U.S. DEPARTMENT OF
ENERGY

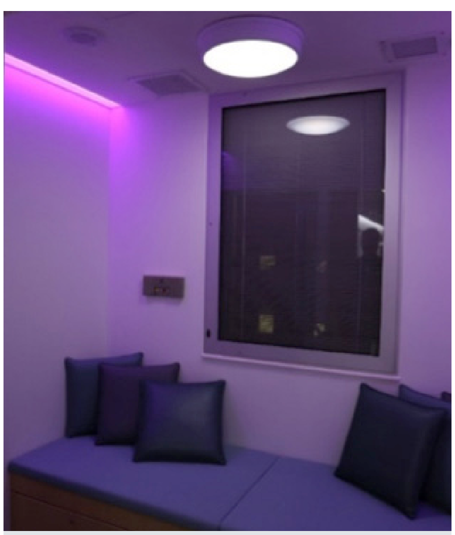
Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

SSL DEMONSTRATION

Evaluating Tunable LED Lighting in the Swedish Medical Behavioral Health Unit

A hospital-unit renovation provided a chance to better understand how LED systems are delivering value to end users, and how those systems can be improved to deliver better quality and efficiency.

The new Swedish Medical Behavioral Health Unit (BHU) in Seattle serves adult patients who are struggling with mental-health conditions. Part of the region's largest nonprofit healthcare provider, it houses 22 beds in 14,911 square feet and required the renovation of two floors in a wing of an existing hospital. Since the new space was a renovation of existing infrastructure, the design sought to compensate for the differences between the old environment—which featured a dedicated outdoor space as well as a large skylight in the common space—and the new, by leveraging biophilic design tenets. The new BHU incorporates color-tunable luminaires in common areas, and the lighting system uses advanced controls for dimming and color tuning, with the goal of providing a better environment for staff and patients.



The serenity room, which provides a quiet space for patients to spend time. They can adjust the SPD of the wall-wash luminaire to suit their mood.

View of dining/activity area from nurse station. The SPD and intensity changed throughout the day. The photo at left shows the initial night scene, and the one at right shows the afternoon scene. The downlights were originally programmed to stay on all night, as shown, but were later reprogrammed by the nursing staff to turn off at night.

Controlling the Intensity and Spectrum of Light

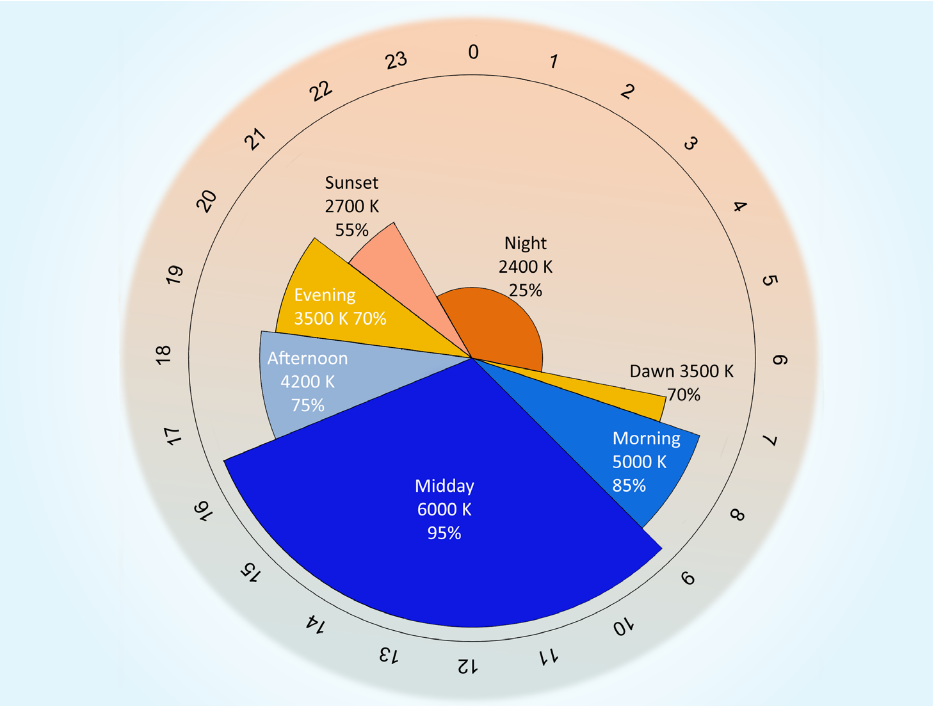
ZGF Architects, which headed the renovation, invited the U.S. Department of Energy's (DOE) Solid-State Lighting (SSL) program to document the performance of the LED lighting systems as part of a GATEWAY evaluation—the first DOE documentation of a color-tunable system specified and installed by building-industry professionals as part of a large-scale renovation project. SSL technology provides new opportunities for controlling the intensity, distribution, and spectrum of light. Tunable LED systems enable adjustments in spectral power distribution (SPD) and light output that are easier to implement than with conventional fluorescent lighting systems. The availability of these new systems, combined with a growing understanding of the nonvisual effects of light, has generated awareness and excitement.

The lighting system for the new BHU's corridors and dining/activity space was designed to operate according to a daily schedule developed by the ZGF team, including a change in the SPD of the downlights throughout the day. The CCT ranged from 2400 K at night to 6000 K midday, aligning with daily color variation of the sky. The intensity level also varied, with lower levels of light through the evening and night, and higher levels in the morning and early afternoon.

Lessons Learned

Following are key takeaways from the project, which provided an ideal opportunity to document possible benefits as well as concerns in the design, installation, and operation of tunable LED lighting systems intended to achieve biophilic and circadian goals in a specialized healthcare application:

- **Tunable LED systems can provide significant energy savings.** For this application, where biophilic and circadian design goals required a tunable lighting system with the ability to vary both spectrum and intensity, the reduced intensity levels



Initial daily schedule for the SPD and intensity-level control setting. The figure shows the initial schedule for the changes in SPD (indicated by CCT) and intensity-level control setting throughout the day. The intensity level is expressed as a percentage of full output. The downlights and coves in the dining/activity area and the coves in the corridors initially changed according to this schedule.

specified for long periods from the downlights enabled estimated annual energy savings of 41% relative to a non-tunable downlight system with the same number of luminaires.

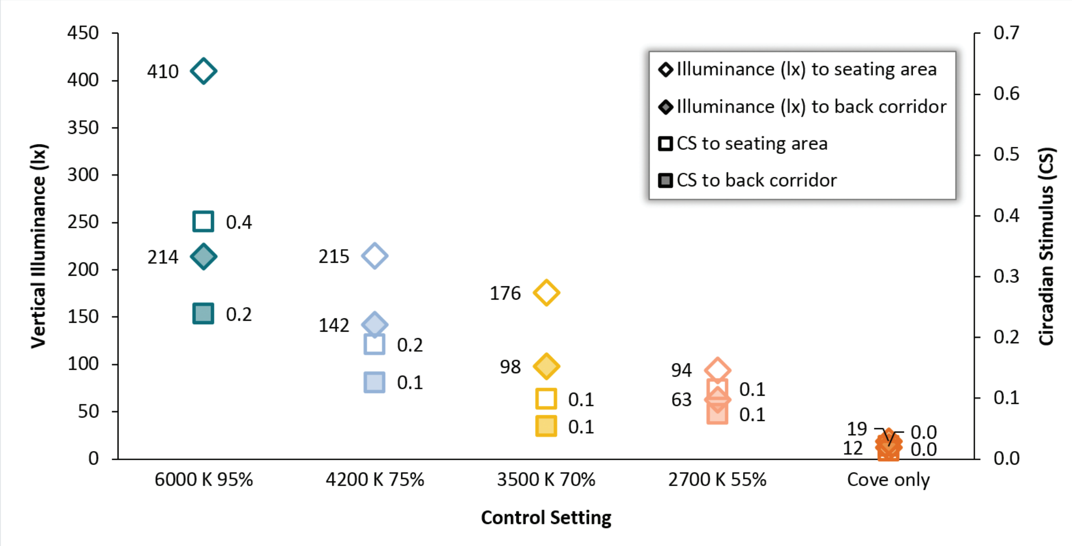
- **Achieving design goals related to circadian and other biological and behavioral effects of lighting sometimes requires higher illuminances than those recommended for visual tasks, and consequently may increase energy use during the hours when those high illuminances are needed.** In this project, 74% of the estimated annual energy use of the tunable lighting system occurred during the six hours each day when the control settings were based on achieving the desired circadian stimulus. Relative to a non-tunable system designed to only meet illuminance criteria for the visual tasks, this tunable system increased estimated annual energy usage by 19%. While the energy reductions that occur during the hours when the lighting is dimmed to lower output levels may offset the increases during these high-output hours, it can be difficult to justify the increased cost and complexity of tunable systems while the evidence of the non-energy benefits is still emerging and not yet fully established.

- **Allowing the building occupant some degree of manual control can increase energy savings**. The original specification for the downlight system that was initially programmed into the automatic controls kept the downlights on at a dimmed level at night. But the nursing staff decided to manually turn off the downlights at night after observing that adequate lighting was provided by the cove system. This reduced energy use and was then programmed into the automatic controls.

- **Commissioning of tunable systems remains a challenge, given current field practices and capabilities**. Field commissioning today is often completed by establishing scene settings based on control settings and/or visual assessment, rather than by confirmation with measured data. For this project, the initial commissioning didn't provide the desired range of chromaticities or illuminances, which were only achieved through a careful second phase of commissioning, where chromaticity and illuminance were measured and adjusted for each scene, and then a third phase that was necessary to achieve the desired smooth transitions between the scenes. Without these additional commissioning phases, the energy savings realized would have been much less, and the desired biophilic and circadian goals would not have been achieved.

- **Developing a detailed specification of the desired control sequences and outcomes early in the design process can help identify potential shortcomings with the specified control solution, and can make the commissioning process more efficient**. Although the initial control specification for this project was more detailed than usual, the resulting iterations in commissioning, measurement, calculation, and system adjustments revealed the need for even greater specificity in the initial specification. Defining these details as early as possible can highlight the expected level of interoperability between different manufacturers' products, the need for early identification of eye positions and viewing directions for determining circadian effects, and the increased level of measurement and care required during commissioning.

- **Estimating and measuring the SPD at expected eye locations is important for implementing circadian design goals, but there's currently no easy way to estimate the effects at possible eye positions in an architectural space**. Common practice for



Scene illuminance and circadian stimulus. The SPDs were measured at seated eye height for one of the seating locations at a table in the dining/activity area in two opposing directions. Measurements were made for each of the five lighting scenes evaluated during the second commissioning.

estimating circadian effects of lighting during design includes calculating the illuminance at the eye and then using the rated SPD of the luminaire to calculate related circadian metrics. But this project demonstrated that the actual SPDs at eye locations vary based on position, viewing direction, architectural surfaces, furnishing, and location of luminaires. Since any biological effects depend on the SPD at the eye, new techniques are needed to predict the SPDs at different eye locations during design and then to measure the SPDs during commissioning. Additionally, the design of spaces where circadian response is important should be carefully considered, and mockups may be necessary.

- **Scientific evidence continues to emerge, relating the medical effects of tunable lighting to proposed lighting metrics, but none of the metrics have been formally adopted for use in lighting practice**. While there's a growing body of literature on the benefits of biophilic design and the circadian effects of light, and several new lighting metrics have been developed and used in some studies, evidence on the medical effects of these techniques and metrics is very limited and hasn't yet been widely accepted within the medical community. Furthermore, the emerging metrics are still being revised and defined, and none have been adopted by standards-setting organizations.
- **Future projects would greatly benefit from collaborative design and research teams with expertise in biophilic design and in lighting and medical research**. To facilitate the growing demand for evidence-based design practices that include the possible biophilic and circadian effects of tunable lighting, assembling design and research teams with the appropriate design, lighting, and medical expertise is critical. ■

DOE/EE-1640 · August 2017