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BETTER BUILDINGS SUMMIT

WASHINGTON, DC ■ MAY 9-11





**Better
Buildings[®]**
U.S. DEPARTMENT OF ENERGY



High Performance Troffer Lighting Solutions

Michael Myer

Pacific Northwest National Laboratory (moderator)

Chris Magee

MGM Resorts International

William Evans

Princeton University

Overview

- Interior Lighting by the Numbers
- Princeton Icahn Laboratory
 - Troffer Retrofit
 - CFL Downlight LED Retrofit
- MGM Resorts
- Interior Lighting Campaign

Interior Lighting by the Numbers

Commercial Buildings

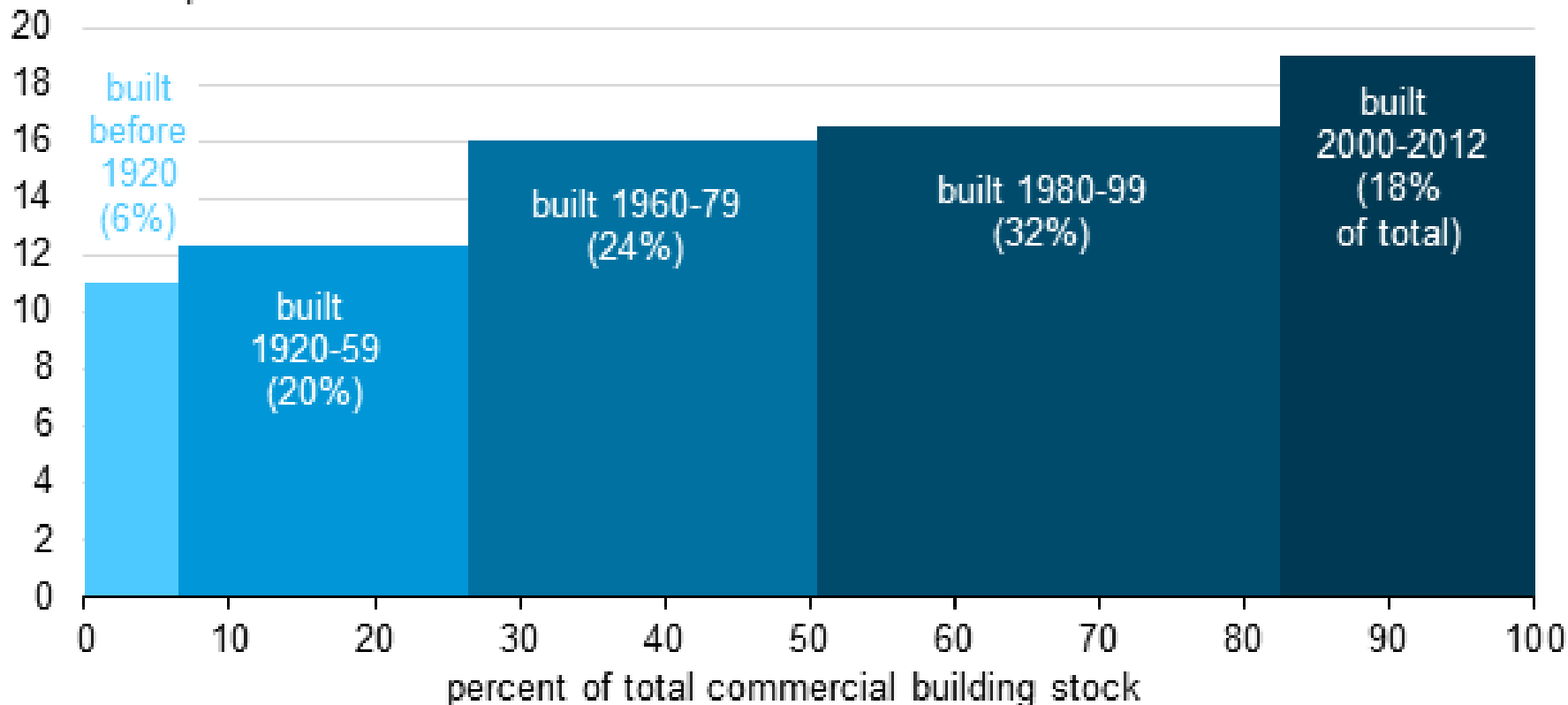
- 5.6 million commercial buildings, comprising more than 87 billion square feet of floor space
 - 14% increase in # of buildings since 2003
 - 21% increase in floor space since 2003
- Commercial building account for:
 - 18% of total energy consumption in the U.S.
 - 28% of green house gas emissions

Interior Lighting by the Numbers

Commercial Buildings

Average commercial building size

thousand square feet



Interior Lighting by the Numbers

Electricity and Costs

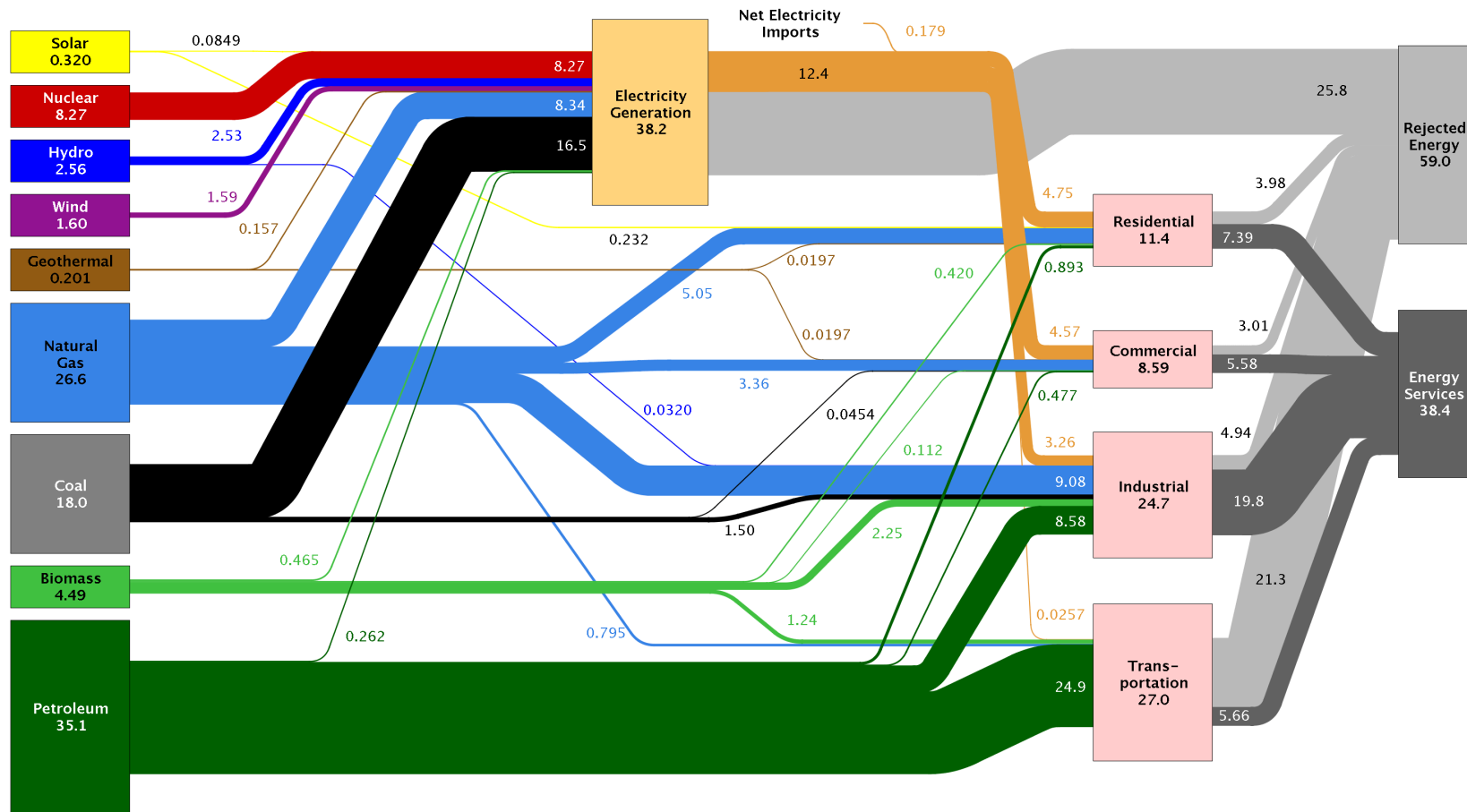
Building Type	Lighting is portion of electricity	Annual Electricity Use (kWh / sf)	Annual Energy Lighting Cost / sf
Grocery Store	23%	52.5	\$1.25
Hospitals	43%	27.5	\$1.22
Hotel/Motel	57%	14	\$0.82
Higher Education	31%	18.9	\$0.61
K-12 Schools	31%	10.0	\$0.32
Laboratories	47%	65.0	\$3.16
Large Offices	40%	20.0	\$0.83
Small/Medium Offices	34%	15.0	\$0.53
Manufacturing	2%	95.1	\$0.20
Quick-Service Restaurants	8%	96.1	\$0.79
Restaurants	24%	97.1	\$2.41
Retail Building	53%	14.0	\$0.77
Warehouses	60%	16.0	\$0.99

Interior Lighting by the Numbers

U.S. Energy Use



Estimated U.S. Energy Use in 2013: ~97.4 Quads



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Interior Lighting by the Numbers

Commercial Buildings

- Commercial lighting is $\approx 2.6\%$ of ALL energy use
- Troffers $\approx 1\%$ of ALL energy use

Interior Lighting by the Numbers

More on troffers



- Estimated 367 million troffers in the US
- ≈ 1 troffer for every 240 square feet

Interior Lighting by the Numbers

Troffer efficacy

- Lighting efficacy – the conversion of power into light (lumens/Watt [lm/W])
- Luminaire Efficacy (LE) or Luminaire Efficacy Rating (LER) is an energy efficiency metric for lighting
 - Very similar to miles per gallon for cars

Interior Lighting by the Numbers

Troffer efficacy

- Current average troffer LER = 66 lm/W
- New troffers are 85 to 120 lm/W



- New equipment more efficient & more features

Interior Lighting



- Represents a significant amount of energy
- New energy efficient technologies exist
- New technologies offer benefits in addition to energy savings

Princeton University

Icahn Laboratory Troffer Retrofit
CFL Downlight LED Retrofit

Carl Icahn Laboratory of the Lewis-Sigler Institute for Integrative Genomics

- 98,000 sq ft overall
- 35,000 sq ft of labs; 2 floors
- 150 person capacity
- Central glass atrium and 2 story curving glass wall joining them
- Glass wall is shielded by 31 external 40ft vertical aluminum louvers that rotate with the sun to maximize shade, minimize thermal loading
- **First building-wide interior LED project on campus**



Carl Icahn Laboratory of the Lewis-Sigler Institute for Integrative Genomics

- Annual lighting energy use
 - 564,000 kWh
 - \$50,000 annual cost
- Lab and office space lighting
 - 815 recessed 2ft x 2ft luminaires
 - each use (2) 31W T8 fluorescent U-lamps
 - acrylic prismatic lens, draw 59 Watts of power
 - operate an estimated 5,000 hours per year
 - 240,425 kWh annually, or about 43% of the facilities annual lighting energy use

Carl Icahn Laboratory of the Lewis-Sigler Institute for Integrative Genomics

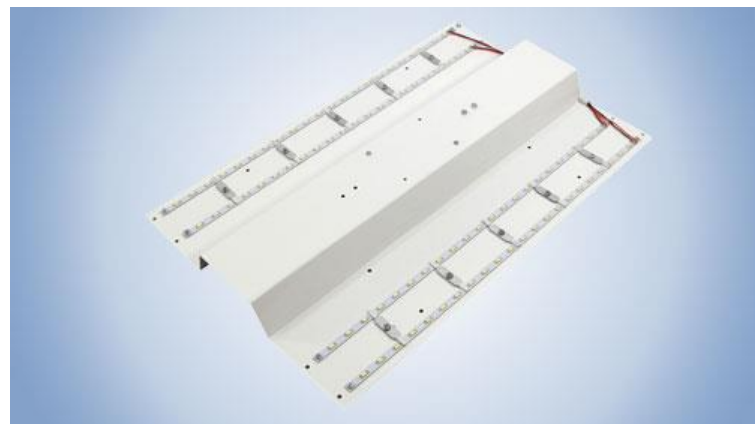
The Issues

- Removal of existing fixtures and replacement with new did not appear cost competitive due to the amount of labor required
- Based on past experience with lab users on campus, a simple on/off type occupancy sensor configuration was considered to be a nuisance by users and had a history of being deactivated

Carl Icahn Laboratory of the Lewis-Sigler Institute for Integrative Genomics

The Troffer Lighting Solution

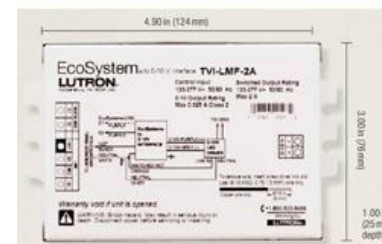
- LED pan type Retrofit kits from Maxlite
 - 3,315 lumens
 - 45 Watt power input
 - CCT of 4,100K
 - Minimum CRI of 82
 - 0-0-10V Control (off at 0V)
 - Safety Certification from ETL
 - Design Lights Consortium's Qualified Products List member (QPL)
 - Yields over 57,000 kWh in annual energy savings, before controls



Carl Icahn Laboratory of the Lewis-Sigler Institute for Integrative Genomics

The Controls Solution

- Lutron Quantum Ecosystem with 0-10V to Ecosystem converters to drive the fixtures
- Lutron Wireless Motion and Daylight Sensors
- Lutron Wireless Dimmer Switches
- Bi-level dimming philosophy in lab areas

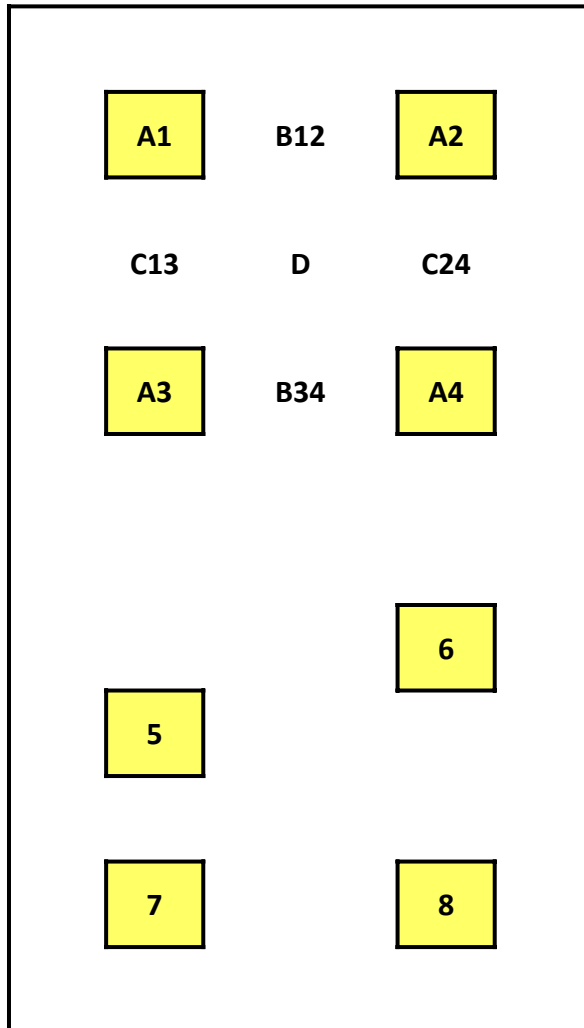


Icahn Lab: Room 222



Icahn Lab: Room 222

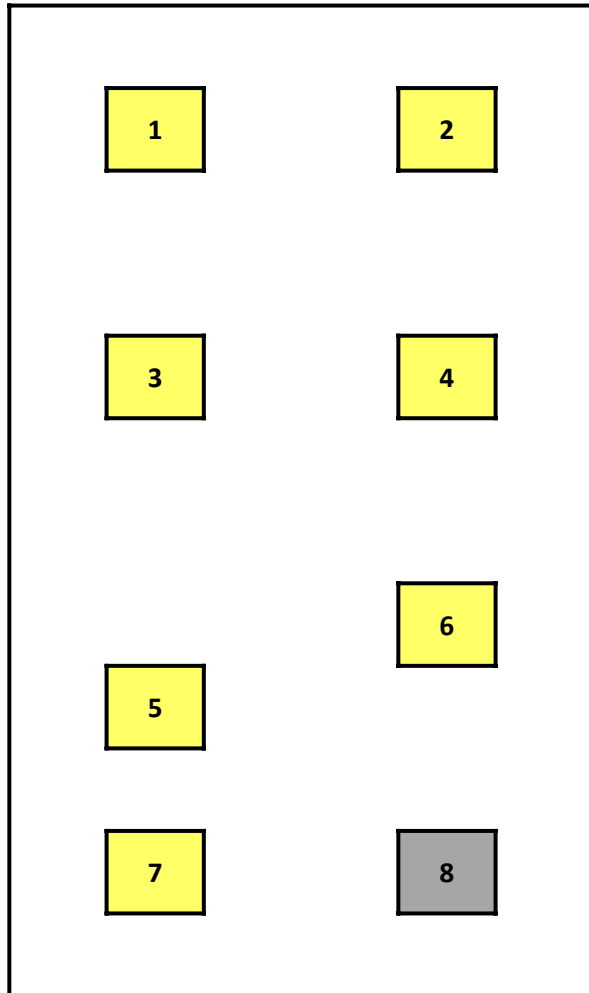
Window Wall



ILLUM (HOR) AT COUNTER HEIGHT			
	FC FL	FC LED	LED/FL
AVE	62.2	103.6	1.67
MAX:MIN	1.34	1.36	
ILLUM (VERT) AT WINDOW TOP			
AVE	56.5	86.1	1.52
ILLUM (HOR) AT TOP SHELF			
AVE	91.9	149.3	1.62
ILLUM (VERT) AT TOP SHELF			
AVE	40.9	65.9	1.61

Icahn Lab: Room 222

Window Wall

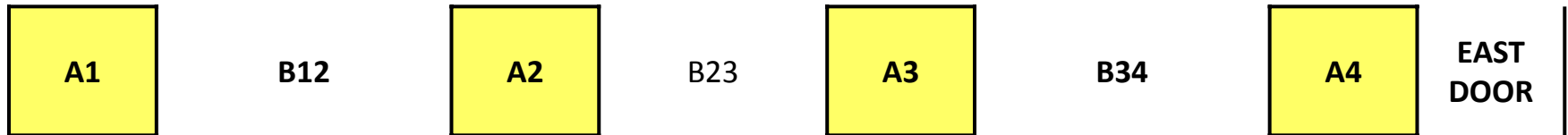


COLOR MEASUREMENTS				
FIXTURE	FL CCT	FL CRI	LED CCT	LED CRI
1	3715	81	4304	85
3	2842	86	4323	85
5	3746	78	4311	85
7	3158	78	4299	85
2	3169	77	4336	85
4	3747	78	4303	85
6	3750	78	4313	85
MAX	3750	86	4336	85
MIN	2842	77	4299	85

Icahn Lab: Corridor 233



Icahn Lab: Corridor 233



- Horizontal illuminances measured at 3' AFF centered under fixture row
- Vertical illuminances measured at 5' AFF along south wall, aligned with horizontal measurement locations

	FL-HOR	LED-HOR	LED/FL
MEAN	53.0	96.8	1.83
MAX:MIN	1.19	1.24	
	FL-VERT	LED-VERT	LED/FL
MEAN	30.4	53.5	1.76
MAX:MIN	1.34	1.16	

Icahn Lab: Open Lab area



Icahn Lab: Open Lab area

- Horizontal illuminances measured along the counter at 2' intervals
- Point 0 is at window end of bench; point 14 at end near inner wall

POINT	FC - FL	FC - LED	LED/FL
0	44.9	72.7	1.62
2	47.5	76.3	1.61
4	52.9	78.3	1.48
6	56.1	76.5	1.36
8	57.5	89.0	1.55
10	57.9	94.8	1.64
12	59.0	98.7	1.67
14	65.1	111.8	1.72
MEAN	55.1	87.3	1.58
MAX:MIN	1.45	1.54	

Icahn Lab: CFL Downlight LED Retrofits

The Downlight Solution:

LED downlight retrofit kits from Terralux

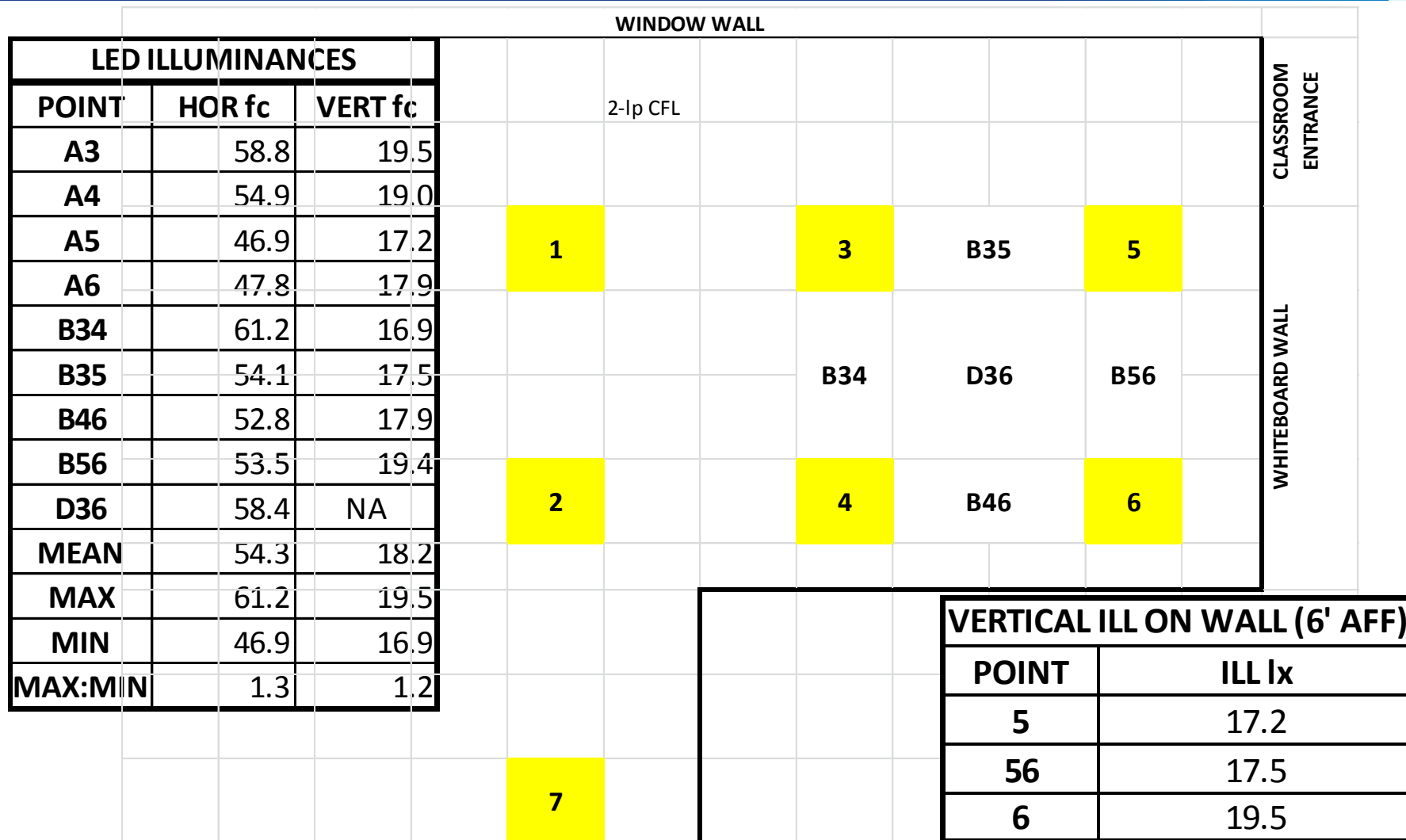
- 60,000+ hour L70 lifetime
- 80+ CRI
- 92 Lumens/watt
- Energy Star



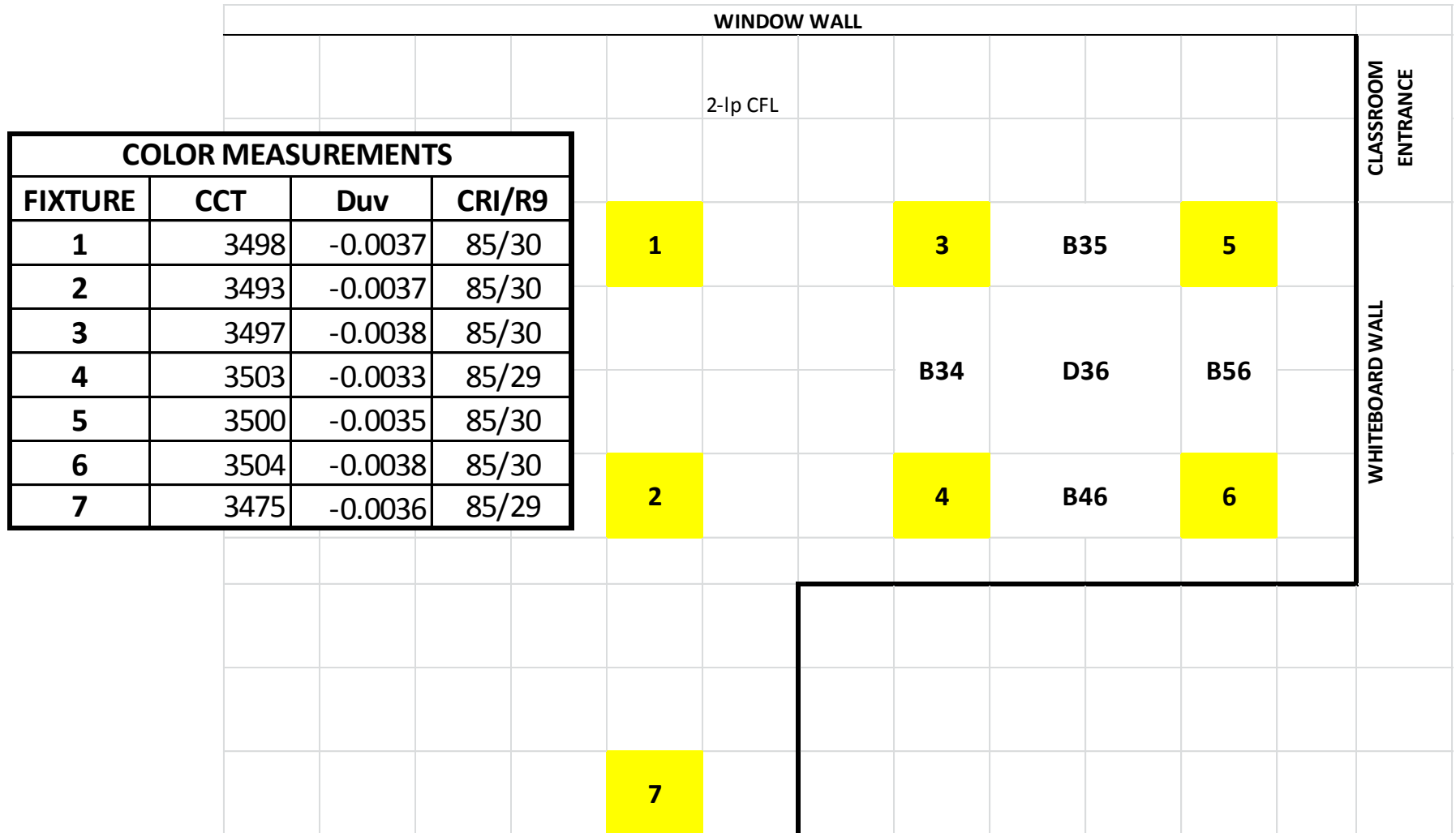
Icahn Lab: CFL Downlight LED retrofits



Icahn Lab: CFL Downlight LED retrofits



Icahn Lab: CFL Downlight LED retrofits



Icahn Lab



Icahn Lab



Icahn Lab



Icahn Lab



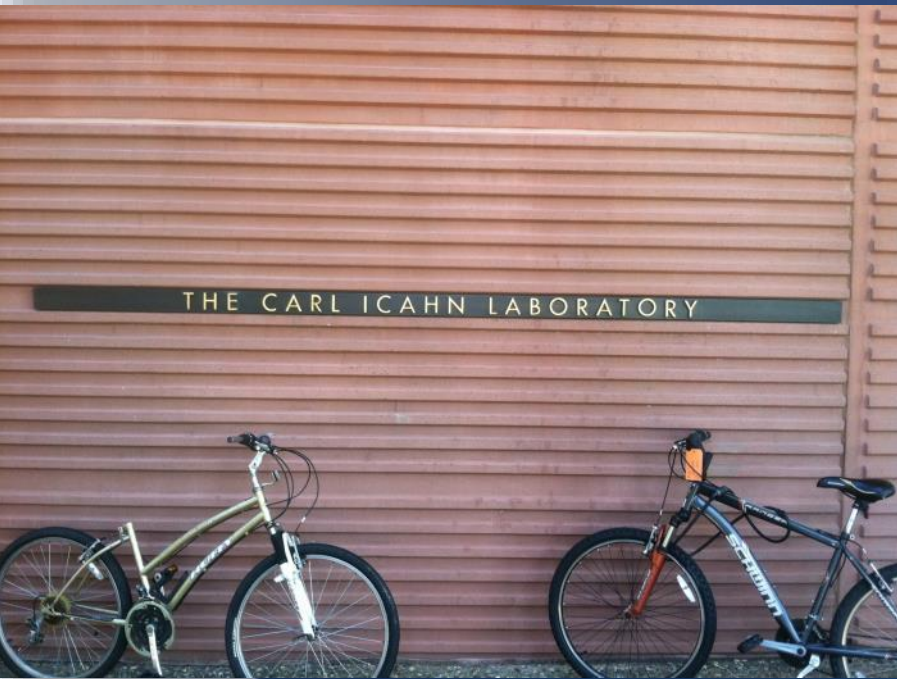
Icahn Lab



Icahn Lab



Summary of Princeton Experience



- 24% energy savings before lighting controls
- Light levels improved

What came before?



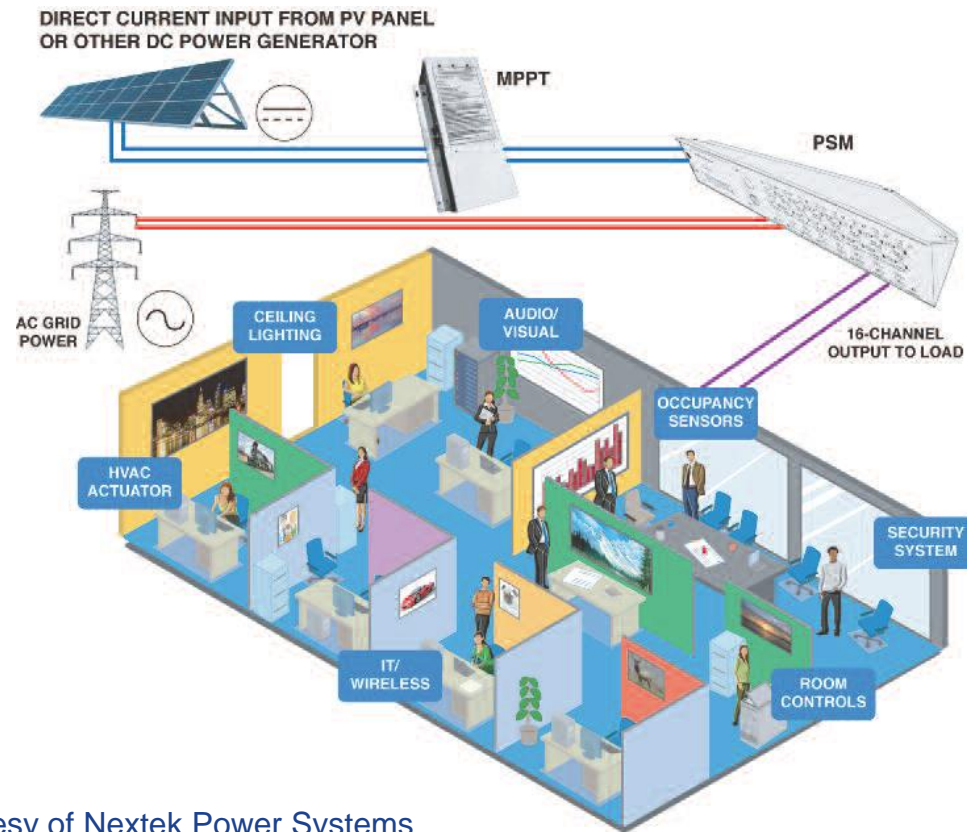
What came before?

15MW Cogen Facility



What comes next?

Low Voltage DC Distribution

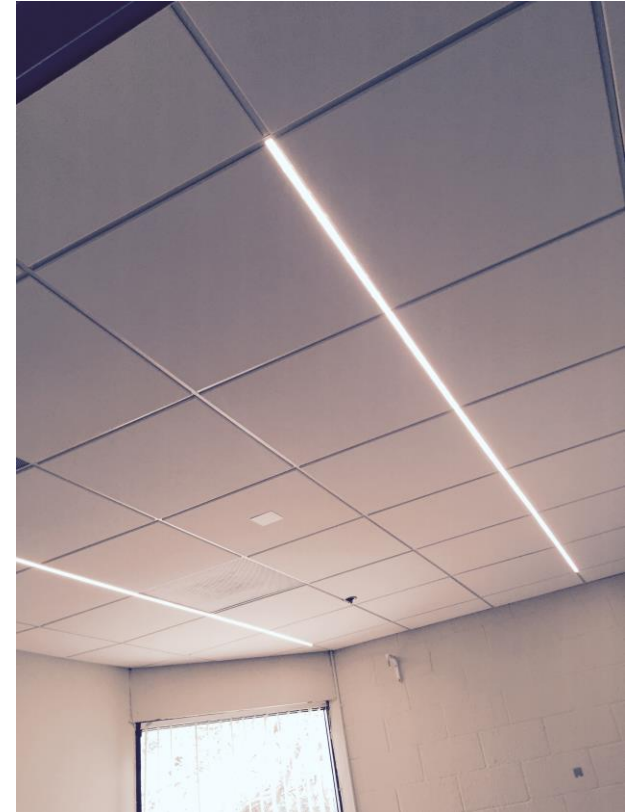
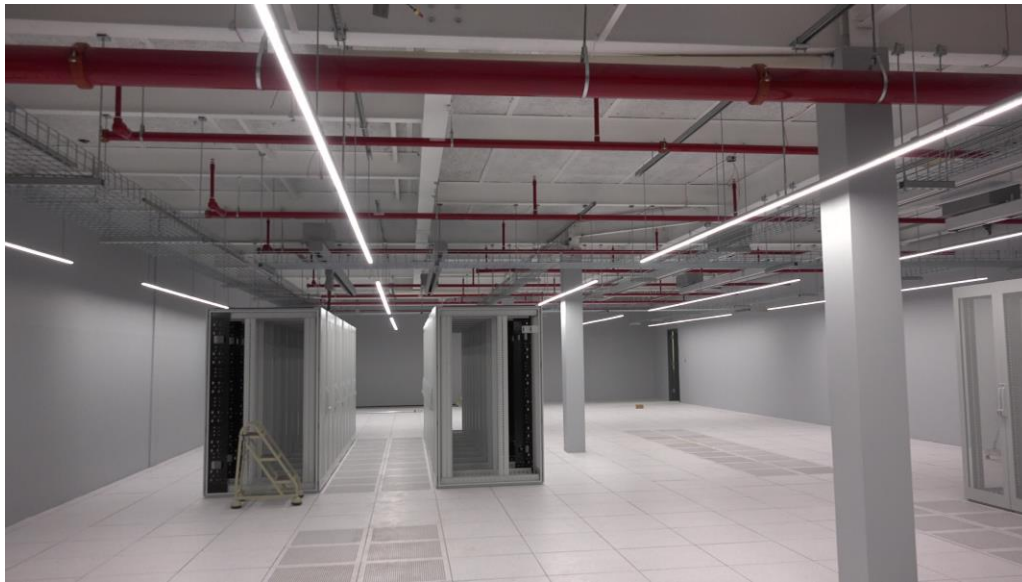


*Illustration Courtesy of Nextek Power Systems

What else comes next?

Think outside the Troffer:

- Low Voltage DC LED lighting



*Photos Courtesy of Steel Orca and Goldeneye

MGM Resorts

Troffer Lighting Retrofit Project

MGM Resorts

New Office Space Analysis

- Installation of 755 High-efficiency Office 2x2 Troffers for Information Technology Building
 - Include full dimming controls
 - LED upgrade over specified linear fluorescent fixtures
 - \$165K lighting spend (\$69K incremental)
 - 68% energy reduction – 125K annual kWh saved
 - 33.9% ROI

MGM Resorts

New Office Space Analysis

- How did we get there?
 - **Option 1 – Baseline 2x4 Linear T8**
 - **Option 2 – Baseline 2x4 Linear T8 w/Controls**
 - **Option 3 – Extended Life 2x4 Linear T8**
 - **Option 4 – Extended Life 2x4 Linear T8 w/Controls**
 - **Option 5 – LED 2x2 Fixture**
 - **Option 6 – LED 2x2 Fixture w/Controls**

MGM Resorts

Options 1 & 2 baseline T8 fixture options

	Option 1	Option 2
Light Source	Linear fluorescent (T8)	Linear fluorescent (T8)
Controls	No	Occupancy sensors only
# of lamps	3	3
Input Power	96 W	67 W (30% expect savings from sensors)
Lamp life	30,000 hours	30,000 hours
Fixture output	5,569 lumens	5,569
Rated Life	2.5	2.5
Realmps	1	1
Install Cost Per Fixture	\$137.44	\$184.69

MGM Resorts

Options 3 & 4 ext. life T8 fixture options

	Option 3	Option 4
Light Source	Linear fluorescent (T8)	Linear fluorescent (T8)
Controls	No	Occupancy sensors only
# of lamps	3	3
Input Power	84 W	59 W (30% expect savings from sensors)
Lamp life	75,000 hours	75,000 hours
Fixture output	5,171 lumens	5,171
Warranty	5	5
Realmps	0	0
Install Cost Per Fixture	\$140.74	\$187.99

MGM Resorts

Options 5 & 6 LED fixture options

	Option 5	Option 6
Light Source	LED	LED
Controls	No	Occ sensors, dimming, & daylight controls
# of lamps	1 module	1 module
Input Power	44 W	26 W (30% expect savings from occ sensors, 10% with dimming, and 10% from daylight dimming)
Warranty hours	50,000 hours	50,000 hours
Fixture output	4,400 lumens	3,960 lumens (90% full output set during commissioning)
Warranty	5	5
Realmps	0	0
Install Cost Per Fixture	\$220.99	\$267.52

MGM Resorts

Options 1 & 2 operating data

	Option 1 (T8)	Option 2 (T8 & Controls)
Annual Energy	288 kWh	176.4
Annual Energy Cost (\$0.11 / kWh)	\$31.68	\$19.40
10-year Energy	2,880 kWh	1,764 kWh
10-year Energy Cost	\$363.18	\$222.45
Relamp Cost: (one relamp)	\$18.04	\$0.00
10-year Cost of Ownership:	\$518.66	\$410.44
Power Density	0.96 W/sf	0.59 W/sf
Lumens / sf	55.4 lm/sf	51.5 lm/sf

MGM Resorts

Options 3 & 4 operating data

	Option 3 (Ext. Life T8)	Option 4 (Ext. Life T8 & Controls)
Annual Energy	252.0 kWh	176.4
Annual Energy Cost (\$0.11 / kWh)	\$27.72	\$19.40
10-year Energy	2,520 kWh	1,764 kWh
10-year Energy Cost	\$317.78	\$222.45
Relamp Cost: (one relamp)	\$0.00	\$0.00
10-year Cost of Ownership:	\$458.52	\$410.44
Power Density	0.84 W/sf	0.59 W/sf
Lumens / sf	51.5 lm/sf	51.5 lm/sf

MGM Resorts

Options 3 & 4 operating data

	Option 5 (LED)	Option 6 (LED & Controls)
Annual Energy	132.0 kWh	76.6
Annual Energy Cost (\$0.11 / kWh)	\$14.52	\$8.42
10-year Energy	1,320 kWh	765.6 kWh
10-year Energy Cost	\$166.46	\$96.54
Relamp Cost: (one relamp)	\$0.00	\$0.00
10-year Cost of Ownership:	\$387.45	\$364.06
Power Density	0.44 W/sf	0.25 W/sf
Lumens / sf	43.8 lm/sf	39.4 lm/sf

MGM Resorts 10-Year Data

Option	Source	10-Year Energy Usage (million kWh)	10-Year Cost of Ownership
1	T8	2.23	\$401,691.50
2	T8 + Controls	0.56	\$354,136.25
3	T8 Ext. Life	1.95	\$355,353.00
4	T8 Ext. Life + Controls	1.37	\$318,091.00
5	LED	1.02	\$300,273.75
6	LED + Controls	0.59	\$282,146.50

Additional Cost & Ancillary Benefits

- For standard AC LED troffers: \$69 of conduit and labor per traditional LED fixture and 1/15th of a wired lightswitch
- For remote driver: \$17 of Cat5 to each fixture and wireless switches @ 1/15th of \$20/ea
- Savings from remote driver in regards to implementing low cost battery back up solution.
- Ability to continuously commission individual & group spaces
- Downloadable App
- Ease of office reconfiguration
- Training & education obtained by electrical contractor
- Maintenance trouble shooting
- Occupancy data

Final Analysis

Description	BASELINE	UPGRADE #1	UPGRADE #2
	2-Lamp T8 Fluor.	LED Lamp Only	LED w/ Controls
Total New Space Statistics:			
No. of fixtures	775	775	775
X installed cost/fixture	\$ 127.02	\$ 201.09	\$ 236.62
Installed cost	\$ 98,440	\$ 155,845	\$ 183,381
Less: utility rebate	\$ -	\$ (5,580)	\$ (14,035)
Installed Cost - Net	\$ 98,440	\$ 150,265	\$ 169,346
Avg. annual operating cost	\$ 27,907	\$ 14,666	\$ 8,506
Addl gross cost vs. Baseline	\$ -	\$ 57,405	\$ 84,941
Addl net cost vs. Baseline	\$ -	\$ 51,825	\$ 70,906
Oper sav vs. Baseline	\$ -	\$ 13,241	\$ 19,401
ROI - Net	N/A	25.6%	27.4%
Payback (years)	N/A	3.9	3.7
10- Year kWh usage	1,966,888	1,085,000	629,300

- Incremental Capx required
- Includes kW @ 4.5% inflation w/ re-lamp cost
- 1.3M kWh saved over code required 2 lamp T8s

MGM Resorts Spaces being upgraded



MGM Resorts Spaces being upgraded



MGM Resorts Spaces being upgraded



What's Next

- How does the IT Office Project Translate to Existing MGM Building Spaces?
 - **Plug & Play**
 - **Direct wire T8**
 - **Troffer retrofit kit**
 - **New LED fixtures**
 - **New LED fixtures with controls**
 - **RFP – Troffer Specification**
 - **CAPX / finance options**
 - **Installation of Bi-level dimming fixtures in stairwells**

Summary of MGM Resorts Experience

- First costs affect decisions even at the behest of energy savings
- Design team / supply chain affects the process
- Comparisons necessary
- Due diligence & test your controls

Interior Lighting Campaign

Interior Lighting Campaign Organizers

- Interior Lighting Campaign officially launched earlier in the Summit by:
 - Department of Energy (DOE),
 - Building Owners and Managers Association (BOMA),
 - Illuminating Engineering Society (IES), and
 - International Facility Management Association (IFMA)



Interior Lighting Campaign Organizers



- 91 associations
- 10 billion square feet of U.S. office space
- Supporting 3.7 million jobs
- Primary source of information on building management and operations, development, leasing, building operating costs, and codes

Contact: Emily Naden
enden@boma.org



- 9,000 members (manufacturers, architects, engineers, consultants, and contractors)
- 95 technical committees
- 1,000 volunteers setting standards, guidelines, and recommended practices

Contact: Jeffrey Davis
jeff@sdcpdx.org



- 134 chapters
- 39 billion square feet of property
- Purchase US \$100 billion in products
- Conducts research that strengthens facility management
- Provides educational courses

Contact: John Perry
John.perry@ifma.org

Officially launched at the 2015 Better Buildings Summit – [visit interiorlightingcampaign.org](http://visit.interiorlightingcampaign.org)

Interior Lighting Campaign Goal

- 100,000 troffers either retrofit (tubes, kits, or new fixtures) or new construction by May 2016
- \approx 10,000,000 square feet of lighted area
- \approx 5,000,000 kWh savings annually or roughly the equivalent annual energy usage of 450 homes
- \approx \$500,000 in savings

Interior Lighting Campaign Resources

High Efficiency Troffer Performance Specification

Version: 5.0
17 APRIL 2015

U.S. DEPARTMENT OF ENERGY

Specifications

Prepared for:
Solid-State Lighting Program
Building Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:
Pacific Northwest National Laboratory

Reports
Fact Sheets

Upgrading Troffer Luminaires to LED

Lighting accounts for roughly 20% of the electricity used in a typical office building. The installation of a new lighting system has been the third most common energy conservation measure in office buildings since 2005. The most common energy conservation measure is the installation of energy-efficient lighting. The most common type of office lighting fixture is the recessed troffer. This fact sheet provides information on how to upgrade troffer luminaires to the most energy-efficient technology available today: LED.

Introduction

This fact sheet provides information on how to upgrade troffer luminaires to LED. It covers the benefits of LED, the types of LED troffer luminaires available, and the steps to take to upgrade a troffer luminaire to LED.

System Factors to Consider

The selection of an LED troffer luminaire involves many factors, including the luminaire's energy efficiency, light output, and compatibility with the building's electrical system. This fact sheet provides information on how to select the right LED troffer luminaire for your building.

System Factor	LED Troffer Luminaire	LED Troffer Luminaire	LED Troffer Luminaire	LED Troffer Luminaire
Energy Efficiency	High	Medium	Low	Very Low
Light Output	High	Medium	Low	Very Low
Compatibility	High	Medium	Low	Very Low
Cost	High	Medium	Low	Very Low

PNEL-21983

Prepared for the U.S. Department of Energy
www.eere.energy.gov/eeemv

EE Richman

October 2012

Pacific Northwest National Laboratory
Funded by the U.S. Department of Energy

M&V guidance

A Program of the U.S. DOE

Lighting Project Evaluator

The Lighting Project Evaluator allows you to estimate the energy savings of a new lighting system against a specified energy code. This tool can also compare proposed lighting upgrades to your existing conditions.

This tool is the preferred method of data submission for the Interior Lighting Campaign, which is a great place to go for troffer-specific lighting resources and to receive awards and recognition for implementing an energy saving lighting system using high-efficiency troffers and controls.

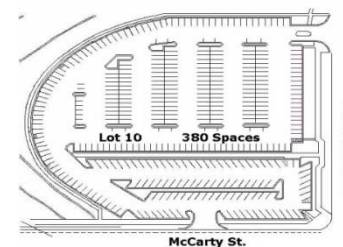
Log In Don't have an account? [Sign up now!](#)

email password

Forgotten your password?

Energy Estimator to compare against code

Technical Assistance (limited)



Indoor Lighting - Troffers (incl retrofit kits), Controls

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

List of utility incentives

Interior Lighting Campaign Awards

- Campaign provides an avenue for recognition for exemplary sites
- Awards for new construction and retrofit sites
- Awards for buildings with a few (under 20), some (20 – 50), and many (50+) troffers
- Awards for multiple sites and innovative use of lighting controls related to troffers

Interior Lighting Campaign Participants & Supporters

■ Participants

- Entities that are end users are eligible to be participants
- Participants can be building owners, building managements, and tenants

■ Supporters

- Anyone not directly related to the operation / management of the lighting
- Supporters are designers, engineers, architects, energy efficiency organizations, utilities, manufacturers

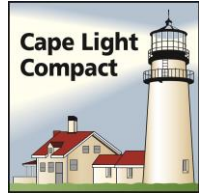
Interior Lighting Campaign Benefits & Features – Participants

- Limited technical assistance available to participants
 - identifying appropriate sites for a high efficiency troffer installation or upgrade
 - properly applying specification guidelines
 - completing Join or Awards applications
- Campaign web site offers:
 - High Efficiency Troffer Performance Specification (released April 2015)
 - case studies
 - technical reports
 - Fact sheets
 - lists of available incentives
 - Lighting project evaluator to estimate potential savings by comparing different lighting equipment and controls
- Recognition and possible award(s)

Interior Lighting Campaign Benefits & Features – Supporters

- Be recognized on the ILC web site Supporter page
 - Show your organization supports the campaign goals
 - Includes link to your web site
- Share ILC resources with your customers
 - Help convince customers that high efficiency troffer lighting solutions are viable now
 - Utilities can leverage ILC resources as part of their troffer lighting incentive initiatives
 - Lighting project evaluator can help you estimate potential savings
- Help your customers gain recognition for their troffer projects
 - Your role in the project will be recognized if an award is received
- Work with ILC Organizers on a customized outreach strategy

Interior Lighting Campaign Founding Supporters



Interior Lighting Campaign Timeframe

- Campaign kicks off at the BBA Summit
- Webinar containing more information Summer 2015
- Phase 1 awards submission deadline is May 2016

Join today at <http://www.interiorlightingcampaign.org/>