Task 1. International Directional Lamp Regulatory Review


A report prepared by: Navigant Consulting Europe, Ltd.

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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ANSLG</td>
<td>American National Standards Lighting Group</td>
</tr>
<tr>
<td>AS</td>
<td>Australian Standard</td>
</tr>
<tr>
<td>BPAR</td>
<td>Blown Parabolic Aluminised Reflector</td>
</tr>
<tr>
<td>BR</td>
<td>Bulge Reflector</td>
</tr>
<tr>
<td>CCT</td>
<td>Correlated Colour Temperature</td>
</tr>
<tr>
<td>CELMA</td>
<td>Federation of national manufacturers associations for luminaires and electrotechnical components for luminaires in the European Union</td>
</tr>
<tr>
<td>CFL</td>
<td>Compact Fluorescent Lamp</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations (US)</td>
</tr>
<tr>
<td>CIE</td>
<td>International Commission on Illumination</td>
</tr>
<tr>
<td>CQS</td>
<td>Colour Quality Scale</td>
</tr>
<tr>
<td>CRI</td>
<td>Colour Rendering Index</td>
</tr>
<tr>
<td>CSA</td>
<td>Canadian Standards Association</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>Defra</td>
<td>Department for Environment, Food and Rural Affairs</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of Energy (US)</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EISA</td>
<td>Energy Independence and Security Act (US, 2007)</td>
</tr>
<tr>
<td>ELC</td>
<td>European Lamp Companies Federation</td>
</tr>
<tr>
<td>ELV</td>
<td>Extra Low Voltage</td>
</tr>
<tr>
<td>ER</td>
<td>Ellipsoidal Reflector</td>
</tr>
<tr>
<td>FR</td>
<td>Federal Register (US)</td>
</tr>
<tr>
<td>HID</td>
<td>High Intensity Discharge</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IES / IESNA</td>
<td>Illumination Engineering Society (of North America)</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
</tr>
<tr>
<td>ITA</td>
<td>Industrial Technical Agreement</td>
</tr>
<tr>
<td>L</td>
<td>Lumens</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>LM</td>
<td>Lighting test method (IESNA)</td>
</tr>
<tr>
<td>lm/W</td>
<td>Lumens per watt</td>
</tr>
<tr>
<td>LSD</td>
<td>Lighting Standards Division (NEMA)</td>
</tr>
<tr>
<td>MEPS</td>
<td>Minimum Energy Performance Standards</td>
</tr>
<tr>
<td>MR</td>
<td>Multifaceted Reflector</td>
</tr>
<tr>
<td>MTP</td>
<td>Market Transformation Programme</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Electrical Manufacturers Association</td>
</tr>
<tr>
<td>NRCan</td>
<td>Natural Resources Canada</td>
</tr>
<tr>
<td>NZS</td>
<td>New Zealand Standard</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Meaning</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td>PAR</td>
<td>Parabolic Aluminised Reflector</td>
</tr>
<tr>
<td>PAS</td>
<td>Publicly Available Specification (IEC)</td>
</tr>
<tr>
<td>R</td>
<td>Reflector</td>
</tr>
<tr>
<td>RP</td>
<td>Recommended Practice (IESNA)</td>
</tr>
<tr>
<td>SSL</td>
<td>Solid State Lighting</td>
</tr>
<tr>
<td>THD</td>
<td>Total Harmonic Distortion</td>
</tr>
<tr>
<td>TM</td>
<td>Technical Memorandum (IESNA)</td>
</tr>
<tr>
<td>TR</td>
<td>Technical Reports (IEC)</td>
</tr>
<tr>
<td>TS</td>
<td>Technical Specifications (IEC)</td>
</tr>
<tr>
<td>TTA</td>
<td>Technology Trend Assessment (IEC)</td>
</tr>
<tr>
<td>UL</td>
<td>Underwriters Laboratories</td>
</tr>
<tr>
<td>US / USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>V</td>
<td>Volts</td>
</tr>
<tr>
<td>W</td>
<td>Watts</td>
</tr>
</tbody>
</table>
1 Introduction

1.1 Context

Starting in 2006, the European Commission (EC) initiated a study of domestic lighting products, called “Lot 19: Domestic Lighting; Preparatory Studies for Eco-design Requirements of EuPs.” The purpose of the Lot 19 study is to provide information on eco-design requirements that could be established for domestic lighting products in order to improve their environmental performance, within the framework of Directive 2005/32/EC. Soon after initiating the Lot 19 study, the EC made a policy decision to accelerate the analysis of non-directional, general service domestic lamps, which resulted in Lot 19 being split into two parts: part 1 on non-directional household lamps and part 2 on directional lamps and household luminaires.

In October 2008, part 1 of the Preparatory Study was finalised, and in March 2009, the Commission adopted Regulation 244/2009. This regulation established new energy efficiency requirements for traditional, non-directional incandescent and halogen lamps, which are being gradually phased in between 1 September 2009 and 1 September 2012. The regulation is designed to eliminate incandescent and inefficient halogen technologies from the European market by the end of 2012.

In October 2009, part 2 of the Preparatory Study was finalised, and the Commission is currently working on developing a proposal regarding energy efficiency requirements for directional lamps. This report reviewing international regulatory activities associated with directional lamps was prepared in support of that activity.

1.2 Overview of this Report

This report presents a summary of the international directional lamp regulations in Australia, Canada, and the United States. This summary includes a discussion on the respective scopes of coverage, the test methods used (including any international test methods they are based upon), the minimum energy performance standards (MEPS), and scheduled phase-in of the MEPS levels. At the end of each chapter, comparisons are made between the regulatory programmes, and key differences and distinctions between the programmes are discussed.

In addition, this report identifies and discusses the test methods in place and some of the major ones under development for Light Emitting Diodes (LEDs). These test methods are identified and briefly described, however the adequacy of these test methods from a regulatory perspective (e.g., for assessing performance and potentially establishing MEPS) is beyond the scope of this assignment. Thus, this chapter of the report focuses instead on presenting a compilation of completed and active work around test methods for LEDs.

Table 1-1 presents the chapters of this report, structured around the topical areas outlined above.
### Table 1-1. Report Outline and Descriptions of the Three Substantive Chapters

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. International MEPS Review</td>
<td>Identification of each country that has MEPS for directional lamps, discuss scope, efficiency requirements, and any key issues or problems associated with that regulation. Provides a cross-cutting comparison of the MEPS for directional lamps, including any scheduled future updates to those regulations (if published).</td>
</tr>
<tr>
<td>3. Test Method for Directional Lamps</td>
<td>A summary of the various test methods used for measuring the performance of directional lamps, including a discussion on the test method, basis for that test method, and measurement accuracy. Provides an update on research initiatives underway on improving the testing of Directional Lamps.</td>
</tr>
<tr>
<td>4. LED Test Methods</td>
<td>A summary of LED Test Methods, including device quality and performance measurement. Provides context / background on the entity issuing that test method, and any known schedules for revision.</td>
</tr>
</tbody>
</table>
2 International MEPS Review

2.1 Overview

There are currently three countries that regulate directional lamps – Australia, Canada and the United States. Although there are differences in coverage between these three countries, generally the regulations for Canada and the United States are similar. Canada and the United States tend to work toward harmonised regulatory requirements in order to reduce burden on manufacturers and associated costs to consumers. In Australia, the scope of coverage is broader than Canada and the United States, and new interim regulatory standards adopted in 2008 are scheduled to be phased in starting October 2010 and then October 2012. The US also recently adopted new regulatory requirements for incandescent reflector lamps, which take effect in July 2012, and Canada is conducting an analysis to determine whether these same levels are appropriate for its market. Overall, after adjusting for voltage differences, the US and Australia have largely comparable efficacy requirements for large diameter lamps, and Australia has stronger efficacy requirements on the small diameter.

Table 2-1. Summary of MEPS for Directional Lamps Internationally

<table>
<thead>
<tr>
<th>Country</th>
<th>Minimum Energy Performance Standards</th>
<th>Adopted</th>
<th>Effective</th>
<th>Lamp Types*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>AS NZS 4934.2(Int)-2008 Incandescent lamps for general lighting services - Minimum Energy Performance Standards</td>
<td>March 2008 (Interim)</td>
<td>October 2010</td>
<td>Low-voltage halogen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>October 2012</td>
<td>Mains voltage reflector lamps</td>
</tr>
<tr>
<td>Canada</td>
<td>CSA C862-01 Performance of incandescent reflector Lamps (Table 1)</td>
<td>Nov. 1995</td>
<td>April 1996</td>
<td>Incandescent and halogen reflector lamps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>April 2003</td>
<td>Jan. 2003</td>
<td>BR lamps; ER lamps other than ER lamps with a nominal power of 50, 75 or 120 W</td>
</tr>
<tr>
<td>Canada</td>
<td>CSA C862-01 Performance of incandescent reflector Lamps (Table 2)</td>
<td>April 2003</td>
<td>Jan. 2003</td>
<td>ER lamps with a nominal power of 50, 75 or 120 W</td>
</tr>
<tr>
<td>USA</td>
<td>10 CFR 430.32(n)(4)</td>
<td>EPACT 1992</td>
<td>Nov. 1995</td>
<td>Incandescent and halogen reflector lamps</td>
</tr>
<tr>
<td>USA</td>
<td>10 CFR 430.32(n)(5)</td>
<td>July 2009</td>
<td>July 2012</td>
<td>Incandescent and halogen reflector lamps</td>
</tr>
</tbody>
</table>

* Note: at the highest level, these are the categories of lamp types covered; however within each regulatory authority, there are specific scopes of coverage which are discussed in the individual sections that follow.
2.2 Australia

Australia’s regulatory programme for directional lamps focuses on establishing MEPS for extra low-voltage (ELV) halogen reflector lamps and mains-voltage incandescent and halogen directional lamps. The following definitions for these two product groups were published in the Interim Australian/New Zealand Standard, “Incandescent lamps for general lighting services, Part 2: Minimum Energy Performance Standards (MEPS) requirements” (AS/NZS 4934.2(int):2008).

**ELV halogen reflector - these lamps have the following attributes:**
- (a) Shapes: MR 11-16.
- (b) Caps: Bi-pin.
- (c) Nominal voltage: 5–24 V (inclusive).

**Mains voltage reflector (including halogen) - these lamps have the following attributes:**
- (a) Tungsten filament or tungsten halogen lamp burner, with reflector.
- (b) Shapes: PAR, ER, R, RE, XR, YR, ZR or MR 11-16.
- (c) Caps: E14, E26, E27, B15, B22d or GU10.
- (d) Nominal voltage >220 V.
- (e) Not including primary coloured lamps.

The Australian scope of coverage for directional lamps is more expansive than that of Canada and the United States. The Australian regulation encompasses all the common base-types found both on low-voltage and line-voltage reflector lamps. Standard line voltage in Australia is 240-250V, therefore having the nominal voltage listed as simply greater than 220V will include vast majority of the market. Furthermore, the scope includes a wide variety of lamp shapes, and is not constrained by lamp diameter or by wattage range.

In terms of constraints, the Australian scope of coverage applies to incandescent and halogen lamps, and does not include reflector lamps that are based on compact fluorescent, metal halide or light emitting diode technologies. It is, however, unclear whether these products may be covered under separate regulations or constitute products that the Australian government is intending to cover in the future.

The current Australian MEPS are based on a single equation that is phased in to the covered product in two stages. Although they may be revised in the interim, the MEPS are scheduled to become mandatory for all ELV halogen reflector lamps beginning in October 2010 and for all mains voltage reflector lamps beginning in October 2012. The minimum efficacy requirement for these reflector lamps is a function of the natural log of the lumen output of the lamp:

\[ \text{Initial efficacy shall be} \geq 2.8 \ln(L) - 4.0 \]

Where:

\[ L = \text{Initial luminous flux of the lamp in lumens} \]

Due to the fact that there is no minimum or maximum nominal lamp wattage, this MEPS level is broadly applicable to reflector lamps sold in Australia. Figure 2-1 plots the Australian regulation, along with the United States’ EPACT 1992 levels for scale. It should be noted that the EPACT 1992 levels were never applicable in Australia, however they represent a
halogen technology level that was required in the United States for certain reflector lamps since 1995 and in Canada since 1996. The EPACT 1992 levels are presented in wattage versus efficacy, and thus have been converted to lumen versus efficacy for this figure. Furthermore, the EPACT 1992 levels were established for 120V wattage lamps, and thus have been adjusted to what levels they would have been (i.e., lower) on a 240V system.

![Figure 2-1. Australian MEPS Compared with Voltage Adjusted EPACT 1992 (240V)](image)

In addition to the efficacy requirement plotted above, the Australian government is also considering the possibility of establishing a maximum wattage limit on MR-16 lamps. The reason for this is to avoid the development of a new group of 50W MR-16 lamps that would take the efficacy requirements and produce more light rather than hold light output constant and lower the wattage. In other words, today's market in Australia includes two types of MR-16 lamp which have approximately equivalent levels of light output – a low efficacy 50W (which represents >95% of sales) and a high efficacy 35W (which has <5% of sales). Consumers can purchase and install lamp as both operate on existing magnetic and electronic control gear. The Australian government is concerned that if the new regulation becomes applicable without a wattage cap, the market may respond by introducing a brighter (i.e., higher lumen flux), more efficacious 50W MR-16 lamp that is compliant with the new MEPS but will not save consumers any energy. By combining an efficacy requirement with the maximum wattage limit for this popular lamp, Australia would ensure the 30% energy savings potential from this technology will benefit consumers in their market. For more detail on this issue, see Annex A.

It should be noted that the Australian regulation also has a minimum median lamp life of 2000 hours and lumen maintenance period of at least 80% of initial lumen output after 75% of rated life. This calculation of lumen maintenance excludes any lamps in the sample that fail prior to the 75% of rated life test.

### 2.3 Canada

In Canada, Natural Resources Canada (NRCan)'s Office of Energy Efficiency establishes regulatory requirements of consumer products and commercial equipment, including incandescent reflector lamps (i.e., directional lamps). In November 1995, Canada updated its Energy Efficiency Regulations (SOR/94-651) to include incandescent reflector lamps, adopting a standard level harmonised with the United States EPACT 1992, and which
became effective in April 1996. Canada then issued Amendment 6 to establish minimum energy performance standards for certain products, including incandescent reflector lamps. Amendment 6 was registered on April 10, 2003 and published in the Canada Gazette Part II on April 23rd. This Amendment, which covered and regulated certain bulge reflector (BR) and ellipsoidal reflector (ER) shaped reflector lamps, started on January 1, 2003. Canada is actively working on revisions to its regulations on incandescent reflector lamps (i.e., Bulletin stating NRCan’s intentions is expected in May 2010), which will raise the efficacy requirements and increase its scope of coverage for BR and ER shaped lamps.

Canadian MEPS for reflector lamps apply to three lamp categories: (1) general service incandescent reflector lamps; (2) BR lamps and (3) ER lamps. Although they are expected to change in the near future, the current regulatory definitions for each of these terms follow below:

"general service incandescent reflector lamp" means an incandescent reflector lamp\(^2\)
(a) with an R bulb shape, a PAR bulb shape or a bulb shape similar to R or PAR that is neither ER nor BR, as described in ANSI C79.1,
(b) with an E26/24 single contact or E26/50 × 89 skirted, medium screw base,
(c) with a nominal voltage or voltage range that lies at least partially between 100 volts and 130 volts,
(d) with a diameter greater than 70 mm (2.75 inches), and
(e) that has a nominal power of not less than 40W and not more than 205W, but does not include
(f) a coloured incandescent reflector lamp, or
(g) an incandescent reflector lamp that
(i) is of the rough or vibration service type with
(A) a C-11 filament, as described in the IES Handbook, with five supports exclusive of lead wires,
(B) a C-17 filament, as described in the IES Handbook, with eight supports exclusive of lead wires, or
(C) a C-22 filament, as described in the IES Handbook, with 16 supports exclusive of lead wires,
(ii) is of the neodymium oxide type and has a lens containing not less than 5% neodymium oxide,
(iii) has a coating or other containment system to retain glass fragments if the lamp is shattered, and is specifically marked and marketed as an impact resistant lamp,
(iv) is specifically marked and marketed for plant growth use and
(A) has a spectral power distribution that is different from that of the lamps described in paragraphs (a) to (e), and
(B) contains a filter that suppresses yellow and green portions of the spectrum, or
(v) is specifically marked and marketed
(A) as an infrared heat lamp,
(B) for heat-sensitive use,
(C) for mine use,
(D) for marine, aquarium, terrarium or vivarium use, or
(E) for airfield, aircraft or automotive use.

"BR lamp" means an incandescent reflector lamp as described in ANSI C79.1, but does not include any of those lamps that have: (a) a diameter of 95.25 mm (BR30) and

\(^2\) The Canadian regulations also define the term "incandescent reflector lamp" as a lamp in which light is (a) produced by a filament heated to incandescence by an electric current, and (b) directed by an inner reflective coating on the outer bulb.
a nominal power of less than 66 W, (b) a diameter of 92.5 mm (BR30) and a nominal power of 85 W, or (c) a diameter of not less than 120.65 mm (BR38) but not more than 127 mm (BR40) and a nominal power of less than 121 W.

"ER lamp" means an incandescent reflector lamp as described in ANSI C79.1.

The pending revisions will address issues such as the diameter (d) in the definition of a general service incandescent reflector lamp. This will be reduced from 2.75 inches to 2.25 inches, to bring it into alignment with the US regulation promulgated by the Energy Independence and Security Act of 2007 (EISA 2007). In addition, the exemption for BR lamps will be narrowed to only include (a) BR30 (95mm) and BR40 (127mm) of 50 watts or less and (b) BR30 and BR40 of 65 watts.

Given these definitions, there are certain reflector lamps that are not included in the Canadian regulations, such as:

- Reflector lamps with base types other than E26 medium screw base, such as common MR-11 and MR-16 base types including 2-Pin GU5.3; GU10, GX5.3 and G4, as well as candelabra and other screw base types smaller than E26.
- MR-16 lamps are a popular directional lamp in the Canadian market, and yet the reflector has a 2-inch diameter, meaning it is not included in the scope of coverage for Canada’s MEPS.
- Compact fluorescent reflector lamps, ceramic metal halide reflector lamps or LED reflector lamps that may be used as replacements for certain halogen directional lamps because the definition of incandescent reflector lamp only applies to heated-filament lamps.
- Certain BR and ER lamps, which exclude the popular 65 watt rated model.

As discussed above, NRCan is in the process of updating its regulatory requirements in to eliminate the separate set of less stringent efficacy requirements for certain ER lamps, and is proposing to adopt one table of efficacy requirements that applies to all covered reflector lamps (see Table 2-2) with a retroactive effective date proposed of June 1, 2009.

<table>
<thead>
<tr>
<th>Nominal Lamp Wattage</th>
<th>Minimum average lamp efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-50</td>
<td>10.5</td>
</tr>
<tr>
<td>51-59</td>
<td>11.0</td>
</tr>
<tr>
<td>60-85</td>
<td>12.5</td>
</tr>
<tr>
<td>86-115</td>
<td>14.0</td>
</tr>
<tr>
<td>116-155</td>
<td>14.5</td>
</tr>
<tr>
<td>156-205</td>
<td>15.0</td>
</tr>
</tbody>
</table>

*Note that this regulation will not apply to BR30 (95mm) and BR40 (127mm) lamps of 50 watts or less and BR30 and BR40 lamps of 65 watts which are excluded by definition.

Although Table 2-2 may look similar to the United States’ EPACT 1992 regulatory level, NRCan has modified two of the nominal lamp wattage ranges to slightly increase the efficacy requirement for one group. Table 2-3 below depicts this change in the second and third product classes. The second and third wattage product classes have been modified to shift lamps with wattages ranging from 60 through 66 watts so they are held to a more stringent efficacy requirement (12.5 lm/W rather than 11.0 lm/W).
Table 2-3. NRCan Modification to Average Lamp Efficacy MEPS

<table>
<thead>
<tr>
<th>Product Class</th>
<th>NRCan Lamp Wattage</th>
<th>US DOE Lamp Wattage</th>
<th>Minimum average lamp efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40-50</td>
<td>40-50</td>
<td>10.5</td>
</tr>
<tr>
<td>2</td>
<td>51-59</td>
<td>51-66</td>
<td>11.0</td>
</tr>
<tr>
<td>3</td>
<td>60-85</td>
<td>67-85</td>
<td>12.5</td>
</tr>
<tr>
<td>4</td>
<td>86-115</td>
<td>86-115</td>
<td>14.0</td>
</tr>
<tr>
<td>5</td>
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</tr>
<tr>
<td>6</td>
<td>156-205</td>
<td>156-205</td>
<td>15.0</td>
</tr>
</tbody>
</table>

In the anticipated regulatory update, if NRCan intends to harmonize with the US DOE’s regulatory standard for incandescent reflector lamps passed in July 2009, Table 2-4 presents the MEPS that would be proposed in Canada.

Table 2-4. NRCan Proposed MEPS for General Service Incandescent Reflector Lamps

<table>
<thead>
<tr>
<th>Rated Lamp Wattage</th>
<th>Lamp Spectrum</th>
<th>Lamp Diameter</th>
<th>Rated Voltage</th>
<th>Minimum Average Lamp Efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 – 205</td>
<td>Standard Spectrum</td>
<td>&gt; 63.5 mm (2.5 inches)</td>
<td>≥125 V</td>
<td>6.8*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;125 V</td>
<td>5.9*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 63.5 mm (2.5 inches)</td>
<td>≥125 V</td>
<td>5.7*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;125 V</td>
<td>5.0*P^{0.27}</td>
</tr>
<tr>
<td>40 – 205</td>
<td>Modified Spectrum*</td>
<td>&gt; 63.5 mm (2.5 inches)</td>
<td>≥125 V</td>
<td>5.8*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;125 V</td>
<td>5.0*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 63.5 mm (2.5 inches)</td>
<td>≥125 V</td>
<td>4.9*P^{0.27}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt;125 V</td>
<td>4.2*P^{0.27}</td>
</tr>
</tbody>
</table>

2.4 United States of America

The United States has regulated incandescent reflector lamps (US term for directional lamps) for nearly 15 years. The original efficacy requirements were established legislatively in the Energy Policy Act of 1992 (EPACT 1992), Public Law 102-486. These efficacy requirements were designed to eliminate the standard incandescent reflector (R) lamp, replacing it with a Parabolic Aluminized Reflector (PAR) halogen lamp. DOE was also required by EPACT 1992 to conduct two subsequent reviews to determine if the efficacy levels established for reflector lamps should be revised. DOE completed the first of those two revisions in July 2009, issuing higher efficacy requirements that will take effect in July 2012. The second review will start in early 2011 and is scheduled to be completed in June 2014. While DOE was conducting the first of its reviews of the EPACT 1992 regulation, Congress passed the Energy Independence and Security Act of 2007 (EISA 2007) to revise the legislative language that had previously excluded BR and ER shaped lamps from regulation. These changes to the statutory law have enabled DOE to now start analysing
efficacy regulations for these lamp types, which it will be doing in a separate standards rulemaking procedure.

According to the definition established by EPACT 1992 and amended by EISA 2007, the following is the scope of coverage for DOE’s regulatory authority for incandescent reflector lamps, blown-parabolic aluminised reflector (BPAR) lamps, bulge reflector (BR) lamps and ellipsoidal reflector (ER) lamps:

**Incandescent reflector lamp** (commonly referred to as a reflector lamp) means any lamp in which light is produced by a filament heated to incandescence by an electric current, which: is not colored or designed for rough or vibration service applications that contains an inner reflective coating on the outer bulb to direct the light; has an R, PAR, ER, BR, BPAR, or similar bulb shapes with an E26 medium screw base; has a rated voltage or voltage range that lies at least partially in the range of 115 and 130 volts; has a diameter that exceeds 2.25 inches; and has a rated wattage that is 40 watts or higher.

**BPAR incandescent reflector lamp** means a reflector lamp as shown in figure C78.21–278 on page 32 of ANSI C78.21–2003.

**BR incandescent reflector lamp** means a reflector lamp that has—

1. A bulged section below the major diameter of the bulb and above the approximate baseline of the bulb, as shown in figure 1 (RB) on page 7 of ANSI C79.1–1994, (incorporated by reference, see §430.3); and
2. A finished size and shape shown in ANSI C78.21–1989 (incorporated by reference; see §430.3), including the referenced reflective characteristics in part 7 of ANSI C78.21–1989.

BR30 means a BR incandescent reflector lamp with a diameter of 30/8ths of an inch.

BR40 means a BR incandescent reflector lamp with a diameter of 40/8ths of an inch.

**ER incandescent reflector lamp** means a reflector lamp that has—

1. An elliptical section below the major diameter of the bulb and above the approximate baseline of the bulb, as shown in figure 1 (RE) on page 7 of ANSI C79.1–1994, (incorporated by reference; see §430.3); and
2. A finished size and shape shown in ANSI C78.21–1989, (incorporated by reference; see §430.3).

ER30 means an ER incandescent reflector lamp with a diameter of 30/8ths of an inch.

ER40 means an ER incandescent reflector lamp with a diameter of 40/8ths of an inch.

The scope of coverage provided by the definitions above do not cover all reflector (i.e., directional) lamps that are sold in the US market. A few of the gaps afforded by this scope of coverage include the following:

- The definition only allows for the coverage of E26 medium screw base lamps, which does not include the common MR-11 and MR-16 base types, such as 2-Pin GU5.3; GU10, GX5.3 and G4.
• Although EISA 2007 extended coverage to small diameter reflector lamps (i.e., down from 2.75 inch diameters to 2.25 inches), the popular MR-16 directional lamp has a 2-inch diameter, and is therefore excluded from coverage.

• The definition only applies to incandescent and halogen lamps, it does not include compact fluorescent, metal halide or light emitting diodes (although metal halide may be covered and regulated by DOE in a separate rulemaking).

Although DOE covers medium screw base compact fluorescent lamps (CFL), as directed by section 135(c) of the Energy Policy Act of 2005 (EPACT 2005), the scope of coverage does not include directional (i.e., reflector) CFLs. DOE’s authority to regulate CFLs is on ‘general service’ CFLs, which (by definition) does not include reflector CFLs.

For high-intensity discharge (HID) lamps, DOE is conducting a determination analysis on whether or not to regulate HID lamps (which may include directional ceramic metal halide lamps), scheduled to be completed in June 2010. If DOE makes a positive determination on coverage and regulation of HID lamps, it is likely that this rulemaking will include directional low-wattage ceramic metal halide lamps that can be found in commercial retail applications replacing halogen reflector lamps.

For light emitting diode (LED) lamps, DOE is scheduled to conduct an energy conservation standards rulemaking on LED lamps starting in 2014 and scheduled to be completed in January 2017. The scope of this rulemaking is ‘general service LED’ lamps, and therefore is subject to the same list of non-general service exclusions that affects CFLs (see footnote 3 on previous page). Therefore, although directional LED lamps are emerging as a popular application for this light source, it is not expected to be covered and regulated in the scope of that rulemaking.

Table 2-5 provides the current minimum average efficacy requirements for incandescent reflector lamps. This table of standards was set by the Energy Policy Act of 1992 and became effective in 1995. This table will remain in effect until it is superseded by the new table of efficacy requirements promulgated by DOE in July 2009 which takes effect in July 2012 (see Table 2-6).

Table 2-5. United States Efficacy Requirements for Incandescent Reflector Lamps

<table>
<thead>
<tr>
<th>Nominal Lamp Wattage</th>
<th>Minimum average lamp efficacy (lm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-50</td>
<td>10.5</td>
</tr>
<tr>
<td>51-66</td>
<td>11.0</td>
</tr>
<tr>
<td>67-85</td>
<td>12.5</td>
</tr>
<tr>
<td>86-115</td>
<td>14.0</td>
</tr>
<tr>
<td>116-155</td>
<td>14.5</td>
</tr>
<tr>
<td>156-205</td>
<td>15.0</td>
</tr>
</tbody>
</table>

3 The statutory definition, as incorporated into the Code of Federal Regulations (10 CFR Part 430.2) states that it does not include lamps that are "(ii) Unlikely to be used in general purpose applications, such as the applications described in the definition of 'General Service Incandescent Lamp' in this section;" The definition of General Service Incandescent Lamp explicitly excludes reflector lamps because general service incandescent lamps and incandescent reflector lamps are regulated separately. Therefore, regulated CFLs in the US only include non-directional (i.e., general illumination service), and directional (reflector) CFLs are outside DOE’s scope of coverage.
Table 2-6 presents the new MEPS for incandescent reflector lamps. In this table, separate minimum average efficacy requirements are established for reflector lamps according to the spectral emission, the lamp diameter and the rated voltage of the lamp. To provide a tangible reference point, the minimum efficacy of a 100 watt incandescent reflector lamp is provided in the right-hand most column of Table 2-6.

Table 2-6. New US Efficacy Requirements for Incandescent Reflector Lamps, 2012

<table>
<thead>
<tr>
<th>Rated Lamp Wattage / Spectrum</th>
<th>Lamp Diameter (inches)</th>
<th>Rated Voltage</th>
<th>Minimum Average Efficacy (lm/W)</th>
<th>Example lm/W for 100W lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 – 205W, Standard Spectral Emission</td>
<td>&gt;2.5</td>
<td>≥125V</td>
<td>6.8*P^{0.27}</td>
<td>23.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;125V</td>
<td>5.9*P^{0.27}</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>≤2.5</td>
<td>≥125V</td>
<td>5.7*P^{0.27}</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;125V</td>
<td>5.0*P^{0.27}</td>
<td>17.3</td>
</tr>
<tr>
<td>40 – 205W, Modified Spectral Emission</td>
<td>&gt;2.5</td>
<td>≥125V</td>
<td>5.8*P^{0.27}</td>
<td>20.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;125V</td>
<td>5.0*P^{0.27}</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>≤2.5</td>
<td>≥125V</td>
<td>4.9*P^{0.27}</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;125V</td>
<td>4.2*P^{0.27}</td>
<td>14.6</td>
</tr>
</tbody>
</table>

Note 1: P is equal to the rated lamp wattage, in watts.
Note 2: Standard spectrum means any incandescent reflector lamp that does not meet the definition of modified spectrum in 430.2.

Figure 2-2 illustrates two of the incandescent reflector lamp MEPS adopted by the DOE in July 2009, compared to the Energy Policy Act of 1992 levels which became effective in 1995. The two shown are the efficacy requirements for 40-205 watt standard spectral emission lamps, less than 125 volts and having a diameter greater than 2.5 inches (“large diameter”) or less than 2.5 inches (“small diameter”). The new MEPS level will supersede the EPACT 1992 levels on the 15th July 2012. Depending on the product class, the new MEPS will require a 100W reflector lamp to increase its efficacy by between 24 and 46 percent over the EPACT 1992 regulations.
DOE has two subsequent energy conservation standard rulemakings scheduled that pertain to incandescent reflector lamps. The first will be to evaluate and potentially establish MEPS for BR and ER lamps and small diameter incandescent reflector lamps. This rulemaking has recently started and is scheduled to be completed by December 2011. The second will be a review (the second cycle) of regulations on incandescent reflector lamps in general. That rulemaking is scheduled to start in the first quarter of 2011 and be completed by June 2014.

### 2.5 Comparison of Scope of Coverage and MEPS

In this section, some of the key differences between the various regulations of Australia, Canada and the United States are discussed. In addition, a comparison of the MEPS levels is presented.

Table 2-7 presents a comparison of the scopes of coverage for the various regulatory standards in Australia, Canada and the United States. It should be noted that all three countries are actively reviewing and potentially revising their regulations. The reviews underway include issues relating to coverage as well as the efficacy requirements and schedule for when these requirements would become effective.

Although the table does not provide all the detail associated with the scopes of coverage (e.g., the treatment of BR lamps), in general terms it enables a reasonably rapid, at-a-glance comparison between the countries reviewed. As shown, the Australian scope is the broadest, in part because it encompasses the MR-16 lamp diameter and base-types.
Table 2-7. Comparison of Scopes of Coverage for Countries Studied

<table>
<thead>
<tr>
<th>Lamp Property</th>
<th>Australia</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp Shapes</td>
<td>PAR, ER, R, RE, XR, YR, ZR or MR11-16</td>
<td>R, PAR, BPAR, BR and ER</td>
<td>R, PAR, BPAR, BR and ER</td>
</tr>
<tr>
<td>&lt; 2.25 Inch Diameter</td>
<td>Yes, includes MR11 – MR16</td>
<td>Not covered</td>
<td>Not covered</td>
</tr>
<tr>
<td>Wattages</td>
<td>All wattages</td>
<td>40 – 205 Watts</td>
<td>40 Watts and higher (although only set MEPS up to 205W)</td>
</tr>
<tr>
<td>Voltages</td>
<td>5-24V and &gt;220V</td>
<td>At least partially between 100 and 130V</td>
<td>At least partially between 115 and 130V</td>
</tr>
<tr>
<td>Base Type</td>
<td>Bi-pin, E14, E26, E27, B15, B22d or GU10</td>
<td>E26 only</td>
<td>E26 only</td>
</tr>
<tr>
<td>Modified Spectrum Lamps</td>
<td>Same MEPS for standard lamps and modified spectrum</td>
<td>Anticipate will adopt US requirements</td>
<td>Same requirement, but will have lower target than new regs for standard lamps in 2012</td>
</tr>
</tbody>
</table>

Figure 2-3 provides a comparison of the MEPS levels that have been adopted by Australia, Canada and the United States. On this graph, it is important to note that the US and Canadian regulations are based on a line-voltage of 120V AC and therefore have been adjusted to be 240V. The Australian regulation is based on lamps operating at 240V AC, which matches that of Europe. The reason voltage conversion is important when plotting efficacy requirements from different countries on the same graph is because higher voltage lamps (e.g., 240V) will require the use of a thinner and longer filament for the same power rating, which will naturally have a lower efficacy than the shorter, thicker filaments used at lower voltages (e.g., 120V). For example, a 100-watt, 120V general service lamp will produce about 17 lumens per watt, while a 100-watt, 240V lamp with the same lamp life will only produce about 12.8 lumens per watt. Therefore, the efficacy requirements for the US and Canada were adjusted below to account for the different voltage of Australia (and the EU), enabling a side-by-side comparison of the efficacy requirements.
A few observations can be made about the MEPS curves for these three countries:

- The slope of all the MEPS shows a similar pattern, based on the physics of the tungsten filament. The efficacy is lower at low wattages and increases at higher wattages.
- All of the new MEPS are higher than the original EPACT 1992 levels, which represent standard halogen technology from nearly twenty years ago.
- The Australian regulation spans a wider range of wattages as it is not confined to the 40-205 watt range like the US and Canada regulations.
- The new large diameter (i.e., greater than 2.5 inches) regulation in the US that takes effect in 2012 is similar to the Australian efficacy regulation, after adjusting for differences in mains voltage.
- The new Australian regulation is also applicable to small diameter directional lamps (i.e., less than 2.5 inches), thus after adjusting for voltage, the Australian MEPS are more stringent than the US regulations for these lamp types.
- The Australian government is also considering a maximum wattage limit on MR-16 lamps in addition to the above efficacy requirement, to ensure consumers will benefit from the energy savings of the more efficacious technology. (see section 2.2 and Annex A)
3 International Test Method Review

3.1 Context
Each of the regulating entities has a test method that is used by lamp manufacturers (or third parties) for measuring the performance of directional lamps. This section discusses measurement techniques for directional lamps, and then gives an overview and comparison of the national test methods used by Australia, Canada and the United States.

Goniophotometer
The most precise way of measuring the light output of a directional lamp is through the use of a goniophotometer, pictured on the right. A goniophotometer is a device that measures the spatial distribution patterns of the intensity of a light source and displays the photometric properties of visible light to the human eye in relation to defined angular positions. Through the rotation of the light sensor (or a mirror directed to a sensor) and the rotation of the lamp under test, measurements can be gathered in all directions from an operating lamp. These measurements can then be integrated to accurately determine the light output from the lamp under test.

There are three angular systems used when conducting measurements with a goniophotometer: the A-Alpha, the B-Beta and the C-Gamma systems. The A-Alpha system is used for automobile headlights; the B-beta system is often used for floodlights and roadway lighting; and the C-Gamma system is the most commonly used system, applied to measurements of both lamps and luminaires. Conversion between these three systems is a simple matter of geometry and interpolation of data.

Focusing on the C-Gamma system, there are two variables that must be defined when taking a measurement – the number of C-planes and Gamma (γ) angles. The C-plane represents the plane in azimuth, around which the γ-angles describe points where readings are taken. The lamp is located in the centre of the C-plane and the γ-angles are measured from the optical axis (nadir).

![Figure 3-1. Illustration of C-planes and γ-angles used by a Goniophotometer](image)
A highly accurate lamp measurement may involve twelve C-planes (each 15° apart) and with measurements taken at one degree γ-angles, ranging from zero through to 360° on that plane. A more common measurement may involve four C-planes (each 45° apart), with measurements taken at every γ-angle.

With an adequate number of C-planes and γ-angles, goniophotometric measurement is considered the most accurate means of quantifying light output from a test lamp. However, it is time consuming in the setup, measurement and data analysis/reporting, which can make it expensive for manufacturers and regulating authorities when a large number of samples from a particular model must be tested for statistical robustness. For this reason, all three countries who currently regulate incandescent reflector lamps allow the use of an integrating sphere for demonstrating compliance with the law.

**Integrating Sphere**

An integrating sphere (also referred to by its proper name, an Ulbricht sphere) is large spherical tool used for measuring light output from a lamp or fixture. The integrating sphere has a hollow interior painted with white paint for high diffuse reflectivity. The integrating sphere works by uniformly scattering and diffusing light (i.e., integrating) throughout the interior of the sphere. Light emissions incident on any one point on the inner surface are distributed equally by multiple scattering reflections to all other such points inside the surface minimizing the losses associated with the original light emission. The integrating sphere is used with a light source and a detector for measuring the optical power of the lamp under test. Compared to the goniophotometer, measuring performance of a lamp in an integrating sphere is much faster (and thus, considerably less expensive).

An integrating sphere is calibrated using a reference lamp, and then measurements are made on test lamps of similar physical size and light distribution. If an integrating sphere has been calibrated using a non-directional lamp (e.g., a 100W A-19 general service lamp), it will not give reliable measurements of directional lamps, particularly narrow-beam lamps. The reason is that the integrating sphere is based on the concept of uniform luminance of the inside surface of the sphere. With a directional lamp source, this doesn’t happen inside the sphere – instead there would be a “hot-spot” where the light from the directional lamp first contacts the sphere surface and then scatters internally. Thus, the orientation of the lamp within the sphere (i.e., toward the sensor or away from it) can lead to unreliable measurements of light output. This issue is accentuated for directional lamps that have narrow beam angles.

The US and Canadian test procedures call for a measurement of lumen output from reflector lamps using either a goniophotometer or an integrating sphere that has been calibrated using a reference lamp. IESNA LM-20-1994 notes that there can be limitations when using an integrating sphere to measure the lumen output of a directional lamp and recommends calibrating the integrating sphere with a similar reference lamp and excluding the unintentional light (by use of a simulated luminaire) from measurement. However, the standard does not specify the preferred reference lamp or tolerances around the beam angle of the reference and test lamps. Furthermore, the test procedure calls for the lamps to be directed downward within the sphere, which is the location where dust collects and thus is the least reliable surface of the sphere for such measurements.
The International Commission on Illumination (CIE) publication number 84 (1989) describes the recommended test method for the measurement of luminous flux of "strongly directional lamps" whereby the test lamp is externally ported to the sphere. However, since the publication of CIE 84-1989, there have been numerous lamp shapes and sizes introduced to the market, particularly in relation to CFL and LED products that make it largely impractical to maintain cost effective laboratory equipment and accessories to facilitate a robust conformity to this test method (e.g., square and rectangular ports, rings and shims that optically seal the lamp to the test port).

The Australian Department of Climate Change and Energy Efficiency has been working on improving the accuracy of measurements of directional lamps by investigating a test procedure with an internally mounted test lamp, and is expected to conclude its work and recommendations in 2010. The interim findings seem to suggest that the Australian Government's enforcement testing programme will adopt a sphere test method for total flux measurement of reflector lamps. This programme will require laboratories to develop a series of directional reference lamps with various beam angles (each measured using a goniophotometer) that can be used to measure directional lamps with similar beam angles. Australian experts involved in directional lamp round-robin testing using integrating spheres calibrated with reference lamps of a similar beam angle, have found the results to have less discrepancy and to be more reliable and repeatable between laboratories.

### 3.2 Australia

The Australian test method for measuring incandescent reflector lamps is being actively revised at this time of publication, however the cited industry reference document is AS/NZS 4934.1(Int):2008, "Incandescent lamps for general lighting service. Part 1: Test methods—Energy performance." It is anticipated that this interim standard will be reviewed in 2010 to reflect the findings of research into sphere test methods (outlined above) and the goniophotometer test requirements. The following table summarises the main parts of this interim test method.

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasoning (burn-in) of lamps under test</td>
<td>Before the initial measurements are made, lamps shall be aged at a voltage between 100% and 102% of rated voltage. The required duration of this aging is 24 hours ±1 hour.</td>
</tr>
<tr>
<td>Test voltage</td>
<td>If the voltage range includes each of the following, the test voltage for lamps intended for sale in Australia is 240V, for lamps intended for sale in New Zealand is 230V and for low voltage lamps is 12V. For lamps marked with a voltage range that does not include 230 V, 240 V or 12 V the rated voltage shall be the midpoint of the range stated. For lamps rated at voltages other than these, the rated voltage shall be the marked rated voltage. For photometric measurements, the test voltage shall be the rated voltage and be adjusted to be within ±2% of the rated voltage.</td>
</tr>
</tbody>
</table>
Test Conditions | Description
--- | ---
Test methods | The Australian Standard offers manufacturers three different methods for measuring the performance of the lamp under test:

Method 1. Integrating Sphere
Method 2. Goniophotometer
Method 3. Spectroradiometer

In all cases, lamp efficacy is reported as the ratio of measured luminous flux divided by the measured lamp power (lm/W).

Method 1. Integrating Sphere: The sphere must have a diameter at least six times the major dimension of the lamp under test. The internal surface of the sphere shall be coated with diffuse non-spectrally selective paint (CIE 84:1989). The sphere shall have as small a screen as is possible to shield the photometer head from direct illumination. The configuration for the integrating sphere shall conform to Figure 7 of CIE 84:1989 for reflector lamps and other lamps with a strongly directional luminous intensity distribution, except that a ring shaped disc shall be placed around the light source to prevent unintentional light in the light source holder from entering the sphere. The lamp holder preventing the unintentional light and supports shall be as small as possible and preferably highly reflective.

Method 2. Goniophotometer: The lamp shall be at least six times the distance of its largest dimension from the photometer. The test lamp must be correctly positioned in relation to the photometer optical axes (see Clause 5.1.2 of CIE 121:1996). Total luminous flux is obtained by averaging readings at Russell angles or via use of zone factors (see CIE 84 and CIE 121). Mechanical obstructions should be avoided and draughts should be kept to a minimum. In all cases, the lamp mounting apparatus should not interfere with light emitted. The photometer must be capable of determining luminous intensity and necessary angular settings in the test planes of the lamp.

When using the Goniophotometer, the test procedure calls for light to be measured from lamps of approximately uniform light distribution, from nadir (0°) to zenith (180°). The readings should include at least 36 vertical half-planes (i.e., angle spaces shall be no more than 10°). The test procedure notes that if measurements are being performed on a light source with strong directional luminous intensity, then gamma angle steps as low as 0.1° may be required. For all tests of directional light sources, a simulated luminaire that prevents unintentional light from being measured shall be incorporated into the test setup to hold the lamp.

Method 3. Spectroradiometer: This test method is fundamentally the same as Method 1, however it uses a different sensor. The accuracy of the spectroradiometer shall be better than ±0.1 nm over the visible spectrum (380-780 nm), and it shall have a wavelength repeatability of 0.1 nm and stray light rejection of $10^{-4}$.

The Australian test procedure then also provides a section giving the procedure for ageing lamps for lumen maintenance and life which are additional requirements beyond efficacy in the Australian reflector lamp regulation.

Australian experts indicate that the revised integrating sphere test method (i.e., incorporating the requirement for calibrating the sphere using reference lamps of a similar beam angle) will become the primary test method used by the Australian Government to test products sampled from the market place for compliance with MEPS. The Australian experts estimate that enforcement testing costs can be reduced by a factor of up to 10 using the revised sphere test method over the goniophotometer test method. This allows for a broader market
sampling (basically 10 times more product tested for the same budget) thereby maintaining a fairer and more competitive market for suppliers of these products (i.e., blocking undercutting by non-compliant inferior products). Recognising that the revised integrating sphere test method has its own testing tolerance ranges, any products that are measured by the sphere method that are deemed to be borderline in terms of meeting compliance may then be re-tested using the goniophotometer test method. This procedure will maximise the value for money of a compliance-check testing programme.

3.3 Canada

In Canada, the test procedure for reflector lamps is published by the Canadian Standards Association (CSA), an independent standards-setting agency that establishes test procedures and efficiency standards that are typically adopted by the Canadian government. The most current Canadian standard for testing incandescent reflector lamps is CSA C862-09, “Performance of incandescent reflector lamps.” This is an update to the previous version, CSA C862-01 (R2006).

The following table summarises the main parts of the new CSA test method.

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasoning (burn-in) of Lamps Under Test</td>
<td>The regulation requires that lamps be seasoned at rated voltage for a minimum of 1% of rated life; or 2 hours if the lamp is a tungsten halogen type, unless a longer period is specified by the manufacturer.</td>
</tr>
<tr>
<td>Test Voltage</td>
<td>When photometric measurements are being taken, the test voltage shall be adjusted to within ±0.2% of the rated voltage of the lamp.</td>
</tr>
<tr>
<td>Test Methods</td>
<td>Measurement of the luminous flux of reflector lamps shall be obtained using photometry methods specified in IESNA LM-20-1994. Total flux may be obtained by calculation from the intensity distribution data (goniophotometer method) or with an integrating sphere. Any non-usable flux (e.g., light emanating from the base/neck area or through the reflective surface of the lamp), shall not be included in this calculation / measurement.</td>
</tr>
</tbody>
</table>

The CSA standard has a requirement of the average initial centre beam intensity of PAR lamps, however it does not have the same requirement of other reflector lamps such as BR lamps. The regulation notes that reflector lamps, other than PAR lamps, are made from blown bulbs. These bulbs do not have the precise optics of the PAR system because the centre beam intensity and beam angle are controlled mainly by the density of the frost on their bulb face. For this reason, BR lamps are evaluated only by their wattage and efficacy.

The requirement of initial centre beam intensity states that the value should be obtained directly from luminous intensity data measured in accordance with IESNA LM-20 (goniophotometer method). The classification of that beam distribution is defined in ANSI C78.379.

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4 lamp type tested shall be not less than (a) 85% of the rated centre beam intensity for lamps with beam angles classified as ≥ 20°; or (b) 80% of the rated centre beam intensity for lamps with beam angles classified as < 20°.
3.4 United States of America

As discussed in Chapter 2, the US regulations on incandescent reflector lamps first became effective in 1995. These regulations establish minimum efficacy requirements by rated lamp wattage. The test procedure for measuring the efficacy of incandescent reflector lamps was adopted by DOE on the 29th of May 1997 (62 FR 29240). DOE reviewed and did not make any fundamental changes to the test procedure for incandescent reflector lamps on the 14th of July 2009 (74 FR 34177).

The US test procedure contained in the Code of Federal Regulations (CFR) is freely available online.\(^5\) This test procedure is fundamentally the following:

- Operate the lamp under test at its rated voltage
- Measure lamp electrical power input and calculate lamp efficacy as the ratio of lumen output to power input.
- Determine lamp lumen output as total forward lumens, either through an integrating sphere or from an average intensity distribution curve

The US test procedure references the Illuminating Engineering Society of North America (IESNA) LM–20–1994, IESNA Approved Method for Photometric Testing of Reflector-Type Lamps, approved December 3, 1994. The following table describes the test conditions for the DOE test procedure:

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasoning (burn-in) of lamps under test</td>
<td>The DOE regulations reference IESNA LM-20-1994, section 5.0 which cross-references IESNA LM-54-1991, the IES Guide to Lamp Seasoning. (N.B., IESNA LM-54-1991 was updated in 1999 and then withdrawn in 2004. IESNA is actively working now on alternative guidance for lamp seasoning.) However, DOE's seasoning period continues to reference LM-20-1994, which references LM-54-1991. Normal seasoning is generally performed at rated voltage for a minimum period of one half of one percent of rated life.</td>
</tr>
</tbody>
</table>

\(^5\) Hyperlink to Electronic Code of Federal Regulations containing the incandescent reflector lamp test procedure: [http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=70643d1a79f2aeddbece96a4973528426&rgn=div9&view=text&node=10:3.0.1.4.16.2.9.6.18&iden=10](http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=70643d1a79f2aeddbece96a4973528426&rgn=div9&view=text&node=10:3.0.1.4.16.2.9.6.18&iden=10)
Test Conditions | Description |
---|---|
Equipment and instrumentation | DOE references LM-20-1994 section 4.2, which states that: • the voltage supply should not vary by more than ±0.1 percent of the specified value; • the AC voltage waveform must have a shape whereby the RMS summation of the harmonic components does not exceed 3 percent of the fundamental (3 percent total harmonic distortion); and • for DC operation of incandescent lamps, see the IESNA Approved Method for Electrical and Photometric Measurements of General Service Incandescent Lamps, LM-45-00. Note that LM-20-1994 section 4.1 provides guidance on requirements for photometric equipment used in testing, however DOE does not cross-reference these requirements in its regulations. |
Test Conditions | DOE references LM-20-1994 section 4.2, which states that: • the distance between the lamp under test and the detector shall be great enough so that the inverse-square law applies. Standard practice for most types of lamps is a 3 m (10 ft) test distance; • ambient conditions must meet the IES Approved Method for Electrical and Photometric Measurements of General Service Incandescent Lamps, LM-45; and • if the beam axis, the photometric axis and the lamp base are not on the same axis, the test lamp should be shifted to place the beam axis on the photometric axis. |

### 3.5 Test Procedure Summary and Comparison

Common to the Australian, Canadian and US test procedures is the measurement of power consumed and lumen flux for the purposes of calculating efficacy. The integrating sphere is the least expensive test method, however it must be calibrated with a reference lamp having a similar beam angle to the lamp under test in order to have reasonable accuracy. As the regulations become increasingly stringent, demonstration of compliance through repeatable and accurate testing will be critical.

Both the US and Canadian test methods reference IESNA LM-20-1994, which allows for determining total flux by calculation from the intensity distribution data (goniophotometer) or with an integrating sphere. However, LM-20-1994 notes the limitations of an integrating sphere, stating in section 7.2: “Integrating spheres have inherent limitations in the ability to accurately integrate the light from a reflector lamp.” The standard notes that “[i]naccuracies may be more evident when small (less than 2 meters in diameter) integrating spheres with low reflectance surfaces (less than 90 percent reflectivity) are used to measure directional lamps with narrow (less than 10° beam angle) beam distributions.” LM-20-1994 then also notes that the lumen output of the narrow beam angle spots produced by reflector lamps may be measured inaccurately if non-directional lamps are used for calibrating the photometer. LM-20-1994 then concludes that it is “desirable that standard lamps used for this calibration have a beam distribution similar to that of the lamp to be tested.” Indeed, this is the work that the Australian government has been engaged in, developing guidelines for recommended beam angle groups that would be applicable to directional lamps under test.
All three test procedures require that directional lamps be tested either in a simulated luminaire to exclude unintentional light from the measurement, or some other means of excluding unintentional light from interfering with the measurement.

### Table 3-4. Summary of Test Methods Referenced

<table>
<thead>
<tr>
<th>Country</th>
<th>Standard</th>
<th>Test Standards Referenced</th>
</tr>
</thead>
</table>
| **Australia** | AS/NZS 4934.1 (Int) 2008 | - AS/NZS 60432 Incandescent lamps — Safety specifications  
- AS/NZS 60432.1:2007 Part 1: Tungsten filament lamps for domestic and similar general lighting purposes  
- AS/NZS 60432.2 Part 2: Tungsten-halogen lamps for domestic and similar general lighting purposes  
- IEC 60064:2005 Tungsten filament lamps for domestic and similar general lighting purposes—Performance requirements  
- CIE 84:1989 The measurement of luminous flux  
- CIE 121:1996 The photometry and goniophotometry of luminaires |
| **Canada** | CAN/CSA-C862-09 | - CSA C22.2 No. 84-05 Incandescent lamps  
- CIE No. 13.3-1995 Method of Measuring and Specifying Colour Rendering Properties of Light Sources  
- IESNA LM-20-94 IESNA Approved Method for Photometric Testing of Reflector-Type Lamps  
- IESNA LM-49-01 IESNA Approved Method for Life Testing of Filament Lamps  
- NEMA/ANSI C78.21:2003 American National Standard for Electric Lamps — PAR and R Shapes  
- NEMA/ANSI C78.379:2006 American National Standard for Electric Lamps — Classification of the Beam Patterns of Reflector Lamps  
| **USA** | 10 CFR Part 430 Subpart B Appendix R | - CIE No. 13.3-1995 Method of Measuring and Specifying Colour Rendering Properties of Light Sources  
- IESNA LM-9  
- IESNA LM-20-94 IESNA Approved Method for Photometric Testing of Reflector-Type Lamps  
- IESNA LM-45  
- NEMA/ANSI C78.21:2003 American National Standard for Electric Lamps — PAR and R Shapes  
- NEMA/ANSI C78.379:2006 American National Standard for Electric Lamps — Classification of the Beam Patterns of Reflector Lamps  
The following table provides a high-level comparison between the three test methods discussed in this Chapter. A more detailed section-by-section comparison is beyond the scope of this study; however it is evident from this cursory review that there is potential for harmonisation across these three test methods, as the metrics and cost constraints are shared by all parties. In the European context, it should be noted that none of these test procedures apply to CFL or LED directional lamps. Europe is the only regulatory entity that is considering a horizontal regulation across all direction lamps (i.e., defined by the application) rather than a regulation on a specific technology (i.e., the approach taken by Australia, Canada and the United States).

Table 3-5. Key Attributes of Test Procedures for Three Target Countries

<table>
<thead>
<tr>
<th>Item in Test Procedure</th>
<th>Australia</th>
<th>Canada</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp Seasoning</td>
<td>Lamps shall be aged at a voltage between 100% and 102% of rated voltage. The required duration of this aging is 24 hours ±1 hour.</td>
<td>Rated voltage for a minimum of 1% of rated life; or 2 hours if the lamp is a tungsten halogen type</td>
<td>One half of one percent of rated life at rated voltage.</td>
</tr>
<tr>
<td>Test Voltage</td>
<td>For photometric measurements, the test voltage shall be the rated voltage and be adjusted to be within ±2% of the rated voltage.</td>
<td>When photometric measurements are being taken, the test voltage shall be adjusted to within ±0.2% of the rated voltage of the lamp.</td>
<td>The voltage supply should not vary by more than ±0.1 percent of the specified value;</td>
</tr>
<tr>
<td>Integrating Sphere</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Goniometer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Efficacy (lm/W) Output</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
4 LED Test Methods and White Papers

There are several standards-issuing organisations working on developing a complete set of product standards for light emitting diodes (LEDs) to help ensure market consistency and quality. The work of these standards organisations is critical for laying the foundation of the technology as LEDs become a more widely used and accepted light source. The following is a list of the organisations discussed in this chapter, and the associated LED standards either developed or in development at the time of this printing:

- American National Standards Institute (ANSI) - www.ansi.org
- Illuminating Engineering Society (IES) - www.iesna.org
- International Commission on Illumination (CIE) - www.cie.co.at
- International Electrotechnical Commission (IEC) - www.iec.ch
- National Electrical Manufacturers Association (NEMA) - www.nema.org
- Underwriters Laboratories (UL) - www.ul.com

4.1 American National Standards Institute (ANSI)

ANSI was founded in 1918, and has its headquarters Washington DC. ANSI is a not for profit organisation with links with a number of international and regional organisations including the: International Organisation for Standardisation (ISO) (official US representative); International Electrotechnical Commission (IEC); Pacific Area Standards Congress; Pan American Standards Congress; Pacific Accreditation Cooperation; and Inter American Accreditation Cooperation. ANSI’s role is to monitor the development, circulation, use and accreditation to conformance of standards and guidelines, of which there are thousands.

ANSI typically does not develop standards. ANSI normally lends their designation to standards that have been developed by other groups, such as the IES or NEMA. However, recognising the demand for standards in a particular area, the ANSI Secretary for Committees C78 and C82 established the American National Standard Lighting Group (ANSLG). The ANSLG, much like ANSI, has voluntary membership and is open to all parties. The ANSLG Secretary is based out of NEMA’s offices, enabling good coordination between the development of testing standards. ANSI currently has the following standards and white papers that relate to LEDs:

- ANSI C82.SSL1: “Power Supply” – specifies the operational characteristics and electric safety of SSL power supplies and drivers.
- NEMA/ANSI C82.77-2002: “Harmonic Emission Limits – Related Power Quality Requirements for Lighting” – provides specification of the maximum allowable harmonic emission of SSL power supplies.
- NEMA/ANSLG/ANSI C78.377-2008 - Specifications for the Chromaticity of Solid-State Lighting Products – this standard specifies recommended chromaticity (colour) ranges for white LEDs with various correlated colour temperatures (CCTs).
4.2 Illuminating Engineering Society of North America (IES or IESNA)

IES has been active for over 100 years advising industry and the general public on lighting best practice through publications, programmes and services. The IES hosts technical committees of lighting professionals, organises research and forums for professionals to discuss lighting practices, developments and recommendations. IES has over 10,000 members from a variety of sectors within the lighting industry such as architects, government, engineers, manufacturers, researchers and academics.

IES publishes technical documents and jointly develops programmes and standards with other organisations. IES has different letter designations for the publications they issue – “LM” for test methods, “RP” for recommended practice and “TM” for technical memorandums. IES also publishes guidelines. Bearing those designations in mind, the following is a list of publications that IES has issued with respect to LEDs:

- IES LM-79-2008: Approved Method for the Electrical and Photometric Testing of Solid-State Lighting Devices - Specifies a standard test method for measuring the photometric properties of SSL devices, allowing calculation of luminaire efficacy. This standard is now entering a review and update phase, although new results will not be available for 1-2 years.
- IES LM-80-2008: Approved Method for Measuring Lumen Depreciation of LED Light Sources - Specifies a standard method for measuring the lumen depreciation of LEDs, allowing calculation of LED lifetime. This standard is now entering a review and update phase, although new results will not be available for 1-2 years.
- IES RP-16 Addendum a: “Nomenclature and Definitions for Illuminating Engineering” - provides industry standard definitions of lighting terms, including all lighting technologies. This “Addendum a” provides definitions of solid-state lighting terms.
- IES RP-16 Addendum b: “Nomenclature and Definitions for Illuminating Engineering” – this standard provides additional relevant terms and definitions for LED. This standard is in the final IES ballast phase
- IES TM-16-05: “Technical Memorandum on Light Emitting Diode (LED) Sources and Systems” – a technical memorandum provides a general description of LED devices and systems, and answers common questions about the use of LEDs.
- IES TM-21: “Lumen Depreciation Estimation Method for LED Light Sources” – provides a method for determining an LED luminaire or integral replacement lamp's expected lumen depreciation as one measure of expected life, based on performance data collected per IES-LM-80. IES TM-21 is currently in development, with multiple models being considered to address the potential degradation paths seen with different LED technologies.
- IES LM-XX1: “Method for the Measurements of High-Power LEDs” – when completed, it will provide a standardized method for thermal, electrical, and photometric measurements of high-power LEDs.
- IES LM-XX2: “LED Characterization of Light Engines and Integrated LED Lamps” – when completed, it will provide a standardized method for measuring the electrical and photometric characteristics of light engines and integrated LED lamps.
- “IES Application Guide: Guidelines for LED Applications” – when completed, will provide information on LED technology and guidance for the appropriate and effective application and installation of LED products.

4.3 International Commission on Illumination (CIE)

The CIE is an international not-for-profit lighting organisation and undertake a variety of activities including: international conferences; development, guidance and publishing of
lighting standards; publication and disseminate lighting related papers; and maintaining relationships and share technical information with other lighting related organisations around the world. The CIE is divided into six divisions which undertake specific allocated technical activities, these are: vision and colour; measurement of light and radiation; interior environment and lighting design; lighting and signalling for transport; exterior lighting and other applications; photobiology and photochemistry. The CIE holds a conference every four years which allows parties with an interest in the CIE’s activities to hear about the latest technological developments and advances in industry. The last CIE conference was held in Vienna in March 2010.

The CIE is currently working on the following new standards and studies pertaining to LEDs:

- **CIE 177:2007: “Colour Rendering of White LED Light Sources”** – a report by a CIE Technical Committee which recommends the development of a new colour rendering index (or a set of new colour rendering indices). The index should not replace the current CIE colour rendering index immediately, but rather would provide information supplementary to the current CIE CRI, and replacement of CRI will be considered after successful integration of the new index. The new index (or set of indices) should be applicable to all light sources and not only to LED light sources.

- **Technical Report 127-2007: “Measurement of LEDs”** (2nd ed) – updating CIE 127-1997, this report captures the significant measurement differences between LEDs and other light sources, providing new quantities for their characterization and measurement conditions. New quantities include "averaged LED intensity" and "partial LED flux". The report provides measurement conditions for these two quantities, and discusses measurements by substitution, which can be simpler, although only comparing similar coloured LEDs or applying colour correction on the measurement results.

- **Technical Committee 1-69: “Colour Quality Scale”** – this committee is working on a Colour Quality Scale (CQS) to address the problems of the CIE Colour Rendering Index (CRI) for solid-state light sources and to enable lighting industry to communicate product performance around colour quality to consumers. The method for calculating CQS is based on CRI, and vision experiments will be conducted to improve and validate the CQS. This working is being led by Yoshi Ohno and Wendy Davis at the National Institute of Standards and Technology at the US Department of Commerce.


- **Technical Committee 2-50: Measurement of the Optical Properties of LED Clusters and Arrays** To produce a technical report for measurement of the optical properties of visible LED clusters and arrays, to derive optical quantities for large area arrays and give recommendations for measurement methods and conditions. Chair: Jens Schuette (DE)

- **Technical Committee 2-58: “Measurement of LED Radiance and Luminance”** – working to prepare a CIE Technical Report recommending measurement methods for the luminance and radiance of LEDs, taking particular account of the specific requirements of relevant photobiological safety standards. Chair: Kohtaro Kohimoto (JP)

- **Technical Committee 2-63: “Optical Measurement of High-Power LEDs”** – working to develop a CIE recommendation on methods for the operation of high-power LEDs in DC and in pulse mode, at specified junction temperatures, for optical measurements. Chair: Yuqin Zong (US)

- **Technical Committee 2-64: “High Speed Testing Methods for LEDs”** – working to prepare a technical report on high speed testing methods for electrical, thermal
and optical quantities during the production of LEDs and the conversion of the values to DC operational conditions including the related time dependent functions. Chair: Günther Heidel (DE)

- Technical Committee 2-66: “Terminology of LEDs and LED assemblies” – working to Review LED and LED assemblies related terms and definitions in other international and regional organizations and prepare a recommendation for CIE. Chair: Janos Schanda (HU)

- Technical Committee 3-50: “Lighting quality measures for interior lighting with LED lighting systems” – working to review relevant CIE publications and standards to evaluate the suitability of existing lighting quality measures when applied to tertiary (commercial) interior light-emitting diode (LED) lighting systems. To identify the gaps and weaknesses in existing quality measures, exhibited in one of two ways: either the criterion is valid, but the evaluation method is not (e.g., colour rendering) or a new criterion needs to be taken into consideration (e.g., overhead glare, binning). To prepare a Technical Report, which will include the findings of the review and recommendations for new lighting quality measures and evaluation methods, as well as suggestions for new research if appropriate quality measures and evaluation methods are missing. Chair: Martine Knoop (NL)

- Technical Committee 4-47: “Application of LEDs in Transport Signalling and Lighting” – working to review the application and methods of measurement of LEDs in transport lighting and signalling as far as they affect the visual performance of the users of the transport system. To prepare a Technical Report which includes the findings of the review and recommendations for the visual characteristics of LED signals and lighting. Chair: Steve Jenkins (US)

- Technical Committee 6-55: “Photobiological Safety of LEDs” – working to report on the differing methods of assessing the photobiological safety of Light Emitting Diodes (LEDs). The assessment measures in the CIE Lamp Safety Standard, CIE S009/E:2002 will be compared to the measures in IEC 60825-1-2001. This entails a review and report on the known effects from a physiological standpoint and a determination of the dose relationships that pose a potential risk for eye injury from excessive irradiation. Chair: Werner Horak (DE)

4.4 International Electrotechnical Commission (IEC)

The IEC develops and publishes international standards for electrotechnical (electrical, electronic and related technologies) products. The IEC was founded in 1906 and its members are national committees as opposed to countries. These national committees review and approve the work of the IEC’s technical committees and subcommittees, of which there are currently 179. The technical committees are made up from experts in the fields of electricity and electronics who work together to produce the IEC’s standards.

The IEC publishes international standards (IEC), Technical Specifications (TS), Technical Reports (TR), Industrial Technical Agreement (ITA), Publicly Available Specification (PAS) and Technology Trend Assessment (TTA). The IEC has the following publications pertaining to LEDs:

- IEC 60061: Lamp caps and holders together with gauges for the control of interchangeability and safety. Part 1: Lamp caps; Part 2: Lampholders; Part 3: Gauges
- IEC 60747-12-3 Discrete semiconductor devices; Part 12-3: Optoelectronic Devices - Blank detail specification for Light-Emitting Diodes (LEDs) for display applications
• BS EN 60838-2-2:2006 Miscellaneous lampholders, providing guidance on particular design requirements and connectors for LED-modules.
• IEC 62031 (2008) LED modules for general lighting - Safety specifications. This International Standard specifies general and safety requirements for light-emitting diode (LED) modules: (1) LED modules without integral control gear for operation under constant voltage, constant current or constant power; and (2) self-ballasted LED modules for use on DC supplies up to 250 V or AC supplies up to 1 000 V at 50 Hz or 60 Hz.
• IEC 62471 – Photobiological safety of lamps and lamp systems. Provides guidance evaluating the photobiological safety of lamps and lamp systems including luminaires. It specifies the exposure limits, reference measurement technique and classification scheme for the evaluation and control of photobiological hazards from all sources of optical radiation, including LEDs.
• IEC/PAS 62612:2009 - Self-ballasted LED-lamps for general lighting services. Specifies the performance requirements for self-ballasted LED lamps with a supply voltage up to 250 V, together with the test methods and conditions required, intended for domestic and similar general lighting purposes, having: (1) a rated wattage up to 60 W; or (2) a rated voltage of up to 250V AC or DC.
• IEC 62663-1 Non-ballasted single capped LED lamps for general lighting - Part 1: Safety requirements
• IEC 62663-2 Non-ballasted single capped LED lamps for general lighting - Part 2: Performance requirements
• IEC TS 62504: Terms and Definitions for LEDs and LED modules in general lighting.
• IEC 62560: Safety Requirements for Self-ballasted LED lamps > 50V

4.5 National Electrical Manufacturers Association (NEMA)

NEMA was formed by the merging of the Electric Power Club and the Associated Manufacturers of Electrical Supplies in 1926. It is the trade association for the electrical manufacturing industry in North America, has over 450 members. NEMA produces and publishes over 500 technical standards, guides and papers and assists in the development of government regulation for the electrical product industry. NEMA publishes lighting standard division “LSD” documents and standards for solid-state lighting “SSL”. NEMA currently has the following standards that pertain to LEDs:

• NEMA LSD 44-2009: “The Need for a New Generation of Sockets and Interconnects” - this report provides the background and history of sockets and interconnects, and recommends standards development for the next generation of lamp and lighting technology. [http://www.nema.org/standards/lstd44.cfm](http://www.nema.org/standards/lstd44.cfm)
• NEMA LSD 45-2009: “Recommendations for Solid-State Lighting Sub-Assembly Interfaces for Luminaires” - this report provides guidance on the design and construction of interconnects (sockets) for solid-state lighting applications. [http://www.nema.org/standards/lstd45.cfm](http://www.nema.org/standards/lstd45.cfm)
• NEMA LSD 49-2010, Solid-State Lighting for Incandescent Replacement—Best Practices for Dimming – this standard focuses on integrated LED lamps intended for replacement of general service incandescent lamps. Future white papers are planned to address other LED dimming topics, such as: colour change; light output and efficiency; dimming protocols; LED modules with auxiliary drivers; and control architectures that dim without modulated power. [http://www.nema.org/standards/lstd49.cfm](http://www.nema.org/standards/lstd49.cfm)
• NEMA/ALA LSD-51: “Solid State Lighting—Definitions for Functional and Decorative Applications” - provides definitions of functional and decorative solid state lighting
luminaires (lighting fixtures) designed for general lighting applications for residential and non-residential areas. The document further provides guidelines for the specification of the major characteristics, performance criteria, and evaluation process needed for these luminaires. See: http://www.nema.org/stds/lsd51.cfm

- NEMA SSL-1: “Electric Drivers for LED Devices, Arrays, or Systems” – a standard providing specifications for and operating characteristics of electronic drivers (power supplies) for LED devices, arrays, or systems intended for general lighting applications”. Under final section ballot, publication expected in third quarter of 2010.
- NEMA SSL-4: “Form Factors” – a standard that is being restarted in NEMA, which focuses on LED product form factors.
- NEMA SSL-6: “Solid State Lighting for Incandescent Replacement – Dimming” (working title, may be revised). This standard is complimentary to NEMA LSD-49-2010. There is a draft in progress, and the publication of the standard is expected by the end of 2010.

4.6 Underwriters Laboratories (UL)

UL provides safety certification and testing standards for over 19,000 products. UL has 68 laboratories and operates in 102 countries. UL Marks appear on over 20 billion products in Asia, Europe and North America. UL has been operating in the lighting industry for over a century and provides testing and certification services for lighting products around the globe. There are over 30 types of UL standard for the lighting industry including: proprietary standards; IEC; CSA; and NOM. UL currently has the following safety standard that relates to LEDs:

- UL 8750: “Safety Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products” – this standard specifies the minimum safety requirements for SSL components, including LEDs and LED arrays, power supplies, and control circuitry.
- UL 1598: “Luminaires” – this standard specifies the minimum safety requirements for luminaires, and should be referenced in conjunction with other documents such as UL 8750 or separately used as part of the requirements for SSL products.
- UL 153: “Portable Electric Luminaires” – this standard specifies the minimum safety requirements for corded portable luminaires, including LED.
- UL 1012: “Power Units Other than Class 2” – this standard specifies the minimum safety requirements for power supplies other than Class 2 (as defined in the National Fire Protection Association 70-2005).
- UL 1310: “Class 2 Power Units” – this standard specifies the minimum safety requirements for Class 2 power supplies (as defined in NFPA 70-2005).
- UL 1574: “Track Lighting Systems” – this standard specifies the minimum safety requirements for track lighting systems.
- UL 2108: “Low Voltage Lighting Systems” – this standard specifies the minimum safety requirements for low-voltage lighting systems, including LED.
4.7 Zhaga Consortium

The lighting industry initiated the establishment of the Zhaga consortium to discuss and develop a set of LED interconnects. This consortium has broad support from a range of players in North America, Europe and Asia, including Cooper, Philips, Toshiba, OSRAM, Panasonic, Zumtobel, Acuity Brands, Havells Sylvania, General Electric and Tyco Electronics. With over 23 members participating in Zhaga, the group is defining interfaces for a variety of application-specific light engines. These standards will address physical dimensions, as well as the photometric, electrical and thermal behavior of LED light engines. By standardizing the interconnects for lamps, consumers will be able to replace LED light engines that fail in their new fixtures rather than have to purchase a whole new fixture and/or have it installed. Zhaga has not issued any standards documents at this time, but it is expected to do so in the future.

4.8 CITADEL Programme

In France, an R&D initiative led by a consortium consisting of the French Centre for Building Science and Technology (CSTB), the major French academic lighting laboratories and Philips Lighting-France has been formed to research and promote the optimal use of LEDs in buildings. This initiative, called CITADEL, is partly modelled after the US DOE’s CALiPER programme, and will work to develop measurement protocols and benchmarking analyses of LEDs, and accelerated life testing of LED lighting products.

CITADEL will work to define new metrics and measures of visual comfort and colour rendering for LEDs. This is a three-year project started in February 2010 with a budget of 1.5M Euro from the French Environmental Agency (ADEME). LED laboratory measurements will be carried out using a range of metrology, microanalysis and aging setups. It will encompass numerical simulations, focus groups, economic calculations, as well as a complete environmental analysis.
Annex A. Australian Proposal on 50W MR-16 Lamps

This report was prepared by Beletich Associates, for use by governments in regulating 12V directional fittings and lamps. The Australian Government is currently considering this initiative.

Worldwide, 12V directional lamps have become exceedingly popular for general purpose illumination in homes and businesses, particularly in a 50W, MR16 format. However these lamps were originally intended for the purpose of spot lighting - their misapplication to general purpose illumination of open space results in the need to use large quantities of fittings, with significant impacts on energy consumption.

For the existing installed stock of MR16 fittings, the only suitable replacement energy-saving lamp is currently a 35W IRC lamp. Known CFL, CCFL and LED lamps in M16 format do not generate enough light to be a viable like-for-like replacement for 50W MR16 halogen lamps. This is largely due to the size restriction of the MR16 envelope, which hinders the light output of CFL/CCFL lamps and the heat transmission from LEDs.

An effective path for dealing with this problem is as follows:

- **Fittings:** require all new fittings to meet a “luminaire efficacy” target that effectively eliminates MR16 halogen fittings, in favour of CFL and LED. For general purpose illumination of open space, these fittings are acceptable. This initiative could be delayed to allow LED fittings to improve in price and performance in the near future.
- **Lamps:** eliminate 50W MR16 lamps in favour of 35W IRC lamps. This proposal is discussed below.

**Luminous Flux and Voltage**

The latest generation of high quality 35 Watt IRC halogen lamps are able to generate luminous flux equivalent to conventional 50 Watt models, and can be readily substituted at the time of lamp failure, or earlier.

Testing of a wide range of MR16 lamps and transformers, recently carried out by Beletich Associates reveals that:

- The most common 50W lamp models generate between 450 and 750 downward lumens.
- High quality 35W IRC models generate between 500 and 700 downward lumens.
- Loading of 50W electronic transformers with 35W did not cause an appreciable voltage rise at the secondary terminals.
- Loading of 50W ferro-magnetic transformers with 35W lamps did cause a slight voltage rise but did not exceed 12 Volts.

These results, together with preliminary discussions with major lamp companies and the existence of large-scale utility-driven 35W lamp replacement programs, indicate that 35W IRC lamps are a suitable alternative to 50W halogen lamps on a large scale.
Proposal – Mandatory Flux and Wattage Limits

In order to eliminate 50W lamps in favour of 35W IRC lamps, the following mandatory limits could be imposed for MR16 lamps:

- Maximum rated wattage of 35W (with tolerance).
- Minimum luminous flux of 500 (downward) lumens (for 35W lamps).
- Minimum lifetime of 4000 hours (all tested IRC lamps were rated 4000-5000 hours).

The incrementally higher consumer cost of IRC lamps, at the time of lamp replacement, is expected to be repaid within 12 months for residential dwellings\(^6\) and within a shorter period for businesses (whose operating hours are longer).

Other Risks and Benefits

Energy savings of 30% would result from the phasing out of 50W MR16 lamps. Including transformer losses, power savings from replacement of 50W lamps with 35W lamps are around 19W (ferro-magnetic transformer) and 16W (electronic transformer).

MR16 lamps are available in 20, 35, 50 and 71W. Eliminating 50W MR16 lamps from the market would allow 71W MR16 lamps to continue to be used, although the market for these lamps is thought to be almost non-existent. In addition, 71W lamps cannot be substituted for 50W lamps as this would exceed the rating of the connected 50W transformer, causing triggering of its thermal overload protection. 71W lamps and fittings could also be eliminated if required in order to prevent an increase in their popularity.

Reduction of MR16 lamp wattage would reduce the insulation fire risk that has become apparent from their use.

\(^6\) Incremental lamp cost of AUD$2.50 from market survey by Beletich Associates; electricity cost of AUD$0.20/kWh; residential operating hours of 2.25 hours/day for MR16 lamps; source: Syneca 2008, Regulatory Impact Statement Consultation Draft, Proposal to Phase-Out Inefficient Incandescent Light Bulbs, Discussion draft for stakeholder comment issued under the auspices of the Ministerial Council on Energy, September 2008, Prepared by Syneca Consulting for DEWHA.
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