

Building Code of Australia

Residential Lighting Control

This report has been prepared at the request of the Australian Building Codes Board in order to investigate the potential for improving the energy efficiency of the lighting in dwellings.

BACKGROUND

The lighting of domestic buildings is not covered by any Australian Standards. As a result the amount and type of lighting is therefore determined by interior design requirements and personal likes.

Traditional Residential Lighting

Traditionally houses and apartments were lit with a single incandescent lamp, or sometimes multiple lamps, in the centre of each room. There were usually contained in a diffuse glass fitting. This gave a good diffuse light throughout the room. Although the light source was inefficient the general lighting scheme is relatively energy efficient compared to many installations with more efficient light sources.

A similar lighting system is still used in the majority of home units.

Incandescent lamps are dimmable however the majority of houses and apartments do not have dimmers and a study carried out by Sydney County Council in the 1980's found that the majority of dimmers were not changed after the first few weeks.

Terminology

The energy performance of a light source is usually compared in terms of 'efficacy' and expressed in **lumens /Watt**.

The luminous flux expressed in **lumens** which is a measure of the total visible light emitted by the source.

Changes to Residential Lighting

There have been several advances that have affected the present and future approach to domestic illumination.

Quality of Housing

There has been an increase in the size and general quality of the interior of the average house. The whole attitude of people as to what is an acceptable house has changed with higher quality furnishings, larger areas and an increased awareness of lighting.

Compact fluorescent (CFL)

Compact fluorescent lamps are available in several forms; integral ballasts, separate ballasts and dimmable integral ballast lamps. The compact fluorescent lamp has a much higher efficacy than incandescent lamps. Table 1 gives an approximate comparison between efficacies of the current residential lamp options.

Compact fluorescent lamps, as with fluorescent lighting generally, have generated some negative reaction by people resulting from experiences of lamps with poor colour rendering and cool colour appearance which create a colourless, cold, harsh interior.

Many of the poor quality lamps that caused these problems will be banned when AS/NZS 4847.2 'Self-ballasted lamps for general lighting services Part 2: Minimum Energy Performance Standards (MEPS) Requirements' is brought into force.

There are still problems with the temperature characteristics of the lamps which mean that there is a delay of several minutes while the lamp warms up to full output. With rooms such as store rooms the person may have left the room before the lamp has reached full output.

Compact fluorescent lamps, by their nature are much more diffuse and provide soft light. They therefore lack the drama of incandescent downlights and spotlights.

If incandescent lamps are simply replaced by compact fluorescent lamps there is a significant reduction in energy consumption but the space may lose some of its sparkle.

Low voltage tungsten halogen lamps

Low voltage tungsten halogen lamps have been generally introduced as dichroic reflector lamps. The lamps have an efficacy of around double that of incandescent lamps; however they have a narrow beam distribution. The common designation for these lamps is MR16, being a metallised reflector that is 16 eighths of an inch diameter.

The common lamps are 50 Watts and have a beam width of around 35 to 38 degrees. As a result a typical 3 m x 3 m room would have at least four low voltage lamps to light the room. Many larger rooms would typically have 9 low voltage lamps. This means that a typical 100 Watt incandescent lamp in the centre of the room is replaced with a total of 200 Watts of low voltage lighting. Some new houses at the upper end of the market have in excess of 100 of these dichroic reflector lamps.

The lamps are available in several beam widths between 10 and 60 degrees.

In addition, although the lamps are manufactured in 20, 35 and 50 Watt versions, the majority of lamps stocked by retailers are 50 Watts. There is a wider range of beam spreads of lamps available in 50 Watts. As the 20 Watt lamp is the same cost as the 50 Watt lamp people tend to buy the 50 Watt lamp either because they don't really know what they need and are taking the safe option or because they think they are getting less value for money by buying the lower wattage lamp for the same price.

There is a 65 and 75 Watt lamp that will fit in these fittings, however they are not common and tend to be used for special applications.

There is also an MR11 Lamp available in 10, 20 and 35 Watts. Although not as common as the MR16 lamp, it has the advantage of a different lamp base so that the maximum lamp that can be put in the fitting is a 35 Watt. Due to the lower demand for the lamp it is usually more expensive than the 50 Watt lamp. There are universal lampholders that will take both lamps. If these were used the fitting would have to be rated as an MR16 fitting.

Although the low voltage reflector lamp is the common lamp, they are one specific example of the wider family of tungsten halogen lamps. In addition to the low voltage reflector lamps there are also low voltage single ended burner lamps that do not require a reflector.

Although these have a much smaller portion on the market there is a move towards them in Europe as they have a much lower embodied energy component and have similar energy performance.

Dichroic reflector lamps and burner lamps are also available in 240 Volt configurations; however the other characteristics of efficacy and beam distribution are not significantly different from the low voltage lamps.

The tungsten lamps have the advantage of giving directional lights that can be used to create a more interesting environment. They can also give more sparkle to objects.

The introduction of AS/NZS 4934.2 'Incandescent lamps for general lighting services Part 2: Minimum Energy Performance Standards (MEPS) requirements' will not only ban the sale of incandescent lamps but also some of the less efficient tungsten halogen lamps. Unfortunately low voltage downlights have become a pseudo standard for a high quality interior. There is also a public misconception that low voltage equates to low energy use. This is partially due to them originally being marketed as energy saving lamps. In practice the low voltage lamp installations generally have the highest energy usage.

The Californian Integrated Energy Policy Report Committee in June 19 2007 stated that "Japanese residential lighting is almost entirely provided by linear fluorescent lamps and less than 50% of the residential lighting in Europe is provided by incandescent lighting" Attachment A :

Committee Questions http://www.energy.ca.gov/2007_energy/policy/notices/2007-06-19_ATTACHMENT_A.PDF

This implies that Australia may be either lagging the world in trends in residential lighting or heading in a different direction.

IRC Tungsten Halogen Lamps

Tungsten halogen lamps are now available with infra-red control (IRC) technology. These lamps reflect the infrared radiation back into the filament, reducing the heat dissipated and therefore reducing the energy required to heat the filament.

A 35 Watt IRC lamp has the same light output as a 50 Watt conventional tungsten halogen lamp.

With the introduction of the MEPS for incandescent lamps, it cannot be automatically assumed that all lamps will be simply replaced by compact fluorescent lamps. The major lamp manufacturers are about to introduce a series of mains voltage tungsten halogen lamps in cases and lampholders that will match the existing incandescent lamps. The result will be that rather than getting the full impact of a compact fluorescent replacement, the majority of the banned lamps will be replaced with a tungsten halogen lamp with an efficacy slightly better than the limit.

Light Emitting Diodes (LEDs)

Light emitting diodes have been heralded as an efficient alternative to incandescent light but are still on a rapid development path.

There is a wide variation in the quality and performance of LEDs and there is currently no Australian or international standards for the photometric testing of LEDs. As a result there is inconsistency in the claims made by manufacturers as compared with the actual performance that will be achieved in an installation.

LEDs are an electronic component rather than a traditional lamp. The specific characteristics of LEDs are determined by sorting or binning after manufacture rather than by quality control during manufacture.

As a result there can be a wide variation in efficacy, colour, colour rendering.

The performance and life is also affected by the thermal characteristics of the fitting that it is used in. The efficacy of the LED is directly related to the junction temperature of the diode. The quoted efficacy is usually measured at 25°C on a very short duration of operations. In an operational fitting the temperature will be considerably higher and it is not unusual for the efficacy of the LED in an operating luminaire to be around 50% of the quoted value.

The majority LEDs in their final installation have a lower efficacy than tungsten halogen and their colour characteristics are inferior.

There are higher efficacy LEDs with good colour rendering available, at a considerably higher price. The difficulty in encouraging their introduction in residential lighting is that it will be extremely difficult for the consumer to be able to determine the difference in quality and performance and with no standards there is no basis to assess claims or to introduce limits. It has been difficult enough to get the message of efficacy and colour of compact fluorescent lamps to the consumer and this is much less complex than the LED situation.

There are several LED replacement lamps for the MR16 available on the market. These generally have lower energy consumption but do not have the same light output or colour rendering of a MR16 tungsten halogen lamp.

The majority of LED replacement lamps for MR16 lamps do not state the light output. A typical one, however, that did quote light output figures, advised that whereas a 20 Watt MR16 lamp produces 400 lumens, one 6.5 Watt LED replacement lamp is quoted as producing 280 lumens. There is an increase in efficacy; however the number of lamps would need to be doubled to achieve the same lighting level. The life and light output of a LED is affected by the junction temperature. If the junction temperature is too high there is a reduction in efficacy and life. With the MR16 lamp replacements there is a limited space and there is therefore always a compromise between the number of LEDs and the amount of heat sink that can be provided in the space available.

Lighting Control Systems

Centralised lighting control systems have started to be introduced into residential developments. These were previously limited to hotels and very high-end residential buildings. With the introduction of C-bus and similar systems the cost has been reduced to enable a significant increase in the level of adoption.

Although the centralised dimming system has increased the usage of dimming and therefore reducing the overall energy consumption of the lighting, the control is often operated on a scene basis where the system turns on multiple switching circuits and possibly in multiple rooms. The result is that more lighting tends to be turned on at a time.

In commercial premises occupancy sensors can cause a significant reduction in the amount of energy used. In theory there would be an equally good opportunity to achieve savings in residential installations. There would probably be some resistance to this as it could limit the lighting in a home to the actual room that was occupied. It would mean that people could not light up parts of their house when entertaining and people who lived alone would be forced to stay in a house that is totally dark except for their immediate space.

One lamp manufacturer has introduced a compact fluorescent lamp with internal control gear that has incorporated a small LED in the base of the lamp. This gives the ability to switch from an operational level of light to a much lower ambient or night light level. Although the integral ballast lamp may not be desirable the concept of having an efficient low level of light to break up the darkness is good.

Due to the aging population there is an increase in visual distinctions in the aged. There should be an exemption for the aged or people with diagnosed visual disorder.

Comparison of light sources

The costs and expected lamp life in Table 1 are typical and will vary with brand, model, wattage and how they are purchased. The prices are based on list prices from reputable manufacturers. We have not included the prices for the unbranded copy lamps. Due to the wide variation in prices we also priced all the lights at the same hardware mega store.

The pricing of some of the items seems to be more dependant on the volume of sales of the retailer than the manufacturing cost of the lamp.

| Lamp Type | Luminous Efficacy (Lumen/Watt) | Colour rendering | Correlated Colour temperature | Expected life | Typical lamp cost | Retail Prices from the same store |
|--|--------------------------------|---------------------|-------------------------------|---------------|-------------------|-----------------------------------|
| Incandescent | 13 | 100 – by definition | ≤2700K | 1000hr | \$1.20 | \$0.83 |
| Tungsten Halogen (MR16) 12 Volt | 22 | 100 – by definition | ≤3000K | 2000 hr | \$4.50 to \$14 | \$3.98 |
| Tungsten Halogen (MR16) 12 Volt | 22 | 100 – by definition | ≤3000K | 5000hr | \$14.30 | \$7.13 |
| Tungsten Halogen (MR16) 240 Volt | 22 | 100 – by definition | ≤3000K | 2000 hr | | \$7.47 |
| Tungsten Halogen (MR11) | 22 | 100 – by definition | ≤3000K | 2000 hr | \$12 to \$17.40 | |
| IRC tungsten Halogen (MR16) | 28 | 100 – by definition | ≤3000K | 4000hr | | N/A |
| Compact Fluorescent integral ballast # | 68 | 82 | 2700K to 6500K | 10000hrs | 18W \$4.80 | \$6.97 |
| Compact Fluorescent separate ballast ## | 58 | 87 | 2700K to 6500K | 10000hrs | 13W \$5.99 | 13W \$16.36 |
| Linear Fluorescent T8 – 36Watts Electronic Ballast | 94 | 85 | 2700K to 6500K | 15000hrs | \$9.80 | |
| Linear Fluorescent T5 – 36Watts | 90 | 85 | 2700K to 6500K | 15000hrs | \$9.80 | |
| LED ### | 22 to 60 ##### | 0 to 90 | 3000 to 6500K | | | |

Table 1
Comparative characteristics of different domestic light sources

Notes:

The efficacy varies with lamp size and from brand to brand

The efficacy varies with the type of control gear used

The characteristics of LEDs varies with brand, model, colour, colour rendering and enclosure

CURRENT LIGHTING ENERGY USAGE

We have prepared lighting designs for the six standard houses based on a traditional lighting design, a traditional design with CFL instead of incandescent lamps, a design with 80% fluorescent light fittings, a typical downlight installation including compact fluorescent lamps as is common in new homes and an installation using a relatively large number of MR 16 lamps.

Note that this does not represent the top end on energy usage as some homes will use considerably more lighting than these installations.

The comparison of lighting power distribution is shown in Table 2. The lamps powers densities are based on assumed designs. As there are no real rules for the designs the energy levels may vary greatly according to the desires of the owner or designer.

The lighting layouts that have been used are enclosed as Appendix A.

The size of the rooms tends to have an effect on the lamp power density. As the room gets smaller there is generally not a linear relationship to the power consumption as lamps come in specific wattages and the lighting has to be adjusted in steps of a whole lamp.

We have not included lamps or lighting within furniture or appliances. We have also not included heater lamps.

External lighting has been ignored in the assessment; however we have included verandah lighting as the verandah in the Queenslander type home represented a significant proportion on the floor area and was considered a living space.

We have separated the garages as these contribute a significant area to the home and the amount of lighting in the garage can hide a lot of lighting energy in the main house.

Observations

The traditional method of lighting residences, although it used a poor efficacy source generally produces a more energy efficient house or apartment than the installations with higher efficacy tungsten halogen lamps.

Probably the most energy efficient lighting installation would be achieved by taking a traditional design and substituting compact fluorescent lamps.

The higher energy usage in the modern design is a result of the narrow distribution of the dichroic reflector lamp used in the downlights and the almost universal usage of the 50 Watt lamp. The simple substitution of 35 Watt IRC lamps in place of 50 Watt lamps would result in a 30% saving, while the use of lower wattage lamps in some applications (35 Watt or 20 Watt (IRC), or 10 Watts).

Porches and small verandahs generally represent an area with a high power density due to the small floor area; however not all porches and verandahs can be ignored due to the significant floor area of the verandah in the Queenslander and Passive Solar house.

The lamp power density for the standard houses with traditional lighting is between 3.3 and 9.1 Watts/ m². This compares to the modern lighting that is predominately low voltage downlights which ranges between 8.1 and 18.8 Watts/ m².

If the traditional lighting is simply replaced with compact fluorescent lighting then the lamp power density ranges between 0.9 and 2.9 Watts/ m².

The compliant option is a blend of the low voltage downlight and compact fluorescent options as an indication of where the limit might be set.

Table 2

| BCA Housing | | | | | | | | | | | |
|-------------------------------|--------------|-----------------------|--|---|---|-------------------------------|---|-----------------------|--|----------------------------------|--|
| | Area | Traditional Design | | Option 1 - Compact Fluoro Integral Ballast | | Option 1a -80% Fluorescent | | Compliant Option | | Option 2 - Modern Low Voltage | |
| | | total lamp wattage | lamp power density W/m ² | total lamp wattage | lamp power density W/m ² | total lamp wattage | lamp power density W/m ² | total lamp wattage | lamp power density W/m ² | total lamp wattage | lamp power density W/m ² |
| Standard House Designs | | | | | | | | | | | |
| House 1 | 152 | 660 | 4.3 | 234 | 1.5 | 567 | 3.7 | 770 | 5.1 | 1458 | 9.6 |
| Porch | 3.7 | 40 | 10.8 | 18 | 4.9 | 11 | 3.0 | 11 | 3.0 | 50 | 13.5 |
| TOTALS | 155.7 | 700 | 4.5 | 252 | 1.6 | 578 | 3.7 | 781 | 5.0 | 1508 | 9.7 |
| House 2 | 187 | 900 | 4.8 | 328 | 1.8 | 985 | 5.3 | 1021 | 5.5 | 2324 | 12.4 |
| + Garage | 48 | 90 | 1.9 | 90 | 1.9 | 144 | 3.0 | 144 | 3.0 | 168 | 3.5 |
| Porch | 4 | 40 | 10.0 | 18 | 4.5 | 11 | 2.8 | 11 | 2.8 | 50 | 12.5 |
| TOTALS | 239 | 1030 | 4.3 | 436 | 1.8 | 1140 | 4.8 | 1176 | 4.9 | 2542 | 10.6 |
| House 3 Ground | 145 | 840 | 5.8 | 238 | 1.6 | 717 | 4.9 | 868 | 6.0 | 1470 | 10.1 |
| House 3 First | 90.4 | 500 | 5.5 | 201 | 2.2 | 358 | 4.0 | 600 | 6.6 | 1265 | 14.0 |
| Average | | | 5.7 | | 1.9 | | 4.6 | | 6.2 | | 11.6 |
| + Garage | 32 | 90 | 2.8 | 90 | 2.8 | 144 | 4.5 | 144 | 4.5 | 168 | 5.3 |
| Porch | 5.5 | 40 | 7.3 | 11 | 2.0 | 70 | 12.7 | 70 | 12.7 | 100 | 18.2 |
| TOTALS | 272.9 | 1470 | 5.4 | 540 | 2.0 | 1289 | 4.7 | 1682 | 6.2 | 3003 | 11.0 |
| House 4 Ground | 43 | 420 | 9.8 | 118 | 2.7 | 273 | 6.3 | 294 | 6.8 | 778 | 18.1 |
| House 4 First | 56 | 480 | 8.6 | 174 | 3.1 | 205 | 3.7 | 273 | 4.9 | 1086 | 19.4 |
| Average | | | 9.1 | | 2.9 | | 4.8 | | 5.7 | | 18.8 |
| + Garage | 18 | 90 | 5.0 | 90 | 5.0 | 72 | 4.0 | 72 | 4.0 | 90 | 5.0 |
| Porch | 2.7 | 40 | 14.8 | 11 | 4.1 | 11 | 4.1 | 11 | 4.1 | 50 | 18.5 |
| TOTALS | 119.7 | 990 | 8.3 | 382 | 3.2 | 550 | 4.6 | 639 | 5.3 | 1954 | 16.3 |
| House 5 | 227 | 760 | 3.3 | 207 | 0.9 | 728 | 3.2 | 1034 | 4.6 | 1839 | 8.1 |
| Verandah | 109.5 | 320 | 2.9 | 144 | 1.3 | 231 | 2.1 | 350 | 3.2 | 500 | 4.6 |
| Undercroft | 228 | 252 | 1.1 | 252 | 1.1 | 552 | 2.4 | 504 | 2.2 | 504 | 2.2 |
| TOTALS | 564.5 | 1332 | 2.4 | 603 | 1.1 | 1511 | 2.7 | 1888 | 3.3 | 2843 | 5.0 |
| House 6 | 162 | 780 | 4.8 | 234 | 1.4 | 629 | 3.9 | 861 | 5.3 | 1537 | 9.5 |
| Verandah | 44 | 120 | 2.7 | 126 | 2.9 | 130 | 3.0 | 126 | 2.9 | 500 | 11.4 |
| | 206 | 900 | 4.4 | 360 | 1.7 | 759 | 3.7 | 987 | 4.8 | 2037 | 9.9 |

Table 2

Summary of the lighting power distribution for the standard houses

EXISTING REGULATIONS

There are existing regulations that apply in some states of Australia. In addition there are some overseas regulations that can be used as a guide.

Queensland₁

The Queensland Development Code, in MP4.1 Sustainable Buildings, contains a requirement for energy efficient lighting for Class 1 and Class 2 buildings stating that "energy efficient lighting to 80% of fixed internal lights." An 'energy efficient light' is define as "...lighting with a minimum output of 27 lumens power watt and excludes lamps used in bathrooms for the purpose of heating".

This requirement excludes the use of all tungsten halogen. It will also exclude a large number of LED lights that are on the market. It is difficult for the consumer to know whether the LED fitting complies and as the efficacy of an LED is very depends on temperature it does not specify if the efficacy is for the base LED or the LED in an operational fitting.

This has been modelled in Table 2, however it has been based on an equivalent design to the other options. With any restriction that is percentage based there is no limit, other than cost, on the total amount of energy used. Higher energy usage can result from lighting solutions like continuous fluorescent coves around the rooms or by increasing the number of LED lights so that the basis for the 20% of inefficient lights that are allowed is increased.

New South Wales

New South Wales has BASIX₂, which applies to Class 1 to 3 buildings. BASIX gives an overall assessment of the energy and water usage of the building. As long as the end figure is achieved the break up within the building design is at the discretion of the designer. Lighting limits can be removed by the addition of more stringent compliance in other areas. For example lighting requirements can be reduced by additional water storage. When fluorescent lighting is required it only has to be the primary lighting source in the room, but it must be a type of lamp that cannot be substituted for an incandescent lamp. LEDs are acceptable as a substitute for fluorescent lighting however there is no limit on the efficacy of LEDs that are used.

Neither Queensland nor New South Wales limit the amount of high efficacy lighting that you can use or the overall energy consumption.

COMPARATIVE STANDARDS OVERSEAS

United States – LEED Standards₃

The LEED requirements are reasonably basic:

- Install at least four compact fluorescent lights
- Exterior lighting to have a motion sensor or integrated PE cell

The California Energy Code₄

Interior Lighting

High efficiency luminaires must be installed in;

A Permanently installed lighting in kitchens

Exception –

- Up to 50% of the lighting may not be high efficiency provided it is switched separately from the high efficiency luminaires

B Permanently installed lighting in bathrooms, garages, Laundries and Utility Rooms

Exception –

- need not be high efficiency if it is controlled by an occupancy sensor that does not switch the lights on automatically and cannot be overridden.

C Permanently installed lighting rooms other than kitchens, bathrooms, garages, Laundries and Utility Rooms

Exception

- controlled by a dimmer switch
- controlled by an occupancy sensor that does not switch the lights on automatically and cannot be overridden.
- In a closets less than 6.5m²

Outdoor Lighting

Lighting shall be high efficiency

Exception

- Motion sensor controlled
- Water features and pools

United Kingdom⁵

The British Building Regulation 2006 Edition – Conservation of fuel and power in new dwellings L1A, specifies fixed internal lighting to have a luminous efficacy of better than 40 lumens per circuit watts. External lighting over 150Watts is either to have a motion sensor or have a luminous efficacy of better than 40 lumens per circuit watts.

Scotland

The Scottish Standards Domestic Handbook 2008⁶ states-

6.5.1 Artificial lighting

A minimum of 50% of the fixed light fittings and lamps installed in a *dwelling* should be low energy type.

The fittings may be either:

- dedicated fittings which will have a separate control gear and will only take fluorescent lamps (pin based lamps); or
- fittings including lamps with integrated control gear (bayonet or Edison screw base lamps).

e.g. tubular fluorescent and compact fluorescent fittings (CFL's) with luminous efficacy at least 40 lumens/circuit watt.

In this guidance:

- a minimum of 50% of fixed light fittings means at least 1 in a *dwelling* which has 2 fittings, 2 where there are 3, 2 of 4, 3 of 5 etc;
- fixed light fittings include only the main light sources to a *room*; not display or feature lighting such as picture lights, *kitchen* wall cupboard lights, over mirror lights. A light fitting may contain one or more lamps and a group of lamps operated by the same switch could be counted as one fitting, e.g. a pair of wall lights;
- low energy light fittings include the provision of lamps/bulbs.

OPTIONS

The principal questions that need to be addressed before a regulated limit can be applied are:

- What proportion of the energy in residential buildings do you want to save?
- How much are we willing to force changes in the appearance and atmosphere of a residence?
- Do you want to virtually ban low voltage downlights in residential buildings?

The answers to these questions will determine at what level the regulation is set and how it is applied.

There appear to be three approaches that are possible to reduce the energy consumption in residential buildings:

Approach 1. A Lamp Power Density Limit

Specify a maximum lamp power density for the dwelling. This could then be achieved using whatever lighting sources and equipment that is allowable under MEPS. This is relatively simple to administer at the stage of initial certification but would need some safeguard to ensure that the energy savings were ongoing. This is consistent with the general approach currently used by the BCA Volume One.

If this is to be followed I would suggest the following criteria for consideration:

- a) The average lamp power density for the dwelling, excluding garage and verandahs shall be no more than 5 Watts/m².
- b) The averages lamp power density for a garage shall be no more than 3 Watts/m².
- c) Verandahs of no more that 5 m² shall be considered outside spaces.
- d) Verandas of greater than 5 m² shall have an average lamp power density of no more than 4 Watts/m².
- e) External lighting shall have an average lumens per circuit watts of greater than 40 unless it is controlled by a motion detector.
- f) Fluorescent lamps that are used shall be of a type that cannot be retrofitted with an incandescent lamp.
- g) Fluorescent lamps shall be used in conjunction with an electronic ballast.
- h) Halogen lamps be on a separate light switch to compact fluorescent lamps in order to limit their day-to-day use.
- i) Batten holders would not be allowed as there is no way of controlling the type or size of lamp that is installed. Bayonet and Edison screw lampholders would only be allowed within a light fitting and the load would be taken as the maximum rating of the fitting.
- j) Compliance will be based on the fittings installed at the certification stage.
- k) Track should be rated the same as BCA Volume One

Note that the disadvantage of allowing a bayonet fitting in the initial installation is that it gives no control over the lamp wattage. The more significant problem is that they are seen as a minimal cost temporary solution until the real fitting is selected. They are inviting change of fitting. As a result there is not real control of the installation.

On the other hand if the high energy efficiency fittings and designs have to be installed before occupation there is a higher investment in the fitting and therefore less likelihood that they will be scrapped.

- l) We cannot rely on market forces to ensure the use of higher efficacy light sources as the cost of energy is still too low. The payback period is often greater than the life.
- m) The exception may be that if tungsten halogen downlights are effectively banned then there will be people who will purchase the high-end LED lights to enable them to achieve the impact and drama that they could have achieved with tungsten halogen.

Even then there is always the problem of having no follow up after occupation. A personal experience occurred with the inspection of emergency lighting systems for a government department. One of the inspectors felt that there was something familiar about a central

battery in a development that he was approving. He went back and checked and he had inspected the same central battery on the last three jobs that he had inspected for that developer. The moral being that if the fittings are expensive enough there may be incentive to pull them out after inspection and reinstall them in the next building requiring compliance.

Approach 2. Nominated high efficiency luminaire usage

This is the common method that appears to be used for regulation of residential codes around the world.

At the most stringent level you have the United Kingdom and California Energy Code that say all fittings shall be high efficiency and then some exceptions or alternatives are allowed.

- A reduced version is that used by the NSW governments where they say that a specific number of rooms shall be lit with fluorescent or high efficiency lighting. If we go this way it is important that the efficacy limit be specified as to what constitutes a high efficiency light as it gives the opportunity for low performing LEDs to creep in under the performance of the better quality units.
- It is also important that we define what actually constitutes fluorescent or high efficacy lighting. For example how do we prevent people also installing tungsten halogen lights in the space with the intention of never using the fluorescent lighting?
- Yet another version is the Scottish system where the specification is by the number of lights rather than specific rooms. In that case they say that 50% of all light fittings are to be high efficiency. It does not specify the relative wattage and one could in theoretically comply if you had 10, 100 Watt incandescent lights and 10, 0.25 Watt LEDs. The Scottish model allows compact fluorescent lamps with integral control gear to be used which leave the option open to retrofit incandescent lamps.
- The Queensland system is similar to the Scottish but has an 80% requirement for fluorescent lights.

I believe that if we go for the nominated high efficiency lamp model then the California model is the best to follow of this style of regulation as there is less ambiguity. The disadvantage of this approach is that it only limits the quality of the lamps and not the number of them.

Generally the standards do not state how the nominated percentage is to be applied. If a nominated percentage of high efficacy lights is to be used then there needs to be some clarification of what the percentage means. It can be applied in different ways with very different outcomes:

- a) If the percentage applies to the number of lamp or fittings it is possible to install a large number of very small LEDs for example to increase the overall percentage.
- b) If the percentage is applied to the total power consumption of the lighting then the inefficient lighting would represent a relatively higher amount as the higher efficacy lights would have a lesser contribution to the total.
- c) Finally it could be a percentage of the total lumens. This gives a result that is closer to the average luminous efficacy below.

If we take an installation with five 26 Watt compact fluorescent lamps and five 35 Watt tungsten halogen lamps; the high efficiency lamps represent 50% of the number of lights or lamps, but approximately 43% of the total watts. The high efficiency lighting however represents approximately 67% of the total lumens produced

Approach 3. Average Luminous Efficacy

The third approach is to simply specify an average efficacy for the entire building. For example the sum of the rated luminous flux of all lights divided by the sum of the rated wattage of all lights shall be greater than 40 Lumens/Watt. This system is generally only used in specific areas or for external lighting but has same potential to be applied throughout the whole installation.

One limiting factor with this is that it is difficult for people to actually find out the luminous flux of many sources. It is not published for reflector lamps and the figure that it generally published for a LED is the cold temperature not the operating temperature.

Again with this system there is no guarantee that the high efficacy sources will actually be used.

I also saw one installation where 150 Watt metal halide uplights were used, when 35 Watts was adequate, to boost the average efficacy of the external lighting system to allow for budlights.

DISCUSSION

The method and extent of control of residential lighting is predominately a political decision rather than a pure lighting and energy one.

Do we want to dictate the appearance of the interiors of a home?

The most efficient way of lighting a residence is to have one or more surface mounted, or suspended, diffuse lights. These lights would be fluorescent.

A significant reduction of energy in lighting in residences would be achieved by the banning of downlights. Even compact fluorescent downlight have a limited beam distribution and result in multiple fittings being used.

Lighting of homes is generally about the appearance of the space and the feeling that the space is lit rather than the need to light a working area.

A spherical glass fitting has a light output ratio or efficiency of around 70 to 90%. As the light leaves in all directions it tends to light all the surfaces in the room and makes the space look lit.

In comparison the majority of compact fluorescent downlights that are used in residential spaces would have an efficiency of less than 50%. In addition due to the distribution they would directly illuminate less than 10% of the surfaces of the room. The illumination of the remainder of the surfaces of the rooms is achieved either by inter-reflection off other surfaces or by the additional light sources.

Irrespective of the efficacy of the light source, downlights are around 30% as efficient in lighting the space as diffuse surface mounted fittings.

The ramification of this is that it dictates the atmosphere of the room. In the past it was the normal way to light a room and in many parts of the world it still is. It is a cultural thing that Australians tend to entertain in their home and therefore want to have an interior that impresses. Most European and Asian societies entertain at restaurants and outdoors, fundamentally due to the small size of the homes.

The restriction would also have an impact on the interior design industry as it will affect how the interiors appear.

Do we want to dictate the ability for people to ‘personalise’ their home?

In the majority of homes, other than ones that are pre-designed by an interior designer or architects, the lights, curtains, carpets etc. are left to the purchaser to select. This is usually after the Certificate of Occupancy had been issued. If energy usage is to be controlled then either all the fittings need to be installed when the Certificate of Occupancy is issued and people are not allowed to change the fittings, or there would need to be a review after occupancy to ensure that people have installed appropriate lighting.

This would mean that the regulations would have to be simple enough for every homeowner to understand, not just professionals in the industry.

As the people would also already have their Certificate of Occupancy there would be little that could be done to ensure compliance other than legal action and it could be a public relations problem to have someone taken to court over the selection of a light fitting.

As there is a perception of low voltage downlights being an indication of quality and atmosphere in a residential space a forced reduction in their use needs to be accompanied by information that reinforces the concept on alternative options. Although they do not cover residential lighting ‘Lighting *knowhow* Series Design Guides’⁷ give a good model of the type of thing that could be done. There needs to be a change in the perception of people not just in the regulations. Some examples of the *Knowhow* series are included in Appendix B.

How do you make the home owner/occupier understand their responsibilities?

If the owner of the home is allowed to change the lights after occupation then there needs to not only be some regulatory mechanism that enables the supervision of these changes, but the regulations also need to be framed in a manner that anybody that owns a home can understand.

In theory it would only need to be the electrician that would need to know. Legally, only a licensed electrician can change a light fitting, other than one that attaches to a batten holder. The lack of regulation in the sale of lighting and general electrical equipment means that this is generally ignored and the majority of people are unaware that they are not allowed to do it.

If however it was enforced that a light could only be changed by an electrician then they could fill out a form at the completion of the job to certify that the lighting installation still complied with the regulations similar to what they do with respect to AS 3000.

This is difficult enough to enforce even though it is a life safety matter. It would be more difficult to gain acceptance of a heavy handed approach to the control of changing light fittings.

SUMMARY

Of the three options, only option 1 gives a predictable level of energy usage. For design approval purposes it should be possible to simply multiply the total floor area by the limit to predict the general power consumption of new developments.

In contrast the other options will make the production of light more efficient, however there is no guarantee that the actual energy consumption will be any lower as there is no limit on the amount of lighting that is installed.

I believe that it is also the simplest to regulate and enforce.

Any regulations that will make a significant impact on energy efficiency will have a significant impact on the perception of people's rights within their homes.

References:

- 1: Sustainable Living, Queensland Building Code
- 2: BASIX Building Sustainability Index, NSW Department of Planning
- 3: LEED for Homes Rating System, Jan 2008
US Green Building Council
- 4: California Code of Regulations Title 24, Part 1 Energy Building Regulations
Revised Sept 2006.
- 5: The British Building Regulation 2006 Edition – Conservation of fuel and power in new dwellings L1A
- 6: Scottish Building Standards – Technical Handbooks Domestic Handbook 2008,
Section 6 Energy
- 7: Lighting *knowhow Series* Design Guides – Designlights Consortium

Appendix A - Representative House designs.

Appendix B - Lighting *Knowhow Series* Examples