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Lighting Controls and the Bottom Line

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U.S. DEPARTMENT OF
ENERGY **BATTELLE**

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Learning Objectives

- Recognize key challenges with lighting controls.
- Apply best practices for designing controls.
- Apply best practices for implementing controls.
- Identify winning approaches for Return on Controls.



Today's Presentation

- DOE's Interest in Lighting Controls
- The Impact of Design
- Implementation
- What we know about Return on Controls



Slow adoption of controls
and disappointing results



Finding Solutions

Ongoing PNNL Research Activities:

- DOE NGLS Living Labs (2017-2023)
- DOE CBI Field Validations (ongoing)
- Guidehouse CLS Stakeholder Research Study (2021)
- DOE Realistic Settings Research (ongoing)
- Industry Interviews (late 2021)

NGLS seeks to provide robust input to those who make the products and those who use them, with the goal of improving the human and energy performance of the next generation of lighting systems.



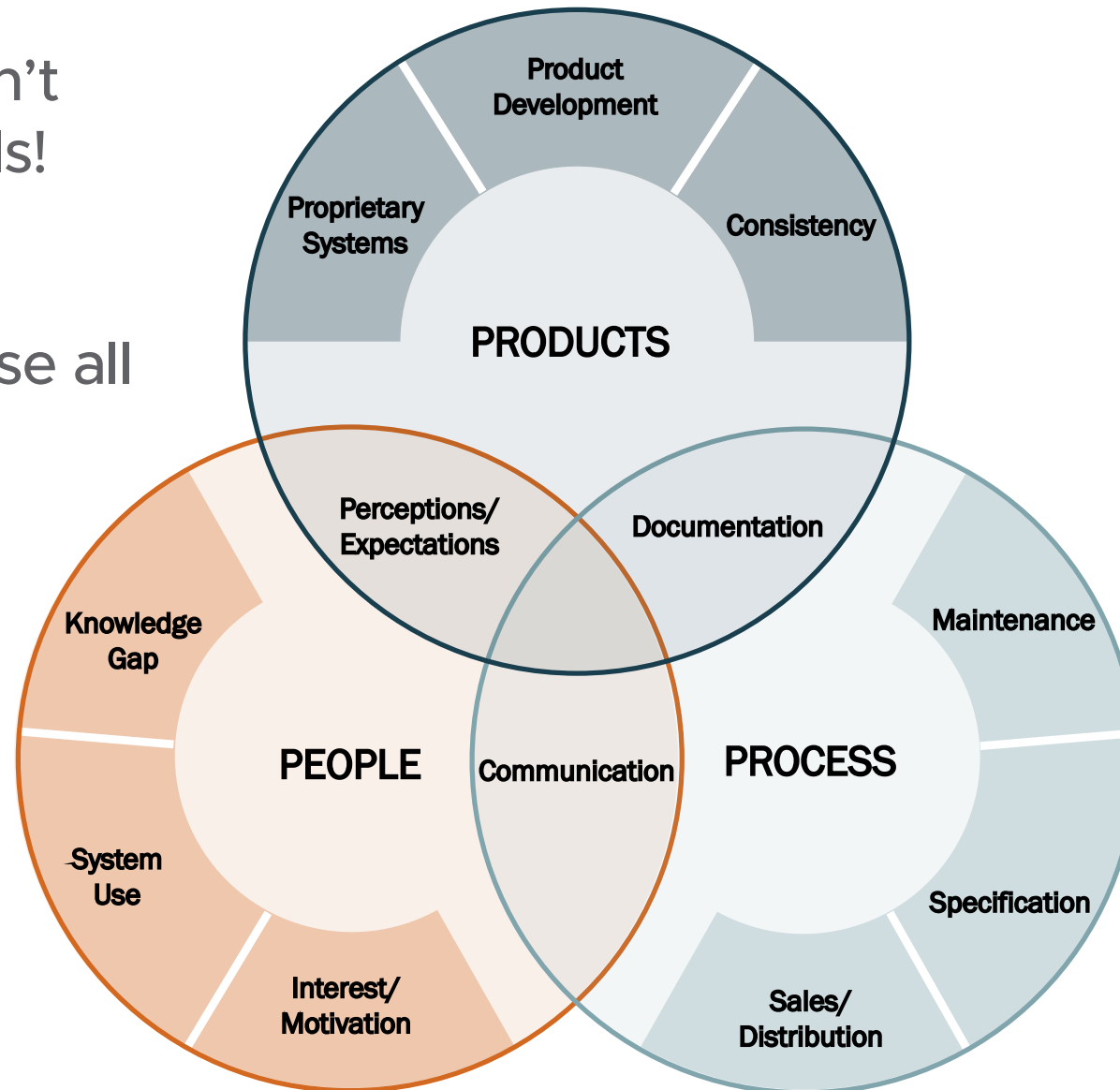
NGLS Living Lab Partners

The Issues: Products, Process, People

Key Challenges Observed in the Industry:

66% of buildings don't have lighting controls!

Many others don't use all installed capabilities.



Slow adoption despite increasing code requirements.

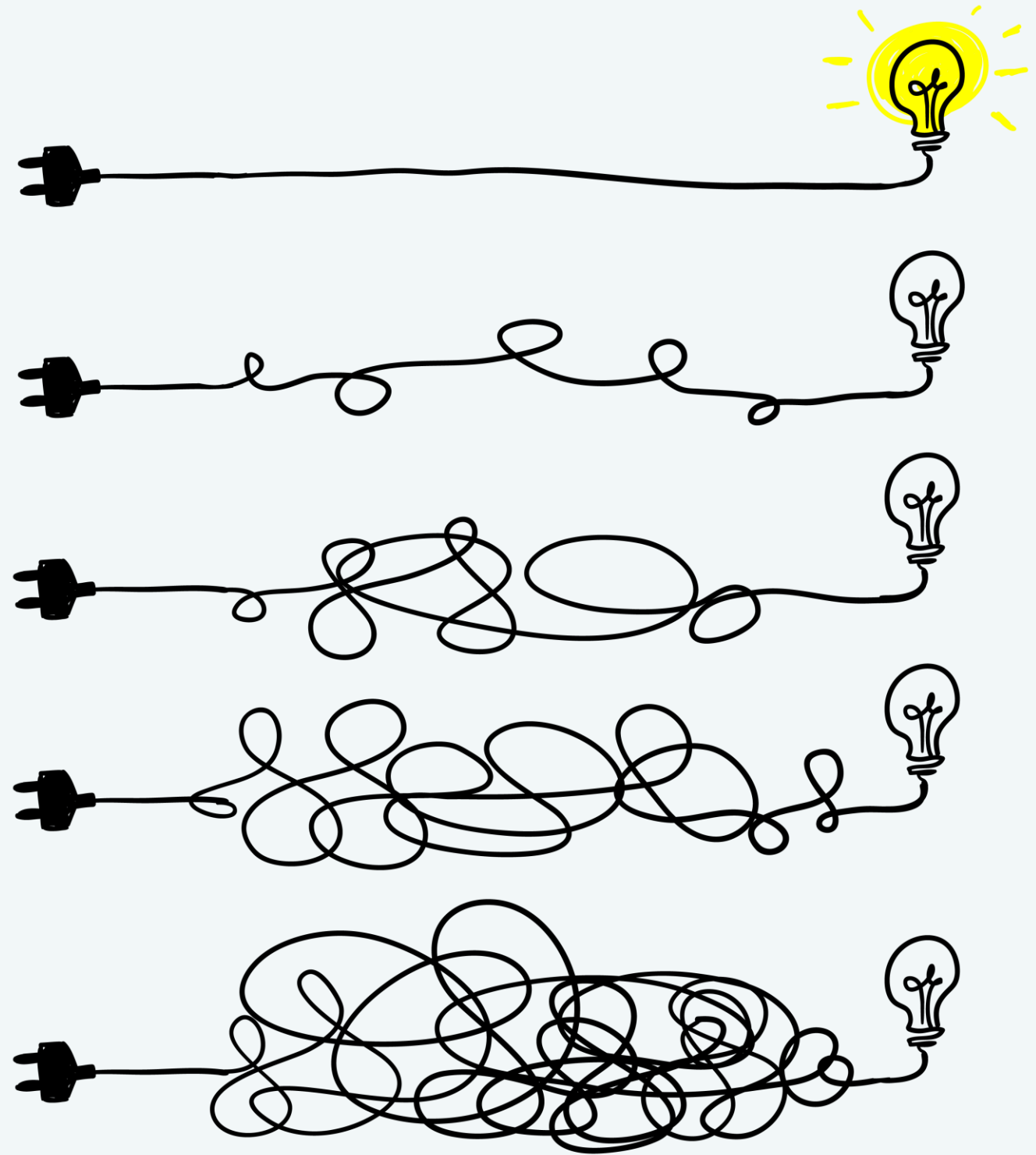
Unsatisfactory operation and end user frustration.

Cost – product and implementation.

Uncertain ROI – dampens demand and interest in getting it right.

At the root of the issues?

COMPLEXITY



PROFIT

Lighting controls provide knowledge- and skill-based opportunities for profit.

Successful installations offer energy savings and may enhance the space.



LOSS

PROFIT



LOSS

Problems during the design, installation, and startup can erode profit.

Systems that don't meet requirements rarely provide expected benefits.



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**Design is Critical
(even if *you* don't do it)**

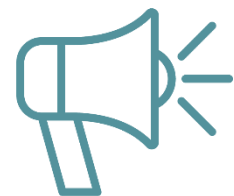


Role of the Designer

The designer translates owner requests into a functional lighting control system, the first step in defining expectations.



Who is the lighting controls designer?

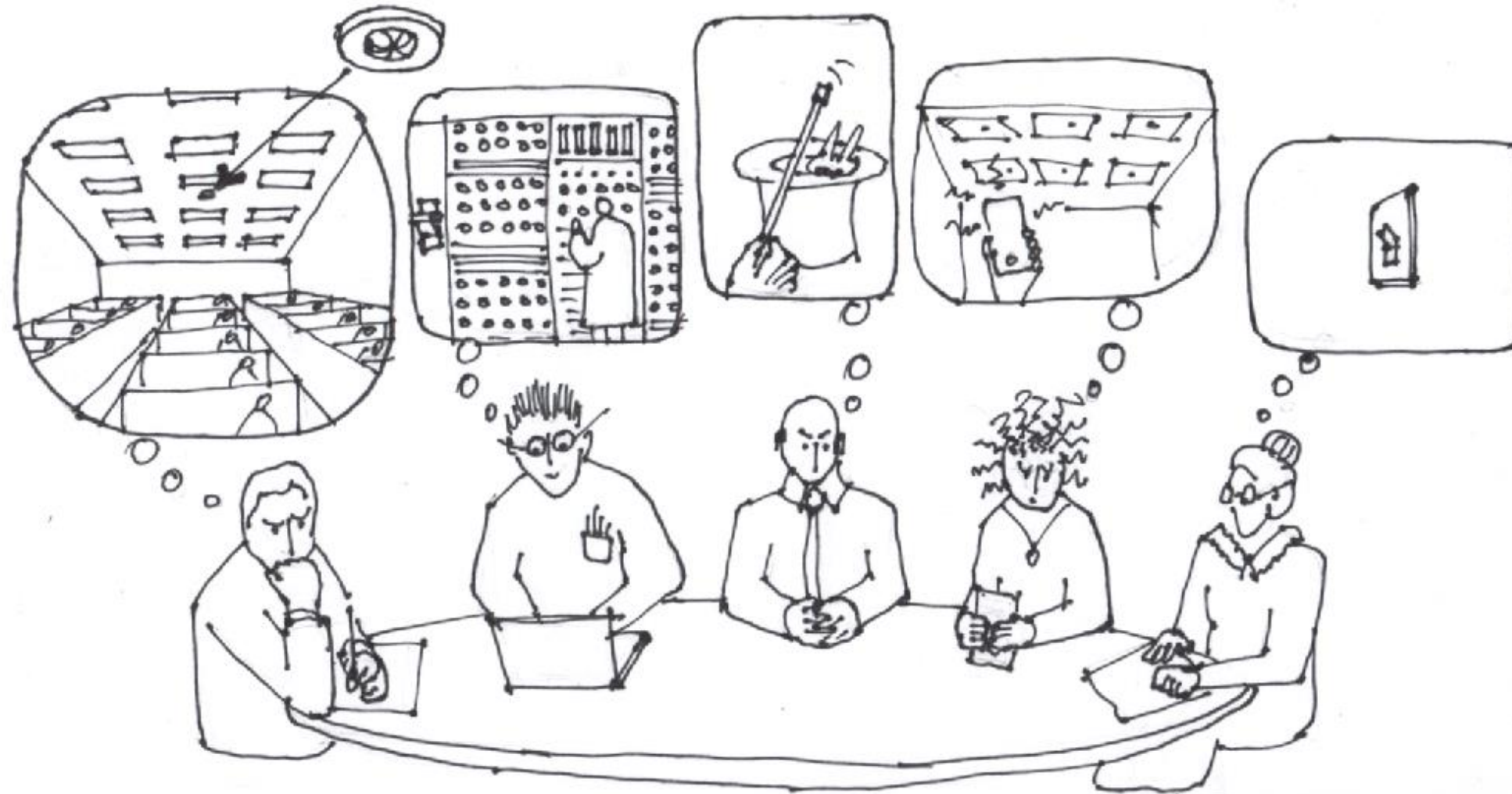


Critical decisions are made throughout the design process that directly influence installation and operation.



Control intent narrative is a plain language document to share with owner and all project team members to clearly communicate design intent and expectations for the system.

Good Outcomes Require Understanding Expectations



"Let's talk about lighting controls for this room"

Energy Code Compliance Misconceptions

- Energy codes are requiring more capabilities, often beyond what owner's are asking for.
- Communicate the capabilities that are necessary to meet code.

Table 9.5.2.1-1 Space-by-Space Lighting Power Density Allowances and Minimum Control Requirements Using Either Method

Common Space Types ^a	LPD, W/ft ²	RCR	The control functions below shall be implemented in accordance with the descriptions found within Section 9.4.1.1. For each <i>space</i> type:							
			Local Control 9.4.1.1(a)	Manual ON 9.4.1.1(b)	Partial Auto ON 9.4.1.1(c)	Multilevel Lighting Control 9.4.1.1(d)	Daylight Response Sidelight 9.4.1.1(e) ^b	Daylight Response Toplight 9.4.1.1(f) ^b	Auto Reduction (Full OFF complies) 9.4.1.1(g)	Auto Full OFF 9.4.1.1(h)
Office										
Office ≤150 ft ²	0.73	8	REQ	ADD1	ADD1	REQ				REQ
Office >150 and ≤300 ft ²	0.66	8	REQ	ADD1	ADD1	REQ				REQ
Offices >300 ft ²	0.56	4	REQ	ADD1	ADD1	REQ	REQ	REQ	REQ	REQ
Parking Garage										
Daylight transition zone	1.06	4					See Section 9.4.1.2.			
All other parking and drive areas	0.11	4					See Section 9.4.1.2.			
Pharmacy Area	1.59	6	REQ	ADD1	ADD1	REQ				ADD2 ADD2
Restroom	0.74	8								REQ
Sales Area (For accent lighting, see Section 9.5.2.2[b].)	0.85	6	REQ	ADD1	ADD1	REQ		REQ		ADD2 ADD2
Seating Area, General	0.21	4	REQ	ADD1	ADD1		REQ	REQ		ADD2 ADD2
Security Screening										
Airport/bus/ship/train/transportation screening	0.93	6	REQ				REQ	REQ		ADD2 ADD2
Airport/bus/ship/train/transportation screening queue	0.56	6	REQ				REQ	REQ		ADD2 ADD2
General security screening	0.64	6	REQ				REQ	REQ		ADD2 ADD2
Stairway										
The <i>space</i> containing the stairway shall determine the <i>LPD</i> and control requirements for the stairway.										
Stairwell	0.47	10					REQ	REQ	REQ	ADD2 ADD2

Informative Note: This table covers common *space* types typically found in multiple *building* types. Table 9.5.2.1-2 covers *building*-specific *space* types typically found in a single *building* type.

The control functions below shall be implemented in accordance with the descriptions found within Section 9.4.1.1. For each *space* type:

- (1) All REQs shall be implemented.
- (2) At least one ADD1 (when present) shall be implemented.
- (3) At least one ADD2 (when present) shall be implemented.

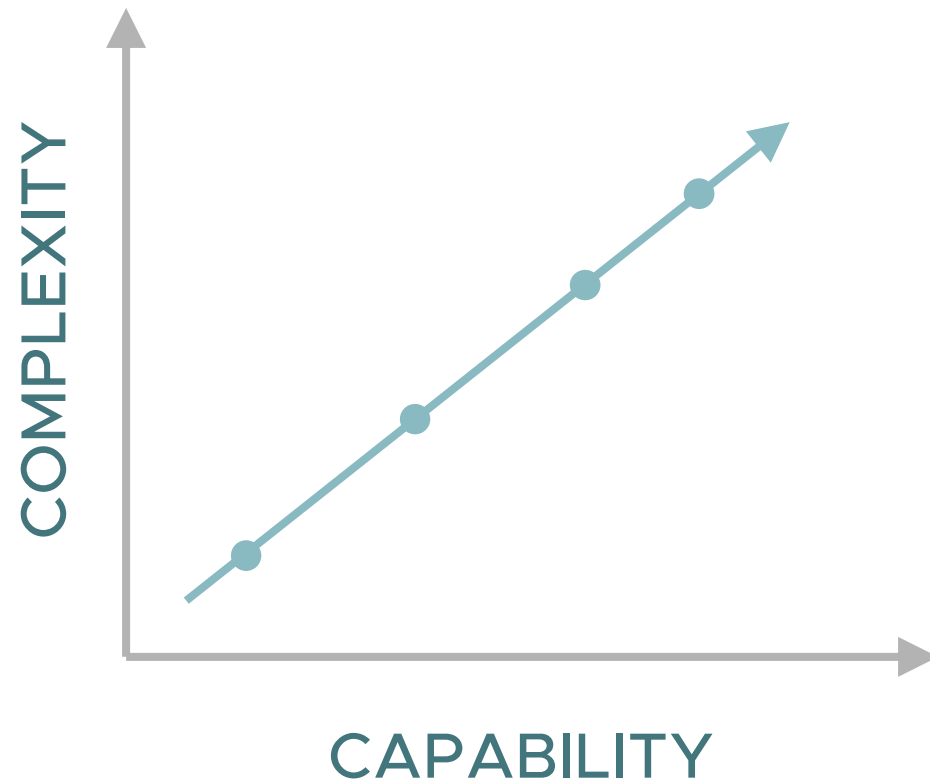
Wanna Do vs. Gotta Do



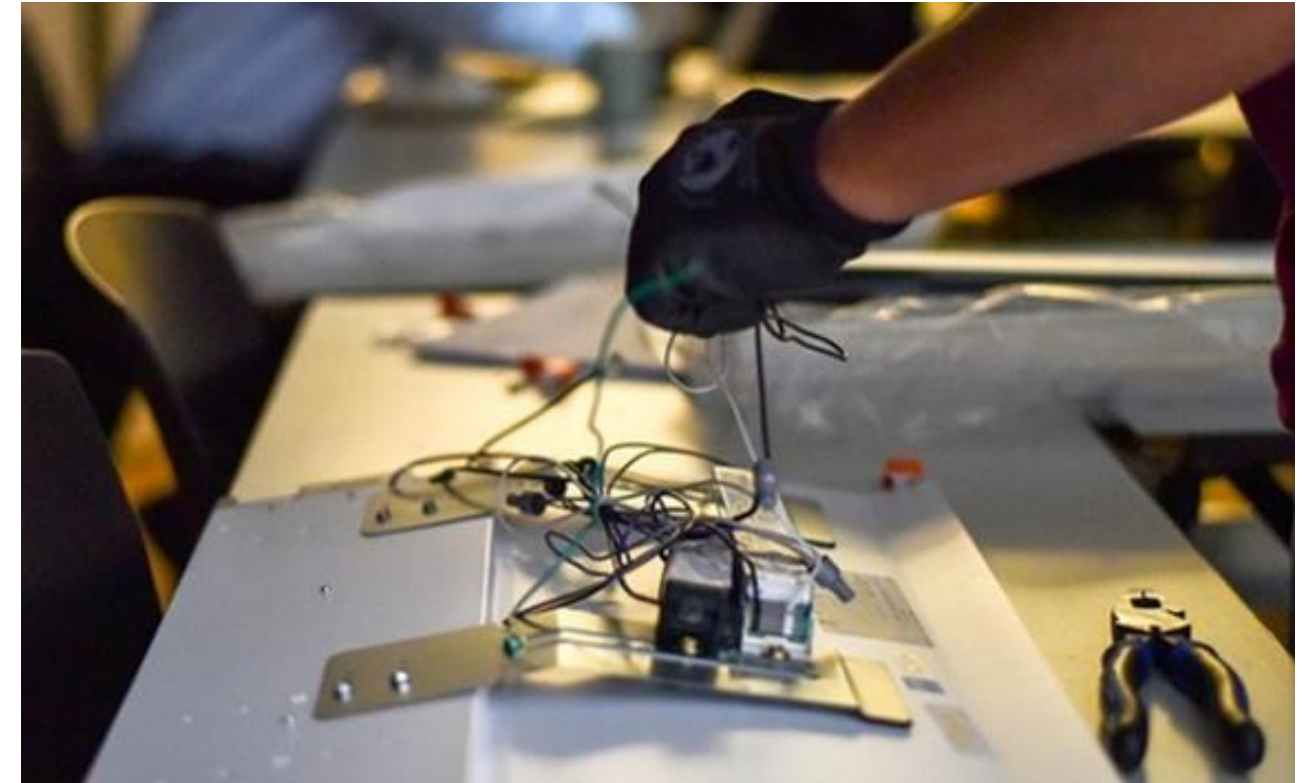
Promise of business benefits rely on owner motivation and resources.

Advanced capability requirements may limit system choices.

Can Do vs. Should Do



Control systems often offer a “bundle” of capabilities – you might not need everything.



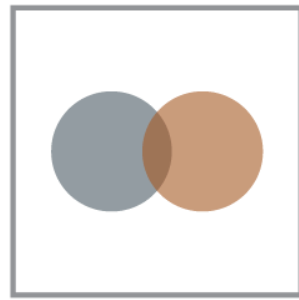
Seller's rarely say “No” and may provide a workaround or suboptimal solution to sell.

Ask the Right Questions

- Understanding expectations is key.
- Many issues are rooted in inadequate communication and inconsistent or incomplete documentation.

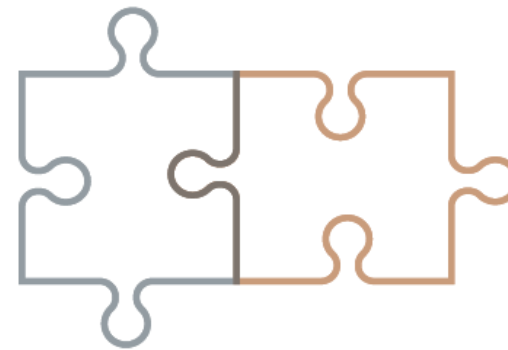


Example - Ways to Think About 'Consistency'



Compatibility

Devices coexist in the same environment.



Interoperability

Devices exchange and readily use defined data.



Interchangeability

Devices can be physically exchanged with identical operation.

Bridging the Gap Between Expectations and Risks

- Some controls decisions introduce more complexity and risk than others.
- Understanding what contributes to the bottom line is important.



Consider System Capabilities in Terms of Owners' Requirements



Energy Code Compliance

Code compliance represents the minimum requirement for most projects and is generally the least costly.



Enhanced Lighting Performance

Improving workforce productivity, wellness, satisfaction, and facility appeal.



Enhanced Energy Management

Energy conservation and management beyond minimal code compliance.



Enhanced Facility Productivity

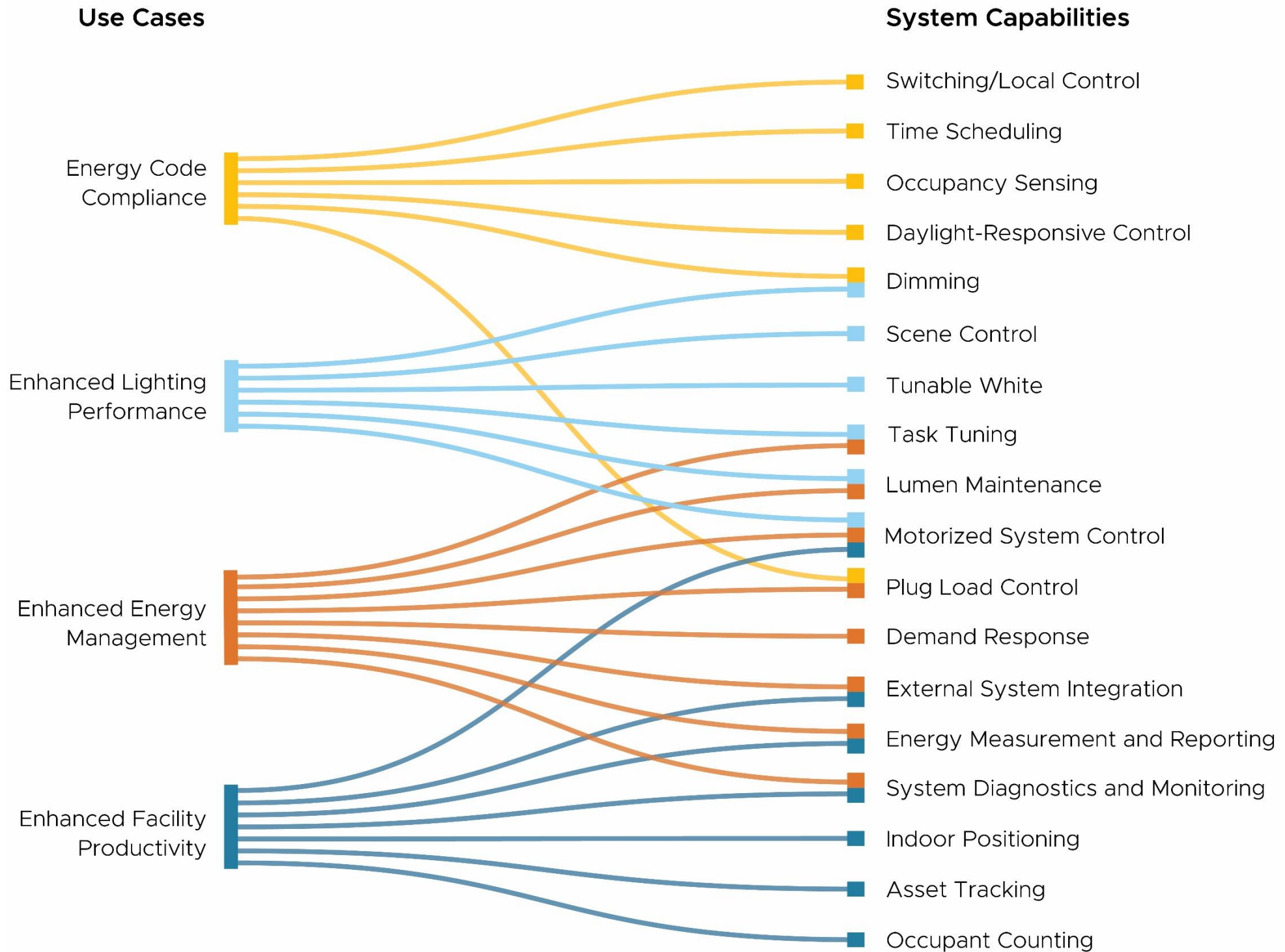
Greater spatial and asset efficiency, improved retail performance, and increased engagement, safety, and security.



Networked Lighting Control Systems are Highly Capable

- Asset Tracking
- Daylight-Responsive Control
- Plug Load Control
- Motorized System Control
- Indoor Positioning
- Scene Control
- Energy Measurement and Reporting
- System Diagnostics and Reporting
- Demand Response
- Dimming
- Lumen Maintenance
- Switching/Local Control
- Occupant Counting
- Task Tuning
- Occupancy Sensing
- Time Scheduling
- Tunable White
- External System Integration

Connect Control System Capabilities to Owner Requests



Consider Risks



External Communication and System Integration

Consider working with a system integrator.

Color Tuning

Slight fixture cost increase.
Compatibility matters. May increase troubleshooting time on site.

“Thin” Contracts

Lead to trouble down the road.
Details matter with lighting controls!

Not Everything is a Risk



NLCs and Advanced Capabilities

Digital systems and NLCs are gaining traction due to increasing code requirements, don't be alarmed!

Unfamiliar Systems

Digital systems often offer installation cost savings, do your due diligence.

Assess Risk and Cost of Capabilities Up Front

- Recognize the risks.
- Late changes tend to cost more than they should and reduce options.
- Limit capabilities that don't align with owner's objectives.
- Hire a knowledgeable team.

Bidding controls is challenging if the design lacks detail.

\$\$\$

A conservative, high bid may lose the job.

\$

An aggressive, low bid may lead to a \$-losing proposition.

What's a Sequence of Operations (SOO)?

- Prepared during design by an electrical engineer or controls designer.
- Important for bidding, essential for set-up.
- Complements drawings, schedules, and specifications.
- Lack of clarity leaves room for interpretation.
- A good SOO is a legally enforceable document.
- Includes device descriptions, space-by-space control requirements and special features.

Interested in learning more? Check out the latest EC&M article.

EC&M



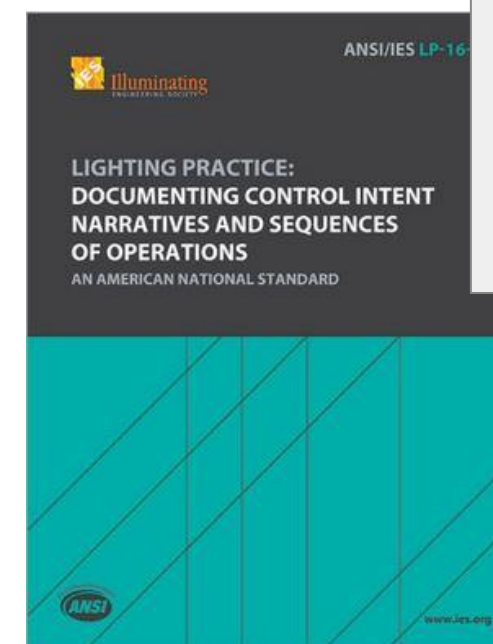
LIGHTING & CONTROL

The Sequence of Operations and Lighting Controls

Sept. 18, 2023

Everything electrical professionals need to know about the sequence of operations (SOO) and why it's so important

Ruth Taylor



Take advantage of new IES LP-16 document.

Sequence of Operations Details the System

- Specifies how the system is supposed to operate . . . in detail.
- Provides information you may not see otherwise.
- Ask for it during bidding and before coming on site.

Where?

The SOO is typically organized by space type.

Room Number	Space Type	Control Group	1 - Line Voltage Switch	2 - On/Off/Raise/Lower Keypad	3 - Scene Select Keypad	4 - Occupancy Sensor (Auto-on)	5 - Vacancy Sensor (Auto-off)	6 - Time Schedule	7 - Daylight Harvesting	8 - Demand Response	9 - Emergency Lighting
101	Lobby	101			●		●	●	●	●	●
102	Private Office	101		●		●		●	●		
103	Conference Room	101			●		●		●	●	
104	Janitor	101	●								
105	Corridor	101		●		●		●		●	●
106	Open Office	101		●		●		●	●	●	●
107	Storage	101	●								

How?

Details and other requirements regarding operation are provided.

What?

Specific control strategies are applied to each space.

- 1 - Manual on/off device.
- 2 - Controls that allow the lighting level to be adjusted up and down.
- 3 - 8-Button Keypad: On, Off, Raise, Lower, and 4 additional scene buttons.
- 4 - Auto-on to 50% of maximum light output. Manual Raise/lower. Manual-off and Auto-off.
- 5 - During normal hours (7 a.m. to 7 p.m.), Auto-off after 15 minutes of vacancy.
- 6 - Lighting controls are enabled during normal hours of operation. Manual override outside normal hours.
- 7 - When daylight illuminance is greater than target illuminance, lighting power shall fade to off.
- 8 - Lighting power shall be reduced by 15% and shall not be allowed to exceed that value during the event.
- 9 - Provide means for the designated luminaires to go to full light output upon loss of the normal lighting power.



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Implementation is Critical



Loss in These Steps can Erode or Erase Profit

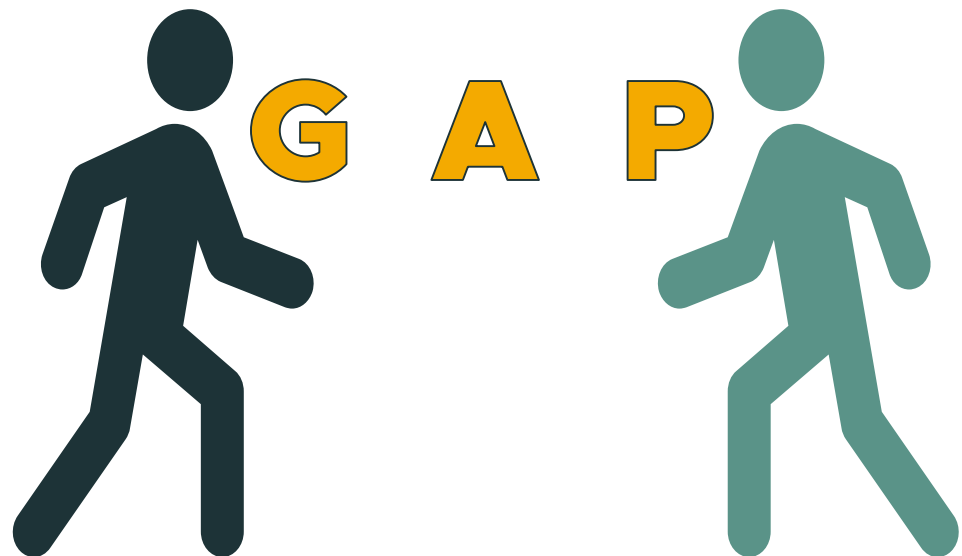
Profits are reduced by mistakes, rework, and delays.



Develop repeatable procedures and checklists to reduce risk.

- Find out who is doing what.
- Request and review documentation ahead of time.
- Manage on-site time and resources.
- Invest in training.

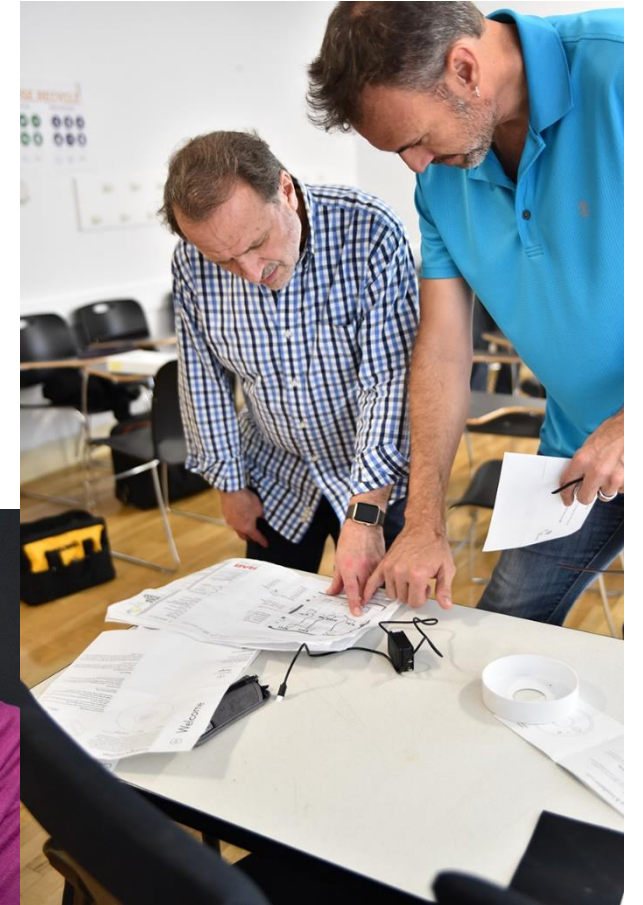
Who's Responsible?



- SOO & Documentation
 - Fixture Specification
 - Procurement
 - Relationship to Client/Owner
 - Installation
 - Initial Setup
 - Programming
-
- Will you need to be on site during programming or commissioning?

Contradictory Documentation Causes Confusion

- Incomplete or inconsistent information from drawings, schedules, and specifications slows installation, creates errors, and causes delays.
- Create a shortlist of key information for your role. Thoroughly review documents and resolve issues ahead of time.



Manufacturer Resources Can be Confusing

- Documentation can be too long or out of date.
- Observed installers found videos to be the most helpful resource.



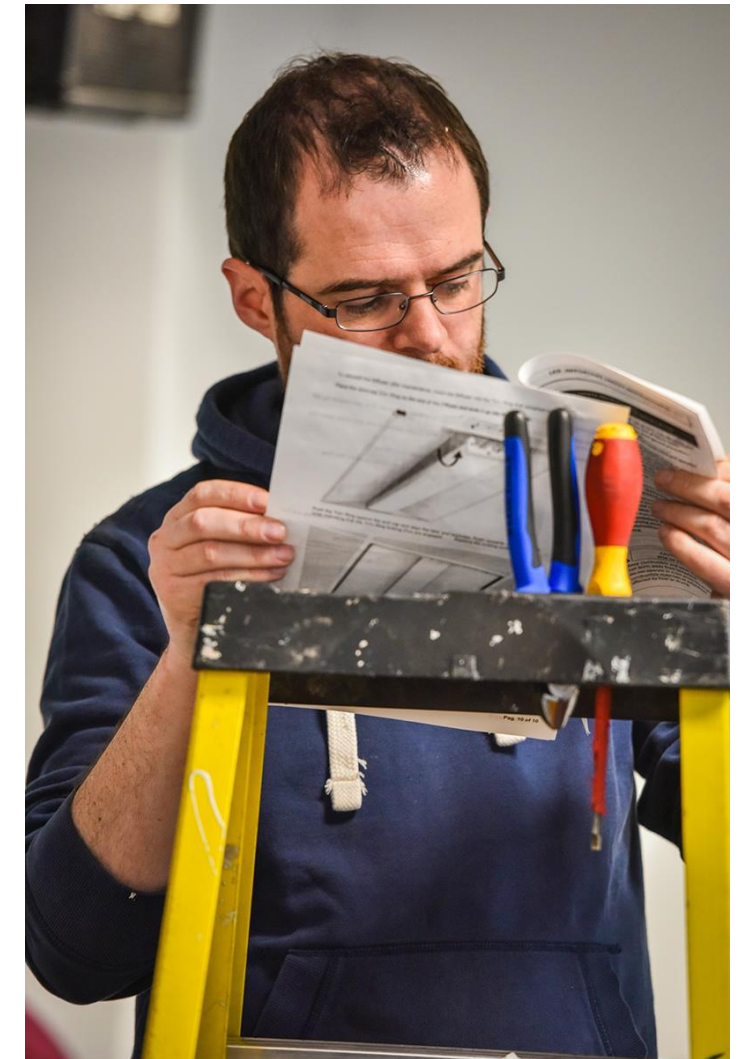
Would You Rather?

Spend 3 hours on the phone
with manufacturer support

OR

Spend 3 days troubleshooting
onsite

So it's not working?



Read the materials before diving in.

Proprietary Products are Confusing

Non standardized systems have produced a highly varied landscape.

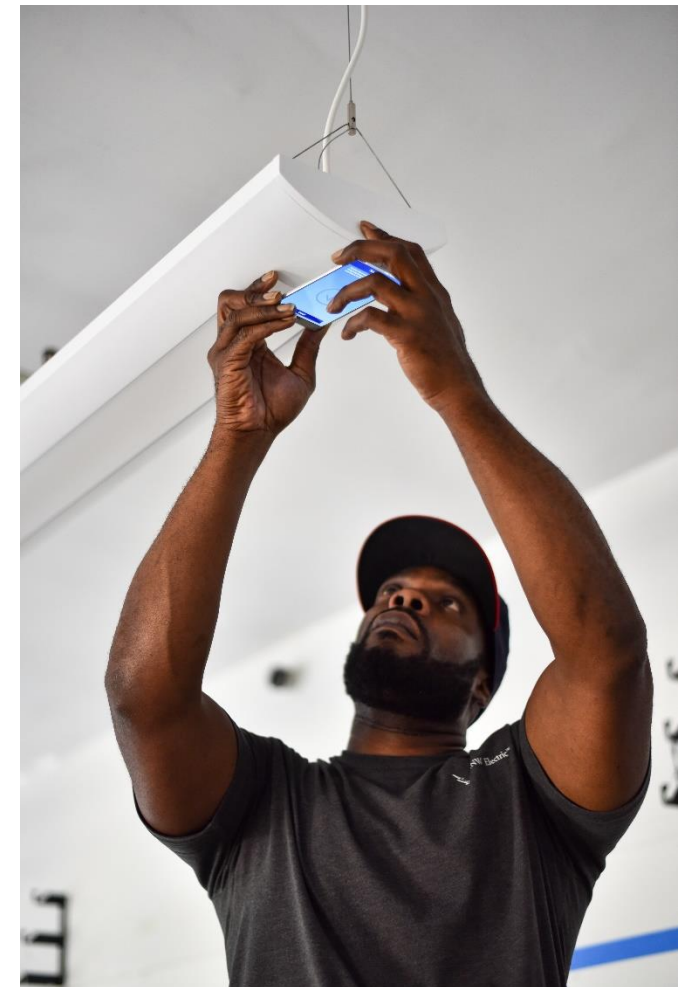
Is it a node, a gateway,
a hub, or an interface?



Become familiar with the basic
structures of control systems.

Startup procedures, equipment,
and level of involvement may vary.

Training for one system may
not be applicable to another.



Use your Resources

- Resources may vary depending on project size, complexity, and budget.
- Ask for clarification when you don't know, talk to controls specialists.
- Have an organized process for implementation with a controls specific checklist.
- Invest in training.
- Hire an experienced team.
- Consider a system integrator for high risk, complex projects, and budget accordingly.





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Gauging Return on Lighting Controls

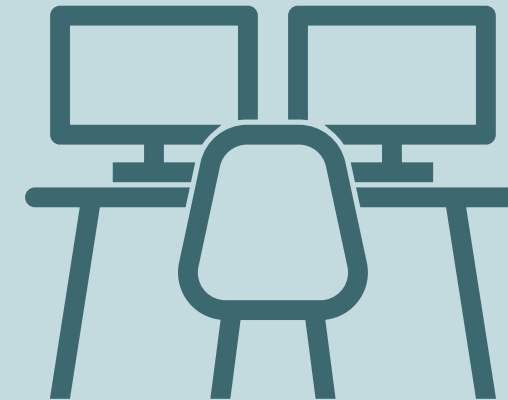


Return on Lighting Controls – What Do We Know?

Benefits generally fall into two categories:

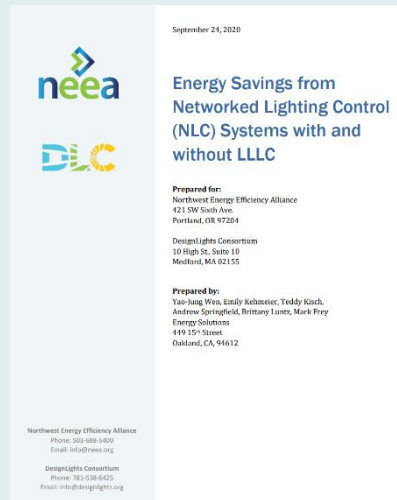


Energy Cost Savings



(Non-energy) Business Benefits

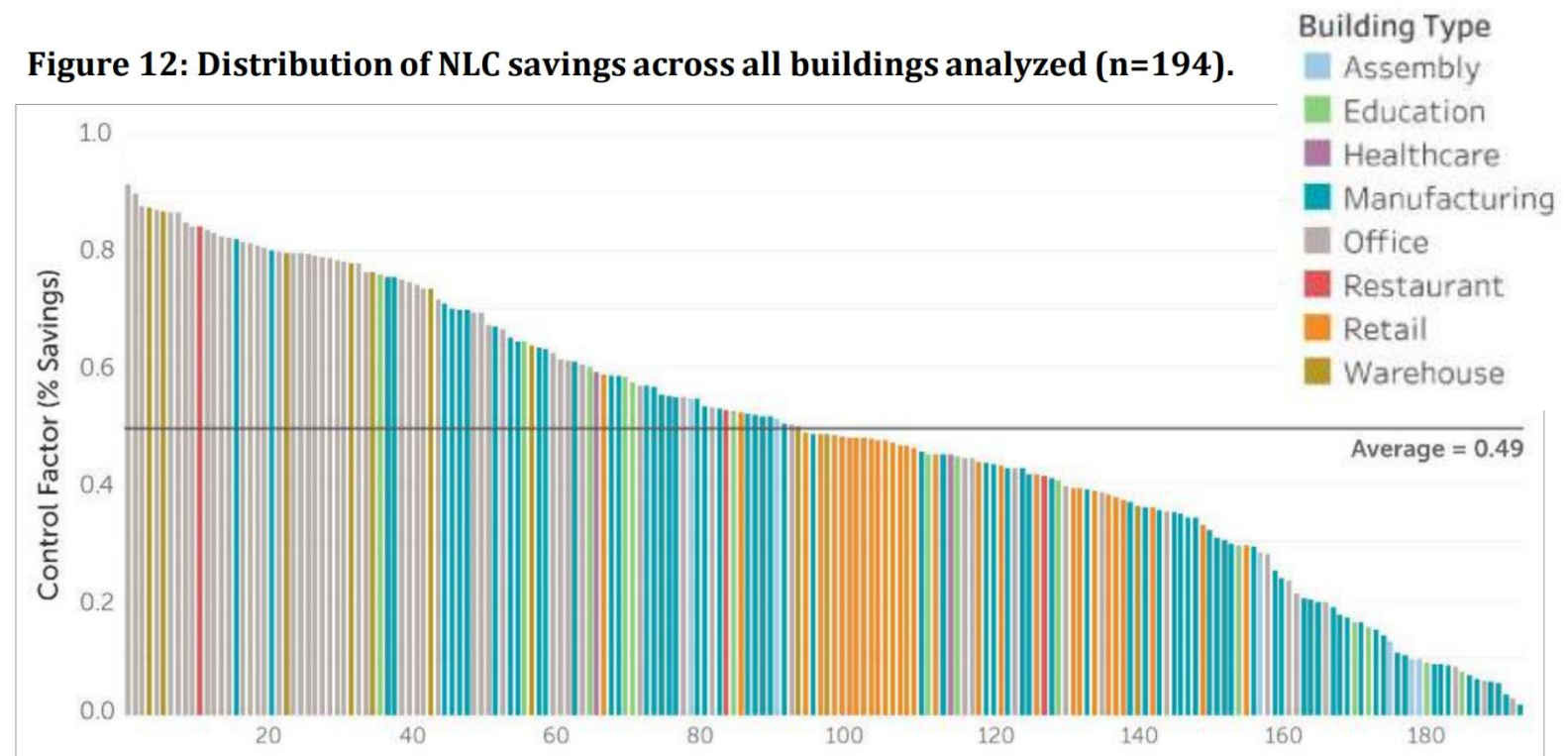
NLC Energy Cost Savings – New Studies



- NEEA/DLC 2020 study analyzed time series energy consumption data
- 194 buildings with networked lighting controls (50% NLC / 50% NLC with LLLC)
- 8 building types (Office, Warehouse, Manufacturing, Healthcare, etc.)
- 12 different manufacturers

- Large variation within buildings of the same type.
- Proper programming and commissioning are critical to achieving energy savings.
- Time series data suggests that many sites are not using all NLC features, such as occupancy sensing or daylight-responsive controls.

Figure 12: Distribution of NLC savings across all buildings analyzed (n=194).



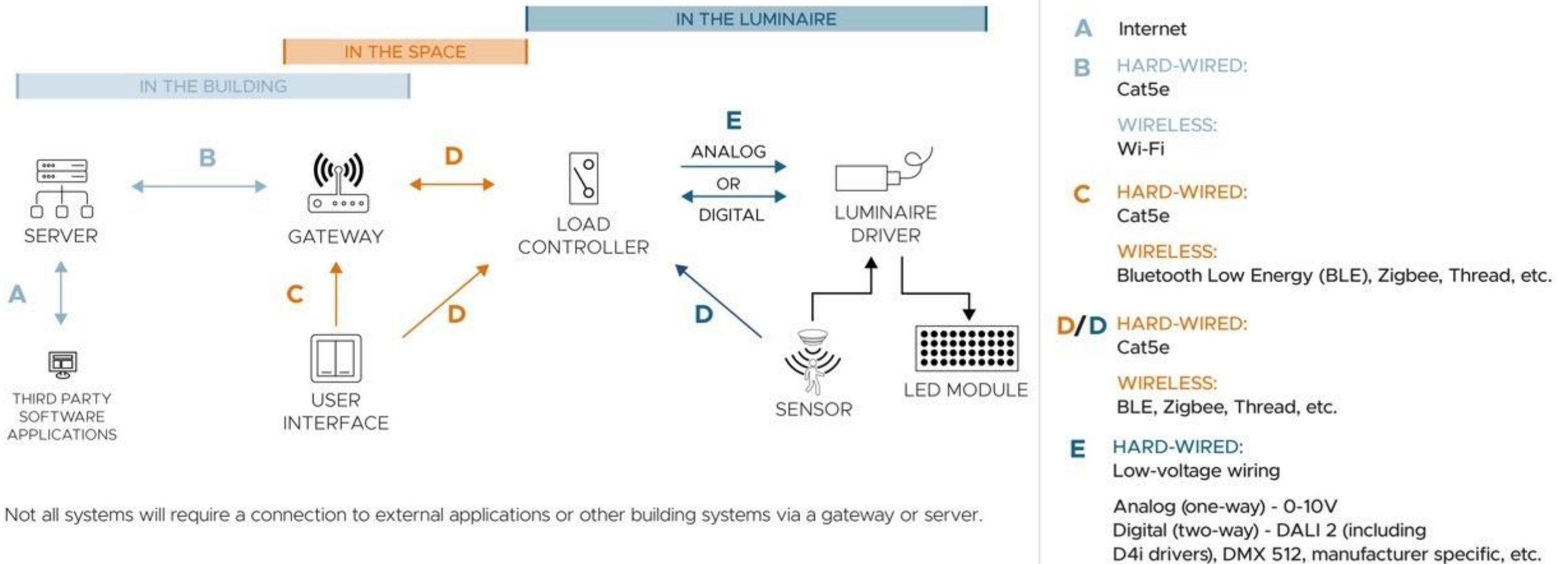
Across the 194 buildings included in the study, NLC reduced lighting energy use by half.



**49% Average Savings
27% High-end Trim
32% Other Control Strategies**

Understanding Luminaire Level Lighting Control (LLLC)

- Integrated sensors that enable luminaire-to-luminaire communication and granular control.
- Luminaires can respond to occupancy, daylight and other input signals individually or as flexible zones.

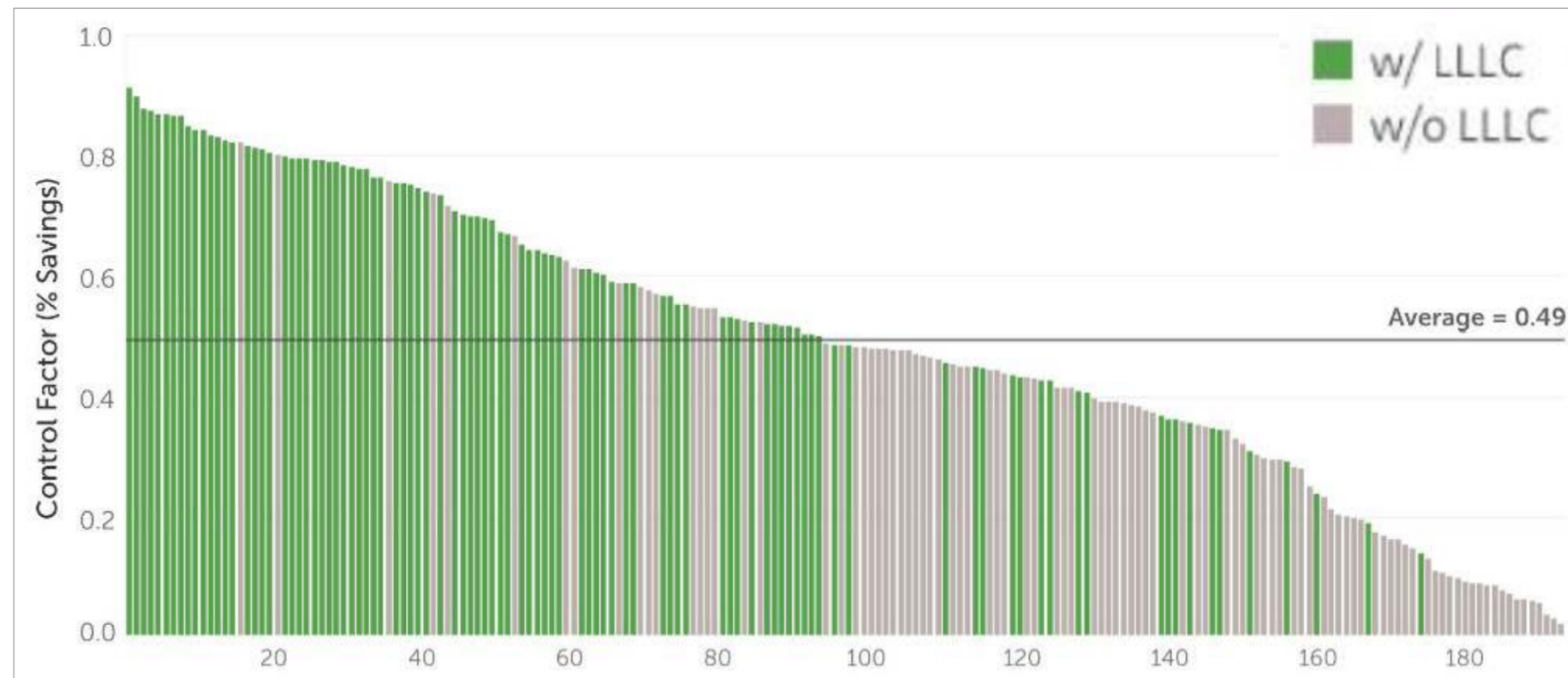


Not all systems will require a connection to external applications or other building systems via a gateway or server.

LLLC Offers Additional Savings

- 63% Average Savings
- 37% High-end Trim; 41% Other Strategies
- More study needed on best-suited applications and user acceptance.

Figure 16. Control factors of NLCs with and without LLLC across all buildings analyzed.



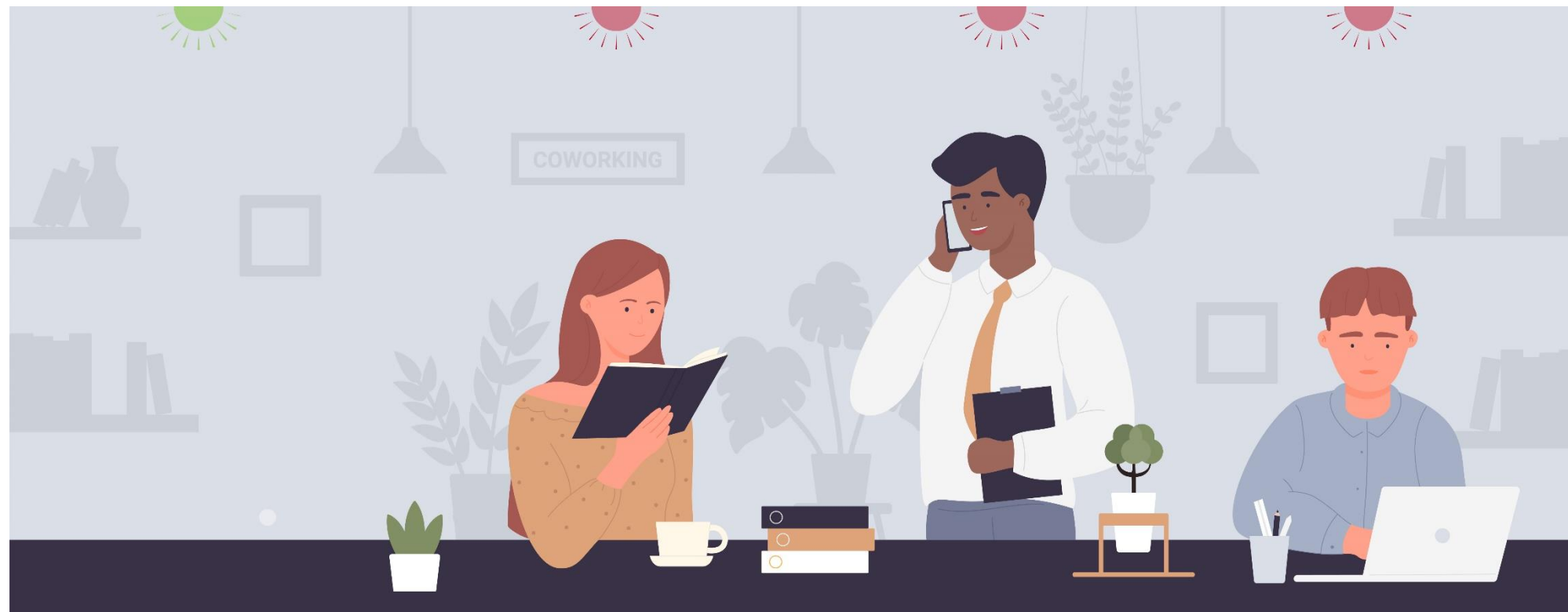
LLLC Installation and Operation

- Integral sensors reduce installation time and complexity.
- Initial setup/programming is complex and typically requires a specialist.
- Flexibility and granularity increase programming complexity and field adjustable settings.
- Miscommunication during programming can cause the owner to miss out on savings and can lead to dissatisfaction.



Speculative Business Benefits

- ROI could be high IF system works and assumptions are realized.
 - People counting, wayfinding, hoteling
- Success depends on owner's commitment.



Essential Business Benefits

- Controls are critical in many applications.
- Needed to establish brand/ atmosphere.
- Essential for the functional support of the space.
- Proven cost savings.

**Simple dimming strategies
can go a long way!**



The Bottom Line



Consistent Practices

Lack of consistency and best practice in design adds cost and reduces profit.



Informed Processes

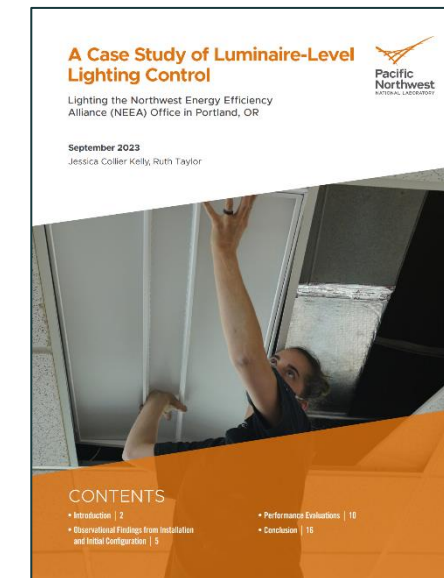
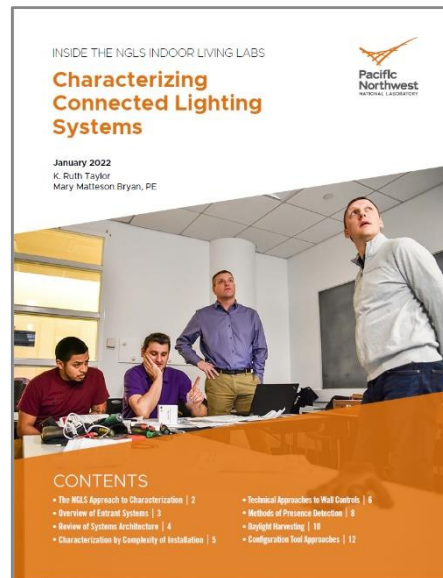
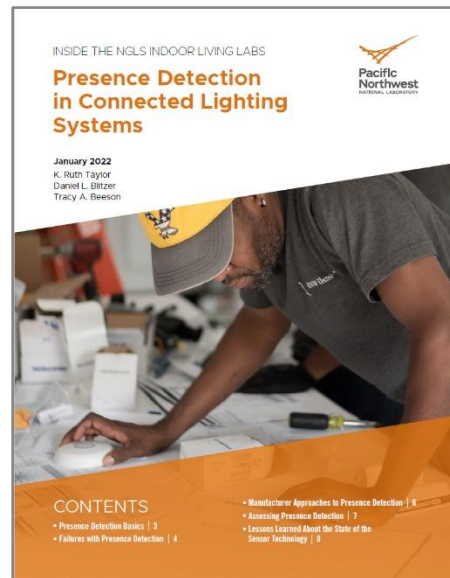
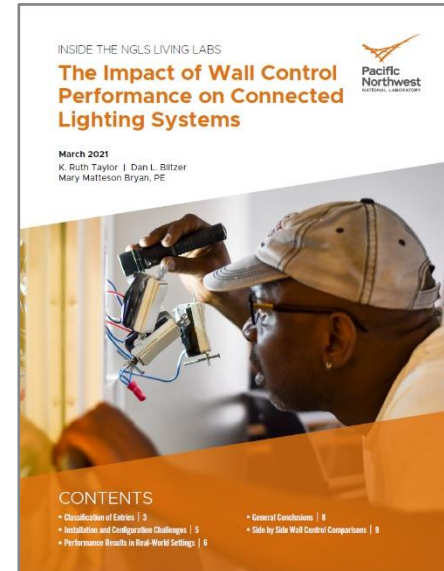
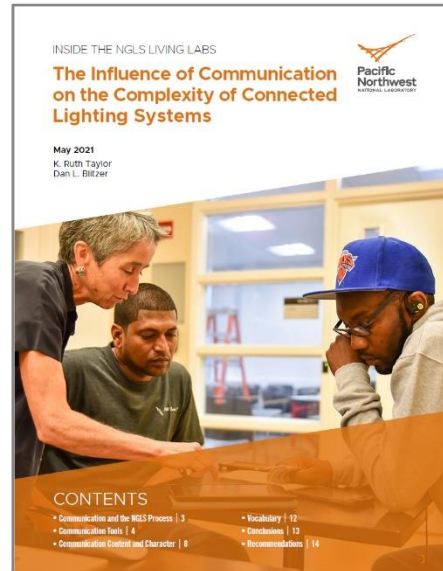
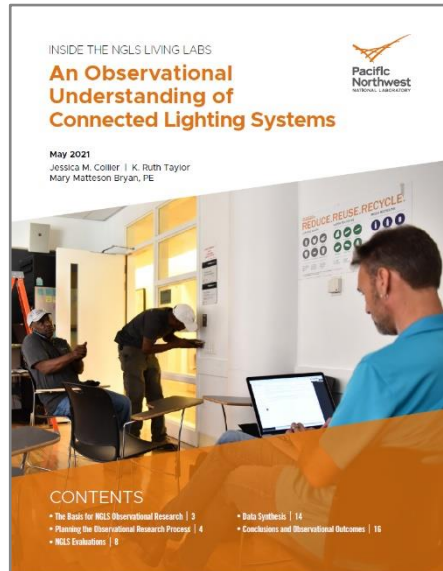
Causal pricing and implementation reduces profit.



People-focused

Lighting controls can save \$, provided they focus on owner needs, are relatively simple, and well implemented.

NGLS Resources



- An Observational Understanding of Connected Lighting Systems
- The Impact of Wall Control Performance on Connected Lighting Systems
- The Influence of Communication on the Complexity of Connected Lighting Systems
- Overview video – Inside the NGLS Living Labs
- Presence Detection in Connected Lighting Systems
- Characterizing Connected Lighting Systems
- A case Study of Luminaire-Level Lighting Control

<https://www.pnnl.gov/projects/observational-research/research-and-publications>

System Selection Resources

Understanding the Potential of Connected Lighting Systems



CONNECTED LIGHTING SYSTEMS

Connected lighting systems provide a platform where integrated control of lighting and other systems can enhance building performance. With detailed information, coordinated systems can deliver lower operating costs and improved return on capital, as well as enhanced occupant wellbeing and productivity.

that sends commands and receives status reports. Advanced sensors detect occupancy (including counting the number of occupants), light, and other environmental variables.

Indoor positioning locates people and equipment. Internet connectivity and system interfaces distribute information and commands beyond the lighting systems.

THE CONNECTED DIFFERENCE

Connected Lighting Systems are networked controls with additional technological features. Connected system features include digital communication

UNLOCKING THE BENEFITS

Connected lighting systems provide a wide array of benefits for many different organizations, including commercial and government offices, educational and healthcare institutions, and retail and distribution facilities. Examples include:



Energy Conservation

Information gleaned from an array of lighting-mounted sensors enables granular system response, reducing waste in lighting and HVAC systems. Building occupancy analytics enable

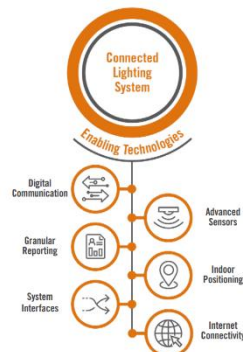
predictive system response and help to optimize allocation of energy sources in support of net-zero-energy strategies. Detailed energy use reporting supports improved resource allocation and zero-carbon strategies.



System Optimization

Information from lighting, HVAC, and other building systems—such as component temperature and run time—permits automatic, real-time optimization of performance. Such

information can reduce energy consumption and extend the useful life of equipment. Real-time reports of equipment and component failure simplifies maintenance operations, as does an integrated dashboard.



Strategies for Success with Connected Lighting Systems



Success with lighting controls depends on establishing clearly defined objectives and taking a disciplined approach to design and implementation. This practical guide describes four common use cases for lighting controls and outlines the implementation process, from planning through maintenance. These recommended best practices reflect the experience of practitioners and serve to reduce complexity and the likelihood of problems when installing and using lighting controls.

Common Use Cases

1. Building and Code Compliance

This use case represents the minimum requirement for most projects and is generally the least costly.

SYSTEM CAPABILITIES INCLUDE:



Although it's a least-cost approach, code compliance alone may not satisfy key organizational objectives. System capabilities generally include manual switches and dimmers; dimming drivers; sensors that detect unoccupied spaces and signal lights to turn off; sensors that detect light and signal lights to dim when daylight is present; and programmable clocks for interior and exterior lighting.

2. Enhanced Lighting Performance

This use case aims at improving workforce productivity, wellness, and facility appeal.

SYSTEM CAPABILITIES INCLUDE:



Enhanced lighting performance aims at improving workforce productivity, wellness, and facility appeal. System capabilities generally include convenient keypad controls for multiple settings in conference and training spaces; AV controls for screens, lights and blinds; and luminaires that provide tunable white with manual or automated settings.

3. Enhanced Energy Conservation

This use case supports both aggressive cost reduction and zero carbon goals.

SYSTEM CAPABILITIES INCLUDE:



Enhanced energy conservation supports both aggressive operating cost reduction and zero carbon goals. System capabilities generally include energy reporting and system optimization to suggest improved operations; interaction of HVAC systems through a building management system; and grid interaction through demand response signaling.

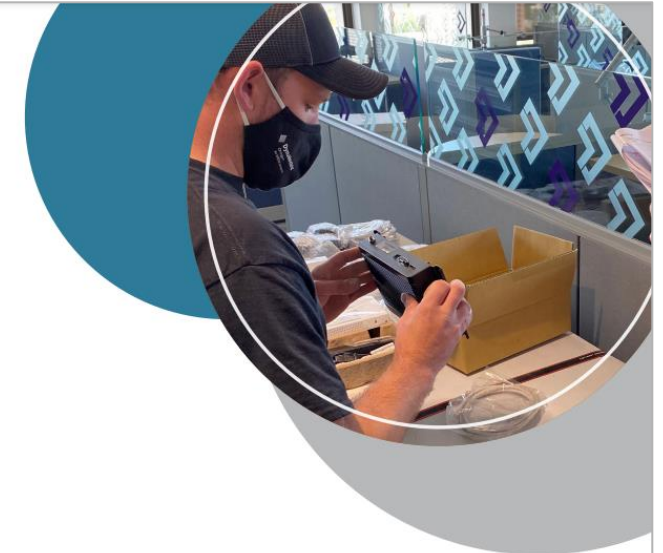
4. Enhanced Facility Productivity

This use case includes increased spatial and asset efficiency, retail performance, safety and security, and engagement.

SYSTEM CAPABILITIES INCLUDE:



Enhanced facility productivity includes optimized management of facility spaces and assets, retail performance, safety and security, and occupant engagement. Indoor positioning, asset tracking, people counting and other advanced sensors, combined with application-specific analytics, enable a lighting control system to provide benefits beyond lighting and energy.



SELECTING LIGHTING CONTROL SYSTEMS

What's Inside: A systematic approach to networked lighting controls

- Controls Objectives and Use Cases
- System Capability Considerations
- Networking and Communication Options
- Documenting a Lighting System

<https://www.pnnl.gov/projects/observational-research/research-and-publications>



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Thank you!

**Questions?
Comments?**

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