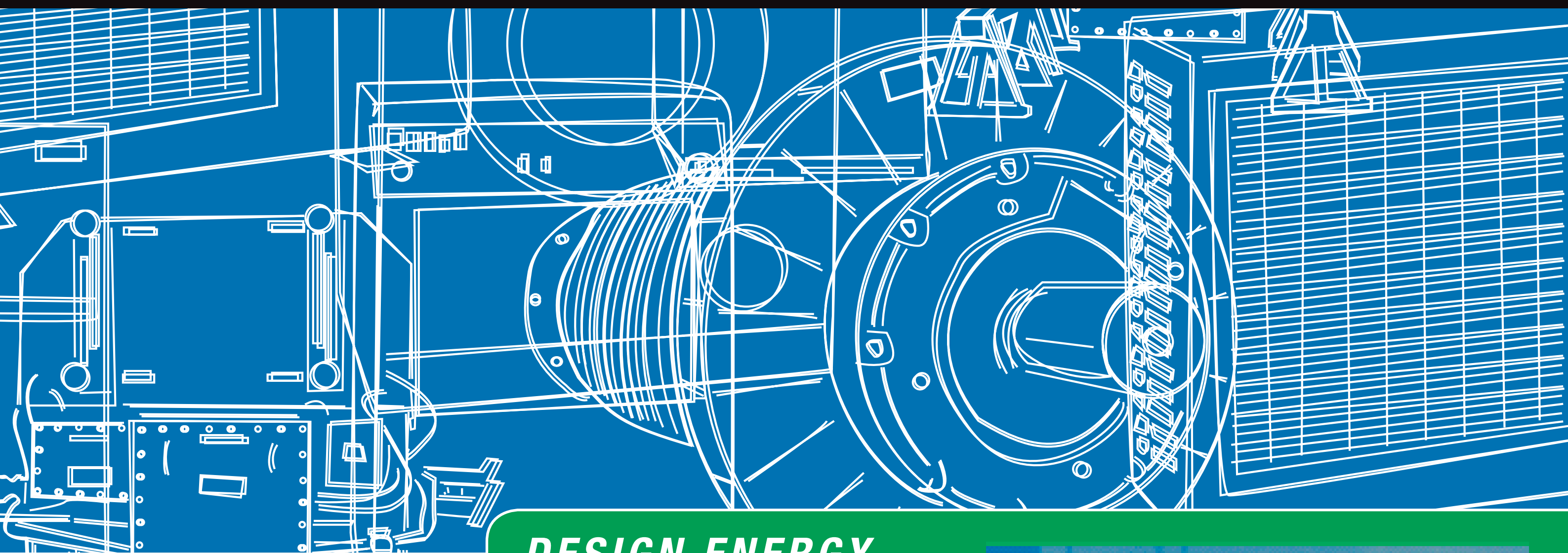
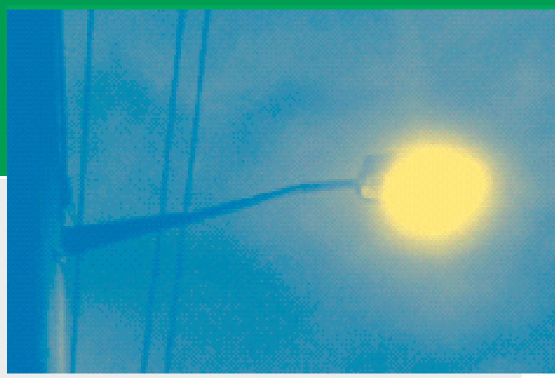
Report No: 2005/18

NATIONAL APPLIANCE AND EQUIPMENT ENERGY EFFICIENCY PROGRAM

Minimum Energy Performance Standards



DESIGN ENERGY LIMITS FOR MAIN ROAD LIGHTING



AN INITIATIVE OF THE MINISTERIAL COUNCIL ON ENERGY FORMING PART OF THE NATIONAL FRAMEWORK FOR ENERGY EFFICIENCY AND NEW ZEALAND ENERGY EFFICIENCY AND CONSERVATION STRATEGY

Minimum Energy Performance Standards - Design Energy Limits for Main Road Lighting

Greenhouse gas emissions from main road lighting (category V lighting as defined in AS1158.0) are estimated at around 0.61 Mt CO_2e p.a. A holistic approach is required to achieve energy and greenhouse gas savings from main road lighting, in order to encourage appropriate technology choice as well as good design practice. Hence NAEEEC's objective is to develop a 'design energy limit' for main road (category V) lighting. Based on reactions to this proposal, NAEEEC will consider expanding its activities to include category P (pedestrian) lighting at an appropriate time in the future.

NAEEEC understands that main road lighting luminaires represent around 30% of the estimated 1.9 million total road lighting luminaires. The vast majority of main road lighting installations are based on one of the following high intensity discharge (HID) lamp systems:

> High pressure sodium lamps, which are very efficient (~100 lumens/watt), with a yellowish appearance and poor colour rendition. They exhibit long life characteristics and remain very popular for road lighting where colour is not critical, such as for main roads.

> Metal halide lamps, which have reasonable efficacy (~75 lumens/ watt), with excellent colour rendering properties. They emit a white light with a strong blue-green component which is good for night vision. Early models had short lifetimes and rapid lumen depreciation, but recently have improved in these areas and continue to do so.

> Mercury vapour lamps, which have poor efficacy (~45 lumens/watt), with fair colour rendering characteristics. They emit a bluish light which is advantageous for night vision. Their light output decreases significantly with age and as a result installations are often over-designed to compensate.

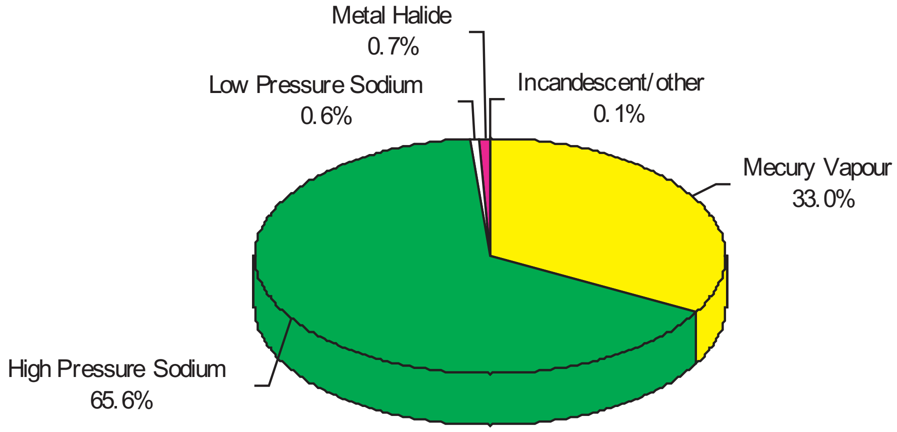
The estimated breakdown of the lamp types used in main road lighting is illustrated in the figure on following page.

STAKEHOLDER COMMENT

NAEEEC invites comments from any interested person or organisation on the measures proposed in this study. Comments should be directed to energy.rating@deh.gov.au by 30 December 2005. Information sessions for industry participants can be arranged during the comment period if requested

Electronic copies of profiles and full reports released for public discussion can be obtained from www.energyrating.gov.au.

Main road lighting lamp types



In recent times there has been a trend to replace inefficient mercury vapour lamps with high pressure sodium lamps on main roads, although mercury vapour lamps are currently still installed in around one third of main road lighting luminaires.

NAEEEC believes there to be potential to reduce the energy consumption of main road lighting using the following two mechanisms:

> Accelerating the replacement of mercury vapour lamps with high pressure sodium lamps on main roads.

> Making incremental improvements to main road lighting efficiency, by ensuring that efficient lamps, ballasts, luminaires and best practice lighting design are all utilised.

NAEEEC considers that a design energy limit would be an appropriate tool to achieve these outcomes for new and existing main road lighting installations.

DESIGN ENERGY LIMIT

A design energy limit will encourage energy efficient practice in main road lighting, whilst allowing a degree of flexibility for lighting designers. It would favour the most efficient lamps, control gear and luminaires, as well as optimum lighting distribution and design geometry. A similar approach to this is currently adopted in the VicRoads Traffic Engineering Manual.

As part of the design energy limit process, the lamp power consumption of a proposed main road lighting installation will be calculated and expressed as total lamp power consumption per linear metre of roadway (watts/metre). New main road lighting installations shall meet a 'mandatory maximum' design energy limit, which has been set to allow them to continue to meet the optical parameters in AS1158. Furthermore, specifiers may opt for an installation to meet a 'high efficiency' limit which is more stringent than the mandatory maximum, thereby delivering additional energy savings.

In addition to the lamp design energy limit requirement, the lamp ballasts will also have to meet maximum loss requirements, which are currently already specified in AS1158.6 (although these are not currently mandatory).

The lamp power design energy limit will apply to the majority of category V lighting applications, with the following exclusions: curves, pedestrian crossings, complex illuminance lighting designs such as isolated intersections, special circumstances where objects impinge on mounting height or pole spacing, and carriageways of width greater than 21m. The ballast loss requirements would apply to all applications.

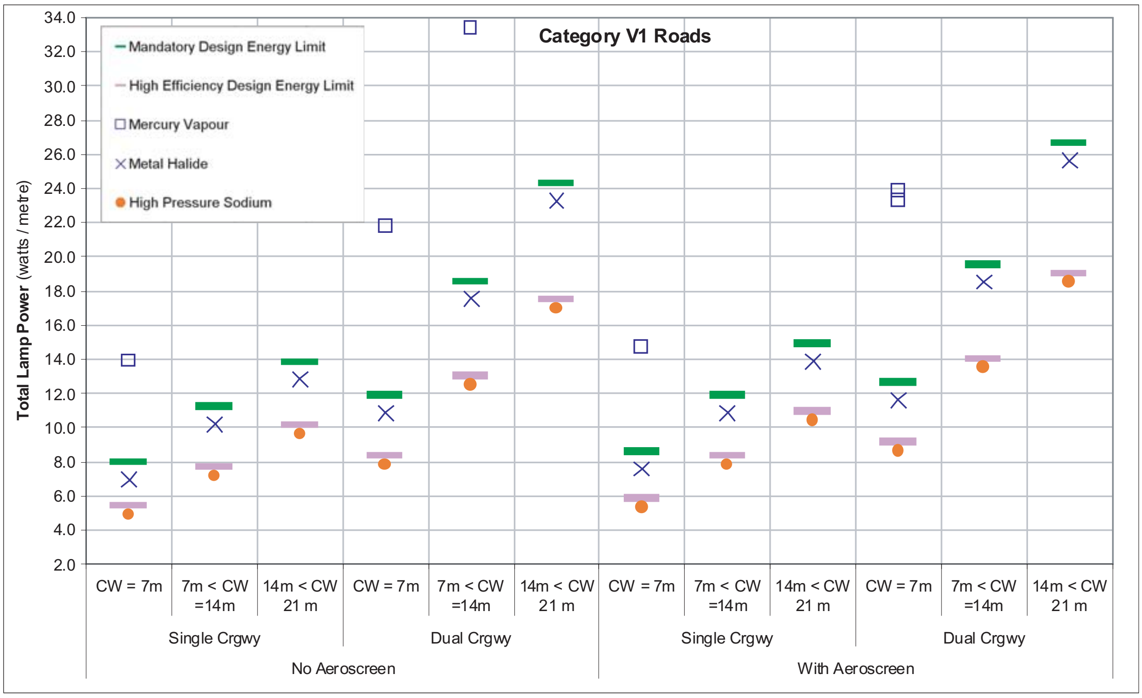
The proposed mandatory maximum and high efficiency limits are based on the most efficient technology choice along with optimised lighting design, as follows:

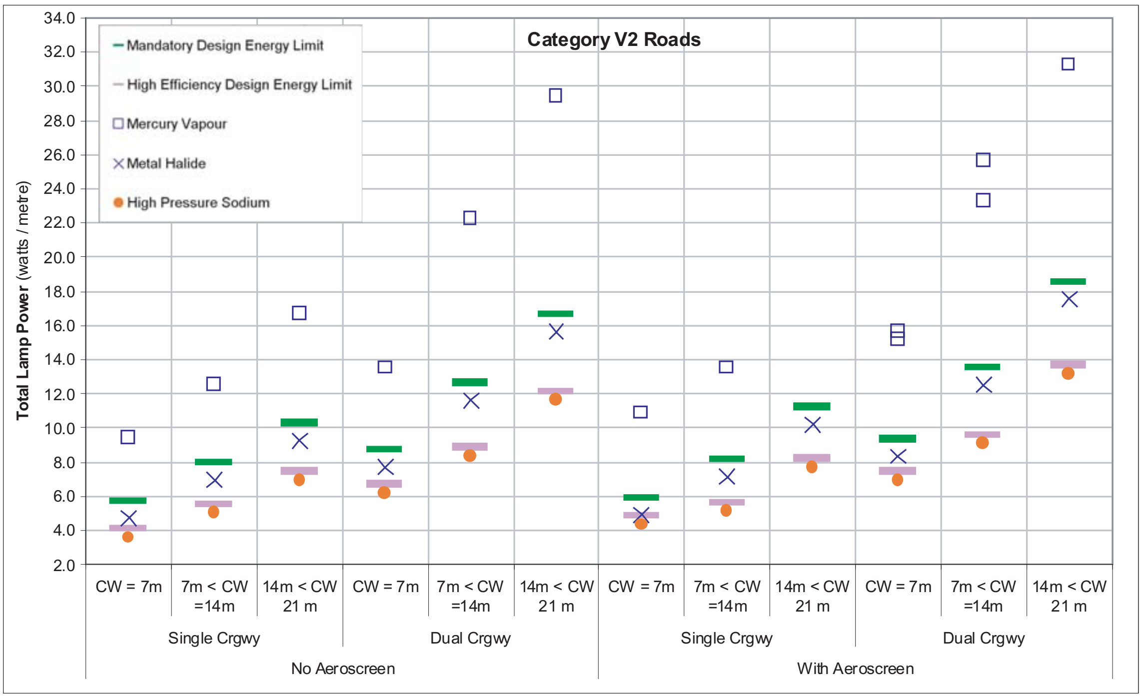
> The mandatory maximum limit is set at the optimum metal halide lamp/luminaire/design performance (in watt/metre) plus 1 watt.

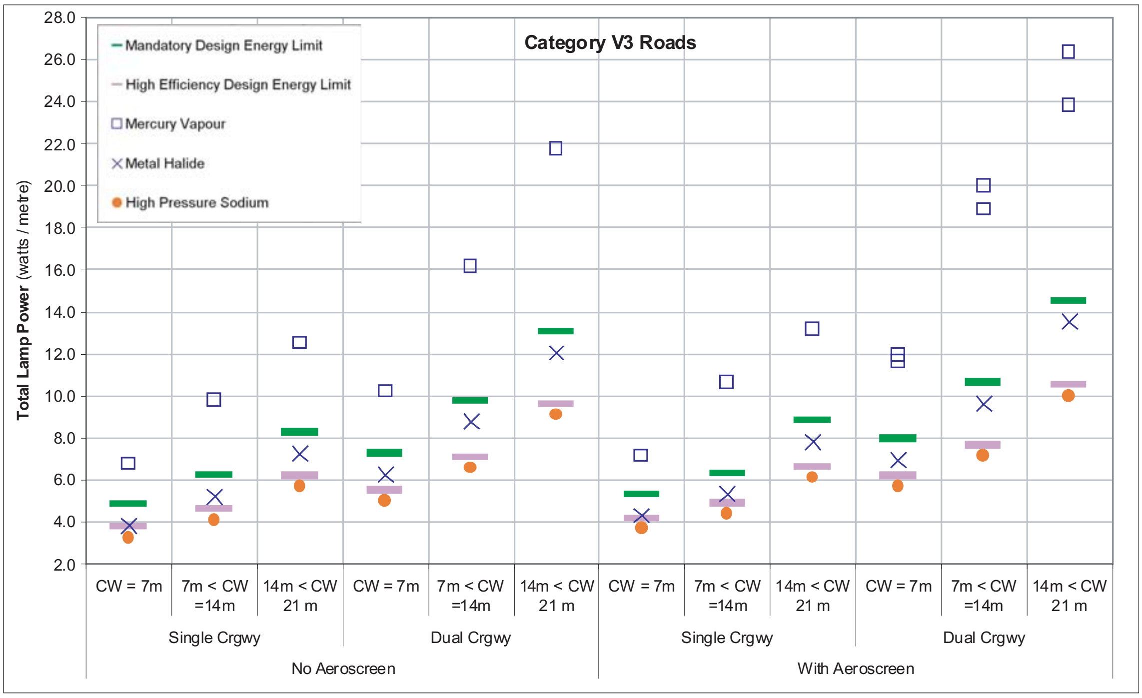
> The high efficiency limit is set at the optimum high pressure sodium lamp/luminaire/design performance (in watt/metre) plus 0.5 watt.

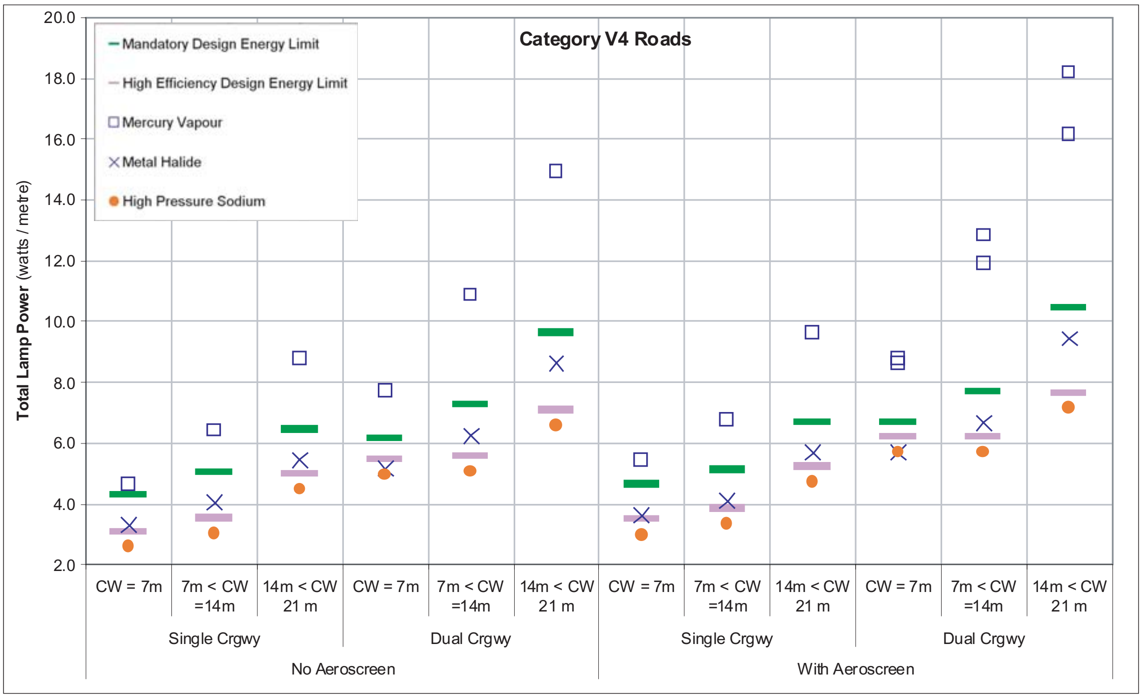
The design energy limits are set for all road categories, and further separated to reflect carriageway widths, single/dual carriageways and inclusion of aeroscreen luminaires (where restriction of upwards light is critical). The proposed limits are listed in a table below. The following figures illustrate the limits for category V1 to V5 roads, along with the modelled performance of the most efficient lamp/luminaire/design choice for each lighting technology. Note that these performance levels include lighting design which has been optimised for energy efficiency whilst meeting the optical requirements of AS1158.

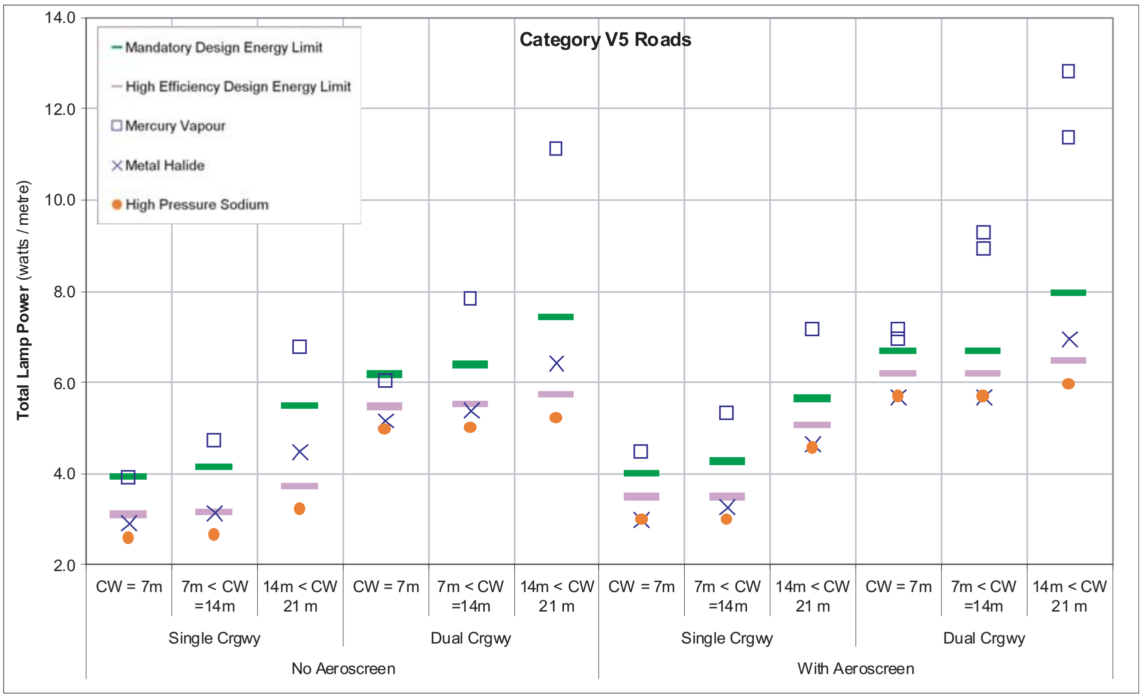
From the following figures it can be seen that the chosen design energy limits, in the majority of cases, exclude mercury vapour technology from main roads, whilst allowing metal halide technology to meet the mandatory maximum limit, and high pressure sodium to meet the high efficiency limit.




Category V2 Roads
Mandatory Design Energy Limit
High Efficiency Design Energy Limit
Mercury Vapour
Metal Halide
High Pressure Sodium
Total Lamp Power (watts / metre)
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
CW = 7m
7m < CW =14m
14m < CW 21 m
Single Crgwy
Dual Crgwy
No Aeroscreen
With Aeroscreen


Category V3 Roads
Mandatory Design Energy Limit
High Efficiency Design Energy Limit
Mercury Vapour
Metal Halide
High Pressure Sodium
Total Lamp Power (watts / metre)
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
CW = 7m
7m < CW =14m
14m < CW 21 m
Single Crgwy
Dual Crgwy
No Aeroscreen
With Aeroscreen





NAEEEC PLAN

The Australian Government will introduce a design energy limit for main road lighting with key components as follows:

1. Scope: New category V road lighting installations, as defined in AS1158.
2. The Australian Standard AS1158.1.1 - Road Lighting Part 1.1: Vehicular Traffic (Category V) lighting - Performance and Installation Design Requirements, will be modified to include lamp power design energy limits.
3. The mandatory maximum and high efficiency limits are as follows:

Road Category	Aeroscreen	Carriageway	Carriageway Width	Mandatory Limit (lamp watts/metre)	High Efficiency Limit (lamp watts/metre)
V1	No Aeroscreen	Single	CW ≤ 7m	7.9	5.4
			7m < CW ≤14m	11.2	7.6
			14m < CW 21 m	13.8	10.1
		Dual	CW ≤ 7m	11.9	8.3
			7m < CW ≤14m	18.5	13.0
			14m < CW 21 m	24.3	17.4
	With Aeroscreen	Single	CW ≤ 7m	8.6	5.8
			7m < CW ≤14m	11.9	8.3
			14m < CW 21 m	14.9	10.9
		Dual	CW ≤ 7m	12.6	9.1
			7m < CW ≤14m	19.5	14.0
			14m < CW 21 m	26.6	19.0
V2	No Aeroscreen	Single	CW ≤ 7m	5.7	4.1
			7m < CW ≤14m	7.9	5.5
			14m < CW 21 m	10.3	7.4
		Dual	CW ≤ 7m	8.7	6.7
			7m < CW ≤14m	12.6	8.8
			14m < CW 21 m	16.6	12.1
	With Aeroscreen	Single	CW ≤ 7m	5.9	4.8
			7m < CW ≤14m	8.1	5.6
			14m < CW 21 m	11.2	8.2
		Dual	CW ≤ 7m	9.3	7.4
			7m < CW ≤14m	13.5	9.6
			14m < CW 21 m	18.5	13.7
V3	No Aeroscreen	Single	CW ≤ 7m	4.8	3.7
			7m < CW ≤14m	6.2	4.6
			14m < CW 21 m	8.2	6.2
		Dual	CW ≤ 7m	7.3	5.5
			7m < CW ≤14m	9.8	7.1
			14m < CW 21 m	13.0	9.6
	With Aeroscreen	Single	CW ≤ 7m	5.3	4.2
			7m < CW ≤14m	6.3	4.9
			14m < CW 21 m	8.8	6.6
		Dual	CW ≤ 7m	7.9	6.2
			7m < CW ≤14m	10.6	7.6
			14m < CW 21 m	14.5	10.5
V4	No Aeroscreen	Single	CW ≤ 7m	4.3	3.1
			7m < CW ≤14m	5.0	3.5
			14m < CW 21 m	6.4	5.0
		Dual	CW ≤ 7m	6.2	5.5
			7m < CW ≤14m	7.3	5.6
			14m < CW 21 m	9.6	7.1
	With Aeroscreen	Single	CW ≤ 7m	4.6	3.5
			7m < CW ≤14m	5.1	3.8
			14m < CW 21 m	6.7	5.2
		Dual	CW ≤ 7m	6.7	6.2
			7m < CW ≤14m	7.7	6.2
			14m < CW 21 m	10.4	7.6

Road Category	Aeroscreen	Carriageway	Carriageway Width	Mandatory Limit (lamp watts/metre)	High Efficiency Limit (lamp watts/metre)
V5	No Aeroscreen	Single	CW ≤ 7m	3.9	3.1
			7m < CW ≤14m	4.1	3.1
			14m < CW 21 m	5.5	3.7
		Dual	CW ≤ 7m	6.2	5.5
			7m < CW ≤14m	6.4	5.5
			14m < CW 21 m	7.4	5.7
	With Aeroscreen	Single	CW ≤ 7m	4.0	3.5
			7m < CW ≤14m	4.2	3.5
			14m < CW 21 m	5.6	5.0
		Dual	CW ≤ 7m	6.7	6.2
			7m < CW ≤14m	6.7	6.2
			14m < CW 21 m	7.9	6.5

4. The standard will come into force as soon as is practical, preferably during early 2007.
5. The Australian Government will work with main roads authorities, relevant local council representative bodies and electricity distribution companies to enforce the mandatory maximum lamp power limits, as well as the ballast loss limits that currently exist in Section 5.3 of AS1158.6:2004.
6. NAEEEC will also investigate the modification of the appropriate State and Territory Government legislation, such that new main road lighting installations comply with these requirements.
7. NAEEEC will also encourage the appropriate parties to upgrade existing main road lighting installations to meet the design energy limit.
8. The timetable for the project is outlined in the table below.

Task	Target Completion Date	Notes
NAEEEC product profile	3rd qtr 05	Report released at NAEEEC Spring Forum
Industry consultation	4th qtr 05	
Draft standards	4th qtr 05– 3rd qtr 06	Draft an additional part to AS 1158.
Consultations with Standards Australia	2nd & 3rd qtr 06	Standards Australia to consider first draft of standard, and subsequently to consider revisions.
Release of Standard for public comment	4th qtr 06	
Final Standard published	4th qtr 06	

IMPACT OF THE DESIGN ENERGY LIMIT

Replacement of all existing category V mercury vapour lamps with high pressure sodium or metal halide lamps has the potential to reduce greenhouse gas emissions by around 60 kt CO_2e p.a.

There is also the potential for additional greenhouse gas savings resulting from: improvements in the design aspects of main road lighting, technological development driven by the design energy limit, energy savings from installations on new main roads, and the expansion of the project to cover all road categories

NAEEEC MEMBER ORGANISATIONS

The Commonwealth, New Zealand, and each state and territory are represented on NAEEEC and participate in its deliberations. Representatives are officials within government departments, agencies and statutory authorities or people appointed to represent those bodies. Representatives are usually a senior officer directly responsible for energy efficiency. The membership is currently under review and may expand to include other agencies working in these fields.

The Australian Greenhouse Office (AGO) is part of the Australian Government Department of the Environment and Heritage. The AGO is responsible for monitoring the National Greenhouse Strategy in cooperation with states and territories and with the input of local government, industry and the community. An AGO officer is the chair of NAEEEC and others provide support for its activities.

The NSW Department of Energy, Utilities and Sustainability provides policy advice to the NSW Government and operates a regulatory framework aimed at facilitating environmentally responsible appliance and equipment energy use.

Energy Safe Victoria is responsible for electricity and gas safety in Victoria. This is achieved by auditing the design, construction and maintenance of all electricity and gas networks and installations and by ensuring that appliances meet stringent safety and energy efficiency standards before they are sold. In addition, a comprehensive public awareness campaign is undertaken to educate the community on the potential dangers of gas and electricity. Its corporate vision is that Victoria will enjoy the safest, most efficient supply and use of electricity and gas.

The Sustainable Energy Authority was established in 2000 by the Victorian Government to provide a focus for sustainable energy in Victoria. The authority's objective is to accelerate progress towards a sustainable energy future by bringing together the best available knowledge and expertise to stimulate innovation and provide Victorians with greater choice in how they can take action to significantly improve energy sustainability.

The Electrical Safety Office, Department of Industrial Relations, is the Queensland technical regulator responsible for electrical safety of equipment and appliance and equipment energy efficiency registration. The office ensures compliance with electrical safety and efficiency regulations throughout Queensland.

The Department of Energy provides policy and regulatory advice to the Queensland Government on issues relating to energy generation, distribution, demand and supply.

Energy Safety WA seeks to promote conditions that enable the Western Australian community's energy needs to be met safely, efficiently and economically.

The Western Australian Sustainable Energy Development Office promotes more efficient energy use and increased use of renewable energy to help reduce greenhouse gas emissions and increase jobs in related industries.

The Office of the Technical Regulator seeks to coordinate development and implementation of policies and regulatory responsibilities for the safe, efficient and responsible provision and use of energy for the benefit of the South Australian community.

The Tasmanian Government's interest is managed by the Department of Infrastructure, Energy and Resources' Office of Energy Planning and Conservation (OEPC). OPEC provides policy advice on energy related matters including energy efficiency.

Electricity Standards and Safety, Department of Infrastructure, Energy and Resources, is the technical regulator responsible for electrical safety throughout Tasmania. Regulatory responsibilities include electrical licensing, appliance approval and equipment energy efficiency.

The ACT Office of Sustainability was established in January 2002 to develop, facilitate and coordinate the implementation of policies and procedures related to sustainability. From the end of 2004, the Office has expanded to take on responsibility for energy and greenhouse policy, including energy efficiency issues. The ACT Planning and Land Authority is the ACT technical regulator responsible for electrical safety and equipment efficiency.

The Department of Employment, Education and Training is responsible for administering regulations in the Northern Territory on various aspects of safety, performance and licensing for goods and services including electrical appliances.

The Energy Efficiency and Conservation Authority (EECA) is the principal body responsible for delivering New Zealand's National Energy Efficiency and Conservation Strategy. EECA's function is to encourage, promote and support energy efficiency, energy conservation and the use of renewable energy sources.

The Ministry for Environment (MfE) is the lead department in New Zealand advising the Minister of Energy on the development of government policy advice on energy efficiency, conservation and the use of renewable sources of energy. It works with EECA and also monitors its performance under the Public Finance Act.

Final Report

Design Energy Limits

for

MAIN ROAD LIGHTING

Prepared for
The Australian Greenhouse Office and NAEEEC
under
The National Appliance & Equipment Energy Efficiency Program
by

Mark Ellis & Associates

September 2005

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Context of this Report

This report describes a project aimed at reducing the energy consumption of lighting installations on Australian roads which carry significant traffic volumes. The project is being developed as part of Greenlight Australia, the agreed Government strategy to improve the efficiency of lighting products and reduce greenhouse gas emissions from lighting over the period 2005-2015. The strategy was developed in consultation with the Australian lighting industry and is supported by Lighting Council Australia.

The strategy and the preceding discussion paper (available from energyrating.gov.au) outline the background to the lighting efficiency projects proposed for the period 2005-2015. Road lighting is one of the high priority projects identified in the strategy.

1.2 Objective

There is considered to be scope for improving the energy efficiency of road lighting, particularly from category V (vehicular) road lighting, from here on described as main road lighting. The energy efficiency of main road lighting installations is not always optimised, due primarily to the disaggregated nature of this marketplace, where multiple parties are typically responsible for the design, installation and maintenance of road lighting, and for the cost of providing these services.

The primary purpose of category P (pedestrian) road lighting is to serve pedestrians. The objective of this project is, initially, to develop measures aimed at removing inefficient practices from category V lighting.

NAEEEC has traditionally implemented mandatory MEPS (minimum energy performance standards), aimed at eliminating poor performing products (such as lamps and ballasts) from the marketplace. Several of these projects, which have the potential to affect main road lighting, are either planned or underway as part of Greenlight Australia. These include MEPS for HID lamps and ballasts, and MEPS for luminaires.

Although some of these projects are likely to reduce energy consumption from main road lighting, it is considered that a holistic approach is also required to ensure that appropriate technology choices as well as good design practice are undertaken. Hence the objective of this report is to investigate and develop a 'design energy limit' for category V lighting installations.

1.3 Scope

This project applies to lighting installed on Australian main roads. For the purpose of this report, main road lighting is limited to category V lighting, which is defined in AS 1158.0:1997 as *lighting which is applicable to roads on which the visual requirements of motorists are dominant*. Category V luminaires represent around 30% of the estimated total of 1.9 million road lighting luminaires (AGO 2005).

The various sub-categories of category V lighting are listed in Table 1. These descriptions are taken from AS 1158.0:1997 and are identical to those in the draft standard DR 03283 (version dated 12 May 2003).

Table 1 - sub-categories of category V lighting as listed in AS 1158.1.1:1997

Sub Category	Description	Operating characteristics	Minimum Average Carriageway Luminance (cd/m^2) (maintained)
V1	Arterial or main roads in central and regional activity centres of capital and major provincial cities, and other areas with major abutting traffic generators	> Mixed vehicle and pedestrian traffic > High to very high vehicle volume > High to very high pedestrian volume > Moderate to low vehicle speeds > Stationary vehicles alongside the carriageway > Through and local traffic > High traffic generation from abutting properties	1.5
V2	Arterial roads that predominantly carry through traffic from one region to another, forming principal avenues of communication for traffic movement, with major abutting traffic generators	> Mixed vehicle and pedestrian traffic > High vehicle volume > High pedestrian volume > Moderate to high vehicle speeds > Stationary vehicles alongside the carriageway > Through and local traffic > High traffic generation from abutting properties	1.0
V3	Freeways, motorways and expressways consisting of divided highways for through traffic with no access for traffic between interchanges and with grade separation at all intersections	> Vehicle traffic only > High to very high vehicle volume > High speeds	0.75
	Arterial roads that predominantly carry through traffic from one region to another, forming principal avenues of communication for traffic movements	> Mixed vehicle and pedestrian traffic > Moderate to high vehicle volume > High pedestrian volume > Moderate to low vehicle speeds > Stationary vehicles alongside the carriageway > Through and local traffic > Moderate traffic generation from abutting properties	
V4* or V5	Sub-arterial or principal roads which connect arterial or main roads to areas of development within a region, or which carry traffic directly from one part of a region to another part	> Mixed vehicle and pedestrian traffic > Moderate traffic volume > Low pedestrian volume > Moderate to low vehicle speeds > Low traffic generation from abutting properties	0.5 (V4) 0.35 (V5)

*V4 is the minimum category recommended for application in New Zealand.

This project is aimed at improving the energy performance of new and existing lighting installations on category V roads.

2 BACKGROUND

2.1 Lighting Technologies

Main road lighting installations typically consist of poles, luminaires, lamps and associated electrical componentry including ballasts, ignitors and in some cases photo-electric cells. A number of lamp types are used for main road lighting, and compatibility between lamp types and associated ballasts and luminaires varies widely. The vast majority of Australian main road lighting installations are based on one of the following high intensity discharge (HID) lamp systems:

- High pressure sodium (HPS)
- Metal halide (MH)
- Mercury vapour (MV).

High Pressure Sodium Lamps

High pressure sodium lamps are very efficient, particularly at higher wattages. They are used in both category V and P lighting applications, and have a yellowish appearance with poor colour rendition (CRI ≤ 40) [AGO 2002]. They exhibit long life characteristics and remain very popular for road lighting where colour is not critical, such as main roadways.

Metal Halide Lamps

Metal halide lamps have reasonable efficacy and are used in town centres, areas with significant pedestrian traffic and places of special interest. They are also suitable for category V applications. They have excellent colour rendering properties (CRI = 75-90) [AGO 2002], emitting a white light with a strong blue-green component, which is particularly good for night vision. Early models had short lifetimes and rapid lumen and colour depreciation. Recently metal halide lamps have improved in these areas and continue to do so.

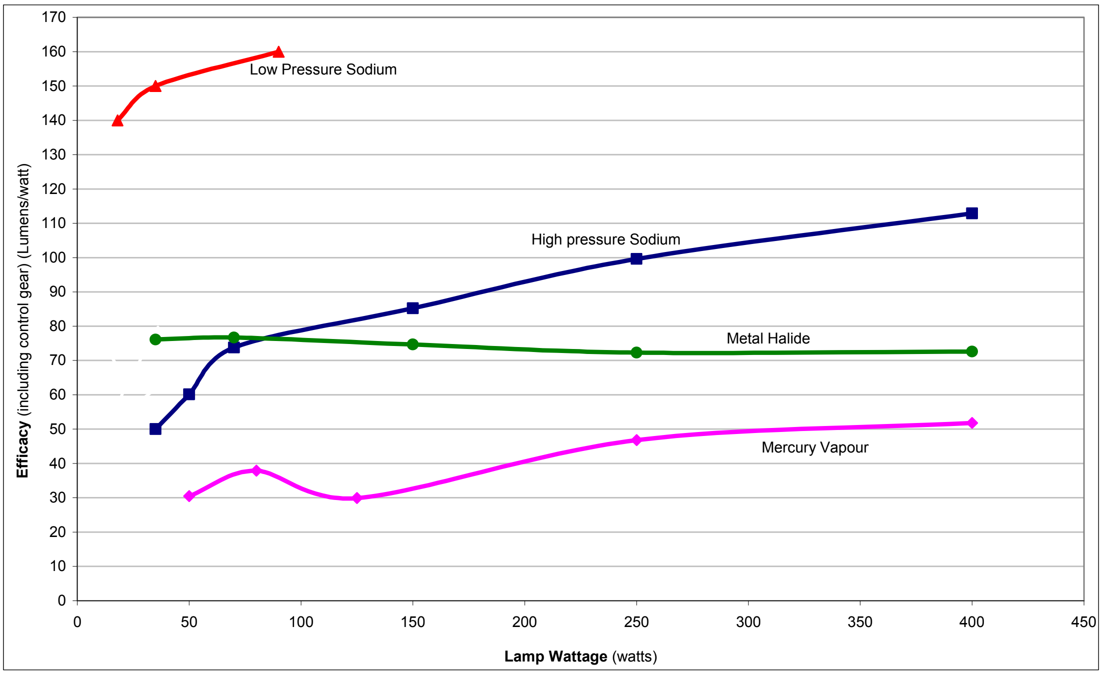
Mercury Vapour Lamps

Mercury vapour lamps have poor efficacy with fair colour rendering characteristics (CRI = 40-60) [AGO 2002]. They are used in both category V and P lighting applications, and emit a bluish light which is advantageous for night vision. Their light output decreases significantly with age and as a result installations are often over-designed to compensate for this depreciation.

Lamp Efficacy

The efficacy of lamps varies widely, as indicated in Figure 1, which is a plot of indicative lamp efficacy versus lamp wattage.

Figure 1 - Lamp efficacy (source: AGO 2002)



From Figure 1 it can be seen that high pressure sodium lamps are generally the most efficient of the common lamps, particularly at higher wattages. Low pressure sodium lamps are currently rarely used in Australia, due to their poor colour characteristics.

For main road lighting installations, lamps in the 150 to 400 watt range are generally used.

Electrical Componentry

HID lamps generally require a ballast and an ignitor, and some fixtures include a photoelectric cell to sense daylight levels for switching purposes. Ballasts consume a significant amount of power, with ballast heat losses typically ranging from 15 to 40 watts. Ballasts can be ferro-magnetic or electronic type. Ferro-magnetic units represent the vast majority of ballasts used for main road lighting, due mainly to their reliability, yet they are less efficient than electronic ballasts.

Loss levels for common ballasts for the major lamp types are compared to loss levels recommended in AS1158.8 in Figure 2 to Figure 4.

Figure 2 – High pressure sodium ballasts

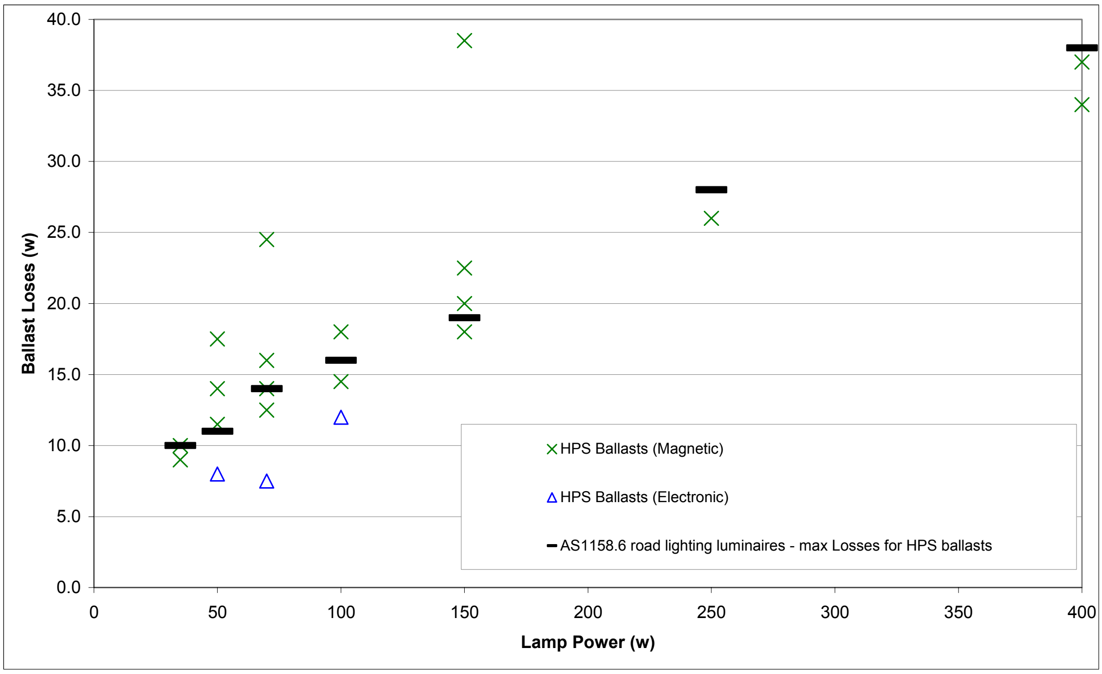


Figure 3 – Metal halide ballasts

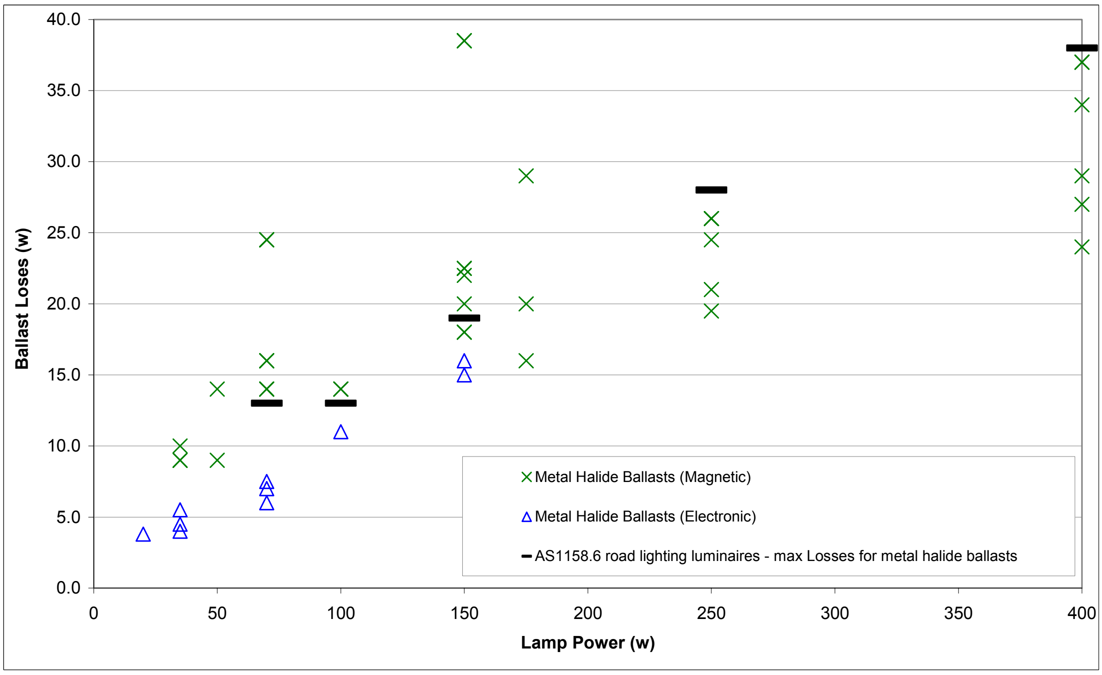
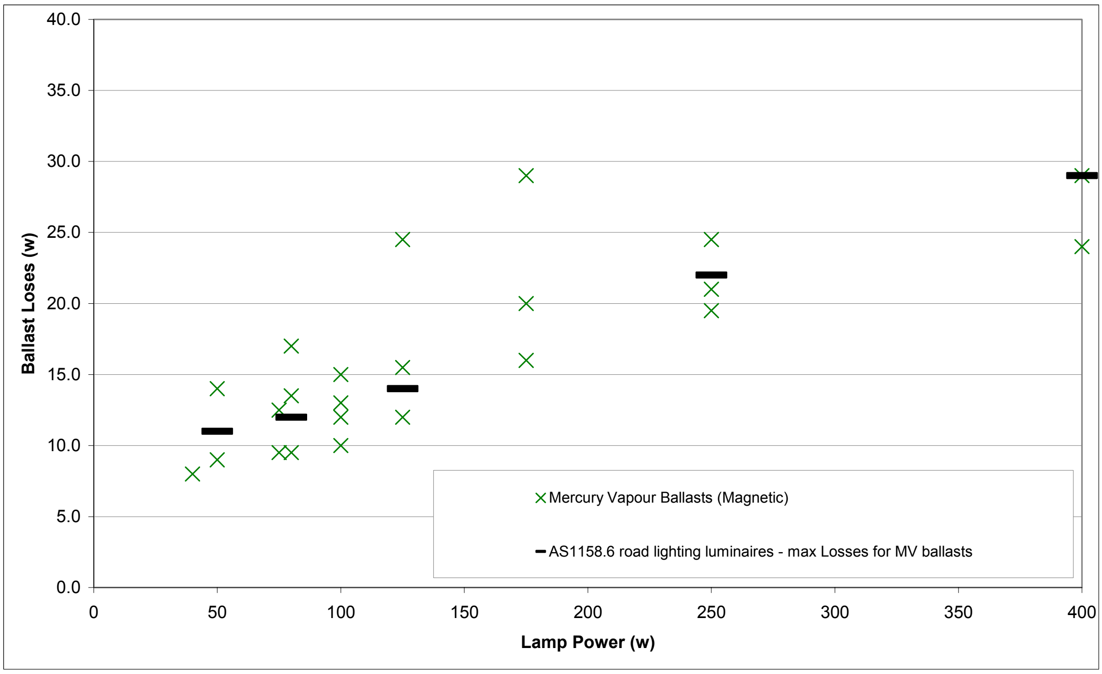


Figure 4 – Mercury vapour ballasts



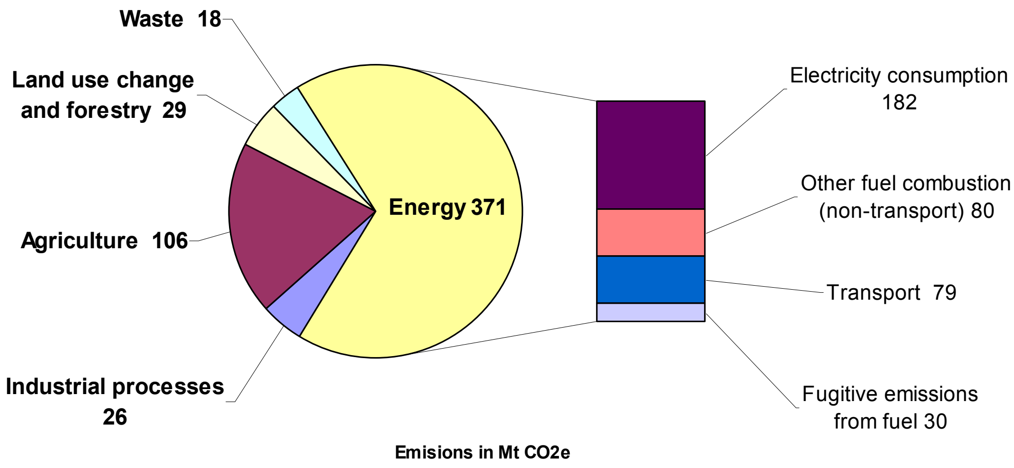
Luminaires and Poles

A road lighting luminaire is generally fixed either to a dedicated lighting pole or other structure such as a power pole. The luminaire is weatherproof and houses the lamp and associated electrical componentry. The luminaire reflector and lens are designed to focus the majority of light onto the roadway beneath. Luminaire design and performance (include internal componentry) is generally governed by AS 1158.6:2004 - Lighting for Roads and Public Spaces - Part 6: Luminaires.

2.2 Energy Consumption and Greenhouse Gas Emissions

In 2002, Australia emitted an estimated total of 550 million tonnes of CO_2e (NGGI 2002). As shown in Figure 5, electricity consumption accounts for around one third of Australia's greenhouse gas emissions.

Figure 5 – Australia's greenhouse gas emissions in 2002 (NGGI 2002)

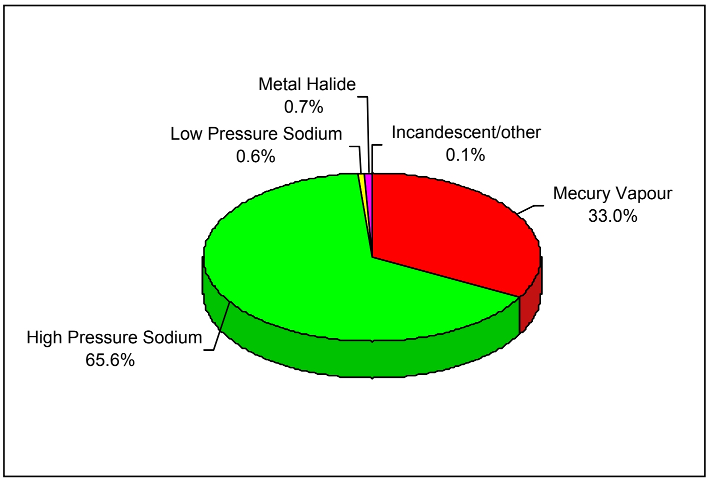


Lighting was responsible for the emission of an estimated 25 Mt of CO_2e in 2002, which represents almost 5% of Australia's total greenhouse gas emissions. AGO 2005 estimates total road lighting greenhouse gas emissions at 1.15 Mt CO_2e p.a., with category V road lighting representing around 53% of this total, or 0.61 Mt CO_2e p.a.

Hence category V road lighting is responsible for an estimated 0.11% of Australia's total greenhouse gas emissions. AGO 2005 also estimates that the energy consumption of road lighting has increased by an average of 2.7% p.a. from 1990 to 2003.

The estimated breakdown of lamp types used in main road lighting is illustrated in Figure 6.

Figure 6 – Proportion of lamp types used in Australian category V roads (AGO 2005)



In recent times there has been a trend to replace mercury vapour lamps with high pressure sodium lamps on main roads. However, from Figure 6 it can be seen that mercury vapour lamps, which are the least efficient of the HID lamps, are currently still installed in around one third of main road lighting luminaires.

There is considered to be potential to reduce the energy consumption of main road lighting using the following two mechanisms:

> Accelerating the replacement of mercury vapour lamps with high pressure sodium lamps on main roads.

> Making incremental improvements to main road lighting efficiency, by ensuring that efficient lamps, ballasts, luminaires and best practice lighting design are all utilised.

It is considered that a design energy limit would be an appropriate tool to achieve these outcomes. This is discussed in detail in section 3.

2.3 Stakeholders

Specification

Main road lighting (category V), as distinct from category P lighting, is generally specified and funded by the main roads authority in each state and territory. In some instances, local councils have some jurisdiction over main road lighting, particularly on arterial roads which run through urban areas. In many cases, the electricity distribution company, as the primary service provider, plays a significant role in the specification of main road lighting.

Installation and Maintenance

Lighting on main roads is typically installed by the main roads authority or the relevant electricity distribution company, or a contractor to one of these parties. Maintenance can be the responsibility of any one of these parties.

Capital and Running Costs

Capital costs, along with the ongoing maintenance and energy costs of main road lighting, are generally born by the main roads authority, or in some cases by the local council, often with a financial contribution from the main roads authority. The roles of each of the Australian state and territory main roads authorities, with respect to main road lighting, are summarised in Appendix B.

3 DESIGN ENERGY LIMITS FOR MAIN ROAD LIGHTING

3.1 Philosophy

3.1.1 Lamp Power

A design energy limit would seek to encourage energy efficient practice in main road lighting, whilst allowing a degree of flexibility for designers of such installations. It would favour the most efficient lamps, control gear and luminaires, as well as optimum lighting distribution and design geometry. A similar approach to this is currently adopted in the VicRoads Traffic Engineering Manual (VicRoads 2001). Canadian standards for road lighting luminaires (CAN 2004) contain a performance requirement for road lighting luminaires, however this does not extend to the design of the lighting installation.

As part of the process, the lamp power consumption of a proposed main road lighting installation would be calculated using lighting software or manually, and the result expressed in terms of total lamp power consumption per linear metre of roadway (watts/metre). Linear road metres are used in the calculation, rather than square metres, as this simplifies calculation. Roadway width is however taken into account when setting the design energy limits (section 3.2).

Lamp power consumption, for the luminaires on a given section of roadway, is calculated as follows:

Lamp power consumption = $\Sigma P_L / L$

where:

P_L = initial lamp power at 250 volts (note that lamp power does not change significantly over the lamp's life)

L = length of roadway.

The objective of the design energy limit would be that a lighting installation, installed on a homogenous section of main roadway, shall meet a 'mandatory maximum limit' for each specified category of roadway. The limit has been set to allow the installation to continue to meet the optical parameters in AS1158. Furthermore, specifiers could opt for their installation to meet a 'high efficiency' level which is more stringent than the mandatory maximum, thereby delivering additional energy savings.

An alternative, although simpler, approach to a design energy limit would be to mandate the use of certain efficient lamp types for main road lighting. However this prescriptive approach could allow poor design practise to continue, and limit the potential energy savings.

If adopted into the AS1158 standard, the design energy limit would be reviewed upon each revision of the standard, allowing for incremental improvements in efficiency over time. At the appropriate time, a design energy limit could be extended to cover Category P lighting.

3.1.2 Ballast Losses

In addition to the lamp requirement, ballasts would also have to meet maximum loss requirements, which are currently already specified in AS1158.6 (although these are not currently mandatory). These are reproduced in Table 2 and previously illustrated in Figure 2 to Figure 4.

Table 2 – Maximum ballast loss under draft Australian Standard

Lamp Wattage	Maximum Ballast Hot Loss (w)	
High Pressure Sodium		
35	10	
50	11	
70	14	
100	16	
150	19	
250	28	
400	38	
Metal Halide		
	Constant Wattage Type	Reactor Type
70	N/A	13
100	N/A	13
150	N/A	19
250	49	28
400	65	38
Mercury Vapour		
50	11	
80	12	
125	14	
250	22	
400	29	

Definitions of 'high efficiency' HID ballasts are currently being developed for the Energy All Stars database (energyallstars.gov.au). However these levels are for both indoor and outdoor HID ballasts, and may not translate directly to road lighting where more stringent reliability is required under harsher conditions.

3.1.3 Exclusions

The lamp power limit would apply to the majority of category V applications, however it was considered that the following special applications would be excluded from meeting the design energy limit:

> Curves.

> Pedestrian crossings.

> Complex illuminance lighting designs such as isolated intersections.

> Special circumstances where objects such as such as electrical transmission lines, overpasses or access driveways impinge on mounting height or pole spacing.

> Carriageways of width greater than 21m, which require specialised lighting design.

The ballast loss requirements would however apply to all applications.

3.2 Proposed Design Energy Limits

Extensive road lighting modelling was undertaken for this report (discussed in section 3.3), in order to set the proposed mandatory maximum and high efficiency lamp limits which would apply for each road category. The limits were based on the most efficient technology choice along with optimised lighting design, as follows:

> The mandatory maximum limit is set at the optimum metal halide lamp/luminaire/design performance (in watts/metre) plus 1 watt/metre. This is in order to allow white light to be used for main roads, where deemed necessary. The 1 watt/metre leeway is to allow for non-typical designs and for the error margins inherent in modelling, etc.

> The high efficiency limit is set at the optimum high pressure sodium lamp/luminaire/design performance (in watts/metre) plus 0.5 watts/metre. A smaller margin of 0.5 watts/metre has been allowed to encourage designers to pursue best practice.

The design energy limits were set for all road categories, and further separated to reflect carriageway widths, single/dual carriageways and inclusion of an aeroscreen luminaire. The proposed limits are listed in Table 3.

Table 3 - Proposed design energy limits

Road Category	Aeroscreen	Carriageway	Carriageway Width	Mandatory Limit (watts/metre)	High Efficiency Limit (watts/metre)
V1	No Aeroscreen	Single	CW ≤ 7m	7.9	5.4
			7m < CW ≤14m	11.2	7.6
			14m < CW 21 m	13.8	10.1
		Dual	CW ≤ 7m	11.9	8.3
			7m < CW ≤14m	18.5	13.0
			14m < CW 21 m	24.3	17.4
	With Aeroscreen	Single	CW ≤ 7m	8.6	5.8
			7m < CW ≤14m	11.9	8.3
			14m < CW 21 m	14.9	10.9
		Dual	CW ≤ 7m	12.6	9.1
			7m < CW ≤14m	19.5	14.0
			14m < CW 21 m	26.6	19.0

Road Category	Aeroscreen	Carriageway	Carriageway Width	Mandatory Limit (watts/metre)	High Efficiency Limit (watts/metre)
V2	No Aeroscreen	Single	CW ≤ 7m	5.7	4.1
			7m < CW ≤14m	7.9	5.5
			14m < CW 21 m	10.3	7.4
		Dual	CW ≤ 7m	8.7	6.7
			7m < CW ≤14m	12.6	8.8
			14m < CW 21 m	16.6	12.1
	With Aeroscreen	Single	CW ≤ 7m	5.9	4.8
			7m < CW ≤14m	8.1	5.6
			14m < CW 21 m	11.2	8.2
		Dual	CW ≤ 7m	9.3	7.4
			7m < CW ≤14m	13.5	9.6
			14m < CW 21 m	18.5	13.7
V3	No Aeroscreen	Single	CW ≤ 7m	4.8	3.7
			7m < CW ≤14m	6.2	4.6
			14m < CW 21 m	8.2	6.2
		Dual	CW ≤ 7m	7.3	5.5
			7m < CW ≤14m	9.8	7.1
			14m < CW 21 m	13.0	9.6
	With Aeroscreen	Single	CW ≤ 7m	5.3	4.2
			7m < CW ≤14m	6.3	4.9
			14m < CW 21 m	8.8	6.6
		Dual	CW ≤ 7m	7.9	6.2
			7m < CW ≤14m	10.6	7.6
			14m < CW 21 m	14.5	10.5
V4	No Aeroscreen	Single	CW ≤ 7m	4.3	3.1
			7m < CW ≤14m	5.0	3.5
			14m < CW 21 m	6.4	5.0
		Dual	CW ≤ 7m	6.2	5.5
			7m < CW ≤14m	7.3	5.6
			14m < CW 21 m	9.6	7.1
	With Aeroscreen	Single	CW ≤ 7m	4.6	3.5
			7m < CW ≤14m	5.1	3.8
			14m < CW 21 m	6.7	5.2
		Dual	CW ≤ 7m	6.7	6.2
			7m < CW ≤14m	7.7	6.2
			14m < CW 21 m	10.4	7.6
V5	No Aeroscreen	Single	CW ≤ 7m	3.9	3.1
			7m < CW ≤14m	4.1	3.1
			14m < CW 21 m	5.5	3.7
		Dual	CW ≤ 7m	6.2	5.5
			7m < CW ≤14m	6.4	5.5
			14m < CW 21 m	7.4	5.7
	With Aeroscreen	Single	CW ≤ 7m	4.0	3.5
			7m < CW ≤14m	4.2	3.5
			14m < CW 21 m	5.6	5.0
		Dual	CW ≤ 7m	6.7	6.2
			7m < CW ≤14m	6.7	6.2
			14m < CW 21 m	7.9	6.5

Figure 7 to Figure 11 illustrate the design energy limits for category V1 to V5 roads, along with the modelled performance of the most efficient lamp/luminaire/design choice for each lighting technology. Note that these performance levels include lighting design which has been optimised for energy efficiency whilst meeting the optical requirements of AS1158.

Figure 7 - Design energy limits for category V1 roads

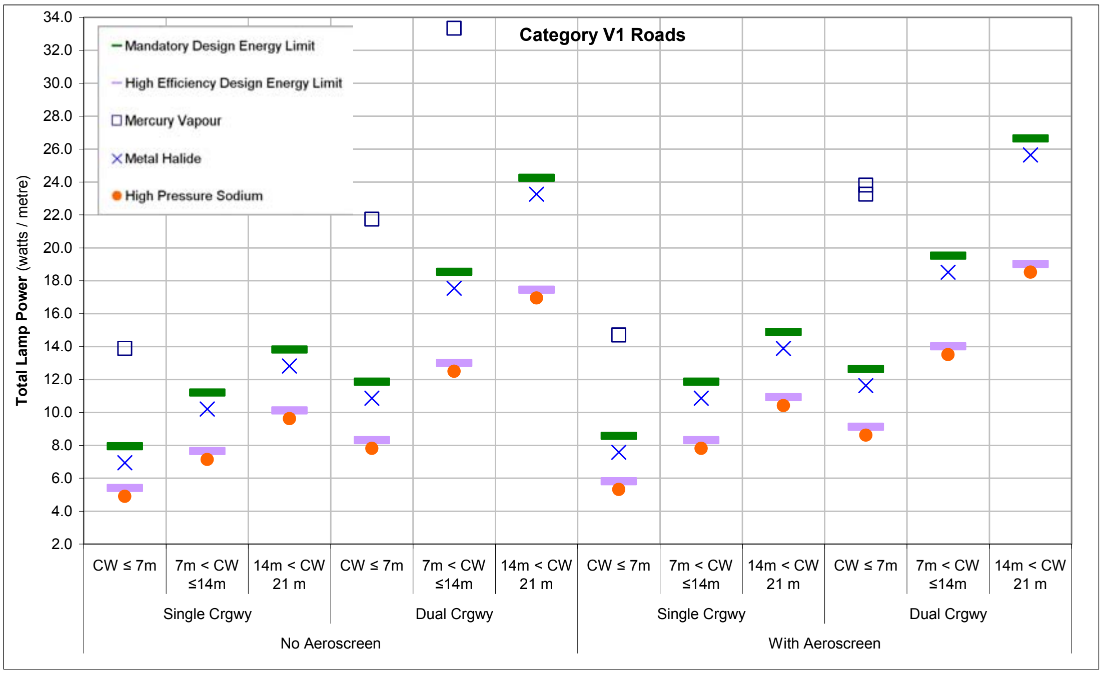


Figure 8 - Design energy limits for category V2 roads

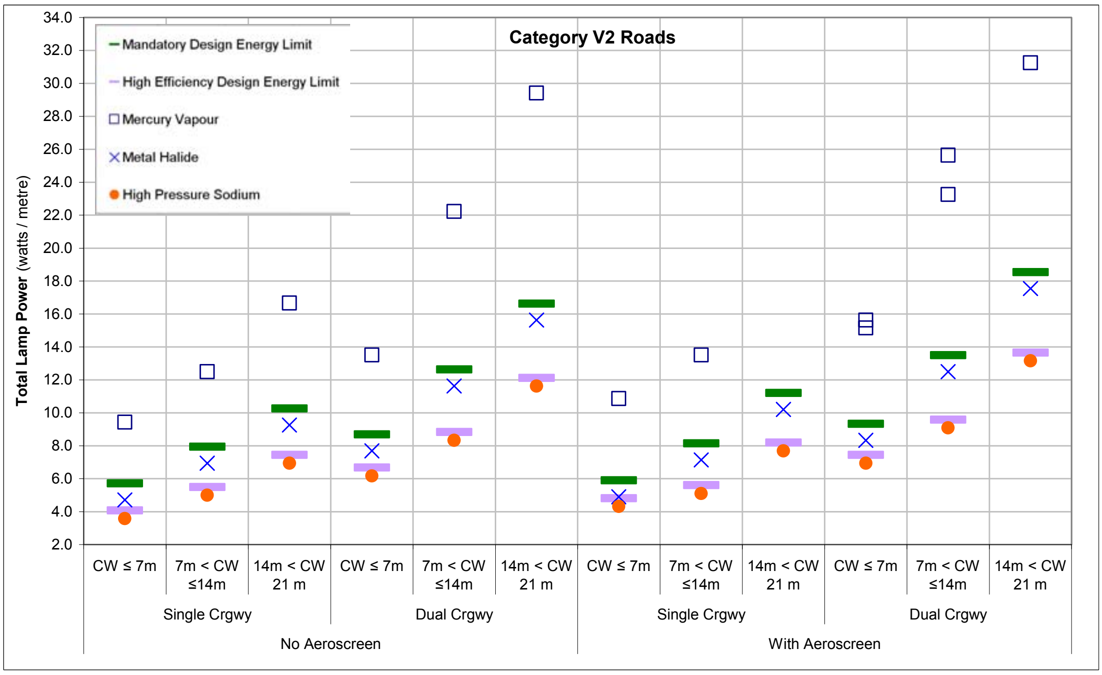


Figure 9 - Design energy limits for category V3 roads

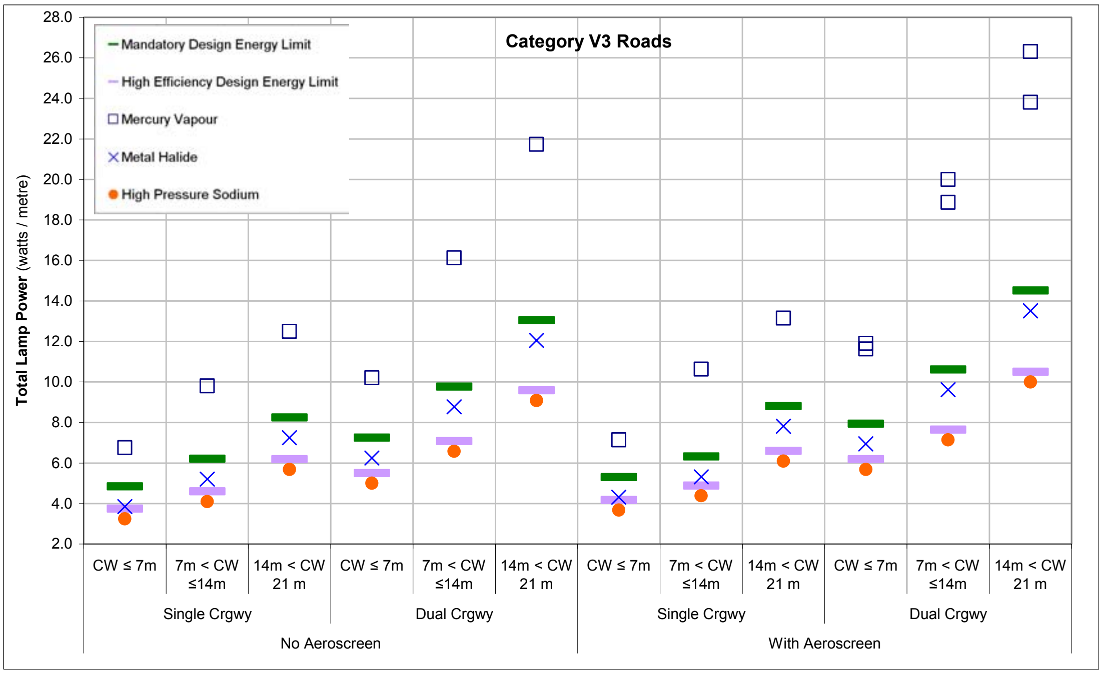


Figure 10 - Design energy limits for category V4 roads

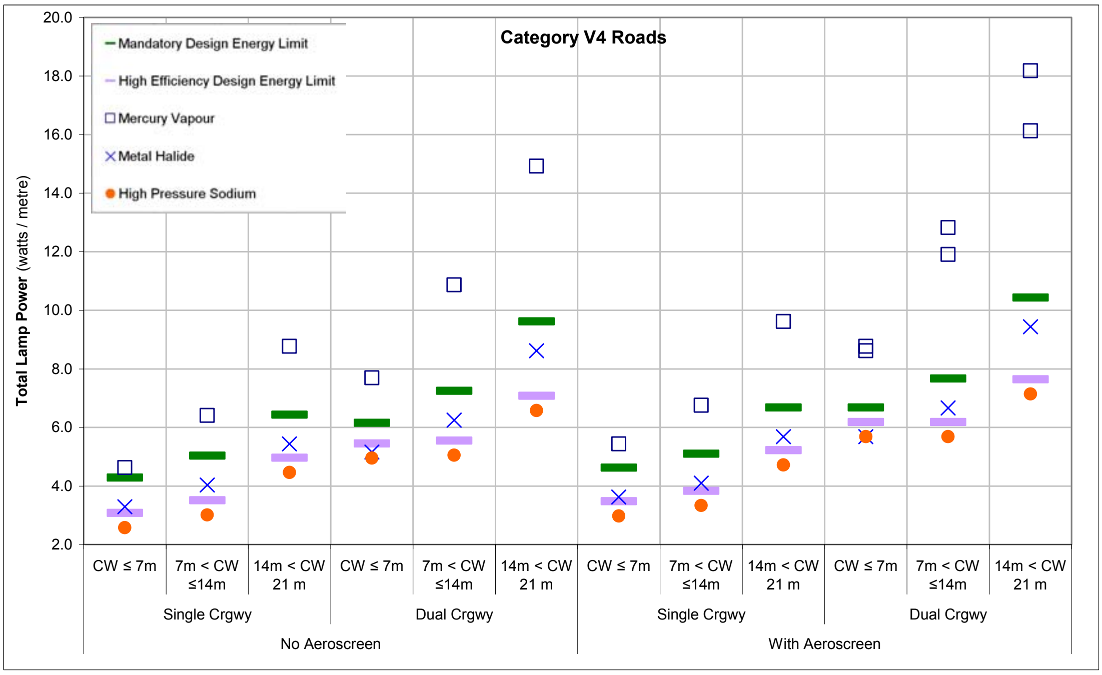
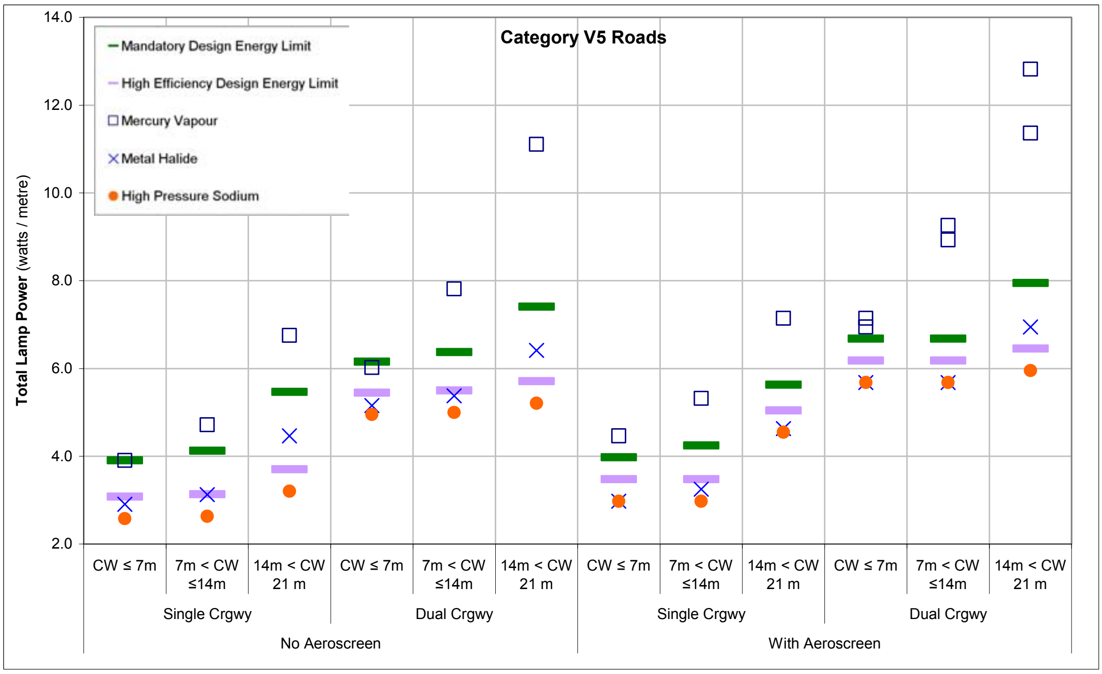


Figure 11 - Design energy limits for category V5 roads



From the above figures it can be seen that the chosen design energy limits, in the majority of cases, exclude mercury vapour technology from main roads, whilst allowing metal halide technology to meet the mandatory maximum limit, and high pressure sodium to meet the high efficiency limit. For the categories where no mercury vapour technology is graphed, mercury vapour was not able to meet the AS1158 optical requirements for that category.

3.3 Modelling

3.3.1 Variables

In order to determine suitable mandatory maximum and high efficiency lamp design energy limits, a large number of typical main road lighting installations were modelled using proprietary lighting design software. The following variables were considered:

> Road lighting categories V1 to V5.

> Preferred luminaire mounting heights of 9, 10, 12 and 15 metres.

> Standard luminaire overhangs of 1, 3 and 5 metres (distance from centre of luminaire to carriageway edge).

> Carriageways of 2, 4 and 6 lanes.

> 6 luminaire/lamp types from 2 manufacturers.

> All lighting arrangements with the exception of arrangement 2 (same as arrangement 1) and arrangement 5S (not optimum). See Figure 12 for arrangement layouts.

> Pole spacings of between 30 and 120 metres in 1 metre increments were modelled (1.36 million spacing calculations in total). The maximum permitted pole spacing (i.e. the least number of luminaires and therefore most efficient design) was calculated for 15,120 road lighting designs.

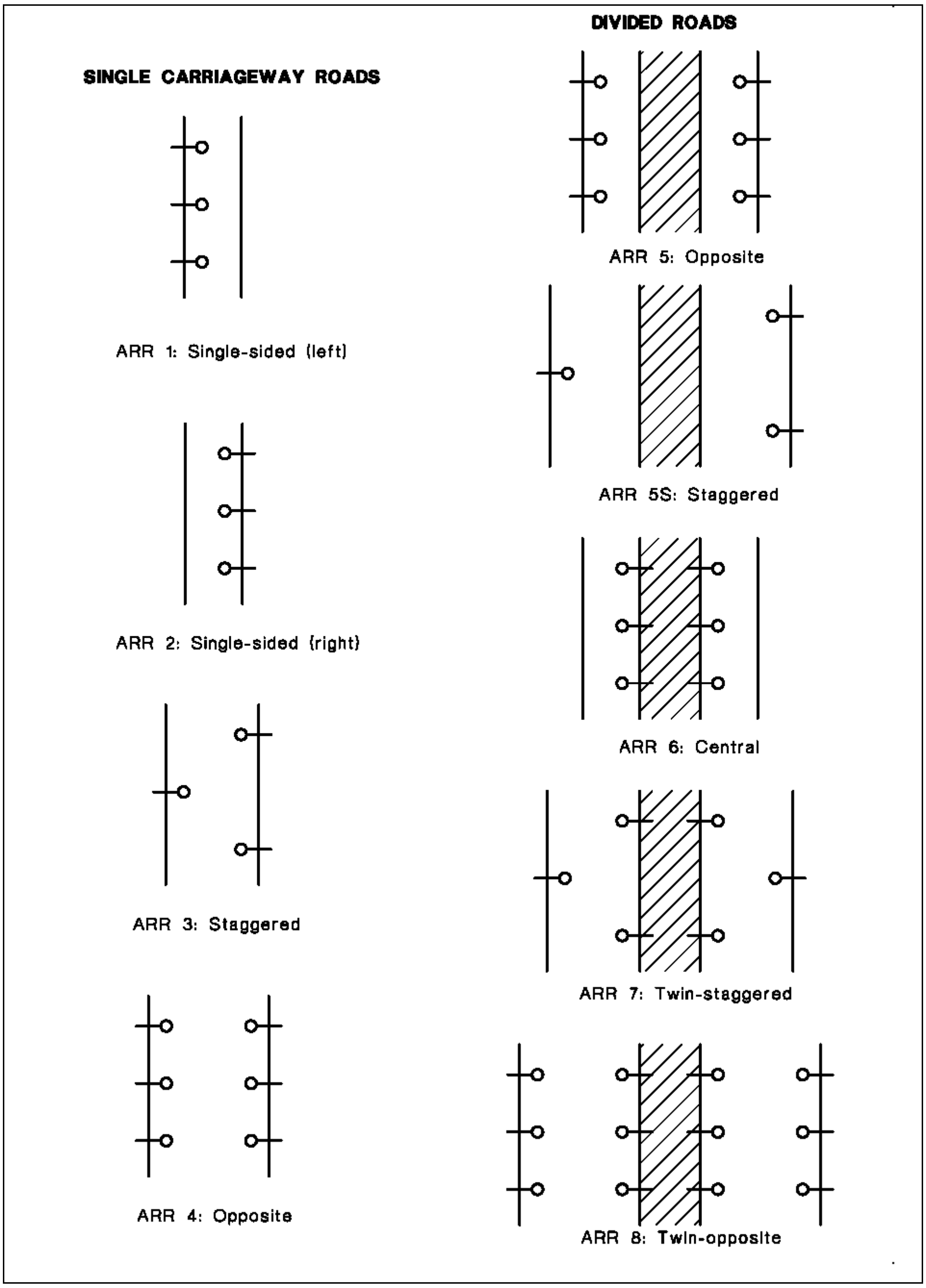
Other parameters used in modelling are listed in Appendix C.

3.3.2 Sensitivity Analysis

A sensitivity analysis was undertaken in order to determine the crucial design aspects affecting lamp power consumption per linear metre of roadway. Lamp design energy limits were then set in order to favour efficient technologies and efficient lighting design. From the sensitivity analysis, the following was found:

Arrangement. Arrangement (see Figure 12) was found to have a significant impact on spacing/energy efficiency. Arrangements 1, 5 and 6 are the most efficient for small carriageways, becoming less efficient as the carriageway widens. Arrangements 4, 7 and 8 are inefficient for small carriageways, becoming more efficient as the carriageway widens. Arrangement 3 remains reasonably constant. Arrangement 3 was selected for typical modelling, with arrangement 1 for smaller carriageways and arrangement 4 for wider carriageways.

Figure 12 - Road lighting arrangements



Overhang. Overhang is the distance from the centre of the luminaire to the carriageway edge. It was found to have a negligible impact (around 1%) on energy consumption for arrangements 1, 4, 5, 6 and 8. Overhang for arrangements 3 and 7 is most efficient at 3 metres.

Mounting height. Mounting height has a significant effect on spacing/energy efficiency for all arrangements.

Visor type. Road lighting luminaires typically have either a standard (also called 'semi-cut-off') visor or an 'aeroscreen' visor (i.e. for use around aerodromes). Aeroscreen luminaires are generally around 25% less efficient than standard luminaires.

Carriageway width. Lighting power was found to be intrinsically linked to the carriageway width. Modelling showed that three limits would be required: for carriageways ≤7m, carriageways >7m and ≤14m, and carriageways >14m and ≤21m.

Lamp/luminaire type. High pressure sodium, metal halide and mercury vapour lamps/luminaires were modelled. 250 watt lamps were modelled in all cases, which is considered to reflect the majority of current practice. The use of 150 and 400 watt lamps was not modelled (as part of the initial 15,120 scenarios). However this is not considered to significantly effect limit setting outcomes. The use of 150 watt lamps in lower road categories (i.e. V5) and 400 watt lamps in higher road categories (i.e. V1) may be modelled in future in order to further fine tune the design energy limits if required.

4 CONCLUSIONS & RECOMMENDATIONS

4.1 Inclusion of Design Energy Limit in Australian Standards

In order to ensure uniformity of application across jurisdictions, it is proposed that the lamp power design energy limit be adopted into the AS1158 series of standards. This series specifies design, installation, operation and maintenance requirements for public lighting in Australia (summarised in Appendix D).

AS1158.1.1 specifies lighting levels of luminance and luminance uniformity of the carriageway surface, as well as glare, limitations of upward light, road classifications, design objectives, maintenance of light technical parameters, etc. The draft standard also contains energy efficiency guidelines with respect to lamp choice and energy auditing. The design energy limit could feasibly reside in table 2.1 of AS 1158.1.1.

This standard also includes requirements for ballast loss levels and it is recommended that these be adhered to as part of the design energy limit process.

4.2 Greenhouse Gas Reduction Potential

Although accurate data relating to the numbers, types and energy consumption of existing main road lighting installations is scarce, an attempt has been made in this section to quantify the potential for greenhouse gas emissions reductions.

AGO 2005 estimates that there are currently around 580,000 main road lighting luminaires in operation in Australia. Of these, some 380,000 contain a high pressure sodium lamp and around 170,000 contain a mercury vapour lamp. Hence there is considered to be potential to further accelerate the trend towards using high pressure sodium lamps in preference to mercury vapour lamps on main roads.

Table 4 contains estimates of the existing HPS and MV lamp stocks on main roads, derived from AGO 2005. Lamp efficacies are from Figure 1 which are used to derive total power consumption for each group of lamps.

Table 4 - Existing HPS and MV main road lamp stocks and power consumption

Lamp Type	Lamp Wattage	Lamp Efficacy (lumens/watt)	Lamp Light Output (lumens)	Lamp Numbers	Total Power (MW)
High Pressure Sodium	150	85	12,750	160,000	24.0
	250	100	25,000	195,000	48.8
	400	112	44,800	20,000	8.0
	Subtotal			**375,000**	**81**
Mercury Vapour	125	30	3,750	50,000	6.3
	250	47	11,750	80,000	20.0
	400	52	20,800	40,000	16.0
	Subtotal			**170,000**	**42**
Total				**545,000**	**123**

Table 5 shows the same information, for the case where 250 watt MV lamps are replaced with 150 watt HPS lamps, and 400 watt MV lamps are replaced with 250 watt HPS lamps.

Table 5 - Existing HPS and MV main road lamp stocks and power consumption

Lamp Type	Lamp Wattage	Lamp Efficacy (lumens/watt)	Lamp Light Output (lumens)	Lamp Numbers	Total Power (MW)
High Pressure Sodium	150	85	12,750	240,000	36.0
	250	100	25,000	235,000	58.8
	400	112	44,800	20,000	8.0
	Subtotal			**495,000**	**103**
Mercury Vapour	125	30	3,750	50,000	6.3
	250	47	11,750	0	0.0
	400	52	20,800	0	0.0
	Subtotal			**50,000**	**6.4**
Total				**545,000**	**109**

From Table 5 we can see that the total installed lamp power would be 109 MW, a saving of 14 MW compared to Table 4. If run for 12 hours per day for 365 days, the estimated maximum potential for energy saving, of switching to HPS lamps, is around 60 GWh p.a. or around 60 kt CO_2e p.a.

Additional potential for greenhouse gas abatement would be provided by replacing 400 watt MV lamps with 150 watt HPS lamps, which is feasible in some applications.

In addition to the greenhouse gas savings discussed above, there are considered to be addition greenhouse gas savings resulting from the following:

> Improvements in the design of main road lighting, arising from adherence to the design energy limit.

> Savings from installations on new main roads not yet constructed or quantified.

> Incrementally increasing the limit in future revisions of AS1158.

> Technological development which is driven by the limit, for example in luminaire construction.

> Inclusion of ballast losses in the design energy limit, thereby creating incentive to fit high efficiency ballasts.

> A design energy limit for category P roads.

4.3 Next Steps

Key to the success of the design energy limit is its inclusion in AS1158. It is proposed that a meeting shall be held of LG002 (the relevant Standards Australia committee) in order to discuss this project.

In addition, it is critical that main roads authorities, relevant local councils and electricity distribution companies enforce the limit once incorporated in AS1158. Therefore these organisations must be engaged in this project at any early stage. To this end, the project will be presented to these stakeholders at relevant representative body technical forums.

NAEEEC will also investigate the modification of the appropriate State and Territory Government legislation, such that new main road lighting installations comply with the design energy limit requirements.

A number of general stakeholders such as lighting manufacturers and motorist groups should be contacted in order to solicit comment on the project.

In order to measure the success of the project once implemented, a selection of new main road lighting installations could be surveyed in order to assess compliance with the design energy limits.

REFERENCES

AGO 2002 Australian Greenhouse Office, Working Energy Program for Local Government Toolkit.

AGO 2005 Public Lighting in Australia – Energy Efficiency Challenges and Opportunities, Draft Report, Australian Greenhouse Office, July 2005.

CAN 2004, Canadian Standard, CAN/CSA-C653-94, Performance Standard for Roadway Lighting Luminaires, Table 1, Limits expressed in W/m^2 for a given design. For comparison purposes this limit translates to 4.17 watts per linear metre for 10m Carriage Width at 250HPS for levels with approximated V3.

NGGI 2002 National Greenhouse Gas Inventory 2002, Australian Greenhouse Office, 2004.

VicRoads 2001, VicRoads Traffic Engineering Manual Vol 1, Chapter 6 - Edition 3, Revision A, February 2001.

APPENDIX A

Abbreviations and Glossary

cd	Candela
CO_2e	Carbon dioxide equivalent units
CRI	Colour rendering index. A measure of the correspondence between the colour of an object and its appearance under a reference light source. To determine the CRI values, eight test colours defined in accordance with DIN 6169 are illuminated with the reference light source and the light source under test. The smaller the discrepancy, the better the colour rendering property of the lamp being tested. A light source with an CRI value of 100 displays all colours exactly as they appear under the reference light source. The lower the CRI value, the worse the colours are rendered.
DC	Divided carriageway (or dual carriageway)
Efficacy	A measurement of the efficiency with which electrical power is converted into visible light. Measured in lumens per watt (lm/W).
HID lamps	High intensity discharge lamps (mercury vapour, metal halide and low/high pressure sodium lamps).
HPS	High pressure sodium
kt	kilotonnes (1,000 tonnes)
Lumen (lm)	Unit of measurement of the visible radiated power (also known as luminous flux) emitted by a light source.
m	Metre
MEPS	Minimum energy performance standards
MV	Mercury vapour
MH	Metal halide
Mt	Megatonne (1,000,000 tonnes)
MW	Megawatts (1,000,000 watts)
MWh	Megawatt hours (1,000,000 watt-hours)
NAEEEC	National Appliance and Equipment Energy Efficiency Committee
NAEEEP	National Appliance and Equipment Energy Efficiency Program
SC	Single carriageway
TRLSS	Traffic Route Lighting Subsidy Scheme
V	Volts
VA	Volt-Amps
W	Watts

APPENDIX B

Main Roads Authorities

New South Wales (NSW). The NSW Roads and Traffic Authority (RTA) funds the design, installation and operation of road lighting on freeways, controlled access roads, tunnels, major bridges and some intersections. Where major roadways pass through urban areas, the RTA provides a subsidy to councils for enhanced lighting on these roads. This scheme is termed the Traffic Route Lighting Subsidy Scheme (TRLSS). The RTA have discretion as to which roads fall under this scheme and lighting must comply with at least category V3. In general, the RTA control the type of lighting on RTA main roads, while local councils control lighting on TRLSS main roads.

Victoria. VicRoads control the lighting on main roads and arterial roads in Victoria, although in some cases local councils do have an input as to the type of lighting installed. The VicRoads Traffic Engineering Manual (VicRoads 2001) includes a guideline for a minimum energy utilisation value (EUV) of main road lighting, measured in m^2/watt. The guideline also specifies that high pressure sodium lamps, or better, must be used for all main road lighting installations.

South Australia. Main and arterial roads in South Australia are controlled by the Transport Services Division of Transport SA, although ETSA Utilities (formerly the Electricity Trust of south Australia) continue to control road lighting on some main roads.

Western Australia. Main Roads Western Australia control the road lighting fitted to major roads.

Queensland. Queensland Main Roads control lighting fitted to highways, freeways and some arterial roads.

Tasmania. Main road lighting is controlled by the Department of Infrastructure, Energy and Resources.

Northern Territory. Main road lighting is controlled by the Department of Infrastructure, Planning and Environment.

Australian Capital Territory (ACT). Roads ACT maintain all street and roadway lighting in the ACT, including parkland, pathway and car park lighting on unleased land.

APPENDIX C

Assumptions, Variables and Constants used in Modelling

Assumptions:

A Single carriageway road is treated as carrying two way traffic.

A Dual carriageway road is treated as carrying one way traffic in each carriageway.

For Average Luminance (Lbar), Overall Uniformity (Uo), Surround Illuminance (Esr & Esl) & Threshold Increment (TI) the observer is placed mid way across the total width of the lanes in the driver's direction only (i.e. ¼ for single and ½ for dual). The full carriageway width is used for the calculation grid.

Spacing is the distance measured longitudinally along road between Luminaires (irrespective of which side of the road the light is on).

Compliance is based on allowing the minimum overall uniformity (Uo) to fall to 0.31 only if the Average Luminance (Lbar) is 10% or more above minimum requirement in Code.

Design Variables:

Arrangements	Category	Mounting Height	Carriage width	Lanes	Over Hang
1 (Single sided)	V1	9 m	7 m	2 lanes of 3.5 m one per direction	1 m
3 (Staggered)	V2	10 m	14 m	4 lanes of 3.5 m two per direction	3 m
4 (Opposite)	V3	12 m	21 m	6 lanes of 3.5 m three per direction	5 m
5 (Divided opposite)	V4	15 m			
6 (Divided central)	V5				
7 (Divided twin staggered)					
8 (Divided twin opposite)					

Constants:

> Median width = 2.5m.

> First and second row have identical overhang.

> Luminaire upcast = 5°.

> Reflectance table = R3 .

> Maintenance factor = 0.7.

> Lane width 3.5m

APPENDIX D

Overview of Australia Standards AS1158 Series

AS/NZS 1158.0:1997 Introduction

> Definitions,

> Symbols

> Abbreviations,

> Categories and application

AS/NZS 1158.1.1:1997 Category V

> Lighting for Vehicles

> New Zealand/ Australian Requirements (levels and Observer position)

> Illuminance (intersections etc) and Luminance Methods (straight sections)

> Table 1.1, Category Descriptors (V1 to V5) lower the number higher the levels

> Table 2.1 Lighting Values

> Arrangements Single Carriageways

- Arr1 Single Sided (Left)
- Arr2 Single Sided (Right) [as Arr1 except for Asymmetric Distributions]
- Arr3 Staggered
- Arr4 Opposite

> Arrangements Divided Carriageways

- Arr5 Opposite
- Arr5S Staggered
- Arr6 Central
- Arr7 Twin Staggered
- Arr8 Twin Opposite

AS/NZS 1158.1.3:1997 Cat V Guide to operation

AS/NZS 1158.2 Computer Calculations

AS/NZS 1158.3.1:1997 Category P

- Lighting for Pedestrians
- New Zealand/ Australian Requirements (levels)
- Table 1.1 to 1.5, Category Descriptors (P1 to P12).
- Road lighting P1 to P5 lower the number higher the levels
- Lighting Values (Environmental)
    - o Glare

    - UWLOR
    - E_{VE}
- Table 2.1 to 2.4, Lighting Values
- Table 2.5 Luminaire Classification
- Table 1.1/2.1 P1 to P5 Road Lighting
- Table 1.2/2.1 P1 to P4 Pathways
- Table 1.3/2.2 P6 to P8 Public Activity Areas
- Table 1.4/2.3 P9 to P10 Connecting elements
- Table 1.4/2.4 P11 to P12 Outdoor Car parks

AS/NZS 1158.4 Pedestrian Crossings

- Lighting for Vehicles and Pedestrians
- Adjacency
- Vertical Levels 45lux.
- Glare/Aiming

AS1158.6 Mechanical Electrical construction

- Maximum Watts Loss for the control gear.
- IP54 (optical)/ IP24 (gear) (IP 6X optical lower maintenance)
- Aluminium Body
- Cat P <= 125W,
    - PE Cell is D2 type, normally closed base (cell out lamp on)
    - Side entry 20NB/25NB, 27mm/32mm Side Entry Spigot
- Cat V >= 100W,
    - PE Cell is NEMA type normally open base (cell out lamp off)
    - Side entry 232NB/40NB, 43mm/48mm Side Entry Spigot
- Semi-Cut Off, Aeroscreen
- Ambient of 40°C
- Decorative Inclusion