SOLLIA: Street and Outdoor LED Lighting Initiative - Asia

Survey Report and Best Practice Guide for LED Street and Outdoor Lighting

APEC Energy Working Group

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ACRONYMS AND ABBREVIATIONS

ANSI – American National Standards Institute
APEC – Asia-Pacific Economic Cooperation
AS – Australian Standards
ASSIST – Alliance for Solid-State Illumination Systems and Technologies
BS – British Standard
BSL – Bureau of Street Lighting
CALiPER – Commercially Available LED Product Evaluation and Reporting
CBEA – Commercial Buildings Energy Alliance
CCT – Correlated Colour Temperature
CDM – Clean Development Mechanism
CIE – Commission Internationale de l´Eclairage (International Commission on Illumination)
CNS – Chinese National Standard
CRI – Colour Rendering Index
CSA – Canadian Standards Association
DOE – Department of Energy
EECA – Energy Efficiency and Conservation Authority
EMC – Electromagnetic Compatibility
EPRI – Electric Power Research Institute
EWG – Energy Working Group
FTE – Fitted Target Efficacy
HPS – High Pressure Sodium
IEC – International Electrotechnical Commission
IESN – Illuminating Engineering Society of North America
IIEC – International Institute for Energy Conservation
ISO – International Organization for Standardization
ITRI – Industry Technology Research Institute
JELMA – Japan Electric Lamp Manufacturers Association
JIS – Japanese Industrial Standards
KS – Korean Standards
LEDs – Light-Emitting Diodes
LRC – Lighting Research Centre
MOEABOE – Ministry of Economic Affairs – Bureau of Energy
NEMA – National Electrical Manufacturers Association
NGLIA – Next Generation Lighting Industry Alliance
NMX – Mexican Standards
NYSERDA - New York State Energy Research and Development Authority
NZS – New Zealand Standards
PAS – Publically Available Specification
PEA – Provincial Electricity Authority
PEMANDU – Performance Management & Delivery Unit
PIARC – World Road Association
SS – Singapore Standards
SSL – Solid-State Lighting
TIS – Thai Industrial Standard
UD – Under Development
UL – Underwriters Electrical Bureau
UNFCCC – United Nations Framework Convention on Climate Change
US – United States

1 EXECUTIVE SUMMARY

The Asia-Pacific Economic Cooperation (APEC) governments pledged to reduce energy intensity in each member economy. To this effect, it is of value to share best practices and experience on energy efficiency and greenhouse gas reduction across APEC member economies. With a growing number of people living in cities, energy consumption from street lighting has been on the rise and represents a significant amount of the total energy consumed in cities. Light-Emitting Diodes (LEDs – also known as Solid-State Lighting - SSL) are an upcoming technology which can potentially provide significant energy and costs savings compared to traditional street and outdoor lighting technologies.

This report was produced as part of the APEC Street and Outdoor LED Lighting Initiative – Asia and provides APEC member economies with a best practice guide for purchase, installation and maintenance of LED street and outdoor lighting. The report also includes a compilation of LED street and outdoor lighting standards and an overview of LED street and outdoor lighting activities in the APEC. The report findings are summarised below and were based on a survey sent to APEC member economies and a complementary literature review.

Status of LED Standards

There are several international entities supporting the development of standards, guidelines, specifications and best practices for LED street and outdoor lighting. International standards for LED product performance are mainly established by the International Commission on Illumination (CIE) and the International Electrotechnical Commission (IEC). These standards cover LED products, modules, control gears and luminaires in terms of safety, testing and performance. International standards are generally adopted as economy-wide standards in a number of APEC member economies – these include the IEC 61347 series on *Lamp Control Gears* and IEC 62384:2009 on *DC or AC supplied electronic control gear for LED modules – performance requirements*. The IEC 60598 series on *Luminaire Safety* are generally applied by almost all APEC member economies in LED street lighting projects.

For street and outdoor lighting standards, the most active international entities are the International Commission on Illumination (CIE), American National Standards Institute (ANSI) and Illuminating Engineering Society of North America (IESNA). To complement their activity, the United Nations Framework Convention on Climate Change (UNFCCC) published a Clean Development Mechanism (CDM) methodology regarding energy efficient outdoor and street lighting technologies. This methodology takes into consideration the requirements and guidelines for roadway lighting such as CIE 140-2000 on *Road Lighting Calculations* and CIE 115-2010 on *Lighting of Roads for Motor and Pedestrian Traffic*.

To date there are no specific international standards applicable exclusively to LED street and outdoor lighting. However, in APEC, the People's Republic of China, Chinese Taipei, Republic of Korea and the United States established their own economy-wide standards pertaining solely to LED street and outdoor lighting and traffic lighting applications:

- China - GB/T 24907-2010: LED lamps for road lighting – performance specifications.
- Chinese Taipei - CNS 15233: Fixtures of roadway lighting with LED lamps.
- Korea - KS C 7528: LED Traffic Signals & KS C 7658: LED Luminaires For Road and Street Lighting.
- United States - ANSI C136.37: Solid-State Light Sources Used in Roadway and Area Lighting.

Government Support

Government support is critical to further understand the performance and requirements of LED street and outdoor lighting as technology matures, and how it differs from other commercially available lighting technologies. APEC member economies such as Chinese Taipei, Japan, Republic of Korea, New Zealand and the United States have approved plans, programs and/or roadmaps to support the implementation of LED street and outdoor projects and trigger the development of a robust LED industry. Generally these include subsidy and incentive schemes and involve municipalities, city councils and/or roadway/highway authorities. The combination of standards, government support and project experience resulted in a number of guidelines, specifications and best practices in APEC member economies. Best practices for purchase, installation and maintenance of LED street and outdoor lighting, particular the latter two, are still under discussion and are based on available recommendations by relevant entities.

Best Practices for LED Purchase

In the purchase and procurement process, best practice by APEC member economies indicates there are seven key questions to ensure LED product quality, performance and safety:

1. LED product specifications follow economy-wide standards?
2. Testing performed by third-party, accredited laboratories?
3. Requirements of illumination quality included in the procurement specifications?
4. Preliminary field trial is a part of the evaluation and selection process?
5. "Application Efficacy" considered as one of the selection criteria?
6. Warranty of LED products is at least 5 years?
7. Warranty bond and penalty included as parts of Warranty Terms and Conditions?

The People's Republic of China, Chinese Taipei, Republic of Korea and United States developed standards and specifications to ensure adequate LED product performance and quality. In addition, a number of APEC member economies setup voluntary product certification schemes for greater market acceptance and to ensure customer confidence such as:

- Australia - SSL Quality Scheme
- Korea - High Efficiency Certification Program for LED traffic lights
- Malaysia - LED Certification Centre
- Mexico - Label Scheme (Sello FIDE)
- The United States - SSL Quality Advocates Scheme

Exceptionally, in Hong Kong (China), the Highways Department and the Electrical and Mechanical Services Department (EMSD) established *Guidelines for Specifying and Producing LED Lighting Products for Lighting Projects*. It covers LED product specifications and terminology which are relevant in the adequate procurement of LED products for street lighting.

Best Practices for LED Installation

Best practices for installation of LED street and outdoor lighting are similar to those applied for other street lighting technologies except for the light levels, uniformity and proposed visual efficacy systems. The light levels and uniformity are based on international standards (e.g. CIE 115-2007 – *Recommendations for the Lighting of Motorized Traffic*) and in some cases economy-wide standards (e.g. AS/NZS 1158.1.1:1997 - *Road Lighting – Vehicular Traffic Lighting*). According to international standards, lights levels and uniformity depend on type of traffic, traffic density and conflict area. These then determine the lighting pole layout, span and height as well as the selection of light source, luminaire and electrical design works.

However, the performance of LEDs differs significantly from traditional street lighting (e.g. high pressure sodium - HPS). Recommendations from expert entities suggest that commercially available light sources for street and outdoor lighting offer a wide range of values for Scotopic/Photopic (S/P) ratio[1], such as HPS lamps with S/P ratio of approximately 0.60 and metal halide lamps with an S/P ratio of approximately 1.50. This suggests that the HPS lamp is not necessarily the optimum light source for street and outdoor lighting. In the case of white LED lamp, the S/P ratio can be as high as 2.0, and therefore more effective for good visual performance for the low light levels encountered in street and road lighting. Based on the S/P ratio, the base light level which is measured in photopic luminance (cd/m^2) should be adjusted when installing LED street and outdoor lighting. Nevertheless, these recommendations have not been adopted by any international standard.

Best Practices for LED Maintenance

A well planned maintenance strategy is essential to ensure and sustain the optimal performance of LED street and outdoor lighting. Based on the survey conducted, there are no specific standards, guidelines or specifications for maintenance strategy for LED street and outdoor lighting in APEC member economies. Therefore, best practices for other lighting technologies are applied but these are not always adequately suited for LEDs. Typically, LEDs do not fail in the same manner as other traditional street lighting technology, and instead tend to fade over time. This means that LED lifetime, which depends on lumen maintenance life and rated life or statistically measured failures, is a critical parameter in determining the most adequate maintenance strategy. This section covers the latest developments on determining lumen maintenance life and rated life or statistically measured failures in APEC member economies.

The Bureau of Street Lighting in Los Angeles provides a guide to Evaluating LED Lumen Maintenance. This is based on the IESNA LM-80-08 - *Approved method for measuring lumen maintenance of LED light sources*. It is one of the few methods available covering lumen depreciation/maintenance testing including LED packages, arrays and modules. Useful lifetime estimates for LED lighting products are typically given in terms of the expected operating hours until light output has diminished to 70 percent of initial levels (denoted L70 life). For example, LED manufacturers claim the L70 life is reached after 35,000 hours or 50,000 hours. However this would prove costly to validate in a testing laboratory and unproductive due to the fast rate of LED technology improvements. Therefore the LM-80-08 provides an indication of the minimum lumen maintenance requirements for 6,000 hours for lifetime claims of 35,000 hours and 50,000 hours. Moreover, the IESNA TM 21-11 - *Projecting Long Term Lumen Maintenance of LED Light Sources* uses the LM-80-08 and provides a method to extrapolate values and enable a more accurate quantification of lumen depreciation as this varies significantly between models and manufacturers.

[1] The S/P ratio, which is the ratio of the luminous output of the light source evaluated according to the CIE scotopic spectral luminous efficiency function *V′(λ)* to the luminous output evaluated according to the CIE photopic spectral luminous efficiency function *V(λ),* is used to characterize the spectral characteristic of a light source.

2 INTRODUCTION

2.1 Background

At the Seventh APEC (Asia-Pacific Economic Cooperation) Energy Ministers Meeting (EMM-7) in Gyeongju, Korea, ministers encouraged APEC economies to adopt further measures to promote energy efficiency and conservation, directed the APEC Energy Working Group (EWG) to identify best practices to assess efficiency improvements, and further directed the EWG to support capacity building efforts in this regard. At the Eighth APEC Energy Ministers Meeting (EMM-8) in Darwin, Australia, energy ministers directed the EWG to "improve energy efficiency by sharing information on energy efficiency policies and measures." At the nineteenth APEC Ministerial (Sydney, Australia, September 2007), ministers welcomed further work by APEC member economies to "share experiences on the range of economic policy instruments for promoting energy efficiency and greenhouse gas reduction." This goal was also endorsed in the APEC Leaders' Declaration on Climate Change, Energy Security, and Clean Development (Sydney, Australia, 9 September 2007).

At their meeting in Sydney, APEC Leaders set an aspirational goal to reduce energy intensity by at least 25 percent from 2005 levels by 2030. As noted at the Ninth Energy Ministers Meeting (EMM-9) in June 2010, "improving energy efficiency is one of the quickest, greenest and most cost-effective ways to address energy security, economic growth and climate change challenges at the same time." Accelerated deployment of energy efficient street lighting is one significant mean for economies to achieve their energy savings potential.

Light-emitting diodes (LEDs) are increasingly the technology of choice for street and outdoor lighting applications in the growing towns and cities of APEC economies, as they use only about half as much energy as conventional sodium streetlights, and they can last for up to 50,000 hours, or over 11 years of use (at 12 hours per day). But large scale LEDs deployment presents a number of practical obstacles. This report's intent is to examine and present the best practices world-wide for putting such technologies in place, which can help to accelerate the introduction of highly efficient lighting, thereby helping to reduce electricity needs and associated carbon emissions in APEC economies.

With the continued trend of urbanization, energy efficient street lighting will be a priority for both developing and developed APEC economies. The United Nations has projected that globally, the portion of people living in cities will grow from 45 percent in 2008 to 56 percent by 2030. This move towards cities is particularly focused in developing economies, which had been less urbanized in the past. Cities account for 70 percent of global energy consumption, of which 15 percent is attributable to street lighting, so street lighting in cities accounts for roughly 10 percent of overall global energy use. Since LEDs are about twice as efficient as conventional streetlights, they have the potential to reduce overall energy use by up to 5 percent. Their potential contribution to energy efficiency and greenhouse emissions reductions is substantial. Combined with solar cell arrays or other renewable energy resources, they can bring low-impact lighting to remote villages and islands of APEC economies that are not connected to power grids (APEC, 2011).

Lighting equipment is widely produced and traded in the APEC region. The next generation of highly-efficient lighting, based on LEDs, is still in its infancy. As technology is applied and economies of scale for LED chips are achieved in the next few years, costs for LED-based lighting are expected to decline sharply and markets for LEDs are expected to grow exponentially. Outdoor and street lighting (including traffic signals) may be one of the earliest widespread cost-effective applications for LEDs since such lighting remains in continuous operation for long periods of time and thus represents an excellent opportunity for cost-effective installations. By sharing best practices for the installation of LEDs in street lighting, this report can help to provide the demand pull that can jump-start the virtuous path of cost reduction and market adoption for LEDs so that the benefits in terms of reduced energy use and carbon emissions can be realized region-wide.

Potential beneficiaries include the citizens of all towns and cities in APEC economies, who may see reduced municipal operating costs and carbon emissions from the accelerated installation of highly efficient street lighting. Specific beneficiaries include local officials and municipal governments that will learn how to choose and install more efficient street lighting in a fast and cost-effective fashion for their people, as well as policy makers who will have a clearer basis for regulations to ensure the quality of LEDs installed. Intended beneficiaries will also be actively involved in the implementation of the project through their provision of information during the survey, data gathering and review stages (APEC, 2011).

2.2 Objective

This Report and Best Practice Guide on LED Street and Outdoor Lighting was produced as part of APEC's SOLLIA (Street and Outdoor LED Lighting Initiative – Asia). The objective of this initiative is to develop a best practice guidebook for the use of highly-efficient LEDs for street lighting and other public outdoor lighting needs as well as compile information on LED street and outdoor lighting standards in APEC economies.

2.3 Methodology

A survey was conducted to compile information on LED Street and Outdoor Lighting in each APEC member economy. A sample of the survey is shown in Annex I. The stakeholders surveyed included government regulatory departments, standardization agencies, municipalities, city councils and lighting industry associations. A list of the stakeholders surveyed and responses received are included in Annex II and Annex III, respectively.

To complement the survey results, the IIEC carried out research on information compiled by industry, municipal lighting authorities and regulatory authorities in APEC member economies. This research covered Technical Specifications, Standards, Guidelines and Best Practices for purchasing, installing and maintaining LED streetlights.

2.4 LEDs and Street Lighting

Light-emitting diodes (LEDs) were first developed in the 1960s and are basically semiconductor diodes – electronic gates – enabling a current to flow in one direction only. LEDs are composed of compound semiconductor materials (similar to consumer electronics), in alternating crystalline layers of conductors and insulators, and are also known as solid-state lighting (SSL). The electronic symbol for LED is shown in Figure 2.1.

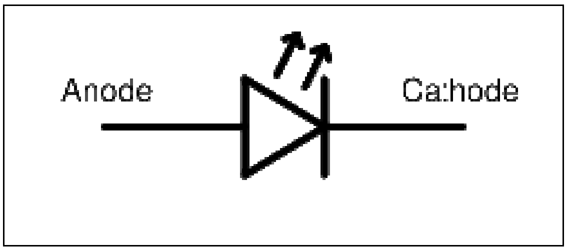


Figure 2.1 – Electronic Symbol for LED

According to the Lighting Research Centre (2003), the two main types of LEDs presently used for lighting systems are aluminium gallium indium phosphide alloys for red, orange and yellow LEDs and indium gallium nitride alloys for green, blue and white LEDs.

An LED lighting system includes a number of components as shown in Figure 2.2. The main components are the lighting source composed of individual LED sources and circuit board (also known as array or **module**[1]), a **driver**[2] (also known as ballast) which provides correct voltage and current to the system, and a **luminaire**[3] to support and control the light emission from the LEDs and control the temperature of the overall system (thermal heat sink). Standards for these three components are essential for the correct installation of LED street and outdoor lighting systems (see Section 3). The **controls** turn the power on/off and can dim the lights, mix colours or create dynamic effects (Conway, 2010; LRC, 2003). According to CELMA (2010), the word "driver" is often used as a synonym of control gear and therefore used interchangeably in international LED standards.

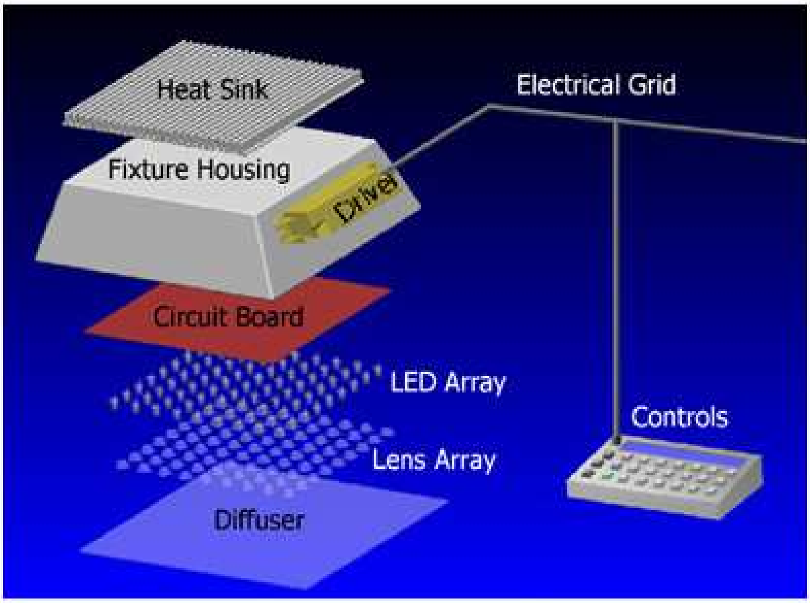


Figure 2.2 – Components of LED lighting system (LRC, 2003)

With regards to street lighting, LEDs typically can deliver up to 50 percent savings over conventional sodium streetlights, if they are designed for efficient light distribution, and can last for up to 50,000 hours or over 11 years of use (at 12 hours per day). Hence, LEDs are increasingly the technology of choice for street and outdoor lighting applications.

Overall, LED technology is in its infancy, with regular on-going developments. In addition, it is still costly as it has not reached an economy of scale which would bring down production costs to a competitive level with other standard lighting technologies. However, currently, street and outdoor lighting is already a cost-effective application for LEDs due to the long operation hours and could potentially enable energy savings and a reduction in maintenance costs (through longer expected lifetime) compared to other types of street lighting (LRC, 2003; Conway, 2010; APEC, 2011; DOE, 2011a).

[1] **LED module -** A component part of an LED light source that includes one or more LEDs connected to the load side of LED power source or LED driver. Electrical, electronic, optical, and mechanical components may also be part of an LED module. The LED module does not contain a power source and is not connected directly to the branch circuit (ANSI/IESN, 2008).

[2] **LED driver** - A power source with integral LED control circuitry designed to meet the specific requirements of a LED lamp or a LED array (ANSI/IESN, 2008).

[3] **LED luminaire** - A complete LED lighting unit consisting of a light source and driver together with parts to distribute light, to position and protect the light source, and to connect the light source to a branch circuit. The light source itself may be an LED array, an LED module, or an LED lamp (ANSI/IESN, 2008).

3 LED Street and Outdoor Lighting Standards

3.1 International Status

3.1.1 International LED Product Standards

Only a handful of international standards for LED street and outdoor lighting have been released recently, as LED technology is still developing at a fast pace, making its standardisation a challenge. Until they are widely available, the lack of suitable standards and credible guidance has generated confusion and frustration in the market. Therefore, governments and regulatory authorities in economies such as the People's Republic of China, Chinese Taipei, Hong Kong (China), Japan and the United States are at the forefront in the development of adequate standards for LED street and outdoor products and lighting systems (based on the level of standards activities and number of LED standards available). At an international level, the key organizations taking the lead on LED related standardization include the Commission Internationale de L'Eclairage (CIE)[1], and International Electrotechnical Commission (IEC).

Table 3.1 provides a summary of existing international standardization documents for LED product design, manufacturing, testing, safety and performance.

Table 3.1 – International Standards for LED Street and Outdoor Lighting Products

Standard	*Title*	*Scope*
IEC 60598 series	Luminaire safety	LED Luminaire Design / Manufacture
IEC 60825-1	Safety of Laser Products – Part 1: Equipment classification and requirements. Applicable to LEDs.	LED Product Testing
IEC 60838-2-2:2006	Miscellaneous lamp holders – Part 2-2: Particular Requirements – connectors for LED modules.	LED Module Design / Manufacture
IEC 61347-1:2007	Lamp control gear - Part 1: General and safety requirements	LED Module Design / Manufacture
IEC 61347-2-13:2006	Lamp control gear – Part 2-13: Particular requirements for DC or AC supplied electronic control gear for LED modules.	LED Module Design / Manufacture
IEC 62384:2009	DC or AC supplied electronic control gear for LED modules – performance requirements	LED Module Performance (*The tests in this standard are type tests*)
IEC/PAS 62722-1:2011*	Luminaire performance - Part 1: General requirements	LED Luminaire Performance
IEC/PAS 62722-2-1: 2011*	Luminaire performance - Part 2-1: Particular requirements for LED luminaires	LED Luminaire Performance
CIE Publication No. 127-2007	Measurements of LEDs	LED Product Testing / Performance
CIE Publication No. 177-2007	Colour rendering of white LED Light Sources	LED Product Testing / Performance

* PAS – Publically Available Specification
Source: Sensing, 2009; IIEC, 2011

In addition, the Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaries in the European Union (CELMA), which comprises of a number of major European lighting manufacturers such as Osram and Philips, produce LED standards and guidelines. As

[1] Also known as the International Commission on Illumination

part of their tasks, CELMA provides guidelines for LED light sources such as the "Selections of Control Gears (drivers) for LED light sources and LED luminaires" (CELMA, 2011).

3.1.2 International Standards for Street and Outdoor Lighting

The Commission Internationale de L'Eclairage (CIE) is one of the main international entities providing standards and guidelines for street and outdoor lighting, particularly roadway lighting. Standard CIE 115-1995 highlights the importance and purpose of street and outdoor lighting in:

- Allowing users of vehicles to proceed safely,
- Allowing pedestrians to see hazards, orientate themselves, recognize other pedestrians and give them a sense of security,
- Improving night-time appearance of the environment.

This is the basis for the development of a series of street lighting standards since 1976 to ensure these three points are satisfied in the design and installation of street and outdoor lighting. Examples of international standards and guidelines applicable for street and outdoor lighting and traffic lighting include:

- CIE 31-1976 – Glare and Uniformity in Road Lightings Installations
- CIE 22-1977 – Depreciation of Installation and their Maintenance (in Road Lighting)
- CIE 47-1979 – Road Lighting for Wet Conditions
- CIE 48-1980 – Light Signals for Road Traffic Control
- CIE 66-1984 – Road Surfaces and Lighting (Joint Technical Report CIE/PIARC)
- CIE 93-1992 – Road Lighting as an Accident Countermeasure
- CIE 132-1999 – Design Methods for Lighting of Roads
- CIE 140-2000 – Road Lighting Calculations
- CIE 136-2000 – Guide to the Lighting of Urban Areas
- CIE 144-2001 – Road Surface and Road Marking Reflection Characteristics
- CIE 115-2007 – Recommendations for the Lighting of Motorized Traffic (updated)
- CIE 180-2007 – Technical Report: Road Transport Lighting for Developing Countries
- CIE 115-2010 – Lighting of Roads for Motor and Pedestrian Traffic
- CIE 119-2010 - Recommended System for Mesopic Photometry Based on Visual Performance

Other International/Economy-Wide Standards of reference include:

- CEN/TR 13201-1 Road Lighting – Part 1: Selection of Lighting Classes
- EN 13201-2 Road Lighting – Part 2: Performance Requirements
- ANSI/IESNA RP-8-00 - American National Standard Practice for Roadway
- **ANSI C136.37 – Solid-State Light Sources Used in Roadway and Area Lighting**
- AS/NZS 1158.1/1-1997 – Road Lighting – Vehicular Traffic Lighting
- AS 1158.2-1971 – Standards Association of Australia (SSA) Public Lighting Code - Lighting of Minor Streets
- AS CA19-1939 - Australian Standard Rules for Street Lighting

ANSI C136.37 is the only international standard focusing exclusively on LED street and outdoor lighting. The standard specifies a number of requirements for LED luminaires based on existing regional and international LED standards such as operating temperature, correlated colour temperature, mounting provisions, dimming, ingress protection, wiring and grounding. The standard aims at providing recommendations and guidance to utilities and manufacturers.

The People's Republic of China, Chinese Taipei, Republic of Korea and the United States are the only APEC member economies with economy-wide standards covering specifically LED street and outdoor lighting applications.

3.1.3 CDM Methodology for Outdoor and Street Lighting

In April 2011, the United Nations Framework Convention on Climate Change (UNFCCC) published a Clean Development Mechanism (CDM) methodology regarding energy efficient outdoor and street lighting technologies – e.g. LED luminaire retrofit. The AMS.II L is part of an indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories.

This methodology takes into consideration the requirements and guidelines for roadway lighting such as CIE 140-2000, CIE 180-2007 and CIE 115-2010 (see Section 3.1.2). This includes a methodology for measuring and calculating average illuminance and guidance on use of mesopic photometry for lighting performance evaluation. It applies to projects that lead to efficient use of electricity through the adoption of energy efficient lamps and/or fixture combinations to replace less efficient lamps and/or fixture combinations in public or utility-owned street lighting systems (UNFCCC, 2011). A copy of the CDM methodology is included in Annex IV.

3.2 Current Status in APEC Member Economies

3.2.1 Summary of LED Standards in APEC Member Economies

Table 3.2 provides a summary of the status of the economy-wide LED standards for each APEC member economy and LED component. The majority of APEC member economies, that are active in LED standards, have adopted international standards or setup economy-wide standards for LED module and luminaire. As LED product technology continues to improve, LED product standards are likely to be further updated in the upcoming years, particularly regarding testing and performance. Overall, there is a clear opportunity for greater collaboration between APEC member economies in terms of standard adoption to meet regional conditions and ensuring necessary testing practices are affordable.

Table 3.2 – Summary of LED standards per APEC member economy

Economy	LED Product	LED Module	LED Control Gear[1]	LED Luminaire
Australia	X	X	X	X
Brunei Darussalam				
Canada	X	X	X	X
Chile				
China	X	X	X	X
Chinese Taipei	X	X	X	X
Hong Kong	X	X	X	X
Indonesia				
Japan	X	X	X	UD
Korea	UD	X	UD	X
Malaysia		X	X	
Mexico	UD	X	X	X
New Zealand	X	X	X	X
Papua New Guinea				
Peru				
Philippines				X*

Russia				
Singapore		X		X
Thailand				X*
United States	X	X	X	X
Vietnam				X*

1 – In some APEC Member Economies the LED product standards for control gears also apply to drivers. However, the available LED standards for control gears tend to only cover safety and general performance aspects.
X – Standard Developed; X* - IEC 60598 (Luminaire Standard); UD – Standard Under Development; Blank – Standard not developed or information unavailable

3.2.2 APEC Member Economies – Leading on LED Standards

3.2.2.1 United States

The United States is at the forefront of developing LED (also known as SSL) standards, and the United States Department of Energy (DOE) supports the industry in establishing LED product standards and testing methods to characterize their performance and safety and enable market adoption and growth (DOE, 2010a). DOE also helps municipalities in establishing guidelines and specifications for purchase, installation and maintenance of LED street and outdoor lighting.

Table 3.3 includes the list of current LED standards and also standards under development in the United States. Most standards are developed by the Illuminating Engineering Society of North America (IESNA), National Electrical Manufacturers Association (NEMA) and American National Standards Institute (ANSI) and cover LED design, manufacturing, testing methodology, performance and installation, not only for the LED lighting but also for the luminaires and whole LED lighting system. The standards for LED drivers are still under development.

Table 3.3 – Example of List of Existing Standards / Guidelines / Best Practices and Standards in Development on LED Street and Outdoor Lighting in the United States

Standard	Title	Summary	Scope
IES LM-79-2008	Approved Method for the Electrical and Photometric Testing of SSL Devices	Enables the calculation of LED luminaire efficacy (net light output from the luminaire divided by the input power and measured in lumens per watt). Luminaire efficacy is the most reliable way to measure LED product performance, measuring luminaire performance as a whole instead of relying on traditional methods that separate lamp ratings and fixture efficiency. LM-79 helps establish a foundation for accurate comparisons of luminaire performance, not only for SSL, but for all sources.	LED Luminaire Performance / Testing
IES LM-80-2008	Approved Method for Measuring Lumen Depreciation of LED Light Sources	Supports an assessment of expected LED lifetime by defining a method of testing lamp depreciation. Unlike traditional filament-based sources, which usually fail completely, LEDs typically do not fail; they simply fade over time, which is referred to as lumen depreciation. LM-80 establishes a standard method for testing lumen depreciation.	LED Product Performance / Testing
IES RP-16	Nomenclature and Definitions for Illuminating Engineering (Addenda a and b)	Provides industry-standard definitions for terminology related to SSL.	LED Design / Manufacture / Purchase / Testing
IES G-2	Guideline for the Application of General Illumination ("White") LED Technologies	Provides lighting and design professionals with a general understanding of LED technology as it pertains to interior and exterior illumination, as well as useful design and application guidance for effective use of LEDs.	LED Product Design / Installation / Performance
ANSI C78.377-	Specifications for the Chromaticity of SSL	Specifies recommended colour ranges for white LEDs with various correlated colour temperatures. Color	LED Product Performance /

2008	Products	range and colour temperature are metrics of critical importance to lighting designers.	Testing
NEMA LSD 45-2009	Recommendations for SSL Sub-Assembly Interfaces for Luminaires	Provides guidance on the design and construction of interconnects (sockets) for SSL applications.	LED Luminaire Design / Manufacture
NEMA LSD 49-2010	SSL for Incandescent Replacement - Best Practices for Dimming	Provides recommendations for the application of dimming for screw-based incandescent replacement SSL products.	LED Dimming Design / Installation / Performance
UL 8750	Safety Standard for LED Equipment for Use in Lighting Products	Specifies the minimum safety requirements for SSL components, including LEDs and LED arrays, power supplies, and control circuitry.	LED Module Design / Manufacture / Installation /
NEMA SSL-6-2010	SSL for Incandescent Replacement - Dimming	Provides guidance for those seeking to design and build or work with solid-state lighting products intended for retrofit into systems that previously used incandescent screw base lamps. Addresses dimming of these products and the interaction between the dimmer (control) and the bulb (lamp).	LED Dimming Installation
IES TM-21	Method for Estimation of LED Lumen Depreciation as a Measure of Potential LED Life	A proposed method for taking LM- 80 collected data and estimating an effective life for LEDs.	LED Product Testing / Performance
Standards in Development			
IES LM-XX1	Approved Method for the Measurements of High Power LEDs		LED Product Testing / Performance
IES LM-XX2	LED "Light Engines and Integrated Lamp" Measurements		LED Product Testing / Performance
IES LM-XX3	Approved Method for Measuring Lumen Maintenance of LED Light Engines and LED Integrated and Non-Integrated Lamps		LED Product Testing / Performance

Source: DOE, 2010a; ICF International, 2011; IESNA, 2011

The DOE is active in the development and publications of guidelines/best practices for application of LEDs. In 2006, DOE established a LED testing program called CALiPER (Commercially Available LED Product Evaluation and Reporting). The program supports the testing of a wide array of LED products in order to (DOE, 2011d):

- Guide DOE planning for SSL R&D and market introduction activities.
- Support DOE demonstrations and technology procurement activities.
- Provide objective product performance information to the public in the early years, helping buyers and specifiers have confidence that new SSL products will perform as claimed.
- Guide the development, refinement, and adoption of credible, standardized test procedures and measurements for SSL products.

3.2.2.2 People's Republic of China

People's Republic of China developed a number of LED standards based on IEC and CIE, including LED standards for road lighting as shown in Table 3.4. In addition, the People's Republic of China has already a total of six laboratories for testing LED radiation safety and established a specific standard for performance of LED road lighting (Sensing, 2009).

Table 3.4 – Example of List of Existing Standards and Standards under Development on LED Street and Outdoor Lighting in the China

Standard	Title	Scope
GB/T 20145-2006	Photobiological safety of lamps and lamp systems	LED Product Testing / Performance
SJ/T 2355-2006	LED Measurement Methods	LED Product Testing / Performance
GB/T 9468-2009	General requirements for photometry and goniophotometry of luminaires	LED Luminaire Testing / Performance
SJ/T 11399-2009	Measurement methods for LED Chips	LED Chip Testing / Performance
SJ/T 11394-2009	Measurement methods for LED modules	LED Chip Testing / Performance
GB 19651.3-2008	Miscellaneous lampholders – Part 2-2: Particular requirements – connectors for LED modules	LED Modules Design / Manufacture
GB 19651.3-2009	Lamp control gear – Part 14: Particular requirements for D.C. or A.C. supplied electronic control gear for LED	LED Control Gear Design / Manufacture
GB/T 24825-2009	D.C. or A.C. supplied electronic control gear for LED modules – Performance requirements	LED Control Gear Design / Manufacture
GB / T 24827-2009	Performance requirements of luminaires for road and street lighting	LED Luminaire Design / Testing / Performance / Installation / Operation
GB/T 24907-2010	**LED lamps for road lighting – performance specifications**	**LED Product Performance**
Under development?	Accelerating testing method for LED lifetime	LED Product Testing
Under development?	Optical radiation safety of LEDs	LED Product Design / Manufacture / Testing

Source: Sensing, 2009

There are also industrial standards available on semiconductor lighting developed by the Technical Standard Working Group from the Ministry of Industry and Information Technology in China.

3.2.2.3 Hong Kong, China

In Hong Kong, the standards shown in Table 3.5 are applicable to LED street and outdoor lighting. The standards cover safety, testing and performance of LED luminaires and control gears.

Table 3.5 – Example of List of Existing Standards on LED Street and Outdoor Lighting in Hong Kong

Standard	Title	Scope
BS EN 60529:1992	Requirements for the classification of degrees of protection provided by enclosures for electrical equipment.	LED Luminaire Design / Manufacture / Installation
BS EN 60598-2-3:2003	Luminaires. Particular requirements. Luminaires for road and street lighting	LED Luminaire Design / Installation / Performance
BS EN 13201-2004	Road Lighting (Performance related)	LED Luminaires Performance
BS EN 61347-2-13:2006	Lamp control gear. Particular requirements for DC or AC supplied electronic control gear for LED modules	LED Control Gear Design / Installation
BS EN 60598-1:2008	Luminaires: General requirements and tests	LED Luminaires Design / Testing
BS EN 62471:2008	Photobiological safety of lamps and lamp systems	LED Product Testing
BS EN 61000-3-3:2008	Electromagnetic compatibility (EMC). Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection.	LED Module Design / Manufacture

Source: ASTRI, 2009

3.2.2.4 Chinese Taipei

The Chinese Taipei is publishing a number of standards for LEDs street and outdoor lighting is one of the four APEC member economies with a specific standard for LED luminaires for road lighting as highlighted in Table 3.6.

Table 3.6 – Example of List of Existing Standards and Standards under Development on LED Street and Outdoor Lighting in Chinese Taipei

Standard	Title	Scope
CNS 14115	Radio disturbance limits for electrical lighting and similar equipment and measurement methods - Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment	LED Product Testing
CNS 14335	General requirements and tests for luminaires	LED Luminaire Testing / Design / Manufacture
CNS 14335-2-3	Luminaires - Part 2-3: Safety requirements for luminaires for road and street lighting	LED Luminaire Testing / Design / Manufacture
CNS 14676-5	Electromagnetic compatibility (EMC) - Testing and measurement techniques - Part 5: Surge immunity test	LED Module Testing / Design / Manufacture
CNS 15174	DC or AC supplied electronic control gear for LED module - Performance requirements	LED Control Gear Performance
CNS 15233	**Fixtures of roadway lighting with LED lamps**	**LED Luminaire Design / Installation / Performance**
CNS 15248	Methods of measurement on LED components for thermal resistance	LED Product Testing / Performance
CNS 15249	Methods of measurement on LED components for optical and electrical characteristics	LED Product Testing / Performance
CNS 15250	Methods of measurement on LED modules for optical and electrical characteristics	LED Product Testing / Performance
Under Review	Optics measurement method for LED lighting system	LED Lighting System Testing / Performance
Under Review	Environment and reliability testing method for LED devices	LED Lighting System Testing / Performance
Under Review	Optical and electrical characteristics measurement method for LED chip	LED Chip Testing / Performance
Under Development	Quality testing method for LED chip	LED Chip Testing / Performance
Under Development	Accelerated life testing method for LED chip	LED Chip Testing / Performance
Under Development	Accelerated life testing for LED device and module	LED Module Testing / Performance
Under Development	Thermal resistance measurement method for LED chip	LED Chip Testing / Performance
Under Development	Power supply measurement method for LED lighting system	LED Lighting System Testing / Performance
Under Development	Environment sustainability testing method for LED lighting system	LED Lighting System Testing / Performance

Source: ASTRI, 2009; ITRI, 2009

The Chinese Taipei also has street lighting standards which could be applicable to LEDs:

- CNS 10779 - Lighting for Traffic Route
- CNS 10780 - Method of Test for Lighting for Traffic Route

3.2.2.5 Japan

In Japan, the standard authorities tend to follow closely the international standards mentioned in Table 3.1. Table 3.7 shows some of the available standards and guidelines for LEDs in Japan. The guidelines on LEDs are not comprehensive at the moment as LED product development is in R&D stage until 2015.

Table 3.7 – Example of List of Existing Standards / Guidelines / Best Practices on LED Street and Outdoor Lighting in Japan

Standard	Title	Scope
JIS C 8121-2-2	Miscellaneous lampholders – Part 2-2: Particular requirements – connectors for printed circuit boards based LED modules	LED Module Design / Manufacture
JIS C 8147-2-13	Lamp control gear – Part 2-13: Particular requirements for DC or AC supplied electronic control gear for LED modules.	LED Control Gear Testing / Manufacture
JIS C 8153	DC or AC supplied electronic control gear for LED modules – Performance requirements	LED Control Gear Performance
JEL 311	General rules for Photometric Method of White LED Lighting	LED Product Testing / Performance
Japan Electric Lamp Manufacturers Association (JELMA)	Basic guide on proper use of LED Lighting	LED Luminaire Installation / Operation
	Basic guidelines for performance of LED Lamp Bulbs	LED Product Performance
Under Development	Gonio-photometric method for Luminaires	LED Luminaire Testing / Performance

Source: JELMA, 2009; JELMA, 2011

3.2.3 Other APEC Member Economies

3.2.3.1 Australia

Australia tends to adopt IEC/ISO standards with minimal or no changes. All IEC safety standards are applicable in Australia once published at IEC. Performance standards for street and outdoor luminaires are not mandated and considered to be covered by manufacturer's warranty. Similarly, **New Zealand** works closely with Australia regarding electrical appliance regulations and standards which are typically based on international specifications and then adapted to local conditions (e.g. temperature). Currently there are no published standards specifically for LED products for road lighting or outdoor lighting.

However, the AS/NZS 60598 standard, which specifies general requirements and testing for luminaires, is being modified by the joint Australian and New Zealand Standards committee to take into account LED developments. This is a regional variation of the IEC 60598 series (Luminaire Standards).

In addition, AS/NZS 1158 standard, which covers performance and design requirements for lighting in roads and public spaces, could be applicable to LED street lighting. The standard specifies road surface luminance, uniformity of illumination and others. It also requires the light output characteristics of luminaires to be stated precisely to enable accurate design of luminaire position, spacing, height and tilt.

3.2.3.2 Canada

In **Canada**, the LED street and outdoor lighting standards followed are those established by IESNA and other national standards such as:

- CAN-CSA C866 - Performance of LED Luminaires
- CAN-CSA C811 - Performance of Highmast Luminaires for Roadway Lighting

3.2.3.3 Indonesia

There are currently no LED related standards adopted at national level in Indonesia.

3.2.3.4 Republic of Korea

In the **Republic of Korea**, LED standards are still under development and consequently there have been challenges in full product development, production and sales. The goal of the Korean standardization authority is to develop and finalize all the relevant LED standards by October 2012. The available standards for LED outdoor and street lighting and traffic lighting include (KOPTi, 2009):

- **KS C 7528: LED Traffic Signals**
- KS C 7653: Recessed and Fixed LED Luminaires
- KS C 7655: DC or AC Supplied Electronic Control Gear for LED Modules
- **KS C 7658: LED Luminaires For Road And Street Lighting**
- KS C 7713: LED Landscape Lighting

The Republic of Korea is the only APEC member economy with standards for both LED traffic signals and LED luminaires for road and street lighting.

3.2.3.5 Malaysia

The Department of Standards **Malaysia**, under the Ministry of Science Technology and Innovation (MOSTI) has approved the following international LED standards, relevant to LED street and outdoor lighting:

- MS IEC 60838-2-2:2008 - Miscellaneous lampholders – part 2: particular requirements – connectors for LED modules.
- MS IEC 62384:2011 - DC or AC supplied electronic control gear for LED modules - performance requirements.

3.2.3.6 Mexico

In **Mexico**, there are several mandatory standards for lighting systems in public roadways and outdoor areas which apply to LED street and outdoor lighting (ICF International, 2011). According to the National Project on Energy Efficiency for Municipal Public Street Lighting (*Proyecto Nacional de Eficiencia Energética para el Alumbrado Público Municipal)*, manufacturers of LED Luminaires must comply with the following international and national standards (CONNUE, 2010):

- IES LM-79-08: Approved method: Electrical and photometric measurements of solid-state lighting products.
- IESNA LM-80-08: Approved method for measuring lumen maintenance of LED light sources.
- NMX-I-201-NYCE-2009: Electrónica – Componentes – Dispositivos de Control Electrónicos Alimentados en Corriente Continua o Corriente Alterna Para Módulos LED - Requisitos de Funcionamiento. (*Performance of control gear for LED modules DC or AC supplied electronic control gear for LED modules – performance requirements*)
- NMX-I-202-NYCE-2009: Electrónica – Componentes – Requisitos Particulares para Dispositivos de Control Electrónicos Alimentados con Corriente Continua o Corriente Alterna para Módulos LED. (*Particular requirements for DC or AC supplied electronic control gear for LED modules*).
- NMX-I-203-NYCE-2009: Electrónica – Componentes – Requisitos Particulares de los Conectores Para Módulos LED. (*Particular Requirements for connectors for LED modules*).
- NMX-J-507/1-ANCE-2005: Coeficiente de Utilización de Luminarios de Alumbrado Público para Vialidades. (*Coeficiente of utilization for street lighting in roadways*).

The LED manufacturers must also conform with the following minimum requirements for LED Luminaires shown in Table 3.8.

Table 3.8 - Minimum Requirements for LED Luminaires for Street Lighting under the National Project for Energy Efficient Street Lighting

Characteristics	Minimum Requirements
Luminaire Efficacy	70 lumen/Watt
Luminaire Depreciation	70% at Nominal Service Life
Correlated Colour Temperature	4,000, maximum 5,000 K
Colour Rendering Index	70
Nominal Service Life	50,000 hours
System Warranty	5 years
Power Factor	0.9

Source: CONNUE, 2010

As there are no accredited laboratories in Mexico for the above standards, the LED luminaires must be certified in accredited laboratories in the United States.

3.2.3.7 Singapore

In **Singapore**, a number of international and economy-wide standards are applicable for LED Street and Outdoor Lighting such as:

- IEC 60598-1- 2003: Luminaires - Part 1 - General Requirements and Tests
- IEC 61347-2-13: Particular Requirements for DC or AC Supplied Electronic Control Gear for LED Modules
- IEC 62384: DC or AC Supplied Electronic Control Gear for LED Modules – Performance Requirements
- IEC 62471: Photobiological Safety of Lamps and Lamp Systems
- SS 263 Luminaires - Part 1: General requirements and tests
- SS 263 Luminaires - Part 5 : Particular requirements for road and street lighting
- SS 531: Lighting of Indoor and Outdoor Work Places

3.2.3.8 Thailand

In **Thailand** there are no national standards applicable to LED street and outdoor lighting. Therefore some of the following international and national standards are applied, by the Provincial Electricity Authority (PEA), when demonstrating LED street and outdoor lighting projects:

- IEC 55015: Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
- IEC 60598-1: Luminaires - Part 1: General requirements and tests
- IEC 60598-2-3: Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting
- IEC 61347-1: Lamp control gear - Part 1: General and safety requirements
- IEC 61347-2-13: Lamp control gear - Part 2-13: Particular requirements for D.C. or A.C. supplied electronic control gear for LED modules
- IEC 62384: D.C. or A.C. Supplied Electronic Control Gear for LED Modules – Performance Requirements
- Thailand Industrial Standards (TIS) 1955: Lighting and Similar Equipment: Radio Disturbance Limits

3.2.3.9 Vietnam

There are currently no LED related standards available in Vietnam. However, IEC standards covering LED modules are likely to be adopted at national level by the end of 2011.

3.2.4 Testing Laboratories in APEC Member Economies

Based on the survey responses, at least nine APEC member economies have certified testing laboratories for LED street and outdoor lighting as shown in Table 3.9. Certified laboratories play key part in certifying LED product quality, safety and performance as well as supporting standards development together with government and lighting industry. APEC member economies, such as New Zealand, Mexico, Thailand and the Philippines, which do not have LED testing laboratories, conduct all the necessary testing and certification of LED product quality in other countries.

Table 3.9 – LED Testing Laboratories in APEC Member Economies

Economy	LED Testing Laboratories
Australia	LightLab, Queensland University Technology
Brunei Darussalam	-
Canada	CSA International
Chile	-
China	Sensing Instruments, National lighting Test Center (Beijing), National Center of Supervision & Inspection on Electric Light Source Quality (Shanghai) China National Lighting Fitting Quality Supervision Testing Centre (CLTC) (Shanghai), China National Lighting Fitting Product Supervision Testing Center (Zhongshan); China National Center for Quality Supervision and Test of semiconductor devices (Shijiazhuang); China National Center for Quality Supervision and Test of Semiconductor light emitting devices (Xiamne); Key Testing laboratory for Semiconductor Optoelectronics products (Jiangmen); National Center for Quality Supervision and Testing of Semiconductor lighting source products (Dongwan); National Center for Quality Supervision and Testing of Semiconductor lighting products (Changzhou)
Chinese Taipei	Industrial Technology Research Institute (ITRI) - Lighting Test and Evaluation Laboratory
Hong Kong	The Hong Kong Laboratory Accreditation Scheme (HOKLAS)
Indonesia	-
Japan	-
Korea	Withlight, Pimacs, J&C Teck
Malaysia	LED Certification Centre (under development)
Mexico	No
New Zealand	No
Papua New Guinea	-
Peru	-
Philippines	No
Russia	-
Singapore	TUV
Thailand	No
United States	NVLAP Certified Testing Laboratories, LA Bureau of Street Lighting
Vietnam	-

Note: - unknown; China's LED testing laboratories sourced also from USAID, 2011.

4 LED STREET AND OUTDOOR LIGHTING PROJECTS AND DEMONSTRATIONS

Below is a compendium of LED Street and Outdoor Lighting projects and demonstrations in several cities and towns in APEC member economies including activities undertaken to support projects. As LEDs products are evolving rapidly, the successful approaches mentioned below represent only a fraction of the on-going activities and achievements reported in the APEC member economies surveyed and information publically available.

4.1 Summary of LED Street and Outdoor Lighting Projects in APEC Member Economies

Table 4.1 provides a summary of the LED street and outdoor lighting projects in APEC member economies based on survey responses and publically available information. Almost all of the economies, active in LED lighting, have LED street and outdoor lighting projects for public parks, roadways, highways, tunnels, bridges, parking lots and/or traffic lighting. The projects tend to be located in the main cities of the APEC member economies for wider exposure.

Table 4.1 – LED Street and Outdoor Lighting Projects in APEC Member Economies

Economy	Public Parks	Public Roads	Traffic Lighting[1]
Australia	X	X	X
Brunei Darussalam			
Canada		X	
Chile			
China		X	X
Chinese Taipei	X	X	X
Hong Kong		X	X
Indonesia			
Japan			X
Korea		X	X
Malaysia			
Mexico	X	X	
New Zealand	X	X	X
Papua New Guinea			
Peru			
Philippines			X
Russia			
Singapore		X	X
Thailand		X	
United States	X	X	X
Vietnam			

X – Known Projects; Blank – No Projects or no information available
1 – LED traffic lighting is already used extensively globally. The table outcome is based on survey responses and APEC member economies with extensive number of installations.

4.2 Framework for Supporting LED Street and Outdoor Lighting Applications

This section provides an overview of the APEC member economies strategies and support for successful implementation LED Street and Outdoor Lighting applications.

Government support for LED Street and Outdoor Lighting projects is seen as critical factor for successful implementation and uptake by municipalities. In APEC member economies, government support can be in the form of:

- **Programs/plans** assist in the development of research, standards and projects on LED street and outdoor lighting supporting LED dissemination, market uptake and installation. Some APEC member economies have specific targets for LED deployment and provide incentives for demonstration projects.
- **Guidelines and manuals** provide voluntary advice to suppliers and installers of LED street lighting projects. These are usually used in addition to standards and specifications. Most APEC member economies have guidelines and manuals for street lighting installation, which are applicable to LED or, in few cases, been adapted for LED street lighting.

4.2.1 Programs/Plans

In at least five APEC member economies have programs and plans with dedicated roadmaps and targets for LED street and outdoor lightings:

- **Chinese Taipei**: The Ministry of Economic Affairs – Bureau of Energy setup a plan to accelerate LED lighting technology research and development through demonstration projects to promote awareness and trigger development of the industry.

- **Japan**: The government plan, led by New Energy and Industrial Technology Development Organization (NEDO), is to finalize research and development by 2015 and to replace all the lightings with LED on shipment basis by 2020. The final goal is to replace all the lightings in Japan with LED lightings by 2030. This plan combined with incentives for industry provides a strong support for the installation of LED street lighting in Japan. In addition, the government has agreed with electric utilities to provide a lower energy charge rate for using LED in public street lighting.

- **Korea**: Under the LED Lighting 2060 Project, the target is to achieve a national LED lighting penetration rate of 60 percent by 2020. This plan provides a roadmap for the development of the LED industry and triggers LED projects and uptake in Korea.

- **New Zealand**: The Energy Efficiency and Conservation Authority (EECA) has established an Efficient Lighting Programme which comprises a road lighting initiative involving local councils, New Zealand Transport Agency, New Zealand Institute of Highway Technology and others. The objective is to provide practical support to councils and others ensuring new road lighting projects follow best practice guidelines for efficiency and performance.

- **United States**: There are both plans and programs set at federal and municipal level, for example,

    - **Federal Level:** The Department of Energy has setup Five-Year SSL Commercialization Support Plan which includes a Municipal Solid-State Street Lighting Consortium. The consortium allows municipalities and experts to share technical information and experience on LED Street Lighting demonstration projects. The Five Year SSL plan also comprises of a LED testing program called CALiPER (Commercially

Available LED Product Evaluation and Reporting). The program supports the testing of a wide array of LED products including those for street and outdoor lighting.

- **Municipal Level**: In Los Angeles, the Bureau of Street Lighting established an LED Street Lighting Energy Efficiency Program to support the installation LED street lighting throughout the city. The Program provides guidelines, minimum requirements for installation and evaluation of operation of LEDs in roadways.

4.2.2 Guidelines and Manuals

The Commission Internationale de L'Eclairage (CIE) produced a number of guidelines for street lighting installation which could be applicable to LED street lighting projects such as:

- CIE 136-2000 – Guide to the Lighting of Urban Areas
- CIE 115-2007 - Recommendations for the Lighting of Motorized Traffic (updated)
- CIE 132-1999 – Design Methods for Lighting of Roads

In addition, APEC member economies have also published their own guidelines and manuals, in some cases particularly directed at LED street lighting installation. For example,

- **Hong Kong** - The Highways Department issued the Public Lighting Design Manual for providing guidance for the design of lighting works on public roads in Hong Kong. The manual applies to covered pedestrian routes, covered public transport interchanges, tunnels, underpasses/under decks, noise enclosures, gantry and roadside directional signs, high mast lighting, conventional and decorative road lighting.

- **Japan** – The Japan Electric Lamps Manufacturer Association (JELMA) offers basic guidelines on LEDs including typical Q&A and terminology.

- **New Zealand -** The Energy Efficiency and Conservation Authority (EECA), the Lighting Council and other partners established a website (http://rightlight.govt.nz) with information on general lighting and road lighting including design and installation guidelines, training resources, tools, requirements/specifications and standards. There are no particular guidelines directed exclusively at LED street lighting but LED products are mentioned and compared with road lighting products in terms of:

    - Typical efficacy (lumens/lamp watt)
    - Colour appearance (K)
    - Colour rendition
    - Typical lamp service life

- **United States** - The Municipal Solid-State Street Lighting Consortium provides guidelines, minimum requirements for installation and evaluation of LED operation in roadways.

4.3 LED Street and Outdoor Lighting Projects in APEC Member Economies

In the majority of APEC member economies, demonstration and pilot projects are applied to better understand the installation process and evaluate the performance of LED street lights compared to existing street lighting technology. These pilot projects are essential in providing knowledge, experience on best practices during installation (e.g. pole height and distance between poles, etc) to avoid repetition of mistakes. The demonstration and pilot projects can then be used to develop installation guidelines, manual, specifications and even installation related standards. The experience and knowledge gained can also be shared amongst other cities or nation-wide through workshops, supporting and facilitating LED street and outdoor lighting installation and operation. For APEC members economies implementing LED street lighting, this is seen as a key step for raising awareness and capacity building.

4.3.1 Australia

Table 4.2 – Summary of Major LED Street and Outdoor Lighting Projects in Australia

Location	Sydney
Number of installations	250 LED Streetlights
Approach	A variety of residential and commercial locations were selected to monitor and collect data on LED operating costs, lamp life, energy efficiency and greenhouse gas emission savings.
Achievements	Potential reduction in electricity and maintenance costs of City Council and Energy Australia (utility)

The City of Sydney was the first city in Australia to install 250 LED streetlights as part of an LED street lighting trial to help determine community acceptance and investigate aesthetics, operational issues, energy use, and capacity to meet the relevant lighting standards. By August 2011, 186 LED street lights had been installed (Figure 4.1).

Figure 4.1 – LED outdoor lighting in park in Sydney, Australia (City of Sydney, 2011)

Sydney has approximately 20,000 street and park lights, of which 12,000 are maintained by Energy Australia and 8,000 by the city council. For example in 2008/2009, the council spent AUS$3.5 million (approximately US$3.8 million) on electricity costs for the 20,000 lights and AUS$2 million (approximately US$2.2 million) on maintenance and upgrades of the 8,000 it maintains.

A variety of installation sites have been selected under the LED street lighting trial including residential, commercial and locations which require significant lighting. Four companies have been invited to install LED street lighting in these locations.

The trial will enable the City of Sydney to monitor the quality and type of lighting, compliance with Australian Standards for public lighting, as well as on-going operating costs, energy efficiency and durability. This includes lamp failures, potential causes of lamp failure and light output performance (e.g. illuminance from luminaire at ground level, mains voltage supply, current supply to luminaire). Upon conclusion of the trial, the data collected will be assessed in terms of operating costs, lamp life, energy efficiency and greenhouse gas emissions (City of Sydney, 2011).

4.3.2 Canada

Table 4.3 – Summary of Major LED Street and Outdoor Lighting Projects in Canada

Location	Greater Toronto Area
Number of installations	> 1,800 LED Luminaires (1,100 in Nova Scotia alone)
Approach	The LightSavers Program promotes best practices in design, installation and evaluation through demonstration projects and knowledge sharing.
Achievements	Accelerate use of LED street and outdoor lighting and supporting municipalities in making the best choices and ensure public acceptance of LED street lighting

The Toronto Atmospheric Fund designed a program called LightSavers to accelerate the use of advanced outdoor lighting and promote best practices in design, installation and evaluation. The program involves pilot testing of LED roadway lighting in a number of municipalities in the Greater Toronto area. Annex V includes a fact sheet on the Nova Scotia Street Lighting Demonstration Project with 1,100 LED luminaires installed and the respective results achieved (Figure 4.2). The program and participants share information on results, energy savings, light quality and public perception. This supports municipal managers in making the best choices for LED street and outdoor lighting (TAF, 2011).

Figure 4.2 – Nova Scotia Street Lighting Demonstration Project - Before using High Pressure Sodium and After using LEDs (TAF, 2011)

As part of the program, there is a *Municipal Policy Options Guide for Advanced Outdoor Lighting* which includes 14 actions that municipalities can take to promote the use of energy-saving street lighting technologies, from using pilot projects to demonstrate the benefits and win public acceptance to developing comprehensive lighting policies that promote greater uptake of the LED technologies (TAF, 2011).

4.3.3 People's Republic of China

Table 4.4 – Summary of Major LED Street and Outdoor Lighting Projects in China

Location	Nation-wide
Number of installations	At least 7.5 million LED streetlights to be installed (target)
Approach	Government established nation-wide LED demonstration project and provides municipalities with funding support through tenders. Other cities, such as Xiamen City, Huizhou, and Guangdong province also developing their own street lighting projects.
Achievements	Supports national LED industry and ensures greater market uptake in a short period.

In the People's Republic of China, the government setup an economy-wide demonstration project for LEDs through a domestic tender and each province and municipality can apply with their LED street lighting projects. A total of 15 LED street lighting projects will be selected (each project must install at least 500,000 LED lights to be eligible).

In addition, a number of cities and provinces established incentives, subsidies and plans for LED industry and LED street lighting project development. For example, in November 2009, the city of Huizhou in Guangdong Province joined the Cree LED City program, an international initiative aimed at promoting the deployment of energy-efficient LED lighting. Huizhou completed several LED streetlight trials and is in the process of deploying LED streetlights in the Zhongkai Hightech Industrial Zone. Xiamen City is also promoting LED street lighting projects including tunnel lighting with a total of 10,000 LED luminaires (LEDs Magazine, 2009).

4.3.4 Hong Kong, China

Table 4.5 – Summary of Major LED Street and Outdoor Lighting Projects in Hong Kong

Location	Hong Kong
Number of installations	1,900 junctions (traffic signals)
Approach	Conducted first pilot project to evaluate the performance and quality of LEDs. Upon confirmation of energy savings and adequate performance, the Hong Kong Transport Department proceeded with replacement of existing traffic signal technology.
Achievements	The Transport Department estimates approximately HK$7.6 million savings (approx. US$975,000) per annum and a reduction in CO_2 emissions of 5,300 tonnes. LED street lighting projects now extended to other districts.

In 2008, the Hong Kong Transport Department initiated a project to replace all the conventional traffic signals at 1,900 junctions (incandescent lamps) in Hong Kong with LED modules. The retrofit of all 1,900 junctions should be completed by the third quarter of 2012. By August 2011, approximately 60 percent of all traffic signals had been replaced with LED traffic signals.

Overall, the department estimates approximately HK$7.6 million savings (approx. US$975,000) per annum and a reduction in CO_2 emissions of 5,300 tonnes. According to the department, these savings were determined through the LED traffic signals pilot scheme completed in early 2008 at 100 junctions.

The total energy consumption of the whole junction including the traffic signal controller, traffic lights and electronics audible traffic signals, pushbuttons was reduced to about one-third before adopting LED. There is no indication on the performance of the LEDs compared to incandescent lamps (Clinton Foundation, 2010a).

In 2009, the Highways Department, in an effort to promote energy efficiency, also started conducting demonstration projects for road lighting using LED in Selkirk Road and Moray Road in Kowloon Tong. The Department extended these demonstrations to other districts with an additional 100 LED luminaires to further test the reliability and efficacy of LED road lighting (Legislative Council, 2010).

4.3.5 Chinese Taipei

Table 4.6 – Summary of Major LED Street and Outdoor Lighting Projects in Chinese Taipei

Location	Nation-wide
Number of installations	Replace all traffic signal lamps with LED lamps by 2012
Approach	National target to accelerate commercialization of LED street lighting supported by government grants
Achievements	Supports and strengthens national LED industry preparing industry also for external markets

The Chinese Taipei has a target of replacing all traffic signal lamps with LED lamps by 2012. According to Industry Technology Research Institute (ITRI, 2009), 10,000 LED modules have been installed by 2008. In 2009, the government provided NT$130 million (US$4.5 million) for another project aimed at replacing mercury lamps with 4,500 LED modules for street lighting. This project is expected to bring savings of 2.5 million kWh per year and accelerate the commercialization of LED street lamps (ITRI, 2009).

The Taipei City also announced in the May 2011 a plan to retrofit 2,000 LED street and outdoor lamps in parks, roads and tunnels in 2011. This is considered a demonstration project due to the on-going development of LED light standards and LED technology. The number of retrofits will be extended as LED technology matures and becomes available at competitive costs (TCG, 2011).

The Ministry of Economic Affairs - Bureau of Energy (MOEABOE) in partnership with the ITRI provides grants for energy efficient demonstration projects using LED street lighting. The objective is to accelerate the application of LED technology and LED lighting industry in the Chinese Taipei. The maximum total grant per project is NT$5 million (approximately US$172,000) (MOEABOE, 2011).

4.3.6 Republic of Korea

Table 4.7 – Summary of Major LED Street and Outdoor Lighting Projects in Korea

Location	Suwon City
Number of installations	4,000 LED traffic light units
Approach	Almost 10 years' experience in LED traffic lights. City has replaced 60% of all LED traffic lights.
Achievements	City has indicated 85% reduction in energy costs compared to previous technology and also a 30% reduction in traffic accidents

In the Republic of Korea, the city councils are taking the lead in LED street and outdoor lighting and traffic lighting.

For example, Suwon City has been installing LED traffic lights since 2002 with over 4,000 LED units installed throughout the city (60 percent of all LED traffic lights). The LED's use only 7 Watt to 15 Watt compared to 100 Watt of the previous traffic lights and the city have managed to save on maintenance and repair cost due to the higher lifetime of LED lights. The City has indicated an 85 percent reduction in energy costs due to LED traffic lighting and also a reduction in traffic accident by 30 percent (Suwon-City, 2011).

The Gwangju Metropolitan City joined the LED City Initiative in 2009, an international program supporting the promotion and installation of LED lighting in cities across the world. At least 50 LED luminaires had been installed by August 2011. It is estimated that by replacing all street lighting with LED, it could save the city an estimated 234,000 kWh resulting in a reduction in carbon emissions estimated at 8.5 tonnes of CO_2 per year. Gwangju City, which holds the country's leading photonics industry and technologies and LED Technical Assistance Center, opted to participate in this initiate to showcase Korean LED lighting products as well as energy and maintenance cost-benefits (CREE, 2009).

4.3.7 Mexico

Table 4.8 – Summary of Major LED Street and Outdoor Lighting Projects in Mexico

Location	Othón Blanco Municipality
Number of installations	25,507 LED streetlights
Approach	City street lighting outsourced to a lighting expert company through a 15 year concession
Achievements	Estimated 51% energy cost savings compared to current technologies

The Federal Government established a national project for energy efficient street lighting. The project provides technical and financial support to municipalities that wish to retrofit their street and outdoor lighting with more efficient lighting such as LED street lighting (CONNUE, 2010).

In 2010, the municipality of Othón Blanco announced a project to install 25,507 LED streetlights supplied by General Electric (GE) through a 15 year concession, making it one of the biggest LED street lighting projects in Latin America with estimated 51 percent energy cost savings compared to current technologies. According to GE, the resulting reduction in greenhouse gas emissions would be equivalent to removing about 40,000 vehicles from the road over a 10 year period (GE, 2010; LEDs

Magazine, 2010). There is no information available on the current status of this project.

In 2011, the Delegation of Miguel Hidalgo in Mexico City installed 23 solar LED luminaries in Parque Canenguin, one of Mexico City's largest urban parks. The solar LED outdoor lighting system eliminated the need for cable throughout the park and could be installed more quickly than the traditional street lights (LEDs Magazine, 2011).

4.3.8 New Zealand

Table 4.9 – Summary of Major LED Street and Outdoor Lighting Projects in New Zealand

Location	Waitakere City
Number of installations	> 230 LED lamps
Approach	Council started a road lighting demonstration project in 2007 to reduce their energy consumption and greenhouse gas emissions. LED technology was assessed successfully, and experience and best practices were shared amongst other cities, which, in turn, initiated their own LED street lighting trials.
Achievements	Achieved 55% energy reduction compared to existing technologies. Following the success of the demonstration project, the largest LED lighting project was implemented in 2010.

Similarly to the Republic of Korea, the city councils in New Zealand have taken the lead and setup a number of LED street and outdoor lighting pilot projects.

For example, Waitakere City Council established a Road Lighting Demonstration Project in 2007 to reduce the council's energy consumption from street lighting and respective greenhouse gas emissions. The lighting technologies used under this demonstration project include New Metal Halides and LEDs. A total of 19 LED units were installed achieving a 55 percent energy reduction compared to previous street lighting technologies. The city council also hosted Advancing New Zealand's Street Lighting Technologies Forum to share information and expertise on energy efficient street lighting technologies. Moreover and following the success of the first project, in March 2010, the council inaugurated a 5.7 km network with 214 LED luminaires, possibly the largest LED public space project in New Zealand (Waitakere City Council, 2011).

North Shore City Council replaced high pressure sodium (HPS) lamps with LED lamps on existing poles to assess energy savings, lighting performance and resident's satisfaction. In conclusion, the retrofit was not as effective using the existing poles and should have been adapted to improve lighting levels (Waitakere City Council, 2011).

Hamilton City Council, also installed 12 40 Watt LED street lights in two roads to assess the performance compared to 80 Watt mercury vapour luminaires which were not meeting national road and public places standard safety requirements. The project achieved an energy consumption reduction of 44 percent, increased average illuminance by 86 percent and minimum illuminance by 400 percent (Waitakere City Council, 2011).

4.3.9 Singapore

Table 4.10 – Summary of Major LED Street and Outdoor Lighting Projects in Singapore

Location	Singapore
Number of installations	69,000 traffic signal lights – 1,500 junctions
Approach	Replacement of existing filament-lamp based traffic signals with LEDs by the Land Transport Authority in 2001.
Achievements	Survey showed 90% of the public was satisfied with the features of the new LED signals particularly in terms of improved visibility and good colour contrast.

4.3.10 Thailand

Table 4.11 – Summary of Major LED Street and Outdoor Lighting Projects in Thailand

Location	Six Municipalities
Number of installations	100 LED Luminaires
Approach	Supported by utility (PEA) and Asian Development Bank as demonstration project for Mainstreaming Energy Efficiency in Thai Municipalities
Achievements	Currently under implementation. If successful, it will be extended to further municipalities nation-wide.

The Government of Thailand received a grant from the Asian Development Bank (ADB) for the implementation of the Mainstreaming Energy Efficiency in Thai Municipalities Project, administered by the Provincial Electricity Authority (PEA). This includes a pilot project on LED street lighting in six municipalities, with a total of 100 LED roadway luminaires to be installed by the end of July 2011.

4.3.11 Philippines

The Department of Energy, with funding from the ADB, created the Philippine Energy Efficiency Project which includes the installation of LED traffic lighting in 247 intersections in 2011-2012 in Metro Manila. The project is currently in procurement stage (as of November 2011).

4.3.12 United States

Table 4.12 – Summary of Major LED Street and Outdoor Lighting Projects in United States

Location	Los Angeles
Number of installations	52,059 LED Streetlights
Approach	The Bureau of Street Lighting is responsible for all the street lighting in the city of Los Angeles and has been in a leading city in the implementation of LED street lighting. In the process, the BSL has developed specifications, minimum requirements and evaluations procedures for LED street lighting to aid installers and other cities in the United States.
Achievements	By September 2011, approximately 21,800 MWh of annual energy savings and annual energy cost savings of US$1.93 million. This will increase with further installations projected. Largest LED street lighting project in APEC member economies.

4.3.12.1 Municipal Solid-State Street Lighting Consortium

The 2005 Energy Policy Act requires the DOE to accelerate SSL technology deployment due to its energy savings potential in street lighting (34 million streetlights in the United States) representing, potentially, savings of at least US$750 million per year. Consequently, the DOE established the Municipal Solid-State Street Lighting Consortium in 2010 to leverage the efforts of cities in evaluating LED street and outdoor lighting.

Examples of LED Street Lighting and Outdoor demonstrations projects under the consortium include (DOE, 2010b):

- LED Roadway Lighting, City of Palo Alto: Demonstration project report provides assessment of energy, economic, and performance impacts of replacing high pressure sodium street lights with LED and induction street lights.
- LED Street Lighting, Lija Loop (Portland, OR): Demonstration project report provides final analysis of the energy and performance impacts of replacing eight high pressure sodium street lights on one residential street with LED luminaires.
- LED Street Lighting, City of San Francisco: Demonstration project report provides performance study of LED street lights from four different manufacturers replacing 100 Watt nominal high pressure sodium luminaires.

- LED Street Lighting, City of Oakland: Demonstration project report provides assessment of energy, economic, and safety impacts of replacing 15 high pressure sodium street lights on two public streets with LED luminaires.

Basically, the Consortium collects, analyses and shares technical information and experience on LED Street Lighting demonstration projects. This enables participants to share data, knowledge, best practices and/or successful approaches in LED street and outdoor lighting.

In addition, it is a source of information on the real-life performance of new LED products and guide on LED specifications for LED street lighting. Currently, the following specifications apply for LED Roadway and Outdoor Lighting (DOE, 2011b):

- Model Specification for LED Roadway Luminaires (System and Material Specification).
- Outdoor Lighting Guidance provides basic assistance to municipalities for evaluating luminaires for common outdoor lighting applications: wall-mounted area lighting (wall packs), parking garage lighting, canopy lighting, and pole-mounted roadway and area lighting. This available at the DOE energy efficiency and renewable energy website - http://www.eere.energy.gov/.
- Guide to Evaluating LED Lumen Maintenance (Annex VI).
- Fitted Target Efficacy (FTE) Performance Metric Calculator.
- Commercial Buildings Energy Alliance (CBEA) High Efficiency Parking Structure Lighting Technology Specification.
- CBEA LED Site (Parking Lot) Lighting Technology Specification.

4.3.12.2 Lighting Research Center and Electric Power Research Institute

The Lighting Research Center, with the support of the New York State Energy Research and Development Authority (NYSERDA), has also carried out demonstration and evaluation of 16 LED luminaires in a business park in Greenbush, New York (LRC, 2010). The LRC also developed a publication with recommendations for evaluating street and roadway luminaires as part of the Alliance for Solid-State Illumination Systems and Technologies (ASSIST). According to the document, the evaluation is based on an assessment of the effectiveness of luminaires at meeting predetermined, application-based photometric criteria and is intended to be used as tool in the process of selecting and rank ordering luminaire choices for street lighting (LRC, 2011).

The Electric Power Research Institute (EPRI) is managing over 20 LED street lighting technology demonstrations throughout the United States. The objective is to compile more and better data on LED performance and enhance collection of field data.

4.3.12.3 Seattle, Los Angeles and Chicago's LED Street Lighting Projects

The cities of Seattle, Los Angeles and Chicago are actively pursuing LED street and outdoor lighting following government incentives and the DOE's Municipal Solid-State Street Lighting Consortium.

In Seattle, Seattle City Light installed a total 10,000 LED street lights (Figure 4.3). The council's target is to install a total of 40,000 LED streetlights in residential areas by the end of 2014, providing estimated energy savings of US$2.4 million per year. The City Light is mainly replacing HPS lights to LEDs and the performance of LEDs has been careful assessed in the following (Seattle City Light, 2011):

- Evaluate the lighting, economic, and energy consumption performance.
- Evaluate the ability for LED products to produce a 40 percent energy savings compared to existing HPS cobra head style luminaires.
- Develop a functional specification and recommendations for the installation and maintenance of these products.

- Identify next steps to increasing energy efficiency of LED lighting.

These steps and approach are essential to ensure future success of LED street and outdoor lighting in the city.

Figure 4.3 – Installation of LED Street Light in Seattle (Seattle City Light, 2011)

In the city of Los Angeles, the Bureau of Street Lighting is responsible for the design, construction, operation, maintenance and repair of the City's Street Lighting System. The Bureau has implemented LED Pilot Projects (Figure 4.4) and LED Street Lighting Energy Efficiency Program with more than 52,059 LED units installed resulting in annual energy savings of 21,800 MWh and annual energy cost savings of US$1.93 million by September 2011. As part of the program, the Bureau has published (BSL, 2011):

- General Specifications for Solid-State Lighting LED Roadway Luminaires (LED Equivalent Replacement for 70 Watt, 100 Watt, 150 Watt and 200 Watt HPS)
- Minimum Requirements for Testing and Evaluation of LED Equipment
- LED Equipment Evaluation Procedures

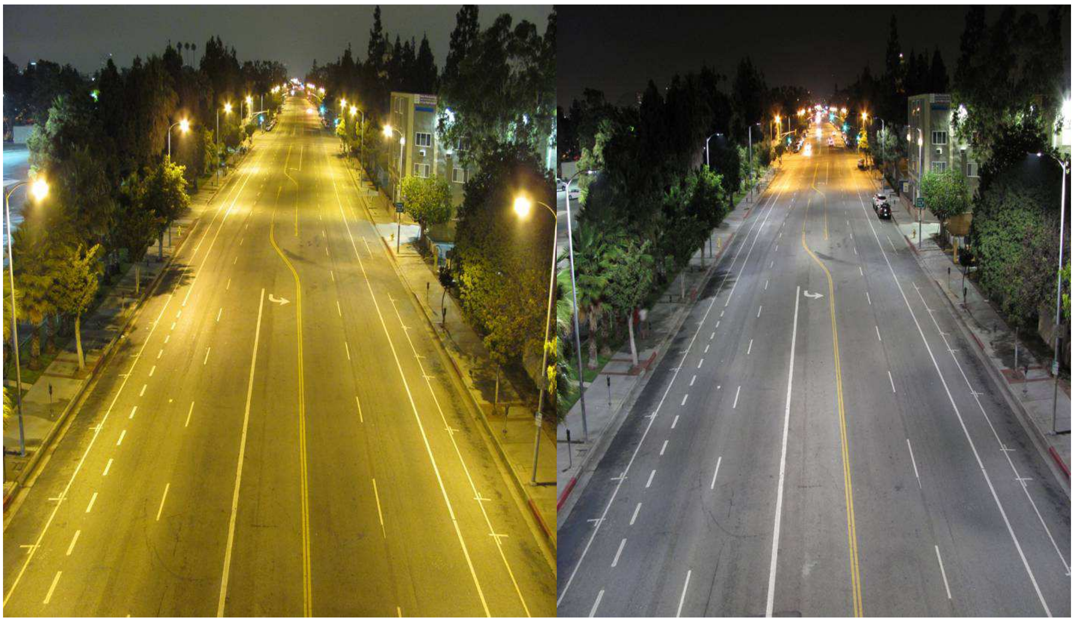


Figure 4.4 – Before (with High Pressure Sodium - left) with and After (with LEDs - right) as part of the LED Conversion Program in Los Angeles (Source: BSL, 2011)

In Chicago, both the Street and Sanitation and General Services Departments, established a project to retrofit and install LED's in all traffic lights representing a total of 2,900 intersections. The project commenced in 2004 with initial funding from the city and ComEd (utility) and was part of a city's plan for energy efficiency to reduce its environmental footprint by 30 percent by 2020. The LED project alone covers 15 percent of this target.

The city stated the project allowed for an annual saving of US$2.55 million in energy savings and US$100,000 annual cost savings in materials. The LED traffic light (12 to 20 Watt) use almost 85 percent less energy compared to previous technologies (100 Watt incandescent lights) enabling a reduction in 23,000 tonnes of CO_2 per year. The project is now funded by City bonds and these bonds are paid back through the energy savings over a period of 6 to 7 years (Clinton Foundation, 2010b).

4.4 Key Stakeholders in LED Street and Outdoor Lighting in APEC Member Economies

Table 4.13 lists which key stakeholders, in each APEC member economy, contribute to specifications, design and selection of products for street and outdoor lighting applications. The table is based on survey responses from each APEC member economy.

Table 4.13 – List of Key Stakeholders for LED Street and Outdoor Lighting according to APEC member economy

Economy	*Electric Utility*	*Local Government Unit / Municipality*	*Department of Transportation/Highway Authority*	*Department of Public Works*	*Professional/Industry Association*
Australia	X	X	X	-	X
Brunei Darussalam	-	-	-	-	-
Canada	-	-	Department of Transport	-	-
Chile	-	-	-	-	-
China	-	City Street Lighting Management Office	Ministry of Industry and Information Technology	-	Lighting Industry, Standards Committee (or test labs)
Chinese Taipei	-	X	X	Bureau of Energy, Ministry of Economic Affairs	LED Street Light Industry Alliance
Hong Kong	-	Architectural Services Department, Electrical & Mechanical Services Department, Housing Department	Highways Department, Transport Department	-	-
Indonesia	-	-	-	-	-
Japan	-	-	-	Ministry of Land, Infrastructure, Transport and Tourism	Japan Luminaires Association
Korea	-	Local Government	National Highway Department	-	-
Malaysia	-	-	-	-	-
Mexico	-	-	-	-	-
New Zealand	X	City and District Councils	New Zealand Transport Authority - State Highways	-	Ingenium
Papua New Guinea	-	-	-	-	-
Peru	-	-	-	-	-

Philippines	X (e.g. Manila Electric Company, electric cooperatives)	Local government units under the Department of Interior and Local Government	Department of Public Works and Highways	-	Philippine Lighting Industry Association
Russia	-	-	-	-	-
Singapore	-	Land Transport Authority	-	-	-
Thailand	-	-	Department of Highway, Ministry of Transport	-	-
United States	X	Municipal Solid-State Street Lighting Consortium, Los Angeles Bureau of Street Lighting	United States Department of Transportation, Federal Highway Administration including State by State Specifications	Los Angeles Bureau of Street Lighting	-
Vietnam	-	-	-	-	-

Note: - unknown; X – Not Specified

5 BEST PRACTICE GUIDE FOR LED STREET AND OUTDOOR LIGHTING

The Best Practice Guide for implementation of LED street and outdoor lighting is based on a review of survey responses received from APEC member economies and relevant literature identified and reviewed in this report. The guide covers specifically the activities of **purchase**, **installation** and **maintenance** of LED street and outdoor lighting in APEC member economies.

The Best Practice Guide is intended for stakeholders involved in street and public lighting of all towns and cities in APEC economies, who may see reduced municipal operating costs and carbon emissions from the accelerated installation of highly efficient street lighting. The guide is also intended to aid local officials and municipal governments in learning how to install more efficient street lighting in a fast and cost-effective manner, as well as policy makers for clearer basis for regulations to ensure the quality of LEDs installed.

Note that this guide represents current, best available information, but as the industry and market changes, other information may supersede what is presented here.

5.1 Purchase

When purchasing LED products for street and outdoor lighting, the typical approach would be to prepare specifications and verify if product specifications match the requirements including product warranty and/or any form of certification of product quality. In a procurement process for a LED street lighting project, the general best practice is to verify the following:

- **LED product specifications follow economy-wide standards?**

  This is an essential requirement to ensure product complies with economy-wide and/or international standards for LED product safety, quality and performance.

- **Testing performed by third-party, accredited laboratories?**

  This requirement is important to ensure product quality. In some APEC member economies, the testing is carried outside the member economy which contributes to higher product costs but typically most international LED suppliers already comply with this best practice.

- **Requirements of illumination quality included in the procurement specifications?**

  When procuring LED lighting systems for street and outdoor lighting, it is important to establish in advance all the requirements on appropriate light levels, uniformity and glare. Such requirements should be based on factors such as road classifications and conflict areas specified in available standards, guidelines and/or best practices. Simulation of light distribution profiles and average illuminance levels may be required to ensure initial technical specifications of LED lighting systems.

- **Preliminary field trial is a part of the evaluation and selection process?**

  When working with a new technology and/or supplier for the first time for street and outdoor lighting, it is best practice by most APEC member economies to carry out a preliminary field trial during LED procurement. The objective is to evaluate LED equipment and performance against prerequisites, specifically on the illumination quality, and aid in the selection process. This is critical as LED technology continues to improve rapidly.

- **"Application Efficacy" considered as one of the selection criteria?**

The Application Efficacy refers to delivering light to where it is needed in the most energy efficient manner. It is defined as the average luminous flux within a specific solid angle per unit of power consumption (lumen/watt). This efficiency metric will ensure that LED luminaires with poor distribution profiles or LED luminaires that waste light by directing it outside the working plane are penalized.

- **Warranty of LED products is at least 5 years? Warranty bond and penalty included as parts of Warranty Terms and Conditions?**

The LED manufacturer or supplier must provide LED warranty for all or key components of the LED luminaire. Generally, the warranty expected for LED products for street and outdoor lighting is a minimum of five years. Based on the survey responses, only Australia, Thailand (ADB project only) and the United States are known to have applied this warranty bond and penalty in LED street and outdoor lighting projects. If procuring LED products for LED pilot/demonstration, a warranty bond and penalty included as parts of Warranty Terms and Conditions should be incorporated in the bid document or procurement contract. The warranty bond ensures the LED product supplier will resolve any product issues during warranty period according to the warranty agreement.

5.1.1 Technical Specifications and Standards

Technical specifications and standards for LED street and outdoor lighting and traffic lighting products are established to ensure product safety and quality, and should be taken into consideration in the procurement process. Currently three APEC member economies have established specific LED standards for street and outdoor lighting and traffic lighting. These economy-wide standards are typically based on extensive on-the-ground experience and should be referenced in the procurement process. For example:

- **China - GB/T 24907-2010: LED lamps for road lighting – performance specifications:**

This standard specifies the technical terms and definitions, technical requirements, test methods, inspections rules, marking, packaging, transportation and storage requirements. This standard applies to LED devices, control circuit and drivers.

- **Chinese Taipei - CNS 15233: Fixtures of roadway lighting with LED lamps:**

This standard applies to LEDs for outdoor use, including the control device (control gear), cooling devices, optical components and associated mechanical structure.

- **Korea - KS C 7528: LED traffic signals & KS C 7658: LED luminaires for road and street lighting** which are particularly related to safety aspects.
- **United States - ANSI C136.37: Solid-State Light sources used in roadway and area lighting**

Other APEC economies, which have not yet developed their own economy-wide standards for LED street and outdoor lighting, could reference international or regional standards, as summarized in Section 3.1 of this report, in their technical specifications. For example in **Thailand**, in the Asian Development Bank's *Mainstreaming Energy Efficiency in Thai Municipalities Project*, the general specifications for LED roadway luminaires are based on IEC, IEC/PAS and CIE publications as shown in Table 5.1, Table 5.2 and Table 5.3.

Table 5.1 - General Specifications for LED Roadway Luminaires for the Mainstreaming Energy Efficiency in Thai Municipalities Project - Luminaire Requirements

Luminaire Requirements:	
Correlated Colour Temperature (CCT)	Shall have a minimum CCT (°K) of 4000
Colour Rendering Index (CRI)	LED module(s)/array(s) shall a minimum CRI of 65.

Luminaire Requirements:	
Off-State Power Consumption	The power draw by the luminaire including power supply(ies)/driver unit(s) shall not exceed 2.5 watts when in the off state.
On-State Power Consumption	Luminaire including power supply/driver unit(s) shall not consume more than 150 watts.
Luminaire Efficacy	Shall have a minimum luminaire efficacy (luminaire light output including fixture efficiency and thermal effects)/luminaire input power (LEDs and drivers) of 50 lumen/watt
Housing	Shall primarily be constructed of metal. Finish shall be grey in colour, power coated and rust resistant. In case the LED driver unit is mounted internally, it shall be replaceable and accessible without tools. Any parts constructed of polycarbonate or acrylic shall be UV stabilized, any lens discoloration shall be considered a failure under warranty.
Protection Class	The entire luminaire, inclusive of the cable entry and gland, shall have at least a protection class of IP 54.
Mounting Arm (Mass Arm) Connection	Luminaire shall mount on the existing mounting/mass arm and shall be adjustable to deliver required uniformity of illumination.
Cooling System	Luminaire shall consist of heat sink with no fans, pumps or liquids and shall not degrade heat dissipation performance.
Light Distribution	Photometric data shall be provided.
Luminaire Performance Testing	IEC/PAS 62612: Edition 1: 2009-06

Table 5.2 - General Specifications for LED Roadway Luminaires for the Mainstreaming Energy Efficiency in Thai Municipalities Project –LED Module / Array Requirements

LED Module/Array Requirements:	
Module Assembly	LED module assembly shall have at least a protection class of IP 66.
Lumen Depreciation	LED module(s)/array(s) shall deliver at least 70% lumen maintenance at 50,000 hours.
Safety	IEC 62031

Table 5.3 - General Specifications for LED Roadway Luminaires for the Mainstreaming Energy Efficiency in Thai Municipalities Project – Power Supply / Driver Requirements

Power Supply/Driver Requirements:	
General Requirements	Power supply/driver unit(s) shall be of constant current or constant voltage type with sufficient capacity to supply rated power required by LED module(s)/array(s) installed in the luminaire.
Input	220±10%Vac, 50Hz
Power Factor	≥ 0.9
Operating Temperature	-20°C - +50°C
Maximum Case Temperature (t_c)	75°C
Safety	IEC 61347-1, IEC 61347-2-13
Electromagnetic Compatibility (EMC)	CISPR 15
Immunity	IEC 61547
Protection Class	Shall have a protection class of IP54
Open circuit protection	Automatic restart
Over load protection	Automatic restart
Short Circuit Protection	Automatic restart
Nominal Service Life	50,000 hours

In the **United States,** in addition to the ANSI C136.37 standard mentioned above, the DOE provides specifications for LED roadway such as the *Model Specification for LED Roadway Luminaires*. There are two optional specifications provided – System (application efficacy) or Material Specification (luminaire efficacy). The System Specification is preferred as it characterizes the luminaire performance based on site characteristics such as mounting height, pole spacing, number of drive lanes, input power, and required light levels and uniformity. The Material Specification characterizes the luminaire performance irrespective of site characteristics. The Lighting Research Institute also provides a tool for evaluating street and roadway luminaires as part of the Alliance for Solid-State Illumination Systems and Technologies (ASSIST) to support in the process of selecting and rank ordering luminaire choices for street lighting (LRC, 2011).

In addition, the Bureau of Street Lighting – City of Los Angeles – provides general specifications for SSL LED roadway luminaires (LED Equivalent Replacement for 70 Watt and 100 Watt HPS) with the best practices specified in Table 5.4, Table 5.5 and Table 5.6. One of the key points in Table 5.4 is the requirement for economies to make sure LED luminaires do not draw power in the off-state. It also is one of the few specifications where dimensions for LED luminaires are indicated.

Table 5.4 – General Specifications for LED Roadway Luminaires (LED Equivalent Replacement for 70 Watt and 100 Watt HPS) – Luminaire Requirements

Luminaire Requirements:	
Correlated Color Temperature (CCT)	Nominal CCT (°K) 4300 +/-300
Color Rendering Index (CRI)	Luminaires shall have a minimum CRI of 65.
Off-state Power Consumption	The power draw of the luminaire (including PE or remote control devices) shall not exceed 2.50 Watts when in the off state.
On-state Power Consumption	Shall not consume more than (not including optional monitoring/control device): -58 Watt for Equivalent Replacement of 70 Watt HPS -85 Watt for Equivalent Replacement of 100 Watt HPS
Warranty	A warranty must be provided for the full replacement of the luminaire due to any failure for six (6) years. The warranty shall provide for the repair or replacement of defective electrical parts (including light source and power supplies/drivers) for a minimum of eight (8) years from the date of purchase.
Weight	Luminaire shall not weigh more than 22 pounds.
Operating Environment	Luminaire shall be able to operate normally in temperatures from -20° C to 50° C.
Cooling System	Shall consist of a heat sink with no fans, pumps, or liquids, and shall be resistant to debris buildup that does not degrade heat dissipation performance.
Dimensions (Approx.)	30" long x 16" wide x 7" tall
Housing	Shall be primarily constructed of metal. Finish shall be gray in color, powder coated and rust resistant. Driver must be mounted internally and be replaceable. Driver must be accessible without tools. All screws shall be stainless steel. Captive screws are needed on any components that require maintenance after installation. No parts shall be constructed of polycarbonate unless it is UV stabilized (lens discoloration shall be considered a failure under warranty). Ingress Protection shall be rated a minimum of IP54.
IESNA Luminaire Classification	Cutoff or using TM-15: B1 U1 G1.
Mounting Arm Connection	Luminaires shall mount on 2.375" O.D. horizontal tenon with no more than four 9/16-inche hex bolts and two piece clamp with vertical tilt adjustment range of +/- 5%.
PE Cell Receptacle	Luminaires shall have a 3-prong twist-lock photo-control receptacle in accordance with ANSI C136.10. The PE socket needs to be able to rotate, so that the PE window can always be positioned to face the North direction.
House Shield	Shall provide option for house side light control.

Source: BSL, 2010

Table 5.5 – General Specifications for LED Roadway Luminaires (LED Equivalent Replacement for 70 Watt and 100 Watt HPS) – LED Module / Array Requirements

LED Module/Array Requirements:	
Lumen Depreciation of LED Light Sources	LED module(s)/array(s) shall deliver at least 70% of initial lumens, when installed for a minimum of 50,000 hours. Assembly shall be rated a minimum of IP66.
Light Distribution	Should be in accordance with IESNA Type II Lighting Distribution. Distribution Type II designated 2X is also acceptable.

Source: BSL, 2010

Table 5.6 – General Specifications for LED Roadway Luminaires (LED Equivalent Replacement for 70 Watt and 100 Watt HPS) – Power Supply / Driver Requirements

Power Supply/Driver Requirements:	
Power Factor	Power supply should have a minimum Power Factor of .90
Max amperage at LED	Maximum rating DC Forward Current at TA 25‹ C should be 1000 mA. Maximum amperage at LED must not exceed driver current to meet Lumen Depreciation value described above and initial lumen values required below, and shall not exceed 700 mA per mm2 of chip. Standard factory setting shall be 525 mA, as delivered from the factory. The Driver and LED arrays shall be designed for multi-current input operation, with switchable ratings at 350 mA, 525 mA and 700 mA.
Transient Protection	Per IEEE C.62.41-2-2002, Class A operation. The line transient shall consist of seven strikes of a 100k HZ ring wave, 10 kV level, for both common mode and differential mode. It should also meet test procedure in accordance with IEEE C62.45.
Operating Temperature	Power Supply shall operate between -20‹ C and 50‹ C.
Frequency	Output operating frequency must be. 120 Hz (to avoid visible flicker) and input operating frequency of 60 Hz.
Interference	Power supplies shall meet FCC 47 CFR Part 15/18 (Consumer Emission Limits).
Noise and Ingress Protection	Power supply shall have a Class A sound rating per ANSI Standard C63.4. Assembly or compartment shall be rated a minimum of IP54.

Source: BSL, 2010

5.1.2 Product Certification

LED technology and products are developing at fast rate and not all products have proven or comparable quality at this stage. To ensure LED product quality, customer confidence and respective market uptake, a number of APEC member economies setup quality assurance, certification programs and/or labeling schemes. Most schemes are voluntary and LED product suppliers and manufacturers have to satisfy the established requirements and test their products in certified/recognized laboratories. Accredited laboratories play key part in certifying LED product quality, safety and performance as well as support standards development together with government and lighting industry. These schemes are likely to contribute to higher product purchase costs but ensures the buyer is purchasing a quality product for their LED street and outdoor lighting project. Synergies between APEC member economies and other economies should be considered to reduce testing costs.

Currently, Australia, Republic of Korea, Malaysia, Mexico, New Zealand and the United States have launched voluntary SSL labeling/certification programs for quality assurance. There is no mandatory labeling program in place at the moment except for China (ICF International, 2011). Examples of quality assurance, certification programs or labeling schemes in APEC member economies are detailed in the sections below.

5.1.3 Australia

In **Australia**, the Lighting Council Australia, setup a SSL Quality Scheme, based on the United States scheme mentioned below. The scheme ensures products perform according to the supplier's claims and provides customer confidence when purchasing the LED equipment. The minimum requirements for the LED luminaire have to be proven by the supplier through third party test reports on (LCA, 2011):

- Luminaire efficacy
- Light output of the luminaire
- Measured input power
- Correlated colour temperature
- Colour rendering index

5.1.4 People's Republic of China

In 2010, the China Quality Certification Center launched the *Energy Conservation Certification Criteria for LED Road and Tunnel Lighting* (CQC 3127-2010) covering technical specifications for testing safety and electro-magnetic compatibility. This is the only mandatory certification scheme available specifically for LED road and street lighting in APEC member economies. It is widely used for government procurement and certification of LED street and outdoor projects.

5.1.5 Hong Kong, China

In Hong Kong, the Highways Department and the Electrical and Mechanical Services Department (EMSD) developed the *Public Lighting Design Manual* and *Guidelines for Specifying & Procuring LED Lighting Products for Lighting Projects*, respectively. The Public Lighting Design Manual applies to covered pedestrian routes, covered public transport interchanges, tunnels, underpasses/underdecks, noise enclosures, gantry and roadside directional signs, high mast lighting, conventional and decorative road lighting (HyD, 2006). The *Guidelines for Specifying & Procuring LED Lighting Products for Lighting Projects* covers LED Lighting construction and light distribution, LED drivers and lighting controls, thermal management, energy efficiency colour quality, life and lumen maintenance, and performance and quality assurance (EMSD, 2011).

5.1.6 Republic of Korea

In the Republic of Korea, there is a voluntary label for high efficiency appliance certification programs for LED traffic lights (ICF International, 2011, KEMCO, 2011). The voluntary program established in 1996 consists of a certificate to inform consumers the appliance is of high efficiency. This means the high efficiency appliance performs above certain energy efficiency and quality standards set by the Korean Energy Management Corporation (KEMCO) (IEA-DSM, 2011).

5.1.7 Malaysia

In Malaysia, in March 2011, the Performance Management & Delivery Unit (PEMANDU) under the Prime Minister's Department, announced a LED Certification Centre to increase awareness and ensure quality of Malaysian LED products for the global market. The facility will carry out certified testing assessment according to ANSI standards (PEMANDU, 2011).

5.1.8 Mexico

In Mexico, the national energy savings agency (FIDE) has a voluntary label scheme called Sello FIDE (FIDE Label) for LED luminaires for roads and pedestrian area (ICF International, 2011). By August

2011, at least 15 companies received the Sello FIDE for their LED luminaires for roads and pedestrian areas. These companies tested their LED products and submitted the test results to a certified laboratory to verify against Sello FIDE requirements (FIDE, 2011).

5.1.9 New Zealand

In New Zealand, as of August 2011, LED light bulbs are eligible for the Energy Star Program, a voluntary labelling scheme for energy efficient products. To be included in the program, the LED product must meet all requirements such as a minimum three year warranty. This program is applicable only to electrical equipment for residential and commercial applications. However, it shows a process by which governments can ensure the quality of an LED product.

5.1.10 United States

In the United States, the DOE and the Next Generation Lighting Industry Alliance (NGLIA) established the SSL Quality Advocates Scheme. It is a voluntary pledge program to assure that LED lighting, as it reaches the market, is represented accurately through use of the Lighting Facts label. It encourages the development of high-quality products that perform as claimed, to ensure customer satisfaction and support market acceptance of LED products (DOE, 2011c). Moreover, the DOE LED testing program CALiPER provides objective product performance information to the general public to ensure buyers and specifiers have confidence that LED products will perform as claimed.

In Los Angeles City, the Bureau for Street Lighting (BSL) established a LED equipment evaluation procedure which tests the LED luminaire against BSL's Minimum Requirements for Testing and Evaluation of LED Equipment. One sample luminaire is installed in the field and performance is measured during 10 weeks. The luminaire is also tested in the laboratory in terms of electrical and mechanical performance, ease of maintenance and aesthetics. If the LED luminaire complies with the minimum requirements it can be purchased by BSL for use in Los Angeles City street lighting (BSL, 2011).

5.2 Installation

Please note this section includes a number recommendation documents which are still under discussion and have not been adopted by any standard.

For new installations, LED street and outdoor lighting typically follows the designs and practices for roadways lighting design being developed, adopted or recognized by each APEC economy. These guidelines and practices generally consider various aspects that would influence design layouts and choices of light sources such as:

- characteristics of road constructions and layouts,
- traffic density,
- required light levels and uniformity, and
- limitation of glare.

These installation guidelines and practices intend to support street and outdoor lighting with LED predecessors, including but not limited to, fluorescent, mercury vapor, high pressure sodium and metal halide. However, they also apply to LED street and outdoor lighting designs and installation because design and installation guidelines and practices for LED lighting are still under development. For retrofitting works, installation can be relatively straight forward, as in many cases modification of civil works is not practical, leaving the scope of the retrofitting works to only luminaire replacement on the existing poles.

5.2.1 Light Levels and Uniformity

Requirements on light levels and uniformity will be the primary focus of the best practice guide for LED street and outdoor lighting installation. There are several technical reports and standard documents outlining requirements of light levels and uniformity of roadway and traffic lighting, including but not limited to:

- CIE 115-1995 (updated 2007) – Recommendations for the Lighting of Motorized Traffic.
- CIE 132-1999 - Design Methods for Lighting of Roads.
- CEN/TR 13201-1 - Road Lighting Part 1: Selection of Lighting Classes.
- EN 13201-2 - Road Lighting Part 2: Performance Requirements.
- AS/NZS 1158.1.1: - 1997 Road Lighting – Vehicular Traffic Lighting.
- ANSI/IESNA RP-8-2000 - American National Standard Practice for Roadway Lighting.
- JIS Z9110 - Recommended levels of illumination, JIS Z9111 - Lighting for roads, JIS Z9116 - Lighting of tunnels for motorized traffic.

The abovementioned documents recommend different light levels and uniformity based on type of traffic (motorized or pedestrian traffic), traffic density, conflict area (intersection of traffic). The required light levels and uniformity will then determine civil design works (lighting pole layout, span and height), selection of light source and luminaire and electrical design works. Requirements on light levels and uniformity recommended by CIE and IESNA are shown below in Table 5.7 and Table 5.8, respectively.

Table 5.7 – Luminance and Uniformity Recommended by CIE 115-1995

Lighting Class	*Luminance (cd/m^2)*	*Uniformity (U_o)*
M1	2.0	0.4
M2	1.5	0.4
M3	1.0	0.4
M4	0.75	0.4
M5	0.5	0.4

Table 5.8 – Illuminance Levels for Different Types of Roads Recommended by IESNA

Road and Pedestrian Conflict Area		Pavement Classification		
Road	**Pedestrian conflict area**	**R1**	**R2 & R3**	**R4**
Freeway Class A		6 lx	9 lx	8 lx
Freeway Class B		4 lx	6 lx	5 lx
Expressway	High	10 lx	14 lx	13 lx
	Medium	8 lx	12 lx	10 lx
	Low	6 lx	9 lx	8 lx
Major	High	12 lx	17 lx	15 lx
	Medium	9 lx	13 lx	11 lx
	Low	6 lx	9 lx	8 lx
Collector	High	8 lx	12 lx	10 lx
	Medium	6 lx	9 lx	8 lx
	Low	4 lx	6 lx	5 lx
Local	High	6 lx	9 lx	8 lx
	Medium	5 lx	7 lx	6 lx
	Low	3 lx	4 lx	4 lx

Source: Table 1, ASSIST Publication on Outdoor Lighting: Visual Efficacy, Volume 6, Issue 2, January 2009

Measurement and evaluation of light level and uniformity of street and outdoor lighting focus on a target task plane (i.e. roadway surface). However roadway uses, dimensions, and lighting systems layout vary from location to location, and therefore it is not practical to measure or model lighting performance for an entire street and outdoor lighting system. CDM Methodology AMS.II-L recommends measurement and evaluation of lighting performance of representative locations to show compliance. Representative locations are defined as sample locations selected during design for each roadway and intersection lighting class including multiple locations within a lighting class if any significant variation in streetlight pole spacing and mounting height, and street dimensions occur.

Measurement and evaluation of lighting performance can either be done through computer modeling of illuminance (e.g. DIALux freeware) or actual field measurements for which measurement of illuminance (the amount of luminous flux falling per unit area - lumens/m^2, or lux) is a simple approach recommended by CDM Methodology AMS.II-L and IESNA. In terms of locations of measurement or simulation points for lighting calculations, CIE and IESNA provide the basis for determining fields of calculation in a given area (see more details on CIE 140:2000 in AMS.II-L – Annex IV).

5.2.2 Proposed Visual Efficacy Systems

Please note this section includes proposed visual efficacy systems which are still under discussion and have not been adopted by any standard.

Besides light level, visual sensitivity also changes with spectrum. The Scotopic/Photopic (S/P) ratio, which is the ratio of the luminous output of the light source evaluated according to the CIE scotopic spectral luminous efficiency function *V'(λ)* to the luminous output evaluated according to the CIE photopic spectral luminous efficiency function *V(λ),* is used to characterize the spectral characteristic of a light source. Basically the higher the S/P ratio, the more effective the visual performance will be for low light levels encountered in street and road lighting (CIE 191:2010).

Commercially available light sources for street and outdoor lighting offer a wide range of S/P ratios, such as high pressure sodium lamps with S/P ratio of ~0.60 and metal halide lamps with an S/P ratio of ~1.50. This suggests that the high pressure sodium (HPS) lamp is not necessarily the optimum light source for street and outdoor lighting. In case of white LED lamp, the S/P ratio can be as high as 2.0, and this makes LED lamps more efficient for outdoor lighting applications. Table 5.9 shows S/P ratios of commercially available light sources.

Table 5.9 – S/P Ratio of Commercially Available Light Sources

Low Pressure Sodium	0.25
High Pressure Sodium (HPS) 250 W clear	0.63
HPS 400 W clear	0.66
HPS 400 W coated	0.66
Mercury vapour (MV) 175 W coated	1.08
MV 400 W clear	1.33
Incandescent	1.36
Halogen headlamp	1.43
Fluorescent Cool White	1.48
Metal halide (MH) 400 W coated	1.49
MH 175 W clear	1.51
MH 400 W clear	1.57
MH headlamp	1.61
Fluorescent 5000 K	1.97
White LED 4300 K	2.04
Fluorescent 6500 K	2.19

Source: Table 2, ASSIST Publication on Outdoor Lighting: Visual Efficacy, Volume 6, Issue 2, January 2009

Several studies have demonstrated the benefits of mesopic street lighting. CIE 191:2000 has recommended the system for mesopic photometry based on visual performance, and shown in the Table 5.10 are the differences between the luminance values calculated using the recommended system. In general, lamps with a relatively high output in the short wavelength region result in decreased (photopic) luminance values. For example, at a photopic luminance of 1 cd.m^{-2}, effective luminance level of HPS lamp (S/P = 0.65) decreases 4 percent, while LED lamp (S/P = 2.25) increases 14 percent. This indicates that photopic light level from LED lamp can be reduced and still deliver the same level of visual performance as with a HPS lamp.

Table 5.10 – Differences Between Mesopic and Photopic Luminances

		Photopic luminance / cd·m^{-2}									
	S/P	0,01	0,03	0,1	0,3	0,5	1	1,5	2	3	5
LPS ~	0,25	-75%	-52%	-29%	-18%	-14%	-9%	-6%	-5%	-2%	0%
	0,45	-55%	-34%	-21%	-13%	-10%	-6%	-4%	-3%	-2%	0%
HPS ~	0,65	-31%	-20%	-13%	-8%	-6%	-4%	-3%	-2%	-1%	0%
	0,85	-12%	-8%	-5%	-3%	-3%	-2%	-1%	-1%	0%	0%
	1,05	4%	3%	2%	1%	1%	1%	0%	0%	0%	0%
MH warm white ~	1,25	18%	13%	8%	5%	4%	3%	2%	1%	1%	0%
	1,45	32%	22%	15%	9%	7%	5%	3%	3%	1%	0%
	1,65	45%	32%	21%	13%	10%	7%	5%	4%	2%	0%
	1,85	57%	40%	27%	17%	13%	9%	6%	5%	3%	0%
LED cool white ~	2,05	69%	49%	32%	21%	16%	11%	8%	6%	3%	0%
	2,25	80%	57%	38%	24%	19%	12%	9%	7%	4%	0%
MH daylight ~	2,45	91%	65%	43%	28%	22%	14%	10%	8%	4%	0%
	2,65	101%	73%	49%	31%	24%	16%	12%	9%	5%	0%

Source: CIE 191:2010

In addition to the above CIE technical report, the Alliance for Solid-State Illumination Systems and Technologies (ASSIST)[a] develops recommendations for determination of appropriate light levels for outdoor electrical lighting systems which are in the mesopic range. The ASSIST recommendation, entitled "Outdoor Lighting: Visual Efficacy", January 2009, proposes a table with unified luminance values based on particular light source S/P ratios and required base light level (Table 5.11). By applying the same unified luminance, an MH lamp (S/P~1.57) will only need to produce about three forth of the photopic illuminance of 0.30 cd.m^{-2} produced by HPS lamp (S/P~0.65), as illustrated in Table 5.11. The latest (10th) version of the IESNA Lighting Handbook also recognizes mesopic multipliers for outdoor lighting of low luminance and provides guidelines for their use.

[a] ASSIST was established in 2002 by the Lighting Research Center at Rensselaer Polytechnic Institute to advance the effective use of energy-efficient solid-state lighting and speed its market acceptance.

Table 5.11 – Values of Unified Luminance for Different Base Light Levels and S/P Ratios

Base light level (photopic luminance (cd/m²)

S/P	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36
0.25	0.0573	0.0704	0.0849	0.1009	0.1184	0.1373	0.1574	0.1788	0.2012	0.2246	0.2487	0.2736
0.35	0.0728	0.0877	0.1037	0.1209	0.1392	0.1585	0.1787	0.1998	0.2217	0.2442	0.2674	0.2912
0.45	0.0864	0.1026	0.1197	0.1377	0.1565	0.1760	0.1963	0.2172	0.2387	0.2607	0.2831	0.3060
0.55	0.0983	0.1156	0.1335	0.1521	0.1713	0.1911	0.2113	0.2320	0.2532	0.2747	0.2966	0.3188
0.65	0.1092	0.1273	0.1459	0.1649	0.1844	0.2043	0.2245	0.2451	0.2659	0.2871	0.3085	0.3301
0.75	0.1191	0.1379	0.1570	0.1764	0.1961	0.2161	0.2363	0.2567	0.2773	0.2981	0.3190	0.3401
0.85	0.1283	0.1477	0.1672	0.1869	0.2068	0.2268	0.2470	0.2672	0.2876	0.3081	0.3286	0.3492
0.95	0.1368	0.1566	0.1765	0.1965	0.2165	0.2365	0.2566	0.2767	0.2969	0.3170	0.3372	0.3574
1.05	0.1448	0.1651	0.1853	0.2054	0.2255	0.2456	0.2656	0.2856	0.3055	0.3254	0.3452	0.3651
1.15	0.1523	0.1730	0.1935	0.2138	0.2339	0.2540	0.2739	0.2937	0.3135	0.3331	0.3526	0.3721
1.25	0.1593	0.1803	0.2010	0.2215	0.2417	0.2617	0.2816	0.3013	0.3208	0.3402	0.3594	0.3786
1.35	0.1661	0.1873	0.2082	0.2288	0.2491	0.2691	0.2888	0.3084	0.3277	0.3469	0.3658	0.3847
1.45	0.1724	0.1940	0.2150	0.2357	0.2560	0.2759	0.2956	0.3150	0.3341	0.3531	0.3718	0.3903
1.55	0.1785	0.2003	0.2215	0.2422	0.2625	0.2824	0.3020	0.3213	0.3402	0.3590	0.3774	0.3957
1.65	0.1843	0.2063	0.2276	0.2484	0.2687	0.2886	0.3081	0.3272	0.3460	0.3645	0.3827	0.4007
1.75	0.1899	0.2120	0.2335	0.2543	0.2746	0.2944	0.3138	0.3328	0.3514	0.3697	0.3877	0.4054
1.85	0.1952	0.2175	0.2391	0.2599	0.2802	0.3000	0.3193	0.3381	0.3566	0.3747	0.3924	0.4099
1.95	0.2003	0.2228	0.2444	0.2653	0.2856	0.3053	0.3244	0.3432	0.3615	0.3794	0.3969	0.4141
2.05	0.2053	0.2279	0.2496	0.2705	0.2907	0.3103	0.3294	0.3480	0.3661	0.3838	0.4012	0.4182
2.15	0.2100	0.2327	0.2545	0.2754	0.2956	0.3152	0.3341	0.3526	0.3706	0.3881	0.4052	0.4220
2.25	0.2146	0.2374	0.2592	0.2801	0.3003	0.3198	0.3387	0.3570	0.3748	0.3922	0.4091	0.4257
2.35	0.2190	0.2419	0.2637	0.2847	0.3048	0.3242	0.3430	0.3612	0.3789	0.3960	0.4128	0.4291
2.45	0.2233	0.2463	0.2682	0.2891	0.3092	0.3285	0.3472	0.3652	0.3828	0.3998	0.4164	0.4325
2.55	0.2275	0.2505	0.2724	0.2933	0.3134	0.3326	0.3512	0.3691	0.3865	0.4034	0.4198	0.4357
2.65	0.2315	0.2546	0.2765	0.2974	0.3174	0.3366	0.3551	0.3729	0.3901	0.4068	0.4230	0.4388
2.75	0.2354	0.2585	0.2805	0.3014	0.3213	0.3404	0.3588	0.3765	0.3936	0.4101	0.4261	0.4417

Source: Table 3, ASSIST Publication on Outdoor Lighting: Visual Efficacy, Volume 6, Issue 2, January 2009

5.3 Maintenance

A well planned maintenance strategy is essential to ensure and sustain the optimal performance of LED street and outdoor lighting. The purpose of maintenance is to clean, repair, replace or refurbish the street and outdoor lighting equipment as and when required.

Based on the survey conducted there are no specific standards, guidelines or specifications for maintenance strategy for LED street and outdoor lighting in APEC member economies. Therefore, best practices are based on international or economy-wide standards for roadways – mainly through the Commission Internationale de L'Eclairage (CIE). However, these are not always adequately suited for LED street and outdoor lighting. LEDs have potentially a number of advantages compared to other street lighting technologies such as reduction in lamp replacement offering higher savings on maintenance costs. It is important that entities and lighting managers responsible for street and outdoor lighting, are aware of the differences in LED maintenance requirements compared to other lighting products and know when LED performance warrants maintenance. For example, typically, LEDs do not fail in the same manner as other traditional street lighting technology, and instead tend to fade over time. This means that LED lifetime, which depends on **lumen maintenance life** and **rated life or statistically measured failures**, is a critical parameter in determining the most adequate maintenance strategy.

This section covers three examples of recommendations for maintenance of LED street and outdoor lighting based on LED lifetime in APEC member economies, in particular lumen maintenance and failure rates.

5.3.1 Hong Kong, China

In Hong Kong, the Highways Department issued *Guidelines for Specifying & Procuring LED Lighting Products for Lighting Projects* which encompasses LED life and lumen maintenance (EMSD, 2011).

The guideline indicates that the rated lifetime depends on lumen depreciation and failure rate and therefore to determine the maintenance strategy it is important to gather the following information from the manufacturer:

- **Lumen depreciation associated to estimated useful life**
- **Electrical failure rate under the claimed lifetime**
- **Failure of other components:** LED driver failure rate and lifetime should be compatible with the LED module.
- **Estimated lumen maintenance curve:** Initial lumen output and the lumen depreciation pattern during the useful life of the LED lighting under design and operating temperature conditions

The guidelines indicate the estimated useful life of LED lighting is the accepted standard of lumen depreciation to 70 percent of the initial lumen output. However, not only the lifetime of the product should be stated but also its electrical failure rate. This includes failure of components other than the LED as these will influence overall lifetime.

The guide also suggests that the warranty should cover repair or replacement of LED lamp or luminaire in case of failure or deficient performance (e.g. excessive lumen depreciation compared with the lumen-lifetime curve or colour shift).

5.3.2 United States

5.3.2.1 Replacement Strategies based on Failure Rates

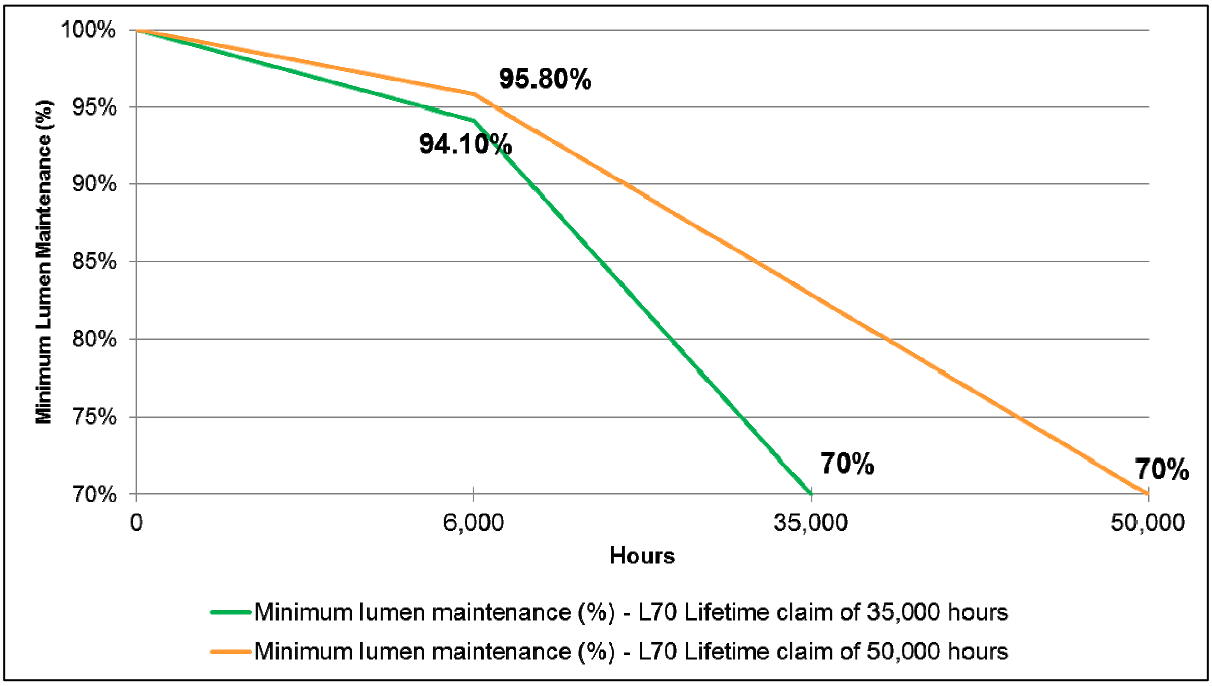
The National Cooperative Highway Research Program established a project in partnership with the Lighting Research Center (LRC) to examine LED traffic signal maintenance and monitoring issues and develop recommendations for replacement strategies. According to the LRC and depending on the failure rates for LED traffic signal modules specified by the manufacturers (LRC, 2009):

- If a 10-year operating life is expected, a replacement period of around 8 years will probably reduce overall long-term replacement costs. In this case, about 12 percent of signal modules would be replaced each year.
- If a 7-year operating life is expected, a replacement period of around 6 years will probably reduce overall long-term replacement costs. In this case, about 17 percent of signal modules would be replaced each year.

5.3.2.2 Lumen Maintenance

The Bureau of Street Lighting in Los Angeles provides a guide to evaluating LED lumen maintenance (Annex VII). This is based on the Illuminating Engineering Society of North America (IESNA) LM-80-08 - *Approved method for measuring lumen maintenance of LED light sources*. This standard is one of the few methods available covering lumen maintenance or lumen depreciation, basically meaning lamp replacement. The IESNA provides a methodology for a comparison of test results among laboratories by establishing uniform test methods. It addresses the measurement of lumen maintenance testing for LED light sources including LED packages, arrays and modules. Useful lifetime estimates for LED lighting products are typically given in terms of the expected operating hours until light output has diminished to 70 percent of initial levels (denoted L70 life). Figure 5.1 illustrates the minimum lumen maintenance requirements for 6,000 hours for lifetime claims of 35,000 hours and 50,000 hours according to the LM-80-08.

Figure 5.1 – IESNA LM-80-08 Minimum Lumen Maintenance for 6,000 hours based on L70 lifetime claim for 35,000 hours and 50,000 hours



The IESNA TM 21-11 - *Projecting Long Term Lumen Maintenance of LED Light Sources* uses the LM-80-08 and provides a method to extrapolate values for L70 lifetime claim beyond the 6,000 hours specified. The objective is to enable a more accurate quantification of lumen depreciation as this varies significantly between models and manufacturers.

5.4 Summary of Best Practices / Guidelines / Codes

Table 5.12 lists which APEC member economies have and have not got best practices, guidelines and codes for street and outdoor lighting applications which are applicable to LED. The table is based on survey responses from each APEC member economies only.

Table 5.12 - List of Best Practices, Guidelines and Codes for LED Street and Outdoor Lighting (Survey based)

Economy	*Design and Selection*	*Purchase*	*Installation*	*Operation and Maintenance*	*Performance Measurement and Quality Assurance*
Australia	Yes	Yes	No	Yes	Yes
Brunei Darussalam	-	-	-	-	-
Canada	-	-	-	-	-
Chile	-	-	-	-	-
China	Yes	Yes	Yes	No	Yes
Chinese Taipei	Yes	Yes	Yes	Yes	Yes
Hong Kong	Yes	Yes	No	Yes	No
Indonesia	-	-	-	-	-
Japan	No	No	No	Yes	Yes
Korea	Yes	Yes	Yes	Yes	Yes
Malaysia	-	Yes	-	-	-
Mexico	-	Yes	-	-	-
New Zealand	Yes	No	Yes	Yes	Yes
Papua New Guinea	-	-	-	-	-
Peru	-	-	-	-	-
Philippines	Yes	No	No	No	No
Russia	-	-	-	-	-
Singapore	Yes	No	Yes	Yes	Yes
Thailand	No	No	No	No	No
United States	Yes	Yes	Yes	Yes	Yes
Vietnam	-	-	-	-	-

Note: - unknown

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7 Annex I – Sample of Survey of LED Street and Outdoor Lighting Standards and Projects in APEC Member Economies

The objective of this survey is to help develop a best practice guidebook for the use of highly-efficient light-emitting diodes (LEDs) for street lighting and other public outdoor lighting needs and help compile information on LED standards for quality and efficient street and outdoor lighting in APEC member economies.

Please fill in the survey using **Adobe Acrobat Reader** and ensure you save the completed pdf document at the end. If you do not have Adobe Acrobat Reader, please print the survey and fill in with clear block writing.

Upon completion of the survey, **please provide your complete contact details including email address and follow the instructions at the end of the survey for returning the survey to us. We will send the electronic copy of the best practices on LED for Street and Outdoor Lighting to you following the completion of this APEC project.**

SECTION I: LED Standards, Street and Outdoor Lighting Guidelines and Codes, and Existing Installations

1. Are you aware of any published standards for LED Street and Outdoor lighting products in your economy?

☐ **Yes** (please list the standards – number and title – for LED modules, LED drivers, and/or LED luminaires for outdoor areas, and/or street lighting)

LED Modules[a] (e.g. IEC 62384: Control Gear for LED Modules)

LED Drivers[b]

LED Luminaires[c]

☐ **No**

[a] **LED module** - A component part of an LED light source that includes one or more LEDs connected to the load side of LED power source or LED driver. Electrical, electronic, optical, and mechanical components may also be part of an LED module. The LED module does not contain a power source and is not connected directly to the branch circuit (ANSI/IESN, 2008).

[b] **LED driver** - A power source with integral LED control circuitry designed to meet the specific requirements of a LED lamp or a LED array (ANSI/IESN, 2008).

[c] **LED luminaire** - A complete LED lighting unit consisting of a light source and driver together with parts to distribute light, to position and protect the light source, and to connect the light source to a branch circuit. The light source itself may be an LED array, an LED module, or an LED lamp (ANSI/IESN, 2008).

If no, are there any LED standards under development in your economy?

☐ Yes (please specify name of standard(s) under development):

____
____
____
____
____

☐ No

2. Are you aware of any best practices, guidelines, codes for Street and Outdoor lighting applications which are applicable for LED in your economy for the following areas?:

2.1 Design and Selection (illuminance level, pole height, spacing, etc.)	☐ Yes	☐ No
2.2 Purchase	☐ Yes	☐ No
2.3 Installation	☐ Yes	☐ No
2.4 Operation and Maintenance	☐ Yes	☐ No
2.5 Performance Measurement/Quality Assurance	☐ Yes	☐ No

If yes, please specify document for our reference and internet link if available online:
____
____
____
____

3. Which agencies in your economy are involved in specifications, design and selection of products for Street and Outdoor lighting applications (tick applicable option or options and specify name of agency):

☐ Electric Utility: ____

☐ Local Government Unit/Municipality:____

☐ Department of Transportation/Highway Authority:_____________________________

☐ Department of Public Works:____

☐ Professional/Industry Association (engineering, lighting industry, municipality):______________

☐ None

4. Do electrical and mechanical works for LED Street and Outdoor lighting applications have to follow any codes or regulations in your economy?

☐ **Yes**, please specify the regulatory body
____

☐ **No**

5. Are you aware of any projects/programs for LED Street and Outdoor installations and/or

demonstrations in your economy?

☐ **Yes** (please specify up to FIVE (5) projects starting with the ones with the largest number of LEDs luminaires installed?)

5.1 Name of Projects/Programs:____

Location (specify city, municipality or state/province/region): ___________________________

No. of LED Luminaires Installed:_______________________

Entity Responsible for project/program:____

5.2 Name of Projects/Programs:____

Location (specify city, municipality or state/province/region): ___________________________

No. of LED Luminaires Installed:_______________________

Entity Responsible for project/program:____

5.3 Name of Projects/Programs:____

Location (specify city, municipality or state/province/region): ___________________________

No. of LED Luminaires Installed:_______________________

Entity Responsible for project/program:____

5.4 Name of Projects/Programs:____

Location (specify city, municipality or state/province/region): ___________________________

No. of LED Luminaires Installed:_______________________

Entity Responsible for project/program:____

5.5 Name of Projects/Programs:____

Location (specify city, municipality or state/province/region): ___________________________

No. of LED Luminaires Installed:_______________________

Entity Responsible for project/program:____

☐ **No (Please go to Section II)**

6. Have you or your agency been involved in any of the abovementioned LED Street and Outdoor installation/demonstration projects/programs?

☐ **Yes** (Please provide additional information on LED Street and Outdoor installation/demonstrations)

6.1 LED product specifications follow economy-wide standards? ☐ Yes ☐ No

6.2 Requirements of illumination quality included in the procurement specifications? ☐ Yes ☐ No

6.3 Field trial is a part of evaluation and selection process? ☐ Yes ☐ No

6.4 Pre- and Post-installation performance measurements and evaluations specified? ☐ Yes ☐ No

6.5 Performance measurements and evaluations have been undertaken periodically after the installation and commissioning? ☐ Yes ☐ No

6.6 Warranty for LED products is at least 5 years? ☐ Yes ☐ No

6.7 Warranty bond and penalty included as parts of Warranty Terms and Conditions? ☐ Yes ☐ No

6.8 Are you aware of any product failure in the mentioned installation/demonstration? ☐ Yes ☐ No

☐ **No**

If all the answers to the SECTION I questions are "NO", please go to SECTION III.

SECTION II: LED Market Stakeholders and LED Market Drivers

7. Are you aware of testing facilities for LED Street and Outdoor lighting products in your economy?

☐ **Yes** (please provide name of agency/ies)____

☐ **No**

8. Are you aware of any local manufacturers or assemblers for LED Street and Outdoor lighting products in your economy?

☐ **Yes** (please provide name of local manufacturers and/or top **FIVE** market leaders)

____

☐ **No**

9. Does your government have an energy efficiency plan and target covering LED dissemination and installation or energy efficient street lighting?

☐ **Yes** (please provide information on energy efficiency plan and targets)

____

☐ **No**

10. In your view, what are the key drivers for the use of LED market in your economy?

Key Driver	**Least Likely <----------->Most Likely**				
	1	**2**	**3**	**4**	**5**
Government Policy (e.g. targets, incentives)					
Electricity Cost					
LED Technology Cost					
Awareness of End-Users/Customers					

Local Availability of LED products					
Other (please specify):					

11. Which relevant agencies, do you recommend, we contact as part of this survey? Preferably, agencies and contacts with experience on LEDs and relevant best practices (e.g. municipal lighting authorities, regulatory authorities, lighting industry associations, local governments, etc).

____
____
____

12. Would you be interested in receiving information and attending a Workshop on the 7th of November 2011 organized by APEC covering Best Practices in APEC member economies on LED Street and Outdoor Lighting in Seoul, Republic of Korea?

☐ **Yes** (please provide your e-mail at the end of the survey)

☐ **No**

SECTION III: Contact Information

Please ensure that your valid contact details including email address are provided so that we can deliver the report on best practices on LED for Street and Outdoor Lighting to you upon completion of this APEC project.

Name of APEC Member Economy:____

Name of Agency:____

Agency Type:

☐ Standard Development Agency ☐ Testing Laboratory

☐ Research & Development Agency ☐ Energy Regulatory Agency

☐ Engineering / Industry Association

☐ Street & Outdoor Lighting Regulatory Agency (e.g. municipality, city government, department of public works, department of highway)

☐ Other (Please specify)_______________________________________

Person Name: ____

Position:____

Telephone Number (including international area code):___________________________

Email:____

Thank you for your time and availability to answer this survey

Please return survey responses via e-mail to APECledsurvey@iiec.org

OR

via fax to +66 2 261 8615

Any questions or comments regarding the survey, please e-mail David Morgado (dmorgado@iiec.org) or Sommai Phon-Amnuaisuk (sphonamnuaisuk@iiec.org) at the International Institute for Energy Conservation (IIEC)

8 ANNEX II - INITIAL LIST OF STAKEHOLDERS FOR SURVEY

Economy	Contact	Agency
Australia	Tim Farrell and Melanie Slade	Department of Climate Change and Energy Efficiency
	Owen Manley and Bryan Douglas	Lighting Council Australia
	Paul Gowans	City of Sydney - Street & Outdoor Lighting Regulatory Agency
Canada	John Cockburn and Veronique Aubry	Natural Resources Canada
Chile	Ivan Jaques	Comision Nacional de Energia
China	Liu Meng	China National Institute of Standardization
	Tounseng Mou	Zhejian University
	Sheldon Xie	Clinton Climate Initiative, C40 cities - Beijing
Chinese Taipei	WenHsin Lin, Jian-Yuan Lin, Shin-Hang Lo and Ruth Lin	Bureau of Energy and Industry Technology Research Institute
Hong Kong	Ek-chin VY and Lap-chi Wong	Electrical and Mechanical Services Department
	Ming Lu	Hong Kong Applied Science and Technology Research Institute (ASTRI)
Indonesia	Abdul Mustar	National Standardization Agency of Indonesia (BSN)
	Maryam Ayuni	Directorate General of Electricity and Energy Utilization, Ministry of Energy and Mineral Resources
Japan	Junichi Noka	The Energy Conservation Center
	Atsushi Suzuki	Japan Electric Lamp Manufacturers Association (JELMA)
Korea	Yungrae Kim	Korea Energy Management Corporation
	Cho Yongick	Korea Photonics Technology Institute (KOPTI)
Malaysia	Asfaazam Kasbani and Faridah Mohamad Taha	Pusat Tenaga Malaysia and Universiti Teknologi
Mexico	José Valenciano, José Gonzalez-Martinez and Ybo Pulido-Saldana	Comisió Nacional para el Uso Eficiente de la Energía
New Zealand	Laura Christen and Carolyn Shivanandan	Energy Efficiency and Conservation Authority
Philippines	Raquel S. Huliganga	Department of Energy
	Mirna Campanano	Lighting and Appliance Testing Laboratory
Russia	Garegin S. Aslanian	Science Institute for Energy Policy
Singapore	Latha Ganesh	Energy Market Authority
Thailand	Asawin Asawutmangkul, Napaporn Phumaraphand	Department of Alternative Energy Development and Efficiency, Electricity Generating Authority of Thailand
	Lertchai Kaewwichian, Kanit Chaiwattana, Charun Boonyakongrat	Provincial Electricity Authority (PEA)
	Wilas Chaloeysat	Metropolitan Electricity Authority
	Pongpat Phanpean	Electrical and Electronic Institute (EEI)
United States	Robert Van Buskirk	United States Department of Energy (US DOE)
	Marc Ledbetter	US DOE – SSL Research and Development Program
	Ed Smalley	US DOE - Municipal Solid-State Street Lighting Consortium
	Phillip Keebler	Electric Power Research Institute
	Konstantinos Papamichael	California Lighting Technology Center
	Elizabeth Ware	American Lighting Association
	Nadarajah Narendran	Lighting Research Centre
	Ed Ebrahimian	City of Los Angeles - Bureau of Street Lighting
Vietnam	Tat ThangHo	Vietnam Standard and Consumers Association
	Phan Hong Khoi, Nguyen Bac Kinh	Vietnam Academy of Science and Technology (VAST)

9 Annex III - Responses Received by APEC Member Economies Surveyed

The survey was conducted from the 11 July 2011 until the 12 August 2011.

Economy	Contact	Agency
Australia	David Boughey and Yogendra Mistry	Department of Climate Change and Energy Efficiency
Australia	Owen Manley	Lighting Council Australia
Australia	Paul Gowans	City of Sydney - Street & Outdoor Lighting Regulatory Agency
Canada	Pierre Gallant	Natural Resources Canada
China	Liu Meng and Zhao Yuejin	China National Institute of Standardization
China	Tounseng Mou	Zhejian University
Chinese Taipei	Henry Lo and Kevin Lin	Bureau of Energy and Industry Technology Research Institute
Hong Kong	Ming Lu	Hong Kong Applied Science and Technology Research Institute (ASTRI)
Hong Kong	KC Lou	Electrical and Mechanical Services Department
Japan	Atsushi Suzuki	Japan Electric Lamp Manufacturers Association (JELMA)
Korea	Cho Yongick	Korea Photonics Technology Institute (KOPTI)
New Zealand	David Cogan	Standards New Zealand and Institution of Professional Engineers NZ
New Zealand	Carolyn Shivanandan	Energy Efficiency and Conservation Authority (EECA)
United States	Ed Ebrahimian	City of Los Angeles - Bureau of Street Lighting
United States	Marc Ledbetter (Bruce Kinzey)	Pacific North-West National Laboratory
United States	Ed Smalley	Municipal Solid-State Lighting Consortium
United States	Konstantinos Papamichael	California Lighting Technology Center
Philippines	Raquel Huliganga	Department of Energy
Singapore	Latha Ganesh	Energy Market Authority
Singapore	Tan Lee Heng	TUV SUD PSB
Singapore	George Sun	Local Transport Authority
Thailand	Piyachat Srikaew	Provincial Electricity Authority

10 ANNEX IV - CLEAN DEVELOPMENT MECHANISM - AMS-II.L.: DEMAND-SIDE ACTIVITIES FOR EFFICIENT OUTDOOR AND STREET LIGHTING TECHNOLOGIES (VERSION 1.0)

TYPE II - ENERGY EFFICIENCY IMPROVEMENT PROJECTS

Project participants shall apply the general guidelines to SSC CDM methodologies, information on additionality (attachment A to Appendix B) provided at: <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved.html> *mutatis mutandis.*

II.L. Demand-side activities for efficient outdoor and street lighting technologies

Technology/measure

This category comprises activities that lead to efficient use of electricity through the adoption of energy efficient lamps and/or fixture combinations to replace less efficient lamps and/or fixture combinations in public- or utility-owned street lighting systems. Project and baseline lamps and/or fixture combinations are referred to here as luminaires, which encompasses all of the components in an individual assembly of street lighting equipment, including lamp, lens and reflector, fixture housing, wiring, and driver or ballast and individual and centralized controls components/system(s). This methodology covers projects involving multiple luminaires used to illuminate roadways.

This methodology is applicable for one-for-one replacements of baseline luminaires with project luminaires or for replacing multiple baseline luminaires with multiple project luminaires.[a] This methodology is also applicable to projects that involve the implementation of lighting controls that reduce total operating hours or average wattage of the lighting system as well as for new construction installations.

This methodology is only applicable if failed project equipment will continuously be replaced based on local maintenance practices, during the crediting period, by equipment of equivalent or better lighting and energy performance specification.

The luminaires selected to replace existing equipment must be new equipment and not transferred from another activity.

Controls covered by this methodology may include simple photocells and/or astronomical time clocks that provide basic streetlight scheduling control. Controls may also include advanced systems that allow for more sophisticated strategies, such as dynamically altering street lighting power (dimming

[a] For example, a project involving replacing a collection of street lighting luminaires with new street lighting luminaires when the number of project luminaries may be more or less numerous than the baseline luminaires, but the project luminaires in total consume less energy than the replaced luminaries.

or multiple levels of operation such as bi-level lighting) based on vehicle and/or pedestrian traffic sensors or schedules, time of night, ambient conditions, etc; a practice known as adaptive lighting.[a]

This methodology applies to street lighting projects that provide lighting performance quality either: (a) Equivalent to or better than the baseline lighting performance; or (b) Equivalent to or better than the applicable street lighting standard. If adaptive controls will be used to vary light output for project luminaires, lighting performance must be proven to meet or exceed baseline performance or the applicable standard for all light output settings. The preferred standard would be the local standard if there is one, in the absence of a local standard the national standard if there is one, or the CIE standards detailed in Annex III if there is no local or national standard.

For retrofit projects, lighting performance quality of project luminaires shall be shown to comply with this methodology through the use of one of the following methods:

(a) Equivalence to existing baseline luminaires: The project participant shall prove that project luminaires provide equivalent or improved total useful illumination (lx), compared to the baseline luminaires being replaced, at each representative location.[b] Either by: (i) Measurements and calculations; or (ii) Computer modeling of average illuminance from baseline and project luminaires at representative locations that shall be determined in accordance with CIE standard 140:2000;[c]

(b) Compliance with applicable street lighting standard:

(i) If a national or local lighting standard is available that prescribes lighting levels for roadway lighting classes, such shall be used to evaluate project luminaire compliance at each representative location. A standard field of calculation shall be defined to field measure or computer model illuminance per Annex II of this methodology. Project luminaires must meet or exceed the illuminance levels prescribed in the standard, as well as uniformity and glare criteria as applicable;

(ii) If no national or local standard exists, the project participant shall use an approved international standard such as CIE's *Lighting of Roads for Motor and Pedestrian Traffic* (CIE 115:2010), which provides a structured model for selection of the appropriate roadway lighting class and gives recommended maintained lighting levels. Alternately, if appropriate, project participant may use the illuminance standards given in CIE's *Technical Report: Road Transport Lighting for Developing Countries* (CIE 180:2007).

[a] The International Commission on Illumination (CIE) Roadway Lighting Standard 115:2010, addresses adaptive street lighting and gives guidance on its application for temporal change in parameters such as traffic volume and composition (CIE 115:2010, section 6.2.2) that effectively alter a location's lighting class. Lighting classes are a system of differentiation amongst areas where streetlights are used based on traffic and pedestrian volume and other considerations. The lighting class for a roadway is normally determined by the most onerous conditions, while the use of adaptive lighting recognizes that roadway conditions are not static. However, care must be taken to ensure that appropriate light levels are always present.

[b] See Annex II.

[c] When a standard or technical report is referenced in this methodology, it is implied that the most current version of the reference should be utilized, or equivalent.

The illuminance, uniformity and glare requirements of both of these standards are provided in Annex III of this methodology.

Illuminance evaluations for comparison of project and baseline luminaires or for compliance with an applicable standard shall either be made on the basis of the photopic response curve, or using the mesopic system of photometry developed by the CIE and relying on photopic and scotopic response curve measurements (See Annex IV).

Determining lighting performance quality is a one-time activity and thus continuous monitoring and verification of lighting system performance compliance with baseline performance or applicable street lighting standards are not required during the crediting period.

In the case of a Greenfield (new construction) project, the existing baseline technology is assumed to be the prevailing street lighting technology used in the region for equivalent roadway types and lighting classes. If it is not common practice in the project's region to illuminate roadways with electric lighting and it cannot be shown that a less efficient street lighting system would be installed in lieu of project activities, this methodology is not applicable.

For Greenfield baseline determination, project participant must be able to document representative locations, as described in paragraph 3, where baseline luminaires are already installed in the same region as the project. The same region is defined as either: (a) Within 200 km of the project's boundary; or (b) Within the same city or town jurisdiction. The project participant must document the type, wattage, and operating schedule of the baseline luminaires at the comparable location and assume this as the baseline for the project representative location. In selecting the baseline technologies to consider, the project participant shall follow the "General guidelines to SSC CDM methodologies" under the section 'Type II and III Greenfield projects (new facilities)."

Steps for defining a Greenfield project's baseline are:

(c) Determine representative locations and construct fields of calculation for all roadway and intersection lighting classes within the project boundary. For large street lighting projects there will likely be various roadway types with different dimensions, uses and lighting classes. Representative locations for each roadway and intersection lighting class and any major variations in roadway dimensions within the project boundary should be documented and labeled in the Project Design Document (PDD) in a consistent way. Representative locations should include any major variations within the project boundary in type of location (urban, semi-urban, rural);

(d) For each representative location within the project boundary, choose a comparable location outside of the project boundary, but within the project's region where the baseline lighting technology is installed and assume this as the baseline lighting system for the representative location. Baseline compliance with a lighting standard is not required;

(e) Extrapolating from the selected baseline system for each representative locations to the entire area within project boundaries, project participant shall inventory the entire hypothetical baseline lighting system that would be installed in lieu of project activities, including total counts for all luminaires by wattage and schedule of operation, documenting all assumptions clearly in the PDD.

The aggregate electricity savings by a single project activity may not exceed the equivalent of 60 GWh per year.

The PDD shall include and/or explain:

(f) Design specifications of project lamps and/or luminaires such as:[a]

(i) Equipment power (in Watts) and output (in lumens);

(ii) Type of controls installed (astronomical time clock, photocell, wireless RF controller, etc.);

(iii) Equipment warranty;

(g) How project procedures eliminate double counting of emission reductions, for example due to project luminaire manufacturers, wholesale providers or others possibly claiming credit for emission reductions for the project luminaires;

(h) How the project design utilizes professional lighting design practices to ensure adequate roadway lighting levels are delivered by project equipment according to accepted practice or local or national roadway lighting standard if one exists;

(i) How the maintenance and replacement practices for the street lighting system will ensure that failed equipment is replaced by equipment of the same or better specification to that of any failed project equipment to assure that lighting and energy performance of the project system is maintained.

Boundary

The project boundary is the physical, geographical location of all project luminaires installed.

Crediting period

With this methodology, Certified Emission Reductions (CERs) can only be earned for one crediting period of up to 10 years.

Emission reductions

Ex ante calculations are done as per the following steps:

(a) Estimate the nameplate/rated power (Watts) of the baseline and project luminaires, or the time-integrated average power if adaptive street lighting controls will decrease lighting power at periods of lower demand; nightly, weekly, seasonally or otherwise. If patterns of variation in parameters such as traffic volume are well known, such as from records of traffic counts, such records shall be used to estimate time-integrated average power based on controls settings;

(b) Default value for daily hours of operation of luminaires is assumed to be equal to:

(i) For luminaires controlled with a standard timer, use the number of hours that the timer will be set during the crediting period for operating hours during an average day; or

(ii) For luminaires controlled by ambient light sensors or astronomical time clock, use the average number of hours between sunset and sunrise; or

[a] If the project participant at a later date chooses different equipment or a different equipment/system supplier, the performance, lifetime, and warranty specifications for the new equipment/systems/supplier(s) should be at least equivalent to those of the originally indicated equipment/systems/supplier(s).

(iii) For luminaires controlled by motion sensors, use the average number of hours between sunset and sunrise divided by ten unless documentation of occupancy patterns can be given to justify another value; or

(iv) For luminaires controlled by advanced controls that allow scheduling options other than light sensing or time clock, use the operating hours that will be programmed into the controls system; or

(v) Scheduling and controls strategies may lead to different default value for daily hours of operation for baseline luminaires and project luminaires.

(c) Calculate the gross electricity savings by comparing the total average power of the project luminaires multiplied by project annual hours of operation, with the average power of the baseline luminaires multiplied by baseline annual hours of operation (daily hours times 365 or other number equal to the number of days per year that the lights are expected to be operated);

(d) Calculate the net electricity saving (NES) by correcting the gross electricity savings for any leakage and transmission & distribution losses.

Once the project is installed, the electricity saved by the project activity in year *y* is calculated as follows:

$$NES_y = \sum_{i=1}^{n} ES_{i,y} * \frac{1}{(1-TD_y)} \quad \textbf{(1)}$$

Where:

$$ES_{i,y} = \left(Q_{i,BL} * P_{i,BL} * O_{i,BL} * (1-SOF_{i,BL})\right) - \left(Q_{i,P} * P_{i,P,y} * O_{i,y} * (1-SOF_{i,y})\right) \quad \textbf{(2)}$$

$$SOF_{i,BL} = AFR_{i,BL} * OF_{i,BL} \quad \textbf{(3)}$$

$$SOF_{i,y} = AFR_{i,y} * OF_{i,y} \quad \textbf{(4)}$$

Where:

NES_y	Net electricity saved in year *y* (kWh)
$ES_{i,y}$	Estimated annual electricity savings for equipment of type *i*, for the relevant type of project equipment in year *y* (kWh)
y	Crediting year counter
i	Counter for luminaire type
n	Number of luminaires
TD_y	Average annual technical grid losses (transmission and distribution) during year *y* for the grid serving the locations where the luminaires are installed, expressed as a fraction. This value shall not include non-technical losses such as commercial losses (e.g. theft/pilferage). The average annual technical grid losses shall be determined using recent, accurate and reliable data available for the host country. This value can be determined from recent data published either by a national utility or an official governmental body. Reliability of the data used (e.g. appropriateness, accuracy/uncertainty, especially exclusion of non technical grid losses) shall be established and documented by the project participant. A default value of 10% shall be used for average annual technical grid losses, if no recent data are available or the data cannot be regarded accurate and reliable

Q_i ($Q_{i,BL}$ and $Q_{i,P}$)	Quantity of baseline (*BL*) or project (*P*) luminaires of type *i* distributed and installed under the project activity (units). Once all of the project luminaires are distributed or installed, $Q_{i,P}$ is normally a constant value independent from *y* unless size of operating luminaire inventory decreases during crediting period, in which case only operating project luminaires shall be credited. Note that $Q_{i\ BL}$ and $Q_{i\ P}$ may represent a different number of luminaries (e.g. a larger number of LEDs with less output), but they must represent the same illuminated area
$P_{i,BL}$	Rated power of the baseline luminaires of the group of *i* lighting devices (kW), or time-integrated average power if equipment operates at various power settings, constant value independent from *y* For retrofit projects, project proponents shall maintain records to demonstrate to DOEs what type of luminaire are replaced
$P_{i,P,y}$	Rated power of the project luminaires of the group of *i* lighting devices (kW), or time-integrated average power if equipment operates at various power settings, normally constant value independent from *y* unless operating schedule or parameters changes during crediting period. Time-integrated average power takes into account controls savings such as dimming or bi-level operation that reduce lighting power for periods of time. For example, if on average, project equipment operates at full power 50% of annual operating hours, and half power 50% of annual operating hours, $P_{i,\ P}$ will be de-rated from full value to 75% of full value ((1 * 50%) + (0.5 * 50%))
O_i ($O_{i,BL}$ and $O_{i,y}$)	Annual operating hours for the baseline and project luminaires in year *y*. May differ from *BL* to *P*. This value is based on continuous measurement of daily average usage hours of luminaires for a minimum of 90 days at monitoring survey sample locations (sampling determined by minimum 90% confidence interval and 10% maximum error margin) corrected for seasonal variation of lighting hours and multiplied by 365 days. The method used to extrapolate the 90 days of data to annual values must be documented. For projects involving the following control strategies, the monitoring for determination of annual operating hours shall be continuous for 365 days per year: (i) Luminaires controlled by motion sensors; (ii) Luminaires controlled by advanced controls that allow scheduling options other than light sensing or time clock. The measurements shall be repeated at the monitoring survey sample locations at the time of *ex post* monitoring as indicated in paragraph 16. In no case can a value greater than the daily average annual number of hours between sunset and sunrise hours, per 24 hour period, be used under this methodology to calculate annual operating hours
$SOF_{i\ i}$ ($SOF_{i,BL}$ and $SOF_{i,y}$)	System Outage Factor (*SOF*) for equipment type *i* in year *y*. *SOF* is calculated as the product of the equipment Outage Factor and the equipment Annual Failure Rate. The value for *BL* is assumed to be the same as monitored for *P* and may vary from year to year

OF_i ($OF_{i,BL}$ and $OF_{i,y}$)	Outage Factor is the average time, in hours, elapsed between failure of luminaires type *i* and their replacement, divided by $O_{i,y}$, annual operating hours. This shall be determined by documented maintenance practice and records of maintenance turn-around time from failure to replacement. The outage factor value during the baseline (*BL)* is assumed to be the same as determined for each year of the crediting period (*y*) and may vary from year to year
AFR_i ($AFR_{i,BL}$ and $AFR_{i,y}$)	Annual Failure Rate of luminaires calculated as a fraction of *Q*. The value for failure rate during the baseline (*BL)* is assumed to be the same as determined for each year of the crediting period *y* and may vary from year to year. Failure rates during the crediting period should be determined *ex post* from maintenance records that indicate the actual fraction of system-wide equipment of type *i* that fail annually. For *ex ante* calculations, failure rate in year *y* could be assumed to equal to $O_{i,y}$ divided by the rated average life for project equipment type *i*

Emissions reduction is the net electricity savings (*NES*) times an Emission Factor (*EF*) calculated in accordance with provisions under AMS-I.D.

$$ER_y = NES_y * EF_{CO2,ELEC,y} \quad \textbf{(5)}$$

Where:

$EF_{CO2,ELEC,y}$	Emission factor in year *y* calculated in accordance with the provisions in AMS-I.D (tCO_2/MWh)
ER_y	Emission Reductions in year *y* (tCO_2e)

The electricity savings from the project equipment installed by the project activity shall be considered from the date of completion of installation of all the project equipment.

Monitoring

Ex post monitoring and adjustment of net electricity savings:

(a) First *ex post* monitoring survey, carried out within the first year after installation of all project luminaires shall provide a value for:

(i) Outage factor (OF_i);

(ii) Annual failure rate (AFR_i);

(iii) Average annual operating hours (O_i);

(iv) Average project equipment power (P_i);

(v) Number of project luminaires placed in service and operating under the project activity ($Q_{P,i}$). While project luminaires replaced as part of a regular maintenance or warranty program can be counted as operating, project luminaires cannot be replaced as part of the CDM monitoring survey process and counted as operating;

(b) Subsequent *ex post* monitoring surveys are carried out at least every other year after the first year of the crediting period (i.e. years 3, 5, 7, 9) to determine *ex post* OF_i, AFR_i, O_i, and $P_{i,P}$ for use in *ex post* emission reduction calculations until such time as CERs are no longer being requested;

(c) For each *ex post* monitoring survey, the project monitoring plan shall include continuous monitoring of equipment run-time for at least 90 continuous days to determine average daily operating hours for extrapolation to annual operating hours (O_i). For projects involving the following control strategies the monitoring must for determination of annual operating hours (O_i) and average project equipment power ($P_{i,P}$) shall be continuous for 365 days per year:

(i) Luminaires controlled by motion sensors;

(ii) Luminaires controlled by advanced controls that allow scheduling options other than light sensing or time clock.

(d) For measurement of average annual operating hours (O_i), a simple recorder of on/off time or direct monitoring over time of power or even light intensity may be used.

Monitoring includes: (a) Recording of luminaire distribution data; and (b) *Ex post* monitoring surveys as defined in paragraph 16:

(a) During project activity implementation, the following data are to be recorded:

(i) Number of project luminaries distributed and installed under the project activity, identified by the type of luminaires, operating schedule and adaptive controls strategy, if any, and the date of installation;

(ii) The number, power, and operating schedules of the replaced devices;

(iii) Information on baseline and project lighting controls. Indicate:

- Use of photocell and type if so;
- Use of timeclock and type if so;
- Dimming or multi-level operation, and type if so;
- Sensor controls – traffic volume, light sensors, etc. and type if so;
- Networked controls with central scheduling, monitoring, and/or reporting features.

(b) The emission reductions are calculated *ex ante* and adjusted *ex post* following the monitoring surveys, as described under the paragraphs above.

Generic instructions for sampling

The following sampling principles shall be followed:

(j) Sampling must be statistically robust and relevant i.e. the survey has a random distribution and is representative of target population (size, location);

(k) The sampling size is determined by a minimum 90% confidence interval and the 10% maximum error margin; refer to the “General guidelines for sampling and survey for small-scale CDM project activities”;

(c) The method to select project installation sample locations is random;

(d) For monitoring survey, individual project luminaires or groups of project luminaires if applicable (i.e. a continuous string of project luminaires on a dedicated electric circuit that can be monitored) shall constitute the population constituents when determining sample size and distribution;

(e) If multiple systems of scheduling and/or controls are installed within the project boundaries, the luminaires under each system of schedules and/or controls shall represent unique population sets for sample sizing and sample location selection;

(f) The (PDD) and monitoring plan must contain the design details of the survey.

Project activity under a Programme of Activities

No special provisions are required.

Annex I

Definitions

Annual Failure Rate: Fraction or % of equipment of a given type within a system that fail annually.

Lighting Classes (roadway and intersection): System of differentiation between areas where streetlights are used, based on traffic and pedestrian volume and other considerations. In the methodology's use of representative locations, lighting classes are the primary means of differentiation between locations. Applying CIE 115:2010 standards also requires the use of lighting class to determine the applicable lighting criteria.

Outage Factor: The average time, in hours, elapsed between failure of equipment and replacement of equipment, divided by annual operating hours. This shall be determined by documented maintenance practice and records of maintenance turn-around time from failure to replacement.

Representative Location: Representative locations are defined here as sample locations selected during project design for each roadway and intersection lighting class (defined in Annex III) found within the project boundaries, and including multiple locations within a lighting class if any significant variation in streetlight pole spacing and mounting height, and street dimensions occur. Fields of calculation for average illuminance shall be laid out for each representative location according to the standard provided in Annex II. Representative locations are used only for comparing baseline and measure lighting performance and are not intended to constitute the sampling plan for ex post power and operating hours monitoring**.**

System Outage Factor: The product of the equipment Outage Factor and the equipment Annual Failure Rate, as defined here; used to de-rate total annual electricity for baseline and project street lighting systems due to equipment outages within the systems.

Total Useful Illuminance: The average maintained illuminance on the target task plane (i.e. roadway surface), from the baseline and project street lighting equipment. *Maintained* illuminance takes into account the depreciation in luminous flux over time, and is defined as illuminance delivered when a product has reached the end of its maintenance cycle. Appropriate depreciation factors should be applied to modeled or measured illuminance values, based on the lighting technology used.

Norms, Specifications and Test Procedures. Relevant report, procedures and specifications for this methodology include:

(a) General guidelines for sampling and survey for small-scale CDM project activities;

(b) General guidelines to SSC CDM methodologies under the section 'Type II and III Greenfield projects (new facilities)";

(c) AMS-I.D "Renewable electricity generation for a grid";

(d) CIE 140:2000. International Commission on *Illumination Technical Report: Road Lighting Calculations*. ISBN 3 901 906 54 1

This report includes guidance for the calculation of luminance, illuminance, and their associated measures of lighting uniformity, as well as disability glare. The conventions adopted for luminance and illuminance grids are also included; these form the basis for Annex II;

(e) CIE 115:2010. 2nd Edition. International Commission on Illumination *Technical Report: Lighting of Roads for Motor and Pedestrian Traffic*. ISBN 978 3 901906 86 2

This report presents a structured model for the selection of the appropriate lighting classes based on the luminance or illuminance concept, taking into account the different parameters relevant for the given visual tasks. The use of adaptive lighting systems that apply time-dependant variables like traffic volume or weather conditions to luminance or illuminance requirements is described. This report also gives recommended maintained lighting levels and lighting quality requirements for roadway classes;

(f) CIE 180:2007. International Commission on Illumination (CIE) *Technical Report. Road Transport Lighting for Developing Countries*. ISBN 978 3 901 906 61 9

This report deals with the part that better lighting and visibility can play in reducing the toll of death and injury from nighttime road accidents; it is addressed to those involved in road safety work, not to lighting specialists… [the] chapter on fixed roadway lighting deals with the basic design of simple installations and explains the many different factors that need to be considered;

(g) CIE 191:2010. International Commission on Illumination *Technical Report: Recommended System for Mesopic Photometry Based on Visual Performance*. ISBN 978 3 901906 88 6

This report deals with visual task performance based approaches to mesopic photometry, with a major aim to establish appropriate mesopic spectral sensitivity functions to serve as a foundation of a system of mesopic photometry. A review of the most important visual tasks and the range of visual conditions typically encountered in night-time driving is given. The report summarizes the justification for the recommended system and gives general guidance for its use and application.

The system of mesopic photometry is complex and cannot be reproduced in this methodology. For the purposes of this methodology it is acceptable to use the system of mesopic photometry described in CIE 191:2010 to establish equivalent or improved lighting performance of a measure lighting technology as compared to the performance of a baseline lighting technology or to demonstrate compliance with illuminance requirements in an applicable street lighting standard (See Annex IV);

(h) IESNA RP-8-00 (2005). Illumination Engineering Society of North America (IESNA) *Roadway Lighting. American National Standard Practice for Roadway Lighting*. Standard Practice Subcommittee of the IESNA Roadway Lighting Committee. ISBN 0 87995 160 5

This standard serves as the North American basis for design of fixed lighting for roadways, adjacent bikeways, and pedestrian ways;

(i) IESNA LM-50-99. Illumination Engineering Society of North America (IESNA) *Guide for Photometric Measurement of Roadway Lighting Installations*;

(j) Gordon McKinlay. Light Up the World Report *Lighting for the Developing World*. Dec. 2006;

(k) Stevens, Cook, Shackelford, and Pang. *Street Lighting Network Controls Market Assessment Report*. Application Assessment Report #0914. PG&E Emerging Technologies Program. January, 2010. P. 55 (See Annex IV).

Annex II

Method for measuring and calculating average illuminance

Evaluating roadway illuminance, a measure of the amount of luminous flux falling per unit area – lumens/m^2, or lux (lx), is a simple comparative basis for roadway lighting systems (McKinlay. Dec. 2006) used in this methodology, though luminance evaluations are common and are also acceptable.[a] Total Useful Illuminance is defined here as the average maintained illuminance on the target task plane (i.e. roadway surface), from the baseline and project luminaires. *Maintained* illuminance takes into account the depreciation in luminous flux over time, which varies from one light source to another, and is defined as illuminance delivered when a product has reached the end of its maintenance cycle. Appropriate depreciation factors should be applied to modeled or measured illuminance values, based on the light source used.

Because roadway uses, dimensions, and lighting systems layout vary from location to location, it is not practical to measure or model lighting performance for an entire street lighting system. It shall be sufficient for this methodology's lighting performance requirements to show compliance at Representative locations within the project boundaries. Representative locations are defined here as sample locations selected during project design for each roadway and intersection lighting class (defined in Annex III) found within the project boundaries, and including multiple locations within a lighting class if any significant variation in streetlight pole spacing and mounting height, and street dimensions occur. Representative locations are used only for comparing baseline and measure lighting performance and are not intended to constitute the sampling plan for *ex post* monitoring of project equipment power and operating hours. Lighting performance and compliance shall be established at the commencement of project activities by competent lighting design professionals.

Quantifying illuminance can either be done through computer modeling of illuminance or actual field measurements. Measurement and calculation of average illuminance from baseline and project luminaires at representative locations shall be determined in accordance with standard practices, such as CIE 140:2000, summarized in Annex II. CIE 140:2000 provides the basis for determining fields of calculation, the location of measurement or simulation points for lighting calculations, and calculation methods for average illuminance values, as well as uniformity and glare values across the field of calculation.

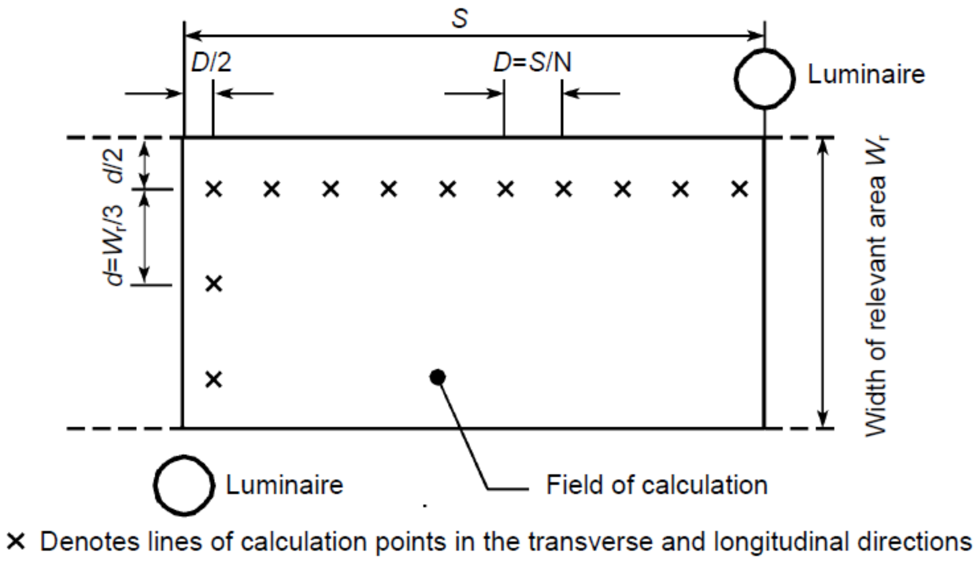
Illuminance comparisons must be made for fields of calculation within each representative location addressed by project activities, based on roadway and intersection lighting class as well as variations in mounting height, distance between luminaires, and roadway dimensions, as described in paragraph 3.

Illuminance equivalence shall be determined following the guidance provided here for illuminance measurements and modeling, based on CIE 140:2000, which provides detailed guidance on the layout of fields of calculation for measuring or simulating illuminance points in a given area. Please refer to CIE 140:2000 for details.

(l) The field of calculation should be typical of the area of the road or intersection which is of interest to the driver and pedestrian, and may include the footways, cycleways, and verges. As shown in the figure below, adapted from CIE 140:2000. it should be

[a] Luminance, a measure of the intensity of reflected light per unit area of an illuminated surface, in candela (cd)/m^2, is another common metric for evaluating street lighting performance. Luminance can be measured in the field or calculated as well and is another acceptable metric for compliance with applicable street lighting standards or comparison of baseline and measure technology performance. See Annex III.

bounded by the edges of the roadway and by transverse lines through two consecutive luminaires;



CIE 140:2000 Illustration of Illuminance Field of Calculation

(m) For staggered installations, consecutive luminaires will be on opposite sides of the road;

(n) The calculation points should be evenly spaced in the field of calculation (see figure above) and their number should be chosen as follows:

(o) In the longitudinal direction, the spacing in the longitudinal direction should be determined from the equation:

$$D = S / N \quad \textbf{(1)}$$

Where:

- *D* Space between points in the longitudinal direction (m)
- *S* Space between luminaires (m)
- *N* Number of calculation points in the longitudinal direction with the following values:
  - $S \le 30$ m, N = 10;
  - $S > 30$ m, N = the smallest integer giving $D \le 3$ m

The first row of calculation points is spaced at a distance D/2 beyond the first luminaire (m).

(p) In the transverse direction:

$$d = W_r / 3 \quad \textbf{(2)}$$

Where:

- *d* Space between points in the transverse direction (m)

W_r The width of the roadway or intersection (m)

The spacing of points from the edges of the relevant area is *D*/2 in the longitudinal direction, and *d*/2 in the transverse direction, as indicated in the figure above.

(q) Number of luminaires included in calculation:

(i) Luminaires which are situated within five times the mounting height from the calculation point should be included in the calculation.

Annex III

Roadway lighting requirements in lieu of national or local standard

The following tables present illuminance, luminance, glare, and uniformity criteria for roadways and intersections from standards that should be referenced in the absence of a prevailing national or local standard for street lighting. The lighting criteria here are adapted from CIE 115:2010, *Lighting of Roads for Motor and Pedestrian Traffic* and CIE 180:2007, *Road Transport Lighting for Developing Countries*. Please refer to the actual standards for detailed information on the criteria, definitions, and specific considerations.

Roadway and intersection lighting classes are an important designation to differentiate between types of areas where streetlights are necessary, based on traffic and pedestrian volume and other considerations. In the methodology's use of representative locations to characterize street lighting installations in project boundaries, lighting classes are the primary means of differentiation. Applying CIE 115:2010 requires the use of lighting class to determine the applicable lighting criteria.

Lighting Classes for Roadways (adapted from CIE 115:2010 Table 1)

Parameter	Options	Value	Selected Value
Traffic Speed	Very High	1	
	High	0.5	
	Moderate	0	
Traffic Volume	Very High	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic Composition	Mixed with high % non-motorized	2	
	Mixed	1	
	Motorized Only	0	
Separation of Roadways	Yes	1	
	No	0	
Intersection Density	High	1	
	Moderate	0	
Parked Vehicles	Present	0.5	
	Not Present	0	
Ambient Luminance	High	1	
	Moderate	0	
	Low	-1	
Visual Guidance / Traffic Control	Poor	0.5	
	Moderate/Good	0	
		Sum	
	Roadway Lighting Class M (6 - Sum):		

Roadway Luminance Requirements (adapted from CIE 115:2010 Table 2)

Lighting Class	**Road Surface**				**Threshold Increment**	**Surround Ratio**
	Dry			Wet		
	Luminance (cd/m^2)	U_o	U_1	U_o	%	R_s
M1	2.0	0.4	0.7	0.15	10	0.5
M2	1.5	0.4	0.7	0.15	10	0.5
M3	1.0	0.4	0.6	0.15	15	0.5
M4	.75	0.4	0.6	0.15	15	0.5
M5	0.5	0.35	0.4	0.15	15	0.5
M6	0.3	0.35	0.4	0.15	20	0.5

CIE 115:2010 only lists luminance requirements for roadway lighting classes. Luminance, a measure of the intensity of reflected light per unit area of an illuminated surface, in candela (cd)/m2, is a common criterion used in street lighting standards. Equivalent illuminance values for given luminance values can be determined from the average luminance coefficient, qo, in cd/m2/lx, if reflective properties of the surface are given. qo relates illuminance to luminance by the following relationship: Luminance (cd/m2) = Illuminance (lx) * qo (cd/m2/lx). A qo default value of 0.07 is often given for typical roadway surfaces; see CIE 115:2010. Such surfaces are typically asphalt roads with aggregate composed of a minimum of 60% gravel, greater than 10mm in size, with a mode of reflectance that is "mixed" (diffuse and specular). The value of 0.07 can also characterize an asphalt road surface with 10–15% artificial brightener in aggregate mix.

Roughly equivalent average illuminance requirements can be listed for three common roadway surface classes:

Illuminance Requirements for Roadways (adapted from CIE 115:2010 Table 4)

Lighting Class	**Average Illuminance (lx); q_o = .05**	**Average Illuminance (lx); q_o = .07**	**Average Illuminance (lx); q_o = .09**
M1	50	30	20
M2	30	20	15
M3	20	15	10
M4	15	10	7.5
M5	10	7.5	7.5
M6	7.5	7.5	7.5

Lighting Classes for Conflict Areas, Intersections (adapted from CIE 115:2010 Table 3)

Parameter	Options	Value	Selected Value
Traffic Speed	Very High	3	
	High	2	
	Moderate	1	
	Low	0	
Traffic Volume	Very High	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic Composition	Mixed with high % non-motorized	2	
	Mixed	1	
	Motorized Only	0	
Separation of Roadways	Yes	1	
	No	0	
Ambient Luminance	High	1	
	Moderate	0	
	Low	-1	
Visual Guidance/Traffic Control	Poor	0.5	
	Moderate / Good	0	
		Sum	
		Conflict Lighting Class C (6 - Sum):	

Requirements for Conflict Areas (adapted from CIE 115:2010 Table 5)

Lighting Class	Average Illuminance	Uniformity	Threshold Increment, %	
	lx	U_o	High, mod. speed	Low speed
C0	50	0.4	10	15
C1	30	0.4	10	15
C2	20	0.4	10	15
C3	15	0.4	15	20
C4	10	0.4	15	20
C5	7.5	0.4	15	25

Considering vehicle types found in less developed countries, the following values are suggested by CIE 180:2007. For areas where the traffic consists mostly of pedestrians and non-motorized vehicles (the first two rows in the table) the figures are for illuminance only. For recognized traffic routes (the remaining rows in the table) the figures are for luminance, but roughly equivalent values for illuminance, for moderately dark road surfaces, are given as well.

Suggested Lighting Standard for Developing Countries (adapted from CIE 180:2007)

Category	Average Lighting Level	Uniformity (U_o)	Uniformity (U_1)	Threshold Increment %

Roadways in residential areas, with pedestrians and many non-motorized vehicles	1 – 2 lx	0.2	n/a	n/a
Largely residential, some motorized vehicles	4 – 5 lx	0.2	n/a	n/a
Major access roads, distributors, and minor main roads	0.5 cd/m^2 8 lx	0.4	0.5	n/a
Important rural and urban traffic routes	1.0 cd/m^2 15 lx	0.4	0.6	20
High speed roads, dual carriageways	1.5 cd/m^2 25lx	0.4	0.7	15

Annex IV

Guidance on use of mesopic photometry for lighting performance evaluation

"The photopic response curve is a function that weights the visual effectiveness of wavelengths in the electromagnetic spectrum according to the human eye's response in levels of adaption over 3 cd/m^2 (e.g. daylight conditions), which are dominated by the eye's cone photoreceptors. Commercial photometry traditionally measures light levels based on this function. However, under the lowest light conditions (adaption less than 0.001 cd/m^2), when the eye's rods are the active photoreceptors, human perception of light follows the scotopic luminous efficiency function. At intermediate levels between daylight and darkness (ambient photopic luminance in the 0.001 to 3 cd/m^2 range) typical of nighttime roadway lighting levels, rods and cones both provide levels of spectral sensitivity, with rods' importance diminishing and cones' increasing as light levels increase. In these intermediate levels, the photopic response curve and the scotopic response curve are both important. This is known as the mesopic range."

Stevens, Cook, Shackelford, and Pang. *Street Lighting Network Controls Market Assessment Report*. Application Assessment Report #0914. PG&E Emerging Technologies Program. January, 2010. P. 55.

Mesopic photometry characterizes the performance of the human visual system under low light levels typical of nighttime roadway conditions. Broad spectrum light sources excite multiple types of photoreceptors in the human eye (rods and cones), and often provide higher performance in the mesopic range than narrow spectrum sources such as Sodium Vapor lamps. Mesopic photometry may better quantify the benefits of efficient broad spectrum light sources such as LED luminaires and induction lamps that may be selected as project luminaires under this methodology.

If mesopic photometry is to be used in the lighting performance evaluation, project participant shall refer to CIE 191:2010 methods to calculate mesopic luminance (and to estimate mesopic illuminance) based on photopic and scotopic luminance levels (field measured or computer modeled) or using photopic luminance and the ratio of light source photopic:scotopic luminous output. The mesopic model will require many calculation steps that should be documented in the Project Design Document.

History of the document

Version	Date	Nature of revision
01	EB 60, Annex 18 15 April 2011	Initial adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		

11 ANNEX V – NOVA SCOTIA STREET LIGHTING DEMONSTRATION PROJECT

LightSavers
ACCELERATING ADVANCED OUTDOOR LIGHTING

Nova Scotia Street Lighting

Robie Street, Halifax, Nova Scotia

Project Contact:
Contact: Darren Chauder, Senior Street Lighting Electrician,
Halifax Regional Municipality
(902) 490-3946
chauded@halifax.ca

Project Overview:
Location: 19 Nova Scotia communities
Application: Street Lighting
Existing Lighting Type: HPS
Replacement Lighting Type: LED
Installation Date: November 2009
Total Fixtures Installed: 1,100
Percent Energy Savings: 53%

Product:
Manufacturer: LED Roadway
Fixture: Satellite Series (S48M, S72M, S96M)

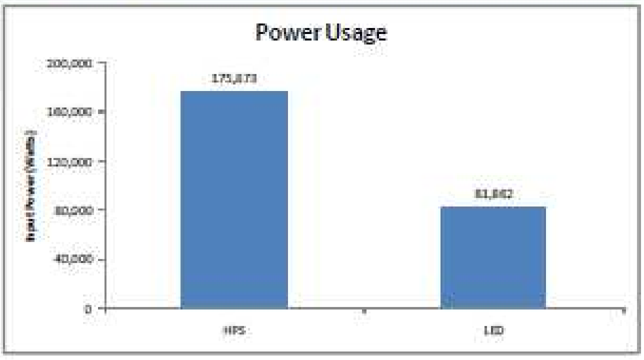
BACKGROUND AND PROJECT DESCRIPTION

LED Roadway Lighting Limited, ecoNova Scotia, Conserve Nova Scotia, and Natural Resources Canada partnered in a pilot project to retrofit existing street lights with new LED street lights in 19 communities throughout Nova Scotia. Eleven Hundred (1,100) exisiting high pressure sodium (HPS) cobra head street lights have been converted to LRL's LED Satellite series street lights.

DMD & Associates Ltd. were retained to review the computer lighting calculations and design factors brought forward by the supplier, review testing procedures and calculate energy savings for the pilot.

RESULTS

Power usage was reduced by 53% which will result in significant annual energy savings. All chosen locations met IESNA Roadway lighting standards (RP-8). An estimated 20 year lifespan with minimal maintenance requirements is expected to result in significant maintenance savings. The greenhouse gas emissions avoided will be approximately 22.8 tonnes eCO_2 /yr*. Please see the reverse page for a description of each project site.



*Based on 0.242 kg eCO_2/kWh

HALIFAX REGIONAL MUNICIPALITY
TORONTO Atmospheric Fund
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LightSavers

ACCELERATING ADVANCED OUTDOOR LIGHTING

Toronto Atmospheric Fund

"Halifax Regional Municipality has replaced over 200 HPS streetlights with LEDs manufactured by LRL. The new fixtures consume 70 - 75% less energy, and on top of the energy savings, the light quality and colour rendering has improved. We are currently exploring retrofitting more streetlights with LEDs due to the success of this pilot."

Darren Chauder, Senior Street Lighting Electrician, Halifax Regional Municipality

Location	Existing Fixture	Wattage Used Per Fixture	LED Roadway Replacement Fixture	Wattage Used Per Fixture	Energy Savings	Number of Fixtures Replaced	Total Wattages Before	Total Wattages After
Annapolis	100W HPS	137	S96M	88	36%	102	13,974	8,976
Annapolis	70W HPS	94	S48M	44	53%	10	940	440
Annapolis	400W HPS	465	S96M	88	81%	15	6,975	1,320
Annapolis	100W HPS	137	S96M	88	36%	8	1,096	704
Yarmouth	100W HPS	137	S96M	88	36%	24	3,288	2,112
HRM	150W HPS	193	S96M	88	54%	40	7,720	3,520
HRM	100W HPS	137	S96M	88	36%	14	1,918	1,232
HRM	150W HPS	193	S96M	88	54%	27	5,211	2,376
HRM	70W HPS	94	S48M	44	53%	32	3,008	1,408
HRM	70W HPS	94	S96M	88	6%	32	3,008	2,816
Yarmouth	70W HPS	94	S72M	66	30%	34	3,196	2,244
Yarmouth	250W HPS	292	S96M	88	70%	2	584	176
Bridgewater	70W HPS	94	S48M	44	53%	31	2,914	1,364
Bridgewater	70W HPS	94	S48M	44	53%	13	1,222	572
Bridgewater	150W HPS	193	S96M	88	54%	16	3,088	1,408
Wolfville	100W HPS	137	S96M	88	36%	7	959	616
Grand Pre	100W HPS	137	S96M	88	36%	3	411	264
Truro	100W HPS	137	S96M	88	36%	16	2,192	1,408
Stanfield Airport	250W HPS	292	S96M	88	70%	14	4,088	1,232
Stanfield Airport	150W HPS	193	S96M	88	54%	11	2,123	968
Berwick	250W HPS *	292	S96M	88	40%	60	4,088	2,464
Parrsboro	400W HPS	465	S96M	88	81%	20	9,300	1,760
Parrsboro	100W HPS	137	S72M	66	52%	19	2,603	1,254
Parrsboro	250W HPS	292	S96M	88	70%	11	3,212	968
Port Hawkesbury	250W HPS	292	S96M	88	70%	10	2,920	880
Richmond County	70W HPS	94	S96M	88	6%	7	658	616
Amherst	100W HPS	137	S96M	88	36%	90	12,330	7,920
Springhill	70W HPS	94	S48M	44	53%	4	376	176
Springhill	100W HPS	137	S72M	66	52%	6	822	396
St Peters	100W HPS	137	S72M	66	52%	9	1,233	594
Arachat	100W HPS	137	S48M	44	68%	9	1,233	396
New Glasgow	250W HPS	292	S96M	88	70%	17	4,964	1,496
New Glasgow	100W HPS	137	S48M	44	68%	43	5,891	1,892
Antigonish	100W HPS	137	S72M	66	52%	60	8,220	3,960
Lunenburg	100W HPS	137	S72M	66	52%	60	8,220	3,960
HRM	70W HPS	94	S48M	44	53%	10	940	440
HRM	150W HPS	193	S96M	88	54%	24	4,632	2,112
HRM	100W HPS	137	S72M	66	52%	10	1,370	660
HRM	100W HPS	137	S72M	66	52%	34	4,658	2,244
Bedford	150W HPS	193	S96M	88	54%	15	2,895	1,320
Bedford	100W HPS	137	S72M	66	52%	15	2,055	990
Dartmouth	150W HPS	193	S96M	88	54%	7	1,351	616
Dartmouth	250W HPS	292	S96M	88	70%	8	2,336	704
Dartmouth	150W HPS	193	S96M	88	54%	18	3,474	1,584
Dept of Trans IR	180W LPS	220	S96M	88	60%	48	10,560	4,224
Dept of Trans IR	180W LPS	220	S96M	88	60%	34	7,480	2,992
HRM	100W HPS	137	S96M	88	36%	1	137	88
					Totals	1,100	175,873	81,862

Note: At Berwick location, LED Roadway changed 14 x 250W HPS fixtures to 28 x S6200 fixtures

Total Estimated Energy Savings 53%

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LightSavers™ is a project of the Toronto Atmospheric Fund. For a detailed findings report on this pilot project, visit **www.lightsavers.ca**.

12 ANNEX VI - GUIDE TO EVALUATING LED LUMEN MAINTENANCE

Useful lifetime estimates for LED lighting products are typically given in terms of the expected operating hours until light output has diminished to 70% of initial levels (denoted L70 life). Recommended lumen maintenance requirements are given in the table below to qualify lifetime claims.

Table 1. Recommended lumen maintenance requirements

L70 lifetime claim (hrs)	*Minimum lumen maintenance at 6,000 hours (%)*
35,000	94.1
50,000	95.8

US DOE, 2011

The applicant may demonstrate compliance with the 6,000 hour lumen maintenance thresholds identified above in one of two ways: Option 1 (Component Performance) or Option 2 (Luminaire Performance).

Option 1: Component Performance

Under this compliance path, the applicant demonstrates that the LED package or module/array (light source) tested per the LM-80 test procedure operates at or below a specified temperature and drive current when operated (in situ) in the luminaire under consideration. To be eligible for the Component Performance option, ALL three of the conditions below must be met. If ANY of the conditions is not met, the component performance option may not be used and the applicant must use Option 2 for compliance.

1. The LED light source has been tested according to LM-80, and the light source must demonstrate minimum percent lumen maintenance as per **Table 1** above.

2. The LED light source manufacturer prescribes/indicates a temperature measurement point (TMPLED) on the light sources.

3. The LED light source TMPLED is accessible to allow temporary attachment of a thermocouple for measurement of in situ temperature. Access via a temporary hole in the housing, tightly resealed during testing with putty or other flexible sealant, is allowable.

The luminaire complies per Option 1 if:

1. The LED light source drive current specified by the luminaire manufacturer is less than or equal to the drive current specified in the LM-80 test report.
Note that the input current to the luminaire is often NOT the input current to the LED light source.

2. For the hottest LED light source in the luminaire, the temperature measured at the TMPLED during In Situ Temperature Measurement Testing (ISTMT) is less than or equal to the temperature specified in the LM-80 test report for the corresponding drive current or higher, within the manufacturer's specified operating current range.

The ISTMT laboratory must be approved by OSHA as a Nationally Recognized Testing Lab (NRTL), must be qualified, verified, and recognized through the U.S. Department of Energy (DOE)'s CALiPER program, or must be recognized through UL's Data Acceptance Program.

The ISTMT must be conducted with the luminaire installed in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires).

Option 2: Luminaire Performance

Under this compliance path, the applicant demonstrates compliance with the lumen maintenance requirement by submitting LM-79 photometric test data for the entire luminaire, comparing initial output (time = 0 hours) to output after 6,000 hours of operation (time ≥ 6,000 hours). The test report must demonstrate a minimum percent lumen maintenance as per **Table 1** above when operated in the appropriate application as defined by ANSI/UL 1598 (hardwired luminaires). The LM-79 test laboratory must hold NVLAP accreditation for the LM-79-08 test procedure or must be qualified, verified, and recognized through DOE's CALiPER program.

Source: US DOE, 2011. Solid-State Lighting – Published Specifications. Guide to Evaluating LED Lumen Maintenance. United States Department of Energy.
http://www1.eere.energy.gov/buildings/ssl/resources.html