FEMP Lighting Initiatives

Hosted by:

FEMP
Federal Energy Management Program

DUKE ENERGY

Jeff McCullough, LC
Pacific Northwest National Laboratory
Order of the Day...

- Lighting industry trends and forecasts
- Federal sector lighting estimates
- Latest FEMP-designated lighting product categories
- The Interior Lighting Campaign (ILC)
- “The Troffer Conundrum”
- The “ABCs”... of UL 1598
- Q&A
Penetration Rates of LED Lighting Applications
Energy Savings Forecast

Source: Navigant

- 15% Savings in 2020
- 40% Savings in 2030

Total LED Potential Energy Savings = 3.0 quads
$26 Billion (US)

= Annual Energy Used by 24 Million US Homes

= 35 Million Vehicles Taken Off the Road
Much Deeper Energy Savings Still Achievable

68% Energy Savings

Reaching DOE efficacy goals AND high controls growth can increase savings by an additional 28%

Source: http://energy.gov/eere/ssl/market-studies
Federal Market Assessments

Federal market assessments for indoor and outdoor lighting

- Energy savings potential of LEDs across portfolios
- Combines multiple databases/models
- Available to federal departments and agencies on a case-by-case basis
Federal Outdoor Energy Use

- Estimated Federal Outdoor Lighting Energy Use by Application (Total 5.0 TWh)
- Federal Sector Outdoor Lamps by Technology (total 6.6 million lamps)

Federal Purchasers MUST Buy FEMP-designated Products

Multiple laws, Executive Orders, and the Federal Acquisition Regulations have established a robust set of requirements that:

**Federal purchasers MUST buy, specify, and contract for ENERGY STAR®, FEMP-designated, and low standby products**

Suppliers must provide only compliant products (look for FAR clause 52.223-15 in your contract)

References:
- Energy Independence and Security Act of 2007 (EISA)
- Executive Orders 13221, 13423 & 13514
- Federal Acquisition Regulation (FAR 23.2 and FAR 52.223-15)
# FEMP-designated Lighting Categories

<table>
<thead>
<tr>
<th>PRODUCT CATEGORY</th>
<th>PRODUCT TYPE</th>
<th>⭐</th>
<th>△</th>
<th>O</th>
<th>+</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent Ballasts</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorescent Lamps, General Service</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorescent Luminaires, Ceiling-Mounted</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorescent Luminaires, Suspended</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial Lighting (High/Low Bay)</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED Luminaires, Commercial and Industrial</td>
<td>Lighting</td>
<td></td>
<td>△</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Bulbs</td>
<td>Lighting</td>
<td>⭐</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Fixtures (Residential)</td>
<td>Lighting</td>
<td>⭐</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Fixtures, Luminaires (Commercial)</td>
<td>Lighting</td>
<td>⭐</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exterior Lighting</td>
<td>Lighting</td>
<td>△</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
FEMP-designated Efficiency Requirements for Commercial and Industrial LED Luminaires

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>Light Output</th>
<th>Luminaire Efficiency (LE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial, linear ambient</td>
<td>≥375 lm/ft</td>
<td>≥103 lm/W</td>
</tr>
<tr>
<td>Commercial, 1-foot by 4-foot troffers</td>
<td>≥1,500 lm</td>
<td>≥99 lm/W</td>
</tr>
<tr>
<td>Commercial, 2-foot by 2-foot troffers</td>
<td>≥2,000 lm</td>
<td>≥100 lm/W</td>
</tr>
<tr>
<td>Commercial, 2-foot by 4-foot troffers</td>
<td>≥3,000 lm</td>
<td>&gt;103 lm/W</td>
</tr>
<tr>
<td>Industrial, low bay</td>
<td>≥5,000 to &lt;10,000 lm</td>
<td>≥103 lm/W</td>
</tr>
<tr>
<td>Industrial, high bay</td>
<td>≥10,000 lm</td>
<td>≥100 lm/W</td>
</tr>
</tbody>
</table>
Interior Lighting Campaign – Learn More

- Free resources
- Free to join
- Free technical assistance

http://www.interiorlightingcampaign.org
#IntLtgCampaign
Interior Lighting Campaign – Overview

• Launched May 2015 by:

  - **First year focus**
    - High-efficiency troffers and controls applications
  - **First year goal**
    - Document by May 2016 – 1M high-efficiency troffers installed or planned for installation by May 2018
    - Retrofit and new construction
    - Includes TLEDs, LED retrofit kits, high-efficiency luminaires
    - Encourages use of controls for added energy savings

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Why Troffers?

- 367 Million Troffers
- 97 billion kWh electricity consumption by troffers in the U.S.
- 262 billion kWh commercial sector electricity consumption for lighting*
- One troffer per person in the U.S.

Troffers consume the equivalent electricity use of 8.9 million homes

Interior Lighting Campaign – WIIFM

Resources
- Incentive lists
- Technology reports
- Case studies
- Calculation tools
- Webinars

Technical Assistance
- Site identification
- Technology option evaluation
- Application of specification
- Award entry content

Be Recognized
- Listed/linked on Campaign website
- Case studies of recognized projects
- Newsletter articles and tweets
- Awards for exemplary projects – 2016 BOMA International Conference and Expo, June 27 plenary event
  - New construction and retrofits awards
  - Small, medium, large project awards
  - Energy savings, portfolio adoption, and use of controls awards

Join as a Participant
- Building owners
- Building managers
- Others end users including federal, state, and municipal buildings

Join as a Supporter
- Energy efficiency groups
- Manufacturers
- Utilities
- ESCOs
- Lighting designers
- Others who influence but don’t directly manage buildings
Interior Lighting Campaign Resources

Specifications

Reports

Fact Sheets

M&V guidance

Energy Estimator to compare against code

Technical Assistance (limited)

List of utility incentives
Information and Resources for Federal Users

Federal sites are encouraged by the Federal Energy Management Program (FEMP) to participate in the ILC.

Benefits:
- **Save Money:** Significantly reduce your site’s energy and maintenance costs. High efficiency troffer lighting technology with controls can cut lighting energy bills by 79% while delivering additional benefits including longer life, reduced maintenance costs, and improved lighting uniformity.
- **Meet Federal Guidelines:** Help ensure that you are meeting federal requirements for energy efficiency.
- **Receive Technical Assistance:** Lighting engineers are available to provide technical assistance to help ensure that your site is designed in a manner to take full advantage of new high efficiency lighting and controls systems.
- **Get Recognized:** In addition to saving money and energy, ILC participants will be recognized on the campaign website and are eligible to receive awards for exemplary energy efficient lighting performance.

JOIN YOUR FEDERAL COUNTERPARTS TODAY!

www.interiorlightingcampaign.org/information-and-resources-federal-users
Top 10 reasons why everyone is interested in TLEDs?

1. They last longer (forever maybe) than fluorescent lamps
2. A TLED is perceived to be the lowest cost option to get the benefits of LED
3. Efficacy has been steadily increasing
4. Prices have been steadily decreasing
5. I get to keep my existing fixture that’s been in my ceiling for 20 years... yippee!
6. They don’t have any of that bad ‘ol mercury
7. Many continue to cling to the old paradigm that... “a-lamp-is-a-lamp” and all lamps interchange “one-for-one”
8. I can potentially do away with my ballasts and get into the “lamps only” business
9. Installation is just a “point” and “click” away
10. They truly are shiniest damn thing in my ceiling!
A True Case Study from a 1st Generation TLED Installation

1st Generation System
• Installed circa 2010
• 16 W, 1400 lm, 87.5 lm/W
• 4200-4600K claimed “cool white”
• Reached < L70 in 6 years and is currently delivering 50% of initial fluorescent levels
• Warranty: 50,000 hour/5 year “life” claimed by manufacturer. No L70!

2016 system
• 18 W, 1950 lm, 108 lm/W
• 4100K (3000-6500K offered)
• L70: 50,000 hours
• Warranty: 5 years (with a 10-year option)
• Resulted in increased energy usage!
## Size of Market

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Mixture</th>
<th>Approx. # of Installations</th>
<th>Hours</th>
<th>Input Power (W)</th>
<th>Estimated Energy (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2’x4’</td>
<td>74%</td>
<td>~272,000,000</td>
<td>10.5</td>
<td>74</td>
<td>77.1</td>
</tr>
<tr>
<td>2’x2’</td>
<td>16%</td>
<td>~59,000,000</td>
<td>10.5</td>
<td>59</td>
<td>13.3</td>
</tr>
<tr>
<td>1’x4’</td>
<td>8%</td>
<td>~29,000,000</td>
<td>10.5</td>
<td>44</td>
<td>4.9</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>~367,000,000</td>
<td></td>
<td></td>
<td>95.3</td>
</tr>
</tbody>
</table>

**Notes:**
- Quantities extrapolated from DOE SSL Niche Report & NEMA LE5-2001
- Power values assume a mixture of lamps, ballast factors, and ballast efficiencies
- TWh = 1,000,000,000,000 watt-hours
Interior Lighting by the Numbers - Commercial Buildings

- Commercial lighting is \( \approx 2.6\% \) of \textbf{ALL} primary energy consumption in the U.S.
- Troffers \( \approx 1\% \) of \textbf{ALL} energy use
- \( \approx 20\% \) of building energy is lighting and troffers are \( \approx 50\% \) of that energy
TLEDs Today (2016)

4-foot LED linear replacements on DLC Qualified Products List by UL Type
4/20/16

Note: Individual Product offerings and not shipments
TLEDs Efficacy

Measured luminaire efficacy of DLC-listed 4-foot LED linear replacement lamps by UL type

4/20/16

Minimum Mean Maximum

TLEDs Efficacy

Min required luminaire efficacy is 85 lm/W
Prior DOE Studies into TLEDs

Reports

Application Summary Report 21: Linear (T8) LED Lamps (March 2014)

- Report 21.2: Linear (T8) LED Lamp Performance in Five Types of Recessed Troffers (May 2104)
- Report 21.3: Cost-Effectiveness of Linear (T8) LED Lamps (May 2014)
- Report 21.4: Summary of Linear (T8) LED Lamp Testing (June 2014)

“Only one product tested for this report could be installed without removing the existing fluorescent ballast, assuming the luminaire was equipped with an instant-start electronic ballast.”

Exploratory Study: Recessed Troffer Lighting (May 2013)

Fact Sheets

www.energy.gov/eere/ssl/led-linear-lamps-and-troffer-lighting
How Do TLEDs Save Energy and $?

• Higher source (system) efficacy (lamp + driver) compared to fluorescent system efficacy (lamp + ballast) = reduced connected wattage.
• Greater fixture efficiency. Directionality of TLED allows for more light (useful lumens) out of the fixture.
• Energy savings of 20-30% are possible with similar light levels but ultimately is a function of the space and the existing fixture type.
• Potential for longer “lamp” life = reduced maintenance costs
• Potential to optimize existing lighting systems (reduce light levels) that are overlighted by current ASHRAE/IES standards
Key Challenges with TLEDs

• There are NO standards for:
  – Wiring configurations. No guarantee that a replacement lamp 5 years from now will be wired the same way
  – Distribution from the lamps. Is beam angle a good surrogate? What about “batwing” distributions?
  – Light output. Fluorescent lamps are interchangeable and have standard lumen/wattage ranges

• How many manufacturers are in the market?

3 manufacturer groups for UL Type A products:
Group 1: Cree, GE, OSRAM SYLVANIA, Philips
Group 2: Lighting Science Group, Litetronics, Maxlite, Ushio, Universal Lighting Technologies, Venture, Westinghouse
Group 3: All others (about 190 companies)
How Do We Design Indoor Lighting Systems?

- Lighting designers “target” a sustained light level based on many factors:
  - The room geometry (e.g. ceiling height, location to work plane, etc.)
  - The reflectances of the room surfaces. You often see “80/50/20” used.
    - 80% for acoustic ceiling
    - 50% for light colored walls
    - 20% for dark carpet
  - Various light loss factors (LLFs)
    - Lamp lumen, dirt, temperature, fixture, ballast, voltage, etc.
    - Lamp lumen depreciation is specified at a point in time (typically 40% of rated life for fluorescents).
    - The lamp lumen depreciation for a “good” quality F32T8 85 CRI fluorescent lamp is ~0.91 or 91%. Some “premium” lamps are capable of up to 94-96% lumen maintenance all the way out to rated lamp life.
  - The initial light levels are generally higher than the space needs so as to deliver ≥ the target light levels at a point in time.
  - As a practical matter light levels are generally allowed to fall about 10% below the target as the human eye will not notice the difference.
  - Some building lease specifications may require a minimum light level at all times.
Design Considerations – Spacing Criteria

Luminaire Spacing = Spacing Criterion x mounting height above work plane (MH)

Courtesy: Acuity Lighting Technical Considerations
LEDs are not “Everlasting Gobstoppers”

- **ALL** light sources degrade - most fail before critical light output level is reached
- LED diodes can survive but also degrade well beyond useful light levels
- Industry considers lumen output as one measure of the **useful life** of an LED diode. Commonly, 70% of initial output is used.
LED Replacement Tube Varieties

- LED replacement tubes come in a variety of distributions
- Directionality is efficacious – but can effect performance in fixtures designed for omnidirectional fluorescent tubes.
What happens when typical LED replacement tubes are retrofitted in various fluorescent fixture types?
Fluorescent Tube vs. LED Tube Distribution Patterns
The Troffer Conundrum – What do I do?

Super T8 Fluorescent Lamp/Ballast

Tubular LED (TLED)

LED Retrofit Kit

New LED Fixture
As with most things... Life is about Choices... and Lighting is no different!

<table>
<thead>
<tr>
<th>Category</th>
<th>Power Supply</th>
<th>Light Source Mounting</th>
<th>Dimming</th>
<th>Controls</th>
<th>Risk</th>
<th>Total Cost</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LED Replacement Lamp (Ballast)</td>
<td>Existing fluorescent ballast</td>
<td>Existing fluorescent socket</td>
<td>Unlikely</td>
<td>Shut-off only (switch or occupancy sensor)</td>
<td>?</td>
<td>$</td>
<td>LED or LFL option, No electrician, matches lens configuration, need for future ballast replacement</td>
</tr>
<tr>
<td>2. LED Replacement Lamp (Mains)</td>
<td>“Mains” voltage</td>
<td>Existing fluorescent socket</td>
<td>Yes, with matching 0-10V system</td>
<td>Shut-off only (switch or occupancy sensor)</td>
<td>??</td>
<td>$$</td>
<td>Matches existing lens configuration</td>
</tr>
<tr>
<td>3. LED Replacement Lamp (Hybrid)</td>
<td>“Mains” voltage or existing fluorescent ballast</td>
<td>Existing fluorescent socket</td>
<td>Only likely if FL ballast removed</td>
<td>Shut-off only (switch or occupancy sensor)</td>
<td>?/??</td>
<td>$$</td>
<td>Matches existing lens configuration</td>
</tr>
<tr>
<td>4. LED Retrofit Kit (Lamp Socket)</td>
<td>Proprietary power supply</td>
<td>Existing fluorescent socket</td>
<td>Yes, with matching 0-10V system</td>
<td>Yes, with matching driver/control</td>
<td>??</td>
<td>$$$</td>
<td>Matches existing lens configuration</td>
</tr>
<tr>
<td>5. LED Retrofit Kit (Free-form)</td>
<td>Proprietary power supply</td>
<td>Free-form</td>
<td>Yes, with matching 0-10V system</td>
<td>Yes, with matching driver/control</td>
<td>???</td>
<td>$$$</td>
<td>Allows for light source relocation/re-alignment</td>
</tr>
</tbody>
</table>
Key Considerations for a Successful TLED Installation

- Give thought to your long term goals for the space. Some choices commit you to certain technology... for a long time!
- A “role” for “control.” As luminaire efficacy increases the ability to add controls later becomes less cost-effective and a potential lost opportunity.
- Use the DesignLights® Consortium Qualified Products List and DOE LED Lighting Facts® to help find products that have been tested and meet your performance goals.
- Consider developing performance-based criteria for the intended application. Why not ask your vendor to deliver a system that meets your requirements (e.g., light levels when installed in your fixtures, maintained light levels at a period in time, etc.)?
- Target Facilities based on existing technology, light levels and energy costs.
- Do an honest life-cycle cost calculation or total cost of ownership.
- A mock-up is ALWAYS a good idea!
The “A,” “B,” “A/B,” and “C”s of TLEDs

In 2013, the lines for troffer “kits” were blurry...

• Many lamps required bypass of the ballast
• Some were wired to line voltage
• Others required an external driver
• Some came with new sockets
• Some had new luminaire optics
• Others didn’t use the sockets at all
• Some you could install as simply as replacing the lamp
• Some you even had to aim!

... Since then, UL has helped bring clarity to some of the many options (UL 1598 certification)...

UL 1598

TYPE A

- Replacement Lamps... plug’n play!
- Does not require mechanical or electrical changes to the fixture
- Can operate off an existing fluorescent ballast however compatibility varies (may not work on rapid start/programmed rapid start ballasts)
- More and more products available
- Efficiency loses due to ballast
- Existing ballast life
- LED life + ballast life... something will fail first!
UL 1598

**TYPE B**

- Internal Driver/Line Voltage Lamp-Style Retrofit Kits
- Sockets are powered by line voltage, does **NOT** operate off the existing fluorescent ballast
- Requires rewiring of the existing fixture to bypass the ballast and send line voltage directly to the lamp holders
- Line-voltage sockets could prove dangerous for installer
- Still various wiring types
UL 1598

**TYPE A/B (hybrid)**

- Internal Driver/Line Voltage Lamp-Style Retrofit Kits
- Dual Mode Internal Driver (UL Type A and Type B):
  - operate off the existing fluorescent ballast
  - also have the ability to operate off of line voltage if the troffer is rewired to bypass the ballast
- Sockets are powered by line voltage, does **NOT** operate off the existing fluorescent ballast
- Requires rewiring of the existing fixture to bypass the ballast and send line voltage directly to the lamp holders
- Line-voltage sockets could prove dangerous for installer
- Still various wiring types
UL 1598

**TYPE C**

- External Driver Lamp-Style Retrofit Kits
- Sockets are powered by low-voltage drive current and does **NOT** operate off the existing fluorescent ballast
- Requires rewiring of the existing fixture to replace the ballast with an external driver
- Still variables within this category:
  - Form-factor,
  - wiring configuration
Considerations - Are Retrofits a Good Idea?

- There is no across-the-board one “best” option
- These are retrofit products. You need to know which system components are staying and compliment them.

<table>
<thead>
<tr>
<th>Condition of sockets</th>
<th>Existing Conditions to Consider</th>
<th>Lamps</th>
<th>Kits</th>
<th>Luminaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look like new</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Some wear but no major cracks</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Look old, blackened, cracks apparent</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Condition of interior surfaces</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Slightly worn but no major scratches or peeling paint</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Very worn, scratches in paint, some peeling paint</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Condition of lens or louvers</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Looks new, very little wear apparent</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Some minor color variations or scratches in surface</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Looks old, obvious cracks or yellowing</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Ceiling access</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>No concerns with working above the ceiling; easy access</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Some concerns about working above the ceiling; limited access</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Working above the ceiling should be avoided</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>
Navigating the Wiring Variables

Existing: Instant Start Ballast

• Lampholders are shunted
  – Internally
  – Externally

Existing: Programmed Start/Rapid Start/Magnetic Ballasts

• Lampholders are unshunted
• Unshunted lampholders can be easily shunted

• Products can be selected to reduce installation time
  - Type A- ballast compatibility
  - Type B- double ended power
  - Type C- double ended power

• Above recommendations will reduce installation time, but new ballasts/lampholders can be installed to accommodate any TLED
Maintenance

• Re-lamping
  – Double-check manufacturer’s wiring configuration (we have seen these change, even with the same model number!)
  – Clear documentation must be provided so the correct type and wiring can be purchased at time of re-lamping
  – Will the re-lamp work in the existing wiring configuration?

• Risks of Mis-lamping
  – Short Circuit at lamp holder
  – Re-installing fluorescent lamps leading to tube failure, socket damage, etc.
Tons of Resources @
www.ssl.energy.gov
Questions and Answers

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