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INSIDE: AMA BLUE LIGHT CONTROVERSY • SATURATED COLOR EXPOSURE • LIGHTING CONTROLS • RAND ELLIOTT ON COLOR, LIGHT, AND PLACE • CHERYL ENGLISH

COLOR EXPLORATIONS

SEPT/OCT 2017

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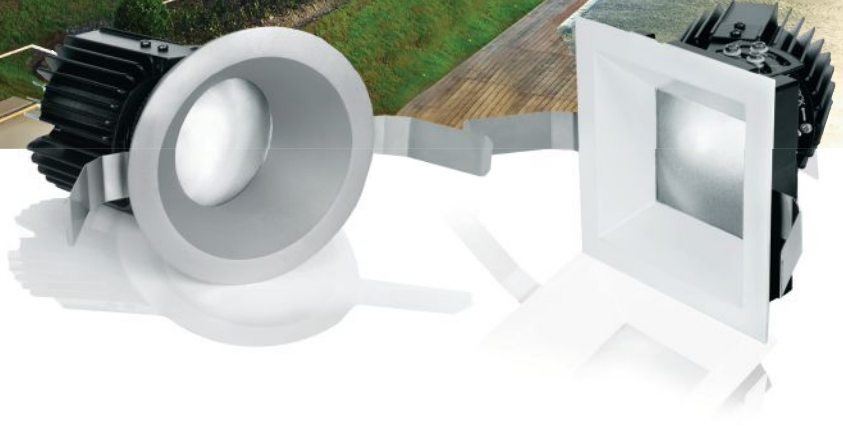

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FEATURE

Detail of Liz West's artwork "Our Colour Reflection" at Kraftwerk Berlin.

DEPARTMENTS

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As always, check out our website for expanded article coverage, videos, and news. Also, subscribe to our email newsletter, AL Notes, and find a link to ARCHITECTURAL LIGHTING's digital edition.

On the Cover: Car Park Three, Chesapeake Energy, Oklahoma City; Photograph by: Scott McDonald © Hedrich Blessing

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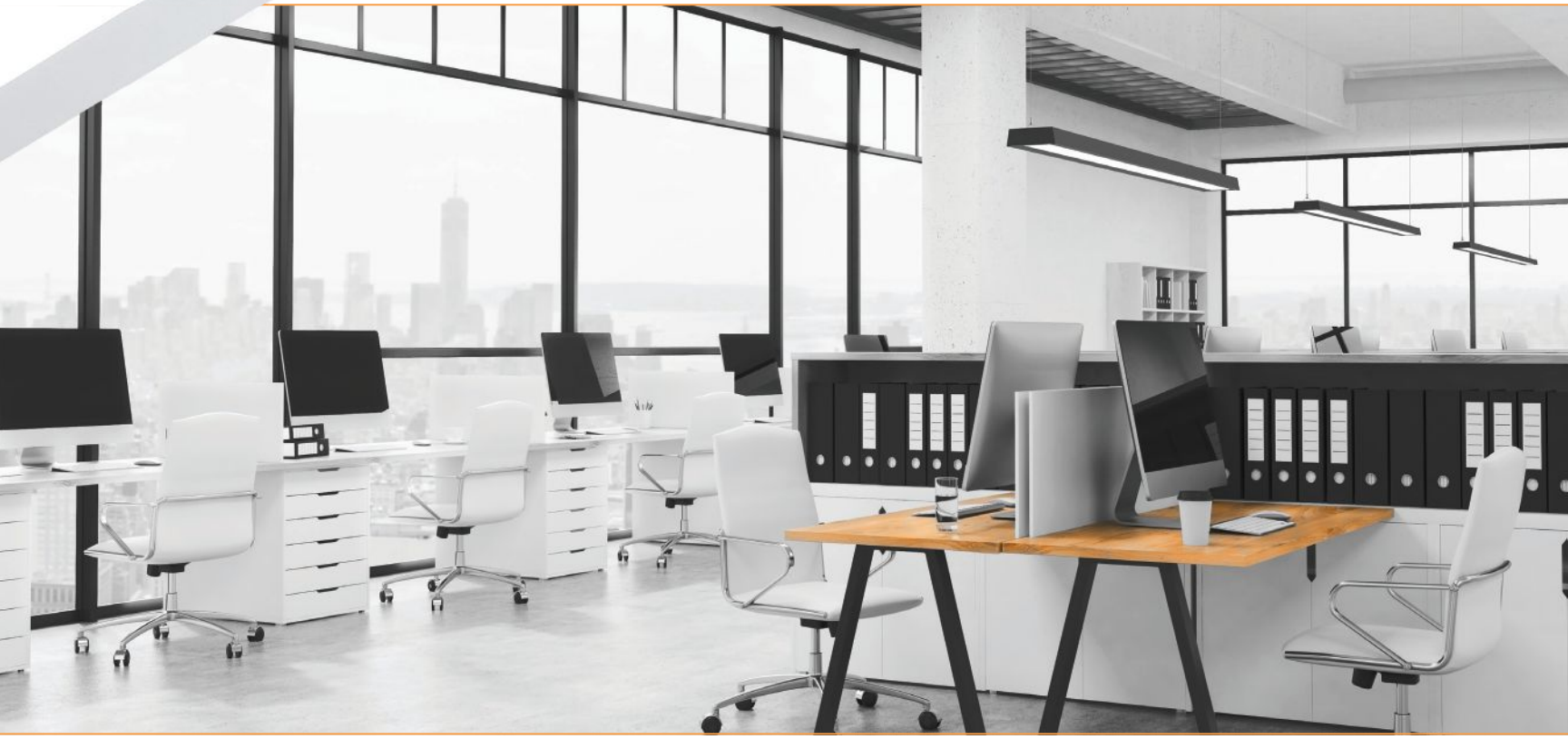

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COLOR SATURATION

Stephen Voss

Over the years, ARCHITECTURAL LIGHTING has covered the topic of color many times, but surprisingly we have never devoted a full issue to the subject. (You can view the online archive of articles at *archlighting.com/tag/color*.) Given the abundant use of color in illumination these days, however, we thought it was about time.

Color is a complex issue. There is a real science behind it, and it lends itself to aesthetic and emotional responses, not to mention different cultural interpretations. As a starting point for this issue of the magazine, we've organized our color discussions around technical issues and design responses. Color has been the subject of some pressing debates of late. Most notable of these has been the controversy surrounding the American Medical Association's warning against the use of blue-rich LEDs, particularly for streetlighting applications. In this issue's Report ("Feeling Blue," page 19), we break down that debate.

In this issue's Technology article ("Red Light, Blue Light," page 28), Mariana Figueiro, director of the Lighting Research Center, examines how rethinking the use of saturated colored light—red and blue, specifically—can aid in increasing daytime alertness and nighttime sleep. It's an important discussion given the increased interest in circadian lighting and the way it has taken hold as a topic in the lighting community, and as lighting manufacturers develop luminaires that incorporate color-tuning capabilities.

From a design standpoint, we look at art installations and projects in our Briefs section (see page 12) that are using color in intriguing aesthetic ways—ways that might seem familiar to those working in lighting design.

And finally, in our cover story, we have a profile of Oklahoma City native Rand Elliott, an architect who has his own particular viewpoint when it comes to the interaction of light and color as a place- and space-making device. Elliott's work transforms everyday building typologies, such as parking garages and offices, into dynamic environments that use color as their organizational structure. His is a refreshing take on the use of color and serves as a reminder about how we use light and color as design elements.

In fact, it seems as though everywhere you look these days there's a building façade, building crown, or monument that is being lit up in a rainbow of colors. Once reserved for special occasions and announcements, color, especially in illumination, is now ubiquitous. This begs the question: If color-changing capabilities are incorporated into every design, are we diluting its purpose? I think so.

This, by the way, is a discussion that has arisen often for us here at ARCHITECTURAL LIGHTING, particularly in the context of the AL Light & Architecture Design Awards Best Use of Color category (see our last issue for the 2017 winners of our annual awards). Every jury that has met over the past 14 years has debated why color is being used on a project, if it has a critical design role, or if it is just being implemented because the technology happened to be available?

When LEDs first started to make their mark in the lighting industry, the technology lent itself to color and made it much easier to incorporate color-changing capabilities into designs than had previous product offerings. But like any technology, it's only as good as the person using it. I wonder: Are we relying too much on technology—in this instance color changing and color programming—to do the designing for us? Moreover, for a generation of lighting designers who know only LEDs, what core design skills are not being fully developed because of this technological reliance?

While color does hold an important place in design, I hope we have further debate as we ask ourselves as designers: What is the value-add in applying color? •

Elizabeth Donoff
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Klaus Bossemeyer

LIGHT AND MIRRORS

For her latest work, "Our Colour Reflection," Manchester, England–based artist Liz West continues her examination of the interplay between light, color, and reflection. The piece, which was most recently on view at Kraftwerk Berlin, an event space housed in a former 1960s East Berlin power station, was part of a group show titled "Perspective Playground," sponsored by camera manufacturer Olympus. The artwork was comprised of more than 765 colored acrylic mirrors in different sizes. The mirrors, which used a palette of 15 colors, were set at different heights from the floor to create a carpet-like kaleidoscope effect through the main hall. The artist relied on the space's existing lighting—electric and natural—to illuminate the artwork, allowing for a dynamic color interplay and ensuring a different visitor experience each time. —**Elizabeth Donoff** • *bit.ly/AL_LWBerlin*

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The Tree of Ténéré, a large-scale artwork conceived of by artist Zachary Smith that involved the participation of a multidisciplinary team of artists and designers from New York, San Francisco, and Amsterdam, debuted at Burning Man 2017 (Aug. 27 to Sept. 4 in the Black Rock Desert of Nevada). The piece, named after a lone African acacia tree that grew despite being in the middle of the Sahara desert, is a symbol of humanity's collective spirit. For the Burning Man installation, the team embedded more than 100,000 LEDs in a canopy of 25,000 leaves to create "a canvas of light." Animation software was developed to produce visual content for the tree—more than 30 interactive light shows, one of which was an adapted version of Studio Drift's 2007 *Flylight* piece, which mimics the movement of a flock of birds. —E.D. • *bit.ly/AL_Tenere*

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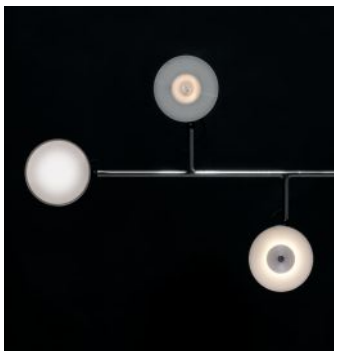

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Ryan Fischer

KINETIC LIGHT

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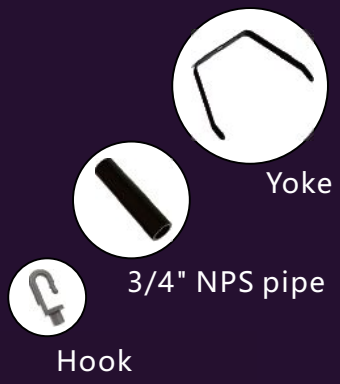

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LED streetlighting illuminates a residential neighborhood in Detroit.

FEELING BLUE

The lighting community responds to the American Medical Association's warning against the use of blue-rich LEDs.

Alex Hall / Courtesy Public Lighting Authority of Detroit

text by Katharine Keane

During its annual meeting in June 2016, the American Medical Association (AMA) announced its adoption of new guidelines regarding the use of LED technology in outdoor applications due to what it saw as "potential harmful human and environmental effects." This was described in the organization's "Guidance to Reduce Harm from High Intensity Street Lights" statement—further detailed by AMA official policy statement H-135.927—which asserted: "Recent large surveys found that brighter residential nighttime lighting is associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning, and obesity." Based on conclusions from a 2016 report (2-A-16) titled "Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting," and produced by the AMA's Council on Science & Public Health (CSAPH), the AMA's statement warned that the use of blue-rich LEDs was a cause for alarm in both lighting and healthcare settings, albeit for different reasons.

The resulting story was far-reaching, garnering attention from major news outlets such as CNN and *The Washington Post*.

THE ISSUE

The AMA's H-135.927 official policy statement (a result of the CSAPH Report 2-A-16) listed three key points:

- *Our AMA supports the proper conversion to community-based LED lighting, which reduces energy consumption and decreases the use of fossil fuels.*
- *Our AMA encourages minimizing and controlling blue-rich environmental lighting by using the lowest emission of blue light possible to reduce glare.*
- *Our AMA encourages the use of 3000K or lower lighting for outdoor installations such as roadways. All LED lighting should be properly shielded to minimize glare and detrimental human and environmental effects, and consideration should be given to utilize the ability of LED lighting to be dimmed for off-peak time periods.*

While the AMA acknowledges that LED lighting reduces energy consumption and reliance on fossil fuels, the organization, in it's "Guidance to Reduce Harm from High Intensity Street Lights" (Policy H-135.927) statement, called for member physicians to "stand against light pollution and [promote] public awareness of the adverse health and environmental effects of pervasive nighttime lighting." Policy statement H-135.927, however, did not include the input of experts and researchers in the lighting community who have scientific knowledge and application experience in this area. The AMA's position statement was generated using research articles "published between 2005 and 2016 … [from] PubMed and Google Scholar databases using the terms 'light,' 'lighting methods,' 'color,' 'photic stimulation,' and 'adverse effects,' in combination with 'circadian rhythm/physiology/radiation effects,' 'radiation dosage/effects,' 'sleep/physiology,' 'ecosystem,' 'environment,' and 'environmental monitoring,'" as described in the methods of the report. Although the report does note that "additional information and perspective were supplied by recognized experts in the field," the expertise of the lighting community's professional associations, the Illuminating Engineering Society (IES) and the International Association of Lighting Designers (IALD), was not solicited.

THE CONTROVERSY

While the lighting industry as a whole has come to embrace LEDs—as of 2014, LEDs comprised 10 percent of outdoor lighting applications with calculated energy cost savings of $1.4 billion, according to the U.S. Department of Energy—speculation and insufficient research has left the public, and even some professionals, in the dark. This has led to misleading coverage in mainstream news outlets. For instance, following the AMA's announcement, CNN reporter Richard Stevens, in his article "Doctors Issue Warning About LED Streetlights," asked, "Can communities have more efficient lighting without causing health and safety problems?" The September 2016 *Washington Post* article "Some Cities Are Taking Another Look at LED Lighting After AMA Warning" by Michael Ollove suggested that the AMA's policy statement adds "credence to the issue and is likely to prompt cities and states to reevaluate the intensity of LED lights they install." While articles that call attention to the challenges posed by new LED streetlighting and the public's unfamiliarity and consequential dissatisfaction with the technology's illumination are not new, those two articles further demonstrate the impact of incomplete or inaccurate information for the public and the confusion it creates.

Following the AMA's 2-A-16 report, the IES released a statement promising to "respond to this through a proper analysis." On June 28, 2017, a little more than a year into discussions with the AMA—but no closer to resolution—the IES published position statement PS-09-17. The IALD endorsed the IES's statement.

Typical of many cities undergoing streetlighting upgrades, legacy sources, such as high-pressure sodium, often co-exist with newer LED luminaires and create a visible contrast.

Haomin Wei / Courtesy Public Lighting Authority of Detroit

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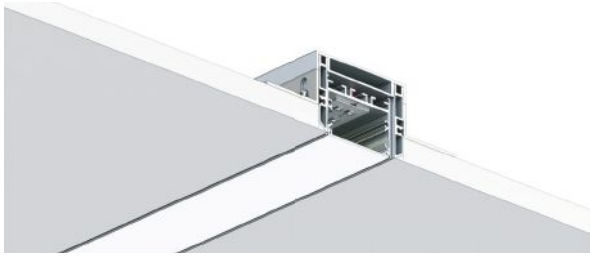

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AMA issues CSAPH Report 2-A-16, "Human Environmental Effects of LED Community Lighting."

June 21, 2016
CNN publishes "Doctors issue warning about LED streetlighting."

June 24, 2016
In response to AMA Report 2-A-16, IES Issues "IES Board Position on AMA CSAPH Report 2-A-16.

June 21-30, 2016
Various entities in the lighting community issue responses to AMA Report 2-A-16.

July 2016
Lighting publications report on the AMA controversy.

Sept. 25, 2016
The Washington Post publishes, "Some cities are taking another look at LED lighting after AMA warning."

June 28, 2017
IES issues Position Statement PS-09-17 (status update of dialogue with AMA).

June 30, 2017
IALD endorses IES Position Statement PS-09-17.

August 23, 2017
U.S. Department of Energy's Solid-State Lighting program issues an activity and research update in its SSL Postings newsletter.

THE RESPONSE

Adding to the complexity of the debate is its multifaceted nature. While the IES concurs with some aspects of the AMA's statement, it completely disagrees with the AMA on others. For example, the IES acknowledges that it concurs with the AMA's understanding of the efficiency and environmental savings of LEDs. But the IES continues and points out that the AMA's findings lack sufficient evidence: "Given the state of current knowledge, it is not possible to weigh the probabilities of health care concerns regarding light-at-night and its effect on sleep disruption from outdoor and roadway lighting against the needs of nighttime driver and pedestrian safety, but such deliberations should precede any policy statement that affects both concerns."

The other point of contention is on the subject of color temperature. The IES does not agree with the AMA's color temperature recommendations. Rather, the IES asserts that melanopic content (which is not correlated to color temperature and can appear at higher levels even at lower color temperatures) has more proven negative effects on circadian rhythms than does correlated color temperature. "Common household incandescent lighting," wrote the IES in PS-09-17, "could therefore have significantly higher melanopic dosing than 3000K outdoor or roadway lighting at night due to relatively higher melanopic content, higher light levels, and longer durations of exposure."

The IES concludes its position statement committing to continued work with the AMA and to engage in "collaborative deliberations … to develop Standards for the benefit of public health and safety." This was an attempt for the organizations to find common ground.

The IALD republished and endorsed the IES response, adding, "While we believe that the scientific research cited by the AMA does not support its policy recommendations, we welcome the AMA's interest in the impact of light on human beings."

WHAT'S NEXT

The AMA, IES, and IALD all declined ARCHITECTURAL LIGHTING's invitation to comment. In an email response, IES technical director of standards and research Brian Liebel wrote, "In light of our past and ongoing discussions with the AMA, it is not appropriate for me to elaborate at this time."

The lighting community continues to find ways to work with organizations outside the profession and to promote the need for

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science-based findings and other critical data for complex lighting issues. Most recently, on Aug. 23, Jim Brodrick, the solid-state lighting technology manager for the U.S. Department of Energy's Building Technologies Office, Office of Energy Efficiency and Renewable Energy, outlined in the DOE's *SSL Postings* newsletter ongoing research initiatives on the subject of sky glow by the Pacific Northwest National Laboratory and Virginia Polytechnic Institute and State University. He also reiterated the sentiment of others in the lighting community criticizing "misperceptions and mischaracterization of the technical information" with regard to sky glow and blue-rich LED lighting, and the disservice imposed on the public when lighting issues are not presented accurately.

Detroit has embarked on a major streetlighting upgrade program. From 2014 to 2016, the city installed 65,000 new LED streetlights.

John Cates / Courtesy Public Lighting Authority of Detroit

ARCHITECTURAL LIGHTING will continue to monitor discussions between the AMA, IES, and other lighting entities on this topic. The controversy is yet another example of the important need for lighting designers and their input on critical lighting issues, with their distinct skill set and expert knowledge, especially given the impact of this information on public discourse and in policymaking.•

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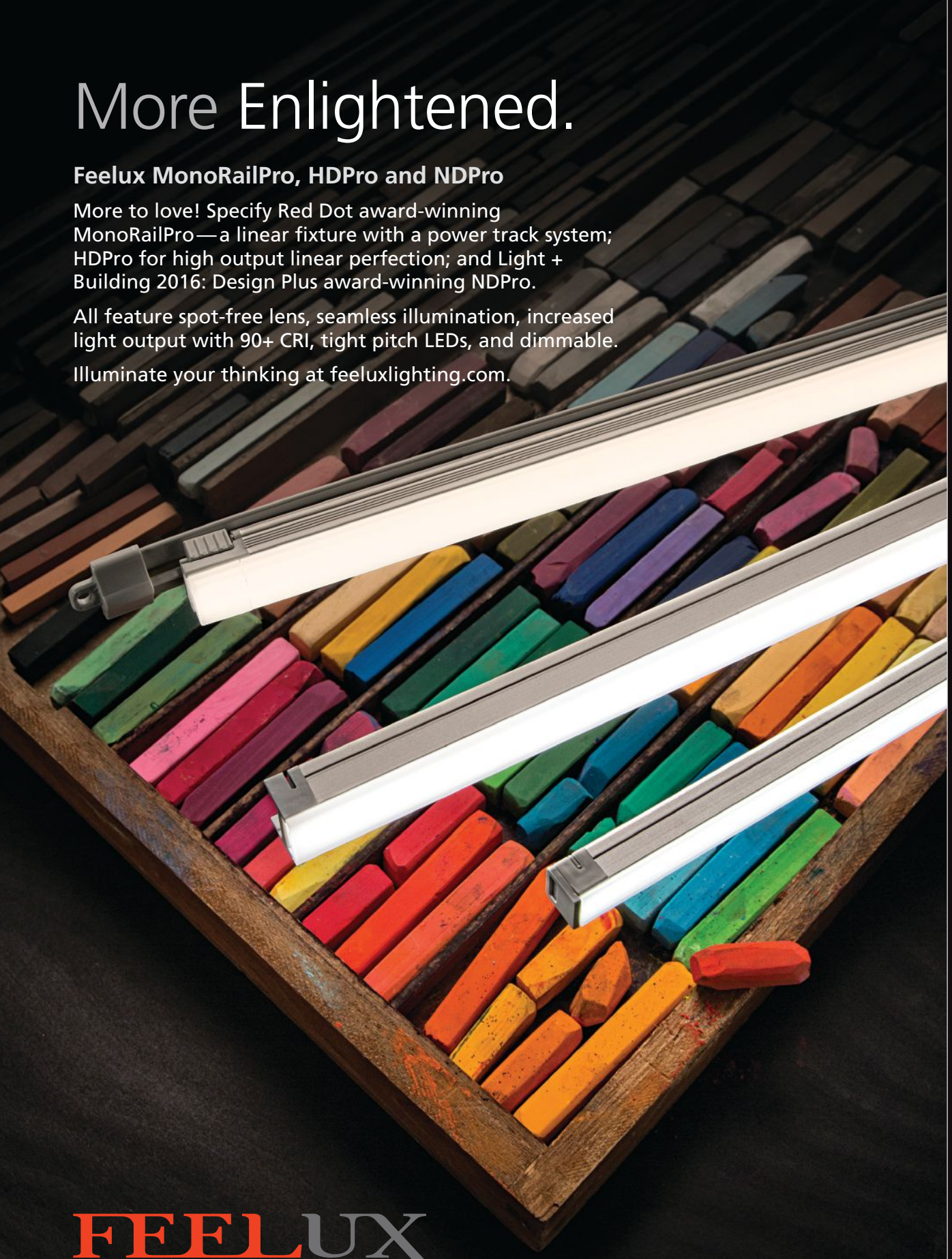

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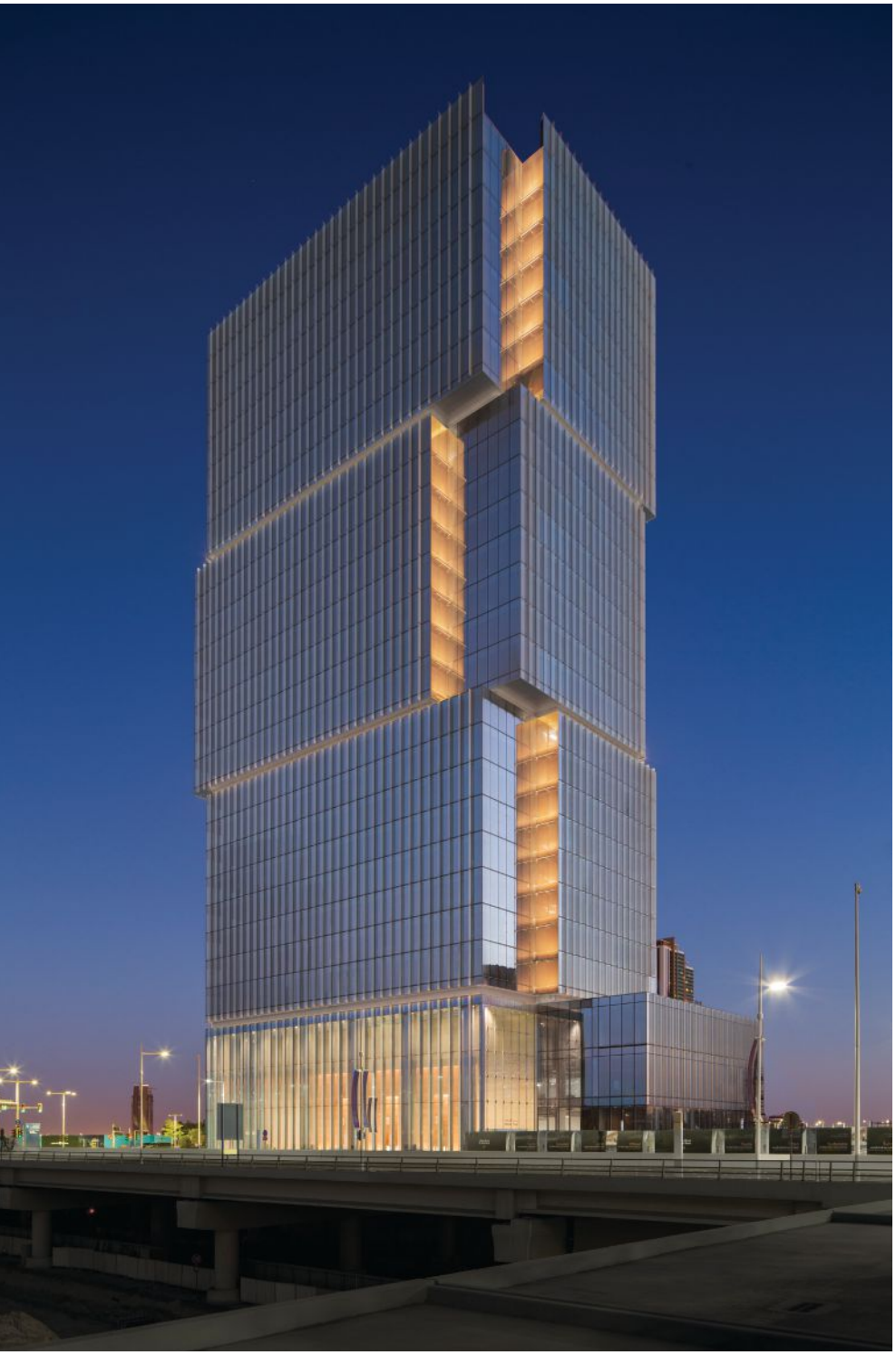


text by Belinda Lanks
photo by Tom Rossiter

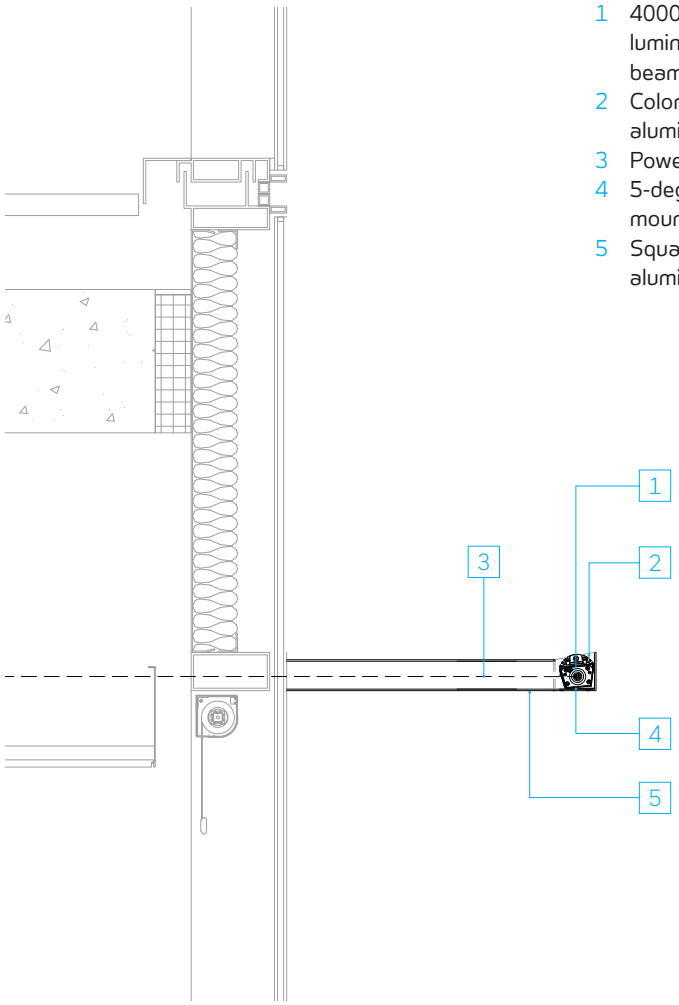
The defining feature of the Al Hilal Bank's new office tower, designed by Chicago-headquartered architectural firm Goettsch Partners, is its shifting masses as it rises 24 stories on Abu Dhabi's Al Maryah Island in the United Arab Emirates. Three cube-shaped volumes sit on top of a podium, stacked like offset blocks. To highlight the reveals between the glass-and-steel boxes, Goettsch enlisted New York–based lighting design firm One Lux Studio to discreetly illuminate the forms, and to accentuate the "push and pull" effect at the building's recessed corners with illuminated vertical bands of orange-colored glass, the client's signature color.

Lighting the volumes' offsets proved relatively simple; this was accomplished using a concealed 4000K 10W grazing fixture dimmed to 70 percent to achieve the desired intensity. Illuminating the orange glass at the corners of the structure, however, was trickier. Glass does not glow unless it contains a medium that accepts light, says One Lux partner Stephen Margulies. His solution, in collaboration with the architects, was to add an orange frit to the glass that was designed to not rankle the tenants. "You wouldn't want a nice, beautiful corner office, and then have an orange-colored glass on the majority of the façade," says Goettsch principal Scott Seyer.

After evaluating a range of options printed on clear acetate, the designers decided on a double-sided frit: orange on the exterior and black on the interior, which yielded an unobtrusive tint visible from inside the space. The team also decided on a frit density of 40 percent and, after experimenting with various light intensities, the addition of a 10W LED luminaire. "There was this constant loop we were going through, because the less frit we had, the less light we needed," says Margulies. "But the less surface area we had, the more light we needed." The next step was to find the color temperature that, in combination with the fritted glass, would render Al Hilal's exact shade of orange. (Another round of mock-ups determined that to be 4000K.)

Determining how to install the fixtures also posed some challenges. One Lux Studio

VERTICAL LIGHTING DETAIL AT FAÇADE



Legend

1. 4000K linear LED façade luminaire with 30x60 degree beam spread and louver
2. Color-coated extruded aluminum housing
3. Power feed
4. 5-degree aiming angle mounting bracket
5. Square-shaped extruded aluminum support

developed a system of bracketed fixtures—suspended on every floor—for the building's curtainwall. The question then became where on the curtainwall to affix the luminaires so that they wouldn't shine light into the offices. When placed at the floor line, the fixtures were visible to occupants, so the lighting designers positioned them at the base of the spandrels and attached them with 0.2-inch angling brackets 2 feet from the façade. Luminosity and three-dimensional studies determined the optimal distance of the fixtures from the building, with the result striking the right balance "between the best technical response and the desired architectural effect," says Seyer. To ensure that the fixtures would be aimed correctly—One Lux Studio would not be on site to do this—Margulies specified that the brackets be locked at a five-degree upward tilt to prevent them from being misaimed. "It was kind of like lighting a picture on the wall," he says, "but instead of hanging it [the luminaire] down toward the picture, we were pointing it up."

According to Margulies, focusing the exterior lighting on the building's major feature—the boxes and their recessed edges—produced a deceptively simple branding scheme for the client, Al Hilal, that "looks like it was developed as part of the architecture, as opposed to something that was just laid over it." The effect is even more pronounced at night, when the subtle fixtures serve a dual purpose of accenting the bank's identity while articulating the building's unique structure. •

DETAILS

Project: Al Hilal Bank Tower, Abu Dhabi, United Arab Emirates • **Client:** Al Hilal Bank, Abu Dhabi • **Architect:** Goettsch Partners, Chicago • **Lighting Designer:** One Lux Studio, New York • **Structural Engineer:** DeSimone Consulting Engineers, New York • **M/E Engineer:** Environmental Systems Design (ESD Global), Chicago • **Project Size:** 87,570 square meters (942,600 square feet) • **Project and Lighting Costs:** Withheld • **Watts per Square Foot:** 3.16 • **Code Compliance:** Estidama 1 Pearl

MANUFACTURERS

Bartco Lighting: 49W per square meter 3000K T5 fluorescent uplight, staggered in lobby • **Kurt Versen (Hubbell):** 167W 3000K metal halide fixture with 20 degree beam spread in lobby; 23W 4000K LED downlights in typical offices; 80W 3000K metal halide downlight at arcade and bridge vestibule; 44W 3000K metal halide wallwashers and downlights in lobby; and 23W 4000K LED downlight in prayer room • **GE Lighting :** 4W per module 3000K LED fixture in lobby, elevator lobby, and backlit glass • **Lucifer Lighting:** 18W 4000K LED fixture in restrooms, downlight at bridge elevator cab • **Philips Color Kinetics:** 4000K LED facade lighting: linear fixture with 30x60 degree beam spread with louver mounted to metal housing projected from facade, and linear 90x60 degree beam spread with glare shield • **Philips Lightolier:** Linear slot fixture at typical office with 63W per 1200mm long 4000K T5 fluorescent • **Specialty Lighting:** 104W per square meter 3000K linear covelight at lobby • **XAL:** 26W 3000K recessed LED slot fixture in lobby • **Zumtobel:** 72W 4000K recessed fluorescent fixtures at security rooms and back-of-house spaces

RED LIGHT, BLUE LIGHT

An LRC study is underway to examine the impact of saturated red light in combination with ambient white polychromatic light.

Courtesy LRC

Rethinking exposure to saturated colored light can be a means of increasing daytime alertness and nighttime sleep.

text by Mariana Figueiro,
Director, Lighting Research Center

Color vision begins with light. A single cone photopigment molecule absorbs a photon, initiating a series of actions that leads to isomerization, the transformation of one molecule into another molecule. Cone photoreceptors in the human retina are responsible for our perception of color and classified by the wavelengths of light to which they are sensitive: long (L), middle (M), or short (S). The cone photoreceptor sensitivity is determined by its likelihood that it will absorb a particular wavelength of light. For example, an S cone will more likely absorb blue light than an L cone.

Two key physical properties of light participate in color vision: wavelength and power. They factor into a light source's spectral power distribution, which describes the amount of light power at each wavelength in the visible spectrum (which ranges from approximately 380 nanometers to 780 nanometers) that is emitted by that particular source. Power is a measure of the amount of light from each wavelength that arrives at a defined location per unit time.

As far as photoreceptors are concerned, however, wavelength and light levels are interchangeable. In other words, individual photoreceptors are "blind" to wavelength, and isomerization is the same regardless of the absorbed photon's wavelength. Because how a photoreceptor counts photons and the number of isomerizations that occurs depend on both properties—that is, the probability of photon absorption (light wavelength) and the number of photons reaching the photoreceptor (amount of light)—changes in the rate of photon absorption by the photoreceptor could result from variations in either the wavelength or the amount of light.

For this reason, the assignment of color to any physical wavelength is erroneous because it implies that the colors we see are properties of a given wavelength. As Mark Rea, a professor at Rensselaer Polytechnic Institute's Lighting Research Center (LRC) and an expert in color vision, has often said, "Color is a pigment of our imagination."

Once a photon is absorbed by the photoreceptor, processing occurs in the retina, and the neurochemical signals resulting from the isomerizations are recombined in the retina's bipolar cells into three neural channels. One of those channels (L plus M cone responses) is achromatic. The other two are color-opponent chromatic channels: the blue versus yellow, or b–y (S cone – [L plus M] cone responses); and red versus green, or r–g (L minus M cone responses). The achromatic channel, which responds to variation

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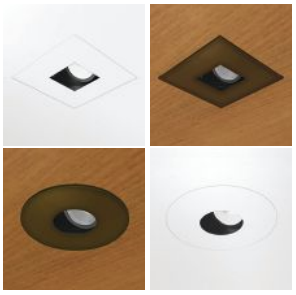

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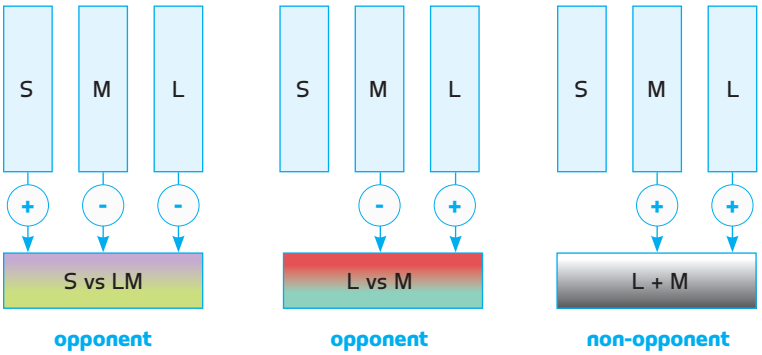
in light and dark, is also referred to as a luminance channel. The chromatic channels are spectrally opponent, which means that responses to one color subtract from the responses to the other color. Opposite opponent colors are never perceived together—that is, we cannot perceive greenish-red or a yellowish-blue color. We see "white" when the L cone and M cone inputs are equal, and therefore, no hue information is generated by the bipolar neurons. When the net-sum signal from the L cone and the M cone is positive, the bipolar neuron signals red; when the net-sum signal is negative, the bipolar neuron signals green. This spectrally opponent information is passed onto the ganglion cell layer and then transmitted to the brain for processing.

NEURAL CHANNELS



A diagram showing opponent (chromatic) and non-opponent (luminance) neural channels formed by different combinations of the S, M, and L cones.

NONVISUAL EFFECTS OF COLORED LIGHT

As color is thus a visual perception and not a physical property, a discussion on colored light's nonvisual effects might seem inconceivable. But the nonvisual effects of colored light can nonetheless be described as the impact of narrowband light stimuli on the retina that evokes responses in the brain's neural channels independent of vision. One of the most studied nonvisual responses to light is the circadian system. The 24-hour light–dark patterns incident on the retina control the timing of the body's biological clock, which generates and regulates our circadian rhythms so that we are awake during the day and asleep at night. In the absence of external cues, our circadian rhythms run on a slightly longer cycle of about 24.2 hours. We require daily exposure to morning light to reset our biological clock and keep us synchronized, or entrained, with a particular time zone.

To promote entrainment, researchers generally recommend exposure to circadian-effective light during the morning, and reduced exposure during the evening. This is because, unlike the visual system, which essentially responds in similar ways to the same light stimulus at any time, a given light stimulus will have different effects on our circadian rhythms when applied at different times of day. For example, light exposures experienced in the morning can advance the circadian system's phase and result in earlier sleep and wake times. On the other hand, if experienced in the evening, light can delay circadian phase and result in later sleep and wake times. Given that our circadian clock runs on a 24.2-hour cycle, it needs to be advanced daily; therefore, to maintain entrainment, we need to be exposed to morning light.

As tunable lighting systems become more prevalent, this guideline typically manifests in the use of color temperatures of 5000K to 6500K during the day, and 2700K or less in the evening. While these rough recommendations are a good start, it is important to consider that in respect to white polychromatic light, varying the spectrum from 6500K to 2700K will increase the circadian effectiveness of the system, but not by very much. It is also important to specify the minimum amount of light needed for activating the circadian system. In general, the circadian system is less sensitive to light than is the visual system. The LRC has shown in many of our field studies that light levels in the built environment are at or below threshold for activation of the circadian system. This can have at least two health consequences: First is that people may not be getting enough morning light to promote entrainment;

Diagram Source: Scholarpedia.org/article/Color_vision

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second is that exposure to low levels of circadian-effective light during the day may increase the impact of evening light, including those coming from bright, self-luminous displays.

When thinking about light level and spectra, however, think beyond white light. For example, if you choose to use desktop lighting that delivers 30 lux of a saturated blue light (peak wavelength = 470 nanometers) at a user's cornea, the impact on the circadian system would be similar to delivering 400 lux of a 6500K source, or 550 lux of a 2700K source, at the cornea. So, while tuning the spectrum to deliver a more bluish white light would be energy efficient, the use of a saturated blue color light would be more than 10 times more effective for delivering the same level of circadian stimulation to the user.

Another less understood, but no less important, nonvisual effect of light is its impact on alertness. In this context, alertness, a construct associated with high levels of environmental awareness, is regulated by the interplay between the circadian timing system (a circadian process) and the duration of time awake (a homeostatic process). The circadian process is regulated by the endogenous circadian pacemaker, which, as noted above, is synchronized daily with the environment by the 24-hour light–dark patterns incident on the retina. In diurnal species, the circadian process promotes alertness during the day and sleep at night. The homeostatic process, on the other hand, accumulates sleep pressure as the number of waking hours increases.

In most studies to date, the light's alerting effects have been linked to their ability to suppress melatonin, a hormone produced at night and under conditions of darkness. It is now well accepted that the circadian system, as measured by acute melatonin suppression, is maximally sensitive to short-wavelength ("blue") light, but not long-wavelength ("red") light. In other words, light suppresses melatonin and fools the brain into thinking that it is daytime, when one is expected to be alert. Recent studies conducted by the LRC, however, have demonstrated that, relative to darkness, exposures to both short-wavelength (saturated blue colored) and long-wavelength (saturated red colored) lights increased objective measures of nighttime alertness, but only the short-wavelength light suppressed melatonin.

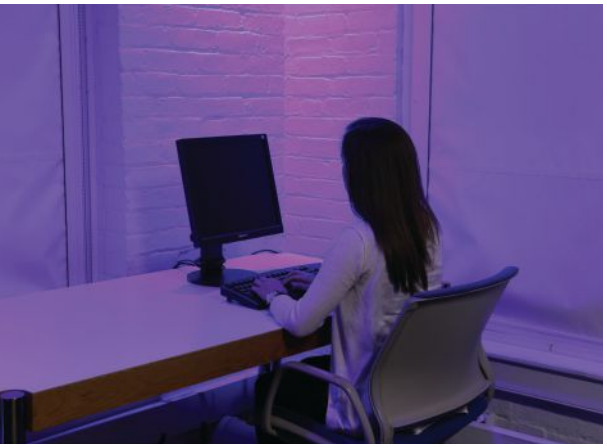
These findings suggest that acute melatonin suppression is not needed for light to affect alertness at night, and are consistent with studies measuring the effects of daytime light exposure on brain activity using functional magnetic resonance imaging. White polychromatic and short-wavelength light exposures have been demonstrated to increase measures of alertness during the daytime, when melatonin levels are low. Corroborating that research, the LRC's studies also demonstrated that saturated red light had a strong effect on objective and subjective measures of alertness, with that effect appearing to be stronger during the daytime, and especially during the afternoon decrement in performance known as the post-lunch dip.

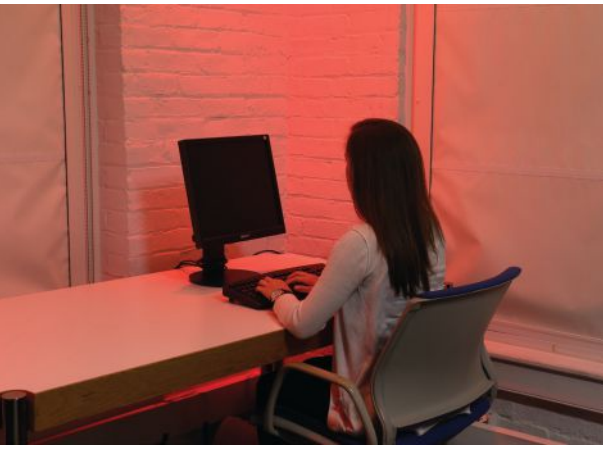
One line of research that we at the LRC are currently pursuing is the impact of saturated red light in combination with ambient white polychromatic light. We are also beginning a series of studies to look at the brain mechanisms associated with these acute alerting effects of saturated light colors.

HOW TO USE SATURATED COLORED LIGHT

With the growing ubiquity of tunable lighting systems over the past decade, lighting designers have grown so accustomed to thinking about light levels and spectra that it has perhaps become easy to forget the other options available to promote circadian entrainment and alertness. So, how can we begin to think beyond ceiling-mounted tunable lighting systems?

An LRC study participant is exposed to saturated blue light in the morning (top), and to counter the afternoon post-lunch dip, a dosage of saturated red light (bottom).





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A good place to start might be to take a step back and return to thinking about filling spaces with layers of light. This would be beneficial not just for visual performance and energy efficiency, but also in how layered light might contribute to entrainment and alertness. And here, it is crucial that vertical illuminance (light at the cornea) and not just horizontal illuminance (light on the workplane) be considered, because it is the light at the cornea that stimulates the circadian system. Delivering stimulus to the eye can be as simple as sitting next to a window, or as elaborate as installing desktop-mounted, self-luminous LED light panels. But the light does not have to come from the ceiling. If you choose to use ceiling light fixtures, make sure the distribution of light is such that the ratio of horizontal to vertical illuminances is at least 7:10.

For example, in order to promote alertness and circadian entrainment in the early part of the day, a strong dose of circadian-effective light could be administered using an LED panel that emits a saturated blue (470-nanometer) light at eye level. On the other hand, to promote alertness after the post-lunch dip, an analogous saturated red (640-nanometer) LED panel could provide a stimulus that would be akin to a cup of coffee. Or, if that particular design were deemed to be impractical or infeasible, a simple red or blue light box could be installed. Another option is to set aside a portion of the space as a "light oasis," to which users would come and obtain their circadian dose during the morning hours.

Also at play are the issues of timing and duration. Discussions of circadian-effective lighting design can sometimes focus on light spectra and levels at the expense of other key, coequal factors that are involved with light and the circadian system—namely, the timing and duration of light exposures and an individual's personal history of such exposures.

In conclusion, while tunable lighting systems provide a dynamic lighting solution that create an aesthetically pleasing environment for users, when it comes to circadian-effective lighting, layers of saturated colored lights delivered at the plane of the cornea, rather than white light coming from the ceiling, may provide a more energy-efficient, comfortable, cost-effective, and aesthetically pleasing design solution. So, use the pigment of your imagination and think colored light in your next design. •

GLOSSARY

Photopigment: The photoreceptor protein of the retina.

Isomerization: A process by which one molecule is transformed into another molecule that has the same formula but a different bonding or arrangement of its atoms. In vision, this photochemical process involves the protein opsin, which gives a photoreceptor its photosensitivity.

Power: The amount of energy consumed per unit of time.

Spectrally Opponent: Human color vision starts in the retina, where the long-, middle-, and short-wavelength-sensitive cone photoreceptors outputs combine antagonistically to produce "red–green" and "blue–yellow" spectrally opponent signals. Simultaneous exposure to multiple-wavelength light can result in less circadian stimulus than would result if either color was viewed separately.

Circadian-Effective Light: Defined as light that is necessary for circadian entrainment, its effectiveness can be determined from the spectral irradiance distribution of the light incident at the cornea and its ability to acutely suppress the body's production of melatonin after a one-hour exposure.

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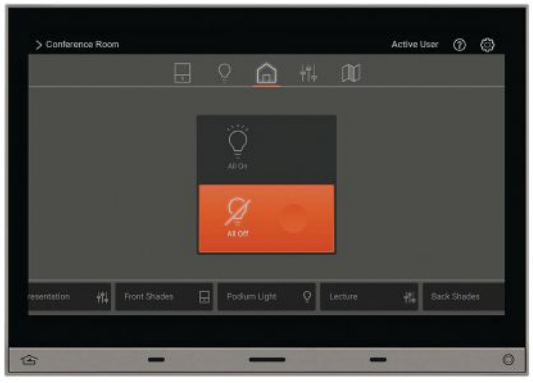

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text by Selin Ashaboglu

1 **IntelliMax, MaxLite** • This wireless lighting control system, which uses the Zigbee protocol, offers full functionality including occupancy sensors, dimmers, and daylight harvesting. The system uses Cortet wireless technology and can operate independently, or through the cloud to collect data. IntelliMax is compatible with Leviton wall switches as well as components from other manufacturers. • *maxlite.com*

2 **Wattstopper Commercial Equinox User Interface (UI), Legrand North America** • For use with the company's Wattstopper architectural dimming platform, this software provides a user-friendly graphical interface that allows occupants, as well as building and facility managers, to control a host of lighting and shading functions simultaneously. The UI includes a series of intuitive buttons for control features that can scale a system from room to building. The program tracks energy usage and can be set to include dynamic white and other color temperatures for circadian lighting applications. Equinox UI is available for in-wall touchscreens, or can be downloaded onto a smartphone or tablet. Commissioning is done via the company's Design Center (3.8.0) software. • *legrand.us*

3 **Lumina RF Standalone Room Controller System, Leviton** • Designed for LED lighting retrofit applications, this wireless room controller system is compatible with Philips' EasySmart technology-enabled InstantFit LED T8 lamps. The system features wireless dimming, occupancy or vacancy sensors and photocells, multizone daylight harvesting, scene control, and keypad room controllers. The keypads come in one-, two-, four-, or eight-button configurations, and can serve as remote keypads for three-way switching applications. System commissioning is done via the Leviton Neuron app. The system also meets lighting control requirements for ASHRAE 90.1, IECC, and California Title 24. • *leviton.com*

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4 **Lightcloud, RAB Lighting** • Lightcloud is a wireless commercial lighting control system that includes a variety of components such as occupancy and daylight sensors, gateway power hub and controller, dimmers, and touchscreens. The system reports real-time and estimated power usage, and features an encrypted 3G connection for secure networking. A wall-mounted, 10"-wide touchscreen or an in-wall dimmer allow users to switch and control fixtures connected to the system. California Title 24–compliant, according to the manufacturer, Lightcloud is the first lighting control system to be qualified by the DesignLights Consortium. • *rabweb.com*

5 **nLight Eclypse, Acuity Controls, Acuity Brands** • nLight Eclypse is an IP and building management interface for Acuity Control's networked digital lighting control systems, nLight and XPoint. The BACnet Building Controller–listed device provides nLight and XPoint luminaires and controls with remote software programming as well as schedule management. A single nLight Eclypse module can manage up to 750 devices using multiple protocols, like Modbus and BACnet/IP, that allow for integration into existing building automation systems. The interface can be used with SiteView Energy, the company's digital platform and power meter that monitors devices and energy performance. • *acuitybrands.com*

6 **Easyfit, EnOcean** • This line of wireless and self-powered LED lighting control wall switches for Bluetooth lighting systems is suitable for new and retrofit applications. Easyfit works with lighting systems from Casambi, Silvair, and Xicato, and the switches are available in two versions: standardized 55mm-square frames and Easyfit switch for North America. Available in single- or double-rocker pads, the interface offers switching, dimming, and temperature control through pushing and releasing the rockers in long or short intervals—made possible by an electro-dynamic energy transducer. A single rocker pad measures 4.95" long by 3.21" wide; a double rocker measures 4.95" long by 4.52" wide. The switches can be commissioned using Near Field Communication. • *easyfit-solutions.com*

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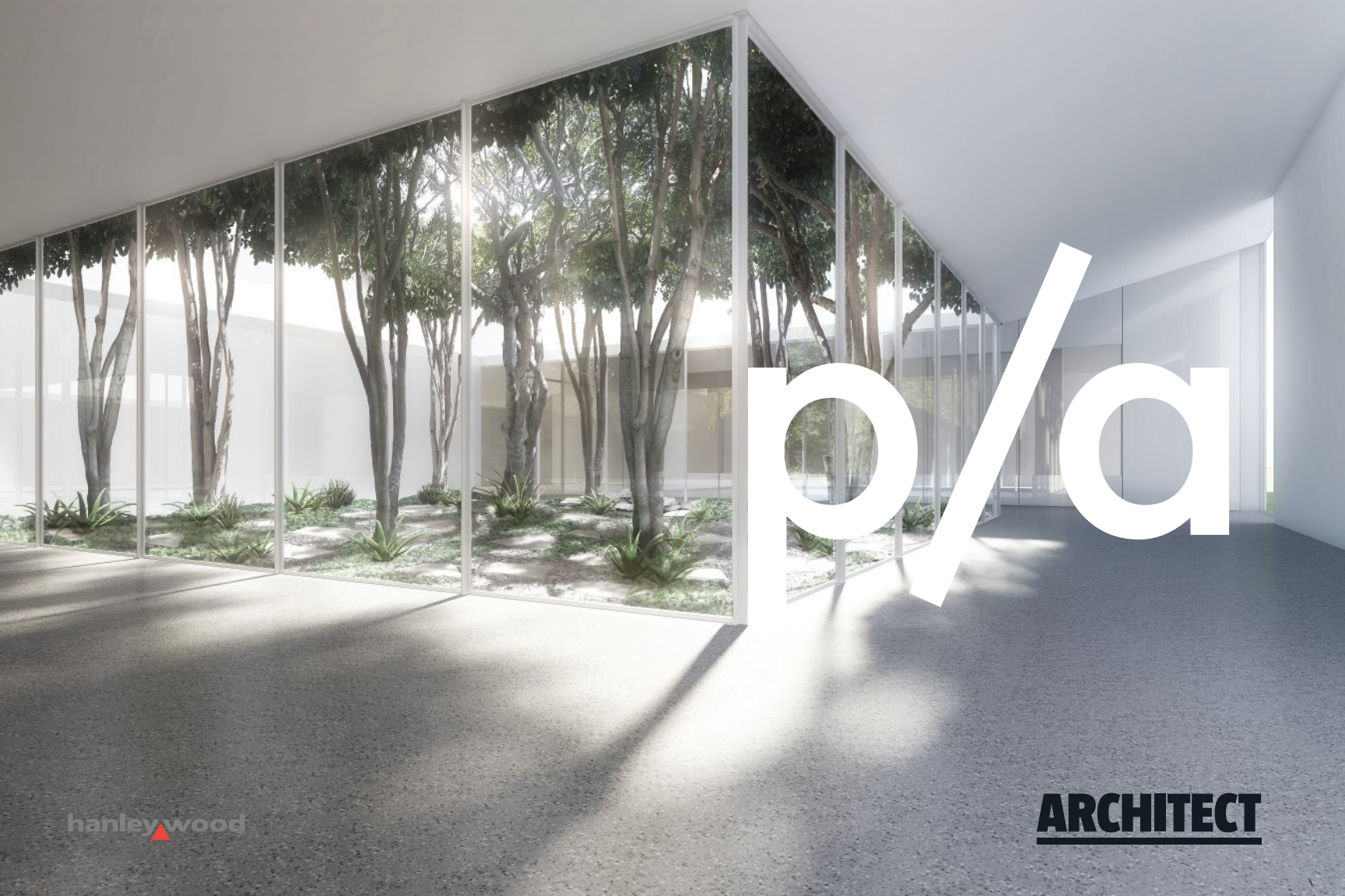

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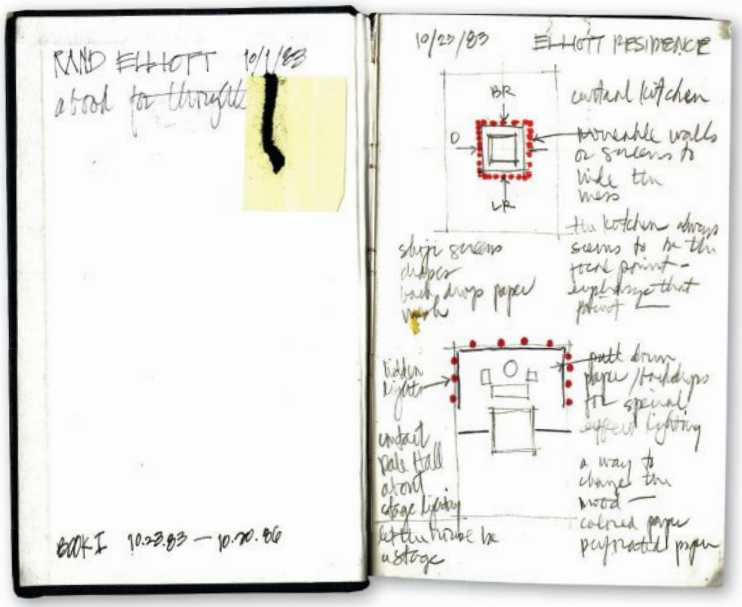
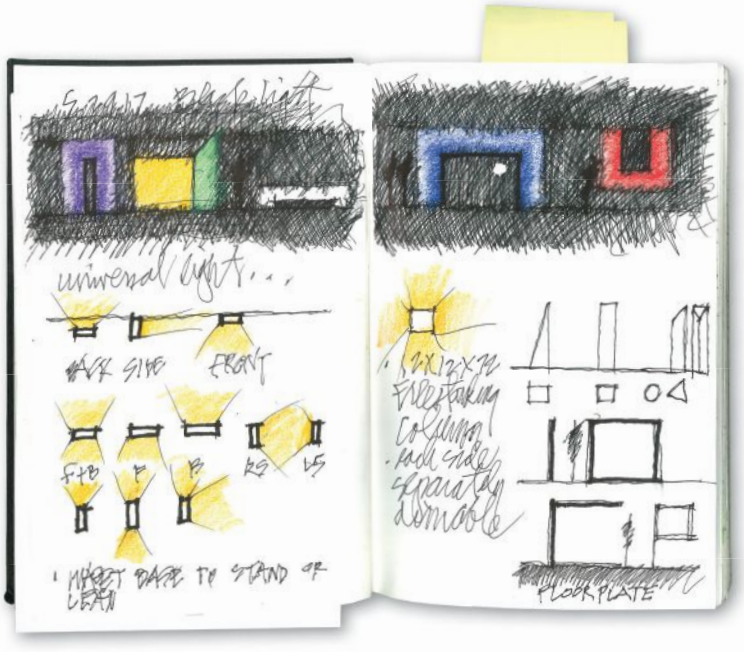
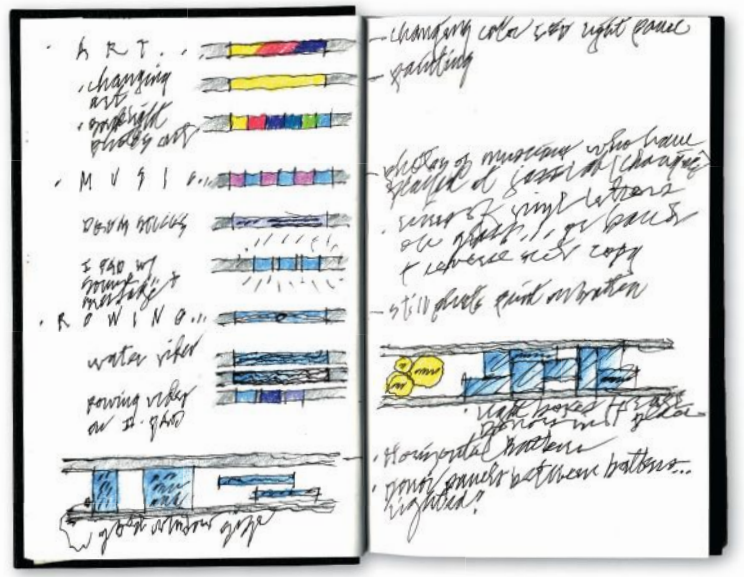
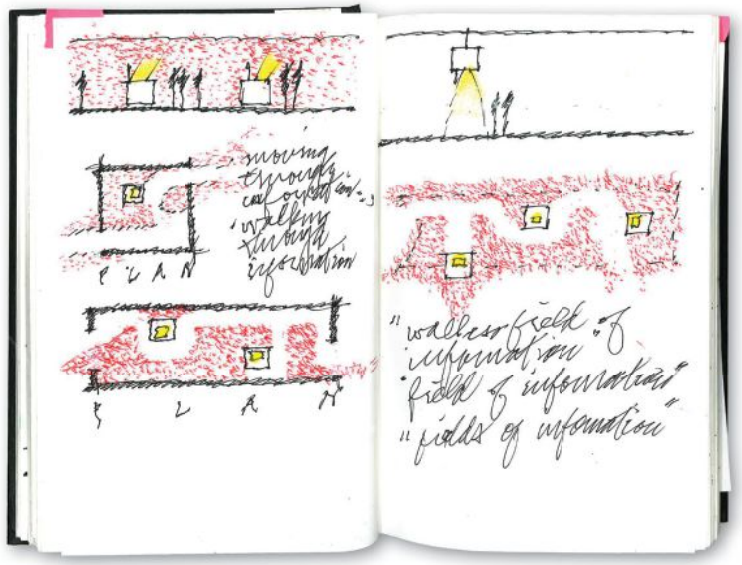


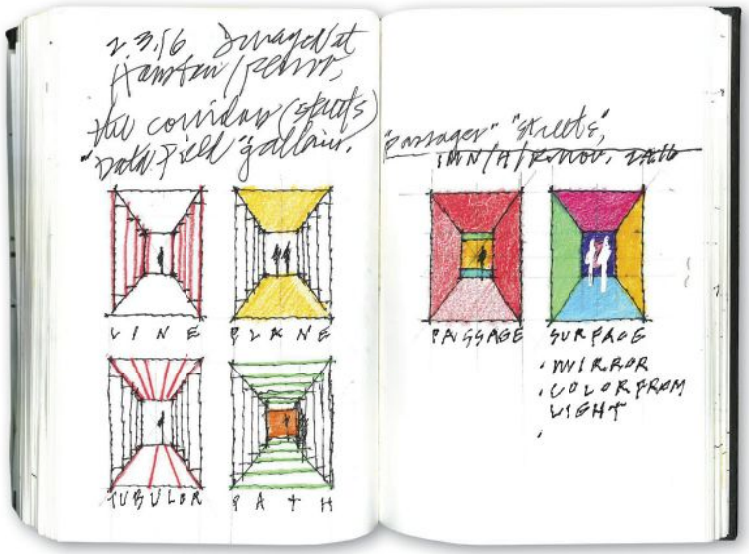


text by Mimi Zeiger | portrait by Ryan McDonald



Oklahoma architect Rand Elliott on color, light, place, and being human.





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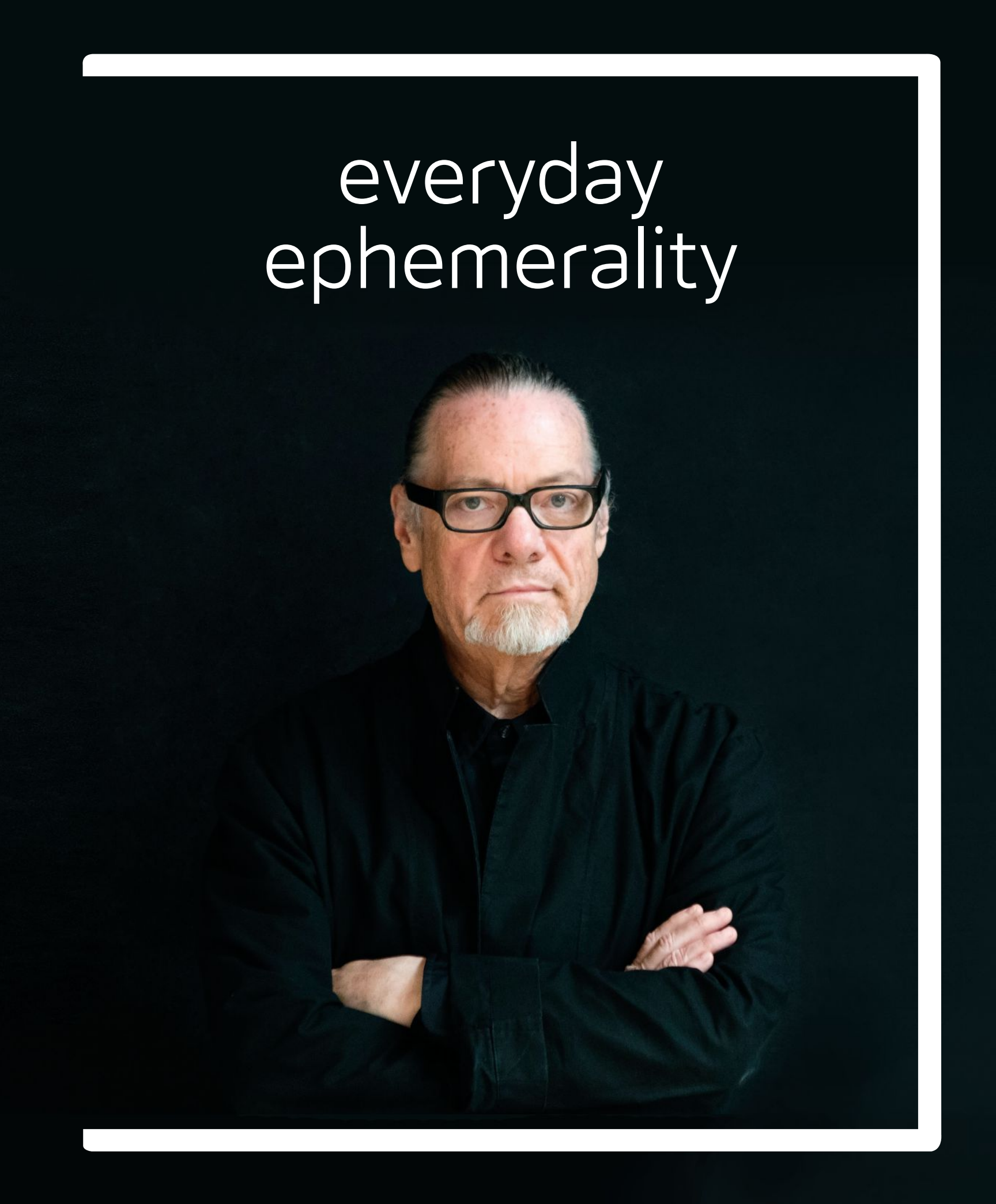

Sketchbooks, 1977 to present (previous spread)
Sketching is an integral part of Rand Elliott's design process. Over the course of his 40-year career, he has produced more than 10,000 sketchbook pages, a visual record of his daily design observations.

Car Park Three, Chesapeake Energy Corporation, Oklahoma City, 2013 (right)
As the company's headquarters in Oklahoma City, has grown, Elliott has played with color in myriad ways: as a wayfinding device, as a spatial organizer, and as a sensory experience. The result is a unique architectural color-blocking vocabulary.

Previous spread: sketchbook images courtesy Elliott + Associates; This page: Scott McDonald © Hedrich Blessing

For

Rand Elliott, every building starts with the light—the quality of the light, its feel, color, and directionality. An Oklahoma City–based architect, he considers light a universal question for his practice that is as vital to his designs as any "big idea." While it would seem obvious that light, both natural and electric, would be a critical part of the museums and residences in his portfolio, what makes Elliott's work remarkable is the care and sensibility he brings to even the most everyday typologies: parking lots, office buildings, gas stations, and more.

"An architect reaches a point of maturity when you can begin to think about the results of lighting, form, and the idea of bringing joy," he explains. "The question of light is so big and infinite in its capabilities that I will never run out of inspiration just chasing the light for the rest of my life."

With some 40 years in practice (he started his firm, Elliott + Associates Architects, at age 27), Elliott approaches his work with the confidence of an artist or dancer. Every day, the muscle memory of his profession—the skills of observation, documentation, and detailing—leads him to his sketchbook, where he jots down concepts, experiences, and research alongside abstract squiggly lines and what he self-deprecatingly calls "ugly drawings." He also uses his sketchbooks to write poetry, or "word paintings." Those texts are his way of trying to describe a building before it happens, to establish an attitude toward structure and program, but also sketch out what is possible and, importantly, to ask "Where's the light coming from?"

Each mark in his sketchbook is an act of practice and ritual. "With my early sketchbooks, I would spend two years on a single one and I would labor over them and be intimidated by them," Elliott says. "But within the last year or so, I finished one in 92 days—210 pages filled to the absolute brim." He's accepting of a wide range of ideas, from the shape of a crack in the sidewalk to the daylight that spills across the rough floorboards of his own 1920s-era house.

Yet decades earlier, Elliott's career could have taken a different turn, one that would have veered away from light and place and into the competitive world of New York City architecture. He tells a story of a time in the early 1980s when his young Oklahoma City practice was hit hard by the economic realities of the oil bust. The downturn sent him to New York to pursue other opportunities, including an interview with Philip Johnson. The famously dapper and bespectacled architect sat across from him in a Ludwig Mies van der Rohe Brno chair and offered him a job. Elliott turned him down. He recalls saying, "Mr. Johnson, you've fulfilled a dream. I can't thank you enough. I have decided to go back to Oklahoma City."

Instead of joining forces with one of the most powerful architects in the country, the young architect decided to root himself in the landscape and the people of Oklahoma. Not long after, he found himself at a Chickasaw tribe pow wow—his wife, Janette, was at the time, writing about the Chickasaw population in Oklahoma. And it was there, in the middle of nowhere, with the dark lit by a bonfire the size of a building and the bodies dancing around him, that he felt truly connected to the spirit of the place.

"There was an appreciation of the spirit of the land, the great starry skies, the wonderful sunsets, the hailstorms, the tornadoes, all of the weather events; and so I decided that I would use those as the beginnings of my inspiration," Elliott says. "I think that the importance and appreciation for light, appreciation of place, begins right under your feet."

Or where you park your car. Elliott's firm has worked for the Chesapeake Energy Corp. for nearly three decades, designing dozens of projects for them. It's the car parks, however, that stand out as a pure expression of Elliott's guiding philosophy. Each one features wayfinding lighting in a rainbow of primary colors with each floor dedicated to a single hue: red, yellow, green, blue, or white.

The success of these projects could be quantified in the awards they've garnered. The nearly 300,000-square-foot Car Park Two took home an AL Light & Architecture Design Award in 2009 for Outstanding Achievement in the Whole Building category, among others, (at the time, the project was referred to as Car Park One; the campus plan has since been updated and buildings renamed) and the 383,250-square-foot Car Park One from 2011 reaped multiple honors from the American Institute of Architects. But perhaps the greatest success is how Elliott's designs defy the stereotype of parking structures as dark and scary places; instead, they are beacons for Chesapeake employees, who in the winter arrive and leave work while it's still dark. Safety and wayfinding are primary issues. His hope is that arriving is a positive and uplifting experience. "[It's] like a friend saying, 'Good morning,'" he jokes. He spins a long, illustrative tale about the importance of place, color, and light. It ends with a killer punch line: "Sir, I drive a yellow car, I park on the yellow level. That's all there is to it."

Technically, every garage follows a similar pattern: Fluorescent T8 3500K lamps, sheathed in colored polyester gels, line the air circulation atrium and stairwells of the poured-in-place concrete structures so that each parking level is bathed in a saturated hue. T8s were chosen for their easy maintenance and the gels, made for the theater industry, are relatively inexpensive. The color temperature was chosen because it is neutral enough to not taint the gel hues to a warm value. Elliott notes that over time LED retrofits may replace the fluorescents for efficiency. "I'm not interested in the fixture itself. I'm interested in hiding the source," he says, stressing that he sees lighting not as decoration, but as part of a holistic concept, an atmosphere.

In speaking with Elliott, it becomes clear that a central question in his work is about the translation of architecture across different physical states. If artists and architects use light to dematerialize how we comprehend

Car Park Two, Chesapeake Energy Corporation, Oklahoma City, 2008 (right)
This four-story parking garage—the recipient of a 2009 AL Light & Architecture Design Award—uses primary colors to denote each level.

Car Park Three, Chesapeake Energy Corporation, Oklahoma City, 2013 (below)
Glass panels are arranged in a color-blocking motif on the parking structure's façade.

Scott McDonald © Hedrich Blessing

ImageNet, Carrollton, Texas, 2015 (This page and facing page, bottom right)
For one of ImageNet's recent offices, the architects used the company's corporate colors—blue and orange—to create distinct spaces, such as the cafe (facing page, bottom right). The main conference room (this page) features a whimsical design element: a lighting installation made from repurposed filing cabinets suspended from the ceiling.

This page and facing page, bottom: Scott McDonald/Gray City Studios; Top right: Robert Shimer © Hedrich Blessing

ImageNet, Dallas, 2004 (left top)
In the reception area for one of ImageNet's first locations, a simple color palette of blue and white provides spatial clarity and reinforces the project's binary code theme, which is further highlighted by a supergraphic projection of "ones" and "zeros" on the side wall.

buildings, Elliott also works in the opposite direction. In a series of projects for ImageNet Consulting, he uses design and light effects to illustrate things we can't necessarily see: technology, electricity, data, and more.

Elliott began working with ImageNet president Tom Russell some 30 years ago. Since then, the company has gone from selling copy machines to being a full information-technology provider for small businesses and large corporations. The role that technology plays in our lives has changed as well: It has become essential, but nearly invisible. In various projects in Texas, Elliott has used saturated color or translucent panels to try to create spaces where ImageNet employees can explain to clients the need for different technological solutions. The challenge is conveying something as abstract as "the cloud" through something as concrete as architecture.

For the 2015 remodel of the company's warehouse and showroom in Carrollton, Texas, Elliott and team decided to "dumpster dive." To represent the company's ethos of environmental responsibility and waste reduction, they created artful partitions made out of the trash of our digital age. One wall is composed entirely of recycled toner cartridges (recycling a single cartridge saves 3.6 pounds of solid waste). In the café, an entire wall is an assemblage of formed foam packing materials salvaged from photocopier packaging, and the whole room is painted a deep orange. In the training room, a suspended ceiling of recycled toner cartridges hang below the side-mounted T8-lamped strip fixtures and aluminum bubble wrap lines the walls, creating both texture and reflection.

But it's the building's lobby and conference room where the architect dares to answer that tricky question about the cloud. Used filing cabinets dangle from the ceiling—chunky blue, silver, white, and orange objects that have lost their value in the new paperless era. Each file cabinet is transformed into a pendant lamp. The design team outfitted each one with an inexpensive LED fixture (a generic lamp socket from Home Depot outfitted with an LED spot), creating little pools of light on the floor. "The whole point is to help Tom's customers understand technology's ones and zeros," Elliott says.

While he cites architects Le Corbusier and Louis Kahn (two masters of sculpting natural light) as major influences on his work, savvy viewers may see in the colored fluorescent tubes references to the artworks of Dan Flavin and Robert Irwin, who also are well know for using gels over T8s in their perceptual installations. That's no coincidence. Elliott has long looked to the members of the Light and Space movement as he explores how illumination can deepen even the most mundane experiences, like the daily chore of parking your car or talking about digital file storage.

"The value of the Light and Space artists is above and beyond the work itself," he says. "James Turrell's light works are … ephemeral. They're taking you to a place that you've never imagined before. I think that's really what architecture should do, it's what art should do: Elevate our lives to a point where there's a realization that we're human." •

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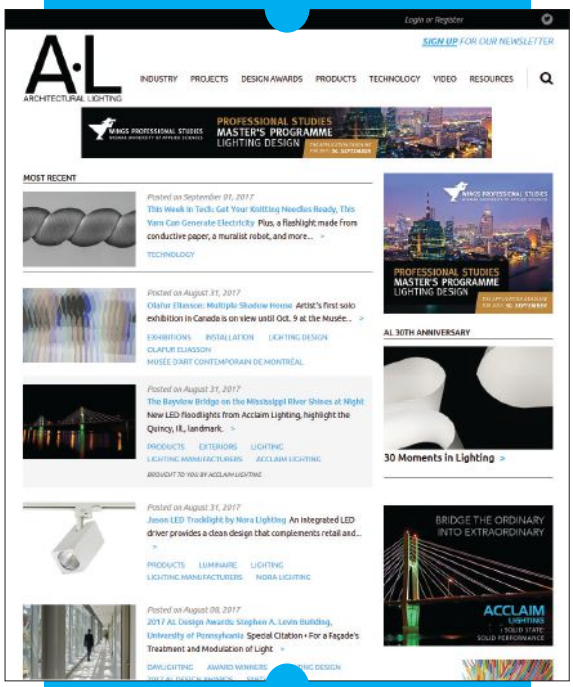

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Dial GmbH	4	dialux.com	
Feelux	25	www.feelux.com	678.668.7005
Hanley Wood's Neal Awards	2	hanleywood.com	
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Hunter Industries	51	holmlighting.com	
Inter-lux	15	inter-lux.com/sattler-avveni	
Ledia Lighting Technology Co., Ltd.	22	www.ledialighting.com	
Lee Filters	50	leefilters.com/architectural	
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Progressive Architecture Awards	39	paawards.com	
Refond Optoelectronics Co, Ltd.	24	www.refond.com	
Shenzhen Green Power Revolution AG	34	WWW.QHGPR.COM	
Signcomplex	35	www.signcomplex.com	
Thailight Semiconductor Lighting Co, Ltd.	18	www.thailight-led.com	
The American Institute of Architects	55	aia.org/join	
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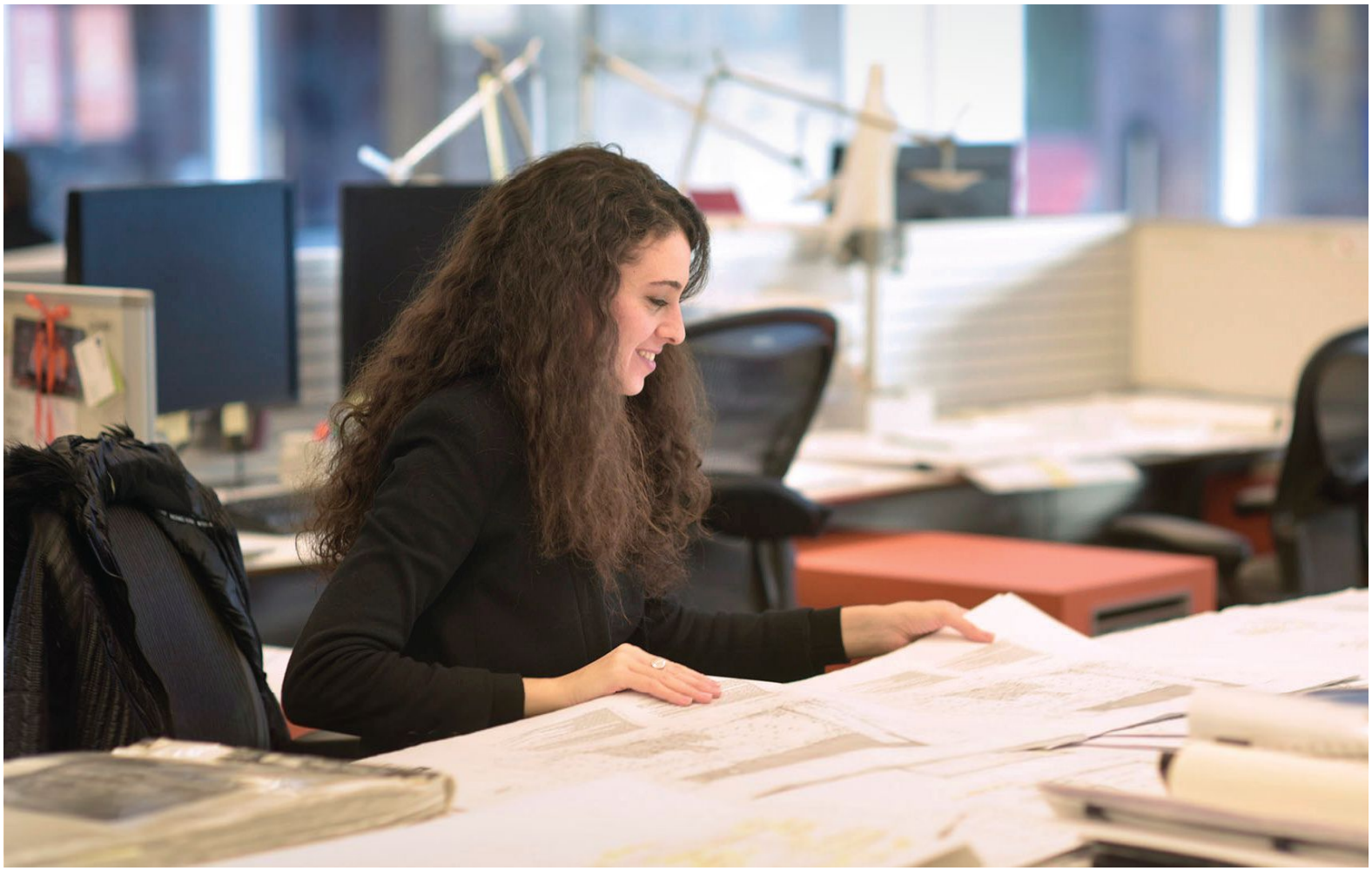

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Cheryl English is part of a select group of lighting professionals who have shaped the industry as we know it. After graduating from the University of Colorado Boulder, she took a job at Lithonia Lighting in Conyers, Ga., (now part of Acuity Brands) and has been with the company for 36 years. During that time, she has worked in all facets of the business—application engineering, software development, and even marketing. In her current role as vice president of government & industry relations, she is recognized as a leading voice on the subject of energy codes as they relate to product development and lighting. English has earned the respect of her peers and those beyond the industry, so it came as no surprise when she was elected 2017–18 president of the Illuminating Engineering Society.

What represents innovation in lighting?
Anticipating people's future needs.

Is there a person or text that's influenced your thinking about light?
Ray Anderson's *Mid-Course Correction: Toward a Sustainable Enterprise: The Interface Model* (Peregrinzilla Press, 1999). Ray was one of the pioneers in focusing on corporate responsibility to people and to the environment.

Where is the lighting industry heading?
It's about progress. However, we can't lose focus on the importance of lighting quality.

Where are energy codes heading?
As technology has changed, policy and regulators have fixated on the energy efficiency of the equipment itself, becoming more stringent on the watts per square foot. It's still a power-based system, but people recognize the desire to move to an energy-based type of system where it's kilowatt-hours per square foot or metering.

What impact will that have on lighting?
There needs to be a step back from product regulations and/or appliance standards. I don't think it means that we have to get rid of them, but we need to put in context how they relate to overall building efficiency—especially now that we're getting into smart systems.

What advice would you give to someone just starting out in lighting?
Learn as much as you can, surround yourself with people you respect, and look forward. •

interview by Elizabeth Donoff
photo by Gregory Miller

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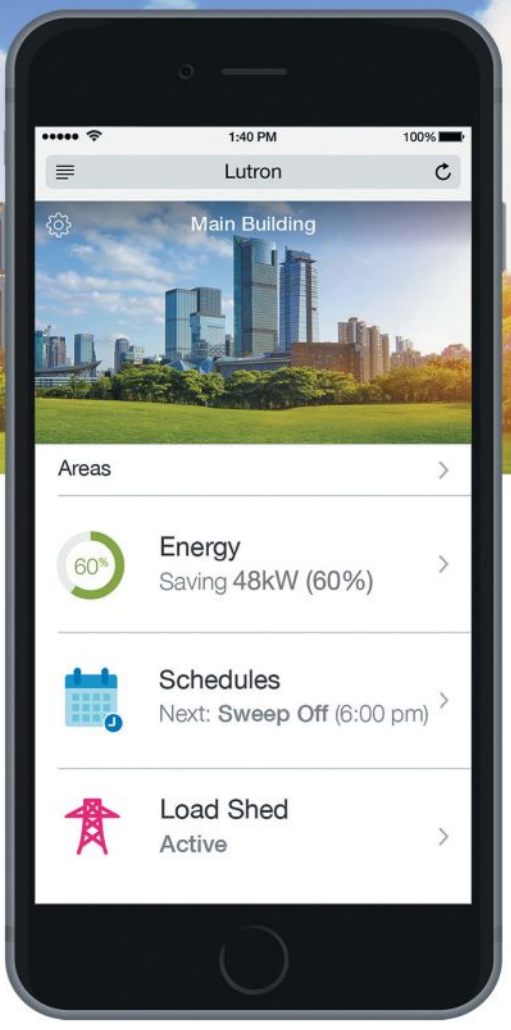

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