Draft ENERGY STAR SSL Criteria

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Overview

• Key Considerations
  – Scope of the criteria

• Overall Requirements

• Category A Proposed Criteria

• Category B Proposed Criteria
Key Considerations

• General illumination applications only
  – Not indication or decoration
  – Not monochromatic light

• Residential and commercial applications

• Based on current and expected white LED performance

• Designed to ensure energy efficiency relative to existing light sources
Terms

Lamp Efficacy = \(\frac{\text{Rated Lamp Lumens}}{\text{Lamp Input Power}}\)

System Efficacy\(_{\text{fluor}}\) = \(\frac{\text{Rated Lamp Lumens} \times BF}{\text{Ballast/Driver Input Power}}\)

Luminaire Efficacy = \(\frac{\text{Luminaire Light Output}}{\text{Ballast/Driver Input Power}}\)
Luminaire Efficacy: Measurement

• Photometric measurement of LED fixture
  – Based on new ANSI/IESNA LM-79 standard in process
• Measure total light output
• Measure input power
• Calculate luminaire efficacy as lm/W
Chromaticity and Correlated Color Temperature

• Draft ANSI Chromaticity Standard C78.377A in process
  – 8 nominal CCTs
  – Flexible color option
  – Uses chromaticity quadrangles
Draft ANSI Chromaticity Standard

<table>
<thead>
<tr>
<th>Nominal CCT</th>
<th>CCT (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2700 K</td>
<td>2725 ± 145</td>
</tr>
<tr>
<td>3000 K</td>
<td>3045 ± 175</td>
</tr>
<tr>
<td>3500 K</td>
<td>3465 ± 245</td>
</tr>
<tr>
<td>4000 K</td>
<td>3985 ± 275</td>
</tr>
<tr>
<td>4500 K</td>
<td>4503 ± 243</td>
</tr>
<tr>
<td>5000 K</td>
<td>5028 ± 283</td>
</tr>
<tr>
<td>5700 K</td>
<td>5665 ± 355</td>
</tr>
<tr>
<td>6500 K</td>
<td>6530 ± 510</td>
</tr>
<tr>
<td>Flexible CCT (2700-6500 K)</td>
<td>$T^{(2)} ± \Delta T^{(3)}$</td>
</tr>
</tbody>
</table>

(2) $T$ is chosen to be at 100 K steps (2800, 2900, ..., 6400 K), excluding the eight nominal CCTs listed.

(3) $\Delta T$ is given by: $\Delta T = 0.0000108 \times T^2 + 0.0262 \times T + 8$
CIE 1976 u’-v’ diagram
Example of 3200K product

CIE 1931 x,y Chromaticity Diagram

An example at CCT = 3200 K

Range of Flexible Color

7-step MacAdam ellipses (CFL)

Nominal CCT 3200 K

Min CCT 2998
Max CCT 3402
Center Duv 0.0002

4 corners (x,y)

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4464</td>
<td>0.4234</td>
</tr>
<tr>
<td>0.4180</td>
<td>0.4116</td>
</tr>
<tr>
<td>0.4046</td>
<td>0.3774</td>
</tr>
<tr>
<td>0.4289</td>
<td>0.3871</td>
</tr>
</tbody>
</table>
Color Rendering Index

- A flawed metric, especially with respect to RGB LEDs
- ENERGY STAR will continue to use CRI until the lighting industry develops a new metric
- DOE is supporting NIST in standard and test procedure development
Overall Requirements

• Color Spatial Uniformity
  – Shall be within 0.004 on CIE u'v' diagram

• Color Maintenance
  – Shall be within 0.007 on CIE u'v' diagram over its lifetime

• Useful Life (L$_{70}$)
  – ANSI/IESNA LM-80 Lumen depreciation LED Light Sources (in process)
  – L$_{70}$ ≥ 35,000 hours
Overall Requirements (cont.)

• Warranty
  – 3 years

• Thermal Management
  – Follow device manufacturer guidelines

• Residential Outdoor Automatic Daylight Control
  – Luminaires > 13 watts must have photosensor
Overall Requirements (cont.)

- **Drivers**
  - Power factor $\geq 0.90$
  - Minimum operating temperature shall be -20°C or lower
  - Maximum measured in-situ case temperature shall not exceed driver manufacturer warranty
  - EMI/RFI  FCC 47 CFR Part 15
    - Consumer limits (residential)
    - Non-consumer limits (commercial)
- **Noise**
  - Class A sound rating
Category A: Niche Applications

- Directed light applications
  - Energy efficiency potential due to directional light source
  - Minimize fixtures losses
- Source relatively close to illuminated surface
- Application requires relatively modest illuminance requirements
- Typically ≤ 50% fixture efficiency
Category A: Overall Approach

• Establish minimum luminaire efficacy
  – Benchmark to fluorescent
    • Consistent with current ENERGY STAR lighting criteria
  – Use ASHRAE/IESNA 90.1 Lighting sub-committee consensus system efficacy for CFL
    • 58 lm/W
    • 50 lm/W (lower wattage applications and E* min.)
  – Use IES recommendations wherever possible: Handbook, RP-33-99, etc.
Category A: Overall Approach (cont.)

- Surveyed existing products in the marketplace for:
  - Fixture efficiency
  - Light Output
  - Photometry
  - Lamp, lamp/ballast wattage

• Establish minimum net light output
• Establish zonal lumen density requirement
Category A: Niche Applications

1. Undercabinet Kitchen
2. Undercabinet Shelf-mounted Task
3. Portable Desk/Task
4. Outdoor Wall-mounted Porch
5. Outdoor Step
6. Outdoor Pathway
7. Recessed Downlights
Formula used for Determining Category A Luminaire Efficacy

\[
\text{Luminaire Efficacy} = \frac{\text{Typical Fixture Efficiency}}{\text{Application CRI}} \times \frac{\text{CFL Efficacy}}{0.8}
\]

Given comments received to date and the fast pace with which LED efficacy is improving, DOE will drop the denominator, thus the equation simplifies to:

\[
\text{Luminaire Efficacy} = \text{Typical Fixture Efficiency} \times \text{CFL Efficacy}
\]
# Assumptions for Establishing Luminaire Efficacy

<table>
<thead>
<tr>
<th>Niche Application</th>
<th>CFL System Efficacy</th>
<th>Typical Fixture Efficiency</th>
<th>CRI</th>
<th>Calculated Luminaire Efficacy</th>
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</thead>
<tbody>
<tr>
<td>Under-cabinet Kitchen</td>
<td>58</td>
<td>40%</td>
<td>80</td>
<td>23</td>
</tr>
<tr>
<td>Under-cabinet Shelf-mounted Task</td>
<td>58</td>
<td>50%</td>
<td>80</td>
<td>29</td>
</tr>
<tr>
<td>Portable Task</td>
<td>58</td>
<td>50%</td>
<td>80</td>
<td>29</td>
</tr>
<tr>
<td>Outdoor Wall-mounted Porch</td>
<td>58</td>
<td>40%</td>
<td>70</td>
<td>27*</td>
</tr>
<tr>
<td>Outdoor Step</td>
<td>50</td>
<td>40%</td>
<td>70</td>
<td>23*</td>
</tr>
<tr>
<td>Outdoor Pathway</td>
<td>50</td>
<td>50%</td>
<td>70</td>
<td>29*</td>
</tr>
<tr>
<td>Recessed Downlight (res)</td>
<td>58</td>
<td>50%</td>
<td>80</td>
<td>29</td>
</tr>
<tr>
<td>Recessed Downlight (com)</td>
<td>58</td>
<td>50%</td>
<td>70</td>
<td>33*</td>
</tr>
</tbody>
</table>

* To be amended
Undercabinet

- Residential kitchens
- Commercial offices
- Photometry available for commercial products
- Provide task lighting on countertop or desk
Category A: Under-cabinet Lighting

Albeo Talea

EnbrytenLED ENBU
Under-cabinet Kitchen

- **Minimum Light Output**
  - 150 lumens per lineal foot
- **Zonal Lumen Density**
  - No more than 75% of total light output within 0-60° zone
- **Luminaire Efficacy**
  - $\geq 23 \text{ lm/W}$
- **CRI**
  - $\geq 80$
Under-cabinet Shelf Mounted Task

- **Minimum Light Output**
  - 150 lumens per lineal foot

- **Zonal Lumen Density**
  - No more than 75% of total light output within 0-60° zone

- **Luminaire Efficacy**
  - ≥ 29 lm/W

- **CRI**
  - ≥ 80
Iso-footcandle Plot
Grayscale Rendering
## Existing Undercabinet Performance

<table>
<thead>
<tr>
<th>Halogen</th>
<th>Fixture Input Watts</th>
<th>Lamp Type</th>
<th># of lamps</th>
<th>Lamp Rated Lumens</th>
<th>Source Rated Lumens</th>
<th>System Efficacy</th>
<th>Fixture η (down)</th>
<th>Net Lumens 0-60°</th>
<th>App. Efficacy</th>
<th>Fixture Length</th>
<th>App. Lumens per lin. ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALKCO LIGHTING -- HG23-SGD</td>
<td>60</td>
<td>T-3 Halogen</td>
<td>3</td>
<td>320</td>
<td>960</td>
<td>16.0</td>
<td>53.3%</td>
<td>443.1</td>
<td>7.39</td>
<td>1.91</td>
<td>232</td>
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<tr>
<td>ALKCO LIGHTING -- LH22</td>
<td>75</td>
<td>T-4 Halogen</td>
<td>3</td>
<td>170</td>
<td>510</td>
<td>6.8</td>
<td>58.9%</td>
<td>245.7</td>
<td>3.28</td>
<td>1.8</td>
<td>137</td>
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<tr>
<td>Xenon</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ALKCO LIGHTING -- XN12</td>
<td>50</td>
<td>T-3.25 Xenon</td>
<td>5</td>
<td>91</td>
<td>455</td>
<td>9.1</td>
<td>74.5%</td>
<td>216.1</td>
<td>4.32</td>
<td>0.98</td>
<td>221</td>
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<tr>
<td>T8</td>
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<tr>
<td>Columbia - UC48-132</td>
<td>30</td>
<td>F32T8</td>
<td>1</td>
<td>2900</td>
<td>2900</td>
<td>96.7</td>
<td>52.2%</td>
<td>1037</td>
<td>34.57</td>
<td>4</td>
<td>259</td>
</tr>
<tr>
<td>Fail-Safe -</td>
<td>27</td>
<td>F25T8</td>
<td>1</td>
<td>2150</td>
<td>2150</td>
<td>79.6</td>
<td>67.3%</td>
<td>1222</td>
<td>45.26</td>
<td>3</td>
<td>407</td>
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<tr>
<td>ALKCO - 332</td>
<td>35</td>
<td>F32T8</td>
<td>1</td>
<td>2900</td>
<td>2900</td>
<td>82.9</td>
<td>49.0%</td>
<td>1018.4</td>
<td>29.10</td>
<td>4.01</td>
<td>254</td>
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<tr>
<td>T5</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Lithonia -- TTL 2L8 120 GEB</td>
<td>15</td>
<td>F8T5</td>
<td>2</td>
<td>400</td>
<td>800</td>
<td>53.3</td>
<td>43.6%</td>
<td>241.7</td>
<td>16.11</td>
<td>1.3</td>
<td>186</td>
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<tr>
<td>Lithonia – UC42</td>
<td>31</td>
<td>F13T5</td>
<td>2</td>
<td>850</td>
<td>1700</td>
<td>54.8</td>
<td>38.1%</td>
<td>481.7</td>
<td>15.54</td>
<td>3.5</td>
<td>138</td>
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<tr>
<td>Lithonia - UC24</td>
<td>19</td>
<td>F8T5</td>
<td>2</td>
<td>400</td>
<td>800</td>
<td>42.1</td>
<td>38.1%</td>
<td>226.5</td>
<td>11.92</td>
<td>2</td>
<td>113</td>
</tr>
<tr>
<td>ALKCO - HP113</td>
<td>16</td>
<td>F13T5</td>
<td>1</td>
<td>833</td>
<td>833</td>
<td>52.1</td>
<td>50.5%</td>
<td>308.8</td>
<td>19.30</td>
<td>1.77</td>
<td>174</td>
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<tr>
<td>ALKCO - HP128</td>
<td>33.8</td>
<td>F28T5</td>
<td>1</td>
<td>2900</td>
<td>2900</td>
<td>85.8</td>
<td>59.8%</td>
<td>1283.4</td>
<td>37.97</td>
<td>3.85</td>
<td>333</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ALKCO - SQ113</td>
<td>16</td>
<td>T-2 FM13</td>
<td>1</td>
<td>860</td>
<td>860</td>
<td>53.8</td>
<td>62.1%</td>
<td>381.4</td>
<td>23.84</td>
<td>1.89</td>
<td>202</td>
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<tr>
<td>ALKCO - SQ213</td>
<td>30.5</td>
<td>T-2 FM13</td>
<td>2</td>
<td>860</td>
<td>1720</td>
<td>56.4</td>
<td>63.5%</td>
<td>790.40</td>
<td>25.91</td>
<td>3.65</td>
<td>217</td>
</tr>
</tbody>
</table>
Portable Desk/Task

- Plug-in portable fixtures
- Wide variety of styles and prices
- Photometry typically not available
- Provide supplemental task lighting on desk or other horizontal work surface
Category A: Portable Desk/Task

6 Watt LED Desk Lamp

Halley LED Desk Lamp
Portable Desk Task Lamps

- **Minimum Light Output**
  - 200 lumens

- **Zonal Lumen Density**
  - Minimum 85% of total light output within 0-60° zone

- **Luminaire Efficacy**
  - ≥ 29 lm/W

- **CRI**
  - ≥ 80
Outdoor Wall-mounted Porch

- **Minimum Light Output**
  - 200 lumens
- **Zonal Lumen Density**
  - Minimum 85% of total light output within 0-90° zone
- **Luminaire Efficacy**
  - ≥ 27 lm/W
- **CRI**
  - ≥ 70
Category A: Outdoor Step
Outdoor Step

- **Minimum Light Output**
  - 100 lumens (initial)
- **Luminaire Efficacy**
  - $\geq 23 \text{ lm/W}$
- **CRI**
  - $\geq 70$

No Requirement
Category A: Outdoor Pathway

Alpha

Delta

Advanced LED Ltd.
Outdoor Pathway

- **Minimum Light Output**
  - 100 lumens (initial)
- **Zonal Lumen Density**
  - Minimum 85% of total light output within 0-90° zone
- **Luminaire Efficacy**
  - $\geq 29$ lm/W
- **CRI**
  - $\geq 70$
Recessed Downlights

• Most common residential installed fixture
  – Insulated ceilings result in high temp environment
• Also very common in commercial buildings
• Ambient lighting
Recessed Downlights

- **Minimum Light Output**
  - $\leq 4''$ Aperture 300 lumens
  - $> 4''$ Aperture 500 lumens

- **Zonal Lumen Density**
  - Minimum 85% total light output within 0-60° zone

- **Luminaire Efficacy**
  - $\geq 29$ lm/W (residential)
  - $\geq 33$ lm/W (commercial)

- **CRI**
  - $\geq 80$ (residential)
  - $\geq 70$ (commercial)
Category B: Luminaire Efficacy Based Performance

- Establishes threshold 1-3 years out
- Exceed efficacy of best CFLs
- No application efficiency requirement
  - No minimum net lumens nor zonal lumen density requirements
- Based on luminaire efficacy
  - Total luminaire lumens/total luminaire watts
LED Efficacy and Color

Production LEDs

as of 7/06
Category B: Performance-Based Specification

<table>
<thead>
<tr>
<th>CCT</th>
<th>Luminaire Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 3000K )</td>
<td>( \geq 50 \text{ lm/W} )</td>
</tr>
<tr>
<td>( 3000K &lt; \text{CCT} \leq 5000K )</td>
<td>( \geq 60 \text{ lm/W} )</td>
</tr>
<tr>
<td>( &gt; 5000K )</td>
<td>( \geq 70 \text{ lm/W} )</td>
</tr>
</tbody>
</table>

• CRI
  – Indoor Luminaires \( \geq 80 \)
  – Outdoor Luminaires \( \geq 70 \)
The Path Forward

• Stakeholder meeting: February 8, 2007
• Issue second draft: March 2007
• Complete final criteria: July 2007
• Effective date: December 2007
Q & A

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