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Report on Energy Savings Opportunities in Streetlighting for

SEDA Sustainable Energy Development Authority

and

ENERGY EFFICIENCY VICTORIA

June 1999

File: 244

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Executive Summary

Aim

This document aims to:

- identify opportunities to reduce the energy consumption of street lighting, while improving the quality of illumination, and
- describe actions and a strategy which will result in realising the potential savings.

Findings

The key findings of this report are:

- present street lighting systems are inefficient, in that:
  - the quality of illumination of both minor and major roads is much lower than can be achieved, and
  - the energy efficiency is low.
- there is a basic mismatch between the light colour produced by many street lights and the light colour which the human eye can use under typical street lighting vision conditions.
- the quality of street lighting can be significantly improved, and the energy consumption at least halved by a combination of:
  - more efficient lamps (eg. metal halide and compact / tubular fluorescent).
  - more efficient lanterns (reflector design, less light loss in diffuser, more accurate light distribution without a refractor bowl),
  - more efficient ballasts, especially electronic ballasts.
  - more accurate control of lighting times (electronic photo-switch rather than the existing cadmium sulphide cells, to reduce burning time by at least an hour per day (9%)).
- the capital cost premium of energy efficient street lighting is small and is justified by the very high return[1] on the small premium, and:
  - the cost of energy efficient street lighting equipment is very likely to fall as the production volumes increase.
  - the cost of upgrading street lighting efficiency is comparatively low ***now*** because the majority of NSW and Victorian minor roads street lights are due for replacement now or within five years.
  - the higher cost of more accurate, electronic photo-switches is justified by their longer life, with energy savings due to shorter lighting hours being a *free* benefit.
- mercury vapour is reputed to have low maintenance costs, but this reputation is largely a result of the practice of not replacing lamps even when light output has fallen excessively because of lamp fading.

Strategy

This report recommends:

- field trials of a range of street lights,
- facilitating manufacture of energy efficient street lighting equipment, and
- SEDA / EEV representation on Standards Australia committees relevant to street lighting.

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[1] 74% p.a. for the street lighting solution described in "*System Costs and Benefits*" on page 20.

Introduction

Aim

Terms of Reference

The brief for this project stated that the aims were:

- assessment of the current technology used in providing street lighting in Victoria and NSW,
- assessment of interstate and international best practice, and
- recommending methods of reducing energy consumption and maintenance costs.

This report does not discuss the issue of competitive supply of street lighting services, as this is well covered by Reference 4 (please see page 23).

Project Team Aim

The project team hope that this document will promote discussion and investigation of the street lighting task and strategies.

Report Organisation

This report is organised into the following sections:

• Street Lighting is Important	One page overview of its importance and impact
• Current Street Lighting Infrastructure	The street lighting task and how it is now tackled
• Best Practice Street Lighting	Providing the greatest? benefits at the lowest cost

Other supporting documentation is in the Appendices.

Project Timing

This is an opportune time to be reviewing street lighting:

- In Victoria, about 200,000 mercury vapour (80 Watt) lanterns were installed starting in 1989. This project saw the replacement of twin 20 Watt fluorescent lamp lanterns. The new street lights have an estimated service life of 15 years, and so planning of the next generation of replacement fittings must start now. This will allow adequate time for design, hardware selection and / or development, and field trials.
- NSW has about 400,000 fluorescent street lighting lanterns[2], which are programmed for replacement now. If NSW were to adopt the same solution to fluorescent lantern replacement which Victoria took:
  - the capital would be about $M70
  - energy consumption for these lanterns would double, and
  - the recurring greenhouse gas emissions will be 146 kilo-tonnes[3] every year.

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[2] Details of the NSW fluorescent street lighting lantern numbers and costs are in Appendix 1 on page 24.

[3] based on 158.9 GWh/year (see Appendix 1) and a greenhouse intensity of 0.92 kg/kWh.

Clearly, the benefits of the NSW replacement of fluorescent street lighting need to be maximised while minimising the costs to the community and the environment.

Street Lighting is Important

Function

Good street lighting contributes to the quality of life, by improving personal safety and perceived safety, and improving the appearance of the local environment. As a corollary, poorly designed lighting systems can degrade the quality of life, for example, by making vision more difficult, or through intrusive unwanted light.

Safety

There is a considerable body of knowledge which indicates that the provision of lighting on roadways has a significant effect on the lowering of accident rates at night. Therefore the provision of acceptable lighting systems on all roadways is not just a matter of amenity, but also quite literally a matter of life and death.

For most people, probably the worst fear when venturing out at night is that they may be accosted by a stranger. If the lighting, and particularly the vertical lighting, is insufficient it will be very difficult for anyone to make a confident judgement as to whether or not someone approaching is a friend or foe. We are of the opinion that this widely felt fear is one of the most significant reasons why people do not wish to go out into public spaces during the hours of darkness.

Cost

However the provision of street lighting systems comes at a significant cost to the community.

Street lighting costs the Australian community about $M156 per year in energy alone. The total cost of providing street lighting, including provision and maintenance of the electricity distribution network and the street lighting equipment, is about 6 times[4] the energy cost alone. This brings the Australian total to about $M900 per year.

Environment

Street lighting affects the local environment (positively and negatively) by the provision of wanted and unwanted light. The global environment is affected by greenhouse gas emissions, and by the depletion of finite fossil fuel and other material resources.

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[4] Source: Reference 2: Coopers & Lybrand, "*Report to IPART on Street Lighting Review"* March 1988.

Overview of Current Street Lighting Infrastructure

The Street Lighting Task

What Should be Illuminated?

Clause 2.1, General Objectives of AS/NZS 1158.1.1, 1997, clearly states :

> "*To accomplish these objectives, the lighting must reveal necessary visual information. This consists of the road itself, the course of the road ahead, kerbs, footpaths, property lines, road furniture and surface imperfections, together with all road users including pedestrians, cyclists and vehicles and their movements, and other animate or inanimate obstacles.*"

Despite this clear statement, *in practice* there is a strong tendency of the standard and designers to concentrate only on the lighting of the road surface and to neglect pedestrian traffic and precinct areas, etc.

Even a casual reflection on this situation will reveal that this is far from an ideal situation. Of all the objects which can be illuminated, the horizontal road surface probably presents the least hazard.

How are the Street Lighting Areas Classified?

The current series of Australian/New Zealand Standards AS/NZS 1158 recognise three categories of lighting systems, and these may be broadly described as follows :

Category V	Applicable where the visual requirements of motorists are dominant
Category B	For roads and other public thoroughfares where the needs of pedestrians are dominant
Category C	

How Should these be Illuminated?

Light direction

The current edition and prior editions of AS1158 have only used horizontal illuminance[5] as the illuminance criteria.

The use of horizontal illuminance is an understandable expediency, as:

- measuring the horizontal illuminance requires only a single measurement at each point, whereas vertical illumination necessitates also deciding in which direction to make the measurement, and recording both the direction and the measurement, and
- it is a natural extension of the practice of measuring horizontal illuminance which is relevant in office and other workstation lighting, where the work (writing, equipment, etc) is horizontal.

But horizontal illuminance is a very poor indicator of the amount of *useful* light upon an object such as the human body. Horizontal illuminance would be a good indicator of an objects visibility from a helicopter, but not from the viewpoint of a motorist or pedestrian. Good street lighting requires good vertical illumination, preferably from more than one direction (please refer to Appendix 2).

[5] Please see the Glossary on page 35 for a description of the key lighting terms used in this report.

Which Lighting Equipment Should be Used?

Overview

The answer to this question lies partly in the answer to the previous one (light direction), and partly in:

• the desired colour of light	(governed by lamp type).
• the desired distribution of light	(lantern characteristics: ▪ lamp ▪ reflector ▪ diffuser / refractor)
• the desired brightness	
• the desired operating hours	(control device, usually a photo-switch but sometimes methods such as ripple control are used).
• mounting options	(usually existing power poles but sometimes dedicated lighting poles).
• cost factors	(energy, maintenance, capital cost, economic life, etc.)

Is Lighting Colour Important?

The colour of light, and especially light from artificial sources, varies widely: from the "warm" glow of candlelight to the very blue light of the mercury vapour lamp and its derivatives (tubular fluorescent and metal halide). But not all lighting colours are equally suitable for all lighting tasks, and this is especially true of most street lighting applications.

To fully understand this matter it is necessary to have an understanding of how the human vision system operates under various lighting conditions.

The human vision system

The human eye has the ability to adapt to ambient lighting conditions in both daylight and night-time conditions; from over 100,000 lux to much less than 0.1 lux (a ratio of more than one million to one). If there is a lot of available light, for example in a well lit office or out of doors in the day time, this condition is described as *Photopic Vision* which means light adapted. Alternatively if the eye is operating in night-time conditions it is described as having dark adapted or *Scotopic Vision*.

However there is an in-between adaptation situation described as *Mesopic Vision*, and the lighting conditions on most of our main roads asks the human eye to operate within this Mesopic Vision range. The human eye is using mesopic vision when the ambient "light level" is between about 0.1 lux and 10 lux.

Why is this important? It must be remembered that luminance is a physical parameter which can be measured by an appropriate photometer, but what the human eye perceives is the sensation of *brightness*[6].

[6] Key lighting terms used in this report are defined in the glossary on page 35

Light colour and vision

The relationship between luminance and brightness is very dependent upon the colour of the light source.

Under mesopic vision conditions, the luminance (measured value) and the brightness (perceived value) of a surface under a blue white light source, is much more closely related than when under an orange-red light source. The eye finds light at the blue end of the visible spectrum much more useful than light at the red end of the spectrum. Light meters are, however, calibrated for the eyes sensitivity to different light colours at much higher lighting levels (ie. under photopic conditions).

Light colour and lighting design

The primary light parameter used in main road lighting is Luminance (candelas per square metre). Table 2.1 of the Australian Standard AS/NZS 1158.1.1, 1997, Road Lighting, Part 1.1 Vehicular Traffic (Category V) Lighting, specifies values for this parameter for various classes of roads.

However, the lamp / lantern performance data used as an input to lighting designs, and the light meters used to assess the resulting lighting installation are based on the total light output (lumens) and illuminance (lux) assuming that the eye will have the same response to the light as it would at much higher lighting levels (eg. daylight, which could be over 100,000 brighter). This project team does not agree with such an extrapolation.

Light colour and lamp selection

Light at the blue end of the spectrum is more of an aid to vision under mesopic conditions, and so this means that the mercury (blue white) based family of lamps is far more appropriate for than is the sodium (orange red) family of lamps.

Unless the lighting or luminance values are very high and at least twice the values recommended in Table 2.1 of AS/NZS 1158.1.1, 1997, people will **not** be using photopic vision.

At the lower luminance (scotopic and mesopic vision), the relationship between luminance and brightness will not be the same as during photopic vision. The correlation which exists for yellow-red light (including high pressure sodium lighting) brightness (visibility) during the day will not exist at the lower luminance.

In other words, the yellow-red light is less effective in aiding vision at low lighting levels, and so much of the light produced is effectively wasted.

Other Equipment Selection Criteria

Lamp

We have described how colour is an important factor in lamp selection. Other factors are:

- efficacy; how much electricity is required to produce the light.
- lumen maintenance; how well is the lamp efficacy maintained throughout the lamp's life.
- lamp life and reliability.
- initial cost.
- physical considerations; size, robustness, lamp holder type, etc.

Lanterns

We have already described the need for street lighting to illuminate vertical surfaces well, and this will influence the selection of lanterns. Other factors affecting the selection are:

- efficiency:

▪ light output ratio (LOR); what portion of the light produced by the lamp actually escapes from the fitting,

▪ suitable distribution of light, and

▪ control of intrusive and upward light.

- service life expectancy,
- maintenance (how easy is cleaning, lamp replacement, photo-switch replacement), and
- capital cost.

How Does the Present Street Lighting Infrastructure Rate?

Light Colour

minor roads / residential streets

In Victoria, most minor road lighting is provided by the fluorescent coated ellipsoidal mercury lamps. Its colour is acceptable, in that its spectral content is mainly at the blue end of the spectrum.

The fluorescent lanterns used to light NSW minor roads would also be biased toward the blue end of the spectrum, though because of the greater selection of tubular fluorescent lamp coatings, the light colour can vary widely.

major roads / traffic routes

In both NSW and Victoria, some major road lighting is provided by mercury vapour lamps, but the majority is provided by sodium lighting. There is also a continuing trend to replace mercury vapour lighting with sodium lighting. We strongly recommend against this move.

(Note: While we are convinced of the correctness of this stance, both by lighting science and our own observations, we understand that other people in the lighting industry will not be persuaded easily. Therefore, we believe field demonstrations will be required. This is discussed on page 21.)

Light Distribution

Vertical illumination and efficiency

The present system design and performance is a result of the concentration on horizontal illuminance. As already discussed, this is not a useful parameter by which to judge street lighting quality.

On main roads especially, providing vertical illumination while controlling glare is a balancing act. There are conflicting requirements of controlling glare, by designing the lantern light "cut-off" and illuminating vertical surfaces. Reducing lantern spacing and increasing mounting height both help, but both incur additional capital costs.

However, a reasonable portion of the light produced by most minor road lighting (mercury vapour B2224 refractor lantern or "flower pots" and fluorescent lanterns) does emit from the lantern as vertical light. However, this is not the result of sophisticated lantern design; it is the result of almost no design which allows the light to go in all directions. And light going in all directions has a cost:

- overall efficiency is reduced,
- light pollution (intrusive and upward light) is increased,

and so more electricity is required to achieve the street lighting task.

Glare

The existing minor road lanterns present a significant visual distraction in that there is either an exposed fluorescent lamp (NSW) or a high brightness refractor (Victoria) in clear view.

Upward and intrusive light

Upward light pollution makes astronomical observations more difficult, degrading the experience of both keen and casual observers. While there will also be light reflected upward from roadways and other objects, reducing direct upward light will clearly assist in reducing the problem. Also, direct upward light is wasted light, and so reduces the efficacy of the street lighting system.

The reflector based HID lanterns used on main roads do not present an upward light problem and do not normally create obtrusive light.

The refractor based mercury vapour lanterns used in Victorian minor roads, and their fluorescent counterparts in NSW produce a significant amount of unnecessary upward light.

Efficiency

Lamp efficacy - sodium vapour lighting

Sodium lighting has a high initial efficacy (lumens per Watt) and a high lumen maintenance (i.e. efficacy stays high throughout the lamp life). However, these lumens are of little real benefit if they register only on lux meters and not in peoples' eyes.

When people go out onto the streets at night, they take eyes, not lux meters

Although mercury vapour lighting has acceptable colour, its low efficacy in terms of lumens per Watt is not acceptable in today's more energy conscious world. Even when new, the efficacy of an 80 Watt mercury vapour lamp is under 50 lumens per Watt, and the efficacy will degrade continuously throughout the lamps service life.

New Technology Fluorescent Lamps

The technology of fluorescent lamps has advanced considerably since the development of the lamps now used in NSW minor roads lanterns. Even in the decade since Victoria replaced most of its fluorescent street lighting, the technology improved greatly:

- lamps with a rated life of up to 24,000 hours are now available, compared with 8,000 for fluorescent lamps of ten years ago and 12,000 for mercury vapour lamps.
- colour rendering has improved.
- efficacy has improved to as much as 100 lumens per Watt for lamps of over 30 Watts.

Therefore, judgement of modern fluorescent lighting should not be based on memories of fluorescent lamp technology of the 1960s and 1970s, or even the 1980s.

In other words, old NSW fluorescent street lighting should not be compared with modern alternatives without also considering modern equivalents of tubular fluorescent and compact fluorescent lamps. This is discussed further on page 15.

Time control

Street lighting should operate when it can make a contribution to visual amenity, and not when it can't. Street lighting control is achieved by photo-switches in Victoria and a mix of photo-switch and electricity mains signalling ("ripple control") in NSW. There is a trend to replace ripple control with photo-switch control, and we expect this trend to continue.

The *standard* street lighting photo-switch uses a cadmium-sulphide cell. This device can be installed in the casing of a single lantern or can be used to control a group of lanterns by switching the power in a dedicated street lighting conductor or "fifth wire".

The cadmium sulphide photo-switches have several disadvantages:

- they have a rated service life of only 7 years.
- they have a switch-off illuminance of three to five times the switch-on illuminance. This means that if the desired switch-on illuminance is set correctly, the switch-off time will be significantly later than needed (adding about 15 minutes[7] to the daily operating time).
- the switch-on setting is typically in the range 30 - 60 lux, which is much higher than the ambient illuminance at which the street light can make a contribution to vision. This unnecessarily adds about a further 20 - 30 minutes[3] per day to burning time.
- the switch on setting drifts by about 10% per year, causing the lights to switch on even earlier and off later. By the end of the 7 year service life, the switch-on point and switch-off point will both have doubled. Again, this will add to unneeded burning time (about another 15 minutes[3] per day, averaged over the service life of the photo-switch).
- they consume about 2 Watts when the lights are turned off. This is not a large power draw, but it is unnecessary.

There is an alternative: electronic photo-switches, which are discussed on page19:

[7] the times described in this section are indicative, being based on readings in Melbourne only, and only during May. A more definitive analysis of the effects of control changes would require further simulation and calculations, and is beyond the scope of this report. However, a more definitive study would not alter the conclusions in this section of the report.

Overall Street Lighting Assessment

Service quality

Minor road lighting (mercury and fluorescent) generally has acceptable colour and a reasonable portion of the total light is delivered as vertical illumination

Major road lighting generally has a red-orange colour which is unsuitable for night vision.

Efficiency

The efficacy of mercury vapour lamps is unacceptably low, and this is further degraded by the inefficiency of the lantern - refractor.

The LOR of most major road lanterns is acceptable, but the overall effectiveness of the lighting is low, because of the poor response of the eye to the light colour.

The lighting system is also degraded by its unnecessary operation, caused by inaccurate photo-switch control.

Potential

These shortcomings provide the potential to improve street lighting quality (safety, amenity, etc.) while also reducing financial and environmental costs. A win-win situation. The fact that these improvements can be made now, when significant capital expenditure is required anyway, makes the potential easier to achieve.

Overview of Best Practice Street Lighting

Australia and New Zealand

New Australian New Zealand Standards :

A new draft of an Australian/NZ Standard for residential areas has recently been prepared and is presently under public review. It is called AS/NZS 1158, Part 2, Pedestrian Area (Category P) Lighting. This draft differs from the old AS 1158.1-1986 in that all lighting for residential roads, pathways and circulation areas will be designated Category P, replacing the older B and C Categories.

A copy of an article by Fisher and Rogers printed in the May 1999 edition of "Lighting," Vol.19, No.3, discusses the changes from Categories B and C to Category P, and is appended (Appendix 2) for your reference. As stated by the authors in their summary, this is a major revision of the Standard in relation to lighting for pedestrian traffic.

The major change is the inclusion of a vertical illuminance parameter, but while this is a useful criterion it is also very simplistic. In our opinion the inclusion of semicylindrical illuminance (E_{hz}) would have been far more meaningful for situations involving the modelling of people. (Appendix 2 refers).

Another concern we have is that the illuminance values quoted in the table of "Values of Light Technical Parameters for Roads in Local Areas and for Pathways" are very low, and we have grave doubts as to the easy availability of photometers to accurately measure these small values.

This is particularly so because the currently used HPS lamp is strongly biased towards the orange-red end of the spectrum, while in a similar manner the metal halide lamp is strongly skewed towards its blue end. These are the colour bands in which the greatest errors will occur if a conventional photopic-calibrated lux-meter is used.

Lighting for Main Traffic Routes :

The current road lighting practice as set out in the Australian New Zealand Standard AS/NZS 1158.1.1-1997 (Category V) follows European practice rather than the IESNA (North American) methodology.

The European practice has evolved from a framework developed over many years by the Commission Internationale De L'Eclairage (CIE), much of it under the guidance of Dr. A. J. Fisher of Sydney, who is the current Chairman of the Standards Australia Road Lighting Committee LG/2.

The European Committee for Standardisation (CEN) produces European road lighting standards which also follow the CIE guide-lines, and so it would be very difficult to make any major break from the principles of AS/NZS 1158. Minor changes depending on local factors are possible, but probably not any national change.

International

This sections gives a brief description of street lighting practice and trends. A more detailed description is in Reference 5 (page 23).

North America

Summary

The trend in North America is toward street lighting standards based on performance, assessed according to the visibility of a standard small "target"[8]. We agree with this move from an assessment of lighting based on simple and inappropriate parameters such as horizontal illuminance.

Description

The current IESNA[9] recommended road lighting design method is based on the use of either illuminance or luminance[10], but this body is now developing a standard based on visibility. Of course, this means that the road lighting design aim will be more closely aligned with the goal of road lighting: to make objects visible. This is a very sensible aim, but a very big task.

With a system based on horizontal illuminance, the focal point of creating the standard is deciding on a value for that single parameter, for a limited number of situations. However, with standard based on assessing visibility afforded by the lighting system it is necessary to decide:

- which factors will affect visibility, and
- how these will be assessed and incorporated into the standard.

The factors identified by the IESNA are:

- adaptation luminance,
- contrast between target and background,
- veiling luminance,
- target size,
- observation time, and
- observer age.

These factors each hide a wide range of options. For example, observation time will clearly be dependent on the speed of the observer and the "target". And if the observer is a motorist, the greater the speed, the more warning is required, and so the target needs to be visible from a greater distance. Target size could represent a black cat, a child, an adult, a cyclist, or some other object, or could represent range of targets. Observer age is also a sweeping simplification; not everyone of the same age has the same visual ability.

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[8] "target" refers to a visual target, but given that the device represents a pedestrian, it is a poor word choice.

[9] Illuminating Engineering Society of North America

[10] please see the glossary on page 35

There are other factors which could be considered such as:

- the difficulty of the driving task (some roads present more hazards and distractions than others).
- the position(s) of the target with respect to the observer (on the road, on the kerb, etc.).

Once such a standard is written, performance of road lighting systems need to be assessed according to the standard. This can be done using:

- computational methods,
- measurement using CCD technology developed for video cameras.

Relevance

We believe that the trend towards this performance assessment based design strategy will continue in North America and be adopted in other countries. Australia needs to watch and participate in this process.

Europe

Developing European street lighting standards involves ensuring that the standards are relevant and acceptable to the member countries. Within this environment, the process focuses on producing a framework for designing lighting systems appropriate to local needs. The four main activities are:

- **classifying** the lighting situation based on factors such as:
  - weather types in that location,
  - type of road (eg. divided carriageway, number of lanes),
  - vehicle speed,
  - background visual complexity.
- deciding on the **performance** required of the lighting system for each road classification. Lighting performance for main roads is based on the silhouette principle, and horizontal luminance is still the main parameter.

  For pedestrian areas, more complex and subtle performance measures are also specified, including semi-cylindrical illuminance (see page 33) hemispherical illuminance and vertical illuminance. This is particularly relevant to some countries where very low mounting height lanterns are used, and achieving horizontal illuminance between the lanterns is almost impossible. With the trend to under-grounding of electricity cables, this will become more of a consideration in Australia.
- **calculation** methods, and
- **assessment** methods.

Street Lighting Recommendations

Equipment

Available Light Sources

The progression of electric lamps for street lighting application has broadly followed the historic development of the electric lamp. The first lamp type to be used was the incandescent filament lamp, and this was followed by the early mercury MA and MB type lamps and the low pressure sodium lamps.

Later replacement of the incandescent lamps with tubular fluorescent lamps for both main roads and residential streets was the next development, and in more recent times these fluorescent lamps have again been replaced by mercury vapour (in Victoria) in lamps of a variety of wattages, and in many main roads by high pressure sodium lamps.

The most recent developments in lamp technology, apart from the Sulphur or Induction lamps, has been in small watt metal halide and compact fluorescent lamps, but to date neither of these lamp types have had wide application in street lighting.

This wide variety of available lamps suggests that it is not unreasonable to question whether or not one type of lamp is better than another.

Comparing Light Sources

As shown in Appendix 3, there is a number of discharge lamps available which have a lumen output approximating that of the 80 Watt mercury fluorescent lamp. All of the lamps shown in Appendix 3 may be considered as long life, when compared to the life of GLS incandescent or Tungsten Halogen lamps. Both of the values; life and lumen output must be viewed with a certain degree of caution, since some manufacturers tend to be conservative in their claims in order to minimise criticism of the performance of their products, while others are more optimistic.

The technical reason for this is based on an assumption about when a batch of lamps is considered to be at the end of its life. The conservative school of thought claims the average life is when 20% of the lamp batch has failed, while the optimistic school says that this point is reached when 50% loss is noted. It is therefore obvious that the conservative group will show a shorter lamp life when compared with the latter group.

Similarly there are several methodologies used for determining the lumen output of lamps so the two groupings of conservative and optimistic are also evident here, but general consensus takes the lower (conservative) figure of approximately 3400 lumens for the average 80 Watt mercury vapour fluorescent lamp.

Each of the lamp types listed in Appendix 3 has weaknesses, as shown below :

- The single ended mercury Halide Group 1 lamps have G type bi-pin bases which do not cope well with rough service or vibration.
- The Group 2 HPS lamps in general, but especially the 50 Watt version, have poor colour renderings and tend to badly distort all colours and especially skin colourings.
- The CFL Group 4 lamps tend to be physically large, and again use pin type electrical connections which suffer from vibration unless fitted with specially designed bases to support the lamps. While this is acceptable, it makes lamp replacement a slower process.

Another lamp that has been recently introduced to Australia is the 16mm diameter tubular fluorescent lamp known as the T5. A similar 14 Watt version (549mm long) produces 1220 lumens which is approximately 10% more than that from the old 26mm, 18 Watt lamp for a lower Wattage[PM1].

The main disadvantage of the tubular lamp for street lighting is that the lumen output of the lamp is considerably reduced when the ambient temperature is low, and this could be of serious concern in Tasmania, some parts of Victoria, and in other “high country” areas under consideration. However, the 14 Watt T5 tri-phosphor lamp is understood have overcome this problem, and will soon be trialled in NSW.

Lamps for the Lighting of Residential Streets

Recommended

Considering the requirements of efficacy, colour, and life, it is our considered opinion that the most appropriate light sources for residential streets are:

- the 35 Watt metal halide lamp with a blue white spectrum, and
- compact fluorescent lamps, also with a blue-white spectrum.

The most appropriate for a given situation will depend on factors such as mounting restrictions (eg. existing poles, new installation, spacing).

A single 35 Watt metal halide lamp in a lantern with appropriate photometric characteristics will replace a standard 80 Watt mercury vapour lantern. This will result in *improved* illumination quality and a power saving of at least 54% (details on page 20).

Compact fluorescent street lighting lanterns are discussed on page 17.

Watching brief

Another lamp type which is very promising is the 50/35 Watt Osram Citylight. This is an acceptable lumen package which gives good colour rendering, good lumen maintenance, and the option to switch to a lower wattage (from 50 to 35). However, this lamp type is so new that we recommend further experience be gained with the lamp before large scale installations are contemplated. Small-scale trials however are recommended (please see page 21).

Lamps for the Lighting of Main Roads:

In general and at this time, the most commonly used ranges of lamps for main roads are the high pressure sodium or mercury vapour 250 and 400 Watt units with occasional use of the 150 Watt lamp. As shown in Appendix 3, the metal halide lamp has more than a 30% higher efficacy than the mercury fluorescent lamp and the use of this lamp would give a 30% increase of light on the road surface.

A change from mercury vapour to metal halide lighting will result in a significant reduction in energy consumption, e.g.: by replacing a 400 Watt mercury lamp lantern (19,000 lm and circuit power of 425 Watts) with:

• a single 250 W	metal halide lamp	(20,000 lm)	268 Watts total	saving 37%
• 2 x 150 W	metal halide lamps	(24,000 lm)	336 Watts total	saving 21%

The savings with a single 250 Watt lamp are higher, though there may be other advantages in using two 150 Watt lamps, either in a single lantern or as two single-lamp lanterns, such as:

- more even illumination,
- less glare, by facilitating closer lamp spacing or greater mounting height and greater light "cut off",
- simple "lumen set-back" by switching one lamp,
- greater reliability, as half lighting will be available in the event of one lamp failing or the arc extinguishing.

Lanterns for Lighting Minor Roads

Metal halide

We have modelled the performance of an efficient minor roads lantern based on photometric test results for a GEC / SLI[11] brand "Urban Minor" model lantern. This shows that the combination of this lantern and a 35 Watt metal halide lamp will produce better illumination than the present GEC model B2224, 80 Watt mercury vapour lantern which is used throughout Victoria.

Compact fluorescent

In order to select a lamp configuration for minor roads, we have relied on first principles. The calculated results can then be used as a "market pull" to encourage manufacturers to supply appropriate lanterns. Given the size of the market and discussions with manufacturers, this approach should be successful.

[11] Sylvania Lighting Industries

What light output is required from the street-light's lamp(s)?

The required lamp light output can be calculated by:

- starting with the light output of present street lighting lamps, and
- reducing this figure according to the higher efficiency of modern street lighting fittings in delivering the light from the lamps to the area requiring illumination.

Light produced by an 80 Watt mercury vapour lamp	**3400 lm**
The existing minor roads lanterns using a refractor glass diffuser with inherent light loss, and an overall indicative LOR of	**60%**
And so the amount of useful light which leaves the lantern is 3400 x 60%	**2040 lm**
We expect a modern, efficient lantern with a clear lens and efficient reflector to have a LOR of:	**80%**
And so the next generation of minor roads lanterns will require a lamp output of: 2040 lumens divided by LOR of 80%	**2550 lm**

Referring to the table in Appendix 3 (page 30), at the lowest power, a suitable fluorescent lamp for a lantern to directly replace the current 80 Watt mercury vapour, is a single 36 Watt compact fluorescent lamp (2800 lumens).

Lanterns for Lighting Main Roads

Because of relatively small changes in lamp technology in recent years, there has been only a small change in the development of lanterns for main road lighting.

Similarly there are only a limited number of suppliers in this country at present, but perhaps if restrictions were eased there could be a market opened up to overseas suppliers, some of whom have already shown interest.

Ballasts

Street lighting should use electronic ballasts, because of the higher efficacy and the lengthening of lamp life. However, there are no reasonably priced and readily available electronic ballasts available for discharge lamps. This is a chicken and egg situation: suitable electronic ballasts are not available because there is insufficient market demand, and the demand is low because of pricing and product availability. Pricing is also directly related to sales and production volumes.

The large scale re-equipping of minor roads street lighting in NSW and Victoria brings the opportunity to overcome this barrier. We recommend that SEDA and EEV facilitate a local manufacturer to equip for the volume production of electronic ballasts to suit the compact fluorescent and HID lanterns described in the preceding pages.

Lighting Control

Electronic (also called solid "state") photo-switches with silicon diode sensors are preferable to cadmium sulphide cells (described on page 10) because they:

- have a rated service life of 12 years, reducing both labour and vehicle costs, and improving lighting system reliability.
- have a switch-off illuminance which is independent (including lower than) the switch-on illuminance.
- are available with a standard switch-on settings of 10 lux, reducing lighting times by about 20 minutes per day compared with a 30 lux level. Further, a lower switching level could be ordered for purchases of large batches.
- have a switch on setting which is stable over the life of the photo-switch.
- consume negligible power.

Electronic photo-switch cost - benefit

The maintenance savings alone justify the price premium of electronic photo-switches. Assuming that replacing a photo-switch costs $70 ($50 for truck and labour, $20 for call centre, purchasing and other administrative costs), the annual cost of standard and electronic photo-switches is:

Photo-switch Type	Initial Cost	Life	Total replacement cost	photo-switch maintenance cost
	$	years	$ each time	$/year
Standard	$9	6	$79	$13.17
Electronic	$15	12	$85	$7.08

So electronic photo-switches are justified even without considering the benefits of energy savings and increased lamp life.

An electronic photo-switch will reduce lantern burning time by an hour per day, and so will increase the interval between lamp replacement by about 10%.

System Costs and Benefits

Minor roads

The following is a comparison of the costs and benefits of a standard 80 Watt mercury vapour street lantern and the proposed 35 Watt metal halide light:

		Before	After
Fitting		B2224	"Urban Minor"
Lamp type		mercury vapour	metal halide
Capital Cost		$65	$80
Photo-switch upgrade		$0	$6
Ballast upgrade		$0	not included or estimated[12]
Total capital cost		$65	$86
Lamp	Watts	80	35
Ballast	Watts	16	8
Circuit Power	Watts	96	43
Energy Use			
Burning time	hours/year	4,335	4,000
Lantern	kWh/year	416	172
Photo-Switch	kWh/year	9	0
Total	kWh/year	425	172
Reduction in energy use		n/a	60%
Energy cost / year	$/year	$34.00	$13.76
Energy Saving	$/year		$20.24
Maintenance			
Initial cost premium ##			$15.00
Annual return on initial premium	% p.a		74%

Appendix 4 shows that the Urban Minor also delivers more even illumination than does the B2224.

Notes:

We have estimated a medium term electricity price (weighted average peak and off-peak) of 8 cents / kWh, including energy and DUOS and NUOS charges. This differs from the IPART approach of assigning a value to each component (Reference 2).

The cost premium does not include the additional cost of an electronic photo-switch, as this premium is already justified by the lower cost of maintaining the photo-switch.

We have not included the benefit of longer effective lamp life. The mercury lamp has a shorter ***effective*** life than a metal halide lamp, because it will reach an unacceptably low efficacy sooner. Of course, the mercury lamp could be left in service for longer than a metal halide lamp, as it will often last many years without fading completely. However, it's light output at that time will be unacceptably low and the quality of street lighting unacceptably poor.

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[12] The price will be very dependent on production volumes and the street lighting market could change the production volume significantly. There is the potential to reduce electronic ballast prices sharply with street lighting projects.

Implementation

We do not expect or anticipate that this brief overview will, by itself, dramatically change Australia's one billion dollar a year street lighting industry. Indeed, we expect that our conclusions will be challenged by many people in the industry, and we hope that this will prompt further discussion and exploration of what the community expects of street lighting, and how this can best be achieved.

We are aware of at least some undertakings which will assist this process:

Field Trials

We strongly recommend that field trials of various street lighting lanterns be conducted with the cooperation of suitably interested electricity distribution businesses and local government. Such trials will serve to:

- allow people to judge street lighting with their own eyes,
- provide an opportunity for innovative manufacturers to demonstrate their wares,
- refine new hardware, including modifying design with the aim of minimising installation time, etc
- render tangible some of the abstract concepts described in this report, and so democratise the process of developing new street lighting systems by facilitating comment by lay people as well as lighting professionals,
- facilitate the involvement of appropriate groups (eg. IESANZ, road safety and research, electricity industry, local government, Standards Australia, etc).

Similar trials / demonstrations were conducted in Sydney in the 1960s, and were known as the "Beecroft Road experiments".

Industry Facilitation

We recommend that EEV and SEDA consider facilitating Australian industry's development of efficient street lighting lanterns which "push the envelope". This need not be an expensive undertaking, indeed we do not recommend any direct subsidy. Instead we envisage acting as a catalyst, by bringing together potential equipment purchasers (local government and electricity distribution network companies) and manufactures, to form buying contracts and volumes which will make the energy efficient equipment viable for both groups.

Representation on Standards Committee

We believe that EEV and SEDA should lobby Standards Australia to influence a future revision of AS/NZ Standard 1158.

Further Investigation

The Installation of Lighting Systems :

Currently roadway lighting systems are very stereotyped and there appears to be very little room to move as far as change is concerned.

Some common European practices such as Catenary lighting[13] have never been adopted in this country, and we would suggest that it might be time to revisit this particular methodology.

With the easy availability of large Elevator Platform Vehicles the opportunity for greater mounting heights and wider spacing of lanterns is now possible, and we believe that these should certainly be considered. Obviously this practice would reduce the number of poles/lanterns required per kilometre, and so achieve a greater saving of energy. The appearance of the urban streetscape could also be enhanced.

Since few manufacturers presently produce lamps with a Wattage of between 400 and 1000 Watts, the use of multiple heads of lamps eg. 3 x 250 Watts or 2 x 400 Watts may be worth considering.

In our opinion, opportunities for savings in energy and capital installation costs will come through the reduction of the number of poles and lanterns provided in any given installation. This concept can be achieved by significantly increasing the presently used mounting heights of the lanterns, and we believe that this recommendation should be fully explored.

Hardware Choice

In current practice the number of types of lanterns used is restricted on the grounds of limiting the number of spares to be held in store. Similarly HPS and MV lamp types and their Wattages have been restricted to a narrow range in the pursuit of standardisation.

While these policies may have had some justification in a large organisation as seen in the older State Electricity Commission, we believe that in the smaller organisations in vogue today in the form of the Distribution Businesses, greater flexibility should be possible.

Distribution Businesses claim to have policies with regard to added service and value adding, so the general public should therefore be able to expect better quality service and more evident concern regarding environmental protection and the need for the conservation of energy.

Demonstration of these concerns could be shown by the purchase and use of better quality photoelectric daylight switches for use with the present lanterns, so as to avoid their burning long after they are required.

It is hoped that with contestability will come not just choice by price or tariffs, but also the offering of a wider choice of equipment in such things as lamps and lanterns. It is also hoped

[13] *Catenary lighting* means lighting provided by lanterns attached to a horizontal suspension cable.

that this contestability will bring about a reduction in maintenance costs and an improvement of services offered to the general public.

Maintenance :

We understand that the decision as to who is to be responsible for the maintenance of the public lighting system has not been made and is still under discussion. In the years following World War 2 the street lighting administration for the Melbourne metropolitan areas was centralised at the Rooney St Richmond Depot, and patrolling officers from this depot were responsible for the maintenance of this system.

It is clear that this system has now gone forever, but given the importance of street lighting within the community it is essential that a similar service level should be resumed. If the general public was encouraged to report malfunctions of the system to a toll free telephone number, surely in these days of the all embracing computer a return to such a service level should not be too difficult.

References

1 Electricity Supply Association Australia "*Electricity Australia 1998*"

2 Coopers & Lybrand in association with Worley Consultants "*Report to IPART on Street Lighting Review*" March 1988

3 Australian / New Zealand Standard AS/NZS 1158.1.1, 1997 Public Lighting

4 Energy Efficiency Victoria, Report: *"Street Lighting and Contestability"* Author Paul Rogers, January 1999.

5 Lighting Magazine, September 1998, Article *"Lighting for Safer Roads on Three Continents"* pp 40-45. Lewin, Simons and Grundy

Appendix 1: NSW Fluorescent Lanterns

Lantern inventory

According to Reference 2, the number of fluorescent street lighting lanterns under the control of the NSW electricity distributors is:

Electricity Distributor	Advance Energy	Australian Inland Energy	energy Australia	Great Southern Energy	Integral Energy	North Power	Total
Total Lanterns	30,612	3,089	343,850	38,566	173,379	60,493	649,989
Fluorescent portion of total lanterns	43%	56%	69%	40%	57%	51%	61%
Fluorescent lanterns	13,163	1,730	237,257	15,426	98,826	30,851	397,253

The fluorescent lanterns are programmed for replacement now. If NSW adopts the same solution to fluorescent lantern replacement which Victoria took, the capital and recurring costs will be about:

Capital cost

		Cost each	Total
Fluorescent lanterns			397,253
Replacement lantern cost	(e.g. B2224 MV 80 Watt)	$65	$M 25.8
Installation cost	(Labour, truck, etc).	$100	$M 39.7
Total cost,	supply and install	$175	$M 65.5

Recurrent cost

Based on replacement of each fluorescent lantern with an 80 Watt mercury vapour fitting (circuit power 100 Watts), the recurrent energy consumption and total cost using recommended (Reference 2) IPART electricity pricing would be:

Distributor		Advance Energy	Australian Inland Energy	energy Australia	Great Southern Energy	Integral Energy	North Power	Total
Fluorescent lanterns		13,163	1,730	237,257	15,426	98,826	30,851	397,253
Installed demand, based on 100W each	MW	1.32	0.17	23.73	1.54	9.88	3.09	39.7
Energy use, based on 4000 hr/ yr	GWh/yr	5.27	0.69	94.90	6.17	39.53	12.34	158.9
Lighting Charge	$/MW.h [14]	$210	$210	$210	$210	$240	$240	
Annual Charge	$M/year	$M1.11	$M0.15	$M19.93	$M1.30	$M9.49	$M2.96	$M34.9

[14] The NSW street lighting cost recovery method converts all fixed and operating costs to an "equivalent" charge per unit of energy consumed. While the project team does not agree with this methodology, it is used here for consistency.

Appendix 2: Magazine Article, New Street Lighting Standard

The following article is reproduced, with permission, from the May 99 edition of "Lighting" magazine.

Lighting for Pedestrians as You Have Never Known it Before

Alec Fisher FIES and John Rogers***

This paper deals with the draft major revision of the Standards for the lighting for pedestrian movement in local roads and public areas by highlighting the differences between it and the previous Standards and the implications to designers and luminaire manufacturers. Discussed are:

- the large number of situations covered,
- the introduction of specific criteria to be considered in the selection of a lighting category,
- the large number of lighting categories by virtue of the above,
- the introduction of the light technical parameter vertical illuminance (Ev) and
- the introduction of environmental parameters.

The stage is set for design skills to be applied, for closer links between client and designer, for the marketing of attractive but efficient luminaires with high DLOR and tailored light distributions — in all another area where the lighting industry can say we are really in front!

A Standard that is different

Those used to AS1158.1-1986 and NZS6701:1983, as their basis for the lighting of residential roads and associated areas, will find the new, draft, AS/NZ 1158 Part 2: *Pedestrian area (Category P) Lighting* a very different beast — except for those who will still be content to install a twin 20W fluorescent or a 50W HPM luminaire on every other reticulation pole!

Figure 1. A footpath beside a traffic route with supplementary under-awning lighting.

* FIES and Chair SA Road Lighting Committee LG/2, E-Consultancy;
** MIES and Member SA Road Lighting Committee LG/2, GEC Lighting.
Paper presented at the 43rd IES Annual Convention, Brisbane, November, 1998.

The first difference is that *all* lighting for residential roads, pathways and areas where pedestrians circulate is designated Category P (replacing the old B and C categories). This emphasises that the design precept for the lighting for these situations is *primarily* to facilitate pedestrian, not vehicular, movement (if you wish to design for vehicles on traffic routes you need to refer to Category V) — see Figure 1.

The other differences are:

- the large number of situations covered,
- the introduction of specific criteria to be considered in the selection of a lighting level or category,
- the large number of lighting categories by virtue of a) and b),
- the introduction of the light technical parameter vertical illuminance (Ev) and

Figure 2. This stairway has good definition of the risers.

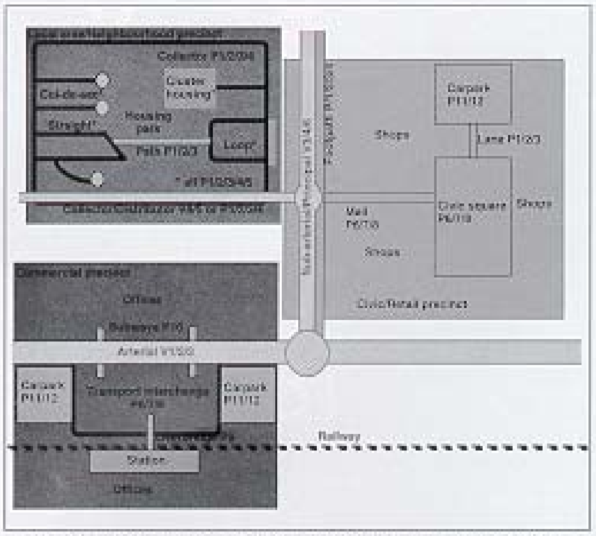


Figure 3. An illustration of the road/area types and indicative lighting categories (from the public draft document).

Figure 4. A pedestrian mall lit to P1 standard with a high vertical illuminance.

- the introduction of environmental parameters.

These and the implications to lighting design are discussed in the relevant sections below — one implication is that the success of P lighting will, indeed, be dependent on the skills of the lighting designer and the luminaire manufacturer.

Situations for lighting

We have tried to cover most situations in the modern urban scene, viz:

- roads in local areas; basically residential including cluster housing;
- pathways not forming part of a local road; walkways, lanes, park paths and cycle paths and, in some instances, footpaths along arterial roads;
- public activity areas; outdoor shopping precincts, malls, town squares, civic centres, transport terminals and interchanges (this is an instance in which vehicular movement is taken into account);
- connecting elements; steps (see Figure 2), ramps, footbridges and subways; and
- outdoor carparks.

These situations are linked together, diagrammatically, for an urban area in Figure 3; note the relation between Category P and V situations. See also Figure 4.

Criteria for lighting level

As well as the usual criterion of level of traffic, two other criteria have been introduced: *fear of crime* and *enhance prestige* in response to current community needs. Both, however, require large increases of light levels necessary to achieve the objective; the Standard indicates to designers (and clients) these levels and a method of evaluating the requirement.

Table 1, a representative Table adapted from the Standard, shows the three selection criteria. The selection criteria of columns should be evaluated separately: the *highest occurring level* taken over the three criteria determines the necessary lighting. Note the rest of the format - there is a general description and basic operating characteristics of the situation to which the Table refers as an aid for the designer in the selection of the most appropriate Table for their situation.

Consider a situation here involving, say, a formed path through a small park which offers a short cut between a railway station and a housing unit development. The following apply:

Potential pedestrian activity	*medium*	(desire for commuters to take shortest way home)
Fear of crime	*medium*	(suburban location but adjacent to station plus isolated route through the park)
Need to enhance prestige	*N/A*	(lighting not required to showoff park)

The necessary lighting will be Category P2 which is determined by the level of the criterion *fear of crime*. Note that this criterion generally requires the higher levels of lighting for its amelioration and that reducing fear or the perception of crime is important, as well as, of course, actual crime, in community action programs.

The example shows that there is need for much initial input from the client and a continuing client/designer interaction at the design stage in order to both achieve the client's aspirations but also to understand the implications in terms of the necessary lighting involved.

Lighting categories

To cover the operating characteristics of all the situation and the criteria there are twelve lighting categories or levels P1 to P12. These levels (in minimum initial average horizontal illuminance) range from the 0.7 lux of P5 (the lowest level for local roads) to 50 lux of P12 (carparking spaces for the disabled). The values are based on CIE and British Standards and, of course, Australian/New Zealand practice and appraisals and

Table 1. Lighting categories for pathways (not forming part of a local road)

Type of pathway		Selection criteria			
General description	Basic operating characteristics	Pedestrian/ cycle activity	Fear of crime	Need to enhance prestige	Applicable lighting category
Pedestrian or cycle oriented pathways*	Pedestrian/ cycle traffic only	N/A High Medium Low	High Medium Low Low	N/A High Medium N/A	P1 P2 P3 P4

* *including those along arterial roads, walkways, lanes, park paths, cycle paths.*

measurements carried out by the drafting Committee.

For continuity the Categories P4 and P5 are equivalent to B1 and B2 of AS1158.1-1986, although P5 is not now recommended for general application and may only be selected where the lighting system utilises reticulation poles. The lighting for these two categories apply across the whole road reserve width whereas the higher Categories P1, P2 and P3, based on the criteria *fear of crime* and *need to enhance prestige*, apply only to the designated, formed footpaths because of the higher lighting levels involved.

The uniformity of illuminance is secured by restrictions on the minimum and maximum illuminances; this is illustrated in Table 2. Note that, as is usual in the road lighting standards, design is based on *initial* values together with a maintenance regime, to ensure that in-service values do not fall below 0.7 the minimum initial requirement.

Vertical illuminances

All lighting categories, except P4 and P5, have a requirement for Ev as in Table 2. This because the lighting that will satisfy the criteria *fear of crime* and *need to enhance prestige* must have a large vertical component to illuminate persons, especially faces, and other vertical surfaces in the particular situation. Note the minimum E_v requirement at a point is the same as that for horizontal illuminance.

Unlike horizontal illuminance E_v can involve many differently oriented planes; to make the design manageable but whilst still essentially fulfilling the basic requirement, provision of E_v is representative, designated planes and at one height only is required. For paths, the plane is set facing the direction of travel along the path; see Figures 5 and 6.

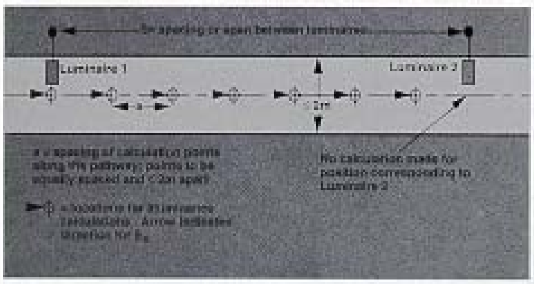


Figure 5. The calculation points for a narrow pathway.

For public areas calculations involve both sides of a vertical surface at each grid point, the plane being in *any* selected, but uniformly adopted, orientation. The intention here is to ensure that light reaching a given point will come from several widely divergent directions, which should ensure reasonable modelling of persons.

For both Eh and E_v the Standard specifies the grids of test points to be used; normal area lighting software can be readily employed (except for Categories P4 and P5 where the custom designed software is needed). Test data is provided for the designer to test the veracity of, at least the basic algorithms, the software.

Environmental parameters

Currently the worth of lighting is appreciated but more so if environmental factors are attended to, with the same diligence as the provision of illuminance.

Glare Control —This is achieved, as previously, by the specification of maximum values of intensity or luminance in given directions, appropriate to the luminaire type. In the tables of the values of the light technical parameters, such as Table 2, is included the types of luminaire that can be used in a given situation. Notice has been given that it is proposed that the glare control for Type 4 luminaires (the type now being used for general local road lighting) be tightened at a later date.

Figure 6. A pedestrian pathway lit to P1 standard by modern luminaires with good glare control and low UWLR, producing high vertical and horizontal illuminances on pedestrians and the pathway.

Table 2 Values of light technical parameters for roads in local areas and for pathways

Lighting category	Light technical parameters: Minimum average illuminance ($\bar{E}$) lx		Minimum initial illuminance at a point (E_{min})	Maximum illuminance uniformity, i.e. ratio $E_{max}/\bar{E}$	Minimum initial vertical illuminance (E_v)
	Initial	Maintained	lx	(U_p)	lx
P1	10	7	3	10	3
P2	5	3.5	1	10	1
P3	3	2	0.6	10	0.6
P4	1.5	1	0.2	10	N/A
P5	0.7	0.5	0.1	10	N/A

Figure 7. This shows what not to do in a carpark, with strong shadows from the single-direction lighting. The new standard requires lighting from two, opposed directions.

Upward Waste Light — The amount of light emitted by luminaires is controlled by specified maximum values of UWLR. This is because it has been established that P lighting makes a large contribution to urban sky glow because of the sheer number of luminaires involved.

Spill Light — The lighting system should be designed to limit, in general, the spill light into neighbouring residential properties. For roads with P4 and P5 lighting and where the building setback is greater than 10m from the property line Ev on the building facade shall not be greater than 1 lux. Where the setback is equal or less than 10m there is no specified requirement because of lighting design problems.

Where the lighting is to Categories P1, P2 or P3 again there is no specified requirement since the higher light levels will be generally installed to meet a community need, e.g. for security. On the other hand lighting installed in public activity areas, e.g. to P11 in carparks, must comply with the relevant provisions of AS4282 (see Figure 7).

Manufacturers will be required to supply data on these environmental parameters in a specific format in order that designers can readily access the merits of luminaires on offer.

Summing up

What we have seen is a major revision of the Standard for lighting for pedestrian traffic, as took place for vehicular traffic a decade ago — this attention is entirely warranted when one considers that P lighting accounts for half the outlays on lighting for our roads, current community aspirations for good lighting and the desire of designers to have an authoritative and comprehensive basis for design.

We have tested aspects of the Standard and we have seen on-paper and installed designs for the higher P categories with attractive, efficient luminaires at S/H ratio down to 3:1, we are confident that the new Standard will "work".

The stage is set for design skills to be applied, for closer links between client and designer, for the marketing of attractive but efficient luminaires with high DLOR and tailored light distributions — in all another area where the lighting industry can say we are really in front!

Appendix 3 Lamps Comparison

Lamps for minor roads / residential streets

Group Type & Nomenclature		Power (Watts)	Brand (example)	Output (lumens)	Efficacy (lm/Watt)
1. Mercury	MBF/U	80	Osram	3400	42
			Thorn	3850	48
2. Metal Halide	a) Single End HCI	35	Osram	3400	97
	b) HQI	70		5500	79
	c) City Light DS	50/35		4500 / 2500	90 / 71
		80/50		6100 / 3400	76 / 68
3. High Pressure Sodium	a) NAV 50	50	Osram	3500	70
	b) NAV 70	70		5600	80
	c) NAV 50 Super	50		4000	80
	NAV 70 Super	70		5000	71
4) Compact Fluorescent Lamps	a) DULUX T	26 (2 x 26)	Osram	1800 (3600)	69
	b) DULUX T/E	42		3200	76
	c) DULUX F	36		2800	78
5) Tubular Fluorescent Lamps	a) Standard 26 mm diameter	18	Osram	1100	61
	b) tri-phosphor "T5" 16mm diameter	14	Osram "lumilux plus"	1220	87

Appendix 3 Lamps Comparison (continued)

Lamps for major roads / traffic routes

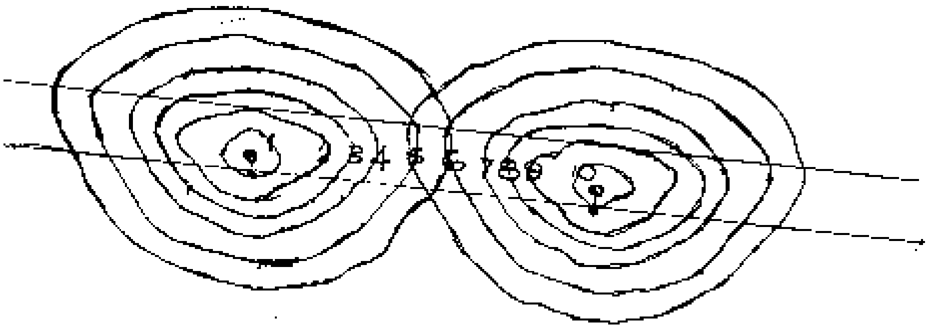
Group Type & Nomenclature	Power (Watts)	Ellipsoidal Lamp Output (lumens)	Ellipsoidal Lamp Efficacy (lm/Watt)	Tubular Lamp Output (lumens)	Tubular Lamp Efficacy (lm/Watt)
1. Mercury Deluxe	250	14,000	56		
	400	24,000	60		
2. Metal Halide (Coated)	250	19,000	76	20,000	80
	400	32,000	80	42,000	105
3. High Pressure Sodium	250	25,000	100	30,000	120
	400	47,000	117	54,000	135

Appendix 4: Comparison of Two Minor Road Lanterns

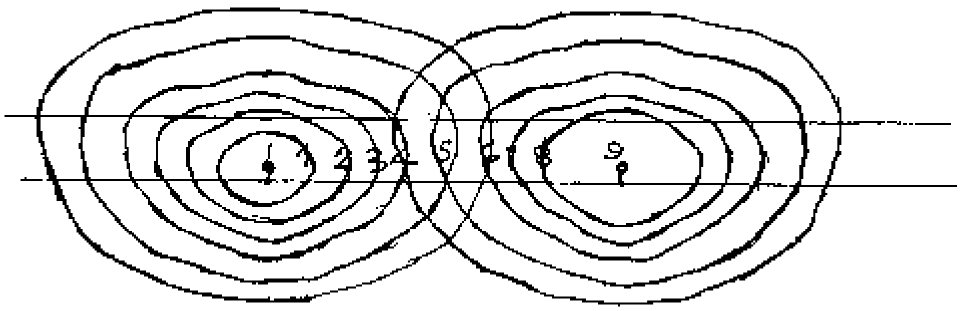
The following charts show the calculated isolux plots for two street lighting lanterns using the same lamp and the same spacing. The lanterns are:

- the B2224 "flower pot" which is the standard minor roads lantern in Victoria, and
- the "Urban Minor"

B2224



Urban Minor



The comparison shows that the Urban Minor provides more even illumination.

Appendix 5 Semi-Cylindrical Illuminance:

In 1992 the CIE published a document entitled “Guide to the Lighting of Urban Areas”, Publication No.92. This recommends that semi-cylindrical illuminance be the preferred light technical parameter to adequately illuminate vertical surfaces, and in particular, the human face.

Semicylindrical illuminance is also the preferred parameter in some Nordic countries where lanterns with low mounting height or bollards are extensively used. These types of lanterns tend to have a poor distribution of horizontal illuminance, but quite satisfactory vertical illuminance.

Earlier studies undertaken in Russia and more recently in Australia, have shown that semi-cylindrical illuminance is a much more acceptable indicator than horizontal or vertical illuminance of the adequacy of lighting in non task areas such as public spaces, railway stations and public buildings.

We believe that this matter of vertical illuminance versus semicylindrical illuminance as indicators for the true modelling of the human body and in particular the human face, should be taken up with Standards Australia. Perhaps it should be considered by a joint meeting between the Standards Australia Technical Committees LG/1 and LG/2. Should you wish us to be a contributor to such a meeting we would be happy to oblige.

A Personal Note from Kevin Poulton.

I have taken a great interest in alternative illuminance parameters since the early 1960s when the late Dr A. Dresler introduced mean spherical illuminance to us as his students at the RMIT. This was a concept which he developed as an alternative to horizontal illuminance during his research days at the Berlin University in the 1930s. In the 1960s the Russian researcher M. M. Espaneshnikov published extensively on the application of the parameter, mean cylindrical illuminance and showed that it was a more adequate indicator for revealing the true shape of the human form than either horizontal or vertical illuminance. Later in the early 1980s Stockmar and Haeger published an article on a calculation method for half or semi cylindrical illuminance and this has since been adopted by both the Danes and the Dutch for sports lighting and the lighting of pedestrian areas.

During the preparation time of the 1990 edition of AS1680, Interior Lighting standard I carried out a series of studies to discover what was an acceptable value of ambient light in non task interior spaces. Using mean semi cylindrical illuminance as the main parameter I found below 100 lux was too low and above 700 lux was too high. Unfortunately the Standards Committee would not accept this study and went back to the conventional parameter of horizontal illuminance.

Thus historically there has been much research and support for the concept of cylindrical illuminance but for some unexplained reason the Western world has been reluctant to adopt this concept.

The difference between semi cylindrical and vertical illuminance is a subtle one, semi cylindrical illuminance has a significant “side lighting” effect which the vertical illuminance has none. Semi cylindrical illuminance brings out the roundness, the three dimensionality of the human form. It is easy to calculate and to measure.

Theoretically any visual environment has two components of illuminance, that is, there is a direct component and an indirect or diffused component. The direct component come directly from the lantern/s. The second component is the diffused component which is reflected from adjacent surfaces or objects. In many interior spaces the diffused component is equal too, or approaching the direct component, hence shadow patterns are very soft or even non existing. However, in most exterior situations the diffused component is often negligible or approaching this, hence as a consequence the dominant illuminance is very directional and thus the strength of the light and shadows patterns is very noticeable.

Vertical illuminance values are very dependent upon the orientation of the subject, especially the human head, with respect to the light source. This means that the vertical illuminance of one face of a cube will be very high but on another face at ninety degree rotation could be approaching zero. Yet these readings do not necessarily reflect the visual reality. In the case of the human face, vertical illuminance does not take into account the roundness of this object.

Appendix 6: Glossary

Key lighting terms

The following key terms used in the report are arranged in a logical (rather than alphabetical order)

lantern	the term traditionally used for a street lighting luminaire, i.e. a complete "lighting fitting" including the lamp, lamp holder, body, lens / diffuser, and control components including ballast, power factor correction, and possibly photo-switch.
illuminance	a measure of the amount of light flowing from a light source incident on a given area. expressed in lux, where 1 lux = l lumen per m^2 .
horizontal illuminance	the illuminance measured by a meter in the horizontal plane, facing directly up. This gives an indication of how much light is falling on a horizontal surface.
vertical illuminance	the illuminance measured by a meter in a vertical plane, facing in a specified direction. This gives an indication of how much light is falling on a vertical surface.
semicylindrical illuminance	please see explanation in Appendix 4
luminance	a measure of the amount of light reflected from an object, and so is dependent on both the amount of light incident upon it (illuminance), characteristics of the incident light (eg. colour) and the reflective properties of the object (colour, gloss, surface texture).
brightness	a term to describe the apparent or perceived amount of light on an object, and so is dependent on: • the illuminance incident on the object, • the luminance of the object, • glare, contrast, and other environmental factors, • the position of the viewer, • the viewer's adaptation to the ambient light, • the quality of the viewer's vision. Brightness is subjective as well as being influenced by measurable parameters.
glare	Unwanted light; light which interferes with vision or visual comfort.
LOR	Light Output Ratio. The portion of the light produced by a lamp which escapes from the lantern, expressed as a percentage.

Appendix 7: About the Authors

Geoff Andrews

Geoff is the founder and Engineering Manager of Genesis Automation, a company specialising in reducing energy consumption while improving the of the energy services delivered. He has specialised in the implementation of energy saving projects, including overcoming the practical and institutional barriers which often impede the full achievement of energy efficiency opportunities.

These services have been applied in a wide range of organisations including many local governments, government, commercial and industrial customers.

Before Genesis Automation, Geoff worked as an in-house energy manager and then as an energy efficiency consultant.

Kevin Poulton

Kevin is well known in the lighting industry, both as a professional lighting practitioner, a teacher, researcher, and a leading light in the Illuminating Engineering Society of Australia and New Zealand.

He has qualifications as both an architect and an electrical engineer.

Kevin is the founder of LightLab International, an Australian independent photometric laboratory and consulting company providing services and equipment to many local and international clients. This role includes designing and testing luminaires.

His street lighting design experience includes working for the SECV[15] as a street lighting designer.

[15] The former State Electricity Commission of Victoria.

