The new state of business

ENERGY SAVER

Energy efficient lighting

Technology report

Second edition 2014

Office of Environment & Heritage

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Preface to the Second edition

With the rapid advancement of lighting technology and continuing decreases in product prices, OEH has updated the *Energy efficient lighting technology report* published in July 2012. This is not a major revision but focuses on the addition of improved business cases for lighting upgrade options. In particular:

- New LED options for upgrading twin 36W T8 linear fluorescent luminaires, 50W MR16 low voltage dichroic halogen lamps and 500W linear lamp shovel and box floodlights
- Inclusion of options for replacement of twin 36 W T8 surface mounted recessed fluorescent luminaires
- Preferred LED options for upgrading 400W mercury vapour luminaires and 400W metal halide high bay luminaires
- Updated costs for all upgrade options for 400W mercury vapour luminaires

This second edition also provides an overview of the proposed changes to the Energy Saving Scheme (ESS) Rule. The ESS rule outlines how to calculate the number of eligible Energy Saving Certificates which can reduce the cost of a lighting upgrade. (p. 20)

Overview

Lighting contributes significantly to business energy use and operating costs. Increasing energy prices highlight the need to reduce the cost of lighting. Energy use associated with lighting systems can be reduced by up to 82 per cent if energy efficient lighting practices are adopted.

Efficient lighting systems not only reduce energy consumption but improve the working environment, increase safety and enhance staff well-being.

This report is designed to help you identify appropriate and reliable energy efficient lighting technology that would be suitable for your facility. The report addresses:

- **general information** – measuring light, common types of lighting, light emitting diodes (LED) as an emerging technology, lamp disposal and recycling and developing a business case (p. 7)
- **interior lighting** – upgrade options for lighting in common commercial, industrial and institutional facilities, such as offices, manufacturing plants, warehouses, schools, libraries and hospitals (p. 23)
- **exterior and road lighting** – upgrade options for floodlighting as well as major and minor road lighting (p. 85)
- **emergency and exit lighting** – energy reduction strategies associated with emergency and exit lighting products (p. 94)
- **lighting control** – potential for saving energy with occupancy sensors, daylight linking, central switching, zone resetting, manual switching, timers and voltage reduction (p. 96)
- **voltage reduction and optimisation** – energy saving technology, particularly in older sites where major lighting infrastructure changes may be difficult (p. 99)
- **energy efficient lighting technical details** – technical specifications for each lighting upgrade option including illuminance, maintenance, safety and background calculations (See the *Energy efficient Lighting technology report – technical details*. Available on the OEH website.)
- **Energy Savings Certificates** – calculating the number of Energy Savings Certificates (ESC) and how to apply for them (See p. 20 *Developing a business case* for details on energy savings certificates).

It is important to review the lighting operations of your facility in a holistic manner. For best practice, follow these steps:

1. assess the available natural light and potential for improvement, introduce natural light into open spaces such as warehouses (e.g. through skylights)
2. link artificial light use to the natural light levels (daylight linking) using sensors and smart control systems to minimise energy use
3. assess options for de-lamping, dimming or multilevel switching to reduce energy consumption
4. identify low activity areas and assess use of occupancy sensors
5. review zoning and increase the number of zones (if appropriate) to allow lights to be turned off when areas are not used
6. identify lights that could be upgraded with more energy efficient lighting
7. ensure the energy efficient lighting that is selected meets Australian Standards.

How to use this report

This report is not intended to be read cover to cover, but should be used as a reference guide for choosing the most appropriate lighting upgrade for your space.

The most commonly used interior and exterior lights are described in the introduction, along with an overview of the factors to consider when upgrading lighting. For each existing light application the potential energy efficient upgrade options are discussed.

Finding the lighting upgrade that applies to you

This report is designed on the premise that the reader is aware of their current lighting system.

Please review the table on the following page to select which types of existing lights are relevant. This table outlines potential upgrade options for that specific type of light, including a summary of the typical costs and energy savings.

For those who are unsure as to their current systems please read general lighting information (p. 7) and Appendix 1 (p. 100).

The *Energy efficient Lighting technology report – technical details* contains additional information for each lighting option including a technical specification, allowing you to make the correct requests to lighting suppliers.

If you cannot find a particular light in the contents page or table please refer to the index.

SUMMARY OF LIGHTING UPGRADE OPTIONS

The options are assigned a colour according to which type of existing lighting system they are to replace. All pages with the corresponding colour tab are specific for that option.

Energy and cost savings associated with typical lighting upgrades

	Upgrade options	Quantity of luminaires	Cost reduction ($ p.a.)	Typical capital cost ($)	Energy saving (kWh p.a.)	Typical simple pay back (yr)	GHG reduction (tCO_2 p.a.)	Energy reduction (%)
Twin 36 W T8 recessed linear fluorescent luminaire (page 24)								
1	Retrofit single 36 W T8 reflector and electronic ballast kit	100	3292	12,000	14,040	3.7	14.8	60
2	New twin 28 W T5 fluorescent luminaire ✓	100	1722	8,500	7800	4.9	8.3	33
3	New single 28 W T5 luminaire ✓	100	3552	13,000	15,600	3.7	16.5	67
4	Linear LED replacement lamps, 2 x 19 W	200 lamps	2704	13,000	13,520	3.8	14.3	58
5	T8 to 28 W T5 conversion kits	200 kits	1722	8,000	7800	4.6	8.3	33
6	New 30W integrated LED luminaire ✓	100	3,824	9,000	15,600	2.4	16.5	67
Twin 36 W T8 surface mounted linear fluorescent luminaire (page 38)								
1	New 43 Watt LED luminaire, Integrated LED module and power supply, fitted with diffuser ✓	100	704	15,500	12,220	2.9	12.9	52
2	New twin 28 W T5 linear fluorescent luminaire	100	1722	11,500	7,800	6.7	8.3	33
3	New complete single 28 W T5 linear fluorescent luminaire ✓	100	3553	10,500	15,600	3.0	16.5	67
4	Linear LED lamps, 2 x 19 W	200 lamps	3408	12,000	13,520	3.5	14.3	58
5	T8 to 28 W T5 conversion kit	200 kits	1722	8,000	7,800	4.6	8.3	33
50 W MR16 low voltage dichroic halogen lamp (page 50)								
1	35 W IRC halogen lamp	100	1651	1200	5200	0.7	5.5	31
	35 W IRC halogen lamp with electronic transformer	100	2015	3200	7020	1.6	7.4	42
2	7 W LED replacement lamp	100	4,152	3400	14,040	0.8	14.8	83

Energy and cost savings associated with typical lighting upgrades

	Upgrade options	Quantity of luminaires	Cost reduction ($ p.a.)	Typical capital cost ($)	Energy saving (kWh p.a.)	Typical simple pay back (yr)	GHG reduction (tCO_2 p.a.)	Energy reduction (%)
3	New 16 W LED luminaire ✔	100	4086	8000	12,740	2.0	13.5	75
4	15 W compact fluorescent lamp replacement	100	3517	5500	13,000	1.6	13.8	77
5	New 13 W compact fluorescent luminaire	100	3962	10,000	13,000	2.5	13.8	77
PAR lamps and other halogen downlights (page 63)								
1	New 35 W ceramic metal halide luminaire	100	4723	20,000	16,120	4.2	17.0	62
2	New 27 W LED luminaire (non-dimmable)	100	6504	25,000	18,980	3.8	20.0	73
3	New 2 x 18 W compact fluorescent (DALI dimmable)	100	5388	25,000	15,600	4.6	16.5	60
4	New 27 W LED luminaire (DALI dimmable)	100	6504	32,000	18,980	4.9	20.0	73
400 W mercury vapour luminaires (page 68)								
1	New 250 W metal halide luminaire ✔	100	9011	20,000	42,120	2.2	44.6	37
2	4 x 54 W T5 fluorescent luminaire	100	11,964	55,000	53,560	4.6	56.7	48
3	New 110 W LED luminaire	100	19,317	55,000	83,720	2.9	88.7	75
4	200 W induction luminaire	100	14,117	65,000	57,720	4.6	61.1	51
400 W metal halide luminaires (page 78)								
1	New 320 W pulse-start metal halide luminaire	100	5893	30,000	27,300	5.1	28.9	51
2	New 210W LED luminaire ✔	180	14,042	63,000	63,440	4.5	67.2	54
3	New 300 W induction lamp luminaire	100	8582	78,000	36,140	9.1	38.3	31
500 W linear lamp shovel and box floodlight (page 86)								
1	New 150 W metal halide luminaire	10	2472	3000	12,012	1.2	12.7	66
2	New 110 W LED luminaire ✔	10	3142	5000	14,196	1.6	15.0	78

Introduction

Lighting upgrades can significantly reduce energy use. The Office of Environment and Heritage (OEH) has produced the *Energy efficient lighting technology report* as part of the Energy Saver program. This program promotes the use of energy efficient technology in NSW.

Two key steps towards improving lighting technology include:

1. identifying lights that can be upgraded
2. preparing a business case for upgrading lights.

This *Energy efficient lighting technology report* can guide you through both of these steps. Once a business case is developed, capital expenditure decisions become easier and a pathway to upgrading lights becomes clearer. An example of a business case is given on p. 18.

Energy efficient upgrades for a range of lighting types are discussed and light quality and risk management are also taken into account. Performance and safety specifications are included for each lighting upgrade option.

The payback period for each upgrade is included, i.e. the number of years in which the capital cost would be repaid. But when lighting is near the end of its life, the *marginal* cost of a high efficiency system compared with a standard system is more realistic, rather than the total cost. When equipment is at the end of its useful life, financial return calculations should be made against the capital cost difference of 'like for like' vs energy efficient equipment.

While the focus of the report is for existing buildings, the principles outlined in this report are also relevant for new buildings.

Training workshops make it possible for you to apply the principles outlined in this report to the specifics of your energy efficient lighting upgrade. For more information on training available and to register for the lighting training workshop, please go to **www.environment.nsw.gov.au/sustainbus/energysaver/training.htm**

Energy and cost savings

Lighting upgrades can significantly reduce energy use (by up to 82 per cent). There are two general types of upgrades: a retrofit and an entire luminaire replacement. A retrofit changes only part of an existing luminaire system, such as lamp or control gear. The other option is to replace the entire luminaire with a new luminaire. The decision will depend on a number of factors. Generally, retrofitting requires less upfront capital and can be easily installed, but installing a new luminaire is often more cost effective in buildings that contain older equipment. Full replacement can also be economical where improvements in technology have led to reductions in price (e.g. light emitting diodes (LED), p. 12)

Compliance with regulations and standards is often more easily achieved with full replacement solutions. Due to the complexity of compliance with regulations, we recommend that a risk assessment is carried out for projects where retrofit upgrades are considered.

In either a retrofit or entire luminaire replacement project, this report assumes that a one for one swap from existing technology to the new technology will satisfy the project needs. This is not always possible. It is important to include the impact of the changed number of luminaires in the total cost of ownership calculations where necessary.

Energy efficient lighting often has a significantly lower heat load than traditional lighting, which means that less energy is required to cool a space. Upgrading lighting can reduce the amount of energy used by heating, ventilation and air conditioning (HVAC) systems. These savings have not been quantified within this report, but should nevertheless be seen as an additional benefit.

While this report provides indicative costs and savings of typical lighting upgrades, calculating accurate energy savings at your specific site will require a site-based assessment.

The OEH website provides a "live" version of the total cost of ownership calculator used within this report. The live tool is called 'Calculight' and can be used to provide total cost of ownership calculations that take into account the variables specific to your site and proposed upgrades. The Calculight tool can be accessed via **www.environment.nsw.gov.au/lightingToolApp/default.aspx**.

General lighting information

There is no substitute for good lighting design, which focuses on light quality as well as light quantity. The environment is lit for people so lighting should be both functional and attractive. Understanding some basic lighting concepts can help when designing energy efficient lighting solutions.

Electric light

Electric light is measured in the four basic ways it interacts with its environment (**Figure 1**):

1. **how much light did we start with? –** the light produced by a light source (typically a lamp) is measured in lumens (lm) and is called luminous flux
2. **where is the light going? –** if light is directed towards a surface, rather than scattered and uncontrolled, the light level will be higher on the surface. This is called luminous flux or light intensity and is measured in candela (cd)
3. **how much light got there? –** the light arriving at a surface is called illuminance and this is measured in lux. Illuminance does not take into account how the surface will respond to the light, only how much gets there
4. **how does the surface look once it has been lit? –** a white wall will reflect a lot of the light directed at it and will effectively become a light source, while a black wall will not reflect much light. The luminance of a surface is measured in candela per square metre (cd/m^2).

Lighting suppliers most commonly use lumens (lm) as the defining characteristic of the light source. When selecting a luminaire we need to understand how much of the produced light will enter the space and where it will land. When

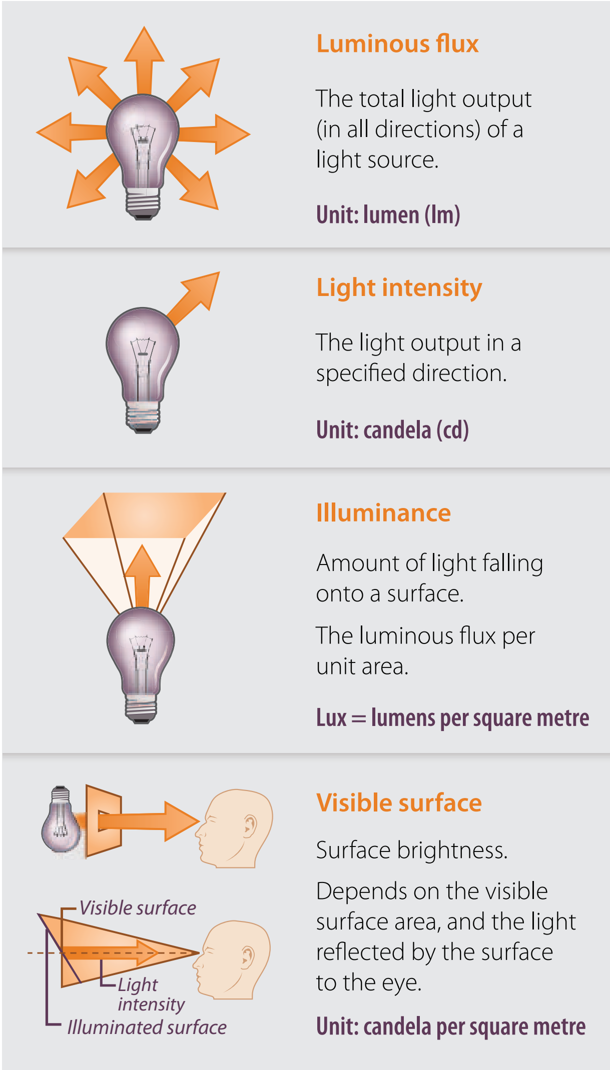


Figure 1: Light measurements

Colour rendering index and correlated colour temperature

Light sources can appear similar in colour but may render, or 'show' the surface colour quite differently. The accuracy can be measured by the colour rendering index or CRI. CRI is typically expressed as a number, where 100 represents the most true to life colour rendering.

The colour appearance of the light source is represented by the correlated colour temperature (CCT). This is often shown on lamps as colour temperature with a unit of Kelvin (K). The higher the CCT the 'cooler' or blue the light is – 2500 K has a very warm or yellow appearance where as 4000 K is a cool blueish light. 4000 K is common in office areas.

A fluorescent tube may have a colour temperature of 3000 K and a CRI of 80. A tube may also be available with a colour temperature of 4000 K and also have a CRI of 80. These tubes will represent the colours in objects equally well, but will appear different in colour.

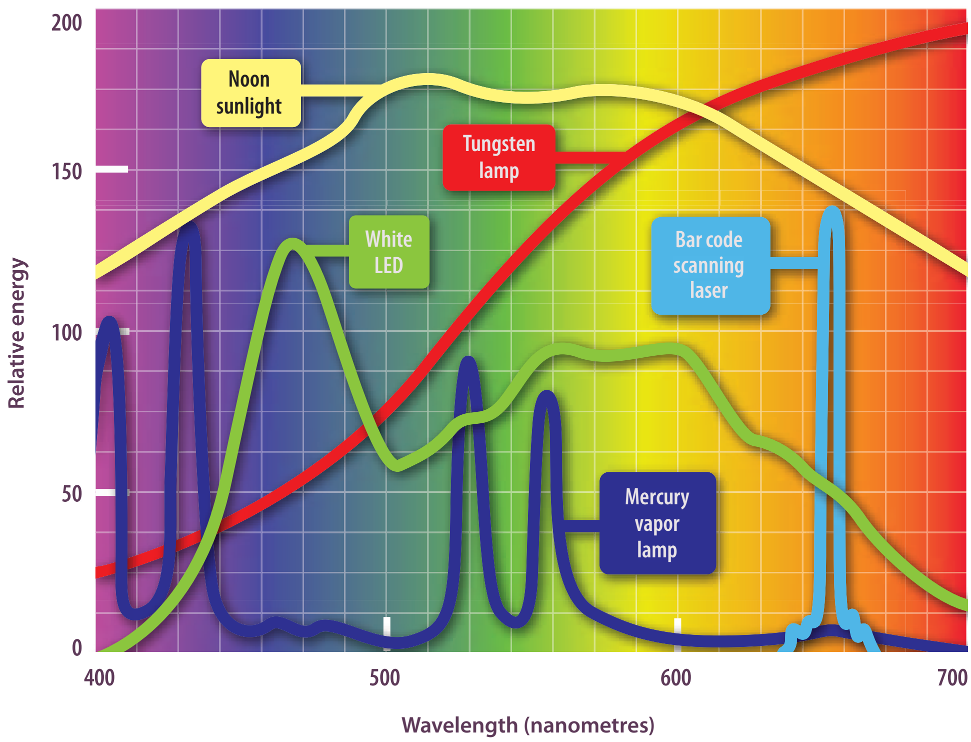


Figure 2: Common sources of visible light

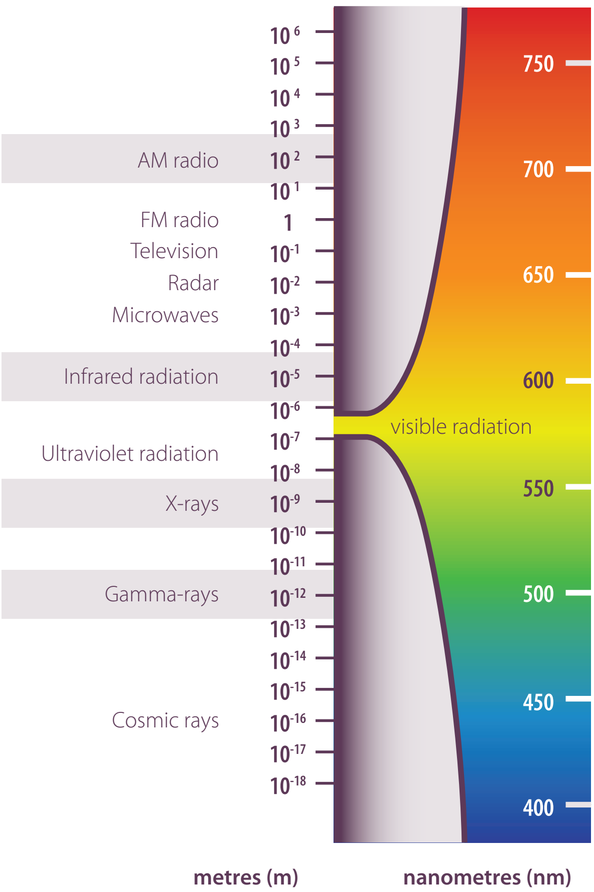


Figure 3: The electromagnetic spectrum

comparing technologies, resist any encouragement from suppliers to focus only on lumens produced. Lighting design software will take into account all areas of light performance.

Light colour

The human eye is capable of seeing a range of colours in the electromagnetic spectrum. This means that if a light source produces enough light within this range, most people will be able to see it and perceive the colour.

When light hits an object, some (or all) of the light is reflected by it, while some is absorbed. The human eye will perceive a colour, depending on the characteristics of the lit object. For example, an object that appears red has absorbed the wavelengths of other colours and reflected those that are red.

The appearance of an object can be affected by the electric light source, as each light source can represent different regions of the spectra (**Figures 2 and 3**).

Common types of lighting

Most luminaires consist of a lamp, lampholder and control gear. The luminaire will also have a means of getting as much light as possible to leave the luminaire and travel in the required direction. This could involve reflectors, louvres, lenses or diffusers.

There are thousands of different lamp holders, tens of thousands of different luminaire types, and even more types of lamps. Here are some of the typical lamps that are used in commercial applications.

Common types of lights *More detailed descriptions can be found in Appendix 1*

General lighting service incandescent lamps (GLS lamps)

GLS lamps are no longer available to purchase due to their poor efficiency.

These lights have often been used in auditoriums and theatres where dimming is needed. Few sites remain where large quantities of these lamps are installed.

Halogen lamps

Halogen lamps are also an incandescent lamp. Where most incandescent lamps contain a tungsten filament and some gasses (typically argon and/or nitrogen), the halogen lamps also contain iodine. This significantly prolongs lamp life and allows the filament to burn hotter and therefore whiter. Halogen lamps are generally more efficient than standard incandescent lamps.

Halogen lamp

Dichroic halogen lamps

Dichroic halogen lamps have coatings on the inside of the reflector that are able to reflect visible light, but are 'clear' to infra-red (heat) and ultraviolet (UV) light. Therefore the majority of heat and UV light produced is passed through the back of the lamp. Dichroic lamps can cause fires when used in combination with flammable substances or ceiling insulation.

In most cases where dichroic lamps are used, the luminaire does little more than hold the lamp in place. The control and direction of produced light is handled by the lamp and its integrated reflector.

Halogen dichroic lamps

GU10

GU5.3

Fluorescent lamps

Fluorescent lamps come in a variety of forms. Linear lamps and compact lamps are the most common types covered by this report. Fluorescent lamps contain mercury which causes the tube to produce light mostly in the UV region of the spectrum. UV light is not useful for general lighting and so the light is shifted to the visible spectrum by a combination of coatings. These coatings are seen as white on the inside of the tube and are known as phosphors. These can provide light in a variety of white shades, depending on the blend of phosphors used. The fluorescent tubes are sometimes known as low pressure mercury tubes.

All fluorescent lamps work in the same manner, regardless of their shape.

Compact fluorescent lamp (CFL)

T8 lamp compared with a T5 lamp

High intensity discharge (HID) lamps

Mercury vapour lamps, sodium vapour lamps and some types of metal halide lamps can be very similar in appearance.

Mercury vapour lamps

These are very similar to fluorescent tubes as they use mercury and phosphors. These lamps are not generally used in new buildings as metal halide lamps are more efficient and offer better light quality.

They were commonly used in high bay fittings and old style street lights. They were occasionally used in downlights within large spaces, such as the foyers of tower buildings. These lamps produce a blueish light.

Sodium vapour lamps

Sodium vapour lamps are generally used in street lighting and occasionally in car park lighting. These lamps use sodium instead of mercury and the light they produce is very orange-yellow in colour. Sodium vapour lamps have become less popular with lighting designers over recent years, most likely due to the better light quality of metal halide lamps.

Metal halide lamps

These lamps have become quite popular over the last ten years due to advances in technology. They contain a number of different metal halides which produce different wavelengths within the visible spectrum. A good white light is produced by metal halides. These lamps are used in a variety of applications because they are efficient and have long operating lives.


Mercury vapour lamp

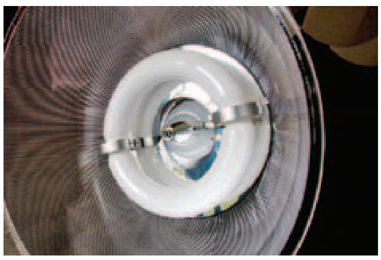

Sodium vapour lamp


Orange-yellow light from a sodium vapour lamp

Metal halide lamps

Induction lamps

These lamps are similar to fluorescent lamps, except that they do not receive their energy by electrodes creating an arc. The mercury in a typical induction lamp is excited into producing light by the use of a powerful magnetic field. The lamps are operated by electronic control gear.



Light emitting diodes (LED)

Electricity is passed through a semiconductor, which produces photons (a basic unit of light). The semiconductor can be made from many different mixes of materials, which means that photons can be produced in a variety of colours. LED can produce more useable white light per unit of energy than metal halide, sodium vapour, fluorescent and halogen light sources.

LED produce a lot of light from a very small source, which helps to control where the light shines. LED can cause a great deal of glare if not managed properly.

Ballasts

Generally, these used to be a copper and iron device, which was quite heavy and relatively inefficient. Conventional ballasts are known by a variety of names, including wound ballasts, magnetic ballasts and copper ballasts. Most conventional ballasts require an external starter to be in circuit.

Electronic ballast systems do not use an external starter. When looking at an installation on-site, if you can see a starter you know that a magnetic ballast is in use.

A conventional ballast and starter, when powered from cold, will typically flicker three to four times and then turn on.

An electronic ballast will simply start the lamp. A slight dimness may be detected at first (less than a second) and then the lamp will light up.

In the cases where electronic ballasts are used, it is very unlikely that energy use can be substantially reduced at the luminaire.

Common lighting terminology

Luminaire – also referred to as light fitting or fixture, including the lampholder and lamp.

Lampholder – part of the luminaire that provides electrical connection to the lamp and holds the lamp in place.

Lamp – the light source mounted within a luminaire.

Control Gear – converts the energy supplied to the building into a form that best suits the light source. Includes starters and ballasts.

Figure 4: 18 W LED

Figure 5: 7 W LED lamp

Figure 6: LED luminaire with integrated heat sink

Figure 7: LED high bay

Check that the colour characteristics are consistent amongst LED lights when they are lit.

Light emitting diodes (LED) – an emerging technology?

LED is considered by many to be an emerging technology, but to others it is a mature technology that has already displaced mainstream lighting technology. Those who consider LED a mature technology view it as an established and effective tool for delivering quality lighting solutions that requires extremely low, or no maintenance and delivers excellent efficacy.

Why such opposing views?

Existing lighting technology is based on lamps whose development cycles have spanned decades, yet are expected to remain cutting edge for 20 to 30 years. LED lighting did not evolve from existing lighting technology and was developed for a different purpose. LED is a product of the electronics industry, where development cycles are measured in months and product life cycles are very short.

Over the last 10 years, mainstream lighting companies have begun investing substantially in LED manufacturing facilities rather than questioning its viability. Major lighting companies no longer view LED technology as emerging, but as a developed technology.

Some lighting manufacturers, who had little investment in the current technology, saw LED lighting as an opportunity and were able to rapidly develop LED lamp and luminaire solutions. An enormous variety of products were developed and as a result the quality ranged from extremely poor to excellent, with little guidance to help consumers. This created some negative impressions of LED technology when it was first adapted to mainstream lighting applications.

LED and the power supply systems that drive them are different enough from traditional lighting technologies to require a different set of standards for their construction and use. Australian authorities are moving to address this gap and provide benchmarks for LED lighting.

Characteristics of LED lighting

LED technology will not make all other energy efficient lighting solutions obsolete. This report outlines some upgrade scenarios where LED technology has performed well, and others where it hasn't performed as well. However, the use of LED technology will become increasingly compelling over time.

There are a number of factors to consider when applying LED technology to lighting projects, including the availability of reputable product suppliers who can provide product support. Some LED characteristics and tips for obtaining the best outcomes are outlined below.

a. Light colour

'White' LED light is produced by LED lights that deliver blue light which is then 'shifted' into the broader spectrum by phosphors. This is much the same as the way fluorescent technology produces 'white' light.

LED light characteristics, particularly light colour, can vary substantially. Selecting LED lights that are manufactured at the same time (from the same lot or bin) will help to make sure that light colour is consistent across lamps. LED lamps are usually available in a variety of colour temperatures. As LED lamps produce 'blue' light, those with cooler colour temperatures generally produce more light. Many manufacturers produce lamps with a very cold colour temperature to make sure that as much light is produced as possible, but very cool coloured light will not be appropriate in most situations.

Once the white colour temperature has been selected for a project, it is important to make sure that lamps of this colour can be consistently delivered. Look at lamps when they are lit to determine if their colour characteristics are consistent. If each LED is a slightly different colour, then they won't generally deliver a consistent light colour over a large area.

b. Light output

The efficacy of each LED is another characteristic that can vary between different lots or bins during manufacturing. Reputable manufacturers will guarantee that their products will be at least as bright as they claim. Look at a number of working lamps at the same time to make sure that they produce similar amounts of light. Light output is the main aspect of LED performance that is still developing. LED technology will increasingly provide appropriate lighting solutions as light output and efficacy improves.

Delivered light is the ideal characteristic to look at when assessing the ability of a luminaire to meet a need. Compare different luminaire and lighting technologies by the amount of light that leaves the luminaire, rather than the amount of light produced by the lamp. This includes any losses from control equipment and will also take into account the light output ratio (LOR) of the luminaire. Considering the LED lumens alone is meaningless.

Ask to see a number of working samples at the same time and make sure they have a similar light output.

c. Heat production

LED lights generate very little heat when compared to other light sources. However, minimising the temperature at the internal junction between the power supply and the LED material is critical to ensure long LED life. LED manufacturers provide information to luminaire manufacturers on the temperatures acceptable at this internal junction. Like most electronic devices, heat management is usually carried out by heat sinks. Typically, the heat sinks are metal fins that sit behind the luminaires.

Try to find a luminaire design that has a heat sink. Ask the supplier to demonstrate that both the LED and the control equipment have been tested.

Look for a design that takes into account heat removal.

Ask your supplier to demonstrate that the LED and control equipment has been tested.

d. Glare

Glare can be a problem with LED lights because of the small size of each light in relation to the amount of light they produce. Luminaire manufacturers are now starting to design around LED characteristics, rather than trying to make LED lights work in luminaires designed for different technology. Prepare a sample area of LED light to evaluate glare.

Install the new LED product in a sample area to allow staff to evaluate glare.

e. Operating life

For conventional light sources, the rated lamp life is the period of time elapsed once 50 per cent of lamps have failed. Testing is carried out by running a number of lamps on a specified switching cycle and monitoring them over time. This test does not tell you if 49 per cent failed on the first day, nor if the amount of light produced changed over time.

LED technology is so different that these testing methods do not apply. The life of an LED luminaire should be expressed by the manufacturer as the time taken for light production to drop to a certain percentage of the original output. At the moment, the accepted life of LED is 50,000 hours to 70per cent of initial light output. Total and sudden LED failure is now extremely rare in commercial quality systems.

The design and construction of LED luminaires can have a profound effect on LED life. It is important to choose a supplier that tests lamp life expectancy and can explain how it has been tested.

What situations are best suited to LED use?

LED lights are known as point source lights, where the light is delivered from a relatively small surface area. A fluorescent tube delivers light from a very large surface area. It is easier to accurately control or direct light in a luminaire from a point source than from a large surface area.

Task lighting

Task lighting, where a high light level is needed on a particular area or object, can be used to supplement ambient lighting. This can improve the quality of the working environment and help to meet lighting standards.

Under cupboard shelf lighting, desk lamps and supplementary downlights are all examples of task lighting.

LED lighting is a simple, low cost option for task lighting.

Good task lighting requires careful attention to glare management.

Remember to include the connected load of the task lights in energy use calculations for the space.

LED technology is best used in areas where controlled light is required – downlights, floodlights and spotlights – and where existing light sources are less than 250 W.

Smart control

LED technology can be dimmed which means that flexible control options are possible. Some manufacturers use a simple on/off control for banks of LED light to achieve multilevel switching. Lower light levels are delivered to areas not in use, whilst maintaining light colour quality and saving energy.

Control options should be considered that address:

- natural light (daylight linking)
- activity
- time
- manual override.

Connection to a central intelligence device can also result in longer lamp life as all LED lights are used equally.

Substantial energy reductions are possible and these should be calculated on a case-by-case basis.

Product quality

LED technology is different from most other light technology. The correct design of luminaires is critical to achieve an acceptable lamp life and quality products have these characteristics:

- good heat sinks – these will take the form of metal fins behind the LED and will be heavy
- separate power supply – the luminaire should be constructed in such a way that heat generated by the LED does not interact with the power supply and vice versa
- smart optics – the LED should be fitted with optical devices, such as lenses, that will deliver light where it is needed.

LED lights are ideally suited to task lighting, where a higher light level is needed on a particular area or object. Generally, large source lamps such as fluorescent lamps are better suited to ambient lighting, where an even amount of light is needed over large areas.

LED technology can deliver significant benefits where existing light sources are less than 250 W and in areas where controlled light is required, such as downlights, floodlights and spotlights.

LED and fluorescent lamp use can crossover into both situations, but the effectiveness of the system will usually suffer. For example, there are LED products available to retrofit fluorescent products, but the form of a fluorescent tube makes cooling the LED difficult. Some manufacturers will lower LED light production to minimise the amount of heat produced.

As the LED are tiny and very bright, the light appears as a series of dots unless a diffuser is placed in front of the LED. Light is lost by introducing a diffuser and trying to emulate a fluorescent tube. In addition, a fluorescent tube produces light around its entire circumference and the existing luminaire is designed with that in mind, to deliver that light efficiently and effectively. This is not the case when a LED is retrofitted.

Finally, the electrical and mechanical systems in a fluorescent luminaire are designed to meet the needs of that lamp type. LED lamps require power in a completely different form and so these luminaires may include power management electronics that are not compatible with all of the existing components. This can create regulatory compliance issues.

In summary, retrofitting LED products to fluorescent products is not a good fit. Using the best case scenario for this example, LED efficacy would be 60 lumens per watt (lm/W), while the efficacy of the existing fluorescent system would be 74 lm/W. Energy efficiency is not improved by retrofitting the LED – real benefits can only come from the reduced costs associated with a longer lamp life.

There are LED replacement lamps on the market that claim to be a complete retrofit for existing discharge lamps. However, LED lamps are unlikely to be able to perform properly when used in this way due to the shape of the existing lamp. Recent tests of this lamp type have shown that extremely high temperatures occurred in areas that are likely to damage the LED.

For all LED lamps and luminaires covered in this report refer to the table on page 4.

LED risk management checklist

- ☐ All components are of the highest quality and sourced from reputable suppliers.
- ☐ A test area has been evaluated and the technology is suitable for widespread installation.
- ☐ Luminaires have an adequate method of dissipating heat.
- ☐ The supplier has provided evidence of lamp life testing.
- ☐ The supplier has provided evidence that the luminaire is compliant with all applicable standards.
- ☐ The supplier has provided evidence that the completed installation delivers appropriate lighting to meet AS1680 requirements.

Upgrading lighting – factors to consider

For each lighting upgrade this report provides the following information:

- **Energy efficient lighting upgrades – options (p. 23):**
  - description of typical existing installation
  - description of proposed upgrade
  - principles behind the technology

For technical details, see the *Energy Saver energy efficient lighting report – technical details* document available on the OEH website:

- illuminance, uniformity, glare
- applicability to specific situations
- lighting quality, including colour and colour rendering maintenance
- compatibility with occupancy sensing and daylight linking
- staff satisfaction and productivity benefits
- potential drawbacks
- analysis of costs, energy savings, maintenance savings, financial return (pay back period, net present value (NPV), internal rate of return (IRR)), estimate of Energy Savings Certificates (ESC)
- technical specifications (including safety).

Figure 8: Typical warehouse using high bay lighting technology

Efficient lighting best practice

Integrating all of the possible energy reduction techniques into an overall lighting strategy creates a holistic solution for your project and is best practice. The following steps should be followed:

1. assess the natural light available and potential for improvement (e.g. skylights) – introduce natural light into open spaces such as warehouses
2. link artificial light use to the natural light levels (daylight linking) using sensors and smart control systems to minimise energy use
3. assess options for zoning, de-lamping, dimming or multilevel switching to reduce energy consumption
4. identify low activity areas and assess use of occupancy sensors
5. review zoning and increase amount of zones (if appropriate) to allow lights to be turned off when areas are not used
6. identify lights that could be upgraded with more energy efficient lighting.

Control systems often have a major part to play in energy efficient design and the estimate of the savings, and therefore should always be considered.

Figure 9: Increasing the use of natural daylight can significantly reduce artificial lighting requirements

Developing a business case for upgrading to energy efficient lighting

The business case should provide sufficient detail to enable the project to be approved. To produce a professional and compelling business case for a lighting upgrade, the following information is required:

- Detailed description of proposed project.
- Product specifications.
- Calculated gas or electricity savings, energy cost savings, other savings, total savings, greenhouse gas (GHG) reductions.
- Payback period, IRR, NPV.
- List of tasks to be completed with any potential disruptions to business operations highlighted in an implementation plan. This must enable the participant to:
  - proceed with the recommendation
  - obtain additional quotations if required
  - brief a contractor or specialist consultant.
- Measurement and verification plan (see Appendix 2 for an outline):
  - what to measure and how to measure it
  - the periods of measurement
  - adjustments to be made for occupancy, units of production, temperature and so on.
- Quantity and approximate monetary value of ESC (see business case on p. 18 and 19 for more information).
- Main assumptions, input data, supporting calculations, specialist reports and data logging to be included in an appendix.
- Cost estimate and breakdown (including labour costs) with reference to quotes provided in an appendix.

Figure 10: Luminaire with induction lighting technology

The Energy Saver program can provide consultancy support to participants undertaking OEH lighting training to assist with implementing lighting upgrades.

For more information visit environment.nsw.gov.au/sustainbus/energysaver

Example business case

To upgrade and retrofit existing lighting system with energy efficient, durable and low maintenance light fittings.

Detailed description

It is proposed to upgrade the existing lighting systems with energy efficient units. The project includes full design, supply, installation, connection and testing for the following systems and locations:

- replace the existing mercury vapour high bays with 5 x 58 W high bay fluorescent luminaires.
- convert twin 36 W lamp T8 fluorescent luminaires to single luminaires with a 36 W lamp and a high efficiency reflector and electronic ballast. The single lamps shall be centred within the luminaires.
- replace 50 W low voltage halogen downlights with low power, high quality LED lamps which can be used in feature lighting and are now available with excellent colour temperature.

For full details of the lighting technologies and product specifications please refer to Appendix X.

Locations

- Workshop, warehouse and storage areas:
  - original product: 82 x 400 W mercury vapour high bay fixtures
  - proposed product: 82 of 5 x 58 W high bay fluorescent fixtures controlling four lamps via high bay motion sensor having one lamp on permanently; 82 x 110° surface mounted sensors
- Office areas, common areas, meeting rooms, toilets, corridors, dining room, etc:
  - original product: 258 of 2 x 36 W fluoro fixtures, T-bar type
  - proposed product: 258 x 36 W fluoro retrofit and mirror reflector; 258 x 180° surface mounted infra-red (IR) sensors
- Ground floor training area:
  - original product: 10 x 50 W halogen downlights
  - proposed product: 10 x 9 W LED downlight kit, 1 x 360° sensor for downlights.

Code requirements

The proposed electrical installation should be developed in compliance with the following standards and codes:

- *Building Code of Australia (BCA) Volume 2*
- AS/NZS 3000:*2007 Electrical installations (known as the Australian/New Zealand Wiring Rules)*
- *AS/NZS 3008.1.1:2009 Electrical installations – Selection of cables – Cables for Alternating Voltage up to and including 0.6/1 kV – Typical Australian Installation Conditions*
- *AS 1680.2.1:2008 Interior and workplace lighting – specific applications – Circulation spaces and other general areas*
- *AS 1680.2.2:2008 Interior and workplace lighting – specific applications – Office and screen-based tasks*
- *AS 2293.1: Emergency escape lighting and exit signs for building – System design, installation and operation.*

Cost

A quote was sourced from Company X for the whole of the lighting retrofit. A breakdown of costs is provided in the quote (refer to Appendix X). Other potential contractors are also listed in Appendix X.

Refer to Table X Appendix X for assumptions used in calculating energy savings.

(Insert calculated figures below)

Electricity savings MWh p.a.	Gas savings GJ p.a.	Energy cost savings $ p.a.	Other cost savings (e.g. maintenance) $ p.a.	Total cost savings $ p.a.	Capital cost $	Payback period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable (over 10 years)

Implementation plan	Steps for implementation include: ▪ obtain additional quotations from nominated specialist contractors using the technical specification provided in Appendix X as a guide ▪ assess tenders and appoint contractor ▪ inspect work in progress and compile defects list ▪ measure illuminance and circuit power before and after upgrade.
Energy Savings Certificates (ESC)	The NSW Energy Saving Scheme (ESS) Rule sets out how Energy Savings Certificates (ESC) can be created. ESC should be calculated using the Deemed Energy Savings Method – Section 9.4 (Commercial lighting energy savings formula). An example using this method can be found below: ▪ measure the illuminance level before and after the installation to ensure the light intensity meets the minimum BCA Volume 2 requirements and industry standards ▪ obtain lamp circuit power (LCP) and operating hours. Note for LED lights: obtain the required agreement with the scheme administrator (Independent Pricing and Regulatory Tribunal – IPART) for the LCP value. Product specification sheets or laboratory test reports shall be provided in advance and control gear losses shall be included in the LCP. ▪ obtain the default lighting operating factors from Energy Savings Scheme Rule (ESS Rule), Table 10: asset lifetime, annual operating hours, control multiplier and air conditioning multiplier ▪ calculate the baseline energy consumption using equation seven or equation eight of ESS Rule, section 9.4 ▪ calculate the upgrade energy consumption using equation nine of ESS Rule, section 9.4 ▪ calculate the deemed energy savings using ESS Rule, section 9.4 ▪ calculate the number of ESC using the certificate conversion factor ▪ The commercial lighting energy savings calculator, which can be downloaded from www.ess.nsw.gov.au facilitates this calculation.
Measurement & Verification (M&V) Plan	▪ A sample M&V Plan is provided in Appendix 2 of the OEH Lighting Guide. Further guidance can be found in OEH Measurement & Verification Guide.

Steps toward upgrading lighting

The steps to reduce the energy used by lighting can be broken down as follows:

- identify existing energy consumption
- consider appropriate sources of light and luminaires that will increase efficiency
- establish compatibility with existing infrastructure
- ensure light quality and quantity will be maintained through appropriate design
- establish control system needs and associated infrastructure requirements
- consider implementation requirements and costs
- encourage users of the space to participate in the process
- apply the identified changes
- confirm that expected benefits have been achieved.

Product suppliers, consultants and designers should endeavour to deliver information and solutions that will make upgrades as easy as possible for end users.

The methods used in this report to assess the different upgrade options could be considered an appropriate template to deliver detailed information to end users.

Funding equipment upgrades

Funding for all of the upgrades in this report is based on the energy and maintenance savings that they generate.

If the existing infrastructure is near to the end of its life, there is a case to be made for comparing the cost of a new luminaire (same as existing) with a new energy efficient luminaire. There is often only a small cost difference between these two options and any additional cost of the energy efficient technology can be met by the delivered savings. This method will significantly reduce the pay back period of a business case you prepare.

Compliance issues with luminaires – total replacement or retrofit of existing?

Risk analysis can help to determine the best energy reduction strategy for a given project. A risk analysis may evaluate installation of brand new luminaires or re-deployment of some components of an existing luminaire.

The higher initial cost of new luminaires is often balanced by the benefits of a complete system that is designed to work together. Installing a new luminaire also means that all of the current standards applicable to luminaire construction and safety are met.

The Lighting Council of Australia, in *Retrofitting Fluorescent Luminaires to Improve Energy Performance* (Light Technical No. 15) states:

'Organisations modifying a luminaire to use a new ballast, lamp or adaptor assumes responsibility for the luminaire that they have constructed. This extends to safety, performance, energy efficiency, EMC, photometrics, emergency operation and any other product related legal responsibilities.'

In most retrofit cases, when a luminaire is altered a new product is created. This newly created luminaire should be fully compliant with all relevant standards before it is connected to the electricity supply. This may require an electrician to certify the newly created luminaire.

The Electrical Regulatory Authorities Council (ERAC) produced information bulletin #0001 dated November 2011 titled "Safety of T8 lamp replacement tubes and modified luminaires", which also covers retrofit LED tubes. This bulletin outlines some of the safety issues that should form a component of the risk analysis when considering these products.

The retrofitting scenarios outlined in this report are based on replacing lamps and control gear that are likely to be at least ten years old and well into, or beyond their intended life cycle. Replacing some components to reduce energy consumption may not address the inefficiencies associated with other components that are worn out or no longer serviceable. Using old components can increase the risk of ongoing maintenance issues and costs. Hence, installing entirely new luminaires would be worth more than the financial benefits shown in the ownership cost scenarios within this report.

Certain compliance and decreased maintenance risks should be balanced against other factors, such as capital costs, payback periods and lighting quality. The value of a new luminaire can be compared to upgrading the existing luminaire by analysing all of these factors.

Lamp disposal and recycling

Failing to recycle some types of lamps poses a very real environmental risk. Recycling all lamps and the metal and glass that form the body of the lamp is encouraged. For information on the available recycling options for lamps, visit the FluoroCycle website **www.fluorocycle.org.au**

Most discharge lamps (mercury vapour, metal halide and fluorescent) contain mercury. Australian Standards limit the quantities of mercury that can be contained in new lamps but many older lamps used higher levels than those set out in the current Australian Standards.

The vast majority of the older lamps are sent to landfill at end of their life and the mercury they contain ultimately becomes a toxic material that permeates the environment. It is estimated that more than 95 per cent of mercury-containing lamps end up in landfill each year. Small consignments of lamps (100 x 26 W T8 lamps) can be collected and recycled for little more than $100 plus GST. Larger quantities can be recycled for significantly less.

Energy Savings Certificates

A lighting upgrade that produces energy savings may be eligible for creating Energy Savings Certificates (ESC) under the NSW Energy Saving Scheme (ESS). The ESS Rule specifies how to calculate the number of ESC that could be created. The Independent Pricing and Regulatory Tribunal (IPART) is the Scheme Administrator.

One ESC is equivalent to 1 tonne of CO_2. ESC can be registered and then sold to electricity retailers and other Liable Entities – at the time of publication the value of one ESC is around $10. ESC can therefore improve a project's financial return and should be considered in a project's business case.

Calculating the number of ESC for a lighting project is explained in the ESS Rule Section 9: Deemed Savings Method. IPART accredits Accredited Certificate Providers (ACP), who are then eligible to create ESC. Organisations saving energy can apply to become ACP but usually it is more convenient and efficient to employ an ACP to do the work – there are many specialist companies that specialise in creating ESC.

For commercial lighting projects, generally the Commercial Lighting Savings Formula is used. ESS Rule Table 9 provides default lamp circuit power (LCP) for luminaires commonly used in commercial lighting. ESS Rule Table 10 provides default Operating Factors for asset life, operating hours, air conditioned spaces and lighting controls. The default asset life is 10 years for Interior lighting projects except T8 to T5 conversions. The full lifetime ESC can be created all at once after project completion. The Commercial Lighting Calculation Tool (Excel) can be downloaded from www.ess.nsw.gov.au to facilitate the calculation.

For small LV halogen lamp replacement projects, ESS Rule Table 1,2 & 3 provides Default Savings Factors (DSFs) e.g. replacing a 50 W LV halogen lamp with a 15 W LED is deemed to save 0.45 MWh over the LED's life. Multiplying the energy savings by the greenhouse gas emissions factor (around 1.06 tonnes CO2/MWh) in NSW) gives the number of ESC.

Other methods specified by the ESS Rule could be used to claim ESC for lighting upgrades if applicable to particular cases. These are:

- **Project Impact Assessment Method** – an engineering assessment using assumptions, measurements and a Confidence Factor
- **Metered Baseline Method** – applicable where the lighting upgraded comprises a significantly large proportion of total energy use.

Proposed ESS Rule change 2014[1]

The ESS has driven a significant increase in energy efficient commercial lighting upgrades since the ESS began in 2009, with about three million ESCs created through commercial lighting activities to date.

That growth has corresponded with significant changes in the commercial lighting market, regulatory framework, and available technologies. The NSW Government has reviewed the ESS Commercial Lighting Energy Savings Formula in order to take these changes into account. Rule changes proposed in late 2013 have been through public consultation and the government is considering the submissions with the aim to have the new rule commenced by May 2014. Proposed changes are outlined below.

Halogen retrofits

Under Minimum Energy Performance Standards (MEPS), since 14 April 2012 it is only legal to sell ELV halogen reflector lamps with an average measured wattage of more than 37 W if it can be proven that they were imported or manufactured prior to the date of the ban. The NSW Government estimates any existing stocks above 37 W will be exhausted by the end of 2013.

Proposed rule change: revise savings factors for activities involving the replacement of 50 W ELV halogen to set the baseline energy consumption has a 35 W ELV halogen reflector lamp.

1 http://www.energy.nsw.gov.au/sustainable/efficiency/scheme

Luminaire retrofits – T5 adaptors, Linear LED tube adaptors and LED lamps

The NSW Government commissioned Beletich Associates, working with lighting consultants Light Naturally, to explore a wide range of commercial lighting issues. The consultants' report provided advice and discussed the importance of achieving quality lighting outcomes through the ESS. One issue raised is concern over the quality of lighting outcomes through the modification of existing luminaires using T5 adaptors and linear LED adaptors, which can lead to sub-standard lighting outcomes, pose potential safety concerns, and can void the warranty of existing luminaires and control gear when retrofitted, leading to early removal.

Proposed rule change: exclude T5 Adaptors and Linear LED Adaptors from the ESS, and all other types of luminaire retrofits that modify parts of the Luminaire apart from the control gear and the lamps.

Lighting giveaway programs

There has been an increase in lighting replacement giveaway programs occurring through the ESS, in particular through halogen downlight and fluorescent tube replacement programs, leading to poor customer engagement and higher compliance costs.

Proposed rule change: require that the end-user pays at least $5 (ex.GST) per MWh of projected energy saved for lighting upgrades, to ensure that customers are engaged with the project to ensure the quality of the lighting is fit for purpose, e.g. that it meets the AS/NZS 1680 recommended minimum requirements.

Voltage reduction units

The consultants' report also raised concerns relating to the certainty of energy savings through the use of Voltage Reduction Units. While T12 and T8 linear fluorescent lamps with magnetic ballasts use reduced energy when Voltage Reduction Units are installed, these lamps are likely to be replaced by more efficient T5 or LED lamps in the near future, negating those savings. Voltage Reduction Units can also be poorly specified, have no standard performance test, and can lower illuminance to unacceptable levels.

Proposed rule change: exclude Voltage Reduction Units from the ESS

LED performance requirements

The consultant's report discussed the need for more stringent product testing requirements to prove the performance claims of Emerging Lighting Technologies, such as LEDs and provide increased certainty of energy savings. To improve product performance requirements, the report proposed using recognised international performance testing standards, such as specified in the US Energy Star and Design Lights certification schemes, where Australian Standards do not exist for a product category.

The current acceptance procedure for LED lamps and other emerging lighting technologies is time-consuming for both ACPs and the Scheme Administrator. Multiple ACPs need to submit applications to have the same product approved, leading to increased costs for businesses and the Scheme Administrator.

Proposed rule change: specify performance testing requirements for all Emerging Lighting Technologies, to improve the quality of lighting upgrades through the ESS, with reference to performance requirements detailed in internationally accepted certification schemes (such as the US Energy Star and DesignLights) to ensure quality of lighting products.

Operating hours

The default operating hours in the ESS are suited to commercial offices and do not suit other commercial workplaces such as retail centres or warehouses. Proving annual operating hours other than the default 3,000 hours per year is time-consuming for both participating businesses and the Scheme Administrator.

Proposed rule change: provide a list of default operating hours for different building types in order to reduce red-tape for commercial lighting projects, based on activities previously accredited.

Additional proposed amendments to the ESS rule

(Refer draft ESS Rule[2]: S9.4, Tables A9, A10.1, A10.2, A10.3 & A10.4)

The NSW Government proposes to:

- accept registration of a product under recognised certification regime as sufficient proof of product performance. Alternatively, a product may be tested against the same standards required by a recognised certification scheme in a National Association of Testing Authorities (NATA), Australia accredited laboratory. The Scheme Administrator will, from time to time, publish a list of recognised certification schemes for Emerging Lighting Technologies
- exclude induction lighting products until an acceptable test standard or certification scheme has been developed
- require that all lighting upgrades are conducted under the supervision of a licensed electrician
- have the Scheme Administrator publish a list of all accepted emerging lighting products so that each product only needs to be accepted once (this will only apply to new applications).

These changes will improve the quality of lighting upgrades for businesses and ensure that incentives are targeted at high quality, additional energy savings.

2 http://www.energy.nsw.gov.au/__data/assets/pdf_file/0020/479000/ess-consultation-paper.pdf

Electromagnetic Compatibility

Electromagnetic interference from lighting has been known to interfere with the operation of devices such as intercoms, phones, radios, occupancy sensors and infrared remote controllers.

The Australian Communications and Media Authority (ACMA) is responsible for the Electomagnetic Compatibility (EMC) regulatory arrangement. This applies to most electrical lighting products that have the potential to unintentionally emit radio frequency energy which can diminish the performance of other nearby electrical devices or disrupt essential communications. Changes to existing luminaires can also cause electromagnetic interference.

The EMC regulatory arrangement imposes an obligation to ensure that devices comply with emission standards before being supplied to market. The arrangement also requires equipment labelling and record keeping.

Changes to existing luminaires must be treated as a different and new device which then requires compliance under the EMC regulatory arrangement.

Inclusions are:

- Changing a light source from incandescent to LED
- Removal of power factor correction capacitor
- Inclusion of a blocking inductor into the luminaire circuit
- Introduction of an electronic ballast
- Reconfiguration of the luminaire wiring layout
- Introduction of an emergency conversion pack.

For more information refer to the ACMA website **www.acma.gov.au** and the Australian and New Zealand standard CISPR15.

1. Interior lighting

This section covers upgrades for:

- **linear fluorescent luminaires** (p. 24):
  - usually found in commercial offices and utility spaces such as corridors and back of house areas
  - typically twin 36 W, T8 recessed troffers, but upgrades are also applicable to twin 40 W, T12 and rapid start systems.
- **halogen downlights** (p. 50):
  - usually found in lift lobbies, foyers, reception areas, corridors and amenity areas, such as kitchens and bathrooms
  - typically 50 W, MR 16 dichroic, but upgrades are also applicable to bipin halogen downlights.
- **high bay and low bay lighting** (p. 67):
  - usually found in warehouses and loading docks
  - typically mercury vapour luminaires, metal halide and sodium vapour luminaires.

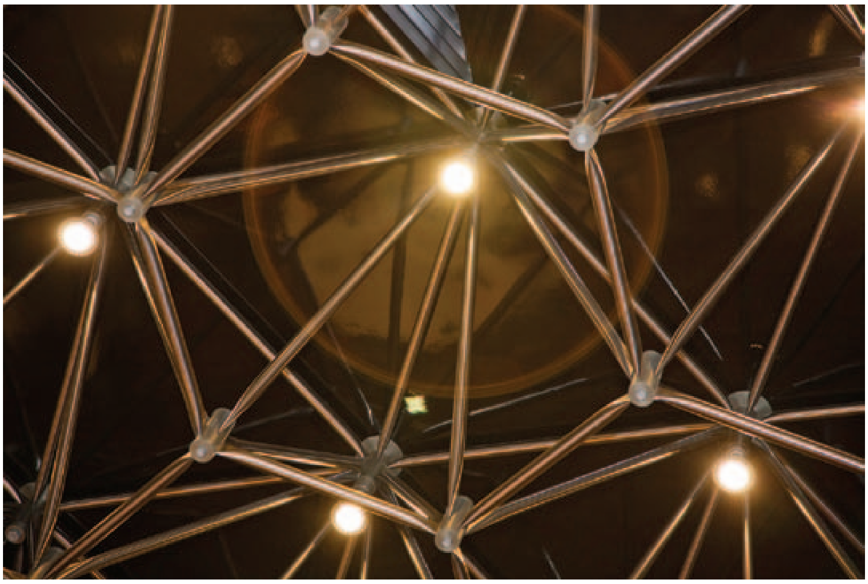


Figure 11: 18 W LED parabolic aluminised reflector (PAR) lamps

Lighting design standards

An effective lighting design must take into account the requirements of the associated standards. The *Building Code of Australia (BCA) Volume 2* references AS/NZS 1680 which is a set of standards covering interior lighting. The requirements outlined in the standards are not just based on meeting targets for illuminance, but for managing glare and illuminance uniformity with respect to office lighting. BCA Volume 2 (Section J6) also outlines the requirements for energy efficient lighting.

As BCA Volume 2 and the associated standards are complex, a suitably qualified lighting design professional may be required to make sure that a project complies with the standards for lighting design.

LINEAR FLUORESCENT LUMINAIRES

This section covers options for upgrading linear fluorescents luminaires, one of the most common types of lighting found in most workplaces. These options provide an excellent opportunity for saving energy.

UPGRADING Twin 36 W T8 recessed linear fluorescent luminaires

The most common lighting systems in offices are based on linear fluorescent lamps. These luminaires are known as recessed troffers and typically contain twin 36 W tubes. There is the opportunity for energy efficicency improvements of up to 67 per cent.

What is a troffer?

A troffer is a recessed fluorescent luminaire. These are often used in ceiling grids but can also be used in plaster sheet ceilings.

Figure 12: Two of the most common types of recessed troffer fittings. The luminaire above uses a louvre to control the direction of produced light, while the luminaire below uses a diffuser.

Assumptions

The following upgrade options assume that the existing luminaire has twin lamps, magnetic ballasts and may have power factor correction capacitors. Diffused luminaires are assumed to have white internal metalware. The luminaire is fitted with a flex and plug.

Typical operating costs per 100 luminaires					
Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
23,400	4680	325	380	5385	24.8

These calculations and recommendations are based on the following general assumptions.

Electricity tariff	$0.20 per kWh
Operating hours	2600 hr/yr (10 hours per day, 5 days per week)
Time to maintain twin lamp luminaire	10 min
Time to maintain single lamp luminaire	5 min
Maintenance labour cost	$70/hr
Existing ballast type	magnetic ballast = 9 W/lamp
ESC	calculated using *ESS Rule* commercial lighting energy savings formula
Bulk re-lamp interval of T5	12,800 hr based on 80% of rated life

Positive change

Any change can be a cause of concern for some people. A smoother transition can occur when information is provided that clearly explains the changes that will be made and the reasoning behind them. Lighting changes are a highly visible way of showing staff your commitment to energy efficiency and the environment.

OPTIONS FOR UPGRADING

Twin 36 W T8 recessed linear fluorescent luminaires

1. Retrofit kit, single 36 W T8 with high efficiency reflector and electronic ballast
2. New twin 28 W T5 linear fluorescent luminaire
3. New complete single 28 W T5 linear fluorescent luminaire
4. Linear LED lamps, 2 x 19 W
5. T8 to 28 W T5 conversion kit
6. New 30 W integrated LED luminaire

Recommendation ✔

OPTIONS 6, 2 and 3 are the preferred options for upgrading fluorescent twin 36 W troffers. These upgrades will provide brand new, fully compliant luminaires that should deliver good energy reductions. These are low risk options and minimal design verification is required.

	1 Retrofit single 36 W T8 kit	2 ✔ New twin 28 W T5	3 ✔ New single 28 W T5	4 Linear LED lamps, 2 x 19 W	5 T8 to 28 W T5 conversion kit	6 ✔ New 30 W integrated LED luminaire
Requires design verification	Y	N	Y	Y	N	Y
Safety compliance	Required	Standard[1]	Standard[1]	Required	Required	Standard[1]
Energy reduction (typical range) %	50–70	30–40	60–67	50–70	20–50	60-67
Typical efficacy lm/watt[2]	85	75	85	65	75	86
Typical, simple pay back yr	2–4	3–5	3–4	3–4	4–5	1–3
Installation by: C = contractor A = anyone	C	A	A	A/C[3]	A	A
Luminaire cost inc. estimated installation costs – $	120	85	130	130	80	90
Lamp life hr	12,000–16,000	16,000–20,000	16,000–20,000	Up to 50,000	16,000–20,000	30,000–50,000
Typical lamp costs $	3–5	15 (pair)	7.50	130 (pair)	15 (pair)	N/A[4]
Recommended ranking, 1= preferred option	5	3	2	6	4	1

Legend to colours	Potential cost or risk	Satisfactory	Low risk/good result

1 New luminaires from reputable manufacturers will be fully compliant out-of-the-box – seek written confirmation.
2 Estimated efficacy of entire system including gear and typical luminaire losses.
3 Some require rewiring and therefore will require a contractor to install.
4 LED luminaires should not need replaceable lamps. Operating life of the source should be the same as the reasonable operating life of the luminaire body.

60% energy reduction

OPTION 1:
Retrofit kit, single 36 W T8 with high efficiency reflector and electronic ballast

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
14,040	2808	223	261	3292	12,000	3.7	14.8	148

Key benefits

- Excellent energy reduction.
- Suitable where metalware needs to be retained for air handling, non-standard ceiling grid etc.
- Low on-going maintenance costs.
- All electrics are replaced, creating a new luminaire with a long, trouble-free operation.

Key issues

- High up-front costs can mean a long pay back period.
- Compliance approvals are required as for new fitting.
- Qualified persons are required for construction/installation.
- High efficiency reflector better suited to prismatic diffusers than louvres.
- Single lamp can lead to dark areas if the lamp fails.

Detailed description

This upgrade method converts the existing luminaire from a twin lamp configuration to a single central lamp, installing a high efficiency reflector designed for a single lamp and replacing magnetic ballasts with an electronic ballast.

This upgrade is most suited to luminaires with existing diffusers.

Existing louvres designed for twin lamps in single lamp applications can be problematic, as the optical characteristics need to match the single lamp position and diameter. The entire back surface of the luminaire, behind the lamp, is generally covered with extremely efficient reflective material and a louvre designed to control the reflected light should be used to maximise efficiency. Good quality options are available for louvre-based luminaires, but to achieve energy reductions to a similar level as diffused luminaires, greater scrutiny during design is required.

A competent electrical contractor can install the upgrade after receiving training on the installation steps and quality control. Quality control inspections must be carried out by an agent independent of the project manager. Care needs to be taken to ensure that light levels meet Australian Standards.

The reflector may be specular or semispecular.

The old ballast and power factor correction capacitors can be left in the luminaire but disconnected.

How energy savings are achieved

This upgrade method reduces energy consumption by removing one of the T8 lamps from the luminaire, installing a high efficiency reflector (saving 36 W) and replacing magnetic ballasts with an electronic ballast (saving 18 W). The total energy saved per luminaire is 54 W.

Although replacing T8 lamps with T5 lamps has become popular, triphosphor T8 lamps with electronic ballasts have an efficacy similar to T5 lamps. However, T8 lamps offer other benefits compared to T5 such as lower lamp cost, achieving maximum output at a lower ambient temperature and a larger surface area for better glare control. T8 lamps are a viable, effective and long-lasting option.

This upgrade is suitable in situations where the existing illuminance is higher than required and a small decrease in illuminance will not breach AS/NZS 1680 recommendations.

The reduction in light flux when converting from twin to single lamps is partly compensated by the high efficiency reflector and electronic ballast. If the existing lamps are halophosphor lamps, then the higher light output of a new triphosphor lamp will further compensate for the associated reduction in flux.

Assuming that the existing ballasts consume 9 W each, the luminaire power would be reduced from about 90 W to about 36 W.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including the technical specification can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 13: An example of de-lamping, where one tube is taken out of the circuit

De-lamping

This is a technique where twin lamp luminaires are changed to single lamp luminaires.

De-lamping involves removing a lamp from a luminaire or rotating it within the lamp holder until it is no longer in circuit. Although substantial energy savings are achieved with this technique, it can often have a detrimental effect on the appearance and aesthetics of the illuminated area and the luminaire itself.

De-lamping may cause the illuminance to fall below recommendations within the Australian Standards. This is a particular problem in areas where lighting is used to increase safety.

It is important to make sure that any energy reduction options comply with the Australian Standards and deliver a comfortable, well-lit environment.

Low wattage fluorescent lamps as an alternative to de-lamping

Sometimes existing lamps are replaced with special tubes that use fewer watts. This technique can decrease energy use, but it is important that illuminance, illuminance uniformity and glare management standards are met. Many lamp manufacturers sell lower wattage lamps in the same dimensions as the existing lamps, but it is important that each option is reviewed carefully.

Factors to consider:

- tube dimension – check that the tube is the same dimension as the original. If the tube size is different consider how the light distribution will be affected.
- lumens – most of these lamps reduce the quantity of light delivered. Will it still be compliant?
- rewiring – check if the system needs rewiring, different ballasts, lampholders and so on. If rewiring is required then this cost will generally outweigh the benefits of other options outlined within this report.
- continuity of supply – check that the supplier can provide the lamp regularly.

33% energy reduction

RECOMMENDED

OPTION 2:
New twin 28 W T5 linear fluorescent luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
7800	1560	20	142	1722	8500	4.9	8.3	83

Figure 14: Twin T5 lamps in luminaires with louvres

Key benefits

- Good energy reduction.
- Easy, quick, low cost solution with minimal risk.
- Low on-going maintenance costs and longer lamp life.

Key issue

- In some luminaires one failed lamp will stop the other lamp from operating, creating dark areas.

Detailed description

This upgrade replaces existing luminaires with a new T5 luminaire with twin 28 W lamps, electronic ballast(s) and louvres. The dimensions suit T-bar ceilings.

T5 lamps have a rated life of at least 16,000 hours and the electronic ballast(s) have a rated life of 50,000 hours. The louvre optics can be either specular or semispecular.

This option is compatible with dimmable electronic ballast(s) and can be used to link the light output to natural light. Energy use would be reduced as only the light needed is delivered. Savings gained from dimming are not calculated in the models in this report, but can lead to significant savings and should be considered best practice. For more information please refer to the Lighting controls section of this report, on p. 96.

How energy savings are achieved

This method reduces energy use by replacing the existing luminaire with a new luminaire. This reduces the wattage of lamps from 36 W per lamp to 28 W per lamp (saving 8 W per lamp). The use of an electronic ballast instead of the existing magnetic ballasts also saves 14 W. The total energy saved per luminaire is 30 W.

Where the 28 W T5 lamps typically produce about 2850 lm, a 36 W T8 triphosphor lamp produces about 3250 lm.

Energy use can be reduced by 30–40 per cent with the electronic ballasts and increased luminaire efficiency. The lighting characteristics will be similar to those of the original luminaires.

The luminaire must be supplied with electronic ballast(s) (50,000 hr life and suitable for the control system specified), triphosphor lamps and a high performance specular louvre designed to provide appropriate glare control.

Higher quality luminaires can deliver improved optics, but this varies substantially between luminaires.

Any new luminaire offered for sale in Australia should comply with all standards, so this option eliminates the risk of creating a luminaire which may not be safe or compliant.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including a technical specification can be found in the *Energy efficient lighting technology report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Bulk lamp replacement

There are substantial hidden costs associated with spot-changing faulty lamps. Spot lamp changing creates a situation where there are always lamps in the building at or beyond their acceptable working life and lamp maintenance is constantly required.

Costs can be significantly reduced when bulk lamp changes are made based on the operating hours elapsed and only replacing single lamps when they fail prematurely. Bulk lamp changes are much easier to manage as they can be cost-controlled and scheduled to minimise interruptions.

Bulk lamp changes should be carried out every five years in this scenario. This is based on an initial lamp life of 16,000 hours, de-rated to 80 per cent (based on standard practice), with the calculations shown below:

- 16,000 hr lamp life/0.8 = 12,800 hr
- 12,800 hr/2600 hr/yr (typical office operation time) = 4.92 yr.

Therefore, the bulk lamp replacement cycle is five years.

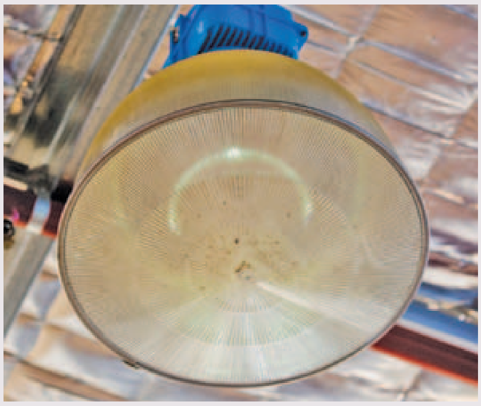


Figure 15: Bulk lamp replacement helps to avoid individual lamp failure

RECOMMENDED

67% energy reduction

OPTION 3:
New complete single 28 W T5 linear fluorescent luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
15,600	3120	172	260	3552	13,000	3.7	16.5	165

Figure 16: A T8 lamp compared with a T5 lamp

Key benefits

- Highest energy reduction with low ongoing maintenance costs.
- Long, trouble-free operation with new luminaire.

Key issues

- One-for-one replacement in the existing layout will not always be possible.
- Light output may not be satisfactory – additional luminaires may be necessary in some locations.
- Achieving rated output when operated at specific temperatures:
  - T5 lamps may not be suitable for outdoor or underground applications such as car parks where temperatures may be outside of this range.
- T-bar ceilings often require luminaires to be manipulated into position.

Detailed description

This option replaces existing luminaires with a new, high quality, T5 luminaire with a 28 W lamp, electronic ballast and louvre. The dimensions suit T-bar ceilings.

The T5 lamps have a rated life of at least 16,000 hours and the electronic ballast(s) have a rated life of 50,000 hours.

The louvre optics can be specular or semispecular.

A competent lighting designer should design the light arrangement using industry standard software.

Dimmable electronic ballast(s) can be used to link the light output to natural light. This would reduce energy use by only delivering the light required, but the specific cost-benefit ratio of this option should be calculated.

This option is compatible with dimmable electronic ballast(s) and can be used to link the light output to natural light. Energy use would be reduced as only the light needed is delivered. Savings gained from dimming are not calculated in the models in this report, but can lead to significant savings and should be considered best practice. For more information please refer to the Lighting controls section of this report, on p. 96.

Similar outcomes can be achieved with a new luminaire containing a single 36 W T8 lamp and an electronic ballast.

How energy savings are achieved

This upgrade reduces energy use by replacing the existing luminaire with a new luminaire. This reduces lamp wattage from two 36 W lamps to a single 28 W lamp (saving 44 W). The use of an electronic ballast instead of the magnetic ballasts also saves 16 W. The total energy saving per luminaire is 60 W.

The quality of the luminaire and its optics are essential to the success of this option.

Energy use can be reduced by 60–67 per cent with the electronic ballasts and with very high luminaire efficiency.

The luminaire must be supplied with a 50,000 hour electronic ballast (appropriate for the control system specificed), triphosphor lamp and a high performance specular louvre, designed to provide appropriate glare control.

Any new luminaire offered for sale in Australia should comply with all standards, so this option eliminates the risk of creating a luminaire which may not be safe or compliant.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 17: Twin T8 louvre lamps

58% energy reduction

OPTION 4: Linear LED lamps, 2 x 19 W

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
13,520	2704	325	379	3,408	13,000	3.81	14.3	Refer to key issues

Figure 18: LED strip 24 W lamp

Figure 19: 20 W LED tube. These are not recommended. Exposed LED lamps can create glare.

Key benefits

- Very good energy reduction.
- Rapid installation with some products.
- Long lamp life leading to low or no maintenance costs.
- Minimal change to luminaire appearance.
- Existing metalware is used, minimising waste.

Key issues

- Reduced system efficacy can lead to lighting that is not compliant.
- Large variety of products available can lead to greater potential for safety, performance and quality issues.
- Light distribution characteristics can vary within available products.
- High up-front costs can result in a long pay back period.
- Compliance approvals are required as for a new fitting.
- Qualified persons are required for construction/installation.
- These lamps are proposed to be removed from the ESS rule and would not be eligible for ESCs calculated through the deemed savings method in the future.

Detailed description

This upgrade replaces lamps within existing luminaires with new linear tubes containing LED lamps.

A lighting designer should use industry standard software to design the system. A photometric file will need to be prepared based on the existing luminaire, with the proposed new lamps tested as a complete luminaire.

The correct connection and installation of these products varies and the supplier should provide wiring information with the product. Some lamps require rewiring to bypass the existing ballasts, starters and power factor correction capacitors and often this old equipment is left in the luminaire.

Where rewiring is necessary, an electrical contractor can install the lamps after training on the installation steps and quality control. As the fitting is altered, the upgrade must be approved as compliant with all relevant standards and regulations. If the lamp can be installed without rewiring the luminaire, then the installation can be carried out by a maintenance person. For large projects, a sample should be approved as compliant and an independent agent used to check that the works completed match the sample.

These lamps generally only produce light that travels forward and this minimises the effect of the luminaires' reflector and optics in collecting, managing and controlling the light.

This means that the light output characteristics of the luminaire will not be the same as after the upgrade. It can also mean that the overall efficiency of the system is less reliant on the quality of the luminaire itself.

Claimed lamp lives vary from 20,000 hours to 50,000 hours and can have varying final output levels, generally 40,000 hours at 70 per cent of initial output.

How energy savings are achieved

This method reduces energy use by replacing 36 W T8 lamps with retrofit LED lamps rated at 23.5 W (saving 25 W). This option also removes the existing ballast and its losses (saving 18 W). The total saving per luminaire is 43 W.

Less light is produced by LED lamps compared to T8 lamps, dropping from 6700 lm to 2400 lm. Most of the light produced by LED lamps is projected forward. This may compensate for the lower light flux by reducing the losses associated with traditional fluorescent lamps that project light forward and backward. LED lamps are likely to light the space differently than the existing system. It is strongly recommended that a test area is installed and evaluated prior to upgrading all areas.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 20: A LED strip 24 W lamp with starter replacement

33% energy reduction

OPTION 5: T8 to 28 W T5 conversion kit

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
7800	1560	20	142	1722	8000	4.6	8.3	Refer to key issues

Figure 21: A T5 lamp with an adapter kit (left) compared with a T8 lamp (right)

Key benefits

- Good energy reductions.
- Simple and rapid installation in most cases, providing power factor correction capacitors do not need to be disconnected.
- Minimal change to luminaire appearance.
- Existing metalware is used, minimising waste.

Key issues

- Compliance approvals are required as if it was a new fitting.
- Correct temperature conditions may not be provided for T5 lamps to operate at their rated light output.
- Quality standards may differ as many product variations are available.
- Unsatisfactory and non-compliant glare can arise in luminaires designed for T8 lamps.
- The lamp circuit power (LCP) may become leading if power factor correction capacitors are installed. To comply with network installation rules, the overall power factor for the site must not be leading.
- These lamps are proposed to be removed from the ESS rule and would not be eligible for ESCs calculated through the deemed savings method in the future.

Detailed description

The upgrade kit converts an existing T8 luminaire to function with T5 lamps. They are either an in-line adapter system or a generic piggyback batten.

Typically, they convert each 36 W T8 lamp on a conventional ballast to a T5 lamp on an electronic ballast. Energy savings are between 30 and 45 per cent.

Installation is simple and usually does not require wiring to be altered. However, it is important to consider the effect on the site's power factor – if the power factor would go to leading, then the power factor correction capacitors must be disconnected. Products should be compliant with all required standards and marked accordingly.

How energy savings are achieved

This method reduces energy use by replacing 36 W T8 lamps with retrofit 28 W T5 lamps and ballast convertors rated at 30 W (saving 12 W). This option also removes the existing ballast and its losses (saving 18 W). The total savings per luminaire is 30 W.

Energy use is reduced by replacing the existing luminaires' connected load of approximately 90 W with a connected load of approximately 60 W. Light production drops from 6700 lm to 5600 lm once the system is replaced.

Introducing an electronic ballast into the circuit delivers long lamp life and energy efficiency, in much the same way as could be achieved with a new T5 luminaire.

This option is effective where low efficiency T8 luminaires have been recently installed. Energy efficiency occurs with minimal waste when the existing hardware is retained.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 22: A replacement T5 lamp with an integral reflector and ballast

RECOMMENDED

67% energy reduction

OPTION 6:
New 30 W integrated LED luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
15,600	3,120	325	379	3,824	9,000	2.35	16.5	165

Figure 23: 30 W integrated LED luminaires

Key benefits

- Highest energy reduction of all the options.
- Long maintenance free operation.
- Dimmable versions are also available which can lead to further energy savings.

Key issues

- One-for-one replacement in the existing layout will not always be possible.
- Light distribution characteristics can vary between available products.
- Some products offered for this application will not be able to meet glare requirements for screen based tasks as detailed in AS/NZS 1680.
- The actual working life is more than 50,000 hours. Coupled with the low initial price any kind of repair on failure is unlikely to be financially viable. This will lead to a total replacement in around 50,000 hours of operation.

Detailed description

This option replaces existing luminaires with a new luminaire that contains integrated LEDs. This means that the fitting does not accommodate replacement LED tubes but instead utilises a LED array that is built into the luminaire. This is a ground up LED solution with LEDs that are not specifically designed to be replaceable. The luminaire comes complete with an integrated electronic power supply designed to operate the integrated LEDs. The dimensions suit T-bar ceilings.

The LED light sources should be rated to 50,000 at L70 or better. Typically these power supplies are rated at 50,000 hours of operation with less than 10 per cent failure. This means that the luminaire will require replacement in 50,000 hours or a little over 19 years based on the operating hours assumed in this report.

A lighting designer should design the light arrangement using industry standard software.

Dimmable versions can be used to link the light output to natural light. This would reduce energy use by only delivering the light required, but the specific cost-benefit ratio of this option should be calculated.Savings gained from dimming are not calculated in the models in this report. For more information please refer to the Lighting controls section of this report, on p. 96.

How energy savings are achieved

This method reduces energy use by replacing two 36 W T8 lamps with a connected load of approximately 90 W with a complete new fitting with a connected load of 30 W, (saving 42 W). It also removes the existing ballast and its losses (saving 18 W). The total savings per luminaire is 60 W.

LED luminaires will deliver 2600 lumens into the space compared to 4355 lumens from the fluorescent luminaire.D luminaires are likely to light the space differently than the existing system. It is strongly recommended that a test area is installed and evaluated prior to upgrading all areas.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software. In particular the design must ensure compliance for illuminance, uniformity and unified glare rating.

Additional information about this option can be found in the *Energy efficient lighting technology report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

UPGRADING Twin 36 W T8 surface mounted linear fluorescent luminaires

What are the options in surface mount fluorescent luminaires?

Surface mount fluorescent luminaires are typically bare tube, enclosed with diffusers in either opal or prismatic or with bare tube but with a wire guard for protection from impact.

The most common lighting systems in fire stairs, plant rooms and car parks are based on linear fluorescent lamps fitted within surface mounted luminaires. These luminaires typically contain twin or single 36 W tubes. Shorter versions with 18 watt single or twin lamp arrays are also used occasionally. The opportunity exists for energy efficiency improvements of up to 70 per cent.

Assumptions

The following upgrade options assume that the existing luminaire has twin lamps, magnetic ballasts and may have power factor correction capacitors. Luminaires are assumed to have white internal metalware and a diffuser. The luminaire is hard wired and fixed to the structure of the building. This means that installation must be carried out by a suitably qualified electrical contractor.

Typical operating costs per 100 luminaires

Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
23,400	4680	325	380	5385	24.8

These calculations and recommendations are based on the following general assumptions.

Electricity tariff	$0.20 per kWh
Operating hours	2600 hr/yr (10 hours per day, 5 days per week)
Time to maintain twin lamp luminaire	10 min
Time to maintain single lamp luminaire	5 min
Maintenance labour cost	$70/hr
Existing ballast type	magnetic ballast = 9 W/lamp
ESC	calculated using ESS Rule commercial lighting energy savings formula
Bulk re-lamp interval of T5 fluorescent	12,800 hr based on 80% of rated life

OPTIONS FOR UPGRADING

Twin 36 W T8 surface mounted linear fluorescent luminaires

1. New 43 W LED luminaire, Integrated LED module and power supply, fitted with diffuser
2. New complete twin 28 W T5 linear fluorescent luminaire with diffuser
3. New complete single 28 W T5 linear fluorescent luminaire with diffuser
4. Linear LED lamps, 2 x 19 W
5. T8 to 28 W T5 conversion kit

Recommendation

OPTIONS 1 and 3
are the preferred options for upgrading surface mount twin 36 W fluorescent luminaires. These upgrades will provide brand new, fully compliant luminaires that should deliver good energy reductions. These are low risk options and minimal design verification is required.

	1 ✔ New 43 W LED luminaire surface mount	2 New twin 28 W T5	3 ✔ New single 28 W T5	4 Linear LED lamps, 2 x 19 W	5 T8 to 28 W T5 conversion kit
Requires design verification	Y	N	Y	Y	N
Safety compliance	Standard[1]	Standard[1]	Standard[1]	Required	Required
Energy reduction (typical range) %	50–60	30–40	60–67	50–70	20–50
Typical efficacy lm/watt[1]	100	75	85	65	75
Typical, simple pay back yr	2–4	5–7	1–3	3–5	3–5
Installation by: C = contractor A = anyone	C	C	C	C	C
Luminaire cost inc. estimated installation costs $	155	115	105	120	80
Lamp life hr	50,000 to L70	12,800	12,800	Up to 50,000	12,800
Typical lamp costs $	0	15 (pair)	7.50	95 (pair)	15 (pair)
Recommended ranking, 1= preferred option	1	2	1	4	3

Legend to colours	Potential cost or risk	Satisfactory	Low risk/good result

1 New luminaires from reputable manufacturers will be fully compliant out-of-the-box – seek written confirmation.
2 Estimated efficacy of entire system including gear and typical luminaire losses.
3 Some require rewiring and therefore will require a contractor to install.

RECOMMENDED

52% energy reduction

OPTION 1:
New 43 Watt LED luminaire, Integrated LED module and power supply, fitted with diffuser

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
12,220	4680	325	379	704	15,500	2.9	12.9	129

Figure 24: 43 Watt LED luminaire, Integrated LED module

Key benefits

- Excellent energy reduction.
- High light output – similar to existing.
- Low on-going maintenance costs.
- Brand new fully compliant luminaire with full warranty.

Key issues

- High brightness of diffuser (due to high output over small surface area of diffuser) may cause glare.
- Single power supply and LED array can lead to dark areas if failure of either occurs.
- Thinner housing than existing may lead to painting or ceiling rectification works.

Detailed description

This upgrade replaces the existing luminaires with a new LED luminaire with a connected load of 43 Watts, an integrated electronic power supply and a diffuser. The length is similar to the existing however the body is narrower.

The LED's have a rated life of 50,000 to 70 per cent of initial output. In the application modelled, this is more than 19 years. The diffuser is typically opal to minimise the risk of dotting, where the LED's can be seen through the diffuser.

This option may deliver variations that can be fitted with a dimming power supply and in that format could be used to link the light output to natural light. Energy use would be reduced as only the light needed is delivered. Savings gained from dimming are not calculated in the models in this report, but can lead to significant savings and should be considered best practice. For more information please refer to the Lighting controls section of this report, on p. 96.

How energy savings are achieved

This upgrade method reduces energy consumption by replacing the existing luminaire and fitting a new one with a connected load of 43 Watts. The original luminaire has a connected load of 90 Watts therefore the total energy saved per luminaire is 47 Watts.

This upgrade is suitable in situations where the existing illuminance is higher than required and a small decrease in illuminance will not breach AS/NZS 1680 recommendations.

The reduction in light flux when converting from T8 to LED is partly compensated by the high efficiency of the light source and also that its efficiency is measured as a complete luminaire in this case. Losses in produced light from the tubes as the light is passed through the standard diffuser and other luminaire losses will mean that overall light levels will not be significantly affected.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including the technical specification can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

33% energy reduction

OPTION 2:
New twin 28 W T5 linear fluorescent luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
7800	1560	20	142	1722	11500	6.68	8.3	82.6

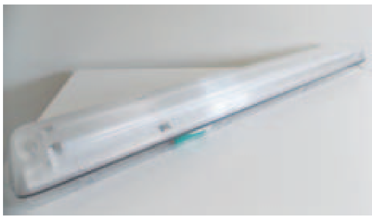


Figure 25: Twin 28 W T5 linear fluorescent luminaire

Key benefits

- Good energy reduction.
- Easy, quick, low cost solution with minimal risk.
- Low on-going maintenance costs and longer lamp life.

Key issue

In some luminaires one failed lamp will stop the other lamp from operating, creating dark areas.

Detailed description

This upgrade replaces existing luminaires with a new T5 luminaire with twin 28 W lamps, electronic ballast(s) and louvres. The dimensions suit T-bar ceilings.

T5 lamps have a rated life of at least 16,000 hours and the electronic ballast(s) have a rated life of 50,000 hours. The louvre optics can be either specular or semispecular.

This option is compatible with dimmable electronic ballast(s) and can be used to link the light output to natural light. Energy use would be reduced as only the light needed is delivered. Savings gained from dimming are not calculated in the models in this report, but can lead to significant savings and should be considered best practice. For more information please refer to the Lighting controls section of this report, on p. 96.

How energy savings are achieved

This method reduces energy use by replacing the existing luminaire with a new luminaire. This reduces the wattage of lamps from 36 W per lamp to 28 W per lamp (saving 8 W per lamp). The use of an electronic ballast instead of the existing magnetic ballasts also saves 14 W. The total energy saved per luminaire is 30 W.

Where the 28 W T5 lamps typically produce about 2850 lm, a 36 W T8 triphosphor lamp produces about 3250 lm.

Energy use can be reduced by 30–40 per cent with the electronic ballasts and increased luminaire efficiency. The lighting characteristics will be similar to those of the original luminaires.

The luminaire must be supplied with electronic ballast(s) (50,000 hr life and suitable for the control system specified), triphosphor lamps and a high performance specular louvre designed to provide appropriate glare control.

Higher quality luminaires can deliver improved optics, but this varies substantially between luminaires.

Any new luminaire offered for sale in Australia should comply with all standards, so this option eliminates the risk of creating a luminaire which may not be safe or compliant.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including a technical specification can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

RECOMMENDED

67% energy reduction

OPTION 3:
New complete single 28 W T5 linear fluorescent luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
15,600	3120	172	260	3553	10,500	2.95	16.5	165

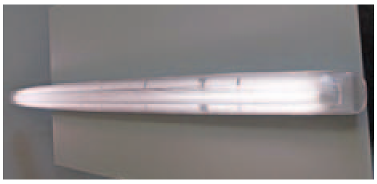


Figure 26: Single 28 W T5 linear fluorescent luminaire

Key benefits

- Highest energy reduction with low ongoing maintenance costs.
- Long, trouble-free operation with new luminaire.

Key issues

- One-for-one replacement in the existing layout will not always be possible.
- Light output may not be satisfactory – additional luminaires may be necessary in some locations.
- Achieving rated output when operated at specific temperatures:
  - T5 lamps may not be suitable for outdoor or underground applications such as car parks where temperatures may be outside of this range.
- T-bar ceilings often require luminaires to be manipulated into position.

Detailed description

This option replaces existing luminaires with a new, high quality, T5 luminaire with a 28 W lamp, electronic ballast and louvre. The dimensions suit T-bar ceilings.

The T5 lamps have a rated life of at least 16,000 hours and the electronic ballast(s) have a rated life of 50,000 hours.

The louvre optics can be specular or semispecular.

A competent lighting designer should design the light arrangement using industry standard software.

Dimmable electronic ballast(s) can be used to link the light output to natural light. This would reduce energy use by only delivering the light required, but the specific cost-benefit ratio of this option should be calculated.

This option is compatible with dimmable electronic ballast(s) and can be used to link the light output to natural light. Energy use would be reduced as only the light needed is delivered. Savings gained from dimming are not calculated in the models in this report, but can lead to significant savings and should be considered best practice. For more information please refer to the Lighting controls section of this report, on p. 96.

Similar outcomes can be achieved with a new luminaire containing a single 36 W T8 lamp and an electronic ballast.

How energy savings are achieved

This upgrade reduces energy use by replacing the existing luminaire with a new luminaire. This reduces lamp wattage from two 36 W lamps to a single 28 W lamp (saving 44 W). The use of an electronic ballast instead of the magnetic ballasts also saves 16 W. The total energy saving per luminaire is 60 W.

The quality of the luminaire and its optics are essential to the success of this option.

Energy use can be reduced by 60–67 per cent with the electronic ballasts and with very high luminaire efficiency.

The luminaire must be supplied with a 50,000 hour electronic ballast (appropriate for the control system specificed), triphosphor lamp and a high performance specular louvre, designed to provide appropriate glare control.

Any new luminaire offered for sale in Australia should comply with all standards, so this option eliminates the risk of creating a luminaire which may not be safe or compliant.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

58% energy reduction

OPTION 4: Linear LED lamps, 2 x 19 W

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
13,520	2704	325	379	3408	12,000	3.52	14.3	143

Figure 27: LED strip 24 W lamp

Figure 28: 20 W LED tube. These are not recommended. Exposed LED lamps can create glare.

Key benefits

- Very good energy reduction.
- Rapid installation with some products.
- Long lamp life leading to low or no maintenance costs.
- Minimal change to luminaire appearance.
- Existing metalware is used, minimising waste.

Key issues

- Reduced system efficacy can lead to lighting that is not compliant.
- Large variety of products available can lead to greater potential for safety, performance and quality issues.
- Light distribution characteristics can vary within available products.
- High up-front costs can result in a long pay back period.
- Compliance approvals are required as for a new fitting.
- Qualified persons are required for construction/installation.

Detailed description

This upgrade replaces lamps within existing luminaires with new linear tubes containing LED lamps.

A lighting designer should use industry standard software to design the system. A photometric file will need to be prepared based on the existing luminaire, with the proposed new lamps tested as a complete luminaire.

The correct connection and installation of these products varies and the supplier should provide wiring information with the product. Some lamps require rewiring to bypass the existing ballasts, starters and power factor correction capacitors and often this old equipment is left in the luminaire.

Where rewiring is necessary, an electrical contractor can install the lamps after training on the installation steps and quality control. As the fitting is altered, the upgrade must be approved as compliant with all relevant standards and regulations. If the lamp can be installed without rewiring the luminaire, then the installation can be carried out by a maintenance person. For large projects, a sample should be approved as compliant and an independent agent used to check that the works completed match the sample.

These lamps generally only produce light that travels forward and this minimises the effect of the luminaires' reflector and optics in collecting, managing and controlling the light.

This means that the light output characteristics of the luminaire will not be the same as after the upgrade. It can also mean that the overall efficiency of the system is less reliant on the quality of the luminaire itself.

Claimed lamp lives vary from 20,000 hours to 50,000 hours and can have varying final output levels, generally 40,000 hours at 70 per cent of initial output.

How energy savings are achieved

This method reduces energy use by replacing 36 W T8 lamps with retrofit LED lamps rated at 23.5 W (saving 25 W). This option also removes the existing ballast and its losses (saving 18 W). The total saving per luminaire is 43 W.

Less light is produced by LED lamps compared to T8 lamps, dropping from 6700 lm to 2400 lm. Most of the light produced by LED lamps is projected forward. This may compensate for the lower light flux by reducing the losses associated with traditional fluorescent lamps that project light forward and backward. LED lamps are likely to light the space differently than the existing system. It is strongly recommended that a test area is installed and evaluated prior to upgrading all areas.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 29: A LED strip 24 W lamp with starter replacement

33% energy reduction

OPTION 5:
T8 to 28 W T5 conversion kit

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
7800	1560	20	142	1722	8000	4.6	8.3	82

Figure 30: A T5 lamp with an adapter kit (left) compared with a T8 lamp (right)

Key benefits

- Good energy reductions.
- Simple and rapid installation in most cases, providing power factor correction capacitors do not need to be disconnected.
- Minimal change to luminaire appearance.
- Existing metalware is used, minimising waste.

Key issues

- Compliance approvals are required as if it was a new fitting.
- Correct temperature conditions may not be provided for T5 lamps to operate at their rated light output.
- Quality standards may differ as many product variations are available.
- Unsatisfactory and non-compliant glare can arise in luminaires designed for T8 lamps.
- The lamp circuit power (LCP) may become leading if power factor correction capacitors are installed. To comply with network installation rules, the overall power factor for the site must not be leading.

Detailed description

The upgrade kit converts an existing T8 luminaire to function with T5 lamps. They are either an in-line adapter system or a generic piggyback batten.

Typically, they convert each 36 W T8 lamp on a conventional ballast to a T5 lamp on an electronic ballast. Energy savings are between 30 and 45 per cent.

Installation is simple and usually does not require wiring to be altered. However, it is important to consider the effect on the site's power factor – if the power factor would go to leading, then the power factor correction capacitors must be disconnected. Products should be compliant with all required standards and marked accordingly.

How energy savings are achieved

This method reduces energy use by replacing 36 W T8 lamps with retrofit 28 W T5 lamps and ballast convertors rated at 30 W (saving 12 W). This option also removes the existing ballast and its losses (saving 18 W). The total savings per luminaire is 30 W.

Energy use is reduced by replacing the existing luminaires' connected load of approximately 90 W with a connected load of approximately 60 W. Light production drops from 6700 lm to 5600 lm once the system is replaced.

Introducing an electronic ballast into the circuit delivers long lamp life and energy efficiency, in much the same way as could be achieved with a new T5 luminaire.

This option is effective where low efficiency T8 luminaires have been recently installed. Energy efficiency occurs with minimal waste when the existing hardware is retained.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 31: A replacement T5 lamp with an integral reflector and ballast

Fluorescent luminaires risk management checklist

- ☐ The supplier's quote covers all costs, including any out-of-hours work to minimise disruption.
- ☐ All components are of the highest quality and sourced from reputable suppliers.
- ☐ The manufacturer has provided a five year warranty.
- ☐ A test area has been evaluated and the technology is suitable for widespread installation.
- ☐ The supplier has provided evidence that the luminaire is compliant with all applicable standards.
- ☐ The supplier has provided evidence that the completed installation delivers appropriate lighting to meet AS/NZS1680 requirements.

Figure 32: B15 halogen lamp

Figure 33: A compact fluorescent GU 10 base halogen replacement lamp

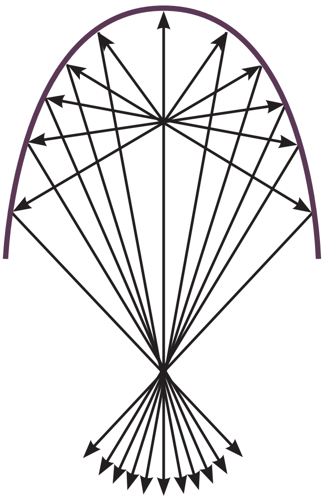


Figure 34: 'Beam crossover' in front of the MR16 lamp

HALOGEN LAMPS

This section covers 50 W MR16 low voltage dichroic halogen lamps as well as 100 W PAR 30 halogen lamps and other downlights (p. 64).

UPGRADING 50 W MR16 low voltage dichroic halogen lamps

Luminaires that use MR16 low voltage dichroic halogen lamps are covered in this section. This light source is used extensively in commercial and residential applications. The light distribution characteristics of these lamps make them one of the best light sources available for task lighting. However, this lamp is used for ambient or general lighting in most cases.

When using this lamp for general lighting, the following outcomes are experienced:

- high energy use
- short lamp life and therefore high maintenance costs
- high glare
- high installation costs due to the quantity (spacing) required
- poor lighting effect (i.e. generally only horizontal surfaces are lit).

Widespread installation has increased the use of poor quality luminaires, lamps and transformers, which amplifies the issues listed above.

Dichroic halogen lamps and LED lamps – comparing apples with oranges

The MR16 dichroic halogen lamp is a specialised item. It delivers a controlled beam of light with many combinations of beam spread and light output available. Beam control is managed by a reflector that is matched to the lamp.

The most commonly used dichroic halogen lamps and the ANSI standard codes used to identify their characteristics (parameters will vary slightly between manufacturers), are as follows:

- 20 W, 10° beam – ESX
- 20 W, 35° beam – BAB
- 50 W, 15° beam – EXT
- 50 W, 25° beam – EXZ
- 50 W, 40° beam – EXN
- 50 W, 60° beam – FNV

MR16 dichroic halogen lamp beam angles are determined by measuring the light delivered at the centre of the beam at a given distance from the front of the lamp. The point where the light is 50% of the illumination at the centre of the beam is then measured. This clearly defines the useful beam spread of the lamp.

LED lamps do not deliver a precise beam like MR16 dichroic halogen lamps and hence their light appears different within the space. LED lamp manufacturers do not usually employ the same method of beam spread measurement.

To replace halogen downlights with a more efficient product without compromising the look and feel of the space:

- use lighting design software to create standard models and compare the technical features of the different products
- ask suppliers to compare the existing products with the LED replacement options
- trial the LED lamps in a small sample area.

This lamp is included as a benchmark for this report due to its widespread use in commercial projects. However, it is important to note that the lamp itself was subject to an import ban from April 2012. The development of 35 Watt IRC lamp technology replicates the performance of the MR16 low voltage dichroic halogen with a lower power use. The use of these lamps instead of the 50 Watt lamps is shown as Option 1 which can form the benchmark for those who have already ceased the use of 50 Watt lamps.

Figure 35: Halogen bipin lamp

Assumptions

The following upgrade options assume that the existing luminaire has a single generic 50 W MR16 dichroic halogen lamp powered by a conventional 50 VA magnetic transformer running a single lamp. The transformer is fitted with a flex and plug for the primary winding and less than one metre of appropriately rated cable on the secondary winding.

Typical operating costs per 100 luminaires					
Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
16,900	3380	780	758	4918	17.9

These calculations and recommendations are based on the following general assumptions:

Electricity tariff	$0.20/kWh
Operating hours	2600 hr/yr (10 hours per day, 5 days per week)
Time to maintain luminaire	5 min
Existing lamp cost	$6/lamp
Maintenance labour cost	$70/hr
Transformer type	conventional iron core transformer
Existing transformer power	15 W/lamp (therefore connected load is 65 Watts)
ESC	calculated using ESS Rule commercial lighting energy savings formula
Typical generic halogen lamp life	2000 hr, based on 50% failure

Figure 36: An existing halogen downlight

Figure 37: 50 W halogen downlight

Recommendation

OPTION 3 is the preferred option for this section. This will deliver excellent energy reductions whilst providing brand new, fully compliant luminaires. Minimal lighting design verification is required with this option and there is minimal risk in its selection and implementation. Using good quality products is an essential element of minimising risk. The market offers a variety of products of this type. Typically 12 to 16 Watts of LED connected load is required to replace the light output of the existing halogens. This would be equivalent to between 800 and 1000 lumens.

OPTIONS FOR UPGRADING 50 W MR16 low voltage dichroic halogen lamps

1. 35 W infra-red coating (IRC) halogen lamp with or without an electronic transformer
2. 7 W LED retrofit replacement lamp
3. New 16 W LED luminaire (lamp and control gear)
4. 15 W compact fluorescent lamp
5. New 13 W compact fluorescent luminaire

	1 35 W IRC halogen lamp	2 7 W LED retrofit replacement lamp	3 New 16 W LED luminaire ✔	4 15 W compact fluorescent lamp	5 New 13 W compact fluorescent luminaire
Requires design verification	N	Y	Y	Y	Y
Safety compliance	Standard	Required	Standard[2,3]	Required	Standard[2,3]
Energy reduction (typical range) %	31–42	60–83[4]	60–80	70–80[4]	70–80
Typical efficacy lm/watt[1]	16	40–60	30–50	20–40	30–50
Typical, simple pay back yr	<1	1–2	1–3	1–2	2–3
Installation by: C = contractor A = anyone	A	A	A	C	A
Luminaire cost inc. estimated installation costs $	12	34	80	55	100
Lamp life hr	2000–6000 (brand dependent)	10,000–50,000 (claimed)	30,000–50,000 (claimed)	8000–16,000	8000–16,000
Typical lamp costs $	12	20–80	70–120	35	60–150
Recommended ranking, 1= preferred option	3	2	1	5	4

Legend to colours	Potential cost or risk	Satisfactory	Low risk/good result

1 Estimated efficacy of the entire system, including gear and typical luminaire losses.
2 Some new luminaires will not be fitted with a flex and plug and therefore will require a contractor to install.
3 New luminaires from reputable manufacturers will be fully compliant out-of-the-box – seek written confirmation.
4 Light output may be very low and not at all like the existing output.

There are a number of factors that should be considered before deciding on a course of action for upgrading low voltage halogen lamps:

- is this the correct method of lighting for this application?
- is a controlled beam of light needed to fall on a surface, such as a painting, sculpture or specific work surface? If so, consider a retrofit if a controlled beam of light is required (Option 1 or 2).
- is a general wash of light needed to cover large areas, corridors or entry foyers? If so, then consider replacement with Options 3 or 4.
- can the amount of light required to achieve an effective outcome be reduced? If so, use lower wattage lamps or dimming where appropriate.

Figure 38: Compact fluorescent downlight

OPTION 1:
35 W infra-red coating (IRC) halogen lamp, with or without an electronic transformer

31–42%
energy reduction

Energy and cost savings summary

Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
Energy savings and financial return per 100 luminaires without electronic transformers								
5200	1040	156	455	1651	1200	0.7	5.5	Refer to key issues
Energy savings and financial return per 100 luminaires with electronic transformers								
7020	1404	156	455	2015	3200	1.6	7.4	74

Energy savings and financial return per 100 luminaires

Key benefits

- Very good energy reduction.
- Maintains light quantity and quality to deliver true retrofit.
- Compatible with glare control luminaires.
- Highly suitable where the existing luminaire is retained due to design requirements. This also minimises waste.
- Reduced upgrade costs with installation during regular maintenance.
- All standards are met.
- Low risk, simple solution.

Figure 39: Low voltage halogen transformer – electronic

Key issues

- Energy reduction is not as high as other options.
- Lamp life is short compared to other options.
- Light colour is too warm if dimming is used to save further energy.
- The 50W MR16 halogen lamp is proposed to be removed as the benchmark existing lamp from the ESS rule and be replaced with the 35W IRC lamp. This will reduce the number of ESCs that can be calculated for this lighting upgrade.

Even greater savings

Energy can also be saved where the environment can support a lower overall light level. Reducing the lamp wattage would mean that a 20 W IRC lamp could deliver 60% of the light. This would reduce energy use by 60%. This could also be achieved by a dimmer.

Detailed description

This upgrade replaces the existing lamp with a new lamp that uses IRC technology. Additional energy savings and financial return can be achieved when conventional magnetic transformers are replaced with electronic transformers, in conjunction with lamp replacement.

Both options retain the existing luminaire, minimising waste and preserving the aesthetic of the space.

How energy savings are achieved

Energy use is reduced by replacing the existing 50 W lamp with a 35 W lamp (saving 15 W). Transformer losses are also typically reduced (saving 5 W). Total savings per luminaire are 20 W. Energy use is reduced further when the upgrade includes an electronic transformer (saving 7 W).

IRC technology uses a coating on the inside of the lamp capsule. This coating redirects the heat produced by the lamp to the filament, allowing it to produce light with less electrical energy.

Energy use can be reduced by as much as 30 per cent, without significantly reducing the delivered light. The light distribution characteristics of IRC lamps are the same as the existing lamps, so the lighting outcomes should be the same. However, it is important to make sure that the angle of the beam in the IRC lamp is the same as the original.

There are a number of brands that offer long lamp life (up to 6000 hours) and there are also products designed to maintain colour quality, as well as light output, for long lamp operating periods. All of these options should be evaluated when choosing an upgrade option.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 40: An example of good lighting design

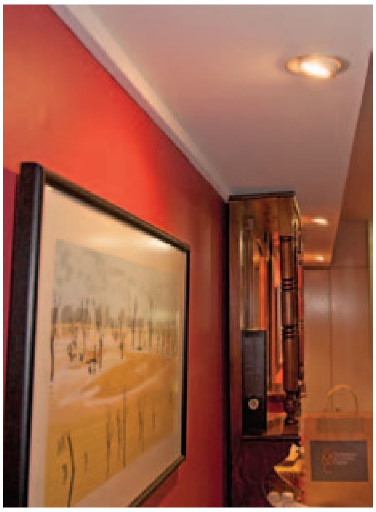


Figure 41: Halogen used to highlight pictures – good practice

OPTION 2:
7 W LED retrofit replacement lamp

83% energy reduction

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
14,040	2808	624	720	4152	3400	.8	14.8	Refer to key issues

Key benefits

- Excellent energy reduction.
- Long maintenance cycles due to long lamp life.
- Dimmable.
- Generates less heat which may reduce loads on HVAC systems.
- Upgrade costs reduced with installation during regular maintenance.

Key issues

- Heat sink design is critical as heat dissipation is the key determining factor to maintain LED temperature within operating limits and achieve long lamp life.
- Huge variety of options that vary in quality.
- Beam control can differ between LED and halogen lamps.
- Lack of confidence in the rated life, unless supported by reliable test results.
- Transformer regulation compliance needed as the lamp contains electronic power converters (see the document *Energy efficient lighting report – technical details* for more information).
- May not be compatible with existing transformer and dimming systems.
- CRI is typically between 75 and 85 and not as high as existing lamps.
- Light output and distribution may be different and not compliant to lighting standards.
- These lamps are proposed to be removed from the ESS rule and would not be eligible for ESCs calculated through the commercial lighting method in the future.

Detailed description

This upgrade replaces the existing lamp with a LED lamp. No additional equipment should be needed.

The replacement lamps will have a connected load between 5 W and 16 W. These will be dimmable in some cases, but for those that cannot be dimmed any existing dimming equipment must be removed.

The light output will be lower than the original 50 W MR16 lamp and the light distribution will rarely be the same. To be compliant with lighting standards, further luminaires may be required to be installed. The beam spread characteristics of the halogen dichroic and LED lamps are different, even if the stated beam angle is the same. This type of LED lamp does not deliver a precise beam and so does not light surfaces in the same way. It is recommended that the design be carried out by a lighting designer, using industry standard lighting design software. It is also strongly recommended that a test area is installed and evaluated prior to upgrading all areas.




Figure 42: LED lamps, fixtures and fittings

How energy savings are achieved

Energy use is reduced by replacing the existing 50 W lamp with a 7 W lamp (saving 43 W). Transformer losses are also typically reduced (saving 10 W). The total savings per luminaire is 53 W.

This upgrade is intended as a simple replacement for an existing lamp and reflector combination. The manufacturer incorporates all of the electronics required to convert the AC 12 V (typically delivered by the existing transformer) into DC voltage to suit LED lamps.

There are a number of different technologies employed in the existing transformers (and dimmers where fitted), which may not be compatible with the new lamps.

Additional information about this option can be found in the *Energy efficient lighting technology report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

RECOMMENDED

75% energy reduction

OPTION 3:
New 16 W LED luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
12,740	2548	780	758	4086	8000	2	13.5	Refer to key issues

Key benefits

- Excellent energy reduction.
- Long lamp life (median of 19 years, based on 50,000 hour life and 2600 operating hours per year) and no regular maintenance is needed during a reasonable fit-out life.
- Luminaires can be designed to meet the specific needs of LED lights, leading to longer lamp life and higher light output.
- Less heat is generated which may reduce loads on HVAC systems.
- Compliant solution for luminaire, lamp and power system must be delivered by supplier.

Key issues

- Varying quality of products in the market.
- Full replacement takes a little longer than lamp retrofit.
- Existing transformer and dimming systems may not be compatible.
- CRI is between 75 and 85, which is lower than existing system.
- More expensive and capital intensive than lamp retrofit (see Option 1 p. 53).
- The 50W MR16 halogen lamp is proposed to be removed as the benchmark existing lamp from the ESS rule and be replaced with the 35W IRC lamp. This will reduce the number of ESCs that can be calculated for this lighting upgrade.

Detailed description

This option involves removing the existing transformer and luminaire and replacing them with a new luminaire and power supply that is specifically designed to operate LED lamps.

These luminaires generally have a connected load between 10 W and 20 W. The light output and light distribution are often similar to the original 50 W MR16 lamp. Lighting provided by the upgrade is likely to be appropriate, but it is recommended that the lighting system is designed by a lighting designer, using industry standard software. Trial a sample area prior to large scale roll out to make sure the outcome will be acceptable.

How energy savings are achieved

This upgrade reduces energy use by replacing the existing 50 W lamp and transformer (loss of 15 W), with a complete luminaire and matched power supply, totalling 16 W (total saving of 49 W).

This option completely replaces the existing luminaire and power supply with brand new components that are designed to work together.

Replacing the entire luminaire is more likely to achieve the same lighting effect as the existing luminaire in most important characteristics. Legally all new luminaires must be supplied compliant with electrical and safety standards.

There are a growing number of products on the market that could be used in this upgrade. Using good quality products is an essential element of minimising risk.

High quality luminaires should deliver an average operating life of 50,000 hours above 70 per cent of initial output. The total cost of ownership is reduced as the lamps do not need to be replaced regularly.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 43: A meeting room with new LED downlights replacing old halogen lights

OPTION 4:
15 W compact fluorescent lamp and lampholder

77% energy reduction

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
13,000	2600	260	657	3517	5500	1.6	13.8	138

Key benefits

- Excellent energy reduction.
- Long lamp life and long maintenance cycles.
- Very short pay back period.

Figure 44: A compact fluorescent GU 10 base halogen replacement lamp

Key issues

- Extremely poor light output compared to LED lighting and the existing lamp.
- Lighting is diffuse rather than focused.
- Lamp takes up to two minutes to reach full brightness.
- Needs installation by an electrical contractor which increases costs (low voltage transformer needs to be disconnected).
- Requires compliance with transformer regulations as the lamp contains an electronic ballast (see the *Energy efficient lighting technology report – technical details* document for more information).
- Not all lamps are dimmable and those that are can be incompatible with existing dimming systems.
- CRI, typically between 75 and 85, is lower than existing lamps.

Detailed description

Low voltage halogen lamps are replaced with compact fluorescent lamps and a GU10 lamp holder wired to mains 240V. Low voltage transformers are removed and discarded.

This upgrade usually needs the lampholder to be replaced to allow for direct mains connection.

Replacement lamps will have a connected load between 9 W and 15 W. These lamps may be dimmable, but existing dimming devices may need to be removed if the lamps are not dimmable.

Compact fluorescent lamps are often larger than the MR16 halogen lamps and may not fit. The luminaires and the recess depth on site should be checked prior to purchase to make sure that the lamps will fit.

The light output will be significantly lower and the light distribution will rarely be the same, so this retrofit will not generally be acceptable. A lighting designer, using industry standard software, is best placed to evaluate this option. Installing and evaluating a sample area prior to large scale roll out is also recommended.

Figure 45: Compact fluorescent replacement lamp in a recessed downlight that was designed for a GLS lamp

How energy savings are achieved

Energy use is reduced by replacing the existing 50 W lamp with a 15 W lamp (saving 35 W). Transformers are removed (saving 15 W) and the total saving per lamp is 50 W.

This upgrade saves energy by replacing the halogen lamp with the more efficient fluorescent lamp and integrated electronic ballast.

The relationship between a light source and reflector is important to system efficiency, as explained in other sections of this report. Fluorescent light sources are significantly larger than filament sources and accurate control of the light requires a larger reflector. These lamps are highly inefficient as they are almost completely unable to reflect any of the light produced at the back of the lamp. Using fluorescent light sources to replace MR16 halogen lamps often leads to disappointment because of the inefficiencies of scale. However, it is possible to significantly reduce the power that each light uses and save energy with this upgrade. Light levels are substantially lower with the upgrade and light quality, beam control and general appearance are compromised.

If compact fluorescent options are being considered, then the light quality of 20 W IRC lamps (covered in Option 1, p. 53) will be superior and save significant energy.

It could be argued that MR16 compact fluorescent lamps had a place in the market prior to the arrival of LED. However, since LED have lighting characteristics closer to those of halogen lamps and are now a viable solution, these fluorescent lamps are no longer an acceptable option. The largest manufacturer of MR16 compact fluorescent lamps has recently introduced a range of LED MR16 replacement lamps.

Additional information, including the technical specification can be found in the *Energy efficient lighting technology report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

OPTION 5:
New 13 W compact fluorescent luminaire

77% energy reduction

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
13,000	2600	699	663	3962	10,000	2.5	13.8	138

Key benefits

- Excellent energy reduction.
- Long lamp life, minimising maintenance.
- Luminaires are designed specifically for compact fluorescent lamps, providing better lamp life and higher light output.
- Compliant luminaire and power system is supplied.

Key issues

- Varying quality of products in the market.
- Larger luminaire that needs a larger ceiling cut-out and greater ceiling depth.
- Full replacement takes a little longer than lamp replacement.
- Compatibility issues may be encountered with existing dimming systems.
- Colour rendering index (CRI), typically between 75 and 85, is not as high as existing lamps.

Detailed description

This upgrade involves removing the existing transformer, luminaire and light source and replacing them with a larger, new luminaire with integrated electronic ballast and compact fluorescent lamp.

These luminaires typically have a connected load of 13–21 W. The light output and distribution will often be similar to the original 50 W MR16 lamp.

While the lighting outcome is likely to be appropriate, it is recommended that the design is conducted by a lighting designer, using industry standard software. Trial a sample area prior to large scale installation to ensure a successful outcome.

How energy savings are achieved

Energy use is reduced through replacement of the existing 50 W lamp with a 13 W lamp (saving 37 W). Transformer losses are also typically reduced (saving 13 W). Total savings per luminaire are 50 W.

This upgrade completely replaces the existing luminaire and transformer with brand new components that are designed to work together. Legally all new luminaires must be compliant with electrical and safety standards when they are supplied.

The new luminaire will be larger than the existing luminaire, so care should be taken to ensure that sufficient space is available to take the new fitting.

Many compact fluorescent luminaires are produced by reputable suppliers. Using good quality products is an essential element of risk management.

High quality, complete solutions should result in an operating life of 50,000 hours (typical electronic ballast life span), with lamps lasting about 16,000 hours. This would make the system life similar to a LED. The total cost of ownership will be very low due to the long maintenance cycles.

Additional information including technical specification can be found in the *Energy efficient lighting report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

UPGRADING Parabolic aluminised reflector (PAR) lamps and other halogen downlights

PAR lamps containing halogen light sources are generally available in two sizes. PAR 20 lamps are 65 mm wide at the front, while PAR 30 lamps are 95 mm wide. PAR lamps are designed to provide a controlled beam of light and are most commonly used in retail display lighting. They are also used where high light levels and dimming are required, such as theatres and conference spaces. Options for upgrading PAR 30 lamps can be found on p. 64.

Some of these replacement lamps do not provide any kind of optical control and rely on the luminaire to control the light. Generating energy savings by replacing the lamp alone is often very difficult and the entire luminaire may need to be replaced.

Many other types of halogen lamps exist and these often feature lamps with connected loads greater than 100 watts.

Linear halogen lamps are typically used in recessed downlights, floodlights and exterior floodlights. These lamps are most commonly produced in two lengths – 78 mm and 118 mm. Typical wattages range from 100 W to 500 W.

Bipin halogen lamps form the core of a dichroic halogen lamp, but without the integrated reflector package. They are produced in a few different capsule sizes and with different pin dimensions. Wattages range from 5 W to 100 W. Low wattage lamps are often used in display cabinet lighting and jewellery displays. Heat management is often a problem when they are used in cabinets and tight spaces.

JD and JDD series lamps are a cylindrical halogen lamp. These are used in specifically designed luminaires and as a retrofit for traditional incandescent lamps. When used as a retrofit, they often alter the beam spread and light distribution significantly because they are a different shape and size from traditional lamps. They are available in a variety of lamp bases (e.g. small and standard bayonet cap; small and standard Edison screw).

Dimming is the main reason that high wattage halogen lamps are used in downlights. If this is the case, care must be taken to make sure that replacement lights fulfil the same needs.

There are many different types of dimming systems and this is important to consider when replacing dimmable luminaires. Not all dimming systems will be compatible with every luminaire and this should be taken into account. For example, leading edge and trailing edge are the two systems used for dimming mains voltage supply to halogen lamps. The dimmer must match the transformer when the luminaires have electronic transformers, i.e. leading edge dimmers cannot be used with trailing edge transformers and vice versa.

Another reason for using high wattage halogen lamps is that the capital cost of the luminaire and lamp is very low. It can be appealing to use these products in situations where the purchaser is not responsible for ongoing costs. They are a very poor solution where the total cost of ownership is considered.

The following tables outline the costs and energy savings that can be expected when replacing halogen PAR lamps using 100 W PAR 30 lamps as an example.

Figure 46: PAR lamp

Figure 47: LED PAR lamp in a recessed downlight

Figure 48: Bipin halogen lamp

Assumptions

Baseline 100 W PAR 30 halogen lamps, assuming dimmers set at 100% output

Total cost of ownership per 100 luminaires, containing 100 W PAR 30 lamps					
Energy use kWh p.a.	Energy cost $ p.a.	Lamp costs $ p.a.	Maintenance labour savings $ p.a.	Total cost of ownership $ p.a.	GHG emission reduction tCO_2 p.a.
26,000	5200	1950	758	7908	27.6

Figure 49: Ceramic metal halide PAR lamp

These calculations and recommendations are based on the following general assumptions.

Electricity tariff	$0.20/kWh
Operating hours	2600 hr/yr
Time to maintain luminaire	5 min
Existing lamp cost	$15/lamp
Maintenance labour cost	$70/hr

Costs associated with changes to the dimming system have not been included in these calculations.

OPTIONS FOR UPGRADING
100 W PAR 30 halogen lamps

One hundred watt PAR 30 lamps are not commonly used, however four options for upgrading are summarised below.

62% energy reduction

OPTION 1:
New 35 W ceramic metal halide luminaire containing electronic control gear replacement lamps

These are not dimmable or compatible with movement sensors.

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
16,120	3224	866	632	4722	20,000	4.2	17	170

OPTION 2:
New 27 W LED luminaire

73% energy reduction

These are not dimmable. Reduced maintenance is required due to very long lamp life.

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
18,980	3796	1950	758	6504	25,000	3.8	20	200

OPTION 3:
New 2 x 18 W compact fluorescent downlights, complete with electronic ballast

60% energy reduction

Replacement lamps assumed to cost $5 each, with a replacement time of 10 minutes.

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
15,600	3120	1747	521	5388	25,000	4.6	16.5	165

OPTION 4:
New 27 W LED luminaire with DALI dimming power supply

73% energy reduction

Reduced lamp maintenance is required due to very long lamp life.

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
18,980	3796	1950	758	6504	32,000	4.9	20	200

Halogen upgrade risk management checklist

- ☐ The supplier's quote covers all costs, including any out-of-hours work to minimise disruption.
- ☐ All components are of the highest quality and sourced from reputable suppliers.
- ☐ The manufacturer has provided a five year warranty.
- ☐ A test area has been evaluated and the technology is suitable for widespread installation.
- ☐ The supplier has provided evidence that the luminaire is compliant with all applicable standards.
- ☐ The supplier has provided evidence that the completed installation delivers appropriate lighting to meet AS/NZS1680 requirements.

2. High and low bay lighting

These luminaires are used in large open spaces such as warehouses. The mounting height dictates the need for high bay or low bay luminaires. The primary difference between the two is their light distribution characteristics. Low bay luminaires often have a wide light distribution at a lower mounting height, while high bay luminaires often have a more tightly controlled light distribution at their higher mounting height.

Traditionally, high intensity discharge (HID) luminaires like mercury vapour, metal halide and sodium vapour luminaires are used in high and low bay lighting. Often the fitting is designed and built to suit either high or low bay lighting and the lamps are generally not cross compatible once the fitting has been built. Lamp power ranges from 150 W to 1000 W. The control gear is usually conventional ferromagnetic control gear, which contributes to system (energy) losses of between 5 and 20 per cent.

This section outlines upgrade options for 400 W mercury vapour lamps (p. 68) and 400 W metal halide high bay luminaires (p. 78).

Important note:

Typically these products operate during the day in areas without air conditioning. Any luminaire that incorporates electronic control gear may be required to operate at temperatures outside of the manufacturers ratings. Make sure that the technology solution offered is able to function within the temperature range encountered at your site without any detrimental effect on operation or operating life.

Inaccessible locations

The life of fluorescent lamps when used with electronic ballasts can range between 16,000 and more than 20,000 hours, which is considered to be quite reasonable.

However, there are many situations that require luminaires to be placed in locations where access for maintenance can be difficult. These situations may warrant the use of lamps that are specifically designed to operate for longer periods. The higher up-front cost of these lamps is rapidly justified when the maintenance costs of difficult access are considered.

Most of the reputable lamp manufacturers offer products that are specifically designed for long life, operating for 30,000–80,000 hours.

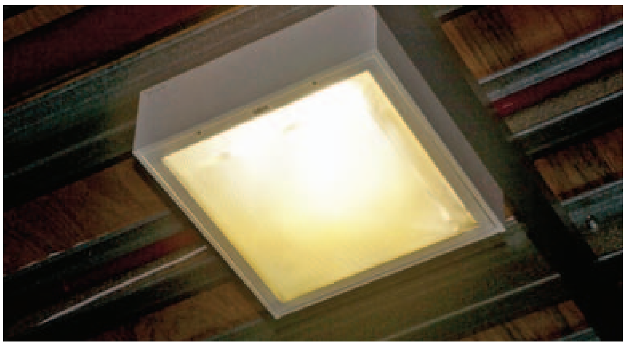


Figure 50: Metal halide low bay luminaire

Figure 52: Metal halide high bay luminaire

Figure 51: Rows of metal halide low bay luminaires

Figure 53: LED high bay lamp and luminaire

UPGRADING 400 W mercury vapour luminaires

Assumptions

The following upgrade options assume that the existing luminaire has:

- a single vertical lamp
- magnetic control gear
- a spun metal reflector fitted with a flex and plug.

The luminaire may also have power factor correction capacitors. Luminaires are group switched, and are turned on at the start of the working day and switched off at closing time. Lamps are not switched on and off due to long restrike times.

Typical operating costs per 100 luminaires					
Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
112,320	22,464	1625	948	25,037	119

These calculations and recommendations and based on the following general assumptions.

Electricity tariff	$0.20/kWh
Operating hours	2600 hr/yr (10 hours per day, 5 days per week) – for a factory running two shifts, the higher operating hours will improve financial return
Time to maintain luminaire	20 min
Ballast type	Conventional iron core ballast
Maintenance labour cost	$70/hr
Existing ballast power	Mercury vapour – 8% of lamp wattage; metal halide – as published
ESC	Calculated using ESS Rule commercial lighting energy savings formula

How old is your infrastructure?

Luminaires containing mercury vapour or sodium vapour lamps are often more than 20 years old and potentially at the end of their life.

Mercury vapour lamps are no longer often used due to poor colour rendering and inefficiency. Sodium vapour lamps are very efficient but produce a very yellow coloured light. These are rarely installed now as metal halide lamps are almost as efficient and deliver much better light quality.

Mounting height

Mounting height is an element of design that should be considered in any system. Lower mounting heights can provide better light levels for task lighting, which can allow the use of lower wattage systems. Good design practices can yield further energy savings with lower mounting heights. However, lower mounting heights can also lead to poor light uniformity.

It is important to take into account the height requirements of fork-lifts when considering the benefits of a lower mounting height.

Maintenance

A maintenance program should be incorporated into any energy efficient upgrade.

Commonly, high bay lighting systems are not well maintained. Cleaning luminaires and replacing lamps that are not producing enough light will improve the light levels. High intensity discharge lamps are often due for replacement long before they fail due to deterioration of lamp light levels.

Figure 54: A deteriorating lamp consumes energy while producing minimal light

OPTIONS FOR UPGRADING
400 W mercury vapour luminaires

In most instances where high or low bay lighting is installed, full replacement with one of these options is recommended.

1. New 250 W metal halide luminaire
2. New 4 x 54 W fluorescent luminaire
3. New 110 W LED luminaire
4. New 200 W induction lamp luminaire

Recommendation

OPTION 3 is the preferred option for this section. This upgrade delivers excellent energy reduction whilst providing brand new, fully compliant luminaires. Lighting design verification is required. Project payback is very fast and when considered with energy reduction presents the best opportunity.

	1 New 250 W metal halide luminaire	2 New 4 x 54 W fluorescent luminaire	3 New 110 W LED luminaire	4 New 200W induction lamp luminaire
Requires design verification	N	Y	Y	Y
Safety compliance[2]	Standard	Standard	Standard	Standard
Energy reduction (typical range) %	30–40	45–55	55–75	40–51
Typical efficacy lm/watt[1]	50	70	100	50–60
Typical, simple pay back yr	2–4	4–5	2–4	4–5
Installation by: C = contractor A = anyone	C	C	C	C
Luminaire cost inc. estimated installation costs $	200	550	550	650
Lamp life hr	10,000	12,800	50,000	60,000
Typical lamp costs $	50.00	7.50 x 4	Not applicable[3]	Not applicable[3]
Recommended ranking, 1= preferred option	2	3	1	4

Legend to colours	Potential cost or risk	Satisfactory	Low risk/good result

1 Estimated efficacy of entire system, including gear and typical luminaire losses.
2 New luminaires from reputable manufacturers will be fully compliant out-of-the-box – seek written confirmation.
3 Primarily due to long pay back period. Volatile nature of market may see a rapid drop in cost therefore a shorter pay back period.

Multilevel switching

Multilevel switching for metal halide lamps involves a form of fixed dimming. This is designed to specifically suit metal halide lamps.

Light colour can be severely compromised when the lamp is dimmed. This is because metal halide lamps produce white light by blending the discharges of a number of different metals. These discharges occur at different temperatures and pressures within the arc tube. Dimming or lowering the power within the arc tube will change the colour blend and compromise light colour.

It is a good idea to ask suppliers to demonstrate how dimming may influence the colour of metal halide lamps.

Multilevel switching is typically bilevel and set at 100% and 50%. However, some systems use trilevel switching (e.g. 100% and 75% and 50% dimmed). This can be controlled manually or connected to movement sensors, light level sensors (to sense sunlight), timers and smart controllers that will deal with logic based combinations.

37% **energy reduction**

OPTION 1:
New 250 W metal halide luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
42,120	8424	271	316	9011	20,000	2.2	44.6	446

Figure 55: Metal halide lamp

Key benefits

- Very good energy reduction.
- Entirely new luminaire that ensures long, trouble-free operation.
- Usually meets lighting needs on a straight swap.
- Reasonable pay back period.

Key issues

- Lamps will degrade in colour quality and output, requiring diligent maintenance.
- Multilevel switching option will yield poor colour when dimmed.
- Dimming for occupancy switching is not recommended.

Detailed description

This option replaces existing luminaires with new fittings containing 250 W metal halide lamps. This reduces the connected load from 432 W to 270 W per lamp.

This upgrade is based on standard quartz metal halide lamps as they are readily available. Ceramic metal halide lamps have better light quality, longer lamp life and lower maintenance costs than quartz metal halide lamps and their use is encouraged.

High quality luminaires utilise reflectors that are typically manufactured from spun aluminium with a semispecular finish. Acrylic and glass reflector options are used in situations where some backlight on the ceiling is needed.

This upgrade will usually deliver a compliant outcome based on a simple one-for-one replacement. However, the design should be carried out by a competent lighting designer using industry standard lighting design software.

How energy savings are achieved

Energy use is reduced by replacing the existing 400 W lamp with a 250 W lamp (saving 150 W). Ballast losses are also reduced (saving 12 W). Total savings are 162 W per luminaire. This represents a reduction of 37 per cent.

The existing 400 W light source delivers about 22,000 lm, but the new 250 W light source can deliver about 20,000 lm and hence has a much greater LOR. Better light colour is an additional benefit.

Any new luminaire offered for sale in Australia should comply with all standards and this upgrade minimises the safety and non-compliance risks.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this upgrade option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Figure 56: Single-ended ceramic metal halide lamp

Figure 57: Double-ended quartz metal halide lamp

48% energy reduction

OPTION 2:
New 4 x 54 W fluorescent luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2p.a.	No. of ESC claimable for 10 years
53,560	10,712	1016	237	11,965	55,000	4.6	56.7	567

Key benefits

- Very good energy reduction.
- Entirely new luminaire with long, trouble-free operation.
- Usually meets lighting needs on a straight swap.
- Dimmable and/or controllable versions are available, increasing possible energy savings.

Key issues

- Risk of lamp failure is increased with more lamps per luminaire.
- High up-front cost.
- Reflectors are susceptible to damage from environmental conditions.

Detailed description of upgrade

This upgrade replaces existing luminaires with new fittings containing 4 x 54 W T5 lamps. This will lead to a connected load of about 226 W per luminaire, compared to the existing 432 W.

Standard T5 lamps, used in this model, deliver a typical operating cycle of 12,800 hours between bulk lamp changes. Long-life lamp alternatives will increase this cycle and these should be considered.

A fully-specular reflector is generally used and this should be protected to maintain high energy efficiency. High temperature ballasts should be used to ensure continuous operation in high bay applications where the environmental conditions may vary.

This upgrade will usually deliver a compliant outcome based on a simple one-for-one replacement. However, the design should be carried out by a competent lighting designer using industry standard lighting design software.

How energy savings are achieved

Energy use is reduced by replacing the existing 400 W lamp luminaire with one containing 4 x 54 W lamps (saving 184 W). The electronic ballasts of the new luminaire further reduce energy use (saving 22 W). The total saving per luminaire is 206 W.

There is a slight reduction in light produced by the lamps. This is balanced by the high LOR of the luminaire due to the high efficiency reflectors.

Where the existing 400 W light source delivers about 22,000 lm, the new light sources deliver about 20,000 lm. This upgrade reduces energy use by 48 per cent and improves light colour.

This upgrade eliminates the risk of creating a luminaire which may not be safe or compliant with the current standards, as any new luminaire offered for sale in Australia should already comply with all standards.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

75% energy reduction

RECOMMENDED

OPTION 3:
New 110 W LED luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
83,720	16,744	1625	948	19,317	55,000	2.9	88.7	887

Figure 58: A high bay LED luminaire complete with in-built LED lamps

Smart control

LED technology can be dimmed, which means there are flexible control options. Some manufacturers also use a simple on/off control for LED banks to achieve multilevel switching. Either option can deliver significant savings by delivering less light to areas not in use, whilst maintaining light colour quality.

Consider control options that address:

- daylight linking
- activity
- time of day
- manual over-ride.

Connection to a central intelligence device can also deliver longevity benefits, by ensuring all LED lights are used equally.

Substantial reductions are possible and these should be calculated on a case-by-case basis.

Key benefits

- Excellent energy reduction.
- New luminaire with long, trouble-free operation.
- Reaches full output quickly, even in cold environments, such as supermarket walk-in coolrooms and freezers.
- Instant on, with no flicker.
- Can be dimmed or section-switched for greater energy reductions.
- Long 19-year rated life span claimed, based on 50,000 hours rated life and 2600 operating hours per annum.

Key issues

- Heat sink design is critical as maintaining LED temperatures within operating limits is a key determining factor of LED longevity.
- Quality varies between the many options.
- Light distribution and beam control characteristics are rarely the same as existing fittings.
- Thermal management of power supplies must be correctly designed.
- Confidence is lacking in stated LED life span unless supported by test results.
- Very high capital expenditure.
- A different luminaire position may be needed, therefore not always a one-for-one swap.

Detailed description

This upgrade replaces existing luminaires with new fittings containing LED and control gear. This will reduce the connected load from 432 W to 110 W.

Light distribution is often handled by lenses fitted to each LED, which can be selected to suit project requirements.

This upgrade will need a full lighting design to be carried out by a lighting designer, using industry standard lighting design software.

How energy savings are achieved

Energy use is reduced by replacing the existing luminaire and its 400 W lamp, with an LED luminaire. Including ballast losses, the total energy saving is 282 W per luminaire.

While the existing 400 W light source is rated at 22,000 lm, some light is lost when moving that light from the source into the space. The delivered light is about 14,520 lm, based on an average Light output ratio (LOR) of 0.66. In the case of a 110 W LED system, at least 12,500 lm is expected to reach the space, with most recent luminaires able to deliver 15,000 lm. This option may require additional luminaires to light the space.

Controlling the light helps to make sure that it reaches the right areas within the environment. For example, a rectangular beam of light can be produced to enhance vertical illumination on pallet racking. A number of LED products are now offered that can deliver shaped distribution in this manner which can allow lower amounts of produced light to deliver a better lighting result.

By installing a new luminaire, this upgrade option eliminates the risk of creating a luminaire which may not be safe or compliant with the current standards. Any new luminaire offered for sale in Australia should already comply with all applicable standards.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including a technical specification can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

LED quality

LED lights are different from most other light sources. Correct design of luminaires is critical to achieve an acceptable LED lamp life span. Many LED products offered for sale are poorly designed.

Things to look for in a quality solution:

- **good heat sinks** – these will take the form of metal fins behind the LED and will be heavy
- **separate power supply** – the luminaire should be constructed in such a way that the heat generated by the LED does not interact with the power supply and vice versa
- **smart optics** – LED lights should be designed to be fitted with optical devices such as lenses, which will deliver the light to where it is needed.

51% energy reduction

OPTION 4:
New 200 W induction luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2p.a.	No. of ESC claimable for 10 years
57,720	11,544	1625	948	14,117	65,000	4.6	61.1	611

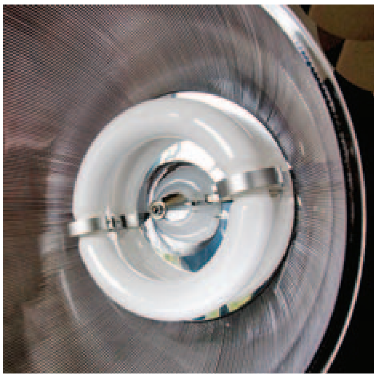


Figure 59: Induction lamp

Key benefits

- Excellent energy reduction.
- New luminaire with long, trouble-free operation.
- Reduced maintenance costs in hard-to-reach locations and high ceilings.
- Economical in areas with long operating hours.
- Full output reached quickly, even in cold environments such as supermarket walk-in coolers and freezers.
- Long claimed life span (23-year rated) based on 60,000 hours rated life and 2600 operating hours per annum.
- Claimed 30 per cent lumen depreciation at 60,000 hours.
- Good where high quality lighting is needed – CRI > 80.
- Instant ignition and restrike.
- Low glare.
- Long warranties are offered, typically five years on lamp, three years on ballasts.

Key issues

- High capital expenditure.
- Major manufacturers do not offer this technology.
- Long pay back periods, outside typical accepted range.
- Lack of confidence in the suggested life span, unless supported by reliable test results.
- Under the proposed ESS rule change induction lighting will need to be compliant with Australian Standards to claim Energy Saving Certificates in NSW.

Detailed description

This upgrade replaces existing luminaires with new fittings containing induction lamps. This upgrade reduces the connected load from 432 W to 210 W.

Light distribution is controlled by a metal reflector with a specular or semispecular surface, as with the metal halide option (Option 1).

This upgrade will require a lighting design to be carried out by a lighting designer, using industry standard software, in cooperation with the luminaire supplier.

How energy savings are achieved

Energy use is reduced by replacing the existing 400 W lamp with a 200 W lamp (saving 200 W). Ballast loses are also reduced (saving 22 W). The total saving per luminaire is 222 W.

While the existing 400 W light source delivers about 22,000 lm, some energy is lost in the process of delivering the light from the source into the space. The actual delivered light is about 14,520 lm based on an average LOR of 0.66. At least 11,250 lm is expected to be delivered with this 200 W induction system.

This upgrade option eliminates the risk of creating a luminaire which may not be safe or comply with the current standards. Any new luminaire offered for sale in Australia should already comply with all relevant standards.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information, including technical specifications can be found in the document *Energy efficient lighting report – technical details*

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

UPGRADING 400 W metal halide luminaires

Assumptions

The following upgrade options assume that the existing luminaire:

- has a single vertical lamp
- has magnetic control gear
- may have power factor correction capacitors. The reflector is made of spun metal and the luminaire is fitted with a flex and plug
- is group switched: turned on at the start of the work day and switched off at closing time (lamps are not switched on and off due to long restrike times).

In this case, the existing model is based on a site using 100 metal halide high bay luminaires fitted with 400 W lamps.

Typical operating costs per 100 luminaires					
Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
118,040	23,608	975	379	24,962	125

These calculations and recommendations and based on the following general assumptions.

Electricity tariff	$0.20/kWh
Operating hours	2600 hr/yr (10 hours per day, 5 days per week) – for a factory running two shifts, the higher operating hours will improve financial return of upgrades
Time to maintain luminaire	20 min
Ballast type	Conventional iron core ballast
Maintenance labour cost	$70/hr
Existing ballast power	Mercury vapour – 8% of lamp wattage; metal halide – 54W (average published value)
ESC	Calculated using ESS Rule commercial lighting energy savings formula

Figure 60: Metal halide lamp

400 W metal halide luminaires

OPTIONS FOR UPGRADING

400 W metal halide high bay luminaires

1. New 320 W pulse-start metal halide luminaire
2. New 210 W LED luminaire
3. New 300 W induction lamp luminaire

Recommendation

OPTION 2 is the preferred option for this section. This upgrade provides excellent energy reductions whilst providing brand new, compliant luminaires. Lighting design verification is required with this option. This option presents a low risk in selection and implementation.

	1 New 320 W pulse-start metal halide luminaire	2 New 210 W LED luminaire ✔	3 New 300 W induction lamp luminaire
Requires design verification	Y	Y	Y
Safety compliance[2]	Standard	Standard	Standard
Energy reduction (typical range) %	20–30	40–54	30–40
Typical efficacy lm/watt[1]	55–60	90-100	70
Typical, simple pay back yr	4–6	4-5	9.1
Installation by: C = contractor A = anyone	C	C	C
Luminaire cost inc. estimated installation costs $	300	630	780
Lamp life hr	32,000	50,000	60,000
Typical lamp costs $	90	Not applicable[4]	Not applicable[4]
Recommended ranking, 1= preferred option	2	1	3[3]

Legend to colours	Potential cost or risk	Satisfactory	Low risk/good result

1 Estimated efficacy of entire system, including gear and typical luminaire losses.
2 New luminaires from reputable manufacturers will be fully compliant out-of-the box – seek written confirmation.
3 Primarily due to a long pay back period. The volatile nature of the market may see a rapid drop in cost and therefore a lower pay back period.
4 LED and induction luminaires will not need replacement lamps. The operating life of the source should be the same as the reasonable operating life of the luminaire body.

23% energy reduction

OPTION 1:
New 320 W pulse-start metal halide luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
27,300	5460	244	190	5894	30,000	5.1	28.9	289

Key benefits

- Good energy reduction.
- New luminaire with long, trouble-free operation.
- Usually meets lighting needs on a straight swap.
- Reasonable pay back period.
- Very long lamp life with good luminous flux depreciation characteristics, minimising maintenance costs.

Key issues

- Lamps will degrade in colour quality and output, requiring diligent maintenance.
- Multilevel switching option will yield poor colour when dimmed.

Detailed description

This upgrade replaces existing luminaires with new fittings containing 320 W pulse-start metal halide lamps. This will reduce the connected load from 454 W to about 349 W per lamp.

This upgrade is based on using pulse-start lamps, which deliver high efficacy, fast warm-up, good lumen maintenance and a long life span. Pulse-start is a matched system of lamps and ballasts designed specifically to provide very high efficiency.

High quality solutions use reflectors which are typically manufactured from spun aluminium in specular and semi-specular finishes. Acrylic and glass reflectors are used when some backlight on the ceiling is needed.

This upgrade will usually deliver a compliant outcome based on a simple one-for-one replacement. However, the design should be carried out by a competent lighting designer using industry standard lighting design software.

How energy savings are achieved

Energy use is reduced by replacing the existing 400 W lamp with a 320 W lamp (saving 80 W). Ballast loses are also reduced (saving 25 W). This gives a total saving of 105 W per luminaire.

There is a slight reduction in the amount of light produced by the new light source, but this can be easily balanced by selecting luminaires with a high LOR.

The existing 400 W light source delivers about 36,000 lm and the new 320 W light source delivers about 31,000 lm. This represents a reduction of 14 per cent.

This option eliminates the risk of creating a luminaire which may not be safe or comply with the current standards. Any new luminaire offered for sale in Australia should comply with all relevant standards.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

Additional information about this option can be found in the *Energy efficient lighting technology report – technical details* document:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

RECOMMENDED

54% energy reduction

OPTION 2:
New 210 W LED luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
63,440	12,688	$975	379	14,042	63,000	4.5	67.2	67

Key benefits

- Excellent energy reduction.
- New luminaire with long, trouble-free operation.
- Reaches full output quickly, even in cold environments, such as walk-in coolrooms and freezers.
- Instant on, with no flicker.
- Can be dimmed or section-switched for greater energy reductions.
- Long 19-year rated life span claimed, based on 50,000 hours rated life and 2600 operating hours per annum.

Key issues

- Heat sink design is critical to maintain LED temperatures within operating limits and is a key determining factor of LED longevity.
- Quality varies between the many product options.
- Light distribution and beam control characteristics are rarely the same as existing fittings.
- Thermal management of power supplies must be correctly designed.
- Confidence is lacking in stated LED life span unless supported by test results.
- High capital expenditure.
- A different luminaire position may be needed, therefore it will not always be a one-for-one swap.

Detailed description

This upgrade replaces existing luminaires with new fittings containing LED and control gear. This will reduce the connected load from 454 W to 210 W.

Light distribution is often handled by lenses fitted to each LED, which can be selected to suit project requirements.

This upgrade will need a full lighting design to be carried out by a lighting designer, using industry standard lighting design software.

How energy savings are achieved

Energy use is reduced by replacing the existing luminaire and its 400 W lamp, with an LED luminaire. Including ballast losses, the total energy saving is 244 W per luminaire.

While the existing 400 W light source is rated at 40,000 lm, some light is lost when moving that light from the source into the space. The delivered light is about 36,400 lm, based on an average LOR of 0.66. In the case of a 210 W LED system, at least 18,000 lm is expected to reach the space, with most recent luminaires able to deliver 21,000 lm.

Controlling the light helps to make sure that it reaches the right areas within the space. For example, a rectangular beam of light can be produced to enhance vertical illumination on pallet racking. A number of LED products are now offered that can deliver shaped distribution in this manner which can allow lower amounts of produced light to deliver a better lighting result.

This upgrade option eliminates the risk of creating a luminaire which may not be safe or compliant with the current standards. Any new luminaire offered for sale in Australia should already comply with all applicable standards.

Compliance with AS/NZS 1680 should be verified using industry standard lighting software.

The additional information listed below can be found in a technical specification in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

High and low bay lighting – other applicable options

LED retrofit replacement lamps fitted within the existing luminaire

LED replacement lamps are available for a complete retrofit of discharge lamps. However, LED replacement lamps are unlikely to be able to perform properly when used in this way, due to the form factor or shape of the existing lamp. Extremely high temperatures have been recorded when LED lamps have been tested in this situation. These high temperatures have been recorded in areas that are likely to damage LED lamps. It is essential to ensure that any solution provides a compliant lighting outcome.

Linear fluorescent trunking systems

Trunking systems are a linear rail that contains a channel for electrical cables as well as a method of connecting linear fluorescent luminaires. Trunking provides a flexible stable platform for the fixing of luminaires at regular intervals for applications such as warehousing and supermarket aisle lighting. In high and low bay applications the light is often unable to be controlled and this can lead to inefficiencies, such as light shining in areas where it is of no benefit (e.g. on the top of shelving). A roof-mounted luminaire with a reflector directs light downwards providing horizontal illumination, but relatively poor vertical illumination.

Racks and shelves that need to be seen clearly are often lit with linear fluorescent systems, similar to those used in supermarkets.

Linear fluorescent trunking systems can be very efficient and yield good financial returns when used instead of high bay lighting.

Active reactor technology

This technology uses a power optimisation strategy to deliver energy savings. In essence, the lamp is turned down to reduce power and less light is produced. According to the manufacturer's documentation, this option delivers 80% of the rated lamp power for a 70% reduction in produced light. While this can reduce energy use, the lower lighting level may not be appropriate.

Active reactor technology should only be considered if the appropriate lighting design calculations have been carried out, to make sure that the lighting is suitable for the space.

31% energy reduction

OPTION 3:
New 300 W induction lamp luminaire

Energy and cost savings summary

Energy savings and financial return per 100 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
36,140	7228	975	379	8582	78,000	9.1	38.3	383

The pay back period of this option exceeds nine years and this is not considered viable. As a result, this option has not been described in more detail but may be explored in future revisions of this report.

High bay risk management checklist

- ☐ The supplier's quote covers all costs, including any out-of-hours work to minimise disruption.
- ☐ All components are of the highest quality and sourced from reputable suppliers.
- ☐ The manufacturer has provided a five year warranty.
- ☐ A test area has been evaluated and the technology is suitable for widespread installation.
- ☐ The supplier has provided evidence that the luminaire is compliant with all applicable standards.
- ☐ The supplier has provided evidence that the completed installation delivers appropriate lighting to meet AS/NZS1680 requirements.

3. Exterior lighting

This section covers upgrades for:

- building or pole mounted floodlights – usually found outside entry areas, along external passageways, around loading docks and on garden areas:
    - halogen floodlighting, typically 500 W linear floodlight (p. 86)
    - metal halide floodlighting (p. 90)
- pole-mounted street or roadway lights – usually found in public areas where vehicle or pedestrian activity requires light for safety and amenity. Road lighting P-category and V-category covered by AS/NZS 1158 (p. 91–93).

Figure 61: Metal halide floodlight

External lighting is generally not given the same priority as internal lighting in energy saving initiatives. A common perception is that few viable upgrade options are available and the load profile of external lighting is often not understood.

As with interior lighting, it is important to consider the external lighting needs. Commercial buildings may need exterior lighting for roadways, car parks, walkways and entry areas as well as security requirements which can sometimes include closed circuit television (CCTV).

Exterior lighting can also be decorative and be used to enhance the prestige of a building.

These types of areas are generally lit with pole top 'road' lighting, floodlighting and luminaires mounted on the building.

The calculations and recommendations in the exterior lighting section are based on the following general assumptions.

Electricity tariff	$0.20/kWh
Operating hours	3640 hr/yr (10 hours per day, 7 days per week)
Time to maintain luminaire	10 min
Maintenance labour cost	$70/hr
ESC	Calculated using ESS Rule commercial lighting energy savings formula
Sample quantity of luminaires	10

HALOGEN FLOODLIGHTING

This section covers the most common types of external floodlighting including halogen and metal halide floodlighting.

UPGRADING 500 W linear lamp shovel and box floodlights

Halogen floodlights (utilising the linear halogen lamp), are very common in residential and some commercial applications. It is not unusual to see these for sale at $20 each, complete with lamp, and this can be very appealing.

The lamps have a maximum rated life span of 2000 hours and are sensitive to burning position, vibration and contact with human skin. Burning position relates to the orientation of the lamp when operating.

Small lamps can usually operate in any position (universal burning position) while linear halogen lamps must be operated with their long side parallel to the horizon. Lamps can heat up unevenly if oils are transferred from skin onto the lamp (skin contact) during installation. The uneven heat pattern can cause the lamp to fail.

The 500 W linear halogen lamps are able to deliver as much as 10,000 lm.

Such a high-powered device often requires a luminaire specifically designed for the light source. There are a few replacement options that use fluorescent lamps, but these do not deliver the required light power in a size to fit the existing luminaire, hence replacing the luminaire is usually the only viable option.

When the floodlights are connected to a motion sensor it is not viable to replace with metal halide luminaires as they have a long warm-up time (60–90 seconds) and will not restrike rapidly (can take up to 10 minutes) once turned off. These time delays make the luminaires unsuitable for use with motion sensors. LED-based solutions are recommended where motion sensors are in the circuit.

Assumptions

The following upgrade options assume that the existing installation uses 500 W linear halogen lamps and that the luminaires are not connected to a movement sensor. The luminaires are hard-wired, operate from dusk to dawn and are fitted directly to the building structure.

Typical operating costs per 100 luminaires

Energy consumption kWh p.a.	Energy cost $ p.a.	Maintenance material costs $ p.a.	Maintenance labour cost $ p.a.	Total cost $ p.a.	GHG emissions tCO_2 p.a.
18,200	3640	91	212	3943	19.3

OPTIONS FOR UPGRADING
500 W linear lamp shovel and box floodlights

1. New 150 W metal halide floodlight
2. New 110 W LED floodlight

	1 New 150 W metal halide floodlight	2 ✔ New 110 W LED floodlight
Requires design verification	N	N
Safety compliance[2]	Standard	Standard
Energy reduction (typical range) %	66	82
Typical efficacy lm/watt[1]	45	90–95
Typical, simple pay back yr	1–2	1–2
Installation by: C = contractor A = anyone	C	C
Luminaire cost inc. estimated installation costs $	300	500
Lamp life hr	10,000	50,000
Typical lamp costs $	50	Not applicable[3]
Recommended ranking, 1= preferred option	2	1

Legend to colours	Satisfactory	Low risk/good result

1 Estimated efficacy of entire system including gear and typical luminaire losses.
2 Legally all new luminaires must be supplied compliant with electrical and safety standards.
3 LED luminaires will not have or need replaceable lamps. Operating life of the source should be the same as the reasonable operating life of the luminaire body.

Figure 62: 500 W halogen with motion sensor

Recommendation ✔

OPTION 2 is the preferred option in this section. This upgrade delivers excellent energy reductions whilst providing a new luminaire that is compliant with Australian Standards. Minimal lighting design verification is required with this option. Choosing high quality products will minimise any risks associated with this option.

66% energy reduction

OPTION 1:
New 150 W metal halide luminaire

Energy and cost savings summary

Energy savings and financial return per 10 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
12,012	2402	-98	168	2472	3000	1.2	12.7	127

Key benefits

- Excellent energy reduction.
- New luminaire with long, trouble-free operation.
- Exceeds existing lumen output with a straight swap.
- Excellent pay back period.

Key issue

- Potentially high lamp replacement costs create an increase in maintenance costs compared to the existing fitting.

Detailed description

This upgrade replaces the existing luminaires with new fittings containing 150 W ceramic metal halide lamps. This will reduce the connected load from 500 W to about 170 W per lamp.

The ceramic metal halide lamps will produce good light quality with very little shift in colour as the lamp ages. The reflector is typically pressed aluminium and is fully or semispecular.

A 150 W metal halide luminaire will usually deliver a higher light level than the existing system.

How energy savings are achieved

This upgrade reduces energy use by replacing a 500 W lamp with a 150 W lamp (saving 350 W). Ballast losses are introduced with the replacement lamp (20 W increase). The total saving per luminaire is 330 W.

More light is produced by the new lamp. Further energy could be saved by using a 70 W version of the floodlight, but this would produce less light (5,200 lumens). If required, confirmation of light output characteristics can be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

OPTION 2:
New 110 W LED luminaire

RECOMMENDED

82% energy reduction

Energy and cost savings summary

Energy savings and financial return per 10 luminaires								
Electricity savings kWh p.a.	Energy cost savings $ p.a.	Maintenance lamp savings $ p.a.	Maintenance labour savings $ p.a.	Total cost savings $ p.a.	Capital cost inc. installation $	Pay back period yr	GHG emission reduction tCO_2 p.a.	No. of ESC claimable for 10 years
14196	2839	91	212	3,142	5000	1.6	15	150

Key benefits

- Excellent energy reduction.
- New luminaire with long, trouble-free operation.
- Can be dimmed or section-switched for greater energy reductions.
- Long operating time without need for lamp change.

Key issues

- High capital expenditure.
- Lack of confidence in the life span claimed, unless supported by test results.

Detailed description

This upgrade replaces existing luminaires with new fittings containing LED lamps and control gear. This reduces the connected load from 500 W to 110 W.

Light distribution is handled by lenses fitted to each LED and these can be selected to suit project requirements.

Selecting high quality LED products is important when upgrading with this option. There is a complex range of quality offerings as well as lower quality products that are not fit-for-purpose. Heat sink design is critical, as dissipating heat and maintaining LED temperatures within operating limits is a determining factor in achieving long LED life. Correct design of the thermal management of power supplies is needed.

How energy savings are achieved

Energy is saved through the higher efficiency of LED products. The connected load is reduced from 500 W to 110 W (saving 390 W).

The success of this option relies on an efficacy of at least 60 lm/W delivered light, which includes light losses from the luminaire. Many manufacturers supply products with at least this efficacy with many reaching 100 lm/W.

The existing 500 W light source delivers about 10,000 lm, although some light is lost during delivery. About 5700 lm is actually delivered into the space, based on an average LOR of 0.57. At least 6600 lm is expected to be delivered by the 110 W LED system.

If required, confirmation of light output characteristics can be verified using industry standard lighting software.

Additional information about this option can be found in the document *Energy efficient lighting report – technical details*:

- lighting quality, including colour and colour rendering (AS/NZS 1680 provides recommendations and guidance)
- maintenance and safety
- compatibility with occupancy sensing and daylight linking
- technical specifications.

Metal halide floodlighting

Metal halide floodlighting is used commercially in a variety of ways.

Metal halide lights are an inherently efficient light source and range from 20 W to 2000 W. Electronic ballasts can be used with lower wattage lamps to further increase efficiency.

Exterior metal halide floodlights generally have built-in control gear which is matched to the lamp. This makes any kind of retrofit to a different lamp expensive and complicated. Light distribution is managed by a reflector which is matched to the original light source. If another lamp type is retrofitted then the light output would change radically.

Floodlighting often sprays light into areas where it is not needed and glare can be a problem. Patchy light and energy inefficiencies can result from a tendency to use the highest watt lamps possible in the least number of luminaires. Approaching the situation from a design point of view can create opportunities to save energy.

A review of floodlighting systems can address some of the following issues:

- what lighting is needed to meet the regulations and to light the space appropriately?
- can boundaries be set around the areas requiring light?
- do lights need to be run all the time or can they have variable outputs?
- are there any issues with glare and spill-light?
- does restricted access or high mounted light make maintenance difficult?

Addressing these issues can often lead to a more efficient system that exploits LED technology. LED luminaires can:

- deliver low base level light for safety and security and maximum light when areas are in use via dimming control or stepped switching (activity, time or manual control)
- accurately control light and only place light where it is needed, maximising efficiency
- reduce maintenance costs, as they operate for 50,000 hours to 70 per cent of initial light level which also minimises risk associated with accessing difficult locations.

If the existing metal halide lamps are greater than 1000 W, it becomes difficult to deliver affordable LED-based solutions. The size and weight of high light output LED lamps can make them impractical and lead to the need for more luminaires. The higher up-front costs associated with additional luminaires means that LED technology is not financially viable in these circumstances.

Professional assistance with lighting design is recommended to make sure that any metal halide floodlight replacements provide a successful outcome.

Exterior lighting management checklist

- [ ] The supplier's quote covers all costs, including any out-of-hours work to minimise disruption.
- [ ] All components are of the highest quality and sourced from reputable suppliers.
- [ ] The manufacturer has provided a five year warranty.
- [ ] A test area has been evaluated and the technology is suitable for widespread installation.
- [ ] The supplier has provided evidence that the luminaire is compliant with all applicable standards.
- [ ] The supplier has provided evidence that the completed installation delivers appropriate lighting to meet AS/NZS1680 requirements.

Road lighting

The lighting of roads and public areas is primarily designed around the principles set out in AS/NZS 1158. Lighting designers will usually refer to this standard in projects where a roadway leads to commercial premises or even an external car park. This standard categorises road lighting into two very separate forms, known as V-category and P-category.

In V-category, the emphasis is on lighting to assist motorists, while lighting classed in P-category places the emphasis on pedestrian's needs.

In simple terms, road authorities are responsible for V-category and local councils are responsible for P-category. AS/NZS 1158 also covers car parks, parks, underpasses and other external areas that need lighting.

AS/NZS 1158.3.1 provides the technical parameters for P-category lighting. The primary measurement methods are horizontal illuminance and uniformity. Vertical illuminance requirements are also specified in some categories. Glare control, upward waste light, light spill and maintenance requirements are also covered in this standard.

AS/NZS 1158.1.1 provides the technical parameters for V-category lighting. The primary measurement methods are luminance and uniformity. Glare control, upward waste light, light spill, maintenance and energy consumption requirements are covered in this standard.

P-category

Local councils will benefit most from this section of the report. The majority of P-category road lighting infrastructure is provided and maintained by energy authorities on behalf of local councils. Many local councils responsible for the GHG street lighting generates are unable to minimise their footprint, as the lighting is managed by energy authorities. A report, *The Alternative Energy Roadmap*, commissioned by a Sydney municipal council, Lane Cove Council, found that street lighting accounted for 25–35 per cent of GHG produced from council activities. Many local councils are now taking ownership of public area lighting from energy authorities when major public works are carried out.

For those that provide public area lighting, finding the balance between increased capital investment, reduced cost of ownership and GHG reduction benefits is a challenge.

LED

LED street lighting is capable of delivering significant energy savings. Energy reductions as high as 73 per cent were recorded at Martin Place in the central business district of Sydney, when LED lighting was installed in place of metal halide lighting (installed in compliance with AS/NZS1158.3.1 for category P6) as part of a City of Sydney trial.

LED-based street lighting products are now offered by a number of lighting suppliers and purchase costs are falling rapidly. Total cost of ownership calculations are now favourable and it is generally a good time to install these products.

Most of the P-category lighting is currently provided by mercury and sodium vapour lamps and to a lesser extent, metal halide and fluorescent lamps. Many councils are now trialling LED technology.

Lamp life is one of the main factors in ownership costs of public area lighting. The cost of changing lamps situated on poles is very high as vehicles with lift systems and lengthy occupational health and safety procedures are needed.

Reducing energy use, even at current energy prices, is unlikely to fund major technology upgrades in public area lighting. However, the total cost of ownership calculations will make a compelling case for change, as seen in other lighting systems.

Figure 63: Typical sodium vapour street lights

A long warranty period which covers maintenance costs would substantially decrease ownership costs, and it may also minimise any perceived risk of adopting this technology. Most mainstream LED manufacturers provide five year warranties, but ten year warranties can be negotiated.

Mercury vapour luminaires

In P-category lighting, typical mercury vapour luminaires use lamps ranging from 50 W to 250 W and their efficacy ranges from 36 lm/W to 52 lm/W. Once control gear and luminaire losses are taken into account, the effectiveness decreases and these luminaires are no longer an energy efficient option.

Poor colour rendering is another reason why fewer mercury vapour luminaires are installed. Although mercury vapour lamps have a very long operating life (up to 30,000 hours), their light output can decrease over time. Lamps that are still glowing are generally not replaced, even when their light output is ineffective. It is good practice for operating hours to guide lamp replacement rather than light output or lamp failure, as sudden and total failure is relatively rare. Operating costs can also be reduced with global lamp changes based on operating hours as random failure changes are minimised.

Sodium vapour luminaires

Sodium vapour lighting can be easily identified by its yellow-orange light. Sodium vapour lighting is considered to be a poor choice if pedestrian safety and crime prevention (through easier identification of people and vehicles) are important elements of the lighting design. As this light source does not render colours, it is unsuitable for areas where human activity occurs.

Sodium vapour lighting is very energy efficient, with lamp efficacies of about 82 lm/W. A typical 70 W lamp has a connected load of 86 W and a lamp life of about 15,000 hours. High maintenance costs associated with lamp access can increase the cost of ownership.

Fluorescent luminaires

Fluorescent luminaires are the most energy efficient solution currently used by energy authorities, particularly on minor suburban roads as covered in sections P4 and P5 of the P-category standard. Installation of fluorescent luminaires has significantly reduced energy use in these situations.

Twin 20 W tubular fluorescent luminaires with conventional ballasts were used in this area which had a total connected load of approximately 50 W. These are now replaced with twin 14 W T5 fluorescent system with a connected load of 30 W. Also used are 32 W and 42 W compact fluorescent lamps.

Eighty watt mercury vapour luminaires with a connected load of more than 95 W were also used and are now replaced with compact fluorescent lamp with a connected load of 46 W.

Lamps are lasting much longer with this newer technology, despite initial concerns around electronic ballast use in exterior lighting.

LED solutions are also available for P4 and P5 category roads. The main benefits of LED lighting are extremely long lamp life, which minimises maintenance, and some reductions in wattage.

Design an energy efficient P-category lighting project

Providing low energy street lighting is a relatively simple process when a business or council can control how an area can be lit (outside of the existing contract arrangements with an energy authority). This can be represented as follows:

- Engage a lighting designer or a supplier with the capability to provide design services (preferably by subcontracting to an impartial lighting designer).
- Confer to establish the scope of works and identify the applicable P-category for the project.
- Select a style of luminaire that delivers the aesthetic required for the project.
- Prepare a model using industry standard lighting design software and analyse a variety of technologies. Consider:
  - glare control
  - maximum pole spacing
  - compliance with light technical parameters
  - low watts per square metre
  - total cost of ownership analysis.
- Analyse the outcomes of the design process and then tender the selected solution through the usual methodology.
- Seek longer warranties and external maintenance services to improve the outcome.

V-category

Existing street lighting for V-category roads typically consists of high pressure sodium lamps, mercury vapour and metal halide lamps. Note that mercury vapour lamps are not permitted in any new designs.

Information provided on light sources in the P-category (p. 91) is also applicable here. LED street lighting is anticipated to become normal practice, based on experiences in other parts of the world. A number of organisations are trialling LED solutions for V-category lighting in Australia.

4. Emergency and exit lighting

Figure 64: A row of single T8 fluorescents being used for emergency lighting

Emergency and exit lighting systems are essential for public safety. The correct use of these systems is governed by AS/NZS 2293 which outlines procedures and methods of delivering a safe system as well as measurement and maintenance criteria.

The requirement to comply with AS/NZS 2293 makes it essential that professional advice is sought when selecting energy reduction strategies for emergency and exit lighting systems.

Emergency and exit lighting can contribute measurably to a building's base load and there can be significant costs associated with system maintenance.

Emergency lighting systems are designed to operate in the event of power failure and they deliver a safe light level to help in building evacuation. Exit lights are designed to indicate egress paths.

Typically, the systems are designed to operate on batteries which are kept charged when mains power is present. The batteries are used to power the light sources during power failures. These systems need to operate without external power for at least two hours. Most systems use battery packs which are local to each luminaire, but some systems utilise remote battery systems. More sophisticated systems use a communications network designed to allow a central device to manage and monitor the system.

The specialised nature of these systems makes a typical scenario difficult to construct. However, some new technology that could save energy is outlined below.

Recessed downlights

Recessed downlights are typically supplied with a power pack and battery unit. These systems are usually 'non-maintained', meaning that they will only operate in the event of power failure. The downlight will usually have an LED indicator lamp and a test switch on the front. They are typically fitted with 10 W halogen lamps and have a connected load of about 8 W. They usually use power, even when they are not illuminated, due to energy losses in the system.

Replacements that utilise LED technology can reduce energy by approximately 65 per cent, whilst also significantly reducing maintenance costs.

Fluorescent battens

These can be either single or twin lamp systems. Typically, these systems are 'maintained', meaning that they operate all of the time and only one lamp is operated by batteries when mains power fails. In some cases, the system is 'sustained', meaning that one lamp operates on mains power and the other lamp only operates on batteries when power fails. These luminaires are rarely configured for 'non-maintained' operation.

These systems are traditionally based on T8 lamp technology. They are not suitable for retrofit with LED fluorescent replacement lamps or with T8–T5 converter systems.

Full replacement T5 emergency luminaires are available and can reduce energy use by 20–40 per cent whilst significantly reducing maintenance costs.

Emergency lighting in fire stairs often delivers significantly higher light levels than are required. Fire stairs are also used to access different levels within a building as part of everyday use. Products are available that deliver the minimum light level needed in the stairs at all times, but when movement is sensed, a much higher light level is produced. It is essential that compliance to AS/NZS 2293 is achieved and that the site is certified compliant by an appropriate authority.

Full replacement with specialised LED-based luminaires can reduce energy use by as much as 90 per cent when used with integrated movement sensing.

Exit signs

AS/NZS 2293 2005 brought about the replacement of the original exit sign with the international 'running man' pictograph. Either type may be present currently but any new products purchased must be of the 'running man' type.

Exit signs are 'maintained', which means that they operate all of the time. Should mains power fail, the battery system will supply power. Most older installations are 10 W, T8 fluorescent lamp systems, with connected loads of about 15 W. It is also important to consider that the 10 W tubes typically have a life of 5000 hours.

Full replacement with 'cold cathode' luminaires will yield an extremely long lamp life and deliver energy savings of 40–60 per cent.

Full replacement with LED-based luminaires will yield an extremely long lamp life and deliver energy savings of 50–70 per cent.

Figure 65: Exit signs – original (top), 'running man' (bottom)

5. Lighting controls

Figure 66: Light switch control panel

Energy use can be reduced by controlling lights to suit specific intensity, time and place requirements. Control systems that manage light can complement the use of energy efficient lamps. The goal of automated control is to provide a highly productive and safe lighting environment. Hence, the ideal automated lighting control system should be undetectable by building occupants and maximise efficiency.

The ability to effectively control building lighting is reliant on three major factors:

- lamp technologies that can be turned on, off and dimmed
- appropriate sensors to detect building use and environmental conditions
- control systems that vary light output according to sensor inputs and user needs across different locations.

Lighting controls can be as simple as an on/off switch or a sophisticated, logic-based, microprocessor controlled system. The simplest of these systems, the light switch, often does not save much energy. When the only method of control is manual switching, lights are often left on longer than needed, particularly in commercial applications. Lighting control systems need to be simple to operate and preferably designed to operate with minimal human intervention. The systems may be complicated, but they should not be complicated to use.

Intelligent light control can deliver substantial energy savings, especially when the entire system is designed with this in mind. Many elements of the system need to be matched to operate together. Products may not work together if they are not purchased with the control strategy in mind. If funds are limited, lights capable of sophisticated control should be purchased initially so a compatible control system can be bought at a later date.

Lighting control decisions can be made based on a large number of factors, such as:

- time of day
- activity
- light level
- temperature
- individual personal requirements
- combinations of the above factors.

Analysing these factors can result in outcomes such as:

- light levels that match the exact needs of the space at any given time
- light delivered in the direction of an exit
- light only delivered in occupied spaces
- security lighting that meets the security needs at any given time.

Make sure that lighting needs are met but not exceeded to minimise the amount of energy used at any given time or activity.

Lighting control systems can be very costly. More sophisticated systems result in better outcomes, but there is a point where the costs and benefits are no longer in balance. This will be different for every project, but can be found through a step-by-step review of the control options, from the simplest to the most complex.

How smart is your smart control?

Central intelligence is where a smart control device operates a number of attached devices and makes all operation decisions.

Local intelligence systems make intelligent control decisions local to the load and often with no communication with other devices.

Large scale lighting control with central monitoring often works by combining elements of these two concepts.

Electrical engineers, lighting designers, lighting manufacturers and control system manufacturers are all able to help in this process.

The typical elements of control systems are outlined below.

Upgrading basic switches to coded switch banks for manual zone switching

Many commercial buildings are wired with a small number of switches that make big changes to large areas. For example, in a large office tower there can be four switches that turn on an entire floor. Generally this leads to an entire floor being lit when only one person is working, as the switches are operated on a first in/last out basis.

Resolving this situation could involve:

- reviewing workspace layout on the floor
- relocating all workspaces used out-of-hours into one area, preferably close to the lifts
- rewiring so that a switch, or group of switches, separates that area from any others.

If switches operate smaller zones within the building then light levels are more likely to suit the actual use of the building. Cultural change is also needed to make sure that people only switch on lights when they are needed.

Manual time delay switches

Time delay switches are more sophisticated lighting control systems. Switches that allow a preset period of light can be used outside of typical business hours. For example, lights could turn on once a switch is pressed and then automatically switch off after an hour has elapsed. This can be repeated if necessary. Time delay switches are common in areas such as toilets where short periods of lighting allow for short blocks of activity.

Automatic time switching

Many lighting applications have very clearly defined operating times. Exterior lights are only needed at night time, although these are often used during the day. Automatic time switching can help commercial businesses make sure that lights are always turned off.

Manual time delay switches, as mentioned above, account for any out-of-hours use and cleaning, but an automatic time switch can turn lights off at a preset 'going home' time. This forces switches to be activated manually when out-of-hours activity takes place.

Occupancy sensing

Occupancy sensing is a very effective method of providing 'fine control'. Fine control refers to the ability of a system to control specific lighting outcomes for small zones or spaces. For example, good light could be provided for a single person working in a large open plan office at night, while other areas would be dimmed or dark. The most sophisticated versions of fine control provide an island of low light around a brightly-lit main work area. This results in a softly lit path for any movement through the area.

Occupancy sensing has been in use for a long time and early adopters were often frustrated by ineffectiveness of older systems. The passive infra-red (PIR) sensors would often switch lights off when people were using the area. Sensor sensitivity or placement issues generally caused these problems.

Figure 67: 500 W halogen with motion sensor

Figure 68: Combining daylight with artificial light delivers benefits and presents challenges

Daylight linking

Using sensors to measure light levels in a space can be very effective. Sensors can be used to detect daylight entering a space and dim lights accordingly.

Daylight sensors can be very simple, stand-alone devices turning lights on/off or complex systems with multiple sensors, logic control and dimming to alter light levels seamlessly.

Take care when placing sensors to ensure that they are not significantly influenced by the artificial light they control. If sensors are influenced in this way they might get stuck in a 'loop'.

Loops can generally be avoided by placing light sensors against a window or where they are not significantly influenced by the artificial light they control.

Daylight in work areas can cause discomfort and make visual tasks difficult.

Always use quality sensors.

Occupancy sensing technology is now very advanced and it is much easier to deliver an effective system. Some of the sensor types available include:

- passive infra-red (PIR) sensors
  - measure heat patterns and react to body heat
  - do not use energy to operate (passive system)
- microwave sensors
  - generate pulses of microwaves and assesses reflected waves
  - use energy to operate (active system)
- ultrasonic sensors
  - generate ultrasonic waves and assess the reflected waves
  - use energy to operate (active system).

These sensors can be combined in hybrid systems to provide a more accurate result. Typically a PIR sensor activates a microwave or ultrasonic sensor, to double check and verify a result. This minimises the amount of energy used to operate the system as PIR sensors do not need energy to operate.

A number of suppliers offer high quality and reliable occupancy sensing solutions.

Building management system (BMS) goals and commissioning control systems

Including lighting in a BMS represents a significant challenge for designers, even though lighting, in conjunction with HVAC, is the main energy cost of commercial and industrial buildings.

Lighting expenditure generally accounts for less than 1 per cent of the revenue generated by productivity within buildings so design of any lighting system is primarily driven by increasing productivity rather than energy efficiency. This does not mean that energy efficiency cannot be improved with a BMS, rather that it is important to look for opportunities where energy efficiency and productivity gains are complimentary.

Areas where a BMS can be used for the complementary improvement of productivity and energy efficiency may include:

- increased use of diffuse natural light
- seamless transition between natural and artificial lighting
- elimination of lighting in unused areas
- effective integration of background lighting with occupant dimming control of local task lighting.

The real challenge for any lighting BMS is to reduce lighting in areas where it is not needed and seamlessly deliver the quality and quantity of light where it is needed with adequate user control of personal task lighting. This would involve the use of daylight and artificial lighting technologies that have a good CRI and fast on/off, along with dimming capability.

Technology improvements in recent years have increased the usability of control technology. However, strong management of the commissioning process is needed as the final step to avoiding common quality issues (e.g. incorrect time switching, poor sensor placement, poor zoning and incorrect time delay).

A control system should be commissioned in a series of stages, where the quantity and time between commissioning events is driven by the complexity of the system. Often the parameters that will decide the system's effectiveness are not known until the space has been occupied for some time. Commissioning a control system in a series of stages will help to account for this. Any patterns of light use can then be identified and system adjustments made.

When designing a control system gather as much information as possible about the expected use requirements of the site. Professional control system suppliers have developed good systems for collecting information and this can help to develop a baseline commissioning plan. Collecting information on any issues within the system can help to refine the control system further.

The contract for design, supply, installation and commission of the control system should provide intensive service in the early stages of building occupation. This should minimise any difficulties that system users may encounter.

To further minimise disruption, appoint an individual within the client organisation to be responsible for collecting information about the BMS successes and failures. This person can then be tasked with ensuring that the commissioning process addresses these issues.

Figure 69: Dimming control panel for LED

Voltage reduction and voltage optimisation

Voltage reduction and voltage optimisation are viable energy saving technologies, particularly in older sites where major lighting infrastructure changes may be difficult.

There are two layers to this technology:

- voltage reduction: small units that are designed to operate on sub-circuits specific to the lighting on site
- voltage optimisation: larger units that are capable of delivering voltage optimisation over an entire site's electrical load.

The smaller units on specific lighting circuits can reduce to a lower voltage and therefore more energy is saved on the lights. While larger units have less actual voltage reduction, they are able to deliver energy savings over the entire site's electrical connected load, including HVAC, pumps, motors and so on.

Reducing voltage will reduce the amount of power drawn and reduce energy use. The larger voltage optimisation systems can also provide improved power quality which can have a beneficial effect on the electrical infrastructure on site. Generally energy use can be reduced by 15–30 per cent.

However, it is important to note that electronic ballasts in a circuit will compensate for the voltage reduction and negate any savings. Therefore voltage reduction is not suitable for use on luminaires with electronic ballasts. Light levels will also be lower when voltage reduction devices are used. The reduction in light output is not generally a problem and the reduction in power use is normally greater than the loss of light. It is important to make sure that this technology will not lead to non-compliant light levels. It is also important to ensure that the lighting is properly maintained when these systems are present.

Lighting voltage reduction products should be designed to provide full voltage at start-up. The voltage is then reduced only after sufficient time has elapsed for luminaires to reach normal operating conditions. The larger scale voltage optimisation entire site units do not require this staged voltage reduction, as the reduced voltage should never be outside the recommended operating voltage range for the connected loads.

In the proposed new ESS rule changes voltage reduction units will be excluded from the commercial lighting deemed savings calculator for generating ESCs.

Appendix 1:
General lighting information

Common types of lights

Most luminaires consist of a light source as well as a means of holding the light source and connecting it to the electricity supply. Many light sources also need a device that converts the energy supplied to the building into a form that best suits the light source. The luminaire will also have a means of getting as much light as possible to leave the luminaire and travel in the required direction.

There are thousands of different lamp holders, tens of thousands of luminaire types and even more light sources. Some typical light sources used in commercial applications are described in this section.

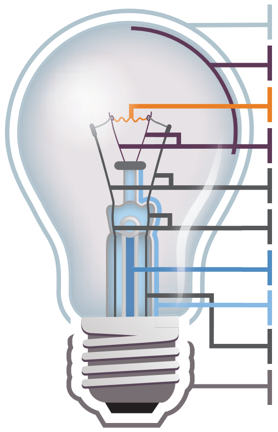


Figure 70: Basic design of GLS lamp

General lighting service incandescent lamps (GLS lamps)

GLS lamps are no longer available to purchase for commercial applications due to their very poor efficiency.

Most were designed to operate on a 240 V supply and therefore had no control gear to operate them.

A range of lamps were developed from this basic technology and found their way into a diverse range of applications These are nearly always connected to mains voltage and therefore have no control devices.

Note that the PAR lamps have an integrated reflector and are therefore usually held in a luminaire without any other optical devices. Light control is handled entirely by the lamp.

These lights are common in auditoriums and theatres where dimming is needed but it is unlikely that many sites remain with large quantities of these lights installed, due to poor efficiency. LED can now deliver good lighting results and can be dimmed.

Figure 71: B15 halogen lamp

Halogen lamps

Halogen lamps are also an incandescent lamp. Where most incandescent lamps contain a tungsten filament and some gasses (typically argon and/or nitrogen), the halogen lamps also contain iodine. This prolongs lamp life and allows the filament to burn hotter and therefore whiter. Halogen lamps are generally more efficient than standard incandescent lamps.

A characteristic of filament lighting is that the filament (and therefore the overall light source) can be made smaller by lowering the voltage. This led to the development of low voltage halogen lamps. A small filament also means that good optical control of the light can be achieved with a smaller reflector. Low voltage does not mean low power. Ohm's law states that 'watts equal volts multiplied by amps'. Energy use is billed in watts, so 50 W lamps use 50 W, regardless of their designed voltage. Lamps will not draw more current if the designed voltage is reduced, but will just dim, which means that it will consume less power. Many voltage control devices, such as dimmers, can be considered a power reduction solution.

A transformer is used to achieve the designed voltage, typically 12 V in the case of low voltage halogen lamps.

Nearly all electronic transformers on the market do not regulate their output. Higher or lower voltages than the mains supply (230 V) will be reflected at the output side as a ratio of the input voltage. The process of reducing voltage uses energy (above and beyond the lamp wattage). When conventional transformers are used they can add as many as 15 W to the load. Electronic transformers add about 5 W to the lamp load. This means that the extra load must be considered as part of on-site load calculations. This is often referred to as the total connected load.

Figure 72: Dichroic halogen lamp

Dichroic halogen lamps

The dichroic halogen lamp design has coatings on the inside of the reflector that are able to reflect visible light but are 'clear' to infra-red (heat) and ultra violet. Therefore the majority of heat and UV produced is passed through the back of the lamp. This can mean that dichroic lamps used in combination with flammable substances, or ceiling insulation, can cause fires.

In most cases where dichroic lamps are used, the luminaire does little more than hold the lamp in place. The control and direction of produced light is handled by the lamp and its integrated reflector.

Figure 73: Compact fluorescent lamp

All incandescent lamps are considered inefficient because they produce light as a small by-product of producing heat. More than 90 per cent of the energy consumed is wasted in heat. They are also very sensitive to over voltage. Too much power will cause them to overheat, the filament will then become too soft and the light will stop working.

These lamps are classed as resistive lamps. Energy resists travelling along the filament and glows at that resistive point. The following lamps are discharge lamps, where current is passed through a gas, usually as a spark or arc, causing the gas to produce light.

Figure 74: Compact fluorescent lamp with GU10 lamp base intended for retrofit in some low voltage luminaires

Fluorescent lamps

Fluorescent lamps come in a variety of forms. The most common types covered by this report are linear lamps and compact lamps. The lamps contain mercury which causes the tube to produce light mostly in the ultraviolet region of the spectrum. The lamps are sometimes known as low pressure mercury tubes. Ultraviolet light is not useful for general lighting and so light is shifted to the visible spectrum by a combination of coatings that can be seen as white on the inside of the tube. These coatings are known as phosphors and can provide light in a variety of white blends, depending on the blend of phosphors used.

These lamps all work in much the same manner, regardless of their shape.

Discharge lamps are based on the principle of 'lightning in a bottle' and control of the arc is very important. If the arc is allowed to flow without any control it will keep increasing until the lamp blows up. The use of a ballast (or choke as they are sometimes called) is required to control the arc within the lamp.

Figure 75: Conventional magnetic ballast

Ballasts

Generally, these used to be a copper and iron device, which was quite heavy and relatively inefficient. Conventional ballasts are known by a variety of names, including wound ballasts, magnetic ballasts and copper ballasts. These conventional ballasts, when used alone, will probably not be able to start the arc so a higher power is used at the initial start-up. This is delivered by the starter which temporarily creates a voltage surge to start the arc, and then switches the ballast back into circuit once the lamp is running.

This is important because electronic ballast systems do not use an external starter. Therefore, when looking at an installation on-site, if you can see a starter you know that you are looking at a fluorescent luminaire with conventional gear. This will help you to understand what can be done to improve the efficiency of this luminaire.

Figure 76: Low voltage halogen transformer – electronic

If the existing luminaire has no starter in circuit, looks very old and has the old style large diameter tubes (T12–38 mm), it may be a rapid start system. The rapid start system was used widely by the NSW Public Works Department and is commonly used in educational facilities and other New South Wales state government sites. It would be safe to assume that if the fitting uses these large diameter tubes, then it has conventional ballasts.

Another way to identify fluorescent technology is to watch how it starts up when it's cold. When a fluorescent with an electronic ballast starts up, it behaves very differently from a conventional ballast with a starter. The start-up behaviour of the two systems is outlined below.

A conventional ballast and starter, when powered from cold, will typically flicker three to four times and then turn on. It usually takes about as long as this description takes to read.

An electronic ballast will simply start the lamp. A slight dimness may be detected at first (less than a second) and then the lamp will light up.

In the cases where electronic ballasts are used, it is very unlikely that energy use can be substantially reduced at the luminaire. There is also little, if any, benefit to be gained by voltage regulation on luminaires containing electronic ballasts. This is because the electronic ballasts are designed to regulate their output to the lamp. The electronic ballast will simply undo what a voltage reduction device has done.

Most fluorescent lamps will increase in brightness for about 2–5 minutes from cold start, regardless of the ballast type installed.

Typical mainstream fluorescent tube diameter designation comparison

Tube diameter designations		Tube diameter measurements				
Imperial-based	**Metric-based**	**Inches**		**Millimetres**	**Socket**	**Notes**
T5	T16	5/8″		15.86	G5 bipin	In Australia these lamps always have electronic ballasts and are generally very efficient, so no substantial savings are likely unless the site is over lit.
T8	T26	8/8″	1″	25.40	G13 bipin	These are the most common tube and are still in use. They are generally used on conventional ballasts but can also be very efficient when used on electronic ballasts.
T9	T29	9/8″	11/8″	28.58	G10q quadpin contact	Circular fluorescent tubes, rarely used in large quantities but usually with conventional ballasts.
T12	T38	12/8″	11/2″	38.10	G13 bipin	Old style 'fat' tube, sometimes rapid start (RS), which is usually marked on the tube.

Properly identifying the technology that is present in the existing system is vital in establishing what energy savings can be delivered.

High intensity discharge lamps (HID)

a. Mercury vapour lamps

Mercury vapour lamps are very similar to fluorescent tubes as they use mercury and usually phosphors. They are not generally specified in new build situations as metal halide lamps are more efficient and offer better light quality.

They were commonly used in high bay fittings and old style street lights. They were also used occasionally in downlights in large spaces, such as the foyers of tower buildings. Generally these lamps are used with conventional ballasts.

b. Sodium vapour lamps

Sodium vapour lamps are generally used in street lighting and occasionally in car parks. They produce a strong orange-yellow colour light, as they use sodium instead of mercury. They have the effect of washing out all other colours

Sodium vapour lamps have become less popular with lighting designers, most likely as metal halide lamps have a better light quality.

Figure 77: Sodium vapour lamp

c. Metal halide lamps

These lamps have become quite popular in a variety of applications over the last ten years, due to some advances in technology. They contain a number of different metal halides which produce different wavelengths within the visible spectrum. A good white light is produced. These lamps are used in a variety of applications because they are efficient and have long operating lives.

The lamps that are constructed with a ceramic arc tube (the more recent versions) also offer very good stability of light colour over their operating life.

The lamps are used internally in downlights, high bay, floodlights and spotlights. Externally, they are used in floodlights, street lighting, sports lighting and so on. They are commonly used at a range of wattages, between 20 W and 2000 W.

Figure 78: Mercury vapour lamp

d. Induction lamps

Induction lighting was introduced in earnest at the turn of the century by the major lamp manufacturers, in particular Philips, Osram and GE. In simple terms these lamps are similar to fluorescent lamps except that they do not receive their energy by electrodes creating an arc. Mercury in a typical induction lamp is excited into producing light by the use of a powerful magnetic field. The lamps are operated by electronic control gear. Induction lighting is not commonly used.

An increasing need for sustainable lighting solutions may be responsible for the recent rebirth of this technology. Induction lighting can be a sustainable lighting solution because of its extremely long lamp operating life and reasonable efficacy.

Make sure that products are protected by a long warranty and the length of operating life can be substantiated by the manufacturers. Ask the lighting designer to check the photometric performance of the luminaire as an element of preparing the overall lighting design.

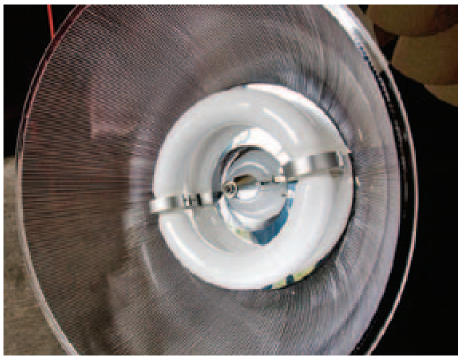


Figure 79: Induction lamp

Light emitting diodes (LED)

Electricity is passed through semiconducting material, which produces photons (a basic unit of light). Different mixes of materials are selected to construct the semiconductor which means that photons can be produced in a variety of colours. Phosphors applied over blue LED create 'white' light.

LED technology has progressed beyond the efficiency of other main stream lighting technology, although to date very efficient LED have been considered too expensive for general lighting applications. LED can produce more useable white light per unit of energy than metal halide, sodium vapour, fluorescent and halogen light sources.

LED are a solid state device, which means that they contain no moving parts. This is why the industry segment is often called solid state lighting (SSL). Solid state devices are very robust and highly resistant to vibrations and other factors often present in lighting applications (e.g. severe cold, poor power quality, impacts).

Very little heat is generated by LED when compared to other light sources. However, minimising the temperature at the internal junction between the power supply and the LED material is critical to ensuring long LED life.

The lighting industry has been very slow to address the methods required to manufacture light fittings containing LED. There are a large number of poorly designed products on the market.

LED produce a lot of light, from a very small source. This helps to control where the light goes but they can produce a great deal of glare if not managed properly. Good quality LED lights can provide a useful operating life in excess of 50,000 hours when used correctly. This equates to just less than six years, when operating 24 hours a day, 7 days per week.

Light output (and therefore efficiency) from the semiconductor material is increasing rapidly. The device architecture has stabilised so luminaire and optic design will not need to change as efficiency increases.

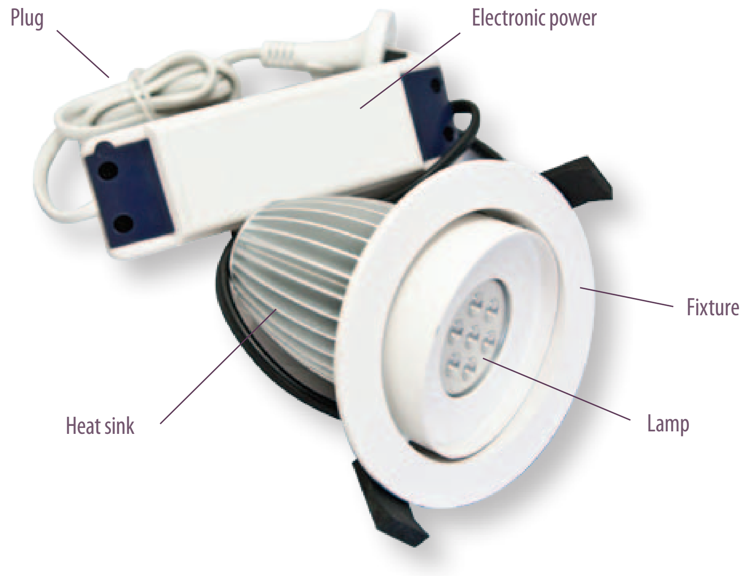


Figure 80: 16 W LED luminaire

Required lux levels according to Australian Standards:

Area	Lux Level
Office work space – task	320
Office work space – background/environment	160
Office work space – fine detail office workspace	600
Corridor	40
Factory floor with non fine detail work	160 to 400
Foyer	160
Internal stairs	80
Car Park – entrance daytime	800
Car Park – entrance night time	160
Car Park – general	40

Figure 81: A well-lit workplace

Lux levels are not the only requirement to be compliant with Australian Standards. Others such as uniformity and glare also need to be considered. To ensure compliance, please refer to the full Australian Standards.

Overall efficiency of light sources

The following table demonstrates the general overall efficiency of different light sources.

Category	Type	Overall luminous efficacy (lm/W)	Overall luminous efficiency (%)
Incandescent	100–200 W tungsten incandescent (220 V)	13.8–15.2	2.0–2.2
	100–200–500 W tungsten glass halogen (220 V)	16.7–19.8	2.4–2.9
	5–40–100 W tungsten incandescent (120 V)	5.0–17.5	0.7–2.6
	2.6 W tungsten glass halogen (5.2 V)	19.2	2.8
	Tungsten quartz halogen (12–24 V)	24.0	3.5
	Photographic and projection lamps	35.0	5.1
Light emitting diodes (LED)	White LED (raw, without power supply)	4.5–200.0	0.66–22.0
	4.1 W LED screw base lamp (120 V)	58.5–82.9	8.6–12.0
	6.9 W LED screw base lamp (120 V)	55.1–81.9	8.1–12.0
	7 W LED PAR20 (120 V)	28.6	4.2
	8.7 W LED screw base lamp (120 V)	69.0–93.1	10.1–13.6
Fluorescent lamps	T12 tube with magnetic ballast	60.0	9.0
	9–32 W compact fluorescent	46.0–75.0	8.0–11.4
	T8 tube with electronic ballast	80.0–100.0	12.0–15.0
	T5 tube	70.0–104.2	10.0–15.6
High intensity discharge (HID)	Metal halide lamp	65.0–115.0	9.5–17.0
	High pressure sodium lamp	85.0–150.0	12.0–22.0
	Low pressure sodium lamp	100.0–200.0	15.0–29.0

Appendix 2:
Measurement and verification (M&V)

Measurement and verification (M&V) is the process of using measurement to reliably determine actual savings for energy, demand, cost and greenhouse gases within a site by an Energy Conservation Measure (ECM). Measurements are used to verify savings, rather than applying deemed savings or theoretical engineering calculations, which are based on previous studies, manufacturer-provided information or other indirect data. Savings are determined by comparing post-retrofit performance against a 'business as usual' forecast.

Across Australia the use of M&V has been growing, driven by business and as a requirement in government funding and financing programs. M&V enables:

- calculation of savings for projects that have high uncertainty or highly variable characteristics
- verification of installed performance against manufacturer claims
- a verified result which can be stated with confidence and can prove return on investment
- demonstration of performance where a financial incentive or penalty is involved
- effective management of energy costs
- the building of robust business cases to promote successful outcomes

In essence, Measurement and Verification is intended to answer the question, "how can I be sure I'm really saving money?"

The following steps are an example of an M&V Plan for inclusion in a lighting upgrade business case. Further guidance is provided in OEH's Measurement and Verification Guide. Generally, lighting project M&V applies the principles of the IPMVP* Option A or Option B.

The steps for a project upgrading luminaires are:

1. Create an M&V Plan that outlines and documents the measurement boundary and what variables will be measured and over what time periods.
2. Establish a baseline by:
   - 2.1. Measuring illuminance before the upgrade, being careful to eliminate the effect of natural light.
   - 2.2. Measure the lighting circuit power before the upgrade. Sometimes just lighting current is measured but this does not provide a measure of real power – if only current and voltage are measured, rather than real power, the power factor must be known or stipulated from experience. The M&V Plan should specify the measurement method.
   - 2.3. Determine the operating hours by reference to lighting timer settings, logs or staff knowledge.
3. Measure energy consumption after retrofit
   - 3.1. Measure the illuminance after the upgrade as for Step 2.1 to confirm that the illuminance meets the specification.
   - 3.2. Measure the lighting circuit power after the upgrade as for Step 2.2.
4. Calculate the power reduction.
5. Calculate the savings in energy consumption.

The measurement of light levels in this guide can also be achieved by utilising industry standard lighting design software to carry out calculation of existing and proposed lighting systems as outlined in AS/NZS 1680.

* International Performance Measurement and Verification Protocol

Glossary

Ballast: an electrical device that regulates the power delivered to fluorescent and high intensity discharge lamps. Conventional ballasts are known as wound ballasts, magnetic ballasts or copper ballasts. Electronic ballasts are a newer more efficient technology than conventional ballasts.

Ballast lumen factor (BLF): the ballast lumen factor shows how much more or less light will be produced by a particular ballast. This is compared to the standard or reference value for the light output, based on a control ballast type. Lamps produce varying amounts of light when fitted to different ballasts.

Candela (cd): the unit of luminous intensity, describing light output in a given direction.

Colour rendering index (CRI): an index of the ability of a particular light source to render colour accurately, compared to a reference light source. The rating is a number between 1 and 100. The higher the number, the more accurate the colour rendering. CRI does not describe the colour appearance of the light source.

Colour temperature: the colour temperature of a light source is the temperature of an ideal black-body radiator that radiates light of comparable hue to that of the light source. Colour temperature is conventionally stated in the unit of absolute temperature, the kelvin or K. Colour temperatures range from a 'warm' 2000 K to more blueish 'cool' or 'daylight' towards 6000 K. These lamps colour temperatures are known as correlated colour temperatures or CCTs.

Connected load: the entire electrical load including gear losses as connected to the mains supply. This is the load that the electricity meter will record.

Control equipment: any type of device that provides some type of regulation to the power that is delivered to the lamp. This includes power supplies, drivers, ballasts and transformers.

Correlated colour temperatures (CCT): see colour temperature.

Cover glass: a glass panel that covers the front of the luminaire or lamp, to minimise moisture or dust entering it, to control UV or to minimise the risk of injury from the rare instance of an exploding lamp.

De-lamp: a technique where one of two lamps in a twin fitting is removed or is twisted in the lampholder to disconnect it from power.

Digital addressable lighting interface (DALI): an industry standard protocol for the control of luminaires which allows communication between devices such as sensors, switches, ballasts and so on.

Discharge lamps: a lamp where current is passed through a gas, usually as a spark or arc, causing the gas to produce light. Common lighting types are mercury vapour, sodium vapour and metal halide lamps.

Efficacy: the amount of light obtained from the energy used. Efficacy is measured in lumens per watt (lm/W).

High intensity discharge (HID) lamps: a group of lamps including mercury vapour, sodium vapour and metal halide lamps (see also discharge lamps).

Flex and plug: a length of cable with a plug connected to the end. In commercial luminaires this consists of a pre-wired cable and standard Australian plug for connection to a plug base. This is common in recessed downlights with integrated ballasts, low voltage transformers and recessed fluorescent troffer luminaires.

Form factor: the critical dimensions of an object that give it its shape or structure.

Glare: the effect of brightness or differences in brightness within the visual field that is high enough to cause annoyance, discomfort or loss of visual performance.

Halophosphor: the type of phosphors used in fluorescent lamps to shift the produced ultraviolet light into the visible spectrum. Typically the efficiency and colour rendering of these halophosphor lamps is well below that of triphosphor lamps.

Illuminance (lm/m^2, lx): the amount of light that falls on a surface. This is measured in lumens per square metre (lm/m^2) and is known as lux (lx).

L70: the percentage of lumens that an LED lamp will produce after a certain number of operating hours, compared to when the lamp was new. In this case the lamp would produce 70 per cent of the initial lumens.

Lamp: the light source that is mounted within the luminaire.

Lampholder: the component of the luminaire that provides electrical connection to the lamp. In some cases the lampholder holds the lamp in a fixed position.

Light output ratio (LOR): the ratio of the amount of light emitted by the luminaire in relation to the amount of light produced by the lamp and usually expressed as a percentage. LOR expresses the efficiency of a luminaire.

Lumen (lm): the total light output of a light source in all directions. Also known as luminous flux.

Luminaire: also referred to as light fitting or fixture, including the lampholder and lamp.

Luminaire efficiency: expresses how much of the light produced by the light source is able to leave the luminaire and provide light into the environment. Often expressed as the light output ratio (LOR).

Luminance: a measurement of the brightness of a light source or a surface that is illuminated. Luminance is directly influenced by the characteristics of the surface and is measured in candelas per square metre (cd/m^2).

Luminous flux: see lumen

Lux: see illuminance.

Metalware: commonly used term to describe the body of luminaires, which are generally made of metal.

Optics: The hardware used to control produced light. This control is typically delivered by refraction, using lenses and diffusers.

Phosphors: white coatings on the inside of fluorescent lamps that shift the produced light to the visible spectrum. These can provide light in a variety of white shades depending on the blend of phosphors used.

Photometrics: a series of measurements of the light distribution of a luminaire or lamp. Usually expressed in a table generated by a testing laboratory. These data have been standardised into a few formats so that they can be incorporated into computer-based lighting design calculations. The most common form of these is the IES format. A **photometric file** is a computer file containing data on the light distribution performance of a luminaire. These files can be used with lighting design software packages to predict the effect of a particular light fitting a space.

Pulse-start: pulse-start is a specific matched system of lamps and ballasts designed to provide very high efficiency.

Re-lamp: replacement of lamps after a predetermined period of use, typically 80 per cent of the rated life.

Restrike: when a discharge lamp is switched off the arc within the tube collapses. The lamp must cool down and de-pressurise before the arc can be restored or 'restrike' can occur. This period is known as the restrike time.

Semispecular reflectors: metallic reflectors with a matt finish. They are efficient but allow for a more diffused reflection than specular reflectors. Good glare control is provided and balanced with good distribution characteristics. These are the most common type of reflector used in offices where screen-based tasks are performed.

Specular reflectors: metallic reflectors with a mirror-like finish. They are usually glossy and offer very accurate reflection characteristics. These are excellent for projects where glare must be minimised, such as screen-based tasks. Specular reflectors deliver a very controlled beam and require careful use to ensure that uniform light levels are achieved.

Stepped switching: dimming preset to occur at a certain percentage(s) of light output.

Triphosphor: lamps that contain the next generation of phosphors and offer improvements in efficiency as well as very good colour rendering.

Troffer: a recessed fluorescent luminaire. Often used in ceiling grids. These can also be used in plaster sheet ceilings.

Trunking system: a linear rail, which is generally made of metal and used to contain electrical cables as well as a method of connecting linear fluorescent luminaires. Trunking provides a flexible stable platform for fixing luminaires at regular intervals and is often used in warehouse and supermarket aisle lighting.

Watt (W): the unit for measuring electrical power. Watts used multiplied by a time period forms the basis of one of the elements of our electricity billing, typically shown as kilowatt-hours (kWh).

Abbreviations and acronyms

AC: alternating current

ACMA: Australian Communications and Media Authority

ACP: Accredited Certificate Providers

ANSI: American National Standards Institute

AS/NZS: Australian Standards/New Zealand Standards

BCA: Building Code of Australia

CCT: colour correlated temperature

CCTV: closed circuit television

cd: candela

CRI: colour rendering index

DALI: digital addressable lighting interface

DC: direct current

EEI: Energy efficiency index

ESC: Energy Savings Certificates

ESS: Energy Savings Scheme

GHG: greenhouse gas

GLS: general lighting service

HID: high energy discharge

HVAC: heating ventilation and air conditioning

IEC: International Electrotechnical Commision

IES: Illuminating Engineering Society

IPART: Independent Pricing and Regulatory Tribunal of NSW

IRC: infra-red coating

IRR: internal rate of return

LCP: light circuit power

LED: light emitting diode(s)

LOR: light output ratio

lm: lumen

lx: lux

MEPS: minimum energy performance standards

MR: multifaceted reflector

NATA: National Association of Testing Authorities, Australia

NPV: net present value

PAR: parabolic aluminised reflector

PIR: passive infra-red

SSL: solid state lighting

VA: volt-ampere

W: watt(s)

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