FEDERAL UTILITY PARTNERSHIP WORKING GROUP SEMINAR

May 18-19, 2016
Cincinnati, OH

FEMP Lighting Initiatives

Hosted by:

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

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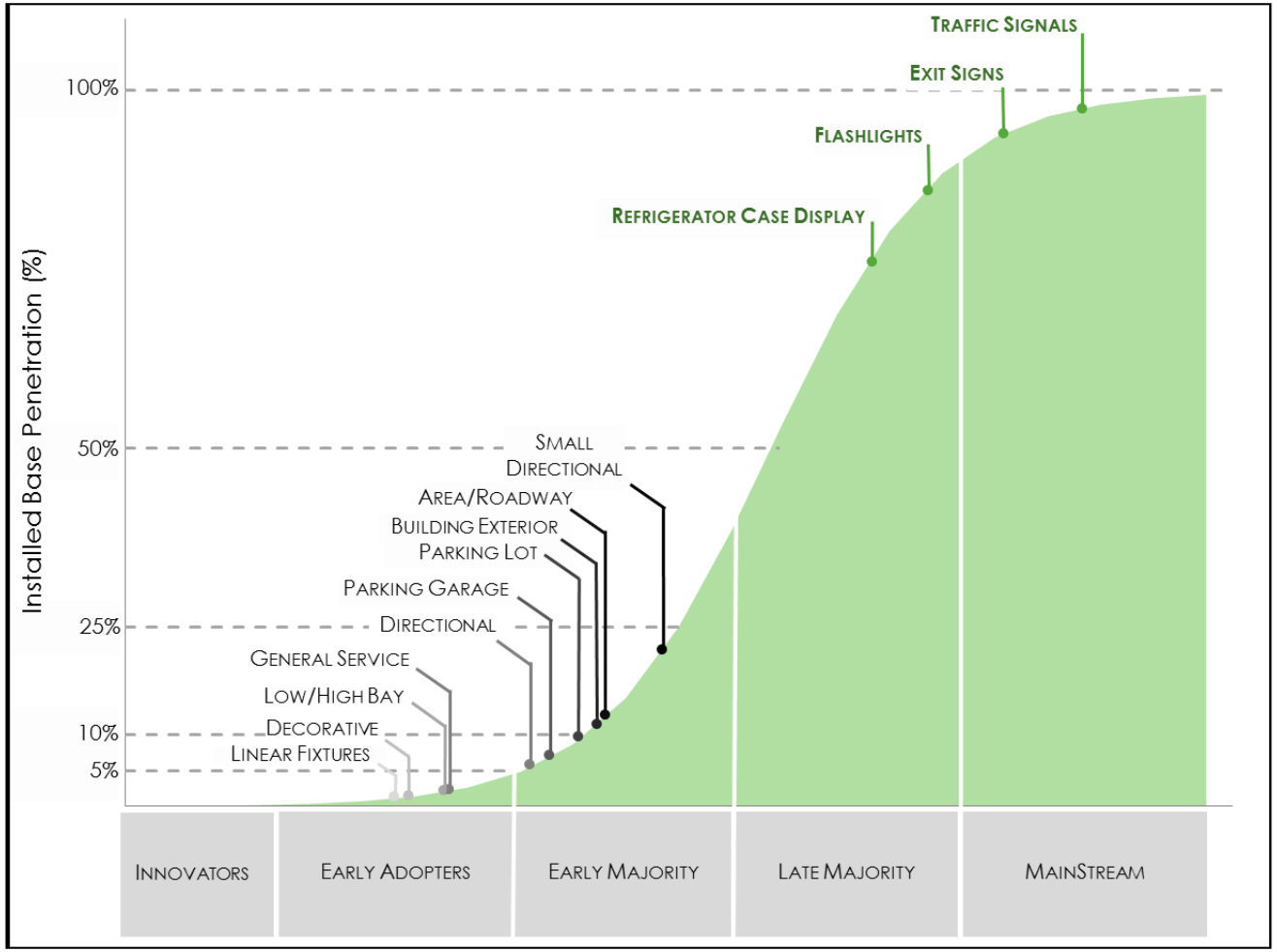
Penetration Rates of LED Lighting Applications



DOE 2015 Adoption of Light-Emitting Diodes in Common Lighting Applications

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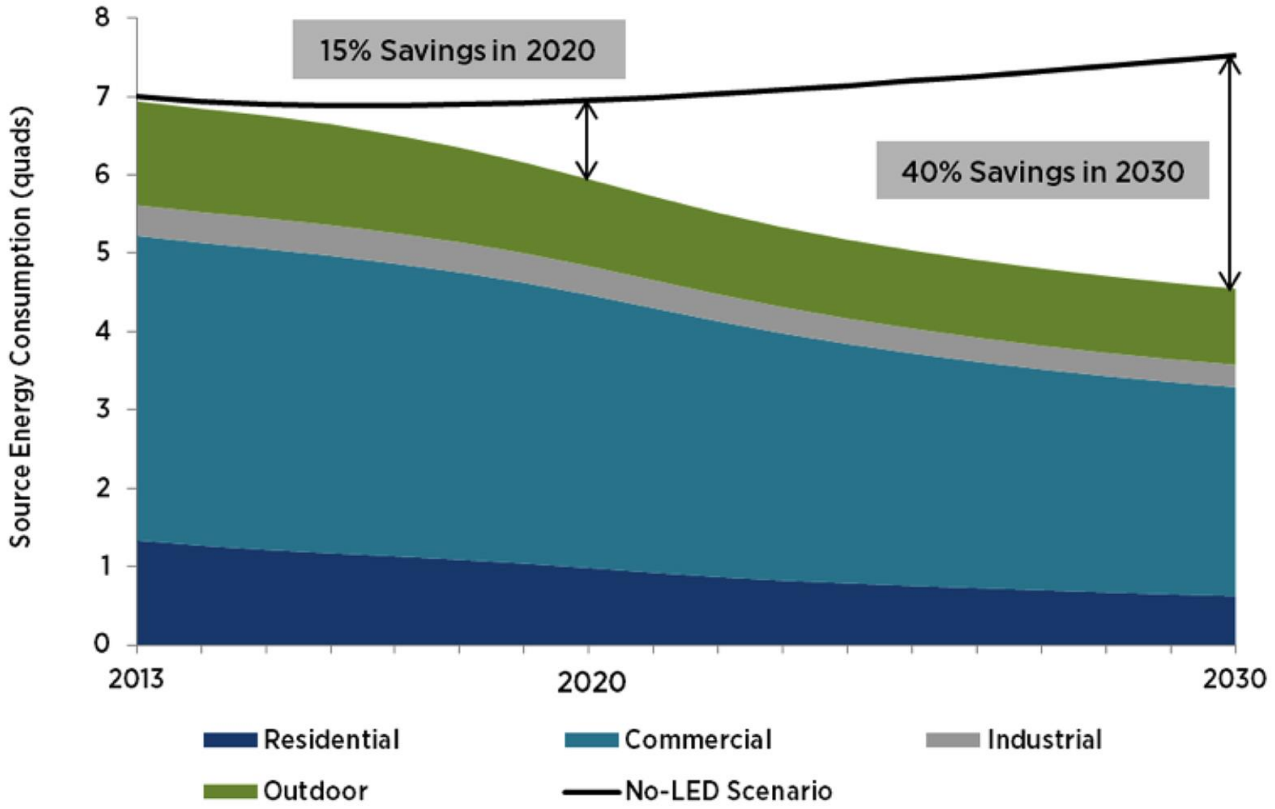
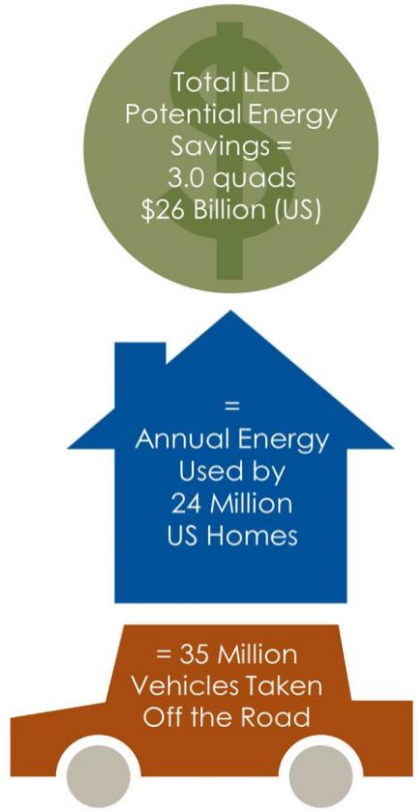
Energy Savings Forecast





Source: Navigant

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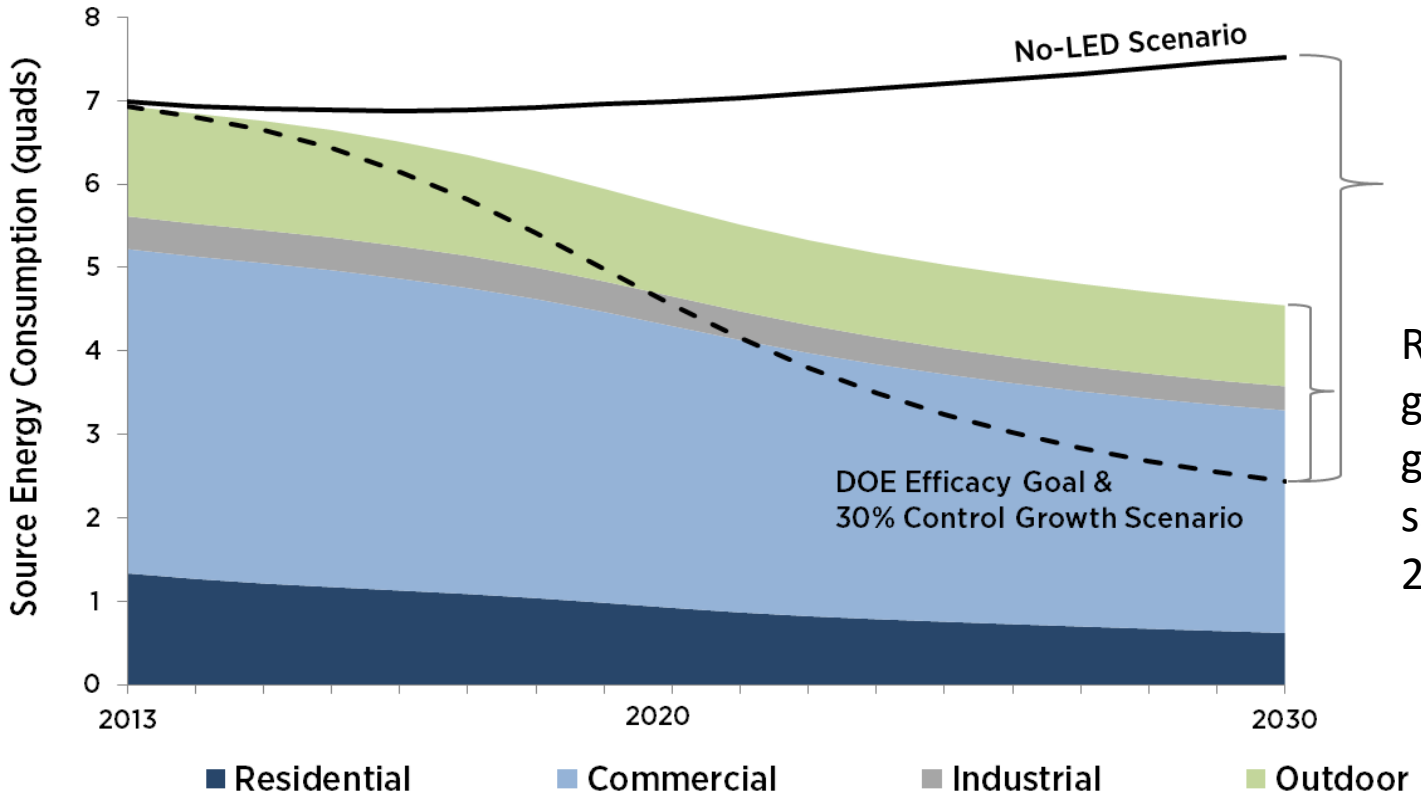
Much Deeper Energy Savings Still Achievable



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

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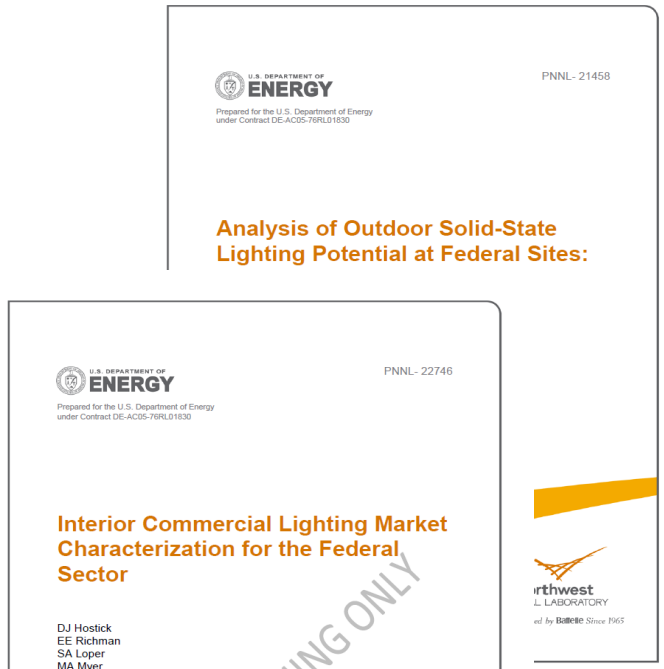
Federal Market Assessments

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



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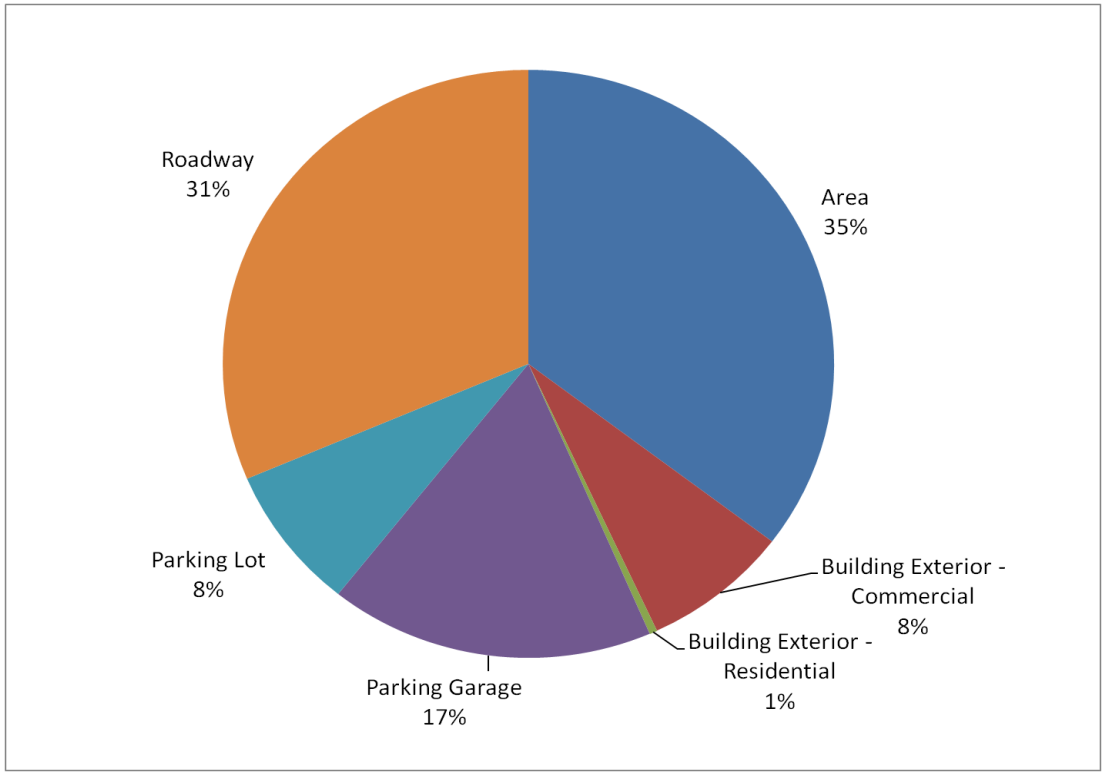
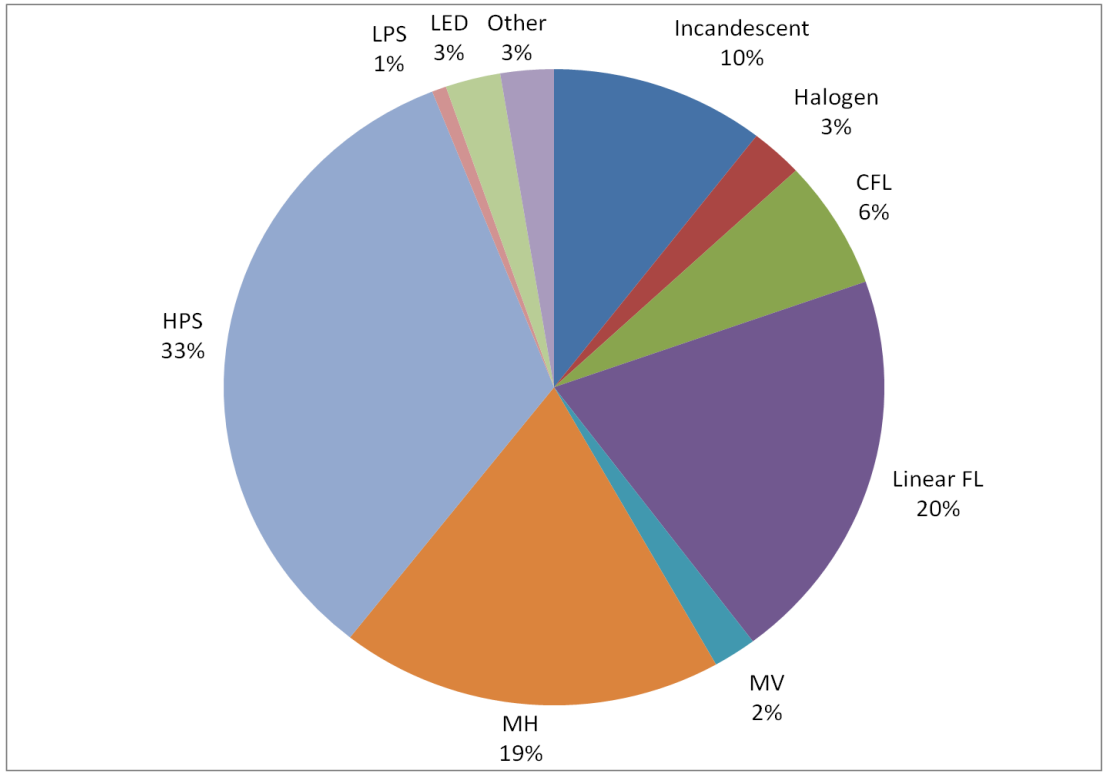
Federal Outdoor Energy Use

- Estimated Federal Outdoor Lighting Energy Use by Application (Total 5.0 TWh)

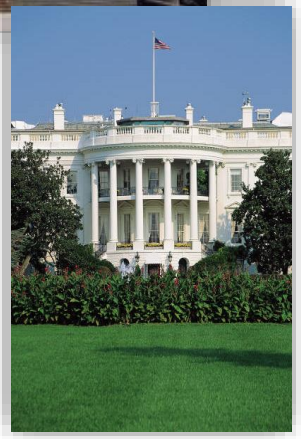


- Federal Sector Outdoor Lamps by Technology (total 6.6 million lamps)



Source: Analysis of Outdoor Solid-State Lighting Potential at Federal Sites: Technical Support Document (PNNL-21458, August 2012)

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)
- Energy Policy Act (EPAct) of 1992 and 2005
- Executive Orders 13221, 13423 & 13514
- Federal Acquisition Regulation (FAR 23.2 and FAR 52.223-15)

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FEMP-designated Lighting Categories

PRODUCT CATEGORY	PRODUCT TYPE	★	△	O	♦	X
Fluorescent Ballasts	Lighting		△			
Fluorescent Lamps, General Service	Lighting		△			
Fluorescent Luminaires, Ceiling-Mounted	Lighting		△			
Fluorescent Luminaires, Suspended	Lighting		△			
Industrial Lighting (High/Low Bay)	Lighting		△			
LED Luminaires, Commercial and Industrial	Lighting		△			
Light Bulbs	Lighting	★				
Light Fixtures (Residential)	Lighting	★				
Light Fixtures, Luminaires (Commercial)	Lighting	★				
Exterior Lighting	Lighting		△			

FEMP-designated Efficiency Requirements for Commercial and Industrial LED Luminaires

TABLE 1. EFFICIENCY REQUIREMENTS FOR COMMERCIAL AND INDUSTRIAL LED LUMINAIRES		
Luminaire Type	**Light Output**	**Luminaire Efficiency (LE)**
Commercial, linear ambient	≥375 lm/ft	≥103 lm/W
Commercial, 1-foot by 4-foot troffers	≥1,500 lm	≥99 lm/W
Commercial, 2-foot by 2-foot troffers	≥2,000 lm	≥100 lm/W
Commercial, 2-foot by 4-foot troffers	≥3,000 lm	≥103 lm/W
Industrial, low bay	≥5,000 to <10,000 lm	≥103 lm/W
Industrial, high bay	≥10,000 lm	≥100 lm/W

Interior Lighting Campaign – Learn More

- Free resources
- Free to join
- Free technical assistance

http://www.interiorlightingcampaign.org
#IntLtgCampaign

U.S. DEPARTMENT OF ENERGY

Interior Lighting Campaign – Overview

- Launched May 2015 by:

Illuminating Engineering Society

BOMA International

IFMA International Facility Management Association

Better Buildings U.S. Department of Energy

GSA

  - 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

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

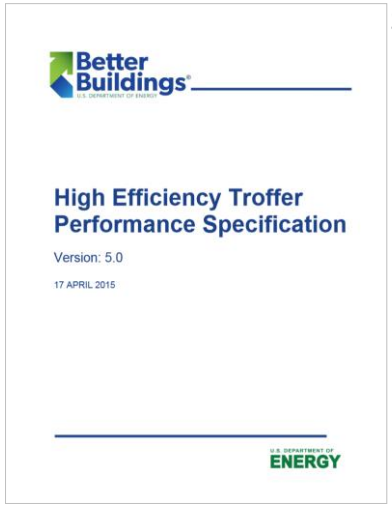
Join as a Participant

- ✓ Building owners
- ✓ Building managers
- ✓ Others end users including federal, state, and municipal buildings

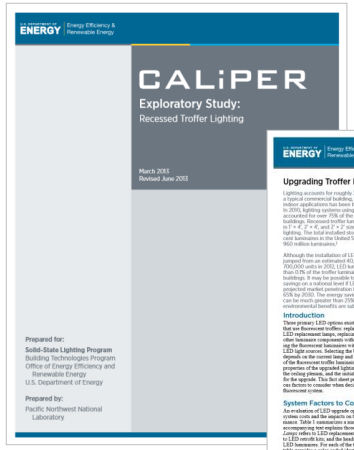
Join as a Supporter

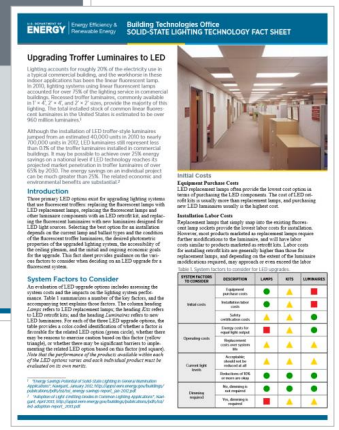
- ✓ Energy efficiency groups
- ✓ Manufacturers
- ✓ Utilities
- ✓ ESCOs
- ✓ Lighting designers
- ✓ Others who influence but don't directly manage buildings

Interior Lighting Campaign Resources



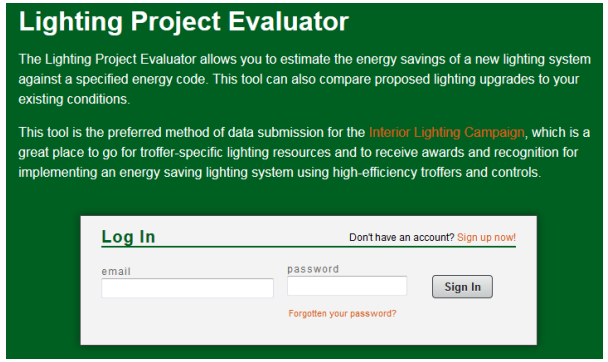
Specifications





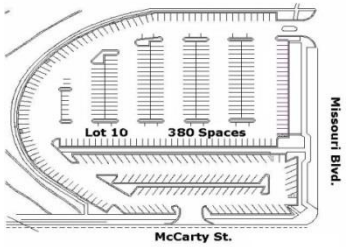
Reports

Fact Sheets



Energy Estimator to compare against code

Technical Assistance (limited)



M&V guidance

DSIRE®

NC CLEAN ENERGY TECHNOLOGY CENTER

LED lighting facts®
A Program of the U.S. DOE

Indoor Lighting - Troffers (incl retrofit kits), Controls

Utility	State	Technology	Product
PPL Electric	PA	Controls	Occupancy S
PPL Electric	PA	Fluorescent	High Perforn
PPL Electric	PA	LED	High Perforn

List of utility incentives

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ILC Resources for Federal Users

www.interiorlightingcampaign.org/information-and-resources-federal-users

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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!

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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 < L_{70} in 6 years and is currently delivering 50% of initial fluorescent levels
- Warranty: 50,000 hour/5 year “life” claimed by manufacturer. No L_{70}!

2016 system

- 18 W, 1950lm, 108 lm/W
- 4100K (3000-6500K offered)
- L_{70}: 50,000 hours
- Warranty: 5 years (with a 10-year option)
- Resulted in increased energy usage!

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Size of Market

Configuration	Mixture	Approx. # of Installations	Hours	Input Power (W)	Estimated Energy (TWh)
2′x4′	74%	~272,000,000	10.5	74	77.1
2′x2′	16%	~59,000,000	10.5	59	13.3
1′x4′	8%	~29,000,000	10.5	44	4.9
Total	100%	~367,000,000			95.3

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

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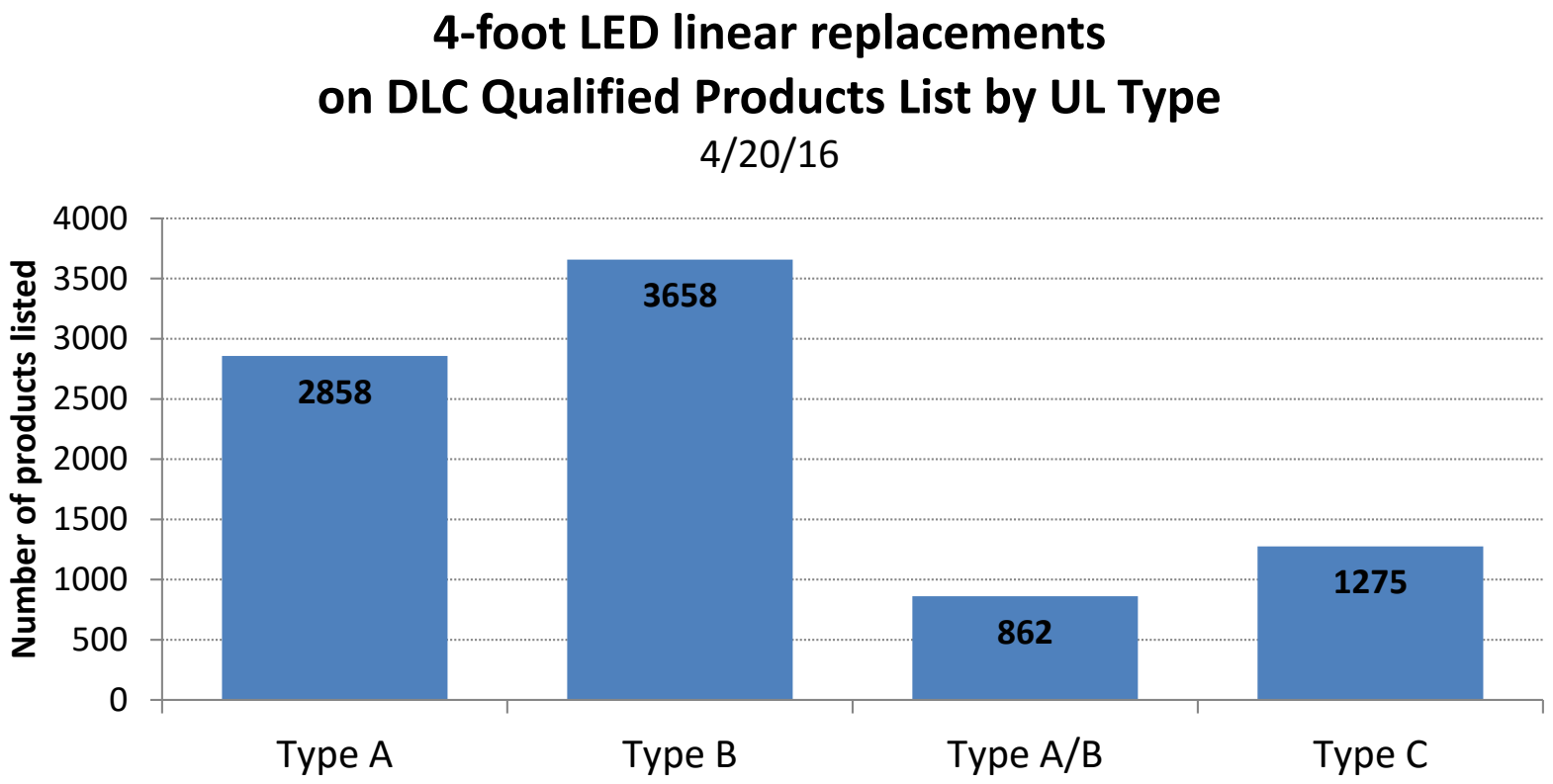
Interior Lighting by the Numbers - Commercial Buildings

- Commercial lighting is ≈ 2.6% of **ALL** primary energy consumption in the U.S.
- Troffers ≈ 1% of **ALL** energy use
- ≈ 20% of building energy is lighting and troffers are ≈ 50% of that energy

TLEDs Today (2016)



Note: Individual Product offerings and not shipments

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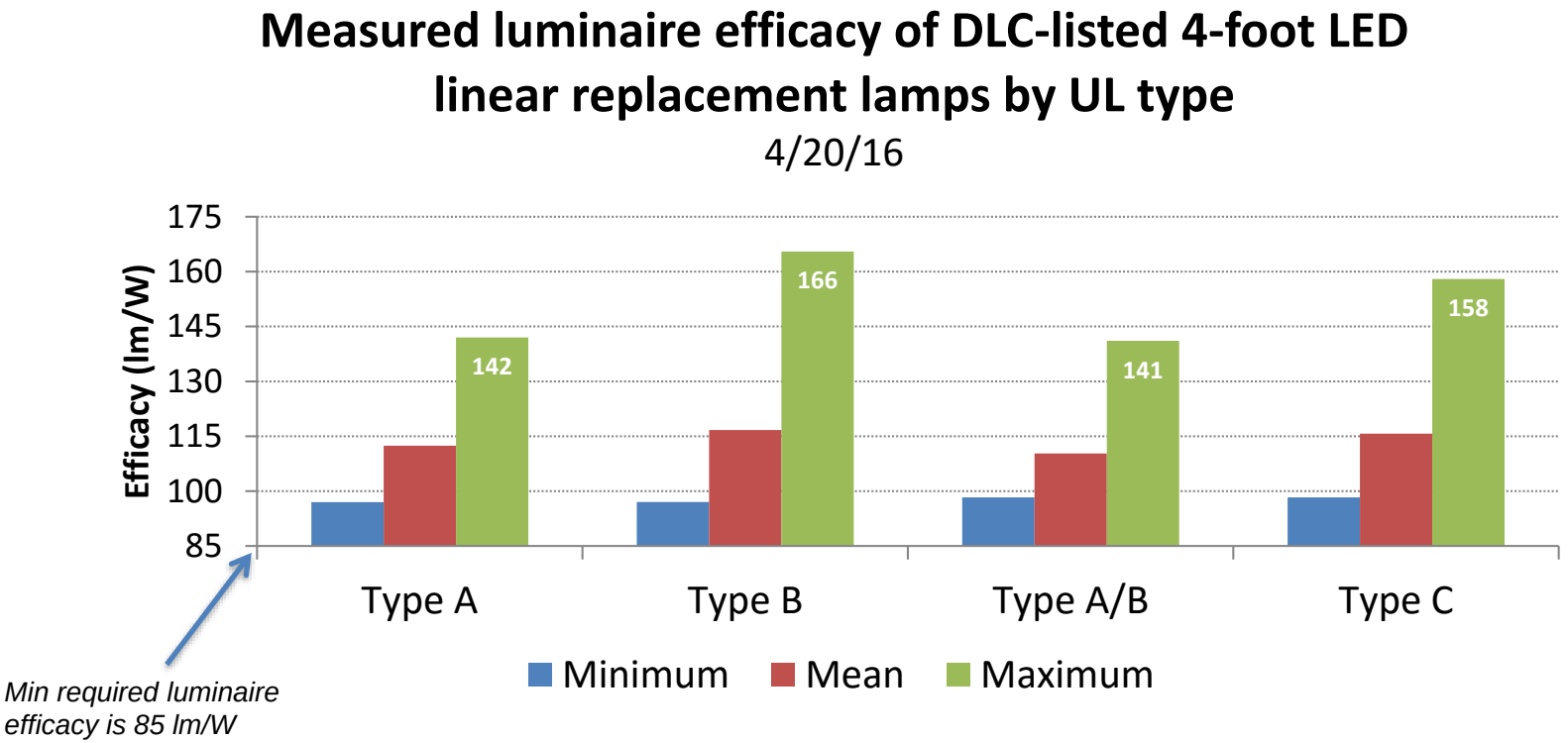
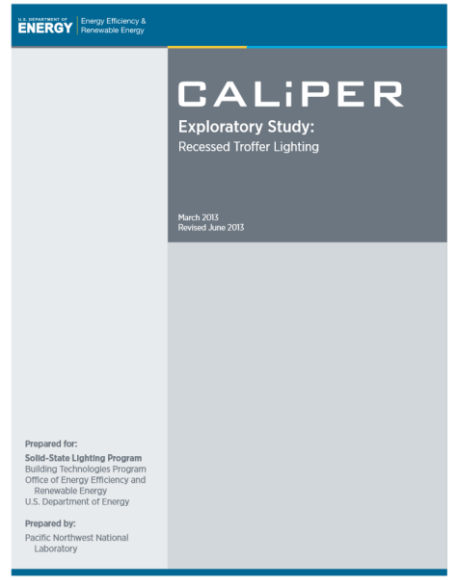
TLEDs Efficacy



Prior DOE Studies into TLEDs

Reports



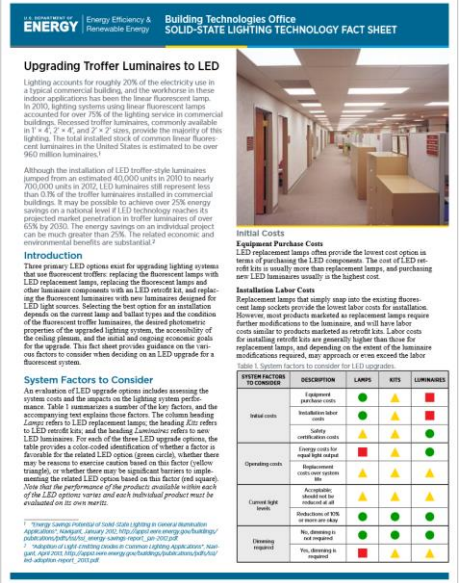
Application Summary Report 21: Linear (T8) LED Lamps (March 2014)

- **Report 21.1:** Linear (T8) LED Lamps in a 2 × 4 K12-Lensed Troffer (April 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

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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

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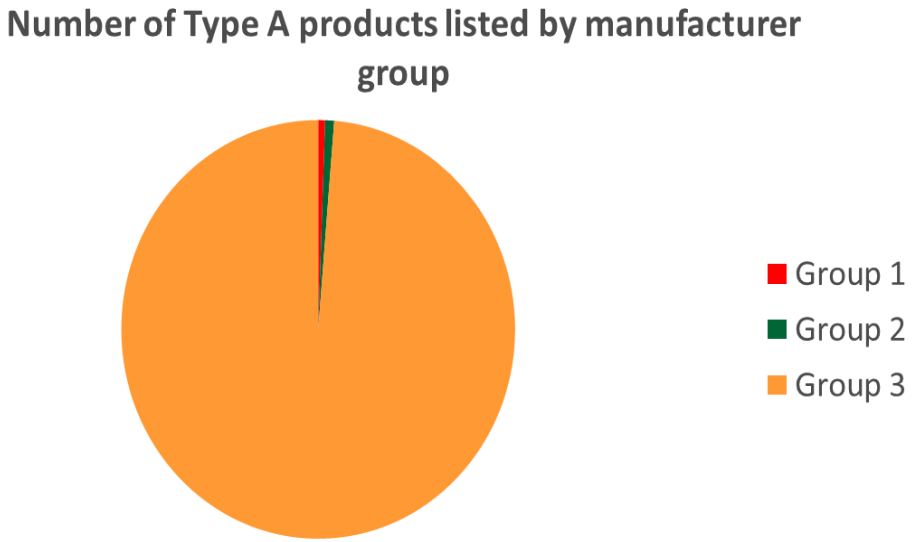
Key Challenges with TLEDs

- 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)



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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.

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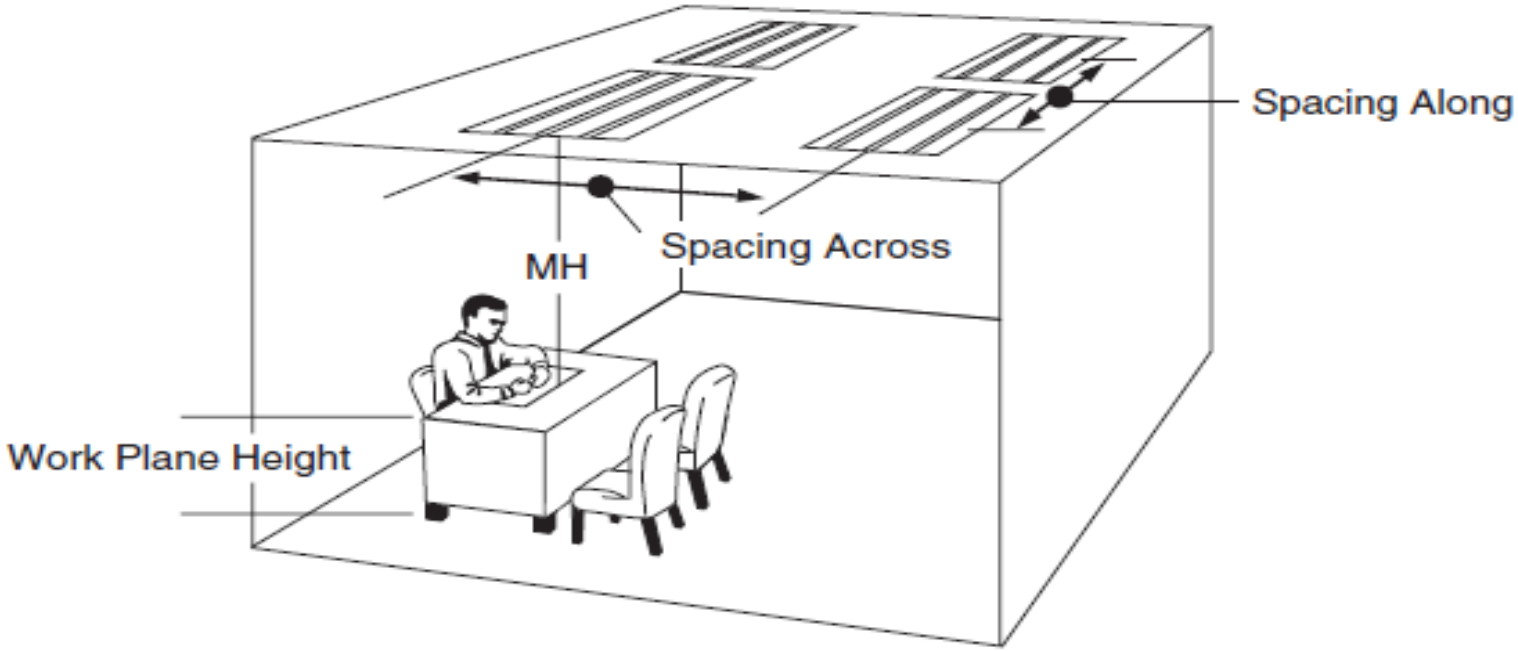
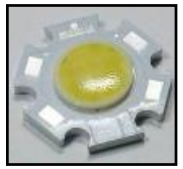
Design Considerations – Spacing Critera



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

Courtesy: Acuity Lighting Technical Considerations

LEDs are not “Everlasting Gobstoppers”



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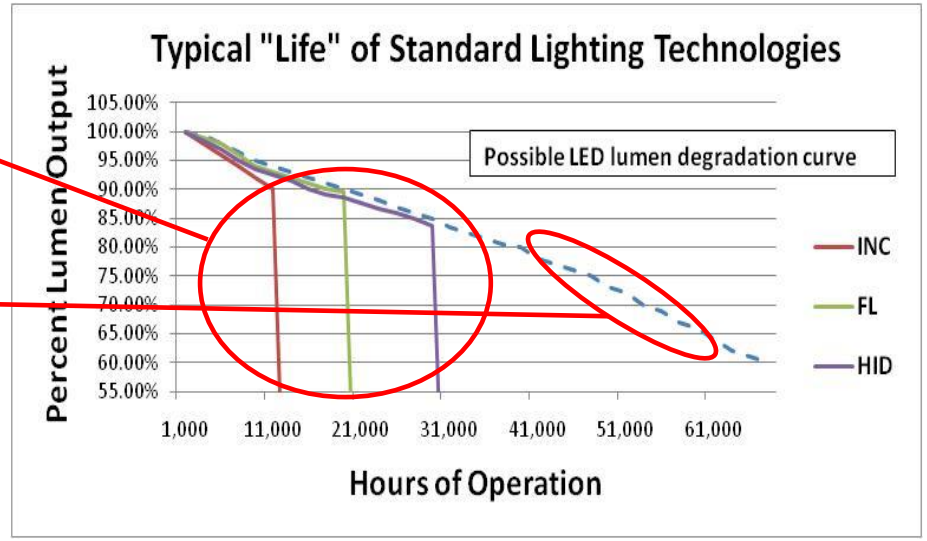
- **ALL** light sources degrade - most fail before critical light output level is reached
- LED diodes can survive but also degrade well beyond useful light levels
- Industry considers lumen output as one measure of the **useful life** of an LED diode. Commonly, 70% of initial output is used.



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Lumen Maintenance Comparisons

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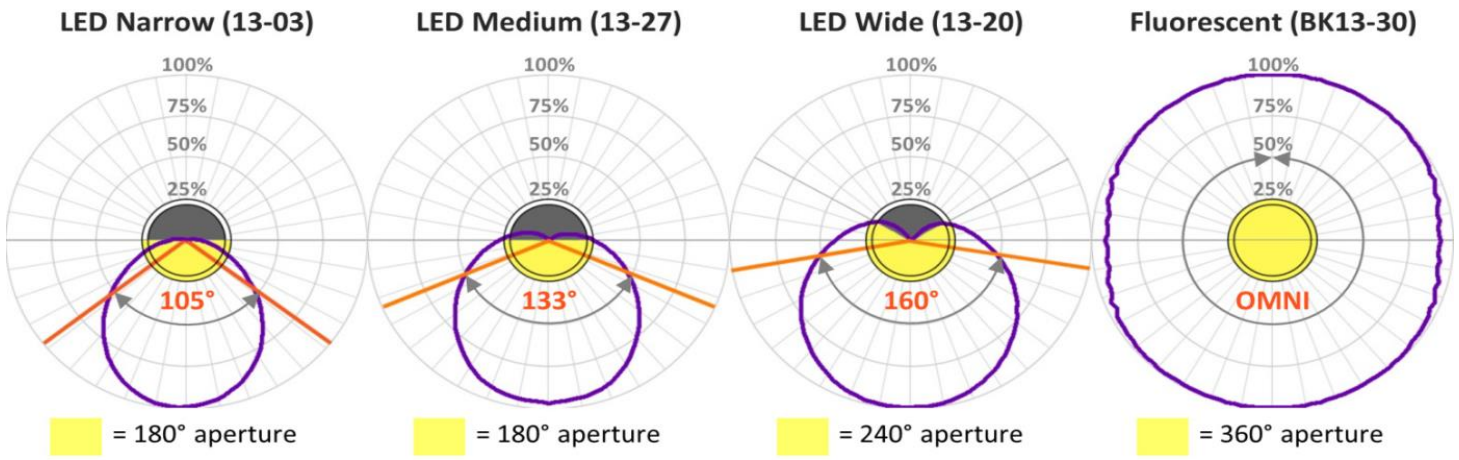
LED Replacement Tube Varieties

- LED replacement tubes come in a variety of distributions
- Directionality is efficacious – but can effect performance in fixtures designed for omnidirectional fluorescent tubes.



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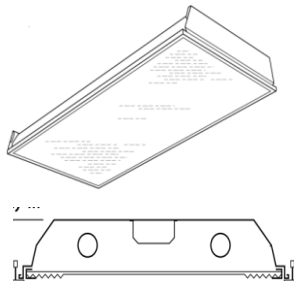
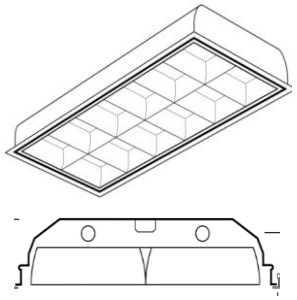
Troffer Geometry

What happens when typical LED replacement tubes are retrofitted in various fluorescent fixture types?

K12 Lens

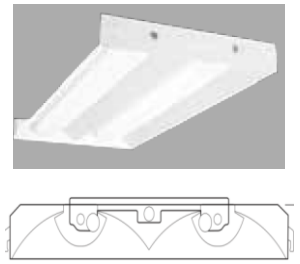


Parabolic

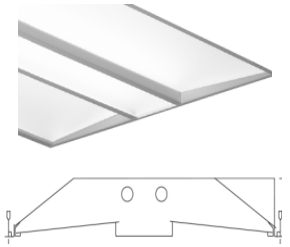


Recessed Indirect

Volumetric



High Performance



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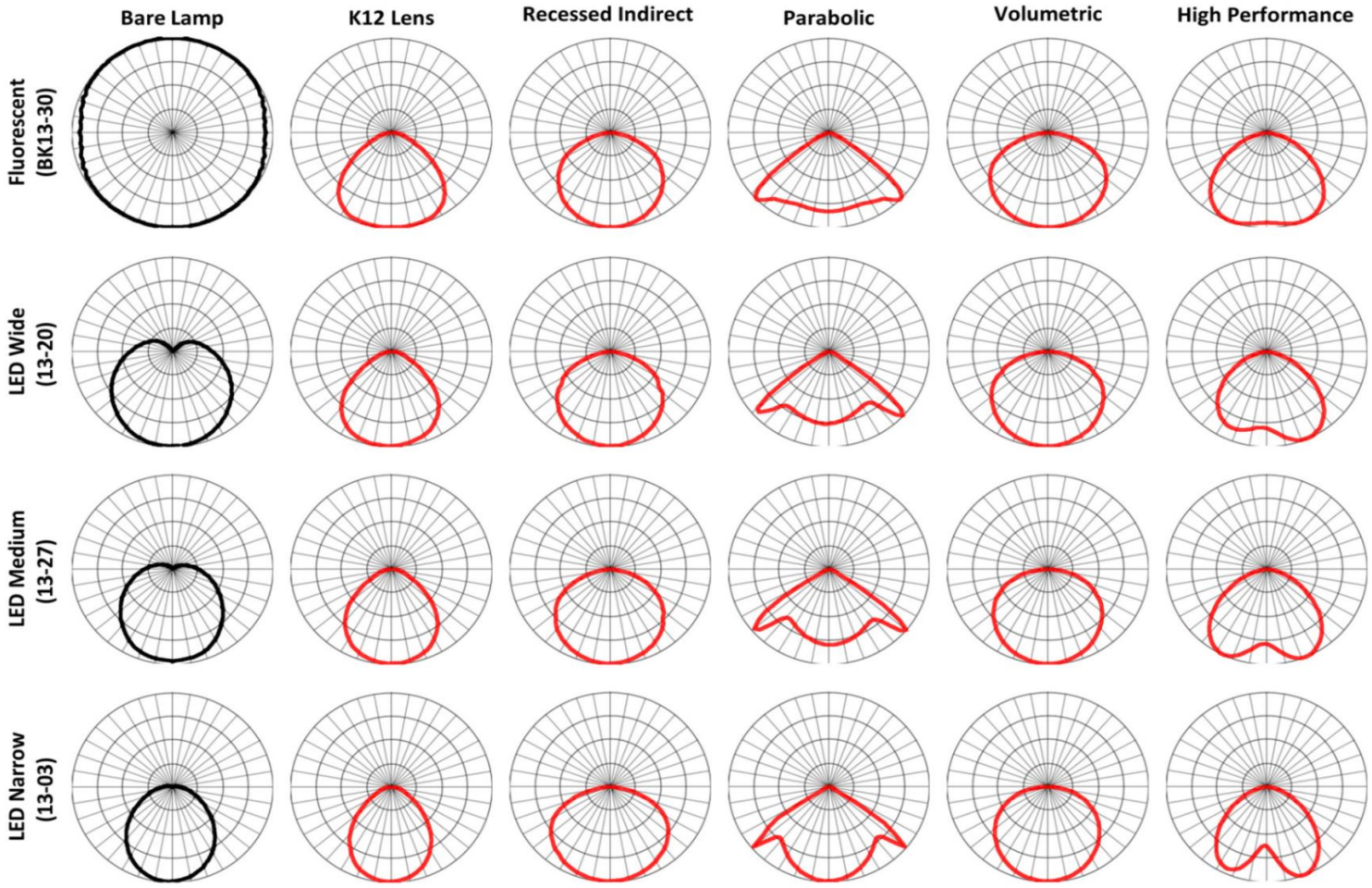
Fluorescent Tube vs. LED Tube Distribution Patterns



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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!

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

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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!

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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)…

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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!

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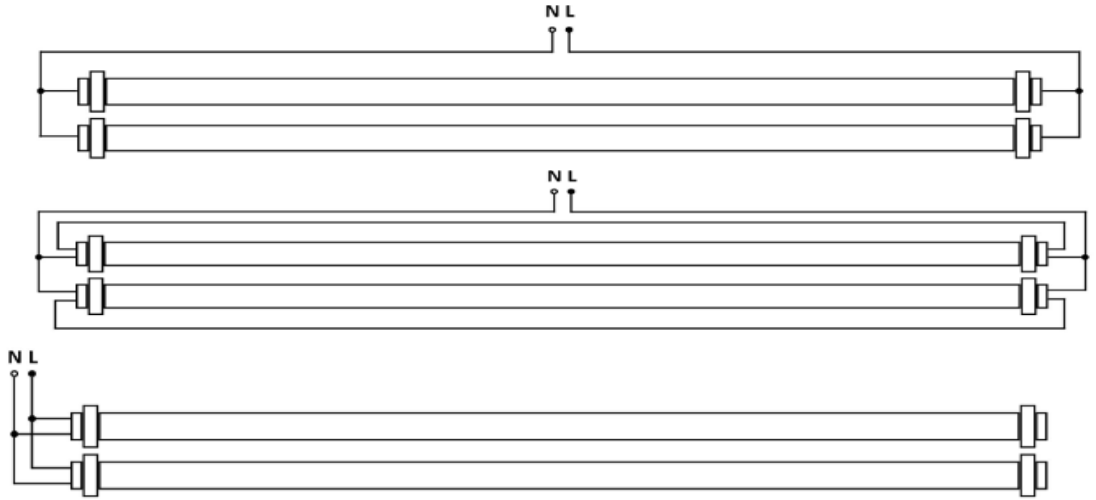
UL 1598

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



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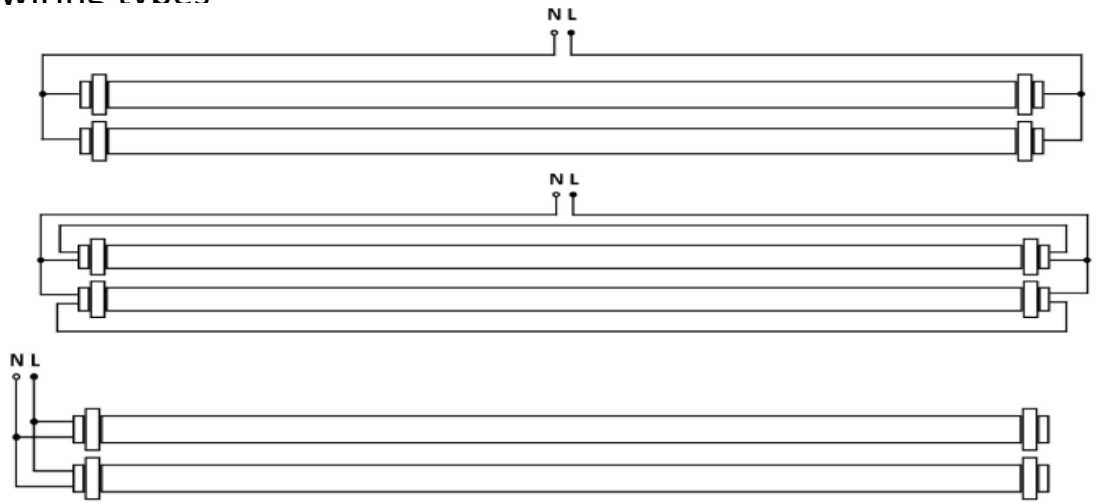
TYPE A/B (hybrid)

- 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



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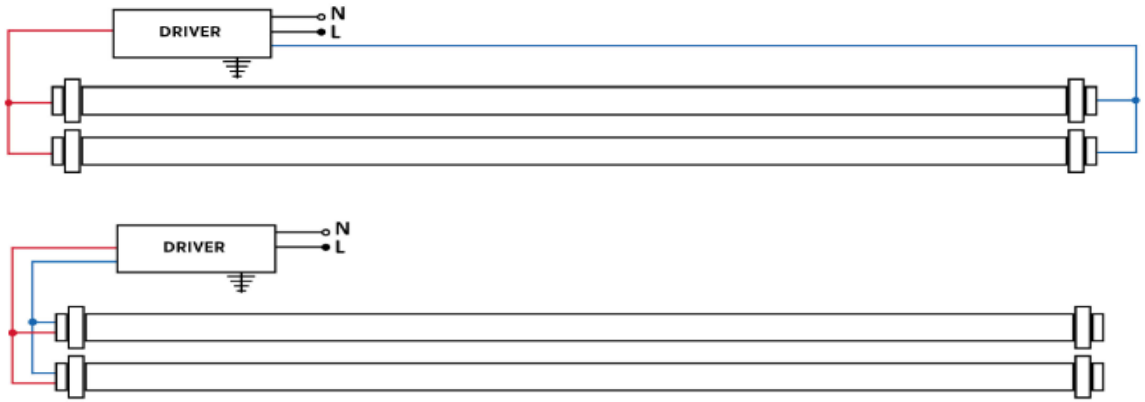
TYPE C

- 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



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Considerations - Are Retrofits a Good Idea?

EXISTING CONDITIONS TO CONSIDER	DESCRIPTION	LAMPS	KITS	LUMINAIRES
Condition of sockets	Look like new	●	●	●
	Some wear but no major cracks	▲	●	●
	Look old, blackened, cracks apparent	■	●	●
Condition of interior surfaces	Nice and white	●	●	●
	Slightly worn but no major scratches or peeling paint	▲	▲	●
	Very worn, scratches in paint, some peeling paint	■	▲	●
Condition of lens or louvers	Looks new; very little wear apparent	●	●	●
	Some minor color variations or scratches in surface	▲	▲	●
	Looks old, obvious cracks or yellowing	■	■	●
Ceiling access	No concerns with working above the ceil-ing; easy access	●	●	●
	Some concerns about working above the ceiling; limited access	●	●	▲
	Working above the ceiling should be avoided	●	▲	■

- 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.

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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

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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

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Questions and Answers

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