ENERGY STAR® Program Requirements for Solid State Lighting Luminaires

Eligibility Criteria – Version 1.0

Draft: 4/9/07

Table of Contents

ENERGY STAR® Program Requirements for Solid State Lighting Luminaires

Eligibility Criteria – Version 1.0

Comment on all criteria: The rapid pace of SSL performance improvements will require DOE to periodically review and amend the criteria to parallel technological advances and ensure the criteria remain up to date. DOE will monitor SSL developments and, at appropriate intervals, revise the criteria. DOE is sensitive to concerns over frequent revisions and stranded product.

Given the early stage of SSL technology development with respect to its application to general illumination, the criteria establish near-term requirements and future performance targets. The near-term requirements (Category A) are for listed lighting application products achieving energy performance equivalent or better than fluorescent light sources used in the same applications. The long-term targets (Category B) are intended to indicate, well in advance, DOE's intent to substantially raise required efficacy to the much higher performance levels projected to be achievable in approximately three years.

Below are the product criteria for ENERGY STAR® qualified luminaires using solid-state lighting (SSL). A product must meet all the criteria in order to be qualified as ENERGY STAR.

Scope

Comment on scope clarification: The Scope section was modified to address comments made by fixture manufacturers concerning whether these criteria applied to decorative luminaires. Newly inserted language makes clear the criteria are intended to include decorative luminaires, so long as those luminaires provide a significant general illumination function. However, those luminaires must meet the same performance requirements as non-decorative luminaires. Language was also added to clarify that the criteria apply only to products intended to be connected to the power grid, and do not apply to indication-type products.

The ENERGY STAR criteria cover the requirements for SSL products used for general illumination, including those with significant decorative function. If a decorative SSL product serves a significant general illumination function, it falls within the scope of these criteria. The criteria apply to both residential and commercial products. The criteria apply only to products designed to be connected to the electric power grid. In addition, they do not apply to SSL products made for indication (such as traffic lights and exit signs); nor do they apply to products exclusively intended for decoration (such as holiday lights).

General Requirements

The criteria are based upon compliance with existing lighting industry reference standards and test procedures, as well as new or revised standards and test procedures currently being developed by lighting industry organizations. These reference standards and test procedures are listed in the appendix.

The following general requirements apply to both Categories A and B. Additional requirements for correlated color temperature (CCT), luminaire efficacy, zonal lumen density, and minimum light output are listed under Categories A and B below.

All Luminaires

Comment on chromaticity requirements: The chromaticity requirements shown below have been proposed by the ANSI C78 Working Group. They are a modification of existing fluorescent lamp standards intended to reflect the current (and near future) state of SSL technology and color binning capabilities. LEDs are binned for chromaticity in the manufacturing process. These bins, when superimposed on the CIE 1931 Chromaticity Diagram, take the form of quadrangles, as opposed to ellipses. Six of the eight quadrangles defined below largely correspond to and overlap with the ANSI 7-step MacAdam ellipses (consistent with the current ENERGY STAR lighting criteria), but include additional space in the corners. The proposed quadrangles therefore have the same nominal CCTs as fluorescent lamps. The two additional nominal CCTs, 4500 K and 5700 K, provide color definition for LEDs that would not otherwise be captured by the current six ANSI defined CCTs.

Comment on changes to chromaticity requirements: The prior draft criteria referenced a flexible color option included in the draft ANSI chromaticity specification. The flexible color option has been removed from this draft for the following reasons: First, DOE believes the increase from the six CCTs currently used in the ENERGY STAR program to eight will already challenge a lighting industry struggling to communicate color to end users. Including a variable CCT will simply allow too many options. And second, DOE believes the best path forward for the emerging SSL industry is to be as consistent as possible with existing lighting paradigms.

Comment on addition of off-state power requirement: Some SSL luminaires tested by DOE draw power in the off-state. These "vampire" loads, while relatively small, have a cumulative impact over time resulting in a significant reduction in energy efficiency. The problem lies with the use of power supplies located upstream from the on/off switch that draw power even though the luminaire is not energized. DOE therefore has prohibited off-state power except in instances where occupancy or photo-controls are incorporated into the luminaire.

<table>
<tr><th colspan="3">Luminaire Requirements:</th></tr>
<tr><td>Correlated Color Temperature (CCT)</td><td colspan="2">The luminaire must have one of the following designated CCTs and fall within the 7-step chromaticity quadrangles as defined in the Appendix.</td></tr>
<tr><td></td><td>Nominal CCT(1)</td><td>CCT (K)</td></tr>
<tr><td></td><td>2700 K</td><td>2725 ± 145</td></tr>
<tr><td></td><td>3000 K</td><td>3045 ± 175</td></tr>
<tr><td></td><td>3500 K</td><td>3465 ± 245</td></tr>
<tr><td></td><td>4000 K</td><td>3985 ± 275</td></tr>
<tr><td></td><td>4500 K</td><td>4503 ± 243</td></tr>
<tr><td></td><td>5000 K</td><td>5028 ± 283</td></tr>
<tr><td></td><td>5700 K</td><td>5665 ± 355</td></tr>
<tr><td></td><td>6500 K</td><td>6530 ± 510</td></tr>
<tr><td>Color Spatial Uniformity</td><td colspan="2">The variation of chromaticity in different directions (i.e., with a change in viewing angle) shall be within 0.004 on the CIE 1976 (u',v') diagram.</td></tr>
</table>

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)	Indoor luminaires shall have a minimum CRI of 75.
Off-state Power	Luminaires shall not draw power in the off state. **Exception:** Luminaires with integral occupancy, motion or photo-controls are exempt from this requirement.
Warranty	A warranty must be provided for luminaires, covering repair or replacement of defective electrical parts (including light source and drivers) for a minimum of three (3) years from the date of purchase. For residential products, the written warranty must be included with the luminaire packaging at the time of shipment.
Thermal Management	Luminaire manufacturers shall adhere to device manufacturer guidelines, certification programs, and test procedures for thermal management.

(1) Six of the eight allowed nominal CCTs correspond to those in the fluorescent lamp specification: 2700 K, 3000 K, 3500 K, 4100 K, 5000 K, and 6500 K.

Device/Arrays

Device/Array Requirements	
Lumen Depreciation of LED Light Sources (L_{70})	The device shall have average rated lumen maintenance of at least 70% of initial device lumens at 35,000 hours.

Outdoor Luminaires

Outdoor Luminaire Requirements	
Residential Automatic Daylight Control	Residential luminaires designed for attaching to buildings and whose power consumption is greater than 13 watts must contain an integral photo-sensor that automatically prevents operation during daylight hours. In addition, the control must automatically reactivate within 24 hours of a manual override or test operation.

Drivers

Comment on power factor changes: The required power factor was reduced from 0.9 to 0.7 for residential luminaires in response to comments about the potential driver cost impacts of requiring 0.9 for residential luminaires. DOE product testing of residential luminaires and discussions with manufacturers indicates 0.7 is readily achievable in residential products.

Driver Requirements	
Power Factor	≥ 0.70 (Residential) ≥ 0.90 (Commercial)
Minimum Operating Temperature	Driver shall have a minimum operating temperature of -20°C or below.

Maximum Measured Driver/Driver Case Temperature During Normal Operation Inside Luminaire(s)	Not to exceed the driver manufacturer maximum recommended driver/driver case temperature during in-situ operation. **Note:** This performance characteristic is separate and distinct from thermal requirements established by UL, which governs safety rather than longevity of the driver. All qualified luminaires are expected to meet this requirement, including linear, suspended, close-to-ceiling, IC, ICAT and Non-IC recessed canisters, etc. as well as those luminaires that may be exempt from UL1598.
Electromagnetic and Radio Frequency Interference	• Drivers designated by the manufacturer for residential applications must meet FCC requirements for consumer use (FCC 47 CFR Part 15 Consumer Emission Limits). • Drivers designated by the manufacturer for commercial applications must meet FCC requirements for non-consumer use (FCC 47 CFR Part 15 Non- consumer Emission Limits).
Noise	Driver shall have a Class A sound rating.
Transient Protection	Driver 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.

Packaging Requirements

Packaging Requirements	
Incompatibility with Controls and Application Exceptions	Included documentation must clearly state any known incompatibility with photo-controls, dimmers or timing devices.

Category A: Near-term Applications

Comment on luminaire efficacy: The ENERGY STAR criteria for SSL Luminaires use Luminaire Efficacy to establish performance as defined below:

$$\text{Luminaire Efficacy} = \frac{\text{Luminaire Light Output (includes fixture efficiency and thermal effects)}}{\text{Luminaire Input Power}}$$

The ENERGY STAR criteria for non-SSL residential light fixtures (commonly referred to as RLF) use system efficacy defined as the light output of the lamp-ballast system divided by the input power measured in a 25°C environment. Established test procedures for fluorescent sources support this approach. However, the program requirements in this document are based upon luminaire efficacy, instead of system efficacy for the following reasons:

- Accurate measurement of the LED light source separate from the fixture is often not possible. LEDs typically are integrated into the fixture and not readily removable without altering the performance of the light source.
- LED performance is significantly affected by elevated temperature. LED devices generate heat that is typically removed by an external heat sink, which may be designed into the luminaire itself. Separating the light source from its heat sink will significantly impact test results. There are no standards or test procedures to measure system efficacy of LEDs. However, standards organizations are developing a test procedure for photometric measurement of LED luminaires. This test procedure is currently in draft form and scheduled to be final in mid-2007.
- Luminaire efficacy provides more realistic energy efficiency information because it accounts for driver, thermal, and fixture losses, thus better meeting the needs of buyers who seek the most light output for the least energy input.

Comment on methodology for establishing luminaire efficacy of near-term applications:
Determination of the luminaire efficacy thresholds for applications stems from an analysis of the currently available fluorescent products in the market, IESNA design guidelines, photometric modeling and the current performance characteristics of commercial LEDs. The selection of Category A applications is primarily based on the following parameters:

- Directed light applications
- Source relatively close to illuminated surface
- Relatively modest illuminance requirements
- Applications in which typical fixture efficiency (with traditional light sources) is 60% or lower

Minimum luminaire efficacy levels are established for each application. They are intended to assure approved luminaires perform at least as well as typical luminaires using fluorescent light sources. To establish these efficacy requirements, the following assumptions were made about the fluorescent luminaires against which they were benchmarked.

Assumptions for Fluorescent Luminaire Benchmarks		
Application	**System Efficacy (lm/W)†**	**Fixture Efficiency**
Under-cabinet kitchen	58.8	40%
Under-cabinet shelf-mounted	58.8	50%
Portable desk/task	58.8	50%
Recessed downlights	58.8	60%
Outdoor porch	58.8	40%
Outdoor step	50.0	40%
Outdoor path	50.0	50%

Comment on dropping CRI adjustment factor: DOE dropped the use of an adjustment factor in our methodology for establishing Category A efficacy requirements. The adjustment factor had the effect of increasing efficacy requirements for products whose required CRI fell below 80.

Comment on change in recessed downlight efficacy: DOE increased the assumed fixture efficiency from 50 to 60%. While 50% fixture efficiency for pin-base CFL fixtures is actually more typical, we adjusted this number upward to reflect the higher fixture efficiencies achieved when reflector CFLs are used in recessed downlights. The use of higher assumed fixture efficiency increased the required luminaire efficacy for residential products from 29 lm/W to 35 lm/W, and from 33 to 35 lm/W for commercial products. (The change in the commercial downlight required efficacy was also affected by dropping the CRI adjustment factor, as explained in the comment above.)

† The ASHRAE/IESNA 90.1 Lighting sub-committee consensus for typical pin-based CFL system efficacy is 58.8 lm/W. The efficacy of applications that typically use lower wattage CFLs was reduced to 50.0 lm/W reflecting the reduced efficacy of these systems.

Comment on addition of allowable CCTs: Allowable CCTs were added to the residential indoor applications to address concerns about potential negative consumer reaction to high CCT products. One of the key lessons learned from CFL market introduction is that color quality has an important and lasting impact on user acceptance of the light source. Currently, the most efficacious LEDs are those with high CCT, typically 5000 K or higher. Standard residential lighting (incandescent and fluorescent) has CCTs of 2700 K to 3000 K. To help ensure user satisfaction with qualified products, CCTs above 3500 K are not allowed for kitchen under-cabinet or residential recessed downlights. For portable desk/task lighting, higher CCTs are allowed, because they are sometimes preferred for detailed task work. No restrictions are placed on outdoor products given the wide range of CCTs used for conventional products in these applications.

Under-cabinet kitchen lighting

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 150 lumens (initial) per lineal foot. The light output requirement is calculated by the following equation: $\frac{\text{Measured Fixture Length (inches)}}{12} \times 150 = \text{Minimum Required Light Output (lumens)}$
Zonal Lumen Density Requirement	Luminaire shall deliver no more than 75% of total lumens (initial) within the 0-60° zone.
Minimum Luminaire Efficacy	24 lm/W
Allowable CCTs	2700 K, 3000 K and 3500 K

Under-cabinet shelf-mounted task lighting

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 150 lumens (initial) per lineal foot. The light output requirement is calculated by the following equation: $\frac{\text{Measured Fixture Length (inches)}}{12} \times 150 = \text{Minimum Required Light Output (lumens)}$
Zonal Lumen Density Requirement	Luminaire shall deliver no more than 75% of total lumens (initial) within the 0-60° zone.
Minimum Luminaire Efficacy	29 lm/W
Allowable CCTs	2700 K, 3000 K, 3500 K, 4000 K, 4500 K and 5000 K

Portable desk task lights

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 200 lumens (initial).

Zonal Lumen Density Requirement	Luminaire shall deliver a minimum of 85% of total lumens (initial) within the 0-60° zone.
Minimum Luminaire Efficacy	29 lm/W
Allowable CCTs	2700 K, 3000 K, 3500 K, 4000 K, 4500 K and 5000 K

Recessed downlights

Application Requirements	
Minimum Light Output	≤ 4" Aperture (nominal): 300 lumens (initial) > 4" Aperture (nominal): 500 lumens (initial)
Zonal Lumen Density Requirement	Luminaire shall deliver a minimum of 75% of total lumens (initial) within the 0-60° zone.
Minimum Luminaire Efficacy	35 lm/W
Allowable CCTs	• 2700 K, 3000 K and 3500 K for Residential products • No restrictions for Commercial
Reduced Air Leakage	Recessed downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E-283 to demonstrate no more than 2.0 cubic feet per minute (cfm) at 75 Pascals (1.57 lbs/ft2) pressure difference. The luminaire must include a label certifying "airtight" or similar designation to show air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283.

Outdoor wall-mounted porch lights

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 150 lumens (initial).
Zonal Lumen Density Requirement	Luminaire shall deliver a minimum of 85% of total lumens (initial) within the 0-90° zone.
Minimum Luminaire Efficacy	24 lm/W

Outdoor step lights

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 50 lumens (initial).
Zonal Lumen Density Requirement	Luminaire shall deliver a minimum of 85% of total lumens (initial) within the 0-90° zone.
Minimum Luminaire Efficacy	20 lm/W

Outdoor pathway lights

Application Requirements	
Minimum Light Output	Luminaire shall deliver a minimum of 100 lumens (initial).
Zonal Lumen Density Requirement	Luminaire shall deliver a minimum of 85% of total lumens (initial) within the 0-90° zone.
Minimum Luminaire Efficacy	25 lm/W

Category B: Future Performance Targets

Clarification of changes in Category B: The intent of Category B is to announce DOE's intent, well in advance, of substantially increasing future performance requirements, and to encourage continued improvement in technology selection and design of luminaires using SSL sources. Category B is not restricted to the applications in Category A. Products for a wide range of general illumination applications will be eligible.

The minimum luminaire efficacy target given for Category B is intended to rival today's most efficient lighting systems using traditional light sources. For example, the best commonly available high-performance T8 fluorescent lamp and electronic ballast systems are rated around 100 lm/W. High-quality fixtures for these lamp-ballast systems are about 70% efficient, yielding 70 lm/W luminaire efficacy.

Based on current commercially available technology, the Category B level of minimum luminaire efficacy is not achievable for LED luminaires. However, DOE anticipates performance will rise rapidly over the coming years due to on-going progress in LED efficacy, LED high temperature tolerance, driver efficiency improvements, and luminaire design.

DOE believes a significant number of general illumination products will be able to achieve 70 lm/W luminaire efficacy within three years after the effective date of these criteria. Accordingly, products will be allowed to begin qualifying under Category B requirements three years after the effective date of these criteria.

Comment on addition of future glare requirement: DOE understands that by setting the luminaire efficacy to high levels in the future there is the potential for luminaires to enter the market with high direct and indirect glare as manufacturers strive to increase luminaire efficacy by maximizing fixture efficiency. Current glare metrics such as Visual Comfort Probability (VCP), Unified Glare Rating (UGR), Glare Index (GI), etc. are based on subjective reports of discomfort for a particular application. In response to these concerns, DOE plans to engage the lighting industry to develop/recommend metrics for use in category B to manage objectionable glare.

Category B is established as a future target for performance of SSL-based luminaires. Products cannot qualify under Category B until three years after the effective date of these criteria.

Future Luminaire Efficacy Target:	
Luminaire Efficacy	≥ 70 lm/W
All Other Requirements:	
Glare requirements	To be developed
All other requirements will be the same as those in effect for Category A at the time Category B becomes effective, except for minimum light output and zonal lumen density requirements, which will not be used in Category B.	

Standards and Documentation

Comment on NVLAP accreditation: DOE expects the key standards and test procedures to be completed in mid-2007 and formally adopted by their respective organizations by Fall 2007. The process to accredit laboratories for the new test procedures can only be conducted once they have been formally approved. In addition, the time necessary to accredit laboratories may limit the available number of third-party laboratories to conduct testing in the near-term. DOE is funding NIST to address this potential shortcoming. However, in order to maintain the program schedule and meet the quality and performance expectations of program stakeholders, DOE will suspend the NVLAP accreditation requirement for a period of one year from the effective date. During this period of time, DOE will conduct an aggressive Quality Assurance (QA) program to insure the highest levels of conformance to the new standards and test procedures.

The NVLAP accreditation requirement will be suspended for a period of one year from the effective date of the criteria.

Performance Characteristic	Methods of Measurement Reference Standards	Required Documentation
Luminaire Efficacy: Light Output Input Power	IESNA LM-79-XX† ANSI C82.2	Laboratory test results must be produced using the specific device(s) and driver combination that will be used in production. Provide a test report from a laboratory accredited by NVLAP or one of its MRA signatories. **Note:** If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.

† Currently being developed by IESNA/ANSI Task Groups in coordination with DOE ENERGY STAR SSL program

Power Factor	ANSI C82.77	Laboratory test results must be produced using the specific device(s) and driver combination that will be used in production. Provide a test report from a laboratory accredited by NVLAP or one of its MRA signatories. **Note:** If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.
Lumen Depreciation (L_{70})	IESNA LM-80-XX†	Laboratory test results must be produced using the specific device(s) and driver combination that will be used in production. See the Qualification Process section below for additional information on Lumen Depreciation testing. Provide a test report from a laboratory accredited by NVLAP or one of its MRA signatories. **Note:** If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.
Color Rendering Index	ANSI C78.377A† IESNA LM-79-XX CIE 13.3-1995 IESNA LM-58	Laboratory test results must be produced using the specific device(s) and driver combination that will be used in production. Provide a test report from a laboratory accredited by NVLAP or one of its MRA signatories. **Note:** If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.

† Currently being developed by IESNA/ANSI Task Groups in coordination with DOE ENERGY STAR SSL program

Chromaticity and Correlated Color Temperature	IESNA LM-79-XX CIE 15: 2004 IESNA LM-58 IESNA LM-16	Laboratory test results must be produced using the specific device(s) and driver combination that will be used in production. Provide a test report from a laboratory accredited by NVLAP or one of its MRA signatories. **Note:** If the laboratory used for this test is accredited by NVLAP or one of its MRA signatories it must also have a scope of accreditation that includes the method of measurement reference standard for this performance characteristic.
Color Spatial Uniformity and Color Maintenance	IESNA LM-79-XX CIE 15: 2004 IESNA LM-58 IESNA LM-16	Self Certification **Note:** A laboratory test report must be submitted upon DOE request.
In-situ Driver/Driver Case Temperature	In-situ Driver/Driver Case Temperature Test	Self Certification **Note:** A laboratory test report must be submitted upon DOE request.
Noise	Class A sound rating: Driver not to exceed 24 dB	Self Certification **Note:** A laboratory test report must be submitted upon DOE request.
Luminaire Warranty		Provide copy of the actual three-year manufacturer luminaire warranty that is included in the packaging.
Safety Portable Fixtures Hardwired Fixtures	 ANSI/UL 153 UL 1598	Provide the cover page of a safety test report or a general coverage statement from an OSHA NRTL laboratory.

Qualification Process

Comment on allowing product variations: DOE received a number of comments concerning the requirement that all luminaires and all versions of those luminaires be tested as a condition of qualifying for ENERGY STAR. DOE understands the time and costs associated with testing all versions of a product. Accordingly, DOE has developed a product group qualification process that allows for limited variations between products tested for qualification and those to which the qualification applies.

In this approach, an applicant may group similar products. The applicant self-defines the product grouping and product variations to which the application applies. DOE would require and verify that all units in this family are essentially identical except for minor variations. Applicants would provide a single luminaire from this family for testing. So long as the product passed ENERGY STAR testing, the entire proposed product grouping would be qualified to carry the ENERGY STAR label.

However, this seemingly lenient approach to product qualification would be backed by an aggressive quality assurance (QA) program. DOE will aggressively test qualified products included in product groupings after their appearance in the market, focusing on models that exhibited characteristics making them likely to perform less well than the tested product. If a QA test found a non-complying product, the entire product grouping would be disqualified. If a QA test found a second test failure in another product grouping from the same applicant, that applicant's rights to use product grouping would be suspended for a year.

The approach combines up-front trust of applicants' product groupings with an uncompromising back-end QA program. DOE believes the price for failing QA testing is high enough to induce applicants into being conservative with their product grouping designations. DOE will encourage them to select for qualification testing the product in a proposed grouping least likely to meet program requirements. If applicants don't follow that advice, they are likely to be subject to product de-listings (which their retailers and distributors will learn about), and they will have to incur significant testing expense for individual product variation testing.

DOE believes this approach to be a reasonable compromise between the competing needs for robust qualification testing and acceptable applicant testing costs.

Comment on alternate testing procedures: Several stakeholders also expressed concerns about the requirements for luminaire testing, citing the additional time and expense this would add to the qualification process. The current status of LED technology and available test procedures preclude qualification of LED fixtures on the basis of platform (i.e., lamp-ballast or LED-driver) testing. There is too much variability in the way LEDs are integrated into fixtures and this integration materially impacts LED performance. Further, the first industry standard photometric test procedure under development is designed to test complete luminaires. At this early stage of LED development, DOE believes quality and end user satisfaction will be best served by qualifying luminaires, rather than platforms. DOE welcomes engagement and industry dialogue on streamlining and simplifying the testing procedures, while still capturing the necessary photometric, electrical, and colorimetric information necessary to ensure product quality and efficiency. Following adoption of these criteria, DOE will convene a process to develop alternative testing approaches, inviting participation by lighting manufacturers, lighting testing laboratories, and research institutions.

Product Variations

In recognition of the significant component substitution that occurs on a manufacturing production line, and in recognition of a range of product variations that may or may not have a material affect on product performance, these criteria allow for limited variation between products tested for qualification purposes, and products qualified as a result of those tests.

Applicants may choose to qualify product groups as a single SKU (one SKU, some variations) or a SKU family (multiple SKUs, some variations). Applicants self define product groupings. Under either option, qualified products must be essentially identical to the tested product. Only limited variation is allowed. The table below summarizes allowable variations.

Variations Within Product Groupings	
Housing/Chassis	not allowed
Heat Sink/Heat Management	not allowed
Finish	allowed
Reflector/Trim	allowed
Shade/Diffuser	allowed
Light Source	allowed, w/ conditions
Driver	allowed, w/ conditions

As seen in the table, housing/chassis variations and heat sink/heat management component variations are not allowed, whether applying for a single SKU or SKU family, because they may materially impact LED performance. Finish, reflector/trim, and shade/diffuser variations are allowed. Light source and driver variations are allowed, subject to conditions described below.

Products qualified under a single application may include LED device(s)/array(s) and drivers from more than one manufacturer, but the LED device(s)/array(s) and drivers must be substitutable components used to manufacture essentially identical luminaires and must be intended to produce the same quantity and quality of light. LED device(s)/array(s) and driver substitutions intended to produce different CCT, CRI, total flux, and other quantitative and qualitative differences in light may not be included in a single product grouping. Further, all LED device(s)/array(s) substitution components must separately comply with the Option 1 (Component Performance) requirements in the Lumen Depreciation section below.

Lumen Depreciation Qualification

The LM-80 test procedure prescribes lumen depreciation testing for the device(s)/array(s) and/or the luminaire. The applicant may demonstrate compliance with either Option 1 (Component Performance) or Option 2 (Luminaire Performance).

OPTION 1: Component Performance

The Component Performance option allows the applicant to demonstrate compliance with the lumen depreciation requirement by demonstrating an LM-80 tested light source (device(s)/array(s)) operates at or below specified temperatures when operated in situ. To be eligible for the component performance option, **ALL** three of the conditions below must be met. If **ANY** of the conditions are not met, the component performance option may not be used and the applicant must use the luminaire performance option for compliance.

1. The LED device(s)/array(s) used in the fixture has/have been tested according to LM-80, and the device(s)/array(s) demonstrated an L_{70} lumen maintenance of 35,000 hours or greater.
2. The device(s)/array(s) manufacturer prescribes/indicates a temperature measurement location on the device(s)/array(s).
3. The device(s)/array(s) temperature measurement location is accessible to allow temporary

attachment of a thermocouple for measurement of in situ temperature. Access via a temporary hole in the housing, tightly resealed during testing with putty or other flexible sealant is allowable.

The luminaire **PASSES** the Lumen Depreciation requirements if:

1. The device(s)/array(s) temperature measured in situ, at the specified temperature measurement location is less than or equal to the temperature(s) specified in the LM-80 test report for the corresponding drive current or higher.
2. The drive current measured in the fixture is less than or equal to the drive current specified in the LM-80 test report at the corresponding temperature or higher.

OPTION 2: Luminaire Performance

The applicant demonstrates compliance with the lumen depreciation requirement by submitting an LM-80 test report for the entire luminaire. The test report must demonstrate an L_{70} lumen maintenance of 35,000 hours or greater.

In-situ Driver/Driver Case Temperature Qualification

The In-situ Driver/Driver Case Temperature Test measures the steady-state temperature of the driver when operated in situ. The luminaire passes the In-situ Driver/Driver Case Temperature Test if the driver/driver case temperature measured, in situ, at the driver/driver case temperature measurement location is less than or equal to the warranted temperature specified by the driver manufacturer.

Qualification Procedures

DOE will separately develop a document describing the specifics of qualification procedures, including application forms.

Quality Assurance Testing

If a product qualified under a Single SKU product grouping or SKU Family product grouping fails QA testing the entire product grouping is de-listed. If two or more variations of a product qualified under a product grouping fail QA testing, the applicant is placed on a probationary list. Applicants on the probationary list temporarily have their rights to use of product groupings suspended. They must individually qualify each unique product, including light source and driver variations within a single SKU. An applicant is removed from the probationary list after one year, making it once again eligible to qualify for product groupings. Applicants will be returned to the probationary list if two or more of their product groupings subsequently fail QA tests.

To limit the probability of test failure during QA testing and subsequent suspension of product grouping qualification rights, applicants are advised to test and qualify the least efficient version of luminaires covered by a single application, and to only use substitute components during manufacturing that perform at least as well as components used in products tested for qualification.

A separate document will be developed by DOE to define the specifics of the quality assurance testing (QA) intended to accompany these criteria.

Effective Date

The effective date for the ENERGY STAR Program Requirements and Criteria for SSL – Version 1.0 will be

(to be determined). However, DOE will not make the criteria effective until all referenced standards and test procedures are in effect. Therefore DOE reserves the right to delay the effective date in the event the relevant standards are not in place by (to be determined).

Future Specification Revisions

Due to the rapid pace of LED technology development, DOE anticipates regular revisions to these criteria. DOE anticipates that new applications will be added to the criteria as LED performance and efficacy improve. Revisions will be announced to all partners with time for input and review.

Appendix

Definitions

A. **A2LA**: American Association for Laboratory Accreditation.
B. **ALA**: American Lighting Association.
C. **ANSI**: American National Standards Institute.
D. **ASSIST**: Alliance for Solid State Illumination Systems and Technologies.
E. **ASTM**: American Society for Testing of Materials.
F. **Automatic daylight shutoff**: A photocell device that automatically prevents operation of a luminaire during daylight hours.
G. **CIE**: Commission Internationale de l'Eclairage (translated International Commission on Illumination).
H. **Color appearance**: The actual color of the lamp is called the color appearance and is defined in terms of the spectral tri-stimulus values (color coordinates) according to the recommendations of the CIE Publication No. 13.3 – 1995. For color coordinates near the black body loci, the correlated color temperature (Kelvin) can be used to define color appearance.
I. **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.
J. **Commercial luminaire**: A luminaire using a Class A power supply.
K. **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 Black Body loci, the correlated color temperature, measured in Kelvin (K), is used.
L. **CSA**: Canadian Standards Association.
M. **Device**: The LED package containing the die, encapsulant, internal optics, electrical connections and heat sinking that delivers light.
N. **Driver**: A device used with light emitting diodes to obtain the necessary circuit conditions (voltage, current, and waveform) for starting and operating.
O. **IEC**: International Electrotechnical Commission.
P. **IESNA**: Illuminating Engineering Society of North America.
Q. **Initial performance values**: The photometric and electrical characteristics at the end of the 100-hour aging period.
R. **LED lumen depreciation (L_{70})**: The length of time declared by the manufacturer at which 70% lumen maintenance of any large number of LEDs is reached.
S. **Luminaire**: A complete lighting unit consisting of an LED(s) and driver(s) together with the parts designed to distribute the light, position and protect the LEDs, and connect the LEDs to the power supply.
T. **Luminaire Efficacy**: The luminous flux of the luminaire divided by the input wattage.
U. **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.
V. **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 (è) specified in Table 1 and 2 of ANSI C78.376-2004, and a defined variance of four steps.
W. **Minimum operating temperature**: The minimum temperature at which the driver will reliably operate.
X. **MRA**: Mutual Recognition Arrangement.
Y. **NVLAP**: National Voluntary Laboratory Accreditation Program.
Z. **Portable luminaire**: A luminaire whose power supply connection is made by means of a cord with or without a plug.
AA. **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).
BB. **Rated luminous flux or lumen output**: Initial lumen rating (based on the measured 100-hour lumens), which is declared by the manufacturer.
CC. **Recessed downlight**: General purpose luminaire designed to provide general or ambient lighting in a space. They are recessed into the ceiling and are designed to produce illuminance on a floor or workplane.

The luminaire encompasses the fixture housing, reflector, trim ring, and light source. For purposes of the ENERGY STAR SSL Luminaires criteria, two categories of recessed downlights are referenced:

1. Recessed downlight fixture housing – the complete luminaire installed in new construction or major renovation.
2. Recessed downlight trim – refers to the portion of the recessed downlight luminaire visible from below the ceiling, including the reflector, trim ring, light source, and parts necessary to connect the trim to the fixture housing. The trim kit can often be used to retrofit an existing recessed downlight fixture housing.

DD. **Residential luminaire**: A luminaire using a Class B power supply.

EE. **UL:** Underwriters Laboratories

Reference Standards and Test Procedures

Standards and Test Procedures in BLUE are currently under development.

Reference Standards and Test Procedures		
Organization	Identifier	Description
ANSI	ANSI C82.XXX	Electronic Drivers for LED Devices, arrays, or systems (In development).
ANSI	ANSI C78.377A	Specifications for the Chromaticity of Solid State Lighting Products (In development).
ANSI	ANSI C82.77 - 2002	Harmonic Emission Limits – Related Power Quality Requirements for Lighting
ANSI	ANSI/IEEE C62.41 - 1991	Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
ANSI/UL	ANSI/UL 153 - 2005	Portable Electric Luminaires
ASTM	ASTM E 283 - 2004	Restricted air movement
CIE	CIE Pub. No. 13.3 - 1995	Method of Measuring and Specifying Color Rendering of Light Sources
FCC	FCC 47 CFR	Electromagnetic interference
IESNA	IESNA LM-16	Correlated Color Temperature
IESNA	IESNA LM-58	Color Rendering Index and Correlated Color Temperature
IESNA	IESNA LM-79	Approved Method for the Electrical and Photometric Testing of Solid-State Lighting Devices (In Development)
IESNA	IESNA LM-80	Lumen Depreciation of LED Light Sources (In Development)
NFPA	NFPA 70 - 2005	National Electric Code
UL	UL 1012 - 2005	Power Units Other Than Class 2
UL	UL 1310 - 2005	Class 2 Power Units
UL	UL 1598 - 2004	Luminaires
UL	UL 1838 - 2002	Low Voltage Landscape Lighting Systems
UL	UL 1994 - 2005	Luminous Egress Path Marking Systems

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 C78.377A 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

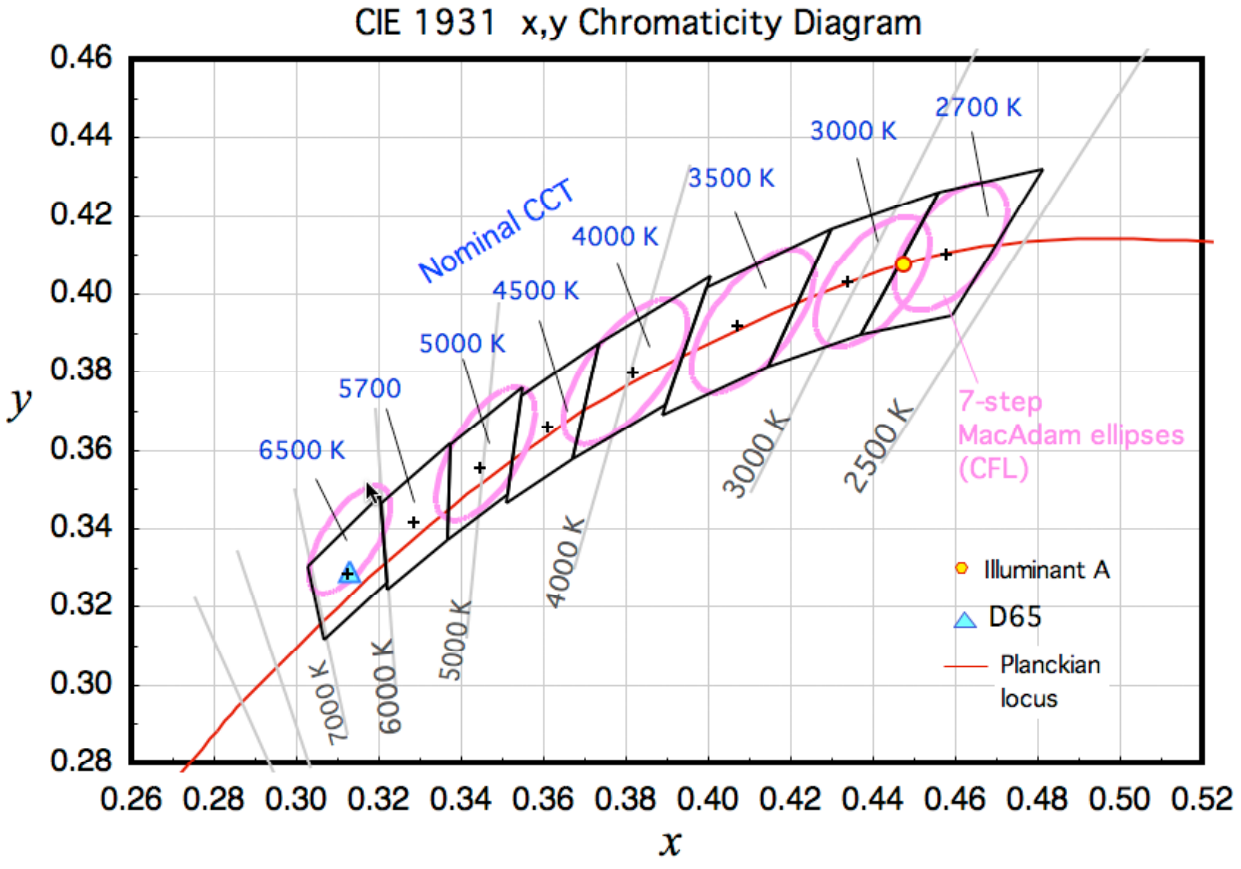

Figure 1. CIE 1931 Chromaticity Diagram Showing the Eight Nominal CCT Quadrangles