

Manufacturing and Warehouses

A GUIDE TO ENERGY EFFICIENT AND COST EFFECTIVE LIGHTING

This guide provides advice on the most appropriate lighting for manufacturing and warehousing facilities and information on running costs, energy efficiency and visual effectiveness of new technologies and techniques.

UP TO
50%
SAVINGS



ENERGY EFFICIENT AND COST EFFECTIVE LIGHTING

Achieving efficient and effective lighting for manufacturing and warehousing facilities requires considering all the tasks undertaken within the different areas. Using the information in this guide will help develop an energy efficient and effective lighting scheme, which will

not only assist productivity but also provide a safe and comfortable environment. By using energy efficient and cost effective lighting you can make significant electricity savings year on year.

OVERVIEW

To attain the best performance from the lighting scheme the system should address the following key characteristics:

- Colour appearance
- Colour rendering
- Visual perception
- Applications, lamps & luminaires
- Controls
- Daylight
- Maintenance and lamp replacement
- Required lighting characteristics



KEY LIGHTING CHARACTERISTICS

- **Colour Appearance** - describes whether the light from the lamp looks 'warm' or 'cool'. This is measured on the Kelvin temperature scale, see Figure 1. In general a 'mid-white' (3,500 K) or 'cool' (4,000 K+) colour appearance light source provides an appropriate visual perception and contrast for factories, warehouses and storage areas.
- **Colour Rendering** - is the ability of a light source to give good colour representation of the colour it is illuminating. It is measured on a scale of Ra 0-100 with Ra 100 representing the best, which is equivalent to daylight. Where accurate colour judgement is required, then Ra 80-90 is necessary. Contrast is also important and should take into account the colour and texture of the work surfaces, background and the lamp colour rendering.
- **Lighting Levels** - is the level of light or 'illuminance' (measured in 'lux'). Lighting levels should meet the defined standards of the task (see table on page 6). If levels are too low or too high, this can make working tasks difficult, cause worker fatigue and possibly produce unsafe working environments.

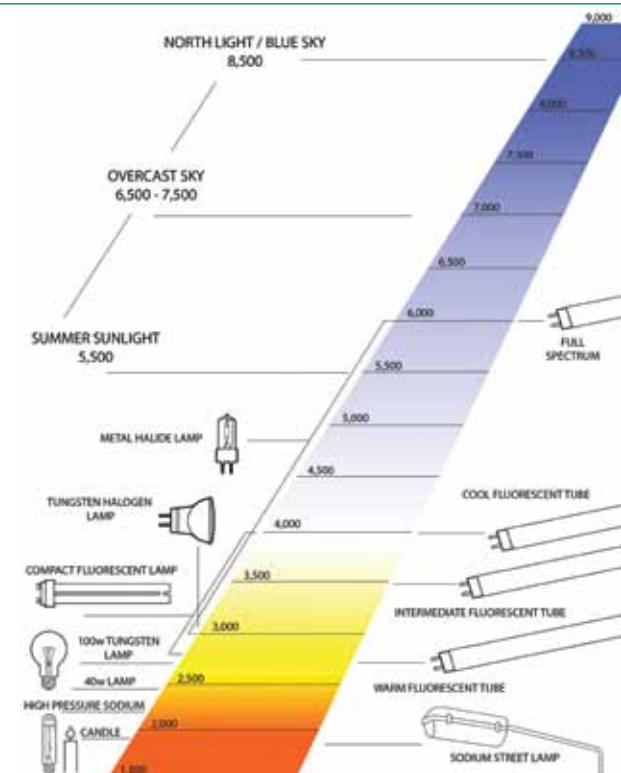


Fig.1. Colour temperature (K) of various light sources

VISUAL PERCEPTION

A better and safer working environment can be achieved by illuminating what is 'seen'. This also provides a perception of 'brightness'.

The two illustrations show practically the same light level but with different visual perceptions. Figure 2a illustrates that luminaires with metal reflectors do not allow light to pass through them and Figure 2b illustrates that luminaires with glass/plastic reflectors that allow a proportion of light to pass through the reflector can illuminate surfaces that are 'seen' such as walls and ceilings. This can make a space appear brighter.

- **Uniformity** – in general terms this refers to how 'evenly' an area is lit. It is not appropriate to have too-high and too-low lit sections in the same area. General illumination with 'task' lighting is appropriate for production tasks, whereas a lower uniform lighting level would be more appropriate for warehousing and storage. Having very 'bright' areas close to 'dim' areas can cause fatigue and may be dangerous.

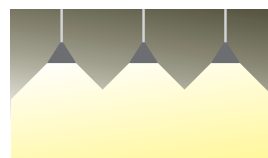


Fig.2a Luminaires with metal reflector



Fig.2b Luminaires with glass/plastic reflector

APPLICATIONS IN MANUFACTURING AND WAREHOUSES

Industrial production and warehousing buildings have a variety of spaces, 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.

The following chart identifies the most appropriate and energy effective lighting for different applications.

Note: More details on the lamp types referenced can be found on page 5.

Industrial Low Bay and Loading Bays	
<p>T5, T8 tubular or compact fluorescent are the preferred light sources with electronic high frequency control gear (with dimming and presence facilities if required). Metal halide HID discharge lighting can also be used which provides good colour rendering and a chosen colour appearance. Metal halide lighting is suitable for infrequent switching and where dimming and presence controls are not required. Metal halide lighting is not suitable for mounting below 3.5m.</p>	
Industrial High Bay	
<p>T5, T8 tubular or compact fluorescent luminaire types with electronic high frequency control gear (with dimming and presence facilities if required) mounted up to 8m. Metal halide HID discharge lighting can also be used which provides good colour rendering and a chosen colour appearance. Metal halide lighting can be mounted above 8m and is suitable for infrequent switching and where dimming and presence controls are not required.</p>	
Cleanrooms	
<p>T5 or T8 tubular fluorescent or compact fluorescent luminaire types.</p> <p>Clean rooms require overall lighting and should use prismatic controllers/covers.</p> <p>Use luminaires with appropriate louvres in laboratories where reduced glare lighting is required due to the existence of reflective materials such as computer screens, instruments, glass and metal containers etc.</p> <p>Always light to task requirements.</p>	
Warehouses	
<p>Small to medium sized interiors</p> <p>Use high output triphosphor tubular fluorescent lamps (T5 or T8) with suitable reflectors.</p> <p>Use lower power (up to 250w) high intensity discharge lamps, either metal halide where good colour rendering is required, or high pressure sodium for areas where good colour rendering is not required.</p> <p>Always select appropriate light distribution and consider that the higher the mounting height the narrower the beam required.</p> <p>Larger spaces, especially for ceiling heights above 5m</p> <p>Use tubular or compact fluorescent luminaires with some upward lighting to illuminate 'seen' surfaces.</p> <p>Metal halide or high pressure sodium high bay luminaires may be considered. Be careful to avoid glare for fork lift operators. Low intensity lamps are therefore more appropriate when glare needs to be avoided.</p> <p>Make sure to provide light on vertical surfaces, where required to read labels etc.</p> <p>Avoid the creation of shadows in aisles and on stored goods etc., by ensuring correct spacing between luminaires.</p>	

LUMINAIRES

A luminaire is the complete lighting unit, consisting of the lamp, the housing/fitting and operating gear and it is important that the right characteristics are achieved. Not all the light from a lamp will emerge from the luminaire, as this depends on the efficiency of the reflectors, or diffusers.

The **Light Output Ratio (LOR)** is a measure of the proportion of the lamp light that emerges from the luminaire. Manufacturers provide information on LORs and in general you should choose the highest LOR to benefit from the highest energy savings. High efficiency luminaires of up to 93% are available. No luminaire under 65%, for

luminaires with louvres, should be considered. When high output luminaires are used, then 3 lamp luminaires instead of 4 lamp luminaires could be more efficient and thereby save on capital, operating and maintenance costs.



High bay fluorescent luminaire

CONTROLS

The best approach to using lighting control is to keep it simple. Consider **daylight sensor controls** (photocells) to ensure that lights are not left on unnecessarily when there is adequate daylight. These controls can either dim the lighting as the daylight levels increase or switch off lamps at a pre-determined lighting level. **Occupancy/presence sensors** are also available and are appropriate

when 'zoning' areas. Dual headed presence detectors and light sensors are also available and should be considered. Note that automatic controls should be appropriately designed when used in conjunction with high intensity discharge lamps that require 'restrike' time.

Further details are available in a separate SEAI guide on **Lighting Controls**.

DAYLIGHT

Daylighting should be considered in appropriate situations. Natural light can make a space attractive and pleasant and improve working conditions. However, direct uncontrolled solar penetration should be avoided as it creates glare and may cause overheating in summer. Maximum energy savings are achieved when daylight availability is integrated with daylight-responsive controls and diffused panels.











MAINTENANCE AND LAMP REPLACEMENT

Regular maintenance is important for maximising energy savings and maintaining lighting levels. Without this, light levels can fall by at least 50% in 2-3 years, when the least efficient fluorescent tubes or high intensity discharge lamps are in use.

Long life versions of T8 lamp types should be used as they can provide 3 times more lamp life than a standard high efficiency fluorescent tube operating on an electronic high frequency ballast.

- Keep windows and skylights clean.
- Keep lamps, luminaires, sensors and surfaces free from dust and dirt.
- Carry out group or bulk maintenance of lamps and fittings at appropriate intervals.

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

Existing Lamp Type	Replacement Lamp Type	Benefits
38mm-diameter (T12) linear fluorescent lamps 	26mm-diameter (T8) linear (triphosphor) fluorescent lamps 	<ul style="list-style-type: none"> - 10% energy savings - approximately 15% more light - higher colour rendering <p>T12 lamps can be directly substituted with T8 lamps to existing luminaires with switch-start control gear, but not with quick start electromagnetic control gear.</p> <ul style="list-style-type: none"> ✓ Request T8 lamps with triphosphor or multiphosphor coating, as these give better performance.
26mm diameter (T8) or 38mm diameter (T12) linear fluorescent lamps 	16mm T5 fluorescent lamp retrofit with electronic adaptor 	<ul style="list-style-type: none"> - up to 50% energy savings - similar light output - better colour rendering
Standard high pressure mercury 	'H' type high pressure sodium 	<p>Plug-in HPS lamps may be considered.</p> <ul style="list-style-type: none"> - energy saving of 12-16% - increased light output of 55-67% <ul style="list-style-type: none"> ✓ Ensure that ballasts/wattages are compatible. ✓ Check the colour rendering of the high pressure sodium lamp to make sure it is sufficient.
Standard high pressure mercury 	HPI Plus metal halide 	<p>Plug-in metal halide lamps 'S' type can be retrofitted with equal wattage lamps to mercury control gear. These lamps will provide approximately 45% more light.</p> <ul style="list-style-type: none"> - higher colour rendering - cool white appearance <p>Check that the lamp wattage of the plug-in metal halide lamps is the same as the existing lamp wattage.</p>

Note: Always use reputable suppliers and products that comply with all national and EU lighting regulations. Trial newer products for their suitability before widescale upgrades. Refer to www.seai.ie/aca for energy efficient products.

EXISTING LUMINAIRE AND LAMP TYPES

Existing High Bay Luminaire & Lamp Type	Possible Replacements for High Bay Mounting	Benefits
Mercury	① T5 or T8 Tubular Fluorescent	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Available as dimmable and with presence detecting.
	① Compact Fluorescent	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Available as dimmable and with presence detecting.
	② Metal Halide	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Good colour rendering. - Available in 'warm' and 'cool' colours.
	③ High Pressure Sodium	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Long life. - Lower colour rendering. - Warm colour.
	④ Inductive	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Extra long life. - Good colour rendering. - Available in 'warm' and 'cool' colours.
High mounted T12 tubular fluorescent	① T5 or T8 Tubular Fluorescent	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Available as dimmable and with presence detecting.
	① Compact Fluorescent	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Available as dimmable and with presence detecting.
	② Metal Halide	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Good colour rendering. - Available in 'warm' and 'cool' colours.
	③ High Pressure Sodium	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Long life. - Lower colour rendering. - Warm colour.
	④ Inductive	<ul style="list-style-type: none"> - Lower wattage to achieve the same light. - Extra long life. - Good colour rendering. - Available in 'warm' and 'cool' colours.
Metal Halide	① T5 or T8 Tubular Fluorescent	<ul style="list-style-type: none"> - Equal efficiency. - Available as dimmable and with presence detecting.
	① Compact Fluorescent	<ul style="list-style-type: none"> - Equal efficiency. - Available as dimmable and with presence detecting.
	④ Inductive	<ul style="list-style-type: none"> - Equal efficiency. - Extra long life.
High Pressure Sodium	① T5 or T8 Tubular Fluorescent	<ul style="list-style-type: none"> - Equal efficiency. - Available as dimmable and with presence detecting.
	① Compact Fluorescent	<ul style="list-style-type: none"> - Equal efficiency. - Available as dimmable and with presence detecting.
	② Metal Halide	<ul style="list-style-type: none"> - Good colour rendering. - Available in 'warm' and 'cool' colours.
	④ Inductive	<ul style="list-style-type: none"> - Equal efficiency. - Extra long life.

LIGHTING TECHNICAL DETAILS

1 TUBULAR AND COMPACT FLUORESCENT LAMPS



The most extensively used light source in warehouses and factories is either the T12 or T8 fluorescent tube. The T12 is the least efficient as shown on page 3 and can be replaced with either a T8 or T5 tubular fluorescent version, these tubes are the most efficient as triphosphor types. The T8 would need to be specified as triphosphor and the T5 is only available in triphosphor. The compact fluorescent lamp is available in high wattages (55W, 80W and 120W). All of these lamp types would need to be operated on electronic high frequency control gear (ballast) to achieve maximum efficiency. The ballast is also available as a dimmable ballast and can be linked to any daylight ingress which may be entering the lit area. Choose extended life models e.g. T8 at 60,000 hours, T5 at 45,000 hours and the 55W compact fluorescent at 36,000 hours.

2 METAL HALIDE DISCHARGE LAMPS



Metal halide (HID) lamps have good efficiency and may be used to provide general lighting in large spaces, and for situations where good colour rendering and different colour appearances are required.

Remember that if turned off during operation, metal halide lamps require a warm-up and restrike period of up to 15 minutes. A backup alternative lighting source is therefore required to provide light during restrike time. This is often achieved with a minimum requirement number of fluorescent luminaires.

3 HIGH PRESSURE SODIUM (SON) LAMPS



High pressure sodium discharge lamps combine high efficacy with long life and are used in industrial high bay or floodlighting applications where colour rendering is less important. Lamps require a warm-up and re-strike period and are therefore not suitable for frequent switching.

4 INDUCTIVE LAMPS



Inductive lamps do not have electrodes or filaments and are based on a principle, which is fundamentally different from that of conventional fluorescent lamps. In induction lamps the electrical energy is supplied to the gas discharge by means of a high frequency electromagnetic field. The life of the system can be extremely long (60,000 to 100,000 hours) with 90% reliability and 70% lumen maintenance. As fluorescent powders are used within the vessel, colour rendering is good with differing colour appearances.

5 TASK LIGHTING



Task lighting should use tubular/compact fluorescent lamps or LEDs.

When using opaque shades, ensure that good reflectors are installed – preferably bright aluminium. White plastic reflectors discolour quite quickly, leading to poor light output.

Ensure that task lighting operates on electronic high frequency control gear in situations where stroboscopic effects could occur, e.g. lighting a lathe chuck.

LIGHTING CHARACTERISTICS

The following table shows the recommended maintained illuminance level and colour rendering for different industrial activities.

Area	Maintained illuminance (lux)	Minimum colour rendering (Ra)
Warehouses		
Storage & warehouse rooms	100	60
Shipping & packing areas	300	60
High bay racking		
Tracks without passenger traffic	20	40
Tracks with passenger traffic	150	60
Control room	150	60
Chemical, plastics and rubber industry		
Continuously occupied workplaces in processing systems	300	80
Pharmaceutical production	500	80
Electrical industry (Assembly work)		
Rough, e.g. large transformers	300	80
Medium-sized, e.g. control panels	500	80
Detailed, e.g. telephones	750	80
Very detailed, e.g. measuring instruments	1000	80
Food and beverage industry		
Workplaces and work zones in: sugar factories, breweries (on malting floors), for boiling in canning and chocolate factories	200	80
Sorting and washing products, milling, blending, packaging	300	80
Cutting and sorting fruit and vegetables	300	80
Workplaces and critical zones in slaughter houses, butcher shops, dairies, mills, on filter floors in sugar refineries	500	80
Production of delicatessen products, kitchen work	500	80
Inspection of glasses and bottles, product inspection, garnishes, sorting, decorating	500	80
Laboratories	500	80
Colour inspection	1000	90
Print shops		
Cutting, gold-plating, stamping, etching of printing plates, working on stones and plates, printing machines, matrix production; paper sorting and block printing.	500	80
Loading bays	150	40

Note: This table is based on information from I.S. EN 12464-1:2002 Light and lighting – Lighting of work places – Part 1: Indoor work places. National Standards Authority of Ireland. 2002. This guidance should be consulted for more comprehensive data.

LAMP COMPARISON CHART

The properties of different light sources for manufacturing and warehouse buildings are shown below. Choose long life versions of lamps where available, and triphosphor T8 fluorescent tubes in preference to the standard (halophosphor) T8 fluorescent tube.

Lamp type	Efficacy (lumens per watt)	Colour temperature (K)	Colour rendering (Ra)	Lamp life (hours)
Daylight		5,500 - 8,500	100	
Compact Fluorescent	45 - 60	2,700 - 4,000	85	8,000+
T8 (26mm dia.) Halophosphor Fluorescent Tubes	37 - 68	2,700 - 4,000	58	6,000+
T8 (26mm dia.) Triphosphor Fluorescent Tubes	71 - 92	2,700 - 6,000	80±	20,000 - 60,000
T5 (16mm dia.) High Efficiency Fluorescent Tubes	66 - 82	2,700 - 6,500	80±	20,000
T5 (16mm dia.) High Output Fluorescent Tubes	62 - 76	2,700 - 6,500	80±	20,000
Metal Halide (Standard)	71 - 83	3,000 - 6,000	65 - 85	8,000 - 20,000
Metal Halide Plus	66 - 75	4,300	69	12,000+
Mercury	31 - 57	3,900 - 4,200	36 - 49	12,000+
High Pressure Sodium	86 - 95	3,000 - 6,000	25	12,000 - 30,000
High Pressure Sodium H	80 - 89	2,000	25	8,000 - 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. When lumens fall to 80%

of initial lumens, this is the rated 'life' and when the lamp should be replaced. 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.

A tax incentive is available through the Accelerated Capital Allowance (ACA) scheme for approved lighting products. Further information and details of manufacturers and suppliers of eligible products are available from www.seai.ie/aca

