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SERIES **15** | MODULE **01** | **LIGHTING TECHNOLOGY**

Replacement lighting to save energy

By Paul Bennett, executive chairman, BSSEC Ltd

Lighting uses 20 per cent of the electricity generated in the UK and over 75 per cent of lighting installations are thought to be out of date and unable to meet current design standards. With the potential to save 25-50 per cent of lighting energy through replacement, this is an important area to 'get it right'. 'Getting it wrong' can result in lighting being unfit for purpose, with inadequate light levels, glare, headaches and serious health and safety risks.

This CPD article will explore lighting as a technology, how energy savings can be achieved and what the risks are when replacing lighting. We will consider different types of lighting and their applications, lighting design considerations, how lighting efficiency is measured, understand how the operation of buildings drives the need for different lighting controls, and typical lighting energy saving opportunities within buildings.

There are many types of lighting systems within buildings, including modular, downlights, pendants, spotlights and wall lights. The luminaire itself contains the lamp, protective housing, control gear, and diffuser or louvre. Considering luminaires from an energy efficiency perspective, the most important factor is the choice of lamp.

Table 1 illustrates the range in lamp efficiency or efficacy by how many lumens (measure of light) can be produced per Watt of electrical energy consumed. Also highlighted is the lamp colour rendering ability (100 being the best match to daylight), the lamp life i.e how often the lamps will require replacement and how long the lamp takes to reach full lighting output.

The lamps in Table 1 can be summarised into four types: incandescent, fluorescent, discharge and solid state.

Incandescent – These are becoming

Table 1 - Light Source Efficacy and Related Selection Factors

Light Source	Efficacy (lumens per watt)	Colour Rendering Ra	Lamp Life in Hours	Run up Time
General Lighting Service	8-14	100	1,000	Instant
Tungsten Halogen	15-25	100	1,500-5,000	Instant
Fluorescent T12	50-80	50-90	8,000-12,000	30 seconds
Fluorescent T8	50-96	50-98	8,000-17,000	30 seconds
Fluorescent T5	50-93	82-95	8,000-19,000	30 seconds
Compact Fluorescent	20-70	85-90	5,000-15,000	15-90 seconds
Low Pressure Sodium	70-180	NA	15,000-20,000	10-20 mins
High Pressure Sodium	40-142	19-83	10,000-20,000	3-7 mins
High Pressure Mercury	33-57	40-50	8,000-10,000	4 mins
Metal Halide	60-98	60-93	2,000-10,000	1-8 mins
LED	30-100	40-85	15,000-60,000	Instant

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obsolete as they are the most inefficient of the lamp types with poor efficacies. These comprise tungsten filament lamps (general lighting service) and low voltage halogen filament lamps (with associated step down transformers). Although the most inefficient, incandescent lamps provide a good quality light appearance with good shadowing effects that people like.

Fluorescent – These include linear fluorescent lamps such as T12, T8, T5 tubes and compact fluorescent tubes (CFL). Fluorescent lamps are internally coated with a fluorescent powder, filled with gas (low pressure mercury vapor and argon, xenon, neon, or krypton) and comprise electrodes at each end of the tube. In order to illuminate, the electrodes need to strike and so control gear is needed. In older T12, T8 and CFL fittings control gear is magnetic and referred to as a choke with starter switch (which can consume a further 20-30 per cent of lamp power owing to magnetic losses). In modern T5 fittings the control gear is electronic (note that most but not all electronic control gear can be dimmed). Light efficiency improves from T12-T8 to T5 being the best. These lamps can have good life and good colour rendering properties. Fluorescent lighting is most commonly used in commercial and public applications e.g. offices, hospitals and schools.

Discharge - This lamp family includes sodium, mercury, metal halide and ceramic metal halide lamps. Similar to fluorescent lamps, they are a gas filled lamp with the addition of a metal. These luminaires also require control gear to strike (consuming a proportion of lamp power). Low pressure sodium lamps were traditionally used for street lighting and have a notable yellow colour. High pressure sodium lamps are mainly used in industrial applications mounted at high levels in spaces where colour rendering is not so important. Similarly high pressure mercury lamps are also used in industrial applications. Metal halide lamps are most often used in retail applications for spot lighting purposes, generating a high quantity of good quality light. These lamps have a longer run-up time than fluorescent lamps.

Solid State – Light Emitting Diodes or LED lighting has become a popular choice for new and replacement lighting projects. This is owing to the combination of high efficacy and long lamp life. LEDs require a driver to operate, and so heat generated by the driver needs to be dissipated. Whilst this may seem the clear lamp of choice

Table 2 – Lighting Design Factors and Risks

Lighting Design Factor	Relevance	Risks / Consequence of Poor Design
Illumination Levels (lux level)	Not all spaces need to be illuminated at the same level. Only 100 lux is needed to walk through a corridor, office work requires 300-500 lux, whereas manual watchmaking can require over 1,500 lux.	Under-illumination and over-illumination can be serious problems. Tasks can not be properly carried out where lighting is too low but where too high energy is wasted.
Glare Index (GI)	The selection of luminaire and its orientation can cause visual glare to the users in a space.	The most common effects of glare are headaches. Poor glare is one of the key factors of sick building syndrome.
Colour Rendering (Ra Index)	An Ra of 100 is ideal. Different light sources show colours differently.	Getting colour rendering wrong can lead to products looking a different colour than they would when looked at in daylight.
Colour Temperature (K) (also known as colour appearance)	Colour temperature is expressed in Kelvin, a unit of measure for absolute temperature. Colour temperatures over 5000 K are called cool colours (bluish white), while lower colour temperatures (2700–3000 K) are called warm colours (yellowish white through red).	Complaints often arise from the colour appearance of light. An example of this is where LED lighting is used outside bedroom windows keeping occupants awake owing to the colour of the light.
Light Output Ratio	The ratio of the total amount of light output of a lamp and luminaire to that of just the bare lamp. LOR can range between 0.6-0.9.	Poor light output ratio of luminaires can result in poor overall efficiency. Not all of the light produced by a lamp leaves the luminaire – light can be lost by as much as 40 per cent inside the luminaire.
Photometric Data	Each different light fitting produces a different spread of light (known as photometric qualities).	Point-for-point luminaire replacements can cause problems as the photometric data varies between the original and the replacement luminaire.

Table 3 – Lighting Selection Factors and Risks

Lighting Selection Factor	Relevance	Risks / Consequence of Poor Selection
Environmental Operating Temperature Rating	Luminaires, lamps and their control gear are rated to operate within different temperature bands. Examples include a refrigerator at -20°C to an office at + 20°C.	Incorrect selection could lead to the failure of luminaires that are not warranted.
Index of Protection (IP)	A measure of protection against ingress of solids and liquids. Luminaires should be selected to match the environment that they are operating within. For example IP65 is suitable for total protection against dust ingress and protected against low pressure water jets.	Incorrect selection could lead to the failure of luminaires that are not warranted. A related example is damage to luminaires and the consequences of broken glass and debris entering products. This is disastrous in the food sector.
Lamp Life	Lamp-life differs from source to source. A short life requires replacement every year whereas a long life lamp could require replacements every 5 years.	An important factor for maintenance costs in terms of the cost of the replacement lamp and the human access to the lamp.
Emergency Operation	Spaces require emergency lighting so that upon power failure safe escape can be made from the space.	If emergency luminaires are being replaced ensure that suitable emergency replacements are provided.
Controllability	Most modern luminaires contain control gear to operate or drive the lamps. This control gear can consume additional energy, have heat dissipation requirements and can affect how luminaires can be controlled and switched by external lighting controls.	The specification of control gear must complement the desired external lighting controls. e.g. can the control gear or drivers achieve dimming?
Maintenance Factor	How clean is the environment where the lighting is located? How often will the luminaire be cleaned? A build-up of dirt will cause the light levels to reduce.	Lighting levels can reduce significantly if there is a build up of dirt resulting in low levels of lighting.

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Table 4 – Automatic Lighting Control Options and Risks

Lighting Control Type	Application	Risks
Time Control	The arrangement of lighting into zones, providing time switching to all or some of the zones to provide multiple light levels according to a changing building use, or to provide on/off timed control throughout the entire space.	The requirement to change between daylight savings time can be problematic and waste energy. Background lighting could be a requirement to prevent total loss of light.
Time Extension	This is useful in spaces such as sports halls which may be operated for 1-2 hour periods at a time.	Background lighting such as a maintained emergency lighting system so that occupants are not literally left in the dark.
Daylight Control	Photocells detecting day light illumination in a space with the intention of either dimming or switching off lighting to benefit from the natural light levels.	Occasionally the sensors can become dirty or fouled so that lighting switches on unecessarily.
Presence Detection	PIR or microwave sensors that detect the presence of a person or persons within a space. These switch the lighting on or off.	Occasionally when people are still PIRs can switch off lighting leaving people waving arms to re-energise.
Dimming	Sensors detect the light level of a space and control the lighting output of luminaires.	Reports from occupants that electric lighting has been switched off.
Addressable	DALI (Digital Addressable Lighting Interfaces). Each luminaire has its own address for independent individual control.	Poor commissioning can lead to complaints and systems being over-ridden.

it is important to consider issues such as colour rendering, colour appearance, driver life, driver heat dissipation, uniformity, light output ratio and glare issues. Get this right and it is the solution of choice, get it wrong and the price is high. Another solid state lamp type is Organic Light Emitting Diodes (OLED) which are still in development and not as yet commercially available to fully illuminate buildings – an OLED is a flat panel giving even diffuse light.

Lighting design factors, risks

In the UK the main lighting design authority is CIBSE, and their published guides are:

- CIBSE SLL Code for Lighting; and
- CIBSE SLL Lighting Handbook.

Lighting should be properly designed and selected by a qualified designer. It is important to understand the key factors involved in lighting design. The key factors that affect lighting design and the key risks are summarised in Table 2.

The factors that should be considered when selecting a final luminaire and lighting solution are more practical. They are however factors that need careful thought and the risks carefully managed. Table 3 provides lighting selection factors and key risks to be managed:

Often overlooked are the operational factors of the organisation and how the organisation operates within a space. Many assumptions are made here akin to the well documented building performance gap – this is where the designer makes assumptions about how a space is used and maintained.

The building occupier should be asked how the space will be used and how it will be maintained. Questions to ask include:

- What are the core hours of use during daily operation – what is the anticipated transient use?
- How will daylight be used or limited in a space on a daily and seasonal basis?
- What times are other activities planned, such as cleaning, security walk arounds, re-stocking (in the example of a retail environment), and shift changes.
- What are the lighting environmental requirements for different activities? A good example here is in a retail environment where during trading an illumination level of approximately 1,000 lux is needed but during cleaning and re-stocking 300 lux would be sufficient.
- Who will carry out the maintenance, how and at what time frames? What means of safe access will they have?

These operational factors will guide the choice of lighting control systems towards either manual or automatic.

There are essentially two basic methods of lighting control. These are manual and automatic. Manual systems can consist of a simple light switch, key switch or pull cord. Manual lighting methods should not be underestimated and can sometimes be the most effective solution if well zoned, complemented with good energy management training and practices are followed by an organisation.

In terms of automatic lighting controls Table 4 provides options, applications and risks.

Energy savings of around 25-50 per cent can be achieved in existing lighting systems. Savings can be achieved through behaviour, lighting controls, technology and improved maintenance.

An often-missed opportunity is to develop a building user-focused standard operating procedure setting out how the building and its lighting systems should be used. This can include operating modes and related lighting configurations for activities such as cleaning and other operating modes. Training is fundamental to the success of behaviour change as is regular feedback, to reward good practice and retrain offenders of bad behaviours.

Lighting control measures are low-medium capital expenditure projects that can work with existing lighting systems. These measures seek to best and most efficiently control lighting systems using automatic controls, including:

- re-wiring of existing luminaires to enable zoned control;
- additional manual controls;
- time control;
- additional occupancy controls;
- daylight controls linked to dimming; and
- addressable lighting controls.

Lighting technology measures can be medium-high capital expenditure projects that require the re-lamping, refurbishment or replacement of entire luminaires. Examples include:

- installing compact fluorescent lamps to tungsten fittings;
- changing low-voltage spotlights for LED equivalents;
- replacement of T12 switch start luminaires with T5 high frequency luminaires (or suitable LED equivalents); and
- replacement of high bay lighting with LED.

Maintenance measures include cleaning the existing luminaires and lamps, changing older diffusers and louvres within light fittings the repair of faulty automatic control sensors and re-setting time controls (especially at day light saving times).

The potential to save energy in lighting systems is suggested between 25-50 per cent and sometimes higher. The benefits of saving energy do need to be balanced against the risks. Good lighting design and selection with a risk management process will ensure that lighting savings are achieved without complaints and incidents.

Further reading on lighting

- CIBSE SLL Code for Lighting
- CIBSE SLL Lighting Handbook
- CIBSE Guide F Energy efficiency in buildings
- CTL161 How to implement lighting controls
- CTL162 How to implement external lighting
- CTL163 How to implement lighting refurbishments
- CTL 164 How to implement LED lighting
- BS EN 16247-1 – "Energy Audits"

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ENTRY FORM

LIGHTING TECHNOLOGY

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. What is the specific energy saving potential in lighting systems as indicated in this article?
- ☐ 75 per cent
- ☐ 1 per cent
- ☐ Between 25-50 per cent
- ☐ Between 5-25 per cent

2. Which of the following luminaire types has the longest start up?
- ☐ LED
- ☐ Low Pressure Sodium
- ☐ Tungsten Halogen
- ☐ Compact Fluorescent

3. Which lighting type is commonly used for spotlights in a retail environment?
- ☐ Incandescent - tungsten filament lamps
- ☐ Fluorescent – T12
- ☐ Discharge – metal halide
- ☐ Solid state - LED

4. What is the definition of the Index of Protection?
- ☐ A measure of protection against ingress of solids and liquids
- ☐ The ratio of the total amount of light output of a lamp and luminaire to that of just the bare lamp
- ☐ The spread of light (known as photometric qualities)
- ☐ The ability to operate within different temperature bands

5. What is a suitable Lux level for manual watchmaking?
- ☐ 100 Lux
- ☐ 300-500 Lux
- ☐ 1,500 Lux
- ☐ 5,000 Lux

6. What is the one principal purpose of interviewing building users and maintenance contractors?
- ☐ To ensure that occupants are aware of the process
- ☐ To understand how the building occupants use the building and how the controls operation should be aligned, and, or to assess if behaviour change is needed
- ☐ To ensure buy in from the occupants and contractors
- ☐ To comply with CIBSE guidelines

7. Which of the following is NOT a lighting control measure?
- ☐ Replacement of high bay lighting with LED
- ☐ Re-wiring of existing luminaires to enable zoned control
- ☐ Additional manual controls
- ☐ Time control

8. Which of the following is a lighting technology measure?
- ☐ Changing out low voltage spotlights with LED equivalents
- ☐ Additional occupancy controls
- ☐ Daylight controls linked to dimming
- ☐ Addressable lighting controls

9. Which is not a risk associated with an incorrectly designed lighting system?
- ☐ Lighting being unfit for purpose
- ☐ Glare and headaches
- ☐ Health and safety risks
- ☐ Lower maintenance requirement

10. Which lamp type has the longest life expectancy?
- ☐ Metal Halide
- ☐ General service lighting
- ☐ LED
- ☐ Tungsten halogen

Please complete your details below in block capitals

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