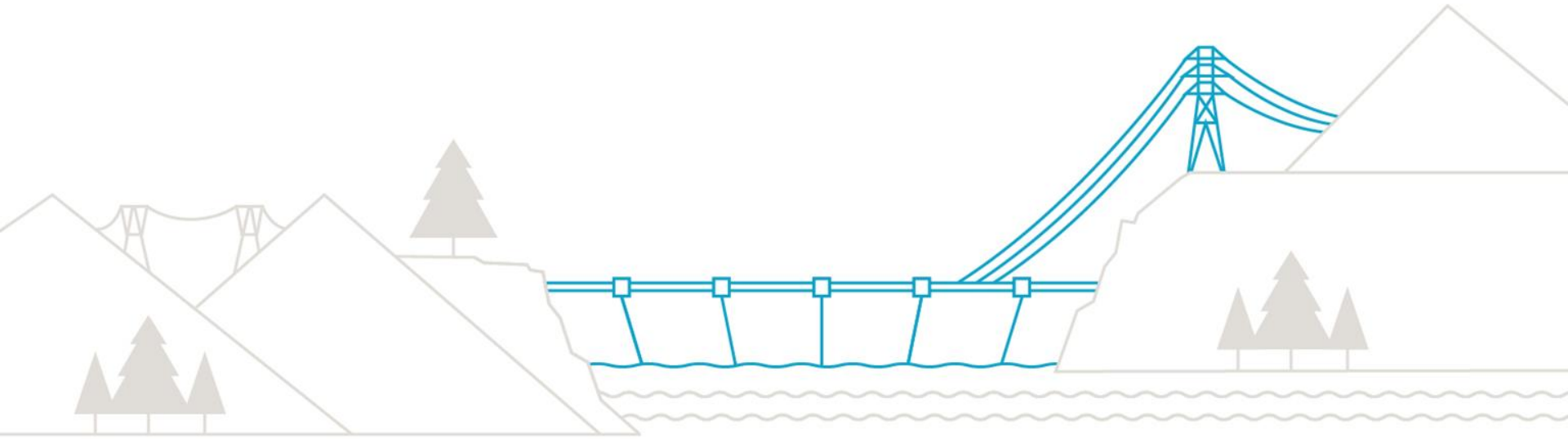
BC Hydro Alliance Industry Trend Series

What's New in Lighting



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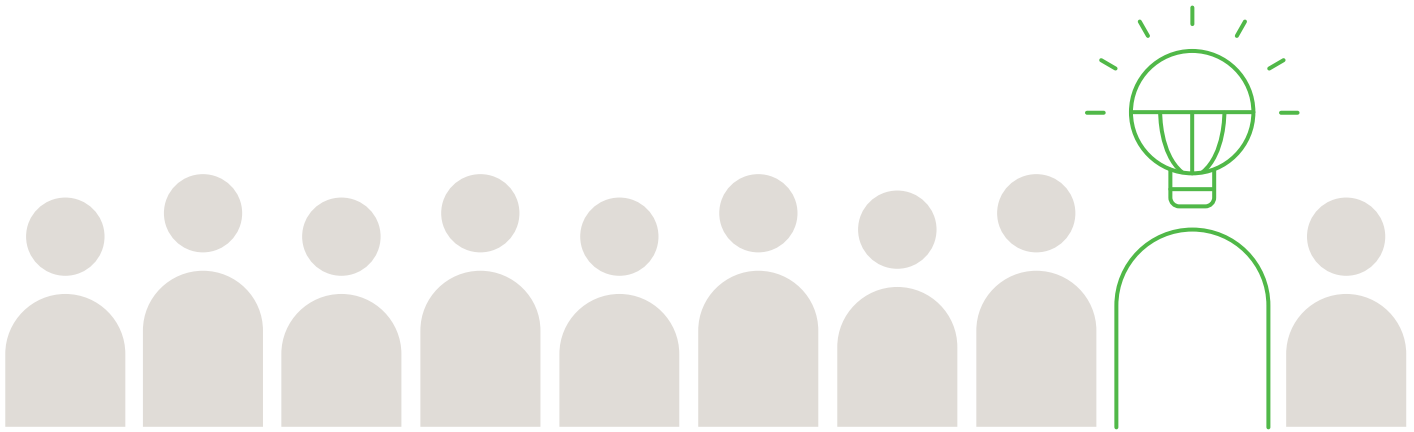
What New in Lighting

Dr. Cristian Suvagau, Peng, LC, CEM



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State of the LED Nation

- LEDs are becoming the norm in lighting (re)design
- LEDs continue to increase efficiency, usability time and lower manufacturing costs
- Plug-and-play LEDs
- TLEDs vs LED luminaire and retrofit kits
- Area luminaires
- LED Serviceability
- Advanced Lighting Controls

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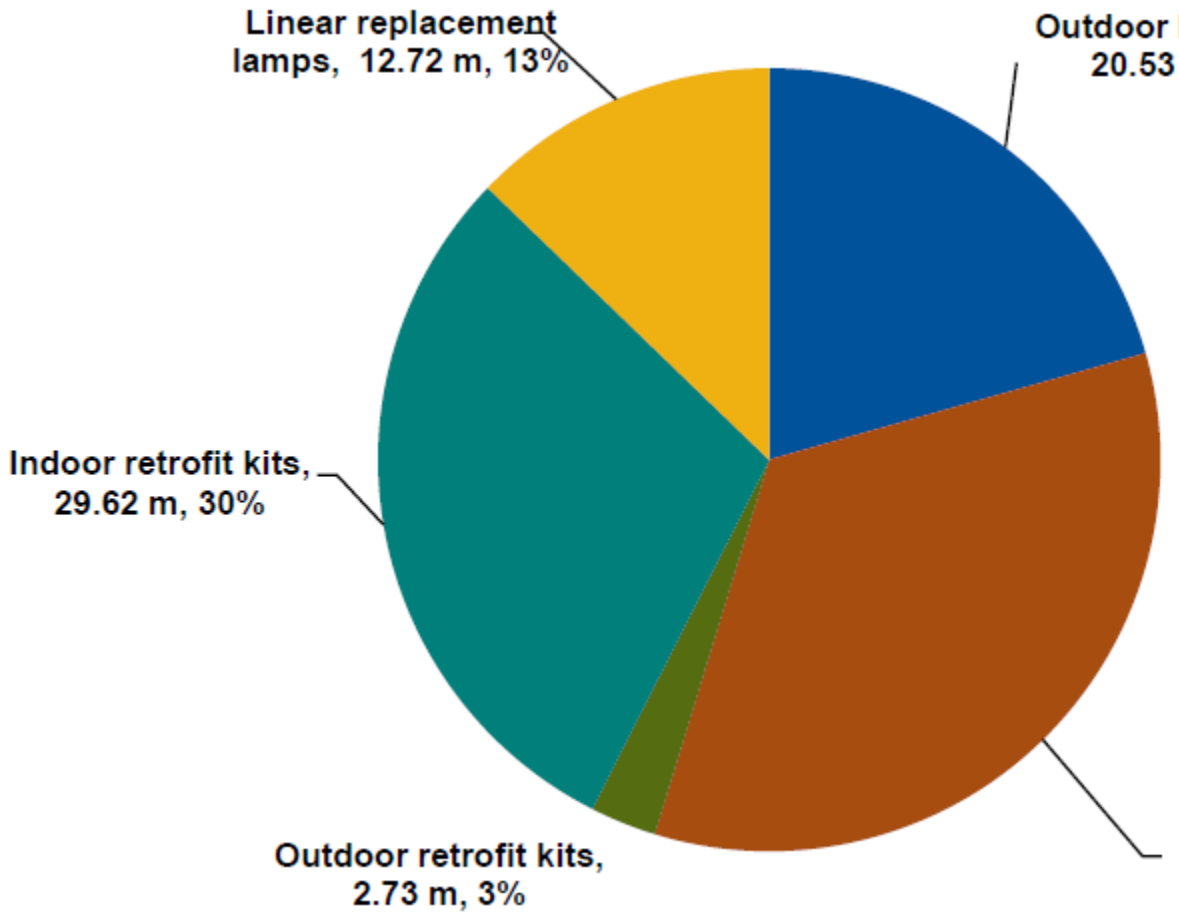
NA Market Transformation



- Over 100 million LED luminaires sold in Canada and US in 2016
- Estimated growth of units sales 24.6% CAGR from 2015-2020
- 3% - 40% of all new sales are LED
- 25% sales due to incentives

Courtesy DOE

QPL

Year	lm/w	% increase
2011	74.7	N/A
2012	79.5	6.40%
2013	87.6	10.20%
2014	92.4	5.50%
2015	100.1	8.30%
2016	105.1	5.00%
2017	117.28	11.59%

2015	Lamp Rated Wattage *(watts)*	Minimum Lamp Efficacy *(initial lm/W)*
Omnidirectional	<15	55
	≥15	65
Directional	<20	40
	≥20	50
Decorative	<15	45
	15≤ W <25	50
	≥25	60

2017	Minimum Lamp Efficacy *(initial lm/W)*	
	CRI ≥ 90	CRI < 90
Omnidirectional	70	80
Directional	61	70
Decorative	65	

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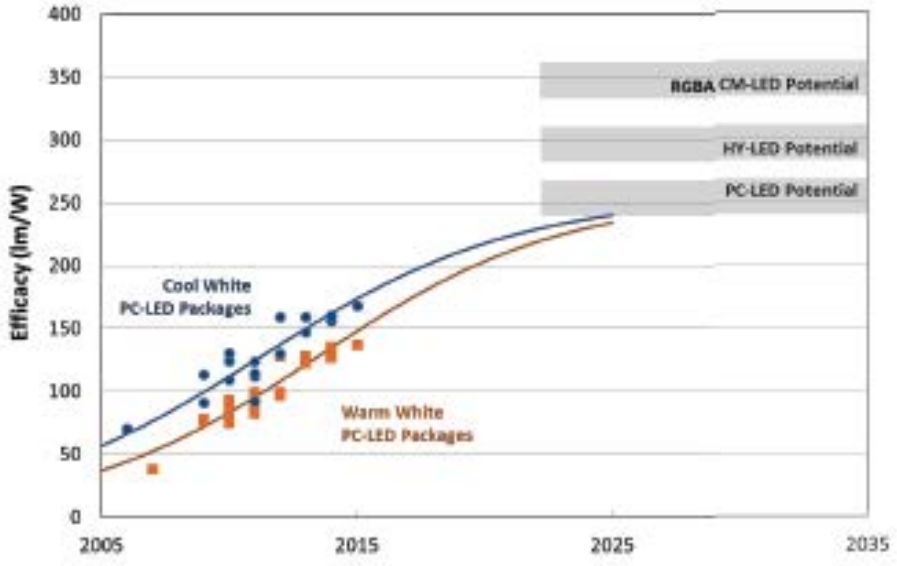
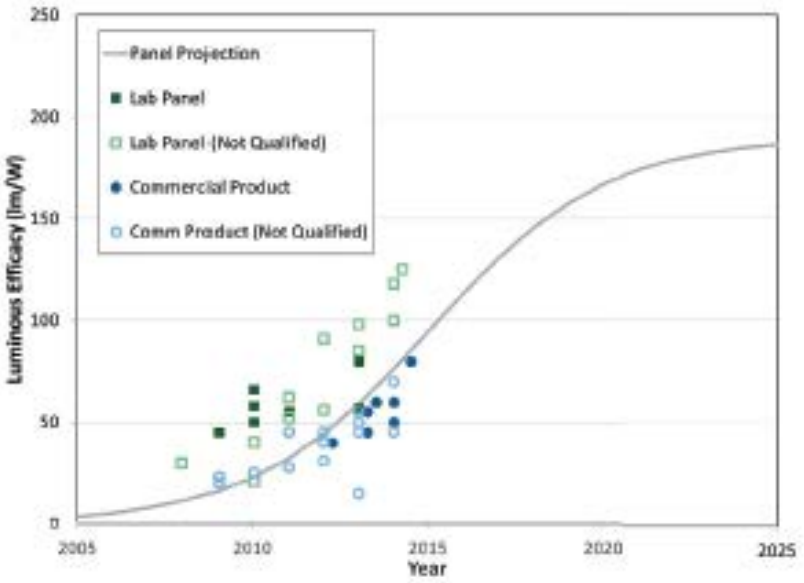
LED Forecast – lm/W



LED



OLED

Courtesy: The US National Academy Press

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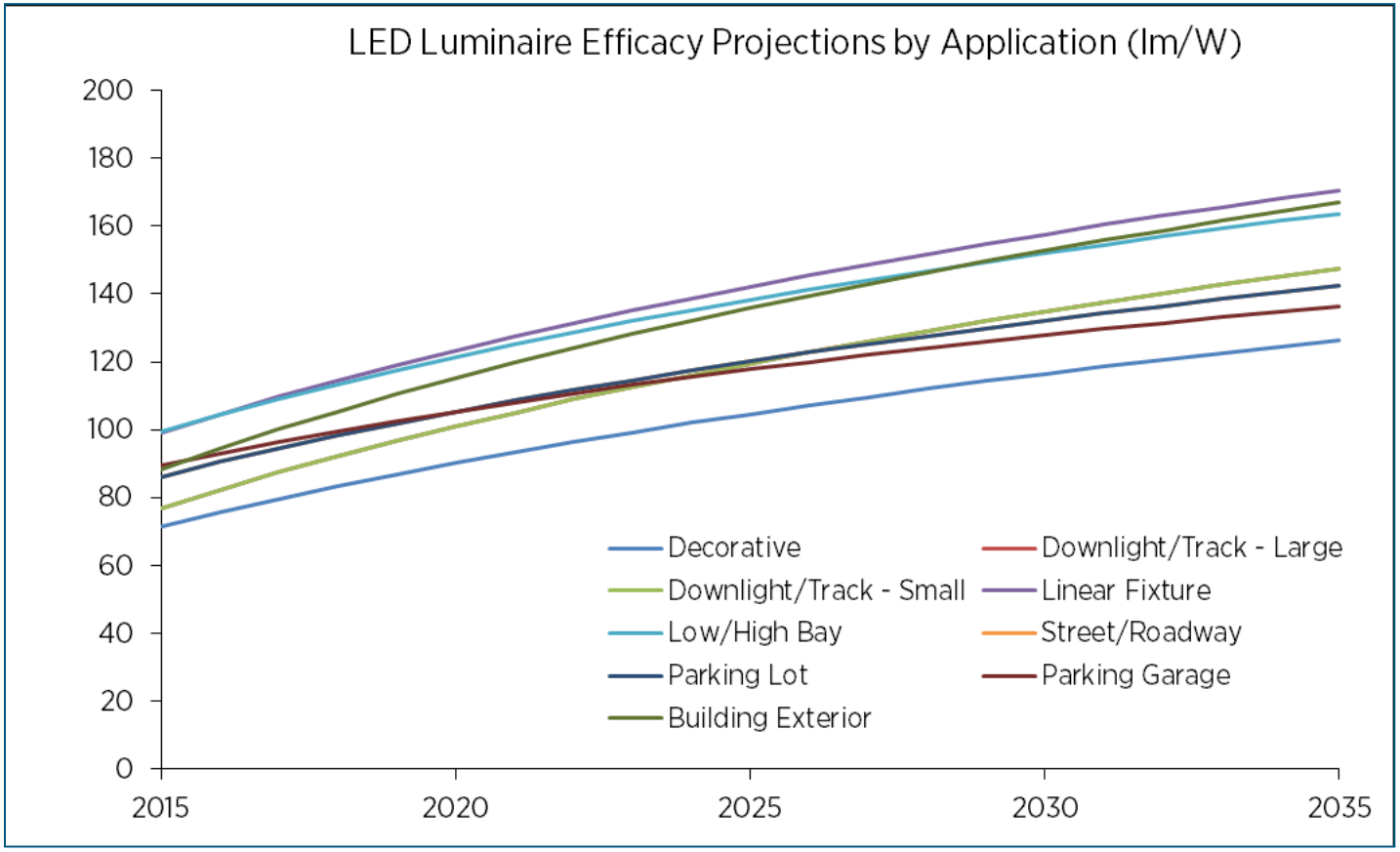
LED Forecast – lm/W



Courtesy DOE

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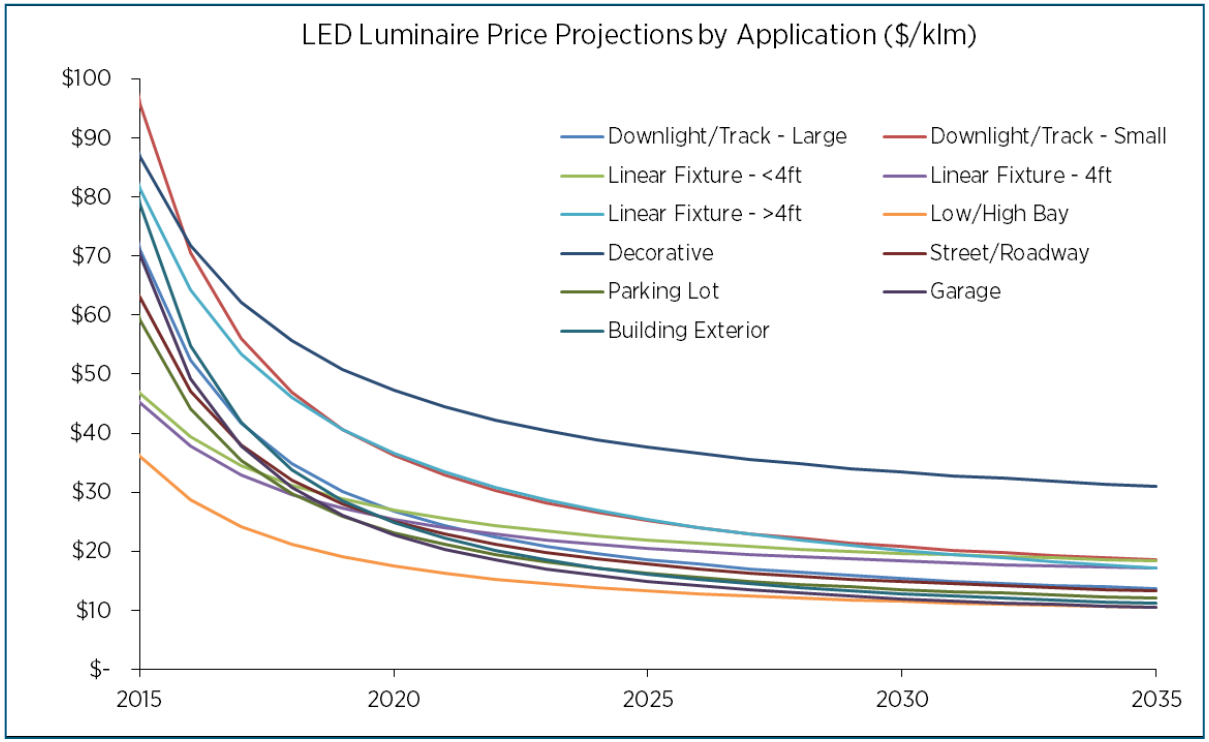
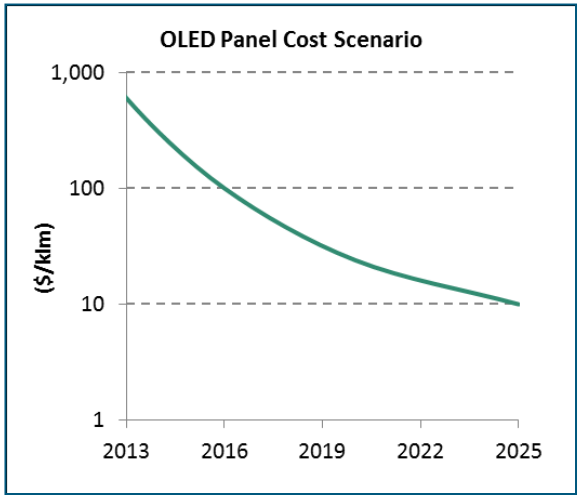
LED Forecast – $





Courtesy DOE

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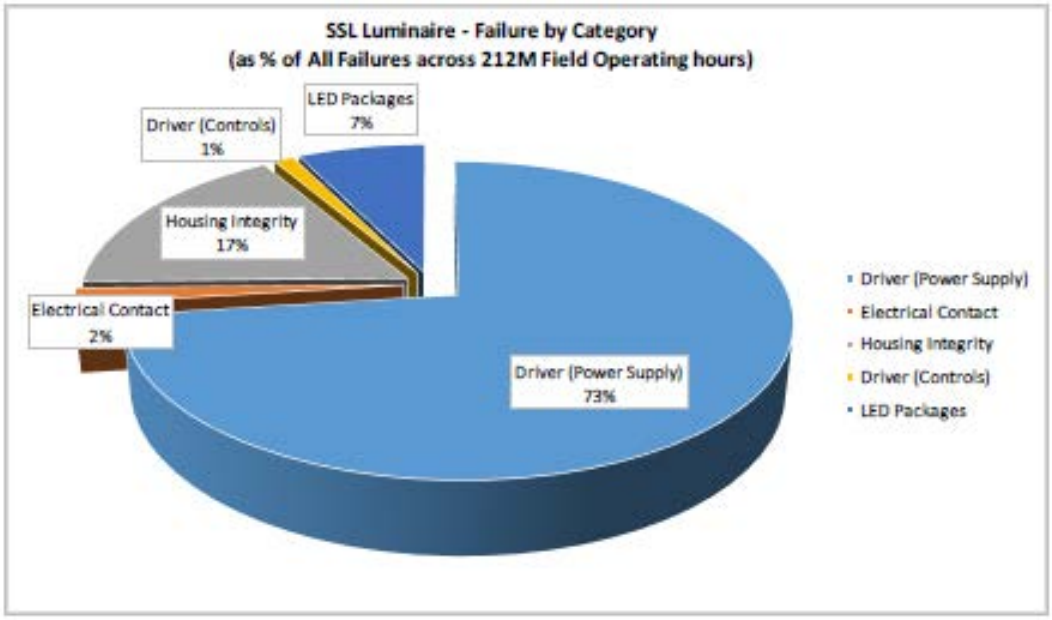
LED Luminaire Efficiency

LED	LED array	Optics	Driver	Luminaire
• Colour temperature • Temperature (T_j) • Drive current	• CCT combinations • Thermal losses (higher T_j)	• Optical losses	• Driver efficiency	
	85 – 90%	*50 – 90%*	*70 – 90 %*	
90 lm/W →	**78 lm/W** →	**48 lm/W** →	**43 lm/W** →	**= system efficiency**

LED Useful Lifetime

- Lumen depreciation is not a proxy for luminaire lifetime. IES LM-80 and TM-21 can predict lumen depreciation but not lifetime
- Colour shifting has become as relevant as lumen maintenance for SSL luminaires
- Operating life of LEDs affected by application environment and on-off switch pattern
- Driver/ power supply is a major factor in low mortality ratios
- Warranties of min. of 5 yrs or more (10yr for streetlighting) are becoming the norm
- Some SSL luminaires are serviceable



Component	Lifetime [hrs]
LED	60,000 @ 70% LM
Optics	180,000
Housing	2,200,000
Driver	45,000
Controls	48,000
SYSTEM	**45,000**

SSL luminaire failure modes - DOE

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DUBAI Lamp

- 200 lm/W efficacy for a LED product achieved in 2016 almost 5 yrs ahead of the technology forecasts
- The bulbs range from 1 to 3 watts, replacing 25 to 60 watt bulbs with a lifespan of 25,000 hours.
- “Dubai lamp”- now mandatory for all new buildings in the emirate

Courtesy of Philips

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Plug-and-Play LED

(No Rewiring Required)

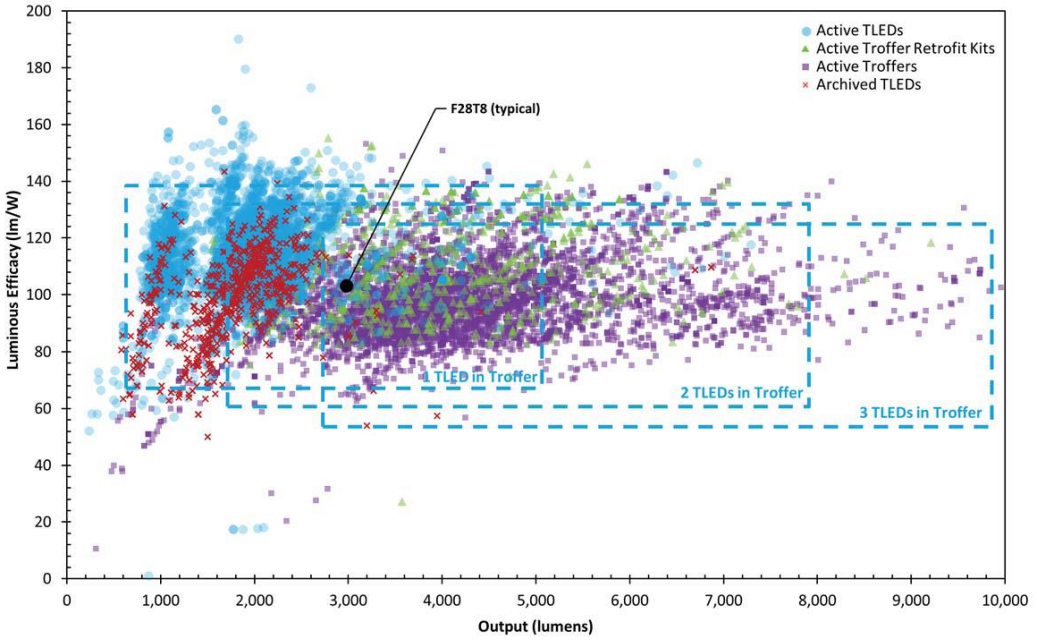
- Plug-and-play T-LED*
- Plug-and-play PL-LED*
- Plug-and-play Edison base LED
- Plug-and-play LED MR16**
- Plug-and-play HID replacement LED

*Must be compatible with existing ballast. Existing dimming may not work
**Must be compatible with existing transformer or driver. Existing dimming may not work

TLED

A Transitory Alternative

- Over 1,500 TLEDs in DLC QPL
- TLEDs now comprise more than 50% of all listed lamps, and more than 10% of all listed products.
- The color and power quality characteristics of TLEDs are generally uniform, with CRI in the low 80s, CCT of 3000 K, 4000 K, or 5000 K, and power factor greater than 0.90.
- About 91% of the currently listed TLEDs exceed 100 lm/W, which is roughly the efficacy of a bare linear fluorescent.
- When evaluating TLEDs, it's important to consider their efficacy when installed in a luminaire.
- Both LED troffer retrofit kits and LED troffer luminaires tend to have lower efficacies compared to bare TLEDs, but when luminaire efficiency is considered, the retrofit kits and troffers are comparable to the high end of TLED efficacy



Courtesy of DOE

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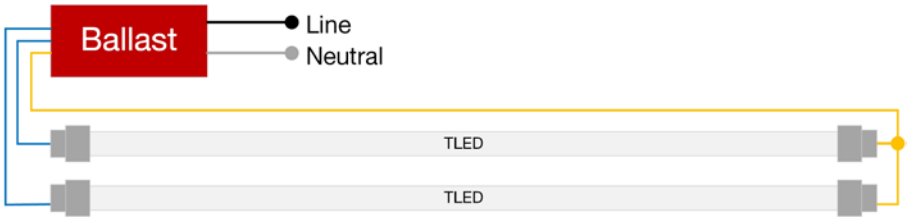
TLED

Type A



Advantages

- Operate on existing ballasts
- Cheapest to install

Disadvantage

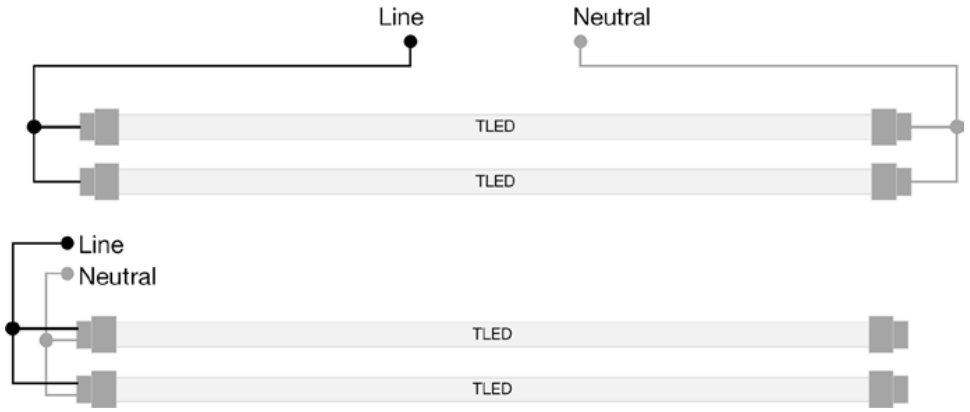
- Lamp-ballast compatibility
- Ballast remains a point of failure
- Ballast losses reduce energy savings (on average 2W /TLED)

Dimming

- Not possible unless with a compatible dimming ballast

TLED

Type B



Advantages

- No additional power losses

Disadvantage

- More expensive to retrofit
- Must use electricians
- Requires recertification
- Maintenance personnel potential exposed to electrical shocks
- Not grounded

Dimming

- Not possible unless with a dimming driver and compatible controls

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TLED

Type C

Advantages

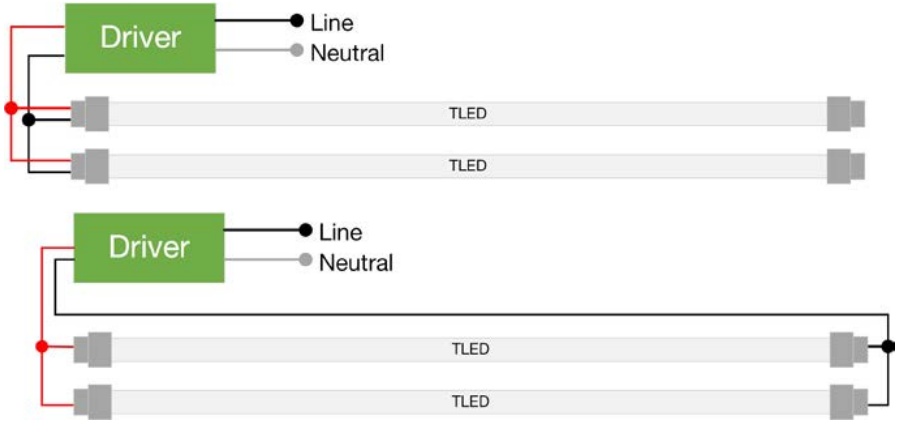
- No additional power losses
- Usually drivers are dimmable

Disadvantage

- The most expensive to retrofit
- Must use electricians
- Requires recertification

Dimming

- Broad control capabilities



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TLED - Smart

Philips InstantFit LED T8 with EasySmart technology

- wireless, network-capable linear Type A -TLED lamp
- dimmable

Leviton Lumina RF Standalone Wireless Room Controller System

- flexible placement with no additional wiring needed
- fully scalable system allows simple programming through advanced control
- an app-based tool allows installers to fine-tune the light during installation and select manual or automated operation
- provides quick commissioning and minimal maintenance
- provides compatibility and future-proof maintenance

Courtesy of Philips

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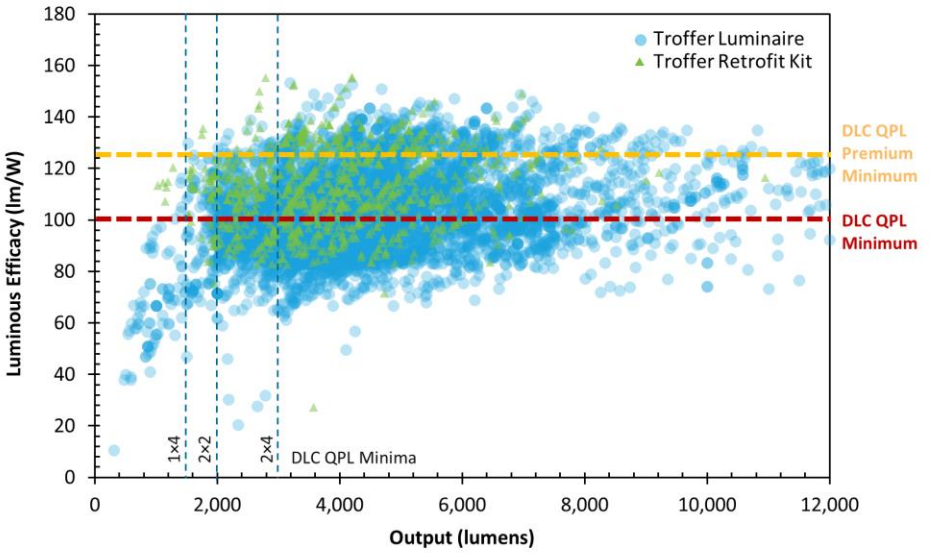
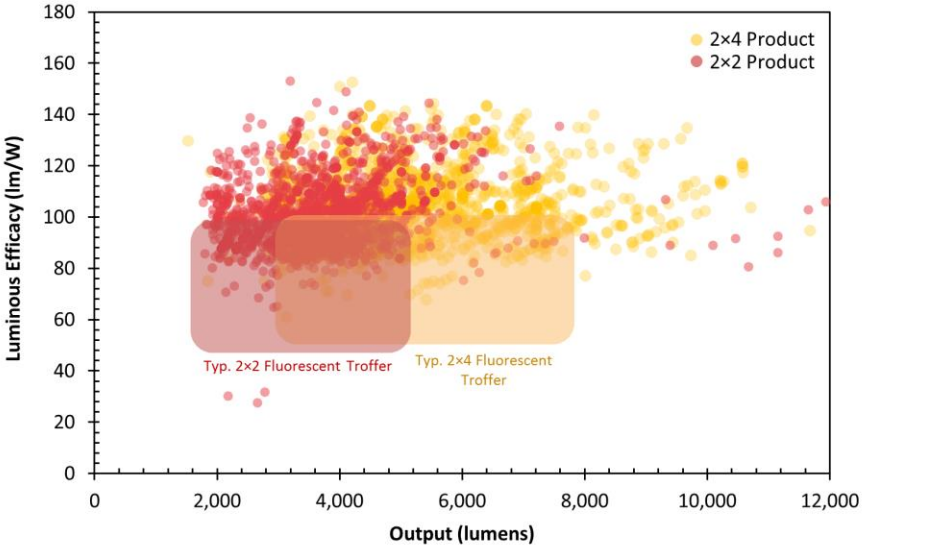
LED Troffers

- The efficacy of LED troffers is notably higher than what is typical of troffers fitted with fluorescent lamps.
- Color and power quality for troffers are similar to that of fluorescent troffers; variety of CCTs, but almost all products have a CRI in the 80s.
- Of the listed troffer luminaire and retrofit kit products (end of 2016) , 56% had a luminous efficacy above 100 lm/W, which is greater than the maximum for fluorescent troffers and the minimum for DesignLights Consortium™ Qualified Products List (DLC QPL) technical requirements. Over 10% of products are higher than 125 lm/W
- The range in efficacy and output is similar to that for the listed troffer luminaires.

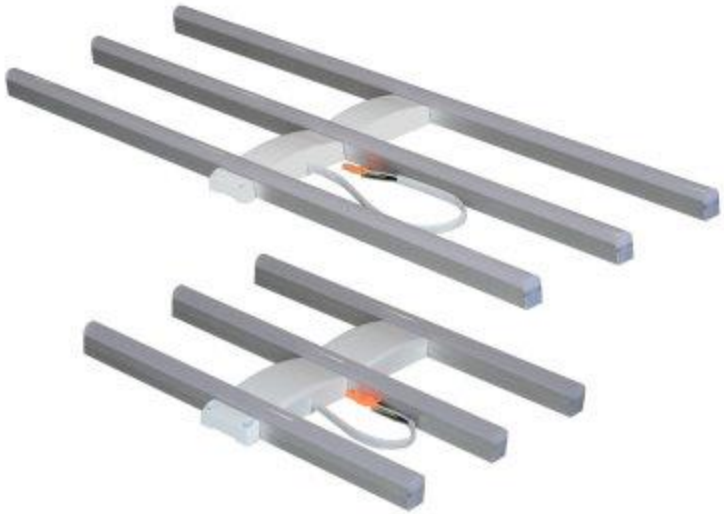




Courtesy of DOE

LED Retro Kits

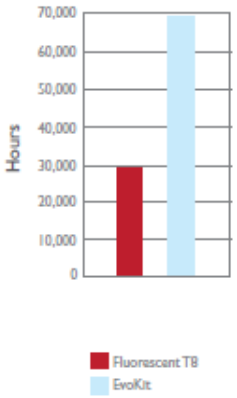
Courtesy of Optilumen



Courtesy of Ledvance-Sylvania

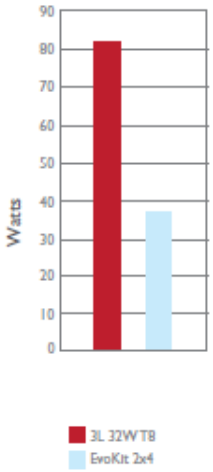
Rated Average Life

230% More Life[1,2]



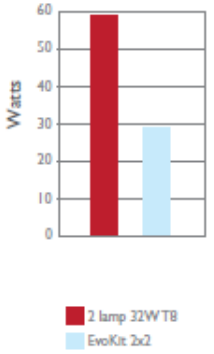
Present Wattage

2x4 Consumes 54% Less Energy[3]



Present Wattage

2x2 Consumes 51% Less



Courtesy of Philips-EvoKit

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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 ceiling; easy access	●	●	●
	Some concerns about working above the ceiling; limited access	●	●	▲
	Working above the ceiling should be avoided	●	▲	■

Courtesy of DOE

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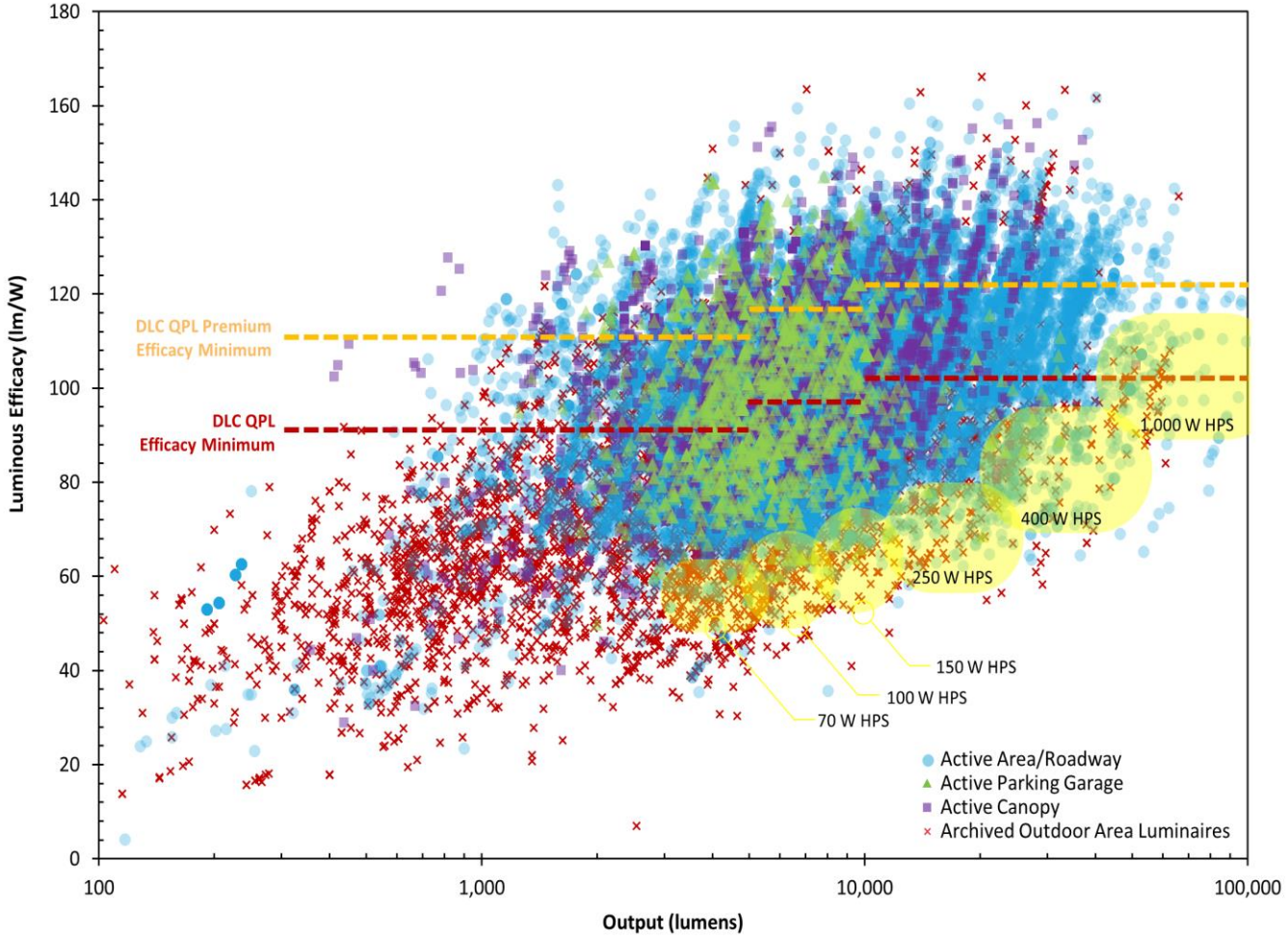
Area Lighting



Courtesy of DOE

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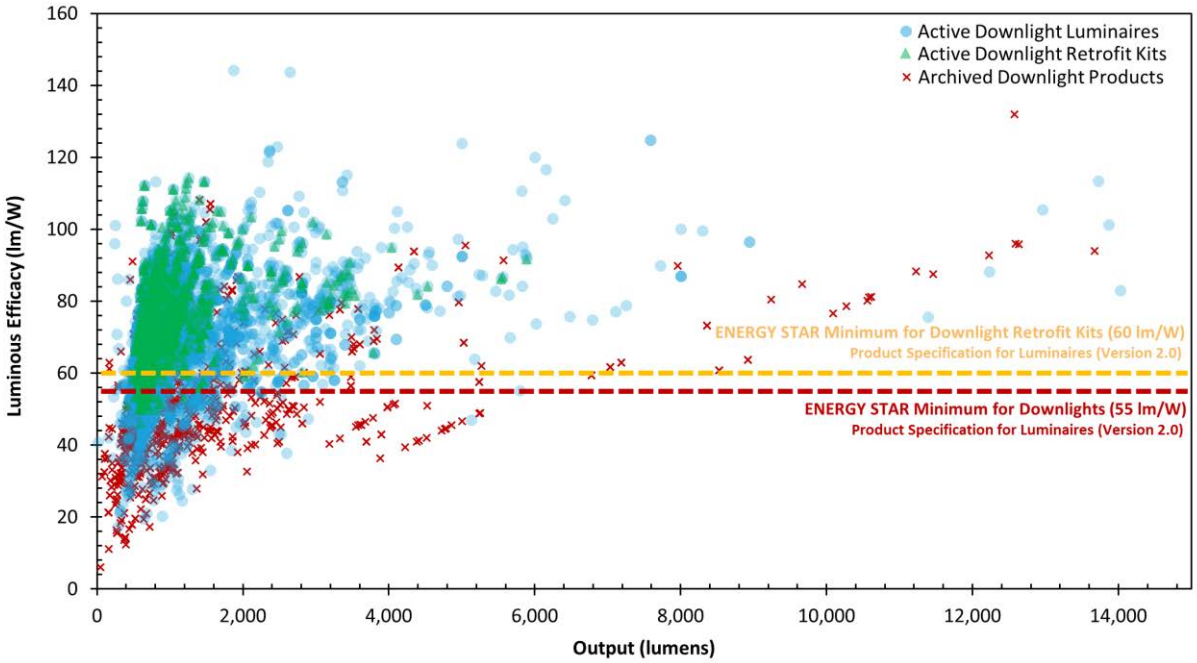
Downlights



Courtesy of DOE

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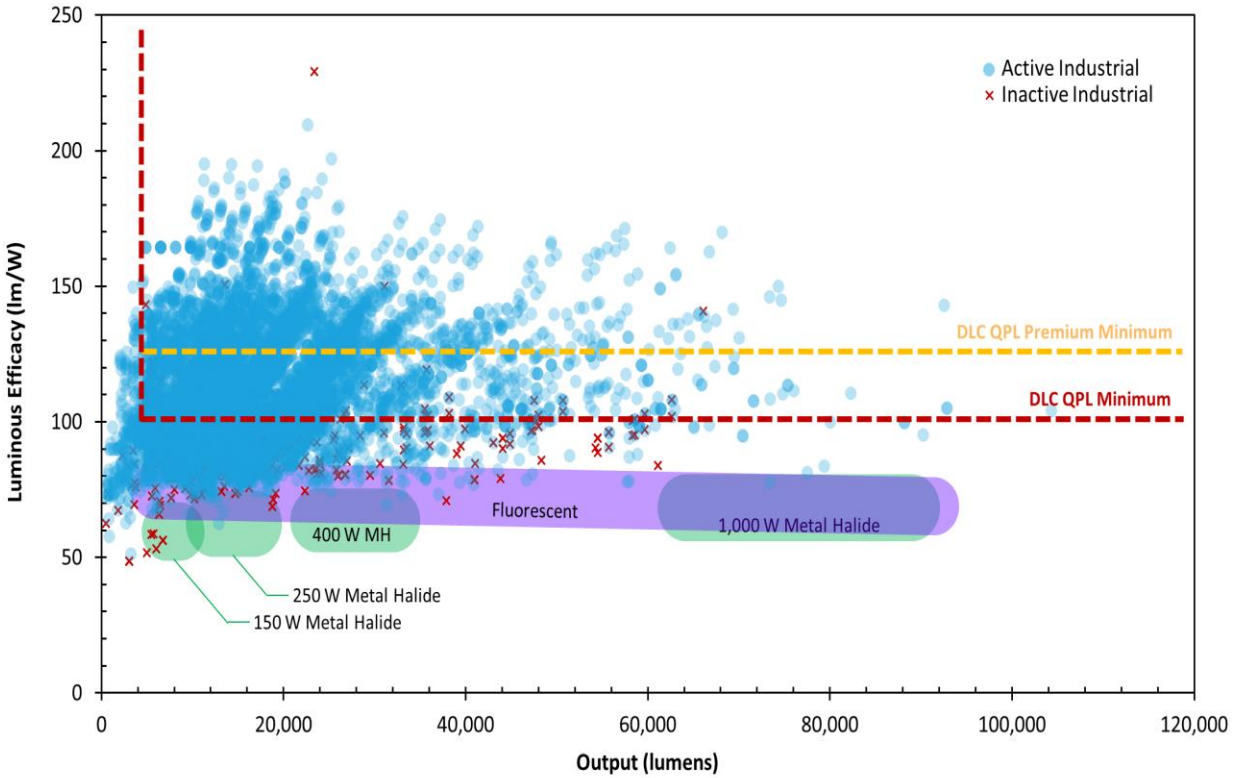
Industrial



Courtesy of DOE

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Specification Challenges

Lighting designers still struggle with specifying SSL technology, especially as the technology continues to evolve:

- There is a need for a method to compare products easily, especially when there is a specification requirement to name a primary product plus two alternative products from different manufacturers.
- There is a lack of transparency with regard to warranty coverage as market and sourcing remains unsettled.
- It is difficult to evaluate products from data. Designers want to physically see each product.
- Information on LED drivers is needed, since driver failures are a problem.
- There is a lack of information and protocols on compatibility with controls.
- Products change so rapidly (during the design process and construction process) that catalog numbers are no longer current or the products are discontinued.

Serviceability

Next Generation LUMINAIRES 2016

HPR series from Finelite

- Recessed LED luminaire with sizes from 1x1 to 2x4, five diffuser shapes and 3 optic configurations
- White tuning functionality between 2700K and 6500K and up to 90CRI
- Dimming from 100% to 10%, standard; 1% available
- Lumen packages up to 5500lm(2x4) at 133 lm/W
- Integrated or networked daylight and occupancy sensors options available
- Drop-down doors and quick-connects for drivers and replaceable LED array light engines simplify repairs.

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Serviceability

Next Generation LUMINAIRES 2016

M-series LED My White from Selux

- Impact resistant lenses protect against dust and ensures high luminaire efficiency CCT tunable between 2700K and 6500K with DALI or DMX dimming drivers
- Three profile sizes M36, M60 and M100 (width in mm), different lengths and mounting versions and a choice of six LED optics for various interior light distributions and applications
- Efficiencies up to 85 lm/W and lumen package up to 900 lm/ft
- Modular and serviceable

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Advanced Lighting Controls

Best Estimates of Average Lighting Energy Savings Potential From Lighting Controls

CONTROL STRATEGY	EXAMPLES	AVERAGE SAVINGS
Institutional Tuning	High-end trim dimming (ballast tuning), task tuning, lumen maintenance, provision of controls for areas/groups of occupants	36%
Personal Tuning	Dimmers, wireless switches, bi-level switches, computer based controls (for personal offices, workstation-specific lighting, classrooms)	31%
Daylighting	Photosensors	28%
Occupancy	Occupancy sensors, time clocks, EMS	24%
Multiple Strategies	Any combination of the above	38%

Courtesy ALG

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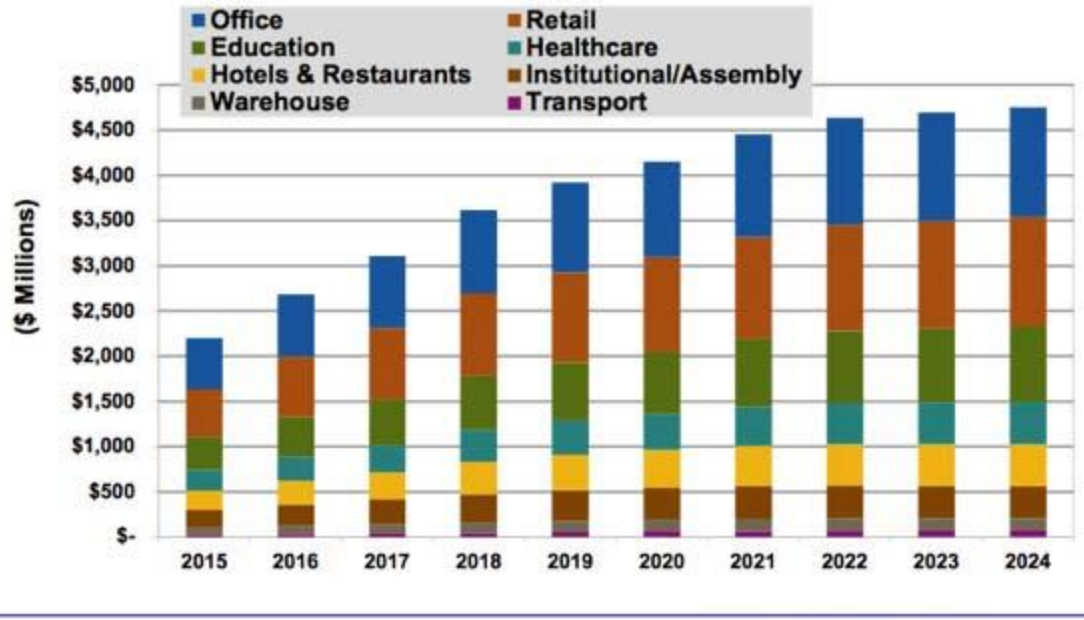
Advanced Lighting Controls

Breaking the Adoption Barriers for ALC

- Technology is changing and improving…FAST!
- Systems designed from the ground up to reduce complexity and cost
- Easier (and less costly) to install, commission, use than ever before
- Analytics that allow continuous, improved energy management

Chart 1.1 Networked Lighting Controls Revenue by Building Type, World Markets: 2015-2024



(Source: Navigant Research)

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New Trends in Lighting

- Innovative Designs
- Connectivity – IoT
- DC Power Distribution – PoE
- VLC - LiFi
- Healing Centric Lighting Design
- OLED
- New Materials

Innovative LED Designs

FLUXWERX

Specification Data

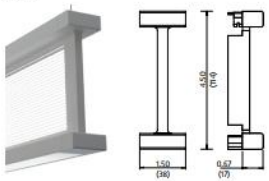
Luminaire	VIEW 70 UP I 30 DN SUSPENDED LED	Type
Project		
Product		
Notes		

Performance Summary	70 Up I 30 Down			
	A	B	C	D
Light (lm)	2300	2900	3700	4500
Energy (W)	24	29	39	49
Efficacy (lm/W)	99.3	99.6	95.4	92.0
Color Rendering (CRI)	83	83	83	83
Color Accuracy (SDCM)	< 2	< 2	< 2	< 2
L70 Estimate (h)	200,000	200,000	200,000	200,000
Lumen Maintenance per TM21 (@ 60,000 h)	L90	L90	L90	L90

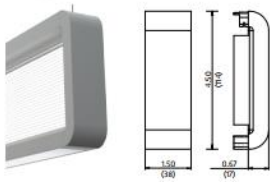
Performance summary values are nominal and based on 4000K CCT
DLC qualified for 29W, 39W and 49W in 4000K and 3500K

ENDCAPS + DIMENSIONS inches (mm)

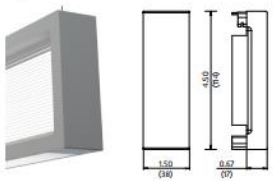
BEAM

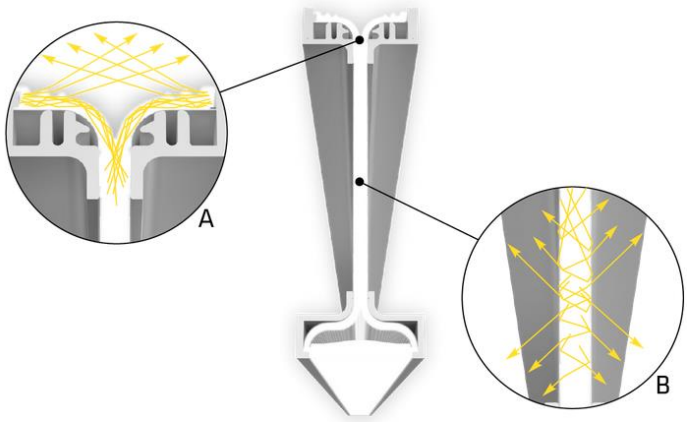


RADIUS



SQUARE

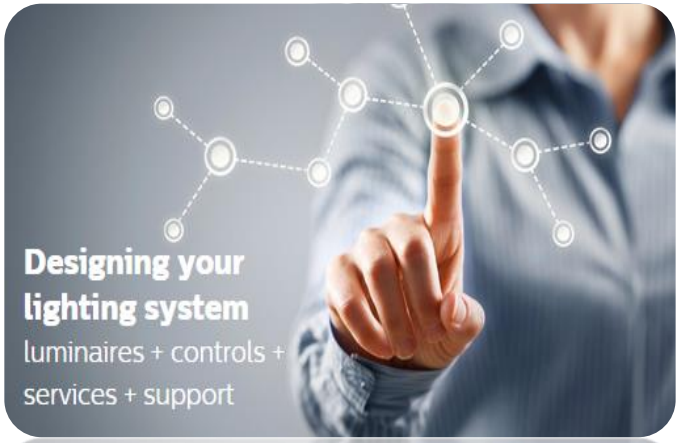




Connectivity

Connected Luminaires

Connected People



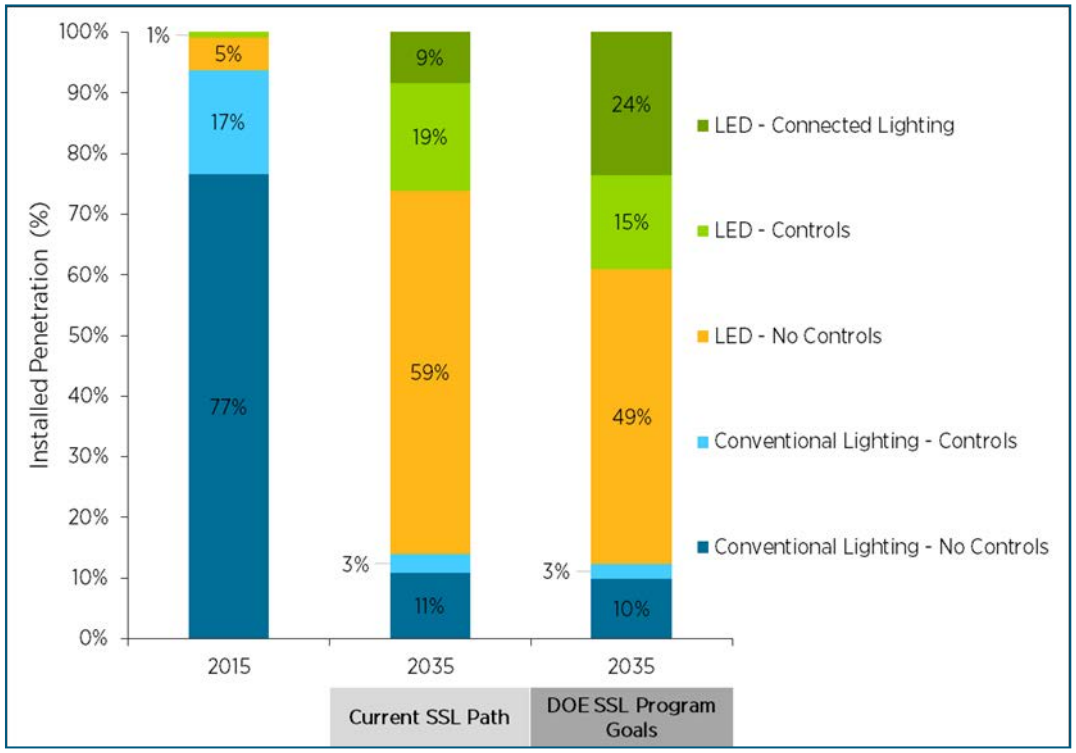
Connected Software

Connected Spaces

Connectivity

By 2035 connected LED lighting (US and Canada) could be:

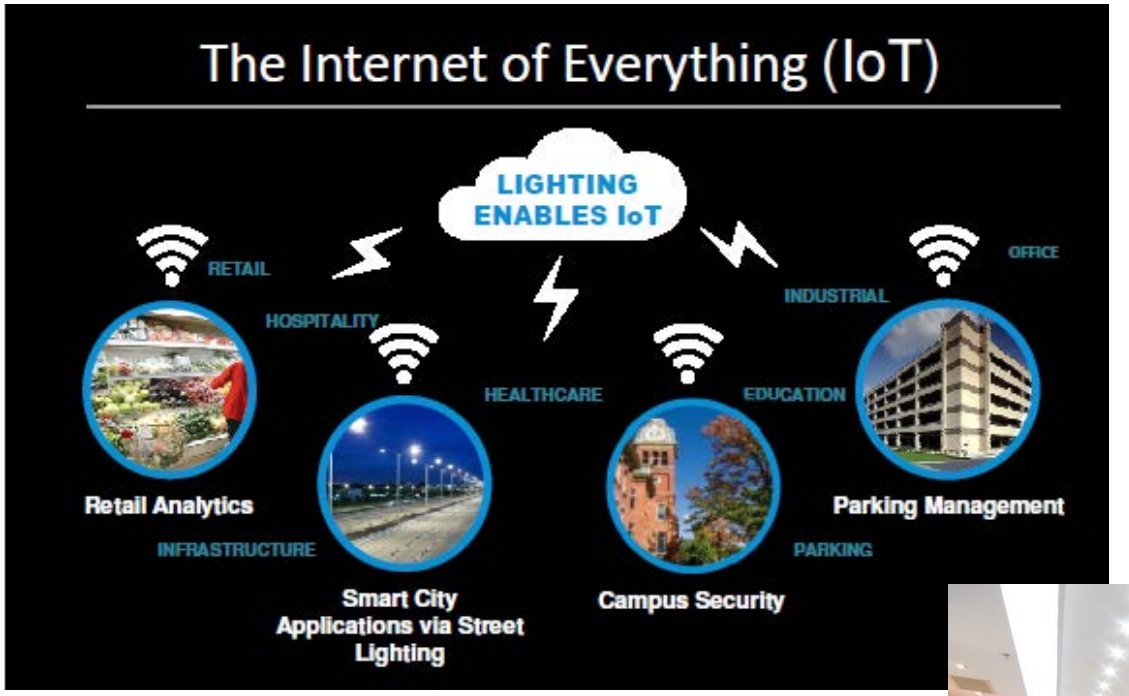
- 75% of the lighting controls energy savings
- ~ 500 TWh/ yr



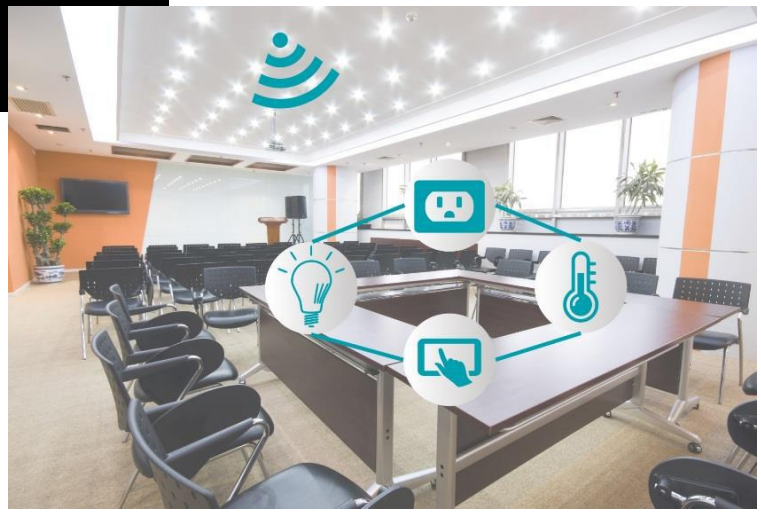
DOE Report Sept 2016: Lighting Controls Installed Penetration for LED vs. Conventional Lighting

Connectivity - IoT

Sensory Networks Connects People, Process, Data & Things



- 50B to 1 trillion "things" connected with economic value of $4 trillion/yr by 2025
- "*The Internet of Everything will have 5-10 times the impact on society as the Internet itself*" (Cisco CEO John Chambers)

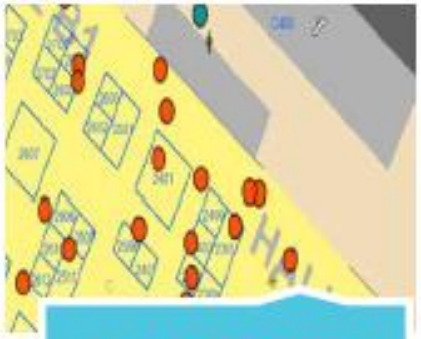


- The Internet of Things involves a lot of sensors
- "*These sensors are being built into many more things and ultimately may even be implanted in people*" (Peter Taylor, VP pf products-Belkin)

Source: Acuity Brands

Connectivity

Drives New Capabilities Beyond Energy



Asset Tracking

Space Utilization

Indoor Positioning

Diagnose and Report

Conference Room Scheduling

Security

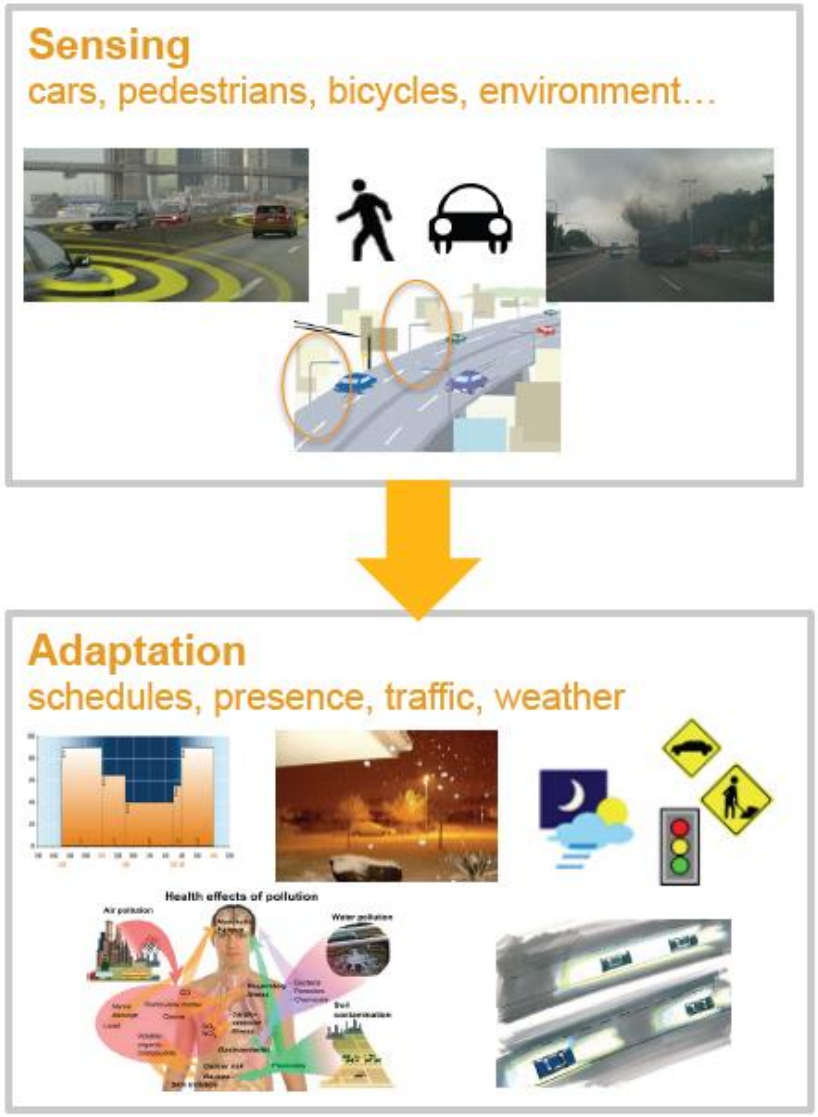
Energy Tracking

Integrate with BMS/HVAC

Connectivity

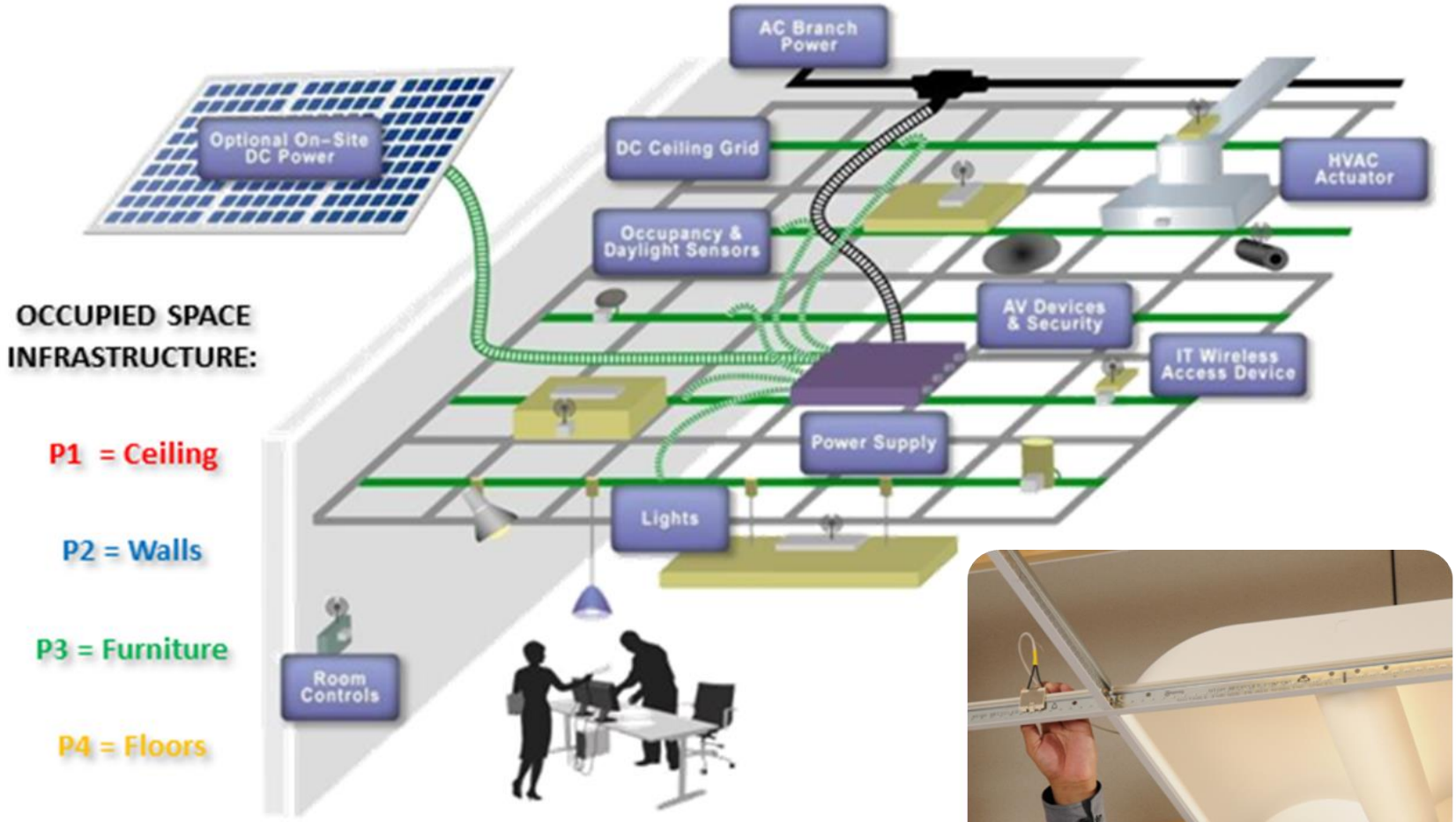
Digital Public Space

- Ambient Light (photocell)
- Traffic (inductive loop, camera-based)
- Occupancy (PIR, camera-based, microwave)
- Environmental conditions
- Video (requires high-bandwidth network)
- Audio (gunshot)
- Air quality (chemical, particle)
- Radiation



Courtesy PNNL

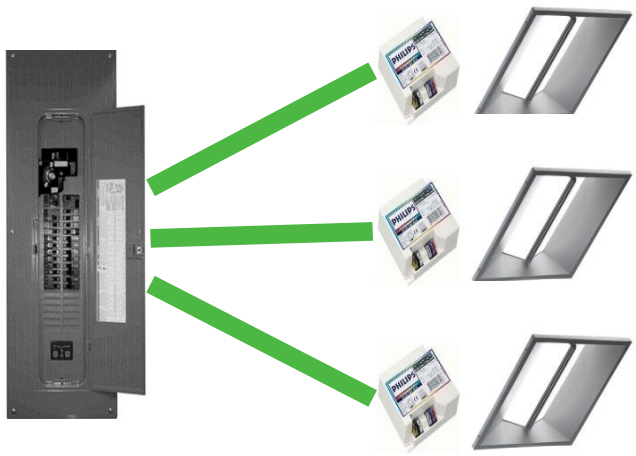
DC Power Distribution



PoE

Conventional

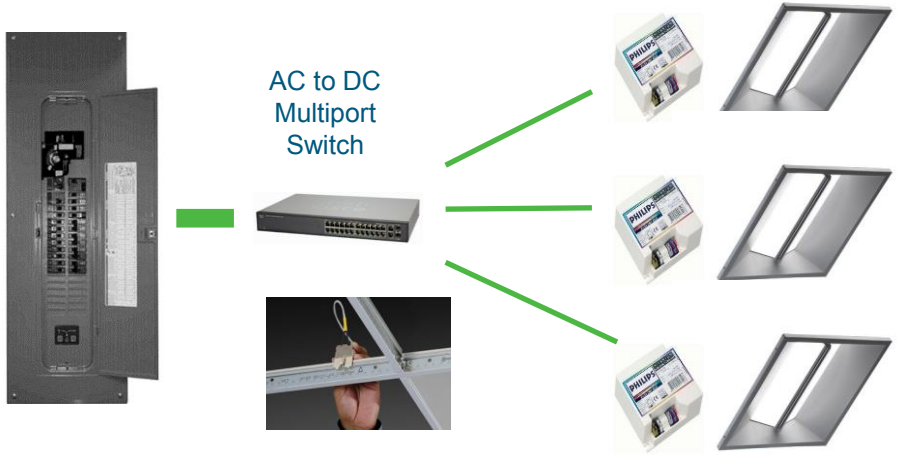
AC to DC Driver



Distributed LV System (DC/PoE)

DC to DC Driver

AC to DC Multiport Switch



Advantages of DC Systems

- Increased system safety (lv) flexibility, modularity and resiliency
- Reduced wiring costs (20-80%)
- Reduced operational costs (3-10%)
- Increased LED efficiency (5-10%)
- Excellent for wireless
- Availability of DC distributed generation, onsite storage and EV charging

Current Limitations of DC Systems

- Components may reduce DC system efficiency 5% than of AC
- More standards/ protocols required
- Limited power switches (60W-90W)
- Expensive

Source; DLC

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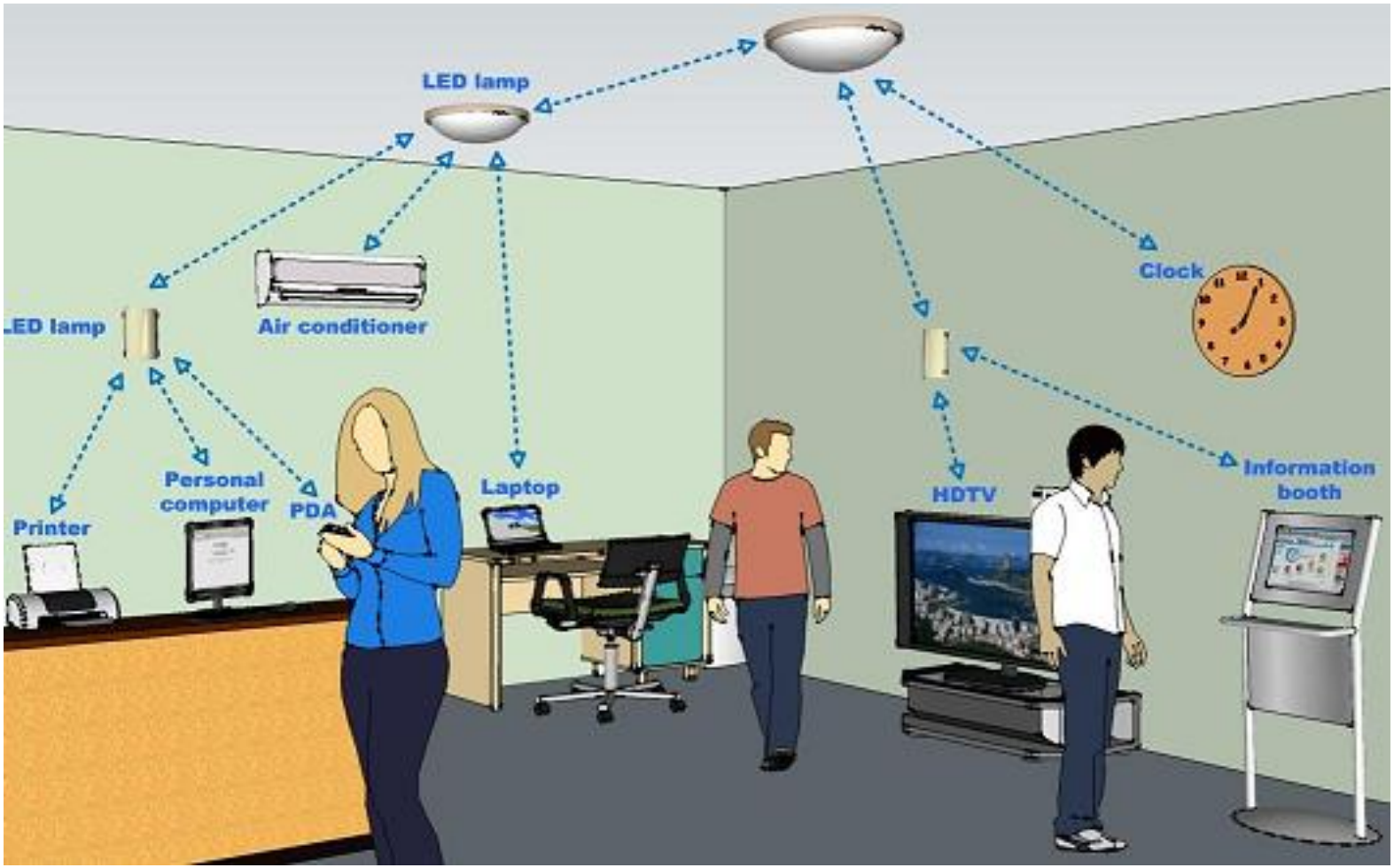
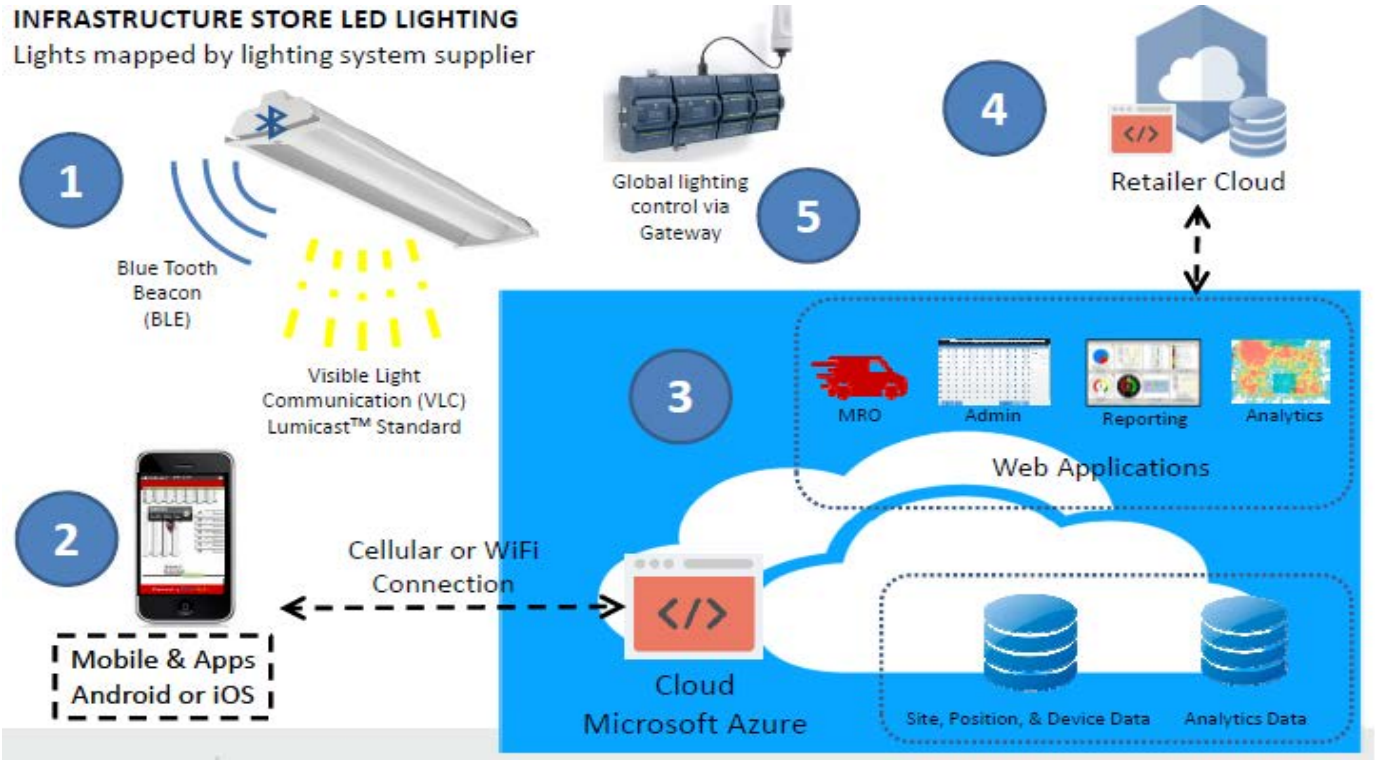
VLC

Visual Light Communication = Lighting + Data



VLC – Indoor Positioning



- Indoor location technology spending - $1.6B by 2018
- Indoor Location Ecosystem Spending- $10B by 2018, aimed at the $700B in mobile influenced purchases (Opus Report-Deloitte 2016)

Source: Acuity Brands

Li-Fi

Li-Fi = Lighting + WiFi

Human Centric Lighting Design

White Tuning

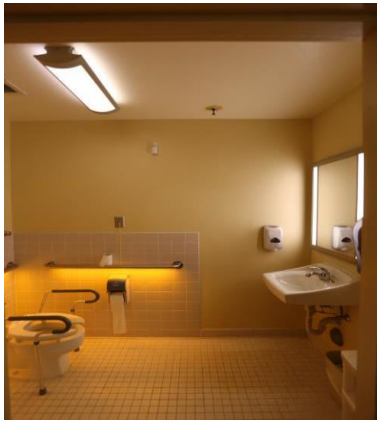
- White tuning is the ability to adjust the CCT of an individual luminaire or light source.
- LED lighting can combine smaller LED sources with different CCTs into a single luminaire, allowing the end user to adjust the CCT to the desired point within a given range (i.e 2700K - 6000K).

Source: DLC, Digital Lumens

Human Centric Lighting Design

White Tuning – DOE Case Study: Care Centre, Sacramento, Ca

- Lighting - 43% electricity use in healthcare facilities
- Over 70% savings (from T8)
- Hallway circadian lighting schedules
  - 7 am – 2 pm: 6500K @ 66% output
  - 2 pm – 6 pm: 4000K @ 66% output
  - 6 pm – 7 am: 2700K @ 20% output



Source: SMUD, DOE

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Human Centric Lighting Design

White Tuning – Wintelre Primary School, Holland

Settings

- Two classrooms were upgraded to tunable white lighting systems
- New system had four scenario settings to be used throughout the day
  - Normal: 4000 K at 50% output
  - Focus: 5500 K at 85% output
  - Energy: 6000K at 85% output
  - Calm: 3000 K at 35% output

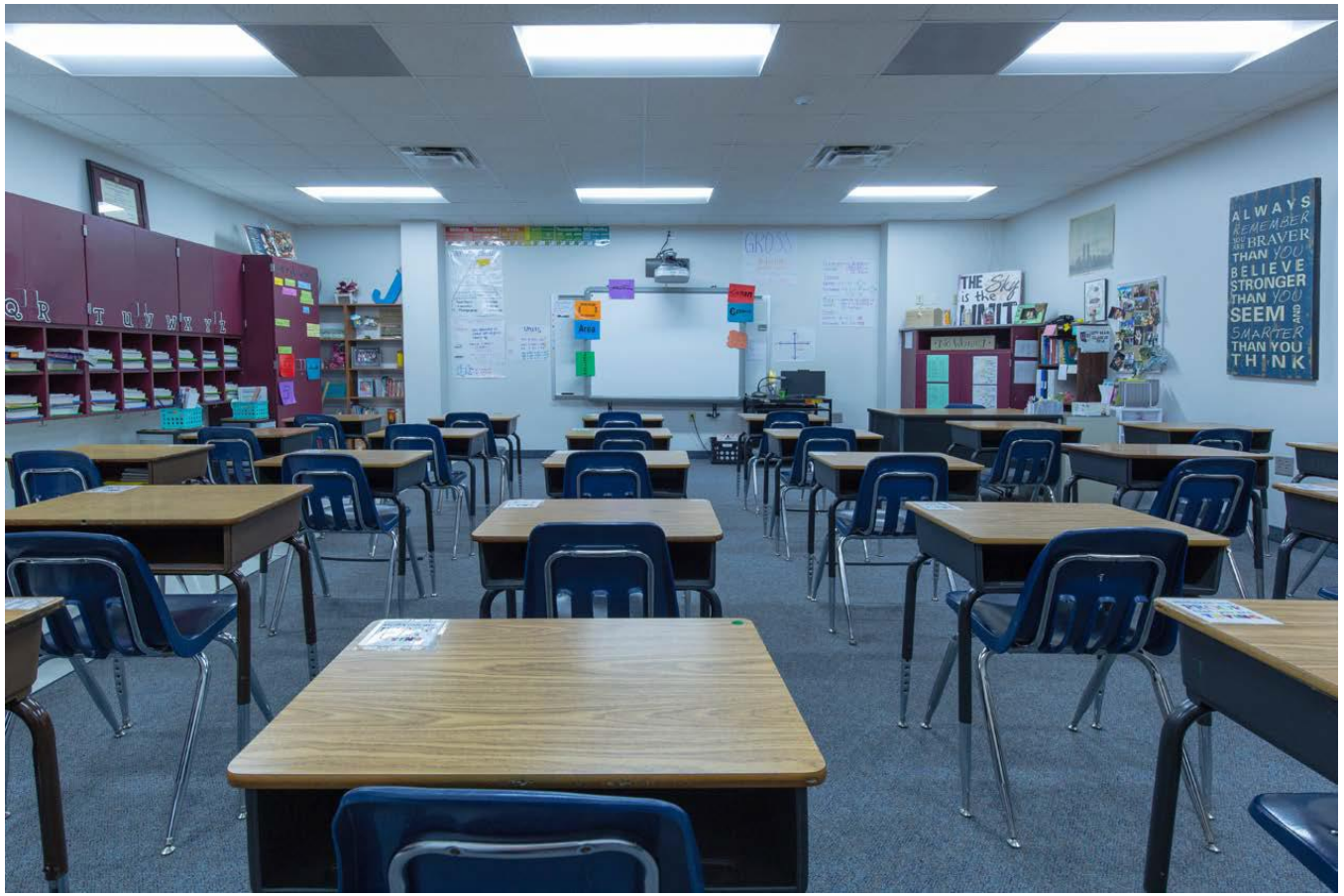
Results

- Concentration increased by 13.6% within the first month
- Energy savings found compared to previous fluorescent system
- Students were more positive and engaged

Source: SMUD, DOE

Human Centric Lighting Design

White Tuning – DOE Case: Farmers Branch Independent Carrollton SD, TX



3200K

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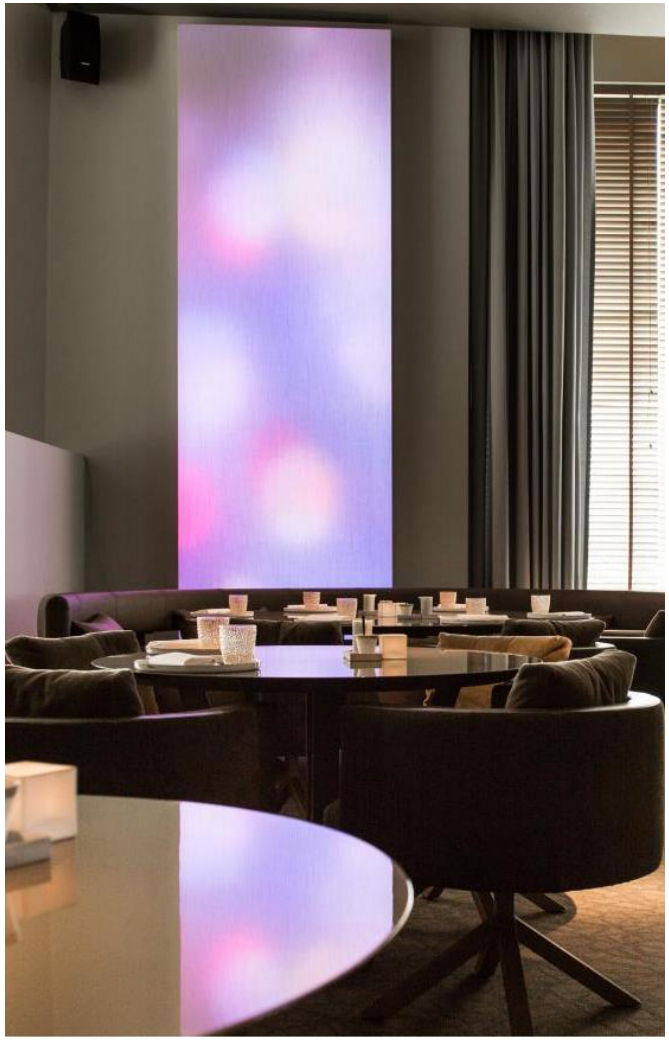
Human Centric Lighting Design

Light Emitting Textiles



Human Centric Lighting Design

Virtual Daylighting – Relaxing Light & Sound

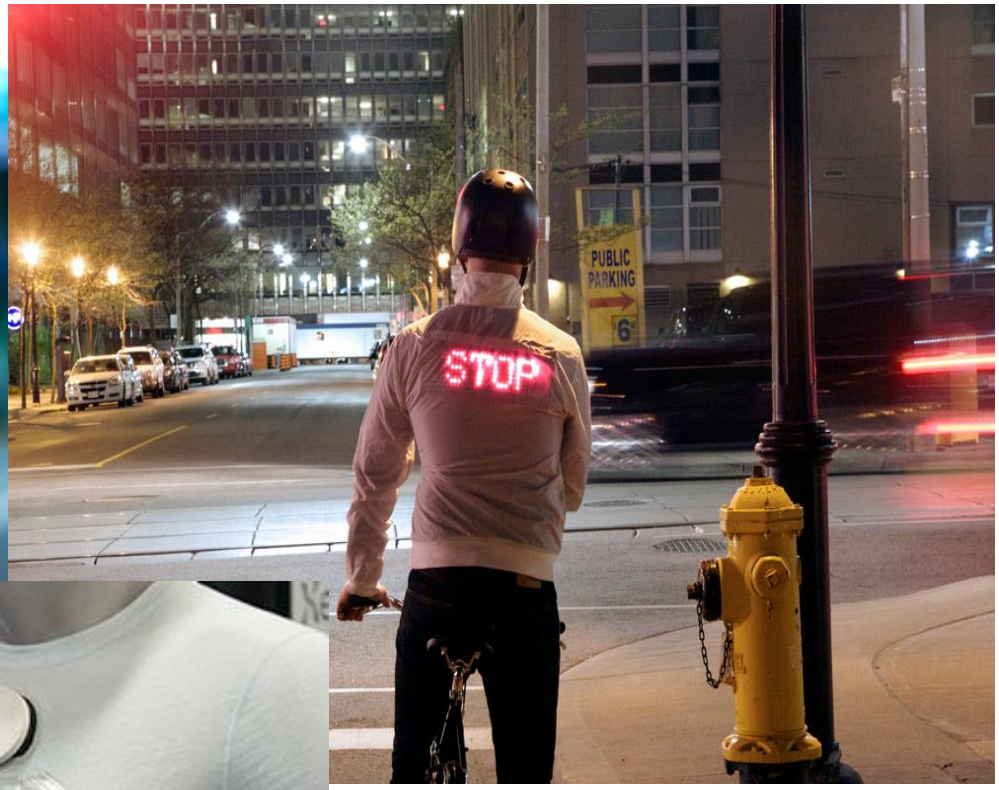
OLED

Source: Acuity Brands

- Exciting creative medium for lighting designers
- User customizable
- Lower efficiency than LED (60-70 lm/W now)
- Limited sizes (1’ x 1’ now)
- Less glary than LEDs
- Better colour quality than LEDs

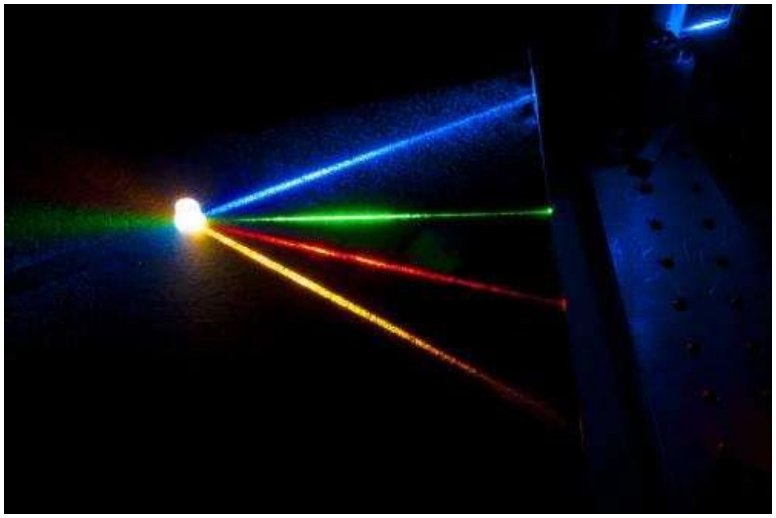
Source: LG Chem OLED

Wearable Lighting



Diode Laser Lighting

Diode Lasers – Gallium-Arsenide lasers of 4 wavelength (RGBY) beams collimate into white light

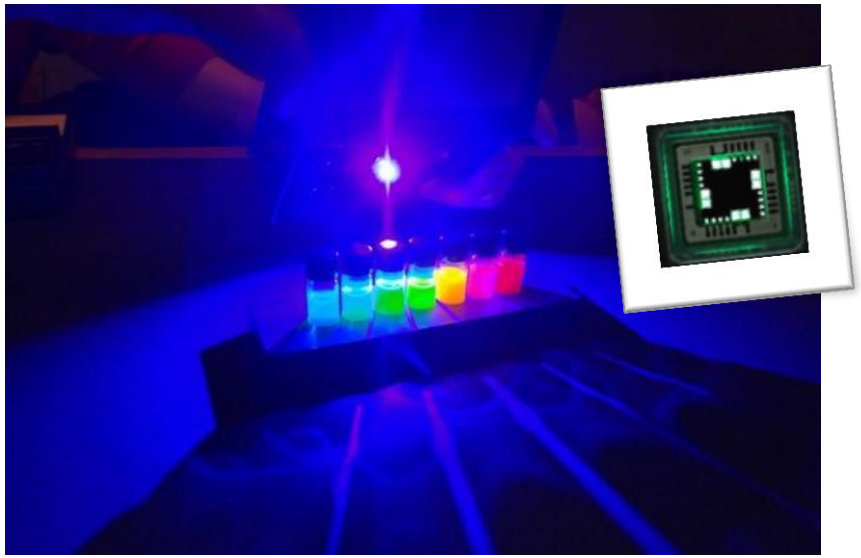


Diode Laser Light advantages:

- **Pure color** – light is 10 times narrower than LED light
- **Low power consumption**
- **Extreme visual target definition** - no scattering, focus light on very small, far-away objects

Quantum Dot LEDs (QLEDs)

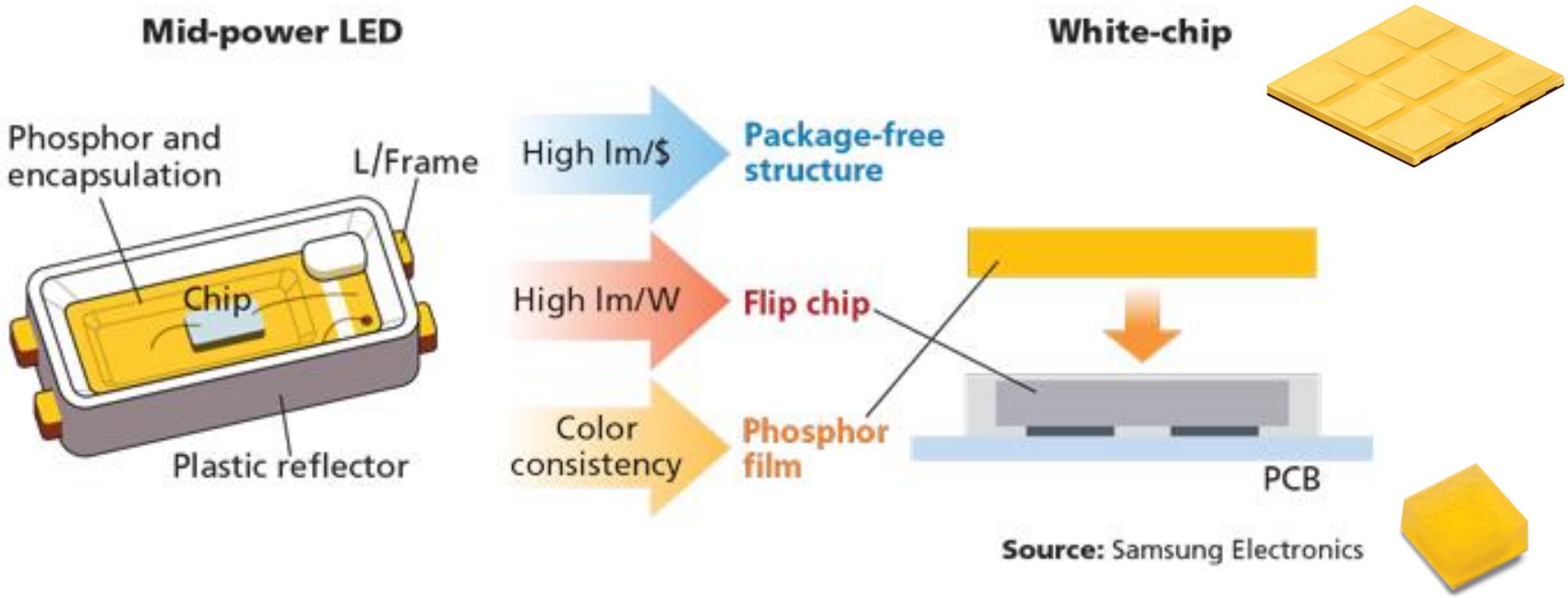
QLEDs – tune the wavelength of the emitted light by adjusting the size of the semiconductor's lattice, rather than having to use different materials to produce different characteristics



QLEDs advantages:

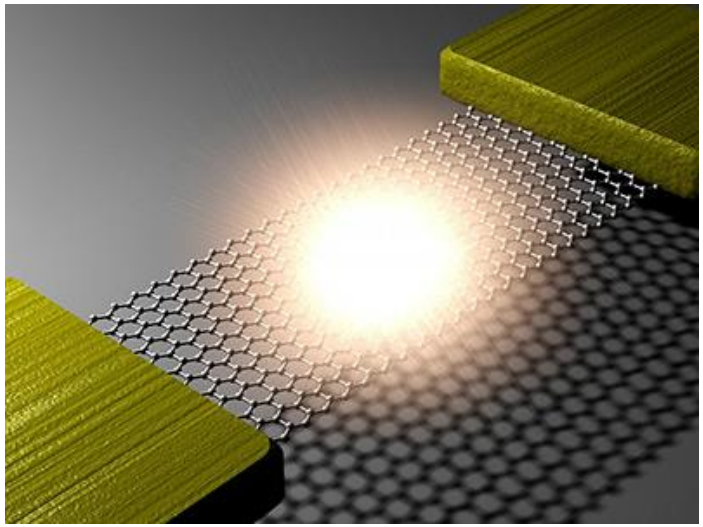
- **Pure color** - 30-40% luminance efficiency over OLEDs at the same color point.
- **Low power consumption** — more than twice as power efficient as OLEDs at the same color purity.
- **Low-cost manufacture** — ultra-thin, flexible prints, large-area substrates to reduce luminaire manufacturing cost.
- **Ultrathin, transparent, flexible form factors** — will enable designers to develop lighting forms not possible with existing technologies.

Chip-scale Packaging (CSP)



- CSP can emit from 5 surfaces (the four sides and the top)
- CSP structure and flip-chip LED architecture is far simpler (less packaging steps) and more flexible (arrays) than the traditional mid-power approach leading better performance and lower costs
- CSP can be extended to high-power LEDs

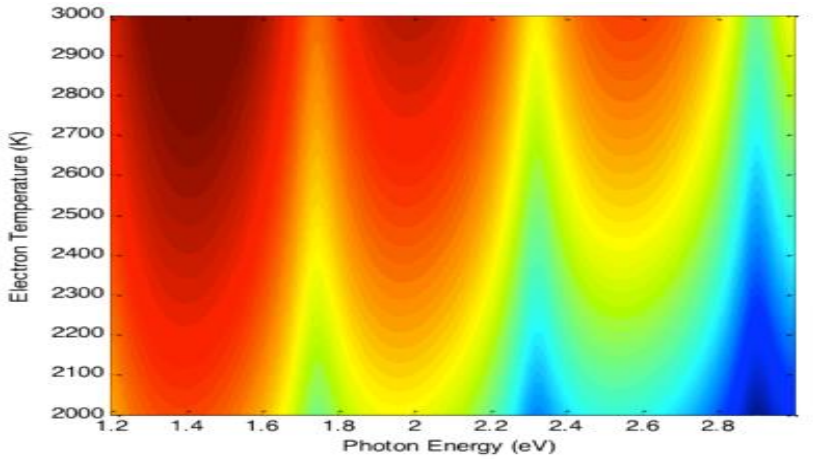
Graphene



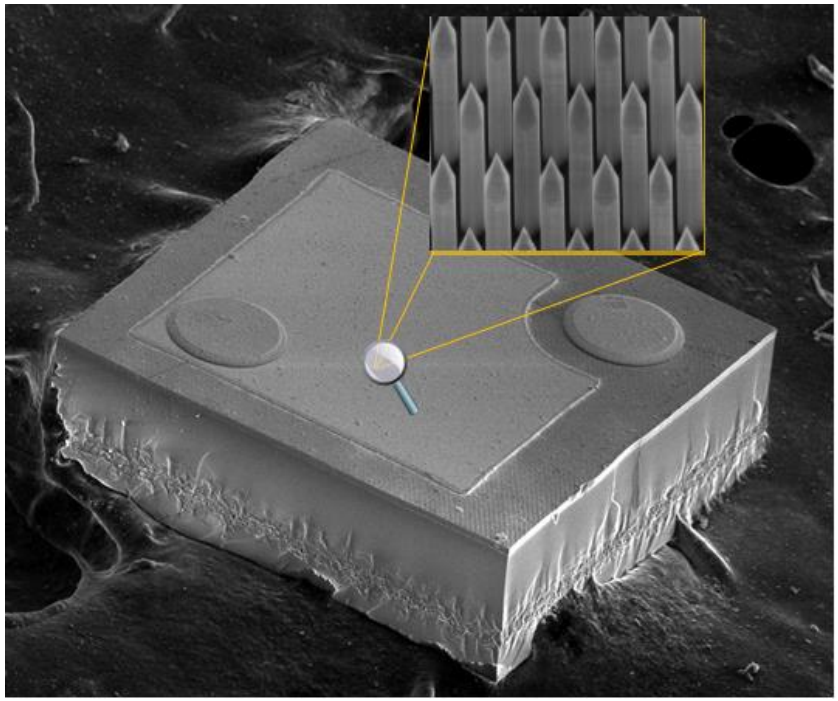
Next generation of LEDs using Graphene:

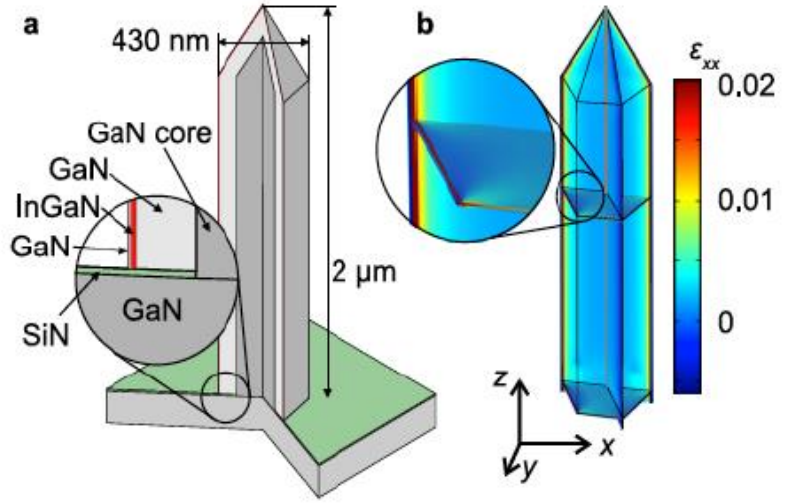
- last longer (less heat management issues)
- operate brighter
- no metal electrodes
- naturally warm CCT (2700K – 3000K)

Graphene is a crystallized, transparent form of carbon, stronger than steel and more conductive than copper and… produces light



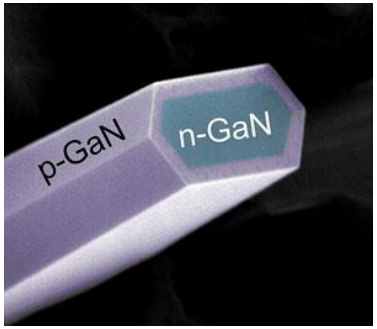
Nanowire LEDs (nLED)





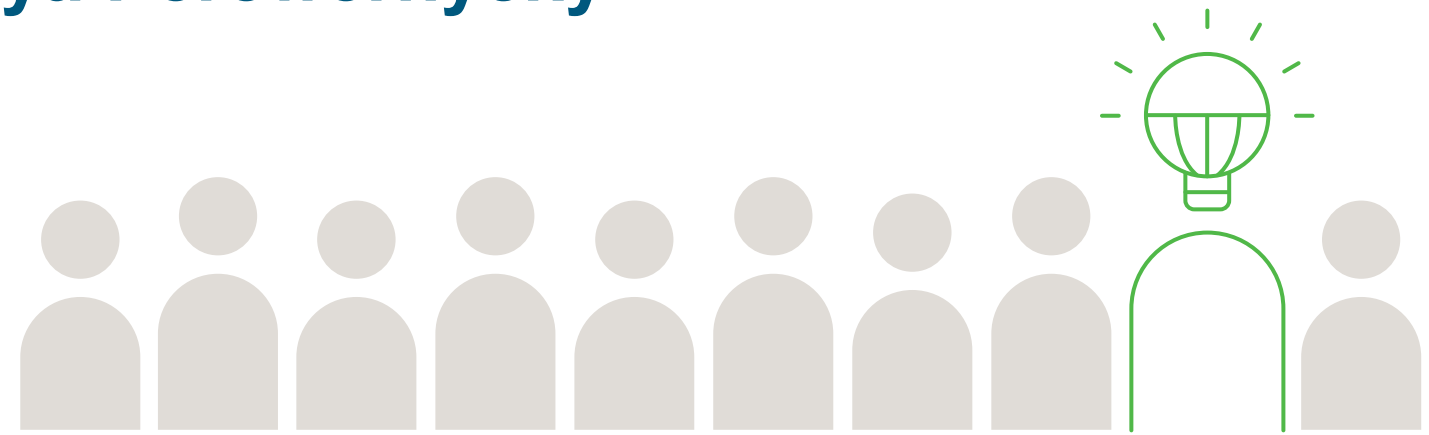
(a) Sketch of an LED nanowire showing the onion-like structure of the layers; (b) Finite element method simulation of strain distribution (credit: Tomas Stankevic, Niels Bohr Institute, University of Copenhagen)

- (GaN) inner core and a layer of (InGaN) on the outside
- 2 μm high (1 micrometer is a thousandth of a millimetre)
- 10-500 nm in diameter (1 nanometer is a thousandth of a micrometer)
- will provide a more natural light in LEDs and use much less power.



January 2018 Programs Update

Tanya Perewernycky



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Amendment 13 Lighting Legislation

January 26, 2018

Federal legislation comes into effect on lighting technologies, including:

- Fluorescent lighting, impacting the accepted baseline for T8 lighting
- Exit signs
- Incandescent bulbs

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Program Impacts

Business Energy Saving Incentives (BESI)

Thursday January 25th, 5:00pm

- The BESI application system will be shut down to implement changes to the program
- **Applications that are submitted to BC Hydro for pre-approval by this time will not be impacted**
- We recommend customers with “Open” applications to start new ones, otherwise you will likely receive an error message

Program Impacts

BESI – Improvements!

EXISTING TECHNOLOGY
4’ 2 lamp T12 magnetic ballast
4’ 2 lamp T8 electronic ballast
4’ 4 lamp T12 electronic ballast
4’ 4 lamp T8 magnetic ballast

EXISTING TECHNOLOGY
4' 2 lamp fluorescent
4' 3 lamp fluorescent
4' 4 lamp fluorescent

LED

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BESI Program Impacts

LED Exit signs

- Removed from application eligibility

Incandescent Lighting

- LED screw-in lamp replacements removed from e
- LED hardwired replacements remain

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Other minor changes

Business Energy Saving Incentives…

Existing HID to Low/High Bay Fluorescent

- Retrofit revised to Low or High Bay **HO** Fluorescent

Removed no longer relevant retrofits:

- Ornamental street lighting
- Flat lens fixtures

LED Wattages

- With ever-changing efficiencies to LEDs, we have lowered the wattages and increased energy savings for most retrofits!

Key Account Customers

Incentive Funding

As in previous years, Key Account Managers are working with their customers to identify projects planned to proceed for the upcoming fiscal year (April 2018)

- Key Account customers are planning their projects for the upcoming fiscal year. Applications will start to be received in February for project approval starting April 2018.
- Key Account customers with Energy Managers on staff will have priority
- BESI applications will be able to be submitted started February 1st
- Remember: without an Energy Manager, Key Account customers ONLY qualify for BESI

Custom & SIP Incentives

New Lighting Calculator!

With the lighting legislation changes, a new lighting calculator is required to accommodate the changes

- **New version 8.1**
- In addition to the legislation changes, this version incorporates a few additional changes….
    - Facility types and areas
    - New LED lamp ‘types’: reflector lamps, T-LEDs and mogul base
    - Removes all macros from the file

New Lighting Calculator

New lighting calculator is mandatory effective January 26th !

Custom applications (for projects starting after April 2018) must be submitted using the new lighting calculator.

Industrial SIP projects will be required to use the new lighting calculator.

- Online application is being revised to match the new “Projected Savings Breakdown” table

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Energy Savings Report

BC Hydro Power Smart ES Lighting Calculator, version 8.1 - 2018.01.02

Primary building type (MANDATORY ENTRY) Missing Info!

Projected savings breakdown

	Estimated Demand Savings		Estimated Energy Savings (kWh)	
	Site	*BC Hydro Peak*	Site	*Potentially incentable*
HID lamps only	-	-	-	-
LED directional screw-in/snap-in replacement to reflector lamps	-	-	-	-
LED exterior signage	-	-	-	-
LED Lighting with Adaptive Control	-	-	-	-
LED/OLED luminaire and retrofit kit	-	-	-	-
LED mogul base	-	-	-	-
LED refrigerated lighting system per door	-	-	-	-
LED tubular lamp (T-LED)	-	-	-	-
Lighting control - New	-	-	-	-
Lighting control - DDC re-scheduling	-	-	-	-
Non-LED lighting retrofit (incl. removal)	-	-	-	-
No incentives (CFL, Fluor, HIR, LED exit, A-type LED screw-in)	-	-	-	-
Non-LED Lighting with Adaptive Control	-	-	-	-
Totals	-	-	-	-

New Lighting Calculator

Energy Savings Lighting Calculator

Please do not use cut and paste. Only use copy and paste.

BC Hydro Power Smart ES Lighting Calculator, version 8.1 - 2018.01.02

Customer: *Project:*

					Existing lighting system			
№	Room name	# of Identical Areas	Space Type	Luminaire type	Luminaire Description	Qty	Pwr	Control type
		Default is 1					W	
1							-	
2							-	
3							-	
4							-	
5							-	
6							-	
7							-	
8		1					-	

Locker Room
Lounge/Recreation
Manufacturing - Detailed Manufacturing
Manufacturing - Equipment Room
Manufacturing - General
Museum - General Exhibition
Museum - Restoration
Office - Enclosed

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Reminders

Project Completion Dates

- As a budget management tool, the selection of project completion date in BESI must be completed
  - Determines the date range within which an application may be declared complete
  - Applications can be extended to March 31st or one year from project submission, whichever comes first
- Now also being applied to SIP!

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Questions

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