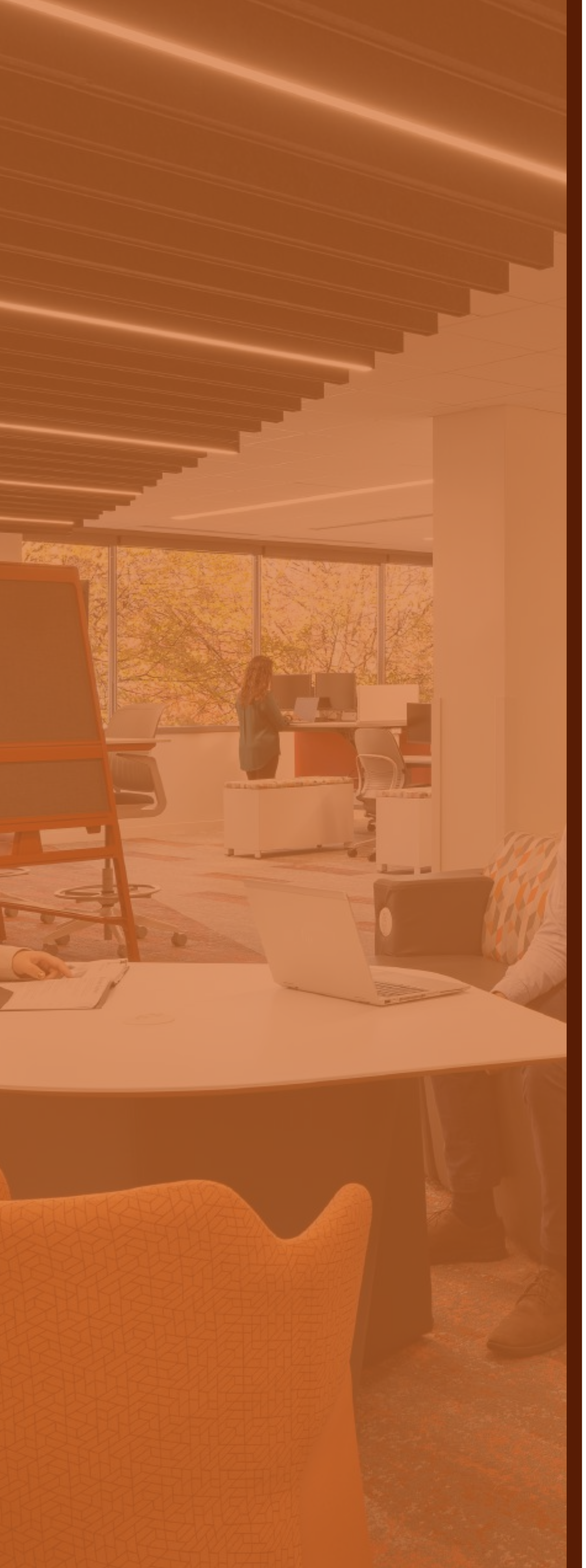
SUMMER EDITION

Lighting & Lighting Controls

CONSULTING - SPECIFYING engineer eBOOK

LUTRON



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Lighting efficiency – More than LEDs alone

As we become more energy efficient, lighting design is a great place to start in the built environment

LED technology has increased efficacy of luminaires resulting in less energy being used to light buildings, however it is not enough to assume that simply using LED technology means that you are producing energy efficient and code compliant designs. Recent code updates have dramatically reduced the permitted connected lighting loads in response to improved equipment capabilities. Between 2016 and 2019, ASHRAE Standard 90.1, energy standard for sites and buildings except low-rise residential buildings, reduced permitted lighting power densities between 14% and 25%, the largest decrease since fluorescent technology replaced incandescent. Lighting efficiency is about more than using LED technology and calculating. This article has been peer-reviewed. Lighting power density. To embrace our quest for net zero and to reduce our energy footprint, we need to provide lighting designs that are both thoughtful and intentional. Lighting design should always involve three steps:

1. Understand task and ambient illumination needs, as well as meeting any codes and standards that apply

2. Specify lighting controls that work with the luminaires and with the occupants.

3. Specify lighting equipment that is suitable for the environment and can be easily maintained or recycled.

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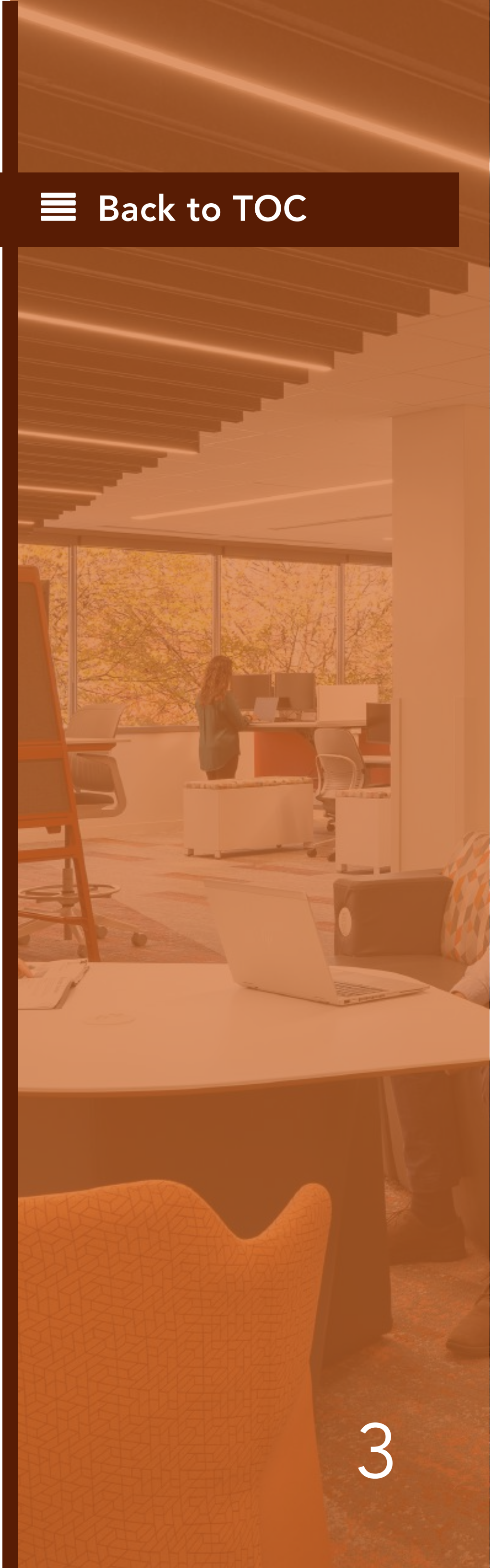

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Figure 1: This shows an example of laboratory lighting that is aligned with the edge of bench eliminating the need for undershelf task lights and luminaires located in the circulation corridor. Courtesy: HDR

The first fundamental approach to providing lighting efficient designs is using a task-ambient design approach. Task-ambient design starts by identifying what tasks will be performed, and if those tasks are limited to select areas of a room or occur throughout the room. Often, high-performance tasks that require higher illumination levels are contained to an area that is smaller than the entire room. Instead of illuminat-

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ing the entire room to the higher illumination level needed for one task, energy can be saved if the higher illumination need is applied only to task performance areas.

Task-ambient designs can also be achieved using nonuniform fixture selections and placements, or through smaller dimmable control zones. Gone are the days of continuous arrays of recessed troffers applied throughout all spaces. Perhaps, the most easily identified example of task-ambient design is seen in laboratories. Laboratory workbenches and shelving require higher and more uniform illumination than corridors and aisleways; often having fixed locations with sinks, gas accessibility and utility connections. Laboratory workbenches typically have luminaires located over the edge to mitigate shadows. This lighting layout that produces 80-100 footcandles at 36 inches above finished floor on the benchtop, will typically produce 10-30 fc in the aisleways without the need for any additional fixtures in the aisles.

Even though these are generally sold as flexible work environments, task-ambient designs should also be used in open office spaces, with desktops spread uniformly through a space. The lighting is often much more uniform, yet like laboratories, these office spaces will sometimes have defined circulation zones, in which the same design approach may be taken. There is also a second layer to the task-ambient approach that is generally applied to open office lighting. This approach provides supplemental task lighting to give the occupant the ability to increase illumination for task specific needs, that are not the dominant task conducted. The majority of office tasks today are computer based, which has lowered the recommended illumination level from 50 fc at 30 inches aff to 30 fc at 30 inches aff. This does not mean that paper-based tasks no longer occur; however, the illumination needs for paper-based tasks are more limited, sporadic and best addressed through task lights that can be individually controlled as needed.

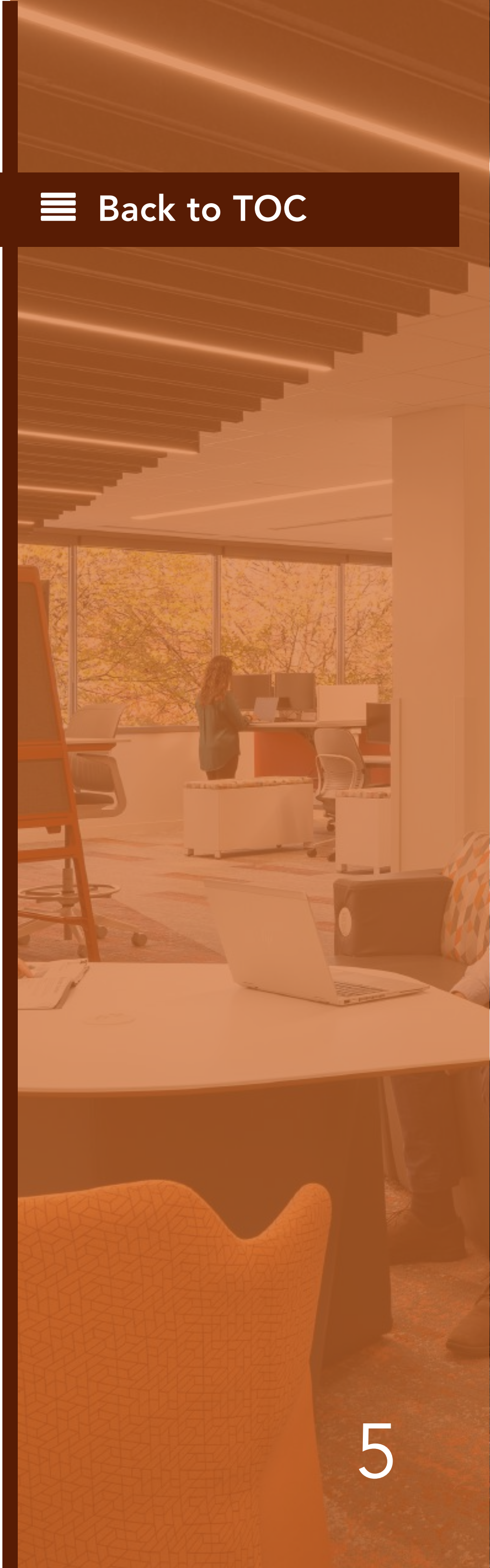

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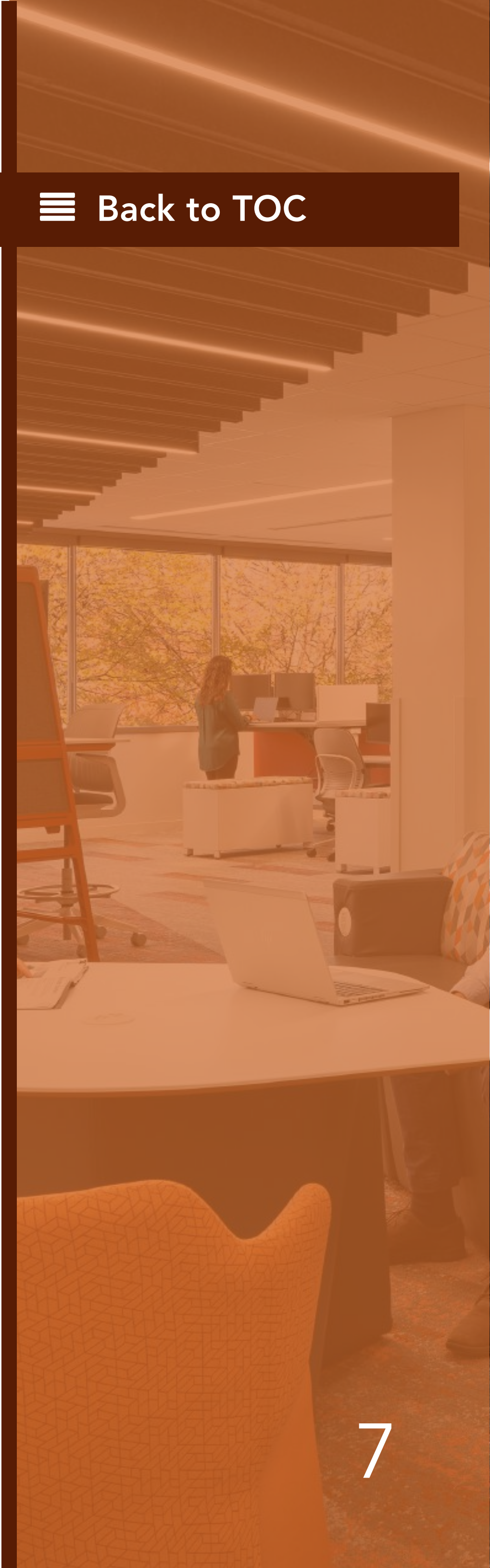
Figure 2: This shows an example of open office lighting that locates the luminaires over the work zone only, leaving the corridor free of unnecessary additional fixtures. Courtesy: HDR

This also means that these fixtures should not be occupancy sensor controlled, turning on simply because someone is sitting in their chair. The best way to control these task lights are via dimmable vacancy sensors. The person who needs additional illumination must manually turn the light on and is able to adjust to their specific need. However, if they forget to turn off and leave their desk area, the light will automatically turn off. It is important to note that several European standards still require offices to be



illuminated with 500 lux; if you are designing to these standards, there is no need for supplemental task lighting.

Understanding the recommended illumination needs for each space is fundamental to providing not only functional, yet energy efficient lighting layouts. Investigate if there are any corporate standards or industry standards related to lighting that must be followed. The Illuminating Engineering Society offers many recommended practices for specialty building types and provides guidance for common applications and exteriors. In these American National Standards Institute approved documents produced by the IES, the illumination tables provide recommendations for both rooms and tasks. When reviewing, be sure to take your time and read the tables – including footnotes. Understand how building occupants plan to utilize the rooms. Is the equipment fixed or is it flexible? Lighting designs tailored to space utilization and visual performance needs will not only conserve energy, this approach will also enhance occupant comfort. Quality lighting must balance brightness and uniformity within visual task areas to avoid an environment that causes eyestrain and fatigue (see Figure 2).

Taking time to understand space utilization within the built environment is instrumental for the second energy conservation design approach – lighting controls. Lighting controls offer the largest opportunity for energy savings. Lighting controls are also the most difficult and overlooked aspect of lighting construction documentation. Due to the plethora of driver types, control protocols, proprietary addressable systems and lack of standardized componentry with LED technology and the associated control devices and systems, it is next to impossible to document a fully detailed control riser, device placement and competitive bid specification identifying all apparatuses.

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If you rely on manufacturers or manufacturer reps to prepare your control specifications and wiring diagrams, you should realize that you are providing a proprietary bid package. The most effective method to offer a competitive bid package is to provide a performance specification. This requires clear communication of all critical components and how the system is to function. Remember to coordinate and communicate any interconnections with other building systems, such as the mechanical building automation system and audio-visual systems. This involves differentiating between primary triggers and overrides, which cannot be achieved simply by showing control devices on a plan. The most effective way to communicate performance is through schedules and verbiage – a written sequence of operation for each control zone.

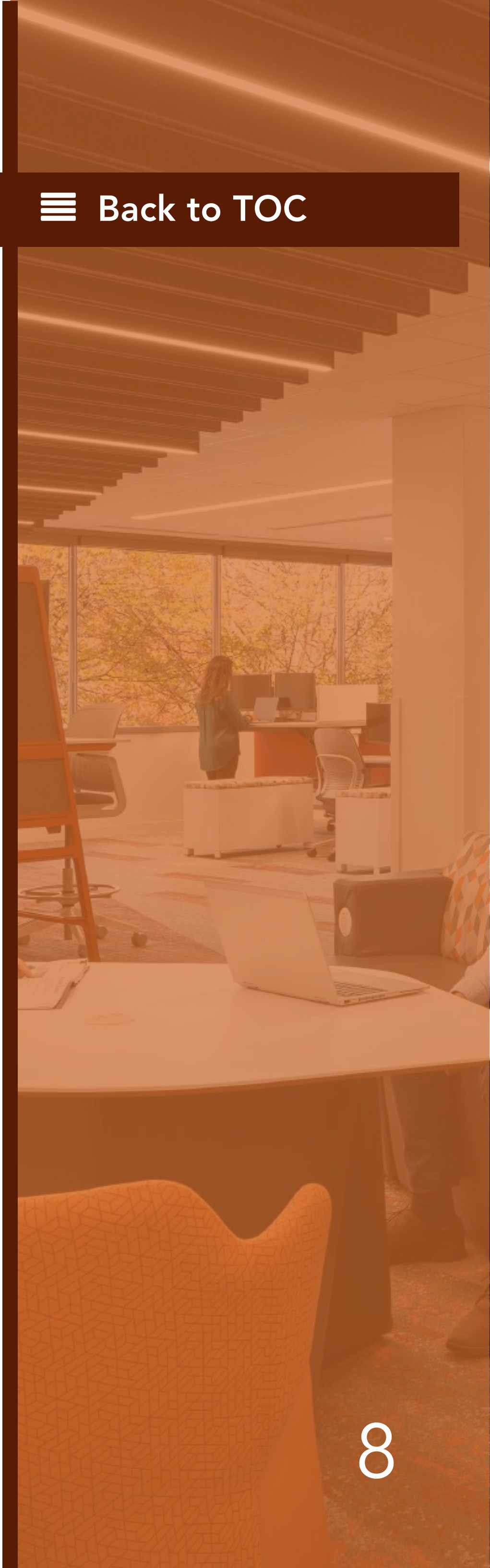
For instance, "occupancy sensor turns lights on and off; daylight harvesting photocell overrides intensity maintaining 30 fc on desktops." The way each and every luminaire is controlled is integral to a lighting design, and every professional lighting designer should develop a documentation system that clearly communicates how each luminaire is controlled. Lighting controls must be understood by multiple project team members, not just the electrical contractor who needs to install them.

1. Clients

Lighting controls should be presented alongside lighting designs for client buy-in. This is often the best time to seek client feedback for how they intend to utilize the space. If the end user does not understand how the system is designed to work and what adjustability it has; the system will not be fully utilized at its optimum.

2. Electrical engineers

The electrical engineer will need to understand the lighting controls to assure the circuit-



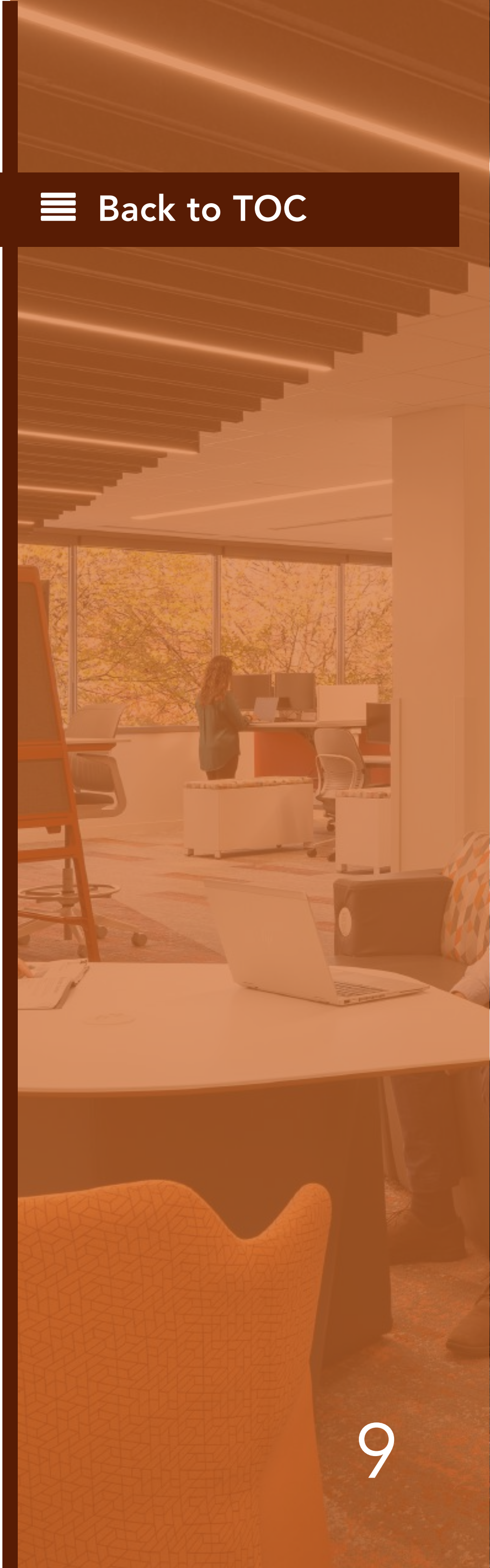
ing is aligned with the control zones and how the emergency lights are controlled. If the lighting designer specifies control zones, these are groupings of luminaires that all act together. One zone may be comprised of one or more relay. One circuit may feed multiple relays, yet one relay cannot be fed from multiple circuits. When emergency lights are controlled, there are typically two methods that can be used and must always be UL924 compliant. One method control uses a UL924 compliant transfer device that switches the luminaire from a normal circuit to an emergency circuit. Another type of UL924 compliant switching device senses the unswitched normal circuit, and when this transmits down the control signals are bypassed leaving the emergency circuit on.

3. Control manufacturer/reps

The vendor must understand the desired performance of the lighting control system, the approved luminaire driver types, and the reflected ceiling plans in order to provide accurate pricing and shop drawings. Field programmable systems often include a field technician who travels to the job site to program and startup the system. This technician is often not the person who curates the shop drawing submittals; however, the technician will be relying on the shop drawings during field startup. Therefore, it is important that the sequence of operation provided in bid documents is reiterated and thoroughly examined during the shop drawing submittal and review process.

4. Commissioning agents

The commissioning agent will need to understand how the system is meant to perform under all conditions. This understanding allows them to establish proper testing methods to assure the system is functioning as designed before owner occupancy and training.



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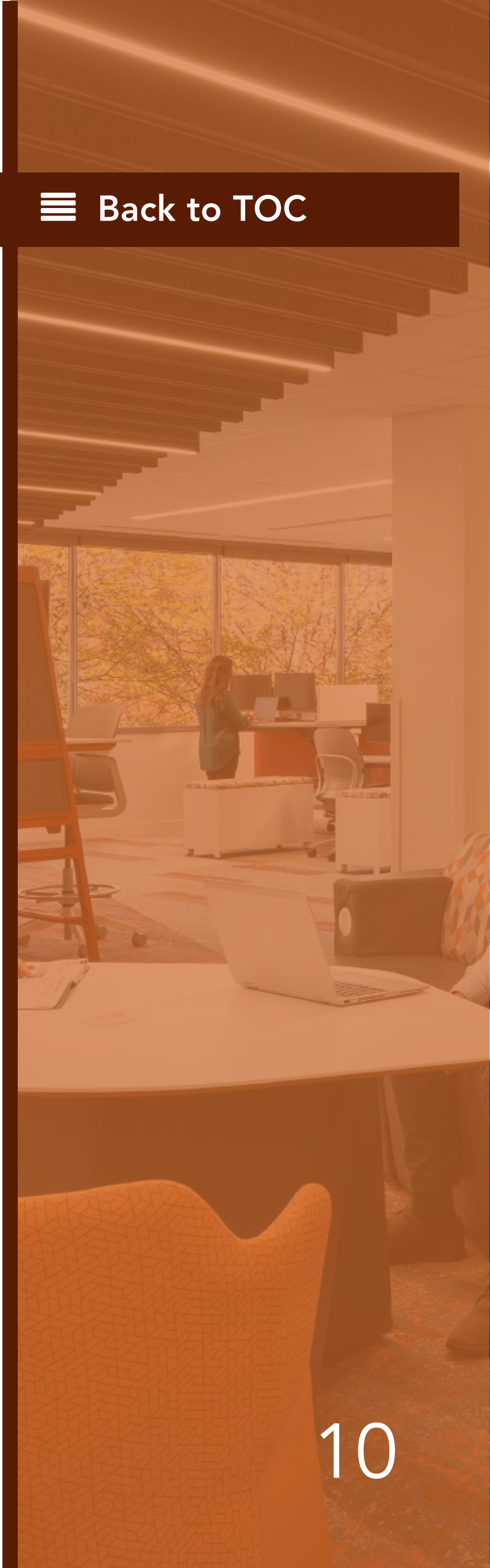
LOW VOLTAGE LIGHTING CONTROL SCHEDULE PART 1

CONTROL ZONE		SPACE: NUMBER	SEQUENCE OF OPERATIONS
Z1N1	Exterior Canopy		Photocell on/off (20fc)
Z1N1E	Exterior Canopy		Photocell on/off (20fc)
Z1W1	Corridor		5am-10pm light ON with Photocell override to maintain 10fc; 10pm-5am Oc Sensor enabed for 100% "on" and 50% dim "off" (10 min delay)
Z1W1E			5am-10pm light ON with Photocell override to maintain 10fc; 10pm-5am Oc Sensor enabed for 100% "on" and 50% dim "off" (10 min delay)
Z1W2	Corridor	D1-99A	5am-10pm 100% on; 10pm-5am Oc Sensor enabled for 100% "on" and 50% dim "off" (10min delay)
Z1W2E	Corridor	D1-99A	100% on; 9pm-5am Oc Sensor enabled for 100% "on" and 50% dim "off" (10min delay)
Z1W3	Corridor	D1-99A	Photocell dims (10fc); 9pm-5am Oc Sensor enabed for 100% "on" and 50% dim "off" (10 min delay)
Z1W3E	Corridor	D1-99A	Photocell dims (10fc); 9pm-5am Oc Sensor enabed for 100% "on" and 50% dim "off" (10 min delay)
Z1W4	WS		Oc Sensor on/off (20min delay) with photocell dimming (40fc)
Z1W5	Office	D1-010	Oc Sensor on/off (20min delay) with photocell dimming (40fc)
Z1W6	Office	D1-009	Oc Sensor on/off (20min delay) with photocell dimming (40fc)
Z1W7	Office	D1-008	Oc Sensor on/off (20min delay) with photocell dimming (40fc)
Z1W8	Lounge, STF	D1-001	Dimming Sw on @50%/off with full range dimming and photocell override to maintain 20fc; Oc Sensor override "off"

Figure 3: This shows an example of a portion of a control schedule identifying the sequence of operations for a lighting control system that appears on construction documentation. Courtesy: HDR

Understanding and respecting the important role that each member plays in the process helps guide the production of clear and concise constructions documentation.

Understanding luminaire construction is also important when balancing luminaire efficacy and performance. For instance, a luminaire without a lens will produce more delivered lumens per watt than a luminaire without a lens. That does not mean that luminaires without lenses should be used. LED modules are very bright point sources that are not comfortable for di-



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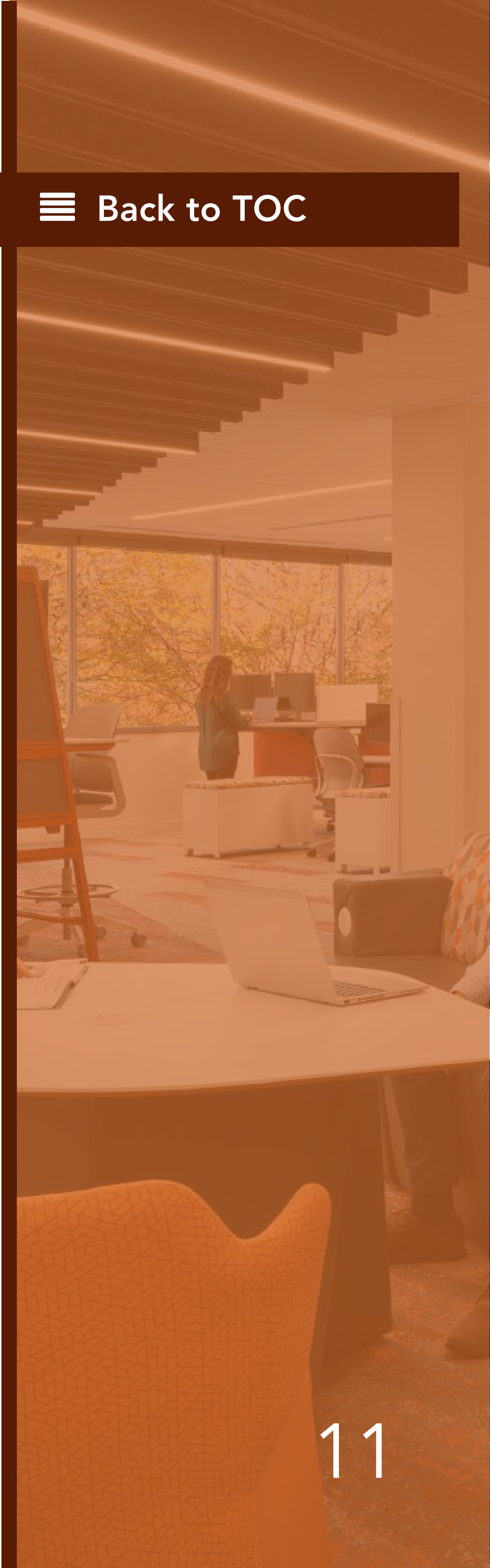
rect viewing. If you need to close your eyes to be comfortable, it does not matter how much more efficient the luminaire is – it is not working effectively. An indirect fixture used where no occupant will have a direct view may not need a lens to prevent glare yet may require a lens in order to create a batwing distribution for more even illumination with fewer fixtures. This also does not mean that only fixtures with lenses should be used. There are other ways to conceal direct views and improve photometric distribution through housing, reflectors and even the LED array design.

As we look to increase lighting efficiency and decrease our carbon footprint, it is also important to keep life cycle efficiency in mind. Can the driver and LED arrays be field replaced, or is a whole new fixture needed when it reaches end of life? LEDs do not last forever. They will produce less light over time and need to be replaced. The published life for LED performance luminaires is when these are expected to dim to 70% of their initial delivered lumens, while the published life for LED decorative luminaires is when these are expected to dim to 50% of their initial delivered lumens. Lighting maintenance impacts our carbon footprint, making this important to specify luminaires that are suitable for the environments the products are placed within. Temperature extremes, water, vibration and impacts can all shorten the expected life of luminaires that are not designed for these conditions. It will not matter if the luminaire has field serviceable LEDs and drivers if the luminaire, itself, does not last long enough to be serviced. Reducing facility maintenance makes for happy clients and a happy planet.

Karen Murphy

Karen Murphy, *LC, IALD, LEED AP, is the Director of Lighting Design at HDR. With more than 30 years of experience as a lighting designer, Murphy provides lighting solutions that support visual performance, enhance design concepts, promote energy efficiency and respects operation and maintenance concerns.*



An Engineer's Guide to Luminaire Level Lighting Control

It is hard to overstate the impact of LED lighting. Over the last 20 years, LEDs became the standard for commercial luminaires, with several U.S. states and Canada recently enacting regulations that effectively ban the use of older fluorescent lamps. As LEDs have made lighting smarter and increasingly efficient, the systems that control them have also become more capable and versatile.

Now, digital, flexible LED control solutions give engineers, lighting designers, and end users almost unlimited opportunities to specify lighting systems that support changing energy codes, accommodate budget constraints, and interpret client control requirements on each project. And, control options scale easily, offering both zone-based control for large, open areas and individual fixture control for enhanced capability, comfort, and design freedom. While wired, fixture-level control has been possible for more than a decade, wireless technology now puts individual fixture-control well within reach for most projects from both budgetary and scheduling perspectives.

Smart, connected Luminaire Level Lighting Controls (LLLCs) magnify the power of LEDs, integrating the benefits of a large, networked control system directly into the individual LED fixtures. The technology helps redefine the way we think about lighting control in applications from a

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small office space to classrooms, retail stores, boutique hotels, conference rooms and large, multi-use commercial buildings.

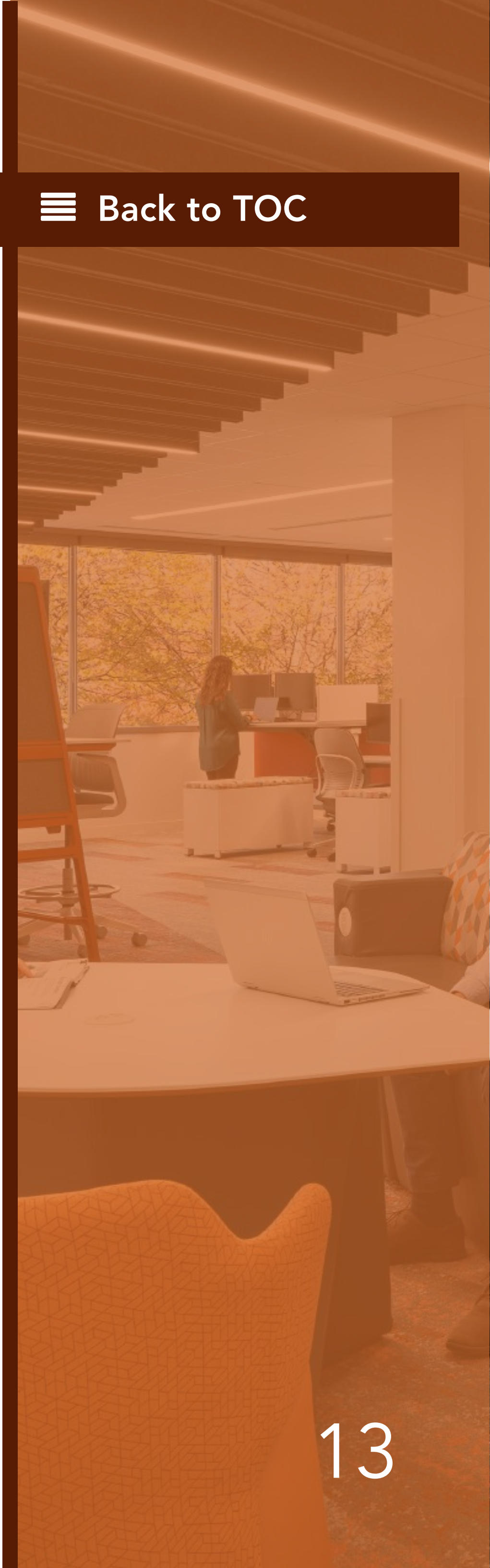
By ensuring the lighting system design can adapt and evolve to accommodate changes during and post construction – even when the system is fully programmed – LLLCs help make the project engineer's job easier and less risky. This versatility is equally important to the owner and tenant who can now use fixture-level occupant data to improve the comfort, efficiency, and even value of their space.

What is Luminaire Level Lighting Control?

LLLCs are wireless devices integrated directly into a lighting fixture, typically by the fixture manufacturer. Equipped with this device, the fixture can be individually controlled or digitally grouped together to create lighting zones that meet the specified design vision and specific customer needs – all without requiring unique, zone-by-zone wiring schemes. LLLCs put advanced intelligence in the fixture, making the lighting system more amenable to changes pre-, during, and post-construction.

The ultra-small, Lutron Athena wireless node is an individual, wireless fixture control engineered to fit a standard fixture knockout; it allows you to adjust light settings by fixture, zone, or a combination of both. Photo courtesy of Lutron Electronics

Depending on the specified fixture, occupancy sensors and daylight sensors can be designed directly into the LLLC device, or the fixture can



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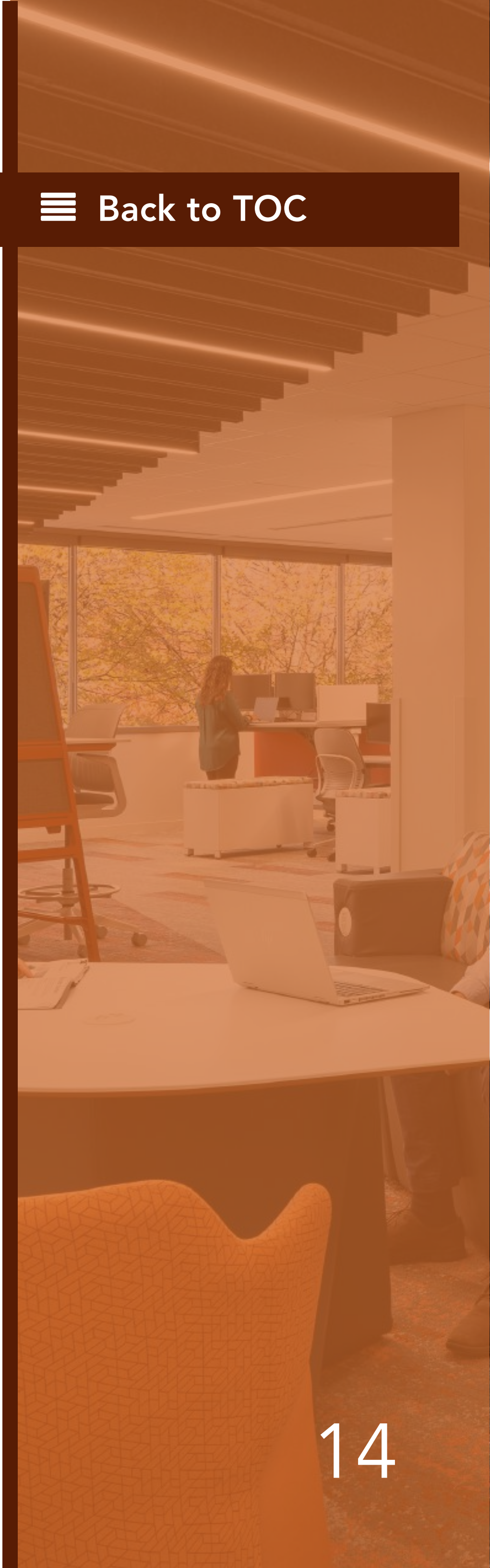
communicate with system sensors in each building area or zone to automatically adjust lighting in response to sensor data. System software can then use that data to help the facilities team manage energy use, make the most of natural daylight in a space, and inform building management decisions.

LLLCs offer benefits at every stage of a project, starting with system design.

The granular control provided by LLLCs simplifies system design. For example, exact zone configurations, lighting scenes, and even control locations are often not available in the early stages of project design. With control at each fixture, engineers can design the system with less up-front information and still be confident the lighting will meet customer needs, even when they inevitably change their minds or rethink space design and layout. Design is almost as easy as counting the number of fixtures on the project.

Lighting levels, scenes, and zones can be fine-tuned at any time without impacting the original system specification, budget, or timeline. Additional lighting zones can be added at the last minute with no risk to the project schedule, and no surprise wiring costs or other lighting system complications. There are significant benefits for the building owner or tenant since LLLCs expand design options, and can provide valuable, fixture-level data to improve the quality, comfort, and efficiency of their building.

Fixture-level control supports code compliance and helps lower energy use while ensuring space occupants won't be left in the dark. Occupancy and daylight sensors facilitate energy-efficient design without the additional overhead of separate sensors on the project, and lighting can automatically be turned off or dimmed when it is not in use.



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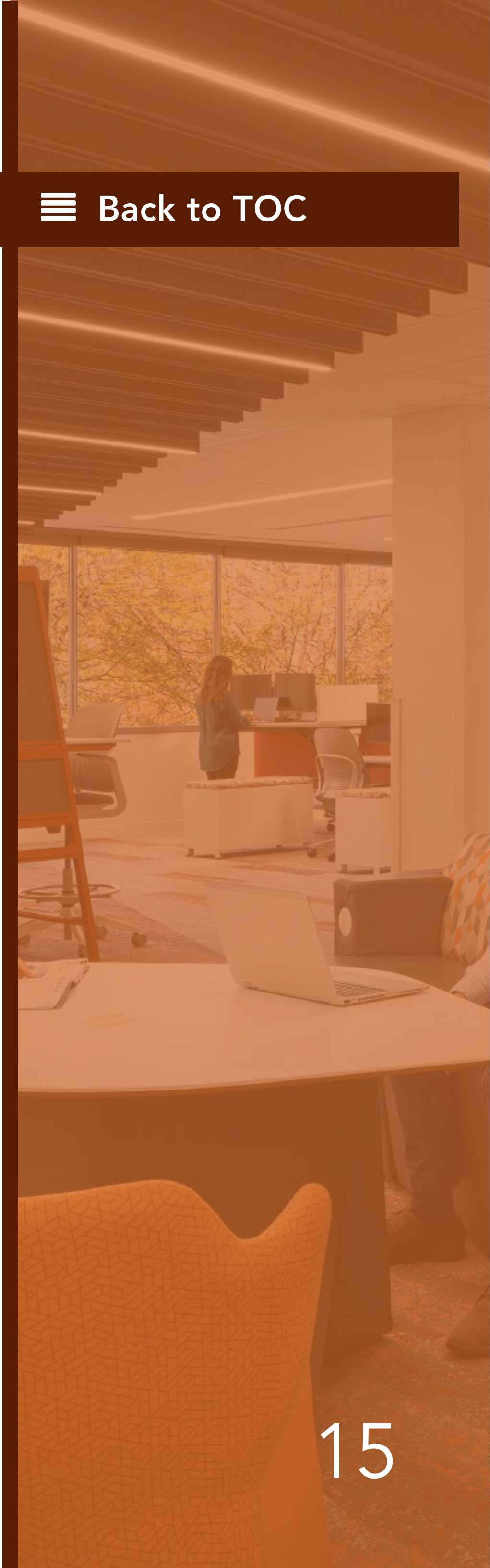
Improved light quality makes a space more comfortable and may help boost productivity. By specifying high-performance LED sources and controls, color temperature and light intensity can be precisely specified for each project, making it easier to put the right light, in the right space, at the right time, and over the life of the building.

Specifying LLLCs Solutions – Wired and Wireless Options

To some extent, all lighting control systems are wired; power must be delivered to the fixtures via line voltage wiring. Wired LLLCs solutions that use low voltage wiring to each control have been possible for more than a decade with technologies such as DALI, and some engineers still consider this the go-to spec for new building construction. However, a traditional, panel-based system is often impractical for retrofits or renovations and is typically more costly in either scenario due to more wire runs back to the electrical closet.

Compared to wired options, wireless lighting control is more flexible and less expensive, putting adjustable, smart control well within reach of most projects. Power wiring is required only to fixtures. Controls communicate to each other, and to the master controller, via over-the-air radio frequency signals – no wiring necessary, and with some manufacturers' systems you won't even need to take up coveted electrical closet space.

System security and signal strength/interference are the most commonly cited reasons for specifiers placing their trust in wired systems. Some clients are more comfortable with the perceived confidence in connectivity, responsiveness, and security provided by the low voltage wiring between the fixtures and controls, but wireless technologies have largely overcome these objections.



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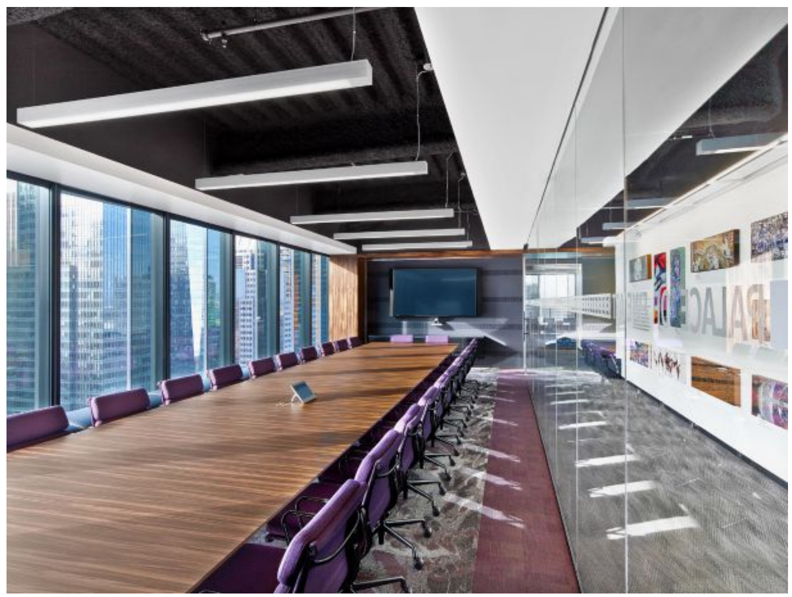
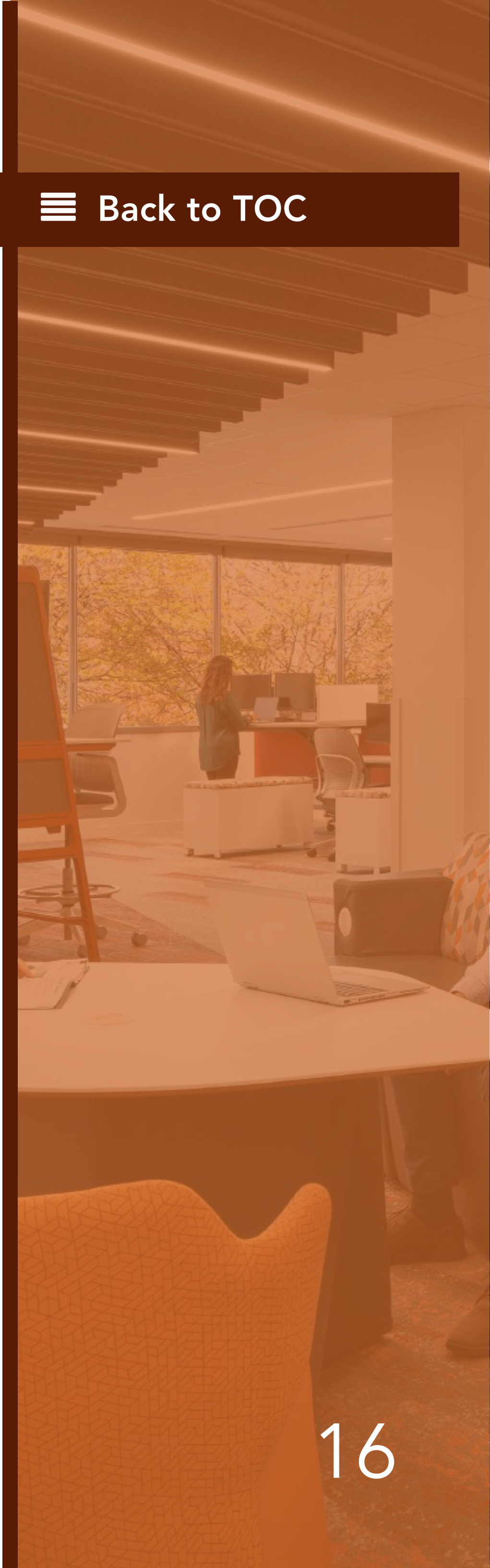
Today's wireless system manufacturers can provide more than 20 years of evidence that their communications protocols are highly reliable, and there is virtually no difference in response time between wired and wireless controls. Wired systems provide familiar, reliable control, but wireless systems add greater design flexibility, support tremendous fixture choice, minimize risk, and can be installed up to 70% faster than a wired solution. The end user gets exactly the lighting they want, when they want it, without getting pigeon-holed into a design that can't accommodate changes to their space layout over time. In the end, the wired vs. wireless decision often comes down to budget, timeline, and client choice.

Wireless LLLC devices amplify the benefits of a wireless system by providing individual fixture control and digital programming. There are a range of ways in which fixtures – or fixture groups – can be controlled, and LLLC models have varying sensing capability. LLLCs are available with or without integrated sensors and can often be mixed and matched within a system ensuring the customer only pays for the technology they need in the space and giving the contractor greater control over the job bid. For example, an open office space with ample daylight may benefit from



LLLC models are available with or without integral sensors and can be mixed and matched within a system to provide the right light, in the right space, at the right time. Photo credit Eric Laignel



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smart fixtures with integrated daylighting capabilities, but a conference room may be more functional with uniform lighting controlled with a standard, area-based daylight sensor associated with one large zone of light.

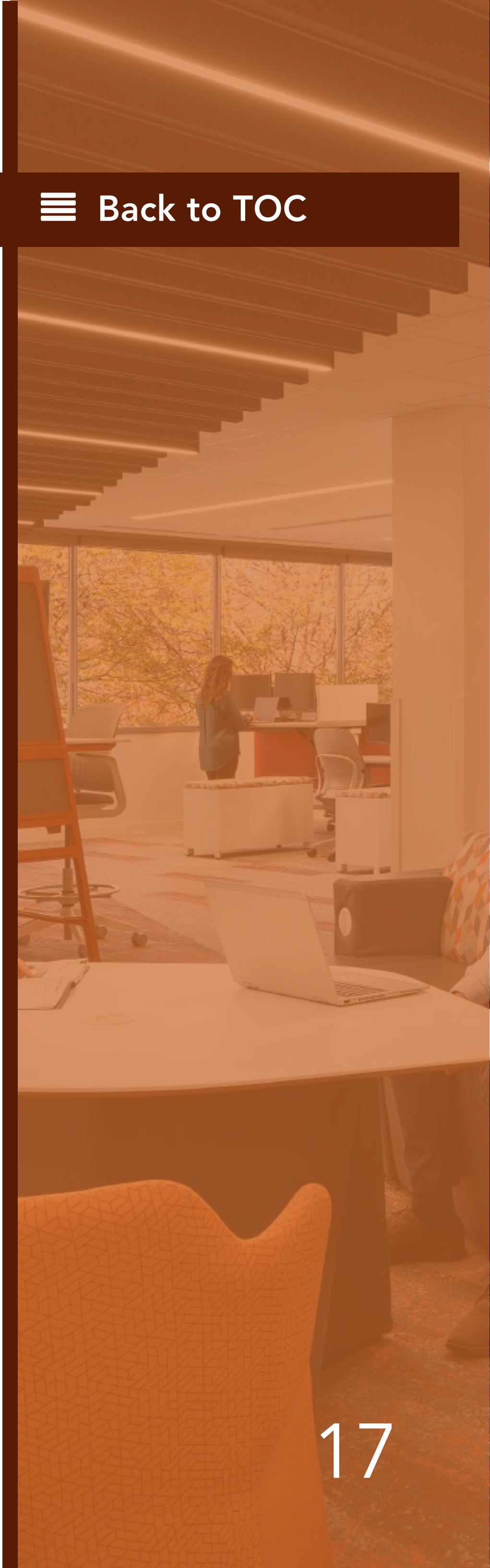
Like daylight sensors, energy codes require an occupancy sensor in most areas, which can either be included as part of the LLLC or as a separate wireless sensor added to the bill of materials. Regardless, with LLLCs the fixtures can be grouped together in any configuration, and easily regrouped if space use changes.

Looking Ahead: The Future of LLLCs and Digital Control Systems

The future of smart buildings and smart lighting control system is flexibility. Picture this: your building meets the design spec, easily accommodates small changes that help your client tailor their system to the way it's actually used and can be updated over time to take advantage of new and emerging technologies. LEDs have already re-defined the lighting landscape. Now, LLLCs are elevating it again with smart, connected, individual fixture control powering human-centric, energy efficient buildings.

FROM DESIGN TO CONSTRUCTION: HOW LLLCs HELP SIMPLIFY INSTALLATION AND ACCOMMODATE CHANGE

For the electrical contractor, a digital LLLC solution can save time and significantly reduce the amount of material required on the job. Power wiring can be run independent of control wiring, and with a wireless LLLC-enabled system, wires do not have to be run to the fixture. Fixture zoning can be determined at any time – even after the installation is complete – and can be just as easily adjusted from an app or dashboard with no new wiring. Ultimately, wireless means greater peace-of-mind for everyone: engineer, contractor, and end-user alike. Not only is it easier to design and install, but the client is not locked into a lighting design that made sense in theory, but not in practice.



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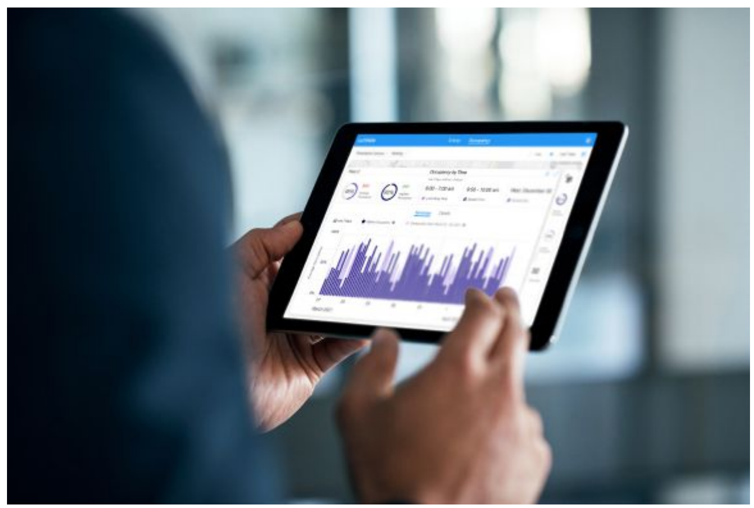
With LLLCs, wiring mistakes are minimized, and zoning decisions can be made after the fixtures are installed. Photo courtesy of Lutron Electronics

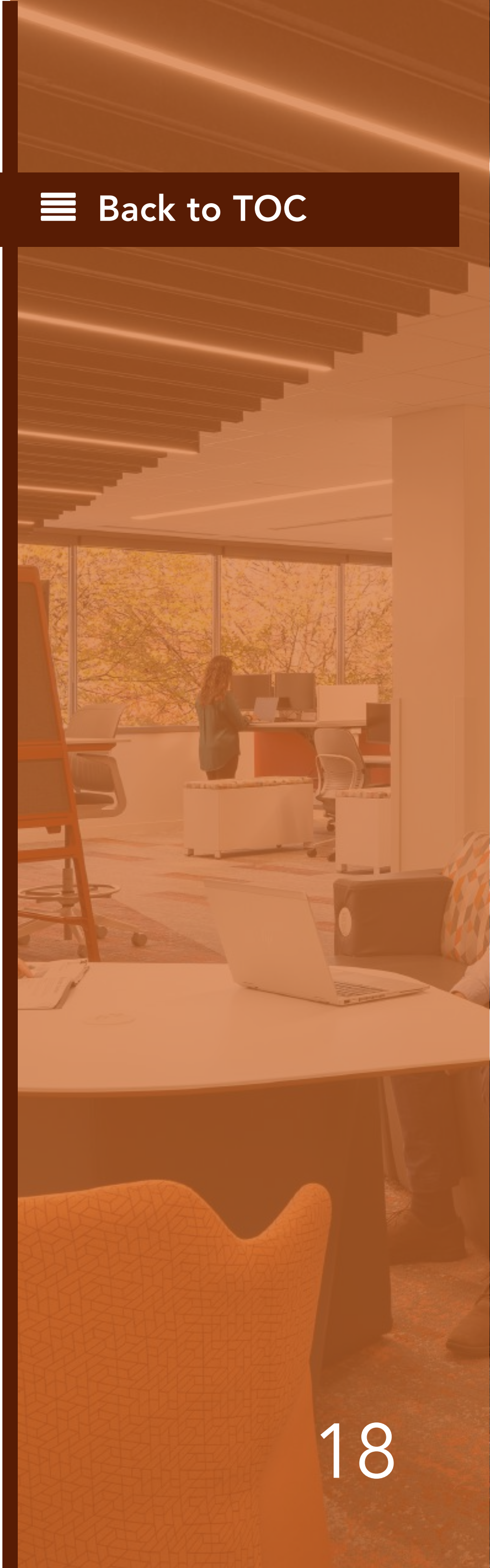
When a project uses wired, 0-10V drivers, contractors need to know exactly how the fixture will be zoned before the job is installed. For the engineer, it is a challenge to forecast exactly how lighting zones should be defined without the benefit of the occupant experience. If the lighting needs to be rezoned as a result of requested project changes, the only solution is rewiring and additional cost. Wireless gives engineers the opportunity to anticipate the unknown and design with expansion in mind.



An owner or tenant can use fixture-level occupant data to improve the comfort, efficiency, and even value of their space. Photo courtesy of Lutron Electronics

When the LLLC devices incorporate sensor options – occupancy and/or daylight sensors – the fixtures gather robust data that stakeholders can use to support advanced energy savings and make more informed business decisions.

When you are using traditional, wired zone-control systems, occupancy sensors and/or daylight sensors have to be installed separately for code compliance and lighting performance, further increasing the number of wire pulls. This adds complexity, time, and cost. In comparison, LLLCs eliminate extra



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steps and minimize system complexity since sensors can be integrated within the LLLC and don't need independent power. There is also no extra time required for installing sensors, no need to associate those additional devices in the system, and less chance of costly, time-consuming wiring errors.

Because LLLC devices are pre-installed in the fixture, engineers and contractors are assured of driver compatibility. After confirming the LLLC works with the specified control system, contractors can be confident the system can be installed and setup easily with limited callbacks.

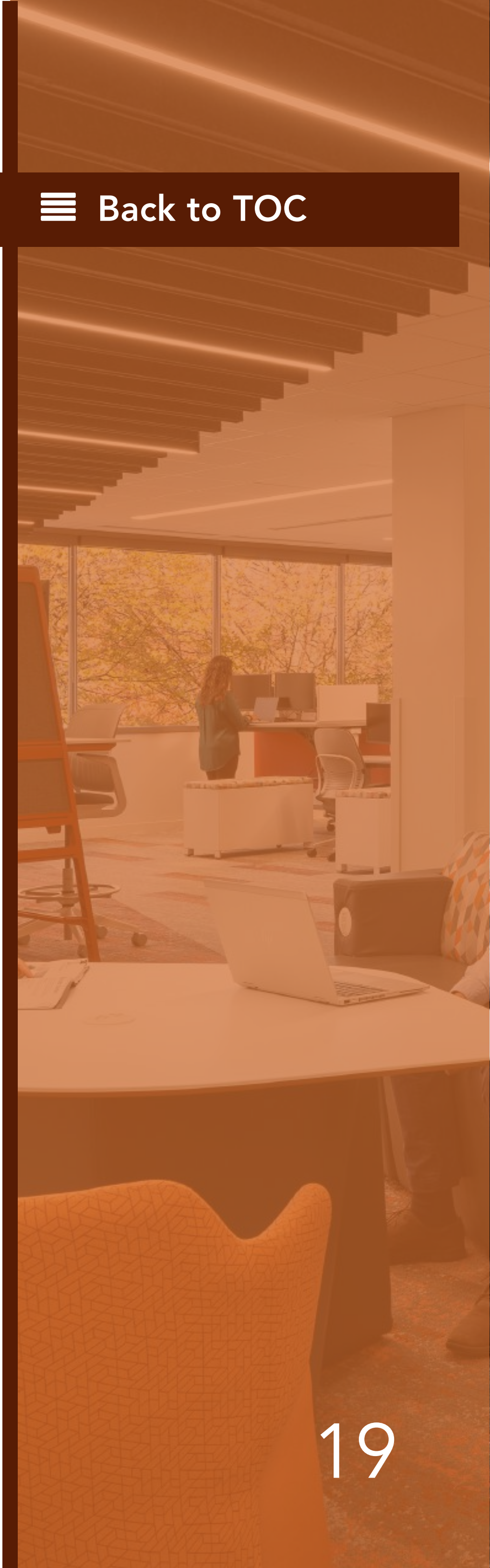
This is a clear win for the contractor, who can bid the job more accurately, and complete it more quickly, but it is also supports a nice return on investment for building owners, occupants, and facilities teams. By reducing wiring and expanding set-up options, LLLCs can save time, lower operating cost, and deliver a more future-proof install. As electrical contractors face persistent labor shortages, LLLCs contribute to simpler installations, reduced callbacks, and can increase the number of jobs a contractor can handle.

HOW WIRELESS SAVES ELECTRICAL CLOSET SPACE

As an engineer, how many times have you finally managed to successfully arrange your electrical equipment to fit in the electrical closet, only to get a call from the building architect saying you need to reduce closet space by another 20%?

Now your electrical hardware does not fit and you have to go back to the drawing board. The tug-of-war between the size of lighting control equipment and the lack of available space remains a pervasive issue.

Previously, there were only a few major lighting control strategies to help alleviate the problem of shrinking closet space: distributed panels, centralized panels, and individual-fixture controls. There are tradeoffs; each of these options have different impacts on electrical closet space and total installed costs.



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Now, Lutron has introduced the Athena Wireless Node, an RF-enabled individual fixture control product that nearly eliminates the need to mount lighting control equipment in the closet. Athena Wireless Node can work in almost any fixture with a DALI-2 or 0-10 V electronic-off driver.

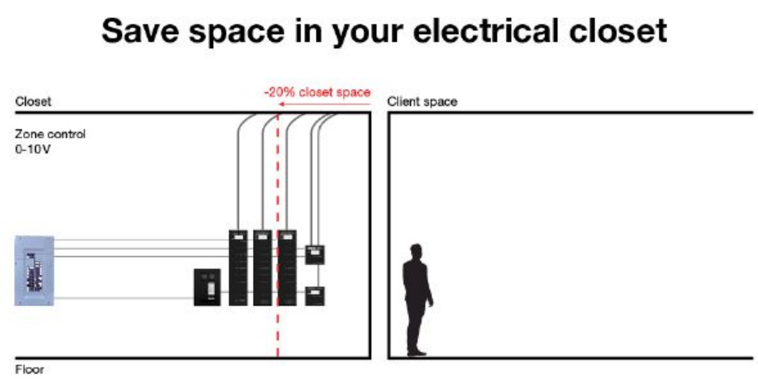
With this new option, the lighting control system is wirelessly enabled, and controllable with granularity down to the individual fixture. In contrast, 0-10V control equipment requires power and control home runs to each lighting zone.

Let's consider two lighting control strategies for a large (26,000 sq. ft.) office space. In the following example, we explore two control strategies and compare their respective impact on material cost and required closet space.

0-10V (Analog) Solution

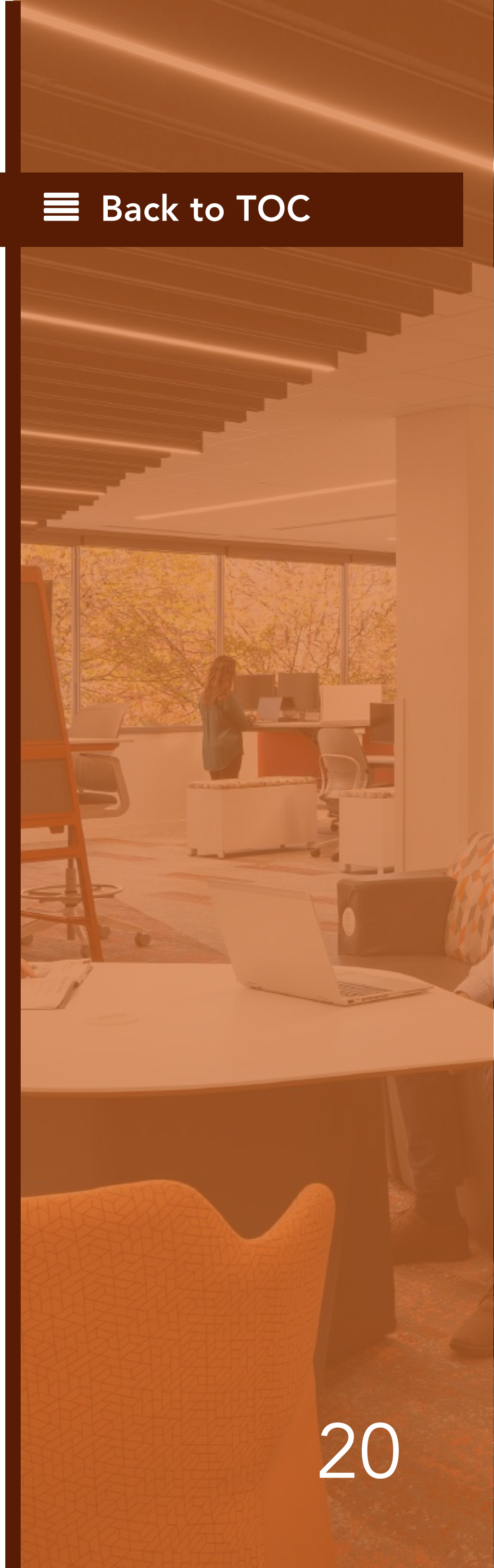
When using a 0-10V zone control solution, contractors must mount and wire the distribution panel as well as each individual panel. In general, installation requires enough wall space in the electrical closet for the breaker panel as well as 1 foot of separation between all devices to accommodate wiring into and out of the panel.

In the following 0-10V solution, each zone is wired back to a control panel.



When the architect reduces available electrical closet space by 20% or more, wired lighting control systems can send you back to the project drawing board. Photo courtesy of Lutron Electronics

In comparison, with individual fixture control you have a wireless device installed in each fixture. Zoning is done entirely through programming; there is no need to home-run



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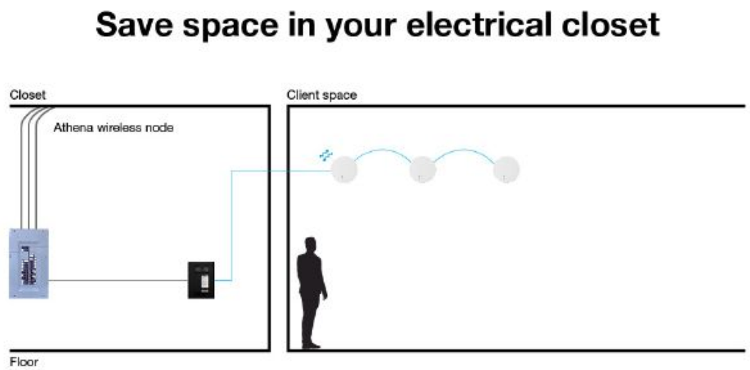
each zone to the panel, meaning less wire and less material to install.

Individual Fixture Control Solution

Although fixture cost is higher with the digital solution, installation labor units and required closet space are significantly lower. In addition to a lower installation cost, the digital solution offers greater flexibility and higher-performance control. With an in-fixture solution there is less risk of miswire during installation and lighting in the space can be easily reconfigured, both during and post-construction. This is a key project differentiator as it ensures the lighting system can accommodate changes to space layout without costly rewiring or third-party commissioning.

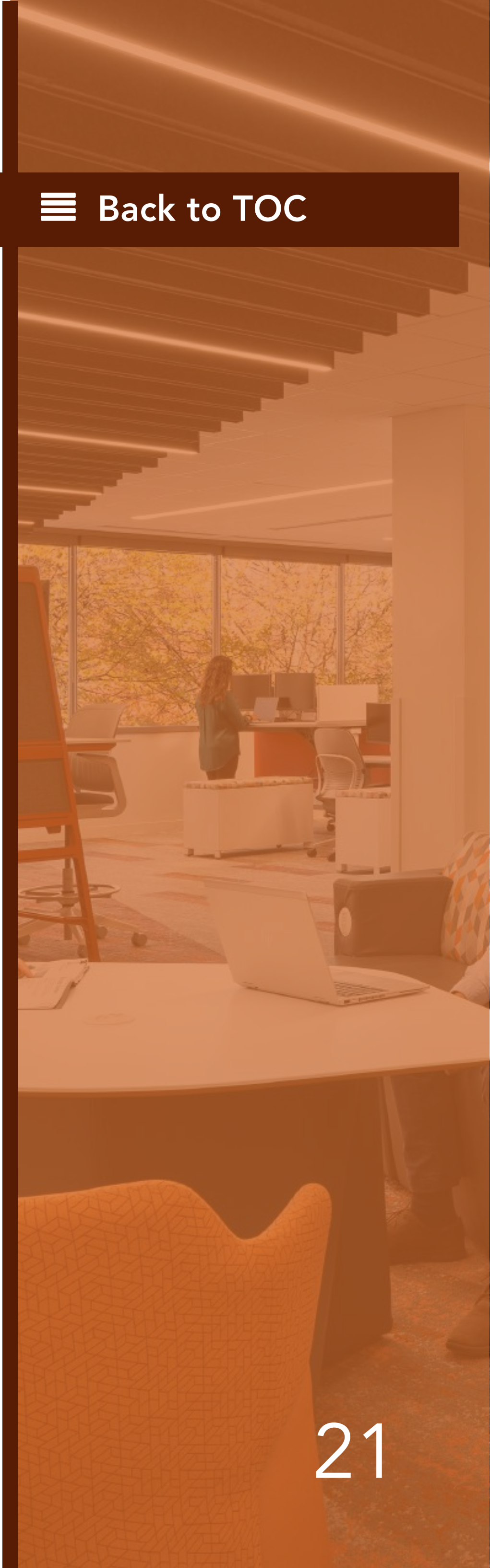


In this LLLC example, a Lutron Athena wireless node is installed in each fixture, and the Athena solution nearly eliminated the need to mount lighting control equipment in the closet. Photo courtesy of Lutron Electronics

Design Depends on your Customers' Priorities

No one system design will be ideal for all your jobs. But LLLCs can offer the design flexibility you need to create the right solution for each client's performance, budget, and space requirements. More and more often your clients expect their lighting control systems to make buildings smarter, more human centric, and even more data centric to maximize building comfort and performance. And they want systems that will continue to perform over time even as technologies improve.

Software-driven, smart systems are changing the way owners and occupants interact with their buildings. LLLCs can make it easier to tailor system performance without adding complexity, exceeding budgets, or compromising the project schedule.



Avoiding total darkness in emergency lighting scenario

Understand the NEC requirements related to component failure in emergency lighting fixtures

NFPA 70: National Electrical Code Article 700.16 contains code requirements related to the avoidance of total darkness in emergency lighting conditions. Emergency illumination may be provided by batteries integral to luminaires, generator back up or lighting inverters. Some emergency illumination luminaires are controlled with adjacent normal lighting under normal conditions and fully energized under emergency conditions, while other emergency luminaires are normally off and only energized under emergency conditions.

Updates to NEC in 2020 account for the differences in lighting technology that have emerged since the widespread adoption of LED luminaires. Legacy sources such as fluorescent, incandescent and high-intensity discharge luminaires had lamps that were separate from the luminaire itself. The light source in LED luminaires is a diode integral to the luminaire though, not a separate lamp. Updates to the indicated portion of the NEC were needed to ensure the language was applicable to LED luminaires.

Many engineers remain unaware of how these changes affect design considerations for emergency lighting. While the changes may seem minor, they must be accounted for at the beginning of a project or else risk costly delays in equipment ordering or occupancy. Failure to follow these new requirements can lead authorities having jurisdiction to require rework, which can include reopening finished walls or ceilings, running new conduits, retrofitting power supplies and installing new equipment.

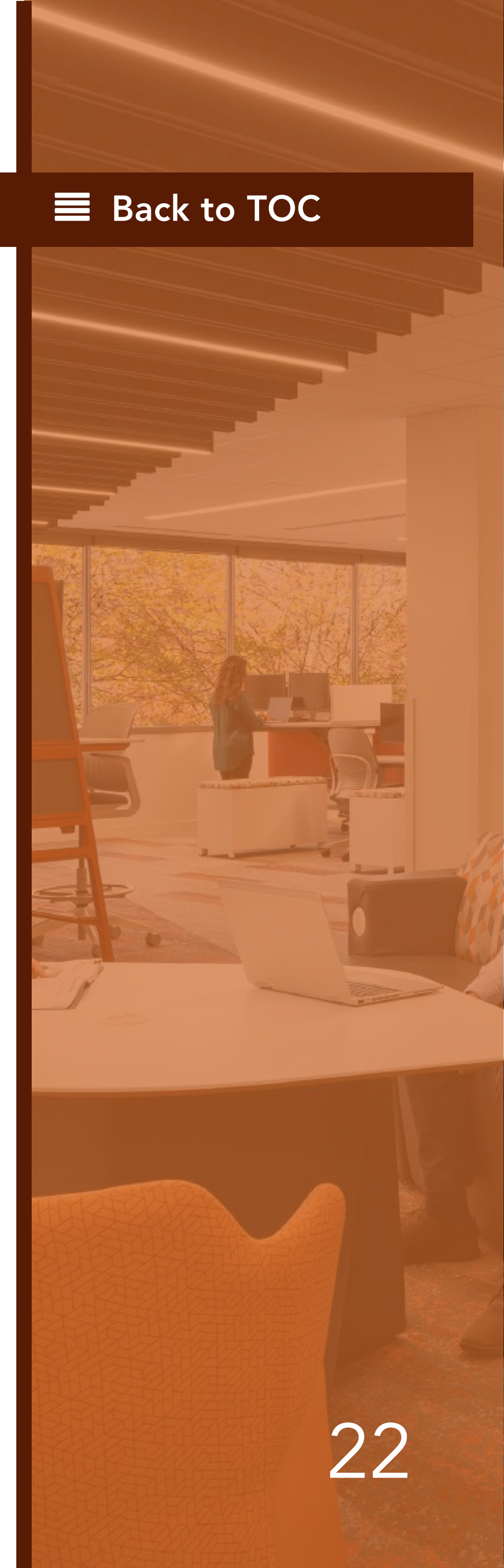


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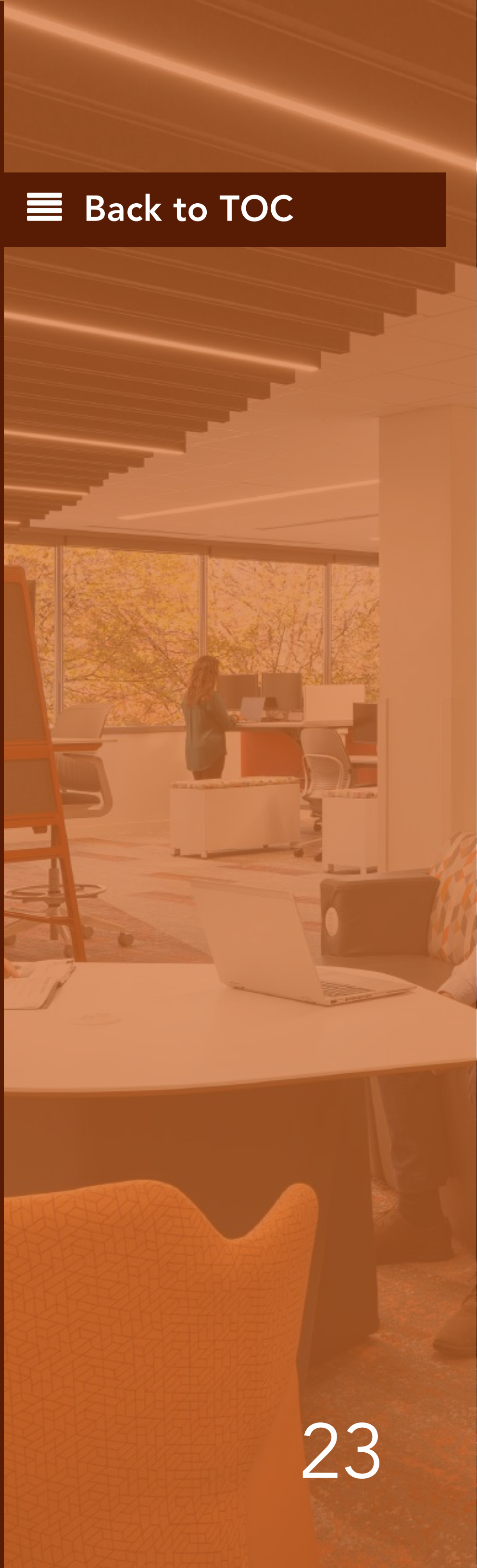
Figure 1: A resort has multiple luminaires by exterior doors, so if more than one was powered by the emergency system, total darkness would be prevented even if one failed. This photo highlights the architectural details of the façade, and also provides wayfinding for the property. Courtesy: LEO A DALY

The scope of this article will specifically focus on the portion of NEC Article 700.16 related to system reliability. It should be noted that this article is not intended to be an exhaustive interpretation covering all requirements related to emergency illumination.

There are other code requirements applicable to emergency lighting contained in, for example, the NEC, NFPA 101: Life Safety Code



and the International Building Code that are outside the scope of this article that the engineer of record must be familiar with to ensure a fully code-compliant design.

Emergency lighting code changes

NEC requirements related to the failure of individual lighting elements were first introduced in 1956 and most recently updated in 2020. The 2017 and 2020 code language can be seen below. Note particularly the change in 2020 NEC 700.16(B) to the "failure of any illumination source" compared to the 2017 wording of the "failure of any individual lighting element, such as the burning out of a lamp."

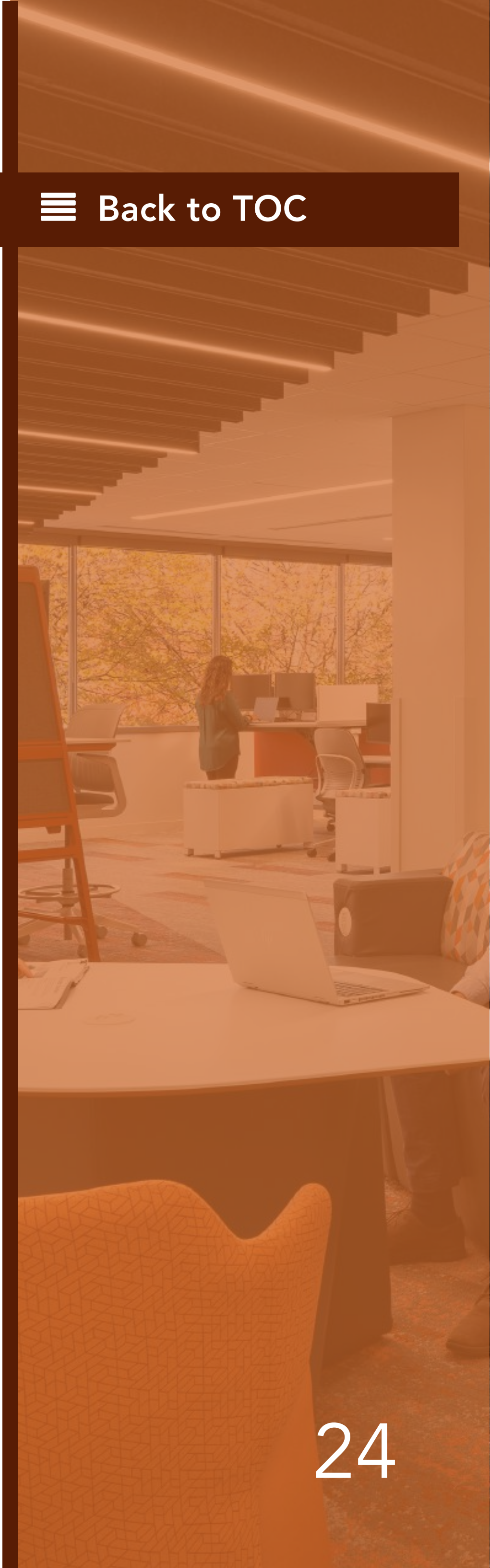
2017 code language:

700.16 Emergency Illumination

Emergency illumination shall include means of egress lighting, illuminated exit signs and all other luminaires specified as necessary to provide required illumination.

Emergency lighting systems shall be designed and installed so that the failure of any individual lighting element, such as the burning out of a lamp, cannot leave in total darkness any space that requires emergency illumination.

Where high-intensity discharge lighting such as high- and low-pressure sodium, mercury vapor and metal halide is used as the sole source of normal illumination, the emergency lighting system shall be required to operate until normal illumination has been restored.



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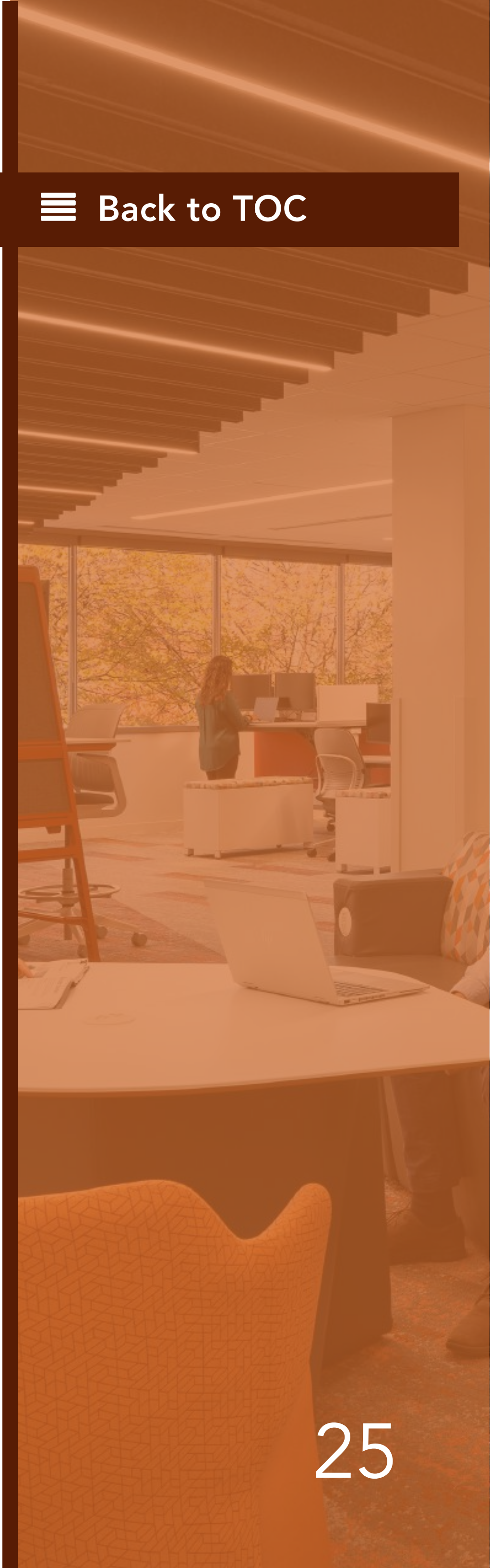

Where an emergency system is installed, emergency illumination shall be provided in the area of the disconnecting means required by 225.31 and 230.70, as applicable, where the disconnecting means are installed indoors.

2020 code language:

700.16 Emergency Illumination.

1. A) General. Emergency illumination shall include means of egress lighting, illuminated exit signs and all other luminaires specified as necessary to provide required illumination.

N (B) System Reliability. Emergency lighting systems shall be designed and installed so that the failure of any illumination source cannot leave in total darkness any space that requires emergency illumination. Control devices in the emergency lighting system shall be listed for use in emergency systems. Listed unit equipment in accordance with 700.12(I) shall be considered as meeting the provisions of this section.

N (C) Discharge Lighting. Where high-intensity discharge lighting such as high- and low-pressure sodium, mercury vapor and metal halide is used as the sole source of normal illumination, the emergency lighting system shall be required to operate until normal illumination has been restored.

N (D) Disconnecting Means. Where an emergency system is installed, emergency illumination shall be provided in the area of the disconnecting means required by 225.31 and 230.70, as applicable, where the disconnecting means are installed indoors.

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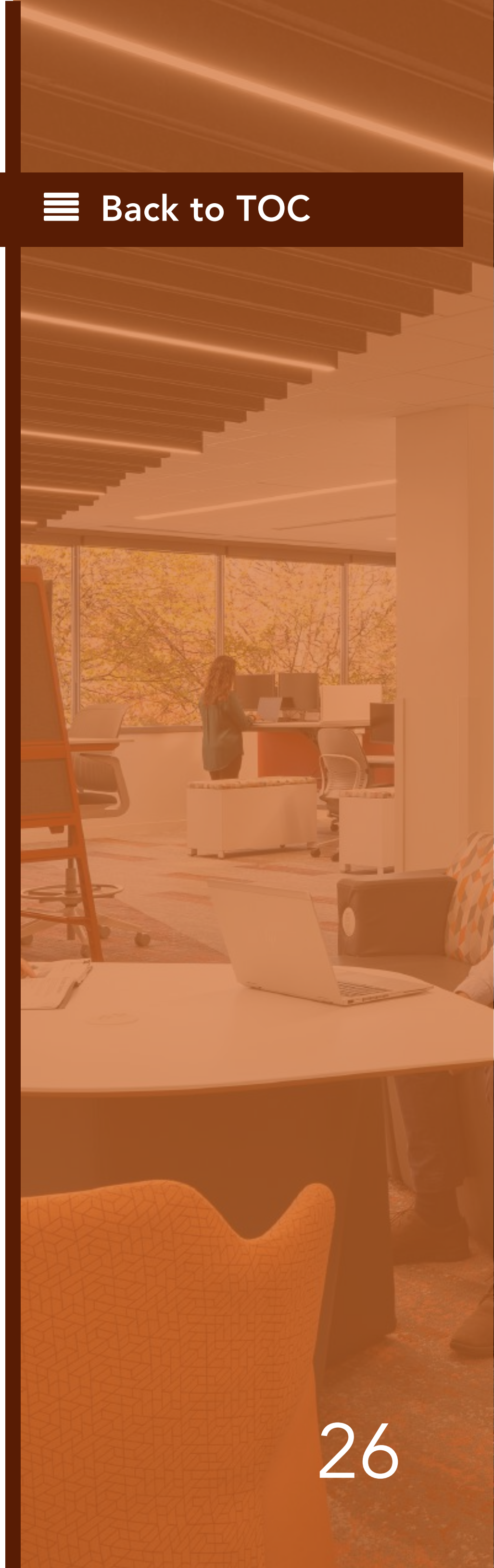


Interpreting NEC Article 700.16

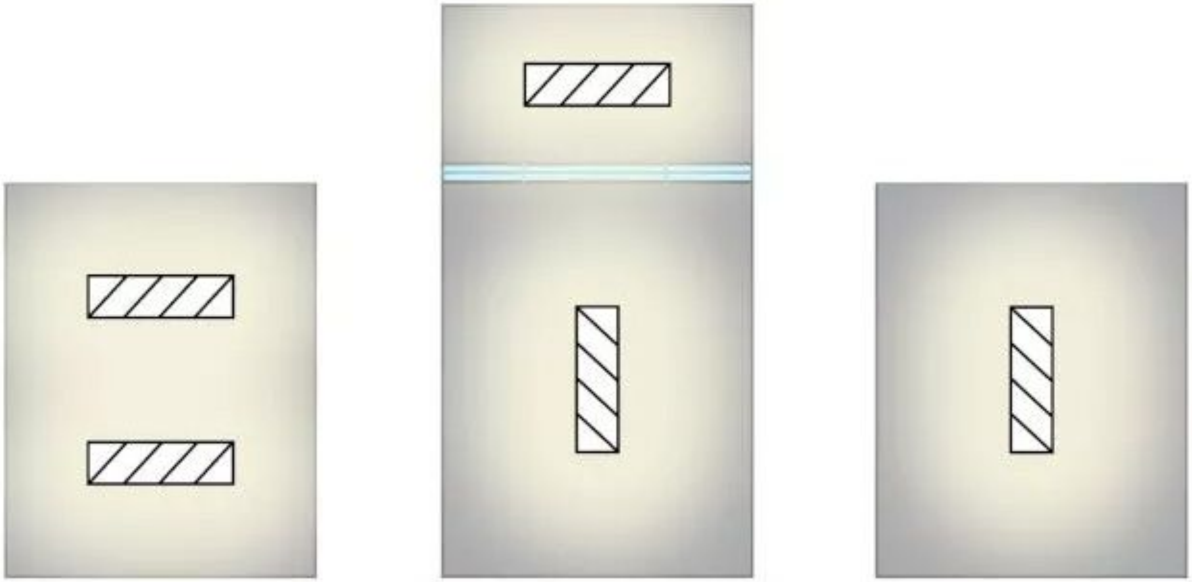
NFPA 70-2017 Article 700.16 and the 2020 edition of Article 700.16(B) are intended to account for possible manufacturing defects of the light fixture, ensuring that a space containing emergency illumination would not be left in total darkness if one component in an emergency fixture was to fail.

With legacy source types, this code section was frequently accounted for by having emergency fixtures furnished with two ballasts and two lamps. If one ballast and/or lamp failed, the fixture would still produce some light and the space in question would not be left in total darkness under emergency conditions.

The updated wording in the 2020 code reflects the industry's movement away from legacy source types to LEDs by revising the wording from "… any individual lighting element, such as the burning out of a lamp …" to "… any illumination source …".

There is a line of thinking that says an LED fixture with multiple diodes would inherently comply with the 2020 edition of NEC because the wording "any illumination source" only applies to the diodes themselves. A multidiode LED fixture that has one diode fail can still provide light via the remaining diode(s).

However, lighting designers have had experience with the authority having jurisdiction interpreting this section of code as meaning that the driver also cannot be a single point of failure for the fixture. If the driver fails, then no light is coming out of the fixture and thus the illumination source failed. As such, the conservative interpretation that neither the driver or light board can be a single point of failure for the fixture is assumed for this article.



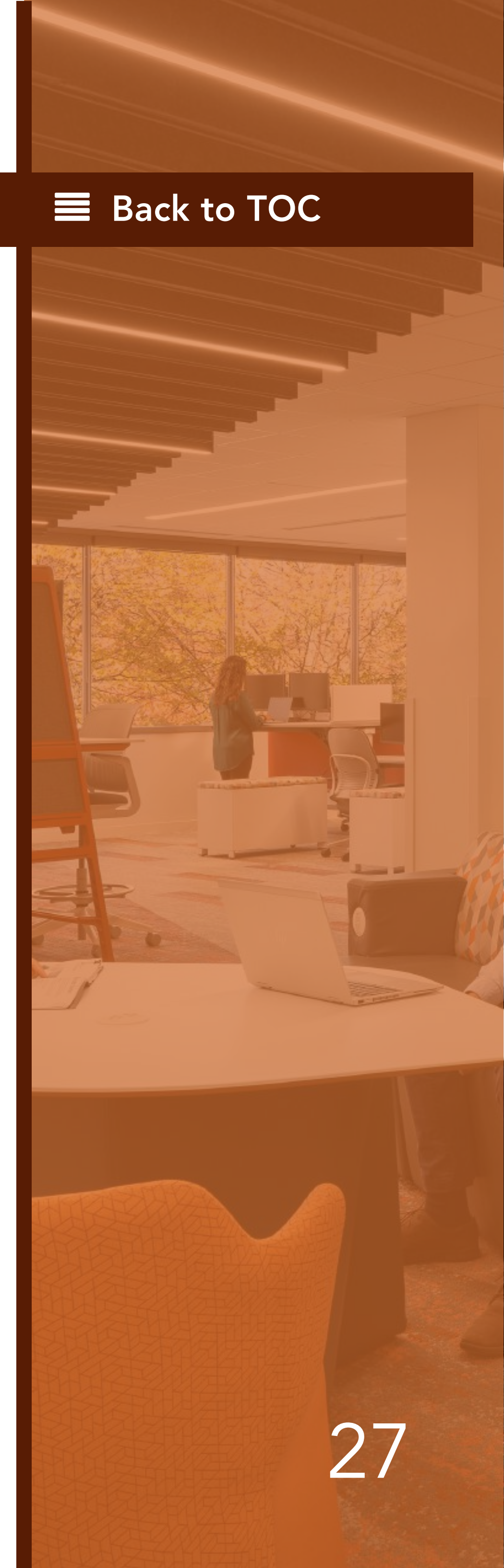
How to handle emergency lighting scenarios

There are multiple ways to comply with this code requirement. Some are listed below, although the list of strategies indicated is not necessarily exhaustive and there may be additional ways to achieve project compliance.

Figure 2: Two emergency fixtures in room, opaque walls. Redundant internal components not needed. One emergency fixture on either side of glass wall. Redundant internal components not needed. One EM fixture in room, opaque walls. Redundant internal components or second emergency fixture needed. Courtesy: LEO A DALY

Scenario 1: Multiple fixtures in an interior space

An interior space that has more than one emergency fixture will typically comply with this portion of code. Should one emergency fixture fail, the other emergency fixture(s) in the space would prevent the space from being in total darkness (see Figure 2).



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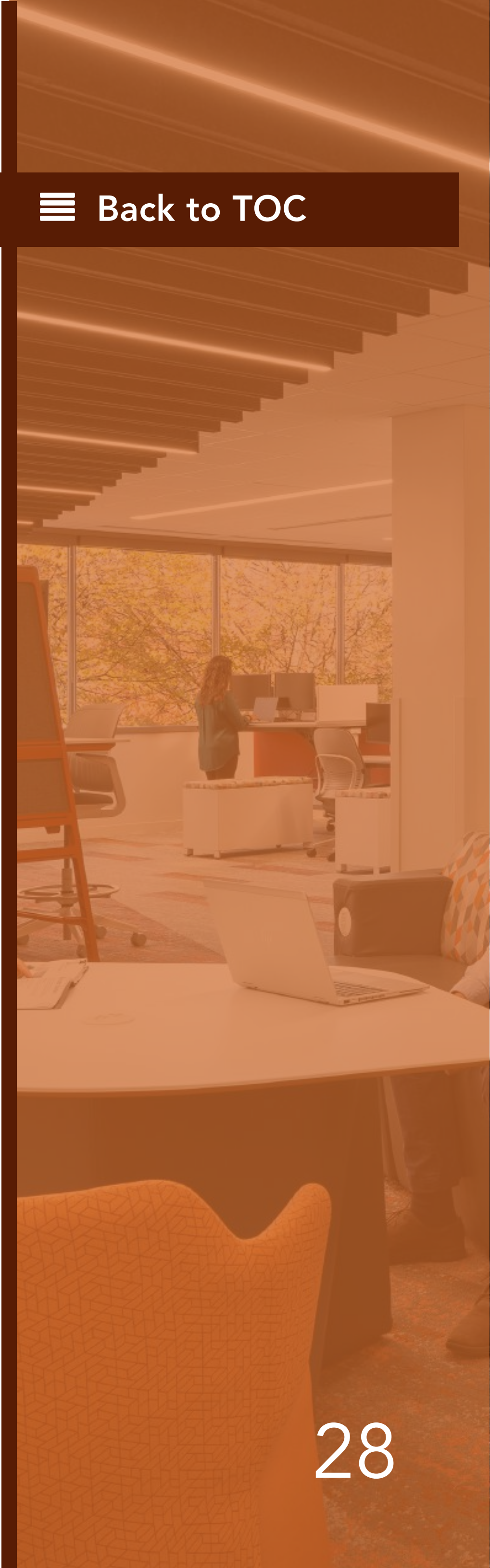

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Scenario 2: One fixture in an interior space with glass wall

If an interior space has only one emergency fixture, but additional emergency fixtures are on the other side of a glass wall or door, it is reasonable to conclude that light from one of the adjacent emergency fixtures shining through the glass wall or door would prevent the space from being in total darkness in the event of an emergency.

Scenario 3: Exterior space with site lighting

For exterior door applications where emergency lighting is provided by a wall pack, recessed downlight or some other form of lighting right outside the door, this section of code can be complied with if there are bollards, pole lights or some other form of site lighting in the area that are also on emergency power. The adjacent site lighting backed up by emergency power would keep the space from being in total darkness should normal power and the fixture by the door both fail (see Figure 3).

Scenario 4A: Exterior space with no site lighting (single driver)

A more challenging situation related to this portion of code is an exterior door that has only one emergency fixture adjacent to it without any other site lighting in the vicinity. A common example of this is an exterior door with one emergency wall pack or sconce above it with no other building mounted lighting or site lighting nearby. One possible solution is to add another emergency illumination source near the door, either by adding a second normally on emergency fixture or by adding a normally off exterior emergency lighting unit.

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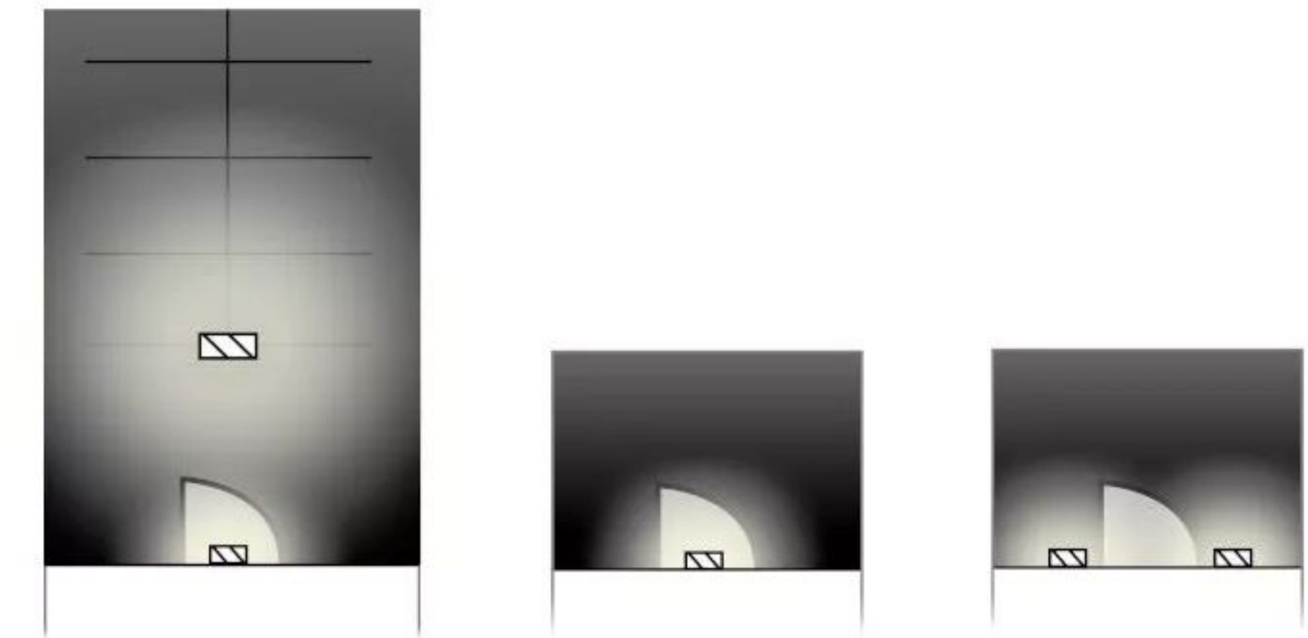


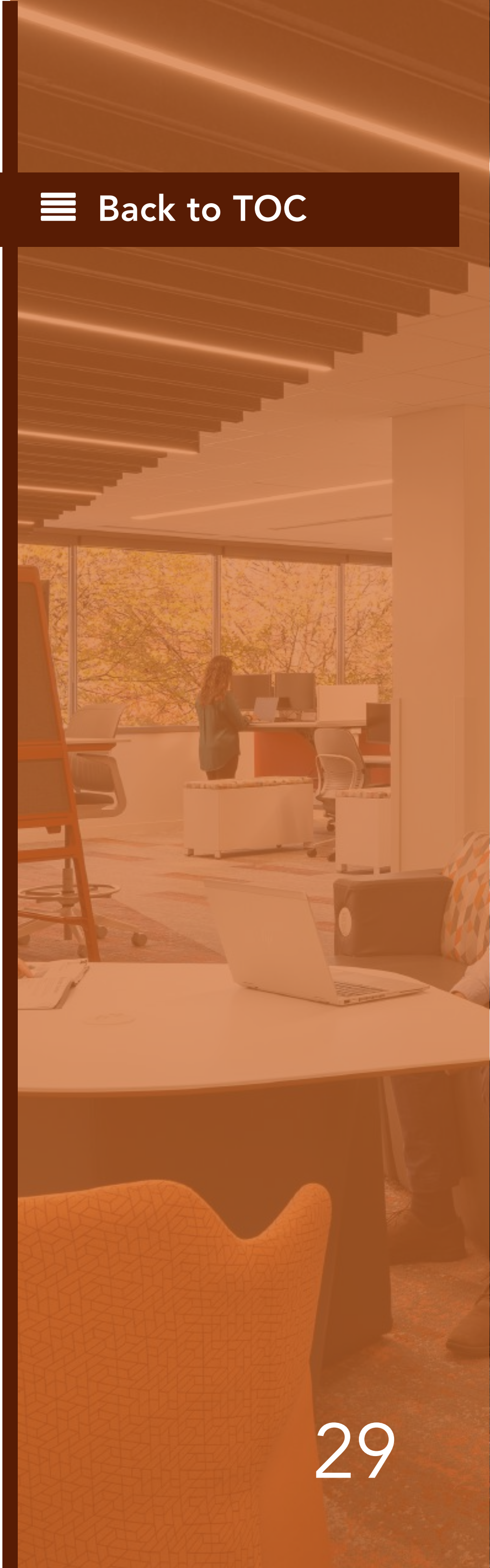
Scenario 4B: Exterior space with no site lighting (dual driver)

Figure 3: Parking lot fixture can prevent total darkness if backed up by emergency source. One emergency exterior fixture not by any others. Redundant internal components or second emergency fixture needed. Two emergency fixtures near each other. Redundant internal components not needed. Courtesy: LEO A DALY

Sometimes aesthetics or practicality make those options not preferred though. In those situations, a good solution is to specify one emergency fixture with dual drivers and dual light engines (see Figure 4). That way if one driver or light engine fails, half of the fixture will still illuminate and the space will not be left in total darkness.

Understanding manufacturer offerings

Multiple manufacturers offer exterior fixtures that have an option of being provided



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with dual drivers and dual light engines. They frequently are not available with integral battery backup or integral control sensors or receivers, as the two separate internal circuits would make the connections cumbersome and the physical size of the fixture larger than typically desired. The two drivers can be controlled separately or tied together external to the fixture and controlled by a common remote switch, photocell or time switch. It is typically a good practice to provide notes and/or a detail on the plans to clarify how these fixtures should be connected to ensure the final install matches the design intent.

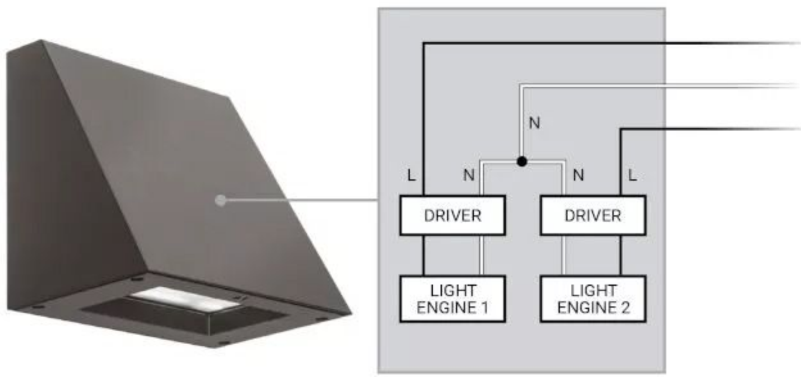
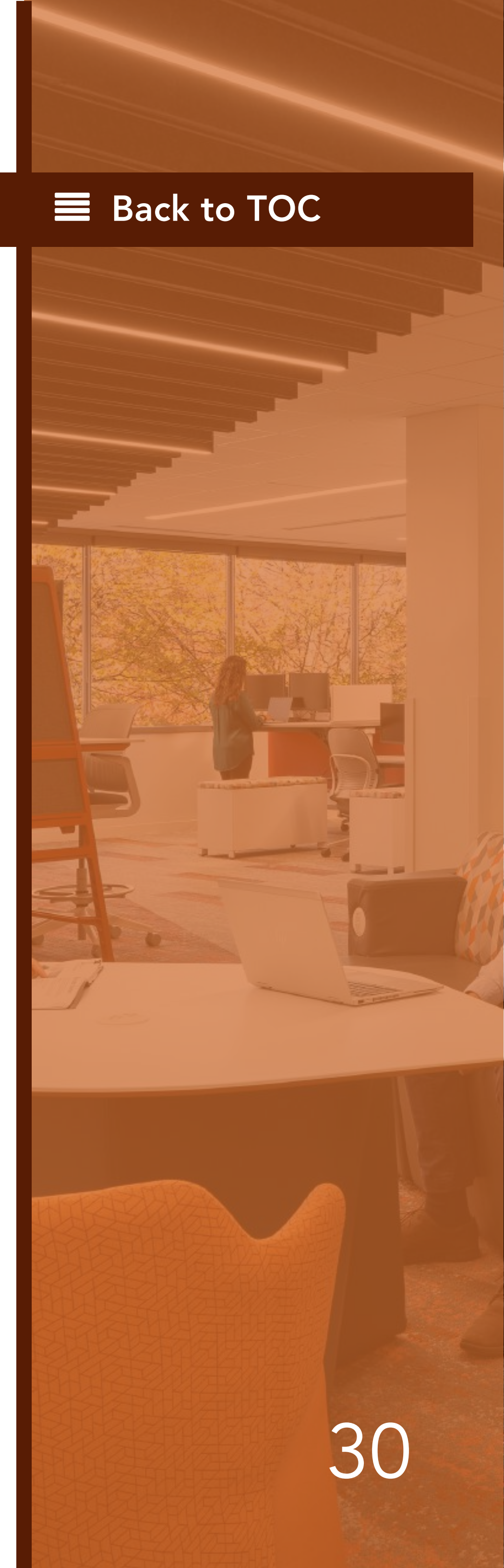


Figure 4: Typical wiring diagram for luminaries with dual drivers and dual light engines. Note: Different manufacturers may provide different wiring connections. Courtesy: LEO A DALY

Interior rooms (Figure 2) requiring emergency illumination that only have one light within and no glass walls or doors are another situation to pay special attention to on a per-project basis to determine the best course of action. Small connecting hallways, vestibules and rooms with electrical panels are common examples of this situation.

In the case of these smaller interior rooms, an interior lighting unit such as a "bug-eye" type fixture, if it meets the requirements of Article 700.12(I), would comply with Article 700.16(B) without the general lighting in the room being backed up by emergency



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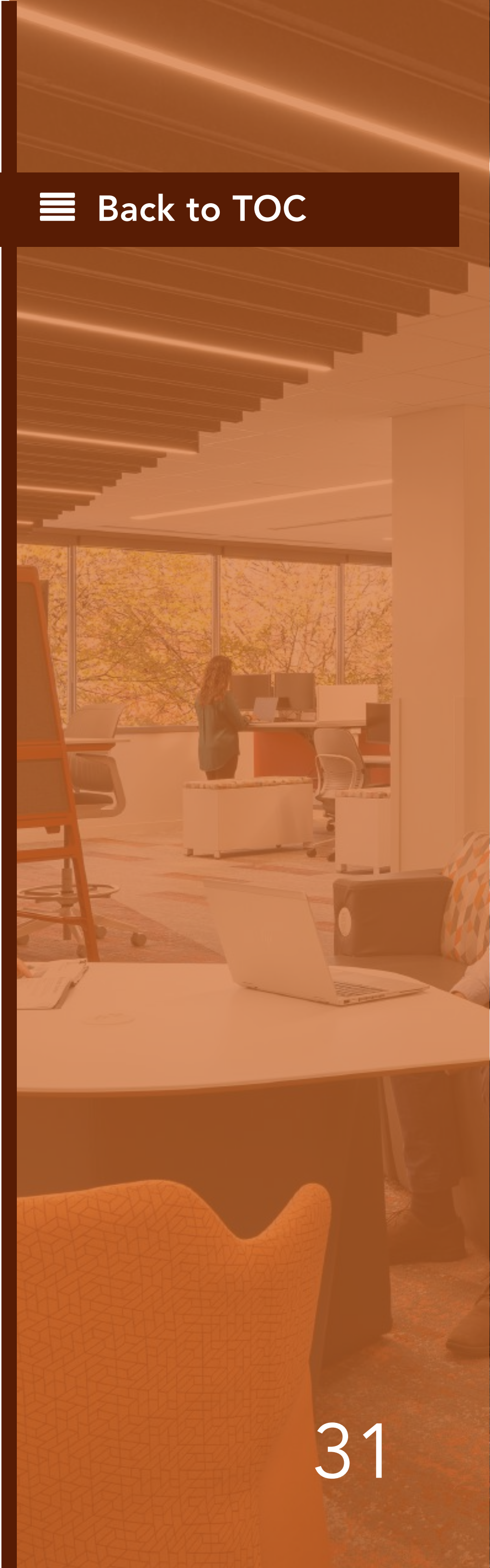

Figure 5: Emergency lighting includes illuminated exit signs and all other luminaires specified as necessary to provide required illumination. Courtesy: LEO A DALY

power. Manufacturers are generally aware of the requirements listed in Article 700.12(I) and most emergency lighting units available do comply with those requirements.

In situations where adding a second light source and/or adding an emergency lighting unit to the room is not preferred, there are some manufacturers that offer strip lights with the option of having dual drivers and dual light engines (see Figure 4), similar to

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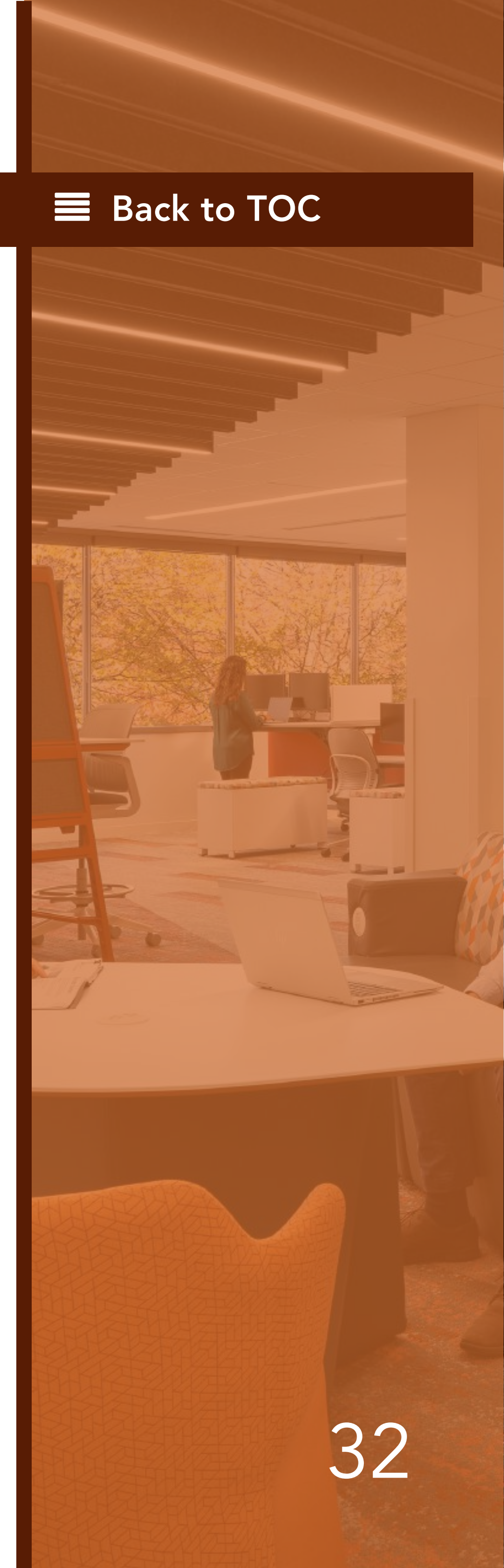
the approach indicated above for select exterior door applications. If such a fixture were provided in the space, the failure of one driver or light engine would not leave the space in total darkness.

Similar to the exterior fixtures discussed above, these fixtures are usually not available with integral battery backup or integral control sensors or receivers. The lines coming off each driver can usually be controlled separately or tied together outside the fixture and connected to a common control device such as a switch. It is typically a good practice to provide notes and/or a detail on the plans to clarify how these fixtures should be connected as well to ensure the final install matches the design intent.

In conclusion, designers and engineers should pay close attention to NEC Article 700.16 and include features in their project to ensure code compliance. While some AHJs may not be in the habit of putting emergency lighting under scrutiny, this should not be counted on. For the safety of occupants and a smooth occupancy process, it's important to get this right the first time.

David Repair

David Repair, *PE, LC, Assoc. IALD, is an electrical engineer at LEO A DALY with expertise in lighting design with a focus on how lighting systems affect building occupants.*



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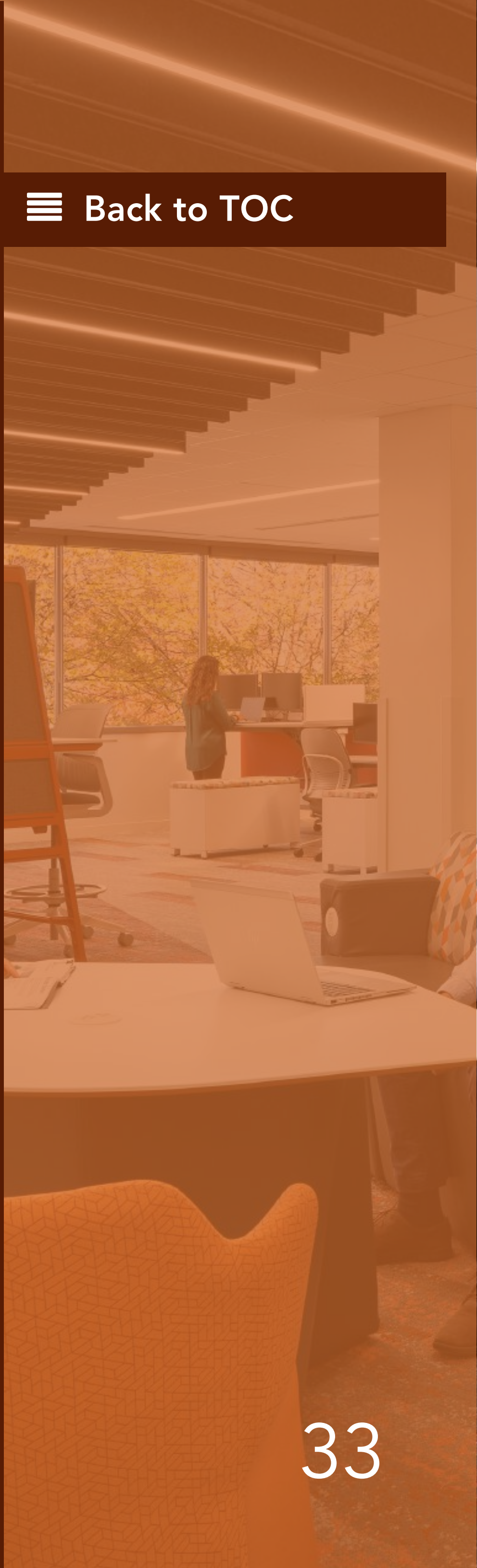

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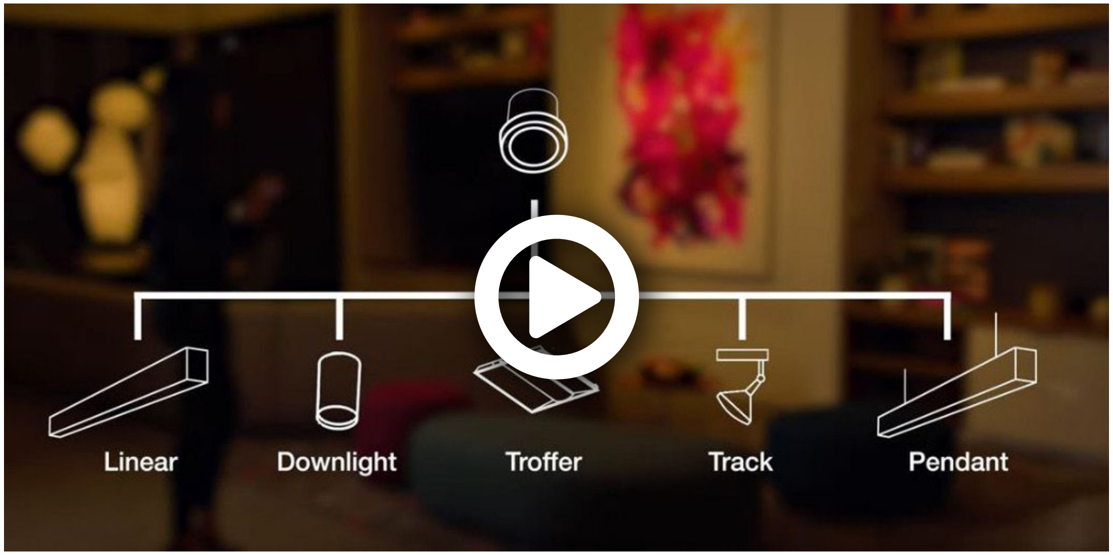

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Designing lighting control for the life sciences sector

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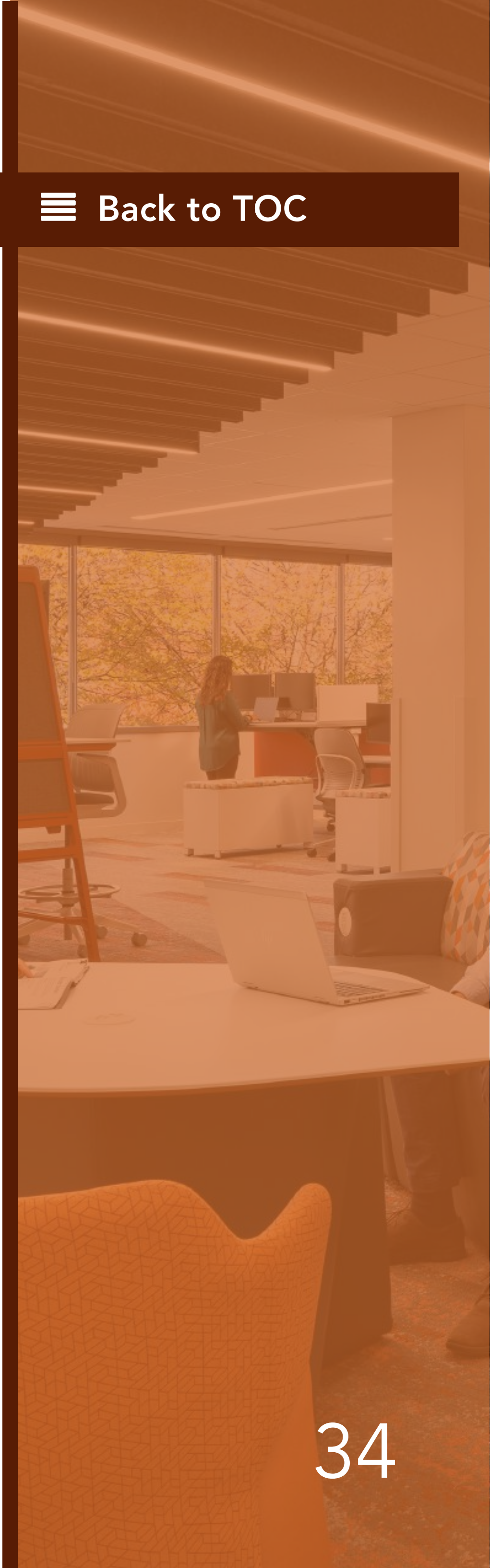
Seven tips for designing lighting systems that meet specialized requirements

Demand for life sciences space is booming, in large part because of the ongoing need for COVID-19 vaccines and treatments. According to the real estate services and investment firm CBRE, lab vacancy in top markets is 5.2% or less in the first quarter of 2022 and a record 31.3 million square feet of life sciences space was under development in the last quarter of 2021. This includes both new construction and conversions of existing commercial space into labs and research facilities, indicating continued, strong growth.

Venture capital funding of life sciences in the U.S. was at $17.8 billion in the second quarter of 2020 while government funding for research remains strong well into 2022.

Electrical specifiers, lighting designers and architects have an opportunity to add significant value to their clients by familiarizing themselves with the special lighting and control requirements in the life sciences sector, which includes pharmaceuticals, biotechnology, biomedical technology, nutraceuticals, cosmeceuticals and others.

Of particular interest with respect to lighting control is the vivarium, an enclosed space for housing live plants and animals for observation and research, under strictly controlled conditions that often simulate their natural environment. Lighting control is most critical in sensitive areas including animal holding rooms, procedure rooms and other spaces where deviation from expected environmental settings can cause animal and research disruption. In these spaces, lighting levels are embedded in the study



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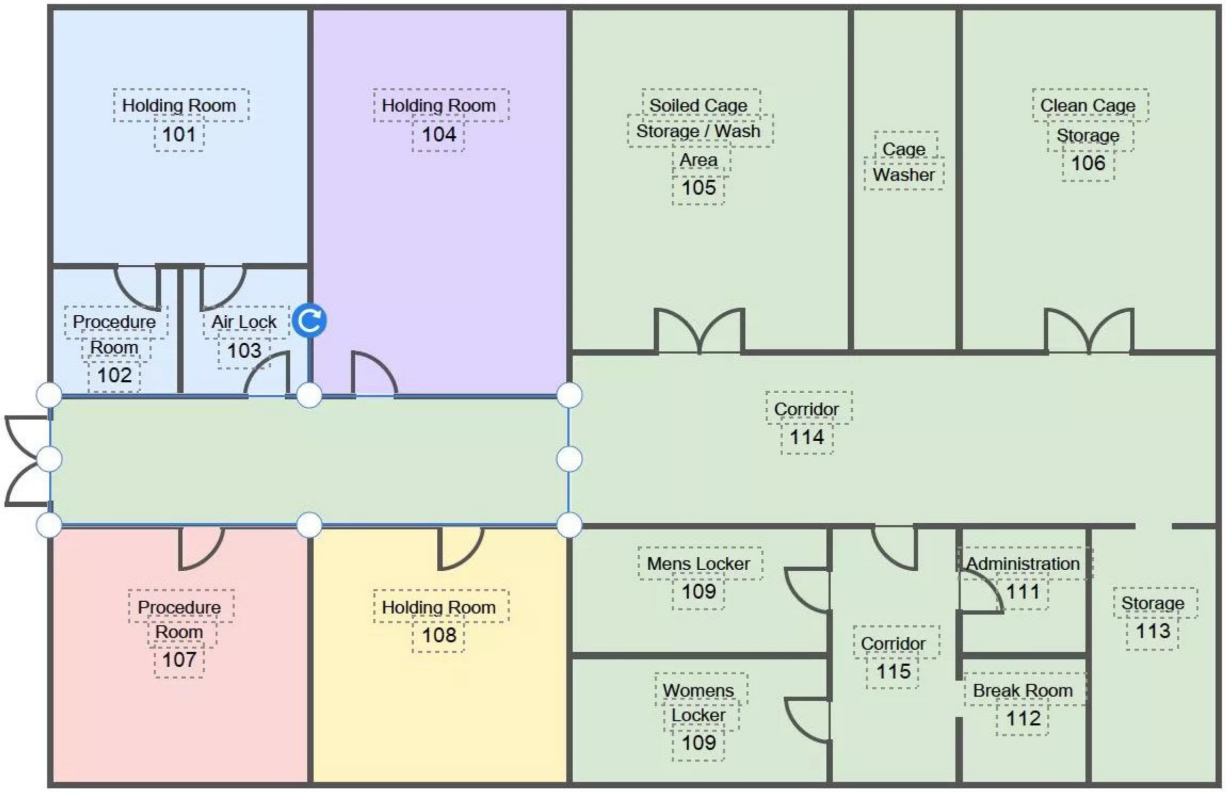
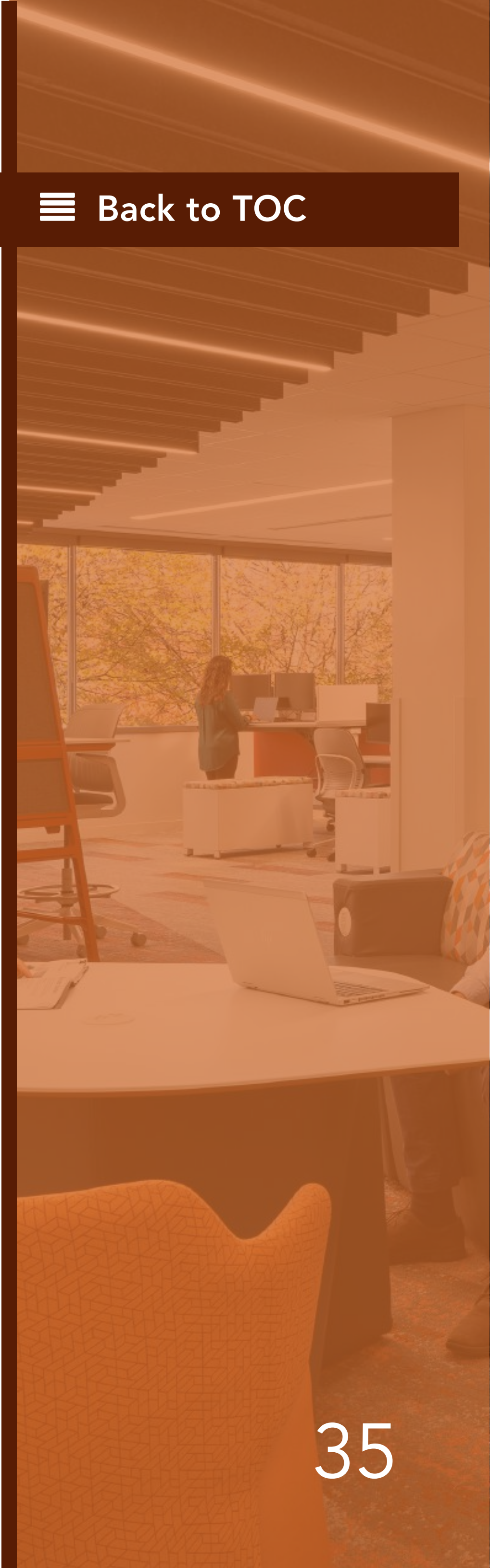


parameters and go well beyond providing a comfortable, productive working space.

Research in the renowned Princeton Neuroscience Institute, for example, supports multiple active protocols (the required sequence of operations for a given experiment). The control system has to ensure lighting mirrors each protocol reliably and consistently. Maintaining

Figure 1: Rooms 104, 107 and 108, are highly sensitive and cannot reasonably be assumed to co-function. They should all be maintained as independently operating spaces unless explicitly directed. The cage wash areas, corridors and administrative spaces are not sensitive or critical; if the lights were stuck on at 100% it would be inconvenient but would not have any effect on the quality of the research. These areas can be grouped together, a failure in one area cascading into other areas doesn't increase the effect to research production. Courtesy: Lutron Electronics



appropriate light schedules is a critical experimental parameter. Any anomaly must be assumed to have an effect on the animal's physiology, metabolic activity and behavioral patterns.

Effective lighting control solutions are a wise investment

Lighting requirements in a vivarium are typically more specialized and tightly regulated than in other life science spaces since vivaria rely on the right lighting and controls to successfully support research. But the advanced strategies used in a vivarium can also inform best practices for a wide range of life sciences applications.

Vivaria house the valuable assets required for conducting vital — often lifesaving — research. This makes both the space design and the chosen systems critically important. Research subjects represent a significant investment in funding and expertise and institutional standards help ensure animal welfare is carefully considered. Properly controlled vivaria must use advanced environmental control technologies to ensure standards are complied with, research goals are met and vendors provide customized and robust solutions for these mission-critical spaces.

Experiments can last several months, even years, with thousands of dollars and hours invested in individual subjects. If research is invalidated due to a lapse in environmental controls, life-saving discoveries may be compromised. It can also be extremely costly, potentially resulting in other research teams completing, publishing or producing a marketable product earlier.

What are practical tips for life sciences lighting designs?

These seven tips can help guide design teams in the intricacies of lighting and lighting control for life sciences projects in general and vivaria in specific:

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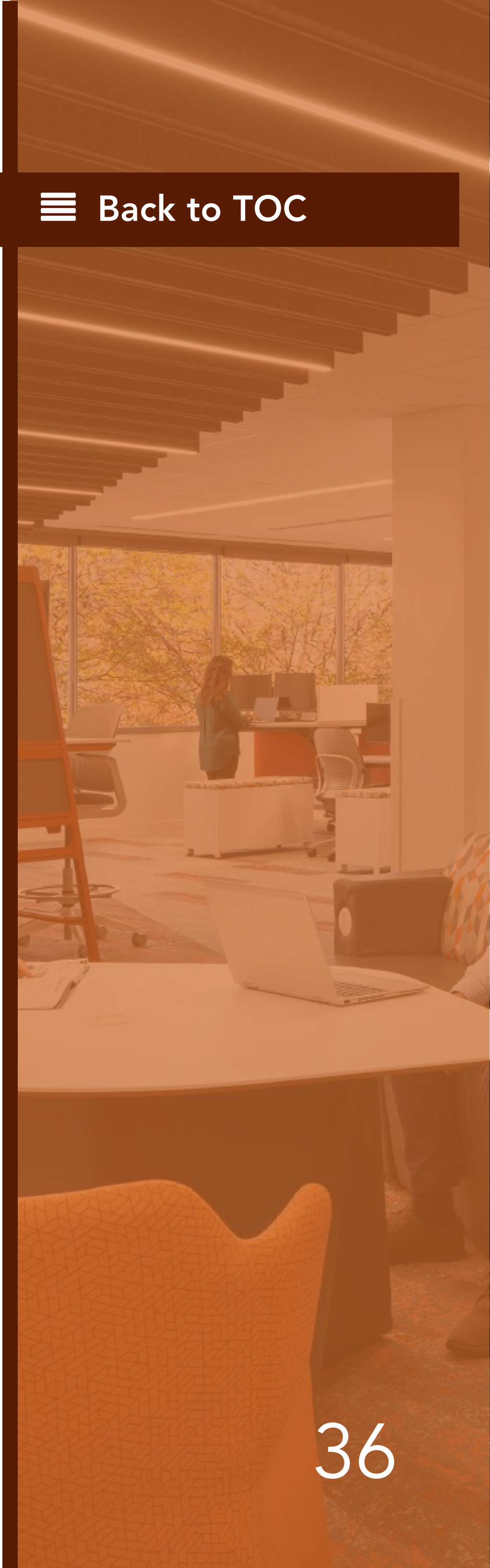

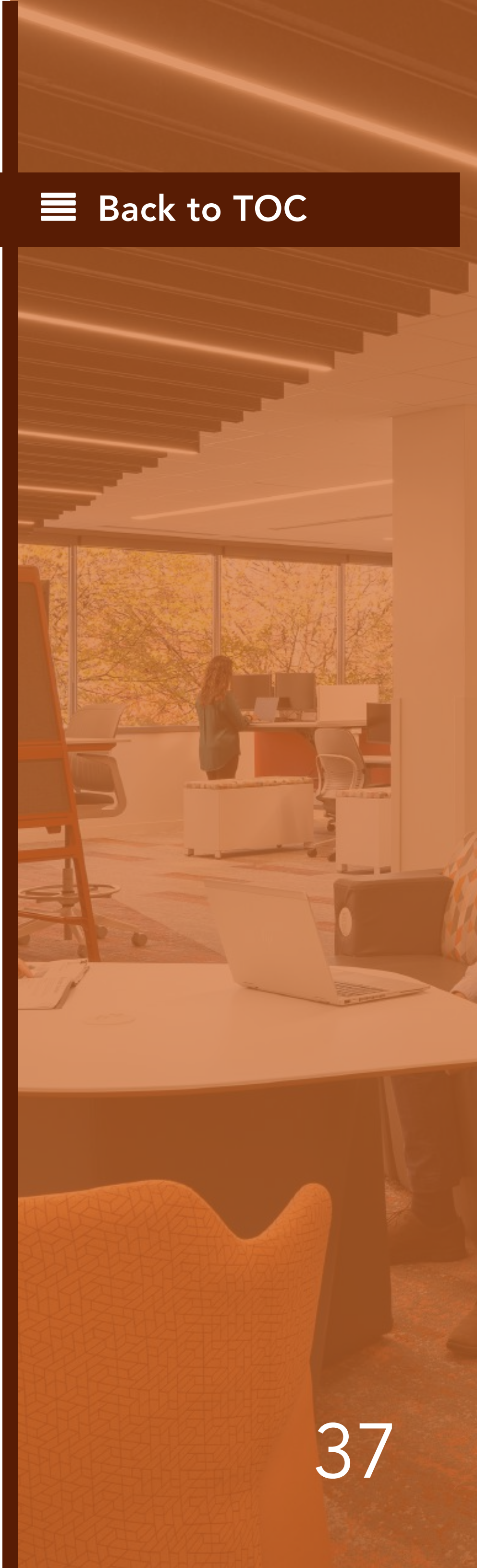

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1. Learn about the space. There is no one-size-fits-all approach to life sciences building or labs. Learn about the science being conducted and its unique space requirements. The amount and type of lighting varies depending on the research. In turn, the type of research will define the appropriate sequence of operations.

Work with the client to develop a written sequence of operations and automation narrative to establish the required lighting control strategies. If they are available, diagrams and illustrations can be used to prevent misunderstanding or poor interpretation. Ideally each room type should have its sequence of operations approved by the research team before system quotation.

This is even more critical for vivaria, which often demand complex time-clock control, automation overrides and integrations. To meet an advanced sequence of operations, the lighting system may require advanced conditional programming, sequenced functions and extensive use of stated variables. The earlier the designers identify these requirements, the better.

2. Get to know the researchers. As with the space, lighting designers will save time and deliver a better design if asking the right questions about the people who will be using the space. At the start of the design process, determine who and how many people use the space and what access each will have to the controls. Researchers may have individual system preferences that need to be accommodated and it is important to identify these unique requirements up front.

Relative to system control software, think about creating individual user accounts to ensure correct privileges are assigned to each system user with respect to how and where they will access the control interface. This will help determine necessary system considerations. Research may require graphical user interfaces that support configurable permissions to help restrict system-user access by space, by role or by a combination of the two. Once permissions are established, the user interface should be accessible from locations convenient to research staff.

3. Consider system integration. Integrating lighting control with other building systems, such as HVAC, building management, security, environmental monitoring and data storage is an essential component of holistic control strategies in life sciences buildings. The following key questions can help ensure vendors and systems will work together to determine and overcome feasibility, function and scope-of-work challenges if engineers are planning to integrate lighting with other building systems:

- What information will other systems need to extract from the lighting control system?
- Are there any points on the lighting system that are controlled by a third party?
- How will the third-party interface with the lighting control system?
- Are there any light-based alarms?
- What system will raise the alarms?
- Which system is responsible for historical data retention?
- Would single-point reporting increase ease of use?

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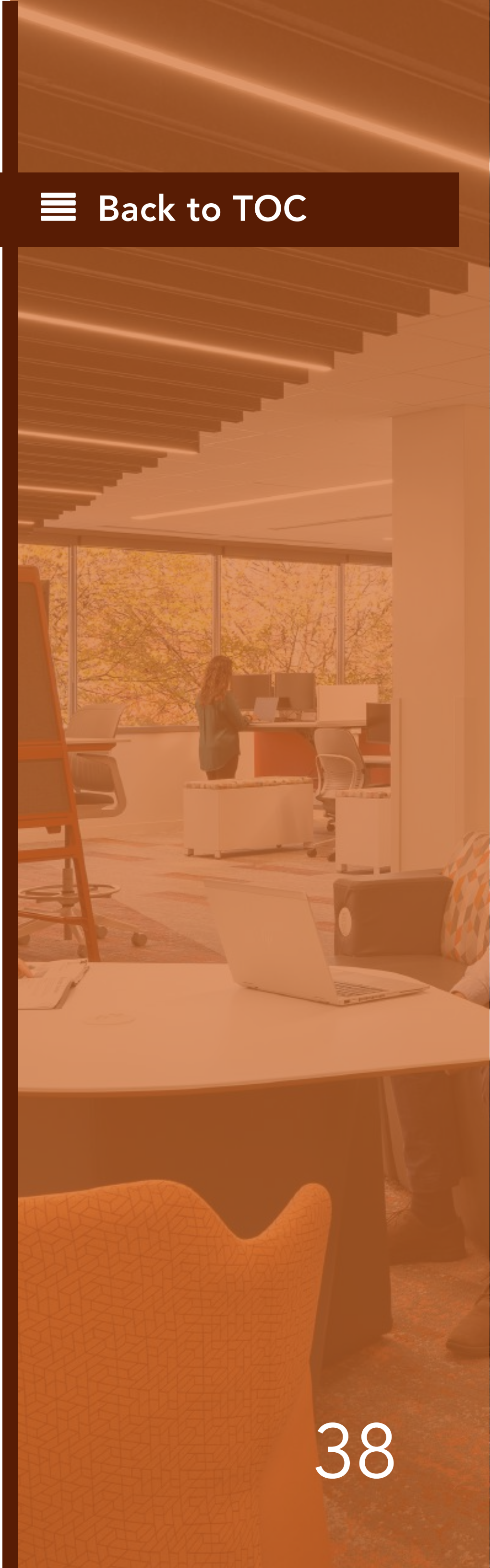


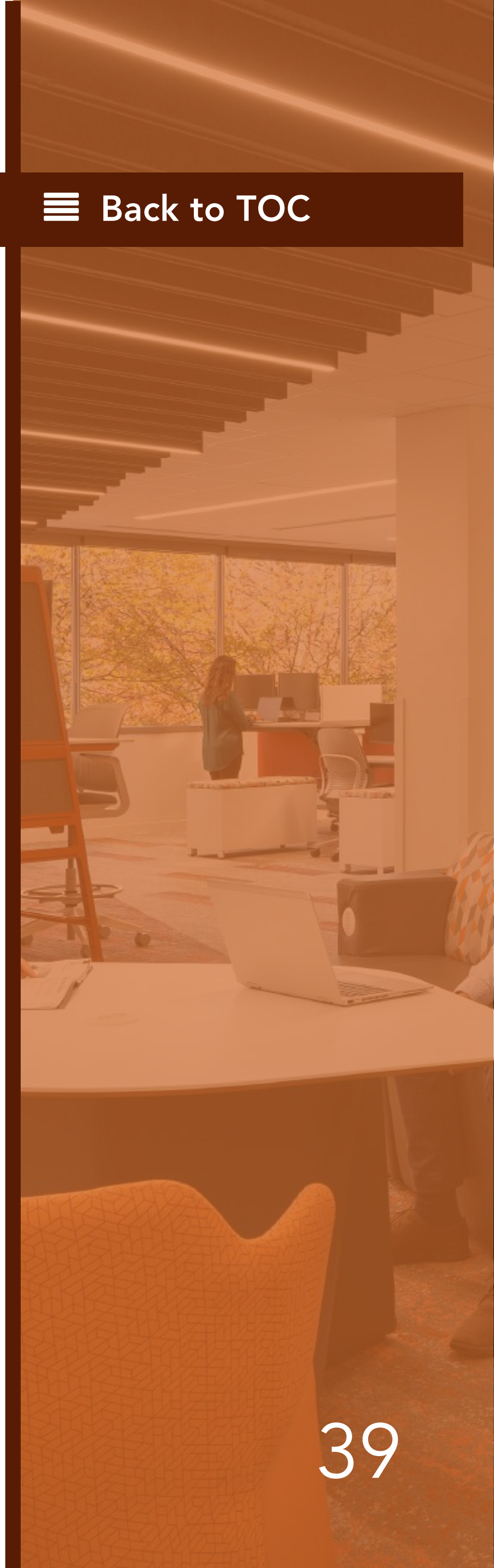
4. Prioritize functional independence of research areas. Vivarium spaces are often broken into distinct working groups or sets of areas (rooms) that are always working on the same group of experimental subjects. Systems should be designed such that a failure in one work group does not affect any other work group.

The number of independently serviceable systems will be determined by the number of independently functional groups. Breaking the system into smaller, logical system blocks increases reliability and robustness but can also increase cost. Consultants will want to design the lighting system such that it accommodates the appropriate number of groups and maximizes system reliability without adding unnecessary complexity and cost.

5. Prepare for the unexpected. Plan for uninterrupted critical lighting in lab settings as well as robust emergency or egress lighting. The lighting system can help ensure a regular diurnal cycle in a vivarium, even in an emergency. Luminaires and controls within critical or sensitive areas should be powered from an uninterruptable power source to keep the room working as normal and ensure uniformity of control and monitoring.

In vivaria, it is essential to maintain normal schedules and manual control so as to not disrupt animals, data collection or research procedures. Most electronic systems have a delayed start, meaning that full function is not instantly restored after power cycle. Therefore, luminaries and controls of critical or sensitive areas should be powered from an uninterruptable power source to preclude loss of function resulting from loss of utility power.

6. Minimize the opportunity for human error. Control systems should be intuitive to the research staff but must also be designed to limit user errors by decreasing the chances of unintentional activation. Sensitive areas commonly require a constant 20 to 30 foot-



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candles during simulated "day," and a low intensity red light during simulated "night." Another frequent requirement is simulated dawn and dusk transitions, i.e., smooth ramping up and down of light levels between day and night light settings respectively.

Research requirements and research subjects, vary widely — the lighting system has to be easily adjustable to accommodate these differences and to support research inputs such as the need to stimulate circadian rhythms in subjects. Fixture components are the primary contributors to achieving required light levels without flicker, variation or interruption. Many fixtures that produce consistent, high-quality light in steady state still exhibit less than ideal performance during transitions. Compatibility between fixtures and controllers is essential in producing quality light output.

Beyond the intricate lighting requirements of vivaria, the lighting design must provide appropriate illumination for standard working conditions, meet code and offer convenient, accessible control to the people in the space. It is important to work with a manufacturer that understands the facility requirements and can help to ensure lighting specifications are built to handle the unique intricacies of life sciences spaces by activating required lighting scenes automatically, consistently and without interruption.

7. Choose the right lighting partner and the right system. Lighting is essential throughout the built environment and especially so in life science research and development facilities. Make it easy for end users to operate and identify the right combination of lighting control strategies across all spaces in the application including:

- Operator control stations.

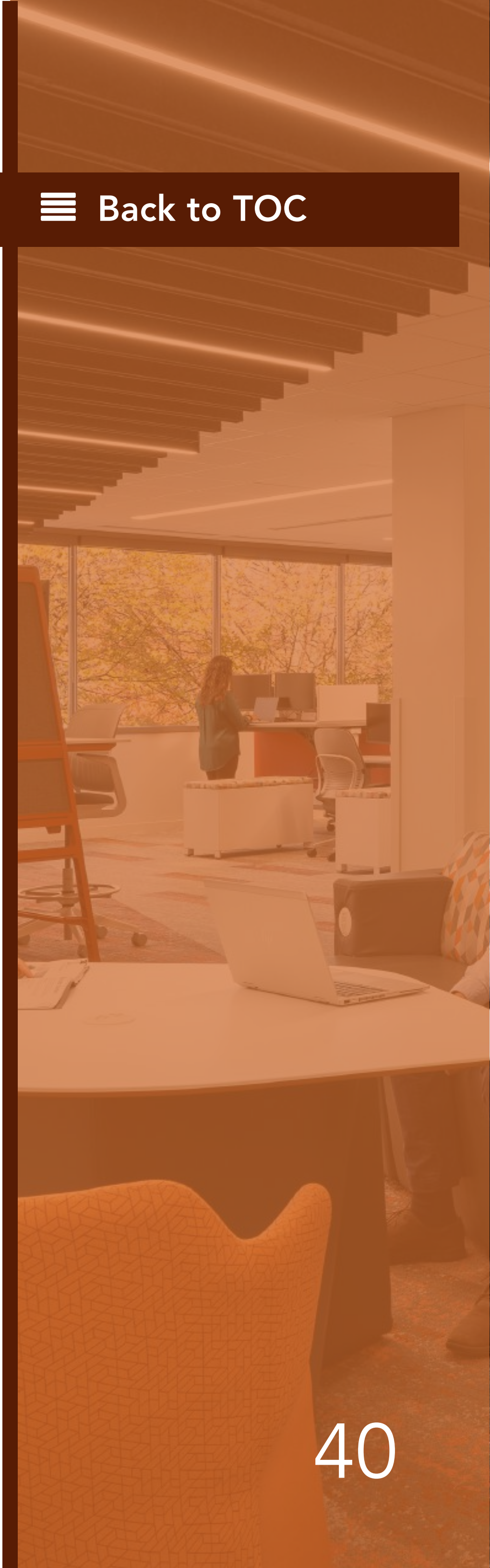
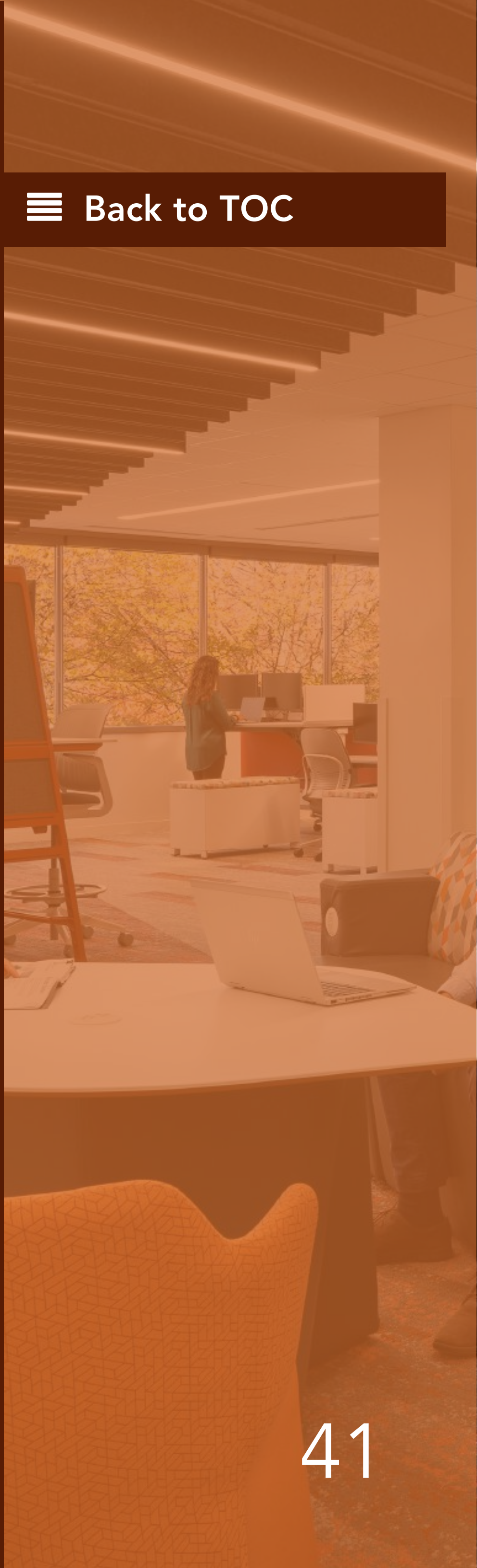


Figure 2: Advanced strategies used in a vivarium can also inform best practices for a wide range of life sciences applications. Courtesy: Warren Jagger Photography, Lutron Electronics

- Space management monitoring apps and software.
- System integration.
- Dimming performance.
- Automation overrides.
- Luminaire level lighting controls.



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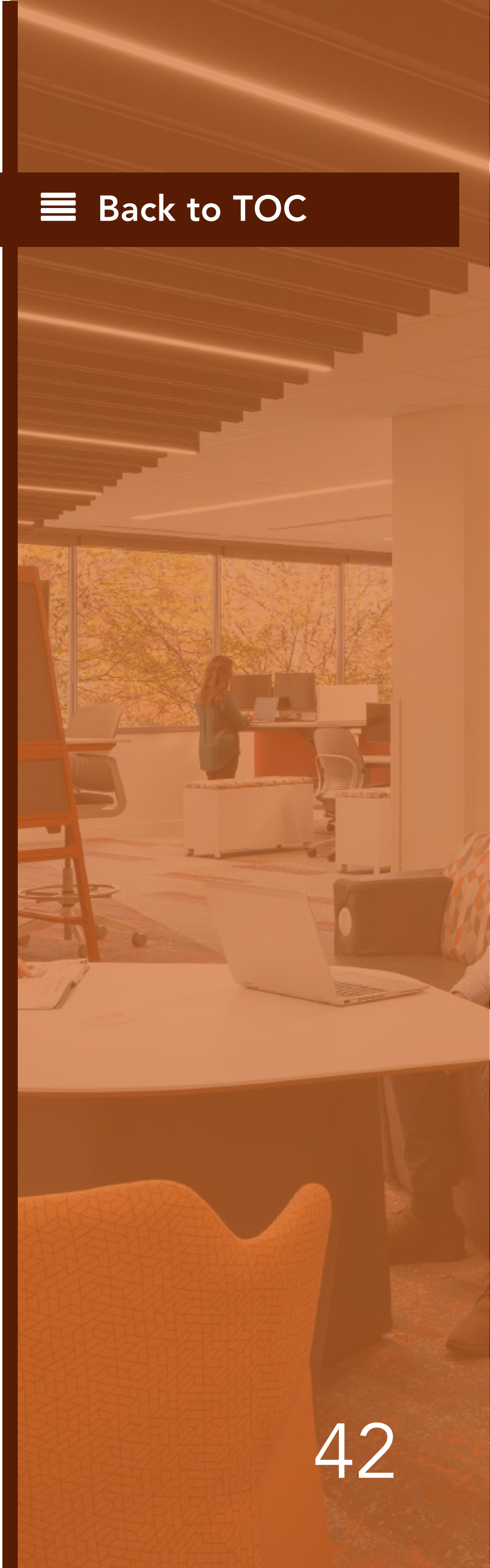


- Alarms
- Shade control in nonvivarium spaces.

Ongoing service and support are especially critical in these applications. Confirm that the selected manufacturer has a proven, consistent record of accomplishment in vivaria, offers 24/7 services to support the lighting system in an emergency and has the ability to update and adjust the system over time as research needs change or the facility identifies new sequences of operation for their next research project.

Following best practices can help save time and protect critical research

Even the most seasoned design professionals often do not have experience with the specialized lighting design and control requirements for life-sciences spaces such as vivaria. Improper system specification can lead to a system that cannot comply with the research team or the subject's complex needs. To avoid construction delays or complications with the research look to the lighting manufacturer to provide design guidance as well as installation and commissioning help. It is critical to work with a lighting controls manufacturer with experience in vivarium systems and the proven ability to propose and implement complementary lighting control solutions.

By following best practices, lighting designers can achieve an appropriate lighting specification, reduce the risk of callbacks and revisions and ultimately avoid lighting systems that do not adequately support scientific discovery.

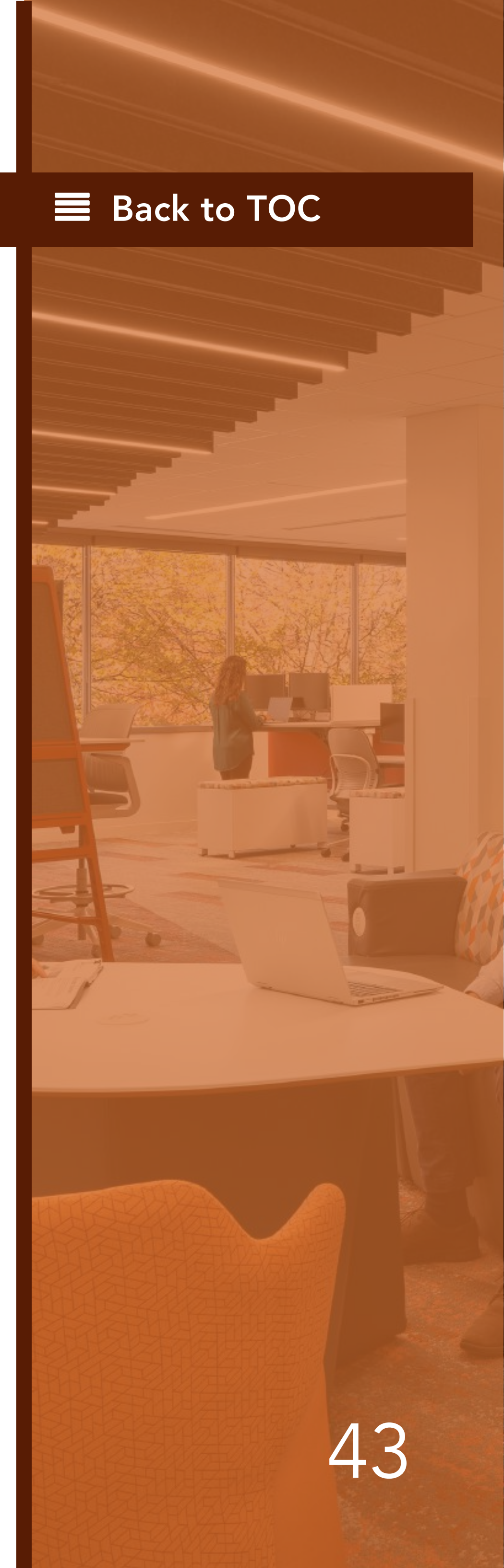
Scott Garrett

***Scott Garrett** is an area systems applications engineering manager at Lutron Electronics.*

Codes, standards drive respondents in this K-12 roundtable

Energy codes and air quality requirements direct design at K-12 schools

Misty DuPré, PE, Principal, Salas O'Brien, Vista, California – Maureen McDonald, LEED AP, Director, Energy Services, Southland Industries, Garden Grove, California – Steven Mrak, PE, Vice President, Peter Basso Associates Inc., Troy, Michigan – Steve Reigh, PE, HBDP, Engineering Leader, DLR Group, Washington, D.C.



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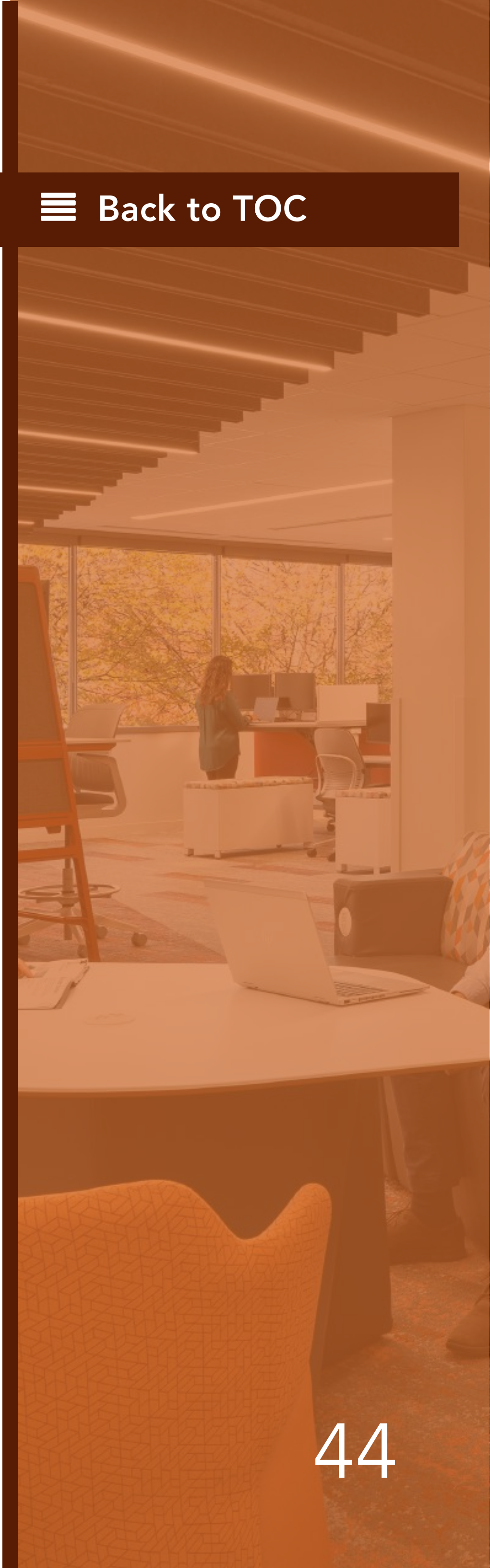
Misty DuPré, PE, Principal, Salas O'Brien, Vista, California – Maureen McDonald, LEED AP, Director, Energy Services, Southland Industries, Garden Grove, California – Steven Mrak, PE, Vice President, Peter Basso Associates Inc., Troy, Michigan – Steve Reigh, PE, HBDP, Engineering Leader, DLR Group, Washington, D.C.

Participants:

- Misty DuPré, PE, Principal, Salas O'Brien, Vista, California
- Maureen McDonald, LEED AP, Director, Energy Services, Southland Industries, Garden Grove, California
- Steven Mrak, PE, Vice President, Peter Basso Associates Inc., Troy, Michigan
- Steve Reigh, PE, HBDP, Engineering Leader, DLR Group, Washington, D.C.

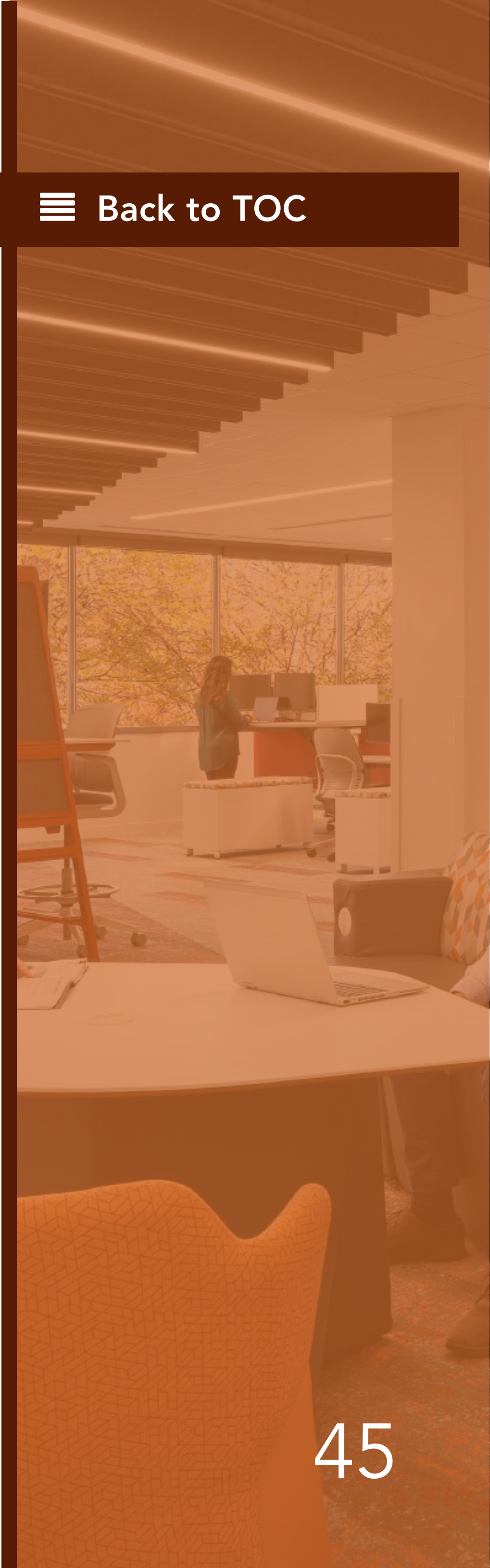
Please explain some of the codes, standards and guidelines you commonly use during the project's design process. Which codes/standards should engineers be most aware of?

Misty DuPré: California green code (CALGreen) and California energy efficiency requirements (Title 24) are the most impactful to our designs currently with regard to maintaining a minimum standard for air quality and energy usage, which have a significant impact in the design choices we make. Of course, ASHRAE, International Association of Plumbing and Mechanical Officials and others are general standards of the industry when it comes to traditional design approach, which we always rely on to make conscientious decisions.



In the Marygrove Early Childhood Center, shown are geothermal field piping header and dedicated outdoor air system energy recovery unit. Courtesy: PBA

Steven Mrak: Besides the typical state adopted construction codes (i.e., Mechanical, plumbing, electrical, energy, building, etc.) there are several standards we reference during our design efforts. Collaborative for High Performance Schools is a



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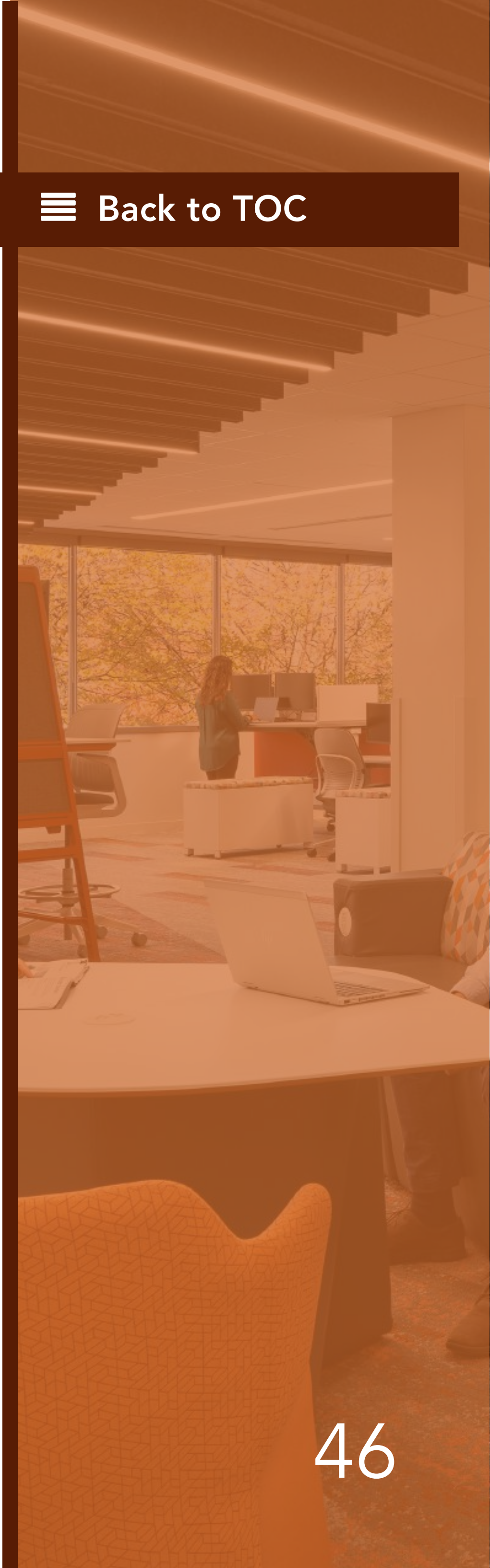
standard targeted specifically at K-12 schools to maximize occupant health, conserve energy and practice good environmental stewardship. ASHRAE also publishes design guides targeted specifically at K-12 construction titled Advanced Energy Design Guide for K-12 School Buildings with guides for different targeted energy savings (30%, 50% or zero energy).

How are codes, standards or guidelines for energy efficiency impacting the design of K-12 schools?

Steven Mrak: Tighter and better performing building envelopes are affecting how we account for dehumidification in our region. A lot of the K-12 school buildings in our area were built in the 1950s and '60s. These building envelopes tend to have higher rates of infiltration/exfiltration. With today's building envelopes, we are finding a need to implement dehumidification at the classroom level. Less solar and skin load during cooling season means mechanical cooling runs less frequently; combine that with increased ventilation requirements, and active dehumidification becomes a necessity for total occupant comfort.

What are some of the biggest challenges when considering code compliance and designing or working with existing buildings?

Misty DuPré: One of the biggest challenges in meeting code on renovation projects is the age of equipment and operating efficiency. If the equipment is still functioning properly, it is not typically desired to spend the funds on replacing it. However, aging equipment makes meeting newer energy goals challenging.



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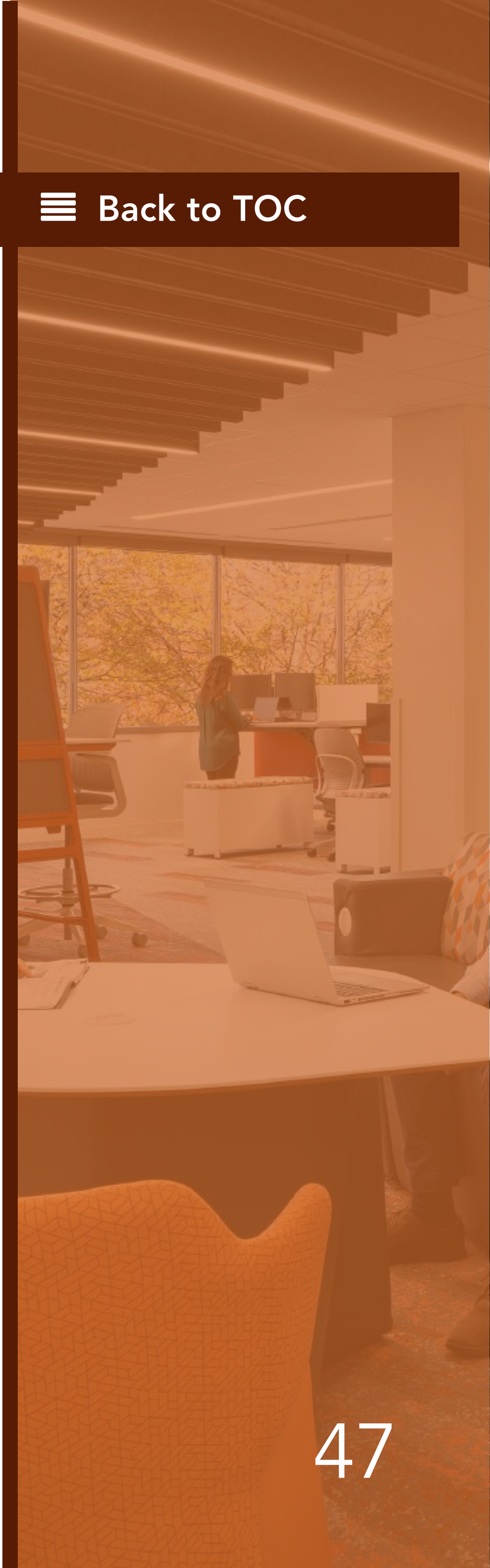
Another challenge is ensuring proper ventilation rates can be met by existing equipment when space usage changes. Often, we see renovations that involve adding air conditioning to existing systems that are heating only. Not only are the HVAC systems themselves affected, but it creates a chain of impact. The furnace room may not be able to accommodate the added cooling coil. Drainage may be required. Condensing units can require additional outdoor space or structural upgrades for rooftop locations. Electrical service and even the ductwork distribution will be affected because cooling load will likely require more airflow than the heating load required.

Steven Mrak: During HVAC renovations of existing buildings, providing infrastructure to support economizer operation can be challenging. While classrooms built 50 or more years ago may have outside air intake louvers for their unit ventilators, rarely did they employ economizer operation and even more rarely did they provide any kind of relief path. Multistory classroom buildings, with interior rooms, can become challenging to route properly sized relief air ducts to allow code required economizer operation. Another challenge can pop up in boiler rooms regarding number of exits. Many older school boiler rooms were partially or fully sunken into the ground and offer only one exit. Our current building code requires two exits for boiler rooms over a certain square footage and certain boiler plant capacity.

Consulting-Specifying Engineer



Considerations for emergency generator systems

Learn about factors to consider when designing a generator for an emergency power system

When designing a new facility one of the first space planning questions by the design team is, "Do we need a generator?" For the engineer, the answer can be obvious — or the project application may be complex and require a code study to determine the need and system configuration.

There are standard building systems that often require defined operational time during a normal power outage, such as egress lighting, but often a designer will plan for a generator if longer runtimes are required or if there are larger operational loads. If a battery cannot support the code requirement, the engineer will look at generators as the next option.

Examples of emergency generator systems applications are fire pumps, high-rise buildings, atriums, chemical exhaust systems and hospitals. Less common examples can include critical operations power systems facilities or high-density storage facilities.

While egress lighting and other life safety systems could be served with a central or distributed battery system, a generator becomes a practical application when other legally required and optional standby loads are introduced into the generator system, as these tend to be considerable electrical loads. In some cases, even when a central battery system or distributed batteries would suffice, the client will find a generator more practical to maintain.

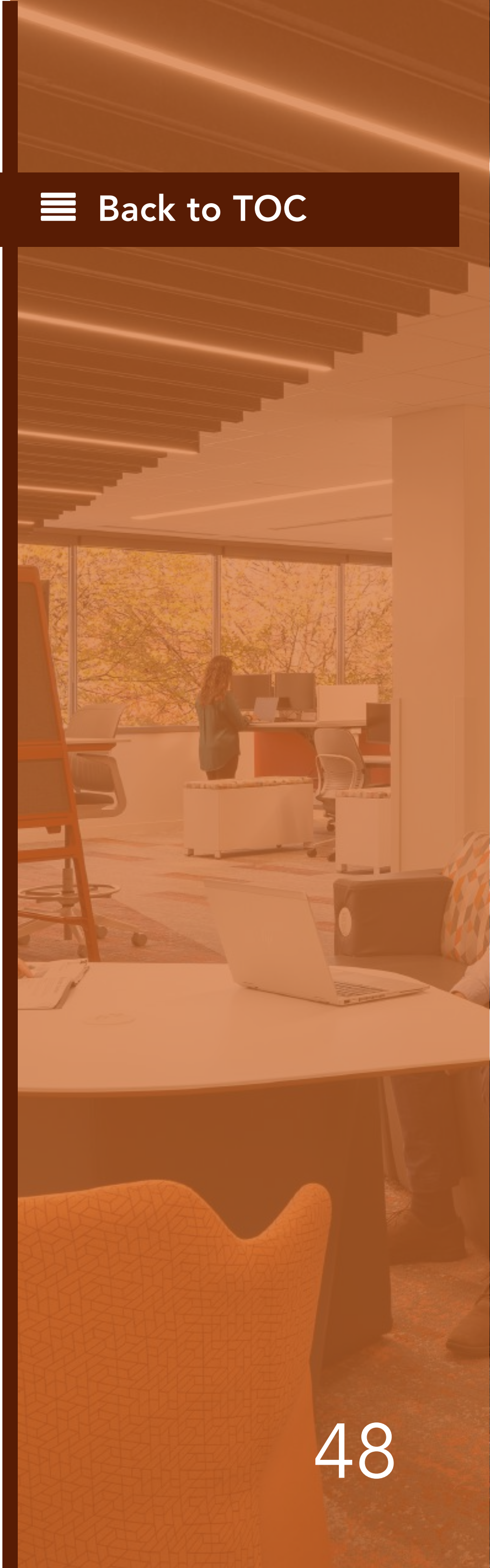


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Figure 1: Perspective rendering of utility yard including generator, medium-voltage transformer and medium-voltage switch, located behind an architectural screen wall, emphasizing the visual cohesion between the utility space and the building exterior, at the Applied Research Building in Tucson, Arizona. Courtesy: Ryan Haines, SmithGroup

Engineering design has a priority obligation to public safety and the liability risk is there to reinforce professional ethics. The National Society of Professional Engineers state as its first canon that "Engineers, in the fulfillment of their professional duties, shall: 1. Hold paramount the safety, health and welfare of the public." The engineering review of emergency systems is essential for every project and should be taken seriously.

When codes and standards require generators

Some projects do not require a generator distribution system per code, but are re-

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quired by the client for operational purposes. Other projects may want to combine standby power systems with the emergency power system, which is allowed if there is a proper load shedding schemes provided. There may also be facilities where medium-voltage generators greater than 600 volts become practical. While often overlapping in architectural considerations, this article will not discuss those unique details.

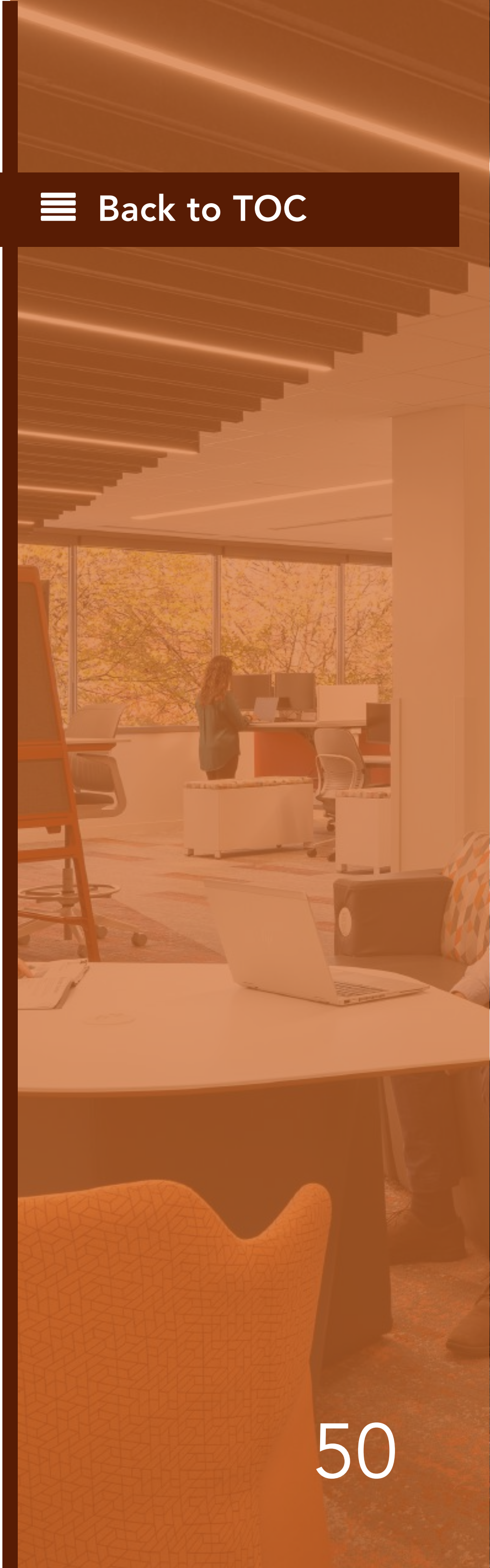
All devices and control devices in the emergency system must be tested and listed by an agency approved by the authority having jurisdiction for their intended use. There are many different types of listings for testing. UL Solutions' 2200 is required for stationary engine generators. UL 1008 is required for transfer switch equipment. UL 924 is required for emergency lighting automatic load control relays.

It is also essential to understand that only some devices are intended for emergency operations. Light fixtures, for example, can be used for egress, but only certain portions of the facility lighting systems are designed for use as an egress system. The egress lighting system can be provided with 90-minute battery backup or supplied from an emergency generator system.

For example, power packs are listed for normal and UL 924 operation. Misapplying and/or missing the listing and testing requirements can be a considerable complication resulting in cascading implications.

What is in an emergency system?

NFPA 110: Standard for Emergency and Standby Power Systems includes two important definitions for emergency systems, emergency power supply, or EPS, and emergency power supply system, or EPSS. EPS is "the source of electric power of the required



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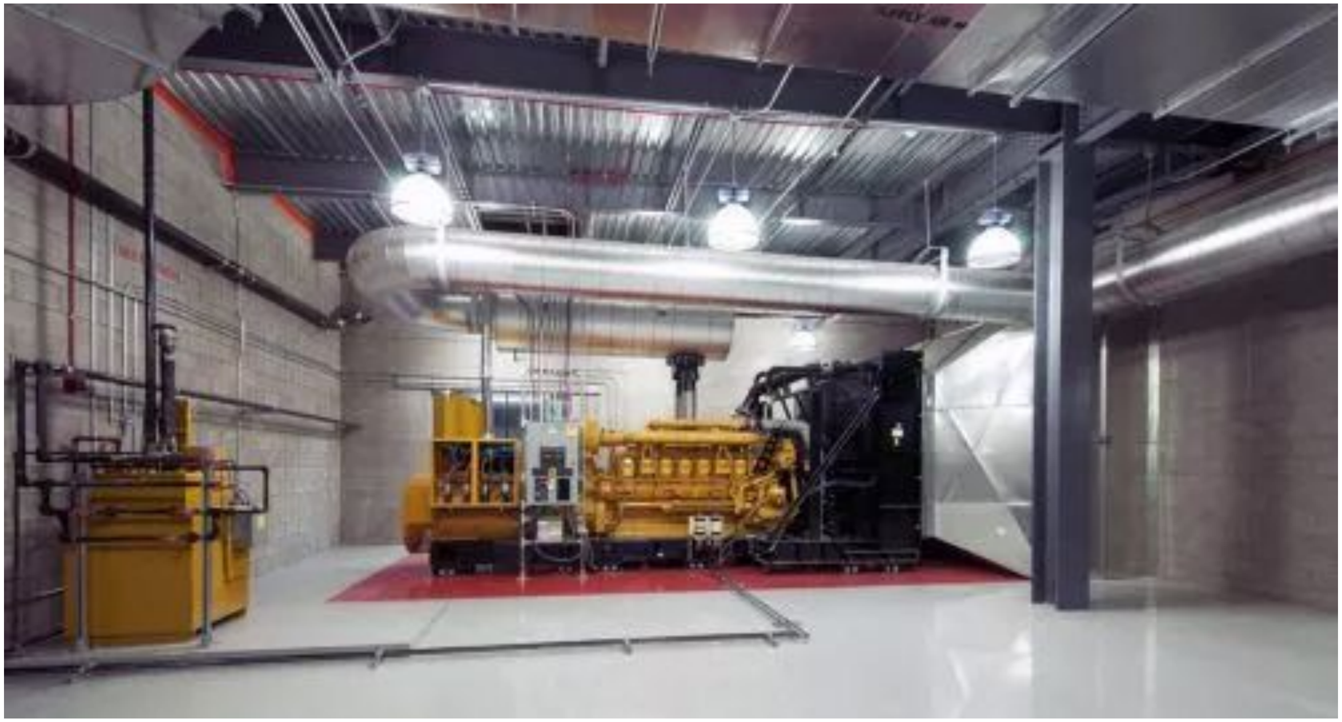

Figure 2: This shows the interior generator installation for a hospital facility located in Phoenix, Arizona. Courtesy SmithGroup

capacity and quality for an emergency power supply system," which is often the generator itself. EPSS is ''a complete functioning system … needed for the system to operate."

A typical system will consist of the generator(s), transfer switches, load banks, temporary generator connections, distribution boards, panelboards, breakers and all the pathways in between. This will apply to all systems requiring emergency support, such as egress lighting, emergency exhaust or critical heating, ventilation and air conditioning.

Where do we put a generator?

The generator and emergency systems can physically reside in the building's interior,

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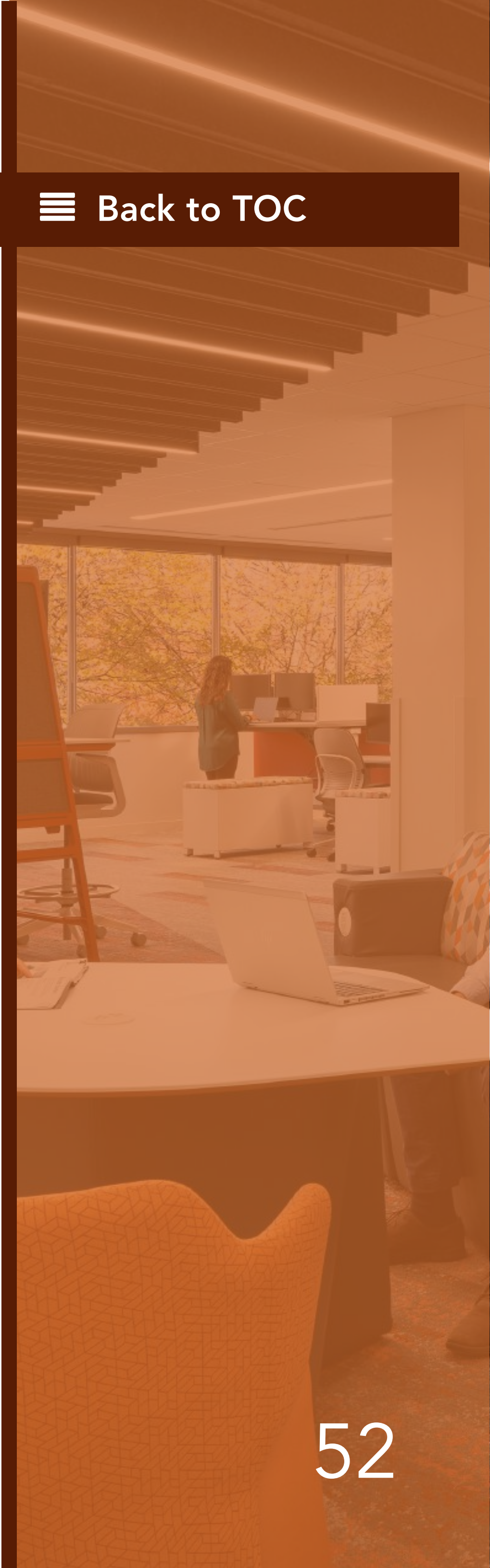

exterior, above grade or even on the roof — and likely a combination of locations if access is limited to qualified persons. Subgrade installation is a possibility but usually avoided due to the potential of water intrusion during a flood scenario. Several factors will determine location, including engineering judgment, code requirements and project parameters, to “minimize the probability of equipment or cable failure” (NFPA 110 7.1.1).

When installed within building interior spaces, EPS units must be in a separate room with a two-hour rating with exclusively EPSS equipment per NFPA 110 7.2.1. Also, consider that if the generator is interior to the building, the motor will likely cause vibrations that some facilities may not tolerate.

When installed outdoors, weather-rated enclosures maintain the functionality of the EPS and are a viable solution, provided the enclosure is rated to resist the ingress of weather to the level required by the local building codes. Appropriate weather-rated housings and a single enclosure often simplify the design for operations and points of risks. The noise attenuation of the outdoor enclosure is also a consideration.

While the electrical engineer may find the generator aesthetically pleasing and worthy of showcasing, there are applications where a generator should be inconspicuously located, either for architectural design or facility/operational considerations. This is important for certain government projects and other sensitive facilities where the generator provides redundancy and resiliency for people or critical systems. An obvious and easily accessible generator can make for a high-value target. As an integrated product, the generator can be incorporated into the visual parameters of the project while providing a level of security when required.

Considerations for emergency generator systems

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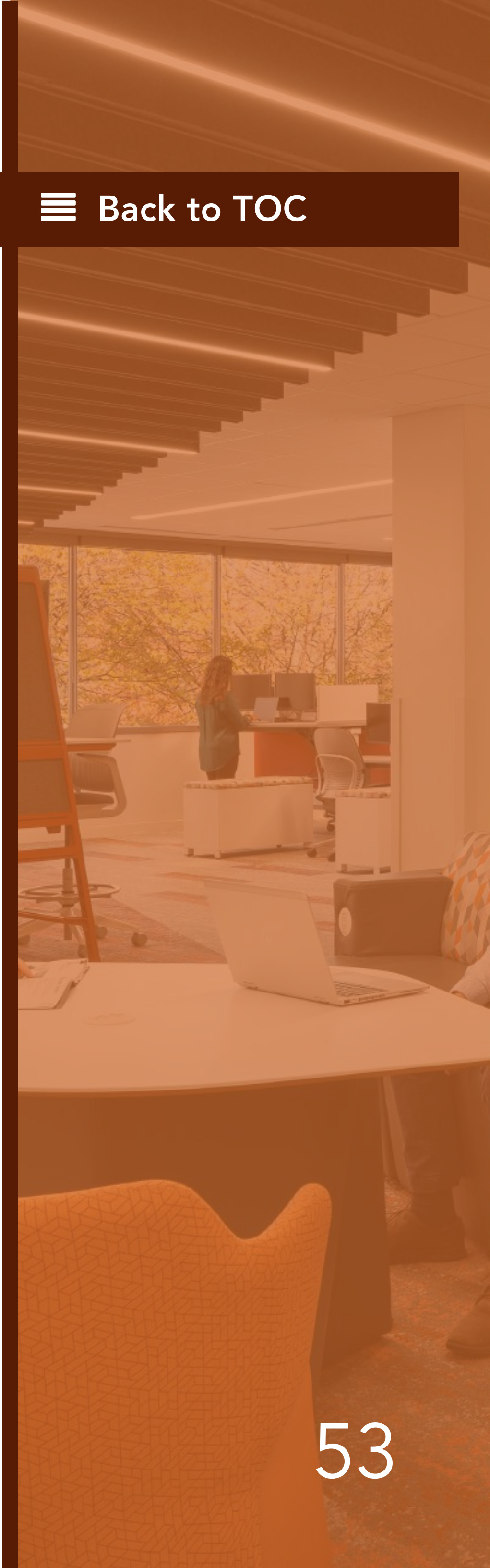
While the electrical rooms can be placed as needed for the architectural program, it is more efficient, constructible, cost-effective and manageable if the interior and exterior equipment are adjacent. Ideally, the generator feeders should be in a direct route to the distribution board. This becomes more critical where there are paralleled generators. A clear and direct route is beneficial because the underground organization can become complicated with adjacent wet and dry systems. A simplified route also has the benefit of reducing the length and, therefore, cost. The actual maintenance, observations and testing become simplified when the generator is adjacent to the space with the transfer switches due to accessibility.

While the generator and distribution system are in areas accessible to only qualified personnel, the associated remote annunciation devices are strategically placed at normally staffed locations to alert them of system status and operational issues.

If the generator is near the building service transformer, required clearances should be reviewed with the AHJ, owner and utility requirements. As well as potential insurance requirements such as FM Global. It is often recommended that an emergency generator be provided with a fire-rated wall in case of fire at either source, or provided the recommended clear distance.

It is also important to consider the practical elements of planning a generator yard. There should be adequate lighting so the generator can be maintained during an outage. That could mean circuiting lighting, access doors and receptacles to a life safety circuit. It is a great benefit to the project or building to have an early run-through of major building components and potential outage procedures with building facilities personnel during design.



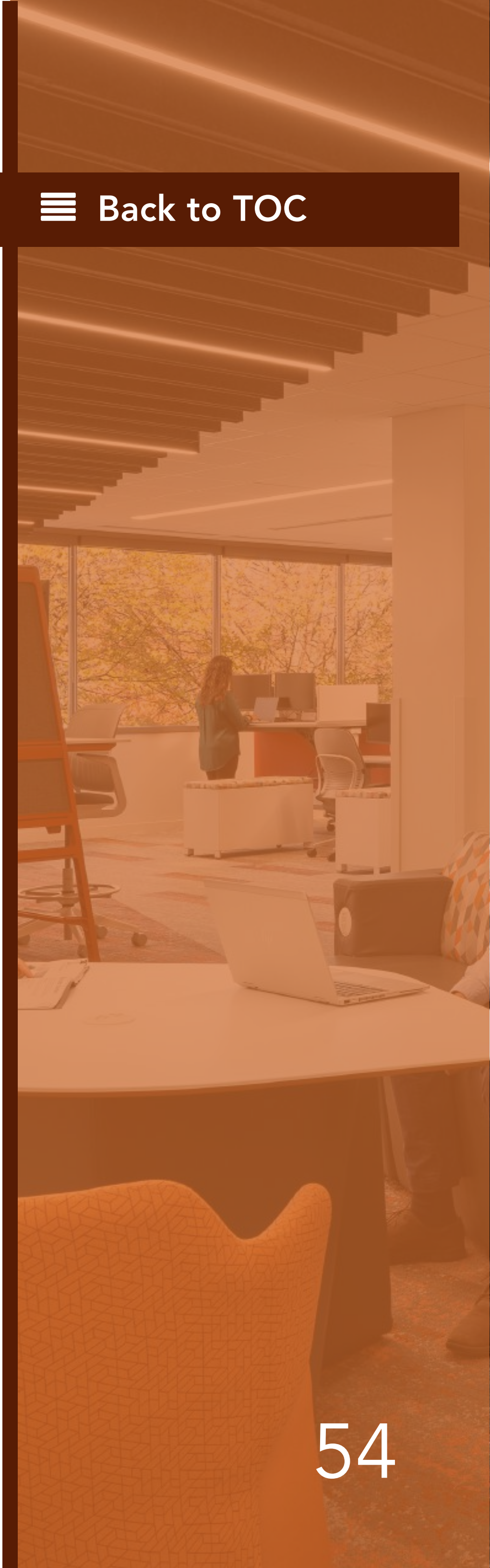
Furthermore, with climate change becoming an increasing issue in electrical systems resiliency, the floodplain is not an item that can be ignored. Great care should be used with locating the emergency systems. Consider if the equipment is in a 100-year or even 200-year flood plain. Is the equipment located in an area with hurricanes and tornadoes? These resiliency considerations will guide the configurational basis of the system.

If the EPS (generator) is located outdoors and Level 1 EPSS equipment is located indoors, the system must have a room separate from the normal service per NFPA 110 7.2.3. When the EPS is located indoors, the room per NFPA 110 7.2.1, must have a two-hour fire rating.

It is often recommended that the EPSS room also has a two-hour fire rating because of the 90-minute operating time required for the egress system or protection requirements for specific types of emergency support systems. Regularly a combination of interior and exterior locations are utilized, but in all scenarios planning to mitigate risk in all forms is critical for an optimal installation.

The NFPA 70: National Electrical Code restricts the height of the disconnecting means to 6 feet, 7 inches per NEC 2017 240.24(A) to allow access with the ability to use "portable equipment" when the "overcurrent device is adjacent to the utilization equipment." Depending on the AHJ, there can be various interpretations.

There are various ways to meet this requirement and the recommended method should be reviewed and approved during design. It could be that a readily accessible ladder or strategically located emergency power off switch meets the intent or a per-



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manent perimeter platform must be installed.

Figure 3: A generator appears in a chiller yard with a utility transformer in the distance, located in Texas. Courtesy: Wade Griffith, SmithGroup

Generator ventilation

It is tempting to provide the minimum clearances around the generator for maintenance, but it is also important to allow enough breathing room for intake and discharge ventilation. While it has always been good practice to provide enough space to walk around the enclosure doors, NFPA 110-2022 codified the clearance requirements in section 7.2.6.1 that generators are to be provided with "36 inches of working space access for

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inspection, repair, maintenance, cleaning or replacement from the outside edge of the enclosure or sufficient space to fully open all hinged doors, whichever is greater."

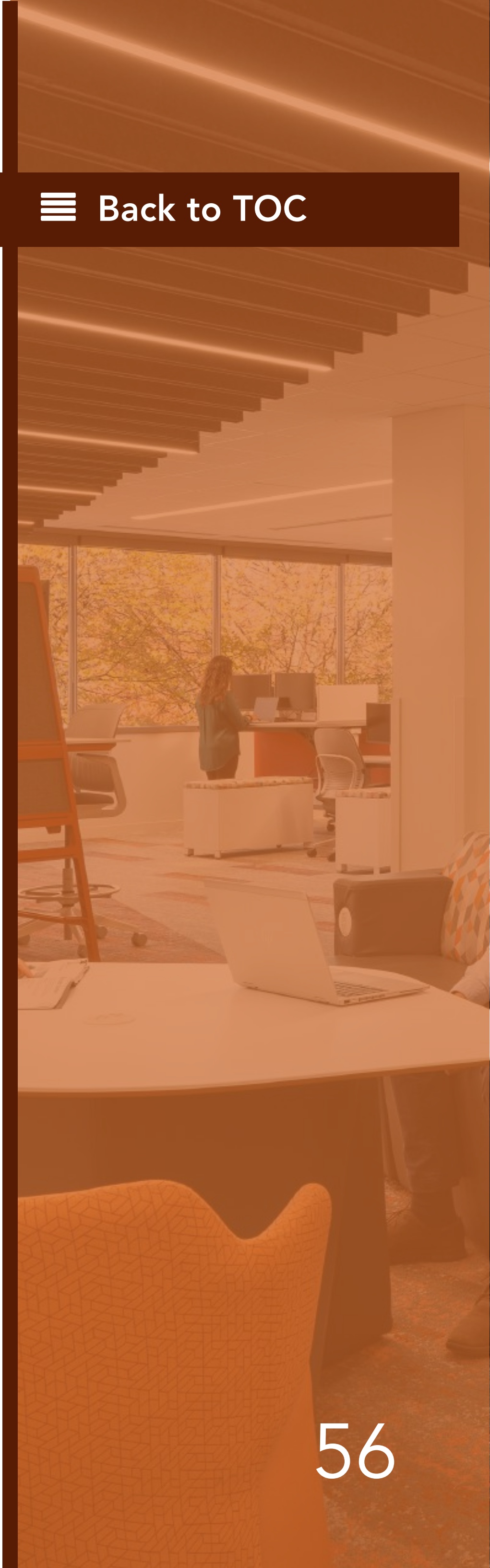
The ventilation needs can vary by manufacturer and accessories. Ventilation is critical in an environment with high heat, such as the desert, so the hot ambient air does not recirculate the already increasing hot air into the generator and overheat the engine. For exterior units, there are accessory options such as low intake or vertical-discharge hoods that help manage the recirculation and could also tighten the space needed, but the dimensions should be confirmed before reducing the expected generator area.

NFPA 110 7.7.1 calls for provisions "to limit the maximum air temperature in the EPS room or the enclosure housing the unit to the maximum ambient air temperature required by the EPS manufacturer." An interior EPS room will require intake, discharge and ventilation directly from the exterior through a wall ''or a two-hour fire-rated air transfer system" per NFPA 110 7.7.2.

Fuel requirements for generators

There is a common misconception that the larger the generator, the longer the runtime, which is inaccurate. Generators are sized to accommodate the required loads, but the fuel tank capacity determines the actual runtime. NFPA 110 5.5.3 indicates that the tank shall "support the duration of the run specified," and NFPA 110 7.9 further clarifies that the "fuel tanks shall be sized to accommodate the specific EPS class."

The generator kilowatt rating and fuel are required to prioritize adequate capacity to Level 1 and Level 2 loads, then optional loads per NFPA 110 7.1.5. The potential runtime



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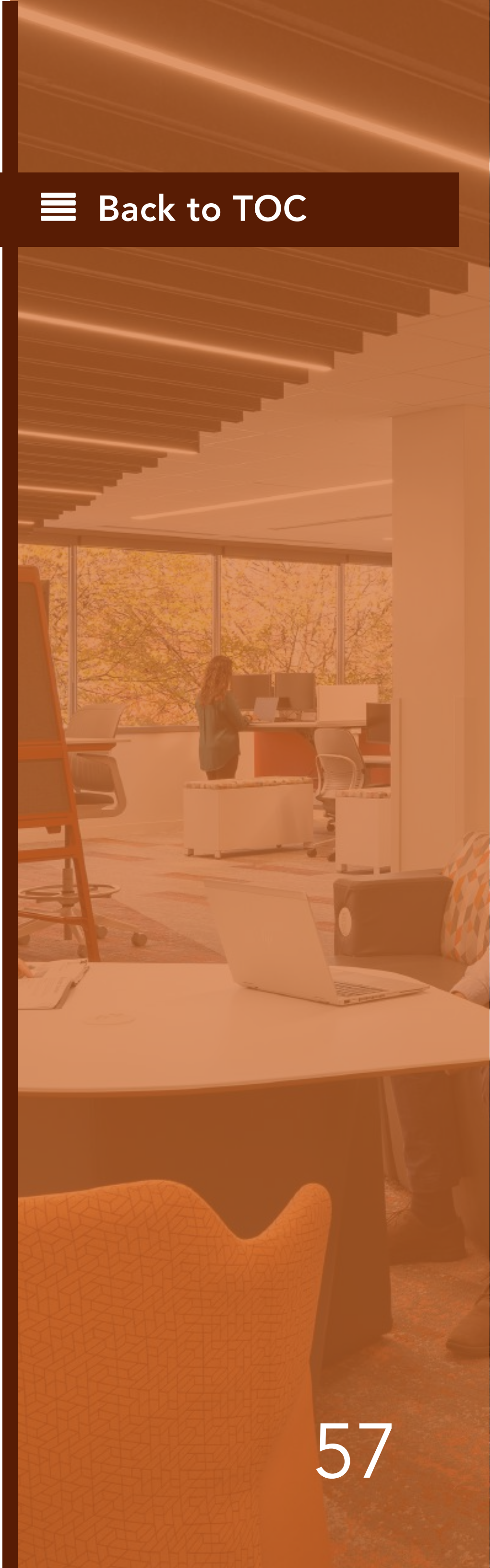
consumption rate of the generator varies by manufacturer, but the operational full load of gallons per hour can be requested.

When considering "the generator cannot ever go down" project parameter, the answer isn't always to add more fuel. Fuel must be cleaned and maintained — commonly referred to as polishing — and the system must also have the varnish periodically removed. Factors such as representative service in the area, distance from the nearest fuel supplier or availability of fuel in the area need to be considered.

A conversation regarding the client's experience in the area can clarify the specific requirements to bring balance to performance and value. NFPA 110 7.9.1.3 clarifies that "tanks shall be sized so that fuel is consumed within the storage life or provisions shall be made to remediate fuel."

Fuel tanks have specific requirements in NFPA 30, 37, 54 and 58 that may also call for additional protections contingent on the type of tank. NFPA 37: Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines defines the requirements and maintains that the engines shall be readily accessible for "maintenance, repair and firefighting" (NFPA 37 4.1.1).

NFPA 37-2021 section 4.1.2.1 calls for engine rooms to have "at least one-hour fire-resistance rating" for walls and floors, with the rating maintained for the ceiling unless it is otherwise protected or noncombustible. Section 4.1.4 calls for outdoor generators in "weatherproof housings that are installed outdoors shall be located at least 5 feet from any openings in the walls of structures" or from structures having combustible walls unless complying to the exception of "the structure having a fire-resistance rating of at least one hour" in nonhazardous locations.



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There are also exceptions to reduce the 5 feet clearance if fire testing is conducted. Similar requirements apply to engines located on the roof.

Regardless of location, containment of fuel in the possibility of a spill or leak should be coordinated with the requirements of the space. It is possible to get a double-walled fuel tank, but containment curbs or pumps should be coordinated if that is not provided.

There is a limit to the amount of fuel that can be placed interior to a building or on the roof. NFPA 110 7.9.5 calls for a maximum quantity of 660 gallons of diesel fuel "inside or on roofs of structures." Often when there is a need to extend the potential runtime of the tank in these locations. A refueling system and day tank, above or below ground, will be required and will need extra planning and discussion with the AHJ. The fuel port will need to be accessible and secure.

Usually, when a fuel port is required, a recirculation system will also have to be provided to get from the ground level up or across a long distance. Refueling systems are also costly because the fuel lines have separate fire protection requirements for safety. Direct routing and immediate adjacency are the most effective and economical.

Additionally, it is important to plan a path for refueling. Hose lengths can vary depending on the supplier, but the general expectation is to plan for a minimum 25-foot hose, with some suppliers having options for extensions. Many fuel vendors also have a small pump to push or pull the diesel gas an extended distance.

If the generator uses natural gas, it doesn't mean fuel planning can be ignored. Nat-

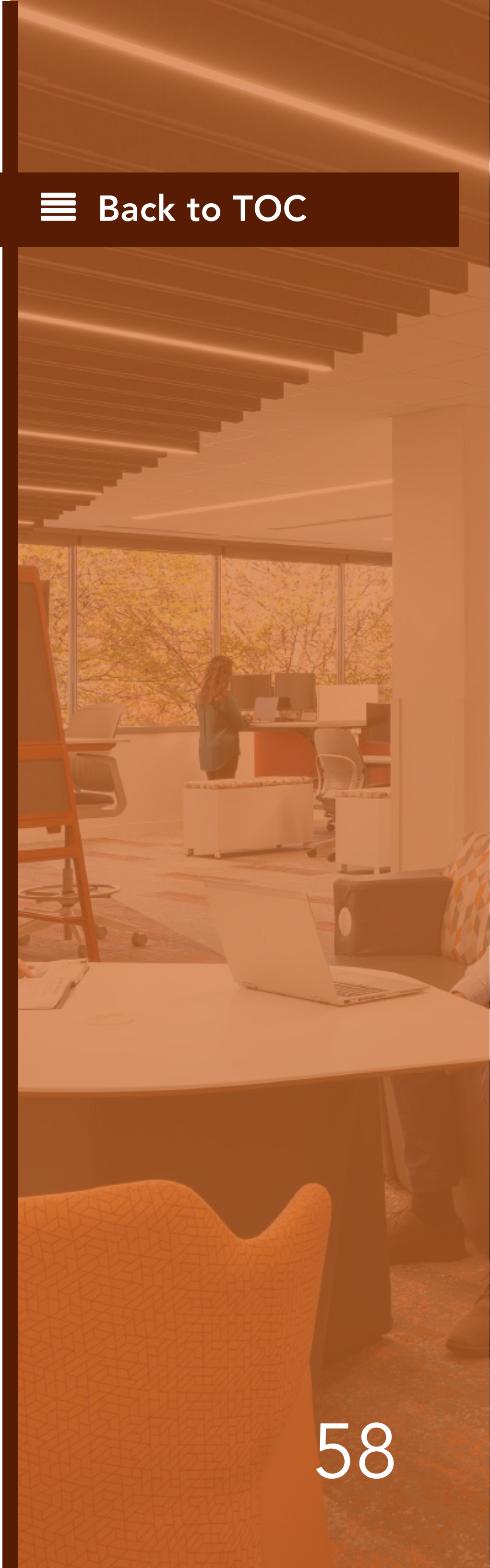
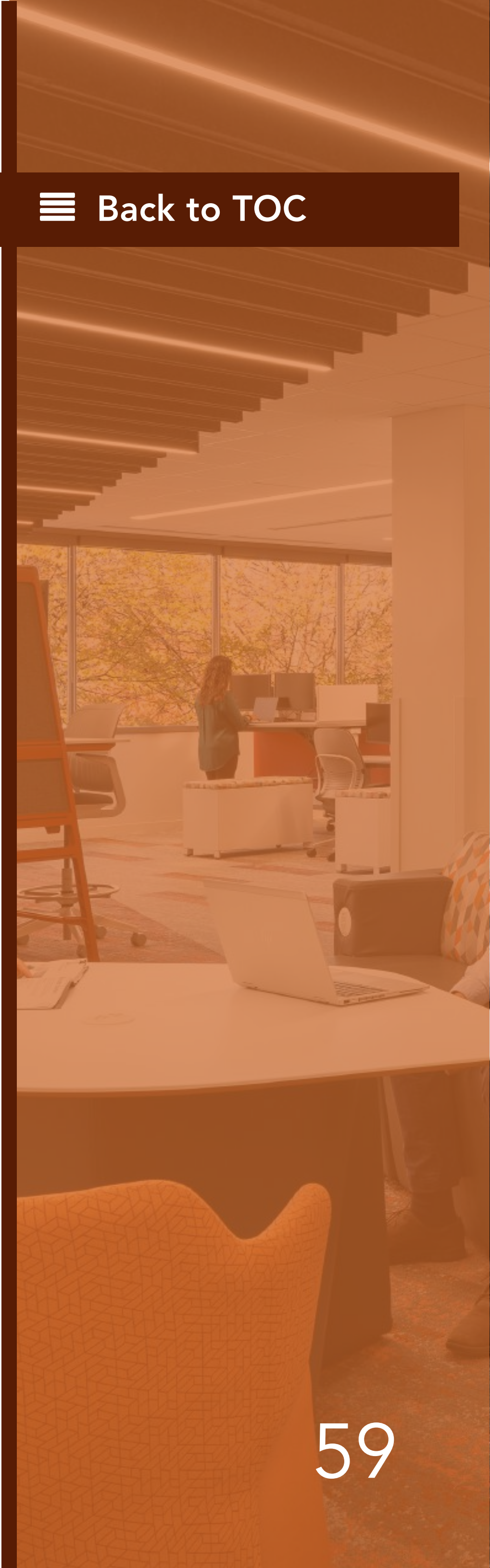


Figure 4: Generator with support platform is located at Johnson County's Medical Examiner Facility. Courtesy: Michael Robinson, SmithGroup

ural gas piping will need access to the generator pad and can be costly if the natural gas piping is not near the electrical utility yard. Natural gas may not be considered a reliable source in all jurisdictions. It is important to note that natural gas generators have a practical operational limitation or rating, for EPSS.

Testing and maintenance

Generators produce considerable sound. It is important to consider the generator's



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location for internal occupants and exterior adjacencies. AHJs have sound ordinances and if located adjacent to any residential neighborhoods; these ordinances can be very strict. Sound is measured in decibels and is a condition of distance. When coordinating the decibel level, a clear understanding of the surrounding environment is essential.

The code requires periodic testing for emergency systems. General requirements of NFPA 110 8.4.1 call for documented ESS testing at least monthly for at least 30 minutes. Periodic testing mitigates the likelihood of a failure during a normal power outage. It is important as a team to communicate that emergency systems will operate based on how well they are maintained.

Additionally, the generator breaker is a part of the coordination, short circuit and arc flash studies. These studies are code required for emergency systems and often require physical confirmation of the configuration. It is important to plan the time and coordination between suppliers for this to occur during the submittal review and before project closeout.

The 2017 edition of the NEC 700.3 (F) requires equipment provisions for a straightforward connection of a temporary power source in the event the permanent generator is out of service due to failure or maintenance. It is important to consider where the temporary generator could be located. The cables connecting to the equipment provisions, often a plug-style or triple switch-like configuration, aren't intended to be in driveways or will require additional protection.

The optimal planned location for a temporary power source is adjacent to the switch-

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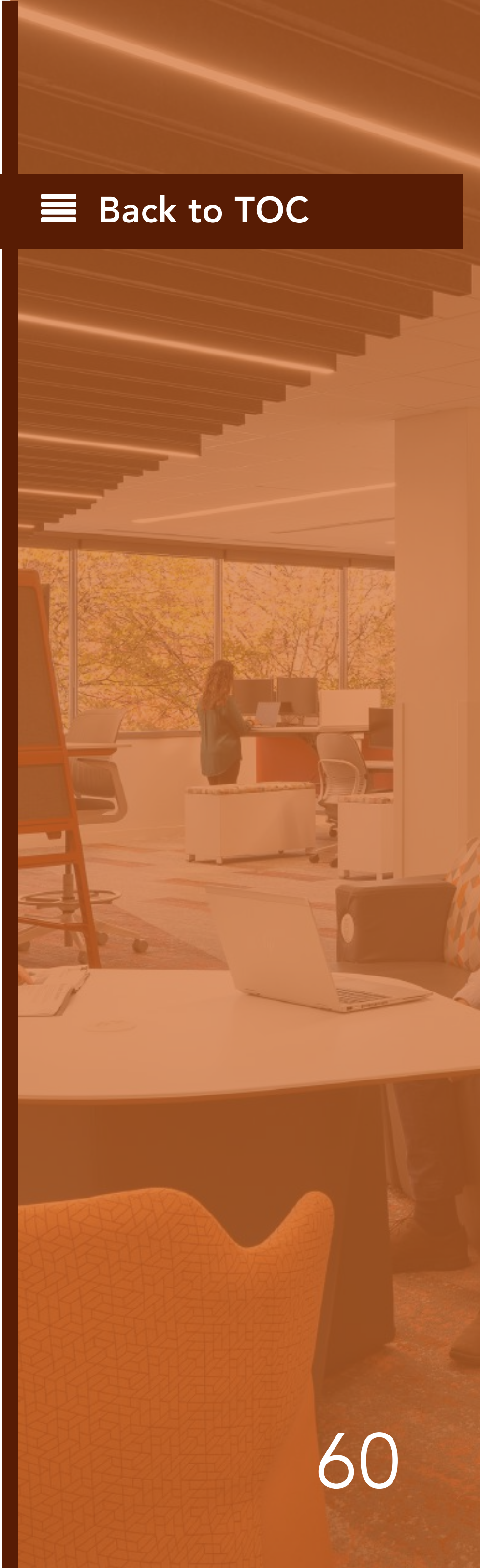
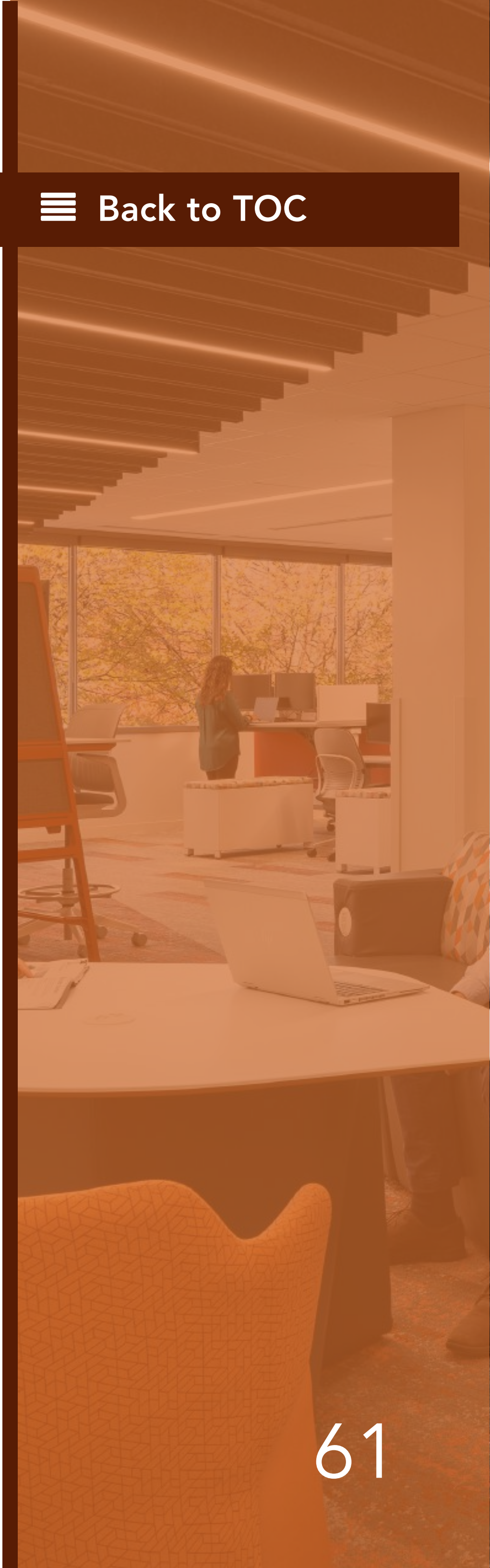


ing means. Planning the parking area for the temporary generator connection can save the operator time during the outage, often saving costs and increasing safety.

Ultimately, the emergency systems cannot be designed in isolation and successful system design will be the product of integrated communication between the AHJ, stakeholders, disciplines and clients.

Bianca Jimenez and Rick Baca

Bianca Jimenez, PE, is a senior electrical engineer at SmithGroup. She has more than 10 years of experience currently focusing on science and technology projects. ***Rick Baca*** is a senior electrical designer at SmithGroup. He has more than 19 years of experience in electrical engineering with a focus in health care.



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