ACC Care Center

Circadian Lighting Project

Sacramento Municipal Utility District

SMUD

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1. Executive Summary

1.1 Introduction

Since 2007, SMUD's Building Leadership Talent program has brought together diverse groups of SMUD employees to help them develop the skills necessary to take on leadership roles at SMUD and in their own communities. The 12-month program consists of classroom instruction, hands-on training and the creation and implementation of a community-benefit project. The 2014-2015 BLT Team chose to support local Alzheimer's organizations and decided to implement two major projects. The first project was to provide funding and assistance to construct a memory garden at the C.L.U.B. (Caring, Laughing, Understanding & Belonging) an organization that provides relief for caregivers of Alzheimer's patients. The second project was to work with SMUD's Energy Research & Development Department to test circadian lighting at the ACC Care Center.

SMUD's Energy Research & Development (ER&D) Department works with customers, manufacturers and researchers to evaluate new or underutilized technologies in real world environments. Completed projects include multiple lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems, daylighting and a variety of other technologies.

One of the current hot lighting research topics is exploring the connection between lighting and health. Studies conducted by the Lighting Research Center (LRC) of the Rensselaer Polytechnic Institute (Troy, New York) and others indicate that different spectrums (i.e. wavelengths) of light can affect production of certain chemicals that affect our sleep and wake cycles. Until recently however, the technologies available to implement these strategies beyond the laboratory setting were very cumbersome and expensive (i.e. multiple banks of fluorescent lamps). The arrival of state-of-the-art LED lighting and controls has made field research a viable option.

1.2 Project Objectives

The ACC Care Center intends to complete a major remodel and expansion project within the next few years and was very excited to work with SMUD to test various lighting and control strategies. The main purpose of this project was to identify which options (if any) ACC should consider incorporating into their upcoming project. Specifically, ACC was interested in lighting strategies that could:

- Improve safety by reducing the number of falls
- Improve the sleeping habits of their residents
- Help ACC Staff provide even better care

1.3 Project Results

Although this project was relatively small (two patient rooms and four common areas), it was an overwhelming success. During the project the following observations were made:

- Dramatic reduction in the number of falls:

  "The quarter before the lights were installed we had five falls on Cherry Lane. The quarter after installation the number reduced to three. But, more importantly, there were no falls on Cherry Lane[1] within the last two months."

  - ACC Administrator

- 41% reduction in the following behaviors: yelling, agitation and crying

- 71% reduction in behaviors for one particular dementia resident. This enabled ACC to reduce the use of psychotropic and sleep medications:

  "Medications are documented on a Medication Administration Record or MAR every time they are administered. Any psychotropic medication includes a target behavior that we are looking to address with the medication. These behaviors are monitored and documented per shift in the health record. Falls are documented in the health record and on our internal Risk Reports. We aggregate data on both psychotropic medications as well as falls for our Quality Assurance Performance Improvement or QAPI meeting monthly. The specific medications that we were able to reduce were Risperdal and Remeron."

  - ACC Administrator

- Improved sleep patterns
  - All three residents are now sleeping through the night
  - All are sleeping in their beds. Previously one of the residents refused to sleep in his bed and would only sleep in his wheelchair.

- ACC has identified several lighting measures to include in their upcoming project:

  "ACC will be incorporating many of the lighting solutions piloted in this project as best practices in terms of fall risk, sleep enhancement and non-pharmacological approaches for behaviors related to dementia."

  - ACC Administrator

[1] Cherry Lane is the name of the wing that was included in this study

1.4 Acknowledgements

While many people contributed to the success of this project, we particularly appreciate the cooperation and help from the following individuals:

- Melanie Segar (ACC)
- Jeff Clay (ACC)
- Tamara Kario (ACC)
- All of the nursing staff who work to improve the quality of life for their residents at the ACC Care Center

- Dr. Robert Davis (Pacific Northwest National Laboratory)
- Dr. Andrea Wilkerson (Pacific Northwest National Laboratory)

- Connie Samla (SMUD)
- Jonathan Knox (SMUD)

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2. Project Description

2.1 Background

ACC Care Center

The ACC Care Center has been serving seniors in the Sacramento area since 1986 and is well known within the community for excellence. The Center provides rehabilitation and nursing services in an atmosphere that feels like home. The average age of the current residents is 87 years old and most of them are wheelchair bound. Many of the residents have been diagnosed with some form of dementia.

The Center currently has 99 beds and is planning an expansion within the next few years. ACC was excited to work with SMUD to explore new lighting concepts for possible inclusion into the planned expansion project.

Lighting Challenges for Senior Care Environments

Providing proper lighting for senior care environments can be very challenging. As we grow older, we need a lot more light, yet are much more sensitive to glare (Figure 1). It also takes much longer for our eyes to adapt from bright to dark environments. In fact, it may take over 30 minutes for a healthy 80 year old person to fully adapt to a darkened room[2]. Consequently, many falls occur while returning to bed after using restrooms at night. And, if all of these factors were not enough of a challenge, seniors often suffer from eye diseases such as cataracts, glaucoma, age-related macular degeneration and diabetic retinopathy.

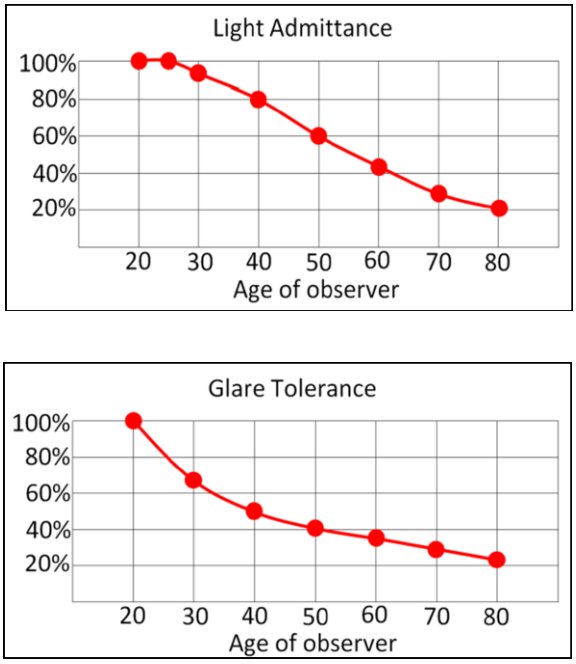


Figure 1: Providing proper lighting for seniors can be very challenging. Seniors need much more light (top graph) yet are much more sensitive to glare (bottom graph).

It's no secret that getting enough high-quality sleep is important to our health. Unfortunately, senior care residents are sometimes disrupted by nurses and caretakers who need enough light to perform wellness checks, administer medication and perform other procedures at night. Furthermore, seniors often have very limited exposure to daylight which may lead to circadian rhythm and sleep cycle disruptions.

[2] ANSI/IESNA RP-28-07

Health Effects of Lighting

It's been known for many years that our eyes contain four types of photoreceptors—rods and three different types of cones. However, around 2002, scientists discovered a fifth type of photoreceptor: intrinsically photosensitive retinal ganglion cells (ipRGCs). These cells transmit light information to the circadian system. People have certain biological cycles (e.g. circadian rhythms) that are linked to natural daylight and nighttime cycles. Studies conducted by the Lighting Research Center (LRC) of the Rensselaer Polytechnic Institute (Troy, New York) and others indicate that different spectrums (i.e. wavelengths) of light can affect production of certain chemicals such as melatonin[3]. Since melatonin causes us to feel drowsy, it is important to produce adequate levels for maintaining healthy sleep cycles. Although many factors can affect sleep and much more research needs to be done to fully understand how lighting affects our health, at least four important factors have been identified:

- Spectral content of the light source
- Intensity level of the light source
- Duration of exposure
- Timing of the exposure

Although the actual science is rather complicated and filled with important details, the Lighting Research Center currently recommends using lighting with more blue content at higher levels during waking hours and warmer sources at lower illumination levels during the evening hours. Until recently however, the technologies available to implement these strategies beyond the laboratory setting were very cumbersome and expensive (i.e. multiple banks of fluorescent lamps).

2.2 Project Objectives

Unlike many other SMUD projects, the main focus of this project was not energy efficiency. This project was part of an overall effort by SMUD's Building Leadership Talent Team to provide support for members of our community suffering from Alzheimer's disease and dementia. Specific goals for the ACC project included:

- Learn more about how tunable-white lighting impacts the irritability and sleep patterns for residents with Alzheimer's or related dementias.
- Improve the quality of sleep and nighttime safety for residents living in the quarters selected for the study.
- Improve the quality of lighting (e.g. reduce glare, improve controllability) in the resident quarters, the adjacent hallway, the nurses' station and the family visitation room.

[3] For more information, please visit the Lighting Research Center website: http://www.lrc.rpi.edu/

- Equip the caretakers and nursing staff to provide even better care during nighttime hours.

- Investigate, evaluate and identify potential lighting products and techniques for ACC's planned remodel and expansion.

- Provide training for ACC staff members regarding lighting needs, considerations and challenges for seniors.

2.3 Project Scope

The scope of this project included upgrading the lighting systems in two resident rooms, two bathrooms, the adjoining hallway, the nurse's station, a family visitation room and the Administrator's office. One of the resident quarters houses two people while the other room has only one.

Resident Rooms

In order to meet the project objectives, the team chose to install and test several different types of lighting systems:

- Dimmable, direct-indirect LED headboard fixtures were mounted on the wall over each bed (Figure 2). These fixtures include a small LED spotlight to enable caretakers to read prescription labels and charts at night without turning on the main lights. The top section of the fixture also flips down to provide an examination light which covers the full length of the bed.

- Tunable-white LED cove lights were installed within plastic gutters on the walls throughout the room (Figure 3). The gutters were used to protect the residents from glare. These lights were programmed to automatically change Kelvin temperatures per Lighting Research Center's recommendations, but could be overridden by ACC Staff members.

Figure 2: Direct-indirect, dimmable LED headboard fixtures provided light over the beds. These fixtures include a small LED spotlight to enable caretakers to read prescription labels and charts at night without turning on the main lights.

The bedroom fixtures were programmed as follows:

7 am – 2 pm: 6000K
2 pm – 6 pm: 4100K
6 pm – 8 pm: 2700K

The team also added a manually activated "nightlight mode" which provided light at 2400K and minimal output levels.

Figure 3: Tunable-white LED cove lights were installed in plastic gutters to shield residents from potential glare.

- To enhance nighttime safety, the team installed amber LED rope lights under the beds, and wall-mounted, amber LED nightlights at about 18 inches above the floor (Figure 4). All of these lights were controlled by motion sensors. 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 the overhead lighting.

Figure 4: Amber LED rope lights and wall-mounted, amber LED nightlights.

Restrooms

The original fluorescent lighting in the restrooms provided adequate light but also produced a lot of glare. Upgrades included:

- Replacing the existing mirrors and fixtures with dimmable, illuminated LED mirrors (Figure 5).
- Removing the existing ceiling-mounted globe lights and installing LED fixtures with diffuse lenses (Figure 6).
- Replacing the existing handrails with new units that include integrated amber LEDs. These LEDs are controlled by motion sensors (Figure 6).

Figure 5: The original vanity lights produced a lot of glare (left side). The Project Team replaced these fixtures with dimmable, illuminated LED mirrors (shown on right).

Hallway

Since the doors to the residents' quarters are usually left open, the team decided to upgrade the lighting in the adjacent hallway. The original fluorescent wraps were replaced with tunable-white, surface-mounted LED luminaires (Figure 7). The new fixtures are controlled via automatic controls for both dimming and Kelvin-changing. The controls were programmed based upon recommendations provided by the Lighting Research Center:

- 7 am – 2 pm: 6500K @ 66% output
- 2 pm – 6 pm: 4000K @ 66% output
- 6 pm – 7 am: 2700K @ 20% output

Figure 6: New handrails include integrated amber LEDs controlled via motion sensors.

Nurses' Station

The nurses' station is located in the central hub of the care facility. ACC caretakers and nursing staff use this area to update medical records and monitor the status of residents. The project team replaced the existing fluorescent lighting with dimmable, tunable-white LED fixtures similar to the fixtures used in the hallway (Figure 8). ACC staff members are able to adjust the Kelvin temperature and brightness of the fixtures at the station via manual controls.

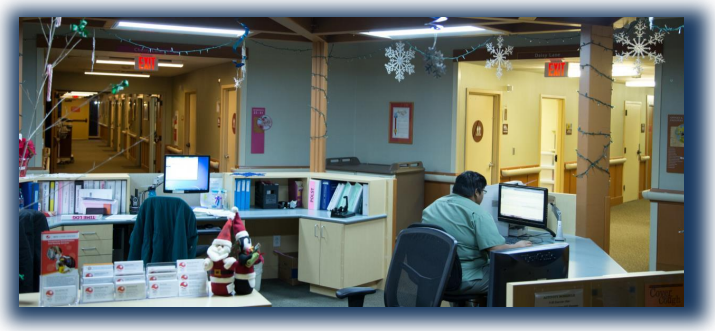


Figure 8: The nurses' station is illuminated by LED fixtures similar to the ones used in the hallways. Feedback received from the nurses was overwhelmingly positive.

Figure 7: The new hallway fixtures were controlled via automatic controls for both dimming and Kelvin-changing.

Family Room

ACC features a conference room for residents to meet with their families. The team replaced the surface-mounted fluorescent fixtures with tunable-white LED fixtures (Figure 9). Users are able to manually adjust the Kelvin temperature and brightness of the fixtures. The Attending Physician at ACC also uses this room to provide light therapy.

Administrator's office

Finally, the lighting was changed in the Administrator's office so that she could explain circadian lighting concepts to new staff members, visitors and the families of current and potential new residents (Figure 10).

Figure 9: The family visitation room is illuminated by LED fixtures similar to the ones used in the hallways.

Figure 10: Lighting in the Administrator's office.

2.4 Research Methodology

Essentially, there were three primary research objectives for this project:

1. Understand the technical properties of the new lighting and control systems.

2. Obtain feedback regarding the new lighting system from ACC staff members and residents.

3. Observe and record behavioral changes for the three residents who received the new lighting systems as well as residents living near the retrofitted hallway.

Technical Properties

The Project Team made extensive lighting measurements before and after the new system was installed. Measurements included:

- **Illumination levels:** the amount of light on various surfaces, typically measured in footcandles or lux. These measurements included horizontal surfaces (e.g. floors, beds) and vertical surfaces (walls). However, due to the unique nature of this project, some vertical measurements were also taken at the average eye level for people sitting in wheelchairs.

- **Luminance levels:** essentially the brightness of light source, typically measured in cd/m^2. This type of measurement is helpful for assessing glare.

- **Correlated Color Temperature (CCT):** basically the appearance (i.e. warmth or coolness) of the light source measured in Kelvin.

- **Spectral Power Distribution (SPD):** light sources produce different wavelengths within the visible light spectrum. It is common practice in the lighting industry to measure and display these characteristics in a SPD graph. It is important to know the SPD since different wavelengths of light can trigger different chemical responses within people and other living organisms.

Equivalent Melanopic Lux (EML): As mentioned previously, we now know that the human eye has five different photoreceptors (cells that sense light). The rods are responsible for night vision, while the three types of cones provide color vision. One type of cone is more sensitive to short (i.e. blue) wavelengths, another type is more sensitive to medium (i.e. green) wavelengths and the third type is more sensitive to long (i.e. red) wavelengths. Around 2002, scientists announced the discovery of a fifth type of photoreceptor: *intrinsically photosensitive retinal ganglion cells* (ipRGCs) that transmit light information to the circadian system. These cells have been linked to the production of melatonin and therefore affect our sleep-wake cycles. The ipRGCs are particularly sensitive to light in the blue spectrum. To account for this, scientists have developed a methodology known as Equivalent Melanopic Illuminance, most commonly expressed as Equivalent Melanopic Lux or EML[4] (lux is the metric unit of illuminance). Melanopsin is the photopigment present in the ipRGCs, so EML expresses the ability of the light source spectrum to stimulate the ipRGCs relative to the standard photopic stimulation of the visual system.

Essentially, this system uses the spectral power distribution (SPD) of a particular light source and applies weighting factors according to the sensitivities of the different photoreceptors in the human eye. The bottom line: lighting sources with higher EML values are more likely to affect our circadian system.

[4] For more information, please refer to the WELL Building Standard v1, available at https://www.wellcertified.com/well

End User Feedback

In addition to the lighting measurements, the Project Team administered on-line surveys and conducted on-site interviews before and after the lighting upgrades. The purpose of the surveys and interviews was to obtain feedback regarding the new LED lighting and control systems and to better understand general opinions and attitudes about lighting. The on-line survey was developed and administered by the Pacific Northwest National Laboratory and included ten questions about the ACC Staff and their opinions regarding the lighting system. These questions are included in Appendix B of this report.

Behavioral Observations

The ACC Care Center uses PointClickCare, an electronic medical record system that contains the residents' entire medical records, as well as point of care reminders and documentation. The Project Team worked with ACC to add questions regarding the residents' nighttime and daytime sleep patterns, moods and behavioral changes into the system. ACC Staff had to enter responses to these questions into the system on a regular basis. Specific questions are included in Appendix C.

3. Project Results

Before talking specifically about the results, it is helpful to remember the purpose of this project and acknowledge its limitations. The primary purpose of this project was to test different lighting strategies and concepts and identify which, if any, may provide benefit to ACC residents and staff. From this standpoint, this project was a glowing success:

"ACC will be incorporating many of the lighting solutions piloted in this project as best practices in terms of fall risk, sleep enhancement and non-pharmacological approaches for behaviors related to dementia."

ACC Administrator

However, since the lighting improvements were limited to only two resident rooms and four common areas, the results of this project should not be considered to be statistically valid. Furthermore, it is impossible for us to know if the positive changes in behavior are due to the circadian lighting, reduced glare, the night lighting systems (under the bed and LED handrails), or a combination of all of these. One thing is for certain: the changes had a profound effect upon the three residents in the rooms with the new lighting and many of the other residents are gravitating to the hallway with the new LED lighting system.

3.1 Technical Properties

Illumination Measurements

Scientists from the Pacific Northwest National Laboratory (PNNL) made extensive lighting measurements before and after the new system was installed. Specific measurements for the different locations are included in Appendix D of this report. Measurements included:

- Ave. HOR: average light levels on a horizontal plane 30" above the floor, which is where light levels are typically measured.
- Ave. VERT: average light levels on a vertical plane, measured at the bed in the resident rooms to assess the light available for reading.
- Ave. VERT Eye: light levels experienced at the eye for a person standing in the hall; this level can indicate glare and is also used to evaluate the circadian stimulation.
- Ave. VERT Eye Melanopic: the level of circadian-stimulating light present at the eye.
- For the hallways, measurements were taken for the original fluorescents as well as for the LED fixtures in each control mode: morning, daytime and nighttime.

Luminance levels

The Project Team used a Minolta Gigahertz Optik P9710 meter to measure the luminance levels (i.e. brightness) of the original fluorescent fixtures and the new LED fixtures. These measurements are shown in Figure 11 below. For seniors, anything above 1200 cd/m^2 (ANSI/IESNA RP-28-07) is likely to cause visual discomfort. Overall the new LED fixtures significantly reduced the amount of glare.

	Fixture type		Luminance (cd/m^2)		
Area	Original	New Fixture	Fluorescent	LED	Comments
Hallways	surface-mounted 4ft. fluorescent wraps	surface-mounted, dimmable & tunable 4ft. LED fixtures	5,900	3,200	LED fixtures were measured at approximately 66% of full output
Bathroom	ceiling-mounted globe with screw-in CFL lamp	ceiling-mounted 3000K LED sconce with leaf pattern lens	2,000	720	LED fixtures were measured at 100% of full output
Bathroom	wall-mounted vanity fixture with two screw-in CFL lamps	vanity mirror fixture with integrated dimmable 3000K LEDs	2,600	1,000	LED fixtures were measured at approximately 20% of full output

Figure 11: Luminance measurements at the ACC Care Center. For seniors, anything above 1200 cd/m^2 is likely to cause visual discomfort.

Correlated Color Temperature (CCT)

All of the fixtures used in this project operated within their rated CCT values (Figure 12). However, the CCT of the light delivered by the LED cove lights was significantly impacted by the color of the walls. Even though the fixtures themselves were measured at around 6100K, the highest CCT measured in the room was only around 5000K.

Location Description	Fixture Brand	Model #	Rated CCT
Resident rooms, above bed	Chrysalite LED, patient bed light	HPW248-120-LED35-2U2D-LV1R-LCL-AM	3500K
Resident rooms, cove lights	Philips iW Cove MX Powercore	523-000002-07	2700K-6500K
Resident rooms, underbed light	1000Bulbs	LED-13MM-WW-10KIT	"amber"
Resident rooms, wall-mounted nightlight	Contech LED step light	STPLAMLV-P	"amber"
Resident restrooms, vanity	Medmaster Vanity Mirror	VL23-38L30K-DCC-120	3000K
Resident restrooms, ceiling	Medmaster Auracyl Sconce	MAS826-PAN-NL-CS-1-19L30K-DCC-DV	3000K
Resident restrooms, handrails	Efficient-Tec International, LLC	S3-SS-3-WR-NR-ST-1-1-6-1	"amber"
Hallway	Samjin Beetle, surface mount	BT-14-032-SK-CT-USR4-surface	2700K-6500K
Nurses' station	Samjin Beetle, recessed troffer	BT-14-024-SK-CT-USR4-recessed	2700K-6500K
Family visitation room	Samjin Beetle, surface mount	BT-14-032-SK-CT-USR4-surface	2700K-6500K
Administrator's office	Samjin Beetle, surface mount	BT-14-032-SK-CT-USR4-surface	2700K-6500K

Figure 12: Correlated Color Temperature (CCT) values for the LED fixtures used in this project.

Equivalent Melanopic Lux (EML)

Scientists from the Pacific Northwest National Laboratory measured the spectral power distribution (SPD) and calculated the Equivalent Melanopic Lux (EML) for the primary settings of the tunable-white LED luminaires used in the hallway, nurses' station, family room and administrator office, as well as for the amber railing light used in the bathrooms. As expected the EML for the LEDs set at 6500K was significantly higher than all of the other options (Figure 13), while the 2700K setting was lower than the existing fluorescent system. Please refer to Appendix A and Appendix E of this report for more details.

Equivalent Melanopic Illuminance (at 100 lx)	
Light Source	Melanopic Illuminance (m-lx)
Fluorescent 4100K	61
LED 4250K	79
LED 6500K	98
LED 2700K	43
LED Amber	11

Figure 13: EML values for the various light sources at ACC. As expected, the EML value for the LEDs at 6500K was significantly higher than all of the other options. Source: Pacific Northwest National Laboratory (PNNL)

Spectral Power Distribution (SPD)

As mentioned earlier, many of the LED fixtures used in this project feature the ability to adjust the Kelvin temperature. The way that this is accomplished is by using LEDs with different SPDs and adjusting their intensity levels. SPD graphs for the fixtures used in the hallways, nurses' station, family room and Administrator's office are shown below in Figure 14.

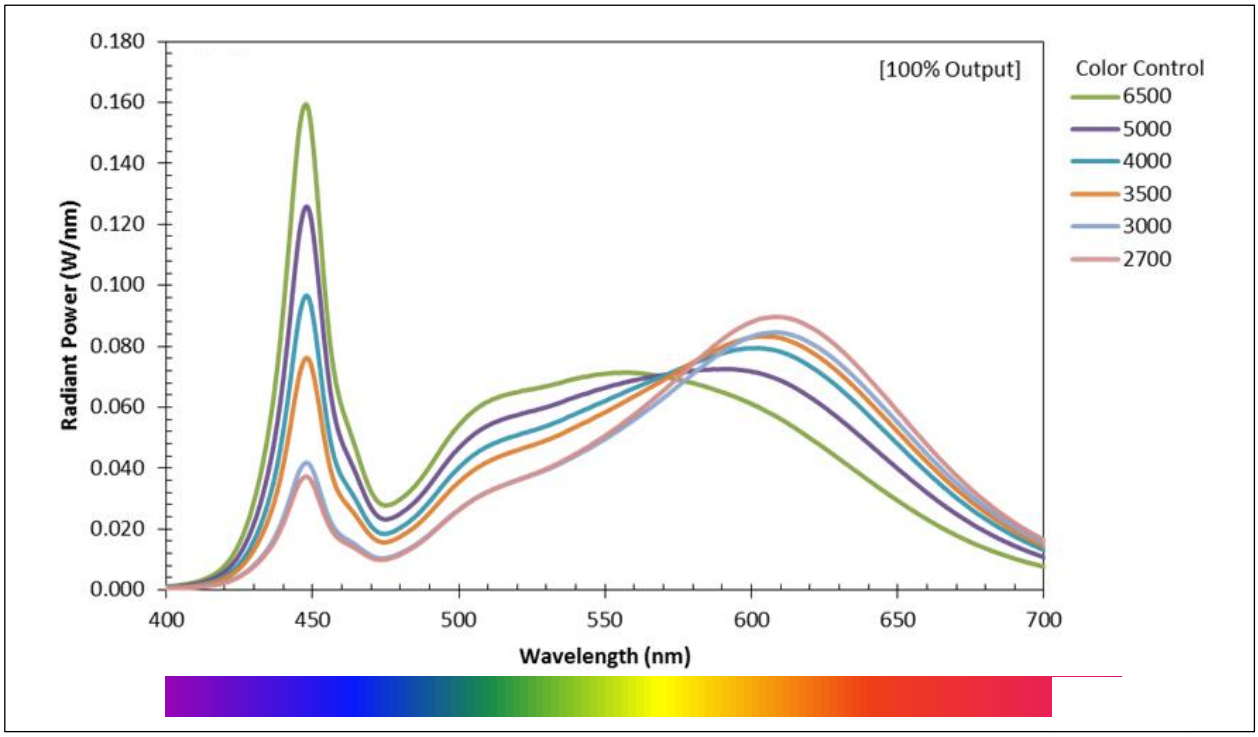


Figure 14: Most light sources emit different wavelengths within the visible light spectrum. The shorter wavelengths (450 nm) appear bluer and tend to have more of an impact upon people's circadian systems. The Kelvin changing fixtures used at ACC vary the spectral power distribution (SPD) by using different types of LEDs and adjusting their relative intensity levels. Source: Pacific Northwest National Laboratory.

Lessons Learned

- **LED cove lights:** by themselves the cove-mounted LED lights used in the bedrooms did not provide enough light during the daytime to promote a robust circadian response. Part of the problem was the relatively low lumen output of the fixtures themselves (maximum of 2471 lumens per 4ft. section). Also since these fixtures were designed to provide indirect illumination, the color of the walls adversely affected the overall lighting levels. The measured illumination levels ranged from 25 to 110 lx (2.5 to 11 fc). Despite these shortcomings, however, the residents and staff responded favorably to the changes in color and especially liked the nighttime mode. Fortunately, the wall-mounted, LED headboard lights provide ample illumination: 280 to 1400 lx (~28 to 140 fc).

- **Controls:** the controls for the LED cove lights were much too complicated and required a representative from the factory to commission. The controls for the hallway, nurses' station, family room and Administrator's office were much more intuitive, yet lacked clear instructions. The electrician who installed the controls had to consult with the manufacturer in order to program them (Figure 15).

- **Hallway fixtures:** the new LED hallway lights performed very well and had a major impact upon multiple residents (more on this later). When properly dimmed, the LED fixtures significantly reduced the amount of glare and used 70% less energy than the fluorescent fixtures they replaced (Figure 16).

Figure 15: The controls for the LED cove lights (left) were much too complicated. The controls for the rest of the lighting were more intuitive yet lacked clear instructions.

- **LED vanity fixtures:** the fixtures selected for this project provided much more light than needed. Installing a wall dimmer was somewhat difficult, yet absolutely essential to reduce glare.

- **Wall-mounted LED night lights**: these were often inadvertently covered by chairs and other items (Figure 17). The LED lights mounted under the beds were much more effective.

Figure 16: The new LED hallway lights significantly reduced the amount of glare and use 70% less energy than the fluorescent fixtures they replaced.

- **Under the bed LED night lights:** During this study, the team used amber LED rope lights plugged into smart power strips with motion sensors. Today, commercially available products are readily available. Regardless of the specific product used, care must be taken to ensure that bedspreads do not obstruct the lights or the motion sensors.

Figure 17: The wall-mounted LED nightlights (left side) did not work well because were often covered by chairs and other items. The LED lights mounted under the beds (right side) were much more effective.

3.2 End User Feedback

The Project Team attempted to use a web-based survey tool to obtain feedback from the staff at ACC. Unfortunately, only about a third of the staff members participated in the survey. Subsequent follow-up determined that language barriers were the primary reason for the low response rate; since most ACC residents are of Asian descent, several of the staff members only speak English as their second language. However, some of the comments received from the survey respondents and subsequent interviews provided some valuable insights:

- Most of the caregivers are primarily concerned about having enough light to perform skin assessments (i.e. checking for any bruises, discolorations, skin tears, or any other abnormalities) especially at night. Some of them bring flashlights because the original room lighting was too dim at night.

- ACC Staff said the ability to adjust the lighting output (i.e. dim) is important—especially for performing different tasks:

  "I think the best thing is the ability to control the brightness of the light. We are able to switch the brightness pertaining to the task we are doing."

  - ACC Staff

  "Need to have adequate light for resident to use, but not too bright during the night as well, nice to have adjusted lighting to use when necessary, particularly during assessments."

  - ACC Staff

- One of the residents complained about the room being too dark (before the lighting systems were upgraded).

- The push button switch for the overhead bed light was too similar to the call light button (Figure 18). Consequently, residents were often confused about which button to push.

- Staff members said they appreciate being able to help residents at night without having to turn on the light and wake them up.

- ACC Staff who work during the night shift really appreciate having the blue light at the nurses' station—they feel that it helps them to stay awake and makes them more alert.

Figure 18: The push button switches for the LED overhead bed lights were too similar to the call light buttons.

3.3 Behavioral Observations

Although this project was very limited in scope, the *magnitude* of the observed behavioral changes has garnered a lot of attention. According to the information logged by PointClickCare over a six month period, the lighting measures produced the following results:

- Dramatic reduction in the number of falls:

  "The quarter before the lights were installed we had five falls on Cherry Lane. The quarter after installation the number reduced to three. But, more importantly, there were no falls on Cherry Lane within the last two months."

  - ACC Administrator

- 41% reduction in the following behaviors: yelling, agitation and crying

- 71% reduction in behaviors for one particular dementia resident. This enabled ACC to reduce the use of psychotropic and sleep medications:

  "Medications are documented on a Medication Administration Record or MAR every time they are administered. Any psychotropic medication includes a target behavior that we are looking to address with the medication. These behaviors are monitored and documented per shift in the health record. Falls are documented in the health record and on our internal Risk Reports. We aggregate data on both psychotropic medications as well as falls for our Quality Assurance Performance Improvement or QAPI meeting monthly. The specific medications that we were able to reduce were Risperdal and Remeron."

  - ACC Administrator

- Improved sleep patterns

  - All three residents are now sleeping through the night

  - All are sleeping in their beds. Previously one of the residents refused to sleep in his bed and would only sleep in his wheelchair.

Other Outcomes

- Some residents living in rooms with the original lighting along Cherry Lane are asking to be wheeled out into the hallway to sit. Other residents from different parts of the facility are also asking to sit in the Cherry Lane hallway.

- Family members are being educated on circadian lighting. Many have asked when their loved one will receive the new lighting.

- ACC's Attending Physician is highly involved. He currently prescribes daylighting and has ordered the use of the 2700K setting to help agitated residents relax.

4. Recommendations and Final Thoughts

The main goal of this project was to evaluate various lighting and control strategies to identify which, if any, should be considered for inclusion in ACC's forthcoming project. As indicated earlier, ACC intends to include several of the options. Although circadian lighting is still relatively new, and much more research needs to be done, the comments below are offered for those who are considering similar projects.

4.1 Observations and Specific Recommendations

Resident Bedrooms

1. LED cove lights: although these lights provided soft illumination, they were expensive to install and did not work well enough to justify the expense. Furthermore, it was often difficult to find enough available wall space to make this approach viable for this application.

2. LED headboard lights (aka patient lights)

    - The LED chart light feature was very popular with ACC Staff members.

    - The Project Team believes that one of the best ways to incorporate circadian lighting would be to use headboard lights which are commonly mounted on the wall above the beds. The lights should be programmable to automatically adjust the Kelvin temperature during different times of the day. Unfortunately, to our knowledge, no manufacturers currently offer this option.

3. Lighting controls need to be sophisticated, yet easy to use.

4. LED under-the-bed lights are definitely worth considering. Commercial products are now readily available. Make sure the bedspreads do not obstruct the lights or motion sensors.

5. LED nightlights mounted in the walls did not work well because they were often inadvertently covered up by chairs, shopping bags and other items.

Resident Bathrooms

1. Since senior care facilities often require handrails, installing rails with integrated LEDs should be considered for new construction or during major remodels. Installing the necessary electrical wiring after the fact (i.e. retrofitting) was somewhat difficult and expensive.

2. Choose fixtures that are dimmable and minimize glare. The ceiling-mounted sconces and LED vanity mirrors generated a lot of positive feedback.

Hallways

1. Since the doors to the resident quarters are often left open in skilled nursing care environments, hallway lights can be a major cause of sleep disruption. Reducing light levels and the CCT to minimum levels at night greatly reduces circadian stimulus, allows the resident to relax and signals everyone that it is time for bed.

2. The cost of the tunable-white LED fixtures used in this project was significantly higher than standard LED fixtures. Fortunately, more manufacturers are starting to offer tunable-white fixtures so future prices should be lower.

Nurse's Station

1. Care facilities usually have a central hub to update medical records and monitor the status of the residents/patients. The nurses and staff at ACC really appreciated having tunable lighting at their station—especially those working during the night shift. We recommend installing independent controls for these areas.

2. Since many care facilities experience staff turnover, regularly educating the staff on the principles of circadian lighting and how to use the controls is vital for success.

Administrator's Office

If you are going to install tunable-white lighting in your facility, we highly recommend installing the system in the Administrator's office. This provides a convenient way to demonstrate the system to new staff members, colleagues and the families of existing or potential new residents.

4.2 Final Thoughts

"With the relatively high energy use intensity of healthcare facilities, the demographics of a rapidly aging global population indicate that energy use for this sector will continue to increase, as the increased demand for healthcare drives a need for new facilities and for renovations of existing facilities. The United Nations estimates that the percentage of the global population that is over the age of 65 years will dramatically increase in the next 30 years, driven in part by the aging of the post-World War II baby boom. Although that percentage has been increasing for several decades, it will remain below 10% through the year 2020, but then it will jump to over 16% by the year 2050[5]. The US Census Bureau estimates that 46 million people living in the US in 2014 were age 65 or older; that number is projected to increase to 98 million by 2060, representing 24% of the US population at that time[6]. This aging population almost certainly will require more healthcare facilities, with an expected corresponding increase in electricity use for lighting these facilities."

- Dr. Robert Davis
  Pacific Northwest National Laboratory

Consequently, many corporations are planning to build new care facilities or expand their existing ones. Fortunately, a lot of research regarding the visual needs of seniors has already been done and some great guidelines have already been created (e.g. ANSI/IESNA RP-28-07). These guidelines should help building professionals provide high quality lighting for senior care environments.

Although the field of circadian lighting research is still relatively new, it is picking up considerable momentum. Information provided by the Lighting Research Center, the Pacific Northwest National Laboratory and other industry leaders, combined with tremendous advances in LED and controls technology, promise exciting new opportunities to improve the quality of life.

[5] United Nations Department of Economic and Social Affairs, Population Division, *World Population Prospects.*
[6] Projections of the Size and Composition of the U.S. Population: 2014 to 2060. Colby, Sandra L. and Jennifer M. Ortman, Current Population Reports, P25-1143, U.S. Census Bureau, Washington, DC, 2014.

5. Appendix A: Equivalent Melanopic Lux (EML)

Equivalent Melanopic Lux (EML)

As mentioned previously, we now know that the human eye has five different photoreceptors (cells that process light). The rods are responsible for night vision, while three types of cones provide color vision. One type of cone is more sensitive to short (blue) wavelengths, another type is more sensitive to medium (green) wavelengths and the third type is more sensitive to long (red) wavelengths. Around 2002, scientists announced the discovery of a fifth type of photoreceptor: intrinsically photosensitive retinal ganglion cells (ipRGCs) that transmit light information to the circadian system. These cells have been linked to the production of melatonin and therefore affect our sleep-wake cycles. They are particularly sensitive to light in the blue spectrum. To account for this, scientists have developed a methodology known as Equivalent Melanopic Lux or EML[7].

Essentially, this system uses the spectral power distribution (SPD) of a particular light source and applies weighting factors according to the sensitivities of the different photoreceptors in the human eye. The graph depicted in Figure 19 shows how different spectrums of light stimulate the five photoreceptors differently. The photoreceptors are represented in the graph by the following designations:

- Rods = “r’
- Cones most sensitive to short (blue) wavelengths = sc
- Cones most sensitive to medium (green) wavelengths = mc
- Cones most sensitive to long (red) wavelengths = rc
- Intrinsically photosensitive retinal ganglion cells (ipRGCs) = z

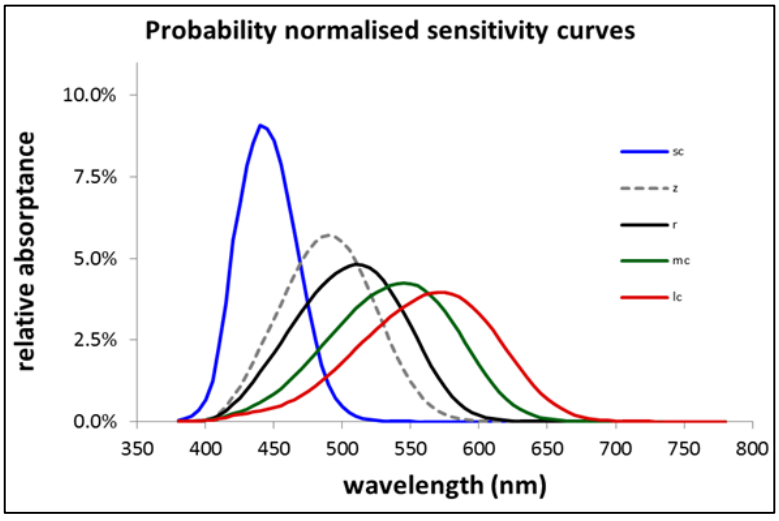


Figure 19: The human eye includes five different types of photoreceptors, which are each more sensitive to certain wavelengths of light. As shown in the graph, light sources with a high blue content (e.g. 6500K LED) produce a stronger response in the “short cones” and the intrinsically photosensitive retinal ganglion cells (ipRGCs). Source: Lucas, Robert J. et al., Trends in Neuroscience, January 2014, Volume 37, No. 1

[7] For more information, please refer to the WELL Building Standard v1, available at https://www.wellcertified.com/well

As shown in the Figure 19 (above), the warmer light spectrum (2700K) gives the most stimulation to the red cones (lc) and less to the blue cones (sc) and the ipRGCs (z). On the other hand, the cooler light spectrum (6500K) provides more stimulation to the blue cones and the ipRGCs.

The EML values (m-lx) for the fixtures at ACC were calculated by using the measured spectral power distribution SPD and the Irradiance Toolbox provided as a supplement to the Lucas et al journal paper mentioned earlier. As expected, the EML values for the tunable-white LED fixtures varied dramatically depending on the settings (Figure 20).

In the hallways at ACC, the cool settings are used in the morning to stimulate the circadian system, while the warmer settings are used at night to minimize stimulation of the circadian system. Since EML values also depend on the intensity of the lighting source, the lights in the hallways and resident bedrooms at ACC are also dimmed at night. The EML value for the amber LED handrails was extremely low.

Equivalent Melanopic Illuminance (at 100 lx)	
Light Source	Melanopic Illuminance (m-lx)
Fluorescent 4100K	61
LED 4250K	79
LED 6500K	98
LED 2700K	43
LED Amber	11

Figure 20: EML values for the various light sources at ACC. Source: Pacific Northwest National Laboratory

The bottom line: lighting sources with higher EML values are more likely to have a stimulating effect upon the human circadian system.

6. Appendix B: Pacific Northwest National Laboratory Survey Questions

ACC / SMUD Lighting Questionnaire for CNAs

Introduction

Lighting systems represent a major energy use in healthcare facilities. But beyond energy, lighting plays an important role in the patient room, and can affect the ability of medical staff to provide proper care as well as influencing the patient's comfort, satisfaction, and overall stress level. The Asian Community Center (ACC) is conducting this questionnaire in cooperation with the Sacramento Municipal Utility District (SMUD) and Pacific Northwest National Laboratory (PNNL) to gather input from medical professionals about the general patient room environment and the lighting systems used. The results of this research will help the cooperating organizations, hospital architects and other design professionals to design better patient rooms in the future.

The questionnaire should take less than 10 minutes and your progress is shown in the bar at the top.

Your participation in this research is voluntary. You may exit the questionnaire at any time by closing the browser window. Individual responses will remain anonymous. If you have any questions or concerns, please address them to the lead researcher at Pacific Northwest National Laboratory in Portland, OR, Dr. Robert Davis, phone (503) 417-7572, e-mail robert.davis@pnnl.gov.

By clicking next you are agreeing to participate in the research.

ACC / SMUD Lighting Questionnaire for CNAs

General Information

The following demographic information is important for analyzing the survey data. An asterisk (*) before any of the questions indicates a required question; other responses are optional.

* 1. This survey is intended for ACC staff working as a Certified Nursing Assistant (CNA); please select that choice if you are a CNA. If you are not a CNA but would still like to complete the survey, please check "Other" and type in your job function.

- ○ Certified Nursing Assistant
- ○ Other (please specify)

* 2. How many years total have you spent in your current profession, at ACC and other facilities?

- ○ Less than 1
- ○ 1 to 5
- ○ More than 5

* 3. How many years total have you spent providing care at ACC?

- ○ Less than 1
- ○ 1 to 5
- ○ More than 5

4. Age (a factor in visual system functioning)

- ○ Under 25
- ○ 25-40
- ○ 41-55
- ○ Over 55

5. Gender (a factor in visual system functioning)

- Male
- Female

* 6. During which shift do you typically work? (If you work different shifts, please select one option and base all of your answers on this selection.)

- Day
- PM
- Night

ACC / SMUD Lighting Questionnaire for CNAs

Lighting Characteristics

For the following questions, please consider the patient rooms in which you most often work, during your normal shift.

* 7. For a typical patient room in which you work, please indicate whether each lighting attribute hinders, is neutral, or helps your ability to perform your professional duties. Feel free to add any optional comments in the box below the ratings.

	Strongly Hinders	Moderately Hinders	Neutral	Moderately Helps	Strongly Helps
Color of light for evaluating skin tone and other colors	○	○	○	○	○
Glare from light fixtures (if you don't notice any glare, check "Neutral)	○	○	○	○	○
Flicker of light fixtures (if you don't notice any flicker, check "Neutral")	○	○	○	○	○
Shadows from people and objects	○	○	○	○	○
Brightness of lighting in work area	○	○	○	○	○
Pattern of light and dark areas	○	○	○	○	○
Control of lights with switches, dimmers, etc.	○	○	○	○	○

Comment

ACC / SMUD Lighting Questionnaire for CNAs

Lighting for Specific Areas

* 8. For a typical patient room in which you work, please rate the lighting for each of the specific areas listed. Check the N/A column if the area is not present in the typical patient room where you work. Feel free to add any optional comments in the box below the ratings.

	Excellent lighting	Good lighting	Neutral	Fair lighting	Poor lighting	N/A
Patient Bed	○	○	○	○	○	○
Computer Monitor	○	○	○	○	○	○
Bathroom	○	○	○	○	○	○
Medical Device Screens or Monitors	○	○	○	○	○	○
Room Entrance	○	○	○	○	○	○
Guest Area	○	○	○	○	○	○
Nighttime Navigation Lighting	○	○	○	○	○	○
Overall System	○	○	○	○	○	○

Comments

* 9. For a typical patient room in which you work, do your professional duties require additional lighting beyond what is provided by the built-in patient room lighting? (If yes, please explain the supplemental lighting below. Examples include a task light that you bring into the room, or a flashlight / mobile phone light.)

- ○ Yes, very frequently
- ○ Yes, occasionally
- ○ No

Comments

ACC / SMUD Lighting Questionnaire for CNAs

Professional Duties

* 10. For a typical patient room in which you work, please rate the frequency of the patient complaints listed. Feel free to add any optional comments in the box below the ratings.

	Very Frequently	Frequently	Occasionally	Rarely	Never
Lights are too bright	○	○	○	○	○
Lights are too dim	○	○	○	○	○
Color of light is bothersome	○	○	○	○	○
Lights flicker	○	○	○	○	○
Lights keep me awake	○	○	○	○	○
Can't see to get to bathroom	○	○	○	○	○
Can't control lights myself	○	○	○	○	○
Bathroom lights are inadequate	○	○	○	○	○

Comments

7. Appendix C: PointClickCare Questions

The questions below were developed by the Project Team and incorporated into ACC's PointClickCare system. ACC Staff were required to enter answers to these questions on a regular basis.

1. Sleep Pattern

- How often did you observe the resident awake at night?
  i. Never
  ii. Once
  iii. Multiple times

- Was the resident's sleep disturbed or interrupted by
  i. Need to use the restroom
  ii. Roommate
  iii. Light used by staff
  iv. Other (please explain)

- Was the resident able to fall back asleep after waking up?
  i. Yes
  ii. No

- Ask the resident how they slept last night
  i. No problem
  ii. Moderate Problem
  iii. Severe Problem

- If unable to answer; Does the resident appear rested
  i. Yes
  ii. No

2. Assessment

- Was this a new environment for the resident?
  i. Yes
  ii. No

- Did the resident sleep during the day?
  i. Napped regularly (at least 1 hour)
  ii. Fell asleep in chair
  iii. Slept most of the day
  iv. None of the above

- Did the resident exhibit any of the following behavioral issues? Check all that apply
  i. Depression
  ii. Agitation
  iii. Combativeness
  iv. Restlessness
  v. Fearfulness or Paranoia
  vi. Listlessness

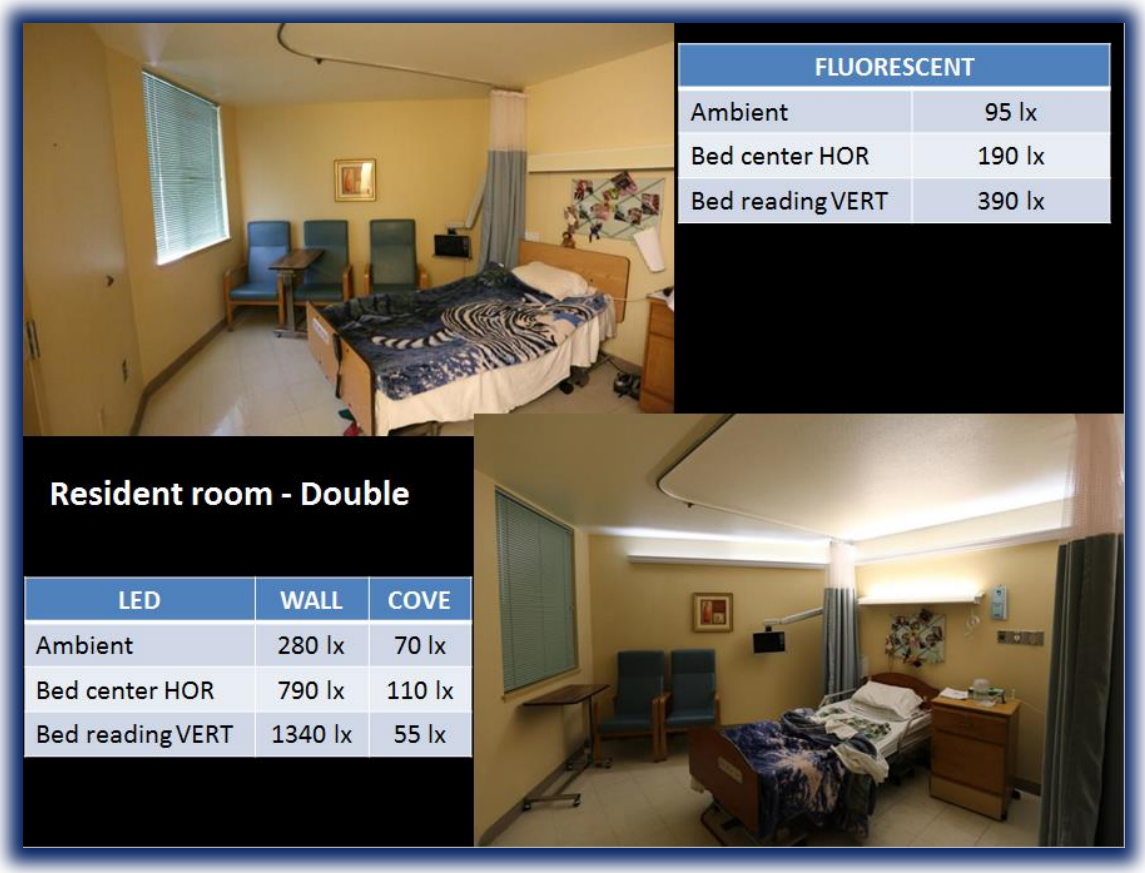
- How was the patient's overall mood for the day?
  i. Good
  ii. Fair
  iii. Poor
  iv. Explanation (required)

8. Appendix D: Illumination Measurements

The following pictures and graphs depict the illumination measurements obtained by Dr. Robert Davis and Dr. Andrea Wilkerson from Pacific Northwest National Laboratory at the ACC Care Center. All measurements were taken using a calibrated Konica Minolta T-10A Illuminance meter. Full details on the measurement methods used and the point-by-point values will be reported in a future DOE GATEWAY report on the project, available at http://energy.gov/eere/ssl/gateway-demonstrations. Values shown here are average values to summarize the relative performance of the lighting systems.

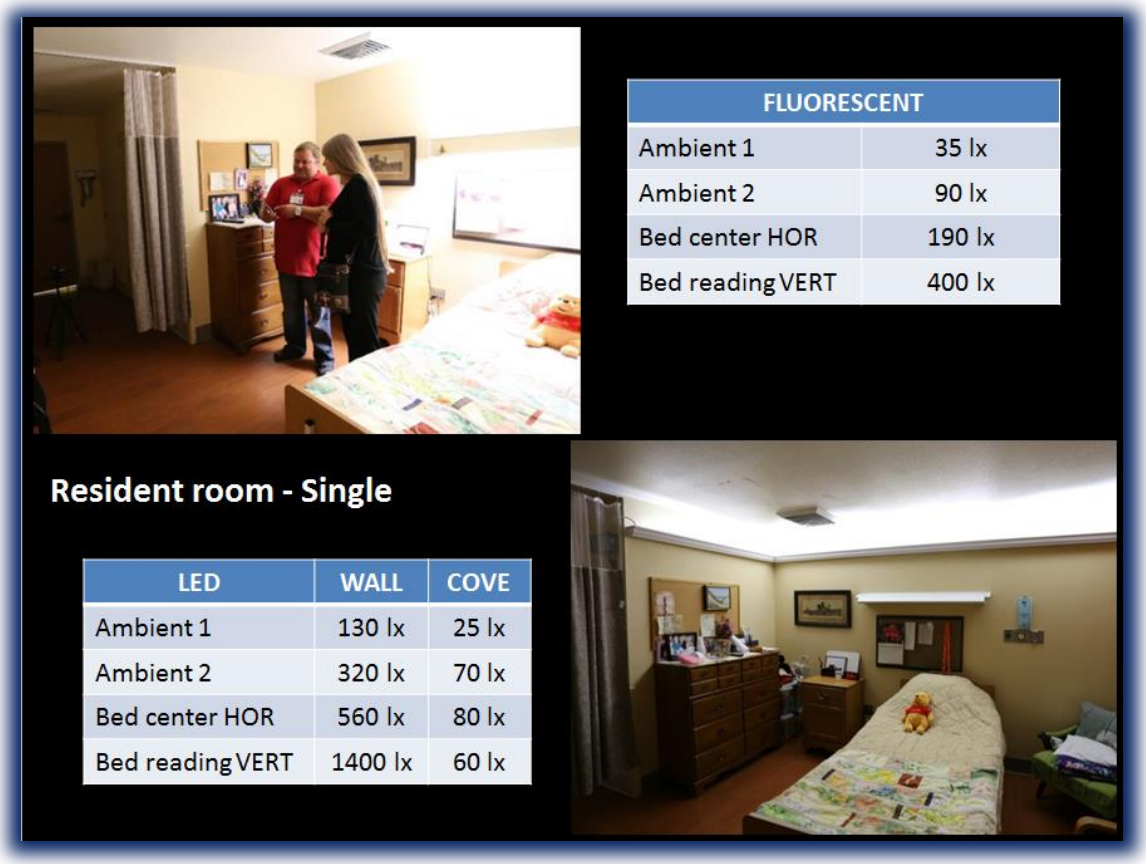
Notes:

- Ave. HOR: the average light level on a horizontal plane 30” above the floor, which is where light levels are typically measured.
- Ave. VERT Eye: light level experienced at the eye for a person standing in the hall; this level can indicate glare and is also used to evaluate the circadian stimulation.
- Ave. VERT Eye Melanopic: the level of circadian-stimulating light present at the eye.
- For the LED system, the blue rows show the light levels for the LED system in the morning setting, 6500K and 66% of full light output. Although the light level is slightly less than the fluorescent system, the circadian (melanopic) level is actually higher with the LEDs.
- The warm-shaded rows show that the LED system in its night setting produces a much lower level of melanopic illuminance than the fluorescent system, both because of its warmer spectrum (2700K) and because it was dimmed down to 20%.



Notes:

- The LED lighting is providing much higher light levels than the fluorescent lighting.
- Ambient: general light throughout the room, measured at 2ft. intervals along two perpendicular lines through the room.
- Wall: measurements taken with only the LED headboard fixture turned on.
- Cove: measurements taken with only the LED cove fixtures turned on.
- Bed Center HOR means the light level at the center of the bed in a horizontal position, and Bed reading VERT means the light level in a vertical plane such as where someone might hold a book if reading in bed.
- The light levels from the fluorescent system were lower than IES recommendations, especially for people over age 65, while the LED light levels meet or exceed recommended levels.



Notes:

- The LED lighting is providing much higher light levels than the fluorescent lighting.
- Ambient: general light throughout the room, measured at 2ft. intervals along two perpendicular lines through the room.
- Bed Center HOR means the light level at the center of the bed in a horizontal position, and Bed reading VERT means the light level in a vertical plane such as where someone might hold a book if reading in bed.
- The light levels from the fluorescent system were lower than usually recommended, especially for people over age 65, while the LED light levels meet or exceed recommended levels.
- Wall: measurements taken with only the LED headboard fixture turned on.
- Cove: measurements taken with only the LED cove fixtures turned on.

Notes:

The LED light levels here were measured with the fixture at its maximum output. The levels shown far exceed what is needed, but the fixture would usually be used at a dimmed setting.

Notes:

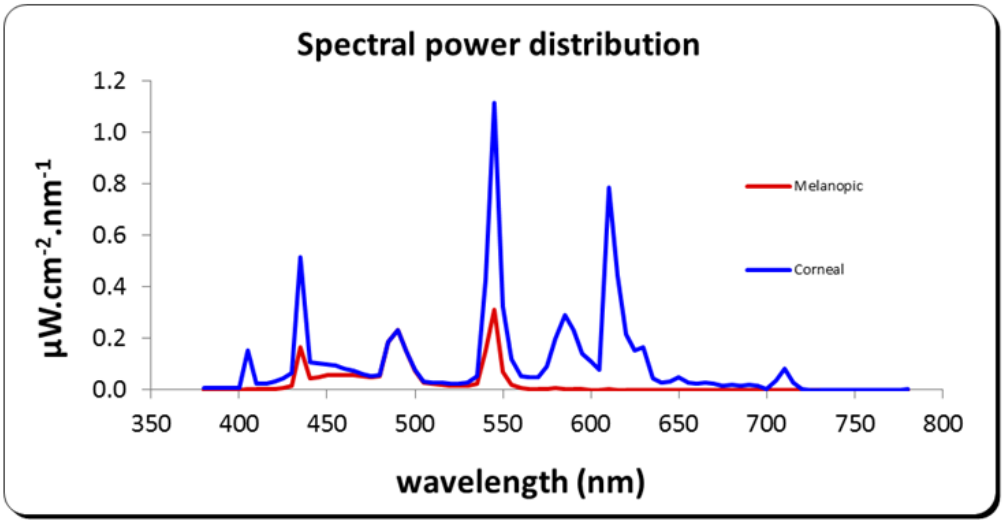
The LED fixture provided twice as much illumination with minimal glare

9. Appendix E: Spectral Power Distribution Measurements

The following graphs depict the spectral power distribution measurements obtained by Dr. Robert Davis and Dr. Andrea Wilkerson from Pacific Northwest National Laboratory. All measurements were taken using a calibrated Konica Minolta CL-500A Illuminance Spectrophotometer. Measurements were made of the LED luminaires in the Family Room, and similar luminaires were also used in the corridor, nurse station and administrator's office. The figures shown here are intended to illustrate graphically the relative effects of the different light source spectra; the absolute values are not comparable since the measurement locations and conditions varied. For comparing the relative effects, the Equivalent Melanopic Lux for each spectrum is shown (with units of m-lux) when normalized to a photopic illuminance of 100 lux, which represents the normal visual response.

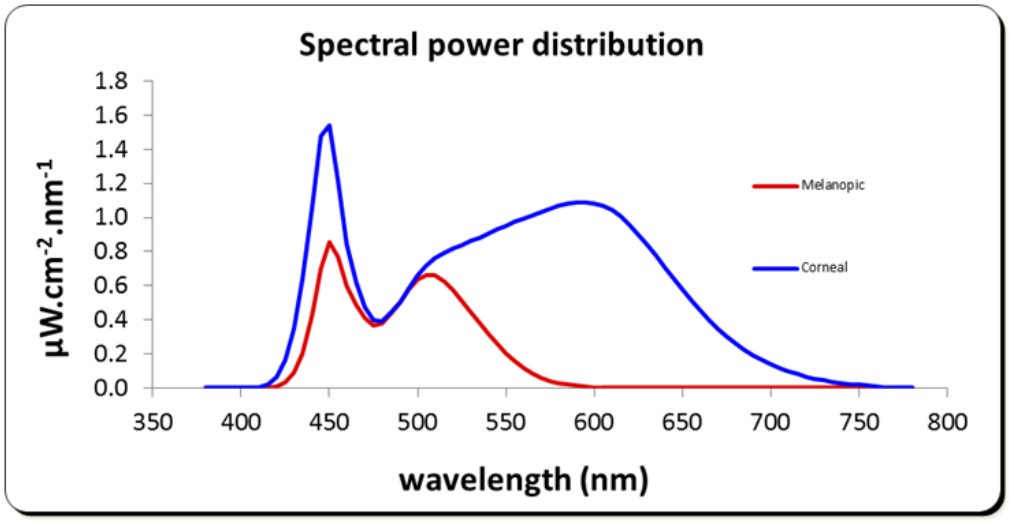
The spectral power distribution graphs show the spectrum produced by the source as it exists at the cornea (blue line), and they show the spectrum when weighted by the spectral sensitivity function of the ipRGCs (melanopic response, shown by the red line).

Incumbent fluorescent (4100K)



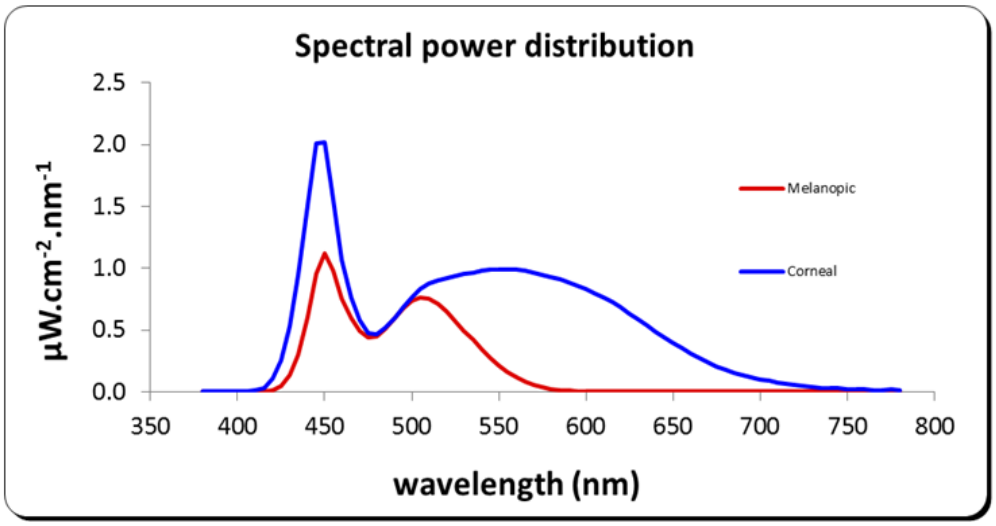
Photopic illuminance: 100 lux
Melanopic illuminance: 61 m-lux

4500K, 100% output



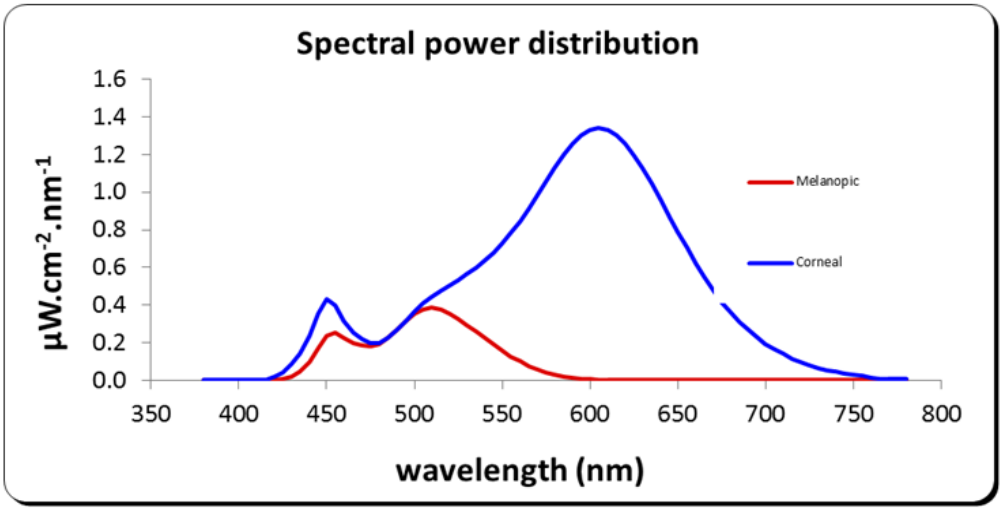
Photopic illuminance: 100 lux
Melanopic illuminance: 79 m-lux

6500K, 100% output



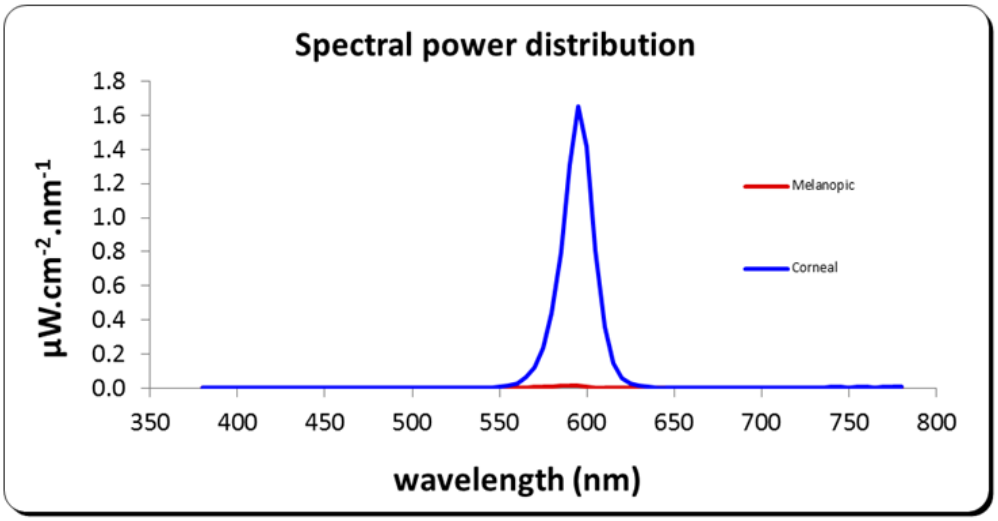
Photopic illuminance: 100 lux
Melanopic illuminance: 98 m-lux

2700K, 100% output



Photopic illuminance: 100 lux
Melanopic illuminance: 43 m-lux

Amber nightlight (rail in bathrooms)



Photopic illuminance: 100 lux
Melanopic illuminance: 11 m-lux