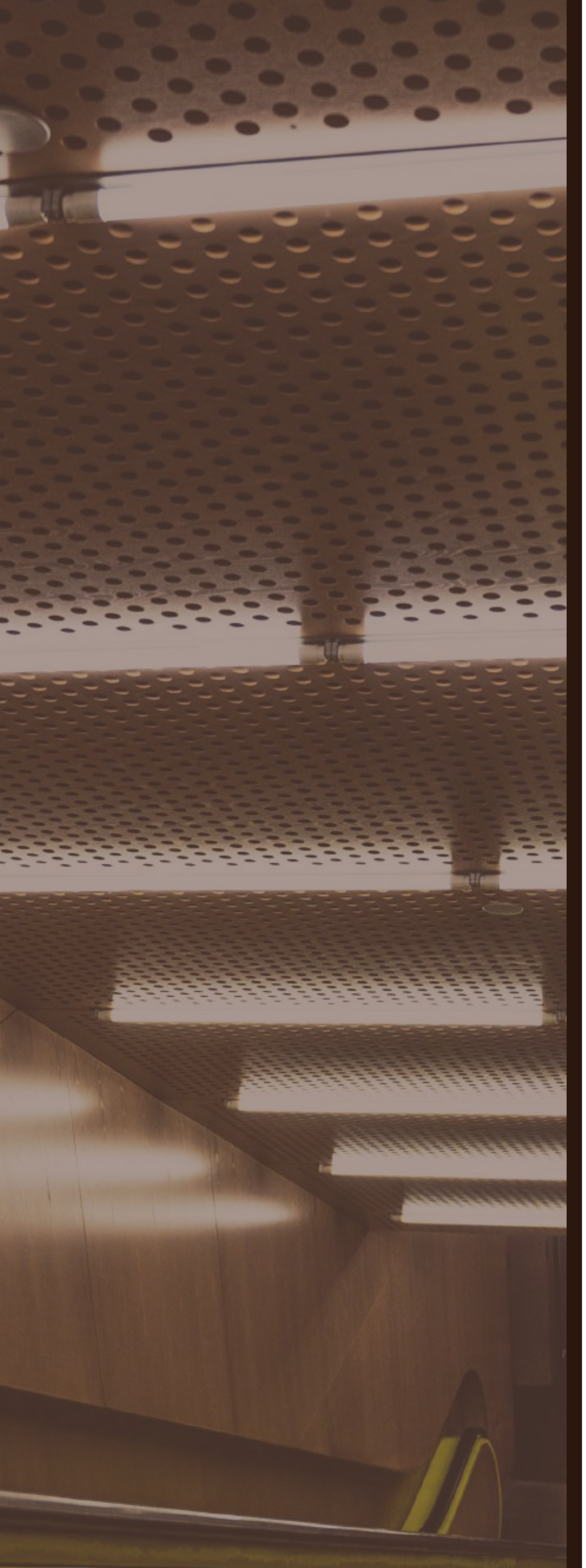
Lighting & Lighting Controls

WINTER EDITION

CONSULTING - SPECIFYING engineer eBOOK | synapse



Contents

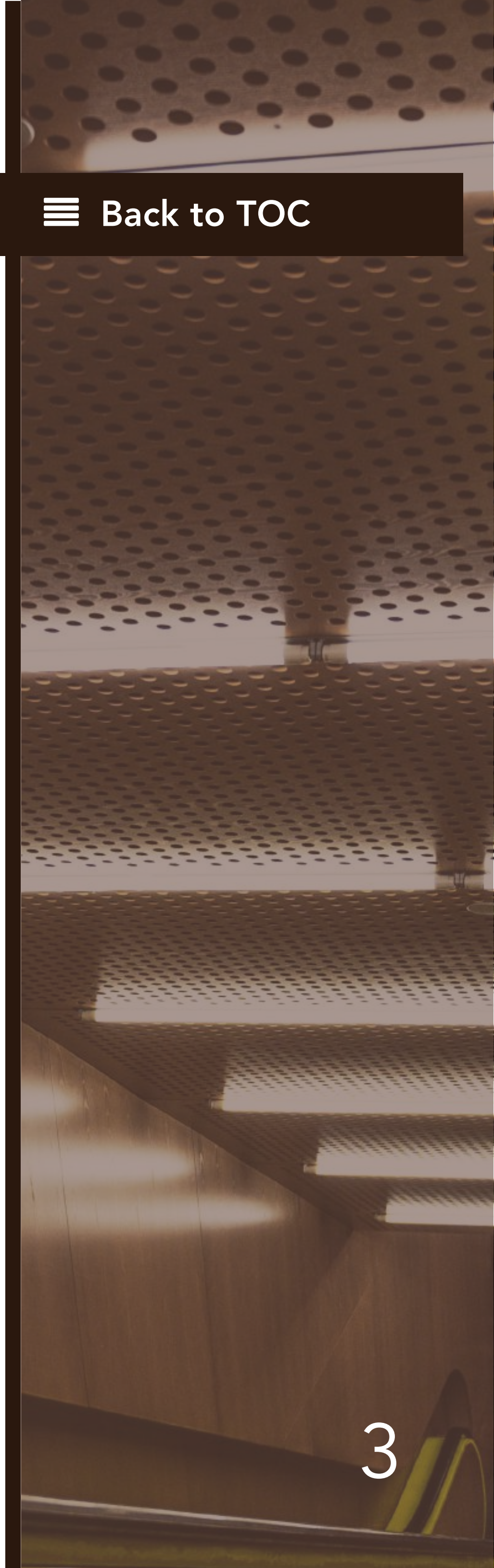
synapse

Lighting design engineers look at LED lighting advancements in K-12 schools

The evolution of lighting from incandescent to light-emitting diode (LED) has resulted in many changes that drove lighting technology.

Today, LED lighting is often required in most new and renovation projects. Besides offering the obvious reductions in energy consumption and maintenance, LED systems continue to provide new and additional benefits. Previous leaps in the evolution of lighting technologies, outweighed the sacrifices that always came with its use. However, pre-electric times aside, the improved light sources always attempted to mimic the old faithful incandescent lamps. High intensity discharge lamps (HID), offered high lumens/watt efficacy, but with a poor color rendering index (CRI), inconsistent correlated color temperature (CCT), and an inability to turn on instantly; not to mention the noise, heat, and bulky hardware required to make it all work. Fluorescents continued with struggling CCT consistency and questionable CRI. Dimming was considered a "specialty." Neither of these advanced technologies were ideal, and drove lighting products to physically larger, bulky designs.

LED lighting has advanced significantly enough that we now have a light source that can mimic the characteristics of incandescent lights without sacrificing quality and aesthetics. We can turn them on/off instantaneously, without sacrificing life by frequent on/off switching. We can also dim LEDs while simultaneously lowering CCT, just as we could with incandescent. Like incandescent, LED retrofit lightbulbs are available in frosted or clear versions that include visible filaments. Two items that technology still



Back to TOC

Back to TOC

needs to improve are bulky drivers for LEDS reminiscent of ballasts, and the flicker often associated with dimming.

While there may always be a place for a variety of 2×4 light fixtures in classrooms, the LED versions are thinner, lighter, easier to install, visually more comfortable, and far more energy efficient than the traditional versions. Much like the explosion in technological advances with LEDs, manufacturers continue to expand the extensive types of LED products that are available to consumers.

Educational facilities are all about learning and inspiring curious minds. LED systems provide an opportunity to support such environments by helping us create visually intriguing spaces. Media centers, collaborative/common spaces, vestibules, exterior facades to name a few, can be designed much like non-educational venues. For example: commercial theaters, entertainment centers, museums, and other commercial/public spaces. Such spaces often required combinations of HID (for performance) and incandescent or fluorescent, to accommodate dimming, accent lighting and life safety instant-on requirements. Some of these functions can be combined using LEDs. Today, there are multiple shapes, colors, lighting distribution and dimming options to choose from that enhance the visual appeal and function of such spaces, making them more interesting and appropriate for evolving age groups.

While LED technology evolves, education facilities also require adaptability. Students with special needs may require rooms with a broad range of lighting functions; with each human condition requiring a different set of lighting preferences.

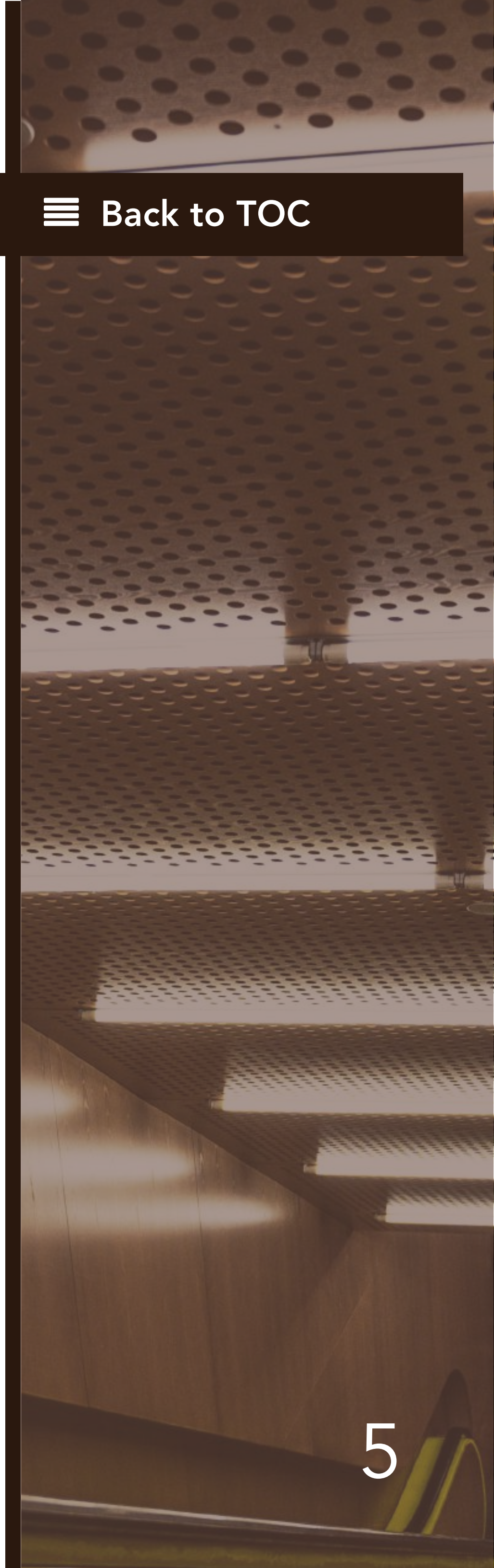
Multiple layers of LED lights with good optical control, combined with programmable digital lighting controls, can provide educators with the flexibility required to accommodate many unanticipated conditions. Spaces can also be partitioned into bright-to-dark versus areas of active-to-calming. Moreover, window shading can be used for complete black-out needs for nap time or for presentations, for example.

LED and controls technology simplify the ability to make lighting changes throughout the day, either automatically or manually.

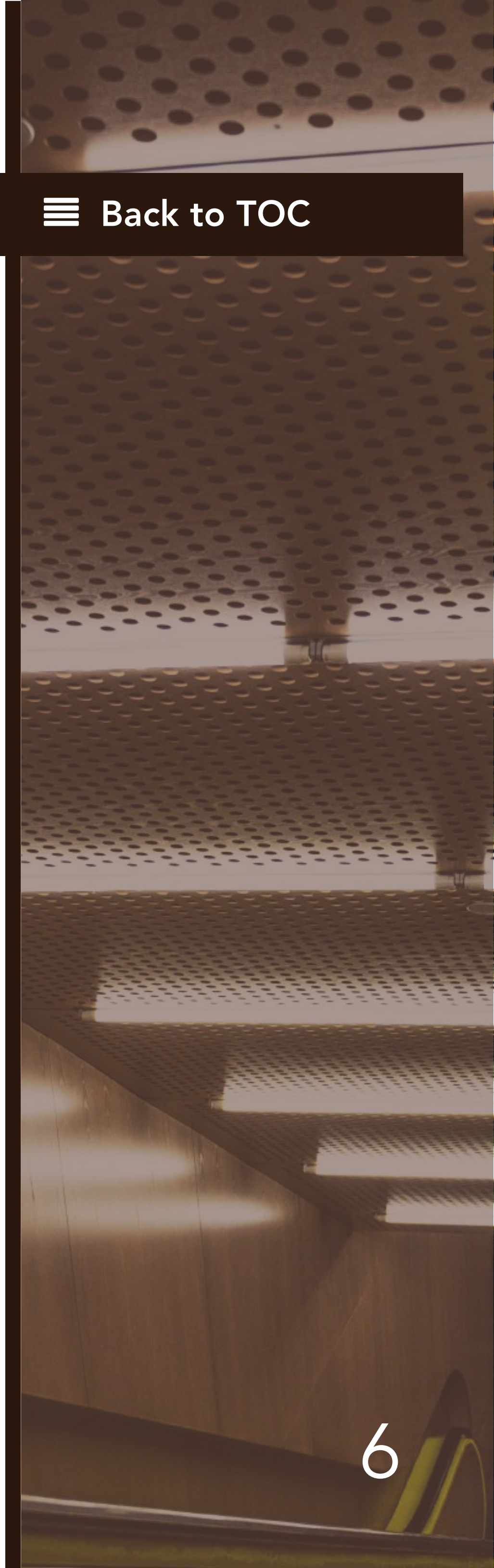
New LED advancements provide a level of capability that previously had been inaccessible to school facilities. Educating administrators and the design community, in the complexities of LED systems will help them better prioritize decisions when designing education facilities.

Lighting designers and engineers that are informed and experienced, can provide guidance to the right LED system solutions for facility or spatial needs.

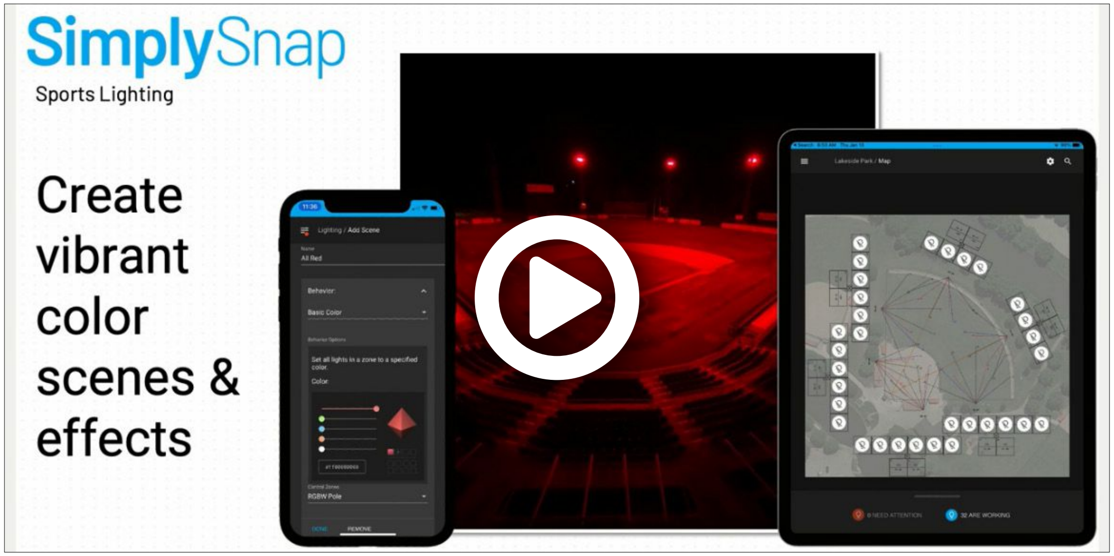
Robert White, Darko Banfic, and Scott Peck
Robert White, *IALD, LC, IESNA,* ***Darko Banfic,*** *LC, IES and* ***Scott Peck,*** *PE*



Back to TOC



Back to TOC



SimplySnap Dynamic Behaviors with Color

Quick overview of how SimplySnap makes it easy to add color control and Dynamic Behaviors with Color to Sports Lighting Applications.

Technology drives K-12 school changes: Electrical, power and lighting

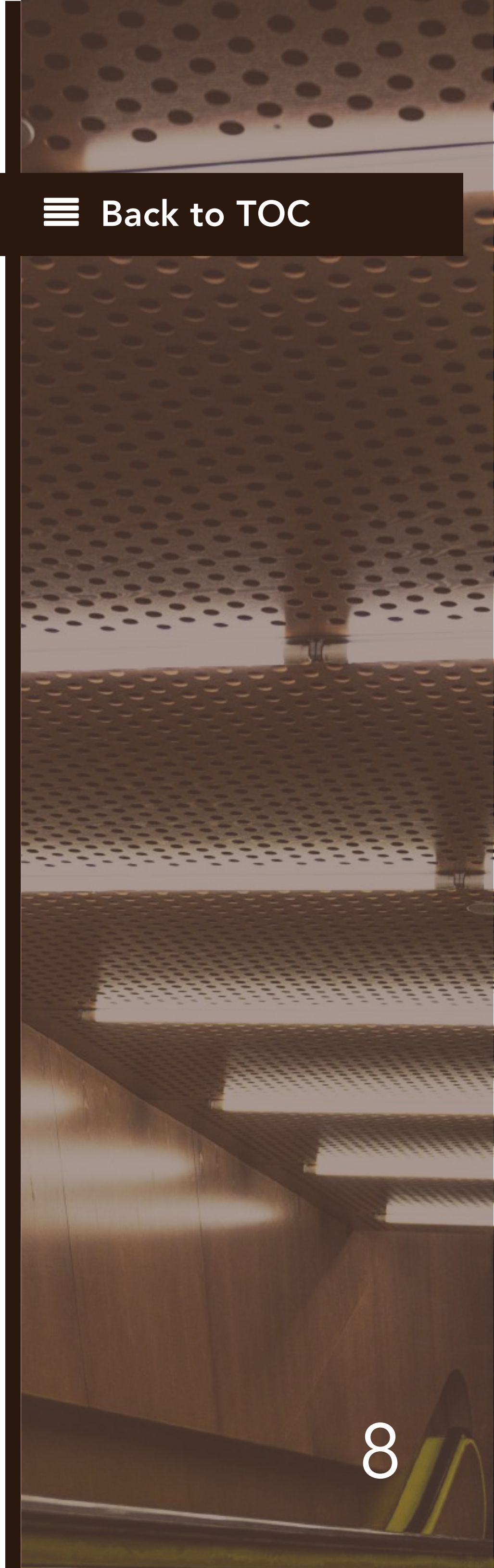
Updates, COVID and tech trends are shifting the way electrical and power systems in K-12 schools are designed

MEP ROUNDTABLE

Luis Alvarez, PE, Electrical Engineer, Associate, Page, Austin, Texas, David Bonaventure, PE, CEM, Principal, Salas O'Brien LLC, Baton Rouge, Louisiana, Lawrin T. Ellis, PE, LEED AP, Managing Principal, TLC Engineering Solutions Inc., Fort Myers, Florida, Keith Hammerschmidt, PE, Senior Project Manager, RTM Engineer Consultants, Overland Park, Kansas, Scott Peck, PE, Vice President, Peter Basso Associates, Troy, Michigan

Back to TOC

Back to TOC



Are there any issues unique to designing electrical/power systems for these types of facilities?

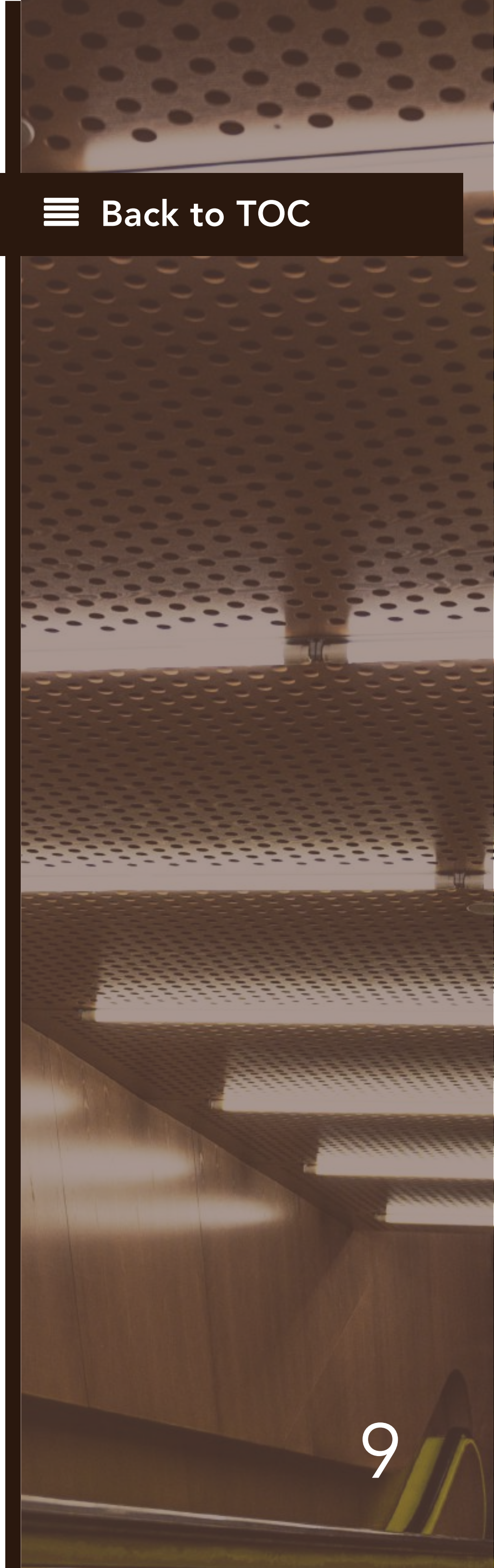
Luis Alvarez: Each school will have its own specific requirements outlined in design guidelines provided by the school district, including specific uses of each space and the demands of the project site. For example, the quantity of receptacles per classrooms, the amount of power required inside the IT rooms, lighting requirements for theater and athletics buildings and many more. These spaces are not dictated per NFPA 70: National Electrical Code, but rather by the standards and needs of the client. Because each school is unique, open dialogue with the building users is imperative to ensure a satisfied client.

Lawrin T. Ellis: Educational facilities often have a wide range of functions that require expertise in varying electrical designs within a common distribution system. These include kitchen/dining, theatrical, laboratories, machine shops, automotive maintenance, data centers, virtual reality and flight simulation labs, indoor and outdoor sports/athletics and multimedia meeting and instructional spaces. Each of these spaces requires unique electrical power and lighting designs and extensive coordination with other trades.

What types of unusual standby, emergency or backup power systems have you specified for K-12 school buildings?

Luis Alvarez: We don't typically see dedicated emergency power systems in K-12 schools. In our experience, emergency lighting is often handled through local battery backups at the fixture level, although a central lighting inverter is another option that can be used. For schools of a certain height, an inverter to power an elevator for

Back to TOC



egress purposes may be necessary as well. Finally, the Austin ISD standards call for provisions to connect a portable generator to the power system, specifically to power the building's main IT room. This is accomplished through the installation of an automatic transfer switch serving a dedicated panelboard in the IT room. The emergency source of the switch is connected to a camlock connection located at the building exterior that allows for the hookup of the roll-up generator.

Lawrin T. Ellis: K-12 schools may include specific systems and equipment that will require emergency power, depending upon the function and programs planned for the school. A project involving the addition of a classroom building on an existing campus required analysis of the existing emergency power system loads and design for expansion or additions to that system. In addition to life safety systems, the school has certain kitchen loads on emergency power including walk-in coolers and freezers.

Technology infrastructure must be maintained for short and long term outages, requiring uninterruptible power supply systems at main and intermediate IT rooms and having these UPS also fed by a standby generator. The requirement for use of portions of the campus as a public emergency evacuation shelter then increase the emergency power loads to serve increase lighting throughout shelter areas, ventilation systems and possible kitchen equipment if the facility will provide meals for the evacuees.

What are some of the challenges when designing low-voltage power systems in K-12 school projects?

Lawrin T. Ellis: Security is now a key design consideration for schools. Access control systems, intrusion alarm and closed-circuit TV systems must be closely coordinated

Back to TOC

with the school district's plan for increasing the safety of students and teachers. This is determined through a coordinated design process, with the proposed architectural floor plan, for entry and exit points and circulation throughout the campus. Coordination of the design for audiovisual and other multimedia systems has also become more critical as the use of technology in teaching has increased. School districts often have design standards that must be reviewed and understood, to provide the owner with systems which the teachers and facility staff are familiar with and can easily use and maintain.

At James Bowie High School in Austin, Texas, the new fine arts and athletic facilities required full integration of audiovisual and information technology to ensure teachers and students can maximize the spaces for creative and interactive uses and experiences. Courtesy: Page

What kind of maintenance guidelines are involved to ensure the project is running efficiently after the project is finished?

Lawrin T. Ellis: Electrically, the key systems requiring maintenance and/or training are the lighting control systems and emergency generators. Programming by a manufacturer's technician and then training the school staff in operation of the lighting control systems for the various types of spaces is important. Often lighting controls are perceived as either not designed or installed properly, when either proper setup by the technician or proper training of the staff have not been provided. There can be long-term effects on the emergency power if proper maintenance is not performed during the life of the system. This includes regular operation of diesel fueled generator engines, running under full load with load bank and maintaining fresh fuel supply.

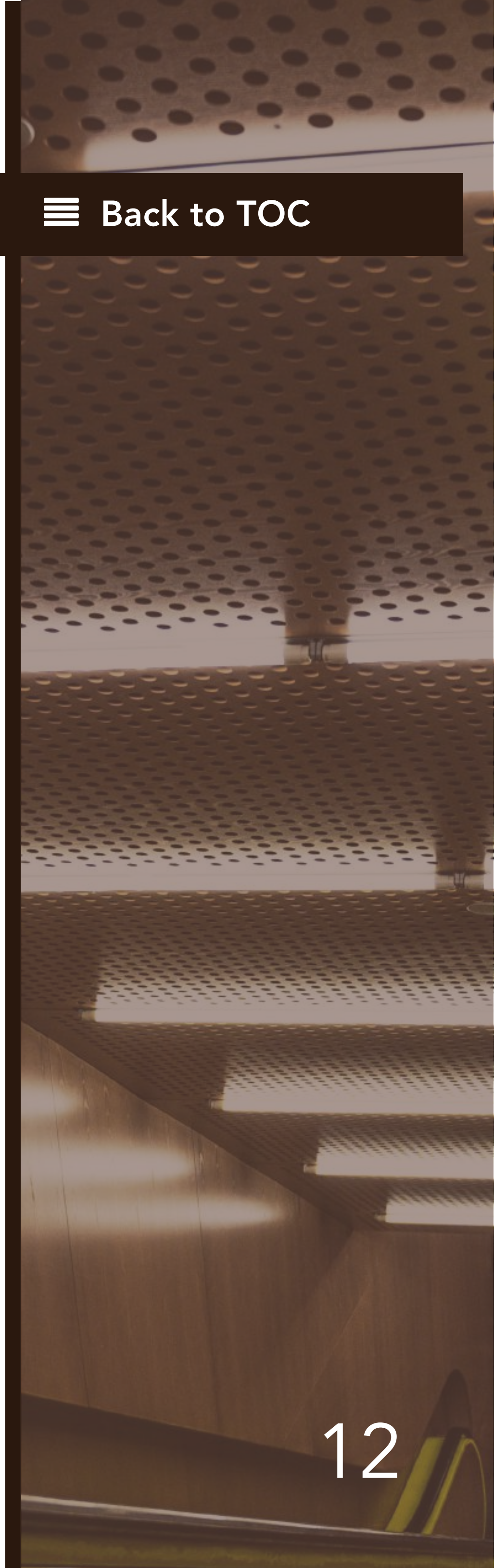
What are some key differences in electrical, lighting and power systems you might incorporate in this kind of facility, compared to other projects?

Luis Alvarez: Fine arts buildings often include unique spaces such as makeup rooms with specific lighting needs in workstations. In theater spaces, it is preferred that all light fixtures are digital multiplex capable so they can dim all the way down to 0.1% without observable flicker instead of the usual 0 to 10 volts that will only get to 10% of output and then turn off. Engaging a theater consultant is often wise as they will have knowledge of the requirements for the schools and what K-12 clients usually install in their facilities.

Lawrin T. Ellis: Educational facilities often have a wide range of functions that require expertise in varying electrical designs within a common distribution system. These include kitchen/dining, theatrical, laboratories, machine shops, automotive maintenance, data centers, VR and flight simulation labs, indoor and outdoor sports/athletics and multimedia meeting and instructional spaces. Each of these spaces requires unique electrical power and lighting designs and extensive coordination with other trades.

Scott Peck: There can be a lot of unique spaces involved with K-12 electrical design most notably when it comes to high schools. Within a high school, in addition to the

Back to TOC



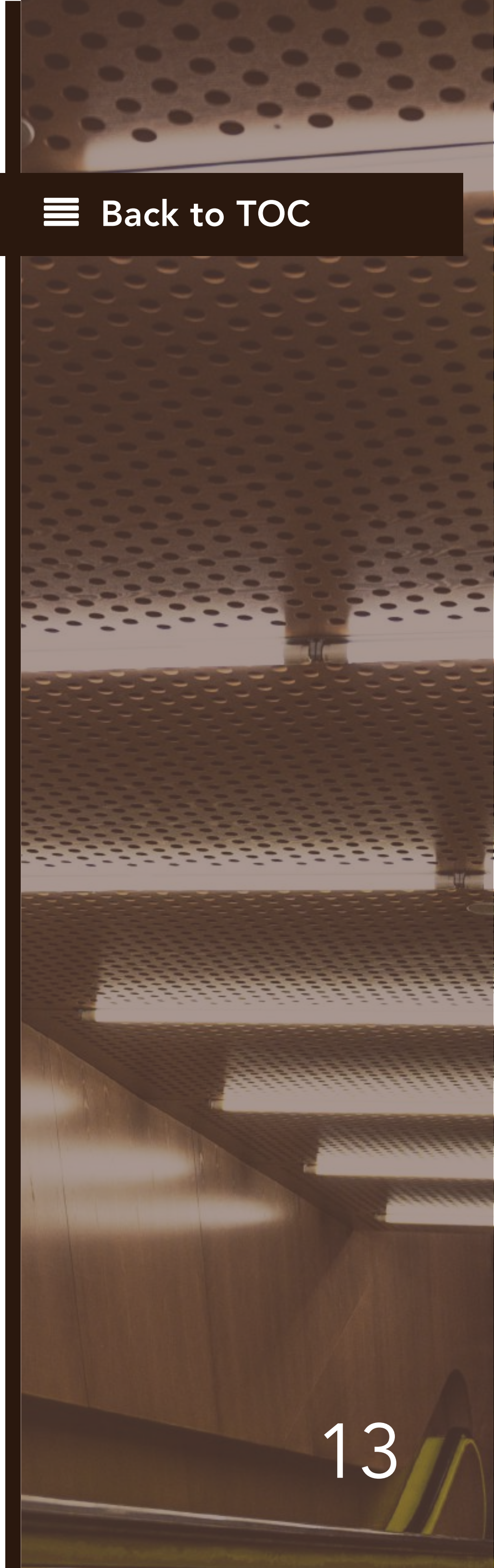
Back to TOC

corridors and classrooms, there are many spaces that have special uses or equipment. Some examples of this are: theaters that have lighting requirements for both the house lighting along with stage lighting, as well as scene shops and dressing rooms with receptacles for curling irons, hair dryers and scene shops; natatoriums with their associated locker rooms and pool equipment rooms; kitchens both for home economics class and for the main building's kitchen and lastly for various shops with specialized equipment such as air compressors, paint booths and emergency power stop buttons.

How does your team work with the architect, owner's rep and other project team members so the electrical/power systems are flexible and sustainable?

Lawrin T. Ellis: School districts typically have design standards, which include systems and equipment that they have extended experience with and are compatible with systems throughout their district. Coordinating with the owner and all other design team consultants to incorporate these standards is a key to providing a project that the owner can successfully operate. Coordination of electrical systems in areas with extensive equipment requirements is also critical. These areas include science labs, tech maintenance and repair training shops and technology in classrooms.

Scott Peck: We take a conscientious approach on where panelboards are located in the building. Some of the items we consider are the length of branch circuits to limit potential voltage drop issues and what obstacles would make running future branch circuits difficult. We also take in to account any future additional electrical load that will be added to the distribution system. This is one of the key ways to have a flexible and sustainable future for the system.



Back to TOC

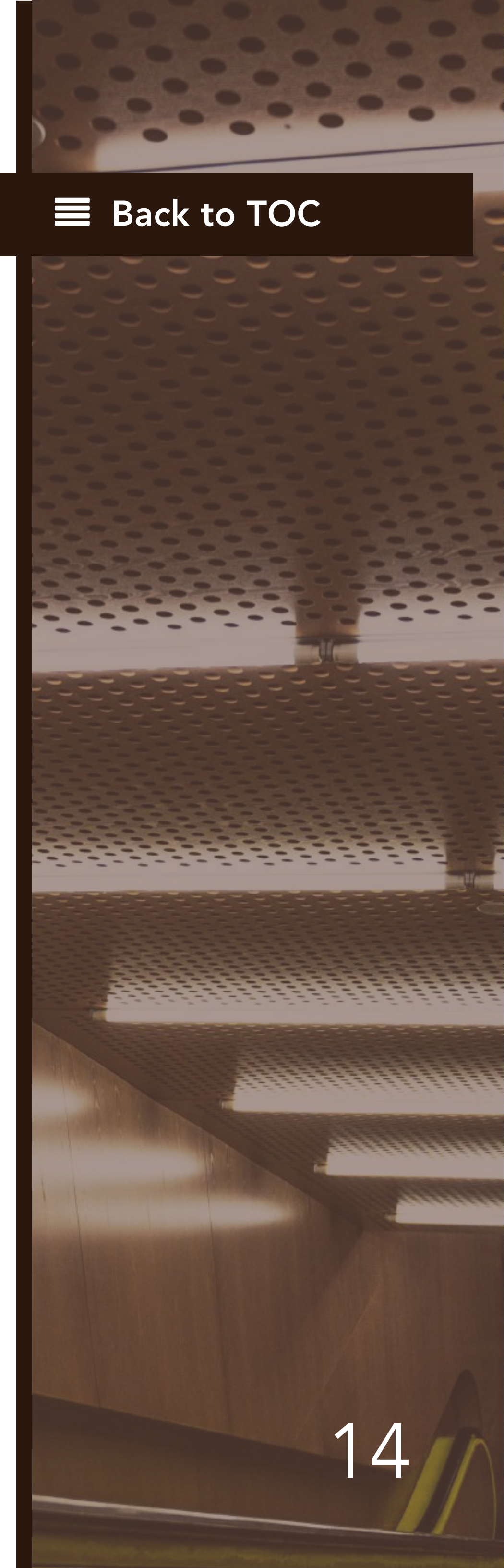
What kind of lighting designs have you incorporated into a K-12 school project, either for energy efficiency or to increase the occupant's experience?

Luis Alvarez: Energy code requires all spaces (except equipment rooms or rooms that can potentially be safety issues for the occupant) to be automatically controlled and have dimming capability, which will enable the end user to control the output of the light for the best experience for the students. Classrooms often require multiple lighting zones, for example independent control of the row of lights closest to the front of the room is a common requirement.

Gymnasiums usually require high-bay lighting and potentially multiple lighting zones controlled from a single location. As mentioned above, specialized spaces such as fine arts and theaters can have very specific lighting requirements. Finally, students with special needs often require fine control of both brightness and color temperature to accommodate their sensory requirements.

Lawrin T. Ellis: LED technology is being used almost exclusively in school lighting design. LED sources allow a wider range of controls to be more easily implemented throughout the school. This includes user-controlled dimming systems, daylight harvesting and varying color temperatures. LED use for athletic facilities both indoors and outdoors provides improved control and better performance over the life of the system.

Keith Hammerschmidt: RTM has designed all of our recent schools with energy efficient LED lighting with lighting controls to help decrease the amount of lights on when a space isn't occupied or lights aren't needed. One unique technique we have used in some schools is to use circadian rhythm LED lighting. Studies have shown how daylight



Back to TOC

and circadian rhythm play a large role in students learning. We have used circadian rhythm LED lighting in spaces where the architect wasn't able to get good daylight into a space. We have also used it in SPED type classrooms. We have received great feedback from school districts that it has helped student attentiveness.

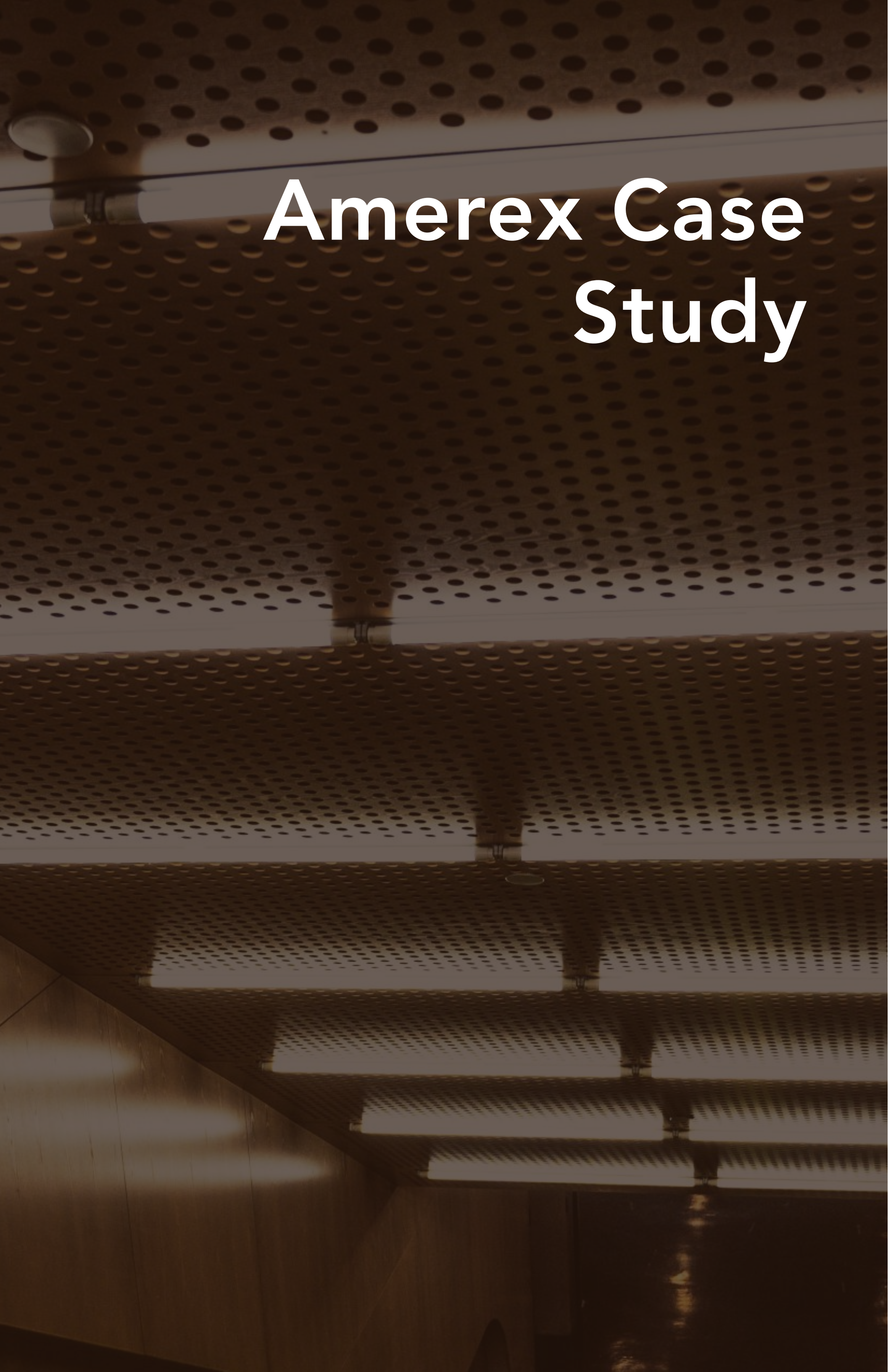
Scott Peck: We recently completed a major addition and renovation for a special needs school. In addition to dimming within all the classrooms, we also added color tuning (tunable white) with individual control located within the classrooms. This allows the teacher to change their room lighting to a warmer, more comforting feel or a cooler more crisp feel when needed.

When designing lighting systems for these types of structures, what design factors are being requested? Are there any particular technical advantages that are or need to be considered?

Lawrin T. Ellis: Maintaining consistent, uniform, code required lighting levels in primary areas of the school are the key design factors. These areas include classrooms and kitchens. Providing flexibility of lighting controls for teaching spaces is also being requested, to allow for wide range of teaching methods.

Scott Peck: With the advancement of LEDs, lighting can now take on many forms. For select spaces in the buildings, we are getting requests from architects and designers for shapes such as rings, triangles, squares and wavy lines to name a few. Also, both recessed and aircraft-mounted. By providing this type of lighting, it gives the building some pop that would have been difficult to achieve using previous K-12 lighting design solutions.

Amerex Case Study



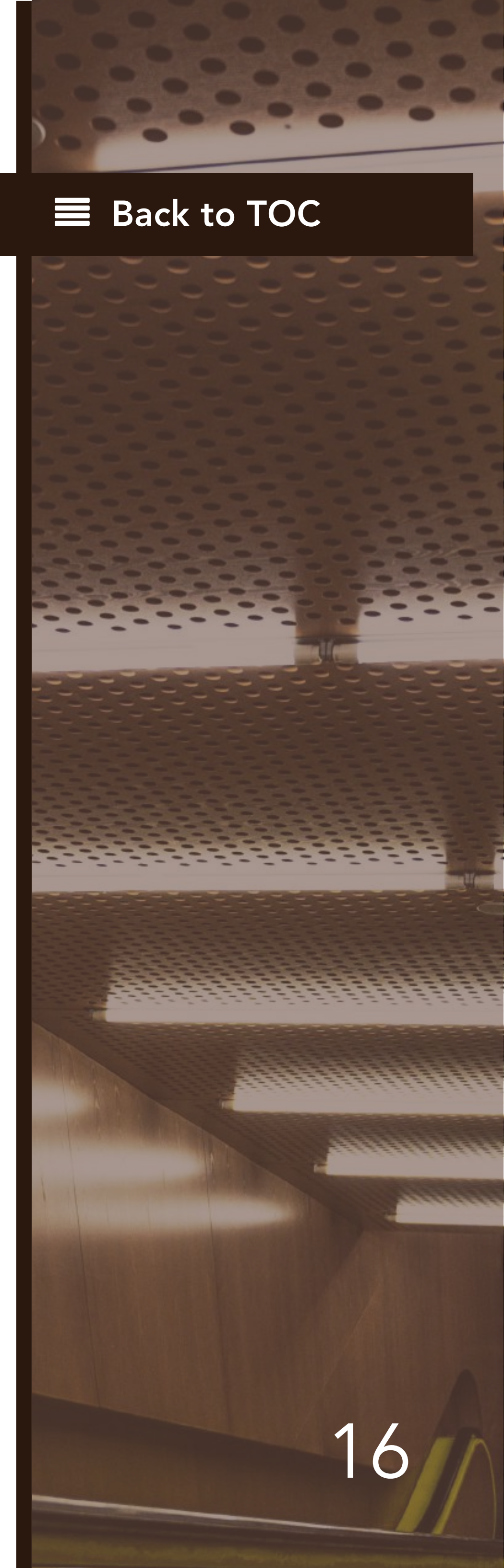
Discover how the Amerex plant started with wireless lighting control and was able to reduce their energy costs by over 50% with this case study.

SITUATION

Amerex is a leading manufacturer of hand portable and wheeled fire extinguishers. The introduction of state-of-the-art gas detection systems along with pre-engineered fire suppression systems for vehicles, commercial cooking operations, and paint spray booths, has earned Amerex a reputation for innovative thinking across the fire protection industry.

The Amerex plant in Trussville, AL, utilizes approximately 2,000 machines to produce over 17,000 fire extinguishers per day. Even with Alabama's low energy rates, the 350,000 square foot facility was spending $154,000 annually for lighting electricity and $180,000 annually on compressed air energy. As a subsidiary of McWane Inc., Amerex was challenged to do their part to help McWane deliver on its mission to significantly reduce energy consumption by deploying smarter, more sustainable methods of manufacturing.

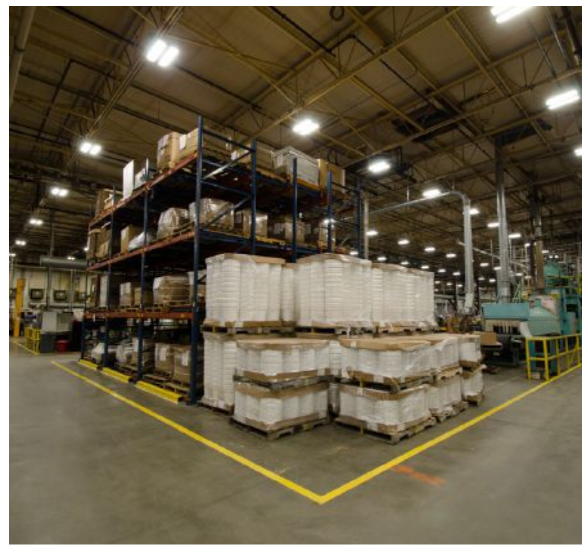
The goal: a 20% reduction in total energy consumption.



Back to TOC

> “There is no single action that will allow us to achieve our environmental goals, instead we see a path to sustainability paved with hundreds of innovations that allow us to work safer, smarter and more energy efficiently.”

ROD REISNER // AVP, Director of Innovation & IoT Program



SOLUTION

To illuminate waste, Amerex started with lighting. Converting the existing lighting system to LED was a source for immediate energy savings and good return on investment. Fitting off-the-shelf LEDs from a leading manufacturer with Synapse’s SimplySnap wireless controls added several key benefits:

1. Utilizing SimplySnap Smart Lighting Controls in place, they were able to create schedules, take advantage of daylight harvesting, task tune lighting to both

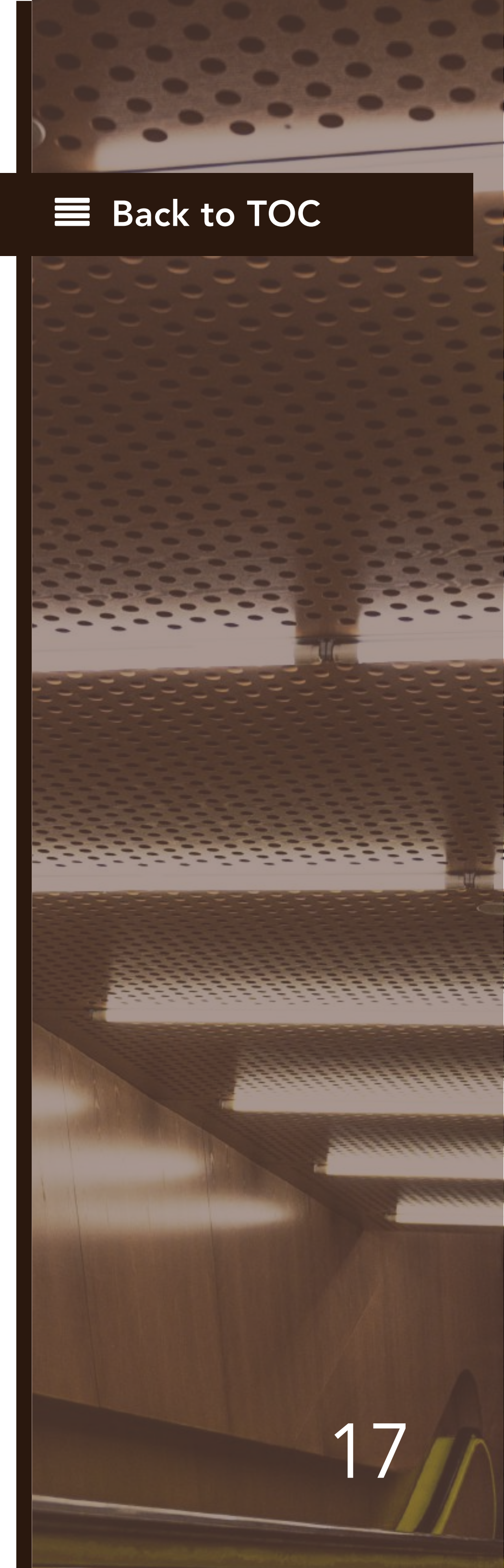
enhance the safety and performance of the space, while also driving energy cost down even further.

2. Once installed, the SimplySnap Smart lighting solution did far more than control lights. The collection of sensors, controls, and gateways creates a wireless mesh network that enables communication and information gathering from other Synapse wireless products. Starting with lighting Amerex gained the framework for integrating other equipment and energy sensors into a simple, fully-integrated energy management system. This is more than a value-added gift with purchase. Through this simple lighting install, Amerex acquired the potential to view energy consumption, and other types of sensors used to monitor machine state and health holistically. When integrated with SimplySnap Energy Insights, their team could now clearly see energy use and cost by zone, department, time, production process, or even focus in on singular pieces of equipment.

3. On top of this freshly deployed mesh network, Amerex added the SimplySnap Energy Insights platform. With the network in place, they could add very inexpensive Circuit Transducers (CTs) to virtually any piece of equipment in the plant and begin measuring its behavior.

Synapse quickly demonstrated that lighting could illuminate so much more.

As a proof of performance test, they started with their compressed air system. Compressed air is often referred to as the fourth utility, because it consumes so much energy and drives so much of the equipment involved in the Manufacturing process. In fact, the first piece of data delivered was how much Amerex was spending on compressed

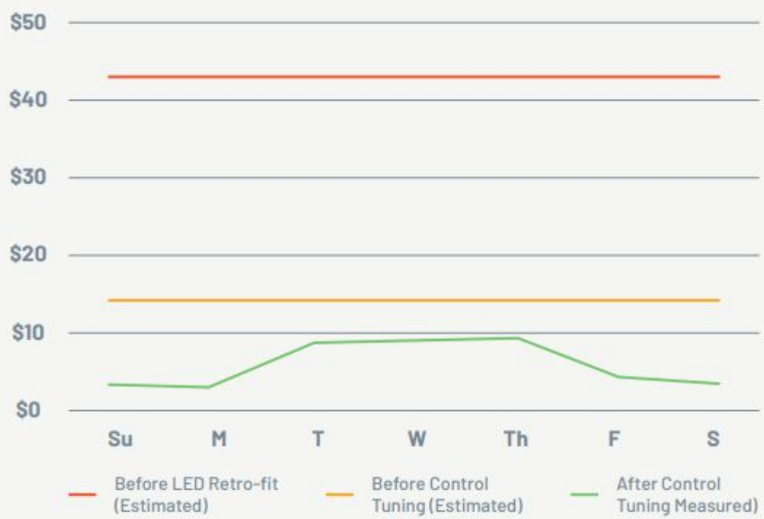


Back to TOC

Back to TOC

air. Previously, that number was buried in the total electrical bill. With Energy Insights they were able to isolate that cost, monitor it and measure it, so it could be effectively managed.

WAREHOUSE LIGHTING ENERGY COSTS

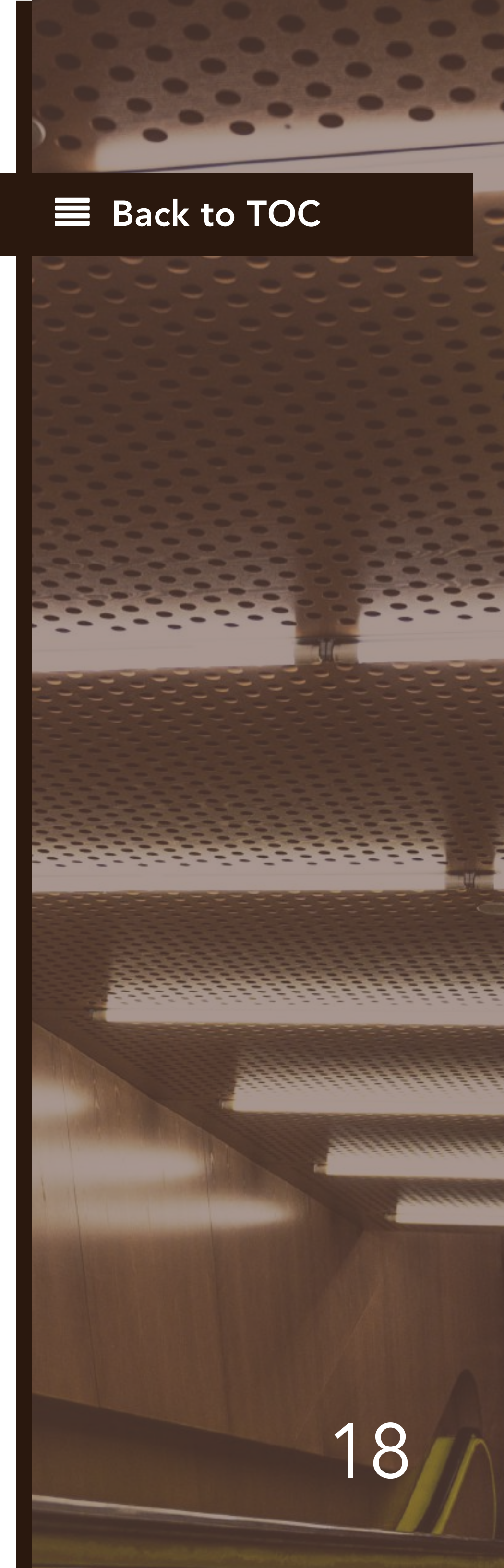


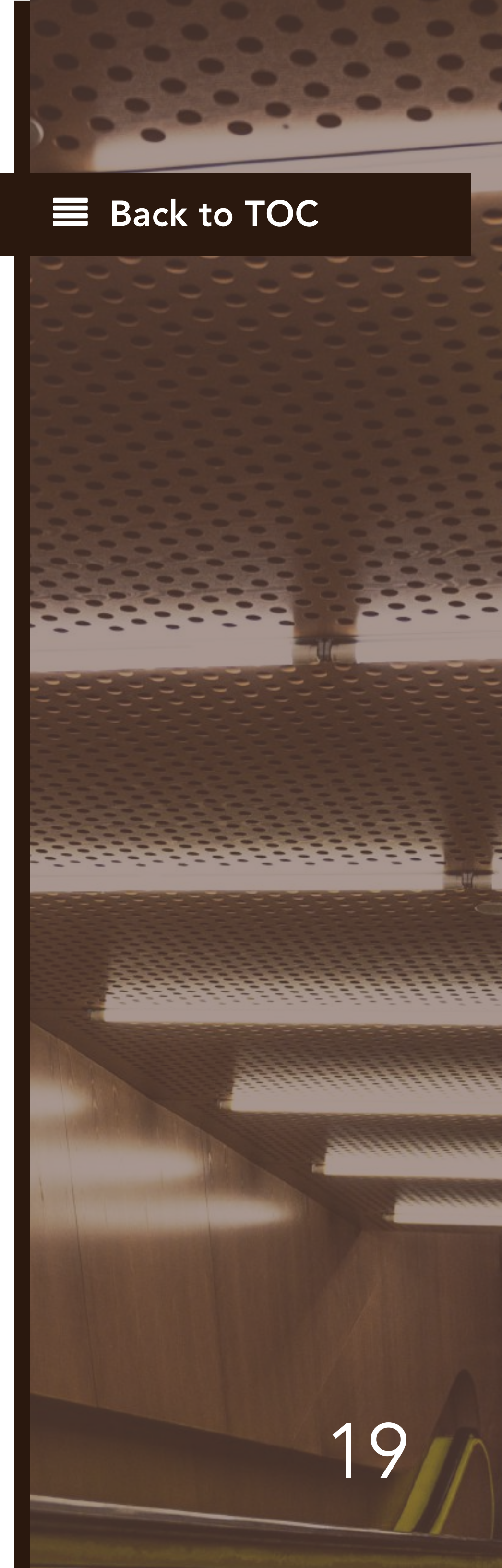
"The lighting install paid for itself in direct cost reductions, but the big win was the mesh network. In essence, if we could shine a literal light on it, we now had the ability to collect data from it. In a matter of months, we turned energy wasting lights into the backbone of a state-of-the-art smart manufacturing plant."

PAUL WOODS
Chief Solutions Officer - Synapse

Over 2,000 pieces of equipment at Amerex are powered by compressed air each day. That adds up to a total cost of $180,000 a year. Further, they discovered that the maintenance and production teams suffered through transient drops in pressure that would slow, or even halt production. The consequences to production, inventory management, and indirect labor cost were unmeasurable and therefore, unmanageable.

The standard "fix" for transient pressure losses was the same as it is for most manufacturers – add another (very expensive) compressor. The Amerex team chose a different





Back to TOC

course. Instead of spending money to add more capacity and burn more energy, they looked to SimplySnap Energy Insights for smarter ways to manage the system they already had.

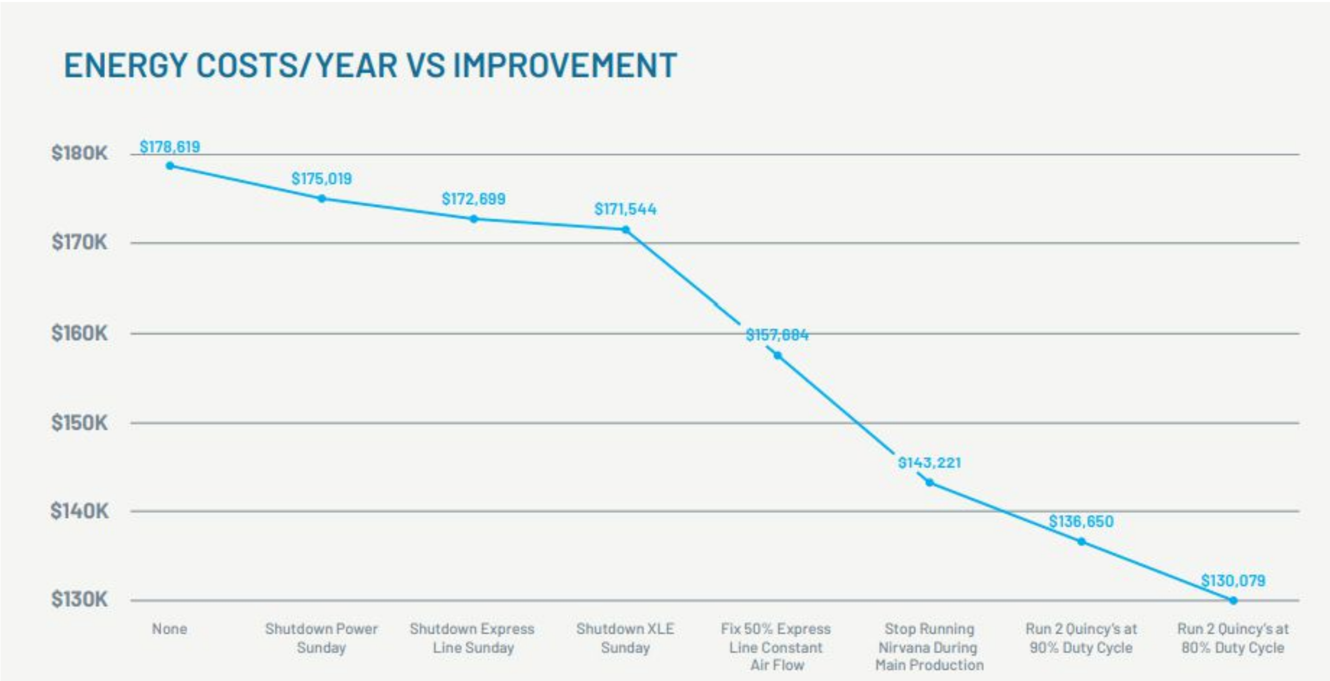
Synapse deployed CTs to the plant's existing compressors, at the trunk and at each consumption point. Through the lighting mesh network, the SimplySnap software was able to measure and communicate sensor data for both airflow and energy use. This data enables Amerex to monitor flow by department, correlate flow and energy consumption into dollars and cents based on the rate schedule for the plant, and provide the facilities management team with the intel they needed to manage air flow more effectively. They could manage airflow by department to zero in on hidden leaks, and they could manage airflow by time – matching capacity demand to production schedules.
With this knowledge Amerex was able to pick a smarter path:

They found they did not need to purchase an extra compressor, which removed a significant capital investment as well as an on-going source of wasteful energy consumption.

They were able to match pressure capacity to demand, reducing wasted man-hours and increasing output.

They were able to reduce energy waste associated with compressed air use.

For the cost of a handful of CTs Amerex was able to gain visibility quickly and easily into waste they did not know existed. Employing SimplySnap Energy Insights, they were able to turn that newfound visibility into meaningful process improvements.

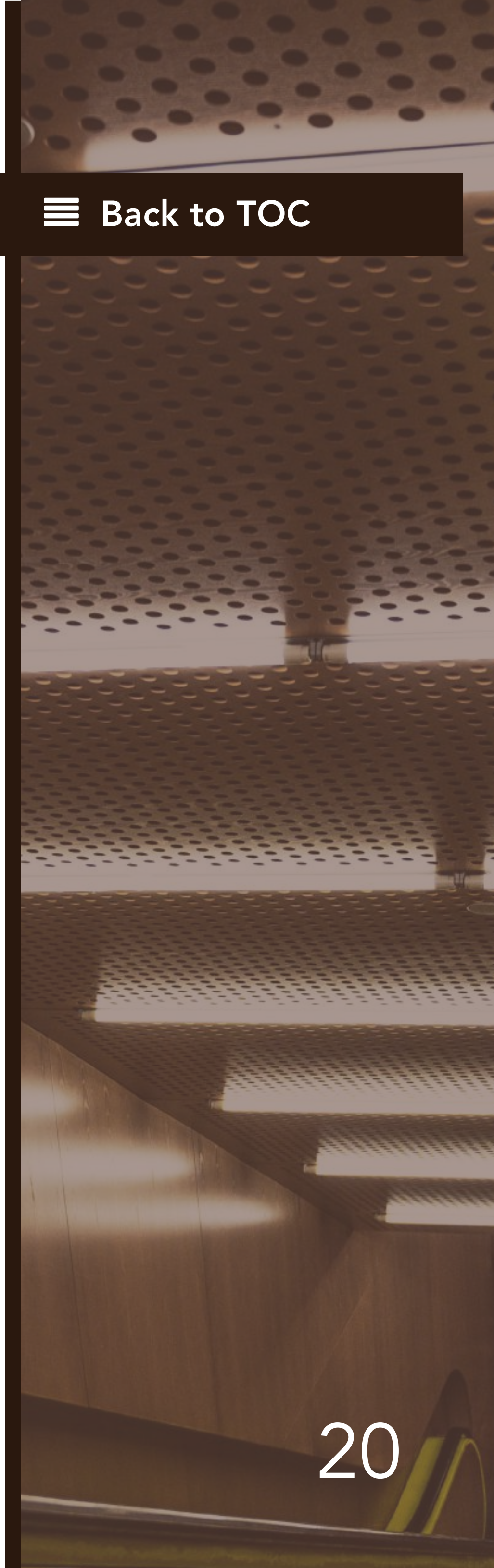


RESULTS

In total, Amerex facilities managers were able to drive down energy use in some areas by a total of 50% doing more than their fair share to help their parent company, McWane, make significant progress toward its sustainability goals.

And, because SimplySnap is user friendly, and easy-to-use, and easy to scale, they have a reliable platform that can be optimized year after year for the life of the plant.

- **Compressed Air Energy Reductions:** Initial projects saved $13,354/year with other identified reductions that will bring the total to just over $48,000 per year in savings once all the projects are completed for the compressed air systems.



Back to TOC

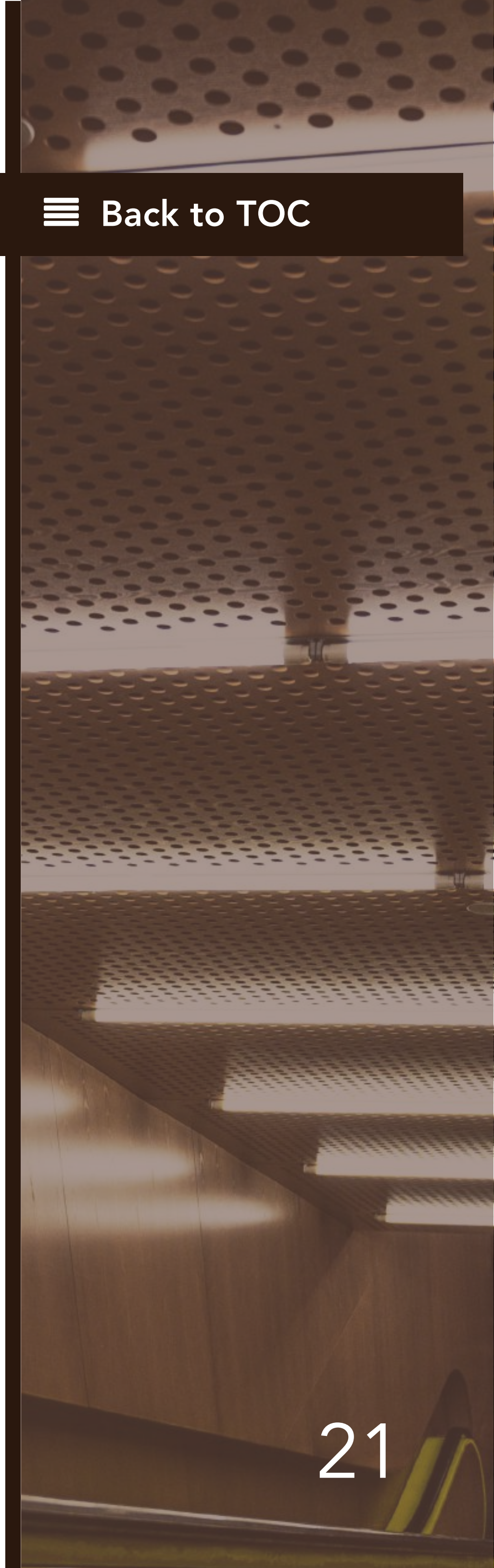
- **Lighting Energy Reductions:** With the LED retrofit and Synapse controls the cost for lighting the facility dropped from around $154,000 per year down to $35,000 for a total savings of $119,000 per year.

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

TOTAL ENERGY COST BEFORE SYNAPSE:
$334,000/year ($154,000 lighting + $180,000 compressed air)

TOTAL ENERGY SAVINGS AFTER SYNAPSE:
$167,000/year ($119,000 lighting + $48,000 compressed air)

TOTAL ENERGY REDUCTION: 50%



Back to TOC

How to use UVGI to mitigate airborne pathogens

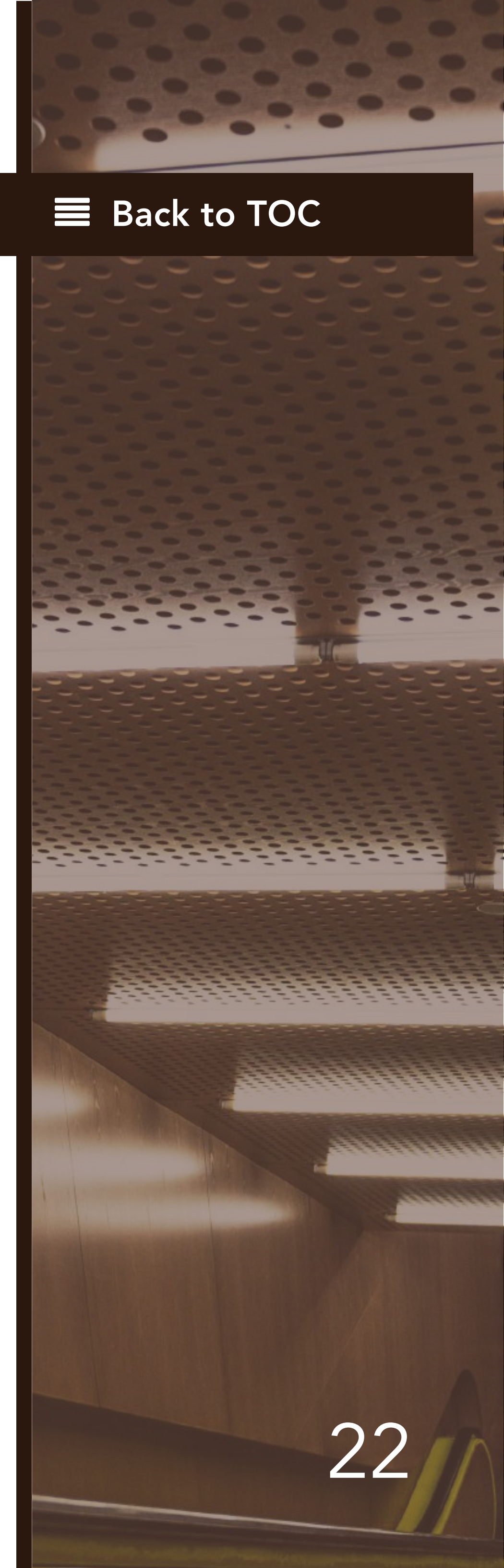
UVGI can be an effective means to mitigate spread of airborne pathogens if selected and installed correctly

Concerns about safety within the workplace have arisen because of the coronavirus outbreak. Questions such as "What methods can owners take to keep a workplace safe?" and "Can heating, ventilation and air conditioning systems help reduce or eliminate the airborne spread of the virus throughout the building?" have been asked of the HVAC design industry.

When considering using the HVAC system with ultraviolet light to combat airborne pathogens, the engineer needs to coordinate the UV product constraints into the mechanical system design.

Ultraviolet germicidal irradiation effectiveness has been studied as early as 1877 for the inactivation of microorganism. Past researchers have made significant strides and advancements in showing that UVGI can be an effective approach for disinfecting surfaces and airstreams.

The realization that tuberculosis was an airborne pathogen and that UVGI could counteract the spread of the tuberculosis bacterium led to the installation of UV light fixtures installed on room walls ("upper room UV") in which lamps would shine above the occupied zone to disinfect the slow convective currents in a room. The efficacy of UV on microorganisms was then incorporated into air conditioning units to mitigate organic growth in cooling coil drain pans.



Back to TOC

Back to TOC

This was followed using UV to inactivate airborne pathogens in an air stream. In response to many different research efforts, ASHRAE Standard 185.1: Method of Testing UV-C Lights for Use in Air-Handling Units or Air Ducts to Inactivate Airborne Microorganisms was developed to standardize UVC light application.

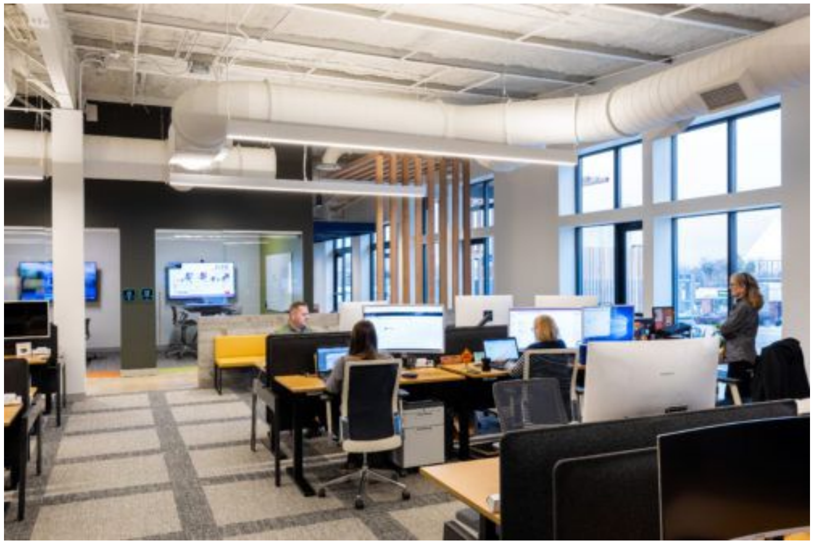


Figure 1: DPR Construction updated its office in Nashville, Tennessee. Courtesy: Jeremiah Hull, Smith Seckman Reid

Incorporating an UV section that provides the intensity and exposure time that results in sufficient dosage to be effective is much easier when designing and installing a new air handling unit. But what about retrofit applications to existing HVAC systems?

Adding a UV section to an existing AHU would involve significant rework and modification of the unit. It would be likely be easier to insert a UV section somewhere in the ductwork, which has additional constraints. To obtain sufficient dosage requires intensity and exposure time; whereas air velocity in AHUs is in the range of 500 feet per minute, ductwork velocities are most likely higher. This means less exposure time and/or greater intensity.

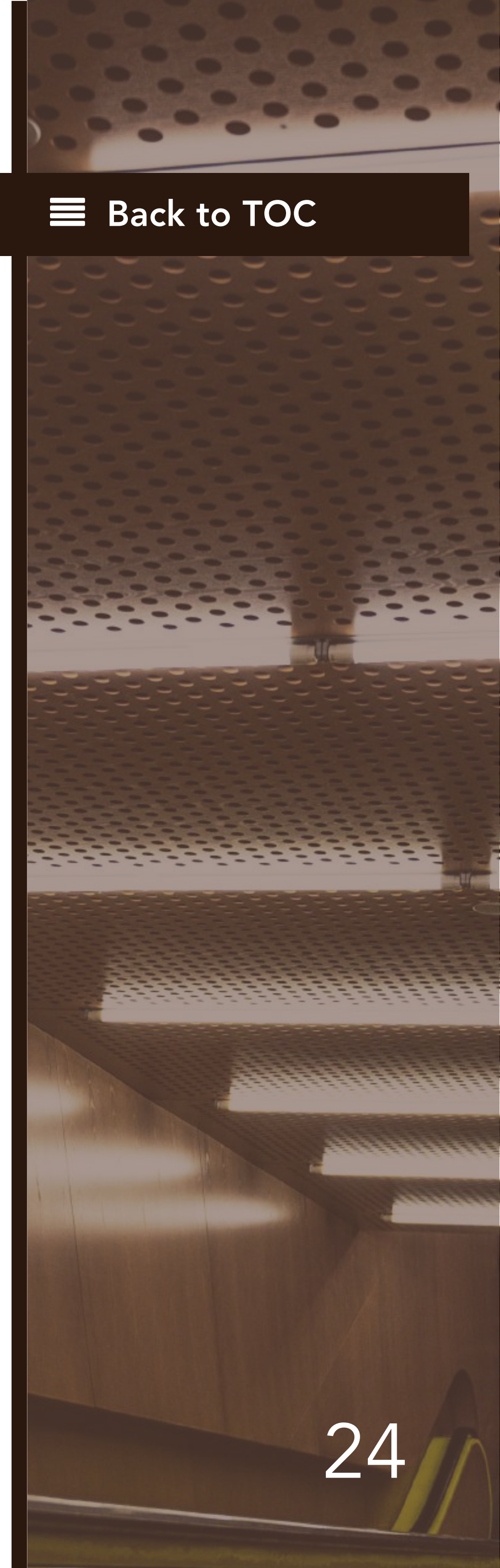
Some manufacturers may have limits on the available intensity of their product; to obtain a sufficient dose, the AHU will likely need to be longer for air path length and/or have wider casing to obtain the required slower velocity to provide sufficient exposure time. This longer AHU then affects mechanical room size. A UV section for cooling coil cleanliness can be added relatively easily but adding a section for UV disinfection of a moving air stream has a bigger impact.

UV lighting can produce ozone. Manufacturers should produce their systems to operate with no ozone production. Equipment provided should come with documentation that the products comply with UL 2998: Environmental Claim Validation Procedure for Zero Ozone Emissions from Air Cleaners. There are other safety aspects in the application of UV systems, such as safety disconnect interlocks with access doors that need to be incorporated. The manufacturer's installation guidelines are the starting point for safe installation.

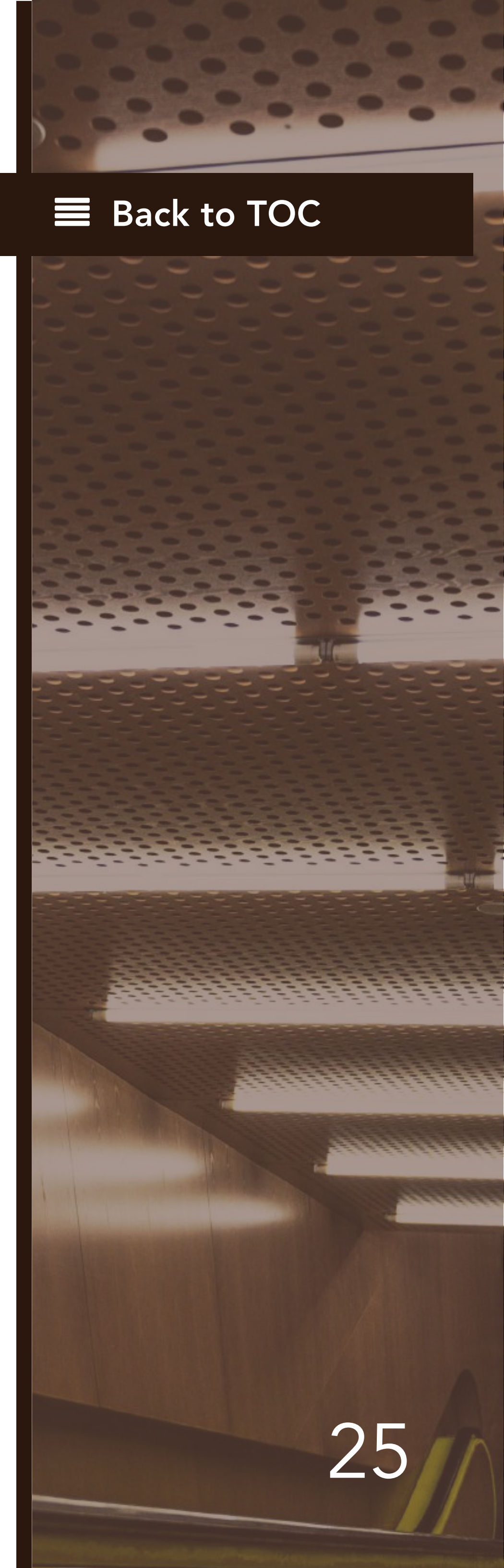
Almost every system installed in a building has parts that wear out or degrade based on time and/or usage and UV lamps are no different. ASHRAE notes that UVC lamps can be expected to last about 9,000 hours if constantly energized, so building owners should expect to change the lamps annually.

Upper air germicidal irradiation

While not exactly part of HVAC systems, upper room UV does focus on the room air distribution. UV lamp fixtures can be mounted on walls above the occupied zone (i.e., at least seven feet or higher) as a means of room disinfection. Upper room UV has been used extensively for more than 70 years. It was primarily focused on mitigation of tuberculosis bacteria. The natural convection currents slowly rise where the airborne pathogens are killed by exposure to the lamps; the slow movement helps provide the



Back to TOC



Back to TOC

exposure time for the dose needed for disinfection. Forced air movement enhances the efficacy of upper air UV systems.

Although the exact effectiveness is dependent on room-specific conditions including room size and arrangement, air distribution patterns, air temperature, relative humidity and occupancy patterns, ASHRAE notes that an installed capacity of 30 to 50 micro-watts/square centimeter is effective in disinfecting room air.(

The fixtures are located so that the lamp output is not in the line of sight of occupants. Installation should follow the manufacturer's guidelines.

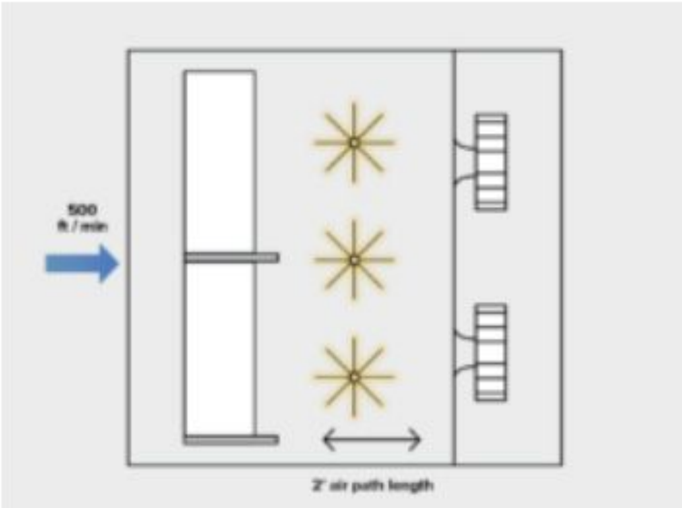
The units should comply with UL 2998 to document that they do not produce ozone. Consistent with other UV lamps, plan to replace them every year.

Photo catalytic oxidation

UV lights can also be used indirectly by photo catalytic oxidation. When UV light hits certain surfaces (titanium dioxide), it starts a catalytic reaction that releases hydroxyl ions into the air stream. The ions are distributed by the supply air into the spaces where they "seek and destroy" airborne pathogens; these ions combine with airborne pathogens to change the biological structure and, in effect, neutralize them into benign, larger particles that are more effectively filtered out of the air stream.

It is relatively straightforward to incorporate PCO systems into an AHU — they can work at normal AHU velocities of 500 feet per minute and add low pressure drop (about 0.1 inch w.c.). They can tolerate saturated air from a cooling coil but should not be used immediately downstream of a humidifier. To prolong effectiveness, an up-

Back to TOC



$$\text{Exposure time} = \frac{\text{Air Path Length}}{\text{Velocity}} = \frac{2\ \text{ft}}{500\ \text{ft/min}} = .004\ \text{min or approx}\ .24\ \text{second}$$

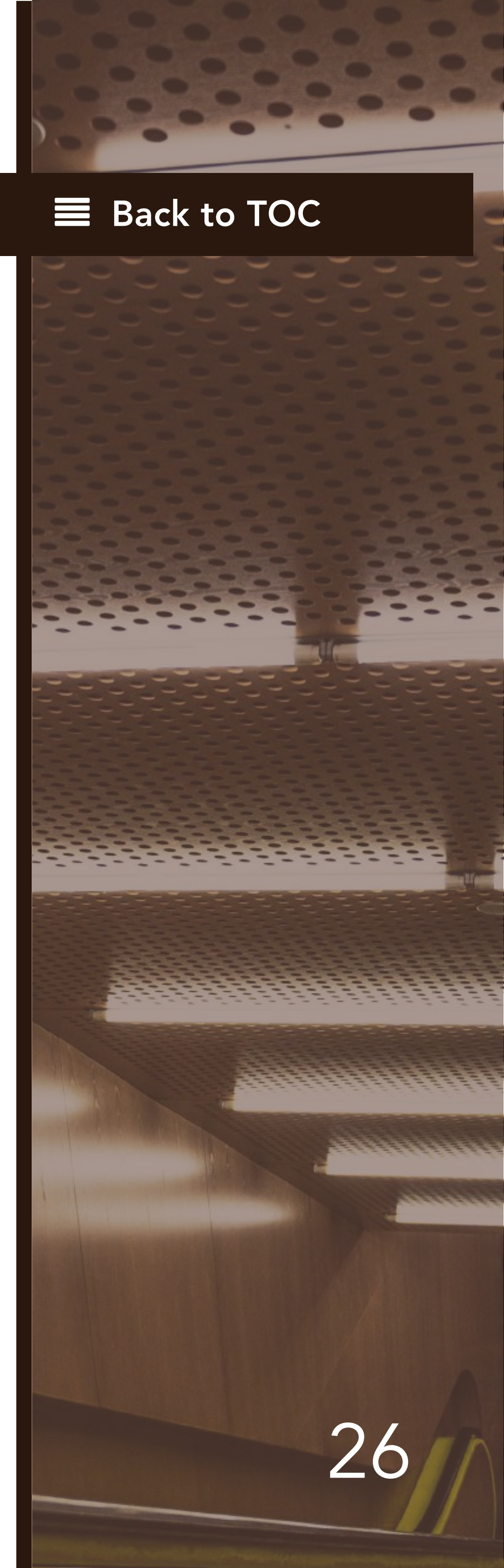
$$\text{Intensity} = \frac{\text{Dose}}{\text{Exposure Time}} = \frac{611\ \text{microwatt-second/sq cm}}{.24\ \text{second}} = 2546\ \text{microwatts/sq cm}$$

Figure 2: For an airstream moving at 500 feet per minute and 2 feet air path length, the required intensity is 2,444 microwatts/square centimeter, which is 24 times the intensity of that required to mitigate growth on a cooling coil. Courtesy: Smith Seckman Reid

stream filter (MERV-8 as a minimum, but preferably MERV-13) is needed to keep the unit clean, like keeping a coil clean to maintain effective heat transfer.

Since PCO is based on using a UV light, the same safeguards apply. The lamps supplied for the PCO product should be UL 2998 compliant. Safety disconnects with access doors prevent maintenance personnel from exposure to the energized lamps. Warning lights that indicate the operation of UV lights provides an additional safety measure.

One safety aspect of PCO is the use of titanium dioxide as the catalyst surface. TiO2 has been mentioned as "carcinogenic" in some published articles. As a material, TiO2 is used in many everyday products — toothpaste, cosmetics, sunscreen — and the Food and Drug Administration has approved it for food additives.



Back to TOC

Some of the concerns about the harmful effects are focused on small, very fine powders or even nano-sized particles. Research was conducted by the National Institute for Occupational Safety & Health on the exposure of workers in TiO2 plants, where concentrations would be expected to be much higher than in common situations.

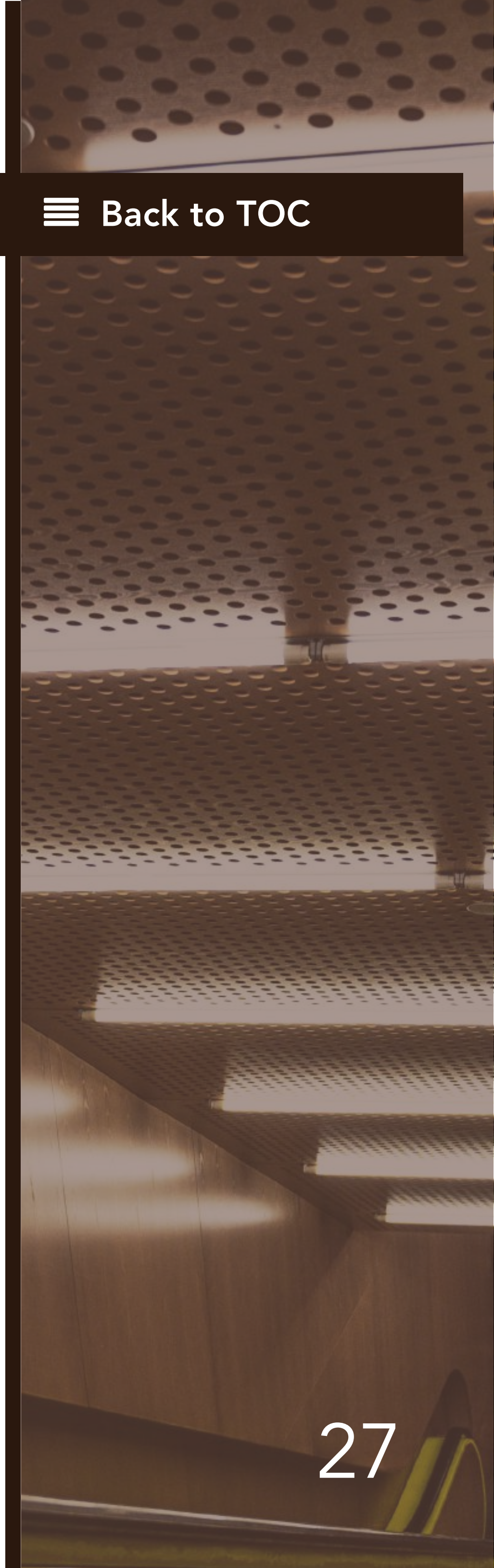
But for environments other than TiO2 factories, manufacturers indicate the TiO2 used in PCO products is bonded to the product so that particles are not released into the airstream. The National Institutes of Health published a study in February 2021 of PCO systems, noting in the abstract that "UV and TiO2 based disinfection technologies may represent a valuable tool to mitigate the spread of airborne pathogens."

One benefit of PCO, depending on the actual product selected, is that some PCO products can be more easily retrofitted to existing AHUs or duct systems. PCO products typically do not require additional air path length and can be added to an existing AHU without significant rework or modifications to the AHU.

Another benefit of PCO is that PCO can help in odor control. The oxidation process that works to break down and neutralize airborne pathogens has the same effect on other organic particulates and volatile organic compounds, many of which have unpleasant odors.

UV technology

UV radiation is invisible to the human eye. It lies on the electromagnetic spectrum between visible light and X-rays. The most common source of UV radiation is sunlight, and it is divided into three types based on wavelength: UVA, UVB and UVC.



Back to TOC

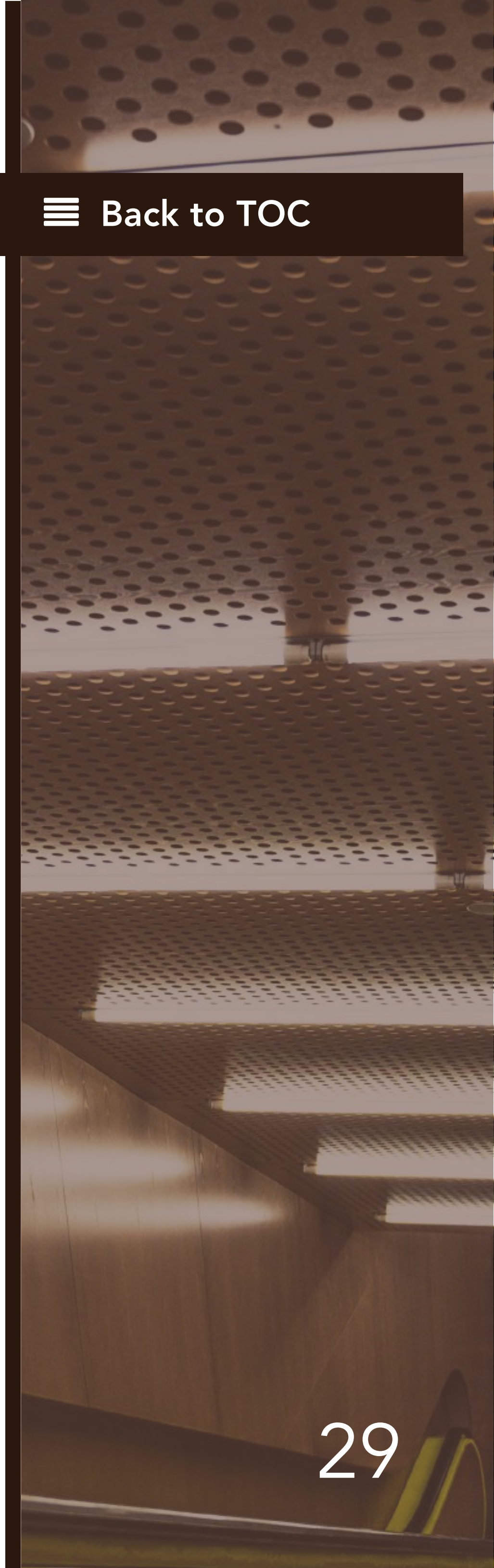
UVA wavelengths are from 315 to 400 nanometers; UVB is from 280 to 315 nanometers; and UVC is from 200 to 280 nanometers. The longer wavelengths have greater penetrating power. The earth's ozone layer absorbs all UVC radiation and most UVB radiation, so the UV radiation that reaches earth's surface is primarily UVA, with some UVB. The only way objects on the earth's surface can be exposed to UVC radiation is from an artificial source.

Low-pressure mercury discharge lamps are commonly used in commercial applications to emit UVC radiation for the purpose of disinfection, known as UVGI. UVC radiation can kill or disable a wide range of microbes by damaging the DNA, making it incapable of replication. Each microorganism species (bacteria, virus or fungi) has a unique susceptibility to UV light.

However, pathogens consistently show a peak DNA absorption near 265 nanometers. For most pathogens, there is a steep drop in sensitivity below 250 nanometers. Low-pressure mercury discharge lamps emit UVC radiation at a wavelength of 253.7 nanometers, very close to the peak absorption point.

UVGI effectiveness depends on the UV dose, which is calculated as the product of the average irradiance, or intensity of the UV radiation, and exposure time. The effectiveness also depends on a species-dependent inactivation rate constant, k. Measured k-values for many species of virus, bacteria and fungi have been published in scientific literature.

However, these values can vary widely between sources depending on the conditions and methods used. Viruses and vegetative bacteria (such as E. coli and the bacteria



Back to TOC

responsible for staph infections and strep throat) are generally the most susceptible to UVC inactivation, followed by Mycobacteria (including Mycobacterium tuberculosis), bacterial spores and fungal spores.

UV precautions

Even though UVC rays have less penetrating power than UVA or UVB lights, exposure can still cause severe burns of the skin and injury to the eye. You should never look directly at a UVC light source, even briefly. The injuries from UVC exposure generally resolve within a week with no known long-term damage, but the injuries are delayed, and can cause severe pain even after only seconds of exposure.

Some UVC lamps may emit small amounts of UVB radiation, so prolonged exposure can potentially lead to cataracts or skin cancer. Additionally, some UVC lamps generate ozone, which is irritating to breathing passages, and can worsen chronic respiratory diseases or increase vulnerability to infection.

Many manufacturers and users have voluntarily developed safeguards against accidental exposure to UV radiation, including signage, personal protective gear and training for installers or maintenance personnel.

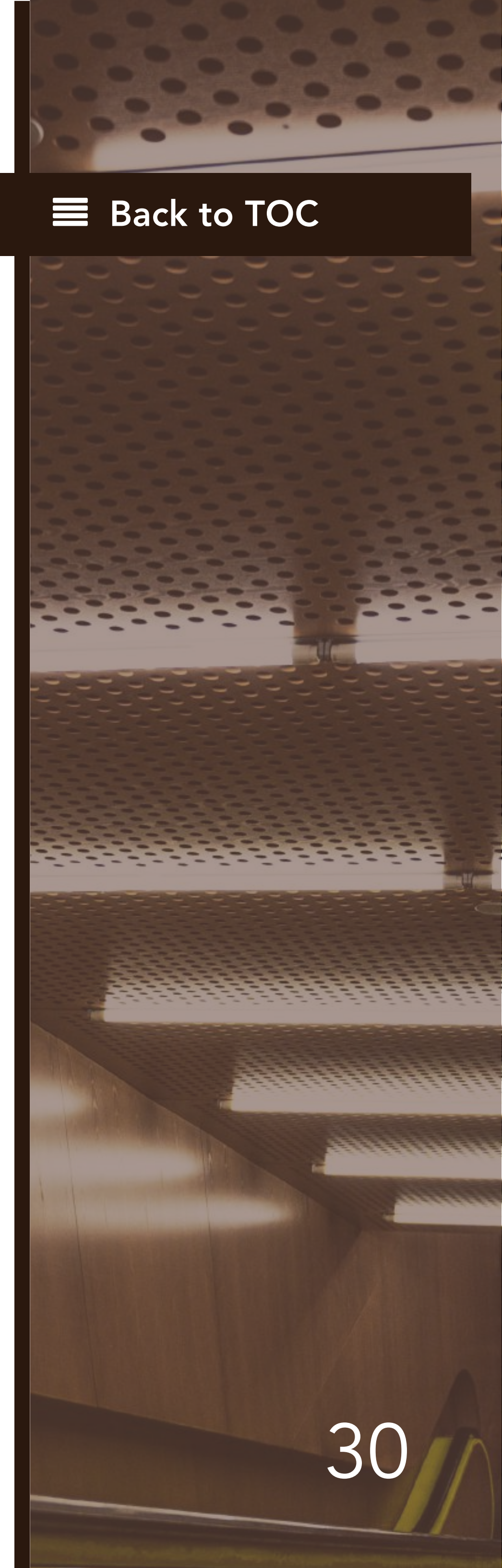
However, these measures were not mandated by code and not applied consistently. In addition, the International Commission on Non-Ionizing Radiation Protection notes that “engineering control measures are preferable to protection clothing, goggles and procedural safety measures.”

The fifth edition of UL 1995: Heating and Cooling Equipment, which covers safety requirements for a broad range of equipment, includes safety requirements that seek to prevent accidental exposure to UV lamps. UV lamps that are factory or field installed in HVAC equipment after November 2019 must comply. UL 1995 prescribes the maximum leakage to surroundings, and requires interlocking mechanisms for access doors, panels or covers that will de-energize the UV source when the UVC irradiance exceeds 1.7 μW/square centimeter. In addition, standardization of warnings and signage are detailed.

Manufacturers should have their products tested and labeled as "zero ozone emissions" per UL 2998: Environmental Claim Validation Procedure for Zero Ozone Emissions from Air Cleaners.

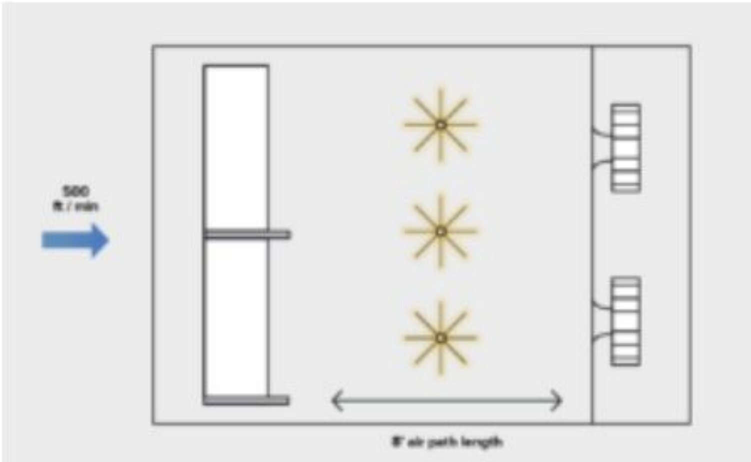
UV applications

Applying UV lighting to HVAC systems can be done in several ways. UV lamps can be installed to shine



Back to TOC

Back to TOC



Exposure time = Air Path Length / Velocity
= 8 ft / 500 ft/min
= .016 min or approx 1 second

Intensity = Dose / Exposure Time
= 611 microwatt-second/sq cm / 1 second
= 611 microwatts/sq cm

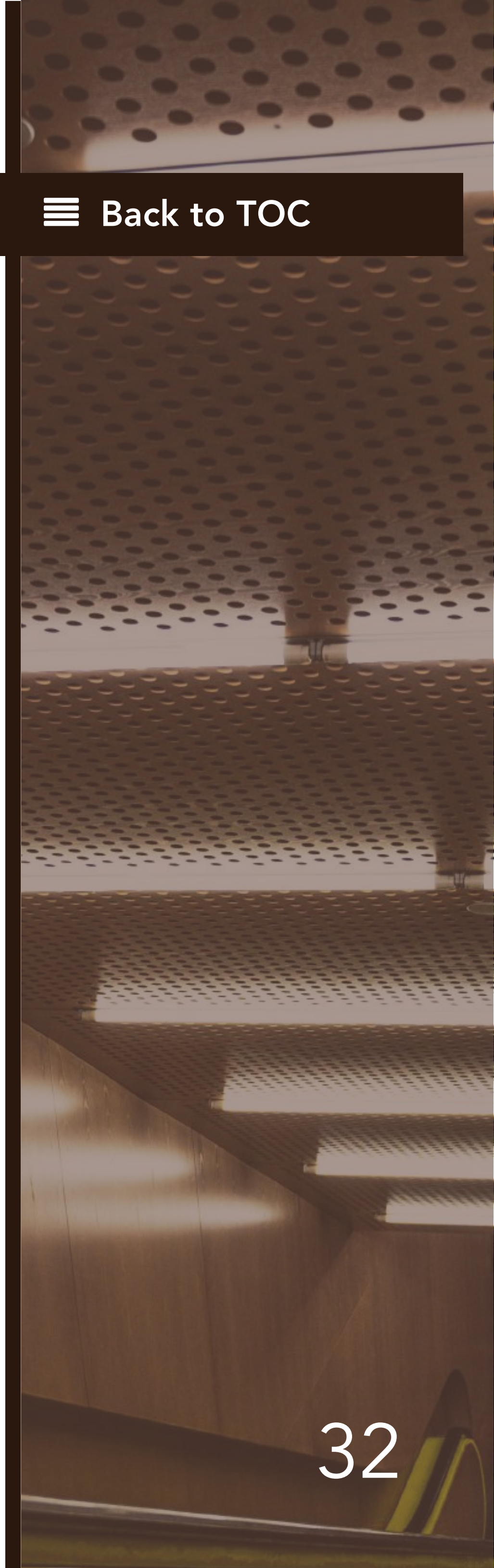
Figure 3: To obtain a sufficient dose, the air handling unit will likely need to be longer for air path length and/or have wider casing to obtain the required slower velocity to provide sufficient exposure time. This longer AHU then affects mechanical room size. Courtesy: Smith Seckman Reid

directly into the moving air stream in an AHU or in ductwork. Another way to use UV directly is upper air or upper room germicidal irradiation in which UV lamp fixtures are mounted on a wall above the occupied zone. UV lamps mounted on pedestals can be used if the room is unoccupied when in operation.

There are also products that use UV light indirectly in a photo catalytic oxidation, or PCO, process that can also be installed in an AHU or in ductwork. The efficacy of each type of system depends on how closely the installation adheres to the manufacturer's guidelines and constraints.

Direct exposure with UV

When applying direct UV lighting in an AHU or duct, it is important to understand the dose required to achieve the goals and the factors that impact the delivery of the



dose. The effectiveness of UV is dependent on the dose of UV; the dose of UV is directly proportional to both exposure time and intensity.

For example, the dose required to mitigate microbial growth on a cooling coil is significantly less than to kill airborne pathogens in a moving air stream. ASHRAE notes that 50 to 100 microwatts/square centimeter is a typical intensity to inhibit microbial growth on cooling coils; this relatively low intensity is sufficient because the lamp shines on a stationary coil so there is almost unlimited exposure time.

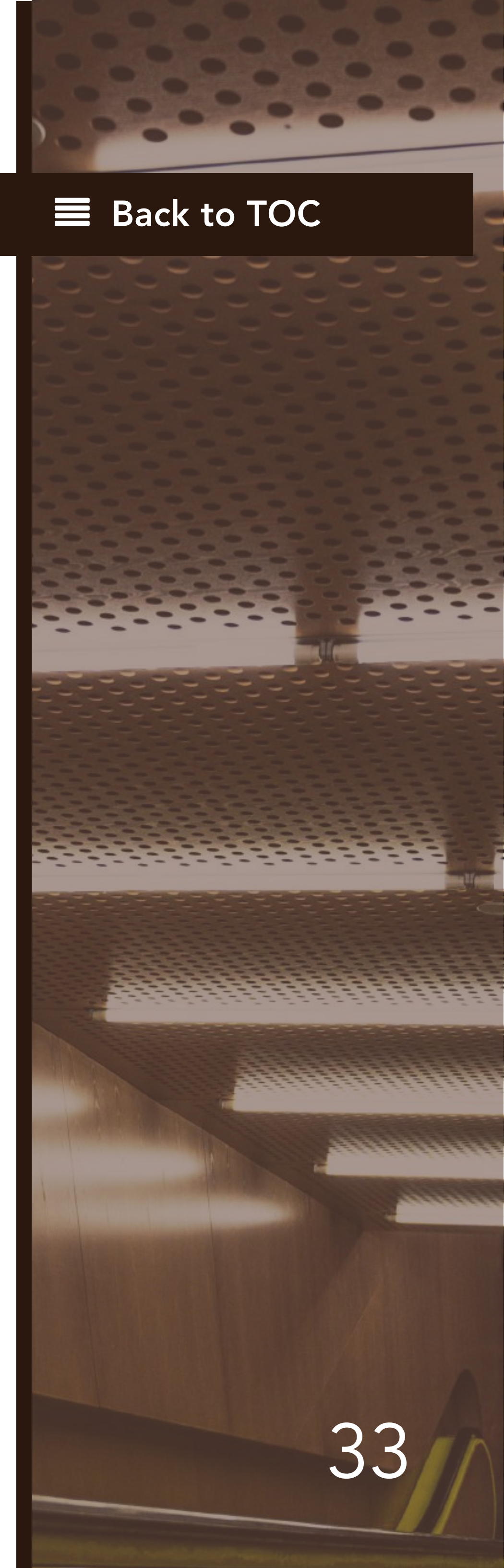
Conversely, to determine the intensity required for a 90% kill rate of the COVID-19 virus in a moving airstream, we have to consider the dose required, which is 611 microwatt-seconds/square centimeter, and the exposure time available. For an airstream moving at 500 feet per minute and 2 feet air path length, the required intensity is 2,444 microwatts/square centimeter, which is 24 times the intensity of that required to mitigate growth on a cooling coil (see Figure 2). This is, however, the first approximation of intensity required.

Manufacturers will take into account other factors, such as the temperature and relative humidity of the air, the quantity and location of lamps and the reflectiveness of the inside AHU or duct surface, to determine the actual required intensity for their product to be effective.

The design engineer has three primary tasks in applying UVC to HVAC systems:

- Understanding the goals of incorporating UVC into a mechanical system.

- Identifying the impact on mechanical and architectural design.



Back to TOC

- Specifying equipment that adheres to applicable safety standards.

It is important to realize the capacities and limitations of UV disinfection of air streams. Different organisms have differing resistances or susceptibilities to UV light and in a building where doors open/close, people come and go, etc., no product or system will provide a 100% mitigation rate.

The engineer needs to advise the owner of not only the capabilities but the limitations of the UVC system so that the owner has realistic expectations. Is the owner expecting to have a facility "free of all airborne pathogens?" Is reducing the presence of seasonal flu the main concern or of some bacteria or mold? The manufacturer of the UV system should include information on the intensity provided, the air path length required to obtain the necessary exposure time and any other requirements for their equipment to work according to ratings and to address the goals of the owner.

Meeting project goals

UVGI can be an effective means to mitigate spread of airborne pathogens if selected and installed correctly. To ensure that a solution meets the project goals:

- Be specific in setting the goal of the project. Understand the owner's expectations; advise them of not only the capacities but also the limitations of the proposed solution. Educate them in the meaning of advertised "kill rates" and how they differ from real world scenarios. Explain the concept of "doses" required to kill different types of pathogens.

- Decide how much impact is allowable for modification to the HVAC system — is this a new project where a separate UV light section can be added to the layout of a new AHU or are there project constraints where a solution with less interruption to the current operations is needed?

- Once a solution is determined, get specific information and guidance from the manufacturer for the specific project application.
    - Ask if their product complies with applicable standards such as UL 2998.
    - Determine how incorporating a product affects HVAC system design (air velocity, air path length, equipment location and arrangement, filtration protection, safeties, etc.)
    - Have the manufacturer review the proposed installation and respond that it includes the necessary constraints for their product to be effective on that specific project. A manufacturer will likely not respond with a "guaranteed number" for effectiveness for a particular project. However, the engineer should obtain some degree of assurance that the installation of a particular system will deliver the expected benefits.
- Acknowledge and identify the maintenance effort to keep the system operating at desired effectiveness and confirm that the owner can provide that effort and expense.

Rick Wood, Jennifer Marsh and Craig Barbee
Rick Wood *is a technical principal, senior mechanical engineer at Smith Seckman Reid Inc. He has more than four decades of experience. Jennifer Marsh is a project manager and mechanical engineer at Smith Seckman Reid Inc. Craig Barbee is a mechanical engineer at Smith Seckman Reid Inc.*

Your questions answered: Lighting and lighting control design

Which questions did you need answered about lighting and lighting controls? Read answers here

During this Aug. 25, 2022, webcast on "Lighting and lighting control design," many questions remained. Here are several answers from the experts.

Lighting designers must consider many factors when specifying lighting systems and lighting controls for nonresidential buildings, including the owner's project requirements. Elements that designers must be aware of that will be touched on are:

- Lighting construction budget.
- Code requirements.
- Desired light source, color temperature, color rendering index, etc.
- Desired luminaire type and style.
- Illumination levels, minimum foot-candle levels, maximum foot-candle levels, maximum to minimum foot-candle ratios, etc.
- Desired controls systems.
- Special requirements such as emergency lighting, daylighting harvesting, dark skies, etc.

Back to TOC

- Sustainability goals.
- Commissioning requirements.
- Training requirements.
- Operations and maintenance requirements.

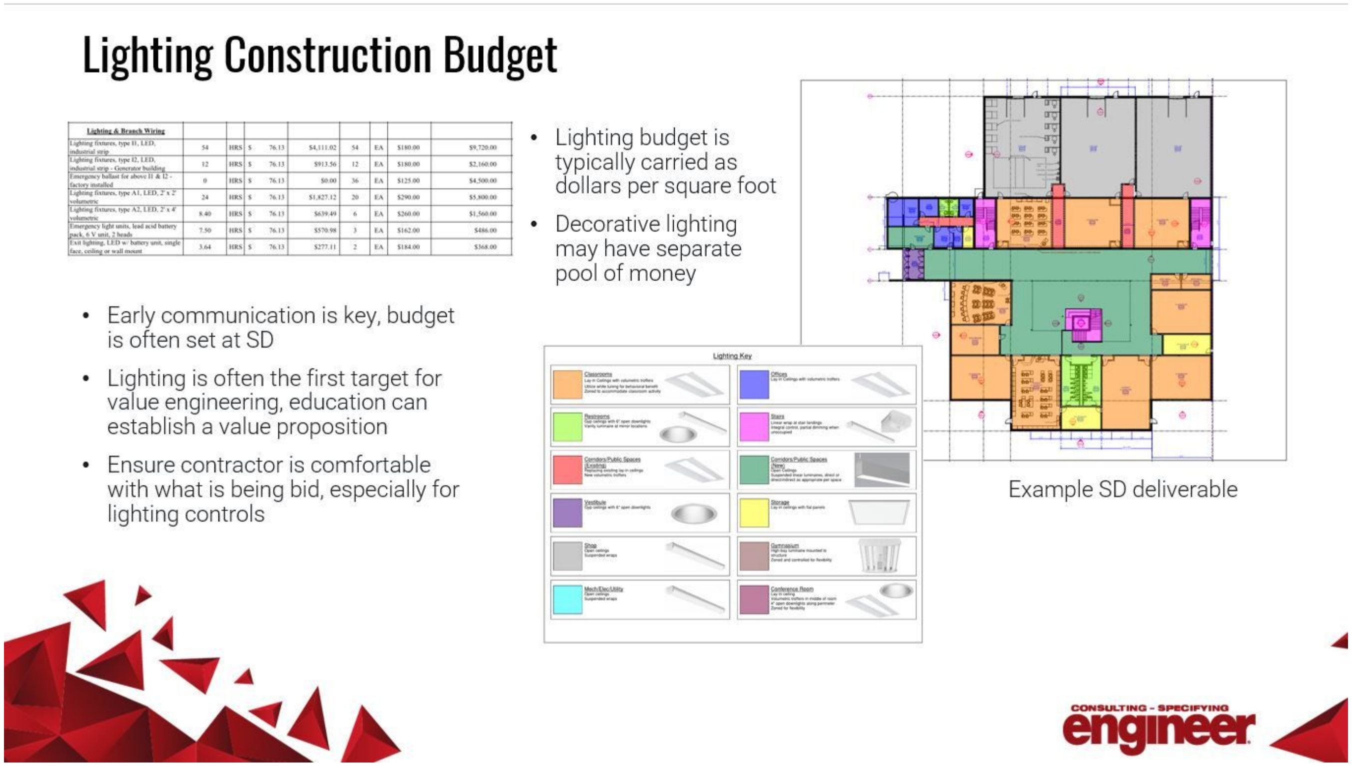
Presenters:

- Michael Chow, PE, CEM, CxA, LEED AP BD+C, principal, Metro CD Engineering LLC, Columbus, Ohio
- Tony Staub, PE, LC, lighting design lead/electrical project engineer, Specialized Engineering Solutions, Omaha, Nebraska

What's the best way to apply "lessons learned" after completing a design you will never see in day-to-day use, and without knowing what the shortcomings of the design are?

Michael Chow: Functional testing/commissioning is required by ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings. The lighting designer or electrical engineer should work with the commissioning agent to implement the functional testing forms and requirements. The completed forms could be reviewed with the lighting designer or electrical engineer.

Back to TOC



The budget for lighting and lighting controls is important to set early in the design process. Courtesy: Consulting-Specifying Engineer

Also, the lighting designer or electrical engineer can require post-occupancy testing. This is required for the optional U.S. Green Building Council LEED Enhanced Commissioning credit.

LEED requires that lighting be separately metered. The lighting designer or electrical engineer can use this data and compare it to the energy model or anticipated lighting usage to determine if the actual data matches the design data. If not, perhaps the lighting controls need to be revalidated or re-commissioned.

Back to TOC

How do you specify a lighting control system while keeping the spec open to multiple manufacturers?

Tony Staub: Using a performance-based specification including a detailed sequence of operations is my method. By defining what the system must be capable of, you can meet the needs of the project without selecting one system.

Can you please elaborate more on "daylight harvesting"?

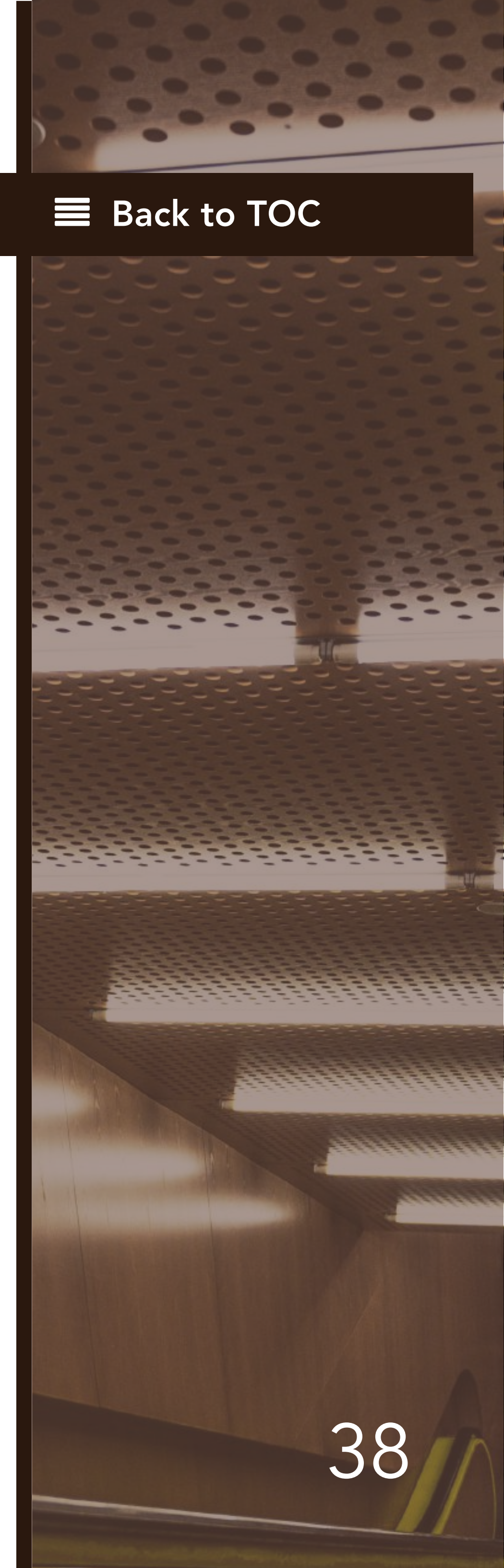
Tony Staub: Daylight harvesting is simply reducing artificial lighting levels (and associated energy) while sufficient daylight is available within a space.

Other than saying the code requires it, how do you sell a client on a controls system who only wants toggle switches on the wall and doesn't want a complicated system? And by that, I mean code minimum dimming, daylight controls and sensors.

Tony Staub: This is highly dependent on the client and the application of the building.

What standards say about the warranty period and battery backup (in hours) of essential lightings fixtures?

Michael Chow: Standards usually do not address the warranty period. NFPA 101: Life Safety Code Section 7.9 requires emergency lighting must remain illuminated for at least 90 minutes. Illumination levels are allowed to decline to an average of 0.6 foot candles (fc), with a 0.06-fc minimum, at the end of the 90-minute period. It is critical



Back to TOC

that the lighting designer or electrical engineer consult with the code official before during the design phase. Code officials may interpret the required illumination levels differently and may lead to increased construction costs and delays if the code official interpretation is not determined during the design phase.

Color rendering index (CRI) gives higher level of color rendering?

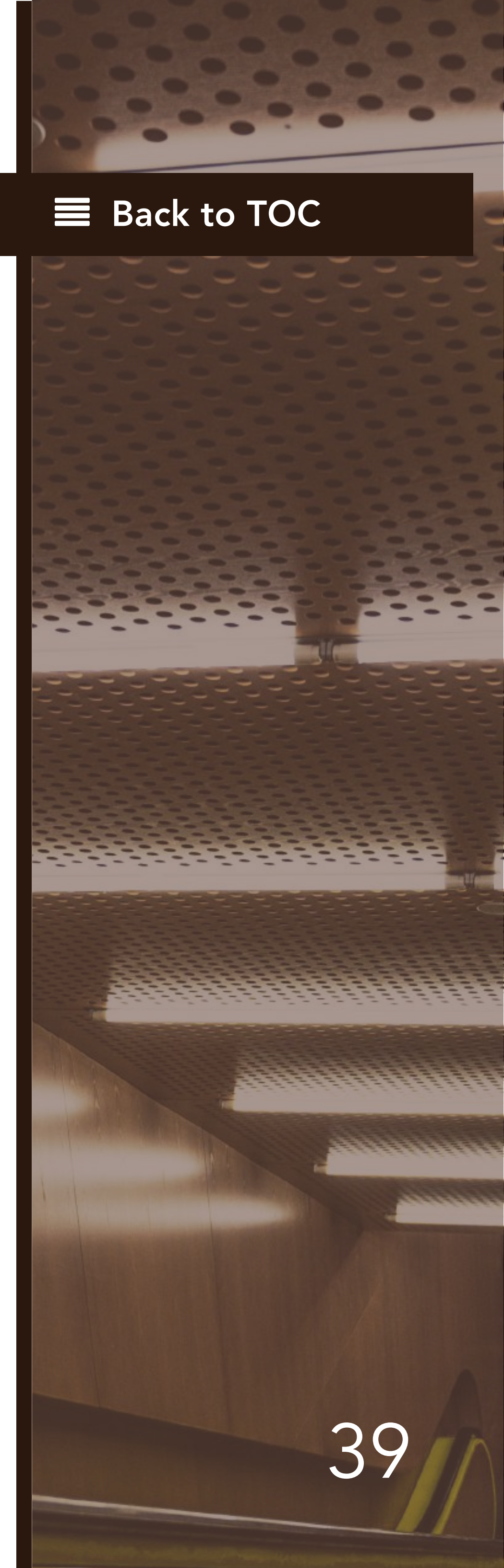
Tony Staub: Theoretically, though CRI is limited in application. CRI is developed using eight reference colors and includes no metric for saturation. In short, a higher CRI should provide better color rendering on average, though that may not be true for specific colors. TM-30 provides additional information, which can be used to better understand the color qualities of a light source.

How does CRI compare to color temperature?

Tony Staub: CRI and correlated color temperature (CCT) are measures of different things, though there is some relationship. CRI compares how light sources render a set of colors as compared to a reference point. Changing CCT would change those reference points slightly, but CRI would still apply in the same way. In short, there is very little relationship between the two.

Isn’t “auto on” a non-energy-conserving spec?

Michael Chow: Occupancy sensors automatically turns on the lights when it detects the presence of a person in its field of detection (usually a major and a minor field) and turns the lights off when no one is present. A feature of occupancy sensors is that they



automatically turn on and turn off when occupancy is detected in either the major or minor sensor coverage areas. It can be programmed to turn on or off only part of the lights during occupancy — some of this is code required. This strategy is also called partial ON/partial OFF control.

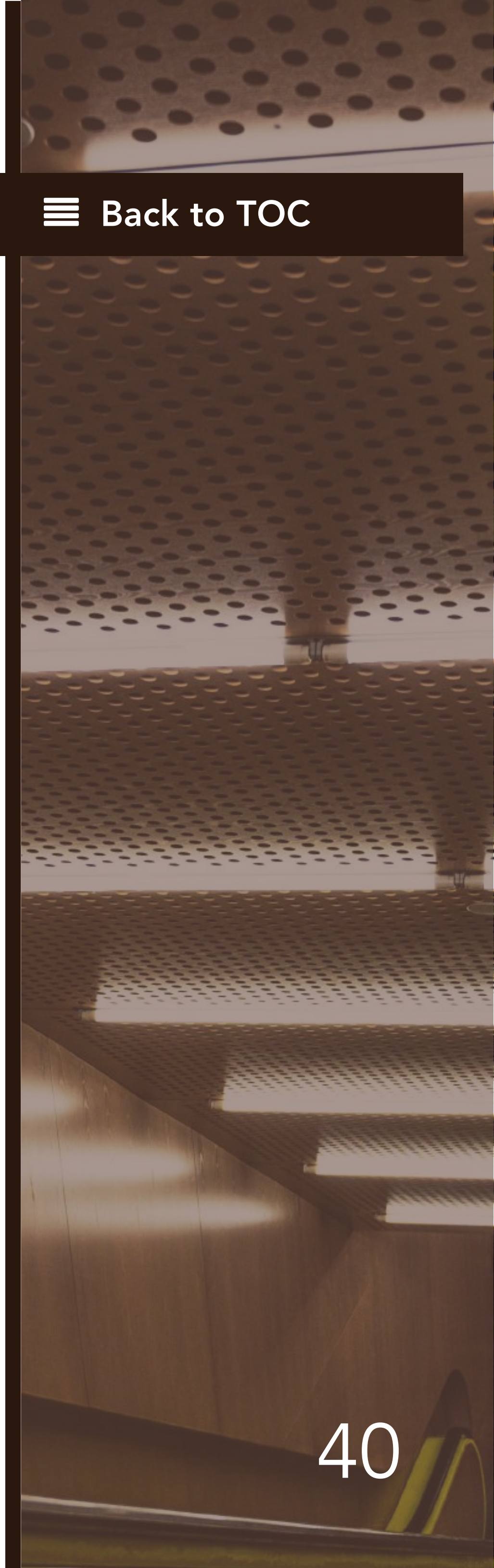
A vacancy sensor can be more energy efficient compared to occupancy sensors. Vacancy sensors will keep the lights off in a room/area unless they are activated manually with a vacancy sensor. This can also be advantageous as a room occupant may not always want artificial lighting. This allows the occupant to control if artificial lighting is present or not. Vacancy sensors turn the lights off when no one is present. This strategy is known as manual ON control.

You talked about CRI, but any thoughts on TM-30 or just CRI+R9?

Tony Staub: I personally believe and hope that TM-30 will continue to gain popularity, as I believe there are a number of TM-30 metrics which could be used in lieu of CRI for more impact.

If ASHRAE 90.1 can be used in lieu of International Energy Conservation Code, does it matter how far back the latest adopted version is?

Michael Chow: IECC for jurisdictions that have adopted the IECC. Use the ASHRAE 90.1 version issued two years before IECC version. However, check with the state and local lighting codes as they may have adopted another version of ASHRAE 90.1 as acceptable.



Back to TOC

Back to TOC

Can mechanical systems use different energy code from the electrical energy code?

Tony Staub: No. The same energy code must be used by the entire design team, including not only the mechanical team but also the architectural team. In fact, there are some code provisions that require the participation of multiple disciplines, such as the "Additional Efficiency Package Options" in the IECC 2018.

Can ultraviolet (UV) lighting be used in retail settings?

Tony Staub: A good UV design can be used in most space types. For a retail space with daily hours, a system set up to provide pulsed UV to disinfect overnight may be a good solution.

Michael Chow and Tony Staub

Michael Chow, *PE, CEM, CxA, LEED AP BD+C, principal, Metro CD Engineering LLC, Columbus, Ohio.* ***Tony Staub,*** *PE, LC, lighting design lead/electrical project engineer, Specialized Engineering Solutions, Omaha, Nebraska*

Back to TOC

How do lighting designers spend their time?

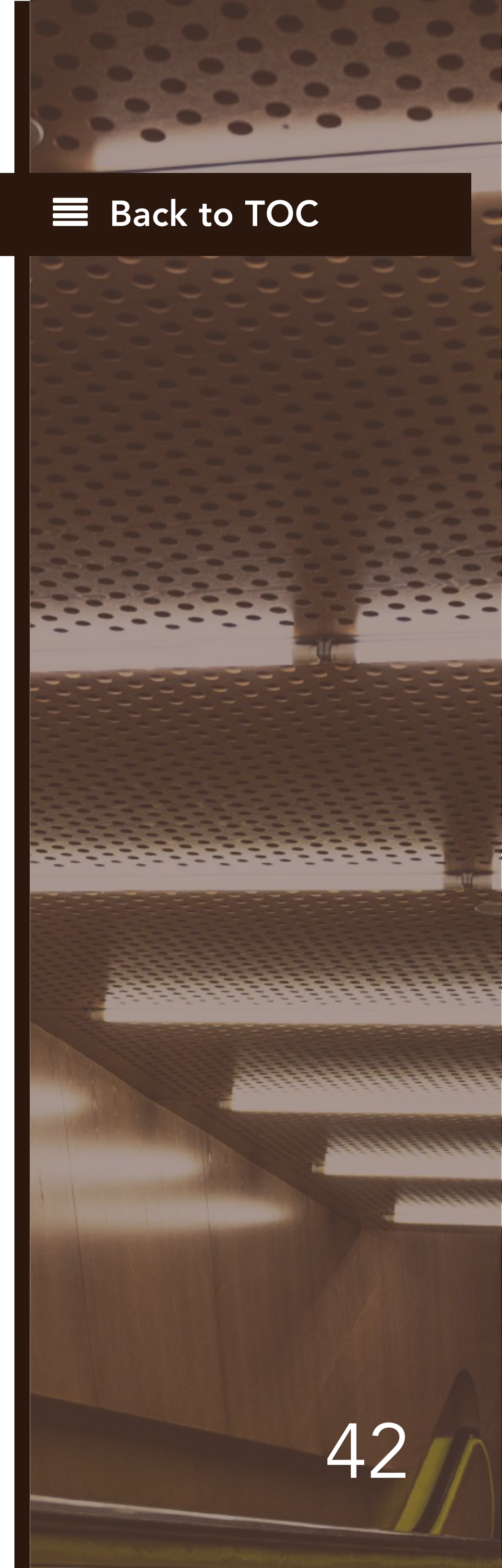
The short answer: most time is spent researching lighting and lighting controls systems

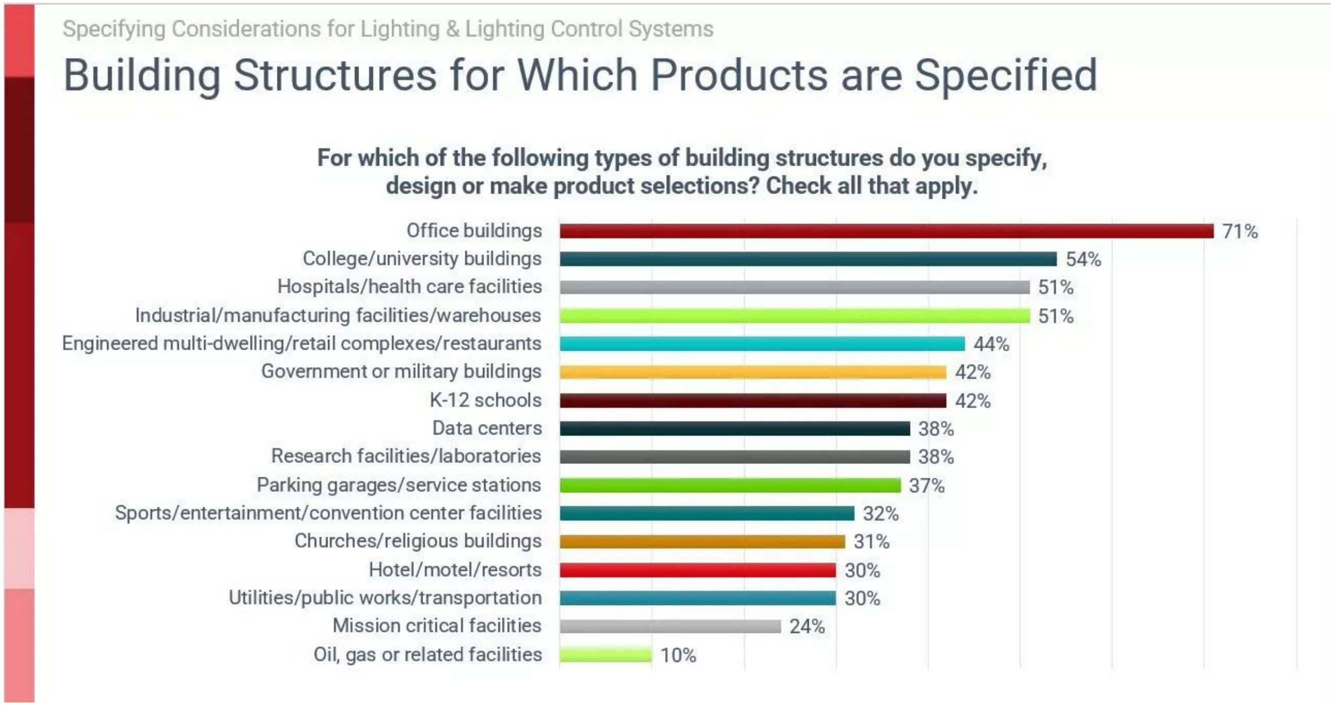
Lighting system designers earn an average of $91,698, according to the 2021 *Consulting-Specifying Engineer* Salary Survey. Lighting designers are tasked with several things, earning their paycheck by: researching, writing specifications and designing new construction and retrofit/renovation projects. Details about how lighting designers break up their time is outlined in the 2022 Specifying Considerations for Lighting & Lighting Controls report.

Most lighting designers expect to see growth in projects that include LEDs, occupancy sensors or multilevel lighting or dimming. These designers are specifying lighting systems into office buildings (71%), college and university buildings (54%), hospitals and health care facilities (51%) and industrial, manufacturing and warehouse buildings (51%).

In this report, four key areas were studied:

- Researching and specifying.
- Vendor considerations.
- Smart lighting systems.
- COVID-19 and specialty systems.

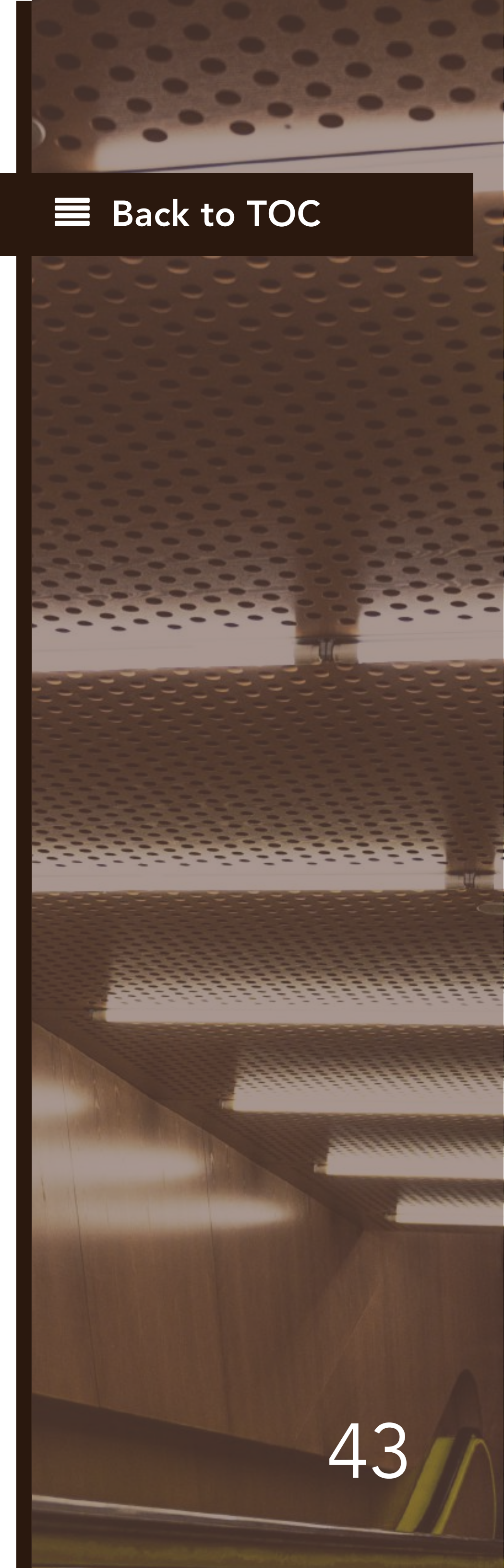




Lighting designers work in a wide variety of building types, with office buildings topping the list again. Courtesy: Consulting-Specifying Engineer

In particular, manufacturers will be interested in research and specification habits of lighting and lighting control systems. For example, when researching and specifying lighting and lighting control systems, the average engineer spends 34% of their time researching vendors on their own, 29% evaluating vendors after speaking with their representatives, 12% sending proposal-like requests for information and 25% writing the specification.

Because about four in 10 respondents to the study indicated the work within a team or committee to design lighting systems, it's especially important that these manufacturers reach the engineer at the right time in the research or specification process.

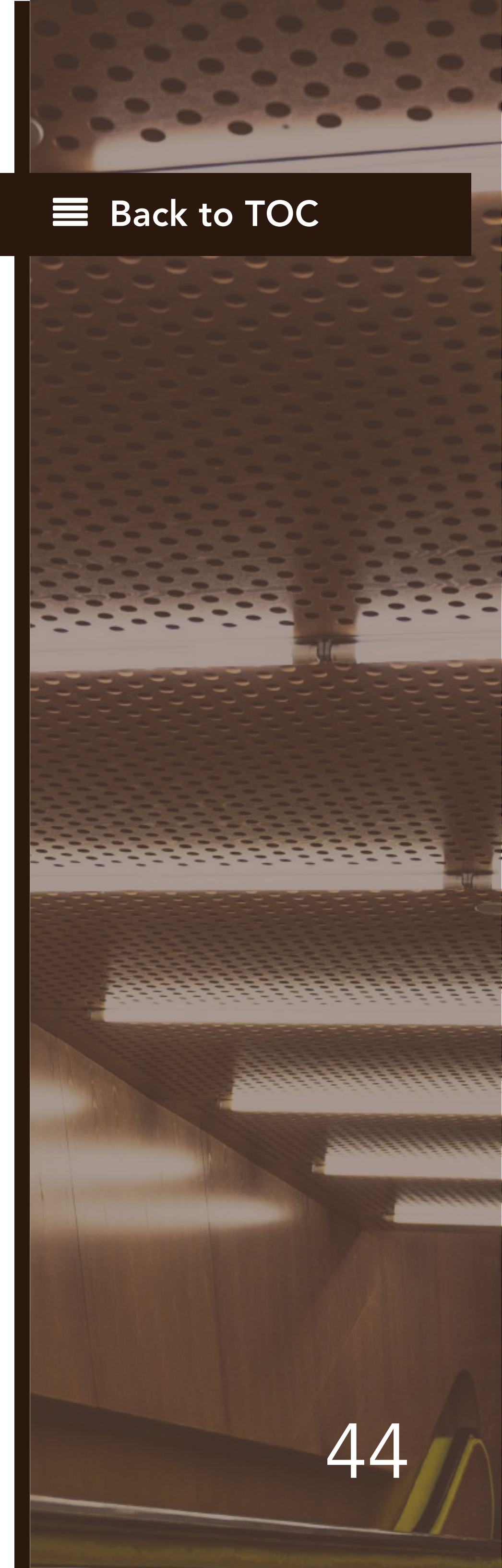


Back to TOC

Smart lighting systems are specified by 43% of respondents, with 22% specifying smart systems more in the past 18 months than before the COVID-19 pandemic. Smart systems have been recently specified by engineers for lighting systems that include LEDs (90%), multilevel lighting or dimming (60%) and daylight harvesting (56%).

For additional details and to download the full report, see the **2022 Specifying Considerations for Lighting & Lighting Controls** study.

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



Back to TOC

Content Archive

Lighting & Lighting Controls

Thank you for visiting the Lighting & Lighting Controls eBook!

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

We would love to hear from you!