Waste, non-haz./ landfill	g	8165	488	**8653**	**119**	**3840**	418	30	**388**	**13000**
13	Waste, hazardous/ incinerated	g	130	1	**130**	**2**	**76**	2105	11	**2094**	**2303**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	46	9	**55**	**15**	**142**	12	8	**4**	**216**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	235	39	**274**	**48**	**836**	25	16	**8**	**1167**
17	Volatile Organic Compounds (VOC)	g	2	1	**2**	**2**	**1**	0	0	**0**	**5**
18	Persistent Organic Pollutants (POP)	ng i-Teq	57	5	**63**	**1**	**22**	3	0	**3**	**88**
19	Heavy Metals	mg Ni eq.	38	12	**50**	**6**	**56**	45	1	**44**	**156**
	PAHs	mg Ni eq.	33	0	**33**	**5**	**7**	0	1	**-1**	**43**
20	Particulate Matter (PM, dust)	g	37	7	**44**	**45**	**18**	215	1	**215**	**322**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	112	0	**112**	**0**	**22**	14	5	**9**	**143**
22	Eutrophication	g PO4	4	0	**4**	**0**	**0**	1	0	**1**	**5**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

The focus areas for improvements are the same as for LCD-display used in offices. However, the solutions may differ because of the different ways of using monitors in homes versus offices.

5.2.7 CRT-displays in offices

Table 90 shows the life cycle environmental impacts of a CRT-display used in an office. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 90 Environmental impacts overview for a CRT-display used in an office.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: CRT in office	0	MZ

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**1964**			1767	196	**1964**	**0**
2	TecPlastics	g			**448**			403	45	**448**	**0**
3	Ferro	g			**126**			6	120	**126**	**0**
4	Non-ferro	g			**236**			12	224	**236**	**0**
5	Coating	g			**6**			0	6	**6**	**0**
6	Electronics	g			**341**			222	119	**341**	**0**
7	Misc.	g			**13276**			664	12612	**13276**	**0**
	Total weight	g			**16397**			3075	13322	**16397**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	824	132	**956**	**404**	**13106**	212	162	**50**	**14515**
9	of which, electricity (in primary MJ)	MJ	377	62	**439**	**0**	**13101**	0	15	**-15**	**13525**
10	Water (process)	ltr	224	4	**227**	**0**	**875**	0	13	**-13**	**1090**
11	Water (cooling)	ltr	445	37	482	0	34930	0	8	-8	35404
12	Waste, non-haz./ landfill	g	5843	347	**6190**	**221**	**15247**	1006	43	**962**	**22620**
13	Waste, hazardous/ incinerated	g	258	1	**259**	**4**	**304**	2289	16	**2273**	**2841**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	42	8	**50**	**31**	**572**	16	11	**5**	**657**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	342	36	**378**	**103**	**3376**	32	23	**8**	**3865**
17	Volatile Organic Compounds (VOC)	g	74	1	**75**	**4**	**6**	1	0	**0**	**85**
18	Persistent Organic Pollutants (POP)	ng i-Teq	7	0	**8**	**1**	**86**	7	0	**7**	**102**
19	Heavy Metals	mg Ni eq.	119	1	**120**	**11**	**226**	58	2	**56**	**414**
	PAHs	mg Ni eq.	25	1	**25**	**8**	**26**	0	1	**-1**	**58**
20	Particulate Matter (PM, dust)	g	270	7	**277**	**112**	**75**	274	1	**273**	**737**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	121	0	**121**	**0**	**86**	18	8	**10**	**217**
22	Eutrophication	g PO4	5	0	**5**	**0**	**0**	1	0	**1**	**6**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Based on the figure above and Appendix 2, the following conclusions are drawn:

- In the use phase, about thirteen times more energy is used than in any other phase. Minimizing energy use during the use phase is therefore an obvious improvement area, if this product is going to remain in the market
- In the production phase: the CRT screen and integrated circuits dominate many impact categories, see Appendix 2. This indicates that the CRT screen and printed circuit assemblies are focus areas for improvements

5.2.8 CRT-displays at home

Table 91 shows the life cycle environmental impacts of a CRT-display used at home. In Appendix 2, the environmental impacts for the production phase are shown in detail.

Table 91 Environmental impacts overview for a CRT-display used at home.

Nr	Life cycle Impact per product:	Date	Author
0	EuP Lot 3 prep study: CRT at home	0	MZ

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**1964**			1767	196	**1964**	**0**
2	TecPlastics	g			**448**			403	45	**448**	**0**
3	Ferro	g			**126**			6	120	**126**	**0**
4	Non-ferro	g			**236**			12	224	**236**	**0**
5	Coating	g			**6**			0	6	**6**	**0**
6	Electronics	g			**341**			222	119	**341**	**0**
7	Misc.	g			**13276**			664	12612	**13276**	**0**
	Total weight	g			**16397**			3075	13322	**16397**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	824	132	**956**	**404**	**6994**	212	162	**50**	**8403**
9	of which, electricity (in primary MJ)	MJ	377	62	**439**	**0**	**6989**	0	15	**-15**	**7413**
10	Water (process)	ltr	224	4	**227**	**0**	**468**	0	13	**-13**	**682**
11	Water (cooling)	ltr	445	37	**482**	**0**	**18631**	0	8	**-8**	**19105**
12	Waste, non-haz./ landfill	g	5843	347	**6190**	**221**	**8160**	1006	43	**962**	**15534**
13	Waste, hazardous/ incinerated	g	258	1	**259**	**4**	**164**	2289	16	**2273**	**2700**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	42	8	**50**	**31**	**305**	16	11	**5**	**390**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	342	36	**378**	**103**	**1802**	32	23	**8**	**2291**
17	Volatile Organic Compounds (VOC)	g	74	1	**75**	**4**	**3**	1	0	**0**	**83**
18	Persistent Organic Pollutants (POP)	ng i-Teq	7	0	**8**	**1**	**46**	7	0	**7**	**62**
19	Heavy Metals	mg Ni eq.	119	1	**120**	**11**	**121**	58	2	**56**	**309**
	PAHs	mg Ni eq.	25	1	**25**	**8**	**14**	0	1	**-1**	**46**
20	Particulate Matter (PM, dust)	g	270	7	**277**	**112**	**41**	274	1	**273**	**704**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	121	0	**121**	**0**	**46**	18	8	**10**	**177**
22	Eutrophication	g PO4	5	0	**5**	**0**	**0**	1	0	**1**	**6**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

The focus areas for improvements are the same as for CRT-display used in offices. However, the solutions may differ because of the different ways of using monitors in homes versus offices.

5.3 Base-case life cycle costs

The input figures in Table 92 were used for the calculations of life cycle costs and EU totals.

Table 92 Input figures for LCC and EU totals.

Description / Base-case	**Desktop office**	**Desktop home**	**Laptop office**	**Laptop home**	**LCD office**	**LCD home**	**CRT office**	**CRT home**	**Total**
Product life (years)	6,6	6,6	5,6	5,6	6,6	6,6	6,6	6,6	
Annual sales (mln. units/year)	8,4	19,6	12	8	7,8	18,2	1,2	2,8	78
EU Stock 2005 (mln. Units)	44,0	102	36,5	24	20,5	47,5	24	57	355,5
Product price (Euro/unit)	620	520	1242	990	201	201	73	73	
Electricity rate (Euro/kWh)	0,136	0,136	0,136	0,136	0,136	0,136	0,136	0,136	
Repair & mainten. (Euro/unit)	125	125	125	125	0	0	0	0	
Discount rate (%)	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	
Present Worth Factor (years)	6,17	6,17	5,28	5,28	6,17	6,17	6,17	6,17	
Overall Improvem. Ratio	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	

The product life and repair & maintenance costs are from Task 4.3.2

Annual sales, EU stock, the electricity price and the discount rate are from Task 2. The EcoReport calculates the Present worth factor automatically. Product price is the average price of the computers and monitors from the summer survey, see Task 2. Value added tax is not added because discounts in the same order of magnitude are very frequent.

The overall improvement ratio is left at the default value 1,0. This means that in the model, there was no significant change in the energy consumption of PCs and monitors between 2002 and 2005.

The Life cycle costs per product are presented in Table 93 below. In Table 94, the life cycle cost per product is aggregated to EU-25 level using sales in 2005.

Table 93 Life cycle costs per product.

Description / Base-case	**Desktop office**	**Desktop home**	**Laptop office**	**Laptop home**	**LCD office**	**LCD home**	**CRT office**	**CRT home**
Product price (Euro)	620	520	1242	990	201	201	73	73
Electricity (Euro)	163	119	70	43	73	39	159	85
Repair & maintenance (Euro)	117	117	117	117	0	0	0	0
Life cycle cost 2005 (Euro)	900	756	1430	1151	274	240	232	158

For desktops and laptops the total life cycle cost is dominated by product price. However, for all product categories, the life cycle electricity cost is between 40-160 Euro. The life cycle cost of electricity is an indicator how much can be spent on energy-saving measures from an economical perspective.

Table 94 Total annual expenditure for all products sold in 2005 in EU-25.

Description / Base-case	**Desktop office**	**Desktop home**	**Laptop office**	**Laptop home**	**LCD office**	**LCD home**	**CRT office**	**CRT home**	**Total**
Product (mln Euro)	5208	10192	14904	7920	1568	3658	88	204	43742
Electricity (mln Euro)	1162	1965	483	195	241	302	617	781	5746
Repair & maintenance (mln Euro)	833	1932	815	536	0	0	0	0	4116
Total annual LCC in EU-25 (mln Euro)	7203	14089	16202	8651	1809	3960	704	986	53604

5.4 EU Totals

EU totals are calculated in two ways: One is based on the computers manufactured and sold in 2005. The total environmental impact in EU-25 in 2005 from the computers sold that year is multiplied by the expected product life, see Table 95. The other way of calculating is based on the installed stock of PCs and monitors in 2005, see Table 96.

*Table 95 EU-25 totals of PCs **sold 2005**, life cycle environmental impacts.*

Description / Base-case	**Desktop office**	**Desktop home**	**Laptop office**	**Laptop home**	**LCD office**	**LCD home**	**CRT office**	**CRT home**	**Total**
Sales 2005 (mln. units/year)	8,4	19,6	12	8	7,8	18,2	1,2	2,8	78
Product life (years)	6,6	6,6	5,6	5,6	6,6	6,6	6,6	6,6	
Total Energy, GER (PJ)	136	246	86	40	56	81	17	24	686
Greenhouse Gases (Mt CO2eq)	6	12	4	2	3	4	1	1	33
Acidifying agents (kt SO2eq)	40	74	24	11	15	21	5	6	196
Volatile Org. Compounds (kt)	0	0	0	0	0	0	0	0	1
Persistent Org. Pollutants (g i-Teq)	2	5	1	0	1	2	0	0	12
Heavy Metals (ton Ni eq)	5	10	3	1	2	3	0	1	24
PAHs (ton Ni eq)	2	4	2	1	0	1	0	0	9
Particulate Matter (kt)	7	16	7	4	3	6	1	2	46
Heavy Metals to water (ton Hg/20)	4	9	5	3	1	3	0	0	24
Eutrophication (kt PO4)	0	0	0	0	0	0	0	0	0

In figure 6, Table 95 is shown in graphical form.

In Figure 6 the base cases are ordered in decreasing total EU-25 impacts, considering sales in 2005. Desktops used in homes dominate total impacts. For comparison, Figure 7 shows life cycle impacts for the base cases per product. Only primary energy and greenhouse gases are shown. At the product level desktops in offices dominate environmental impacts due to more intensive usage, see Figure 7.

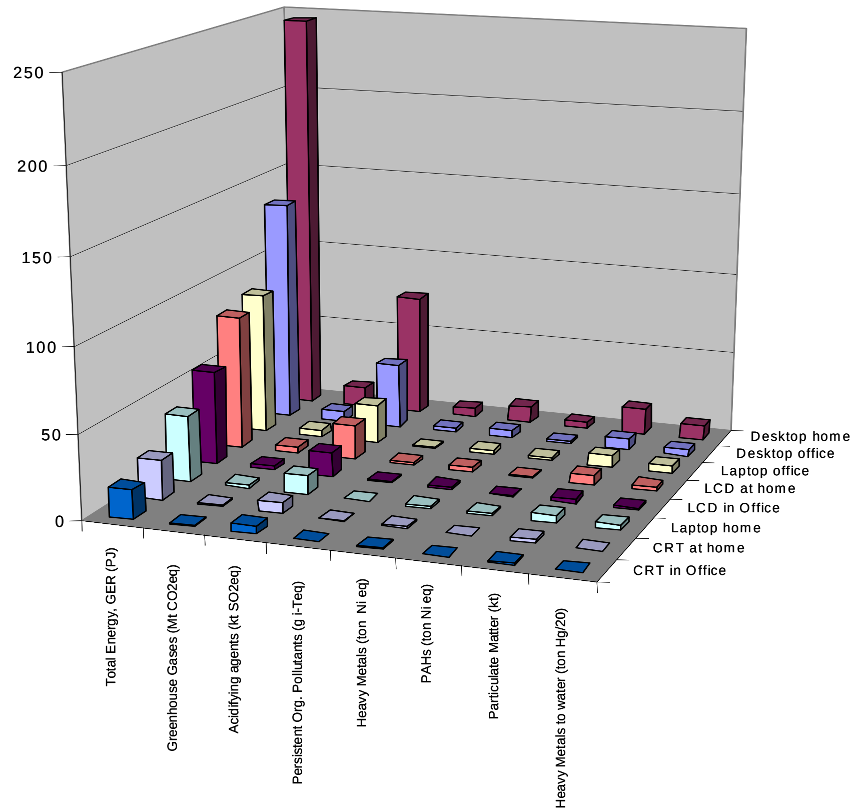

Figure 6 EU-25 totals of PCs and Monitors sold in 2005

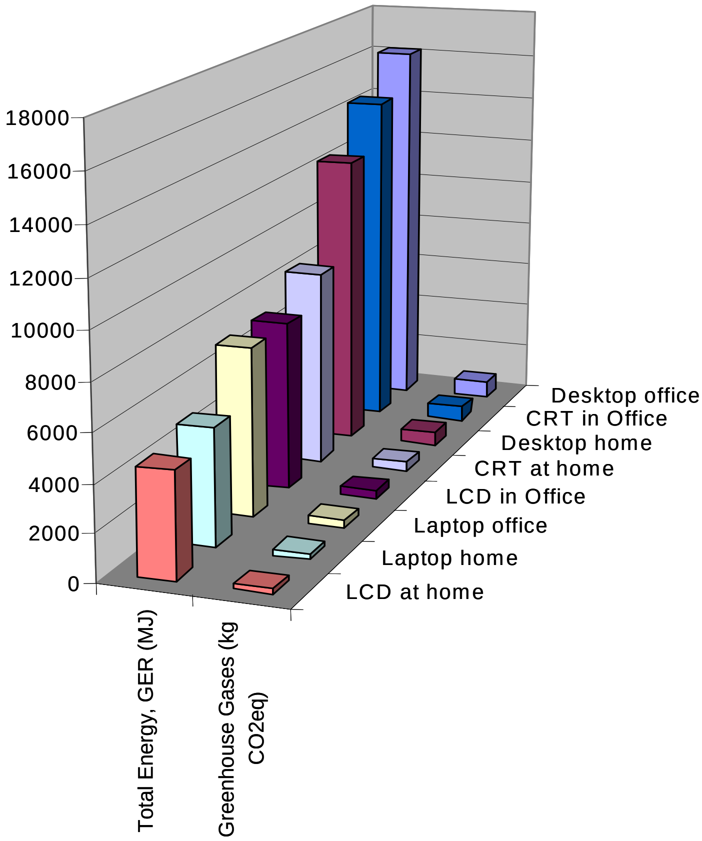

Figure 7 Life cycle impacts per product.

Table 96 EU-25 total environmental impacts of ***stock*** *of PCs in 2005.*

Description / Base-case	Desktop office	Desktop home	Laptop office	Laptop home	LCD office	LCD home	CRT office	CRT home	Total
EU Stock 2005 (mln. Units)	44,0	102	36,5	24	20,5	47,5	24	57	355,5
Total Energy, GER (PJ)	112	204	54	26	28	46	49	64	585
Greenhouse Gases (Mt CO2eq)	5	10	3	1	1	2	2	3	28
Acidifying agents (kt SO2eq)	34	63	16	8	7	12	13	17	170
Volatile Org. Compounds (kt)	0	0	0	0	0	0	0	0	1
Persistent Org. Pollutants (g i-Teq)	2	5	1	0	1	1	0	0	11
Heavy Metals (ton Ni eq)	4	9	2	1	1	2	1	2	22
PAHs (ton Ni eq)	2	3	2	1	0	1	0	0	9
Particulate Matter (kt)	6	14	5	3	2	6	1	2	40
Heavy Metals to water (ton Hg/20)	4	8	4	3	1	2	0	1	24
Eutrophication (kt PO4)	0	0	0	0	0	0	0	0	0

A reason that environmental impacts are higher for PCs and monitors sold in 2005 compared to impacts from the stock 2005, is that annual sales 2005 multiplied by product life implies more units (circa 495 million) than the stock in 2005 (350 million). More PCs and monitors means more environmental impact everything else being equal. But future technologies have already been implemented in 2006 and 2007 years models, so everything else is not going to be equal. This will be discussed in Tasks 6 and 7.

Figures 6 and 7 indicate that the following priorities of improvements would be relevant:

- In a EU-perspective, desktops used in homes should be prioritized for improvements since they contribute to most environmental impacts, see Figure 6.
- At the product level, desktops in offices and CRTs in offices contribute to most environmental impacts. This could be an incentive to organisations to implement energy efficiency programs
- In an energy perspective, laptops are preferable to desktops and LCD-screens are preferable to CRT-screens.

5.5 EU-25 Total system impact

As discussed in Task 4, a PC, can be part of many different systems but mostly operates within its own system. Thus, no calculations are made of the PC as part of a larger system than in 5.4.

The EIPRO study [2006], does not contain figures enabling a comparison of environmental impact from PCs.

5.6 References

- Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. May 2006 Technical Report EUR 22284 EN
- MEEUP Methodology Report. Final Report. Methodology Study Ecodesign of Energy-using Products. 28.11.2005. VHK for European Commission. Available at http://www.vhk.nl/

6 Technical Analysis BAT

6.1 Task and Procedure

The main task of this part of the report is to describe best available technologies, BAT, for Personal Computers and Computer Monitors. By BAT, we here mean technologies, which are best from the environmental and energy efficiency point of view based on the findings in task 5:

For desktops (both for office and home) the focus areas found in task 5 are

- Energy use during the use phase
- During the production phase the motherboard including the processor, the power supply and the steel casing dominate most impact categories.

For laptops (both for office and home) the focus areas found in task 5 are

- Energy use during use phase
- During the production phase the motherboard including the processor and the battery dominate most impact categories.

For LCD-displays (both for office and home) the focus areas found in task 5 are

- Energy use during use phase
- During the production phase the Cu-wire; integrated circuits, galvanized steel and polyamide dominate the impact categories.

For CRT-displays (both for office and home) the focus areas found in task 5 are

- Energy use during use phase
- During the production phase the integrated circuits and the CRT-screen dominate the impact categories.

There are several options for improving the PC of today both from the energy consumption point of view and from the view of other environmental impacts of the PCs and computer monitors. Many improvements are already introduced in the products by the producers while others are in the pipeline. We can foresee a range of improvements in the near future. The improvements range from hardware changes to simplifications in the systems to promote users to accept and adopt the different power management options already available today.
The PCs of tomorrow will in some cases move from the previous concept of being just a computer to become a multimedia station for different everyday tasks and the PCs will be a part of the furniture in the living room.

This change in user pattern will either require other selling arguments for the PC or other implementing measures. There will be a need for education in the marketing organizations and an information campaign aimed towards the consumers.

The clock frequency of the processor in the PC is one example. From a user perspective the clock frequency of the processor is of limited value when the performance of a PC is measured. There are several other issues that need to be addressed in order to make an intelligent choice. Among these the type of

processor, single or multi core, the bus frequency, the size of the internal memory (RAM) and the size of the hard drive are of importance. Also the power consumption when the PC is on and off will be of importance for customers. In addition the selection of operating system is complex since it influence both the possible hardware and software that can be used on the PC.
From energy consumption point of view the trend has been that every new generation of PCs have consumed more energy than the previous generation. This trend has, however, been broken in 2006 with the introduction of multi core processors and other improvements.
When adequate in the presentation the difference between Desktop and Laptop PCs are indicated. The Built-In type of PC can incorporate the same benefits and drawbacks as other PCs but the market penetration of this type of PC is less than 2% so no special considerations are made for this product.

The complexity of a modern PC is similar to that of a car. The best PC for one user is different from the best PC for another user just like the most appropriate car for one family is different from the most appropriate car for another family. It all depends on the purpose of the PC or car. Another similarity is the feeling users have that they don't understand what's going on inside the cabinet or under the hood. There is a need for user/consumer education regarding both the use of the PCs and the process of purchasing a PC.

The procedure to gather information to this report is based on IVF survey [IVF survey 2006] among stakeholders followed by in-depth interviews in order to clarify some information. In addition literature studies combined with our own experience has been used. In particular a study performed in the United States sponsored by the US Government with the title "Energy Consumption by Office and Telecommunication Equipment in Commercial Buildings, Volume II: Energy Savings Potential", [TIAX] has been used.

This report entails a technical analysis not only of current products on the market but on currently available technology, expected to be introduced at product level within 2-3 years. It provides part of the input for the identification of part of the improvement potential (task 7), i.e. the part that relates especially to the best available technology.

6.2 State-of-the-art in applied research for the product (prototype level)

6.2.1 Best available products

In order to give an idea about the possible improvements, products, considered as "Best available" on the market (home and office combined), are gathered. To be noted is that the products are "best" regarding energy consumption, and that the other performances has not been discussed although the products are in the range of products described in this study. Computers are taken as the best of Energy star list of Computers "Final computer dataset 10-20-06". It is a list of computers gathered by Energy Star in order to decide limits for Energy Star. Industry has provided Energy Star with product information for the list, following the test methods of Energy Star 4. LCD and CRT computer monitors are taken as the best of all monitors labeled at TCO 2005. For reasons of confidentiality, the brand and model names are not included.

Desktop computer

A desktop computer, included in the Energy Star list, equipped with dual core processor and processor speed of 1,67 GHz, total system memory of 512 MB, hard drive storage of 80 GB and a power supply with ≥85% average efficiency, has the following energy consumption:

- Off/standby mode: 1.10W
- Sleep mode: 2.6 W
- Idle mode: 23 W

Laptop computer

A laptop computer, included in the Energy Star list, equipped with total system memory of 1024 MB, hard drive storage of 80 GB and a power supply with ≥84% average efficiency has the following energy consumption:

- Off/standby mode: 0.38W
- Sleep mode: 0.82 W
- Idle mode: 6.8 W

Note that the screen is shut off during the energy measurements.

LCD Monitor

A LCD Monitor,labeled by TCO in 2005, with size 17", format 4x3 and resolution 1024x768 has the following energy consumption:

- Off/standby mode: 0.67W
- Sleep mode: 0.67 W
- On mode: 17.1 W

CRT Monitor

A CRT Monitor, labeled by TCO in 2005, with size 17", format 4x3 and resolution 1024x768 has the following energy consumption:

- Off/standby mode: 3.8W
- Sleep mode: 3.8 W
- On mode: 51.7 W

LED Monitors and Laptops

Up to the summer of 2006 the backlights available for computer monitor size displays have been typically mercury-filled fluorescent lamps. Since then a few big manufacturers have realised some full size monitories with LED (light emission diode) backlights that are commercially available. NEC's and Samsung's monitories can be bought now, and Acer and LG will also start selling in the near future. There is also a Sony notebook computer series sold with LED backlight units in the monitors. The LED screen as a component is produced by very few manufacturers. It is estimated by Samsung that in 2006 about 3% of all LCD monitors sold was equipped with LED backlight units. The LED technology promises improvements in many of the focus areas described in task 5, such as energy use during use phase and environmental impact from the PWB and electronic components. LED technology have an energy saving potential of approximately 25 % compared to LCD technology . One main benefit of the LED products is that they do not use any mercury. Until now, LED monitors have not realized the improvement promised by the technology, they are expensive and does not use much less energy than ordinary LCD screens. Compared to LCD monitors the not yet mature LED technology also has a shorter lifetime.

6.2.2 Product improvements regarding energy use at computer system level

Computers are usually built of a lot of standard components, put together in order to provide a working system. The components have to be compatible and the system of components needs to be coordinated and handled in a proper way to give the system a good performance. To coordinate the system, computers are provided with operating systems.

There are several operating systems on the market.. A majority of the PCs today use some version of Microsoft's operating system. Major competitors are Apple and Linux. For the general discussion here we select the operating system from Microsoft due to their dominant position on the market if an example is needed.

The complexity of the operating system is high and even if there is a clear candidate for a particular user due to company preference, software applications to be used etc. there are many versions to select between. Also, the process of adapting the operating system for particular processor technologies mean that in order to gain benefits from the newest low power processors the latest operating system need to be installed.

A general trend concerning new operating systems is that they require better hardware, faster processors, more RAM and more hard disk space.

6.2.2.1 Improvements in the user pattern of the power management

An open industry standard was released in December 1996 called the Advanced Configuration and Power Interface (ACPI) that put the operating system in control over the power management of the PC and the monitor. For the "Sleep Mode" there are five states (S1 to S5) of which S3 and S4 are the most important in this discussion. The complete specification can be downloaded from ACPI and contains more than 500 pages. [ACPI]

There are several power save options supported by the operating system in a PC. The most common are "suspend to RAM" S3, "suspend to disk" S4 and "soft-off" S5 according to ACPI while the PC during normal operation is denoted S0 or "on-idle". There is one big difference in the states S3 versus S4 when it comes to the power consumption of the PC. If the PC turns off to the state "suspend to disk" everything from RAM is saved to the hard disk and when the PC wake up the information must be read back from the hard drive to the RAM. This takes several seconds, 30 seconds or more, and from a user perspective this is a long time. The result is that users often turn off the power save functionality if suspend to disk is the available option. If the power save functionality is suspend to RAM the PC will start within a few seconds during wake up. Users generally accept this.
The reason why the option "suspend to RAM" was not generally implemented in PCs in 2005 was hardware related. Hardware that supports the option "suspend to disk" are cheaper than hardware supporting "suspend to RAM". PCs shipped today are generally supporting the suspend to RAM functionality.
Another improvement since 2005 is that many computers today are shipped with the power save functionality enabled and that only a few home users, less than 10%, change these settings. For office use the power management settings can be done remotely by the IT support. Those that do change their settings have good reasons for doing so and generally know what they do. One reason for changing

the settings is the infrastructure the PC is connected to or the peripherals connected to the PC.

As an example of where the design of the PC in co junction with the infrastructure it is connected to influence the power management settings is the network connection.
Most PCs today are connected to a network of some sort. In the industry most companies have a corporate network that include servers for mail and storage etc. In the home environment it is common that there are networks for sharing an Internet connection, a printer and additional storage. Peripherals in these networks are normally powered by an external power supply and these are the task for another part of the European project. The peripherals by themselves normally have no power save functionality but are included in the ACPI standard.

The network communication between the PC and the peripherals like routers, switches, modems an so on is done using the Ethernet standard. Regardless if the network is wired or wireless the basic standard for communication is Ethernet. There is one major drawback with this standard regarding the power save options for the PC. When a communication channel is established in an Ethernet network it often rely on the protocol DHCP (Dynamic Host Configuration Protocol). By this protocol the PC, the printer and all other equipments in the network are assigned IP addresses by the DHCP-controller. When the PC enters the power save mode the power to the network card in the PC is lost while the information regarding the IP address for the PC is saved on disk or in RAM. During wake up the PC can loose the connection to the network since the DHCP-controller noticed that the PC was no longer available (when the power to the network card was lost) but the PC still have the IP address since it was saved during shut down. This leads to a conflict between the PC and the DHCP controller and from a user perspective the PC is no longer on line. It is relatively simple to fix this by the “Control Panel” in Windows and “Repair” the connection but this task is not common knowledge by the average PC user. The only occasion when this is a large problem is when the network has a limited range of IP addresses. It is a task for the IT-organization to provide a good working environment in the network but for the average PC user this can lead to situations where computers are never shut off for fear of loosing their network connection.

It should be noted that this type of networking hassle usually is simple to solve for someone with a good understanding of the different technologies involved. For the average user this is not the situation. There is a general fear for changing anything in the setup of the computer if everything is working.

The situation will likely improve in the future due to more peripherals being compliant with the ACPI standard.
In the Business sector the energy consumption of the PCs can be managed remotely. Computer settings can be monitored remotely be the technology “Wake on LAN” and even set to the preferred mode (on) if users turn them off.
An improvement in the power management setting can be observed in the latest version of Microsofts operating system Vista. The help files associated with the settings are more user friendly and easier to understand.

Advantages: The advanced power management system in a modern PC can save a lot of energy, more than 60 %.

Disadvantages: None.

Problems: Hardware limitations discourage users from using the functionality. Consumer knowledge is limited. Complicated settings with non-intuitive labeling.

6.2.2.2 Optimum selection of the size of the internal memory

The size of the internal memory (RAM) in the PC is important because when the RAM is full the PC will swap information from the RAM to the hard drive. If a PC has too little RAM for normal applications the hard drive will have to work hard. The energy consumption will increase and the PC will be slow. A simple solution would be to purchase all the RAM that the computer design can handle but this is expensive, in particular if it is a high performance PC with a high bus speed. In addition, the purchase of additional RAM is a process that requires good understanding of the technical requirements for the PC and the installation requires the PC to be opened.

The energy consumption of the RAM memory as such is not the major issue even though a small amount of energy can be saved by using two 1 Gb RAM instead of four 512 Mb RAM to get 2 Gb memory size. More important is the impact an appropriate RAM size has on the performance of the PC for the desired task. A high end PC with insufficient RAM can perform as a medium PC with sufficient amount of RAM.

A potential customer generally has an understanding of the intended use of the home PC today but cannot make the appropriate selection without guidance. Furthermore the understanding of the possible future applications for the PC is impossible to foresee. Generally the buyer purchase the fastest PC the budget allow for without taking the amount of RAM that includes into account.

For the office use the intended applications are easier to foresee and the purchasing departments are often well educated and follow the market more closely.

Advantages: Optimum amount of internal memory make the PC perform better and consume less energy.

Disadvantages: Added cost of the PC.

Problems: Installing more memory in a PC requires the PC to be opened. Although relatively simple to do many home users do not identify their PC problems to the amount of installed RAM.

6.2.2.3 Impact of operating system regarding the hard drive

The problem with fragmentation of the hard drive is of importance for the energy consumption of the PC. The fragmentation occurs when the hard drive store files to the disk and does not find enough free space for the file but splits the file into smaller pieces on the drive. When the file is read back to the RAM the hard drive need to work harder since it need to perform more mechanical movements to gather all the pieces of the file which will slow down the computer and consume more energy.
The solution is to maintain the hard drive on regular intervals and perform a disk defragmentation.
There are at least two problems associated with this process. First, the user will not sense the need for disk defragmentation until the hard disk is so full of data that the performance of the PC will be poor. When the disk is full there will be no space available for the system to perform a defragmentation. Second, it requires an understanding of the internal processes in the computer that an average user does not possess.
With the new operating system Vista from Microsoft the disk defragmentation can be performed automatically which is one good step forward both from energy consumption point of view and for the users sense of performance. The PC will perform its task for a longer period of time and increase the lifetime.

One problem regarding this issue is that an upgrade of the operating system is costly and that older PCs usually don't support the new versions. Even if the PC will run on a new operating system all the hardware functionality will not be fully supported.

The energy savings due to disk fragmentation is low but it increases the lifetime of the PC, which is an important issue.

Advantages:	If the operating system handles the fragmentation of the disk the PC will perform better and consume less energy.
Disadvantages:	None
Problems:	Manual disk defragmentation generally not performed due to limited knowledge of the problem. Upgrading a PC with new operating systems are often impossible due to hardware limitations.

6.2.3 Noise reduction of PCs

Since the Ecoreport tool does not handle noise, we need a separate discussion on the issue.

Background

The dominant noise emission standards world wide are the test standard ISO 7779 and the result is declared according to ISO 9296.

Statistics on Declared A-weighted sound power levels according to ISO 9296
The statistics declared here are based on measurements done on a limited number of desktop and notebooks computers made by TCO Development when developing the TCO labelling system for computers.
The declared Idle mode is when the computer is in stand by mode with no hard disk drive operation.
The declared Operating mode is when the hard disk drive is operating for at least 50% of the measured time and the fans are operating during 100% of the measured time.

Desktop computers:

Sound Power levels measured 2003	
Idle	*Operating HDD (Hard Disk Drive)*
3.3 B (Mean value of 3 models tested)	4.0 B (Mean value of 3 models tested)
Sound Power levels measured 2004	
Idle	*Operating HDD*
3.8 B (Mean value of 3 models tested)	3.9 B (Mean value of 3 models tested)
Sound Power levels measured 2005	
Idle	*Operating HDD*
3.8 B (Mean value of 3 models tested)	3.9 B(Mean value of 3 models tested)

Notebook computers:

Sound Power levels measured 2003	
Idle	*Operating HDD (Hard Disk Drive)*
2.9 B (Mean value of 15 models tested)	3.9 B (Mean value of 15 models tested)
Sound Power levels measured 2004	
Idle	*Operating HDD (Hard Disk Drive)*
2.1 B (Mean value of 3 models tested)	2.4 B (Mean value of 3 models tested)

These figures are very close to the sound levels given from the stakeholders in the IVF survey, where it was also stated that the monitors are quiet.

As a reference, the de-facto standard from “stadskontoret” in Sweden, which is often used for office equipment, recommend upper limits of declared A-weighted sound power level according to the following table:

Equipment for use in quiet office areas, classrooms, conference rooms and home environment.

Product	Lwad B, operating	Lwad B, idle
Desktop computers	5.0	4.5
Laptop computers	4.5	4.0

It is obvious that the products available at the market today are “enough” silent for ordinary office use. Still, if the equipment is to be used as a media centre, for example for musical use, the need for silence is even higher.

Best available technology regarding noise

The noise of a PC needs to be addressed taking the surrounding environment into account. In an office there are normally ventilation and possibly cooling systems that give a certain level of background noise. The noise level of the PC is disturbing if the added noise level is significant compared to the surrounding noise. For a Media PC where the location is the living room in a home the noise from the PC must be very low. Manufacturers have noticed this and since the noise is generated by the cooling fan a simple solution is to reduce the requirements for cooling. Reduced cooling requirements will lower the energy consumption from the fan. This, together with the battery life are the main driving forces for designing more energy efficient PCs.
The hard drive also generates noise. This is recognized by the manufacturers so new hard drives are generally more silent than the previous generation.
It is noted that the requirement for a silent PC is something specific for the market in the North of Europe. It is also here that the requirements for a PC with low power consumption can bee seen. For these reasons chip manufacturers and PC manufacturers have selected the Scandinavian market as a test markets for new PC concepts.

A PC designed for low noise can reduce the noise level from 4.4 to 3.7 B (L_{WAD}) measured according to the standards ISO 7779 and ISO 9296.

Advantages:	Reduced noise and reduced energy consumption are benefits for the user. Noise reduction by 0.7 B.
Disadvantages:	None.
Problems:	None.

6.3 State-of-the-art at component level (prototype, test and field trial level)

The energy consumption of a PC is mainly divided into the following parts: the processor, the loss in the internal (or external) power supply, the motherboard including graphics processor and several other parts of the PC. For a desktop PC the processor will use approximately 40 % of the supplied power, 25 to 35 % of the power consumption will be lost in the power supply and the mother board will consume approximately 20 %. The rest will be distributed to the hard drives, fans etc. These numbers should be regarded as rough estimates and there will be variations in the actual numbers between different PC suppliers. Also, a typical Laptop PC differs regarding the actual distribution. It is, however, good to have these numbers as a background in order to keep the focus on the appropriate parts of the very complex device under investigation, the PC. Also note that the monitor is not included.

In the Task 4 report of this study the energy consumption for different parts are listed. The table below summarizes these results. These data are for PCs and monitors on the market 2005.

Table 97 Electricity use figure selected for the base cases.

Product cases ***Operational modes***	**Desktop**	**Laptop** (Screen on)	**LCD-screen**	**CRT-screen**
Idle (Watt)	78,2	32	31,4	69,5
Sleep (Watt)	2,2	3	0,9	1,5
Off (Watt)	2,7	1,5	0,8	1,5

Improvements can be made both in the hardware and in the user pattern of the PC. In many cases these improvements go hand in hand.

6.3.1 Improvements in energy use in the hardware of a PC

Technologies, which are best from an environmental and energy efficiency point of view based on the findings in task 5, are described below, For hardware of PC, the main focus area for improvement is energy use during the use phase, but also the production of the motherboard including the processor, the power supply and the steel casing and the batteries are of importance. Batteries for laptops will be described separately.

6.3.1.1 Energy savings due to the type of processor

One major improvement in the PCs supplied today is better processors, such as the multi core processors. Multi core processors are available from several manufacturers. The basic idea is that in a multi core processor several tasks can be performed in parallel with each other instead of one task after the other. In principle a dual core processor is as fast as a single core processor with twice as high clock frequency. Since the energy consumption is proportional to the clock frequency the energy consumption could be reduced by half in a dual core processor. The reality is not that good but a substantial improvement can be seen in the multi core processors delivered today. Another benefit with multi core processors is the ability to shut down or reduce the clock frequency of one or more of the cores for specific tasks. This can be useful for instance when the PC shall perform only one simple task like streaming a video or audio file. For such a task the PC can be operated in a mode with only one core running.

Of course, the operating system and the applications need to be designed so that they make use of the capacity of the processor design.

In data provided by computer and processor manufacturers a decrease in energy consumption of more than 60 % can be seen for a PC processor of the multi core type compared with a single core processor.

It would be interesting to compare two PC that have identical performance from a user point of view where one PC would be based on a single core processor and the other based on a multi core processor. It would highlight the difference in energy consumption and the difference in price. This can however not be done since such PCs are not found of the shelf.

The consumer price for a single core processor of 2005 intended for a Desktop PC was 40 Euro and for a Laptop PC 55 Euro respectively. When a dual core processor have a high market penetration the consumer price for the Desktop processor will be 50 Euro and for the Laptop PC 70 Euro.

One challenge is to educate the consumers that the processor clock frequency is of limited importance for the "feel" of the computer capacity. Multi core processors with relatively low clock frequency are as good or even a better alternative for most practical applications. The facts that it saves energy and requires less cooling are additional benefits.

Advantages:	Low power consumption for a dual core processor. Compared to a single core processor 30-40% less power consumption.
	Reduced noise.
Disadvantages:	New technology, 20% more expensive.
Problems:	User awareness of the different alternatives is limited.

6.3.1.2 Energy savings by adaptive clock frequency

One method of reducing the power consumption of a PC is to reduce the clock frequency of the processor when the needed capacity is reduced. This was often applied in Laptop PCs in order to increase the battery time. For instance, the processor speed can be reduced when the graphics card is working hard.

This technology is introduced into the desktop PCs due to the problems of heat generation in the processor. As much as 40 % of the power consumption of the processor can be saved if adaptive clock frequency is used. Of course, the savings depend to a large extent on the user pattern and what applications the PC runs.

Naturally, the technology of adaptive clock frequency could also be adapted for the processor at the graphics card but this is not implemented today.

Advantages: Reduced power consumption by 40 %.

Disadvantages: None.

Problems: None.

6.3.1.3 Energy savings of the motherboard

When data is transferred between the hard drive, the optical media (CD or DVD), the RAM etc. and the processor the communication runs by the internal data bus on the computers motherboard. The data rate is controlled be the clock that controls this data bus.

Over the years there has been a similar evolution of the data bus speed as for the processor speed. An indication of this can be found in the range of accepted bus speeds that the internal memory can handle, the RAM. The data bus clock frequency today can range from 266 MHz to 1033 MHz. (The steps are: 266, 333, 400, 550, 667, 800, and 1033 MHz today).

The situation today is that a high end PC usually has high frequency both for the processor and for the internal bus. The bus speed is more related to the particular processor used and cannot be selected arbitrarily.

Depending on the application the bus speed can be more important than the processor speed for the experienced performance of the PC. However, the bus speed is often neglected in the marketing of the PC. A user can experience that a PC with a low clock frequency of the processor but a high bus speed is faster than a PC with a high clock frequency and a low bus speed. Thus, a consumer could purchase a PC with a relatively slow processor and save both money and energy if the overall performance of the PC meets the consumer needs.

Advantages: Optimized PC for the intended application.

Disadvantages: Not an available option.

Problems: User awareness of the alternatives is limited.

6.3.1.4 Energy savings by the design of the power supply

The efficiency of the main power supply can be designed to a high standard. With modern technology of switched power supplies the efficiency can be as high as

90%. The drawback of an efficient power supply is the emission of unwanted signals in the power line, which can be solved by the use of filters. This, however, increase the cost of the power supply. The requirements of the power supply are recognized by for instance Energy Star and manufacturers are compliant with these standards. There is an initiative from the industry to build more efficient power supplies called “80-plus”. These requirements state that the power supplies shall have an energy efficiency of greater than 80 % at 20 %, 50 % and 100 % of rated load with a true power factor of 0.9 or greater. [80-plus]. A typical PC with a power consumption of 100 W in idle mode can reduce that by 20 % using an “80-plus” power supply for as little as 5 Euros extra cost. The stand by power consumption of such a power supply is less than 3 W.

Advantages: Reduced energy consumption by 20 %.

Disadvantages: 5 Euro higher cost.

Problems: None.

6.3.1.5 Energy savings by the design and selection of a hard drive

Flash drives

There are alternatives to a conventional hard drive in the form of Flash drives. The Flash memory is common in devices like USB memory sticks, memory cards, MP3 players etc. From a technical point of view it would be possible to build a PC without a hard drive and rely on Flash memory for storage but this option would be expensive. Currently the cost for the Flash memory is at least ten times as high as the same capacity for an ordinary hard drive.

The power consumption of the PC could be reduced by the few Watts that the hard drive consumes with this alternative.

The real benefit of a solution with a flash hard drive is the time it takes for the PC to start both from states S4/S5 and to boot. This could dramatically change the user pattern of a PC due to power management being enabled.

Advantages: Reduced noise since no fan is required for the hard drive.
Reduced energy consumption by 7 W.
Increased use of power management.

Disadvantages: Higher cost.

Problems: Not available.

Hybrid Hard Disk

An intermediate step between the ordinary hard disk and a Flash disk is the hybrid disk that combines the two technologies. A flash memory with the size of minimum 50 Mb is used in combination with the ordinary hard drive that allow the hard drive to be spun down when not in use. The flash memory is used also when the disk spins up again and works as a Cache memory for the drive.

The power consumption of the PC can be reduced since the hard drive can be spun down more often with this alternative.

Another benefit of a solution with a hybrid hard drive is the time it takes for the PC to start both from states S4/S5 and to boot will be only a few seconds. This would change the user pattern of a PC due to power management being enabled.

The hybrid hard disk technology is supported by Windows Vista.

Advantages: Reduced noise. Reduced energy consumption.

Disadvantages: Higher cost.

Problems: Requires support by the operating system.

6.3.1.6 Energy savings by other cooling technologies

The common cooling technology in a modern PC is by careful design and by a fan that force air to flow through the cabinet. Often the cooling fan is temperature controlled particularly for Laptop computers.

Alternative systems for cooling are available such as liquid cooling but the indications today are that the technology is not mature and that the pull from the market is not here. It remains as a technology for enthusiasts for the moment.

The main benefit of the liquid cooling is not the energy savings but the fact that the processor can be kept at a very low temperature. An additional benefit is that the system of liquid cooling can be quiet.

Advantages: Reduced noise.

Disadvantages: High cost.

Problems: Not a mature technology.

6.3.2 Reducing the environmental impact from board assembly

For all the products in the study, the focus areas found in task 5 included production of PWB and components (board assembly). Board assemblies include a lot of scarce and/or hazardous substances, which can be minimized by following the trend towards smaller and smaller components. The bonding between the components and the PWB is also of great importance, both because of the content of scarce materials as Sn, and because the bonding methods often limit the opportunity to use smaller components.

The products in this study are all lead-free due to the present legislation. The most common lead-free solder used today is the SnAgCu alloy. Even if lead is banned there is still an environmental impact from the new solder alloys Sn and Ag. If alternative electrical interconnection technologies could be used the amount of solder would be reduced. The relative material consumption for different electrical interconnect technologies are compared in the Figure below.

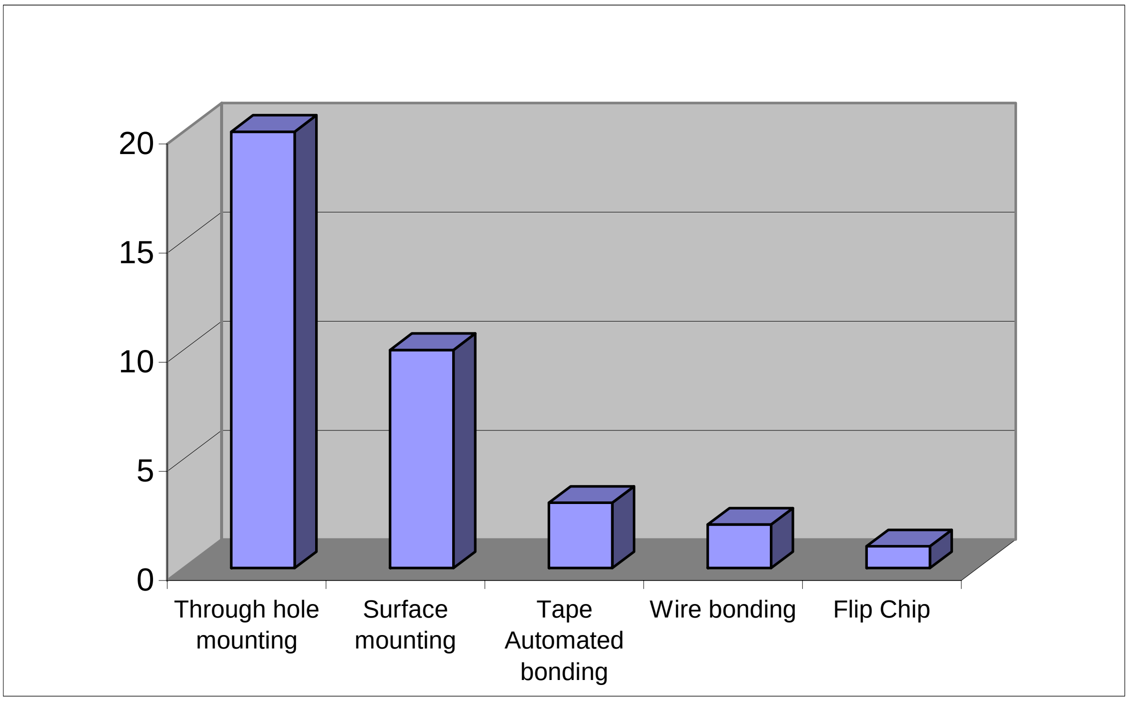

Figure 8 The relative material consumption for different electrical interconnect technologies

One example of a new technology is the concept for 3-D packaging In this technology several chips are stacked on top of each other and wire bonded to a carrier. The whole stack is then packaged leading to a small footprint (area on the PWB).

The production of PWB´s follows the different legislations concerning both environment and the applicable work safety regulations. The general trend is to avoid as many problematic chemicals and processes as possible without jeopardizing the reliability of the product. The use of halogen free flame-retardant in polymers in PWBs reduces the environmental impact. The RoSH directive have no direct influence, as the halogen flame-retardant used in PWB are not included in the legislation. However there are several new halogen free alternatives both for epoxy used in the electronic components and for the epoxy used in the printed circuit boards.

6.3.3 Improvements in Monitors for PCs

One general comment regarding monitors for PCs is that market forces drive manufacturers to design for high brightness while most users set the brightness to a level of 125 to 150 Candela for convenient viewing. The maximum brightness of many monitors are in the range 250 to 300 Candela. The monitors are often designed for high efficiency at the maximum brightness leading to decreased efficiency during normal use.

6.3.3.1 LED backlight for LCD Monitors

There is many advantages whit changing the fluorescent lamps to LED backlights, such as it will improve the LCD's colour saturation capabilities, contrast and black levels. The backlight unit, (BLU), will contain no mercury. The lifetime of the BLU and thereby of the monitor could increase to up to 100 000 h with little or no degradation. [CI Displays]. LED BLUs is believed to be able to reduce the energy consumption when the technology matures. Compared with ordinary LCD screens the energy consumption could be reduced by 25 %. It is also possible to dynamically dim the backlight in any part of the screen and thereby improve the black level and energy consumption.

The LED backlight for LCD displays will increase the quality of the image, prolongs the lifetime of the monitors and has a potential to save energy.

Advantages:	No mercury in the screen. Power consumption reduced by 25 %. Longer Lifetime.
Problems:	Not a mature technology giving a high price and currently too high energy consumption.

6.3.3.2 Possibility to take the lamps out of the LCD for End of Life treatment

Make the lamps containing mercury easy to disassemble from the rest of the LCD screen in order to take care of the mercury in a proper way in the End of Life treatment. This means that the housing must be possible to open and the connections have to be easy to take apart in order not to damage the mercury lamps. Gluing and welding must not be used to bond parts and make removal of the lamps complicated. [TCO´03]

The amount of Mercury in a normal 17" LCD monitor is 8 micrograms.

Advantages:	Gives the opportunity to treat the lamps containing mercury in a proper way and thus minimising the mercury emissions from LCD.

Disadvantages: Can perhaps make the product slightly more expensive, by hindering welding and gluing.

6.3.4 Minimizing the content of flame retardants in plastics

The ecoreport tool does not explicitly handle flame retardants, and they are therefore not pointed out as focus areas in task 5, but they are still of environmental importance for all the products in the study.

Even if RoHS is now applied to this kind of equipment, and some flame-retardants (polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE)) are nowadays forbidden, there are still some hazardous substances left in the products. The substitute flame-retardants are often quite new and not enough investigated, and may emerge as environmentally problematic in the future. For a product such as an LCD screen, there are often about 2 kg plastics that can contain up to 40% flame-retardants. These flame-retardants have to be considered as a quite considerable environmental risk even if this risk cannot be quantified today.

There are ways to minimise the use of flame-retardants in plastics in order to minimise the emissions of hazardous substances. One possibility is to exchange the plastics into hard wood, which is much more flame retardant than plastics [TCO´03] [project Heatsun], other possibilities are to reduce heat generation or to use metal housing.

Advantages: Minimise the emission of hazardous substances from the products. Design might also become beneficial, since many people find wood more beautiful than plastics.

Disadvantages: Wood is not that easy to form freely to different geometries, and thus a change to wood can make the product more expensive. Metal is heavy and difficult to give a free geometry.

6.3.5 Change to renewable plastics

The plastics was of some importance when discussing the focus areas in task 5, even if it was not the most important issue. All the products in the study are containing rather big volumes of plastics, and therefore a discussion on renewable plastics can be of interest for all of them.

There is an ongoing discussion on the use of non-renewable materials, including plastics (made of oil). New technologies are developed in order to make these materials renewable. One such technology is to use biofiber-reinforced bioplastics. The biofiber can for example be made of linen, kenaf or cellulose. Plastics can for example be made through a polylactid acid polymerisation, from corn to polymer. There are already mobile phones on the market using these technologies. However, the environmental qualities of bio-plastics have not yet been adequately documented so the potential improvement cannot be quantified.

Advantages: Going from non-renewable to renewable materials

Disadvantages: The lifetime of the renewable polymers are sometimes less than those of non-renewable polymers. Not yet a mature technology. Environmental qualities of bio-plastics are not yet fully documented.

6.3.6 Batteries for Laptops

Batteries for laptops are one of the focus areas described in task 5. Batteries used for Laptops are mainly of the Lithium-ion type, even if also Lithium-polymer batteries are used. The difference between the two of them is that the electrolyte in the latter is bound in a polymer. One of the important characteristics for batteries of mobile equipment is energy per weight, where both these types are good solutions. They both also have a rather low self-discharge rate. Another important quality of rechargeable batteries is how they behave when not fully charged. Old time batteries such as Ni/Cd have a memory effect, making them less effective after "bad" charging habits and are therefore no longer used for laptops. Regarding the environmental impact, there are a few main things to bear in mind:

- Energy efficiency. How much of the charger energy goes into the battery for storage, and out to be used.
- Aging. Most rechargeable batteries loose their charging capacity over time, often the capacity (possible use time of the equipment) can decrease by 50% during the first year, depending on battery quality, ambient temperatures etc. Many times, laptop computers are exchanged due to insufficiently working batteries, because new batteries are often very expensive to buy.
- Toxic substances. Li-ion and Li-polymer batteries contain some toxic substances, for example lithium itself and organic solvents, and needs to be taken care of in the end of life treatment.
- Risk for explosions or fire. Li-ion and Li-polymer batteries self ignite and can cause an explosion at temperatures of 180-200 degrees Celsius. This can happen when overcharging the batteries or if a short circuit occurs.

6.3.6.1 Make it easy to remove the batteries

In order to improve the end of life treatment, it is of importance to make the batteries easy to remove from the product. That will stop the toxic and dangerous (explosive) substances from the batteries to spread in the environment

6.3.6.2 Effective charging methods

There are always energy losses in the charging process. In order to minimise that, the charging process should be as effective as possible. In docking units for laptops, the charging is often always on, which gives losses all the time, even if the battery is fully charged. The charging should preferably stop when the battery is fully charged, because this will reduce charging losses and extend battery service life

6.3.6.3 Minimise battery aging

Because of aging, battery capacity is often reduced by half in only one year. The aging starts directly after manufacturing, and it is therefore of importance not to store batteries before they are used. The aging is also very much depending on the ambient temperature. The lower the ambient temperature (but not frozen the longer battery life! Lower temperature can be achieved by good cooling of the product, but also by giving the user instructions and possibility to disconnect the batteries and put them in a cooler place than in a hot computer when the laptop is connected to the mains.

6.3...4 New battery chemicals (Best Not Yet Available Technology)

There is a development of new chemicals for batteries ongoing. Much of that development aims at giving safer batteries (less risk for explosions or fire) but also in order to make them cheaper or giving higher energy capacity per weight. These new chemicals are for example, Lithium-Mangan-Oxide-Spinell ($LiMn_2O_4$), which is safer, but have less energy capacity and Ion-Phosphate ($FePO_4$), which is cheaper than today's chemicals. Another solution is Zinc-air batteries (today used in hearing aids), where oxygen in the surroundings is used as one of the chemicals in the process, making the need to carry all the chemicals less. There is also an ongoing development of new electrolytes in order not to use the toxic organic ones.

6.3.6.4 Fuel cells (Best Not Yet Available Technology)

Fuel cells generate electricity from an electrochemical reaction, in which oxygen and a fuel (eg. hydrogen) combine to form water. There are several different types of fuel cells but they are all based on a central design. Direct methanol fuel cells (DMFC) draws hydrogen from liquid methanol. This type of fuel cell is the most appropriate for PC laptop applications, but has not so far reached the market in any substantial volumes.

6.3.7 Best Not Yet Available Technologies

6.3.7.1 OLED Displays (organic light-emitting diode)

"OLED displays stack up several thin layers of materials. They operate on the attraction between positively and negatively charged particles. When voltage is applied, one layer becomes negatively charged relative to another transparent layer. As energy passes from the negatively charged (cathode) layer to the other (anode) layer, it stimulates organic material between the two, which emits light visible through an outermost layer of glass." [Kodak 2006]

At present OLEDs are used in small and relatively short-lived portable colour video displays such as mobile phones and digital camera screens.
Large-screen colour displays have been demonstrated, but their life expectancy is still too short, especially for the blue colour, < 1000 Hrs, to be practical.
The estimate from the industry is that full size computer displays with the OLED technique is still 4-5 years away.

The plastic, organic layers of an OLED are thinner, lighter and more flexible than the crystalline layers in an LED or LCD. OLEDs are brighter than LEDs. Because the organic layers of an OLED are much thinner than the corresponding inorganic crystal layers of an LED, the conductive and emissive layers of an OLED can be multi-layered. Also, LEDs and LCDs require glass for support, and glass absorbs some light. OLEDs do not require backlighting like LCDs and consumes therefore much less power. OLEDs produce their own light, so they have a much wider viewing angle. The response time for OLEDs is faster than for LCD displays. OLED can produce a true black and infinite contrast ratios, and have the potential to be easier to produce and can be made to larger sizes.

Disadvantages with the OLED technique

Lifetime for OLED is still quite short. While red and green OLED films have long lifetimes (10,000 to 40,000 hours), blue organics currently have much shorter lifetimes (only about 1,000 hours). Manufacturing processes are expensive in this stage of the development and water can easily damage OLEDs.

The OLED technique has the potential to show both moving and still images with much higher quality and with much less energy consumption than todays LCD monitors, if the lifetime and manufacturing problems are solved. Currently it is unclear if this technology will enter the market for PC monitors.

Advantages: Low power consumption and better imaging quality.

Disadvantages: Not tested as a monitor for a PC yet.

6.3.7.2 Solid state Lasers for projection systems and backlights for LCD Monitors

Both Mitsubishi Digital Electronics America, Inc and the also US based company Novalux has developed solid states Lasers for big screen televisions based on the back projection technique. They have both demonstrated working television prototypes: Mitsubishi in Huntington Beach (USA) in April 2006 and Novolux together with the Australian company Arasor in Australia in October 2006. Novalux has expressed an intention to develop the technique for use in computer monitors. Both Mitsubishi and Novalux /Arasor have stated that big screen televisions with the Laser technique will be commercially available in the end of 2007. Other companies developing Laser units for use in displays are: Coherent, http://www.coherent.com/ and Principia LightWorks, www.principia-lightworks.com.

Advantages whit Lasers
Lasers have a very large color gamut, and high brightness compared to fluorescent lamps or LCD backlights. They have high power conversion efficiency and are long lived. The solid state Laser units have the potential to be relatively inexpensive to manufacture.

The solid state Laser will take the quality of the images a big step forward. They will prolong the lifetime of the monitors and they are also power efficient.

Advantages: Low power consumption and high imaging quality.

Disadvantages: Not yet tested as a monitor for a PC.

6.3.7.3 Electronic Paper, e.Ink

The e.ink technology gives the same feeling as viewing a paper. As with paper it relies on reflected light and has no backlight. The brighter the incident light the better the reading conditions. The technology is based on proprietary electronic ink applied on a circuit board. The appearance of the ink is changed by an electric field. Products with this display technology in black and white are available on the market and consist of devices such as e-book readers, USB-memories with a display etc. Colour prototypes are available.

One benefit with this display technology is the low power consumption and that it only consumes power when the image is changed. Another benefit is that the electronic ink can be applied on virtually any surface with an electric circuit. The surface can even be flexible.

The e.Ink corporation believe that the technology will enter the market for mobile phones and GPS receivers in addition to the existing market for e-book readers. In the future the technology can be used for a PC monitor.

Advantages: Low power consumption.

Disadvantages: Not tested as a monitor for a PC.

6.4 State-of-the-art of best existing product technology outside the EU

The manufacturers of computers and monitors act on a global market and most of the hardware is manufactured outside the EU. The technologies described above are covering the global market.

6.5 References

- IVF Industrial Survey, 2006.
  Several stakeholders did answer the questionnaire from IVF during the summer 2006. Due to secrecy agreements, they are not named here, but the list covers the main players for both computers and monitors, also covering companies from Europe, the USA and Asia. The number of respondents to the questionnaire was 16.
- TIAX. Energy Consumption by Office and Telecommunication Equipment in Commercial Buildings, Volume II: Energy Savings Potential. TIAX Reference No. D0065-11.08, December 2004.
- ACPI (ADVANCED CONFIGURATION AND POWER INTERFACE SPECIFICATION). Revision 3.0b, October 10, 2006. http://www.acpi.info/spec.htm
- 80 Plus, www.80plus.org
- CI Displays, www.cidisplays.com
- Kodak 2006 www.kodak.com
- TCO´03 Displays Flat panel Displays, version 3.0
- Project Heatsun, www.projectheatsun.com
- Energy star list of products “Final computer dataset 10-20-06”

7 Improvement potential

Task 7 consists of identifying the design improvement options, quantifying the influence they have on the environmental focus areas described in task 5, and rating them in terms of Life Cycle Costs (LCC) for the consumer. The option or combination of options with the Least Life Cycle Costs (LLCC) should be pinpointed. Key technical improvement options have been identified in task 6 based on the focus areas described in task 5. The analysis in task 7 will focus on key options from an energy-saving point of view since that is the main focus area described in task 5 for all the products.

7.1 Options

7.1.1 Power management

As stated in Task 6, the problem with power management is that so few people use it. The idea is simple, the PC should only use energy when actually needed. Many PCs are today shipped with the power management feature enabled, but lots of users switch the feature off for various reasons discussed in Task 6. Improvements in power management are relevant to all eight bases cases as defined in Task 5.

Estimations on potential savings from using power management vary a lot. In the calculations is assumed 50% savings in the idle power state, i.e. the idle time is decreased by 50% and the sleep time is increased by the corresponding number of hours. This leads to a corresponding decrease in electricity consumption.

Although power management is mainly a user attitude issue, there are also hardware related problems. Some peripherals lose contact when the computer falls asleep, the speed of wakening up from sleep mode could be shortened by technology like flash memory etc. However, as these are indirect effects, no changes in bill of materials are assumed.

7.1.2 The processor

The processor in a 2005 desktop computer takes roughly 40% of the energy, see Figure 8 below.

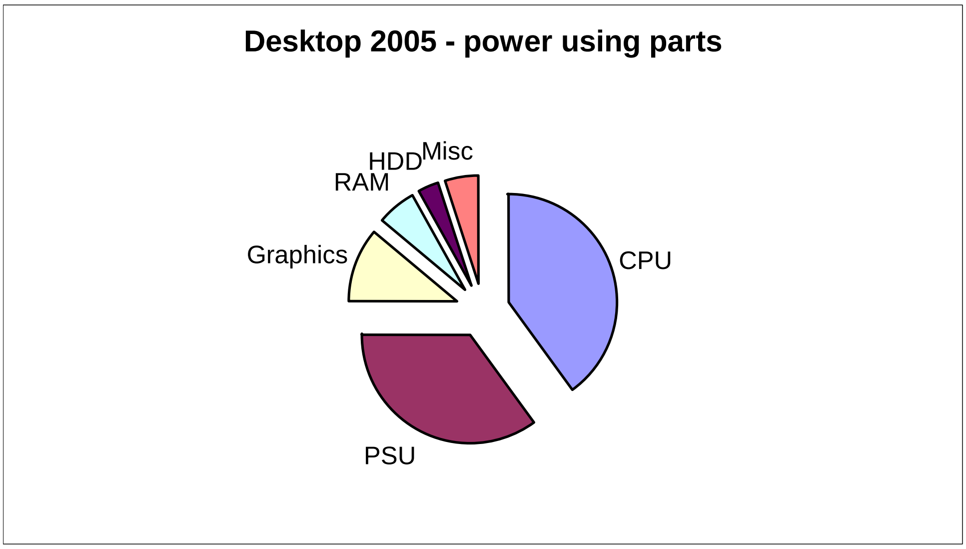

Figure 9 Distribution of power use in desktops from 2005.

In a laptop, which also has an LCD-screen, the processor uses around 20% of the energy, se Figure 9 below.

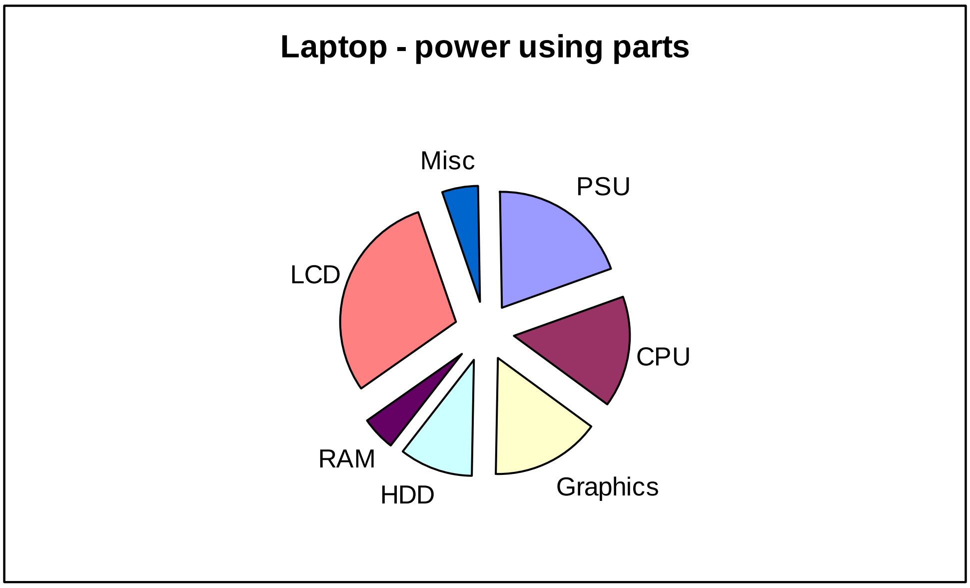

Figure 10 Laptop-power using parts.

Dual core technology, offers 60% savings in processor energy use, see Task 6. Processor improvements are only relevant for desktops and laptops, not for monitors. In the calculations is assumed 0,60*0,40=24% energy savings on desktops, and 0,6*0,2=12% savings on laptops (in the use phase).

The price difference between single core and dual core when the technology has matured a bit more than it had 2007, is expected to be 10 Euro for a desktop processor and 15 Euro for a laptop processor. See Task 6 for a more detailed discussion on processor price developments.

There are no visible or weight changes in a dual core chip compared to a single core chip. Thus it is assumed that the BOM does not change, and that the environmental impact from the production phase is not changed.

7.1.3 Adaptive clock frequency

One method of reducing the power consumption in a desktop is to reduce the clock frequency of the processor when the need for capacity is reduced. This is often applied in laptops in order to increase the battery time. As much as 40 % of the power consumption of the processor can be saved if adaptive clock frequency is used. Adaptive clock frequency is only relevant for desktops. In the calculations is assumed 0,40*0,40=16% energy savings on desktops (in the use phase).

No extra cost is foreseen for this option in the longer term. Nor should it entail significant changes in the BOM and thus the environmental impact from the production is not changed..

7.1.4 Power supply units (PSU)

By using a switched power supply designed to high standard, the power supply efficiency can be increased from currently 70% (2005) to 80% or even 90%. It should be noted that Energy Star 4.0 requires “80-plus” power supplies. For further description of the technology, see Task 6.

Power supply units are relevant to all eight bases cases as they are focus areas defined in Task 5.

As described in Task 6, there is no evidence that increasing the efficiency would lead to changes in the weight of the power supply, i.e. no changes in the BOM is assumed and thus the environmental impact from the production is not changed This assumption is supported by the Lot 7 study [2007] on external power supplies.

An “80-plus” PSU will reduce idle mode power with approximately 20%, see Task 6. Reductions in sleep and off modes are assumed to be more related to the threshold levels in Energy Star 4.0 for computers and Energy Star 4.1 for displays than to percentage reductions, since the 80% efficiency cannot be maintained in the low power ranges. See Table 98 below.

Table 98 Energy Star 4.0 requirements for computers and Energy Star 4.0 4.1 for displays on power in sleep and off modes.

Base-case / Mode	**Sleep (W)**	**Off (W)**
Desktop, office and home	4	2
Laptop, office and home	1,7	1
Displays, office and home	2	1

The approximate additional cost for an “80-plus” PSU is 5 Euros, according to several computer manufacturers, see Task 6.

7.1.5 Using LCDs instead of CRTs

This option, which is already being implemented by private and public consumers to a large degree, is already quantified in the base case calculations. It includes of course quite large changes also in the bill of materials.

7.1.6 Using laptops instead of desktops

This option is to an extent already being implemented by private and public consumers, see Task 2.2.2.1. It includes quite large changes also in the bill of materials. This option is of course only relevant to desktops.

If no external display is needed for the laptop, then an LCD-display should be added to the desktop to get a fair comparison. This situation is assumed realistic in home use.

If an external display is needed also for the laptop, laptop values are adjusted to account for not using the internal LCD-screen. This means lowering the idle power with 10 Watts, see Task 4.3.3.2. This situation is assumed realistic in office use. Since both setups require an LCD-display, the display can be disregarded in the comparison.

7.1.7 Hybrid hard disks

A hybrid hard disk is a hard disk combined with quite a large flash memory. The advantage being very quick wake-up times from sleep mode, hibernation mode and fast boot time. This technology could therefore help in implementing power management savings. Since the hard disk consumes a few watts, also some direct energy savings are possible. Early 2007, the hybrid hard disk was not yet available on the market and no cost information was available.

7.1.8 LED backlight screen

LED screens are quite new, and came to the market recently and there are very few manufacturers producing LED screens today. The technology have a future potential to reduce the power consumption for the screen by approximately 25% compared to an average LCD backlight screen. For monitors the power in idle mode is reduced by 25 % in the calculations. For Laptops, the screen uses approximately 30% of the energy in idle, which gives a 7.5 % reduction in power if LED backlight is used. No changes in the BOM are assumed (due to lack of information) and thus the environmental impact from the production is not changed. An extra cost for LED compared to LCD screens is assumed to be 50€ in the calculations. The cost today are higher, but will probably due to the rapid development decrease.

7.2 Impacts and costs

Table 99 gives two environmental indicators and LCC per product for all eight bases cases. Most of the improvement options will not lead to changes in the Bill of material (BOM) and thus the environmental impact from the production is not changed.

These improvements thus concern energy use in the use phase, where total primary energy and/or total greenhouse gases, can represent any of the other impact indicators.

Table 99 Impacts and costs per product for the base cases.

Base cases Life cycle impact/cost	Desktop office	Desktop home	Laptop office	Laptop home	LCD in Office	LCD at home	CRT in Office	CRT at home
Total Energy, GER (MJ)	16165	12529	7200	4995	7231	4473	14515	8403
Greenhouse Gases (kg CO2eq)	761	603	348	251	336	216	657	390
Product price (Euro)	620	520	1242	990	201	201	73	73
Electricity (Euro)	163	119	70	43	73	39	159	85
Repair & maintenance costs (Euro)	117	117	118	118	0	0	0	0
Total Euro	900	756	1430	1151	274	240	232	158

7.2.1 Power management

Table 100 gives total primary energy, total greenhouse gases and LCC per product for the improvement that power management in average was improved by 50%. Since there is no cost involved, only decreased electricity use, the environmental impact and the LCC is decreased for all base cases.

Table 100 Impacts and costs for implementing power management 50% better.

Base cases Life cycle impact/cost	Desktop office	Desktop home	Laptop office	Laptop home	LCD in Office	LCD at home	CRT in Office	CRT at home

Base cases Life cycle impact/cost	Desktop office	Desktop home	Laptop office	Laptop home	LCD in Office	LCD at home	CRT in Office	CRT at home
Total Energy, GER (MJ)	10166	8363	4973	3811	4498	3112	8422	5369
Greenhouse Gases (kg CO2eq)	500	421	250	200	217	157	391	258
Product price (Euro)	620	520	1242	990	201	201	73	73
Electricity (Euro)	90	68	43	29	40	23	85	48
Repair & maintenance costs (Euro)	117	117	118	118	0	0	0	0
Total Euro	827	705	1403	1136	241	224	158	121

7.2.2 Improved processors

Table 101 gives total primary energy, total greenhouse gases and LCC per product for the improvement to implement dual core processor technology. The environmental impact is decreased for all relevant base cases. The LCC is lower for desktops and higher for laptops, compared to the base-cases.

Table 101 Impacts and costs for implementing improved processors.

Base cases Life cycle impact/cost	Desktop office	Desktop home	Laptop office	Laptop home
Total Energy, GER (MJ)	13085	10392	6554	4701
Greenhouse Gases (kg CO2eq)	627	509	319	239
Product price (Euro)	630	530	1257	1005
Electricity (Euro)	126	93	62	39
Repair & maintenance costs (Euro)	117	117	118	118
Total Euro	872	740	1437	1162

7.2.3 Adaptive clock frequency

The table below gives total primary energy, total greenhouse gases and LCC per product for the improvement to use adaptive clock frequency in desktops. The environmental impact (and the electricity bill) can be reduced and the LCC will decrease correspondingly since no extra cost is assumed.

Table 102 Impacts and costs per product for implementing adaptive clock frequency.

Base cases Life cycle impact/cost	Desktop office	Desktop home
Total Energy, GER (MJ)	14080	11082
Greenhouse Gases (kg CO2eq)	670	540
Product price (Euro)	620	520
Electricity (Euro)	138	101
Repair & maintenance costs (Euro)	117	117
Total Euro	875	738

7.2.4 Improved power supplies

Table 103 gives total primary energy, total greenhouse gases and LCC per product for the improvement to use "80-plus" power supplies. Since there is very little extra cost involved, the environmental impact and the LCC are decreased for all base cases.

Table 103 Impacts and costs for implementing 80+ power supplies.

Base cases Life cycle impact/cost	Desktop office	Desktop home	Laptop office	Laptop home	LCD in Office	LCD at home	CRT in Office	CRT at home
Total Energy, GER (MJ)	13542	10610	5895	4119	6102	3910	11942	6994
Greenhouse Gases (kg CO2eq)	647	519	291	213	287	192	545	329
Product price (Euro)	625	525	1247	995	206	206	78	78
Electricity (Euro)	131	96	54	32	59	32	127	68
Repair & maintenance costs (Euro)	117	117	118	118	0	0	0	0
Total Euro	873	738	1419	1145	265	238	205	146

7.2.5 Using LCDs instead of CRTs

Table 104 gives total primary energy, total greenhouse gases and LCC per product for the improvement to use LCD-screens instead of CRT-screens. The environmental impact (and the electricity bill) can be approximately halved, but the LCC will increase due to higher price for LCD-screens.

Table 104 Impacts and costs per product for using LCDs instead of CRTs.

Base cases Life cycle impact/cost	LCD in Office	CRT in Office	LCD at home	CRT at home
Total Energy, GER (MJ)	7231	14515	4473	8403
Greenhouse Gases (kg CO2eq)	336	657	216	390
Product price (Euro)	201	73	201	73
Electricity (Euro)	73	159	39	85
Repair & maintenance costs (Euro)	0	0	0	0
Total Euro	274	232	240	158

Since the BOM is changed, Figure 11 is included to show that also the other impact categories are decreased when using LCDs instead of CRTs. Figure 10 shows that this is true except for persistent organic pollutants that show a small increase. Since the greenhouse gas difference for this option is smaller in homes than in offices, the above statement will also hold true in offices.

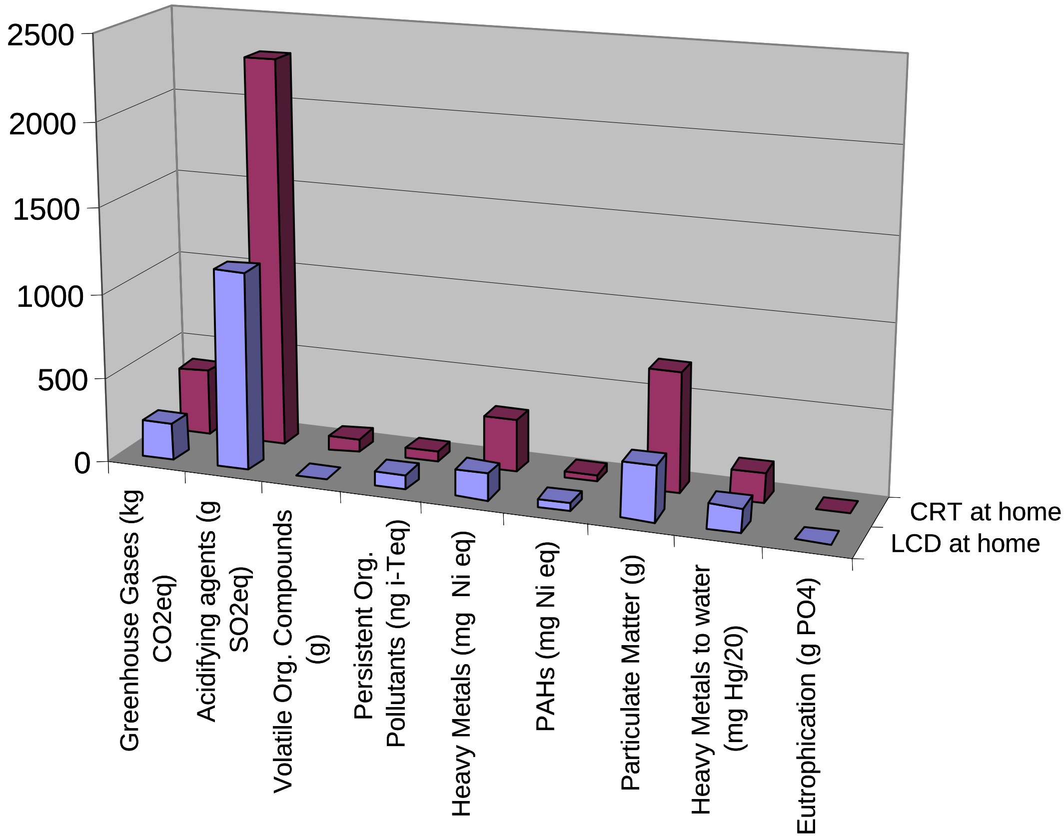

Figure 11 Environmental impact when changing from CRT to LCD.

7.2.6 Using laptops instead of desktops

The table below gives total primary energy, total greenhouse gases and LCC per product for the improvement to use laptops instead of desktops. The environmental impact (and the electricity bill) can be more than halved, but the LCC will increase due to higher price for laptops. Note also that laptops have a shorter service life than desktops: 5.6 compared to 6.6 years. This means that the laptop cost will have to be paid more often, every 5.6 year instead of every 6.6 year.

Table 105 Impacts and costs per product for using laptops instead of desktops.

Base cases **Life cycle impact/cost**	**Desktop office**	**Laptop office, adj**	**Desktop home**	**LCD at home**	**Desktop with LCD in home**	**Laptop home**
Total Energy, GER (MJ)	16165	5663	12529	4473	17002	4995
Greenhouse Gases (kg CO2eq)	761	281	603	216	819	251
Product price (Euro)	620	1242	520	201	721	990
Electricity (Euro)	163	51	119	39	158	43
Repair & maintenance costs (Euro)	117	118	117	0	117	118
Total Euro	900	1411	756	240	996	1151

Since the BOM is changed, Figure 12 is included to show that also the other impact categories are decreased when using laptops instead of desktops in offices. Figure 11 shows that this is true for all impact categories. Since the greenhouse gas difference for this option is smaller in offices than in homes, the above statement will also hold true in homes.

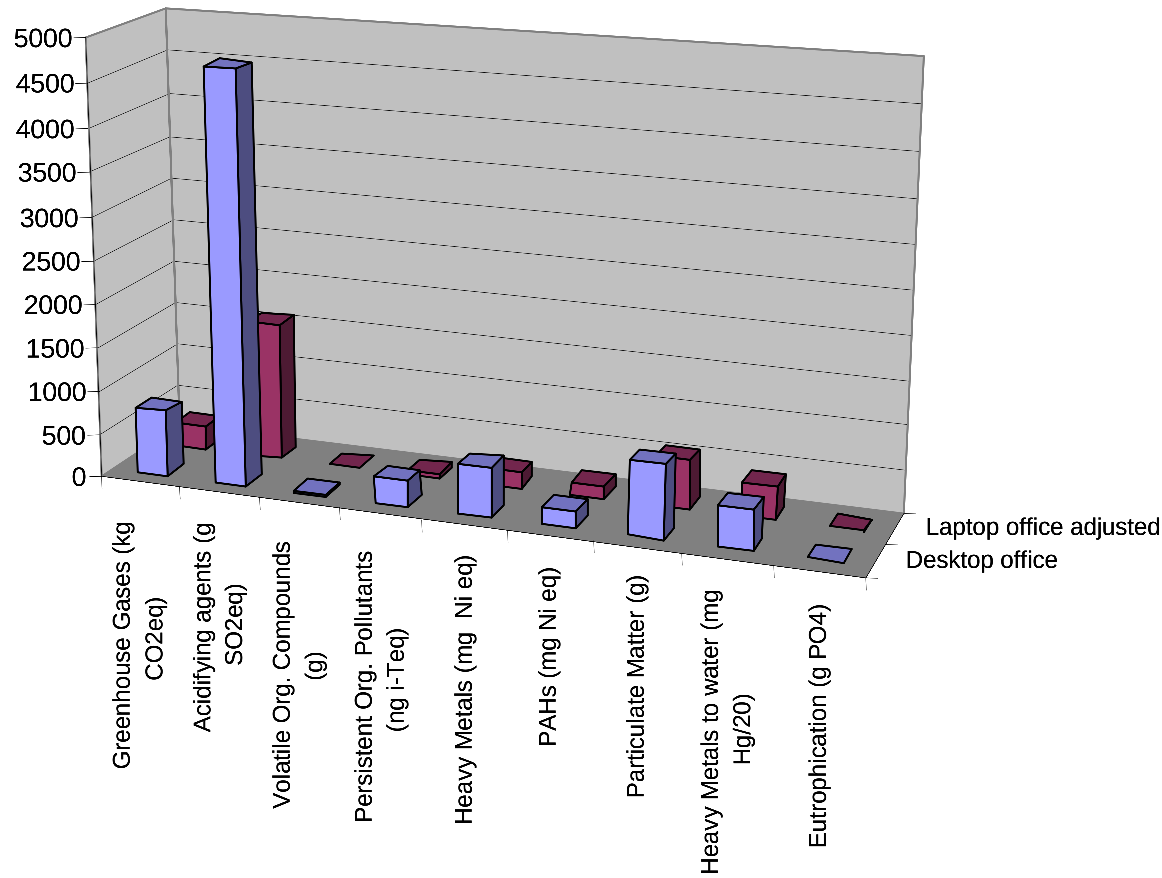

Figure 12 Environmental impact when changing from desktop to laptop.

7.2.7 Change from LCD to LED backlight Screens

The table below gives total primary energy, total greenhouse gases and LCC per product for the improvement to use LED backlight screens instead of LCD screens. The environmental impact (and the electricity bill) can be reduced, but the LCC will increase due to higher price for LED screens.

Base cases Life cycle impact/cost	Laptop office with LED	Laptop home with LED	LED Monitor office	LED Monitor-home
Total Energy, GER (MJ)	6831	4799	5824	3771
Greenhouse Gases (kg CO2eq)	331	243	275	186
Product price (Euro)	1292	1040	251	251
Electricity (Euro)	65	41	56	31
Repair & maintenance costs (Euro)	118	118	0	0
Total Euro	1475	1198	307	282

7.3 Analysis LLCC and BAT

7.3.1 Desktop office

The improvement options relevant for office desktops are listed in the Table below.

Table 106 Impacts and costs per product and improvement option (one by one) for office desktops.

Base cases Life cycle impact/cost	Base case	Power manage-ment	Dual core processor	Adaptive clock	80+ PSU	Replace ment laptop
Total Energy, GER (MJ)	16165	10166	13085	14080	13542	5663
Greenhouse Gases (kg CO2eq)	761	500	627	670	647	281
Product price (Euro)	620	620	630	620	625	1242
Electricity (Euro)	163	90	126	138	131	51
Repair & maintenance costs (Euro)	117	117	117	117	117	118
Total Euro	900	827	872	875	873	1411

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 107 Impacts and costs per product and improvement option added for office desktops.

	Base case	Power Management (PM)	PM +>80PSU	PM+> 80PSU +improved proc	PM+> 80PSU +improved proc +adaptive clock freq	Change to laptop
Total Energy, GER (MJ)	16165	10166	8934	7749	7148	5663
Greenhouse gases (kg CO2eq)	761	500	446	394	368	281
Product price (Euro)	620	620	625	635	635	1242
Electricity (Euro)	163	90	75	61	54	51
Repair and Maintenance costs (Euro)	117	117	117	117	117	118
LCC (Euro)	900	827	817	813	806	1411

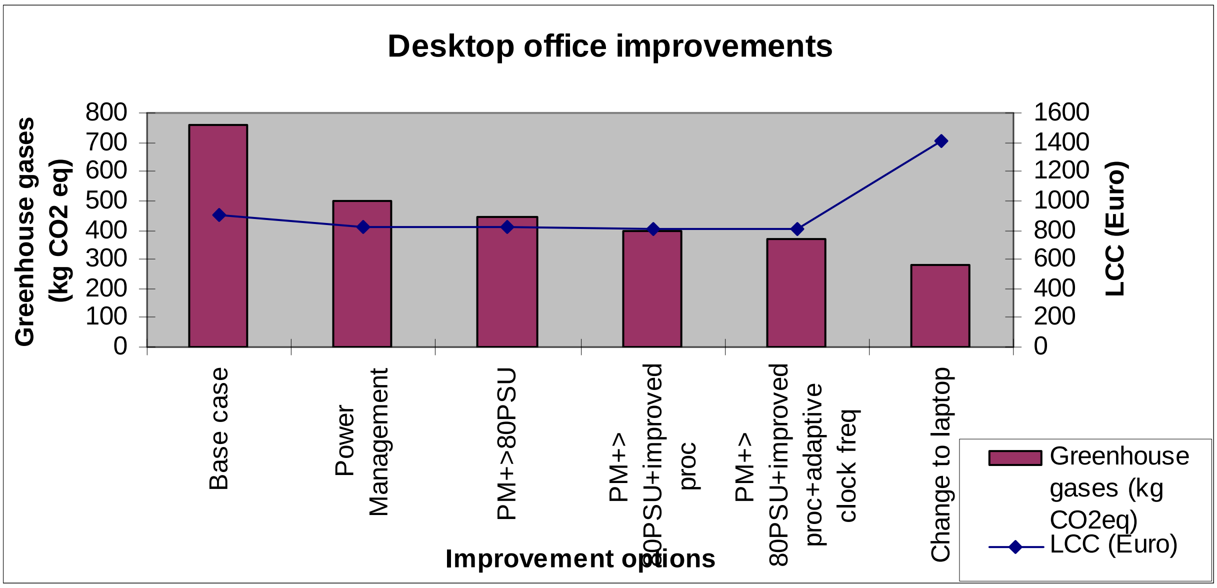

Figure 13 LCC and Greenhouse gases for Desktop office improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for desktop office products can be achieved by using Power Management, "80-plus" Power supply unit, improved processor (such as dual core) and adaptive clock frequency, all at the same time. Greenhouse gas emissions can be more than halved, while reducing the cost to the consumer by nearly 100 Euro.

7.3.2 Desktop home

The improvement options relevant for home desktops are listed in the Table below. They are identical (but not numerically) to the improvement options for office desktops with the exception of the replacement laptop, which should be compared to a desktop and a LCD-screen.

Table 108 Impacts and costs per product and improvement (one by one) for home desktops.

Base cases Life cycle impact/cost	**Base case**	**Power management**	**Dual core processor**	**Adaptive clock**	**80+ PSU**	**Desktop with LCD in home**	**Laptop home**
Total Energy, GER (MJ)	12529	8363	10392	11082	10610	17002	4995
Greenhouse gases (kg CO2eq)	603	421	509	540	519	819	251
Product price (Euro)	520	520	530	520	525	721	990
Electricity (Euro)	119	68	93	101	96	158	43
Repair & maintenance costs (Euro)	117	117	117	117	117	117	118
Total Euro	756	705	740	738	738	996	1151

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 109 Impacts and costs per product and improvement added for home desktops.

	Base Case	**Power Management (PM)**	**PM+>80PSU**	**PM+> 80PSU+ improved proc**	**PM+> 80PSU+ improved proc+ adaptive clock freq**	**Change to laptop**
Total Energy, GER (MJ)	12529	8363	7508	6686	6269	4995
Greenhouse gases (kg CO2eq)	603	421	384	348	329	251
Product price (Euro)	520	520	525	535	535	990
Electricity (Euro)	119	68	58	48	43	43
Repair and Maintenance costs (Euro)	117	117	117	117	117	118
LCC (Euro)	756	705	700	700	695	1151

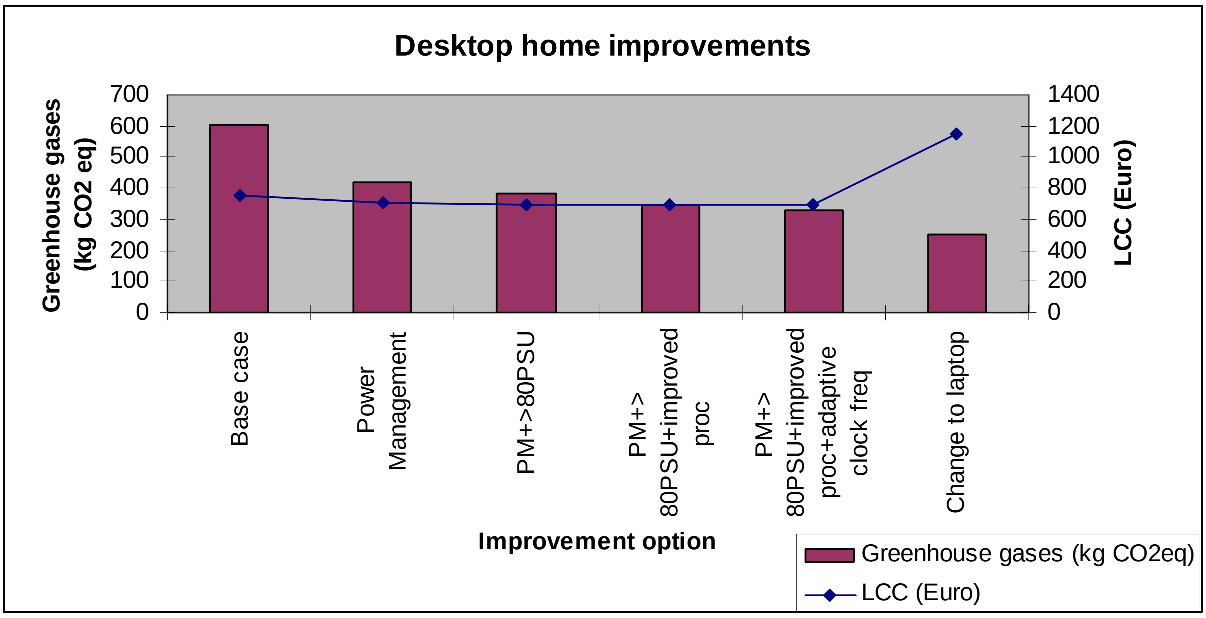

Figure 14 LCC and Greenhouse gases for Desktop home improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for desktop home products can be achieved by using Power Management, "80-plus" Power supply unit, improved processor (such as dual core) and adaptive clock frequency, all at the same time. Greenhouse gas emissions can be almost halved, while reducing the cost to the consumer by approximately 50 Euro.

7.3.3 Laptop office

The improvement options relevant for office laptops are listed in the Table below.

Table 110 Impacts and costs per product and option, one by one, for office laptops.

Base cases Life cycle impact/cost	Base case	Power manage-ment	Dual core processor	80+ PSU	LED-screen
Total Energy, GER (MJ)	7200	4973	6554	5895	6831
Greenhouse Gases (kg CO2eq)	348	250	319	291	331
Product price (Euro)	1242	1242	1257	1247	1292
Electricity (Euro)	70	43	62	54	65
Repair & maintenance costs (Euro)	118	118	118	118	118
Total Euro	1430	1403	1437	1419	1475

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 111 Impacts and costs per product and improvement added for office laptops.

	Base case	**Power Management**	**PM+>80PSU**	**PM+> 80PSU +improved proc**	**PM+> 80PSU +improved proc+LED**
Total Energy, GER (MJ)	7200	4973	4481	4243	4113
Greenhouse gases (kg CO2eq)	348	250	229	219	213
Product price (Euro)	1242	1242	1247	1262	1312
Electricity (Euro)	70	43	37	34	32
Repair and Maintenance costs (Euro)	118	118	118	118	118
LCC (Euro)	1430	1403	1402	1414	1462

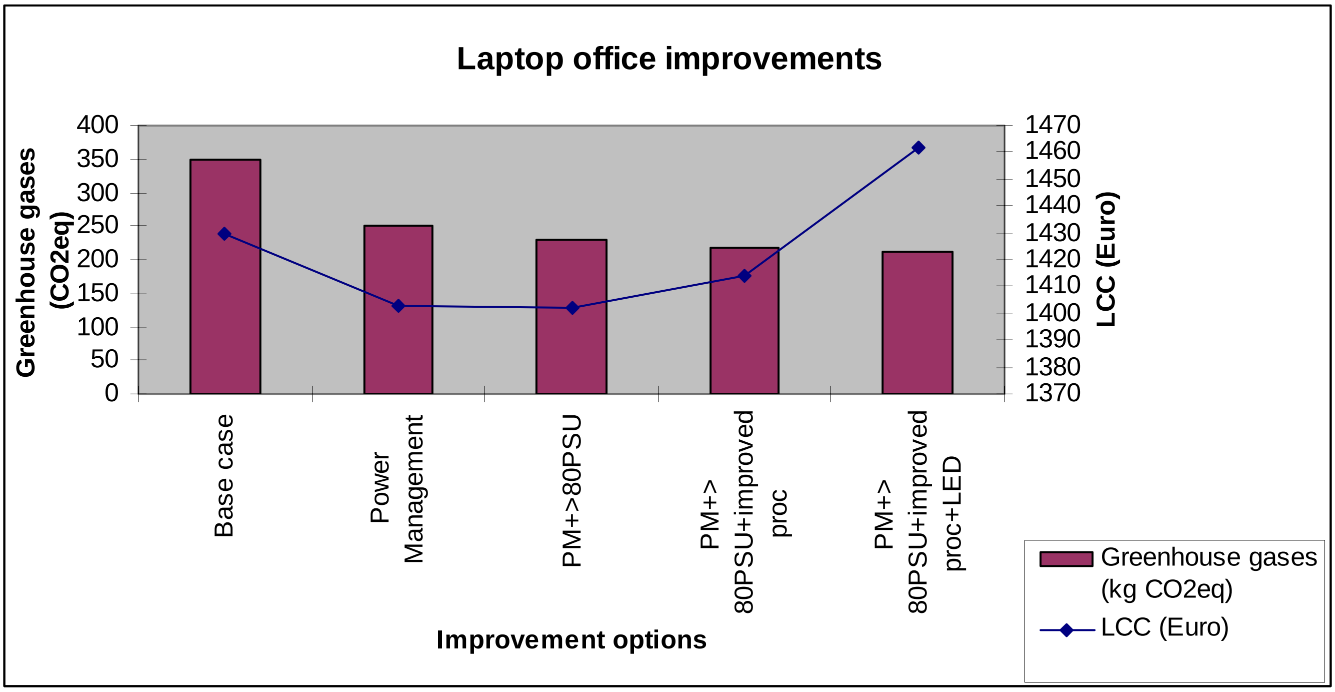

Figure 15 LCC and Greenhouse gases for Laptop office improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for laptop office products can be achieved by using Power Management, "80-plus" Power supply unit, at the same time. Greenhouse gas emissions would then be reduced by 35%, while reducing the cost to the consumer by approximately 30 Euro.

7.3.4 Laptop home

The improvement options relevant for home laptops are listed in the Table below.

Table 112 Impacts and costs per product and improvement one by one, for home laptops

Base cases Life cycle impact/cost	Base case	Power manage-ment	Dual core processor	80+ PSU	LED-screen
Total Energy, GER (MJ)	4995	3811	4701	4119	4799
Greenhouse Gases (kg CO2eq)	251	200	239	213	243
Product price (Euro)	990	990	1005	995	1040
Electricity (Euro)	43	29	39	32	41
Repair & maintenance costs (Euro)	118	118	118	118	118
Total Euro	1151	1136	1162	1145	1198

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 113 Impacts and costs per product and improvement added for home laptops.

	Base case	Power Management (PM)	PM+>80PSU	PM+> 80PSU+improved proc	PM+> 80PSU+improved proc+LED
Total Energy, GER (MJ)	4995	3811	3550	3423	3355
Greenhouse gases (kg CO2eq)	251	200	188	183	180
Product price (Euro)	990	990	995	1010	1060
Electricity (Euro)	43	29	25	24	23
Repair and Maintenance costs (Euro)	118	118	118	118	118
LCC (Euro)	1151	1136	1138	1152	1201

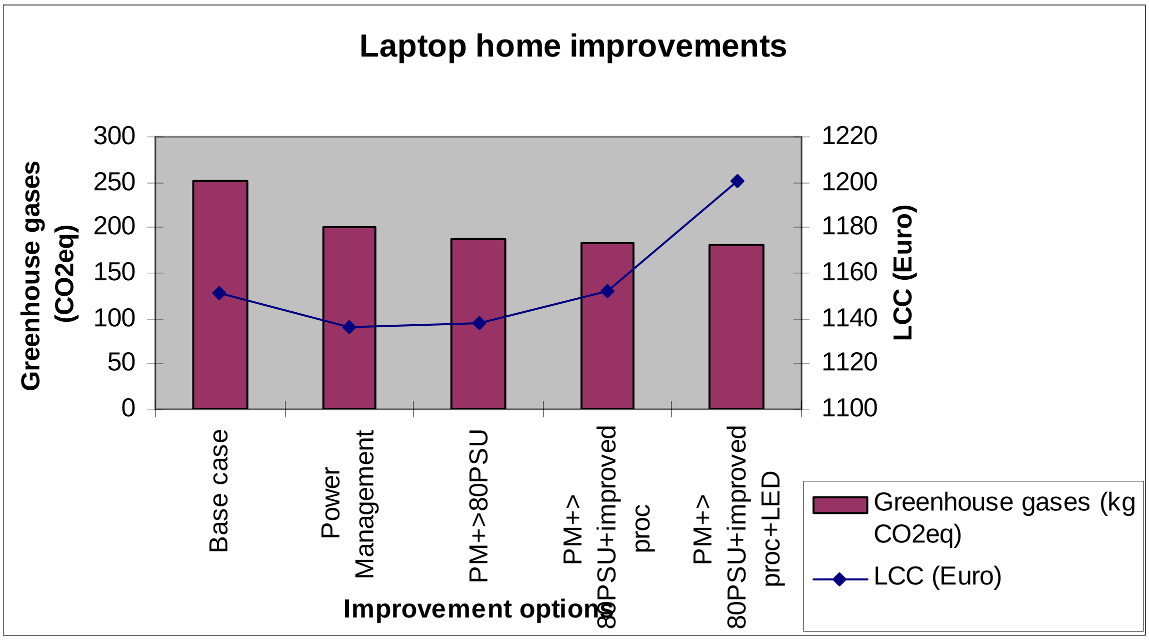

Figure 16 LCC and Greenhouse gases for Laptop home improvements, added.

Conclusion from this is that LLCC (least life cycle cost) for laptop home products can be achieved by using Power Management as a single feature. The reason for not getting less LCC with “80-plus” PSU, is that that the energy use during use phase from laptops used at home, is relatively small.

7.3.5 LCD in office

The improvement options relevant for LCD-screens in offices are listed in the Table below.

Table 114 Impacts and costs per product and option one by one for LCD-screens in offices.

Base cases Life cycle impact/cost	Base case	Power manage-ment	80+ PSU	LED instead of LCD
Total Energy, GER (MJ)	7231	4498	6102	5824
Greenhouse Gases (kg CO2eq)	336	217	287	275
Product price (Euro)	201	201	206	251
Electricity (Euro)	73	40	59	56
Repair & maintenance costs (Euro)	0	0	0	0
Total Euro	274	241	265	307

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 115 Impacts and costs per product and improvement added for office LCD.

	Base case	Power Management	PM+>80PSU	PM+>80PSU +LED
Total Energy, GER (MJ)	7231	4498	3934	3371
Greenhouse gases (kg CO2eq)	336	217	193	168
Product price (Euro)	201	201	206	256
Electricity (Euro)	73	40	33	26
Repair and Maintenance costs (Euro)	0	0	0	
LCC (Euro)	274	241	209	282

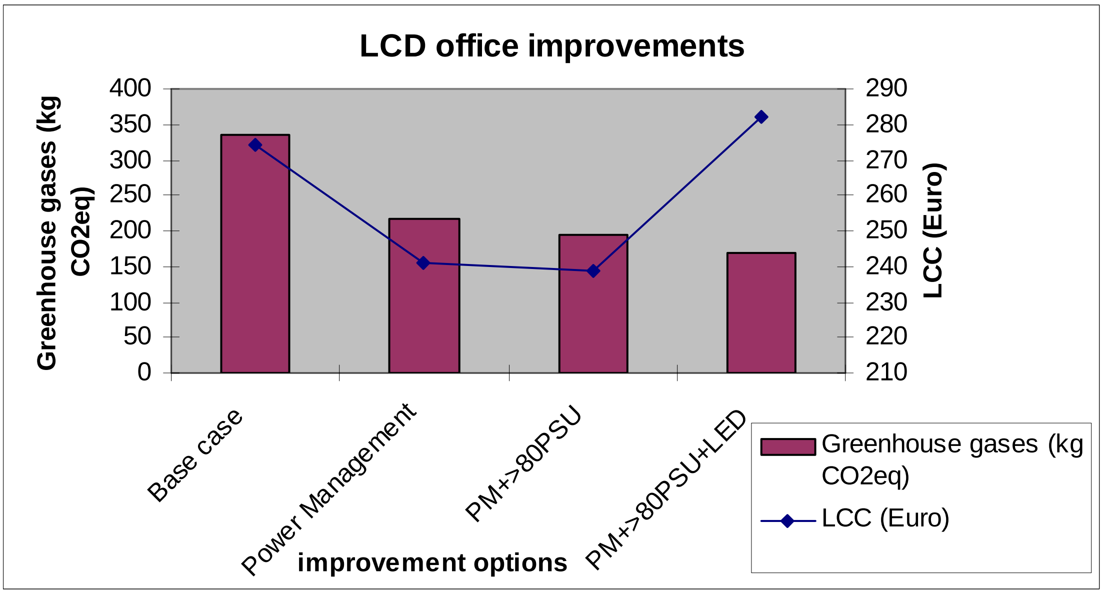

Figure 17 LCC and Greenhouse gases for LCD office improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for LCD office products can be achieved by using Power Management and "80-plus" Power supply unit at the same time. Greenhouse gas emissions can be reduced by 23%, while reducing the cost to the consumer by approximately 70 Euro.

7.3.6 LCD in home

The improvement options relevant for LCD-screens in homes are listed in the Table below.

Table 116 Impacts and costs perproduct and option one by one for LCD-screens in homes.

Base cases Life cycle impact/cost	Base case	Power manage-ment	80+ PSU	LED instead of LCD
Total Energy, GER (MJ)	4473	3112	3910	3771
Greenhouse Gases (kg CO2eq)	216	157	192	186
Product price (Euro)	201	201	206	251
Electricity (Euro)	39	23	32	31
Repair & maintenance costs (Euro)	0	0	0	0
Total Euro	240	224	238	282

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 117 Impacts and costs per product and improvement added for home LCD

	Base case	Power Management	PM+>80PSU	PM+>80PSU +LED
Total Energy, GER (MJ)	4473	3112	2830	2549
Greenhouse gases (kg CO2eq)	216	157	144	132
Product price (Euro)	201	201	206	256
Electricity (Euro)	39	23	19	16
Repair and Maintenance costs (Euro)	0	0	0	0
LCC (Euro)	240	224	225	272

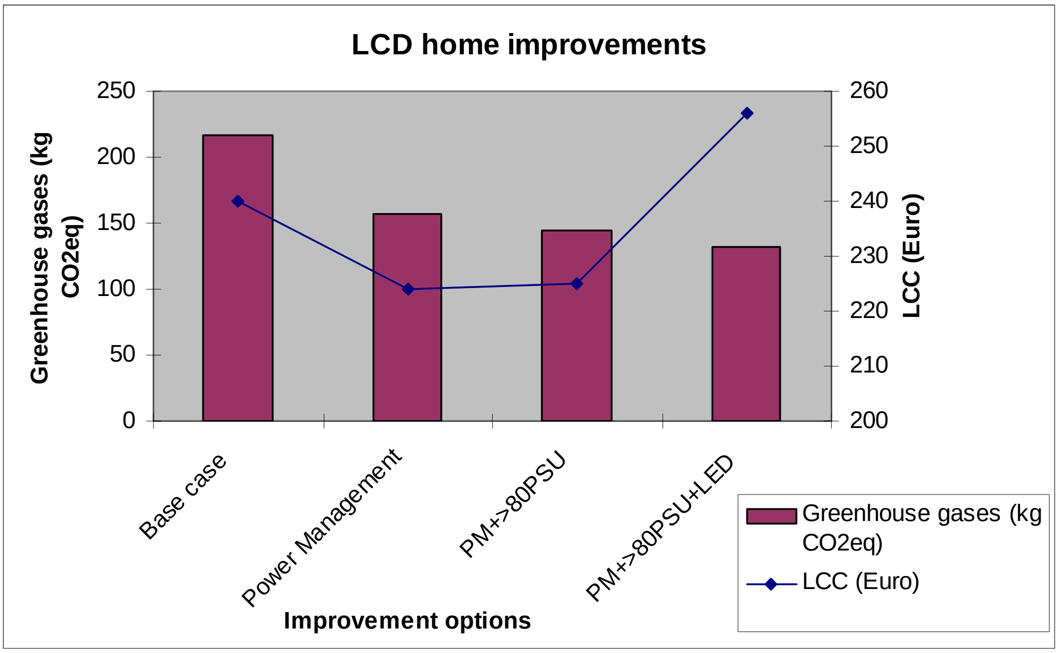

Figure 18 LCC and Greenhouse gases for LCD home improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for LCD home products can be achieved by using Power Management as a single feature. The reason for that is that the energy use during use phase from LCD used at home is relatively small.

7.3.7 CRT in office

The improvement options relevant for CRT-screens in offices are listed in the Table below.

Table 118 Impacts and costs per product and improvement one by one for CRT-screens in offices.

Base cases **Life cycle impact/cost**	**Base case**	**Power manage-ment**	**80+ PSU**	**LCD-screen**
Total Energy, GER (MJ)	14515	8422	11942	7231
Greenhouse Gases (kg CO2eq)	657	391	545	336
Product price (Euro)	73	73	78	201
Electricity (Euro)	159	85	127	73
Repair & maintenance costs (Euro)	0	0	0	0
Total Euro	232	158	205	274

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool.

The calculation order of the options is chosen to give the largest impact on LCC first.

Table 119 Impacts and costs per product and improvement added for office CRT.

	Base case	Power Management	PM+>80PSU	LCD-screen
Total Energy, GER (MJ)	14515	8422	7177	7231
Greenhouse gases (kg CO2eq)	657	391	337	336
Product price (Euro)	73	73	78	201
Electricity (Euro)	159	85	70	73
Repair and Maintenance costs (Euro)	0	0		
LCC (Euro)	232	158	148	274

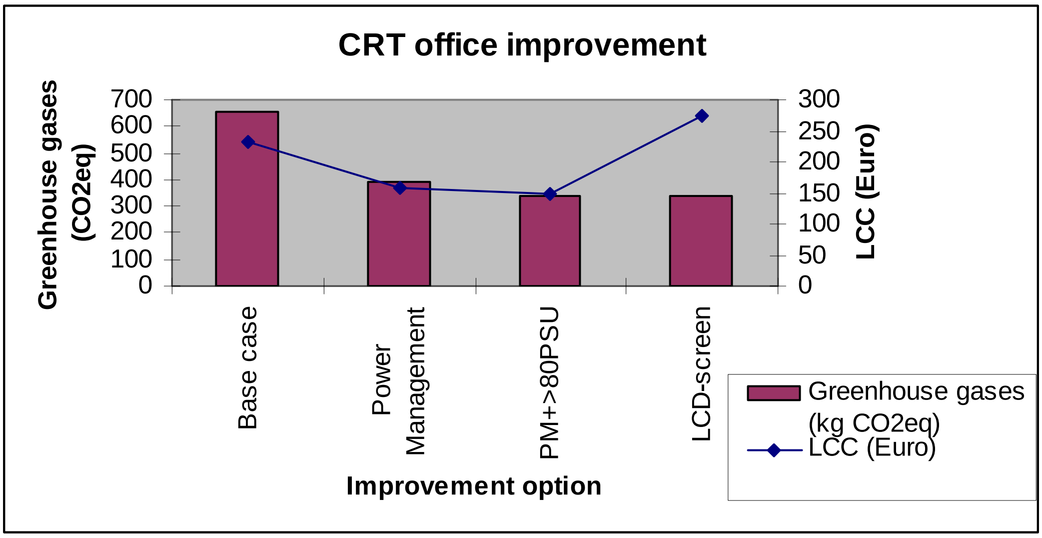

Figure 19 LCC and Greenhouse gases for CRT office improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for CRT office products can be achieved by using Power Management and "80-plus" Power supply unit at the same time. Greenhouse gas emissions can be almost halved, while reducing the cost to the consumer by almost 100 Euro.

7.3.8 CRT in home

The improvement options relevant for CRT-screens in homes are listed in the Table below.

Table 120 Impacts and costs per product and option (one by one) for CRT-screens in homes.

Base cases **Life cycle impact/cost**	**Base case**	**Power manage-ment**	**80+ PSU**	**LCD-screen**
Total Energy, GER (MJ)	8403	5369	6994	4473
Greenhouse Gases (kg CO2eq)	390	258	329	216
Product price (Euro)	73	73	78	201
Electricity (Euro)	85	48	68	39
Repair & maintenance costs (Euro)	0	0	0	0
Total Euro	158	121	146	240

In order to find out the impact and LCC if more than one improvement option is used, combinations of the options have been calculated with the Ecoreport tool. The calculation order of the options is chosen to give the largest impact on LCC first.

Table 121 Impacts and costs per product and option added for CRT-screens in homes.

	Base case	**Power Management**	**Power Management +>80% PSU**	**Change to LCD**
Total Energy, GER (MJ)	8403	5369	4747	4473
Greenhouse gases (kg CO2eq)	390	258	231	216
Product price (Euro)	73	73	78	201
Electricity (Euro)	85	48	40	39
Repair and Maintenance costs (Euro)	0	0		
LCC (Euro)	158	121	118	240

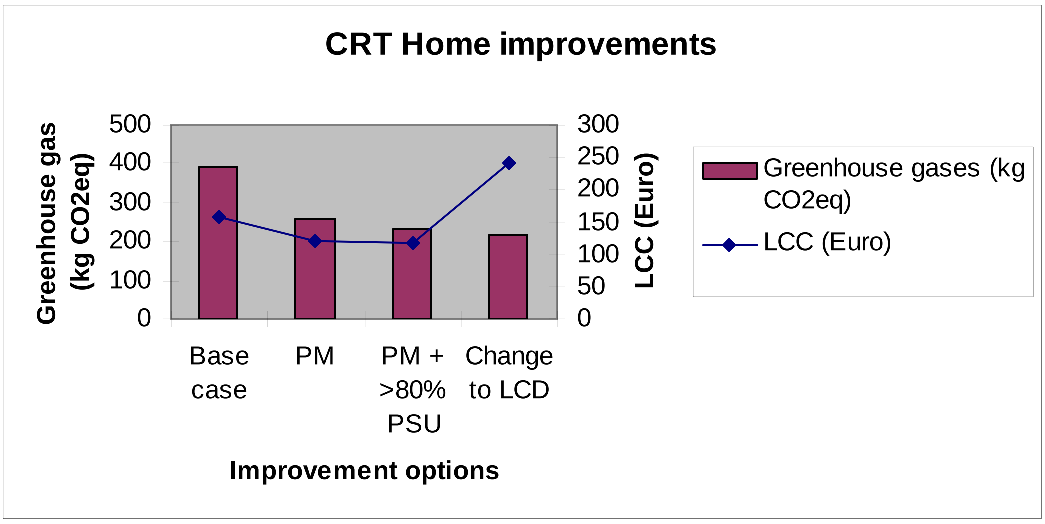

Figure 20 LCC and Greenhouse gases for CRT home improvements, added.

From the above figure it can be concluded that LLCC (least life cycle cost) for LCD home products can be achieved by using Power Management and a "80-plus" power supply unit at the same time. Greenhouse gas emissions can be reduced by 40%, while reducing the cost to the consumer by almost 40 Euro.

7.3.9 Conclusions

For all the products evaluated, it is obvious that power management has a very high potential for improvement. It is of even more value if the future behavior of the users of the products, due to broadband connections and other features, induces that people leaves the products on all the time. Highly efficient power supply units do also have a high potential for improvement, even if the LCC increases slightly for products that are used less frequently. For most products and usage patterns, the highly efficient power supply units decrease the LCC. For desktops, it is obvious that highly efficient processors, such as dual core, and processors with adaptive clock frequency have a high potential for improvement. The reason why that is not the case for laptops, is that for these products that improvement is already implemented.

7.3.10 Impact of improvements on EU totals

Below it is shown what it would mean to total emissions in EU-25, if all the options with LLCC, as described above, would be implemented.

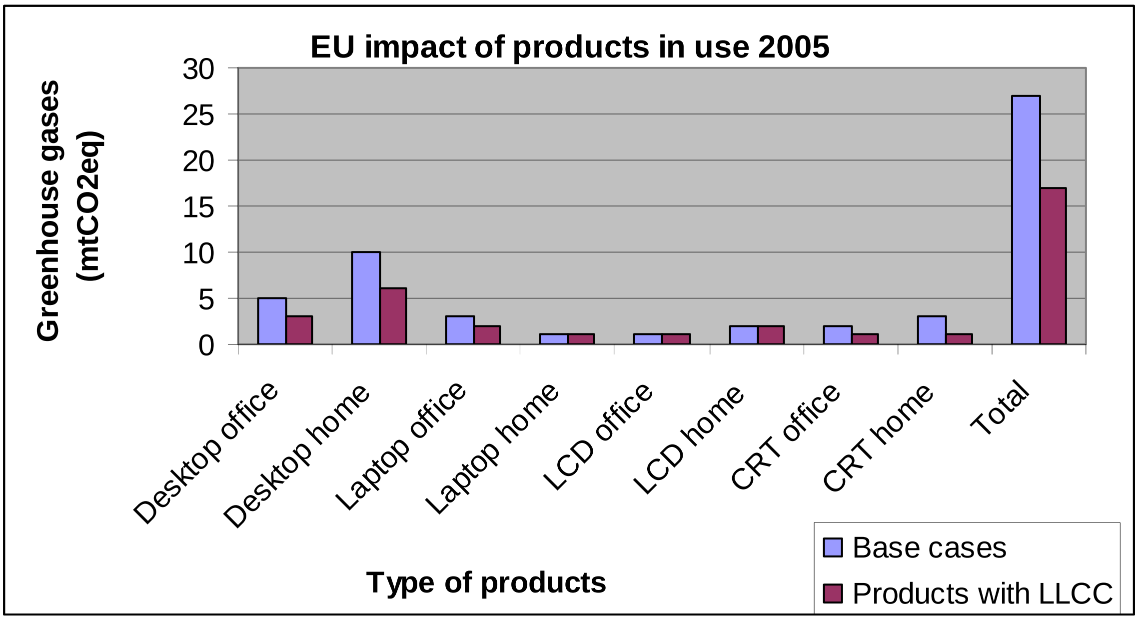

Figure 21 EU Impact of Products in 2005 (produced, in use, discarded) Greenhouse gases (mtCO2eq) for base case products and LLCC products.

A conclusion from this is that there is a lot of greenhouse gases to save, approximately 10 mega tones ($10*10^{9}$ kg) CO2-eq, if all the products in use 2005 were changed to the ones with the least life cycle cost LLCC.

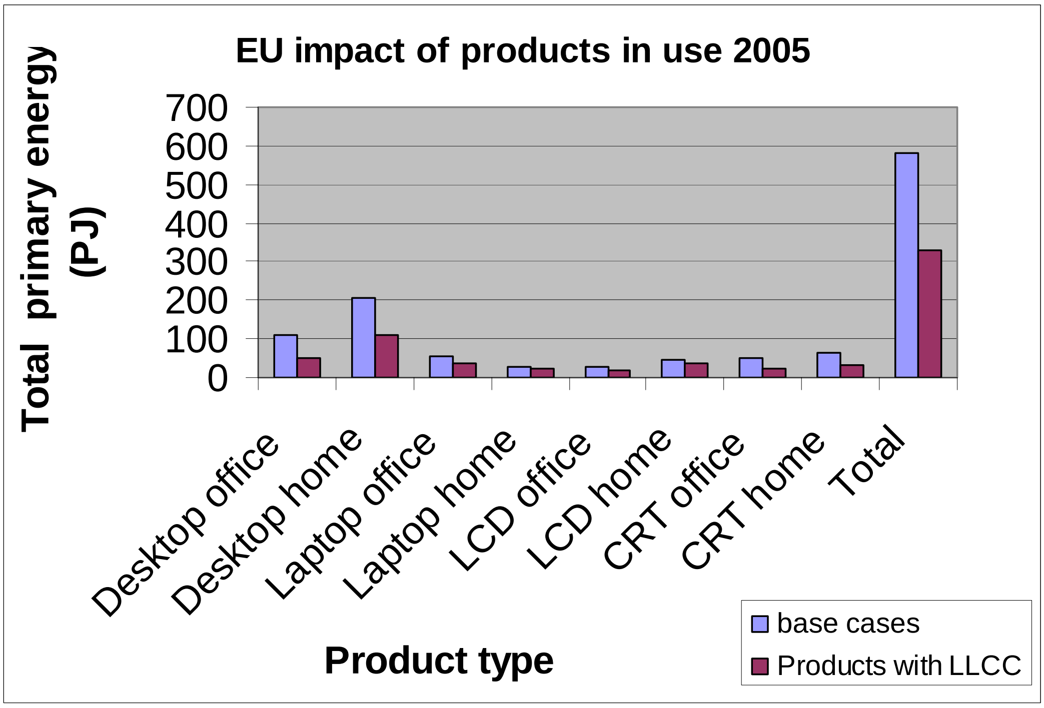

Figure 22 EU Impact of Products in 2005 (produced, in use, discarded), total primary energy for base case products and LLCC products.

Figure 21 shows that the potential to save primary energy if all products in use 2005 were changed to the ones with least life cycle cost, would be approximately 255 PJ (255 $*10^{15}$ Joule).

7.4 Long-term targets (BNAT) and systems analysis

7.4.1 Thin Clients

A thin client is a PC without a hard drive. It contains an operating system in RAM but relies on a server for other software applications. The normal configuration is that the server supports a number of thin clients that can run the applications on that server. The intended uses for these types of PCs are normal office applications. There are several benefits of using a thin client. The energy consumption of the thin client is low, the start up time is short since the operating system is in RAM, and since the software applications are located on a server the maintenance of the software is simple. The major draw back of the thin client is that it cannot be used as a stand alone PC. It relies on the network connection to the server to function as intended.
Due to the low energy consumption there has been an increased interest in this type of PCs for office use the last years. The thin client is, however, not a part of this EuP study.

7.4.2 Influence from Software

The performance of software is not within the real scope of this study, but since the effects on the LCC of computer products are quite significant it is still worth to comment.

The potential positive influence from power management, have been covered in several of the previous chapters, but it is also obvious that the full potentials of the hardware power management functions, very seldom are utilized due to software problems or even perceived software problems.

The recently introduced operating system Vista include much more powerful power management functionality than the previous operating systems, but due to the increased demands for computer capacity for other functions, the improvements from Vista in environmental aspects is questionable.

The increased capacity and functionality from new software is obvious, more graphics, easier to use, better integration of different applications and so on. But seen from another standpoint, the relation, real improvements in capacity versus increased demands for computing power are not that positive. The documents written in a brand new word-processor are not that much better than the documents written a couple of years ago using much less computing power and energy, neither are the spread-sheets.

The potential for better LCC from dedicated software development with energy efficiency in focus is quite high, but it has probably not yet become a strong enough selling argument, to influence the new products.

7.4.3 Consumer behavior

The consumer behavior has a great impact on the environmental performance of products evaluated in this study. One option with high improvement potential not calculated here could therefore be consumer information. The information would help the users to understand and use power management in a proper way, and could also offer guidance in purchasing choices. Information can be delivered in many ways; such as implementing easy access tutorial tools integrated in the computer software or at a website. Another solution might be to educate all pupils at school, to provide them with a “driving license for computers”. The impact of such educations could be huge. Today information given from the manufacturers and/or suppliers of computers is not good enough to help most people to use power management in a proper way.

7.5 References

- Battery chargers and external power supplies. Final report. Lot 7. January 23 2007
- Computer Memorandum of Understanding (Version 3.0) between The United States Environmental Protection Agency
- Energy Star® Program Requirements for Computer Monitors Eligibility Criteria (Version 4.1)
- Energy Star® Program Requirements for Computers: Final Draft Version 4.0
- MEEUP Methodology Report. Final Report. Methodology Study Ecodesign of Energy-using Products. 28.11.2005. VHK for European Commission. Available at http://www.vhk.nl/

8 Abbreviations used

ACPI Advanced Configuration and Power Interface

Ag, silver

BAT, Best Available Technology

BOM, Bill of Materials

BNAT, Best Not yet Available Technology

CPU Central Processing Unit

CRT, cathode-ray tube

EIA, Environmental Impact Assessment

GPU Graphics Processing Unit

HDD, Hard Disk Drive

LED, light emitting diode

LLCC, Least Life Cycle Cost

LCD, liquid crystal display

OLED, organic light emitting diode

PSU, power supply unit

PWB, printed wiring board

RAM, Random Access Memory

SMD, surface mounted devices

Sn, tin

9 Appendix 1, Data collection

9.1.1 Choice of product cases

The choice of relevant product cases had the following starting points:

- The product definition from Task 1: "Within the scope of this study are desktops, integrated computers, laptops and computer monitors. What constitutes a desktop, an integrated computer, a laptop and a computer monitor is defined by Energy Star definitions" [Computers, Final Draft Version 4.0 and Monitors, Version 4.1].
- The economic and market analysis from Task 2.
- The different usage patterns for homes and offices analyzed in Task 3
- The stakeholder dialogue, ie:
    - the stakeholder meeting 30 May 2006 at IVF in Mölndal Sweden,
    - the subsequent questionnaire during summer 2006 and
    - the feedback received in October on the tentative choice of product cases
    - the datasets received for the different product cases (including also numerous e-mail and telephone contacts for checking data consistency)

The base-case calculations should serve dual purposes: one is to assess the total energy consumption and environmental impact in EU25 from personal computers and monitors in 2005, the other is to give knowledge about design options that could reduce the environmental impact with focus on energy consumption. Other important considerations in the choice of base-cases are:

- At the stakeholder meeting in Mölndal, the computer industry strongly recommended separate base-cases for PCs for the home and office market respectively.
- The purpose to assess the total energy consumption and environmental impact from personal computers and monitors in 2005 suggests that base-cases should represent the best-sellers[13] in that year
- From energy per unit point of view, the processor is the most essential component[14]. This component is also the most essential from a computer performance point of view.

[13] The VHK-methodology prescribes the use of EU average data. Through the first questionnaire [IVF, July 2006], data covering around 17% of computer sales in 2005 was obtained. They represent the best selling brands and models in Europe.

[14] Battery chargers and external power supplies may also be very important but they are covered in a parallel study, Lot 7 [Lot 7, November 2006]. For laptops, the LCD-screen is an important energy user.

- To follow as closely as possible the most current version of the Energy Star Requirements, with respect to grouping of computers and monitors, because Energy Star is well accepted by both industry and public bodies.

With this background and the above product definition, the following product cases representative for personal computers and monitors sold in 2005 were chosen:

- Laptop for office use[15] with a modern energy efficient processor
- Laptop for home use[15] with a desktop replacement processor[16]
- Desktop high-end, ie with a high-performance processor and graphics card. This could be a high-end desktop for home use even though these are not selling quite as much as value desktops. The high-end desktop is supposed to fall under Energy Star category B[17].
- Desktop office value best seller with single core medium performance processor falling under Energy Star category A[18]. No separate graphics card.
- 17" TN-based TFT LCD
- 17" CRT for office use

Other categories that have been discussed include:

- Workstations, but they fell outside the product definition, and
- High-end desktops meeting specifications for Energy Star category C, but few if any such machines were sold during 2005

9.1.2 Supply of data for product cases

Already at the Mölndal workshop in May 2006, industry declared a willingness to support the study including supplying data. However, it was also clear that data would be supplied only under non-disclosure agreements. Since the study is public, a strategy has been devised to only publish data that has been aggregated to a level where it is not possible to trace any data back to any specific manufacturer.

Since an insufficient number of datasets were received (to enable aggregation as described above), all laptops were aggregated into one case and all desktops aggregated into one case. What this means for the robustness of the conclusions is discussed in Task 8.

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[15] Both laptop base-cases are supposed to fall under Energy Star category A for laptops, ie their GPU have less than 128 Mb of dedicated, non-shared memory.

[16] Desktop replacement processor is the terminology used by industry when a processor designed for desktops is used in a laptop

[17] To qualify under Energy Star category B desktops must have: Multi-core processor(s) or greater than 1 discrete processor and minimum of 1 gigabyte system memory.

[18] All desktops that do not meet the definition of Energy Star category B desktops

Doing a life cycle assessment, LCA, with any software tool involves doing a number of assumptions about materials, volumes, processes etc because the data available is always limited. Doing an LCA with the EuP EcoReport is no exception. To ensure that all these assumptions are done in something close to a uniform way, one person should feed the data into the tool. This person must of course make the assumptions in a consistent way. Therefore industry has been asked to supply data in a form fitting the EuP EcoReport[19], but not feed data themselves into the tool. To this end a questionnaire containing 21 questions related to data on specific product cases was designed and sent out to industry 11 November 2006. The questionnaire is given in Table 83.

Table 122 Questionnaire for provision of LCA data.

Question		**Your answer**
1. Name of product		
2. E-mail and telephone number to person who can give more information about the data provided		
3. How many of this product was sold in 2005 in EU 25?		
4. State accessories that are included, such as keyboard, mouse, display		
5. Average price to customer in EU25 in 2005 in Euro		
6. Processor (Brand, model, (speed GHz))		
7. Graphic card built-in or separate and name of graphic card		
8. Size (Width [mm]/Depth [mm]/Height [mm]) and shape (tower, microtower, etc) of product		
9. Volume of packaged final product in m^3?		
10. Weight of product [kg]?		
11. Power consumption [W] during idle mode, (measured according to Energy Star version 4.0)		
12. Power consumption [W] during sleep mode, (measured according to Energy Star version 4.0)		
13. Power consumption [W] during off-mode (hibernate/stand-by/soft off), (measured according to Energy Star version 4.0)		
14. An estimate of number of transport kilometers over product-life used for services and repairs?		
15. How many grams of the	LDPE[21]	
	HDPE[22]	

[19] See http://ec.europa.eu/energy/demand/legislation/doc/eup_ecoreport_v5_en.xls for the EcoReport.

Question		Your answer
1. Name of product		
following bulk plastics does the product contain as shipped[20]?	LLDPE[23]	
	PP[24]	
	PS[25]	
	EPS[26]	
	HI-PS[27]	
	PVC	
	SAN[28]	
	ABS[29]	
	Other, please specify	
	Other, please specify	
	Other, please specify	
16. How many grams of the following technical plastics and fillers does the product contain as shipped[20]?	PA 6[30]	
	PC[31]	
	PMMA[32]	
	Epoxy	
	Rigid PUR[33]	
	Flex PUR	
	Talcum Filler	
	E-glass fibre	
	Aramid fibre	
	Other, please specify	
	Other, please specify	
	Other, please specify	
17. How many grams of the following ferro metals does the product contain as shipped[20]?	Steel sheet galvanized	
	Steel tube/ profile	
	Cast iron	
	Ferrite	
	Stainless 18/8 coil	
	Other, please specify	
	Other, please specify	

[20] including packaging, manuals etc
[21] Low Density Poly Ethylene
[22] High Density Poly Ethylene
[23] Linear Low Density Polyethylene
[24] Polypropylene
[25] Polystyrene
[26] Expanded polystyrene
[27] High impact polysterene
[28] Polystyrene acrylonitrile)
[29] (Poly) Acrylonitrile Butadiene Styrene
[30] Polyamide
[31] Polycarbonate
[32] Polymethylmethacrylate
[33] Polyurethene

Question		**Your answer**
1. Name of product		
	Other, please specify	
18. How many grams of the following non-ferro metals does the product contain as shipped[20]?	Al sheet/ extrusion	
	Al diecast	
	Cu winding wire	
	Cu wire	
	Cu tube/sheet	
	CuZn38 cast[34]	
	ZnAl4 cast[35]	
	MgZn5 cast[36]	
	Other, please specify	
	Other, please specify	
	Other, please specify	
19. How many grams of the following coatings does the product contain as shipped[20]?	Pre-coating coil[37]	
	Powder coating	
	Cu/Ni/Cr plating	
	Au/Pt/Pd plating	
	Other, please specify	
	Other, please specify	
	Other, please specify	
20. How many m^2 screen does the product contain as shipped[38]?	LCD screen m^2 (viewable screen size)	
	CRT screen m^2 (nominal screen size)	
21. How many grams of the following electronics does the product contain as	Big caps & coils[39]	
	Slots /ext. ports[40]	
	Integrated Circuits, 5% Silicon, Au[41]	
	Integrated Circuits, 1% Silicon[41]	

[34] 38% Zink

[35] 4% Aluminium

[36] 5% Zink

[37] Pre-coated steel or aluminium sheet metal

[38] For computers: Only applicable when screen is integrated or part of shipment. The glass in the LCD and the lead and glass in the CRTs should not be specified elsewhere. No double-counting of these materials!

For monitors: The glass in the LCD and the lead and glass in the CRTs should not be specified elsewhere. No double-counting of these materials!

[39] Large capacitors and coils components on a printed wiring board typical for power conversion functions.

Question		Your answer
1. Name of product		
shipped[20]?	SMD & LEDs avg[42]	
	PWB ½ lay 3.75 kg/m2[43]	
	PWB 6 lay 4.5 kg/m2[44]	
	PWB 6 lay 2 kg/m2[45]	
	Solder SnAg4Cu0.5[46]	
	Other, please specify	
	Other, please specify	
	Other, please specify	
22. How many grams of the following materials does the product contain as shipped[20]?	Glass for lamps	
	Bitumen	
	Cardboard	
	Office paper	
	Concrete	
	Other, please specify	
	Other, please specify	
	Other, please specify	
For further explanation of the above questions and abbreviation used, please see The MEEUP Methodology Report pages 88-89 and 93-97 or contact Mats.Zackrisson@ivf.se, telephone +46 8 20 39 53.		

9.1.3 Data assumptions

For received data not fitting the EcoReport format, assumptions presented in this appendix have been used consistently in the study. Names in *italics* correspond to material names in the EuP EcoReport, see MEEUP Methodology Report pages 88-89 and 93-97 and/or the EuP EcoReport.

1. Unspecified ferrous&non-ferrous metal assumed to be equivalent to 90% *galvanized steel* and 10% *Al sheet*, because it represents a likely worst case (in primary energy)

2. Unspecified plastics assumed to be equivalent to *PA 6*, because it represents worst likely case (in primary energy)

---

[40] Printed wiring board mounted slots for RAM-chips, PCI-cards and external ports

[41] The two integrated circuits represent extremes of the current range of integrated circuits. The 5% Silicon with gold content represent a large IC including memory, the 1% silicon represents a small surface mounted type IC

[42] Surface mounted devices such as diodes, thyristors, RF etc

[43] Standard FR4 printed wiring board

[44] Multilayer standard FR4 printed wiring board

[45] Multilayer printed wiring board with microvias

[46] Lead-free tin solder with 4% Ag and 0,5% Cu

3. Non-recyclable Plastic assumed to be equivalent to the thermoset *epoxy* that cannot be recycled

4. The distribution between coat and material on coated objects is based on 100 µm on 1 mm sheet steel, where the distribution between materials is: =100/1000000*1*1490/7800/1/0.001 = 2% pulver, ie 98% material.

5. Wires and cables internal assumed to be equivalent to *Cu wire*

6. External Electric cables assumed to be equivalent to 80% *Cu wire* and 20% *PVC*.

7. 17" CRT with 4/5 relationship between sides (1280*1024)[47] corresponds to 910 cm2 nominal surface (17*2.54=43.18; $(5^2+4^2)^{1/2}$=6.4; 43.18*5/6.4=33.73; 43.18*4/6.4=26.99; 26.99*33.73=910 cm2= 0.0910 m2. Same for LCD but actual viewing surface. 1000*0.091 inserted in the EcoReport!

8. 15.4" LCD with 8/5 relationship between sides (1280*800)[48] corresponds to 688 cm2 nominal surface (15.4*2.54=39.12; $(8^2+5^2)^{1/2}$=9.43; 39.12*8/9.43=33.19; 39.12*5/9.43=20.74; 20.74*33.19=688 cm2= 0.0688 m2.) Same for LCD but actual viewing surface. 1000*0.0688 inserted in the EcoReport!

9. 15" LCD with 4/3 relationship between sides (1024*768)[49] corresponds to 697 cm2 nominal surface (15*2.54=38.1; $(4^2+3^2)^{1/2}$=5; 38.1*4/5=30.48; 38.1*3/5=22.86; 30.48*22.86=697 cm2= 0.0697 m2.) 1000*0.0697 inserted in the EcoReport!

10. 17" CRT with 4/3 relationship between sides (1024*768)[50] corresponds to 894 cm2 nominal surface (17*2.54=43.18; $(4^2+3^2)^{1/2}$=5; 43.18*4/5=34.54; 43.12*3/5=25.87; 34.54*25.87=894 cm2= 0.0894 m2.)

11. The materials in the LCD screen subassemblies are allocated according to below following an Environmental Product Declaration of LCD screens made by LG Electronics, see www.environdec.com.

LCD allocation	Weight %
Steel	49,5
Copper	0,4
Eps	10,7
PMMA	7,7
LDPE (PET+PE+Other)	8,3
PC	6,5
Glass	15,6
PWB 6 lay 4.5 kg/m2	0,25

[47] 1024*768 corresponds to sides 4/3

[48] 1024*768 corresponds to sides 4/3

[49] 1024*768 corresponds to sides 4/3

[50] 1024*768 corresponds to sides 4/3

Slots / ext. ports	0,40
IC's avg. 5% Si, Au	0,10
IC's avg., 1% Si	0,10
SMD&LEDs avg	0,13
Solder	0,02

Where the glass is booked as Misc material without subcategory in the Ecoreport.

12. Unspecified filled plastics in LCD assumed to be equivalent to PC with 30% glass fibre

13. Components containing refractory ceramic fibers assumed to be equivalent to *aramid fibre* (which is believed to be carcinogenic)

14. Unspecified batteries assumed to be equivalent to *big caps & coils*

15. Printed circuit assemblies >10 cm2 in desktops and displys (except for power supply) assumed to be equivalent to:

Electronics	**%**
PWB 6 lay 4.5 kg/m2	25
Slots / ext. ports	30
Big caps & coils	10
IC's avg. 5% Si, Au	10
IC's avg., 1% Si	10
SMD&LEDs avg	13
Solder	2

16. Printed circuit assemblies >10 cm2 in laptops (except for power supply) assumed to be equivalent to:

Electronics	**%**
PWB 6 lay 4.5 kg/m2	25
Slots / ext. ports	40
IC's avg. 5% Si, Au	10
IC's avg., 1% Si	10
SMD&LEDs avg	13
Solder	2

17. Printed circuit assemblies >10 cm2 in computers for power supply assumed to be equivalent to:

Electronics	**%**
PWB 1/2 lay 3.75 kg/m2	10
Big caps & coils	65
IC's avg., 1% Si	5
SMD&LEDs avg	15
Solder	5
Sum	100

18. PET assumed to be equivalent to LDPE (because similar Ecoindicator 99 value in IVF database)

19. Mylar assumed to be equivalent to LDPE (because it is based on PET)

20. POM assumed to be equivalent to LDPE (because similar Ecoindicator 99 value in IVF database)

21. Ni assumed to be equivalent to Cu wire (because similar Ecoindicator 99 value in IVF database)

22. Switch assumed to be equivalent to 50% *slots and external ports* and 50% *ICs SMD*

23. Batteries assumed to be equivalent to *big caps and coils* (because there was no better alternative. Lot 7 made the same assumption). An important improvement suggestion for the EcoReport is better modelling capabilities for batteries!

10 Appendix 2, Environmental impacts during the production phase

Nr: 0 | Product: EuP Lot 3 prep study: Office desktop PC | Date: 00-01-00 | Author: MZ

MATERIALS EXTRACTION & PRODUCTION

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght in g	cat.	material	GER MJ	electr MJ	feedst MJ	water (proces ltr.	water (cool) ltr.	haz. Waste g	non-haz. Waste g	GWP kg CO2eq	AD g SO2eq	VOC mg	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	Metal mg Hg/20eq	EUP mg PO4 eq
1	LDPE	246	1-BlkPlastics	1-LDPE	19,14	3,27	12,68	0,74	11,07	1,09	10,87	0,47	1,83	0,12	0,00	0,00	0,03	0,23	0,00	6,55
2	ABS	380,75	1-BlkPlastics	10-ABS	36,18	2,65	17,43	3,54	62,82	3,81	35,00	1,26	6,77	0,00	0,00	0,00	0,69	1,10	0,74	239,81
3	PA 6	137,68	2-TecPlastics	11-PA 6	16,45	2,08	5,36	2,20	30,15	2,62	24,27	1,18	5,38	0,00	0,00	0,00	0,06	0,74	6,75	257,78
4	PC	264,25	2-TecPlastics	12-PC	30,87	3,93	10,04	3,70	30,12	2,64	46,65	1,43	6,72	0,00	0,00	0,00	0,10	1,77	0,04	133,19
5	Epoxy	97,9	2-TecPlastics	14-Epoxy	13,78	2,40	4,17	1,86	37,59	1,86	39,80	0,65	4,30	0,00	0,00	0,00	0,01	1,47	0,00	944,72
6	Flex PUR	1,5	2-TecPlastics	16-Flex PUR	0,16	0,03	0,06	0,11	0,45	0,05	0,82	0,01	0,05	0,00	0,00	0,00	0,03	0,01	0,01	8,53
7	Steel sheet galvanized	6312,3	3-Ferro	21-St sheet galv.	214,62	14,38	0,47	0,00	0,00	0,00	10866,70	17,85	47,12	0,86	164,12	22,37	0,44	17,09	22,41	411,37
8	Steel tube/ profile	106,5	3-Ferro	22-St tube/profile	1,81	0,49	-0,02	0,00	0,00	0,00	85,27	0,15	0,38	0,01	1,28	0,28	0,00	0,11	0,17	4,08
9	Cast iron	482,5	3-Ferro	23-Cast iron	4,83	0,07	-0,03	0,63	1,77	0,00	152,16	0,51	1,56	0,06	2,90	0,96	0,01	6,76	0,44	12,66
10	Ferrite	0	3-Ferro	24-Ferrite	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Stainless 18/8 coil	9,5	3-Ferro	25-Stainless 18/8 coil	0,59	0,09	0,04	0,72	0,08	0,00	9,50	0,06	0,53	0,00	0,07	1,41	0,00	0,08	0,82	22,12
12	Al sheet/ extrusion	314,53	4-Non-ferro	26-Al sheet/extrusion	60,59	0,00	0,00	0,00	0,00	0,00	1232,96	3,25	21,17	0,02	1,57	1,14	30,36	5,32	11,01	1,56
13	Al diecast	15	4-Non-ferro	27-Al diecast	0,83	0,00	0,00	0,00	0,00	0,00	11,25	0,05	0,23	0,00	0,50	0,01	0,27	0,06	0,10	0,02
14	Cu winding wire	257	4-Non-ferro	28-Cu winding wire	36,68	0,00	0,00	0,00	0,00	0,21	5150,28	1,89	78,09	0,01	1,02	14,53	1,42	0,78	1,66	40,66
15	Cu wire	333,5	4-Non-ferro	29-Cu wire	38,87	0,00	0,00	0,00	0,00	0,08	6674,00	2,07	97,42	0,00	1,25	18,36	1,79	0,95	31,38	51,53
16	Cu tube/sheet	66,5	4-Non-ferro	30-Cu tube/sheet	3,39	0,00	0,00	0,00	0,00	0,00	532,93	0,18	4,16	0,00	0,68	2,20	0,36	0,10	2,50	4,12
17	Powder coating	1,62	5-Coating	39-powder coating	0,58	0,10	0,07	0,03	0,62	0,03	0,80	0,03	0,10	0,00	0,00	0,00	0,00	0,02	0,00	15,64
18	Big caps & coils	482,5	6-Electronics	44-big caps & coils	184,93	0,00	0,00	16,72	26,54	9,46	289,76	10,46	68,43	0,06	1,04	3,70	98,74	17,18	35,81	3,44
19	Slots /ext. Ports	310	6-Electronics	45-slots / ext. ports	57,99	18,39	0,00	23,14	79,16	5,30	95,38	3,11	57,15	0,00	0,43	11,78	0,60	4,02	9,86	2005,62
20	Integrated Circuits, 5% Silicon, Au	69	6-Electronics	46-IC's avg., 5% Si, Au	380,14	369,73	0,00	346,17	0,00	17,38	357,52	29,22	192,33	4,68	3,37	30,81	1,01	5,03	258,06	1482,19
21	Integrated Circuits, 1% Silicon	95,5	6-Electronics	47-IC's avg., 1% Si	83,48	64,29	0,29	58,40	9,89	61,56	166,96	5,62	77,95	0,00	0,94	17,67	0,28	2,31	0,92	410,30
22	SMD & LEDs avg	193,5	6-Electronics	48-SMD/ LED's avg.	574,47	558,36	0,00	179,07	0,00	25,29	547,78	32,32	313,56	1,45	2,90	81,60	0,88	9,83	2,85	424,83
23	PWB ½ lay 3.75 kg/m2	78	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	21,92	11,74	0,67	13,26	5,99	135,19	204,78	0,88	16,67	0,18	0,21	2,82	0,28	0,40	1,15	287,54
24	PWB 6 lay 4.5 kg/m2	162,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	59,67	23,75	1,39	78,82	12,48	307,42	661,91	2,55	64,35	0,17	0,83	11,38	1,12	6,02	20,38	396,95
25	Solder SnAg4Cu0.5	48	6-Electronics	52-Solder SnAg4Cu0.5	11,23	9,30	0,00	3,37	0,00	0,22	10,94	0,56	3,10	0,00	0,06	0,16	0,09	0,07	0,00	0,29
26	Cardboard	2286,5	7-Misc.	56-Cardboard	64,02	4,57	36,58	16,11	0,00	0,11	119,62	1,61	2,38	0,00	0,03	0,08	0,01	0,03	0,03	196,78
	TOTAL	0	0	0	1 917,20	1089,61	89,19	748,60	308,74	574,30	27327,92	117,33	1071,72	7,63	183,20	221,27	138,57	138,57	81,46	407,10

MANUFACTURING

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght in g	cat.	NDX	GER MJ	electr MJ	feedst MJ	water proces ltr.	water (cool) ltr.	haz. g	non-haz. g	GWP kg CO2eq	AD g SO2eq	VOC g	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	Metal mg Hg/20eq	EUP mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	1128,1	0	20	46,08	27,74	1,59	0,42	13,09	0,00	144,39	2,56	11,02	0,00	0,00	0,00	0,01	1,70	0,00	26,94
202	Foundries Fe/Cu/Zn (fixed)	482,5	0	34	1,06	0,64	0,04	0,01	0,30	0,00	3,32	0,06	0,25	0,00	0,00	0,00	0,00	0,04	0,00	0,62
203	Foundries Al/Mg (fixed)	15	0	35	0,10	0,06	0,00	0,00	0,03	0,00	0,31	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,06
204	Sheetmetal Manufacturing (fixed)	6702,8	0	36	101,41	61,05	3,49	0,92	28,80	0,00	317,76	5,63	24,26	0,01	0,00	0,00	0,00	3,74	0,00	40,01
205	PWB Manufacturing (fixed)	1343,5	0	53	172,62	4,31	6,41	15,83	48,04	5,67	143,47	11,45	65,83	4,17	0,13	1,18	3,47	20,20	0,57	952,83
206	Other materials (Manufacturing already in	3080,6	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	1675,7	0,25	37	20,07	8,23	0,03	0,00	0,00	0,10	301,91	1,34	6,01	0,15	18,04	42,27	0,01	0,86	0,02	0,38
	TOTAL	12753			341,34	102,02	11,57	17,18	90,26	5,78	911,16	21,04	107,41	4,33	18,17	43,44	3,50	26,55	0,60	1020,84

Nr: 0	Product:	EuP Lot 3 prep study: Laptop	Date:	00-01-00	Author:	MZ

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	43	1-BlkPlastics	1-LDPE	3,35	0,57	2,22	0,13	1,94	0,19	1,90	0,08	0,32	0,02	0,00	0,00	0,01	0,04	0,00	1,14
2	PP	4	1-BlkPlastics	4-PP	0,29	0,03	0,21	0,02	0,16	0,02	0,11	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,06
3	PS	2,6667	1-BlkPlastics	5-PS	0,23	0,01	0,13	0,01	0,47	0,00	0,06	0,01	0,05	0,00	0,00	0,00	0,32	0,00	0,00	0,15
4	EPS	50,333	1-BlkPlastics	6-EPS	4,21	0,17	2,41	0,29	8,86	0,05	1,91	0,14	0,91	0,00	0,00	0,00	3,06	0,09	0,00	6,27
5	PVC	23,333	1-BlkPlastics	8-PVC	1,32	0,26	0,54	0,26	1,45	0,12	1,57	0,05	0,35	0,00	0,00	0,00	0,00	0,07	0,07	7,33
6	ABS	141,83	1-BlkPlastics	10-ABS	13,48	0,99	6,49	1,32	23,40	1,42	13,04	0,47	2,52	0,00	0,00	0,00	0,26	0,41	0,28	89,33
7	PA 6	280,54	2-TecPlastics	11-PA 6	33,53	4,24	10,92	4,49	61,44	5,33	49,45	2,40	10,95	0,00	0,00	0,00	0,11	1,51	13,75	525,25
8	PC	267,1	2-TecPlastics	12-PC	31,20	3,97	10,15	3,74	30,45	2,67	47,16	1,44	6,79	0,00	0,00	0,00	0,10	1,79	0,04	134,62
9	PMMA	36,333	2-TecPlastics	13-PMMA	4,00	0,48	1,52	0,36	0,94	0,05	3,81	0,22	1,58	0,00	0,00	0,00	0,00	0,19	0,10	75,14
10	Epoxy	2,6667	2-TecPlastics	14-Epoxy	0,38	0,07	0,11	0,05	1,02	0,05	1,08	0,02	0,12	0,00	0,00	0,00	0,00	0,04	0,00	25,73
11	Steel sheet galvanized	489,23	3-Ferro	21-St sheet galv.	16,63	1,11	0,04	0,00	0,00	0,00	842,22	1,38	3,65	0,07	12,72	1,73	0,03	1,32	1,74	31,88
12	Al sheet/ extrusion	37,9	4-Non-ferro	26-Al sheet/extrusion	7,30	0,00	0,00	0,00	0,00	0,00	148,57	0,39	2,55	0,00	0,19	0,14	3,66	0,64	1,33	0,19
13	0	0		0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	Cu wire	60	4-Non-ferro	29-Cu wire	6,99	0,00	0,00	0,00	0,00	0,01	1200,72	0,37	17,53	0,00	0,22	3,30	0,32	0,17	5,65	9,27
15	Cu tube/sheet	15,2	4-Non-ferro	30-Cu tube/sheet	0,77	0,00	0,00	0,00	0,00	0,00	121,81	0,04	0,95	0,00	0,16	0,50	0,08	0,02	0,57	0,94
16	MgZn5 cast	121,67	4-Non-ferro	33-MgZn5 cast	19,69	0,00	0,00	14,42	1,59	0,68	582,30	2,24	5,48	0,01	3,33	0,32	5,93	1,11	2,18	0,44
17	Powder coating	4,7933	5-Coating	39-powder coating	1,71	0,29	0,20	0,09	1,84	0,10	2,36	0,09	0,30	0,00	0,00	0,01	0,00	0,07	0,00	46,27
18	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
19	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	LCD screen m2 (viewable screen size)	63,167	6-Electronics	42-LCD per m2 scrn	225,07	143,39	0,00	2,84	42,32	0,06	3,28	11,64	3,74	0,03	0,02	0,05	0,01	0,04	0,02	0,00
21	Big caps & coils	501	6-Electronics	44-big caps & coils	192,03	0,00	0,00	17,36	27,56	9,82	300,87	10,86	71,05	0,06	1,08	3,84	102,53	17,84	37,19	3,58
22	Slots /ext. Ports	132,93	6-Electronics	45-slots / ext. ports	24,87	7,88	0,00	9,92	33,95	2,27	40,90	1,33	24,51	0,00	0,19	5,05	0,26	1,72	4,23	860,04
23	Integrated Circuits, 5% Silicon, Au	46,833	6-Electronics	46-IC's avg., 5% Si, Au	258,02	250,95	0,00	234,96	0,00	11,79	242,66	19,83	130,54	3,17	2,29	20,91	0,69	3,41	175,16	1006,03
24	Integrated Circuits, 1% Silicon	31,167	6-Electronics	46-IC's avg., 5% Si, Au	171,71	167,00	0,00	156,36	0,00	7,85	161,49	13,20	86,87	2,11	1,52	13,92	0,46	2,27	116,56	669,49
25	SMD & LEDs avg	50,267	6-Electronics	47-IC's avg., 1% Si	43,94	33,84	0,15	30,74	5,21	32,40	87,88	2,96	41,03	0,00	0,49	9,30	0,15	1,21	0,48	215,96
26	PWB ½ lay 3.75 kg/m2	4,8	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	1,35	0,72	0,04	0,82	0,37	8,32	12,60	0,05	1,03	0,01	0,01	0,17	0,02	0,02	0,07	17,69
27	PWB 6 lay 4.5 kg/m2	76,867	6-Electronics	50-PWB 6 lay 4.5 kg/m2	28,22	11,24	0,66	37,28	5,90	145,42	313,10	1,21	30,44	0,08	0,39	5,39	0,53	2,85	9,64	187,77
28	Solder SnAg4Cu0.5	6,9667	6-Electronics	52-Solder SnAg4Cu0.5	1,63	1,35	0,00	0,49	0,00	0,03	1,59	0,08	0,45	0,00	0,01	0,02	0,01	0,01	0,00	0,04
29	Glass for lamps	0,6667	7-Misc.	54-Glass for lamps	0,01	0,01	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
30	Cardboard	921	7-Misc.	56-Cardboard	25,79	1,84	14,74	6,49	0,00	0,04	48,18	0,65	0,96	0,00	0,01	0,03	0,00	0,01	0,01	79,26
	TOTAL	0	0	0	1 117,72	630,41	50,51	522,45	248,86	228,70	4230,63	71,15	444,69	5,57	22,63	64,69	118,54	118,54	36,88	369,06

MANUFACTURING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	851,81	0	20	34,80	20,95	1,20	0,32	9,88	0,00	109,03	1,93	8,32	0,00	0,00	0,00	0,01	1,28	0,00	20,34
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	121,67	0	35	0,79	0,48	0,03	0,01	0,22	0,00	2,48	0,04	0,19	0,00	0,00	0,00	0,00	0,03	0,00	0,46
204	Sheetmetal Manufacturing (fixed)	542,33	0	36	8,21	4,94	0,28	0,07	2,33	0,00	25,71	0,46	1,96	0,00	0,00	0,00	0,00	0,30	0,00	3,24
205	PWB Manufacturing (fixed)	800,57	0	53	102,86	2,57	3,82	9,43	28,63	3,38	85,49	6,82	39,23	2,48	0,08	0,70	2,07	12,04	0,34	567,77
206	Other materials (Manufacturing already in	1462,2	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	135,58	0,25	37	1,62	0,67	0,00	0,00	0,00	0,01	24,43	0,11	0,49	0,01	1,46	3,42	0,00	0,07	0,00	0,03
	TOTAL	3778,6			148,28	29,60	5,33	9,83	41,06	3,39	247,14	9,36	50,19	2,50	1,54	4,12	2,08	13,72	0,34	591,85

Nr: 0 | Product: EuP Lot 3 prep study: LCD displays | Date: 00-01-00 | Author: MZ

MATERIALS EXTRACTION & PRODUCTION

nr	Product component	wght in g	cat.	material	Energy GER MJ	electr MJ	feedst MJ	Water water (proces ltr.	water (cool) ltr.	Waste haz. Waste g	non-haz. Waste g	Emissions to Air GWP kg CO2eq	AD g SO2eq	VOC mg	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	to Water Metal mg Hg/20eq	EUP mg PO4 eq
1	LDPE	164	1-BlkPlastics	1-LDPE	12,76	2,18	8,45	0,49	7,38	0,73	7,25	0,31	1,22	0,08	0,00	0,00	0,02	0,15	0,00	4,37
2	EPS	278,7	1-BlkPlastics	6-EPS	23,32	0,94	13,32	1,59	49,05	0,26	10,55	0,75	5,05	0,00	0,00	0,00	16,96	0,50	0,00	34,73
3	PVC	42,8	1-BlkPlastics	8-PVC	2,42	0,48	0,98	0,47	2,65	0,21	2,87	0,09	0,64	0,00	0,00	0,00	0,00	0,12	0,12	13,44
4	ABS	679,1	1-BlkPlastics	10-ABS	64,53	4,72	31,08	6,32	112,05	6,79	62,43	2,25	12,07	0,00	0,00	0,00	1,23	1,97	1,32	427,73
5	PA 6	422,22	2-TecPlastics	11-PA 6	50,46	6,39	16,43	6,76	92,47	8,02	74,42	3,61	16,48	0,00	0,00	0,00	0,17	2,28	20,70	790,51
6	PC	384,75	2-TecPlastics	12-PC	44,94	5,72	14,62	5,39	43,86	3,85	67,93	2,07	9,78	0,00	0,00	0,00	0,14	2,58	0,06	193,92
7	PMMA	152,85	2-TecPlastics	13-PMMA	16,84	2,00	6,39	1,50	3,97	0,21	16,01	0,92	6,66	0,00	0,00	0,00	0,00	0,78	0,43	316,10
8	E-glass fibre	119,75	2-TecPlastics	18-E-glass fibre	7,88	2,53	1,29	6,50	32,49	0,84	37,27	0,40	3,49	0,00	0,00	0,00	0,01	0,98	5,67	377,38
9	Aramid fibre	6,5	2-TecPlastics	19-Aramid fibre	1,67	0,53	0,27	1,38	6,88	0,18	7,89	0,09	0,74	0,00	0,00	0,00	0,00	0,21	1,20	79,89
10	Steel sheet galvanized	1854	3-Ferro	21-St sheet galv.	63,04	4,22	0,14	0,00	0,00	0,00	3191,70	5,24	13,84	0,25	48,20	6,57	0,13	5,02	6,58	120,82
11	Al sheet/ extrusion	39	4-Non-ferro	26-Al sheet/extrusion	7,51	0,00	0,00	0,00	0,00	0,00	152,88	0,40	2,62	0,00	0,19	0,14	3,76	0,66	1,37	0,19
12	Cu wire	189,6	4-Non-ferro	29-Cu wire	22,10	0,00	0,00	0,00	0,00	0,05	3794,28	1,18	55,38	0,00	0,71	10,44	1,02	0,54	17,84	29,30
13	Powder coating	1,03	5-Coating	39-powder coating	0,37	0,06	0,04	0,02	0,40	0,02	0,51	0,02	0,06	0,00	0,00	0,00	0,00	0,02	0,00	9,94
14	LCD screen m2 (viewable screen size)	91,3	6-Electronics	42-LCD per m2 scrn	325,32	207,25	0,00	4,11	61,17	0,09	4,75	16,83	5,40	0,04	0,03	0,07	0,01	0,05	0,03	0,00
15	Big caps & coils	41,35	6-Electronics	44-big caps & coils	15,85	0,00	0,00	1,43	2,27	0,81	24,83	0,90	5,86	0,01	0,09	0,32	8,46	1,47	3,07	0,30
16	Slots /ext. Ports	36,55	6-Electronics	45-slots / ext. ports	6,84	2,17	0,00	2,73	9,33	0,62	11,25	0,37	6,74	0,00	0,05	1,39	0,07	0,47	1,16	236,47
17	Integrated Circuits, 5% Silicon, Au	12,85	6-Electronics	46-IC's avg., 5% Si, Au	70,79	68,86	0,00	64,47	0,00	3,24	66,58	5,44	35,82	0,87	0,63	5,74	0,19	0,94	48,06	276,03
18	Integrated Circuits, 1% Silicon	20,35	6-Electronics	47-IC's avg., 1% Si	17,79	13,70	0,06	12,44	2,11	13,12	35,58	1,20	16,61	0,00	0,20	3,76	0,06	0,49	0,20	87,43
19	SMD & LEDs avg	10,7	6-Electronics	48-SMD/ LED's avg.	31,77	30,88	0,00	9,90	0,00	1,40	30,29	1,79	17,34	0,08	0,16	4,51	0,05	0,54	0,16	23,49
20	PWB ½ lay 3.75 kg/m2	30	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	8,43	4,52	0,26	5,10	2,30	52,00	78,76	0,34	6,41	0,07	0,08	1,08	0,11	0,15	0,44	110,59
21	PWB 6 lay 4.5 kg/m2	19,6	6-Electronics	50-PWB 6 lay 4.5 kg/m2	7,20	2,86	0,17	9,51	1,51	37,08	79,84	0,31	7,76	0,02	0,10	1,37	0,13	0,73	2,46	47,88
22	Solder SnAg4Cu0.5	7,55	6-Electronics	52-Solder SnAg4Cu0.5	1,77	1,46	0,00	0,53	0,00	0,03	1,72	0,09	0,49	0,00	0,01	0,03	0,01	0,01	0,00	0,05
23	Glass for lamps	26	7-Misc.	54-Glass for lamps	0,42	0,34	0,00	0,22	0,00	0,01	0,35	0,02	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,01
24	Cardboard	650	7-Misc.	56-Cardboard	18,20	1,30	10,40	4,58	0,00	0,03	34,01	0,46	0,68	0,00	0,01	0,02	0,00	0,01	0,01	55,94
25	Office paper	54,5	7-Misc.	57-Office paper	2,18	0,33	1,47	4,15	0,00	0,02	3,68	0,03	0,27	0,01	0,00	0,01	0,00	0,09	0,00	288,22
26	Misc glass	307,6	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
27	Cast iron	1165	3-Ferro	23-Cast iron	11,65	0,16	-0,07	1,51	4,26	0,00	367,39	1,23	3,77	0,14	6,99	2,31	0,02	16,31	1,06	30,56
	TOTAL	0	0	0	836,04	363,58	105,31	151,09	434,16	129,61	8165,00	46,34	235,29	1,58	57,46	37,77	32,56	32,56	37,07	111,93

MANUFACTURING

nr	Product component	wght in g	cat.	NDX	Energy GER MJ	electr MJ	feedst MJ	Water water proces ltr.	water (cool) ltr.	Waste haz. g	non-haz. g	Emissions to Air GWP kg CO2eq	AD g SO2eq	VOC g	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	to Water Metal mg Hg/20eq	EUP mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2250,7	0	20	91,94	55,35	3,17	0,83	26,11	0,00	288,09	5,10	21,99	0,01	0,00	0,00	0,03	3,39	0,00	53,74
202	Foundries Fe/Cu/Zn (fixed)	1165	0	34	2,56	1,54	0,09	0,02	0,73	0,00	8,02	0,14	0,61	0,00	0,00	0,00	0,00	0,09	0,00	1,50
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	1893	0	36	28,64	17,24	0,99	0,26	8,13	0,00	89,74	1,59	6,85	0,00	0,00	0,00	0,00	1,06	0,00	11,30
205	PWB Manufacturing (fixed)	158,6	0	53	20,38	0,51	0,76	1,87	5,67	0,67	16,94	1,35	7,77	0,49	0,02	0,14	0,41	2,38	0,07	112,48
206	Other materials (Manufacturing already in	1340,4	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	473,25	0,25	37	5,67	2,32	0,01	0,00	0,00	0,03	85,26	0,38	1,70	0,04	5,10	11,94	0,00	0,24	0,01	0,11
	TOTAL	6807,7			149,18	76,96	5,01	2,98	40,64	0,70	488,04	8,56	38,93	0,54	5,11	12,08	0,44	7,17	0,07	179,13

Nr: 0 | **Product:** EuP Lot 3 prep study: CRT-display | **Date:** 00-01-00 | **Author:** MZ

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	EPS	165	1-BlkPlastics	6-EPS	13,80	0,56	7,89	0,94	29,04	0,15	6,25	0,45	2,99	0,00	0,00	0,00	10,04	0,30	0,00	20,56
2	PVC	43,8	1-BlkPlastics	8-PVC	2,48	0,49	1,00	0,48	2,72	0,22	2,94	0,09	0,66	0,00	0,00	0,00	0,00	0,13	0,12	13,75
3	ABS	1754,8	1-BlkPlastics	10-ABS	166,74	12,20	80,31	16,32	289,53	17,55	161,31	5,83	31,18	0,00	0,00	0,00	3,17	5,09	3,40	1105,22
4	PA 6	447,47	2-TecPlastics	11-PA 6	53,48	6,77	17,41	7,16	98,00	8,50	78,88	3,83	17,47	0,00	0,00	0,00	0,18	2,42	21,93	837,79
5	PC	0,55	2-TecPlastics	12-PC	0,06	0,01	0,02	0,01	0,06	0,01	0,10	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,28
6	Steel sheet galvanized	126	3-Ferro	21-St sheet galv.	4,28	0,29	0,01	0,00	0,00	0,00	216,91	0,36	0,94	0,02	3,28	0,45	0,01	0,34	0,45	8,21
7	Al sheet/ extrusion	14	4-Non-ferro	26-Al sheet/extrusion	2,70	0,00	0,00	0,00	0,00	0,00	54,88	0,14	0,94	0,00	0,07	0,05	1,35	0,24	0,49	0,07
8	Cu wire	222,2	4-Non-ferro	29-Cu wire	25,90	0,00	0,00	0,00	0,00	0,05	4446,67	1,38	64,91	0,00	0,83	12,23	1,20	0,63	20,91	34,33
9	Powder coating	6,03	5-Coating	39-powder coating	2,15	0,37	0,26	0,11	2,32	0,12	2,97	0,11	0,38	0,00	0,00	0,01	0,00	0,09	0,00	58,20
10	CRT screen m2 (nominal screen size)	90,2	6-Electronics	43-CRT per m2 scrn	285,84	192,22	0,00	26,18	0,00	4,42	222,61	15,42	97,15	72,25	1,26	84,16	0,00	254,63	1,26	56,80
11	Big caps & coils	37,5	6-Electronics	44-big caps & coils	14,37	0,00	0,00	1,30	2,06	0,74	22,52	0,81	5,32	0,00	0,08	0,29	7,67	1,34	2,78	0,27
12	Slots /ext. Ports	40	6-Electronics	45-slots / ext. ports	7,48	2,37	0,00	2,99	10,21	0,68	12,31	0,40	7,37	0,00	0,06	1,52	0,08	0,52	1,27	258,79
13	Integrated Circuits, 5% Silicon, Au	17	6-Electronics	46-IC's avg., 5% Si, Au	93,66	91,09	0,00	85,29	0,00	4,28	88,08	7,20	47,38	1,15	0,83	7,59	0,25	1,24	63,58	365,18
14	Integrated Circuits, 1% Silicon	13,5	6-Electronics	47-IC's avg., 1% Si	11,80	9,09	0,04	8,25	1,40	8,70	23,60	0,79	11,02	0,00	0,13	2,50	0,04	0,33	0,13	58,00
15	SMD & LEDs avg	12,5	6-Electronics	48-SMD/ LED's avg.	37,11	36,07	0,00	11,57	0,00	1,63	35,39	2,09	20,26	0,09	0,19	5,27	0,06	0,64	0,18	27,44
16	PWB ½ lay 3.75 kg/m2	96	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	26,98	14,45	0,82	16,32	7,37	166,39	252,03	1,08	20,52	0,22	0,26	3,47	0,34	0,49	1,42	353,90
17	PWB 6 lay 4.5 kg/m2	23,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	8,63	3,43	0,20	11,40	1,80	44,46	95,72	0,37	9,31	0,02	0,12	1,65	0,16	0,87	2,95	57,40
18	Solder SnAg4Cu0.5	11	6-Electronics	52-Solder SnAg4Cu0.5	2,57	2,13	0,00	0,77	0,00	0,05	2,51	0,13	0,71	0,00	0,01	0,04	0,02	0,02	0,00	0,07
19	Glass for lamps	6,5	7-Misc.	54-Glass for lamps	0,11	0,08	0,00	0,06	0,00	0,00	0,09	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	Cardboard	1880	7-Misc.	56-Cardboard	52,64	3,76	30,08	13,25	0,00	0,09	98,36	1,32	1,95	0,00	0,02	0,06	0,01	0,02	0,02	161,80
21	Office paper	280	7-Misc.	57-Office paper	11,20	1,68	7,56	21,32	0,00	0,09	18,91	0,16	1,41	0,06	0,01	0,03	0,00	0,46	0,01	1480,75
22	Misc glass	11110	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	823,99	377,05	145,61	223,72	444,52	258,14	5843,02	41,96	341,90	73,83	7,16	119,31	24,58	24,58	269,78	120,92

MANUFACTURING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2411,6	0	20	98,51	59,31	3,39	0,89	27,97	0,00	308,68	5,47	23,57	0,01	0,00	0,00	0,03	3,63	0,00	57,59
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	140	0	36	2,12	1,28	0,07	0,02	0,60	0,00	6,64	0,12	0,51	0,00	0,00	0,00	0,00	0,08	0,00	0,84
205	PWB Manufacturing (fixed)	237,5	0	53	30,52	0,76	1,13	2,80	8,49	1,00	25,36	2,02	11,64	0,74	0,02	0,21	0,61	3,57	0,10	168,44
206	Other materials (Manufacturing already in	13608	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	35	0,25	37	0,42	0,17	0,00	0,00	0,00	0,00	6,31	0,03	0,13	0,00	0,38	0,88	0,00	0,02	0,00	0,01
	TOTAL	16397			131,57	61,51	4,60	3,71	37,07	1,01	346,99	7,64	35,84	0,75	0,40	1,09	0,64	7,30	0,10	226,87