ELECTRICAL APPLIANCES OF LIGHTING

This section describes and quantifes the current use of electrical energy for lighting in Australia. It then describes how lighting energy use can be reduced by more than 90% in some applications, primarily by installing currently available light-emitting diode (LED) technology. Australia-wide, the electrical energy savings possible with the recommended upgrades is approximately 20 TWh per year, which is greater than the amount of electricity produced by one continuously operating Hazelwood (Latrobe Valley, Victoria)-sized coal-fired power station.

The other advantages of LEDs are described, such as the reduced maintenance effort required for changing light bulbs, given that LEDs can last more than 50 times longer than other currently used types of lighting (i.e. incandescent lighting including halogen incandescents).

The problem: ineffective and inefficient lighting

Lighting consumes approximately 13% of household electrical energy, 30% of the electrical energy used in commercial buildings, and up to 80% in some retail premises [94].

Inefficiency. Traditional lighting technologies such as the incandescent globe and halogen downlights convert up to 98% of the electrical energy into heat.Illustrating this, the outside surface of a halogen bulb can reach temperatures of over 300°C.

Halogen downlights. Halogen lights are a form of incandescent light filled with a halogen-based gas that allows operation at higher temperatures than traditional incandescent lights. Inappropriate installation of ceiling-recessed halogen downlights has led to a significant increase in house fires[7]. The unwanted heat generated by lighting often has to be removed from living and working spaces by expending more energy on air conditioning. This consequential impact adds to the strain of providing electricity at peak demand times.

Draught-inducing. As discussed above in Draught-proofing, recessed halogen downlights present additional energy problems because they usually allow draughts.

Ceiling-recessed halogens are inappropriate for general room illumination because they are designed to be directional spotlights with a narrow beam angle[7]. This means that many halogens are required to illuminate any given room to the same extent as a single omnidirectional light globe suspended from the ceiling or used with a floor or table- mounted lamp. Certain rooms in Australian homes are often lit using electrical energy in excess of $25W/m^2$ of floor area, whereas from 2011 new homes are specified not to use electrical energy for lighting in excess of $5W/m^2$ [95].

Recognition of the poor performance of traditional incandescent and halogen lighting led to a lighting regulation in Australia in 2009 that requires a minimum performance standard [96]. Unfortunately, the current Australian performance standard falls far short of what can be achieved with available LED technology; however, it has led to an increased use of compact fluorescent lighting (CFLs). Although significantly more energy efficient than traditional incandescents and halogens, consumers have perceived CFLs to have negative features such as a delay in reaching full brightness, inappropriate light colour, dimness, inability to be dimmed, vibration or noise generation, and mercury content. Due to the limited future scope for significant improvement in fluorescent technology, some lighting manufacturers such as Philips have discontinued research on compact fluorescents in favour of greater research into LEDs.

With the latest LED technology, lighting energy densities of less than $2W/m^2$ can be achieved (see Appendix 4 Residential Case Study).

The 2009 Australian lighting performance standard still allows halogen lights to be sold and their use continues to grow. Halogen downlights are popular largely because of low ceilings, light quality and other aesthetic reasons, and also because of a lack of understanding of the energy costs involved with their operation. Halogens have long been marketed as "low-voltage" devices, which many buyers confuse with low energy use.

The solutions: ZCA Buildings Plan recommendations

According to the United Nations International Panel on Climate Change (IPCC), [97] lighting energy use can be reduced by 75% to 90% compared to conventional practice through:

- use of daylighting with occupancy and daylight sensors to dim and switch off electric lighting
- use of the most efficient lighting devices available
- use of such measures as ambient/task lighting.

This plan recommends the incorporation of the following as building retrofits:

- replacement of traditional incandescent, halogen incandescent and fluorescent lighting with LEDs
- lighting sensors and controls in commercial and institutional buildings, with growth in this area projected to be 20% per year through to 2020 [98]
- increased daylight levels in big box retail and shopping centres, coupled with daylight dimming capability
- better selection of luminaires producing appropriate illumination levels (a luminaire is a lighting unit consisting of one or more electric lamps with all of the necessary parts and wiring)
- additional switches for downlights so that fewer are controlled from any single switch.

FIGURE 3.22
Examples of commercially available LED lights that can be used as direct replacements for incandescent bulbs, fluorescent bulbs and halogen downlights.[Source: R Keech]

FIGURE 3.23
Example of commercially available LED light used to replace fluorescent tubes. [Mcapdevila]

FIGURE 3.24
4W LED light bulb showing corresponding driver circuitry and surface-mounted LED packages. [Source: R Keech]

This plan does not propose altering the current mix of lighting types (e.g. lamp versus downlight) for existing buildings. Although the introduction of LEDs is likely to drive the invention of new luminaires, this plan does not recommend specific types of luminaires. Instead, this plan applies the derived efficacy of LED products to all luminaire types while delivering the necessary illumination level for occupant use.

For new buildings, this plan recommends minimal use of downlights in favour of omnidirectional lamps that better use lighting energy. Downlights should be used only where focused directional lighting is required such as for displaying feature items.

The following sections provide detailed information about LED lighting technology.

LED lighting technology

LEDs are available now as a lower-energy lighting solution with superior economic return for nearly every lighting need. The rapid development and global deployment of the LED has led some commentators to predict the near total demise, within as little as ten years [99], of all other types of lighting technologies used [100]in applications ranging from street lighting to commercial lighting to residential. Figures 3.22 and 3.23illustrate examples of currently available LED lights that are being deployed.

LEDs are semi-conductors that produce light when electric current flows across a diode and releases energy in the form of photons. LED bulbs or lamps consist of an LED package which is made up of one or more LEDs, electrical connections and a module that contains an assembly of LED packages on a circuit board.

An LED package may include optical, thermal, mechanical and electrical components, a driver, a connecting base, a heat sink to dissipate heat and other components.

Figures 3.24 shows some of these components.

LEDs are also being manufactured as a complete luminaire: the complete light fitting that connects to the electricity supply and diffuses and directs the light output.

LEDs have been used in electronics and vehicle lighting for decades. However, high power white-light LEDs suitable for general illumination are a relatively new development. Led by funding from the US Department of Energy (US DOE), LED performance has improved over the last 40 years consistent with Haitz's Law. This "law" states that every decade the cost per lumen (a unit of useful light emitted) for LEDs falls by a factor of 10, and the amount of light generated per LED package increases by a factor of 20.

In recent years, the rate of LED development has exceeded even Haitz's Law. The US DOE chart below (Figures 3.25) shows the trajectory of improvement of LED energy efficiency compared with other technologies.

A measure of lighting performance is *luminous efficacy*: the amount of light emitted, or luminous flux measured in units of lumens, divided by the electrical power input to the light. This is specified as lumens per watt, signified as lm/W.

In August 2011, Philips won the US DOE Bright Tomorrow Lighting Prize (L Prize) with a replacement for the 60 W incandescent bulb: a 9.7 W, 910 lumen, warm white bulb with a lifespan of 25,000 hours and efficacy of 93.4 lm/W. Significant further improvement is expected with the US DOE (Figures 3.25) supporting a realistic goal of reaching 200 lm/W by 2025. In December 2012, CREE announced an LED lighting package (not a full luminaire) able to produce 186 lm/W under certain conditions [101].

LED benefits – compared with other lighting technologies

LEDs have many benefits when compared with other types of lighting technologies:

- **High energy efficiency** – projected to be the highest of any lighting technology within 10 years
- **Quality and colour of light** – colour rendering index (CRI, ability of a light source to produce the true colour of a lighted object) and correlated colour temperature (CCT, representing "warmness" of a light source) similar to incandescent lighting. LED light characteristics can also be varied across a wide range of colours for various applications.
- **Versatility** – LEDs can be used as a replacement for nearly all lighting types and applications [102]

- **Reliability and lifespan** – up to 100,000 hours (or more than 20 years if used 13 hours per day), allowing lighting maintenance and replacement that is less costly, more predictable and less intrusive [103]
- **Safety** – cooler to the touch than incandescents (including halogen incandescents), reducing the risk of burns and fires
- **Improved compatibility** with ceiling insulation
- **Dimming ability** – LEDs work well with sensors and dimmers (although not all products are dimmable)
- **"Instant-on"** – no flicker or delay in achieving full brightness
- **No mercury in LEDs**, so few toxicity issues upon disposal
- **Directionality** – LEDs are less dependent on reflectors, so less light is lost in the fitting.

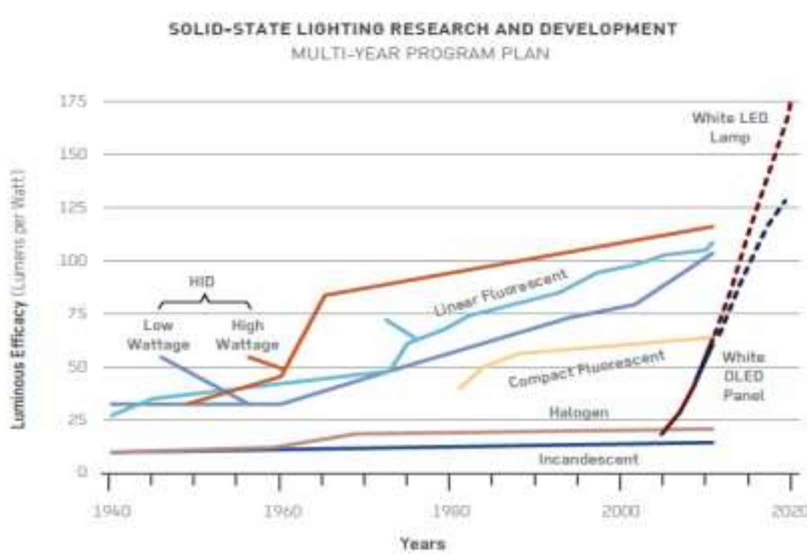

FIGURE 3.25
Lighting performance for different technologies over time.

LED energy reduction potential

Table 3.12 shows the energy consumed by typical conventional lighting types compared with LED-based lighting replacements.

The LED replacements recommended in this plan have a colour rendering index (CRI) above 80 for residential and commercial applications. Warm-white lamps are specified for residential applications, neutral-white for most commercial applications and cool-white for warehouse/industrial applications. For the modelling undertaken for this plan, an LED efficacy of 150 lm/W was used to reflect the average value achievable for lighting installed over the next 10 years.

Analysis by Beyond Zero Emissions indicates that Australia-wide, the electrical energy savings possible with a complete lighting upgrade is approximately 20 TWh per year, which is equivalent to the amount of electrical energy that could be produced by one continuously-operating Hazelwood (Latrobe Valley, Victoria)-sized coal-fired power station.

LED costs and economics

LED lighting costs have fallen rapidly in the last few years. This has been driven by the US DOE initiated programs, more efficient design and higher than expected demand through "big box" retail stores in America.

Prices for LED lights remain relatively high in Australia but are falling fast. An example of the price difference between Australia and the US is the 12W A19

Philips LED bulb. At the US department store Home Depot, this bulb retails for US$23. The same bulb retails in Australia for AU$58 (as at January 2013). However, this price in Australia is 25% less than it was one year before.

TABLE 3.12
LED energy reduction potential

Examples of conventional lighting type to be replaced with LEDs	Applications	Non-LED Lighting			LED Lighting	
		Light output – midpoint of a range of values (lm)	Typical electrical power requirement (W)	Luminous efficacy (lm/W)	LED electrical power requirement (W)	Electrical energy reduction achieved with LEDs (%)
Conventional incandescent (Type A, originally commercialised by Thomas Edison)	Residential	800	60	13	4.0	93%
	Residential	1,100	75	15	5.5	93%
	Residential	1,600	100	16	8.0	92%
Halogen MR16 GU10 (240 volts)	Residential	900	50	18	4.5	91%
Halogen MR16 GU5.3 (12 volts)	Residential	263	20	13	1.3	94%
Linear fluorescent T8 (one inch diameter)	Commercial	2,700	40 (36 without ballast)	68	14.0	65%
Linear fluorescent T5 (5/8th inch diameter)	Commercial	2,200	32 (28 without ballast)	69	11.0	66%
High-pressure sodium (a type of high-intensity discharge light or HID)	Outdoor area lighting, street lights	15,000	150	100	75.0	50%
Metal halide (a type of high-intensity discharge light or HID)	Commercial, industrial, public spaces	10,500	150	70	53.0	65%

Note: LED performance assuming performance of 200 lm/W, assumed to be readily available before 2020.

The US DOE projects that the price of LED lamps will fall from US$30/kilolumen currently to US$10/kilolumen in 2015 and US$5/kilolumen by 2020 [104].

McKinsey projects that LEDs will take a 70% share of general lighting by 2020.

For homes, replacing halogens with LEDs can pay back the money invested in as little as six months.

Specific LED product issues

LED lighting technology delivers clear benefits in terms of reduced energy use and greenhouse gas emissions.

Their long lifetime also reduces the materials required for their manufacture. However, there are potential environmental impacts in the extraction and processing of materials to manufacture LEDs. These impacts include air, soil and water pollution, energy consumption and resource use.

The LEDs used for lighting are manufactured by the following methods:

- using a yellow phosphor
- from a mix of red, green and blue diodes (RGB method).

The yellow phosphor method is more common today. The blue diode used in this method is based on an indium/ gallium/nitride compound. Cerium-doped yttrium aluminium garnet is commonly used to cause the blue diode to produce the required white light spectrum. Indium and gallium fit into the broad category of "rare" metals while cerium and yttrium are classified as "rare earth" materials. A recycling program which ensures re-use of these valuable materials coupled with the long lifetimes of LEDs will reduce the need for virgin materials.

Solid state lighting also encompasses Organic Light Emitting Diodes (OLEDs). These consist of an emissive electroluminescent layer made from a film of organic compounds that emit light in response to an electric current. OLEDs are made in sheets that provide a diffuse-area light source rather than the small point source light of other LEDs. OLEDs are particularly suitable for large area light-emitting elements and show promise in complementing LED lighting in the future.

Toward the end of this decade, OLED lighting technology may improve sufficiently to compete with other LED products [105].

Source: http://decarboni.se/publications/zero-carbon-australia-buildings-plan/4-electrical-appliances-and-services