CALIFORNIA STATEWIDE
UTILITY CODES AND STANDARDS PROGRAM

2019 Title 24 Codes & Standards Enhancement (CASE) Proposal

Nonresidential Indoor Lighting Power Density

September 8, 2016

Bernard Bauer L.C., Integrated Lighting Concepts
Mike McGaraghan, Energy Solutions
Chris Uraine, Energy Solutions

Proposed Code Change Overview

- Revise prescriptive lighting power densities (LPD) for nonresidential indoor lighting systems
- Not mandatory – trade-offs allowed between areas and Power Adjustment Factors
- Build on ASHRAE 90.1/189.1 proposals *(all LED basis)*
- Propose new indoor LPD requirements for nonresidential buildings including task/ambient design in offices
- Investigate potential quality requirements for LED GSL lamps and tubes in NR spaces
- Investigate how to account for variable CCT systems

Background

- LPDs in Title 24 are prescriptive
  - Besides trade-offs between spaces, performance approach allows trade-offs with envelope and HVAC
- Lighting Power Density x Area = Allowed Watts
- Installed watts can be reduced by Power Adjustment Factors (PAFs)
  - Adjusted lighting power reduced by PAF x Controlled Watts
    - Daylight dimming + OFF (0.10), DR control (0.05)
    - Large office occ sensing of small zones (0.20 - 0.40),
    - Institutional Tuning (Daylit 0.05) (Non-daylit 0.10)

Prescriptive Requirements

- Complete Building Method, Table 140.6-B
  - Allowed Power = Whole Bld LPD x Bld Area
- The Area Category Method, Table 140.6-C
  - Allowed Power = ∑Space LPD x Space Area + Additional Lighting Power (see Table C footnotes)
- Tailored Lighting Method Table 140.6-D to G
  - Allowed Power = General + Use-it-or lose-it
    - General allowance adjusted by Room Cavity Ratio
  - Use-it of lose-it = Display + Task + Ornamental
    - Display allowance adjusted by mounting height
- Power Adjustment Factors Table 140.6-A,

Why are we proposing this measure?

- Little change to nonresidential indoor lighting requirements have since the 2013 standards
- LED performance has been increasing and replacing more lighting technologies
- LED performance levels are projected to improve even further by 2020.
  - LED efficacy increase of 25% by 2020
  - LED prices decrease of 25% by 2020
- LPDs in other codes are dropping
- LED sources have capability and amenity to replace general lighting, display lighting and ornamental lighting for all applications.
- **Do you agree?**
  - If not where are LED's not providing sufficient amenity?

LED Luminaire Efficacy Increase by 2020

Luminaire Types	LED Luminaire Efficacy		Efficacy Increase
Sector Submarkets	2015	2020	2020
Commercial			
General Service Lamp*	81	102	26%
Directional	66	82	24%
Small Directional (MR16)	66	82	24%
General Service Linear Fixtures	106	131	24%
Low/High Bay	101	121	20%
Other	106	131	24%
Industrial			
General Service Lamp*	81	102	26%
Directional	66	82	24%
General Service Linear Fixtures	106	131	24%
Low/High Bay	101	121	20%
Other	106	131	24%

* Lamp efficacy not luminaire efficacy comparison

Data from Table E.6 *Average LED Lamp and Luminaire Efficacy Projections by Sector and Submarket Navigant*. Prepared for USDOE. **Energy Savings Forecast of Solid-State Lighting in General Illumination Applications**. August 2014.

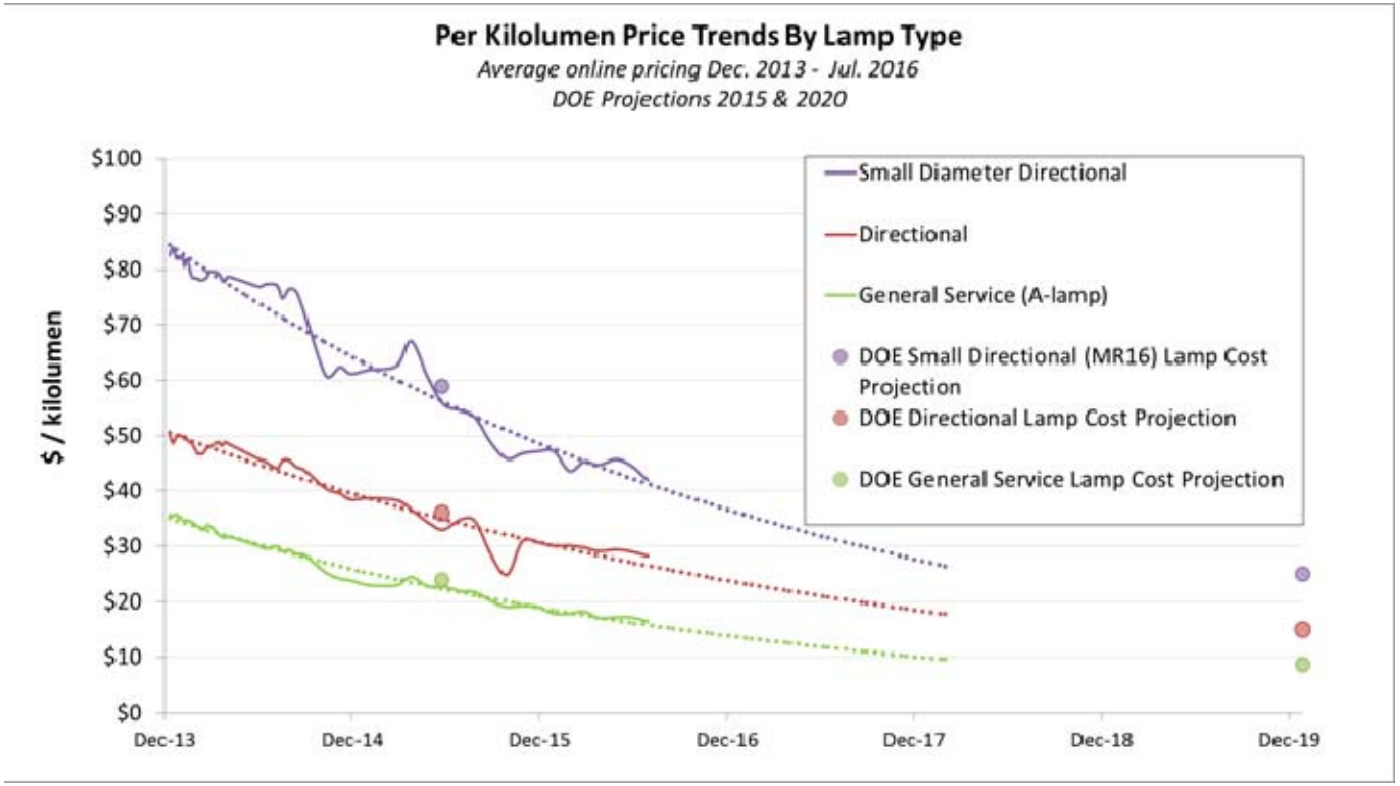
DOE Projections: 2020 Luminaire Price Decrease

Subsector markets	Lamp Cost ($/kLm)		Luminaire ($/kLm)		% Change from 2015	
	2015	2020	2015	2020	Lamp 2020	Luminaire 2020
Commercial						
General Service	$24.00	$8.70			-64%	N/A
Directional	$36.00	$15.00	$82.00	$59.00	-58%	-28%
Small Directional (MR16)	$59.00	$25.00	$82.00	$59.00	-58%	-28%
General Service Linear Fixtures	$89.00	$60.00	$89.00	$62.00	-33%	-30%
Low/High Bay			$89.00	$62.00	N/A	-30%
Other	$36.00	$15.00	$89.00	$62.00	-58%	-30%
Industrial						
General Service	$24.00	$8.70			-64%	N/A
Directional	$36.00	$15.00	$82.00	$59.00	-58%	-28%
General Service Linear Fixtures	$89.00	$60.00	$89.00	$62.00	-33%	-30%
Low/High			$89.00	$62.00	N/A	-30%
Other	$36.00	$15.00	$89.00	$62.00	-58%	-30%

Table E.9 *Average LED Lamp and Luminaire Price Projections by Sector and Submarket Navigant.*
Prepared for USDOE. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications. August 2014.

Incremental Cost Estimation

- Projected decrease in LED costs
  - Price projections curve applied to actual LED cost data, and observed historical trends, compared to DOE data

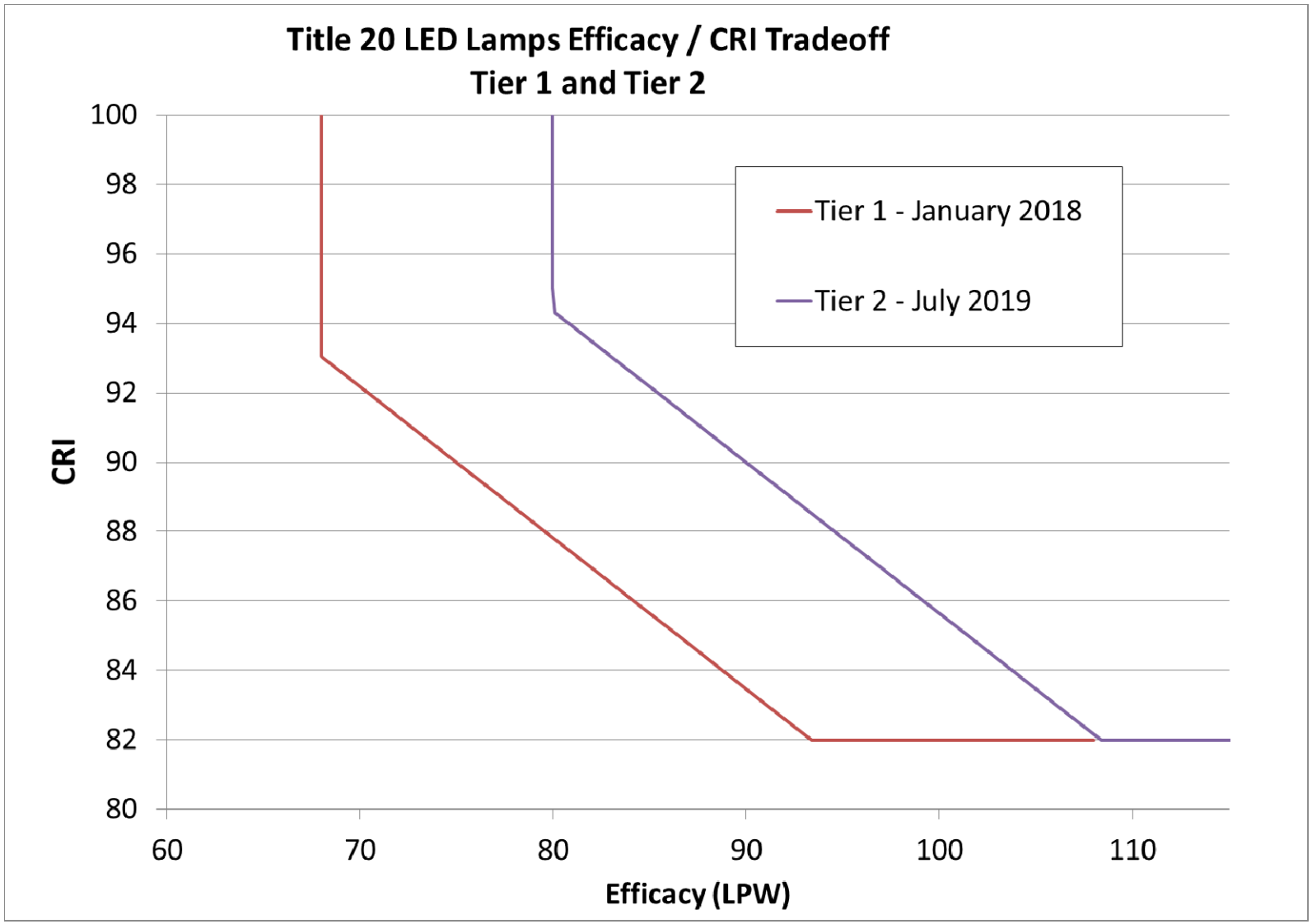


California and Federal Lamps Standards

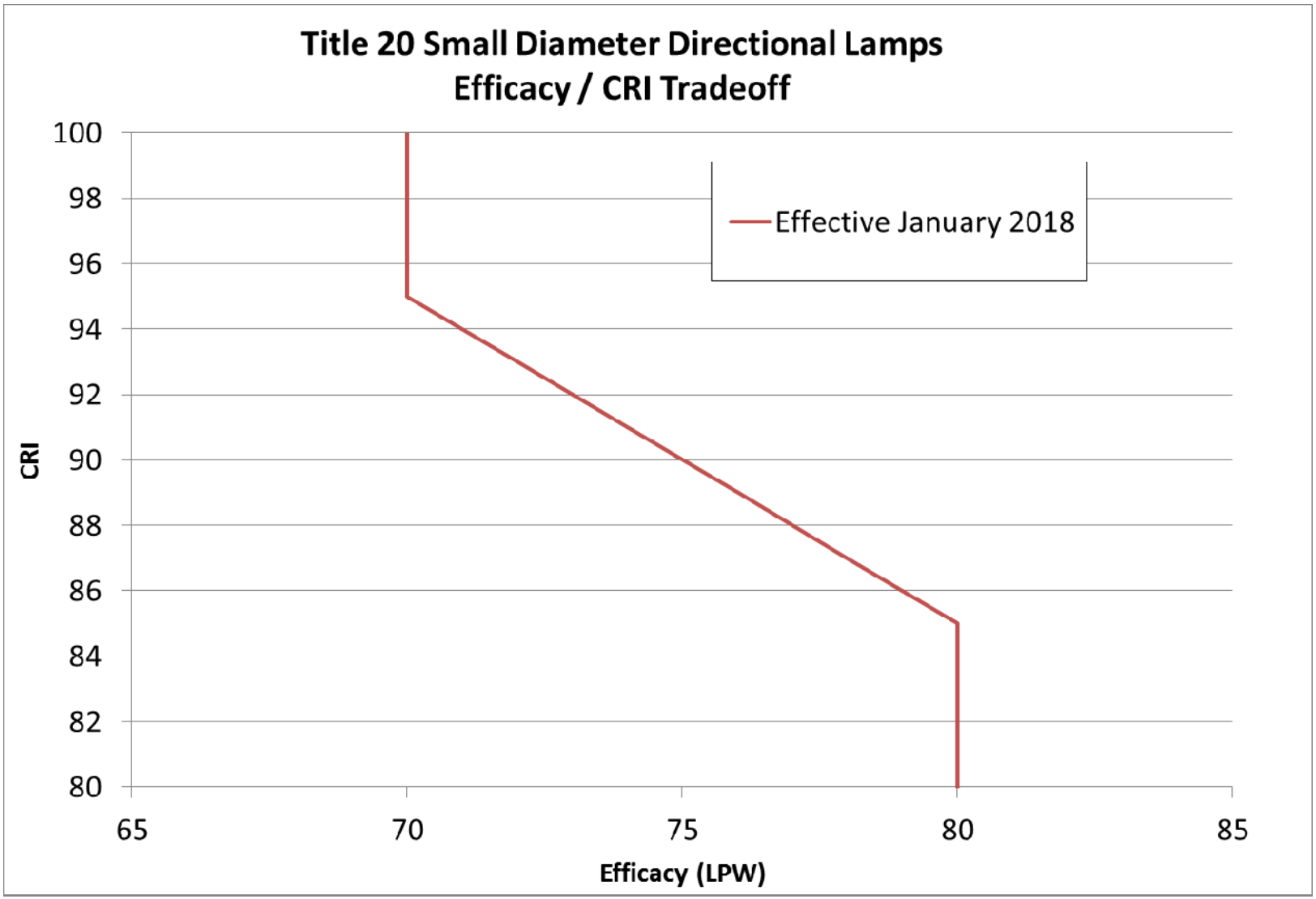
- Title 20 Standards
  - All General Service Lamps: **45 lpw.** Eff. Jan 2018
    - Excludes incandescent reflector and linear/tube lamps
  - LED lamps: **80 lpw.** Effective July 2019
    - Larger directional and omni LED lamps.
    - Excludes tubes or dedicated LED luminaires.
  - Small Diameter Directional Lamps: **70-80 lpw**
    - Effective January 2018
    - Covers MR16, PAR 16, MR11, etc.
- Federal Appliance Standards (in process)
  - General Service Lamps **~90-100 lpw**
  - Likely effective by January 2020
  - It does not impact incandescent reflector lamps (e.g. PAR), nor linear/tube lamps (e.g. T8/T5)

Title 20 CRI and Efficacy trade-off for LED lamps

(LED omnidirectional, larger directional, downlights, etc.)



Title 20 CRI and Efficacy trade-off for Small Diameter Directional Lamps (all technologies)



Current California Design Practice

- Retail
  - LED general lighting *(direct/indirect and downlights)*
  - LED wall wash, cove and valances
  - LED Accent and display
  - LED cabinet and shelf lighting





Current California Design Practice

- Dining & Hospitality
  - LED General Lighting *(chandeliers and downlights)*
  - LED Specialty *(wall wash, coves and wayfinding)*
  - LED Decorative *(chandeliers, sconces and luminous art)*

Current California Design Practice

- Museums
  - LED Exhibit Lighting *(directional, casework and special effects)*
  - LED Service Area Lighting *(restoration, archives and storage)*

Current California Design Practice

Other Spaces?

- Offices
  - LED General Lighting *(direct/indirect pendants and troughers)*
  - LED Wall Wash *(corridors, conference room pentation)*
  - LED Under Counter *(work station task lighting)*
- Warehouse & Industrial
  - LED High Bay, Low Bay or LED Industrial Strips
- Schools
  - LED General Lighting *(direct/indirect pendants and troughers)*
  - LED Wall Wash *(teaching wall – white boards)*
- LED Penetration in Additional Spaces?

Description of Surveys and Interviews

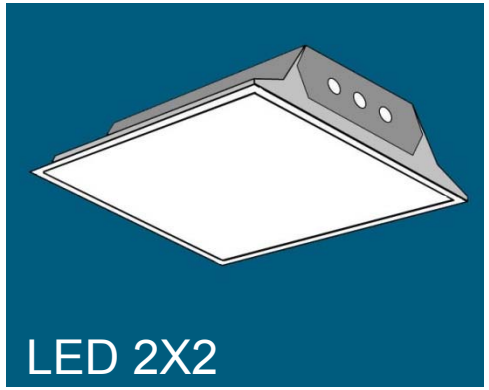
- Field surveys
  - Building Types
  - Space Types
- Interviews
  - Distributors
  - Lighting designers
  - Electrical engineers
  - Building departments *(perhaps review lighting plans?)*

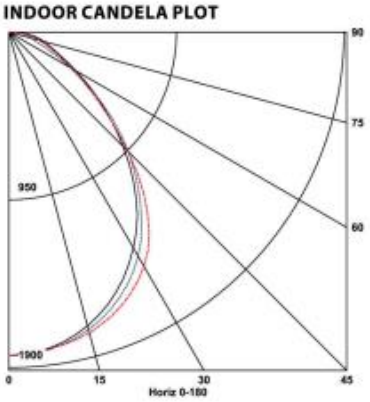
Incremental Cost Estimation

- Luminaire Costs from interviews with manufacturers and referencing distributer pricing
- Installation costs not calculated
  - Installation less than or equal to incumbent technology
  - Is this a reasonable assumption?
- See sample costs on next slide
- Given price trends collected by Energy Solutions and by DOE forecasts
  - Is it reasonable to decrease LED costs?
  - If yes, by how much?

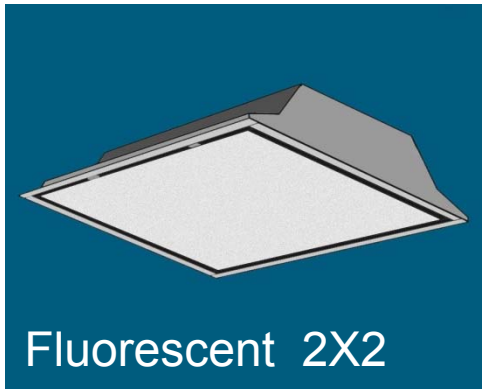
Example of comparison costing

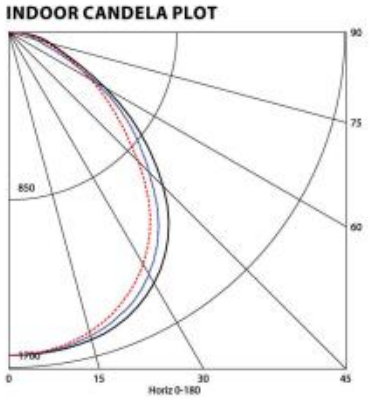
2 X 2 LED Versus 2 X 2 FLUORESCENT





LED
Watts = 45W
Lumens = 4000L fixture
Dimming = Yes *(standard offering)*
First Cost = $132.00

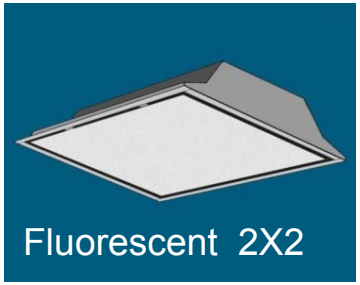




FLUORESCENT
Watts = 58W
Lumens = 4100L fixture *(5600 lamp)*
Dimming = NO *(except as adder)*
First Cost = $100.00

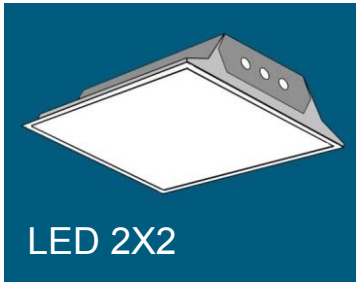
Life Cycle Costing – 2 x 2 troffer

2 X 2 LED Versus 2 X 2 FLUORESCENT



Fluorescent 2 x 2 Troffer
Operating Hours = 3,000 hr/yr
Expected Life = 15 Years
PV Cost = $390.71

Incumbent Tech	Fixture Cost	Lamp Cost ($/lamp)	Number of lamps	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number relamp period	Discounted Maint Cost	Incumbent Tech Total PV Cost
Fluorescent	$77.00	$11.50	2	$5.00	24,000	50	150	$ 22.50	$ 268.60	$100.00	8.0	27%	1	$22.10	$390.71



LED 2 x 2 Troffer
PV Cost = $346.88

Present Valued Savings	Benefits	Costs	B/C ratio
$43.82	$75.82	$32.00	2.37

Proposed LED Tech	Fixture Cost	Lamp Cost	Lamps per luminiare	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number lamp replace	Maint Cost	Proposed LED Total PV Cost
Dedicated LED	$132.00	$0.00	0	$5.00	50,000	40	120	$ 18.00	$ 214.88	$132.00	16.7	64%	0	$0.00	$346.88

Example of comparison costing

TRACK: LED HEAD Versus INCANDESCENT HEAD

LED

Watts	=	14 W + 18 W + 26 W
Lumens	=	1,050L + 1,350L = 1,500L
Color/CRI	=	3000K / 90+ CRI
Dimming	=	Yes *(most lamps)*
First Cost	=	$66.00
Lamping	=	25,000 Hours

HALOGEN IR

Watts	=	50 W + 70 W + 80 W
Lumens	=	900L + 1,300L = 1,600L
Color/CRI	=	2850K / 100 CRI
Dimming	=	Yes *(inherent design)*
First Cost	=	$35.00
Lamping	=	2,500 to 3,000 Hours

Life Cycle Costing: Track Head

TRACK: LED HEAD Versus INCANDESCENT HEAD

PAR Halogen
Life Cycle Cost = $581.52

Incumbent Tech	Fixture Cost	Lamp Cost ($/lamp)	Number of lamps	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number relamp period	Discounted Maint Cost	Incumbent Tech Total PV Cost
Halogen PAR 38 Types	$30.00	$5.00	1	$5.00	2,500	75	225	$ 33.75	$ 402.91	$35.00	0.8	2%	18	$143.61	$581.52

PAR LED
Life Cycle Cost = $198.21

Present Valued Savings	Benefits	Costs	B/C ratio
$383.30	$414.30	$31.00	13.36

Proposed LED Tech	Fixture Cost	Lamp Cost	Lamps per luminiare	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number lamp replace	Maint Cost	Proposed LED Total PV Cost
LED A lamp replacement	$30.00	$36.00	1	$6.00	25,000	19	56	$ 8.33	$ 99.38	$66.00	8.3	28%	1	$32.83	$198.21

High Bay Comparison Costing

LED HIGH BAY Versus METAL HALIDE HIGH BAY

LED
Watts = 200 W *(LED & driver)*
Lumens = 21,600 *(useable maintained)*
Color/CRI = 4000K / 70+CRI
Dimming = Yes *(available option)*
First Cost = $480.00
Lamping = 80,000+ Hours

METAL HALIDE
Watts = 435 W *(lamp & ballast)*
Lumens = 21,800 *(useable maintained)*
Color/CRI = 4000K / 65CRI
Dimming = No *(possible but not practical)*
First Cost = $216.00 *(includes lamp)*
Lamping = 20,000 Hours

High Bay Comparison Costing

LED HIGH BAY Versus METAL HALIDE HIGH BAY

Metal Halide High Bay
Life Cycle Cost = $2,596

Incumbent Tech	Fixture Cost	Lamp Cost ($/lamp)	Number of lamps	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number relamp period	Discounted Maint Cost	Incumbent Tech Total PV Cost
Metal Halide 250-400W Types	$192.00	$24.00	1	$5.00	20,000	435	1,305	$195.75	$2,336.85	$216.00	6.7	22%	2	$43.37	$2,596.22

LED High Bay
Life Cycle Cost = $1,554

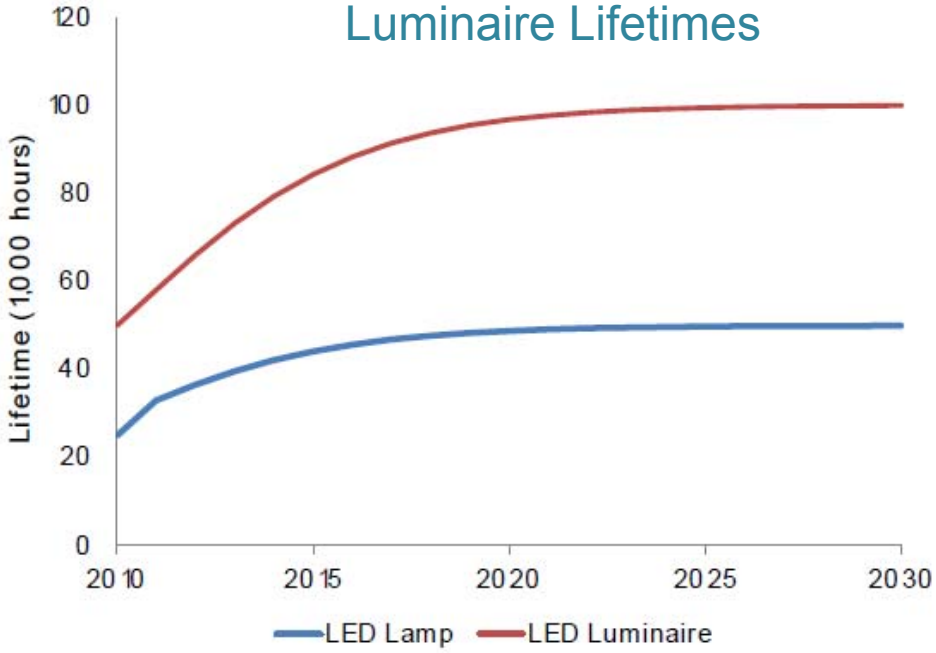
Present Valued Savings	Benefits	Costs	B/C ratio
$1,041	$1,305	$264	4.95

Proposed LED Tech	Fixture Cost	Lamp Cost	Lamps per luminiare	Lamp maint labor cost	Lamp Life	Fixture Watts	Fixture kWh/yr	Annual Electricity Cost	Present Value Elec Cost PV$	First Cost	Lamp replacement period (yr)	Effective discount rate per period	Number lamp replace	Maint Cost	Proposed LED Total PV Cost
Dedicated LED	$480.00	$0.00	0	$5.00	50,000	200	600	$90.00	$1,074.41	$480.00	16.7	64%	0	$0.00	$1,554.41

Maintenance Cost

- Legacy products: use manufacturer's data for lamp lifespan
- Assume luminaires last 15 years except retail
- For retail, shorter 7 year lifespan *(what this does to cost-effectiveness?)*
- Are 15 year and 7 year reasonable assumptions?

DOE Projection of LED Lamp and Luminaire Lifetimes



Should DOE's projection of increased life span of LEDs by 2020 be used to assume lower lamp lumen depreciation for LEDs?

Data from Figure E.1 *LED Lamp and Luminaire Lifetime Projections.* Navigant Prepared for USDOE. **Energy Savings Forecast of Solid-State Lighting in General Illumination Applications**. August 2014. http://www.energy.gov/sites/prod/files/2015/05/f22/energysavingsforecast14.pdf

Methodology for Energy Cost Savings Analysis

1. Start with ASHRAE 90.1 assumptions or prior Title T24 analysis for illuminance for general, task, ornamental and wall washing and compare against IES Handbook
2. Use lumen method to calculate W/sf based on high performance, high efficacy luminaires with CU's and LLF.
3. Compare new calculated LPD versus 2016 LPD, this yields a kW/sf savings
4. Multiply kW/sf savings by operating hours to calculate kWh/sf-yr savings.
5. Apply appropriate load profile of savings and multiply by hourly TV's to calculate life cycle present valued savings.

Cost-effectiveness calculation

- Cost effectiveness is based on life cycle costing analysis.
  - Uses real (nominal – inflation) discount rate of 3%.
- Measure is cost-effective if present valued Benefits (savings) are greater than present valued Costs.
- PV Benefits = PV energy cost savings, + PV maintenance cost savings (if decreased)
- PV costs = Incremental costs + PV maintenance costs (if increased)

Assumptions for Statewide Energy Impacts

- Operating hours: based on Title 24 ACM lighting schedule by building type
- Frequency of space types in major building types (see whole building calculation in VAN)
- Area of new buildings: Use CEC statewide nonresidential construction forecast by building type.
- Retrofits – assume 1/15th of building stock has their lighting systems replaced
- Energy savings: 2016 LPDs versus 2019 LPDs
- Any recommendation of data sources?

Other Issues

- Color changing systems (variable CCT)
  - RGB and “warm and cool” module blending for achieving tunable white
  - Input power changes with color settings - defining maximum rated power needed to determine compliance with LPDs
  - Define input power based on setting or maximum achievable?
  - Will these be prevalent by 2020?
  - Comparable efficacy versus baseline LED?
  - In which spaces, beside hospitality, should Variable CCT be considered?

Other Issues

- Current limiters and track lighting
  - Aware of issue and will investigate
  - Reduction of minimum W/lin-ft if current limiter used?
  - Allow same approach for down lights?
- Lumen method calibrated with AGI 32 runs
  - Which space types do you believe require detailed lighting simulations?
    - importance or deviation from lumen method assumptions

Standby Power

- Luminaires with “soft switch” control consume power all the time
  - Wireless systems
  - Low voltage controlled systems
- Title 20 limit on standby power of LED lamps
  - 0.2 W/lamp
  - No limit for integral fixtures currently
- Standby power from smart/connected/LLC systems
  - Prevalence, current values, measurability?
  - Part of the LPD?
- Standby dealt with on lighting sources but not lighting controls
  - Aware of issue and will investigate
  - How to address?

Preliminary Proposal

- Section 130.0
  - Added wattage to account for standby power for luminaires with “soft switches”
- Section 140.6
  - Update wattages in Tables 140.6-B, C, D, &G
- What do you think of this proposal?
- What else should we be considering?

Financial and Environmental Impacts on State

- Proposed regulation is not qualitatively different than current regulation (just the numbers change)
- No difference in effort to enforce than current lighting requirements.
- There is a performance alternative
- Net increase in wealth of Californians
- Net impact on jobs is negligible
- Small impact on cost of lighting systems
- Reduces toxics (mercury)
- Reduces environmental impacts of energy production.
- Do you agree with the above statements?
  - If not why not?

Compliance and Enforcement

- CASE Team will be interviewing stakeholders to identify potential barriers to code compliance and enforcement

- Will need to update existing compliance forms related to nonresidential indoor lighting

Compliance and Enforcement—Tasks

Market Actor	Task(s)	Success Criteria
Lighting Designers	- Design lighting system to meet Title 24 code - System performs to owner specifications & needs. - Compliance forms	- System meets owner needs - Do this quickly and within budget and schedule - Do this cost-effectively - System is Title 24 compliant
Contractor/Builder	- Build system exactly as designed to meet code - Purchase system from retailers/distributors - Coordinate with other market actors - Work on-site	- Do this quickly and within budget and schedule - Do this with minimal paperwork - System is Title 24 compliant

Compliance and Enforcement—Tasks

Market Actor	Task(s)	Success Criteria
Electrician	- Install lighting system - Follow lighting design - Coordinate with contractor/builder	- System is Title 24 compliant - Install to meet owner specifications - System functions properly - On schedule and within budget
Energy Consultant/Modeler	- Generate compliance documentation and fill out paperwork - Provide assistance in code interpretation - Run compliance model if necessary	- Compliance documents are properly filled out and system is compliant - Avoid redesigning related code requirements - Minimal energy code related plan check comments - Do this virtually/ remote

Compliance and Enforcement – Market Actors, Tasks, Success Criteria, Resources, and Tools

- Who would be involved in implementing this measure?
  - Lighting Designers
  - Contractor/Builder
  - Electrician
  - Energy Consultant/Modeler
  - Others?
- What Compliance and Enforcement Tasks or Success Criteria are missing?
- What resources or tools are typically used for compliance?

Feedback Request from Stakeholders

- Please provide additional feedback and/or data to the CASE Team
  - Bernie Bauer, L.C.
    - ilclighting@verizon.net
    - (805)497-6604
  - Mike McGaraghan
    - mmcgaraghan@energy-solution.com
    - (510)482-4420 ext.242
  - Chris Uraine
    - curaine@energy-solution.com
    - (510)482-4420 ext.243

Questions?