# Topten Product Criteria Paper on Computer Monitors

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Supported by

Coordinated by

## The Project in brief

Topten is part of the international Euro-Topten Plus initiative supported by the European programme Intelligent Energy Europe and several national institutions (energy agencies, WWF, consumer associations, research institutes). On global level, Topten is coordinated by TIG, the Topten International Group. This association promotes to the Topten Charter, TIG statutes and Rules of Procedure (www.topten.info).

Topten is a service that supports the market for energy efficient products. It aims at making energy efficient products the first choice for consumers, by offering them a user-friendly tool for product comparison and selection. The key element is an online information platform for consumers presenting the most energy efficient appliances currently available in various product categories, including household appliances, office equipment, consumer electronics and cars. Information on energy consumption and performance of products as well as several other characteristics (i.e. brand, model, price, picture) is provided. Product data is based on labels and standardized declarations as well as tests from accepted well-known institutions. The service is independent of manufacturers and retailers.

## Consortium

The project is co-ordinated by the Agence de l'Environnement et de la Maitrise de l'Energie (ADEME). The other 19 project partners are:

| Project Partner | Country |
|---|---|
| Austria : Austrian Energy Agency | AT |
| Belgium: World Wide Fund for Nature – vzw/asbl | BE |
| Belgium: WWF European Policy Office | BE |
| Czech Republic: SEVEn, o.p.s | CZ |
| Finland: Motiva Oy | FI |
| France: WWF Fonds Mondial pour la Nature | FR |
| Germany: dena, Deutsche Energie-Agentur | DE |
| Germany: Oeko-Institut e.V. | DE |

| | |
|---|---|
| Germany: Wuppertal Institute | DE |
| Germany: ICLEI, European Secretariat | DE |
| Greece: WWF Greece | GR |
| Italy: WWF Italia Onlus | IT |
| Lithuania: LNCF, consumer federation | LT |
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| Poland: FEWE Polish Foundation for Energy Efficiency | PL |
| Portugal: Quercus | PT |
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| Spain: ADENA / WWF, Asociacion para la defensa de la natureza | ES |

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## Contents

# 1 Introduction

Criteria papers provide a central tool for the Euro-Topten Plus partners to collect and analyse product data and to establish a national Topten selection. Appropriate selection criteria and technical specifications are a crucial precondition for meaningful and well-accepted Topten websites. The purpose of this criteria paper is to provide a common basis for the definition of technical specifications. Obviously, the range of products differs significantly in European member States in terms of price level, configuration, energy classes and energy consumption corresponding to levels of purchasing power and behavioural aspects (mentality, customs, etc.).

Within the European wide Topten project, an aligned approach for technical specifications for all national Topten websites is aimed at. A high level of uniformity and congruency of the different national websites will enhance the awareness amongst manufacturers. Good quality product data at national level furthermore allows to analyse the situation at European level and to make policy recommendations, which are shown on www.topten.eu.

This paper contains the product specification for Topten computer monitors. A product should meet all criteria described in Chapter 4 in order to be listed on www.topten.eu as a Best Available Technology.

In an ideal situation, criteria are based on international or European standards. In some cases widely accepted and strictly defined standards are missing – (e.g. for products in the consumer electronics segment). Within the methodology of WP3, it was intended to use the implementation measures of the Ecodesign directive as a basis for the criteria definition. The information in this criteria paper is therefore mainly based on the “Preparatory studies for Eco-design Requirements of EuPs (EuP Lot3, Personal computers-desktops and laptops-and computer monitors, 2005) and the corresponding implementing measure.

# 2 Product Definition

This chapter provides an overview of computer monitors. It also gives a technical analysis of the product and explains EU and national relevant product and test standards.

## 2.1 Product Category

Computer monitors are relatively new products in society. The first computer monitors used Cathode Ray Tubes (CRT), which was the dominant technology until they were replaced by Liquid Crystal Display (LCD) Monitors in the 21st Century.

Since the eighties, there has been a quite fast development of the computer monitors, which have followed the rapid development of computer processors. That issue, from an Eco-design point of view can 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(EuP, Lot 3, 2005).[1]

The original functionality of computer monitors was to be used with computer units while television receivers were used for entertainment. From the 1980s onwards, computers (and their monitors) have been used for both data processing and entertainment, while televisions have implemented some computer functionality. The common aspect ratio of televisions, and then computer monitors, has also changed from 4:3 to 16:9. [2]

There are more than one definition, concerning the computer monitors. In the current study we consider as most appropriate the definition given by the EuP preparatory study concerning the computers and the computer monitors.

Thus, according to the EuP preparatory study Lot 3, a computer monitor can be defined “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. The computer monitors included in this definition must have a viewable diagonal screen size greater than 12 inches and must be capable of being powered by a separate alternate current (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 this scope"(EuP Lot 3, 2005).[3]

Energy Star has introduced the following definition which is basically the same to the one proposed from EuP preparatory study, differing only in the definition of the specifications under which the products qualify as Energy Star:

A commercially available electronic product with a display screen and its associated electronics encased in a single housing that is capable of displaying 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 monitor must be capable of being powered from either a 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.

Nevertheless, the aforementioned is not the only definition, as computer monitors have been defined by Energy Star label in the report "Programme Requirements for computer monitors version 4.1[i]

## 2.2 Product Types

The classification of the current computer monitors in sub categories could be the following, according to the EuP eco-design preparatory study requirements.

### 2.2.1 Computer monitors with cathode-ray tube (CRT)

The CRT monitors make use of the cathode-ray tube technology, which was the dominant one until the beginning of the 21st century. Nowadays, there are manufacturers and the monitors are still distributed, outside EU in countries such as India, Pakistan, China etc. In the countries of EU they are not distributed any more in the official shop chains, but they can be found in second hand shops and they still exist in some businesses.The cathode ray tube (CRT) is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen, with internal or external means to accelerate and deflect the electron

[i] ENERGY STAR. Programme Requirements for computer monitors version 4.1 http://www.energystar.org.tw/pdf/MONITORD4E.PDF

beam, used to create images in the form of light emitted from the fluorescent screen. The image may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets and others. The CRT uses an evacuated glass envelope, which is large, deep, heavy, and relatively fragile.[4]

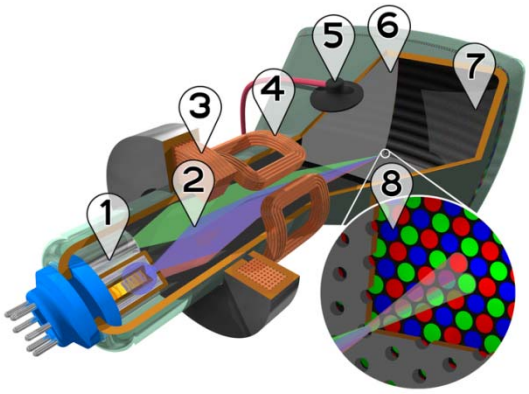



**Image 1 Cutaway rendering of a colour CRT: 1. Three Electron guns (for red, green, and blue phosphor dots), 2. Electron beams, 3. Focusing coils, 4. Deflection coils, 5. Anode connection, 6. Mask for separating beams for red, green, and blue part of displayed image, 7. Phosphor layer with red, green, and blue zones, 8. Close-up of the phosphor-coated inner side of the screen. (source: wikipedia)**

More precisely, concerning the CRT monitors, the beam of electrons scans across the monitor from left to right and top to bottom in a raster pattern to create the image. A special metallic screen called a shadow mask (in most implementations) has holes spaced and angled in an extremely precise manner. For color CRTs that employ shadow masks, a trio of dot phosphors is often grouped in a triangle for each hardware picture element. The separate electron beams that control red, green, and blue only strike their own phosphors at the correct angle to cause them to glow. The glow of the phosphors decays very quickly, requiring the electron beam's regular return to each phosphor to sustain the glow. The more dot phosphors that are placed in a given area, the better the image quality at higher resolutions. [5]

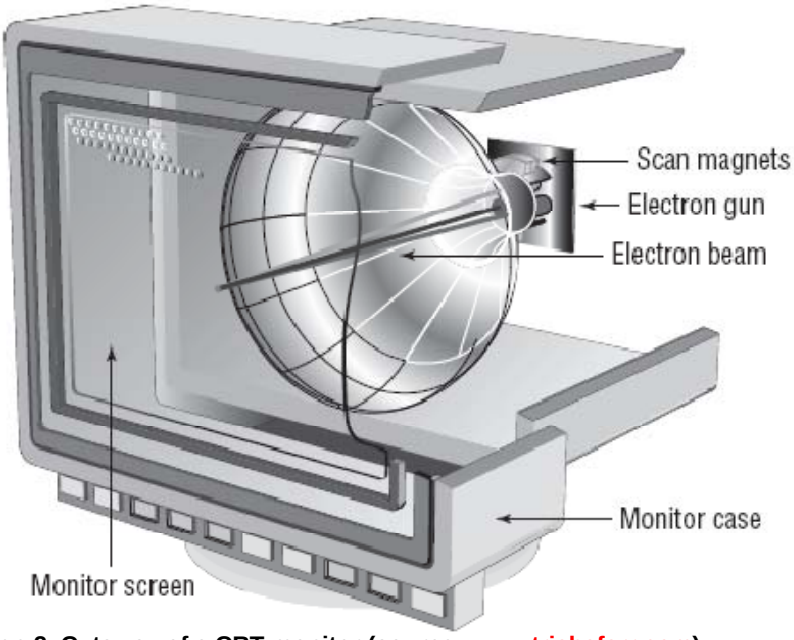



**Image 2. Cutaway of a CRT monitor (source: www.trishafarr.com)**

## ***Pros and cons***

**Pros:**

- High dynamic range [ii](up to around 15,000:1), excellent color, wide gamut [iii]and low black level. The color range of CRTs is unmatched by any display type except OLED.
- Can display in almost any resolution and refresh rate
- No input lag
- Sub-millisecond response times
- Near zero color, saturation, contrast or brightness distortion. Excellent viewing angle.

[ii] In image processing, computer graphics, and photography, **high dynamic range imaging** (**HDRI** or just **HDR**) is a set of techniques that allows a greater dynamic range between the lightest and darkest areas of an image than current standard digital imaging techniques or photographic methods. This wide dynamic range allows HDR images to more accurately represent the range of intensity levels found in real scenes, ranging from direct sunlight to faint starlight, and is often captured by way of a plurality of differently exposed pictures of the same subject matter (source:wikipedia http://en.wikipedia.org/wiki/High_dynamic_range_imaging).

[iii] In color reproduction, including computer graphics and photography, the **gamut**, or **color gamut** is a certain *complete subset* of colors. The most common usage refers to the subset of colors which can be accurately represented in a given circumstance, such as within a given color space or by a certain output device (source: wikipedia http://en.wikipedia.org/wiki/Gamut)

- Allows the use of light guns/pens

**Cons:**

- Large size and weight, especially for bigger screens (a 20-inch (51 cm) unit weighs about 50 lb (23 kg))
- High power consumption High power consumption.
- Generates a considerable amount of heat when running
- Geometric distortion caused by variable beam travel distances
- Can suffer screen burn-in
- Produces noticeable flicker at low refresh rates

### 2.2.2 Computer monitors with Liquid Crystal Display (LCD)

The term liquid crystal is used to describe a substance in a state between liquid and solid but which exhibits the properties of both. Molecules in liquid crystals tend to arrange themselves until they all point in the same specific direction. This arrangement of molecules enables the medium to flow as a liquid. Depending on the temperature and particular nature of a substance, liquid crystals can exist in one of several distinct phases. Liquid crystals in a nematic phase, in which there is no spatial ordering of the molecules, for example, are used in LCD technology. One important feature of liquid crystals is the fact that an electrical current affects them. A particular sort of nematic liquid crystal, called twisted nematics (TN), is naturally twisted. Applying an electric current to these liquid crystals will untwist them to varying degrees, depending on the current's voltage. LCDs use these liquid crystals because they react predictably to electric current in such a way as to control the passage of light.

The function of a simple LCD is as depicted in the following image. The electrode is hooked up to a power source like a battery. When there is no current, light entering through the front of the LCD will simply hit the mirror and bounce right back out. But when the battery supplies current to the electrodes, the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle untwist and block the light in that region from passing through. That makes the LCD show the rectangle as a black area (fujitsu, white paper)[6].

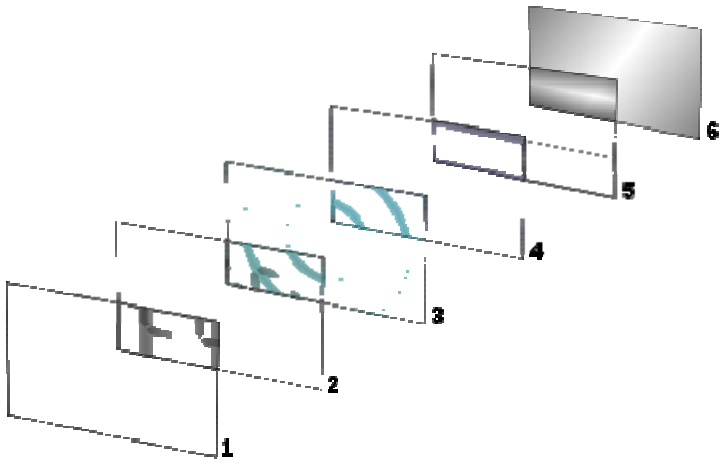



**Image 3. 1. Polarizing filter film with a vertical axis to polarize light as it enters. 2. Glass substrate with ITO electrodes. The shapes of these electrodes will determine the shapes that will appear when the LCD is turned ON. Vertical ridges etched on the surface are smooth. 3. Twisted nematic liquid crystal. 4. Glass substrate with common electrode film (ITO) with horizontal ridges to line up with the horizontal filter. 5. Polarizing filter film with a horizontal axis to block/pass light. 6. Reflective surface to send light back to viewer. (In a backlit LCD, this layer is replaced with a light source.). (source: www.wikipedia.org)**

There are several types of LCD monitors:

***Transmitive and reflective LCDs*** (fujitsu, white paper)***.*** Liquid crystal materials do not emit light on their own. Small and inexpensive LCDs are often **reflective**, which means, that in order to display anything they must reflect the light from external light sources (e.g. the numbers in an LCD watch appear where the small electrodes charge the liquid crystals and make the crystals untwist so that the light is not transmitting through the polarized film).

**Backlit LCD displays** are lit with built-in fluorescent tubes or any other light source such as LED above, beside and sometimes behind the LCD. A white diffusion panel behind the LCD redirects and scatters the light evenly to ensure a uniform display. On its way through liquid crystal layers, filters and electrode layers, more than half of this light is lost such as in LCD displays on personal computers. In the reflective mode, available light is used to illuminate the display. This is achieved by combining a reflector with the rear polarizer. It works best in an outdoor or well-lit office environment.

**Transflective LCDs** are a mixture of the reflective and transmissive types, with the rear polarizer having partial reflectivity. They are combined with backlight for use in all types of lighting conditions. The backlight can be left off where there is sufficient light, conserving power. In darker environments, the backlight can provide a bright display.

***Liquid Crystal displays types***[7]

LCDs are broken up into two main groups: passive displays and active displays.

Passive and active refer to the circuits that are responsible for activating pixels.

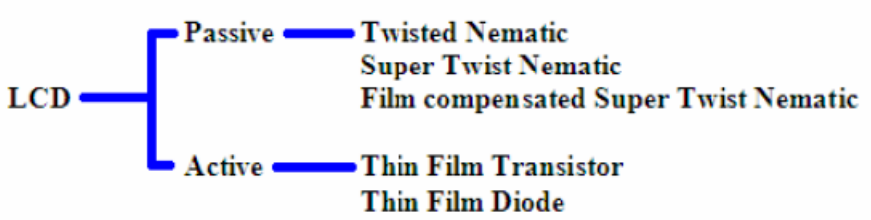



**Image 4. Passive and active display diagramme (source: Lytica White paper)**

**Passive LCDs** use electrical components that do not supply their own energy to turn 'on' or 'off' desired pixels. A passive matrix LCD is made up of a set of multiplexed (a method of reducing the number of I/O lines needed) transparent electrodes. The electrodes are made of a conductive film, usually indium-tin oxide or ITO and are placed above and below the liquid crystal layer in a row/column formation. The rows and columns are then connected to integrated circuits, which control when and where charge is delivered. To address a pixel the column containing the pixel is sent a charge; the corresponding row is connected to ground. When sufficient voltage is placed across the pixel, the liquid crystal molecules align parallel to the electric field.

**Active LCDs** have a similar construction to the passive implementation. Just like a passive display, active LCDs use a semi transparent conductive grid to supply charge to the liquid crystal layer. The important difference is that the active displays have a transistor built into each pixel. This thin film transistor (TFT) acts like a switch precisely controlling the voltage each pixel receives. As shown in the diagram below the basic structure of an active matrix LCD or a TFT display is a common electrode placed above the liquid crystal matrix. Below the liquid crystal is a conductive grid connected to each pixel through a TFT. Inside each pixel the structure is as follows, the gate of each TFT is connected to the row electrode, the drain to the column electrode, and the source to the liquid crystal. To activate the display voltage is applied to each row electrode line by line. To turn on a pixel the gate lines have to be activated; this closes the switch and allows charge from the drain to flow to the source setting up an electric field between the source and the common electrode above. The column electrodes connected to the drain carry the data voltages (which pixels to activate and to what shade) and are synchronized to the gate pulses. Connected to the source of each TFT in parallel with the liquid crystal is a small capacitor. When a pulse is sent to the gate, charge flows from the drain to the source where the capacitor charges to the desired level. The purpose of the capacitor is to keep voltage applied to the liquid crystal molecules until the next refresh cycle. Capacitors are sized large enough to keep a constant voltage on activate pixels, over the entire refresh cycle.

***Pros & Cons*** [8]

**Pros:**

- Very compact and light
- Low power consumption. On average, 50-70% less energy is consumed than CRT monitors
- No geometric distortion
- Little or no flicker depending on backlight technology
- Not affected by screen burn-in
- No high voltage or other hazards present during repair/service
- Can be made in almost any size or shape
- No theoretical resolution limit

**Cons:**

- Limited viewing angle, causing color, saturation, contrast and brightness to vary, even within the intended viewing angle, by variations in posture
- Bleeding and uneven backlighting in some monitors, causing brightness distortion, especially toward the edges
- Smearing and ghosting artifacts caused by slow response times (>8 ms) and "sample and hold" operation
- Only one native resolution. Displaying resolutions either requires a video scaler, lowering perceptual quality, or display at 1:1 pixel mapping, in which images will be physically too large or won't fill the whole screen
- Fixed bit depth, many cheaper LCDs are only able to display 262,000 colors. 8-bit S-IPS panels can display 16 million colors and have significantly better black level, but are expensive and have slower response time
- Input lag
- Dead pixels may occur either during manufacturing or through use

- In a constant on situation, thermalization may occur, which is when only part of the screen has overheated and therefore looks discolored compared to the rest of the screen

- Not all LCDs are designed to allow easy replacement of the backlight

- Cannot be used with light guns/pens

### 2.2.3 Economic lifetime

According to Comission´s EuP Lot3[9], concerning the computers and computer monitors, the computer monitors are not usually changed because of break down or worn out. The main reason for the replacement of the computer monitors is the increased demand for functionality, often created by new versions of software. Nevertheless, a large volume of this product category is used in a "Second Life". The second life can be estimated to be about half of the first life time and it is more likely for the high quality and value computer monitors (It is considered that the 20% of the monitors have a second life time).

The following tables depict the average lifetime of the "first life", as long as the economic lifetime of the total life of computer monitors (including the "second lifetime").[iv]

**Table 1. Economic lifetime of computer monitors (source: Preparatory studies for Eco-design Requirements of Eup, Lot3)**

| Monitor type | Average first life economic lifetime (years) | Average economic lifetime including second lifetime (years) |
|---|---|---|
| **CRT** | 6 | 6,6 |
| **LCD** | 6 | 6,6 |

### 2.2.4 Energy consumption

Computer monitors use most power in on-mode. The notion that the resolution is linked to the power consumption is not true for many types of monitors, including LCD. The screen size is much more correlated to the power consumption because of the way a LCD monitor brings the picture to the screen. The notion that the energy use correlates to the resolution [Megapixels] stems from when the standard was a plasma screen where each pixel element is an individual light source that is illuminated as needed. LCD, on the other hand, always has a backlight running, and rather than lighting up pixels, an LCD monitor will BLOCK them, so the light doesn't get through. Whether the grid of liquid crystal is made of many small elements as for a high-resolution screen or fewer larger elements as

[iv] In the calculations, concerning the second lifetime, has been taken under consideration that 20% of the products have a second life of 3 years

for a low resolution screen will almost not affect the power consumption of the display. More than 90% of the power consumption in a LCD monitor relates to the backlight. That means that the power consumption for LCD screens is relatively independent of the resolution in the liquid crystal filter in front of the backlight. For CRT monitors the power consumption is also depending on the screen size, as the electron beam has to activate a larger area of phosphorous for a larger screen. It is therefore natural that we can see a correlation between screen size and power consumption also for CRT monitors. Even for new technologies such as LED backlight, the correlation is that the larger the screen, the more energy it will use, caused by either higher number of lamps, or bigger lamps using more energy.

The latest published database (2008-2009) of European Energy Star contains only one CRT model, where the previous one (2007-2008), was depicting more than 100 CRT monitors. This is a sign that the energy consumption of LCD systems has improved a lot in the latter years and that the aforementioned monitors are now dominating the market.

The following table sourcing from the website www.topten.eu depicts the energy consumption for some of the most efficient computer monitors that exist in the european market nowadays and for different sizes.

**Table 2. Energy consumption of the most efficient monitors of the EU market (source: www.topten.eu, Energy Star database archivesand own elaboration)**

| | 19” | | | | 22” | | | | 23” | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brand** | **EIZO** | **TERRA** | **ineffi-cient model** | **19”CRT monitor** | **Philips 22”** | **SAMSUNG 22”** | **ineffi-cient model2** | **22”CRT monitor** | **Hewlett-Packard 23”** | **Dell 23”** | **ineffi-cient model3** |
| **Model** | S1902-SH | LCD ME185W GLP | | | 221S3LSS | BX2235 | | | LA2306x | E2311H | |
| **Signal input** | D-SUB + DVI-D, Audio | VGA | | | VGA, DVI | DVI | | | D-SUB, DVI, Display Port | DVI, VGA | |
| **Resolu-tion (Pixel)** | 1280x1024 | 1366x768 | | | 1920x1080 | 1920 x 1080 | | | 1920 x 1080 | 1920x1080 | |
| **Colours** | 16.77 Mio | 16.7 Mio | | | 16.7 Mio | 16.7 Mio | | | 16.7 Mio | 16.7 Mio | |
| **Contrast** | 1000 | 10000 | | | 1000 | MEGA >1Mio. | | | 3000 | 1000 | |
| **Bright-ness (cd/m2)** | 250 | 250 | | | 250 | 250 | | | 250 | 250 | |

| | 19” | | | | 22” | | | | 23” | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brand** | **EIZO** | **TERRA** | **ineffi-cient model** | **19”CRT monitor** | **Philips 22”** | **SAMSUNG 22”** | **ineffi-cient model2** | **22”CRT monitor** | **Hewlett-Packard 23”** | **Dell 23”** | **ineffi-cient model3** |
| Label | TCO 5.1 | TCO 5.0 | | | TCO 05, Epeat Silver | | | | | | |
| Power On (Watt) | 15 | 18 | 110 | 130 | 16,8 | 18 | 120 | 135 | 32 | 30 | 120 |
| Power Sleep (Watt) | 0,6 | 0,4 | 1 | 12,5 | 0,1 | 0,3 | 3 | 2 | 1 | 1 | 3 |
| Power Off (Watt) | 0,6 | 0,3 | 1 | 2,5 | 0,1 | 0,3 | 1 | 2 | 0,5 | 1 | 1 |
| Energy con-sumption in five years (Kwh) | 105 | 111 | 641 | 863 | 96 | 110 | 706 | 816 | 197 | 203 | 706 |

As it can be understood from the above table and is depicted in the graph below, the energy consumption of the latest computer monitor models, during their utile lifetime, is very low comparing to non efficient models and to past models of CRT technology. Another observation that can be made is that the electricity consumption rises with the size of the monitors.

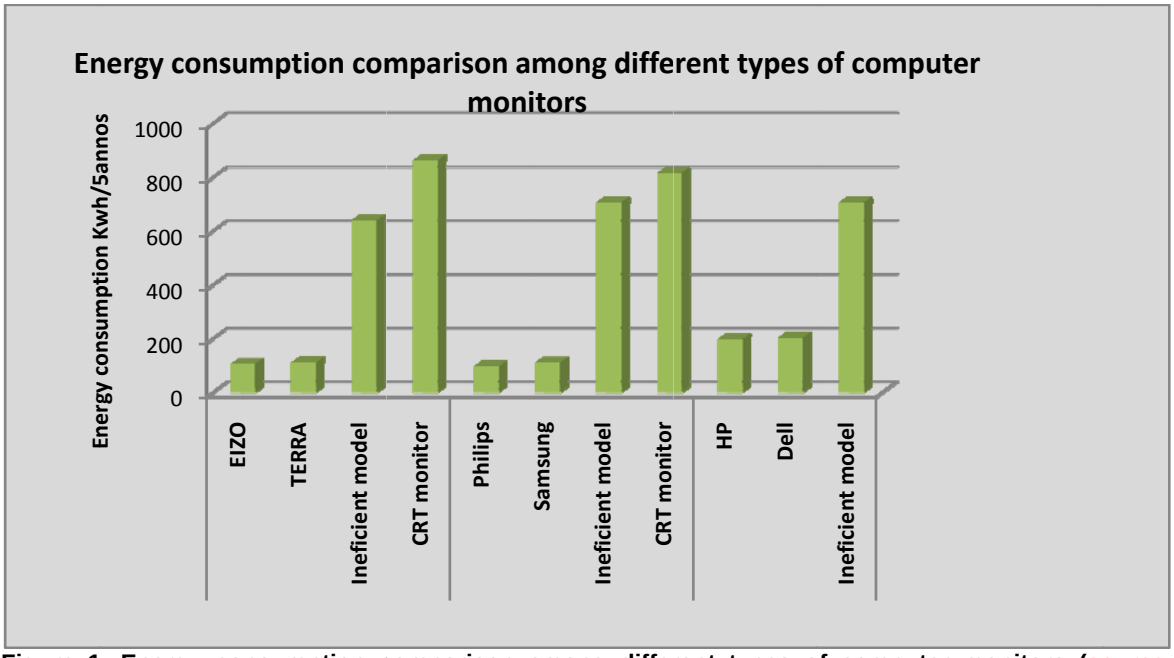



**Figure 1. Energy consumption comparison among different types of computer monitors (source: www.topten.eu Energy Star EU database Archives, own elaboration)**

## 2.3 Best Available Technology

### 2.3.1 CCFL backlight (Topten)[10]

In the cold cathode fluorescent lamp construction it typically includes a hollow glass cylinder that has been coated on the inside with a phosphor material composed of rare earth elements such as zinc silicate and various types of halophosphates.

The tube is then sealed at both ends, each of which also contains a mercury-dispensing electrode and an iron-nickel cathode connected to copper sheathed iron alloy leads. Lamps normally contain 2 to 10 milligrams of mercury, and a mixture of gasses such as argon and neon.

When high voltage is applied to the electrodes, ultraviolet energy at 254hm is produced as the mercury and the internal gasses are ionized. The resulting ultraviolet energy from the mercury discharge stimulates the phosphor lining inside the lamp producing visible light output in the 380 to 780nm range.

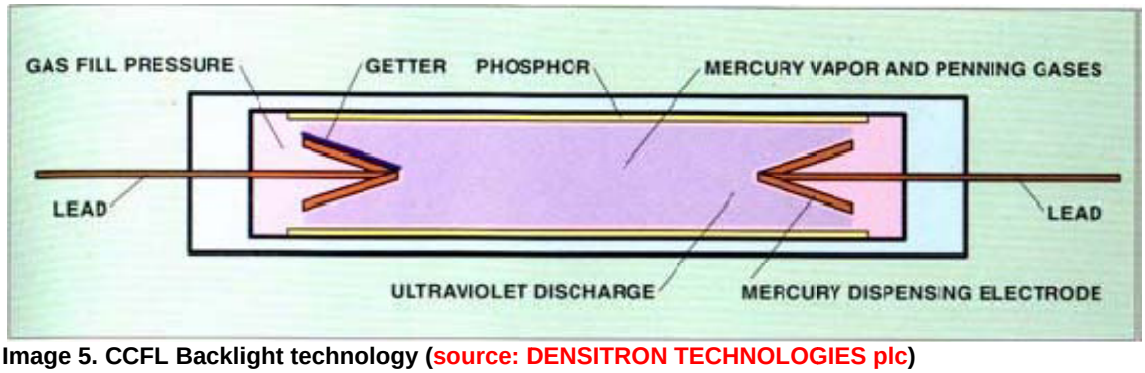



**Image 5. CCFL Backlight technology (source: DENSITRON TECHNOLOGIES plc)**

### 2.3.2 LED-backlit LCD monitors

The LED consists of a chip of semiconducting material doped with impurities to create a *p-n junction*. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers—electrons and holes—flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and thus its color depends on the band gap energy of the materials forming the *p-n junction*. In silicon or germanium diodes, the electrons and holes recombine by a *non-radiative transition*, which produces no optical emission, because these are indirect band gap materials. The materials used for the LED have a direct band gap with energies corresponding to near-infrared, visible, or near-ultraviolet light.

LED technology has started to be used as the lighting source in LCD monitors the last years and is projected that they will replace the other types of backlit bulbs in the near future.

*The main advantages of LEDs are:*

- Long Service Life
  - 100,000 hours time to ½ life- YG, Red and Amber
  - 50,000 hours Green
  - 20,000 to 40,000 hours for Blue and White
- Good environmental performance including high UV, high temperature and high humidity resistance
- High MBTF
- Solid state chip embedded in epoxy- nothing to break or burn out
- LED consumption is increasing, driving costs down
- Low heat generation
- No EMI or RFI[v]
- Low Power (5 to 30 mA at 3.6 or 2.2 Vdc)
- ew narrower beam, light focusing packages that are better utilized in light guides

[v] *Electromagnetic interference* (or **EMI**, also called **radio frequency interference** or **RFI**) is disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. (Source: wikipedia, http://en.wikipedia.org/wiki/Electromagnetic_interference)

- Many color choices

*The main disadvantages of LEDs are:*

- Sensitive to ESD
- Sensitive to voltage spikes
- Heat dissipation in some applications
- Not true full spectrum White LED (unless tri-color)

## 2.4 Not yet available best technologies

### 2.4.1 Organic light-emitting diode (OLED)[11]

An organic light-emitting diode (OLED) is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compounds which emit light in response to an electric current. This layer of organic semiconductor material is situated between two electrodes. Generally, at least one of these electrodes is transparent. OLEDs are used in television set screens, **computer monitors**, small, portable system screens such as mobile phones and PDAs,watches, advertising, information, and indication. OLEDs are also used in large-area light-emitting elements for general illumination. Due to their low thermal conductivity, they typically emit less light per area than inorganic LEDs.

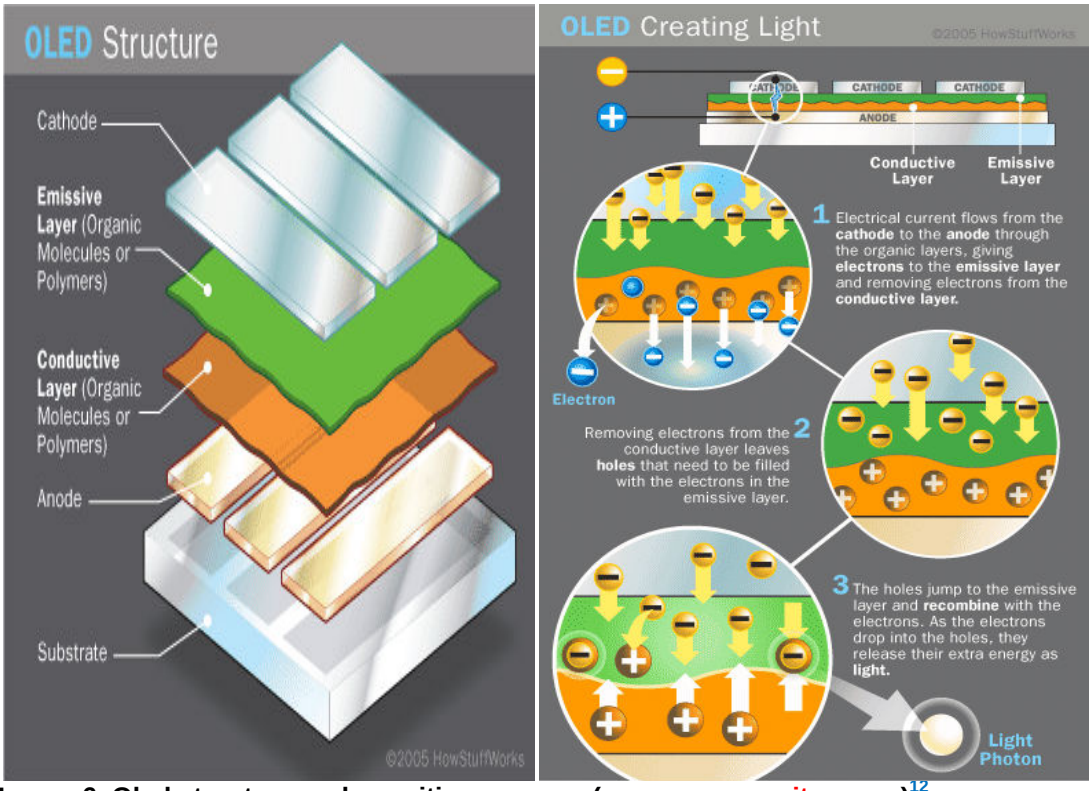



**Image 6. Oled structure and emmiting process (source: pcmonitors.org)**[12]

The most significant advantages of an OLED monitor, in comparison to a LED monitor are the better energy efficiency, the wider viewing angles and the higher contrast ratio and their light weight. Nevertheless there are still disadvantages and bottlenecks that have to be solved in order this technology to be competive. Such disadvantages are, the high costs (a computer monitor may cost up to 6.000€), the shorter lifespan and the power consumption.

Nowadays numerous electronic technology companies have started to present their models of OLED computer monitors, such as SONY (mainly for professional use), LG, Samsung and ACER.


**Image 7. OLED technology monitors**

### 2.4.2 field emission display (FED)

A field emission display (FED) is a display technology that incorporates flat panel display technology that uses large-area field electron emission sources to provide electrons that strike colored phosphor to produce a color image as a electronic visual display. In a general sense, a FED consists of a matrix of cathode ray tubes, each tube producing a single sub-pixel, grouped in threes to form red-green-blue (RGB) pixels. FEDs combine the advantages of CRTs, namely their high contrast levels and very fast response times, with the packaging advantages of LCD and other flat panel technologies. They also offer the possibility of requiring less power, about half that of an LCD system.

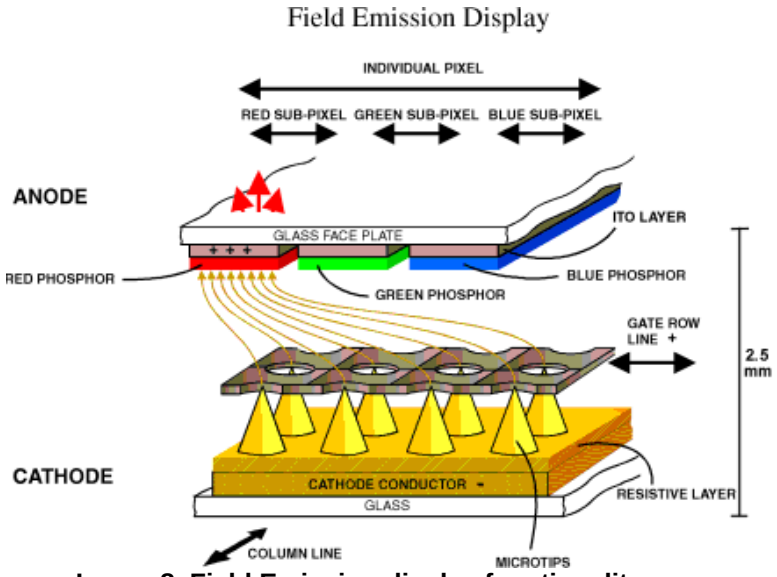



**Image 8. Field Emission display functionality**

FED display operates like a conventional cathode ray tube (CRT) with an electron gun that uses high voltage (10 kV) to accelerate electrons which in turn excite the phosphors, but instead of a single electron gun, a FED display contains a grid of individual nanoscopic electron guns. A FED screen is constructed by laying down a series of metal stripes onto a glass plate to form a series of cathode lines. Photolithography is used to lay down a series of rows of switching gates at right angles to the cathode lines, forming an addressable grid. At the intersection of each row and column a small patch of emitters are deposited, typically using methods developed from inkjet printers. The metal grid is laid on top of the switching gates to complete the gun structure.

A high voltage-gradient field is created between the emitters and a metal mesh suspended above them, pulling electrons off the tips of the emitters. This is a highly non-linear process and small changes in voltage will quickly cause the number of emitted electrons to saturate. The grid can be individually addressed but only the emitters located at the crossing points of the powered cathode and gate lines will have enough power to produce a visible spot, and any power leaks to surrounding elements will not be visible.

The non-linearity of the process allows avoidance of schemes – once the pixel lights up, it will naturally glow for some time. Non-linearity also means that the brightness of the sub-pixel is pulse-width modulated to control the number of electrons being produced, like in plasma displays.

The field emmission displays are still in prototype stage and they are developed by SONY. Thus, there are not energy consumption data available to the public, even though it is claimed that they could consume less energy than the LCD monitors.

## 2.5 Legislations and Labels

### 2.5.1 International labels

*U.S.A.*

**ENERGY STAR**. It is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping save money and protects the environment through energy efficient products and practices. The Energy star programme requirements for displays version 5.0[vi] determine the energy consumption requirements in order a product to be characterizes as Energy Star.

*Other international labels*

| Label | Country | Link |
|---|---|---|
| | **USA** | http://www.epeat.net/ |
| | **Japan** | **Eco Leaf** |
| | **Japan** | **The Eco Mark programme** |

[vi] http://www.energystar.gov/ia/partners/product_specs/program_reqs/Displays_Program_Requirements.pdf

| Label | Country | Link |
|---|---|---|
| | Korea | Korea Eco-Label |
| | Taiwan | The Greenmark Programme |
| | Singapore | Singapore Green Labelling Scheme |
| | China | http://www.sepacec.com/cecen/ |

## 2.5.2 European labels

### 2.5.2.1 European labelling

**EU ENERGY STAR PROGRAMME**[13]. The EU ENERGY STAR programme follows an Agreement between the Government of the US and the European Community (EU) to co-ordinate energy labelling of office equipment. It is managed by the European Commission. [14] The current displays specifications V. 5.0 define maximum On mode power consumption values depending on the screen area.

### 2.5.2.2 Relevant National Criteria

*Germany*

**Blue Angel.**[15] The Blue Angel is the first and most well known eco-label worldwide. Since 1978, it has set the standard for eco-friendly products and services selected by an independent jury in line with defined criteria. The Blue Angel is awarded to companies as kind of a reward for their commitment to environmental protection. They use it, to professionally promote their eco-friendly products in the market. The Blue Angel is an

ecological beacon showing the consumer the way to the ecologically superior product and promotes environmentally conscious consumption[vii].

*Nordic countries (Finland, Norway, Sweden, Denmark, Iceland)*

**TCO Certified.**[16] TCO Certified is a third party verified program, where every product model is tested by an accredited, independent laboratory. We also back up our quality assurance process with regular after-market checks and test rounds. Purchasers and users look to the TCO program as a credible tool when specifying products to meet environmental and performance needs. The TCO label is international – the same criteria apply throughout the world, making it a tool for global products.

According to TCO, there are two levels of certification:

- **TCO Certified Displays 5** his is the fifth and the latest TCO certification for computer monitors which are intended for professional office use. TCO Certified Displays 5 covers criteria for minimal climate and environmental impact, picture quality and user safety.[17]

- **TCO Certified Edge Displays** TCO Certified Edge is a supplement certification for displays that are at the leading edge of innovation in the areas of Usability/ Human factors or which offer proven reduced impact on the natural environment. Every display with the TCO Certified Edge label meets the requirements of both TCO Certified for displays AND an additional criterion in TCO Certified Edge.[18]

**Nordic Swan Ecolabel**.[19] The Nordic Ecolabel is the official Ecolabel of the Nordic countries and was established in 1989 by the Nordic Council of Ministers with the purpose of providing an environmental labelling scheme that would contribute to a sustainable consumption. It is a voluntary, positive Ecolabelling of products and services. The Nordic Ecolabel was initiated as a practical tool for consumers to help them actively choose environmentally sound products. It is an ISO 14024 type 1 Ecolabelling system and is a third-party control organ. Today there are 63 product groups, and companies who have products within these groups and who meet the criteria requirements, can apply for a Nordic Ecolabel licence.

The latest version of Nordic Swan Ecolabel is the version 5.1 that was published in June of 2007.The requirements that the computer monitors must fulfil before a Nordic Ecolabel can be granted focus on the following aspects:[20]

[vii] http://www.blauer-engel.de/en/products_brands/search_products/produkttyp.php?id=529

- Power consumption
- Design (upgradeability and disassembling)
- Plastics and their additives, e.g. flame retardants
- Heavy metals
- Recycling of discarded products
- Performance such as noise level, ergonomics and electrical and magnetic fields

## 2.6 Legislation

The European Commission Regulation with regard to the **Ecodesign requirements** for standby and off mode electric power consumption of electrical and electronic household and office equipment [21] sets limits of 1W (Off) and 2W (Standby) which will be tightened to 0.5W and 1W in 2013.

An Ecodesign regulation for computers, monitors and digital frames is discussed since 2009. The final draft is still expected.

The European Community Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE) and its amendments, together with the Directive 2002/95/EC on Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) became European Law in February 2003, setting collection, recycling and recovery targets for all types of electrical goods. The directives aim on reducing the environmental impact of electrical and electronic equipment also through design measures, which support disassembly and reuse. The **WEEE** applies to computer monitors under category 3 of Annex IA, IT and Telecommunications Equipment, stating that the rate of recovery shall be increased to a minimum of 75% by an average weight per appliance; while component, material and substance reuse and recycling shall be increased to a minimum of 65 % by an average weight per appliance. Annex II of WEEE declares selective treatment for materials and components of waste electrical and electronic equipment in accordance with Article 6.[22]

The **RoHS** applies to all electronic and electrical appliances (e.g. printers) well and prohibits the use of the heavy metals lead, mercury, cadmium, hexavalent chromium, and brominated flame-retardants (poly-brominated diphenylethers and poly-brominated biphenyls) in new electrical and electronic equipment placed on the market after 1 July 2006.[23]

## 2.7 Test Standards

There are several voluntary initiatives working on improvement of the environmental performance of the products within the scope of this study. Two of 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 tighter requirements to keep stimulating improved environmental performance. The results of energy consumption measurements are totally depended on how the different measurement standards have chosen to set up the unit under test, especially in the Active/Idle mode.

Within the Topten network the standards that are used in order to assess the energy consumption in on, off and sleep mode of the computer monitors, are those set by Energy STAR version 5.0[viii] and are described later in this paper.

[viii] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer/Version5.0_Computer_Spec.pdf

# 3 Economic and Market Analysis

## 3.1 Market and Stock data and trends

LCD monitors are the second biggest segment (following tvs) of the display industry with revenues of about €18 billion in 2007. In terms of unit volumes, more desktop monitors were sold in 2007 than either LCD TVs or notebook PCs. It has been projected that the desktop monitor market is prepared for growth at least until 2015, with LCD monitors continuing to dominate. The current trends are towards notebooks and laptops substituting for desktops and a move towards wider and larger screen sizes. CRT monitor shipments, still available as an entry-level display technology in emerging markets, will continue to shrink[24].

In particular computer buyers are increasingly looking to buy notebook PCs, and are not generally using these with separate monitors. Furthermore, LCDs do not get fuzzy as they age, although they do get dimmer. This can mean that replacement cycles are longer. As a result of these factors, there is little growth in the desktop monitor market in Western Europe although there are still growth opportunities in Central and Eastern Europe[25].

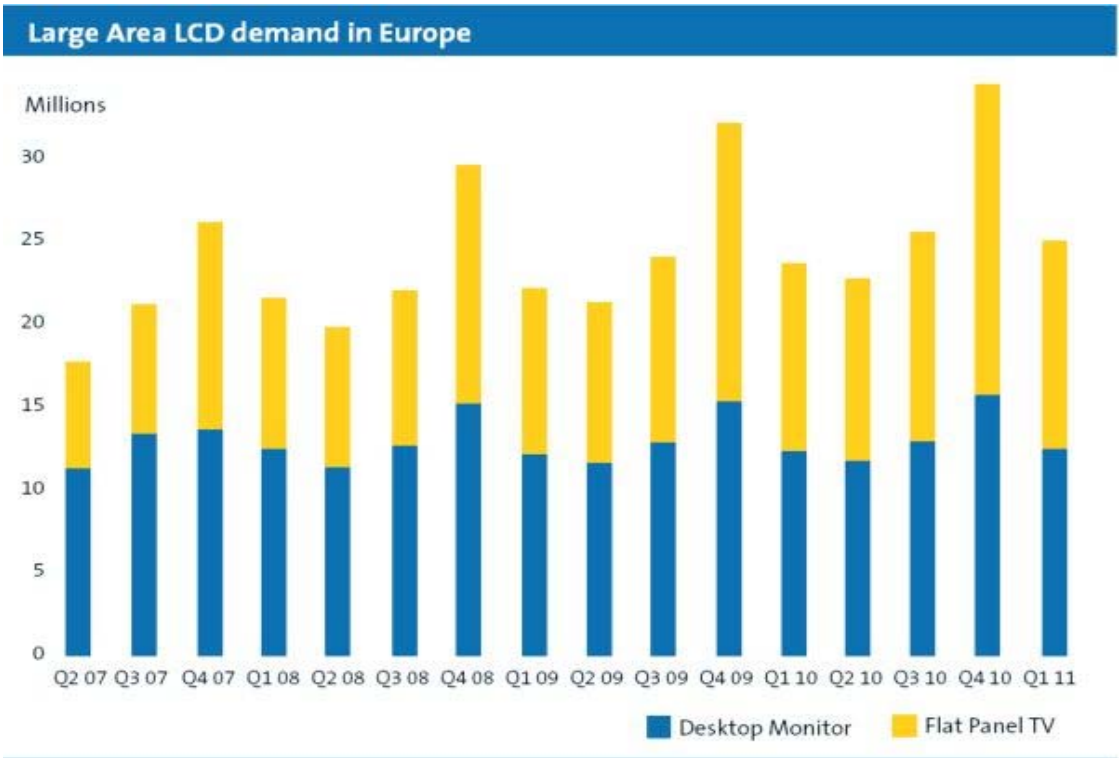
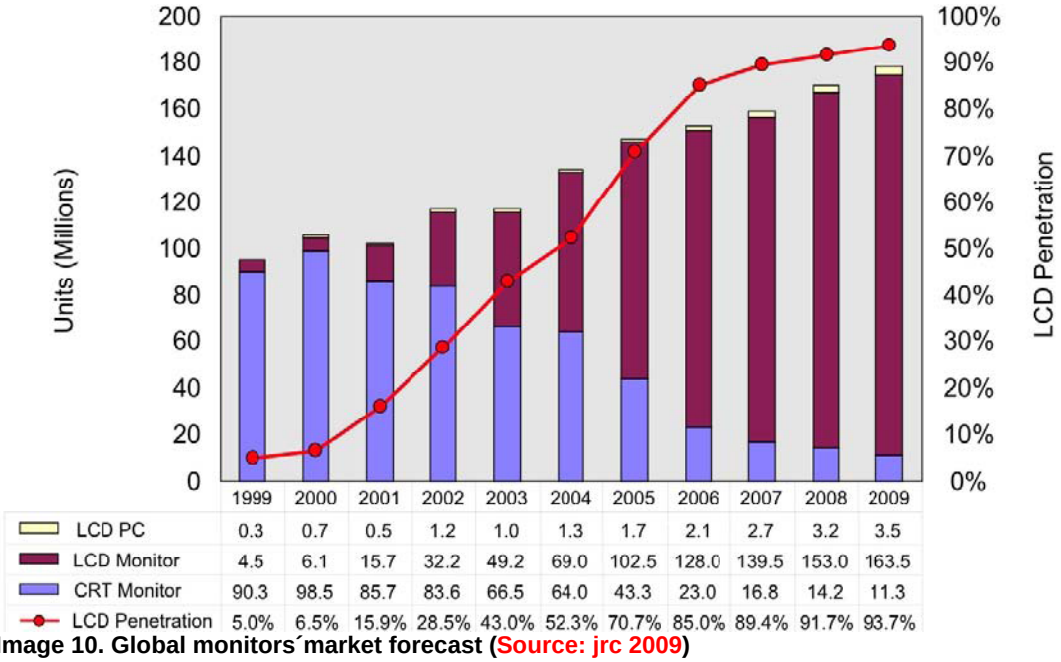



**Image 9. Large Area LCD demand in Europe (measured in 2008 with projections to 2011) (source: German Flat Panel Display Forum)**

Of the three major trends driving desktop monitor growth, organic growth in emerging markets such as China, Latin America and Asia Pacific is the most noteworthy. Green IT initiatives and transitions in monitor sizes and resolutions are also important. China is forecast to grow rapidly over the next five years and will overtake the North American market to become the world's second largest market for desktop flat panel LCD monitors by 2011. The EMEA region with Europe will remain the world's largest market for such products.




| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LCD PC | 0.3 | 0.7 | 0.5 | 1.2 | 1.0 | 1.3 | 1.7 | 2.1 | 2.7 | 3.2 | 3.5 |
| LCD Monitor | 4.5 | 6.1 | 15.7 | 32.2 | 49.2 | 69.0 | 102.5 | 128.0 | 139.5 | 153.0 | 163.5 |
| CRT Monitor | 90.3 | 98.5 | 85.7 | 83.6 | 66.5 | 64.0 | 43.3 | 23.0 | 16.8 | 14.2 | 11.3 |
| LCD Penetration | 5.0% | 6.5% | 15.9% | 28.5% | 43.0% | 52.3% | 70.7% | 85.0% | 89.4% | 91.7% | 93.7% |

**Image 10. Global monitors´market forecast (Source: jrc 2009)**

## 3.2 Manufacturers and Distributors

| Brand | European Headquarters address | Link |
|---|---|---|
| acer | Acer Europe SA<br>Via Cantonale, Centro Galleria 2<br>6928 Manno, Switzerland | www.acer-euro.com |
| hp | Cain Road<br>Bracknell, Berkshire, RG12 1HN | http://www8.hp.com/uk/en/home.html |
| lenovo | Les Renardières<br>1, place Victor Hugo<br>92400 Courbevoie<br>Paris, France | http://www.lenovo.com/products/xe/en/ |
| PHILIPS | PO Box 218, Bldg. SAQ<br>Eindhoven, NL-5600 MD<br>Netherlands | http://www.philips.nl |
| EIZO | Eizo Nordic AB<br>Lövängsvägen 14 SE-194 45<br>Upplands Väsby, Sweden | http://www.eizo.com/global/contact/index.html |
| FUJITSU | Diamantlaan 25<br>2132 WV Hoofddorp<br>The Netherlands | http://www.fujitsu.com/global/ |
| SAMSUNG | Samsung House, 1000<br>Hillswood Drive,<br>Chertsey, Surrey, KT16 0PS<br>United Kingdom | www.samsung-europe.com/ |
| DELL | Dell Europe<br>Dell House<br>The Boulevard<br>Cain Road<br>Bracknell<br>Berkshire RG12 1LF | www.dell.co.uk |
| WORTMANN AG terra IT's my world | WORTMANN AG<br>Siegbert Wortmann<br>Bredenhop 20<br>32609 Hüllhorst | www.wortmann.de |

| Brand | European Headquarters address | Link |
|---|---|---|
| SONY | Sony Europe Limited, Zweigniederlassung Deutschland Kemperplatz 1 10785 Berlin | http://www.sony-europe.com/pages/europe/sony_europe.html |
| AOC EYES VALUE | AOC International (Europe) GmbH Lahnstr. 86a 12055 Berlin | http://www.tpvaoc.com/ |
| LG | LG House, 250 Bath Road, Slough, Berkshire, SL1 4DX | http://www.lg.com/uk/index.jsp |

# 4 Selection Criteria

This chapter does not define specific target values to be met by Topten products in all Euro-Topten partner countries. Nevertheless, it suggests energy efficiency guidelines, such as the registration of the Topten appearing computer monitors in the Energy Star database or the completion of similar requirements, which are in line with the Topten concept. Thereafter, each country has to develop its specific Topten lists, which depend on the products availability on the national market. Thus, the specific thresholds for Topten lists depend on the products offered at national level and will be more or less stringent depending on the number of efficient products available.

Topten.eu makes a first selection for the national teams who then have to take the European list and confront it to their national markets. If producers say they have more models, national teams can check that they indeed correspond to the Topten criteria and then inform the European team – this is the quality control we mention at each meeting between the european and the national lists.

The intention is rather to provide some recommendations regarding the criteria to be considered in Topten product listings and to give an idea of the efficiency of products currently offered on the market.

## 4.1 Current Criteria

### 4.1.1 Topten.eu criteria

In order to be displayed on www.topten.eu, computer monitors must

- Be labelled by Energy Star Version 5.0
- Be labelled by TCO
- Be available in at least one European country
- Have a maximum Sleep and Off mode power consumption of 0.8 Watt
- Have a maximum On mode power consumption according to Energy Star Version 5.0:

**Table 3. Maximum on mode power consumption (source, Energy Star V5.0)**

| Display Category | Maximum On Mode Power Consumption (W) |
|---|---|
| Diagonal Screen Size < 30 inches Screen Resolution ≤ 1.1 MP | Po=6*(MP) + 0,05*(A) +3 |
| Diagonal Screen Size < 30 inches Screen Resolution > 1.1 MP | Po=9*(MP) + 0,05*(A) +3 |
| Diagonal Screen Size 30-60 inches All Screen Resolution | Po = 0,27*(A) + 8 |

### 4.1.2 National criteria

The national Topten websites present a uniformity and compliance with the criteria set by Topten.eu. There are a few countries that still use the old Energy Star criteria, but they will shift the new ones as soon as they update their product lists.

## 4.2 New Energy Efficiency Criteria

The energy efficiency criteria, concerning the computer monitors are suggested to be the following:

1. The computer monitors must be labelled by Energy Star Version 5.0
2. The computer monitors must be labelled by TCO
3. The computer monitors must be available to the national markets
4. The computer monitors must have a maximum Sleep and Off mode power consumption of 0.8 Watt
5. Have a maximum On mode power consumption according to Energy Star Version 5.0

**Table 4. Maximum on mode power consumption (source, Energy Star V5.0)**

| Display Category | Maximum On Mode Power Consumption (W) |
|---|---|
| Diagonal Screen Size < 30 inches Screen Resolution ≤ 1.1 MP | Po=6*(MP) + 0,05*(A) +3 |
| Diagonal Screen Size < 30 inches Screen Resolution > 1.1 MP | Po=9*(MP) + 0,05*(A) +3 |
| Diagonal Screen Size 30-60 inches All Screen Resolution | Po = 0,27*(A) + 8 |

**Table 5 Example: On Mode Maximum Power Consumption Requirements (source, Topten.eu)**

| Size (diagonal) | Resolution | Max. power On |
|---|---|---|
| 15-inch monitors | 1024x768 | 13 W |
| 17-inch monitors | 1280x1024 | 22 W |
| 19-inch monitors | 1280x1024 | 24 W |
| 22-inch monitors | 1680x1050 | 29 W |
| 23-inch monitors | 1920x1080 | 32 W |
| 24-inch monitors | 1920x1200 | 36 W |
| **Sleep mode** | | **0.8W** |
| **OFF(but not disconnected)** | | **0.8W** |

Apart from the energy efficiency criteria the consumer will be interested to find in the topten tables information such as:

1. The electricity costs in five years time (monitor´s mean lifetime). As price of the electricity should be considered the national prices of electricity.

2. The diagonal display size in inches or/and centimetres.

3. The screen resolution in Pixels.

4. The contrast (e.g. typical contrast ratio 200 meaning contrast of 1:200).

5. The brightness, which is the image´s typical brightness measured in candela per $m^2$.

6. The power input in the “On” mode of the monitor, in Watt.

7. The power input in the “Sleep” mode of the monitor, in Watt.

8. The power input in the “Off” mode of the monitor, in Watt.

9. The colours projected by the screen

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[3] European Commission DG TREN Preparatory studies for Eco-design Requirements of EuPs. Lot 3 Personal Computers (desktops and laptops) and Computer Monitors. Final Report (Task 1-8), p22, August 2007.
http://extra.ivf.se/ecocomputer/downloads/Eup%20Lot%203%20Final%20Report%20070913%20published.pdf

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[13] http://www.eu-energystar.org/en/index.html#note1

[14] http://www.eu-energystar.org/downloads/legislation/20030408/Council_Decision_2003_269_en.pdf

[15] http://www.blauer-engel.de/en/index.php

[16] http://www.tcodevelopment.com/

[17] TCO Certified Displays 5.2
http://tcodevelopment.com/tcodevelopmentnew/Tillverkare/TCO_Certified_Displays_5_2.pdf

[18] TCO Certified Edge Displays
http://www.tcodevelopment.com/tcodevelopmentnew/Tillverkare/TCO_Certified_Edge_Displays_1.1_Release_100903.pdf

[19] http://www.nordic-ecolabel.org/apply/

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http://www.nordic-ecolabel.org/criteria/product-groups/

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http://www.topten.eu/uploads/File/Ecodesign%20Regulation_Standby_1208.pdf

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http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0024:0038:EN:PDF

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