GREENBUILD 2011
LED T8 Replacement Lamps: How well do they compete?

Naomi Miller, FIES, FIALD, LC
Senior Lighting Engineer
Pacific Northwest National Laboratory

GreenBuild
October 2011
LEDs – Offer so much promise
Marketplace for lamps in T8 and T12 fixtures is huge

LED Manufacturers claim
• Longer life than fluorescent
• Better color than fluorescent
• Higher efficacy than fluorescent
• No ballasts to be replaced
• No recycling costs on spent lamps

Can these LED lamps be a viable replacement technology?
LED T8 Replacement lamps

Steps in GATEWAY study

Selected best LED T8s from CALiPER studies. Criteria:
• Wide light distribution
• High LPW
• High lumen output
• Timely arrival to test site

CALiPER 9-107

CALiPER 10-16

CALiPER 10-18
# LED T8 Replacement Lamps

<table>
<thead>
<tr>
<th>Thumbnail</th>
<th>Light Source</th>
<th>Category</th>
<th>Round</th>
<th>Test Date</th>
<th>CAL/PER Reference #</th>
<th>Power (W)</th>
<th>Initial Light Output (lm)</th>
<th>Initial Efficacy (lm/W)</th>
<th>CCT (K)</th>
<th>CRI</th>
<th>Power Factor</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Fluorescent Lamp" /></td>
<td>Fluorescent</td>
<td>Replacement Lamp (48” linear in situ) Fluorescent</td>
<td>11</td>
<td>04/2010</td>
<td>09-67U</td>
<td>55</td>
<td>4,045</td>
<td>74</td>
<td>1.00</td>
<td>View Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td><img src="image2" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>07/2010</td>
<td>09-107</td>
<td>22</td>
<td>1,539</td>
<td>70</td>
<td>3,548</td>
<td>73</td>
<td>0.57</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image3" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>07/2010</td>
<td>10-16</td>
<td>15</td>
<td>1,368</td>
<td>93</td>
<td>5,389</td>
<td>77</td>
<td>0.73</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image4" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear in situ)</td>
<td>11</td>
<td>07/2010</td>
<td>10-16T</td>
<td>29</td>
<td>2,173</td>
<td>74</td>
<td></td>
<td></td>
<td></td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image5" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>07/2010</td>
<td>10-17</td>
<td>19</td>
<td>1,362</td>
<td>70</td>
<td>3,249</td>
<td>65</td>
<td>0.61</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image6" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear in situ)</td>
<td>11</td>
<td>07/2010</td>
<td>10-17T</td>
<td>39</td>
<td>2,194</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image7" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>07/2010</td>
<td>10-18</td>
<td>17</td>
<td>1,533</td>
<td>91</td>
<td>5,602</td>
<td>75</td>
<td>0.94</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image8" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>07/2010</td>
<td>10-19</td>
<td>22</td>
<td>1,951</td>
<td>90</td>
<td>5,253</td>
<td>71</td>
<td>0.99</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image9" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear in situ)</td>
<td>11</td>
<td>07/2010</td>
<td>10-19T</td>
<td>43</td>
<td>3,247</td>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image10" alt="Fluorescent Lamp" /></td>
<td>Fluorescent</td>
<td>Replacement Lamp (48” linear) Fluorescent</td>
<td>11</td>
<td>08/2010</td>
<td>10-34</td>
<td>32</td>
<td>3,353</td>
<td>105</td>
<td>3,387</td>
<td>82</td>
<td>0.99</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image11" alt="Fluorescent Lamp" /></td>
<td>Fluorescent</td>
<td>Troffer (24” x 48” panel) Fluorescent</td>
<td>11</td>
<td>08/2010</td>
<td>10-34T</td>
<td>38</td>
<td>2,708</td>
<td>71</td>
<td></td>
<td></td>
<td></td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image12" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear)</td>
<td>11</td>
<td>10/2010</td>
<td>10-36</td>
<td>18</td>
<td>1,628</td>
<td>90</td>
<td>4,300</td>
<td>70</td>
<td>0.86</td>
<td>View Report</td>
</tr>
<tr>
<td><img src="image13" alt="SSL Lamp" /></td>
<td>SSL</td>
<td>Replacement Lamp (48” linear in situ)</td>
<td>11</td>
<td>10/2010</td>
<td>10-36T</td>
<td>36</td>
<td>2,785</td>
<td>78</td>
<td></td>
<td></td>
<td></td>
<td>View Report</td>
</tr>
</tbody>
</table>
### LED T8 replacement products

<table>
<thead>
<tr>
<th>Product</th>
<th>Measured Wattage</th>
<th>Measured Power Factor</th>
<th>CALiPER Test No.*</th>
<th>Luminous Flux (lumens)*</th>
<th>CCT*</th>
<th>CRI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED01</td>
<td>18.5 W</td>
<td>0.78</td>
<td>(**)</td>
<td>1453**</td>
<td>5638K**</td>
<td>75.6**</td>
</tr>
<tr>
<td>LED02</td>
<td>17.0 W</td>
<td>0.86</td>
<td>10-16</td>
<td>1366</td>
<td>5394K</td>
<td>77.1</td>
</tr>
<tr>
<td>LED03</td>
<td>22.0 W</td>
<td>0.58</td>
<td>09-107</td>
<td>1539</td>
<td>3548K</td>
<td>72.9</td>
</tr>
</tbody>
</table>

*Shaded cells indicate results derived from separate testing of these products by the CALiPER testing program, except LED01 (**) where CALiPER had tested a preceding generation of the product. This earlier generation product corresponds to CALiPER product test 10-18. Values provided for reference only.
LED T8 Replacement lamps

Steps in GATEWAY study

Baselines:
• Fluorescent 32W 735 T8s with IS electronic ballast
• Fluorescent 34W CW T12s with HPF magnetic ballast

Compared
• (3) T8 LED products with ballast disconnected
• (1) T8 25W SS XL/XP on same IS electronic ballast
• (1) T8 32W XL/XP 835 with new LBF High Efficiency IS ballast
LED T8 Replacement lamps

Steps in GATEWAY study

Compared to T8 and T12 lamps in conventional recessed fluorescent troffers
- 2 and 3 lamp prismatic lens, IS electronic ballast
- 2 and 3 lamp semi-spec parabolic louver, IS electronic ballast
- 2 and 3 lamp basket fixture, IS electronic ballast
- 2-lamp “volumetric,” “non-planar,” “prismatic high-lumen” fixture, IS electronic ballast
LED T8 Replacement lamps

Steps in GATEWAY study

Installed in mock-up space at Seattle Lighting Design Lab
• 16’ x 16’ x 9’ ceiling
• 75-50-20 reflectances
• 30” work plane height
• 4 troffers, spaced 8’ o.c.
LED T8 Replacement lamps

Steps in GATEWAY study

Illuminance measurements (footcandles)
- Horizontal illum on 30” workplane grids
- Vertical illum on walls 4’ to 6’ above floor

Power measurements (Watts) for each luminaire combination
Power factor
## Results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline T8 (735) FL</td>
<td>2.00</td>
<td>28.5</td>
<td>2800</td>
<td>0.88</td>
<td>86.5</td>
<td>39.1</td>
<td>22.2</td>
</tr>
<tr>
<td>High lumen T8 FL, low BF</td>
<td>4.55</td>
<td>25.0</td>
<td>3100</td>
<td>0.78</td>
<td>96.7</td>
<td>38.3</td>
<td>23.3</td>
</tr>
<tr>
<td>Obsolete T12</td>
<td>1.85</td>
<td>38.0</td>
<td>2650</td>
<td>0.95</td>
<td>77.5</td>
<td>36.9</td>
<td>22.2</td>
</tr>
<tr>
<td>LED 01</td>
<td>89.69</td>
<td>18.5</td>
<td>1400</td>
<td>N/A</td>
<td>75.7</td>
<td>31.1</td>
<td>17.9</td>
</tr>
<tr>
<td>LED 02</td>
<td>63.75</td>
<td>17.0</td>
<td>1343</td>
<td>N/A</td>
<td>79.0</td>
<td>28.9</td>
<td>16.2</td>
</tr>
<tr>
<td>LED 03</td>
<td>120.00</td>
<td>22.0</td>
<td>1590</td>
<td>N/A</td>
<td>72.3</td>
<td>31.2</td>
<td>17.5</td>
</tr>
<tr>
<td>Comparison 25W T8 FL***</td>
<td>5.50</td>
<td>22.5***</td>
<td>2400</td>
<td>0.88</td>
<td>93.9</td>
<td>34.6***</td>
<td>19.6***</td>
</tr>
</tbody>
</table>

**Compare lamp cost, power, LPW, footcandles**
Results – Higher FC from fluorescent, lower W from LED
– LEDs don’t perform well in basket fixtures
LED T8 Replacement lamps

Results – Better workplane FC uniformity from fluorescent in prismatic and parabolic troffers
Results – Better FC uniformity on wall from fluorescent in parabolic troffers; other troffers equivalent

**Vertical Avg to Min Illuminance**

2-Lamp Luminaires

- LED
- FL T8
- FL T12

**Avg to Min Ratio**

- Prismatic LED
- Parabolic LED
- Basket LED
- Prismatic (T12)
- Prismatic T8
- Parabolic T8
- Basket T8
- Prismatic T8 (High Lumen)
- Parabolic T8 (High Lumen)
- HP Lensed
LED T8 Replacement lamps

- LED T8 Fluorescent lamps often change intended light distribution

- Always test the specific lamp with the specific luminaire
Results – Energy Efficiency

- IF LED lamp output could be increased to deliver same workplane FC, and they didn’t affect light distribution, then they **could** be viable in terms of delivered FC-per-watt.

**Power Savings vs. Std T8**

2-Lamp w/Same Horizontal Illuminance
Results – Life Cycle Cost Input

- $0.11/kwh melded electrical rate
- RS Means derived spot and group relamping costs
- RS Means derived labor costs for disconnecting or changing ballasts
- 3% discount rate, 0% escalation rate
- 3000 hrs/yr operation
- 50,000 hour study period (16 years 8 months)
- Lamp prices as purchased by Seattle Lighting Design Lab
Results – Economics

- At current prices for lamps, no LED lamps will payback over 50,000 hour study period

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Initial Cost (PV)</th>
<th>Life Cycle Cost (PV)</th>
<th>Lowest LCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>F40T12/34W/CW/RS and magnetic ballast</td>
<td>$31</td>
<td>$1458</td>
<td></td>
</tr>
<tr>
<td>F32T8/735 lamp and IS ballast</td>
<td>$32</td>
<td>$1099</td>
<td></td>
</tr>
<tr>
<td>F32T8/25W XL/XP/SS lamp replacement</td>
<td>$60</td>
<td>$898</td>
<td>******</td>
</tr>
<tr>
<td>F32T8/835/XPS lamp and LBF IS ballast</td>
<td>$203</td>
<td>$1129</td>
<td></td>
</tr>
<tr>
<td>LED 02 and ballast disconnect</td>
<td>$629</td>
<td>$1243</td>
<td></td>
</tr>
<tr>
<td>LED 01 and ballast disconnect</td>
<td>$839</td>
<td>$1517</td>
<td></td>
</tr>
<tr>
<td>LED 03 and ballast disconnect</td>
<td>$1079</td>
<td>$1886</td>
<td></td>
</tr>
</tbody>
</table>
LED T8 Replacement lamps

What happens when we consider lamp lumen depreciation?

Light Level Over Time With Replacements on Burnout

Anticipated FL T8 lumen depreciation applying industry developed standard 90% depreciation (90% of initial lumen output at rated life).

Anticipated LED lumen depreciation assuming industry standard L70 life rating (70% of initial lumen output at rated life). Actual results may be higher or lower.
Summary recommendations

If your space is overlighted by 30% now, using std. T8 lamps and IS ballasts:

- Replace lamps with low-wattage T8 high-performance lamps (36,000 hours life)

If your space is overlighted by 30% now, using T12 lamps and ballast:

- FOR GOODNESS SAKE, change them RIGHT THIS MINUTE to T8 high-performance lamps and LBF Program-start ballasts (52,000 hours)

If your space is overlighted by 30% now, and has very high electrical rates ($>0.15/kwh) and very high relamping costs ($>50 per lamp), and >5000 hrs operation per year:

- Do a life-cycle cost analysis. If you can get the LED lamps at low prices ($<90 per lamp), they may be economically viable.

If your space is not overlighted:

- Don’t use LED T8 replacement lamps until they are emitting 2000 lumens. Then the delivered FC will be equivalent to T8 fluorescent lamps.
LED T8 Replacement lamps

In summary… The good news:

- The efficacy of the T8 LEDs is rising fast
- The T8 LED doesn’t need to deliver equivalent lumens to deliver equivalent FC
- Economic viability may arrive when lumen output rises and LED lamp costs drop

If you want to try out the new cool technology as a test, then try LED T8 replacement lamps. Label the altered fixtures prominently with warnings. Alert the maintenance staff to the change.

Try a few before you commit to many. The color may surprise you.

Also consider using dedicated new LED luminaires instead of LED lamp retrofits for a higher-quality, higher efficiency, similar-cost solution.

Photos courtesy Philips Wide-Lite, Cree Lighting, Axis Lighting
Postscript

Not all LED replacement lamps are wired the same.

• Shunted sockets (instant start) vs. Rapid-start sockets.
• Not all LED T8s interchangeable.

Safety issues

• Requires disconnecting ballast and rewiring sockets. Are sockets in good shape?
• Prominently label fixture so that fluorescent lamps can’t be reinstalled.
• Install lamps with power shut off to fixture. Retrain maintenance workers.
• UL Certification is still a question/issue.
LED T8 Replacement lamps

Postscript

T8 LED lamp replacements won’t work for many T8 fluorescent fixtures

• Luminous area of the lamp must be oriented properly for the fixture’s distribution. Test before you commit to the purchase.

Photos courtesy: Elliptipar, Lightolier, Focal Point, and Finelite
LED T8 Replacement lamps

That’s all folks!
Any pesky questions??

Naomi . Miller @ PNNL . gov