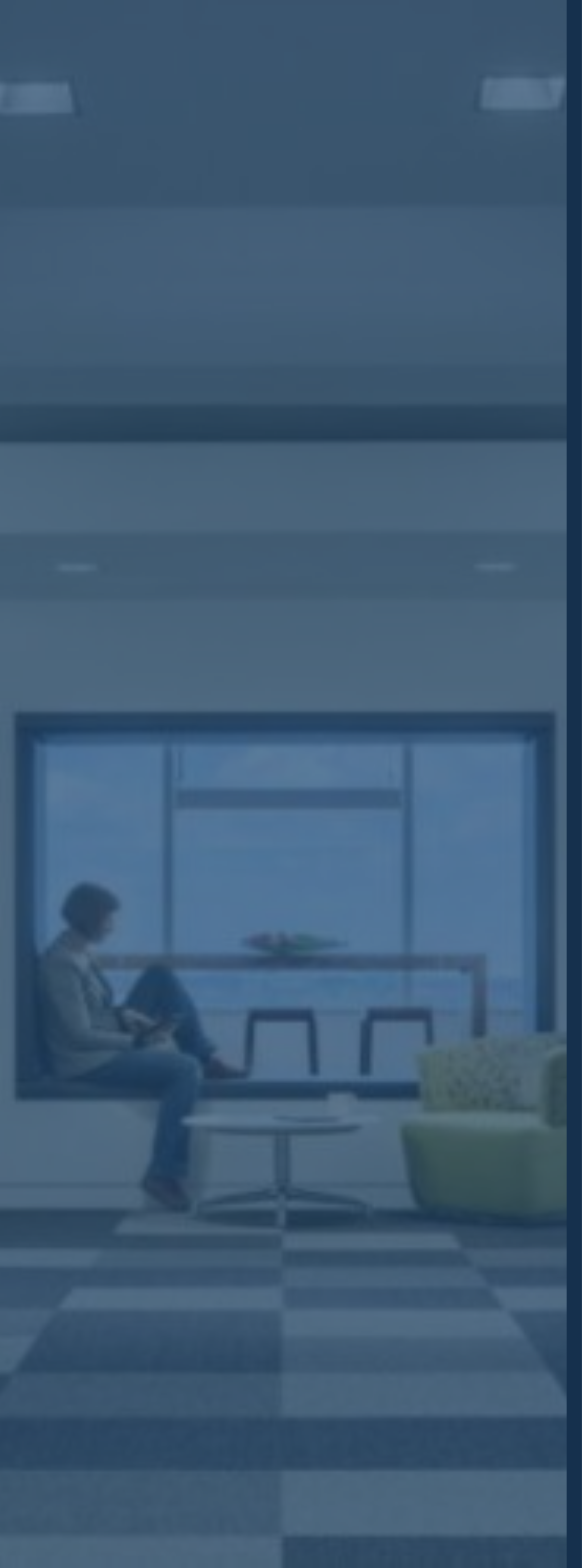
Lighting & Lighting Controls

SPRING EDITION

CONSULTING - SPECIFYING engineer eBOOK | synapse



Contents

How to use sequence of operations for lighting controls

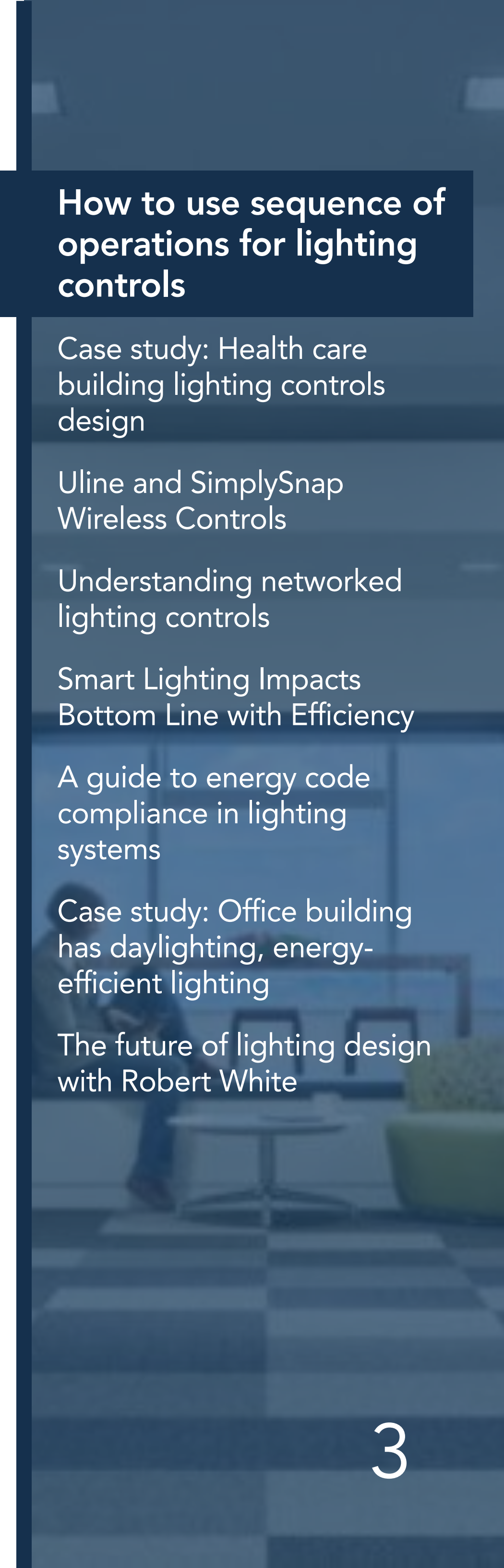
Sequence operations provides a clear, concise and client-friendly method of communicating lighting design intent

Advances in lighting technology and continued adoption of stricter energy codes have changed the way electrical engineers design lighting controls. In states that have adopted International Energy Conservation Code 2012 or newer (which is most of them), traditional wall switches are becoming a thing of the past. In their place, digital lighting control systems have emerged as the solution of choice to maximize energy savings and satisfy building codes.

For nonresidential buildings, lighting is controlled by smart networks of "internet of things" devices — relays, occupancy/vacancy sensors, photocells, button stations, touchscreens, etc. — that optimize lighting conditions and energy use dynamically according to performance-based design parameters.

As a consequence, electrical engineers have had to reinvent how to communicate design intent to contractors and clients. Rather than specify lighting equipment to be installed, engineers now specify functional rules for how the lighting system is intended to operate. How long should office lights stay on after the occupancy sensor stops detecting movement? How bright should lighting become when a person reenters? These kinds of questions are now addressed by code, and they must be addressed in design documents.

This is the central problem of lighting design in the age of energy-conscious building



codes. While codes mandate that we must specify the function of lighting systems, they do not tell engineers how. Each design firm is left to its own devices when devising a system for communicating lighting system function. The result is a mishmash of styles of documentation, a lack of efficiency for designers and potential missed opportunities for competition among subcontractors.

At LEO A DALY, we've put considerable effort over the last few years into updating and standardizing our lighting control documentation. Our approach, known as the sequence of operations, provides a clear, concise and client-friendly method of communicating design intent when specifying lighting control systems.

A brief history of smart lighting code

The history of smart lighting controls in code begins with IECC 2012. Before this code iteration, smart lighting controls were in their infancy. While technologies for digital monitoring and control of lighting systems existed, they were not required by code.

IECC 2012 introduced new requirements for occupancy sensors, limiting operation in many spaces to vacancy (manual-on, automatic-off) or partial-on functionality. A partial-on approach saves energy by automatically activating lights to a set output, commonly set at 50% to satisfy code. Occupants may use manual controls to raise light levels to full, but in many cases they won't if a lower light level is adequate for their tasks.

IECC 2015 introduced or expanded several more requirements aimed at cutting energy.

- The occupancy sensor-based shut-off requirement, which enables automatic shut-off of lighting within 30 minutes of all occupants leaving the space, was expanded in 2015. IECC 2015 added to the list: restrooms, storage rooms, janitorial closets, locker rooms, warehouses and any space 300 square feet or less that is enclosed by floor-to-ceiling partitions.

- IECC 2015 removed the 2012 lighting reduction exception that allowed an occupancy sensor to be used in lieu of light reduction controls. In 2015 code and later, both occupancy sensors and lighting reduction must be used.
- Daylight-responsive control function was added as a new requirement in IECC 2015. Artificial lights in spaces adjacent to windows and skylights must automatically change their output in response to daylight conditions. In these spaces, photo sensors measure reflected light in the room on a continual basis and provide feedback to the smart lighting control system, which then supplements with artificial light until a threshold has been met. This saves energy by expending just the right amount of light, but no more.
- The exterior lighting setback requirement, added in IECC 2015, saves energy in two primary ways. For decorative applications, exterior lighting is required to be dimmed immediately outside of business hours. Where needed for safety, exterior lighting must be shut down an hour after closing, to resume an hour before opening.

IECC 2018 added a "sub-zoning" requirement for open plan office areas larger than 300 square feet. C405.2.1.3 occupant sensor control function in open plan office areas requires open plan offices to be broken down into separate control zones, each of which can be controlled individually or all together.

Technological impacts of code changes

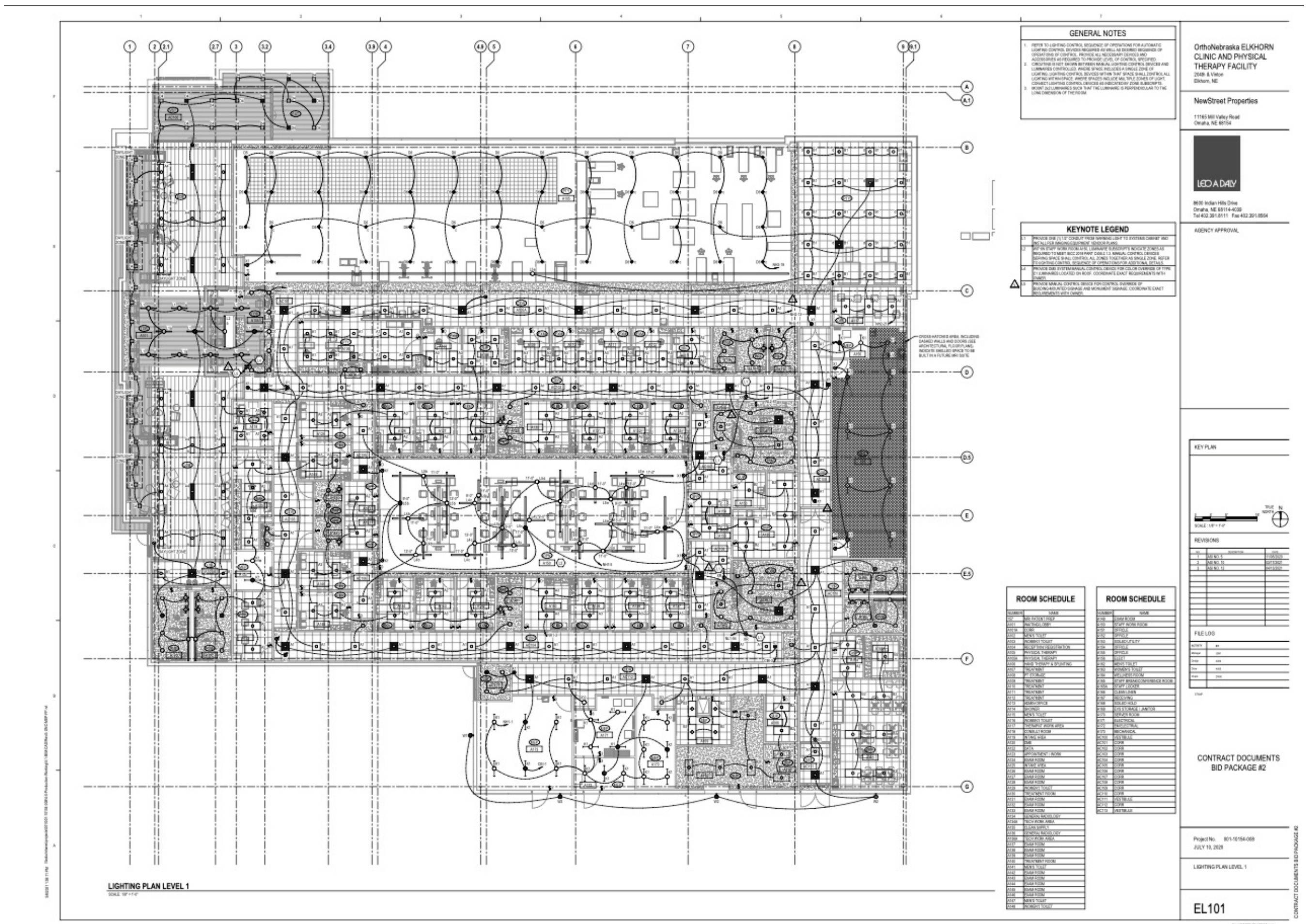
The overall result of these code changes is that traditional lighting controls are no longer suitable for many building types. Starting with IECC 2012 and, in particular, with the vacancy/partial-on requirement, a higher level of sophistication and intelligence was required of lighting controls.

A number of competing smart lighting control solutions emerged, with one thing in common: they all use data rather than power to control lighting function. Instead of a line-voltage wall switch, lighting began to be activated and controlled by a networked system of low-voltage devices. Rather than communicating on/off by the absence or presence of a circuit, devices received packets of data delivered through low-voltage cabling. In place of a relatively "dumb" analog system, these lighting systems operated digitally and were required to have some form of "intelligence."

In the U.S., each manufacturer of smart lighting equipment uses a proprietary language and equipment to communicate the data needed to control the lighting. Unlike the past, there is no "standard" switch. Pieces and parts from different manufacturers cannot be mixed and matched. The choice of a vendor for the lighting control system is a decision with long-lasting impacts. Electrical engineers specifying these systems must be familiar with the capabilities and limitations of every system in order to properly advise clients and contractors.

Why a sequence of operations?

Before smart lighting controls, electrical engineers specified lighting equipment without paying a lot of attention to how that equipment was used. Energy codes were lax enough that control systems were specified and installed with default settings. And the



equipment was simple enough that there wasn't a lot of functional information to communicate to the contractor and user.

Page 2 of this .pdf shows an example of the plan component of Sequence of Operations; Page 3 shows an example of the schedule component of sequence of operations. Courtesy: LEO A DALY

All that has changed. Energy codes are more demanding, the functionality of lighting control systems is complex and solutions vary significantly between manufacturers. One manufacturer might use 10 parts to achieve the desired functionality; another might use six. One might use Cat5 cable; another communicates wirelessly. Engineers should consider the following parameters:

- **Function:** Can the lighting control do what the code requires?
- **Performance:** Will the system be optimized beyond “default” settings to achieve design intent?
- **Support:** Which vendors offer the most robust support in the client’s geographical area?
- **Cost:** Can competition among vendors reduce the client’s cost?
- **Efficiency:** How efficiently can design time be used across multiple projects?
- **Accuracy:** Is the specification process set up to avoid errors and omissions?

Specifying using a sequence of operations satisfies all of these criteria.

A sequence of operations is a document, added to the end of the drawing set, that specifies the functionality of the lighting control system. Using a spreadsheet, each space in the floor plan is identified according to a three-letter code. Each code is given a set of rules that must be followed in order to maximize energy efficiency and optimize the utility of every space according to the client’s needs. The sequence of operations is supplemented with a section in the general specifications identifying vendors and products that have been vetted by the design team.

Many engineering firms use a standardized sequence of operations on every lighting design project. This provides clear instructions for subcontractors on the function needed to meet code and the performance needed to meet aggressive energy-savings goals. It then becomes the subcontractor's job to select vendors from the electrical specifications that are known to provide adequate support in their specific geographic region. When bidding on the project, subcontractors are forced to compete on cost. And because these documents are standardized and kept up-to-date continually, engineering teams are able to operate efficiently and avoid errors and omissions (accuracy).

There are other ways to specify smart lighting controls. Engineers have the option to specify exactly which vendors and equipment to use, starting from scratch on every project. But for many designers, the benefits to using the sequence of operations method are simply too great to ignore. It takes a little upfront time to do the research necessary to standardize the sequence of operations and electrical specifications, but it pays off in both the short term and long term.

See example of the plan component of the sequence of operations in this .pdf. Page 2 shows an example of the plan component of Sequence of Operations. Page 3 shows an example of the schedule component of sequence of operations.

Setting up the sequence of operations

The sequence of operations is an organized, standardized way of communicating the functional requirements for every space included in a lighting design project. It includes three main components: The plan component, schedule component and specification component. The following is a narrative explanation of each component, and the visual examples are indispensable to understanding how it works.

Plan component: The first layer of information in a sequence of operations is given on the electrical floor plan. The plan shows the circuits and electrical systems as usual, except that it does not specify every component in the lighting control system. The exact locations and types of relays, sensors, photocells, power packs and junction boxes are omitted. Because these components vary between manufacturers, engineers leave these specifics up to them to create a set of plans to meet the design intent.

To ensure convenient access to occupants, the plan does specify the location and type of manual lighting control devices in each space. With each manufacturer offering an array of different manual control options, designers want to ensure that the final product best meets the client's needs

In place of detailed wiring diagrams and components, each space is tagged with an oval containing a three-letter code unique to that space type. For example, open offices are tagged with OPN; enclosed offices with OFF; lobbies with LOB, etc. These three-letter codes refer the reader to the schedule component, which contains the functional information needed to meet design intent.

In spaces that include multiple lighting subzones, such as open offices, engineers add a unique tag in subscript. Where applicable, luminaires within daylight zones are indicated on plans to assist manufacturers in locating photocells.

Schedule component: The schedule is a table at the end of the drawing set that specifies the minimum functional performance of the lighting control system. This gives clients, manufacturers and subcontractors a clear and concise understanding of how the lighting control system needs to behave in order to meet code and design intent.

It is organized in the following way:

- Title: "lighting control sequence of operations." This is it. The much-discussed sequence of operations.
- Glossary: The first section defines abbreviations used throughout the rest of the table. This allows the table to be condensed enough to provide quick reference on a single page.
- Space type and tag: These two columns identify the three-letter tag with its full name. Every space type and subtype is given a unique code that is then defined in terms of the devices required and their minimum functionality.
- Devices: This column is subdivided into four categories.
    - OCC: This sub-column identifies the type of occupancy sensor required in the space type identified. For example, if the OCC column reads DT, a dual technology occupancy sensor (e.g., passive infrared and ultrasonic/microphonic) is required in that space.
    - PHOTO: This sub-column, answered in Y/N format, tells whether a daylight harvesting photocell is required in the space.
    - NETWORK: This sub-column, answered in Y/N format, tells whether a network connection to the system head-end is required. A network connection allows for scheduled control from the system time clock, remote control and monitors and remote programming.

- UL 924: This sub-column, answered in Y/N format, tells whether egress lighting within the space must be controlled along with space lighting. This allows code-required override control of egress lighting where multiple lighting branch circuits serve the same control zone.

- Sequence of operations: This column is the most important part of the table. It provides specific lighting control rules that must be followed in the space type identified. The section is written in plain English, spelling out the code-required performance of lighting in a way that clients can understand. (e.g., For decorative exterior lighting, "Lights to 100% at 15 minutes before dusk.")

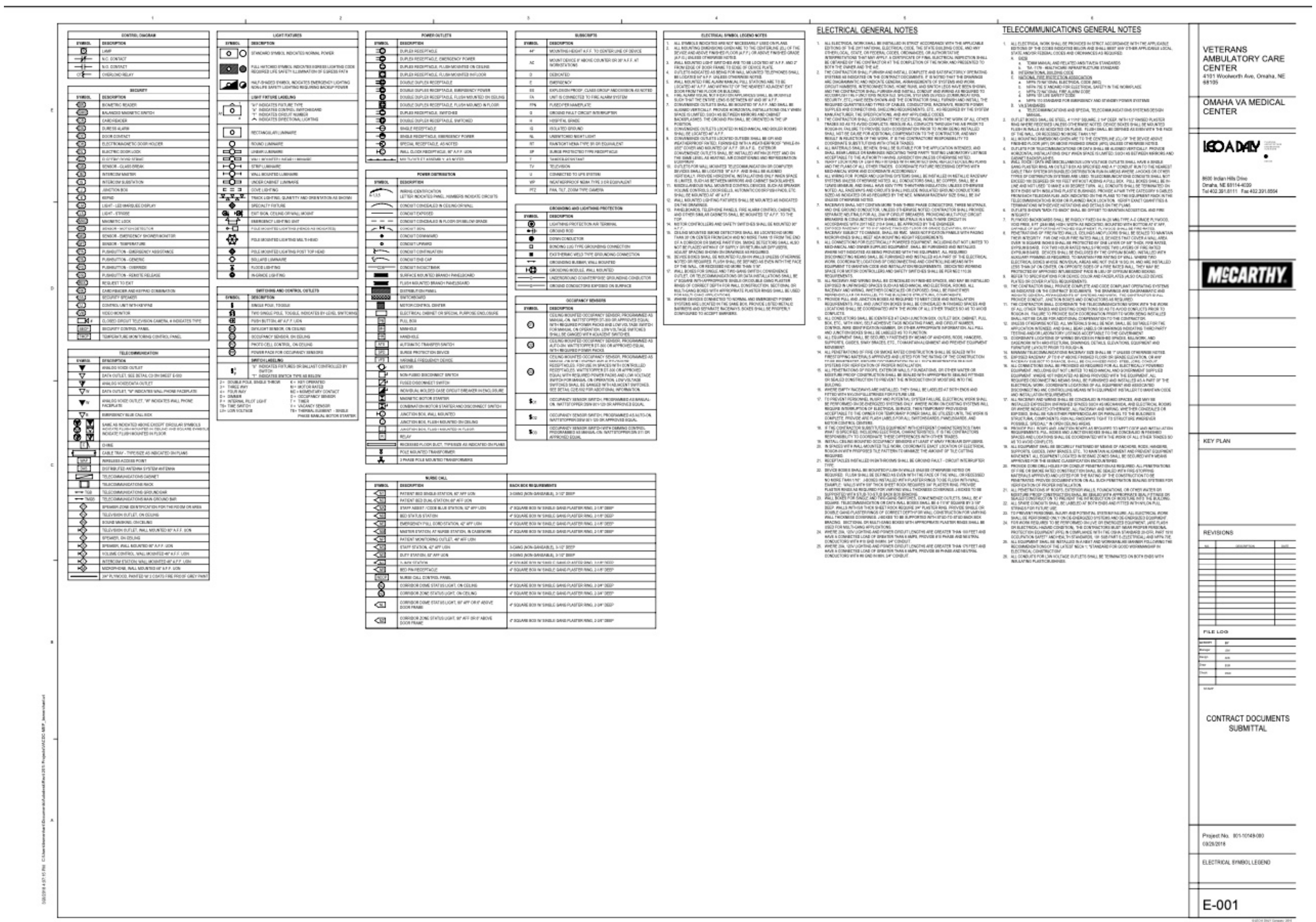
- Notes: This section provides clarifying information, such as the presumed operating hours of the business.

Specification component: The specification component is the final piece of making the sequence of operations method work for lighting control systems. Where the prior two components provide the functionality required to meet code, the specification component provides a level of quality control to the systems used in the final buildout.

The specification component is a section of the design firm's master specifications document, which includes a list of approved manufacturers that have been vetted by the designer and are known to comply with code requirements.

Additional benefits of sequence of operations

As more states begin to adopt more aggressive energy codes, it will take some time for the building and engineering industry to catch up.



Lighting plan example from before LEO A DALY's transition to sequence of operations. Click on the image to see more information. Courtesy: LEO A DALY

In summary, sequence of operations:

- Makes lighting controls easier to understand and discuss with clients by divorcing the "what" from the "how." When talking to a client, most of them will not understand or care how the specific solution achieves its results. They care about the results themselves. With sequence of operations, designers have a plain-spoken method to show the client how the building will operate. Anyone can read the sequence of operations and know immediately what will happen in any space, making it extremely easy to make decisions and achieve the right design intent.

- Is manufacturer-agnostic. The "old way" limits competition by locking contractors into an overly specific solution.

- Saves more energy. With device settings identified on a room-by-room or task-by-task basis, clients have greater control over the part that matters — the function. This allows clients to pursue more aggressive efficiency strategies by giving more complex control over spaces. If the client sees an opportunity for greater optimization, it's easy to just create a new three-letter tag and dial in customized settings for that room type.

- Makes engineers more accurate and efficient. Once a standard sequence of operations has been developed for one project, it becomes extremely efficient for it to be used on future projects. In addition, it avoids errors and omissions that could be caused by starting from scratch every time.

- Simplifies commissioning. Instead of being given a list of parts and having to deduce the design intent, commissioning agents know immediately how the space is supposed to function. In addition to making the commissioning agent's job easier and faster, it helps designers avoid calls for clarification from the field.

- Keeps design intent information out of the spec. There are other ways to communicate design intent with smart lighting controls; one option is to include the system's function in the master spec. Because most contractors do not carry a copy of the spec into the field, this can cause ambiguity. By locating all functional information on one page, in the plan set, contractors become efficient and less likely to make mistakes.

Energy codes have fundamentally changed and so design needs to change too. One way or the other, designers need to be able to describe to clients and builders not just what equipment needs to be installed, but how it needs to function. Sequence of operations accomplishes this.

How to create in-house specifications

Not all lighting system types are included in a master specification, so firms may need to produce their own

Most design firms use AIA MasterSpec, the industry-standard product research and specification resource for design professionals. Developed by Deltek, MasterSpec has more than 900 master guide specifications covering more than 7,000 products and is the most comprehensive and trusted collection across architecture and design. However, at the time of writing, it does not cover all of the system types we most commonly use.

To overcome this, LEO A DALY conducted a thorough review of the lighting control systems available through major manufacturers and created its own specification titled, "Addressable lighting control systems." This required personal outreach to sales representatives from several lighting control manufacturers, a detailed analysis of each of the specifications and the merging of the relevant information into a custom specification for use by our electrical engineers.

While this presents a barrier to entry for engineers unfamiliar with lighting control systems, it is an important step to becoming knowledgeable enough to specify them. Once a firm has gone through the work of developing a custom specification for lighting control systems, only minor updates are needed each year to stay current with the different options from manufacturers.

With the specification component completed, engineers have everything they need to specify smart lighting control systems, meet code and aggressively pursue energy savings for clients. With a thorough specification in hand, clients are free to pursue an open-bid contracting process that encourages efficiency, cost-effectiveness and innovation.

Tony Staub

Tony Staub *is an electrical engineer at LEO A DALY. He combines a passion for lighting design with extensive knowledge of lighting and lighting control technologies.*

Case study: Health care building lighting controls design

A lighting sequence of operations met energy codes in this medical building

LEO A DALY provided full architectural and engineering services for OrthoNebraska's new 31,707-gross-square-foot orthopedic clinic and physical therapy clinic in Elkhorn, Nebraska. The project, due to open in fall 2021, provides a prototype for expanding OrthoNebraska's clinical, physical therapy and ambulatory surgery practice.

The project incorporates a medical office clinic of 16 exam rooms and two larger treatment rooms with two general radiology rooms to support this clinic. Rooms are organized in the patient-aligned care team model, which optimizes efficiency of exam rooms for patient scheduling while enhancing staff collaboration within a central teamwork area. This approach creates an environment of staff comfort and patient privacy by separating onstage and offstage areas.

The building's physical therapy component supports sports therapy with a 9,000-square-foot gym and turf section, highlighting the healing process that patients will experience. The patient's healing journey concludes with athletes' performance and agility being on display, creating an exciting and active environment for new patients to observe.

The site is planned for a future ambulatory surgery center to be added as patient volumes increase and this need and the practice grows.

The building's physical therapy component supports sports therapy with a 9,000-square-foot gym and turf section, highlighting the healing process that patients will experience. Courtesy: LEO A DALY

Lighting control sequence of operations

This is the first LEO A DALY project in the state to use a sequence of operations process since Nebraska adopted International Energy Conservation Code 2018. Previously, building code in the state conformed to IECC 2009, having skipped both the 2012 and 2015 code updates. With this leap forward, Nebraska adopted one of the most progressive codes in the country, a fact that challenged the design team to reinvent its process for electrical design specifications.

LEO A DALY provided full architectural and engineering services for OrthoNebraska's new 31,707-gross-square-foot orthopedic clinic and physical therapy clinic in Elkhorn, Nebraska. Courtesy: LEO A DALY

Lighting controls represented the main challenge for LEO A DALY's engineering team, as the 2015 and 2018 code updates required the implementation of many new energy savings requirements and the use of cutting-edge lighting control systems. The design team used the sequence of operations process to pursue an aggressive sustainability agenda.

- Partial automatic-on is used in lieu of fully automatic-on/off to reduce energy use in most spaces, including offices and work rooms. Specifying this functionality reduces energy use because, although lights are on more of the time, they are on at a lower output level.

- Automated daylight harvesting is done in spaces with access to daylight. Photocells are used to detect the amount of light reflected off surfaces and dim the lights as needed to optimize spatial quality and reduce energy use.

- Wireless lighting controls are used on exterior site lighting, with each pole individually dimmed according to a schedule, cutting energy use and meeting new code requirements. One hour after closing, exterior lighting dims by at least 30%.

- Lighting subzones are used in the open-plan office areas, which strategically reduce lighting when the space is not fully occupied. Detailed functional instructions are included in the sequence of operations.

The use of sequence of operations allowed the developer to meet code while providing maximum flexibility to the end user and optimizing energy use in every space.

Tony Staub

Tony Staub *is an electrical engineer at LEO A DALY. He combines a passion for lighting design with extensive knowledge of lighting and lighting control technologies.*

Uline and SimplySnap Wireless Controls

Uline is the leading distributor of shipping and packaging solutions to businesses throughout North America. Family owned for over 40 years, Uline has built its brand on customer service. Order accuracy, quick delivery, and low prices are the core of their promise to their customers.

Understanding networked lighting controls

This reviews the types and configurations needed to specify modern lighting controls

The lighting control industry has been evolving faster than the engineering or design industry can keep up with. Despite the evolution of lighting controls, the way lighting control systems are shown seem to have changed very little. Networked controls and programmable, addressable light fixtures and button stations have been replacing traditional toggle switches for the past decade; however, many designs still use traditional symbols and specifications have traditional switches.

Anyone who has been in the design or construction field for more than 10 years is very familiar with the traditional toggle switch form of lighting controls. These components switch line voltage, typically 120-volt or 277-volt in the U.S. When more than one switch location is needed, three- or four-way switches are used with “traveler” conductors between each switch.

While this configuration has worked well for nearly a century, it requires a substantial amount of line voltage wiring. When controls need to removed or added, changes are fairly inflexible on how they need to be wired. Lighting relay systems have been used for more than 70 years and these systems can use low voltage (which NFPA 70: National Electrical Code classifies as 50 volts or less) to control groups of relays. Adding control points can be fairly easy, given the ability to use low-voltage cabling, but adding circuits can be costly depending on the capacity of the relay panel and distance to the space served for line voltage wiring in raceway.

Relay or motorized component panels have been evolving to include programmable features and network capability, and these systems are well-suited for large areas such as conference centers, manufacturing or industrial spaces. When the panels are co-located with the electrical distribution serving the loads, the additional wiring cost can be minimized. The primary disadvantage of these systems is the cost and complexity of changing zoning or moving luminaires to alternate zones can be high, depending on the arrangement.

Figure 1: IMEG's architectural lighting design for Zebra Technologies' headquarters features a mix of LED and linear fluorescent lamp sources to minimize energy use and maintenance while remaining cost effective. The control system bridged a variety of protocols and worked in conjunction with the audiovisual system and shading to create one highly functional yet simple-to-use system that will repay the owner in energy savings and an enhanced user experience. Courtesy: Christopher Barrett Photography, IMEG

Lighting controls

Electrical design drawings have several traditional ways of showing lighting controls, which have been consistently typical over the past decade. Modern lighting controls have adapted to account for technology that can now be integrated into lighting fixtures. Luminaire control options have expanded over the past decades to include:

- Occupancy or vacancy sensing.
- Daylight sensing and control.
- Addressable networking for programmable assignment.
- Wireless controls using Bluetooth, ZigBee or Wi-Fi topologies.
- Time-of-day scheduling.
- Tunable white or RGBW control.

Lighting controls have evolved in response to wireless and addressable lighting fixtures. Programming lighting controls can be done over wired low-voltage, such as CAT-5E cabling or with wireless communication protocols. The obvious advantage with these controls is that the traditional line voltage control wiring of old is no longer needed at each control point and the programming flexibility allows for adjustments to occur at any time without the need to rewire the system when each luminaire is addressable.

There are two primary categories for addressable lighting controls: room-by-room control and network control. A building can also contain traditional stand-alone line voltage devices and complex theatrical lighting control systems. Specifying engineers and designers should have a system that allows for a clear understanding of which system is intended to be used. In a room-by-room configuration, it is common for an addressable relay module to control a large group of luminaires, which is similar to the way relay-based controls worked in the past (see Figure 2)

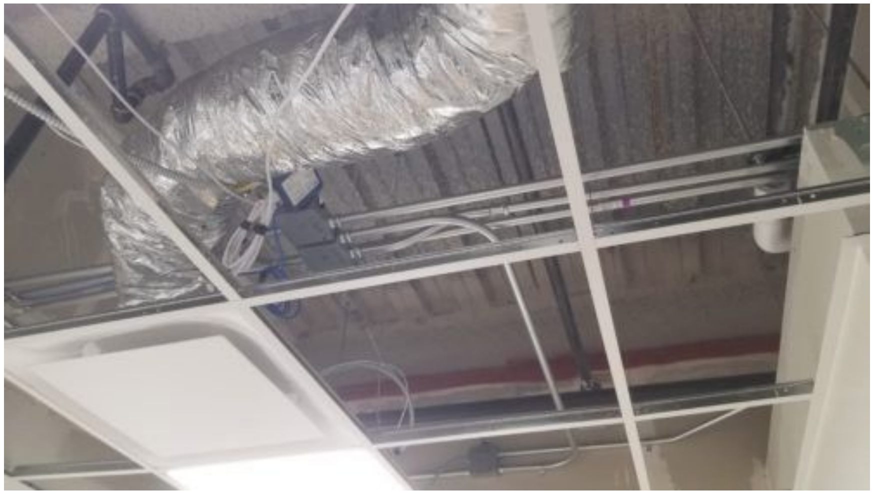


Figure 2: Image of a low-voltage lighting control relay connected to a junction box. Courtesy: IMEG

Designers can simply show the traditional line voltage devices and let vendors and contractors substitute for addressable systems if they feel those systems have a financial advantage. The downside to this approach is that the specifying engineer or designer loses some control over the components that are provided and making new requests during shop drawing review is not fair to the vendor and contractor. Another downside to this design approach is that the control systems being submitted weren't coordinated with the owner and users during design.

The traditional method of showing a "$" at the doorway may not convey sufficient information for an addressable system. The type of control station — wireless, wired or network — should be conveyed and related to a specification section or material list. Zoning information is also needed, which allows for a correlation between the control device and precise fixtures used. Historically, the industry used linework to indicate zoning but more recently, subscript-based zone indication is being used. Lighting fixture labels also include a fixture ID and a circuit indication when no line-work is used for circuiting or control (see Figure 3).

Sequence of operations

Three-dimensional computer-aided drafting now allows for model elements to contain properties such as voltage, wattage, control association and panel association. Using these modeling tools tends to encourage using a subscript-based control system because the necessary properties can be assigned to both controls and fixtures. Unique symbols can be used to represent line-voltage, room-based, network-based and theatrical lighting control systems to allow for unique specification of the respective components.

One of the main challenges that designers face is developing drawings and specifications that are compatible with all possible or approved manufacturers. This challenge is commonly used to excuse detailed wiring diagrams, which results in a performance specification for addressable lighting controls. This approach does allow for flexibility as technology evolves and new feature sets are added. The primary downside to a performance specification is that designers may not understand how the systems actually work, reducing their ability to assist the client with design and troubleshooting.

Narrative descriptions of lighting control schemes, sometimes called a sequence of operations, are becoming more common. Each room, area or space gets a sequence tag or label on the floor plan. These labels correlate to a sequence of operations table that is commonly located on the same sheet as the luminaire schedule. It's easier for vendors to get a complete picture of the control requirements if all of the lighting sequences, schedules and diagrams are grouped together on the same sheet(s).

Sequence of operations tables can be mostly narrative or can look like a matrix. The benefit to a matrix approach is that designers get a predetermined list of features and options and contractors or vendors can quickly see what options apply to each sequence tag. The benefit to a narrative style is that the designer can tell a story to convey the intent of controls. The following control options are used in a matrix or narrative:

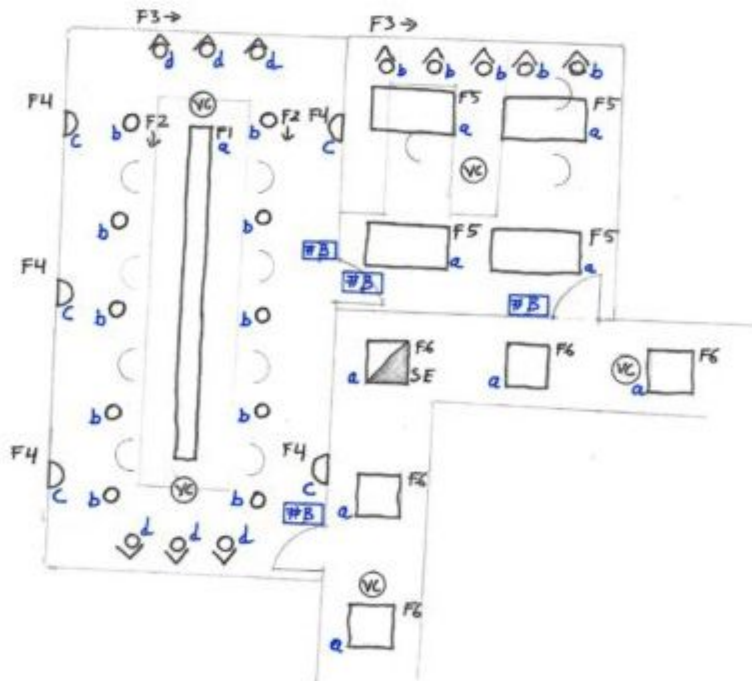


Figure 3: Sketch of a typical multizone conference room using room-by-room addressable controls where letter subscripts denote control zones for the wall mounted button stations (#B). Courtesy: IMEG

- Manual on/off.
- Occupancy sensor on.
- Vacancy sensor off.
- Daylight sensor dimming or multilevel.
- Time-delay off.
- Receptacle control.
- Heating, ventilation and air conditioning control.

The sequence of operations can also reference details to convey the arrangement and labeling of button stations. These button station details should be coordinated with the client during design. Button stations can be on/off, dim up/down or offer preset selection. Each sequence can reference a unique button station detail or, in some cases, button stations can be the same for multiple sequences.

When the types of controls available are more complicated or require multiple scene selections, a graphical interface may be recommended. Common applications include conference rooms, large meeting areas, large open areas or any space with multiple scenes or control zones. Graphical screens have evolved from the monochrome LCD of old. Full color touch screens with programmable pages are the norm now and designers will need to describe what the client wants on each screen or page.

Addressable lighting systems

Addressable systems use low-voltage cabling, typically Category 5E or 6 for power and communication between the controls, hubs and power packs. This cabling is typically run open as opposed to line voltage in conduit or other approved raceways. Designers need to ensure the specifications cover the installation requirements for low-voltage controls.

The hubs and modules that interface with the controls connect to standard 4-inch square junction boxes with knock-out connectors. This separates the low voltage wiring from the line voltage wiring. The downside is that the low-voltage cabling and connectors are external from the enclosure and typically lack strain relief. This presents a concern for the reliability of the control system (see Figure 5). Ideally, the controllers would be mounted in consistent locations within the space, such as above entry doors, so maintenance personnel can locate the connections.

Designers can specify appropriate locations for controllers and require strain relief for low-voltage connections. Referencing the Construction Specifications Institute Division 27: Communications Manufacturers sections for installation requirements is an option, but those sections do not account for CAT 5E connections being made above ceilings on the side of junction boxes.

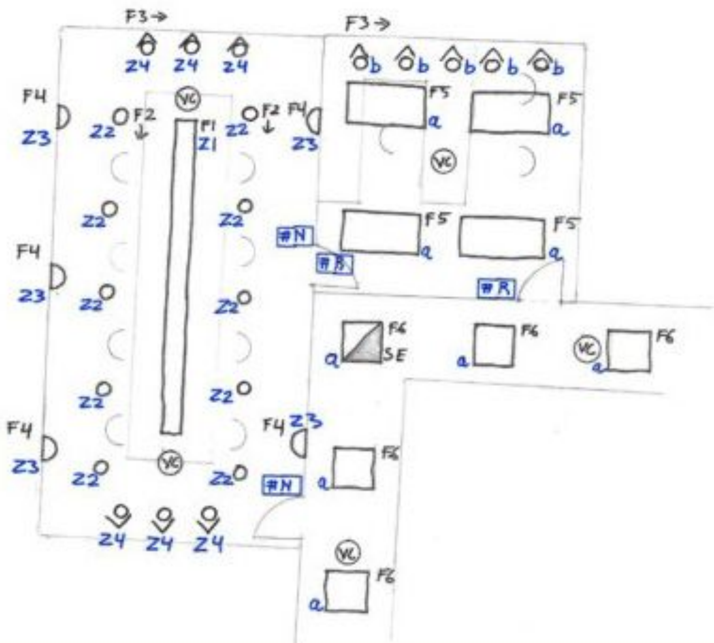


Figure 4: Sketch of the same multizone conference room except with delineation of a network control system where "Z#" is the subscript format used for zones and #N is used for network-based control stations. Courtesy: IMEG

The importance of system commissioning increases as the system complexity increases. Where projects are broken into phases or installation sequences, multiple programming periods may be required. Designers should include appropriate programming requirements, so that controls are fully functional for the final punch of each phase.

When addressable or network, such as DALI or IEC, control systems are specified, the number of programming iterations can also be specified. Because some clients may not be familiar with modern lighting control systems, it is prudent to specify on-site training for the client. It may be desirable to have a two- or three-month return trip included in the specifications to make adjustments to the control schemes based on user input. System complexity may warrant a service contract with the vendor.

Figure 5: Image of a low-voltage lighting control relay with cabling installed in a haphazard method where the duct and ceiling tile will put strain on the connections. Courtesy: IMEG

Labelling tends to be a weak point when specifying controls. It is not uncommon to see a bank of four or eight lighting switches without labels indicating what is being controlled. Button stations can include custom engraving to indicate operations or scene names. Designers should meet with users and the client to agree upon naming conventions so that the labels make sense to those using the space. While the labels visible to users indicate function, labels on the backside of covers can indicate the location of hubs and device addresses. As-built drawings can include field-installed locations where typical CAT 5E connections are being made, to reduce troubleshooting time in the future. It can be helpful to building owners and maintenance staff for lighting control hubs and connections to be consistently located in the building. One example would be to locate the addressable relays above the door inside each room.

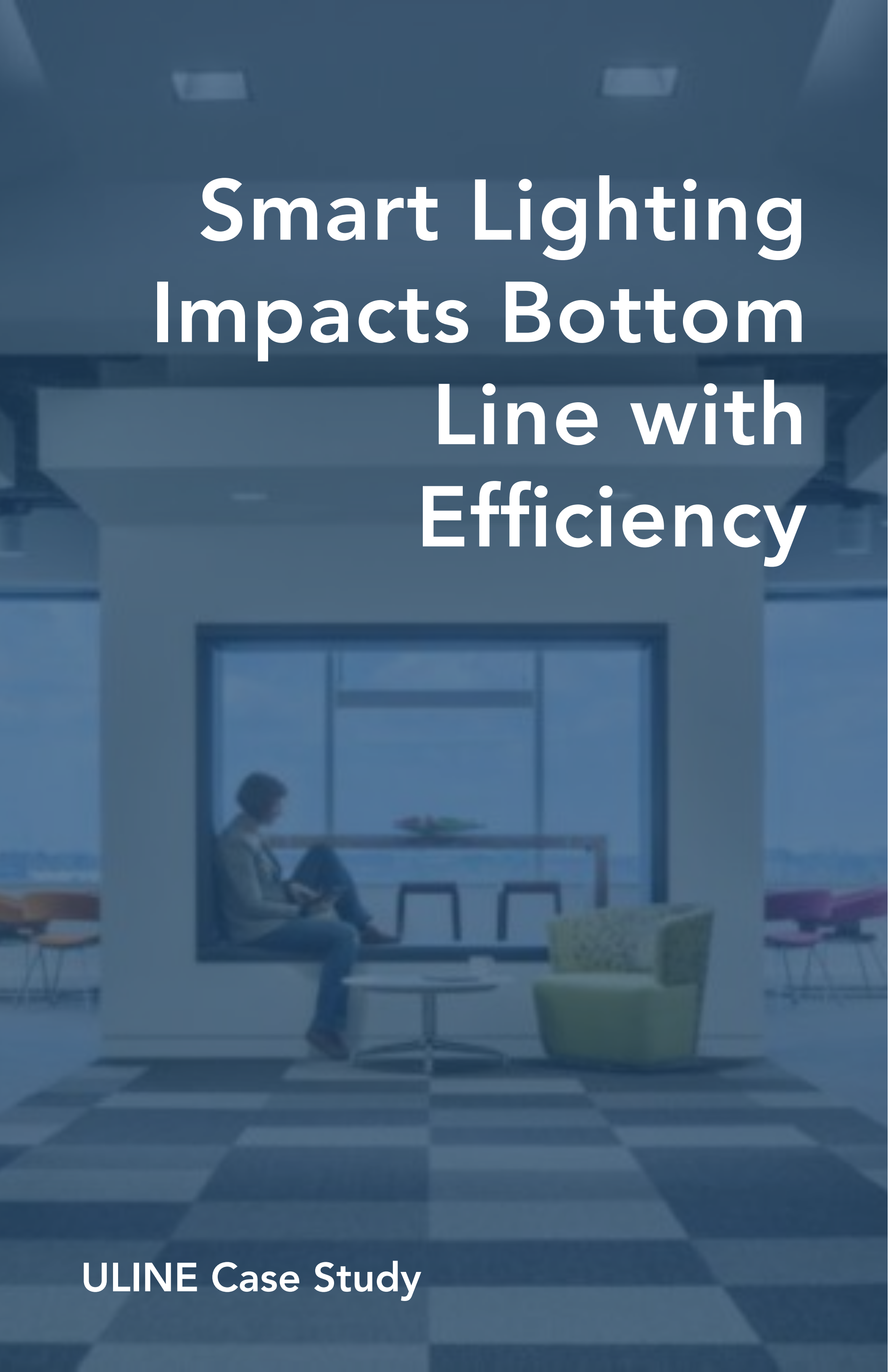
As systems continue to evolve, engineers and designers need to keep up with changing technology and ensure that the drawings and specifications reference what will be provided. Addressable lighting control symbology should reflect the system components available and the specific options and requirements should be coordinated with the client during design.

The type of lighting control system should be clarified and represented in the lighting sequences. Sequences should provide sufficient detail to allow for all required components to be determined by the vendor during bidding. Lastly, designers should coordinate with the client for labeling requirements and control zones.

Richard Vedvik

Richard Vedvik *is a senior electrical engineer and acoustics engineer at IMEG Corp. Vedvik has experience in the health care, education, commercial and government sectors. He is a member of the Consulting-Specifying Engineer editorial advisory board.*

Smart Lighting Impacts Bottom Line with Efficiency



ULINE Case Study

Discover how ULINE reduced energy use by 28% by implementing scheduling and controls strategies, met the stringent energy codes required by the state of Washington, standardized on SimplySnap for all new facilities, and met the performance requirements and successfully integrated with existing BMS system.

SITUATION

Uline is the leading distributor of shipping and packaging solutions to businesses throughout North America. Family-owned for over 40 years, Uline has built its brand on customer service. Order accuracy, quick delivery, and low prices are the core of their promise to their customers. With a robust, 800-page catalog and over 38,000 products, everything in their facilities is expected to contribute to this promise.

And by everything, that means each and every one of the warehouse's 3,014 lights.

Uline's director of Engineering, Mike McConnell, is tasked with finding efficiency wherever it may be hiding, and he understood the strategic importance of optimizing light to improve both operational and financial performance.

Uline needed the lighting at its facilities operating at its best - energy efficient, task tuned to enhance order accuracy and simple to operate. Mike wanted his team focused on moving product, not wrestling with technology. Each day, dozens of tractor trailers carrying tons of product are distributed from their 800,000 square foot Lacey, Washington facility. Uline identified a luminaire that best fit their facility's needs, but they had issues finding a reliable lighting controls provider that could deliver a solution at this scale to meet stringent energy codes and zoning requirements they needed. A few things were necessary: The lights in the entire facility had to operate as a single system with one interface, they had to adjust to natural lights from the skylights for daylight harvesting, and the technology needed to work with Uline's existing IT system.

> "Everything that we put into these buildings has to speak towards our passion and advance our mission, which is to get you the right product, as soon as we can, and at the best price we can offer."

MIKE MCCONNELL // Director of Engineering at Uline

The facility consisted of hundreds of aisles, each needing their own independent zone. Having all lights in each zone come on at once was paramount; a facility of this size houses thousands of individual luminaires, and instantaneous light for each zone was top priority. When you're operating at peak efficiency there are several literal tons of product that must get to customers on a daily basis, you've got to be able to see what's in front of you - not in 10 seconds, but right now.

Other providers offered a mix of wired and wireless systems that were complex and cumbersome. The wired systems were hard to install and maintain. The wireless solutions couldn't scale to meet the size of the facility and were slow. None of the other systems could meet Uline's IT requirements, nor deliver the desired user experience of the control system: It needed to be reliable, and it needed to be simple to operate. With mounting energy costs and a bustling workload, Uline needed the Washington facility's lights to light the way. Mike didn't have time (or energy) to waste on complex solutions that didn't deliver optimality.

> "We had the top three lighting control companies in here trying to do wireless mockups. We wanted them to come in and perform, and show us that we could bring these lights on together, and they failed miserably."
>
> *MIKE MCCONNELL // Director of Engineering at Uline*

SOLUTION

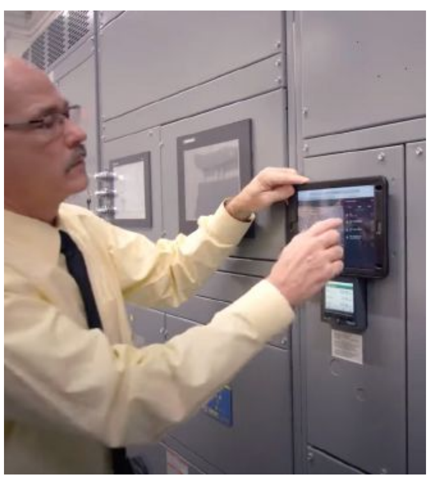
Synapse got to work on a smart lighting solution that would meet Uline's logistical needs and impact their bottom line.

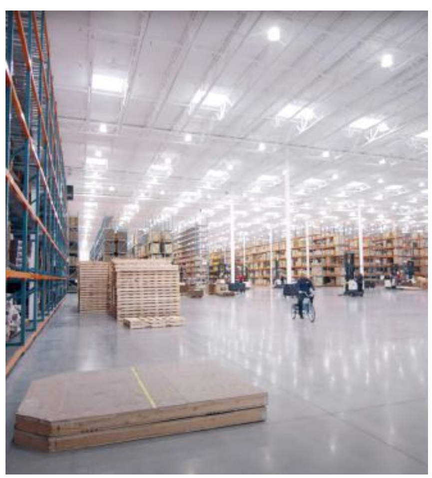
Smart Lighting Impacts Bottom Line with Efficiency

3,014 high-bay luminaires were installed at the Uline facility and then integrated with Synapse's SimplySnap wireless controls. SimplySnap, is a scalable wireless platform that can manage multiple locations and single sites up to 10,000 lights. It allows Uline to set up, control, monitor, and manage every light from a single user interface that integrates with Uline's existing building management system (BMS).

The high-bay lights respond instantly without delay (check) and are optimized through SimplySnap's precision controls and scheduling to respond to the natural lights from the warehouse's skylights and enable daylight harvesting (check).

The SimplySnap lighting solution comprises software and hardware components that are adaptable to multiple applications, providing reliable connectivity and control. Our lighting controllers use the secure, and robust Synapse SNAP® mesh network, providing a dependable solution that just works – as promised, all the time. The intuitive control and interface allowed for the creation of custom settings and schedules, which maximized Uline's savings while giving them complete control of each light, bank, and zone.





The SimplySnap system worked so well at the Lacey, Washington facility that it was chosen as the standard system for all of Uline's future deployments, including parking lots, signage and building lighting.

> "I walked him through setting up the configuration, and he [Mike] was up and running quickly, controlling the lights from his iPad."
>
> *ROB PADGETT // Field Engineer*

RESULTS

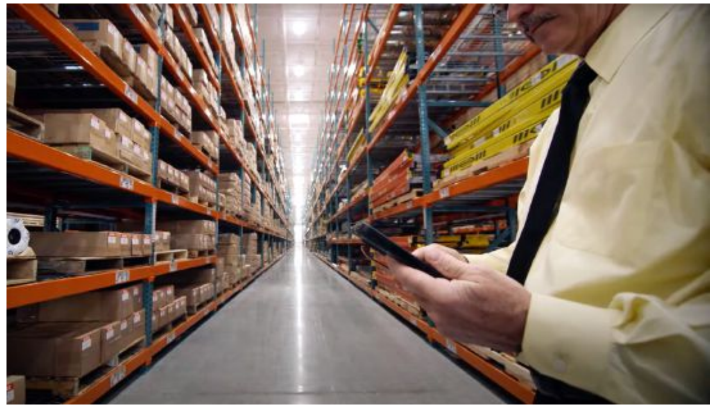
- **Reduced energy use by 28%** by implementing scheduling and controls strategies.
- **Met the stringent energy codes** required by the state of Washington
- Met the performance requirements and **successfully integrated with existing BMS system**
- **Standardized on SimplySnap** for all new facilities

The SimplySnap solution addressed each of Uline's needs seamlessly: it's cost effective, energy efficient, simple to use and provides a well-lit, optimal working environment for employees.

And that's not all:

The SimplySnap solution also meets the stringent Washington State Energy Codes.

OUTCOME

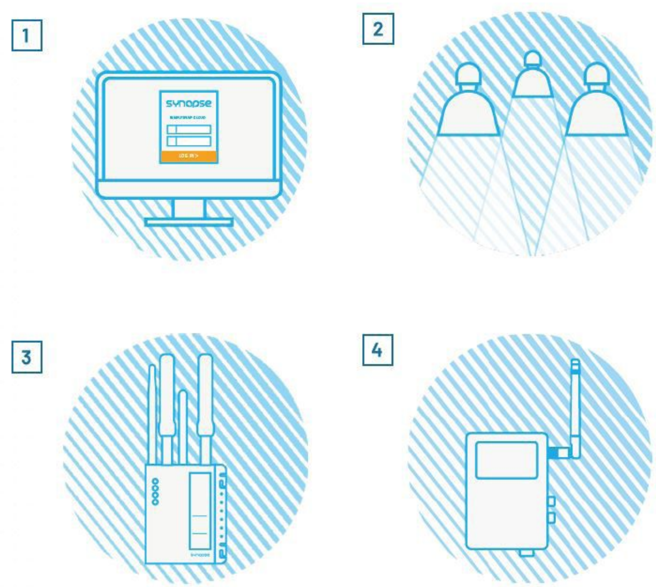


- 800,000 SQUARE FEET
- 3,014 LIGHTS
- 221 ZONES
- 563 MOTION SENSORS

BMS INTEGRATION
WASHINGTON ENERGY CODES: **MET**
1 MANAGEMENT PLATFORM - **SIMPLYSNAP**

SYNAPSE CONTROL PRODUCTS

1. SimplySnap
2. High-bay luminaire with embedded Synapse Controls
3. SS450 Site Controller
4. BMS Gateway



Visit **www.synapsewireless.com** to learn more or speak with one of our sales representatives

A guide to energy code compliance in lighting systems

Architecture, engineering and construction professionals must apply emerging technologies to satisfy the rigorous demands of energy codes while meeting their clients' operational goals and budgetary constraints

Since building energy codes were first released, the approach to efficiency has evolved to include lighting system control and design. As the design team determines which code is best for its project, it's important to understand how the codes developed to their current state, the nuances between each code and how different standards can impact lighting design.

The first official energy code began to take shape in the early 2000s. Code requirements were initially regarded as routine for project completion. Additionally, there were few significant updates for several years.

The building codes' progression toward energy efficiency accelerated in 2009, when different lighting power densities were established for different types of spaces and general on/off controls were mandated. Lighting technology had developed to provide more advanced control strategies and more light output with less energy input. In turn, the codes and standards progressed rapidly, transforming many professionals' design approach.

Lighting power densities have decreased as technology has advanced from incandescent lamps to LED technology. Daylight controls, as well as occupancy and vacancy controls, have become mandatory requirements in codes and standards; even considerations for skylights in certain types of spaces may be required to maximize natural daylight.

Today, ASHRAE and the International Energy Conservation Code set the standards for energy consumption in newly constructed buildings.

ASHRAE is a well-known entity that establishes globally accepted energy consumption standards. Around the world, ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings is used as a benchmark for setting minimum energy performance standards and energy codes, as well as minimum requirements for energy-efficient design. Compliance is performance-based, meaning that a building's energy consumption report must be data-driven, with calculations and analyses to support the results of efficiency efforts. Reporting energy data to code officials is voluntary in areas of the United States without an existing building energy code. However, owners, developers and investors could reduce a typical building's energy consumption by as much as 50% with ASHRAE's practices.

This standard provides minimum energy-efficiency requirements for designing and constructing new buildings and new additions to existing buildings, including new lighting system design and equipment. It also outlines how design teams and project partners can ensure compliance with various requirements. ASHRAE 90.1 is updated continually to address more efficient technologies and emergent research as quickly as possible. While this standard provides the framework for many codes in the U.S., ASHRAE's members are from over 132 different countries and their focus is on efficiency standards that can be applied around the world.

The IECC establishes baseline energy-efficiency standards for newly constructed projects. It addresses the design of walls, floors, ceilings, lighting, windows, duct leakage and more, in relation to energy efficiency. The IECC is sometimes referred to as the United States' "model energy code" because there is no federal energy-efficiency code.

As a U.S.-based organization, its aim is to provide guidance for states adopting building energy codes. Every three years, officials across the nation vote on changes to IECC standards to ensure that new projects incorporate the latest best practices, systems and technologies to meet the most up-to-date thresholds for safety and efficiency.

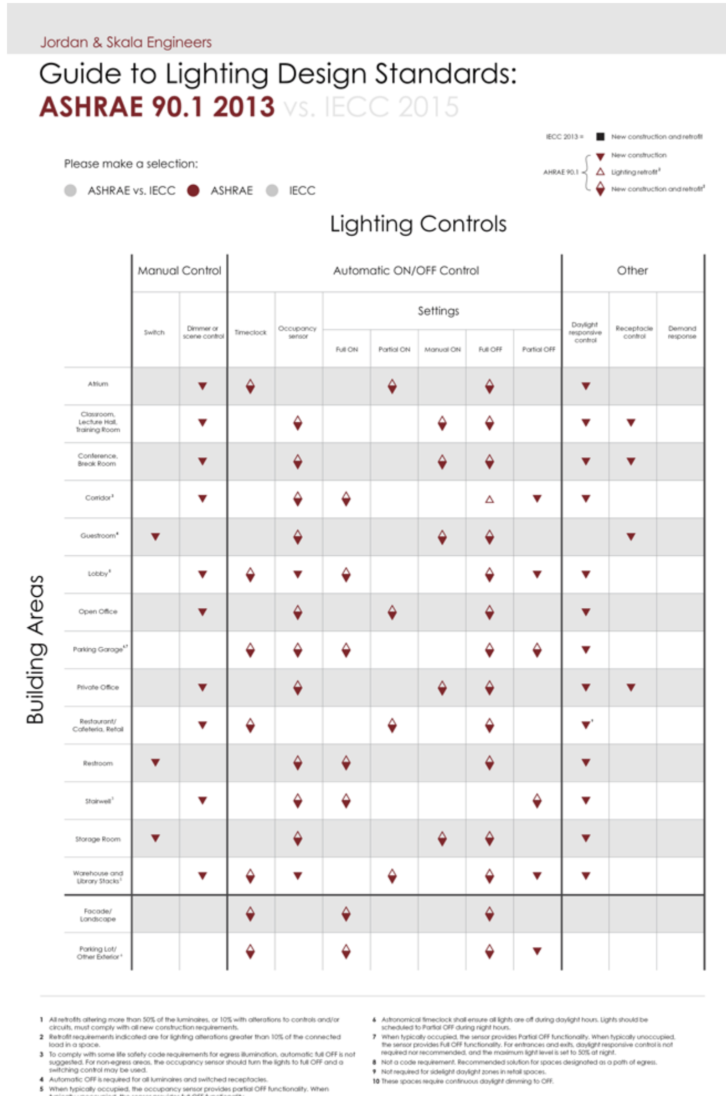
Comparing the standards

ASHRAE Standard 90.1 and the IECC address many aspects of building energy consumption, including energy efficiency in plumbing, building envelopes, insulation, roofs, heating, ventilation and air conditioning and more. Both standards represent pathways to achieving code-compliant lighting design and controls; however, one standard might not be appropriate for certain buildings.

The ASHRAE standard does not address low-rise residential buildings, like single-family homes, making the IECC the primary resource for such projects in the U.S. Additionally, while one engineer or design professional may have extensive experience with ASHRAE, another professional may adhere to the IECC.

Many owners and developers who build and sell assets quickly aim to keep first costs low; contrastingly, long-term asset holders may be more interested in energy savings over time. The "right" standard is the one that meets the objectives; the choice of which standard to use for a project should be based on the efficiency goals and the standard that will best achieve them, as neither is inherently better than the other.

Collaboration among project partners, owners, developers and investors is key when deciding which standard is most appropriate for a project. Building types and mechanical systems are often drivers when determining which standard will be more first-cost effective or which will better support long-term energy savings. For example, high-rise residential buildings in certain climates need specific mechanical systems; however, ASHRAE doesn't provide guidance for many of the equipment and systems that directly affect building occupants, including information technology equipment and elevators.



Architects, electrical engineers and other project partners should compare compliance avenues not only among each other, but with owners and developers. Understanding whether first costs or operating costs are most important, selecting the best compliance route and ensuring adherence to both priorities takes a team of experts.

A guide to lighting design standards featuring a comparative look between ASHRAE 90.1-2013 and IECC 2015. Courtesy: Jordan & Skala Engineers

The coordination, communication and extensive, detailed knowledge required to meet each need and objective warrants combined expertise across multiple disciplines. The same standard must be adhered to by project partners, including architects, during the planning and design phases, as well. If an architect begins a project using IECC standards, for instance, it's imperative that the engineer continues using the IECC. Otherwise, the building would be at risk of a code violation for combining ASHRAE Standard 90.1 and the IECC. Licensed professional engineers and sustainability experts can collaborate to help ensure that selected energy-efficient systems and equipment achieve code compliance and energy savings according to the priorities.

Lighting design and controls

Achieving code-compliant lighting power densities can be challenging without proper guidance. But collaborative, qualified professionals who understand the latest codes and the most effective technology can help meet project goals and code requirements.

In lighting design, "efficacy" is defined as the lumens per watt of a lighting fixture or luminaire, itself; the density is the number of watts per square foot allowed in a room based on the type of occupancy. Density requirements in building and electrical codes provide lighting control guidelines for different types of spaces, buildings, etc. They can involve controls for automatic shut-off, daylight responsiveness, bilevel switching (where alternate rows of light features or fixtures are independently controlled) and more.

The birth of LED technology was a significant step forward for lighting density standards. When it was first introduced, electrical codes decreased the allowable watts per square foot because LED made it possible to achieve better lighting with lower wattage. The density has been further reduced as LED technology has developed and become more common, as well as effective. Engineers and design professionals would be unable to meet current power density objectives using previous technologies, such as fluorescent, high-intensity discharge and incandescent lights, due to their high wattage.

Although residential units are exempt from lighting power density requirements, the IECC mandates that luminaires in these dwellings must meet a specific efficacy requirement; however, fluorescent and LED lighting easily help meet this requirement. The code drove innovation in the architecture, engineering and construction industry by providing incentives to manufacture and implement LED lighting, which has resulted in progress for density standards and, in turn, energy efficiency.

Lighting controls

Code requirements for lighting controls are critical components of lighting design. Once lights are designed to meet a certain wattage standard, lighting controls can be established to help ensure the optimal efficiency of lighting sensors, systems and more with automatic, timed-based settings.

Electrical codes have never had occupancy requirements to automatically turn lights on upon sensing activity, for example, but they do call for manual controls to turn lights on, as well as automatic controls to turn them off. It's unnecessary to have lights turn on automatically in response to activity, as windows often provide more than enough natural light to see indoors during the day.

However, there was previously a requirement for either an occupancy sensor or two switches near the entrance to a room: one to turn lights on at 50% brightness and the other to turn lights on at full brightness.

NFPA 70: National Electrical Code is the most widely adopted electrical code in the U.S., as well as several other countries. This set of regulations acts as the standard for electrical safety in residential and commercial buildings, including the latest requirements for electrical wiring safety, overcurrent protection and watts per square feet.

While they share some basic similarities, the NEC, ASHRAE and the IECC are inherently different. All are updated every three years and make modern guidelines widely available. Any of the three can also be implemented by any jurisdiction internationally. Contrastingly, ASHRAE and the IECC address building energy consumption, while the NEC is specific to safety standards for electrical systems and equipment. NEC takes precedence over both IECC and ASHRAE, as governing bodies can codify their standards, including energy standards to be enforced by the NEC.

Different methods can be used to incorporate effective lighting controls design.

- **Wireless:** The newest method, wireless systems involve a power pack installed on the line voltage circuit to provide power to luminaires. All controls are wireless, communicating with the power pack via a gateway that turns luminaires on/off and adjusts the fixtures' light levels. Wireless controls do not require an electrician to install wiring to each control device; however, they do contain batteries that eventually need to be replaced. These systems are easily modified, as the controls can be moved anywhere. Additional controls can easily be added with no wires involved, providing future scalability for the owner or developer.

- **Low-voltage:** Low-voltage lighting controls operate similarly to wireless controls, but with low-voltage cabling between the control device(s) and the power pack.

Once installed, relocating or adding devices can be difficult because of the wiring connections; however, these controls allow for customization of lighting control zones. Low-voltage wiring can also be installed by someone other than a licensed electrician, which can help reduce labor costs.

- **Line voltage:** Line-voltage lighting control is the longest-standing method and provides the basics required for lighting control. These systems connect to the line voltage of the lighting circuit and are not easily modified or adjusted once installed. All wiring for these systems must be installed by a licensed electrician.

However, guidelines for lighting control efficiency differ between ASHRAE and the IECC. For instance, the ASHRAE requirement for daylight responsiveness stipulates that lights within a certain number of feet from windows (typically 15 feet) must have sensors that automatically dim or brighten the artificial light according to how sunny it is outside. Versions of the IECC also require daylight responsive controls in spaces with more than 150 watts, based on the distance from the top fenestration height to the floor.

Regardless of which standard is selected, project partners across multiple disciplines (architecture, electrical engineering, etc.) must communicate to select and design around, the same standard. While adhering to one standard might save costs in some areas, it could have a different effect on another aspect of the project.

For example, if a project using ASHRAE includes a parking garage, it may trigger an immediate expense but lower long-term energy costs because recent versions of ASHRAE require automatic lighting controls in residential parking structures. Experienced electrical engineers, lighting designers and registered professional engineers collaborate with their clients to prioritize the standards and systems that meet owner and developer's goals for first costs, as well as operating expenses.

In addition to varying guidelines, lighting design can prove challenging because every product is different and the technology is proprietary. Occupancy sensors, for example, differ significantly by manufacturer. Including each sensor in computer-aided design or Autodesk Revit renderings can also make the design appear cluttered.

Experienced electrical engineers and design professionals can mitigate these issues by taking a matrix approach and by collaborating to ensure that appropriate products and systems are applied throughout planning and design. Rather than draw every component, a matrix approach relies primarily on equipment schedules that are based on the types of rooms or buildings, as well as the types of lighting devices. Once the schedules are drawn, the contractor can learn how to control the different types of rooms' lighting according to each type of device. ASHRAE and IECC standards can be just as nuanced as building code requirements, but skilled project partners can help navigate energy-efficient technologies to ensure compliance.

Green building programs

Today's energy code standards are on par with those set by green building programs. Building code updates have even standardized many sustainability initiatives that are not necessarily related to a specific energy program. As a result, green building programs are not as costly as they used to be, although there are nuances in each program's lighting standards.

Achieving both green building certification and energy code compliance may add another layer of complexity to a project. While some requirements overlap, different green programs can have different requirements, some of which might even seem more stringent than energy codes.

For example, the National Green Building Standard has 13 practices for multifamily lighting design and controls that address topics from induction cooktops to smart appliances; however, there are no similar practices provided by U.S. Green Building Council's LEED. While LEED does not require a certain percentage of light fixtures in residential spaces to be high efficiency, the NGBS does.

Experienced third-party sustainability consultants also help meet building envelope requirements. Recent versions of the IECC and ASHRAE order commissioning and/or testing of lighting and lighting controls. During a project's construction and final inspection, function testing is required to ensure that lighting and daylight controls were installed and operate as originally intended.

Energy-efficiency codes can also have prescriptive and performance specifications. The IECC and ASHRAE both include prescriptive specifications, which are energy-efficiency requirements that must be met. Performance specifications are based on energy modeling results and help determine whether a building in operation is meeting its efficiency objectives. How and when these specifications must be met are strategic decisions, best made by project partners who understand the owner or developer's goals. When each partner intentionally communicates with the others, they help ensure that they'll be the best stewards of the project's budget and their client's success.

The evolution of building energy codes provides multifamily owners, developers, and investors and with options to help maximize building efficiency and lower utility expenses. Each standard can differ significantly, however, in terms of their requirements and how they influence savings.

Tim Milam and Ross Bush

Tim Milam *is a Principal with Jordan & Skala Engineers. He led the firm's electrical discipline for more than two decades.* ***Ross Bush*** *is a Principal at Jordan & Skala Engineers. He brings more than 20 years of electrical design and leadership experience; he is the current leader of the firm's electrical discipline.*

Case study: Office building has daylighting, energy-efficient lighting

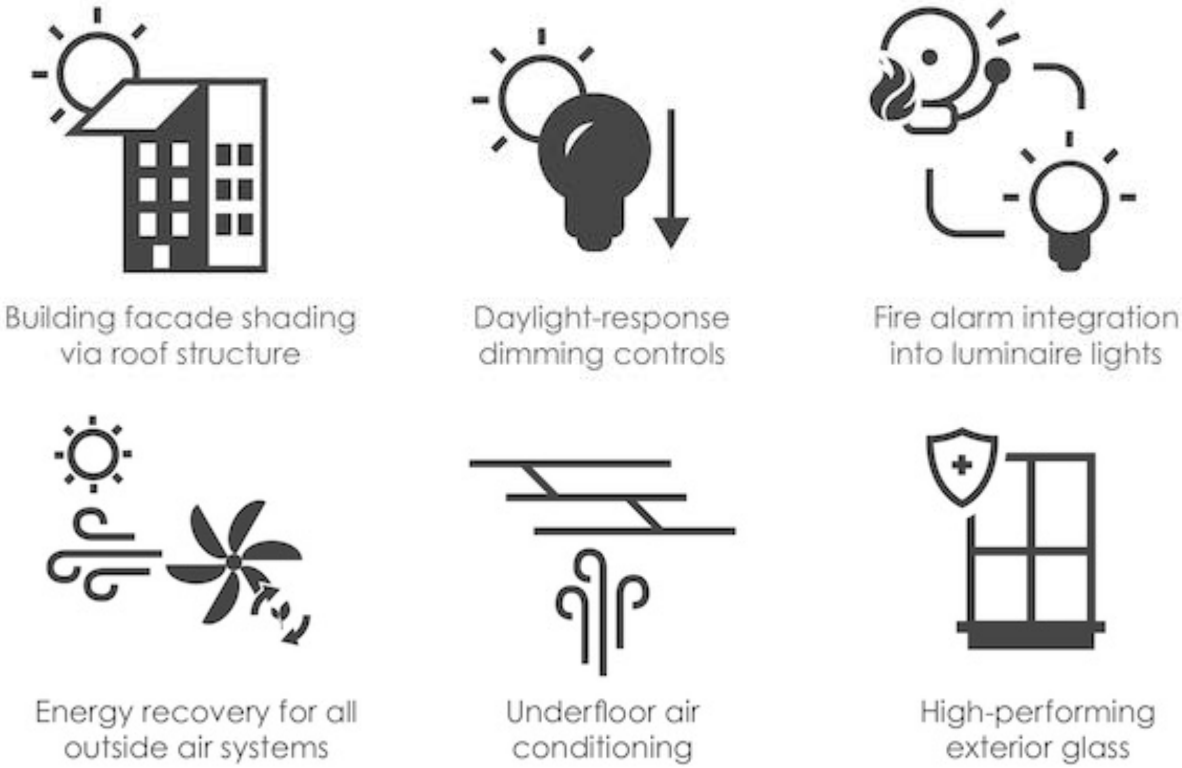
The PGA Tour Global Home was designed with a cohesive lighting design strategy in mind

Lighting design is a balancing act between ownership and energy consumption goals, municipal code requirements and budgetary restraints. These considerations become more intricate on commercial office developments, where occupant productivity and well-being, as well as spatial ambiance, also factor.

The Global Home of the PGA Tour offers a balanced example of cohesive lighting design strategy, energy efficiency and psychological considerations for tenants. The 187,000-square-foot, three-story building sits on a large freshwater lake in Ponte Vedra Beach, Florida, with a focused connection to the surrounding greenery and wetlands.

The new headquarters features an open layout design, with floor-to-ceiling windows and skylights that fill the space with natural light. According to design leader Foster + Partners, these elements of light, air and surrounding landscape enhance building occupants' well-being. The psychological and physical benefits are attributed to the principle, biophilia, which explores humans' innate connection and affinity toward nature.

With an eye on sustainability and its environmental footprint, the PGA Tour Global Home targeted U.S. Green Building Council LEED Gold certification for the project. The project was required to comply with the 2017 Florida Energy Conservation Code, which is modeled from the 2015 International Energy Conservation Code/2013 ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings.



Iconography reflecting three lighting design elements and strategies featured in the PGA Tour Global Home development that helped optimize the working environment. Courtesy: Jordan & Skala Engineers

Because LEED compliance is tilted toward ASHRAE criteria, the team set forth to meet LEED benchmarks per the ASHRAE 90.1 path. To achieve the rigorous requirements of this path and to meet the ownership's goals for innovation, the building's design features include:

- Energy recovery for all outdoor air systems.
- Underfloor air conditioning to maximize the effectiveness of air distribution.

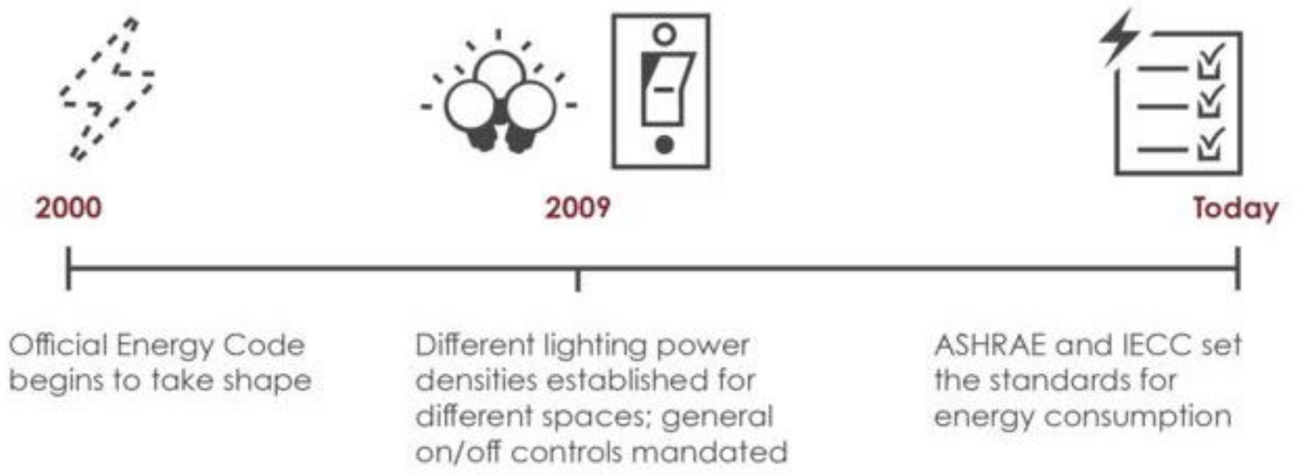
Iconography reflecting three building design elements featured in the PGA Tour Global Home that moved the development towards its sustainability goals. Courtesy: Jordan & Skala Engineers

- High-performing exterior glass.
- Building facade shading via the roof structure.

Lighting design elements

Lighting design is the core of the building's energy efficiency and its optimized working environment. The strategies used include:

- Daylight-responsive dimming controls along building fenestration.
- Fire alarm integration for emergency activation of luminaires to full brightness.
- Zoning of lighting controls, based on group/task illumination requirements.
- Energy reduction for enclosed offices by using occupancy sensors for 50% lighting power and switched receptacles.



Iconography reflecting three building design elements featured in the PGA Tour Global Home that moved the development towards its sustainability goals. Courtesy: Jordan & Skala Engineers

- Occupancy sensors on outdoor pole lighting that reduce to 50% lighting power during inactive periods.

The PGA Tour Global Home showcases lighting design as a vital consideration for developments. It seamlessly integrates tangible aspects, such as costs and codes, with intangible elements, such as morale, productivity and well-being. Owners, Developers and other architecture, engineering and construction design professionals must consider consultants who understand this importance and are highly experienced with lighting design best practices, code requirements and actionable next steps.

Tim Milam and Ross Bush

Tim Milam *is a Principal with Jordan & Skala Engineers. He led the firm's electrical discipline for more than two decades.* ***Ross Bush*** *is a Principal at Jordan & Skala Engineers. He brings more than 20 years of electrical design and leadership experience; he is the current leader of the firm's electrical discipline.*

The future of lighting design with Robert White

Illuminart's Robert White shares insights about lighting design trends.

Lighting design in commercial buildings has many elements, which are deliberated in this conversation with Robert White. From LEDs to ultraviolet lights to combat COVID to lighting controls, the future of lighting design is discussed.

Robert White is a principal with Illuminart, a division of Peter Basso Associates, based in Troy, Michigan. White has been creating innovative lighting design solutions for more than 30 years. He's an award-winning lighting designer, and also teaches lighting design at several Michigan colleges. Peter Basso Associates is a CFE Media content partner.

Amara Rozgus
***Amara** is the Editor-in-Chief/Content Strategy Leader for Consulting-Specifying Engineer.*

Content Archive

2021 Winter Edition

2021 Fall Edition

2021 Summer Edition

2021 Spring Edition

Lighting & Lighting Controls

Thank you for visiting the Lighting & Lighting Controls eBook!

If you have any questions or feedback about the contents in this eBook, please contact CFE Media at *customerservice@cfemedia.com*

We would love to hear from you!