Sustainable Lighting: 50 Q&A

SECTION A : Measuring lighting efficiency

1. How do you measure an energy efficient lamp?

A light source is measured in lumens of light output per watt of electricity input – this is called *Efficacy*.

2. Is it the same for a light fitting?

No, a light fitting is measured in luminaire lumens / circuit watt or *Exit Lumens*, i.e. how much light actually leaves the fitting for all the power, including gear losses, consumed by the fitting.

3. What about a complete lighting project?

A lighting project is usually measured in either watts/m2/100 lux (1 lux= 1 lumen/m2) or more simply watts/m2.

4. Is that used for Energy Performance Certificates?

No, that is something different again called a Lighting Energy Numeric Indicator (LENI), which multiplies the watts/m2 by an annual usage in hours. This calculation produces a yearly energy consumption in Kilo Watt Hours (kWh) for the building.

5. What is Part L (Building Regulations) measuring?

In commercial lighting Part L is measuring average Exit Lumens (2 above) for all the products on the project, with a current threshold of 45 lumens/watt (a threshold that will probably increase in October 2010).

6. How are savings from lighting controls measured?

Both Part L and the LENI incorporate separate calculation factors, which are applied to the use of daylight and occupancy controls.

7. What is the most useful of these measurements?

For a lighting scheme it is probably watts/m2, because it is easy to verify. This also forms the installed base for the crucial kWh & CO_2 measurements that need to be reduced.

8. What other measurements are important?

Measuring quantitative efficiency without some measurements of quality can be pretty meaningless. Otherwise we could light all of our buildings with sodium street lamps.

9. What are the key measurements of quality?

Unfortunately there is no simple answer because this is an application specific issue. Lux, colour rendering and colour temperature (CRI & CCT), uniformity, luminance levels and glare index can all be relevant. Ideally an engineer/designer with the right experience should decide on the quality criteria before energy efficiency is assessed.

10. Is there a correlated measurement of quality and efficiency?

This is difficult to achieve. One method combines a quality measurement, the Ergonomic Lighting Indicator (ELI), with the LENI to provide a combination ratio. The difficulty is that the ELI is itself a complicated set of factors for anyone to navigate.

SECTION B : Designing low energy lighting

11. How do you start to design a low energy scheme?

Start by deciding on an ambient light level that is high enough for safe circulation of people around the space you are designing. This level will vary for different space, but it will be some way below the recommended task levels for that space (as in BS EN 12464). A typical level would be between 100 and 300 lux.

12. Will that be enough light for people working?

It depends on the people, the work and the space. With sufficient daylight many people will work with no electric lighting at all for much of the year.

13. Can offices work without lights on in the UK?

Yes even in the UK offices have been designed to allow daylight to provide all the working light for a significant period of the working year. This is often referred to as the period of *daylight autonomy* (see Section E). Electric lighting can then be planned around sources of daylight so that it can be used with sensors to progressively 'top up' the daylight to the desired ambient level.

14. Will higher light levels be required sometimes?

Yes, it is fair to assume that there will tasks that require higher light levels for periods of time. However this extra lighting can be provided from localised light sources – desk and freestanding lights - or fixed lighting that can be intensified in one area of the space as required. One of the most wasteful lighting practices is the "500 lux everywhere" mantra that is widely applied across the industry.

15. Will the space feel gloomy if it is lit to a low level?

That is a certainly a risk, but it can be avoided. One way to do this is to ensure that walls and ceiling are in light finishes and well illuminated. Using lamps with higher colour temperatures (above 5000k CCT) also provides a greater apparent brightness. This high colour temperature lighting generally combines best with warmer colour finishes with earthy red and yellow hues present.

16. Which are the best type of ambient light fittings?

A good approach is to use light from more than one direction. This could be from suspended light fittings with light that is emitted upwards as well as down. Equally it could be from recessed ceiling lights that are combined with wall lights or uplighters. Variety adds visual interest, which makes for more pleasant space.

17. Which method is better if budget is paramount?

The ceiling recessed fitting is probably the most cost effective ambient lighting, with the linear T5/HE 14w lamps being one of the most efficient light sources. Select a fitting with wide distribution (ask to see a polar curve) and a light output ratio (LOR) of over 70%. Using a 2x14w format, the ambient fitting can provide 2-300lux at under 5w/m2. Then some uplighters or wall lights can be used to add visual interest without much extra energy consumption.

18. What if some areas must be lit to a higher level?

Options include specifying a circuit with a more powerful version of the same fitting (3 or 4x14w). Making fittings dimmable adds flexibility to power consumption and user preference. This approach can provide the flexibility to use a greater intensity (and power) when required, but would not embed the power consumption at that higher level.

19. Is there another simple option that is flexible?

One option would be to use an intelligent ballast that would allow either 14w or 24w (they are the same length) T5 lamps to be used in the same fittings. The output of certain fittings could then be increased by nearly 50%, but only where required, by using the 24w lamps.

20. What lighting controls should be used?

Primarily it depends on the space. The main issues are the daylight availability and occupancy. In a well daylit space linking light sensors to dimmable (or even switched) fittings can save a lot of energy. In a sparsely occupied office with cellular space PIR sensors that turn off lights in empty rooms are recommended. Alternatively if there is a lighting control system but no sensors, the internal clock can be used to ensure lights are not left on at night.

Section C : Designing lighting quality for sustainability

21. What does light quality have to do with sustainability?

It is crucial in achieving acceptance of energy saving in an organisation. Lighting is central to the quality of a working environment. People will be unhappy and unproductive when it is poor. In order to make energy savings successful it is often necessary to increase other aspects of the lighting quality.

22. What are the important elements in light quality?

Colour temperature and rendering is important, but so is good distribution and glare control. We recommend high colour temperature light (6000k) for working areas and warmer (3000-4000k) light for relaxation space. Colour rendering should be above 80 on the Ra14 index. The room surfaces (which contribute to the lighting design) should be complementary to the light source colour – warmer finishes with cooler light and vice versa.

23. Why use high colour temperatures (CCT) for working areas?

Higher colour temperature (CCT>5000k) light is rich in blue (short wavelengths) spectrum light in a similar proportion to daylight. The shorter wavelengths are much more effective at suppressing the melatonin sleep hormone in humans. The result is that alertness is increased and the body's natural day/night cycle is reinforced. For this reason light that is rich in blue is said to have a high *Circadian factor*. Research (*Berman*) suggests that visual acuity can also increase with high CCT light, leading to lower visual stress and increased task performance.

24. What is colour rendering?

A Colour Rendering Index (CRI) is used to measure how well a light source allows people to perceive certain test colours in reference to daylight (CRI=100). The CRI is also used as a key indicator of whether wavelengths of light across the whole visible spectrum are present. For offices it is recommended that only light with a CRI above 80 is used.

25. Why is light uniformity important?

Uniformity is important in relation to task lighting to prevent the eye having to making involuntary accommodations for different levels whilst trying to focus. The additional visual stress caused by a lack uniformity (>0.7 minimum-average) in the task area will lead to premature fatigue. However a common design error is to then apply this principle of task uniformity across an entire floor area. This will result in a bland lighting effect and may waste a lot of energy. In fact only >0.2 min/max ratio is required as the lowest *diversity* recommendation for the main area space. The diversity level provides much more creative freedom to design interesting comfortable space.

26. What is meant by good distribution?

The main surfaces of a working space should not be too far out of balance with each other. For example the office lighting guide (SLL) LG7 suggests walls should be lit to at least 50% of working plane level and the ceiling to 30%. As with task lighting this is to prevent the eye having to adjust too many times to be comfortable. Avoid dark wall surfaces, which can contribute to a luminance imbalance as much as poor distribution.

27. How important is light quantity?

Increasing light levels usually produces better visual performance, but for it to become functionally noticeable the quantity usually needs to increase by around 50%. This is why the recommended steps in light intensity levels are large (300, 500,750 lux etc.). Very high acuity can require very high intensity levels – for example diamond sorting takes place in 3000lux – and glare control and CRI are as important at these levels.

28. What is the best task lighting?

Lighting a task is very application specific – affected by shape, size, colour and reflectance, position and person. However, most flat tasks are best lit fairly uniformly from the side at a level some 50% - 100% above the ambient level. High CRI is often important and sometimes filters (polarisation) can help reduce veiling reflections.

29. What is the best way to control glare levels?

Glare is the eye experiencing an abrupt and large change in brightness in its visual field. Therefore any light fitting can cause glare by being much brighter than the rest of the room. If a light, or part of a light, that can be seen directly, is more than 10 times brighter than the immediate surrounding surfaces this may be source of discomfort. A car headlight does not cause glare during the day, but does so at night, because of the drop in ambient level. Glare thresholds can be passed with visible light sources of almost all types and therefore, particularly in workplaces, we would usually recommend indirect light or light that shrouded by lenses or diffusers.

30. Can lighting controls add to light quality?

Yes, controls can definitely offer a lot in this area. Firstly they work psychologically, because they provide user control of aspects of the work environment, which most people enjoy. Controls can also offer versatility, by adjusting light levels for different types of people and work - for example older people tend to want more light. For advanced applications dynamic lighting, where the colour and intensity of light is varied throughout the day to mimic daylight, relies on sophisticated control to be effective. The idea behind dynamic lighting is that it can be valuable, particularly in the northern hemisphere winter, in reinforcing the human circadian day/night cycle that helps with health and well-being.

Section D : Sustainability in the supply of luminaires

31. What are the main issues in sustainable supply

The most important supply factors are minimising toxic content, reducing future consumable waste, product longevity, reusable components, promoting recycling, supporting sustainable application and minimising organisational impact.

32. What are the main toxic elements in lighting products?

Mercury in fluorescent lamps is a significant element, but so also is cadmium in emergency batteries and rare earths in phosphors. There are also smaller amounts of toxic elements in the electronic and semiconductor components.

33. Are there ways of reducing these toxic elements?

Yes, green cap T5 lamps have mercury levels (1.5mg) that are under 5% of the levels of the older T12 lamps and some of the cheaper lamps still sold today. Cadmium is no longer necessary for emergency batteries since Nickel Metal Hydride (NiMH) can do the same job. LED technology is better than fluorescent for emergency lighting, partly because it can be effective with smaller and longer lasting NiMH batteries.

34. Can consumable waste be reduced?

Yes, many lighting components, including consumables, are available as longer life versions. Standard ballasts are rated for 50,000 hours, but 100,000 hour versions exist, but only in the most common formats. Standard T5 fluorescent lamps will last 25,000 hours, but there are versions that will last over twice as long. As above (in #33), using LED emergency lighting would reduce battery waste. Some LED technology in the right general lighting applications offers the potential to offer a zero consumable service life of 50,000 hours.

35. What is the impact of product longevity?

Lighting products are sometimes disposed of as waste because they have lost output and become too expensive to maintain. This is often because they were never designed to be upgraded, or sometimes even repaired, after installation. This situation is a cause of unnecessary waste as 90% of the fitting may still be fit for purpose, but one element has degraded or failed. In contrast light fittings designed with easily replaceable elements can be upgraded in the future and will minimise future waste flows.

36. What are the issues surrounding reusability?

The principle issue is that reusing components generally has less impact on the environment than recycling the material and so it is desirable to have products that contain reusable parts. For example light fittings can involve large amounts of packaging to prevent damage and much of this is potentially reusable, which is preferable to recycling.

37. How is recycling best promoted?

The lighting industry has legal recycling obligations, with many companies being members of the main recycling organisations, Recolight (for lamps) and Lumicom (for luminaires). These organisations will recycle existing 'legacy' waste if new fittings are bought from their members. Every lighting 'producer' should be a member of a registered recycling scheme. For their part luminaire designers can promote recycling by designing products that do not involve bonding multiple different materials together and by making luminaire disassembly easier.

38. How is sustainable application supported?

It must be emphasised that the primary impact of lighting on the environment is in the energy consumption of use. Therefore lighting companies have the greatest beneficial impact by advising customers, through design and consultancy, on how to use the least energy. These services must be normally provided free and therefore they are a measure of the commitment of the makers towards the sustainable application of their products. In contrast to this approach, the unit price selling focus of much of the industry often encourages wasteful energy use by putting the emphasis on initial capital cost over the cost of energy in use.

39. How is Organisational impact minimised?

Organisation impact does not just mean the energy used in production and the impact of the immediate organisation supporting that production. Included are all of the organisational supply chain inward delivery of components and the wider impact of component manufacturers. Lighting is a very global business with most products assembled from components manufactured all over the world – this is true of even 'local' products which may still have electronics made in China, lamps from Poland, steel from Romania and plastics from the USA. It is hard for any single manufacturer to break this pattern, but they can ask their suppliers to adopt a high standard of environmental practice in their own organisations.

40. Could you summarise the environmental priorities?

Energy use in operation is the critical impact – so producing low energy products and advising on low energy schemes is the top priority. After energy, consumable toxicity and waste are next. The organisational and supply chain factors are the most intractable and probably least significant, but should not be ignored. Efficient organisations with a sustainable management approach are as important in lighting as any other business.

Section E : Making the most of natural light

41. What are the main issues in natural lighting?

Just as the largest impact of lighting firms is the energy consumed by their products, the greatest potential of natural light is that the electric lighting be hardly used. The *daylight autonomy* of a space is the proportion of time when only daylight is used to provide lighting to a required level. *Daylight autonomy* is a therefore product of the degree of light availability (from geographical position & working times), the *Daylight Factor* and the required light level.

42. What is the Daylight Factor?

The *Daylight Factor* is the amount of light present on the internal working plane expressed as a percentage of the light present on the equivalent external plane. In other words, the proportion of daylight within a space – typically 2-5% of daylight levels values are found in offices. If 5000 lux (a cloudy day) is present outside, a space with a DF of 2% would have 100lux average across the working plane. Increasing the DF from 2% to 5% has a major impact on daylight autonomy, because even on this cloudy day 250 lux would available, which is often enough for ambient lighting.

43. How can the Daylight Factor be increased?

In simple terms the answer is 'with more glazing', but this must be practical. For new build architecture, BRE has issued good guidance documents on the design, techniques and applications of daylighting. However for existing buildings it is obviously much more difficult, because increasing north facing glazing is often not an option. Yet there are still simple practices that can help – using lighter colours for wall and floor surfaces for example. Brighter paints (i.e. those using Lumitec™) can be used that also help. Light shelves or daylighting blinds may be used to bounce light further into the room, whilst also protecting people near the window from direct sunlight.

44. What about spaces where no direct daylight is available?

Architects have in the past used light wells and laylights for this type of space. The modern equivalents are light pipes, which can be polymer or aluminium tubes, into which sunlight is directed from the nearest available point. There are a number of systems and the latest technology combines heliostat (sun tracking) light collectors with fibre optics to carry the light into previously inaccessible spaces. Inevitably some of this technology requires significant investment, but it also offers the potential to reclaim virtually unusable workspace.

45. What about the problems of solar glare and heat gain from too much glazing?

Advanced glazing products are much better capable of reducing heat gain, but these are real issues. However there are plenty of design option, for example either *Brise Soleil* or dynamic facades. The latter have fins or shading louvres that adjust according to the sun's position. This form of architecture is still quite rare in the UK, yet there is a good degree of low winter sun available.

46. What about rooflights?

There are a number of toplighting options ranging from the old sawtooth factory roofglazing to dynamic roof structures using inflated polymer pillows. For controlled heat and glare products incorporating highly diffusive interlayers (i.e. Nanogel) are available for most types either glass or polymer structures. Toplighting is probably underused as an architectural technique in the UK, given its potential for improved daylighting.

47. What about internal elements to control heat and glare?

There are some good fabric blind systems available, which can be more effective than Venetian style louvred blinds at allowing comfortable daylight into a space. Then there are tensile fabric structures that can be used as both reflectors and diffusers to control and distribute the light.

48. How do you best save energy from using daylight?

The key element is to have an electric lighting system that is responsive to the daylight level – either through manual or automatic control. Lights should be automatically off until required. Lights can be turned on manually, but if so they will probably stay on when not required anymore. For this reason it is more effective to set up the electric lighting with sensors calibrated to a desired lux level. When daylight is present at above this level, the lights will automatically turn off or dim themselves out.

49. Do we gain some commercial benefit from investing in daylighting?

Daylighting is an effective way to reduce carbon consumption, because for every watt saved 3 watts need not be generated. Daylighting investment is often preferable to investment in renewable energy, because the inefficiencies of local renewable generation are avoided and the standby capacity not required – pure light energy is converted directly into pure electricity savings. Savings in CO2 are significant and the value of these in carbon costs will rise in the coming years. Meanwhile savings in energy consumption costs provide some immediate payback. The last, but not insignificant, benefit can come through an improved asset rating for the building on its EPC (via an improved LENI, which incorporates daylighting data from EN15193).

50. Are there any other commercial benefits from better daylighting?

It depends on each organisation, but almost certainly there are some significant ergonomic benefits. Studies (e.g. Heschong Mahone – 1999) have shown better retail sales and improved pupil performance in schools associated with higher daylight levels. The strong circadian (endocrinal) link to the higher cognitive performance of people at work in relation to daylight is also established. It is argued by leading ergonomists that these qualitative benefits would be more significant for many organisations then the energy cost savings, whether in commercial, educational, healthcare or retail buildings.