

A Guide to Energy Efficient and Cost Effective Lighting

This guide provides information on how specifiers and designers can improve the quality and cost effectiveness of lighting schemes through the use of energy efficient lighting technologies.



INTRODUCTION

An energy effective lighting installation is energy efficient while at the same time delivers the necessary lighting requirements for a particular application. It is also low maintenance and leads to reduced operating costs. This Guide illustrates how energy effective lighting can be achieved by following a step by step design process. It is a practical checklist for those involved in specifying lighting for most applications.

The steps are presented as a number of individual 'Lighting Criteria' that need to be considered. An energy effective design solution will balance all of these lighting criteria against the requirements of the area or space to be illuminated.

The criteria to be considered are summarised below with further details, applications and illustrations given on the following pages.

LIGHTING CRITERIA – SUMMARY

STEP 1 – CONSIDER THE EFFICIENCY OF THE LIGHT SOURCE

Choose the most efficient light source that can deliver the desired lighting characteristics required for the application. While the efficiency of the light source is a key component of an energy effective lighting solution, it is only one of a number of selection criteria. Take a low pressure sodium lamp as an example, it is a very efficient light source but its poor colour rendering characteristics make it unsuitable for most applications.

STEP 2 – CONSIDER COLOUR APPEARANCE

Decide the colour of 'white light' that best suits the application. This is referred to as colour appearance and can be different for each type of lamp or can vary among models of the same lamp type. Choosing the most appropriate colour 'white' can enhance the objects being lit or the ambience of the space. For instance, the lighting in a doctor's waiting area should use a colour of 'white' that is 'warm' so that people feel comfortable.

STEP 3 – CONSIDER COLOUR RENDERING

Lamps can be good or bad at rendering or reproducing colours. Define the quality of colour reproduction required. Low pressure sodium is particularly poor at reproducing colours but its efficiency makes it very suitable for street lighting where reproduction of colour is not of primary importance.

STEP 4 – CONSIDER LAMP LIFE

Try to choose a lamp with the maximum life expectancy. Expected lamp life may vary on individual lamp types as well as between different lamp types. It is always cost-effective to purchase the longest-life lamp available for a particular lamp type even if it costs a little more.

STEP 5 – CONSIDER LUMINAIRE EFFICIENCY

This is provided by all reputable manufacturers in their technical descriptions and is referred to as the Light Output Ratio (LOR) of the luminaire (light fitting). LOR is the ratio of the light output of a luminaire to the total light output of the individual lamp it contains. Choose the luminaire with the greatest light output.

STEP 6 – CONSIDER LIGHT DISTRIBUTION

Choose a wide or narrow light distribution pattern depending on the application. An office normally requires wide and even light distribution with good uniformity, whereas a narrow distribution suits warehouse aisles.

STEP 7 – CONSIDER LUMINAIRE POSITION AND MAINTENANCE

Ensure that the luminaires are mounted to provide effective illumination and are in accessible locations without the necessity of hiring or buying special equipment to maintain them. The luminaires should be easy to clean and lamps should be easily accessible for replacement.

STEP 8 – CONSIDER CONTROLS AND USE OF DAYLIGHT

Lighting controls should provide the right quantity of light as and when required. Lighting can be controlled by time, occupancy and daylight availability. There are a number of ways to add controls to existing lighting installations and opportunities to maximise the use of daylight in buildings.

LIGHTING CRITERIA – TECHNICAL DETAILS

STEP 1 – EFFICIENCY OF THE LIGHT SOURCE (Lm/W)

Lumen efficacy is defined as the ratio of light emitted by a light source to the power consumed by the light source, including power consumed by any auxiliary control gear (Lumens provided per Watt consumed).

The higher the lumen efficacy, the more efficient the source is at producing light. Table 1 (page 5), Lamp Comparison Table, gives the efficacies of a range of different lamp types.

STEP 2 – COLOUR APPEARANCE (K)

Colour appearance defines a lamp's 'whiteness' which is either 'blueish' (cool) or 'redish' (warm) in appearance. The 'whiteness' of different lamp types varies from 1,800 Kelvin (very warm, amber) to 8,000 Kelvin (very cool). There are many colours of 'white' available in the popular ranges of lamps for general use, these are:

- a warm colour 'white' (2,600 to 2,700 K)
- a medium colour 'white' (3,000 to 3,500 K)
- a cool colour 'white' (4,000 K)
- very cool 'white' (6,000 K)

STEP 2 – COLOUR APPEARANCE (K) (CONTINUED)

Fig. 1 shows the wide range of 'white' available in the most common light sources and how the same light source is available in different colours.

Recommended colour appearance ratings for different applications are shown below.

Domestic	2,600 – 2,700 K
Hospitality	2,700 – 3,000 K
Retail	3,000 – 6,000 K
Factory	3,500 – 4,000 K
Leisure Centre	3,500 – 4,000 K
Office	3,500 – 4,000 K
Libraries	3,500 – 4,000 K
Schools	3,500 – 4,000 K

The Lamp Comparison Table gives the colour appearance of a range of different lamp types.

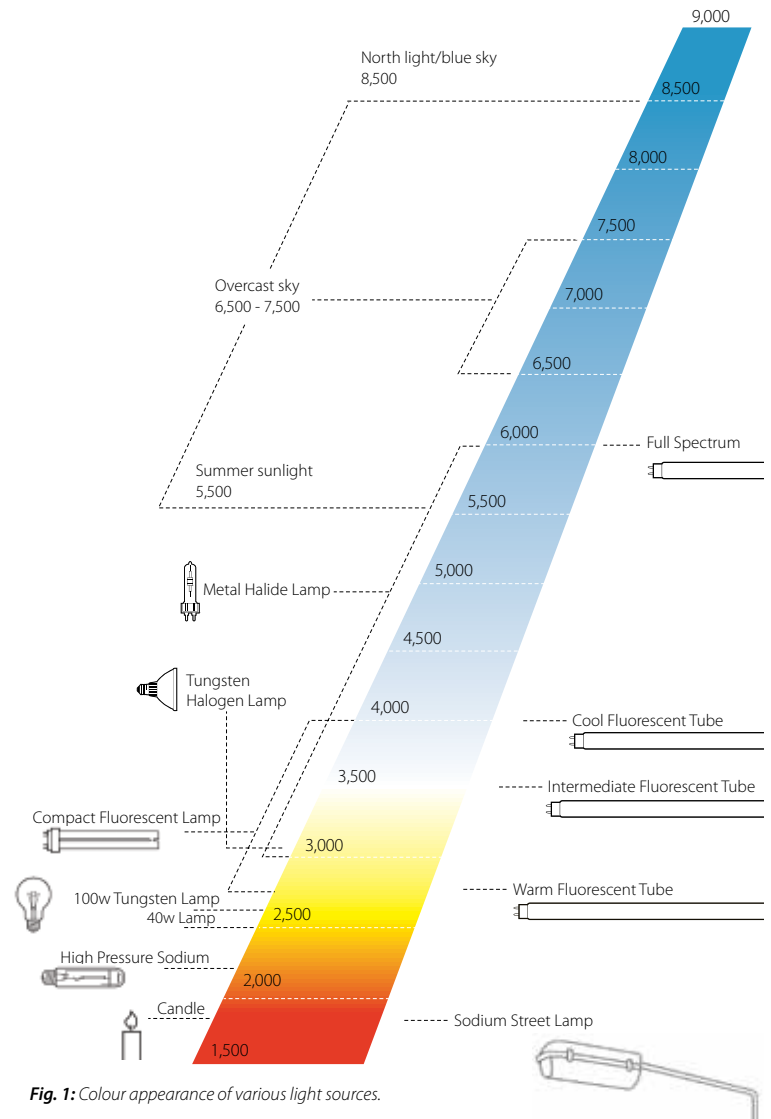


Fig. 1: Colour appearance of various light sources.

STEP 3 – COLOUR RENDERING



Fig. 2: Colour rendering characteristics of 3 different light sources
 (a) Daylight= Ra 100, (b) Tungsten = Ra 100, (c) Single phosphor cool 'white'= Ra 58.

The colour rendering properties of a light source indicate the ability of the source to reproduce the colour relative to the same colour, or colours, illuminated by a reference source (daylight). Colour rendering properties of a light source are specified by the Colour Rendering Index and measured in Ra. Good colour rendering equates to a high Ra value, the highest value is daylight with a colour rendering index of 100. Poor colour rendering equates to a low Ra, and the poorest colour rendering for a light source is low pressure sodium which has an Ra of 0.

The three pictures in Fig. 2 demonstrate that daylight (5,500 K) has a cool appearance on white walls and shows the red ceramics as their true



Fig. 3: Low pressure sodium lamps with poor colour rendering.

colour. The tungsten light has a 'warm' appearance and therefore shows the white walls as 'warm' (2,600 K) and accentuates the a colour red. Whereas the cool 'white' of the single phosphor fluorescent light has a cool appearance (6,000 K) on white walls and provides a reduced colour rendering on the ceramics.

Low pressure sodium would always be the recommended light source if efficacy were the only issue, but with its characteristic poor colour rendering (Ra 0) it is unsuitable for most forms of lighting. It is used mainly for street lighting (Fig. 3), where colour rendering is not as important. Table 1 (page 4) gives values of Ra for a range of lamp types.

STEP 4 – LAMP LIFE (HOURS)

Lamp life is classified in two ways depending on the type of lamp. The first is lamp expiry time also referred to as lamp mortality. This term refers mainly to light sources with filaments such as tungsten lamps. When the filament breaks, the life of the source has ended. The second classification is based on when the light output of the light source falls to 80% of the maintained lumens (lumens given at 2,000 hours). This is used

for discharge forms of light source such as fluorescent, metal halide and sodium. Most of these light sources will continue to give light for longer periods of time, but will continue to decrease in light output until they expire. When a single lamp type is listed with varying life hours in the Lamp Comparison Table it indicates that these types are available with differing life expectancies. Always specify the lamp with the longest life.

STEP 5 – LUMINAIRE EFFICIENCY

The Light Output Ratio (LOR) is the ratio of the light output of a luminaire to the total light output of the bare lamp. The LOR from luminaires varies considerably, even when they are the same type, as the majority of luminaires have some form of cover (diffuser or louvre) which restricts the amount of light produced by the light source from being emitted from the luminaire.

LOR data is provided by the manufacturer in graphical format or given as a percentage of the light emitted as shown in Fig. 4. Once you have decided on the type of luminaire you require, compare versions from different manufacturers. Choose the most efficient model, this will have the highest Light Output Ratio.

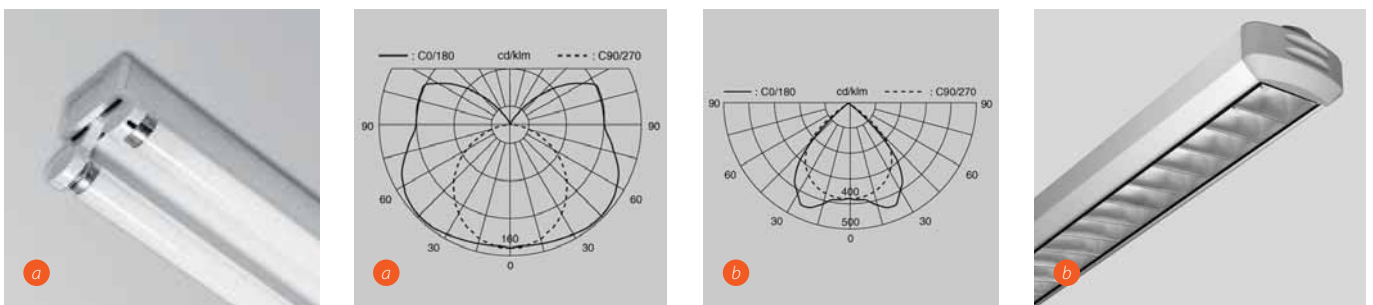


Fig. 4: Light Output Ratio from manufacturer's data.

(a) A graph of the light emitted from a standard twin fluorescent batten luminaire. The LOR total is 0.96 (96%). This breaks down into an Upward LOR of 0.38 (38%) and a Downward LOR of 0.58 (58%).

(b) A graph of the light emitted from a twin fluorescent luminaire with a reflector/louvre. The LOR total is 0.63 (63%). In this case there is no Upward LOR showing that no light is emitted in an upward direction.

The Downward LOR is 0.63 (63%).

STEP 6 – LIGHT DISTRIBUTION

Good distribution of light is an essential part of a successful design solution. A simple rule of thumb is to always 'Light what you see'. When lighting wall areas use tubular or compact fluorescent asymmetrical wall wash luminaires.

The light distribution strategy will depend on the particular application. Offices tend to have uniform light distribution over wide areas, while retail lighting will concentrate on illuminating the products with general 'ambient' lighting required for circulation areas.

An application may require illumination of a space or feature from different angles. In all cases glare can be avoided by obscuring the lamp from normal viewing positions and selecting appropriate beam angles as shown in Fig. 5.

Retail premises need to look 'bright', therefore 'light what you see', from the outside to show an inviting shop which is noticeably open for business and from the inside to light the merchandise, as shown by the green areas in Fig 5.

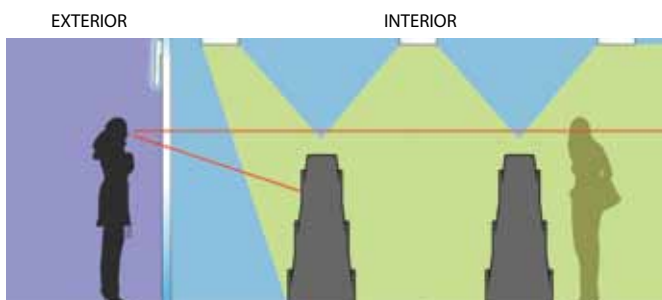










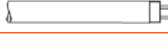


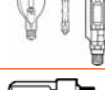

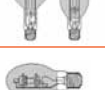




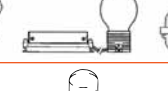
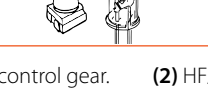



Fig. 5: Light what you see, particularly vertical surfaces while avoiding glare.

LAMP COMPARISON TABLE

The table below gives a comparison of the lighting criteria covered in Steps 1 to 4 for different light sources as indicated.

Type	Lamp	Luminous Efficacy (Lm/W) Circuit Watts	Colour Appearance (Kelvin)	Colour Rendering (Ra)	Life (Hours)
Tungsten		12	2,600	100	1,000
Tungsten Halogen		8.75 5.25 18 – 20	2,500 2,500 3,000	100 100 100	6,000 16,000 2,000 – 8,000
Compact Fluorescent (2)		47 – 82	2,700 – 4,000	85	8,000+
38mm T12 White F/Tube (1)		36 – 71	3,500	59	7,000+
25mm T8 White F/Tube (1)		37 – 68	3,500	58	8,000+
25mm T8 White F/Tube (2)		55 – 80	3,500	58	8,000+
25mm T8 Full Spectrum Multiphosphor (2)		64	5,000	95	17,500
25mm T8 H/F Triphosphor (2)		71 – 92	2,700 – 6,000	80+	12,000 – 24,000
25mm T8 H/F Triphosphor Extreme (2)		71	3,000 – 4,000	80+	40,000 – 60,000
25mm T8 H/F Triphosphor (2)		57 – 82	2,700 – 6,000	90+	12,000+
16mm T5 H/F Triphosphor (HE)(2)		66 – 82	2,700 – 6,500	80+	16,000+
16mm T5 H/F Triphosphor (HO)(2)		62 – 76	2,700 – 6,500	80+	16,000+
7mm T2 H/F Triphosphor (2)		55	3,500 – 6,000	85	8,000 – 12,000
Metal Halide (1)		71 – 83	3,000 – 6,000	65 – 85	8,000 – 20,000
Metal Halide (2)		86 – 95	3,000 – 6,000	65 – 85	8,000 – 20,000
Mercury (1)		31 – 57	3,900 – 4,200	36 – 49	12,000+
Mercury D/Luxe (1)		31 – 57	3,300 – 3,500	47 – 58	12,000+
Low Pressure Sodium/E (2)		148 – 173	1,800	0	6,000
High Pressure Sodium (1)		65 – 103	2,000	25	12,000 – 30,000
High Pressure Sodium D/L (1)		78 – 85	2,200	65	12,000
White sodium (2)		31 – 46	2,500	80	8,000+
Induction (2)		62 – 70	2,700 – 4,000	85	10,000 – 60,000
Light Emitting Diodes (LEDs) (2)		50/100	Saturated 3,000 – 6,000	70/80	50/100,000

(1) S/G – Standard electromagnetic control gear. (2) HF/G – High frequency control gear.
HE = High Efficiency HO = High Output

Table 1: Comparison of key characteristics for different lamps and lamp types.

STEP 7 – LUMINAIRE POSITION AND MAINTENANCE

The position of luminaires can greatly influence the effectiveness of the lighting solution. There are some mounting positions where maintenance of luminaires is difficult, e.g. over stairwells or in excessively high positions where scaffolding may be needed to clean the luminaire or replace lamps. In many cases these mounting locations can be avoided with no loss in the lighting's effectiveness, and in some instances the illumination effect can be greatly enhanced.

Examples – Fig. 6

Fig. 6a, lights over stairwells should be avoided and alternative lighting solutions proposed, such as mounting high efficacy uplighters on stairwell flanking walls and bouncing the light off the ceiling with narrow beam floodlights. In Fig. 6 b, The low voltage (12v) dichroic light sources mounted at high level in the cross bars near the ceiling do not adequately illuminate the space and are not easily accessible. A more effective solution would be to convert the existing ineffective 'Globe' light to an uplighter with integrated reflector (Fig. 6c) enabling localised lighting to illuminate the required area. This action would enable the low voltage dichroic lamps to be removed or replaced with long lasting LEDs for visual effect only.

Tips and examples for designers

Reduce the maintenance costs of luminaires in hard to access areas by considering how to:

- bounce light off reflective surfaces or ceilings (Fig. 6c and Fig. 7a)
- mount high efficacy uplighters on the walls of stairwells rather than luminaires mounted in the stairwell ceilings
- use long-life light sources in accessible mounting positions.



(a)

Fig. 6



(b)



(c) Convert ineffective 'Globe' light to uplighter with integrated reflector

Examples – Fig. 7

Fig. 7a, wall mounted luminaires with high efficiency and long life metal halide lamps (Fig 7c) are located over the gangway. Fig. 7b shows an example of metal halide luminaires that are in positions which are difficult to access.

The lights mounted in the ceiling are low voltage (12v) dichroic lamps (2,000 hours), but these could be replaced with LED (Fig. 7d) retrofit-type light sources (10,000 hours) to provide a longer lamp life and reduce the maintenance costs.



(a)

Fig. 7



(b)



(c) Metal halide light source narrow beam floodlight



(d) LED

Examples – Fig. 8

Choose luminaires that provide easy access to the lamp and are easy to clean. With these compact fluorescent luminaires, an open glass cover makes lamp replacement quicker and collects less dust.



Fig. 8

STEP 8 – CONTROLS AND USE OF DAYLIGHT

The frequency of building occupation and the amount of natural daylight that enters a workspace or area should influence design decisions on the type and nature of lighting controls to be utilised.

If an area is infrequently used and lights are not routinely switched off when not required a simple presence detector, appropriately positioned, would be a useful automatic control. This would automatically switch lights on and off when personnel entered or left the area. If there is a significant amount of natural light entering into the area, then it would also be prudent to include either a separate daylight sensor or a daylight sensor which is integrated within the presence detector. These sensors are available for recessing into the ceiling or to be surface mounted and can be adjustable on site or factory set.

Lighting controls are available with different methods of occupancy detection, infra-red, ultrasonic or microwave. When deciding on which type of detector to use it is important to understand some limitations of the technologies. For example, an infra-red sensor which reacts to changes in heat patterns in a space works best in small open spaces rather than areas with partitions, cabinets etc. which can block the beams. The further away a moving object is from an infra-red sensor the larger the motion needs to be to register with the device.

Both ultrasonic and microwave sensors detect in a sonic manner and unlike infra-red sensors do not need a direct line of sight of the motion source. They will detect very slight movement but this can sometimes lead to false signals, e.g. a draught moving a piece of paper, or movement beyond a glass partition or window.

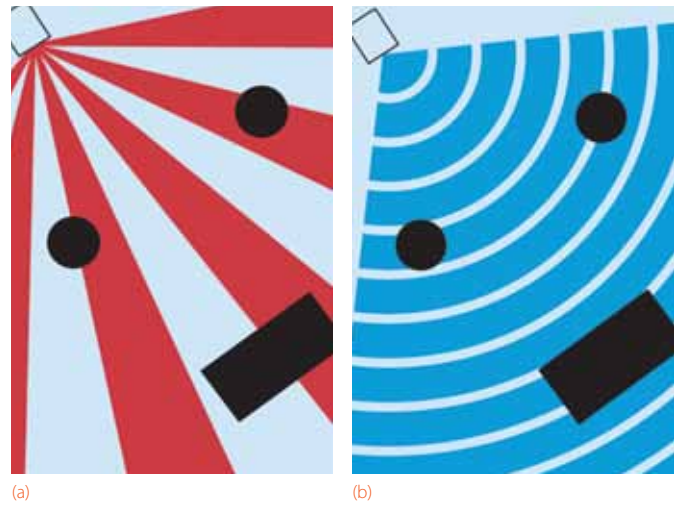


Fig. 9: (a) Infra-red and (b) sonic occupancy detection coverage.

Another aspect of control to consider is whether the link between the sensor or sensors is to a single luminaire or to a number of luminaires. If the link is to a single unit individual connection from the sensor to the luminaire or its supply line is all that is required. This link can provide presence detection and also daylight sensing. Daylight sensing for instance can either switch the lamps on or off, or gradually dim the light sources depending on the availability of daylight, this method of control is referred to as 'constant lux' dimming. Fig. 10 illustrates a simple control strategy using on/off daylight sensing coupled with occupancy detection.

The sensors can be hard-wired to any number of luminaires and information is passed through pulse signals using industry protocols such as Digital Addressable Lighting Interface (DALI). Remote signalling such as radio signals, have the advantage of no hard-wiring between sensors and recipient units.

Most sensors provide the facility to accept a signal from a hand held remote control. This allows the lighting to be switched off when the area is occupied if low lighting levels are preferred, e.g. when viewing a presentation on a screen. Control systems can be centralised which enables monitoring of the system status at any point in time for reasons of occupancy, emergency lighting testing, statistic gathering etc. Controls can also be linked across multiple sites.

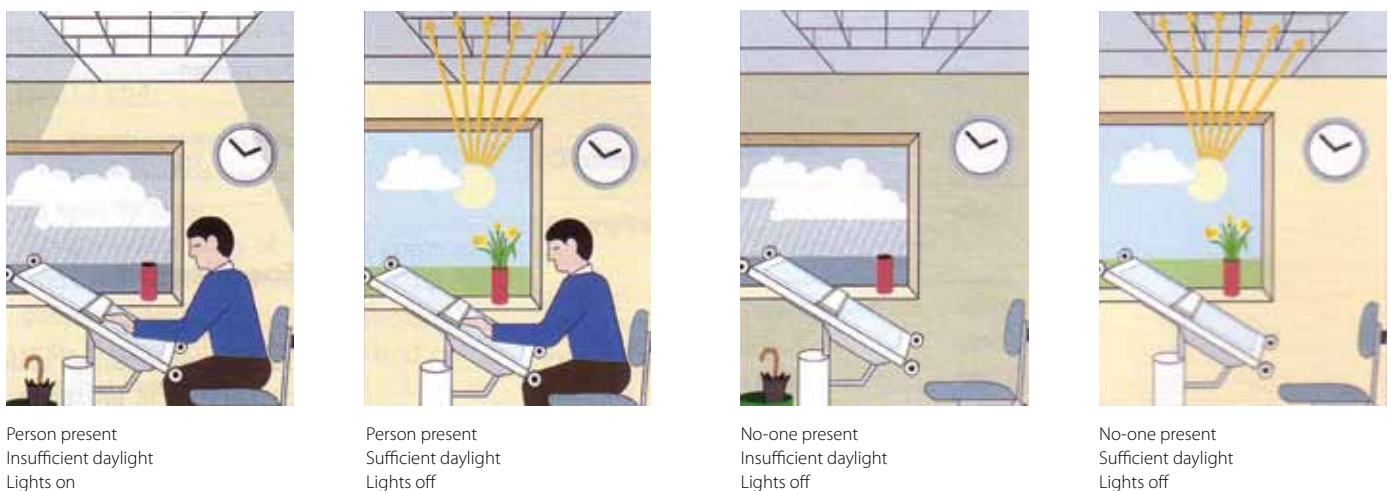
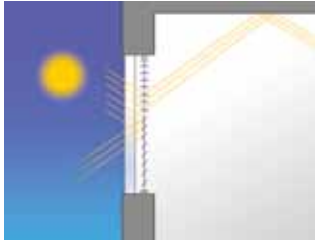


Fig. 10: Control strategy for an intermittently occupied space.

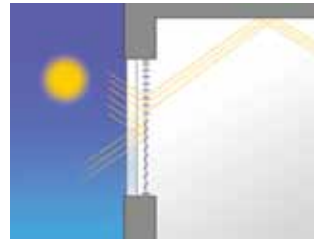
Daylight blinds

Some office areas that receive good quantities of natural light could benefit from using 'daylight blinds'. These blinds reduce glare and allow daylight to enter the space in a controlled way, instead of the more common standard horizontal or vertical blinds which cut out the light to the working space when they are drawn to alleviate glare or excessive sunlight.

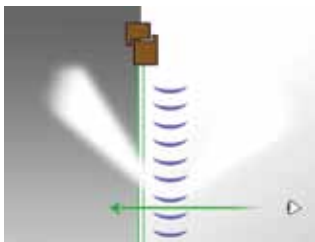
There may be little need to use artificial lighting during normal office working hours, especially during sunny periods, if daylight blinds are installed. They are a great energy saving retrofit option. Fig. 11 shows how the blinds work in practice.



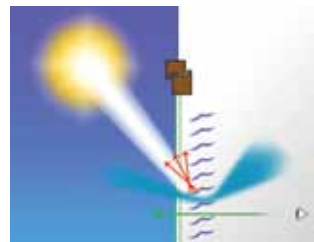
The lower part of the daylight-optimised Venetian blind provides for a dazzle-free workstation. The upper slats, on the other hand reflect the sunlight against the ceiling and illuminate the room evenly.



The daylight-optimised Venetian blind with concave mirror slats provides for illumination of the depths of the room.



If the sky is overcast or clear without the sun, the slat is folded up. In this way, the entire slat surface is available to guide the daylight.



The hinged slats reflect the direct sunlight without the glare.

Fig. 11: Using daylight blinds to make the most use of natural light while reducing glare.

The EC-directive 90/270/EEC on the minimum safety and health requirements for work with display screen equipment, deals with the problem of reflection and glare at computer workstations.

"Computer work stations are to be set up in a way that light sources such as windows and other openings, transparent or translucent partitions and bright furnishings and walls do not create direct glare nor reflections on the screen. The windows must be equipped with a suitable, adjustable daylight protection device through which the intensity of the incidence of daylight on the workstation can be reduced."

Clearly window treatments and blind systems that can effectively direct natural light go a long way to meeting these requirements while maximising lighting energy savings over a wide range of external daylighting conditions.

REVIEW

Energy effective lighting design requires an appreciation of the characteristics of low energy light sources, knowledge of the levels of visual amenity required for different applications and close attention to operational control and maintenance.

Consideration of the lighting criteria set out in Steps 1 to 8 and the application of these principles will deliver high quality lighting designs with long-life performance and associated energy and cost saving benefits.

It is intended that the information in this guide will help complement other more specialist sources of guidance on lighting design and highlight the need to achieve more energy efficient and effective lighting. For detailed guidance on lighting specification, readers should consult professional bodies such as CIBSE and ASHRAE or other specialist sources on lighting design.

For further information please visit www.seai.ie

An attractive tax incentive is available through the ACA scheme for specific Lighting equipment that meet minimum efficiency criteria. Equipment eligible for the ACA can be found on the Triple E Products Register on www.seai.ie/aca.



The ACA covers in addition to Lighting a wide range of other energy efficient technologies, details of which can also be found on the ACA website.