



# ENERGY STAR® Program Requirements for Integral LED Lamps DRAFT 2 – May 19, 2009

## Scope

These criteria apply to integral LED lamps<sup>1</sup>, defined as a lamp with LEDs, an integrated LED driver, and an ANSI standardized base designed to connect to the branch circuit via an ANSI standardized lampholder/socket. These criteria include integral LED lamps intended to replace standard general service incandescent lamps of 25 watts or greater, decorative (candelabra style) lamps, and standard reflector lamps of 20 watts or greater, as well as non-standard lamps. Other types of replacement lamps may be added in the future as LED technology improvement makes LED use in other replacement lamp types viable.

## All Lamps

Lamp Requirements:			
Correlated Color Temperature (CCT) and Duv	Lamp must have one of the following designated CCTs (per ANSI C78.377-2008) consistent within the 7-step chromaticity quadrangles and Duv tolerances listed below (see Appendix for definitions).		
	<u>Nominal CCT</u>	<u>Target CCT (K) and tolerance</u>	<u>Target Duv and tolerance</u>
	2700 K	2725 ± 145	0.000 ± 0.006
	3000 K	3045 ± 175	0.000 ± 0.006
	3500 K	3465 ± 245	0.000 ± 0.006
	4000 K	3985 ± 275	0.001 ± 0.006
Color Maintenance	The change of chromaticity over the lifetime of the product shall be within 0.007 on the CIE 1976 (u',v') diagram.		
Color Rendering Index (CRI)	Minimum CRI of 80.		
Dimming	<p>Lamps may be dimmable or non-dimmable. Product packaging must clearly indicate whether the lamp is dimmable or not dimmable.</p> <p>All lamps must be “dimmer safe”, i.e., they will not suffer permanent damage if placed on a dimming circuit.</p> <p>Manufacturers qualifying dimmable products must maintain a web page providing dimmer compatibility information.</p>		

<sup>1</sup> ANSI/IESNA RP-16-05, Addendum “a”. IESNA. 2008.

Warranty	A warranty must be provided for lamps, covering repair or replacement for a minimum of three (3) years from the date of purchase. The written warranty must be included with the lamp packaging at the time of shipment.
Lamp Life/Lumen Maintenance	Lamps shall deliver at least 70% of initial lumens for at least 25,000 hours.
Allowable Lamp Bases	Must be a lamp base listed in ANSI_ANSLG Standard C81.61-2007.
Power Factor	$\geq 0.70$
Minimum Operating Temperature	Integral lamp shall have a minimum operating temperature of -20°C or below.
LED Operating Frequency	$\geq 120$ Hz  <b>Note:</b> This performance characteristic addresses problems with visible flicker due to low frequency operation and applies to steady-state as well as dimmed operation. Dimming operation shall meet the requirement at all light output levels.
Electromagnetic and Radio Frequency Interference	Integral LED lamps designated by the manufacturer for residential applications must meet FCC requirements for consumer use (FCC 47 CFR Part 15 Consumer Emission Limits).
Audible Noise	Integral lamp shall have a Class A sound rating.
Transient Protection	Power supply shall comply with IEEE C.62.41-1991, Class A operation. The line transient shall consist of seven strikes of a 100 kHz ring wave, 2.5 kV level, for both common mode and differential mode.
Operating Voltage	Lamp shall operate at 120 volts, +/- 10%.

## Packaging Requirements

<b>Packaging Requirements</b>	
Warranty	Product packaging must state "Warranty" or "Limited Warranty" and have a toll-free (e.g., "800") number, or mailing address, or web site address ( <i>if applicable</i> ) for consumer complaint resolution.
Product Packaging Language	In English, or English with additional languages. For products that will be sold in Canada, packaging must include both English and French.
Incompatibility with Controls and Application Exceptions	Lamp package <u>must clearly state</u> any known incompatibility with photo controls, dimmers or timing devices. In addition, packaging should state specific application exceptions.
Dimmable lamps	Lamp package and product information sheet must include a caution label indicating the lamp may not be compatible with all dimmers and identifying the web address (URL) to find up-to-date dimmer compatibility information. Label format TBD.
LED MR-16 Lamps Intended for use on Low-Voltage Circuits	Lamp package must state compatibility with low-voltage transformers.  Lamp package and product information sheet must include a caution label indicating the lamp may not be compatible with all low-voltage transformers used in existing light fixtures and identifying the web address (URL) to find up-to-date low-voltage transformer compatibility and appropriate use information. Label format TBD.
Non-Standard Lamps	Lamp package must indicate lighting applications and fixture types for which the non-standard lamp is intended.
Product Equivalency Claims (for Replacement Lamps)	For replacement lamps (not non-standard lamps), product packaging and marketing material may only reference ANSI standard lamp type indicated on ENERGY STAR product application. Performance comparisons to other types of lamps or lamp powers is not allowed. For example, an integral LED lamp approved by ENERGY STAR as a replacement for a 45W BR30 incandescent lamp may not claim equivalency to a 65W BR30 or a 45W A lamp.
Lighting Facts Label	Manufacturers must use the Lighting Facts label that is part of the DOE Quality Advocates program: <a href="http://www.lighting-facts.com">www.lighting-facts.com</a> .

## Non-Standard Lamps – for LED lamps of non-standard lamp type or form

Lamps in this category may not state equivalency to existing standard electric lamps in terms of wattage or type. In addition to the requirements above, the following performance and information requirements apply to Non-standard Lamps. These criteria are not applicable to LED lamps intended to replace linear fluorescent or high-intensity discharge (HID) lamps.

<b>Non-Standard Lamp Requirements</b>	
Minimum Luminous Efficacy	55 lumens per watt (lm/W)
Minimum Light Output	400 lumens
Luminous Intensity Distribution	No specific distribution is required. Must submit goniophotometry report (LM-79-08, Section 10) showing luminous intensity distribution produced by the lamp.  Product label must indicate beam distribution in graphical form, consistent with the above report. Format TBD.
Intended Applications	Product submission materials must indicate lighting applications and fixture types for which the non-standard lamp is intended.

## Replacement Lamps – for lamps intended to replace existing standard electric lamps (per ANSI C79.1-2002)

All lamps stating equivalency to a standard lamp wattage or type in product packaging, literature, or other materials must provide the following information about the lamp to be replaced (i.e., the target lamp):

- 1) Target lamp type, using standard lamp designations defined in ANSI C79.1-2002. For example, A, R, MR, PAR, etc.
- 2) Target lamp diameter in eighths of an inch. For example, A19, MR16, PAR38, etc.
- 3) Target lamp nominal wattage.
- 4) For directional lamp types, target lamp beam angle in degrees.

These criteria are not applicable to LED lamps intended to replace linear fluorescent or high-intensity discharge (HID) lamps.

Minimum performance and dimensional criteria are provided below for omnidirectional, decorative, and directional lamp replacements.

### Omnidirectional Lamp Requirements

Applicable lamp types	For LED lamps intended to replace the following ANSI standard lamp types (ANSI C79.1-2002):  A, G, P, PS, S	
Minimum luminous efficacy (lumens per watt, lm/W) LED lamp power <10W LED lamp power ≥10W	50 lm/W 55 lm/W	
Minimum light output	Lamp shall have minimum light output (total luminous flux) at least corresponding to the target wattage of the lamp to be replaced, as shown below. Target wattages in between the given levels may be interpolated.	
	Nominal wattage of lamp to be replaced (watts)	Minimum light output of LED lamp (lumens)
	25	250
	40	450
	60	800
	75	1,100
	100	1,600
	125	2,000
	150	2,600
Luminous intensity distribution	Products shall have an even distribution of luminous intensity within the 0° to 135° zone (axially symmetrical). 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%.	
Maximum lamp diameter	Not to exceed target lamp diameter.	
Maximum overall length (MOL)	Not to exceed MOL for target lamp as per ANSI C78.20-2003.	

### Decorative Lamp Requirements

Applicable lamp types	For LED lamps intended to replace the following ANSI standard lamp types (ANSI C79.1-2002):  B, BA, BT, C, CA, DC, F	
Minimum luminous efficacy	40 lumens per watt (lm/W)	
Minimum light output	Lamp shall have minimum light output (total luminous flux) equal to the target wattage of the lamp to be replaced multiplied by 7.	
Maximum lamp diameter	Not to exceed target lamp diameter.	

**Directional Lamp Requirements**

Applicable lamp types	For LED lamps intended to replace the following ANSI standard lamp types (ANSI C79.1-2002):  BR, ER, K, MR, PAR, R  For MR and PAR lamps, the following lamp diameters are included at this time:  MR16, PAR16, PAR20, PAR30S, PAR30L, PAR38
Minimum luminous efficacy - Lamp diameter ≤ 20/8 inch - Lamp diameter > 20/8 inch	40 lm/W 45 lm/W
Color Spatial Uniformity	The variation of chromaticity in different directions (i.e., with a change in viewing angle) shall be within 0.004 from the weighted average point on the CIE 1976 (u',v') diagram.
Maximum lamp diameter	Not to exceed target lamp diameter.
Maximum overall length (MOL)	BR, ER, PAR, R lamps: Not to exceed MOL for target lamp as per ANSI C78.21-2003.

**For PAR and MR16 Lamps Only**

Minimum center beam intensity – <b>PAR and MR16 lamps</b>	Models based on statistical analysis of 432 PAR and 122 MR16 lamps produced by NEMA manufacturers are used to set minimum center beam intensity requirements. For a given target lamp wattage and target beam angle, mathematical functions for each lamp type yield the minimum required center beam intensity in candelas (cd). The minimum requirement is within two standard deviations of the center beam intensity predicted by the model.	
	Lamp family	Functions
	PAR	<a href="http://www.drintl.com/temp/ESIntLampCenterBeamTool_5_19.xls">http://www.drintl.com/temp/ESIntLampCenterBeamTool_5_19.xls</a> Please enter the following information into the online tool: 1. PAR diameter in eighths of an inch (i.e., 16, 20, 30, 38) 2. Target lamp nominal wattage 3. Target lamp beam angle in degrees
	MR16	<a href="http://www.drintl.com/temp/ESIntLampCenterBeamTool_5_19.xls">http://www.drintl.com/temp/ESIntLampCenterBeamTool_5_19.xls</a> Please enter the following information into the online tool: 1. Target lamp nominal wattage 2. Target lamp beam angle in degrees
Field angle requirement – <b>PAR and MR16 lamps</b>	At 1.3 * beam angle + 3 degrees the intensity must be at least 10% of maximum intensity.	

<b>For BR, ER, K, and R Lamps Only</b>	
Minimum light output – <b>BR, ER, K, and R lamps</b>	Lamp shall have minimum light output (total luminous flux) equal to the target wattage of the lamp to be replaced multiplied by 10.
Luminous intensity distribution – <b>BR, ER, K, and R lamps</b>	BR, ER, K, and R lamps are required to state the beam distribution in terms of Spot, Narrow Flood, or Flood, defined as follows:  Spot: 10°-20° beam angle Narrow flood: 20°-30° beam angle Flood: >30° beam angle

### Testing and Documentation

<b>Performance Characteristic</b>	<b>Methods of Measurement Reference Standards</b>	<b>Required Documentation</b>
Integral LED Lamp Efficacy: Light Output Input Power	IESNA LM-79-2008 ANSI C82.2-2002	Laboratory test results must be produced using the specific module(s)/array(s) and power supply combination that will be used in production.
Power Factor	ANSI C82.77-2002	Laboratory test results must be produced using the specific module(s)/array(s) and power supply combination that will be used in production.
Lumen Maintenance (L <sub>70</sub> ) for LEDs	IESNA LM-80-2008	Minimum 6,000 hour lumen maintenance data for the LED package(s)/array(s)/module(s) used in the integral LED lamp. Lumen maintenance data must meet at least the following conditions: <ul style="list-style-type: none"> <li>- Collected at LED case or solder joint temperature (Ts) equal to or greater than the verified TMP temperature of the integral LED lamp; and</li> <li>- Measured at a forward drive current equal to or greater than the drive current applied to the LEDs in the integral LED lamp.</li> </ul>
Reliability	DOE is evaluating several reliability test procedures to address long term reliability of integral LED lamps. These include: <ul style="list-style-type: none"> <li>- Short term burn-in test (per NEMA; procedure to be developed)</li> <li>- Wet high temperature operating life (WHTOL) test per EIA/JESD22-A101-B</li> <li>- Elevated temperature tests combined with rapid cycle stress tests referenced in ENERGY STAR Program Requirements for CFLs, version 4.0</li> </ul>	

Color Rendering Index	ANSI C78.377-2008 IESNA LM-79-2008 CIE 13.3-1995 IESNA LM-58-94	Laboratory test results must be produced using the specific module(s)/array(s) and power supply combination that will be used in production.
Chromaticity and Correlated Color Temperature	ANSI C78.377-2008 IESNA LM-79-2008 CIE 15: 2004 IESNA LM-58-94 IESNA LM-16-93	Laboratory test results must be produced using the specific module(s)/array(s) and power supply combination that will be used in production.
Color Spatial Uniformity and Color Maintenance	IESNA LM-79-2008 CIE 15: 2004 IESNA LM-58 IESNA LM-16 IESNA LM-80	Self Certification
Audible Noise	Class A sound rating: Power supply not to exceed 24 dB	Self Certification
Integral LED Lamp Warranty		Provide copy of the actual three-year manufacturer warranty included in the packaging.
Safety Lamps	UL 8750	Provide the cover page of a safety test report or a general coverage statement from an OSHA NRTL laboratory.

## Appendix A: Definitions

- A. **A2LA**: American Association for Laboratory Accreditation.
- B. **ANSI**: American National Standards Institute.
- C. **ASTM**: American Society for Testing of Materials.
- D. **CIE**: Commission Internationale de l'Eclairage (translated International Commission on Illumination).
- E. **Color rendition**: The effect the spectral characteristic of the light emitted by the LED has on the color appearance of the objects illuminated by it is called color rendition. The color rendering index (CRI) is defined in terms of a comparison of the spectral tri-stimulus values of the objects under test illumination and standard illumination according to the recommendations of CIE Publication No.13.3-1995.
- F. **Correlated Color Temperature (CCT)**: The actual color of the LED is called the color temperature and is defined in terms of the spectral tri-stimulus values (color coordinates) according to the recommendations of IESNA LM-16. For color coordinates near the blackbody loci, the correlated color temperature, measured in Kelvin (K), is used.
- G. **CSA**: Canadian Standards Association.
- H. **Duv**: the distance to the closest point on the Planckian locus on the CIE 1976 ( $u'$ ,  $v'$ ) diagram, with + sign for above and - sign for below the Planckian locus.
- I. **IEC**: International Electrotechnical Commission.
- J. **IESNA**: Illuminating Engineering Society of North America.
- K. **LED array**: An assembly of LED packages on a printed circuit board or substrate, possibly with optical elements and additional thermal, mechanical, and electrical interfaces. The device does not contain a power source, does not include an ANSI standardized base, and is not connected directly to the branch circuit.
- L. **LED driver**: A power source with integral LED control circuitry designed to meet the specific requirements of a LED lamp or a LED array.
- M. **LED lumen maintenance ( $L_{70}$ )**: The length of time declared by the manufacturer at which 70% lumen maintenance of any large sample of LEDs is reached.
- N. **LED luminaire**: A complete LED lighting unit consisting of a light source and driver together with parts to distribute light, to position and protect the light source, and to connect the light source to a branch circuit. The light source itself may be an LED array, an LED module, or an LED lamp. The LED luminaire is intended to connect directly to a branch circuit.
- O. **LED module**: A component part of an LED light source that includes one or more LEDs connected to the load side of LED power source or LED driver. Electrical, electronic, optical, and mechanical components may also be part of an LED module. The LED module does not contain a power source and is not connected directly to the branch circuit.
- P. **LED package**: An assembly of one or more LED dies that contains wire bond connections, possibly with an optical element and thermal, mechanical, and electrical interfaces. The device does not include a power source, does not include an ANSI standardized base, and is not connected directly to the branch circuit.
- Q. **Luminaire efficacy**: The luminous flux of the luminaire divided by the input power.
- R. **Lumen maintenance**: The luminous flux at a given time in the life of the LED and expressed as a percentage of the initial luminous flux.
- S. **MacAdam color ellipse**: An elliptical region of chromaticity coordinates that is defined using a centroid, a tilt angle relative to a horizontal axis, and a defined level of variance. Such a region defines what chromaticity coordinates can be acceptably associated with a target Correlated Color Temperature. For these criteria, standardized color ellipses are defined using centroids based upon objective chromaticities ( $x,y$ ) and tilt angles ( $\theta$ ) specified in Table 1 and 2 of ANSI C78.376-2004, and a defined variance of four steps.
- T. **Manufacturer designated Temperature Measurement Point (TMP)**: The temperature measurement point designated by the manufacturer correlating to photometric, life or warranty values.
- U. **Minimum operating temperature**: The minimum temperature at which the power supply will reliably operate.
- V. **MRA**: Mutual Recognition Arrangement.
- W. **NVLAP**: National Voluntary Laboratory Accreditation Program.
- X. **Power factor**: The active power divided by the apparent power (i.e., product of the rms input voltage and rms input current of a driver).
- Y. **UL**: Underwriters Laboratories

## Appendix B: Chromaticity Specification and Tolerance Quadrangles

This chromaticity specification below was developed by ANSI to be as consistent as possible with existing fluorescent lamp standards, and to reflect the current (and near future) state of SSL technology and color binning capabilities. Each of the eight quadrangles as defined below overlap the six current the ANSI 7-step MacAdam ellipses (consistent with the current ENERGY STAR lighting criteria), and thus have the same nominal CCT as ENERGY STAR fluorescent lamps. Two additional CCTs (4500 and 5700K) are included to encompass the additional CCTs available in SSL. Each quadrangle is defined by the range of CCT and the distance from the Planckian locus on the chromaticity diagram. Refer to ANSI C78.377-2008 for the details of these definitions. Figure 1 shows the plot of these chromaticity quadrangles and the table below shows (x,y) coordinates of the center points and the corners of each quadrangle.

	2700 K		3000 K		3500 K		4000 K		4500 K		5000 K		5700 K		6500 K	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y
Center point	0.4578	0.4101	0.4338	0.4030	0.4073	0.3917	0.3818	0.3797	0.3611	0.3658	0.3447	0.3553	0.3287	0.3417	0.3123	0.3282
Tolerance quadrangle	0.4813	0.4319	0.4562	0.4260	0.4299	0.4165	0.4006	0.4044	0.3736	0.3874	0.3551	0.3760	0.3376	0.3616	0.3205	0.3481
	0.4562	0.4260	0.4299	0.4165	0.3996	0.4015	0.3736	0.3874	0.3548	0.3736	0.3376	0.3616	0.3207	0.3462	0.3028	0.3304
	0.4373	0.3893	0.4147	0.3814	0.3889	0.3690	0.3670	0.3578	0.3512	0.3465	0.3366	0.3369	0.3222	0.3243	0.3068	0.3113
	0.4593	0.3944	0.4373	0.3893	0.4147	0.3814	0.3898	0.3716	0.3670	0.3578	0.3515	0.3487	0.3366	0.3369	0.3221	0.3261

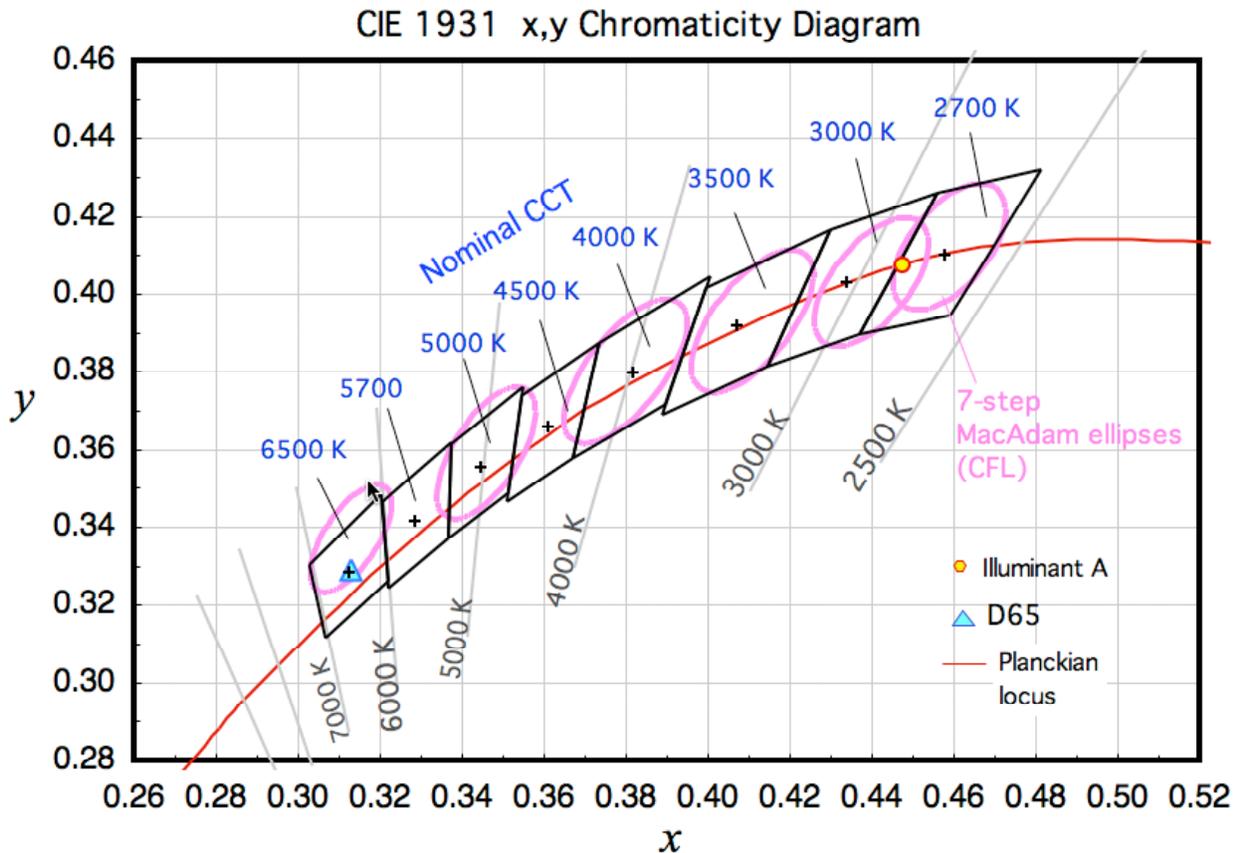


Figure 1. CIE 1931 Chromaticity Diagram Showing the Eight Nominal CCT Quadrangles