The Power to Change

A white paper independently produced by Meko Ltd and sponsored by Lenovo.

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Executive Summary

Lenovo has developed new LCD monitors for desktop computer applications that use new technology to reduce the level of power needed in the backlight to make the monitors more efficient. The company asked us to make a report on the advantages and disadvantages of their approach and to evaluate samples of two 19” wide monitors, one new model (L197) with the technology and one (L194W) without. We were also asked to consider the likely implications of the technology if widely implemented.

We found that the new monitor did show substantially reduced power usage, in line with the company’s claims. Although the maximum brightness of the unit was reduced from the level of the previous model, we found that there was plenty of brightness available for office tasks, even in high ambient brightness. We also estimated that the brightness of the unit should be more than adequate to ensure a good lifetime.

We looked at the power savings that could come from a switch by the whole of the monitor industry to this kind of power consumption and established that the power saving would be significant and worthwhile.

Finally, we took a brief look at the current standards and approvals for low power consumption and environmental issues related to monitors with reference to the new monitor.

Background

Monitors and office equipment take a lot of power. Monitors are a significant segment of that energy consumption[1]. Reducing power use is important for cost and other environmental reasons.

LCDs differ from many other kinds of electronic display by being transmissive. The display system consists of a liquid crystal image generating sheet that is illuminated from behind by a bright light, normally from a number of cold cathode fluorescent lamps (CCFLs). In desktop monitors, these lamps are continuously lit and are normally at

[1] The US Environmental Protection Agency (EPA) estimates that by the end of 2006, its Energy Star campaign had saved 170 billion kWh of electricity from changes to monitors alone– equivalent to lighting 95 million homes and reducing CO_2 emissions by 33 million tonnes per year.

the edges of the display in an LCD monitor. The light is reflected into a light guide and from there is transmitted through the polarisers and filters of the LCD.

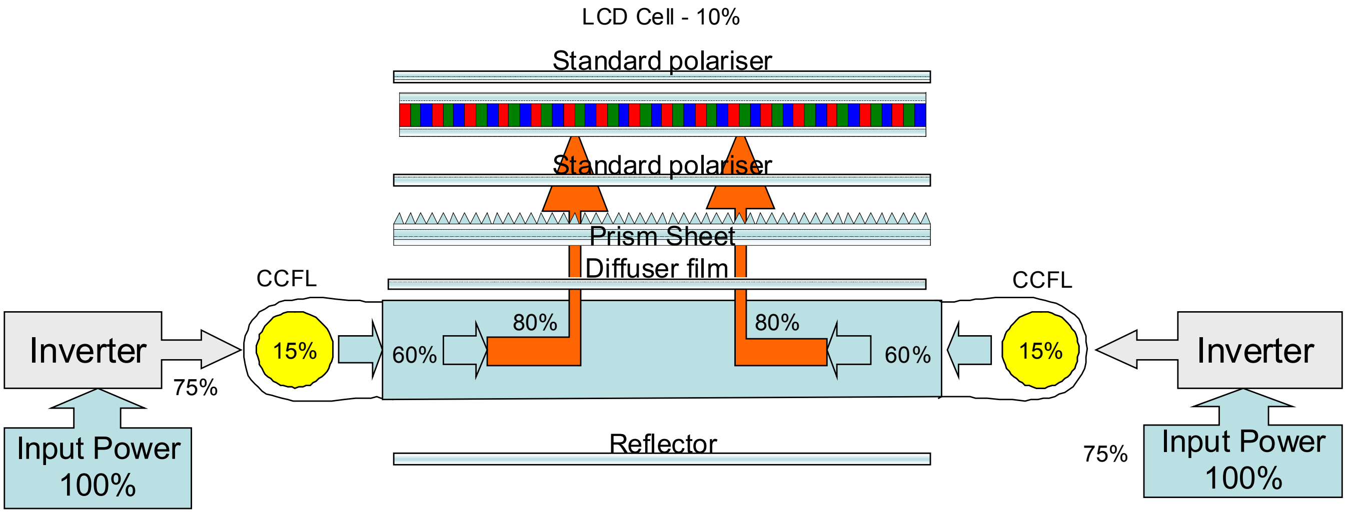


Fig 1. Typical efficiencies at each stage of an LCD module[2]

Like the CRTs that dominated the personal computer screen world from the 1980s until recently, LCDs are fundamentally very inefficient devices. Of the light that is emitted from the backlight of an LCD, as little as 5% - 10% will actually be emitted from the front of the display as visible light, with the rest being emitted as heat. Improving the efficiency of the light transmission of an LCD using improved technology could either boost brightness, or reduce energy consumption if the brightness level is held constant.

In the table below, we've shown the effect of each stage on the efficiency of a typical LCD.

	Power Input	Efficiency	Power Output
Inverter	100.00	75%	75.00
Lamp/reflector	75.00	15%	11.25
Optical coupling of lamp to light guide	11.25	60%	6.75
Output of light guide	6.75	80%	5.40
Cell (inc polarisers & filters)	5.40	10%	0.54

Table 1. Typical efficiencies at each stage of an LCD module

http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/monitors/Monitor_Webinar.pdf
[2] Source –Based on data presented by Toshiba – DisplaySearch US FPD Conference - 2005

The new monitor that Lenovo submitted to us uses a special reflective polariser technology to replace the standard entry polariser. Normally, some of the light is not correctly polarised for the input polariser of the LCD and is absorbed as heat by the polariser. By using a special reflective film, the light that is incorrectly polarised can be reflected back into the light guide. The light can then be reflected back again with modified polarisation to be re-presented to the polariser. In this way, much of the light that would be lost can be reused.

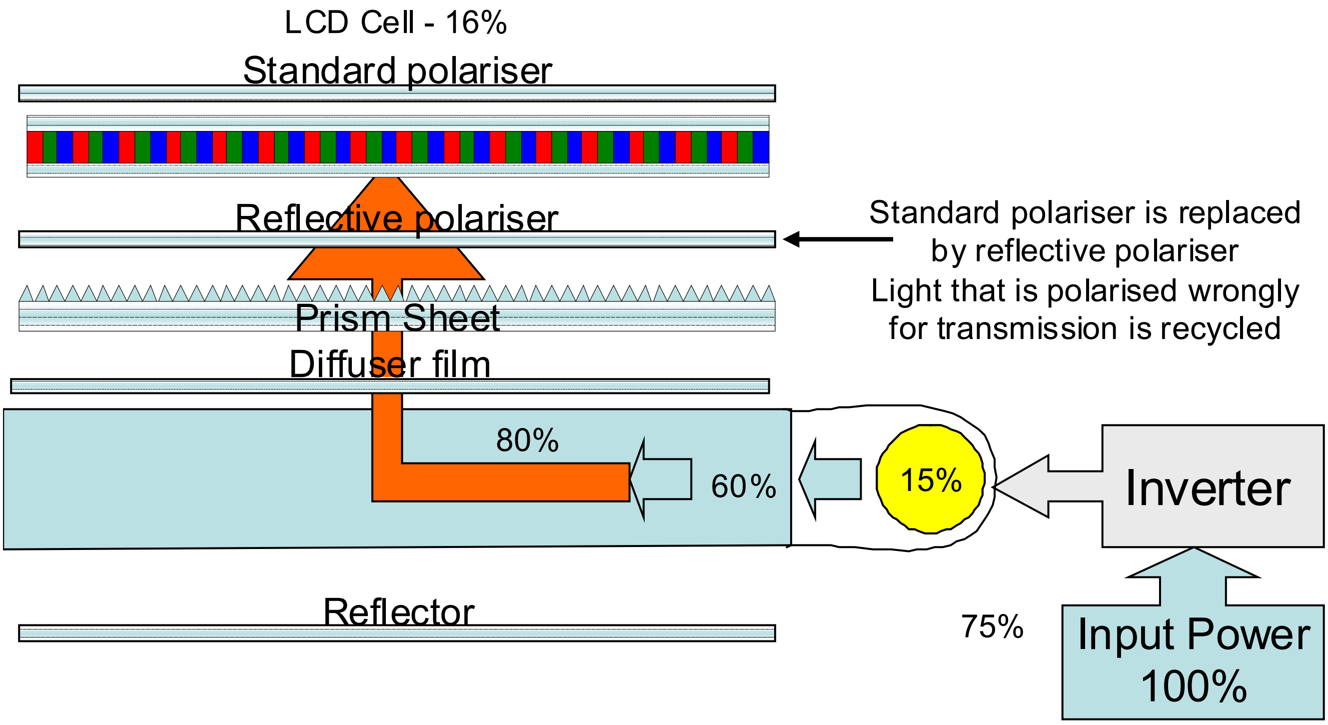


Fig 2. By changing the polariser, the overall efficiency of the LCD cell can be increased, allowing half of the backlight CCFLs to be removed.

	Power Input	Efficiency	Power Output
Inverter	100.00	75%	75.00
Lamp/reflector	75.00	15%	11.25
Optical coupling of lamp to light guide	11.25	60%	6.75
Output of light guide	6.75	80%	5.40
Cell (inc reflective polariser & filters)	5.40	16%	0.86

It can be seen that by this single change, the amount of light output is increased by 60% for the same power input.

Appropriate Display Brightness

LCDs are much brighter than the CRT displays that went before. CRT monitors typically had maximum brightness in the range of 80-120cd/m^2. LCD monitors for desktop computer applications typically have a maximum brightness in the range of 250 cd/m^2 - 300cd/m^2. Is there really a need for more brightness?

For some applications, such as TV viewing, there may be a desire for higher brightness in order to emulate the high contrast and visual impact of CRT displays. However, the guidance from ergonomists and lighting engineers[3] is that the correct brightness on the display depends on the environment in which it is being used. On the one hand, the reflected light from other objects (not on the display screen) in the visual field of display screen users should be in the range 20cd/m^2 to 200cd/m^2. On the other hand, the same recommendations suggest a maximum ratio of 10:1 between the screen brightness and the surrounding environment. If the darkest object is 20cd/m^2 then a 10:1 ratio implies a maximum brightness of 200cd/m^2 for the display.

Even the low end of the current commercial desktop monitor range at 250cd/m^2 means a ratio higher than the recommended level, so the case for increasing the screen brightness to the 450-500 cd/m^2 level of typical LCD TVs cannot be made, unless the whole lighting environment is specially designed.

Looking to other recommendations, TCO Development, the testing organisation owned by the Swedish Confederation of Professional Employees and known for promoting the best visual ergonomics for its members, recommends in its TCO 03 certification requirements that the minimum brightness of displays should be 150 cd/m^2.

The International Standards Organisation (ISO) has a new version of its 9241 ergonomic requirements that is expected to be approved and published shortly after this white paper is published. The original standard (9241-3) had a low requirement of brightness of just 35cd/m^2 and this level was intended for typical office environments of 250-750 lux.

The new ISO standard is expected to have a lower level requirement for very dark rooms but will also have a higher requirement for bright rooms

[3] Recommendation taken from the UK Chartered Institution of Building Services Engineers – Lighting guide LG3 – 'The visual environment for display screen use' – now out of print but considered by CIBSE still to provide 'useful guidance for such applications'.

in the 1,000-1,500 lux range – equivalent to a domestic living room with large windows and blue sky outside. Even in those conditions, the new standard recommends a brightness range on the screen of 80-140cd/m^2.

The American HFES100 standard specifies a minimum screen brightness of 100cd/m^2.

Allowing for Lifetime

The reality is that, for all displays that are based on the emission of light from phosphor, whether CRT or LCD[4] type, the efficiency declines with use and age. That is to say, for a given power input, the amount of light output declines with time. Therefore, to ensure a reasonable lifetime, it is best to start with more potential brightness than would be typically used so that after time, the level of brightness is still adequate.

Most CCFL backlights for LCDs are rated at around 50,000 hours to half brightness (normally taken as the end of life)[5]. Other parts of the LCD or backlight system, such as the inverter that drives the lamps, may fail before the lamp has reduced to 50% brightness. However, 50,000 hours represents 20 years' use in a year of fifty weeks and fifty hours per week use. It's unlikely in most IT environments that any product will last anywhere near that long because it is likely to be superseded.

The degradation of phosphors tends to be coulombic – that is to say, the speed of efficiency reduction depends on the total accumulated amount of energy used to excite the phosphor, so is broadly linear[6]. It makes sense, then, when choosing a monitor for an office application, with, if we take the TCO recommendation, 150cd/m^2 as the minimum acceptable level, to start with more brightness (say 250-300cd/m^2) to ensure sufficient brightness after the phosphor has faded.

In the chart below, we have considered three typical applications for LCD monitors, with varying levels of usage. We have assumed a lifetime of the CCFL tubes of 50,000 hours to half brightness and steady degradation according to the hours of use, We have considered three different applications of a monitor

[4] LCDs have the advantage here. In the days of CRT monitors, not only did brightness fade, but increasing the beam current to overcome the reduced brightness caused a degradation of focus performance. For LCDs, although brightness will fade, there is no reduction in image sharpness from the backlight.
[5] Because this figure depends on how the display is used, vendors are nervous about quoting an actual figure.
[6] It also depends on other factors such as temperature.

- Standard office use – this is based on a 50-hour usage week
- Retail application or call centre – this is based on 80-hour usage per week
- Airline check in – this is a very intensive application and the calculations are based on a 140-hour usage per week.

We have calculated the lifetimes to minimum acceptable brightness of 150 cd/m^2, assuming high levels of lighting equivalent to a well designed office.

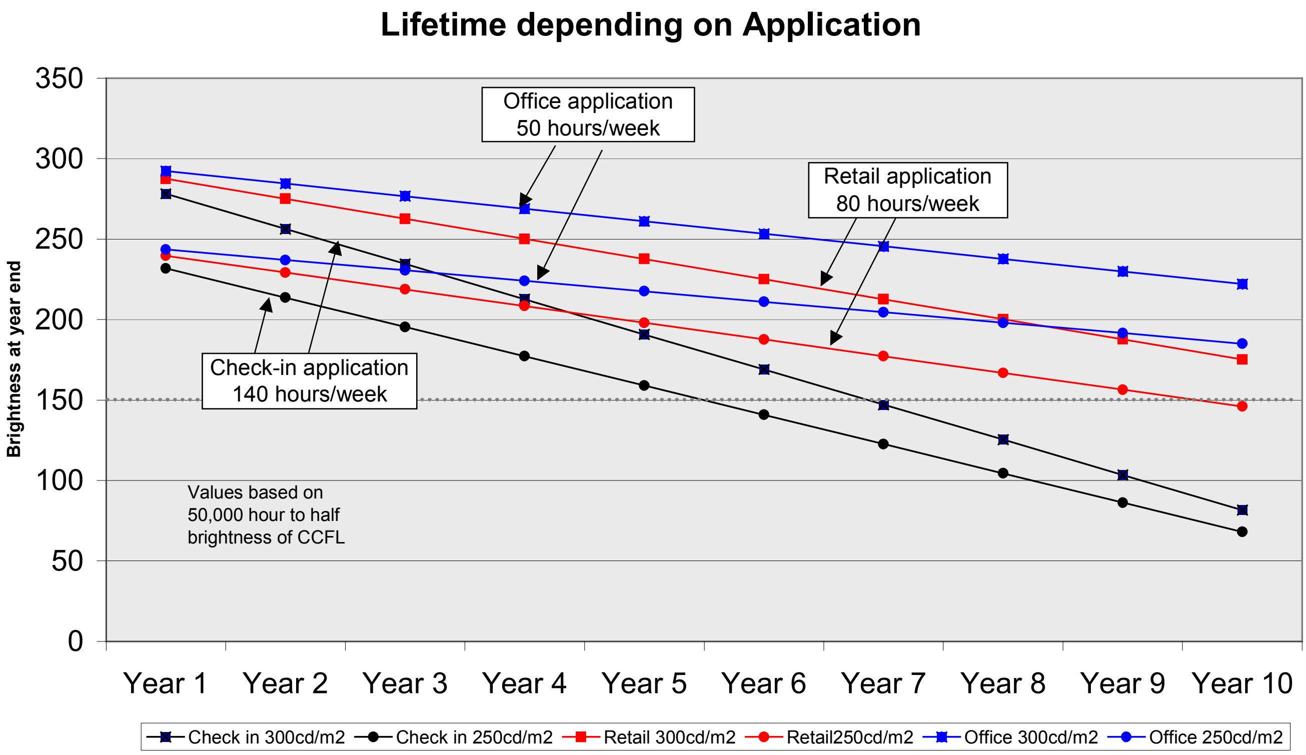


Fig 3. The output of the CCFLs in an LCD start to fade from new. Therefore, a monitor needs to start with more than the minimum final desired brightness.

As can be seen from the chart, even with a starting brightness of 250cd/m^2 and a very intensive application such as an airline check in, a monitor should still give good results for five or six years. If we take the US HFES100 recommendation of a minimum of at least 100 cd/m^2 then a life of eight or nine years should be possible.

Practical evaluation

We evaluated the two monitors in a range of typical office applications in a number of different lighting environments, including one office with three large windows which provided high levels of ambient light. In all cases, the brightness of both monitors was more than adequate, and in extended use, we found the maximum brightness level of the L194W (rated at 300 cd/m^2) to be too bright, although initially the 'visual punch' of the display made it look attractive.

Running the monitors through a range of tests using the DisplayMate test software[7], it was possible to see that the L197W had reduced brightness compared to the L194W. It also had slightly reduced white uniformity when viewing a full white screen. However, this was not apparent when running a range of different office and graphics packages.

Both monitors had a low black level, so there was plenty of detail and large area contrast available to give high image quality and easy readability.

Power Consumption

We found a significant decrease in power consumption between the two monitors. The 197W low power monitor ran at 20W but gave a good image quality at that level of power consumption. The 194W ran at 33W at full brightness. The power consumption could be reduced to 22W using the brightness control, but this reduced the display brightness to levels that were unacceptable, in our view.

The 197W does not have a hardware power switch and the 'power off' mode (invoked using the front panel 'off' switch) uses less than the previous model at 1W or less. Standby and 'Power off' power savings are very important because in a standard office environment, a monitor may be in standby mode for more than 75% of the time.[8]

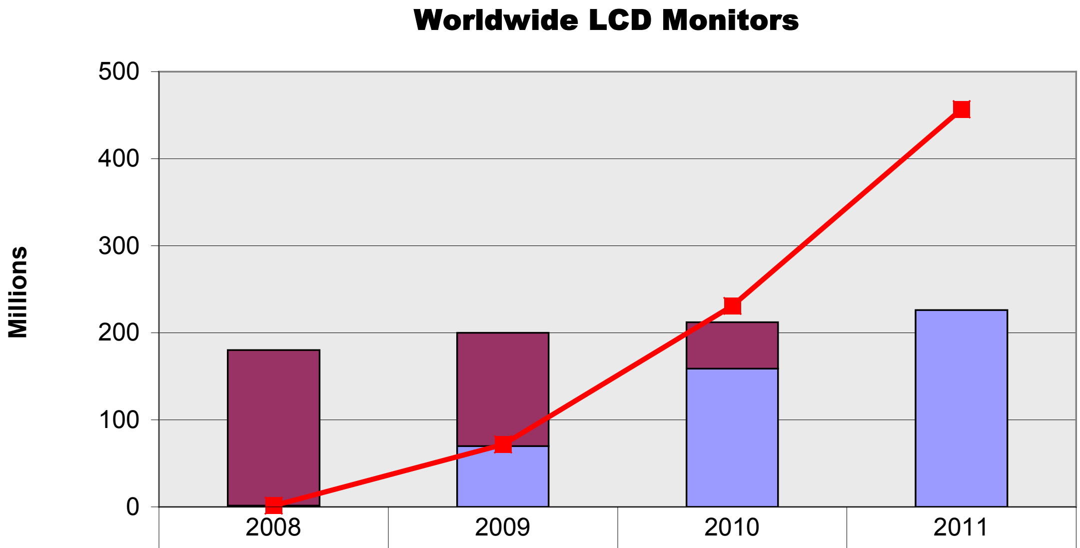
Power Implications

Lenovo claims a 6W typical power saving if the new low power technology is used. This seems a conservative, but reasonable value to

[7] http://www.displaymate.com/
[8] Lenovo told us that the power in the 'power off' state is less than 0.5W and is <1W in the standby mode, but at publication time we were not able to confirm this accurately.

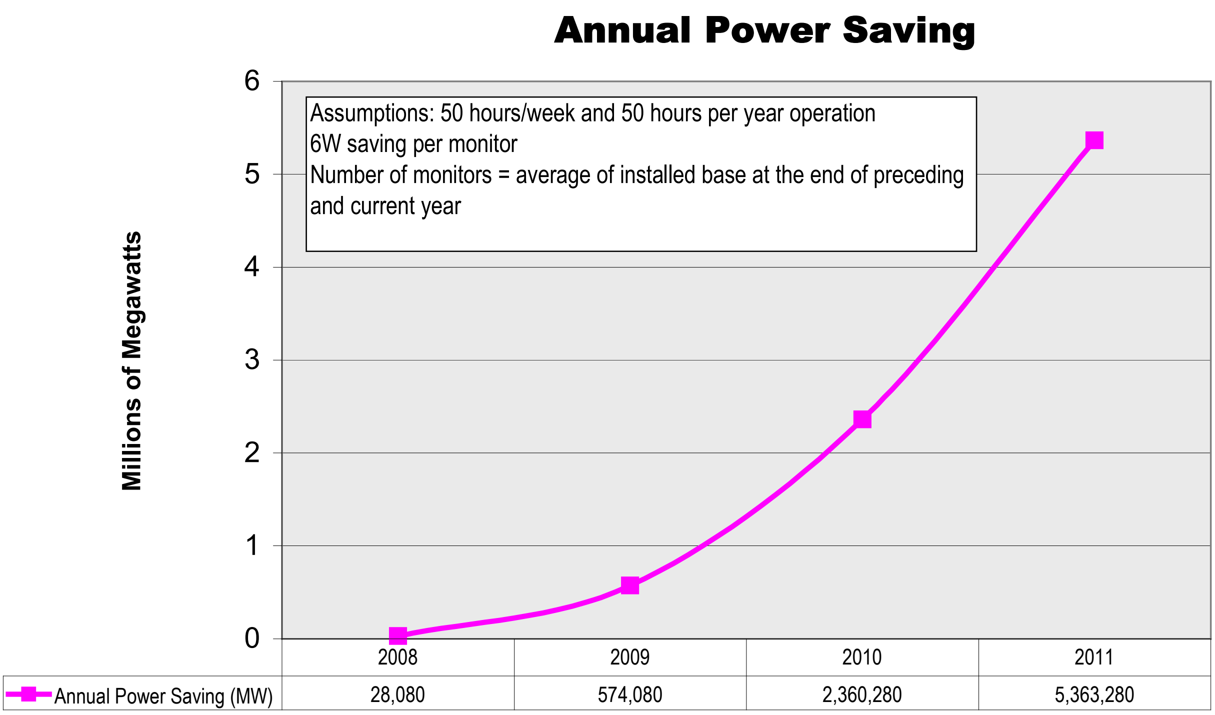
us on the basis of our tests. If similar low power technology was adopted by other vendors so that the whole market converted to low power monitors by 2011, with a ramp up from 1% of the market in 2008, 35% in 2009 and 75% in 2010, what would the power implications be?

The chart below shows the number of LCD monitors that would be affected if the low power technology was implemented at the rate detailed above.



	2008	2009	2010	2011
Standard Monitors	178.2	130	53	0
Low Power Monitors	1.8	70	159	226
Cumulative Low Power Monitor Sales	1.8	71.8	230.8	456.8

Clearly, the benefit of the low power operation depends on the total number in the installed base of monitors. We have used an average of the installed base at the end of the preceding year and the graphed year to generate numbers for the savings.



This calculation allows us to calculate some equivalents to give a sense of scale to the difference that the change could make. One barrel of oil has the equivalent energy of 1,700kWh[9]. Oil-fired power generation is 34% efficient on average around the world.[10] This means that the output in electricity generation from one barrel of oil is 578kWk. One barrel of oil is 42 U.S. gallons, so we can calculate the equivalent of oil saved. By 2011, the total is 389 million gallons of oil per year. (see chart below)

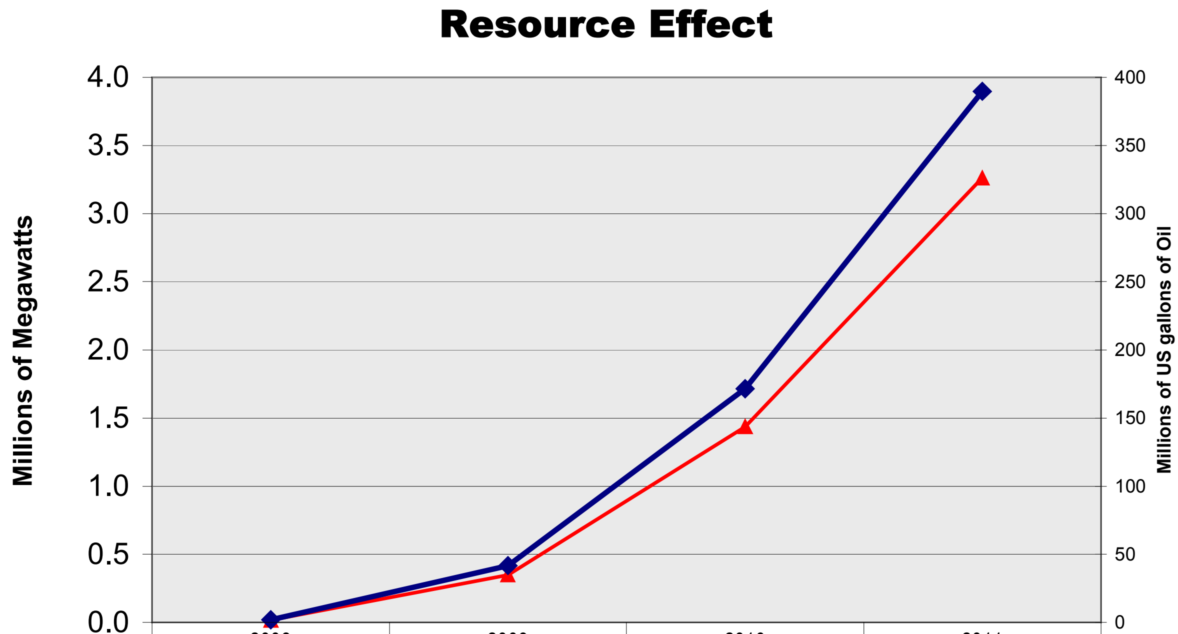
Another way to consider the amount of electricity that could be saved is to look at the number of households that the saving is equivalent to. According to the US Energy Information Administration, total electricity consumption worldwide was 15,746 billion kilowatt hours. The same organisation estimates that 11% of the consumption was in homes, equivalent to 1,732 billion kWh. Given a world-wide number of households of 1,723 million[11]. This means an average consumption of 1005 kilowatt hours/household. Therefore, the saving of electricity from power saving if low power monitors were adopted is equivalent to the

[9] http://bioenergy.ornl.gov/papers/misc/energy_conv.html

[10] International comparison of energy efficiency of fossil power generation
W.H.J. Graus, M. Voogt and E. Worrell
Energy and Climate Strategies, Ecofys Netherlands BV, Kanaalweg 16-G, 3526 KL Utrecht, Netherlands
Energy PolicyVolume 35, Issue 7, July 2007, Pages 3936-3951
[11] United Nations Global Urban Observatory and Statistics Unit
http://ww2.unhabitat.org/habrdd/conditions/world.htm

total electricity consumption of around 5.33 million households worldwide by 2011.

Another advantage of energy saving is to reduce CO_2 emissions. In the US, producing a single kW hour of electricity generates 0.6083 kg of CO_2.[12] Applying this figure to the total of electricity saved gives a total saving of 3,262,308 tonnes of CO_2 saved per year by 2011.



	2008	2009	2010	2011
CO2 Tonnes	17,080	349,194	1,435,681	3,262,308
US Gallons of Oil Saved	2,040,415	41,715,156	171,508,235	389,719,308

Low Power Standards

There are a number of standards and approvals around the world that are intended to encourage low power or 'green' initiatives. These include, but are not limited to:

- Energy Star[13]
- Blue Angel[14]
- EU Flower[15]

[12] http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2emiss.pdf
[13] http://www.energystar.gov/
[14] http://www.blauer-engel.de/willkommen/willkommen.htm
[15] http://ec.europa.eu/environment/ecolabel/index_en.htm

- TCO[16]
- Nordic Swan[17]

Looking specifically at power saving, all of these except TCO require the meeting of the US EPA Energy Star programme for power saving. TCO has its own requirements and the Lenovo monitors meet both sets of criteria.

In addition to the labels above, the industry and regulators have developed overview 'green' standards taking into account not only power consumption and energy efficiency, but also hazardous substances, recycling, packaging, safety etc. Some of these are:

- EPEAT – based on IEEE1680 and US-based[18]
- ECMA-370 based on ISO14021, ECMA-341 and others and broadly aimed towards the EU[19]

Both of these approvals are intended to help buyers to identify 'green' products and to assist with procurement. Although they differ in detail, each is a good guide to broadly 'environmentally friendly' products.

ECMA-370 is a voluntary and self-certified standard, while EPEAT, although self-certified like ECMA-370, includes a verification system that is designed to check some products for conformity. EPEAT has a grading system of Bronze, Silver and Gold. Bronze level is for products that meet the mandatory requirements of IEEE1680, while Silver and Gold mean that the product meets more optional criteria. While the L194W meets the EPEAT Silver criteria, the L197 meets the Gold Standard.

[16] http://www.tcodevelopment.com/
[17] http://www.svanen.nu
[18] http://www.epeat.net/
[19] http://www.ecma-international.org/publications/standards/Ecma-370.htm

Conclusion

The new Lenovo L197 adopts new film technology to successfully reduce the energy consumption of a mainstream commercial monitor. Although the specification of maximum brightness is slightly reduced from that of previous models in the class, the performance is good and more than adequate for office use even in challenging lighting conditions.

If the industry adopted the same, or similar, technology to reduce the energy consumption of monitors, then substantial amounts of power could be saved and there would be a useful reduction in CO_2 emissions.

The L197 monitor meets the appropriate industry standards for power saving and for ‘environmental friendliness’.

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