SLSC
STREET LIGHTING | SMART CONTROLS

Roadmap

STREET LIGHTING AND SMART CONTROLS PROGRAMME

2016/17

IPWEA
INSTITUTE OF PUBLIC WORKS ENGINEERING AUSTRALASIA

Australian Government
Department of the Environment and Energy

IPWEA gratefully acknowledges the support and advice of its public and private sector Street Lighting and Smart Controls (SLSC) Programme Partners:

SLSC Council Members[1]

Technical Advisory Group (TAG)

- Eaton Lighting
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- Aldridge Traffic Technologies
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- Southern Sydney Regional Organisation of Councils (SSROC)
- Lighting Council New Zealand (LCNZ)
- Local Government New Zealand (LGNZ)
- VRT Systems
- Telematics Wireless

1 Next Energy is a member of the SLSC Council in an advisory capacity on behalf of IPWEA with SLP acting as an alternate

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The authors and IPWEA explicitly acknowledge that the contributions and advice noted above do not represent an endorsement of the contents of this document. Street lighting technology, standards and regulations are evolving rapidly with many of these developments subject to differing interpretations. A wide variety of viewpoints were carefully considered in the compilation of this Roadmap.

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Roadmap Authors

This Roadmap was compiled by independent consultants Strategic Lighting Partners Ltd (Godfrey Bridger and Bryan King) and Next Energy Pty Ltd (Graham Mawer) as advisors to the IPWEA Street Lighting and Smart Controls Programme.

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Contact

Institute of Public Works Engineering Australasia, Level 12, 32 Walker Street, North Sydney NSW 2060 Australia
Phone: 1300 416 745

Email: admin@ipwea.org

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EXECUTIVE SUMMARY

Working with government, industry associations and industry partners, the Institute of Public Works Engineering Australasia's (IPWEA) two year-initiative, the Street Lighting and Smart Controls (SLSC) Programme is designed to help accelerate the deployment of LED street lights and smart controls in Australia and New Zealand. This initiative builds on IPWEA's close monitoring of street lighting developments since 2012. In 2014, it published its well-received Practice Note 11: Towards More Sustainable Street Lighting. *IPWEA's vision with the SLSC Programme is to see near full deployment of LED street lighting and smart controls by 2027. Achieving this goal will deliver a range of financial, energy productivity, environmental, road safety, public safety and community liveability objectives as outlined in this Australian Roadmap for the SLSC Programme.*

1.1 Background

Street lighting has three main purposes: to increase pedestrian and vehicle safety; to reduce street crime; and to provide comfort and amenity to all street and footpath users.

Street lighting technology has evolved slowly over past decades, but there have been substantial recent advances with the emergence of energy efficient and cost effective LED lighting, high-reliability electronic power supplies and sophisticated control systems. In a few short years, LED lighting has become the dominant technology for most new street lighting deployments internationally. Large-scale replacement programmes are underway worldwide.

The early work of state-based local government associations and regional organisations of councils in securing deployment of LEDs, deploy other earlier types of energy efficient lighting and to opening up important questions about the need for regulatory and pricing reform is acknowledged by the IPWEA. Of particular note was the pioneering work of the MAV and SSROC in securing early energy efficient lighting deployments and the work of LGSA, LGAT, LGANT and WALGA in opening up important regulatory and policy debates about street lighting in their respective jurisdictions. The more recent work of LGIS in seeking an improved approach to street lighting in Queensland is also acknowledged.

IPWEA believes that Australia should similarly accelerate the replacement of its street lighting with LEDs and smart controls to help meet a variety of public policy objectives in economic development, road safety, transport, public health, environment, energy productivity and smart cities.

1.2 Benefits of Large-Scale Replacement of Street Lighting

Based on research and modelling undertaken in the preparation of this Roadmap, the benefits of widespread Australian deployment of LEDs and smart controls are summarised as follows:

- **Energy and Greenhouse Gas Savings** – A 52%+ reduction in street lighting energy use and consequent Greenhouse Gas (GHG) emissions and a further 10-20% improvement if smart controls are included.
- **Maintenance Savings** – A 50%+ reduction in the street lighting maintenance burden from the greatly improved reliability of LEDs as compared to previous luminaire technologies and through the better asset management capabilities of smart controls.
- **Overall Cost Savings** – At least a 25% reduction in total long-term costs for councils and main road authorities from a combination of maintenance and energy savings.
- **Safer Roads** – A material reduction in road crashes (and consequent fatalities and serious injuries) at night by potentially increasing lighting levels that can reduce crashes by as much as 30%. Widespread use of high quality white LED light with better colour rendition and optical control, together with higher levels of reliability may add further safety benefits. This could materially contribute to achieving the government's challenging National Road Safety Strategy goals by 2020.
- **Environmental Benefits** – The reduction of carbon emissions, elimination of 90kg of the mercury currently used in legacy street lighting lamps, reduced obtrusive light, reduced upward waste light and consequent sky glow, and reduced impacts on Australia's ecology when smart controls are used to better control lighting outputs.

- **Facilitating the Smart City** – Improvements in the delivery of community services, productivity, disaster resilience and liveability by using street lights as an enabling platform for transmitting community-wide data and establishing connectivity with other devices in the public domain.
- **Night-time Enhancement** – Enhancing the amenity, ambience, and safety of streets, parks, and the business prospects of entertainment and tourist precincts at night.

The wide ranging benefits available suggest the need for a street lighting strategy that leverages a whole-of-government approach. Overall, the business case for a national LED replacement programme is summarised in Table 1 which only values capital cost and the energy and maintenance cost savings.

Table 1: Overall Investment Performance of Accelerated LED Replacement if Only Electricity and Maintenance Savings Counted

Estimated Capital Costs of Large-Scale Replacement Programme	Estimated Energy Savings (based on typical costs of all charges proportional to energy consumption of $0.15c/kWh)	Estimated Maintenance Savings (based on 50%+ reduction in current spot and bulk maintenance costs)	Total Estimated Energy and Maintenance Savings	Simple Payback Period	Net Present Value (at 4% discount rate over 15 years including initial capital cost and savings)
$1.1 billion	$180 million/yr	$60 million/yr	$240 million/yr	4-5 yrs	$1.6 billion

Importantly, these figures are based on large-scale deployment and do not account for the widely variable carrying amounts of old lighting, as claimed by some electricity distribution DNSPs and which are highly jurisdiction-specific and even customer-specific. Excluded from consideration above are the potential additional benefits of smart controls as well as the range of consequent indirect societal benefits outlined previously.

1.3 Barriers to Deployment

A range of regulatory, commercial, standards, knowledge, financial and communications barriers have been summarised in this Roadmap with specific initiatives identified to address each of these proposed.

Of greatest concern to many stakeholders is the range of regulatory barriers. Foremost amongst these is the absence of a clearly defined basis of service for most Australian street lighting and the lack of alignment between legal responsibility for providing the service and control over the service. Many consulted in the course of preparing this Roadmap suggested that this creates fundamental challenges for all parties in administering street lighting efficiently and that regulatory and policy reform is urgently needed.

One option is reform of the current DNSP ownership model. This would involve establishing a clear basis of service, better aligning control over key decisions with responsibility, establishing minimum service standards and establishing a more robust basis of pricing. In addition such a change might also address the need for transparency in pricing, for pricing to be based on minimising the total cost of service, for flexibility in carrying amount payment approaches and providing clear incentives to move to more energy efficient and reliable technology.

A second reform option is the opening up of competition under a robust access and contestability framework that would allow councils and main road authorities to choose their service provider and make their own decisions about technology and service levels. Current policy settings incorrectly assume competition is facilitated, but in the decade since they have been in place, no meaningful competition to the provision of street lighting services has resulted.

Under either reform path, establishing minimum acceptable electricity supply service levels for street lighting and investigating the high claimed asset carrying amount in several jurisdictions will need to be addressed.

1.4 Current Infrastructure and Costs

Fifteen DNSPs and the ACT Government provided detailed information on their street lighting assets and policy positions as a key input to this Roadmap. This information established that there are about 2.3 million street lights in Australia owned by, managed by or otherwise directly connected to the electricity distribution networks. This information has been key to understanding both the current situation and the potential benefits of change.

Residential road lighting makes up 67% of the national portfolio and more than half of this is currently mercury vapour lighting, the least efficient of any street lighting technology deployed in the past 50 years. Intermediate roads constitute a further 7%, split largely between mercury vapour and high pressure sodium. Main roads constitute 26% of road lighting and more than 90% of main road lighting is high pressure sodium. With regards to LEDs, 98% of LED deployments on the DNSP networks to date are on residential roads and uptake rates vary widely by state. Overall, LEDs make up about 6.5% of utility lighting based on DNSP inventory quantities but are likely to be closer to 9.5% in the coming months, based on supplier sales figures. In the last few years, LED street lighting has emerged as the dominant technology for most new street lighting deployments internationally. With growing confidence in this technology, DNSPs in Australia are starting to transition from trials to installations.

The levelised annual costs of street lighting are estimated at $420m per year, based on the average of total annual costs of: capital, maintenance, retail energy, network distribution, electricity losses, environmental charges, and market charges for the most common types of utility-owned luminaires across four major utilities in four different jurisdictions. The costs of dedicated columns and underground electricity supply may be adding a further $200m per year in levelised terms.

While the number of lights rises broadly in line with population growth, energy use and consequent GHG emissions from street lighting have declined by about 12% from previously studied 2011 levels, but a significant opportunity exists to cut remaining consumption by a further 52% or more, based on detailed modelling of the current national portfolio against replacement LEDs of types already deployed by at least one DNSP.

At present, two thirds of all Australian DNSPs offer LEDs as a standard lighting option for residential roads while one third are believed to be trialling LEDs for main roads. Demonstrating their growing interest in the technology, the DNSP responses to the IPWEA survey were unanimous in their willingness to share LED maintenance data under a properly managed information exchange programme. Half of the DNSPs are currently investigating smart controls systems though none have yet deployed them.

A survey of LED luminaire and smart controls suppliers was undertaken in June 2016. This was conducted to provide a second data source on the adoption rates of LEDs and smart controls in addition to the survey of DNSPs. A total of twenty suppliers participated and provided sales data on a confidential basis. The total of LED luminaires reported sold to date was 245,000, with 94% deployed on Category P roads and 6% on Category V roads. The total of smart controls reported was about 2,200 lightpoints, with 88% on Category P roads and 12% on Category V roads.

1.5 SLSC Programme Deliverables

In this Roadmap, IPWEA is proposing an ambitious two-year programme of deliverables to address the barriers to rapid deployment of LEDs and smart controls, including:

- **Policy Engagement** – Identifying possible legislative, regulatory policy and standards changes for detailed stakeholder consultation;
- **Model Documents** – Preparing model LED street lighting, smart controls specifications and other documents to improve market efficiency;
- **Training** – Developing website, webinars, workshops and other tools to educate all stakeholders.

1.6 Managing Risks

The first group of risks are to IPWEA and SLSC Programme stakeholders, that:

1. Councils may be under-resourced and lacking sufficient internal expertise to optimise the potential and benefits of the SLSC Programme;
2. Government department silos may be a barrier in achieving a whole-of-government solution;
3. The complex regulatory issues require high level interventions and may not receive sufficient priority over other reform activities.

The second group of risks is for the lighting asset owners and stakeholders, and these are that:

1. Incremental change to business-as-usual approaches to procurement, specifications and tendering processes will not be sufficient and there may be reluctance to take the ‘clean-sheet’ approach required to preemptively mitigate project risks;
2. Wider strategic opportunities for major improvements in amenity, safety and revenue generation may be overlooked as the easy wins of energy and maintenance savings appear adequate in themselves. Lack of appetite for significant reform risks missing a major opportunity to do so.

1.7 Importance of Stakeholder Engagement

IPWEA recognises that street lighting is a complex, multi-faceted issue with a wide variety of stakeholders, many of whom have not previously been involved in street lighting issues. Effective stakeholder engagement will be key to achieving significant change and has been a core focus in the early stages of the SLSC Programme. Modernising street lighting with LEDs and smart control systems is a rare opportunity to engage with stakeholder groups on issues that result in such large net benefits that it is likely to strengthen faith in governance.

IPWEA gratefully acknowledges the support and advice of its public and private sector SLSC Programme Partners: Department of the Environment and Energy, Energy Networks Australia, Lighting Council Australia, Australian Local Government Association, GE, Philips, Gerard Lighting, Cisco and Silver Spring Networks and a rapidly growing range of luminaire, smart controls, industry associations and major cities who have agreed to contribute as part of its Technical Advisory Group.

1.8 Recommendations

The central conclusion of this Roadmap is that overwhelming evidence exists to warrant investing significant effort to address barriers and facilitate accelerated replacement of legacy street lighting with LEDs and smart controls. Note that the following recommendations are those of IPWEA and do not represent the views of, or come with endorsement from, any Commonwealth, state or local government or other organisation. Other conclusions and recommendations are provided in Section 14 and summarised here:

1. **IPWEA to implement ANZ SLSC Programme –** IPWEA to implement SLSC Programme deliverables outlined in this Roadmap including preparing a policy discussion paper, developing a series of model specifications and other templates, developing and delivering a series of educational and training initiatives (e.g. website, webinars, training workshops, conferences, newsletters), working with standards organisations and helping to facilitate applied research.
2. **Establish smart cities street lighting group –** Provide formal input into the Australian Government's Smart Cities Plan to ensure street lighting is appropriately leveraged into that programme like it is in other parts of the world.
3. **Establish an electricity network street lighting group –** With membership from ENA and other relevant stakeholders to address the issues identified in this Roadmap and integrate street lighting modernisations together with ENA's Network Transformation Roadmap.
4. **Implement public lighting codes –** State and territory governments, in consultation with the AER and AEMC, consider adopting an enforceable public lighting code to assure good public lighting outcomes. This would apply to all DNSP street lighting service providers and include consideration of regulation and enforcement models (within jurisdiction or nationally).[2]
5. **Offer new financing models –** All DNSPs provide the option for councils to pay the RAB carrying amount for the old technology in instalments over a number of years or to cover capital costs of new lights via electricity and maintenance savings over time (avoiding the need for local government to fund capital investment upfront and allow cost neutral capital investment).
6. **Contestability and access framework –** Establish a national contestability and access framework to facilitate competition in street lighting, smart controls and smart city assets in each jurisdiction.
7. **Transport and infrastructure council –** Establish an advisory group to reduce injuries and fatalities at night and leverage the new investment in LED street lighting and smart controls to materially contribute to achieving the National Road Safety Strategy 2011–2020 targets.
8. **Hold state-based workshops –** Workshops to be held in each state and territory with street lighting stakeholders (DNSPs, state, ALGA, LG and main road authority representatives) to discuss the Roadmap and workshop actions to facilitate effective LED and smart controls adoption.
9. **Nominate state representatives –** State and territory governments nominate a government representative to work with IPWEA to facilitate discussions between street lighting stakeholders in their jurisdiction and take a leadership role as part of the SLSC to progress agreed action.
10. **Make LEDs an option everywhere by 2018 on all classes of roads and complete deployment by 2027 –** All street lighting service providers to offer LED luminaires by 2018 in consultation with stakeholders and to aim for full replacement of the existing lighting base by 2027.
11. **Initiate national smart controls project –** Initiate a project to define smart control user requirements in city, metropolitan and regional areas considering cost/benefits for all parties as well as potential changes to unmetered/metered arrangements for street lighting for discussion with AEMO.
12. **Pursue standards reform –** A submission is made to Standards Australia to continue the modernisation of AS/NZS 1158 to better reflect international best practice and the needs of Australia and New Zealand.
13. **Establish an official committee** – To specify minimum security requirements for smart street lighting control systems and their application to smart cities.
14. **Establish an official group to consider the ecological, human health, dark sky and other light pollution aspects –** Use international best practice and knowledge to minimise the harmful effects of the night light and maximise its positive effects.
15. **Establish a street lighting research advisory group –** Identify where research needs to take place to confirm relationships between white LED lighting dosage[3] and crashes, injuries, fatalities, crime, human behaviour, ecological impact and dark sky needs to take place and where funding can be attracted. These and other important subjects for research are included in Section 9.13.

2 Victoria is currently the only jurisdiction with enforceable service standards. The purpose of the enforceable code would be to specify minimum standards and obligations of street lighting service providers and public lighting customers to provide a safe environment for pedestrian and vehicle movement during times of inadequate natural light.

3 Lighting dosage is the product of the intensity level multiplied by the duration for which it is experienced.

2

INTRODUCTION

2.1 The Institute of Public Works Engineering Australasia (IPWEA)

The Institute of Public Works Engineering Australasia (IPWEA) is a peak not-for-profit association covering the essential public works and services delivered by local, state and federal tiers of government. Its membership of more than 4,000 encompasses both the public and private sectors. IPWEA is an industry leader in the area of asset management, and its National Asset Management Strategy (NAMS) programme is a highly recognised and widely utilised infrastructure management service throughout Australia, New Zealand and in parts of Canada.

In addition to having members from almost every local government in Australia and New Zealand, almost all of Australia and New Zealand's professional consultancy firms that specialise in public sector infrastructure – including roads, water, power, rail, ports and airports – have managers and staff who are members of IPWEA.

IPWEA has initiated the Street Lighting and Smart Controls (SLSC) Programme in response to queries from members seeking advice on the effective management of street lighting services. IPWEA aims to provide best practice guidance on the effective management of this service for the benefit of members and the wider community.

2.2 Street Lighting and Smart Controls Programme (SLSC)

IPWEA's Street Lighting and Smart Controls Programme, aims to:

- Show how a strategy of wholesale renewal of road lighting infrastructure that takes advantage of large improvements in lighting technology can leverage benefits that apply across multiple government policy and industry objectives;
- Help accelerate the adoption of modern street lighting technologies and practices.

The SLSC Programme is supported by government agencies seeking to improve the energy efficiency of street lighting in Australia to reduce energy use (which in turn reduces electricity bills) and emissions for the benefit of the community. This support is through the Department of the Environment and Energy and also through the separate budgets of the Commonwealth, state and territory and New Zealand *Equipment Energy Efficiency Program (E3 Program)*.

Working together with government and industry, implementation of this Roadmap will help achieve a range of cost saving, energy efficiency, climate change, road safety, public security, smart city, innovation, productivity and other public policy and industry objectives. To date, adoption of city-wide or complete towns with LED and smart controls technologies has been slow in Australia and New Zealand in comparison to many other locations around the world.

There are information gaps around the relatively new LED and emerging smart control technologies, creating obstacles for public works managers trying to navigate street lighting asset management. IPWEA has identified an opportunity to take a leadership role in bringing stakeholders together to address issues and facilitate the achievement of benefits that LED and smart control technology can deliver for the community.

2.3 SLSC Roadmap

This SLSC Roadmap examines Australia's policy objectives that relate to modernising street lighting and, where possible, quantifies the benefits of widespread adoption of best practice lighting technologies. This Roadmap also summarises the current situation, identifies current barriers to uptake – including structural and market impediments – to ensure the Roadmap is relevant to government policy. The Roadmap has been developed in consultation with key stakeholders within and outside government and identifies the key risks to be managed and mitigated. It provides an update to, and builds upon, the Draft National Street Lighting Strategy (2011), commissioned by the E3 Program.

This Roadmap contains the most comprehensive and up-to-date data analysis and review ever undertaken of the whole-of-industry impacts on Australia's street lighting and emergent smart controls industry. It also appears to be a world first for such an all-embracing analysis. Like all firsts, knowledge gained during the process has morphed the original document brief from identification of issues to the formulation of options. The Roadmap presents significant options and recommendations for governments and industry to focus upon in identifying an agreed action plan. Future versions of this Roadmap, or one specifically drafted for New Zealand, are intended to include information relevant to New Zealand. This version restricts itself to Australia.

The Roadmap is therefore the foundation document setting the direction for all subsequent SLSC activities and publications which will build upon its findings. It portrays the development of a coherent pathway towards achieving the goals of government and the SLSC Programme.

2.4 Authorship and Consultation

This Roadmap was prepared by Strategic Lighting Partners and Next Energy for the Institute of Public Works Engineering Australasia (IPWEA) with support from the Department of the Environment and Energy. Consultation has taken place at all draft levels with this draft having been contributed by about 35 different people and/or organisations.

3

GOVERNMENT POLICY ISSUES

Street lighting can reduce night-time fatalities by as much as 30%. White LED lighting adds further safety benefits.

Street lighting is one of the most cost-effective road safety measures with Benefit Cost Ratio (BCR) greater than 4.

2.3 million street-lights provide a physical base for smart city infrastructure.

- Street lighting energy efficiency could be improved by more than 50%, directly contributing to achievement of the National Energy Productivity Target to improve energy productivity by 40% by 2030.
- Financial savings from reduced crimes could be achieved after introducing street lighting (exceeding costs by 2-10 times).
- National Road Safety Strategy 2011 - 2020 goals could be substantially enhanced by a road lighting strategy.
- Up to 20% faster driver reaction times with white light on V4 Category Roads.
- Remove mercury from the environment by eliminating legacy lighting.

3.1 Introduction

LED lighting is well-recognised as being capable of increasing energy efficiency by more than 50% and reducing maintenance costs by more than 50%, and this has justifiably attracted significant policy focus, including in this Roadmap. Provision of improved street lighting infrastructure also addresses other important government policy priorities including enhancing road safety, improving value for money, improving environmental sustainability, reducing street crime and increasing community liveability. A lighting infrastructure change to LED for economic reasons suggests that this is also a significant opportunity to make an assessment of where more or less lighting - either through physical location or illumination levels - should be applied for the most net gain of public benefit, be it road safety, crime, ecology, dark sky or other public health reasons.

Some of these policy benefits relate to LED and/or smart controls alone, whereas some relate to all street lighting. This Roadmap advocates a fundamental policy examination of this important infrastructure because it has been overlooked for a long time. Thus, new LED and controls technology provide an important opportunity to re-examine how street lighting could substantially improve the quality of Australian lives in many ways.

Street lighting has three main purposes: to increase pedestrian and vehicular safety; to reduce street crime; and to provide comfort and amenity to all road and footpath users. Historical investment and management decisions have largely accepted the benefits of street lighting without question and without the same systemic approach to quantify costs and benefits as has been applied to many other infrastructure assets.

Street lighting technology has evolved slowly over past decades but recent substantial advances in lighting and controls technology, and an increased understanding of the social and environmental impacts of lighting, now provides a significant opportunity to provide additional important benefits if the right policy settings are applied. An economically justified large-scale lighting upgrade of dated lighting infrastructure is also an opportunity to make the case for change even more compelling by consideration of other policy benefits beyond the energy and cost savings. This section outlines where those opportunities exist from a government policy perspective. The benefits of street lighting are treated in the four policy areas of public health, energy, environment and smart cities. Each of these are dealt with in this section by identifying credible research or best practices for input into policy.

3.2 Public Health

Public Health is defined by the World Health Organisation (WHO) as *"... the art and science of preventing disease, prolonging life and promoting health through the organised efforts of society."* The WHO emphasises that road safety and interpersonal violence are public health issues. Figure 1 shows the proportion of each of the nine peer countries' population that has died as a result of road injuries (in blue) and interpersonal violence (black) which is categorised by WHO to include crime. This subsection on public health discusses the relevance of street lighting to this high level perspective.

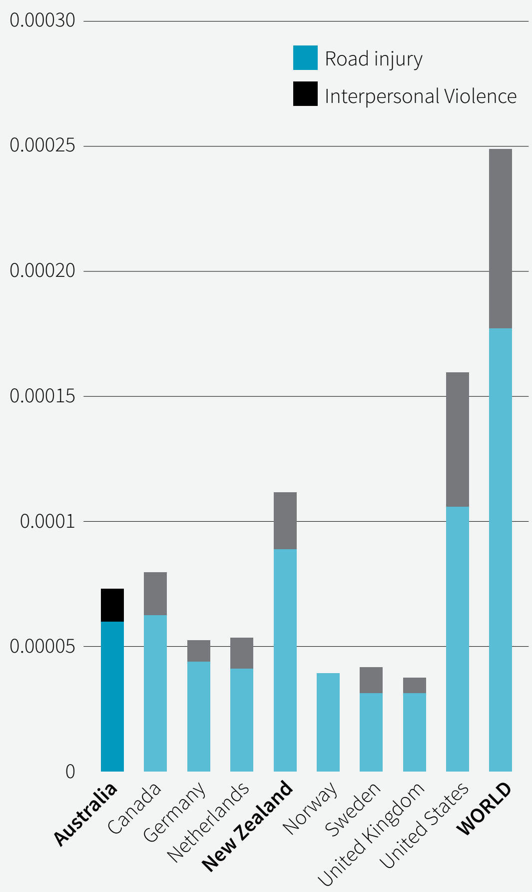

Figure 1 – Proportion of population dying from road injuries and interpersonal violence in 2012 (WHO)

WHO estimates that every year there are 1.25 million deaths caused from road injuries[4] but observes that the estimated 50 million road injuries that do **not** result in death[5] cause much greater economic and social damage. However, because the data gathering methods widely vary across the world these injuries are not analysed. With its eight states and territories, Australia suffers the same problem[6]. In 2011, there were 1,151 deaths in Australia from road injuries[7] but 52,989 *"... hospitalised injuries arising from transportation."*[8] The economic cost caused by road injuries and fatalities is very large and estimated to be between $18 and $27 billion per year[9] depending on the economic methods used for calculation.

3.2.1 Road Safety

In Australia, road safety policy is governed by the Australian Transport and Infrastructure Council,[10] a sub-committee of the Council of Australian Governments[11] (COAG) and through several implementation agencies including the Commonwealth's Department of Infrastructure and Regional Development which has published the National Road Safety Strategy 2011–2020.[12] The strategy follows United Nations and OECD guidelines and advocacy of the 'Safer Systems' approach which separates road safety policy and strategy into four categories: 'Safe Roads', 'Safe Speeds', "Safe Vehicles' and 'Safe People'. The strategy is ambitious and best described using its own words:

"... elevate Australia's road safety ambitions through the coming decade and beyond. It is firmly based on Safe System principles and is framed by the guiding vision that no person should be killed or seriously injured on Australia's roads. As a step towards this long-term vision, the strategy presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. These targets will be challenging: they compare, for example, with a 23 per cent reduction in road deaths achieved over the last decade. The casualty reduction targets for 2020 are ambitious, but achievable."[13]

While Australian states and territories and New Zealand have independent responsibility for road transport infrastructure, those jurisdictions share many standards, guides, practices, and technical services. This also includes research and analysis of road safety. The organisation that co-ordinates these is Austroads Ltd which was formed by the state, territory and NZ transport agencies to deliver technical transport services across Australia and New Zealand.

4 *World Status Report of Road Safety 2015,* World Health Organisation, Section 1, page 2

5 Ibid., Background, page x

6 "Australia does not have systems in place to reliably measure national indicators of injuries from road crashes, in part because of jurisdictional differences in injury definitions and reporting arrangements." *Road Safety Annual Report 2016,* OECD, International Traffic Safety Data and Analysis Group (IRTAD), page 52

7 *Road Trauma Australia 2014 Statistical Summary,* Department of Infrastructure and Regional Development, Bureau of Infrastructure, Transport and Regional Economics (BITRE), Table 3.2 Fatal crashes by crash type and time of day, page 34

8 Pointer, S., *Trends In Hospitalised Injury,* Australia 1999–00 to 2010–11, Australian Institute of Health and Welfare, Canberra, 2013. page 8

9 *National Road Safety Strategy 2011-2020,* Australian Transport Council, page 4

10 Membership consists of Commonwealth, state, territory and New Zealand Ministers with responsibility for transport and infrastructure issues, as well as the Australian Local Government Association (ALGA)

11 The members of COAG are the Prime Minister, state and territory Premiers and Chief Ministers and the President of the Australian Local Government Association (ALGA)

12 Available from http://roadsafety.gov.au/nrss/files/NRSS_2011_2020.pdf

13 *National Road Safety Strategy 2011-2020,* Australian Transport Council, page 3

i. Night-time Road Injuries

Street lighting's primary function is to remove darkness[14] and improve vision – a fundamental requirement for mobility. It is therefore important to know what proportion of the deaths caused by road injuries occur at night. Australia's Bureau of Infrastructure, Transport and Regional Economics (BITRE) publish important reports in regards to road safety and Figure 2[15] shows that between 30% and 50% of all fatalities are at night. In 2014, there were 388 night time fatalities corresponding to 37% of all deaths[16] from road injuries in Australia.[17] If that 37% proportion is applied to all transport injuries, it suggests that night time accidents cost the Australian economy $7-10 billion per year.

ii. Road Categories

In relation to street lighting, Standards Australia and Standards New Zealand provide a suite of standards called AS/NZS 1158 that are used across Australia and New Zealand. This complex engineering standard is made up of seven parts that provides detailed guidance on how to establish the appropriate amount of light on the on the road and surrounding surface according to road activity and conditions. This standard is universally used across both countries and divides roads into two different categories: 'V Category' (vehicle predominant) and 'P Category' (pedestrian predominant). However, compliance with the standard does not require field measurement or verification and relies only on CAD software that models the physics of lighting from the lighting parameters and road geometry. Furthermore, the decision to choose one of nine road categories to apply - which determines the lighting level - is a subjective decision not covered in the same very precise detail required by the rest of the standard.

V Category Roads

Category V road lighting is designed to keep vehicle drivers safe while driving in high volume traffic situations. The standard describes the different subcategories of roads and streets in subjective language and therefore leaves the interpretation of these descriptions to the judgement of traffic engineers.

P Category Roads

Category P road lighting is designed to keep pedestrians safe in low volume and relatively low speed mixed pedestrian and vehicular environments. Like V category roads, the standard describes the different subcategories of P category roads in subjective language and leaves the interpretation of this description to the judgement of traffic engineers.

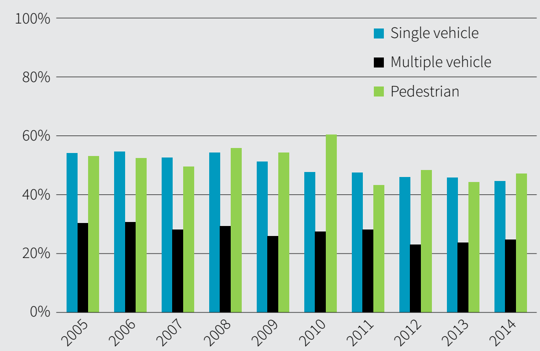

Figure 2 – Proportion of fatal crashes occurring during night-time (BITRE)[15]

iii. Street Lighting Effects on Road Injuries

A substantial body of research shows that the existence of street lighting delivers significant reductions in injuries and fatalities. In reviewing a range of international studies, AS/NZS 1158[18] concluded that street lighting can reduce night time road accident rates by 30%. More recent material in *The Handbook of Road Safety Measures,*[19] which is widely used internationally by road safety engineers, identifies that *"... the largest number of studies are for road lighting and..."*[20] According to the authors of this Handbook, Elvik et al, *"For motor vehicles, the risk of having an accident in darkness is about 1.5 – 2 times higher than in daylight."*[21]

The US Federal Highway Administration's Lighting Handbook August 2012 suggests the risk of travelling at night is significantly greater:

"Driving or walking on, or across, a roadway is less safe in darkness than in a lighted area, due to the reduced visibility of hazards and pedestrians. Though the number of fatal crashes occurring in daylight is about the same as those that occur in darkness, only 25 percent of vehicle-miles travelled occur at night. Because of that the night time fatality rate is three times the daytime rate..."[22]

This is acknowledged by Elvik et al with the statement that, *"According to a study from the USA, about 25% of all traffic travels during the hours of darkness while 50% of all fatal accidents occur in darkness."* The range of results from having road lighting is tabulated in Table 2,[23] but summarised by the sentence in the

14 Though later discussion in this Roadmap identifies how it provides a growing use for electronic sensors and communications infrastructure for smart cities during the day as well as at night

15 *Road Trauma Australia 2014 Statistical Summary*, Bureau of Infrastructure, Transport and Regional Economics, Department of Infrastructure and Regional Development, Canberra, Australia, July 2015, page 34

16 Noting that distances travelled are much reduced at night compared to day

17 *Road Trauma Australia 2014 Statistical Summary,* Table 3.2, page 34. Note that this excludes all fatalities which were not recorded with a time of day

18 AS/NZS 1158.1.1:2005 Vehicular traffic (Category V) lighting, Preface, page 2

19 Elvik, R, Hoye, A, Vaa, T, and Sorensen M (2009), *Handbook of Road Safety Measures,* Institute, of Transport Economics, Oslo, Norway, Emerald Group Publishing Ltd, 2nd Edition, October 2009, Part II, Section 1.0 Table 1.0.1 page 145 – 155 and pp 272 – 281

20 Ibid. page 147

21 Ibid. page 272

22 Paul Lutkevich, Don McLean, Joseph Cheung, FHWA Lighting Handbook, Office of Safety, Federal Highway Administration, August 2012, page 4

23 Høye, A. et al. (2016). *The Handbook of Road Safety Measures* (web edition, in Norwegian). Extracted from Table 1.18.1 page 184 and translated by Prof Rune Elvik. Accessible at www.toi.no

English 2nd edition: *"According to the results in Table 1.18.1,* ***road lighting reduces fatal accidents by 60% and injury and property-only accidents by around 15%****"* (emphasis added).

In the USA and Europe the response to this research was to significantly increase required lighting levels and some researchers have suggested that over-lighting is probably taking place – which is discussed below. However, in Australia and New Zealand, historical lighting levels were not changed and lighting levels for typical roads in comparison to those in the USA and Europe are between 17% and 75% of the levels required in Europe as shown in Figure 3. The USA has different standards to Europe, but have similar relativity to the Australian and New Zealand lighting levels.

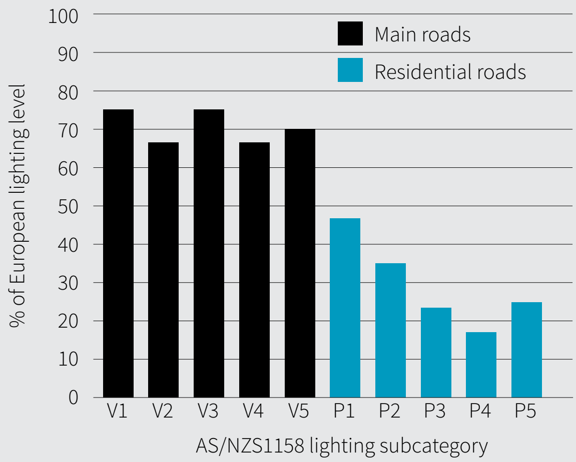

Figure 3 – AS/NZS Lighting level standards as a % of European standards (Source: SLP from relevant standards – AS/NZS, and EN)

Table 2: Effects of Road Lighting on the Number of Accidents in the Dark, Percentage Change in Number of Accidents

		Percentage change in the number of accidents	
Accident severity	**Accident types affected**	**Best estimate**	**95% confidence interval for effect**
	All types of road		
Fatal accidents	All accidents in darkness	-52	(-59; -45)
Personal injury / unspecified	All accidents in darkness	-26	(-33; -19)
Fatal accidents	Pedestrian accidents in darkness	-78	(-88; -62)
Injury accidents	Pedestrian accidents in darkness	-51	(-63; -36)
Injury accidents	Accidents on pedestrian crossings in dark	-53	(-66; -37)
	Roads in urban areas		
Personal injury / unspecified	Accidents on stretches outside corner	-10	(-41; +36)
	Accidents at intersections	-36	(-51; -18)

iv. Street Lighting Levels

The question of how lighting levels relate to road injury is important, especially now that LEDs and smart lighting controls can vary lighting levels from zero to 100% as required. And, as wholesale replacement programs provide an ideal opportunity to reconsider required lighting levels.

A New Zealand study by Jackett and Frith in 2012[24] concluded that the greatest reduction in injury crashes is shown to be in mid-block road sections (between intersections) where an increase of 0.5 candela/m^2 reduces injury crashes by 33%. In other parts of the network the decrease in injury crashes is less than this, but there is still a significant reduction.

24 Jackett, M and Frith, W (2012), Quantifying the impact of road lighting on road safety – A New Zealand Study, Australasian Road Safety Research, Policing and Education Conference 2012

For all sites (including mid-block) an average 19% reduction in crashes would result from that same 0.5 candela/m² increase.[25] These results were obtained from a survey of 7,944 crashes, so the results have very high confidence levels and are shown in Figure 4.

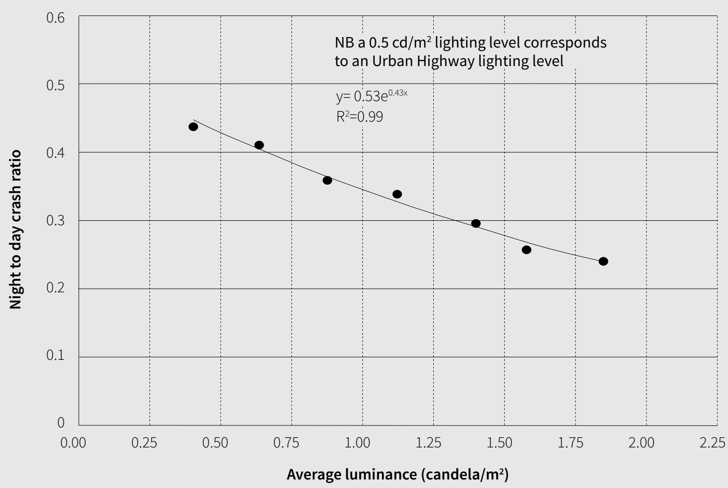

Figure 4 – Jackett & Frith Findings 2012

In a more recent study by the same authors for NZTA in 2015, they investigated street lighting on NZTA's high speed network (80-100k/h) where before-and-after comparisons could be made.

Their observation in the executive summary is that:

"The crash reductions for motorways in the relational study were: 33% for all crashes, 42% for injury crashes and 67% for serious and fatal crashes. These figures were derived by comparing the grouped night-to-day crash ratio of 57 lit sections of motorway with similar figures from six unlit sections. While the sample of unlit sections is by necessity small, the figures do appear consistent with other international and New Zealand studies, and the increasing crash reduction with greater injury severity is a common theme in the international literature."

"Once the motorway was illuminated, motorway crashes showed very little dose-response to increasing levels of average luminance. In fact the current level of V3 which has commonly been adopted for motorway design in New Zealand seemed from this data to be close to the optimum."

This research is corroborated by a large study by Gibbons[26] of 23,845 crashes in four US states in locations where lighting levels covered some of the lower lighting levels found in Australia and New Zealand. Note however, in the USA (and Europe) the lighting levels are generally substantially higher than in New Zealand and Australia as discussed above. Gibbons et al., showed that in general, lighting levels above 5 Lux[27] (higher levels than found on most New Zealand and Australian roads) had little effect on the incidence of injury crashes. At the lighting levels equivalent to those found in New Zealand (and Australia) the same relationship was found – that increasing light levels was associated with decreased night to day crash ratio.

As Gibbons states, *"…Anywhere there is less than five lux horizontal illuminance, injuries will be reduced by increasing light levels."*[28]

This research suggests that a significant number of Australian and New Zealand injuries and deaths could be prevented by increasing street lighting levels where they are currently below 5 lux.

A large-scale LED lighting upgrade presents an ideal opportunity to reconsider this issue and notably, smart controls may allow increases in lighting levels during the periods of greatest risk while still achieving significant energy and cost savings. Consultation is required with the departments responsible for transport infrastructure at Commonwealth and state jurisdiction level.

v. Driver Reaction Times

Clanton and Gibbons[29] investigated the colour characteristics of road lighting for a US State Energy Efficiency agency in 2014, and made some remarkable findings. They confirmed older research by Lewis[30] which showed that white light (produced in pre-LED days by Mercury Vapour and Metal Halide technology) reduced driver reaction times from those observed in yellow and orange light. At 1 candela/m², the difference between reaction times for white metal halide lighting and yellow high pressure sodium was 100ms, whereas at 0.1 candela/m² this increased to 300ms. In practical terms, this means that at a vehicle speed of 50km/hr, the stopping distance might be reduced by 4.2m while and at 100km/hr, it might be reduced by 8.3m. As shown in Figure 5, the reaction time difference between white and yellow lighting at the V4 Category level is 150m which corresponds to a 20% improvement in response time.

25 0.5 candela per square metre is about the same as the lighting level required for AS/NZS1158 subcategory V4 roads (sub-arterial road)

26 Gibbons, R., Guo, F., Medina, A., Terry, T., Du, J., and Lutkevich, P., *Design Criteria for Adaptive Roadway Lighting,* Federal Highway Administration (FHWA), Department of Transport, USA, March 2014

27 16 Lux for Arterial roads in the USA

28 Ibid, and P*resentation to Road Lighting 2014,* Auckland, New Zealand, March 2014

29 Clanton, Nancy, Ronald B. Gibbons, Jessica Garcia and Travis Terry, *Visual Quality, Acuity, and Community Acceptance of LED Streetlight Sources,* Northwest Energy Efficiency Alliance, REPORT #40385, March 2014

30 Lewis, A., *Visual Performance as a Function of Spectral Power Distribution of Light Sources at Luminances Used for General Outdoor Lighting,* Journal of the Illuminating Engineering Society, Winter 1999

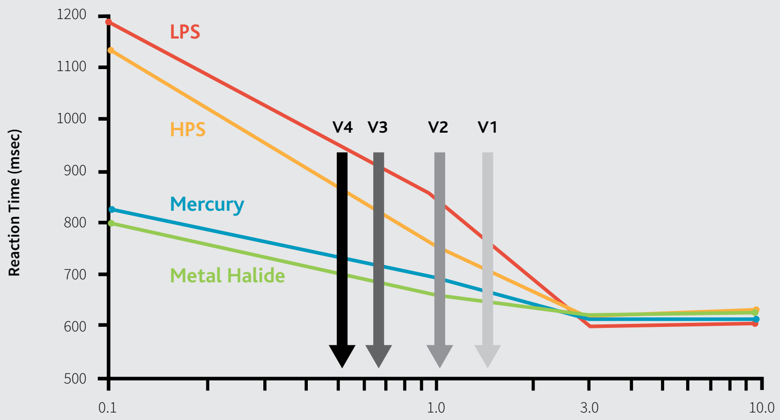

Figure 5 – Australian Highway Lighting Categories, reaction times improved by white light (Davis 1999, Arizona DoT, SLPC))

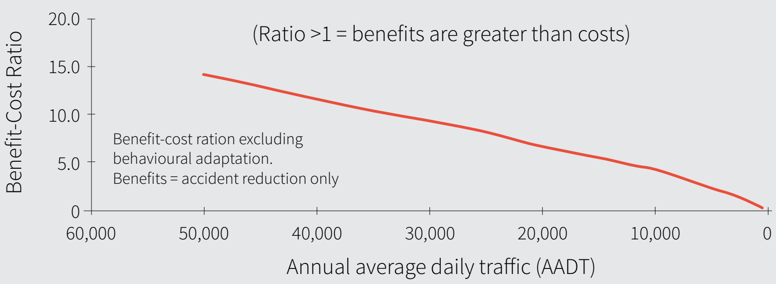

Figure 6 – Benefit-cost ratios for street lighting for a range of traffic flows

Figure 7 – An extract from Adelaide road map showing AADT levels (Austroads)

Gibbons' 2014 research compared yellow HPS lighting with white LED lighting, and showed that white LED lighting dramatically reduced driver reaction times and stopping distances. Gibbons' statement that most aptly summarises these findings is: *"146W LED white light dimmed to 25% of its rated output provided the same stopping distance (due to reaction times) on wet roads compared with full intensity 250W High Pressure Sodium street lighting on dry roads."* Faster driver reaction times strongly implies – but doesn't prove - that white light is likely to save lives and injuries. This Roadmap suggests this research is completed (discussed in Section 9.13) to confirm and further quantify the road safety benefits of replacing yellow street lighting with white light.

vi. Cost Effectiveness

Professor Rune Elvik, arguably the world's leading authority on the economics of road safety, suggests that road lighting is **the** most cost effective road safety measure available and yet remains the least well recognised – even amongst leaders in the field such as the Netherlands, Sweden and Norway. Professor Elvik is the lead editor of the English 2nd edition of the *Handbook of Road Safety Measures* and has provided data[31] to support these observations.

Figure 6[32] shows the relationship between the benefit-cost ratio (BCR) for street lighting and annual average daily traffic flows (AADT, the standard measure of vehicle traffic flow). The graph shows data gathered from many international studies and demonstrates that even for low levels of traffic flow, the benefits quickly outweigh the costs and at traffic flows of 10,000 AADT, the reach benefits are five times the costs after the time value of money is included[33]. At levels of 35,000 AADT the BCR reaches an extremely high ten times. To provide a sense of how this applies in the real world, Figure 7 provides an extract from a map of Adelaide[34] showing a range of AADT that covers all the AADT levels in Figure 6.[35] Note that the research relates AADT to cost effectiveness, not vehicle speed, although there is a relationship between the two.

31 Elvik, R, Institute of Transport Economics, Norway, *Presentation to Road Lighting 2014,* Auckland, March 2014

32 Ibid

33 Thus all costs and savings are discounted to the present by an average cost of capital

34 Provided by Austroads and downloaded from http://www.dptiapps.com.au/traffic-maps/flowmap_urban.pdf

35 Elvik, R, Institute of Transport Economics, Norway, Presentation to Road Lighting 2014, Auckland, March 2014

vii. Meeting National Road Safety Strategy Goals

The National Road Safety Strategy 2011–2020, *"...presents a 10-year plan to reduce the annual numbers of both deaths and serious injuries on Australian roads by at least 30 per cent. These targets will be challenging: they compare, for example, with a 23 per cent reduction in road deaths achieved over the last decade."*

Neither the National Road Safety Strategy 2011–2020 nor its implementation action plan updates[36] make any mention of reducing road fatalities and injuries by improving street lighting. The summary of international research evidence presented above suggests that there is an opportunity to make a significant contribution to attaining these challenging strategic targets through improved lighting, both by moving to white light from LEDs and by potentially raising lighting levels during the periods of greatest risk.

viii. Meeting Department of Infrastructure and Regional Development Goals

Addressing the above issues would also contribute towards meeting the Department of Infrastructure and Regional Development's Transport Strategy to *"...develop a safer road transport system by working to make vehicles and occupants safer, and drivers more informed..."*[37]

3.2.2 Crime and Security from Violence at Night

As identified in the introduction to public health in Section 3.2, crime and security from violence is a focus of the World Health Organisation which defines violence to include night time crime. The relationship between night crime and street lighting has been the subject of research with mixed conclusions and debate. A thorough review of all available research was conducted by Farrington and Welsh for the UK Government's Home Office in 2002[38] and the study sponsor[39] concluded that:

"The eligible studies found that improved street lighting led to significant reductions in crime and with an overall reduction in recorded crime of 20 per cent across all the experimental areas.

The review assesses why street lighting has this impact on crime. The authors conclude that lighting increases community pride and confidence and strengthens informal social control and that this explains the recorded impacts, rather than increased surveillance or deterrent effects ...

The authors conclude that improvements in street lighting offer a cost-effective crime reduction measure and should be considered an important element in situational crime reduction programmes."

However, this study was severely criticised by Marchant[40] who said *"on close examination, the statistical claims and methods were unfounded. In three cases examined there is a clear conflict between the evidence and the reviewers interpretation of this."*

Another thorough study in 2000 by Morrow[41] with extensive controls and before-and-after measurements showed an *increase* of 21% in crime after improved lighting. In another comparison between before and after installation of part night lighting with newly installed controls in Ipswich, UK, where there were serious concerns over resultant crime[42], they observed that crime had *decreased* by 18% after lighting levels had also been *decreased* or switched off. Another surprising benefit from this installation was that emergency services more easily located fire and ambulance events where street lights were off, but the house lighting were was "blazing".

There are other studies that show both negative and positive correlations with street lighting. However, a later literature review conducted in 2009 by Rea and Bullough[43] et al concluded[44]:

"In summary, it appears that lighting has a positive effect on reducing crime and the positive benefits are similar to those observed for roadway lighting reducing crashes. As with roadway lighting, the positive benefits of outdoor lighting must be based on improved visibility."

Finally, in an example of one research study where the financial benefits of improving street lighting in comparison to unimproved lighting were considered, the study concluded[45] that, *"In the two projects, the financial savings (from reduced crimes) exceeded the financial costs by between 2.4 and 10 times after one year. It is concluded that improved street lighting can be extremely cost-effective."*

The research is clearly not conclusive, but what does come across very clearly is that people have strong views over the relationship between lighting and crime. These views are dependent on their own circumstances. This suggests the view that allowing the community (including its emergency services) to control street lighting is likely to be better than an autocratic decision.

3.2.3 Part-Night Lighting

As identified in later sections of this Roadmap (Section 5), the United Kingdom leads the world in reducing street light levels ('dimming') or turning them off completely ('part night lighting')

36 *National Road Safety Strategy 2011–2020,* Implementation status report, November 2015

37 *Corporate Plan 2015-2016,* Department of Infrastructure and Regional Development, page 12

38 Farrington, D., and Welsh, B., *Effects of Improved Street Lighting on Crime: a Systematic Review,* Home Office Research Study 251, Home Office Research, Development and Statistics Directorate, August 2002

39 In the Forward by Carole F Willis, Head of Policing and Reducing Crime Unit, page i

40 Marchant, P.R., *A Demonstration that the Claim that Brighter Lighting Reduces Crime is Unfounded,* British Journal of Criminology, 2004, Leeds Metropolitan University, Leeds, UK

41 Morrow, E., Hutton, S., *The Chicago Alley Lighting Project:Final Evaluation Report,* Illinois Criminal Justice Information Authority, April 2000

42 Webster, R., *Two years of Experience with Control systems that Reduce Crime - as well as Energy!,* Suffolk County Council, presentation to Road Lighting 2015, Auckland, NZ

43 Rea, M., Bullough, J., Charles R. Fay, C., Brons, Van Derlofske, J., and Donnell, E., *Review of the Safety Benefits and Other Effects of Roadway Lighting Final Report,* prepared for National Cooperative Highway Research Program Transportation Research Board of The National Academies

44 Ibid. page 29

45 Painter, K., Farrington, D., *The Financial Benefits of Improved Street Lighting, Based on Crime Reduction,* Lighting Res. Technol. 33,1 (2001) page 3–12

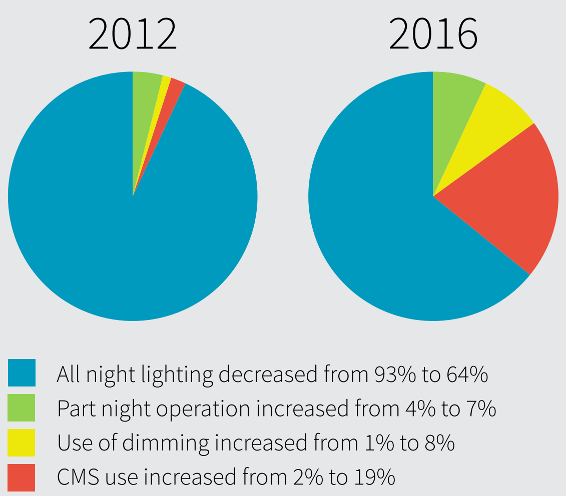

Figure 8 – UK trends in street lighting control (Telensa)

when they are not required, through the use of control systems. This is illustrated in Figure 8[46] and is in marked contrast to Australia.

Research was commissioned[47] by the UK Institute for Health Research (NIHR) (called the LANTERNS project) to find out if road safety and crime rates were being negatively impacted. The study examined 62 of the 174 Councils in England and Wales to find out whether the introduction of white light (replacing the yellow HPS lighting) and the introduction of variable lighting instead of all-night lighting had negative impacts.

The study concluded that:

"The results provide no evidence that switch off, part-night lighting, dimming, or white light adaptations to street lighting were associated with night-time traffic collisions. The results also provide no evidence that these lighting strategies are associated with an increase in crime at an area level. Results suggest that in the aggregate, dimming and white light regimes were associated with reductions in crime, though estimates were imprecise."

This is a very important finding, but some commentators inaccurately concluded from this research that street lighting has no effect on traffic injuries or night time crime rates. The fact is that all the interventions to reduce lighting were prudently designed by UK councils to take place where and when road and street traffic was at its lowest levels and traffic accident frequency was at its lowest - after midnight and before 7am. Similarly, the surveillance deterrent effect provided by street lighting is of no benefit if most residents are asleep and cannot witness and report crime. Indeed, late night street lighting may actually be facilitating some types of crime and anti-social behaviour during these periods and it is during this period that UK councils are dimming lighting.

To date, only the UK appears to have systematically applied the logic outlined above and have only been able to implement this action because they have smart street lighting control systems to allow implementation.

3.2.4 Public Health Effects of Night Lighting

There is much recent media commentary and sectoral reports on the subject of the potential negative impacts of LED light at night. The subject can be divided into three areas: human physiological reaction to lighting which is the public health issue dealt with in this sub-section; the ecological effects on the natural world; and light pollution that obscures the stars from general visibility or astronomical observation. The last two are dealt with in the Section 3.4 on the environment.

Photoreceptors within the human eye have a peak sensitivity to blue light and they control the release of the hormone melatonin. When humans are exposed to light with a high blue spectral content (such as that produced by some LEDs), melatonin release is suppressed resulting in sleep deprivation and associated difficulties. The evidence for this is available in many scientific publications. Most recently The American Medical Association (AMA) issued a report on the subject[48].

i. The American Medical Association (AMA) Report

In June 2016, the AMA generated considerable US and international media attention when they published a report on the Human and Environmental Effects of LED Lighting.[49] Much of the mainstream media coverage has not been accurate in reporting the findings and recommendations of the AMA. Specifically, the AMA has **not** made a general finding against LED street lighting. Their position has in fact been the opposite in saying:

"That our American Medical Association (AMA) support the proper conversion to community-based Light Emitting Diode (LED) lighting, which reduces energy consumption and decreases the use of fossil fuels."

However, the AMA report did provide a warning on the problems of LED street lighting when improperly designed and/or having higher than necessary blue light content. The key AMA recommendation is:

"That our AMA encourage the use of 3000K or lower lighting for outdoor installations such as roadways. All LED lighting should be properly shielded to minimise glare and detrimental human and environmental effects, and consideration should be given to utilise the ability of LED lighting to be dimmed for off-peak time periods."

A colour temperature of 3000K or lower is generally referred to as 'warm white' and contains lower blue light content than light of higher colour temperatures.

46 Gibson, W., CEO Telensa, *Presentation to Road Lighting Conference 2015,* Auckland, New Zealand, March 2015. Original information from Power Data Associates

47 Steinbach R, Edwards, P., et al, *The Effect of Reduced Street Lighting on Road Casualties and Crime in England and Wales: Controlled Interrupted Time Series Analysis,* Department of Population Health, London School of Hygiene and Tropical Medicine. J Epidemiology Community Health 2015;0:1–7 doi:10.1136/jech-2015-206012, 3 June 2015

48 Kraus, L., *Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting,* American Medical Association. Action of the AMA House of Delegates 2016 Annual Meeting: Council on Science and Public Health Report 2 Recommendations Adopted and Remainder of Report Filed

49 http://www.ama-assn.org/ama/pub/about-ama/our-people/ama-councils/council-science-public-health/reports/2016-reports.page (will require free registration)

ii. US Department of Energy (DoE)

The US Department of Energy is a highly credible source of impartial scientific information on LED application and their response statement to the AMA is recommended.[50] [51] The key issues distilled from this are that:

- Colour temperature does not accurately provide the measure of blueness attributed to the potentially harmful aspects of lighting (the melanopic content[52]). Light Spectral Power Distribution (SPD) provides the best scientific measure;
- Using SPD, it is clear that almost all street lighting has some blue light content with these potentially harmful lights including yellow HPS lighting;
- The potential for harm to humans is highly dependent on the intensity of the light source and the time exposed to the light. Neither of these important issues were identified in the AMA report;
- As the DoE suggests,[53] *"The 'raw' melanopic content produced by a light source is only one contributor to any ensuing environmental or health impacts actually realised. Focusing exclusively on a single measure ignores the various means of controlling or offsetting the increased harmful melanopic content of white light sources, and particularly those that are enabled by LED technology such as improved photometric distribution, dimming capability etc."*

iii. Australian Standards

In Australia, luminaire technical specification, SA/SNZ TS 1158.6:2015 Luminaires - Performance (which carries less weight than a Standard), states that 4000K is the preferred colour temperature for road lighting. The decision to suggest 4000K was made in 2014 when this was the warmest readily available colour temperature available at the time. This situation has now changed with an increasing number of luminaires with 3000K LEDs (or less) becoming available.

iv. Increasing Public Attention Needing a Policy Response

With the potential negative effects of white lighting receiving more publicity, conversion to white LED lighting will require more attention from all levels of government. It could also require further policy development in order for a research-informed response of the particular choice of LED colour temperature recommended or required to balance the positive and negative net effects of white lighting.

Professor Abraham Haim, the head of the Center for Interdisciplinary Chronobiological Research at the University of Haifa and the Israeli partner in a research study 'Limiting the impact of light pollution on human health, environment and stellar visibility'[54] suggests that, *"Just as there are regulations and standards for 'classic' pollutants, there should also be regulations and rules for pollution stemming from artificial light at night."*[55]

The authors of the paper referred to above[54] conclude:

"... an effective law to control light pollution should implement this set of rules:

- *Do not allow luminaires to send any light directly at and above the horizontal;*
- *Do not waste downward light flux outside the area to be lit;*
- *Avoid over lighting;*
- *Shut off lights when the area is not in use;*
- *Aim for zero growth of the total installed flux;*
- *Strongly limit the short wavelength 'blue' light."*

These are sound principles that are generally in line with the AMA's recent recommendation. To be delivered, they require precisely the capabilities identified in this Roadmap through best practice design, appropriate LED lighting and astute use of smart control systems.

3.3 Energy

3.3.1 Street Lighting Energy

As covered in Sections 5, 6 and 7, the estimated energy use of street lighting based on DNSP inventories is 1,184 GWh/yr in 2016[56] and the expected total potential saving is about 616 GWh/yr based on 52% energy saving from replacement by LEDs and a further 10-20% saving from the use of control systems. In total, this corresponds to about 653,500 tonnes saved per year of carbon dioxide equivalent greenhouse gases. This will materially contribute to the National Energy Productivity Target of improving energy productivity by 40% by 2030 on the levels experienced in 2015.[57]

3.3.2 Equipment Energy Efficiency (E3) Program

With such large potential energy savings, street lighting equipment has had an ongoing policy focus to accelerate these savings from the Equipment Energy Efficiency (E3) Program which gives effect to the Greenhouse and Energy Minimum Standards (GEMS) Act 2012.

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50 http://energy.gov/sites/prod/files/2016/06/f32/postings_06-21-16.pdf posted on 21 June 2016 by the Municipal Solid State Lighting Consortium, a directorate within the DoE Solid State Lighting programme

51 http://energy.gov/sites/prod/files/2016/07/f33/msslc_enews_jul2016.pdf and many others on a large variety of subjects at http://energy.gov/eere/ssl/information-resources

52 "Melanopic content is of interest because it is regarded as a primary indicator of the relative potential for the listed light sources to stimulate the human biological responses that are the subject of much of the AMA's statement" DoE MSSLC July 2016 newsletter *The Light Post*

53 Bruce Kinzey, MSSLC Director, Pacific Northwest National Laboratory in the July "Light Post" of the MSSLC

54 Falchi, F., et al., *Limiting the Impact of Light Pollution on Human Health, Environment and Stellar Visibility,* Journal of Environmental Management (2011), doi:10.1016/j.jenvman.2011.06.029

55 Retrieved from http://medicalxpress.com/news/2011-09-white-suppresses-body-production-melatonin.html

56 Calculations are provided in Section 7

57 *National Energy Productivity Plan 2015–2030 Boosting Competitiveness, Managing Costs and Reducing Emissions,* Council of Australian Governments Energy Council, December 2015.

The objectives of that Act are:

- To give effect to the obligations that Australia has under the United Nations Framework Convention on Climate Change; and
- To promote the development and sale of products that use less energy and result in the production of fewer greenhouse gases, or that help reduce the energy used or the greenhouse gases produced by other products.

Until 19 July 2016[58], the E3 Program was administered by the Department of Industry Innovation and Science (DIIS) but was transferred to the newly named Department of the Environment and Energy (DEE).

IPWEA's Street Lighting and Smart Controls (SLSC) programme has many alignments with the current E3 Programme:

1. It builds upon work undertaken by E3 to improve the energy efficiency of street lighting in Australia including, the E3 Draft Street Lighting Strategy 2011, reports on best practice energy efficiency requirements for road lighting designs and luminaires, along with investigations into market barriers;
2. It is equipment based, has many technological complexities and thus benefits greatly from a cross-jurisdictional approach and leverages existing E3 staff capabilities;
3. Industry is keen to have one approach across all eight jurisdictions to simplify and reduce cost, and there are many significant reasons identified later in this report that re-enforce that;
4. It already has an industry engagement structure in place that has the same objectives as those for the other parts of the E3 Programme, including significant funding; and
5. New Zealand is a 15.6% cost contributor to E3 through EECA who were early supporters of accelerating LED street lighting in New Zealand[59] and therefore are an informed partner.

Another significant benefit of being part of the E3 Programme is that the synergies from the Department of the Environment and Energy's collection of climate change programmes will now be more easily obtained by the Street Lighting and Smart Controls Programme.

3.3.3 Climate Change and Energy Productivity

The investment required to convert from legacy street lighting technologies to the most efficient LED lighting and smart controls is probably between $1.2 and $1.4 billion[60], depending on a variety of technology and deployment choices. This is a substantial investment but the characteristics of the projects make it a fitting investment for the variety of carbon abatement and energy productivity enhancement programmes for which the Department of the Environment and Energy are responsible. In addition, some of the states and territories also have their own incentive schemes so there is a significant opportunity to work across states and territories to provide a mechanism like the other jurisdiction-wide E3 programmes. The opportunity is to provide a jurisdiction-wide street lighting programme that works equally well in a seamless way across all jurisdictions so that the 500+ councils in Australia have ready access to these climate change incentives to accelerate efficient street lighting initiatives.

3.4 Environment

3.4.1 Mercury Pollution

According to the Global Environment Facility (GEF)[61], *"Mercury is a neurotoxin. Exposure to elemental mercury, mercury in food, and mercury vapors poses significant health risks including kidney, heart and respiratory problems, tremors, skin rashes, vision or hearing problems, headaches, weakness, memory problems, and emotional changes."*[62]

Reduction or removal of mercury from the environment is a public health priority established by the 2013 United Nations Environmental Programme (UNEP) Minamata Convention on Mercury[63] to which Australia is a signatory[64] but has not yet ratified it. The risk to human health from mercury is due to its toxicity at concentrations as low as two parts per billion, a concentration which corresponds to two grams of mercury dissolved in a million litres of water.

Typical high intensity discharge (HID) lamps[65] have a mercury content of 50 mg Hg/lamp and Fluorescent lamps (LFL and CFL) have a mercury content of 4 mgHg/lamp.[66] LED lighting has no mercury content.

58 http://www.dpmc.gov.au/resource-centre/government/aao-amendment-19-july-2016

59 EECA supported an investigation study for accelerated LED replacement of street lighting in Hamilton, New Zealand and provided sponsorship for the two Road Lighting Conferences in 2014 and 2015

60 Based on the $1.1 billion LED investment plus the approximate cost of controls identified of $100-200 per lighting point identified in Section 9

61 The GEF's 18 implementing partners include the Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), World Bank Group (WBG), and the World Wildlife Fund Inc. (WWF-US)

62 *Global Environmental Facility, Mercury and the GEF,* R. Dixon et al, June 2012

63 UNEP Minamata Convention on Mercury. October 2013, Annex A page 46, http://www.mercuryconvention.org/Convention/tabid/3426/Default.aspx

64 Australia signed the Minamata Convention on 10 October 2013

65 HID lamps include Low and High Pressure Sodium (LPS, HPS) and Mercury Vapour (MV) lamps, which make up a large majority of all street lighting in Australia

66 *Life Cycle Assessment of Product Stewardship Options for Mercury-Containing Lamps in New Zealand: Final Report,* Peter Garrett and Michael Collins, Environmental Resources Management (ERM), for the Ministry for the Environment. June 2009. Section 3.3 page 24

Based on an analysis of electricity distributor data provided as part of an IPWEA survey for this Roadmap, removing the existing national portfolio of mercury-containing lamps used in street lighting would reduce mercury by about 90kg. This is a very considerable amount as mercury is toxic to humans at concentrations of as low as two parts per billion.

If Australia ratifies the Minamata Convention, the importation of mercury vapour lamps will be banned after 2020. Replacing these lamps with LEDs free of mercury will reduce the future amount of mercury requiring disposal. Consequently, after 2020 the remaining inventory of MV luminaires will decline as replacement lamps will be either unavailable or in diminishing supply. Such policy pressure is likely to assist with the transition to more efficient LED technology and provide both public health and economic benefits though will require a substantial initial investment in the hundreds of millions of dollars as mercury vapour makes up more than a third of the national lighting portfolio.

3.4.2 Night Sky Light Pollution

With increasing light pollution, the urban public is becoming increasingly aware of the loss of the night sky. Scientific research is also responsible for raising awareness and changing attitudes. A recent paper called *The new world atlas of artificial night sky brightness* was published by Falchi et al.[67] in June 2016 (Figure 9)and its abstract provides a summary of the findings:

"Artificial lights raise night sky luminance, creating the most visible effect of light pollution — artificial sky glow. Despite the increasing interest among scientists in fields such as ecology, astronomy, health care, and land-use planning, light pollution lacks a current quantification of its magnitude on a global scale. To overcome this, we present the world atlas of artificial sky luminance, computed with our light pollution propagation software using new high-resolution satellite data and new precision sky brightness measurements. This atlas shows that more than 80% of the world and more than 99% of the U.S. and European populations live under light-polluted skies. The Milky Way is hidden from more than one-third of humanity, including 60% of Europeans and nearly 80% of North Americans. Moreover, 23% of the world's land surfaces between 75°N and 60°S, 88% of Europe, and almost half of the United States experience light polluted nights."

Figure 10 lists the G20 counties by population experiencing light pollution and Australia has the sixth worst pollution level for its residents because a high proportion of its population is urban (see Section 3.5.1). The six different colours in the bar chart provide an indication of the proportion of the population exposed to varying levels of light pollution, with black being the highest levels and yellow virtually no pollution.

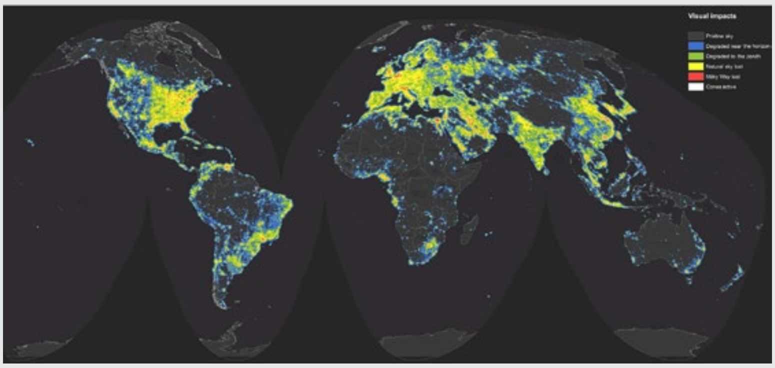

Figure 9 – The world's light pollution measured by Falchi et al

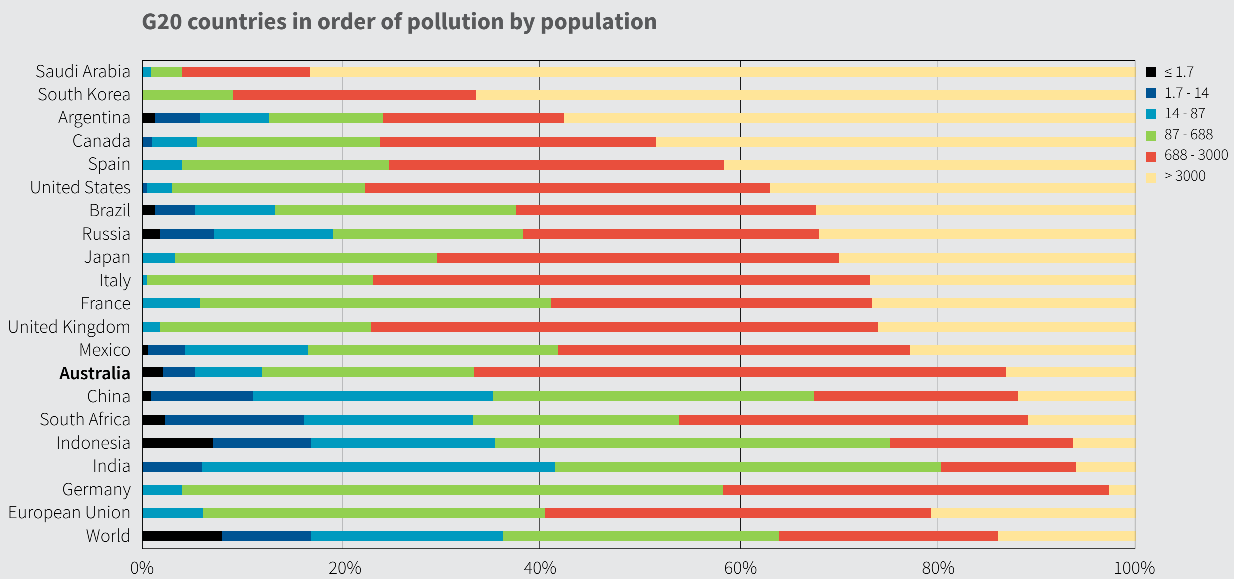

Figure 10 – Light pollution as a proportion of country population (Falchi et al)

67 Fabio Falchi,et al, *The New World Atlas of Artificial Night Sky Brightness,* American Association for the Advancement of Science, Science Advances 2016

3.4.3 Ecological Impacts of Street Lighting

*The Environment Protection and Biodiversity Conservation Act 1999 (*EPBC Act) is the Australian Government's key piece of environmental legislation which *"... focuses Australian Government interests on the protection of matters of national environmental significance, with the states and territories having responsibility for matters of state and local significance."*

A substantial body of literature has demonstrated the negative impact of artificial light at night (abbreviated to ALAN by the experts) on a broad range of insects, birds, reptile and mammal species[68].

The impact of artificial light on marine turtles has been recognised since 1911 and has been well studied in all species over the intervening years[69 70 71 72]. For example, artificial lighting may adversely affect hatchling seafinding behaviour in two ways: disorientation, where hatchlings crawl on circuitous paths; or misorientation, where they move purposefully and consistently in the wrong direction (i.e. typically landward), towards artificial lights. The consequences of this disruption are increased risk of predation, dehydration and exhaustion, and thus increased risk of extinction for endangered species.

Another example of the ecologically harmful effects of ALAN are the documented source of significant global mortality of shearwaters and petrels. Evidence from the Azores found that approximately 80% of all deceased shearwaters were found in areas with medium to high lighting intensity. ALAN can both attract and disorientate birds and is particularly detrimental to young birds. Artificial lights lead to incorrect visual orientation in the young due to their difficulty discriminating between the visual cues provided by artificial lights and natural sources of light such as moon and star light.[73]

Urban light pollution has also been shown to disrupt breeding cycles in Tamar Wallabies. Exposure to lights suppresses melatonin levels and delays births leading to a disconnect between peak food availability and the birth of joeys.[74]

A local example of disruption to a rare species of shearwater has been reported from Kaikoura, New Zealand which hosts the sole remaining breeding colony of Hutton's Shearwaters[75] The colony experienced a systematic loss of newly fledged young each year as a results of the disorienting influence of street lighting until full cut off LED lights together with CMS controls and seasonally managed switching options were introduced.

3.5 Smart Cities

3.5.1 Introduction

According to the United Nations, 89% of Australia's population was urban in 2014[76] and the rate of growth in that urban population was 1.92% per year over the period of 2005-2010.[77] This leads the United Nations to forecast that by 2050, Australia's urban population will be 92.9% of its total population.[78]

3.5.2 Smart Cities Plan

The Australian Government published its *Smart Cities Plan* in April 2016.[79] The Smart Cities Plan recognises the importance of urban planning for the future and has many points of intersection with a smart road lighting strategy. Its forward by the Prime Minister and Assistant Minister for Cities and Digital Transformation provides a good introduction and summary:

"Australia's growth as a knowledge based economy, and the prosperity this offers, goes hand in hand with the growth of our cities and the regions surrounding them. Knowledge based industries rely on the successful concentration of industries and organisations in particular locations. To succeed in the 21st Century economy our cities need to be productive and accessible, but they also need to be liveable with a clear focus on serving their citizens. Great cities attract, retain and develop increasingly mobile talent and organisations, encouraging them to innovate, create jobs and support growth...

Real time data and smart technology will lead to better utilisation of infrastructure, clean energy and energy efficiency, improvements in services and better benchmarking of cities performance."

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68 Rich, C., Longcore, T. (2006). *Ecological Consequences of Artificial Night Lighting.* Washington, DC: Island Press.

69 Hooker, D. *Certain Reactions to Color in the Young Loggerhead Turtle.* Papers Tortugas Lab., Carnegie Institute Washington; 1911,v. 3, p. 71-76.

70 Witherington, B. E. and Martin, R.E.(1996) *Understanding,Assessing,and Resolving Light - Pollution Problems on Sea Turtle Nesting Beaches,* Rep. No. FMRI Technical Report TR-2. Florida Department of Environmental Protection.

71 Bertolotti,L. and Salmon, M. *Do Embedded Roadway Lights Protect Sea Turtles?* Environmental Management 2005, v. 36, no 5, p. 702-710.

72 Pendoley, K. and Kamrowski, R. *Sea-Finding in Marine Turtle Hatchlings: What is an Appropriate Exclusion Zone to Limit Disruptive Impacts of Industrial Light at Night?* Journal for Nature Conservation 2016, vol. 30, p. 1-11.

73 Rodriguez, B. Rodriguez, A. J. Curbelo, A. Perez, S. Marrero and. J. Negro (2012), *Factors Affecting Mortality of Shearwaters Stranded by Light Pollution.* Animal Conservation, Volume 15, Issue 5, pages 519-526, October 2012. Article first published online: 17 Apr 2012. DOI: 10. ll /j.1469-1795.2012.00544 .x © 2012 The Zoological Society of London.

74 Robert, K. A., Lesku, J.A., Partecke, J., and Chambers, B. *Artificial Light at Night Desynchronises Strictly Seasonal Reproduction in a Wild Mammal.* 2016 4th International Conference on Artificial Light at Night, September 26-28, Cluj-Napoca, Romania

75 http://www.acap.aq/en/news/latest-news/2075-crash-landed-hutton-s-shearwater-fledglings-get-rescued-from-the-effects-of-light-pollution-in-new-zealand-while-research-on-their-at-sea-movements-continues

76 Ibid. Table A1 page 201

77 Ibid. Table A6, page 261

78 Ibid. page 52

79 *Smart Cities Plan,* The Department of the Prime Minister and Cabinet, Australian Government, April 2016

3.5.3 Street Lighting Relevance to the Smart City Plan

A new road lighting strategy across Australia will contribute as described in Sections 3.1 to 3.4 to road safety, crime reduction and environmental improvements and thus to the Smart City Plan. In addition, the use of an accelerated upgrade of road lighting and smart controls across Australia is an significant opportunity to provide the foundation of smart city and town sensor networks to build the cities of tomorrow through, *"...thinking of technology solutions first."*[80]

The Smart City Plan proposes three pillars of 'Smart Investment', 'Smart Policy', and 'Smart Technology' discussed next.

i. Smart Investment

The Plan describes Smart Investment as:

1. Prioritising projects that meet broader economic objectives
2. Treating infrastructure funding as an investment wherever possible
3. Getting [government] involved early to ensure rigorous planning and business cases
4. Increasing investment

All four of the above strategies are applicable to upgrade dated street lighting to infrastructure that has many more purposes than lighting. For example, the Smart City Plan observes:

"The concentration of so many people in one place inevitably results in crowded transport systems in parts of our cities. Urban congestion is estimated to cost over $16.5 billion every year, and forecast to reach between $27.7 and $37.7 billion by 2030.[81]

A new 'smart technology' street lighting system could provide a real and significant contribution through, for example, sensors that measured progress towards mitigating urban congestion costs through the planned $50 billion infrastructure investment. Planning for integration between street lighting infrastructure and major projects needs to be done early as recognised in the Smart City Plan which observes that such planning, *"... now needs to happen earlier than has traditionally been the case."*

ii. Smart Policy

The plan observes that, *"Successive Productivity Commission reviews and the Australian Infrastructure Plan have consistently emphasised the need for reform in our cities to drive strategic planning to make it easier to invest and do business."*

One of the drivers of the Smart City Plan's pillars of smart policy is 'Measuring Success' and a new smart street lighting infrastructure with embedded sensors could be utilised for precisely measuring a wide range of city liveability, resilience, and other infrastructure performance characteristics.

iii. Smart Technology

The subject of this Roadmap, smart lighting and controls, is a very close 'technology solution' fit with the Department of Prime Minister and Cabinet's (DPMC) Smart City Plan concept of 'Smart Technology'. It has identified three parts to this:

1. Thinking of technology solutions first
2. Leveraging open and real time data
3. Driving use of energy efficient technologies

In describing 'leveraging open and real time data' the Plan says that, *"For example, data and analytics can inform city planning and infrastructure investment with great potential to improve decision making. Digital communications have the potential to revolutionise the way governments engage with communities in the development of metropolitan and local plans and services. Sharing anonymised data from our cities will make urban problems and solutions more contestable—an essential platform for innovation."*

Some examples where a smart street lighting strategy is likely to contribute to meeting specific needs in DPMC's plan include:

- Smart street lighting sensor systems to monitor the improvement of air quality in urban areas for cleaner and lower emission vehicles and fuel; and
- Use of vehicle monitoring systems based on street lighting infrastructure that facilitates long-term reforms to create a more effective market for road transport by providing electronic means to accurately measure vehicle travel and thus levy according to use in congested areas rather than per vehicle or total distance travelled.

3.5.4 Leveraging European Experience – "The Humble Lampost Initiative"

Like Australia, the European Commission (EC) has recognised the strategic opportunities that exist in developing smart cities. Furthermore, EC has recognised the importance of street lighting to a smart cities strategy which is also relevant to the combination of Australia's smart cities initiative with this Roadmap.

The EC published a report called *"Lighting the Cities, Accelerating the Deployment of Innovative Lighting in European Cities."* In it they say that, *"The larger roll-out of intelligent LED lighting systems in cities will be part of the creation of sustainable smart cities: cities where lighting innovation is interlinked to other smart city networks (communications, renewable energy, building or traffic management systems). This is the ideal way to offer dynamically adaptable optimised lighting services to citizens and businesses."*[82]

80 Ibid, page 26

81 *Smart Cities Plan,* The Department of the Prime Minister and Cabinet, Australian Government, 2016, page 11, quoting from Bureau of Infrastructure, Transport and Regional Economics (BITRE), Traffic and congestion cost trends for Australian capital cities, Information Sheet 74, 2015

82 *Lighting the Cities, Accelerating the Deployment of Innovative Lighting in European Cities,* European Commission, June 2013, Forward by NeelieKroes, Commission Vice-President for the Digital Agenda for Europe

The Commission sums up the significance of street lighting to smart cities which applies directly and accurately to street lighting and smart cities in Australia:

"Lighting in a city is everywhere. It is typically treated in a very tactical manner, evidenced by the aging assets that exist, and volume of citizen complaints (in some cities it represents 20% of the contact centre calls). Light does not come cheap – savings on energy bills is of growing attractiveness. Quality low-energy lighting is required for 'place-making', for public safety and security. It is also too often on when not needed – wasting power and money; and can result in light pollution. The lamppost is also typically a single purpose asset – for light; however that is not necessarily the only role it can play. New ICT-technologies can help transform the role of the "humble lampost."

The European Commission's strategy for street lighting to contribute towards the smart cities strategy could possibly be customised for Australian purposes:

"The aim is to have between 30-50 cities and partners to collaborate and bundle demand to install up to 10 million intelligent lampposts, networked with LED lighting and other features such as WiFi, e-charging, sensors, etc. By joining forces, they would get a better understanding of value cases of the various features, future-proof their investments and most importantly create a market which would reduce the cost."[83]

This appears close to what the SLSC initiative is recommending.

3.5.5 Local Government and Corporate Collaboration on Smart City Public Lighting

There is a growing number of position papers emerging from lighting and ICT corporates internationally about the linkages between public lighting infrastructure and forthcoming smart city initiatives and how the interaction may affect the fabric of city functions and operations.

On the basis of such linkages, some cities are choosing to collaborate with key commercial partners. Some examples are:

- City of Adelaide with Cisco
- City of Los Angeles with Philips/Ericsson
- City of San Diego with Current by GE
- Wellington City with NEC

One such paper that lays the platform for such collaboration is the Cisco and Philips publication called *The Time Is Right for Connected Public Lighting Within Smart Cities.*[84] The paper observes that:

"... Infrastructure will become a dynamic platform enabling continuous innovation. It thus needs to be looked at from a different point of view: Total Value of Ownership (TVO). Only then does the case in favor of sustainable, livable infrastructure become clear.

Developing infrastructure with a TVO-based approach includes:

1. *Linking the project to the city's vision in terms of livability, economic growth, and sustainability.*
2. *Defining the connected public lighting infrastructure as a "network of networks" and a platform for service innovation.*
3. *Working actively with stakeholders such as city officials, retailers, shop owners, police, telephone operators, ISPs, and, of course, citizens to create meaningful use cases.*
4. *Investing operational cost savings (not only from lighting) in the platform to enable new functionalities.*
5. *Measuring the total value generated year-over-year in terms of savings and revenues, jobs created, and livability improvements."*

Such overviews highlight the potential future of smart public lighting and smart cities integration. The governance and policy framework development of a city or region may well benefit from such collaboration and practical research.

3.6 Conclusion

The substantial and wide ranging benefits available from accelerating the introduction of LED street lighting and smart controls appear to warrant integration of several government policy areas. The nature and complexity of the issues, risks, breadth of stakeholders, and opportunities for policy development suggest that a street lighting strategy is required.

83 Brochure on European Innovation Partnership on Smart Cities and Communities, available at https://eu-smartcities.eu/sites/all/files/brochure_WEB_eusmart2_5.pdf

84 Crowther, J., Herzig, C., Feller, G., *The Time is Right for Connected Public Lighting within Smart Cities,* Cisco Internet Business Solutions Group (IBSG), October 2012, page 5

4

CURRENT STREET LIGHTING REGULATORY STRUCTURE AND APPROACH

This section outlines the legal and regulatory framework under which street lighting is governed and identifies the issues that may be working against the timely adoption of new street lighting technology and economic efficiency.

The ideas presented have been suggested in consultations for this Roadmap and are summarised below. Note that this section is an input into a work stream for IPWEA's SLSC Programme that will test, expand on, and develop policy options for consultation with stakeholders including government departments.

4.1 Electricity Law

Like most services, street lighting is governed by a pyramid of laws, regulations, rules, standards, policies, guidelines and conventions. The organisations responsible for formulating each of these begin with Parliaments and range down to the level of individual Distribution Network Service Providers (DNSPs), main road authorities, local governments and even contractors performing a service and compiling their own guidelines and staff policies.

4.1.1 Governance and Regulation in Eastern and South Eastern Australia

In terms of electricity law, the top of the pyramid in eastern and south eastern Australia is the National Electricity Law (NEL) first introduced with South Australia passing the first National Electricity (South Australia) Act in 1996. The National Electricity Law is set out in the schedule to the National Electricity (South Australia) Act 1996 which each participating state or territory enacted in their own parliament. The Acts gave effect to the National Electricity Market (NEM) applying within the eastern and south-eastern Australia. The Acts also recognise and/or empower several entities;

- The Council of Australian Government's (COAG) Energy Council – The COAG Energy Council is made up of all eight state and territory Ministers of Energy as well as their New Zealand counterpart. This body is a sub-committee of COAG. This is the, *"... premier policy leadership body with responsibility for the Australian energy market."*[85]
- Australian Energy Markets Commission (AEMC) – The AEMC's role is, *"... to make rules which govern the electricity and natural gas markets, including the retail elements of those markets. In addition [they] support the development of these markets by providing advice to the.."*[86] COAG Energy Council. In the context of street lighting, any changes to the National Electricity Rules (NER) that stakeholders wished to see would have to be proposed to the AEMC. On 1 July 2016 the AEMC became the rule maker in the Northern Territory (NT) for parts of the National Electricity Rules. Similarly, on 22 June 2016, the Western Australian Government introduced proposed changes that seek to adopt the NEL in the main South West Interconnected Network in Western Australia.[87]
- Australian Energy Regulator (AER) – The AER's role is to monitor, investigate and enforce compliance with national energy legislation and rules. It monitors *"... participant bidding and rebidding, market dispatch and prices, network constraints and outages, demand forecasts and forecasts of production and capacity."*[88] With the exception of SA, the AER is also responsible for pricing approval of electricity network distribution services including street lighting maintenance, capital and energy distribution charges. The AER has recently taken on responsibility for the regulation of services classified as standard control services in the Northern Territory (NT). However, in NT the AER is not responsible for approval of prices classified as alternative control services under which street lighting is classified. As noted above, the Western Australian (WA) government has proposed that the AER take on regulatory responsibility for that jurisdiction as well.
- Australian Energy Market Operator Ltd (AEMO) – AEMO's role is to balance the demand and supply of electricity by dispatching the generation necessary to meet demand, and *"... to plan, develop, and operate markets that are responsive to energy sector needs and support long-term investment in Australia . . . [for the ultimate benefit of] all energy consumers*

85 *Review of Governance Arrangements for Australian Energy Markets,* Vertigan, Yarrow and Morton, October 2015

86 AEMC website http://www.aemc.gov.au/About-Us/About-the-AEMC, retrieved June 2016

87 https://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/Electricity_Market_Review/Information-Paper-Transitioning-to-the-National-Electricity-Regulatory.pdf

88 AER website https://www.aer.gov.au/about-us/our-role retrieved June 2016

Figure 11 – The SWIS and NWIS (Federal Parliament)

across eastern and south-eastern Australia"[89]. AEMO is also responsible for managing unmetered load tables which establish the assumed electricity consumption attributed to each type of street light. The AEMO has recently taken over responsibility for operation of the South West Interconnected Network (SWIN) of Western Australia.

Street lighting in the eastern part of Australia is closely linked to the law, rules and organisations identified above that govern the electricity market. Until recently the western and northern regions of Australia have operated completely independently of the National Electricity Market but in 2015 and 2016 both regions have started the process of legislative integration, and this is covered below.

4.1.2 Governance and Regulation in Western and Northern Australia

Western Australia and the Northern Territory are not physically connected to the National Electricity Market (NEM) due to the economic costs of connecting their load and generation centres over vast distances to the eastern and south-eastern interconnected system. However, as noted above, the Northern Territory has adopted parts of the National Electricity Rules (NER) and is considering adopting other parts of the rules in the future. Western Australia is also currently considering parts of the National Electricity Law (NEL), which would mean that all states and territories may be integrated into one national framework in the near future.

Western Australia and the Northern Territory are broadly divided into three administrative categories: the South West Interconnected Network (SWIN); the North West Interconnected Network (NWIN), and; the Northern Territory where electricity and street lighting is provided by the Power and Water Corporation which is a wholly owned and operated entity of the Northern Territory (NT) Government.

4.1.3 Northern Territory

As its name suggests, Power & Water is also responsible for power and water supply across an area of more than 1.3 million square km, but recent changes have made it even more unique as its ownership of all street lighting will be transferred to local government councils on 1 January 2018. In 2014, the NT parliament split the electricity generation and retailing functions of Power & Water into a generator, Territory Generation, and an electricity retailer, Jacana Energy.

4.1.4 South West Interconnected System (SWIS)

The SWIS, which includes Perth and Kalgoorlie, is reasonably analogous to the open competitive electricity market in the Eastern States. Like Eastern and South Eastern Australia's NEM, generation and retail functions have been separated from the single monopoly network (Western Power) which is now regulated by theEconomic Regulation Authority (ERA)[90] while market operation and management has recently[91] transferred to the Australian Energy Market Operator (AEMO). The Board of Western Power reports to Western Australia's Minister of Energy. Street lighting is treated similarly to the NEM where local governments are customers with separate pricing arrangements to other classes of electricity customers.

Figure 12 – Horizon power service areas

4.1.5 The Rest of Western Australia

The rest of Western Australia is provided with electricity by Horizon Power[92] who, like Western Power, is wholly owned by the state of Western Australia. However, unlike Western Power, Horizon Power is a completely vertically integrated company that handles everything from generation to retail activities.

Horizon Power is unique in Australia as it operates 38 separate independent networks including the North West Interconnected System (NWIS). It provides generation, distribution and retailing electricity across 2.3 million square km (10 times the size of Victoria) for only about 46,000 customer connections with about 100,000 residents and 10,000 businesses.[93] It currently operates without the oversight of a pricing regulator.

89 AEMO Pivotal to Australia's Energy Future, Corporate Brochure, July 2014

90 The State Government has announced that the SWIN will be regulated by the AER instead of the ERA

91 Took over from the Independent Market Operator (IMO) in November 2015

92 Legal name is "Regional Power Corporation"

93 Horizon Power Company Profile from website http://horizonpower.com.au/media/1589/company-profile.pdf,retrieved June 2016

4.1.6 Efficient Street Lighting Achievements

It is understood that at least 97 Local Governments have replaced legacy lighting systems with improved street lighting technologies and negotiated special tariffs with their DNSPs. The majority of these have been in Victoria and although they mostly use older technology T5 fluorescent and compact fluorescent (CFL) luminaires. They represent a significant achievement over the legacy technologies they replace, and the programme that implemented this change represents a good foundation on which to base future improvement to LEDs and smart controls.

4.2 Electricity Objectives

Section 7 of the National Electricity Law[94] states that:

"The objective of this Law is to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to—

(a) price, quality, safety, reliability and security of supply of electricity; and

(b) the reliability, safety and security of the national electricity system.

These are generally referred to as the National Electricity Objective (NEO). These objectives apply across seven states and territories despite the different methods of achieving them. The eighth state, Western Australia, has objectives that are worded differently[95] but have the same effect. In the east and southeast, the achievement of the objectives needs to take place through regulation of the market where the private sector is allowed to own electricity generation, transmission and distribution (in some jurisdictions) and retail functions. The eastern and south eastern states and territories have established the National Electricity Market (NEM) to create a regime where private or public monopolies, such as electricity distributors, operate on the same basis and are required to comply with the same regulations to meet the above objectives.

In the extremely low population density areas of the Northern Territory and Northwest Western Australia the similar objectives are obtained through ownership and management by the Western Australian and Northern Territory governments. The southwest of Western Australia is in a position closer to that of the NEM, with ownership still in the hands of the Western Australian governments but current laws are not harmonised with the NEL because their networks are completely physically independent from the NEM in the east. However, that is soon to change in important respects as the SWIN is now operated by the AEMO and is expected to be regulated by the AER, albeit under slightly different arrangements.

One of the many factors that makes street lighting regulation difficult to understand is that, as the Marsden Jacob report observes, *"Neither the Rules nor the guidelines are drafted at a level that contemplates specific services such as street lighting."* Street lighting is therefore a service not identified in the rules, but what the rules say must nevertheless apply to street lighting. This is underlined by the fact that the National Electricity Objective identified above, also applies to street lighting – in all jurisdictions irrespective of how they are regulated. Notably however, the National Electricity Objective appears to only relate to electricity supply and does not clearly address the myriad types of technology, service level and environmental issues associated with an end-use appliance such as a street light.

4.2.1 Street Lighting

Although street lighting is governed by the National Electricity Rules that apply in six states and territories and soon partially in WA and NT, and it must meet the statutory objectives, the way it is treated by the rules varies according to jurisdiction. Street lighting is generally considered to be a potentially contestable electrical distribution service where competition could potentially enter to provide greater economic efficiency. However, a Marsden Jacob and Associates report[96] notes that, *"... effective competition for this service has not emerged even though the opportunity has existed for over a decade."* This is corroborated in IPWEA's *Practice Note 11 – Towards More Sustainable Street Lighting*,[97] and subsequently from the authors' diverse consulting experience and consultations undertaken for this Roadmap.

The AER, in its 2013 Framework and Approach paper for NSW distributors, carefully considered the status of street lighting in the lead up to its 2014-2019 NSW pricing determination and considered the potential for street lighting competition in that jurisdiction before deciding how to classify the service. It concluded that it would leave public lighting under its regulatory control on the following basis:

"Given the current circumstances, we consider a direct form of regulation is necessary. We consider there to be significant barriers preventing third parties from providing public lighting services. While the NSW distributors do not have a legislative monopoly over these services, a monopoly position exists. This is because the NSW distributors own the majority of public lighting assets. That is, other parties would need access to poles and easements for instance to hang their own public lighting assets. However, the NSW distributors own and control such supporting infrastructure. Therefore, similar to network services, ownership of network assets restricts the operation, maintenance, alteration or relocation of public lighting services to the NSW distributors. There is some limited scope for other parties to provide some public lighting services. For example, other parties may construct new public lights or perform works on independently owned public lighting assets. Apart from these limited exceptions, the AER considers that a high barrier exists preventing third parties from entering this market. This limits competition in public lighting."[98]

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94 The National Electricity Law is a schedule starting on page 22 of the National Electricity (South Australia) Act 1996, current version published on 30 January 2015. Section "7 National Electricity Objective" is in "Part 1 Preliminary" on page 38 of the South Australian Act (page numbering starts from the beginning of the Act, not the schedule)

95 Section 2.1 of the Electricity Networks Access Code 2004, states: "The objective of this Code ("Code objective") is to promote the economically efficient: (a) investment in; and (b) operation of and use of, networks and services of networks in Western Australia in order to promote competition in markets upstream and downstream of the networks"

96 *Street light asset value determinations in the NEM and WEM,* Marsden Jacob Associates, July 2014, page 3

97 Published July 2014, available at http://www.ipwea.org/publications/bookshop/ipweabookshop/towards-more-sustainable-street-lighting

98 *AER Stage 1 Framework and Approach NSW,* Distribution March 2013, page 42

Similar to the situation in NSW described above by the AER, more than 90% of the street lights in Australia are owned by the 15 Distribution Network Service Providers (DNSPs), who are regulated monopolies. There are currently two electricity regulatory authorities (down from three as recently as 2015) which treat street lighting in three different ways summarised in Table 3.

Table 3: Type Of Regulatory Treatment Of Street Lighting

	Jurisdiction ▹	National Electricity Market (NEM) and Northern Australia	Western Australia
Type of Regulation for Street Lighting ▿	*Regulator* ▹	Australian Energy Regulator (AER)	Economic Regulation Authority (ERA)
Alternative Control Service	Separate from monopoly electricity network distribution services: service-based charging[99]	QLD, NSW, VIC, TAS	WA SWIN[100] (Western Power)[101]
Negotiated Service	Only in situations where negotiations don't conclude in agreement, will the regulator get involved	SA[102]	
Non-regulated Service	No regulation	ACT[103], NT (Power & Water Corp)[104]	WA: NWIN[105] (Horizon Power)

4.2.2 Street Lighting Services

Street lighting services consist of repair, replacement, and maintenance of existing street lighting assets and the provision of new street lighting assets. In most cases, the services provided by the DNSPs also include the long-term financing of replacement lighting.

DNSPs provide a number of these services. These services are more lightly regulated and the rules and AER call them alternative control services because i) they are user specific, ii) asset specific, iii) can be charged separately and iv) historically street lighting has been simple and has reflected the same slow moving technological progress as their core power electricity distribution services. Nevertheless, even DNSP core monopoly standard direct control services that are strictly regulated by the AER, provide substantially more quality of service key performance indicators than does the street lighting category. This is covered in more depth in Section 4.3.9.

4.2.3 Regulating Street Lighting Services

Apart from the distinction made between: strictly regulated standard direct control services; the light handed regulation by the AER for street lighting as alternative control services; even lighter handed negotiated services regulation in South Australia, or unregulated services in ACT, NT and the north of Western Australia, street lighting is not explicitly mentioned in the National Electricity Rules.

Street lighting is a vital public service proven to reduce road deaths and injuries and to mitigate antisocial street behaviour, so its provision needs to meet requirements for careful regulation and oversight.

With limited exceptions, under the current approach in all jurisdictions, local governments and main road authorities, while having exclusive legal responsibility for providing street lighting, generally have no rights to authorise appropriately accredited parties to maintain, add, modify or remove public lighting on their behalf that is currently owned by the DNSP. In short, there is no access or contestability framework to facilitate competition in public lighting services in most jurisdictions (apart from the ACT and a limited form of contestability which exists in Victoria for large-scale replacements under the Victorian Public Lighting Code though even this does not appear to be accepted by all DNSPs).

4.3 Apparent Lack of Economic Efficiency in Current Regulatory Approach

The fundamental purpose of regulating the electricity market is to facilitate economic efficiency in operation and investment as identified in Section 7 of the NER and summarised in Section 4.2.

A key facilitator to achieving this where sufficient market size exists is through facilitation of competition. With a population of about 20 million and about two million street lights, the eastern and south-eastern parts of Australia have sufficient market size, but no competition to the DNSPs has eventuated despite the National Electricity Laws (NEL) and Rules (NER) having been drafted 20 years ago to encourage such competition and efficiency. Furthermore, many local governments have reported that delays by DNSPs in accepting higher performing LED lighting despite many city-wide and

99 "An alternative control service is potentially a contestable service where costs are able to be allocated to customers based on service requests" – Marsden and Jacob report page 1, 2

100 South West Independent Network is not physically part of the NEM, but will be regulated by the same regulator AER

101 Soon to be regulated by the AER

102 Unlike other Australian jurisdictions, all street lighting in the ACT is owned by the Territory Government which is also the road authority

103 Regulated by the AER since 1 July 2015

104 North West Interconnected Network

105 Marsden and Jacob report page 12

regional conversions overseas suggests that the current regulatory approach is not operating as it was originally desired and that this is not economically efficient with respect to street lighting.

This sub-section covers the possible reasons for the apparent lack of economic efficiency in the current regulatory approach to street lighting. The ideas in this section have been sourced from council, regional organisations of councils, DNSPs, lighting and smart controls equipment suppliers, industry bodies and through the authors' own consulting assignments.

4.3.1 Misalignment of Ownership with Legal Responsibility

With limited exceptions, public lighting in Australia is owned and provided as a monopoly service by DNSPs to local councils and main road authorities. Due to the monopoly DNSP ownership of most street lighting, the absence of competition and the lack of a clear regulatory or contractual basis of service, councils and main road authorities do not have meaningful control over the service level or technology choice in most of Australia, yet they have exclusive legal responsibility for providing the service for public safety reasons. Although DNSPs might ultimately be liable for lack of service, it would require secondary legal action by Council to recover damages. This creates a misalignment of incentives.

Under the current regulatory arrangement, there's little or no incentive for DNSPs to replace public lighting with modern alternatives because they would lose network distribution revenue from lower energy consumption and lose maintenance revenue because of a reduction in allowable maintenance charges from more reliable lights.[106] This lack of systemic incentive has meant that DNSPs understandably place a higher priority on other service areas and tend to retain the status quo in street lighting or be slower to adopt new technology, and rely on RAB values to provide stable revenue. Despite the lack of systemic incentive, in response to council requests, some DNSPs have nevertheless installed a modest number of LEDs or offered them as an alternative. With reform, there is an opportunity to address current policy shortcomings to facilitate several government policy goals through improvements that incentivise energy productivity, economic efficiency of local government, road safety, public security and a number of environmental objectives.

One possible approach to reform is to have the NEL recognise the roles of councils and main road authorities under their respective Road Acts and Local Government Acts in a manner that recognises that road authorities should have final say over lighting technology choice as they are the party with exclusive legal responsibility for deciding whether to light, to what level to light and how to deliver public lighting. Without this type of reform, the NEL may ultimately be in conflict with the Roads and Local Government Acts. Rapidly growing pressure to roll out LEDs, smart controls and smart city infrastructure will likely bring this potential conflict to the fore.

4.3.2 Lack of DNSP Incentives to Move to More Reliable Lighting

Street lighting maintenance charges are one of the largest single components of street lighting costs for councils and other road authorities. In recent AER network distribution pricing determinations, street lighting maintenance charges have been set separately for each lighting type based on the assumed failure rate for that type of light source. The approach is effectively a cost-plus regime that provides for higher revenues to support the least reliable technologies. Some council groupings have suggested that this approach may not provide sufficiently clear incentives for the DNSPs to migrate to more reliable and lower cost technologies.

Beyond manufacturers' claims of reliability, there is a growing body of domestic and international evidence that LED lighting achieves markedly higher levels of reliability than all legacy lighting types, even when used in locations with extreme heat, humidity and with high levels of lightning activity. As such, a reformed pricing approvals approach should create an incentive for DNSPs to consider the economic benefit of this enhanced reliability. Some two-thirds of Australian DNSPs now offer LEDs as a standard luminaire choice or alternative choice for residential roads but this appears largely due to concerted council requests. Adoption of LEDs in the higher energy consuming categories of intermediate and main roads appears nascent. Notably, some utilities continue to install mercury vapour luminaires despite its particularly low efficiency.

4.3.3 Low Customer Negotiating Power

Councils have very low negotiating power for a number of practical reasons. They include: a lack of competitive alternatives to monopoly provision of the service by the DNSP, fragmentation (500+ councils in Australia negotiating with only 15 much larger DNSP organisations), a lack of expertise in public lighting as a result of not directly managing public lighting for many decades, a complex regulatory pricing approach, the lack of a clear regulatory basis of service and a rapidly moving technology revolution. All this leaves councils disempowered and particularly vulnerable negotiators.

Customer influence is an important ingredient in the regulatory mix that relies on the tension between the customer's interest and those of its provider. In contrast to the perception that councils, who are street lighting customers, are experienced in the details of street lighting pricing and technology and are therefore best placed to make such decisions, all but the largest councils are very poorly resourced for electricity pricing and regulatory issues in general and particularly for street lighting. Some DNSPs are now adopting a more collaborative approach in working with groups of councils and other public lighting customers. Notably, most regions where progress on LEDs has been made involve groupings of councils and the DNSPs engaging directly.

4.3.4 Lack of Mandatory Minimum Service Standards

Street lighting is a vital public service for the community that provides safety, security and may enhance the future liveability of our cities by facilitating the deployment of smart city technology.

106 The price cap regime that operates in South Australia is suggested to remove this disincentive

However, in most jurisdictions[107] there are no mandatory service standards that DNSPs need to meet to deliver street lighting services to the community. For such a vital public service, it is appropriate for a minimum service level to apply, removing ambiguity between local councils and DNSPs in the delivery of the service and providing a minimum level of protection to the community.

The absence of a clearly defined and enforceable street lighting service level in most jurisdictions also makes the task of the pricing regulator particularly challenging. Pricing cannot be reasonably set without reference to a service level and the consequence for non-performance being robustly defined.

The National Electricity Rules govern the regulation of prices by DNSPs in the National Electricity Market. Where public lighting services are undertaken by DNSPs, the prices are regulated by the AER (except for SA and ACT) in accordance with provisions under Chapter 6 of the NER. Importantly, the role of the AER is limited to that of a price regulator only (or arbitrator in the case of SA). The AER does not have powers under Chapter 6 of the NER to mandate service levels.

Most states or territories do not regulate street lighting service levels and only Victoria and SA have set binding (but limited) state-wide street lighting requirements. New South Wales has a voluntary public lighting code that is currently being reviewed. Even standard AS/NZS 1158 covers only a relatively small part of what is needed to define reasonable minimum service levels and in any event, is not mandated in most jurisdictions.

Councils in a number of jurisdictions have cited the lack of minimum street lighting service standards as an on-going source of concern. To address this, minimum service levels would need to be defined in regulation by the states and territories or under the NEL and recognised as the basis for AER pricing decisions. Given the negotiating imbalance in monopoly service provision noted above, few service level agreements have eventuated as a substitute for well-defined minimum service levels though this approach is under discussion in South Australia. Examples of minimum service standards that should be considered are shown in Table 4.

Table 4: Examples of Minimum Service Standards for DNSPs

	Examples of Minimum Service Standards Relating to DNSPs	Desired Public Good Outcome
1	Management plans	Maximise long term economic efficiency, safety, energy productivity, community comfort, smart city functionality and minimise environmental pollution.
2	Service availability	Maximised lighting to minimise vehicle and pedestrian injuries.
3	Maintenance standards and associated service level guarantees;	Minimise lighting delivery failure (from several sources including vegetation encroachment, lack of maintenance etc).
4	Performance monitoring and reporting	Financial and performance accountability for a public service.
5	Lighting inventory accuracy and effective information provision	Efficient management and charging for services. Transparency of a public service allowing effective analysis. Provision of sufficient quality information on which to make prudent investment decisions.
6	Mechanism to encourage efficient innovation	Improve efficiency of delivering safety, comfort and liveability outcomes.

4.3.5 Fragmented Responsibility for Setting Minimum Service Standards

The responsibility for setting minimum service standards generally appears to rest with each of the eight state and territory governments but potentially could be addressed by the Australian Energy Market Commission (AEMC) or at a COAG level.

Conventionally the advantage of this issue being the responsibility of each jurisdiction is that it allows the minimum street lighting service standard to be matched to regional and social characteristics of the jurisdiction. The advantage of it being embedded in the National Electricity Rules is that it would allow a single implementation approach across all eight jurisdictions. If customisation of the minimum service standards was required by some jurisdictions, that can be accommodated in the NEM.

However, the need for customisation of minimum standards to eight states and territories is highly debatable. For example, just as it is recognised that a single AS/NZS 1158 standard generally applies across all road lighting in Australia and New Zealand, a set of internationally informed minimum street lighting service standards are likely to have equal applicability across jurisdictions. Put simply, the physiology of the human eye, the performance of lighting and accident risks for given road types do no vary appreciably amongst the jurisdictions. Furthermore, because all-encompassing minimum service performance standards do not currently exist in any jurisdiction, there is a strong argument for greater centralisation and thus greater policy efficacy and policy development efficiency.

107 Victoria has a binding but limited Public Lighting Code and the ACT directly controls its public lighting

The responsibility for setting minimum standards needs clear allocation to state or territories or nationally by the AEMC and COAG in order for important safety related public services to be adequately delivered. Examples of minimum service levels applicable to DNSPs are shown in Table 4[108] and examples that are applicable to councils, states and territories are shown in Table 5.

Table 5: Examples of Minimum Service Standards for Councils, States and Territories

	Examples of Minimum Service Standards Relating to Councils, Main Road Authorities, States and Territories	Desired Public Good Outcome
1	Road traffic conditions (e.g. AADT traffic flow, pedestrian presence etc) objectively established for each AS/NZS 1158 road lighting category[108]	Maximise safety and economic efficiency by removing interpretation ambiguity in lighting levels for widely varying road traffic conditions.
2	Levels of uniformity, colour rendition, energy productivity, light pollution and other important factors	Maximise safety and economic efficiency by removing ambiguity or where standards are currently silent and where research supports introducing minimum requirements.
3	Smart city functionality (e.g. Central Business District parking, sensors, CCTV, resilience improvement)	Improve liveability, workability and community resilience in face of disasters.
4	Systematic incorporation of aesthetic values	Provide opportunity for efficient community involvement to maximise community engagement and pride.

4.3.6 Lack of Access and Contestability Frameworks

In most jurisdictions, there is no clear framework under which councils or main road authorities can authorise appropriately qualified third parties to remove, modify, install or replace street lights on utility distribution poles. This lack of an access and contestability framework is a key barrier to meaningful competition in street lighting.

The ability for non DNSP third parties to provide street lighting services depends on being able to efficiently negotiate and reach agreements between the DNSP lighting and network owner and the council responsible for both delivering the service and paying for it. Unless a set of guidelines clearly identifying obligations of each of the three parties exists – arguably set by a fourth disinterested but publicly motivated regulator – competition to the DNSP by the private sector will be difficult. The term economists use for such guidelines is "access and contestability frameworks" and they are vital for an efficient market to operate.

The importance of these guidelines and frameworks can be emphasised by two examples in Australia. The only large scale competitive tender for street lighting services (79,000 luminaires) was issued in August 2016 by the Australian Capital Territory which is the only local government of that scale to own its own street lights. In contrast, the Sunshine Coast Council which does not own its own lights, has been negotiating for years to conclude a deal where the successful third party tenderer (Citelum) was awarded the contract about two years ago. The project has not progressed, probably due to the difficulty of the need for a complex three-party agreement.

4.3.7 Use of RAB[110] Valuations Instead of Simple Depreciated Value

Under the current regulatory framework, local councils and main road authorities can request that DNSPs replace existing public lighting with more energy efficient lighting before the end of the existing asset's economic life. However, if these customers decide to replace an asset early, they will be required to pay the DNSP the carrying amount of the old asset as well as for the new LED asset. Note that this applies only when and if the council or main road authority requests a change regardless of what choice of technology is sought.

The current requirement to pay the residual cost of existing assets ensures distribution businesses can recover the *depreciated value of the modern engineering equivalent* and is intended to preserve the NPV of the return on, and return of, capital over the remaining expected life of the asset but based on the depreciated valuation of the modern engineering equivalent, *not the original installation cost.*

A number of councils and groupings of councils have identified this approach to valuation as representing both a major barrier to timely adoption of LEDs and an inappropriate application of the RAB concept. They suggest that the RAB concept is a regulatory pricing tool that was never intended for use as an exit mechanism. In some cases, it has led to claimed carrying amounts that appear close to the cost of new assets even when lights are aged, in poor condition and obsolete. Importantly, claimed RAB values vary widely amongst utilities and jurisdictions even for substantially identical lighting of a similar age.[111]

108 DNSPs in some jurisdictions meet many of the minimum service levels in Table 4 though not necessarily under a regulated or contractually guaranteed arrangement

109 While AS/NZS 1158 sets a clear numerical relationship for lighting levels to the category of road (P1, P2 , V1, V2 etc) no similarly clear numerically objective guidelines exist to relate more widely varying traffic parameters such as AADT traffic flow etc. to these P1, P2 etc. road categories. This lack of systematic objectivity undermines the objective of the highly complex and numerically prescriptive AS/NZS 1158 standard

110 Regulated Asset Base

111 As noted previously, it is understood not to be happening in SA where they are rolling over the asset costs into the new tariffs

One innovative approach under discussion in South Australia involves rolling over the RAB into the tariffs for new lights. A similar approach is being used in parts of the United States. Another approach to addressing this issue is the use of the depreciated book value of the assets. Some states in New England and the US have adopted this approach for situations where municipalities wish to exit current utility arrangements and roll out LEDs themselves.

Using the depreciated book value of the street lighting assets is likely to lead to a write-down of DNSP assets and therefore a charge to the profit and loss account. However, potentially off-setting this is the new higher RAB value if the utilities fund the replacement lights.

A precedent for variation from the established treatment of capital equipment purchases exists. To encourage the market to introduce new technology electricity meters, the AER has allowed the carrying amount of existing meters to be both valued differently and spread over the life of the new meter to avoid the barrier that paying for the full carrying amount of the old meter would have represented.[112]

4.3.8 Up-front Payments for Carrying Amount

The Marsden Jacob report suggested that for cash-constrained councils, upfront payments for the carrying amount[113] of street lights being replaced by LEDs by councils may act as a financial barrier to the early adoption of LED lighting. Neither the NER nor the AER in its application of the NER, specify whether or not local councils should pay the carrying amount to the DNSP upfront or pay it off over time. Therefore, the logical suggestion was to propose that DNSPs allow councils to pay over time as they had for the lighting service up to that point.

While this represents a useful change that will lower the barrier a little, its effect is very small compared to the other barriers such as lack of access and contestability frameworks and over-valuation of old, obsolete or severely degraded assets.

Notably, this approach does not change the NPV of the carrying amount that may be judged to be too high and may even increase the NPV from a customer perspective as the allowable cost of capital for the DNSPs (the WACC[114]), generally exceeds the cost of capital of the councils and main road authorities.

4.3.9 Lack of Quality of Service Performance Indicators

From the early stages of the NEM, street lighting was considered not to require the quality of service and reliability reporting requirements from electricity distributors as they are required to provide for the monopoly direct control services. This view appears to have originally arisen because of a mistaken view that street lighting was already contestable in most jurisdictions.[115] The consequences of originally considering street lighting to be a contestable service has been a particularly challenging for council and main road authority customers. Not only have they been denied competition, but they have been denied the regulatory oversight of minimum quality-of-service performance to ensure that the public lighting service they are legally obliged to provide has been of adequate quality and reliability.

Currently DNSP pricing for public lighting is generally laid out in the same format as pricing for direct standard control services to minimise administrative effort. However the services provided are very different and certainly street lighting, unlike direct standard control services, is provided with no quality-of-service performance assurances, such as supply reliability targets for unplanned System Average Interruption Duration Index (SAIDI), unplanned System Average Interruption Frequency Index (SAIFI) etc. for each network segment).

Without measurement of reliability of supply to street lighting, without reporting and without financial consequence for supply failure, there can be no reasonable belief that the current regime provides effective signals to the electricity distributors operating the vast majority of street lights. Reform of reliability measures to include supply to street lighting assets is clearly needed.

The AER is arguably well qualified and very experienced in monitoring service level compliance for network services worth billions of dollars so the option of extending this function to street lighting appears to be an efficient use of resources.

4.3.10 Street Light Distribution Network Tariffs

A foundation of monopoly regulation specifically embodied in the National Electricity Rules is the accurate and fair valuation of assets and costs associated with a service so that charges are cost reflective, service based, fair and do not cross-subsidise any other service.

However, the basis for allocating DNSP street lighting network distribution charges is not sufficiently transparent to determine whether the charges are cost reflective and they do not appear to be service-based as street lighting supply reliability is currently excluded from measures of network reliability and there is no financial consequence for non-performance (as outlined in Section 4.3.9). At the same time, street lighting network distribution tariffs often appear high in comparison to other network distribution tariffs, particularly when the off-peak nature of consumption is considered. Reform is clearly needed in this area, if only to bring confidence in the price setting approach and to ensure that price signals are economically efficient for all parties at a time of rapid technological change with respect to street lighting, smart controls, smart city devices and integrated solar PV.

112 Discussions with Mr John Skinner and AER staff on 20th July 2016

113 The term "residual value" commonly used by many DNSPs is not the appropriate term. The correct term is “Carrying Amount” which is defined in the current Australian Accounting Standard, as per AASB 116, Property, Plant and Equipment, Para 6, as the amount at which an asset is recognised after deducting any accumulated depreciation and accumulated impairment losses. Importantly, the term “residual value” has a different meaning to that intended in current usage by DNSPs and refers to the disposal value of an asset which in the case of many old street lights would be nil.”

114 Weighted Average Cost of Capital

115 Current reporting requirements appear to generally be based on the national guidelines first established by the Standing Committee on National Regulatory Reporting Requirements (SCONRRR) and as detailed in the National Regulatory Reporting for Electricity Distribution and Retailing Businesses - Utilities Regulators Forum Discussion Paper March 2002 which appeared to erroneously conclude that street lighting supply was contestable

4.3.11 Misconception that DNSPs are Incentivised to Invest in New Lighting Technology

The regulatory framework provides incentives to DNSPs to adopt new technologies in their core strictly regulated direct standard control services where they are motivated by being able to increase their return on a greater level of capital expenditure if they can demonstrate the overall financial benefits of new technologies. This is then perceived to occur for street lighting, when the evidence shows the opposite.

In practice, utilities earn less distribution revenue if they install more efficient street lights (50% less on average with LEDs) and, over time, may earn less maintenance revenue if they install more reliable lights (again perhaps 50% less with LEDs as the AER recognises their maintenance benefits over time).

4.3.12 Lack of Life-Time Costing

It is unlikely that the current approach of the DNSPs or the AER considers minimising the total long term cost to the council electricity customer. When selecting street lighting equipment, the electricity distributors currently focus on the capital costs of equipment and the potential maintenance costs, and the AER regulates what they can charge for these two components and these alone. However, the DNSPs and the AER do not necessarily consider the total costs to the customer of specific technology choices including network distribution charges, retail electricity charges, losses, market and environmental charges. If these additional costs to the customer are not properly considered, it can have the effect of eliminating good technologies from consideration with slightly higher capital costs but with lower long-term total cost of ownership.

Revision to or clarification of the National Electricity Objective may be needed to ensure that minimising total cost of street lighting to the customer is the primary objective, not just consideration of the capital and maintenance costs of the DNSPs.

4.3.13 Misconception that State and DNSP Safety and Technical Requirements are a Barrier

The NER do not preclude third parties from providing public lighting services. On the contrary, the NER stipulates in Chapter 5 that nothing in the rules is to be read or construed as preventing anyone connecting network assets. The price caps determined under the AER regulatory approach permits the DNSPs or a third party to provide the services at a lower cost. Through this approach, the AER is seeking to encourage greater competition in the provision of public lighting services.

Some parties consider the lack of competition is likely to be attributable, to a large extent, to state government polices around safety standards which lead to DNSPs restricting third parties from accessing electricity poles to carry out a range of services including replacement of existing lighting assets with LED lighting.

This issue does not, on examination, appear to be the key barrier. All jurisdictions have well developed access regimes for third parties doing work on their network (e.g. contestable works guidelines) and third parties already own many devices mounted on and supplied with power directly by the network (e.g. telecommunications and cable television equipment). These parties meet all relevant safety standards in doing their work and this framework is well-developed in most jurisdictions. What is more, *AS/NZS60598.2.3:2015 Particular requirements – Luminaires for road and street lighting,* adherence to which is generally required by authorities, sets robust requirements for product safety. Street lighting is not electrically complex and appropriately qualified linesmen could manage any street lighting installation or maintenance requirements safely and efficiently.

The lack of street lighting access and contestability frameworks, discussed in more detail above, appears to be a better explanation of the barriers at present.

4.3.14 Lack of Transparency

Councils have regularly cited concerns about pricing complexity, lack of transparency and lack disclosure about the basis of street lighting valuations, capital charges and maintenance charges in AER submissions across multiple jurisdictions.

This lack of transparency is preventing councils from having confidence in the regulatory pricing regime and from effectively calculating the savings from replacing existing public lighting assets with those of higher performance and greater reliability.

At the same time, while key pricing inputs and assumptions are not transparent, the sheer volume of the data that is provided by some DNSPs to the AER also creates a barrier for the councils to analyse. Data is not information, and councils are under-resourced to be able to analyse the often complex and unfamiliar data provided by a well-resourced DNSP and AER whose objectives – in contrast to councils - are to analyse this type of data.

4.3.15 Five-year Pricing Reviews Incompatible with 20 Year Investment Decisions

The five-yearly AER pricing reviews are incompatible with 20 year investment decisions[116]. When councils request that their utility replace a street light with a new and more efficient type, they are making an investment decision on an asset that is expected to last an average of 12-20 years. In assessing the business case for that financial decision, they are taking on a 12-20 year capital commitment yet are unable to assess the financial implications of their investment decision beyond the current regulatory period which on average is only two and a half years away in a five year review cycle.

4.4 Electricity Network Transformation Roadmap to 2027 and 2050

Energy Networks Australia (ENA) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have very recently released[117] what is believed to be a world first its most ambitious and credible planning paper for electricity networks, called

116 Not in the case in SA under the negotiate/arbitrate form of regulation, where they are able to agree mutually acceptable long-term arrangements with customers

117 *CSIRO and Energy Networks Australia 2016,* Electricity Network Transformation Roadmap: Key Concepts Report, 6th December, 2016.

Electricity Network Transformation Roadmap: Key Concepts Report. This section discusses the substantial synergies that exist between that $1,000 billion electricity *Transformation Roadmap to 2050,* and the $2 billion *Street Lighting and Smart Controls Roadmap.* While the former is 500 times larger than the latter, the ability of each transformation to substantially benefit the other is remarkable.

4.4.1 Relevance of Street Lighting Transformation to Electricity Networks Transformation

As identified elsewhere in this SLSC Roadmap:

- 90% of street lighting is owned by electricity distribution companies,
- That is currently virtually 100% powered by network electricity,
- Which needs regulatory reform for increased efficiency,
- And is undergoing a technology revolution with energy reductions of 50+%, and maintenance cost reductions of 50+%.

Street lighting is also undergoing major improvements from utilisation of intelligent control systems to provide new amenity from sensors and services, asset management efficiency, and maintenance. Furthermore, street lighting will be a substantial participant and beneficiary from solar PV, battery storage and electric vehicle charging technologies.

Each of these fundamentally significant drivers is deeply interrelated within the *Electricity Transformation Roadmap* and are directly or indirectly mentioned in the *Electricity Network Transformation Roadmap: Key Concepts Report* – though not in direct relation to street lighting which is only a meager 1.4% of the sector's revenue. Nevertheless, that relationship must be robustly established.

4.4.2 Value of Street Lighting Greater Than its Revenue to Electricity Networks

Street lighting has substantially greater economic and social value to Australia than its small proportion of the electricity distribution sector's revenue suggests.

As identified in Section 3, research shows that street lighting has substantial impacts on road injuries and fatalities, with scientifically established reductions from lighting ranging from 10% to 78%[118], but Australian lighting levels are at only 17% to 75% of what they are in Europe and USA[119]. This SLSC Roadmap does not suggest lighting levels should be increased per se, instead it suggests that a transformation like that of the electricity networks where everything about street lighting is reviewed to ensure:

- It is targeted at the right places,
- At the right time and
- In the right way and
- At the right cost.

If a 10% reduction in injuries and fatalities eventuated from these changes this would represent a saving of between $700 million and $1 billion to the Australian economy <u>per year</u>[120]. To 2050 (33 years) even at a high 8% discount factor this represents a Present Value of $11 billion and therefore a Net Present Value of $8 billion just from road safety benefits.

However, street lighting is significantly more important to the Australian economy even than even this substantial safety benefit.

Together with intelligent controls and sensors and ability to leverage smart city services, street lighting has the potential to provide the foundation for smart city services. It becomes the backbone or DNA to facilitate smart city deployments. The European Commission calls it the *Humble Lamp Post* initiative. A transformation in electricity networks and street lighting is an opportunity to leverage a transformation in urban living. The existing asset geography and 24 hour permanent power of light poles makes them the most efficient and practical delivery mechanism for smart cities.

As with any positive change, there are other factors that require managing. Research has shown that street lighting needs to be carefully positioned so as not to impact sleep patterns, , as well as on the ecological environment of birds, animals, insects and plants, as well as the night sky. Such matters can be mitigated through widespread use of controls and intelligent systems which provide a method to trade-off the benefits against these dis-benefits.

The transformational changes being made to change the electricity network are an ideal opportunity to work together with the changes to street lighting to obtain synergies that maximise the benefit for Australia economy from both sources.

4.4.3 Predicted "Sea Change" to Electricity Networks

The ENA and CSIRO's *Electricity Network Transformation Roadmap: Key Concepts Report* suggests the following very major changes will occur:[121]

- *"Reduction in cumulative total expenditure of $101 billion by 2050"*
- *"Network charges 30% lower than 2016"*
- *"Networks pay distributed energy resources customers over $2.5 billion <u>per annum</u> for grid support services by 2050."* [our emphasis]
- *"By 2027, over 40% of customers have adopted on site distributed energy resources supported by simple and supportive network information services."*[122] And by 2050 *"almost 2/3 customers use onsite resources ..."*[123]
- *"Electricity sector achieves zero net emissions by 2050"*
- *"$16 billion in network infrastructure investment is avoided by orchestration of distributed energy resources"*

These are predictions of truly massive proportions. They represent an industry undergoing a generational *sea change* and as they observe

118 See Table 2, p9 extracted from Høye, A. et al. (2016). *The Handbook of Road Safety Measures* (web edition, in Norwegian). Extracted from Table 1.18.1 page 184 and translated by Prof Rune Elvik.

119 See Figure 3.

120 See Section 3.2.1 ii.

121 Ibid., Summary Report, p2

122 Ibid., p18

123 Ibid., Overview of the Roadmap, page v, extracted to Table 1

A future where up to 50% of all electricity is generated by customers in 2050 – at the opposite end of the system from its original design – presents a very significant range of technical, economic and regulatory challenges. Other major changes for customers are signalled in the attached Table 1 extracted from their Executive Summary.

The ENA and CSIRO further suggest that *"Without a well planned approach to navigate this transformation, Australia's energy system will be unable to efficiently and securely integrate the diverse technologies, large scale renewable energy sources and customer owned distributed energy resources."* These statements very closely reflect the issues identified in this Street Lighting and Smart Controls Roadmap and therefore make a strong case for integrating the two Roadmaps.

4.4.4 Technical Enablers

Section 12[124] of the ENA/CSIRO report identifies a four year action plan for the electricity network transformation over the 2017-27 decade. A key technical enabler identified in the plan is electricity and communication systems standardisation based on IEC international standards. Such a suite of standards must also include those concerning street lighting control systems.

The four year action program fits well with the needs and intentions of street lighting equipment and service suppliers and with street lighting buyers/users/consumers, but the details will need very careful consideration to achieve balanced and effective outcomes for the wide variety of stakeholders in the street lighting consumer arena.

Even at this very structured technical level, the electricity network transformation Roadmap is very closely aligned with the needs of street lighting and this therefore illustrates how compatible both the network transformation Roadmap is with the Street Lighting and Smart Controls Roadmap.

4.4.5 Conclusion

In conclusion, we quote the CSIRO/ENA statement, which also applies to street lighting when minor word changes are made to apply to street lighting customers rather than power customers: *"However, timely action is required. The agility with which networks can connect, integrate and incentivise new, lower carbon energy choices will directly influence the cost, fairness, security and reliability of customer outcomes. Urgent regulatory and policy changes will be needed to retain power system security, while saving customers money through efficient use of distributed energy resources, standalone systems and micro-grids. The timely development of technical standards and new information platforms will be required to animate new distributed energy resources markets and support enhanced customer services."* The only changes that need to be made to this statement are to replace *"Power system security"* with *"lighting system security"*, and *"micro grids"* with *"micro grids and smart lighting control systems".*

This Roadmap strongly recommends that the ENA/CSIRO Electricity Network Transformation Roadmap be integrated with the Street Lighting and Smart Controls Roadmap.

Overall Customer Outcomes by	
2027	**2050**
CUSTOMER CHOICE AND CONTROL	
Over 40% customers use onsite resources: 29 GW solar and 34 GWh of batteries. Concessions to support those who need it most.	Almost 2/3 customers us onsite resources, including 1/3 customers on a new stand-alone system tariff.
LOWER BILLS FOR VALUED SERVICES	
Avoid over $1.4 BN in network investment. Average network bills 10% lower than 2016.	Total system spend is $101 BN lower to 2050. Save households $414 pa by 2050. Network charges 30% lower than 2016.
FAIRNESS AND INCENTIVES	
Networks pay over $1.1 BN pa for DER services. Over $1.4 BN in cross subsidies avoided, saving $350 pa for med size family without DER.	Networks pay over $2.5 BN pa for DER services. Over $18 BN in cross subsidies avoided, saving $600 pa for med size family without DER.
SAFETY, SECURITY, RELIABILITY	
Planned and efficient market response avoids security and stability risks. Robust physical and cyber security management.	Real time balancing reliability and quality of supply at small and large scale, with millions of market participants.
CLEAN ENERGY TRANSITION	
Electricity sector carbon abatement to reach 40% by 2030 – greater than current national target of 26-28%	Electricity sector achieves Zero Net Emissions by 2050.

Figure 13 – ENA and CSIRO Modelled Customer Outcomes

4.5 Conclusion

Table 6 overleaf provides a summary of the required regulatory changes suggested. The absence of a clearly defined basis of service for street lighting and the lack of alignment between legal responsibility for providing the service and control over the service are creating fundamental challenges for all parties in administering street lighting efficiently and suggests that reform is urgently needed.

One option is reform of the current DNSP ownership model. This would involve establishing a clear basis of service, better aligning control over key decisions with responsibility, establishing minimum service standards and establishing a more robust basis of pricing, including addressing the need for transparency in pricing, for pricing to be based on minimising the total cost of service, for flexibility in RAB payment approaches and providing clear incentives to move to more energy efficient and reliable technology.

A second reform option is the opening up of competition under a robust access and contestability framework that would allow councils and main road authorities to choose their service provider and make their own decisions about technology and service levels.

124 Ibid., Section 12 Technical Standards and Regulations, p 88-91

A third option is to provide encouragement for partnerships between DNSPs and councils or their Regional Organisations of Councils (ROCS) to invest and operate together on equitable commercial basis. Due to the existing conditions, independent guidelines and oversight will be necessary.

Under either reform path, establishing minimum acceptable electricity supply service levels and addressing high claimed residual asset values in several jurisdictions will need to be addressed.

Table 6: Summary of the Required Regulatory Changes Suggested

Suggested Change	Key Options	Primary Agency Responsible	Additional Key Stakeholders
Clarify NEO as it Applies to Street Lighting (Section 4.2 and 4.3.12)	• No change • Issue clarifying document • Revise NEO	COAG and/or AEMC	States, AER, ENA, ALGA, IPWEA
Develop Contestability and Access Framework (Section 4.3.6)	• No change • Adopt national framework • Implement state-based regulation (individually or under a national framework) • Declare street lighting under Part IIIA of the Competition and Consumer Act 2010	COAG and/or AEMC for national framework; states for implementation	AER, ENA, ALGA, state local government associations, IPWEA
Develop Minimum Service Levels and Enforcement Mechanism (Section 4.3.4 and 4.3.5)	• No change • Adopt national framework • Implement state-based regulation (individually or under a national framework)	COAG and/or AEMC for national framework; states for regulatory changes; AER for enforcement	ENA, ALGA, state local government associations, IPWEA
Better Align Technology Choice with Responsibility (Section 4.3.1)	• No change • Modifications to NEL to recognise role of road authorities • State-based recognition of road authority role in Public Lighting Codes or other mechanism	COAG and/or AEMC for NEL changes; states for regulatory changes	AER, ENA, ALGA, state local government associations, IPWEA
Extend Supply Reliability Standards (Section 4.3.9)	• No change • Modify network supply reliability (e.g. SAIDI/SAIFI) to no longer exclude supply to street lighting	COAG and/or AEMC for NEL changes; AER for implementation	ENA, ALGA, IPWEA
Introduce Greater Transparency (Section 4.3.14)	• No change • Modify NEL to require greater disclosure of pricing model, modelling assumptions and maintenance data	COAG and/or AEMC for NEL changes; AER for implementation	ENA, ALGA, IPWEA
Reform Maintenance Pricing (Section 4.3.2)	• No change • Modify maintenance pricing to more clearly incentivise reliable lighting technologies	AER	ENA, ALGA, IPWEA
Create Alternative to RAB for Exit (Section 4.3.7)	• No change • Adopt depreciated book value on exit as per New England states • Adopt other valuation mechanism	COAG and/or AEMC	States, AER, ENA, ALGA, IPWEA
Flexible RAB Payment Approach (Section 4.3.8)	• No change • Issue clarifying guidance • Set requirements for DNSPs	AER	ENA, ALGA, IPWEA
Facilitate Metering by Smart Street Lighting and Smart City Devices (Section 5.3 and LCA Paper)	• No change • Modify existing metering classification • Create new metering classification	AEMO	ENA, ALGA, IPWEA, LCA, Smart Controls/ Smart City Suppliers, National Measurements Institute (NMI)
Revisions to AS/NZS 3000 to Clarify Connection Requirements (Section 11)	• No change • Modify to clarify connection requirements for non-DNSP owned street lighting assets	Standards Australia	ENA, ALGA, IPWEA, LCA

5

STREET LIGHTING TECHNOLOGY

LED Efficacy and Costs Continue to Improve

LED Failure Rates Less than 1/10 of Legacy Technologies

Smart Controls Being Widely Deployed Overseas

LED Street Lights – Lower total costs, lower energy, more reliable, less maintenance, better lighting control.

Smart Controls – Lower energy, longer life, better adaptive control, better asset management.

Smart City – Smart street lighting controls a key enabler of improved community services and revenue generation.

This section of the Roadmap presents an overview of the new street lighting and controls technologies available for about the last five years that provide performance and cost advantages as well as a range of additional features and benefits over legacy street lighting technologies.

5.1 Technology Background

The first electric lighting technology to be commercially developed was the incandescent lamp patented and commercialised by Thomas Edison in 1878. The two subsequent technologies were fluorescent lamps in the 1920s, high intensity discharge lamps in the 1930s including High Pressure Sodium lamps in the 1960s. These technologies are illustrated on the graph in Figure 13[125] which shows their recent efficiency improvement over time on the horizontal axis and lighting efficacy measured in Lumens per Watt on the vertical axis[126]. The most recent technology that has rapidly superseded virtually all others is that of Light Emitting Diodes or LEDs as shown on the top right in blue.

LEDs were developed by NASA in 1962 as low power sources of light for control panel status indication. More recently white light LEDs have been developed for high power applications in vehicle lighting general lighting and road lighting.

The physics on which LEDs are based is fundamentally very different to the three lighting generations before it and because it is based on similar physics to the solid semiconductor transistor it is referred to as "Solid State Lighting". Figure 15 illustrates some of the physical elements of a LED.

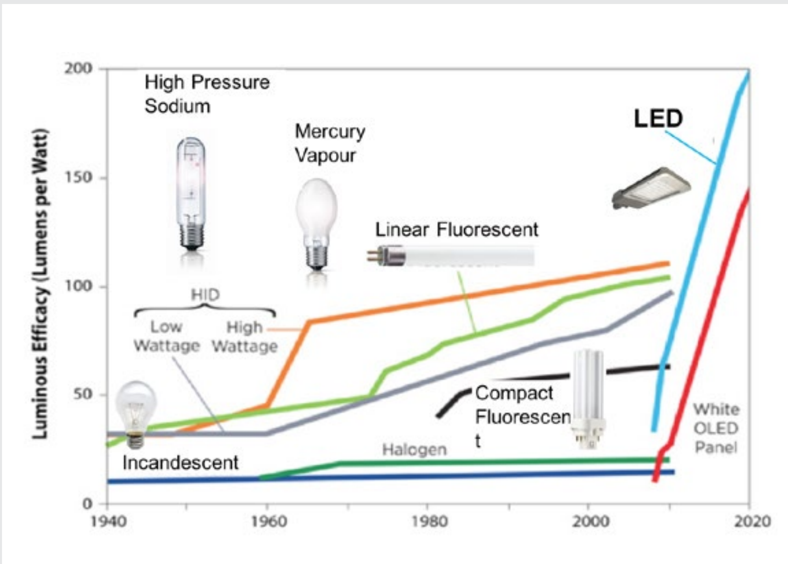

Figure 14 – Comparison of efficacy of conventional lighting technologies with LED (US department of Energy via Digital Lumens & SLP)

125 http://www.digitallumens.com/resources/webinars/ *The Future of Intelligent Lighting*

126 The Lumen is the international (SI) measurement unit of lighting output, and the Watt is the measure of Power in Joules per second.

Figure 15 – Diagram and photos of Light Emitting Diode (LED) (CREE, US DoE)

Among the variety of benefits available from LED lighting, is the ability to integrate closely with computers to vary or adapt illumination levels (the industry calls this "dimmable") to match required usage, reduce maintenance through improved longevity and to reduce lighting pollution due to its physical beamspread characteristics. Additionally, there is instant illumination when power is applied, reduced toxic substance pollution at end-of-life, reduced energy usage over life with a consequent lower carbon footprint. As the international management consultancy McKinsey & Company said about LED technologies *"This totally different technology for emitting light is upending the role of the replacement business and transforming the landscape of the lighting industry value chain entirely..."* [127]

5.2 Street Lighting Terminology

Figure 16 illustrates key street lighting component terminology with traditional analogue technology shown on the left and newer digital technology on the right.[128]

Figure 16 – Street lighting terminology (IPWEA)

5.3 Light Characteristics of LED Technology

LED technology is substantially more efficient at converting electrical energy into light (i.e. luminous energy).

For the same lighting application and light level (i.e. illumination level) the energy required is much lower. There are also many other additional maintenance and visual performance advantages strengthen the business and societal case for LED adoption.

Depending on what activity we are undertaking, some light sources are more appropriate and accommodating to the eyes than some others. There are two key parameters that affect the human response to light.

The first one is colour temperature, where a low temperature represents a warm yellowish light and a high temperature is a bluish white light. The second measure is the Colour Rendering Index (CRI). This is a measure of how accurately the light portrays the actual colour of an object. These concepts are further explained in the following sections.

The principal attraction of LED technology is its substantially greater efficiency at conversion of electrical energy into luminous energy (i.e. light) and the resultant lower energy consumption for given illumination levels illustrated in the graph shown in Figure 13. However, many other additional maintenance and visual performance advantages strengthen the business and societal case for LED adoption.

127 *Lighting the Way: Perspectives on the global lighting market,* McKinsey & Company, July 2011, Page 18

128 http://www.digitallumens.com/resources/webinars/ *The Future of Intelligent Lighting*

5.3.1 Colour Temperature

Light colour temperature, specified as degrees Kelvin (K), is a measure of the warmth or coolness of light as illustrated in Figure 17. LED luminaires can be purchased depending on user applications and desires, with warmer (lower) temperatures being more preferable for human comfort and for ecological reasons and for reducing light pollution[129], and cooler (higher) temperatures for alertness and driving safety reasons. LED lighting – unlike most of the legacy technologies – is available in a range of colour temperatures.

The whiter/bluer light improves human visual acuity and driver reaction times and thus leads to shorter driver stopping distances and improved road safety outcomes.[130] Notably, the highest risk location for accidents at night that result in injuries and death is on main roads which, in Australia, have been primarily lit with high pressure sodium lighting. HPS has the lowest colour rendering capabilities of all commonly used street lighting technologies.

5.3.2 Colour Rendering (CRI)

Colour rendering is a measure of a light source's ability to portray colours in a suitably accurate and human-attuned manner. This is generally measured by the Colour Rendering Index (CRI) which ranges from 0-100 with 100 being full and accurate colour rendition. Legacy high pressure sodium has been very poor in this regard with a CRI of 20 and mercury vapour is middle ground with a CRI of 50. In contrast, white light LED light sources typically have a high CRI of between 70-80. This superior LED colour rendering performance delivers visual conditions at very low light levels that are much improved over legacy technologies. LED street lighting therefore provides substantially better facility to recognise and discern people and vehicles and thus perform an improved safety and security role.

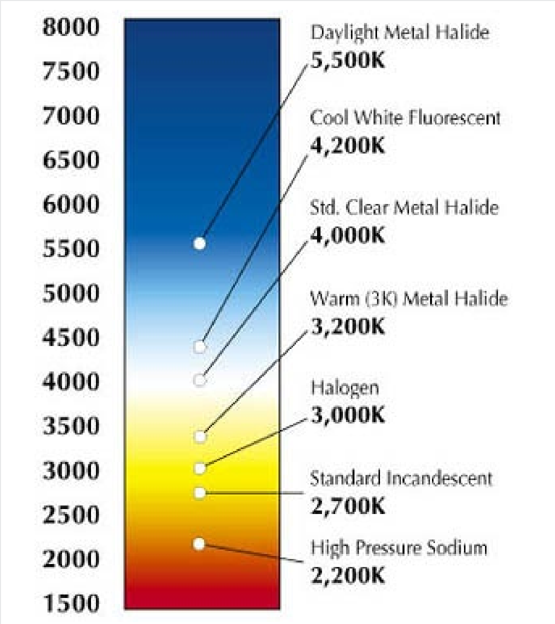

Figure 17 – Colour temperature

5.4 Maintenance Characteristics of Street Lighting

Legacy street lighting technologies require a relatively high rate of planned and unplanned maintenance visits with about a 7-15% per annum rate of maintenance visits being typical.[131] Bulk replacement[132] of traditional lamps is required on a 3-5 year cycle as lamp failure is determined by both outage and depreciation of light output over time.

In contrast, LED luminaires are designed for a 12-20 year life without replacement of either components or the luminaires themselves, but occasional (perhaps 5-8 year cyclical) optical cleaning and inspection will be required. Survey information from US municipalities[133] has indicated that the failure rate for LED luminaires is cumulatively less than 1% over the five plus years of experience to date. Information supplied by Australian LED users is of a similar order.[134] The cost saving implications of this much reduced maintenance are as significant as the energy savings. A further indirect benefit is the resultant reductions in traffic management costs and economic losses from disruptions to traffic movements caused by lighting maintenance activities.

Product failure warranties for legacy luminaires have seldom been for more than one year. In contrast, the norm for warranties in Australia is trending towards ten years for street light LED luminaires, significantly indemnifying the asset owner from early and mid-life product failure risk.

Figure 18 – Maintaining LED luminaire (Colorado Lighting, USA)

129 US DoE Postings, June 21 2016, Dr Jim Brodrick http://energy.gov/sites/prod/files/2016/06/f32/postings_06-21-16.pdf

130 *The Safety Effects Of Road Lighting – What International Research Tells Us*, Dr. Ronald Gibbons, Virginia Tech Transportation Institute, RoadLighting 2015, March 2015, Auckland New Zealand

131 Ebrahimian, E., *City of Los Angeles and a range of AER submissions by DNSPs, councils and their advisors*

132 Bulk Lamp Replacement (BLR) is the practice of replacing a large number of lamps on a regular rotating basis so that the whole inventory is replaced over a planned cycle. This is more economical than spot replacement. This is only applicable to non-LED lamps which require replacement cycles of between 3 and 5 years (depending on lamp type). LED luminaires typically have a predicted product lifespan without component changes of 12-20 years

133 Kinzey, B., MSSLC - *LEDs at 5+ Years – The Scoop on Street and Area Lighting Applications,* LFI NYC May, 2015

134 E.g. City of Sydney reported failures since 2012 of 0.4% on 6500 installations, Ausgrid reported failures since 2013 of 0.61% on 25,000 installations to January 2016

5.5 Electricity Metering and Unmetered Loads

The current approach to street lighting energy use quantification is to use a calculated ("deemed") load for most street lights owned and/or managed by utilities. Each new luminaire type has its energy consumption verified by independent testing and, when agreed to by AEMO, is published in AEMO unmetered load tables.[135] Energy retailers and service providers use these tables as input to calculate estimated energy use for street lighting for which councils and main road authorities are then invoiced.

Importantly, while testing of luminaire energy consumption in a laboratory may be highly accurate, it may not relate well to actual consumption of all street lights in the field over time for the following reasons:

- Lack of accuracy in street lighting inventories;
- Energy consumption may increase as lamps age and some components (such as capacitors) fail; and
- Photocells, used to turn lights on and off, change their responsiveness as they age and with dirt accumulation.

The deemed load approach assumes that all street light luminaires are operating at full power for all of the hours of darkness. With the increasing use of smart control systems (both stand-alone and internet based) this assumption is no longer universally valid as energy use can be varied with:

- **Trimming –** Has several meanings: Reducing full output for the life of the luminaire to exactly meet required lighting design levels and/or; turning lighting on later or off earlier and/or; turning lighting on or off gradually in response to ambient lighting levels;
- **Constant Light Output –** Gradually raising power levels over time to keep lighting delivery at compliance levels as the LEDs age;
- **Dimming –** Dimming lighting in off-peak hours in response to greatly reduced traffic or pedestrian volumes;
- **Off-Peak Shut-Off –** Turning off lighting completely in off-peak hours at, for example, in rural communities where there is community support for minimising lighting late at night; and
- **Brightening –** Raising lighting levels during special events or in response to poor weather or to emergency situations.

Figure 19 – Individually controlled and metered LED luminaire in UK (Telensa)

5.5.1 Metering Individual Luminaires

Newly available smart street lighting control systems (discussed further in Section 5.9 and onwards) provide electricity usage monitoring of each luminaire together with much operational information in addition to being able to provide variable lighting levels. These capabilities raise important questions about how this will be accommodated in the Australian regulatory framework and by DNSPs.

Figure 20 – Selection of typical Australian market LED street lighting luminaires

135 http://www.aemo.com.au/Electricity/Policies-and-Procedures/Metrology-Procedures-and-Unmetered-Loads/NEM-Unmetered-Loads

5.6 Legacy Luminaire Technologies

Table 7 summarises the key attributes of legacy street lighting technologies and their future prospects.[136]

Table 7: Legacy Luminaire Technologies

Luminaire Technology	Strengths	Weaknesses	Future Prospects
Tungsten Halogen A variant of the traditional tungsten filament lamp, used in some older pedestrian crossings and flood lighting.	• Warm white light • Low capex cost • Excellent CRI	• Very low efficacy • Very short lamp life • High heat and fire risk • Vibration sensitive • High opex cost	Obsolete.
Mercury Vapour (MV) Old technology high-pressure gas discharge lamp using vaporised mercury. Very widely deployed on Cat P and to a lesser extent, Cat V roads.	• Long lamp life • Low capex cost	• Bluish-green white light • Poor-moderate CRI • Low efficacy • Output decays quickly • High opex cost • Mercury hazard	Obsolete. Not permitted by AS/NZ 1158 for new schemes.
High Pressure Sodium (HPS) High-pressure gas discharge lamp using sodium and vaporised mercury. Very widely deployed on Cat V roads.	• Good efficacy • Medium lamp life • Low-medium capex and opex cost	• Yellow light • Poor CRI • Mercury hazard	Phasing out with the rise of LED.
Metal Halide (MH) High-pressure gas discharge lamp using vaporised mercury and metal halide additives. Used in parks and reserves and prestige public precincts.	• White light • Good efficacy[128] • Med-excellent CRI (depending on quartz or ceramic)	• Shorter lamp life • High capex cost • High opex cost • Mercury hazard • Poor colour consistency with quartz MH	Phasing out with the rise of LED.
Linear Fluorescent (LFL) T8 Old technology low-pressure gas discharge lamp using vaporised mercury and phosphor coating. Previously widely deployed on residential streets.	• White light • Moderate efficacy[128] • Good colour rendering • Low capex cost	• Medium lamp and starter life • Vibration sensitive • Medium-high opex cost • Mercury hazard	Obsolete.
Linear Fluorescent (LFL) T5 Low-pressure gas discharge lamp using vaporised mercury and phosphor coating. Widely deployed on residential streets.	• White light • Good efficacy • Good CRI • Medium lamp life	• Vibration sensitive • Mercury hazard	Phasing out with the rise of LED.
Compact Fluorescent (CFL) Low-pressure gas discharge lamp using vaporised mercury and phosphor coating. Widely deployed on residential streets.	• White light • Good efficacy • Good CRI • Medium lamp life • Medium capex /opex cost	• Vibration sensitive • Mercury hazard	Phasing out with the rise of LED.

136 The lighting industry uses the term "efficacy" instead of the more common term "efficiency." Because it is in such wide use in the lighting industry, this Roadmap uses "efficacy"

5.7 New Luminaire Technologies

Table 8 identifies the attributes of new luminaire technologies and the future prospects of the various approaches.

Table 8: Luminaire Technologies

Luminaire Technology	Strengths	Weaknesses	Future Prospects
LED High brightness solid state light source suitable for all street lighting, area lighting and flood light applications.	• Lower total cost of ownership • Lower opex cost • Range of output colours • Highest efficacy for almost all applications • Dimmable and optically controllable • Simple replacement of legacy luminaires with LEDs will result in improvement and meet all requirements if good lighting design principles are applied • Now well-proven	• Higher capex cost, particularly high output models	Likely to be the most common mainstream technology for the foreseeable future.
Induction Low pressure electrode-less mercury gas discharge light source using magnetic induction.	• Excellent CRI • Very long lamp life • Good efficacy	• Physically large light source and thus luminaire size • Optical design difficult • Higher capex than LED • Mercury hazard	Limited future application potential.
High Efficiency Plasma (HEP) High output small point source electrode-less microwave-driven technology.	• Very high light output • Very high efficacy • Long life • Excellent colour rendering • Optically controllable	• Electromagnetic emissions need care • Physically large luminaires	Likely to remain as niche tech for large area high-mast applications.
Blue Laser Diode Emerging technology starting to be used in prestige car headlights.	• Physically very small • Potentially greater efficacy than LEDs • Very high output with highly controllable optics	• Very high capex	Not likely to be suited to street light applications within the near future.

5.8 Legacy Lighting Control Technologies

Table 9 shows the attributes of legacy controls technologies and the future prospects of the various approaches.

Table 9: Lighting Control Legacy Technologies

Controls Technology	Strengths	Weaknesses	Future Prospects
D2 Photocell Detects darkness and turns luminaire on. Compact bayonet type twist-lock photocell used only in Australia and Japan for residential street lighting.	• Low capex • Compact size	• Low international acceptance • Usually short-life thus higher overall opex • Appears incompatible with most smart controls	Effectively obsolete. Low likelihood of significant future use.
NEMA 3-pin Photocell Detects darkness and turns Luminaire on. Plug-in cell and receptacle. Twist-lock action.	• Commonly used worldwide except continental Europe • Long-life versions now available	• No integration with CMS controls • Physically large	Likely to have some shorter term use but has been largely superseded by NEMA 7-pin replacement.
Minicell Photocell Detects darkness and turns luminaire on. Small diameter photocell using 20mm luminaire hole. Used for small street light luminaires and décor pole-top types.	• Very small and discreet • Long-life permanent photocell	• Not "plug and play" • Luminaire Ingress Protection (IP) rating may be affected thus additional IP testing required • Cannot integrate with smart controls	Steady but small scale intermediate term use for decorative luminaires.
Ripple Control A dated but effective method of central switching street lighting using coded signalling on electrical power lines.	• Lower capex if DNSP is already using ripple control for domestic hot water cylinder peak-load switching	• Only applies to DNSPs who support this on/off switching method • Not flexible • Not widely used in Australia	Not likely to develop beyond existing use.
Central Photocell Automated central switching of dedicated street lighting circuits using a master photocell (instead of a photocell on each luminaire).	• Lower capex	• Will not allow daytime electricity supply to lighting poles (for alternative uses) • Not flexible • Limited to use on dedicated circuits	Not likely to expand beyond existing use.

5.9 New Smart Lighting Control Technologies

Adding intelligence and communications capabilities to street lights will give councils and main road authorities the ability to monitor and dynamically control the lighting to improve urban lighting services delivered, reduce operating costs, achieve energy savings and possibly gain asset life extension. Table 10 identifies the attributes of these new controls technologies and the future prospects of the various approaches.

All LED luminaires, whether or not controls enabled, have a control gear module (most often called a driver) that is housed inside the luminaire. Even for standalone non-networked applications there are now programmable options available,[137] often at negligible additional cost. The electronic control gear in the luminaire can be factory programmed by the luminaire manufacturer to suit project performance requirements precisely specified by the customer or their designers. Near Field Communications (NFC)[138] technology is now being offered to quickly and accurately programme the control gear drive currents and a variety of other parameters to tailor precise light output for project needs. Programming can be actioned via an application enabled smartphone, iPad or similar field device.

If the luminaire is controls enabled it will have a driver that will be either 1-10V analogue protocol or the more modern Digital Addressable Lighting Interface (DALI[139]) protocol. There are a range of reasons and/or advantages for selecting DALI, but the main one is that a DALI driver can store a wide range of luminaire identity, production and setup parameters that can be readily accessed by CMS smart control systems. This is becoming increasingly advantageous for asset management reasons with the availability of CMS/AMS integrated operating software. The cost differences between DALI and 1-10V are usually negligible.

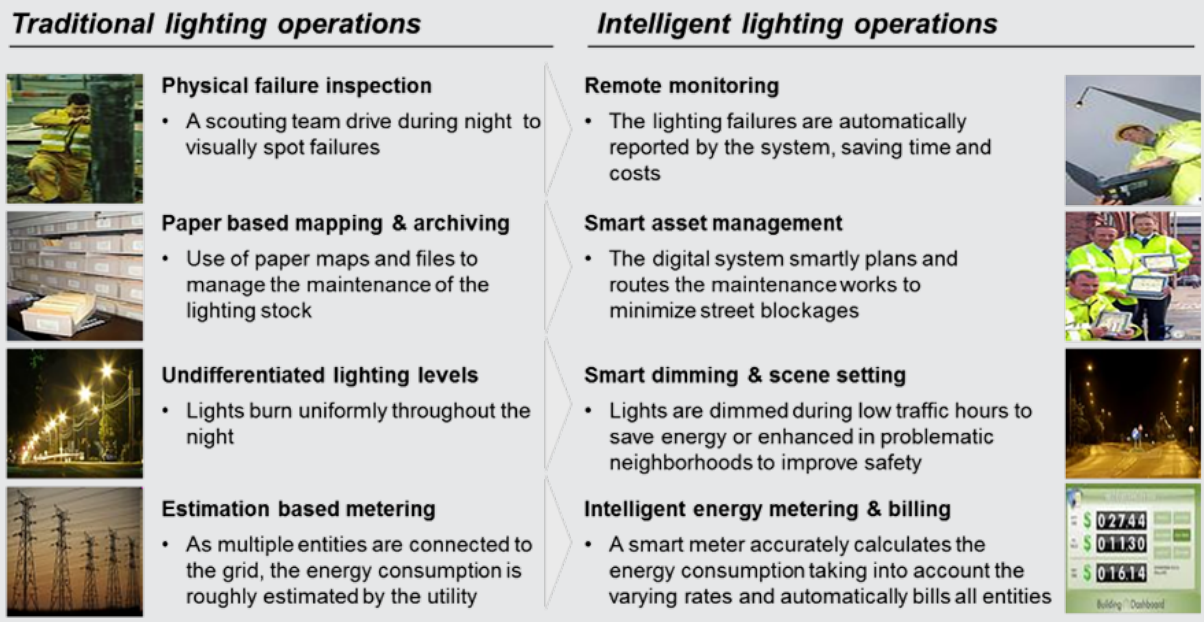

Figure 21 – Moving from traditional to intelligent lighting networks (Cisco Philips)

137 images.philips.com/is/content/PhilipsConsumer/PDFDownloads/United%20Kingdom/oem/ODLI20160331_001-UPD-en_GB-leaflet_MultiOne.pdf

138 Near Field Communication (NFC) is a short-range wireless connectivity standard (ISO/IEC 18092) that uses magnetic induction to communicate between devices when touched or brought with close range of each other

139 http://www.dali-ag.org/discover-dali/dali-applications.html

Table 10: New Smart Lighting Control Technologies

Technology	Strengths	Weaknesses	Future Prospects
Programmable LED Driver Scheduled Control: An individual configurable luminaire control method suitable for fixed lighting applications such as outdoor car parks.	• Very low capex • Simple • No visible components	• Non-networked • Needs user training for programming • Not flexible, needing visit to each luminaire to change programme	Small ongoing prospects for niche use. Likely to be superseded as CMS prices reduce.
CMS Controls Over Power Line (PL) Network: Central Management System controls using Power Line signalling over mains power lines.	• Moderate capex • No visible field components	• Only suitable where circuits not interrupted by equipment such as some transformers • Can be challenging to implement • Permission from lines owner required • Suitable for motorway, tunnels, closed campus applications	Steady ongoing prospects in niche applications such as tunnels, campuses and corporate sites.
CMS Controls Over Radio Frequency (RF) - Short Range Mesh Network: Central Management System controls using RF mesh for shorter range communications and monitoring. 2.4Ghz RF. Up to 100m urban.	• Fast response (low latency) • Good smart city potential • Fast firmware updates • Enables sensor-based adaptive lighting • Good data collection	• Lower node/gateway ratio is more costly • Only suitable for short range • CBD area interference challenges • RF interference can occur	Excellent wider scale prospects in larger citywide deployments.
CMS controls over RF - Mid Range Mesh Network: 900Mhz RF. Up to 2km urban and 20-30km in flat rural applications.	• Very fast response (very low latency) • Good smart city potential • Fast firmware updates • Good data collection	• No network standardisation	
CMS Controls Over RF - Ultra Narrow Band (UNB) Long Range Star Network: Central Management System controls using Ultra Narrow Band Star network for long range communications, control and monitoring. LoRA Type A&B and Sigfox are not considered here since they don't allow 'pushing' schedules or calendar updates down to each smart lightpoint.	• Suitable for longer distances • Cost-effective for long distance coverage • Good smart city potential	• More restricted in data capacity • Relay stations may be needed in CBDs • Greater limitations on two-way communications due to delays which may limit sensor-based options • Firmware update timing delays	Excellent wider scale prospects in citywide deployments and also for rural areas.
CMS Controls Over Cellular Communications (Mobile Phone) Network: Central Management System controls using telco cell network for long and short range communications and monitoring.	• Low capex • Very easily implemented where mobile phone coverage exists • No gateway field devices needed	• Potentially higher opex • Hardware upgrades needed for each luminaire when mobile phone technology changes • Could cause overload of existing cell network • May require additional antennas • May limit provision of local dynamic sensor based lighting control	Excellent wider scale prospects in collaboration with telcos on larger citywide/ regional deployments.

5.10 Network Strategies

Modern street lighting control systems currently require a fundamental choice between one of the mutually exclusive communications technologies identified in Table 10 and shown in Figure 22. Because the investment in choosing each option is large, and can only be changed by a visit to every lighting pole, the decision is likely to last for the lifetime of the infrastructure which is anywhere between 10 and 20 years.

The decision about which communications technology approach to use is all the more challenging because street lighting controls technology and related smart city technology is in a rapidly changing evolutionary stage of development. There is as yet no clear dominant best value technology approach and limited compatibility amongst some of the different approaches. There are four fundamentally different network communication technologies identified in Table 10[140]: Power Line; RF Mesh; RF Star and mobile phone. These are illustrated schematically in Figure 22 below and key aspects are explained in the sections that follow.

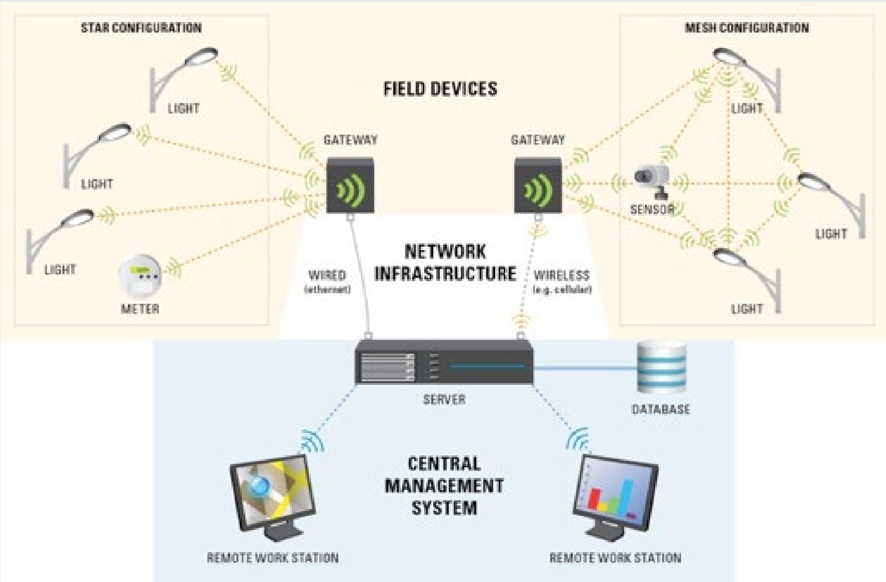

Figure 22 – Smart control system architecture for star and mesh technology (California Lighting Technology Center – University of California, Davis)

5.10.1 Power Line (PL)

Ten to fifteen years ago digital communications over power lines appeared to be the most promising street lighting communications technology. Substantial effort was invested to develop this approach from its commercial origins with a product called LonWorks[141] by Echelon into an international open standard, ISO/IEC 14908.1. However, application of power line communications is complicated in comparison to RF. The controls infrastructure required has to be co-located and interfaced with that of the electricity distributors which significantly adds to technical and commercial complexity.

Power line communication has not become as accepted in Australasia or the USA as it has in Europe (due to EC legislative intervention). However, since more than 90% of street lighting in Australia is owned by the electricity distribution companies (DNSPs) it is arguably a technology that might be attractive for DNSPs to use to control street lighting.

On the basis that power line communication is the least flexible of the major options and there appears to be limited support or further investment in the technology, this Roadmap does not consider it further.

5.10.2 Single or Multi-supplier Radio Frequency (RF) Network

Whether using mesh or star-based RF networks (or a mix of both), a strategic decision is required to choose a single supplier, or a multi-supplier business model. The single supplier model involves one supplier providing all components and software to manage a street lighting controls network (GE and Philips are examples of this approach). This model is potentially simpler to manage and is likely to have greater accountability.

The multi-supplier model involves committing to one network platform that supports a number of component and software suppliers (Silver Spring Networks and Cisco are examples of this approach). As demonstrated in other spheres, the multi-supplier network platform approach has significant potential for innovation and price reduction due to competitive forces.

Each approach has its advantages and disadvantages but once made, the decision may be challenging to unwind and is unlikely to be re-visited until the next infrastructure refresh. Key characteristics of these approaches are summarised in Table 10.

140 The first row of Table 10 shows technology that is being made effectively obsolete by the other four

141 http://www.circon.com/wp-content/uploads/2011/03/LonWorks-Fundamentals.pdf page 1

5.10.3 Mobile Phone Telco Alliance Network

An important recent addition to the communications options is that of an alliance between a street lighting supplier and a mobile phone infrastructure equipment manufacturer. The first to offer this approach are Philips / Ericsson as demonstrated by initial deployments in Los Angeles and San Jose illustrated in Figure 23. In this approach, one or more telco carrier companies provides access to the mobile phone network for all street lighting communications. The telco enabled street light columns are deployed in the ratio of about 1:15 with conventional columns, i.e. each communication column is about 700-800m apart. This business model is also compared in Table 10.

Figure 23 – City of Los Angeles street light and mobile phone transmission column (Philips / Ericsson)

5.11 Control Systems Network Security

As with any ICT system, data security is extremely important, particularly when safety critical public assets are concerned. A systematic test is therefore needed to establish appropriate confidence levels as system security is only as good as the weakest link. The weakest link can often be the access to the operating supervisor's smartphone or tablet. Therefore independently conducted 'Penetration Tests' [142] (also known as 'Pen Tests') are available to stress-test the control and communication systems. Each of the three IT system layers - Software, Network and Hardware - is required to pass security requirements by a Pen Test as well as the system as a whole. Part of the required security is for the appropriate encryption standards to be used, which is currently the American developed Advanced Encryption Standard, AES 128 and now AES 256[143] now accepted as the worldwide industry standard for cybersecurity.

5.12 CMS Integrated Asset Management Systems

Central Management Systems (CMS), reside on desk-based computers that provide overall supervisory control of a network of smart controls as identified below:

1. CMS software - Graphical User Interface (GUI), software to interface with third party systems (called APIs), central data collection, central alarming and data analysis mechanisms and central databases server or cloud engine, database, APIs), software on servers delivering user interfaces to smart phones, tablets, laptop and desktop computers that display luminaire operational control and maintenance status.
2. Network communications infrastructure that provides the channel for bi-directional information and control signals;
3. Luminaire based hardware and firmware (software embedded in devices) that receives the instructions for, and transmits the status of, the luminaire back to the CMS.

Asset Management Systems (AMS) are software applications that integrate with CMS controls. Information from the CMS is imported by the AMS and used for operational, administrative, customer service and financial functions. Figure 24 shows one such system. Many European street lighting PPPs, for which most of these systems were originally developed, are largely administered and managed by street lighting CMS and AMS.

When well implemented, these systems allow the customer and service provider to share all information about the lighting network, transparently measure a range of KPIs, optimise deployment of crews, and streamline accounting and stakeholder liaison. The overall effect is to increase asset utilisation and efficiency, and reduce costs.

Figure 24 – Control and asset management system (Philips)

142 http://www.forbes.com/sites/ericbasu/2013/10/13/what-is-a-penetration-test-and-why-would-i-need-one-for-my-company/#611c6c4442da

143 http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf

Table 11: CMS Technology Frameworks

	Single Supplier RF	Multi Supplier RF	Single Supplier Mobile phone Telco
Project Responsibility	Lighting supplier (at this stage)	Systems integrator	Lighting supplier (at this stage)
Relationship Length	Longer term	Shorter or longer term	Longer term
Relationship Type	Lighting turnkey	Competitive model for devices and software applications	Lighting/telco turnkey
Client Management Input	Low	High	Low
Contract Term	Middle/longer	Flexible	Very long
Business Model	Turnkey, like city garbage processing contracts	Competitive, like commercial IT contracts	Turnkey, like PPP or EPC contracts
Innovation	Internal/experimental (At this stage. Innovation potential varies case by case).	External/contractual (At this early stage. Innovation potential varies case by case).	Internal/experimental (At this early stage. Innovation potential varies case by case).
Tenderer	Lighting supplier	Systems Integrator	Lighting supplier
Typical Suppliers	GE, Telensa, Harvard Engineering, Zodion, Schreder, Telematics	Citelum, Electrix/Citeos Broadspectrum, Downer Mouchel	Philips
Software	As above - package	SLV, Cimcon	Philips
Network	As above - package	SSN, Cisco, Sensus, Cimcon	Ericsson
Lighting Hardware	As above - package	Telematics, SELC, Enlight, Cimcon, Rongwen, Paradox Engineering	Philips / Ericsson
Future proofing	Head contractor to provide internally driven innovation pathway for new value creation with pre-agreed benefit sharing formula.	Council or DNSP to operate a series of periodic tenders and re-tenders to capture best practice and best pricing.	Head contractor to provide a contractual pathway from 2G/3G/4G NB-IoT onwards for telco hardware upgrades over the contract term. Agreed benefit sharing formula needed.
Comment	Technology platform can be Short Range Mesh, Long Range Star.	Technology platform can be Short Range Mesh, Long Range Star.	Contractor provides <25 yr head lease. Telco equipment supplier supplies comms hardware. Various telco carriers sub-lease mobile phone comms facilities and transmit lighting and general cell traffic.

5.13 Street Lighting's Pivotal Role in the Smart City

As LED street lighting and control systems have matured, so too have a range of other digital outdoor infrastructure elements falling broadly under the umbrella of the smart city. Globally, a city's street lighting infrastructure is being increasingly recognised as the likely enabling platform for much of this smart city infrastructure.[144]

Two basic characteristics make street lighting particularly important to the future smart city:

1. Being up in the air, away from buildings and above the road surface makes street lighting ideally situated for a range of smart city communication devices, sensors, cameras and other infrastructure that will be required to enable the future smart city; and
2. By definition, street lights already have a support structure and a supply of electrical power.

As discussed in previous sections, adding intelligence and communications capabilities to street lighting will give councils and main road authorities the ability to monitor and dynamically control the lighting to improve urban lighting services delivered, reduce operating costs and achieve energy savings.

In addition, thanks to their ubiquitous nature, connected street lights can act as an Internet of Things (IoT) platform for sensors and critical infrastructure. This will enable councils and other public agencies to rapidly deploy many types of smart city infrastructure in a cost-effective manner, including:

- **Traffic controllers and transportation** – sensors essential for monitoring and implementing active traffic management strategies.
- **Parking vacancy sensors** – to support smarter parking and payment systems.
- **Environmental sensors** – to detect and respond to motion, noise, temperature, rain, flood, humidity, air quality, gas leakages, vibration etc.
- **Utility metering and leakage sensors** – Electricity, water and gas
- **Speakers and messaging billboards** – Music and/or emergency broadcast speakers.
- **Electric vehicle charging stations**
- **Public safety, security and intelligence**
- **Enhanced communications** – Including enhanced mobile phone capabilities and a variety of communications technologies, such as WiFi, LiFi, LoRa, and others.

These smart city technologies will not only dramatically improve the information available to councils and other public agencies, but some of the new services they will enable for the community could also provide new sources of revenue.

Cities such as Copenhagen[145], Barcelona[146], Glasgow[147], San Diego[148] and Los Angeles[149] and others are all implementing smart, connected street lighting projects that support other smart city functionality.

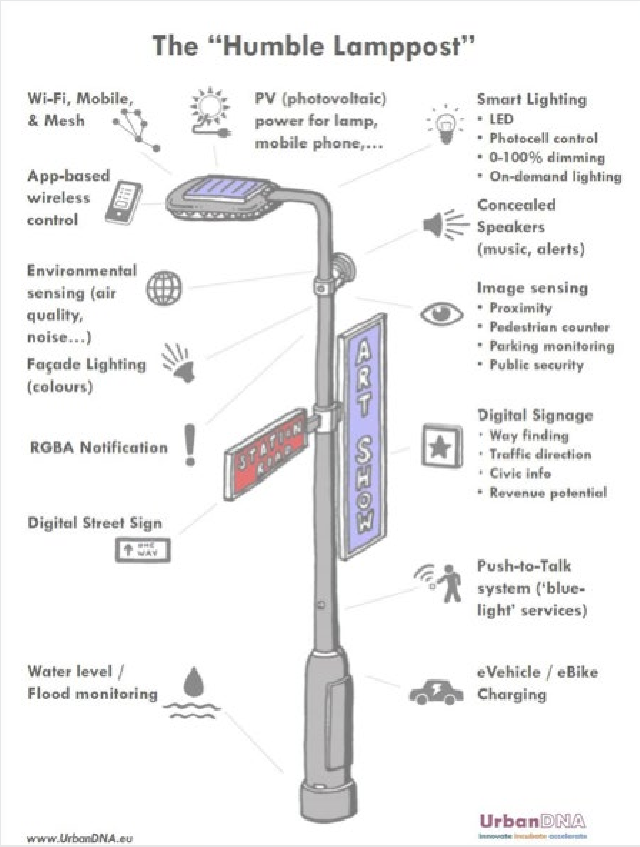

Figure 25 – Some of the smart city functions and services deliverable from street light columns (Urban DNA UK)

Integrating smart street lighting controls with broader smart city initiatives may make strong commercial sense. While developments in this area are rapidly evolving, such services may reduce overall costs for a DNSP or council and may offer the potential for new independent revenue streams. It is therefore important that project planners do not work in silos, and engage at an early stage with other service providers so that software, communication and street real-estate platforms are not duplicated, do not conflict and can be configured to work together.

144 https://eu-smartcities.eu/content/eip-scc-working-smarten-humble-lamppost-across-europe
145 http://www.silverspringnet.com/customer/copenhagen/
146 https://www.youtube.com/watch?v=k1yJ1x4X8RA
147 http://futurecity.glasgow.gov.uk/intelligent-street-lighting/
148 https://www.youtube.com/watch?v=sMhLLkj7os4&feature=youtu.be
149 http://www.ledsmagazine.com/articles/2015/04/philips-lighting-will-supply-network-technology-for-los-angeles-led-street-lights.html

5.14 Renewable Energy Systems

Another very important rapidly developing technology is Solar Photo-voltaic (PV) electricity generation. Its rapidly improving economic performance is set to have a fundamental effect on the electricity sector and consequently the street lighting sector. Its ability to power the modest needs of lighting, controls and smart city sensors independently of the distributed monopoly networks is likely to substantially change the street lighting landscape over the lifetime of this infrastructure.

The cost of all types of solar PV electricity has reduced substantially in recent times. In some parts of Australia, the cost of solar PV electricity generation has reached grid parity[150] and therefore solar PV powered street lighting may be economic in remote location applications and increasingly elsewhere as the cost of LED luminaires, solar PV panels, control systems and battery storage steadily decreases. The power requirement for an LED luminaire to deliver a standards-compliant lighting solution is also decreasing, meaning that the required off-grid energy generation and storage capacity is further reducing.

Solar PV street lighting systems can be on-grid or off-grid. Those that are on-grid have no battery storage and are connected to the electricity distribution system. When electricity is generated by on-pole solar panels during the day it is sold to the grid and used by other consumers at that time. At night, the street lighting system draws electricity from the distribution system as it would normally. There may be a notional matching of the solar capacity to the luminaire consumption but they are not actually linked in any way.

Off-grid systems represent a major departure from current Australian practice but are widely deployed internationally. No electrical connection is required to the electricity distribution system and electricity generated during the day is stored in batteries for use at night. The additional cost of batteries and power management systems can make the economics challenging, but can be suitable for locations that require expensive new underground cable trenching and reticulation. Typically, locations more than 20-30m from existing grid connection warrant consideration of solar options.

Beyond solar, small wind turbines can be mounted on street light columns and having two sources of renewable electricity may be useful, but the economics of such systems have yet to be widely demonstrated.

Some councils and municipalities have regulations and restrictions on the physical design and form of renewable energy assets. This is usually for aesthetic and urban design impacts, and sometimes for maintenance reasons. The Municipality of Abu Dhabi[151], for example, prohibits the use of angled solar PV panels only allowing vertically mounted solutions.

Figure 26 – Solar PV off-grid column with savonious wind turbine (Forgen Renewables)

Figure 27 – Solar PV on-grid column (Petra Systems)

150 *Clean Disruption, Why Conventional Energy and Transportation will be Obsolete by 2030*, Tony Seba, Swedebank Nordic Energy Summit, 16 March 2016, Oslo, Norway, available at https://www.youtube.com/watch?v=Kxryv2XrnqM

151 Abu Dhabi Lighting Manual – Issue 1, 14th February 2016, Abu Dhabi, UAE

5.15 Conclusion

LED street lighting is the dominant and now clearly proven street light luminaire technology worldwide for new and major retrofit deployments and is likely to remain so for the foreseeable future. Legacy technologies are all in their sunset phases for all but failure replacements and minor project continuations.

Observation of international LED applications does not indicate a single dominant supplier of LED luminaires or indeed a single dominant product design configuration. The same can be said for smart control systems approaches.

Luminaire concepts and construction materials are evolving progressively and are providing steady improvements in price/performance ratios. The large annual reductions in luminaire pricing experienced over the last five to six years have slowed, but there appears to be an opportunity for further price reductions, particularly in the higher output LED luminaire segments.

Smart controls are being deployed for cost saving and for strategic business reasons. A dominant smart controls technology and smart controls application approach has not yet emerged and it is likely that for some time, different technical platforms and business models will be relevant according to the application needs of the project and the client.

Most large-scale international rollouts of LED luminaires now include CMS controls of some type. Smart control system approaches vary widely and single supplier RF, multi supplier RF, and telco cellular networks are all in evidence. Not all of major international LED/smart controls projects plan to use the controls for dimming purposes. Other than energy and maintenance economics, some of the reported reasons are strategic commercial positioning for future IoT revenue generating services and access to high mounted physical assets (i.e. street lighting columns) for electricity smart meter radio frequency communication access.

6

CURRENT INFRASTRUCTURE AND COSTS

2,317,000 DNSP Luminaires in Australia

69% Residential
7% Intermediate
26% Main Roads

39% of National Inventory is Mercury Vapour

Typical Bulk Luminaire Cost – $200-$300/unit for P Category

Typical Bulk Control System Cost – $100-$200/unit capex

Typical Bulk Luminaire Installation Cost – $100-200/unit for P Category

In order to quantify the benefits of upgrading from old technologies and systems, an estimate of Australia's current street lighting assets (by type) is required for each utility and region. This information was gathered by a survey conducted in June and July 2016 with the assistance of the Electricity Networks Association (ENA).

The survey also asked several qualitative questions to assess:

- The extent to which street lighting contributes to each DNSPs goals and objectives;
- The willingness of DNSPs to provide access for third parties to mount luminaires on their network;
- Whether the DNSPs would be willing to share their maintenance data on LED street lighting;
- Whether the DNSPs have adopted LEDs as a standard luminaire for customers for P and V category streets;
- Whether the DNSPs are investigating road lighting remote monitoring and control systems; and
- Whether the DNSPs have installed smart controls in actual field operating conditions.

This section covers the results of this survey, which builds on earlier work from the *2011 Draft Street Lighting Strategy*.

6.1 Australian Street Lights by Type and Jurisdiction

Table 12 lists the luminaire quantities by lighting type and owner. In all cases except the Australian Capital Territory (ACT)[152] the lights are owned by the DNSPs that operate in each jurisdiction.

152 Unlike other jurisdictions, public lighting in the ACT is directly owned by the ACT government and currently managed under contract by ActewAGL

Table 12: Street Lights by Lighting Type and Owner[153]

STATE / TERR	OWNER (DNSP / AUTHORITY)	MV	CFL/T5	T8	HPS	LED	OTHER inc MH and LPS	TOTAL
ACT	TAMS / ActewAGL	6,696	20,912	-	27,414	1,980	25,971	82,973
NSW	Ausgrid	111,642	45,843	-	55,496	24,381	13,545	250,907
	Endeavour Energy	83,767	34,902	95	50,322	19,847	15,636	204,569
	Essential Energy	24,121	57,978	-	67,850	33	4,027	154,009
NT	Power & Water	6,812	2,876	92	5,692	1,171	927	17,570
QLD	Energex	156,621	34,656	9,265	150,408	3,345	4,443	358,738
	Ergon Energy	92,177	81	-	46,786	337	647	140,028
SA	SA Power Networks	90,944	9,102	17,997	80,340	134	32,193	230,710
TAS	TasNetworks	25,830	6,822	57	10,681	5,170	617	49,177
VIC	Ausnet Services	43,537	37,642	-	35,459	26,237	189	143,064
	CitiPower / Powercor	55,206	42,037	-	64,481	50,148	4,199	216,071
	Jemena	14,466	28,896	-	21,920	6,349	142	71,773
	United Energy	40,700	35,355	3	35,771	7,758	370	119,957
WA	Horizon Energy	8,089	1,401	-	3,804	3,395	2,025	18,714
	Western Power	149,979	31,576	12	59,688	-	18,142	259,397
	TOTAL	**910,587**	**390,079**	**27,521**	**716,112**	**150,285**	**123,073**	**2,317,657**
	%	**39.3%**	**16.8%**	**1.2%**	**30.9%**	**6.5%**	**5.3%**	**100%**

6.1.1 Table 12 Observations

Of note in Table 12 is that mercury vapour – a very dated technology - makes up a very high 39% of the national portfolio (and 53% of residential road lighting). Also the quantity of LEDs reported installed on DNSP networks are 6.5% which is lower than the 9.6% that the suppliers' survey found for this Roadmap.

Reasons for this disparity may include:

1. The time lag between luminaire purchase order placement and actual supply;
2. The time lag between luminaire installation and the updating of inventory records; and
3. As an interim measure, DNSPs may have listed early LED deployments under "other" lighting descriptions in inventories as they had no approved charging category for LEDs.

153 Key for column abbreviations of luminaires described previously MV = Mercury Vapour, CFL = Compact Fluorescent, T5 and T8 are particular types of Tube Fluorescent Luminaires, HPS = High Pressure Sodium, LED = Light Emitting Diode, LPS = Low Pressure Sodium

6.1.2 Street Lights by State or Territory Jurisdiction

Table 13 shows luminaire quantities by lighting technology type and the state or territory jurisdiction.

Table 13: Street Lights by Lighting Type and Jurisdiction[154]

STATE / TERR'Y	MV	CFL/T5	T8	HPS	LED	OTHER (incl MH and LPS)	TOTAL
ACT	6,696 (8%)	20,912 (25%)	0 (0%)	27,414 (33%)	1,980 (2%)	25,971 (31%)	82,973
NSW	219,530 (36%)	138,723 (23%)	95 (0%)	173,668 (28%)	44,261 (7%)	33,208 (5%)	609,485
NT	6,812 (39%)	2,876 (16%)	92 (1%)	5,692 (32%)	1,171 (7%)	927 (5%)	17,570
QLD	248,798 (50%)	34,737 (7%)	9,265 (2%)	197,194 (40%)	3,682 (1%)	5,090 (1%)	498,766
SA	90,944 (39%)	9,102 (4%)	17,997 (8%)	80,340 (35%)	134 (0%)	32,193 (14%)	230,710
TAS	25,830 (53%)	6,822 (14%)	57 (0%)	10,681 (22%)	5,170 (11%)	617 (1%)	49,177
VIC	153,909 (28%)	143,930 (26%)	3 (0%)	157,631 (29%)	90,492 (16%)	4,900 (1%)	550,865
WA	158,068 (57%)	32,977 (12%)	12 (0%)	63,492 (23%)	3,395 (1%)	20,167 (7%)	278,111
TOTAL	**910,587 (39%)**	**390,079 (17%)**	**27,521 (1%)**	**716,112 (31%)**	**150,285 (6%)**	**123,073 (5%)**	**2,317,657**

6.1.3 State and Territory Observations

i. Mercury Vapour

Mercury vapour (MV) usage is interesting because it represents the most dated and least efficient lighting technology available. Table 13 shows that its use varies widely from a low of 8% in the ACT to a high 57% in Western Australia.

ii. CFL and T5

In terms of efficiency and uptake, CFL and T5 lighting is the pre-cursor technology to LED. Queensland and South Australia have not widely adopted CFL or T5 lighting types in the years prior to LEDs emerging.

iii. Conversion to LED

The jurisdictions with the highest percentage of LEDs to date are Tasmania (11%) and Victoria (16%) while the lowest LED take-up has been in South Australia (0%), Queensland (1%) and Western Australia (1%).

154 Key for column abbreviations of luminaires described previously MV = Mercury Vapour, CFL = Compact Fluorescent, T5 and T8 are particular types of Tube Fluorescent Luminaires, HPS = High Pressure Sodium, LED = Light Emitting Diode, LPS = Low Pressure Sodium

6.1.4 Street Lights by AS/NZS 1158 Lighting Category

Table 14 identifies luminaire quantities allocated to AS/NZS 1158 lighting application categories. 'P' categories are for pedestrian predominant lighting used on residential and intermediate roads, and V categories are for vehicular predominant lighting used on main roads. This classification by street/road application type (broadly low/medium/high output) provides an insight into how the various luminaire types and sizes are being used, and thus inform a future road lighting strategy.

Table 14: Asset Technology Type by AS/NZS 1158 Lighting Category[155]

Road Type	Lighting Category	MV	CFL/T5	T8	HPS	LED*	OTHER (incl MH and LPS)*	TOTAL
Residential	P4, P5	783,382	390,079	27,521	119,206	147,636	82,316	1,550,141 (67%)
Intermediate	P3, V5 and Other	78,877	—	—	71,015	379	8,427	158,698 (7%)
Main - Low Traffic	V - 150W HPS Equiv	33,177	—	—	227,847	1,135	14,702	276,861 (12%)
Main - Med Traffic	V - 250W HPS Equiv	14,438	—	—	272,681	1,135	16,165	304,419 (13%)
Main - High Traffic	V - 400W HPS Equiv	714	—	—	25,362		1,462	27,538 (1%)
	TOTAL	**910,587**	**390,079**	**27,521**	**716,112**	**150,285**	**123,073**	**2,317,657**

6.1.5 Observations on Street Lighting by AS/NZS1158 Category

i. Residential Roads

Residential roads constitute 67% of all road lighting and more than half the luminaires (783,382 out of 1.55 million) are mercury vapour, with a wide array of other technologies making up the balance.

ii. Intermediate roads

Intermediate roads constitute a further 7% with luminaires on this category split almost equally between mercury vapour and high pressure sodium luminaires.

iii. Main roads

Main roads constitute 26% of street lighting and more than 90% of main road lighting is high pressure sodium.

iv. LED lighting

98% of DNSP LED deployments to date are on residential roads.

6.2 Current Costs of Lighting Types for Customers

The costs estimates shown in Table 15 were derived from averaging of capital, maintenance, retail energy, network distribution, losses, environmental and market charges for the most common types of DNSP-owned luminaires across four major DNSPs in four different jurisdictions. These estimates exclude any additional costs of dedicated street lighting columns and underground power supplies.

Levelised costs are the typical costs projected for the lifetime of the lighting asset, discounted to the present (using the principle of time value of money) and divided by the number years of life to obtain a fixed 'levelised' cost per year which fairly represents the real costs and can be easily compared.

155 Key for column abbreviations of luminaires described previously MV = Mercury Vapour, CFL = Compact Fluorescent, T5 and T8 are particular types of Tube Fluorescent Luminaires, HPS = High Pressure Sodium, LED = Light Emitting Diode, LPS = Low Pressure Sodium

Table 15: Estimated Levelised Cost of Australian Public Lighting in 2015/16

Luminaire Type	Typical Cost per Luminaire	Number of Luminaires	% of National Portfolio	Levelised Cost per Year	% of Total Cost
Residential Roads (P4/P5)	$143 /yr	1,550,141	67%	$222 million	52%
Intermediate Roads (P3,V5 and Other)	$197 /yr	158,698	7%	$31 million	7%
Main Roads (150W HPS Equivalent)	$251 /yr	276,861	12%	$70 million	17%
Main Roads (250W HPS Equivalent or greater)	$301 /yr	331,957	14%	$100 million	24%
TOTAL	–	**2,317,657**	**100%**	**$423 million**	**100%**

6.2.1 Observations on Lighting Costs by AS/NZS 1158 Category

i. Average Costs to Councils Include Capital Charges

Some councils are paying substantially less than these typical annual costs shown in Table 15 because they are not paying capital charges (e.g. because those assets were funded by a developer, road authority or other third party) and they may therefore not be adequately provisioning for future capital replacement costs. Over time, as the original luminaires are replaced, costs will trend towards the typical costs per luminaire shown in the table.

ii. Lighting Column Costs

The levelised capital cost of a dedicated street lighting column and underground electricity supply would typically add a further $400/yr to the above numbers for the typical cost per luminaire, but these costs vary widely with column type and size so they have not been included.

iii. Dedicated Street Lighting Columns

While most Australian street light luminaires are mounted on wooden utility distribution poles, many newer suburbs in Australia have underground electricity supply with dedicated street lighting columns. In these areas the additional costs of dedicated columns and underground electricity supplies adds an estimated $200 million a year to councils' total street lighting bills in levelised terms. Overall, perhaps 20-25% of Australian street lighting is mounted on dedicated street lighting columns but this is concentrated in outer metropolitan areas.

iv. Underground Supply and Dedicate Lighting Columns

Undergrounding of power and the use of dedicated street lighting columns became common in many parts of Australia in subdivisions built from the 1970s onwards. Many of these columns are at or near the end of their useful asset lives. These lighting assets were typically gifted or vested by a developer via the council to the DNSP which has maintenance responsibility for the luminaires but does not collect a capital charge for the columns and therefore does not have asset replacement responsibility.

The DNSPs typically hold such assets on their asset registers at a zero or low valuation. At the end of asset life, councils are often fully liable for the cost of asset replacement – including not just the luminaires but the columns on which they are mounted or they must move to a higher tariff including capital components. Councils with significant underground-supplied dedicated street lighting assets need to incorporate these assets (and the off-balance sheet liabilities) into their financial planning, irrespective of not directly owning or maintaining them.

6.3 Comparison of 2016 Lighting Inventories with those of 2011

Table 16 compares the 2011 E3 Lighting Strategy DNSP survey data with the data from the June-July 2016 SLSC survey.

Table 16: Comparison of 2011 vs 2016 Luminaire Quantities

STATE / TERRITORY	DNSP/AUTHORITY	TOTAL 2011*	TOTAL 2016	% CHANGE
ACT	TAMS/ActewAGL	73,188	82,973	13%
NSW	Ausgrid	245,688	250,907	2%
	Endeavour Energy	188,887	204,569	8%
	Essential Energy	145,130	154,009	6%
NT	Power & Water	22,410	17,570	-22%
QLD	Energex	319,964	358,738	12%
	Ergon Energy	134,424	140,028	4%
SA	SA Power Networks	218,631	230,710	6%
TAS	TasNetworks	48,047	49,177	2%
VIC	Ausnet Services	127,778	143,064	12%
	CitiPower and Powercor	229,744	216,071	-6%
	Jemena	77,271	71,773	-7%
	United Energy	139,310	119,957	-14%
WA	Horizon Energy	32,189	18,714	-42%
	Western Power	211,607	259,397	23%
	TOTAL	**2,214,268**	**2,317,657**	**5%**

** Excludes 67,680 luminaires main road authorities previously reported in 2011 to avoid significant potential for double-counting*

6.3.1 Observations on 2016 with 2011 Lighting Inventories

i. Increases in Luminaire Numbers

Over the five years from 2011 to 2016, the total increase in luminaires was five percent, which is less that Australia's population increase over that period of eight percent. The unexpected decline in reported luminaire numbers by five utilities in the table above is to be investigated further.

ii. Increase Rate vs Replacement Rate

The five percent *increase* corresponds to an increase of 100,000 luminaires over the five year period. However, the published *replacement* rate is about 100,000 luminaires *per year* or five times the increase rate (even without accelerated replacements). Therefore the choice of technology used (e.g. LED vs HPS) for replacement programme lighting types (generally referred to as Standard Luminaires by the DNSPs) have a dramatically higher impact on long-term costs, energy consumption and GHG emissions.

6.4 Greenhouse Gas Comparisons 2011 to 2016

Calculated GHG emissions from the DNSP survey data are approximately 1,252,000 tCo2-e in 2016. The comparable 2011 figure was 1,422,000 tCo2-e (having removed the contribution from main road authority lights which appear to present a risk of double-counting). Overall, this is a 12% decline in GHG emissions as a result of street lighting over the 2011-2016 period.

The calculations have had to be done in aggregate as the 2011 source data by DNSP and lighting types was not available.

There are a variety of contributors for the 12% decline in emissions:

- Widespread CFL and T5 technology uptake in some jurisdictions;
- Continuing transition from old mercury vapour to high pressure sodium on main roads;
- Some early LED uptake.

6.5 Qualitative Responses to the DNSP Survey

This section summarises the responses from the DNSPs that answered several qualitative questions. The following are responses to the qualitative questions in the DNSP survey.

i. Extent to Which Street Lighting Contributes to Your Organisation's Strategic Goals and Objectives

Street lighting is generally viewed as a positive contribution to DNSP goals and strategies as shown in Figure 28.

ii. Willingness to Provide Access to Third Parties to Mount Luminaires on Your Network

As shown in Figure 29, at present there is a general reluctance/unwillingness by DNSPs to allow access by third parties to mount luminaires on their distribution network which is understandable, given the lack of a clear access and contestability framework.

iii. Willingness to Share Maintenance Data on LED Street Lighting

DNSPs were unanimous in their willingness to share LED maintenance data under a properly managed programme.

iv. Adoption of LEDs as a Standard Luminaire for Council Customers for P Category Streets

Two thirds of DNSPs have adopted LEDs as a standard P Category luminaire as shown in Figure 30.

v. Investigating Road Lighting Remote Monitoring and Control Systems

One half of DNSPs are investigating lighting remote monitoring and control systems as shown in Figure 31.

vi. Installation of Controls in Actual Field Operating Conditions

No DNSPs report having installed controls in actual field operating conditions.

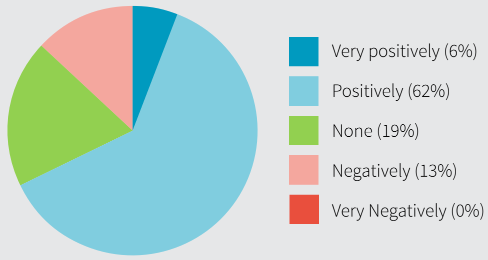

Figure 28 – Contribution to goals

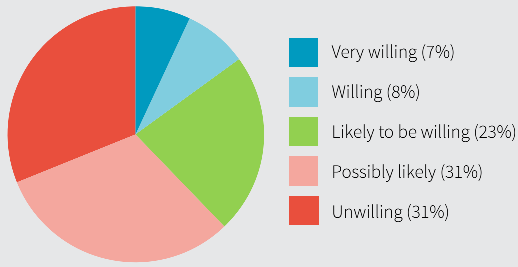

Figure 29 – Willingness to provide third party access

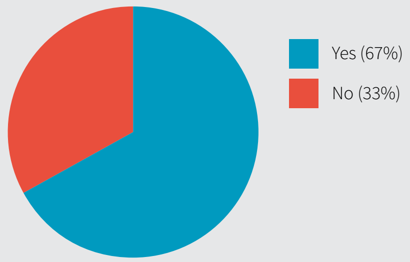

Figure 30 – Adoption of LED as standard P Category luminaire

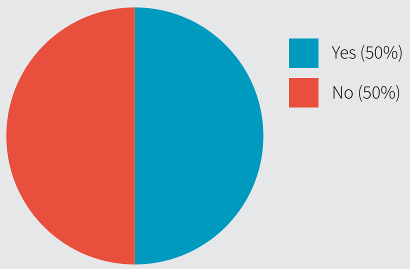

Figure 31 – Investigating remote monitoring and control

6.6 Lighting and Controls Supplier Survey

A survey of LED luminaire and smart controls suppliers was conducted from late May to late 30 June 2016. This was conducted to provide a second data source on the adoption rates of LEDs and smart controls in addition to the survey of DNSPs. The survey requested sales data sorted by customer type and by road lighting category P or V under AS/NZS1158 for residential street (Category P), and for main roads (Category V). The results of that survey are tabulated in Table 17.

Table 17: LED Luminaire Deployments at 30 June 2016

Customer Type	P Category Luminaires	V Category Luminaires
DNSP	107,885	2,116
Council (Luminaires for their own specific needs)	104,010	5,132
Main Road Authority (Luminaires for use on main roads and arterial roads)	482	4,578
Private Motorway Operator (PPP-owned luminaires for private site motorways and/or adjoining shared pathways)	3,660	154
Military, University, Mine Site, Airport, Hospital	6,641	3011
Other (Parks, Reserves, Car Parks)	6,470	100
TOTALS	**229,148**	**15,091**
OVERALL TOTAL		**244,239**

Note that many luminaires identified in Table 17 as having been sold to councils are ultimately gifted on to utility asset registers under a mechanism in the Victorian Public Lighting Code that allows councils to directly tender for replacement lighting and its installation, but requires the assets to be gifted to the utilities on completion.

6.6.1 Smart Controls Survey

There are a number of smart controls trials and/or pilot projects installed in Australia, but no full smart controls deployments of anything other than very small projects. The survey requested that sales data be separated into the customer types and market sectors in the same manner as for LED luminaires and is shown in Table 18.

Table 18: Control System Pilots or Trials at 30 June 2016

Customer Type	P Category Controls	V Category Controls
Utility	200	10
Council	716	210
Main Road Authority	0	50
Private Motorway Operator	0	0
Military, University, Mine Site, Airport, Hospital	0	0
Other (Parks, Reserves, Car Parks)	1,000	0
TOTALS	**1,916**	**270**
OVERALL TOTAL		**2,186**

6.6.2 Suppliers Contacted

Surveys were sent to 44 suppliers in total. The list was compiled using the lighting and controls industry experience and contacts of SLSC project team members. Of the 44 suppliers invited to participate in the survey, 31 were suppliers of LED luminaires only, eight were suppliers of LED luminaires plus controls, and five were suppliers of controls only.

6.6.3 Confidentiality

As the survey requested sales information from a competitive marketplace an undertaking was given on behalf of IPWEA and the authors that the information supplied would be treated as commercial-in-confidence and would only be reported in aggregate.

6.6.4 Response Rate

Of the 44 companies on the contact list, 20 responded with completed surveys, three declined to participate and 21 did not respond at all, or did not respond in a meaningful way. The majority of 21 non-responding companies were in general smaller niche suppliers or new market entrants. The authors estimated that the collective LED sales for these companies would be no more than 2,000-3,000 luminaires. The three companies that declined to supply data on the basis of confidentiality concerns are estimated by the authors to have collective LED sales of around say 5,000 luminaires. These estimates of additional LED installations are not reported in the tables below but would not greatly affect overall findings.

7

BENEFITS OF LED STREET LIGHTING AND SMART CONTROLS

52% Energy and GHG Savings With LEDs

Smart Controls Could Take Energy Savings to 60-70%

25%⁺ Reduction in Total Costs of Public Lighting

- Safer Roads – Researchers establish link between white light and road safety.
- Crime Reduction – Los Angeles claims 10% reduction in night time crime.
- Environmental Gains – LEDs Eliminate mercury and improve control of light pollution.
- Smart City Infrastructure – Liveability and workability increase from facilitation of smart cities.

7.1 Identifying the Benefits

The deployment of LED street lighting and smart control systems brings a wide range of benefits which could be direct or indirect, short term or long term. However, the human, ecological, and light pollution impacts need careful attention in design deployment in order to deliver overall net benefits to the community and eco-system.

Implementing the SLSC Roadmap would deliver savings in energy use, carbon emissions and operating costs, plus achieve improvements in road and street safety, improved environmental outcomes and will help to deliver future smart city services through innovation with LEDs and smart controls. This section relates each of the benefits to key government policy objectives as discussed in Section 3.

Based on the June/July 2016 survey of Australian DNSPs conducted by IPWEA for this Roadmap it is estimated that there are a total of 2,317,000 street lights in 2016 owned, managed, maintained or otherwise present in utility inventories[156] by the 15 electricity distributors in Australia.

There are perhaps as many as 100,000 additional street lights on the inventories of the main road authorities of the states and territories although many of these are also in the inventories of the electricity distributors, for only energy billing purposes.[157] To avoid double-counting, only the great bulk of street lighting owned, managed, maintained or in their inventories for energy billing purposes is considered in the analysis of benefits for this Roadmap. The conclusions are however equally applicable to the other small pockets of road lighting owned and managed directly by the main road authorities, private motorway operators and other private and public sector owners of street lighting.

156 Passed on by the electricity distribution companies to the energy companies for electricity billing purposes

157 Because these electrical loads are not metered, the inventory is still required to calculate the energy in kWh used for each light

7.2 Energy Use

Improved luminaire efficacies combined with good lighting design and application leads to lower energy consumption. The application of smart CMS controls can provide further energy savings through trimming[158], constant light output controls, dimming and off-peak shut-offs during periods of low or no human presence on street and roads. Combined, this can result in direct energy savings of 30-70%+, depending on the approach and which legacy technology is being replaced. In addition to energy reduction, a range of other environmental parameters are improved from reductions in by-products of coal-fired power generation, and therefore energy use reductions also contribute significantly to other environmental benefits not quantified here.

With the current mix of street lighting technologies, the estimated energy use of street lighting based on DNSP inventories or maintained by them is 1,181 GWh/yr in 2016. An IPWEA survey of Australian LED street light luminaire suppliers in June 2016 indicated that there were 245,000 LED luminaires already installed with 220,000 of these installed mainly by electricity distributors.[159] This represents about 9.5% of the total installed base of all street lights. On the other hand, the figures provided by the DNSPs suggest that only 150,000 LED luminaires (representing 6.5% of the total) have been installed. These figures may not be incompatible with each other as there is an appreciable lag between the time of sale and installation and updating of DNSP inventories.

If all the luminaires on utility inventories that are not already LEDs were converted to LEDs by 2027, total net energy consumption in 2027 would be 617 GWh/yr or a net energy savings across the whole portfolio in excess of 52% of current consumption. This translates to a gross savings figure of about 266 kWh per light per year. Overall, the expected energy savings to councils and main road authorities from a mass LED replacement programme is $177m/yr based on typical costs of all charges proportional to energy consumption (e.g. retail electricity, network distribution, losses, environmental and market charges).

This savings estimate is conservative because it uses already adopted luminaire types not necessarily representative of the most efficient LED luminaires available and assumes that no further energy efficiency gains in LEDs will occur. In practice, LED energy efficiency has continued to improve in recent years at an average of about 4-5% per year and is likely to continue.

Not included in the above estimate is the additional potential energy savings from the introduction of smart controls. In practice, Australia has less potential for dimming than in other countries because of already very low lighting levels. However, main interconnecting roads may have potential for dimming during off-peak hours and there is potential for further savings from trimming to match compliance levels and the use of constant light output control gear. While these smart control applications have yet to be demonstrated on a large-scale in Australia, they have the potential to increase total energy savings to 60%-70%.

Across the national street lighting portfolio, the estimated achievable energy savings from replacing just the residential road lighting (Category P) is 74%. This high figure is because P Category residential lighting is currently dominated by the 860,000 dated and inefficient mercury vapour (MV) luminaires which represent more than 39% of the national total luminaire population.

In the same way the largest savings are achievable from replacing the more than 48,000 remaining high wattage mercury vapour lights on main roads under the Category V classification. More modest but nonetheless significant energy savings are also available from replacing over 525,000 high pressure sodium (HPS) luminaires on main roads and the combined result is an energy saving of 38% for all Category V roads.

7.3 Carbon Emissions

With the current mix of lighting technologies, the estimated total national carbon emissions for street lighting in 2016 is 1,252,500 tonnes of carbon dioxide equivalent per year (tCO_2e/yr). On the basis of the energy savings potential outlined above, a 52% carbon emission saving (of 654,000 tCO_2e/yr) is projected if there is a national deployment of LEDs. This figure would increase to 60-70% if LEDs were accompanied by smart controls employing trimming, constant light output and dimming where appropriate. Thus without controls the carbon emissions savings average out at about 281 kg CO_2e/yr per lighting point. With controls the emissions savings average out at close to 350 kg CO_2e/yr per lighting point.

158 Has several meanings: Reducing full output for the life of the luminaire to exactly meet required lighting design levels and/or; turning lighting on later or off earlier and/or; turning lighting on or off gradually in response to ambient lighting levels

159 In contrast, the IPWEA survey of DNSP street lighting inventories at the same time showed that only 153,435 LED luminaires had been installed

7.4 Maintenance Costs to Councils and Main Road Authorities

The maintenance needs of street lighting has a major bearing on DNSP operating charges and their charges to councils. Legacy technology luminaires have high spot maintenance intervention rates of up to 7-15% per year driven by the need to rectify spot lamp, power supply, photocell and other miscellaneous failures as well as the cost of a Bulk Lamp Replacement (BLR) typically at three to four year intervals.

LED technology suppliers typically claim operating lives of 50,000-100,000 hrs (12-23+ years) for LED luminaires with maintenance cost savings of 50% over MV or HPS technology. These claims have been substantiated in practice with the City of Los Angeles citing its first four years of experience with a very low 0.3%[160] failures from 140,000 luminaires, and the US Department of Energy Municipal Solid State Lighting Consortium survey citing 0.6%[161] average failure rate over five years of experience.

Even with very high levels of reliability, all luminaires require some degree of maintenance, cleaning or occasional inspection. Opinions differ, but a realistic estimate is that optical cleaning and luminaire inspection will be required at least every five to six years with LEDs.[162]

While maintenance costs are not disaggregated in many DNSP pricing approaches, currently legacy technology maintenance is estimated to cost council about $123 million/yr in 2016163 or about $53 per light.

7.5 Road Crashes at Night

Reducing the number of road deaths and serious injuries from crashes during night time hours is an important benefit of street lighting that has been substantiated by international research.

The greatest risk of night-time accidents resulting in death or injury is on main roads where traffic speeds and volumes are the highest. The impending conversion of main and arterial roads to high colour rendering white light is a significant change from the low colour performance HPS which makes up 90%[164] of the main road lighting infrastructure in Australia.

As identified in Section 3.3.1, research[165] [166] indicates that there is highly likely to be a positive impact in reducing the number of deaths and serious injuries from road crashes due to better driver hazard detection and shorter emergency stopping distances as a consequence of improved visual conditions with widespread deployment of white light from LEDs. With between 40% and 50% of all fatalities occurring at night but only 25% - 30% of all travel occurring at this time[167] it is highly likely that fatalities and injuries will significantly reduce when white light is used everywhere. The Australian Transport Council[168] estimates that the economic cost to Australia from road transport deaths and injuries is between $18 and $27 billion per year which translates to $6.3 billion to $9.45 billion loss per year from night time crashes. If white light improved these statistics by just 8%[169] this would correspond to a national benefit of between $500-750 million **per year**.

The upgrade to LED lighting is an excellent opportunity to closely monitor and correlate street lighting to crash reductions in Australian conditions.

160 Ed Ebrahimian, Director City of Los Angeles Bureau of Street Lighting, Sydney presentation, March 2014

161 US DoE MSSLC, Bruce Kinzey MSSLC Survey – Presentation LightFair International, New York City, May 2015

162 British Standard BS 5489-1:2013 Code of Practice for the Design of Road Lighting cites design maintenance factors for up to 6 year cleaning intervals. Table B1 page 57

163 Estimate based on 2011 figures from July 2012 Revised Draft E3 National Street Lighting Energy Efficiency Strategy and author's calculations benchmarking against current utility inventories and estimate of average utility lighting inventory CAGR growth rates at 1.4%

164 DNSP data submitted as part of a survey for this Roadmap

165 *The Safety Effects Of Road Lighting –What International Research Tells Us,* Dr. Ronald Gibbons, Virginia Tech Transportation Institute, RoadLighting 2015, March 2015, Auckland New Zealand

166 *Tale of Four Cities,* Nancy Clanton, Clanton and Associates, Dr. Ron Gibbons, Virginia Tech Transportation Institute MSSLC Symposium. March 6 2012 Seattle WA USA

167 See Section 3.2.3

168 See Section 3.2.1, Subsection i

169 8% was chosen because it represents an average of the most conservative numbers found in literature for street lighting

7.6 Street Crime Incidents at Night

The number of reported street crime incidents during night time hours is important as improving public safety outcomes is a prime reason for the lighting of urban and suburban streets.

The conversion of urban and suburban streets to high colour rendering white light from LED will be a substantial change from the low colour rendering performance of HPS and MV legacy technology. As identified in Section 3.3.2, research on the effect of improved lighting on certain types of night time suggests more than 20% improvements are possible. In the City of Los Angeles, where the largest LED deployment in the world was commenced in 2009 and completed in 2013, the City is reporting reductions in key measures of night time crime of about 10%[170] which it partly attributes to white LED deployment as that was the only material change occurring at that time.

Higher quality white light allows people to see better at night and makes them more comfortable being out on the streets at night. This in itself is an important deterrent factor as is the potential for improved police apprehension rates because of improved night visual conditions with white light.

Conversion of yellow HPS and LPS[171] lighting provides an important opportunity to relate this conversion to reported street crime incidents during night time hours. The conversion process could provide world class research if it was closely monitored and correlated to white light LED installations to determine the linkage between improved lighting and any reductions in night time street crime.

To provide some very approximate estimations of the possible benefits, the Australian Institute of Criminology estimates that crime (excluding fraud) costs Australia $27.5 billion per year.[172] Statistics suggests (see Figure 32)[173] that violent crime increases at night, but falls markedly during the hours before sunrise so overall averaging the rate of crime equally suggests that total cost of crime over the hours of darkness in Australia is about $11.5 billion per year. If street lighting with improved colour and visibility benefits could reduce crime at night by 10%, similar to that reported by the City of Los Angeles, this would suggest that a potential saving of $1.2 billion/yr may be possible. Exactly what proportion of this large figure is experienced from the SLSC activities is unknown, but the statistics should be monitored when the change is made, to discover the correlation.

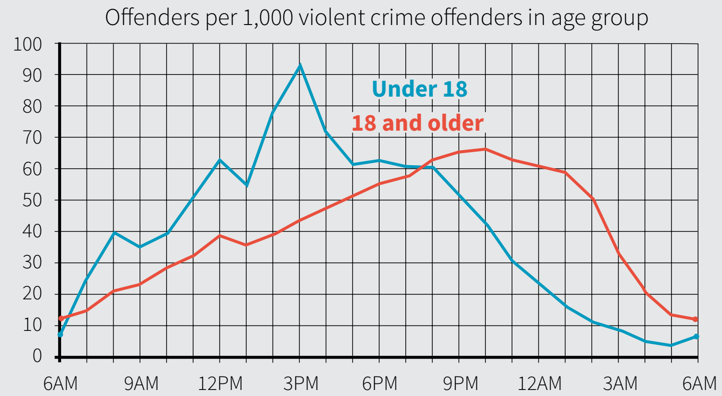

Figure 32 – Violent crime by time of day provides a rough indication of night crime (US Dept of Justice)

7.7 Human Health Benefits

The American Medical Association[174] are supporting the conversion to LEDs but advising that warm colour temperature LED light is preferable for minimising the impacts on human health and wellbeing. As LED street light luminaires can now be procured in a range of warmer colour temperatures such as 3,000K, 2,700K or 2,400K the ability to manage the potential for negative spectral impacts is at hand.

The most significant public health benefits from the implementation of the SLSC Programme will occur due to the greater awareness of health issues and the judicious selection of colour temperatures, with warmer choices used where applicable. Additionally, the use of smart controls with higher colour temperature light maximises safety performance at time periods when fast reaction times are needed (in high traffic conflict areas at peak use) and allows the minimisation of light levels at times when there is lower need and people need to sleep. These issues are discussed in a policy context Section 3.2.2.

170 US Dept. of Energy, “The City of Los Angeles LED Streetlight Program” http://energy.gov/eere/ssl/city-los-angeles-led-streetlight-program

171 LPS is Low Pressure Sodium lighting which is very dated technology with extremely low Colour Rendition Index (CRI) lighting that appears orange and is only found in a few areas in Australia

172 Australian Institute of Criminology, Australian Government, retrieved from http://www.aic.gov.au/crime_community/communitycrime/costs.html

173 US Department of Justice website retrieved from http://www.ojjdpagegov/ojstatbb/offenders/qa03401.asp?qaDate=2010

174 American Medical Association http://www.ama-assn.org/ama/pub/news/news/2016/2016-06-14-community-guidance-street-lighting.page

7.8 Lamp Mercury

Mercury (chemical symbol Hg) is a hazardous substance[175] because it is a neurotoxin. Exposure to elemental mercury and mercury in the food chain poses very significant health risks. Minimisation of the amount of mercury in circulation by retiring obsolete mercury containing technologies provides a strong societal benefit.

Typical high intensity discharge (HID) lamps[176] have a mercury content of 50 mg Hg/lamp and Fluorescent lamps (LFL and CFL) have a mercury content of 4 mgHg/lamp[177] LED lighting has no mercury content.

Based on an analysis of electricity distributor data provided as part of an IPWEA survey for this Roadmap, removing the existing national portfolio of mercury-containing lamps used in street lighting would reduce mercury in the system by about **89kg**. This is a very considerable amount as mercury is toxic to humans at concentrations of as low as two parts per billion in drinking water (i.e. 2 grams in 100 million litres).

Because mercury is so harmful, the number of milligrams of mercury (mg Hg) in the public lighting system should be monitored closely for a given lighting deployment area and information aggregated for Australia. Furthermore, the disposal of old lighting fixtures should be managed carefully and monitored nationally.

Electric power generation from coal-fired power stations releases mercury into the atmosphere. Australian electricity generation is 61% coal-fired,[178] so any energy saving achieved through the deployment of LED street lighting and smart controls technologies will also reduce atmospheric mercury emissions.

7.9 Ecological Benefits

There are also ecological issues with the inappropriate use of light at night with the potential for disruption for animals, birds and insects. The negative effects of street lighting include for example changing animal behaviour (including sleep patterns), bird migration patterns, bat feeding patterns and insect behaviour. These effects are all now well documented and the subject of a growing body of on-going research.

This Roadmap recognises the potential negative impact of LED lights on plant and animals globally. However, this risk can be significantly mitigated through the use of smart lighting controls, so that white lighting is only used when it is beneficial enough to human beings to warrant the risk of the negative effects on the ecology.

7.10 Astronomical Impacts of Light at Night

The use of artificial light at night is a human intervention into the natural environment made in the interests of the greater good of public safety and amenity. Unfortunately, the negative consequences are made worse by inappropriate design or poor product and application choices.

Modern LED street light luminaires almost always provide "full cut-off light" which means that no direct light is emitted skyward. This feature is in marked contrast to almost all traditional street light luminaire technologies which allow appreciable direct light to spill to the night sky and also into the windows of nearby houses.

In addition, if smart lighting controls applying variable light levels are used to only deliver light when and where it is needed, night sky, and other pollution impacts will be reduced even further.

Therefore the use of full cut-off LED luminaires of warmer colour temperatures such as 3,000K, and adaptive controls with off-peak dimming or switchoff is likely to significantly reduce light pollution impacts. As identified in Section 8, research to corroborate this is part of the proposed SLSC research initiative.

7.11 Reduced Transport and Traffic Management Costs

The improved reliability of LED street lighting and smart controls offers a further energy and carbon saving opportunity through the reduction in service vehicle petrol and diesel usage due to the elimination of the need for night patrol inspections and from reductions in maintenance truck activity for spot and planned maintenance including re-lamping of legacy luminaires.

On the basis of reliability feedback surveys from US Municipalities[179] substantiated by Australian DNSP experience, the need for annual maintenance visits will drop from a rate of more than 7-15% per year with legacy technologies to perhaps 2-3% per year for LEDs. In addition, LED failures after installation are being observed at well under 1% per year in comparison to the approximate 10% rate for legacy technologies. This reduction in total maintenance directly corresponds to the lowering of truck usage and the consequent diesel consumption, traffic impediments and other costly traffic management operations.

175 *Global Environmental Facility, Mercury and the GEF,* R. Dixon et al, June 2012

176 HID lamps include Low and High Pressure Sodium (LPS, HPS) ,Mercury Vapour (MV) , which make up a large majority of all street lighting in Australia. Metal Halide (MH) is an HID lamp used in targeted areas

177 *Life Cycle Assessment of Product Stewardship Options for Mercury-Containing Lamps in New Zealand: Final Report,* Peter Garrett and Michael Collins, Environmental Resources Management (ERM), for the Ministry for the Environment. June 2009. Section 3.3 page 24

178 *Energy in Australia 2015,* Department of Industry Innovation and Science, 2016, page 40

179 Bruce Kinzey Director, *Municipal Solid-State Street Lighting Consortium LEDs At 5+ Years – The Scoop on Street and Area Lighting Applications,* LightFair NYC May, 2015

7.12 Reduced Environmental Impact

LED technology reduces environmental impact by improving manufacturing and supply-chain efficiency with product size reductions, yield improvements and better material utilisation. New clean sheet design concepts give opportunity to greatly reduce the amount of materials required for luminaires both initially and over lifetime.

A Life Cycle Assessment (LCA) study sponsored by the US Department of Energy (US DoE) in 2013[180] across all lighting sectors determined that LED lamp products have been making substantial progress and have reduced the total energy consumption during the manufacture, distribution and use phases by about half compared to the performance of five years previous. previous. Figure 32 from this report compares performance of CFL and LED against a baseline of incandescent lighting (the outside blue line, CFL (red) and 2012 and projected 2017 LED technologies (green and blue respectively). The study forecasted that the improvements would continue in line with increasing systemic improvements in product efficacy and systems efficiency. Whilst this study is not specific to LED street lighting luminaires, it is a good indicator of the nature and scale of the environmental improvements likely with wide-scale introduction of LED street lighting and the benefits that will accrue to Australia.

Reduction of the amount of material used in products is a first step in lowering the embodied energy in the system. This applies particularly to the use and re-use of energy-intensive materials such as aluminium. The use of ISO standardised Life Cycle Assessment (LCA) techniques at the product design stages is an effective way of quantifying the impacts of changes and improvements and to better understand the total environmental outcomes of product design, lifetime use and re-use of street light luminaires. Some LED outdoor luminaire suppliers such as Zumtobel Group[181] and We-ef[182] are using Life Cycle Analysis techniques combined with ISO 14025 and EN15804 standardised reporting methods to quantify environmental performance benefits with third party verification to measure and benchmark their performance and progress and to avoid any perception unsubstantiated environmental claims in product marketing.

7.13 Scarce and Sensitive Materials

The change to LED technology delivers substantial reductions in the use of manufacturing materials that are scarce and/or politically sensitive. The use of LED luminaires delivers large reductions in the use of the rare-earth materials[183] that are used in the arc-tubes and the colour conversion phosphors (white coatings) in HID and fluorescent lamps. LED luminaires also use rare-earth based colour conversion phosphors (to convert the blue light generated to a white light output) but in dramatically smaller quantities compared with traditional lighting technologies.[184] Most of the world supply of rare-earth elements used in lighting products is imported from China. In recent times China has imposed quotas on the export of rare-earths causing concerns about limitations with availability and the stability of supply.[185]

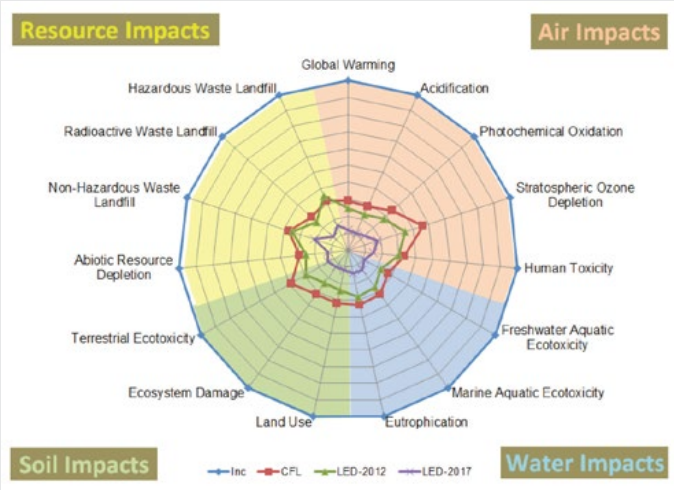

Figure 33 – Environmental impacts of general LED compared to legacy (US DoE)

180 DoE SSL Program, *Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products,* April 2013 http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lca_factsheet_apr2013.pdf

181 http://www.zumtobel.com/com-en/company.html#sustainability

182 http://www.weef-test.com/united-kingdom/en/news/environment/All/

183 US DoE Critical Materials Strategy http://energy.gov/sites/prod/files/DoE_CMS2011_FINAL_Full.pdf page 5

184 US DoE Critical Materials Strategy http://energy.gov/sites/prod/files/DoE_CMS2011_FINAL_Full.pdf page 23

185 http://www.ledsmagazine.com/articles/print/volume-8/issue-2/features/led-phosphor-suppliers-are-affected-by-china-s-rare-earth-export-quotas-magazine.html

8

A VISION FOR STREET LIGHTING

Ten Year Vision of 100% LEDs and Smart Controls Liveability	SLSC Two Year Vision of five Measured Deliverables	New Business Models that Spur Innovation and IoT

Lower Impacts – Lower environmental impacts, lower energy and lower costs.

Smart Lighting and Smart Controls – Smart cities using IoT for improved liveability, workability and sustainability.

New Business Models – Risk managed, performance-based, collaborative revenue generation benefits for cities and towns.

8.1 SLSC Ten-Year Vision for Australian Street Lighting

The mission of the SLSC Programme is to accelerate the efficient adoption of modern street lighting and smart controls technologies and best practices throughout Australia and New Zealand, that contribute to government policy agendas in economic development, transport, public health, environment, energy and the more recent addition of the government's Smart Cities agenda.

The vision of the SLSC Programme is to see this mission delivered through a near full deployment of LEDs and smart controls in Australia by 2027.[186]

As outlined in Section 7, on a like-for-like basis, this will enable:

1. A 52%+ reduction in street lighting energy use.
2. A 52%+ reduction in consequent GHG emissions.
3. A 25% reduction in total costs for councils and main road authorities.
4. A material reduction in road crashes (and consequent fatalities and serious injuries) at night.
5. A reduction in the fear of crime and actual street crime at night.
6. The elimination of mercury in street lighting.

Overall, street lighting luminaires are expected to have an economic life of 20 years. The SLSC Programme vision therefore represents a doubling of the natural rate of attrition-based street lighting replacement. Such desirable improvements will depend on the actual rate of replacement of the old by the new. With accelerated replacements, some jurisdictions are highly likely to achieve the target within three to five years while other may take longer due to a range of factors.

Beyond quantitative measures of improvements in street lighting performance, there are a number of more qualitative measures of an improved lighting service that bring benefits for city productivity, day and night liveability and the perception of street lighting:

1. **Improved Lighting Service**[187] – Improved uptime,[188] quality of light, colour, comfort and standards compliance.
2. **Improved Infrastructure Resilience** – Improved reliability, reduced downtime,[189] longevity and disaster recovery.[190]
3. **Improved City Productivity** – Fewer maintenance interruptions, good vision enabled by good lighting.
4. **Facilitating the Smart City** – Capturing of citywide data, connectivity with other services, enhanced services and liveability.
5. **Protecting the Night Sky** – Reducing upward waste light and skyglow.

186 The SLSC Programme transformation horizon of 2027 has been deliberately chosen to match the timing of the Energy Networks Australia's Electricity Network Transformation Roadmap. IPWEA both finds this medium-term planning horizon a useful concept and notes the potential complementary nature of the two initiative.

187 Refer to Section 5, Street Lighting Technology, and Section 4, Current Street Lighting Regulatory Structure and Approach

188 Proportion of time for which street lighting is performing its specified function (i.e. not failed)

189 Proportion of time which street lighting is not providing light or other specified functions

190 A control and communication system that has embedded resiliency sensors (e.g. flood, fire, noise, toxicity) will both provide additional communications resilience as well as data and knowledge that will assist resiliency

6. **Protecting the Environment** – Reduced obtrusive light and reduced disruption to the ecosystems of insects, birds and animals.
7. **Protecting Human Health** – Reduced circadian rhythm and sleep disruption.
8. **Civil Defence** – Sensing natural disasters and supporting the efforts of emergency services to communicate with the population.
9. **Night-time Enhancement** – Enhancing the amenity, ambience and safety of entertainment and tourist precincts at night.

These more qualitative improvements are only achievable if the deployment of LEDs and smart controls is appropriate, well designed and well implemented. Any technology can be used badly and there are risks of bad outcomes if these issues are not properly addressed.

8.2 SLSC Two-Year Programme Vision

IPWEA has a vision of achieving the following five goals over the SLSC Programme by the end proposed two-year horizon which are tracked in Section 9 with appropriate measurable outcomes:

1. Information, template business cases and models, strategic plans, lighting and controls specifications and case studies are freely available to all councils and organisations who have an interest in street lighting.
2. Reported sales of all legacy luminaire types[191] have ceased by the end of 2018 unless a specific business case is demonstrated for their continued deployment.[192]
3. Legislative, regulatory, policy and standards issues constraining the take up of LEDs and smart controls have been thoroughly analysed and options presented for action by respective agencies and government departments.
4. That applied research seeking to confirm the technical, financial, societal and environmental benefits of improved street lighting is funded.

8.3 Future Vision – Ten Emerging Street Lighting Trends

While the above vision and the modelling that supports it is based on currently available technology, technology development will continue to rapidly evolve and provide transformational change and benefits.

The following innovation trends are currently available technologies and business models that are in the early stages of bringing further transformational change to the international street lighting market and all its stakeholders. Such innovations have the potential to drive further savings and benefits beyond those quantified in this Roadmap. Many of these additive pathways forward are not yet well-defined or demonstrated, but are presented as substantive trends that are in the early stages of market impact and which may further transform our collective thinking about street lighting.

Figure 34 – A smart sensor light point controller plugs in to a luminaire mounted NEMA receptacle (Philips)

8.3.1 Luminaires with Low-Cost Sensors

The ubiquitous nature of street light columns together with increasing availability of low cost sensors and CMS communications is being recognised and this makes street lighting the pre-eminent physical platform for smart city ICT implementation. Internet-connected lighting infrastructure can carry a broad range of city data at a very low marginal cost. Sensors can measure parameters such as traffic volumes, traffic speeds, parking availability, temperature, rain, humidity, air quality, noise and seismic movements. This information can interact with data captured by other city infrastructure networks and will result in a variety of smart city services that we cannot currently conceive. The beginning of this trend is the plug-and-play approach using standard NEMA receptacles shown in Figure 34 that is an increasingly common futureproofing method used by forward looking asset managers.

191 As identified in Section 5, Street Lighting Technology

192 Consistent with New Zealand NZTA M30 Specification approach where all non-LED deployments must be supported by a business case justifying their use in comparison to LEDs

8.3.2 Luminaires with Low-Cost Cameras

With the dramatic increase in digital cameras including in millions of smart phones, miniature low cost cameras are increasingly being used for street lighting control and data capture.[193] Embedded in outdoor luminaires or with flexible plug-and-play mounting, they are redefining the role of the luminaire as a multi-function device. An example of such a luminaire is seen in Figure 35. Cameras are often more versatile than traditional infrared, ultrasonic or microwave sensors for detecting vehicle and human presence and, with embedded computational power, can accomplish considerable data processing at the source of data capture.

Figure 35 – Detection camera equipped luminaire (GigaTera)

8.3.3 Self-Learning Control Systems

Device learning or artificial intelligence is emerging to enable systems to self-commission and learn how a lighting scheme is being used over time. Expensive setup and commissioning was once a necessary part of digital outdoor lighting control deployment practice but ever increasing device intelligence is reducing costs and user complexity.

8.3.4 Integrated Services Street Light Columns

Lighting columns are becoming recognised as highly valuable city real-estate. These assets are physical carriers of integrated service systems comprising not just street lights but cameras, sensors, microphones, loudspeakers, dynamic signage, EV charging, phone and WiFi communication devices[194]. Integrating columns with a range of devices can improve city aesthetics by reducing street clutter and create innovative commercial revenue generation opportunities for councils. An example of such a lighting column is shown in Figure 36.

Figure 36 – Integrated services street light column luminaire (Schréder)

8.3.5 New Generation Optical Materials

New optical materials with tolerance to high temperatures are redefining the nature of street lighting luminaires. 3D printed optical manufacturing, edge-lit LED light pipes and optical silicone rubbers can deliver sophisticated lenses for super-optimised and potentially, super-customised light distribution, as illustrated in Figure 37.

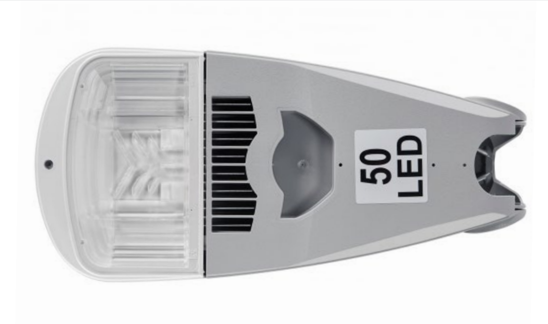

Figure 37 – Luminaire with new generation prismatic optics (Cree)

8.3.6 Smaller, Lighter Luminaires

Replacement of aluminium alloys by lightweight high-tech plastics for luminaire bodies is contributing to reducing the size and weight of luminaires, and the consequent need for substantial and heavy lighting column and outreach arm structures.[195] Lower material mass means lower manufacturing costs and lower handling and transportation costs. Environmental Product Stewardship is also better served with lower resource use and minimised overall life-cycle environmental impacts.

193 *2016 DoE Solid-State Lighting R&D Workshop,* Himamshu Prasad, Global Product Manager – Outdoor Controls GE Lighting

194 *The Humble Lamp Post – Kick Start Event Presentation,* Dec 3 2014, European Union, Section 4.1 Solution Architecture

195 US Dept of Energy Solid State Lighting R&D Plan June 2016, Section 2.4, page 13

8.3.7 Low Voltage DC Power Networks

Power over Ethernet (PoE) allows luminaires and related devices to be treated as part of a computer network. Plug and play, low-voltage, low-power electrical and data connectivity with either USB, Cat6 NEMA or new interfaces will enable multi-function and flexibly configured device micro-grids within lighting columns that can be changed or updated without the need for licenced electricians.

8.3.8 Sensor Based Light on Demand

Delivering the precise lighting requirements for the task at any particular time is European Union's lighting philosophy which aims to provide *"... a framework that establishes the 'value of light to society' by delivering the right light in the right place at the right time of day or night."*[196] In street lighting this is a form of adaptive lighting referred to variously as, 'Light on Demand', 'Light-bubble' or 'Follow-me Lighting.' Lighting is turned-on, or illumination increased, by presence sensors. Smart controls that deliver the exact lighting needs for any given period of high or low night time activity as required can optimise safety needs without wasting resources on unnecessary light.

8.3.9 Net-Zero Energy Street Lighting

As rooftop solar PV generation provides commercial and residential consumers with the opportunity to become generators, a parallel opportunity exists for street lighting owners. Solar PV equipment mounted on individual lighting poles/columns can provide distributed power generation particularly to meet hot summer air conditioning power demand, and thus cost, peaks. CMS lighting controls with solar power management software provide two-way communication, control analysis, to provide net revenue or cost optimisation. Off-grid solar PV powered street lighting including battery storage is a further option that will become more economic.

8.3.10 Profitable Street Lights

Street lighting columns are being referred to by some parties as, the most valuable square foot of real estate in the city due to their potential to raise new sources of revenue or offset costs. Telecommunication carriers need access to this ubiquitous street infrastructure for mini-cell mobile transmitters for phone and data device deployment and there are a host of real estate, marketing, liveability and safety services that are emerging based on camera and sensor data collection and analysis. Entrepreneurial business opportunities exist that are likely to turn some street lighting from a cost centre into a profit centre. Some examples of this include:

- Parking vacancy identification and parking payment systems;
- Pedestrian footfall-based dynamic pricing for outdoor advertising billboards;
- Vehicle and pedestrian footfall reports to support CBD retail property lease valuations;
- CBD apartment ambient noise reports for pre-purchase due diligence;
- Lighting column solar PV electricity sales;
- Police and Civil Defence real-time audio and video messaging;
- City event and entertainment audio and video messaging;
- Asset condition monitoring sensors mounted in street infrastructure; and
- Use of short range wireless technologies to provide location based marketing and communications services for retailers, municipalities and other providers.

Sub-leasing of device mounting rights on street lighting columns to capture data from a host of sensors may create data wholesaling service sales that would have the capability to partly or wholly offset lighting infrastructure costs.

196 LightingEurope calls for light quality and human wellbeing legislation, LEDs Magazine,:June 27, 2016, available on website; http://www.ledsmagazine.com/articles/2016/06/lightingeurope-calls-for-light-quality-and-human-wellbeing-legislation.html

9

SLSC DELIVERABLES AND TIMEFRAME

Ambitious 2 Year SLSC Programme of Deliverables

Engagement of diverse stakeholders

Carefully structured governance and action programme

Policy Engagement – Identifying possible legislative, regulatory policy and standards for stakeholder consultation.

Model Documents – Preparing model specifications and other documents to improve market efficiency.

Training – Developing website, webinars, workshops and other tools to educate all stakeholders.

This section outlines the proposed actions to be taken under the SLSC Programme and the delivery timetable to facilitate the accelerated deployment of efficient LED street lighting and smart controls. Table 19 provides a summary of the proposed SLSC Programme activities proposed under this Roadmap and each project is discussed in further detail in the following sections. At this stage, only part of this proposed set of deliverables is funded and the SLSC Council, while having endorsed the overall plan, will need to make choices about priorities from amongst the deliverables listed in the following table.

9.1 Roadmap, Launch, Council and Technical Advisory Group

This Roadmap is the foundation for planning IPWEA's Street Lighting and Smart Controls Programme which was officially launched in Australia on 24 May 2016 (with New Zealand to be included later). The first SLSC Council meeting was also held on that day. The SLSC Council is an advisory board to IPWEA. As per its adopted Terms of Reference:

"... The role of the Street Lighting and Smart Controls (SLSC) Council is to provide high-level advice to the CEO of IPWEA on the SLSC Programme. This will be in order to guide and support the SLSC Programme in undertaking an integrated package of projects and activities to overcome or alleviate the major impediments to the early and widespread adoption of modern solid state street lighting technologies and smart controls throughout Australia and New Zealand."

The relationship of the SLSC Council to IPWEA and other elements of the SLSC Programme is illustrated in Figure 38. The SLSC Council is comprised of nominated representatives of key stakeholding organisations from industry and government which are identified in Table 20. The Terms of Reference and guidance to members adopted at the first meeting is provided in Appendix II: SLSC Council Terms of Reference.

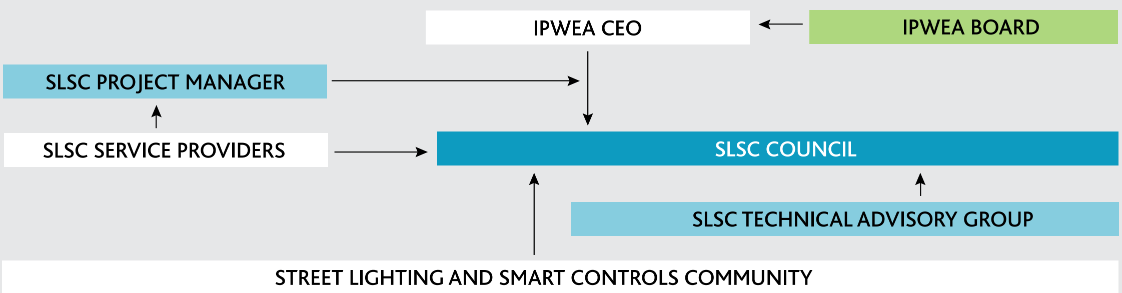

Figure 38 – SLSC governance structure

Table 19: SLSC Programme Summary

PROJECT	Q2 2016			Q3 2016			Q4 2016			Q1 2017			Q2 2017			Q3 2017			Q4 2017			Q1 2018		
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
8.1 Roadmap (this document)																								
8.2 SLSC Launch 24 May 2016																								
8.2 SLSC Council Meetings																								
8.3 Policy and Stakeholder Engagement																								
8.4 Model LED Lighting Specification																								
8.4 Model LED Controls Specification																								
8.4 Model Investment-Grade Business Plan																								
8.4 Model Street Lighting Strategy																								
8.5 SLSC Australian Practice Note 2017																								
8.6 Self-assessed Maturity Matrix																								
8.7 SLSC NAMS Benchmark																								
8.8 Website Portal																								
8.9 Webinar Series																								
8.9 Face-to-face Training workshops																								
8.9 CPD Training Programme																								
8.10 Monthly E-Newsletter																								
8.11 Public Lighting Conference																								
8.12 Tender gateway																								
8.13 Standards Organisations Consultation																								
8.14 Research Programme																								

Table 20: SLSC Council Members

	SLSC Council Members
1	Institute of Public Works Engineering Australasia (IPWEA)
2	Department of the Environment and Energy
3	Energy Networks Australia (ENA)
4	Australian Local Government Association (ALGA)
5	Lighting Council Australia (LCA)
6	GE
7	Philips
8	Gerard Lighting
9	Silver Spring Networks
10	Cisco Australia
11	Next Energy/Strategic Lighting Partners (as advisers to IPWEA)

9.2 Technical Advisory Group

A Technical Advisory Group (TAG) has also been constituted to assist the SLSC Programme by providing technical and commercial input to SLSC products, tools and training.

Further TAG members will be invited as the programme develops. IPWEA will be seeking further TAG membership from a number of respected organisations under each of the following sector categories where prospective members have demonstrated high levels of technical knowledge in street lighting, smart controls and smart city issues

Table 21: Technical Advisory Group

Technical Advisory Group	
Eaton Lighting	Illuminating Engineering Society of Australia and New Zealand
Toshiba	City of Adelaide
Pecan / LED Roadway Lighting	City of Brisbane
Aldridge Traffic Technologies	City of Darwin
Telensa	City of Ipswich
Eye Lighting	City of Sydney
Oak Electronics	Southern Sydney Regional Organisation of Councils (SSROC)
Orangetek	Lighting Council New Zealand (LCNZ)
Schréder	Local Government New Zealand (LGNZ)
Electrix / Citeos	VRT Systems
Citelum	Telematics Wireless
Kurrant	

Table 22: Technical Advisory Group Sector

TAG Sector
Leading councils
Main road authorities
Lighting suppliers
Smart controls / smart city technology suppliers
Smart city network platforms / software / telecoms
Street lighting service providers
State, New Zealand and government agencies
DNSPs
Associations
NGOs
Consultants

9.3 Policy Discussion Paper and Engagement

Section 3 on Policy Context, 4 on Current Regulatory Approach, and 11 on Barriers in this Roadmap provide the foundation for further work to identify potential regulatory reform. Table 19 shows this work stream continuing for the duration of the SLSC Programme to provide ongoing dialogue and discussion papers for state and Commonwealth departments and agencies.

It is hoped that government officials, regulators and industry organisations which have identified responsibilities in the recommendations Section 14 of this Roadmap will develop implementation plans relevant to their area to achieve the agreed outcomes.

The SLSC Council would be informed of these action plans and implementation timetable, which when combined, will form a cohesive and integrated "SLSC Implementation Plan for the Accelerated Rollout of LED Street Lighting and Smart Controls for Australia."

9.4 Model Specifications, Business Plan and Strategy

A wide range of stakeholders including suppliers, contractors, consultants and advisers have provided feedback to IPWEA that LED luminaire and control system procurement is at present, very disjointed. Procurement parties are excerpting parts of guidance documents from diverse domestic and international sources, often in an incoherent, inconsistent and internally contradictory manner.

There is a pressing need for the preparation of a robust set of freely available model specifications and other template documents to assist with procurement and application for suppliers, councils and electrical distribution utilities, and for model business plans and strategy documents for those considering making the investments, including third parties such as financiers, insurers and purchasers. In all circumstances model documents will facilitate the accelerated uptake of the new and beneficial technologies.

Table 23 lists the four model documents that are proposed to be delivered as per the timetable identified in Table 19.

Table 23: Model Documents to be Developed

	Name	Description
1	Model LED Lighting Specification	This will use precedents from the US Department of Energy's Municipal Solid State Lighting Consortium (MSSLC) and other benchmarks such as the US DesignLights Consortium, LightSavers Canada Program, NZTA M30 Specification and the Chicago Infrastructure Trust. The Model Specification will build on SA/SNZ TS 1158.6 and other relevant performance standards, specifications and guidance documents by augmenting AS/NZ and SA/SNZ documents that are currently silent or have not kept up with international developments. A fundamental tenet of overseas model specifications is that they are driven by user groups not supplier groups and that they change quickly to adapt to changing user needs and available technologies.
2	Model Smart Controls Specification	The same approach for the Model LED Lighting Specification will be taken for smart controls. With the exception of the UK and Europe, this is a significantly less mature market for a variety of reasons including the complexity of technologies and issues, the rapidly developing nature and variety of technologies, the more distant financial returns, the significance of large social benefits available with less quantifiable or direct returns, and the fact that unless informed decisions are made before LED luminaires are installed, later options are unintentionally foreclosed.
3	Model Investment-Grade Business Plan	Substantial investment is required to upgrade to new lighting technologies so the business case for that investment needs to be robust. Projects of this size need to ensure that all the requirements of a business case are identified to ensure that the decision-making body overseeing the investment decision is fully informed, including of the risks and risk mitigation measures. The Model Investment-Grade Business Plan will provide a template that should meet most investors' needs, including those of councillors, financiers and government agencies.
4	Model Street Lighting Strategy	The business plan provides a strategically coherent business case that emphasises economic issues in a mass upgrade situation. However, local governments need to meet the short and long term lighting needs of a wide range of stakeholders including ratepayers, electors and regulatory authorities. For infrastructure that affects public safety, security, and is highly visible, an overall street lighting strategy is highly recommended. This type of strategy typically provides guidance on minimum acceptable lighting levels, lighting design requirements and the basis for council requirements with public lighting. It can also provide guidance about the strong advantages, and the often mis-informed disadvantages of upgrading street lighting.

9.5 Update IPWEA Practice Note 11

IPWEA has been closely monitoring developments with street lighting since 2012 and in 2014 it published its *Practice Note 11: Towards More Sustainable Street Lighting*. IPWEA subsequently staged well-attended training workshops around Australia. Significant changes with street lighting and smart controls have occurred since 2014 and an update to the practice note is required. This is programmed for the second half of 2017 as identified in Table 19.

9.6 Self-Assessed Maturity Matrix

An over-riding objective of the SLSC Programme is to facilitate those responsible for street lighting performance to become cost-effectively self-sufficient in managing their street lighting. Thus training programmes discussed below are very important, and to assist local government and DNSPs to identify the gaps themselves, IPWEA proposes developing a self-assessed maturity matrix which would be made available on the Programme website at the end of 2017 as shown in Table 19.

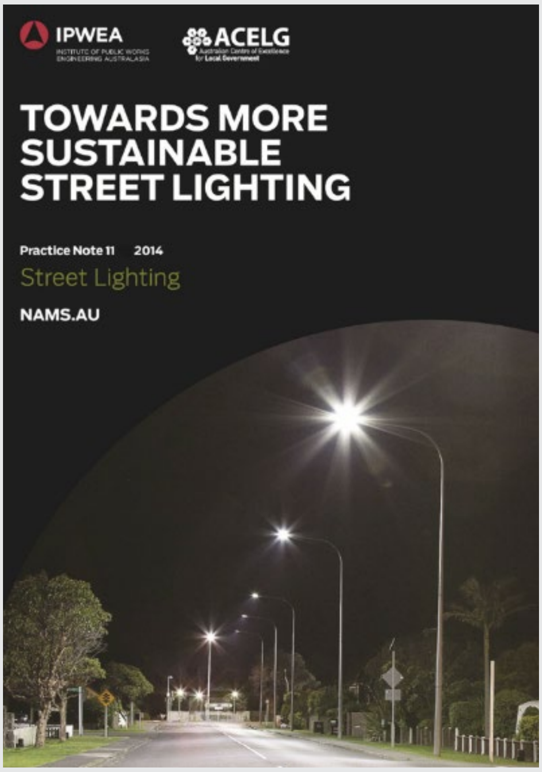

Figure 39 – *Practice Note 11: Towards More Sustainable Street Lighting*

9.7 SLSC NAMS Benchmark

IPWEA operates a world class asset management system called NAMS that is widely used in Australia and New Zealand as well as in Canada and other countries. It has been designed to cover all asset classes found in public works engineering but of course it is particularly suited to transport, hydrological and building construction.

At about the end of 2017 or start of 2018 the SLSC Programme proposes to develop a module to be included within the NAMS.Plus suite. This module would provide local governments and road authorities with a complete asset management plan for their public lighting assets.

9.8 Website Portal

An SLSC Programme website portal has been constructed and is available at www.slsc.org.au. Continuous development will be needed to keep the site current, with significant updates needed probably every six months. Figure 40 illustrates the initial website.

9.9 Training

A significant component of the SLSC Programme is the delivery of training – through webinars, face-to-face workshops and continuing professional development (CPD) programmes.

9.9.1 Webinar Series

Webinars are an efficient method to transfer knowledge and IPWEA uses them to deliver training across many of its programmes and is therefore an experienced webinar training provider. IPWEA estimates that the SLSC Programme will deliver webinars at a rate of roughly one every two months. Webinars will be recorded and made available for later download on the SLSC website. IPWEA has initially identified 17 potential webinar topics listed below which draw on the material developed as part of other SLSC activities and Programme Partner expertise. Currently, the SLSC Programme is aiming to secure budget to deliver at least ten webinars, but Commonwealth and state governments and agencies or commercial sponsors might be found to fund further topics.

Potential topics for the SLSC webinars include:

1. SLSC Introduction and Roadmap;
2. LED Street Lighting Basics;
3. Smart Street Lighting Controls Basics;
4. Using the Model LED Lighting Specification;
5. International LED Deployment Case Studies;
6. International Smart Controls Deployment Case Studies;
7. Using the Model Investment Grade Business Plan for Street Lighting Upgrades;
8. Financial Modelling for Street Lighting;
9. Alternative Street Lighting Deployment Approaches (PPPs, ESCOs, EPCs);
10. Street Lighting Design Basics;
11. Street Lighting Asset Management Overview;
12. Street Lighting Procurement and Tendering;
13. Smart Lighting Controls Technologies;
14. Smart Lighting Controls Application;
15. Using the Model Smart Controls Specification;
16. Street Lighting Energy Performance Calculations;
17. IPWEA Maturity Matrix for Street Lighting Assets.

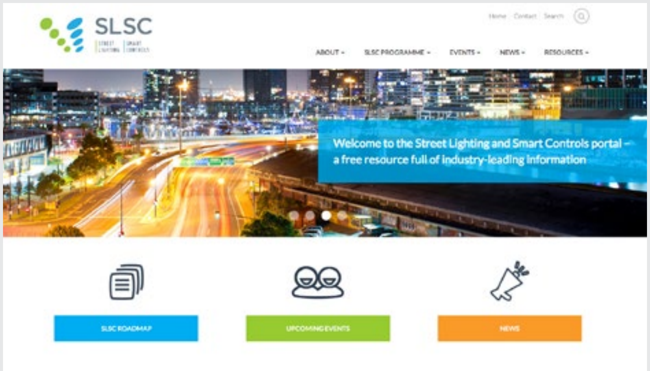

Figure 40 – Home page of the SLSC website at www.slsc.org.au

9.9.2 Face-to-face Training Workshops

Face-to-face training workshops and seminars cannot be fully replaced by webinars as they still have many advantages such as meeting the needs of those that are uncomfortable with learning from computer screens, being able to more naturally communicate with presenters and peers and to establish valuable contacts. But they are significantly more expensive to host, particularly outside the largest capital cities, so IPWEA has programmed them for roughly every two months in the alternate months that webinars are not being held.

9.9.3 CPD Training Programme

IPWEA operates a Continuing Professional Development programme for several professional disciplines and is proposing to add the SLSC Programme to this capability towards the end of its second year, once all the key material has been generated.

9.10 Monthly E-newsletter

An important part of facilitating the acceleration of LED street lighting and smart controls and their associated technologies is the regular communication of developments and achievements by peers and colleagues in the industry.

The SLSC Programme is proposing to produce and circulate a regular monthly e-newsletter to the approximately 3,000 stakeholders in the industry free of charge. This will increase awareness of the many diverse issues and also provide a reliable and regular mechanism to distribute international developments to the Australian sector to encourage international best practice.

9.11 Public Lighting Conference

IPWEA is working together with Strategic Lighting Partners Ltd to co-host a third regional public lighting conference, this time in Brisbane, Australia, on the 14-17 March 2017. Previous conferences in Auckland have received high appreciation, attendance and sponsorship. Of particular note was the conferences' success in securing a large number of high profile expert international speakers to address world best practice in street lighting. Feedback from sponsors, presenters and attendees has been strongly positive with 50% of the attendees rating the event with an average score of 9/10 or more. The conference website is at www.streetlightingconference.com.au

The unique point of difference is that its purpose and content revolves around the fundamental and far reaching strategic and tactical changes that SLSC is trying to bring to public lighting in Australia (and NZ). Effectively, the conference will be inviting speakers who can facilitate those changes through their experiences. Because of this, the ability to attract high calibre speakers is greater, and the ability to attract the audience and participation of Sponsors and Exhibitors will also be greater. For example, the presence of the person who is leading the conversion of an American investor owned electricity distributor (DNSP) to 600,000 LED luminaires a high proportion of which will be fully electronically controlled will provide invaluable knowledge that no amount of advice or advocacy can accomplish. Real experience from real people is a powerful driver. This will act as a further motivator and lead generator for councils and regulators to accelerate the rollout of LEDs and smart controls.

9.11.1 Tender Gateway

A public lighting tender gateway website may be developed if IPWEA can substantiate demand and funding is sufficient. This would be a relatively sophisticated website that allows calls for tenders to be made with all the prudential and security requirements to allow councils, road authorities or DNSPs to easily tender for public lighting or related services.

9.12 Standards Organisations Consultation

An important part of the SLSC Programme is to work consultatively with Standards Australia (SA) and Standards New Zealand (SNZ) to:

- Address the imbalances on some standards committees, identify vacancies or a lack of representation on relevant committees by local government, new-entrant suppliers and those with expertise in smart controls and their application to adaptive lighting , identify suitable candidates to fill vacancies, nominate candidates and provide appropriate briefing and support to nominees; and
- Ensure that standards reform proposals support the timely deployment of LEDs, smart controls and smart city technology.

Standards Australia have existing arrangements that allow for local government representation. Identification of appropriately qualified representatives is required to ensure this input is effective. IPWEA also recognises that any model specifications it develops under the SLSC Programme have the potential to be passed on for consideration for national adoption under the Standards Development Organisation (SDO) auspices.

9.13 Research Programme

The large scale introduction of new technologies across the street, road safety and security infrastructure sectors is a significant opportunity to discover useful knowledge that is highly likely to improve a range of wider societal outcomes. For example, few studies worldwide have investigated the direct relationship between lighting level and quality, and any consequent correlation of road accident rates at night.

There are many other opportunities to investigate and generate applied learning from improvements in city liveability, the night economy street safety and vandalism at night. In Los Angeles, for example, when the conversion to white LED lighting was completed in the CBD area, the city experienced a sudden and unexpected increase in the night economy boosted by hospitality and entertainment sector activity.

IPWEA will be working with Australian and international research and special interest organisations to identify and plan practical and applied research projects that will add value for stakeholders. This has the potential to develop better outcomes for street lighting users, asset owners and suppliers and to develop intellectual property opportunities for the research organisations involved.

It is envisaged that IPWEA collaboration will involve identifying projects of high value to councils, road authorities, DNSPs and suppliers, then seeking to identify suitable researchers to lead these projects and helping facilitate research funding by matching the appropriate parties. IPWEA's SLSC Programme would also likely have a significant role in project planning and overall supervision and dissemination of results, with execution and initial reporting led by the research organisations involved.

Table 24 identifies potential research project possibilities that are of direct relevance to Australian street lighting economics, safety and user satisfaction, and that represent current voids of knowledge.

Table 24: Examples of Potential Research Projects

Potential Research Projects	Key Objective
LED lighting application and road safety effectiveness.	Substantiate road safety benefits of white light.
Australia and New Zealand database of LED street lighting and controls system reliability.	Substantiate reliability claims to boost market confidence.
Experiential validation of LED and smart controls systemic performance over time.	Substantiate performance claims to boost market confidence.
Entomological studies of insect attraction to LEDs of differing colour temperatures in areas of known spider-web and insect accumulation issues on luminaires.	Identify potential benefits of lower colour temperatures and related spectral characteristics.
Study of night time vandalism and crime pre and post LED deployments.	Substantiate crime mitigation benefits of white light.
Street lighting site light measurements in Australia and New Zealand.	Establish and validate Australian site light measurement methods.
Australia and New Zealand application of solar PV LED street lighting and smart controls.	Substantiate performance and cost claims for solar PV street lighting.
Camera based sensing of traffic flows for real-time adaptive lighting control.	Proof of concept in an Australian context.
Assess blue light hazard risk in Australian street lighting designs and explore mitigation strategies.	Provide guidance on blue light risk and mitigation.
Astronomical skyglow measurement and benchmarking in Australia and New Zealand.	Benchmarking current skyglow levels for future comparison.
Smart controls data and cybersecurity risks.	Independently test security of smart controls systems.
Environmental life cycle modelling of LED and smart control street lighting.	Substantiate environmental claims across life cycle.

10

INVESTMENT

Total Replacement Cost Around $1.1 Billion	Less than 5 Year Payback on Electricity and Maintenance Savings Alone	Equipment Costs Vary Greatly with Specifications

Typical Bulk Luminaire Cost – $200-$300/unit for P Category.

Typical Bulk Control System Cost – $100-$200/unit capex.

Typical Bulk Luminaire Installation Cost – $100-200/unit for P Category.

This section identifies the investment required for equipment, installation and project management services to replace legacy technologies with new LED and smart controls technology across Australia. This uses inventory information provided by DNSPs and estimates current 2016 pricing based on author's experience to project future costs.

10.1 Factors Influencing Investment

Infrastructure investment from a tender process is significantly affected by:[197]

1. **Scale** – Small projects versus large projects (e.g. quantities of thousands or tens of thousands);
2. **Product specifications** – International norms versus localised requirements;
3. **Competition** – The number of eligible and motivated tenderers at the time;
4. **Serious intent** – Casual enquirer versus committed buyer;
5. **Project type** – Greenfield versus brownfield (retrofit);
6. **Project stage** – The first stage of a multi-stage project will attract stronger competition;
7. **Project status** – Prestige project versus nondescript project;
8. **Buyer support** – High buyer pre and post-sales support needs versus self-contained buyer;
9. **Warranties** – Realistic cover versus over-indemnification;
10. **Sales management opportunity cost** – Convoluted versus straightforward tender process;
11. **Supply chain selection** – Reseller handling margins versus direct supply by principal;
12. **Information completeness** – Complete information lowers risk for the bidder and thus the price;
13. **Outcome based** – Specifications should be outcome-based, not prescriptive, and provide enough flexibility to allow for innovation that may provide improved value;[198]
14. **Whole of life** – Investment analysis considers whole of life impacts, only up-front costs;
15. **Clarity over other revenue sources** – Rights to project income/subsidies need to be identified.

The above factors all have a significant impact on pricing and the estimates provided in this Roadmap can only be approximate – probably in the region of +/- 20%.

10.1.1 Alternative Business Models

In Europe and in parts of North and South America, Energy Performance Contracts (EPC), Private Public Partnerships (PPP) and such 'blended finance' business models in street lighting have emerged as an option to a traditional capex-based lowest cost approach. The EPC/PPP capex + opex best value decision shares risk with the bidder, and is considered internationally a prime option for larger scale infrastructure projects.

There is a long history of the use of Energy Service Companies (ESCOs) to deliver on Energy Performance Contracts, which is described in "A Best Practice Guide to Energy Performance

Contracts[199] as allowing *"... facility owners and managers to upgrade ageing and inefficient assets while recovering capital required for*

197 European Commission, *Lighting the Cities: Accelerating the Deployment of Innovative Lighting in European Cities,* June 2013, page 27

198 Ibid page 14

199 *The Australasian Energy Performance Contracting Association for the Energy Efficiency Best Practice Program in the Australian Department of Industry Science and Resources,* 2000, ISBN: 0 642 72127 0

the upgrade directly from the energy savings guaranteed by the ESCO. The ESCO takes the technical risk and guarantees the savings. The ESCO is usually paid a management fee out of these savings (if there are no savings, there is no payment) and is usually obligated to repay savings shortfalls over the life of the contract. At the end of the specific contract period the full benefits of the cost savings revert to the facility owner.

The methodology of Energy performance Contracting differs from traditional contracting, which is invariably price-driven. Performance contracting is results-driven: ensuring quality of performance. ESCOs search for efficiencies and performance reliability to deliver contractual guarantees."

This EPC business model is very well suited to upgrading street lighting to LED, but as identified in this Roadmap, the benefits available to a performance driven business model are significantly greater than just for the energy savings. This is particularly relevant to the barriers and risks identified in Section 4 from the current regulatory environment. Thus PPP and other blended finance models are also highly appropriate to be considered for street lighting infrastructure upgrades.

If bids for both types are to be compared, tender configuration is required to accommodate this to avoid mixing blended finance options with lowest up front approaches.

The estimates used in this section do not assume blended finance models but assume that whole-of-life costing and risk management has been covered.

10.2 Lighting Poles and Columns

The capital costs of lighting columns and/or poles in new-build greenfield projects are usually very significant and can be five to ten times the installed cost of a luminaire or more with multi-function CBD poles. For retrofit brownfield sites, the LED luminaires are usually selected to suit the existing street pole spacing and mounting heights with no changes required to poles and column infrastructure. As this Roadmap is largely aimed at the street lighting LED/CMS retrofit market, poles and columns are assumed to be already present and therefore not requiring investment.

10.3 LED Luminaire Investment

New-build greenfield projects provide the ability to vary and often extend (with new LED optics) lighting column spacings depending on the optical properties of the luminaire. This means that a capex cost of per luminaire is not an appropriate metric as it does not account for variations in luminaire optical performance that may allow for longer spacings.

However, for brownfield retrofit projects, which is by far the predominant situation for the implementation of the SLSC Programme across Australia, street lighting poles/columns are existing and fixed, so that $/luminaire is the appropriate metric. This Roadmap assumes this approach for investment analysis purposes.

10.3.1 LED Luminaire Specifications

Pricing is directly related to specification, so in order to estimate the investment required for Australia, this Roadmap makes the following specification assumptions:

1. Compliance with luminaire Standard AS/NZS 60598.2.3:2015 and luminaire Technical Specification SA/SNZ TS 1158.6:2015
2. Ability to comply with the lighting design requirements of AS/NZS1158.3.1 for P Category and AS/NZS1158.1.1 for V Category application with the scheme geometry typical in Australia (e.g. broadly equivalent to or better than the optical performance of the typical luminaires that they would replace)
3. Controls enabled with NEMA ANSI C136.41 7-pin receptacle and dimming control gear (either 1-10-V or DALI)
4. Colour Temperature (CCT) 4000K. While 3000K is sometimes preferred for P Category applications and recommended by the American Medical Association[200], pricing information is more readily available for 4000K and so this is used for investment modelling.

10.3.2 LED Luminaire Power Equivalency

Legacy luminaire technologies are designated by their power rating in Watts because the historic relationship of light output (in lumens) to Watts has remained relatively stable. As the function of any luminaire is to provide light (lumens, not Watts) the introduction of LED technology – with ever increasing lumen per Watt efficacy – has required luminaire specifications to state light output in lumens.

This poses an investment modelling challenge, as although the lumens needed for any given application is constant, each new model LED luminaire released decreases the power to generate those lumens. Therefore the equivalency between LED power rating and legacy technologies continuously changes with each LED model release, and the estimates provided here are only valid for a limited time. Fortunately, over time the luminaire cost of lighting a given application will decrease - by about 4% per year (for the USA) as estimated by the US DoE.[201] So most cost estimates encountered will likely be conservative.

At the time of writing, the range of current equivalency has been established by recent large volume proposals for councils, main road authorities and through discussions with suppliers. These figures are set out in Table 25. In this context, “large” refers to deployment of many thousands or tens of thousands and the costs associated with such deployments bears little relationship to low volume installations in the tens or hundreds of luminaires.

200 See Section 3.2.3 Public Health Effects of Night Lighting

201 *US DoE R&D Plan*, June 2016, DoE EE-1418, page 19

Notably, these price estimates are higher than international benchmarks for large-scale deployments which is probably due to the fact that few large-scale deployments of LEDs have proceeded via open public procurement processes in Australia to date. It is probable that LED luminaire prices will trend steadily downwards at a moderate rate from those shown below with the combined effects of technology improvements, competitive pressures and economies of scale. However, the very large LED cost reductions experienced over the last few years are unlikely to continue at a similar rate as the opportunities for manufacturing savings reaches a plateau.

Table 25: Luminaire Power Equivalency, Estimated Quantities and Costs

	P4/P5 Categories 80W MV[202] Equivalent	Intermediate Roads P3/V5/ Other	V Category 150W HPS[204] Equivalent	V Category 250W HPS Equivalent	V Category 400W HPS Equivalent
LED Luminaire Power/unit (W)	20-30W	30-50W	85-100W	140-200W	230-300W
LED Luminaire Cost/unit (large volume) ($)	$200-300	$300-400	$400-600	$600-800	$800-1000
Large Scale LED Luminaire Installation Cost/unit($)[203]	$100-$200	$100-$200	$180-$280	$180-$280	$180-$280
Number of Luminaires in Australia	1.484m	255,000	265,000	281,000	27,000
Cost of Large Scale Deployment Programmes	$540m	$103m	$179m	$261m	$30m
TOTAL ESTIMATED COSTS	**$1.1 billion ± 20%**				

Table 26: Overall Investment Performance of SLSC when only Including Electricity and Maintenance Savings

Estimated Capital Costs of Large-Scale Replacement Programme	Estimated Energy Savings (Based on Typical Costs of All Charges Proportional to Energy Consumption of $0.15c/kWh)	Estimated Maintenance Savings (Based on 50%+ Reduction in Current Spot and Bulk Maintenance Costs)	Total Estimated Energy and Maintenance Savings	Simple Payback Period	Present Value @ 4% Discount Rate Over 15 Years Including Initial Capital Cost and Savings
$1.1 billion	$180 million/yr	$60 million/yr	$240 million/yr	4-5 yrs	$1.6 billion

202 MV stands for mercury vapour. Other common lighting types in this category include linear fluorescent, compact fluorescent and some low wattage sodium lighting

203 See Section 10.7.6

204 HPS stands for high pressure sodium, and accounts for 90% of V category lighting with the balance being primarily mercury vapour.

10.3.3 National Business Case for LED Replacement Programme

Table 26 summarises the results of savings and investment return calculations for a nationwide LED replacement programme excluding any financial benefits other than Energy and Maintenance. This information has been calculated from known figures for maintenance charges for Mercury Vapour 80W and 125W, and High Pressure Sodium 100W, 150W and 250W and used to extrapolate across the nation.

From Table 26 a $1.1 billion investment yields a return of $240 million per year providing a Net Present Value of $1.6 billion and a simple payback of under five years. Savings are based only on energy cost savings combined with maintenance savings. **No account has been taken of the positive economic gains from reduced injuries and fatalities or any other factors mentioned in the Roadmap.**

10.3.4 Luminaire Installation

Luminaire installation costs are highly variable and specific figures are required for actual project financial modelling. The price ranges listed in Table 25 are based on recent Australian quoted prices from established and specialised road lighting installation and service contractors. Actual costs are dependent on all the variables identified in Section 10.1 as well as other factors including levels of commercial competition.

A particularly influential cost factor is traffic management requirements which are dictated by the traffic safety requirements for the type of street or road in question. There are many developments emerging with fast deployment optimised elevated work platform vehicles and with IT based field processes that increase luminaire installation productivity and reduce costs.

10.4 Estimation of Central Management System (CMS) Controls Investment

At present, smart control systems are at a very early stage of deployment in Australia making domestic cost estimates particularly uncertain. There are also many systems available that work in a wide range of different ways and costs generally have both capex and opex components. The capital cost is identified per luminaire (often called a lightpoint by the industry) and includes equipment supply, software supply, installation and commissioning, and operating costs cover outsourced cloud computing services.

10.4.1 CMS System Specification

Specifications of the benchmark CMS system used to estimate the required investment, assumed the following:

- **Fully featured CMS system with scheduled control, monitoring and data logging;**
- **Business model –** Single or multi source (see Section 5);
- **Technology platform –** RF short range mesh, RF long range star, or telco cellphone;
- **Equipment –** Software, network devices, luminaire nodes, gateways;
- **Including Services –** Installation, data loading, commissioning and training;
- **NEMA ANSI C136.41 7 Pin receptacle and dimming control gear on luminaire;**
- **Outsourced (cloud based) server –** annual fees apply.

10.4.2 CMS Product and Service Costs

The costs below have been identified from a range of recent international large-scale CMS deployments and from discussions with leading suppliers. This pricing is on the basis of a large scale deployment of at least 10,000 lightpoints.

- **CMS Controls Capex –** Total system Cost $100-200/lightpoint;
- **CMS Controls Opex –** Cloud computing service, Annual Cost <$1-$20/lightpoint/yr.

10.4.3 Trends in Smart Controls Costs

At present prices for small-scale and pilot smart controls deployments in Australia are well above international benchmarks. However, it is likely that prices will steadily reduce towards international benchmarks through the combined effects of technology improvements, competitive pressures and economies of scale.

The first large scale Australasian rollout of CMS controls is in New Zealand implemented by Auckland Transport and deployment costs appear to be in reasonable alignment with international levels for large projects.

10.4.4 Useful International Organisations

Organisations and programmes exist internationally that work collaboratively to apply harmonised model specifications, collective management and tender processes. Some examples are the US Municipal Solid State Lighting Consortium (MSSLC),[205] LightSavers Canada[206] and Lighting Urban Community International (LUCI)[207] France. At the regional level the Connecticut Conference of Municipalities Street Light Program[208] is a US example of community focused activity to bring lower costs and greater deployment effectiveness. The IPWEA SLSC Programme is a similar initiative.

Figure 41 – LiDAR high speed street lighting luminaire and pole survey vehicle (Haks Inc)

10.5 Investment and Project Implementation

A number of factors and project steps require attention and management in order to effectively implement a LED/CMS infrastructure investment project. These are covered in the subsections below. The estimated costs of these items are discussed in Section 10.5.6.

10.5.1 Project Planning and Management

Specialist skills are required in a range of disciplines:

- Project management and planning,
- Luminaire technologies,
- Controls technologies,
- Lighting design,
- Standards and regulations: lighting, electrical, communications,
- Asset management,
- Financial modelling and analysis,
- Specification compilation and procurement processes.

Even the largest of city councils are unlikely to have all of the skills available in-house and suitable consultancy and advisory resources will need to be utilised. This is particularly the case in Australia where street lighting responsibility in most regions has been historically outsourced for many decades to DNSPs and to regional county councils before them leaving many councils with little in-house lighting expertise.

10.5.2 Investment Grade Audit

Best practice large-scale international LED replacement programmes use investment grade asset audits to fully understand the condition and consequences of replacing the lighting assets.

This pre-investment due diligence process usually highlights the often substantial discrepancies in current inventory records and asset condition, and thus value. The results of these surveys not only provide reliable investment figures, but also act as reference points to chart the future progress of performance. The approximate costs of such a service at large-scale is around $50-100/km. Modern surveying tools such as LiDAR[209] mapping are particularly useful to provide rapid and accurate audits of this kind, illustrated in Figure 41. This translates into a cost of between $4 and $8 per luminaire for columns spaced at 80m intervals.

205 http://energy.gov/eere/ssl/doe-municipal-solid-state-street-lighting-consortium
206 http://www.canurb.org/lightsavers/
207 http://www.luciassociation.org
208 http://www.ccm-ct.org/street-lighting-program
209 LiDAR - Acronym for Light Detection and Ranging. A surveying technology that measures distance by illuminating a target with a laser light http://pointgeodata.co.nz/services/

10.5.3 Lighting Design

Best practice large-scale international LED replacement programmes, prepare a lighting Masterplan to re-evaluate lighting needs of the community and standards compliance before actioning new LED deployment. This uses the opportunity presented by the update of technology to address the often long and complicated history of street lighting where pole locations have changed from the original design, poles have been removed as development has occurred, road usage has changed over time, tree canopies have matured etc.

Reviewing the lighting design is highly desirable but of course it comes at a cost. For a 10,000 luminaire installation the design assignment is likely to be in the region of $80,000 - $120,000 or $8-$12/luminaire.

The alternative is to adopt a 'better-than-before' one-for-one luminaire replacement approach with only generalised design done at the planning stages and then luminaires are installed on a pragmatic luminaire like-for-like basis. This is a seemingly economic approach and may be suitable in some circumstances but is not generally recommended as it makes lighting design assumptions that may not reflect the actual situation in the field. A common practical approach used internationally is to ensure that the design process achieves a better-than-before result.[210] This means that regardless of the design process used, the results for consumers should be a positive outcome and a demonstrably better result than before (i.e. BAU).

10.5.4 Procurement

Good procurement is an especially vital process for LED luminaires and controls because of their relative newness to the Australasian market and their greater ability to meet a wide range of requirements. But with greater complexity and choice, risks also increase. Good procurement processes pre-emptively manage and mitigate these risks (see Section 13).

Luminaires and controls are international products and technical specifications used in procurement processes should be internationally aligned and specify desired outcomes as previously identified. In addition, technical requirements must be based on objective evidence or standards, not opinions, and comply with ethical and prudential guidelines, international trade rules and national and state public procurement criteria. There are a significant number of early LED deployment examples in Australia where these general guidelines on good procurement have not been met.

As procurement operations are a capability that is required across all council or DNSP purchasing functions, this has not been identified as an additional investment cost.

10.5.5 Ongoing Monitoring of Performance

Street lighting infrastructure changes over time as a result of aging components, interference from vegetation, water, dust, or physical movement resulting from vehicular vibration or impact. Safety and amenity functions my have been delivered when constructed, but this deteriorates over time as with any other physical asset. Although LED maintenance requirements (due to reliability) are significantly lower than with traditional technologies, it still needs to be carried out mainly due to cleaning requirements. An annual (or less frequent periodic) audit of street-level lighting performance is a worthwhile asset management and performance management measure for safety assets that will last for up to two decades with good maintenance.

For large deployments, advanced technology vehicle-based survey and monitoring techniques based on GPS and LiDAR mapping are available. This is also a very practical and effective basis for luminaire warranty claim enforcement. As mentioned above, the costs of this performance monitoring is between $6 and $8 per lightpoint per audit and one form of the monitoring is shown in Figure 42.

Figure 42 – Dynamic street mapping of actual comparative illumination performance (Odyssey Energy)

10.5.6 Overall Project Management Investment Costs

The cost of undertaking these project management tasks are difficult to accurately quantify for application across Australia. An estimated cost of 10% is used as an average figure for modelling purposes in this Roadmap and included in the installation costs in Table 25. This is based on consultant experience and includes a realistic estimate of the cost of in-house management time and resources as well as consultancy fees for outsourced assistance. Project management cost for projects does not vary linearly with size, as some baseline tasks are fixed cost, so smaller retrofit projects will have larger project management costs on a per unit basis.

210 Ed Ebrahiminian, Director, Bureau of Street Lighting, City of Los Angeles, Personal communication March 2014

11

BARRIERS

This section outlines the barriers and impediments to an efficient marketplace where the successful adoption of modern street lighting can take place to provide the appropriate safety, security and comfort outcomes. Identification and analysis of these barriers is important because the advantages available to the community from modern street lighting technologies can provide substantial public benefits as identified in earlier sections, and which appear to be unnecessarily impeded and/or delayed in Australasia.

11.1 Introduction

With at least a 50% reduction in maintenance costs, 50% reduction in energy use and a host of other benefits, US consulting firm Navigant estimated that more than 13 million LED street lights had been deployed worldwide by 2014. In contrast, LED street lighting has been slow to be adopted in Australia with at most 9.5% of the 2.3 million luminaires being LED.

This section approaches the topic from the perspective of market experience gained from street lighting advisory work for local governments and is also informed by references publications that have addressed this issue listed below:

1. *Analysis of Essential Energy Proposal to the Australian Energy Regulator (For Street Lighting),* Strategic Lighting Partners Ltd, August 2014.
2. *Assessing the Potential Cost Savings from Accelerating the Rollout of LED Road Lighting,* PwC New Zealand, October 2014.
3. *Barriers to Energy Efficient Street Lighting,* PricewaterhouseCoopers (PwC), July 2011.
4. *Draft Street Lighting Strategy for Australia,* Ironbark Sustainability, July 2011.
5. *EECA Review on the Likely Impact of an Uptake in LED Road Lighting,* PwC New Zealand, October 2014.
6. *Implications of Evolving Technologies for Pricing of Distribution Services,* Submission to the New Zealand Electricity Authority (EA), IPWEA, 2 February 2016.
7. *Lighting the Way to Road Safety – a Policy Blindspot?,* G Bridger and B King, Australasian Road Safety Research, Policing and Education Conference, October 2012.
8. *Practice Note 11 - Towards More Sustainable Street Lighting,* Institute of Public Works Engineering Australasia (IPWEA), July 2014.
9. *Strategic Road Lighting Opportunities for New Zealand,* Bridger Beavis and Associates Ltd, May 2012.
10. *Street Light Asset Value Determinations in the NEM and WEM,* Marsden Jacob Associates, Financial and Economic Consultants, July 2014.

Barriers to uptake outlined in this section are divided into six categories: regulatory and contractual, economic, standards, knowledge (including technical and training), and capability.

11.2 Electricity Regulatory Barriers

More than 90% of the street lights in Australia are owned by the 15 Distribution Network Service Providers[211] (DNSPs) who are regulated monopolies subject to a complex set of rules and practices outlined in Section 4.

211 *Practice Note 11 - Towards More Sustainable Street Lighting, Institute of Public Works Engineering Australasia (IPWEA),* July 2014, page 7

Table 27: Regulatory Barriers to Efficient Market Operation

	Name	Description
1	Responsibility not aligned with ownership	Local councils are legally obliged to consider whether to provide, and to what level of service, street lighting is to be provided to the community under local government acts and roads acts, but the 15 DNSPs own more than 90% of the street lights. Councils, DNSPs, regulators and other stakeholders have been able to muddle through these misaligned incentives for several decades while lighting technology has been relatively stable. However, this situation is changing rapidly with the advent of commercially viable LEDs and smart control systems. Pressure to widely adopt new street lighting technologies is growing rapidly around the world and is testing existing approaches to the management of street lighting, particularly where DNSPs own the street lights.
2	Lack of cost-reflective and service-based pricing[212 213]	The pillar of monopoly regulatory policy is that the service provided is transparently cost reflective and service-based and is undermined by pricing that does not reflect: • Reduced service performance levels (street lighting is not subject to SAIDI[214], CAIDI[215] etc. performance monitoring); • Service reliability levels below that of the rest of the electricity network (i.e. those regulated as "direct control services"); • Entirely predictable loads consisting of broadly 80% off-peak usage. Street lighting is effectively a Time-of-Use tariff as the load is known with a high degree of precision based on sunset and sunrise times and AEMO unmetered load tables. DNSP charges do not reflect this; • Transparent street lighting network asset inventories and valuations (in comparison to luminaires and poles which are transparently documented); • The range in $/GWh revenue raised for street lighting (alternative control service) is greater than the range for the total network (standard direct control service).
3	Inappropriate metering certification	Current demand is calculated, not metered (Metering Type 7)[216], but regulations require replacing that crude and un-metered system by modern controls to inappropriately onerous certified accuracy levels incompatible with individual street lighting loads that are less than 100th of that for which meters are currently regulated (Type 4).[217] Furthermore, current metering certification systems appear to provide insufficient monetary savings from energy savings.
4	High carrying amount[218]	Perhaps the biggest economic challenge to the widespread adoption of energy efficient lighting in some jurisdictions is the high residual asset value claimed by some Australian utilities for existing street lights. Claimed carrying amounts can be up to several hundred dollars per light, despite asset registers that are incomplete and/or with little or no condition information reflecting their obsolete or poor condition. Councils would either have to pay out these residual asset values before new lights are installed (making the economics of mass deployment potentially unattractive) or the utilities would have to write-down the value of these old lighting assets.
5	Delayed approval[219]	Surveys of councils have indicated that delays by DNSPs in providing street lighting type approvals are a barrier to change to modern street lighting products. These approvals are required to ensure lights are safe and meet the requirements of the DNSP network.
6	DNSP certification to AS 3000	DNSPs are not required to meet AS 3000 wiring standards because they are separately regulated to meet safety and reliability standards that result in outcomes that are equal or higher to those resulting from AS 3000. However, as soon as another non DNSP entity takes over the street lighting network, it will need to meet AS 3000 standards. Because DNSPs are not familiar with AS 3000 nor have ever needed to certify that they comply with it, local government councils are understandably reluctant to support a transfer to a non-DNSP entity without specific DNSP confirmation of such compliance which is unlikely without regulator intervention. This is therefore a barrier to street lighting providers competing with DNSPs.

212 Submission to AER on Ausgrid's Tariff Structure Statement by SSROC

213 Submission to New Zealand Electricity Authority, IPWEA, 2 Feb 2016

214 System Average Interruption Duration Index

215 Customer Average Interruption Duration Index

216 David Ripper, AEMO, Smart Street Lighting Forum, 12 May 2016

217 <750 MWh per year, whereas an individually metered street light load is < 0.75 MWh

218 *Practice Note 11 – Towards More Sustainable Street Lighting*, Institute of Public Works Engineering Australasia (IPWEA), July 2014

219 *Draft Street Lighting Strategy for Australia,* Ironbark Sustainability, July 2011

11.3 Commercial Barriers

IPWEA has identified that the barriers shown in Table 28 represent commercial barriers to an efficient market operating in the street lighting sector.

Table 28: Commercial Barriers to Efficient Market Operation

	Name	Description
6	Uncertainty of asset condition[220]	Information on street lighting asset condition is generally unavailable unless the asset was recently installed or an asset audit taken place before ownership is to change. Uncertainty relating to asset condition is a barrier to market entry as it represents a significant investment uncertainty risk.
7	Poor asset condition	Where scrutiny of assets has taken place, unusually old and poor asset conditions have indicated that a “wave” of re-investment will be required to sustain street lighting performance. Together with the uncertainty identified in item 6, the size of re-investment required to keep street lighting infrastructure in an operable state could amount to a substantial barrier to investment.
8	No contractual Service Level Agreements (SLAs)[221]	Despite hundreds of millions of dollars changing hands annually, no contractually binding service level agreements exist in most jurisdictions.
9	Lighting level determination	Investment levels appropriate to delivering required safety outcomes through the determination of illumination levels are not objectively defined. The decision to select a AS/NZS1158 road subcategory (V1 to V5, and P1 to P5 which determine the lighting levels) for a particular road is a subjective decision made according to many factors. One of the few objective measures used (only) for V category roads is Annualised Average Daily Traffic flow (AADT) which as the name suggests, still rather unsatisfactorily averages daily traffic flow across the year.
10	Poles and column categorisation and condition	Columns and poles provide structural support to the luminaires and their cabling and are the highest capital cost category in the street lighting portfolio. Uncertainty in whether replacement costs are council’s or DNSPs or lack of condition status data provides significant barriers to efficient market operation. For example, if a significant fraction of poles are near the end of their economic life and need replacement, councils or third party providers could face substantial investment uncertainty.
11	Barriers to trade	Trade protection and competition reducing issues have hindered the timely introduction of modern practices and technologies and includes prescriptive luminaire Standards and specifications that have specified how outcomes are achieved rather than what outcomes should be achieved, and procurement practices that effectively stipulate brands or manufacturers rather than agnostic specifications.

11.4 Barriers from Standards

Where councils are responsible for public services that could result in accident or injury they need to demonstrate that they have exercised a required duty of care. This is usually done by reference to technical standards, specifications and best practice guidelines established by industry bodies including those like IPWEA and Standards Australia (SA).

With respect to public lighting, councils in Australia have almost universally adopted standards series AS/NZS 1158 Lighting for Roads and Public Spaces. The way that such standards are funded, implemented and promoted means that they have significantly contributed to the raising of barriers to an efficient market place as outlined in Table 29.

220 From various consultancy assignments by NE and SLP

221 *Practice Note 11 – Towards More Sustainable Street Lighting*, Institute of Public Works Engineering Australia (IPWEA), July 2014, s 7.3, page 32

Table 29: Standards Barriers to Efficient Market Operation

	Name	Description
11	Substantial lag time in standards development[222]	The AS/NZS 1158 standard series cited by virtually all road controlling authorities has been extremely slow to catch up with new technologies and design techniques. For example, it was only in October 2015 that a replacement of the prescriptive and restrictive luminaire standard removed the "not permitted" status of LED lighting (which was ignored by many councils). Other important technical advances are still not accommodated in this standard series so this imposes a serious time lag on innovation in the sector.
12	Lack of understanding	Responding parties to surveys[224] cited that standards were a barrier and frequently referred to a lack of understanding. The detailed requirements and complexity of the standards make understanding difficult by all except highly specialised practitioners.
13	Lack of compliance[223]	Complexity, lack of focus on asset condition and lack of understanding makes a strong contribution to the generally poor compliance levels attained in the field. In the few instances where surveys of lighting levels have been conducted, compliance is achieved on usually less than 50% of the roading network.
14	Lack attention to asset lifetime performance	Current standards are focused on designs for new or retrofit lighting schemes. Street lighting luminaires have a design life of 20 years and the measurements and verification of performance and safety dependent functions over that lifetime is not covered in the standards.[225] This leaves an important asset condition monitoring function without any formal requirement, which will eventually result in non-compliant performance over time.

11.5 Knowledge Barriers

Up until about 2012, street lighting was a very slow moving and conservative sector. With the introduction of LED lighting and controls systems, it has evolved and expanded very quickly with much new knowledge required to make the most of the new developments and opportunities. The knowledge gaps represent significant barriers to an efficient market and are identified in Table 30.

Table 30: Knowledge Barriers to Efficient Market Operation

	Name	Description
15	Technical challenges	The rapid pace of change in street lighting technology has created substantial challenges for all players in attempting to keep up with current practice. The pace at which new LED luminaire models are released, the diversity of approaches to luminaire design, unknown product lifetimes and the large number of new suppliers are also particularly challenging for councils, consultants and DNSPs. There is a need for specific guidance, documentation and training to address these gaps.
16	Overstated and unsubstantiated claims	Commercial practices by some suppliers have served to impede progress, such as over-hyped and/or unsubstantiated product performance claims, poor warranties and lack of specific street lighting application experience.
17	Lack of in-house expertise	With some notable exceptions, most Australian councils have little or no in-house street lighting technical expertise and have historically, been totally dependent upon their electricity distribution utility for technical advice. This has left many senior staff in councils unaware of the opportunities now emerging in street lighting and this has significantly delayed progress in adopting new technologies.

222 AS/NZS 1158 Series, *Lighting for Roads and Public Spaces*

223 *Draft Street Lighting Strategy for Australia*, Ironbark Sustainability, July 2011

224 Lighting surveys in three council areas: Sunshine Coast, Waipa and Hamilton

225 AS/NZ1158 series has general and non-specific motherhood statements about good maintenance, but no tangible requirements on ongoing performance measurement and verification

11.6 Financial Barriers

The financial barriers are identified in Table 31 appear to be the easiest to mitigate.

Table 31: Finance Barriers to Efficient Market Operation

	Name	Description
18	Lack of capital finance	Lack of capital to finance upgrades and capital constraints (i.e. caps) in local government borrowing is seen by some as a barrier.[218] However, the CEFC and private sector are very keen to provide capital for street lighting as the demand for the underlying service is stable, secure and long term. New street lighting technologies are climate change friendly and thus meet public and private policy requirements for support eligibility. With respect to the availability of CEFC financing, this is only of use if local governments and main road authorities are able to finance lighting upgrades. As identified elsewhere in this Section, some utilities have not yet accepted LEDs, many have not agreed to accelerated replacements of lighting and some do not allow external financing of lighting on their networks. In some jurisdictions, claimed carrying amounts of existing lighting make replacement of lighting financially unattractive.
19	Mismatched carbon emissions financial incentives	The Commonwealth and state incentive schemes (e.g. ERF, ESS, VEET, EEIS) aimed at increasing energy productivity and/or reducing Australia's emissions have in many cases not to date been taken up widely for public lighting upgrades. Some have not contained mechanisms for public lighting (e.g. EEIS and VEET), some have not been well tailored to the issues encountered in public lighting (e.g. ESS) and some do not appear to provide a sufficient financial incentive to motivate behaviour change (e.g. ERF). Recent reform to the NSW Energy Savings Scheme appears to address previous challenges with the rules for public lighting in that jurisdiction and the VEET scheme has recently introduced a mechanism for public lighting but further development is likely required in other jurisdictions to see widespread take-up of incentives.

11.7 Communication Barriers

Updating street lighting and control systems represents a significant opportunity to engage the public in a highly positive, visible and viable initiative. Opportunities of this type are not common, but like all initiatives, there are negative issues to manage such as a recent announcement by the American Medical Association (AMA) which media incorrectly identified as being against LED lighting (see Section 3.2.2 where this issue is discussed). The communication barrier is identified in Table 32.

Table 32: Communication Barrier to Efficient Market Operation

	Name	Description
20	Lack of stakeholder engagement	There is a compelling need for councils and utilities implementing changes to street lighting technologies to communicate in a proactive manner with stakeholders. The risk of not doing this is that misinformation and unsubstantiated claims can become commonplace, as is the case with all emerging technologies. A focused and well-presented storyline is needed to address the interests and concerns of senior council staff, utility management, government, regulators, lighting suppliers and community groups with an interest in public lighting. This should provide clear and balanced messages about the energy, monetary, environmental, safety and public health benefits of the adoption of improved lighting technologies.

226 *Draft Street Lighting Strategy for Australia,* Ironbark Sustainability, July 2011

12

STAKEHOLDER ENGAGEMENT

This section outlines the important issues that relate to effective stakeholder engagement. Without excellent stakeholder engagement, few significant changes and improvements are able to be enacted. In today's internet age, the ability to engage with stakeholders is assisted and improved, but it is also made more difficult by the clutter of competition from other calls for engagement.

Until very recently, street lighting has suffered from lack of focus and attention – and thus engagement - by any wider stakeholder group, mainly because it was taken for granted as a necessary fact of life and neither its advantages or disadvantages were questioned. With the advent of new white LED lighting and controls, recognition of light pollution, the loss of the night sky and public lighting's effects on ecology, the whole subject is becoming more relevant to the wider community and worthy of engagement. This section of the Roadmap identifies a systematic approach to stakeholder engagement.

The three key issues in stakeholder engagement are:

- Defining the stakeholders
- Defining the messages
- Determining when and how the messages are communicated.

Only the first two are considered in this Roadmap as how and when messages are to be delivered are part of an action plan that only follows if the findings of this Roadmap are accepted and are to be implemented.

12.1 Introduction

At the very fundamental level anyone who experiences and relies on street lighting is a stakeholder. However, for the purposes of this report that implicit level stakeholder is considered to be represented by the various organisations who *are* considered to be stakeholders in this section. These include local, state and Commonwealth government and non-government organisations (NGOs).

Street lighting application and service delivery requires a surprisingly multi-disciplinary approach and therefore has a wide range of stakeholders. These stakeholders can be broadly categorised by those involved in the public interest and those that have commercial interest, though each stakeholder may have some characteristics of both. The public interest sector can be further divided into government and non-government organisations.

This wide range of stakeholders provide both a threat and an opportunity for the public sector. The threat is that any change provides significant "knock-on" effects and consequences that need to be considered. On the other hand the authors believe that communicating all the issues to the public provides substantial net positive public relations opportunities for those responsible stakeholders as long as everything is communicated with integrity. Accelerating LED lighting and smart controls correctly is very likely to receive enthusiastic engagement by the public because the advantages are so much greater than the disadvantages.

12.2 Government Organisations

Australian street lighting is governed to a greater or lesser extent by its three levels of government, the Commonwealth, the eight states and territories[227] and more than 500[228] local government councils. Each of these have departments, divisions, or sections that have interests or responsibilities that intersect with street lighting.

Table 33 identifies those stakeholders at Commonwealth or national level, or at a level that includes more than one state, as for example the National Electricity Market (NEM) and the government organisations that are responsible for it, including the Australian Energy Regulator (AER).

Table 33: Government Stakeholders Above State Level

Government Level	Organisation	Division or Section	Role (relevant to street lighting)
Commonwealth government	Department of the Environment and Energy (DEE)	Energy (incl COAG Energy Council), Climate Change and Renewables Innovation	Policy and programmes on equipment energy efficiency, enabling technologies, and policy and investment in clean environment including climate change.
	Department of Infrastructure and Regional Development	Infrastructure, Transport, local government	Policy and investment in roads (including intelligent transport systems), local government and safety.
	Department of Prime Minister and Cabinet	Smart Cities	Advice and programmes to PM, cabinet and portfolio ministers.
National agencies (completely or majority funded by governments)	Australian Energy Regulator AER (part of the ACCC[229])	Electricity Networks Investment and Pricing	Regulates electricity and street lighting economics in the NEM (NSW, VIC, QLD, SA, TAS, ACT).
	Australian Energy Market Operator AEMO	Operations, Corporate Development	Efficient electricity market and system operation for the long-term interests of consumers.
	Australian Energy Market Commission AEMC	Electricity Network Reform	Sets and reviews electricity market rules in the NEM.
	Austroads (Association of Australasian road transport and traffic agencies)	Asset Program, Safety Program	Expert technical advice for input into policy, improving practice and operational consistency.
	National Transport Commission NTC	National Land Transport Productivity	Develops regulatory and operational reform of road transport.
	Clean Energy Finance Corporation CEFC	Corporate and Project Finance	Co-finances and invests in clean energy projects and technologies.
	Clean Energy Regulator	Regulatory Obligation and Coordination	Administers legislated schemes for measuring, managing, reducing or offsetting carbon emissions.
	Australia New Zealand Policing Advisory Agency	Preventing Crime, Road Safety	Advises federal, state and territory police who all need street lighting for their operations.

227 Counting ACT as one, although sometimes it is reported together with NSW.

228 Before amalgamations the Department of Infrastructure and Regional Development reported there were 571 in its Annual Report 2014-15 (page 2). The Australian Local Government Association reports that there are now 536 Councils (email 16 November 2016).

229 ACCC is Australian Competition and Consumer Commission.

12.3 State Government Organisations

With eight states and territories each having their own stakeholder organisations relating to street lighting, Table 34 provides New South Wales as an example of relevant stakeholders in the largest state (by population) to be engaged in any significant change. [230]

Table 34: NSW State Government Stakeholders

NSW Organisations	Divisions or Sections	Role (Relevant to Street Lighting)
NSW Department of Industry, Skills and Regional Development	Resources and Energy Division	Securing, regulating and delivering NSW's electricity resources.
Transport for NSW	Transport Projects, NSW Centre for Road Safety	Policy and investment in roads and safety initiatives.
Roads and Maritime Services RMS	Roading infrastructure	Investment in road operations including lighting for state roads.
NSW Police	Road Safety	Compliance with safety and criminal laws at night.
Department of [Land[230]] Planning and Environment	Growth, Design and Programs, Policy and Strategy, Planning Services	Principal government agency responsible for driving sustainable growth in NSW through land development.
Office of Local Government NSW	Policy and Sector Development	*"The Office has a policy, legislative, investigative and program focus in matters ranging from Local Government finance, infrastructure, governance, performance, collaboration and community engagement."* Street lighting is clearly part of this role.
Independent Pricing and Regulatory Tribunal of NSW	Energy and Transport, Local Government	Independent regulator that determines the maximum prices that can be charged for retail energy, water and transport services and also determine local government rates.
Infrastructure NSW	Transport, Social and Cultural Infrastructure	Independent infrastructure agency with long and medium term planning advisory functions without regulatory powers but able to take over management of infrastructure projects for the government.

12.4 Local Government Councils

With responsibility for 85% of roads, local government councils[231] are clearly one of the most important street lighting stakeholders. According to the Department of Infrastructure and Regional Development (DIRD) there were 571 local councils in 2013 in Australia[232]. The Department administers a grant scheme to all councils and does this by categorising them according to several characteristics they use to calculate untied grants of $2.7 billion[233] (able to be spent under full discretion of the council).

This categorisation divides 245 councils into 13 different urban categories shown in Table 35 and 319 councils into nine rural categories shown in Table 36[234]. This categorisation is useful for stakeholder engagement as it allows communications messages and engagement to be tailored appropriately. DIRD provides the names of all 571 councils each identified by one of the 22 different categories shown in the following tables

230 The formal name of the organisation does not contain the word "Land" but it is needed for this abbreviated table.

231 From Austroads http://www.austroads.com.au/about-austroads/local-government

232 Before amalgamations the Department of Infrastructure and Regional Development reported there were 571 in its Annual Report 2014-15 (page 2). The Australian Local Government Association reports that there are now 536 Councils.

233 Per e-mail from ALGA 16 Nov 2016

234 Note that the council numbers for these tables add up only to 364 because there were fewer councils in 2013 than there are now

Table 35: Local Government Urban Council Categories[235]

Council Type	Size	Identifiers	Category Name	Total Councils
Capital City (CC)			UCC	7
Metropolitan Developed (D) Part of an urban centre of more than 1,000,000 or population density more than 600/square kilometre	Small (S) Medium (M) Large (L) Very Large (V)	up to 30,000 30,001–70,000 70,001–120,000 more than 120,000	UDS UDM UDL UDV	14 23 27 24
Regional Towns/City (R) Part of an urban centre with population less than 1,000,000 and predominantly urban in nature	Small (S) Medium (M) Large (L) Very Large (V)	up to 30,000 30,001–70,000 70,001–120,000 more than 120,000	URS URM URL URV	38 44 12 13
Fringe (F) A developing LGA on the margin of a developed or regional urban centre	Small (S) Medium (M) Large (L) Very Large (V)	up to 30,000 30,001–70,000 70,001–120,000 more than 120,000	UFS UFM UFL UFV	8 15 6 14
Total Urban Councils in 2013				**245**

Table 36: Local Government Rural Council Categories[235]

Council Type	Size	Identifiers	Category Name	Total Councils
Significant Growth (SG) Average annual population growth more than three per cent, population more than 5,000 and not remote			RSG	2
Agricultural (A)	Small (S) Medium (M) Large (L) Very Large (V)	up to 2,000 2,001–5,000 5,001–10,000 10,001–20,000	RAS RAM RAL RAV	65 52 56 62
Remote (R)	Small (S) Medium (M) Large (L) Very Large (V)	up to 400 401–1,000 1,001–3,000 3,001–20,000	RTX RTS RTM RTL	18 13 29 22
Total Rural Councils in 2013				**319**

235 Department of Infrastructure and Regional Development (DIRD), *Local Government National Report 2013-14,* Appendix F, page 201, Table F1

12.5 Distribution Network Service Providers (DNSPs)

Other important stakeholders are the 15 Distribution Network Service Providers who own more than 90% of Australia's street lighting assets[236] which are listed in Table 37.

Table 37: Distribution Network Service Providers[237]

Network	Number of Streetlights	Network Length (km)	Asset Base ($ million)	Owner	State
ActewAGL	82,973	5,151	848	ACTEW Corporation (ACT Government) 50%; Jemena (State Grid Corporation 60%, Singapore Power International 40%) 50%	NSW
Ausgrid	250,907	41,271	14,555	NSW Government	NSW
AusNet Services	143,064	44,842	3,190	Listed company (Singapore Power International 31%, State Grid Corporation 20%)	VIC
CitiPower and Powercor	216,071	78,662	4,828	Cheung Kong Infrastructure /Power Assets 51%; Spark Infrastructure 49%	VIC
Endeavour Energy	204,569	35,492	5,698	NSW Government	NSW
Energex	358,738	52,097	10,880	QLD Government	QLD
Ergon Energy	140,028	160,083	9,007	QLD Government	QLD
Essential Energy	154,009	183,481	6,881	NSW Government	NSW
Jemena	71,773	6,161	1,106	Jemena (State Grid Corporation 60%, Singapore Power International 40%)	VIC
SA Power Networks	230,710	88,083	3,638	Cheung Kong Infrastructure /Power Assets 51%; Spark Infrastructure 49%	SA
TasNetworks	49,177	22,496	1,520	Tasmanian Government	TAS
United Energy	119,957	12,823	1,930	DUET Group 66%; Jemena (State Grid Corporation 60%, Singapore Power International 40%) 34%	VIC
Power & Water	17,570	10,265		NT Government	NT
Horizon Power	18,714	8,186	1,600	WA Government	WA
Western Power	259,397	100,303	9,780	WA Government	WA

236 *Practice Note 11 – Towards More Sustainable Street Lighting*, IPWEA, July 2014, page 7

237 AER and Annual Reports for WA and NT, and survey of DNSPs by IPWEA, 2016.

12.6 Non-government Organisations (NGOs)

Non-government organisations are *"...not-for-profit organisations that are independent from state and international governmental organisations"*[238] and represent public interest issues. An example of an NGO in this category is the Australian Local Government Association, ALGA. A sub-category of the NGO are the Advocacy or Special Interest groups who represent and advocate on behalf of the collective interests of a group of commercial or self-interested members. An example of this category of NGO is Lighting Council Australia (LCA), whose membership is made up of lighting manufacturers and importers. Each category of NGO is tabulated below separately.

12.6.1 Public Interest NGOs

A non-exhaustive list of independent NGOs is shown in Table 38.

Table 38: Independent Non-government Organisations

Organisation	Role (relevant to street lighting)
Standards Australia (SA)	Peak organisation that drafts standards through consultation with industry and government. Responsible for several standards directly relating to street lighting.
Institute of Public Works Engineering Australasia (IPWEA)	Professional organisation providing member services and advocacy for those involved in and delivering public works and engineering services to the community both in Australia and New Zealand.
Local Government Professionals Australia	Peak organisation representing Australia's Local Government Professionals.
Australian Smart Communities Association (ASCA)	Recently formed association targeted at local government councils and industry with strong collaborative objectives and government support.
CIE Australia	Professional scientific organisation devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting.
Cities and the Built Environment Taskforce	New cross-government taskforce formed by government to increase benefits from city growth through planning integration between infrastructure, digital, and greening initiatives.
International Dark Sky Association of Victoria (IDSA Vic)	The representative organisation of the International Dark Sky Association in Australia with strong interests to reduce white light street lighting pollution.
Australian Automobile Association (AAA)	Peak organisation representing Australia's motoring public, with a combined membership of eight million Australians.
Smart Cities Council	Well-funded International organisation based in Washington USA, with many multinational partner members and likely interest in Australia.
Police Associations	Police are sensitive to the absence of street lighting. Their associations include: Australian Federal Police Association; Police Association of New South Wales; Police Association of South Australia; Police Association of Victoria; Queensland Police Union; Western Australian Police Union.

238 https://en.wikipedia.org/wiki/Non-governmental_organization

12.6.2 Local Government NGOs

The distinction between public interest and advocacy NGOs is sometimes difficult to make when the NGO is advocating on behalf of other public good organisations such as for example the local government associations. In this report they are therefore categorised separately. Clearly these associations are an important category of stakeholder that should be used to communicate street lighting issues.

Table 39: Australian Local Government NGOs

Organisation	Website
Australian Local Government Association ALGA	http://alga.asn.au/
Local Government New South Wales	http://www.lgnsw.org.au/
Local Government Association of South Australia	http://www.lga.sa.gov.au/
Municipal Association of Victoria	http://www.mav.asn.au/
Local Government Association of Tasmania	http://www.lgat.tas.gov.au/
Local Government Association of The Northern Territory	http://www.lgant.nt.gov.au/
Local Government Association of Queensland	http://www.lgaq.asn.au/
The Western Australian Local Government Association	http://www.walga.asn.au/
Council of Capital Cities Lord Mayors	http://lordmayors.org

12.6.3 Advocacy NGOs

These are NGOs whose members either have commercial interests or strong advocacy positions.

Table 40: Advocacy NGOs

Organisation	Role (relevant to street lighting)
Lighting Council Australia (LCA)	Lighting Council Australia represents Australia's lighting manufacturers and importers. Its goal is to encourage the use of environmentally appropriate, energy efficient, quality lighting systems.
Energy Networks Australia (ENA)	Peak Australian body representing the gas and the 15 electricity network (called Distribution Network Service Providers, DNSPs) companies who collectively own more than $100 billion in infrastructure assets. The DNSPs own more than 90% of all street lights.
Urban Taskforce Australia	Represents Australia's most prominent property developers and equity financiers.
Australian Tourism Export Council (ATEC)	Peak industry body representing more than 850 members in Australia's $33.4 billion tourism export sector. As an organisation, our views are informed by the broadest cross-section of the Australian tourism industry. Street lighting is relevant to their members, especially those with a night time interest.
Institution of Engineers Australia	National forum for the advancement of engineering and the professional development. With over 100,000 members it is the largest and most diverse professional body for engineers in Australia.
Illuminating Engineering Society of Australia and New Zealand (IESANZ)	Advances *"... the art and science of illumination and the dissemination of knowledge to all interested parties. The Society's diversified membership includes engineers, architects, educators, students, contractors, manufacturers and designers."*

12.7 Key Messages

The key messages identified in Table 41 have been derived from the previous sections in the Roadmap. They are intentionally simplified to increase impact, but they require significant support information to justify the high level message.

Table 41: Key Stakeholder Messages

No.	Message Name	Target Audiences	Message Description
1	**Safety**	Transport agencies, councils, their associations and state government, DNSPs	White light significantly improves driver reaction times over yellow light (40% of all lighting in Australia). Higher light levels quantitatively reduces crash numbers. Pedestrian safety and security is not adversely affected by off-peak dimming or switch-offs – i.e. midnight to 6am.
2	**Carbon Footprint**	Councils, their associations and state government	With Australia's large proportion of coal and gas fired generation, the 40%-80% energy saving converts into large greenhouse gas emission reductions.
3	**Energy Performance**	Councils, their associations and state government	LED street lighting and smart controls can save between 40% and 80% of electrical energy used by councils whose street lighting makes up about 40% of its electricity bill.
4	**Maintenance**	DNSPs, transport agencies, councils, their associations and state government	LED luminaires have a reliability record ten times better compared to legacy technologies.
5	**Asset Management**	DNSPs, transport agencies, councils, their associations and state government	Smart digital control systems proactively monitor and control operations, reducing or eliminating expensive service trips. The systems use asset management software to allow a quantum leap in asset management efficiency and planning.
6	**Light Pollution**	Transport agencies, councils, their associations and state government, DNSPs	LED luminaires have much better light-spill control than legacy technologies. Smart controls enable light levels to be reduced or switched-off during off-peak night periods .
7	**Mercury Pollution**	Councils, their associations and state government	LED lighting contains no hazardous mercury. Unlike legacy technologies.
8	**Green Investment**	Clean Energy Regulator, Clean Energy Finance Corporation, councils	LED Street lighting is a very environmentally effective and financially productive infrastructure investment – either via debt or equity.
9	**No contracts**	Councils, DNSPs and their associations	Despite the more than $400 million/yr council cost for street lighting, no contractually binding service level agreements exist.
10	**Inadequate Standards Development**	Standards Australia (and MBIE Standards NZ), Commonwealth government	The inability to keep AS/NZS standards up to date with international design and technology impedes safety, economic and productivity outcomes.
11	**Arbitrary Standards Application**	Transport agencies, MBIE Standards NZ, councils, state and Commonwealth government	Loose and subjective criteria are often used by inexperienced council staff for lighting procurement and application of AS/NZS1158 based lighting solutions.
12	**Site Performance and Ongoing Performance Monitoring**	Transport agencies, councils, their associations, Commonwealth and state governments, DNSPs	Street Lighting to AS/NZS1158 compliance is a designed service. There are no requirements for actual performance to be measured and monitored initially or ongoing, like other safety critical infrastructure. Unlike Europe, no AS/NZS Standards exists for site measurement and there are no regulations covering the need for ongoing compliance.
13	**Intelligent Urban Spaces**	Transport agencies, councils, their associations and state government, DNSPs	LED lighting upgrades are a once-in-a-generation opportunity for an infrastructure refresh. Concurrently installed smart controls future proof urban areas for current and forthcoming intelligent "smart city" applications.

13

RISKS

All but largest local councils likely to be under-resourced to take full advantage of SLSC Programme.	Large number of responsible Commonwealth and state gov't departments make whole-of-government solution difficult.	Complex regulatory issues are barriers that require several high level interventions by statutory agencies.

SLSC Programme Goals are valuable and likely to be supported by all political parties – wide range of opportunities for significant gains exist.

A high risk is that opportunity to address several strategic issues may be overlooked – because energy and maintenance gains appear to be enough in themselves.

Extended product warranties significantly reduce project risk – more reliable LED luminaires, ten year warranties for LED luminaires, five year warranties for smart controls make risks acceptable.

This section examines the potential for ownership, sponsors and governance risk for the Street Lighting and Smart Controls programme to accelerate LED and smart controls deployment. The analysis is at a high strategic level and identifies the probability and impact of the risks and proposes risk mitigating actions. The next section identifies the strategic risks that face the organisations responsible for upgrading the street lighting including DNSPs, councils, and main road authorities. The final section identifies important project risk mitigation tools of warranties and insurance that have recently become available with the introduction of the new technologies – and were not previously used for legacy street lighting.

13.1 SLSC Programme Risk

Analysis of SLSC Programme risks to various stakeholders is provided in Table 42. These are a list of risks, the probability of the risk occurring, its impacts and risk mitigating actions for the owners, sponsors and governors of the SLSC Programme including the Commonwealth government and other funding partners.

13.2 Strategic Risks to Major Street Lighting Stakeholders

Table 43 identifies the high level strategic risks for stakeholders undertaking an upgrade to street lighting and smart controls. The consequences of these overarching risk factors impinge on all stakeholders, both public sector and private sector.

Table 42: SLSC Programme Risks to Programme Owners and Stakeholders

Stakeholder Group	Risk Description	Risk Level	Consequences	Mitigation
Federal government	Large number of policies involved in SLSC leads to fragmentation of Commonwealth Departmental support.	**High**	SLSC does not take a whole-of-government approach and positive Australia wide impact lost.	Strong communication of Roadmap and benefits to all relevant Departments. For example advocacy of SLSC's role in Smart City Plan (another cross-government initiative).
Local councils	All but largest councils have insufficient resources to participate in SLSC.	**High**	Does not participate in, use or support SLSC resources and thus their communities miss-out on the benefits.	Obtain state and federal government funding to sponsor participation of training courses and conference especially travel costs as these are extremely difficult for councils to fund.
Federal government	COAG, AEMC, AEMO, and AER do not support the SLSC perhaps because it represents too large a change.	**High**	ENAs may be negative to SLSC Programme as it may be seen as encouraging change unwanted by DNSPs.	IPWEA CEO to engage with ENA and DNSPs that have differences in economic viewpoints. SLSC to encourage regulatory intervention as part of regulated monopoly oversight.
Suppliers and contractors	Perceived by SMEs suppliers and contractors to favour large multinationals.	**Medium**	SLSC does not encourage a vigorous and innovative SME economy and risks not taking creative approaches.	SLSC Council and TAG functions need to be funded to promote and communicate to all participants in the market, not just the largest (which is always less costly).
Local councils	Local councils unaware of SLSC Programme.	**Medium**	Does not participate in, use or support SLSC resources.	Ensure strong advertising and PR channel activity to councils and promote SLSC Conference strongly.
State and territory governments	Lack of state or territory government support for SLSC Programme.	**Medium**	SLSC Programme has less leverage to obtain buy-in with local council and private sector partners slowing down achievement of outcomes.	Close ongoing communication between supporting Federal departments and IPWEA to the relevant state government to promote the significant state and territory benefits available.
DNSP	With 90% ownership of street lighting DNSP perceive SLSC Programme as a threat (e.g. to valuations, revenue etc).	**Medium**	Slower implementation of SLSC targets and increased dissatisfaction of councils with DNSPs.	Continue strong inter-disciplinary consultation with all parties, and prefer quality over speed.
Federal government	Insufficient funding support from the Commonwealth government (due to alternative priorities).	**Medium**	SLSC Programme has insufficient resources and fails to deliver required outcomes.	Close ongoing communication between IPWEA and Commonwealth government, influential advocacy, identify other funding sources such as state, territory and commercial sources.
State and territory governments	State and territory transport agencies perceive SLSC to be a threat.	**Medium**	Without strong support from transport agencies who have large technical experience and substantial influence the programme could stumble.	Commonwealth and state government enlisted to advocate the benefits of the SLSC Programme to transport agencies. IPWEA and governments to liaise with the prime association of transport agencies Austroad.
DNSPs	DNSPs do not give Street lighting priority in the face of other strategic priorities such as distributed generation and smart grids.	**Medium**	DNSPs may be negative to SLSC Programme and thus significantly slow the programme down.	Advocate the synergies between smart grid, smart distribution, smart cities, smart consumers and the opportunity to remove a cause of significant stress between councils and DNSPs.
Federal government	Goals of new Commonwealth government are not aligned with those of the SLSC Programme.	**Low**	SLSC Programme support is withdrawn and thus fails to deliver required outcomes.	Close ongoing communication with IPWEA CEO and project advisors to consider ways of aligning and/or Programme adaption, promotion of SLSC as delivering cross-party policy outcomes.

Table 43: Strategic Risks for Street Lighting Owners and Major Stakeholders

	Risk Type	Description	Probability	Explanation	Impact	Consequences	Level	Mitigation
1	**Sub-optimal Investment Scope**	Overlooking the upfront opportunity to gain wider strategic benefits.	High	The strong focus on energy and maintenance can overlook other strategic benefits.	High	Once missed, further investment will be tactical with little or no ability to make significant improvements.	High	Invest in understanding the wider value opportunity. SLSC information and publicity to assist.
2	**Electricity Metering Regulatory Barriers**	Electrical regulatory delay approval of CMS metering as the basis for payment.	High	Electricity regulators may be slow to approve the CMS technology that allows metering by individual light.	High	Until approval occurs the full energy saving benefits of LED and controls streetlights are not realised.	Medium	Part of SLSC role. Engagement with senior levels of government and ALGA to advocate for regulator approval.
3	**Lack of DNSP Standard Luminaires**	DNSP Failure to adopt best performing Luminaires as DNSP Standard.	High	For DNSP owned assets the adoption of Standard luminaires has a major effect on availability and cost.	High	Restricted availability of best practice luminaires.	High	Monitor DNSP choices and lobby for best practice options via the SLSC Programme.
4	**Sub-optimal Procurement**	Procurement process is not designed or timed for best value outcomes.	High	Procurement of LED and CMS is more complex than for legacy technology. Insufficient modern knowledge and lack of replacement with LED and controls at the same time are significant risks.	High	All infrastructure procurement processes have large and enduring impacts.	Low	Experienced international and local procurement experience provided by SLSC Programme.
5	**Inadequate Procurement Specifications**	Procurement technical specs not international best practice.	Medium	New LED and CMS technologies means few experienced advisors. International suppliers and consultants required.	High	Inappropriate specs have major negative investment consequences.	Low	Experienced international and local procurement experience provided by SLSC Programme.
6	**Lack of Life Cycle Economics**	Excessive investment decision-making focus on capital costs.	Medium	Traditional methods overlook the real total cost of ownership.	High	Projects are nor approved as the may be perceived as too expensive.	Medium	Adopt modern procurement methods and financial analysis using the SLSC modelling deliverables.
7	**Electricity Distribution Charges**	Legacy DNSP tariffs may result in low financial savings despite reductions in energy use.	Medium	Tradition distribution charging structures assume fixed energy use and don't allow realisation of the benefits of variable light levels and timing.	Medium	Financial savings on network line charges lost despite large savings in energy use.	Medium	Engage and lobby ACCC and AER regarding DNSP distribution charges as part of ongoing SLSC Programme actions.
8	**Energy Benefits Overstated**	Energy savings provided by investment is less than expected.	Low	International experience suggests about 50%+ energy savings without controls, and about 70%+ with controls.	Medium	Energy savings are expected to be about 40-50% of the total financial savings achieved.	Low	Luminaires must deliver on performance claims. Warranties mitigate other risks.
9	**Maintenance Benefits Overstated**	Maintenance savings delivered by the investment is less than expected.	Low	Maintenance costs will be reduced by up to 80%. Caution needed as maintenance costs are often less transparent than other services.	Medium	Non-achievement of at least 50% maintenance saving will have a medium level financial impact on the business case.	Medium	Risk share with suppliers, or transfer risk to private sector with EPC or PPP Business model education and training as part of SLSC actions.
10	**Safety Benefits Overstated**	Safety benefits delivered by the investment are less than expected.	Low	Safety benefits should be conservatively estimated and only used to supplement the investment case.	Low	The financial risk is virtually zero as safety benefits are not currently overtly valued.	Medium	Correlate road safety outcomes to light delivery, using CMS and road crash statistics.

13.3 Mitigation of Project Delivery Risks

As for all project management, good outcomes and lowered risks are the result of careful and diligent attention to detail and ensuring that good internal and external communication is carried out through all phases of the project. Two important risk mitigation techniques of supplier warranties and performance insurance are discussed below:

13.3.1 Supplier Product Warranties

Almost all credible LED street light luminaire suppliers now provide ten year warranties for all relevant aspects of LED performance. The usefulness of product warranties depends on the tangible provisions in the warranty as well as the ability of the supplier to make good. Clear and simple definitions of what performance lapses constitute product failure are an essential feature of an effective product warranty.

Most LED luminaire warranties are “back to base” with users bearing the product removal and reinstallation costs, but some councils/municipalities[239] and electrical distributors are now requiring that labour and related traffic management costs also be included in the warranty. Most CMS control system suppliers are offering five year warranties on equipment and hardware, sometimes with lesser periods for software and support. Such terms and conditions are usually negotiable and can be tailored to suit exact user needs for project indemnification. All such risk cover and related user and investor protection has either explicit or implicit costs and thus will be factored into supply pricing. Project managers will therefore need to carefully consider the cost benefit balance of indemnifying against all such risks.

13.3.2 LED Street Lighting Performance Insurance

LED performance Insurance[240] for street lighting projects is available from several global reinsurance companies. This is a risk transfer mechanism to indemnify investors and/or users in case of technical or financial product or contractor short comings. This is a non-cancellable supplier warranty back-up and indemnifies asset owners and investors where:

- Products fail to technically perform as expected;
- The project fails to deliver financial savings as expected;
- The supplier or contractor fails and/or has survival or liquidity problems.

Such insurance products were first developed for the green energy and solar PV sectors and are intended to cover any risk during the project payback period (usually the first five to ten years). These financial instruments can also minimise stress on balance sheets for supply chain participants, particularly for smaller suppliers, thus facilitating potentially encouraging much wider participation and commercial competition. Additionally, some national and state government entities[241] provide long term warranty underwriting schemes to support export trade from their home regions.

239 Abu Dhabi Lighting Manual Issue 1 Feb 14 2016

240 Michael Schrempp - *Sustainable LED Performance Warranty and Risk Mitigation,* Munich Reinsurance, Road Lighting 2015 Conference, Auckland, March 10 2015

241 Nova Scotia Canada. J.Libis, Halifax Nova Scotia - Personal Communication March 9 2015

14

CONCLUSION AND RECOMMENDATIONS

The central conclusion of this Roadmap is that overwhelming evidence exists to warrant investing significant effort to address barriers and facilitate accelerated replacement of legacy street lighting with LEDs and smart controls. This section summarises the key conclusions and recommendations made throughout the Roadmap and as a consequence of issues raised in the Roadmap. Note that the following conclusions and recommendations are those of IPWEA and do not represent the views of, or come with endorsement from, any Commonwealth, state or local government or other organisation. Recommendations are numerically identified and the first recommendation summarises the actions outlined in this Roadmap that IPWEA proposes to take and that are within its power to deliver.

The rest of the recommendations require the cooperation of a range of stakeholders. IPWEA is one of those stakeholders and is willing to play an active part in seeing each recommendation delivered but many of these recommendations will require participation and leadership from other stakeholders. It is IPWEA's hope that this Roadmap serves as a basis for discussions, to begin with these stakeholders on how best to implement these recommendations.

14.1 IPWEA Education and Training

1. **IPWEA to implement ANZ SLSC Programme –** IPWEA to implement SLSC Programme deliverables outlined in this Roadmap including preparing a policy discussion paper, developing a series of model specifications and other templates, developing and delivering a series of educational and training initiatives (e.g. website, webinars, training workshops, conferences, newsletters), working with standards organisations and helping to facilitate applied research.

14.2 Smart Cities

Governments worldwide are investing in this large but potentially high return area for communities. The Australian Government has formally budgeted $50 million over the next five years and as identified in this Roadmap, street lighting represents a fundamentally important foundation to smart cities. In the Europe Union this is delivered by the "Humble Lamppost" programme and by many other national programmes such as "Growing Smart Cities in Denmark".

2. **Establish smart cities street lighting group –** To provide formal input into the Australian Government's Smart Cities Plan to ensure street lighting is appropriately leveraged into that programme like it is in other parts of the world.

14.3 Electricity

The electricity sector is critically important to the Australian economy recognised by the fact that it represents one of the few sectors that operates almost across all internal Australian borders, and that Commonwealth approach is continuing to increase. The Distribution Network Service Providers (DNSPs) that provide electricity to all parts of the economy are facing the largest strategic changes ever experienced through the effect of modern technologies in the areas of smart grids, distributed generation and co-opetition occurring – all at the same time street lighting is also undergoing major change.

More than 90% of street lighting is owned by the DNSPs in this sector even though the responsibility for delivering light at night on pathways, roads, parks and reserves is that of the 571 Australian councils. It is therefore critically important that the electricity sector is strongly engaged in, and integrated with, all aspects of the changes identified in this Roadmap.

3. **Establish an electricity network street lighting group –** With membership from ENA and other relevant stakeholders to address the issues identified in this Roadmap and integrate street lighting modernisations together with ENA's Network Transformation Roadmap.
4. **Implement public lighting codes –** State and territory governments, in consultation with the AER and AEMC, consider adopting an enforceable public lighting code to assure good public lighting outcomes. This would apply to all DNSP street lighting service providers and include consideration of regulation and enforcement models (within jurisdiction or nationally) .
5. **Offer new financing models –** All DNSPs provide the option for councils to pay the RAB carrying amount for the old technology in instalments over a number of years or to cover capital costs of new lights via electricity and maintenance savings over time (avoiding the need for local government to fund capital investment upfront and allow cost neutral capital investment).
6. **Contestability and access framework –** Establish a national contestability and access framework to facilitate competition in street lighting, smart controls and smart city assets in each jurisdiction.

14.4 Transport

Like electricity, transport is governed across the eight states and territories, but regulated much more state by state. Street lighting has wide international acceptance of its role in decreasing injuries and fatalities but it has not been given the same management and policy attention as transport measures. For example, despite about 50% of all fatalities occurring at night (costing Australia $7-10 billion per year) when about 30% of all road travel takes place, the National Road Safety Strategy 2011–2020 covers all strategic transport issues but does not mention street lighting once. Another concern is that the rest of the world has accepted the research in the 70s and 80s that showed that night lighting decreased injuries and accidents, Australia and NZ didn't increase their illumination levels as did Europe and USA.

This Roadmap recommends accelerated replacement of legacy lighting by LED and control systems which represents an investment of about $2 billion that provides substantial economic and community net benefits. This large investment is an opportune time to re-examine the fundamental purpose and performance of lighting to reduce night time injuries and fatalities.

7. **Transport and Infrastructure council –** Establish an advisory group to reduce injuries and fatalities at night and leverage the new investment in LED street lighting and smart controls to materially contribute to achieving the National Road Safety Strategy 2011–2020 targets.

14.5 State and Territory Initiatives

Like electricity and transport, governing street lighting differently for each state and territory adds unnecessary complication and costs with few or no corresponding benefits. This Roadmap recommends that all governance of street lighting is handled at a federal level, with operational management at a local level. To this end the following recommendations are suggested:

8. **Hold state-based workshops –** Workshops to be held in each state and territory with street lighting stakeholders (DNSPs, state, ALGA, LG and main road authority representatives) to discuss the Roadmap and workshop actions to facilitate effective LED and smart controls adoption.
9. **Nominate state representatives –** State and territory governments nominate a government representative to work with IPWEA to facilitate discussions between street lighting stakeholders in their jurisdiction and take a leadership role as part of the SLSC to progress agreed action.
10. **Make LEDs an option everywhere by 2018 on all classes of roads and complete deployment by 2027 –** All street lighting service providers to offer LED luminaires by 2018 in consultation with stakeholders and to aim for full replacement of the existing lighting base by 2027.
11. **Initiate national smart controls projects –** Initiate a project to define smart control user requirements in city, metropolitan and regional areas considering cost/benefits for all parties as well as potential changes to approach to unmetered/metered arrangements for street lighting for discussion with AEMO.

14.6 Standards

Standards perform a vital role, but when they fall behind, as AS/NZS 1158 has done, they act as an impediment, rather than a facilitator, to progress.

12. **Pursue standards, updates and reform –** A submission is made to Standards Australia to continue the scope review and modernisation of AS/NZS 1158 and other related luminaire standards including systems standards to better reflect international best practice and the needs of Australia and New Zealand.
13. **Establish an official committee to specify minimum security requirements for smart street lighting control systems and their application to smart cities.**

14.7 Human Health, Ecology, Environmental Pollution and Dark Sky Protection

These issues are difficult to quantify, but nevertheless receive strong sentiments from the voting public. We live in an environment where humans have changed the environment very markedly, mostly for the worse, so governments worldwide, including Australia, are taking more notice of the issues. The Roadmap identifies these as needing serious attention to gather, analyse, and synthesise into a form that will balance and optimise the interests of all Australians. If smart controls are installed this 'intelligent' infrastructure will be able to balance the safety and security interests of local communities against the health, ecology and environmental pollution interests of those same local communities.

14. **Establish an official group to consider the ecological, human health, dark sky and other light pollution aspects –** And use international best practice and knowledge to minimise the harmful effects of the night light and maximise its positive effects;

14.8 Research

Robust, credible, research should underpin all policy measures and public investment. Street lighting enjoyed significant research activity a decade or two ago, but in the last two decades has been largely crowded out by other branches of Road Safety research. This lack of priority needs to be urgently changed as the introduction of LED, controls and smart city technologies should be accompanied by similar investment in research to determine how this technology can improve, not worsen, livability.

15. **Establish a street lighting research advisory group –** To identify where research needs to take place to confirm relationships between white LED lighting dosage[242] and crashes, injuries, fatalities, crime, human behaviour, ecological impact and dark sky needs to take place and where funding can be attracted. These and other important subjects for research are included in Section 9.13.

242 Lighting dosage is the product of the intensity level times the duration for which it is experienced.

APPENDIX I: GLOSSARY

Adaptive Lighting	The use of smart controls to dim or brighten street light levels in response to higher or lower traffic or pedestrian volumes, environmental factors or other external inputs.
American National Standards Association (ANSI)	The US Standards Development Organisation.
Asset Management Systems (AMS)	Software for optimising street lighting maintenance and operations.
Australian Energy Market Operator (AEMO)	The body responsible for operating gas and electricity markets and power systems in eastern and southern Australia.
Australian Energy Markets Commission (AEMC)	The statutory rule maker for the gas and electricity markets in eastern and southern Australia and an advisory body to governments via the Council of Australian Government's Standing Council on Energy and Resources.
Australian Energy Regulator (AER)	The regulator of energy market pricing under national energy market legislation with functions mostly relating to eastern and southern Australia. A division of the Australian Competition and Consumer Commission.
Brightening	Raising street lighting levels during events or in response to bad weather or emergencies.
Bulk Lamp Replacement (BLR)	A preventive maintenance strategy involving the replacement of a large quantity of street light lamps on a proactive regular rotating basis so that the whole inventory is replaced over a planned cycle in advance of lamps reaching output levels that are non-compliant or periods of high spot failure rates in later life.
Central Management System (CMS)	An internet-based networked street lighting control system.
Colour Rendering Index (CRI)	A visibility measure of how accurately a light source renders colours.
Colour Temperature	The scale by which colour temperature is measured (degrees Kelvin).
Column	The structure on which a street light luminaire is mounted and also known as a pole, post or standard.
Compact Fluorescent Lamp (CFL)	A low-pressure gas discharge lamp using vapourised mercury and a phosphor coating. Widely deployed on Australian residential streets between 2008 and 2013.
Constant Light Output	Power regulation over time to provide a constant light output from the luminaire to compensate for the light loss caused by the ageing of the light source.
Depreciated Optimised Replacement Cost (DORC)	A regulatory pricing setting mechanism used to value assets based on the cost of a modern engineering equivalent asset that has been optimised and is then adjusted for depreciation to reflect the reduced lifespan of the original asset.
Digital Addressable Lighting Interface (DALI)	An IEC-standardised digital lighting control protocol.

Dimming	Lowering street lighting levels during off-peak hours in response to reduced traffic or pedestrian volumes at those times.
Distribution Network Service Provider (DNSP)	Electricity distribution businesses that own and/or operate street lighting.
Economic Regulation Authority (ERA)	Provides the equivalent function in Western Australia as the AER in the National Electricity Market. In the process of transferring all responsibility to the AER.
Efficacy	The effectiveness of a light source at converting electrical energy into light (lumens/Watt).
Energy Performance Contractor (EPC)	A private contractor that designs, builds, finances, operates and maintains street light on a long-term performance contract.
Energy Services Company (ESCO)	A private contractor that designs, builds, finances, operates and maintains street light on a long-term performance contract.
High Pressure Sodium (HPS)	A yellow light high-pressure gas discharge lamp using sodium and vapourised mercury. Widely used on arterial roads and highways in Australia and on all types of roads in New Zealand.
Lamp	The light source in a traditional luminaire. Also known as a bulb or globe.
Light Emitting Diode (LED)	A form of solid state lighting used for street and general lighting.
Light Source	The modern term for a traditional lamp or an LED module.
Lighting as a Service (LaaS)	A new business model that delivers a long-term contract-based lighting service without the need to purchase capital equipment.
Linear Fluorescent Lamp (LFL)	A white light low-pressure gas discharge lamp using vapourised mercury and phosphor coating. T5 type widely used on Australian residential streets over the past decade and previously in T8 versions.
Luminaire	A device that generates and distributes light. Also known as a light fitting, light or fixture.
Mercury Vapour Lamp (MV)	An old technology high-pressure gas discharge lamp using vapourised mercury. Historically used on residential streets and arterial roads and highways.
Metal Halide Lamp (MH)	A white light high-pressure gas discharge lamp using vapourised mercury and metal halide additives. Traditionally used in parks and reserves and prestige public precincts.
National Electricity Law (NEL)	The legislative framework under which the National Electricity Market operates.
National Electricity Manufacturers Association (NEMA)	US standards development organisation.
National Electricity Market (NEM)	The wholesale electricity market covering eastern and southern Australia with rules set by the AEMC, pricing set by the AER and operated by AEMO.
Off-Peak Shut-Off	Turning street lighting completely off during off-peak hours, for example, 12pm-5am in rural communities where there is support for minimising lighting late at night.
Photoelectric Cell/Photocell/PE Cell	An ambient light detector plugged into a mating receptacle on the exterior of a luminaire that switches the light source on and off.

Power Supply	The module inside a luminaire that controls voltage and current. Also known as control gear, ballast or choke in traditional luminaires, and control gear or driver for LEDs.
Public Private Partnership (PPP)	An agreement between a council and a private contractor that designs, builds, finances, operates and maintains street light on a very long-term performance contract.
Regulatory Asset Base (RAB)	The assumed value of a group of installed assets used to calculate allowed pricing under a regulated pricing regime.
Smart Grid	Internet-based monitoring and communications enabled systems for real-time automated information about electricity supply and consumption.
Smart Metering	An electronic meter that records consumption of electricity and communicates that information to customers and back to the utility for monitoring and billing purposes.
Solid State Lighting (SSL)	The overarching term for various types of LED lighting technology.
Standards Development Organisation (SDO)	A national standards organisation (such as Standards Australia).
Trimming	Has several meanings: Reducing full output for the life of the luminaire to exactly meet required lighting design levels and/or; turning lighting on later or off earlier and/or; turning lighting on or off gradually in response to ambient lighting levels.
Tungsten Halogen	A variant of the traditional GLS tungsten filament lamp. Used in some older pedestrian crossings and flood lighting applications.

APPENDIX II: SLSC COUNCIL TERMS OF REFERENCE

Adopted 24 May 2016

16. Role/Purpose

The role of the Street Lighting and Smart Controls (SLSC) Council is to provide high-level advice to the CEO of IPWEA on the SLSC Programme. This will be in order to guide and support the SLSC Programme in undertaking an integrated package of projects and activities to overcome or alleviate the major impediments to the early and widespread adoption of modern solid state street lighting technologies and smart controls throughout Australia and New Zealand.

17. Term

This Terms of Reference is effective from 24 May 2016 (or later date if appropriate) and continues until terminated by agreement between the parties.

18. Membership

The SLSC Programme will be guided by an SLSC Council, whose membership comprises the nominated representatives (or alternate representatives) of:

- IPWEA;
- Australian Department of Environment and Energy (DEE);
- Energy Networks Australia;
- Australian Local Government Association (ALGA);
- Lighting Council of Australia;
- Tier 1 Programme Partners; and
- Organisation.

19. Overarching Principles

The following Overarching Principles should guide all of the SLSC Programme, which is to be:

- Inclusive of all relevant stakeholders;
- Commercially neutral, but pro competition;
- Technologically agnostic;
- Open and sharing;
- About achieving measurable progress; and
- Delivering social, economic, environmental and governance benefits.

20. Roles and Responsibilities

The SLSC Council is accountable for:

- Strategic and project-specific advice to the CEO of IPWEA in respect to the SLSC Programme;
- Fostering collaboration between the street lighting industry and the SLSC Programme;
- Providing support for, and helping remove obstacles to the Programme's successful delivery of its projects and activities;
- Promoting the adoption and use of Programme products by industry;
- Maintaining focus at all times on the Programme's adopted Mission and KPIs; and
- Monitoring and managing the factors outside its control that are critical to the Programme's success.

Members of the Council will commit to:

- Attending all formal and informal Council meetings or, when unable to attend a meeting, ensure that the organisation's nominated alternate attends the meeting instead;
- Wholeheartedly championing the Council and the SLSC Programme within and beyond their organisation;
- Arranging any support their organisation can reasonably provide to help the SLSC Programme deliver its projects / activities at less cost and/or to a higher standard;
- Sharing all communications and information across all Council members;
- Responding to all SLSC communications as soon as practicable;
- Making timely decisions and taking action so as to not hold up progress;
- Notifying members of the Council as soon as practical, if any matter arises that could adversely affect the harmonious and effective operation of the Council; and
- Recognising that competing commercial entities are participants in the SLSC, all participants agree to take all reasonable steps to fully meet the requirements of the Australian Competition and Consumer Act and immediately notify the IPWEA CEO should they become aware of any activity or potential activity under the SLSC Programme that is or could be in breach of the Act.

Members of the Council will expect:

- That each member will be provided with complete, accurate and meaningful information in a timely manner;
- To be given reasonable time to make key decisions;
- To be alerted to potential risks and issues that could impact on any SLSC Programme project or activity, as they arise;
- Open and honest discussions, without resort to any misleading assertions; and
- Periodic reviews of the effectiveness of the Council, including the working relationships between members.

21.Meetings

All meetings will be chaired by CEO of IPWEA, as chairperson of the Council, or in his absence by the deputy chairperson

A meeting quorum will be half the number of members plus one.

Decisions shall be made by consensus (i.e. members are satisfied with the decision even though it may not be their first choice). If not possible, the Council chairperson makes the final decision

Meeting agendas will be prepared and distributed by the SLSC Programme Manager, this includes preparing agendas and supporting papers, and then meeting action notes (draft within one week and final within two weeks) and any follow-up information.

Meetings will be held at the date, time and place set out in the adopted Meetings Schedule, with adequate notice given by IPWEA of any changes to the schedule in respect of an upcoming Council meeting.

If required, sub-committee/ sub-group meetings will be arranged outside of these times at a time convenient to sub-committee/ sub-group members.

22.Amendment, Modification or Variation

This Terms of Reference may be amended, varied or modified in writing after consultation and agreement by the Council and IPWEA.

APPENDIX III: SLSC PROGRAMME LEADER AND AUTHOR BIOGRAPHIES

Robert Fuller

Chief Executive, Institute of Public Works Engineering Australasia (IPWEA), Principal Contact

Robert was appointed CEO of IPWEA Australasia on 1 June 2015 and leads a dedicated team of high calibre professional IPWEA staff across Australia and New Zealand to meet the current and future needs of IPWEA's members and the public sector infrastructure industry. Robert is highly experienced across several sectors including: construction, infrastructure, fleet assets, education and government. Robert has been in executive management at BP Australia, Honeywell Engineering, and the Master Builders Association (MBA). He has been on many project management teams and has led the construction industry for over 23 years overseeing $0.5b of critical government projects including defence, health, education and energy projects. This has provided Robert with the blended depth of knowledge and coalface experience to proactively lead industry, engage with members and work collaboratively with government.

As former CEO, Newcastle Master Builder Association; NSW GM and Deputy CEO, Printing Industry Association of Australia; QLD State Director, CEDA (Committee for Economic Development of Australia); and CEO, Hunter Valley Training Company, Robert brings a wealth of professional industry Association management expertise in business and industry transformation.

Dr Stephen Lees

Director Sustainability, Institute of Public Works Engineering Australasia (IPWEA)

Stephen is an engineer with 40 years executive management experience. He has practiced in the fields of water resources, environmental and natural resources management, and sustainability, with a specific focus on catchment, floodplain and stormwater management, climate change science and adaptation. For 16 years he was CEO of the Upper Parramatta River Catchment Trust, a catchment flood control utility in western Sydney, and CEO for three years of the Sydney Metropolitan Catchment Management Authority. Stephen spent four years with a major private sector engineering consultancy specialising in water resources, sustainability and climate change adaptation. More recently Stephen has worked for IPWEA as its Director Sustainability, and on consulting assignments for several industry and public sector bodies.

Godfrey Bridger

Managing Director, Strategic Lighting Partners

Godfrey has more than 20 years' experience in the energy and infrastructure sectors ranging from business development and consultancy to governance. He is a former Chief Executive of the Energy Efficiency and Conservation Authority (EECA), and was a board member of Mercury Energy (now called Vector) when it was the largest electricity distribution company in New Zealand. He has senior management and business development experience in both electricity distribution and government research sectors. With SLP, Godfrey has undertaken street lighting consulting assignments for the New Zealand Transport Agency (NZTA), EECA, the South Australian Department of State Development, NSW and QLD councils, New Zealand councils, and IPWEA. He was a co-organiser of the *Road Lighting 2014* and *Road Lighting 2015* conferences held in Auckland.

Bryan King

Director, Strategic Lighting Partners

Bryan is an experienced lighting practitioner and an authority on road lighting practices worldwide. Bryan has a 30 year history of leadership of lighting supply businesses, and consultancies for the government and local government sectors. He is a member of the AS/NZS1158 LG-002 Road Lighting committee, convener of the Energy Performance Working Group, a member of AS/NZS 60598 EL-041 committee and New Zealand head of the IEC Standards National Committee TC34-Lamps and Luminaires. Bryan was the founding Chairman of Lighting Council New Zealand and is currently Executive Director of LCNZ. As a principal of SLP, Bryan has undertaken street lighting consulting assignments for EECA, the South Australian Department of State Development, NSW and QLD councils, New Zealand councils and IPWEA. He has also undertaken lighting consultancy for the IFC World Bank. He was a co-organiser of the *Road Lighting 2014* and *Road Lighting 2015* conferences held in Auckland.

Graham Mawer

Managing Director, Next Energy

Graham leads a major street lighting initiative for 35 local governments in the Sydney area addressing pricing, technology and service issues for the consortium. He has also worked for other private and public sector clients on street lighting projects over the past decade including for NSW Road and Maritime Services, Westlink M7, IPWEA, the West Australian Government's Department of Premier and Cabinet and individual councils in a number of jurisdictions. His street lighting work includes technology reviews, tender work, LED lighting trials, maintenance monitoring, service level negotiations with utilities, preparation of strategic plans and regulatory filings on behalf of local governments.

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