The corridor's new tunable lighting, shown at the morning setting (specified as 6500K at 66% output, left), the afternoon setting (specified as 4000K at 66% output, center), and the nighttime setting (specified as 2700K at 20% output, right).

Tuning the Light in a Senior-Care Facility

A pilot project aims to leverage the potential for tunable white LED luminaires to improve the sleep-wake cycle

BY JAMES BRODRICK

In the U.S., the healthcare industry accounts for 9 percent of the energy used in commercial buildings, with lighting systems representing the largest electricity end use in healthcare. Assisted-living inpatient care facilities rank fourth in energy-use intensity, behind food service, hospitals and grocery stores. But the growing body of knowledge of the nonvisual effects of light, including its importance to the sleep-wake cycle, means that healthcare lighting can no longer only address visual needs.

With that in mind, the U.S. Department of Energy's (DOE) Gateway Program participated in a trial installation of tunable-white LED lighting systems at Sacramento's (California) ACC Care Center, which provides rehabilitation and nursing care services in a residential atmosphere to seniors, most of whom are wheelchair-bound and many of whom have dementia.

The project was coordinated by the Sacramento Municipal Utility District (SMUD), which invited DOE to document the performance of the LED lighting systems. The design and installation of the LED systems were completed by SMUD and ACC staff, while the photometric evaluations of the lighting systems were completed by DOE and SMUD staff. ACC staff tracked various behavioral and health measures of the residents.

LIGHT'S NONVISUAL EFFECTS

Light that stimulates human photoreceptors is known to play a role in suppressing the release of melatonin, a hormone that helps control the sleep-wake cycle. Normally, melatonin levels begin to rise late in the day, remain high for most of the night and then decrease in the early morning. Exposure to light, especially short-wavelength light, stimulates the body to suppress melatonin. Therefore, exposure to light in the morning can help support normal sleep-wake cycles, while exposure at night can disrupt this natural cycle. These nonvisual effects of light seem to depend on the spectrum, intensity, duration, timing and temporal pattern of light exposure. Concerns about the nonvisual effects of light are heightened for residents of senior-care facilities and nursing homes, where disturbed sleep patterns are common due to normal aging processes and ailments such as Alzheimer's disease.

This was one of the motivating factors behind the trial installation at the ACC Care Center, where a primary goal was to leverage the emerging tunable-white LED technology to avoid lighting

that suppresses the production of melatonin during the evening and nighttime hours. Solid-state lighting technology provides new opportunities for controlling the intensity, distribution and spectrum of light, with the introduction of a growing number of color-tunable or white-tunable LED luminaires and systems that enable adjustments in spectral power distribution (SPD) and light output that are much easier to implement than with conventional fluorescent lighting.

PROJECT FOCUS

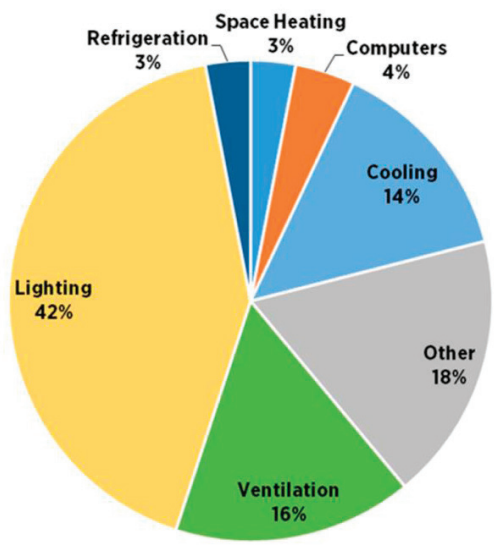
SMUD identified four primary project goals:

- Investigate, evaluate and identify potential lighting products and techniques for ACC's planned remodel and expansion.
- Learn more about how tunable-white lighting impacts the sleep patterns, nighttime safety and other behaviors of residents, including those with Alzheimer's or related dementias.
- Better equip the caretakers and nursing staff to provide excellent care by improving the quality of lighting (e.g., reduced glare, better controllability) relative to the incumbent lighting.
- Train ACC staff on lighting needs, considerations and challenges.

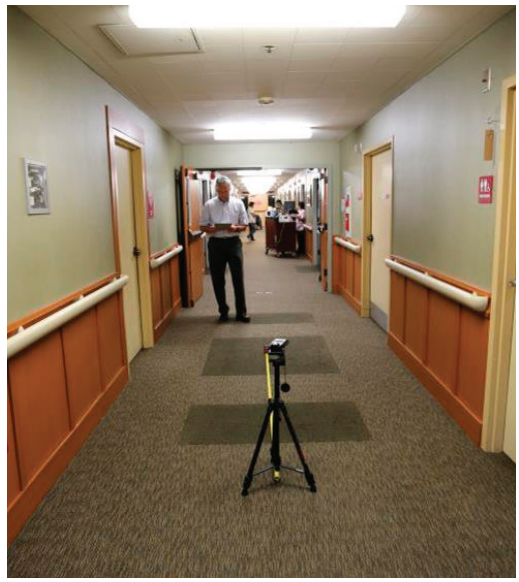
DOE's role consisted of documenting the incumbent luminaires and controls, conducting pre- and post-installation field measurements of illuminance and color quality, advising SMUD on equipment to specify, and analyzing energy consumption of the new system in comparison to the old one. The lighting solutions were chosen by SMUD, working with the ACC staff and the installing contractor, and following guidelines published by Mariana Figueiro at the Lighting Research Center at Rensselaer Polytechnic Institute, which include providing no more than 100 lux at the cornea from a circadian-ineffective white-light source in the evening hours, and providing low-level nightlights to allow safe navigation through the space without disrupting sleep.

The ACC Care Center has five primary corridors that extend from a hexagonal hub at the central nursing station. One of these corridors, named Cherry Lane, was used for the trial installation, along with a double resident room and a single resident room along that corridor. Other spaces included in the trial were the nurse station, a nearby common room (called the family room) and the administrator's office.

Cherry Lane Corridor. While the incumbent fluorescent system provided adequate task lighting for the staff, it didn't provide the needed flexibility of spectrum and intensity. The corridors also provided an opportunity to reduce lighting-energy use, since the incumbent system used fluorescent luminaires that operated at full power for more than 13 hours each day, with about half of the luminaires remaining on at full power at all times. At the time of specification, there were very few suitable tunable-spectrum luminaires available. To replace the incumbent luminaires one-for-one in the corridors, SMUD selected the 32-W Beetle luminaire from Samjin, which can continuously vary the CCT within the range of 2700K to 6500K, with full-range dimming possible at each CCT and a CRI of 83. The CCT and light output from the nine corridor luminaires are controlled by a Samjin proprietary controller.



Average electricity end uses in healthcare facilities as a percentage of total electricity use.



The incumbent fluorescent lighting system in the ACC Care Center corridor.

The corridor lighting system was designed to change the CCT and light output levels automatically through a programmed script that could be overridden by the staff and that called for the luminaires to be tuned to 2700K and dimmed through the evening and night hours to minimize melatonin suppression. The short-wavelength content and intensity of light was increased during the morning and daytime hours to support melatonin suppression, as follows:

- 7 a.m.–2 p.m.: 6500K @ 66 percent output
- 2 p.m.–6 p.m.: 4000K @ 66 percent output
- 6 p.m.–7 a.m.: 2700K @ 20 percent output

Nurse Station. To replace the six incumbent fluorescent luminaires at the nurse station, a 24-W version of the Samjin Beetle luminaire was chosen. A wall-mounted controller of similar design to the corridor controller was mounted within the nurse station, but the CCT and output were manually controlled rather than scripted. The nurses were free to vary the CCT and light output according to their preferences, and they received training in the possible effects of the different CCT and intensity settings on melatonin suppression.

Family Room and Administrator's Office. The six luminaires installed in the family room were the same as those in the corridors but operated only by manual control of the CCT and light output, in part to accommodate a physician who often saw patients there. The same luminaire type was also installed in the administrator's office, replacing the three incumbent luminaires on a one-for-one basis, and also operated only by manual control of the CCT and light output. The ACC Care Center administrator uses this system to educate the staff, as well as current and potential residents and their families, about the tunable LED lighting used at ACC.

Resident Rooms and Bathrooms. *Room ambient lighting*. Ambient lighting in each resident room was provided by a CCT-tunable cove lighting system (Philips Color Kinetics iW Cove MX Powercore) installed near the top of the wall at the beds and on the side walls. A total of 44 ft of this cove fixture was installed in the two rooms, providing indirect lighting onto the ceiling. The light was then reflected throughout the room, providing overall ambient lighting. The cove lighting provides CCT tuning from 2700K-6500K, with a 2400K night-light option, and was programmed as follows:

- 7 a.m.–2 p.m.: 6000K
- 2 p.m.–6 p.m.: 4100K
- 6 p.m.–8 p.m.: 2700K
- Night-light option: 2400K

This script ran automatically but had a manual override, allowing the resident or a caregiver to change the CCT for any reason. After an override, the cove system returned to its programmed script at the next scheduled time change.

Room task lighting. For visual tasks, the 4-ft long Chrysalite LED patient room wall light (Acuity) was wall-mounted at the head of the bed, in the same position as the prior fluorescent headwall luminaire. The luminaire was specified with two rows of LEDs in the uplight chamber and two rows in the downlight chamber, for a total rated input power of 126 watts. CCT-tunable luminaires were not available in this luminaire

type at the time of the project, so a fixed CCT of 3500K was specified. The downlight portion of each of these luminaires was controlled by the resident through a low-voltage bedside "pillow" switch, and the uplight portion was controlled by a simple on-off switch on the wall near the entry door to the room. In the double room, the uplight portion for both luminaires was controlled by the wall switch, while each bed had its own local controller to separately switch the respective downlight portion. For the task-lighting needs of nurses or other caregivers at the bed, the uplight chamber of this luminaire is hinged and can be raised to a position that directs the light along the length of the bed, greatly increasing the illuminance delivered. In addition, an optional 3-W LED chart light was included at one end of each luminaire, with a separate switch located directly on the luminaire, so that a nurse or family member could read a medical chart without disturbing the resident's sleep.

Bathroom lighting. For the lighting near the sink and mirror in each bathroom, Kenall's Medmaster Vanity Mirror (VL23 Series) was installed. This 30-in. by 28-in. unit is wall-mounted, with a full-length LED strip integrated into each side of the mirror surface. The LEDs are rated for 3000K CCT and 90 CRI, and are fully dimmable with a 0-10-V controller. For general lighting in both bathrooms, the incumbent ceiling-mounted globe luminaire was replaced by an 8-in. by 26-in. by 4-in. Kenall Medmaster Auracyl Sconce (MAS Series) with a specified CCT of 3000K.

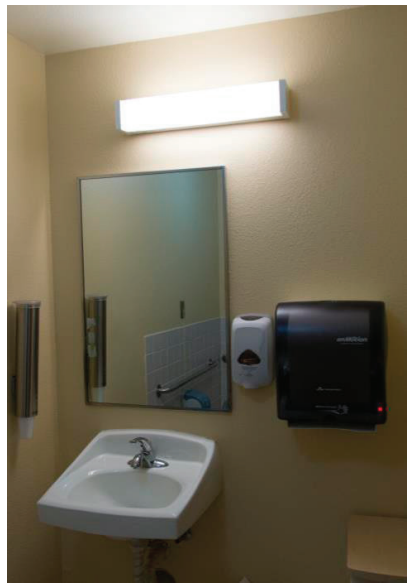
Night lighting. To enhance nighttime safety, amber LED rope lights were installed under the beds, and wall-recessed, amber LED night-lights (ConTech Lighting STPL Step Light Accent Series) were installed 18 in. above the floor in the resident rooms. All of these were controlled by motion sensors to be activated by a resident getting out of bed or a nurse entering the room. The main purpose of these lights was to provide enough illumination for the residents to safely navigate to and from the bathroom at night, without having to use overhead lighting. A secondary purpose was to provide low-level navigation lighting for nurses who entered the room at night, without the need to turn on additional lighting. The amber color was selected because it avoids wavelengths that can stimulate the body to suppress melatonin. Inside the bathroom, amber LED lighting was integrated into new handrails (Efficient-Tec International, MYRIS Stainless Steel System) and controlled by motion sensors, providing additional low-level lighting to facilitate safe navigation while mitigating melatonin suppression.

FINDINGS

Illuminance. For the Cherry Lane corridor, while the fluorescent system provided more than enough light for daytime or nighttime use, the ability to adjust the output of the LED system allowed it to more closely match the IES-recommended levels, avoiding the wasted energy associated with over-lighting the space.

For the nurse station, both the LED and incumbent systems produced lower illuminance than the IES-recommended value, but this was not considered a concern because a) the output of the LED system (measured at the 66 percent output setting) could be increased if desired, b) there is often abundant daylight in this space and c) many of the visual tasks are computer-based rather than paper-based.

For the resident rooms, the LED systems greatly increased the illuminances relative to the fluorescent systems, which had produced horizontal illuminances much lower than the recommended values at the center of the beds, and the levels decreased farther toward the foot of the beds. This finding was consistent with anecdotal reports from ACC staff, indicating difficulty in examining residents' feet and legs under the fluorescent lighting.



Left: Incumbent bathroom lighting.

Right: A mirror with integrated LED lighting was installed above the bathroom sink, and a surface-mounted LED luminaire with decorative lens was installed above the toilet area. The amber LED night lighting that was integrated into the railings is also shown.

The LED systems exceed IES recommendations, and the illuminances for examination would be even greater with the LED system when the top section of the luminaire is placed into the examination position. While the fluorescent and LED systems all satisfy recommended levels for reading in a patient bed, higher values may be appropriate, given the advanced ages of the ACC residents; and the LED systems provide the ability to achieve higher levels if needed, along with the flexibility to reduce the level (and related energy use) when desired.

The fluorescent system in the bathroom of the private room met the IES recommendation for average horizontal illuminance, but not for the vanity area. The fluorescent system in the double-room bathroom areas failed to meet any of the IES-recommended illuminance levels. The LED systems exceeded IES recommendations in all areas.

Color properties. The actual CCTs when measured at several control settings were higher than the planned settings by about 200K to 300K. This minor discrepancy is not considered important and could be adjusted if desired so that the actual CCT more closely matched the specified value. However, it does reveal one of the difficulties in commissioning tunable LED luminaires; namely, that the person doing the commissioning usually is establishing the settings based on control settings internal to the system, without measuring the output of the luminaires. Instruments to measure spectral data are not commonly used by commissioning agents, but they are necessary for verifying that the specified settings are being achieved in the applications. Color consistency for the tunable LED luminaires used in the corridors, nurse station, family room and administrator's office was very good between luminaires and very good over the dimming range.

Equivalent melanopic illuminance. Melanopic illuminance values were calculated based on the SPDs of the sources, and indicate that the morning setting of the LED corridor system may be more likely to suppress melatonin than the incumbent fluorescent system, while the night setting of the LED corridor system may be less likely to cause melatonin suppression than the incumbent fluorescent system. However, melatonin suppression is based on a combination of variables, including spectrum, intensity, duration and prior exposure to light, and the project team made no attempt to measure the actual biological effects of lighting on the ACC Care Center resi-

dents. Consequently, the effects of the different levels of melanopic illuminance are not known, but the LED system does change the melanopic illuminance as appropriate for different times of day, and in that sense the LED system is an improvement compared to the fluorescent system.

Health-related outcomes. Although DOE was not directly involved in measuring any health-related outcomes, ACC staff documented health-related benefits that may have been attributable, at least in part, to the lighting changes. For the three months following the LED trial installation, target behaviors such as yelling, agitation and crying were reduced by an average of 41 percent for the three residents in the study, relative to the three months immediately preceding the installation. Nursing staff noted that all three residents had been consistently sleeping through the night ever since the installation, and that one resident now slept through the night in his bed, whereas he had previously refused to sleep there and instead had slept in his wheelchair.

ACC staff also noted that psychotropic and sleep medication use had been significantly reduced for one of the residents, and reported that in the Cherry Lane corridor, five falls had been recorded during the three months prior to the LED installation, while three falls were recorded during the three months following the installation, and no additional falls were recorded during either the fourth or fifth month following the installation. What's more, it's reported that residents whose rooms are located in other corridors are now spending time "hanging out" in Cherry Lane, either wheeling themselves to that area or asking a staff member to take them.

Energy. Based on the assumed operating characteristics, the incumbent system in the Cherry Lane corridor had an estimated annual energy use of 3,641 kWh. The LED luminaires reduced the input power of each luminaire from 58 to 32 watts, with a script that specified that they operate at 66 percent during the morning and afternoon, and at 20 percent during the evening and night. The resulting annual energy use is estimated to be 1,182 kWh, a 68 percent reduction relative to the incumbent system.

Although this was just a pilot study with a very small number of rooms and residents involved, the results made a significant impression on the staff and managers of the ACC Care Center, which is incorporating many of the lighting solutions and strategies implemented as best practices in terms of fall risk, sleep enhancement and non-pharmacological approaches for behaviors related to dementia. ☐

Lessons Learned

- Contractors are not yet familiar with tunable systems and controls.
- Controls must be simple.
- Commissioning of tunable-white LED systems requires extra care and proper instruments.
- Finding the proper balance of automatic versus manual tuning of the spectrum and intensity of the lighting is challenging.
- Wall-mounted lighting can be difficult to install in a retrofit project.
- Night-lights installed near the floor may have limited effectiveness if located where other objects can be placed in front of them.
- Implementing new lighting solutions in senior-care facilities requires both initial and ongoing education for residents and caregivers.

THE AUTHOR

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