Product Profile: Light Emitting Diodes (LEDs)

LED Lighting in Australia and New Zealand

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1 Executive summary

1.1 Background

This product profile reports on the current Light Emitting Diodes (LED) market and scope for energy efficiency and technological improvements. It explores possible actions to encourage the uptake of energy efficient LED lighting, including the feasibility of developing Minimum Energy Performance Standards (MEPS) for LED lamps, under the Greenhouse and Energy Minimum Standards Act 2012 (GEMS) in Australia and the Energy Efficiency (Energy Using Products) Regulations (2002) in New Zealand.

It is estimated that the phase-out of incandescent light bulbs in 2009 in Australia (along with state based energy efficiency obligations schemes) is saving around 2.6 terawatt-hours (TWh) of electricity each year. This saving is equivalent to the total annual electricity consumption of 150,000 homes. The average household is estimated to be saving 300 kWh and $75 per annum (may vary depending upon tariff). It is projected that a full transition to efficient lighting such as compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) could reduce residential lighting energy use in Australia by a further 65%, which equates to an additional $180 saving per year. Options for the further phase-out in Australia of incandescent and halogen lamps as LED and CFL replacements become available was discussed, and stakeholder input sought, in the Incandescent and CFL Product Profile released in November 2014 (E3 2014).

The New Zealand Government does not wish to limit consumer choice, and prefers to provide energy efficiency information. For this reason incandescent lamps are likely to remain for sale in New Zealand. However MEPS is supported for products where there is a range of efficiencies and room for improvement, as with CFLs or potentially LEDs.

Efficient LED lamps are widely available in Australia and New Zealand, but many consumers still use older inefficient lamps (mains voltage halogens in Australia and incandescent bulbs in New Zealand). Monitoring of LED lighting in the market indicates that technology is developing rapidly with LED lighting having the potential to broaden the range of energy efficient lighting options available to consumers. LED lamps are becoming more affordable as well. However evaluation of LED products currently available in the marketplace indicates a wide variation in quality and efficacy.

Due to these quality and efficacy variations, there is a concern that consumer experience of expensive, poor quality LEDs will impact upon their willingness to buy LED products in the future. Negative consumer experience is likely to reduce uptake and the energy savings that could be gained from adoption of this new technology as a replacement for inefficient lighting. An LED MEPS has the potential to improve performance and consumer confidence, which could lead to greater uptake. An LED MEPS could also increase the overall energy savings achieved by the transition to LEDs through removing less efficient LEDs from the market.

The scope of this product profile is LED lighting, including household lamps and commercial luminaires, in Australia and New Zealand. This includes those of a non-standard form and those intended to replace standard general service incandescent, decorative, reflector and linear fluorescent lamps.

1.2 The LED lighting market

LED lighting is largely manufactured outside Australia and New Zealand. A brief market survey found over 50 LED lamp brands. Products are sold in a range of outlets including “Big-box” hardware stores, supermarkets, general lighting retail, specialist lighting stores, and electrical retail suppliers, (all of which have online options for purchasing). In addition, online-only lighting retailers and direct manufacturer/suppliers were also identified.

While the 2010 intrusive lighting survey showed limited household use of LED lighting, more recent data in the Queensland Household Energy Survey 2014 (Colmar Brunton 2014) found that between 2010 and 2014, ownership of LED lighting increased from 15% to 37% of households.

This product profile evaluates the quality and performance of LED lighting available in the market, referencing test results of a range of LED lamps purchased by E3 in 2010, 2012, 2013 and 2014, as well as overseas testing. Based on these test results, the report identifies key quality and performance challenges for LED lighting including:

- Significant variations in lamp efficacy, with some LED products that would fail the current minimum energy performance standard (MEPS) for CFLs;
- Significant variations from rated wattage with differences of 20-50% in products tested;
- Inaccurate lamp equivalency claims, with testing showing that the lumen output of some lamps were close to half the rated value declared by the manufacturer or supplier;
- Some LED lamps purchased in 2014 still exceeded the allowable colour deviation although chromaticity tolerance testing has shown that lamp colour has improved significantly;
- Colour rendering issues, with 10 of the 18 products tested in 2014 found to have a CRI of below 80 (the level generally recommended for office and residential applications), while significant differences were also found between tested and rated colour temperatures;
- Some lamps with a power factor below 0.5;
- Challenges with lumen maintenance, with nearly half the products tested by the US DOE in 2014 predicted to have failed lumen maintenance requirements by their rated lifetime;
- Energy use impacts of 'Smart' lighting, with standby power use accounting for half or more of a lamp's total annual energy use, resulting in LED lamps that consume more power than CFLs, and in some cases are closer to incandescent lamps in terms of efficacy.

The report also assesses possible health impacts as a result of lamp flicker and blue light levels.

1.3 Energy consumption

Individual lamps do not consume large quantities of energy. However, the average Australian home has 48 lamps (E3 2013) and the average New Zealand home has 34.5 lamps (Ipsos 2012). When aggregated, lighting accounts for a significant proportion of the average household's electricity use in Australia and New Zealand - typically around 12% (EES 2008; current EECA End Use Database (enduse.eeca.govt.nz))[1].

MEPS and technology improvements have increased the efficiency of lamps in recent years with average households now using 27% (300 kWh p.a.) less energy to light their homes. However, significant numbers of consumers and businesses continue to be exposed to unnecessarily high lighting energy costs because their lamps and lighting systems are not as efficient as they could be.

The Incandescent, Halogen and Compact Fluorescent Lamps Product Profile report (E3 2014) released in November 2014 identified further steps in making the transition to efficient lighting that could result in potential savings of up to approximately 1 TWh (3.4 petajoules (PJ) p.a.) in New Zealand and 5.4 TWh (19.3 PJ p.a.) in Australia through fully transitioning from incandescent and halogen lamps to CFLs and LEDs. Measures to remove barriers and encourage the uptake of efficient quality LED lighting will contribute to achieving these identified savings by ensuring minimum performance levels for LED lighting efficacy and quality and assisting consumers in selecting effective and efficient product.

1.4 International programs

A number of countries have already implemented, or are the process of implementing, regulatory or voluntary mechanisms for LED lighting products including MEPS, Comparative Labelling Schemes and Endorsement Labelling Schemes.

This product profile identifies the countries that have voluntary and mandatory regulatory regimes for LED lighting products, including the scope of LED products covered and the test methods used, for the purpose of identifying which programs are considered appropriate for further investigation by the Australian and New Zealand governments. At the time of publication, while several countries have implemented labelling schemes or voluntary measures relating to LED products, mandatory MEPS for LED lamps have been implemented in only a

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[1] Note however that this proportion varies considerably depending on how significantly gas is used as a fuel.

few economies including the EU, Mexico and Malaysia. In several other countries, including the USA, Jordan and Nigeria, MEPS requirements are under development.

The work of the IEA 4E Solid State Lighting Annex, supported by 9 countries, including Australia, also provides a source of technical and policy guidance relating to performance levels and testing of LED products and is thus referenced in this product profile.

Regulatory and voluntary mechanisms require test methods by which each nominated parameter shall be measured. Given the global nature of LED lighting products, international standards, where available, are the preferred source of test methods with the following entities currently providing relevant standards and guidance:

- International Commission on Illumination (CIE)
- International Electrotechnical Commission (IEC)
- Illuminating Engineering Society of North America (IESNA)
- National Standards organisations (e.g. Standards Australia, Standards New Zealand)

It is proposed that an Australian and New Zealand LED test standard be developed, drawing upon available international standards where possible.

1.5 Policy options

Policy options to further transition from inefficient lighting to quality energy efficient LED lighting are examined in Chapter 9 and summarised below. More than one option could be implemented at the same time. Potentially these policy options could be implemented alongside action to further phase out (Australia) or improve (New Zealand) inefficient incandescent lighting by increasing existing MEPS levels to some or all halogen lamps (discussed in detail in the Incandescent and CFL Product Profile).

Policy options investigated in a Regulation Impact Statement (RIS) would be subject to further consultation in both countries, and to Ministerial approval in New Zealand.

Option 1: *Introduce LED MEPS with a minimum efficacy level set to remove the lower performing lamps in the Australia and New Zealand Market. Efficacy level to be either:*

- *One or more linear levels; or*
- *A curved level.*

Option 2: *Set a timetable of increases to minimum efficacy levels via MEPS.*

Option 3: *LED MEPS to also include a range of performance parameters (that address important quality and performance issues found in market testing) to ensure that LED lighting provides an effective as well as efficient lighting alternative.*

Option 4: *Include optional extreme conditions performance specifications in the Australian and New Zealand Standard and/or MEPS.*

Option 5: *In the MEPS include a preferred range of rated luminous flux values to be used on lamp packaging, along with a requirement for lumens per Watt to be included on packaging in order to assist consumers in selecting replacement lamps.*

Option 6: *Suppliers be required to include efficacy and performance information on LED product packaging and/or the LED product to enable customers to choose a suitable and efficient model.*

Option 7: *That Australia adopt and implement the New Zealand specification of voluntary ENERGY STAR labelling for high efficiency CFL and LED products to provide guidance on high performance lamps.*

Option 8: *Develop and apply the Australia / New Zealand Energy Rating Label to all lamp technologies available for specified range of lamp applications to provide customers with comparative information on lamp efficacy.*

Option 9: *If a regulated MEPS is not implemented, Australia and New Zealand establish the Lighting Facts scheme (or similar program) for LED products to provide consumers with accurate lamp performance information.*

Option 10: *An Australian - New Zealand LED test standard be developed with reference to available international test standards including CIE S 025.*

Option 11: *Implement a consumer education campaign about LED lighting (in cooperation with the lighting industry and retailers) either:*

- *alongside the introduction of MEPS for LEDs;*
- *alongside the introduction of a labelling scheme; or*
- *as a stand-alone initiative.*

2 Introduction

2.1 Purpose

This consultation document forms part of an investigation into possible actions to encourage the uptake of energy efficient LED lighting, including the feasibility of developing Minimum Energy Performance Standards (MEPS) for LED lamps, under the *Greenhouse and Energy Minimum Standards Act 2012* (GEMS) in Australia and the *Energy Efficiency (Energy Using Products) Regulations (2002)* in New Zealand. The document serves two purposes:

1. To provide an update on the state of LED technologies, their capacity for improved energy efficiency and performance, and the current and projected markets for sales in Australia and New Zealand. This information has been collected for the benefit of policy makers; however, stakeholder feedback is sought in verifying the report's findings.
2. To signal to stakeholders the options that will likely form the basis of initial stakeholder consultation. Final policy options would be subject to detailed investigation and cost benefit analysis through a Regulation Impact Statement (RIS). In New Zealand, approval of Ministers is required for any proposed regulatory option that might be modelled by a RIS.

2.2 Where to from here

2.2.1 Consultation on this Product Profile

Readers are asked for feedback on the information and proposed policy options put forward in this document, and where possible to provide robust data to support their response. Stakeholder consultation meetings will also be held in Australia and New Zealand.

Feedback from industry stakeholders will be important in formulating the most appropriate policy approach. Responses to the Key Questions below would be of particular assistance.

Comments should be sent via e-mail and be received by 9 October 2015.
The subject should be clearly titled 'LED Lighting Product Profile' and sent to:

- **Australia:** EER-Lighting@industry.gov.au
- **New Zealand:** regs@eeca.govt.nz

2.2.2 After consultation on this Product Profile

The material in this Product Profile, supplemented in light of any written submissions made by stakeholders and/or issues raised at stakeholder meetings, will aid governments in determining:

- whether to proceed with developing options to improve the energy efficiency and performance of LED lighting
- the reliability of the information currently available to consumers, and
- what other voluntary options may be suitable.

If the preferred option(s) involve regulation (e.g. MEPS and/or labelling), a RIS will be prepared to analyse the costs, benefits and other impacts of the proposal. Consultation will be undertaken with stakeholders prior to any final decisions being made. Final decisions on policy will be made by the relevant Council of Australian Governments (COAG) Ministerial Council in Australia and by the New Zealand Cabinet.

Options for improving energy efficiency and performance of LED lighting will be considered alongside options for incandescent, halogens and CFLs, which are the subject of another Product Profile released in November 2014. Options for a range of commercial lighting products will be considered in a third product profile.

2.2.3 LED Lighting Product Profile – key questions

Readers are invited to comment on any aspect of this Product Profile. Responses to the key questions listed in the following box would be of particular assistance in determining the future direction of the lighting program.

The Problem

- To what extent do the market barriers, 'principal-agent problem' and 'split incentives' exist for LED lighting? For example, are landlords and property developers not investing in LED lighting? Are they having consideration for energy efficiency, product quality and performance?
- Are experiences with poor performing (e.g. efficiency, life, quality) LED lighting products or uncertainty on appropriate retrofit lamps affecting the rate of take up of this new technology?
- Can you provide robust supporting data?

Product description and Scope

- Input from industry is requested to assist in developing clear definitions of LED luminaires to avoid ambiguity and not include luminaires outside of the scope of this Product Profile. Can you provide recommended definitions for LED luminaires?
- Can you comment on the key LED lamp and luminaire types in terms which are likely to have a significant market share in the future?
- If a MEPS scheme for LED lighting was to be introduced, what scope of products (including lamps and integrated luminaires) should be subject to the MEPS requirements?
- Can you suggest ways to better collect product identification data for lighting products during the registration process in order to assist with compliance activities?

Market profile

- Can you provide information on the market share and market trends for LED lighting in the Australian and New Zealand markets?
- Can you provide data to support the anecdotal evidence that LED lighting is replacing (or could replace in the future) a range of other lighting technologies including:
    - pilot lamps
    - Incandescent lamps 25W and below
    - Mains voltage omnidirectional incandescent lamps
    - Mains voltage reflector incandescent lamps
    - Extra low voltage reflector incandescent lamps
    - Linear fluorescent lamps
    - Existing lighting systems including those with dimming circuits and motion detectors?

Performance and testing standards

- Can you comment on the options canvassed in Chapter 8 for LED tests standards and minimum performance parameters and levels that could be applied in Australia and New Zealand?
- In setting a possible minimum energy performance level, would a lumen-dependent MEPS curve (as per EU MEPS, and AU CFL MEPS) or a flat cut-off MEPS line (as per IEA 4ESSL) be appropriate?
- Can you comment on the current and likely future availability of LED lighting which would meet the proposed regulatory levels?

Technological advances

- How can the parasitic energy consumption implications of 'Smart' lighting be minimised or avoided?

Policy options

- Do you think the policy options discussed in Chapter 8 could feasibly address the Problem outlined in Chapter 2, in terms of market failures inhibiting improved energy efficiency of residential lighting?
- What additional costs do you think the policy options discussed in Chapter 8 would place on industry compared to the current situation?
- What do you think would be the best way for governments to facilitate an increase in the average energy efficiency of lighting in relation to LED lighting?
- Stakeholders are asked to provide data to support in-depth cost-benefit analyses of the policy options discussed in Chapter 8?

Incandescent and Halogen Phase-out (Australia)

- Stakeholder views are also invited on an option considered in the Incandescent, Halogen and Compact Fluorescent Lamps Product Profile regarding the development of MEPS in Australia to phase out incandescent and halogen lamps and replace with CFL/LED technology, with a staged implementation in different lamp categories as and when LED technology has matured sufficiently. Stakeholders are encouraged to consider and comment on that option further in the context of this LED product profile, and in particular provide advice on the timing of the implementation of such a MEPS in Australia. Following the analysis in the previous product profile and given the advances in LED lighting, Table 1 outlines a phase-out timetable for a range of incandescent and halogen lamps. Scope and exclusions would be generally consistent with those specified in AS 4934.2 with the exception of reinforced construction (rough use) lamps, which would no longer be excluded. Further advice from industry stakeholders is required, in particular regarding the compatibility issues related to the timing of the phase-out of low voltage halogen reflector lamps.

Table 1. Proposed Incandescent Lamp Phase-out Dates in Australia

Product Category	Phase-out Date
Decorative, fancy round and candle incandescent and halogen lamps ≥10W	2017
GLS mains voltage omnidirectional halogen lamps	2018
Mains voltage reflector incandescent and halogen lamps < 150W	2018
Extra low voltage halogen reflector lamps	2018
Extra low voltage halogen omnidirectional lamps	2018
Luminaires – may not be supplied with an incandescent or halogen lamp	2017

3 The problem

3.1 Scope

This scope of this product profile is LED lighting, which encompasses LED light sources including omnidirectional and reflector lamps (including those with integral and non-integral drivers) and luminaires in Australia and New Zealand. This includes those of a non-standard form and those intended to replace standard general service incandescent, decorative, reflector and linear fluorescent lamps. Organic LEDs are not within the scope of this product profile. The range of LED products is further described in Chapter 4.

3.2 Objective

The objective is to consider options to increase uptake of quality energy efficient LED lighting products supplied in the Australian and New Zealand markets to reduce energy consumption and emissions by addressing market failures such as information failure and principal-agent problems. This includes:

- Consideration of measures such as consumer information, voluntary standards, Minimum and/or High Energy Performance Standards and product labelling that do not increase the life-cycle cost of appliances and deliver net public economic benefits to Australia and New Zealand.
- Development of robust photometric and electrical performance standards and associated test methods in Australian/New Zealand Standards to determine individual product energy efficiency and quality performance.
- Ensure that any approach is harmonised between Australia and New Zealand, and with available international standards, to the extent possible.
- Ensure that stakeholders and consumers are consulted regarding proposed measures and informed of measures prior to implementation.

3.3 The problem

Individual lamps do not consume large quantities of energy. However, the average Australian home has 48 lamps (E3 2013) and the average New Zealand home has 34.5 lamps (Ipsos 2012). When aggregated, lighting accounts for a significant proportion of the average household's electricity use in Australia and New Zealand - typically around 12% (EES 2008; current EECA End Use Database (enduse.eeca.govt.nz))[2].

MEPS and technology improvements have increased the efficiency of lamps in recent years with average households now using 27% (300 kWh p.a.) less energy to light their homes (E3 2014). However, significant numbers of consumers and businesses continue to be exposed to unnecessarily high lighting energy costs because their lamps and lighting systems are not as efficient as they could be. Market failures, including principal-agent problems and information failures, are inhibiting the uptake of more efficient lighting and government intervention may be justified.

Principal-agent problems exist when an agent does not act in the best interests of the principal due to "split incentives". For example, a builder (the agent) may choose cheaper, less efficient lighting to minimise their build costs. Even in cases where the builder may select LED lighting, they may choose relatively cheaper models that are comparatively less efficient or of poor quality and reliability when compared to other efficient lighting alternatives. This is not always in the best interest of the building occupant (the principal) who is exposed to the operating costs of the lighting system installed. In the case of LED lighting, the exposure to higher operating costs or poor quality may occur over a long lifetime.

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[2] Note however that this proportion varies considerably depending on how significantly gas is used as a fuel.

Information failure can also be a problem when buyers are not able to compare the lifetime costs or comparative quality and performance of different lamp technologies, and therefore make sub-optimal purchase decisions. For example, market research (Winton Sustainable Research Strategies 2011) has shown that consumers often lack knowledge about estimating the energy use, equivalency and running costs for different lighting technologies. They may also make decisions based on incorrect information or limited understanding, for example that low voltage halogen lighting is efficient ("low energy"), or that LED lighting is always the most efficient alternative. The low unit cost of lamps also makes it less likely that consumers will invest the time required to make an informed decision.

In the case of commercial lighting, both suppliers and specifiers of lighting systems may lack sufficient knowledge of new linear lamp technologies and their costs and benefits, to select the optimal equipment for the purpose of the lighting system. The entry of LED lighting alternatives in the commercial lighting market has increased the complexity of these decisions.

While it can be expected that the market may make a natural shift towards LEDs over the next few years, the experience with the uptake of CFLs has shown that there is a risk of a consumer backlash due to variation in quality, performance, lifetime, light output and inaccurate equivalency claims. With LED lighting, the relatively higher purchase cost of these products may exacerbate consumer reaction to poor experience with these potentially efficient alternatives. If this occurs, the transition to efficient lighting may remain incomplete, with missed opportunities in terms of energy savings.

The Incandescent, Halogen and Compact Fluorescent Lamps Product Profile report (E3 2014) identified further steps in making the transition to efficient lighting that could result in potential savings of up to approximately 1 TWh (3.4 petajoules (PJ) p.a.) in New Zealand and 5.4 TWh (19.3 PJ p.a.) in Australia. This is the approximate potential of energy savings available from fully transitioning from incandescent and halogen lamps to CFLs and LEDs. Measures to remove barriers and encourage the uptake of efficient quality LED lighting will contribute to achieving these identified savings by ensuring minimum performance levels for LED lighting efficacy and quality and assisting consumers in selecting effective and efficient products.

4 Product description

LEDs, or Solid State Lighting (SSL), use one or more semiconductor diodes (solid state chip) to emit non-coherent optical radiation (light) in the visible spectrum. This radiation can either be in the visible spectrum (i.e. the LED directly produces visible light), or the visible light can be produced indirectly, e.g. with the radiation exciting phosphor which in turns emits the visible light in a similar way to CFLs. LEDs are currently available to replace many types of lamps and continue to evolve rapidly to cover many different lighting applications. The performance of LED lamps is variable, and while in the last 2-3 years significant improvements in performance of good quality lamps have been observed, testing indicates that poor quality lamps are still present in the market. LED lighting is sometimes referred to as solid state lighting (SSL) – this refers to the fact that the light is emitted from a solid object rather than a vacuum or gas tube. Figure 1 shows examples of integrated and semi-integrated LED lamps (with integral power supply electronics).

Omnidirectional-replacement LED

Directional LED lamp

LED MR16

Figure 1.Examples of integrated (left, middle) and semi-integrated (right) LED integral lamps (images courtesy Barryjoosen and Lee, E.G. via Wikimedia Commons)

An **LED light source** is a lamp based on LED technology, either provided with a lamp-cap according to IEC 60061, or manufactured as a module (LED) or other component, made in order to produce an optical visible radiation to be used or incorporated into a luminaire (IEC 62504:2014).

An **LED luminaire** is a complete lighting unit consisting of LED-based light emitting elements and a matched driver together with parts to distribute light, to position and protect the light emitting elements, and connect the unit to a branch circuit (IES RP-16-10; Energy Star® Program Requirements for Luminaires – Version 1.1).

LED lamps and module products can be broken into three basic groups in relation to how they are connected to electrical power. This terminology can be applied to both lamps and modules:

- Integrated LED (LEDi)
- Semi-integrated LED (LEDsi)
- Non-integrated LED (LEDn) or (LEDni)

The International Commission on Illumination (CIE) Test Method for LED Lamps, LED Luminaires and LED modules, (CIE TC 2-71) defines an **integrated** LED lamp or module (LEDi) as an "LED lamp/module incorporating LED control gear, and any additional elements necessary for stable operation of the light source, designed for direct connection to the supply voltage". Typical examples of this will be LED lamps which have a cap designed to be plugged directly into 240V power.

A **semi-integrated** LED (LEDsi) is defined as an "LED lamp/module which carries the control unit of the LED control gear, and is operated by the separated power supply of the control gear". Examples include MR16, MR11 (with bi-pin bases GU5.3, GU4 respectively) which have an integrated driver and though they are attached to a transformer to step down 240VAC to 12VAC/DC, the transformer is not the driver, even though by its nature it restricts current flow.

A **non-integrated** LED lamp or module (LEDni) is an “LED lamp/module which needs separate control circuitry or LED control gear to operate”.

LED luminaires are emerging as a cost effective non-directional and directional lighting solution for domestic and commercial applications.

LED luminaires can replace traditional luminaires (that have lamp holders that potentially allow lamps of different technologies to be used). Purpose-designed LED luminaires provide the opportunity for better optical efficiency due to the removal of the physical size/shape, light distribution, and restrictions of traditional lamp classes (e.g. A19 shape lamp). However, this also means that, for some luminaires, the LED chip is an integral and permanent part of the luminaire (unless in module form) and any improvement in energy efficiency of the luminaire requires the replacement of the entire luminaire, at a higher cost than the replacement of a non-integrated lamp (this would be expected to occur at the end of life, which is typically declared as greater than 25,000 hours of operation). Market research of lamps sold in Australia shows that the average retail price of LEDn luminaires is approximately AUD$39, and for LEDi lamps it is AUD$27. Thus the initial purchase decision for an LED luminaire has more significant and longer lasting operational life implications than a non-integrated lamp.

LED luminaires are penetrating both domestic and non-domestic markets. If there is to be implementation of regulation for LED luminaires, the regulation may need to define an appropriate restriction point for the scope of LED luminaires to be included, due to the fast development of a very wide range of LED alternative products. The key markets that may require protection from low performing products will be those which typically do not engage professional lighting designers. Options include limiting to:

- domestic style LED luminaires only (this would be achieved most effectively by limiting the initial lumen output of products covered);
- common interior commercial and domestic LED luminaires (limited by initial lumen output);
- common (interior and exterior) commercial and domestic LED luminaires (limited by initial lumen output);
- common industrial, (interior and exterior) commercial and domestic LED luminaires (limited by initial lumen output).

4.1 Context

Energy efficiency is widely accepted as a low cost approach to reducing greenhouse gas emissions. Modelling by the International Energy Agency (IEA) shows that as much as half the savings in greenhouse gas emissions required by 2050 can be achieved by adopting energy efficiency measures. Improvements to energy efficiency can also help to reduce demand on electricity supply systems (such as during peak periods) with consequent savings in capacity requirements.

The following benefits arise from use of more energy efficient technology:

- Enhanced economic growth through increased productivity
- Improved energy security by reducing energy demand
- Improved energy affordability by reducing consumer energy costs
- Deferred need for more expensive energy supply by making better use of existing energy resources
- Reduced greenhouse gas emissions from energy consumption.

In Australia, residential lighting energy consumption, per dwelling, was estimated at around 1100 kilowatt-hours (kWh) in 2010. For New Zealand, this was estimated at around 1020 kWh in 2012 (noting that these estimates do contain some weaknesses). In both countries, more than 75% of residential lighting energy consumption is estimated to come from incandescent and halogen lamps (E3 2014B).

Australia was one of the first countries in the world to announce regulations aimed at eliminating inefficient incandescent lamps from its market. This announcement occurred in February 2007 and was followed by the development of a MEPS program for incandescent, halogen and compact fluorescent lamps along with MEPS for low voltage halogen lighting transformers.

The program was implemented in a staged fashion, commencing with an Australian import restriction on tungsten filament incandescent lamps used for general lighting service (GLS; traditional A-shaped (pear shaped) "light bulb") lamps on 1 February 2009. In November 2009 GLS tungsten filament and extra-low voltage halogen non-reflector lamps were subject to the more traditional "point of sale" MEPS in Australia. The scope of MEPS for incandescent and halogen lamps was then broadened regularly until October 2012. CFLs have been subject to MEPS in Australia since November 2009, and in New Zealand from October 2012. The New Zealand Government does not wish to limit consumer choice, and prefers to provide energy efficiency information. For this reason incandescent lamps are likely to remain for sale in New Zealand. However MEPS is supported for products where there is a range of efficiencies and room for improvement, for example, CFLs.

Voluntary ENERGY STAR® labelling for high efficiency CFL and LED lamps is available in New Zealand so that consumers can choose a high performance lamp.

MEPS have been a key mechanism to drive performance improvements for lighting products manufactured in or imported into Australia. To date it is estimated that the phase-out of incandescent light bulbs (along with state based energy efficiency obligations schemes) is saving around 2.6 terawatt-hours (TWh) of electricity each year. This saving is equivalent to the total annual electricity consumption of 150,000 homes. The average household is estimated to be saving 300 kWh and $60 per annum (E3 2014).

It is projected that a revised MEPS for incandescent, halogen and compact fluorescent lamps, by shifting the market from incandescent and halogen lamps to efficient lighting such as compact fluorescent lamps (CFLs) and light emitting diodes (LEDs), could help reduce residential lighting energy use in Australia by approximately 65% by ensuring inefficient lighting is not available on the market.

MEPS for incandescent lamps and CFLs are currently under review, the Incandescent, Halogen and Compact Fluorescent Lamps Product Profile Product Profile (www.energyrating.gov.au/for-industry/consultations/incandescent-halogen-and-compact-fluorescent-lamps-product-profile-consultation/) was released for stakeholder comment in November 2014. That Product Profile discusses the importance of the availability of viable, efficient alternatives for each class of lamp. The timing of the availability of these alternative products will help determine further revision to existing Lighting MEPS. The Incandescent, Halogen and Compact Fluorescent Lamps Product Profile sought stakeholder advice regarding the timing of the availability of these efficient lighting alternatives including LED lighting. An option considered in that product profile was the development of MEPS in Australia to phase out incandescent and halogen lamps and replace with CFL/LED technology, with a staged implementation in different lamp categories as and when LED technology has matured sufficiently. Stakeholders may wish to consider and comment on that option further in the context of this LED product profile.

Available energy efficiency measures include the use of new technologies and processes to reduce energy use in residential, business, industry and manufacturing applications. Further transition to high efficiency lamps would reduce greenhouse gas emissions by up to 2219 kilotonne CO_2-e p.a. for Australia and 966 kilotonne CO_2-e p.a. for New Zealand and therefore the cost of carbon abatement (E3 2014). Improvements to residential lighting have a significant negative abatement cost, at about negative $40 per tonne of CO_2-e (Lewis and Gomer 2008).

Since the commencement of the Australian phase-out of inefficient lighting, the global lighting market has changed considerably, particularly with the introduction of LED lighting, which has the potential to broaden the range of energy efficient lighting options available to consumers and remove the need for inefficient lighting to remain in the market.

Monitoring of LED lighting in the market indicates that technology is developing rapidly, improving in efficacy and light output level and at lower cost. However, testing of a range of LED products available in Australia and overseas has shown significant variation in quality and efficacy, and between claimed and measured performance. In some cases, consumers who choose LED lighting may find they achieve increased efficacy at the cost of light levels, light quality and higher purchase price. In the worst cases even the expected efficacy benefits may not be achieved.

Variations in efficacy and quality across the market and also between claimed and actual performance may lead to consumers purchasing LED lighting products that do not fully realise the potential energy savings that efficient lighting can achieve.

There is a concern that consumer experience of relatively expensive, poor quality LEDs will impact upon their willingness to buy LED products in the future. Negative consumer experience that leads to decreased consumer uptake would reduce the energy savings that could be gained from adoption of this new technology as a replacement for inefficient lighting.

4.2 Product Scope

LED lamps and luminaires included in the scope of this product profile are:

- Integral LED lamps that are considered alternative or replacement lamps for currently regulated domestic lamps (integral compact fluorescent, incandescent and halogen lamps as set out in AS4934.2 and AS/NZSAS4847.2):
  - all shapes
  - nominal wattage ≥ 1 watt (no upper limit)
  - Mains Voltage (MV), caps: E14, E26, E27, B15, B22d, GU10, GX53, GU24
  - Extra Low Voltage (ELV), caps: GU5.3, GU4
- LED linear lamps, including replacements for currently regulated tubular fluorescent lamps.
- LED replacement lamps for other fluorescent lamps currently under consideration for regulation (e.g. circular fluorescent lamps).
- LED luminaires with an integrated LED-based light emitting element other than a replaceable LED lamp (i.e. LED packages, LED arrays, LED light engines) connected to the mains supply
  - Includes integrated downlights, suspended and surface mounted, recessed, panels, battens, high-bay and low-bay LED luminaires
  - All shapes
  - Nominal initial lumen output
    - If domestic products only ≥ 30 lumens and ≤ 3000 lumens (equates to an incandescent range of approximately 5W to 149W)
    - All applications (except high-bay and low-bay and street lights) ≥ 30 lumens and ≤ 10000 lumens
    - High-bay and low-bay – no limits

Colour: all colour temperatures. ‘Coloured’ lamps not intended for general lighting excluded. Scope would need to define this exclusion and also specify how colour adjustable lamps would be tested and evaluated against MEPS (may need to state efficacy at more than one colour temperature).

Exclusions:

- lamps having the following chromaticity coordinates x and y:
  - $x < 0.200$ or $x > 0.600$
  - $y < -2.3172 x^2 + 2.3653 x - 0.2800$ or
  - $y > -2.3172 x^2 + 2.3653 x - 0.1000$
- lamps having:
  - 6% or more of total radiation of the range 250-780 nm in the range of 250-400 nm (UVA),
  - The peak of the radiation between 315-400 nm (UVB)[3]

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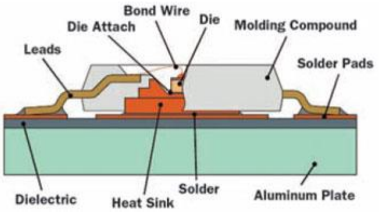
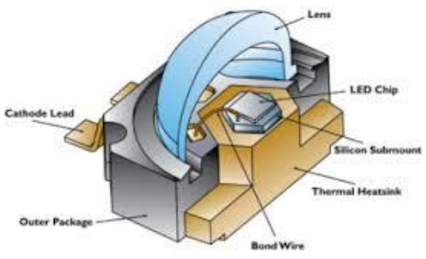
[3] Based on EC244/2009. This provides scope for white light (all possible CCT) along black-body locus. This excludes ‘colour’ lamps but provides a very wide acceptance band (far beyond the ANSI quadrangles that are used for binning). UVA/UVB lamps excluded for medical reasons.

- linear strip/rope;
- Road lighting fixtures (included in the current review of AS/NZS1158 Lighting for roads and public spaces series)
- Note: a threshold minimum wattage is recommended so as to not include novelty/decorative lights not intended for general lighting applications.

The definitions for each type of luminaire within the scope will have to be carefully worded so as to not be ambiguous and include luminaires not intended for possible MEPS regulation. Support/input from industry will be required to make these definitions clear. Where possible, definitions should align to available international standards.

Table 2. LED Components and Concepts

LED Heat sink	A part of the thermal system that conducts or convects heat away from sensitive components, such as LED dies and electronics.
LED Die (or Chip)	A small block of light-emitting semiconducting material on which a functional LED circuit is fabricated.
LED Package   	A single discrete component encapsulating one or more LED die(s), possibly with optical elements and thermal, mechanical and electrical interfaces. Power source and standardised bases (per IEC 62560) and are not incorporated into the device. The device cannot be connected directly to the branch circuit.

LED Array or Module  	LED light source having no cap, incorporating one or more LED package(s) on a printed circuit board, and possibly including one or more of the following: electrical, optical, mechanical and thermal components, interfaces and control gear. A power source and ANSI standard base are not incorporated into the device. The device cannot be connected directly to the branch circuit. Built-in LED modules are generally designed to form a replaceable part to be built into a luminaire, a box, an enclosure or the like and not intended to be mounted outside a luminaire, etc. without special precautions.
LED 'Circuit On Board' COB 	LED arrays constructed as an assembly of LED dies on a printed circuit board (PCB)
LED Control Gear 	Electronic components designed to control a power source by adjusting output voltage, current or duty cycle to switch or otherwise control the amount and characteristics of the electrical energy delivered to a LED package (component) or an LED array (module). LED control circuitry does not include a power source.
LED Light Engine 	An integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed and does not use an ANSI standard base.

LED Driver 	A device comprised of a power source and LED control circuitry designed to operate a LED package (component), or an LED array (module) or an LED lamp.
LED Lamp integrated (LEDi Lamp, self-ballasted LED lamp)  	LED lamp, incorporating LED control gear, and any additional elements necessary for stable operation of the light source, designed for direct connection to the supply voltage.
Retrofit LED lamp	LED lamp intended as a replacement for a non-LED lamp without requiring internal modification of the luminaire.
LED Lamp (non-integrated) 	An assembly comprised of an LED array (module) or LED packages (components) and ANSI standard base. The device is intended to connect to the LED driver of an LED luminaire through an ANSI standard lamp-holder (socket). The device cannot be connected directly to the branch circuit. This may include LED replacement lamps for low voltage halogen lamps.
Semi-integrated LED lamp (LEDsi, semi-self-ballasted LED lamp) 	LED lamp which carries the control unit of the LED control gear, and is operated by the separated power supply of the control gear. This may include LED replacement lamps for low voltage halogen lamps.

LED Luminaire  	A complete lighting unit consisting of LED-based light emitting elements and a matched driver together with parts to distribute light, to position and protect the light emitting elements, and to connect the unit to a branch circuit. The LED based light emitting elements may take the form of LED packages (components), LED arrays (modules), LED Light Engine, or LED lamps (including panels). The LED luminaire is intended to connect directly to a branch circuit. Some luminaires may be non-repairable, factory-sealed LED luminaires which cannot be dismantled without being permanently damaged.

4.3 Omnidirectional and Directional LED Lamps

Unlike an incandescent filament or the tube of a compact fluorescent lamp, an LED is an inherently directional light source. However, with individual optics and arrangement in arrays, LEDs can be made to approximate the broader light distribution of an incandescent or CFL A-shaped omni-directional lamp. The problem with many of the A-shape LED bulbs that have emerged on the market is they do not necessarily provide any light beyond a 180° hemisphere, some even less; others throw the majority of light outward in an orthogonal direction to the nadir/zenith axis (Figure 2). So despite these lamps being designed to look like a traditional incandescent bulb, their light output distribution is very different, and in some applications will be quite inappropriate for a direct retrofit into existing fittings or lamp shades.

Figure 2. Reflector lamp with GX53 cap. These are 'reflector' shape with GX53 cap, informally known as a 'puck' light (creative commons; sourced from http://leds.beleuchtung-mit-led.de/led-gx53-lamp)

Figure 3.A shape LED lamp a GU24 cap. This cap is being used in 110V-240V systems. (creative commons. Sourced from www.halcolighting.com/index.jsp?path=product&part=7534&ds=dept&process=search&ID=,Lamps,LED,A.Shape&prev=find)

Figure 4.'Omnidirectional' LED lamp. (Licensed image. http://en.wikipedia.org/wiki/File:LED_bulbs_2012.jpg)

Without a reasonable definition for an 'omnidirectional' lamp included as part of a standard, it could be permissible to have an A-shape LED lamp be marketed as an incandescent retrofit lamp, yet to have the lamp emit zero direct light into zones expected for an omnidirectional lamp. For example, a lamp with incomplete light distribution may fail to emit light below the bottom of a table lamp light shade, which happens to be where the bulk of the illumination is supposed to be provided by the luminaire. This issue provides a reason for a clear definition of an omnidirectional lamp.

Definitions for directional, non-directional and omnidirectional LEDi lamps vary between international organisations, to allow for different efficacy requirements (e.g. US Energy Star, Europe, IEA 4E SSL). For this Product Profile the following definitions of LEDi lamp classifications are proposed (modified from CIE S 025 and IEA 4E SSL):

- Directional LEDi lamp – 50% of flux shall be in declared beam angle which is ≤ 120˚.
- Non-directional LEDi lamp – those lamps which are not directional lamps.
- Omnidirectional LEDi lamp (for A-shape incandescent lamp equivalence claim) – Products shall have an even distribution of luminous intensity within the 0° to 135° zone (symmetrical about the vertical axis). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux must be emitted in the 135° - 180° zone. Distribution shall be vertically symmetric in three vertical planes, 0°, 45°, 90°.

4.4 Linear LED lamps - Equivalency

LED linear lamp replacements for tubular fluorescent lamps have become very popular recently with many brands now available. These are designed to replace the T8 (T26 in metric) fluorescent lamps as there is currently limited (or no energy) saving potential in replacing T5 fluorescent lamps.

There is also a more recent trend in LED circular lamp replacements for circular fluorescent lamps.

The actual method of retrofit varies between products and two main features are critical points for discussion. As a retrofit lamp, the expectation is that the LED replacement lamp will provide the same luminous flux output and luminous intensity distribution from the fixture as the replaced fluorescent lamp. In addition, the electrical configuration is expected to remain the same (i.e. the ballast) or will be modified such as not to provide an electrical hazard (particularly if the previous lamp technology is returned at a later date). These issues apply to both the linear and the circular LED replacement lamps.

Most currently available linear LED lamps generally do not have the same 360˚ intensity distribution about the centre line of the tube as linear fluorescent lamps do – instead they emit light in a hemisphere (180˚) or less (e.g. 120˚). Therefore, a linear fluorescent lamp luminaire that has optical elements, particularly in the back of the fixture (such as reflectors for direct lighting or refractors for indirect lighting applications), to produce a specific intensity distribution will not have the same or even similar distribution once the LED lamp is installed. This may impact upon lighting quality or illumination levels in; for example, office space and retail premises; in which case, areas which are subject to illuminance, glare and uniformity design standards (i.e. AS/NZS 1680) would be required to provide a new assessment of compliance.

In order to make consumers aware of the potential variation in light distribution between the linear LED and fluorescent lamps it is proposed that there be a differentiation. For the purposes of this Product Profile, a retrofit linear LED lamp will be defined as having "omnidirectional distribution with even luminous intensity distribution 360° around the lamp" (IEA 4E SSL (www.ssl.iea-4e.org/task-1-quality-assurance))in order to claim equivalence to a linear fluorescent lamp.

LED linear lamps not meeting this definition may still provide an acceptable lighting service in non-retrofit situations provided the more limited light distribution is taken into account in the selection of luminaires and the lighting design.

While safety issues are not the responsibility of the Equipment Energy Efficiency program, it should be noted that there have been electrical safety concerns in relation to the design of some LED fluorescent replacement products and that these have been the subject of a safety information bulletin issued by Electrical Regulatory Authority Council (ERAC).

If the luminaire has been modified then the Electrical Regulatory Authorities Council recommends that the luminaire should be marked with a warning label that is visible whilst replacing lamps. This warning label should be legible and indelible and show the intent of: *'Warning - not for use with any fluorescent lamps, use only <Brand><Model Number><Type> Lamp'*.

4.5 LED Performance and Known Quality Issues for LED products

Currently LED lamps have a higher initial cost that is expected to be paid back via lower energy consumption and lower cost replacement and maintenance schedules over a longer life. Good quality LED lamps currently equal or exceed the efficacy of CFLs, and the point source nature of LED light make them more suitable for directional lighting. Testing in Australia and New Zealand and overseas shows that LED products continue to improve in terms of light output, efficacy and compatibility, while rapidly reducing in price. However there have also been a number of quality and performance issues identified with LED lighting.

This section examines some of the known challenges with LED lighting. It should be noted however that these issues relate to some, not all LED products available in the market place.

4.5.1 Light Output and Efficacy

Testing of LED products available in the market has shown significant improvements in efficacy over the last few years as indicated in Figure 5, Omnidirectional product purchased for testing provided lumen output equivalent to 20W and 40W incandescent omnidirectional lamps, with equivalent products also emerging in 60W and higher categories. Directional LED products tested also offered equivalency to standard 35W halogen MR16 lamps for ≤ 63.5 mm (see Figure 6) and equivalency to tungsten filament PAR lamps > 63.5 mm (see Figure 7). There are currently few small profile directional LED lamps that can offer a similar lumen package to 50W and 35W IRC lamps. Many LED lamps sold as replacements for 50W and 35W IRC lamps generally have an extended physical profile which may not fit in some existing fixtures.

Similarly, testing by the U.S. Department of Energy (DOE) CALiPER program concluded that in the US market there are now very good LED options to compete with 60 W, 75 W, and 100 W incandescent GLS lamps, and 75 W halogen PAR30 lamps (US DOE Feb 2014). While CALiPER testing found that MR16 replacement lamps have shown less progress, acceptable alternatives were available for 35 W, 12 V halogen MR16 lamps and 50 W, 120 V halogen MR16 lamps for some applications while other uses, such as in enclosed luminaires, may require more development.

In addition recent assessment of products sold in the European market has shown that there has been a rapid improvement in light output and efficacy, and significant drops in cost per lumens, exceeding previous predictions (Bennich et al 2015).

In contrast, at the other end of the performance scale, this testing indicates that even some recently purchased products would not meet the minimum efficacy requirements currently applied to CFLs under MEPS. This is demonstrated in Figure 5 where several lamps, including some purchased as recently as 2014, fall under the Australian/New Zealand CFL MEPS efficacy curve.

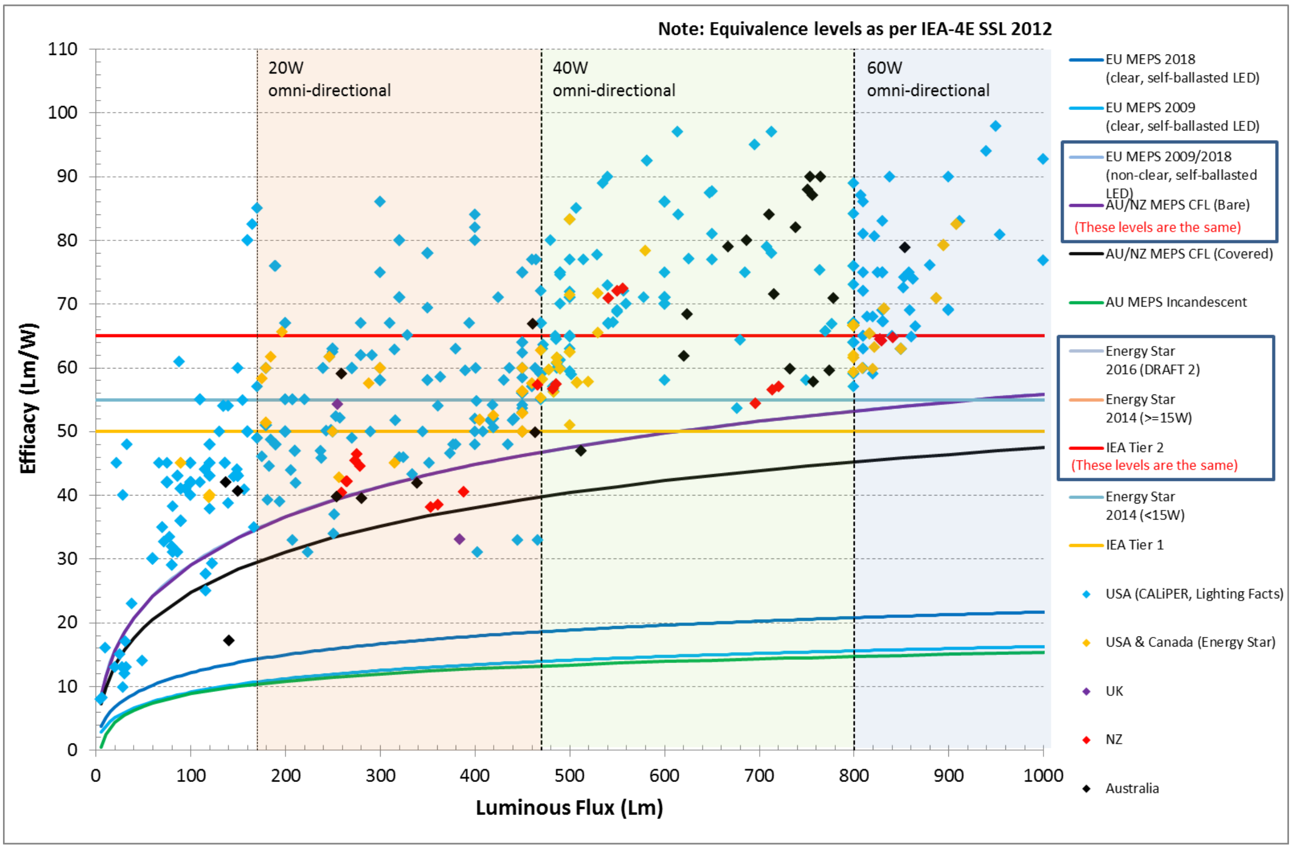


Figure 5. Lamp Performance (luminous Flux and Efficacy) of Omnidirectional Purchased in Australia 2009-2014. Equivalence levels as per IEA 4ESSL 2012.

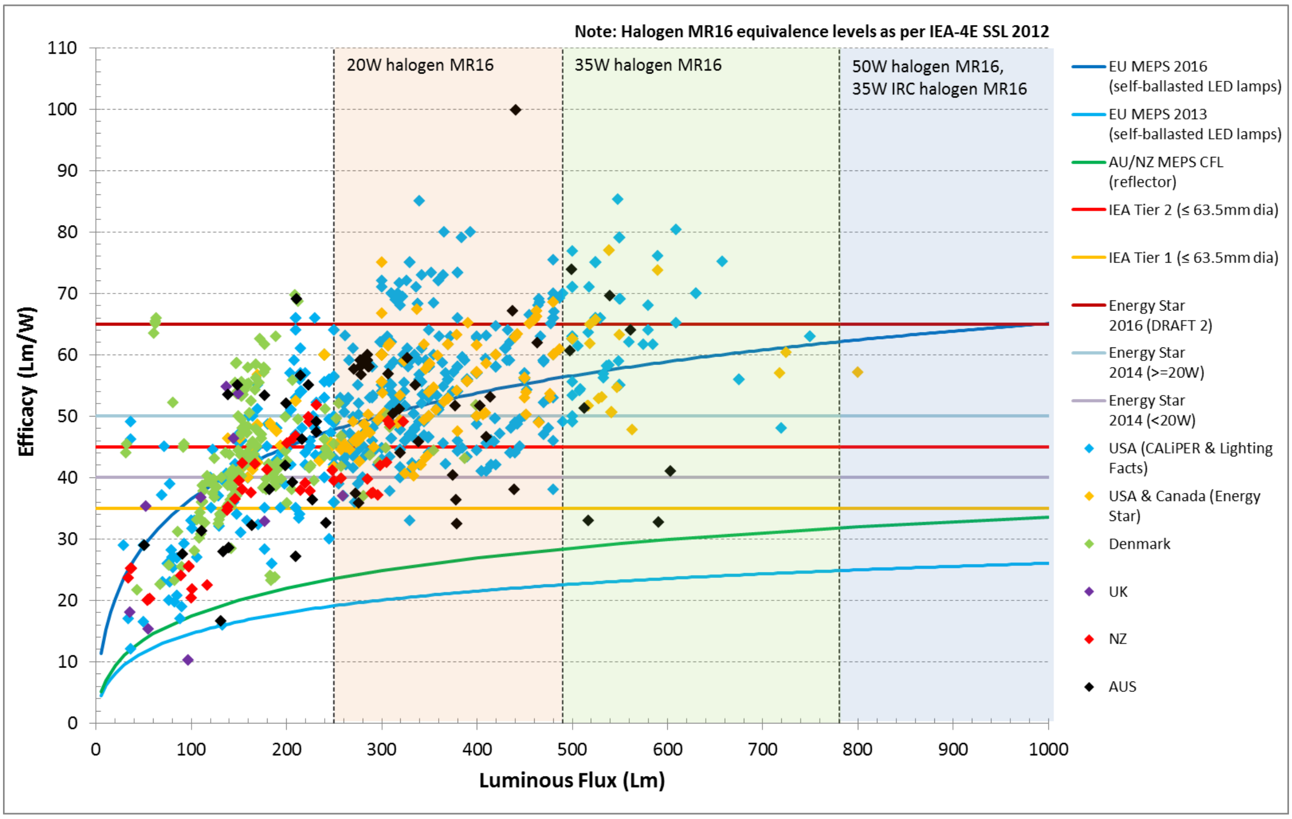


Figure 6.Lamp Performance (luminous Flux and Efficacy) of Directional lamps of diameter ≤ 63.5mm tested internationally between 2010 and 2014.

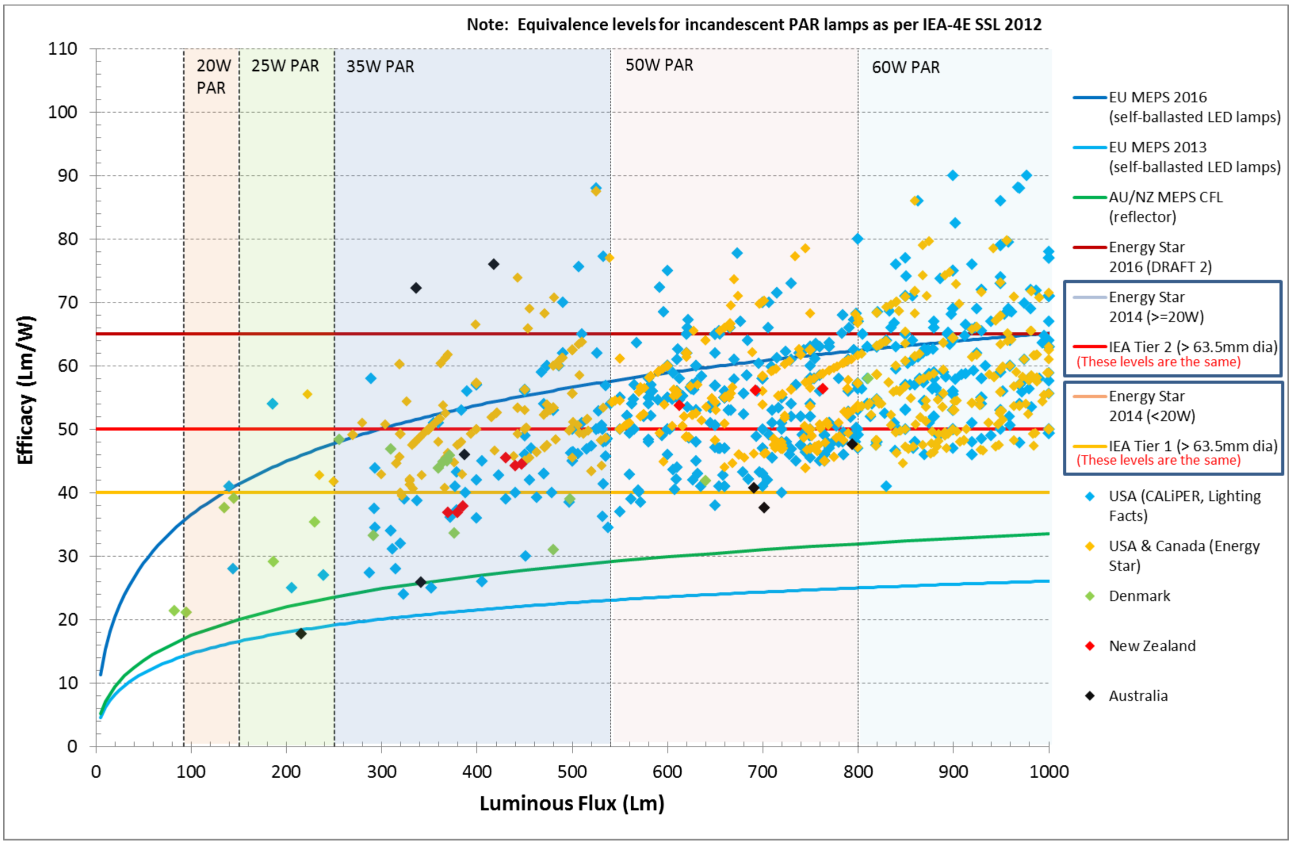


Figure 7.Lamp Performance (luminous Flux and Efficacy) of Directional lamps of diameter >63.5mm tested internationally between 2010 and 2014.

In terms of linear LED lamps, less testing has been conducted to date. Anecdotally it is understood that in previous years some linear LED products claiming to be more efficient than linear fluorescent lamps have actually been less efficient or comparable, resulting in commercial office retrofits that did little to save energy. Four models purchased in 2014 exceeded the Australian and New Zealand linear fluorescent MEPS efficacy level and met or exceeded the more recent EU T5 MEPS (Figure 8). Measurement of luminous flux and efficacy does not however take into account possible loss of light output and appropriate light distribution when retrofitted into existing fluorescent luminaires, as outlined in the section above on equivalency. In louvered (low brightness) style luminaires, the directional linear LED light can offer significant advantages in comparison to linear fluorescent lamps. Linear fluorescent luminaires which provide more non-directional lighting will not perform well when retrofitted with typical directional linear LED.

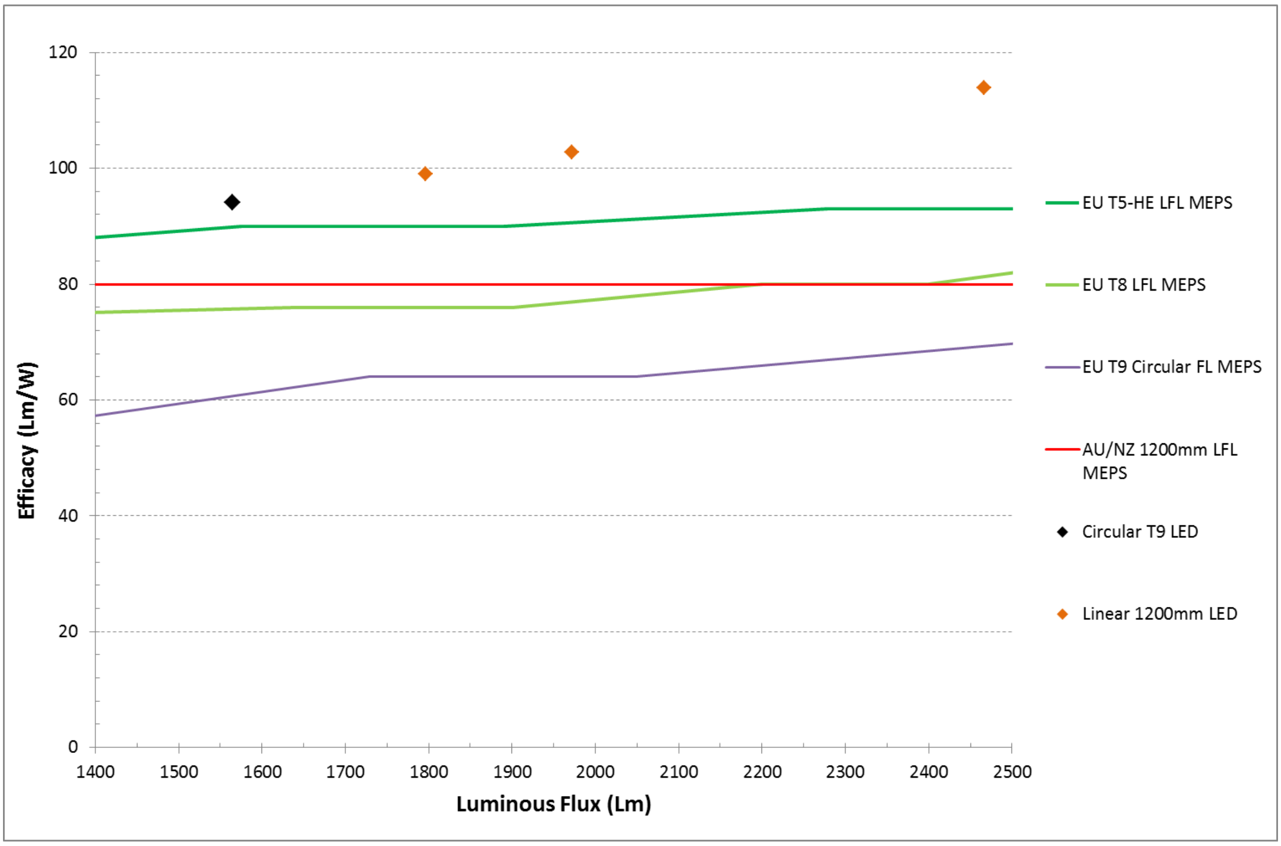


Figure 8. LED Replacement Lamp Performance against Fluorescent Lamp MEPS (Lamps Purchased in Australia and New Zealand 2014)

While LED lighting already equals or exceeds the efficacy of other technologies in many applications, there is potential for continued improvement in LED efficacy, and therefore further energy savings opportunities. Currently commercial LED packages can achieve around 200 lm/W, although this is reduced significantly when incorporated into lamps and luminaires. Research by the US National Institute of Standards and Technology has indicated that the LED emission spectra with good colour quality and LER could theoretically achieve values in the range of 350 to 450 lm/W, with the estimated practical achievable efficacy for LED packages at closer to 250 lm/W with further research (US DOE 2015). This indicates that in addition to the current opportunities in addressing the range of less efficient LED lighting, there will also be significant opportunities to continue to drive the uptake of progressively more efficient LED lighting as these become available on the market.

4.5.2 Power Consumption

Test results of power (Watts) have also shown some significant variations from rated wattage with variations of 20-50% in products tested in 2013 and 2014 as shown in Figure 9. Incorrect reporting of power use prevents consumers from accurately comparing products in terms of energy use and efficacy.

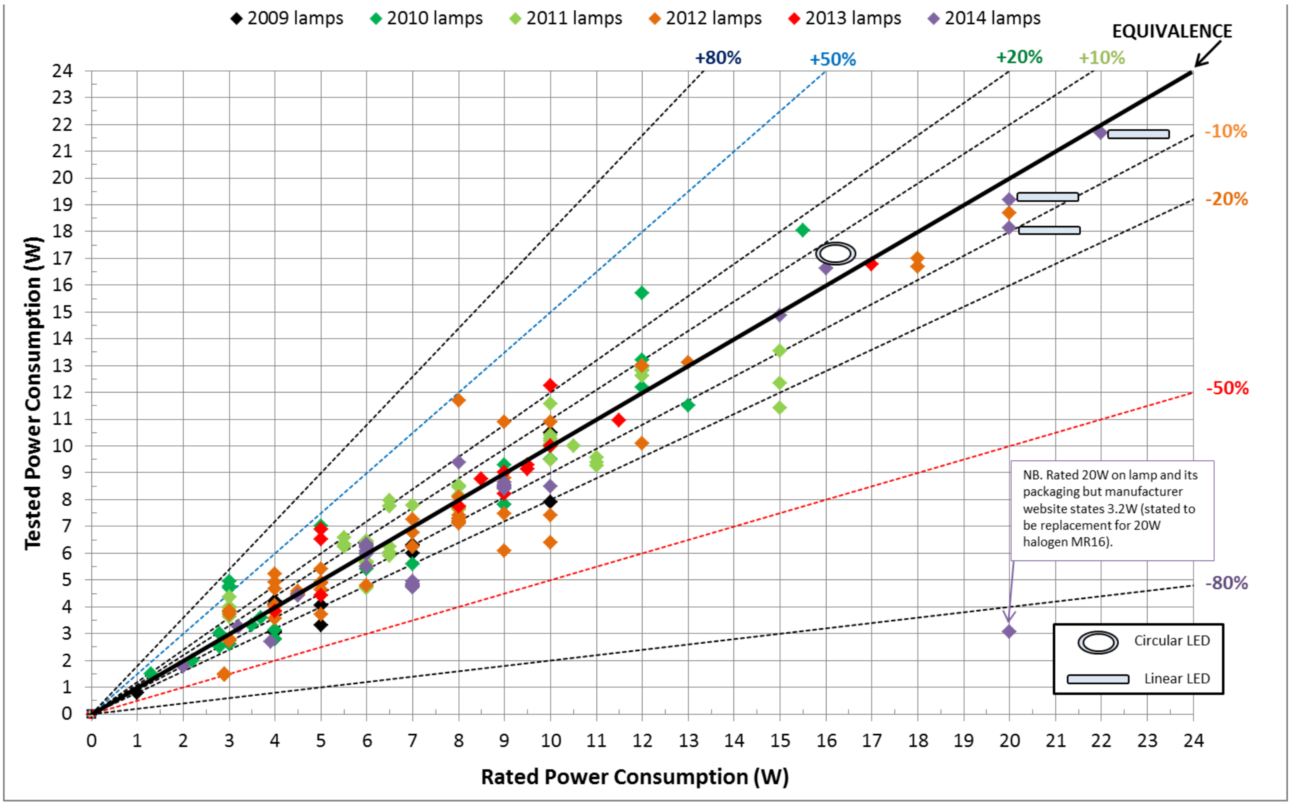


Figure 9. LED Power Consumption – Variation between Rated and Test Values.

4.5.3 Lamp Cost

While the cost of LED lighting is still significantly higher than halogen or even CFL products, this cost has reduced rapidly over the last several years (Figure 10). As shown in Figure 11, of the products tested, the cost per 100 lumens of light output has reduced from $33 in 2009 to $7 in 2014. Note that the 2014 value excludes multiple lamps of the same brand/model and the smart lamps also tested. The higher cost of efficient lighting such as CFL and LEDs can be expected to be recovered through savings over the life of the lamp, which is expected to be significantly longer than incandescent lamps. This is a particular attraction for commercial and other applications where lamps are left on for long durations and maintenance costs are actively taken into account in evaluation of overall lighting costs. However significant differences in purchase prices may pose a barrier to uptake, particularly in lower income sectors of the community.

One possible issue with decreasing costs suggested by the US Department of Energy (US DOE 2015) is that product quality could become a concern as a result of decreasing cost. As thermal management materials, such as aluminium heat sinks are reduced or eliminated to save cost, the efficiency, lifetime, and colour shift of LED lamps may be impacted. In cases where fewer LEDs are used in order to reduce costs, each individual LED component may be driven harder, impacting on colour shift, lifetime, and efficiency. Lower cost assembly techniques may also lead to a compromise in quality and an increased early failure rate. The US DOE notes that it is important that the drive for lower first cost does not cause performance or lifetime deficiencies or it will reduce consumer confidence in LED technology, reduce adoption, and limit the total energy saved.

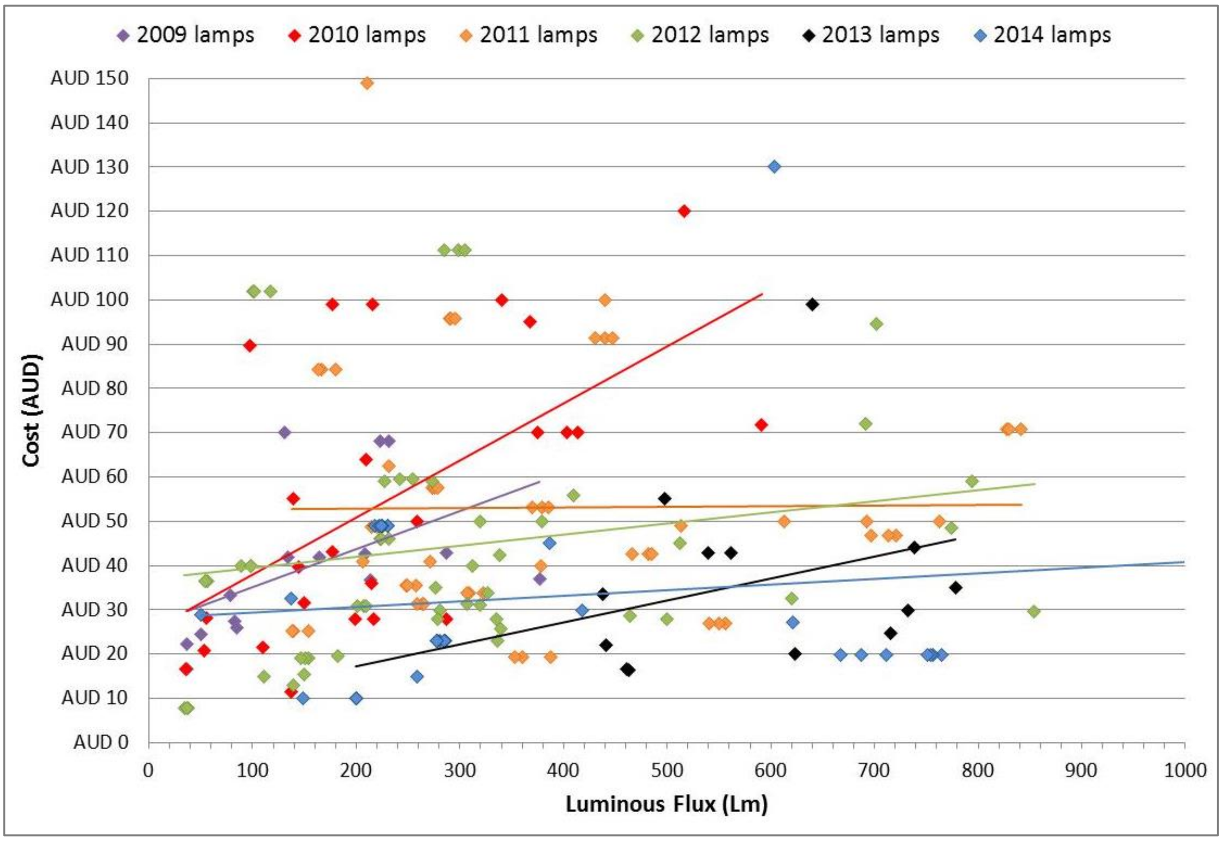


Figure 10.Normalised purchase price of LED Lamps as a function of Luminous Flux output (lamps purchased in Australia, New Zealand, United Kingdom, United States 2009-2014)

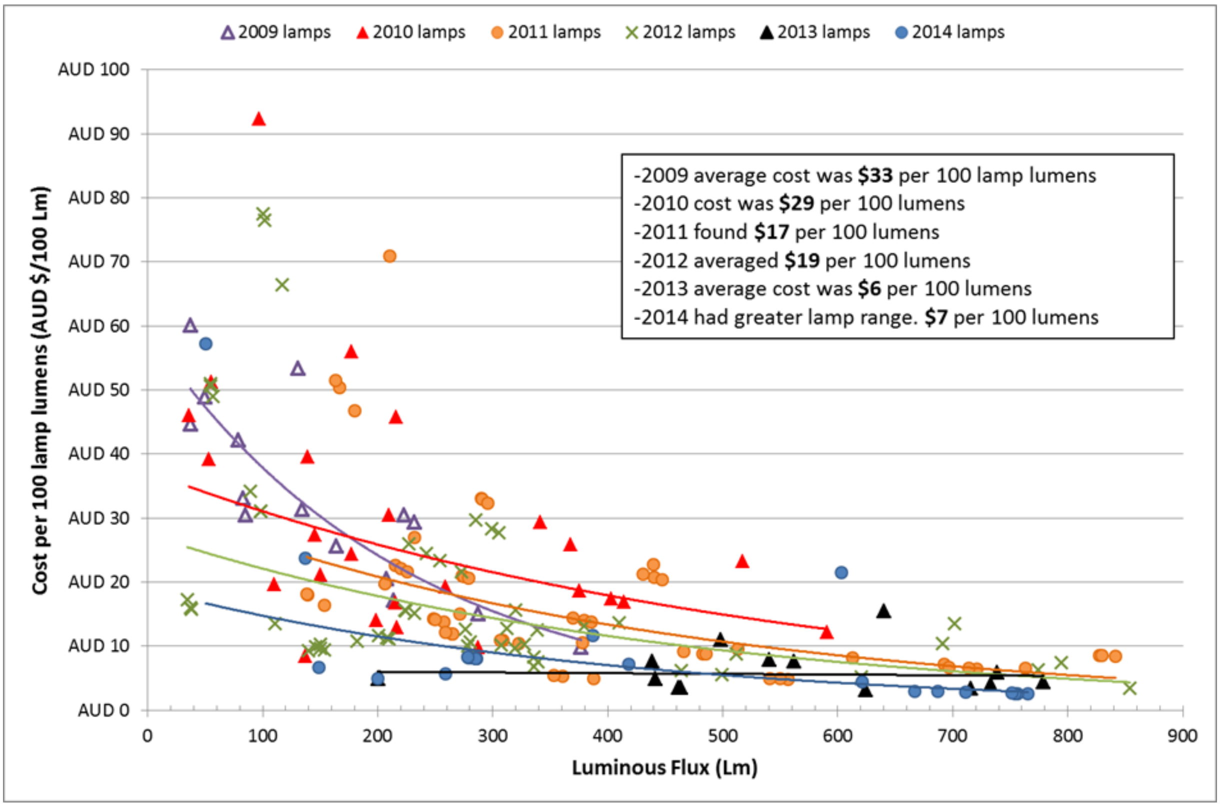


Figure 11.LED Lamp normalised cost per 100 Lumens (lamps purchased in Australia, New Zealand, United Kingdom and United States 2009-2014)

4.5.4 Claims of Equivalency

Acceptable light output levels are of the highest importance for safe working and living conditions. As with compact fluorescent lighting, currently most LEDi lamps are intended to replace other lighting technology such as tungsten filament and incandescent lighting. In order for consumers to correctly select a replacement lamp, they must be able to accurately compare the performance of the LEDi lamp with the lamp to be replaced. This may be based on a comparison between the performance information on the LEDi packaging (or perhaps supplier website), with what the consumer knows about the performance of the lamp to be replaced (this knowledge may be incomplete and often limited to the wattage of the lamp); or based on specific claims of equivalency on the LEDi packaging.

Testing of LEDi lamps selected from the Australian and New Zealand market indicates there are, for some products, significant variations between claimed performance and test results including in some cases:

- tested lumen output found to be close to half the rated value;
- inaccurate claims of equivalency to light output of other lamps.

The 2014 US DOE CALiPER study also found that of the lamps tested, 43% of tested products failed to completely meet their equivalency claim and 20% of products failed to match the manufacturer's performance data.

Figure 12 shows the difference between claimed efficacy (based on claimed luminous flux and wattage) and tested efficacy from products purchased between 2009 and 2014. While in recent years of testing the difference between claim and tested values has lessened (and in some cases indicated under claims), a revised approach to product sampling in 2014 (to capture a broader range of product quality) has shown that over claiming products are still in the market. Many of the differences between claimed and tested luminous flux are so significant as to potentially guide consumers to purchase lamps that would not provide equivalent light output in comparison to incandescent lamps that they may be intended to replace, thus resulting in consumer disappointment and loss of confidence in LED products. For example, an LED omnidirectional lamp rated at 600lm could be expected to provide a similar level of light output as a 40W tungsten filament lamp. When six samples of one such lamp was purchased and tested in 2014, the samples were consistently found to have a light output of less than 300 lm, which is towards the lower end of the light output that could be expected of a 25W tungsten filament lamp.

Anecdotally we understand that some over claims of luminous flux levels (and thus efficacy) may result from LEDi packaging performance information being derived from original bench test reports of the luminous flux of the LED die contained in the lamp. This is unlikely to be accurate as it does not take into account performance constraints imposed by other components of the LEDi such as the electronics, heat sink or reflector.

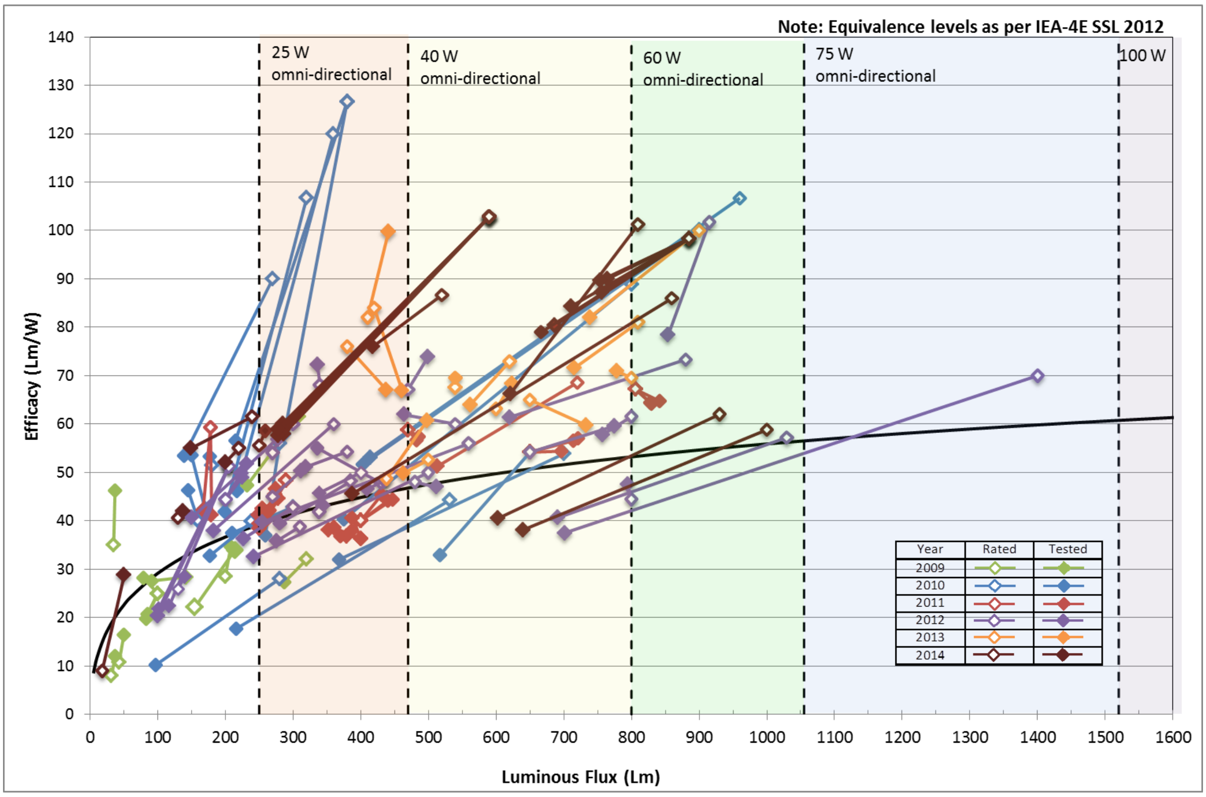


Figure 12.Variance Between Rated and Tested LED Lamp Efficacy (lamps Purchased in Australia 2009-2014)

Fewer linear LED lamps have been tested. Figure 13 shows that rated claims for these products are if anything, under-claims, with the four products purchased in 2014 found to have higher than rated efficacy levels.

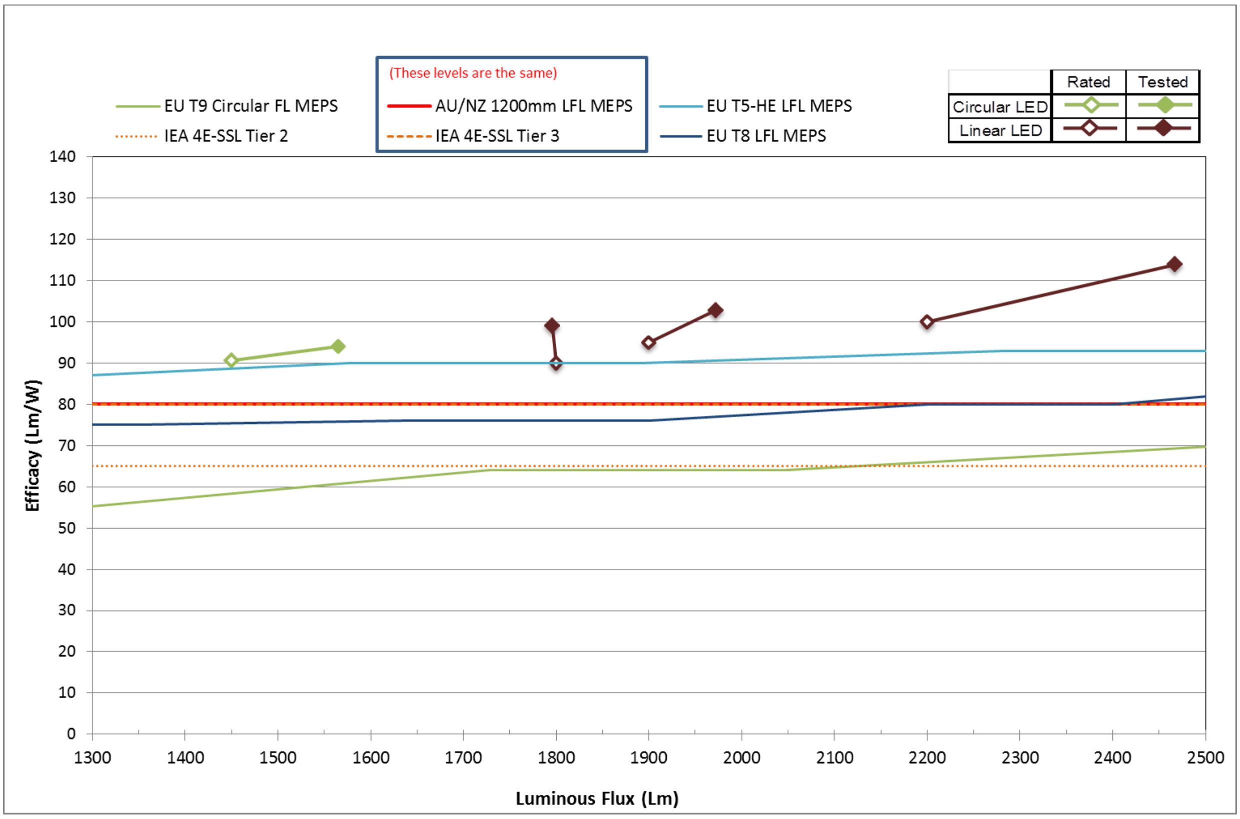


Figure 13.Variance between Rated and Tested Efficacy of Tubular Fluorescent Replacement LED Lamps

4.5.5 Lumen Depreciation

For all LED devices, the lumen output slowly depreciates over time. High lumen maintenance over time helps to justify the higher initial cost of SSL lighting products. The point in time when lumen output depreciates to 70% of the initial lumen output is, for general lighting, defined as the end of the useful life of an LED. The design and quality of production can influence the rate of lumen depreciation due to the degradation of the phosphor, chip and other components. High operating temperatures, either due to failure to conduct heat away from sensitive components, or a high temperature operating environment may contribute to lumen depreciation. Rapid lumen depreciation will result in shortening of the useful life of the LED device. This may be particularly relevant to the use of LED lighting in high temperature areas, particularly hot climates, or lamps installed in luminaires recessed into ceiling cavities, and in enclosed fittings.

Recent US DOE testing (US DOE Dec 2014) of 17 LED lamps at a continuous 45° for more than 7,500 hours, (Figure 14) resulted in two products at the end of the test with average lumen maintenance below 65%, constituting a failure within the test period. In nearly half of the products tested, the lumen maintenance was sufficiently low at 6,000 hours to indicate that a further seven of the products were unlikely to have lumen maintenance above 70% at their rated lifetime (which was usually 25,000 hours).In contrast, three lamps remained above 99% of initial output for the duration of the study period.

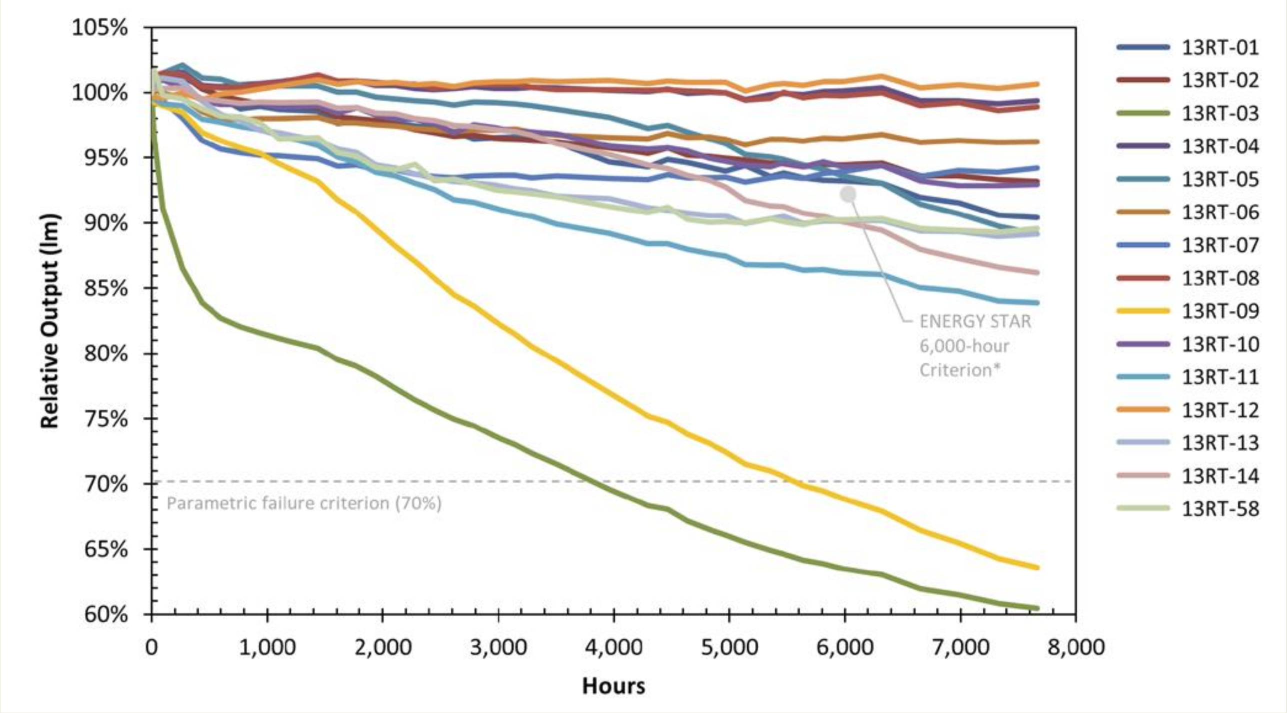


*Figure 14.Average lumen maintenance for each of the 15 LED lamp models tested for CALiPER (US DOE Dec 2014). *The ENERGY STAR criterion shown is for lamps with a 25,000-hour rated lifetime; the criterion is higher for longer rated lifetimes.*

4.5.6 Lamp Failures and Lifetime

Imperfections and defects in the structure of the LED chip may result in early catastrophic failures (the LED chip stops working). Higher operating temperatures, a high drive current or the junction temperature of the LED die, may accelerate the appearance of such defects leading to failure. Initially LED products may experience defects with rapid failures, then a long period with a low failure rate, followed by an increase in failure rate as the products wear out. The use of multiple LED packages within a lamp may mean that each LED chip may fail at a different time, thus resulting in a decrease in the overall lumen output, and changes to light distribution.

Lifetime for lamps is usually defined as the amount of time that it takes for 50% of a statistically significant sample to fail. As discussed above, end of life includes lumen depreciation below 70%. Measurement of lamp lifetime is usually the longest product test for any lamp technology (for example the 6,000 hour lifetime test for CFL MEPS takes 9.5 months) and the very long lifetime claims for LED products makes full lifetime testing impractical in terms of rated values of individual models, product registration or compliance testing. This is particularly the case at present given the rapid release of new models onto the market.

However, having a reliable, but expedited approach to lifetime testing is very important, as LED lighting products must have longer lifetimes to justify the high initial cost of LED lighting. If SSL products are able to meet their lifetime claims, they can cut long-term energy consumption and save the consumer money, however if claims are not met, some or all of the potential savings will not be achieved and consumers may be reluctant to invest in further LED products.

While a number of different metrics are used to characterise lifetime of LED products in some countries, there is currently no internationally agreed test method. International standards bodies such as the IEC are still working on this issue. The IEA 4ESSL Annex is currently preparing an overview report for governments to provide advice on the proper characterisation of product lifetime, and which metrics and test methods are best to use for accurately describing and quantifying the lifetime performance of SSL products.

4.5.7 Correlated Colour Temperature and Colour Stability

Correlated colour temperature (CCT) is stated in Kelvin (K). Colour temperatures over 5,000K are described as cool (bluish), while lower colour temperatures (2,700–3,000 K) are described as warm (yellowish to red). For white light sources that correspond somewhat closely to the radiation colour of a black body radiator (such as the Sun) at various temperatures (called the Planckian locus), a correlated colour temperature can be assigned.

The metric is usually described for consumers in terms such as 'warm-white' or 'daylight'. This helps consumers to select the appropriate product depending on their colour temperature preference and also helps to match colour temperature across different manufacturers' lighting products. This way, when different manufacturers' lamps are used in the same space there is not an unintended mix of cool- white lighting with warm-white lighting. Thus, as with CFL lamps, the accuracy and consistency of the packaging description is important for consumer satisfaction and confidence.

LED lighting may also experience a shift in colour over time. This may have implications in cases where multiple lamps are in use and a divergence of lamp colour may be experienced, which might also be picked up when additional or replacement lamps are added. The US DOE CALiPER testing (US DOE Dec 2014) found three of 17 lamps tested exhibited substantial colour shift over the 7,500 hour test.

4.5.8 Chromacity Tolerance

Chromaticity Tolerance (Du'v') specifies the allowable deviation in the lamp's colour. This criterion is important to ensure that the light from an LED product does not have an unacceptable pink or green tint. Chromaticity measurement of LED lamps gives an indication of how closely the output corresponds with the Planckian locus. Light sources that have a spectrum that places them above the Planckian locus will appear more green or yellow (not enough blue or red content in their spectrum); those that are below this line will appear pinkish (not enough green wavelength content). Figure 15shows the chromaticity values of LED lighting products purchased between 2009 and 2014, and their relation to the Planckian locus or black body curve and the tolerance quadrangles for colour specifications recommended in ANSI C78.377 - 2008. In the earlier years, 2009-2010, LED light sources were not satisfactorily recreating white light that resembled that of a black body radiator - the majority of the warmer colour temperature lamps had a greenish yellow appearance, and the cooler colour temperature lamps produced a straight greenish appearance. From 2012-2014, a significant improvement is recorded.

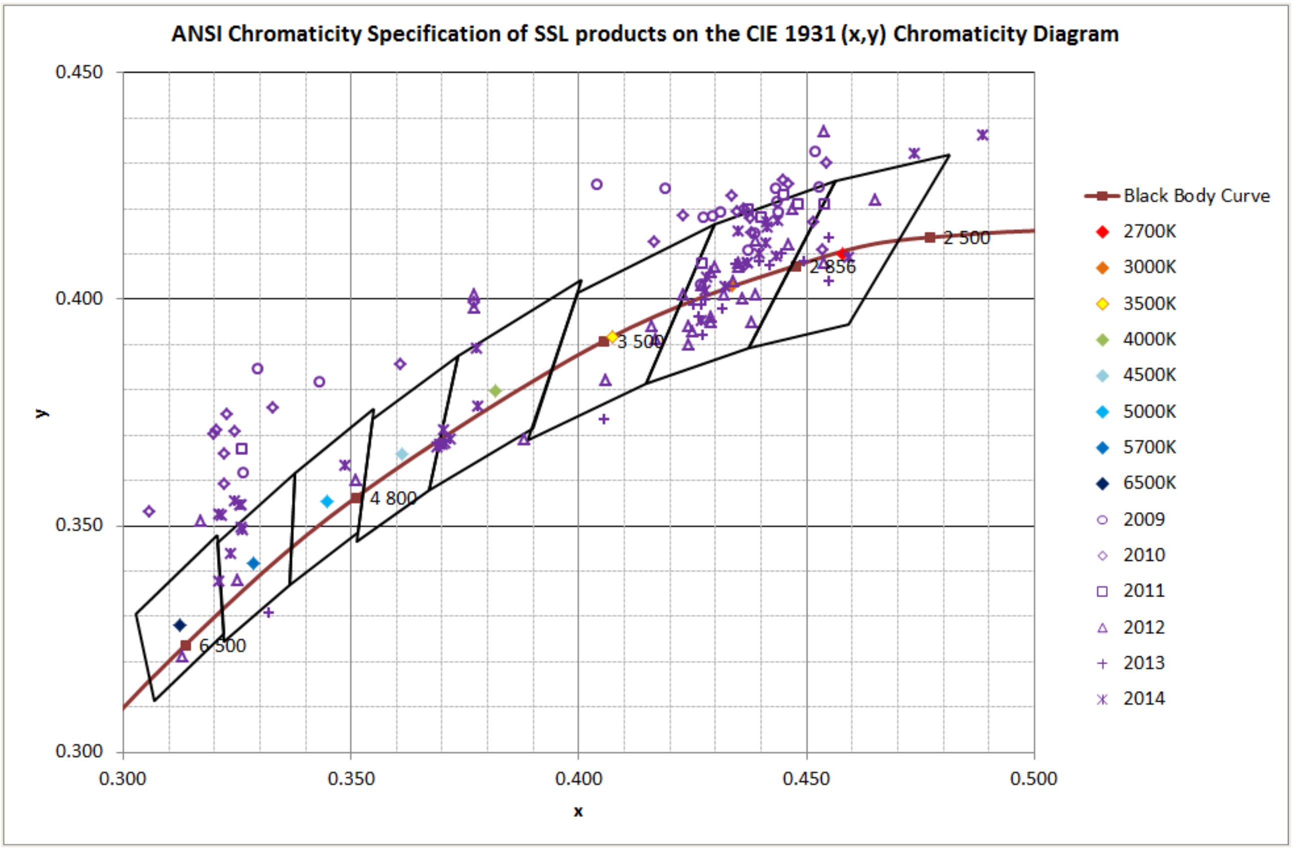


Figure 15.Chromaticity of LED lamps tested by Australian Government 2009-2014.

However as shown in Figure 16, testing of individual lamps purchased in 2014 in the Australian market indicates that some LEDi lamps still exceeded the chromaticity tolerance specification (ANSI C78.377 – 2008). Further analysis of this testing is available in Appendix A.

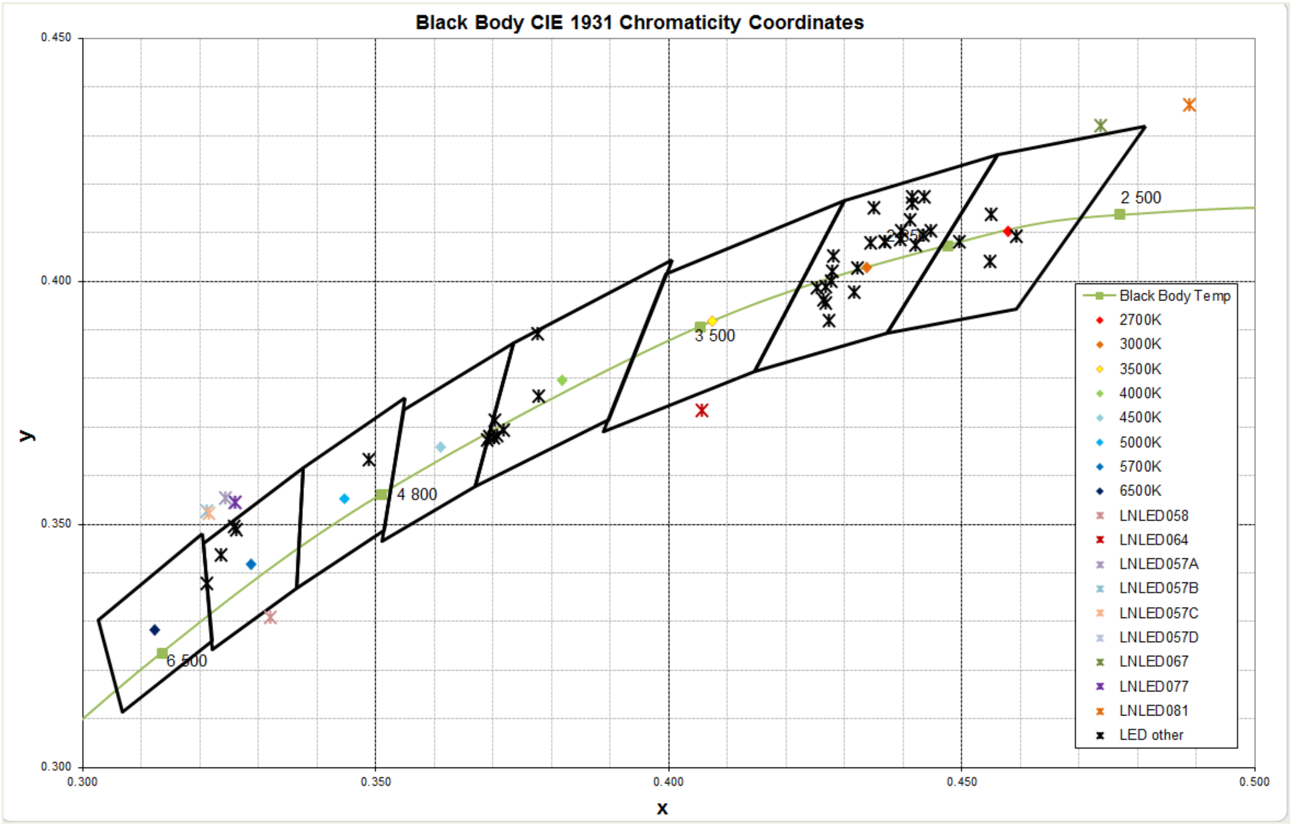


Figure 16.Mapping of Chromaticity Tolerance for lamps purchased in Australia (2014). Those lamps shown outside of the black boundaries may display a noticeable green or pink tint.

Compliance with this criterion is also important to ensure that all lamps and luminaires of the same claimed colour temperature appear to be the same colour when installed – if a purchaser wishes to replace an old compact fluorescent lamp which they know to be a 2700 K lamp, and the LED lamp packaging states that it is a Warm White lamp with colour temperature of 2700 K, if this claim is proven untrue the purchaser is likely to be dissatisfied with their purchase. Figure 17shows the difference between tested and rated colour temperatures.

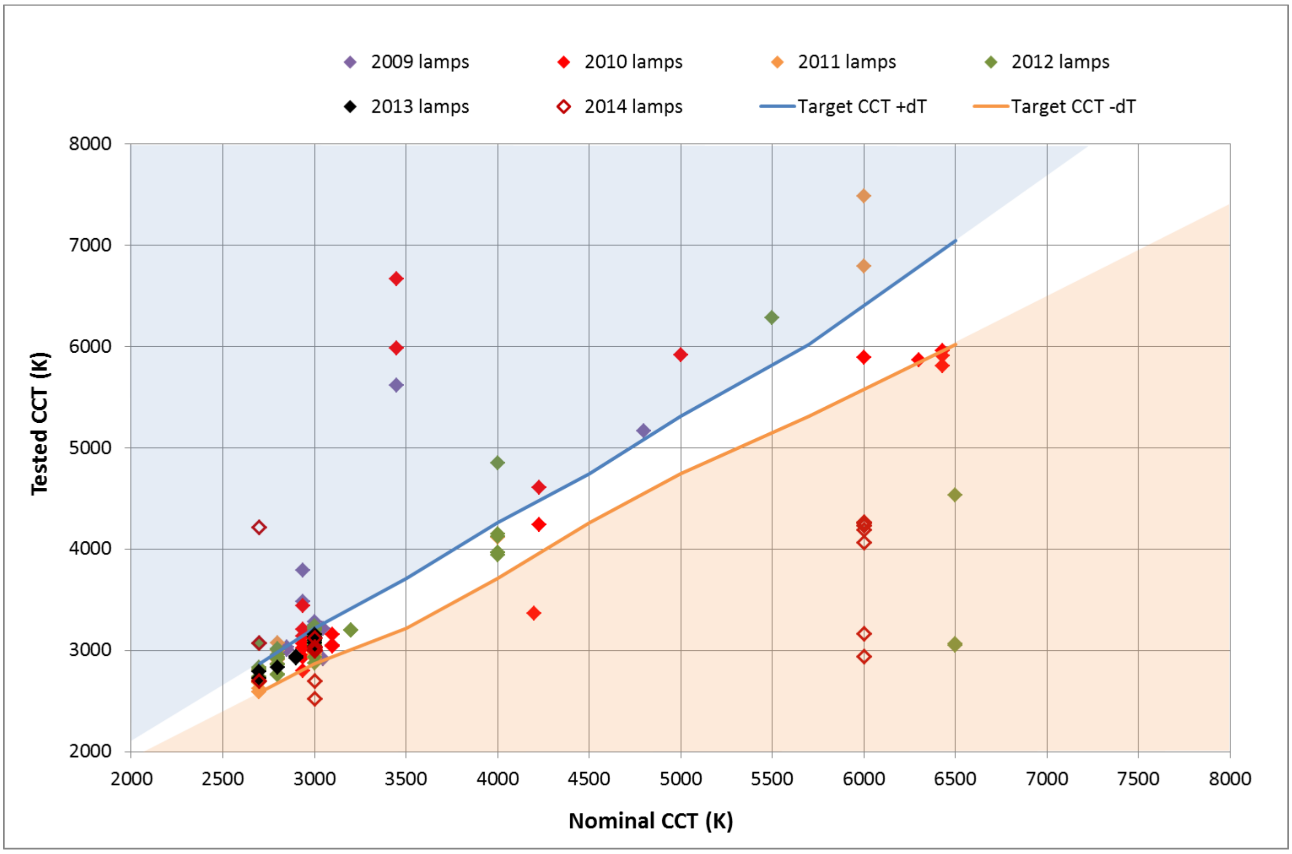


Figure 17.Tested vs Manufacturer's Nominal CCT (with ANSI C7.377 nominal target CCT tolerance levels)

4.5.9 Colour Rendering Index

Colour rendering is a measure of how similar object colours appear under one light source as compared to the object colours under a reference light source (usually an incandescent light or daylight). Colour rendering is very important for consumer satisfaction with a lighting product. Often, a CRI of 80 is required for office work, and recommended for use in residential applications. A CRI of 90 is usually recommended for tasks that require high colour discrimination. The Australian and New Zealand MEPS for CFLs requires a CRI of 80. Testing in 2014 of Australian LEDi lamps indicated significant issues with CRI quality, with 10 of the 18 products tested found to have a CRI of below 80.

4.5.10 Luminous Intensity Distribution and Beam Angle

Luminous intensity distribution describes the measured distribution of light of a lighting product. Many LED products currently being sold poorly approximate the light distribution of the conventional products they claim to replace. As discussed previously, the emergence of lamps designed to resemble a traditional incandescent omnidirectional lamp but do not provide any light beyond a 180° hemisphere is an issue in terms of equivalency claims and consumer satisfaction (Figure 18). Poor light distribution in directional lamps may also create unwanted variations in the light beam, particularly with edges of light distribution washing on walls.

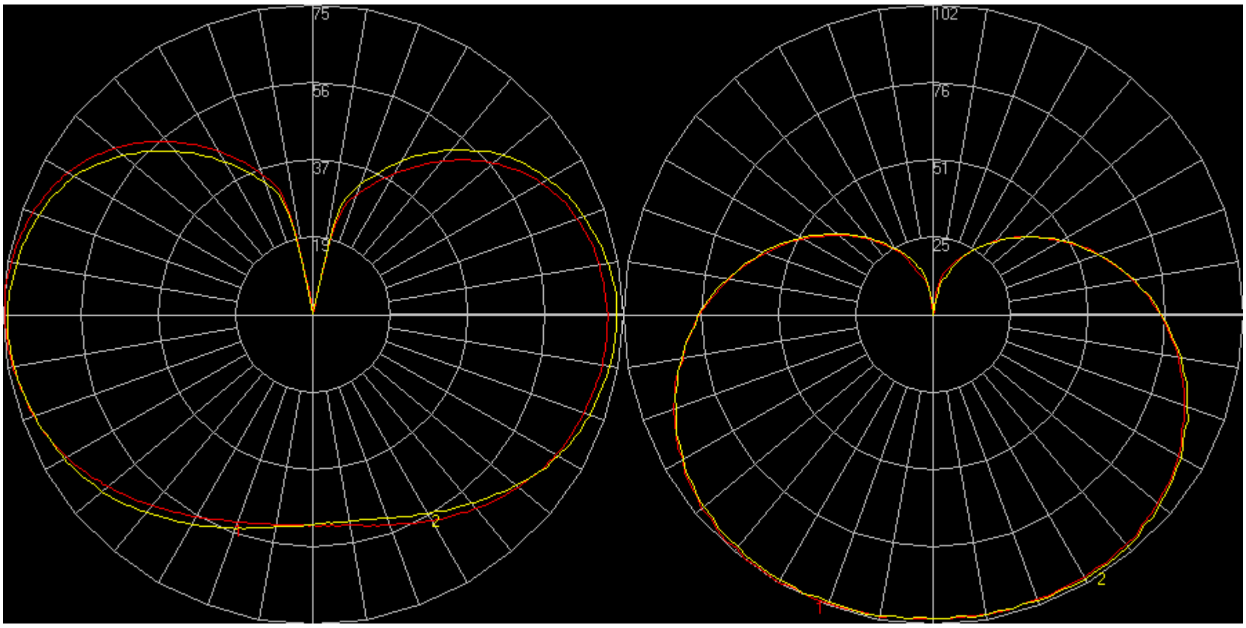


Figure 18. Tungsten halogen omnidirectional A-shape lamp distribution (left) compared to a hemispherical distribution from an LED A-shape lamp (right).

For directional lamps, centre beam luminous intensity - the measurement of the intensity of the light on the optical beam axis - is also important. Testing of directional lamps purchased in the Australian market in 2014 showed that some products had significant differences between rated and tested beam angles for directional lamps (Figure 19).

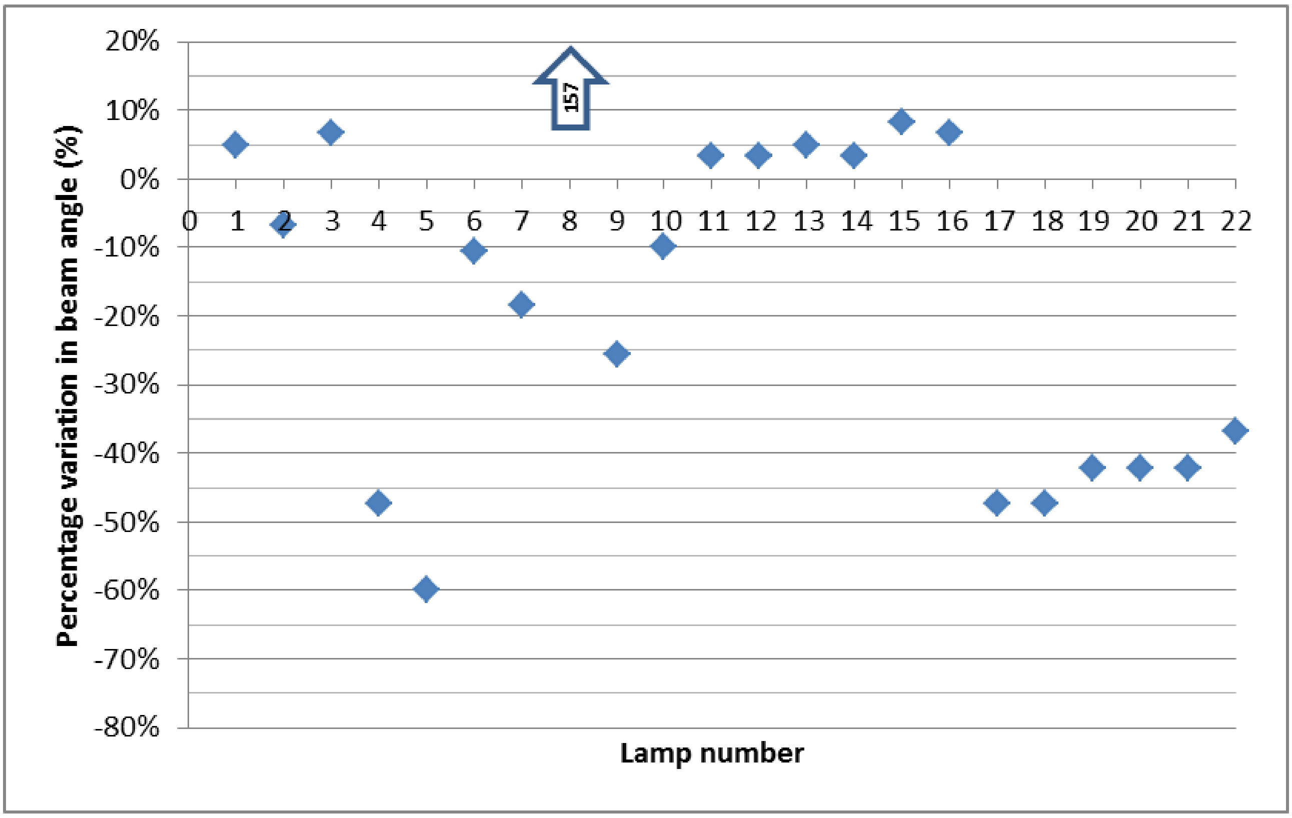


Figure 19. Percentage variation of tested beam angle relative to rated value for Australian and New Zealand lamps tested in 2014.

4.5.11 Flicker

Flicker is the modulation of the light output that can be induced by fluctuations of the mains voltage supply, residual ripples in the DC current powering, or deliberate modulations of the LED input current such as the pulse-width modulation (PWM) used for dimming applications.

Visible flickering of a light source obviously degrades the quality of the lighting service provided, however it is also known that exposure to light flicker (in particular at frequencies between 3 Hz and 65 Hz)can cause photosensitive epileptic seizures in various forms, depending on the individuals and their visual pathology (IEA 4ESSL 2014). Light flicker combined with rotating motion or spatial patterns may be responsible for stroboscopic effects which may, in turn, induce accidents to workers in proximity to rotating machines and tools which can appear to be rotating significantly more slowly or even be stationary.

Most rates of flickering from lamps are not detectable by the human brain (studies suggest that one per cent of people can detect a flicker rate of up to 60 times per second), and are also well above the range of flicker commonly associated with photosensitive epilepsy at 5-30 times per second.

Laboratory testing (KITSINELIS 2013; ZISSIS 2013) has demonstrated that some readily available consumer LED products have very high flicker behaviour. Light flickering behaviour was often observed at twice the mains frequency (in Europe mains frequency is 50 Hz thus the observed flicker frequency is equal to 100 Hz). This light flicker is mainly due to the residual voltage fluctuation after the AC/DC rectifier in the lamp power supply and in particular whether they include reliable AC/DC rectifiers and filters.

Testing of the amplitude of light variation in the flicker for each lamp has shown a wide variation, with some LED lamps having close to zero and others a variation of close to 100%. In comparison, a tungsten filament lamp will have a flicker amplitude of about 10% and a good CFL will have an amplitude of less than 20% (IEA 4ESSL 2014).

In order for a lighting product to offer an effective and efficient alternative to inefficient incandescent lighting, it should be expected to not exceed flicker rates in frequencies that may have health or safety impacts or be visible. Given the variations in the level of flicker found in LED lamps, consideration should be given to setting mandatory maximum values to limit flicker in LED products.

4.5.12 Dimmer and low voltage compatibility

Dimmer compatibility is important for consumers as many LEDi products are often not completely compatible with commonly available dimmers currently found in homes. This can be particularly challenging in Australia and New Zealand due to the wide variety of dimmers and lighting controls present in homes and commercial premises. If incompatible, these controls would require a qualified electrician in order to be replaced or modified.

Analysis by CLASP of a range of LEDs (CLASP 2014) indicates that “dimmable” LED replacement lamps can be found for the common base types (e.g., B22, E27, E14, and B15). To a certain extent, the question of whether LED lamps are compatible with the existing dimmer stock is to do with the quality of the dimmer circuit used in the LED lamp. Manufacturers of LEDs can choose to install intelligent LED drivers which can detect and adapt to an installed dimmer. Such Integrated Circuit (IC) solutions have been promoted by companies like Cirrus Logic, Marvell and iWatt since early 2012.

It may be worth considering a requirement on manufacturers who market their products as “dimmable” to incorporate intelligent adaptive LED drivers. It is not clear however that compatibility is currently available for all current lighting systems. Further investigation and industry consultation is required to evaluate the availability of these products and any impacts upon product price, efficacy or other parameters.

For LED replacements for 12V lighting systems (halogen downlights), there are also some instances of compatibility problems with existing electronic step-down transformers, although compatibility is improving in new LED products. Consumers would benefit from compatibility information provided by manufacturers and suppliers of LED MR16 retrofit products.

4.5.13 Power Factor / Harmonic Distortion

Power factor is the ratio of the real power flowing to the load over the apparent power of the circuit. For the Electrical power supplier, this is of high importance; and for street lighting, customers may be subject to a penalty charge if power factor is below 0.9. It is less of a direct issue for residential and commercial consumers.

Power factor was an issue examined when considering MEPS for CFLs, and a minimum power factor of 0.5 was set for Australia, while New Zealand set a minimum power factor of 0.9 (in recognition of the sensitivity of the New

Zealand electricity network). Of the 122 LED products tested in Australia to date, 18 were found to have a power factor under 0.5, while 58 lamps had a power factor of 0.9 or above.

Harmonic distortion is a measure of waveform distortion which measures how the lighting product will affect the quality of the electrical utility's grid. The total harmonic distortion is important in order to maintain the quality of the electrical grid. High harmonic distortion may cause a loss of reliability of switch pulse information that in some cases is used for remote control of electrical products on the electricity distribution network.

4.5.14 Wireless LED and Smart Lighting Developments

Amongst the rapidly expanding range of LED lighting products on the market there has been a recent emergence of lamps that offer an enhanced range of lighting and other services (such as wireless operation, dimming, colour adjustment, power and communication via USB, and internet connectivity). While these developments may provide exciting and useful additional services to the consumer, and in some cases offer additional energy savings opportunities, this trend may also work against increasing lighting efficacy levels by causing the consumption of additional energy (or the reduction of lighting performance) without consumers being aware.

When these lamps are not emitting light, they may switch to a standby mode waiting for a signal from the end-user to switch-on again or they may actually be serving as part of a local wireless network, in a more active energy consuming mode. This means that the lamps are consuming energy even when they are not emitting light.

Tests on a limited number of smart wireless LED lamps purchased in Australia, USA and Europe have revealed that these products can have substantial standby power consumption. In sockets operated 1-2 hours per day – common in many residential applications – some lamps will consume half or more of the lamps' total annual energy use while the lamps are 'off' for 22–23 hours every day. The total energy use is thus much higher than for a simple LED lamp of equivalent light output operated by the normal on/off switch. These test results are similar to experiences with standby consumption for other products where manufacturers first focused on the new features before turning their attention to reducing the standby power consumption.

Testing of two wireless operation LED lamp products available in the Australian market(including measuring standby power consumption) found that one of these lamps (Lamp A) had standby power of about half a Watt while the second (Lamp B) consumed about 3 Watts in a standby mode. Considering Australian houses have on average approximately 48 lamps in-situ, the transitioning to these LED lamps with wireless capability by even a portion of this lamp stock means that the collective standby power consumption will have real implications for household energy consumption and in some cases could reverse energy savings gained from moving to LED lighting.

The Figure 20 and Figure 21 present power consumption, including standby mode, for the two lamps tested when they are turned ON for one hour every day throughout the year. Taking into account standby power use, in this scenario Lamp B actually uses more power than an equivalent inefficient tungsten filament incandescent lamp (now phased out) would use when turned ON for the one hour each day. Including standby power, both wireless models consumed more energy than an equivalent CFL lamp and used more energy during the standby period than during the hour of operation.

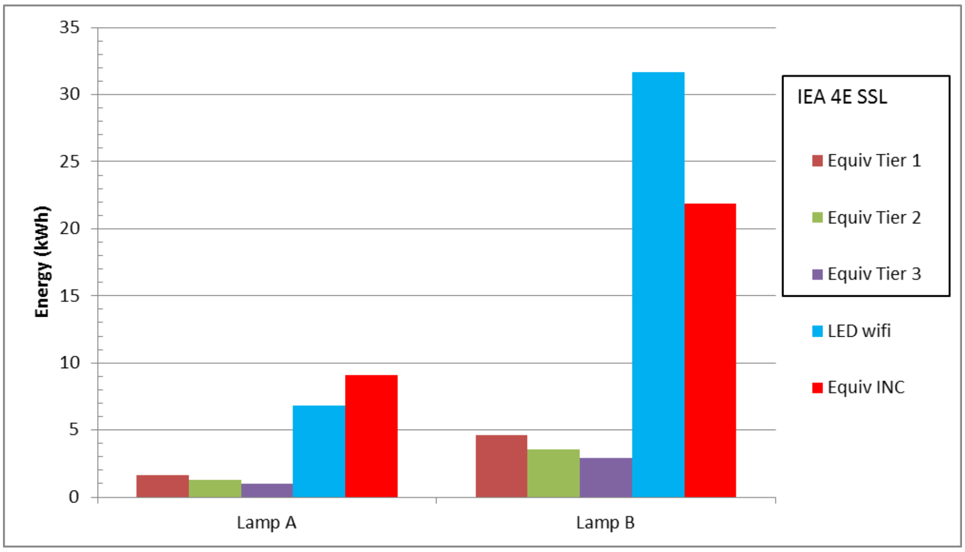


Figure 20. Annual power consumption for 1 hour per day ON, including standby mode for the two LED lamps, compared with the equivalent lumen output incandescent lamp and hypothetical LED lamps at the IEA 4E Tier levels.

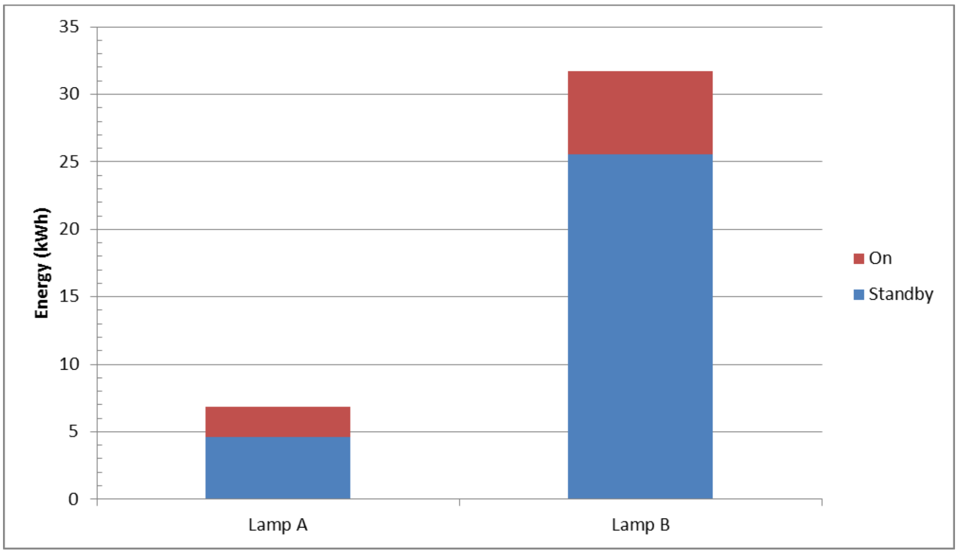


Figure 21. Standby versus lamp ON power consumption for 1 hour per day ON for the tested LED lamps

The longer the daily use of a lamp, the less significant the standby mode power consumption is relative to the power consumed when ON, however the average residential time of use (i.e. when turned ON) for lamps in Australia is only between 1–2 hours.

The Figure 22 compares the measured efficacy (lumens per Watt) of the tested lamps to similar incandescent lamps and the IEA 4ESSL recommended LED efficacy levels.

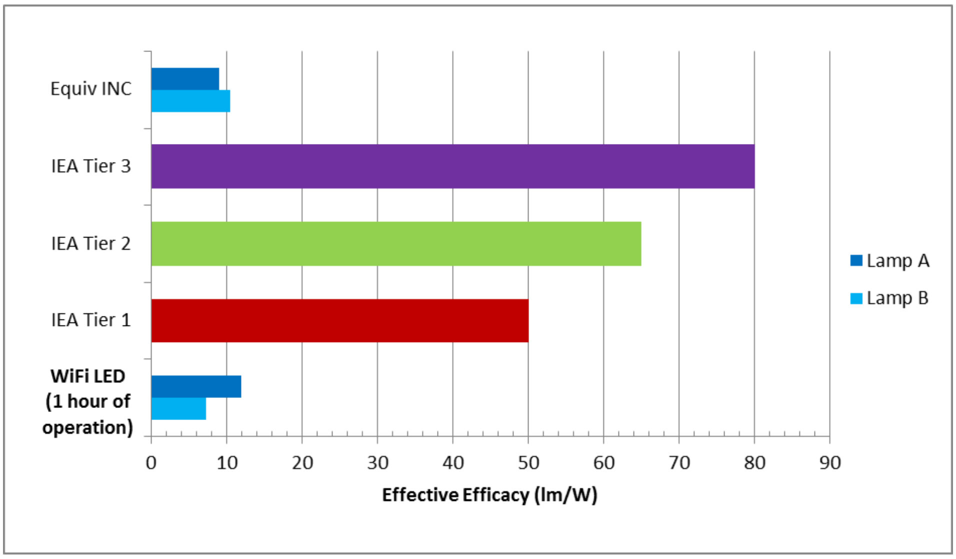


Figure 22.The measured efficacy of the tested lamps compared to an equivalent lumen output incandescent lamp and the IEA recommended LED efficacy levels.

Other new developments have seen lamps emerging that increase power use over time to maintain constant lumen output, or vary lumen output in order to reduce the impacts of overheating. While addressing technical challenges with LED lighting, these approaches also make it more challenging to test the performance of these lamps, and for consumers to understand the service and associated energy consumption being provided.

Lamps that have the ability to vary colour or colour temperature will also need to be taken into account in specifying how lamp performance, including efficacy is claimed, measured and evaluated.

These emerging features of LED lighting technology pose challenges for the measurement of the performance and efficacy of products, and potentially diminish the energy savings potential of LED lighting. It will also increase the complexity for consumers trying to understand lighting energy consumption and performance. It is essential that additional functionality is taken into account in the development of LED test standards, and performance specifications. The Australian government is working with a number of other countries in the IEA 4E SSL Annex to investigate this issue further.

4.5.15 Possible Health Issues

During the phase-out on inefficient incandescent lamps in Australia, a number of concerns were raised by members of the public relating to possible health impacts of efficient CFL lamps. While the absence of mercury content is one significant difference between LED and fluorescent technology, the two technologies do have in common that they contain electronic components and emit light in a different manner to incandescent lighting.

The Australian Government has worked with other countries in the IEA 4E SSL Annex to review available knowledge and studies of these issues.

In 2014, the SSL Annex published a comprehensive review (http://ssl.iea-4e.org/health-environment/health-impacts) of the current literature on health-related impacts of energy-efficient LED systems in our homes, buildings and outdoor areas (IEA 4ESSL 2014).

The study evaluates electrical risks, exposure to electromagnetic fields, glare, photobiological hazards, light flicker (discussed above) and non-visual effects of light. The report found that SSL technology is not expected to have more direct negative impacts on human health with respect to non-visual effects than other light source technologies. It also concluded that in the case of electromagnetic fields, emissions by SSL products are generally much smaller than those corresponding to discharge lamps or certain household appliances.

In relation to glare, the study found that in a typical LED, the radiance and luminance levels may be extremely high, much higher than the values found in the case of common lamps used in general lighting, making them more susceptible to producing glare. While glare does not constitute a risk in itself, it is a potential source of discomfort and temporary visual disability. It can also be the indirect cause of accidents. The study provided recommendations regarding the evaluation of the potential for glare from LED products by specifying maximum luminance, and how this should be taken into consideration in lighting design.

The report also examines the blue light hazard that potentially results from two characteristics of LED light sources:

- Most LED components are very bright small sources of visible light (high luminance and radiance values)
- The vast majority of commercial white light LEDs have an emission spectrum which exhibits a blue peak.

High levels of blue light exposure is recognised as being harmful by causing photochemical damage to the retina, particularly as a result of short periods of high intensity exposure (although low intensity exposure over long periods can also contribute). Testing has shown that the retinal blue light exposure levels produced at a distance of 200 mm by blue and cold-white LEDs often exceed the exposure limits after an exposure between a few seconds (blue LEDs) to a few tens of seconds (cold-white LEDs). In normal circumstances a person would blink or look away from such a light source but in some cases the exposure limit may be shorter than this response. As a consequence, the short distance potential toxicity of these LED components cannot be neglected. Note however the exposure being evaluated involves direct viewing or staring at the light source rather than exposure from viewing an area illuminated by such a light source.

However, when the viewing distance is increased beyond one metre, the maximum exposure duration rapidly increases to a few thousands of seconds, even up to a few tens of thousands of seconds. These very long exposure durations provide a reasonable safety margin to assert than there is virtually no possible blue light retinal damage from LEDs at longer viewing distances (statement valid for state of the art LEDs at the time of writing).

The international standard IEC 62471 provides a system of classification of light sources into several risk groups according to the maximum permissible exposure duration assessed at a given distance: Risk Group 0 or Exempt group (no risk), Risk Group 1 (low risk), Risk Group 2 (moderate risk), Risk Group 3 (high risk). The IEA 4ESSL Health report recommends that products rated RG2 should be labelled in accordance with IEC TR 62471-2, in order to inform the user “not to stare” at the operating lamp as it may be harmful to the eyes. The report also recommends that SSL products aimed at consumer applications (retrofit LED lamps for instance), be limited to risk group to RG1 at 200 mm, which can be considered as the shortest viewing distance encountered at home.

The report does not consider LED applications not related to general lighting (for example, toys using LEDs, automotive lights and testing and adjustments of LEDs in manufacturing facilities) and also notes that IEC 62471 currently does not take into account the sensitivity of certain specific population groups, which can be characterized by an accrued sensitivity to visible light including:

- People having pre-existing eye or skin condition for which artificial lighting can trigger or aggravate pathological symptoms
- Aphakics (people with no crystalline lens) and pseudophakics (people with artificial crystalline lenses) who consequently either cannot or can only insufficiently filter short wavelengths (particularly blue light)
- Children, as their skin and visual system is not mature
- Elderly people as their skin and eyes are more sensitive to optical radiation

In relation to these current limitations, the report recommends that the photobiological standards relative to lighting systems should be extended to cover children and aphakic or pseudophakic individuals, taking into account the corresponding phototoxicity curve published by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) in its guidelines. The report also notes that occupational guidelines and protective equipment may also be necessary for certain categories of workers that may be exposed to high doses of artificial light (long exposure times and/or high retinal irradiance levels) during their daily activities (examples: lighting professionals, stage artists, etc.).

New generations of LEDs emitting white light are currently being developed using violet and UV chips. The 4ESSL report recommends that the photobiological safety of these LEDs and the products using them should also need to be carefully assessed because of potential residual UV and violet radiation in the emission spectrum and that a careful assessment of the aging of these products should also be conducted as the possible degradation of the luminophores may raise the level of short wavelength radiation, thereby increasing the retinal exposure levels.

Recent studies, including the discovery of a new type of photoreceptive cell (the ipRGCs) in the eye, have provided stronger evidence regarding the influence that light has on the regulation of circadian rhythms through the suppression of the production of melatonin. These non-visual effects of light are known to depend upon the illuminance level and exposure duration as well as the time at which the exposure is received. There is the potential for light to be used to delay or advance the circadian clock, with both beneficial and undesirable effects. The influence of light varies across the wavelength range with light richer in yellow, orange and red colours (rather than blue and green colours) being less effective to activate non-visual response such as the melatonin suppression. Inversely, light sources containing blue and blue-green components producing high retinal irradiance which can be used to promote the activation of ipRGCs and the non-visual effects of lights.

While this is an issue for all artificial light, the flexibility of LED lighting in terms of the variety of spectra it can produce offers an opportunity for greater control of this effect upon our circadian rhythm. However in the future, the low cost and high efficacy of LED lighting, combined with greater flexibility in form may increase the use of artificial lighting (indoors and outdoors), and this increase in overall exposure may heighten potential non-visual effects.

4.5.16 LED Product Lifecycle

Studies of LED lifecycle costs have faced challenges in relation to the complexity of the products, the rate of technological improvements, and the confidentiality of manufacturing and component data. The issue of confidentiality led the US Department of Energy lifecycle assessment (US DOE 2013) to undertake chemical analysis of a variety of LED, CFLs, and incandescent lamps using standard hazardous material testing procedures in order to help complete the missing data.

In 2014 the IEA 4E SSL Annex published a review (http://ssl.iea-4e.org/health-environment/lifecycle-assessment) that examined nine life-cycle assessment (LCA) reports published between 2009 and 2013 (including the recent series of reports by the US Department of Energy) that compare LED lamps and luminaires with conventional sources (IEA 4ESSL 2014B). The review found that on average, 85% of the environmental impact of an LED product is linked to the use phase, while the remaining 15% is shared mainly between manufacturing and end-of-life treatment. The environmental impact of the transport phase only accounts for 1% to 2%.

Thus while the energy used for the manufacturing of an LED product is almost 1.5 times higher than that used for the manufacturing of traditional light sources, overall the replacement of low efficacy lighting (such as incandescent and high-pressure mercury lamps) with high efficiency, long-life LED-based lamps and luminaires brings a strong environmental benefit, primarily through significant reductions in operational energy use.

The review also found that high quality CFLs with a lifespan of more than 12,000 hours and efficacy up to 65 lm/W have an impact currently comparable to good quality LED products (assuming the average lifespan of an integral LED lamp is 20,000 hours). As LED technology is still improving, higher efficacy and improved design and manufacturing techniques are expected to further reduce the environmental impact of LED products in the next few years as shown in Figure 23.

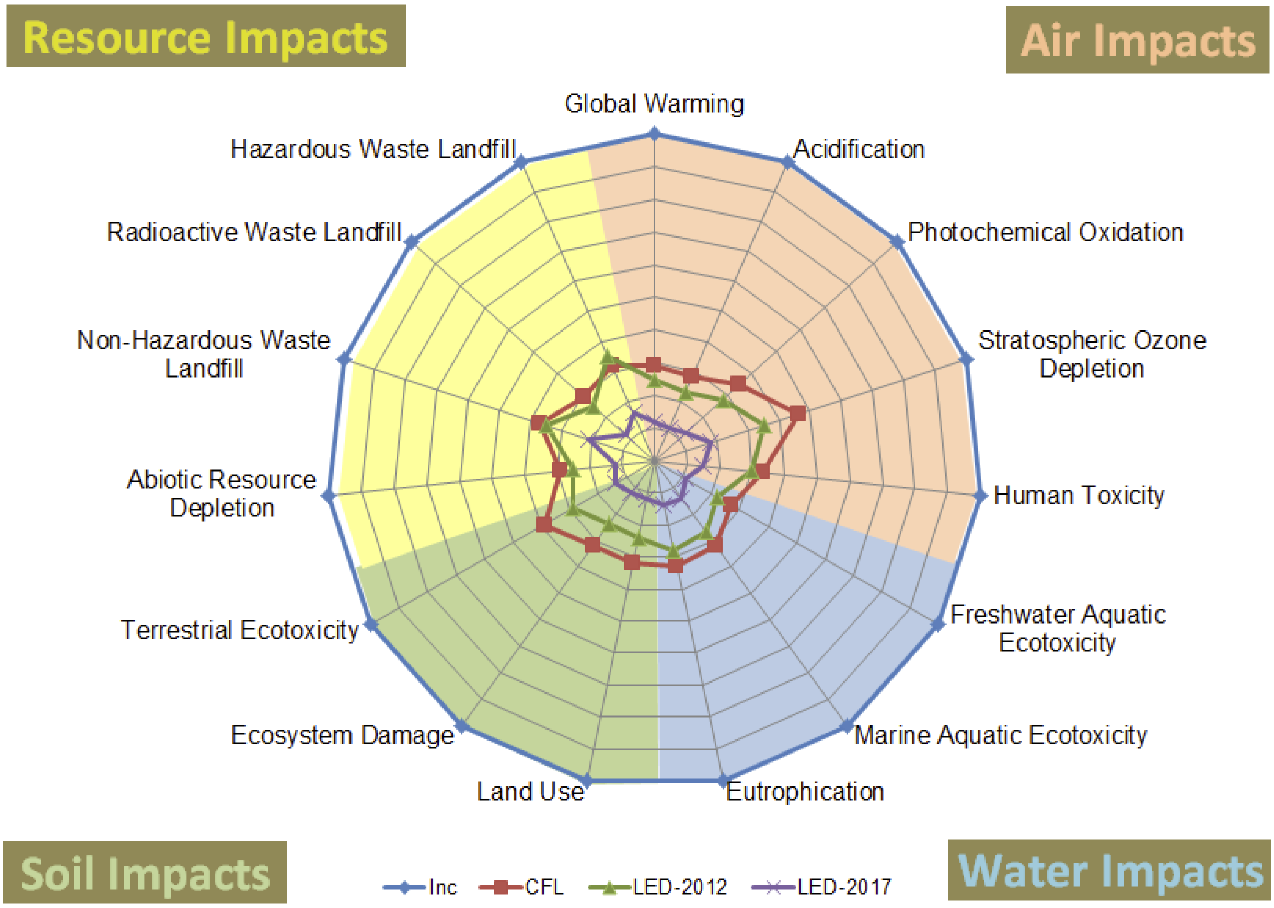


Figure 23.Life-cycle environmental impacts of three household lamp technologies including current (2012) and future (2017) LED lamps (US DOE 2012)

LED components with the highest contribution to environmental impact include aluminium components (e.g., heat sink), electronics (the driver) and LED packaging. The recent development and use of ceramic heat sinks (replacing aluminium) in LED products is expected to help to reduce the environmental impact if broadly adopted. The production of an LED electronic driver also has a significant impact, as it often includes many discrete components as well as integrated circuits, and many processes involved in the manufacturing of a printed circuit board. Of interest is the conclusion of the US DOE study (US DOE 2012) that one area where LEDs may currently have a marginally higher impact than CFL lamps is hazardous waste disposal due to the manufacturing of the large aluminium heat sink used in LED lamps.

Although LEDs contain recyclable components and materials, LED products are often not recycled. The end-of-life for LED products is thus comparable to other electronic waste. These wastes contain rare materials such as gallium and indium that are considered strategic metals; however standard waste recycling processes can't recover these materials today. With or without recycling, the impacts of the end-of-life of LED products appear to be very low compared to the use stage. However investigations into the recycling LED products to extract valuable materials would further reduce environmental impact.

5 Market characteristics

5.1 Manufacturers, importers and suppliers

The number of manufacturer or retailer brands of LED lamp being sold in Australia/New Zealand is constantly changing. During research for this product profile, at least 53 LED lamp brands were identified as being available in these markets. Data on a subset of these were gathered (based on catalogue or other supplier data) and analysed for their performance specifications as part of this study as a sample of the models of LED lamps that are available. The 50+ included brands are listed in Table 3.Examples of LED lamp brands in Australia and New Zealand.(many lamps were 'unbranded' and were thus grouped into a singular category). The table shows that there are a growing number of LED lighting product brands, many of which are new to the lighting industry; and this shows that suppliers are providing a reasonable range of products for consumer choice.

Note that the presence of these particular brands here is in no way indicative of high or low lamp performance.

Table 3.Examples of LED lamp brands in Australia and New Zealand.

LED lamp brands (non-exhaustive list)				
Accent	Atom	Array	Bacol	Bobby
Boss	Brightgreen	Brilliant	Cree	Crompton
Ecofire	EcoLightUp	Epistar	Equinox	GE
Get Green	GRC	Ecolamp	EcoLightUp	Epistar
Equinox	Get Green	Hi Power	Jinxiao	LEDion
LEDlux	Lumenmax	Marexim	Martec	Matrix Lighting Inc
Megaman	Mort Bay	NaturaLED	Nelson	Nemo
OPTILED	Osram	Philips	Premium	Prime
Rock	Shadowline	SMD	Sylvania	Unbranded (many sources)
Upshine	Verbatim	Viribright	Vibe	Z LED

Performance data of LED lamps that are available in Australia and New Zealand was obtained from the suppliers listed below. Almost all suppliers are locally-based, and range from the "Big-box" hardware store, to general lighting retail, specialist lighting stores, and electrical retail suppliers, (all of which have online options for purchasing); in addition, online-only lighting retailers and direct manufacturer/suppliers were also identified.

In addition to sourcing of claimed performance data from available supplier information, a range of LED lamps were tested by DCCEE and EECA in 2010, 2012, 2013 and 2014. Most of these were obtained from suppliers in the Australian and New Zealand markets while some lamps tested in 2010 were obtained from the United States and United Kingdom, to provide an international viewpoint on LED performance.

Table 4. Examples of LED lighting product suppliers in Australia.

Supplier	**Outlet type**
Alternative Technology Association (ATA)	specialist energy efficiency retail
Andrews Light Up	specialist lighting retail
ANL Lighting	specialist energy efficiency retail
Artemis Building Systems (ABS)	specialist lighting retail
Beacon Lighting	general lighting retail
Bunnings	big box hardware retailer
Crompton Lighting	manufacturer/supplier
Eurolight (online)	online retail
Ideal Electrical Suppliers	electrical retail
iGlobe (online)	manufacturer/supplier
IKEA	big box retailer
Jaycar	electrical retail
John R. Turk	electrical retail
LED Australia	online retail
LED lights Down Under (online)	online retail
LEDCentral.com.au	online retail
Lighting Illusions	general lighting retail
Lighting matters (online)	online retail
Lighting Pro Australia	specialist lighting retail
Lighting Store (Online)	online retail
LiquidLEDs.com.au	online retail
Megaman	manufacturer/supplier
Milton Lighting	specialist lighting retail
Planet LED (online)	online retail
Prime Electronics	electrical retail
Pro Lamps	specialist lighting retail
Securemart (online)	online retail
Vibe Lighting	manufacturer/supplier

5.2 Australian LED lighting market

5.2.1 LED Lamp Types

Lamps currently sold in Australian and New Zealand retail and online outlets can be summarised into approximately 20 categories; some lamp types are more typically used in commercial spaces while others are more relevant for residential use. Further, some of these lamp categories are specialised and/or professional lighting products likely to be of low volume and therefore provide only a limited opportunity for energy saving.

Table 5. LED Lamp Types Sold in Australia and New Zealand. Note: products that have a 'cap' are an integrated form of LED, i.e. LEDi. Data in this table is not a definitive categorisation, and will be constantly changing with new product development.

Description	LEDi	LEDsi	LEDn
GLS non-directional lamps	✓		
Candle	✓		
Fancy round	✓		
MV GU10 downlights	✓		
ELV MR16 downlights		✓	
PAR lamps	✓		
AR111 spot lamps	✓		
High bay lamps	✓		
Linear tube lamps		✓	✓
Circular tube lamps		✓	✓
In-ground LED tiles		✓	✓
Strip lighting (flexible)			✓
Rope lighting			✓

In addition to LED lamps, LED luminaires were also found in the following categories:

- Module downlights (gimbal/fixed style)
- Oyster lights
- Profile lights
- Wall washers, spot lights and flood lights
- Ceiling panels

5.2.2 Stock and sales

The E3 Committee commissioned a comprehensive lighting audit of the residential sector in 2010, one year after the commencement of the incandescent lamp phase-out program (E3 2010). The purpose was to quantify the lighting stock and characteristics of lighting in Australian households.

The intrusive survey covered 150 houses, including 43 houses in Queensland (Brisbane), 36 houses in New South Wales (Newcastle and Sydney), and 71 houses in Victoria (Melbourne and Gippsland). Fieldwork was undertaken in the period October 2010 to March 2011.

The study yielded an overview of the number of lamps installed in the average house, plus the performance characteristics in Lumens and Watts by lamp technology, as per Table 6.

*Table 6. Number of lamps, Lumens and Watts by Technology in the typical Australian house. * Unknown and missing 'technologies' are included in the share numbers as incandescent lamps.*

Average Per House	Incandescent*	Mains Voltage Halogen	Low Voltage Halogen	Compact Fluorescent	Linear Fluorescent	LED	Totals /Averages
Number of Lamps	10.5	4.3	11.9	14.4	4.2	0.7	46
Number Share	22.0%	8.9%	24.8%	30.1%	8.9%	1.4%	96.1%
Watts Total	755	294	558	195	142	4	1948
Watts Share	37.6%	14.6%	27.8%	9.7%	7.0%	0.2%	96.9%
Watts per Lamp	72.7	74.5	44.0	13.6	33.3	5.1	42.3
Lumens Total	9059	4704	8925	10742	12743	179	46352
Lumens Share	19.2%	10.0%	19.0%	22.8%	27.1%	0.4%	98.5%
Approximate average Lumens/Watt	12	16	16	55	90	45	24 (weighted average)

The study found that in 2010 the penetration of installed LED stock was 1.4%, representing less than 1 LED lamp per household (on average, it was 0.7 lamps per household). The average power consumption of installed LED lamps was approximately 5 Watts, reportedly producing an average 179 lumens of light and therefore efficacy was an average 45 lumens per watt: a number lower than the typical efficacy of other efficient lighting technologies such as 55 lumens per watt for the average CFL, or 90 lumens per watt of the average linear fluorescent fitting.

Australian census statistics of 2011 summated the total number of private dwellings to be 9.1 million. A translation of the values found from the comprehensive lighting audit allows for an Australia-wide estimation of installed lamp stock in 2010 as shown in Table 7.

Table 7.Installed lamp stock Australia 2010 (based on average installed lamps from 150 sample homes).

Residential Australia 2010: Average Per House	Incandescent	Mains Voltage Halogen	Low Voltage Halogen	Compact Fluorescent	Linear Fluorescent	LED	Totals
Number of lamps	95,728,847	39,203,242	108,492,693	131,285,275	38,291,539	6,381,923	419,383,518
MegaWatts Total	6,883	2,680	5,087	1,778	1,295	36	17,760

It is acknowledged that the age of this data is not ideal and the two key factors of the likely further impact of the phase-out MEPS regulation on the market and the continued emergence of LED lamps suggest that there will have been further significant change in the household lighting stock over the last five years, as indicated in the discussion on import data below. A new household lighting survey is planned for the second half of 2015 to feed into analysis for the proposed Regulation Impact Statement. Any industry data on lighting stock would also be appreciated.

More recent data does indicate a higher uptake for LED lighting. The Queensland Household Energy Survey 2014 (Colmar Brunton 2014 – online and hardcopy survey of 4000 Queenslanders) found that between 2010 and 2014, households increased ownership of LED lighting from 15% to 37% of households (with one or more LED lamps) while ownership of CFL lighting decreased from 77% to 59% of households (with one or more CFLs), Figure 24. This suggests that at least some of the transition to LED lighting may be from comparatively efficient CFL lamps rather than halogen or incandescent lighting. The extent of transition has also increased significantly, with only 5% of those surveyed in 2010 reporting LED lighting in ‘most or all lighting’ to 22% in 2014.

The US Department of Energy reports that in 2014, LEDs were estimated to make up less than 4% of the installed base (in lumen-hours, across all sectors)in the USA and that by 2030, LED lighting is forecast to account for the majority of installations, equivalent to 88% of all lumen-hours being produced for general illumination (US DOE 2015). It should be noted that this is for lumen hours in all sectors of lighting (including commercial, industrial, street lighting etc.) and that the percentage of predicted market penetration varies according to lamp type, with 99% for general service lamps, 74% for directional lamps, 83% for linear lamps and 73% for high bay/low bay lighting.

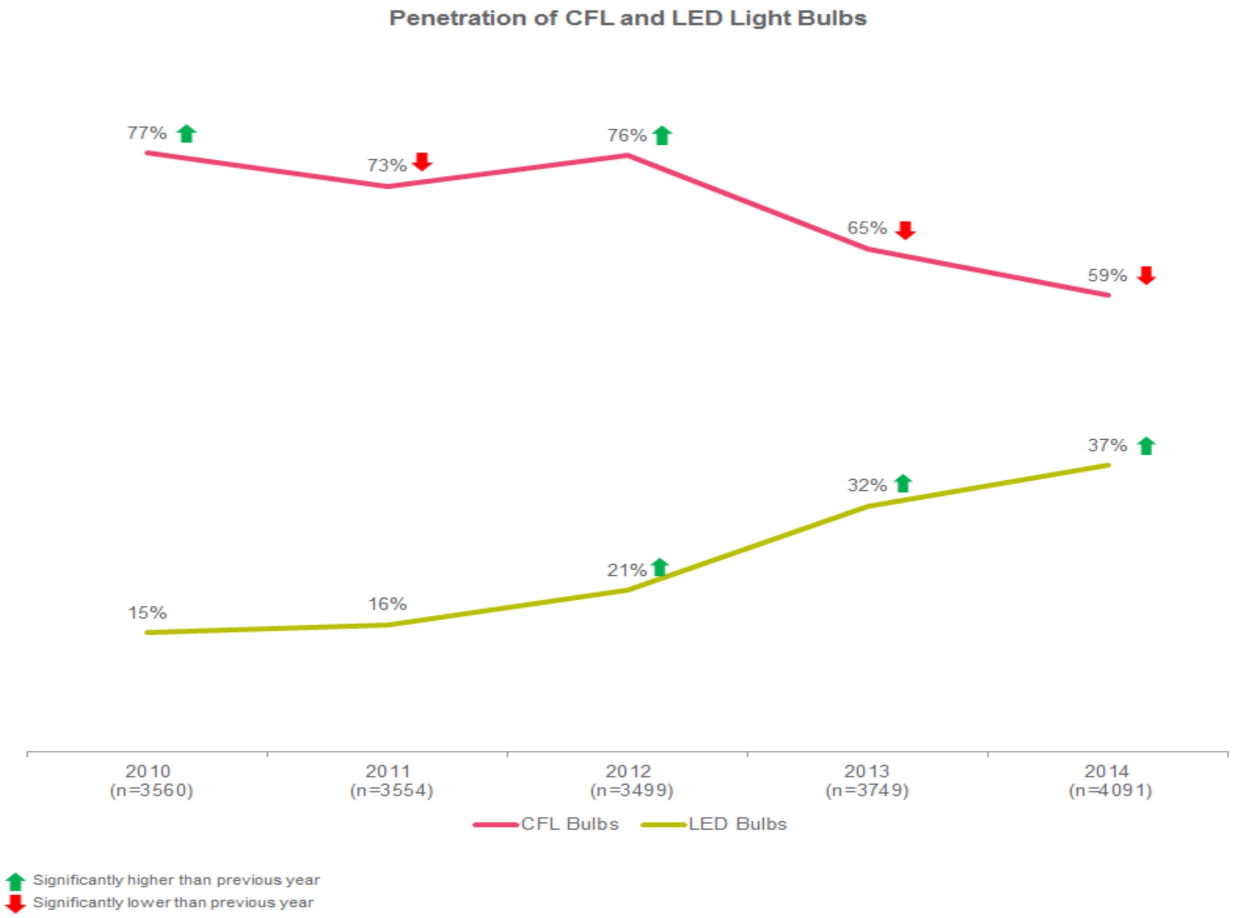


Figure 24. Penetration of CFL and LED lamps in a sample of Queensland Households 2010-2014 (Colmar Brunton 2014)- Graph shows percentage of households with at least some of CFL or LED technology lamps.

5.2.3 Lamp Supply

Based on ABS import data between 2002 and 2007 average growth in the Australian lamp market was 6.1% per year, though on a year to year basis these figures fluctuated. In the last seven years there has been an overhaul in the profile of lamp uptake in both the residential (and commercial) markets. ABS lamp importation records provide information on all major residential lamp types with the exception of LED lamp technologies (Figure 25); from the data it can be seen that in recent years there has been a significant reduction in import numbers of several lamp types. Contributing factors are likely to include the reduction in tungsten filament lamps due to the import prohibition and application of MEPS, and the uptake of lamps which have a longer lifespan (such as CFLs with a minimum mean 6,000 hour life) since the incandescent phase-out in 2009 (thus a falling necessity to replace products at the same rate). Many of the lamps purchased around this time would only be ready for re-lamping in 2012-2013. The beginning of a transition to LED lighting is also expected to be a contributing factor, particularly in the decline of imports of low voltage halogen lamps.

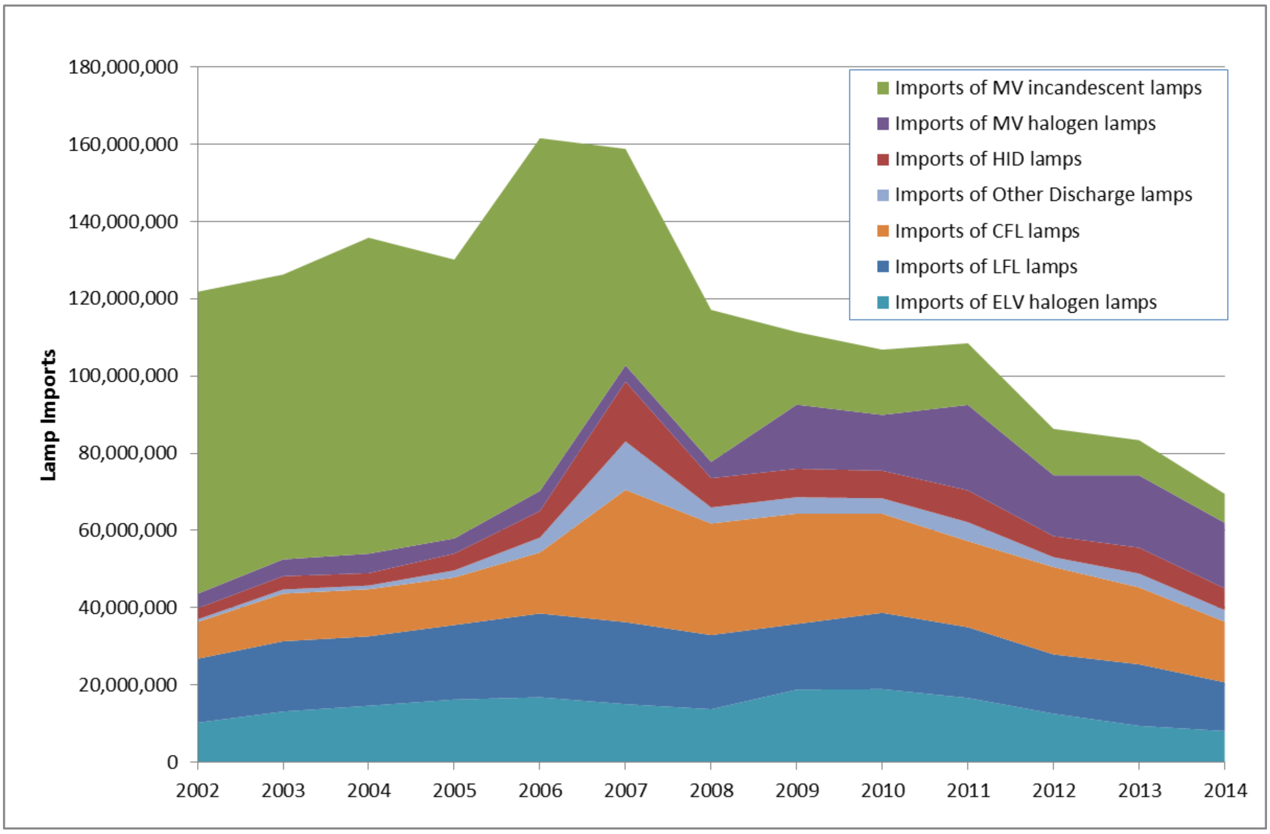


Figure 25.ABS import data for mains-voltage (MV) incandescent, MV and extra-low-voltage (ELV) halogen, high intensity discharge (HID) and other discharge, compact fluorescent (CFL) and linear fluorescent (LFL) lamps.

Total historical Australian lamp imports are shown in close detail in Figure 25. Predictions for future stock in this report are based upon world average uptake of technologies (including LEDs) as extensively researched and reported by McKinsey & Company in 2012 in their overview of the global lighting market (not that Australia was not specifically addressed in the McKinsey reports), and using the current Australian import data and stock model over which to apply the incremental changes in the lighting market. Specific Lamp attributes used in the model are in Appendix D.

Australia is at the forefront of the incandescent phase-out in comparison to the rest of the world; as such the search for new lamp technology alternatives by consumers is well imbedded. Market observation while purchasing lamps for benchmark testing showed a significant increase in the number of brands and models available for purchase in local outlets. In terms of exports from China, one of the major manufacturers of LED lighting, Australia ranks as the 11th destination of LED products with approximately 10 million units annually (note that due to current limitations on international export codes relating to LEDs, this category is likely to include a range of LED products other than those used for general lighting). Approximately 1 million units are currently shipped to New Zealand from China (CALI pers. com).

The recently released IEA 4E Lighting Benchmarking report (IEA 4E 2015) also found that Australia is comparatively well advanced in the transition from incandescent lighting to efficient lighting (to date, largely CFLs). The benchmarking study found that of the countries studied, Australia had progressed to having one of the lowest levels of incandescent lamp supply.

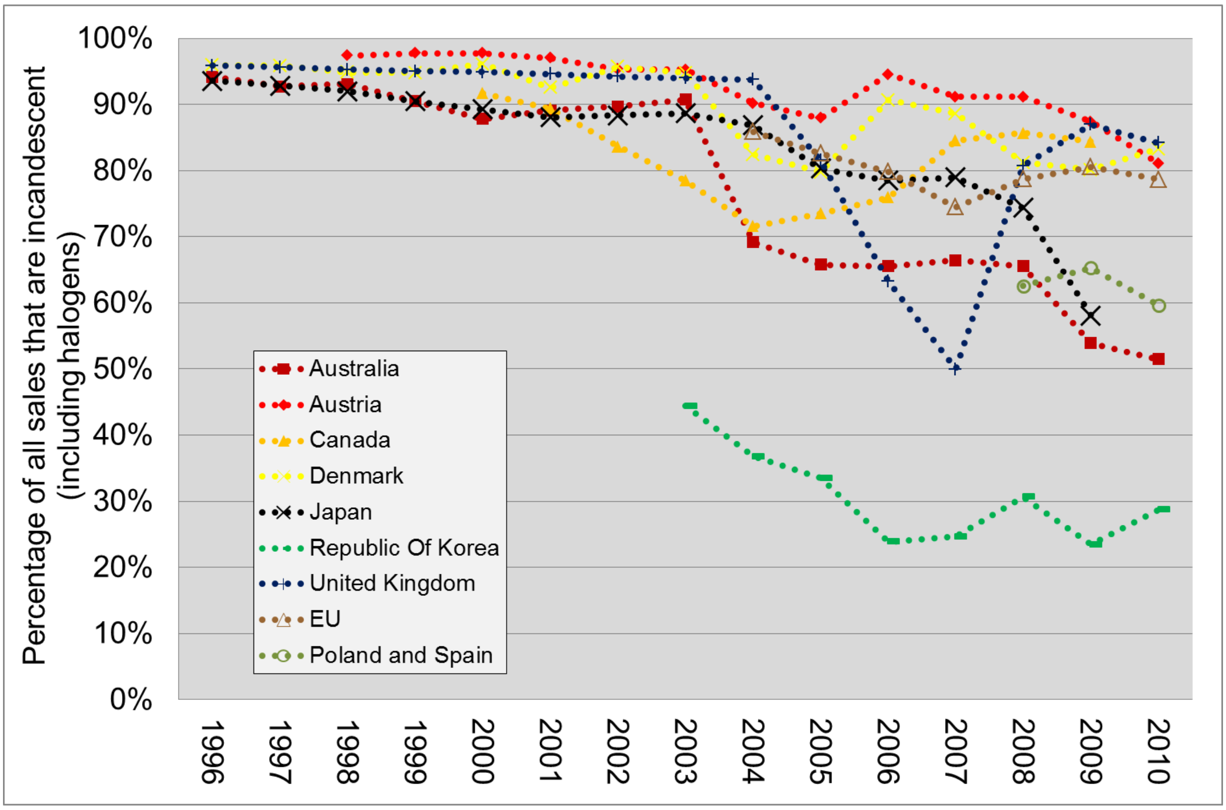


Figure 26.Percentage of all sales that are Incandescent Lamps including Halogens in a range of Countries (IEA 4E 2015)

Across the countries studied, market average efficiencies of lamp sales have typically risen from 12-15lm/W to 17-20lm/W. Australia has achieved an average of 27lm/W due to higher levels of CFL sales as a result of MEPS and associated educational measures.

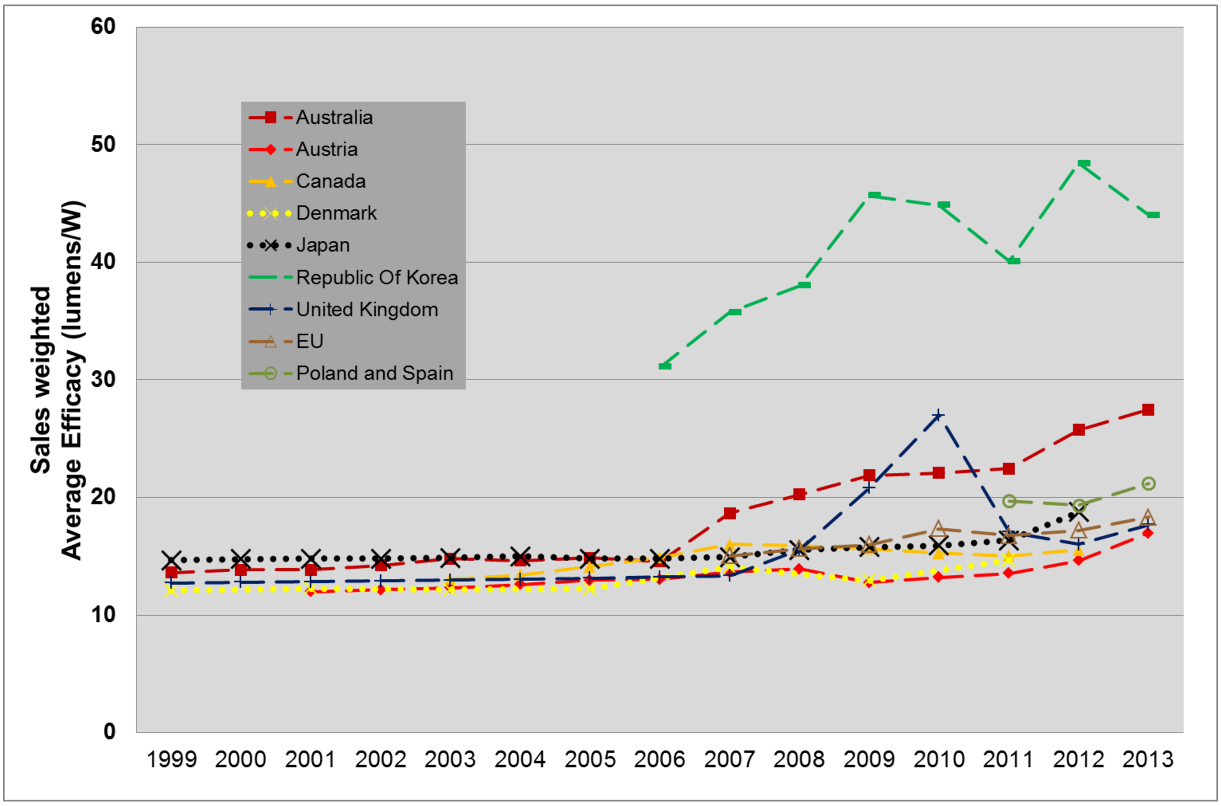


Figure 27.Average Lamp Efficacy in a range of Countries (IEA 4E 2015)

While in Australia approximately 50% of the mains voltage omnidirectional lamp supply had transitioned to mains voltage halogen lamps rather than CFL or LED lamps, this is still more progressive than outcomes in the EU where combined sales of incandescent and halogen lamps moved from around 90% of all sales before the introduction of regulations, to 80% now. These results suggest that there is flexibility in a significant portion of the market to transition to efficient lighting, but that there is still some way to go.

5.2.4 Projected trends

In the Australian commercial sector there has been significant movement away from use of the traditional inefficient lamp technologies, where advances in emergent technologies such as LED opened new opportunities for novel design with high efficiency, making the transition a feasible one. In part the change has also been due to the introduction of lighting power density limits (in watts per square metre) in the 2005 edition of the Building Code of Australia's National Construction Code, which applies to any new-build or significant refurbished commercial space. The code has since been reviewed and updated in 2011, with power density limits further tightened for some building applications. Aggressive price erosion of LED lighting products is also cited as a vital instigator of change to the long-term forecasts of the lighting market.

A commercial lighting market model has been created for the Australian market, which provides projections of the technology mix that will be in use in Australian non-industrial commercial spaces is shown in Figure 28, where LED lamp and luminaire use to 2030 is projected to rise to approximately 85% as use of all other lamp types diminishes, though linear fluorescent lamps are considered to keep a small presence in the market (E3 2015). Further information on the foundations of this model is provided in Appendix D.

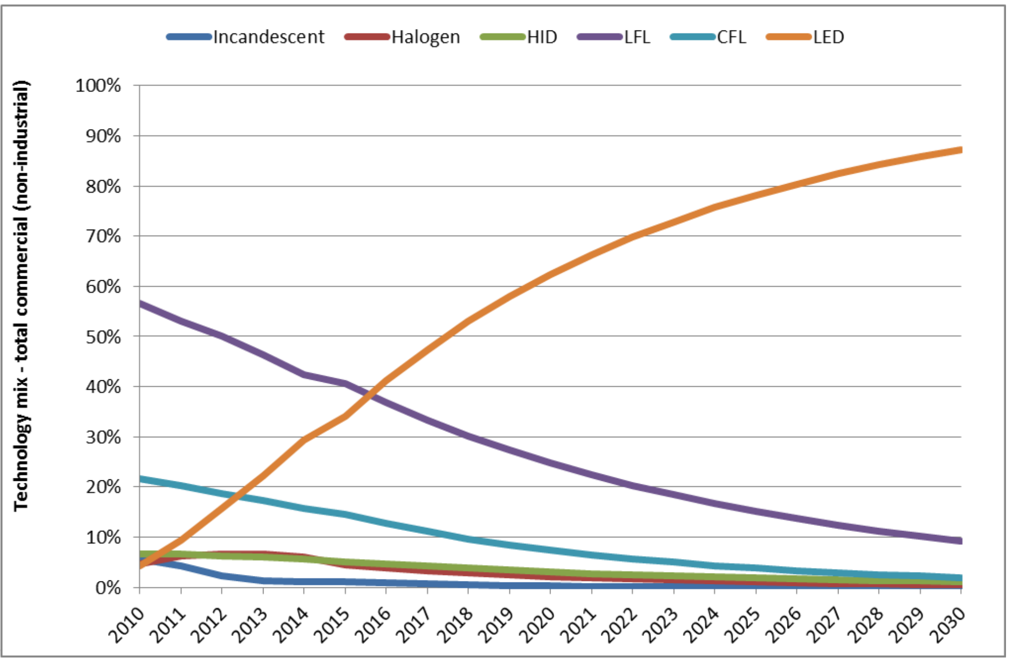


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Figure 28. Projected mix of lamp technologies used to light commercial spaces in Australia 2010 - 2030 (E3 2015).

Using the projected trends for lamp technology use, this has been applied to growth forecast for commercial space in Australia as given in the Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia (Nov 2012), with extrapolation to 2030. Projections of installed lamp stock in commercial (non-industrial) and residential spaces are provided respectively, in Figure 29 and Figure 30.

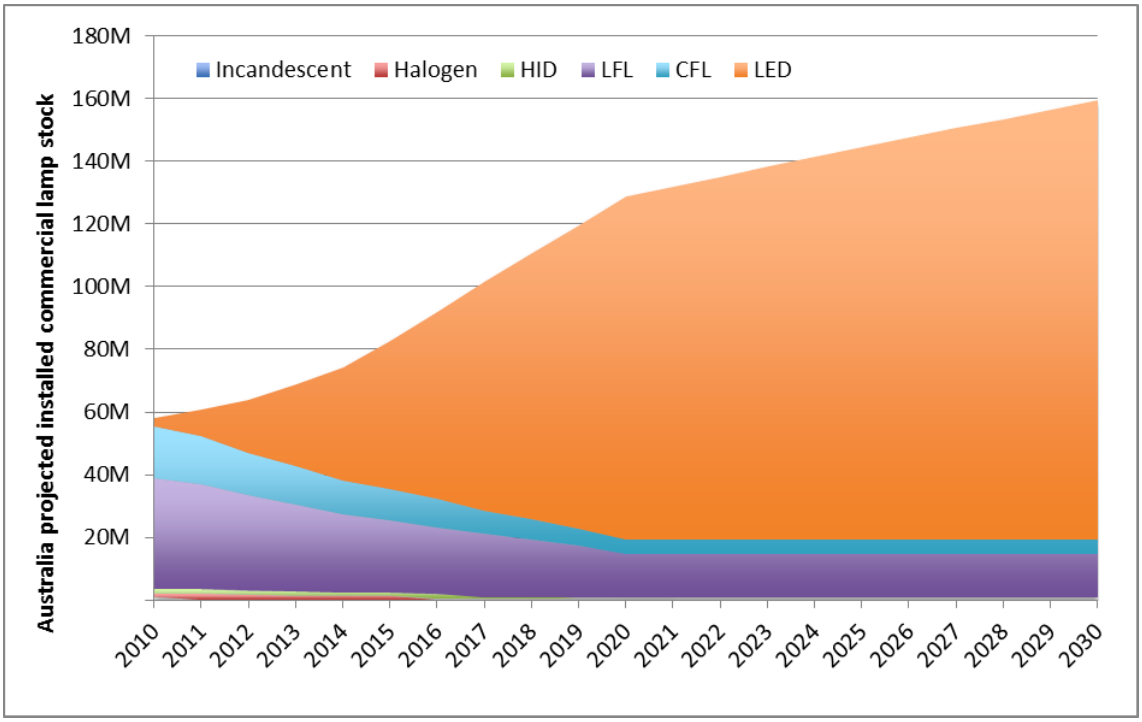

Figure 29. Projected installed commercial lamp stock in Australia 2010 to 2030.

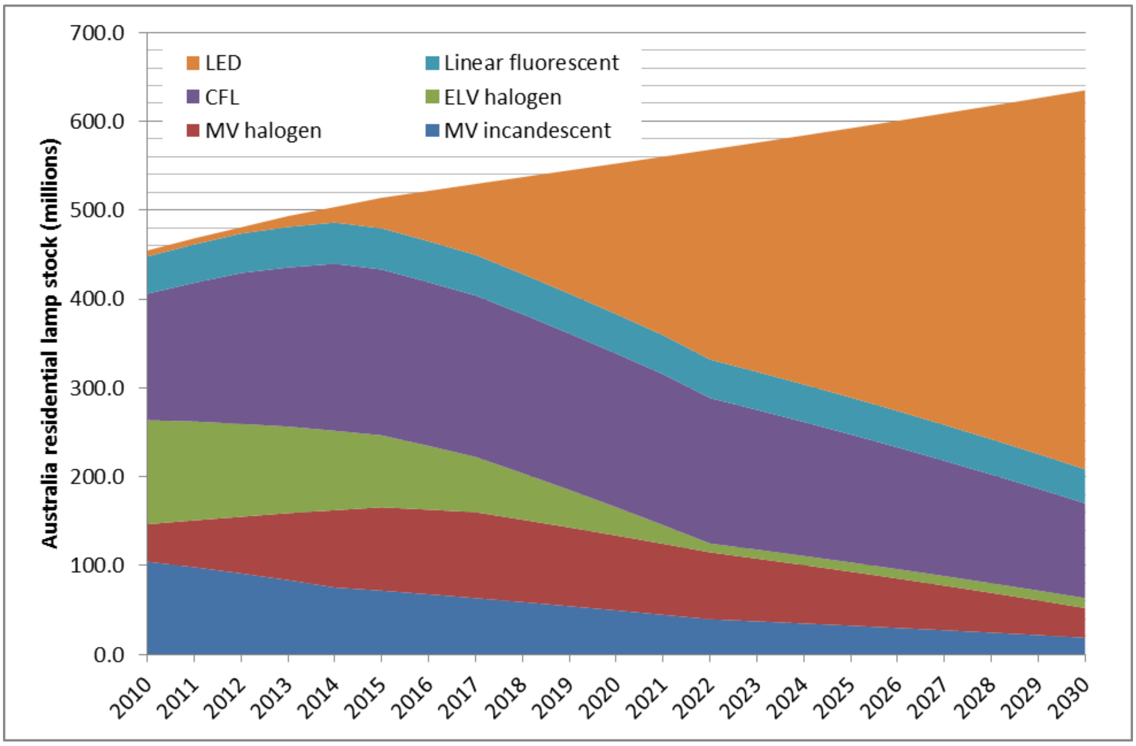

Figure 30. Projected installed residential lamp stock in Australia 2010 to 2030.

The projection of lamp growth in the commercial sector as shown in Figure 29 is that the market will grow at a rate of approximately 8% until 2020, and thereafter will grow at approximately 3 %. Lamp stock in 2014 is estimated to be 74 million units, growing by 2030 to 159 million. In the residential sector, it is expected that market growth with remain fairly consistent with housing growth at a rate of 1.7%, with 2014 numbers given at 504 million, projected to be 635 million in 2030. Note that due to the different lifetimes of different types of lighting technology, the number of imports of each category does not directly translate to the proportion of installed stock.

- CFLi lamp numbers may diminish due to current international discussions on phasing out, due to the emergence of viable cost effective alternative (LED).
- MV halogen numbers are also expected to diminish further as LED lighting emerging as a viable cost effective alternative - possibly leading to a market decline from 7% to below 5% in 2020.
- ELV halogen numbers are expected to diminish further than McKinsey prediction, due to LED lighting emerging as a viable cost effective alternative - possibly leading to a market decline from 7% to below 5% in 2020. Replacement of ELV halogen lamps with LED retrofit models are currently constrained in part by low voltage converted compatibility issues.

The projections in Figure 29 and Figure 30 do not take into account any further increase in MEPS requirements for incandescent lighting in Australia. The expected market share for LED lighting will in part be determined by how broad the consumer acceptance of the new technology becomes. This will be driven by a number of factors including:

- consumer understanding of how LEDs may be selected and used to effectively replace current technology to deliver a comparable or improved lighting service;
- consumer understanding of the overall comparative cost of each lighting technology;
- confidence in the quality and reliability of the lighting service provided; and,
- an understanding of the benefits of changing to more efficient and long life lighting technology at a higher up-front cost.

The current uptake of LED lighting may not automatically result in an overall market adoption of this technology if these factors are not addressed. Failure of LED lighting to be taken up by consumers would result in a less dramatic change to the lighting market and reduced opportunities for energy savings.

Further analysis of market trends with a residential lighting focus is available in chapter four of the Product Profile on Incandescent, Halogen and CFL Lamps (E3 2014).

5.3 New Zealand LED lighting market

5.3.1 Stock and sales

In 2011-2012, EECA and IPSOS surveyed 149 New Zealand homes. This was a comprehensive in-home survey of residential lighting in New Zealand, complemented by a survey to understand demographics and behaviour. The study comprised an in-home visual survey by trained personnel, as well as paper-based survey. This was an update of an EECA survey on lighting undertaken in 2009.

The study found an average of 34.5 lamps per New Zealand home, of which 9.5 were efficient types, and 25 inefficient types. On average 8.3 lamps were CFLs (an increase of 38% since 2009) and 1 fitting was fluorescent. 19.7 GLS incandescent lamps and 3.5 halogen lamps were present. On average, LEDs were less than 1% of total lamps found. A breakdown of lamp types found can be seen in Figure 31.

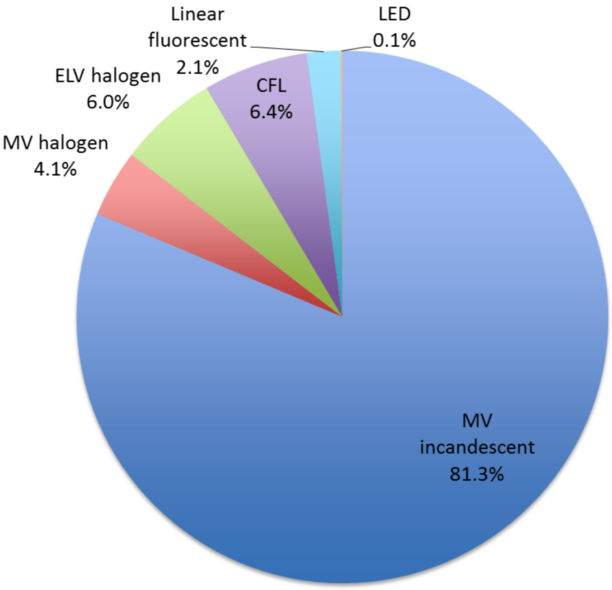

Figure 31. Lamp technology breakdown in the average residential house in New Zealand. Data from the EECA/IPSOS Lighting Report 2012 (survey).

Imports of lamps into New Zealand is considered a good proxy for lamp sales, however sales and import statistics can be inconsistent as warehouse inventory will fluctuate over time. The categorisation of lamps that are imported into New Zealand is not clearly detailed, which creates some complication in identifying lamps and their prospective install location, whether it be residential or commercial/industrial.

Similar to Australia, lamp importation records provide information on all major residential lamp types with the exception of LED lamp technologies. In categorisation of the lamps, 'halogen' lamps include mains and extra low voltage models; 'other filament' may incorporate incandescent, halogen and/or carbon filament types; 'fluorescent' is expected to contain both linear and compact fluorescent (CFLi, CFLn) lamp types.

Figure 32 illustrates imports of lamps into New Zealand between 2002 and 2013. From the data it can be seen that in recent years there has been a reduction in import numbers mains voltage incandescent and 'other filament' lamps, and an increase in imports of halogen and fluorescent lamps. Imports of HID and other discharge lamps into New Zealand are relatively low compared to other lamp types, and the numbers appear to increase on a 3-5 year cycle.

In the absence of import data sales of LED are difficult to predict, however according to EECA there are low supermarket sales of LED lamps while there has been a significant uptake of CFL products. More information would enable NZ to make a better informed case for MEPS.

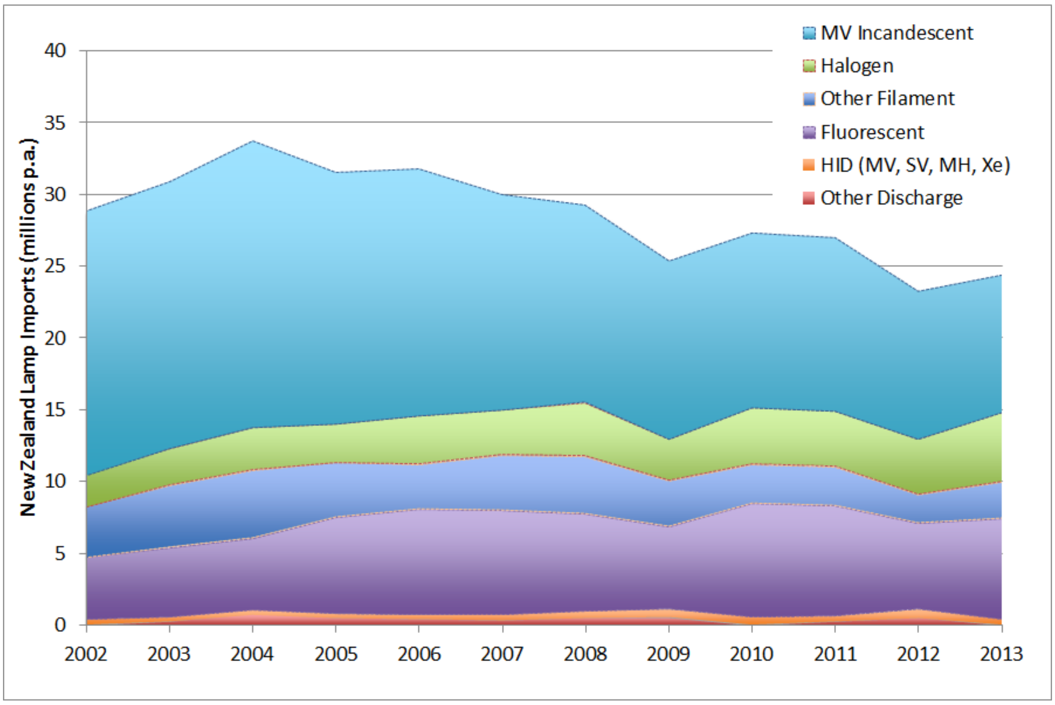

Figure 32. Imports of lamps, from Statistics New Zealand import data.

5.3.2 Projected trends

The projection of lamp growth in the New Zealand commercial sector as shown in Figure 33 is that the market will grow at a rate of approximately 9% until 2020, and thereafter will grow at approximately 4%. Lamp stock in 2014 is estimated to be 8.7 million units, growing by 2030 to 25.7 million, in line with growth estimates of the commercial sector.

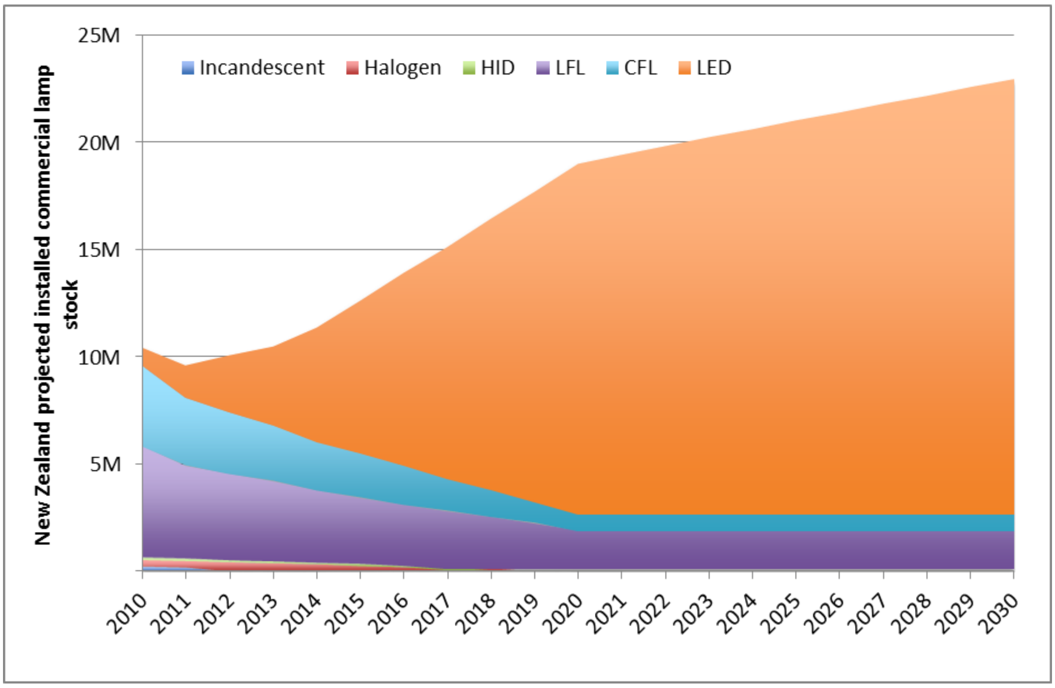

Figure 33. Projected installed commercial lighting stock in New Zealand, 2010 to 2030 (E3 2015).

In the residential sector, it is expected that market growth with remain fairly consistent with housing growth at a rate of 1.3%, with 2014 numbers given at 1.7 million, projected to be 2.1 million in 2030 (E3 2014).

The New Zealand lighting industry is invited to provide input.

6 Energy consumption and greenhouse gas emissions

6.1 Energy consumption

Lamp efficacy is a measure of efficiency, in lumens of light output from a lamp per Watt of electricity consumed. In order of increasing efficacy, residential, commercial and industrial lamps are typically as presented in Figure 34.

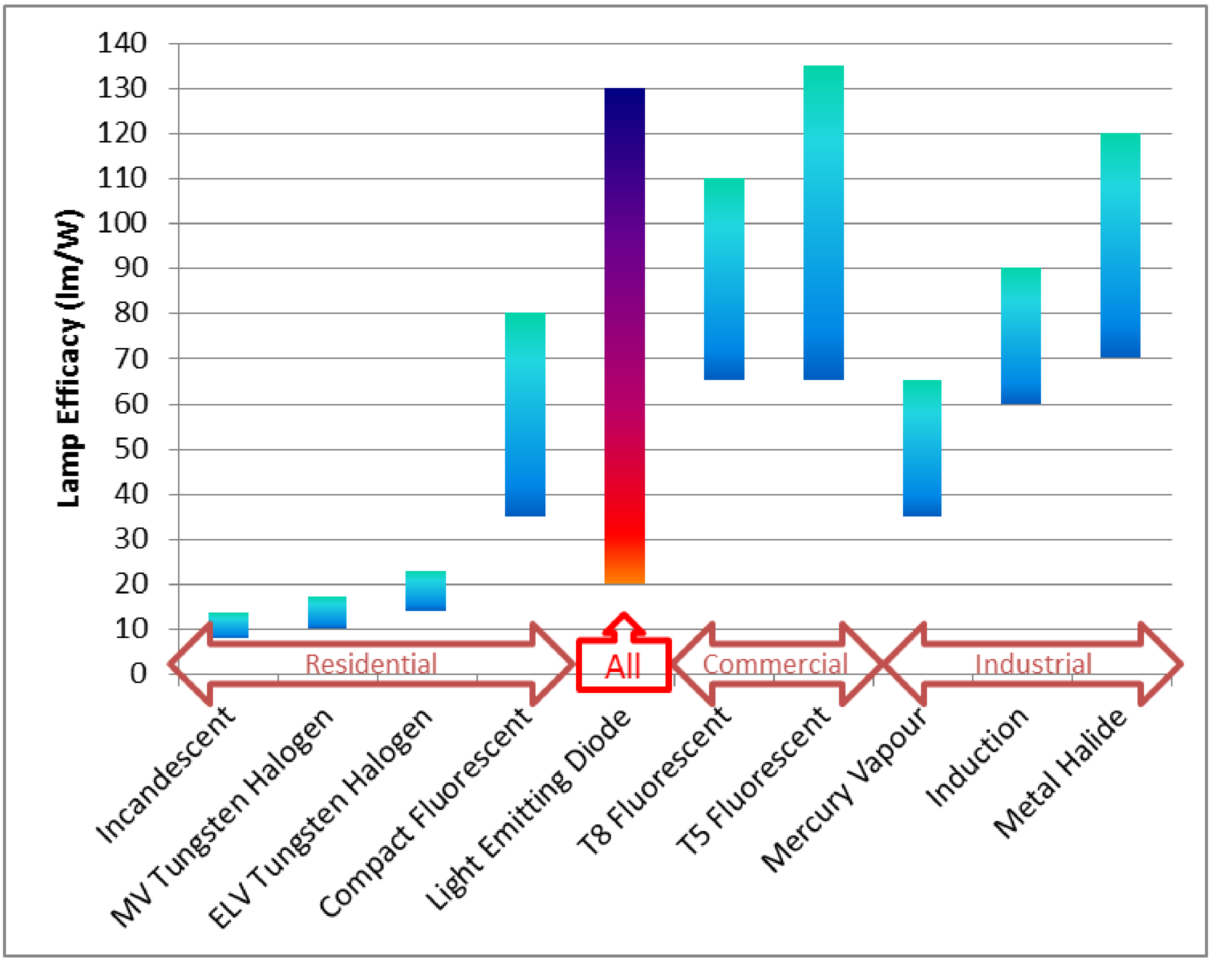

Figure 34 Typical efficacies of lamp technologies in residential, commercial and industrial applications.

Energy consumption by LED lamps would currently be a small percentage of overall lighting energy use, and the efficacy of LED lighting is expected to continue to improve over the next several years. The primary opportunity in achieving energy savings with LED lighting technology is through the replacement of less efficient technologies with LED lighting. Continued savings could also be made by removing poorer performing LED lighting from the market as the technology improves.

Annual residential lighting energy consumption is estimated at around 11 TWh (40 PJ) for Australia and 1.7 TWh (6 PJ) for New Zealand (E3 2014). Residential lighting is around 5% of total national electricity consumption.

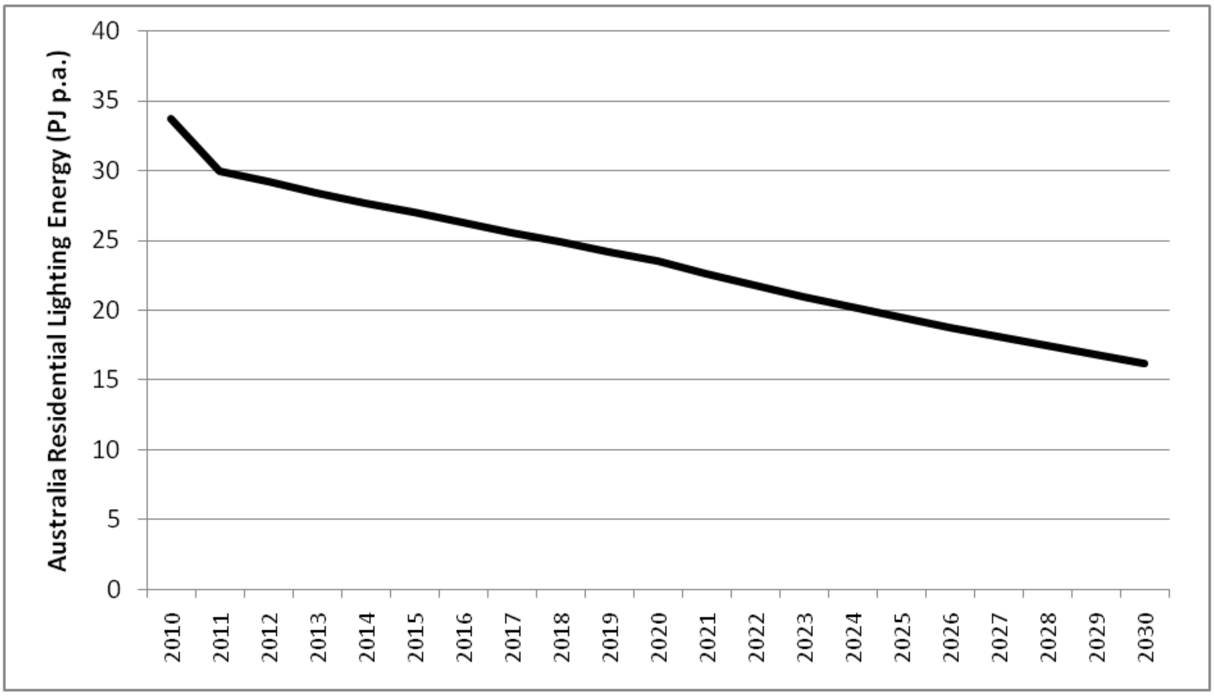

Figure 35. Estimated Australian residential lighting energy consumption to 2030

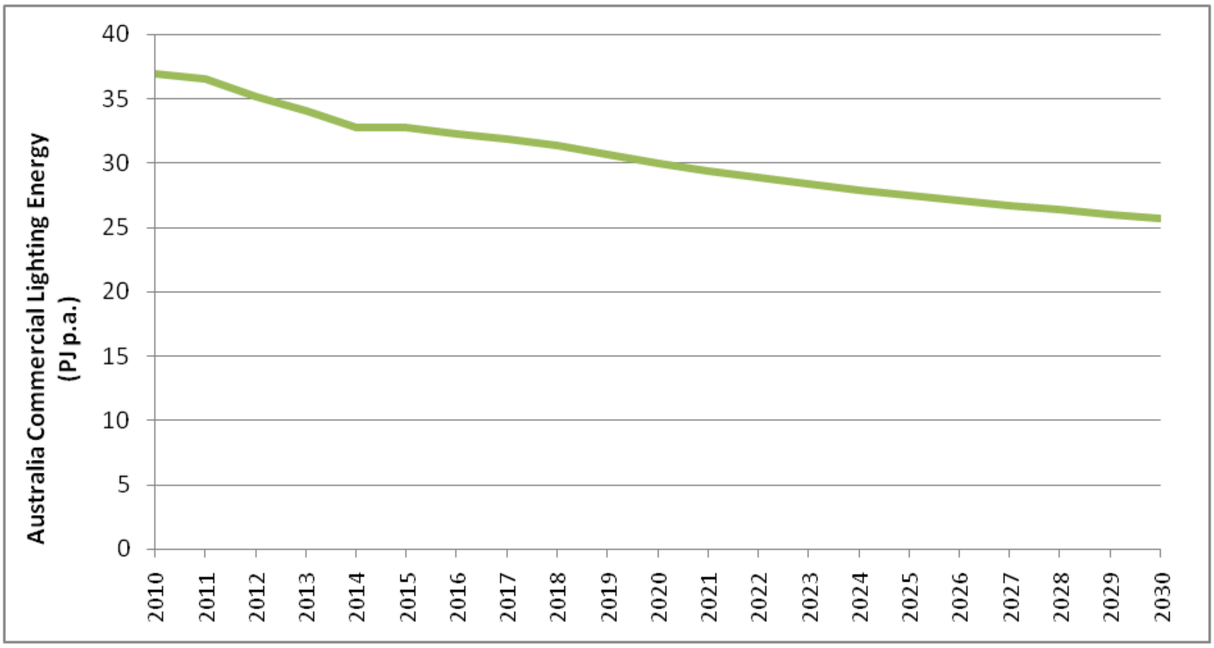

Figure 36. Estimated Australian commercial lighting energy consumption to 2030.

Estimated Australian residential lighting energy consumption is shown in Figure 35; and for commercial lighting in Figure 37. Estimated residential lighting energy consumption for New Zealand is shown in Figure 37. It is estimated that the New Zealand commercial sector consumes 8.9 PJ p.a. energy (Branz 2014) with projections currently not available. The total combined energy consumption for all lighting in Australia is currently 60 PJ p.a. and this value is projected to fall to 42 PJ p.a. by 2030. This assumes that the technology mix of lamp types in commercial spaces will evolve as shown in the previous section, and as given in Table 8 and 9, without further regulatory intervention. This model also assumes that LED efficacies will improve by approximately 5 lm/W per year (on average), where current values are approximately 70-75 lm/W, and will rise to a hypothetical 150 lm/W by 2030.

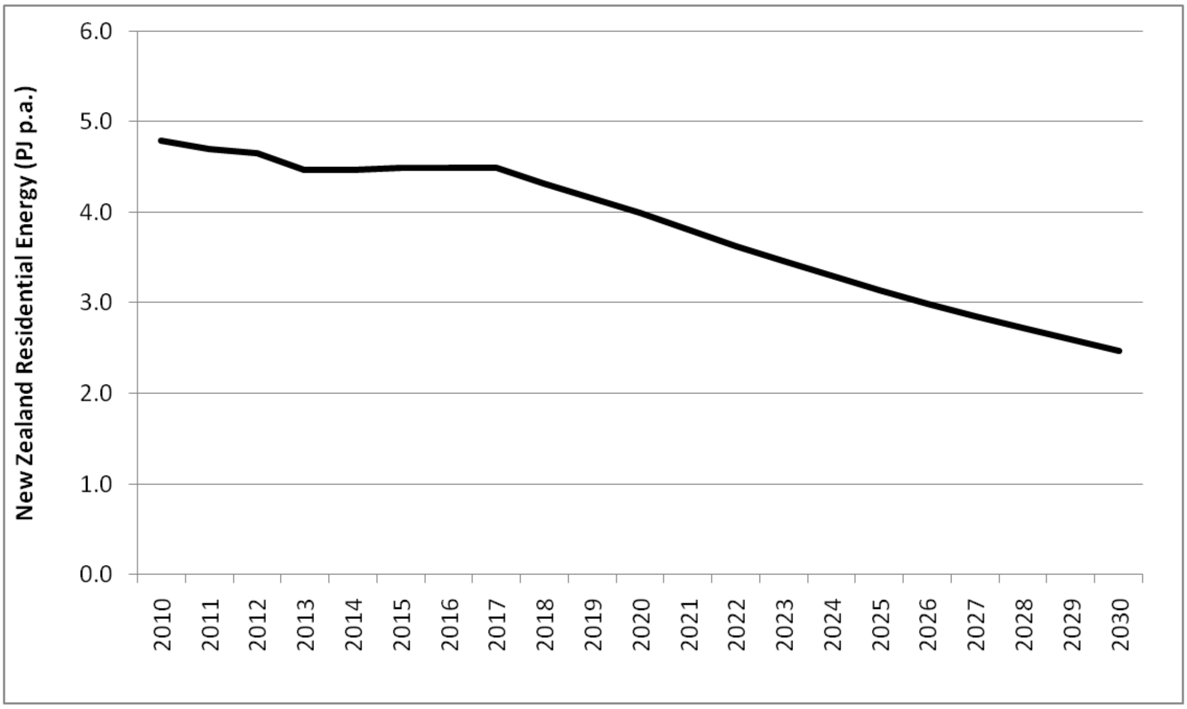

Figure 37. Projected energy consumption by residential lighting sources in New Zealand, 2010 to 2030 (without intervention).

Table 8. Technology mix in commercial (non-industrial) spaces estimated for 2014 and predicted in 2020 (McKinsey 2012) and 2030 without further regulatory intervention.

	2015	2020	2030
Incandescent	1.2%	0.3%	0.0%
Halogen	4.5%	2.2%	0.5%
HID	5.1%	3.1%	1.1%
LFL	40.6%	24.8%	9.2%
CFL	14.5%	7.4%	1.9%
LED	34.1%	62.3%	87.2%

Table 9. Technology mix in residential spaces estimated for 2014 and predicted in 2020 (McKinsey 2012) and extrapolated to 2030 without further regulatory intervention.

	2015	2020	2030
Incandescent	14.0%	9.0%	3.0%
MV Halogen	18.3%	15.3%	5.3%
ELV Halogen	15.8%	5.8%	1.8%
LFL	9.0%	8.0%	6.0%
CFL	36.3%	31.3%	16.8%
LED	6.7%	30.7%	67.2%

Installed stock projections suggest that overall; there will be average growth in installed units Australia-wide of approximately 1.5% in residential settings and 6.4% in non-residential settings, which will deliver 3.4% growth yearly average in installed stock (Figure 30).

6.2 Greenhouse gas emissions

In the combined residential and commercial sectors of Australia and New Zealand, the energy savings introduced in the previous section which would be incurred with majority uptake of LED technologies (without further regulatory intervention) would amount to a saving of 4.4 megatonnes of greenhouse gas emissions in Australia (, as 2015 estimates show that emissions are currently 14.6 megatonnes, but could fall to 10.1 megatonnes Co_2-e. In New Zealand, national estimates for combined residential and commercial lighting suggest current greenhouse gas emissions are 1.25 megatonnes, which would fall to 0.91 megatonnes Co2-e, translating to a saving of 0.34Co_2-e.

Table 10. Summary of energy consumption and greenhouse gas emissions in Australia and New Zealand in 2015, and projected in 2020 and 2030 (without further regulatory intervention).

Australia		**2015**	**2020**	**2030**
Energy consumption (PJ p.a.)	Residential	27.0	23.5	16.2
	Commercial	32.7	29.9	25.7
	Total	**59.7**	**53.4**	**41.9**
Greenhouse gas emissions (Mt Co$_2$-e)	Residential	6.6	5.7	3.9
	Commercial	8.0	7.3	6.3
	Total	**14.6**	**14.0**	**10.2**
New Zealand		**2015**	**2020**	**2030**
Energy consumption (PJ p.a.)	Residential	4.5	4.0	2.5
	Commercial	8.9	7.9	6.7
	Total	**13.4**	**11.9**	**9.2**
Greenhouse gas emissions (Mt Co$_2$-e)	Residential	0.17	0.15	0.10
	Commercial	2.2	1.9	1.6
	Total	**2.4**	**2.1**	**1.7**

6.3 Full Transition to Efficient lighting (Residential)

Residential energy savings which could be afforded from a full conversion to LED and CFL lamps (most likely requiring some government intervention) are detailed in Table 12. Household annual energy savings, from these calculations, would be around $180 p.a. per household for both Australian and New Zealand households (assuming an electricity cost of 25c/kWh).

Table 11 Current Average technology mix in Australian and New Zealand Households

Current (2010/2012)							
Lamp mix per house	**Lamps AU 2010**	**Lamps NZ 2012**	**Av Lamp Power (W)**	**Energy kWh p.a. AU 2010**	**Energy Cost (@25c/kWh) Australia 2010**	**Energy kWh p.a. NZ 2012**	**Energy Cost (@25c/kWh) NZ 2012**
MV incandescent	11.0	20.8	73	438	109	829	207
MV halogen	4.4	1.5	51	123	31	42	10
ELV halogen	12.3	2.3	49	330	82	62	15
CFL	15.0	8.7	14	112	28	65	16
Linear fluorescent	4.4	0.9	41	100	25	21	5
LED	0.7	0.2	10	4	1	1	0
Total	**48**	**34.5**		**1106**	**277**	**1019**	**255**

Table 12 Potential for household lighting energy savings from converting to CFL and LED (compared to Australia 2010 and New Zealand 2012.

Potential					
Lamp mix per house	**Av New Lamp Power (W)**	**Energy kWh p.a. AU Potential**	**Energy Cost (@25c/kWh) Australia**	**Energy kWh p.a. NZ Potential**	**Energy Cost (@25c/kWh) NZ**
MV incandescent -> **LED/CFL**	15	88	22	166	41
MV halogen -> **LED/CFL**	15	35	9	12	3
ELV halogen -> **LED/CFL**	8	54	13	10	3
CFL	14	112	28	65	16
Linear fluorescent	41	100	25	21	5
LED	10	4	1	1	0
		392	**98**	**275**	**69**
Energy saving %		65%		73%	
Energy Cost Savings			$179		$186

7 Relevant standards and regulations in Australia and New Zealand

7.1 Test and efficiency standards/labelling

There are currently no efficacy and performance test standards or mandatory MEPS or labelling schemes in place for LED lighting in Australia or New Zealand. However there are a range of regulations, programs and voluntary schemes outlined below that relate to lighting energy use more generally and in this way can influence LED lighting.

7.1.1 Current Australian and New Zealand test laboratory capability

There are at least four lighting testing laboratories in Australia and three in New Zealand that are able to perform lighting compliance tests, particularly in compliance with international standards. However, as outlined below, until 2015 there was an absence of international LED test standards, meaning that test laboratories may have been testing against an assortment of national level standards from other countries. In 2013, three test laboratories from Australia and one from New Zealand took part in an international inter-laboratory comparison exercise organised by the IEA 4E SSL Annex that compared the measurement accuracy of 110 laboratories worldwide testing LED lamps and luminaires. Proficiency testing is used to establish whether a laboratory can be accredited for a specific test standard.

Additional lighting test laboratories are also available in other countries in the region.

7.1.2 MEPS Regulations for Appliance Energy Efficiency

In Australia, determinations under the GEMS Act set out specific product requirements. Requirements are described either directly in the determination, or the determination will refer to the applicable clause in a product standard – for lighting products the latter applies with some clarifications contained within the determination itself. Currently lighting determinations under the GEMS Act apply to: incandescent, CFLi, linear fluorescent, ballasts for fluorescent lamps, and transformers and convertors for halogen lighting.

In New Zealand, certain lighting products are covered by the *Energy Efficiency (Energy Using Products) Regulations 2002* and must meet certain requirements before they can be legally sold. General requirements are set out in the regulations, and specific details for each product type, such as MEPS and labelling details, are described in product standards. New Zealand has MEPS for CFLi, linear fluorescent, ballasts for fluorescent lamps, and transformers and convertors for halogen lighting.

7.2 Other Relevant Standards, Regulations and Government Programs

7.2.1 Interior lighting

The AS/NZS 1680 series for interior lighting contain minimum recommended illumination levels for performing a range of visual tasks efficiently and without visual discomfort. The standards which comprise AS/NZS 1680.2 provide recommendations for specific applications, while Part 4 of the Standard provides recommendations for maintenance techniques of lighting systems. This includes cleaning, relamping and ensuring the luminaires are suited to the lamp to prolong operating time. Only a limited part of the standard is referred to in regulation. The guidance on lighting levels provided by the standard is particularly relevant to evaluating the adequacy of lighting levels delivered by LED retrofit installations.

7.2.2 National Construction Code and Building Code of Australia

The Building Code of Australia (BCA) lighting efficiency provisions first came into effect in May 2005 and various lighting provisions have been added since, for both commercial and residential buildings. The primary mechanism for these provisions is a maximum illumination power density requirement (Watts/m^2) for new construction or significant renovation. Since May 2011, the maximum aggregated lamp power density of hard-wired electric residential lighting is:

- 5 Watts/m^2 for internal areas
- 4 Watts/m^2 for exterior areas
- 3 Watts/m^2 for garages.

For non-residential buildings, the lighting power density is dependent on the building use and space (Table 13). The illumination power density includes power loss through ballasts and control devices. The power densities given in Table 13are based on lighting design that complies with the Australian Standard for interior lighting (AS 1680), but also provide a safety margin, take into account physical limitations of lighting installations and are set at a level that can be achieved through a combination of practical surface reflectance, high efficacy lamps and efficient control gear and luminaires (ABCB 2010).

Table 13.BCA maximum illuminated power densities for select spaces in commercial buildings, and corresponding AS 1680 lighting levels and lumens per watt (ABCB 2010).

Building Space	Watts/m^2	Recommended Lux Level (AS/NZS 1680 Interior Lighting)	Lumens/Watt
Board room and conference room	*10*	*240*	*24*
Corridors	*6*	*160*	*27*
Entry lobby from outside the building	*15*	*160*	*11*
Office – artificially lit to an ambient level of 200 lux or more	*9*	*320*	*33*
Office – artificially lit to an ambient level of less than 200 lux	*7*	*160*	*23*
School – general purpose learning areas and tutorial rooms	*8*	*320*	*40*

An adjustment can be applied to the maximum illuminated power density to recognise the use of energy control devices such as dimmers, timers and daylight sensors. The adjustment factor is a graduated scale, depending on the area of lights controlled by devices such as occupancy sensors.

7.2.3 Commercial Building Disclosure (CBD) (Australia)

CBD is a national program which requires premises, of 2000 m^2 or more, to disclose a National Australian Built Environment Rating System (NABERS) rating and the results of a tenancy lighting assessment, when being offered for sale or lease. The tenancy lighting assessment measures the power density of the installed general lighting system by calculating the Nominal Lighting Power Density (NLPD) of the relevant functional space in the building and can also include proposed lighting systems. The lighting provisions came into force in November 2011 (see the CBD website (www.cbd.gov.au) for more information). NABERS has been adopted on a voluntary basis in New Zealand.

7.2.4 New Zealand Building Code

The New Zealand Building Code (NZBC) is the first schedule of the *Building Regulations 1992*. The NZBC is a performance-based regulation that sets the standards building work must meet. It covers a variety of building aspects including energy efficiency.

Clause H1 Energy Efficiency of the NZBC prescribes energy efficiency performance standards. The objective of Clause H1 is to facilitate the efficient use of energy. One of the functional requirements is that ‘Buildings must be constructed to achieve an adequate degree of energy efficiency when that energy is used for … providing artificial lighting’. This requirement only applies to commercial buildings and communal non-residential buildings with a floor area greater than 300 m^2. The provisions of the NZBC are that artificial lighting fixtures must be –

- located and sized to limit energy use, consistent with the intended use of space; and
- fitted with a means to enable light intensities to be reduced, consistent with reduced activity in the space.

Artificial lighting in commercial buildings must comply with NZS 4243.2:2007 Energy efficiency – Large buildings – Lighting, sections 3.3 or 3.4, to satisfy the above provisions. The maximum lighting power density in the standard is 12W/m2.

Clause G8 Artificial Light of the NZBC has been developed to protect people from injury due to inadequate lighting, and stipulates that illuminance at floor level must be no less than 20 lux. There are no specific requirements for lighting energy efficiency of residential premises in the NZBC.

7.3 Voluntary programs, incentive schemes and education

7.3.1 Energy Star (New Zealand)

ENERGY STAR is a voluntary energy efficiency program originally established by the U.S. Environment Protection Agency. The New Zealand Energy Efficiency and Conservation Authority administers the New Zealand Energy Star voluntary labelling scheme for a range of products including LED and CFLi lighting and a range of luminaires as a way for consumers to identify the most efficient and best performing products.

The ENERGY STAR program uses an endorsement mark to indicate those models produced by participating manufacturers and suppliers that are performing at a high-efficiency level (top 25% most energy efficient products), as defined under the relevant specification. This provides an independent verification of energy efficiency to consumers, and provides a selling point that manufacturers, suppliers and retailers can use in their promotion of lighting products. New Zealand currently uses the ENERGY STAR program with significant success with consumer brand awareness measured at 78% (2012).

However, as this is a self-selecting program and only addresses energy performance at the high end of the scale, the program on its own is less effective in addressing the energy efficiency of products than when it is used to complement measures such as MEPS and comparative energy labelling.

The specification applies to integral LED lamps, defined as a lamp with LEDs, an integrated driver and an ANSI standardised base designed to connect to the branch circuit via an ANSI standardised lampholder/socket, including:

- lamps of a non-standard form
- replacements for standard general service incandescent lamps, decorative (candelabra style) lamps and reflector lamps.

The requirements of the LED specification are identical to those in the US ENERGY STAR specification, with additions to the allowable lamp bases and operating voltage. The requirements specified for all lamps are: correlated colour temperature (CCT); colour maintenance; colour rendering index (CRI); allowable lamp bases; power factor; minimum operating temperature; LED operating frequency; EMC; noise; transient protection; operating voltage; safety requirements; and packaging. Additional requirements are specified for non-standard lamps, replacement lamps lumen maintenance and lifetime claims.

The New Zealand ENERGY STAR specification for luminaires came into effect on 1 November 2012 in New Zealand. The objective is the save money on energy bills and bulb replacements and distribute light more efficiently and evenly than standard fixtures, with qualifying luminaires using only a quarter the energy of traditional lighting. The requirements are identical to those in the US ENERGY STAR specification, with the exception of some amendments (additional lampholder types and changes to the downlight types to meet New Zealand electrical safety requirements).

The luminaire ENERGY STAR specification is primarily for residential luminaires and some commercial luminaires (excludes commercial street, high bay, recessed troffers or other types of lighting employed for general office illumination). This includes solid state lighting (SSL) downlight retrofits and all inseparable SSL luminaires including non-directional inseparable SSL luminaires.

There are currently 5 models of LED lamps and 26 models of LED luminaires registered with NZ ENERGY STAR.

7.3.2 SSL Quality Scheme

The SSL Quality Scheme is a voluntary industry labelling program operated by Lighting Council Australia for SSL luminaires (note, only members of Lighting Council Australia or Lighting Council New Zealand can participate in the scheme). The SSL Quality Scheme is based on the US Department of Energy 'Market Facts' label and suppliers must report on a minimum set of critical parameters to participate in the scheme.

- Luminaire efficacy
- Light output of the luminaire
- Measured input power
- CCT
- CRI

The label is intended to provide the market with confidence that a luminaire with the scheme label matches the performance claims made by the supplier – however it does not set minimum performance requirements like programs such as regulated MEPS schemes or ENERGY STAR. Scheme participants must provide test reports or other evidence to Lighting Council Australia to verify their claims, and Lighting Council Australia then registers the product on a database(www.lightingcouncil.com.au). There are currently 194 products registered.

7.3.3 Incentives

7.3.3.1 Australia

The NSW Energy Savings Scheme (ESS)(www.ess.nsw.gov.au/Projects_an_equipment/Lighting) includes lighting retrofits in commercial or industrial facilities. Evidence is collected on the lighting configuration before and after an upgrade, and testing is conducted to ensure that the final lighting configuration meets relevant lighting standards so output and service levels are maintained. The Commercial Lighting Energy Savings Formula is used to calculate energy savings from an upgrade and energy savings certificates are created, which purchased by electricity retailers. Over 2.1 million certificates for commercial lighting upgrades have been surrendered since 2009 – this represents 2.1 million tonnes of CO_2e that has been reduced or removed from the atmosphere.

The Victorian Energy Efficiency Target (VEET) scheme(www.veet.vic.gov.au) entitles a commercial energy consumer to a discount on the product installed (an Energy Saver Incentive) when undertaking a commercial lighting upgrade using a business accredited under the scheme to make the energy efficiency improvements. The accredited business creates a Victorian energy efficiency certificate (VEEC) for every one tonne of greenhouse gas abated. Up to mid-2015 0.48 million certificates have been generated from business lighting upgrades at 1,725 sites; 7.80 million certificates have been generated from replacing incandescent light globes (mainly residential) with low energy lamps (mainly CFLs) at 825,811 sites; and 3.74 million certificates have been generated from replacing 12 volt halogen downlights (mainly residential) with LED lamps at 147,659 sites.

The ACT Energy Efficiency Improvement Scheme (EEIS)(www.environment.act.gov.au/energy/energy_efficiency_improvement_scheme_eeis) began on 1 January 2013 and sets a Territory-wide energy savings target, including obligations for ACT electricity retailers to meet an individual Retailer Energy Savings Obligation (RESO). The EEIS is based on existing schemes such as VEET, ESS and the Residential Energy Efficiency Scheme (South Australia) but is not based on creating and trading certificates. The scheme was recently extended to include ACT business premises.

The South Australian Retailer Energy Efficiency Scheme (http://www.sa.gov.au/topics/water-energy-and-environment/energy/rebates-concessions-and-incentives/retailer-energy-efficiency-scheme-rees) commenced on 1 January 2015 and builds on the Residential Energy Efficiency Scheme, which operated from 2009 to 2014. The objective of the scheme is to reduce household and business energy use, with a focus on low-income households. Energy retailers that exceed certain thresholds are set annual targets for the delivery of energy efficiency activities to households and/or businesses. In addition, retailers with larger residential customer bases are set targets for ensuring that a certain amount of the energy-efficiency activities they deliver go to low-income households; and providing energy audits to low-income households. Energy efficient activities that maybe offered under the scheme include the installation of energy efficient lighting in homes and businesses.

7.3.3.2 New Zealand

EECA offered Commercial Project Grants for lighting efficiency projects until July 2015.

7.3.4 Education

The New Zealand Energywise Website (www.energywise.govt.nz) contains detailed information on efficient lighting. The website includes calculators, tabulated information and extensive guidance on lighting performance and choices.

The E3 Energy Rating website (www.energyrating.gov.au/) contains information on lighting energy efficiency including a retailer training guide on efficient lighting and design, an efficient lighting training manual for related trades and professionals (under revision to include more information on LED lighting), and a consumer guide to buying LED lighting.

8 International energy efficiency programs

A number of countries have already implemented, or are the process of implementing, regulatory or voluntary mechanisms for LED lighting products. These can include:

- Minimum Energy Performance Standards (MEPS)
- High Efficiency Performance Standards (HEPS)
- Comparative Labelling Schemes
- Endorsement Labelling Schemes

The base levels of both performance standards, i.e. MEPS and comparative labelling schemes, are typically mandated. Whereas higher levels for performance standards, i.e. HEPS and endorsement labelling schemes, are typically voluntary.

Each of these regulatory mechanisms requires test methods for which each nominated parameter shall be measured. The test methods for some or all of the specified parameters may be incorporated within the regulation or be referenced from third party entities, such as:

- International Commission on Illumination (CIE)
- International Electrotechnical Commission (IEC)
- Illuminating Engineering Society of North America (IESNA)
- National Standards organisations (e.g. Standards Australia, Standards New Zealand)

Appendix B summarises the economies that have voluntary and mandatory regulatory regimes for LED lighting products, the scope of LED products covered and the test methods used, for the purpose of identifying which programs are considered appropriate for further investigation by the Australian and New Zealand governments. At the time of publication, while several countries have implemented labelling schemes or voluntary measures relating to LED products, mandatory minimum energy performance standards for LED lamps have been implemented in only a few economies including the EU, Mexico and Malaysia. In several other countries, including the USA, MEPS requirements are under development.

Regulatory and voluntary approaches applied to incandescent and CFL lamps are discussed in the Incandescent and CFL Product Profile 2014.

8.1 European Union

The scope of the EU regulation includes lamps (including LED lamps) that have standard single ended caps for domestic use as well double ended halogens. All lamp technologies are covered but have different “weighting” functions based on the inherent efficiency/power relationship of each technology. These weighting functions facilitate the moderation of technology performances and the use of a unified Energy Efficiency Index, EEI, which benchmarks relative to a “standard” incandescent lamp.

This methodology becomes problematic where the increase in wattage for a particular technology (e.g. LED) does not provide an increase in efficacy (which is the basis/theory of the original baseline curve for the “standard” incandescent). Using this baseline presents the issue of whether to provide a secondary weighting function to compensate/correct it to a more realistic function for LED technologies or to accept that the energy efficiency performance is less onerous for lower wattage lamps. The latter is the approach that has been adopted by the EU. The current (2013) MEPS levels for lower wattage non-directional lamps in EC Regulation 244/2009 are therefore relatively low for the capability of LED products when compared to IEA 4E SSL Tier 1, which is discussed below.

The EU non-directional household lamps regulation came into force in September 2009. This regulation specifies an energy efficiency requirement (generic to all lamp technologies) but no other light quality and performance requirements for LED non-directional lamps. Countries that have adopted this regulation are Jordan, Switzerland

and Turkey. The regulation is set out in 6 stages. Requirements for the first 4 stages have eliminated low-efficacy lamps, such that all general purpose tungsten filament incandescent lamps should have been phased-out from the EU market by 1 September 2012. These stages also specify minimum functionality requirements for incandescent and CFL lamps including minimum rated lamp lifetime, lumen maintenance, number of switching cycles, starting time, heat-up time, premature failure rate, UVA+UVB radiation, UVC radiation, lamp power factor and colour rendering index. Stage 5 (from 1 September 2013) increases the stringency of these requirements.

Stage 6 (was to apply from 1 September 2016 but on March 2015 this was delayed to 2018) sets more stringent efficacy requirements for halogen lamps – specifically, an efficacy increase of 25% (corresponding to the lower limit value of the 'B' energy class) for two types of clear lamps:

- Low voltage non-directional halogen lamps
- Mains voltage non-directional halogen lamps, excluding G9 and R7s.

Although this is not as stringent as already applies to CFL and LED lamps, this would effectively remove these halogen lamp categories from the market as they would not be able to comply with the new efficacy requirements.

The EU regulation for directional lamps, light emitting diodes and related equipment (EC Regulation 1194/2012) came into force in July 2012. As well as the energy efficiency requirements and other light quality and performance requirements for directional lamps (including LED but specific to each lamp technology), this regulation also provides the specific light quality and performance requirements for non-directional and directional LED lamps (which were not included in the regulation above) including:

- Efficacy;
- Lamp survival;
- Lumen maintenance;
- Switching withstand;
- Start time;
- Run up time;
- Premature Failure Rate;
- Colour rendering;
- Colour Consistency; and
- Power Factor

The United Arab Emirates has recently adopted this regulation. The regulation does not specify test methodology, leaving this to member countries.

In terms of directional lamps, the EU has taken the approach of using performance criteria that firstly defines a directional lamp. This is: a directional lamp is "a lamp having at least 80% light output within a solid angle of π steradians (corresponding to a cone with angle of 120°)". In terms of then measuring lamp efficacy, only the luminous flux that is defined as "useful lumens" within a specific cone is to be measured. The argument presented was that for a directional lamp, light outside this designated cone provided no useful value to luminous environment; for directional lamps with a beam angle ≥ 90° this means a 120° cone, and for all other directional lamps (i.e. < 90° beam angle), it means a 90° cone.

This approach has brought crossed purposes to MEPS (which is fundamentally for energy efficiency) by linking the energy performance parameter and associated criteria to an application issue (i.e. beam control). The resulting regulation now dictates/limits the luminous flux that can be included in the measurement of lamp efficacy regardless of whether the extraneous flux (outside the arbitrary cone) contributes in a particular application. There is a valid argument that this "non-useful" luminous flux always contributes to the ambient lighting of the space. From the consumers perspective the validity of this approach is dependent upon the use of the directional lamp – if used as a downlight for general area lighting (as in many Australian and New Zealand homes), the EU definition would exclude consideration of light that will provide a useful service; if the lamp is instead used for a specific beam angle to, for example, illuminate a feature on a wall, then the EU approach would be more accurate.

The useful lumens metric also creates difficulties in affordable test methods (in terms of time and equipment required); measurement can only be achieved with the use of a goniophotometer (rather than an integrating sphere). This is an expensive asset to purchase and to maintain accreditation for test methods. The cost of a typical total luminous flux test is approximately five times that of a test using an integrating sphere. This may potentially be a disincentive for new manufacturers to enter the market as well as for governments to conduct compliance check testing. At this stage we are not aware of any published results of compliance check testing on directional lamps covered under this regulation (it is the responsibility of the member states within the EU to conduct their own compliance check testing).

There is no registration system employed by the EU regulations. The philosophy is that products bearing the CE marking will be regarded as conforming to the relevant provisions. Manufacturers (or authorised representatives) are to retain relevant documents relating to conformity assessment performed and declarations issued.

Alongside the current staged approach to lighting MEPS in the EU, a review of the system is also being undertaken including consideration of further product consolidation of lighting MEPS. The study is expected to be released by the end of 2015, with revisions to regulations being published at a later date and target implementation dates of 2020 and 2024.

8.2 Mexico

The Mexican Minimum Performance Standard for LED Lamps applies to all integrated LED lamps omnidirectional and directional, which are used for general illumination in electrical voltages supply of 100 V to 277 V AC, 50 Hz or 60 Hz (with some specified exemptions). This regulation includes energy efficiency and functional requirements and the test methods are incorporated within the regulation. Parameters include:

- Efficacy;
- Colour temperature;
- Maintained luminous flux;
- Colour rendering;
- Power Factor;
- Transient overvoltage;
- Thermal shock; and
- Switch withstand.

8.3 International Energy Agency

The International Energy Agency, Energy Efficient End-use Equipment, Solid State Lighting Annex (IEA 4E SSL) was established in 2009 for the purpose of providing advice to its ten member countries which were seeking to implement quality assurance programs for SSL lighting. The collaboration brought together the governments of Australia, China, Denmark, France, Japan (currently not active), The Netherlands, Republic of Korea, Sweden, United Kingdom and United States of America.

A key collaborative task for IEA 4E SSL has been development of performance tiers for a number of LED product categories. The categories are: non-directional lamps, directional lamps, downlight luminaires, linear LED tubes (retrofit and non-retrofit), and streetlights/outdoor lighting. Performance tiers for other products namely planar fixtures, troffer retrofit kits, high bay and low bay commercial fixtures are currently being developed, while there are also plans to update the initial series of performance tiers.

The tiers are designed to provide a limited (rationalised) set of performances that could be adopted by countries for their energy efficient lighting programs, including MEPS, HEPS, endorsement labels, incentive schemes, procurement schemes and the like. Tier 1 is intended to be the minimum acceptable performance when products are used for grid-connected applications. This would be an appropriate level to consider as a MEPS regulation for a country.

The performance thresholds for these products, unlike the EU regulation, are flat, acknowledging that efficacy is not directly linked to power for these product categories but more so to the product size and ability to manage thermal heat dissipation. This is further discussed in Section 9.2.2.

As part of the IES 4E SSL 2013 Inter-laboratory Comparison, which compared 110 testing laboratories around the world, the Annex developed a common laboratory proficiency test, drawing upon available national test standards. However future Annex work on testing will be directed support and evaluation of the recently published test method developed by CIE TC 2.71 for all relevant metrics.

The SSL Annex also recommends suitable accreditation frameworks for SSL testing laboratories, to ensure a structure for worldwide interim reliability of SSL testing laboratories' performance data.

The SSL Annex has also commenced a review of LED lifetime metrics and testing in order to provide advice to governments on this issue.

8.4 Test Methods

The primary test methods relevant to LED lighting products that are referenced by regulatory programs are produced by three organisations: the International Electro-technical Commission (IEC); the International Commission on Illumination (CIE) and the Illuminating Engineering Society of North America (IES). The IES published the initial set of LED test procedures in 2008 and became at that time the de-facto international test methods as neither the CIE nor IEC had published test methods specific to the needs/sensitivities of LED products.

Whilst the IES test procedures are referenced by some countries, mainly for measuring performance metrics within their more established labelling programs, the countries with more recent MEPS regulations have been adopting international test methods from the IEC and CIE.

Until the publication of CIE TC 2.71 in 2015, there was no international test method for SSL products. This presented difficulties for accreditation bodies to carry out SSL proficiency testing of test laboratories as part of their ISO/IEC 17025 accreditation (issued by laboratory accreditation bodies, this provides formal recognition of a laboratory's competency for testing and calibration for specific international standards). The absence of an international test method has also caused inconsistencies in the way that manufacturers test and rate product performance. CIE TC 2.71 will provide an internationally recognised extensive test method to support future MEPS programs.

8.4.1 IES LM-79 Electrical and Photometric Measurements of Solid-State Lighting Products

This IESNA approved method describes procedures and precautions in performing reproducible photometric measurements of LEDs for the following parameters:

- total luminous flux (lumens)
- electrical power (Watts)
- luminous efficacy (lm/Watt)
- chromaticity

The scope applies to LED-based products incorporating control electronics and heat sinks for products requiring mains voltage or DC power supply. It includes complete LED luminaires and integrated LED sources (LED chips with heat sinks), but does not cover LED products requiring external operating circuits or fixtures designed for LED products but sold without a light source.

Traditionally, photometric evaluation of lighting products is based on separate tests for lamps and luminaires ('relative' photometry) however for SSL products, LED lamps typically cannot be separated from their luminaire because of heat effects. For this reason, LM-79 requires complete luminaire testing, and is therefore 'absolute' photometry.

8.4.2 IES LM-80 Measuring Lumen Maintenance of LED Light Sources

This provides the IESNA approved method for measuring lumen maintenance of solid-state (LED) light sources, arrays and modules. This standard essentially applies at the component level and does not cover measurement of luminaires. The standard was developed out of a necessity to define the time taken to reach 'operational failure'. For most light sources, end of life is categorised by when they 'burn out', and lamp life is typically rated at 50% failure rate of the sample. LED light sources typically don't fail in this way as they have no filament to 'burn' (however more recently early failure of electronic components has also emerged as a factor), and so life for LEDs had to be redefined by its useful light output or lumen maintenance – at a given point in the gradual decline of lumen output it would be determined that the LED had reached 'life'.

Using this test method, the lumen maintenance is measured under strictly controlled conditions. Measurement is performance at multiple temperatures to address in-situ conditions. Addendum A for LM-80 (January 2014) made adjustment to the chosen case temperatures at which the LED light source is to be tested; it is now required that only two case temperatures be used for LM-80 testing, one of which must be either 55 °C or 85 °C.

LM-80 does not define or provide methods for estimation of lamp life – a separate estimation method was developed for this, IES TM-21 'Projecting Long Term Lumen Maintenance of LED Light Sources', which is a calculation based application of test results yielded from LM-80.It should also be noted that in only measuring arrays, packages and modules, this results of this method may not accurately reflect the performance of an integrated LED lamp or luminaire.

8.4.3 IES LM-84 Measuring Luminous Flux and Colour Maintenance of LED Lamps, Light Engines, and Luminaires

This provides the IESNA approved method for measuring the lumen and colour maintenance of LED lamps light engines and luminaires under strict standardised conditions. It was developed because component other than LEDs, such as optical elements, also contribute toward lumen decay over time in LED lamps and luminaires, and a more holistic approach to lumen maintenance testing at the final product level is necessary (compared to LM-80). A new TM-28 standard outlines calculation methods of projecting the measured data from LM-84 to a predicted lifetime. The approach parallels the way the LM-80 and TM-21 are used to project LED component lumen maintenance.

8.4.4 CIE TC2.71 Test Method for LED Lamps, LED Luminaires and LED Modules

The International Commission on Illumination (CIE) is a non-profit professional organisation that is the international authority of light, illumination and colour. Through research by a range of technical committees, standards and technical reports are developed and are accepted throughout the world. TC2.71 is a new international LED test method published in 2015. It covers test methods for measurement of initial parameters for luminous flux, luminous intensity distribution and colour qualities. Specifically, these are:

- Minimum light output (lumens) and equivalent wattage
- Minimum lamp luminous efficacy (lumens/Watt)
- Minimum fixture luminous efficacy (lumens/Watt)
- Correlated colour temperature (CCT) (degrees Kelvin)
- Colour rendering index (CRI)
- Chromaticity tolerance (Du'v')
- Colour spatial uniformity
- Luminous intensity distribution 0-360°
- Centre beam luminous intensity

Note that CIE TC2.71 only covers photometric and electric parameters, and does not include operational performance characteristics such as switching cycles, endurance over the life of the neither product, nor UV and flicker; some of these additional parameters are covered by IEC documents discussed in the following sections.

8.4.5 IEC 62612 Self-ballasted LED lamps for general services – Performance requirements

The International Electrotechnical Commission (IEC) prepares and publishes International Standards for all electrical, electronic and related technologies. This standard was published on 18 June 2013, and covers LED lamps with rated power up to 60 W, with supply voltage between 50 V and 250 V, and having lamp cap as listed in IEC 62560; these being B15d, B22d, E11, E14, E17, E26, E27, GU10, GZ10, GX53.

The standard includes marking requirements for lamp packaging and specifies test conditions for testing electrical and photometric characteristics that are to be performed on a minimum of 20 test lamps.

The following parameters are 'initial' measurements, to be tested at the beginning of lamp life:

- Lamp wattage - not exceeding rated wattage by > 15 %
- Luminous Flux - not less than 90% rated luminous flux
- Luminous efficacy – not less than 80 % of the rated LED lamp efficacy as declared by manufacturer or vendor

For determination of the following parameters, test measurements are to be taken at 25% rated lamp life, with a maximum duration of 6000 hrs:

- Colour Temperature – within 2700-6500 K with a tolerance category of 7-step MacAdam ellipse size
- Colour Rendering (CRI) – variation of < 5 points from rated CRI
- Lamp life – defined as the combined result of lumen maintenance performance and the life of the built-in electronic ballast. An endurance test is performed on both lamp and ballast to indicate reliability and life
- Lumen maintenance – uses approximation methods to determine expected life (L_{50} or L_{70}), lamps are grouped into "lumen maintenance categories" where each represents the measured luminous flux decreasing in increments of 10 %

Note that the life of an LED lamp is the combined effect of gradual light output degradation, mostly caused by material degradation and abrupt light output degradation, mostly caused by electrical component failure [4]. For this reason, both elements are tested as part of this standard.

IEC FDIS 62612 Section 11.2 includes notes on the significance of lumen maintenance measurement which give an insight into the challenges of measuring LED lifetime:

> NOTE 1 - As the typical life of an LED lamp is (very) long, it is regarded as impractical and time consuming within the scope of this standard to measure the actual lumen reduction over life (e.g. *L*70). For that reason this standard relies on test results to determine the expected lumen maintenance code of any LED lamp.
>
> NOTE 2 - The actual LED behaviour with regard to lumen-maintenance can differ considerably per type and per manufacturer. It is not possible to express the lumen-maintenance of all LEDs in simple mathematical relations. A fast initial decrease in lumen output does not automatically imply that a particular LED will not make its rated life.
>
> NOTE 3 - Other methods providing more advanced insight into lumen depreciation over LED lamp life are under consideration.

Endurance testing for a built-in electronic ballast must be performed on the complete LED and includes:

- A temperature cycling shock test, to be performed on a non-energised lamp
- Supply voltage-switching test
- A high temperature performance test, with lamp operating at 45 °C until a test period of 25% rated lamp life (maximum of 6000 hrs) then cooled to room temperature

Test conditions include stability requirements for ambient test-room temperature, test voltage, harmonic content of power supply, orientation of the lamp and general positioning; as well as requirements for thermal stabilisation of the lamp.

8.4.6 IEC/PAS 62722-2-1 Luminaire performance Part 2-1: Particular requirements for LED luminaires

Published June 2011, this standard covers performance and environmental requirements for LED luminaires with rated voltage up to 1000 V.

The standard defers to general requirements of IEC 60598-2, Luminaires – Particular requirements (with separate sections for luminaires of various specific types, such as general purpose, recessed, floodlights, portable garden use, etc.). Requirements include the following information:

- Photometric data including intensity distribution, as appropriate for the luminaire type and in accepted regional format.
- Light Output Ratio (LOR) must not be > 10 % from rated value
- Electrical parameters: rated voltage, input power, standby power losses, emergency lighting charging power; none of these must deviate > 10 % rated values
- Luminaire efficacy to be obtained using the rated light source as the reference lamp in performance tests

Environmental aspects of luminaire life cycle are assessed; with provision that manufacturers respect safety regulations in region of manufacture, sale and use of the luminaire. They are to provide information on maintenance operations and disassembly and recycling methods for end-of-life.

8.4.7 IEC/PAS 62717 LED modules for general services – Performance requirements

Published June 2011, this standard specifies performance requirements, test methods and conditions for LED modules. As with IEC/PAS 62612, lifetime and maintenance parameters are validated at a defined finite test time (25 % rated life, with a maximum of 6000 hours).

The following aspects are required to be tested and reported in order to adhere to this standard:

- Mandatory marking on lamp packaging and/or manufacturer's website or brochures
- Dimensions including dimensional tolerances
- Module wattage – not exceeding ± 10 % of the rated value

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[4] From IEC FDIS 62612 Section 11.1:

- Luminous flux – not less than 90 % rated value in any individual LED module; does not include an upper confidence limit for values greater than rated
- Luminous efficacy – not less than 90 % rated value
- Chromaticity coordinates – (initial and maintained) must fit into one of four tolerance categories based on 7-step MacAdam ellipse size
- Correlated colour temperature – Must be stated, with rounding to nearest 100 K; preferred values to ensure interchangeability are not yet assigned (though they are in IEC/PAS 62612)
- Colour Rendering (CRI) – initial, variation of < 3 points from rated CRI; maintained, variation of < 5 points from rated CRI

For directional lamps:

- Peak intensity value – not less than 75 % rated value
- Beam angle – must be within 25 % rated value
- Lumen maintenance – validated at time designated above; categories 9, 8, 7 correspond to maintenance ≥ 90 %, 80 %, 70 %
- Endurance testing:
- Temperature cycling test (with lamp energised)
- Supply switching test
- Accelerated operation life test

A new concept of module families allows the LED module manufacturer to use data from previous photometric tests of an existing baseline product as pre-verification of performance for later models in the family. Conditions of acceptance for a module's inclusion in a family are specified, and must be based on consistency in materials, manufacture techniques and proven quality assurance measures. Compliance testing of family members accepts family data for chromaticity coordinates, colour rendering, lumen maintenance and accelerated lifetime testing.

The IEC is also giving consideration for family definitions for self-ballasted LED lamps under IEC 62612; however pre-verification may only extend to endurance and lifetime testing in that case.

Definitions for products and product families would be one issue to consider if MEPS were to be developed for LED lighting. The current rapid evolution of LED technology and frequent release of new products could place extra pressure on product registration systems and supplier obligations. However registration systems in Australia and New Zealand are a key aspect of ensuring compliance, and clear product definitions, with requirements for submission of tested performance information an important element of this.

8.5 Labelling and Endorsement Programs

Appendix B details a number of mandatory and voluntary labelling programs that encompass LED lighting. The following are some examples.

8.5.1 USA

8.5.1.1 Lighting Facts

The US has two 'Lighting Facts' labels. The US Department of Energy (DOE) launched the voluntary LED lighting Facts label in 2008 to promote the accurate and consistent reporting of LED product performance claims. Manufacturers that list their products with LED Lighting Facts voluntarily pledge to report their products' performance results according to accredited laboratory measurements. Those results appear on the LED Lighting Facts label and website, intended to help retailers and other industry buyers make informed purchasing decisions for their lighting inventory.

The label includes information about lumen output, watt, lm/W, CRI and CCT to be shown on the individual package of each lamp along with optional information on lumen maintenance and warranty. This label is primarily aimed at retailers and other industry stakeholders with some technical knowledge. The label does not set minimum performance levels, and aims to promote accuracy in claims of performance rather than minimum or high performance, with product testing required. The Lighting Council Australia SSL Quality Scheme is based on the Lighting Fact label.

In 2012 the US Federal Trade Commission also introduced a Lighting Facts label – which must be included on all medium screw based bulbs (including LEDs in that category). No testing is required to support the information included on the label. Emphasising information on lumen output, this label is more aimed at consumers. To prevent overlap with the DOE Lighting Facts Label, DOE removed all medium screw base lamps from its program, creating a scheme in which the FTC Lighting Facts label applies to medium screw base lamps, and the DOE Lighting Facts label applies to all other lighting product categories, lamps and luminaires. For FTC labelling, prominent information on the lumen output and energy cost is located on the front of the packaging, while the label on the back of the packaging provides information on:

- Brightness (lumens)
- Energy cost
- Life expectancy
- Light appearance (colour temperature)
- Wattage
- Whether the bulb contains mercury

8.5.1.2 Energy Star

In the USA, the ENERGY STAR Program run by the EPA aims to encourage industry best practice by forming partnerships with manufacturers and setting performance targets for appliances. The ENERGY STAR is a voluntary program and has specifications for integral LED lamps and luminaires.

Further information on Energy Star is discussed above in relation to the New Zealand Energy Star label.

8.5.2 European Union

EU regulation No 874/2012 for Energy Labelling of Electrical Lamps and Luminaires specifies energy labelling of household lamps and luminaires designed to operate such lamps. The regulation requires display of energy efficiency class, lumen, and estimated yearly power consumption (in kWh). In addition, beam angle is also required for directional lamps. The regulation also requires the display of the EU comparative energy performance label.

EU Regulation No. 244/2009 (non-directional lamps) specifies the display lumen output, lifetime, CCT, warm-up time and a warning if the lamps cannot be dimmed.

EU LED Quality Charter – The European LED Quality Charter is a voluntary set of criteria established by the European Commission JRC in collaboration with a number of private and public organisations.

The role of the European LED Quality Charter is to set important voluntary requirements for white LED lamps (not covering modules or luminaires) that can be used now by governments, municipality, energy savings, utilities and other active parties that may subsidise LEDs to ensure the quality of LEDs on the market. Limited to LED lamps intended primarily for use in the residential sector, the charter recommends that CRI is displayed on the package. Participating lamps may display the European Quality Charter logo. The European Commission reserve the right to test, review or ask for additional information for any product that a participating manufacturer claims is meeting the European LED Quality Charter criteria.

8.5.3 Hong Kong

The Hong Kong Voluntary Energy Efficiency Labelling Scheme (VEELS) for LED Lamps, started June 2011. The scheme applies to directional and non-directional LED lamps intended for general lighting purposes having the following characteristics:

- a rated voltage up to 240 V AC or DC, and
- a rated voltage frequency of 50 Hz for AC, and
- a rated lamp wattage up to 60 W.

It applies to LED lamps designed with or without dimming operations.

VEELS does not cover:

- LED tubes
- LED lamps that intentionally produce tinted or coloured light
- Organic LED (OLED)

This is a recognition label which shows that the product is certified to meet the minimum energy efficiency and performance requirements.

8.5.4 Efficient Lighting Initiative (ELI)

ELI is a lighting certification program currently administered by the China Standard Certification Center. It includes the ELI Voluntary Technical Specification for Self-Ballasted LED Lamps for General Lighting Services.

- ELI applies exclusively to non-directional self-ballasted LED lamps, with a screw or bayonet cap, rated power up to 60 W and a rated voltage of up to 250 V AC or DC.
- Certifies electromagnetic and radio frequency interference, harmonics, power factor, electromagnetic compatibility immunity, transient protection, operating conditions, minimum starting temperature, switch withstand, lifetime, safety, CCT, CRI, initial luminous flux, lumen maintenance, colour rendering stability, efficacy (variable depending on CCT), labelling and comparison, warranty.

9 Policy options

Possible policy directions for LED lighting products within the scope of this Product Profile are discussed below. More than one option could be implemented at the same time. Policy options are discussed in terms of no action (business as usual), MEPS, labelling, test methods and education.

Potentially these policy options could be implemented alongside action to further phase out inefficient incandescent lighting in Australia by increasing existing MEPS levels for some or all halogen lamps. These options are discussed in detail in the Incandescent and CFL Product Profile.

Policy options investigated in a RIS would be subject to further consultation, cost benefit analysis and government approvals in both Australia and New Zealand.

9.1 No action

This scenario assumes no changes to policy. The LED lighting market would continue to operate as it does now, without introduction of government initiatives such as LED MEPS, labelling or education. It is likely that improving LED lighting technology would continue to replace incandescent, halogen and CFL lamps as part of business as usual, in Australia, and New Zealand. Possible outcomes of this scenario, based on available market modelling, are discussed in Chapter 5.

However the recent history of transition to halogen and CFL alternatives indicate that a voluntary transition to efficient lighting could be slow and incomplete and result in significant lost savings opportunities.

Barriers to the uptake of LED products such as the presence of poor quality models in the market and inaccurate performance and equivalency claims would not be addressed. Unlike traditional lamp technologies, there is a very wide range in the energy efficiency (about 20 – 120 lumens per Watt) and performance parameters such as lifetime (10,000 – 50,000 hours) of LED lighting products. The continued presence of lower efficacy LED models continuing in the market and a potential lack of consumer trust with new technology is likely to result in lost energy savings opportunities.

This option would come at a cost of the lost opportunity to fully realise reduced energy consumption and greenhouse gas emissions and lower savings for householders.

9.2 Introduce MEPS for LED Lamps and Luminaires

Options under this approach would involve the introduction of MEPS for a range of LED lamp and luminaire types under the Australian *Greenhouse and Energy Minimum Standards Act 2012* and the New Zealand *Energy Efficiency (Energy Using Products) Regulations 2002*. The scope of product types to be covered could include:

- Integral LED lamps that are considered alternative or replacement lamps for currently regulated domestic lamps (integral compact fluorescent, incandescent and halogen lamps as set out in AS4934.2 and AS/NZSAS4847.2):
    - all shapes
    - nominal wattage ≥ 1 watt (no upper limit)
    - Mains Voltage (MV), caps: E14, E26, E27, B15, B22d, GU10, GX53, GU24
    - Extra Low Voltage (ELV), caps: GU5.3, GU4
- LED linear lamps, including replacements for currently regulated tubular fluorescent lamps (see discussion in section 4.4).

- LED replacement lamps for other fluorescent lamps currently under consideration for regulation (e.g. circular fluorescent lamps and non-integrated compact fluorescent lamps).
- LED luminaires with an integrated LED-based light emitting element other than a replaceable LED lamp (i.e. LED packages, LED arrays, LED light engines) connected to the mains supply
  - Includes integrated downlights, suspended and surface mounted, recessed, panels, battens, high-bay and low-bay LED luminaires
  - All shapes
  - Nominal wattages
  - If domestic products only ≥ 3W and ≤ 25W
  - All applications (except high-bay and low-bay) ≥ 3W and ≤ 100W
  - High-bay and low-bay – no limits

Possible exclusions: linear strip/rope, road lighting fixtures (subject to AS/NZS1158 Lighting for roads and public spaces series), novelty/decorative lights not intended for general lighting applications (minimum wattage).

Where possible, definitions of the categories would be based on available international standards. It may also be appropriate for there to be a staged approach to the introduction of MEPS across the product categories.

9.2.1 MEPS Scope

MEPS for LED lighting could take a similar approach to the MEPS for CFLs in place in Australia and New Zealand – setting both minimum efficacy levels and also setting minimum requirements for a range of performance issues that have been documented in testing of LED products in Australia and New Zealand and other countries (see Chapter 3). Such an approach would ensure that the LED products available in the market were both efficient and effective alternatives to less efficient lighting, giving consumers confidence to make the transition and ensure potential energy and costs savings are achieved. Given that LED lighting technology is still rapidly improving, it would be appropriate for there to be a timetable of future increases in the requirements for efficacy and some performance parameters.

In developing energy efficiency and functional MEPS requirements suitable for Australia and New Zealand, where possible these could be derived from the EU regulations (244/2009 and 1194/2012) and the 4E SSL performance tiers.

The timing of EU regulations have recently been reviewed and the outcome is a delay until 2018 in the introduction of stage 6 (relating to clear non-directional lamps including incandescent, CFL and LED lamps) which would effectively ban clear non-directional halogen lamps. As noted above, a further review of EU regulations for lighting products is underway, but is not expected to be implemented before 2020 and may be more relevant to timetabling of future MEPS increases rather than any initial levels.

The current IEA 4E SSL performance requirements were developed in 2011 and there is sufficient evidence from recent benchmarking of market available products to either consider the possibility of using Tier 2 (as opposed to Tier 1, originally developed as the on-grid minimum acceptable performance), which is more in line with current product performances or, if completed in time, consider the revised Tier performance levels from the announced review being conducted by the IEA 4E SSL during 2015. Harmonisation where possible would enable access to a wider range of efficient lighting products and also open up future options for cooperation on monitoring, verification and enforcement.

In determining the appropriateness of the energy efficiency performance levels and the scope of lamps to be included, an analysis has been conducted with available test data from a number of countries (namely USA and Canada, Denmark, and Australia and New Zealand). This is discussed below.

9.2.2 Minimum Efficacy Levels

Available test data shows a significant variation in the efficacy levels achieved across the full range of lumen output in both non-directional and directional lamps, thus indicating that minimum efficacy level could achieve improved energy savings by removing the lower performing lamps from market.

Figure 38and Figure 39 show the energy efficiency requirements for both the EU and IEA 4E SSL for self-ballasted lamps. The obvious feature of the EU MEPS curve is the sharply declining tail of the curve which has come about due to accommodating the physics of traditional lighting technologies that use a heated filament (incandescent and halogen) lamp or gas discharge (compact fluorescent) lamp where increased efficiency is achieved at higher wattages when generating an increasing quantity of light. However, for LED technologies, there is no improved efficiency in creating an increasing quantity of light. However there is potentially a decrease in efficiency in cases where a smaller product form factor is required (such as MR16 replacement lamps) due to the inability to effectively dissipate thermal heat generated by the LED chip. This is taken into account by the IEA in having a lower Tier line for relatively high lumen output small form factor lamps which are most common in directional lamps (≤ 63.5 mm diameter).

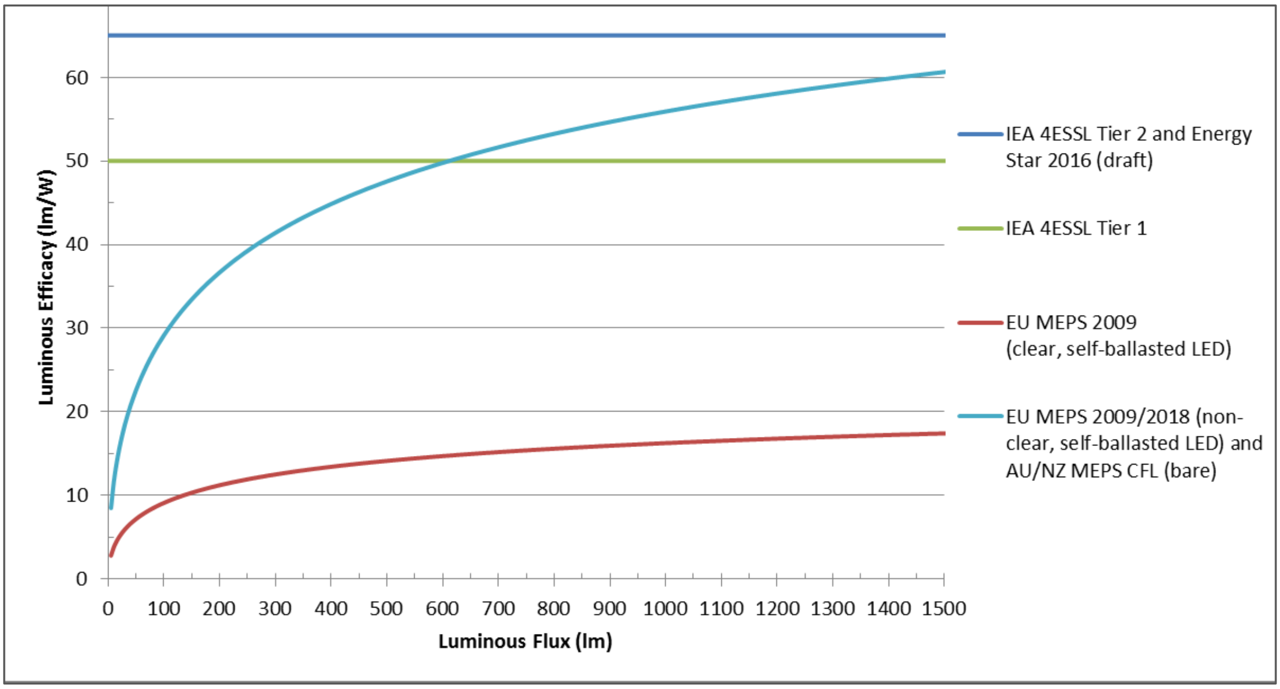

Figure 38. EU, IEA 4ESSL Tier 1 and 2, Energy Star 2016 (Draft) and AU/NZ bare CFL minimum efficacy requirements for Non-Directional Lamps.

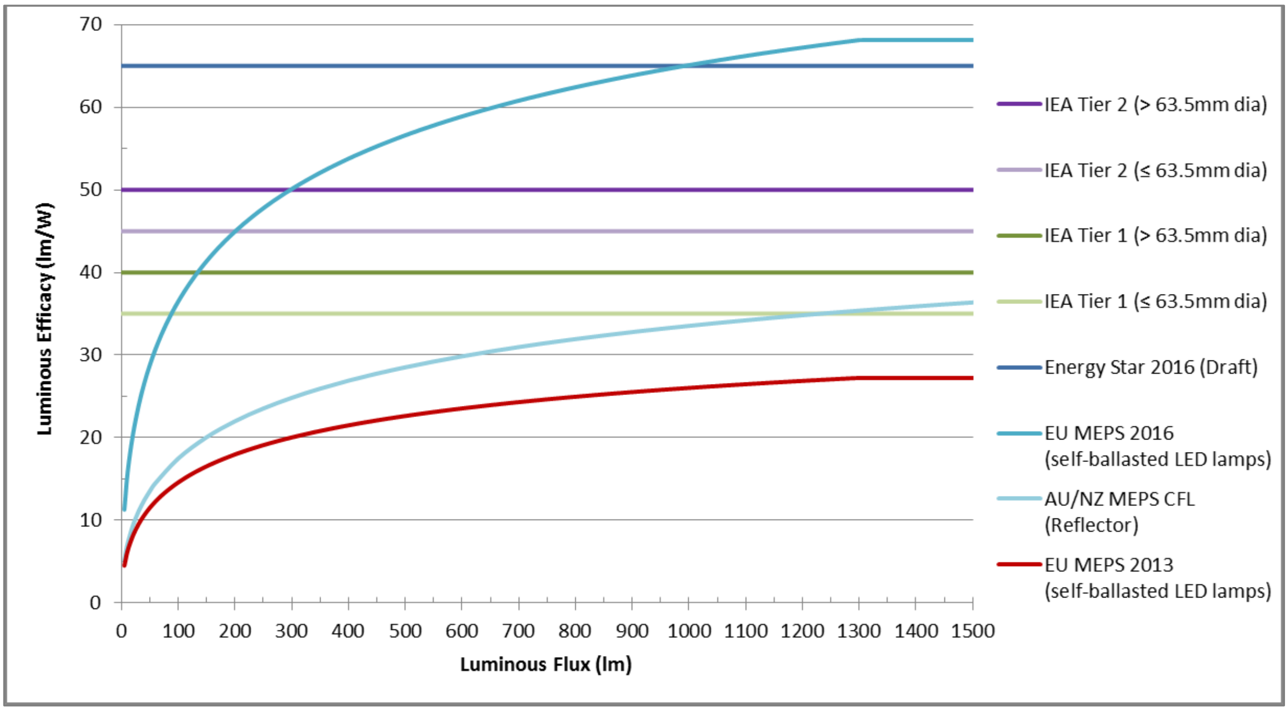

Figure 39. EU, IEA 4ESSL Tier 1 and 2, Energy Star 2016 (Draft) and AU/NZ reflector CFL minimum efficacy requirements for Directional Lamps. Note that EU MEPS 2016 for directional lamps currently under review.

Note that the EU Directional Lamps MEPS are efficacy curves based on "useful lumens" and not total lumen output from a lamp. This means when comparing the IEA and EU efficacy requirements, depending on the beam angle of the lamp, the EU line is approximately 10% (for very wide beam angles) to 20% (for very narrow spot beam angles) lower than the IEA 4ESSL Tiers efficacy line. This is because the IEA 4ESSL tiers are based on "total lumens" efficacy while the EU measurement can only take into consideration the "useful lumens". As stated above, the IEA 4ESSL performance tiers for these lamps are currently under review (and may be adjusted upwards), and the introduction of the EU MEPS 2016 for directional lamps is also currently under review for a scheduled decision as to whether the EU will go forward or abandon this stage.

The IEA 4E SSL linear approach to minimum efficacy takes advantage of the nature of LED lighting to deliver a minimum requirement that is simpler to understand and apply for suppliers, consumers and regulators. However test results indicate that lamp performance does appear to show an overall increasing luminous efficacy with luminous output, particularly at the low lumen output end. As shown in Figure 40 the *range* between the highest and lowest efficacy performers does not appear to be a function of luminous flux, as a fairly consistent range of approximately 50 lumens/Watt is present in the omnidirectional LED market, regardless of lumens. For example, a person wishing to purchase a 200 lumen omnidirectional LED lamp would be choosing from products which perform between 30 lm/W (~7 W) and 85 lm/W (~2.5 W). If they wanted to purchase a 700 lumen product, the performance range would be between 54 lm/W (~13 W) and 97 lm/W (~7 W). This range indicates an opportunity to achieve energy savings through the application of a minimum efficacy level.

This current data could provide a reason to choose a lumen-dependent MEPS curve (as per EU MEPS, and AU CFL MEPS) over using a static cut-off MEPS line (as per IEA Tier 1), both styles of which are shown in Figure 40. However consideration needs to be given as to why these performance variations are emerging and whether a MEPS level that accepted this upward trend may be locking in unnecessarily low efficacy in the lower lumen output range. The upward trend may be evident for a number of reasons:

- Difficulties in designing smaller retrofit products (including fitting in a satisfactory heat sink), with these products more likely to be in the lower lumen output range.
- Current research and development focusing on achieving higher lumen output could be increasing efficacy achieved for those products, (that may later be transferred to lower lumen output products);
- Imports of cheaper, lower quality products are likely to be at the lower light output range.

If the first possibility above is found to be true, then a MEPS curve (or a second lower linear efficacy level for small products) would be seen as warranted due to the current technical constraints, however if either the second or third possibilities were true, this would suggest that a linear MEPS would result in products of increased efficacy at the lower lumen levels on the market. It is worth noting here that lamps with luminous flux of less than 200 lumens are equivalent to tungsten filament incandescent lamps that are less than 25W and as such are quite ineffective in general lighting applications and less relevant in determining the approach to efficacy.

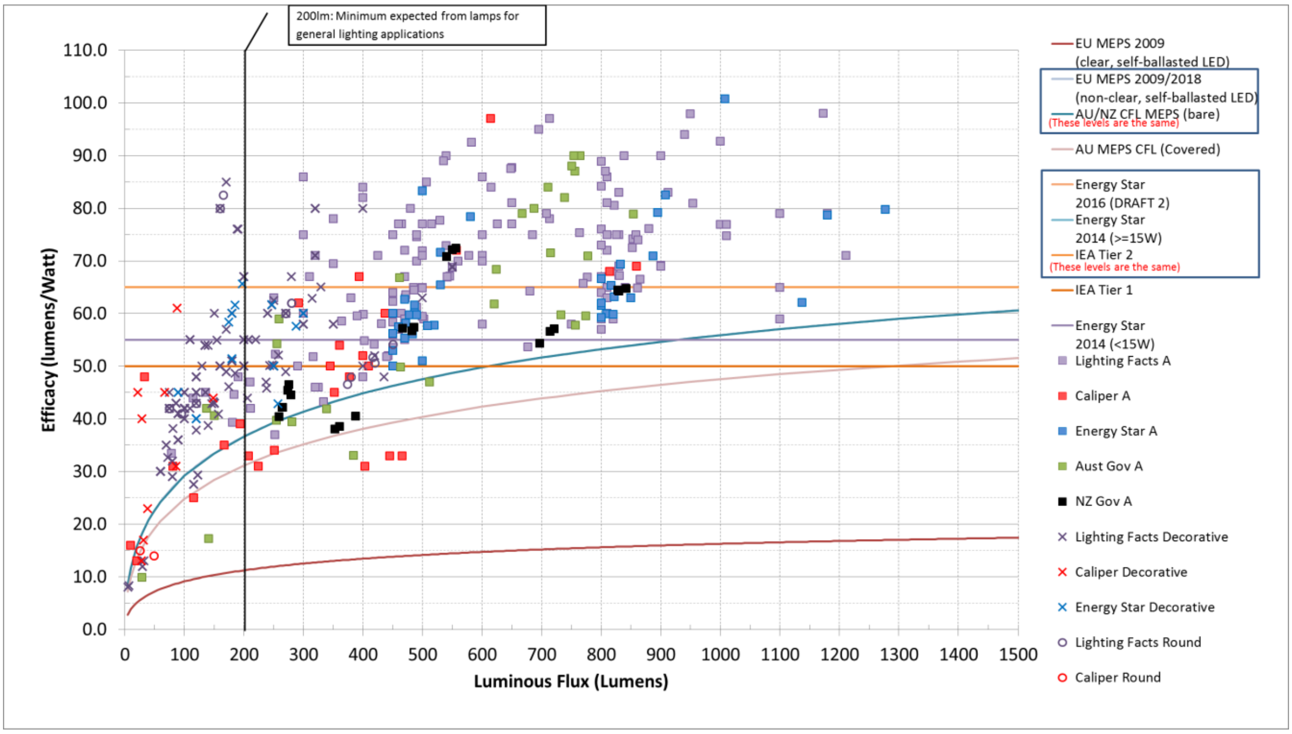

Figure 40. Tested Efficacy of Non-directional LED Lamps (USA, EU, Australia, New Zealand).

Test results yielded from the same six international testing programs for directional LED replacement lamps has been subdivided into two categories; lamps with front face diameter ≤ 63.6 mm (20/8", i.e. PAR 20 size and smaller, which includes MR16), and > 63.5 mm (ie.AR111, PAR 30 and larger) as, due to performance gains obtainable by larger lamps, these are categories that IEA 4E SSL have used for directional LED lamps. Efficacy performance results for these categories are in Figure 41 and Figure 42, respectively.

Figure 41 specifically shows results for 12V lamps: MR11, MR16, and 240V: PAR16, R20 and PAR20 lamps. The EU 2013 MEPS and 2016 MEPS (implementation under review) lines for self-ballasted LED are displayed, as well as IEA Tier 2 for ≤ 63.5 mm diameter lamps, and AU/NZ reflector CFL MEPS lines. Figure 42 shows results for AR111, general R, PAR, BR lamps, as well as R30 and PAR30, R38 and PAR38 lamps. The EU 2013 MEPS and 2016 MEPS lines for self-ballasted LED are displayed, as well as IEA Tier 1 and 2 for > 63.5 mm diameter lamps, and AU/NZ bare CFL MEPS lines.

From both charts it would appear that the same upward trend of the efficacy range versus luminous flux is present for directional lamps of all sizes. This is also confirmed by the evidence that larger sized lamps (which typically supply higher lumens) are shown to be significantly better performers, even at the same luminous flux level as their smaller packaged equivalents. Again it is worth noting the minimum light output that would be expected from traditional lamps for general lighting applications. For small diameter (<63mm) lamps, a minimum luminous flux of approximately 120 lumens would be provided by tungsten filament incandescent reflector lamps (PAR and R types) that are 20W or more. And, for larger diameter (>63mm) lamps, a minimum luminous flux of approximately 350 lumens would be provided by tungsten filament incandescent reflector lamps (PAR and R types) that are 50W or more.

In relation to the IEA Tier 2 and EU MEPS levels for all sizes of directional lamp:

- Only LED lamps at mid to low lumen output are effectively targeted by the flat IEA Tier 2 MEPS line; this means that the range of available lamps will be curtailed for lower lumen products, but the majority of presently available lamp stock at higher lumens would be allowed to remain in the market. This would result in a broader range of products remaining available for larger profile lamps at the high lumen end.

- Only one model fails to meet the 2013 EU MEPS; however more than half of all models tested would not meet the requirements of 2016 EU MEPS (timing under review).
- AU/NZ reflector CFL MEPS is slightly more stringent than EU 2013 MEPS for self-ballasted LED. If enforced instead, benefits would be marginal with only a few more of the (tested) LED products removed from the market.

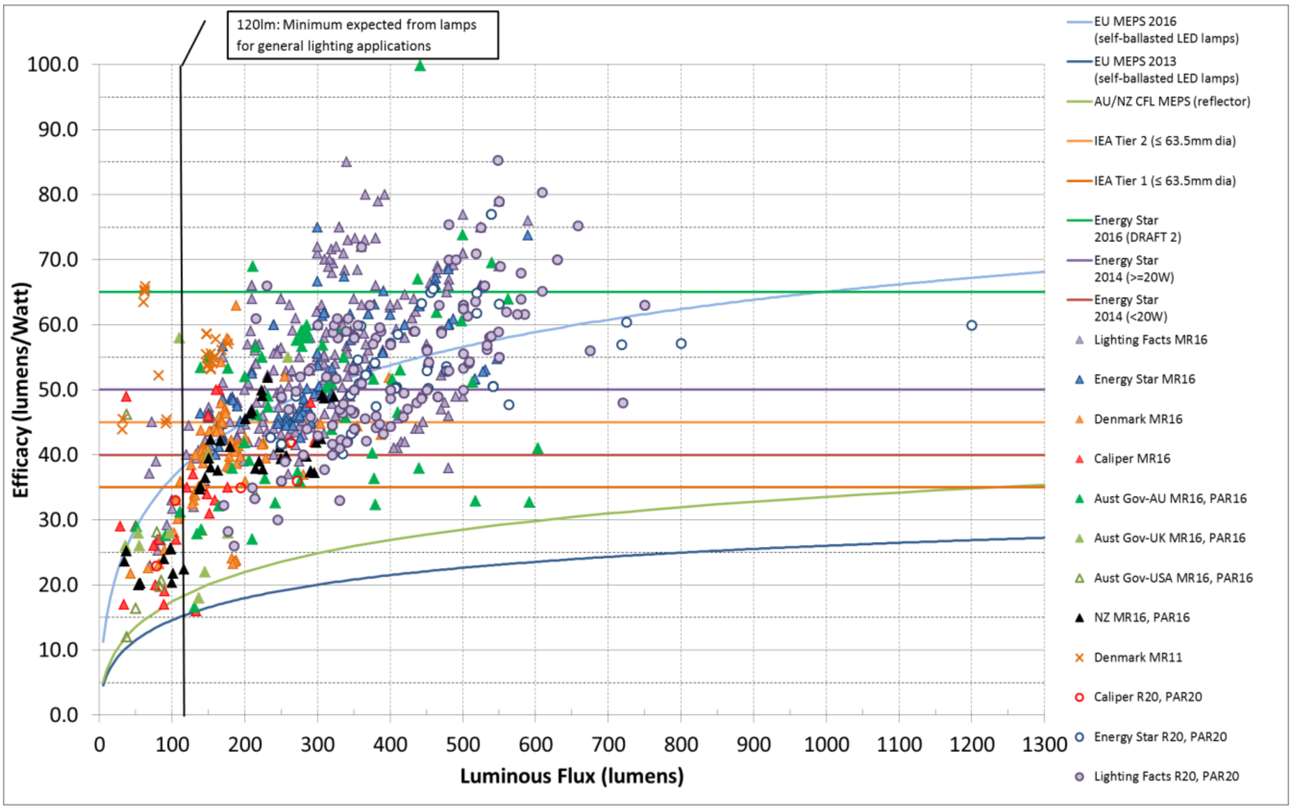

Figure 41.Efficacy levels of directional LED lamps with face diameter up to 63.5 mm (20/8"), across six international testing programs.

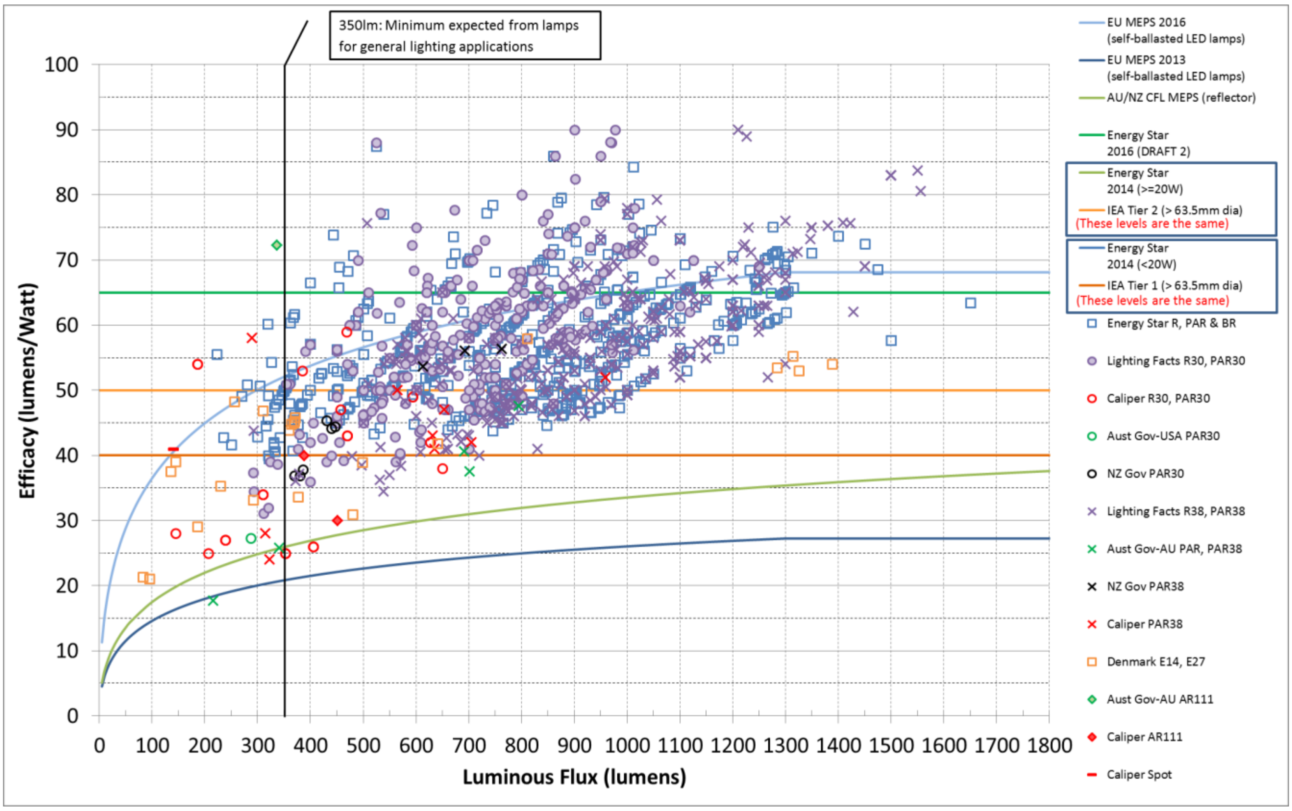

Figure 42.Efficacy levels of directional LED lamps with face diameter greater than 63.5 mm (20/8"), across five international testing programs.

Between 2009 and 2014 lamps were purchased and tested by the Australian and New Zealand Governments. Results from this testing is displayed in separate tables and charts for omnidirectional (Table 14 and Figure 45) and directional (Table 15, Table 16, all sizes, Figure 46) LED lamps. Also displayed are the Australian MEPS levels for bare CFL and incandescent lamps, IEA Tier 1 and 2 MEPS for all diameters of LED lamp, EU 2013 and 2016 (deferred to 2018) MEPS curves, as well as EU HEPS (higher energy performance standards) levels used for the EU Energy Label.

Results show that a 75% of omnidirectional LED lamps purchased after 2010 would meet Australian bare CFL MEPS levels; whereas this has only been the case since 2013 for meeting the 2016 (deferred to 2018) EU MEPS for self-ballasted LED lamps. 57% of omnidirectional lamps would meet the 4E SSL tier 1, with 34% meeting Tier 2 (Figure 43).

Table 14.Number of Australia / New Zealand Omnidirectional LED Lamps that would pass a range of possible MEPS efficacy levels (by year of purchase)

Year of purchase	No of lamps purchased	Pass AU/NZ MEPS bare CFL	Pass EU MEPS			Pass IEA 4E-SSL	
			2009 clear	2018 clear	2009/2018 non-clear	Tier 1	Tier 2
2010	2	1 (50%)	2 (100%)	2 (100%)	1 (50%)	0	0
2011	21	18 (86%)	21 (100%)	21 (100%)	18 (86%)	12 (57%)	3 (14%)
2012	9	6 (67%)	9 (100%)	9 (100%)	6 (67%)	4 (44%)	1 (11%)
2013	8	7 (87.5%)	8 (100%)	8 (100%)	7 (87.5%)	6 (75%)	5 (62.5%)
2014	21	14 (67%)	21 (100%)	21 (100%)	14 (67%)	13 (62%)	12 (57%)

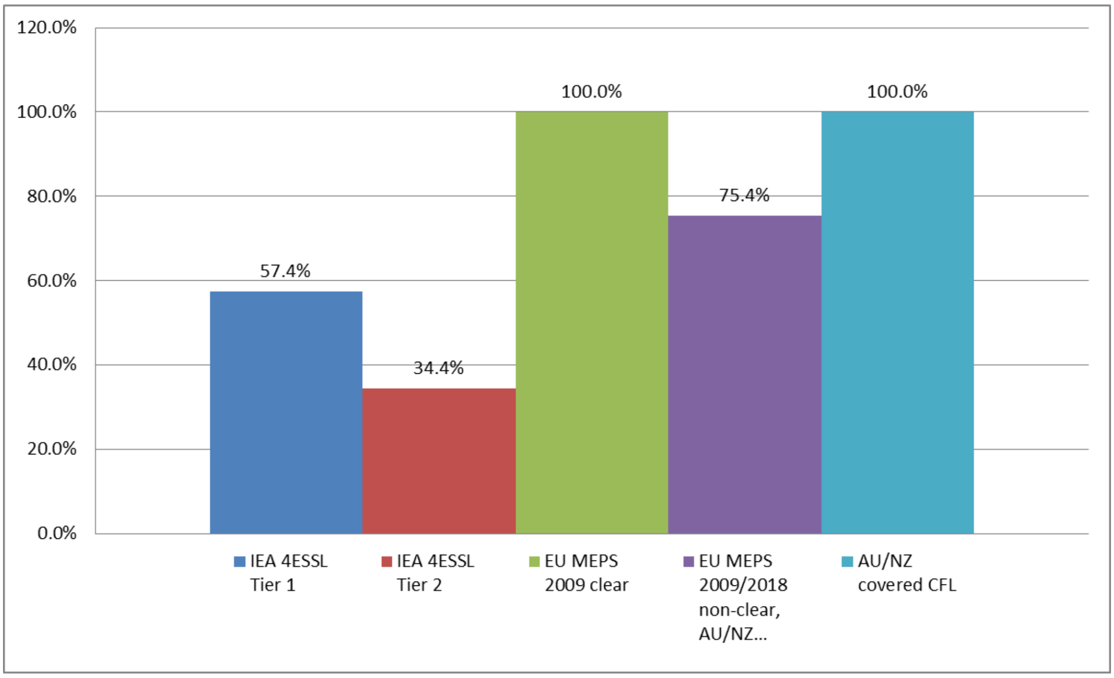

Figure 43. Percentage of non-directional LED lamps which are passing the different standards from 2009 to 2014.

Table 15.Number of Australia / New Zealand Directional LED Lamps ≤ 63.5 mm that would pass a range of possible MEPS efficacy levels (by year of purchase)

Year of purchase	No of lamps purchased	Pass AU/NZ MEPS reflector CFL	Pass EU MEPS		Pass IEA 4E-SSL	
			2013	2016	Tier 1	Tier 2
2010	18	18 (100%)	17 (94%)	9 (50%)	12 (67%)	8 (44%)
2011	25	25 (100%)	25 (100%)	3 (12%)	23 (92%)	6 (24%)
2012	43	43 (100%)	43 (100%)	13 (30%)	27 (63%)	16 (37%)
2013	6	6 (100%)	6 (100%)	6 (100%)	6 (100%)	6 (100%)
2014	11	11 (100%)	11 (100%)	9 (82%)	10 (91%)	9 (82%)

Table 16.Number of Australia / New Zealand Directional LED Lamps > 63.5 mm that would pass a range of possible MEPS efficacy levels (by year of purchase)

Year of purchase	No of lamps purchased	Pass AU/NZ MEPS reflector CFL	Pass EU MEPS		Pass IEA 4E-SSL	
			2013	2016	Tier 1	Tier 2
2010	5	5 (100%)	4 (80%)	0	3 (60%)	2 (40%)
2011	9	9 (100%)	9 (100%)	0	6 (67%)	3 (33%)
2012	4	4 (100%)	4 (100%)	1 (25%)	3 (75%)	1 (25%)
2013	0	0	0	0	0	0
2014	2	2 (100%)	2 (100%)	1 (50%)	2 (100%)	1 (50%)

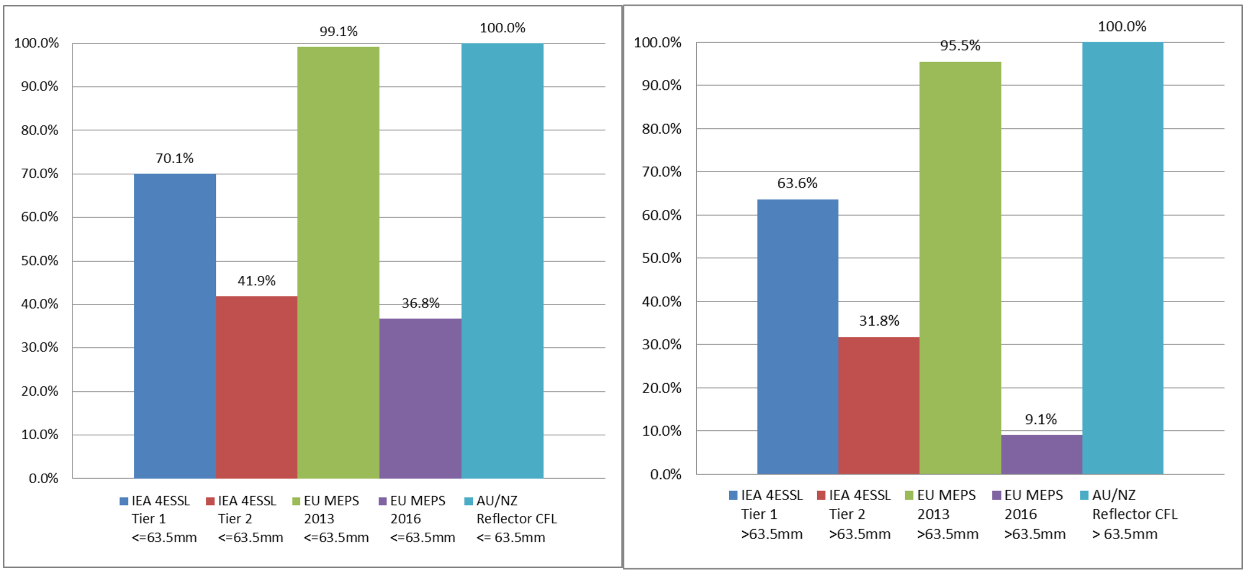

Figure 44. Percentage of directional ≤ 63.5mm (left) and > 63.5mm (right) LED lamps(2009-2014) that would pass IEA 4E-SSL, EU and AU/NZ CFL standards.

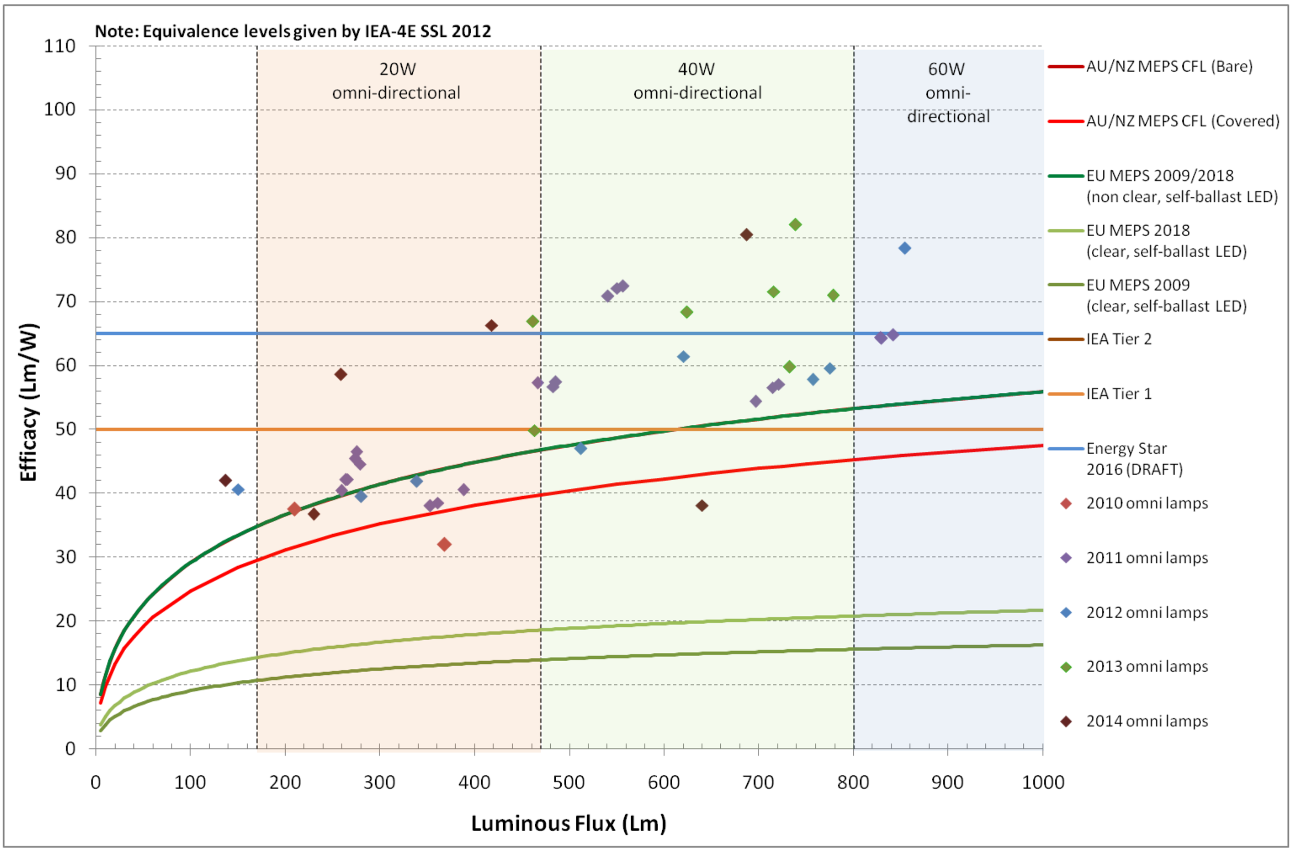

Figure 45. Efficacy levels of omnidirectional LED lamps purchased in Australia and New Zealand between 2010 and 2014.

Of the directional lamps purchased in Australia and New Zealand (Figure 46), all 2013 models pass AU reflector CFL MEPS and EU 2016 LED MEPS levels; whereas as significant portion of the 2012 market does not meet either of these performance standards. Approximately 60% of the directional lamps would pass 4E SSL Tier 1 and 50% Tier 2, noting that the achievable efficacy of LED lamps would likely have improved further by the time any MEPS levels were put in place.

Figure 46 also shows the lumen output ranges of equivalence to a 20W, 35W and 35W IRC/50W halogen MR16 lamp. Note that only one lamp (2012 model) reaches the lumen output level of a 35W IRC halogen (i.e. 50W halogen).

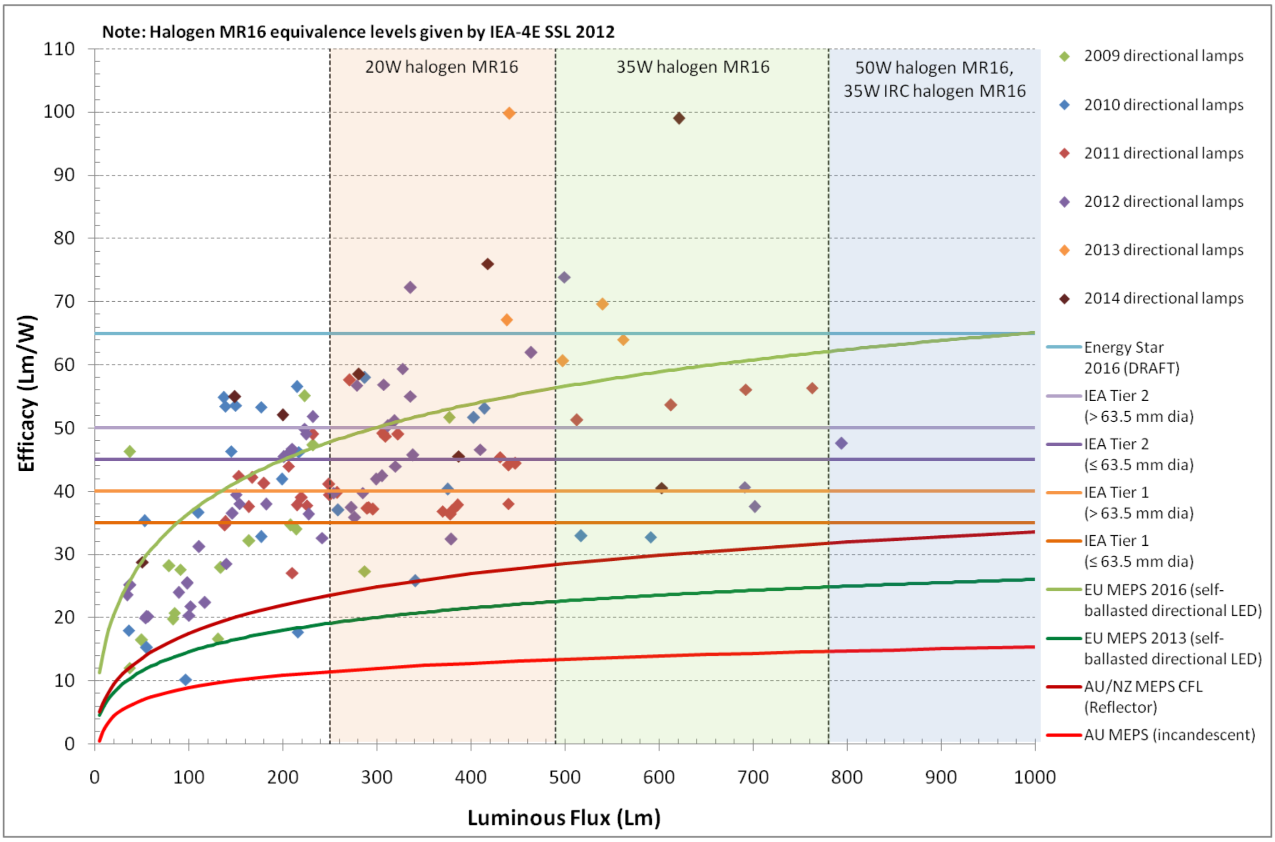

Figure 46.Efficacy levels of directional LED lamps purchased in Australia and New Zealand between 2009 and 2014.

Input is invited on the most appropriate approach to setting efficacy levels for LED lamps, in particular whether a curved or linear level would be most appropriate. Given the rapid and ongoing improvement in LED efficacy, it may also be appropriate for a timetable of increasing efficacy requirements to be set.

Option 1: Introduce MEPS with a minimum efficacy level set to remove the lower performing lamps in the Australia and New Zealand Market. Efficacy level to be either:

- ***One or more linear levels; or***
- ***A curved level.***

Option 2: Set a timetable of increases to minimum efficacy levels via MEPS.

9.2.3 Other Performance Parameters

The following Table 17 lists additional performance parameters that can help to ensure that LED products are able to provide an effective lighting service at least comparable to existing lighting technologies such as incandescent and fluorescent products. These parameters could be included in a regulated MEPS for LED lighting. If some parameters were seen as less critical to ensuring the availability of effective and efficient products, consideration could be given to those parameters only being included in an Australian and New Zealand Standard. Thus the regulated MEPS would include efficacy and core performance requirements (minimising test cost), while manufacturers / suppliers could also go further and test products against the extended range of parameters in order to claim compliance with the AS/NZS standard. It should be noted however that parameters not included in the MEPS would not be subject to monitoring and compliance activity under the respective Australian and New Zealand energy efficiency regulations.

While ground-breaking, there are several elements of the EU approach to LED MEPS that require further consideration. In addition to the concerns about appropriate evaluation of reflector lamps outlined in chapter 7 and the approach to minimum efficacy outlined above, there are also challenges in the way that the EU has attempted to establish one MEPS to be applied to incandescent, CFL and LED technology. This has resulted in what could be considered confusing regulations that do not necessarily provide optimum guidance for the performance of LED products due to catering for other technology products. When proposing performance specifications for LEDs it is also important to be mindful that a significant portion of LED manufacturers have little knowledge or experience with other lighting technologies, thus a combined universal performance specification may cause unnecessary confusion and inadvertent non-compliance in these sectors of the market.

The proposed MEPS levels are therefore largely derived from the recommended performance levels developed by experts from ten countries participating in the IEA 4E SSL annex, except where otherwise noted. The proposed levels and parameters set out as an example in the table below are predominantly focused on requirements for omnidirectional and directional LED retrofit lamps. In some cases the parameters and levels may vary for LED luminaires and linear/planar LED lamps. For example for LED luminaires a longer lumen maintenance and lifetime requirement would be reasonable.

Note that the IEA 4E SSL Annex performance specifications are currently under review and may be adjusted in light of advances made by LEDs since their publication.

Table 17.Possible Performance Parameters for LED MEPS

Criterion	**Description**	**Why it is important**	**Existing Performance Standards**	**MEPS Levels** Derived from IEA 4E SSL unless otherwise specified
Claimed Equivalent wattage /minimum light output (lm) (*retrofit lamps only*)	If equivalency is claimed to an incandescent lamp the minimum light output requirement ensures that the LED product produces at least the same amount of light (on average over its life) as an incandescent light source of a given wattage;	These levels assist in evaluating manufacturer claims of equivalence for consumers choosing replacement lamps. Acceptable light output levels are of highest importance for safe working and living conditions.	IEC 62612 (Self ballasted LED) IEC 62717 (LED modules)	For non-directional 20W = 170 lm; 25W = 250 lm; 30W = 325 lm; 35W = 395 lm; 40W = 470 lm; 60W = 800 lm; 75W = 1055 lm; 100W = 1520 lm; 125W =2000 lm; 150W = 2452 lm; 200W = 3452 lm Directional – see IEA 4E SSL tables in Appendix C
Minimum luminous efficacy (lm/W)	Ratio of total light output of a lamp to the power consumed in producing it (lumens/watt). The higher the efficacy value, the more energy efficient the lighting product.	This criterion informs the consumer and society on how efficient the light source is at producing visible light. An important indicator for saving energy and money.	IEC 62612 (Self ballasted LED) IEC 62717 (LED modules)	For non-directional: IEA 4E SSL Tier 1 > 50 lumen/watt For directional: IEA 4E SSL Tier 2 ≤ 20/8 inches (63mm): >45 lm/W > 20/8 inches (63mm): >50 lm/W (note IEA Tiers currently under review)
Luminous intensity distribution	The measured distribution of light output for a lighting product	For lighting design it is important that the specifications closely approximate the light distribution properties of the lamp. Many ‘omnidirectional’ lamps provide a curtailed light distribution.	IEC 62612 (Self ballasted LED) IEC 62717 (LED modules)	Directional: Must be provided by manufacturer and 50% of flux shall be in declared beam angle

Zonal lumen density	The spatial distribution of light into particular angular zones.	Important for consumers; avoids products having too much light distribution in zones other than where designated by their status. I.e. directional lamps to have majority of light in forward direction; while typical non-directional lamps to have a more consistent light spread through most zones.	Energy Star Product Specification for Lamps V1. Ecodesign	To be considered only for inclusion in the standard. Omni-Directional: Products shall have an even distribution of luminous intensity within the 0° to 135° zone (symmetrical about the vertical axis). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux must be emitted in the 135° -180 ° zone. Distribution shall be vertically symmetric in three vertical planes, 0°, 45°, 90°.
Centre beam luminous intensity (*directional lamps only*)	The measured intensity of light output on the optical beam axis for directional lamps (with beam angle < 65°)	Important in accurately evaluating the performance of directional lamps/products for where the consumer wants directed illumination. Also provides equivalent intensity to the traditional lamp being replaced	IEC 62612 (Self ballasted LED) IEC 62717 (LED modules)	IEA 4E SSL For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool: http://www.energystar.gov/ia/products/lighting/iledl/IntLampCenterBeamTool.zip
Colour rendering index (CRI)	A measure of the ability of a light source to reveal the colours of various objects faithfully in comparison with an ideal or natural light source (such as incidental sunlight). The highest CRI attainable is 100, with the scale dropping to negative values for some light sources. Typical LEDs have about 80+ CRI.	Colour rendering is important for consumer satisfaction with a lighting product. High CRI of 90+ is necessary for specialised tasks where colour is important (e.g. food preparation, applying makeup, and painting). For general use in residential and office locations, a minimum CRI of 80 is recommended.	IEC 62612 (Self ballasted LED) IEC 62717 (LED modules)	IEA 4E SSL ≥80

<table>
<tr>
<td>Correlated colour temperature (CCT) in Kelvin (K)</td>
<td>Specifies the colour ‘shade’ of white light emitted by a lamp, relating to the colour of light from a reference source when heated to a particular temperature, measured in Kelvin. Spectrally, light sources which appear a “warm” white contain more red light content and are at lower Kelvin (2700-3500 K), while those appearing “cool” white contain more blue (4000-6500+ K) to create their appearance.</td>
<td>CCT helps consumers select the appropriate product depending on their light colour preference and match light colour across different manufacturer lighting products. This way, when lighting products from different manufacturers are used in the same space there is not an unintended assortment of light sources with some appearing a coolish white and others a warmish white.</td>
<td>ANSI C78.377 defines target colour temperatures and allowable tolerances (below)
IEC 62612 (Self ballasted LED)
IEC 62717 (LED modules)</td>
<td>Follow ANSI C78.377, excluding flexible CCT
<table>
<tr><th>Nominal CCT (K)</th><th>Target CCT (K)</th><th>Tolerance (K)</th></tr>
<tr><td>2700</td><td>2725</td><td>± 145</td></tr>
<tr><td>3000</td><td>3045</td><td>± 175</td></tr>
<tr><td>3500</td><td>3465</td><td>± 245</td></tr>
<tr><td>4000</td><td>3985</td><td>± 275</td></tr>
<tr><td>5000</td><td>5028</td><td>±283</td></tr>
<tr><td>5700</td><td>5665</td><td>± 355</td></tr>
<tr><td>6500</td><td>6530</td><td>± 510</td></tr>
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<tr>
<td>Colour spatial uniformity</td>
<td>The maximum allowable variation in the colour appearance of a light source when viewed from different angles.</td>
<td>Ensures that there are no extreme, perceptible colour variations in light output of a lamp. (Colour blotches are often perceptible in poor quality products)</td>
<td>Energy Star Product Specification for Lamps V1.1</td>
<td>To be considered only for inclusion in the standard.
Directional lamps: The variation of chromaticity across the beam and field angles shall be within 0.007 from the weighted average point on the CIE 1976 (u'v') diagram</td>
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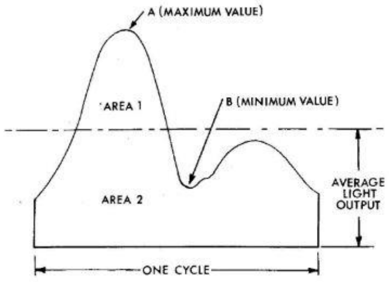
<tr>
<td>Chromaticity tolerance (Du’v’)</td>
<td>Specifies the allowable deviation in light colour; technically defined to be the distance of the light chromaticity from the Planckian (black body) locus as per ANSI C78.377</td>
<td>Ensures that all lamps of the same claimed colour temperature (CCT) appear to be the same colour when installed. Protects consumers from LED products that produce unacceptable pink or green tinted light.</td>
<td>ANSI C78.377
IEC 62612 (Self ballasted LED)
IEC 62717 (LED modules)</td>
<td>Centre points based on ANSI C78.377, excluding flexible CCT
<table>
<tr><th>Nominal CCT</th><th>Target Du'v'</th><th>± Tolerance</th></tr>
<tr><td>2700</td><td>0.000</td><td>± 0.006</td></tr>
<tr><td>3000</td><td>0.000</td><td>± 0.006</td></tr>
<tr><td>3500</td><td>0.000</td><td>± 0.006</td></tr>
<tr><td>4000</td><td>0.001</td><td>± 0.006</td></tr>
<tr><td>5000</td><td>0.002</td><td>± 0.006</td></tr>
<tr><td>5700</td><td>0.002</td><td>± 0.006</td></tr>
<tr><td>6500</td><td>0.003</td><td>± 0.006</td></tr>
</table>
</td>
</tr>
<tr>
<td>Colour maintenance (Δ u’, v’at 6000 hours)</td>
<td>The allowable colour shift of a lighting product as it ages.</td>
<td>Ensures that as the product ages, perceived colour of the light does not shift a noticeable extent – important for colour matching replacement lamps with existing lamps within an installation.</td>
<td>Energy Star</td>
<td>Δ u’, v’ (6000 hours) < 0.007</td>
</tr>
<tr>
<td>Start time</td>
<td>Amount of time for a lighting product to begin emitting light after power is turned on.</td>
<td>Short start times are necessary for emergency situations, and are preferable in tasks where the light will only be on briefly (i.e. Stairways, pantry, outdoor security). However this has not found to be a significant problem with LED lamps to date apart from lamps which are specifically designed to ramp up to full light output.</td>
<td>Energy Star</td>
<td><0.5sec until continuous light output</td>
</tr>
</table>

<table>
<tr>
<td>Minimum lumen maintenance (time to L_{70})</td>
<td>Indicates the amount of time it takes for a lighting product’s total light output to degrade to 70% of initial lighting levels</td>
<td>Lumen maintenance helps the consumer determine the time it will take for the lighting product to degrade to the point that it is no longer usable. High lumen maintenance over time helps to justify higher initial cost of LED lighting products.</td>
<td>IEC 62612 (Self ballasted LED)

IEC 62717 (LED modules)</td>
<td>At 15,000h, Lumen Maintenance > 70% of initial</td>
</tr>
<tr>
<td>Flicker (flicker index)</td>
<td>Measures the perceived photometric flicker of a lamp. Presently defined:

$$\text{Flicker Index}=\frac{\text{Area 1}}{\text{Area 1+Area 2}}$$



Source: IESNA Lighting Handbook, 9th Edition (Rea 2000)</td>
<td>Important for consumer satisfaction and resultant acceptance of LED products.

- Certain human health conditions are characterised by severe reactions to light sources that flicker at certain frequencies, with effects ranging from headaches to extreme seizures.
- Flicker can make rapidly moving objects seem like they are stationary
- Can also leave residual images of bright spots in the visual field

Flicker requirements minimise these stroboscopic effects.</td>
<td>IEEE PAR 1789</td>
<td>At full power: flicker index ≤ 0.3

Flicker index defined by Area 1/(Area 1+Area2); replaced by new metric under development by IEEE PAR1789 which accounts for frequency, when available (Link: http://grouper.ieee.org/groups/1789/)</td>
</tr>
</table>

Minimum rated lamp life (B_{50})	Typically defined as the amount of time that it takes for 50% of a statistically significant sample of lamps to fail.	It is unrealistic to physically measure very long lifetimes for LED products. Having a credible B_{50} estimation is very important, as longer LED lighting product lifetimes help to justify the high initial cost through accrued energy savings. Ultimately, if SSL products are able to meet their lifetime claims, they can cut long term energy consumption, save on manufacturing waste, and save money for consumers.	Energy Star	Minimum lifetime should be 50%at 15,000 hours. Inclusion in MEPS would require a practical, and preferrably internationally agreed test method to be available. IEA 4E SSL currently reviewing available methodology.
Maximum premature lamp failure rate	Defined as the maximum percentage of a lamp sample that is allowed to have failed within a percentage of the rated life of the lamp	This parameter is intended to reduce the number of early lamp failures. In the absence of a minimum lifetime test it could also serve as a substitute for lifetime in a MEPS.	IESNA LM84	10% at 30% of rated life. Or ≤ 5% early failures at 6000 hours
Endurance test	Includes supply switching test, temperature cycling test and accelerated operation test: Ability of LED product to be rapidly switched on and off, to simulate how the product will be used over its lifetime	The purposes of the tests are to check for catastrophic failures, the endurance of the built-in electronic components and the mechanical strength of the assembly. The endurance tests can help verify that an LED product will not fail when installed and used.	IEC 62612 Energy Star	Refer to section 11.3 of IEC 62612
Warranty duration	The duration in years from date of manufacture that the product has warranty cover for manufacturing faults	Important for consumers to have a guarantee of minimum amount of time that LED products will perform as claimed (justification of price).	SEAD:	With rated life <15,000 hrs, min warranty 2 years Life ≥ 15,000 hrs, min warranty 3 years (this option subject to confirmation of legislative feasibility).

Safety requirements	Specifies that a product meets electrical safety and marking requirements in an economy.	All products must meet all safety regulations of the region in which it is sold and used. This is covered under Australian / New Zealand electrical safety standards.	IEC 61000.3	n/a – safety standards and regulation
Safety marking	Specifies that a product meets electrical safety requirements and marking requirements	Provides assurance that the product meets all safety regulations of the region.	ANSI/UL 1598 CE mark	n/a – safety standards and regulation
Photobiological hazard class (UV & blue light)	Ultraviolet (UV) and blue light hazard (BLH) classes as defined in AS/NZS 62471 specify the allowable amount of optical radiation emitted by an LED product in range of 100-400 nm 400-500 nm spectrums, respectively.	Important for consumer safety; UV and blue light can cause damage to eyesight. Some human health conditions result in high sensitivity to UV wavelengths. Products must be evaluated to determine their appropriate photobiological hazard class.	IEC 62471 / CIE S009	RG0 or RG1 unlimited (IEC TR 62778:2015)
Minimum power factor	The ratio of real power flowing to the load to the apparent power in the circuit	Of high importance to the electricity distributors as they must generate more than the minimum volt-amperes necessary to supply the real power, which increases generation and transmission costs.	AS/NZS 61000.3	Low voltage lamps exempt. ≤5W: no requirement; >5W, PF >0.55 High power factor claim: 0.9

Harmonic distortion	Harmonic distortion is the addition of non-linear overtones in the waveform of electrical supply. This metric indicates how the lighting product will affect the quality of the electrical utility's grid. The metric is the mathematic ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.	Total harmonic distortion (THD) affects the quality of the electrical grid, causing a loss of reliability of switch pulse information used to remotely control equipment connected to the electrical supply. Therefore it must be kept as minimal as possible.	ANSI C82.77 Harmonic Emission Limits EN 61000-3-2 LED EMC/harmonics	Comply with IEC 61000-3-2
Electromagnetic Compatibility (EMC)			IEC 61547 C tick	n/a – regulated by ACMA / NZ Radio Spectrum Management (RSM), Ministry of Business, Innovation and Employment.
Dimmer compatibility	An evaluation of whether the LED lighting product will operate sufficiently well with installed dimmers used for incandescent light sources.	High importance for the consumer as many LED products are not completely compatible with commonly available dimmers.	NEMA SSL 7A-2013	Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. See details in Product Packaging section below.
Recyclability (%)	An indication of the proportion on an LED product which must be recyclable.	Important for management of electronic equipment waste so as to reduce the environmental burden of these products. Ideally products should be designed for easy of recyclability	ISO 14021	Not to be included in MEPS but manufacturers encouraged to principles of self- declaration found in ISO 14021
Standby Power	Power used by the lamp when not providing a lighting service.	Important as in some cases standby power draw can be as much if not more than the active energy use of the lamp during operation of lighting service.	AS/NZS 62301	<0.5W

Smart Lighting – controlled variations in power consumption	Power used by the lamp in addition to that used providing a lighting service – may include active standby and networking. May also include variations in power use and lumen output in response to changes in ambient conditions.	Important as may significantly reduce overall efficacy of the lighting product. May also make it harder to test and measure the product in relation to any compliance.		To be considered following the outcomes of investigations by the IEA 4E SSL and G20 working groups

Option 3: LED MEPS to also include a range of performance parameters (that address important quality and performance issues found in market testing) to ensure that LED lighting provides an effective as well as efficient lighting alternative.

9.2.4 Tropical Performance

In some parts of Australia LED products are likely to be frequently or constantly operated in conditions more extreme than the conditions that lamps are usually tested under in lighting test laboratories. As electronic devices, higher temperatures can impact upon performance or operating life. The lites.asia forum has released a set of additional performance criteria for lamps that are used in conditions of extreme temperatures, voltage fluctuations and insect infiltration conditions (www.lites.asia/downloads/tropical-performance-criteria) that would be tested in accordance with IEC 62612. Provision for optional compliance to some or all of these additional requirements could be included in the Australian and New Zealand Standard and/or MEPS so that products that comply with the additional tropical performance specifications could make such a claim on product packaging.

Option 4: Include optional extreme conditions performance specifications in the Australian and New Zealand Standard and/or MEPS.

9.2.5 Equivalency of Energy Efficient Lamps for Consumers

Consumers are now faced with a variety of lighting alternatives that make selection of replacement lamps by wattage impractical, while the diverse range of lumen outputs available can also be difficult for consumers to compare and understand or appreciate the significance (acceptability) of the variance between products. One option to address this issue may be the classification of lamps within a simplified range of luminous flux. A proposal by China has been approved by the IEC TC34 Committee to amend IEC 62612 to state that for non-directional LED lamps, the rated luminous flux LED lamps be preferably one of the following values:

- **100lm, 150lm, 250lm, 350lm, 500lm, 800lm, 1000lm, 1500lm, 2000lm, 3000lm**

For most consumers, only 6 of these values would be relevant (these are: 150 lumens or approximately 25 W tungsten filament, through to 1500 lumens approximately 100 W tungsten filament). If this approach was to be taken on packaging in Australia and New Zealand, consideration would need to be given to requiring that the initial luminous flux of each individual lamp in the measured sample would be within a specified range around the particular level (for example, not less than the rated luminous flux by more than 10%, and not be more than the rated luminous flux by more than 20%). The allowance for variations in the rated luminous flux on packaging would not however extend to compliance for MEPS. Such a system could be applied to the full range of omnidirectional lamp types including compact fluorescent, LED and halogen lamps. It would also be beneficial to consumers for the lumens per Watt to be included on packaging. Consumer education material could be prepared to explain this approach, combined with guidance on lamp equivalency.

Option 5: In the MEPS include a preferred range of rated luminous flux values to be used on lamp packaging, along with a requirement for lumens per Watt to be included on packaging in order to assist consumers in selecting replacement lamps.

9.2.6 Packaging Requirements

The availability of consistent energy use and performance specification on products and product packaging, backed up by further details in technical information and on supplier websites can assist consumers in selecting the correct efficient lighting product for their needs and using it correctly. This is particularly important with LEDs where consumers are being encouraged to make the transition from other less efficient lighting technology. Consistent packaging can also assist with compliance and enforcement if MEPS requirements are regulated. In some cases the inclusion of information on the product itself (such as lumen output) would help consumers with selection of a replacement product at a later date when the original packaging may have been disposed of. In addition to the proposed preferred range of rated luminous flux values discussed above (option 5), consumers would benefit from the following information being included on product packaging and/or the product in a consistent manner:

- Lumens,
- Efficacy (lumens per Watt) ;
- Watts (in a smaller font than efficacy in order to encourage consumers to judge product equivalency by light output);
- Lifetime;
- Correlated colour temperature (CCT) in Kelvin (K);
- Dimability compatibility information;

- ELVC converter compatibility information (for products intended to serve as retrofits for low voltage halogen lamps);
- Website link for compatibility and disposal information;
- Linear LED retrofit statement regarding compatibility and whether the product meets the definition of a retrofit linear LED;
- Standby energy use;
- Product identification number as used for product registration.

The issue of compatibility of LED lamps with existing dimmers and ELVC converters is important in terms of ensuring that a range of efficient LED products are available to be installed in lighting systems in use in Australian and New Zealand homes.

It is proposed that if a product is declared as dimmable, the manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer could also be required to list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.

For products claiming to be retrofit replacements for MR16 halogen lamps, a requirement for similar information to be provided on compatibility with the range of ELVC converters (and maximum number of lamps that can be connected) would also assist consumers in selecting a compatible product.

Option 6: Suppliers be required to include efficacy and performance information on LED product packaging and/or the LED product to enable customers to choose a suitable and efficient model.

Packaging information is also important to assist in product identification during compliance activities. Past experience with compliance surveys of lighting products has shown that it is often difficult to match a product found for sale with the range of registered products. One option may be to require additional identification information to be provided during product registration. Such information would need to be able to be found on all lamps or packaging – bar codes may be one example. Stakeholder input is requested in order to establish the best way to collect product identification data for lighting products during the registration process in order to assist with compliance activities.

9.2.7 Labelling and HEPS

Product energy labelling has its influence primarily at the point of consumer product purchase, thereby encouraging manufacturers to produce more efficient equipment. Energy labelling includes comparative labelling (e.g. a star rating) or the use of voluntary endorsement labelling such as ENERGY STAR. New Zealand runs an active ENERGY STAR scheme for a number of electrical appliances; including CFLs and LEDs (see Chapter 7). An option would be for Australia to adopt the New Zealand specification of ENERGY STAR for CFL and LED products. This would provide an added means of encouraging lamp suppliers to meet high energy performance levels voluntarily.

The main disadvantage of any voluntary labelling scheme is that it is generally only the high efficiency products (typically the top 20% of the market) which are labelled and, while it would make it easier for consumers to identify these products, they would not be able to compare the performance and benefits with the lower efficiency products. Such a scheme would also have less impact in large parts of the commercial lighting market, subject to a split incentive where the appliance is purchased by the building owner who often isn't the end-user and bill payer.

Endorsement schemes also need to be supported by a robust compliance regime (potentially competing for compliance resources with enforcement of MEPS) and considerable marketing and promotion if consumers are going to use and have confidence in endorsement labels. In the case of lighting, a performance label by itself would not realise the savings that can be gained by imposing MEPS but, when combined, may add to savings. This could be facilitated by Australia following the lead of New Zealand in adopting the US Energy Star high performance label in addition to MEPS for CFLs and LEDs.

Given the wide range of efficacy now available (and likely to broaden further in the future); another alternative would be to apply the Australia New Zealand Energy Rating Label to a range of lighting products. In order to be effective and equitable, the label would need to be required for all technologies available on the market for particular applications – for example, residential omnidirectional and directional lamps.

A further option would be to open the US Lighting Facts labelling scheme to the Australian and New Zealand market (or establish a similar scheme in Australia and New Zealand). Consideration is currently being given in the

IEA 4ESSL Annex as to how the US Lighting Facts Scheme could be extended to other markets (if agreed by the US administrators). As discussed in Chapter 4, Lighting Council Australia currently administers a very similar scheme, but this is only open to Council members. This approach would be most relevant if a decision was made to not go ahead with regulated MEPS requirements for LED lighting. By requiring test validation of performance claims, the label could ensure that participating products accurately report performance, but, as no minimum performance levels would be applied, such information in itself may be of limited assistance to less technically knowledgeable consumers.

Option 7: That Australia adopt and implement the New Zealand specification of voluntary ENERGY STAR labelling for high efficiency CFL and LED and luminaire products to provide customers with comparative information on lamp efficacy.

Option 8: Develop and apply the Australia / New Zealand Energy Rating Label to all lamp technologies available for specified range of lamp applications to provide customers with comparative information on lamp efficacy.

Option 9: If a regulated MEPS is not implemented, Australia and New Zealand establish the Lighting Facts scheme (or similar program) for LED products to provide consumers with accurate lamp performance information.

9.2.8 Establishment of an Australian and New Zealand LED Test Standard

While essential if a regulated MEPS was to be introduced, an integrated LED test standard would still be of use if MEPS were not introduced as it would give a common baseline for LED performance testing and validation of performance claims in the Australian and New Zealand market. As outlined in Chapter 7, manufacturers and test laboratories have until recently had to rely upon a range of national level test methods in order to determine product performance. The release of the international CIE S 025/E:2015: Test Method for LED Lamps, LED Luminaires and LED Modules offers an opportunity to establish a AS/NZS LED test standard with reference to CIE S 025. However CIE S 025 does not cover all parameters that may be necessary for LED performance testing, so in some cases testing specifications may need to be drawn from other resources including IEC standards.

Appendix C sets out possible tests that could be included in an Australian and New Zealand LED performance test standard. The table in the appendix reviews the published CIE S 025 for the specific test methods required for each of the parameters and, where no such test method is provided in CIE - 025, a recommendation from the international standards bodies (IEC, CIE) or a national regulatory authority (USA Energy Star) is provided. Where a relevant test method is available in AS/NZS 4847: Self-ballasted lamps for general lighting services Part 1: Test methods – Energy performance this is also noted.

Option 10: An Australian - New Zealand LED test standard be developed with reference to available international test standards including CIE S 025.

9.3 Information and education

Influencing Lighting Design

Good lighting design can further reduce overall lighting energy consumption (as well as provide better lighting quality). Influencing lighting design can be undertaken at the point of building design and also at the point of building renovation or tenancy turnover. This option could be explored further and might be achieved by training of lighting professionals, trades, retailers, etc.

The Australian government has previously worked with the National Electrical Communications Association (NECA) in developing an Energy Efficient lighting training resource as part of their EcoSmart Electricians Program. This has also been used as a resource document in other programs run by the Illuminating Engineering Society of Australia and New Zealand and it is planned that this document be reviewed and updated.

A specialist lighting retailer training package has also now been released in Australia which is intended to help retailers and customers achieve improved energy efficiency outcomes through the selection of more efficient lighting and understanding of better lighting design. The New Zealand government has also developed the Energywise website, which includes tips on lighting design and a virtual designer tool.

The maximum illumination power density requirements for new buildings and significant renovations contained in the Building Code of Australia also encourage efficient lighting design.

Ultimately, the ability of information to influence a market toward efficient lighting design relies on relevant information being made available and consumers or installers seeking out the information and/or acting on it at the time they make a purchase or recommend a product.

Changing Consumer Behaviour

Changing consumer behaviour can target buying behaviour and operating behaviour, and can be achieved using educational initiatives and incentives such as lamp exchange programs or point of sale information.

At the start of the Australian phase-out of inefficient lighting in 2009, the initial focus of the communication strategy was to educate consumers and store assistants in-store of the most appropriate energy efficient lamp alternative to the traditional incandescent light globe.

In consultation with Australian retailers, E3 created and distributed to retailers a range of Change the Globe (CTG) branded POS materials, including consumer and staff posters, CFL stylised hanging posters, light globe and globe conversion guides (as stand-alone cards and tear-off forms), and shelf-strips. More detail on the phase-out, including Frequently Asked Questions and fact sheets on health aspects, were included on the then Department of Environment, Water, Heritage and the Arts website (now on the Energy Rating website).

A research study assessing the POS campaign (Winton Sustainable Research Strategies 2011) in mid-2010 found that most people were aware of the phase-out before the POS campaign materials and associated publicity were released. Less than half the sample recalled seeing any POS materials to do with the phase-out and, despite being supplied to participating retailers, little POS materials were found in stores. At the time of the survey two years after the commencement of the phase-out, most people thought that the CTG POS material was no longer needed in its current format since the phase-out had largely occurred. However, many consumers felt there was still a need for some kind of POS material containing information to assist with:

- choosing the appropriate “brightness” of light to meet their needs;
- choosing the appropriate colour of light;
- clearly explaining LEDs; and
- providing advice on a range of common concerns and issues mainly related to CFLs (e.g. flickering, slow start-up, mercury, correct disposal).

The recently released specialist Lighting Retailer Training Package (developed in consultation with retailers and the lighting industry) is intended to help retailers and their customers achieve improved energy efficiency outcomes through the selection of more efficient lighting and understanding of better lighting design.

A guide to purchasing LED lighting has also been provided on the E3 website, however with the increasing emergence of LED lighting technology there is potential benefit in further information being provided on selecting and using LED lamps and luminaires.

In New Zealand, Energywise website information is available to compare running costs of lamps, there have been POS promotions, TV commercials and ENERGY STAR labelling to promote efficient lighting.

The option of encouraging or requiring preferred rated luminous flux values outlined in section 9.2.5 accompanied by consumer education, would be one way of assisting consumers to select appropriate “brightness” of light for their needs in LED lamps.

One of the disadvantages of an information campaign alone is that awareness and promotional activities only have a limited effect to establish new practices and norms. The awareness and promotional phase cannot be maintained indefinitely due to the large operational costs involved. It is also dependent upon retailers being willing to have material in-store.

Encouragement of efficient lighting such as LEDs and CFL lamps over halogen lamps through information and education (by industry and/or government) may be explored as an option. However, the significant difference in the level of transition from incandescent lighting between Australia (62% where MEPS has been in place since 2009) and New Zealand (32% where MEPS is not in place for incandescent lamps and only since 1 October 2012 for CFL lamps), it is clear that a combination of MEPS and education will result in significantly more uptake of efficient lighting alternatives than education programs alone.

Any further consumer awareness initiatives addressing the issues outlined above would benefit from evaluation and testing with consumers and the lighting industry prior to release.

Option 11: Implement a consumer education campaign about LED lighting (in cooperation with the lighting industry and retailers) either:

- ***alongside the introduction of MEPS for LEDs;***
- ***alongside the introduction of a labelling scheme; or***
- ***as a stand-alone initiative.***

Grants and Subsidies

Grants and subsidies can reduce financial barriers to energy efficient lighting. They include tax incentives, rebates and energy efficiency obligation schemes which generate subsidies for retrofit of efficient lighting. Section 8.8.3 of the E3 2014 Incandescent, Halogen and Compact Fluorescent Lamp Product Profile discusses current grants and subsidy programs in place for efficient lighting in Australia and New Zealand.

9.4 Summary of policy options

Possible policy directions for LED lighting products within the scope of this Product Profile are summarised below. More than one option could be implemented at the same time. Policy options investigated in a Regulation Impact Statement (RIS) would be subject to further consultation in both countries, and to Ministerial approval in New Zealand.

Option 1: *Introduce LED MEPS with a minimum efficacy level set to remove the lower performing lamps in the Australia and New Zealand Market. Efficacy level to be either:*

- *One or more linear levels; or*
- *A curved level.*

Option 2: *Set a timetable of increases to minimum efficacy levels via MEPS.*

Option 3: *LED MEPS to also include a range of performance parameters (that address important quality and performance issues found in market testing) to ensure that LED lighting provides an effective as well as efficient lighting alternative.*

Option 4: *Include optional extreme conditions performance specifications in the Australian and New Zealand Standard and/or MEPS.*

Option 5: *In the MEPS include a preferred range of rated luminous flux values to be used on lamp packaging, along with a requirement for lumens per Watt to be included on packaging in order to assist consumers in selecting replacement lamps.*

Option 6: *Suppliers be required to include efficacy and performance information on LED product packaging and/or the LED product to enable customers to choose a suitable and efficient model.*

Option 7: *That Australia adopt and implement the New Zealand specification of voluntary ENERGY STAR labelling for high efficiency CFL and LED products to provide guidance on high performance lamps.*

Option 8: *Develop and apply the Australia / New Zealand Energy Rating Label to all lamp technologies available for specified range of lamp applications to provide customers with comparative information on lamp efficacy.*

Option 9: *If a regulated MEPS is not implemented, Australia and New Zealand establish the Lighting Facts scheme (or similar program) for LED products to provide consumers with accurate lamp performance information.*

Option 10: *An Australian - New Zealand LED test standard be developed with reference to available international test standards including CIE S 025.*

Option 11: *Implement a consumer education campaign about LED lighting (in cooperation with the lighting industry and retailers) either:*

- *alongside the introduction of MEPS for LEDs;*
- *alongside the introduction of a labelling scheme; or*

- *as a stand-alone initiative.*

9.5 Cost-benefit analysis

The level and timing of energy productivity benefits of the transition to LED lighting will in part depend upon the speed at which lighting consumers make the transition from less efficient lighting such as the remaining incandescent and halogen lamps. This in turn will be influenced by policies and regulation for both efficient and inefficient lighting.

The Incandescent, Halogen and Compact Fluorescent Lamp Product Profile proposes an accelerated phase-out of these products through increasing the MEPS for incandescent/halogen lamps in Australia to a level that would result in the removal of these products from the market, as effective and efficient alternative products (such as LEDs and CFLs) become available at a reasonable cost (see Sections 8.2 and 8.3). Note that under New Zealand's existing policy settings, MEPS would only be considered where it does not risk eliminating a lighting technology from the New Zealand market (as is the case with the existing MEPS for CFLs).

Table 18 shows the results of the preliminary cost-benefit analysis for scenarios involving a complete transition to efficient CFL and LED lighting for the residential sector. The options assessed have positive NPVs and IRRs of at least 34%. Note that the national energy savings shown depend on all residential lamps being affected by MEPS, noting that there will be further savings from lamps in the commercial sector (example shown below), and that natural market forces will also play a role - MEPS cannot take credit for all of these savings (although the level of anticipated business-as-usual activity is very difficult to forecast).

This further transition to high efficiency lamps would reduce residential lighting energy use in Australia by approximately 65% and reduce greenhouse gas emissions by up to 2219 kilotonne CO2-e p.a. for Australia and 966 kilotonne CO2-e p.a. for New Zealand and therefore reduce the cost of carbon abatement. Improvements to residential lighting have a significant negative abatement cost, at about negative $40 per tonne of CO2-e (Lewis and Gomer 2008).

Table 18.Preliminary cost benefit analysis and energy savings (from a consumer perspective).

	Complete Transition from MV incandescent & halogen lamps to CFL and LED	**Complete Transition from ELV halogen lamps to CFL and LED**
Power saving per lamp (W)	40	26
Energy cost saving per lamp p.a. (@ 1.5hrs/day, 25c/kWh)	$5.48	$3.56
Additional cost per lamp (note LED lamp cost is likely to be significantly lower in the medium term)	$10.00	$10.00
Net present value @ 7% over 10 years (per lamp)	$28.45	$15.00
Internal rate of return (IRR) over 10 years	54%	34%
Benefit : cost ratio (nominal over 10 years)	5.5	3.6
No. lamps affected per house (Australia)	15.4	12.3
No. lamps affected per house (New Zealand)	22.3	3.8
Annual national energy savings (Australia) (TWh p.a.)	3.4	1.8
Annual national energy savings (Australia) (PJ p.a.)	12.3	6.4
Annual national energy savings (New Zealand) (TWh p.a.)	0.8	0.1
Annual national energy savings (New Zealand) (PJ p.a.)	3	0.2

Energy savings in the commercial sector would be achieved through conversion of linear fluorescent lamps to LED lamps. The typical linear fluorescent lamp consumes 40W power and provides 3500 lumens of light, a proportion of which is absorbed in the reflector cavity of a luminaire, whereas the typical LED linear replacement or LED panel runs on 28W and provides 2100 lumens with very low luminaire losses. Using these figures, and based on a daily runtime of 12.6 hours, the change to LED would yield immediate savings (in 2015) of 670 GWh per year in Australia and 130 GWh per year in New Zealand, translating to a saving of 590 megatonne CO_2-e p.a. and 18 megatonne CO_2-e p.a. of greenhouse gas emissions, respectively, as shown Figure 47.[5] By 2030, in consideration of growth of Australian and New Zealand commercial spaces, the energy savings could potentially have risen to 1540 GWh in Australia and 570 GWh in New Zealand during that year.

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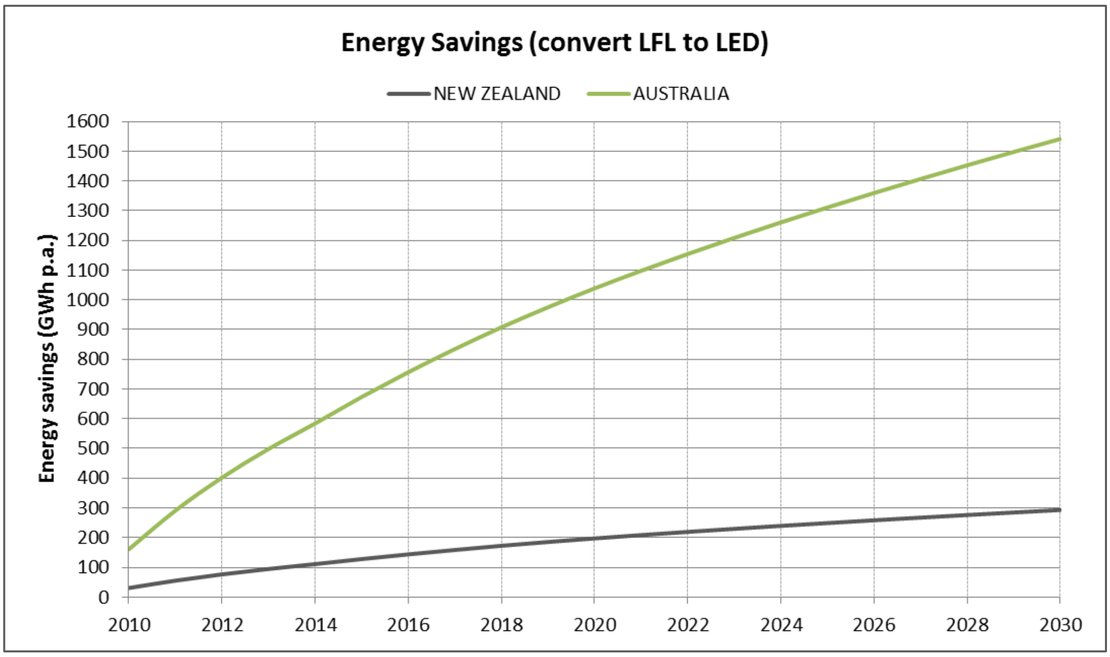
[5] Australian greenhouse gas emission factor as at 2014 given as 0.8774; New Zealand emission factor 0.1380 in 2015.

Figure 47.Energy savings to be achieved through changeover of all linear fluorescent lamps to LED lamp technology.



With or without a further accelerated regulated phase-out of inefficient lighting, government actions to encourage the transition to efficient lighting including LEDs can help ensure that a larger portion of the market will change, and at an earlier point in time. The introduction of a MEPS for LED lighting in particular would provide an assurance to consumers of the minimum quality and performance of LED products, ensuring greater consumer satisfaction with LED products and less chance of a consumer backlash and return to less efficient products. By setting a minimum efficacy level, MEPS would ensure that consumers making the transition do not lose some of the energy saving benefits available through the presence of less efficient LED products in the market.

It is estimated that the introduction of a minimum efficacy level, by increasing the average efficacy achieved by LED lighting, could increase the energy savings of a household with 75% LED lighting installed from 25% to 29% dependent upon MEPS level. If 75% of installed residential lighting became LED; with a household technology breakdown as depicted in Figure 48, this would translate to an additional energy saving above those outlined in

Table 18 for Australia and New Zealand of between $209 and $243 million.

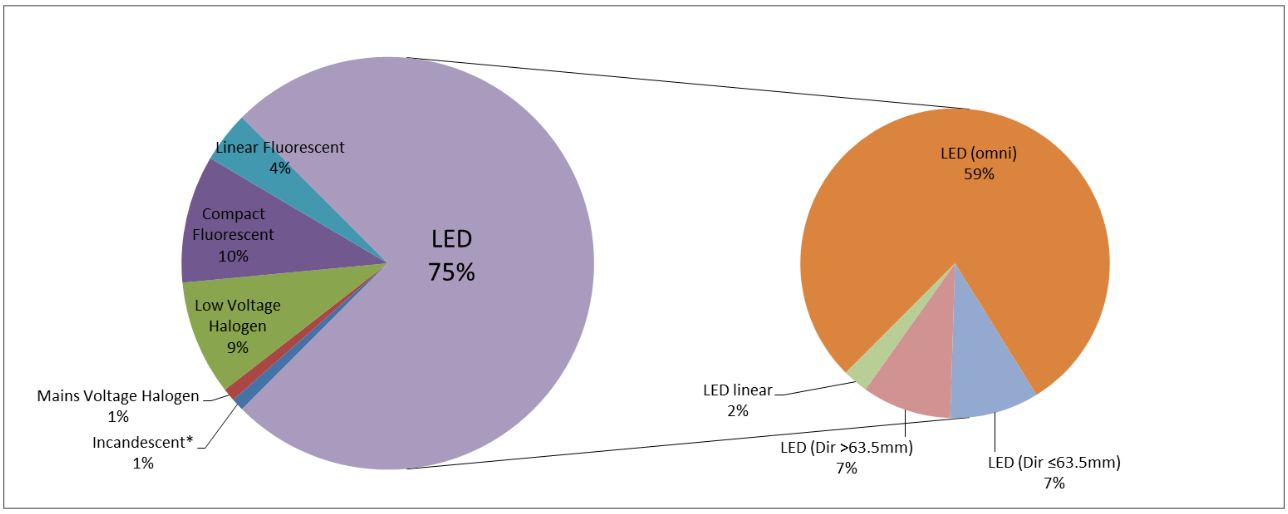


Figure 48. Hypothetical lamp technology breakdown in a residential house where 75 % of lamps are LED lamps (circle left), further breakdown of LED lamp types provided (circle right).

In Australia, with approximately 9.1 million homes and where there are 46 lamps in the average household, the additional energy saving, indicated in Table 18, would be 91.8 kWh per year (25%) for each home and 837 GWh per year across Australia, upon introduction of MEPS at a level equal to IEA Tier 1. The energy savings increase to 106.8kWh per year (29%) in homes and 974 GWh per year Australia-wide with introduction of an IEA Tier 2 level.

Table 19. Predicted energy savings for Australian homes with 75% LED lamps installed, upon introduction of MEPS equal to IEA Tier 1 and Tier 2 minimum efficacies.

Australia – 75% LED Installed Stock Scenario			
Status Quo (no LED MEPS)	**Per Household**		
	Lighting energy consumption (kWh p.a.)	363	
	Energy cost (AUD)	$91	
	National		
	Energy consumption (GWh p.a.)	3,313	
	Total energy cost (AUD)	$828,354,804	
		IEA Tier 1	**IEA Tier 2**
Introduce LED MEPS	**Per Household**		
	Lighting energy consumption (kWh p.a.)	272	257
	Current energy cost (AUD)	$68	$64
	National		
	Energy consumption (GWh p.a.)	2,477	2,340
	Total energy cost after transition (AUD)	$619,228,242	$584,923,739
Savings	**Per Household**		
	Energy savings (kWh p.a.)	91.8	106.8
	Energy savings (% p.a.)	**25%**	**29%**
	Cost savings (AUD)	$23	$27
	National		
	Total energy savings (GWh p.a.)	837	974
	kt GHG-e (kg CO2-e/kWh)	734	854
	Total cost savings (AUD)	$209,126,562	$243,431,065

Similarly for New Zealand, which has approximately 1.7 million homes and where there are 35 lamps in the average household; the additional energy saving, indicated in Table 19 would be 69.8 kWh per year (25%) for each home and 122 GWh per year across Australia, upon introduction of MEPS at a level equal to IEA Tier 1. The energy savings increase to 81.3 kWh per year (29%) in homes and 142 GWh per year across the country with introduction of an IEA Tier 2 level.

Table 20.Energy savings for New Zealand homes with 75% LED lamps installed, upon introduction of MEPS equal to IEA Tier 1, Tier 2, 45 lm/W and 60 lm/W minimum efficacies.

New Zealand			
Status Quo (No MEPS)	**Per Household**		
	Lighting energy consumption (kWh p.a.)	277	
	Energy cost (NZD)	$72	
	Nationally		
	Energy consumption (GWh p.a.)	484	
	Total energy cost (NZD)	$125,710,646	
		IEA Tier 1	**IEA Tier 2**
Introduce MEPS	**Per Household**		
	Lighting energy consumption (kWh p.a.)	207	195
	Energy cost (NZD)	$54	$51
	Nationally		
	Energy consumption (GWh p.a.)	361	341
	Total energy cost after transition (NZD)	$93,973,720	$88,767,688
Savings	**Per Household**		
	Lighting energy savings (kWh p.a.)	69.8	81.3
	Energy savings (% p.a.)	**25%**	**29%**
	Cost savings (NZD)	$18	$21
	Nationally		
	Total energy savings (GWh p.a.)	122	142
	kt GHG-e (kg CO2-e/kWh)	17	20
	Total cost savings (NZD)	$31,736,926	$36,942,958

Through this modelling there is a clear indication that positive energy saving outcomes might be achieved through implementation of regulatory action that would encourage the uptake of energy efficient lighting solutions.

All policy options for further consideration would be subject to thorough analysis of costs and benefits in a consultation RIS.

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Appendix A – Chromaticity

The CIE 1931 Chromaticity Diagram represents all colours that the human eye can perceive. The curve that forms the periphery of the diagram is called the spectral locus, and this corresponds to the spectral colours in the visible light spectrum. These are the wavelength values of hue. The colours located in other areas are not spectral; the bottom straight line represents a line of pink/purples, while the interior are unsaturated colours composed of a mix of a spectral colours.

For white light sources that correspond somewhat closely to the radiation colour of a black body radiator (such as the Sun) at various temperatures (called the Planckian locus), a correlated colour temperature can be assigned.

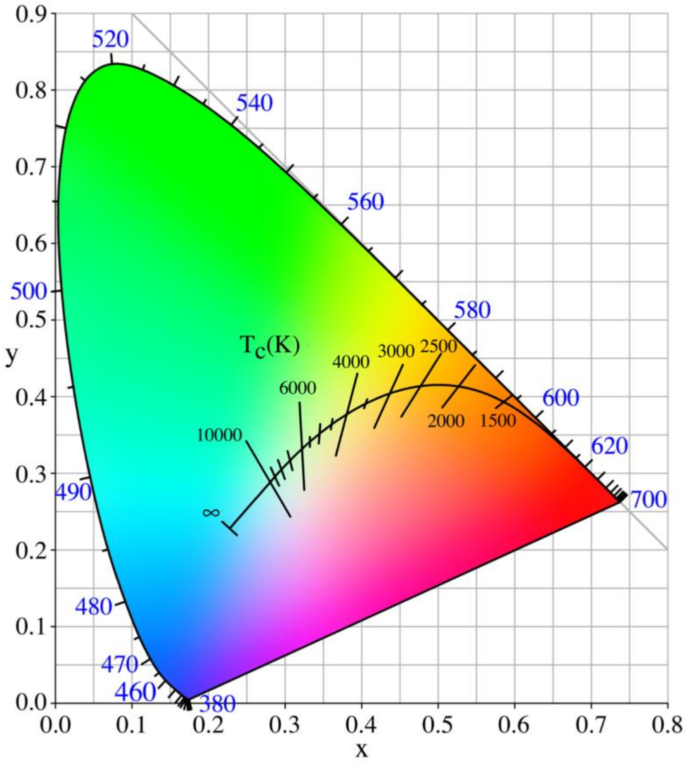


Figure 49. CIE 1931 x, y chromaticity space, showing the chromaticities of black-body radiating light sources of various temperatures (called the Planckian locus), and lines of constant correlated colour temperature (Tc).

Chromaticity measurement of LED lamps gives an indication of how closely the output corresponds with the Planckian locus. Light sources that have a spectrum that places them above the Planckian locus will appear more green or yellow (not enough blue or red content in their spectrum); those that are below this line will appear pinkish (not enough green wavelength content). ANSI chromaticity specifications as given in standard C78.377-2008 ‘Specifications for the Chromaticity of Solid State Lighting Products’ provide a target center point and tolerance quadrangle, the latter which approximately correspond to the 7-step MacAdam ellipses used in the compact fluorescent lamp chromaticity specification. These quadrangles define perceptible colour differences.

Figure 49 shows the chromaticity values of LED lighting products purchased between 2009 and 2014, and their relation to the Planckian locus or black body curve.

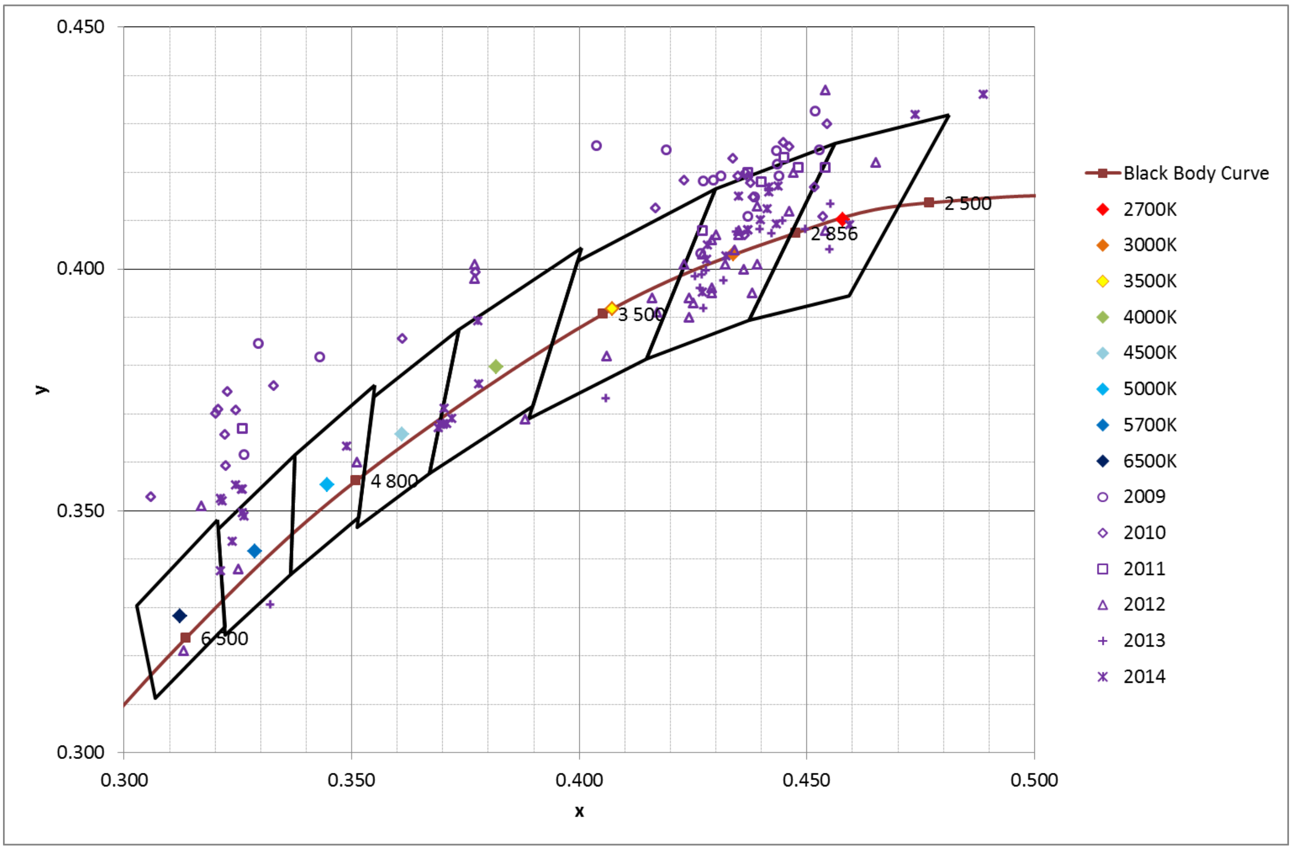


Figure 50. Chromaticity of LED lamps tested by Australian Government 2009-2014.

It is evident in Figure 50 that in the earlier years, 2009-2010, LED light sources were not satisfactorily recreating white light that resembled that of a black body radiator; the majority of the warmer colour temperature lamps had a greenish yellow appearance, and the cooler colour temperature lamps produced a straight greenish appearance. From 2012-2014, a significant improvement is recorded.

The following series of (8) charts provides the same data as in Figure 50, now with CCT test results displayed on separate charts for each colour temperature category that are based on the rated CCT as provided by the manufacturer. This provides a visual assessment tool for determining whether the lamp tested to have a Tc that corresponds with rated value, which has been rounded to group in with the Nominal CCT values as outlined in ANSI C78.377-2008. For example, where the manufacturer has indicated that the lamp is 2800 K, the tested value for that lamp will appear on the Chromaticity Diagram for 2700 K; if the tested value was 3500K, it will still appear on the 2700 K chart.

This has been done to illustrate the result from the perspective of the home buyer of the lighting product – if purchaser wishes to replace an old compact fluorescent lamp which they know to be a 2700 K lamp, and the LED lamp packaging states that it is a Warm White lamp with colour temperature of 2700 K, if this claim is proven untrue the purchaser is likely to be dissatisfied with their purchase.

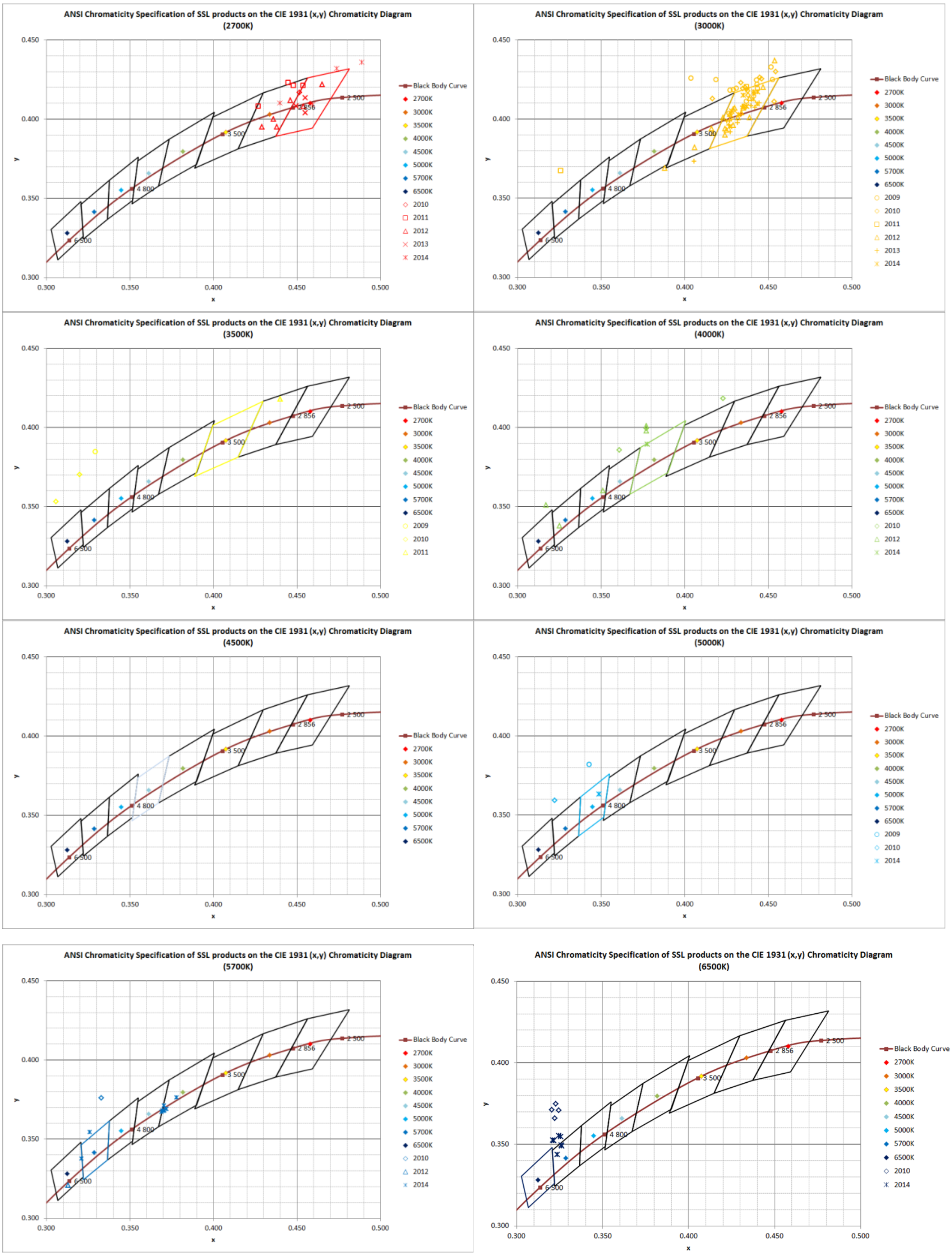


Figure 51 ANSI Chromacity Specification of SSL products on the CIE 1931 (x,y) Chromacity Diagram by colour temperature

Appendix B – International Test Methods and Regulatory Regimes

Introduction

Australia has implemented Minimum Energy Performance Standards (MEPS) for a number of lighting products.

- Linear fluorescent lamps (2006)
- Ballasts for linear fluorescent lamps (2006)
- Incandescent (tungsten filament and halogen) lamps (2008)
- Halogen lamp extra-low voltage (ELV) transformers (2008)
- Self-ballasted compact fluorescent (CFLi) lamps (2008)

Since the introduction of these standards, LED lamps and luminaires have become available in forms, which claim direct replacement capability for the traditional lighting products. The LED products were originally very expensive and not comparable in light output (and other light quality features) to typical domestic lamps such as 60W, 75W, 100W omnidirectional incandescent lamps and 50W MR16 halogen directional lamps (12V and 240V). Advances in LED lighting product development have now reached a point where some of these products are comparable, cost effective alternatives to the traditional lamps.

Research to date has identified that there is a significant range in the quality and performance and energy efficiency of LED products and consequently some form of action to protect the consumer and to achieve the potential energy savings (and associated greenhouse gas reductions) needs to be considered.

Australia is participating in the International Energy Agency, Energy Efficient End-use Equipment program for Solid State Lighting (IEA 4E SSL) which is working towards agreed performance tiers for particular LED lighting products.

A number of countries have already implemented, or are the process of implementing, regulatory mechanisms for LED lighting products. These can be either mandatory or voluntary include:

- Minimum Energy Performance Standards (MEPS)
- High Efficiency Performance Standards (HEPS)
- Comparative Labelling Schemes
- Endorsement Labelling Schemes

The base levels of both performance standards, i.e. MEPS and comparative labelling schemes, are typically mandated. Whereas higher levels for performance standards, i.e. HEPS and endorsement labelling schemes, are typically voluntary.

Each of these regulatory mechanisms requires test methods for which each nominated parameter shall be measured. The test methods for some or all of the specified parameters may be incorporated within the regulation or be referenced from third party entities, such as:

- International Commission on Illumination (CIE)
- International Electrotechnical Commission (IEC)
- Illuminating Engineering Society of North America (IESNA)
- National Standards organisations (e.g. Standards Australia, Standards New Zealand)

This appendix summarises the economies which that have voluntary and mandatory regulatory regimes for LED lighting products, the scope of LED products covered and the test methods used, for the purpose of identifying which programs are considered appropriate for further investigation by the Australian and New Zealand governments.

Regulatory Regimes

A summary diagram has been adopted in order to convey the regulatory frameworks being implemented in each economy in which the four regulatory mechanisms discussed above are represented as quadrants of a circle. These are colour coded based on:

- Grey indicates No regulation in place
- Green indicates Voluntary regulation in place
- Orange indicates Mandatory regulation in place

For those with regulation in place the associated text box provides the name of the regulatory program as well as listing four categories of LED lighting product qualities that could be included in the regulation.

- Energy efficiency
- Light quality parameters
- Electrical quality parameters
- Product quality parameters

If a parameter associated with a category is specified in a regulatory mechanism (e.g. MEPS) then that category marked, with a green tick, as being included within that mechanism. If no parameters from a category are included the category is marked accordingly with a red cross.

Due to there being many parameters within each category, with the likelihood of only subsets from within each category being regulated by an economy, if any single parameter within a category is included in a regulatory program, then the category is ticked green.

The categories with their associated parameters are:

- Energy efficiency

— Efficacy (lumens per Watt)
— Power limit (Watt) – maximum for a product type or

- Light quality parameters

— Correlated colour temperature (CCT)
— Colour rendering index (CRI)
— Colour shift – spatial and temporal
— Colour difference
— Lumen maintenance
— Start time
— Run-up time

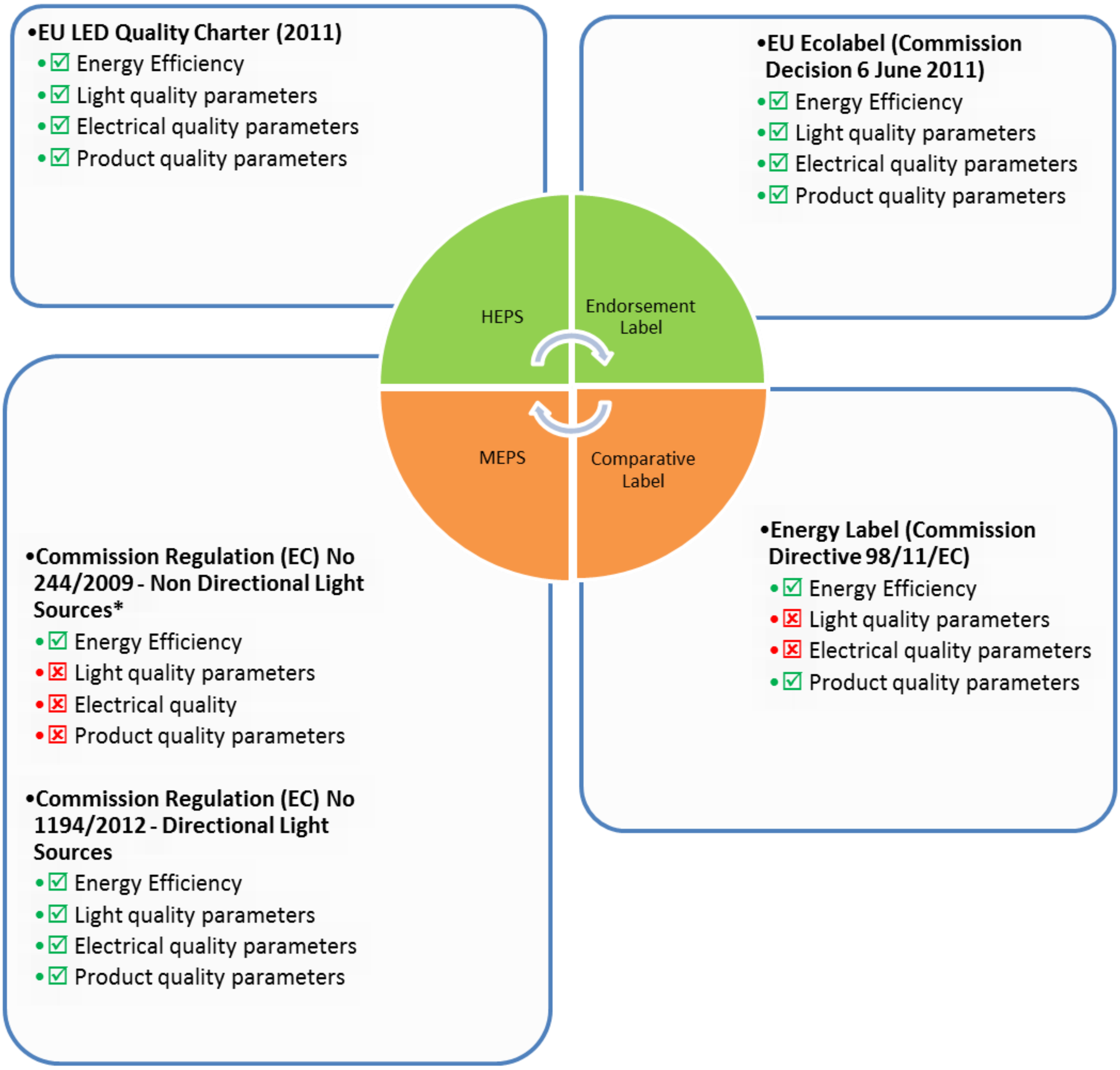
- Electrical quality parameters

— Power factor
— Harmonic distortion
— Dimmability

- Product quality parameters

— Lifetime
— Switching withstand
— Operating temperatures
— UV limit
— Blue light hazard

European Union



EU LED Quality Charter (2011)
- ☑ Energy Efficiency
- ☑ Light quality parameters
- ☑ Electrical quality parameters
- ☑ Product quality parameters

EU Ecolabel (Commission Decision 6 June 2011)
- ☑ Energy Efficiency
- ☑ Light quality parameters
- ☑ Electrical quality parameters
- ☑ Product quality parameters

Commission Regulation (EC) No 244/2009 - Non Directional Light Sources*
- ☑ Energy Efficiency
- ☒ Light quality parameters
- ☒ Electrical quality
- ☒ Product quality parameters

Commission Regulation (EC) No 1194/2012 - Directional Light Sources
- ☑ Energy Efficiency
- ☑ Light quality parameters
- ☑ Electrical quality parameters
- ☑ Product quality parameters

Energy Label (Commission Directive 98/11/EC)
- ☑ Energy Efficiency
- ☒ Light quality parameters
- ☒ Electrical quality parameters
- ☑ Product quality parameters

*Note EC244/2009 does have quality/performance requirements other than efficacy for a range of lamp types but not LEDs. LED quality/performance requirement were subsequently issued as part of 1194/2012.

Commission Regulation No 244/2009

Scope

This Regulation establishes ecodesign requirements for the placing on the market of non-directional household lamps, including those marketed for non-household use or when they are integrated into other products. It also establishes product information requirements for special purpose lamps.

Exclusions:

- lamps having the following chromaticity coordinates x and y:

— $x < 0.200$ or $x > 0.600$
— $y < -2.3172 x^2 + 2.3653 x - 0.2800$ or $y > -2.3172 x^2 + 2.3653 x - 0.1000$;

- directional lamps;
- lamps having a luminous flux below 60 lumens or above 12,000 lumens;
- lamps having:

— 6 % or more of total radiation of the range 250-780 nm in the range of 250-400 nm,
— the peak of the radiation between 315-400 nm (UVA) or 280-315 nm (UVB);

- fluorescent lamps without integrated ballast;
- high-intensity discharge lamps;
- incandescent lamps with E14/E27/B22/B15 caps, with a voltage equal to or below 60 volts and without integrated transformer in Stages 1-5 according to Article 3 of the Regulation.

Performance requirements

There are a number of performance requirements that are only applicable to certain lamp technologies (e.g. “for compact fluorescent lamps only” or “for lamps excluding compact fluorescent and LED lamps”). The performance requirements set out below are those that are applicable to LED lamps and have come into force as at 1 September 2013.

Unlike other lamp technologies, there are no functionality requirements for LED lamps in this regulation (see EC 1194/2012 below).

Parameter	Requirements		Test Method
Efficacy	*Maximum power, P_{max}, for a given luminous flux ($\emptyset$)* *Clear lamps:* $P_{max} = 0.8 * (0.88\sqrt{\emptyset} + 0.049\,\emptyset)$ *Note from 1 Sept 2016:* $P_{max} = 0.6 * (0.88\sqrt{\emptyset} + 0.049\,\emptyset)$ *Non-clear lamps:* $P_{max} = 0.24\sqrt{\emptyset} + 0.0103\,\emptyset$ *Applicable correction factors for LED lamps:*		*EN 50285:1999*
	Non-clear lamp with CRI ≥ 90 and $P \leq 0.5 * (0.88\sqrt{\emptyset} + 0.049\,\emptyset)$	$\frac{P_{max}}{0.85}$	
	Non-clear lamp with second envelope and $P \leq 0.5 * (0.88\sqrt{\emptyset} + 0.049\,\emptyset)$	$\frac{P_{max}}{0.95}$	
	LED lamp requiring external power supply	$\frac{P_{max}}{1.1}$	
Equivalence (If making a claim)	*The claimed equivalent incandescent lamp power shall be:*		*CIE 84: 1989*
	LED rated lamp luminous flux (lm)	*Claimed equivalent incandescent lamp power (W)*	
	136	*15*	
	249	*25*	
	470	*40*	
	806	*60*	
	1055	*75*	
	1521	*100*	
	2452	*150*	
	3452	*200*	

Commission Regulation (EC) No 1194/2012

Scope

Ecodesign requirements and energy labelling for directional lamps, light emitting diode lamps (non-directional and directional) and halogen lighting converters was adopted 13 July 2012. Final regulation was published in the Official Journal 14 December 2012, entered into force 3 January 2013 with the following stage dates:

- Stage 1: 1 September 2013
- Stage 2: 1 September 2014
- Stage 3: 1 September 2016.

No test methods are specified within the regulation but it does state, “Member State authorities shall use reliable, accurate and reproducible measurement procedures, which take into account the generally recognised state-of-the-art measurement methods, including methods set out in documents whose reference numbers have been published for that purpose in the Official Journal of the European Union.”

Performance requirements

<table>
<tr><th>Parameter</th><th colspan="2">Requirements</th><th>Test Method</th></tr>
<tr><td rowspan="5">Efficacy</td><td colspan="2">Maximum Energy Efficiency Index (EEI) as determined by
$$EEI = \frac{P_{cor}}{P_{ref}}$$
Where:
P_{cor} is the rated power measured with the following corrections:
$P_{cor} = P_{rated}$ for self-ballasted LED lamps
$P_{cor} = 1.10 * P_{rated}$ for LED lamps operating on external control gear
P_{ref} is the reference power obtained from the useful luminous flux ($\emptyset_{use}$) by the following formulae
$\emptyset_{use} < 1300$ lumens: $P_{ref} = 0.88\sqrt{\emptyset_{use}} + 0.049\ \emptyset_{use}$
$\emptyset_{use} \geq 1300$ lumens: $P_{ref} = 0.07341\ \emptyset_{use}$
Note: $\emptyset_{use}$ is equal to the rated luminous flux within a:
• 120°cone($\emptyset_{120°}$)for directional lamps withbeam angle ≥90°
• 90°cone ($\emptyset_{90°}$) for all other directional lamps
The maximum Energy Efficiency Index for LEDS:</td><td rowspan="5">Conducted by reliable, accurate and reproducible measurement methods</td></tr>
<tr><td>Stage</td><td>EEI</td></tr>
<tr><td>1</td><td>0.5</td></tr>
<tr><td>2</td><td>0.5</td></tr>
<tr><td>3</td><td>0.2</td></tr>
<tr><td>Lamp survival</td><td colspan="2">Lamp survival factor at 6,000 h ≥ 0.90 (from stage 2)</td><td></td></tr>
<tr><td>Lumen maintenance</td><td colspan="2">Lumen maintenance at 6,000 h ≥ 0.80 (from stage 2)</td><td></td></tr>
<tr><td>Switching withstand</td><td colspan="2">Switching cycles before failure
• ≥ 15,000 (for rated life ≥ 30,000 h)
• Otherwise ≥ half the rated life in hours</td><td></td></tr>
<tr><td>Start time</td><td colspan="2">≤ 0.5 s</td><td></td></tr>
<tr><td>Run up time</td><td colspan="2">0.95 * ϕ< 2 s</td><td></td></tr>
<tr><td>Premature failure rate</td><td colspan="2">≤ 5% at 100 h</td><td></td></tr>
<tr><td>Colour rendering</td><td colspan="2">Ra ≥ 80
Ra ≥ 65 (if lamp intended for outdoor or industrial applications)</td><td></td></tr>
<tr><td>Colour consistency</td><td colspan="2">CCT spread within 6-step MacAdam ellipse</td><td></td></tr>
<tr><td rowspan="5">Power factor</td><td>Power (W)</td><td>PF</td><td rowspan="5"></td></tr>
<tr><td>P ≤ 2</td><td>N/A</td></tr>
<tr><td>2 < P ≤ 5</td><td>> 0.4</td></tr>
<tr><td>5 < P ≤ 25</td><td>> 0.5</td></tr>
<tr><td>25 < P</td><td>> 0.9</td></tr>
</table>

Energy Label (Commission Directive 98/11/EC)

Scope

This Regulation establishes requirements for labelling of and providing supplementary product information on electrical lamps such as

- filament lamps,
- fluorescent lamps,
- high-intensity discharge lamps,
- LED lamps and LED modules.

This Regulation also establishes requirements for labelling luminaires designed to operate such lamps and marketed to end users, including when they are integrated into other products that are not dependent on energy input in fulfilling their primary purpose during use (such as furniture).

The following products are excluded from the scope of this Regulation:

(a) Lamps and LED modules with a luminous flux of less than 30 lumens.

(b) Lamps and LED modules marketed for operation with batteries.

(c) Lamps and LED modules marketed for applications where their primary purpose is not lighting, such as:

  (i) emission of light as an agent in chemical or biological processes (such as polymerisation, photodynamic therapy, horticulture, pet care, anti-insect products);

  (ii) image capture and image projection (such as camera flashlights, photocopiers, video projectors);

  (iii) heating (such as infrared lamps);

  (iv) signalling (such as airfield lamps).

These lamps and LED modules are not excluded when they are marketed for lighting.

(d) Lamps and LED modules marketed as part of a luminaire and not intended to be removed by the end-user, except when they are offered for sale, hire or hire purchase or displayed separately to the end user, for example as spare parts.

(e) Lamps and LED modules marketed as part of a product whose primary purpose is not lighting. However, if they are offered for sale, hire or hire purchase or displayed separately, for example as spare parts, they shall be included within the scope of this Regulation.

(f) Lamps and LED modules that do not comply with requirements becoming applicable in 2013 and 2014 according to Regulations implementing Directive 2009/125/EC.13

(g) Luminaires that are designed to operate exclusively with the lamps and LED modules listed in points (a) to (c).

Performance requirements

Energy Efficiency Class	Non-directional Lamps	Directional Lamps
A++	*EEI ≤ 0.11* *Class currently empty, apart from some low pressure sodium lamps used in street lighting.* *Soon to include best LEDs*	*EEI ≤ 0.13* *Class currently empty, soon to include best LEDs*
A+	*0.11 < EEI ≤ 0.17* *Best LED lamps in 2012, best linear fluorescent, compact fluorescent and high intensity discharge (HID) lamps.*	*0.13 < EEI ≤ 0.18* *Best LED lamps in 2012.*
A	*0.17 < EEI ≤ 0.24* *Average LEDs in 2012, average compact fluorescent lamps and poor linear fluorescents and poor HIDs (for the latter two, phase-out between 2010 and 2017).*	*0.18 < EEI ≤ 0.40* *Average LEDs in 2012, average to good compact fluorescents and HIDs (proposed to be phased out in stage 3 in 2016).*
B	*0.24 < EEI ≤ 0.60* *Poor compact fluorescent lamps and LEDs (phased out in 2009 with a few exceptions), best (infrared coated) lamps.*	*0.40 < EEI ≤ 0.95* *Poor compact fluorescent lamps and LEDs (proposed to be phased out in stage 1 in 2013), best extra low-voltage halogen reflector lamps infrared coated or xenon-filled).*

EU LED Quality Charter

Scope

The scope of the present version LED Quality Charter is limited to LED lamps intended primarily for use in the residential sector. At this stage the European Quality Charter for LED does not include LED modules, luminaires and lamps specific for use in the commercial sectors.

Performance requirements

The following table provides the minimum requirements for directional and non-directional lamps. The test methods specified are in the last column of the table.

Parameter	Minimum requirements							Test Method
Efficacy	*LED Lamp type*	*CRI*	*Min efficacy (lm/W)*					*IES LM79-2008*
			2011	*2012*	*2013*	*2014*	*2015*	
	Non Directional Light Source (NDLS)	*>80*	*61*	*65*	*70*	*75*	*80*	
		>90	*52*	*55*	*60*	*65*	*70*	
	Directional Light Source (DLS)	*>80*	*50*	*55*	*60*	*65*	*70*	
		>90	*40*	*45*	*50*	*55*	*60*	
Lumen maintenance	• *At 1 000 hours of operation no more than 5% of lamps shall have a lumen maintenance below 85%* • *($L_{85}F0_5$ ≥ 1,000 hours)* • *At 15 000 hours of operation no more than 50% of lamps shall have a lumen maintenance below 70%.* • *($L_{70}F_{50}$ ≥ 15,000 hours)*							*IEC/PAS 62612 Ed 1*
Lamp start time	*< 0.5 second*							*IES LM79-2008* *IES LM80-2008*
Lamp Run-up time	*95% of the stabilised light output < 2 seconds*							*IES LM79-2008* *IES LM80-2008*
Colour Rendering	*CRI > 80*							*CIE No 13.3 - 1995*
Colour Temperature	*CCT shall be within 2600 -3500 K with a tolerance category of 7-step MacAdam ellipse size*							*IEC/PAS 62612 Ed 1* *IEC 60081 Annex D2 mod*
Glare and blue light hazard	*The visible radiation hazard class shall be 0 or 1.*							*IEC 62471-2*
Flicker	*The frequency of light output is to be greater than 100 Hz.* *No flicker is to be visible the dimmed to all output levels.*							*IEC61000-3-11*
Power Factor	*PF ≥ 0.5 for lamps of wattage 2 – 25W.*							*IEC61000-3-2:2006*

EU Ecolabel (Commission Decision 6 June 2011)

Scope

The product group 'light sources' is comprised of all light sources with luminous flux ≥ 60 lumens and ≤ 12000 lumens for general lighting applications with direct or indirect connection to the public electricity supply equipped with a lamp cap listed in EN 60061 and made in order to produce a visible radiation.

The following types of light sources are not included in the product group: directional lamps, high-intensity discharge lamps, coloured lamps, projector lamps, photographic lighting, solarium tubes, battery driven systems and other light sources that are not intended for general lighting applications. The following types of light sources are not included in the product group if they are not supplied directly from the mains: integral compact fluorescent lamps, filament lamps, LED lamps.

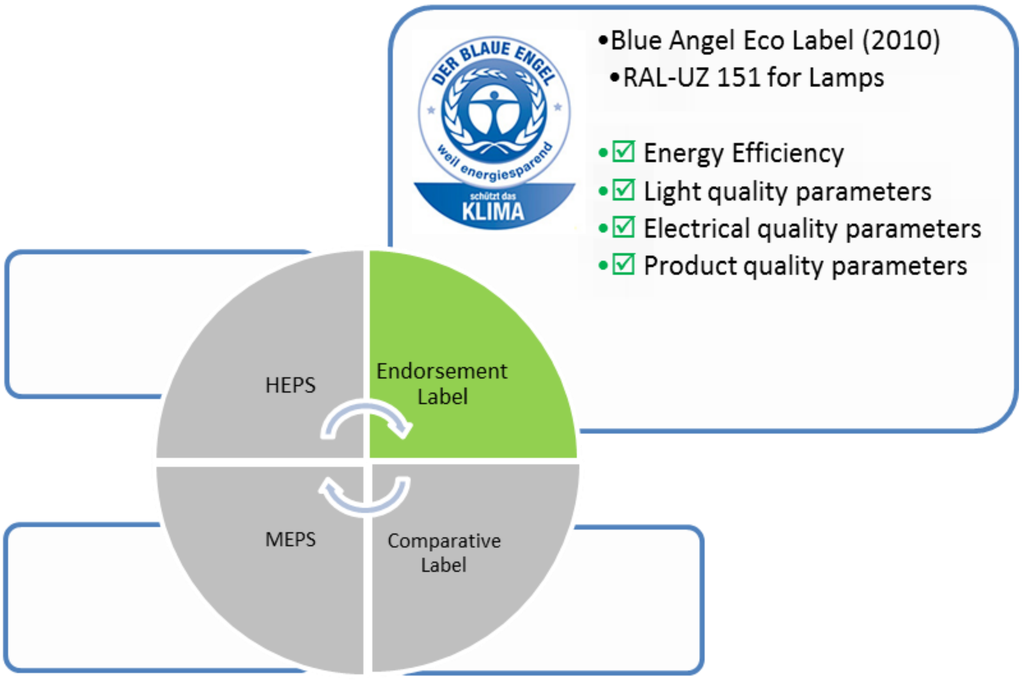
Performance requirements

Parameter	Minimum requirements	Test Method
Efficacy	*EEI that is 10% better than the Class A*	*Unspecified for LED*
Life time	*Single ended: 15,000 h* *Double ended: 20,000 h*	*Unspecified for LED*
Lumen maintenance	*Single ended: 80% at 9,000 h* *Double ended: 90% at 16,000 h*	*Unspecified for LED*
Switching withstand	*Switching cycles before failure > rated life in hours* *If claiming withstand to frequent switching:* *Switching cycles before failure > 60,000 cycles*	*Unspecified for LED*
Colour Rendering	*Ra > 85*	*CIE No 13.3 - 1995*
Colour Consistency	*CCT shall be within a tolerance category of 3-step MacAdam ellipse size*	*Unspecified for LED*

Countries following EU standard EC 244/2009

<table>
<tr><th>Country</th><th></th><th colspan="3">Details</th></tr>
<tr><td rowspan="2">Jordan</td><td>Technical Regulation on Ecodesign requirements for Non Directional Household lamps (2012)</td><td colspan="3">MEPS: The following stages of enforcement apply:
Stage 1 – 1 January 2014
Stage 2 – 1 January 2016
Stage 5 –
Stage 6 –</td></tr>
<tr><td>Energy Label (Commission Directive 98/11/EC) (2012 Voluntary - 2013 Mandatory)</td><td colspan="3">Energy Label:
2013 – Optional
2014 - Mandatory</td></tr>
<tr><td rowspan="3">Switzerland</td><td>Commission Regulation (EC) No 244/2009 - Non Directional Light Sources</td><td colspan="3">MEPS: As per EC 244/2009</td></tr>
<tr><td>Energy Label (Commission Directive 98/11/EC) (2002)</td><td colspan="3">Energy Label: As per Commission Directive 98/11/EC (2002)</td></tr>
<tr><td>EU Ecolabel (Commission Decision 6 June 2011)</td><td colspan="3">Ecolabel: As per EU Ecolabel (Commission Decision 6 June 2011)</td></tr>
<tr><td rowspan="3">Turkey</td><td>Turkish Official Gazette No 28038 (Commission Regulation (EC) No 244/2009) - Non Directional Light Sources (2011)</td><td colspan="3">MEPS: Transposition of the EU Commission Regulation (EC) No 244/2009) - Non Directional Light Sources</td></tr>
<tr><td>Turkish Official Gazette No 24852 (Transpositon of Commission Directive 98/11/EC) (2002)</td><td colspan="3">Energy Label: Transposition of EU Energy Label (Commission Directive 98/11/EC) (2002)</td></tr>
<tr><td>EU Ecolabel (Commission Decision 6 June 2011) - (?) to be transposed</td><td colspan="3">Ecolabel: As per EU Ecolabel</td></tr>
<tr><td rowspan="8">United Arab Emirates</td><td>Requirements for Approval and Registration of Lighting Products (NDLS and luminaires) (2013)</td><td colspan="3">MEPS: As per EC 244/2009</td></tr>
<tr><td rowspan="7">Requirements for Approval and Registration of Lighting Products (NDLS and luminaires) (2013)</td><td colspan="3"> The comparative label is based on the European Union Commission Directive 98/11/EC (see section 0Performance requirements) but uses star ratings instead of the A++, A+, A, B, C energy classifications of the Energy Efficiency Index (EEI) of the European Union. The translation between the classification systems is provided below.</td></tr>
<tr><td>United Arab Emirates Energy Efficiency Class</td><td>Non-directional Lamps</td><td>European Union Energy Efficiency Class</td></tr>
<tr><td>5-Star
(most efficient)</td><td>EEI ≤ 0.11</td><td>A++</td></tr>
<tr><td>4-Star</td><td>0.11 < EEI ≤ 0.17</td><td>A+</td></tr>
<tr><td>3-Star</td><td>0.17 < EEI ≤ 0.24</td><td>A</td></tr>
<tr><td>2-Star</td><td>0.24 < EEI ≤ 0.60</td><td>B</td></tr>
<tr><td>1-Star
(least efficient)</td><td>0.60 < EEI ≤ 0.80</td><td>C</td></tr>
</table>

10.1.1.1 Germany



Scope

This scope applies to lamps meeting the following requirements. They:

- are directly powered from the mains (230 V, 50 Hz) and therefore need no external ballast, power supply pack or the like
- are suitable for indoor use;
- have a luminous flux Φ of 60 ≤ Φ ≤ 6,500 lumens.

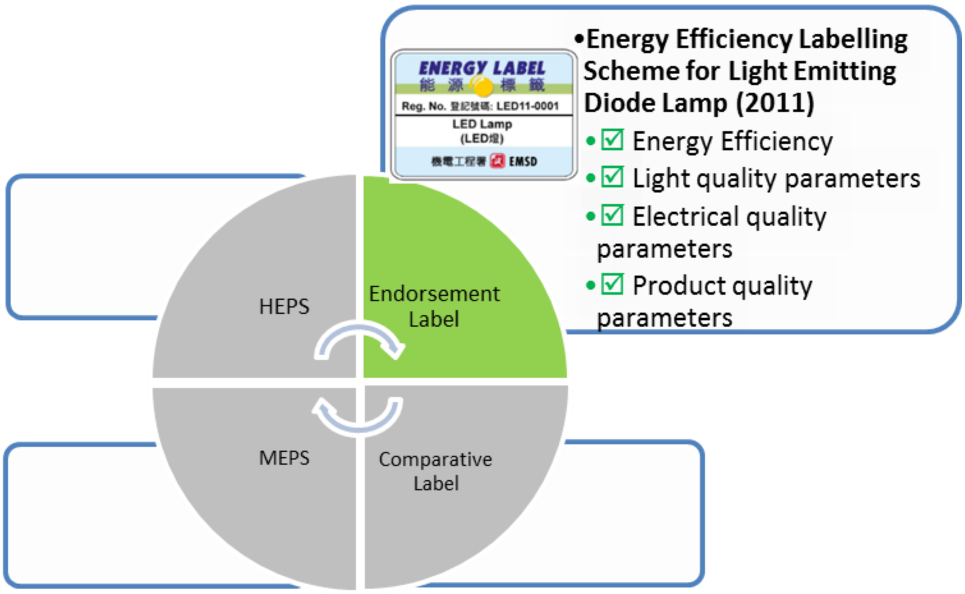
Performance requirements

Parameter	Minimum requirements		Test Method
Power consumption Index	*EGN ≤ 10.16 + 0.291 x Ra* *This is a complex calculation based on luminous flux, colour rendering, power consumption (all averaged over life).* *See "Basic Information and Instructions for Applying for the Blue Angel Eco-label RAL-UZ 151 for Lamps"*		*DIN 5032-1* *DIN EN 61000-3-2:2006* *CIE 13.3:1995* *CIE 15:2004* *CIE 84:1989* *DIN 6169-2*
Power factor	*Lamp Power P (W)*	*Power Factor for LED Lamps*	
	P < 25 W	*≥ 0.75*	
	P ≥ 25 W	*≥0.90*	
Colour Rendering	*Ra ≥ 80*		
Colour temperature	*Colour difference between measured and stated lamp ≤ 0.007 units on CIE 1976 u'v'diagram*		
Colour homogeneity	*Colour difference measured between any lamp samples ≤ 0.006 units on CIE 1976 u'v'diagram*		
Hue preservation	*Colour difference measured between a lamp 3,000 h and 6,000 h ≤ 0.007 units on CIE 1976 u'v'diagram*		
Lumen maintenance	*> 90% at 6,000 h operated at a minimum of :* • *25℃ for lamp power < 10W* • *45℃ for lamp power ≥ 10W*		
Life time	*≥ 6,000 h*		*EN 60969*
Switching withstand	*Switching cycles before failure ≥ the greater of 20,000 cycles*		
Premature failure	*≤ 2%*		*CIE 97:2005*
Run-up time	*80% of initial stabilised luminous flux ≤ 30 s*		*EN 60969*

Parameter	Minimum requirements	Test Method
UV radiation	*At 20 cm from light centre:* • *Actinic UV radiation ≤ 0.01 mW/m²* • *UVA ≤ 100 mW/m² based on 1,000 lux*	*DIN EN 62471*
Electromagnetic fields	*At 30 cm from the lamp* • *F ≤ 0.3%* *(Note: F is defined in the referenced standard)*	*DIN IEC 62493*

There are currently no registered products.

Hong Kong



Scope

This scheme applies to directional and non-directional LED lamps that are intended for general lighting purposes and having the following characteristics:

(a) those with a rated voltage up to 240 volts AC or DC;

(b) those with a rated frequency of 50 Hz for AC;

(c) those with a rated lamp wattage up to 60 Watts; and

(d) those with a rated CCT value from 2700K to 6500K.

The scheme shall apply to LED lamps designed with dimming or non-dimming operations.

The scheme does not cover:

(a) LED tubes, and

(b) LED lamps that intentionally produce tinted or coloured light

(c) Organic LED (OLED) lamps.

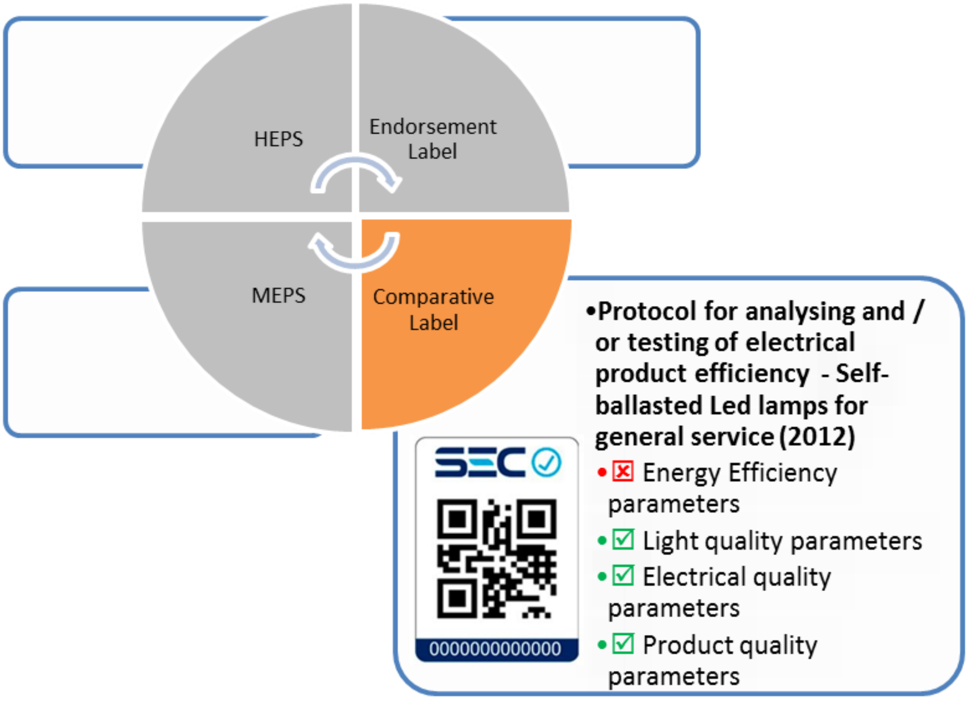
Performance requirements

Parameter	Minimum requirements				Test Method
Efficacy	*Non-directional Lamps*		*Directional Lamps*		
	Rated Lamp Wattage (Lw)	*Efficacy (lm/W)*	*Lamp Diameter (Ld mm)*	*Efficacy (lm/W)*	
	Lw< 10W	*50*	*Ld ≤ 65*	*40*	
	10W ≤ Lw	*55*	*Ld> 65*	*45*	

<table>
<tr><th>Parameter</th><th>Minimum requirements</th><th>Test Method</th></tr>
<tr><td>Luminous flux</td><td>
All lamps:
• Initial luminous flux ≥ 90% of rated luminous flux
For non-directional lamps:
• If claiming equivalence luminous flux must exceed
<table>
<tr><td>Claimed equivalent wattage incandescent lamp (W)</td><td>Minimum luminous flux of LED lamp (lm)</td></tr>
<tr><td>15</td><td>117</td></tr>
<tr><td>25</td><td>214</td></tr>
<tr><td>40</td><td>404</td></tr>
<tr><td>60</td><td>693</td></tr>
<tr><td>75</td><td>907</td></tr>
<tr><td>100</td><td>1308</td></tr>
<tr><td>150</td><td>2108</td></tr>
<tr><td>200</td><td>2968</td></tr>
</table>
For directional lamps:
• ≥ 80% of measured light output is within a 120 ° cone (i.e. solid angle of π sr)
• If claiming equivalence for:
○ lamp with integrated driver, excluding PAR or
○ lamp with non-integrated driver, excluding MR16
measured initial LED lamp luminous flux ≥ 10 times the rated wattage of the target lamp
</td><td>IES LM-79
or
IEC/PAS 62612</td></tr>
<tr><td>Centre Beam Intensity</td><td>
For PAR and MR16 LED lamps to claim equivalence with directional lamps, the minimum centre beam intensity (cd) is:
PAR16
<table>
<tr><td></td><td></td><td colspan="12">Rated Wattage of Target Lamp (W)</td></tr>
<tr><td></td><td></td><td>5</td><td>10</td><td>15</td><td>20</td><td>25</td><td>30</td><td>35</td><td>40</td><td>45</td><td>50</td><td>55</td><td>60</td></tr>
<tr><td rowspan="9">Beam Angle of Target Lamp (degree)</td><td>5</td><td>933</td><td>1115</td><td>1329</td><td>1579</td><td>1870</td><td>2208</td><td>2599</td><td>3051</td><td>3571</td><td>4160</td><td>4847</td><td>5622</td></tr>
<tr><td>10</td><td>605</td><td>723</td><td>861</td><td>1023</td><td>1211</td><td>1430</td><td>1684</td><td>1977</td><td>2313</td><td>2699</td><td>3140</td><td>3642</td></tr>
<tr><td>15</td><td>409</td><td>489</td><td>583</td><td>692</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="11">Tables included for PAR 20, 30, 38 and MR16 are not shown here.</td><td></td></tr>
</table>
</td><td></td></tr>
</table>

<table>
<tr><th>Parameter</th><th colspan="6">Minimum requirements</th><th>Test Method</th></tr>
<tr><td></td><td colspan="6"></td><td></td></tr>
<tr><td></td><td colspan="6"></td><td rowspan="20"></td></tr>
<tr><td>Beam Angle</td><td colspan="6">For directional lamps: measured beam angle within 25% of rated bema angle.
Additionally if claiming equivalence: rated beam angle of the LED lamp is equal to the rated beam angle of the target lamp.</td></tr>
<tr><td>Lumen maintenance</td><td colspan="6">> 90% at 6,000 h operated at a minimum of :
• 25℃ for lamp power < 10W
• 45℃ for lamp power ≥ 10W</td></tr>
<tr><td>Colour Rendering</td><td colspan="6">Ra ≥ 80
And ≤ 3 points below rated Ra</td></tr>
<tr><td rowspan="10">Colour temperature</td><td colspan="2">Rated CCT (K)</td><td colspan="2">Target CCT and Tolerance (K)</td><td colspan="2">Target Duv and tolerance</td></tr>
<tr><td colspan="2">2700</td><td colspan="2">2725 ± 145</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">3000</td><td colspan="2">3045 ± 175</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">3500</td><td colspan="2">3465 ± 245</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">4000</td><td colspan="2">3985 ± 275</td><td colspan="2">0.001 ± 0.006</td></tr>
<tr><td colspan="2">4500</td><td colspan="2">4503 ± 243</td><td colspan="2">0.001 ± 0.006</td></tr>
<tr><td colspan="2">5000</td><td colspan="2">5028 ± 283</td><td colspan="2">0.002 ± 0.006</td></tr>
<tr><td colspan="2">5700</td><td colspan="2">5665 ± 355</td><td colspan="2">0.002 ± 0.006</td></tr>
<tr><td colspan="2">6500</td><td colspan="2">6530 ± 510</td><td colspan="2">0.003 ± 0.006</td></tr>
<tr><td colspan="2">Flexible CCT
(2700-6500 K)</td><td colspan="2">$T \pm \Delta T$
T is chosen from 100 K steps (2800, 2900,…, 6400 K)
$\Delta T=1.08*10^{-5} xT^2 + 0.0262 xT + 8$.</td><td colspan="2">Duv ± 0.006
$Duv =7700x(1/T)^2 – 44.6x(1/T) + 0.0085$</td></tr>
<tr><td>Colour shift</td><td colspan="6">≤ 0.007 on the CIE 1976 u’v’ diagram</td></tr>
<tr><td rowspan="4">Power Factor</td><td colspan="3">Rated Lamp Wattage (Lw)</td><td colspan="3">Minimum Power Factor</td></tr>
<tr><td colspan="3">Lw ≤ 5W</td><td colspan="3">0.5</td></tr>
<tr><td colspan="3">5W <Lw ≤ 25W</td><td colspan="3">0.7</td></tr>
<tr><td colspan="3">25W <Lw</td><td colspan="3">0.9</td></tr>
<tr><td>Switching withstand</td><td colspan="6">Switching cycles before failure > the greater of 10,000 cycles or half rated life in hours</td></tr>
</table>

Chile



Scope

Establishes the certification process efficiency for self-ballasted LED lamps for domestic and similar general lighting purposes,

(a) with power ratings up to 60 Watts,

(b) a nominal voltage up to 250 volts AC or DC and

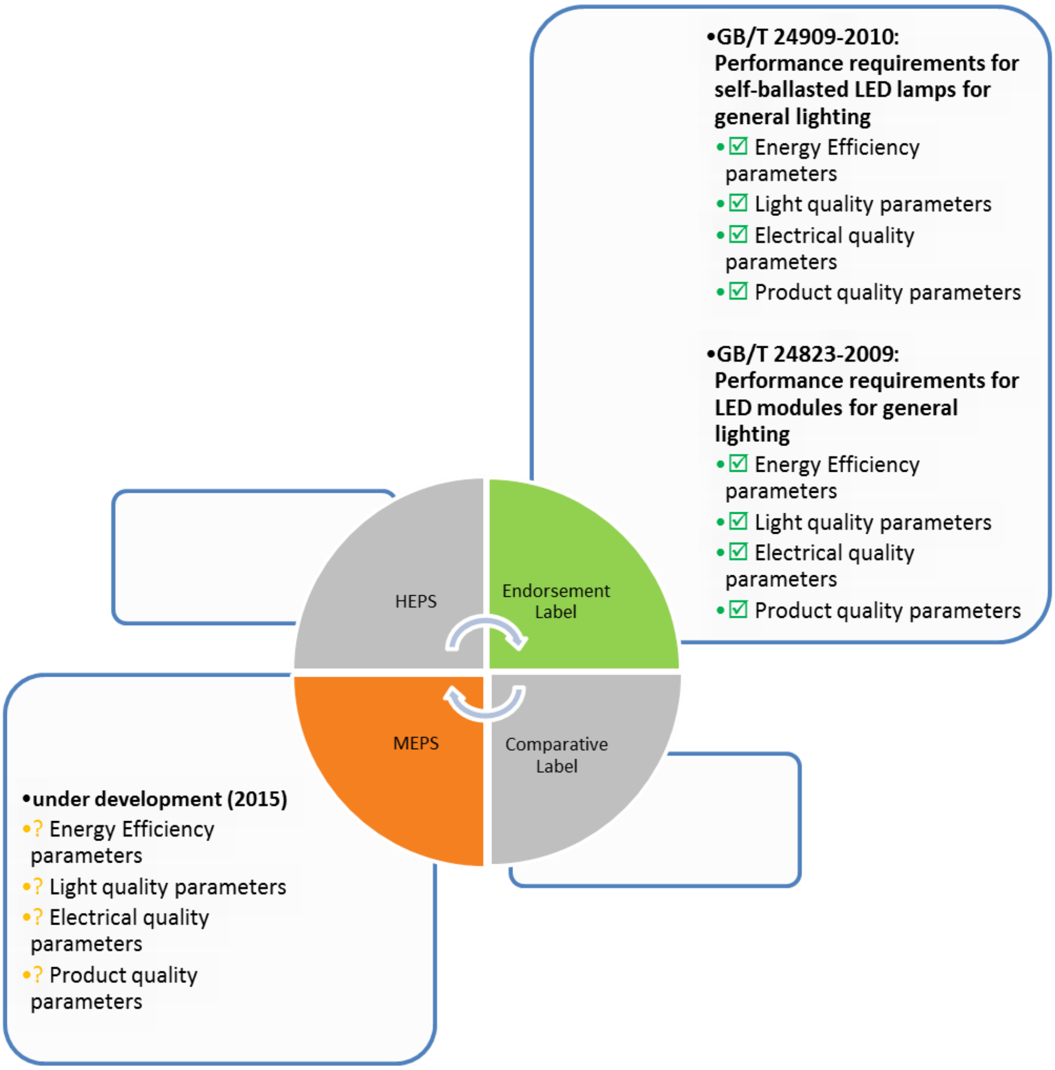
(c) caps B15d, B22d, E11 , E12, E14, E17, E26, E27, GI.J1 0, GU10 and GX53,

according to the scope and applicability of the Pro-Standard IEC / PAS 62612 2009-06, "Self-ballasted LED-lamps for general lighting services - Performance Requirements ".

Performance requirements

Parameter	Requirements	Test Method
Lamp power	*As per IEC/PAS 62 612 2009-06 clause 6*	*IEC/PAS 62 612 2009-06*
Luminous flux	*As per IEC/PAS 62 612 2009-06 clause 8*	
Colour rendering	*As per IEC/PAS 62 612 2009-06 clause 9* *Except that test conducted at 25% of stated lamp life up to a maximum of 6,000 h*	
Colour temperature	*As per IEC/PAS 62 612 2009-06 clause 9* *Except that test conducted at 25% of stated lamp life up to a maximum of 6,000 h*	
Lamp Life (Lumen Maintenance)	*As per IEC/PAS 62 612 2009-06 clause 10.1* *Except that test conducted at 25% of stated lamp life up to a maximum of 6,000 h*	

China



- **GB/T 24909-2010: Performance requirements for self-ballasted LED lamps for general lighting**
  - ☑ Energy Efficiency parameters
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

- **GB/T 24823-2009: Performance requirements for LED modules for general lighting**
  - ☑ Energy Efficiency parameters
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

- **under development (2015)**
  - ? Energy Efficiency parameters
  - ? Light quality parameters
  - ? Electrical quality parameters
  - ? Product quality parameters

GB/T 24908-2010: Performance requirements for self-ballasted LED lamps for general lighting

Scope

Self-ballasted LED lamps used for domestic and similar general lighting purpose, having:

(a) a rated wattage up to 60 W;

(b) a rated voltage of up to 250 V AC or DC; and

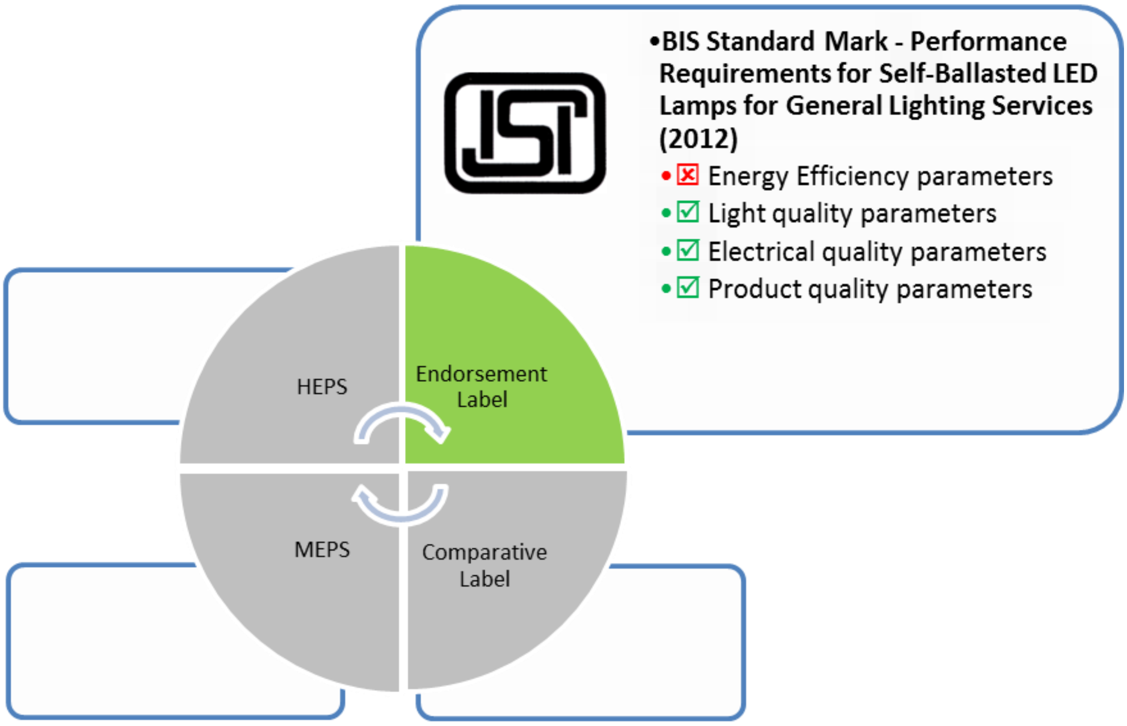
(c) lamp cap according to relevant GB standards.

Performance requirements

Parameter	**Requirements**					**Test Method**
Efficacy	*Rated lamp power, P (W)*	*Colour Temp (K)*	*Efficacy (lm/W)*			*GB/T 24824*
			Grade I	*Grade II*	*Grade III*	
	1 ≤ P ≤ 5	*<4,000*	*55*	*45*	*35*	
		≥4,000	*60*	*50*	*40*	
	6 ≤ P ≤ 10	*<4,000*	*65*	*55*	*45*	
		≥4,000	*60*	*50*	*40*	
	11 ≤ P ≤ 25	*<4,000*	*65*	*55*	*45*	
		≥4,000	*60*	*50*	*40*	

Parameter	Requirements					Test Method
	26 ≤ P	*<4,000*	*55*	*45*	*35*	
		≥4,000	*60*	*50*	*40*	
	Note: The colour temperature is classed by a code in the Chinese standard representing the standard fluorescent illuminant sources.					
Colour rendering	*≥ 80*					
Colour temperature	*Colour & (code)*	*CCT (K)*	*Chromaticity Co-ords*			
			x	*y*		
	Daylight (RR)	*6430*	*0.313*	*0.337*		
	Neutral white (RZ)	*5000*	*0.346*	*0.359*		
	Cold white (RL)	*4040*	*0.380*	*0.380*		
	White (RB)	*3450*	*0.409*	*0.394*		
	Warm white (RN)	*2940*	*0.440*	*0.403*		
	Incandescent (RD)	*2720*	*0.463*	*0.420*		
	Chromaticity tolerance is to be within 7 SDCM					
Life expectancy	*Average life ≥ 25,000 h*					
Lumen Maintenance	*The luminous flux (relative to initial luminous flux)* *≥ 92% at 3,000 h* *≥ 88% at 6,000 h* *≥ 70% at 70% of rated life*					
Switching withstand	*Switching cycles before failure > 15,000*					
Harmonics	*As per test standard*					*GB 17625.1*

India



- BIS Standard Mark - Performance Requirements for Self-Ballasted LED Lamps for General Lighting Services (2012)
  - ☒ Energy Efficiency parameters
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

Scope

This standard (Part 2) specifies the performance requirements for self-ballasted LED lamps with d.c. supplies up to 250 V or a.c. supplies up to 1 000 V at 50 Hz, together with the test methods and conditions, required to show compliance with this standard, intended for domestic and similar general lighting purposes, having,

(a) a rated wattage up to 60 W;

(b) a rated d.c. supplies up to 250 V or a.c. supplies up to 1 000 V at 50 Hz; and

(c) a lamp cap according to IS 16102 (Part 1): 2012 ‘Self-ballasted LED lamps for general lighting services: Part 1 Safety requirements’.

This standard does not cover self-ballasted LED-lamps that intentionally produce tinted or coloured light neither does it cover OLEDs.

Performance requirements

The BIS Standard Mark may be obtained by manufacturers who comply with IS 16102 (Part 2): 2012 “Self Ballasted LED Lamps for General Lighting Services, Part 2 Performance Requirements”. This standard is based on IEC 62612 “Self Ballasted LED Lamps for General Lighting Services for voltage above 50V - performance requirements” but with the following modification:

(a) Made applicable for d.c. supplies up to 250 V or a.c. supplies up to 1 000 V at 50 Hz;

(b) Schedule of type test and acceptance test has been incorporated;

(c) Ambient test condition changed to 27°C;

(d) Selection of samples incorporated;

(e) Conditions of compliances incorporated;

(f) Data for chromaticity co-ordinates and CCT values for 5 700 K added;

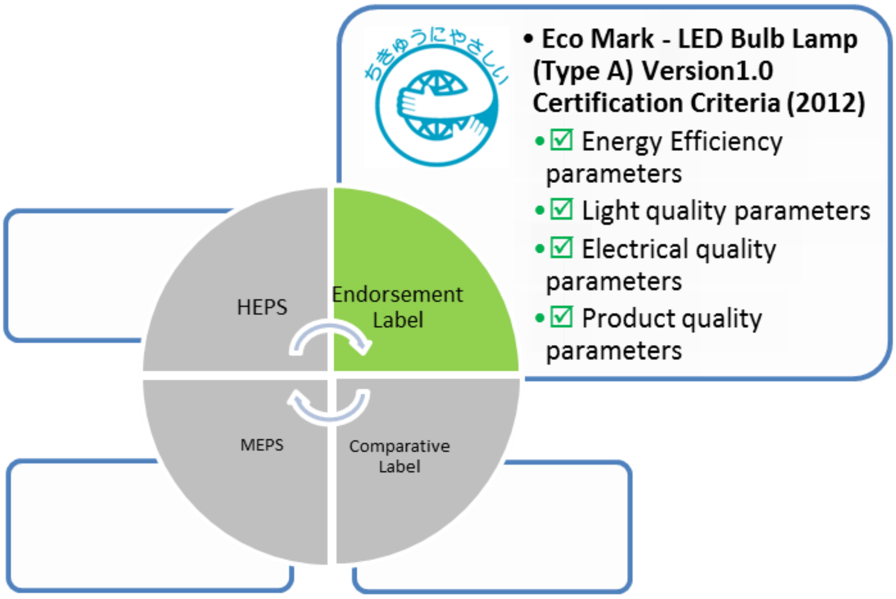
(g) Requirements of harmonics and p.f. have been added; and

(h) Tolerance for lamp power (see 8) increased to 15 percent and for luminous flux (see 9) decreased to 90 percent.

Note that there are no efficacy requirements included.

Parameter	**Requirements**		**Test Method**
Lamp power	*Measured lamp power ≤ 115% of rated lamp power*		*IEC/PAS 62 612 2009-06*
Luminous flux	*Measured lamp luminous flux ≥ 90% of rated lamp luminous flux*		
Colour rendering	*As per IEC/PAS 62 612 2009-06*		
Colour temperature & variation	*As per IEC/PAS 62 612 2009-06*		
Lamp Life & Lumen Maintenance	*As per IEC/PAS 62 612 2009-06*		
Endurance testing of integrated driver	*As per IEC/PAS 62 612 2009-06*		
Power factor	*≥ 0.9*		
Harmonic Distortion	*Harmonic order, n*	*Max Harmonic current as percentage of input fundamental frequency*	
	2	*2*	
	3	*30 λ*	
	5	*10*	
	7	*5*	
	9	*7*	
	11 - 39	*3*	
	Where λ is the circuit power factor.		

Japan



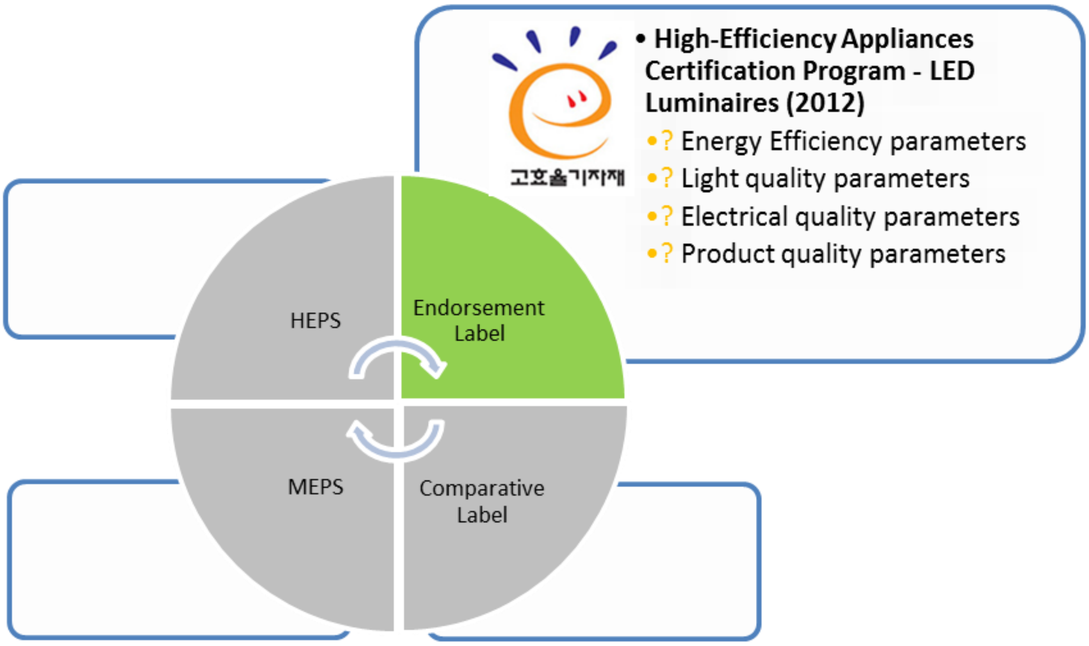
Scope

LED lamps of A type and forms in Annex B (Normative) in JIS C 8157 "Self-ballasted LED - lamp s for general lighting services > 50 V -- Performance requirements" and have a cap of E17 or E26 and emit light according to the light - source colours defined in the JIS Z 9112 "Classification of fluorescent lamps based on light - source colours and colour rending properties".

Performance requirements

Parameter	**Minimum requirements**		**Test Method**
Efficacy	*Light Source*	*Efficacy (lm/W)*	*JIS C 7801*
	Bulb	*≥ 70*	
	Warm	*≥ 85*	
	White		
	Day		
	Daylight		
Life time	*> 40,000 h*		*JIS C 8157*
Colour Rendering	*Ra ≥ 70*		*JIS C 8157* *JIS C 7801*
Power Factor	*≥ 0.6*		*Unspecified*

Korea



High-Efficiency Appliances Certification Program

The program certifies products for industry and buildings as high-efficiency appliances, where the energy efficiency and quality test results are above the certification standards set by the government. KEMCO issues a high-efficiency appliance certificate. Financial supports are provided for high-efficiency LED lighting equipment and few other high-efficiency appliances.

High-efficiency and high energy efficiency products are certified by KEMCO where they satisfy the energy efficiency and quality certification standards of the designated testing institutes.

Scope

Currently 34 appliances/products including LED guide lights, LED lamps (internal converter), LED Lamps (external converter), recessed and fixed LED light fixtures, LED security light fixtures, LED sensor light fixtures, LED converters.

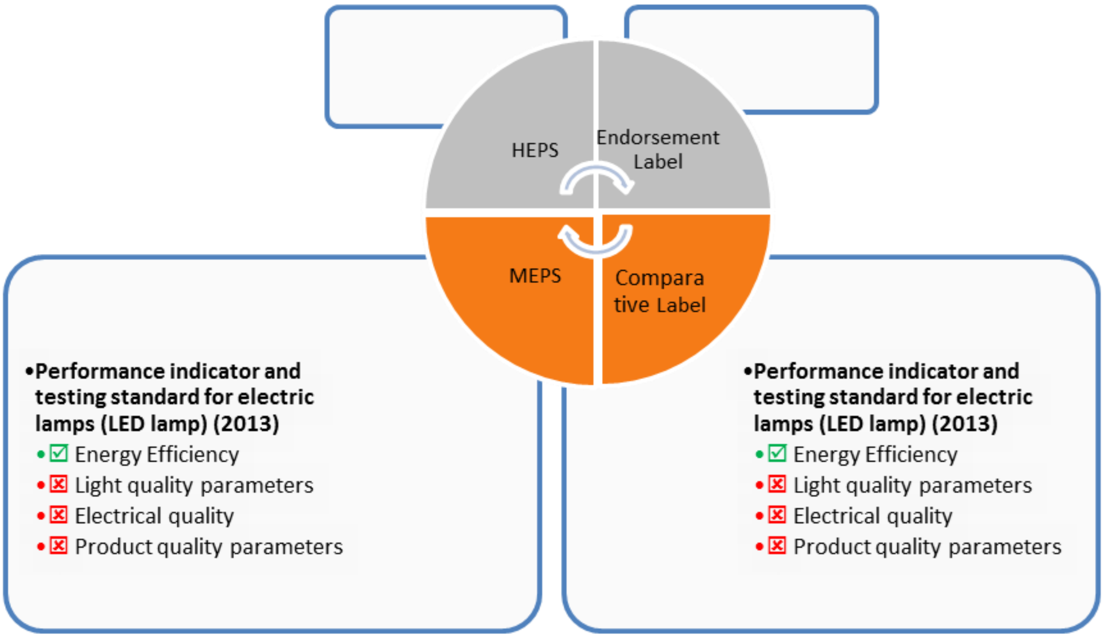
Performance requirements

Performance parameters are:

- Energy Efficiency Ratio
- Rated power consumption
- CO2 emission per 1 hour
- Energy Efficiency Level

The details of the performance requirements for LED products have not been ascertained for this report.

Malaysia



Scope

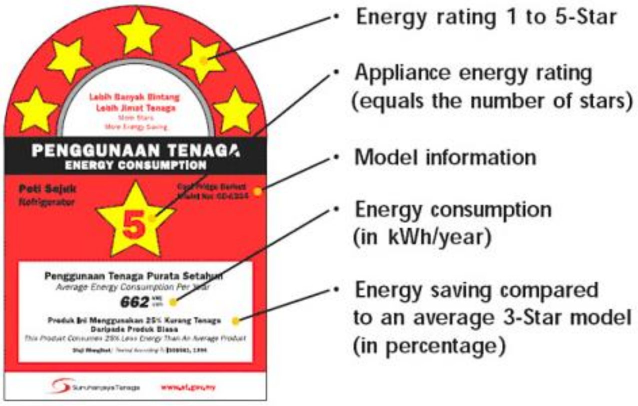
The scope for this standard is for self-ballasted LED lamps.

Performance requirements

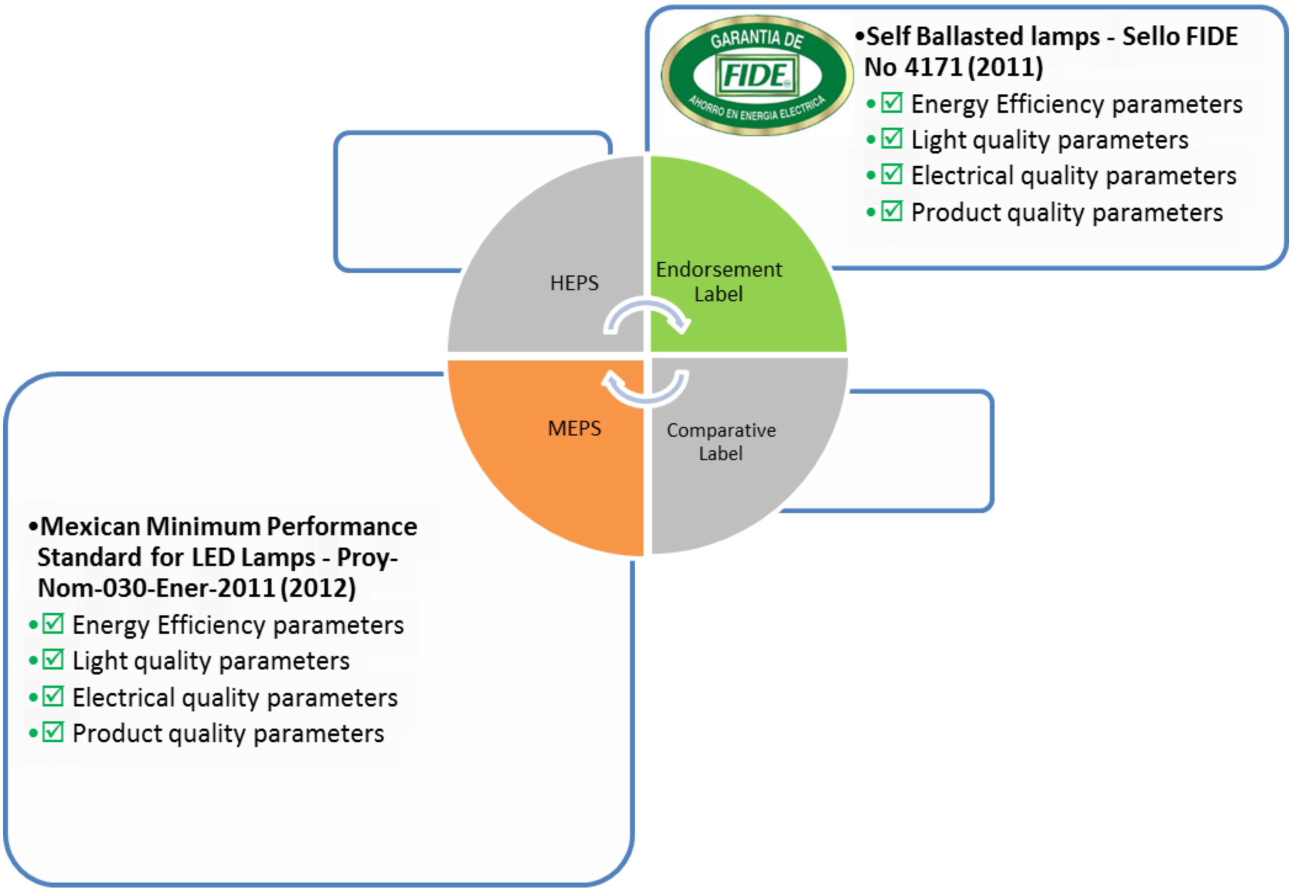
1. LED lamps are required to meet a minimum luminous efficacy of 55 lm/W.
2. Lumen maintenance of 80% after 1,000 hours and 70% after 6,000 hours.
3. Mortality rate of 10% after 1,000 hours and 6,000 hours.

Appliances should have at least a 2 STAR rating.
Performance testing is to be done by Standards and Industrial Research Institute of Malaysia (SIRIM) or any laboratory recognised by Standard Malaysia.

Comparative label



Mexico



- **Self Ballasted lamps - Sello FIDE No 4171 (2011)**
  - ☑ Energy Efficiency parameters
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

- **Mexican Minimum Performance Standard for LED Lamps - Proy-Nom-030-Ener-2011 (2012)**
  - ☑ Energy Efficiency parameters
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

Mexican Minimum Performance Standard for LED Lamps

Scope

This Mexican Official Standard applies to all integrated LED lamps omnidirectional and directional, which are used for general illumination in electrical voltages supply of 100 V to 277 V AC, 50 Hz or 60 Hz, which are manufactured or imported for marketing within the territory of the United Mexican States.

Exceptions apply to products that are set in another Standard Mexican Official in energy efficiency, as well as LED luminaires and modules LED.

Performance requirements

Parameter	Minimum requirements		Test Method
Efficacy	*Omni directional: The measured initial luminous flux of all lamps should not be less than 90% of the nominal value marked on the product.* *Lamp shapes A, BT, P, PS & T*		*Included within*
	Rated luminous flux ϕ *(lm)*	*Efficacy (lm/W)*	
	$\phi \le 325$	*50*	
	$325 < \phi \le 450$		
	$450 < \phi \le 800$	*55*	
	$800 < \phi \le 1{,}100$		
	$1{,}100 < \phi \le 1{,}600$	*60*	
	$1{,}600 < \phi$		
	Lamp shapes BA, C, CA, F & G		
	Rated luminous flux ϕ *(lm)*	*Efficacy (lm/W)*	
	$\phi \le 150$	*40*	
	$150 < \phi \le 300$		

Parameter	**Minimum requirements**		**Test Method**
	$300 < \phi$		
	Directional: Lamp shapes BR, ER, MR, PAR and R only		
	Lamp diameter (mm)	*Efficacy (lm/W)*	
	$\phi \le 63.5$	*40*	
	$63.5 < \phi$	*45*	
Colour temperature	*CCT must be within tolerance at:* *initial measurement and* *25% of life to a maximum of 6,000 h*		
	Nominal CCT (K)	*Tolerance of CCT (K) after 25% of life (maximum of 6,000 h)*	
	2700	*2580 ≤ CCT < 2870*	
	3000	*2870 ≤ CCT < 3220*	
	3500	*3220 ≤ CCT < 3710*	
	4000	*3710 ≤ CCT < 4260*	
	5000	*4745 ≤ CCT < 5311*	
	6500	*6200 ≤ CCT < 7040*	
Maintained luminous flux	*Rated Lifetime, T_{life} (h)*	*Maintained minimum luminous flux after 25% of life (maximum of 6,000 h) (%)*	
	$T_{life} < 15{,}000$	*83.2*	
	$15{,}000 \le T_{life} < 20{,}000$	*86.7*	
	$20{,}000 \le T_{life} < 25{,}000$	*89.9*	
	$25{,}000 \le T_{life} < 30{,}000$	*91.8*	
	$30{,}000 \le T_{life} < 35{,}000$	*93.1*	
	$35{,}000 \le T_{life} < 40{,}000$	*94.1*	
	$40{,}000 \le T_{life} < 45{,}000$	*94.8*	
	$45{,}000 \le T_{life} < 50{,}000$	*95.4*	
	$50{,}000 \le T_{life}$	*95.8*	
Colour Rendering	*Ra ≥ 77*		
Power Factor	*Rated Lamp Wattage (Lw)*	*Minimum Power Factor*	
	Lw ≤ 5W	*N/A*	
	5W <Lw	*0.7*	
Transient overvoltage	*All integrated LED lamps must not fail for 15 minutes after withstanding the application of a transient 7 form wave ring (ring wave) of 100 kHz at a level of 2.5 kV. (details in the Mexican Official Standard NOM-030-ENER-2011)*		
Thermal shock	*All integrated LED lamps must not fail for 15 minutes after 5 cycles of thermal shock from -10 ℃ to +50 ℃*		
Switch withstand	*Switching cycles before failure > half rated lamp life in hours*		

Energy Efficiency Guarantee Label - Sello FIDE - No 4171 - Self Ballasted lamps for Interior Use

Scope

The scope includes integrated LED lamps and luminaire products for indoor use.

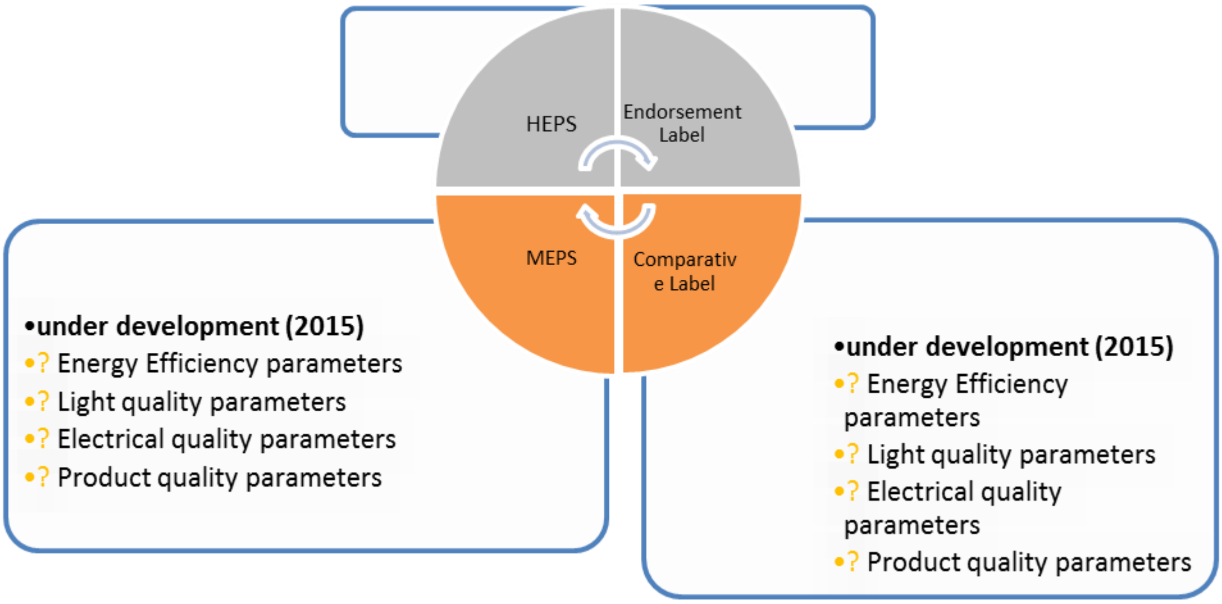
Performance metrics

Performance metrics below relate to the replacement target lamps.

Replacement lamp or similar application	**Power of replacement lamp (W) or Diameter of lamp (mm)**	**Efficacy of the integrated LED lamp (lm/W)**	**Mammon luminous flux of the integrated LED lamp (lm)**	**Test Method**
Special lamps	*< 10 W*	*50*	*200*	*IES LM-79-08*
	≥ 10 W	*55*		
Omnidirectional lamps (A, BT,	*< 25 W*	*50*	*200*	

Replacement lamp or similar application	Power of replacement lamp (W) or Diameter of lamp (mm)	Efficacy of the integrated LED lamp (lm/W)	Mammon luminous flux of the integrated LED lamp (lm)	Test Method
P, PS, S, T)	*25 W*	*55*	*200*	
	35 W		*350*	
	40 W		*450*	
	60 W		*800*	
	75 W		*1,100*	
	100 W		*1,600*	
	125 W		*2,000*	
	150 W		*2,600*	
Directional lamps *(BR, ER, K, MR, PAR, R)*	*≤ 6.35 mm*	*40*	*The integrated lamp with LEDs, at least 80% of its light output should be within a solid angle included in a cone with an angle of 120 °*	
	> 6.35 mm	*45*		

Nigeria



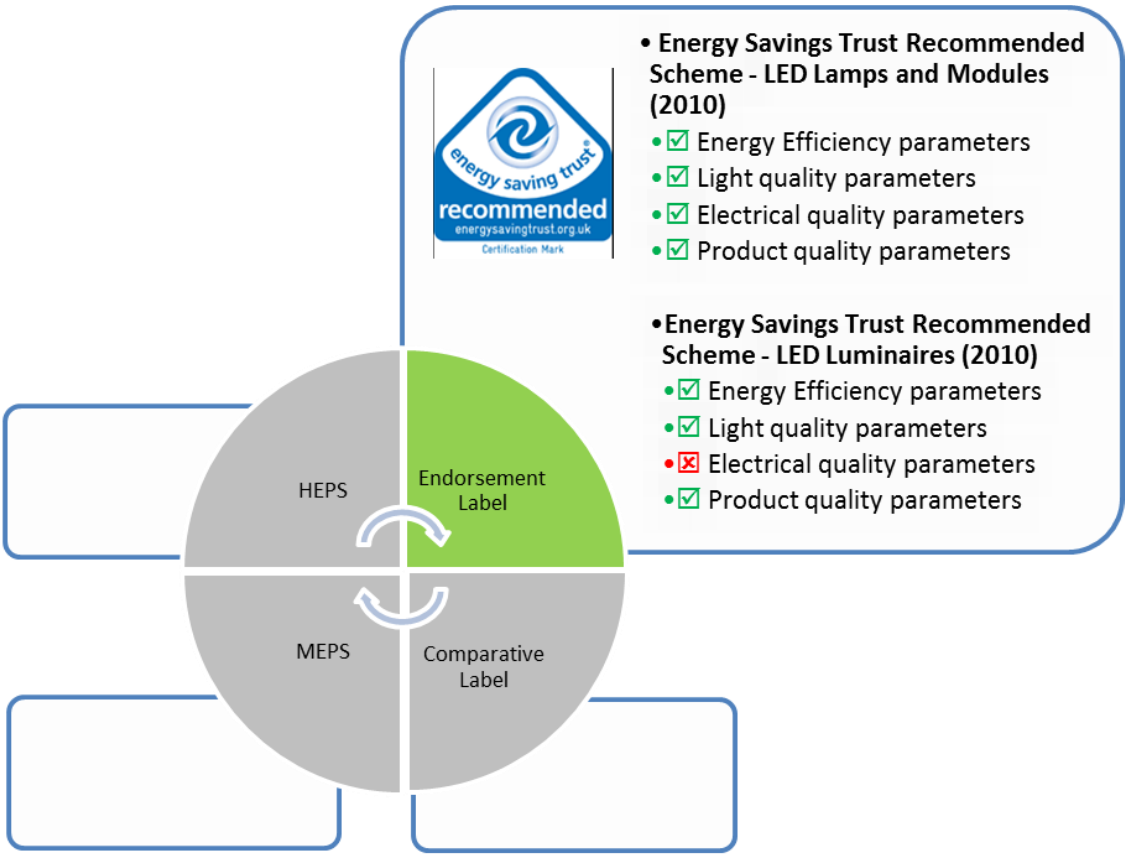
Scope

Under development.

Performance requirements

Under development.

United Kingdom



Energy Savings Trust Recommended Scheme - LED Lamps and Modules

Scope

This scheme is for LED products that provide an energy efficient alternative to standard incandescent or halogen lamps specifically:

(1) mains voltage LED lamps with integral driver designed to replace existing lamps of comparable light output performance

Class 1: Directional LED lamps to replace GU10 reflector lamps

Class 2: Type A LED lamps meeting EU Regulation No 244/2009 definition of “non-directional”

Class 3: Type B directional LED lamps meeting EU Regulation No 244/2009 definition of “directional”

Class 4: Directional LED lamps designed to replace lamps

(2) LED lamp/modules with non-integral driver

Class 21: LED modules designed to physically replace existing low voltage MR16 halogen lamps in standard downlight luminaires

Class 22: LED lamps intended to replace existing low voltage reflector lamps (MR16 type) with typically GU5.3 bases.

Performance requirements

Requirements for all Classes:

Parameter	**Minimum requirements**	**Test Method**
Colour temperature	*Warm white* *2700 K ≤ CCT ≤ 3500 K* *and ≤ 5 MPCD of target chromaticity co-ordinates*	*ANSI/NEMA/ANSLG C78.377*
Earlier failure	*No lamps at 3,000 h*	

Parameter	Minimum requirements		Test Method
Lamp life	*$L_{70}F_{50}$ ≥ 15,000 h*		IEC/PAS 62612 IEC62384
Lamp Power, L_w	*Directional lamps as per EU Reg No 244/2009):* *L_w ≤ 25% of power of lamp claimed to replace*		
Power factor	*Class 1, 2, 3, 4*	*≤ 0.7*	
	Class 21, 22	*≤ 0.9*	
Colour rendering	*> 80*		

Requirements for specific classes:

	Minimum Peak Beam Intensity (cd/lux)	Half peak beam angle (deg)	Beam angle to 10% of peak beam intensity (deg)	Test Method
Class 1 GU10 reflector lamps				*IEC 61341*
20W halogen equivalent	*200*	*30-40*	*60-75*	
35 W halogen equivalent	*400*	*30-40*	*60-75*	
50 W halogen equivalent	*600*	*30-40*	*60-75*	
Class 4PAR16 & R50 lamps				
25 W incandescent replacement	*200*	*26 - 36*	*N/A*	
40 W incandescent replacement	*320*	*26 - 36*	*N/A*	
Class 4PAR20 & R63 lamps				
25 W incandescent replacement	*250*	*26 - 36*	*N/A*	
40 W incandescent replacement	*390*	*26 - 36*	*N/A*	
60 W incandescent replacement	*670*	*26 - 36*	*N/A*	
Class 21 MR16reflector modules				
20W halogen equivalent	*405*	*30-40*	*60-75*	
35 W halogen equivalent	*745*	*30-40*	*60-75*	
50 W halogen equivalent	*1,215*	*30-40*	*60-75*	
Class 22MR16reflector lamps				
20W halogen equivalent	*360*	*30-40*	*60-75*	
35 W halogen equivalent	*660*	*30-40*	*60-75*	
50 W halogen equivalent	*1,080*	*30-40*	*60-75*	

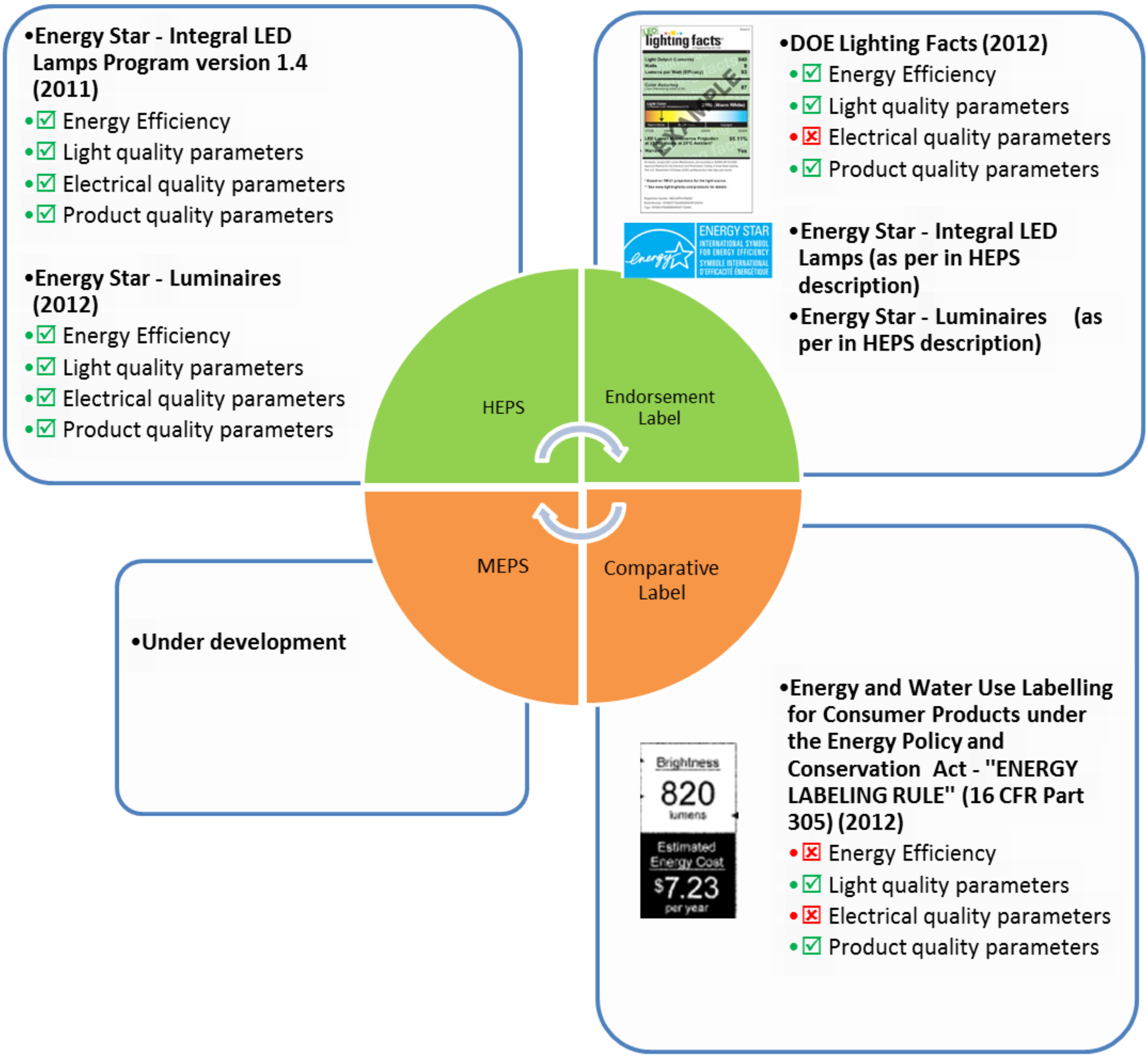
	Minimum requirements	Test Method
Class 3GLS style directional lamps		
Light output and direction	*≥ 200 lm within 90 ° cone*	*IEC/PAS 62612*
Class 2 Non-directional lamps		
Light output direction	*Luminous flux output ≥ 2π steradians*	*IEC/PAS 62612*
Efficacy (lm/W)	*≥ 35*	
Lumen output (lm)	*≥ 200*	

Minimum light output for LED lamp to claim equivalence to Incandescent source

GLS Wattage (W)	LED Min Output (lm)	GLS Wattage (W)	LED Min Output (lm)	GLS Wattage (W)	LED Min Output (lm)	GLS Wattage (W)	LED Min Output (lm)	GLS Wattage (W)	LED Min Output (lm)
15	*136*	*42*	*504*	*69*	*955*	*96*	*1446*	*123*	*1949*
16	*147*	*43*	*520*	*70*	*972*	*97*	*1465*	*124*	*1968*
17	*159*	*44*	*537*	*71*	*989*	*98*	*1484*	*125*	*1987*
18	*170*	*45*	*554*	*72*	*1005*	*99*	*1502*	*126*	*2005*
19	*181*	*46*	*571*	*73*	*1022*	*100*	*1521*	*127*	*2024*
20	*193*	*47*	*588*	*74*	*1038*	*101*	*1540*	*128*	*2042*

				Minimum requirements						Test Method
21	204	48	604	75	1055	102	1558	129	2061	
22	215	49	621	76	1074	103	1577	130	2080	
23	226	50	638	77	1092	104	1595	131	2098	
24	238	51	655	78	1111	105	1614	132	2117	
25	249	52	672	79	1130	106	1633	133	2135	
26	264	53	688	80	1148	107	1651	134	2154	
27	278	54	705	81	1167	108	1670	135	2173	
28	293	55	722	82	1185	109	1689	136	2191	
29	308	56	739	83	1204	110	1707	137	2210	
30	323	57	756	84	1223	111	1726	138	2229	
31	337	58	772	85	1241	112	1744	139	2247	
32	352	59	789	86	1260	113	1763	140	2266	
33	367	60	806	87	1279	114	1782	141	2284	
34	382	61	823	88	1297	115	1800	142	2303	
35	396	62	839	89	1316	116	1819	143	2322	
36	411	63	856	90	1335	117	1838	144	2340	
37	426	64	872	91	1353	118	1856	145	2359	
38	441	65	889	92	1372	119	1875	146	2378	
39	455	66	906	93	1391	120	1893	147	2396	
40	470	67	922	94	1409	121	1912	148	2415	
41	487	68	939	95	1428	122	1931	149	2433	
								150	2452	

United States of America



- **Energy Star - Integral LED Lamps Program version 1.4 (2011)**
  - ☑ Energy Efficiency
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters
- **Energy Star - Luminaires (2012)**
  - ☑ Energy Efficiency
  - ☑ Light quality parameters
  - ☑ Electrical quality parameters
  - ☑ Product quality parameters

- **DOE Lighting Facts (2012)**
  - ☑ Energy Efficiency
  - ☑ Light quality parameters
  - ☒ Electrical quality parameters
  - ☑ Product quality parameters
- **Energy Star - Integral LED Lamps (as per in HEPS description)**
- **Energy Star - Luminaires (as per in HEPS description)**

- **Under development**

- **Energy and Water Use Labelling for Consumer Products under the Energy Policy and Conservation Act - "ENERGY LABELING RULE" (16 CFR Part 305) (2012)**
  - ☒ Energy Efficiency
  - ☑ Light quality parameters
  - ☒ Electrical quality parameters
  - ☑ Product quality parameters

Energy Star - Integral LED Lamps

Scope

The scope of this program is integral LED lamps defined as having:

- a lamp with LEDs,
- an integrated LED driver,
- an ANSI standardized base designed to connect to the branch circuit via an ANSI standardized lamp holder/socket.

These criteria include integral LED lamps of non-standard form, and those intended to replace standard general service incandescent lamps, decorative (candelabra style) lamps, and reflector lamps.

Performance Requirements

Parameter	Minimum requirements		Test Method
Efficacy	*Omni-directional Lamps & Non-standard lamps. Non-standard lamps may not state equivalency to existing standard electric lamps in terms of wattage or type/shape.*		*IES LM-79-08*
	Rated Lamp Wattage (Lw)	*Efficacy (lm/W)*	
	Lw< 10W	*50*	

<table>
<tr><th>Parameter</th><th colspan="6">Minimum requirements</th><th>Test Method</th></tr>
<tr><td rowspan="6"></td><td colspan="3">10W ≤ Lw</td><td colspan="3">55</td><td rowspan="6"></td></tr>
<tr><td colspan="6">Directional Lamps</td></tr>
<tr><td colspan="3">Lamp Diameter (Ld mm)</td><td colspan="3">Efficacy (lm/W)</td></tr>
<tr><td colspan="3">Ld ≤ 63.5</td><td colspan="3">40</td></tr>
<tr><td colspan="3">Ld> 63.5</td><td colspan="3">45</td></tr>
<tr><td colspan="6">Decorative lamps: efficacy ≤ 40 lm/W</td></tr>
<tr><td rowspan="18">Luminous flux</td><td colspan="6">Non-standard lamps: Total luminous flux ≥ 200 lm
Omni-directional lamps: ≥ 5% of total measured light output is emitted in the 135°to 180°zone
If claiming equivalence total luminous flux must exceed</td><td rowspan="19"></td></tr>
<tr><td colspan="3">Claimed equivalent wattage incandescent lamp (W)</td><td colspan="3">Minimum luminous flux of LED lamp (lm)</td></tr>
<tr><td colspan="3">25</td><td colspan="3">200</td></tr>
<tr><td colspan="3">35</td><td colspan="3">325</td></tr>
<tr><td colspan="3">40</td><td colspan="3">450</td></tr>
<tr><td colspan="3">60</td><td colspan="3">800</td></tr>
<tr><td colspan="3">75</td><td colspan="3">1100</td></tr>
<tr><td colspan="3">100</td><td colspan="3">1600</td></tr>
<tr><td colspan="3">125</td><td colspan="3">2000</td></tr>
<tr><td colspan="3">150</td><td colspan="3">2600</td></tr>
<tr><td colspan="6">Decorative lamps: If claiming equivalence luminous flux must exceed</td></tr>
<tr><td colspan="3">Claimed equivalent wattage incandescent lamp (W)</td><td colspan="3">Minimum luminous flux of LED lamp (lm)</td></tr>
<tr><td colspan="3">10</td><td colspan="3">70</td></tr>
<tr><td colspan="3">15</td><td colspan="3">90</td></tr>
<tr><td colspan="3">25</td><td colspan="3">150</td></tr>
<tr><td colspan="3">40</td><td colspan="3">300</td></tr>
<tr><td colspan="3">60</td><td colspan="3">500</td></tr>
<tr><td colspan="6">Directional lamps: (lamp types BR, ER, K, R only)
• ≥ 80% of total measured light output is within a 120° cone (i.e. solid angle of π sr)
• measured total luminous flux ≥ 10 times the rated wattage of the target lamp</td></tr>
<tr><td>Luminous intensity distribution</td><td colspan="6">Omni-directional lamps:
• Luminous intensity within the 0°to 135°zone:
• Is vertically axially symmetrical
• At any angle has a variation ≤ 20% from the mean of the zone</td></tr>
<tr><td>Centre Beam Intensity</td><td colspan="6">PAR and MR16 LED lamps:
Minimum centre beam intensity (cd) is determined by an online tool with results based on lamp diameter, target lamp wattage and target beam angle.</td><td></td></tr>
<tr><td>Lumen maintenance</td><td colspan="6">Omni-directional, Directional and Non-standard lamps:
≥ 70% lumen maintenance at 25,000 h
(Ambient temp of 25℃ for lamp power < 10W, and 45℃ for lamp power ≥ 10W)
Decorative lamps:
≥ 70% lumen maintenance at 15,000 h
(Ambient temp of 25℃ for all lamps)</td><td>IES LM-80-08</td></tr>
<tr><td>Colour Rendering</td><td colspan="6">Ra ≥ 80, and
R9 ≤ 0</td><td>IES LM-79-08
CIE13.3-1995</td></tr>
<tr><td rowspan="5">Colour temperature</td><td colspan="2">Rated CCT (K)</td><td colspan="2">Target CCT and Tolerance (K)</td><td colspan="2">Target Duv and tolerance</td><td rowspan="5"></td></tr>
<tr><td colspan="2">2700</td><td colspan="2">2725 ± 145</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">3000</td><td colspan="2">3045 ± 175</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">3500</td><td colspan="2">3465 ± 245</td><td colspan="2">0.000 ± 0.006</td></tr>
<tr><td colspan="2">4000</td><td colspan="2">3985 ± 275</td><td colspan="2">0.001 ± 0.006</td></tr>
<tr><td>Colour maintenance</td><td colspan="6">Chromaticity shift over 6,000 h ≤ 0.007 on the CIE 1976 u'v' diagram</td><td></td></tr>
</table>

Parameter	Minimum requirements		Test Method
Colour spatial uniformity	*Variation in chromaticity within the beam angle ≤ 0.006 on the CIE 1976 u'v' diagram*		
Power Factor	*Rated Lamp Wattage (Lw)*	*Minimum Power Factor*	
	Lw ≤ 5W	*N/A*	
	5W <Lw	*0.7*	
Switching withstand	*Switching cycles before failure > half rated L70 "life" in hours*		*IES LM-65-01* *ANSIC78.5-2003*

Energy Star Label - Integral LED Lamps

Specifications are as per stated above in section "Energy Star- Integral LED Lamps" above.

Lighting Facts Label

Scope

The scope of allowable products includes:

- Complete luminaires and replacement lamps
- Low-voltage replacement lamps
- Products with separate power supplies
- Linear/modular products.

Solar and or battery powered lighting products as well as light strips/rolls are excluded.

Performance metrics

Parameter	Allowable tolerance	Test Method
Mandatory		*IES LM-79-08*
Light output (lm)	*± 10% of tested lumen output*	
Input power (W)	$[P_{measured}*0.9-0.5]<P_{stated}<[P_{measured}*1.1+0.5]$	
Lamp efficacy (lm/W)	*State either:* *Exact as measured, or* *Calculated as quotient of stated lumens to stated power*	
Colour Rendering Index	*± 2.0*	
Colour temperature (K)	*State either:* • *Exact as measured, or* • *Flexible CCT in 100 K increments* • *Nominal CCT*	
Optional		
Power factor	*None specified*	
Chromaticity co-ords	*None specified*	
R_9 *value*	*None specified*	
D_{uv}	*None specified*	
Beam angle	*None specified*	
Centre beam intensity	*None specified*	
Zonal lumen summaries	*None specified*	
Lumen maintenance Stated at either: • *10,000 h, or* • *15,000 h, or* • *25,000 h*	*None specified*	*IES LM-80-08* *IES TM-21-11*

Code of Federal Regulations, Title 16: Commercial Practices – Part 305: Energy and Water Use Labelling for Consumer Products under the Energy Policy and Conservation Act – Section 305.15: Labelling of lighting products

Scope

The scope includes fluorescent lamps ballasts and luminaires and general service lamps

Parameter requirements

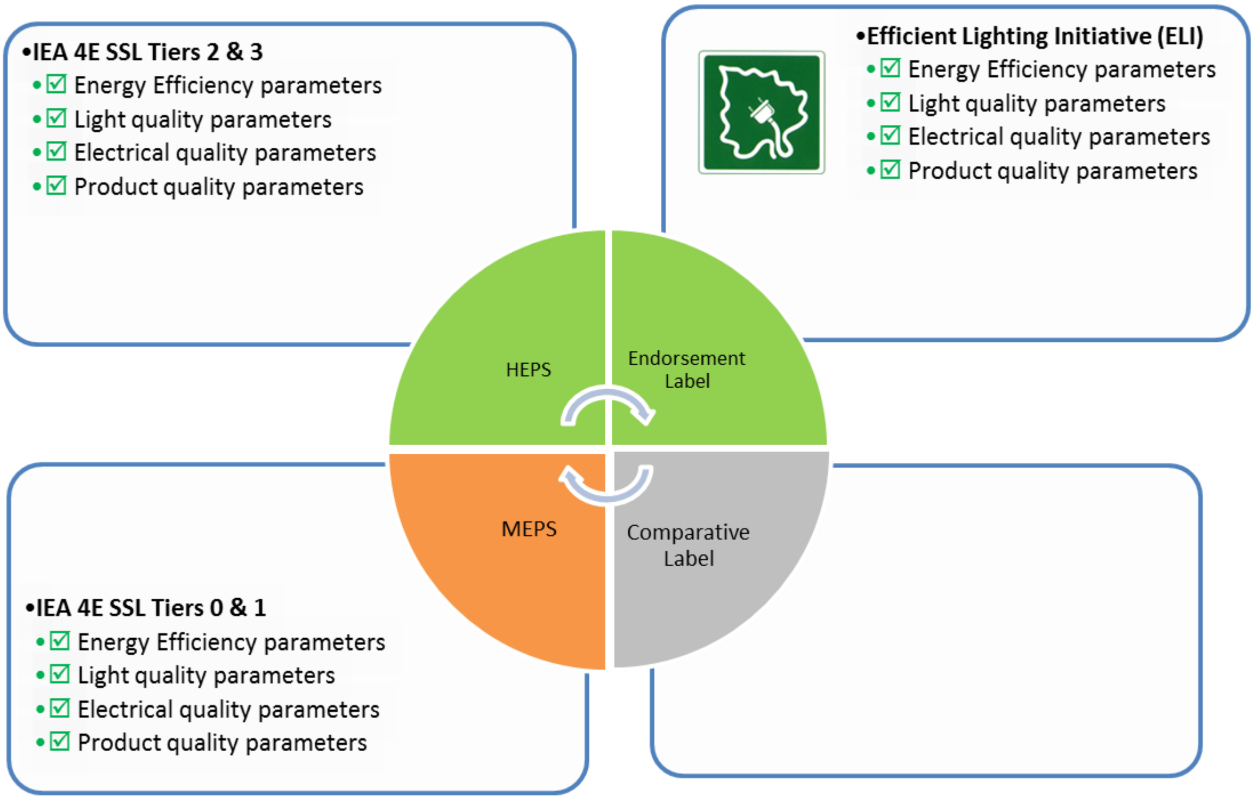
Mandatory requirements:

- Light output expressed as "Brightness"
- Estimated energy cost per year (based on 3 hours per day operation and 11 cents per kilowatt hour

Countries following USA

<table>
<tr><th>Country</th><th></th><th colspan="4">Details</th></tr>
<tr><td>Canada</td><td>Energy Star for Integral LED Lamps (2010)
Energy Star for Solid State Lighting (SSL) Luminaire (2009)</td><td colspan="4">MEPS: Specifications are as per stated for the United States of America</td></tr>
<tr><td rowspan="5">New Zealand</td><td rowspan="5">Energy Star for Integral LED Lamps (2010)
Energy Star for Solid State Lighting (SSL) Luminaire (2009)</td><td colspan="4">MEPS: Specifications are as per stated the United States of America with the exception:
1. Electrical Safety: Products must comply with all relevant local New Zealand Electrical (Safety) Regulation 2010 requirements.
2. Specification: Products must comply with all the requirements of the US Energy Star specification for
LED light Bulbs with the following 2 changes (shown in blue) to Clause 4 Requirements for all Lamps (can be found on pages 3 & 4 of the US specification):</td></tr>
<tr><td>Criteria Item</td><td>Energy Star requirements</td><td>Reference Standard/Test Method</td><td>Sample Size/Specific Requirements</td></tr>
<tr><td>Allowable lamp bases</td><td>Must be a lamp base listed by ANSI or BA 22D bayonet base as listed by IEC</td><td>ANSI/ANSLG C81.61-2009
IEC 60061-1</td><td>N/A</td></tr>
<tr><td>Operating Voltage</td><td>Lamp shall operate at rated nominal voltage of 120, 230, 240, or 277 VAC, or at 12 or 24 VAC/ VDC</td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="4">Note: LED Operating Frequency – if the product is tested at an input supply frequency of 50Hz it must have an operating frequency of ≥ 100Hz.
Otherwise the US ENERGY STAR criteria applies.</td></tr>
</table>

International



Efficient Lighting Initiative – Self Ballasted LED Lamps for General Lighting Services

Scope

This specification applies exclusively to non-directional Self-Ballasted LED Lamps. These lamps have an integrated means for stable operation and are intended for general lighting purposes. They have screw or bayonet caps, a rated power up to 60W and a rated voltage of up to 250V AC or DC.

Performance requirements

<table>
<tr><th>Parameter</th><th colspan="7">Requirements</th><th>Test Method</th></tr>
<tr><td rowspan="6"><i>Efficacy</i></td><td rowspan="2"><i>Rated lamp power, P (W)</i></td><td colspan="6"><i>Efficacy (lm/W)
for different Colour Temp (K)</i></td><td rowspan="31"><i>IEC/PAS 62612</i></td></tr>
<tr><td><i>6500K</i></td><td><i>5000K</i></td><td><i>4000K</i></td><td><i>3500k</i></td><td><i>3000K</i></td><td><i>2700K</i></td></tr>
<tr><td><i>1 ≤ P ≤ 5</i></td><td colspan="2"><i>50</i></td><td colspan="4"><i>45</i></td></tr>
<tr><td><i>6 ≤ P ≤ 10</i></td><td colspan="2"><i>55</i></td><td colspan="4"><i>50</i></td></tr>
<tr><td><i>11 ≤ P ≤ 25</i></td><td colspan="2"><i>55</i></td><td colspan="4"><i>50</i></td></tr>
<tr><td><i>26 ≤ P ≤ 60</i></td><td colspan="2"><i>50</i></td><td colspan="4"><i>45</i></td></tr>
<tr><td rowspan="11"><i>Light output</i></td><td colspan="7"><i>Equivalency compared to luminous flux of incandescent lamp for general lighting services.</i></td></tr>
<tr><td colspan="4"><i>Light output (lm)</i></td><td colspan="3"><i>Power of standard GLS (W)</i></td></tr>
<tr><td colspan="4"><i>≥230</i></td><td colspan="3"><i>25</i></td></tr>
<tr><td colspan="4"><i>≥415</i></td><td colspan="3"><i>40</i></td></tr>
<tr><td colspan="4"><i>≥570</i></td><td colspan="3"><i>50</i></td></tr>
<tr><td colspan="4"><i>≥715</i></td><td colspan="3"><i>60</i></td></tr>
<tr><td colspan="4"><i>≥940</i></td><td colspan="3"><i>75</i></td></tr>
<tr><td colspan="4"><i>≥1,227</i></td><td colspan="3"><i>90</i></td></tr>
<tr><td colspan="4"><i>≥1,350</i></td><td colspan="3"><i>100</i></td></tr>
<tr><td colspan="4"><i>≥2,180</i></td><td colspan="3"><i>150</i></td></tr>
<tr><td colspan="4"><i>≥3,090</i></td><td colspan="3"><i>200</i></td></tr>
<tr><td><i>Colour rendering</i></td><td colspan="7"><i>≥ 80</i></td></tr>
<tr><td rowspan="9"><i>Colour temperature</i></td><td colspan="2" rowspan="2"><i>Colour Indication</i></td><td colspan="2" rowspan="2"><i>CCT (K)</i></td><td colspan="3"><i>Chromaticity Co-ords</i></td></tr>
<tr><td colspan="2"><i>x</i></td><td><i>y</i></td></tr>
<tr><td colspan="2"><i>F 6500</i></td><td colspan="2"><i>6400</i></td><td colspan="2"><i>0.313</i></td><td><i>0.337</i></td></tr>
<tr><td colspan="2"><i>F 5000</i></td><td colspan="2"><i>5000</i></td><td colspan="2"><i>0.346</i></td><td><i>0.359</i></td></tr>
<tr><td colspan="2"><i>F 4000</i></td><td colspan="2"><i>4040</i></td><td colspan="2"><i>0.380</i></td><td><i>0.380</i></td></tr>
<tr><td colspan="2"><i>F 3500</i></td><td colspan="2"><i>3450</i></td><td colspan="2"><i>0.409</i></td><td><i>0.394</i></td></tr>
<tr><td colspan="2"><i>F 3000</i></td><td colspan="2"><i>2940</i></td><td colspan="2"><i>0.440</i></td><td><i>0.403</i></td></tr>
<tr><td colspan="2"><i>F 2700</i></td><td colspan="2"><i>2720</i></td><td colspan="2"><i>0.463</i></td><td><i>0.420</i></td></tr>
<tr><td colspan="7"><i>Chromaticity tolerance is to be within 7 SDCM</i></td></tr>
<tr><td><i>Colour rendering sustainability</i></td><td colspan="7"><i>Change in chromaticity after 6,000 h ≤ 0.007 on CIE1976 (u'v')</i></td></tr>
<tr><td><i>Life expectancy</i></td><td colspan="7"><i>Average life ≥ 25,000 h</i></td></tr>
<tr><td><i>Lumen Maintenance</i></td><td colspan="7"><i>The luminous flux (relative to initial luminous flux)
≥ 96% at 3,000 h
≥ 91.8% at 6,000 h
≥ 70% at 70% of rated life</i></td></tr>
<tr><td><i>Switching withstand</i></td><td colspan="7"><i>Switching cycles before failure > 12,500
(based on 50% of life in hours)</i></td></tr>
<tr><td><i>Power factor</i></td><td colspan="7"><i>≥ 0.5</i></td><td></td></tr>
<tr><td><i>Harmonics</i></td><td colspan="7"><i>Comply with standard</i></td><td><i>IEC 61000-3-2</i></td></tr>
<tr><td><i>Electromagnetic and radio interference</i></td><td colspan="7"><i>Comply with standard</i></td><td><i>CISPR 15</i></td></tr>
</table>

Parameter	Requirements	Test Method
Electromagnetic Compatibility Immunity	*Comply with standard*	*IEC 61547*
Transient protection	*Comply with standard*	*IEC 61547*

International Energy Agency, Energy Efficient End-use Equipment, Solid State Lighting (IEA 4E SSL)

This program is still active and ongoing in the development of tiered performance requirements for LED lighting products and as such has not been adopted by any economy at this stage.

Scope

The current 4E SSL performance criteria apply to generic:

(a) Non directional lamps for indoor residential applications

(b) Directional lamps for indoor residential applications

(c) Downlight luminaires

(d) Linear fluorescent LED replacement lamps

(e) Streetlight

Performance requirements

Non-directional Lamps

Tier	Tier0	Tier1		Tier2		Tier3	
Claimed equivalent wattage(W) and minimal initial light output (lumens)	*N/A: a large number of these products will be used in off-grid applications where light has never been used before. Equivalency in these applications has no meaning.*	*20W*	*170lm*	*20W*	*170lm*	*20W*	*170lm*
		25W	*250lm*	*25W*	*250lm*	*25W*	*250lm*
		30W	*325lm*	*30W*	*325lm*	*30W*	*325lm*
		35W	*395lm*	*35W*	*395lm*	*35W*	*395lm*
		40W	*470lm*	*40W*	*470lm*	*40W*	*470lm*
		60W	*800lm*	*60W*	*800lm*	*60W*	*800lm*
		75W	*1055lm*	*75W*	*1055lm*	*75W*	*1055lm*
		100W	*1520lm*	*100W*	*1520lm*	*100W*	*1520lm*
		125W	*2000lm*	*125W*	*2000lm*	*125W*	*2000lm*
		150W	*2452lm*	*150W*	*2452lm*	*150W*	*2452lm*
		200W	*3452lm*	*200W*	*3452lm*	*200W*	*3452lm*
Minimum lamp luminous efficacy (lm/W)	*50lm/W*	*>50lm/watt*		*>65lm/watt*		*>80lm/W*	
Colour temperature target **(K) and tolerance**	*N/A*	*Follow ANSIC 78.377, excluding flexible CCT* *2700K (2725±145)* *3000K (3045±175)* *3500K (3465±245)* *4000K (3985±275)* *5000K (5028±283)* *5700K (5665±355)* *6500K (6530±510)*		*Follow ANSIC 78.377, excluding flexible CCT* *2700K (2725±145)* *3000K (3045±175)* *3500K (3465±245)* *4000K (3985±275)* *5000K (5028±283)* *5700K (5665±355)* *6500K (6530±510)*		*Follow ANSIC 78.377-2011* *Table6A, for 4-step quadrangle excluding flexible CCT* *2700K (2723±82)* *3000K (2940±98)* *3500K (3397±125)* *4000K (4036±154)* *5000K (4991±220)* *5700K (5665±270)* *6500K (6432±340)*	

Tier	Tier0	Tier1	Tier2	Tier3
Chromaticity tolerance (Du'v')		*Follow ANSIC 78.377, excluding flexible CCT* *0.000 ± 0.006* *0.000 ± 0.006* *0.000 ± 0.006* *0.001 ± 0.006* *0.002 ± 0.006* *0.002 ± 0.006* *0.003 ± 0.006*	*Follow ANSIC 78.377, excluding flexible CCT* *0.000 ± 0.006* *0.000 ± 0.006* *0.000 ± 0.006* *0.001 ± 0.006* *0.002 ± 0.006* *0.002 ± 0.006* *0.003 ± 0.006*	*followANSIC78.377-2011* *Table6A,for4-stepquadrangleexcludingflexibleCCT* *0.0006±0.0033* *-0.0008±0.0033* *-0.0002±0.0033* *0.0016±0.0033* *0.0033±0.0033* *0.0024±0.0033* *0.0071±0.0033*
Color Maintenance (Δu',v' at 6,000h)	*N/A*	*<0.007*	*<0.007*	*<0.004*
Luminous intensity distribution 0-180°	*N/A*	*N/A*	*Products shall have an even distribution of luminous intensity within the 0° to 135° zone (symmetrical about the vertical axis). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux must be emitted in the 135° - 180° zone. Distribution shall be vertically symmetric in three vertical planes, 0°, 45°, 90°.*	*Products shall have an even distribution of luminous intensity within the 0° to 135° zone (symmetrical about the vertical axis). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux must be emitted in the 135° - 180° zone. Distribution shall be vertically symmetric in three vertical planes, 0°, 45°, 90°.*
CRI	*N/A*	*≥70*	*≥80, R9>0*	*≥80, R9>0*
Lag start time	*N/A*	*<0.5 sec until continuous light output*	*<0.5 sec until continuous light output*	*<0.5 sec until continuous light output*
Lumen Maintenance (Minimum time to L_{70})	*At5,000hLumenMaintenance* *>70%ofinitial*	*At 15,000h, Lumen Maintenance* *>70% of initial*	*At 25,000h, Lumen Maintenance* *>70% of initial*	*At 25,000h, Lumen Maintenance* *>70% of initial*
Minimum Rated Lamp lifetime (B_{50})	*At 5,000h,* *50% of population will be operative*	*At 15,000h,* *50% of population will be operative*	*At 25,000h,* *50% of population will be operative*	*At 25,000h,* *50% of population will be operative*
Flicker (Amplitude Modulation Depth)	*At full power (no dimming), percent flicker (calculated as (max-min) /(max+min) luminous flux) ≤10%*	*At full power flicke r index ‡* *≤ 0.3*	*At full power flicker r index ‡* *≤ 0.3*	*At full power flicker r index ‡* *≤ 0.3*
Minimum power factor	*Current Crest Factor (calculates as Ipeak/Irms) ≤ 3*	*≤5W: no requirement;* *>5W, PF>0.50*	*≤5W: no requirement;* *>5W, PF>0.50*	*≤5W: no requirement;* *>5W, PF>0.50*
Harmonic distortion	*N/A*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*
Dimmer compatibility	*N/A*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*

Tier	Tier0	Tier1	Tier2	Tier3
Photo biological hazard class (UV & blue light)	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*
Safety marking	*Must meet regional requirements for marking, if they exist, for non-grid connected devices*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*
Warranty Duration	*Minimum 1 year warranty against catastrophic failure unless regional requirement is higher*	*Minimum 1 year warranty against catastrophic failure unless regional requirement is higher*	*Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.*	*Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.*
RoHS Compliant	*Yes*	*Yes*	*Yes*	*Yes*
Recyclability (%)	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*
Endurance Test	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*

Directional Lamps

Tier	Tier0	Tier1						Tier2						Tier3					
If claiming equivalence to filament lamp wattages (by lamp type)	*N/A: a large number of these products will be used in off grid applications where light has never been used before.* *Equivalency in these applications has no meaning.*	*Watts (W)*	*MR 11 (lm)*	*MR16 (lm)*	*AR111 (lm)*	*R (lm)*	*PAR (lm)*	*Watts (W)*	*MR 11 (lm)*	*MR16(lm)*	*AR111(lm)*	*R(lm)*	*PAR(lm)*	*Watts (W)*	*MR 11 (lm)*	*MR16(lm)*	*AR111(lm)*	*R(lm)*	*PAR(lm)*
		20	*390*	*250*	*380*	*120*	*92*	*20*	*390*	*250*	*380*	*120*	*92*	*20*	*390*	*250*	*380*	*120*	*92*
		25			*564*	*170*	*150*	*25*			*564*	*170*	*150*	*25*			*564*	*170*	*150*
		30			*660*	*200*		*30*			*660*	*200*		*30*			*660*	*200*	
		35	*650*	*490*	*930*		*250*	*35*	*650*	*490*	*930*		*250*	*35*	*650*	*490*	*930*		*250*
		50		*780*	*1030*	*400*	*540*	*50*		*780*	*1030*	*400*	*540*	*50*		*780*	*1030*	*400*	*540*
		60				*700*	*800*	*60*				*700*	*800*	*60*				*700*	*800*
		75		*1300*		*850*	*1030*	*75*		*1300*		*850*	*1030*	*75*		*1300*		*850*	*1030*
		100					*1200*	*100*					*1200*	*100*					*1200*
		120				*1500*		*120*				*1500*		*120*				*1500*	
		150				*1600*	*1370*	*150*				*1600*	*1370*	*150*				*1600*	*1370*
		200					*2270*	*200*					*2270*	*200*					*2270*
		240					*3100*	*240*					*3100*	*240*					*3100*
Center beam luminous intensity	*N/A*	*For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool (www.energystar.gov/ia/products/lighting/iledl/IntLampCenterBeamTool.zip)*						*For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool (www.energystar.gov/ia/products/lighting/iledl/IntLampCenterBeamTool.zip)*						*For MR or PAR lamps with a beam angle <65°, center beam intensity should meet equivalent levels using the online tool (www.energystar.gov/ia/products/lighting/iledl/IntLampCenterBeamTool.zip)*					

Tier	Tier0	Tier1	Tier2	Tier3
Minimum lamp luminous efficacy (lm/W)	*50lm/W*	*≤20/8inches (63mm): >35lm/W* *>20/8inches (63mm): >40lm/W*	*≤20/8inches (63mm): >45lm/W* *>20/8inches (63mm): >50lm/W*	*≤20/8inches (63mm): >55lm/W* *>20/8inches (63mm): >60lm/W*
Color temperature target (K) and tolerance	*N/A*	*Follow ANSIC 78.377, excluding flexible CCT* *2700K (2725±145)* *3000K (3045±175)* *3500K (3465±245)* *4000K (3985±275)* *5000K (5028±283)* *5700K (5665±355)* *6500K (6530±510)*	*Follow ANSIC 78.377, excluding flexible CCT* *2700K (2725±145)* *3000K (3045±175)* *3500K (3465±245)* *4000K (3985±275)* *5000K (5028±283)* *5700K (5665±355)* *6500K (6530±510)*	*Follow ANSIC 78.377-2011* *Table 6A, for 4-step quadrangle excluding flexible CCT* *2700K (2723 ±82)* *3000K (2940 ±98)* *3500K (3397±125)* *4000K (4036±154)* *5000K (4991±220)* *5700K (5665±270)* *6500K (6432±340)*
Chromaticity tolerance (Du’v’)	*N/A*	*Follow ANSIC 78.377, excluding flexible CCT* *0.000 ± 0.006* *0.000 ± 0.006* *0.000 ± 0.006* *0.001 ± 0.006* *0.002 ± 0.006* *0.002 ± 0.006* *0.003 ± 0.006*	*Follow ANSIC 78.377, excluding flexible CCT* *0.000 ± 0.006* *0.000 ± 0.006* *0.000 ± 0.006* *0.001 ± 0.006* *0.002 ± 0.006* *0.002 ± 0.006* *0.003 ± 0.006*	*followANSIC78.377-2011* *Table6A,for4-stepquadrangleexcludingflexibleCCT* *0.0006±0.0033* *-0.0008±0.0033* *-0.0002±0.0033* *0.0016±0.0033* *0.0033±0.0033* *0.0024±0.0033* *0.0071±0.0033*
Colour spatial uniformity	*N/A*	*The variation of chromaticity across the beam and field angles shall be within 0.007 from the weighted average point on the CIE 1976 (u'v') diagram*	*The variation of chromaticity across the beam and field angles shall be within 0.007 from the weighted average point on the CIE 1976 (u'v') diagram*	*The variation of chromaticity across the beam and field angles shall be within 0.004 from the weighted average point on the CIE 1976 (u'v') diagram*
Colour Maintenance **(Δ u',v' at 6,000h)**	*N/A*	*< 0.007*	*< 0.007*	*< 0.004*
Luminous intensity distribution 0-180°	*N/A*	*Must be provided by manufacturer and 50% of flux shall be in declared beam angle*	*Must be provided by manufacturer and 50% of flux shall be in declared beam angle*	*Must be provided by manufacturer and 50% of flux shall be in declared beam angle*
CRI	*N/A*	*≥ 80*	*≥ 80, R9> 0*	*≥ 80, R9> 0*
Lag start time	*N/A*	*< 0.5 sec until continuous light output*	*< 0.5 sec until continuous light output*	*< 0.5 sec until continuous light output*
Lumen Maintenance (Minimum time to L_{70})	*At 5,000h, Lumen Maintenance* *> 70% of initial*	*At 15,000h, Lumen Maintenance* *> 70% of initial*	*At 15,000h, Lumen Maintenance* *>70% of initial*	*At 25,000h, Lumen Maintenance* *>70% of initial*
Minimum Rated Lamp lifetime (B50)	*At 5,000h, 50% of population will be operative.*	*At 15,000h, 50% of population will be operative.*	*At 15,000h, 50% of population will be operative.*	*At 25,000h, 50% of population will be operative.*

Tier	Tier0	Tier1	Tier2	Tier3
Flicker (Flicker index)	*At full power (no dimming), percent flicker (calculated as (max-min)/(max+min) luminous flux) ≤10%*	*At full power flicker index ‡ ≤ 0.3*	*At full power flicker index ‡ ≤ 0.3*	*At full power flicker index ‡ ≤ 0.3*
Glare Luminance (cd/m²)	*N/A*	*Above 60 degrees, no more than 10,000 candela/m^2*	*Above 60 degrees, no more than 10,000 candela/m^2*	*Above 60 degrees, no more than 10,000 candela/m^2*
Minimum power factor	*Current Crest Factor (calculates as Ipeak/Irms) ≤ 3*	*≤5W: no requirement;* *>5W, PF>0.50*	*≤5W: no requirement;* *>5W, PF>0.50*	*≤5W: no requirement;* *>5W, PF>0.50*
Harmonic distortion	*N/A*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*	*EAC7.3 A/B* *FCCCFR47 Section15 and 18*
Dimmer compatibility	*N/A*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*	*Lamps may be dimmable or non-dimmable. Product packaging shall clearly indicate whether the lamp is dimmable or not dimmable. If a product is declared as dimmable, manufacturer shall also declare the conditions under which a lamp will operate as declared, and shall provide a web address for a website that lists dimmer makes and models with which the lamp is compatible. For each compatible dimmer, the manufacturer must also list the minimum and maximum number of lamps that can be satisfactorily dimmed with a given dimmer and the minimum relative luminous flux level a given dimmer-lamp combination can achieve.*
Photobiological hazard class (UV & blue light)	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*	*RG0 orRG1 at 200mm*
Safety marking	*Must meet regional requirements for marking, if they exist, for non-grid connected devices*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*	*Must meet regional requirements (ANSI/UL1993or CE Mark)*
Warranty Duration	*Minimum 1 year warranty against catastrophic failure unless regional requirement is higher*	*Minimum 1 year warranty against catastrophic failure unless regional requirement is higher*	*Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.*	*Minimum warranty of at least 1 year for every 15,000 hours of rated lifespan unless the national or regional requirement or business practice is different.*
RoHS Compliant	*Yes*	*Yes*	*Yes*	*Yes*

Tier	Tier0	Tier1	Tier2	Tier3
Recyclability (%)	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*	*Yes, following the principles of self-declaration found in ISO14021*
Endurance Test	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*	*Using section 10.2 of IEC62612 (on/off for 30 seconds each), product must survive one cycle for every hour of rated life.*

Appendix C

Possible Test conditions and methods - LED lamps for general service lighting

The following table sets out possible tests that could be included in an Australian and New Zealand LED performance test standard. The table reviews the published CIE S 025/E: 2015: Test Method for LED Lamps, LED Luminaires and LED Modules for the specific test methods required for each of the parameters and, where no such test method is provided in CIE - 025, a recommendation from the international standards bodies (IEC, CIE) or a national regulatory authority (USA Energy Star) is provided. Where a relevant test method is available in AS/NZS4847: Self-ballasted lamps for general lighting services Part 1: Test methods – Energy performance this is also noted.

Test conditions	**CIE S 025**	**AS/NZS4847**	**Test method details to be included in AU/NZ LED MEPS(including criteria from other entities)**
Air movement and temperature	Satisfactorily covered		CIE S 025
Electrical conditions	Satisfactorily covered		CIE S 025
Measurement instruments (photometry & general electrical)	Satisfactorily covered		CIE S 025
Operating position of lamp	States as per designed operating condition	Cap up unless specified otherwise	Consider Energy Star: equal no of lamps in each of 3 orientation axes, or as specified by manufacturer.
Lamp Mounting	Satisfactorily covered		CIE S 025
Lamp Operating Conditions	Satisfactorily covered for ambient temperature. Matters partially addressed: • Dimmable, • Internal thermal feedback, • Adjustable colour, • Adjustable white, • multicolour		CIE S 025 and Dimmable: Maximum and other specified relative levels. Internal thermal feedback Adjustable white (CCT): need to specify settings Adjustable colour: At standard CCTs
Lamp aging	In accordance with LED product performance standard	100 hrs. (2.75 ON 0.25 OFF) Aging environment: T_a 25±1°C, RH≤65%	IEA 4E SSL IC2013 protocol suggested a Preconditioning of 24hrs (US DOE rule making: 1000 hrs.)

Test conditions	**CIE S 025**	**AS/NZS4847**	**Test method details to be included in AU/NZ LED MEPS(including criteria from other entities)**
Lamp stabilisation	Measurements of light output and electrical power at minimum intervals of 1 minute. No criteria for stabilised operation provided	After 15 min of operation the light output variation from the minimum reading is less than 1%	CIE S025 test method: “changes of total luminous flux (for integrating sphere) or luminous intensity in a fixed direction (for a goniophotometer setup) and electrical power are less than 0.5 % over a 30 minute window by monitoring the signal every minute” IEC 62612: luminous intensity in a fixed direction is less than 0.5 % and electrical power is less than 1.0 % are over a 15 minute window when monitoring the signal every minute
Initial total luminous flux	Satisfactorily covered for spheres and goniophotometers (except for measurement angles as discussed for “intensity distribution” below)		CIE S 025
Maintained luminous flux	Not covered	Section D5: Measurements at 100, 2000, 5000, 0.4xrated life	Consider referencing IEC 62612 or IESNA LM80/TM21
Centre beam and beam angles	References IEC61341:2012		CIE S 025 / IEC61341:2012
Intensity distribution	Covers test distance for far-field photometry but no requirements for measurement angles (i.e.ΔC &$\Delta\gamma$)	Section D3.3.1 for measurement angles and planes ($\Delta C \leq 10°$&$\Delta\gamma \leq 10°$)	Will need to specify measurement planes and angular step (i.e. ΔC &$\Delta\gamma$) for omni-directional & various beam angle directional lamps
Partial luminous flux (Useful lumens)	Equation and general measurement procedure provided (no definition of the useful lumen solid angle)	Not covered	If deemed a requirement: Need to define the solid angle for useful lumens.
Omni-directional assessment	Not covered	Not covered	Energy Star has test method & criteria (used in IEA performance Tiers) which are under review.
Initial colour measurements	Satisfactorily covered for chromaticity co-ordinates, CCT, CRI, angular chromaticity uniformity		CIE S 025

Test conditions	**CIE S 025**	**AS/NZS4847**	**Test method details to be included in AU/NZ LED MEPS(including criteria from other entities)**
Maintained colour measurements	Not covered	Not covered	Consider using particular subset of time intervals used for maintained luminous flux measurement above. Need to determine which parameters to measure (chromaticity co-ordinates, CCT, CRI, angular chromaticity uniformity)
Harmonics & EMC	Not covered	Section 4.13: references AS/NZS 61000.3.2:2007, AS/NZS CIPSR 15, IEC 61547	Same as methods referenced in AS/NZS4847
Start time	Not required	Covered but may not be applicable to LED	Not required?
Switch withstand	Not covered	Section F: 30s ON, 270s OFF for No. of cycles = 2 x life hrs.	IEC 62612: 30s ON, 30s OFF for No. of cycles = 1/2 x life hrs.
Lamp Life - endurance	Not covered	ON/OFF cycle same as aging. Time to 50% of lamps failing (defined as failing to light or delivers <50% light output)	IEC 62612: combination of switch withstand and lumen maintenance Consider: (Early failures + predicted failures) & (lumen maintenance + predicted maintenance) To be further considered following IEA 4ESSL review of LED lifetime metrics and testing.
Temperature cycling shock	Not covered	Not covered	IEC PAS 62612: non-energised lamp 5 x 1 hr. cycles of -10°C then +50°C
Endurance	Not covered	Not covered	Consider: IEC PAS 62612: operation for 25% of life (max 6000hrs) at =45°C Lites.asia Tropical performance criteria
Photo biological (Blue light & UV)	Not covered	Not covered	Reference: CIE S009/IEC62471
Flicker	Not covered	Not covered	Consider Energy Star test method
Dimmer compatibility	Not covered	Not covered	Consider basic test method such as NEMA SSL7a

Appendix D

E3 2015 Commercial Lighting Stock Model -Data Sources and Assumptions

The Australian Commercial Lighting Stock Model builds on the lighting model that was developed for the Australian Residential Lighting Overview Report (December 2014). The model is designed to capture the Australian lighting market for general lighting, including commercial and residential components for the sales calculations, but does not include figures for industrial lighting due to a lack of data related to industrial spaces. It also does not include outdoor lighting.

In constructing the market model, several simplifying assumptions were necessary to manage the analytical complexity and dearth of factual data for explaining the Australian lighting market. Assumptions were guided by estimates given by industry experts, technical reports released by the Australian Government and international lighting market modelling, as well as lamp import data (which does not provide specificity between linear fluorescent or compact fluorescent lamp types, and does not include any information at all regarding LED lighting imports). Due to the high level of uncertainty and lack of data in the areas listed below, no attempt is made to quantify the magnitude of the effects.

A number of data sources and reports were referenced for building the Australian commercial stock model; these are listed below with a statement as to how they were adopted for use.

Data Sources

McKinsey Reports 1st, 2nd Editions (2011, 2012)

The commercial lighting stock model follows an internationally derived model developed by McKinsey & Company for the 2011 and 2012 “Lighting the way” report, which was put together to provide an overview of the global lighting market. Although Australia was not specifically one of the countries investigated, the McKinsey report looked at Europe, North America, Asia (including China), Latin America, the Middle East & Africa; taking into consideration the world’s ongoing financial turbulence, impacts of the European debt crisis on global and regional economic growth, and also how rising energy demand and costs and increasingly stringent lighting regulations around the world have fuelled the penetration of more energy efficient lighting sources. Aggressive price erosion of LED lighting products is also cited as a vital instigator of change to the long-term forecasts of the lighting market. The study provides market projections to 2020 for installed fixtures, annual new installations and lamp/module replacements.

McKinsey assesses the lighting market in terms of a range of lighting technologies and groupings in various situational applications in the following way:

Technology mix between:

- Incandescent
- Halogen
- HID
- LFL
- CFL
- LED lamp - group: LED
- LED module

Groupings in 7 lighting applications:

- residential
- office
- shop - group: commercial
- hospitality
- industrial - outside data availability
- outdoor - outside scope
- architectural - small market (negligible)

Application of this model into the Australian context saw some category groupings; LED lamp (retrofit) and LED module are grouped simply as ‘LED’; for lighting applications, office, shop and hospitality was grouped into a category ‘commercial’.

Estimates of LED market share (from McKinsey) were established following a global lighting survey of lighting professionals and consumers in June 2011. Questions in this survey targeted 1) levels of price acceptance in order to estimate LED market share, and projections were calculated using responses and the future lighting product price trend by technology. The survey also addressed 2) levels of payback time acceptance, by calculating lamp technology payback time trends against the traditional technology by application based on different countries' current electricity prices. 3) Major technology barriers were surveyed with inclusion of a timeline by which the barrier was expected to disappear. 4) Lighting professionals with high levels of expertise were asked to provide general estimations of LED market share by application, with adjustments applied for country-specific positive/negative bias.

Building Code of Australia's (BCA) National Construction Code (NCC)

Section J6 Artificial Lighting and Power
The NCC outlines maximum power density limits for all building categories in Australia.

In this stock model, the impacts of limiting allowable power consumption in commercial spaces are given as a boundary condition.

Residential Lighting Australasian Model Project (ReLAMP)

(www.energyrating.gov.au/products-themes/lighting/lighting-and-phase-out-general-information/lighting-data/)

- Includes LED
- Data to 2012
- For residential market only
- No projections for commercial lighting

Australian Bureau of Statistics import data to 2013

This includes import data of lighting products, as grouped into specific categories. This applies to all market applications whether they are used for residential, commercial, or other purposes.

- MV incandescent
- MV halogen
- ELV halogen
- CFL (a combination of CFLi and CFLn numbers)
- linear fluorescent lamps <=600mm
- linear fluorescent lamps =1200mm
- linear fluorescent lamps, other than <=600mm, 1200mm
- HID

Report: Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia, November 2012 (DoI)

(www.industry.gov.au/Energy/EnergyEfficiency/Non-residentialBuildings/Documents/CBBS-Part-1.pdf)

Provides data and projections of non-residential, non-industrial building stock in Australia 1999-2020, in the form of floor area in '000m^2.

- Stand-alone offices
- Hotels
- Retail
- Hospitals
- Schools, universities
- VET buildings
- Public buildings
- Law courts

This stock model used 2009 as the 'base' year.

2010 E3 Residential Lighting Report

The report provides insight into the average number of lamps used within residential homes, with these broken down into technology types with performance levels given for power consumption and lumen output. Combining this information with data on the total number of residential properties in Australia enables an estimation of the total number of lamp types being used in Australian homes.

Photometric Test Data 2009-2014.

Sourced from

- Australian Government Department of Industry and Science
- Energy Efficiency and Conservation Authority, New Zealand Government
- Technical University of Denmark (DTU)
- Commercially Available LED Product Evaluation and Reporting (CALiPER), US Department of Energy
- Energy Star, United States and Canada
- Lighting Facts, US Department of Energy

Light Naturally Market Research 2009-2015.

Research into characteristics of LED products sold in local and international markets.

Definition of general lighting applications

Residential

Includes permanently installed fixtures and portable plug-in fixtures. Permanent fixtures are purchased by home builders via wholesale purchase and manufacturers' representatives. Portable fixtures are purchased by the home owner in retail stores and include pendants, table and floor lamps.

Offices & Public Buildings

Comprises lighting for office buildings, healthcare institutions, educational buildings, and other buildings that are utilized for public or commercial purposes. This includes meeting rooms, work spaces, receptions, hallways, staircases, basements.

Hospitality & Retail

The retail component of this category consists of display lighting, decoration as well as general shop floor area lighting. Types and levels of lighting will vary depending on the specifics of products being sold – ranging from jewelry, clothing, cosmetics, groceries. Hospitality includes general lighting for hotels, bars and restaurants and decorative lighting that spans an entire spectrum from mood lighting to orientation lighting.

Lamp attributes

Lamp efficacy (lm/W, product average)

Values of lamp efficacy were based on market research, E3 registration data and results from lamp benchmark testing conducted by the Australian Government between the years 2009 and 2014.The model uses average values that are predicted to be installed in commercial properties, rather than those representing 'best available technology' (BAT).

For LED products, where there is no Australian/New Zealand MEPS in place, two alternative stock models have been produced: the first provides a projection of average LED lamp efficacies increasing at a rate of approximately 5 lumens per Watt per year, which is happening in the market as a result of improvements in the technology (no government intervention); the second is an hypothetical model which predicts possible additional changes with the introduction of an LED performance MEPS level of a minimum 45 lumens per watt, beginning in 2016. Possible outcomes of this introduction were played out using benchmarking test data (Table 21). The data shows that there would be an 11 lm/W improvement in the average performance of LED lamps being sold in the Australian and New Zealand markets with the introduction of the suggested MEPS.

Table 21. Tested LED lamp average efficacy in Australia and New Zealand 2009-2014 and the effect on these averages if a MEPS of 45 lm/W were introduced.

Year of lamp purchase	LED average luminous efficacy (lm/W)		Difference in average lm/W
	AU/NZ test results	AU/NZ test results, where lamps minimum ≥ 45 lm/W	
2009	31	50.1	19.0
2010	39	52.7	13.8
2011	47	56.5	9.9
2012	42	55.3	13.5
2013	70	70.3	0.0
2014	64	74.7	10.4
Average yearly change (lm/W)	(6.6)	(4.9)	(11.1)

Predicted increase in the average efficacy (lm/W) due to introduction of MEPS is promulgated through the stock model by implementing a 4 year changeover – this is the average lifetime of linear fluorescent (5 years) and compact fluorescent (3 years) lamps, as these lamp technologies would be the types that LED products would be replacing in the commercial context. Therefore, over each of the four years, the average efficacy of LED lamps would increase by an additional 2.8 lm/W, bringing the increase in LED efficacy up to 7.8 lm/W per year for the four years following a 2016 MEPS introduction date.

Lamp power (total circuit watts per lamp, product average)

Calculated on property lamp lumens remaining static, while efficacy improves

Lamp lifetime (hours/years, product average)

From market reports, McKinsey predictions

Current CFL MEPS requires a minimum lifetime of 6,000 hours. With typical yearly use in a residential setting of approximately 1,000 hours per year, this results in a 6 year refit cycle. Linear fluorescent MEPS requires a minimum lifetime of 20,000 hours, although most products are operating at 24,000 hours life. Typical usage in a commercial setting is 4,000 hours per year, which also results in an approximate 6 year refitting cycle.

Lamp operating hours per day

Based on values in Table 22. These were applied across 365 days per year.

Table 22. Average lamp operating hours per day

Building Category	Operating time (hours)
Offices	11.0
Hospitals	24.0
Education	12.0
Public Buildings	11.0
Hospitality	9.0
Retail	12.0

The underlying assumptions on average luminaire lifetimes are summarised in Table 23

Table 23. Average luminaire lifetimes 2010-2020 (McKinsey & Co)

Building Category	Luminaire lifetime (years)
Offices (including hospitals, education and public buildings)	12
Hospitality	8
Retail	7

Commercial property attributes

Total floor area (m^2)

CBBS Part 1: Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia (BIS Shrapnel, Nov 2012)

The model created for this report created a primary metric of floor space measured in thousands of square metres ('000m^2). The report separates non-residential buildings into categories that are based on selected classifications from the Australian Bureau of Statistics functional classifications of buildings. For this study, these were further summarized into the groups found below so that they would match alternative categories provided by other data sources applied in the stock model.

Offices
Incl. Stand-alone offices
  Hospitals
  Education buildings
  Public buildings
  Law Courts

Hospitality

Retail
Incl. Shopping Centres

Average power density (W/m^2)

Building Code of Australia's (BCA) National Construction Code (NCC)

The maximum power density limits outlined in Section J6 of the NCC are a fundamental input for the stock model. These limits have been applied to the total floor area of commercial properties in Australia to allow a reasonable prediction of the total power that will be used for lighting in these properties.

Section J of the NCC was introduced in 2005, prior to this date there were no limits in place. Since its introduction there has been one major update in 2011(Table 24) to the allowable limits in commercial spaces.

Table 24. BCA National Construction Code lighting power density limits (W/m^2)

BCA NCC Lighting power density limits	2005	2011
Offices	10	9
Hospitals	15	10
Education	10	8
Public Buildings	10	10
Hospitality	10	9
Retail	25	22

These changes to the building code are not immediately discernable in the overall market as the code is required to be applied only to 'new-build', renovation and renewed property fit-outs; therefore a factor was introduced to account for the delay in NCC compliance that is intended to be reflective of the 7-12 year commercial property fit-out cycle. Statistics from the Australian Government's commercial building disclosure (www.cbd.gov.au/overview-of-the-program/statistics) indicated that as at 2013, the average nominal lighting power density in commercial office spaces is 12.97 W/m². This means that in practical terms, there is a multiplying factor of approximately 1.4, which provides the bridge between changes to the NCC and reflection of these changes in the real world.

Lumen density (lm/m²)

Although it is predicted that the number of lamps per square meter in commercial spaces is going to increase over time, this does not necessarily result in an overall increase in average light levels provided in these spaces. Rather, we are likely to see lumen levels remain static, while improvements in lamp efficacies will drive the wattages (required to produce this same number of lumens) downward.

Technology mix for commercial property categories

Projections to 2020 for the relative mix of lighting technologies used in commercial spaces were based on predictions in the 2011/2012 reports by McKinsey &Co. Further projection to 2030 conducted through data analysis of the McKinsey trends.

Total Greenhouse Gas Emissions

The conversion ratio of energy use to total greenhouse gas emissions in Australia was obtained from the National Greenhouse accounts factors webpage 2015, each Australian state was given a weighting based on overall energy use to determine a weighted Australian average emission factor.

E3
Equipment Energy
Efficiency