Topten Product Criteria Paper on Computer Monitors

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The Project in brief

Topten is part of the international Euro-Topten-Max 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.eu).

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 20 project partners are:

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Lithuania: LNCF, consumer federation	LT
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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).

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 nowadays are widespread in European consumer households . 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 of the 20st Century, 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 and 16:10. [2]

There are more than one definition, concerning the computer monitors. In the current study we consider the definition given by the Environmental Label "Blue Angel" (RAL-UZ 78c)[3], Edition August 2014 for computer monitors.

Thus, according to the Blue Angel, a computer monitor can be defined as a "commercially available, electronic product with a display screen and its associated electronics encased in a single housing that as its primary function displays visual information from the following units:

- computer[4], workstation or server via one or more inputs, such as set-VGA, DVI, HDMI, Display Port, IEEE 1394, USB, or
- External storage device (eg USB flash drive, memory card, or network connection)

[1] 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), p14, August 2007.
http://extra.ivf.se/ecocomputer/downloads/Eup%20Lot%203%20Final%20Report%20070913%20published.pdf

[2] http://en.wikipedia.org/wiki/Computer_monitor

[3] https://www.blauer-engel.de/en

[4] A computer means a device which performs logical operations and processes data, is capable of using input devices and outputting information to a display, and normally includes a central processing unit (CPU) to perform operations. If no CPU is present, then the device must function as a client gateway to a computer server which acts as a computational processing unit. The term 'computer' includes both personal computers (desktop computers, integrated desktop computers, small-scale servers, thin clients and workstations) and portable computers (notebooks, tablet computers, slate computers, mobile thin clients, et al). Definition given by the Environmental Label "Blue Angel" (RAL-UZ 78a), https://www.blauer-engel.de/en

Computer monitors typically have a screen size greater than 12 inches (30.5 cm) and a pixel density greater than 5,000 pixels per square inch (in2)."

Energy Star[5] has introduced the following definition of an Electronic Display and a Computer Monitor which is basically the same to the one proposed from the Blue Angel , differing only in a more detailed description and the additional distinction between Computer Monitor (see below), Digital Picture Frame and Signage Display:

"Electronic Display (Display): A commercially-available product with a display screen and associated electronics, often encased in a single housing, that as its primary function displays visual information from (1) a computer, workstation or server via one or more inputs (e.g., VGA, DVI, HDMI, DisplayPort, IEEE 1394, USB), (2) external storage (e.g., USB flash drive, memory card), or (3) a network connection.

a) Computer Monitor: An electronic device, typically with a diagonal screen size greater than 12 inches and a pixel density greater than 5,000 pixels per square inch (pixels/in^2), that displays a computer's user interface and open programs, allowing the user to interact with the computer, typically using a keyboard and mouse.

(1) Enhanced-Performance Display: A computer monitor that has all of the following features and functionalities:

a) A contrast ratio of at least 60:1 measured at a horizontal viewing angle of at least 85°, with or without a screen cover glass;

b) A native resolution greater than or equal to 2.3 megapixels (MP); and,

c) A color gamut size of at least sRGB as defined by IEC 61966 2-1. Shifts in color space are allowable as long as 99% or more of defined sRGB colors are supported."

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 ac mains, via an external power supply, or via a bridging or network connection. Products with an integrated television tuner or dual function television computer monitors that are marketed and sold as televisions are not included in this specification.

[5] ENERGY STAR® Program Requirements Product Specification for Displays, Eligibility Criteria Version 6.0.

2.2. Product Types

Computer monitors have different technologies for image reproduction. The most common types are computer monitors with Liquid Crystal Display (LCD) and different backlight-technologies. 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.

Following backlight-technologies for LCD-monitors are typical:

- Cathode Fluorescent-backlit (CCFL = Cold Cathode Fluorescent Lamp) (see chapter 2.2.1.1)
- LED-backlit (LED = Light Emmitting Diodes) (see chapter 2.2.1.2)

The different backlight-technologies CCFL- and LED-backlight use the same TFT LCD (thin film transistor liquid crystal display) technology as described below. The quality is primarily based on TFT LCD technology, independent of backlight type.

2.2.1. 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].

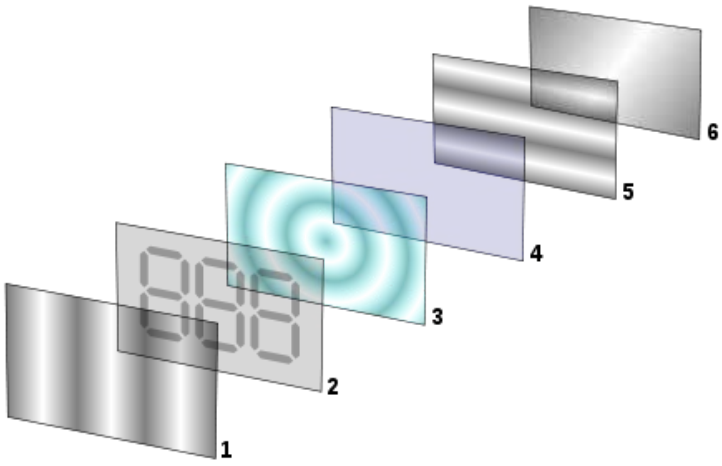

Image 1. 1. Polarizing filter film with a vertical axis to polarize light as it enters. 2. Glass substrate with ITO electrodes. The shapes of these electrodes will determine the shapes that will appear when the LCD is turned ON. Vertical ridges etched on the surface are smooth. 3. Twisted nematic liquid 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 were multiple technologies which have been used to implement liquid crystal displays (LCD), e.g. active or passive monochrome, passive color or active matrix color (TFT). But the monochrome and passive color technologies were dropped from most product lines and so the active matrix TFT-LCD technology is now the dominant technology used for computer monitors:

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. The basic structure of an active matrix LCD or a TFT display

[6] Fundamentals of Liquid Crystal Displays –How They Work and What They Do. Fujitsu Microelectronics America, Inc. White paper 2006, p.3
http://www.fujitsu.com/downloads/MICRO/fma/pdf/LCD_Backgrounder.pdf

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.

2.2.1.1. CCFL backlit LCD monitors [7]

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.

[7] Backlight Technology Overview. DENSITRON TECHNOLOGIES plc. Michael Yu, February 2006, pp15-17.http://www.densitron.com/uploadedFiles/Displays/Products/whitepaper17.pdf

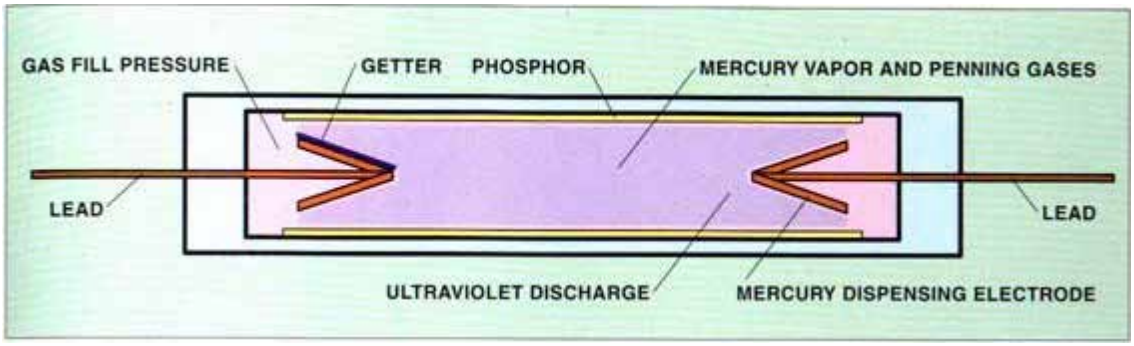

Image 2. CCFL Backlight technology (source: DENSITRON TECHNOLOGIES plc)

The main advantages of CCFL are:

- Ø High Brightness of 2000 to 5000 cd/m^2 (depending on technology)
- Ø Full spectrum whites for good color balance
- Ø Easy to achieve display uniformity
- Ø Thin profiles (2 mm & less) available for tight packages
- Ø Long service life (up to 50,000 hours)
- Ø Power efficiency (1 to 5 watts depending on inverter and number of tubes)
- Ø Efficacy- high power vs. light output ratio
- Ø Infinitely dimmable between 20 and 100%
- Ø Well established technology

The main disadvantages of CCFL are:

- Ø High voltage and frequency
  - o Some systems -1000 Vac & 30-40KHz
- Ø Glass tubes can require special handling & packaging
- Ø Tube thickness can be an issue
  - o Not a good choice in small portables
  - o Thinner tubes have lower output (less phosphor surface means less light)
- Ø Inverters require 25 X 100 mm of PCB (printed circuit board) space

Ø Flicker

Ø Cold starts & low temperature performance

2.2.1.2. LED-backlit LCD monitors

LED-backlit LCD display is a flat panel display which uses LED backlighting instead of the cold cathode fluorescent (CCFL). LED-backlit LCD displays use the same TFT LCD (thin film transistor liquid crystal display) technologies as CCFL-backlit LCD displays.

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[8]:

Ø 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

Ø Good environmental performance including high UV, high temperature and high humidity resistance

Ø High MBTF (mean time between failures)

Ø Solid state chip embedded in epoxy- nothing to break or burn out

[8] Backlight Technology Overview. DENSITRON TECHNOLOGIES plc. Michael Yu, February 2006, http://www.densitron.com/uploadedFiles/Displays/Products/whitepaper17.pdf

- Low heat generation
- No EMI or RFI[9]
- No mercury
- Low Power (5 to 30 mA at 3.6 or 2.2 Vdc)
- Many color choices

The main disadvantages of LEDs are:

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

In 2009 and into 2010, a great drive has been made by PC monitor and TV manufacturers to replace the usual CCFL (Cold Cathode Fluorescent Lamp) backlights of LCD monitors with LED backlights. Today within desktop displays, LCD monitors with LED backlight technology are dominating with nearly 100% of all desktop displays shipped worldwide while CRT monitors are rather completely obsolete from the mainstream worldwide computer monitor market. (JRC 2013)

2.3. Economic lifetime

According to Comission´s EuP Lot3[10], 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 assumed that 20% of the monitors have a second life time).

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[9] *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)

[10] 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), p104, August 2007.
http://extra.ivf.se/ecocomputer/downloads/Eup%20Lot%203%20Final%20Report%20070913%20published.pdf

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").[11]

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)
LCD	6	6,6

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 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.. Even for 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 following table sourcing from the websites www.ecotopten.de and 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.

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

Table 2. Energy consumption of the most efficient monitors of the EU market (source: www.ecotopten.de and www.topten.eu)

	19”			22”			24”		
Brand	**EIZO**	**LG**	**inefficient model**	**EIZO**	**LG**	**inefficient model**	**EIZO**	**Fujitsu**	**ineffi-cient model**
Model	S1903H	19MB35 PM-B	-	EV2216WF S3	22MB35PU -B		EV2416WF S3	B24W-7 LED	-
Resolution (Pixel)	1280 x 1024	1280 x 1024	1280 x 1024	1680 x 1050	1920 x 1080	1680 x 1050	1920 x 1200	1920 x 1200	1920 x 1200
Label	-	EPEAT Gold	-	-	EPEAT Gold	-	-	EPEAT Gold	-
Power On (Watt)	11	11.1	29	12	15,1	39	11	16,7	54
Power Sleep (Watt)	0.3	0.2	0.4	0.2	0.2	0.7	0.1	0.2	1
Power Off (Watt)	0.2	0.2	0.3	0	0.2	0.7	0	0.1	0.8

As it can be understood from the above table the annual energy consumption of the latest computer monitor models is low comparing to non-efficient models.

2.5. Not yet available best technologies

2.5.1. Organic light-emitting diode (OLED)[12]

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.

[12] http://en.wikipedia.org/wiki/Organic_light-emitting_diode

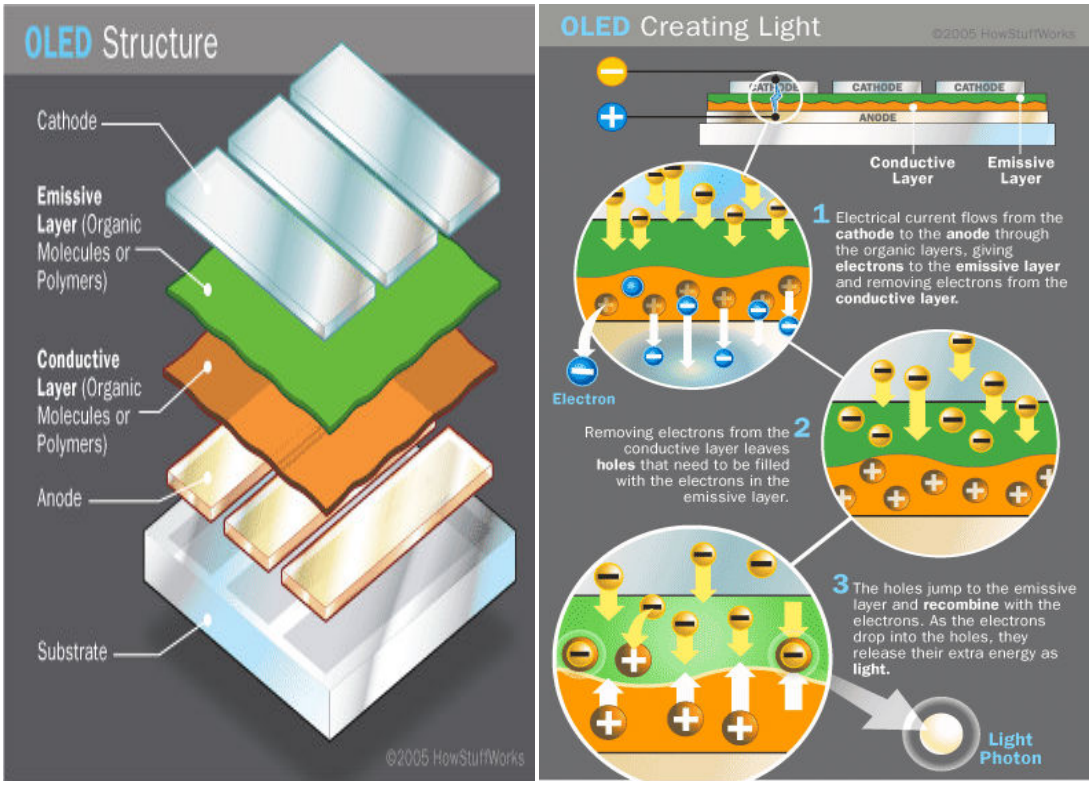

Image 3. Oled structure and emiting process (source: pcmonitors.org)[13]

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. When these hit the mass-market they could be over 10 times as efficient as the best LED-backlit LCD monitor of today. 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 and the shorter lifespan.

Numerous electronic technology companies are investing heavily in OLED technologies at the moment, e.g. Samsung and LG. Strides are being made by Samsung and partners to increase the lifetime of OLED pixels of all colors.[14]

2.5.2. 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

[13] http://www.pcmonitors.org/articles/oled-monitors

[14] http://pcmonitors.info/articles/oled-monitors

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.

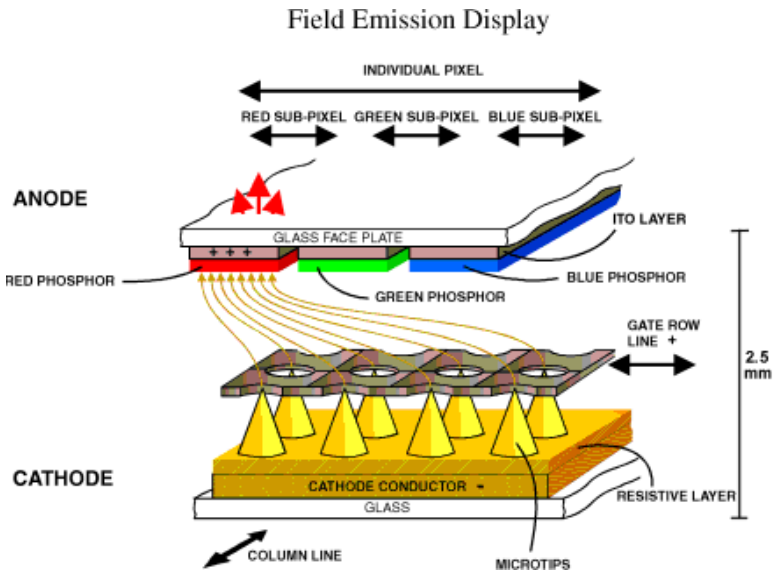

Image 4. Field Emission display functionality

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 with Sony being the most important protagonist.But in 2009 Sony announced that the project was closing down due to the inability to raise capital[15]. Hence the technology is still in the research stage and there are no plans to begin mass production at this moment.

2.6. Legislations and Labels

2.6.1. 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 6.0, Rev. Oct-2014 [16] 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

[15] http://www.macworld.com/article/1060360/fed.html

[16] download: http://www.energystar.gov/sites/default/files/FINAL%20Version%206.0%20Display%20Program%20Requirements%20%28Rev%20Oct-2014%29_0.pdf

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

2.6.2. European labels

2.6.2.1. European labelling

EU ENERGY STAR PROGRAMME[17]. 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[18]. The current displays specifications V. 6.0 establishes new On-Mode power consumption requirements for displays with a viewable diagonal screen size from 12 to 30 inches and for computer monitors greater than 30 inches. It also establishes a new maximum Sleep Mode power requirement of 0.5 W for all displays, and a power management requirement that all computer monitors must enter Sleep Mode after the connection to a host is discontinued.

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

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

2.6.2.2. Relevant National Criteria

Germany

Blue Angel.[19] 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[20].

The current displays specifications of the Blue Angel for "Computer Monitors" (RAL-UZ 78c) define power consumption in on mode, sleep and off modes, power-saving requirements, recyclable design, material requirements, backlight and liquid crystal compounds, ergonomics and consumer Information.

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

TCO Certified.[21] 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 6.0** his is the sixth and the latest TCO certification for computer monitors which are intended for professional office use. TCO Certified Displays 6.0 covers criteria for visual ergonomics, work load ergonomics, emissions, electrical safety, environmental requirements (energy consumption (climate), environmentally hazardous substances, product lifetime (warranty and

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

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

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

spare parts), preparation for recycling, product packaging) and corporate social responsibility (based on the eight ILO core conventions and local legislation.[22]

- **TCO Certified Edge Displays 2.0** 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. Current qualifying criteria are halogen free display, minimum 85% post-consumer recycled plastic content, full function ergonomic display stand. To comply with TCO Certified Edge Displays it is enough to fulfil only one of the cutting edge criteria. To apply for a TCO Certified Edge certificate it is also necessary that the product is certified according to the regular TCO Certified program.[23]

Nordic Swan Ecolabel.[24] 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 64 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 6.5 that was published in June of 2009.The requirements that the computer monitors must fulfil before a Nordic Ecolabel can be granted focus on the following aspects:[25]

- Power consumption
- Design (disassembling)
- Plastics and their additives, e.g. flame retardants

[22] TCO Certified Displays 6.0

download: http://tcodevelopment.com/files/2013/04/TCO-Certified-Displays-6.0.pdf

[23] TCO Certified Edge Displays
download: http://tcodevelopment.com/files/2014/04/140401_TCO-Certified-Edge-Displays-2-0_final-version.pdf

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

[25] Nordic Ecolabelling of Computers version 6.5, p.3
download: http://www.nordic-ecolabel.org/criteria/product-groups/?p=1

Mercury content Performance such as ergonomics and electrical and magnetic field

EPEAT EPEAT®-registered electronic products meet environmental measures referred to as criteria. EPEAT criteria reflect several categories of environmental attributes that cover the full lifecycle of electronic products. Products are measured against both required and optional criteria. A product must meet all of the required criteria in its category to be added to the registry. It is then rated Bronze (meets all required criteria), Silver (meets all required plus at least 50% of optional criteria) or Gold (meets all required plus at least 75% of optional criteria). The "PC and Displays" standards[26] address corporate performance, materials selection, reduction/elimination of environmentally sensitive materials, design for end of life, packaging, energy conservation, product longevity/life extension and end-of-life management.

EU-Ecolabel The EU-Ecolabel for personal computers[27] also defines criteria for displays, e.g. the energy efficiency performance in active mode shall exceed the energy efficiency requirements set out in Energy Star v5.0 by at least 30 %; the sleep mode power must not exceed 1 W; off mode power shall not exceed 0,5 W, energy consumption in on-mode ≤ 100 W (measured when set to maximum brightness); no mercury or its compounds shall be added to the backlights of the display.

2.7. 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[28] sets limits of 0.5W (Off) and 1W (Standby) since 2013.

EU-Member States discussed and voted on a draft Ecodesign regulation for computers in February 2013. The proposed rules on ecodesign requirements for computers and servers were adopted by the committee of member states at the end of February 2013. Ecodesign

[26] Source: http://www.epeat.net/resources/criteria-discussion/pc-display-criteria/

[27] 2011/337/EU: Commission Decision of 9 June 2011 on establishing the ecological criteria for the award of the EU Ecolabel for personal computers (notified under document C(2011) 3737
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011D0337:EN:NOT

[28] Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment
http://www.topten.eu/uploads/File/Ecodesign%20Regulation_Standby_1208.pdf

requirements for other types of equipment such as notebook computers and sleep and off modes are also set in the same annex to the regulation (annex II). The regulation will be published after being scrutinised by MEPs.

For displays other than televisions and television monitors (ENER Lot 3), a draft of the ecodesign Working Document on displays was discussed at the Consultation Forum meeting back in October 2009. Designing a separate measure for displays, however, has proven to be difficult because the convergence of products has made it difficult to clearly define separate product categories.

Traditional product category definitions relied on different input signals and the presence of a tuner for televisions. Any display can be designed to accept a variety of input signals, including broadcast signals for which a tuner is required. Also the importance of the tuner/receiver regarding energy consumption has decreased significantly. Furthermore, the experience with the current definitions on televisions and television monitors in the Regulations is not positive regarding providing a clear distinction for products on the market. Therefore, it has been decided to merge the review work on the television Regulations with the work on the draft Regulation on display products and to prepare one set of ecodesign and energy labelling requirements for all electronic displays, including televisions, computer monitors and digital photo frames.

On 8 October 2012, a discussion paper on the review of the Ecodesign and Energy Labelling Regulation for televisions and on the draft Regulation on electronic displays, including computer monitors, has been presented and discussed with stakeholders at a Consultation Forum Meeting. Currently, the proposals discussed at this meeting are being amended and an impact assessment on the draft regulations on electronic displays has been started. It is expected that the TV review under Ecodesign will terminate before the end of this project.

The Directive on waste electrical and electronic equipment (WEEE) 2012/19/EU (commonly referred to as WEEE-Directive) regulates the separate collection, treatment and recycling of end-of-life electrical and electronic equipment. The Directive 2012/19/EU replaces Directive 2002/96/EC of 27 January 2003, which entered into force on 1st of July 2006. Amongst others, Directive 2012/19/EU requires member states to achieve quantitative collection targets (e.g. 65% of the average weight of EEE placed on the market in the three preceding years). It also requires Member States to ensure that producers provide for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE (Article 12)[29].

The WEEE-Directive classifies EEE in various categories. In this system, computers are classified under category 3 “IT and telecommunication equipment”. Nevertheless, this

[29] While this requirement is mandatory for WEEE from private households, for WEEE from users other than private households, Article 13 allows alternative agreements for financing.

classification is under transition and will follow a new logic from 15th of August 2018 on. Under this new system, computers and computer displays will not be classified in one single category

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. The Directive 2011/65/EU replaces Directive 2002/95/EC, which entered into force on 1st July 2006.

2.8. 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 5.1 and are described later in this paper.

3. Economic and Market Analysis

3.1. Market and Stock data and trends

Figure 1 illustrates the global large-area (9”+) TFT LCD monitor shipments from 2009 to 2011 . It can be seen that there is a slight growth from 2009 to 2010 whereas the number of shipments has remained at a rather stable level between 2010 and 2011.

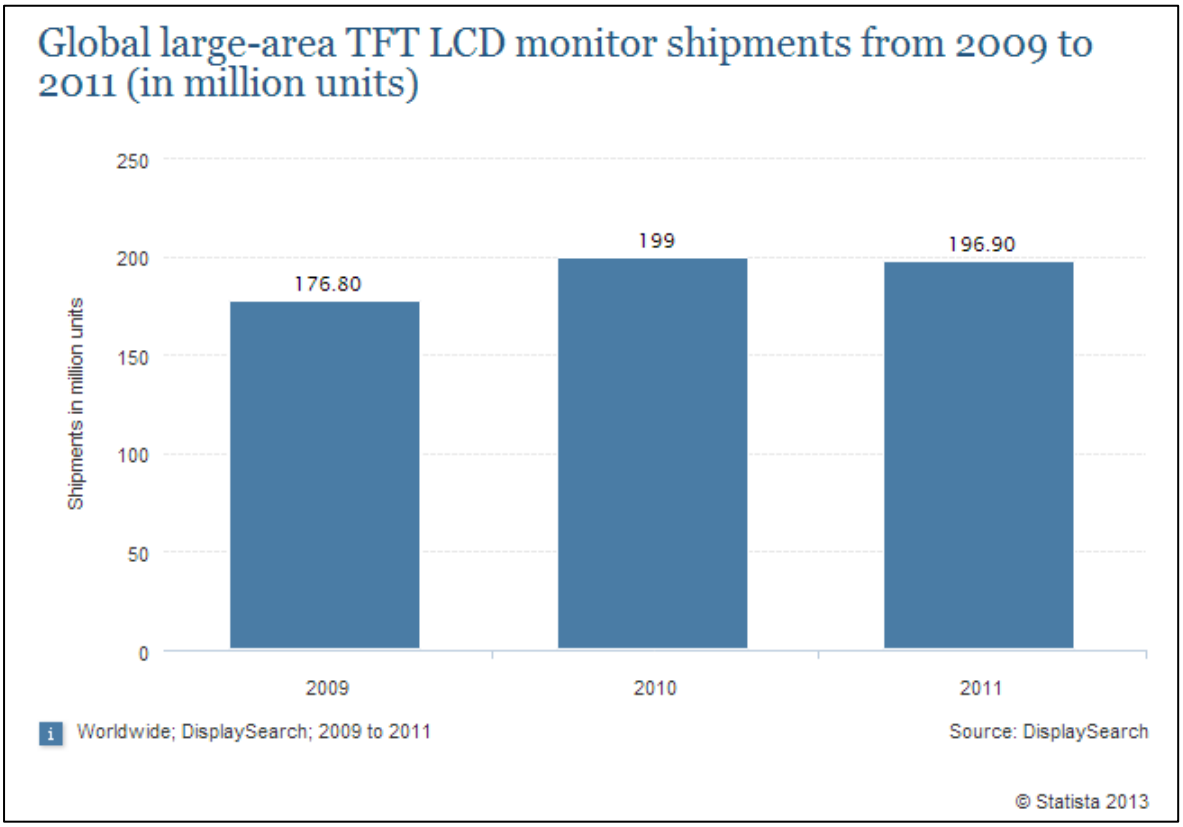

Figure 1: LCD monitors shipments from 2009 to 2011 (Source: Statista 2013[30])

In 2010, the average diagonal size of LCD computer displays was 17 inch, which accounted for 43% of screen sizes in the United States. The size of 19 inch had a proportion of 27%; sizes larger than 20 inch accounted for 15% (see Figure 2)[31].

According to iSuppli[32] , in 2012 the average monitor sold worldwide was already 21 inches, indicating the trend to increasing screen sizes.

[30] Source: http://www.statista.com/statistics/221640/global-large-area-tft-lcd-monitor-shipments-since-2009/

[31] Source: http://www.statista.com/statistics/216680/lcd-monitors-in-the-us-by-screen-size/

[32] Source: http://www.nytimes.com/2012/02/08/technology/for-multitaskers-multiple-monitors-improve-office-efficiency.html?pagewanted=all&_r=0

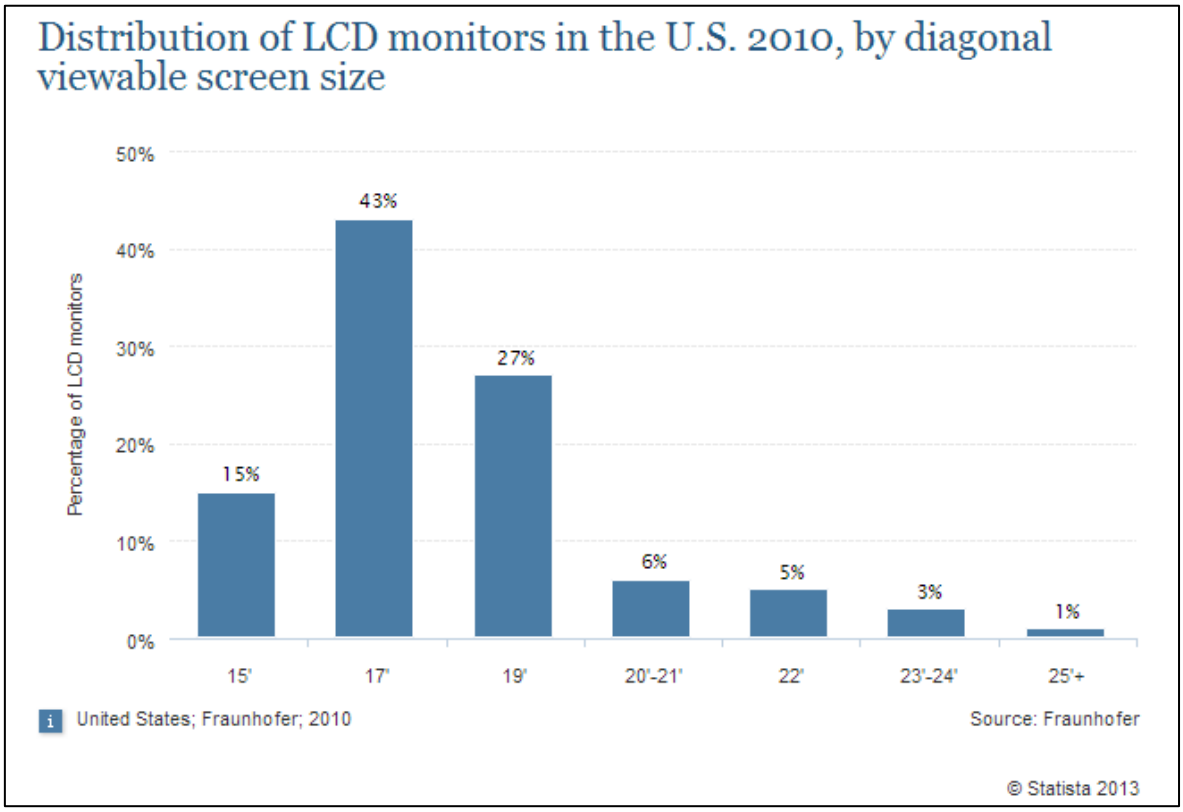

Figure 2 **Distribution of LCD monitors in the U.S. 2010 by screen size (Source: Statista 2013)**

Within desktop displays, LCD monitors with LED backlight technology are dominating with nearly 100% of all desktop displays shipped worldwide while CRT monitors are rather completely obsolete from the mainstream worldwide computer monitor market. Also within notebook PCs, the LED backlit technology reached 98% of the market by the end of 2010. Notebooks with CCFL backlight almost phased out with only 1.6% of the total market by 2011.(JRC 2013)

3.2. Manufacturers and Distributors

Important vendors of computer displays are Dell, Samsung, LG Electronics, HP, Acer, and further companies (see Figure 3).[33]

[33] Source: http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/100607_pc_and_peripheral_companies_remain_bullish_on_desktop_monitors.asp

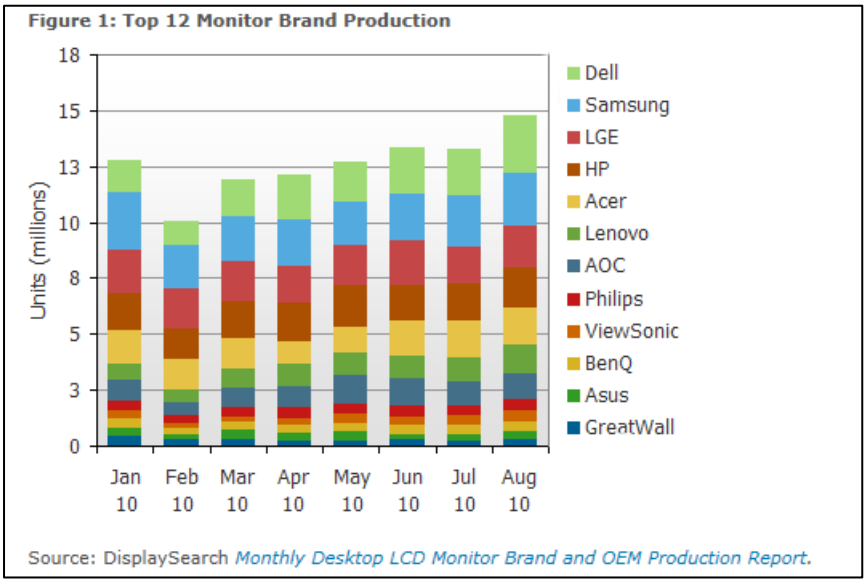

Figure 3: Top 12 monitor brand production 2010 (Source: DisplaySearch)

In the following table the European Headquarters and Links of important brands are compiled:

Brand	European Headquarters address	Link
acer	Acer Europe SA Via Cantonale, Centro Galleria 2 6928 Manno, Switzerland	www.acer-euro.com
hp	Cain Road Bracknell, Berkshire, RG12 1HN	http://www8.hp.com/uk/en/home.html
lenovo	Les Renardières 1, place Victor Hugo 92400 Courbevoie Paris, France	http://www.lenovo.com/products/xe/en/
PHILIPS	PO Box 218, Bldg. SAQ Eindhoven, NL-5600 MD Netherlands	http://www.philips.nl
EIZO	Eizo Nordic AB Lövängsvägen 14 SE-194 45 Upplands Väsby, Sweden	http://www.eizo.com/global/contact/index.html

Brand	European Headquarters address	Link
FUJITSU	Diamantlaan 25 2132 WV Hoofddorp The Netherlands	http://www.fujitsu.com/global/
SAMSUNG	Samsung House, 1000 Hillswood Drive, Chertsey, Surrey, KT16 0PS United Kingdom	www.samsung-europe.com/
DELL	Dell Europe Dell House The Boulevard Cain Road Bracknell Berkshire RG12 1LF	www.dell.co.uk
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
BenQ	BenQ BenQ Deutschland GmbH Essener Straße 5 46047 Oberhausen	http://www.benq.com/
ASUS	ASUSTek UK Ltd. 1st Floor, Focus 31, West Wing, Mark Road, Hemel Hempstead, HP2 7BW, United Kingdom	www.asus.com
ViewSonic See the difference™	ViewSonic United Kingdom ViewSonic Europe Ltd. Level 10, Tower 42, 25 Old Broad Street, London, EC2N 1HQ United Kingdom	www.viewsoniceurope.com

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 6.0 or 5.1
- Be labelled by TCO
- Be available in at least one European country
- Have a maximum Sleep mode power consumption of 0.5 Watt
- Have a maximum On mode power consumption according to the following table :

Diagonale (inches)	Max. On mode power
15 ≤ d < 17	13 Watt
17 ≤ d < 20	18 Watt
20 ≤ d < 22	20 Watt
d ≥ 22 inches	22 Watt

On mode power values must be declared according the Energy Star Requirements Version 6.0 or 5.1 for Displays.

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 6.0
2. The computer monitors must be labelled by TCO Certified Displays 6.0
3. The computer monitors must be available to the national markets
4. The computer monitors must have a maximum On mode power consumption according to Energy Star Version 6.0

Table 3. Calculation of Maximum on mode power consumption (P_{ON_MAX}) (source, Energy Star Version 6.0)

Product Type and Diagonal Screen Size, *d* (in inches)	$P_{ON\ MAX}$ where $D_p \leq 20{,}000$ pixels/in^2 (in watts) *Where:* ▪ *r = Screen resolution in megapixels* ▪ *A = Viewable screen area in in^2* ▪ *The result shall be rounded to the nearest tenth of a watt*	$P_{ON\ MAX}$ where $D_P > 20{,}000$ pixels/in^2 (in watts) *Where:* ▪ *r = Screen resolution in megapixels* ▪ *A = Viewable screen area in in^2* ▪ *The result shall be rounded to the nearest tenth of a watt*
$d < 12.0$	$(6.0 \times r) + (0.05 \times A) + 3.0$	$((6.0 \times r_1) + (3.0 \times r_2) + (0.05 \times A) + 3.0)$
$12.0 \leq d < 17.0$	$(6.0 \times r) + (0.01 \times A) + 5.5$	$((6.0 \times r_1) + (3.0 \times r_2) + (0.01 \times A) + 5.5)$
$17.0 \leq d < 23.0$	$(6.0 \times r) + (0.025 \times A) + 3.7$	$((6.0 \times r_1) + (3.0 \times r_2) + (0.025 \times A) + 3.7)$
$23.0 \leq d < 25.0$	$(6.0 \times r) + (0.06 \times A) - 4.0$	$((6.0 \times r_1) + (3.0 \times r_2) + (0.06 \times A) - 4.0)$
$25.0 \leq d \leq 61.0$	$(6.0 \times r) + (0.1 \times A) - 14.5$	$((6.0 \times r_1) + (3.0 \times r_2) + (0.1 \times A) - 14.5)$
$30.0 \leq d \leq 61.0$ *(for products meeting the definition of a Signage Display only)*	$(0.27 \times A) + 8.0$	$(0.27 \times A) + 8.0$

Table 4 Example: On Mode Maximum Power Consumption

Size (diagonal)	Max. power On
20 inch monitors	17 Watt
30 inch monitors	29 Watt
40 inch monitors	59 Watt
42 inch monitors	66 Watt
47 inch monitors	85 Watt
52 inch monitors	107 Watt

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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