energy saving trust®

The right light

Selecting low energy lighting

introduction for designers and house builders

Produced in association with

NHBC Foundation

Housing research & guidance

Contents

Acknowledgements

Energy Saving Trust is grateful to the NHBC Foundation for funding the development of this guide and providing support during its preparation.

Energy Saving Trust thanks PhotonStar LED Ltd for supplying much of the imagery used in this guide.

1. Welcome

To appreciate the recent advances in lighting, we should consider the historical perspective. Though there was a move towards the use of fluorescent light tubes in the 1960s, incandescent light bulbs remained our main source of domestic lighting for over 90 years. Standard solutions for lighting our homes became established with the typical 40, 60 or 100 watt incandescent lamps available, and any slight deficiencies in lighting were easily addressed with a higher wattage bulb or by investing in a multi-lamp fitting. Energy was cheap and we had little concern over the fact that our light bulbs were only 10% efficient, generating only a miserly dozen or so lumens of light per watt.

A very different attitude to lighting has emerged in the last few years. Partly driven by legislation, but also by a growing public appreciation of the role good lighting can play in improving their homes. Lighting has become a lifestyle statement. Homeowners are now looking for wall washes, spot-lit features, subtle accent lighting, clever use of colour temperature and colour rendition, and the ability to control lighting for different moods and activities. In addition they are increasingly aware of the environmental benefits, reduced lighting bills and flexibility that LED technology can provide.

Energy Saving Trust hopes 'The right light' will provide a useful starting point for designers and house builders who have not yet developed expertise in the use of low energy lighting, and want to prepare themselves for a future which will inevitably be dominated by LED technology. With increasing choice, covering a range of lighting characteristics, this guide makes a timely contribution to ensuring that LED product selection is as informed as possible.

Energy Saving Trust

2. Introduction

Historically, lighting has accounted for just under 3% of the annual overall energy use in homes, and was not viewed as a priority for energy efficiency measures or initiatives. Once the emphasis shifted to addressing carbon emissions, lighting, with its dependence on grid electricity (with relatively high emissions per kW generated) became a significant consideration for Government.

Since 2000, a number of drivers, including national and international legislation, together with standards, such as the Code for Sustainable Homes, have stimulated innovation in low energy lighting technology, and its adoption in new and existing homes. Compact fluorescent lamps (CFLs) and halogen incandescent lamps initially offered the main alternatives to traditional tungsten incandescent bulbs, which were phased out from 2009. However, it is LED (Light emitting diode) technology that seems set to truly revolutionise the energy efficiency of lighting.

With LED lighting, the speed and magnitude of change is quite remarkable. The traditional incandescent light bulb, which offered about 12 lumens per watt and a life of about 1,000 hours, can now be replaced by an LED lamp with an output exceeding 100 lumens per watt and potentially 35,000 hours of use or more. In addition, LEDs have been adapted to overcome their earlier limitations: they can now provide a range of colour temperatures to create ambience, many are fully dimmable and a range of beam angles are available to tailor light distribution. The critical change over the last eighteen months has been on affordability; good quality lamps are now available for under £6, often less than half the price they were a year ago.

In terms of running cost, research[1] has shown that in a typical home the fixed lighting alone accounts for round 15% of all electricity use (a figure which rises considerably if plug in lighting is also included). In new homes, despite the requirement to include a proportion of low energy lighting (with CFLs the predominant choice), any efficiency benefits may be offset by the greater number of light fittings used, particularly in kitchens and bathrooms. However, a switch to 100% LED lamps would significantly reduce electrical consumption for lighting, compared with the typical CFL/halogen solution. It is noted that some house builders are already aware of the benefits of LEDs, and are beginning to install them routinely.

1 Powering the nation. Household electricity-using habits revealed. Energy Saving Trust.2012

3. Low energy lighting – definition, compliance and safety

European perspective

Since 1998 there has been European guidance on the energy efficiency of lighting, initially through EU Commission Directive 98/11/EC. This established an energy efficiency rating scale for lamps (originally A to G) similar to that already introduced for electrical appliances such as refrigerators and washing machines. Initially, the term 'energy efficient' was applied to lamps which used less power (for a given light output) than the standard tungsten incandescent light bulb available at the time. Initially, products with only a marginal improvement over standard lamps (such as halogen incandescent lamps) were accepted as part of the product mix available for energy efficient lighting.

Subsequent European legislation which came into effect from 2009 has served to refine what is meant by energy efficient lighting, with tungsten incandescent lamps and most halogen lamps (all those with energy rating E and some in rating D) being excluded. In April 2015 the European Commission announced plans to increase these minimum efficiency requirements and current proposals are for a phase out of the majority of D rated halogen lamps from September 2018.

With the least efficient lighting now being phased out, new ratings (A+ and A++) were introduced at the top of the efficiency scale to recognise the high-end innovation in lamp technology. Figure 1 illustrates some of these changes and shows the range of performance for the main types of domestic lamps. It is now a legal requirement to display the rating scale on packaging for domestic lighting. Proposals to re-base the rating scale to establish new A to G ratings are currently being consulted on by the EU Commission.

Status	Energy Rating	Comparative energy use*
New European ratings from 2013, for highly efficient lamps	A++	Less than 11%
	A+	11 to 17%
	A	17 to 24%
	B	24 to 60%
	C	60 to 80%
To be phased out from 2018	D	80 to 95%
Products now **being phased out**	E	100%
These older European ratings now deleted E & F rated lamps now phased out for everyday domestic use	F	100 to 130%
	G	More than 130%

Ranges for lamp types

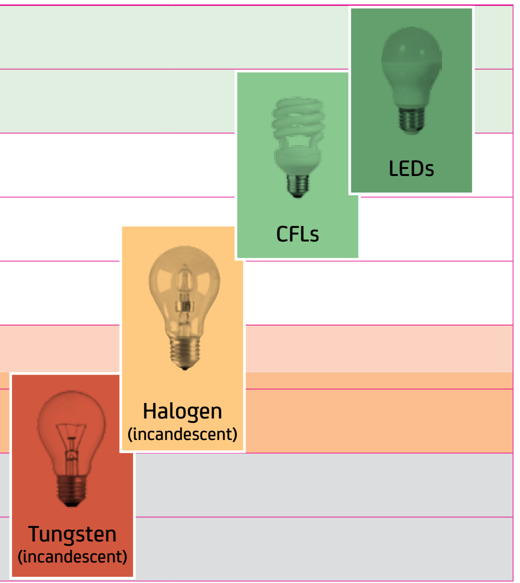


Figure 1 Understanding European energy ratings for lamps. This chart compares non-directional (bulb-like) lamps.
*Compared with the energy use of a typical tungsten incandescent bulb.

UK perspective

In England, low energy domestic lighting is defined in the Domestic Building Services Compliance Guide, which supports Part L1A of the Building Regulations. In summary, new homes, built to either 2010 or 2013 editions of Part L1A are required to have energy efficient lamps in a minimum of 75% of the interior light fittings. More detail on compliance to the English Building Regulations is shown below.

Meeting Building Regulations (England) Part L1A 2013

Summary of requirements for fixed lighting as set out in the Domestic Building Services Compliance Guide (England), together with explanatory notes

- **At least 75% of the interior light fittings must be fitted with low energy lamps.**
  Explanation: a light fitting may hold one lamp (e.g. a typical downlight) or several lamps (e.g. a chandelier).
  Exemption: when working out the 75%, exclude light fittings in cupboards, wardrobes and other similar places where light is needed rarely or for very short periods.
- **A low energy lamp must provide a minimum of 45 lumens per circuit watt.**
  Explanation: Only fluorescent lamps and LEDs achieve these levels. Halogen lamps don't qualify. A 'circuit watt' includes all electrical loading on the circuit including the lamp (it should not be confused with the efficacy of the lamp itself, expressed in lumens per watt, which will be a higher value).
- **Light fittings consuming less than 5 circuit watts are not counted towards the 75% target.**
  Explanation: This requirement was included to ensure that low wattage decorative lamps etc., were not included as part of the 75% low energy light fitting compliance in Part L. If using LEDs be aware that many LED products rated at around 5 watts are on the market: for these to be included within the 75% compliance figure, each lamp must exceed a minimum light output (see below).
- **Fittings must have an output greater than 400 lumens.**
  Explanation: Low output lamps (400 lumens or below) are considered to make a limited contribution to a home's lighting and cannot be counted towards the 75% low energy lighting target in Part L. Note that the 'over-400 lumens' target relates to the whole fitting (the luminaire). However for typical downlights, which are flush mounted on ceilings, the lumen output of the lamp itself can be used for compliance.

Energy Saving Trust
Selecting low energy lighting

- **One switch should operate no more than six light fittings with a maximum load of 100 circuit watts.**
  Explanation: this is unlikely to be a limitation if LED lamps are used. There might be some constraints if you are considering using higher output CFLs. Halogen lamps will considerably reduce flexibility for linking more than one fitting to a single light switch.
- **Lampholders may be dedicated or standard.**
  The Building Regulations no longer require dedicated lampholders/sockets for low energy lamps. Standard bayonet or Edison screw sockets are acceptable for all low energy lamps with integral control gear (like LEDs and CFLs). Pin fittings will still be required for linear fluorescent lamps and others with separate control gear.
- **For fixed external lighting there are two compliant options.**
  For energy efficient lamps (with efficacy above 45 lumens per circuit watt) automatic switch-off is needed when daylight is sufficient, but manual control of light fittings allowable.

  For less efficient lamps (up to 100 lamp watts per fitting) automatic controls are required for switch-off when daylight is sufficient and when the lit area is unoccupied.

These requirements are the minima that might be specified in a design to meet Part L1A. To comply with Part L1A, the design team may have put greater reliance on lighting in meeting the Design Emission Target (DER) of the home, and in practice the design may call for a higher (more energy efficient) specification than that shown above.

While the legal requirements for lighting are similar throughout the UK, each country has its own Building Regulations:

England The Building Regulations 2010 Conservation of Fuel and Power in new dwellings, Approved Document L1A. (2013 edition). See Domestic Building Services Compliance Guide for guidance.

Wales The Building Regulations 2010 Conservation of Fuel and Power, Approved Document L1A: New dwellings (2014 edition).

Scotland Building (Scottish) Regulations 2004, Technical Handbook – Domestic 2015 Section 6: Energy.

Northern Ireland Building Regulations 2012, Technical Booklet F: Conservation of Fuel and Power (October 2012).

Best Practice

Building Regulations set minimum standards of performance to be achieved. Careful selection of lighting can achieve better value for householders, and achieve lower carbon dioxide emission rates from lighting in design calculations. Today, good practice would be the adoption of low energy lighting lamps in 100% of a home's light fittings. Best practice would be a 100% adoption of high efficiency LED lighting with efficacy above 100 lumens per watt.

Safety standards

Specified lighting systems must be CE tested (European Conformity) with accompanying compliance documentation from credible sources.

EU safety and performance standards for LEDs are explained in the 2012 IEP publication: A Guide to the Specification of LED Lighting Products. Special care should be taken when installing downlighters (see below).

Notes on the installation of downlighters

When installing downlighters there are a number of practical considerations which should be considered:

Fire resistance

For ceilings, plasterboard normally provides part of the fire resistance of the home. If downlighters are to be installed in ceilings, they must not reduce fire resistance below that required in Building Regulations Approved Document B. It is important to ensure that the type of downlighter used has test evidence to support its use in a particular situation.

Overheating and thermal performance

Unless there is adequate air space around a downlighter, the lamp and surrounding air can overheat. Overheating will reduce the performance and life of lamps, and in the case of halogen lamps in particular, with their high operating temperatures, can result in a fire risk. Manufacturers provide guidance on the air space required around downlighter units, and maximum operating temperatures are included in the specifications for LED lamps.

Special care is needed where downlighters are to be installed in insulated ceilings at loft or roof level. Special supports are available to keep insulation a suitable distance away from downlighters installed at loft level. For rooms in the roof, keeping an air gap around downlighters will cause a cold bridge in the roof and the additional heat loss will need to be accounted for in thermal performance calculations.

Moisture control

If downlighters are to be used in bathrooms, showers or wet rooms it is important that they do not allow moist air to spread to other parts of the home, such as roof spaces, where condensation can occur. For rooms that generate moisture, select downlighters which provide a vapour seal.

4. Domestic lighting – available technology

This section introduces the main types of low energy lighting available for domestic use. Figure 2 gives an overview of equivalence between the three main lamp types available today, compared with the now obsolete tungsten incandescent lamps. Figure 3 shows how lamps have evolved over time and in particular the rapid improvements in efficiency achieved and projected for LED lamps. Many of the terms and performance characteristics included in this section are explained in more detail in Section 5 of this guide.

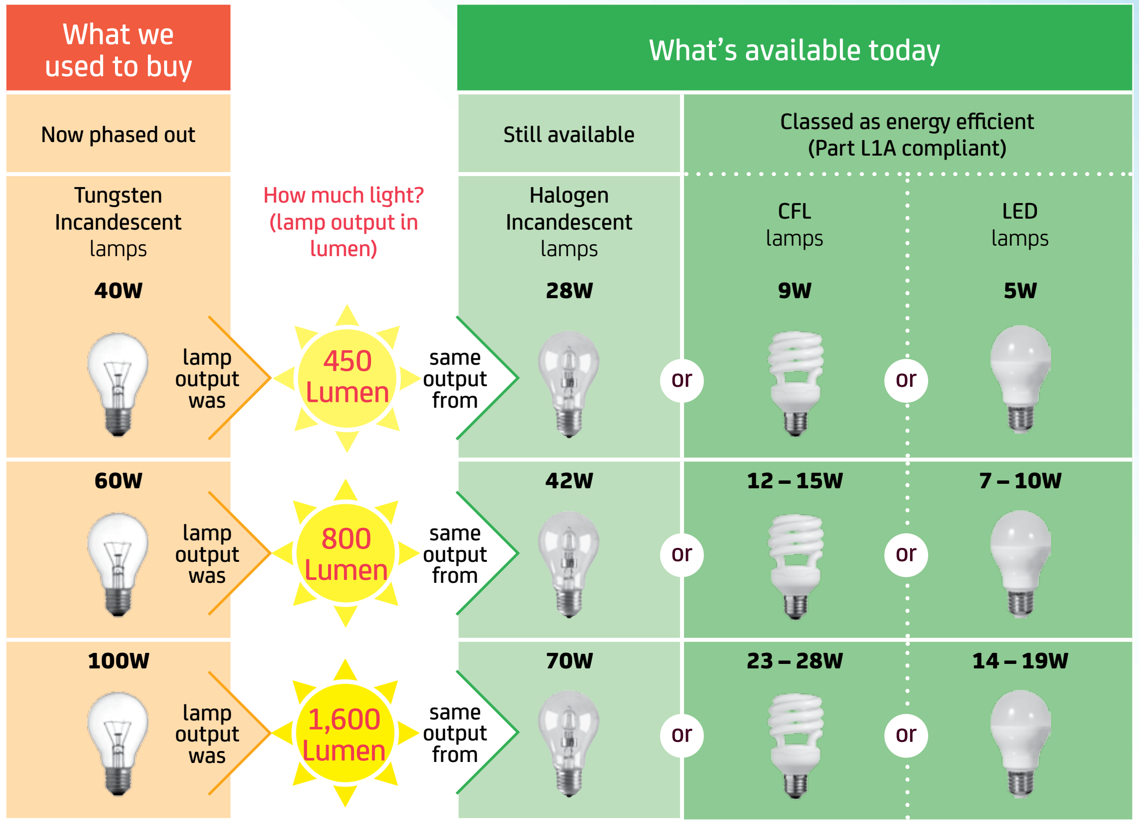


Figure 2 Compared with tungsten incandescent light bulbs, modern lamps, particularly CFLs and LEDs, require a fraction of the power to generate an equivalent level of light.

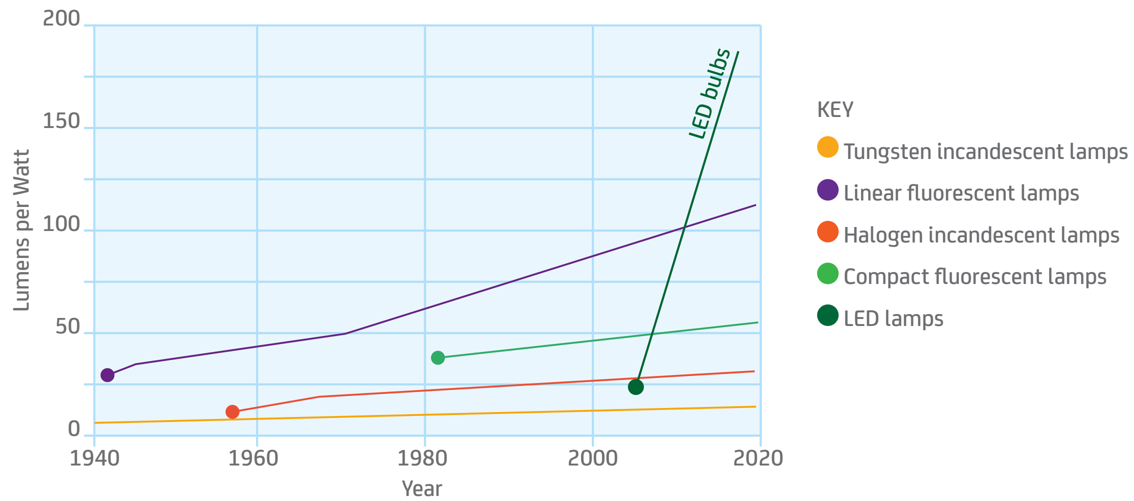


Figure 3 Domestic lighting – performance development over time.

Halogen lamps

Halogens are incandescent lamps using a filament suspended in a small amount of halogen (iodine or bromine) gas. They work at high temperature and can be more efficient than traditional tungsten incandescent bulbs. Halogen lamps produce an attractive bright white light, reach full lighting level immediately and can last from 1,000-3,000+ hours. Currently, they do not meet the 45 lumens/circuit watt requirement for low energy lighting in Part L1A of the Building Regulations. From 2018, even the most efficient halogen lamps will be phased out of producton.

Though halogens lamps have been used very commonly for downlighting, their high energy consumption and relatively short service life are now recognised disadvantages. Even the best halogen lamps have efficacy ratings and service lives which are well short of the performance offered by CFLs and LEDs. If considering halogen lamps, choose a product with the best possible service life (some offer 3,000 hours) and select energy class B.

Positives

- Low purchase price
- Colour temperature: good, although limited to around 3,000K
- Colour rendering: excellent (CDI near to 100)
- No warm up time
- Easily dimmable.

Negatives

- The best products are in energy efficiency rating B: halogens are therefore not classed as 'energy efficient' in Part L1A of the Building Regulations
- High running costs
- Short life: 2,000 hours typical
- Very high surface temperature.

Energy Saving Trust
Selecting low energy lighting

Fluorescent lighting

Inside a fluorescent lamp or tube an electrical charge is passed through mercury gas. This generates UV light, which then excites a phosphorescent coating on the inside of the tube to generate visible light.

A ballast is needed for fluorescent lighting to supply a suitable amount of current for startup: this can be incorporated into the bulb's design or can be an attachment on the light fitting.

Fluorescent lighting offers long service life and is very energy efficient, with most types complying with Part L1A requirements for low energy lighting. Though associated with cool light and slow start up times, advances in fluorescent lighting have led to a range of products which are satisfactory in many domestic situations. Fluorescent lamps are manufactured in two distinct types: linear fluorescent lamps (LFLs) and compact fluorescent lamps (CFLs).

Linear fluorescent lamps (LFLs)

LFLs are the familiar 'light tubes', which have been in common use from the 1960s. They typically produce very bright light. In domestic settings this has made LFLs popular for task lighting in kitchens (e.g. under cabinets), in home offices, utility rooms and bathrooms.

Unlike CFLs (see next page) LFLs do not have integrated ballasts, and require a dedicated fitting.

Positives

- Energy efficiency class A, and classed as 'energy efficient' in Part L1A of the Building Regulations
- Low running costs
- Long life: 20,000 hours+
- Range of colour temperatures: 2,700K-6,000K.
- Colour rendering: triphosphate or multiphosphate types – very good/excellent (CRI 80+)
- Warm up time very short
- Some can be dimmable but need special control gear.

Negatives

- Must have ballast/ control gear as part of the light fitting
- Contain mercury and must be disposed of carefully
- Colour rendering: halophosphate types – poor or moderate (up to CRI 69).

Compact fluorescent lighting (CFLs)

When incandescent bulbs were being phased out, CFLs were the most obvious replacement, offering potential savings of up to £50 over the lifetime of the lamp. CFLs are highly energy efficient (usually class A) and remain a good choice for areas requiring long periods of lighting, for example living rooms, however it is clear that LED alternatives are now offering even greater advantages. Earlier CFLs had inconveniently long warm up times before reaching a good level of light output, however this aspect of performance is less of a concern with newer CFL technology.

Both CFLs (and dedicated fittings for CFLs) are available in a wide range of sizes, shapes and colours. Some CFLs are suitable for dimming but require specialist, compatible control gear.

Some CFLs have glass that is bent or spiraled to achieve a more compact shape. There are also 'bulb' designs although these include a second layer of glass and are therefore less efficient, typically energy class B.

Positives

- Normally energy efficiency class A: rated as 'energy efficient' under Part L1A of the Building Regulations
- Low running costs
- Long life: 8,000-15,000 hours
- Wide range of colour temperature: 2,700K-6,000K
- Colour rendering: very good to excellent (some offering CRI 100)
- Some have integral control gear allowing dimming
- Some have minimal warm up time.

Negatives

- Short warm-up time needed in some products
- Contain mercury and must be disposed of carefully
- Some not suitable for dimming using pre-existing 'standard' domestic dimmer switches.

A note about mercury content

CFLs do contain small amounts of mercury but at legal limits – only 3-5 milligrams. Care should be taken when fluorescent light bulbs are broken however, with disposal carried out in line with manufacturer's recommendations.

The following characteristics are important when specifying CFLs:

- Minimum lamp lifetime of 10,000 hours
- Lumen maintenance of >76 per cent at 10,000 hours
- Colour rendering index not less than 80 CRI
- Power factor not less than 0.9
- Colour temperature of 2,700K
- Luminous efficacy >55 lumens per watt
- Minimum 35 per cent lumen output 2 seconds after switching on
- Minimum 80 per cent lumen output 60 seconds after switching on.

LEDs (Light emitting diodes)

In an LED lamp, an electrical current is passed across semiconductor material (usually silicon). As electrons migrate between charged atoms in the semiconductor, photons of light are released. LEDs, and the less well known OLEDs (organic light-emitting diodes) and PLEDs (polymer light-emitting diodes) are different categories of solid state lighting.

LED lighting is the most efficient type of lighting system currently available for domestic use. Technological advances, continuing cost reduction, rapid product innovation and diversity make it almost inevitable that LEDs will be the predominant form of lighting in the near future.

They are very efficient and many offer 80 to 100 lumens per watt, though note that some products may be only marginally more efficient that the best CFLs. In addition, they have very long lifetime expectancy (many offering 35,000 hour life or more).

LED lamps are now available for almost every domestic lighting purpose. Lamps are available that can be fitted into traditional pendant light fittings containing bayonet, cap or Edison screw lamp holders. Downlights, traditional bulb-shaped lamps, linear tube types and candle style lamps are all available.

It is recommended that only dedicated LED luminaires, dimmer switches and other control gear are specified for LED lamps. When using LEDs as replacements there can be operational issues associated with existing transformers and dimmer switches, and these should be replaced with LED-compatible electronics.

Summary guidance on selecting LEDs is given below, but Section 5 gives more detail about key selection criteria.

Positives

- Energy efficiency class A+: rated as 'energy efficient' under Part L1A of the Building Regulations
- Low running costs – significant lifetime cost savings
- Long lamp life: 30,000 hours or more predicted for many products
- Wide range of colour temperature 2,700-6,000K
- Good colour rendition available
- Minimal heat output
- Wide range of lumen outputs/ beam angles.

Negatives

- Higher purchase price (but prices falling rapidly)
- Variation in quality and performance
- For dimming, specific circuits and lamps must be specified.

The following characteristics are important when specifying LEDs:

- Lumen output
- Luminous efficacy (lumen output per watt of power used)
- Lumen maintenance and rated life
- Colour temperature (this may be expressed as a CCT measure)
- Colour rendering (CRI index)
- Operating temperature.

A comparison of today's main low energy lighting options

Table 1 (for individual lamps) and Figure 4 (for a typical home) highlight the benefits of specifying LED lighting. It is clear that halogen lighting is expensive to operate and lamps will need to be replaced frequently. CFLs offer a significant additional energy saving and will typically last for over 10 years. LEDs offer the dual benefit of very low energy consumption and a long lamp life of up to 30 years.

Cost per lamp: LEDs compared with CFLs and halogens. Table 1

	LED	CFL	Halogen
Watts (equivalent lamps)	6W	11W	35W
Purchase price per lamp	£6.00	£3.50	£2.00
Typical annual lamp use (hours)	1,000h	1,000h	1,000h
Typical lamp lifetime (in hours)	30,000h	10,000h	2,000h
Typical lamp lifetime (years)	30 years	10 years	2 years
Cost of lamp purchases over 30,000 hours/30 years	£6.00	£10.50	£30.00
Annual energy consumption per lamp	6kW	11kW	35kW
Annual electricity cost per lamp at 14.05/kW	£0.84	£1.55	£4.92
Total cost per lamp per year (averaged over a typical LED lamp life – 30 years)	**£1.04** per year	**£1.90** per year	**£5.92** per year

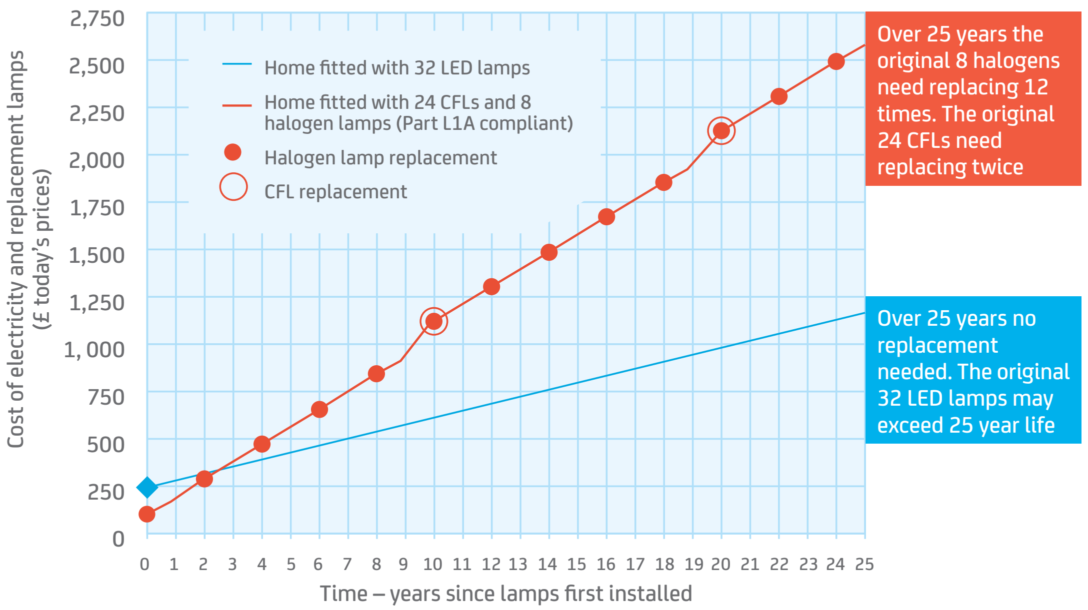
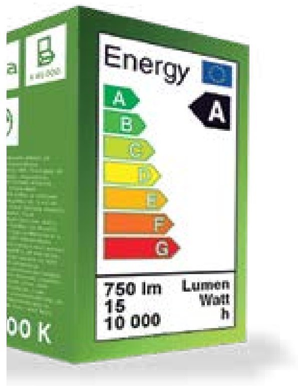


Figure 4 Cost of low energy lighting in a typical home with 32 lamps. Cumulative costs of 100% LED lighting compared with a Part L1A compliant solution (75% of fittings using CFLs and 25% of fittings using halogen lamps).

Replacement intervals: halogen = 2 years, CFL = 10 years, LED = 25 years+. Cost of electricity = 14.05p per kWh. Equivalent lamp output specifications. Single-lamp fittings throughout.

5. Considerations when selecting low energy lamps

Lighting is an important part of a home. Well-considered lighting saves energy, provides flexibility for creating the right ambience and will contribute to the well-being of occupants. The guidance below, which includes some special considerations when choosing LED lamps, will help to get the most out of electrical lighting and avoid some of the pitfalls in lamp selection.



Is the lamp energy efficient? Think in lumens, not watts

Low energy lamps must state their light output (lumen) and the power (watts) used to create that light. This enables selection on how efficient lamps are at generating light from electricity.

Innovation, particularly among LED manufacturers, is rapidly increasing the lumen output for each watt of power used (see Figure 3). Today, the most advanced LED lamps may achieve as much as 120 lumens per watt, far superior to the performance of tungsten incandescent lamps (which typically offered 12-14 lumens per watt) or CFLs (which might achieve 40-60 lumens per watt).

The number of lumens per watt (described as the efficacy of a lamp) is the key market differentiator in the low energy lighting market, and a key consideration for specifiers, or those choosing lamps for their own home. Efficacy varies significantly between different LED products, so always check this value before purchasing. Tests of LED lamps show that efficacy levels stated by manufacturers are generally achieved in practice.

A note about lamp recycling

CFLs and LED lamps should be recycled in an appropriate manner and not disposed of in household rubbish. In Europe the collection and recycling of CFLs and LED lamps is compulsory under the Waste Electrical and Electronic Equipment (WEEE) Directive. There are two main options for recycling lamps. The first is to take the lamps to a local council waste recycling centre, which will have dedicated receptacles for their disposal. Alternatively, an increasing number of 'Bulbstore' containers can be found located in the recycling areas of retail car parks and inside larger retail outlets.

Further information on lamp recycling can be found on the Recolight website **(http://www.recolight.co.uk)**, a recycling initiative set up by the lighting industry in 2005.

How much light? Don't confuse lumens and lux

The lumen rating printed on packaging tells you how much visible light a lamp generates (how bright it is as a source of light). As light leaves a lamp source, it spreads out and illuminates any surfaces it encounters. Illumination levels on surfaces (measured in lux) are highest near to the lamp but decrease rapidly as the distance from the lamp increases, as shown in Figure 5. A lux value is the amount of light (the number of lumens) illuminating a square metre of surface.

Lighting design aims to achieve target lux (illumination) levels on key surfaces – for example on floors, stairs and worktops. There are recommended lux levels for different rooms in a home and these are included in Section 6.

As Figure 5 shows, lumens and lux are not equivalent/interchangeable units and care is needed to ensure that lamps are capable of meeting a target lux level in homes. So for a floor illumination target of 150 lux, a seemingly 'generous' 220 lumen rating for a downlighter lamp (Figure 5b) does not meet the target (even though the lamp has a fairly narrow beam angle). In this case, a 320 lumen lamp is needed to achieve a typical target of 150+ lux for this kitchen floor (Figure 5a).

In the examples shown in Figure 5, the lamps are flush fitting and have no additional luminaire lenses or diffusers – in such cases the lumen rating of the lamp can be used to calculate lux levels. Where lamps are fitted within luminaires with additional transparent covers or diffusers (and any situation where a lamp shade is required), it is important to consider the lumen output from the fitting, not just the lamp.

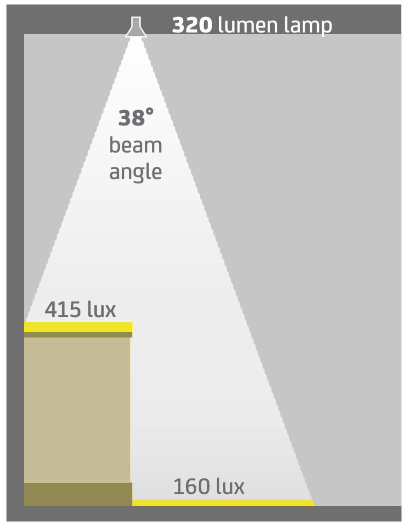


Figure 5a

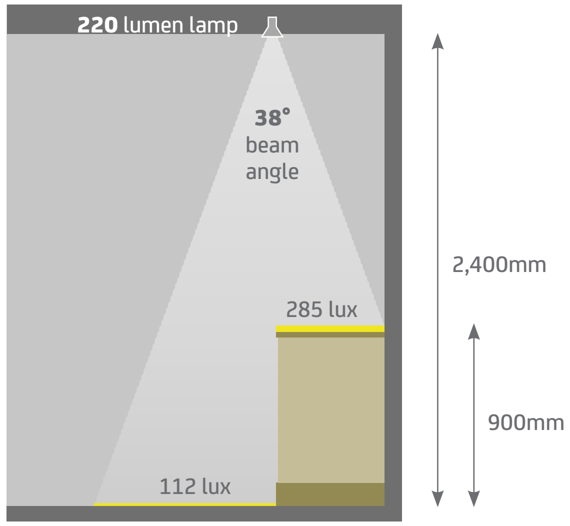


Figure 5b

Figure 5 Lumen and lux should not be confused. The light output of a lamp is measured in Lumen. Illumination levels of surfaces (in lux) are dependent on the lumen output of the lamp, but distance from the lamp and the beam angle (how much the lamp concentrates its light) have to be taken into account.

Importance of beam angle – concentrated or diffuse light

Beam angle is an important characteristic in lamp choice, particularly for downlighting. With traditional tungsten and halogen incandescent bulbs, light emerges in most directions and is not 'directional' (Figure 6). A feature of LEDs and downlighter lamps is that they are 'directional' and concentrate most of their light output within a specified beam angle. Even 'bulb' shaped LEDs have a beam angle, typically between 110º and 160º and, compared with an incandescent light bulb, more of the light they generate is emitted in a useful direction.

For a given lumen output, an increase in beam angle dramatically reduces the lux levels achieved on surfaces (Figure 7). Also note how narrower beam angles can result in surprisingly high lux levels on surfaces relatively near to a lamp (Figure 5).

For downlights, a beam angle of 38º or more is normally sufficient for general lighting, however achieving the right balance between beam angle and lumen output is crucial to avoid surfaces being poorly illuminated, unevenly lit or possibly over-lit.

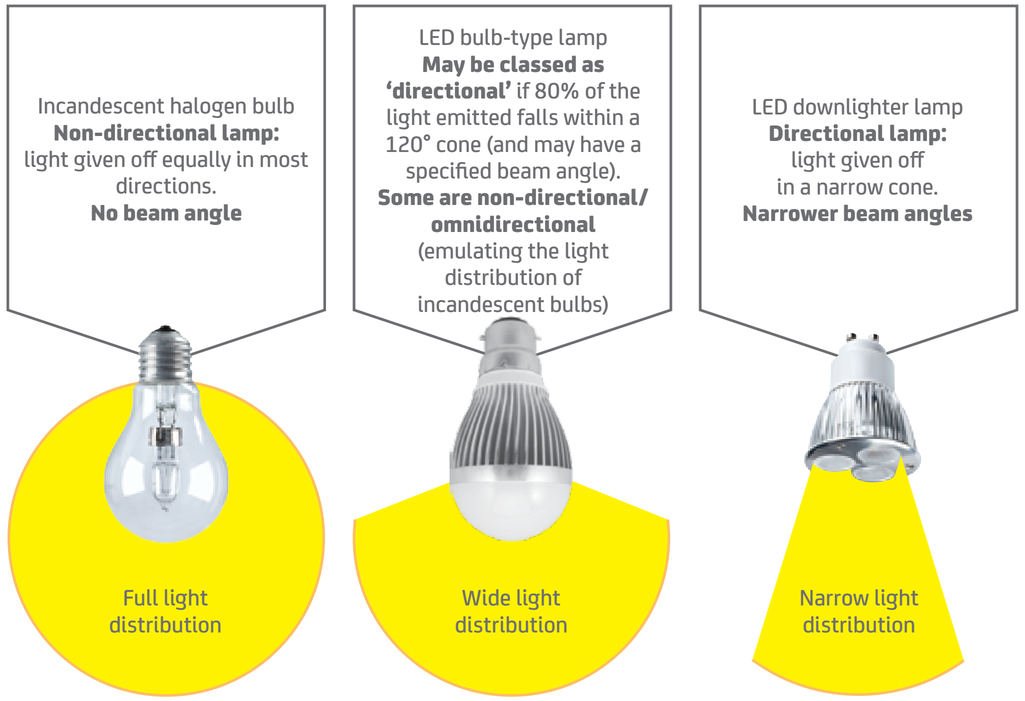


Figure 6 Distinguishing non-directional and directional lamps. Beam angle is a feature of many types of LED lamps, not just downlighter lamps.

Figure 8 illustrates the lux levels delivered by a variety of lamp specifications in an example kitchen space (with a minimum illumination target of 150 lux for the floor). A variety of solutions work well, but some may be impractical or unsuitable. Note that for the higher beam angles (90° and 110°) each lamp illuminates the whole area and their individual lux contributions can be added together to achieve the 150 lux target. For example, four lamps, each delivering 40 lux across the whole floor, provide 160 lux overall. In this example the 90° beam angle lamps will need to be concentrated centrally over the floor area. In all cases the inclusion of different configurations of downlighters should not reduce the fire resistance of the ceiling: this should be checked with the downlighter manufacturer.

Beam angle is also important in creating the right level of task lighting and accent lighting in rooms. If the incorrect lamps are fitted in the wrong positions the necessary task lighting or the desired effect from the lighting may not be achieved.

In practice, the recommended levels for lux in Section 6 should be relatively easy to achieve with domestic lighting. A number of websites offer lumen to lux, and lux to lumen conversions for different beam angles and varying distance between light source and target surfaces. They also allow you to calculate the light coverage (m^2) and spread (m). A rule of thumb is to ensure that the edges of the spread meet, but do not fall short (creating dull areas) or overlap (creating areas that are too bright).

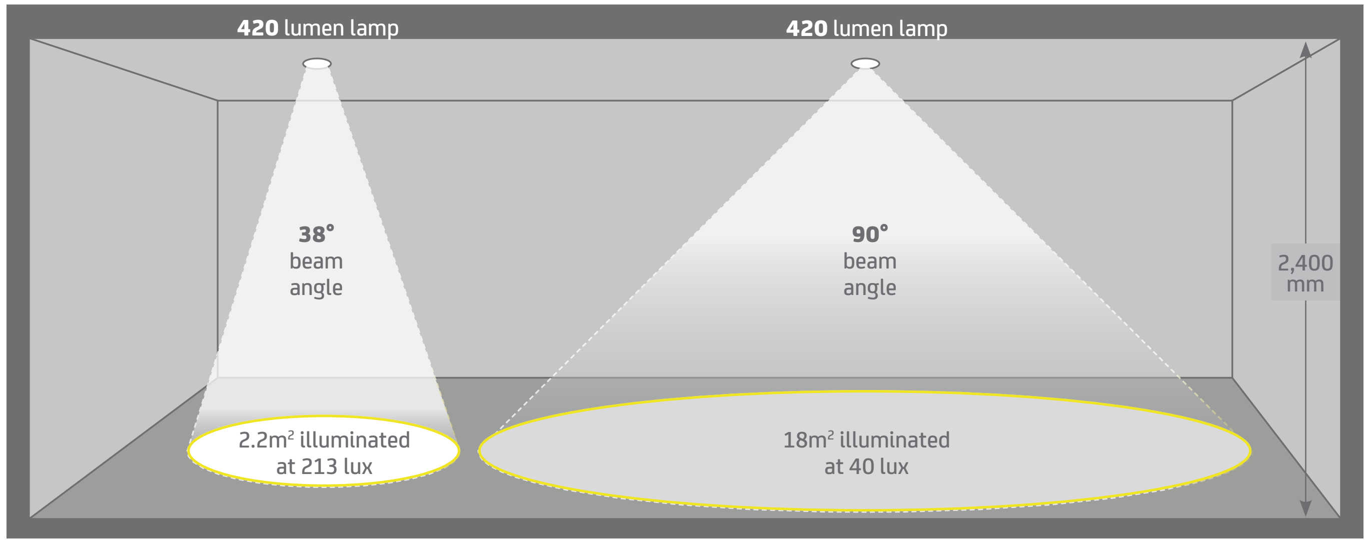


Figure 7 Importance of beam angle. These two low-energy lamps (with the same lumen output) generate a quite different illumination level (lux) and light coverage area (m^2) at floor level.

Energy Saving Trust
Selecting low energy lighting

	Beam Angle			
	38° (each lamp illuminates only about 15% of the kitchen floor)	**45°** (each lamp illuminates only about 25% of the kitchen floor)	**90°** (each lamp illuminates 100% of the kitchen floor)	**110°** (each lamp illuminates 100% of the kitchen floor)
220 lumen lamps (note: this lumen output is too low to qualify as low energy lighting in Part L)	1 lamp provides **111 lux** at floor level; To meet at least **150 lux**, **18** of these lamps are needed	1 lamp provides **80 lux** at floor level; To meet at least **150 lux**, **8** of these lamps are needed	1 lamp provides **21 lux** at floor level; To meet at least **150 lux**, **8** of these lamps are needed	1 lamp provides **14 lux** at floor level; To meet at least **150 lux**, **11** of these lamps are needed
420 lumen lamps	1 lamp provides **213 lux** at floor level; To meet at least **150 lux**, **9** of these lamps are needed	1 lamp provides **153 lux** at floor level; To meet at least **150 lux**, **4** of these lamps are needed	1 lamp provides **40 lux** at floor level; To meet at least **150 lux**, **4** of these lamps are needed	1 lamp provides **27 lux** at floor level; To meet at least **150 lux**, **6** of these lamps are needed
625 lumen lamps (close to the maximum currently available for downlighter lamps)	1 lamp provides **317 lux** at floor level; To meet at least **150 lux**, **9** of these lamps are needed	1 lamp provides **227 lux** at floor level; To meet at least **150 lux**, **4** of these lamps are needed	1 lamp provides **59 lux** at floor level; To meet at least **150 lux**, **3** of these lamps are needed	1 lamp provides **41 lux** at floor level; To meet at least **150 lux**, **4** of these lamps are needed

Figure 8 How many downlighters in a 4x4m kitchen? As the chart shows, it depends on the lumen output and beam angle of the lamps selected. Green choices may be the most economic, orange choices are intermediate and red choices may be uneconomic/impractical. The purple options will result in floor illumination levels that may be too bright for some people.

This example is for a 4x4m kitchen with a 2.4m ceiling height and worktops with their own task lighting on two walls. A design illumination level of 150+ lux has been selected for the floor.

Colour temperature – warm or cool effect?

Initially many low energy lamps, particularly LEDs, produced light with cooler colour temperatures – too stark for many uses in the home. But today low energy lamps are available which produce comfortable warm white light, similar to that produced by tungsten incandescent lamps. Figure 9 shows the colour temperature scale used in lighting design. It is based on the colour profile of light emitted from an increasingly hot filament. A reference point is the 'warm white' light generated by a traditional tungsten incandescent lamp, with a colour temperature of 2,800K.

For all uses in the home, warm white lamps (close to 2,800K) are normally the most suitable, though in kitchens and bathrooms, colour temperatures of around 3,000K may be preferred by some people.

Non-incandescent lamps have to be tested for alignment with the colour temperature scale: they have what is termed a 'correlated colour temperature' (CCT). While they may match a point on the colour temperature scale, they achieve this with spectral characteristics that are different from daylight, and this may affect the ability of a lamp to illuminate colours well. For this reason, fluorescent and LED lamps are also rated for 'colour rendering'.

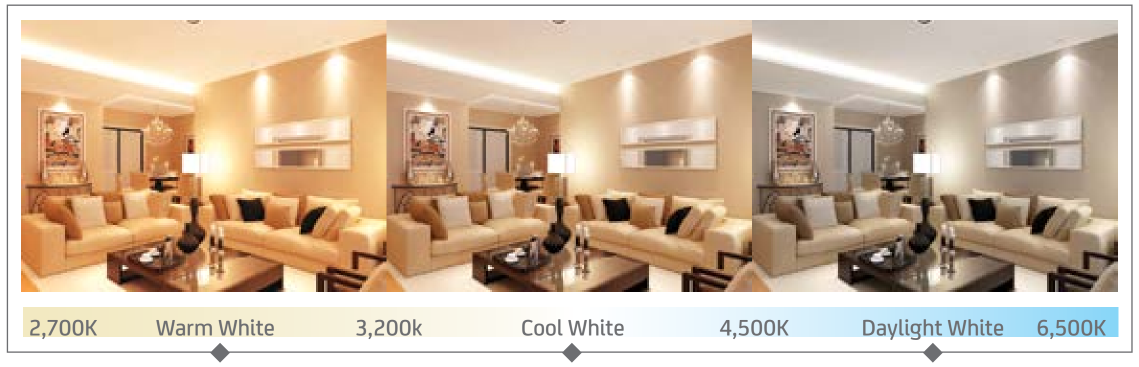


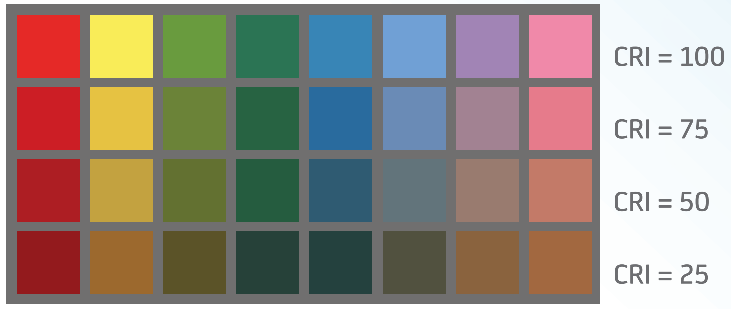
Figure 9 The standard international colour temperature scale
Image from www.lightingever.co.uk

Colour rendering – bright or dull colours?

Colour rendering is a measure of how natural the colours of surfaces appear. It is expressed by a colour rendering index (CRI) up to 100, see Figure 10. As tungsten incandescent lamps generated a full spectrum of visible light colour, and like daylight, have a CRI of 100, good colour rendering could be taken for granted. However, low energy lamps do not all provide the required level of colour rendering and this is an important consideration in their choice. For most domestic purposes a CRI of 80 or more is considered adequate, however a CRI above 85 may be preferable for some activities in the home or if you want to ensure vibrant, natural colours from low energy lamps.

Colour rendering has been a critical performance consideration for manufacturers of linear and compact fluorescent lamps and high CRI values of 90-95 are available. Though a weakness with early LEDs, many now offer good or excellent colour rendering and CRI values are included on packaging or manufacturers' specifications. CRI is an important characteristic of domestic lighting and it is worth comparing samples from different manufacturers.

Figure 10 Good colour rendering brings out the vibrancy of colours in a home. As the colour rendering index (CRI) approaches 100, colours appear more natural.



Lumen maintenance – will lamps stay bright?

Lumen maintenance is concerned with how long a lamp retains its lumen output. It was not an issue for incandescent lamps because these typically failed suddenly before there was any noticeable deterioration in light output. For a long-lasting lamp it's crucial to know how well it sustains its claimed lumen output. Indeed for LEDs (which are more likely to fade than to fail completely) a drop in lumen output below a particular level marks the end of the lamp's life (see rated life, below).

LED testing methodology is evolving. Currently lumen maintenance is being estimated by many manufacturers from tests running for 6,000 hours. Their estimates of lamp life are based on the expected deterioration of the semiconductor within the LED and this enables them to offer lumen maintenance projections in technical specifications.
A lamp might be described as having:
More than 90% lumen maintenance by 50% of lamps at 35,000 hours.

This means that 50% of this batch of lamps is expected to maintain 90% (or more) of the original lumen output after 35,000 hours of use. More accurate indications of lumen maintenance will become available in future years, but in the meantime it is recommended that lamps with the highest levels of lumen maintenance (i.e. 90% or more) are selected for domestic use. Lumen maintenance is one of the most important performance measures for LED lighting and ideally you should ensure that manufacturers' claims are backed by independent test data. Most manufacturers provide lumen maintenance figures in their technical specifications and these may be coded as below. For illustrative purposes the decline in output for a 420 lumen lamp is shown for each code rating in Table 2.

Lumen maintenance: What the lumen maintenance codes mean in practice. Table 2

Lumen maintenance (%)	Code	Lumen maintenance for an example lamp, initially rated at 420 Lumens:
>90	9	Steady decline to ≈378 lumens during life*
>80	8	Steady decline to ≈336 lumens during life*
>70	7	Steady decline to ≈294 lumens during life*
		* Figures above show likely average decline for a lamp manufactured to a particular Lumen Maintenance Code.

Rated life of LEDs – how long should they last

'Rated life' indicates how many hours of use you can expect from a lamp. So an LED product with a rated life of 30,000 hours, used for a typical 1,000 hours a year, could last for 30 years. Note however that at 30 years, 50% of this particular product will be functioning below its lumen maintenance threshold, including some that may have failed completely. The lumen maintenance value (or code), see above, tells you how serious the light depreciation could be for a particular product. Always view rated life and lumen maintenance values together.

The life of an LED lamp is determined by a range of factors related to proper installation and use. When selecting LEDs, check that there are no limitations or conditions on the warranty that conflict with the intended installation of a particular product. Some manufacturers have strict conditions to qualify for their warranties. These may include limits to total number of annual operating hours and maintenance considerations. You should check that the warranty applies to all parts of a lamp, including the integral drivers, which may be less durable than the light emitting diodes themselves.

Operating temperature – don't let them overheat

LEDs generate far less heat than incandescent lamps, however about 50% of energy used by an LED may be converted into heat. To avoid overheating of the semiconductor material and to operate efficiently, LEDs have integral heat sinks. However, it is important that the air temperature around an LED should be within limits specified by the manufacturer.

These vary and you should seek advice when LEDs are to be recessed or incorporated in places where there is limited air flow. Often a maximum ambient air temperature of 40°C is specified and this can easily be exceeded if LEDs are inappropriately installed. Special care should be taken when downlighters are recessed into insulated ceilings (see page 06).

Drive current – don't overload

For proper operation of LEDs, the power supply and internal electronics must provide a well-controlled DC drive current. Drive current affects LED operating temperature and thus its lifetime and light output. Normally, products quoting a drive current of 350mA are suitable for homes, although the values can be higher. The higher an LED is driven the brighter it will be but this may impact on lifetime and efficiency, and all controls (particularly dimmer switches) must be rated appropriately for the fittings being used. If replacing existing lamps with LEDs, dimmer switches will need to be replaced with suitable products or de-rated.

Cost – Homeowners' perspective

Until recently, the upfront cost of purchasing LED lamps has been a major barrier to wide-scale use. For homeowners, however, the recent price reductions, coupled with greater awareness of the other advantages of LED lighting has changed the picture quite dramatically. LED lighting is increasingly seen by the public as the technology of choice, and many people are investing in them. Although initial outlay might be a little more than other lighting options (Figure 4), LED lamps soon generate financial savings for homeowners because of their very low use of energy.

House builders' perspective

While LEDs remain more expensive to purchase than CFLs, and while the Part L requirements allow CFLs as part of compliance, house builders have no direct financial incentive to install LED lamps. Some house builders however are offering LEDs as an option for home buyers who request them, and some are offering them as standard. The current downward trajectory for LED lamp prices, if it continues, will soon see very little differentiation between the price of LEDs and CFLs and at that point it seems likely that the majority of house builders will switch and join those who have already started to adopt LEDs.

Specifying good quality LEDs

Due to rapid developments in LED lighting over recent years, many lighting manufacturers inexperienced in the production of quality LEDs have introduced products to the market. Product quality can vary significantly. Good quality products, which meet the criteria suggested in this guide, can be selected by ensuring that all appropriate conformity and testing documentation is in order. This should be freely available from the manufacturer. Ideally, manufacturers' claims should be backed by independent test data.

If manufacturers' own test data is supplied, it is recommended that they also supply evidence that confirms their test facility is operated under an appropriate quality assurance regime, accredited to ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories. Accreditation to this standard should be awarded by an accrediting body that operates within the charter established by the International Laboratory Accreditation Cooperation (ILAC). In the UK this is the United Kingdom Accreditation Service (UKAS).

It is important to evaluate manufacturers' claims on a consistent basis – so when requesting LED performance specifications always ask for data that has been measured in compliance with the latest IEC/PAS documents.

6. Lighting guidance for the home

Careful design of electric lighting will ensure that the right amount of light can be switched on conveniently where and when it is needed. It avoids any over-lit areas, and gives control and flexibility to create lighting effects for different situations. Well-designed lighting will be inherently easier to use and more likely to be operated in an energy-efficient way.

Overall approach – three levels of lighting

General lighting
should provide satisfactory minimal lighting levels in rooms. Decide on the target illuminance levels required (lux). In living rooms and bedrooms, in particular, allow some flexibility (through control settings/dimmers) so that occupants can raise or lower the general lighting around the target level. Design to the higher end of lux ranges in homes intended for older people, who generally appreciate higher levels of general lighting. A minimal level of general lighting is required for safe movement around the home, particularly on stairs, but sufficient general light is considered to be important for general well-being.

Task lighting
is needed for specific activities within the home such as reading, food preparation and home working. Lamps must be carefully selected, correctly positioned and controlled. Lamps or socket outlets are needed in the right places to give flexibility in the availability of task and accent lighting. Task lighting may be needed at different levels, depending on the task. Also, colour rendering of the light is very significant for some activities.

Accent lighting
contributes to the ambience of a home. As with task lighting lamps (or socket outlets) are needed in the right places to emphasise architectural features, furniture and ornaments. Accent lighting is a more personal consideration, with spotlight through to flood light effects being appropriate depending on circumstances.

For each of these levels of lighting, controls can provide a range of lighting options. So in a kitchen there could be separate controlled circuits for:

- general lighting (typically ceiling downlighters)
- task lighting (typically positioned under the wall units) and
- any accent lighting (for example inside units or around pelmets).

Similar patterns of control can be considered in other rooms, with dimmers providing a range of lighting ambience in lounges, dining rooms and bedrooms. Advanced controls, sometimes controlled by a mobile phone or tablet 'app', which allow remote adjustment of the amount of light and its colour are now emerging. Lighting is becoming established as a lifestyle statement and homes which incorporate new and innovative lighting systems are perceived to have a marketing advantage.

External lighting

The selection of external lighting will largely depend upon its purpose and the way it is to be used. Where lighting is required in the garden, for example to light a path while it is in use, LED products are ideal.

Building Regulations require external lighting products to include a photocell (to stop the light being used in daylight). With less efficient lamps, the Building Regulations require that the external lamp is controlled by a presence detector, to switch off the lamp when no-one is in the illuminated area. With low energy lamps, the regulations are more relaxed, and allow manual control of the lighting.

In recent years considerable levels of light pollution have been generated by high powered incandescent external floodlighting, typically in the 200-400W range. These are expensive to run and provide far more light than required. In domestic settings a 150W lamp is generally sufficient but best practice would involve specifying an LED floodlight, where a 20-30W product should be sufficient.

Individual rooms

Hallways

Flush ceiling fittings can maximise headroom in what is often a small area and downlighting is often the most appropriate solution. Since hallways are often lit for long periods, the use of LED lighting will maximise energy savings. A lux level of between 100-150 is recommended at floor level.

Stairs and landings

As in the case of hallways, flush fittings are useful when headroom is limited. To provide adequate lighting stairs may require luminaires either along them, above them, or in close proximity on the landing. To avoid falls on stairs, lighting should be operated by two-way switching situated at both the top and the bottom of flights.

Lighting should be positioned to ensure that stairs are easily visible (by providing contrast in lighting between treads and risers). Ideal colour temperature for lighting on stairs and landings is around 3,000K and lighting for stair treads should be at least 100 lux. Lighting on stairs and landings (including daylight as well as artificial light) should be designed to minimise glare.

Elderly and partially-sighted people need enhanced lighting

If you are developing a lighting scheme for older people use the higher end of lux ranges recommended in this section and consider providing a greater number of point light sources for activities. Seek specialist advice (see further information) if you are making lighting provision for partially-sighted occupants in line with manufacturer's recommendations.

Living rooms

Living rooms need a relaxed atmosphere and some flexibility in lighting level and the position of lighting. Controls should ensure that living room floor illumination can be set at around 100-150 lux with the flexibility to be reduced to subdued levels of around 60 lux. This may require a variety of light sources. Avoiding glare is also important and wall-mounted uplighters can meet this need.

The living room's long hours of use will mean that LED lighting will achieve significant energy and cost savings, even when compared to CFLs. 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.

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. There are many LED products that lend themselves well to creating this 'wash' effect, that provides comfortable indirect lighting.

Lighting specified in dining rooms should have a colour temperature within the limits of 2,700K-3,000K, and provide about 150 lux at floor level. In many homes, dining room tables, are used for variety of activities as well as dining. For this reason some flexibility in lighting for the dining table top is recommended: it should be possible to provide flexibility for dining between 150 and 200 lux, and between 400 and 500 lux for situations when the table is used for other tasks, such as homework and hobbies. Dining room lighting should have excellent colour rendering.

Kitchens
The detailed tasks being carried out in kitchens require high levels of lighting, particularly as sharp tools will be in use. For kitchen floors, appropriate illuminance levels are 150-200 lux for floors and around 400 lux at worktop, hob and sink levels (downlights placed under units can achieve these levels and, if the kitchen is centrally-lit, prevent people having to work in their own shadows).

Bedrooms
Bright central light sources, while providing good general light levels, can create glare. This can be reduced by directing light onto the wall surfaces. Providing a separate circuit specifically for bedside lighting, with lighting socket outlets and two-way switching will help ensure lights are not left on unnecessarily. Lighting levels in bedrooms should be controllable, with flexibility to provide subdued levels of 60 -100 lux at floor level and a maximum of about 150 lux. There should be provision of good task lighting for activities such as reading, offering localised illumination of up to 400 lux. Good colour rendering is an important consideration in bedrooms to help in the choice of clothes for example.

Colour temperature

In the past for rooms that used to have a functional use, such as kitchens and bathrooms, it was considered right to have cooler colour temperatures in the region of 3,000 to 3,500K. This may still be suitable for some internal designs, and be favoured by some householders. However for modern living the trend is to provide lighting within the 'warm white' light range 2,700-3,000K throughout the home.

Energy Saving Trust
Selecting low energy lighting

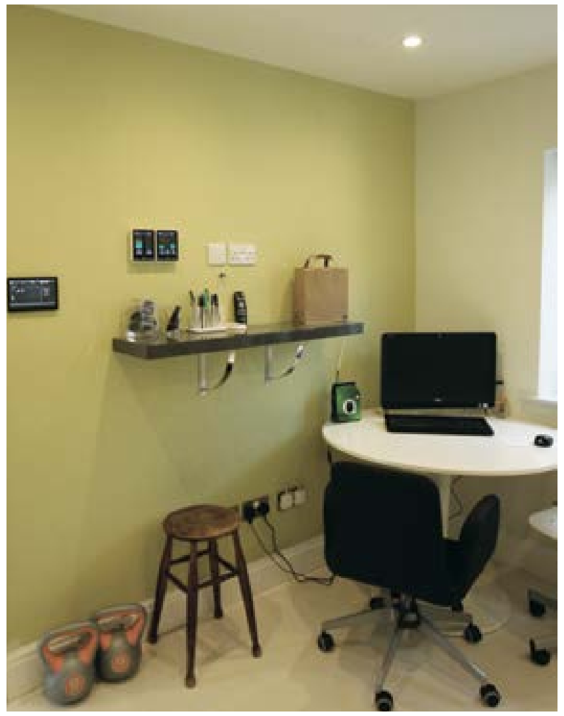
Bathrooms
Although bathrooms are not lit for long periods, the use of low energy long-life LED lighting can be particularly appropriate for enclosed fittings where lamps may be difficult to replace. LED downlights are particularly suitable for bathroom lighting where they can be positioned to provide lighting where it is needed, for example over the bath and shower. Aim for good task lighting levels around bathroom mirrors and illumination levels of 250-300 lux for bathroom floors.

When specifying bathroom lighting, take care to check how far from a water source it can be fitted. A bathroom is divided into zones 0 to 3 and bathroom lighting is marked with the zone in which it can be used.

It is recommended that general bathroom lighting and task lighting (eg lighting for mirrors) are on separate circuits.

Studies and home offices
Harsh lighting can create glare on computer screens and paper-covered desks. This can be avoided by arranging diffuse background lighting. Dedicated wall uplighters can be used to create a general wash of light. Task lighting can be provided by using portable lamps and there is an increasing range of LED desk lamps on the market.

Studies and home offices require good levels of lighting with between 400 and 500 lux for task lighting on desks. If more intricate work is being undertaken, aim for 750 lux.



7. Information sources

Relevant organisations and websites

Lighting Industry Association
www.thelia.org.uk
Tel: 01952 290905

Energy Saving Trust
www.energysavingtrust.org.uk
Tel: 020 7222 0101

Institute of Engineering and Technology
http://www.theiet.org/
Tel: 01438 313 311

Institute of Lighting Professionals
www.theilp.org.uk
Tel: 01788 5764925

Electrical Contractors' Association
www.eca.co.uk
Tel: 020 7313 4800

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

SELECT (Scotland's Trade association for the electrical industry)
www.select.org.uk
Tel: 0131 445 5577

LIGHTINGEUROPE
http://www.lightingeurope.org/home

Recolight
http://www.recolight.co.uk/

Building Regulations (England)
http://www.planningportal.gov.uk/buildingregulations/approveddocuments/partl/

Thomas Pocklington Trust Guide – design guide for developing housing for people with sight loss.
http://www.pocklington-trust.org.uk/researchandknowledge/lighting/professionals/design-guide.html

PremiumLight

The PremiumLight programme is a good place to begin when specifying CFL and LED lighting. The project has carried out laboratory testing of a variety of light bulbs across the EU to showcase the best performing products on the market, providing direction and assurance on the best quality product available.
http://www.premiumlight.eu/

Index

Energy Saving Trust
21 Dartmouth Street
London, SW1H 9BP
Advice line: 0845 602 1425
Email: certification@est.org.uk

energysavingtrust.org.uk