CE61

Energy efficient lighting – guidance for installers and specifiers

energy saving trust®

Contents

1 Introduction

Home energy use is responsible for 27 per cent of UK carbon dioxide (CO_2) emissions, which contribute to climate change. Increased insulation levels, especially in new homes, have driven down the energy needed for heating. This means that electricity for lighting is a growing proportion of energy used in the home. The high cost of electricity – and the emissions associated with it – makes lighting a prime candidate for action to improve energy efficiency. By following the Energy Saving Trust's best practice standards, new build and refurbished housing will be more energy efficient – reducing these emissions and saving energy, money and the environment.

Designers, builders and electrical installation contractors all have a role in ensuring that lighting is as energy efficient as possible through the specifications they use and the advice they give to clients.

This guide focuses on:

- Options for greater energy efficiency of lighting in the home.
- Opportunities to improve lighting design.
- Savings that are available with different lighting technologies.

Technical terms underlined in this guide are explained in the glossary on page 19.

Most of the technologies and approaches outlined in this guide apply to all types of residential accommodation including houses, hostels, care homes and student accommodation. However, it should be noted that these latter categories may be considered as 'non-domestic' for the purposes of building regulations, and additional specific regulations may apply.

1.1 Reducing demand

Energy demand for lighting can be reduced by:

- Using energy efficient lamps and luminaires (light fittings).
- Directing light to where it is needed.
- Controlling the use of lighting.
- Making the most of daylight and using reflective room surfaces.
- Influencing user behaviour.

Immediate results can be made in the first three items listed through basic home improvement, although the greatest potential for savings will be realised in new homes or, for existing buildings, during periodic refurbishment work such as rewiring.

The fourth item on the list can really only be satisfactorily addressed during the initial design and construction of the dwelling, or in the course of major improvements; while the fifth is a combination of direct advice and careful thought, for example, placing controls where occupants are more likely to use them.

1.2 Potential savings

On the basis that dwellings are rewired on an average cycle of 40 years[1], the total number of homes undergoing major electrical work in any year (including installation in new properties) is around 790,000 (or 2.5 per cent of the housing stock). If, in each of these, half the rooms were fitted with energy efficient lighting, the electricity savings would be equivalent to nearly 230 million kilowatt hours (kWh) in the first year. This would mean reductions in energy bills of over £18 million.

Yet these savings are not 'one offs' – they continue to accumulate. And each year more houses would be made more energy efficient, adding to the total number. The cumulative impact on energy consumption over a 10 year period can be seen in Figure 1. In fact, by the end of this time, a total of over 12,500 million kWh (45 petajoules (PJ)) would have been saved, worth some £990 million at 2006 prices.

There are important environmental benefits too. Most UK electricity is generated by power stations using fossil fuels, which releases large amounts of CO_2 into the atmosphere. The potential emissions savings over 10 years is equivalent to nearly 5,300,000 tonnes of CO_2 – the same as one year's emissions from nearly 900,000 houses.

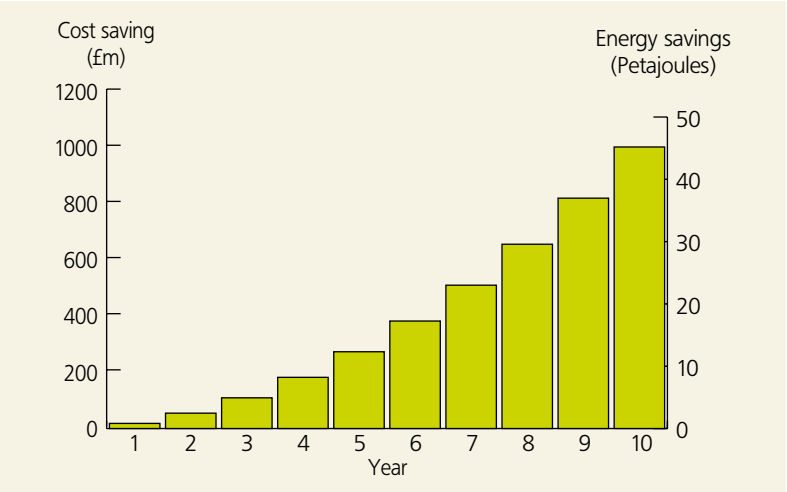


Figure 1 Energy and cost savings from increased use of energy efficient lighting. 1PJ is equivalent to 278 million kilowatt hours (kWh).

1 The National Inspection Council for Electrical Installation Contracting (NICEIC) recommends inspection every 10 years and on changes of occupancy.

2 Light sources

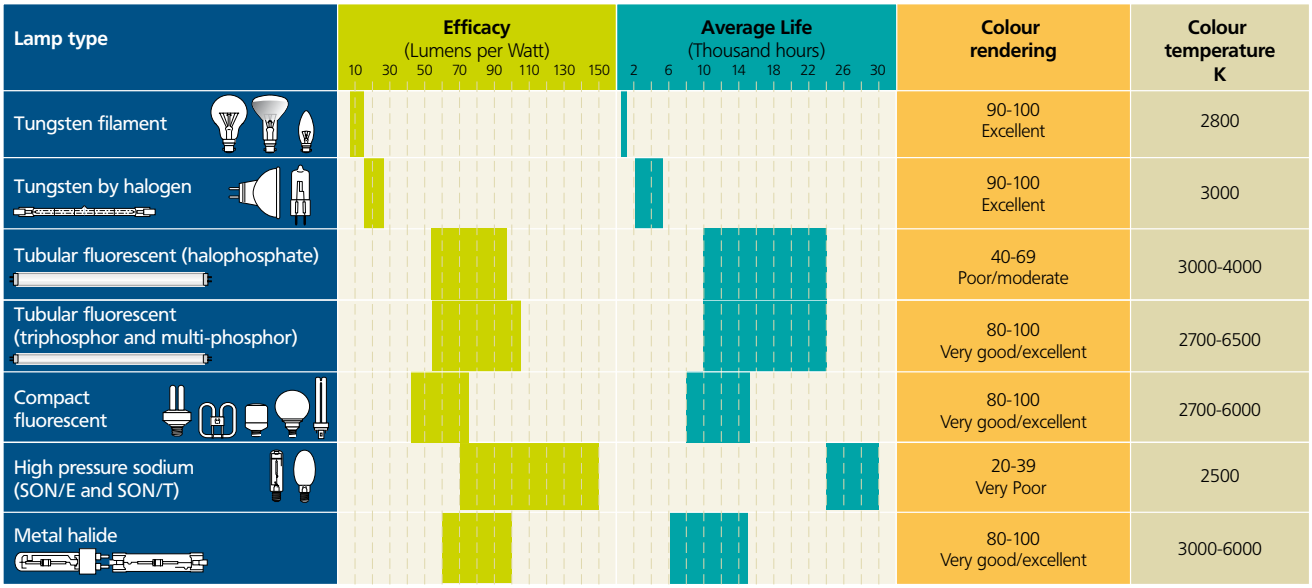


Figure 2 Performance characteristics for a range of lamp types

Figure 2 compares the performance of the different types of lamp that are commonly available. Some lamp types may only be appropriate for communal areas or multi-residential housing, but they have been included for completeness.

2.1 Performance characteristics

Efficacy

Efficacy is a measure of how effectively a lamp transforms electricity into light (or luminous flux) in lumens per Watt. The efficacy ratings in Figure 2 are based on a lamp's performance when new. Efficacy varies, depending on a number of factors including wattage, operating frequency and type of phosphor coating, so the results are displayed in bands. However, it should be noted that the amount of light reaching the occupant will depend heavily on the direction of the light and the characteristics of the complete light fitting (luminaire). Section 4 gives more information on this.

Average life

Lamp life can be measured in different ways, which can result in misleading comparisons between different types. The method used for all discharge lamps in Figure 2 (that is, all types except tungsten filament and tungsten halogen) is based on rated average lamp life. This is the time taken for 50 per cent of a sample batch to fail under test conditions.

As with efficacy, lamp life is shown in bands because it can vary with operating voltage, wattage and type of control gear. It can also be affected to a lesser extent by the operating position. Frequent switching of lamps can also affect operating life, particularly in the case of fluorescent lighting (although specialist fluorescent lamps are now available with are designed to withstand such use).

Although switching may affect operating life, it is not true that fluorescent lamps consume large amounts of energy every time they are switched on – they should always be turned off when not required.

Colour rendering and colour temperature

Colour rendering is a measure of how accurately the colour of surfaces appears under different light sources. It is expressed by a colour rendering index (Ra) of up to 100. An Ra of between 80-89 is considered very good, while one between 90-100 is regarded as excellent. In general, an Ra greater than 80 is adequate for all domestic situations and wherever accurate colour judgements are necessary.

Colour temperature gives an indication of the appearance of the light. Lower colour temperatures mean a 'warmer' appearance. Early fluorescent lamps had a high colour temperature giving a very 'cold' appearance; but now a wide range of colour temperatures is available, including some that are similar to incandescent lamps. Lamps of different temperatures should not normally be used in the same room, unless a specific effect is required.

2.2 Incandescent tungsten filament lamps

These are the most common type of lamp and include general lighting service (GLS) lamps. Decorative versions are available (e.g. candle-shaped lamps). 'Incandescent' literally means light produced from heating, and in these lamps the heat is created by an electric current passing through a thin tungsten wire (filament). This filament is quite delicate and burns out after about 1,000 hours. Some 'double life' lamps are available but the gain in working life is made at the expense of light output (e.g. GLS lamps with a 2,000 hour life have approximately 10 per cent less light output).

These lamps, which are used in most homes, only have an efficacy of 8-15l/W.

2.3 Tungsten halogen lamps

These are tungsten filament lamps that contain a small quantity of halogen (iodine or bromine). This prevents blackening of the glass which can lead to loss of light output over the life of the lamp.

Extra low voltage (ELV) versions are available in 6V, 12V and 24V ratings – with 12V being by far the most popular. Efficacy is typically 15-20l/W, although new models offer around 28l/W. Life span can be up to five times that of a tungsten filament lamp. The small filaments provide excellent beam control when used with precisely contoured integral reflectors. ELV lamps require transformers, but these are normally small lightweight electronic units that can be dimmed (although this requires special phase control dimmers suitable for inductive loads).

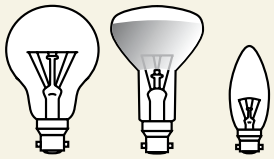
These lamps will save energy when used to replace tungsten filament lamps, but they cannot be used to comply building regulations because the regulations require an efficacy of 40 lumens per Watt (see Section 5).

Mains voltage tungsten halogen lamps offer 10-15 per cent more light and double the working life of tungsten filament lamps. Modern models are very compact – almost as small as ELV lamps. They can be easily dimmed with conventional phase control dimmers designed for resistive loads.

Lamps from reputable manufacturers have integral fuses for safe end-of-life failure. Poor quality lamps may have inadequate fuses – or no fuse at all – leading to violent shattering and permanent damage to any dimmer in the circuit.

Both types of tungsten halogen lamp must only be used in the appropriate luminaires – for example, mains voltage lamps must not be used in ELV fittings and vice versa.

Tungsten filament lamps



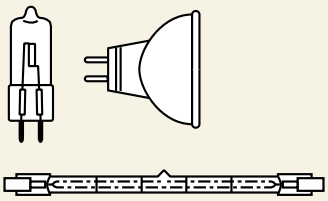
Advantages

- Low purchase price.
- Excellent colour rendering.
- No control gear required.
- Full lighting level immediately when switched on.
- Easily dimmed.
- Sparkle lighting effects can be achieved.
- Universal operating position.

Disadvantages

- Low efficacy – only 8-15l/W.
- Short working life – usually about 1,000 hours.
- High running costs.
- Not rated as energy efficient under building regulations.

Tungsten halogen lamps



Advantages

- Higher efficacy than conventional tungsten filament lamps.
- Bright, white light.
- Life of 2,000-5,000 hours depending on model.
- Excellent colour rendering.
- Full lighting level immediately when switched on.
- Dimmable.
- No transformer required for mains voltage models.

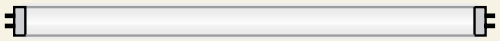
Disadvantages

- Transformer required for ELV lamps.
- Very high operating temperature.
- Double-ended types must be used in horizontal position.
- Not rated as energy efficient under building regulations.

Ultraviolet (UV) radiation

Concern has been expressed about ultraviolet radiation from electric lights. It is true that lamps used for general lighting will emit some UV. However, this is at a much lower level than would be experienced just by being outdoors.

Under typical indoor lighting, the UV radiation from bare fluorescent lamps would be less than 1 per cent of that received in average daylight (see LIF Technical Statement No.8, www.lif.co.uk) ten filament lamps hardly emit any UV because the UV is absorbed by the glass envelope. Most tungsten halogen lamps are now made with UV-filter quartz and this removes the need for additional filters in most applications. Further information is available from lamp manufacturers.



Tubular fluorescent lamps

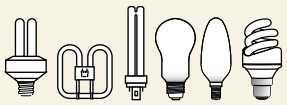
Advantages

- Low running costs.
- High efficacy: 55-104l/W.
- Colour rendering is excellent or very good (except halophosphate).
- Long life in normal use (up to 24,000 hours for a T5 lamp).
- Minimal loss of output during working life.
- Prompt start and re-start (with HF electronic control gear).
- Full light output level achieved quickly.
- Up to 10 per cent energy saving with 10 per cent more light by replacing a T12 lamp with a T8 lamp in switch-start luminaires.
- Universal operation position.
- Range of colour temperatures (2700-6500K).

Disadvantages

- Frequent switching shortens life (less pronounced with HF control gear).
- Control gear is required.
- Dimming requires special control gear and dimmer.

Compact fluorescent lamps (CFLs)



Advantages

- Low running costs.
- High efficacies: 50-75l/W (some small CFLs may be less than 40l/W).
- Life: 8,000 to15,000 hours (depending on type).
- Suitable for replacing tungsten filament lamps.
- Very good colour rendering (some lamps give excellent rendering).
- Range of colour temperatures for pin-base lamps: 2700-4000K.
- Full light output level achieved quickly.
- Prompt start and re-start.
- Four-pin lamps can be dimmed (with specialist control gear and dimmer).
- Universal operating position.

Disadvantages

- Frequent switching shortens working life (although specialist lamps are available to address this issue).
- Control gear required (which is built-in on some lamps).
- Not suitable for dimming using standard domestic dimmer switches (although specialist CFL-dimming equipment is available).

2.4 Tubular fluorescent lamps

These have between four and 10 times the efficacy of tungsten filament lamps and can last up to 24 times longer, depending on lamp type and control gear. (All fluorescent lamps need control gear.) Any flicker from these lamps is due to the control gear, not the lamp itself. It can often be eliminated by using high frequency (HF) electronic control gear (see Section 4).

Tubular fluorescent lamps work in a different way from incandescent lamps. The tube contains an inert gas, usually argon or krypton at low pressure, together with a small amount of mercury. When an arc is struck between the tube's electrodes, the mercury atoms emit UV radiation. This excites the phosphor coating on the inside of the tube, which gives off visible light (the coating fluoresces).

The quality of this light depends on the coating used. Older halophosphates degrade over the life of the lamp resulting in loss of light output; the newer tri-phosphor and multi-phosphor coatings last much better with the latest tri-phosphor lamps, maintaining most of their output throughout their working lives. The tri-phosphor coatings also achieve very good colour rendering and are available in a range of colour temperatures – including the warmer 2700K and 3000K temperatures suitable for domestic use.

Older fluorescent tubes of 600mm or more in length were usually 38mm in diameter (known as T12 lamps). Most new fittings use T8 lamps (26mm in diameter). They will save up to 10 per cent of the energy consumption while giving 10 per cent more light. T8 lamps are available in the same lengths and can be used as replacements for T12 lamps in the same switch-start luminaires.

Newer 16mm diameter T5 lamps have even higher efficacies (90-104l/W) but need different fittings. (A wide variety are now available.) Where very discrete light sources are required, specialist luminaires with 7mm diameter T2 lamps can be used.

2.5 Compact fluorescent lamps (CFLs)

CFLs are very energy efficient and are ideal for locations where heavy use (more than four hours a day) may be expected, or where areas are likely to be lit continuously: in living areas; in circulation zones such as halls, stairways, landings and shared passageways outside buildings. Their low operating temperature makes them particularly suitable for luminaires where heat build-up should be avoided, such as flush-wall and ceiling fittings. Their long life makes them attractive for locations where access to change the lamp could be difficult for occupants, such as above stairwells, or where residents are less able (e.g. sheltered accomodation), and enclosed applications such as bathroom mirror lights.

CFLs fall into two main categories:

- Pin-base lamps.
- Lamps with integral control gear (CFLi).

Comparing costs: CFLs and tungsten filament lamps

Figure 3 compares the costs of using an 18W pin-base CFL and 100W GLS tungsten filament lamp over a 12,000 hour operating period. (12,000 hours is a typical CFL lifespan.) The calculations are shown below:

	100W GLS	18W CFL (plus electronic control gear consuming 3W*)
Cost	£0.50	£3.70
Life (hours)	1,000.00	12,000.00
Total lamp costs (over 12,000 hours)	£6.00	£3.70
Total electricity costs (@ 7.9p per kWh)	£94.80	£18.96
Total costs	£100.80	£22.66
Saving		**£78.14**

* electronic control gear extends lamp life and allows the CFL to run at a lower wattage (17W assumed) for the same light output – see section 3.

The additional cost of the dedicated low energy fitting is in the order of £6-12 (excluding installation costs) compared with one designed to accept an incandescent lamp. As this is a one-off cost not incurred when replacing lamps, it has not been included in these calculations.

Over 90 per cent of the energy used by incandescent lamps is given out as heat. This means that they contribute to meeting the heat demand of a building during the heating season. Consequently, changing to energy efficient lighting will result in an increase in energy used for heating (known as the heat replacement effect). This additional energy used for heating will partially offset the cost and savings attributed to energy efficient lighting. Savings from lamps used in unheated areas (external lights, garages, etc.) are not affected.

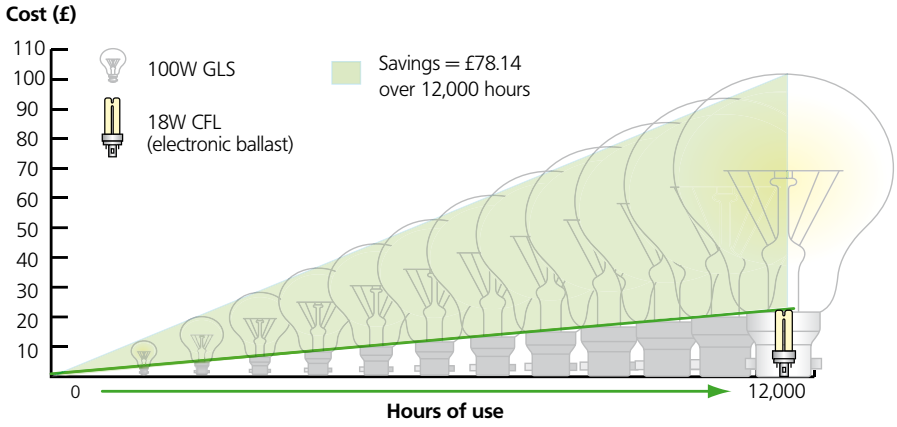


Figure 3 Comparative costs of buying and using CFLs and tungsten filament lamps

CFLi

CFLi may have bayonet or Edison screw caps and can therefore be used as direct replacements for incandescent lamps in most existing luminaires. Almost all CFLi have a colour temperature of 2700K, the same as that of tungsten filament lamps.

Pin-base

Pin-base lamps need separate control gear and luminaires specially designed for them (sometimes referred to as dedicated fittings). They cannot be replaced with incandescent lamps when they fail, and so the savings from using high efficiency lamps continue throughout the life of the luminaire.

They are available in a wide range of colour temperatures, including those most commonly encountered in domestic situations: 2700K – the same as the tungsten filament lamp; and 3000K – the same as tungsten halogen lamps. Pin-base lamps can be used to meet the Energy Saving Trust's standards for new housing and can be used to comply with the building regulations (see section 5).

The manufacturer's stated wattage for pin-base lamps does not include the power consumed by the separate ballast. While dedicated fittings may take slightly lower wattage lamps, the total energy consumed will be very similar to CFLi.

General

CFLs with a wattage of about 20 – 25 per cent that of an incandescent lamp will give a similar light output. However, the distribution of light from a CFL may be different (Section 4), and this may influence the choice of lamp type and its wattage.

Lamps in both categories are available as 'sticks' where the fluorescent tube is visible and 'look-alikes' where the tube is shielded by a casing and resemble other lamp shapes including GLS, candle and spotlights.

Stick lamps have the greatest efficacy and are ideal where the lamp is not visible to the occupant e.g. in uplighters. Longer, two-finger sticks (generally pin-based) are ideal in low profile luminaires designed to 'wash' surfaces. Four-finger models and 'hoops' are used where a more compact lamp is desired.

Where the lamp is visible to occupants then look-alikes are preferable. Just as the diffuser of a luminaire reduces light output, the casing may also reduce the lamp efficacy slightly. However, there will be more even light distribution and this type of lamp is more acceptable to occupants. An increasing number of CFLi are look-alike.

Both pin-base and CFLi lamps are available in a wide variety of outputs, making them an attractive option for specifiers and end-users. Those using electronic control gear – which is standard on most CFLi – reach full output within a few seconds of switching on and there is no flicker on start-up or in use.

CFLs should not be used with the standard domestic wall-mounted dimmer switch. It is possible to dim four-pin lamps, but this requires specialist control gear and a compatible dimming controller.

CFLs usually have a working life of between 8,000 and 15,000 hours. Many manufacturers produce 'economy' lamps that are cheaper, but these have shorter lives (5,000 – 8,000 hours).

Many CFLs have energy saving recommended certification, meaning that they have been independently tested to verify their overall quality and the energy efficiency claims made for them. A full list is available at www.est.org.uk/recommended

Certification mark

2.6 High pressure sodium (SON) lamps

The high efficacy and very long life of these lamps make them ideal for floodlighting. They come in two shapes – elliptical (SON/E) and tubular (SON/T).

However, they are not designed for frequent switching so should not be used with automatic presence detectors for security lighting.

Although they are suitable for illuminating external communal areas around housing developments they are not normally regarded as 'domestic' lighting.

2.7 Metal halide lamps

Metal halide lamps are high pressure discharge lamps that produce daylight quality white light. This outstanding colour rendering makes them ideal for situations where colour perception is critical.

Newer technology ceramic arc-tube versions offer even better colour rendering, combined with less light loss over time and a longer service life.

They require similar control gear to SON lamps and cannot be frequently switched. Although they are suitable for illuminating external communal areas around housing developments they are not normally regarded as 'domestic' lighting.

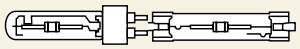
High pressure sodium lamps

Advantages

- Very low running costs.
- Very high efficacies: 70 – 150l/W.
- Very long life: up to 30,000 hours.
- Large choice: 50 – 1,000W.
- Universal operating position.

Disadvantages

- High purchase cost.
- Very poor colour rendering.
- Control gear required.
- Several minutes from start up to full output.
- Cannot be restarted when hot.



Metal halide lamps

Advantages

- Daylight quality white light.
- Low running costs.
- High efficacies: 60 – 100l/W.
- Very long life: from 6,000 – 15,000 hours.
- Large range of outputs: 20 – 2,000W.
- Range of colour temperatures: 3000 – 6000K.
- Several configurations: single- or double-ended and reflector versions available.

Disadvantages

- High purchase cost.
- Control gear required.
- Several minutes from start up to full output.
- Only double-ended lamps can be restarted from hot, but these need special control gear.

Light emitting diodes (LEDs)

LEDs are extremely small semi-conductors that emit coloured light when energised by a low-voltage DC current. The light is in single, unmixed colours, i.e. red, orange, yellow, green or blue. If white light is required, it has to be produced either by combining red, green and blue LEDs or by using phosphor technology to convert ultra violet or 'blue' light to white.

LEDs are generally too small to be used singly, and so are supplied in arrays or modules of differing shapes and sizes. They have very long life and fast improving efficacy (most white light LEDs are currently around 20 – 30l/W but the new generations are about 60 – 70l/W). They are highly suitable for decorative lighting, particularly outdoors, and in emergency signage.

They are not yet developed sufficiency to be an efficient alternative for general internal lighting.

3 Control gear

HF control gear

Advantages

- Reduce lamp energy consumption.
- Near perfect power factor.
- Silent in operation.
- Lamps start at first attempt without flickering.
- Lighter in weight than wire-wound equivalents.
- Promote longer lamp life (typically 50 per cent longer).
- Eliminate flicker and strobe effects (lamps run at between 20 – 40kHz).
- Prevent adverse effects from variations in supply voltage.
- Automatically switch off at end-of-life, eliminating lamp flashing.

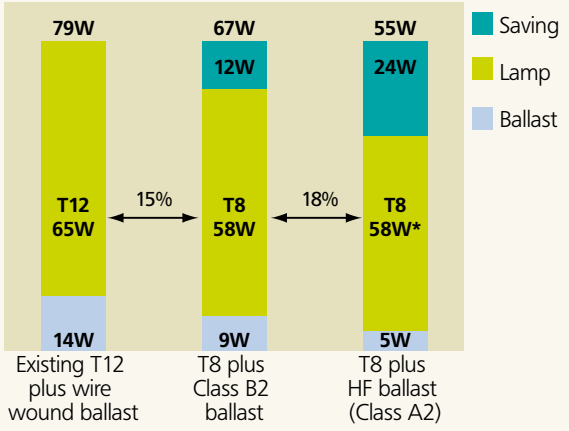


Figure 4 Load savings (per cent and absolute) based on a 1,500mm long tubular fluorescent lamp and control gear.
*Rated power consumption. HF ballasts reduce actual consumption.

The Ballast Directive

Inefficient ballasts are being steadily phased out across the European Union following the adoption of the Ballast Directive (2000/55/EC). The Directive came into effect on 21 May 2002. It requires manufacturers to mark ballasts, indicating their efficiency, and it bans the sale of inefficient ballasts throughout the EU.

The main ballast categories under the Directive are:

- Class A: electronic control gear.
- Class B: 'low loss' magnetic ballasts.
- Class C: 'normal' magnetic ballasts.
- Class D: least efficient magnetic ballasts.

The sale of Class D ballasts has been banned since 21 May 2002. Class C ballasts have been banned since 21 November 2005. A date for the phasing out of the less efficient Class B ballasts (Class B2) may be set if EU sales of Class A ballasts do not increase sufficiently.

All discharge lamps (including all types of fluorescent lamps) need control gear. It creates the right conditions to start the discharge and to regulate the voltage and current. Different models of lamp require specific electrical inputs – and different control gear – to drive them. Manufacturers should be consulted if there is any doubt about the suitability of particular items.

The 'conventional' wire-wound iron-cored inductance, often called a magnetic ballast or choke, controls the current through the lamp and has been a standard component since fluorescent lamps were first developed. However, it causes a phase shift between the current and voltage resulting in poor power factor: this is corrected by placing a capacitor in the circuit. These components, together with a starter switch, make up the control gear.

3.1 High frequency (HF) electronic control gear

All control gear consumes electricity, but high frequency (HF) electronic control gear uses less than half that required by conventional wire-wound types. This, combined with the fact that they allow lamps to run at a lower wattage for similar light output, can result in a reduction of nearly 25 per cent in the electricity required to run the lamp when compared with a luminaire using a Class C ballast. (That is why Class C ballasts are being phased out by the EU Ballast Directive – see box.)

HF electronic control gear generally provides additional functions such as end-of-life shutdown and it operates at near perfect power factor (1.0). The units can either have instant-start or pre-heat 'soft-start' which involves a moment's delay. Soft-start gear prolongs lamp life and should be used on frequently switched lamps.

Some HF gear responds to an external signal, allowing light output to be varied. These may be termed 'dimming', 'regulating' or 'variable output' control gear. They can provide a means of reducing energy consumption when maximum illuminance is not required, because the energy used is, in this case, generally proportional to light output over most of the dimming range.

Figure 4 shows the difference in connected load and the savings to be made through changing an existing 65W T12 fluorescent tube with 'conventional' wire-wound ballast to a modern 58W T8 lamp with HF electronic control gear.

Many luminaires designed for use with fluorescent lamps are normally supplied with magnetic ballasts, although most manufacturers offering upgrades to electronic ballasts. All pendant-type energy efficient fittings use electronic ballasts.

4 Luminaires for CFLs

Lighting equipment essentially consists of a lamp, controls and control gear if needed, and a luminaire. Each contributes to the overall efficiency. So there is no point in putting an efficient lamp in an inappropriate fitting: always select the most efficient components for the best overall result.

For new luminaires or pendant fittings specifically designed for use with CFLs, the manufacturer will state the type of lamp to be used. Where a tungsten filament lamp is being replaced by a CFL in an existing fitting, care needs to be taken so that the correct type of lamp is chosen – making sure that it fits into the luminaire, see Figure 5. While several types of CFL may have the same light output as the lamp they are replacing, they may distribute it in different ways. For example, lamps which emit most of their light sideways should not be placed in shades designed to direct light vertically. By looking at a lamp from different angles, an estimate of light distribution can be made. In general, the amount of light emitted in any direction will depend on the area of lamp surface visible in that direction.

Figure 6 gives a visual guide to light distribution from CFLs and indicates which types to use in common luminaires. The relative size of the arrows on the light distribution graphic shows the proportion of light in that direction. Dedicated low energy fittings for most applications and styles are widely available today. Many of these have energy saving recommended certification.

A full list of energy saving recommended fittings is available at www.est.org.uk/recommended

Images of most of these are available at www.lightingassociation.com

Figure 5 Example of poorly matched lamp and luminaire. The lamp was also 3500K – far too cool for a hotel bedroom

energy saving® recommended
www.energysavingtrust.org.uk

Certification mark

Luminaire \ CFL						
Translucent shade	✔	✔		✔	✔	
Opaque shade		✔	✔	✔	✔	
Translucent cylinder	✔	✔				✔
Translucent drum	✔			✔	✔	✔
Translucent sphere	✔	✔				
Wall uplighter	✔					✔
Pendant/freestanding uplighter		✔		✔	✔	

Figure 6 A guide to light distribution from CFLs, and which to use in common luminaires

5 Standards for energy efficient lighting

5.1 Building regulations requirements

The building regulations set the minimum standard required for lighting, but higher standards and greater efficiency can easily be achieved by adopting the Energy Saving Trust standards (see 5.2).

The building regulation requirements for lighting vary across the UK. All parts of the UK have lighting requirements for 'buildings other than dwellings' whereas only England and Wales have requirements for 'dwellings'. However, Northern Ireland is expected to adopt similar proposals to England and Wales from June 2006. The distinction between these two categories of buildings also varies across the UK and advice should be sought from the local building control body if there is any doubt.

Buildings such as student accommodation, hostels and houses in multiple occupation are generally classified as 'buildings other than dwellings' but this will depend on the nature of the building and its size. Guidance on how the building regulations can be met is given in the appropriate publication (see box) for each part of the UK.

UK legal requirements for lighting

England and Wales (dwellings)

- The Building Regulations 2000 Conservation of Fuel and Power, Approved Document L1A: Work in new dwellings (2006 edition).
- The Building Regulations 2000 Conservation of Fuel and Power, Approved Document L1B: Work in existing dwellings (2006 edition).

Scotland

- Section 6: Energy, of the Technical Handbooks on possible ways of complying with the Building (Scotland) Regulations 2004.

Northern Ireland

- Building Regulations (Northern Ireland) 1994, Technical Booklet F: Conservation of Fuel and Power (December 1998) (revised publication expected June 2006).

New dwellings

From April 2006 all new dwellings in England and Wales must meet increased requirements for energy efficient lighting. This requirement also applies to situations where new dwellings are created as a result of 'material change of use' (e.g. house conversions and barn conversions), and to extensions to existing dwellings.

The guidance given in Approved Document L1A states that the requirement would be met by installing one of the following:

- One energy efficient light fitting per 25m^2 of dwelling floor area (or part thereof).
- One per four fixed light fittings.

An energy efficient light fitting must comprise the lamp, control gear, and **an appropriate housing, reflector, shade or diffuser.** The fitting must be capable of only accepting lamps having a luminous efficacy greater than 40 lumens per circuit Watt.

Tubular fluorescent and compact fluorescent lighting fittings would meet this requirement. Tungsten filament and tungsten halogen lamps (both mains voltage and low voltage) do not meet the requirement.

These requirements mean that lighting schemes such as those using high numbers of individual tungsten halogen lights will significantly increase the number of energy efficient fittings that will be required.

Lighting fixed to the external surface of the dwelling must satisfy one of the following:

- Only take low energy lamps.
- Be limited to a maximum lamp capacity of 150 Watts and have controls that turn the lamp off when there is enough daylight or when not required at night. A fitting controlled by a photocell and a passive infra red detector (PIR) would meet this requirement.

Existing dwellings
In existing dwellings the same requirements apply when a property is extended or undergoes material change of use. Both of these will require building regulations approval.

The building regulations also apply when an existing lighting system is being replaced as part of rewiring works. In this instance the components are more likely to be specified by the lighting installer in conjunction with the homeowner. In this situation the installer will be responsible for ensuring that the required number of energy efficient fittings are installed.

5.2 Energy Saving Trust standards

New dwellings
For new housing there are three Energy Saving Trust performance standards. These go beyond the building regulations, and each standard has specific requirements for lighting. The standards and their lighting requirements are as follows:

- Good practice: set just above building regulations in specific energy efficiency areas.
- Best practice: represents a readily achievable higher standard and is suitable for all general housing.
- Advanced practice: an extremely demanding standard aimed at exemplar housing.

Lighting requirement

Standard	Percentage of fixed internal fittings to be low energy*
Good practice	40
Best practice	75
Advanced practice	100

* i.e. fittings that will only accept lamps with a luminous efficacy of greater than 40 lumens per circuit Watt. Excludes fittings in garages and cupboards.

Existing housing
In existing housing every opportunity should be taken to replace existing fittings with dedicated energy efficient ones so that 75 per cent of fittings are low energy.

Where fittings are not being replaced then CFLi should be used to replace standard tungsten filament lamps wherever possible.

All lamps should have a colour temperature of 2700K, except for special situations.

External lighting (new and existing)
All external lighting should use one of the following:

- Incandescent lamps with photocells (daylight sensors) together with presence detectors (PIRs) and have a maximum lamp capacity of 150W.
- Energy efficient lamps (efficacy of at least 40l/W) and compatible photocell or timer.

Full details of these standards can be found on the Energy Saving Trust website at: www.est.org.uk/housingbuildings/standards

Recessed fittings and airtightness
As of April 2006 a key requirement for builders in England and Wales will be to ensure that new homes reach a set airtightness standard.

Using large numbers of recessed light fittings can significantly worsen the airtightness of a dwelling even if care is taken.

6 Opportunities for energy efficient lighting

In conventional housing, the opportunities for introducing more energy efficient lighting – and experiencing the benefits – vary from house to house and even room to room. This section outlines ways of improving lighting and saving energy.

More information on specific situations is given in Low energy domestic lighting – looking good for less (CE81/GPCS441) (see Further reading).

The energy efficiency of the lighting in a dwelling can be improved at different times in its life regardless of whether building regulations compliance is required. Clearly, the construction phase provides the opportunity to address the issue in a coordinated and thorough way, but there are also opportunities as a home is redecorated, either on a room-by-room basis or as part of a larger refurbishment.

Wiring should be inspected every 10 years or when there is a change of occupancy, and this too provides an occasion for the electrical contractor to suggest alternative lighting layouts and to advise home owners or building owners on the choice of equipment.

6.1 Lighting design

When considering alternative lighting arrangements or styles, it is important to recall the basic principles of lighting design. Designers divide lighting into three types:

- General – such as a central hanging light.
- Task lighting – for example, a desk or table lamp.
- Atmospheric or ornamental – such as a spotlight on a picture.

The following guidelines can help in making the correct choices:

- Decide what the lighting is really needed for; then design a scheme and choose the position of the lights where they will be used. Include task lighting and provide sockets for reading lights.
- Direct light where it is required.
- Use lamps appropriate for the fitting.
- Use lighting to aid safety.
- Use lighting for effect – reduced background lighting will create more contrast in a room as well as saving energy.

Direct light to where it is required

An important principle of energy efficient lighting design is to make the most of any light sources available by directing the light to where it is needed. It can often happen that a room – or even the whole house – is lit to a uniform level but an individual may not have enough light for a particular detailed task, such as reading, sewing or writing. This is clearly an inefficient use of resources. Outdoors, uncontrolled light emitted upwards is wasted and also the cause of 'light pollution', which reduces visibility of the night sky.

6.2 Lighting control

- If each fitting has its own switch it can be switched on and off independently when needed.
- If switches are conveniently situated, occupants will be more inclined to switch lights off when not required.
- Dimmers can be used to vary lighting in an energy efficient way (depending, for example, on daylight levels). Ensure that the dimmer, lamp (and the control gear if needed) are all compatible (see Section 7).
- Use automatic controls where appropriate.

Hallways
A central fixture can provide a warm reception for visitors. Flush ceiling fittings maximise headroom in this often small area. Fluorescent lamps are particularly suitable here as their low running temperatures reduce potential heat build-up in flush fittings.

Since hallways are generally lit for long periods, the use of low energy lighting will maximise savings. A warm lamp (2700K) should be specified.

Living rooms
Living rooms need a relaxed atmosphere and some flexibility in lighting provision: this requires a variety of light sources. Avoiding glare from the lamps is also important and wall lights such as uplighters can meet this need.

Central, flush ceiling luminaires will also reduce glare by hiding the light source. There is a wide range of fittings designed for use with CFLs.

The room's long hours of use mean that CFLs will achieve significant energy and cost savings. Good ambient background lighting can be supplemented by portable fittings such as table or standard lamps, which provide the higher localised levels of lighting required for reading or other detailed activities.

CFLs with a colour temperature of 2700K should be specified, unless tungsten halogen lamps are also used in the same room, when 3000K lamps may be more appropriate.

Dining rooms
Lighting can be used to create different 'moods'. A wash of light over one wall or the ceiling can provide a background level of lighting against which a variety of lighting effects can be achieved using portable luminaires. The wash can be created using tubular fluorescent lamps shielded in such a way that light is directed down the wall or across the ceiling.

The light level can be varied with compatible dimming equipment. The use of high frequency control gear will not only eliminate flicker on start-up and in use, but will also eliminate the low-level hum that wire-wound control gear causes.

The very long life of tubular fluorescent lamps means that dust can build up and an occasional wipe with a dry cloth may be required. Ceiling-mounted spotlights or low hanging pendant fittings can be used to light the table if required. These should be switched independently of the other lighting.

Figure 7 Dimmable fluorescent lighting 'built in' to a room can create a variety of moods

Kitchens
The detailed tasks being carried out in a kitchen require high levels of lighting, particularly since many of activities involve the use of sharp tools. Fluorescent lighting under kitchen cabinets provides this and helps to reduce risk to people who might otherwise be working in their own shadows in a centrally lit room. Where lighting is used to supplement daylight, a cool colour temperature (3500-4000K) can be chosen.

Figure 8 Under-cabinet lighting improves safety on work surfaces as well as having a high degree of permanence

Figure 9 Use of a CFL in a double height space to reduce risk of falls

Recessed low energy downlighters can be used away from the work surfaces to provide background lighting and to illuminate eating areas. Separate switching should be provided. However, recessed fittings can have a significant impact on the airtightness of a dwelling if they are not very carefully installed and allowed for in the design (e.g. by the use of service voids).

Stairs and landings
As in the case of hallways, flush fittings maximise headroom in these 'transit' areas, but there are also other issues to consider. Stairs must have adequate lighting and this will generally require luminaires either along them or above them – or in close proximity on the landing. The risks of falls associated with replacing lamps can be reduced considerably by using CFLs because they have a much longer service life than incandescent lamps.

Bedrooms
While providing good general light levels, bright central light sources can create glare for occupants reclining in bed. This can be reduced by directing lighting onto surfaces. Providing a separate circuit specifically for bedside lighting, with lighting socket outlets and two-way switching, will help to ensure that lights are not left on unnecessarily.

Bathrooms
Although bathrooms are not lit for long periods, the use of low energy lighting with a long service life can be particularly appropriate for enclosed fittings where lamps may be difficult to replace.

Studies
Harsh lighting can create glare on computer screens and paper-covered desks. This can be avoided by arranging a low level of background light: CFL dedicated wall uplighters can be used to create a general wash of light.

Lighting the surface behind a computer monitor will reduce eye strain. A desk lamp directed at the wall will achieve this (many modern models will only take CFLs). As these are often positioned close to the user, the low running temperature of a CFL will improve comfort.

Style and permanence
To achieve long-term savings, energy efficient lighting fittings should only be able to accept high efficacy lamps and they should not be easy for occupants to remove. This is particularly important when dwellings are being built or when they are being refurbished before sale: the tastes of the new occupants are unlikely to be known.

To minimise the risk of them being removed, select fittings that do not make a strong style statement – plain uplighters, for example, or fittings that have interchangeable shades. However, the best solution is to provide discrete lighting that is part of the fabric of the building or part of the fixtures. This could include under-cabinet lighting, pelmet lighting, etc.

External lighting
The selection of external lighting will largely depend upon its purpose and the way it is to be used. Where lighting is only required for short periods – for example to light a path while it is in use – then a standard incandescent lamp may be suitable, provided it has adequate controls. These might include a photocell (to prevent the light being used in daylight) and a presence detector.

The use of 300-500W tungsten halogen flood lamps is not recommended for most domestic situations. They are comparatively expensive to run and, if badly sited, can give rise to light pollution as well as dazzling passing pedestrians and motorists. In domestic settings a 150W lamp (with appropriate controls) is usually sufficient. If not, it is preferable to install two separately controlled fittings.

Low energy light sources such as CFLs should be used where the lighting is required for longer periods. Ideally, these would also be controlled to prevent use when not required (with timers and photocells, for example). However, care should be taken to ensure that any controls are compatible with CFLs.

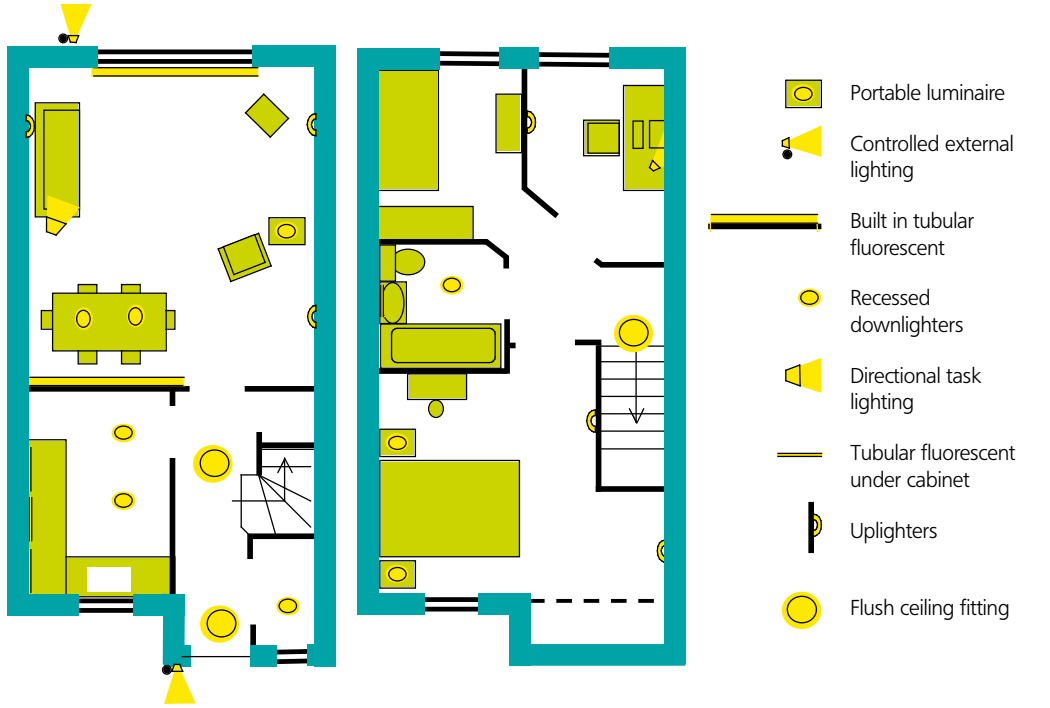


Figure 10 Opportunities for low energy lighting in housing

7 Dimming

The mood of the lighting can be changed easily by dimming. Dimmed to 25 per cent of full light output, a lamp – or the lit area – is likely to appear about half as bright. When dimmed to just 10 per cent, it will appear about one third as bright. This effect is due to adaptation. There may be a noticeable change in the apparent colour of the light from a tungsten lamp – to a warmer tone – but fluorescent light will appear the same.

A dimmer must only be used with the type of lamp for which it is designed. It must match the lamp, the control gear or transformer, and the load current.

7.1 Dimmers for incandescent lamps

Modern domestic phase-cut dimmers for use with incandescent lamps do save energy. A tungsten filament lamp dimmed to half light output, for instance, will consume about 40 per cent less electricity and lamp life will be extended by up to 10 times. However, lamp efficacy (l/W) will be reduced by 30 per cent.

Not all transformers used with extra low voltage (ELV) lamps are compatible with domestic phase-cut dimmers. Transformers for ELV lamps should state whether or not they are dimmable, but the best advice is to check with the manufacturers of both. Some types of transformers will need a pre-heat (soft-start) dimmer in which the lamp is always on, albeit in a dimmed state. In addition, some transformers may cause electromagnetic interference when used with domestic phase-cut dimmers. Lamp-flicker may also occur.

Laminated, open wire-wound transformers, and some electronic transformers, are most likely to be compatible with phase-cut dimmers. Most electronic transformers, though, require dimmers that are compatible with inductive loads.

7.2 Fluorescent lamps

Two-pin fluorescents and CFLi cannot be dimmed.

All tubular fluorescents and four-pin CFLs can be dimmed with specialist control gear, but not always to extinction. Most HF dimmable control gear will only allow dimming down to 1 per cent of full light output. Over most of the dimming range, the percentage energy savings roughly equates to the reduction in light output for electronic HF dimming, regulating and variable output control gear.

8 Glossary

Adaptation
The process which takes place as vision adjusts to the brightness or the colour of the visual field.

Ballast
A component of conventional control gear. It is an inductance which controls the current through the lamp. The term is sometimes used loosely to mean control gear.

Choke
Alternative name for ballast.

Colour rendering
An indicator of how accurately colours can be distinguished under different light sources. The colour rendering index (measured in Ra) compares the ability of different lights to render colours accurately with an Ra of 100 being 'ideal'.

Colour temperature
The colour temperature provides an indication of the light colour and is expressed in Kelvin (K). Most lamps are rated between 2700K (warm) and 6500K (daylight).

Connected load
The total load connected to the mains including lamp, control gear, transformers, etc.

Control gear
A 'package' of electrical or electronic components including ballast, power factor correction capacitor and starter. High frequency electronic control gear may include other components to allow dimming, etc.

Dedicated fitting/luminaire
A lighting outlet that will only accept an energy efficient lamp so preventing the use of less efficient lamps.

Diffuser
A translucent screen used to shield a light source, at the same time softening the light output and distributing it evenly.

Discharge lamp
A lamp whose illumination is produced by an electric discharge through a gas, a metal vapour or a mixture of gases and vapours.

Efficacy (luminous efficacy)
Strictly speaking, the term 'efficacy' compares two quantities with the same units e.g. Watts output to Watts input. However, light output is not normally measured in Watts (the Wattage ratings on lamps are measures of the electrical input or consumption), so it is actually correct to refer to a lamp's luminous efficacy – the ratio of the lumens (light) emitted by the lamp compared to the power consumed – which is expressed in 'lumens per Watt' (l/W). When the control gear losses are included it is expressed as lumens per circuit Watt.

Extra low voltage (ELV)
Refers to anything under 50V. Electrical engineers term 'mains' voltage as low voltage (50-1,000V) because they are used to dealing with voltage levels of 1,000V and above. (There is a further category, safety extra low voltage (SELV) which refers to supplies also under 50V but supplied through an isolating transformer.)

General lighting
Lighting of a whole area.

Illuminance
The amount of light falling on a surface of unit area. The unit of illuminance is the lux, equal to one lumen per square metre.

Lumen
Unit of luminous flux, used to describe the amount of light produced by a lamp or falling on a surface.

Luminaire
The correct term for a light fitting. An apparatus which controls the light from a lamp and includes all components for fixing and protecting the lamps, as well as connecting them to the supply.

Operating position
The orientation or plane in which a lamp is used. A lamp with a universal operating position can be used in any plane.

Power factor
The ratio of real power (Watts) to apparent power (volt-amps). The higher the power factor the better, 1 (unity) being the maximum.

Rated average lamp life
The time when half the number of lamps in a batch failed under test conditions.

Further information

The Energy Saving Trust sets energy efficiency standards that go beyond building regulations, for use in the design, construction and refurbishment of homes. These standards provide an integrated package of measures covering fabric, ventilation, heating, lighting and hot water systems for all aspects of new build and renovation. Free resources including best practice guides, training seminars, technical advice and online tools are available to help meet these standards.

The following publications may also be of interest:

- Domestic Lighting Innovations (CE80/ADH001)
- Low energy domestic lighting (GIL20)
- Low energy domestic lighting – looking good for less (CE81/GPCS441)

To obtain these publications or for more information, call 0845 120 7799, email bestpractice@est.org.uk or visit www.est.org.uk/housingbuildings

Relevant organisations and websites

BEAMA Installation Ltd
Tel 020 7793 3013 www.beamainstallation.org.uk

Electrical Contractors' Association
Tel 0207 313 4800 www.eca.co.uk

Lighting Association
Tel 01952 290905 www.lightingassociation.com

National Inspection Council for Electrical Installation Contracting (NICEIC)
Tel 0870 013 0391 www.niceic.org.uk

SELECT (previously The Electrical Contractors' Association of Scotland)
Tel 0131 445 5577 www.select.org.uk

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