

# 5

## Energy Efficiency Best Practice Guide Lighting

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# 1 Introduction

This document is a step-by-step guide to improving energy efficiency in lighting systems and achieving best practice. By following this guide, you will be able to determine what changes can be made in order to reduce operating costs, improve the environment and improve the operation and performance of equipment.

The guide has been developed to lead decision makers and service providers through changes to lighting systems; it is not intended to be a thorough technical guide. References for more detailed technical information are provided.

Good lighting serves a myriad of functions. Fundamentally, light is used to illuminate an area so that a task may be carried out safely, but good lighting can also improve productivity, improve mood and reduce errors.

Every task has different lighting requirements: light level, colour and time required. The most appropriate lighting technology for each task varies; lighting an area effectively and efficiently not only requires a lamp but other technical and human-interface instruments.

Best practice in lighting depends highly upon the application. When assessing the opportunities for improvement presented by an existing lighting system, the first step is to measure how effectively the existing light levels and characteristics serve their function. There are many opportunities for cost-effective retrofits to an existing lighting system and it is possible to simultaneously increase lighting levels and use less energy if the most efficient technology and practices are used. The business benefits of an appropriate lighting system should also be considered.

## 2 The business benefits of good lighting

Beyond the obvious financial gains that may be achieved through improved lighting efficiency, there are broader business benefits available from good lighting. Figure 1 lists some of benefits.



**Figure 1: The business benefits of good lighting**

### 2.1 Improved productivity

The ability of the human eye to manipulate objects efficiently is influenced by illumination levels. High-efficiency lighting may allow businesses such as those that rely on manual handling to increase the level of illumination without financial impact. This could, in turn, improve productivity as well as reduce the occurrence of errors.

### 2.2 Improved safety

As with productivity, proper lighting levels can help workers avoid accidents. For example, hazards may be more easily visible and other health and safety issues such as eyestrain can be improved.

### 2.3 Improved colour rendering

An object can appear different colours under different lights. If the products that your business sells require accurate colour rendering, selecting the right light source will be an important consideration.

### 2.4 Improved aesthetics

Lighting can make a big difference to the appearance of a room. The proper use of ambient, task and accent lighting can change the mood and appearance of a space, affecting the disposition of workers and customers.

### 2.5 Reduced running costs

The focus of this guide is in reducing the life cycle cost of lighting. High-efficiency lighting can provide bottom line benefits.

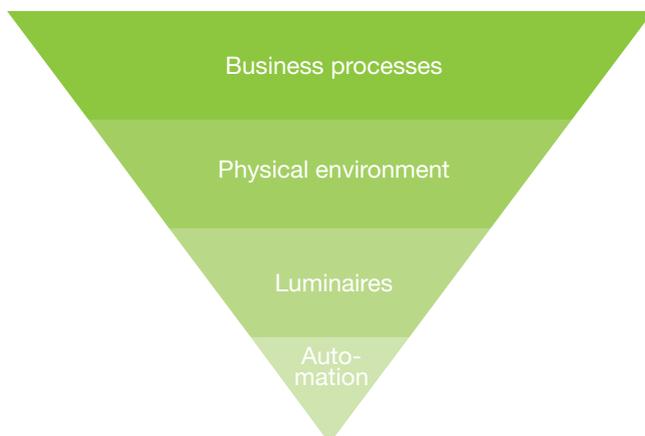
## 3 The lighting design hierarchy

Business owners that become interested in improving lighting are often motivated by a realisation that one or more of the business benefits shown in Figure 1 could be realised in their business. For example, a business owner may notice that:

- Workers are complaining of eye-strain
- Accidents are occurring in the workplace due to lack of good lighting
- Productivity is lower than expected

These and other problems can, to a certain extent, be improved with the use of energy efficiency lighting, but an interest in energy efficient lighting is typically driven by a perception that high efficiency lighting can reduce energy costs.

When talking about lighting efficiency, it is tempting to start by looking at the light sources themselves, but there are many ways to reduce the cost of lighting that do not involve lamps replacement. The suggested hierarchy shown in Figure 2 can be used as a general guide to implementing the measures that are likely to have the highest return on your investment first.



**Figure 2: The lighting design hierarchy**

- Business processes relate to the way that workers interact with lighting
- Physical environment refers to the physical design of the room in which the lights operate
- Luminaires refer to the equipment that creates and reflects the light
- Automation refers to auxiliary switching equipment that controls lighting for an area

### 3.1 Process changes

Changing the way that lights are used is often the simplest and cheapest option and can yield immediate results with very short payback periods. Examples of process changes that can improve lighting efficiency include:

- educating workers to help them understand the cost and greenhouse gas emissions that are associated with lights being switched on
- removal of excess lamps from luminaires when light levels are greater than needed
- training staff to clean luminaires more frequently.

Australian Standard 1680.4 demonstrates that dust accumulation on luminaires results in significant reduction in effective light output. Cleaning lamps, luminaires and surfaces can increase light output by 20%, which may avoid the need for a light upgrade, or may otherwise enable a de-lamping regime. This is pictorially depicted in Appendix B.

## 3.2 Environmental changes

Illumination levels vary by task. Australian Standard AS1680.1 recommends the following lighting levels:

**Table 1 – Recommended minimum light levels.<sup>1</sup>**

Minimum Illuminance (lux)	Task difficulty and examples
40	Corridors, walkways
80	Change rooms, loading bays, bulky storage.
160	Simple tasks. Waiting rooms, rough bench work, general fabrication
240	Moderately easy tasks. Food preparation areas. Medium woodworking
320	Moderately difficult tasks. Routine office work.
400	Moderately difficult tasks. Fine woodworking.
600	Difficult tasks. Drawing boards, inspection tasks, fine machine work, fine painting, colour matching
800	Very difficult tasks. Fine inspection tasks, colour matching of dyes.
1200	Extremely difficult tasks. Graphic arts inspection, extra fine bench work
1600	Exceptionally difficult tasks. Jewellery, watch making

Source: Extract from Table 3.1 AS 1680.1 – Recommended Maintenance Illuminances for Various Tasks, Activities or Interiors

If lighting is too dim, changes to the surroundings in which lights operate can often improve the illumination to safer or more productive levels without increasing wattage. Examples include:

- Changes to wall, ceiling and/or floor colours
- Use of daylight, via installation of skylights and windows
- Repositioning of tasks so that they are located under lights, or away from sources of glare

An extract from Australian Standard 1680.1, included in Appendix C, provides the reflectance of some typical surface finishes.

## 3.3 Luminaires and lamps

Although potentially incurring a higher capital expense than the previous options, selecting high efficiency luminaires can reduce energy bills substantially. Lamp efficacy depends on many factors including ballast, age, and temperature; some efficacy ranges are presented in Figure 3. Lamps must also be operated efficiently, whether by switching or dimming according to available natural light or the presence of occupants in the room. Other factors to consider, such as lamp lifetime, are presented in Table 2.

## Best Practice Guide

### Lighting

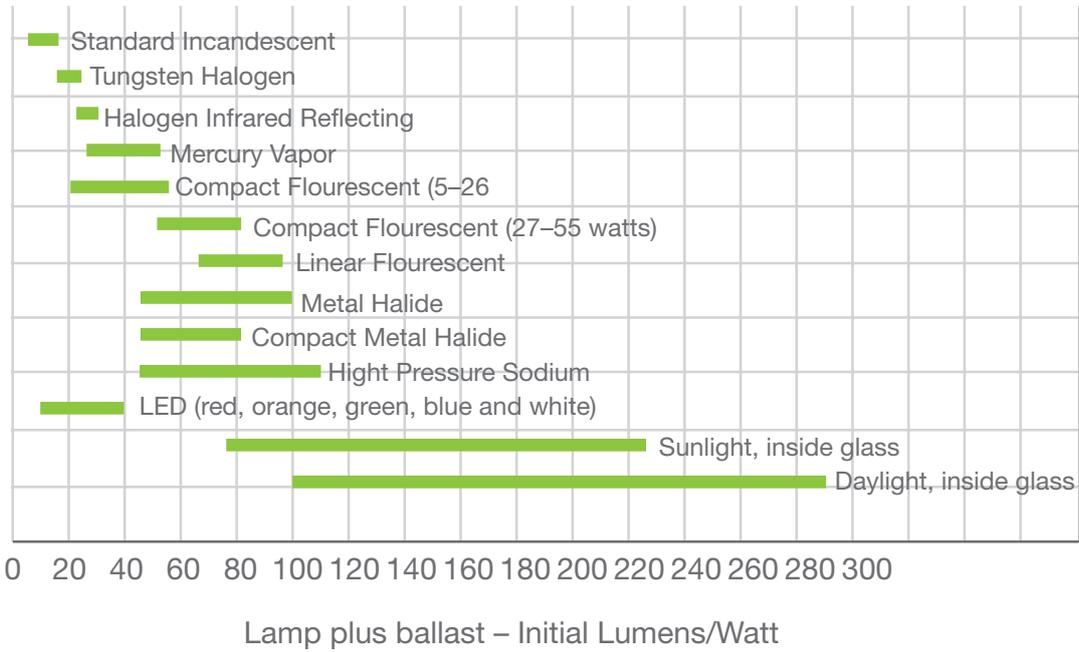


Figure 3: Efficacy comparison of light sources.

**Best Practice Guide**  
Lighting

Characteristics	Incandescent		Incandescent		High Intensity Discharge		
	Light Globes	Quartz Hallogen	Flourescent Tube	Compact Flourescent	Mercury Vapour	Metal Halide	High Pressure
<b>Installation cost</b>	Low	Low	Low	Low	Moderate	Moderate to High	Moderate to High
<b>Efficacy* (Lumens/Watt)</b>	Low (8-17)	Low (20-30)	Moderate to High (60-100)	Moderate to High (40-65)	Low to High (15-70)	High (60-100)	High (60-120)
<b>Normal Wattage Range</b>	up to 1,500 W	up to 1,000 W	8-120 W	7-20 W	40-10,000 W	70-200 W	35-1,000W
<b>Running Cost</b>	Highest	Highest	Moderate to Low	Moderate to Low	High to Moderate	Moderate to Low	Low
<b>Lamp Life (Hours)</b>	Shortest (less than 1,000)	Short (2,000-3,000)	Moderate (6,000-8,000)	Moderate (6,000-8,000)	Moderate to long (6,000-24,000)	Moderate (8,000-10,000)	Long (14,000-24,000)
<b>Replacement Costs</b>	Low	Medium	Low	Medium	Low	High	High
<b>Colour Rendering</b>	Excellent (100)	Excellent (100)	Medium to Good (50-98)	Medium to Good (50-80)	Poor (15-50)	Medium to Good (60-90)	Poor (17-25)
<b>Best Applications</b>	Areas where lighting is on for short periods.  Task lighting for rotating machinery, or in areas where colour rendering is important.	Small reflector lamps can be used for spot lighting displays.  High wattage linear lamps can be used for security lighting if controlled by a movement sensor.	Areas where lighting is on for long periods, and ceiling height is below 5 metres.  Exterior lighting for small areas.	To replace light globes in suitable fittings.  Uplighting and lighting small rooms in areas where lights are on for long periods.	Exterior lighting, and lighting in factories and warehouses where colour rendering is not important.  High pressure sodium is usually a better choice.	Lobby lighting, lighting in offices and shops where ceiling height is greater than 4 metres.	Exterior lighting, continuous security lighting, and lighting in factories and warehouses where colour rendering is not important, and ceiling height is greater than 4 metres.

\* Includes power consumption of control gear, or ballast, as well as power consumption of the lights

**Table 2 – Lamp Characteristics.**

Minimum energy performance standards apply to linear fluorescent lamps and ballasts, and a phase out of lamps with efficacy less than 20 lumens per Watt will commence in October 2008, effectively preventing the sale of incandescent globes.

### 3.3.1 Incandescent

- Incandescent lamps, such as tungsten-filament and tungsten halogen, are generally the least efficient means of lighting a space and the least appropriate choice in industrial lighting. Use incandescent lights only when relatively frequent switching is required. Incandescent lights will be phased out in Australia from 2008.
- Halogen lamps are more efficient than standard incandescent lamps, although there are other considerations that should be taken into account when selecting a fixture. If recessed, halogen lamps can significantly reduce ceiling insulation levels, which can in turn reduce the thermal performance of the building. Externally mounted fixtures can overcome this issue to a certain extent.
- Low voltage does not necessarily mean low power. Because of halogen downlights' directionality, power density can be higher than for a single incandescent light globe. Downlights are better suited to directional or presentational lighting, not for general space lighting.

#### Retrofit

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Micro-fluorescent lamp downlights are available as a retrofit for halogen downlight fittings

### 3.3.2 Fluorescent

- Fluorescent lamps often represent the most efficient lighting choice, particularly when light output depreciation and the eye's spectral response is taken into account.
- Many different fluorescent lamps are available and not all are equal. Ensure that specifications are compared at the operational temperature of the fixture and that the starting mechanism is suitable to your needs.
- In general, an electronic ballast is preferable to a mechanical ballast, as it has lower losses and can enable dimming.
- Select an appropriate fluorescent colour temperature for your environment. Some fluorescent lamps claim to closely match sunlight's spectrum, which may have a benefit upon occupant health. However, these lamps are somewhat less efficient than leading fluorescent alternatives.
- Some fluorescent lamps can be dimmed in response to available natural light. Depending on the model, this may reduce lamp lifetime slightly, but often this is more than compensated for by the cost savings that result from increased energy efficiency.
- While frequent switching may reduce a lamp's operational hours, it almost invariably extends the lamp's calendar lifetime, saving energy and money in the process.
- Induction lamps, which have no electrodes, last for up to five times as long as a typical fluorescent lamp – around 100,000 hours. This makes them suitable for inaccessible locations, but they cost more

#### Retrofit

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- Existing T8 lamps can be retrofitted with high-output T5 lamps without necessarily changing the fixture, presenting some opportunity for efficiency increase.
- Changing a magnetic ballast to an electronic ballast can save a significant amount of energy, with payback generally less than one year. This can also enable dimming. The lamp and fixture need not be changed.
- Energy consumption of existing banks of fluorescent lamps may be reduced by de-lamping (removing excess lamps) or voltage reduction.
- Compact fluorescent lamps (CFLs) are suitable replacements for incandescent globes. Compared to strip fluorescents, CFLs' low luminosity and shorter lifetime make them less appropriate for industrial settings such as warehouses and factories.

#### Best Practice:

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- Banks of high-output T5 fluorescent lamps are increasingly seen as best practice replacements for high intensity discharge (HID) lamps when fixtures are less than 6–8 m above the floor. This is due to fluorescents' sustained light output over their lifetime, high colour rendering ability and because they may be more easily dimmed and switched. They also create a more diffuse light than HID lamps, which benefits industrial tasks. Another benefit is that failure of a single globe does not result in the total absence of light in that region.

### 3.3.3 High Intensity Discharge

- The HID lamp family includes high- and low-pressure sodium, metal halide and mercury vapour lamps.
- Some HID lamps may have two levels of light output. In the case where ambient lighting conditions are variable, this can result in an overall reduction in energy.
- HID lights operate at higher temperatures than fluorescent lamps, which can create uncomfortable working conditions in many warehouses and factories.
- Some HID lamps and luminaires need carbon filters to prevent dust accumulation when lamps cool down. Otherwise, regular cleaning is necessary to maintain output brightness.
- Sodium lamps are generally the most efficient lamps in terms of lumen output per Watt, but their poor colour rendering ability makes them inappropriate for many industrial settings.
- Mercury vapour lamps have a better colour rendering ability than high-pressure sodium, although their light efficiency drops steadily to below that of fluorescent lamps.
- Metal halide (MH) is the industry-standard, high-efficiency option. Pulse-start metal halide lamps have significant advantages over standard metal halide and can be retrofitted to existing luminaires.
- Magnetic ballast MH lamps have lower efficiency than fluorescent lamps, but electronic ballasts are available, some with dimming capability.

- Ceramic MH is an excellent option where high colour rendering is required, outperforming fluorescent lamps in non-switched, high colour rendering index (CRI) applications. However, they may be a costly option.
- Consider using an Active Reactor, an Australian invention that saves energy by modulating the input power to achieve a constant light output over the life of the lamp, thereby saving 15–25% of power and extending lifetime by 50% on metal halide and sodium lamps.

#### Retrofit

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- Sodium lamps can be directly swapped with metal halide lamps, thus improving CRI without needing to change the entire fixture.
- A metal halide retrofit kit is available for mercury vapour lamps, producing more light for the same energy input. Alternatively, the fitting can be changed.

#### Best Practice:

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- For light fixture heights above 8–10 m, metal halide lamps with a ceramic ballast present a more cost-effective installation than fluorescent lamps, owing to the high (1000+ watt) output. At such heights in factories, temperatures above 70°C can prevent the use of electronic ballasts, in which case two-stage light output ferromagnetic ballasts represent best practice.

### 3.3.4 Other Lamps

- Neon lamps are not very efficient, nor very suitable, for industrial applications.
- Cold cathode lamps are efficient but do not generally produce sufficient light output for industrial applications.
- At present, light emitting diodes (LEDs) are a less efficient option than HID and fluorescent lamps. However, for low-wattage applications requiring directional light and long light times and for high-frequency switching applications – for example, traffic signals – they may be a good choice. They can also be efficient retrofits for emergency exit signs.

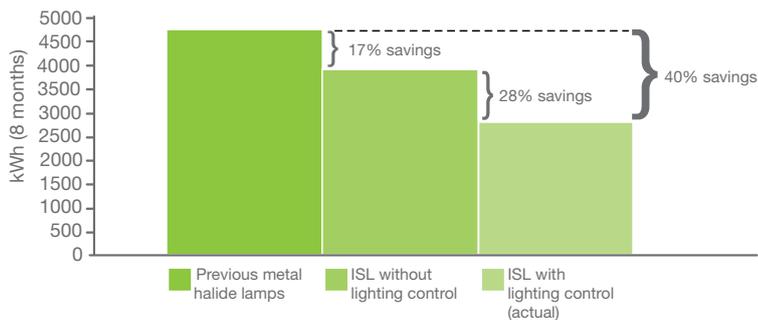
### 3.3.5 Daylight

- Increases in worker productivity and mood, and decreases in absenteeism and errors are commonly stated advantages of daylighting (utilising natural light).
- Skylights that minimise the transmission of heat are highly advisable.
- Glare-reducing skylights are essential.
- Natural lighting can only reduce energy consumption if dimming or switching occurs in response to available sunlight. Automating this process typically results in maximum energy savings. Although hi/low HID lamps can respond to light fluctuations, dimming HIDs, fluorescent lamps or switchable banks of fluorescent lamps present a more energy-efficient option without abrupt changes in light output that may distract workers.

**Best Practice:**

- Daylighting is often the most energy-efficient lighting option, particularly for warehouses that have large roof areas with large open spaces.

Figure 4 depicts the savings possible from retrofitting metal halide lamps with fluorescent lamps and the additional saving possible when daylight-responsive controls are used.



**Figure 4: Energy savings from three integrated skylight luminaires<sup>2</sup>**

### 3.3.6 Luminaires

- The essential function of luminaires is to distribute light without creating glare. Of the many ways of doing so, lenses reduce the light output and should be avoided if possible, unless they are required for safety purposes.
- Improperly designed luminaires can cause lamp or ballast overheating and reduce product lifetime. Ensure that the luminaires are suited to the lamp power.
- Some luminaires collect dust and should be cleaned regularly. Cleaning will result in improved lighting output, essential for maintaining a safe, well-lit workplace.

### 3.3.7 Other strategies

Aside from the selection of the luminaire itself, other strategies that can assist to reduce energy consumption include:

- Repositioning lights so that fewer lights are required
- Rewiring lighting arrays into smaller zones per light switch, so that flexibility is increased.
- Mixing high illumination task lighting with lower illumination ambient lighting.

## 3.4 Automation

The light that uses the least power is the light that is switched off. Automation systems can supplement process changes to make sure that lights are switched off when they are no longer required. Examples of automation systems include:

- Timers
- Motion Detectors
- Photo-electric Sensors
- Dimmers
- Intelligent Building Automation Systems

### Retrofit

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- Most lighting automation systems mentioned below can be retrofitted easily.

### 3.4.1 Switches

- Beyond the simple on-off switch, switches with programmable delay can be simply installed without significant cost.
- Manual dimmers can be highly valuable. A study reported that 84% of occupants dim their lights when given the chance.<sup>3</sup>
- Key-locked switches can ensure only licensed operators are able to control lighting; however, personal lighting controls greatly improve occupant workplace satisfaction.
- Switches should be placed near work areas for maximum effectiveness (rather than in a 'gang' type application at the entrance of the building).
- Smaller sizes of light banks (that is, more switches) enhance users' ability to implement manual lighting-efficiency practices and also ensure future flexibility as workplace functions evolve. Light banks near windows should be on their own switch or circuit to allow for adaptation to existing daylight (often called perimeter lighting).
- Re-wiring is an effective way to upgrade existing systems to improve manual lighting-efficiency practices and provide workspace flexibility.

### 3.4.2 Responsive illumination

- Occupant sensors offer the automated assurance that lights will be switched off when there is nobody in the room.

- Set the delay as short as possible, taking into account the switching characteristics of the lamp.
- High/low HID lamps may be used with occupant sensors to adjust to changes in ambient light levels, circumventing the re-strike delay problem.
- Select the correct occupant sensor for the function, taking into account the sensor sensitivity, monitoring beam pattern and sensing technology used. Dual-technology sensors protect against accidental de-illumination. Masking a sensor to avoid accidental illumination when a vehicle passes by an aisle entry can reduce light switching.
- Place occupant sensors in areas that are frequently vacated, including lunch rooms, conference rooms and storage areas.
- Photosensors detect illumination levels from natural light and decrease artificial light accordingly. These offer the maximum possible energy savings in daylight areas.
- Photosensors work best with lights that are able to gradually dim, as abrupt changes in lighting intensity can be disconcerting for workers.
- Clouds' short-term reduction in natural light can be accommodated by selecting appropriate photosensor sensitivity and thresholds.

### 3.4.3 Voltage reduction

For banks of lights that are on a common circuit, voltage reduction can reduce energy costs.

Voltage reduction panels are available that mount on a wall near the distribution board. Reducing the voltage drop across a fluorescent light by around 30% has a minimal effect on the light level but reduces power consumption and running cost. System providers quote a payback of 12 to 18 months.

### 3.4.4 Automation

Building automation systems can be installed to automatically control lights within buildings. These systems can operate on timers, motion detectors and other inputs to remove human error – for example, somebody forgetting to switch a light off – from the process.

## 4 Deciding what to do

### 4.1 Considerations

Figure 5 shows some of the main considerations that should be taken into account when comparing lighting-efficiency options. While not all of the considerations given below will be applicable to every situation, a selection can be used in most situations.



Figure 5: Considerations

Lighting manufacturers indicate that advances in efficient lighting systems are occurring through control and operational strategy rather than lamp technology. Do not miss the opportunity to invest in an efficient lighting system in the hope of a future technology revolution.

#### 4.1.1 Financial

Often the consideration given the greatest weighting, the investment value of the lighting design can be calculated using any of the commonly used assessment metrics, such as return on investment, payback period or net present value.

#### 4.1.2 Physical environment

The physical environment refers to the surroundings in which the light operates. For example:

- Light reflection from walls and horizontal surfaces contributes significantly to illumination levels and quality.
- Colour and reflectance of walls, furniture and carpets impacts on comparative brightness, which can create glare.
- As the eye ages, its sensitivity decreases.
- Abrupt changes in lighting intensity can cause visual difficulties. Intense light from windows, including that from the sun, can create visibility difficulties in seeing contrast and forcing the eye to frequently adjust.
- Colour, efficiency and lifetime can vary with ambient temperature.
- Some lights run hot and are unsuitable for areas that are sensitive to high temperature (for example, flammable environments).

#### Glare Control

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When brightness ratios exceed maximum recommended values, disturbing or debilitating glare can result. To minimise glare-producing conditions, consider the following:

- Use more lower wattage fixtures to reduce individual lamp brightness while maintaining required light levels
- Locate control panels and computer screens facing away from windows or bright light fixtures. If these elements are fixed, adjust the lighting fixture locations and shade the windows.
- Raise bright fixtures above normal field of view
- Direct some light toward the ceiling to balance space brightness ratios and reduce contrast between the ceiling and fixtures.

#### Seeing and productivity

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Ability to see well is based on several conditions including the age of the worker. A 40-year-old person generally requires twice as much light to perform a task as a 20-year old. The size of the task and the amount of time available to see it dramatically affects the need for light. For example, small font text, moving rapidly past a reader and out of sight, needs a significant amount of light for comprehension. Large, stationary objects are easier to see in lower light levels

### 4.1.3 Ecological

Three considerations are relevant to the ecological footprint of a light:

- Disposal:
  - Mercury is present in most energy-efficient lights. There are low-mercury options, but no cost-effective alternative to mercury vapour has been identified in fluorescent, mercury vapour, or induction lamps, although mercury levels are gradually decreasing over time.
  - Mercury vapour HID lamps present the greatest disposal challenge.
  - Magnetic ballasts may be easier to recycle than electronic ballasts.
- Increasingly, the CO<sub>2</sub> emissions resulting from a light's energy consumption is viewed as its greatest environmental impact.
- The embodied energy of a lamp refers to the energy required to manufacture it. Since emissions are generally proportional to energy use, those individuals that are concerned with life cycle emissions of products will need to consider embodied energy.

### 4.1.4 Operational

The operational characteristics of an energy efficient lamp include:

- The ability of the light to accurately render colour
- The preference of the individual as to the colour of the light
- The level of illumination required to properly execute the task
- The parts of the light spectrum in which the light operates

### 4.1.5 Purpose

Lighting can fulfil many different functions. The typical uses for a light are:

- **Task:** lighting that is used to illuminate a particular activity, such as manipulating parts or reading a document
- **Ambient:** lighting that is used to provide general lighting to a room or space
- **Accent:** usually a highly directional light, accent lighting that is used to highlight a feature in a room
- **Decorative:** lights that are used for effect, for example chandeliers or strip lights

## 4.2 Decision process

Figure 6 can be used as a process to help decide how to go about improving a lighting situation. A lighting professional can assist in this process.



Figure 6: The lighting decision process

### 4.2.1 Determine lighting requirements

Section 4.1 lists the considerations, such as illumination level, financial payback and CO<sub>2</sub> emissions, which may be used to develop lighting requirements. This list of requirements will drive the design of the new lighting scheme.

### 4.2.2 Audit existing lights

For existing installations, it is important to develop an understanding of the “as-is” situation. This will include tasks such as a map of the area, showing the type and location of each light in the room. A calibrated light meter should be used to measure and record illumination levels at key points in each room.

### 4.2.3 Rank options

Once the “to-be” situation (requirements) and “as-is” situation (existing lights) have been documented, a gap analysis can be performed to determine what changes to the lighting arrangement are required. While some specific requirements, such as illumination level, will be quite clearly visible, more general requirements, such as return on investment, or ambience, may require more analysis.

### 4.2.4 Implement preferred option(s)

The implementation of the preferred system is an important step that is often not properly planned or managed. Good project management is required to correctly scope, plan and manage the execution of the works. Large projects may require the involvement of professional engineers and/or contractors.

### 4.2.5 Assess effectiveness of improvement

A calibrated light meter should again be used to measure and record the new lighting levels, as compared to those prior to the lighting upgrade. Monitoring lighting levels throughout the year will ensure the ongoing effectiveness of the lighting system.

## 4.2.6 New systems

The primary difference between existing projects, or retrofits, and new projects such as greenfields sites and expansions is the wider range of options available to the designer due to the absence of “stranded asset” considerations.

For example, a designer on a greenfields site can often specify the orientation of the building, the size and location of windows and skylights and the colour of internal surfaces without concern for the value of serviceable equipment that would be discarded.

Nonetheless, the basic process is the same in both cases.

## 5 Selecting a service provider

### 5.1 Questions to ask service providers

#### 5.1.1 Will they take a systems approach?

As noted earlier, there are many ways of reducing energy costs from lighting. Suppliers should look beyond simply retrofitting luminaires to encompass the measures shown in Figure 2.

#### 5.1.2 Will they guarantee energy savings?

Contracting lighting suppliers can be carried out in two broad ways:

- 1 Contract for service, in which the supplier agrees to perform certain actions for an agreed price. For example, the scope of work may consist of installing new luminaires.
- 2 Energy performance contracting, in which the supplier agrees to meet certain energy reduction levels in return for a share of the savings. For example, the contractor may agree to a reduced upfront price to design and install the system.

Neither arrangement is necessarily right. For example, Energy Performance Contracts should result in a lower up-front cost and a higher likelihood of energy savings being achieved, but may cost more overall, once incentive payments are taken into account.

#### 5.1.3 How will they confirm energy savings?

Once the work has been completed, it is important to verify that the expected energy savings have materialised. Under an energy performance contract, this activity should occur automatically as part of the contract, but even in the absence of an energy performance contract, it will be important to be able to confirm that the expected energy savings have resulted.

#### 5.1.4 Are they registered?

The Illumination Engineering Society of Australia and New Zealand holds a register of lighting professionals that maintain high standards of lighting practice through a continued professional development course. Engaging a registered practitioner should ensure a quality outcome.

### 5.2 Database of lighting service providers

A database of lighting service providers can be found at the following link:

[www.iesanz.org/content/vic-corporate-members](http://www.iesanz.org/content/vic-corporate-members)

## Appendix A

### Examples of good lighting practice

Location	Description
VicUrban Melbourne Office <sup>4</sup>	Daylighting, small lighting zones, manual-on auto-off, after hours delay timer override
40 Albert Road <sup>5</sup>	Daylighting, zoned BMS, occupant sensors, ducted vacuum cleaner
Lincolne Scott <sup>6</sup>	Daylighting, staff education, light paint, voltage reduction, occupant sensors, separate perimeter light control, timer, well-labelled switch panel at entry
Mt Newman House <sup>7</sup>	Triphospor lights, motion sensors in lift lobby in conjunction with access cards, after hours timer

# Appendix B

## Maintenance to offset lumen decrease

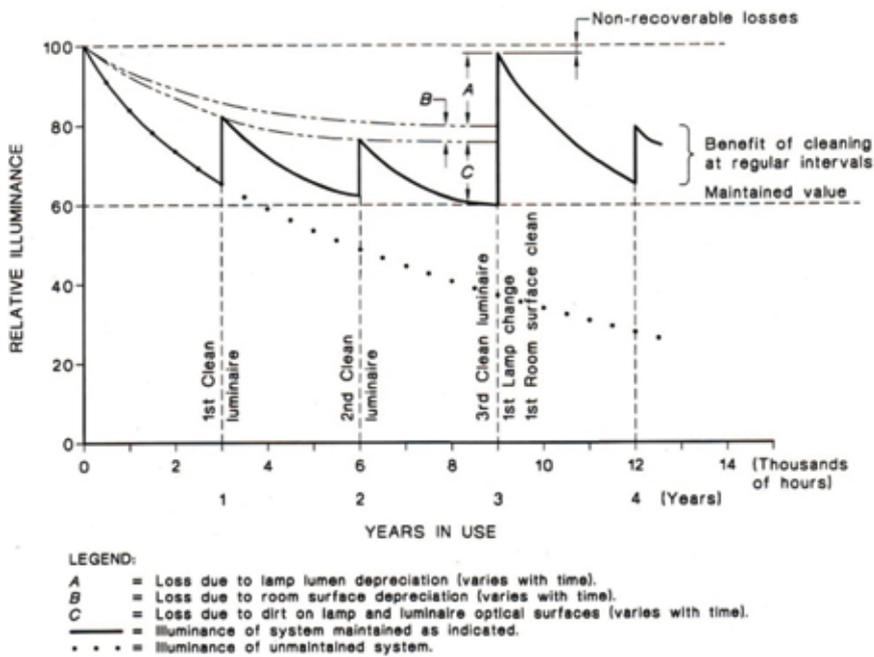


FIGURE 2.1 THE EFFECT OF MAINTENANCE STRATEGIES ON ILLUMINANCE WITH TIME

Figure 7: The effect of maintenance strategies on illuminance with time.<sup>8</sup>

## Appendix C Surface Reflectance

Table 3 – Approximate reflectances of typical finishes.<sup>9</sup>

Building surface	Reflectance	Material or finish
Ceilings	0.8	White water-based paint on plain plasterboard
	0.7	White water-based paint on acoustic tile
	0.6	White water-based paint on no fines concrete
	0.5	White water-based paint on wood-wool slab
Walls	0.8	White water-based paint on plain plasterboard; Tiles: white glazed
	0.4	White fibre cement; Brick: concrete, light grey; Portland cement, smooth
	0.35	Stainless steel
	0.3	Brick: common
	0.25	Concrete, light grey; Portland cement, rough (as board marked); Brick: red; Timber panelling: light oak, mahogany, gaboony
	0.2	Timber panelling: teak, medium oak; Brick: concrete, dark grey
	0.15	Brick: dark hard-fired
	0.05	Chalkboard, painted black (new)
Floors and Furniture	0.8	Paper, white
	0.45	Cement screed; PVC tiles: cream; Carpet: light grey, middle buff
	0.35	Timber: light
	0.25	Timber: medium; OVC tiles: brown and cream marbled; Carpet: turquoise, sage green
	0.2	Timber: dark; Tiles: cork, polished
	0.1	Quarry tiles: red, heather brown; Carpet: "low maintenance"; PVC tiles: dark brown; Timber: very dark

## Appendix D Glossary

Term	Meaning
Ballast	<p>A device that limits the amount of current flowing in an electrical circuit. The most common ballasts used in lights are:</p> <ul style="list-style-type: none"><li>• Magnetic</li><li>• Electronic</li><li>• Mechanical</li></ul>
Colour Rendering Index the	<p>The Colour Rendering Index (CRI) numerically measures how a light source makes colour of an object appear to human eyes and how well subtle variations in colour shades are revealed, compared to a reference source.</p> <p>A higher value CRI (up to 100 for natural light, traditional incandescent light bulbs and some halogens) gives a better colour rendering. Leading fluorescent lamps achieve an excellent CRI of 92, though CRIs above 80 are acceptable for non-critical colour discernment activities.</p>
Efficacy electrical	<p>Light efficiency is termed 'efficacy' and is measured in light output per unit of input level, or lumens per Watt. In general, a higher efficacy means a higher efficiency. Each lamp type has different typical efficacy, and some brands of light far outperform other brands.</p> <p>However, a lamp's initial efficacy is only one factor in an efficient lighting system. Luminaires, ballasts, spectral output, CRI, and brightness over the course of the lamps lifetime also strongly contribute to ensuring an effective lighting system with minimal energy consumption, as does a light's ability to be switched or dimmed.</p> <p>Figure 3 compares the efficacy of various lamps.</p>
Illumination	<p>The amount of light emitted from a lamp is measured in lumens. The amount of light hitting a surface is measured in lux, or lumens per square meter.</p> <p>Different work tasks require different levels of lighting. Australian Standard AS1680: Interior Lighting and the Visual Environment provides guidance on lighting levels in buildings.</p>
Lamp	<p>The component of the luminaire that produces light, for example, an incandescent light bulb.</p>
Luminaire	<p>The assembly of lamp, reflector, aperture, housing, ballast and power connection.</p>

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Term	Meaning
Photopic and scotopic efficacy	<p>According to lighting theory, lights with high scotopic to photopic ratio (such as fluorescent) will provide better perceived illumination levels and quality than those with lower ratios (such as HID).</p> <p>Photopic lumens represent the relative sensitivity of the eye under intense lighting such as full outdoor sun. Photopic lumen output is the amount of light registered by the cones in the human eye and is measured by standard lumen meters.</p> <p>Scotopic lumens represent the sensitivity of the eye under typical interior lighting conditions and cannot be measured directly with a standard light meter. Scotopic lumen output is the amount of light registered by the rods of the human eye and also controls pupil size directly effecting visual acuity for tasks.<sup>10</sup></p>
Temperature	<p>A light's colour relates to the temperature of the source, although the light spectrum produced is also of consideration. A range of choices of temperature are available that affect the perceived colour warmth. They are generally classified as warm white (reddish 3000K), daylight (white), or cool white (bluish 4000K).</p> <p>Daylight at noon has a high ("white") temperature of 5500K, while the incandescent lamps that people have grown accustomed to provide a lower temperature ("redder") colour.</p> <p>Colour, efficiency and lifetime can vary with operational temperature.</p>

## Appendix E

### Further Reading / References

#### Further Reading

The following manuals provide more detailed technical information and exhaustive best practice methods for improving lighting efficiency:

*Energy Efficiency and Conservation Guidelines for Malaysian Industries, Part 1: Electrical Energy-use Equipment*, ptm Malaysia Energy Centre, 2007  
[www.plantservices.com/articles/2005/544.html](http://www.plantservices.com/articles/2005/544.html)

Further reading on specific topics can be found at the following websites:

High bay applications and best practice  
[www.lightcorp.com/PDFs/industrial/learn/HibayAllAbout\\_DD19F.pdf](http://www.lightcorp.com/PDFs/industrial/learn/HibayAllAbout_DD19F.pdf)  
[www.designlights.org/downloads/highbay\\_guide.pdf](http://www.designlights.org/downloads/highbay_guide.pdf)

High intensity discharge lamps  
[www.energyallstars.gov.au/products/linear\\_fluorescent\\_lamps/choosing\\_the\\_right\\_product.html](http://www.energyallstars.gov.au/products/linear_fluorescent_lamps/choosing_the_right_product.html)  
[www.aboutlightingcontrols.org/education/papers/hiddimming.shtml](http://www.aboutlightingcontrols.org/education/papers/hiddimming.shtml)  
[www.lrc.rpi.edu/programs/nlpip/publicationDetails.asp?id=125&type=2](http://www.lrc.rpi.edu/programs/nlpip/publicationDetails.asp?id=125&type=2)

Induction lamps  
[www.archlighting.com](http://www.archlighting.com)

Industrial lighting applications and best practice  
[www.aboutlightingcontrols.org/education/papers/high-low-bay.shtml](http://www.aboutlightingcontrols.org/education/papers/high-low-bay.shtml)

Lighting controls  
[www.nema.org/stds/lighting-controls.cfm#download](http://www.nema.org/stds/lighting-controls.cfm#download)

Low bay applications  
[www.designlights.org/downloads/industrial\\_lowbay.pdf](http://www.designlights.org/downloads/industrial_lowbay.pdf)

Occupancy sensor design and application guide  
[www.wattstopper.com/getdoc/OSappsNewDesignFinal.pdf](http://www.wattstopper.com/getdoc/OSappsNewDesignFinal.pdf)

Skylights in warehouses and daylighting  
[www.designlights.org/downloads/skylighting\\_Warehouse.pdf](http://www.designlights.org/downloads/skylighting_Warehouse.pdf)  
[www.pge.com/003\\_save\\_energy/003c\\_edu\\_train/pec/daylight/di\\_pubs/SchoolsCondensed820.PDF](http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/di_pubs/SchoolsCondensed820.PDF)

T5 lamps and ballasts  
[www.lrc.rpi.edu/programs/NLPIP/lightinganswers/pdf/view/LAT5LB.pdf](http://www.lrc.rpi.edu/programs/NLPIP/lightinganswers/pdf/view/LAT5LB.pdf)

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## References

- 1 Extract from Table 3.1 AS 1680.1 – Recommended Maintenance Illuminances for Various Tasks, Activities or Interiors
- 2 [www.lrc.rpi.edu](http://www.lrc.rpi.edu)
- 3 [www.lrc.rpi.edu/resources/pdf/dorene1.pdf](http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf)
- 4 [www.sustainability.vic.gov.au](http://www.sustainability.vic.gov.au)
- 5 [www.sustainability.vic.gov.au](http://www.sustainability.vic.gov.au)
- 6 [www.energy.wa.gov.au/](http://www.energy.wa.gov.au/)
- 7 [www.energy.wa.gov.au/](http://www.energy.wa.gov.au/)
- 8 AS/NZS 1680.4:2001
- 9 AS/NZS 1680.1:2006
- 10 [www.fullspectrumolutions.com](http://www.fullspectrumolutions.com)

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