Living with Technology, Volume 2, Issue 4 Autumn 2004

Energy Saving Gets the Green Light

Part 1

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It has been estimated that approximately 20% of all electricity generated is used for lighting, amounting to some 58,000 GWh (gigawatt-hours) per year in the UK. If only a proportion of this energy could be saved, it would have the dual benefit of reducing the amount of fossil fuels burnt and save considerable sums of money for domestic and business users.

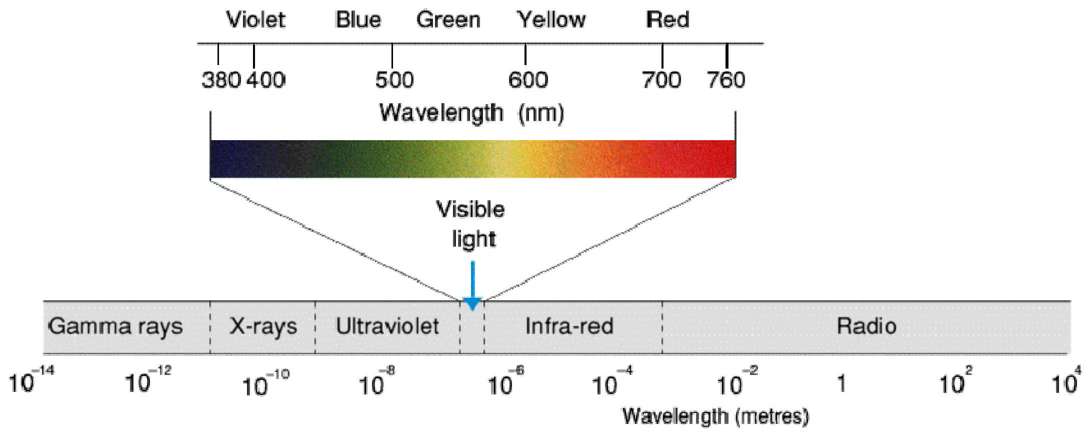
This article arose from a discussion on the LwT forum and is intended to explain what low energy lighting is and also help you to achieve some of your own savings (added value from your investment in an LwT subscription!). The article is in two parts. Part 1 discusses the history of low energy lighting, relative lamp efficiencies and what types are suitable for domestic use. Part 2 looks at the compact fluorescent lamp in detail, covering the range of products, advantages and disadvantages, savings based on recommended retail prices, and where to get them at a discount.

One source (Powergen) has quoted average savings for domestic electricity consumers of about £9 per annum for each 'ordinary' (GLS) 100W light bulb that is replaced by a low energy bulb of the same light output. Replacing the five most used GLS bulbs in the house, could easily give a saving in your electricity bill of £45 per annum. Many people are put off by the high initial cost of the bulbs compared to 'ordinary' light bulbs, and therefore delay buying them as replacements.

In Part 2, we will cover 'Total cost of ownership', where we take into account the initial cost, the reduced running costs and the expected life of the bulb to show overall savings per year.

A brief history of low energy lighting

To be useful as a source of lighting a device needs to generate visible light from electricity. Visible light is a small section of the electromagnetic spectrum, having a wavelength from 380nm to 760nm (nanometres = 10^{-9} metres). White light is an approximately equal mixture of all of these wavelengths from violet through to red.



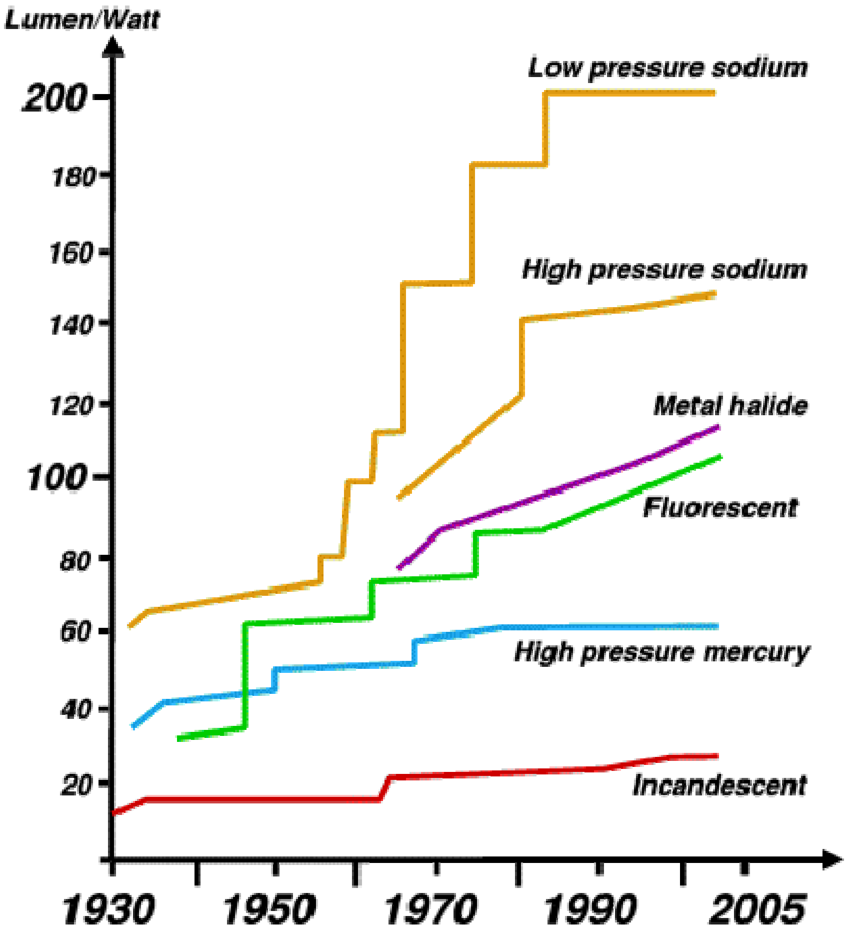
'Ordinary' (GLS) light bulbs use incandescent technology to create light. Electrical power is supplied to a tungsten filament in the bulb which gets hot and glows, generating the light. Most of the light generated is infrared and therefore, as a device, they are much more effective at heating than they are at lighting. Only a small proportion (5%) of the electrical energy supplied to the bulb is converted into visible light. Despite this drawback, they remained the main type of lamp used in the home and for commercial lighting for decades owing to their low production costs and simplicity of use.

A different technology was needed to radically improve the efficiency of light production. This was made possible by Michael Faraday's discoveries in the 1830's of an electric glow discharge in rarefied gases. It was many years though before this and other discoveries led to a practical electrical discharge lamp.

The first examples of this type of lighting were mercury lamps. The very first ones were used in the 1860s, but it wasn't until 1932 that GEC overcame the many problems (e.g. dangerous UV emissions) and marketed their 'Osira' bulb. This lamp had an efficiency about four times that of an incandescent lamp, but only worked at high power (>240W) and was therefore not suitable for domestic use. Further developments were made, and mercury lamps were quite widely used for street lighting and in industry for many years. They have been almost entirely superseded now by the more efficient metal halide and sodium lamps, and have been classed as undesirable due to the high toxicity of mercury in the environment.

In parallel with the development of mercury lamps was the development of the electrical discharge sodium lamp. In 1931, both Philips and Osram made the first viable low-pressure sodium lamps. These had an efficiency which was about 25% better than the mercury lamps. Improvements in the technology continued for the next 50 years, culminating in the Philips SOX-E lamp marketed in 1983.

This lamp still has the highest efficiency of any commercial lamp, having reached the landmark figure (see graph) of 200 lumen/watt (16-20 times the efficiency of an incandescent lamp). The reason sodium lamps are so efficient at producing visible light is that they emit yellow light which almost coincides with the peak sensitivity of the human eye. Although developments have resulted in a broader light spectrum with the high pressure sodium lamp (at the expense of efficiency), they are still not suitable for domestic use.

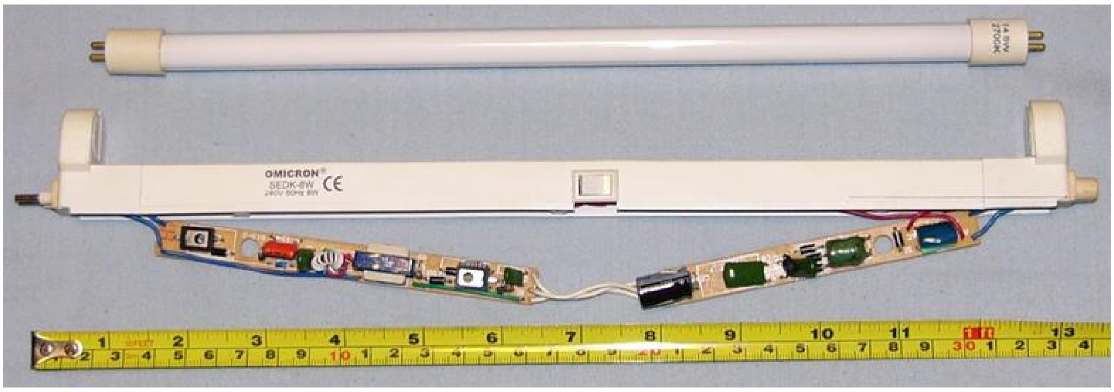


Graph showing the improvements in efficiency of low energy lighting Compared with incandescent lamps

Metal halide lamps were developed from the research into improving mercury lamps. GE in the US patented the first metal halide lamp in 1961; this was marketed in 1964 as a direct replacement for the mercury lamp. It was two to three times more efficient than the mercury lamp it was intended to replace and had a much broader spectrum of light output. The next 15 years saw rapid advances which resulted in a broad product range with power ratings from 175 to 5000W, but which were still not suitable for domestic use.

Unsuccessful attempts were made in the 1980s to produce a version which was suitable for replacing incandescent lights in the home. The problems that could not be overcome were the fact that the bulb couldn't be relit when it was hot, plus the prohibitive cost compared to incandescent bulbs. Today, the lamps are an alternative to high pressure sodium lamps for street lighting as they have a similar efficiency. It has also been found that the bluish light emitted performs better than the orange of high pressure sodium lamps because of the way our eyes see in low light conditions. This is explained later under colour rendering.

Fluorescent lighting was also a spin-off from research on mercury lamps. The lamps were coated internally with phosphorescent chemicals which converted harmful UV light, generated by the electrical discharge, into useful visible light. The first lamps were demonstrated in the US in 1935, and in Europe in 1936. By 1938, fluorescent tubes were available from most major manufacturers. The tubes were 38mm in diameter with an efficiency about three times that of an incandescent lamp and had a moderate colour output, which was good enough for use at home.



A small fluorescent striplight fitting and tube, showing electronics (ballast) needed to operate the lamp. The tube is a T4 (13mm diam.).

GEC made a breakthrough in 1942 with the discovery of a new phosphor. This appeared in lamps in 1946, doubling the efficiency of the previous lamps and giving much improved colour rendering. The next major advance was the introduction of triphosphors in 1973 by Philips. The new phosphor improved efficiency by a further 50% and also led to the reduction of tube diameters from 38mm (T12) to 26mm (T8), and then to 16mm (T5) in the early 1980s. In the 1990s, Osram made a further reduction in tube diameter with a 7mm (T2) lamp.

This reduction in tube size allowed the development of the compact fluorescent lamp (CFL) with integrated electronic controls (the 'ballast'). The development of compact fluorescent lamps and how they work is described in Part 2. Further advances in tube technology are extending the life of the lamps and allowing ever smaller tubes to be made. The most recent advances have been in the introduction of electrode-less versions of fluorescent lamps.

Low energy options in the home?

Fluorescent lamps are the only low energy lamps which have made it into our homes. As you have seen from the brief history, other low energy lighting systems have significant drawbacks which prevent them from being used domestically. These may be the minimum power of the lamp, the colour output or the cost of the light bulbs.

When low energy lighting is mentioned, the type of lamp that most people think of is the compact fluorescent lamp (CFL). This has been publicised extensively, together with various product promotions to encourage domestic consumers and businesses to use less electricity.

Fluorescent tubes are sometimes used in the home. They have a slight advantage over CFLs in efficiency, but are less convenient to install. The most likely places for them to be useful are the garage, kitchen or utility room or for specialist use such as reptile or fish keeping.

How does it fit in the range of options?

As we have shown, there are two main types of electric lamp - those that emit light by heating a metal filament until it glows (incandescent light) and those that emit light via an electrical discharge through a gas (e.g. fluorescent light). There is also a third type which has started to increase in popularity recently with advances in technology - the LED (light emitting diode).

The LED has been used for many years in consumer devices in mainly low power circuits but it is now seeing a new use, for example in traffic lights which are even visible in bright sunlight, and for outdoor lighting. These are niche lighting applications, however, and the comparisons that we make will concentrate on incandescent and electrical discharge lighting.

(I've seen LEDs in the rear lights of cars, and I have an LED rear light on my push bike! I've also used an LED traffic light for the title of this article. Ed.)

What is the light output?

Factors to consider for the light output of any particular lamp are:

1. energy efficiency of the lamp - how much light do we get for our money?
2. colour spectrum of the light - how close to daylight is it?
3. the colour rendering - how do coloured objects appear in the light?

Obviously, the latter two are closely associated. Within each type of lamp, there can also be variations in efficiency and colour range.

League table of energy efficiencies

The energy efficiency of each type of lamp is measured in the amount of light given out (lumens) for the amount of electricity consumed (watts). The higher the amount of light given out per watt of electrical energy consumed, the greater the efficiency of the lamp. The current range of efficiencies for the different types of lamp is shown in the league table.

League Position	Type of Lamp	Efficiency Range (lumens/watt)
1	Low pressure sodium	100-190
2	High pressure sodium	65-140
3	High pressure metal halide	70-100
4	Tubular fluorescent	65-100
5	Compact fluorescent Lamps (CFL)	50-85
6	Incandescent – Tungsten Halogen	12-24
7	Incandescent – GLS (Tungsten filament)	8-12

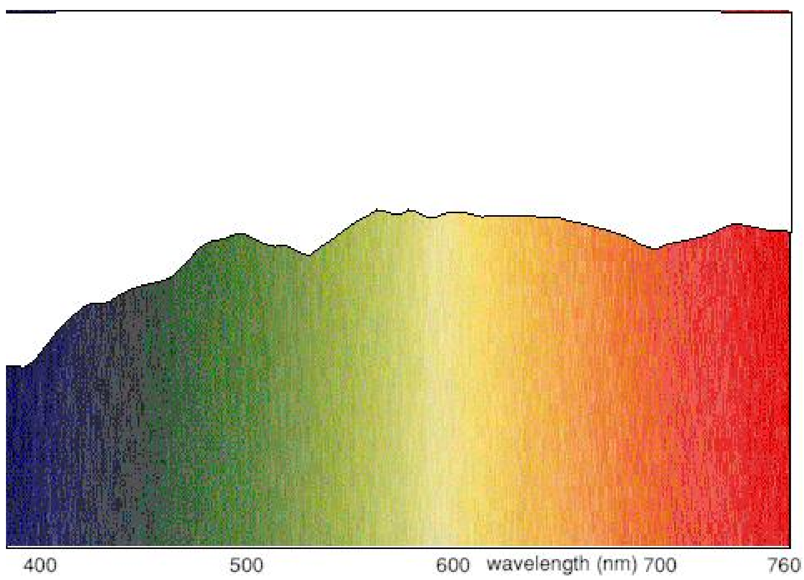
League table of relative efficiencies

The highest efficiency lamps are twelve to fifteen times more efficient than the normal incandescent lamp. It would therefore only cost 7-8p to provide the same amount of light provided for £1 from a GLS lamp.

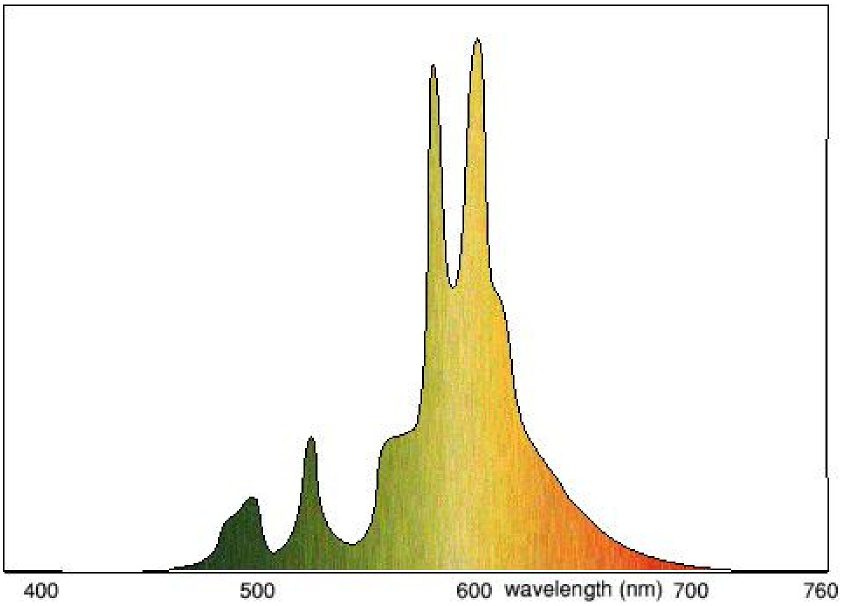
The range of values in efficiency reflects a number of factors. For example, electrical discharge lighting tends to become more efficient as the power increases. Continuous small improvements in efficiencies are also seen as the electronics used to drive this type of light become smaller and more efficient (see later in the article for more information about the electronic controllers known as 'ballasts').

Light spectrum output

There are other considerations than efficiency though. One of these is the type of light provided.



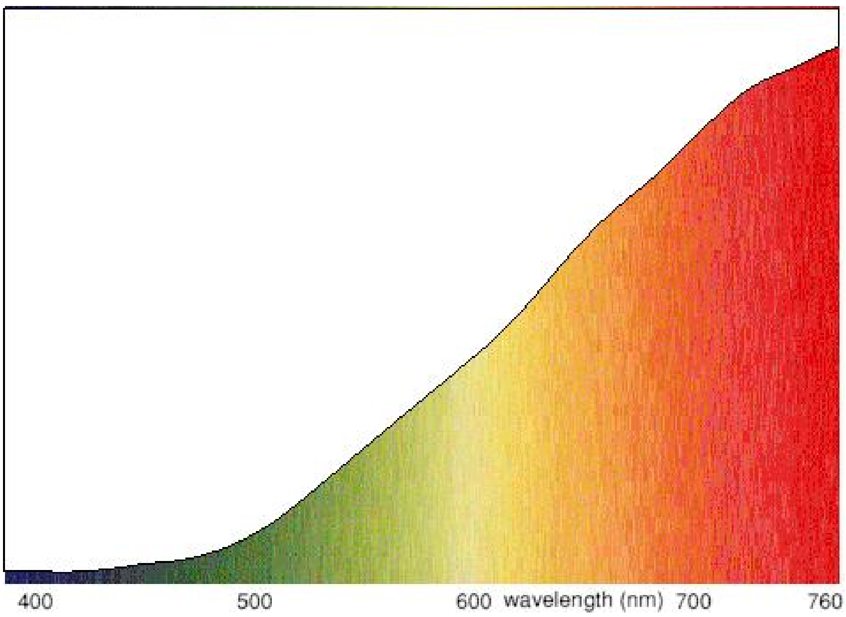
Light spectrum of daylight on a sunny day



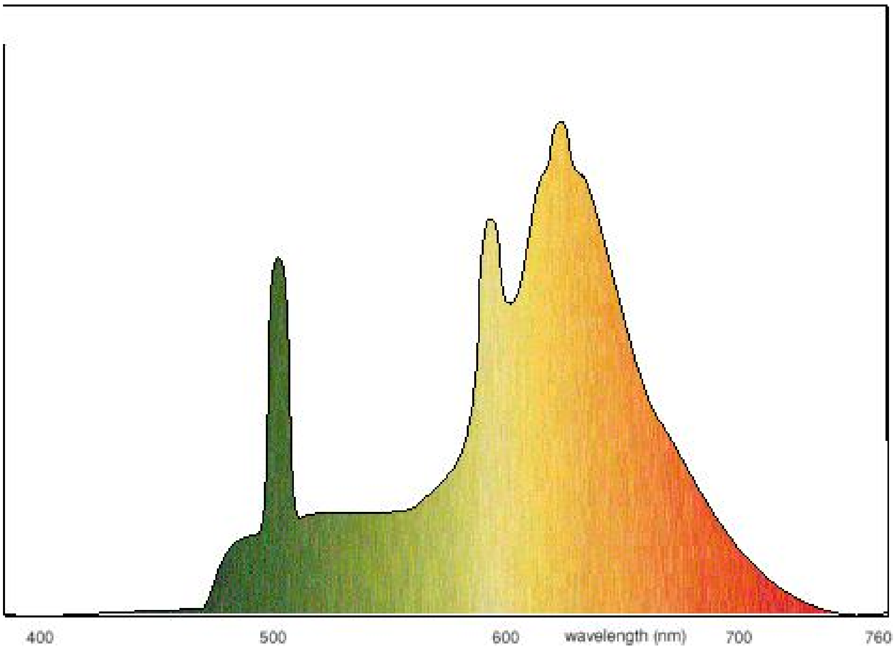
Light spectrum of a high pressure sodium lamp

The highly efficient sodium lamps, familiar to everyone as the main type of lamp used for street lighting, provide a narrow spectrum of mostly yellow light output. This is fine for street lighting, particularly as our eyes are more sensitive to yellow light. We are more interested in seeing the other vehicles than knowing what colour they are. (We also like to think that our taxes are being spent wisely.) Sodium lamps aren't very useful in the home, however.

In domestic lighting, the general preference is for a light which simulates daylight, or gives a warm light which can be more restful. Although referred to in the singular, daylight is actually a lot of different lights as it is influenced by many factors including whether the sun is shining, the amount of cloud and the time of day. Natural daylight on a sunny day has an even balance of colours from the violet to the red end of the spectrum.



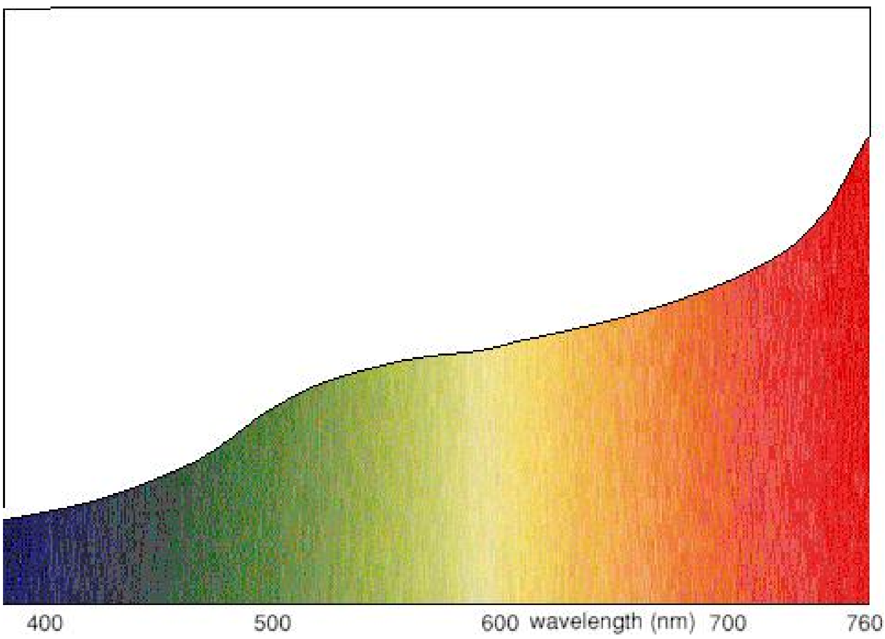
Spectrum of an 'ordinary' GLS incandescent lamp



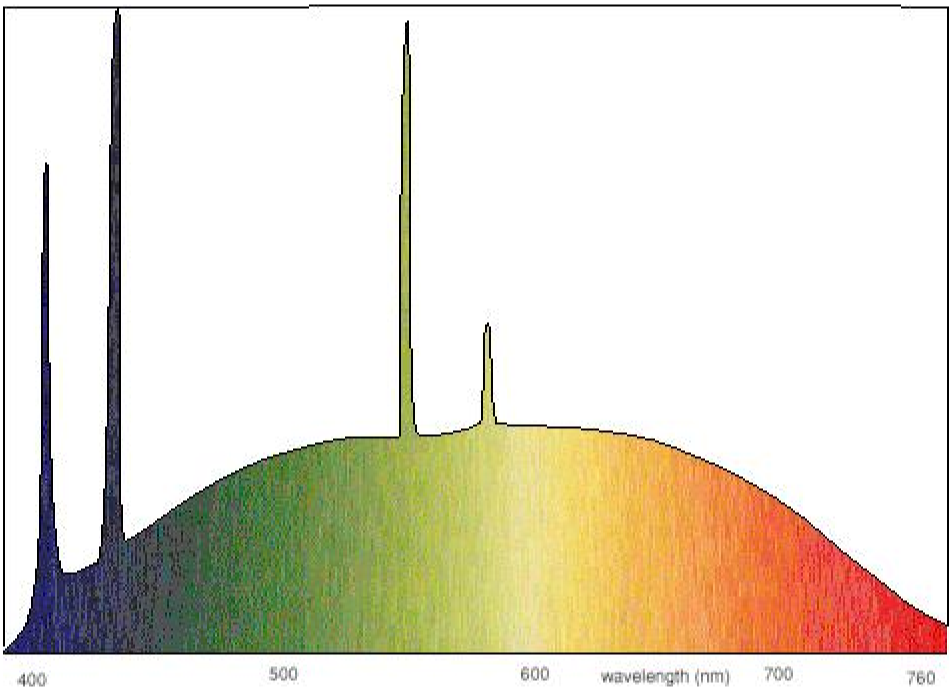
Spectrum of a standard 'white' fluorescent tube

In comparison to daylight, the traditional incandescent (GLS) lamp produces much more of its light towards the red end of the light spectrum. This gives a warmer light which has been very acceptable for nearly 100 years since electric lighting started to be used.

The halogen incandescent lamp gives a much closer reproduction of daylight. It gives a broad coverage from blue to red in the light spectrum, with an increased amount of red light compared to daylight. The light appears bright and colours are much sharper (see later on colour rendering). This can be an advantage for certain areas of the home such as the home office and reading areas. The low voltage (12V) versions of the halogen lamp are popular for up or down lighters giving a crisp light which reflects true colours (they are also more energy efficient than the 240V mains halogen lamps).



Spectrum of a halogen incandescent lamp



Spectrum of a 'triphosphor white' fluorescent

Tubular fluorescent lamps are the most varied in colour of light output. In the standard tubes, there are the normal choices of warm white, white and cool white (nothing to do with being fashionable!). Warm white is described as being 'warm and welcoming for schools, restaurants and fabric retail stores', white is 'suitable for general and commercial applications' and cool white is described as a 'bright, crisp light for offices, factories and retail stores'.

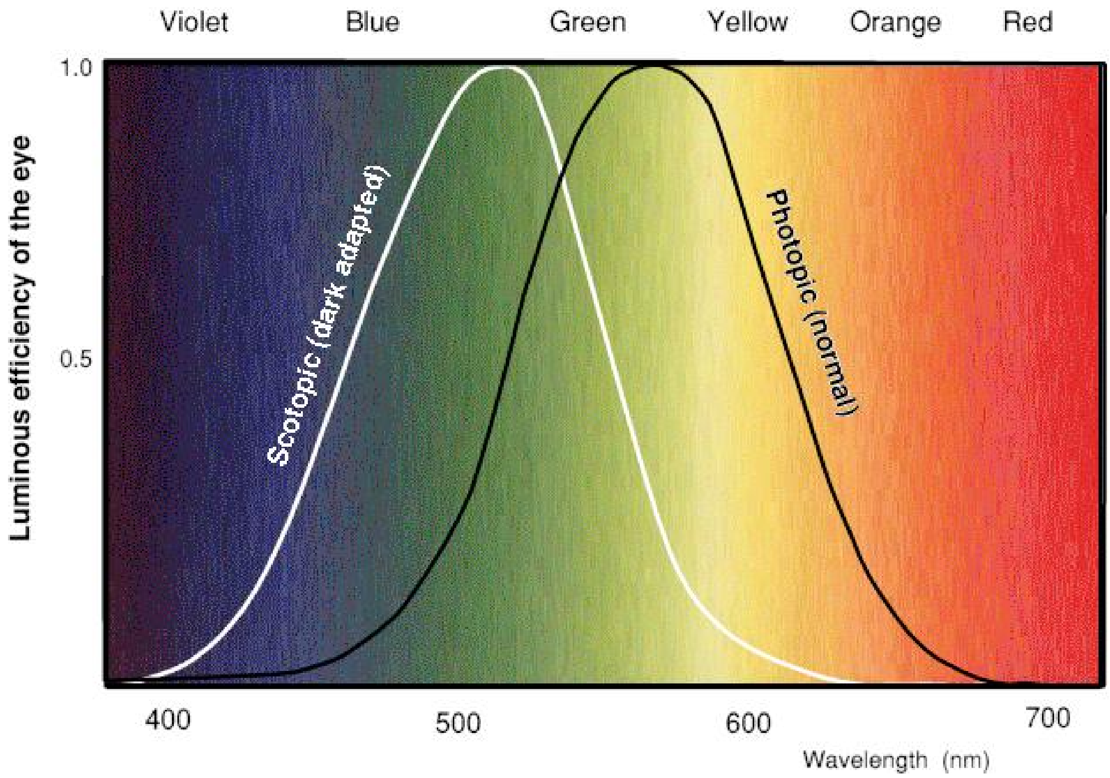
There are also colour tubes for displays such as those which enhance the colour of meat in the butchers shop. 'Daylight' tubes have been around for some time, although the name can sometimes be more to do with marketing than the spectrum of light output. A real daylight simulation tube is unlikely to be in the cheapest range.

There's also a range of specialist tubes which includes, for example, 'black' light (UV) tubes for parties *(presumably because the UV causes fluorescence of the phospors in washing powder, most notably on white garments such as ladies' underwear! Ed)*, simulated desert sun tubes and under-sea tubes for use in reptile and fish keeping. Another recent addition to the range of fluorescent tubes is one which provides 'virtual daylight' especially created to help prevent SAD (Season Affected Disorder).

Colour rendering

Colour rendition is the ability of the eye to distinguish the true colour of an object. True colour is generally considered as the way we see objects in natural daylight, and to be able to see true colours, the eye requires a good colour balance from the light source.

Although the colour from the light source is important in colour rendering, it's not the only factor. There are two other factors.



The colour sensitivity of the eye changes at low light levels from being most sensitive to yellow light (photopic) to being most sensitive to blue-green light (scotopic). This can be important for poorly lit areas, but for most artificial lighting situations, photopic sensitivity applies.

In addition, to complicate matters, the brain can modify the image received by the eye. When the colour of the light source changes, the colour of the image as seen by the eye also changes. For familiar objects, however, the brain knows that they haven't actually changed colour and therefore adjusts the visual signal so that we 'see' the usual colour. This minimises the effects of changes in daylight (sunny to cloudy conditions) and the differences from reflected light. It is known as 'colour consistency' and is one of the reasons a photograph doesn't always show what we 'see'.

The best light sources that enable the eye and brain to see true colours provide a continuous spectrum of all of the colours from violet to red. Incandescent (GLS and halogen) lamps produce continuous spectra and therefore generally produce less distortion of the viewed colours and hence give good colour rendering.

Fluorescent lamps produce lower level continuous spectra which are dominated by one or two peaks. These peaks will result in some colours being intensified and others reduced, resulting in a distorted colour image and hence poor colour rendering. Much research on fluorescent lighting has concentrated on getting better colour rendering. The introduction of triphosphors by Philips in 1973 was a major step forward and there have been significant advances in recent years.

Other lamp types tend to provide light in discrete bands (e.g. sodium lamps) which give very distorted colour rendering.

Lamp	Type of Lamp	Colour Temp (K)	CRI (Ra)	Colours Enhanced	Colours Subdued
GLS	Incandescent	2700	99	Orange, Red	Blue, Green
Standard White	Fluorescent tube	3450	54	Green, Yellow	Blue, Red
Polylux XL840	Tri/multi phosphor fluorescent tube	4000	80+	Blue, Green, Yellow	Orange, Red
Polylux 940	Tri/multi phosphor fluorescent tube	4000	95	Blue, Green, Orange	Deep red
Kolorarc	Metal halide	4200	70	Blue, Green, Yellow	Red
Lucalox	High pressure sodium	2100	25	Yellow, Orange	Blue, Green, Red

Comparison of colour rendering from various lamp types

Colour rendering is quantified as the Colour Rendering Index (CRI or Ra). It is on a scale of 1 to 100, where the higher the value, the better the colour rendering. An ideal light source has a value of 100. The table shows a comparison of CRI (Ra) for several different GE Lighting products and gives an indication of the ability of different lamp types to show true colours. A lamp with a value of 90-100 is described as having accurate colour rendering and a value of 80-90 is appropriate for making colour judgements. If the Ra is below 80 then colour judgements will be impaired. CRI measurement is a complex subject and there's not sufficient room to include a detailed explanation here. Strictly speaking, for example, the CRI can only be compared for lamps with the same colour temperature. For those who want to find out more, the GE Lighting Institute website includes a good explanation at:

http://www.gelighting.com/eu/resources/firstlight/module10/01.html

In Part 1, we have given you a brief history of the development of low energy lighting and the relative attributes and efficiencies of the different lamps compared to the 'ordinary' GLS incandescent lamps. We concluded that fluorescent lighting is the only low energy solution for domestic use and that the compact fluorescent lamp (CFL) is the most convenient application of fluorescent lamp technology. In Part 2, we will look at CFLs in detail, covering the range of products, advantages and disadvantages vs. GLS, savings based on recommended retail prices and where to get them at a discounted price.

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This article is the first of a series of related articles