Luminaire Level Lighting Controls

Monique "Q" Gagne – Initiative Manager
Center for Energy and Environment
Efficient Technology Accelerator

SCALE
Smart Controls Accelerating Lighting Efficiency

Who am I?

Monique "Q" Gagne
Initiative Manager

- 10 years in the lighting controls industry
- Commercial Specification Sales in Ontario, Canada for Lutron
- Field Service, Systems Engineering in North American Market for Signify (Philips Lighting)

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Who we are

Minnesota's Efficient Technology Accelerator (ETA) is a statewide market transformation program that **accelerates deployment** and **reduces the cost** of **emerging and innovative efficient technologies**, bringing lower energy bills and environmental benefits to Minnesotans.

ETA is a partnership funded by the state's investor-owned utilities (IOUs), administered by the Minnesota Department of Commerce, Division of Energy Resources (DER), and implemented by Center for Energy and Environment (CEE).

Who we are

Center for Energy and Environment

ETA's implementer, **CEE seeks a healthy, carbon-neutral economy that works for all people**. A 501(c)(3) clean energy nonprofit with more than 30 years' experience in energy efficiency, we align our strategies behind technical research, program development and implementation, community engagement, policy advocacy, and project financing. Working across homes, businesses, and communities, CEE discovers and deploys the most effective energy solutions to improve the environment and strengthen the economy for everyone.

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Who we are

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Smart Controls Accelerating Lighting Efficiency

SCALE (Smart Controls Accelerating Lighting Efficiency) is a program bringing the benefits of advanced lighting controls to businesses across Minnesota. By equipping the market with practical know-how and resources to ensure lighting serves the needs precisely when and where it matters most. By embracing smart lighting solutions, we'll grow businesses, reduce electric bills and together light the way.

Agenda

- Introduction to Lighting Controls
- Market Case
- Applications

Introduction to Lighting Controls

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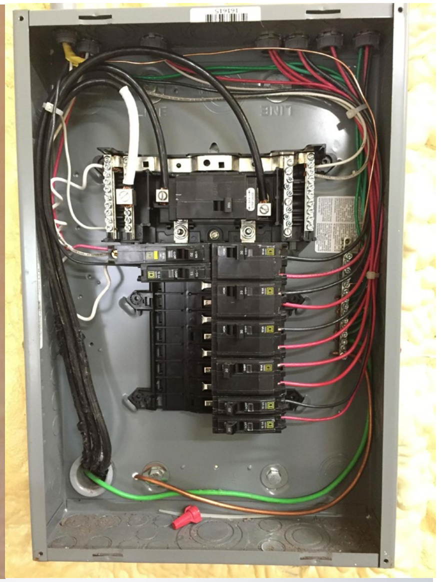
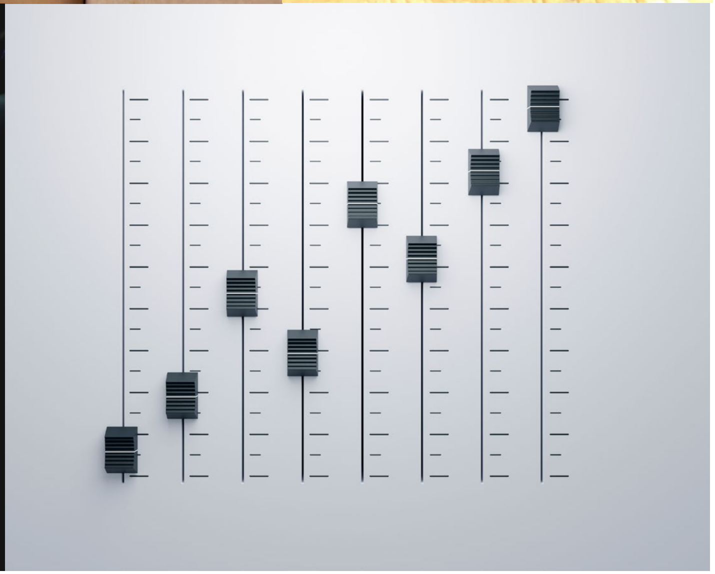
What are Lighting Controls







Why Control Lighting?

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Enable the delivery light

Where
- Roads & Streets of a City
- A room of a building
- A single luminaire

When
- At sunset
- Upon occupancy
- Upon power outage

How
- Every other tube on
- Fade off over 2 seconds
- Mimic daylight color temperature

It is desired

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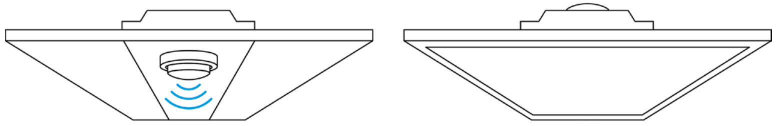
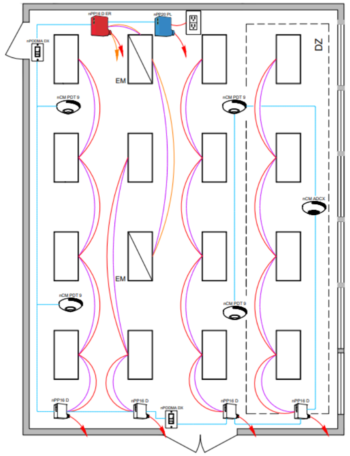
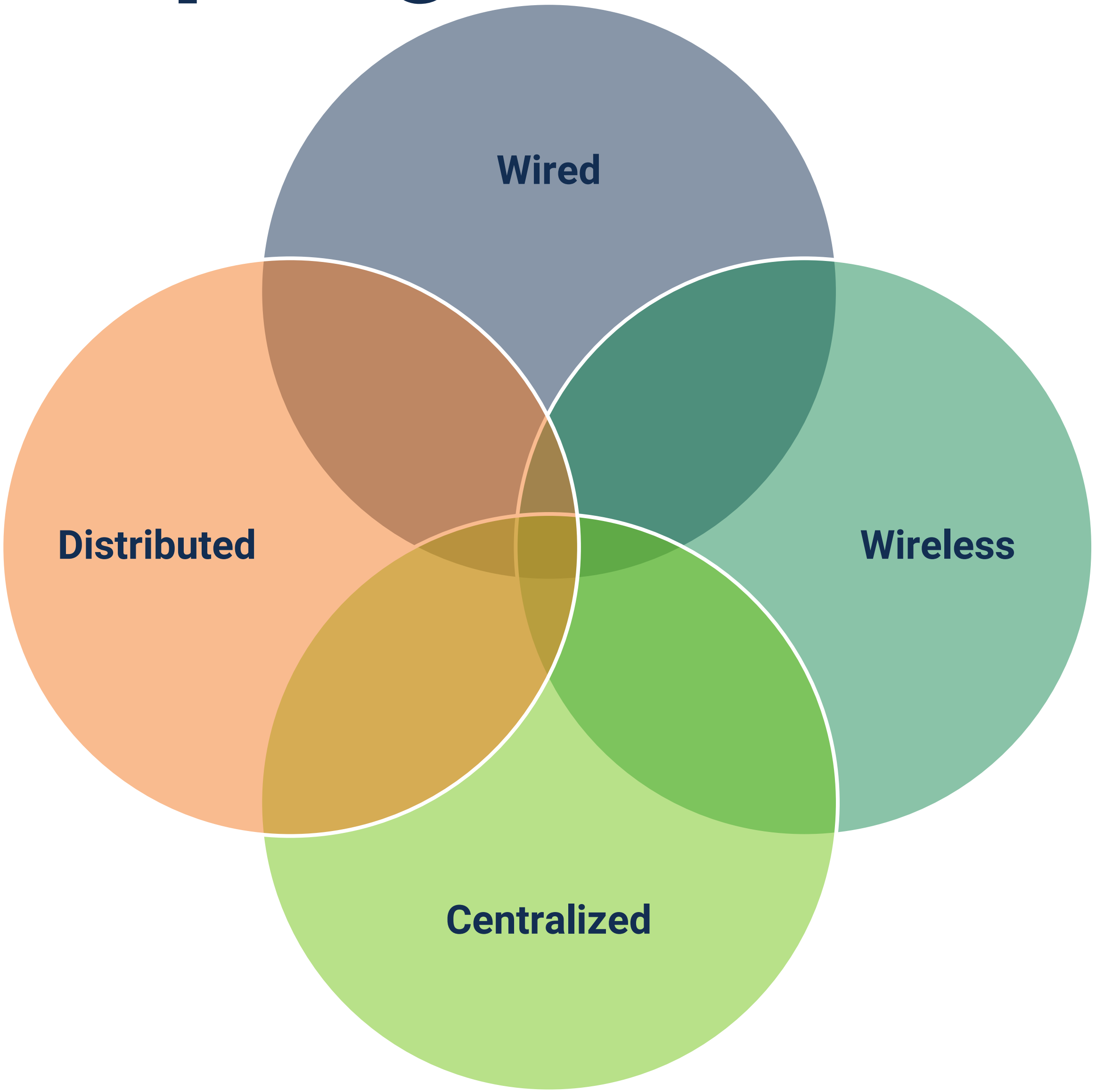
Lighting Control Architectures

- **Networked** Lighting Controls (NLCs)
  - Luminaire Level (LLLCs)
  - Networked Zone Controls
- **Standalone** Lighting Controls
  - Power Packs & Photocells or Motion Sensors
  - Switches, Dimmers, Relay Panels, Contactors





System Topologies



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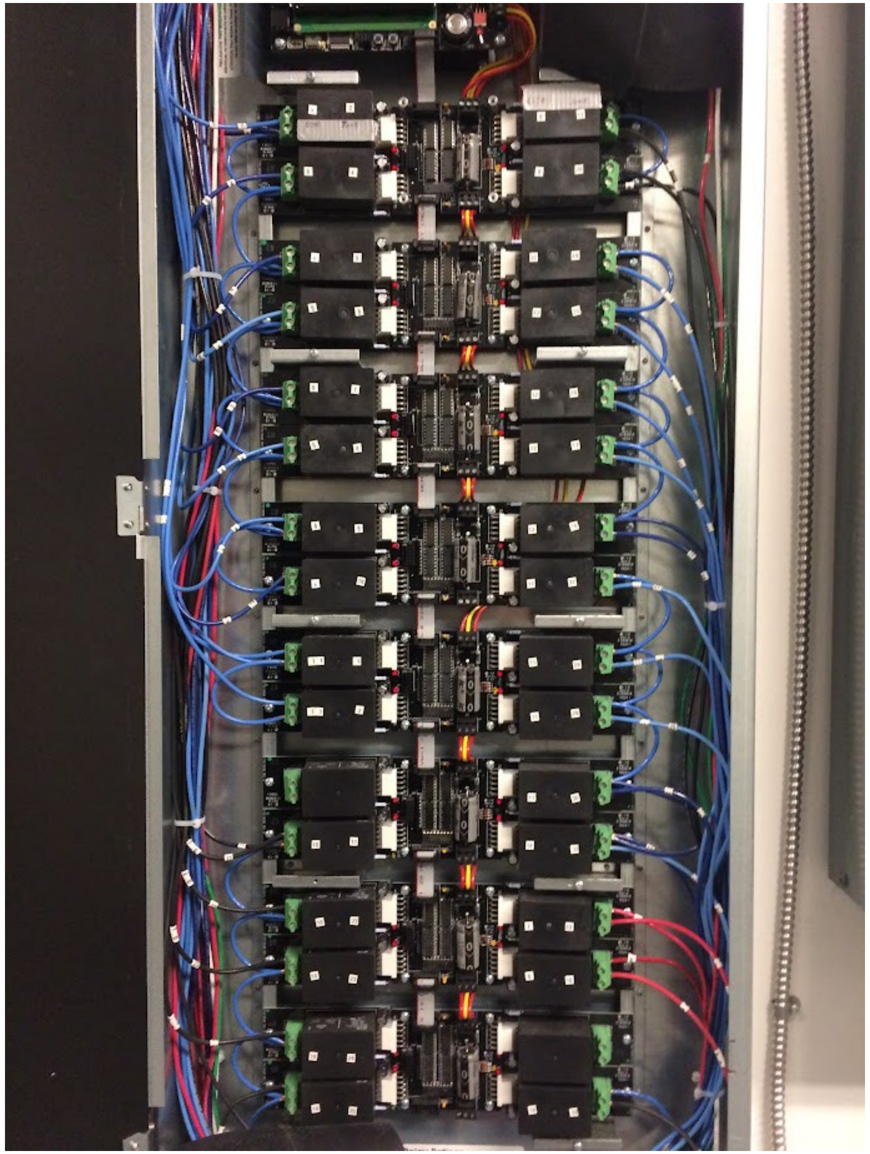
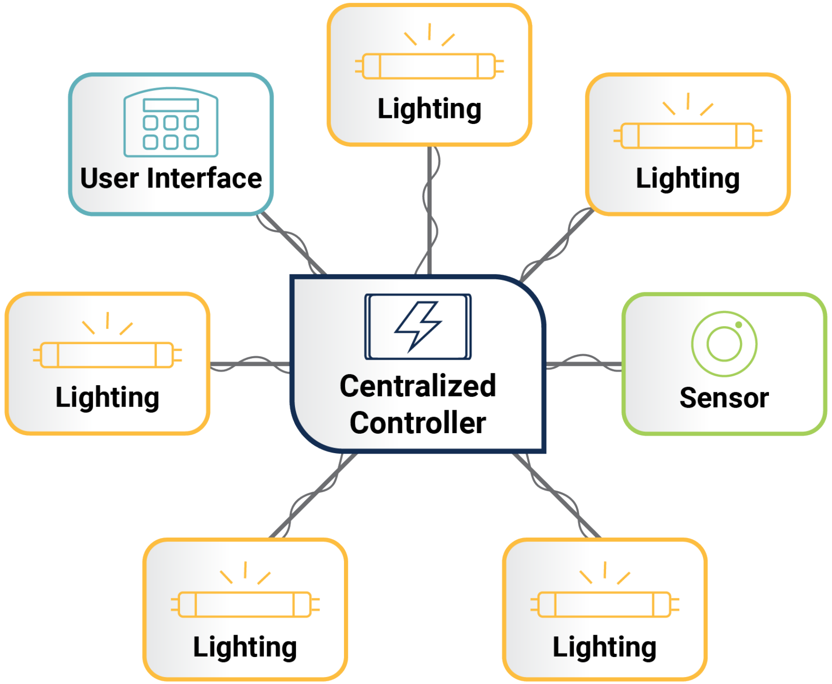
Distributed or Centralized?





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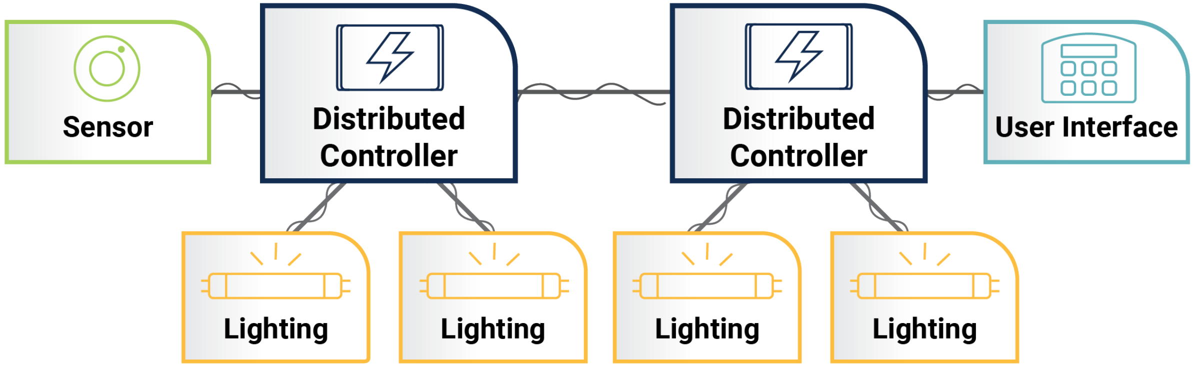
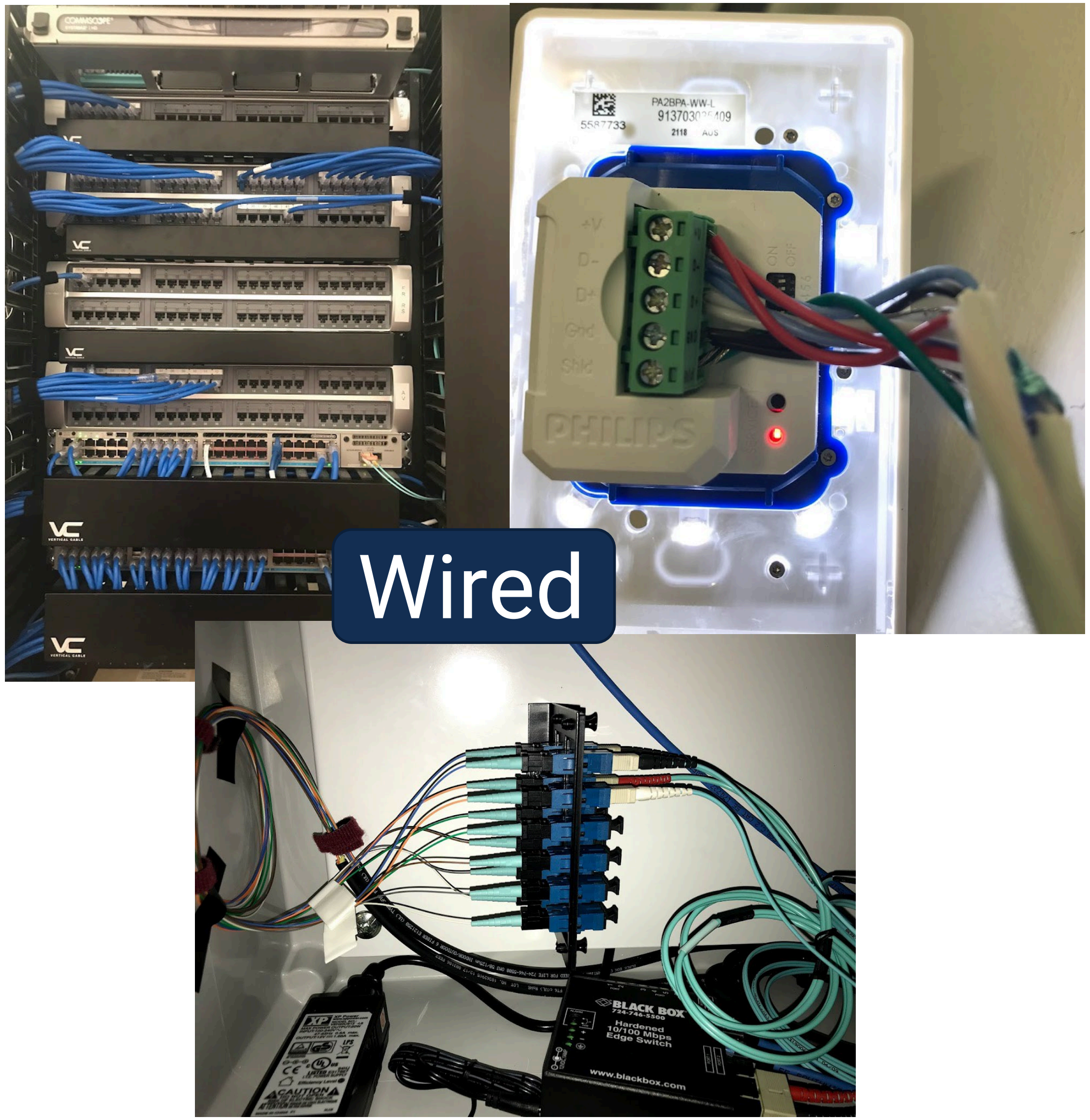
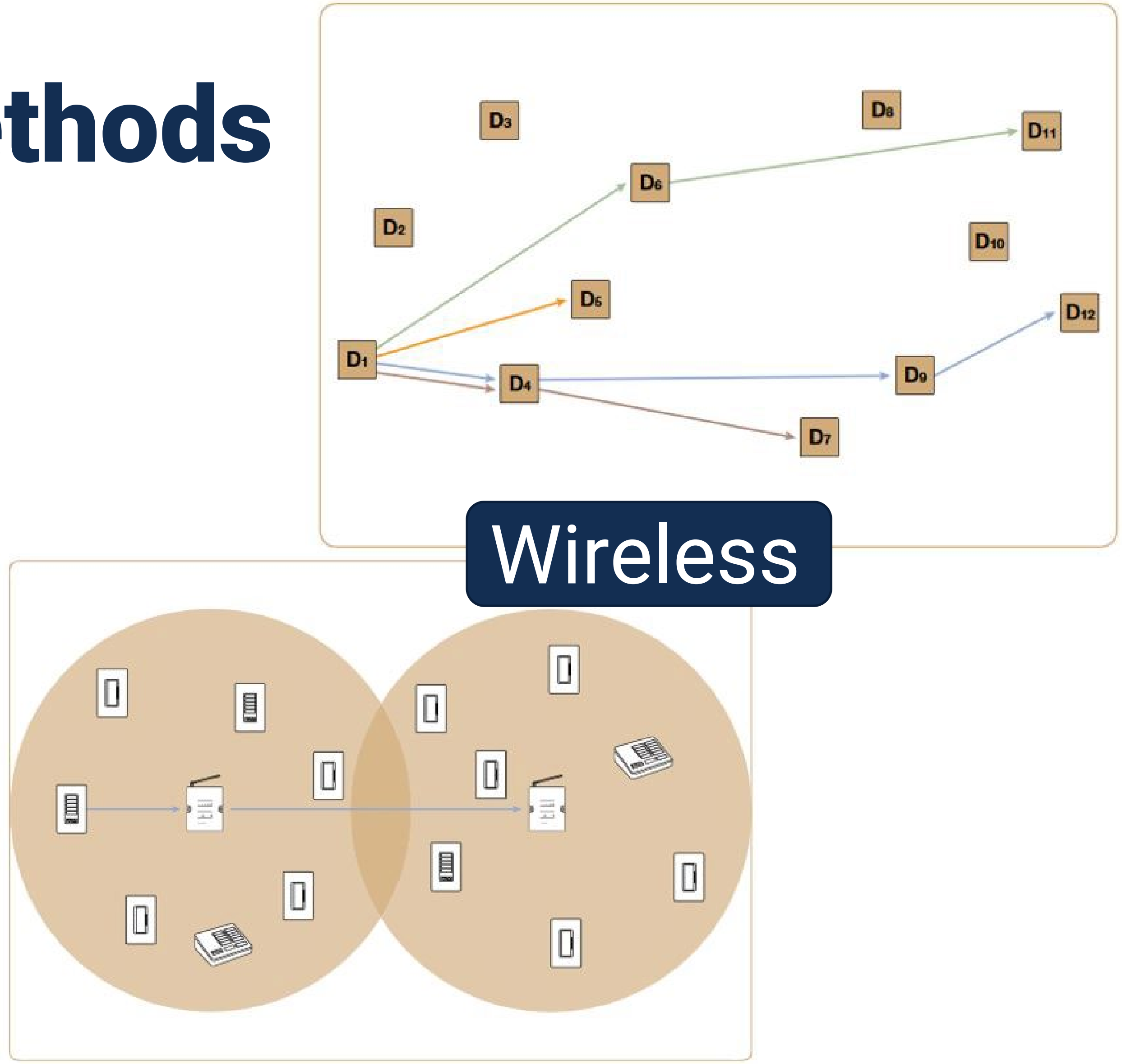
Distributed or Centralized?



Communication Methods





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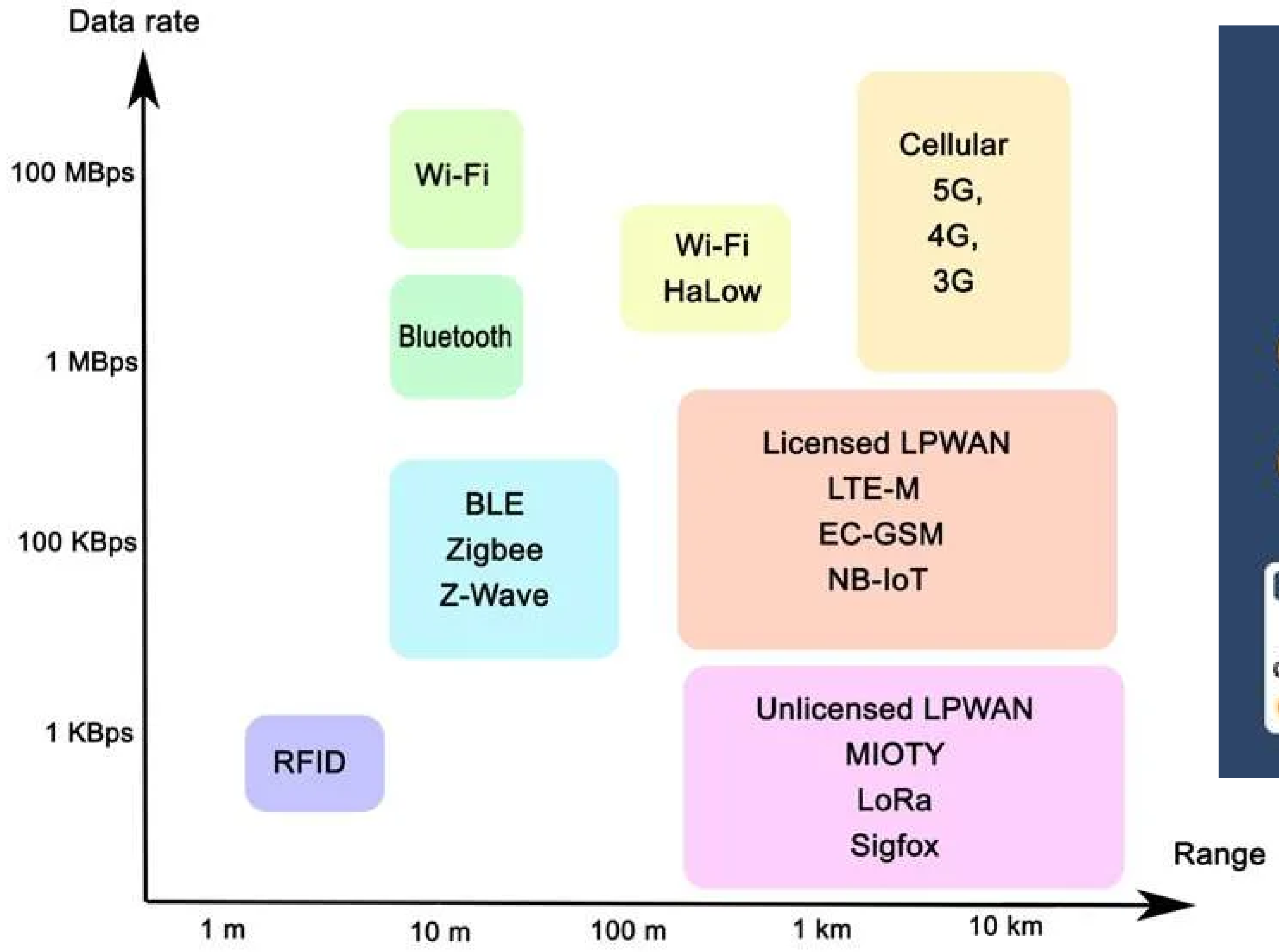
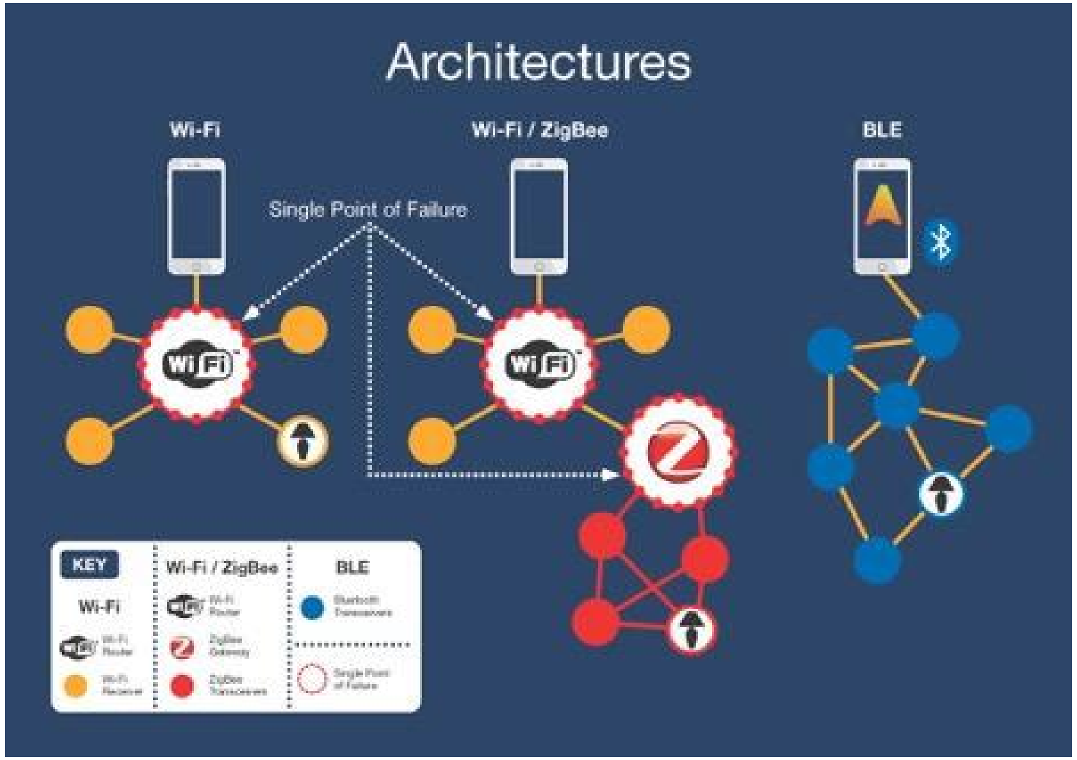
Wireless Protocols





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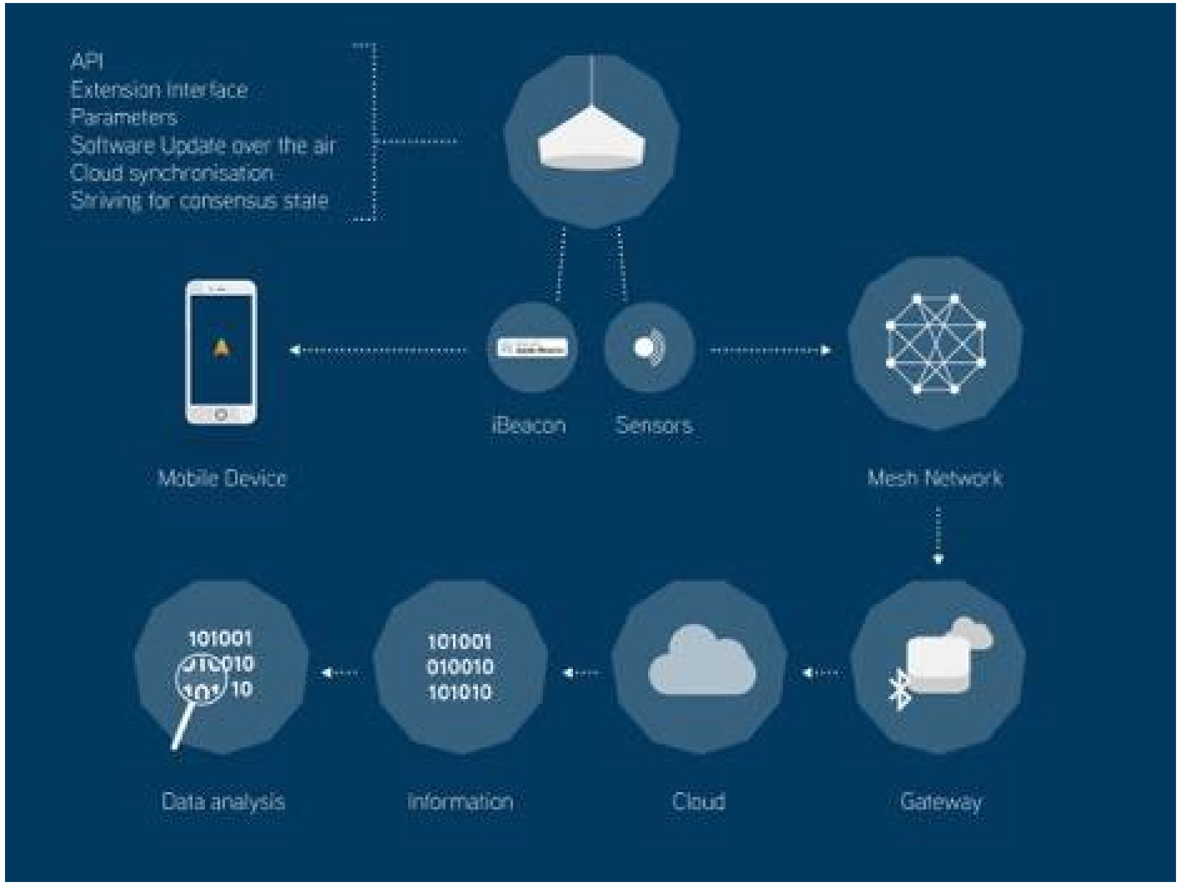
Wireless Protocols

- Hub/Gateway Required?
- Remote Control?
- What happens when the internet goes out?
- Interoperability
  - Proprietary
  - Open Standard
  - Proprietary built on open standard
- Can system be configured with an app-based device?



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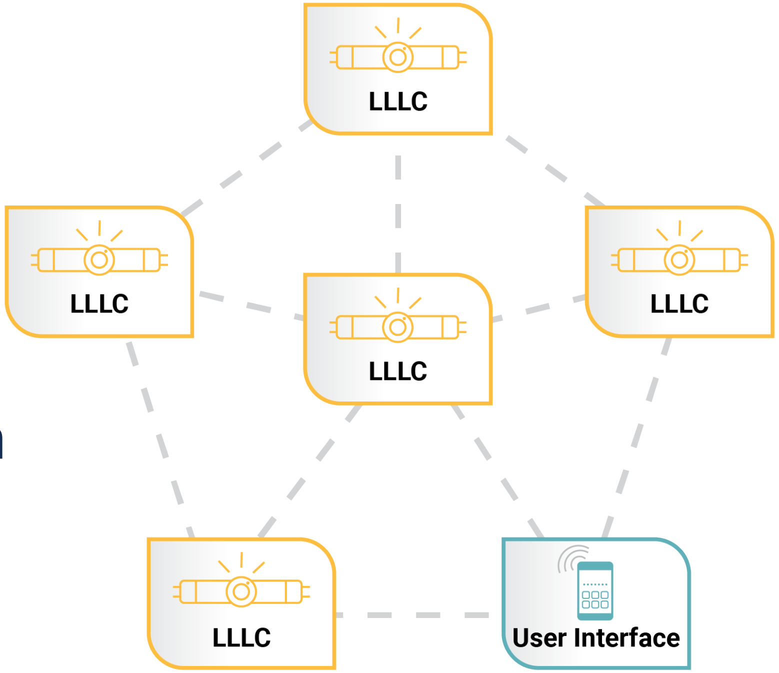
LLLCs – What Are They?

Luminaire Level Lighting Controls

Connected systems of luminaires that individually contain control and sensor components.



Design Light Consortium's
NLC Qualified Product List (QPL)

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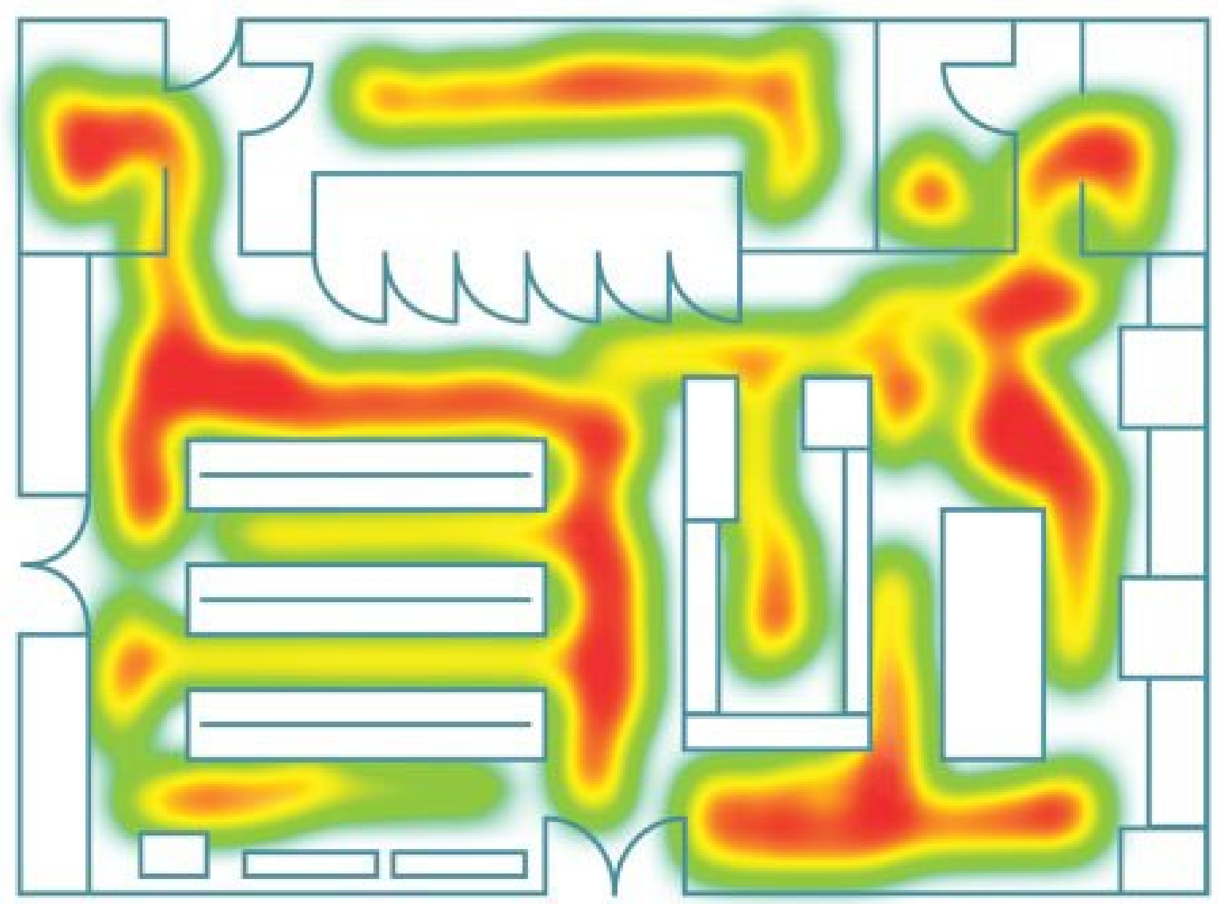
What can LLLCs do?



Typical retail hot-map analytics enabled by Lighting Controls IoT Ecosystem

- Rezone Flexibly
- Asset Tracking
- Occupancy Tracking
- Environmental Monitoring
- Navigation
    - Indoor positioning
    - Wayfinding

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Market Case

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Lamp Replacements

Type A

Reuse/require ballasts

- Compatibility
  - Instant, rapid or programmed start?
  - Dimmable?
- Obsolescence

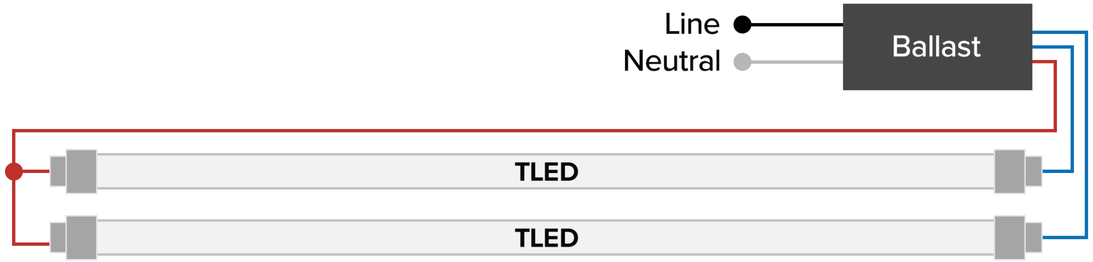

Figure 1: UL Type A TLED wiring example

Type B

Requires re-wiring to remove ballast

- No ballasts required
- Typically, no dimming
- Maintenance impact, potential shock hazard at socket (now that it's 120V)

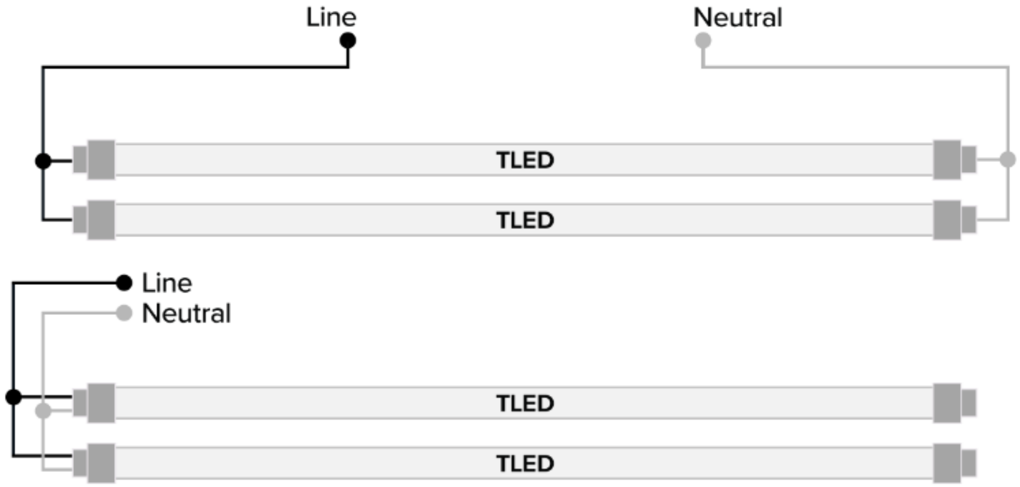

Figure 2: UL Type B TLED wiring example

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Fixture Replacements

New Luminaires

Cons

- More labor required than lamp replacements
- May require plenum access

Pros

- No ballasts to replace
- Aesthetics, light distribution
- Controls can be integrated, more straightforward
- Higher incentives available

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Energy Code Requirements

- ASHRAE 90.1 – 2019
  - Local Control
    - Manual On
    - Dimming control
  - Auto Off
    - Scheduling
    - Motion & timeout
  - Continuous Daylight Dimming required for all spaces (replacing stepped dimming)
  - Plug loads
    - Scheduling
    - Motion & timeout
  - Verification & testing required

Stairwells and Corridors in Schools

Lighting power for each luminaire required to be reduced by at least 50% when no activity is detected for 20 minutes and OFF when building is scheduled to be unoccupied.

Parking Garages

- **Motion Control**
  Lighting power for each luminaire (including stairwells) required to be reduced by at least 50% when no activity is detected for 10 minutes (zones up to 3600 ft^2).
- **Schedule**
  Lighting OFF when closed
- **Continuous daylight dimming** down to 50% required for luminaires within 20 ft. of wall openings

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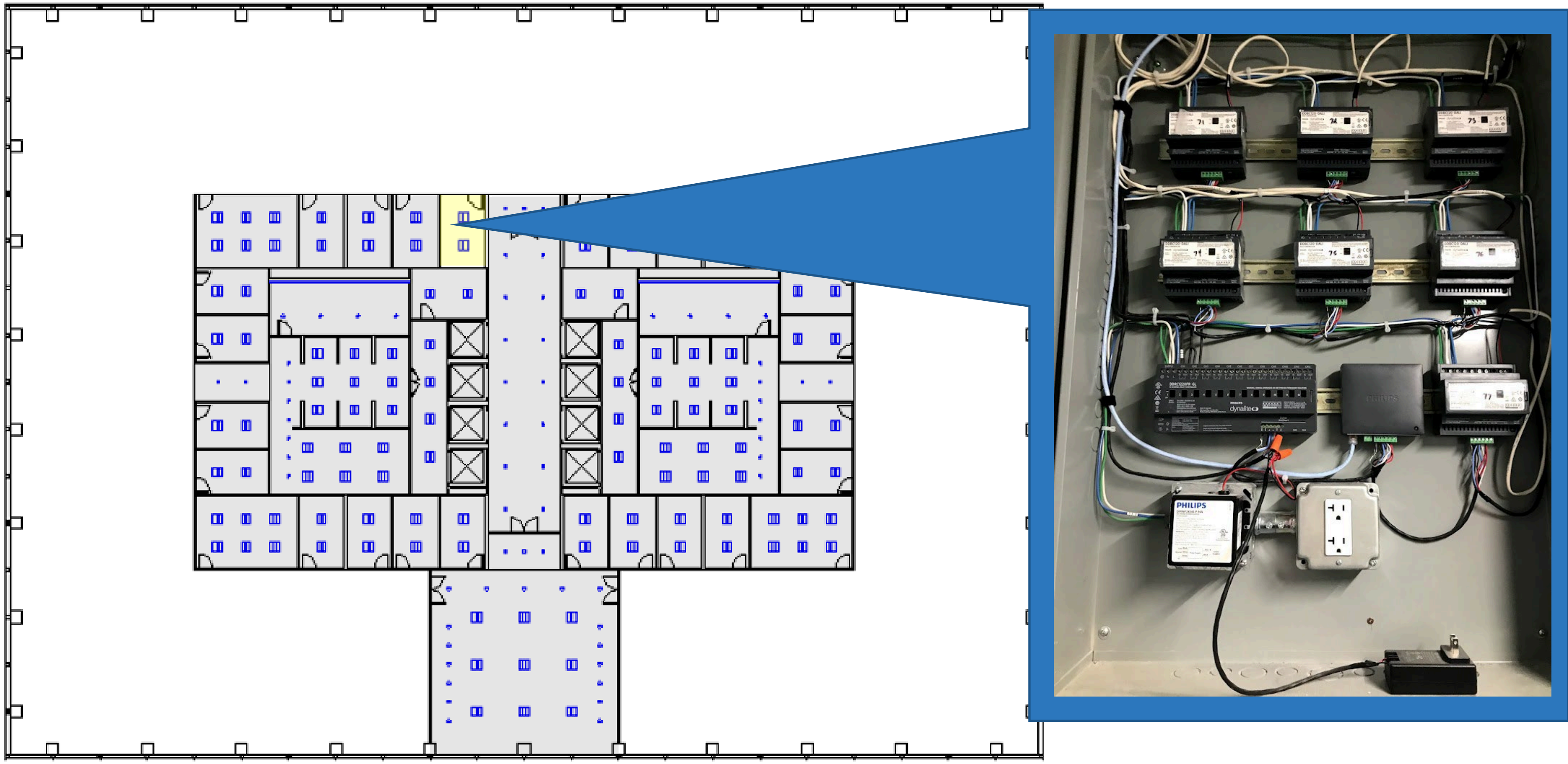
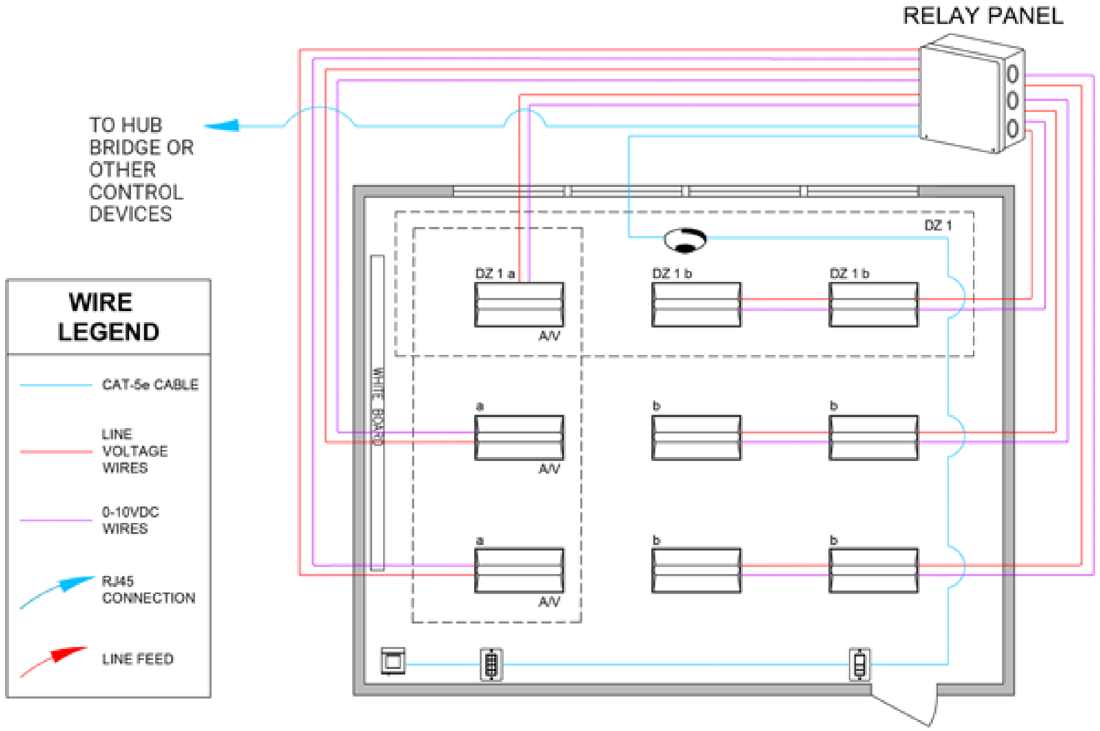
Wired digital Networked Lighting Control (NLC) system

LEGEND:



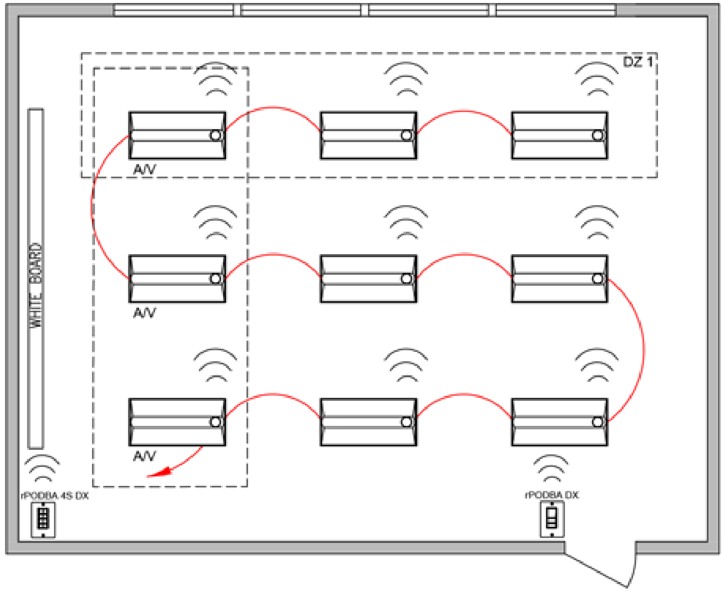
Installing LLLCs – What's Different?

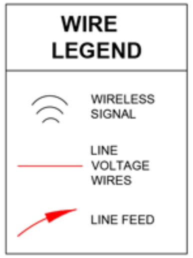


Networked Lighting Controls (NLC) without LLLCs

- Fixtures have 0-10V Dimming
- CAT5 to keypads & sensors
- Room-based controller
- Daylight harvesting zone
- A/V zone for projector

(line feed to panel not shown)





LLLC

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RCPs courtesy of AcuityBrands

Energy Savings

Control Type	Building type	Savings Factor	SF Source
Occupancy Sensor	Office	0.22	Ref. 2, Table 7 For warehouse new construction, occupancy sensors with 50% dimming are required (Ref. 8). This reduces the baseline NC savings factor in this scenario to SF_{OCC} * (1 - 0.50) = 0.31 * 0.50 = 0.16
	Warehouse	0.31 (upgrade) 0.16 (NC baseline)	
	Lodging	0.45	
	Education	0.18	
	Assembly	0.36	
	Healthcare, outpatient	0.23	
	Other / unknown	0.24	Ref. 2, Abstract
Daylighting	Office	0.27	Ref. 2, Table 7
	Warehouse	0.28	
	Education	0.29	
	Retail	0.29	
	Assembly	0.36	
	Other / unknown	0.28	Ref. 2, Abstract
Personal tuning	Office	0.21	Ref. 2, Ref. 5: 0.35 x 0.22 / 0.36 = 0.21 (see Notes)
	Education	0.04	Ref. 2, Ref. 5: 0.06 x 0.22 / 0.36 = 0.04 (see Notes)
	Other / unknown	0.19	Ref. 2, Ref. 5: 0.31 x 0.22 / 0.36 = 0.19 (see Notes)
Task tuning	Office	0.37	Ref. 6 and Ref. 9, see Notes
	Education	0.26	
	Manufacturing	0.05	
	Warehouse	0.07	
	Other / unknown	0.22	Ref. 5
Multiple of the above		0.38	Ref. 2, Abstract

Control Type	Subtype	Savings Factor		
		With LLLC	Without LLLC	Unknown
Networked lighting controls	Assembly	0.32	0.24	0.28
	Manufacturing	0.51	0.26	0.40
	Office	0.77	0.40	0.64
	Education	0.52	0.35	0.41
	Restaurant	0.67	0.51	0.59
	Retail	0.50	0.38	0.44
	Warehouse	0.78	0.58	0.68
	Other / unknown	0.63	0.35	0.49

Otter Tail Prescriptive Incentives for Retrofits

REBATE RATES FOR EXISTING LIGHTING SYSTEM RETROFITS

EXISTING TECHNOLOGY	REPLACED WITH	REBATE PER WATT SAVED
Low-efficiency incandescent / CFL / fluorescent	Screw-in LED indoor (with and without removal prevention devices)*	20¢
	Screw-in LED outdoor (with and without removal prevention devices)*	10¢
	Hard-wired LED indoor	60¢
	Hard-wired LED outdoor	40¢
Standard T8 fluorescent lamps	LED lamp-only retrofit	40¢
Mercury-vapor	Hard-wired LED indoor	60¢
	Hard-wired LED outdoor	40¢
	Screw-in LED indoor*	40¢
	Screw-in LED outdoor*	20¢
Standard high-intensity discharge (HID)	Hard-wired LED indoor	60¢
	Hard-wired LED outdoor	40¢
	Screw-in LED indoor*	40¢
	Screw-in LED outdoor*	20¢
Exit lighting fixtures	High-efficiency LED exit lighting (based on maximum demand reduction of 20 watts/fixture)	60¢
Occupancy/daylight sensing controls		$200 per connected kw

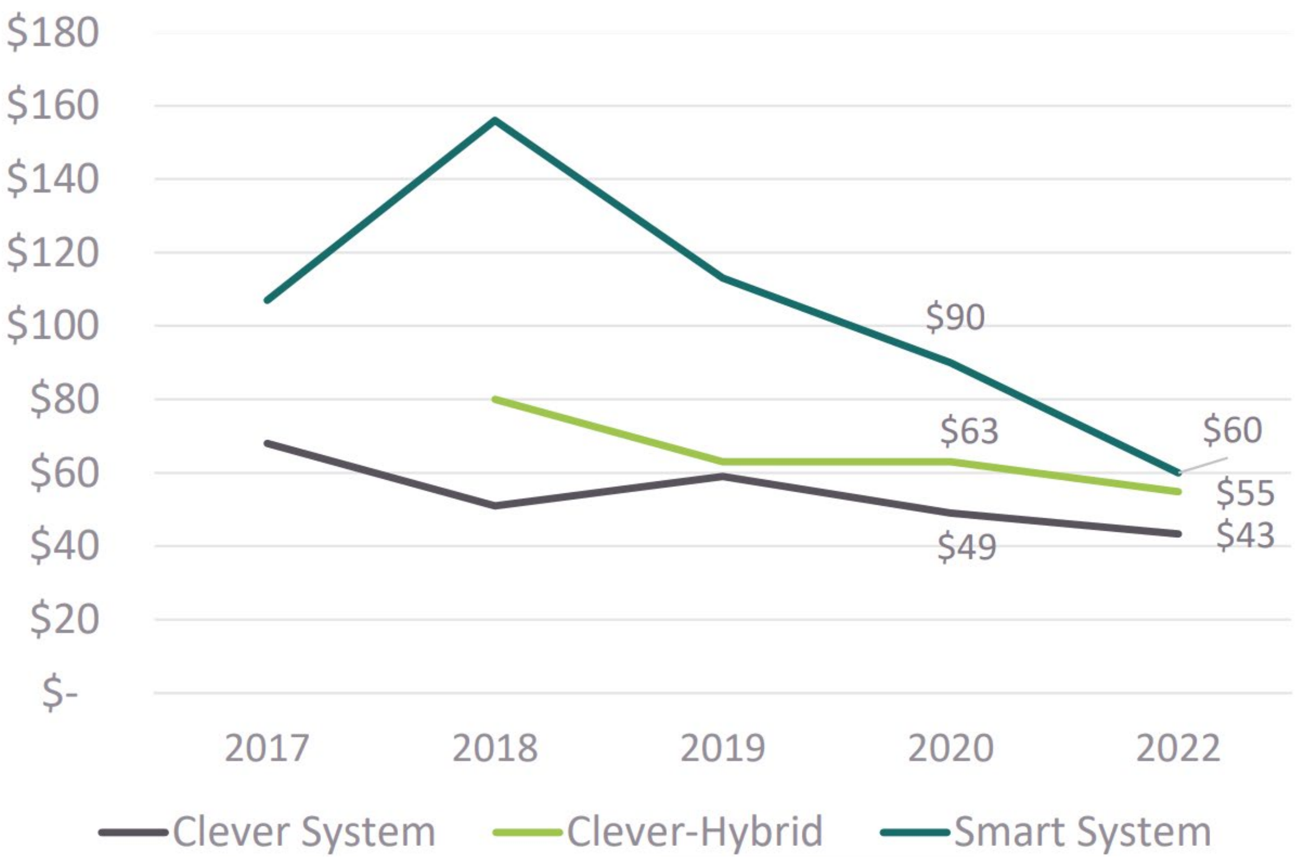
Technology	Rebate/ Watt Saved	Total Rebate for QTY 100-32W Reduction Units
T8 to LED Lamp-only	$ 0.40	$ 1,280
Fluorescent to LED Fixture Indoor	$ 0.60	$ 1,920
Occupancy/daylight sensing controls	$ 0.20	$ 640
Fluorescent fixture to LLLC	$ 0.80	**$ 2,560**

TWICE the rebate for LLLCs compared to TLEDs

Note: Otter Tail caps rebates at 75% of cost

Incremental Cost of LLLCs over LED Fixtures

2022 Luminaire Level Lighting Controls Incremental Cost Study



	2020-2022	2017-2022
Clever	-12%	-36%
Clever-hybrid	-13%	-31%[4]
Smart	-33%	-44%

With OtterTail's incentives in MN, the incremental cost for 100 LLLCs over similar LED fixtures for a retrofit is about $3,660-5,360

Otter Tail Prescriptive Incentives for New Construction

REBATE RATES FOR NEW CONSTRUCTION LIGHTING SYSTEMS

Installed Lighting	Wattage	Rebate per Unit
LED fixtures (interior)	<30	$15.00
	30 to 49	$25.00
	50 to 79	$35.00
	80 to 99	$50.00
	>99	$75.00
LED fixtures (exterior)	<30	$10.00
	30 to 49	$15.00
	50 to 79	$20.00
	80 to 99	$25.00
	>99	$30.00
LED screw-in (interior)*	<10	$1.25
	10 to 24	$3.50
	25 to 49	$8.00
	50 to 75	$13.50
LED screw-in (exterior)*	<10	$1.00
	10 to 24	$1.50
	25 to 49	$3.50
	50 to 75	$6.00
Controls (motion/daylight sensors)		$200 per connected kw

*Available to commercial customers only. Residential customers are not eligible for screw-in rebates.

Note: Otter Tail caps rebates at 75% of cost

LED Fixture	Wattage	Rebate per Unit	Rebate per LLLC	% Increase	Net Incremental Cost per LLLC
Ambient Linear	16	$ 15.00	$ 18.20	21%	$ 24.80
2x2	20	$ 15.00	$ 19.00	27%	$ 24.00
2x4	40	$ 25.00	$ 33.00	**32%**	$ 10.00
Stairwell Fixture	50	$ 35.00	$ 45.00	29%	**$ (2.00)**
High Bay	106	$ 75.00	$ 96.20	28%	**$ (53.20)**

Otter Tail Incentives

For South Dakota

Replacement lighting

Existing	Replaced with	Rebate per watt saved
Low-efficiency incandescent	Screw-in LED indoor (with and without removal prevention devices)	10¢
	Screw-in LED outdoor (with and without removal prevention devices)	5¢
	Hard-wired LED indoor	25¢
	Hard-wired LED outdoor	15¢
Low-efficiency fluorescent	Hard-wired LED	25¢
Standard T8 fluorescent lamps	LED lamp-only retrofit	15¢
Mercury-vapor lamps	Hard-wired LED indoor	25¢
	Hard-wired LED outdoor	15¢
	Screw-in LED indoor	10¢
	Screw-in LED outdoor	5¢
Standard HID	Hard-wired LED indoor	25¢
	Hard-wired LED outdoor	15¢
	Screw-in LED indoor	10¢
	Screw-in LED outdoor	5¢
Exit lighting fixtures	High-efficiency exit lighting (based on maximum demand reduction of 20 watts/fixture)	25¢
Occupancy/daylight sensing controls		$100/connected kW

New construction high-efficiency lighting

LED technology	Wattage	Rebate per fixture or lamp
Indoor LED fixture	<30	$10.00
	30 to 49	$15.00
	50 to 79	$25.00
	80 to 99	$30.00
	>99	$50.00
Outdoor LED fixture	<30	$5.00
	30 to 49	$7.50
	50 to 79	$10.00
	80 to 99	$15.00
	>99	$20.00
Screw-in indoor LED	<10	$1.00
	10 to 24	$2.25
	25 to 49	$5.00
	50 to 75	$10.00
Screw-in outdoor LED	<10	$1.75
	10 to 24	$1.00
	25 to 49	$2.50
	50 to 75	$4.00
Occupancy/daylight sensing controls		$100/connected kW

Note: Otter Tail caps rebates at 75% of cost

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Applications

Control Strategies

Manual
- Local
- Remote

Motion
- Occupancy
- Vacancy

Timeclock/Schedule

Light Control & Daylight Harvesting

Trim
- High-end
- Low-end

Demand Response

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Manual Control

- Local
- Central/Remote

Motion Control

Occupancy

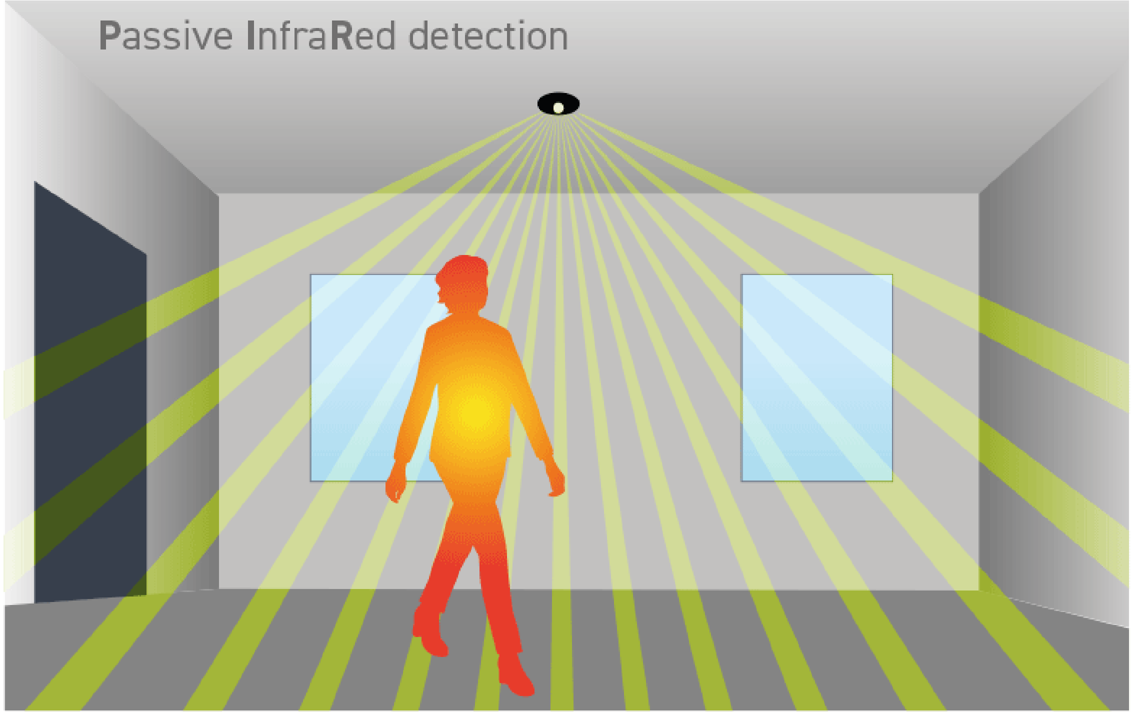
Timeout

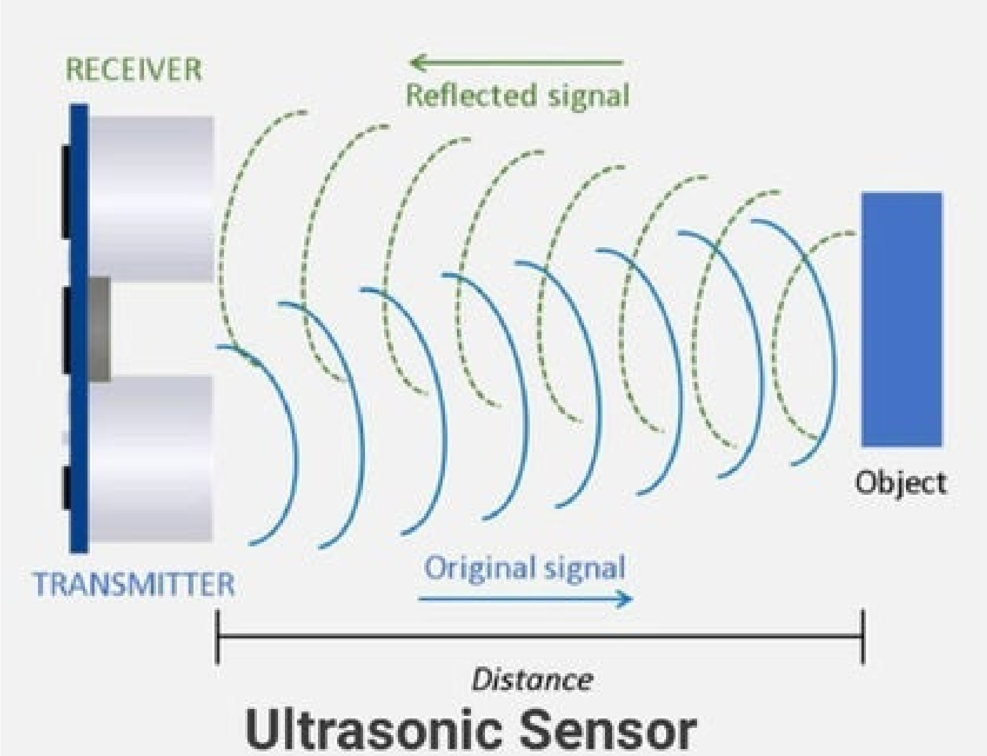
Passive Infrared

Major & minor motion

Vacancy

Ultrasonic





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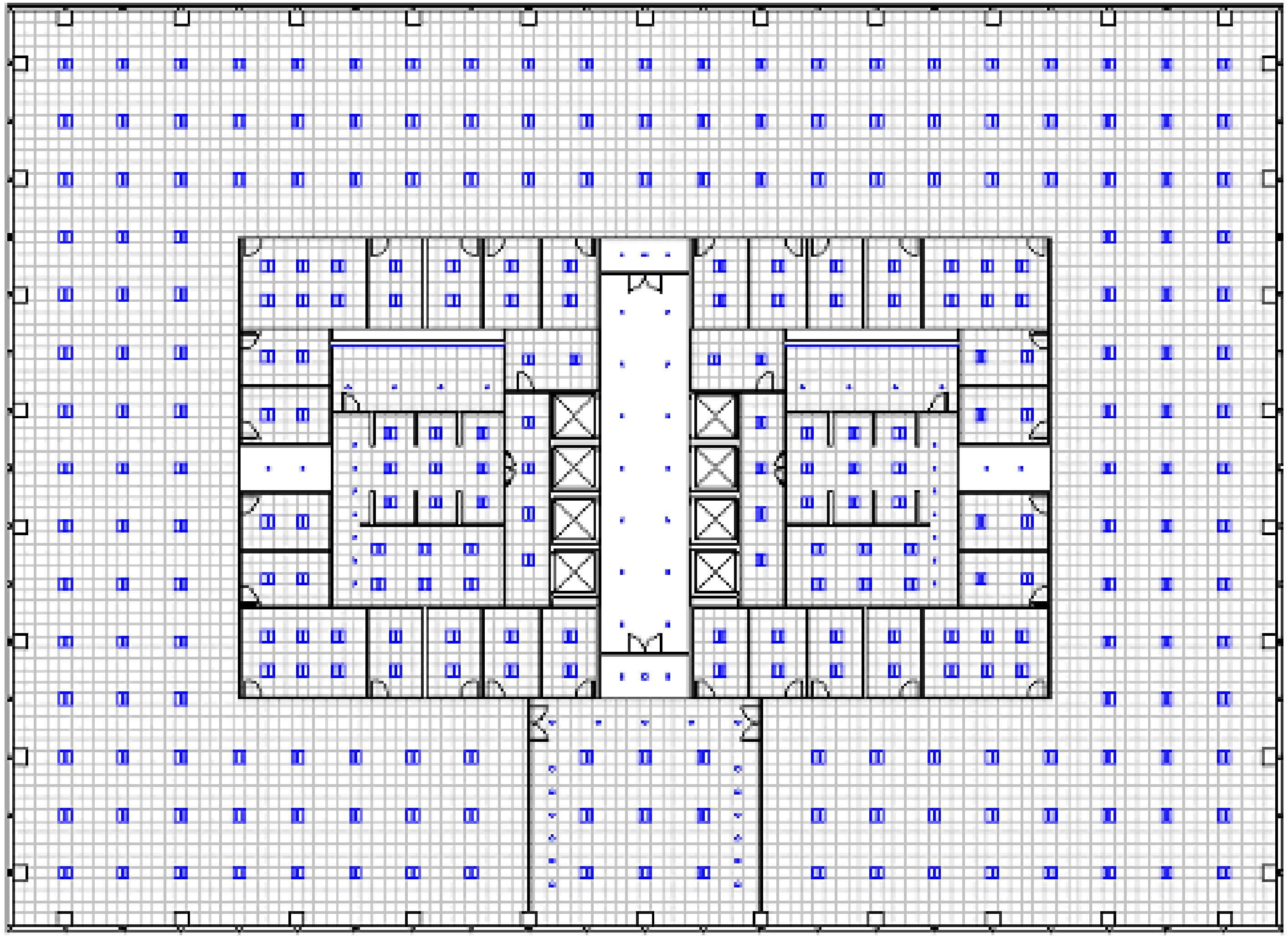
Occupant sensor controls

LLLC (fixture-integrated, 100 ft^2/sensor)



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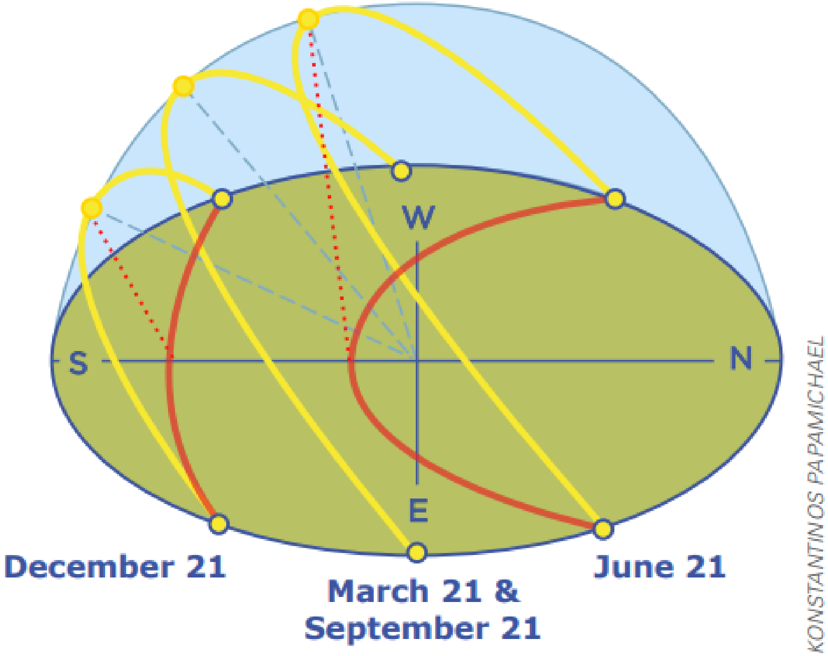
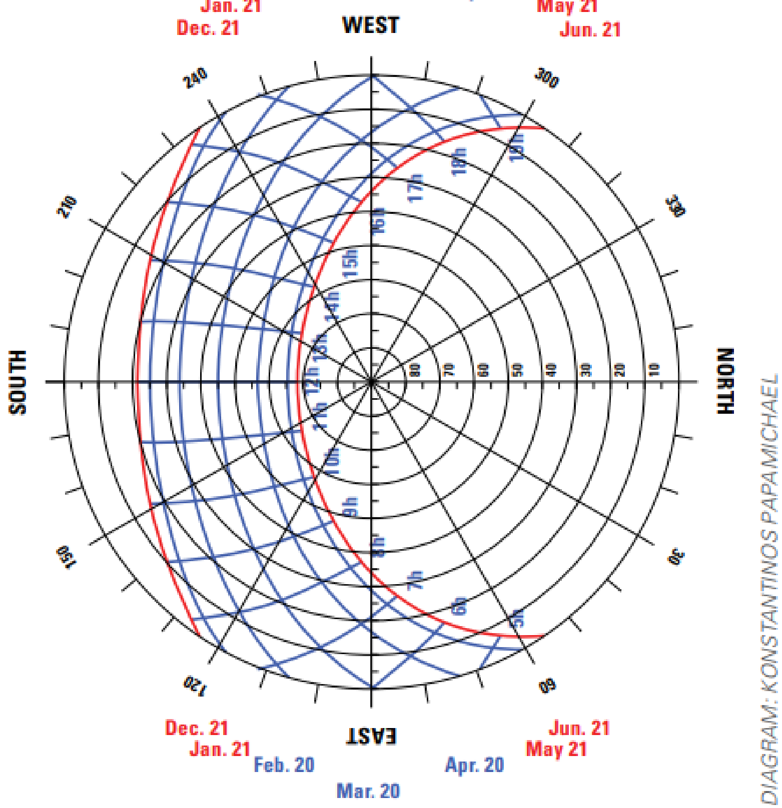
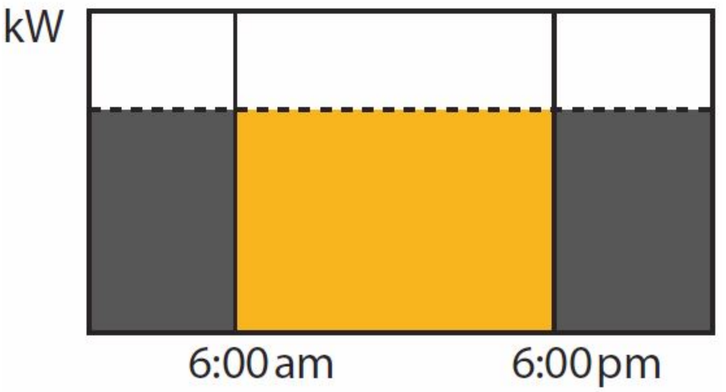
Schedules

- Building hours
  - Weekdays
  - Weekends
  - Holidays
- Astronomical
  - Sunset & sunrise
  - Location-based







OPENING HOURS

MONDAY	9.00 - 5.30
TUESDAY	9.00 - 5.30
WEDNESDAY	9.00 - 5.30
THURSDAY	9.00 - 5.30
FRIDAY	9.00 - 5.30
SATURDAY	9.00 - 12.00
SUNDAY	CLOSED

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Light Control

Light level setpoints

Application	Light level (foot-candles)
Discount/Warehouse/Drug/ Convenience (Ambient)	50
Gas Station Canopy	12.5
Classroom (Typical Applications)	15
Gymnasium-Class III (High School)	75
Open Office (Desk)	40
Stairs	5

Daylight Harvesting

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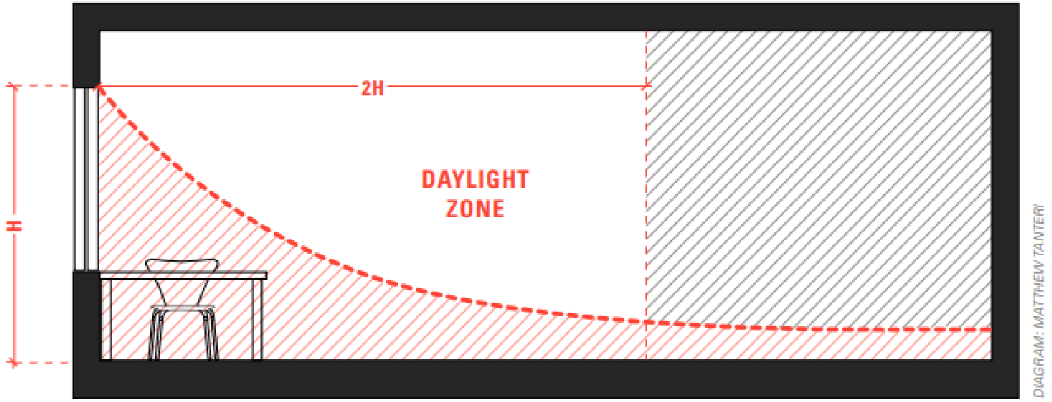
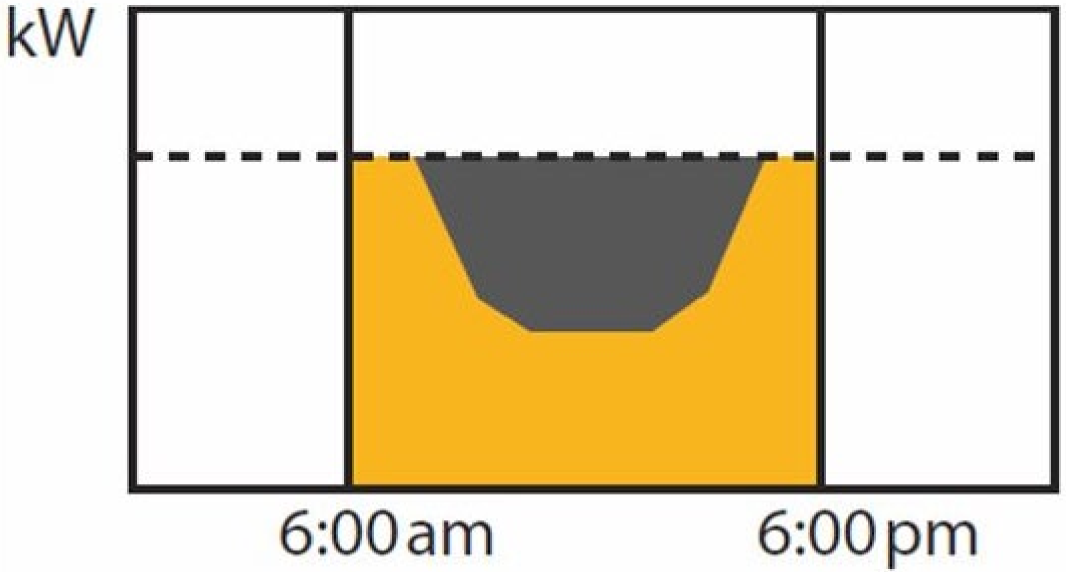
Light Control

Open Loop

- Light levels not affected by electric light
- Photocell typically measuring light outdoors





Closed Loop

- Considers impact of electric light
- Photocell typically aimed at “work surface”

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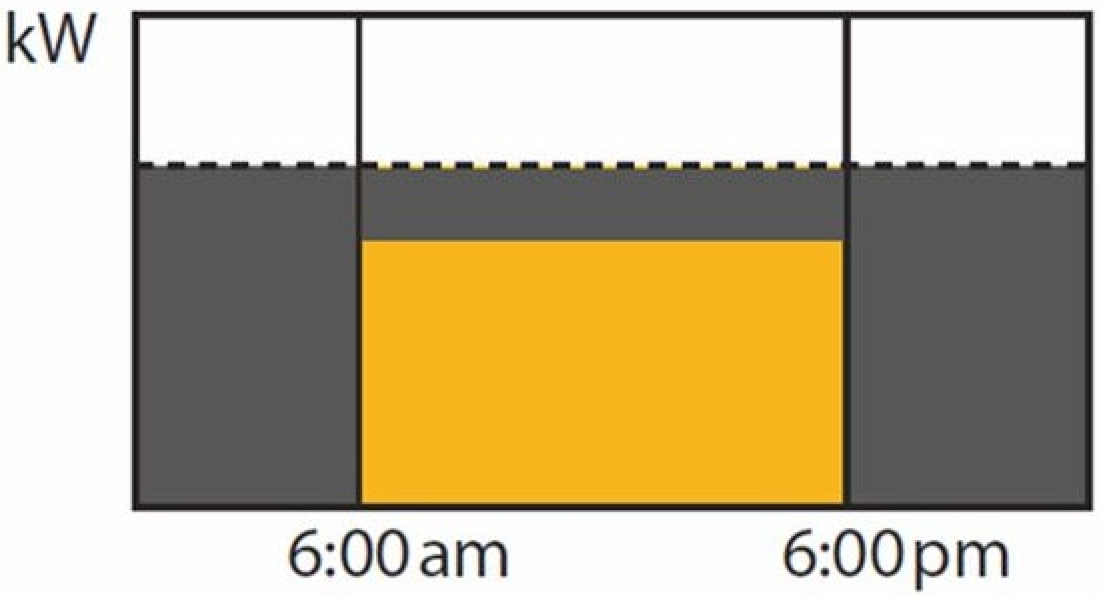
Trim



High-end Trim

- AKA “Task Tuning” or “Institutional Tuning”
- Sets the maximum level
- Energy savings strategy
- Can be used to mitigate lumen depreciation

Low-end Trim

- Sets the minimum level
- Ensures lights not dimmed below this level
- Used to mitigate flicker

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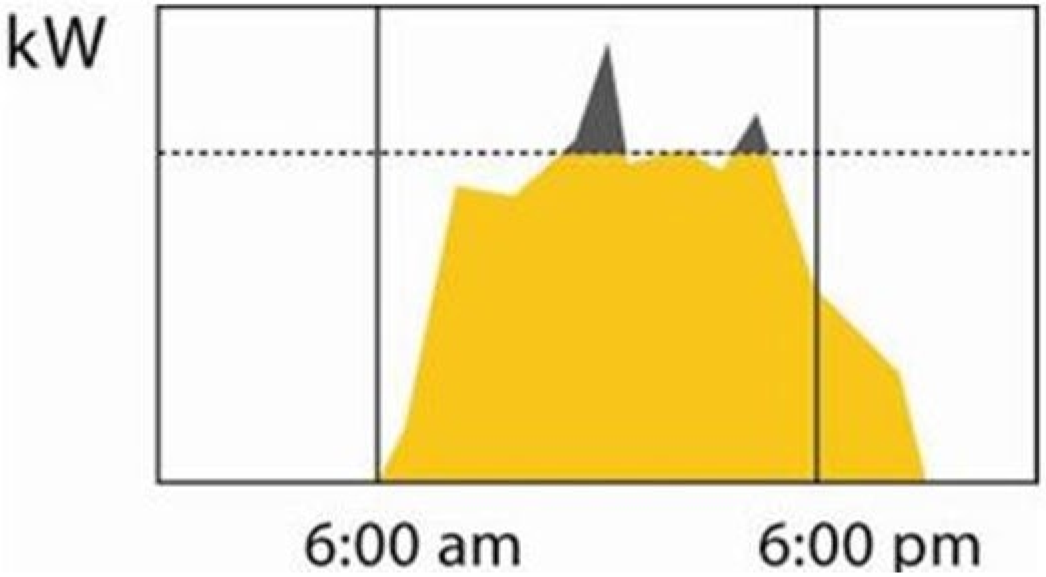
Demand Response

- Peak load reduction
- Pre-determined energy saving configuration
- Can be configured as an automatic input or a manual override



What About…?

- Emergency Lighting
- Integration
  - Room Partitioning
  - A/V System
  - HVAC
- Color Tuning

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Emergency Lighting

- 2023 National Electrical Code® (NEC), NFPA 70®
- ANSI/UL924 Standard for Emergency Lighting and Power Equipment
  - Section 700.24 - New in 2023 for Directly Controlled Emergency Luminaires
- Applications
  - Battery Backups
  - Alternate Power Source
    - Generator
    - Inverter

Other Relevant Standards

- ANSI/UL 1008 Standard for Transfer Switch Equipment
- ANSI/UL 1573 Standard for Stage and Studio Luminaires and Connector Strips
- ANSI/UL 1574 Standard for Track Lighting Systems
- ANSI/UL 1598 Standard for Luminaires
- ANSI/UL 2108 Standard for Low Voltage Lighting Systems

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Emergency Lighting

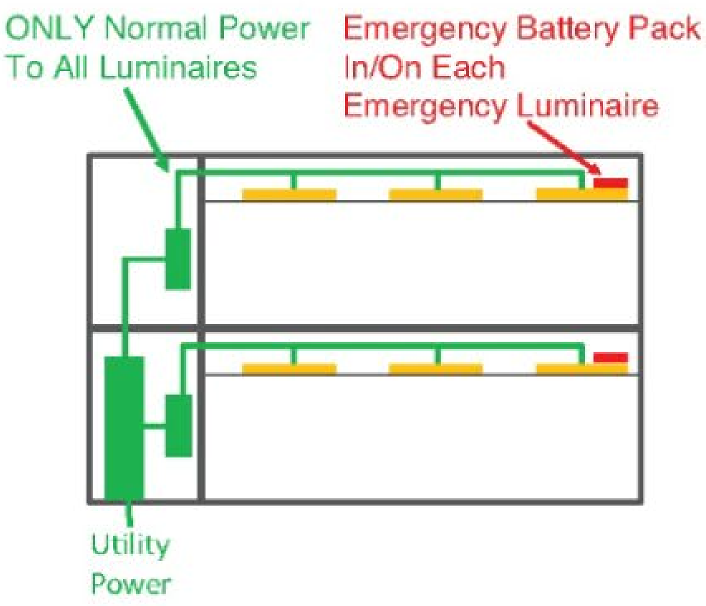


Fig 1 Distributed
Emergency Battery Packs

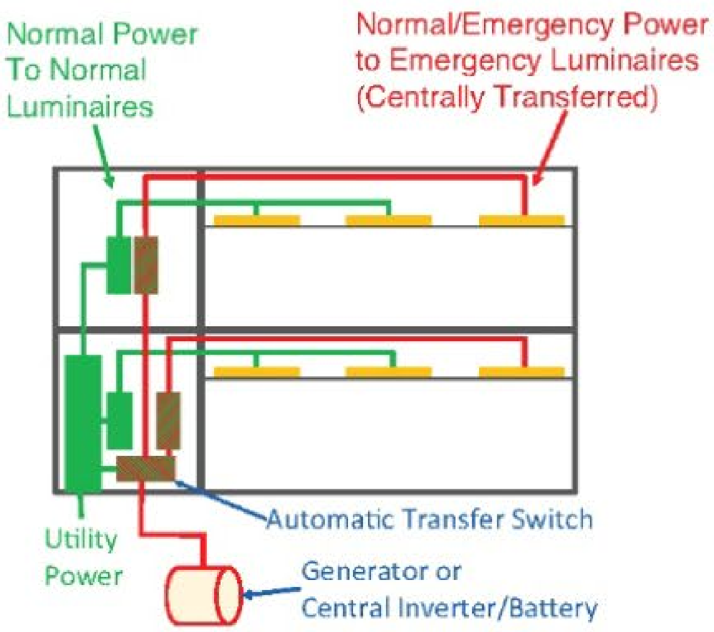


Fig 2 Centrally Transferred
Normal/Emergency

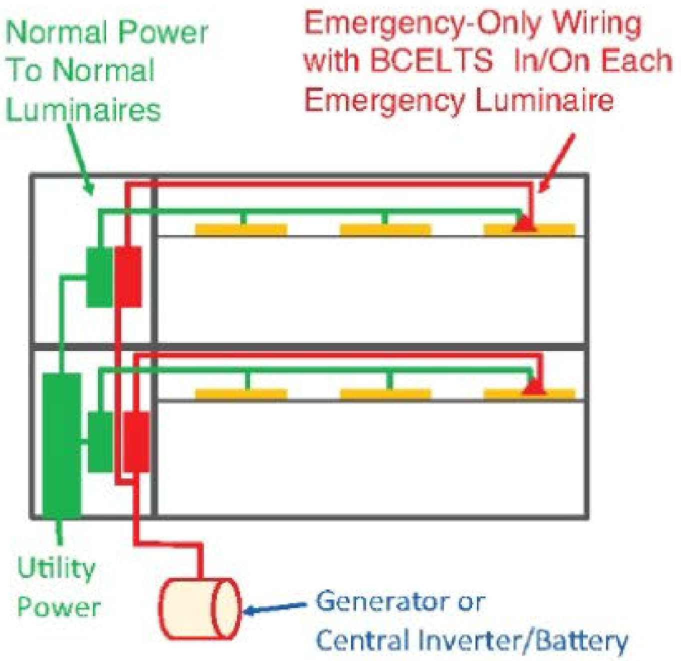


Fig 3 Luminaire Transferred
Emergency

Fig 1.1
Line voltage control
Under normal power, control Off

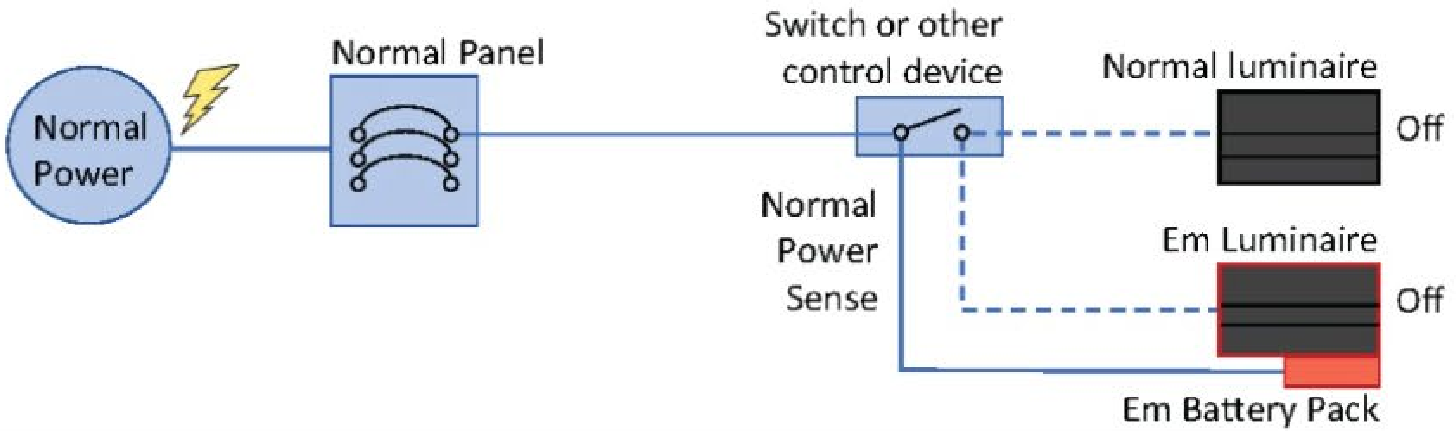


Fig 1.2
Line voltage control
Under normal power, control On

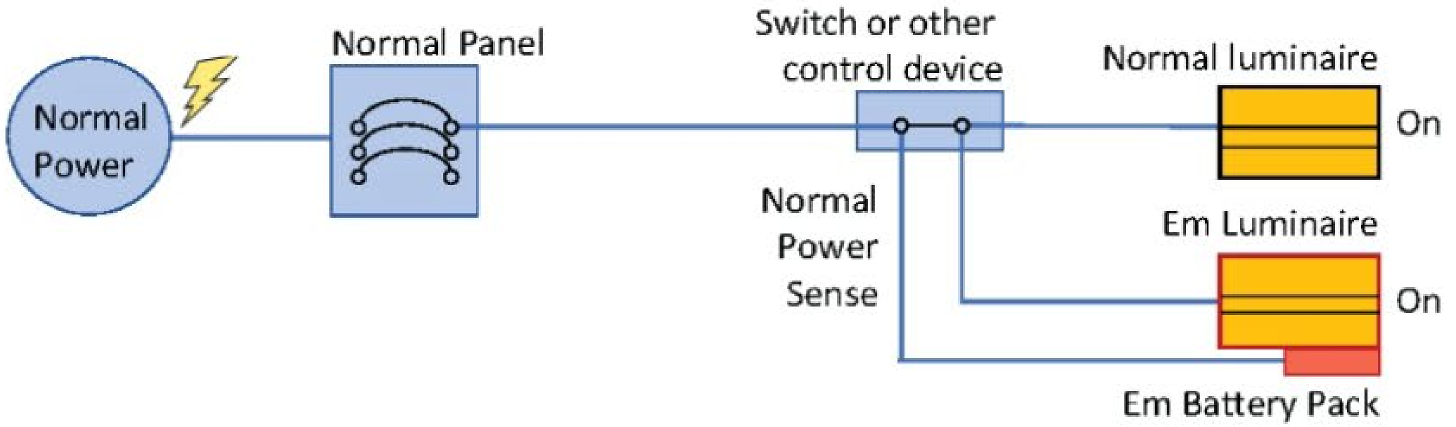
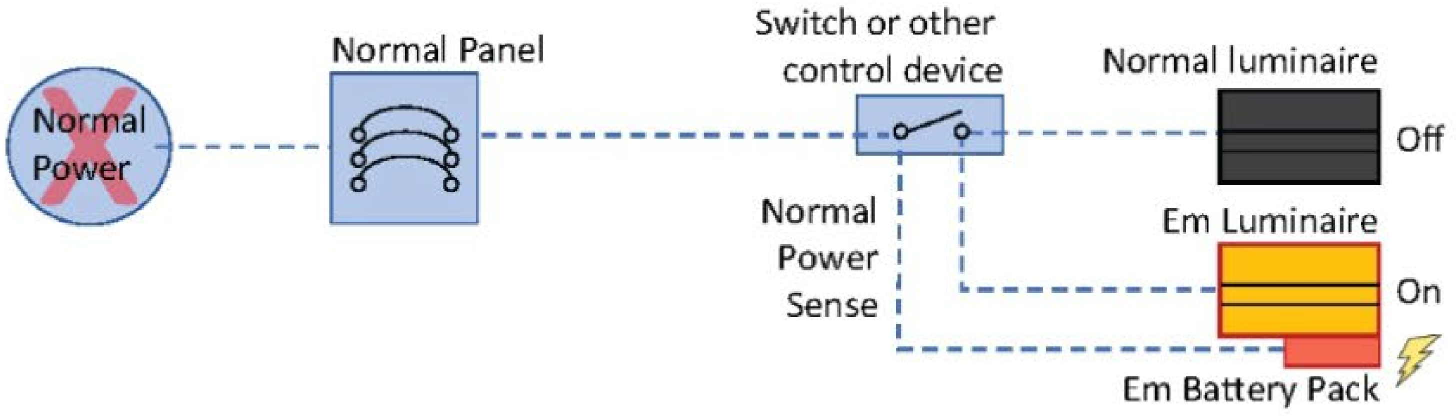


Fig 1.3
Line voltage control
Loss of normal power, control On or Off



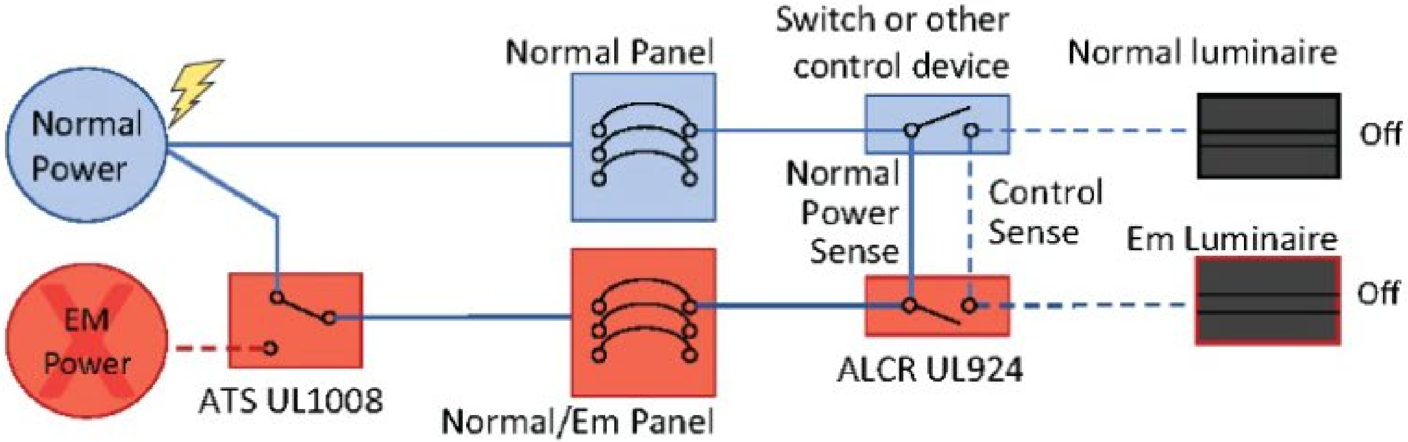


Fig 2.1
Line voltage control
Under normal power, control Off

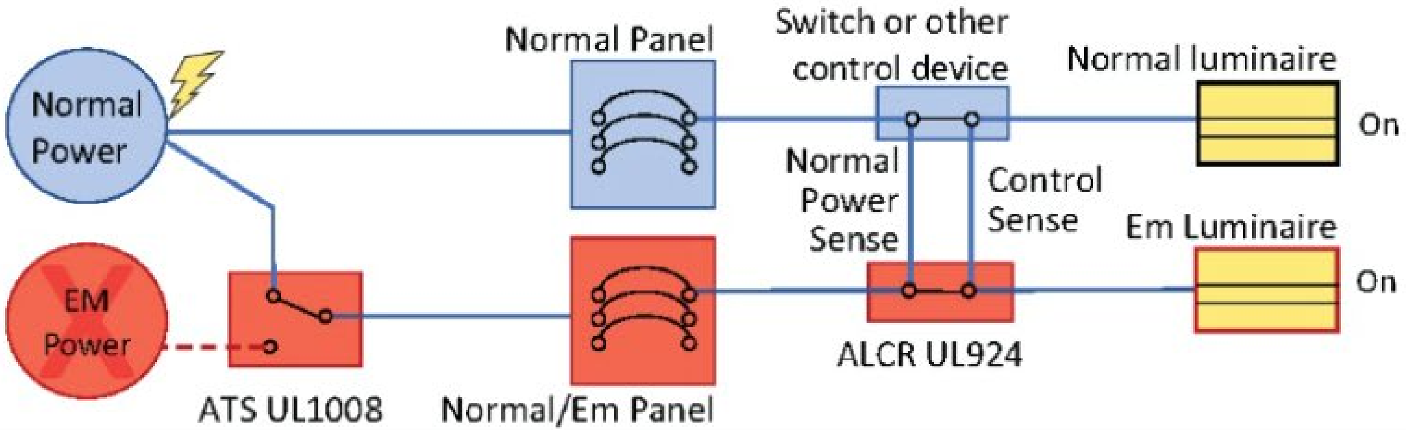


Fig 2.2
Line voltage control
Under normal power, control On

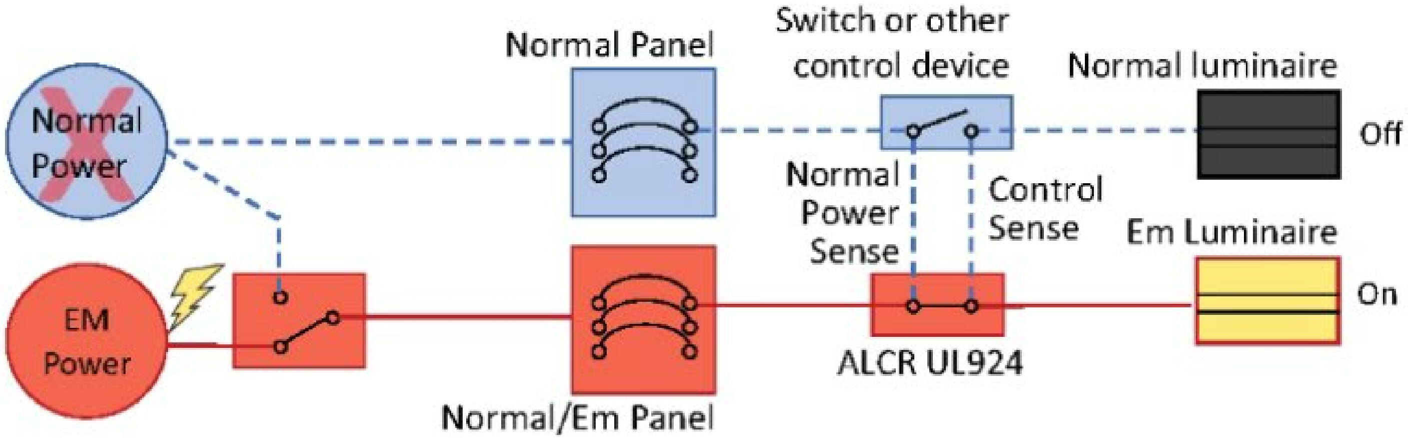


Fig 2.3
Line voltage control
Loss of normal power, control On or Off

But what about luminaires with embedded controls?

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Option 1:

Or Option 2…

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Fig. 3.1
Line voltage control
Under normal power, control Off

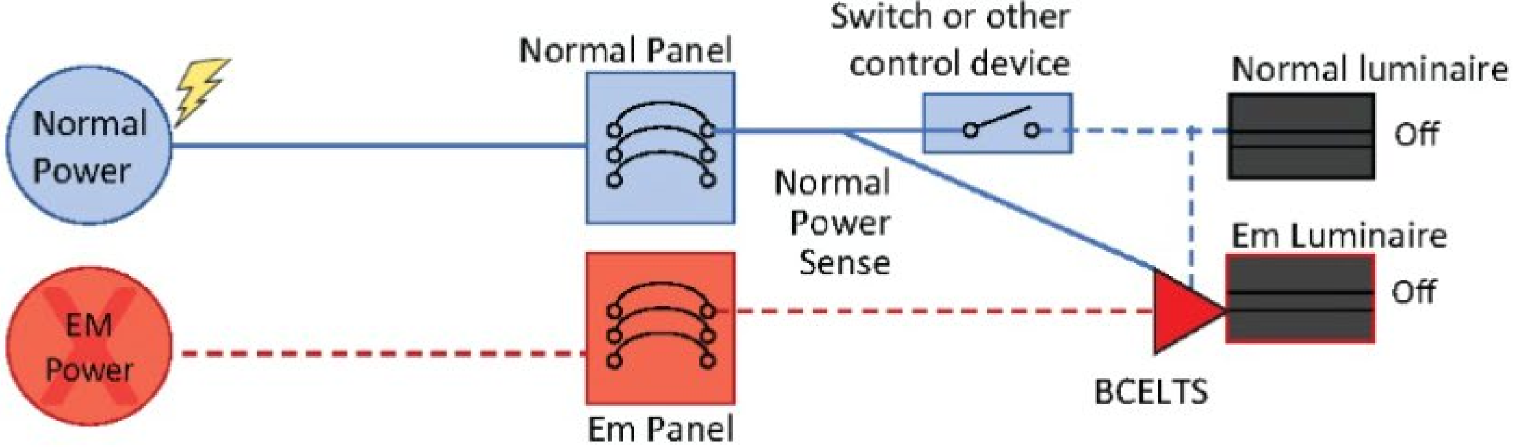


Fig. 3.2
Line voltage control
Under normal power, control On

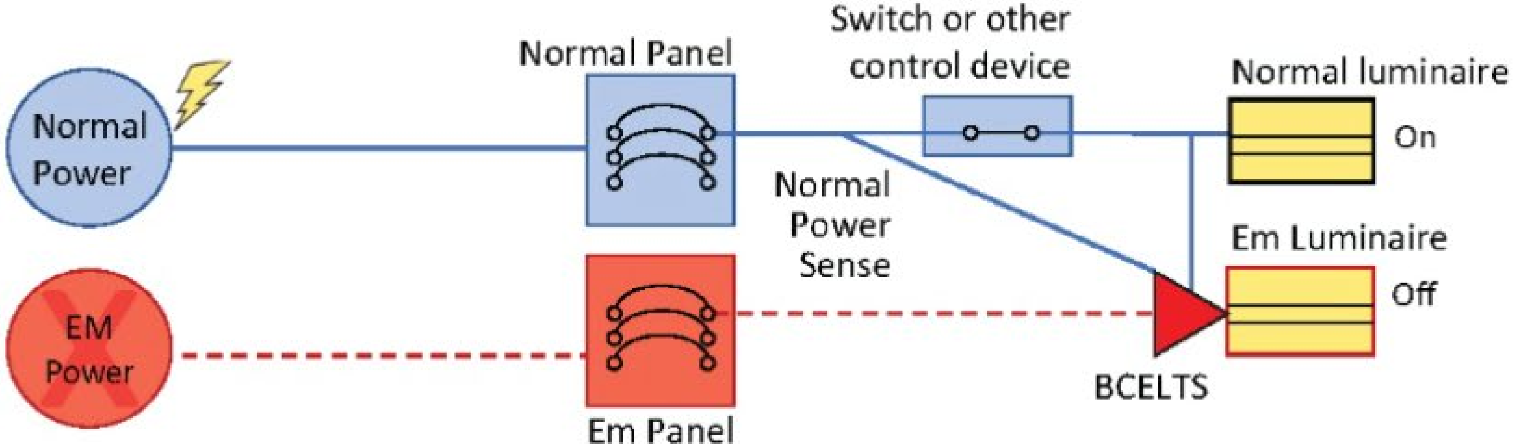
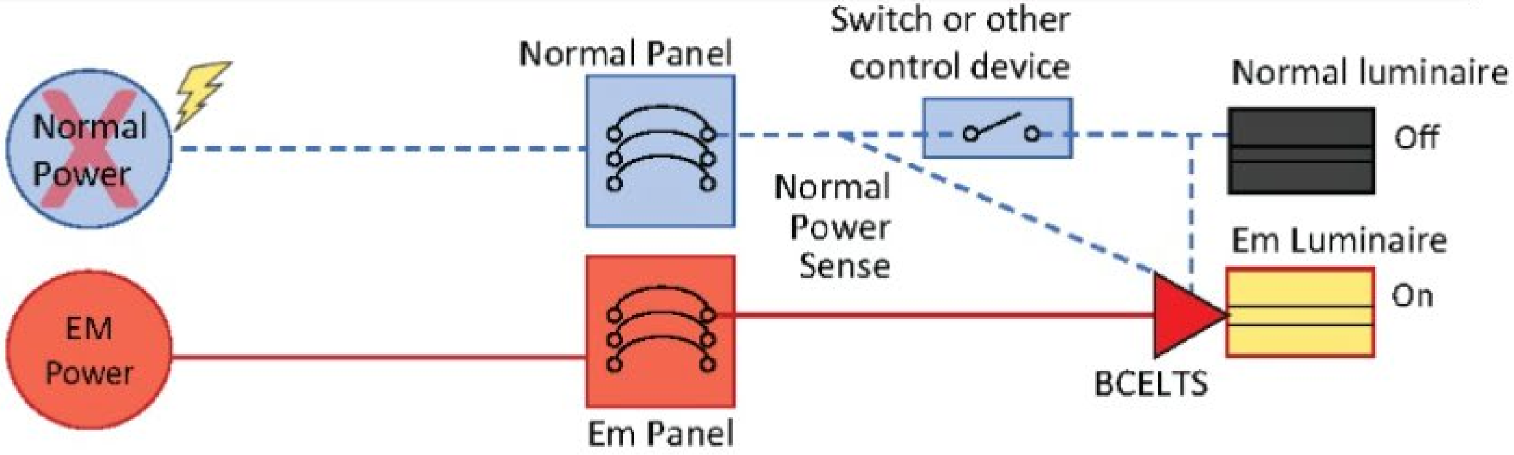


Fig. 3.3
Line voltage control
Loss of normal power, control On or Off



Automated Emergency Testing

National Electrical Code® (NEC), NFPA 70® requires monthly and annual testing of emergency lighting

Wireless Enables:

- Maintenance labor savings
- Reports easily accessible when inspections occur

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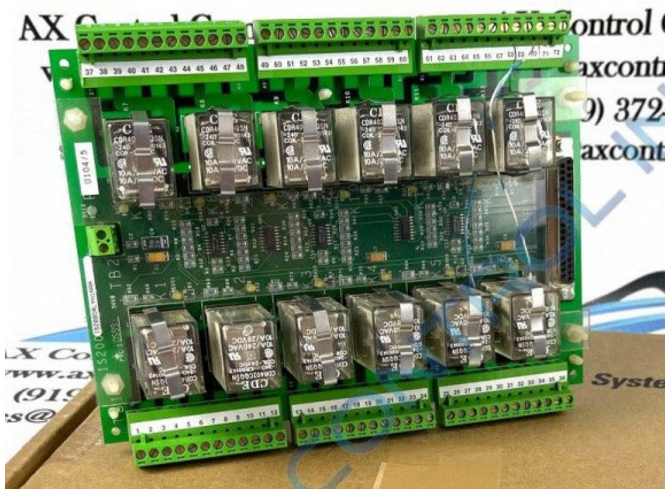
System Integration



Building Management

HVAC

Audio/Visual

Security

Fire Alarm

Automated Shades

ASHRAE BACnet™

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Light & Color Tuning

Standard:
Bright light is preferred for everyday activities/interactions[3,10,11].

Presentation:
Warmer light with lower intensities is preferred for more "emotional" activities, such as an interactive learning or a class assignment showcase session[3,10,11].

Focus:
Bright light at higher intensities is best during instructions and exams when students are expected to focus and concentrate[3,10,11].

Calm:
Warm, dimmed lighting conditions support relaxed activities, cooperation, and creativity[3,10,11].

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Questions?

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Smart Controls Accelerating Lighting Efficiency

Thank You!

Reach out for support or so we can highlight your success

scale@etamn.org

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