SUSTAINABLE ENERGY IRELAND

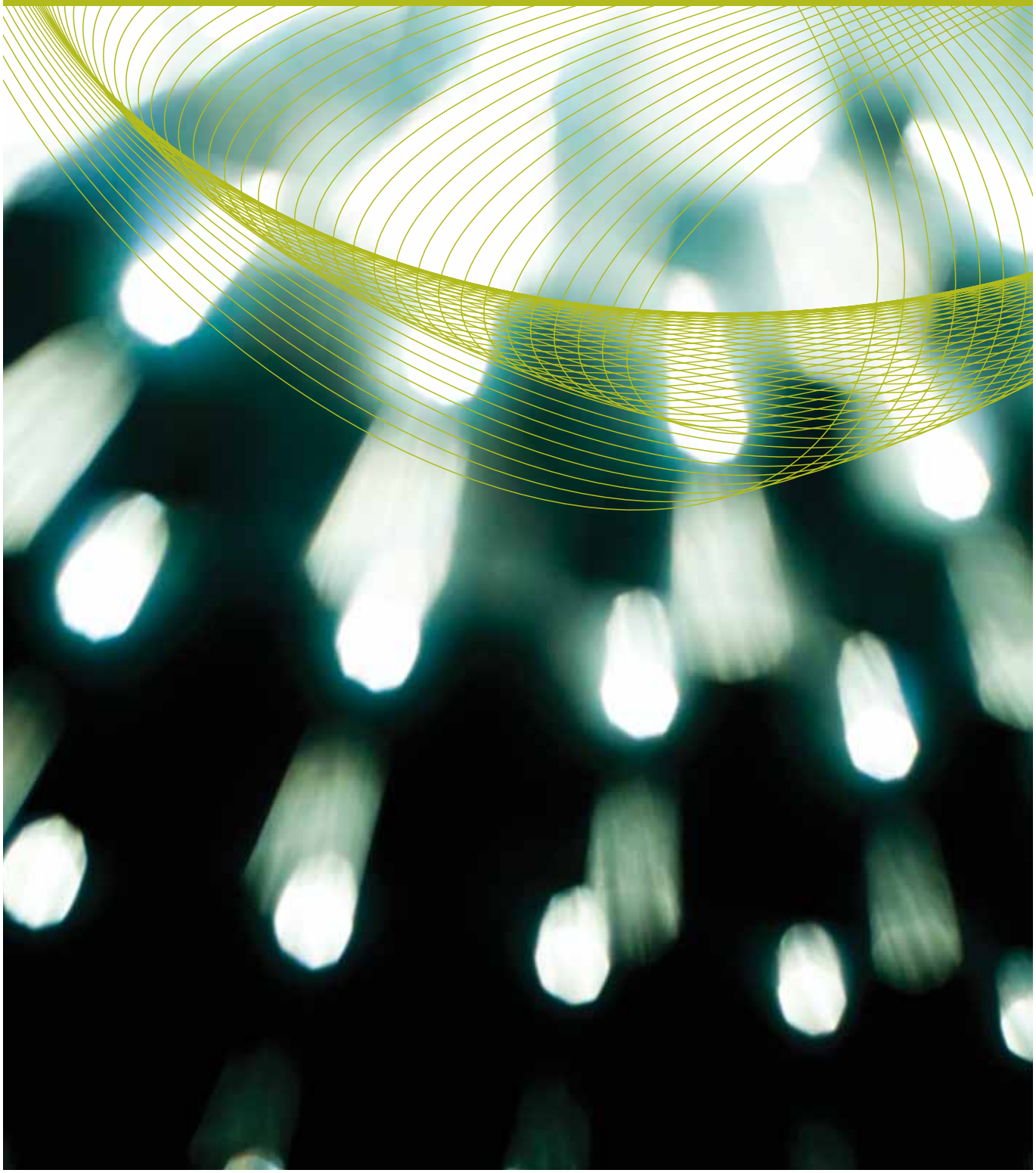
AN ROINN OIDEACHAIS AGUS EOLAÍOCHTA | DEPARTMENT OF EDUCATION AND SCIENCE

Schools

A GUIDE TO ENERGY EFFICIENT AND COST EFFECTIVE LIGHTING

UP TO 25% SAVINGS

This guide provides information on how to improve the effectiveness of lighting in school buildings by using energy efficient lighting technology and techniques. The information provided follows Department of Education and Science Technical Guidance Documents. This guidance document will help to maximise visual comfort, light performance and efficiency, reduce lighting energy consumption, cut maintenance costs and improve the appearance of the learning environment.



ENERGY EFFICIENT AND COST EFFECTIVE LIGHTING

Light plays a significant role in creating a pleasant environment where students and teachers can interact and engage in the education process. Independent research has shown the benefits of good daylighting and of good artificial lighting to educational productivity in schools. On average, lighting accounts for about 30% of school energy costs. This guide highlights some of the key decision areas, and shows the synergies that exist between passive solar design, good use of daylight, good electric lighting and energy efficient operation. It is written to complement Department of Education and Science Technical Guidance Documents.

LIGHTING OVERVIEW

Good lighting in schools delivers visual comfort, good visibility, good colour reproduction where required, uniformity of light and minimises glare. When considering new lighting, it is essential to look holistically. There is a far bigger picture that must be considered than mere selection of the cheapest possible light fittings, installed at the lowest cost.

Lighting in schools should:

- ensure good visibility for all school activities to the required lighting levels
- take into account the function of each space, e.g. classroom, laboratory, communal areas
- take into account the visual needs of the pupils, staff and other users
- use the most efficient lamps and luminaires (light fittings) to light the space
- minimise artificial lighting requirements by linking to daylight and having light coloured walls and ceilings
- use appropriate lighting controls and optimise control of lighting zones
- ensure that maintenance and cleaning can be easily carried out

LIGHTING REQUIREMENTS

There are a number of requirements that should be taken into account to achieve the desired lighting objectives for the different areas of the school building:

- Colour appearance – the colour of a lamp, measured on the Kelvin temperature scale (K), describes whether the light looks 'warm' or 'cool'. For general classrooms, lamps with a classification of 3,000-4,000 K should be used. Tubular and compact fluorescents are available in this range. The colour temperatures of a range of lamp types are shown in Figure 1 and highlighted in the Lamp Comparison Chart on page 7.

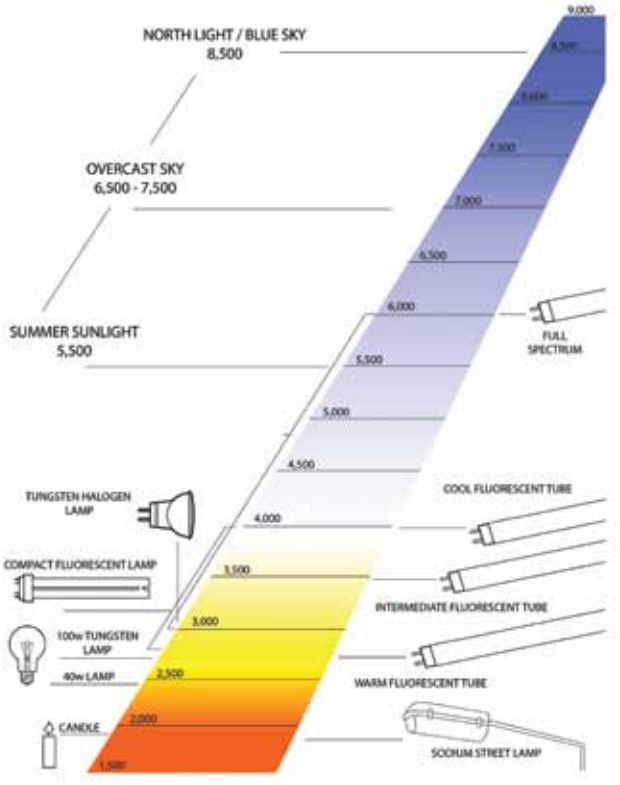


Fig.1 *Colour temperature (K) of various light sources*

- Colour and contrast is important, and light sources should have a good 'colour rendering' performance. Colour rendering is the ability of a light source to give good colour representation of the colour it is illuminating. This is particularly important for art and design classes. It is measured on a scale of Ra 0-100, with Ra 100 representing the best, which is equivalent to that provided by daylight. Where accurate colour judgement is required, e.g. in specialised art & design, then Ra 80+ is desirable. Figure 2 illustrates the colour rendering properties of 3 different light sources.
- Functional or task lighting is required to enable students and teachers to carry out their activities easily and without visual discomfort. For the basic activity of reading and writing, a minimum level of illuminance is required with good uniformity over the task area. Illuminance describes the light level on a particular surface and is measured in `lux'. It depends on the luminaire placement, its light output intensity, and its light distribution. A maintained illuminance of 300 lux will be appropriate for most school tasks. However, for areas where intricate tasks are undertaken, such as science labs or art & design, a level of 500 lux or higher may be required. Task lighting at 1200 to 2000 lux may be needed for particularly intricate work, such as sewing. Appropriate lighting levels are covered on page 7 for different school areas.
- Visual comfort is important, in order to avoid the possibility of eye strain and headaches. Bright lights reflected on to surfaces such as computer screens or glossy printed material may cause glare and visual discomfort. Electronic high frequency ballasts operating fluorescent tubes overcome strobe effects and guidance on avoiding glare on computer screens is available from the Chartered Institution of Building Services Engineers (Lighting Guide 7).
- Appearance of the space - to create an environment that is conducive to learning, it is important that the space should appear 'bright' and 'interesting/attractive'. Light colour finishes on walls and ceilings and variation in brightness from artificial lighting help achieve this. Dark areas/dark surfaces should be avoided. The illumination of walls helps make a space appear brighter.

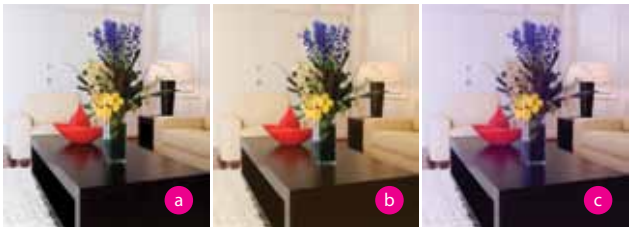


Fig.2 *Colour rendering characteristics of 3 different light sources*
(a) *Daylight = Ra 100,* ***(b)*** *Tungsten = Ra 100,* ***(c)*** *Single phosphor 'cool' white = Ra 58*

LAMPS AND LUMINAIRES

Schools have a variety of spaces, and many of these are used for different types of activities and at different times of the day. The lighting selected should therefore be appropriate for the particular activities that take place in each type of space. Below are some examples of suitable lamps and luminaires for use in schools.

Lamps

For the majority of areas within schools the two types of light sources shown are mostly used in various sizes and colour 'whites'. T5 (16mm) tubular fluorescent lamps are the recommended choice as they only work with high frequency control gear. For more details refer to page 7.

A	Tubular Fluorescent		B	Compact Fluorescent	

Luminaires

The luminaire is the complete lighting unit and consists of the lamp and its fitting. Not all the light from a lamp will emerge from the luminaire due to the presence of reflectors, refractors and diffusers.

Each luminaire has a Light Output Ratio (LOR) which is the measure of light output that emerges from the luminaire. The most popular type of louvered luminaire will have a typical LOR between 36% to 80%. Manufacturers provide information on LORs and in general you should choose the highest LOR. A higher efficiency luminaire with translucent diffusers can have LORs of up to 93%. In practice, LORs in the region of 65%+ for louvered luminaires and 80%+ for luminaires with translucent diffusers would minimise the numbers of luminaires required for a particular space and reduce the cost of ownership.

Flush/recessed luminaires create shadows on the upper levels of walls and tend to create a dark ceiling which in large rooms looks noticeably gloomy.

They are not permitted in new school lighting designs. See Figure 3.

Ceilings and upper walls tend to look dark with flush mounted luminaires. The lighting designer's common solution is to increase the lighting level (lux) by 50% or even more until the ceiling is acceptably bright. This increases the capital cost of the luminaires, as well as increases the electricity cost for lighting – by 50% or more. Simply increasing the lighting level is not a competent or sustainable way to design lighting.

Ceiling mounted luminaires, as shown in Figures 4 and 5, are the most appropriate form of lighting for school applications.

Fig.3 *Ceilings appear dark with flush/recessed luminaires*

Fig.4 *Ceiling mounted luminaires are the best design solution*

Fig.5 *Example of a ceiling mounted luminaire*

APPLICATIONS IN SCHOOL BUILDINGS

The following lighting applications show the most appropriate light sources for different areas of the school building as part of lighting refurbishment work or new design. Guidance on the lighting characteristics most suited to the tasks carried out in these areas are also highlighted.

General Purpose Classrooms – 300 lux

Use high-efficiency T5 tubular fluorescent lamps.

Particular care must be taken to ensure that lighting does not shine onto whiteboards and wash-out the projected image. T5s are more suited to higher mounting heights. The appropriate diffusers should be chosen for T5 lamps used on lower ceilings.

Specialist Subject Rooms – 500 lux

Use high-efficiency T5 tubular fluorescent lamps.

Higher illuminance may be required for areas where intricate tasks are undertaken such as meter readings or detailed observations. If the task is particularly demanding then an illuminance level of not less than 500 lux will be necessary.

Computer Rooms – 300 lux

T5 tubular fluorescent lamps with appropriate louvered diffusers and lux levels of 300 are generally considered to be suitable for computer work.

Where possible, computer monitors should have matt screens, and be placed at right-angles to windows and located between rows of overhead lights. Similar fittings to those referred to in General Purpose Classrooms may be used if the luminaire cannot be seen as a reflected image on the screen.

General Purpose Halls – 300 lux

Use T5 fluorescent lighting to attain 300 lux at 700mm above the finished floor level with general overall distribution.

Corridors, Stairs and Circulation Areas – 120 lux

Luminaires should generally use T5 tubular fluorescent lamps, CFLs may also be appropriate in limited numbers.

An average illuminance of 120 lux should be provided at 700mm from finished floor level for corridors and stairs.

LIGHTING OF WHITE BOARDS AND CHALK BOARDS

Whiteboards must not receive high intensive direct lighting. T5 fluorescent tubes within an asymmetrical luminaire can be used at a suitable distance above and in front of whiteboards.

LIGHTING FOR PUPILS WITH VISUAL IMPAIRMENTS

Often, more can be done through the use of coloured surfaces instead of elaborate or enhanced lighting schemes, to help the visually impaired in recognising and identifying locations. In some situations the use of local lighting or higher than normal task illumination may be of help.

The control of glare from overhead lighting is important for students with a visual impairment, and measures should be taken to minimise it. High frequency electronic ballasts for fluorescent lamps are preferable as they avoid subliminal flicker. Good lighting is particularly important for lip-reading and downlighting should be avoided as it may cast shadows on the speaker's face.

There is unlikely to be a single solution for students with visual impairments, and users should seek specialist advice or as a first step consult the National Council for the Blind of Ireland. **www.ncbi.ie**

CONTROLS

The best approach to electric lighting control in schools is to keep it simple.

Automatic lighting controls should be based on manual on/off switching, with absence detection and daylight sensing where appropriate daylight factors of 4.5 or greater are achieved.

This system will mean that lights must be switched on manually and will dim/turn off automatically depending on the signals from the automatic controls.

Lighting control in classrooms/teaching spaces should be such that all lights in the space are linked to one sensor so that all lights respond in the same manner to the control signals.

Lighting controls in ensuite toilets to be based on manual on/off switching with automatic absence detection only. One linear high frequency fluorescent fitting per cubicle and lobby should suffice.

Corridor lighting should be linear fluorescent and zoned with appropriate local individual light switches and where appropriate daylight detection/absence detection controls.

DAYLIGHT

Daylighting is probably the most important aspect of lighting in schools. Daylight can make a room attractive and pleasant and stimulate learning. Research has shown that students in classrooms with good quality daylight perform better and progress faster than students in rooms with inadequate daylight. However, direct solar penetration should be avoided as it creates glare and possible overheating in summer.

Daylight can replace artificial lighting for much of the day in school buildings. Maximum energy savings are achieved when daylight availability is integrated with daylight-responsive controls.

- Use daylight sensor controls (photocells) to ensure that light output is reduced or lights are not left on unnecessarily when there is adequate daylight.
- Blinds of a light coloured basket-weave sunscreen with an open weave factor of 5% (50% visible light transmission) may be used for all teaching spaces. 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.
- Sun pipes with short tube lengths (less than 1m) should be considered, especially for corridors, as they can achieve good lighting levels (Figure 6).
- Ensure a good quality day-lighting distribution in the room with average day-lighting factor in the range of 4.5 to 5.5%.

(Daylight Factor (DF), describes the ratio of outside illuminance over inside illuminance, expressed as a percentage. The higher the DF, the more natural light is available in the room).

Fig.6 *Sunpipes used to deliver natural lighting to a school corridor.*

ENERGY SAVING REPLACEMENTS AND RETROFITS IN EXISTING SCHOOLS

Use the following guidance when deciding to replace existing inefficient lamps or fittings.

Existing Installation	Direct Lamp Replacement	Benefits
Incandescent GLS 40W 60W 75W 100W 150W 	CFLi (integral ballast) 9W-11W 11W-14W 15W-19W 20W-25W 26W-29W 	75% energy saving Up to 12 times the lamp life of incandescent lamps Use 'warm white' (2700 K) CFLi lamps
38mm-diameter (T12) linear fluorescent lamps 	26mm-diameter (T8) linear (triphosphor) fluorescent lamps 	T12 lamps can be directly substituted with T8 lamps to existing luminaires with switch-start control gear, but not with other types of conventional control gear, e.g. rapid-start. Request T8 lamps with triphosphor or multiband phosphor coating, as these give better performance. ▪ 8% energy saving ▪ approximately 10% more light output (lumens) ▪ higher colour rendering
T12 (38mm) or T8 (26mm) switch start luminaires 	T5 (16mm) High Efficiency fluorescent tube 	30% to 50% energy saving Twice the lamp life An electronic adaptor is required

***Note**: the more efficient T5 tubes can be retrofitted into existing light fittings by using a conversion kit. Conversion kits with a high frequency ballast are available as a plug-on to the end of the T5 tube, so the original T12 or T8 fitting can be used. Alternatively, a completely new T5 light fitting can be installed. If using conversion kits, carry out a trial on a few fittings, before undertaking bulk replacement. Always use reputable suppliers and products that comply with all national and EU lighting regulations.*

MAINTENANCE

Regular maintenance is important for maximising energy savings and maintaining lighting levels. Without this, light levels can fall by 20% – 30% in 4 years.

- Keep windows clean and blinds open whenever it is practical to do so.
- Keep lamps, luminaires and sensors free from dust and dirt.
- Replace flickering, blackened, dim, or failed lamps and lamps at the end of their useful life, e.g. when tubes start to flicker or lighting levels drop. Electronic high frequency ballasts should be used rather than switch-start ballasts as they automatically switch off lamps which have expired.
- Older types of opal plastic diffusers become discoloured with age, and can absorb more than 50% of the light output from the tubes. Always replace with prismatic UV stabilised diffusers.

SAFETY

Suspended luminaires are not encouraged in school applications, as they can present health and safety issues for children.

It is important to use enclosed diffusers so that in the event of a lamp shattering all glass is contained in the diffuser. Non-thermoplastic diffusers are to be used on escape routes and wire guard protection to be provided on PE hall light fittings.

LIGHTING TECHNICAL DETAILS

A Tubular fluorescent lamps

T5 (16mm) fluorescent tubes with the appropriate colour appearance and colour rendering are the recommended lamps for new schools. They operate on electronic high frequency control gear and should be interfaced with appropriate daylight/presence controls for most applications in schools. For T8 (26mm) fluorescent tube replacement choose triphosphor fluorescent tubes operated on electronic high frequency control gear.

B Compact fluorescent lamps

When the ballasts for these lamps are integrated within luminaires, dimming models are available and should be used when appropriate. A CFLi (integral ballast) with either a Bayonet Cap (BC) or Edison Screw (ES) base can often replace ordinary tungsten filament lamps, some of these types are available in dimming models.

LIGHTING REQUIREMENTS IN SCHOOL AREAS

Area	Maintained illuminance (lux)	Colour rendering (Ra)	Colour temperature (K)	Recommended lamp
General classrooms/Teaching spaces	300	80+	3,000 – 4,000	A
Computer rooms	300	80	3,500 – 4,000	A
Specialist subject rooms	500	80+	3,000 – 4,000	A
Book shelves/Library areas	300	80	3,500 – 4,000	A
Gen. purpose/Assembly hall	300	80	3,500 – 4,000	A
Sports halls	400[1]	80	3,500 – 4,000	A
Corridors/Stairs/Circulation areas/Waiting rooms	120[2]	80	3,500 – 4,000	A B

1. *1m above finished floor level (FFL);* ***2.*** *700mm above FFL*

LAMP COMPARISON CHART

The best light sources for schools are highlighted in green in the table below.

Lamp type	Efficacy (lumens per watt)	Colour rendering (Ra)	Colour temperature (K)	Lamp life (Hours)
Daylight		100	5,500 – 8,500	
Tungsten Mains Voltage	12	100	2,600 – 2,700	1,000 – 2,000
Tungsten Halogen Mains Voltage	18	100	3,000	2,000 – 8,000
Compact Fluorescent	45 - 60	85	2,700 – 4,000	8,000+
T8 (26mm dia.) Halophosphor Fluorescent Tubes	37 - 68	58	2,700 – 4,000	6,000+
T8 (26mm dia.) Triphosphor Fluorescent Tubes	71 - 92	80±	2,700 – 6,000	20,000 – 60,000
T5 (16mm dia.) High Efficiency Fluorescent Tubes	66 - 82	80±	2,700 – 6,500	20,000
T5 (16mm dia.) High Output Fluorescent Tubes	62 - 76	80±	2,700 – 6,500	20,000

Efficacy is the ratio of light emitted by a lamp to the power consumed by it, i.e. lumens per Watt. A lumen is a measure of the quantity of light emitted by a lamp.

Lamp life is the variance in lamp life indicated due to some lamp models having differing life hours available. One of the objectives of the lighting design should be to ensure that the lamps and fittings chosen will require the minimum amount of maintenance. Always seek to use long life versions to maximise savings in energy and maintenance costs.

When selecting equipment, hardware and control systems for projects, you are encouraged to benchmark your specifications against the energy efficient equipment specified by SEI for the Accelerated Capital Allowance (ACA) tax incentive scheme. This equipment meets minimum energy efficiency criteria. Lists of qualifying equipment are available at **www.sei.ie/aca**

The Energy in Schools website from The Department of Education and Science allows schools to stay updated with regards to energy efficiency opportunities in schools.
www.energyeducation.ie

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