CURRENT STATUS AND PROSPECTS FOR LIGHTING TECHNOLOGIES IN SENIOR LIVING FACILITIES

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by
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Abstract

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IN SENIOR LIVING FACILITIES

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This case study of five senior living facilities in Northwestern North Carolina explains the current lighting scenarios commonly found in assisted living and skilled nursing long-term healthcare communities. The study argues existing lighting conditions in the indoor environments ordinarily found in these facilities–activity rooms, dining rooms, hallways, residents' rooms, and bathrooms–do not meet current recommended lighting standards. Many qualitative benefits such as health and well-being relate to the technical qualities of artificial lighting including, but not limited to, the following: illuminance, color temperature, luminance, and value contrast. Current technologies–for example, BIOS technology and tunable white light–can help with elderly vision and circadian rhythm simulation. Additionally, with the advancement of LED technology, there are economic considerations for switching to a new lighting design. An extended examination of one of the five case study facilities substantiates that a retrofit LED lighting design will bring about annual energy cost savings and a short payback time as shown by a calculation of the return on investment.

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Chapter 1: Introduction

Artificial lighting is an important component for functional, aesthetically pleasing, and economical indoor environments in a building. Lighting consumes an average of 15% of the total energy consumption by end use for non-domestic, commercial buildings (Pérez-Lombard, Ortiz, & Pout, 2008). The recent shift in the lighting industry towards solid state lighting (SSL) has proven to be an important energy and cost saver (United States Department of Energy [USDOE], n.d.-e). More advanced technology has allowed for flexibility in lighting control systems, allowing automation to reduced usage and energy consumption efficiently.

In health care, lighting also plays a vital role, not only functionally and aesthetically, but also as an influence on residents' behavior. Functionally, artificial light allows users to navigate through a space and perform necessary tasks. Aesthetically, the quality and quantity of light may enhance the user's experience in a space. Beyond functionality and aesthetics, there are non-visual effects of lighting, such as the effect on mood and sleeping patterns. A great deal of research has been done to define lighting standards and guidelines health care institutions should follow to achieve an optimal indoor environment (Agrawal, 2017; Brodrick, 2016; Illuminating Engineering Society of North America [IESNA], 2011; Marquardt, Bueter, & Motzek, 2014).

Senior living facilities as a subset of health care pose a unique lighting challenge. Not only does lighting affect functional needs and health issues, it is also perceived differently through the eyes of the elderly. Senior living facilities are a division of health care that fall in the sector of long-term, semi-residential occupancy. Many residents make these living facilities their permanent home and desire a residential atmosphere over an institutional environment. In this sector of health care, it is important to consider the preferences and comfort of this population.

Statement of the Problem

Lighting in senior living facilities has an impact on occupant health, behavior, and circadian rhythm, yet studies show this has often been overlooked in the design process of these facilities; the result of this oversight include various technical aspects such as color temperature (Figueiro et al., 2015, p. 323), intensity, and spectrum (White, Ancoli-Israel, & Wilson, 2013, p. 62) in the luminaires typically used in such facilities. These problems stem from the need for practicality and functionality for staff, without consideration of the effects of poor lighting on residents (White et al., 2013, p. 73). The effects of lighting may seem overrated, but lighting is subtly rooted in issues of occupants' mental and physical health.

The target population housed in long-term senior living facilities is above the age of 65, the threshold where vision begins to deteriorate. In fact, age-related vision issues become noticeable at the age of 40 (Illuminating Engineering Soceity of North America [IESNA], 2016). Loss of vision, erratic circadian rhythms, scatter, as well as various visual diseases like cataracts, diabetic retinopathy, glaucoma, and macular degeneration are common for this age population. Alzheimer's disease—and related dementia (ADRD)—is the most common mental disorder for elderly Americans, affecting an estimated 5.1 million in the year 2010 (Figueiro et al., 2014).

One of the underlying problems in healthcare facilities is the lack of adequate lighting. There are clear guidelines and recommendations for proper lighting installation at the point of construction or as a retrofit application when new SSL technologies such as light emitting diodes (LEDs) come to the common market. Certain national codes set minimum requirements while the Illuminating Engineering Society (IES) establishes recommendations for different applications. Unfortunately, facility planners, designers, and managers are not implementing and incorporating correct lighting design in these buildings, instead focusing only on meeting the minimum energy code. Even if there was a process to design a good lighting scheme within one of these facilities, most facilities' lighting environments are dictated by the experience of a younger individual or by the designer, without proper consideration of how the eyes of the elderly perceive light (Cheng, Ju, Sun, & Lin, 2016).

Purpose of the Study

This research investigated existing lighting conditions in five senior care facilities in Northwestern North Carolina to document the current state of lighting practices and determine what benefits might be achieved by updating current lighting systems. The counties in Northwestern North Carolina included in this study were Ashe, Avery, Caldwell, and Watauga. The study collected detailed information about the current lighting environments in five different senior living facilities to illuminate current practices, the extent to which lighting falls short or exceeds recommended standards, and the cost and energy savings that would be associated with updating a facility's lighting systems to reflect current lighting technologies, such as LEDs and dimmable and tunable controls.

There is a common perception of a significant initial cost when updating a lighting system; however, this research showed the payback time for a simple retrofit design is short. This paper also covers the different health and financial incentives earned when renovating a lighting system for any senior living facilities, whether in Northwestern North Carolina, the state, or nationally.

Research Questions

The following questions were the basis for this research:

1. What are the current lighting scenarios in five assisted living facilities in Northwestern North Carolina?
2. Are the five facilities meeting the recommended lighting technical specifications, as established by the Illuminating Engineering Society of North America (IESNA)?

3. What are the qualitative and quantitative benefits of bringing LED and other current lighting technologies into long-term home health care facilities?
4. What are the current technical specifications of lighting that assist the elderly in their functional quality of life?
5. What are the potential economic benefits of retrofitting an existing facility using current retrofit fixtures, luminaires, and control systems?

Definition of Terms

Key terms in this study use the following operational definitions:

Ballast efficacy factor (BEF) is the measured ability of how efficient ballasts are driving the same number of the same types of lamps. BEF = BF x 100/system wattage

Ballast factor (BF) is how hard a ballast drives a lamp. Higher BF means more light and more wattage. Lower BF means less light and less wattage. Lamp lumens and wattage ratings in lamp catalogs are based on a 1.0 reference ballast.

Color rendering index (CRI) refers to the accuracy of rendering eight pastel colors and how natural that color looks. Daylight and incandescent lamps are considered to have a score of 100 – a perfect score – while low pressure sodium (LPS) lamps have a score of 0. LEDs tend to render bright saturated colors better than pastel colors so their CRIs stay within the 70-90 range, typically.

Cones are one of the three photoreceptors in the human eye and are responsible for color discrimination (Walerczyk, 2014). There are approximately 40 million cones in the retina (Illuminating Engineering Soceity of North America [IESNA], 2011).

Correlated color temperature (CCT) is a measurement to differentiate the various hues of white, artificial light sources. CCT is measured in degrees Kelvin (K), and this temperature rating indicates what tone of white light is emitted from a lamp. Sunlight is around 5,000 degrees K.

Dose is light intensity plus light spectra multiplied by duration of light exposure. (Dose = (intensity + spectrum) x duration) (White et al., 2013, p. 62)

Efficacy is the measurement of lighting efficiency, measured in lumens per watt (LPW). A higher efficacy indicates a more energy-efficient lighting system. Fluorescent lamps have an efficacy that ranges from 80 to 93lm/W while LEDs can have an efficacy rating up to 200lm/W (Kibert, 2016).

Fixture is also known as a lighting fixture or luminaire. (Refer to *lamp*.)

Fixture efficiency is the percentage of light that is emitted from the fixture in comparison to the full efficacy of the lamp.

Foot-candles (fc) is the amount of light that hits a target and is measured by a light meter. All horizontal measurements in this study were taken at 30" above the floor while all vertical measurements were taken on a wall. Foot-candles are a unit of measurement for *illuminance*.

Human centric lighting (HCL) is lighting for human health and well-being. It can also be called human factors in lighting, biophilia, and more. HCL includes several design strategies such as daylighting and the tuning of white LED light products (Walerczyk, 2014).

Illuminance is the density of light on a surface and is measured in *foot-candles* or *lux*. The Illuminating Engineering Society of North America (IESNA) *Lighting Handbook* (10th ed.) offers illuminance targets for different applications using *lux* as the unit of measurement.

Intrinsically photoreceptive retinal ganglion cells (ipRGCs) are one of the three photoreceptors in the human eye. These cells are responsible for the non-visual effects of light on the circadian rhythm and are important during the process of phototransduction where the retina converts light into neural signals for the suprachiasmatic nuclei (SCN)—a circadian pacemaker—which generates a biological clock rhythm that repeats approximately every 24 hours (Konis, 2017; Rea, Figueiro, Bierman, & Hamner, 2011; Walerczyk, 2014; White et al., 2013).

Lamp – the term lamp is a layman's term for what is a *fixture* or *luminaire* – the housing for the source of light. *Lamp* is the proper terminology for what most would call a "lightbulb."

Light emitting diode (LED) is a semiconductor device that emits visible light when voltage is applied. Most LEDs are monochromatic – occurring at one wavelength ("LED," n.d.).

Light reflectivity value (LRV) is a measurement of visible light from a light source when reflected off a surface. LRV equals reflected light over incident light multiplied by 100 to achieve a percent value.

Lumens are the amount of light that a light source generates in all directions.

Lumens per watt (LPW) is the unit of measurement for *efficacy* in lamps.

Luminance can be considered as brightness of an object or surface.

Lux – a unit of measurement; 10 lux is approximately 1 foot-candle.

Payback = (initial cost – rebate, if there is one)/1st year savings

Rods are one of the three photoreceptors in the human eye. There are approximately 100 million rods in the retina (Illuminating Engineering Soceity of North America [IESNA], 2011).

Spectral power distribution (SPD) is a graph of the radiant power emitted by a light source as a function of wavelength. The graph shows how the light source will accurately render different colors.

Solid state lighting (SSL) refers to the type of lighting that uses semiconductor light-emitting diodes (LEDs), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED).

Limitations of the Study

Several limitations were present in this study.

First, there was no direct interaction with the residents in the five facilities, only interaction with the staff. The behavior effects due to lighting were not tested or collected for analysis. This is an opportunity for further research.

The first phase of this study involved five facilities, but after initial data collection and assessment of all five facilities listed, the study was narrowed to just one facility for extended case study analysis. Thus, the findings were specific only to the selected facility and do not apply directly to other, similar facilities; however, the findings may enable other senior care facilities to better understand the importance of proper lighting in the interior environment, and can provide a guide for a retrofit design in case other facilities want to implement this retrofit design.

The research examined artificial sources of light only. Natural daylighting was not considered in this study. For the sake of this study, 6mil black plastic and black cotton cloths were pinned over windows to prevent any daylight from entering through exterior penetrations during the data collection process. All opaque interior doors were shut to keep other sources of light from entering the room; however, interior glass doors and windows were not covered to correctly portray the source of light from adjacent rooms that is consistent throughout the day. The surface reflectance value of the black cloth was not considered. By eliminating natural daylighting factors, the study makes no consideration of building orientation and geographical location.

The Sekonic C-500 light meter measured color temperature of existing light fixtures in each facility. A limitation of this meter was the range of color temperatures the meter registered. Anything below 2300K registered as “Under” on the meter.

The readings of incident and reflected light to calculate the light reflectance values (LRV) of surface finishes is subject to user error. Reflected light is measured typically at a range of two to four inches from the surface and can vary for each measurement taken. Additionally, not all surfaces were measured, which affected the value contrast of luminance calculation between adjacent surfaces, such as the floor and the wall. For example, the LRV of the floor and wall can be close in value, resulting in a low contrast, but the LRV of the baseboard finish may provide the recommended contrast.

The accessibility to rooms varied between facilities. In all cases, a vacant resident's room was examined, however, the state of the room varied between facilities. Some were fully furnished while others were not. The Foley Center of Chestnut Ridge did not allow blackout curtains to be hung, so measurements had to be taken at night with blinds closed. The resident's room examined at the LCC of Banner Elk was not in the wing of interest and the lighting in the rooms in the selected wing of interest was different than the room that was examined.

Modeling the proposed lighting design in DIALux has a few limitations. Not all lighting manufacturers have photometric, .ies files created for the selected products, so .ies files of products with similar photometric data had to be used and adapted to create a virtual, projected illuminance map of the rooms.

When economic savings were calculated in this study, the researcher used estimated operational times of artificial lighting that the maintenance director provided during an interview. With additional time and resources for the study, an accurate lighting time schedule could be created by observing usage patterns over an extended period or with the help of cumulative lighting loggers.

An assumption was made that the amount of time the lights are on would remain the same after an SSL retrofit system was installed. In the case a retrofit design is indeed implemented, the usage amount may change because the new light source will have a significant change in lumen output. For the purpose of this study, prior usage amounts were assumed as a fixed variable and the focus was on the energy savings that could be achieved merely by switching from incandescent or fluorescent lamps to LEDs. The retrofit proposed is not a one-to-one retrofit.

Moreover, all initial costs of proposed luminaires are at current market rate and are subject to change over time. Cost of labor and installation estimates rely on an RS Means database but will vary based on labor rates of the team hired to perform the work. In addition, recommended dimmable controls and occupancy sensors are not included in the initial pricing.

Finally, at the time of this study, tunable-white lighting and lighting such as BIOS demonstrate new and upcoming control technologies presenting a large initial cost, defeating the purpose of a reasonable payback time. Therefore, this study proposes two schemes; the second scheme incorporates these new technologies but further emphasizes the added initial cost to the system.

Significance of the Study

This study evaluates the current lighting design in senior care facilities located in Northwestern North Carolina. In addition, the study provides useful information for the management of the facilities to realize the health, environmental, and economic impacts of lighting. This study will raise awareness of the necessity for facilities of the same function and occupancy type to implement the recommended guidelines for lighting, but also the benefits of such an implementation.

In line with the application of solid state lighting technologies in similar facilities, future designs for senior care facilities will be interested in this study's findings for further implementation and development. While a retrofit application may not apply to most new construction projects, this study sheds light on several different incentives for why it is important to incorporate SSL into any new construction building.

Chapter 2: Review of Literature

Introduction to Lighting

Visible light, as defined by Walerczyk (2014), is "a very narrow band from about 380 to 770 nanometers in the electromagnetic scale, bordered by ultraviolet on one side and infrared on the other" (p. 7). Light is relative to the way a human eye perceives it. Within the human eye is the retina. The retina is the beginning of the visual pathway of the visual system and functions, in essence, as a part of the brain housed in the eye (Illuminating Engineering Soceity of North America [IESNA], 2011). Inside the retina, among many other cells, are the photoreceptors.

The photoreceptors consist of rods and cones. Each eye contains roughly 100 million rods and 40 million cones. The role of the photoreceptor is to convert optical radiation and release a neutral transmitter chemical. The more radiation that is absorbed, the more transmitter is released (Illuminating Engineering Soceity of North America [IESNA], 2011). "Rods facilitate peripheral vision and vision in dim lighting conditions, with peak sensitivity to green-blue light (498 nm). Cones facilitate daytime vision and color perception, and the peak sensitivity for the sensation of brightness with this system occurs at green-yellow light (555 nm)" (International WELL Building Institute, 2017, p. 93). A third kind of photoreceptor, referred to as Intrinsically Photoreceptive Retinal Ganglion Cells (ipRGCs), is critical to the circadian rhythm.

The spectrum of light emitted, therefore, serves a large role in how the eye perceives light and transmits information to the brain. Different light spectrums create different chemical reactors which, in turn, produce various hormones that affect a person's health. This will be discussed in further detail later in relation to the human circadian rhythm.

As light is perceived through the human eye, the creation of lighting patterns influences the human's perception of objects (Cuttle, 2015). The amount of illuminance on an object largely influences how we perceive an object's attributes. In indoor environments, there is an emphasis on proper illuminance so that a human eye can accurately perceive entire visual scenes. The opposite is true in outdoor scenes; the goal is to simply create brightness patterns that do not necessary allow the viewer to accurately understand an object's attributes, such as depth and texture.

Duration of light exposure is another important consideration. The amount of light a human is exposed to in a day directly relates to the intensity and spectrum discussed previously. A well-lit bathroom, for example, does not have as much impact on a human's vision than a well-lit bedroom, as more time is typically spent in the bedroom than in the bathroom.

These three different technical factors of lighting correlate together in what is defined as dose. Dose is equal to the intensity, or illuminance, of lighting plus the spectrum of light exposure multiplied by duration. The human's response to light is dependent on dose – if dose increases, the response to light increases as well (White et al., 2013).

Prior light exposure, known as photic history, also plays a big role. A study showed that exposure to daylight (between 50,000 lux and 100,000 lux) can diminish the effect of evening treatment light of 2,000 lux (Zeitzer, Friedman, & Yesavage, 2011). Without proper consideration of prior light exposure, extensive measures to use light as a treatment for the residents' functional quality of life may be ineffective. Further discussion on the effects of prior light exposure on human circadian rhythms follows later in this document.

Another consideration is how the human eye evolves over age. Careful examination of the vision characteristics of the elderly population is necessary when designing for this group of individuals. The recommended amount of illuminance, intensity, duration to light exposure, dose, and prior light exposure, among other factors, will change when dealing with this population.

Many variables influence a well-executed lighting design: the function and needs of the space, practicality of the application in terms of efficiency and costs, and the technical specifications of the different light sources. Some technical specifications that influence the nonvisual effects of light include illuminance levels, direction, color temperature, color rendering index, spectral distribution, duration, timing, and contrast, to name a few (Brodrick, 2016). These technical specifications and characteristics of good lighting practices and applications will be discussed in further detail later.

Finally, lighting is not only limited to technical specifications. Lighting also has a large influence on the monetary cost of a building's operation. There are many ways artificial lighting may reduce cost. Also factored into this equation are the lumens per watts (LPW) and heat load on the HVAC system associated with lighting. Another key factor is the consideration of easy maintenance. A good lighting design considers the maintenance and instinctive grouping of various fixtures for easy replacement, which can significantly cut labor costs.

Types of Artificial Lighting

There are many types of artificial lighting available for a wide variety of different functional and aesthetic applications. The most common types of lighting technology found in senior living facilities were reviewed, highlighting the benefits and drawbacks of each, including incandescent lighting, fluorescent light and LEDs.

Incandescent Lighting

Although slowly fading from use, incandescent lamps are still around. Incandescent lamps are used most often in portable residential applications for their warm, 2700K CCT. By definition, incandescents have a CRI of 100. Incandescents have a low manufacturing cost and work with both alternating and direct current. They are also inexpensive to buy, turn on instantly, and are available in a wide range of sizes and shapes (USDOE, n.d.-d) However, on the negative side, incandescents are a source of heat-driven emissions and therefore are less energy efficient, and they have a shorter life span than other types of lamps (Tanushevski, Rendevski, & Emirates, 2016).

Fluorescent Lighting

Fluorescent lighting is still commonly used in many commercial buildings because it is efficient and easily controlled (Kibert, 2016). Fluorescent lamps were originally not known to provide good color rendition but the introduction of rare-earth phosphors made this feasible. Fluorescents are gas-discharged lamps using electricity to excite mercury, therefore fluorescents are not environmentally-friendly (Tanushevski et al., 2016). Nonetheless, mercury content in fluorescents has gone down to about 3 milligrams, compared to the previous 15 milligrams. Most fluorescents have an "internal protective shield technology" that reduces the light depreciation to a predicted 5% over the lifespan of the lamp (Kibert, 2016, p. 300).

All fluorescent lamps require a ballast to operate (Tanushevski et al., 2016). An electromagnetic ballast, which is less efficient than an electric ballast, primarily regulates the common T12 tube lamp. A T8 lamp, with a one-inch diameter, operates on either an electromagnetic or electric ballast and is considered the middle of the ground for efficiency of tube lamps, averaging an efficacy of around 89lm/W. The T5 lamp runs exclusively on an electric ballast and has a high efficacy of 93lm/W (Kibert, 2016). Compact fluorescent lamps (CFL) have an integrated ballast with the same base as an incandescent lamp, allowing an easy retrofit option (Tanushevski et al., 2016).

LEDs

Light-emitting diodes (LEDs) are a subset of Solid State Lighting (SSL) technology. SSL technology allows for easy flexibility for adjusting the intensity, distribution, and spectrum of light (Brodrick, 2016). Along with LEDs, there are organic light-emitting diodes

(OLEDs) and light-emitting polymers that are included in SSL (Rensselaer Polytechnic Institute, 2015). Since the development of SSL technology and LEDs, there has been a push for the implementation of this technology. The reason: “it is estimated that switching to SSL could reduce national lighting energy use by 75 percent in 2035, saving 5.1 quadrillion Btus—nearly equal to the total annual energy consumed by 45 million U.S. homes” (USDOE, n.d.-e, para. 2).

The drive towards LED lighting is a result of the many benefits that SSL lighting provides. LED lamps have a long life, up to an estimated 50,000 hours or more, reducing maintenance costs. An incandescent lamp has an average lifespan of 1,000 hours and a fluorescent lamp has a lifespan in the range of 6,000-15,000 hours (USDOE, n.d.-c) . There are clear energy savings—a clear white LED lamp can provide up to three times more luminous efficacy than an incandescent lamp (Rensselaer Polytechnic Institute, 2015). The maximum efficacy of an LED can be up to double the luminous efficacy of a fluorescent lamp (Kibert, 2016). LEDs are commonly found in cool blue color temperatures and have the capacity to change color temperatures; however, the more the lamp temperature is modified, the lower the lumens and LPW (Walerczyk, 2014). However, changing color temperature for colored lighting applications is simple with LEDs because a filter is not required. Although keeping the original state of the LED may be more energy efficient, other soft savings related to color temperature may outweigh the energy savings which would support the need for tunable LED lighting. Furthermore, LEDs have a better light quality and color rendering index (CRI), allowing colors to be accurately perceived by the human eye. SSL is also fundamentally safe, cool to the touch, generally low voltage, and durable (Rensselaer Polytechnic Institute, 2015).

The Department of Energy has created a table showing the energy comparison of the three different kinds of lamps that have been discussed (see Table 1).

Table 1

Comparisons Between Incandescents, CFLs, and LEDs (USDOE, n.d.-c)

Comparisons between Traditional Incandescents, Halogen Incandescents, CFLs, and LEDs						
	60W Traditional Incandescent	43W Energy-Saving Incandescent	15W CFL		12W LED	
			60W Traditional	43W Halogen	60W Traditional	43W Halogen
Energy $ Saved (%)	-	~25%	~75%	~65%	~75%-80%	~72%
Annual Energy Costs*	$4.80	$3.50	$1.20		$1.00	
Bulb Life	1000 hours	1000 to 3000 hours	10,000 hours		25,000 hours	

*Based on 2 hrs/day of usage, an electricity rate of 11 cents per kWh, shown in U.S. dollars

Lighting Benefits

The benefits of lighting are broken into two categories: qualitative and quantitative. Non-visual effects such as health and well-being are soft savings and are typically more qualitative; this is a current area of much research. Included in the qualitative benefits are the visual environmental benefits that can influence a human being's perceptive vision of his or her built environment. Economic savings are quantitative in nature and include the cost and energy savings, tax rebates, and even maintenance savings (Walerczyk, 2014). The five categories of human centric lighting (HCL)—circadian rhythms, mood, visual acuity, energy savings and sustainability, and improved productivity—are all addressed here, divided into two overarching categories (Walerczyk, 2014).

Qualitative Benefits

Lighting has been established as a contributor for many health-related topics. A current and fertile topic of research, lighting-related problems and benefits to health are being discovered every day. Although it is important to acknowledge lighting as a significant contributing factor, typically other factors are also in the equation for any health-related problem or benefit. This section will cover different behavioral attributes that prior research has shown related to lighting.

Circadian rhythms. Before the creation of artificial light, the cycle of natural light was the only light that existed. This cycle had a pattern that started out in the morning with a low light level and warm correlated color temperature (CCT), a high light level and cool CCT during mid-day, a low light level and warm CCT in the evening, and an extremely low light level and warm CCT through the night. Before artificial lighting, we spent 90% of our day outside, but with the invention of artificial lighting, the average human spends 90% of his waking time under electric lighting (Walerczyk, 2014). It is very possible that the senior population spend more than 90% of their waking hours inside.

The problem with this (relatively) new habit is that CCT remains constant in typical indoor environments, instead of the variation of CCT found in the natural environment. Hormone production is dependent on the lightness and darkness one experiences. With a natural circadian rhythm, the body produces the hormones dopamine, serotonin, and cortisol during the day and melatonin during the night. Melatonin is a natural hormone that promotes drowsiness and sleep (Rea et al., 2011; Terrapin Bright Green, 2012; Walerczyk, 2014).

With the discovery of the third photoreceptor, the ipRGC, a large amount of research on how light can influence the circadian rhythm resulted. These cells are important in the process of resetting our internal clocks and are particularly responsive to blue light (Konis, 2017; Walerczyk, 2014). These cells demonstrate peak sensitivity in the 460-500 nanometer range (International WELL Building Institute, 2017; Konis, 2017; Rea et al., 2011; Walerczyk, 2014; White et al., 2013). This blue light suppresses melatonin but increases dopamine, serotonin, and cortisol, resulting in higher alertness, productivity, and muscle coordination. Red light, on the other hand, helps increase melatonin and is considered to be in the 570-650 nanometer range. When converted to CCT, it is safe to assume that a higher color temperature suppresses melatonin levels and a lower color temperature helps increase melatonin. Therefore, exposure to blue light before bedtime has an effect on a human's internal clock, resulting in disrupted sleep-wake cycles, restlessness, and wandering (van Hoof, Aarts, Rense, & Schoutens, 2009).

This leads back to the discussion on dose. "Exposure to light is the most important stimulus for synchronizing the biological clock, suppressing pineal melatonin production, elevating core body temperature, and enhancing alertness" (van Hoof & Kort, 2009, p. 146). It is important to have the correct dose of blue light (spectrum) at the right intensity for a proper amount of time, also known as exposure. During the day, blue light should be predominant to facilitate the production of dopamine, serotonin, and cortisol. Before one goes to sleep, it is essential that red light dosage be implemented to help with the production of melatonin.

Light used during the night should also be on the red spectrum of color temperature, in order for the circadian rhythm to not be interrupted. Ironically, night lights are on the higher kelvin color temperature spectrum, which is the blue side of the spectrum. Some digital alarm clocks have a blue light interface. For example, in hospitals, work lights that the nurses use during the night lean towards the blue spectrum of color temperature (White et al., 2013). Typically there are no light sources currently in hospitals that provide this valuable simulation of the circadian rhythm (Figueiro et al., 2015). For the same reason, it is important to consider the spectrum of light located in residents' rooms in senior care living facilities, keeping in mind that nurses or health care providers will turn these lights on during the night. Circadian rhythms can become sensitized to dim light if a bright blue exam light over the bed is constantly switched on during the night or if residents have bright daylight exposure before going inside for the evening (White et al., 2013). Overall, good circadian rhythm allows people to be alert during the day and to sleep well during the night (Walerczyk, 2014).

The Lighting Research Center at Rensselaer Polytechnic Institute has completed a great deal of research on lighting to help the circadian rhythm, including many articles and research studies by noted researcher Marianna G. Figueiro. There is a circadian stimulus calculator designers may use to select light levels and sources that will contribute to effective circadian rhythms. It is important to note there is not one specific optimal light output level and designers should not rely heavily on CCT; designers should request the spectral power distribution (SPD) of the light sources from each manufacturer (Figueiro et al., 2016). For further reading about lighting for circadian stimulus, see Appendix A.

Mood. Besides the hormones discussed in the previous section, there are many other mood related issues directly related to lighting. Seasonal affective disorder (SAD) is one of the known moods. According to the American Psychological Association, around 10 million people in America are diagnosed with SAD. It is often treated as a form of depression. Symptoms can occur when natural light is not prevalent; they include mood changes, loss of appetite, and disrupted sleeping patterns. Light on the blue end of the color temperature spectrum with a high foot candle output is typically used to treat this disorder, but before LEDs, these were high consumers of energy. With the introduction of LEDs, there are now blue lights that have better efficacy and wattage (Walerczyk, 2014).

The absence of proper lighting application in many of the older, existing care facility has resulted in many different symptoms. As discussed above, one of these symptoms is an unstable circadian rhythm, resulting in depression, napping during the day, wakefulness during the night, no clear pattern of when to wake up and when to sleep, experiencing hunger at odd times, and loss of cognitive ability (White et al., 2013).

The lighting elements that largely influence these behavioral symptoms are spectrum, intensity, duration, time of day, color rendering index (CRI), and photic history (White et al., 2013). The flexibility of these elements to change throughout the day is key.

Finally, control systems and the accessibility for these to be coordinated with the occupants' behavioral patterns is another aspect that plays an important role.

Prior to tunable white light, bright light therapy was a common practice to help with behavioral symptoms, such as depression, agitation, and physical or verbal abuse (Figueiro et al., 2014). Studies show mixed results. Some showed that exposure to bright white light (2,000 lux) for an hour in the morning resulted in better nighttime sleep and reduced evening agitation (sundowning), while other studies showed an increase in agitation (Chaudhury et al., 2013; Figueiro et al., 2014). Kim, Song, and Yoo (2003) compiled a comprehensive review of previous bright light therapy research projects and concluded that the development of this therapy still had methodological flaws such as the amount of dosage to apply, the time of the day, and objective outcome measures to make a claim on the effectiveness of bright light in treating behavioral disorders. Today, light therapy has shifted towards tunable white light throughout the day instead of small amount of bright light dosages throughout the day.

Improved productivity. For the purpose of this study, the term productivity is used to describe the senior residents' functional quality of life. It covers a wide span of physical operations including wayfinding and navigation throughout the space, mobility, and instrumental activities of daily living such as the ability to read, write, dress, and eat (Pérès et al., 2017). This includes the ability of the residents to control their indoor environment as desired or needed for their participation in various tasks.

Hedge and Rhodes (2009) explored the gap between recommended light levels and what the elderly thought of such light levels. The research showed that most elderly people did not feel confident navigating through the environment when they encountered low light levels around 8.0 fc-22.6 fc. Elderly eyes take longer to adapt to lower light levels; therefore, in the built environment, the transition area between outdoor and indoor spaces, such as the lobby and entrance way, needs high lighting illuminance levels. This is an important aspect of the user's capacity to navigate the space successfully.

Visual acuity. Visual acuity is defined as the sharpness of vision, measured by the ability to discern objects such as letters or numbers at 20 feet away (Walerczyk, 2014). Inadequate lighting affects a human's visual acuity (Brawley, 2001). Visual acuity is a factor associated with many falls in senior living facilities.

The color of light affects visual acuity. Light sources with higher amounts of blue make the eye's pupil smaller, resulting in better visual acuity and allowing one to see more clearly. The measurement of blue in a lamp is measured on a ratio of scotopic to photopic (S/P), which is the spectral distribution and pupil size, respectively. "Higher S/P values indicate more blue in the light spectrum" (Walerczyk, 2014, p. 189).

Another aspect of visual acuity that needs to be considered for senior care facilities is the deteriorating vision of older people. Eiia (2013) describes this clearly:

> The eyes of an older adult become more sensitive to glare. The pupil becomes smaller and less responsive to variations in light. The lens of the eye begins to lose elasticity, which leads to loss of focusing power or lens accommodation known as presbyopia. On top of that, the lens of the eye will gradually yellow with age, making it difficult to see differences in color like blue, blue-green and violet. Bulbs with a color rendering index, or CRI, of 80 will improve sight because of improved color rendering. (p. 18)

The aging population is also sensitive to short wavelengths. "The optical density of a normal, 60-year-old person's crystalline lens is about 0.2 greater at short wavelengths than a 20-year-old observer's; thus, the relative crystalline lens transmission for a normal 60-year-old at short wavelengths would be 63% of that a normal 20-year-old" (Mariana G. Figueiro et al., 2015, p. 325). This means that a 60-year-old observer will perceive that a blue light is 25% closer than the same light would appear to be to a 20-year-old.

Another study shows good lighting illuminance levels reduces falls, infection rates, and creates a sense of safety and security (Huisman, Morales, van Hoof, & Kort, 2012). Most falls occur in a resident's room when getting out of bed or going from the bed to the bathroom. While other factors such as musculoskeletal problems or lack of proper equipment, handrails, or slip-resistant surfaces may lead to this issue, proper lighting levels play a role in reducing the number of falls that occur.

Besides lighting playing a role in visual acuity, the spatial characteristics and surface finishes are also factors warranting consideration. When addressing surface finishes, it is important to consider light reflectance values (LRV), or what percentage of light is being reflected off the surface. Another important factor is value contrast, especially at changes of planes from floor to wall or stair tread from riser. The recommended minimum value contrast is 30 (Illuminating Engineering Soceity of North America [IESNA], 2016, p. 16). The greater the contrast, the easier it is for a user to be aware of an elevation change while navigating through the space. Surface sheens are also important to consider as a gloss finish will likely cause glare, therefore it is recommended that floors have a matte finish. Texture can be good because it provides a sensory experience and subtly hints visual cues. Finally, the use of patterns can mask important visual cues or confuse the user. For example, change in floor finishes without a change in elevation can result in the user thinking there is a step down or up where there is none.

Not only is the visual acuity of the resident and staff important, the visual acuity of the staff is also a key factor. Huisman et. al. (2012) made a direct correlation between lighting and the decrease of errors made by the staff. The rate of prescription-dispensing errors is associated with illuminance levels.

Quantitative Benefits

There are many economic benefits stemming from SSL use in buildings. Included in this discussion are energy savings, labor savings, tax rebates, and other incentives. There are also an increasing number of tax deductions and rebate incentives for efficient building systems, including the implementation of LED lighting systems. As mentioned previously, there are also strategies on how to save labor costs in proper maintenance of these systems throughout the building, such as designing with a maintenance plan in mind from the very beginning.

Energy costs. SSL, such as LED lighting, are at present the most energy efficient and sustainable lamp option available. LEDs have a low carbon footprint and contain no mercury content, as is true of compact fluorescent lamps (Walerczyk, 2014). LEDs and OLEDs are compact in size, have long life, and are inherently dimmable and controllable—all factors in reducing their energy usage. The U.S. Department of Energy (USDOE) has an SSL Lighting program focusing on promoting R&D to advance SSL technologies. Despite fast-paced development, SSLs are still in the early stages of adoption, and the USDOE claims that "when it comes to U.S. energy savings, almost 95% of its potential remains untapped" (USDOE, n.d.-a, para. 2).

Incentives. There has been an increasing amount of tax deductions and rebate incentives for building more efficient systems, including the implementation of LED lighting systems. A good resource to find current rebate and incentive programs is the Database of State Incentives for Renewables & Efficiency (DSIRE), funded by the DOE. Another useful resource is RealWinWin, a private company that helps find rebates and fill out rebate applications (Walerczyk, 2014).

The Energy Policy Acts of 1992 and 2005 provided incentives for efficient lighting systems (Winchip, 2005). The 2005 policy provided a tax deduction for energy-efficient commercial buildings, with a maximum incentive of $1.80 per square foot. Although the Energy Policy Act of 2005 has expired, owners of new or existing buildings were able to receive this rebate if they installed interior lighting, along with other eligible efficiency technologies, to reduce their building's total energy and power cost by 50% or more compared to the minimum requirements as established by ASHRAE Standard 90.1-2007 (*Energy Policy Act of 2005*, 2005).

The Consortium for Energy Efficiency (CEE) of the United States and Canada has a list of initiatives and initiative resources including a 2017 Commercial Lighting System Initiative that highlights "currently active voluntary efficiency programs aimed at reducing energy consumption in commercial lighting systems" (Hart, 2017, para. 1). There are three project types that qualify for different incentives: lamp replacement, fixture retrofit, or lighting system design or redesign. Different incentives include mail-in rebates, prescriptive rebates such as T8 retrofit programs, and incentives per W or kWh reduced (Hart, 2016). "Most rebates organizations require T8 lamps and electronic ballasts to be approved by the CEE" (Walerczyk, 2014, p. 160). To read more about the CEE, see Appendix A.

Building assessment programs such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, and the WELL Building Standard are also incentives to implement an efficient lighting system. Both existing and new buildings can achieve these certifications. Interior artificial lighting is only one component in a series of different requirements to achieve full certification. The United States Green Building Council's (USGBC) LEED program has one available point for healthcare interior lighting, requiring individual controls for at least 90% of staff areas, controls accessible from residents' beds, and multi-zone control systems that enable occupants to adjust the lighting with at least three levels or scenes (United States Green Building Council [USGBC], 2017, p. 131). Part L of the UK's assessment system, BREEAM, recommends the use of energy efficient luminaire fittings above 60lm/W (Agrawal, 2017). Finally, the WELL Building Standard has an entire section on lighting that focuses not only on control locations and flexibility or energy efficiency, but on occupants' health, including lighting for circadian rhythms, melanopic light intensity, surface reflectivity, color quality, visual acuity for focus, and glare avoidance (International WELL Building Institute, 2017, pp. 94–102).

Maintenance savings. As mentioned previously, there are also strategies on how to save labor costs in proper maintenance of these systems throughout the building. One aspect of maintenance is relamping, of which there are two kinds: spot relamping and group relamping (Walerczyk, 2014, p. 13). Changing one lamp when each individual lamp goes out (spot relamping) ends up being more expensive than changing a group of lamps when they reach 70% to 80% of their rated lamp life (Walerczyk, 2014, p. 13). Limitations on the amount of different lamp types used should also be enforced (Walerczyk, 2014, p. 9), because this adds to the complexity of maintenance.

Figure 1. Tunable lighting in the hallway at ACC Care Center.

Case Study: ACC Care Center

A crucial research project by the Department of Energy's GATEWAY program was to install and document the performance of tunable-white LED lighting systems in several spaces in a senior living facility in Sacramento, California—the ACC Care Center (formerly known as The Asian Community Center of Sacramento Valley). The project involved installing retrofit tunable-white lighting systems in the resident rooms and bathrooms, corridors, and nursing stations. The key results from this project relate directly to the health, environmental, and economic benefits of lighting:

- Energy savings for the tunable white LED luminaires used in the corridors was 68% relative to the fluorescent system based on the LED system's reduced power and the automatic dimming implemented.
- Illuminance levels in resident rooms and bathrooms were inadequate with the older fluorescent system but exceeded IES recommendations for the over 65 age group with the LED system.
- Color consistency for the tunable white LED luminaires used in the corridors, nurse station, family room, and administrator's office was very good among luminaires and very good over the dimming range.
- The combination of spectral tuning and dimming with the LED systems in the residents' rooms, the adjacent corridor, and the nurse station provided the opportunity to stimulate the ipRGCs (intrinsically photosensitive retinal ganglion cells) during the times of day when melatonin suppression is desirable (morning and mid-day), and to reduce stimulation of the ipRGCs during times of day when melatonin production is desirable (evening and night).
- The amber LED lighting installed under the beds and in the bathroom handrails, controlled by motion sensors, proved very effective for providing low-level nighttime lighting that supported safe navigation while likely minimizing the stimulation of the ipRGCs.
- Although this pilot study involved a very small number of rooms and residents, ACC Care Center staff documented important health-related benefits that may have been (at least in part) attributable to the lighting changes. For example, target behaviors such as yelling, agitation, and crying

were reduced by an average of 41% for the three residents. Nursing staff noted that all three residents had been consistently sleeping through the night since the installation, and that psychotropic and sleep medication use had been significantly reduced for one of the residents whose room was included in the trial installation. (Davis, Wilkerson, Samla, & Bisbee, 2016, pp. iii–iv)

Current Practices in Senior Living Facilities

Types of Senior Care Living

There are several different classifications of senior living facilities. The two overarching categories are independent and assisted. Independent senior living facilities include senior living communities where there are apartments or houses that are geared towards elderly individuals who can independently live by themselves and do all the necessary activities of daily living (ADL) unassisted. The line between independent and assisted living facilities becomes blurry beyond this point. Some independent living facilities will offer assistance for ADL for an added cost. Assisted living facilities began to branch out into more dormitory-styled facilities with individual resident rooms where nurses are on staff 24/7 assisting with ADL. Further assistance beyond five daily activities branches into skilled nursing facilities. Finally, memory care units are for residents with dementia and Alzheimer’s and are housed in a locked wing of the assisted living facility.

Typical Layout

Most residential senior living facilities follow the same form and structure of hospitals, with the only difference being the residential function. The floor plans typically resemble that of a row of attached homes. Typically, the rooms follow a repetitive pattern, like that of a hospital, and the overall form takes an L, H, or U-shape as this allows for a narrow depth building allowing for flanking units on each side of a central corridor, also called a double-loaded corridor. There is typically more than one wing, often organized in a radial form with fully enclosed paths of circulation (Ching, 1996; Rengel, 2007). Also, aesthetics are low priority because economic and functional constraints on institutional nursing homes take precedence. Regional materials are sometimes employed in an attempt to make the building environment aesthetically pleasing (Feddersen & Lüdtke, 2009).

Typical Lighting Scenarios

Most facilities do not have LED lighting and employ basic surface-mounted fixtures with either incandescent or CFL lamps. Commonly found above a resident's bed is a wall mounted cool fluorescent light tube with a long string dangling down to the bed, giving the resident easy control of the light. Traditionally, many facilities provided over-the-bed lights because it was believed that this was part of the federal requirements, however, federal nursing home requirements (F-256) only require lighting that is comfortable and adequate for the tasks at hand (Cutler & Kane, 2005). The over-the-bed lighting scenario is not ideal in many ways. For example, it provides light at the wrong color temperature at night, assuming this is the last light to be turned off before the resident retires for bed. All other lights are at low illuminance levels and the controls are typically switches that are not within the residents' reach (Huisman et al., 2012; White et al., 2013).

Recommended Lighting Practices

There are several governing boards that establish lighting level standards for every typical area in each building occupancy type. These governing boards include the Illuminating Engineering Society (IES), National Fire Protection Association (NFPA), and the Occupational Safety and Health Administration (OSHA).

Required Lighting Regulations

In the National Fire Protection Association (NFPA), there are specific code requirements in the NFPA-101 Life Safety Code, stating the following:

> **7.9.2.1.1** Emergency lighting facilities shall be arranged to provide initial illuminance that is not less than an average of 1 ft.-candle (10.8 lux) and, at any

point, not less than 0.1 ft.-candle (1.1 lux), measured along the path of egress at floor level.

7.9.2.1.2 Illumination levels shall be permitted to decline to not less than an average of 0.6 ft.-candles (6.5 lux) and, at any point, not less than 0.06 ft.-candles (0.65 lux) at the end of 1½ hours.

7.9.2.1.3 The maximum-to-minimum illumination shall not exceed a ratio of 40 to 1. (National Fire Protection Association, 2018, p. 101–87)

Recommended Lighting Specifications

According to the IES, in *The Lighting Handbook 10th Edition*, the recommended lighting application for a senior care facility, classified under Health Care, should follow certain guidelines. These address the color quality of light, germ and dust management, lighting controls, systems coordination, hazardous materials, medications, and medical equipment interference (Illuminating Engineering Soceity of North America [IESNA], 2011, p. 27.3).

All lamps should have a CRI ≥ 82, because light has a large effect on skin tones, which affects the caregivers' assessment of the resident's condition and the resident's self-esteem (Illuminating Engineering Soceity of North America [IESNA], 2011, p. 27.3).

For germ and dust management, luminaire finishes, lenses, and dust covers can help. This is an ongoing management issue, and specific maintenance directions should be given to ensure proper cleaning is executed, because this will have an effect on the UL and IP ratings of the fixture (Illuminating Engineering Soceity of North America [IESNA], 2011, p. 27.3). This is known as luminaire dirt depreciation (LDD).

Lighting controls should be kept within reach of all operating patrons. For resident courtesy lighting, in resident rooms or common areas for the resident's use, controls should be kept easily accessible for the resident. All other controls should be located for easy access and functionality of the staff (Illuminating Engineering Soceity of North America [IESNA], 2011).

There are several control options to help match daylighting in artificial interior lighting. There are exterior sensors that will sense the outdoor light levels and tune the indoor lighting in coordination. There is also a 365-day digital clock programmed for specific locations, because the daylighting patterns in different regions of the world differ (Walerczyk, 2014).

A summary table of the recommended illuminance levels, as recommended by the IES, for the mutual spaces shared among the five facilities is shown in Table 2 (Illuminating Engineering Soceity of North America [IESNA], 2016, pp. 2–3).

Table 2
Minimum Maintained Illuminance Recommendation

Areas	***Ambient Light lux (fc)***	***Task Light***	***Notes***
Indoor circulation/lobby/lounge areas (night)	1000 (100)	500 (50)	
Indoor circulation/lobby/lounge areas (day)	200 (20)	500 (50)	
Activity/Meeting/Common Rooms	300 (30)	500 (50)	
Bedroom	200 (20)	750 (75)	Reading Work Surfaces
Bathroom	200 (20)		Min (meas. Horiz @30” AFF)
Countertop	300 (30)		Min. (meas. on surface)
Sink	500 (50)		Min. (meas. Horiz at sink)
Toilet	200 (20)		Min. (meas. @ 30” AFF)
Shower/Bathing Rooms	200 (20)		Avg. at 30” AFF
Dining Table/Desk		500 (50)	Min. (meas. on surface)
Hallways (Active Hours)	200 (20)		On the floor, within 24” radius of handrail wall
Hallways (Sleeping Hours)	50 (5)		On the floor, within 24” radius of handrail wall
Dining (Active Hours)	200 (20)	500 (50)	(on table surface)

Finally, the color temperature of the light fixtures should be adjusted through the day to facilitate a proper circadian rhythm. Light in the hallways should be programmed as shown in Table 3.

Table 3
Resident's Spaces CCT Schedule (Brodrick, 2016, p. 44)

Time of Day	CCT	% of Output
7 am – 2 pm	6500K	66%
2 pm – 6 pm	4000K	66%
6 pm – 7 am	2700K	20%

In the resident rooms and bathrooms, the change in color temperature throughout the day should follow the pattern shown in Table 4 or similar.

Table 4
Resident's Spaces CCT Schedule (Brodrick, 2016, p. 44)

Time of Day	CCT
7 am – 2 pm	6000K
2 pm – 6 pm	4100K
6 pm – 8 pm	2700K
Night-light option	2400K

This is based on the case study project by the Department of Energy for the ACC Care Center in Sacramento, CA (Davis et al., 2016). It is important to note this was the programmed script for this study and does not establish it as an optimal sequence. The sequence is dependent on the light sources and fixtures specified. To reach maximum circadian stimulus, use the circadian rhythm calculator as created by The Lighting Research Center (Rensselaer Polytechnic Institute, 2015).

Recommended Lighting Products

There are many different LED products available on the market today for a suitable lighting design in a senior care facility. Listed below are some of the products and methods of application that have good reviews per previous research and application:

BIOS lighting. BIOS technology is counteractive to the current trend towards tunable white light sources. BIOS strives to produce LEDs that are unlike typical LED products that have an unhealthy spike of blue hazardous light in the 420-450nm range and instead mimic the sky with "sky blue frequencies" range, peaking at 490nm. This sky blue is coined "good blue," "which aligns with novel circadian photoreceptor melanopsin" (BIOS, 2017, para. 5). With SkyBlue technology applied to light sources, it does not matter what color temperature the light source is because the sky-blue frequencies will give the best circadian impact. BIOS SkyBlue technology also features high efficiency and high CRI. This technology also helps with the discoloration of the lens in aging vision. Light sources with SkyBlue technology will appear white in the eyes of an elderly person with yellowing lenses. Currently, LEDRA Brands (Alphabet, Bruck, and Wila), Pinnacle Architectural Lighting, and Envirobrite Troffers have products with SkyBlue technology.

HealWell by Philips Lighting. A system developed by Philips, called HealWell, "uses high-lumen, high-CCT lighting for morning to mid-afternoon, and then lower-lumen, lower-CCT lighting for late afternoon" (Walerczyk, 2014, p. 150). HealWell is specifically designed to automatically change brightness and hue of the light throughout the day and has been tested in the cardiology department of the Maastricht University Medical Center in the Netherlands with positive results (Philips Lighting Holding B.V., 2017).

PlanLED. This product is an indirect/direct fixture with wireless controlled independent dimming and color changing up and down light. "Indirect/direct lighting with no more than 30% downlight is very good for older people" (Walerczyk, 2014, p. 209). These fixtures also allow for the rotation of the light panels to direct the beam spread either upwards, downwards, or directionally towards a wall. There are recommended horizontal and vertical illuminance levels for different applications, and this flexibility allows for adaptability in a multipurpose interior space such as a resident's room.

With the increasing popularity of available SSL products, it is hard to know where to begin a search for lamps and fixtures. Below are several different databases and approved lists as a starting point.

DLC approved lists. The DesignLights Consortium (DLC) is a non-profit organization whose goal is widespread adaption of efficient, SSL solutions. For the past 10 years, the DLC has compiled a comprehensive database called the Solid-State Lighting Qualified Product List (SSL QPL), the largest verified list of high performing LED light products. One can search this list at www.designlights.org/search.

Lighting Design Lab. Like the DLC list, the Light Design Lab also has a database of LED products. There is a list for lamp and tubes and a list for fixtures. Although this QPL has been discontinued, it is accessible until July 31, 2018. This list can be found here: www.lightingdesignlab.com/led-qualified-products-list-qpl.

Energy STAR bulbs and fixtures. Energy STAR is a well-known, established, governmental seal of approval for everything energy efficiency. There is a list of approved Energy STAR Certified Light Bulbs (www.energystar.gov/productfinder/product/certified-light-bulbs) and Certified Fixtures (www.energystar.gov/productfinder/product/certified-light-fixtures).

In conclusion, SSL technology is still a relatively new technology and the market of available products will exponentially increase in the near future. With lighting in healthcare sectors as a subject undergoing intense study and slowly becoming implemented, the next ten to twenty years will reveal many more recommendations and systems for this topic.

Chapter 3: Research Methods

This research project involved a quantitative method of collecting data in different senior facilities in Northwestern North Carolina. The study was broken into two parts. In part one, the current indoor artificial lighting conditions of five facilities were evaluated to determine if required and recommended lighting practices are being implemented. Based on the first round of data collection a single facility was selected for the second round of research, in which a retrofit design was evaluated. For the purposes of this study, the selected facility was called the "case-study facility." Further research into the economic benefits of lighting that the case-study facility could receive if LEDs are implemented occurred during the second phase of the study.

Figure 2. Map of selected facilities.
Location of the five senior care living facilities in Northwestern North Carolina: (1) Brookdale Lenoir, (2) Deerfield Ridge, (3) The Foley Center at Chestnut Ridge, (4) Forest Ridge, and (5) Life Care Center of Banner Elk.

Sample

Five senior care facilities in Northwestern North Carolina were selected for this study. The selected facilities include: [1] Brookdale Lenoir, [2] Deerfield Ridge, [3] Foley Center at Chestnut Ridge, [4] Forest Ridge, and [5] Life Care Center of Banner Elk. All of them are located within a 30-mile radius of Appalachian State University and are in four counties: Watauga, Ashe, Avery, or Caldwell County (see Figure 2).

All five facilities were contacted prior to beginning the research and an initial meeting was conducted between the primary investigator and each facility's executive director to describe the nature of the study. Written consent from each facility was received before the first round of data collection took place.

Brookdale Lenoir

Located on 1145 Powell Road NE, Lenoir, NC 28645, Brookdale Lenoir is an assisted living facility. The building is a 29,073 square-foot, single-story facility. The facility opened in 1997 and has 43 units, with a maximum capacity of 55 residents. Brookdale Lenoir is in Caldwell County. The main contact at this facility was Mark Mitchell, executive director.

Deerfield Ridge

Under Ridge Care, Inc., Deerfield Ridge Assisted Living on 287 Bamboo Road, Boone, NC 28607 was opened in 2005 and is 29,087 square feet large. There is a total of 53 rooms in the community. Before Ridge Care, the building was a retirement center called Deercroft Retirement Center. Deerfield Ridge is in Watauga County. The main contact at this community was Melissa Deskins, executive director.

Foley Center at Chestnut Ridge

The Foley Center at Chestnut Ridge is under the management of the Appalachian Regional Healthcare System and is located at 621 Chestnut Ridge Parkway, Blowing Rock, NC 28605. This facility in also in Watauga County. The newest facility, constructed in 2016 and opened on January 4th, 2017, Foley Center is an assisted-living, skilled nursing, and short-term rehabilitation community. It is a two-story building that houses a total of 112 beds. Susan Ashburn, Administrative Assistant, was the contact for this facility.

Forest Ridge

Located in West Jefferson on 151 Mt Jefferson State Park Road, Forest Ridge Assisted Living is under the same management company as Deerfield Ridge – Ridge Care, Inc. This community is in Wilkes County, a 45-minute drive from Appalachian State University. The single-story building was originally built in 2005 by Vannoy Construction as the Villages of Wilkes and leased by Forest Ridge in 2008. In 2009, Ridge Care bought the property and established Forest Ridge—an assisted living facility with a previous total of 44 resident rooms. A memory care wing was added in 2013, including a small addition and renovation, for an overally total of 51 rooms. The memory care wing is called Horizons and houses 23 rooms. The memory care wing houses 18 resident rooms. The direct contact for this facility is Cameron Keziah, executive director.

Life Care Center of Banner Elk

Under Life Care Centers of America (LCCA), the Banner Elk location is 20 miles outside of Boone, at 185 Norwood Hollow Road in Avery County. The facility is a skilled nursing home, as 75%-80% of their residents are long-term residents who either need 24/7 assistance with at least two or more of their daily activities or have extreme medical conditions requiring a nurse to be on staff at all times. There is also a wing focused on short-term rehabilitation. The executive director at this location, Sheree Byrd, was eager to have this facility involved in this research study because they will soon reopen a skilled nursing wing focused on dementia residents and their goal is to incorporate LED lighting that will help with the circadian rhythm of their current and future residents. This single-story building was constructed in 1981 and is approximately 35,000 sq. ft. in size. There are 108 beds in the facility, most of which are housed in semi-private rooms, with only eight private rooms in the entire facility.

Phase 1 of Data Collection & Analysis

Data Collection Procedures

The first major data collection for this research project was an evaluation of the current lighting applications for the five senior facilities. Five interior spaces in each facility were evaluated: a typical resident's room, a resident's bathroom, the main hallway or corridor, a common shared living room or activity area, and the dining room. Each room was evaluated by four variables: illuminance, color temperature, light reflectance values (LRV), and value contrast. Using these variables, the conditions of the existing spaces were analyzed to determine the case-study facility (see Appendix B).

General spatial characteristics. Before the four variables were recorded, the general spatial characteristics of each of these spaces was documented in accurate detail. The characteristics included the dimensions of the room; the existing fixtures and lamps and their location within the room; the overall dimensions of each room; geographical orientation of the room; number and location of any fenestrations such as windows and doors; floor, wall, ceiling, and task surfaces finishes; and any window treatment. The layout of light sources and type of lamps was recorded. The number of controls and their location and height was also recorded. Each room was photographed in detail.

As stated previously, only artificial lighting was evaluated in this study. However, the date and time of each collection were noted and recorded. In order to focus only on artificial lighting, all interior doors leading to adjacent interior rooms were shut. All natural light through windows were covered. A total black-out effect was achieved by pinning up 6-mil black plastic sheeting over all exterior wall fenestrations with a black cotton cloth over the plastic to prevent extra reflection. The size of the windows and doors was measured and recorded. The prepared interior space was recorded by another round of photographs.

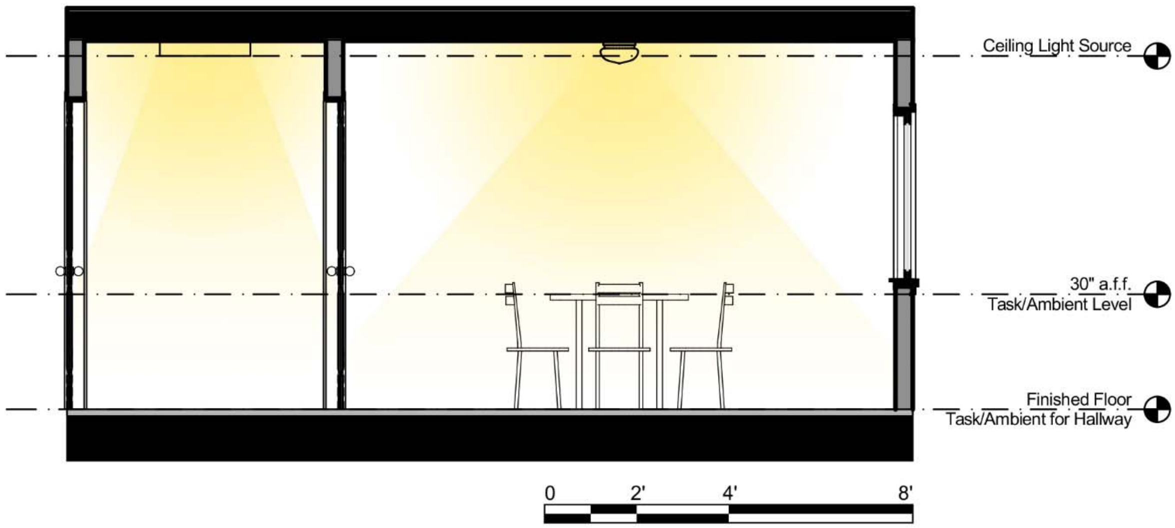

Figure 3. Generic section of room types with illuminance heights.

Illuminance. The first variable, illuminance, refers to the average lighting levels achieved within each individual space by the existing artificial light sources. For this step, a light meter, The Cooke Corporation cal-LIGHT 400 meter was used to measure the ambient and task lighting in each of the dedicated areas. In rooms where there is no dedicated horizontal task surface, such as the living room, bedroom, and shower area, ambient lighting levels were taken at 30" above finish floor (a.f.f.). In the dining room and bathroom, task areas were defined as the table surface and countertop surface respectively. Illuminance was measured at the floor for circulation paths in the hallways (see Figure 3). Task illuminance in the bedrooms was measured at the bed. In the bathroom, illuminance measurements were taken above the water closet at 30" a.f.f., and at the vanity sink at countertop level.

Depending on the layout of light sources and the shape of the room, the average illuminance was calculated by dividing all non-uniform or asymmetrical rooms into equal squares, at standard two-foot increments as recommended by the IES. The illuminance was taken in the center of each square. The light levels were recorded at a minimum of 12 different locations in each room with locations directly below a light source, between light sources at 90-degree directions and diagonally, as close to a uniform grid layout as possible (Richman, 2012). For symmetrical and uniform rooms and luminaire layouts, a method described by the IES Lighting Handbook was used to measure the average illuminance of the room. Rooms with one or two rows of light fixtures were evaluated differently than rooms with a single light source (see Figure 4).

Each room was mapped out by a detailed sketched plan showing location of points of measurements with dimensions pointing to a permanent feature in the space. In the case that a retrofit lighting system is installed, post-evaluation of the lighting levels can be compared using this pre-evaluation documentation.

Color temperature. The second variable measured was color temperature. The Sekonic C-500 Prodigi Color Meter was used for this procedure. The steps followed to obtain this measurement using the Sekonic meter follows: (1) select the ambient light mode on the meter, and (2) click the measure button to obtain a reading of the environment. The correlated color temperature (CCT) in Kelvin will appear on the screen. The color temperature was measured directly under the lamp source. If there was more than one type of lamp in the room, each lamp source's CCT was taken. As previously discussed in the limitations, the Sekonic C-500 meter had a threshold of 2400K and read as "Under."

Luminance. Value or luminance was the third variable examined. This was measured by a light reflectance value (LRV) on a percentage scale of 0 to 100, indicating the percentage of incident light that is reflected off a surface. Incident light was measured holding the meter to the surface. Reflected light was measured by slowly retracting the meter two to four inches away from the surface until a constant reading was achieved (Illuminating Engineering Soceity of North America [IESNA], 2016). An example of the LRV calculation for an incident light measuring 70 fc and the reflected light measuring 45 fc is below:

$$\boldsymbol{LRV = \frac{reflected\ light}{incident\ light} = \frac{45}{70} = 64\%}$$

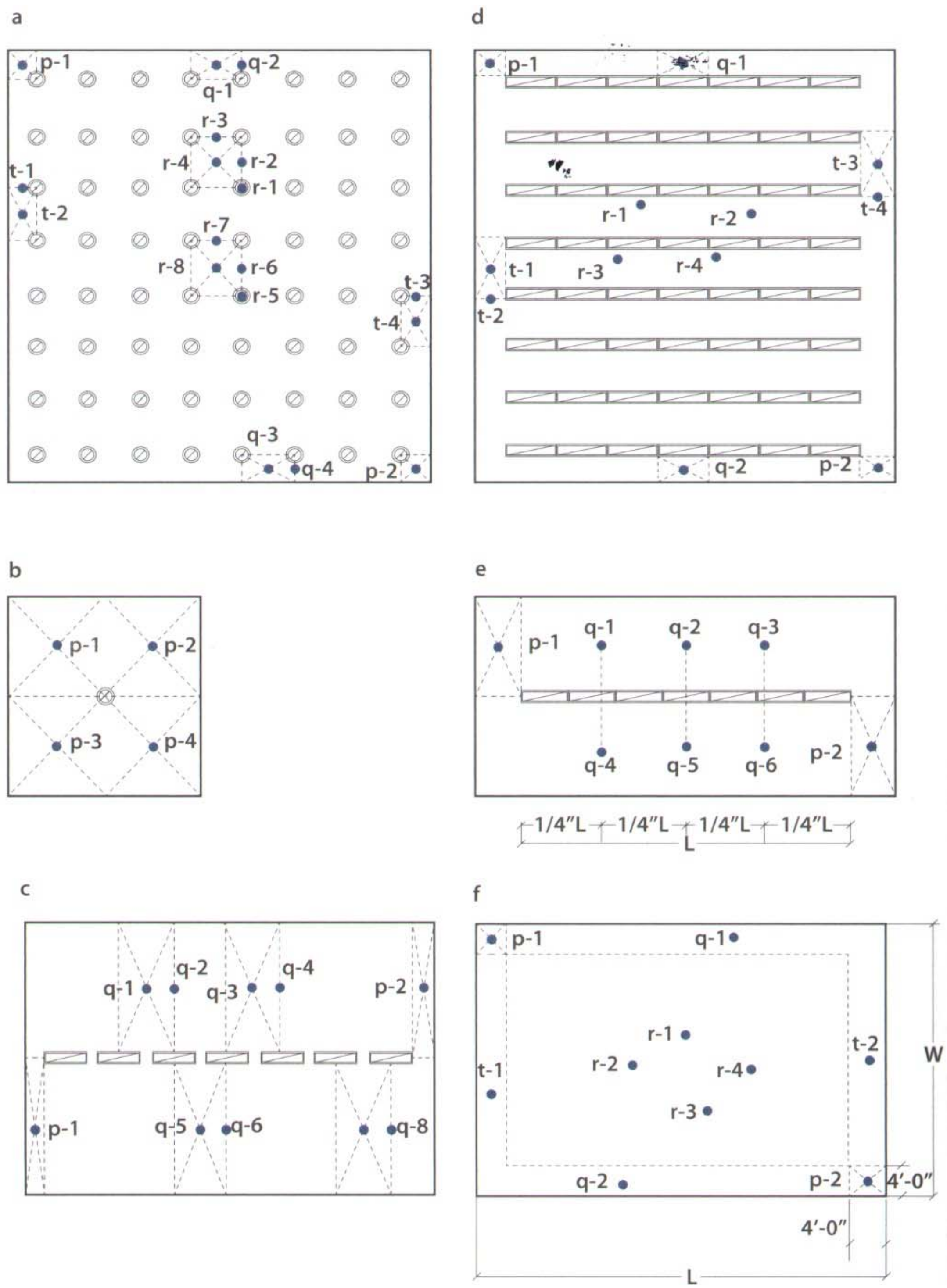

Figure 4. IES Survey measurement stations.
Locations of illuminance measurement locations for various rooms: (a) regular area with symmetrically located luminaires, (b) regular area with symmetrically located single luminaire, (c) regular area with single row of continuous luminaires, (d) regular area with two or more continuous rows of luminaires, (e) regular area with single row of continuous luminaires, and (f) regular area with uniform indirect lighting. (Illuminating Engineering Soceity of North America [IESNA], 2011, p. 9.30)

The LRV was recorded for the overall horizontal and vertical surfaces in each room. For the horizontal planes, the floor, the task surface when applicable (i.e., tables or countertops), and the ceiling was measured. The LRV for all walls within the room was also measured. Measurements were taken throughout the room in 10 different locations for each surface allowing an average LRV to be calculated.

Along with recording light level readings of the reflected light, the LRV of surface finishes was estimated on site using a Sherwin-Williams paint chip catalog and comparing finishes to the paint swatches (Illuminating Engineering Soceity of North America [IESNA], 2016). The paint color was recorded and the corresponding LRV to the color was compared to the calculated value to validate the accuracy of the measurements of reflected light.

Value contrast. The fourth variable measured was value contrast. The average LRV of the wall surface in the room was compared to the average LRV of the floor to determine a contrast value in percentage points. A minimum value difference of 30 is recommended (Illuminating Engineering Soceity of North America [IESNA], 2016).

Data Analysis Procedures

To determine which facility to select for continued detailed data collection, the four variables were analyzed and compared between the five selected senior living facilities. Each variable’s current status in each facility was compared to the recommended value. The deviation score for each variable was compared among the five facilities to determine which facility scored the lowest. The facility with the lowest score was chosen for extended data collection and analysis.

Illuminance. For non-uniform and unsymmetrical rooms, the average illuminance was calculated by adding up all the foot-candle readings taken in a two-foot grid divided by the total number of readings taken.

For symmetrical and uniform spaces, the average illuminance was calculated based on the method developed by the IES depending on the light sources layout in the room (see Figure 4). This method has been found to reliable with an accuracy of 10% (Illuminating Engineering Soceity of North America [IESNA], 2011, p. 9.28-9.30):

<u>Regular Area with Symmetrically Spaced Luminaires in Two or More Rows.</u>

The average illuminance, Ē, in such a space (see Figure 4. [a]) can be determined from

$$\bar{E} = \frac{R(N-1)(M-1) + Q(N-1) + T(M-1) + P}{NM}$$

Where:

N = number of luminaires per row

M = number of rows

R = Average of measurements at: stations r-1, r-2, r-3, and r-4 for a typical inner bay and at stations r-5, r-6, r-7, and r-8 for a typical centrally located bay

Q = Average of measurements at: q-1, q-2, q-3, and q-4 in two typical half bays on each side of the room

T = Average of measurements at: stations t-1, t-2, t-3, and t-4 in two typical half bays at each end of the room

P = Average of measurements at: stations p-1 and p-2 in two typical corner quarter bays

<u>Regular Area with Symmetrically Located Single Luminaire.</u>

The average illuminance, Ē, in such a space (see Figure 4. [b]) can be determined from

$$\bar{E} = P$$

Where:

P = Average of measurements at: stations p-1, p-2, p-3, and p-4 in all four quarter bays

<u>Regular Area with Single Row of Individual Luminaires.</u>

The average illuminance, $\bar{E}$, in such a space (see Figure 4. [c]) can be determined from

$$\bar{E} = \frac{Q(N-1)+P}{N}$$

Where:

N = number of luminaires per row

Q = Average of measurements at: stations q-1 through q-8 in four typical half bays located two on each side of the area

P = Average of measurements at: stations p-1 and p-2 for two typical corner quarter bays

The calculated average illuminance, $\bar{E}$, was then plotted against the recommended average illuminance as established in Table 2. The difference between the recommended illuminance level and the current illuminance level was calculated and plotted to determine which facility had the highest and lowest ambient and task illuminance. The two variables of ambient and task were combined to achieve an average deviation.

Color temperature. Research shows that artificial lighting should have changing correlated color temperature (CCT) throughout the day, imitating daylight. To analyze this variable, a color temperature sequence based on the case study at ACC Care was used to compare the existing color temperature measurements (Table 5).

Since all the facilities do not have correlated color temperature changing capabilities, the color temperature of each room was plotted on a table showing time of day and recommended CCT for each hour. The deviation from the recommended value was then plotted per hour. Finally, the average deviation per room was calculated.

Table 5
Recommended CCT During the Day

Time of the day	Recommended CCT
12am-6am	2700K
6am-2pm	6500K
2pm-6pm	4000K
6pm-12am	2700K

Luminance. An average LRV for the wall, floor, and ceiling of each room was calculated. The average ratio percentage was compared to the recommended surface reflectance as shown in Table 6. LRV measurements that fell within the recommended range received a score of 0. For the measurements that did not fall somewhere within the recommended range, the deviation value from the range was calculated. This was first calculated per plane—ceiling, wall, and floor—before an average deviation was calculated for overall luminance.

Table 6
Recommended Surface Reflectance
Taken from Lighting for Hospitals and Health Care Facilities (Illuminating Engineering Soceity of North America [IESNA], 2006, p. 42)

Surface	Reflectance Equivalent Range (Percentage)
Ceiling Finishes	70-80
Walls	40-60
Floors	20-40

Value contrast. A contrast minimum of 30 is recommended. Similar to the analytical procedure for luminance, all value contrasts that were 30 or more received a score of zero. All value contrasts that fell below 30 receive a negative number showing the difference between the current contrast and 30. The deviation value was plotted per room per facility to see how each facility compared to one another.

Phase 2 of Data Collection & Analysis

Selection of Case-Study Facility

The deviation scores from the recommended values were accumulated and totaled to rank the facilities from lowest to highest per the four categories. The facility with the majority lowest score in most of the variables was selected for further extended research into the economic benefits of LEDs.

Once a specific facility was selected, more in-depth data was collected from that facility to determine the details of its lighting design: specific information about the quantity, quality, and type of lighting in use, as well as typical lighting usage within the facility. The purpose of this phase of the research was to discover the economic benefits of switching to a retrofit LED system.

Data Collection Procedures

As available, any electrical plans or reflected ceiling plans were obtained from the selected facility. All available maintenance records were also obtained. A comprehensive lighting inventory was conducted on the selected facility. Electrical plans for the case study facility were updated or drafted as needed. Switching circuits and voltage capacity were identified. Using each fixture's projected wattage usage, an overall facility average energy usage for lighting was calculated. The facility was also requested to share any electric bills and the electrical rate schedule was obtained.

The facility's maintenance team was interviewed to determine the typical procedure for the maintenance of lighting. Included in the questionnaire were questions related to when lights are turned off, flexibility of lighting levels, typical daily usage of lights, and overall facility history. Below is the list of questions that were asked:

- What lights are turned off (if any), and what times are they off?
- Can you give me an estimate of how long it takes you to change one lamp?

- If you were to change all the lamps in the entire facility, what is an estimated amount of time that would take you?
- Do you clean any fixtures and if so, how often? How long does it take you?
- Can I know what kind of lamps are used in the facility? How much do these lamps cost to buy?
- What is your rate schedule? Can I get a copy of a recent electric bill?

The interviews were not recorded. The questionnaire form can be found in Appendix C. Identities of the staff members interviewed remains confidential. Handwritten notes are stored under the possession of the researcher. All typed data was stored on a personal, locked computer.

Data Analysis Procedures

The analysis process for this second phase of data collection included creating a proposal for modifications to the building's lighting design. The proposal includes a detailed lighting schedule for a retrofit lighting design for a portion of the facility to switch to LEDs. Recommended luminaires and lamps were selected, followed by a detailed schedule and preliminary estimate. Light fixtures and lamps were selected based on the "Recommended Lighting Practices" section in Chapter 2. Also, included in this proposal are energy costs savings comparing current operational costs to projected operational costs. Finally, the proposal includes an LED lighting return on investment (ROI) with initial costs of the new system included in the calculation.

The end lighting retrofit design proposal includes the following (as documented by Walerczyk, 2014, p. 150):

- kWh rate, with a breakdown of peak and normal loads
- existing number of each type of fixture
- existing wattage of each type of fixture

- existing annual hours of operation for each fixture in each room
- existing kWh of each fixture in each room
- specific recommendation for maintaining existing fixtures, fixture for fixture replacement, removing some fixtures, or complete new layout
- proposed unit wattage, kWh, cost, and rebates
- total KW, kWh, cost, and rebates
- unit financials, including payback and ROI
- total financials, including payback and ROI
- a detailed electrical plan of the entire facility with room-by-room listings with corresponding numbered map
- existing and new illuminance maps showing the overall coverage of artificial light, not including daylighting

The proposal will be offered to the management of the case-study facility as a summary of this research project and as a suggestion for implementation. If the proposal is implemented, there would be many avenues for further research on the actual health, economic, and environment benefits in comparison to the estimated, projected savings calculated in this study.

Chapter 4: Research Findings

First Round Results

The findings of the first round of data collection answered the first two research questions of this study: (1) what are the current lighting conditions at facilities in Northwestern North Carolina, and (2) how do they compare to the recommended lighting scenarios as established by the IES?

Overall, the five selected facilities share similar characteristics. All the facilities have several wings. The most common lamp is the compact fluorescent lamps (CFL), typically in decorative, surface mounted housings, typically found in residential applications. Most windows have blinds and decorative valances. The average task height throughout all the spaces is at 30 inches a.f.f. Hallways typically have a chair rail with a different wainscot finish on the bottom. There is little variation between the general spatial characteristics of each room type. Public spaces tend to be more decorative and serve a common function as community spaces for the residents. Resident rooms are generally the same square footage with an entry way leading into a rectangular-shaped room. All bathrooms are fully enclosed interior spaces without windows. A detailed description of each facility and each of the five rooms examined follows.

Brookdale Lenoir

Brookdale Lenoir is a locked facility that has four central corridors that form a rectangle around a center courtyard (Figure 5). This single-story, 29,073 square-foot building has an entry that houses the public spaces such as the main lobby, administrative offices, dining room, kitchen, and activity rooms. The overall layout of the entire facility is a mirrored, symmetrical plan. Brookdale is primarily an assisted living facility.

Figure 5. Aerial map of Brookdale Lenoir.

Activity Room. There are two activity rooms that are at opposite ends of the main corridor and are similar in general spatial layouts (Figure 6). Both these rooms have large windows to the exterior on two walls and one interior wall partition with windows to the hallway. One activity room has a small kitchenette in the corner. It is important to note that there are different kinds of light fixtures in the identical activity rooms but only one of the two rooms was observed for this study.

Figure 6. Panorama of activity room at Brookdale Lenoir.

General spatial observations. This activity room is used for a variety of different activities, such as bingo or staff trainings. There is a medium-sized kitchenette equipped with a double sink, microwave, range, and plenty of upper and lower cabinet storage. There is also a popcorn machine. The rest of the room has large 3-foot by 6-foot tables, each with chairs. The task height for the tables is 30 inches a.f.f.

Layout and configuration of room. The activity room observed measures roughly 24.5 feet by 23 feet, totaling 563.5 square feet. The ceiling height is eight feet, equaling around 4,324 cubic feet in volume. The north and east walls are exterior partitions with large double-hung windows covering about 60% of the exterior walls. The windows have decorative, pink valances as the only exterior fenestration treatment. There are also three small sliding windows and a pair of French doors on the interior partition walls looking into the main interior corridor.

Finishes. The finishes in the room are detailed in Table 7.

Table 7
Finishes in Brookdale Lenoir's Activity Room

Location	**Finish**	**LRV**
Floor	Linoleum vinyl tile (LVT) wood plank	9%
Wall	Gypsum wall board, medium beige paint	44%
Task	Plastic laminate tabletop	10%
Ceiling	Stucco textured ceiling, white paint	86%

Artificial lighting characteristics. The room is illuminated by two unique kinds of light sources (Table 8). In no organized arrangement, there are decorative surface mounted ceiling fixtures. There are four track lighting fixtures, in various lengths, approximately two feet from the perimeter of the room. The two longest lengths run along the long north and east axis, with the track heads directed toward the center of the room. The purpose for these fixtures is unclear, because there are no needed tasks occurring along the perimeter of the room. The two short track fixtures are in the kitchenette and directed towards the countertop task surface. Because the light sources are not distributed symmetrically throughout the space, the room was divided into a 2-foot grid and the general ambient illuminance was measured in the center of each grid.

Table 8
Artificial Lighting in Brookdale Lenoir's Activity Room

Fixture Type	Lamp Type	Qty
Decorative surface mounted	(2) CFL or LED	7
Track lighting	Halogen PAR	16

Illuminance. The average ambient illuminance taken at 30 inches a.f.f. was calculated to be 10.42fc. The average task illuminance was 10fc.

Color temperature. The track fixtures read as "Under" on the Sekonic color temperature meter, indicating that they are at 2400K or below. The surface mounted ceiling fixtures have a color temperature of 3350K.

Controls. There are four occupancy sensors in the activity room that turn on the lights in the room based on occupancy usage. The sensors are located at 46 inches a.f.f.

Dining Room. The dining room is divided into two areas with two wide cased openings separating the spaces. One of the areas flank the exterior walls, allowing plenty of daylight into the room. The other portion of the room sits adjacent to the central corridor and main lobby. For the sake of this study, the portion of the dining room that is adjacent to the central corridor was examined.

General spatial observations. One of the largest dining rooms observed in this study, the dining room at Brookdale had a certain residential feel because the large space was divided in two. The dining room is used three times a day when daily meals are served. There are no other activities that take place in this room. In the portion of the room that was observed for this study, there are a total of six tables that are 3-foot square.

Layout and configuration of room. The overall dimensions of this space are 32 feet 8 inches by 18 feet 8 inches, equaling an area of 610 square feet. The height of the room is 10 feet, measuring around 6,100 cubic feet of volume. Two of the four interior wall partitions have interior windows that look out into the lobby and hallway (Figure 7). The 6-foot-wide cased openings are on the north face elevation and have interior transoms. There are three French doors into the dining room and one steel door into the kitchen.

Figure 7. View of dining room at Brookdale Lenoir.

Finishes. Table 9 details the finishes in Brookdale Lenoir's dining room.

Table 9
Finishes in Brookdale Lenoir's Dining Room

Location	Finish	LRV
Floor	Mustard brown low, loop pile carpet	8%
Wall	Gypsum wall board, beige paint with chair rail	49%
Task	Dark purple tablecloth	9%
Ceiling	Stucco, textured ceiling, white paint	88%

Artificial lighting characteristics. There are decorative surface mounted ceiling light fixtures and a centrally located suspended chandelier (Table 10). The fixtures are symmetrically spaced throughout the room so the average illuminance formula for regular areas with symmetrically spaced luminaires in two or more rows was used.

Table 10
Artificial Lighting in Brookdale Lenoir's Dining Room

Fixture Type	Lamp Type	Qty
Decorative surface mounted	(2) CFL or LED	8
Track lighting	(8) Edison candlesticks	1

Illuminance. The average ambient illuminance taken at 30 inches a.f.f. of the dining room was calculated to be 5fc. The average task illuminance was 5.5fc on the tables.

Color temperature. The color temperature of the surface mounted CFLs was measured at 3450K. The color temperature of the chandelier was not measured.

Controls. There are three standard switches located by one of the entry doors into the room. The switches are one-way controls. Occupants entering through the other two entry doors do not have access to these switches. The switches are mounted at 46 inches a.f.f.

Hallway. There are four main hallways in the building that all intersect each other at the corners of the building. The hallways form an overall rectangular, mimicking the overall shape of the building. The hallway examined was the Sunshine Way Hallway (Figure 8). The artificial lighting from the other two flanking perpendicular hallways was not blocked or eliminated for this study.

General spatial observations. The hallway observed is a heavy traffic circulation path for residents as they go to and from their rooms to the public areas in the building. The hallway had low ceilings and the light created many shadows. Task height for the hallway was assumed at finished floor since the only task that occurs in this space is navigation.

Layout and configuration of room. The overall length of the hallway is 99 feet long. The width of the hallway is 5 feet, equaling a total area of 495 square feet. The height of the hallway is 8 feet tall, with a total volume of 3,960 cubic feet. There were double egress doors located in the center of the hallway dividing the space in half. A total of 13 interior doors leading to adjacent interior rooms flanked the sides of the hallway.

Figure 8. View of Brookdale Lenoir's hallway from end.

Finishes. The overall finishes selected for the hallway are monochromatic browns. Table 11 details the finishes in the hallway.

Table 11
Finishes in Brookdale Lenoir's Hallway

Location	Finish	LRV
Floor	Brown low, loop pile carpet	9%
Wall	Gypsum wall board, brownish-beige paint with chair rail	59%
Ceiling	Stucco, textured ceiling, white paint	94%

Artificial lighting characteristics. The entire hallway has seven surface-mounted ceiling CFL fixtures, six wall sconces mounted at 6 feet a.f.f., and two ceiling mounted spot lights directed as accent lighting towards two paintings on the wall (Table 12).

While the luminaires were not perfectly symmetrical, the average illuminance was calculated using the formula for a “regular area with single row of individual luminaires.”

Table 12
Artificial Lighting in Brookdale Lenoir’s Hallway

Fixture Type	Lamp Type	Qty
Decorative surface mounted	(2) CFL or LED	7
Wall sconces	(1) CFL	6
Ceiling-mounted spot lights	(1) CFL or PAR	2

Illuminance. The average illuminance of the hallway was calculated to be 3.45fc.

Color temperature. The CFLs in the ceiling decorative fixtures measured at a color temperature of 3010K while the wall sconces measured at 3100K. The two spot lights registered at a recorded low of 2350K.

Controls. There was one switch at the end of the hall mounted at 46 inches a.f.f. The switch did not turn off all the lights as some are on the emergency circuit to ensure there would always be the required illuminance for egress.

Resident’s Room. There is a total of 43 rooms in the facility. Of the 43, there are 12 semi-private rooms. The room examined (Figure 9) is a private room on the Sunshine Way Hallway. Each room has its own private bathroom attached.

General spatial observations. The bedroom is furnished with a single twin-sized bed in a traditional bed frame, a dresser, bedside table and portable table lamp, and a lounge chair. There is an adjacent closet and bathroom. The room also comes with a sink in the bedroom with adequate lower cabinet storage space.

Layout and configuration of room. The overall dimensions of the room are 14 feet by 12 feet for an average total area of 168 square feet. This is not including the entryway of the resident’s room where the door to the closet and bathroom are. The sink is also in this entry portion of the room. The ceiling height is 8 feet, equaling 1,344 cubic feet of volume. There is one twin-double-hung window as the point of emergency egress in the room.

Figure 9. Panorama of resident's room at Brookdale Lenoir.

Finishes. Table 13 details the finishes in the resident's room.

Table 13
Finishes in Brookdale Lenoir's Resident's Room

Location	**Finish**	**LRV**
Floor	Low, loop pile, brown carpet	14%
Wall	Gypsum wall board, tan-beige paint	43%
Task	Dark brown bedspread	46%
Ceiling	Stucco, textured ceiling, white paint	87%

Artificial lighting characteristics. There are three light sources in the bedroom (Table 14). There is a vanity light over the sink, a small surface mounted fixture in the entry portion of the room, and a larger surface mounted fixture in the main bedroom section. The average illuminance was taken by dividing the room into two rectangles, measuring the illuminance in all eight quadrants, and finding the average.

Table 14
Artificial Lighting in Brookdale Lenoir's Resident's Room

Fixture Type	Lamp Type	Qty
Wall-mounted vanity light	(3) CFL or LED	1
Surface-mounted fixture	(1) CFL	1
Decorative ceiling fixture	(2) CFL	1

Illuminance. The average ambient illuminance was 10fc. The task illuminance at the sink was measured at 35fc.

Color temperature. The color temperature at the vanity measured at 4240K. The larger, two-lamp, fixture measured at "Under" while the smaller, ceiling-mounted fixture measured at a color temperature of 2730K.

Controls. There are two controls to the right of the door when the occupant enters that controls both the ceiling fixtures on different circuits. There is a light switch by the sink to control the vanity light. All switches are mounted at 46 inches a.f.f. and are standard on/off switches.

Bathroom. All bathrooms adjacent to the resident's room contain a water closet and a shower stall. There is a heat lamp in each bathroom which remained off for this study.

General spatial observations. While there is a shower seat and grab bars located in all appropriate locations, the bathroom does not meet ADA standards. The overall size of the bathroom seemed very small and nonfunctional (Figure 10).

Layout and configuration of room. The overall dimensions of the room are 3 feet by 8 feet 7 inches. The shower stall measures 2 feet 6 inches by 3 feet. The total square footage of the bathroom is 25.75 square feet. The total volume comes up to 206 cubic feet with an 8-foot ceiling height. The door leading to the bathroom is 3 feet wide.

Figure 10. (Left) View of bathroom, (Right) view of sink in resident's room.

Finishes. Table 15 details the finishes in the resident's bathroom.

Table 15
Finishes in Brookdale Lenoir's Bathroom

Location	Finish	LRV
Floor	Linoleum sheet	32%
Wall	Gypsum wall board, off-white paint	69%
Ceiling	Stucco, textured ceiling, white paint	86%

Artificial lighting characteristics. The bathroom has one light source that is slightly offset above the water closet. The fixture is surface-mounted and houses a CFL, identical to the fixture in the resident's room entrance way (Table 16).

Table 16
Artificial Lighting in Brookdale Lenoir's Bathroom

Fixture Type	Lamp Type	Qty
Surface-mounted light	(1) CFL	1

Illuminance. The average ambient illuminance measured at 11.5fc. The task illuminance above the water closet at 30 inches a.f.f. read at 14fc.

Color Temperature. The Sekonic meter read the color temperature as "Under".

Controls. There is one switch on the right of the door that turns on and off the single luminaire in the space. The switch is mounted at 46 inches a.f.f.

Deerfield Ridge

Originally called Deercroft Retirement Center, the building itself was constructed in 2003. In 2005, Ridge Care bought the facility and it became Deerfield Ridge. Deerfield Ridge has four wings that radiate from the public spaces (Figure 11): the main lobby, front offices, activity room or chapel, and dining room.

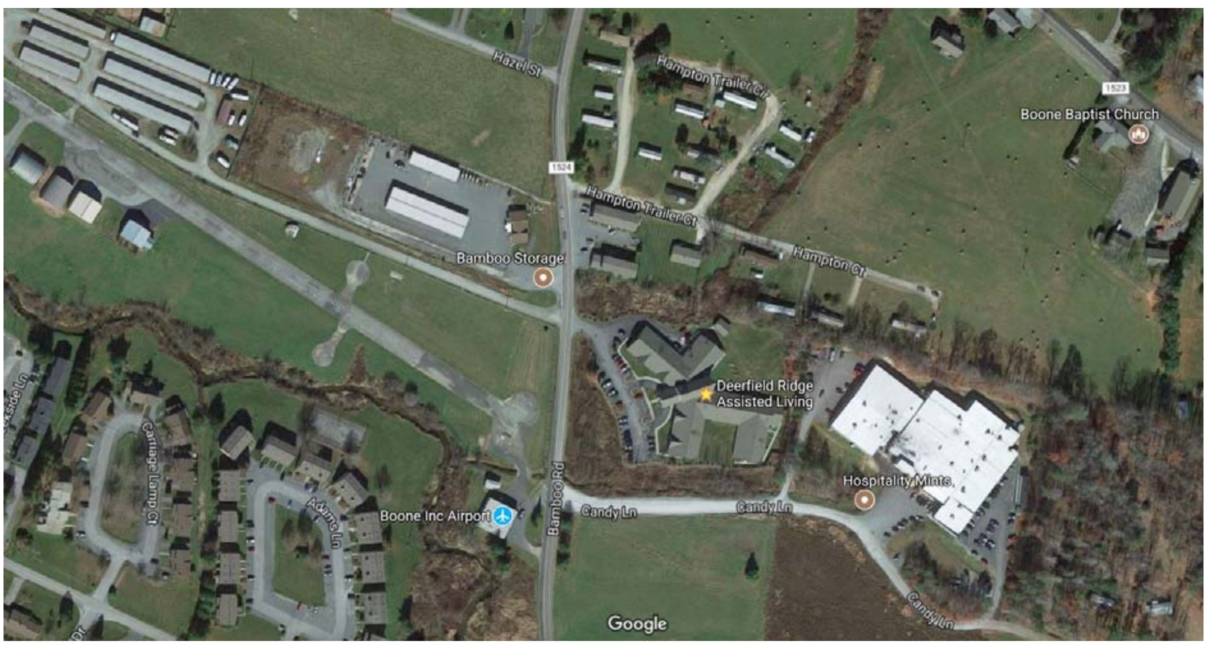

Figure 11. Aerial map of Deerfield Ridge.

Activity Room. The activity room or chapel is a large pentagon shaped room in plan view with a stage at the far end (Figure 12). Most arranged activities occur in this room. The room also serves a dual purpose as an office for the activities director. There are rows of chairs set up for activities or performances. There was one round foldable table set up when the research was conducted.

Figure 12. Panorama of activity room at Deerfield Ridge.

General spatial observations. A vaulted ceiling runs along the central axis of the building from the main lobby into a large activity room or chapel. The ceilings start at 16 feet at the lowest point and rise to a total of 22 feet. These tall ceilings pose a challenge when changing lamps in the main lobby as well as the activity room because special equipment must be rented. According to the maintenance director at Deerfield, the lamps gets changed once a year. Because of the inaccessible ceiling, the LRVs could not be measured for this room.

Layout and configuration of room. The room measures 26 feet 9 inches by 22 feet. The total area equals roughly 600 square feet accounting for the unique angular shape of the room. The overall volume of the room is estimated to be 3,500 cubic feet. There are two single doors with sidelights on either end of the south wall leading into the room. On both angled walls, there is a twin-double hung window centered in each wall. There are blinds and gray curtains over each window.

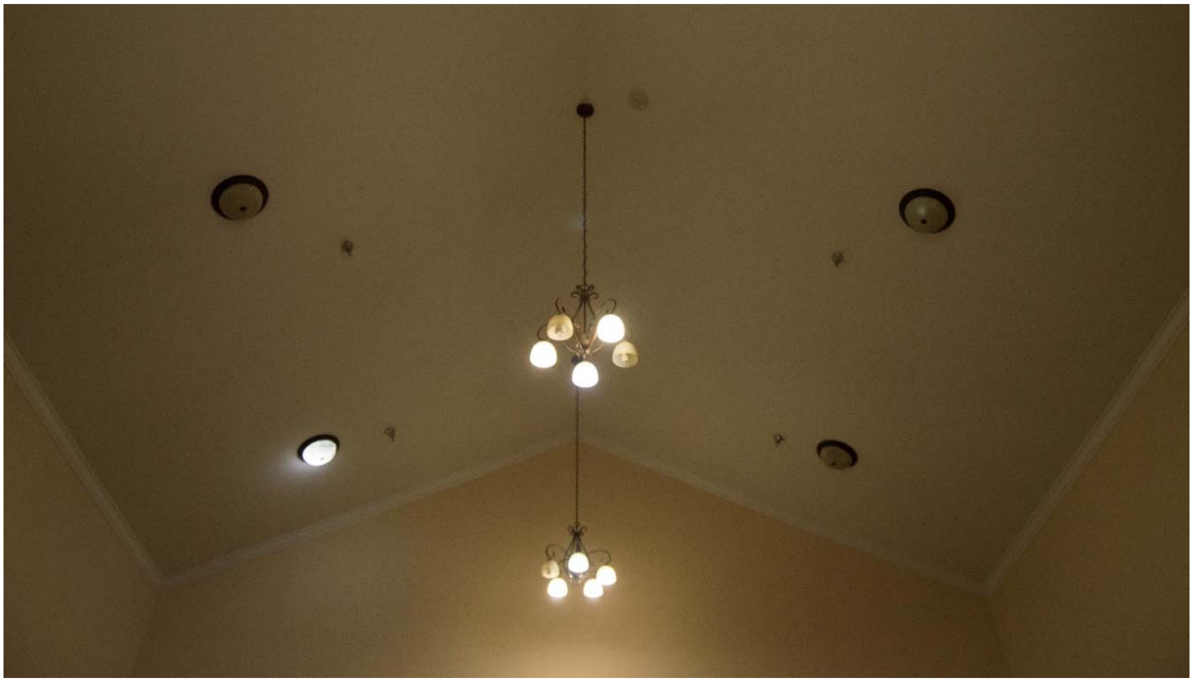

Figure 13. Photo of Deerfield Ridge's activity room's ceiling.

Finishes. The finishes in the room are listed in Table 17.

Table 17
Finishes in Deerfield Ridge's Activity Room

Location	**Finish**	**LRV**
Floor	Red low, loop pile carpet	7%
Wall	Gypsum wall board, beige paint with chair rail	61%
Task	Foldable table	60%
Ceiling	Gypsum wall board, white paint	Unknown

Artificial lighting characteristics. There are four ceiling mounted decorative fixtures and three chandeliers suspended from the ridge of the ceiling (Table 18). The fixtures are symmetrically spaced throughout the room.

Table 18
Artificial Lighting in Deerfield Ridge's Activity Room

Fixture Type	**Lamp Type**	**Qty**
Decorative surface-mount	(2) CFL or LED	4
Chandeliers	(5) CFL or LED	3

Illuminance. When the room was evaluated, more than half of the lamps were burned out (see Figure 13). The average ambient illuminance was calculated to be 8.5fc. The average task illuminance was 10fc on the table.

Approximately a month later, the researcher returned to Deerfield Ridge to reevaluate the Activity Room after all the lamps had been replaced. With all the lamps on, the average illuminance was calculated to be 12fc, only 3.5fc brighter.

Color temperature. The color temperature did not register on the Sekonic meter.

Controls. There are two standard switches located by each of the entry doors into the room. The switches are three-way controls. The switches are mounted at 45.5 inches a.f.f.

Dining Room. Beyond the central axis is the dining room. The dining room is the largest dining room of the five facilities and is equipped with a small kitchenette. There are 12 tables that measure 42 inches square. The height of the table is at 30.5 inches a.f.f. The dining room is used three times a day.

Figure 14. Dining room at Deerfield Ridge.

Layout and configuration of room. The dining room measures 47 feet by 33 feet 9 inches, equaling a total of 1,586 square feet. The room is 8 feet tall for an overall volume of 12,690 cubic feet. There are seven twin-double-hung windows on the north and east elevation, with an adjacent sunroom to the north partition wall (Figure 14). All exterior windows have decorative valances. The kitchen is adjacent to the west of the dining room. There is an egress double door in the far north-east corner of the room. Double French doors are the main entrance to the room on the south elevation. Also on the same wall are interior windows overlooking a private dining room or conference room for small groups of 10 people or less.

Finishes. Table 19 details the finishes in the dining room.

Table 19
Finishes at Deerfield Ridge's Dining Room

Location	**Finish**	**LRV**
Floor	LVT "wood" plank	20%
Wall	Gypsum wall board, beige paint	62%
Task	Pink tablecloth	12%
Ceiling	Gypsum wall board, white paint	91%

Artificial lighting characteristics. There are 13 decorative, ceiling mounted fixtures in three rows of four (Table 20). The luminaires are symmetrically arranged in the space.

Table 20
Artificial Lighting in Deerfield Ridge's Dining Room

Fixture Type	**Lamp Type**	**Qty**
Decorative surface-mount	(2) CFL or LED	13

Illuminance. The average ambient illuminance measured at 5fc. The task illuminance taken at the current table locations measured at an average of 5fc.

Color temperature. The color temperature for surface mounted fixtures measured at 2510K while the ceiling fixture in the kitchenette measured at a temperature of 2700K.

Controls. There are two switches located on the flanking right wall to the main entrance into the room. The switches are standard on/off switches that turn off all the lights in the room except for three lights.

Hallway. There are four main hallways in the facility. These hallways are the main path to egress with a single egress door with a sidelight at the end of each corridor. Two of the four hallway are separated from the rest of the building by a double egress door.

General spatial observations. The hallway is wide and visually interesting as the walls are stepped back every 12 feet, creating a break in the visually long plane. The door openings on each side are also defined by the widening of the hallway (Figure 15).

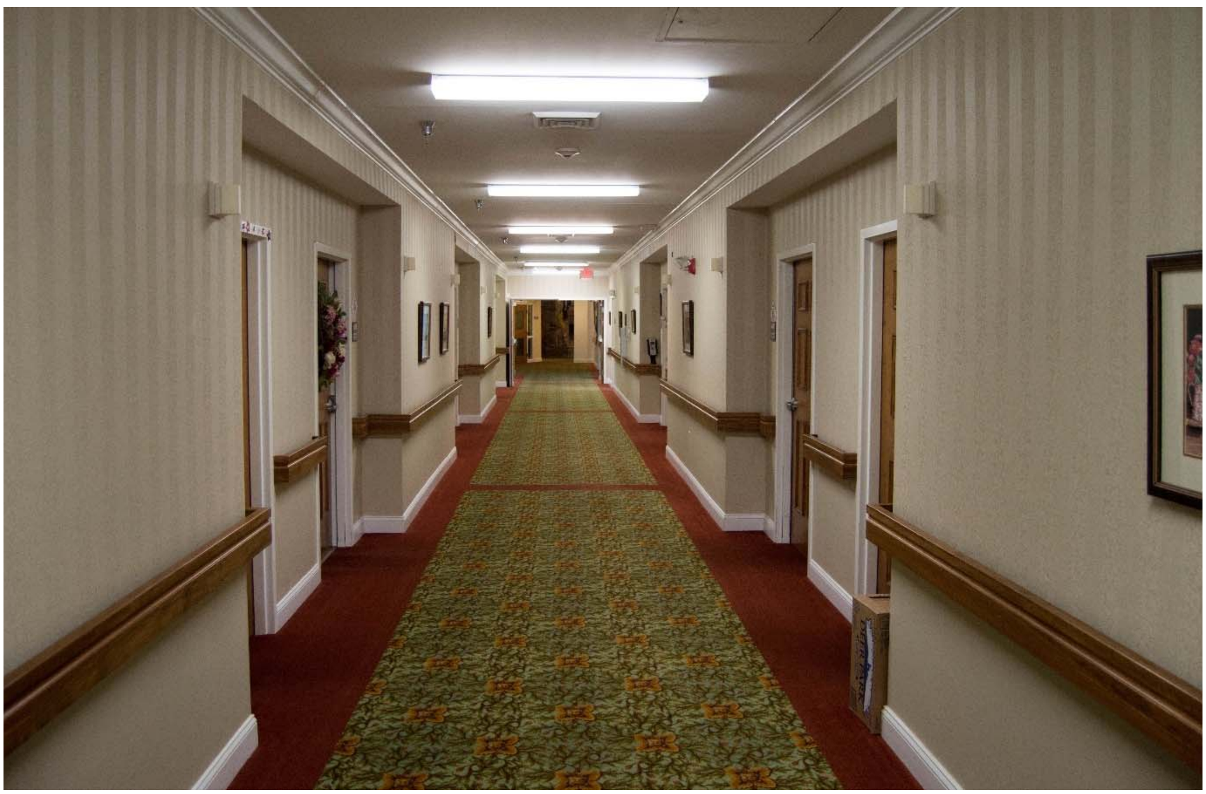

Figure 15. Hallway at Deerfield Ridge.

Layout and configuration of room. The hallway is a total length of 94 feet with the width varying between 8 to 10 feet wide. The overall area of the hallway is approximately 736 square feet. The 8 foot 10 inches tall ceilings make the overall volume of the hallway 5,888 cubic feet. There are 15 interior doors along the hallway leading to adjacent interior rooms.

Finishes. The finishes in the room are listed in Table 21.

Table 21
Finishes at Deerfield Ridge's Hallway

Location	**Finish**	**LRV**
Floor	Green patterned low, cut pile carpet with red low, cut pile carpet perimeters	6%
Wall	Gypsum wall board, beige paint with chair rail and wallpaper above	52%
Ceiling	Gypsum wall board, white paint	92%

Artificial lighting characteristics. There are eight surface-mounted 2' x 4' ceiling troffers housing a mixture of different lamps (see Table 22). There is a high possibility that the T12 troffer has an electromagnetic ballast. The luminaires are spaced evenly; therefore, the average ambient illuminance was calculated using the "regular area with single row of individual luminaires" formula as recommended by the IES.

Table 22
Artificial Lighting in Deerfield Ridge's Hallway

Fixture Type	**Lamp Type**	**Qty**
2' x 4' surface-mounted troffer	(2) T8 Fluorescent	6
2' x 4' surface-mounted troffer	(2) LED bypasses	1
2' x 4' surface-mounted troffer	(2) T12 Fluorescent	1

Illuminance. The average ambient illuminance was measured at 10fc.

Color Temperature. The color temperature measured at 3620K.

Controls. There are two controls at each end of the hallway in a three-way circuit. The manually controlled circuit is only connected to every other fixture to ensure that there is always illuminance for the path of egress on an emergency circuit.

Resident's Room. There is a total of 53 resident rooms in the facility. Each room comes with a single twin-sized bed, a dresser, lounge chair, bedside table, and portable lamp. Each bedroom has an adjacent closet and full bathroom (Figure 16).

Figure 16. Views of the resident's room at Deerfield Ridge.

Layout and configuration of room. The overall dimensions of the room measured 12 feet by 13 feet for a total of 156 square feet. The ceiling height is at 8 feet tall, equaling a volume of 1,248 cubic feet. There is one double-hung window in the room with blinds as the window treatment. There are three interior doors in the room: one leading to the bathroom, one to the hallway, and the other to a closet.

Finishes. Table 23 details the finishes in the resident's room.

Table 23
Finishes at Deerfield Ridge's Resident's Room

Location	**Finish**	**LRV**
Floor	Brownish-red low, loop pile carpet	7%
Wall	Gypsum wall board, beige paint	50%
Task	Blue plaid bedspread	22%
Ceiling	Gypsum wall board, white paint	94%

Artificial lighting characteristics. There is a single light source in the room located in the center of the main bedroom space. The source of light comes from a ceiling mounted circular fixture that houses two CFLs (Table 24). The average illuminance was measured in the center of each quadrant of the room.

Table 24
Artificial Lighting in Deerfield Ridge's Resident's Room

Fixture Type	**Lamp Type**	**Qty**
Decorative surface-mounted	(2) CFL or LED	1

Illuminance. The average ambient illuminance was calculated to be 4fc. The task illuminance hitting the bed at 30 inches a.f.f. was measured at 5fc.

Color temperature. The Sekonic meter read a color temperature of 2420K.

Controls. There is one switch to the right of the entry door that controls the one light source in the room. There are no dimmable options.

Bathroom. All bathrooms contain a water closet, pedestal sink, and shower stall. There is a shower seat and grab bars, meeting all ADA standards (Figure 17).

Layout and configuration of room. The overall dimensions of the room are 9 feet 3 inches by 6 feet. The total area is 55.5 square feet. The ceiling is 8 feet tall with a volume of 444 cubic feet. There are no exterior fenestrations.

Finishes. Table 25 details the finishes in the bathroom.

Table 25
Finishes at Deerfield Ridge's Bathroom

Location	**Finish**	**LRV**
Floor	12" x 12" brown tile	20%
Wall	Gypsum wall board, beige paint	50%
Task	Porcelain vanity sink	42%
Ceiling	Gypsum wall board, white paint	86%

Artificial lighting characteristics. There is a single source of task lighting that also provides the general ambient lighting in the room. A four-lamp wall-mounted vanity fixture is mounted 7 feet a.f.f. The bathroom that was examined has two middle lamps of the four that are retrofit LED lamps while the flanking two lamps are CFLs (see Table 26).

Figure 17. Views of bathroom at Deerfield Ridge.

Table 26
Artificial Lighting in Deerfield Ridge's Bathroom

Fixture Type	Lamp Type	Qty
Wall-mounted vanity light	(4) CFL or LED	1

Illuminance. The ambient illuminance was taken in four different locations throughout the bathroom and in the center of the shower to calculate the average illuminance at 17fc. The task illuminance above the water closet was measured at 19fc.

Color temperature. The CFL read as "Under" on the Sekonic meter. The retrofit LED lamps read at 2840K.

Controls. There is one switch to the left of the door that controls the one light source.

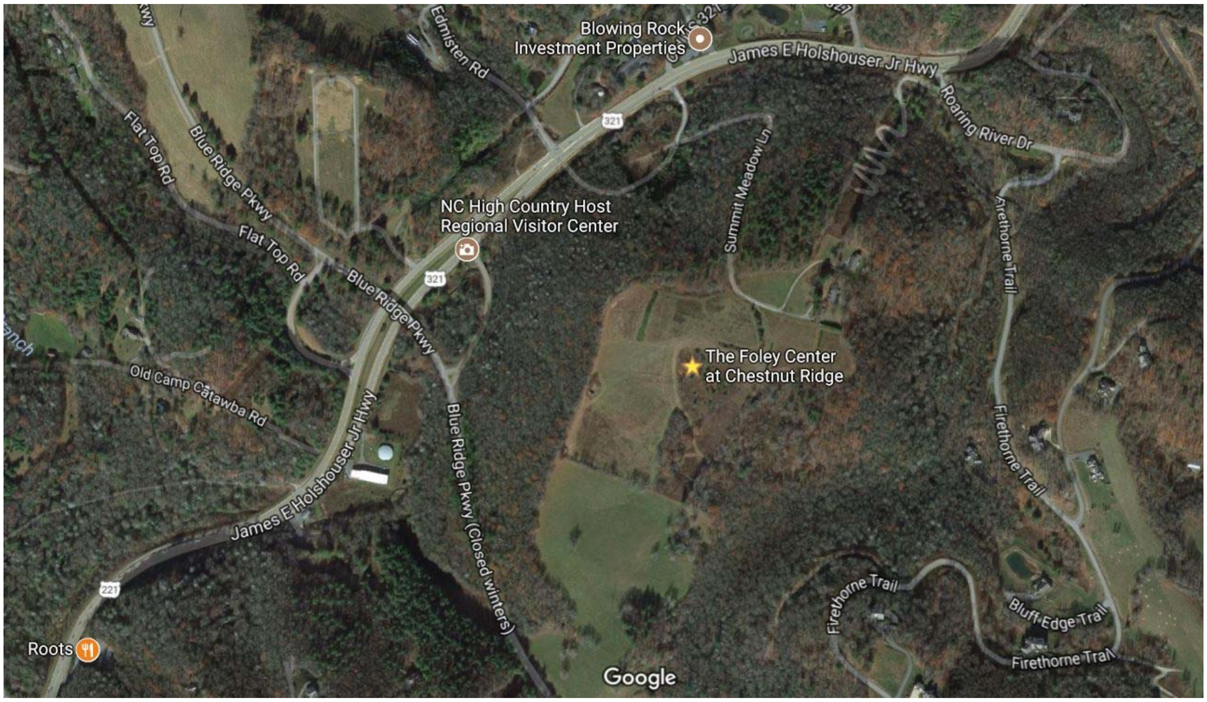

Figure 18. Aerial view of location of The Foley Center.

The Foley Center at Chestnut Ridge

The Foley Center is a two-story building with four wings or communities on the main floor and two wings on the ground level. The facility recently opened at the beginning of 2017. At the time of this study, Google Maps is not currently updated to reflect the new building and road leading to it (see Figure 18). As a subset of the Appalachian Regional Healthcare System, The Foley Center at Chestnut Ridge also includes a Village Pharmacy in partnership with Boone Drug, a Davant Medical Center, and the largest rehab gym in the region. The community that was examined for this study was Hall 300 on the main level. Of all the five facilities, the Foley Center was the only facility to completely use all LED fixtures.

Activity Room. Each community has a living room at the end of every wing. All living rooms have a large open space with tables and lounge furniture, a built-in desk with a computer in one corner, and a small niche with a couch and a built-in entertainment center. Hall 300's living room has two 3-foot by 6-foot tables and a square 30-inch table. There is bariatric accommodating furniture in the living rooms.

Figure 19. View of activity room at the end of Hall 300.

General spatial observations. Common throughout the building was the use of many different finishes. In the activity room itself, there are three different types of floor finishes and four paint colors on the wall. All living rooms (or activity rooms) have two exterior walls with floor-to-ceiling windows covering the majority of the wall surfaces (Figure 19).

Layout and configuration of the room. The overall dimensions of the large common area measures 31 feet by 24.5 feet. The TV niche measures 12 feet 9 inches by 13 feet 10 inches (Figure 20). The total area of the room is 942 square feet. With 9-foot-tall ceilings, the total volume of the room is 8,476 cubic feet. There are eight fixed windows that run from the floor to ceiling and one twin-double-hung window directly opposite of the entertainment center. All windows have blinds. There are no interior fenestrations dividing the living room from the hallway. There is an egress door leading to an emergency stairwell.

Finishes. The finishes in the room are listed in Table 27.

Table 27
Finishes at The Foley Center's Activity Room

Location	**Finish**	**LRV**
Floor	Hardwood planks	11%
Wall – South/West	Gypsum wall board, light blue paint	36%
Wall – North	Gypsum wall board, white paint	57%
Wall – East	Gypsum wall board, red paint	22%
Wall – Wainscot	Off-white wallpaper	44%
Task	Wood veneer tabletop	24%
Ceiling	Acoustical ceiling tile	81%

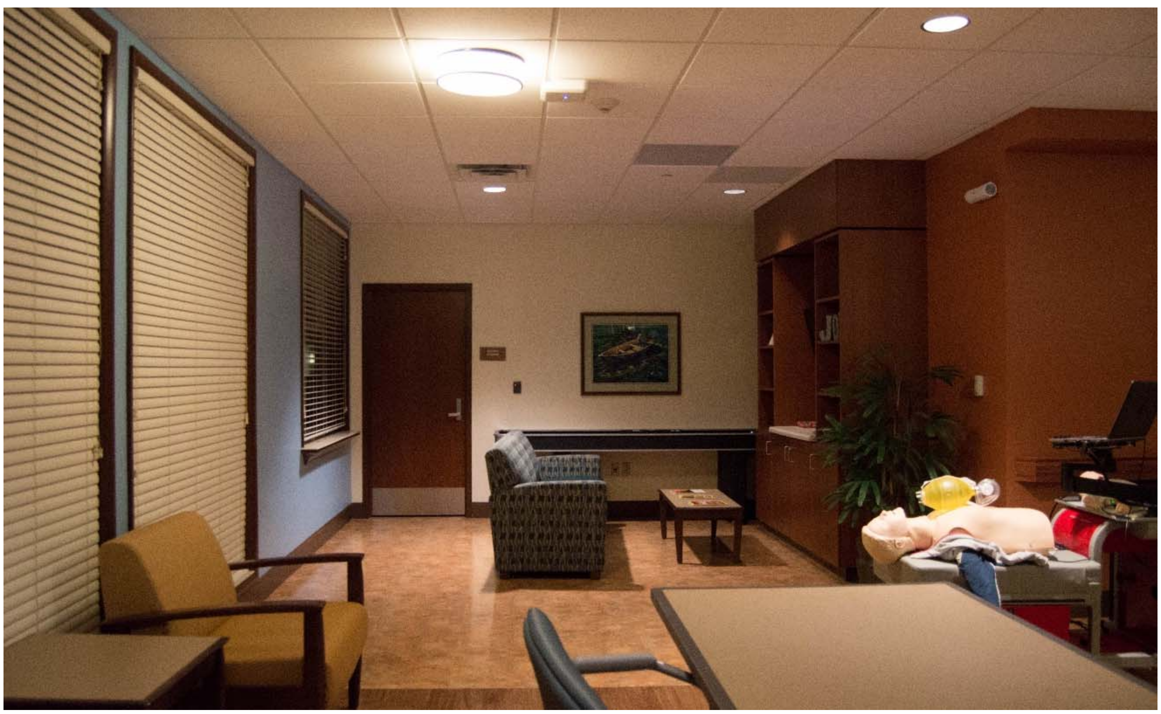

Figure 20. View of "TV niche" in each living room.

Artificial lighting characteristics. There are two types of light fixtures in the living room. The first is a surface mounted, circular housing. The second light source is a 5-inch aperture downlight with a total of 10 in the room (Table 28). The lights were arranged symmetrically with two extra downlights by the desk.

Table 28
Artificial Lighting in The Foley Center's Activity Room

Fixture Type	Lamp Type	Qty
Surface-mounted fixture	LED	5
5" downlight	LED	10

Illuminance. The average ambient illuminance measured at 9fc. The task illuminance as measured at the locations of the table averaged at 11fc.

Color temperature. The downlights have a color temperature of 2620K while the color temperature of the surface mounted fixtures registered as "under" on the meter.

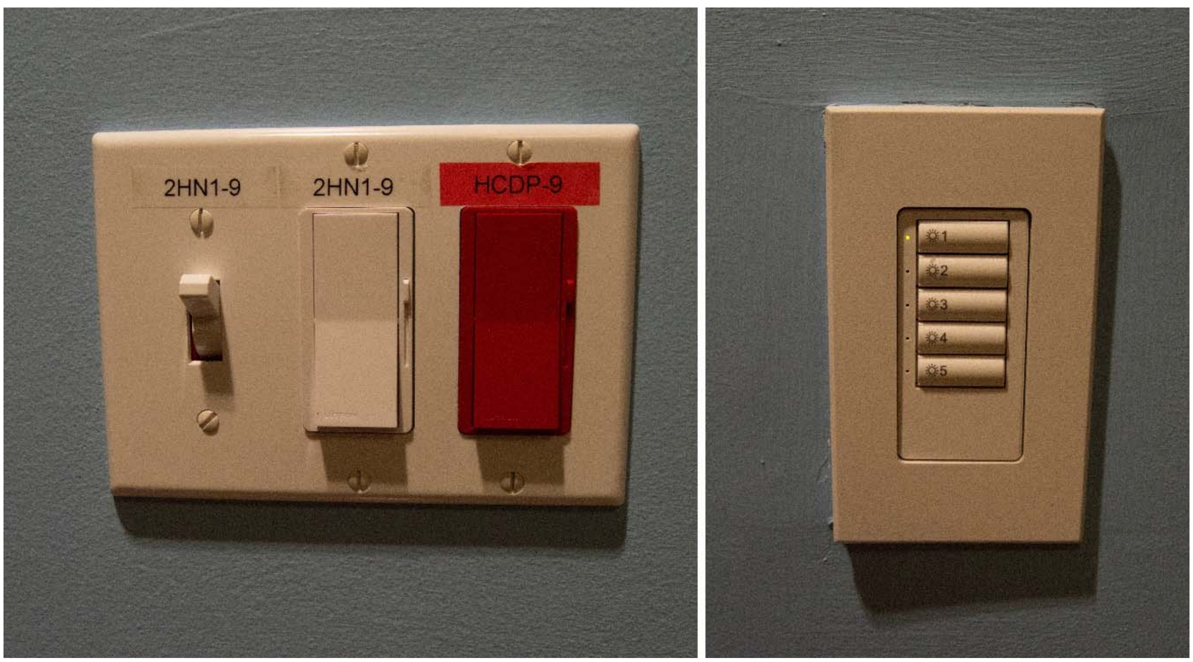

Figure 21. Types of controls in the activity room.

Controls. There is one switch by the egress door that controls all the luminaires except for three downlights on an emergency circuit. Behind the desk are three more switches, two that are dimmable controls for the downlights. There is a programmable scenes control, however, no scenes were programmed on the date surveyed (Figure 21). All controls were mounted at 48 inches a.f.f.

Figure 22. View of dining room in The Foley Center.

Dining Room. The two communities share a dining room at the intersection of the two wings. There is a total of four dining rooms in the entire building. Each dining room shares an identical shape and has a fireplace and small kitchenette with a serving island and an adjacent storage room.

General spatial observations. The dining room is an architecturally interesting room with different floor patterns and finishes, four different wall paint colors including a chair rail and wainscot finish on two of the walls, and a stone fireplace. The ceiling plane consists of drop down soffits to define the space, with the majority finish an acoustical ceiling tile with dropped wooden beams (Figure 22). The space is separated from the main corridor by half walls and square columns and a change in ceiling elevation.

Layout and configuration of room. The overall shape of the room takes on a unique angular shape with a total of nine different walls in various angles. The seating area is roughly 26 feet by 22 feet. The total area of the room is 846 square feet. The tallest ceiling plane is at 10 feet tall, with the dropped soffits at a height of 9 feet, estimating 8,400 cubic feet of volume. On the east elevation is a twin-double-hung window with flanking single double-hung-windows on both sides.

Finishes. Table 29 details the finishes found in the dining room.

Table 29
Finishes at The Foley Center's Dining Room

Location	Finish	LRV
Floor	Hardwood planks	25%
Wall – South	Gypsum wall board, green paint	32%
Wall –West/East	Gypsum wall board, beige paint	71%
Wall – North	Gypsum wall board, blue paint	12%
Wall – Wainscot	Off-white wallpaper	47%
Task	Wood veneer tabletop	7%
Ceiling	Acoustical ceiling tile	90%

Artificial lighting characteristics. There are six suspended chandeliers. Furthermore, there are 12 recessed downlights. The luminaires are symmetrically spaced in the three bays created by the dropped soffits and beams. There is one downlight used as an accent light on the fireplace mantel and three downlights in the kitchenette (Table 30).

Table 30
Artificial Lighting in The Foley Center's Dining Room

Fixture Type	Lamp Type	Qty
Chandeliers	(5) LED	6
5” downlight	LED	12

Illuminance. The average ambient illuminance was 25fc. The task illuminance measured on the surfaces of the tables, averaged at 32fc.

Color temperature. The chandeliers registered as “Under” on the Sekonic meter. The recessed downlights had a color temperature of 2610K.

Controls. There are three switches located in the kitchenette that control the lights. All switches are standard two-way switches. The downlights in the seating area are all on one circuit, the chandeliers are on another circuit, and the three downlights in the kitchenette are on a separate circuit. When all the switches are in the 'off' position, there are two downlights that remain on. All switches are mounted at 48 inches a.f.f.

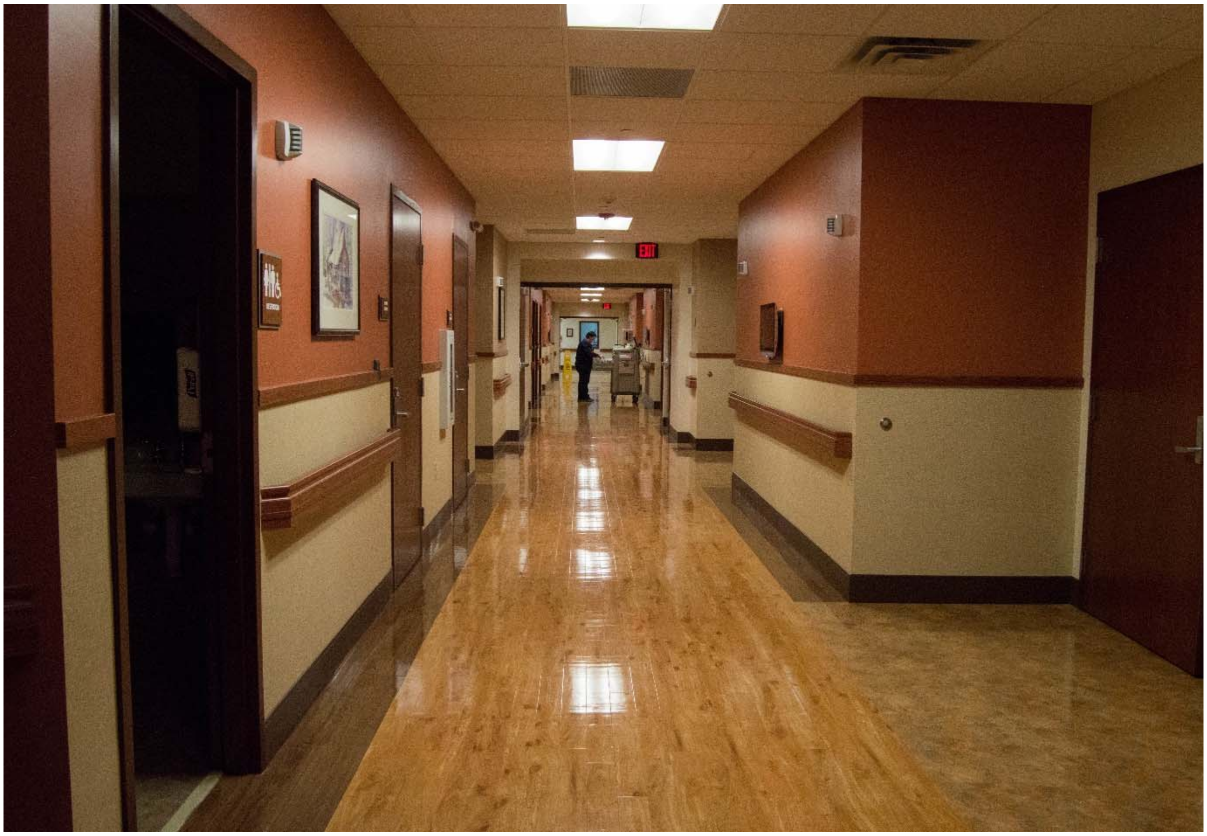

Figure 23. View of Hall 300 at The Foley Center.

Hallway. There are four main hallways on the main floor. Each long hallway is divided by a double egress door in the center. For this study, only the end half of Hall 300 up to the center double door was examined.

General spatial observations. Each hallway has a chair rail to transition from one wall finish to another along with a wheelchair wall guard. Similar to the living room and dining room, the floor finishes form a pattern, with a darker hardwood border running the perimeter of the space. Doors and trim are dark and contrast the wall finishes. There is visual interest created by widening and narrowing the room along the length of the hallway. As seen in Figure 23, there is glare from the troffers on the glossy floor.

Layout and configuration of room. The dimensions of the portion of hallway that was examined for this study measures 39 feet 4 inches by 8 feet at the narrowest point and 12 feet at the widest point. The total area equals 426 square feet. The total volume of the space equals 3,692 cubic feet with 7 feet 8 inch ceilings. There are no exterior fenestrations.

Finishes. The finishes in the room are listed in Table 31.

Table 31
Finishes at The Foley Center's Hall 300

Location	Finish	LRV
Floor	Hardwood planks	24%
Wall –West	Gypsum wall board, red paint	28%
Wall – East	Gypsum wall board, light brown paint	38%
Wall – Wainscot	Off-white wallpaper	43%
Ceiling	Acoustical ceiling tile	70%

Artificial lighting characteristics. There are three recessed 2x4 troffers and a single downlight (Table 32). The formula for a single row of luminaires was used to calculate the average illuminance.

Table 32
Artificial Lighting in The Foley Center's Hallway

Fixture Type	Lamp Type	Qty
2' x 4' recessed troffers	LED	3
5" downlight	LED	1

Illuminance. The average illuminance in Hall 300 was 17fc.

Color temperature. The color temperature of the troffers was measured at 2620K. The single downlight had a color temperature of 2740K.

Controls. There is one switch on the east wall by the double egress door that controls the single downlight and the center troffer. Two troffers are on the emergency circuit. The switch is mounted at 48 inches a.f.f.

Figure 24. View of resident's room at The Foley Center.

Resident's Room. Each community on the main floor houses 15 resident rooms. The two communities on the ground floor house 20 patient rooms each. There is a total of 100 rooms. There are two semi-private rooms per community. Typically, a semi-private room describes a room with two beds, however, in the Foley Center, this describes a room that breaks off into two rooms after an entry foyer and a shared bathroom. There are also four bariatric rooms in the entire facility.

General spatial observations. Each room comes with a single hospital bed that is adjustable, a tall wardrobe, chest of drawers, chair, and bedside table. All rooms have an adjacent bathroom attached to the room. The entrance way to the room has a different floor finish than the rest of the room. One wall is painted with an accent wall color (Figure 24). The Foley Center is the only facility in this study that has window casing around the windows in the residents' rooms.

Layout and configuration of room. The room measures 14 feet 4 inches by 12 feet. The total area is 196 square feet. The ceiling in the resident's room is 9 feet tall to equal a total volume of 1,767 cubic feet. There is one twin-double-hung window on the south wall. The bathroom door is on the north wall. The entry door leading to the room is 44 inches wide – the largest sized door in all the resident rooms examined for this study.

Finishes. Table 33 lists the finishes in the resident's room.

Table 33
Finishes at The Foley Center's Resident's Room

Location	Finish	LRV
Floor	Hardwood planks	11%
Wall	Gypsum wall board, off-white paint	60%
Wall – West/Accent	Gypsum wall board, red paint	30 %
Task	Tan bedsheet	35%
Ceiling	Acoustical ceiling tile	76%

Artificial lighting characteristics. There are two recessed downlights providing ambient illuminance in the resident's room. Additionally, there is one surface mounted circular fixture above the bed (Table 34). The luminaires are not symmetrically spaced in the room so the ambient illuminance was measured in a 2-foot grid.

Table 34
Artificial Lighting in The Foley Center's Resident's Room

Fixture Type	Lamp Type	Qty
Surface-mounted fixture	LED	1
5" downlight	LED	2

Illuminance. The average ambient illuminance was calculated to be 8fc. The task illuminance at the bed measured 9fc.

Color temperature. The color temperature of the downlights was 2650K. The surface mounted fixture above the bed had a color temperature of 2560K.

Controls. There are two, three-way switches. The first pair of switches is to the right of the door upon entering the room. One switch controls the downlights while the other switch controls the surface mounted luminaire. The second pair of switches are located to the left of the bed. All switches are mounted at 48 inches a.f.f., however, there have been multiple complaints that the switches by the bed are not easily accessed from the bed. There has been a large influx of bed lamps as a result of this issue.

Figure 25. Views of bathroom at The Foley Center.

Bathroom. All bathrooms are ADA accessible with the necessary 5-foot turnaround, required grab bars, and roll-under sink. The bathrooms also are 'European' style, where the shower is not separate from the rest of the bathroom.

General spatial observations. Overall, the bathroom was brightly lit and one of the largest bathrooms examined in this study. However, there were complaints that the door threshold has a large transition strip causing residents to trip. The second half of the bathroom is considered the shower portion and there are floor-to-ceiling tiled walls (Figure 25).

Layout and configuration of room. The bathroom is a perfect rectangle, measuring 3 feet 2 inches by 6 feet 5 inches, for a total area of 20 square feet. The ceilings are 9 feet tall. The total volume of the room is 183 cubic feet. There are no exterior fenestrations. The bathroom door is 3 feet wide for ADA accessibility.

Finishes. The finishes in the room are listed in Table 35.

Table 35
Finishes at The Foley Center's Bathroom

Location	**Finish**	**LRV**
Floor	2' x 2' beige tiles	24%
Wall - Paint	Gypsum wall board, off-white paint	66%
Wall – Tile	Glazed ceramic tile	541%
Task	Cultured marble countertop	36%
Ceiling	Gypsum wall board, white paint	80%

Artificial lighting characteristics. There are two luminaires in the space: one wet-rated recessed downlight providing general illuminance and one wall-mounted sconce above the vanity providing task illuminance (Table 36).

Table 36
Artificial Lighting in The Foley Center's Bathroom

Fixture Type	**Lamp Type**	**Qty**
Wall-mounted vanity light	LED	1
5" downlight (wet-rated)	LED	2

Illuminance. The average ambient illuminance in the bathroom was 33fc. The task illuminance hitting the vanity countertop at 34 inches a.f.f. was 31fc. The illuminance over the water closet at 30 inches a.f.f. measured at 33fc.

Color temperature. The downlight had a color temperature of 2470K. The vanity luminaire had a color temperature of 2890K.

Controls. One switch is located on the north wall, to the right of the door. The switch is mounted at 48 inches a.f.f. and controls both the downlight and vanity lamp. There are no dimmable options.

Figure 26. Aerial view of Forest Ridge Assisted Living.

Forest Ridge

Forest Ridge in West Jefferson takes the shape of a traditional cruciform building with the two wings extending from two sides of a main core (Figure 26). There is an assisted living wing and a locked memory care wing. The assisted living wing was renovated in 2013; however, the only spatial difference between the assisted and memory care wings is that the memory care wing has laminate wood planks while the assisted living wing has carpeted floors. The main core houses the offices, a private dining room for residents' families, the dining room, breakfast room, kitchen, and activity/living rooms.

Activity Room. There are two activity rooms at Forest Ridge that qualified for this study. The room picked for further study is known by the residents and staff as the living room. Directly to the right as you enter the community, the living room serves a dual functionality during the day for daily scheduled activities as well as for leisure.

Figure 27. Panorama of the activity room at Forest Ridge.

General spatial observations. The room is large and furnished with a seating arrangement in front of a built-in entertainment center and bookcases (not shown in photograph), break-out groupings of lounge chairs, and a small table (Figure 27). Two walls of windows allow plenty of daylight to penetrate the room, bringing much appeal to the room during the day. There are blinds and decorative valances on all exterior windows.

Layout and configuration of room. The living room measures 34 feet by 20 feet, totaling 680 square feet. A 32-inch-wide, 9-foot-tall soffit runs along the perimeter of the room and then slopes up to an 11-foot-tall ceiling. The total volume of the room is 6,970 cubic feet. There is a large 88-inch-wide double glass door to enter the room, with two large interior sidelights on each side. There is a total of five twin-double-hung windows on the two exterior walls of the south corner of the building.

Finishes. Table 37 details the finishes in the activity room.

Table 37
Finishes in Forest Ridge's Activity Room

Location	Finish	LRV
Floor	LVT "wood" plank	11%
Wall	Gypsum wall board, SW 7688 Sundew paint	46%
Task	Plastic laminate tabletop	5%
Ceiling	Gypsum wall board, white paint	91%

Artificial lighting characteristics. There are two central suspended chandeliers in the space. Additionally, there are eight recessed downlights in the perimeter soffit (Table 38). At the time of the study, there were several CFLs and several LED retrofit lamps.

Table 38
Artificial Lighting in Forest Ridge's Activity Room

Fixture Type	Lamp Type	Qty
Chandeliers	(8) CFL or LED	2
5" downlight	CFL or LED	8

Illuminance. The average ambient illuminance was measured at 12.5fc. The task illuminance measured at the location of the table at 30 inches a.f.f. was at 12fc.

Color temperature. The CFL lamps had a color temperature of 2600K. The LED retrofit lamps had a color temperature of 2900K.

Controls. There are two switches to the far right of the right sidelight when entering the room. One switch controls the chandeliers while the other switch controls the downlights. The switches are mounted at 48 inches a.f.f.

Figure 28. Panorama of dining room at Forest Ridge.

Dining Room. There is a large dining room where three meals per day are shared among the residents as well as a small private dining room that can be reserved for family members to use.

General spatial observations. As observed in Figure 28, there is plenty of natural light that illuminates about half of the dining room, while the other half of the room sits in darkness. There is an adjacent kitchen and serving window with a tray counter on the east elevation. There is a total of nine tables.

Layout and configuration of room. The overall dimensions of the dining room are 51 feet 5 inches by 21 feet 5 inches. The total area is 1,240 square feet. Similar to the ceiling in the living room, a 9-foot-tall soffit runs along the perimeter and down the middle. The rest of the ceiling stands 11 feet tall. The overall volume of the space measures an estimated 12,540 cubic feet. There are four twin-double-hung windows on the south elevation and interior glass windows on the north and west elevations. Two double French doors on either end of the north elevation are the entrances into the room.

Finishes. The finishes in the room are listed in Table 39.

Table 39
Finishes in Forest Ridge's Dining Room

Location	Finish	LRV
Floor	LVT "wood" plank	11%
Wall	Gypsum wall board, SW 7688 Sundew paint	36%
Task	Blue tablecloths	21%
Ceiling	Gypsum wall board, white paint	83%

Artificial lighting characteristics. There are two central suspended chandeliers in the center of each 11-foot-tall ceiling division. There are also eight recessed downlights in the 11-foot-tall ceiling and 10 recessed 5-inch downlights in the 9-foot-tall soffits (Table 40). A variety of CFLs and relamped LED retrofit lamps are used in the fixtures. The luminaires are in a symmetrical pattern.

Table 40
Artificial Lighting in Forest Ridge's Dining Room

Fixture Type	Lamp Type	Qty
Chandeliers	(9) CFL or LED	2
5" downlight	CFL or LED	8

Illuminance. The average ambient illuminance of the dining room measured at 12fc. The task illuminance hitting the tables at 29.5 inches a.f.f. measured at an average of 13fc.

Color temperature. The LED retrofit lamps had a color temperature of 2900K. The CFL lamps had a color temperature that ranged between 2500K to 2600K.

Controls. There are four switches around the corner left of the door in the north-west corner of the room. Each chandelier is controlled by an individual switch. The other two switches control several downlights each. There is one switch by the other entrance doors into the room and is a three-way switch for most of the downlights in the soffit. When all the switches are in the 'off' position, there are 14 downlights on the emergency circuit. The controls are mounted at 48 inches a.f.f.

Hallway. There are two main hallways in the building – the assisted living hallway and the locked memory care, or Horizons, hallway. For this study, the Horizons Hallway was examined.

General spatial observations. Only half of the memory care wing's hallway is examined for this study. The hallway is broken into three bays, the first and the last bay are narrower than the middle bay (Figure 29). Each bay contains four doors leading to adjacent rooms, two doors per side. There is one double egress door at one end of the hallway while the other end intersects a corridor running perpendicular with a nurses' station, living room, and dining room area, specific for the memory care wing.

Layout and configuration of room. The overall length of the hallway measures 75 feet 8 inches long. The hall width starts at 8 feet and then widens to 12 feet before falling back to 8-feet-wide. The total area is 704 square feet. The two flanking bays of the hallway have a ceiling height of 9-feet-tall. The center bay slopes up to a flat ceiling plane that measures at a height of 11 feet. The estimated volume of the hallway is 6,930 cubic feet.

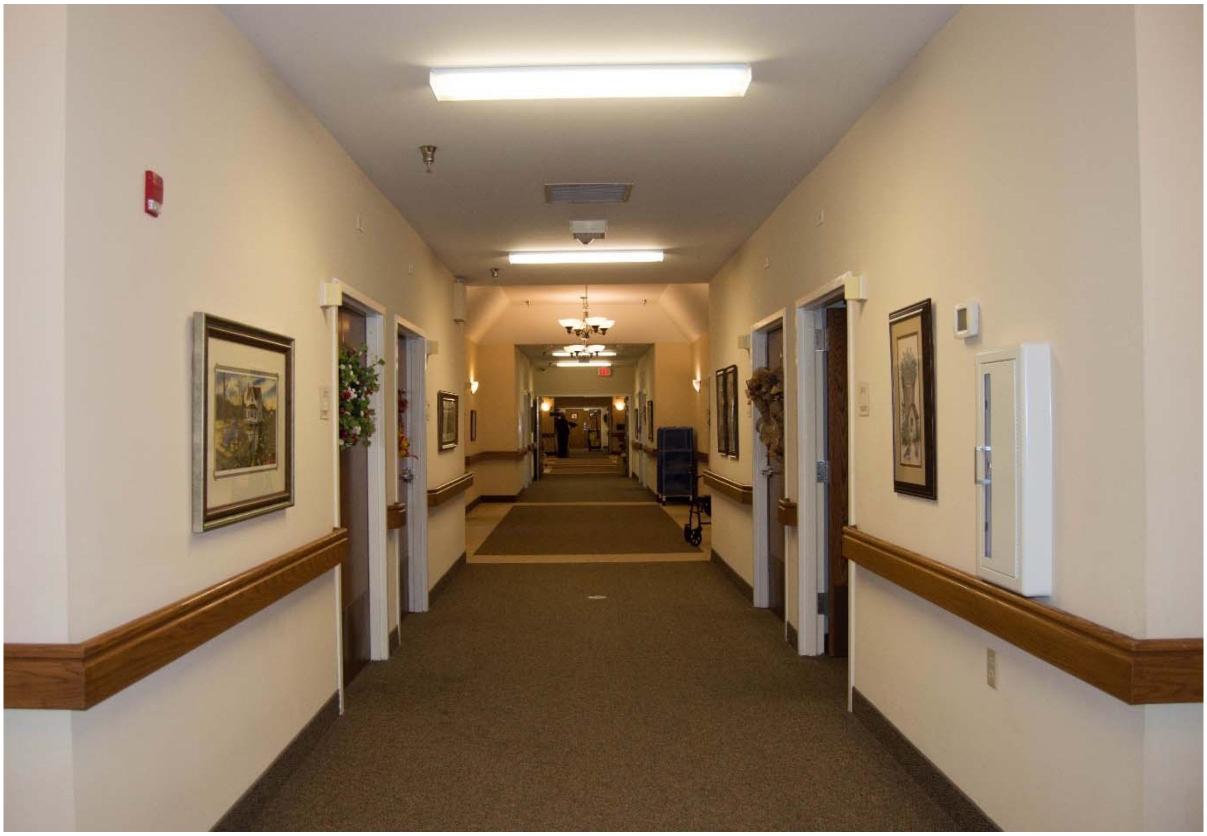

Figure 29. View of Horizons Hallway in Forest Ridge.

Finishes. **Error! Not a valid bookmark self-reference.** details the finishes found in the Horizons Hallway.

Table 41
Finishes in Forest Ridge's Hallway

Location	Finish	LRV
Floor	Brown low, loop pile carpet	9%
Wall	Gypsum wall board, SW 7688 Sundew paint	50%
Ceiling	Gypsum wall board, white paint	73%

Artificial lighting characteristics. The two flanking end bays have two surface-mounted 2' x 4' fluorescent troffers that house two T8 lamps each. The central bay in the hallway has two suspended chandeliers with four lamps in each fixture (Table 42). There is a mixture of CFL and LED lamps in the chandeliers. There are also four wall-mounted sconces in the center bay, two on each side, mounted at 80 inches a.f.f. in each corner.

Table 42
Artificial Lighting in Forest Ridge's Hallway

Fixture Type	Lamp Type	Qty
2' x 4' surface-mounted troffer	(2) T8 Fluorescent	2
Chandelier	(4) CFL or LED	2
Wall-mounted sconces	(1) CFL	4

Illuminance. The average illuminance measured at 12fc.

Color temperature. The color temperature of the troffers was 3220K. The CFLs had a color temperature of 2730K. The LED retrofit lamps had a color temperature of 2970K.

Controls. There are two switches at the beginning of the hallway on the wall to the left of the double egress doors. One switch does not control any lights in the hallway. The other switch controls two of the four troffers. Both switches are mounted at 48 inches a.f.f.

Resident's Room. A resident's room in the memory care wing was examined for this study. All rooms in either wing are identical except for the floor finish. The memory care wing has LVT "wood" planks while the assisted living wing has carpeted floor. There are 23 rooms in the assisted living wing and 28 rooms in the memory care wing.

General spatial observations. Each resident's room has a twin sized bed, a bedside table, a dresser, and one or two chairs (Figure 30). Every room has an adjacent bathroom.

Layout and configuration of room. The overall dimensions of the room are 11 feet by 11 feet 8.5 inches with a long entry that is 6 feet by 10 feet 6 inches. There is also a niche for the freestanding dresser. The overall area of the room is 200 square feet. The volume of the room is 1,800 cubic feet with 9-foot-tall ceilings. There is one 70-inch-wide sliding window for egress.

Figure 30. View of resident's room at Forest Ridge.

Finishes. The finishes in the room are listed in Table 43.

Table 43
Finishes in Forest Ridge's Resident's Room

Location	Finish	LRV
Floor	LVT wood plank	7%
Wall	Gypsum wall board, SW 7688 Sundew paint	49%
Ceiling	Gypsum wall board, white paint	72%

Artificial lighting characteristics. There are three surface-mounted, circular luminaires. Some lamps have been replaced by LED retrofit lamps (Table 44). Since the luminaires are not symmetrically spaced, the illuminance was measured at the center of a 2-foot grid.

Table 44
Artificial Lighting in Forest Ridge's Resident's Room

Fixture Type	Lamp Type	Qty
Surface-mounted fixture	(2) CFL or LED	3

Illuminance. The average ambient illuminance measured at 8fc. The task illuminance measured at an average of 9fc above the bed.

Color temperature. The room had a color temperature of 2550K.

Controls. There is one switch to the right of the entry door that is mounted at 48 inches a.f.f. The switch controls all three fixtures.

Figure 31. A resident's bathroom at Forest Ridge.

Bathroom. The adjacent bathroom to the patient's room is ADA-compliant and has a roll-under sink, grab bars, and a seat in the shower (Figure 31). The door leading to the bathroom is 3-feet-wide. There are no exterior fenestrations.

Layout and configuration of room. The overall dimensions of the bathroom are 10 feet by 6 feet. The shower measures 3 feet by 5 feet 6 inches. There is a small transition strip between the shower and floor. The ceiling measures 9 feet tall. The total area is 60 square feet and the total volume is 540 cubic feet.

Finishes. Table 45 details the finishes in the bathroom.

Table 45
Finishes in Forest Ridge's Bathroom

Location	Finish	LRV
Floor	12" x 12" VCT	20%
Wall	Gypsum wall board, off-white paint	49%
Task	Porcelain sink	39%
Ceiling	Gypsum wall board, white paint	74%

Artificial lighting characteristics. There is a single luminaire mounted above the vanity with two LED retrofit lamps and two CFLs. A single LED downlight is centered above the shower (Table 46).

Table 46
Artificial Lighting in Forest Ridge's Bathroom

Fixture Type	Lamp Type	Qty
Wall-mounted vanity light	(4) CFL or LED	1
5" downlight (wet-rated)	(1) CFL	1

Illuminance. The average ambient illuminance measures at 19fc. The task illuminance over the water closet measured at 19fc. The task illuminance over the sink measured at a high of 42fc.

Color temperature. There were two different color temperatures above the vanity – 3040K and 2840K, because of the variety of different lamps in one fixture. The downlight in the shower had a color temperature of 2780K.

Controls. There is one switch to the left of the door that controls both of the fixtures. The switch is mounted at 48 inches a.f.f.

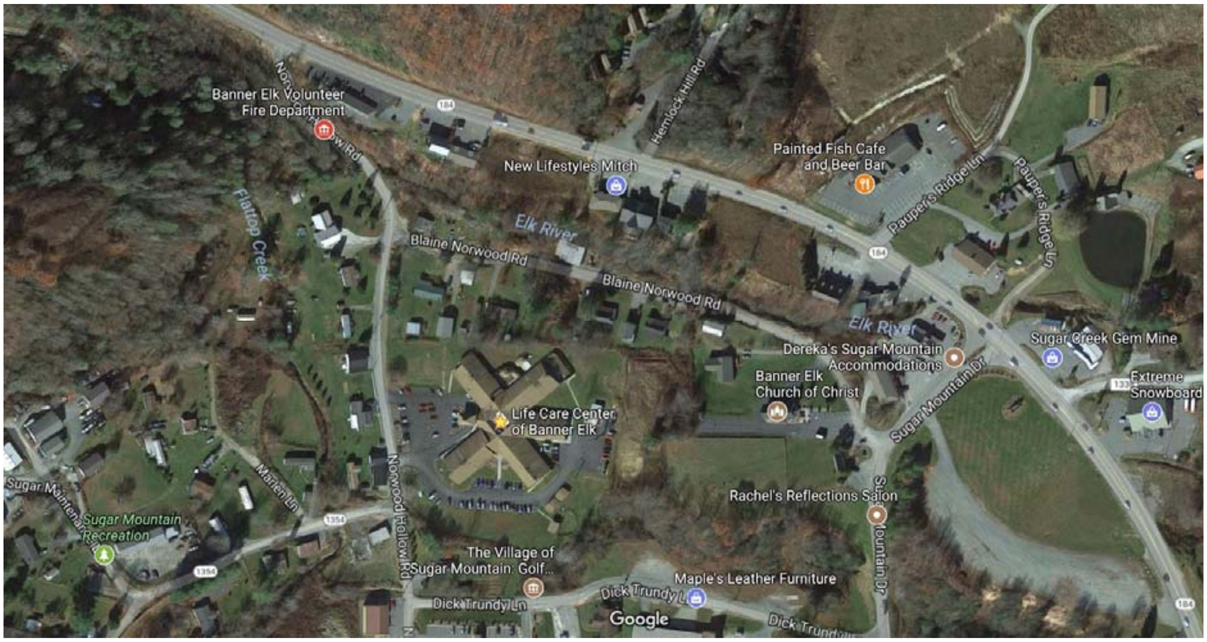

Figure 32. Aerial map of Life Care Center of Banner Elk.

Life Care Center of Banner Elk

Life Care Center (LCC) of Banner Elk is composed of a star-like, radial form with four different wings (see Figure 32). The 400 Hall is in the process of becoming a certified dementia wing. The ceilings were lowered in 1995 and range from 7'-5" to 8'-0" tall ceilings. LCC of Banner Elk is the only facility that was examined that had the same, continuous flooring—a 12" x 12" vinyl tile—throughout the entire facility. This can be advantageous or a disadvantage for the residents, depending on what visual cues are important to communicate by different finishes.

Activity Room. Life Care Center still follows a traditional layout with a day room for each of the four wings. The day room is a small room, similar to the size of an average residential living room, for residents to sit during the day and watch TV.

General spatial characteristics. The room contains a large couch, several lounge chairs, a rocking chair, bench, small table, and a wall-mounted television. A small arched opening overlooks a nurses' station (Figure 33).

Figure 33. Panorama of the day room at LCC of Banner Elk.

Layout and configuration of room. The room measures 22 feet 7 inches by 12 feet 8 inches for a total of 286 square feet. The volume of the room is 2,288 cubic feet with an 8-foot-tall ceiling. There is one door leading into the room. The access door to the adjacent nurses' station is located in the day room . There is also one sliding window and a 4-foot-wide egress glass steel door with sidelight.

Finishes. Table 47 details the finishes in the day room.

Table 47
Finishes in LCC of Banner Elk's Day Room

Location	**Finish**	**LRV**
Floor	12" x 12" VCT tile	42%
Wall	Gypsum wall board, green paint	60%
Ceiling	Gypsum wall board, white paint	68%

Artificial lighting characteristics. There are three 2' x 4' surface mounted fluorescent troffers mounted on the ceiling. Each troffer contains two T8 fluorescent lamps (see Table 48). The main space, not including the entry way with one troffer, was measured using the "regular area with symmetrically spaced single row of luminaires" formula.

Table 48
Artificial Lighting in LCC of Banner Elk's Day Room

Fixture Type	Lamp Type	Qty
2' x 4' surface-mounted troffers	(2) T8 Fluorescent	3

Illuminance. The average ambient illuminance measured 12 fc. The average task illuminance at the table location measured at 16fc.

Color temperature. The color temperature in the space measured at 2490K.

Controls. There is one switch to the left of the door that turns on and off two of the three troffers in the space. The third troffer is on an emergency circuit. The switch is mounted at 52 inches a.f.f.

Figure 34. View of LCC of Banner Elk's dining room.

Dining Room. There are two rooms that serve dual functions as dining rooms and as activity rooms. The dining room that was examined for this study is adjacent to the memory care wing. There are two entrances into the room from the interior, one through the memory care wing and the other from the central, main corridor. Both the doors from the main hallway to Hall 400 and the adjacent dining room are locked.

General spatial observations. Overall, the dining room did not have an aesthetically pleasing quality and felt very sterile (Figure 34). There are eight round dining tables that are 42 inches in diameter.

Layout and configuration of room. The room is an unusual shape with overall dimensions at 35 feet by 22 feet 5 inches. The total area is 627 square feet. The ceiling is 8-feet-tall, equaling a total volume of 5,016 cubic feet. There are two entrances into the room. From the memory care wing, there is one single door. From the central corridor of the facility, there is one single glass door with two sidelights.

Finishes. The finishes in the room are listed in Table 49.

Table 49
Finishes at LCC of Banner Elk's Dining Room

Location	**Finish**	**LRV**
Floor	12" x 12" VCT tile	40%
Wall	Gypsum wall board, pink-beige paint	60%
Task	Burgundy tablecloths	6%
Ceiling	Gypsum wall board, white paint	78%

Artificial lighting characteristics. There are seven ceiling mounted 2' x 2' fluorescent troffers with two lamps in each fixture (Table 50). The luminaires were symmetrically located given the odd shaped room.

Table 50
Artificial Lighting in LCC of Banner Elk's Dining Room

Fixture Type	**Lamp Type**	**Qty**
2' x 2' surface-mounted troffers	(2) U-bend T8	7

Illuminance. The average ambient illuminance in the dining room was 8fc. The task illuminance was measured in the center of each table and divided by eight to calculate the average measured at 9fc.

Color temperature. There were two obvious differences in color temperature although the same kind of fixture is found throughout the room. Three of the seven troffers measured at a color temperature of 2800K while the other four measured at 3500K.

Controls. There is one switch to the left of the glass door accessed from the main corridor. The switch is mounted at 45 inches a.f.f. and controls five of the seven troffers.

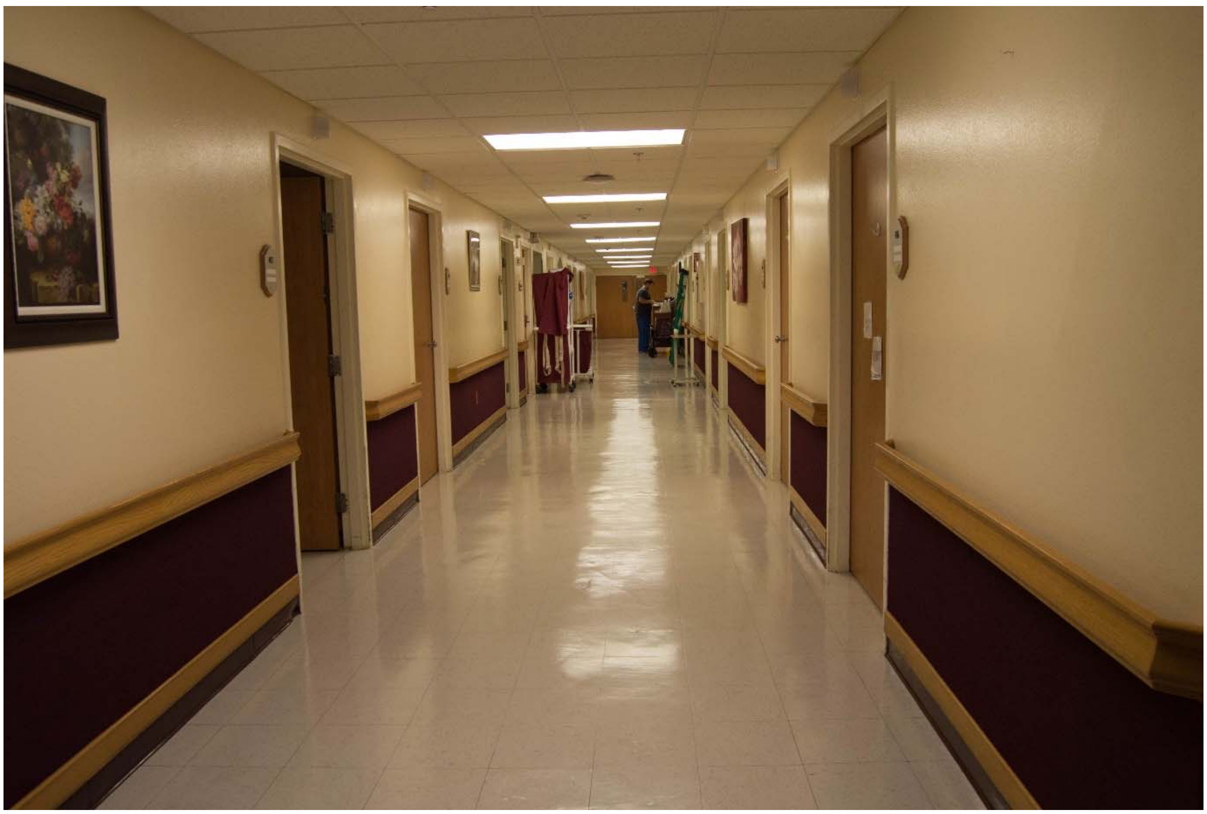

Figure 35. View of 400 Hall in LCC of Banner Elk.

Hallway. All four hallways have similarities. All hallways have a dayroom, an adjacent dining room, and a central shower room. There are no showers in each resident's room, so each central shower room has three shower stalls.

General spatial observations. The hallway is wide and functional for circulation and there is no change in flooring material between the hallway and adjacent rooms. There are no architectural elements that visually break up the long plane. An extremely dark carpet is used as the wainscot material – an inexpensive wall finish that protects the walls from wheelchairs and medical carts but is not easily cleaned. It does provide contrast between the floor and wall plane (Figure 35).

Layout and configuration of room. The overall length of the 8-foot-wide hallway is 111 feet 8 inches. The ceiling is 7 feet 6 inches tall. The total surface area of the hallway is 893 square feet and the total volume is 6,700 cubic feet. There is a locked double egress door on one end of the hallway and an alarmed egress door on the other end. There is a total of 20 doors to adjacent rooms: 15 resident rooms, a dining room, the day room, an office, the central shower room, and an emergency egress door.

Finishes. Table 51 details the finishes found in the hallway.

Table 51
Finishes at LCC of Banner Elk's Hallway

Location	Finish	LRV
Floor	12" x 12" VCT tile	40%
Wall	Gypsum wall board, beige paint	71%
Wall – Wainscot	Burgundy low, loop pile carpet	4%
Ceiling	Acoustical ceiling tile	74%

Artificial lighting characteristics. There are nine 2' x 4' recessed fluorescent troffers (Table 52). These luminaires are evenly spaced in a single line.

Table 52
Artificial Lighting in LCC of Banner Elk's Hallway

Fixture Type	Lamp Type	Qty
2' x 4' recessed troffers	(2) T8 Fluorescent	9

Illuminance. The average illuminance in the hallway was calculated to be 37.05fc.

Color temperature. The color temperature of the troffers was 2790K.

Controls. There is one switch at the beginning of the hall on the left wall when you first enter the hallway through the double egress doors. The light switch is mounted at 46 inches a.f.f. and controls six of the nine luminaires.

Figure 36. A resident's room at LLC of Banner Elk.

Resident's Room. There is a total of 58 rooms: 50 semi-private rooms and eight private rooms. On Hall 400, there are 15 resident rooms. At the time of this study, there were no vacant rooms on the Hall 400, so a room in Hall 200 was examined. The only difference between the halls is the addition of two 2' x 4' ceiling-mounted T8 troffers in each resident's room in Hall 400.

General spatial observations. Each resident's room contains two beds, a pedestal sink, and an adjacent toilet room. Other furnishings include a bedside table, a millwork wardrobe in the entrance of the room, and a chair per bed (Figure 36).

Layout and configuration of room. The overall dimensions of the room are roughly 20 feet by 11 feet. The total area is 197 square feet. The ceiling is 7 feet 10 inches for a total volume of 1,543 cubic feet. Each room has a 70-inch-wide sliding window with blinds and a decorative valence. A 3-foot-wide door leads to the adjacent toilet room.

Finishes. The finishes in the room are listed in Table 53.

Table 53
Finishes at LCC of Banner Elk's Resident's Room

Location	Finish	LRV
Floor	12" x 12" VCT tile	44%
Wall	Gypsum wall board, off-white paint	53%
Task	Tan blanket	29%
Ceiling	Gypsum wall board, white paint	86%

Artificial lighting characteristics. There are two wall-mounted four lamp fixtures over each bed. There is a wall-mounted vanity fixture over the sink that houses two lamps. For the resident rooms in Hall 400 there are two extra 2' x 4' ceiling-mounted fluorescent troffers in the middle of the space (Table 54). In the wall-mounted fixtures, there was a combination of CFLs and LED retrofit lamps.

Table 54
Artificial Lighting in LCC of Banner Elk's Resident's Room

Fixture Type	Lamp Type	Qty
2' x 4' surface troffers (Hall 400)	(2) T8 Fluorescent	2
Patient bed light with chain	(4) CFL	2
Wall-mounted vanity light	(2) CFL	1

Illuminance. The average ambient illuminance in the room in Hall 200 measured at 9fc. The task illuminance measured at the bed was calculated at an average of 12.5 fc. The task illuminance hitting the sink was 21fc.

Color temperature. The color temperature of the CFLs in one of the wall-mounted fixtures registered as "Under" on the Sekonic meter. The color temperature of the LED lamps measured at 4120K. The vanity fixture had a color temperature of 4570K.

Controls. There are two switches in the room. One switch is to the right when first entering the room. This switch controls the uplighting for the wall-mounted fixtures over the bed. Most of the time these switches did not work or the lamp was burned out. The second switch is by the vanity to control the vanity luminaire. Both switches are mounted at 46 inches a.f.f.

It is important to note that the residents' rooms in Hall 400 have two extra switches, one by each bed. The mounting height is the same and each switch controls its respective ceiling-mounted troffer over each bed.

Figure 37. View of bathroom at LCC of Banner Elk.

Bathroom. All adjacent bathrooms to the residents' rooms contain only a water closet and one grab bar to the side of the water closet. The bathroom (or more appropriately, a toilet room) is not ADA-compliant (Figure 37).

Layout and configuration of room. The overall dimensions of the bathroom are 4 feet by 4 feet 11 inches. The total area is 20 square feet. The ceiling is 7 feet 5 inches for a total volume of 146 cubic feet.

Finishes. Table 55 details the finishes found in the bathroom.

Table 55
Finishes at LCC of Banner Elk's Bathroom

Location	Finish	LRV
Floor	12" x 12" VCT tile	30%
Wall	Gypsum wall board, off-white paint	66%
Wall – Wainscot	Gypsum wall board, grey paint	69%
Ceiling	Acoustical ceiling tile	85%

Artificial lighting characteristics. There is a single surface-mounted fixture in the center of the small space. The fixture houses a single T9 circline lamp (Table 56).

Table 56
Artificial Lighting in LCC of Banner Elk's Bathroom

Fixture Type	Lamp Type	Qty
Surface-mounted fixture	(1) T9/D	1

Illuminance. The average illuminance measured at 11fc. The illuminance directly above the water closet measured at 12.5fc.

Color temperature. The color temperature of the single lamp was 4120K.

Controls. There is one switch mounted at 45 inches a.f.f. and located on the wall to the right of the door.

Chapter 5: Research Analysis

Analysis of Data

The five room types examined varied in shape, size, and name but all shared common functions between the facilities. For the sake of this study, the findings will be disseminated based on the variables as described in Chapter 3: illuminance, correlated color temperature (CCT), luminance or LRV, and value contrast.

Illuminance

The first variable, illuminance, is broken into two categories – ambient and task illuminance. The IES recommends different ambient and task illuminance based on the function of the room. Based on the calculated averages listed in Chapter 4, the current illuminance in each room per facility is compared to the recommended levels.

Activity Room. For the activity room, an ambient illuminance of 30fc is recommended. Based on the averages calculated, all five facilities did not meet the recommended levels for ambient illuminance (see Figure 38). The task illuminance recommended for an activity or living room is 50 fc. Again, the task illuminance hitting the tables in all five facilities significantly failed to meet this recommendation, with an average deviation of negative 38.15 (see Figure 39).

Dining Room. The average recommended ambient illuminance in a dining room is 20fc. The only facility to reach and even exceed this recommendation was The Foley Center at Chestnut Ridge. The other four facilities fell within the 5-15fc range (see Figure 40). The recommended task illuminance for this space is 50fc, however, the dining room task illuminance fell far below this recommended level (see Figure 41).

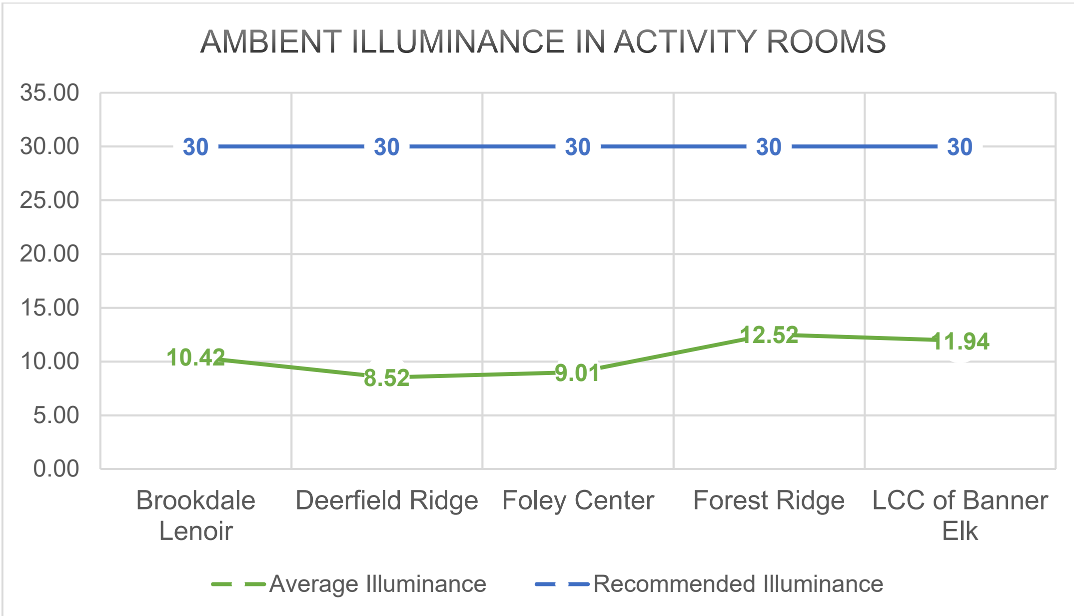

Figure 38. Average ambient illuminance in activity rooms.
Existing ambient illuminance as compared to the recommended level of 30fc.

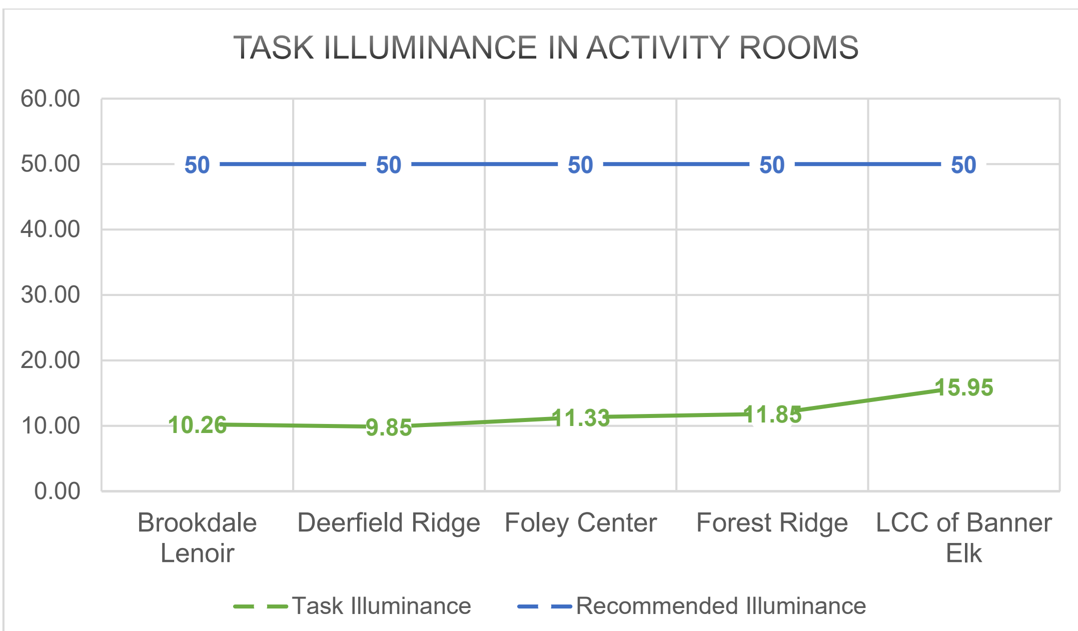

Figure 39. Average task illuminance in activity rooms.
Existing task illuminance as compared to the recommended level of 50fc.

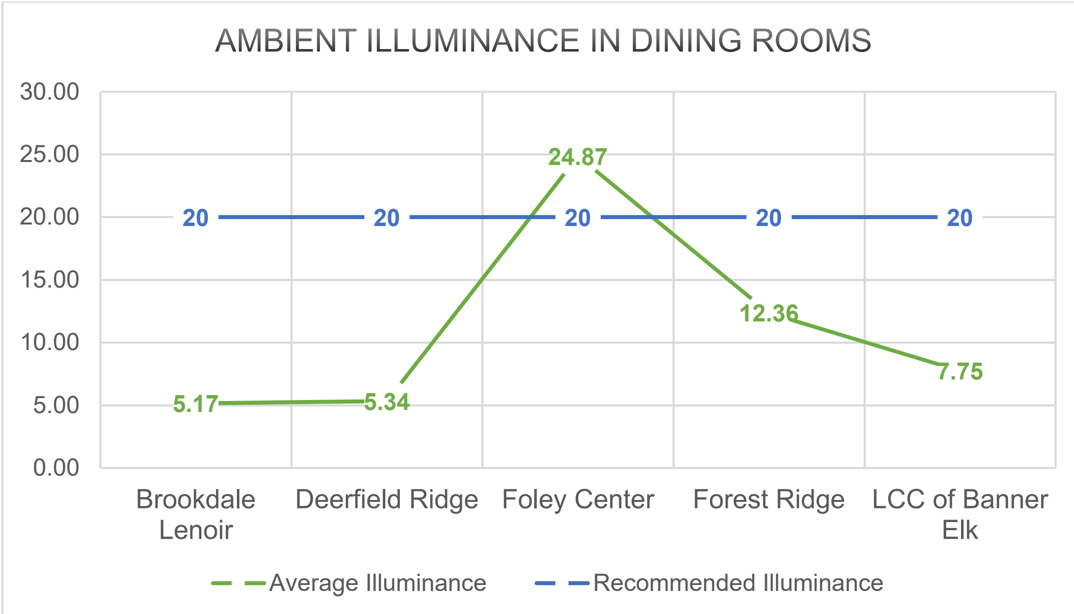

Figure 40. Average ambient illuminance in dining rooms.
Existing ambient illuminance as compared to the recommended level of 20fc.

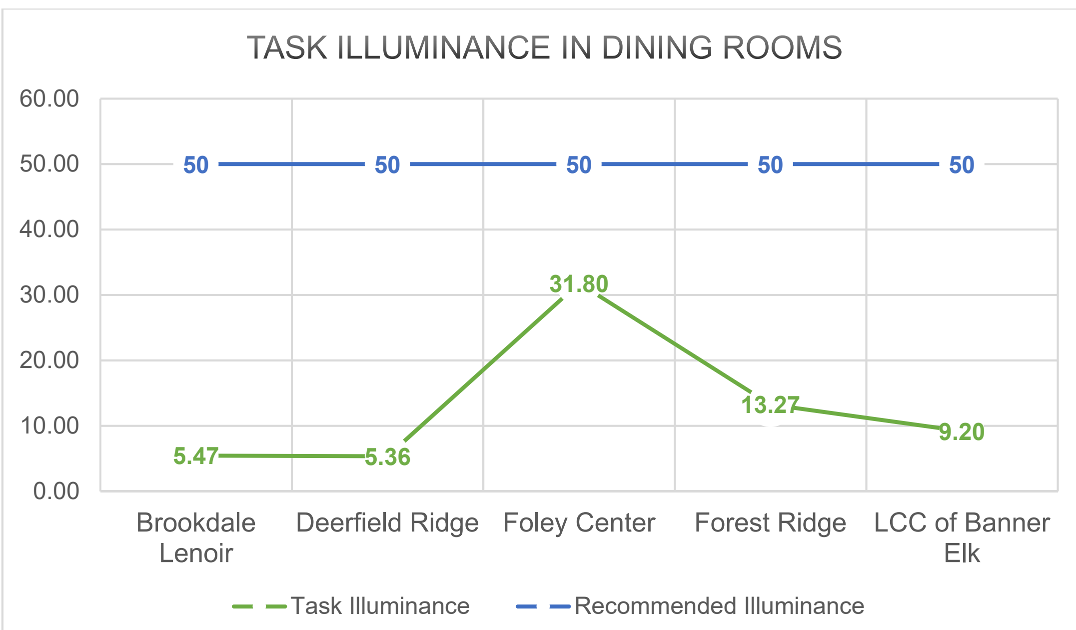

Figure 41. Average task illuminance in dining rooms.
Existing task illuminance as compared to the recommended level of 50fc.

Hallway. Since the primary task in a hallway is to navigate through the space, there is no division between ambient and task illuminance. All illuminance is measured at the floor level, as recommended by the IES. The recommended illuminance level is 20fc (see Figure 42). Four out of the five facilities fell below the recommended levels, while LCC of Banner Elk exceeded the recommended levels. This is not necessarily a positive result, as light in hallways can infiltrate into the residents' rooms, especially at night.

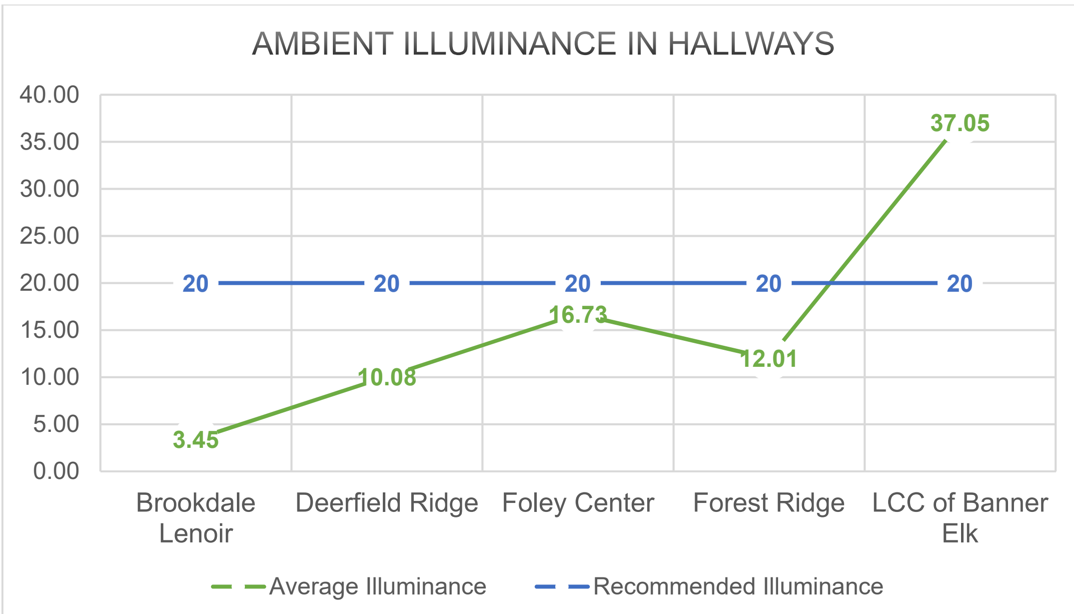

Figure 42. Average ambient illuminance in hallways.
Existing ambient illuminance as compared to the recommended level of 20fc.

Resident's Room. The recommended ambient illuminance in the bedroom is 20fc (see Figure 43). Task illuminance at reading work surfaces should be at around 75fc (see Figure 44). Since it is hard to determine if residents read or write in bed, a good solution is to provide a task light by the bed that satisfies this illuminance recommendation. Of the five facilities, there were no permanent task light sources by the bed. Several had table lamps on the bedside table by the bed and The Foley Center provides a bed lamp that clips to the side of the bed when patients request one. Portable fixtures were not assessed in this study.

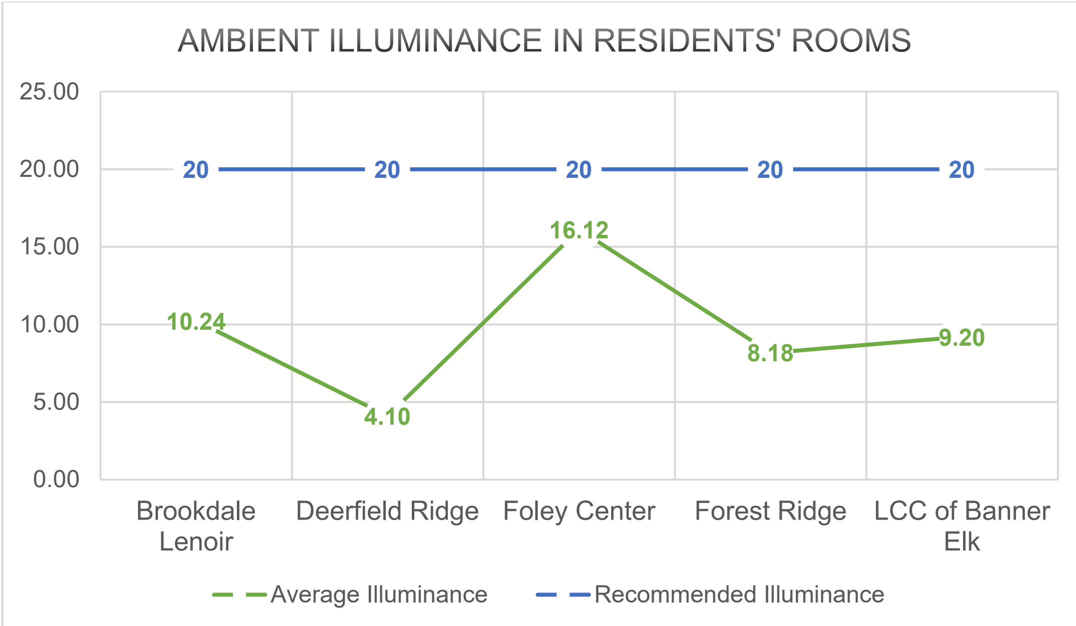

Figure 43. Average ambient illuminance in residents' rooms.
Existing ambient illuminance as compared to the recommended level of 20fc.

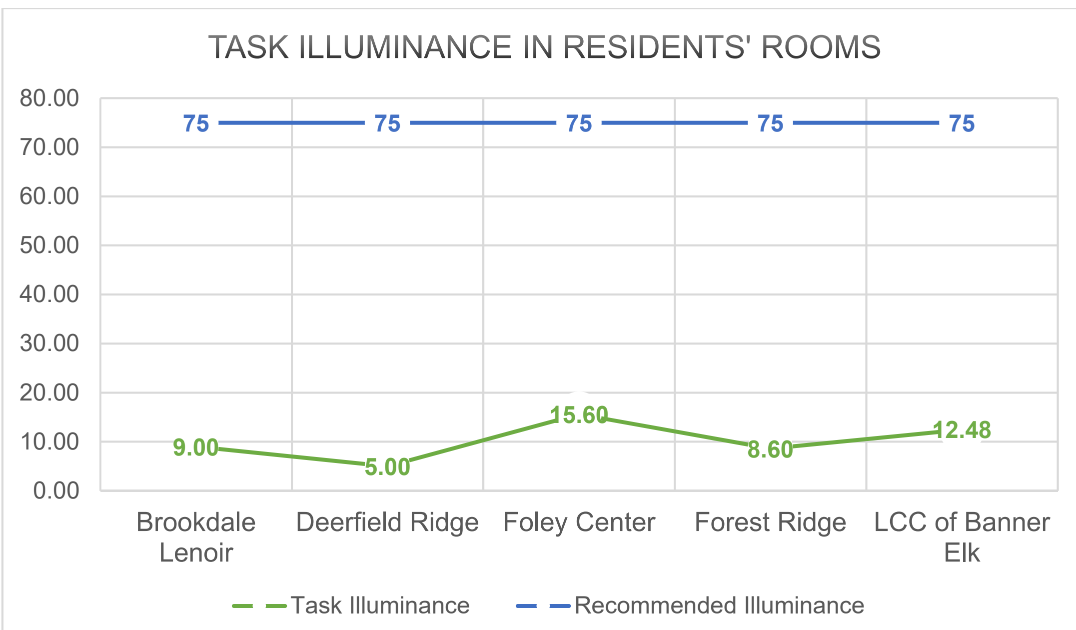

Figure 44. Average task illuminance in residents' rooms.
Existing task illuminance as compared to the recommended level of 75fc.

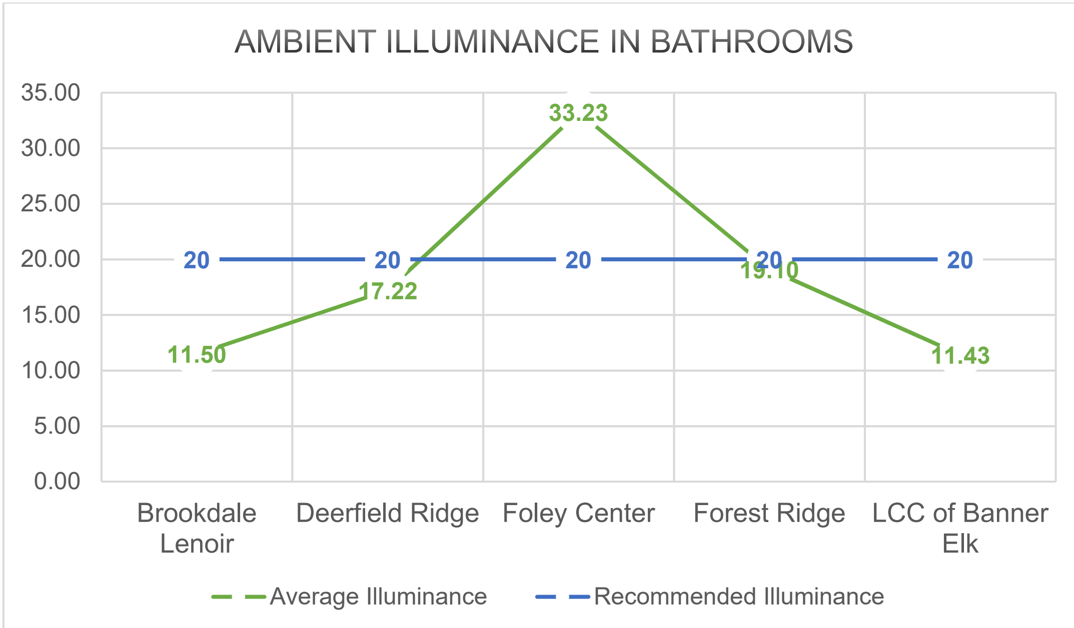

Figure 45. Average ambient illuminance in bathrooms.
Existing ambient illuminance as compared to the recommended level of 20fc.

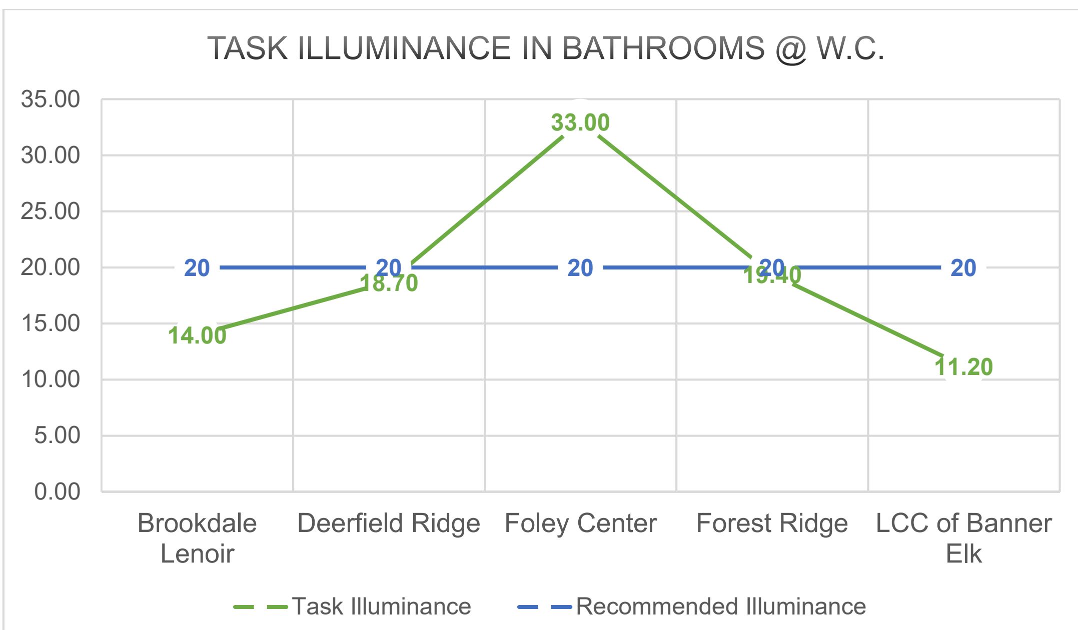

Figure 46. Average task illuminance over water closets in bathrooms.
Existing task illuminance as compared to the recommended level of 20fc.

Bathroom. The ambient illuminance in the bathroom should average around 20fc (see Figure 45). The recommended task illuminance levels for the bathroom are provided based on location in the bathroom. The recommended illuminance at the water closet is 20fc (see Figure 46). Similarly, the shower should also have a task illuminance of 20fc. There should be an illuminance level of 50fc at the sink. The only facility meeting this requirement was The Foley Center.

Correlated Color Temperature (CCT)

Recommendations for CCT change throughout the day are still being defined as more lighting designers are seeing the benefits of using tunable white light and imitating the sun. The color temperature sequence is listed in Table 5. There are no color temperature changing luminaires in any of the five facilities.

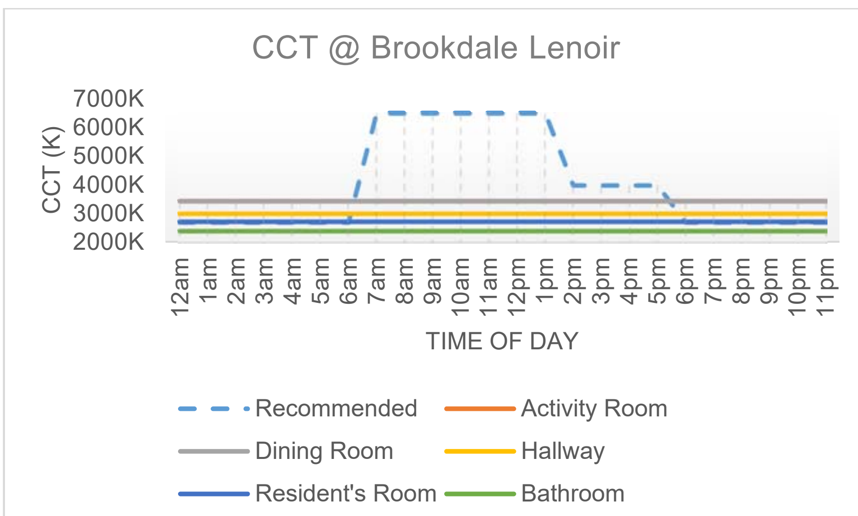

Figure 47. CCT as shown throughout the day at Brookdale Lenoir.

Brookdale Lenoir. Based on the recommended CCT throughout the day, the resident's room was the only room that met the recommended CCT during the times for 5:00 pm to 6:00 am (Figure 47). This environment facilitates acclimation before retiring to bed but does not help in the morning when circadian rhythms need to be reset. Depending on the location and orientation of their room, not all residents' rooms can rely solely on daylight in the morning.

Deerfield Ridge. Four of the five rooms examined at Deerfield Ridge fell under the 2700K CCT range. However, in the activity and dining rooms, lights are turned off 75% of the time during the hours between 6:00 pm to 6:00 am. Therefore, if activity or dining rooms were to have a fixed color temperature, they should fall within the range of 4000K to 6500K because those rooms are typically used during the daylight hours (Figure 48).

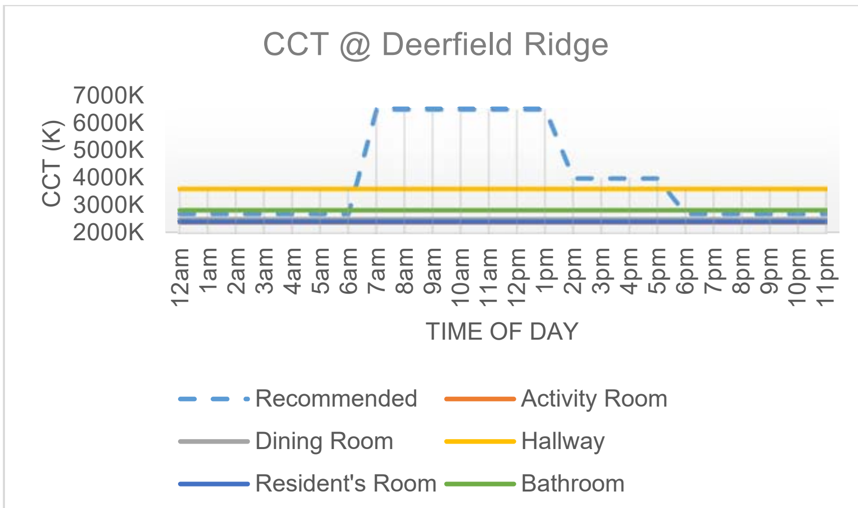

Figure 48. CCT as shown throughout the day at Deerfield Ridge

The Foley Center at Chestnut Ridge. The color temperature throughout this facility falls tightly within a range of ±1000K to 2700K (Figure 49). As stated previously, such a warm CCT will result in residents feeling sleepy throughout the day.

Forest Ridge. The overall CCT throughout the facility also fell close to 2700K, with the highest CCT of 3200K in the hallway (Figure 50). Since the hallway is mainly used during the day, a higher CCT is recommended. However, it is also important that the CCT can be adjusted at night so any light that seeps into the resident's rooms or any night wanderers are not disrupted by a cool CCT (Miller & North, 2005).

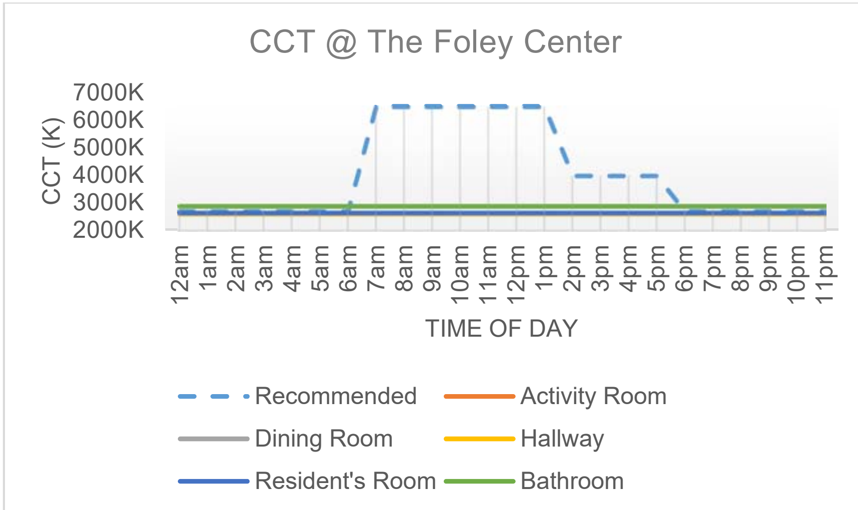

Figure 49. CCT as shown throughout the day at The Foley Center at Chestnut Ridge.

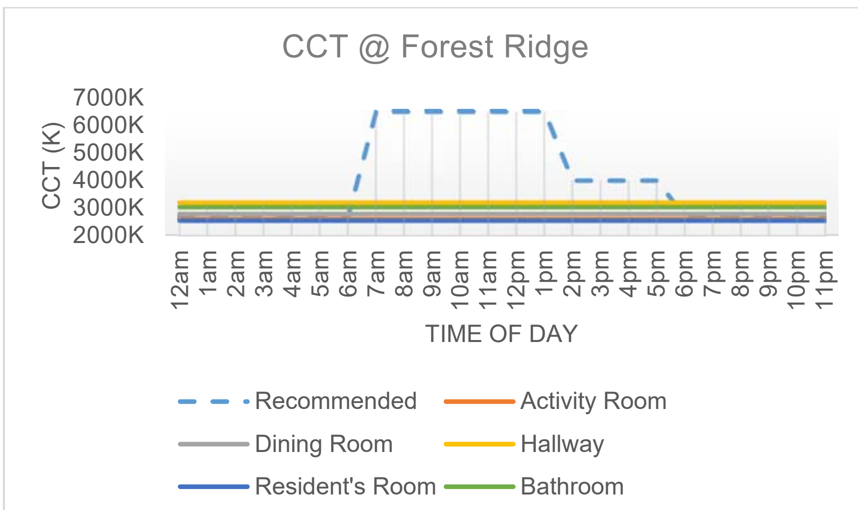

Figure 50. CCT as shown throughout the day at Forest Ridge.

LCC of Banner Elk. Of the five facilities, LCC of Banner Elk had the most variety of luminaires in different color temperatures. While variety can be good, considering room types and times of day these rooms are typically used, it is a general rule of thumb for all luminaires in one space to have the same color temperature. This is not the case at LCC of Banner Elk. In the residents' rooms and dining room, there are obvious variations of lamps with different CCT in each fixture.

The primary concern with the CCT in LCC of Banner Elk is that the highest CCT are in the residents' rooms and bathrooms (Figure 51). These two rooms are arguably the most important rooms when it comes to CCT since lights turned on during the night have the biggest impact on a resident's circadian rhythm. Many residents wake up during the night and switch on the lights to assist them as they navigate their way to and within the bathroom. Ideally, if tunable light is not an option, a warm CCT in the 2700K to 3000K range should be selected for the residents' rooms and bathrooms.

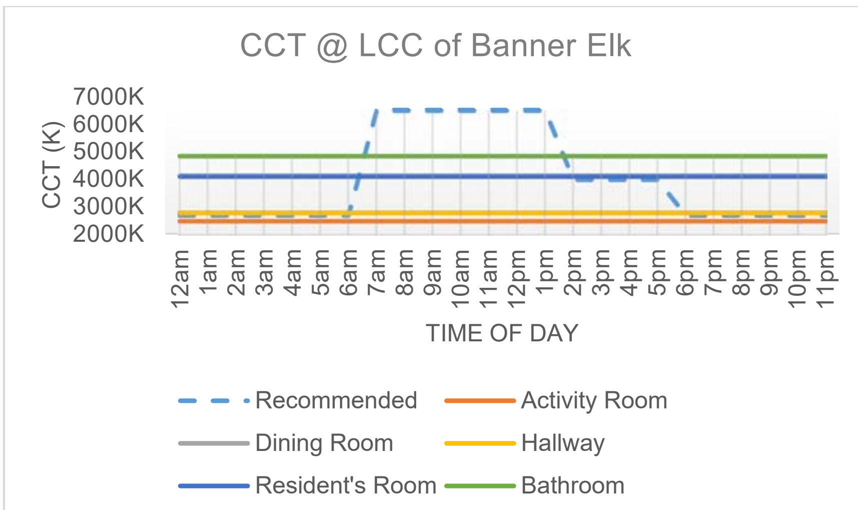

Figure 51. CCT as shown throughout the day at LCC of Banner Elk.

Luminance

Similar to correlated color temperature (CCT), the LRV recommendations are not room specific. The recommendations are listed in Table 6. There is a range measurement for ceilings, walls, and floors.

Ceilings. Ceiling LRVs should fall within the 70-80% range. Based on the measurements taken, most of the ceilings throughout the facilities met the recommended LRV values or exceeded them (Figure 52). There is only one ceiling, the activity room at LCC of Banner Elk, that did not have an LRV of above 70%. Many ceilings painted white—such as all the ceilings at Brookdale Lenoir and Deerfield Ridge—achieved a LRV of above 80%.

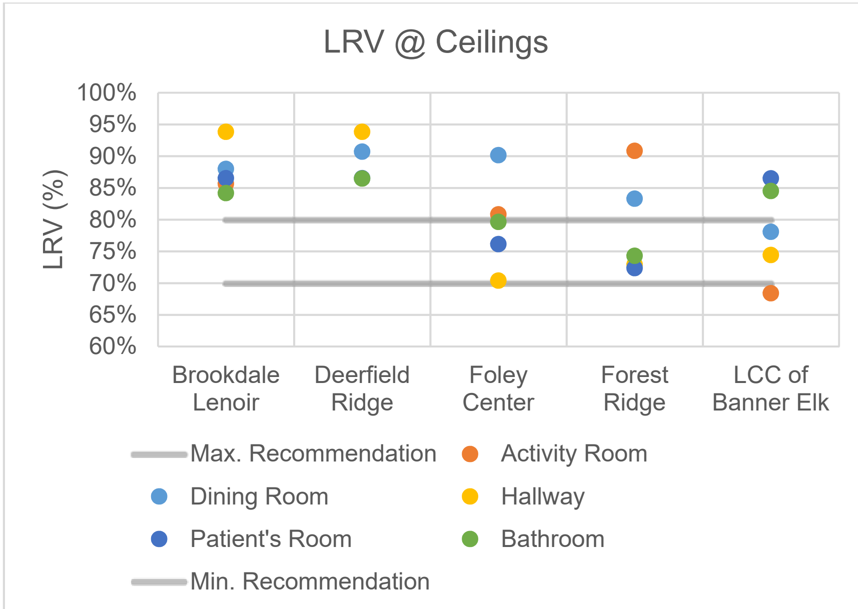

Figure 52. Comparison of ceiling LRV across the five facilities.

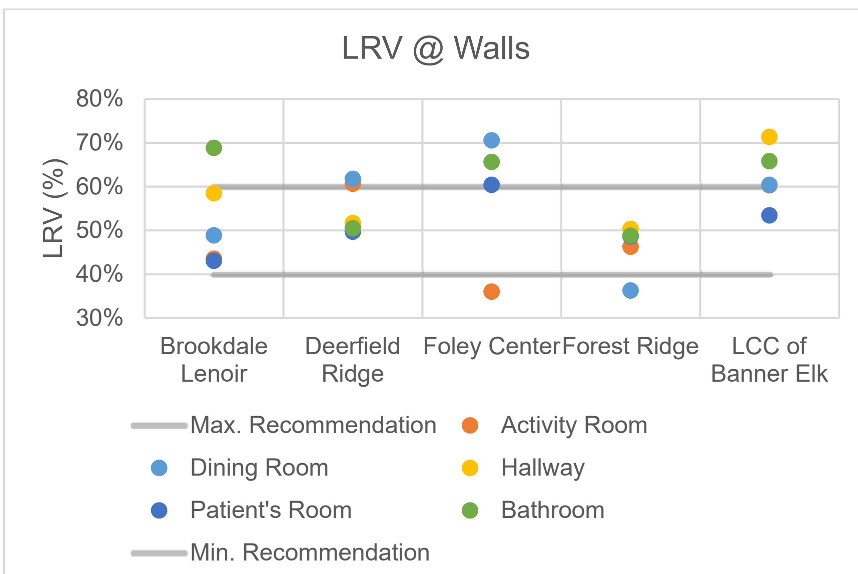

Figure 53. Comparison of wall LRV across the five facilities.

Walls. Wall LRVs should fall within the 40-60% (see Figure 53). For the comparison of LRV on walls, the majority wall finish in a room was the one compared. For example, if there was an accent wall color, the LRV of that wall was not used because it was not the majority finish. In cases where there was a chair rail and different wainscot finish, the finish above the chair rail was the one considered.

Interestingly, the paint colors in the newest facility, The Foley Center at Chestnut Ridge, did not meet the recommended LRV. Both facilities under Ridge Care—Deerfield Ridge and Forest Ridge—had similar wall colors that mainly fell within the 40%-60% range.

Floors. The recommended LRV range for floors is between 20-40% (see Figure 54). The LRV for floors is the lowest of the three planes in a room because typically not much light hits the floor to be reflected up into the space. There is also the issue of glare in one's eye if the floor is glossy.

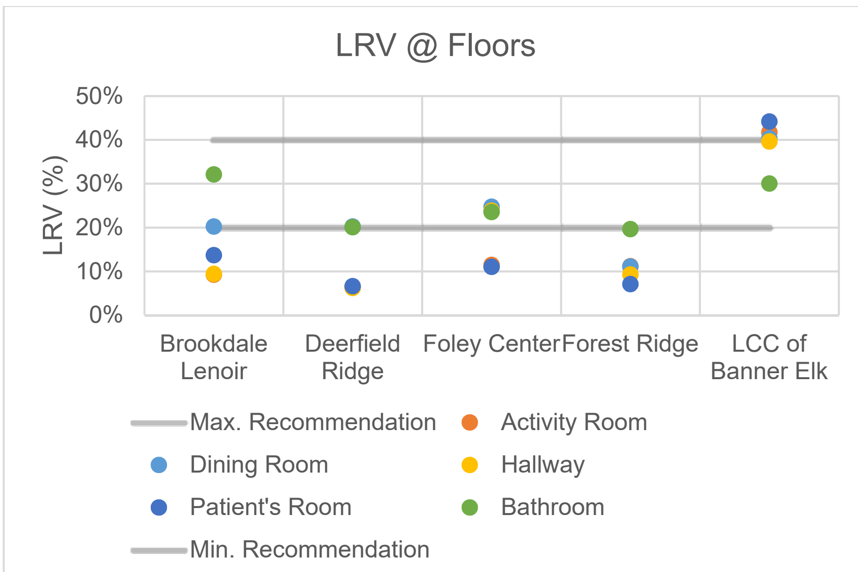

Figure 54. Comparison of floor LRV across the five facilities.

Most of the facilities' flooring finishes fell below the recommended range for LRV. LCC of Banner Elk had the highest floor LRV, which explains the glare from the floor as shown in the photographs.

Value Contrast

Once existing LRV are determined, a difference of 30 or more between adjacent planes or objects against backgrounds is recommended. For this study, the difference between the wall and floor planes was evaluated. The contrast between the floor and wall was evaluated because it is vital that a resident can differentiate this change of plane while navigating through the space.

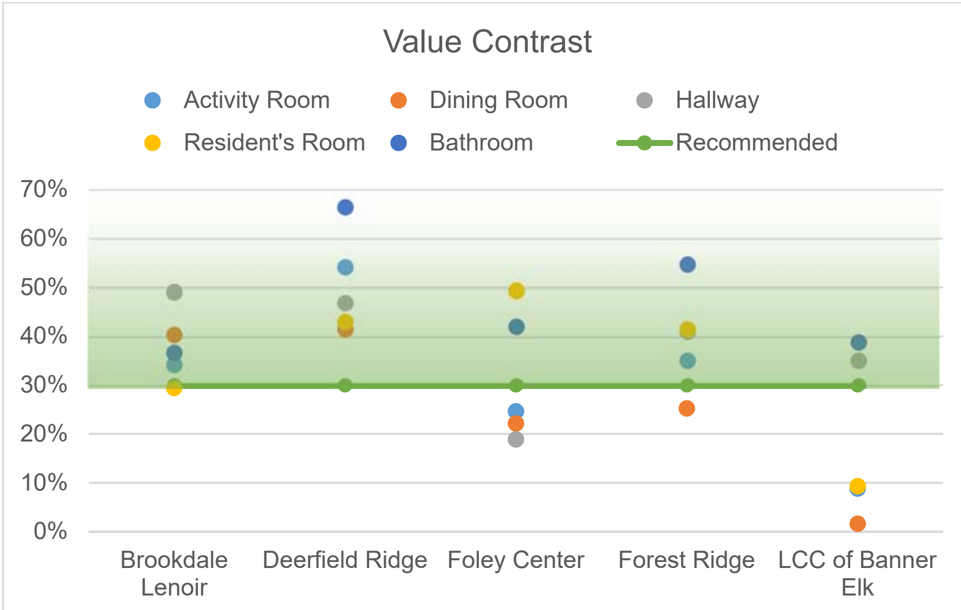

Figure 55. Value contrast for the five facilities.

Overall, Brookdale Lenoir, Deerfield Ridge, and Forest Ridge met the recommended value contrast (see Figure 55). The Foley Center's public spaces did not meet the recommended value but it is important to note that these rooms have a tall, dark, wood baseboard that has strong hue contrast with the floor and the wall. LCC of Banner Elk did not have sufficient value contrast between the floor and wall in the resident's room, day room, and dining room. The patient's room does have a dark baseboard that wraps the perimeter of the floor. The other two rooms have very little hue or value contrast between the off-white 12" x 12" vinyl tile, baseboard color, and wall finish.

Assessment and Selection of Case Study Facility

Each variable per room within each facility was assessed to determine the deviation from the recommendations. A score of 0 indicates the implementation or fulfilment of the recommendation. The further the absolute value is from 0, the larger the deviation from the recommendation. All deviation values per facility were summed to attain which facility scored the highest and lowest for each of the four variables.

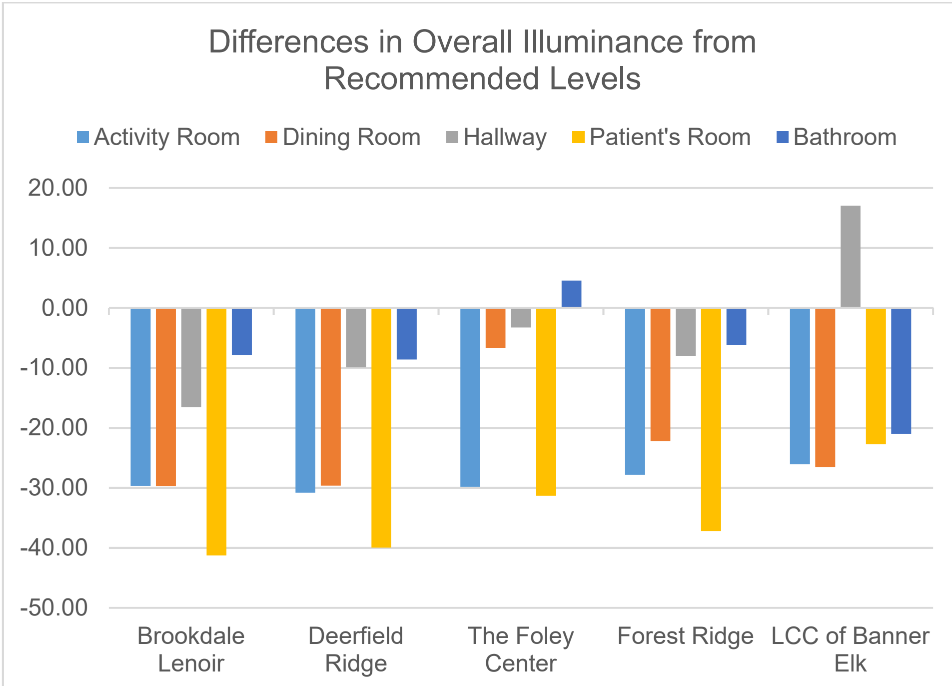

Figure 56. Deviation values for overall illuminance from recommended levels.

Overall Illuminance

For the first variable, overall illuminance was calculated by combining both ambient and task illuminance (Figure 56). The facilities rank in the following order from highest to lowest in overall illuminance, shown in Table 57.

Table 57
Overall Illuminance Facility Ranking

Rank	Facility Name	Deviation Score
1.	The Foley Center	-66.55
2.	LCC of Banner Elk	-79.27
3.	Forest Ridge	-101.39
4.	Deerfield Ridge	-118.96
5.	Brookdale Lenoir	-125.06

Correlated Color Temperature (CCT)

Since the recommended CCT changes through the day, the difference between the recommended CCT and existing, stagnant CCT was calculated for all 24 hours throughout the day and then an average deviation score was achieved (Figure 57). The facilities rank in the following order from highest to lowest CCT (see Table 58).

Table 58
Overall CCT Facility Ranking

Rank	Facility Name	Deviation Score
1.	LCC of Banner Elk	-3085K
2.	Brookdale Lenoir	-5058K
3.	Forest Ridge	-5945K
4.	Deerfield Ridge	-6335K
5.	The Foley Center	-6735K

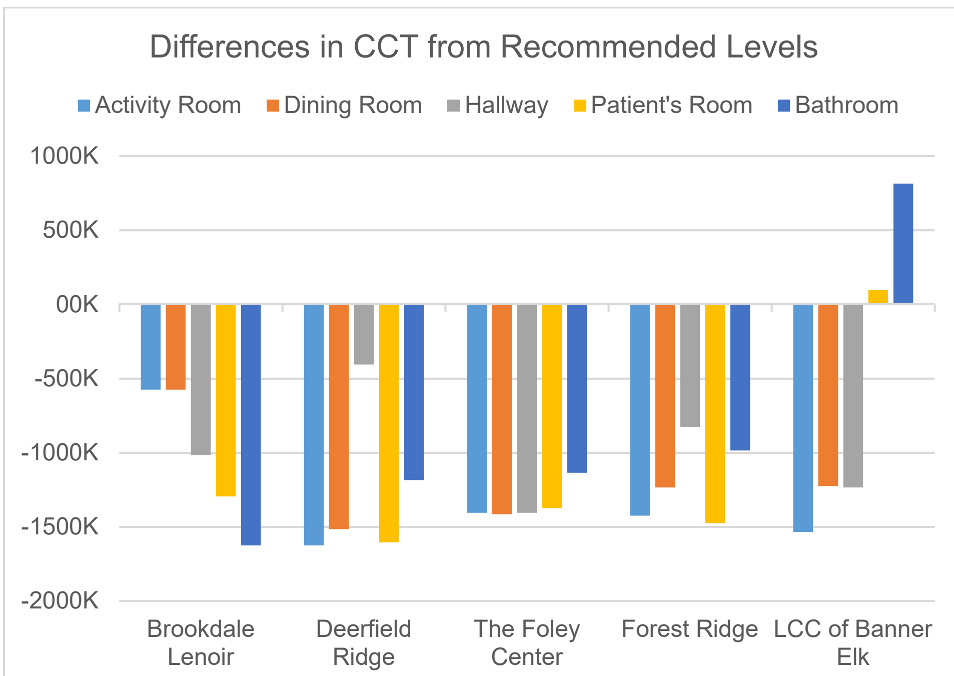

Figure 57. Deviation values for overall CCT from recommended levels.

Luminance

There is a recommended LRV range for the ceiling, wall, and finish (see Figure 58). To assess the overall deviation for LRV of each facility, ceiling, wall, and floor LRV deviation scores from the recommended range was averaged for the assessment of overall luminance (Table 59).

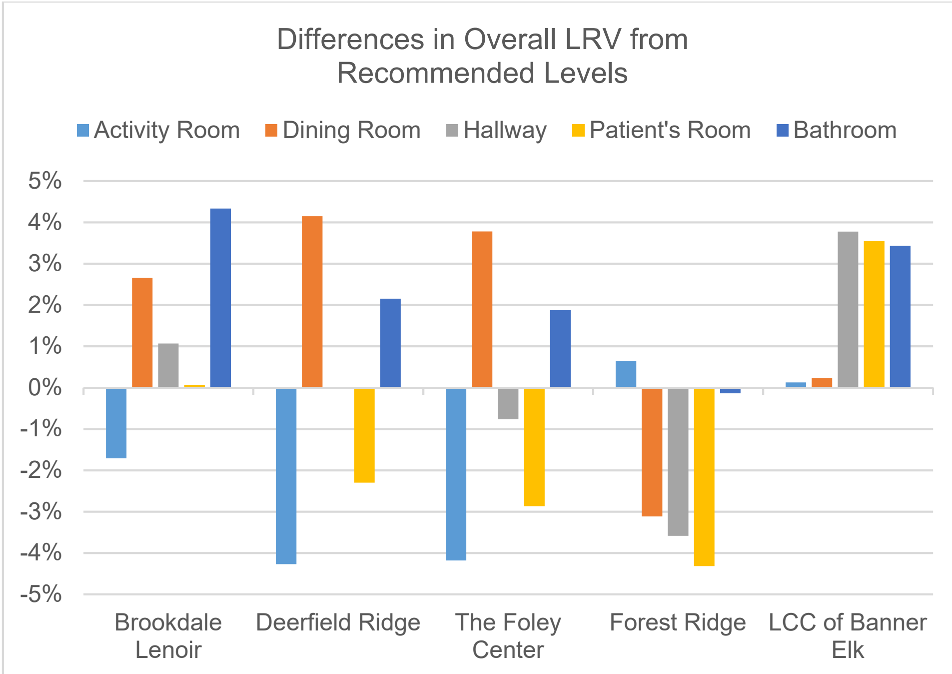

Figure 58. Deviation values for overall LRV from recommended levels.

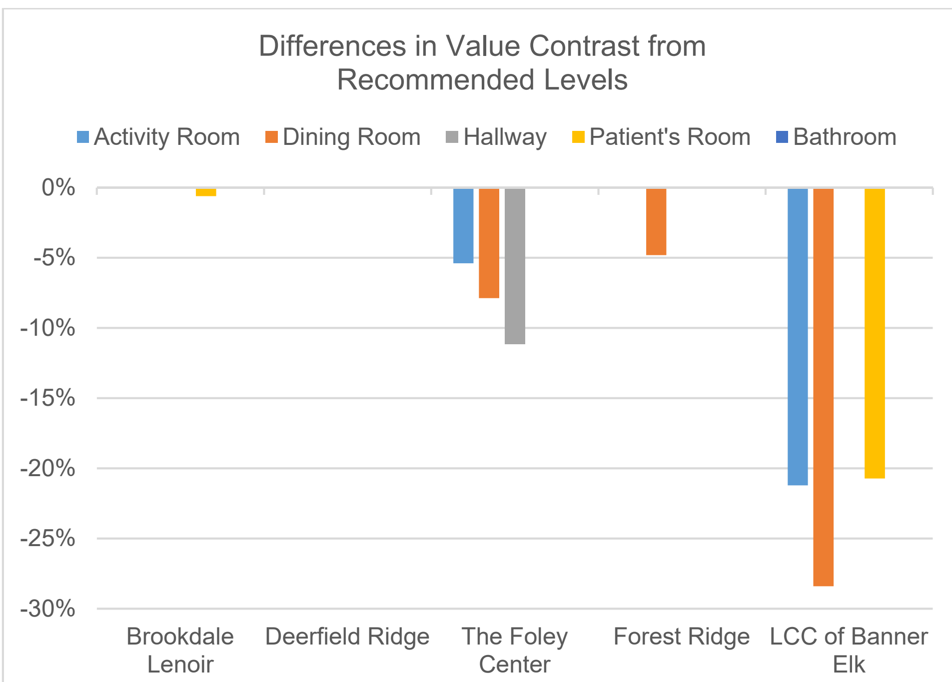

Figure 59. Deviation values for value contrast from recommended levels.

Table 59
Overall LRV Facility Ranking

Rank	Facility Name	Deviation Score
1.	Deerfield Ridge	|-0.28%|
2.	The Foley Center	|-2.16%|
3.	Brookdale Lenoir	|6.41%|
4.	Forest Ridge	|-10.51%|
5.	LCC of Banner Elk	|11.11%|

Value Contrast

All value contrasts 30 and above received a score of 0. If the number fell below 30, the difference was calculated (Figure 59). The facilities were ranked from best to worst with the least amount of deviation from the recommended amount of value contrast (Table 60).

Table 60
Overall Value Contrast Facility Ranking

Rank	Facility Name	Deviation Score
1.	Deerfield Ridge	0%
2.	Brookdale Lenoir	-0.62%
3.	Forest Ridge	-4.81%
4.	The Foley Center	-24.43%
5.	LCC of Banner Elk	-70.35%

Selection of Facility

Based on the quantitative results of the four variables, Life Care Center of Banner Elk scored the lowest for two of the four categories of assessment: luminance and value contrast.

While LCC of Banner Elk did score the highest in CCT, an accurate quantitative assessment of CCT was hard to achieve. Although LCC of Banner Elk did have the smallest deviation from color temperature throughout the majority of the day, it is difficult to quantifiably assess if that is better or worse than a CCT in the range of 2500K to 3500K in all the rooms of the facility. In the case of this facility, the CCT in the patient's room and bathroom were closer to the recommended CCT during the hours of 6:00 am to 6:00 pm, resulting in alert residents during the day. However, during the night, a cool CCT does not help facilitate a healthy sleeping pattern. Perhaps a warmer CCT in the private rooms, like that of the other four facilities, is more ideal. This would allow for an indoor environment more suited for the evening and night hours when residents are normally in their rooms. During the day, the facility may rely on natural light and the public spaces to provide recommended CCT levels. Instead, CCT values were reversed at LCC of Banner Elk.

As a result, Life Care Center of Banner Elk was selected for extended data collection and analysis by majority selection because the facility scored lowest on most of the four variables. This, coupled with the facility's planned remodeling to create a memory care unit, made it the best candidate for the extended analysis conducted in Part 2 of this study. A detailed proposal and analysis of cost savings follows.

Chapter 6: Extended Data Collection and Analysis

Extended Data Collection

Life Care Center of Banner Elk was selected for further data collection and analysis of the economic benefits of LEDs based on the results of the first round of data analysis. This facility scored the lowest in luminance values and value contrast. Since the facility is in the process of opening a dementia and memory care wing, the extended analysis on this study focused on this one wing of the facility.

At the time of the study, no electrical or architectural drawings were available. Instead, the researcher drafted a simple floorplan for initial fixture inventory. A walk-through and interview with the assistant maintenance director occurred and information on the lighting usage and existing lamps was obtained.

The dementia wing at LCC of Banner Elk includes a double-loaded corridor that was 111 feet long, 15 resident rooms, a central shower room, a day room, nurses' station, a private office, and a dining room. The total area of the wing is an estimated 5,740 square feet with a total volume of 44,342 cubic feet. The ceilings in the hallways and bathrooms are 7 feet 5 inches tall while the rest of the space has 8-foot-tall ceilings.

A detailed existing electrical plan is available for reference in Appendix D.

Existing Fixtures

In the hallway, there are a total of nine 2' x 4' fluorescent troffers recessed into the acoustical ceiling tile. Each resident's room has four fixtures each: two 2' x 4' surface-mounted troffers mounted to the ceiling that house two T8 lamps and two wall-mounted fixtures, one fixture over each bed. Each patient bed light houses four CFLs or LED A-series lamps and is controlled by a pull chain. Finally, there is one wall-mounted fixture above the vanity sink that houses two A-series lamps. In the bathroom attached to each resident's room is one ceiling-mounted T9/D circular fixture. In the central shower room, there are three surface-mounted 2' x 4' fluorescent troffers that house two T8 lamps. Similarly, there are also three 2' x 4' surface-mounted troffers in the day room. The nurses' station and adjacent private office each have one 2' x 2' surface-mounted troffer that contains two U-bend T12 lamps. Identical luminaires are in the dining room, with a total count of seven fixtures and 14 lamps.

Fixture Count. A summary of the total amount of fixtures and lamps per fixture as categorized by kind of luminaire is listed in Table 61. The total wattage of each fixture is calculated with the assumed ballast factor of 1 (Sylvania Lighting, 2005).

Table 61
Partial Fixture Count at LCC of Banner Elk. Total Number of Fixtures = 114.

Code	Description of Fixture	Type of Lamp	Wattage	Qty
L1	Recessed 2' x 4' fluorescent troffer	(2) 4-foot linear T8	64W	6
L1-E(S)	Emergency 2' x 4' fluorescent troffer	(2) 4-foot linear T8	64W	4
L1-S	Surface-mounted 2' x 4' fluorescent troffer	(2) 4-foot linear T8	64W	35
L2	Surface-mounted 2' x 2' fluorescent troffer	(2) U-bend T12	80W	7
L2-E	Emergency 2' x 2' fluorescent troffer	(2) U-bend T12	80W	2
L3	Wall-mounted patient bed fixture	(4) A-series CFL	52W	30
L4	Wall-mounted vanity fixture	(2) A-series CFL	26W	15
L5	Bathroom ceiling-mounted fixture	(1) T9/D	22W	15

Table 62
Time of Day Lights are Off

Room Name	Time Off	# of Lights Off	Annual Hours*
Hallway	10pm-6am	6 out of 9	5840
Resident's Room	9pm-5am	all	5840
Bathroom	9pm-5am	all	5840
Central Shower	8pm-9am	all	4015
Day Room	8pm-6am	2 out of 3	5110
Nurses' Station	always on	all	8760
Private Office	6pm-8am	all	3650
Dining Room	8pm-6am	5 out of 7	5110

*annual hours do not include the emergency 24/7 fixtures

Luminaire Usage. According to the interview with the assistant maintenance director as well as consulting a nurse who typically works in this wing, the usage schedule for the rooms in the dementia wing is reported in Table 62.

Maintenance Practices

The process of changing one lamp, also known as spot relamping, would take roughly five minutes. For group relamping, the assistant maintenance director estimated around seven hours to change and clean all the lamps on Hall 400. The average cost of labor is $20/hr.

Electrical Charges

Life Care Center of Banner Elk's electrical provider is Mountain Electric Cooperative. The average price per kilo-watt hour is $0.08 per hour. There is an estimated annual cost of $3,800 in electricity for the lighting in Hall 400. The electrical demand rate is $13.77/kW/mo. after the first 50kW. Annual demand charge is included in the overall energy cost.

Recommendations

A lighting system designed to minimize energy costs, maintenance costs, and to meet the recommended lighting standards as established in Chapter 2 in order to reap both quantitative and qualitative benefits in presented by this study. There are two schemes proposed: Scheme 1 and Scheme 2. The difference between the schemes applies only in the residents' rooms because this is where occupants spend the majority of their time. A detailed schedule of the proposed lighting products can be found in Appendix E. Additionally, all manufacturer specifications sheets for the products selected can be found in Appendix F.

Room Prototypes

The five rooms examined in the first part of this research study were virtually modeled in DIALux—a free professional lighting design software—to demonstrate the change in illuminance with the proposed lighting design in place. The existing illuminance maps drawn in Excel used conditional formatting and are shown for comparison. The objective of this exercise was to ensure that the proposed fixtures meet the recommended illuminance levels as described in Table 2. These schemes reflect the existing finishes in each room. A subsequent analysis would need to be done if finishes were replaced based on renovation recommendations.

The proposed electrical plans of both schemes are available in Appendix G.

Activity Room. The existing activity room had an average illuminance of 12fc. By putting retrofit LED kits into the existing 2' x 4' surface-mounted troffers, the average illuminance of the room would become 30.5fc, corresponding exactly with the recommended level of 30fc (Figure 60). The products selected for this room correspond with Type L1-S and L1-ES on the schedule. Directly under the luminaires in the main space, a high of 75fc would be achieved, reaching the target task illuminance.

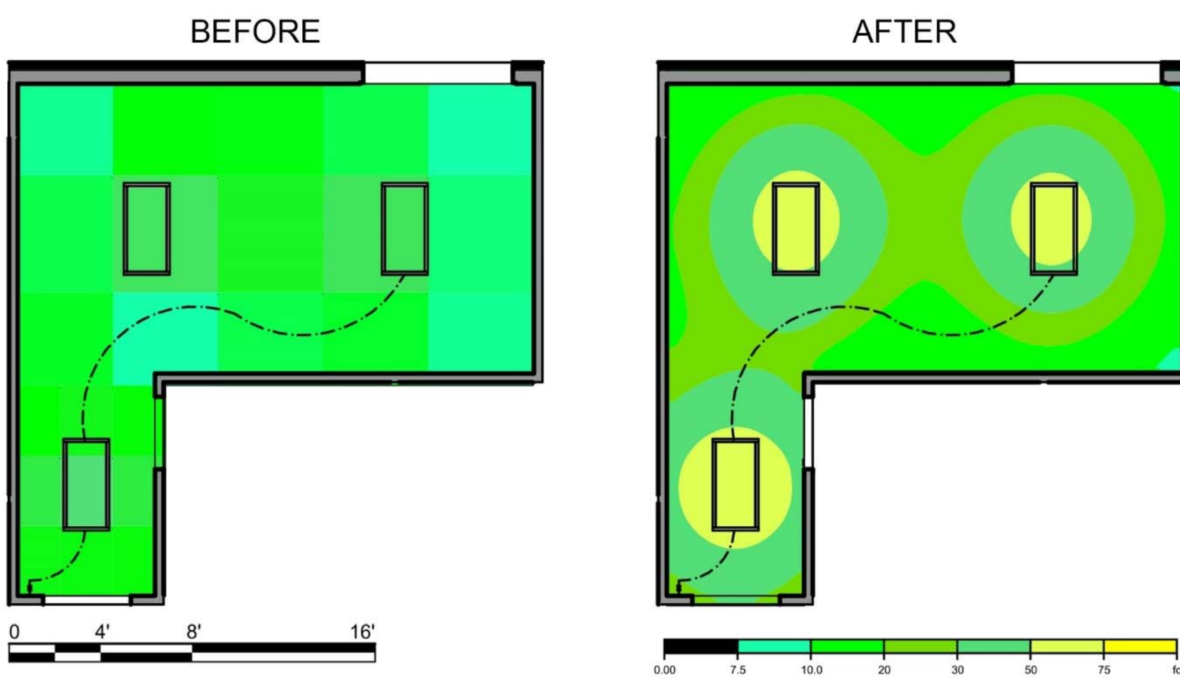

Figure 60. Before and after illuminance map of the day room.

Dining Room. The dining room should have an average ambient illuminance of 20fc, but the dining room in LCC of Banner Elk has an average ambient illuminance of 8fc. To achieve the recommended levels, a 2' x 2' retrofit LED kit for a new wattage of 24w can be installed in each of the existing troffers to gain a new average of 28.5fc (Figure 61). The dining tables should be placed directly below the fixtures so that task illuminance can reach its optimal, and recommended level, of 50fc. The products selected for this room correspond with Type L2 and L2-E on the schedule.

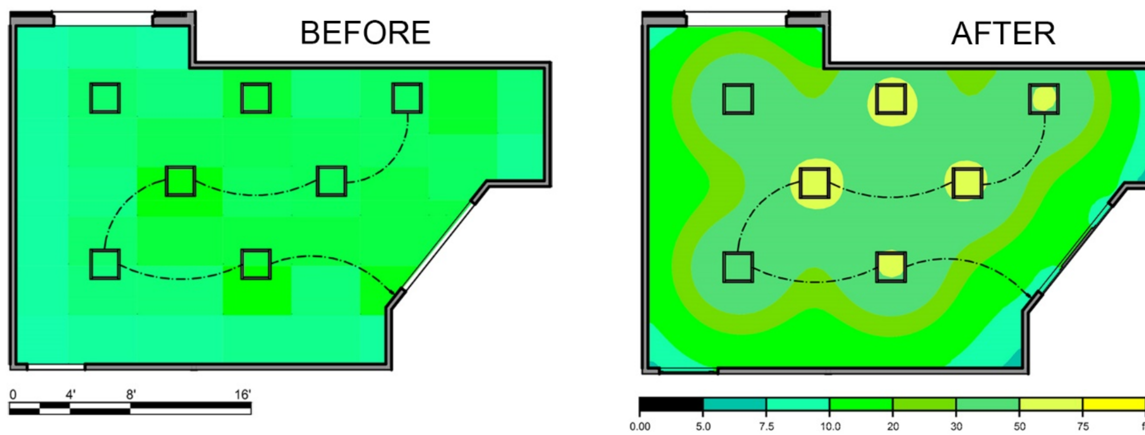

Figure 61. Before and after illuminance map of the dining room.

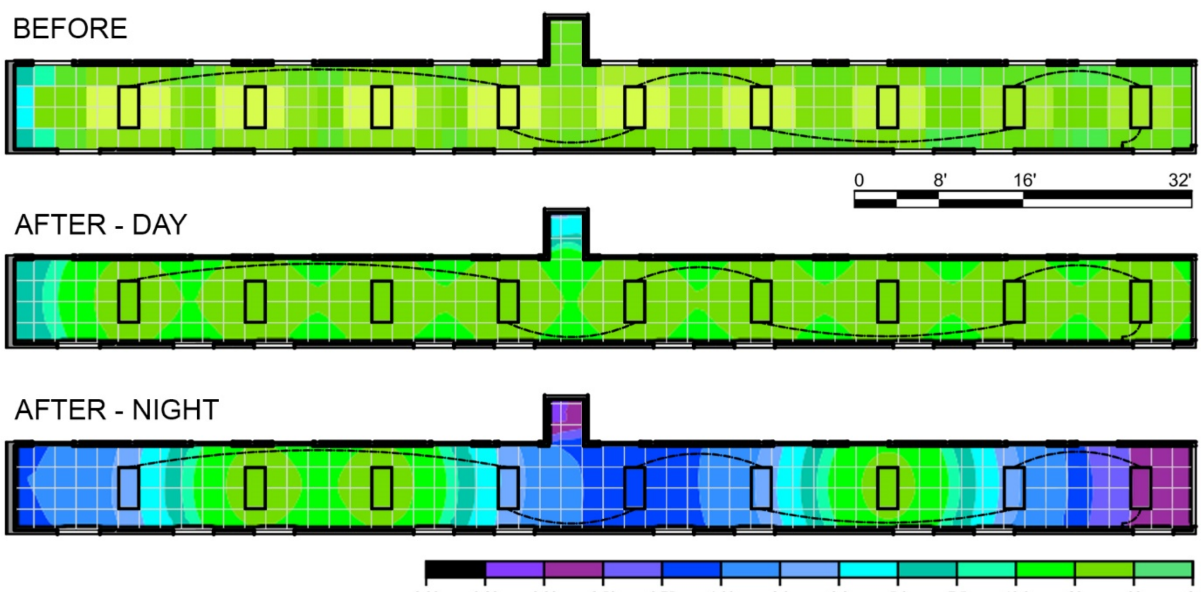

Figure 62. Before and after illuminance map of the hallway.

Hallway. The concern with LCC of Banner Elk's hallway is not a lack of illuminance; instead, the hallway is over lit by almost double the recommended levels. This is a waste of lumens and electricity and allows unnecessary light to encroach into the adjacent rooms during the night. The recommended average illuminance is 20fc; however, this hallway has an average of 37fc (Figure 62). The retrofit LED kit has a lower wattage, resulting in less luminous output, reducing the overall illuminance to an average of 21.5fc. At night, the three fixtures on the emergency circuit provide an average illuminance of 7fc. The recommended illuminance at night is 5fc. The products selected for this room correspond with Type L1 on the schedule.

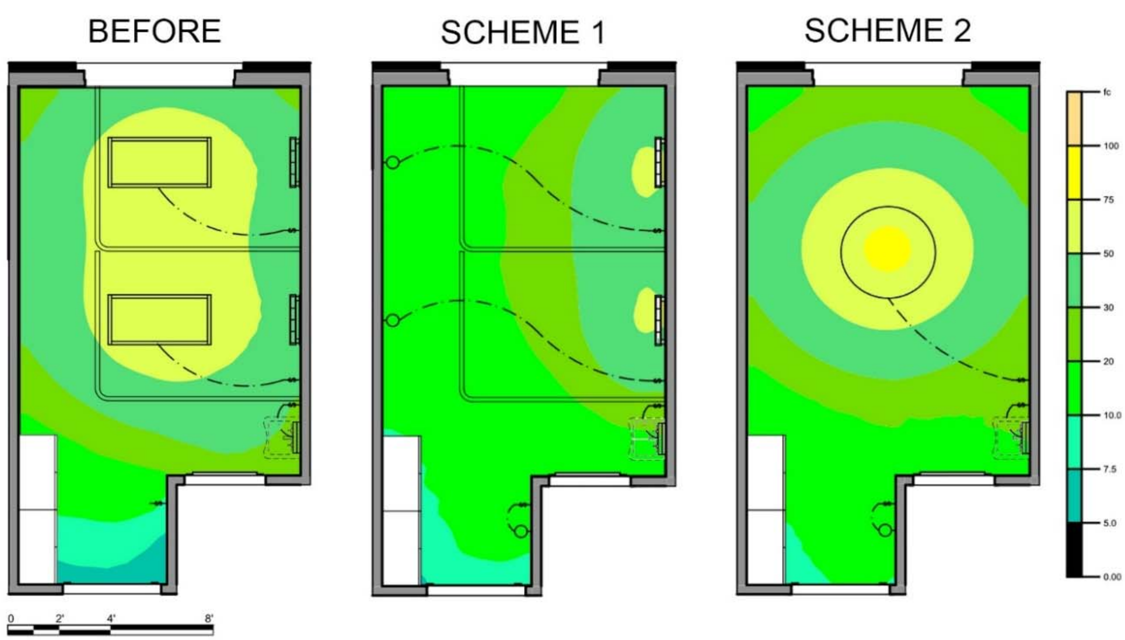

Figure 63. Before and after illuminance map of the resident's room.

Resident's Room. Since a resident room in Hall 400 could not be examined because all rooms in this hallway were occupied, a virtual illuminance map of the existing conditions was created in DIALux. The current average illuminance was at a predicted 40.5fc (Figure 63). This is double the recommended ambient level of 20fc. The added two 2' x 4' troffers in the resident rooms in Hall 400 add an unnecessary amount of light.

According to the study of a resident's room in Hall 200, the illuminance without the troffers averaged 9fc, half of the recommended levels. The products selected for this room correspond with Type L1-S, L3, L4, L6, and L7 on the schedule.

Scheme 1. To achieve an accurate balance of 20fc of overall, ambient illuminance throughout the room, as well as a task illuminance of 75fc at the head of the beds, the researcher proposes the removal of the existing 2' x 4' troffers. As a replacement strategy, an efficient wall-mounted, patient bed luminaire was selected with both direct, task lighting and indirect ambient lighting. Additionally, three extra wall-mounted sconces are specified, one in the entry way of the room to ensure that there is an even distribution of light in the path of circulation, and the other two on the wall opposite of the beds. The projected average illuminance would be 21fc. This scheme would require an extensive amount of rewiring from existing ceiling junction boxes down to the wall opposite of the switches, including extra wire and drywall patching.

Scheme 2. The second proposed scheme would use Visa Lighting's Symmetry 44-inch-diameter recessed tunable white light. The two 2' x 4' ceiling troffers and two wall-mounted, patient bed lights would be eliminated. For this scheme, however, the curtain tracks in the ceiling must be removed. While this can still accommodate two occupants per room, privacy will not be provided in this scheme. One of the existing ceiling junction boxes would need to be relocated to the center of the room. The residents would be able to experience the benefit of changing CCT values throughout the day. Different CCT provide a different amount of delivered lumens for a varied average ambient illuminance throughout the day. At 3000K, pictured above, the room would have an average illuminance of 32fc. However, this number would be reduced because this fixture is dimmable as well as tunable.

This scheme would require a DMX controller in each of the resident's rooms to make use of the tunable function. The control adds to the initial cost almost three-fold the price of the actual fixture. Additionally, it can cost up to $500/control on programming fees. While the price of the control was calculated in the initial cost of the system, the cost of programming was not included in this study as it fluctuates significantly depending on unknown factors such as labor rates, complexity of programming scenarios, and intricacy of the control device itself. Depending on the cost of programming, it may add up to five years to the payback time of the entire lighting scheme. However, residents will experience the qualitative benefits that tunable white light provides – benefits that are hard to quantify.

Because of the large added initial cost to this scheme and the extended amount of labor and commissioning requirements, it is possible to divide this renovation scheme into several phases. For example, there are currently four single-occupancy resident rooms in Hall 400. The removal of the curtain tracks will not affect these occupants. These four rooms could be included in the first phase of the renovation and the remaining 11 rooms could be left untouched. The other rooms may be renovated progressively depending on the success of the first phase of the renovation.

Another alternative option is to conduct a pilot program to test out both schemes in two different rooms. This could be in the form of a grant or cooperate partnership—for example, Visa Lighting could donate one or two fixtures for testing. Behavioral effects and energy savings can be quantified to determine if subsequent renovations should be pursued.

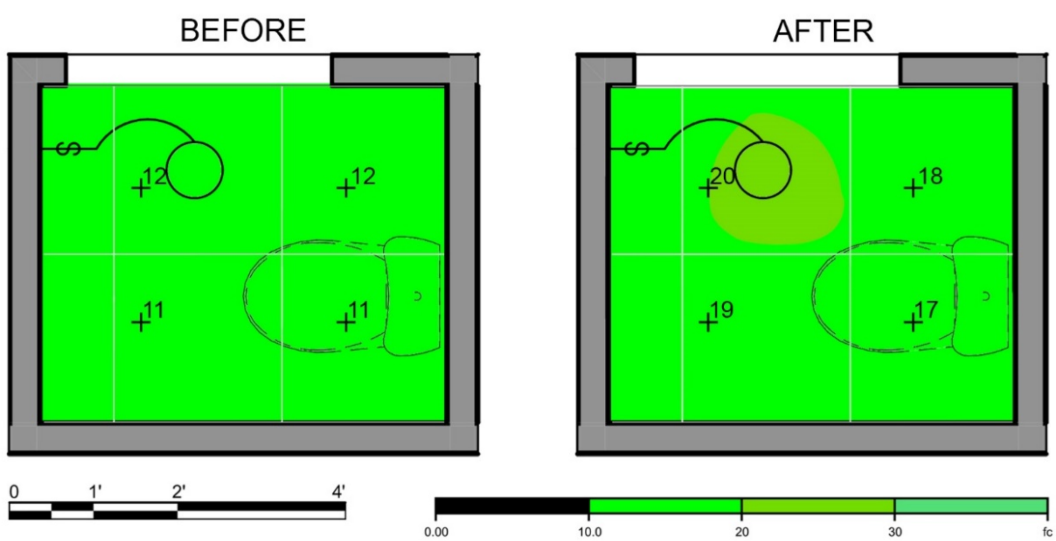

Figure 64. Before and after illuminance map of the bathroom.

Bathroom. Since the bathroom houses a water closet, the recommended illuminance above the toilet is at 20fc. The existing condition with a T9/D fluorescent lamp provided an average illuminance level of 11fc. A replacement fixture would raise the illuminance level to an average of 17.32fc (Figure 64). The product selected for this room corresponds with Type L5 on the schedule.

Description of Products

LED Troffers. LED Living Technologies has a product for an LED retrofit kit for fluorescent 2' x 4' and 2' x 2'. The product is on the DLC Qualified Product List and promises a 65-80% energy savings over fluorescent lamps. A 4000K CCT is specified for the hallway, central shower, day room, nurses' station, private office, and dining room. For the resident's room, the two troffers can be eliminated and replaced with alternative fixtures to achieve the recommended illuminance. The Type L1 and L2 designations in the schedule refers to these products.

Alternative products. Eaton's Metalux product line also offers an LED retrofit kit for 2' x 4' and 2' x 2' fluorescent troffers. This product's efficacy is slightly less than the product by LED Living Technologies. Alphabet by LEDRA Brand's has the 2BIOS Troffer in both 2' x 4' and 2' x 2' that can be specified with BIOS technology, providing the optimal spectrum of visible blue light without focusing on the CCT of the product.

Patient Bed Light. For this retrofit, a 49" Headwall product in the Unity series by Visa Lighting is specified that is designed to be mounted on the wall above a bed. There are several illuminance levels for reading, general ambience, as well as exam lighting. There is also an amber night light option. Type L3 in the schedule refers to this product.

Alternative products. Cooper Industries Fail-Safe has a wall-mounted patient bed fixture called the MPBL LED. This fixture allows for a variety of different scenarios: one or two modules with both indirect and direct light, in three output levels. A pull chain can be specified for easy control by the residents. However, this product is not cost effective.

Wall-mounted Vanity Luminaire. Selected for adequate lumens as well as its cost effectiveness and energy efficacy is the 12" Linear LED Bath Light NI by Kichler. This fixture only uses 10 watts and has a life span of 45,000 hours. The type designation for this product in the schedule is Type L4.

Alternative products. Teron Lighting offers many simple but efficient vanity lights. The Janzen LED vanity fixture is low in energy consumption at 12w and is ADA compliant. Another option is the Overland MSI LED 24" vanity light. Both fixtures provide similar lumen outputs.

Ceiling-mounted LED Fixture. Eaton's Metalux has an 8-inch flush mount round ceiling fixture that is inexpensive and functional. The FMLED fixture uses only 8w and is ideal for replacing circline (round) fluorescent lamps, such as the current fixture in the bathroom. Type L5 in the schedule refers to this product.

Alternative products. Alphabet by LEDRA Brands has a 4-inch downlight that can either come in BIOS technology, without the unhealthy LED blue spike, or in Lumenetix, which is a tunable white technology. Ideally, this product can be hooked up to a control system that can be programmed so when residents use the bathroom at night, a very warm CCT turns on versus a cool blue light.

Wall Sconce. A 12" ADA wall sconce by Visa Lighting in the Unity series is specified for the entrance of the residents' rooms. This product has a night amber light option and can be left on during the night as a nightlight. While there is no fixture placed there currently, there is a pocket of darkness in the main circulation path from the hallway to the main section of the resident's room. The switch located by the door can be rewired to control this new light fixture with minimal installation and labor costs. The type designation for this product in the schedule is Type L6.

For Scheme 1, two similar wall sconces are placed on the wall opposite of the beds to achieve the recommended ambient illuminance in the residents' rooms. These fixtures require new junction boxes and additional rewiring from the existing ceiling junction boxes to the opposite wall. The ceiling is hung gypsum board, so only minimal drywall patching will occur in the wall. The existing switches by the bed can control these new fixtures.

Tunable White Light Fixtures. For Scheme 2, a tunable white light product is specified by Visa Lighting in the Symmetry series. This 44" in diameter recessed luminaire can be fully programmable to adjust color temperatures and lumen output throughout the day. The cost of this luminaire without the tunable function is an estimated price of $155/fixture. The additional tunable function raises the price to $262/fixture.

Alternative products. Finelite has a patient bed light in its Tunable White Series, the 17 LED ADA Wall Mount fixture. Several other manufacturers of tunable white products include Pathway and Intense Lighting and they have a variety of LED downlights that are tunable or have dynamic dimming. There is also a tunable-white troffer by Samjin in PlanLED's Beetle Series.

Controls. The only control specified in this study is the control needed for Scheme 2's tunable white light fixture in the residents' rooms. The product requires a DMX control from any source. For this proposal, a Self-Contained DMX Control Device by Eaton called the ArchiDMX is specified in each room and runs $700 per unit. Alternatively, a central DMX controller with multiple channels and a wall switch may be an option because all rooms will be programmed for the same scenarios throughout the day and may reduce initial costs or break even with the reduced programming fees.

Other controls are not specified in this proposal, but since LED fixtures already have dimmable ballasts, if the facility so desires, new low-voltage wiring can be installed to incorporate dimmable switches. Eaton has a decorative dimmer wallstation that runs around $52 per unit. Eaton also has a product that combine a dimmer and an occupancy sensor into just one wallbox device. Occupancy sensors in rooms that are sporadically occupied such as bathrooms or the activity room are highly recommended to reduce usage times.

Maintenance Recommendations

The maintenance procedures for LED lighting are different than the maintenance procedures for fluorescent lighting. Because of the nature of LED fixtures and the rated lifespan of these fixtures of 50,000+ hours, it is common practice to replace the entire fixture when a lamp burns out. This new practice reduces the annual maintenance costs significantly.

Additionally, fixtures should be replaced using group relamping techniques, meaning all fixtures of one kind or in this same room type should be replaced at the same time. Group relamping saves time and allows the fixtures to depreciate at the same rate. There are two kinds of depreciation when it comes to fixtures: lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD), so it is equally important that the fixtures are cleaned on a regular basis and at the same time.

Renovation Recommendations

While retrofitting the design of the lighting was the primary focus of Part 2 of this study, based on the first round of data collection, the LCC of Banner Elk also has finishes that do not fall in the required luminance value range, nor does the value contrast between the floor and wall plane meet the recommended contrast. Therefore, several quick recommendations t0 change finishes in the interior environment are listed below.

A new coat of paint for all the walls throughout the facility would help with the contrast difference between the floor and wall plane. The paint color selected should have a LRV that falls in the 40%- 60% range. A paint sheen of eggshell or satin will ensure that the surface will be easily maintained and not promote glare. An alternative to painting is to install baseboard with an LRV around 10% to achieve a contrast of 30 from the flooring. The hallway wainscot finish, currently a dark red low, loop pile carpet, should be replaced with a Type III wallcovering or paint that has a value contrast from the floor. The current carpet wall finish is hard to clean this high-traffic area, therefore an alternative finish would result in easier maintenance and withstand heavy use.

Although it would represent an extensive renovation, the flooring material throughout the facility should be changed to a material with a lower light reflectance value (LRV) of between 20%-40%. Currently, the vinyl tile has a reflectance value of 40% but its color hue is light, resulting in glare into the occupant's eyes. In addition, the current hue does not hide dust. While the gloss finish may connote a clean finish, it is a harder finish to maintain. A new flooring will solve the issues of glare, maintenance, and cleanliness.

Summary of Expenses

Existing Expenses

Overall, the existing costs of the current lighting system was calculated using the estimate time of usage, an average ballast factor of 1, the watts per specification of the existing lamps, and the projected life span of the lamp as established by the manufacturer (Table 63).

Table 63
Summary of Current Annual Lighting Expenses

Total yearly kWh usage	34,876.48 kWh
Total yearly energy costs	$3,761.73
Yearly maintenance costs	$752.01
Total annual costs	$4,513.74

Projected Expenses

Table 64
Summary of Proposed Annual Lighting Expenses

Scheme 1		Scheme 2	
Total fixture count	129 fixtures	Total fixture count	84 fixtures
Total yearly kWh usage	20,136.32 kWh	Total yearly kWh usage	17,420.72 kWh
Total yearly energy costs	$2,175.20	Total yearly energy costs	$1,881.12
Yearly maintenance costs	$206.40	Yearly maintenance costs	$134.40
Total annual costs	$2,381.96	Total annual costs	$2,015.52

Since the existing lighting system is primarily fluorescent lamps, the savings in energy efficiency are not as drastic as a switch from incandescent to LEDs. While there will be slight energy savings, most importantly, the proposed lighting system will reduce maintenance costs and provide the recommended illuminance levels in the rooms (Table 64).

Projected Savings

Based on the numbers above, the total amount of savings for both schemes are shown in Table 65.

Table 65
Total Energy Savings for Scheme 1 and 2

	Scheme 1	Scheme 2
Annual kWh saved	14,470.16 kWh	17,455.76 kWh
Annual energy cost saved	$1,586.53	$1,880.61
Annual maintenance cost saved	$545.61	$617.61
Total annual cost saved	$2,132.14	$2,498.22

Initial Costs

The cost of the proposed lighting system is broken down in Table 66. The products selected can be found through a variety of lighting representatives in the area, including Bodwell Associates, TEAM Lighting, and S.L. BAGBY, all located in Charlotte, NC. City Electric Supply in Boone is the closest electrical distributor to Banner Elk. A retrofit energy and cost spreadsheet comparing existing fixture with proposed fixture can be found in Appendix H.

Labor cost and time are accounted into the overall cost of installation using an estimated labor rate of $28/hour. The electrical labor cost per hour is taken from RS Means from Year 2017, Quarter 1 for the Hickory, North Carolina region.

Table 66
Summary of Proposed Initial Costs

Scheme 1		Scheme 2	
Total fixture count	129 fixtures	Total fixture count	84 fixtures
Total fixture cost	$$7,023.00	Total fixture cost	$8,698.00
Total installation costs	$2,985.60	Total installation costs	$12,645.60
Total initial costs	$10,008.60	Total initial costs	$21,343.60

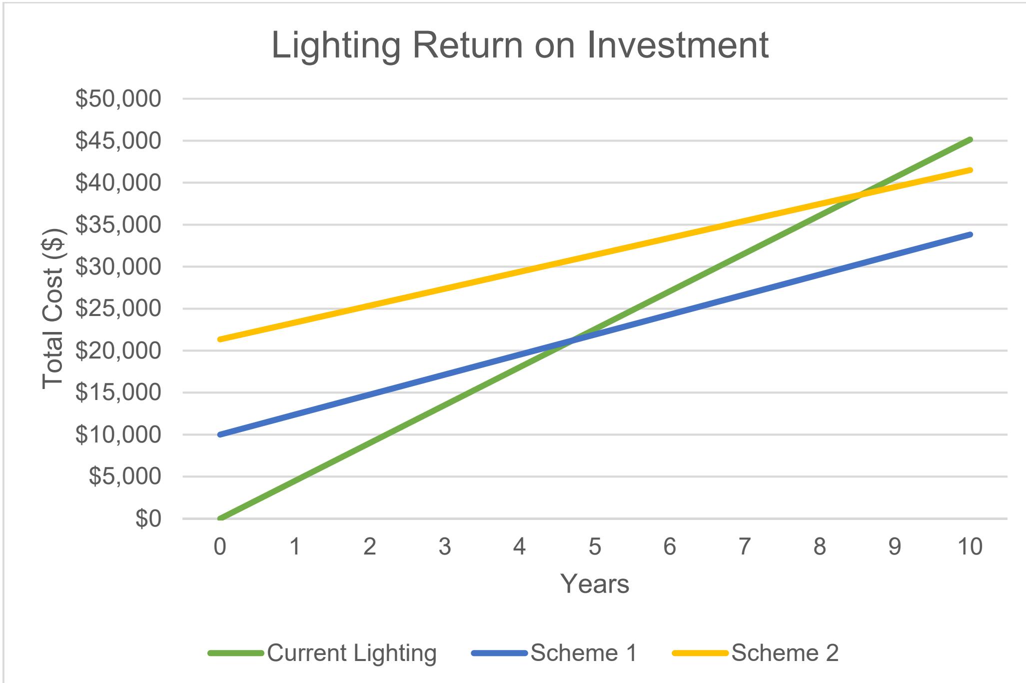

Figure 65. Lighting return on investment for proposed lighting system.

Return on Investment

The payback time, or return on investment (ROI), can be found by taking the initial cost, $7,110.60, and dividing it by the annual energy cost savings, $2,118.52 (Table 67). Figure 65 graphs the estimated projected return time for both schemes and shows the increased cost of remaining with the current lighting scheme. By 10 years and counting, the facility would have spent more money in electricity and maintenance if one of the schemes was implemented.

Table 67
Return on Investment Payback Time

	Scheme 1	Scheme 2
Estimated payback time	4.69 years	8.54 years

Lighting Proposal Resources

An example of the system comparison calculator spreadsheet used to calculate all the savings for this proposal can be found in Appendix I. This resource was adapted from the book *Lighting Retrofit and Relighting* by Benya and Leban (2011, p. 257). Using this spreadsheet, LCC of Banner Elk and similar facilities can change different variables such as quantity of lamps, amount of wattage, annual usage, price of fixture, and labor rate to automatically calculate the energy and cost savings and payback time of the system. This Excel spreadsheet is available to download for readers of this study on the researcher's website at www.hazelchazel.com/lighting-retrofit.

Application for Other Facilities

Table 68 provides an estimation of the savings that can be obtained based on the type of lamps in current senior living facilities. Using this table, other facilities can use this study to create a quick estimate of energy costs for current lighting scenarios.

Table 68
Estimated Annual Energy Cost Savings per Fluorescent Lamp

Type of Lamp[1]	Energy $ Saved (%)	Annual Energy Costs[2]
2-lamp F40 T12 w/Mag Ballast (97W)	-	$42.50
2-lamp F40 T12 w/EEMag Ballast (87W)	~10%	$38.10
U-tube 2 lamp – T12 FB40ES w/ Std Mag (82W)	~15%	$35.90
2-lamp F34 T12 w/Mag Ballast (80W)	~17%	$35.00
U-tube 2 lamp – T12 FB40ES w/ EEMag (72W)	~25%	$31.50
2-lamp F34 T12 w/EEMag Ballast (67W)	~30%	$29.40
60W Traditional Incandescent	~40%	$26.30
2-lamp F20 T12 – 2ft (56W)	~42%	$24.50
2-lamp F32 T8 w/Elec. Ballast (56W)	~42%	$24.50
1-lamp F40 T12 w/Mag Ballast (51W)	~48%	$22.30
1-lamp F34 T12 w/Mag Ballast (50W)	~50%	$21.90
U-tube 1 lamp – T12 FB40 (48W)	~50%	$21.00
43W Energy-Saving Incandescent	~55%	$18.80
1-lamp F34 T12 w/EEMag Ballast (42W)	~57%	$18.40
1-lamp F40 T12 w/EEMag Ballast (41W)	~58%	$18.00
1-lamp F20 T12 – 2ft (28W)	~70%	$12.30
1-lamp F32 T8 w/Elec. Ballast (28W)	~70%	$12.30
15W CFL	~84%	$6.60

[1]Wattage of typical lamps is taken from Ameren Illinois Energy Efficiency Programs (1991)
[2]Based on 15 hrs/day of usage, an electricity rate of 8 cents per kWh, shown in U.S. dollars

Chapter 7: Conclusion

Summary of Findings

The results of this study confirm that the senior living facilities in Northwestern North Carolina do not meet the recommended lighting standards as established by the IES. Instead, the majority of the rooms fell far below the recommended illuminance levels. Moreover, there was almost complete oversight of proper task illuminance and luminaires that were specifically placed for task lighting. A general assumption can be made, based on the five facilities studied, that most senior living facilities have lighting that mimics a healthcare or residential scenario. The lights were on opposite ends of the spectrum, from soft (characteristic of residential) to harsh (characteristic of healthcare) lighting. Consideration towards an elderly person's eyesight was overlooked.

Based on the literature review, there is clear evidence that explains the qualitative benefits to be gained from use of appropriate lighting technologies in long-term home health care facilities. As the technology of health-related lighting continues to advance, designers will begin to see the importance that light plays on the occupant's wellbeing in the indoor built environment. Furthermore, the initial cost of such technologies is expected to become more affordable and cost efficient in the near future.

As emphasized in this study, the technical aspects of lighting are not the only consideration when evaluating an overall lighting scenario. The tasks performed in the space must be considered. The finishes of the interior surfaces are also factors that influences the way lighting is perceived in the space and the examined facilities did not always meet recommendations. Luminaire dirt depreciation (LDD) and lumen lamp depreciation (LLD) can affect the overall quality of the lighting. Maintenance practices are also critical. This is an aspect where LEDs have an advantage as lamps do not need to be replaced nearly as frequently as other kinds of lamp sources.

Additionally, as LED technologies begin to evolve and become more and more energy efficient, the payback time will shorten drastically. The current, middle-of-the-line energy efficient fluorescent tubes will become obsolete and ineffective. At the time of this study, there is a longer return on investment time for SSL lighting technologies because traditional T8 fluorescent tubes are reasonably energy efficient, and the initial costs of quality luminaires and the controls associated with such LED technologies are currently steep but expected to decrease in price as the technology develops.

Recommendations for Further Study

This study establishes many platforms for further research. The researcher acknowledges that no study can be fully comprehensive and has listed several avenues for further development on the problem.

An obvious track for further research is the topic of lighting's effects on human behavior. This would entail use of human research subjects, but the findings from such a research project would be informative on the subject of human centric lighting. If the design proposal in this study was to be implemented, it would be ideal if data collection on the existing conditions of the residents' behavior such as sleeping patterns, number of falls, and competency in performance of daily tasks, to list a few, was first observed and recorded. Upon completion of the lighting renovation, a subsequent observation of these previous behavioral aspects could lead to conclusive results on how lighting influences the behaviors of the residents. A controlled environment will be hard to achieve because this population introduces many other variables besides lighting that could potentially influence behavior. Barring formal research, even informal, systematic data collection on the part of a facility's staff could yield evidence to support the benefits of this type of lighting retrofit.

Furthermore, in the event that the proposal is implemented, identical data collection should occur in the original five rooms that were examined in the data collection process of this study. The new values for illuminance, color temperature, luminance, and value contrast could be compared to the existing conditions to assess the results of the renovation. The actual illuminance could also be compared to the modeled, projected illuminance. Additionally, projected and actual equivalent melanopic lux—a measurement of the biological effects of light on humans—can be calculated to determine if proper circadian rhythm stimulation can be achieved. The WELL Building Standard has established standards for EML. This is an "alternate metric that is weighted to the ipRGCs instead of to the cones, which is the case with traditional lux or footcandles" (International WELL Building Institute, 2017, p. 96).

Likewise, it would also be noteworthy to see how the projected energy savings aligns with actual energy savings. Clear documentation of the installation, upfront cost of labor and materials, maintenance costs, and the energy savings every month for a year should be obtained. The payback time could then be calculated accurately based on the actual savings over a year. Conclusions could be drawn about the accuracy of projected savings to actual savings.

With the advancement of healthcare lighting, a similar study is recommended in a few years when the initial cost of innovative lighting technologies has reduced significantly. At the time of this study, there is a small market of products that are focused on lighting technologies for healthcare applications such as BIOS technology, tunable white lighting, and amber night lights. There is currently a premium for such technologies, not unlike the premium placed on LEDs when first introduced to the market, but we might expect to see similar, rapid reductions in cost over time.

This study is focused entirely on artificial light; however, adding natural light back into the equation could potentially shift the focus of the study. Provided there is adequate daylighting, tunable white light may no longer be necessary when exterior glass fenestrations are present. The subject of daylighting effects on health is vast, offering many more possibilities for further research.

The current proposal segregates qualitative and quantitative benefits. Scheme 1 specifically favors quantitative—ie. economic—benefits, while Scheme 2's initial cost does not economically represent the qualitative savings. Further evaluation and partnership with an economist can help to quantify the soft savings associated with lighting. For example, much emphasis is placed on fall prevention in healthcare, and if lighting can play a role in prevention methods, quantifying those savings could further encourage a senior living facility to switch to an LED lighting system that meets recommended lighting standards.

Additional analysis could be conducted with little additional data collection on the finishes of the facility and how an aging eye perceives the different hues. Also, since existing finishes were assumed for the modeled illuminance calculations, a study could be done to determine how much light reflectance values of the overall floor, wall, and ceiling affects the overall average illuminance in the room.

A subject of interest that arose during this study was the huge margin of difference between the existing illuminance levels and recommended illuminance levels. There is a large disconnect between what is required of lighting as established by the building code and what is recommended per *The Lighting Handbook 10th Edition*. What factors are keeping the International Code Council (ICC) and the Illuminating Engineering Society (IES) separated? Does this constitute an ethical issue in which designers are not pushing for the enforcement of these recommendations as required standards? The code needs to be changed to reflect specific tasks and primary users of the occupancy classification of different buildings. A single set of standards across healthcare settings does not adequately take into account the lighting needs of the elderly in a semi-residential setting.

As lighting technology continues to improve and awareness of both the visual and non-visual needs of the human eye becomes more apparent, senior living communities will find that an effective and appropriate lighting system will be indispensable. This study, along with others of its precedent, is only the beginning of a trend towards energy-efficient, health-benefitting, and visually-appropriate lighting technologies that affects the health, safety, and welfare of the occupants in senior care facilities.

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Appendix A: Further Reading

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Appendix B: Data Collection I Worksheet

Current Status and Prospects for Lighting Technologies in Senior Living Facilities
Principal Investigator: Hazel Chang

Facility Name: ______________________________ Date: ____________________

Room Name: ______________________________ Time: ____________________

NOTE:
- Overall dimensions
- Fenestration locations & sizes
- Control locations
- Light sources locations & heights
- Ambient illuminance measured @ a min. of 30" a.f.f.
- North arrow

EVALUATE:
- Lighting levels
- Color temperature
- Value (luminance)
- Value contrast
- Controls

PHOTOGRAPH:
- Overall room before
- Overall room after
- Finish comparisons with paint color swatches

Appendix B: Data Collection I Worksheet Cont.

RECORD:

Window Qty and Sizes:		______					
Window Treatment:		______					
Window/Door Head Ht:		______					
Type of lamp(s):		______					
Ceiling Height:		______					
Task Height:		______					
Color Temperature:		______					
LRV:	Floor:	______	______	______	______	______	
	Task:	______	______	______	______	______	
	Ceiling:	______	______	______	______	______	
	North:	______	______	______	______	______	
	East:	______	______	______	______	______	
	South:	______	______	______	______	______	
	West:	______	______	______	______	______	
Finishes:	Floor:	______			Color #: ______		
	Task:	______			Color #: ______		
	Ceiling:	______			Color #: ______		
	North:	______			Color #: ______		
	East:	______			Color #: ______		
	South:	______			Color #: ______		
	West:	______			Color #: ______		
Controls:	Amount:	______					
	Height:	______			______		

Appendix C: Data Collection II Worksheet

Current Status and Prospects for Lighting Technologies in Senior Living Facilities
Principal Investigator: Hazel Chang
Department: Sustainable Technology & the Built Environment
Contact Information:
Hazel Chang
changht@appstate.edu
(207) 205-5354

Facility Name: ______________________________

Person Interviewed: ______________________________

Date and Time: ______________________________

Data Collection II: Economic Questionnaire

Questions to Ask Maintenance/Housekeeping Director

- What lights are turned off (if any) and what times are they off?

  Activity/Living/Day Room: ______________________________

  Dining Room: ______________________________

  Hallway: ______________________________

  Resident's Room: ______________________________

  Bathroom: ______________________________

- Can you give me an estimate of how long it takes you to change one lamp?

  Length of time: ______________________________

  Labor rate per hour: ______________________________

- If you were to change all the lamps in the entire facility, how long would that take you?

  Entire facility: ______________________________

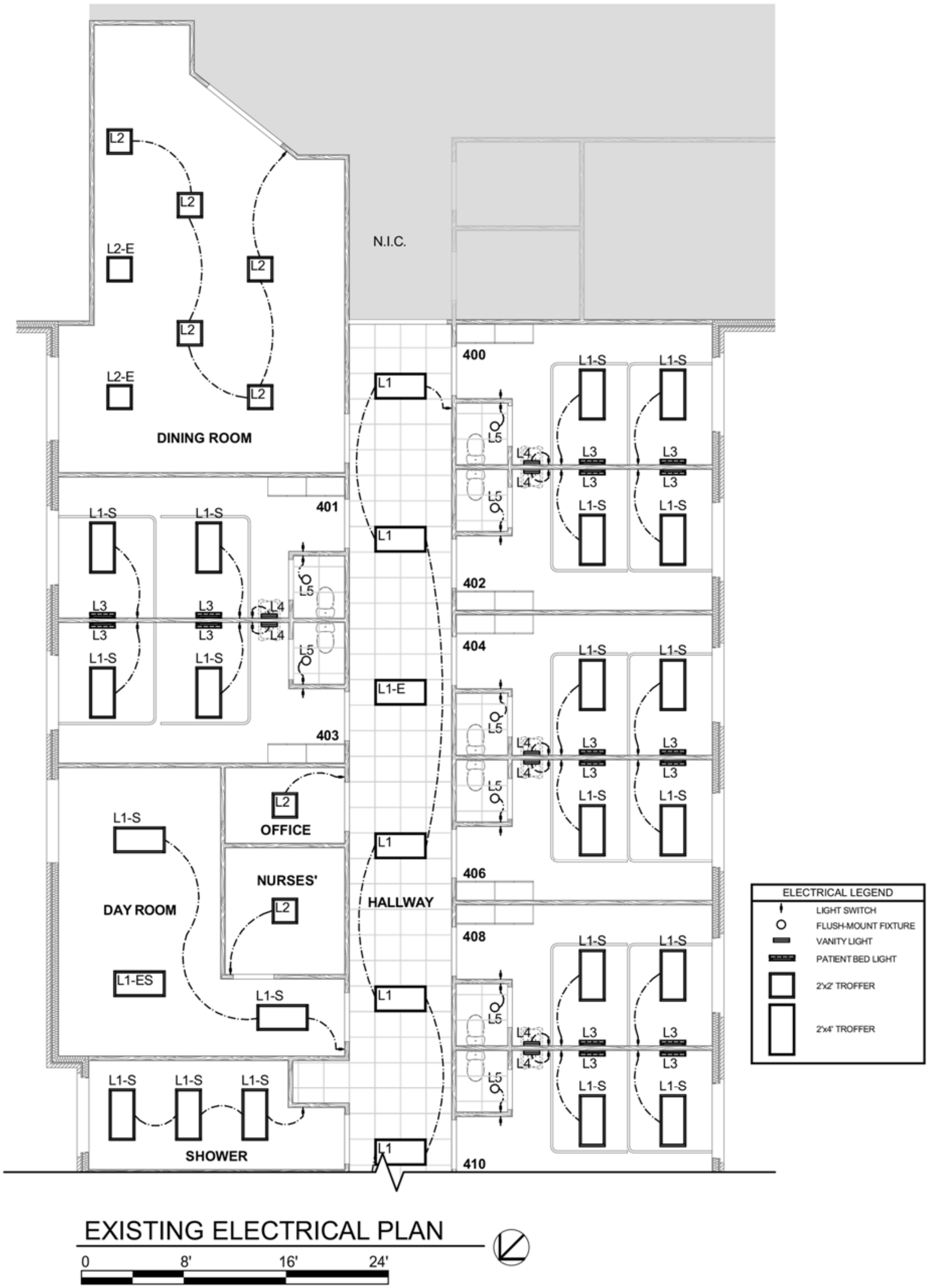
  Just one wing: ______________________________

- Do you clean any fixtures and if so, how long does it take you?

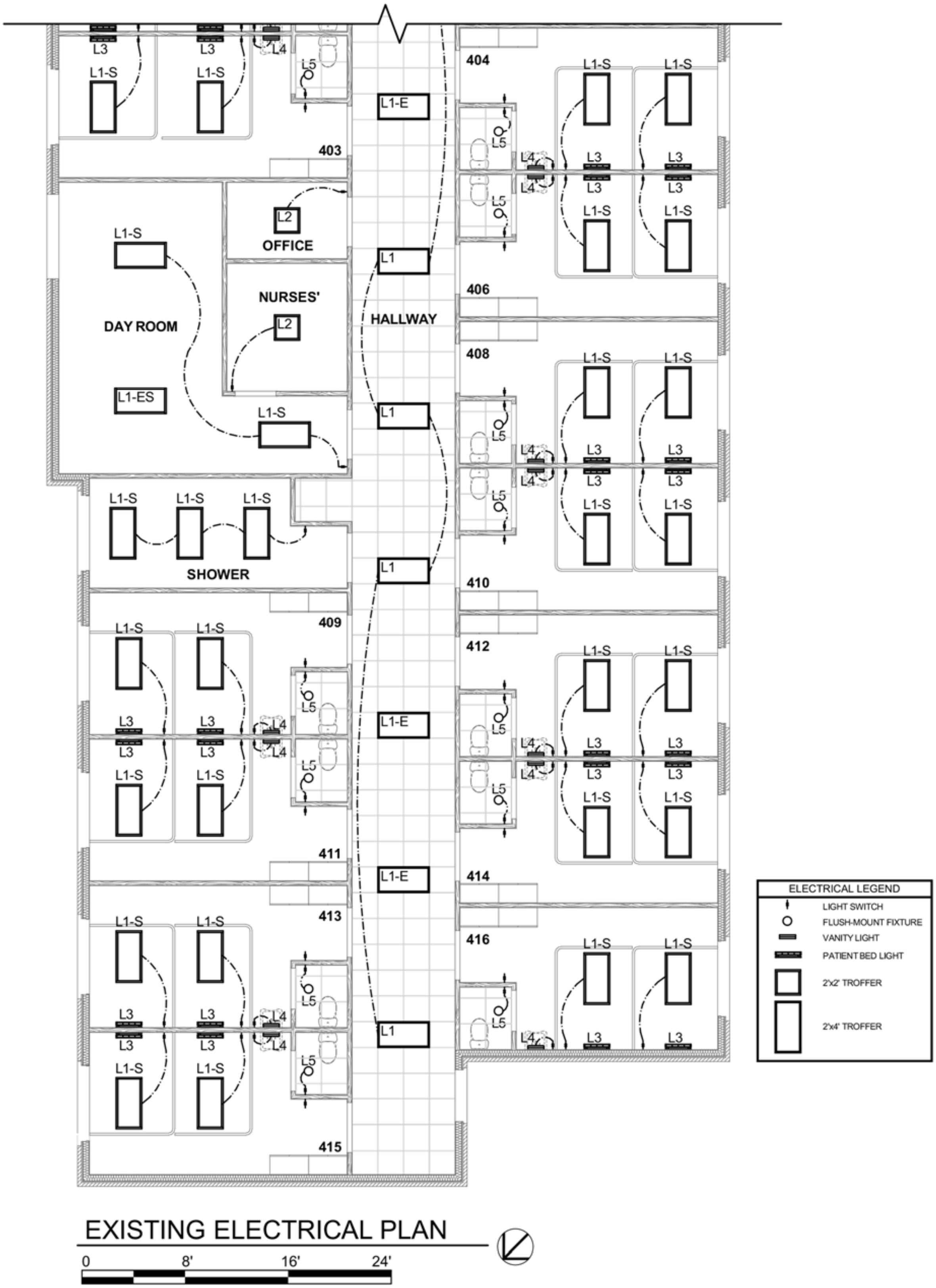
- Can I know what kind of lamps are used in the one wing of interest? How much do these lamps cost to buy? (Take pictures of product.)

- What is your rate schedule? Can I get a copy of a recent electric bill?

Appendix D: Existing Electrical Plan



Appendix D: Existing Electrical Plan cont.



Appendix E: Proposed Lighting Schedule

Lighting Fixture Replacement Schedule						
Type	**Manufacturer**	**Description**	**Catalog Number**	**Qty**	**Estimated Pricing**	**Total Price by Type**
L1	LED Living Technology	GEN2 CLARIS LED Retrofit Kits 2’ x 4’ Linear Troffer (Recessed)	G2CLA-24-4-D-40-1K-24-LENS24	9	$113.00	$1,017.00
L1-S	LED Living Technology	GEN2 CLARIS LED Retrofit Kits 2’ x 4’ Linear Troffer (Surface-mounted)	G2CLA-24-4-D-30-1K-24-LENS24	6	$113.00	$678.00
L2	LED Living Technology	GEN2 CLARIS LED Retrofit Kits 2’ x 2’ Linear Troffer	G2CLA-16-2-D-40-1K-22-LENS24	9	$85.00	$765.00
L3	Visa Lighting	Unity 49" Headwall	CB1904-L30K-MVOLT-90CRI-AG7038-MWAC-NGT	30	$39.00	$1,170.00
L4	Kichler	12in Linear LED Bath Light NI	11141NILED	15	$81.00	$1,215.00
L5	Cooper Industries Metalux AP Series	8" FMLED Ceiling Flush Mount Fixture	FM-LED-8-WH-830-PR	15	$36.00	$1,080.00
L6	Visa Lighting	Unity 12" Wall Sconce	CB1900-L35K-L-MVOLT-WHTTR-NGT	45	$36.40	$1,638.00
L7	Visa Lighting	Symmetry Recessed CM1974 Tunable	CM1974 TUN-MVOLT AG7038	15	$262.47	$3,937.00

Appendix E: Proposed Lighting Schedule cont.

Lighting Fixture Replacement Schedule cont.								
Type	**Voltage**	**Lamp**	**Wattage**	**Lumen Output**	**Efficacy (lm/W)**	**CRI**	**CCT**	**Projected Life Span**
L1	Univ.	LED	24	3800	158	83-86	4000K	60000
L1-S	Univ.	LED	24	3800	158	83-86	4000K	60000
L2	Univ.	LED	16	2500	158	82-86	4000K	60000
L3	Univ.	LED	66	7500	115	83	3000K	
L4	120	LED	10	640	64		3000K	45000
L5	Univ.	LED	8	577	73.5	88	3000K	35000
L6	Univ.	LED	13	1300	103	83	3000K	
L7	Univ.	LED	68-159	3600-10400	52-66	89-93	1650K-8000K	

Appendix F: Proposed Product Specification Sheets

GEN2 CLARIS LED Retrofit Kits
2'x4' Linear Troffers

PROJECT NAME
LCC of Banner Elk / Hall 400 Redesign
ORDERING #
G2CLA-24-4-D-40-1K-24-LENS24

LED Living Technology's GEN2 CLARIS LED Retrofit Kit is the next generation in energy efficient LED upgrades for linear fluorescent troffers. Payback has never made more sense with 65-80% energy savings over fluorescent lamps and up to 24 years operation once installed.

2'x4' upgrades include system efficacies ranging from 148-164lm/W, increased thermal performance for extended LED lifetimes exceeding 200,000hrs, and the integration of permanent rare-earth magnets for easy and quick installation.

KEY SPECIFICATIONS

Housing For Upgrade LED Retrofit	2'x4' (610mm x 1220mm)
Input Power	24W, 30W, 45W, 68W
Input Voltage	120-277VAC
Delivered Light Output*	24W - up to 3800 lms
	30W - up to 4900 lms
	45W - up to 7000 lms
	68W - up to 10,200 lms
System Efficacy w/LED Power Supply*	24W - up to 158 lm/W
	30W - up to 164 lms/W
	45W - up to 157 lms/W
	68W - up to 148 lms/W
CRI	83-86 CRI
CCT	2700K, 3000K, 3500K, 4000K, 5000K
System Lifetime	>60,000 hours (LED Power Supply)
LED Lifetime (L80 Lumen Maintenance)	>110,000 hours [see LED Lifetime chart for kit specific]
Controls	Standard – D Option: 1-10V; PWM; Resistance Dimming Line Voltage – T Option: 120VAC ELV Dimming; 120VAC TRIAC Dimming; 120/277 VAC 1% 0-10V Dimming LUTRON – A Option: Hi-lume™ 1% EcoSystem™ LED driver LUTRON – E Option: 5-Series EcoSystem™ LED driver
Mounting	Existing linear flourescent fixtures, w/Permanent Neodymium Magnets, and Rapid Thermafuse Technology
Limited Warranty	7 Years LED Power Supplies, 10 Years all other components.

Not all products are qualified on the DLC QPL. To view our DLC qualified products, please consult the DLC Qualified Products List at www.designlights.org/search.

Emergency Battery Pack Ordering Example: CLA-**EM10**

Root	Emergency Battery Pack	Mounting Options
CLA	**EM5** - >800 lumens / 5 Watts **EM7** - >1200 lumens / 7 Watts **EM10** - >1600 lumens / 10 Watts	**Blank** - Standard Integral Style No-Flex Unit **TM**** - Top Mount Non-Flex Unit **A**** - External Mount Dual Flex Unit **J**** - Box Mount Unit Single Flex Junction Box **R**** - Dual Flex w/Reflector-Mount **R-J**** - Single Flex w/Reflector-Mount

SEE PAGE 3 FOR DETAILS

KIT ORDERING

Example: G2CLA-24-4-D-40-1K-24

Model Root	Kit *	Dimming	LED Color	Quantity Of Kit Per Housing	Housing Type	Lens Adders
G2CLA	**24-4** - 2 Lamp, 24W approx. 3700 lms, 930 lm/ft **30-4** - 2 Lamp, 30W approx. 4600 lms, 1,150 lm/ft **45-4** - 2 Lamp, 45W approx. 6500 lms, 1,630 lm/ft **24-6** - 3 Lamp, 24W approx. 3800 lms, 950 lm/ft **30-6** - 3 Lamp, 30W approx. 4800 lms, 1,200 lm/ft **45-6** - 3 Lamp, 45W approx. 6800 lms, 1,700 lm/ft **68-6** - 3 Lamp, 68W approx. 9700 lms, 2,430 lm/ft **30-8** - 4 Lamp, 30W approx. 4800 lms, 1,200 lm/ft **45-8** - 4 Lamp, 45W approx. 7000 lms, 1,750 lm/ft **68-8** - 4 Lamp, 68W approx. 10000 lms, 2,500 lm/ft	**D** - Standard 0-10V Low Voltage **T** - Triac / ELV - Available only in 24W, 30W **A** - LUTRON Hi-lume™ 1% EcoSystem™ LED driver **E** - LUTRON 5-Series EcoSystem™ LED driver **LWM** - LUTRON 0-10V Wireless RF Fixture Module 1A 0-10V products by others. DLC QPL Listed Networked Lighting Controls with Lutron Vive LWM ONLY: Clear Connect. Wireless LWM/A/E: vive, GRAFIK Eye QS, EcoSystem. Enabled	**27** - 2700K† **30** - 3000K **35** - 3500K **40** - 4000K **50** - 5000K	**1K** - Standard 1 Kit **2K** - Custom 2 Kits	**24** - 2X4	**BLANK** - No Lens **LENS24** - 2'x4' Prismatic Overlay Lens **SL21** - Frosted Snap-On LED Strip Covers for Parabolic Application

* Lumen value are based on an LED CCT of 5000K maintaining a tolerance of +/- 5% ** Special Order † Not currently listed on the DLC QPL

Please see product specification sheet or DLC QPL list for DLC approved model numbers.

GEN2 CLARIS LED Retrofit Kits
2'x4' Linear Troffers

PRODUCT SPECIFICATIONS

The GEN2 CLARIS LED Retrofit Kit was designed as a powerful step-up over existing LED Upgrade retrofit kits. Power Supply Efficiency, LED Efficiency, Thermal Performance, Ease of Installation, and Controllability were all optimized and improved upon with the latest and most advanced components. Affordability through innovation, has always been LED Living Technology's design approach and with the GEN2 CLARIS LED Retrofit Kit, LLT has once again raised the bar in LED retrofit kit performance, while improving upon energy savings, and cost.

ELECTRICAL PERFORMANCE

Input Voltage: 120-277VAC ALL LED DRIVERS
Frequency Range: 47 ~ 60Hz

MODEL	DIMENSIONS	CONTROL COMPATIBILITIES: Dimmable Range	0-10V	Ω	PWM	TRIAC (120V)	ELV	LUTRON Hi-lume™ 1% EcoSystem™ LED driver; Hi-lume™ 3-wire LED driver	LUTRON 5-Series EcoSystem™ LED Driver	PROTECTIONS	THD (TOTAL HARMONIC DISTORTION)	POWER FACTOR	AMBIENT OPERATING TEMPERATURE
G2CLA-XX-X-D	L 163mm x W 43mm x H 32mm L 6.41in x W 1.69in x H 1.26in	10%	✓	✓	✓					Short Circuit/Over Current [95-108%] Over Voltage [28 ~ 35V]/Over Temp.	<20%	>.9	-40°F (-40°C) ~ 122°F (50°C)
G2CLA-XX-X-T	L 84mm x W 40mm x H 25.3mm L 3.3in x W 1.57in x H 1in	1%	✓			✓	✓			Short Circuit/Over Current/Over Temp/Output Open Load	<20%	>.9	-22°F (-30°C) ~ 122°F (50°C)
G2CLA-XX-X-A	L 359mm x W 30mm x H 25mm L 14.13in x W 1.18in x H 1in	1%						✓	✓	Short Circuit/Inrush Current limiting <2A / Over Temp/ Open Circuit Protected Output	<20%	>.9	32°F (0°C) ~ 122°F (50°C)
G2CLA-XX-X-E	L 359mm x W 30mm x H 25mm L 14.13in x W 1.18in x H 1in	5%							✓	Short Circuit/Inrush current less than NEMA 410-2011 limit/Overload-protected output/Open Circuit Protected Output	<20%	>.9	32°F (0°C) ~ 122°F (50°C)

THERMAL PERFORMANCE & LED LIFETIME

Information in the chart below reflects individual LED Drive Currents, Measured LED Junction Temperatures installed in troffer housing, and LED Lifetime LM80 Testing.

MODEL	LED JUNCTION TEMPERATURE @25C [77°F] AMBIENT	LUMEN MAINTENANCE @10,000 HRS	L80 LUMEN MAINTENANCE*	L70 LUMEN MAINTENANCE**
G2CLA-24-4	35°C	99.55%	630,000 hrs	>850,000 hrs
G2CLA-30-4	35°C	99.16%	240,000 hrs	380,000 hrs
G2CLA-45-4	40°C	98.1%	110,000 hrs	180,000 hrs
G2CLA-24-6	30°C	100.1%	>850,000 hrs	>850,000 hrs
G2CLA-30-6	32°C	99.77%	>850,000 hrs	>850,000 hrs
G2CLA-45-6	35°C	99.13%	250,000 hrs	400,000 hrs
G2CLA-68-6	40°C	98.1%	110,000 hrs	190,000 hrs
G2CLA-30-8	29°C	100.1%	>850,000 hrs	>850,000 hrs
G2CLA-45-8	32°C	99.66%	>850,000 hrs	>850,000 hrs
G2CLA-68-8	36°C	98.88%	190,000 hrs	310,000 hrs

*Time in operation hours before an LED system reaches 80% lumen maintenance. **Time in operation hours before an LED system reaches 70% lumen maintenance.

ADDITIONAL LUTRON TF-WHUB/TF-WMOD COMPATIBLE ACCESSORIES

10 Maximum on TF-LWM

10 Maximum on TF-LWM

1 Maximum on TF-LWM

10 Maximum on TF-LWM

For pricing and availability for Lutron Pico remote controls, Radio Powr Savr sensors, and photocells, please contact your local Lutron representative.

More information is available at www.lutron.com/en-us-pages-SupportCenter/support.aspx

WIRELESS CONTROLS ACCESSORIES

LUTRON WIRELESS

TF-LWH

Vive Wireless Hub

Programming is quick and easy with the Vive Wireless Hub, a valuable accessory when grouping fixtures and controls.

DLC QPL Listed Networked Lighting Controls with Lutron Vive

vive

Clear Connect. Wireless

TF-LWM

0-10V Wireless RF Fixture Module for 1A 0-10V products by others

This fixture mount with 1/2" knockout wireless control module is a radio frequency (RF) control that operates the power supply(ies) in the Tfive LED Retrofit Kit based on input from Pico remote controls and Radio Powr Savr sensors, made possible by Lutron Clear Connect RF Technology.

Integrates with BACnet when used with Lutron Vive.

LED LIVING TECHNOLOGY

GEN2 CLARIS LED Retrofit Kits
2'x4' Linear Troffers

COMPONENTS & MATERIALS

GEN2 CLARIS LED Retrofit Kits are RoHS Compliant, and vibration resistant. LED Boards are mounted with high performance slow-bonding thermally conductive adhesive, reinforced with permanent Neodymium magnets. All components are thermally managed, including LED power supply, for maximum system lifetime.

Table of Components

MODEL	TOTAL LED RAPID THERMAFUSE STRIPS	QTY DRIVER	CONNECTOR BOARDS	QTY 36" JUMPER CABLES	QTY 4" JUMPER CABLES	POWER SUPPLY SCREWS	OPTIONAL LED STRIP SCREWS	UL 1598c LABEL
G2CLA-24-4-W-XX-1K-24 G2CLA-30-4-W-XX-1K-24 G2CLA-45-4-W-XX-1K-24	4	1	1	2	2	2	4	1
G2CLA-24-6-W-XX-1K-24 G2CLA-30-6-W-XX-1K-24 G2CLA-45-6-W-XX-1K-24 G2CLA-68-6-W-XX-1K-24	6	1	1	3	3	2	6	1
G2CLA-30-8-W-XX-1K-24 G2CLA-45-8-W-XX-1K-24 G2CLA-68-8-W-XX-1K-24	8	1	1	4	4	2	8	1

EMERGENCY BATTERY PACK *CONSTANT POWER FOR UP TO 120 MINUTES WITH NO LIGHT DEGRADATION*

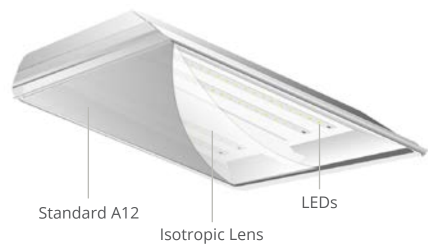
NEW

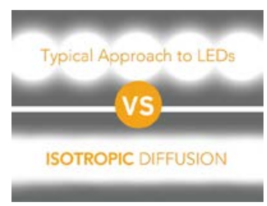
- Exceeds standard 90 minutes of illumination minimum
- Features IOTA's constant power technology for maximum sustained light output
- Able to purchase separately or at a later date and still maintain UL1598C rating
- Can be installed in past CLARIS LED RetroFit Kit Installations
- See CLA-EM Spec Sheet for specifications on new EM Battery Packs

LENS ACCESSORIES

LENS24 - Prismatic Upgrade Applications

Description: This .033" thick acrylic film diffuser overlays over existing Prismatic 2x4 A12 lenses. With beam shaping isotropic diffusion, individual LED hot spots are beam shaped into one continuous line for additional eye-comfort.





Typical Approach to LEDs
VS Isotropic Diffusion

SL21 – Parabolic / Open Housing Applications

Description: Diffusion installs literally with a snap, with LED Living Technology's new and exclusive snap on frosted strip lenses. Designers will find an increased area of diffusion, as the LEDs and snap on diffuser are mounted directly to the back of the housing, effectively eliminating unsightly dark shadowing.

SL21 - Parabolic
Snap on Lens Cover

2x4 Parabolic
24W 3 Strip Lens with SL21

ADDITIONAL SPECIFICATIONS

PHOTOMETRICS

Due to the quantity of options available we ask that you please contact an LED Living Technology lighting representative for Photometrics of your specific kit configuration. Photometrics are tested to IESNA LM-7908 standards.

THERMAL MANAGEMENT

LED Boards 21.3" x 1" and LED High Performance Drivers are equipped with Rapid Thermafuse Technology: thermally conductive industrial strength adhesive for recycling existing housing as effective heat sink material.

MOUNTING

5-10 minute install. Housing maintains its UL rating with the kit installed (UL1598C). Fluoresent lamps and ballasts are removed, housing is cleaned with a 70% min. alcohol solution. LED Strips in LED Upgrade Retrofit Kit are installed in existing housing with thermally conductive adhesive reinforced with **permanent rare earth magnets,** LED Power supply is mounted underneath existing ballast cover plate. Plug and play design.

Please refer to installation guide for complete installation instructions. Retrofit Housings will retain UL listing if complete Claris LED Retrofit kit is installed utilizing provided installation guide.

WARRANTY

10 Year Limited Warranty on all components with the exception of LED Power Supply.
7 Year Limited Warranty on LED Power Supply.

GEN2 CLARIS LED Retrofit Kits
2'x2' Linear Troffers

PROJECT NAME
LCC of Banner Elk / Hall 400 Redesign
ORDERING #
G2CLA-24-4-D-30-1K-24-LENS24

LED Living Technology's GEN2 CLARIS LED Retrofit Kit is the next generation in energy efficient LED upgrades for linear fluorescent troffers. Payback has never made more sense with 65-80% energy savings over fluorescent lamps and up to 24 years operation once installed.

2'x2' upgrades include system efficacies ranging from 151-158lm/W, increased thermal performance for extended LED lifetimes exceeding 200,000hrs, and the integration of permanent rare-earth magnets for easy and quick installation.

KEY SPECIFICATIONS

Housing For Upgrade LED Retrofit	2'x2' (610mm x 610mm)
Input Power	16W, 24W, 30W, 45W
Input Voltage	120-277VAC
Delivered Light Output	16W - up to 2500 lms 24W - up to 3700 lms 30W - up to 4600 lms 45W - up to 6800 lms
System Efficacy w/LED Power Supply	16W - up to 158 lms/W 24W - up to 151 lm/W 30W - up to 151 lms/W 45W - up to 151 lms/W
CRI	82-86 CRI
CCT	2700K, 3000K, 3500K, 4000K, 5000K
System Lifetime	>60,000 hours (only driver replacement required)
LED Lifetime (L80 Lumen Maintenance)	>110,000 hours [see LED Lifetime chart for kit specific]
Controls	Standard Line Voltage – D Option: 1-10V; PWM; Resistance Dimming – T Option: 120VAC ELV Dimming; 120VAC TRIAC Dimming; 120/277 VAC 1% 0-10V Dimming LUTRON – A Option: Hi-lume™ 1% EcoSystem™ LED driver LUTRON – E Option: 5-Series EcoSystem™ LED driver
Mounting	Existing linear flourescent fixtures, w/Permanent Neodymium Magnets, and Rapid Thermafuse Technology
Limited Warranty	7 Years LED Power Supply, 10 Years all other components.
	Not all products are qualified on the DLC QPL. To view our DLC qualified products, please consult the DLC Qualified Products List at www.designlights.org/search.

Emergency Battery Pack Ordering Example: CLA-**EM10**

Root	Emergency Battery Pack	Mounting Options
CLA	**EM5** - >800 lumens / 5 Watts **EM7** - >1200 lumens / 7 Watts **EM10** - >1600 lumens / 10 Watts	**Blank** - Standard Integral Style No-Flex Unit **TM**** - Top Mount Non-Flex Unit **A**** - External Mount Dual Flex Unit **J**** - Box Mount Unit Single Flex Junction Box **R**** - Dual Flex w/Reflector-Mount **R-J**** - Single Flex w/Reflector-Mount

SEE PAGE 3 FOR DETAILS

KIT ORDERING

Example: G2CLA-24-2-D-40-1K-22

Model Root	Kit*	Dimming	LED Color	Quantity Of Kit Per Housing	Housing Type	Lens Adders
G2CLA	**16-2** - 2 Lamp, 16W approx. 2400 lms, 1,200 lms/ft **24-2** - 2 Lamp, 24W approx. 3400 lms, 1,700 lms/ft **16-3** - 3 Lamp, 16W approx. 2500 lms, 1,250 lms/ft **24-3** - 3 Lamp, 24W approx. 3600 lms, 1,800 lms/ft **30-3** - 3 Lamp, 30W approx. 4500 lms, 2,250 lms/ft **16-4** - 4 Lamp, 16W approx. 2500 lms, 1,250 lms/ft **24-4** - 2 UBend/ 4 Lamp, 24W approx. 3700 lms, 1,850 lms/ft **30-4** - 2 Biax Lamp, 30W approx. 4600 lms, 2,300 lms/ft **45-4** - 2/3 Biax Lamp, 45W approx. 6500 lms, 3,250 lms/ft **45-6** - 3 Biax Lamp, 45W approx. 6800 lms, 3,450 lms/ft	**D** - Standard 0-10V Low Voltage **T** - Triac / ELV *Available only in 16W, 24W, 30W **A** - LUTRON Hi-lume™ 1% Eco-System™ LED driver **E** - LUTRON 5-Series EcoSystem™ LED driver **LWM** - LUTRON 0-10V Wireless RF Fixture Module 1A 0-10V products by others. DLC QPL Listed Networked Lighting Controls with Lutron Vive LWM ONLY: Clear Connect. Wireless LWM/A/E: vive GRAFIK Eye QS EcoSystem. Enabled	**27** - 2700K† **30** - 3000K **35** - 3500K **40** - 4000K **50** - 5000K	**1K** - Standard 1 Kit **2K** - Custom 2 Kits	**22** - 2X2	**BLANK** - No Lens **LENS22** - 2'x2' Prismatic Overlay Lens **SL21** - Frosted Snap-On LED Strip Covers for Parabolic Application

* Lumen value are based on an LED CCT of 5000K maintaining a tolerance of +/- 5% ** Special Order † Not currently listed on the DLC QPL

Please see product specification sheet or DLC QPL list for DLC approved model numbers.

157

1598c 8750 BUY AMERICAN

GEN2 CLARIS LED Retrofit Kits
2'x2' Linear Troffers

PROJECT NAME
LCC of Banner Elk / Hall 400 Redesign
ORDERING #
G2CLA-24-4-D-30-1K-24-LENS24

PRODUCT SPECIFICATIONS

The GEN2 CLARIS LED Retrofit Kit was designed as a powerful step-up over existing LED Upgrade retrofit kits. Power Supply Efficiency, LED Efficiency, Thermal Performance, Ease of Installation, and Controllability were all optimized and improved upon with the latest and most advanced components. Affordability through innovation, has always been LED Living Technology's design approach and with the GEN2 CLARIS LED Retrofit Kit, LLT has once again raised the bar in LED retrofit kit performance, while improving upon energy savings, and cost.

ELECTRICAL PERFORMANCE

Input Voltage: 120-277VAC ALL LED DRIVERS
Frequency Range: 47 ~ 60Hz

MODEL	DIMENSIONS	CONTROL COMPATIBILITIES: Dimmable Range	0-10V	Ω	PWM	TRIAC (120V)	ELV	LUTRON Hi-lume™ 1% EcoSystem™ LED driver; Hi-lume™ 3-wire LED driver	LUTRON 5-Series EcoSystem™ LED Driver	PROTECTIONS	THD (TOTAL HARMONIC DISTORTION)	POWER FACTOR	AMBIENT OPERATING TEMPERA-TURE
G2CLA-XX-X-D	L 163mm x W 43mm x H 32mm L 6.41in x W 1.69in x H 1.26in	10%	✓	✓	✓					Short Circuit/Over Current [95-108%] Over Voltage [28 ~ 35V]/Over Temp.	<20%	>.9	-40°F (-40°C) ~ 122°F (50°C)
G2CLA-XX-X-T	L 84mm x W 40mm x H 25.3mm L 3.3in x W 1.57in x H 1in	1%	✓			✓	✓			Short Circuit/Over Current/Over Temp/Output Open Load	<20%	>.9	-22°F (-30°C) ~ 122°F (50°C)
G2CLA-XX-X-A	L 359mm x W 30mm x H 25mm L 14.13in x W 1.18in x H 1in	1%						✓	✓	Short Circuit/Inrush Current limiting <2A / Over Temp/ Open Circuit Protected Output	<20%	>.9	32°F (0°C) ~ 122°F (50°C)
G2CLA-XX-X-E	L 359mm x W 30mm x H 25mm L 14.13in x W 1.18in x H 1in	5%							✓	Short Circuit/Inrush current less than NEMA 410-2011 limit/Overload-protected output/Open Circuit Protected Output	<20%	>.9	32°F (0°C) ~ 122°F (50°C)

THERMAL PERFORMANCE & LED LIFETIME

Information in the chart below reflects individual LED Drive Currents, Measured LED Junction Temperatures installed in troffer housing, and LED Lifetime LM80 Testing.

MODEL	LED JUNCTION TEMPERATURE @25C [77°F] AMBIENT	LUMEN MAINTENANCE @10,000 HRS	L80 LUMEN MAINTENANCE*	L70 LUMEN MAINTENANCE**
G2CLA-16-2	35°C	98.98%	220,000 hrs	350,000 hrs
G2CLA-24-2	41°C	97.95%	110,000 hrs	170,000 hrs
G2CLA-16-3	32°C	99.72%	>850,000 hrs	>850,000 hrs
G2CLA-24-3	35°C	98.98%	220,000 hrs	350,000 hrs
G2CLA-30-3	38°C	98.42%	130,000 hrs	210,000 hrs
G2CLA-16-4	32°C	100.05%	>850,000 hrs	>850,000 hrs
G2CLA-24-4	33°C	99.55%	630,000 hrs	>850,000 hrs
G2CLA-30-4	35°C	99.16%	240,000 hrs	380,000 hrs
G2CLA-45-4	40°C	98.10%	110,000 hrs	180,000 hrs
G2CLA-45-6	35°C	99.13%	250,000 hrs	400,000 hrs

*Time in operation hours before an LED system reaches 80% lumen maintenance. **Time in operation hours before an LED system reaches 70% lumen maintenance.

ADDITIONAL LUTRON TF-WHUB/TF-WMOD COMPATIBLE ACCESSORIES

10 Maximum on TF-LWM

10 Maximum on TF-LWM

1 Maximum on TF-LWM

10 Maximum on TF-LWM

For pricing and availability for Lutron Pico remote controls, Radio Powr Savr sensors, and photocells, please contact your local Lutron representative.

More information is available at www.lutron.com/en-us-pages-SupportCenter/support.aspx

WIRELESS CONTROLS ACCESSORIES

LUTRON WIRELESS

TF-LWH

Vive Wireless Hub

Programming is quick and easy with the Vive Wireless Hub, a valuable accessory when grouping fixtures and controls.

DLC QPL Listed Networked Lighting Controls with Lutron Vive

vive

Clear Connect Wireless

TF-LWM

0-10V Wireless RF Fixture Module for 1A 0-10V products by others

This fixture mount with 1/2" knockout wireless control module is a radio frequency (RF) control that operates the power supply(ies) in the Tfive LED Retrofit Kit based on input from Pico remote controls and Radio Powr Savr sensors, made possible by Lutron Clear Connect RF Technology.

Integrates with BACnet when used with Lutron Vive.

LED LIVING TECHNOLOGY

GEN2 CLARIS LED Retrofit Kits
2'x2' Linear Troffers

COMPONENTS & MATERIALS

GEN2 CLARIS LED Retrofit Kits are RoHS Compliant, and vibration resistant. LED Boards are mounted with high performance slow-bonding thermally conductive adhesive, reinforced with permanent Neodymium magnets. All components are thermally managed, including LED power supply, for maximum system lifetime.

Table of Components

MODEL	TOTAL LED RAPID THERMAFUSE STRIPS	QTY DRIVER	CONNECTOR BOARDS	QTY 25" JUMPER CABLES	POWER SUPPLY SCREWS	OPTIONAL LED STRIP SCREWS	UL 1598C LABEL
G2CLA-16-2-W-XX-1K-22 G2CLA-24-2-W-XX-1K-22	2	1	1	2	2	2	2
G2CLA-16-3-W-XX-1K-22 G2CLA-24-3-W-XX-1K-22 G2CLA-30-3-W-XX-1K-22	3	1	1	3	2	3	1
G2CLA-16-4-W-XX-1K-22 G2CLA-24-4-W-XX-1K-22 G2CLA-30-4-W-XX-1K-22 G2CLA-45-4-W-XX-1K-22	4	1	1	4	2	4	1
G2CLA-45-6-W-XX-1K-22	6	1	1	6	2	6	1

EMERGENCY BATTERY PACK *CONSTANT POWER FOR UP TO 120 MINUTES WITH NO LIGHT DEGRADATION*

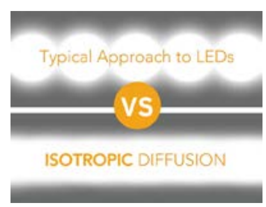
NEW

- Exceeds standard 90 minutes of illumination minimum
- Features IOTA's constant power technology for maximum sustained light output
- Able to purchase separately or at a later date and still maintain UL1598C rating
- Can be installed in past CLARIS LED RetroFit Kit Installations
- See CLA-EM Spec Sheet for specifications on new EM Battery Packs

LENS ACCESSORIES

LENS24 - Prismatic Upgrade Applications

Description: This .033" thick acrylic film diffuser overlays over existing Prismatic 2x4 A12 lenses. With beam shaping isotropic diffusion, individual LED hot spots are beam shaped into one continuous line for additional eye-comfort.

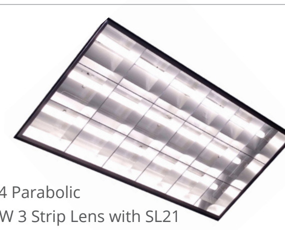


Typical Approach to LEDs
VS Isotropic Diffusion

SL21 – Parabolic / Open Housing Applications

Description: Diffusion installs literally with a snap, with LED Living Technology's new and exclusive snap on frosted strip lenses. Designers will find an increased area of diffusion, as the LEDs and snap on diffuser are mounted directly to the back of the housing, effectively eliminating unsightly dark shadowing.

SL21 - Parabolic
Snap on Lens Cover



2x4 Parabolic
24W 3 Strip Lens with SL21

ADDITIONAL SPECIFICATIONS

PHOTOMETRICS

Due to the quantity of options available we ask that you please contact an LED Living Technology lighting representative for Photometrics of your specific kit configuration. Photometrics are tested to IESNA LM-7908 standards.

THERMAL MANAGEMENT

LED Boards 21.3" x 1" and LED High Performance Drivers are equipped with Rapid Thermafuse Technology: thermally conductive industrial strength adhesive for recycling existing housing as effective heat sink material.

MOUNTING

5-10 minute install. Housing maintains its UL rating with the kit installed (UL1598C). Fluoresent lamps and ballasts are removed, housing is cleaned with a 70% min. alcohol solution. LED Strips in LED Upgrade Retrofit Kit are installed in existing housing with thermally conductive adhesive reinforced with **permanent rare earth magnets,** LED Power supply is mounted underneath existing ballast cover plate. Plug and play design.

Please refer to installation guide for complete installation instructions. Retrofit Housings will retain UL listing if complete Claris LED Retrofit kit is installed utilizing provided installation guide.

WARRANTY

10 Year Limited Warranty on all components with the exception of LED Power Supply.
7 Year Limited Warranty on LED Power Supply.

LED LIVING TECHNOLOGY

CB1904 – UNITY™

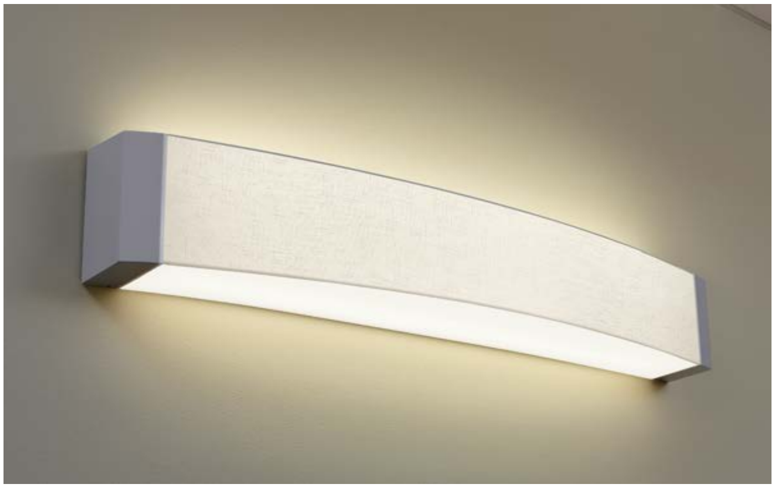
VISA LIGHTING

Type: **Project:**

VisaLighting.com/products/Unity

Fill in shaded boxes using information listed below

Order Code:	CB1904	–					
	MODEL	A SOURCE	B VOLTAGE	C LED SOURCE OPTION	D END CAP FINISH	E DIFFUSER OPTION	F OPTION(S)

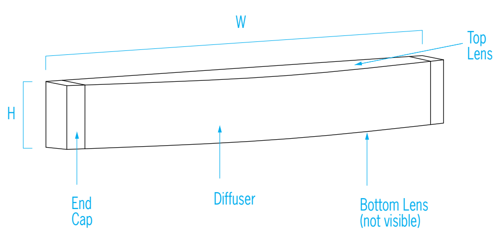


Incorporating gradual curves along with the soft glow of an illuminated lens and a cleanable fabric, Unity creates a calm and relaxing environment. Providing attractive and holistic solutions for your healthcare lighting needs.

DIMENSIONS

W = Width H = Height D = Depth

W	49"	(1245 mm)
H	7-1/4"	(184 mm)
D	7-1/8"	(181 mm)



A SOURCE (Select one) B VOLTAGE

MVOLT fixture accepts 120 through 277 input voltage
LED sources are 83CRI, within 3-step MacAdam and are dimmable 0-10V to 1%

LED Sources	CCT	Function	Delivered Lumens	Power (Watts)	Voltage
• **L30K**	3000K	Reading	2500	23	**MVOLT**
		Ambient	5100	44	
		Reading & Ambient	7500	66	
L35K	3500K	Reading	2500	23	
		Ambient	5100	44	
		Reading & Ambient	7500	66	
• **L40K**	4000K	Reading	2600	23	
		Ambient	5200	44	
		Reading & Ambient	7800	66	

Fluorescent Sources		Voltage
3FO32	32w T-8, medium bi-pin base (One downlight, two uplights)	Select **MVOLT, 120V, 277V,** or **347V**

C LED SOURCE OPTION

83CRI within 3-step MacAdam is standard if option is not selected

90CRI Color rendering index 93; minimum R9 value of 50 (lumen output reduced by 15%)

D END CAP FINISH OPTIONS (Select one)

See page 3 for color chart

Powder Coat Painted Finishes (Standard)

AG7038	Agate Grey	**GLIM**	Glimmer	**PB1035**	Pearl Beige
BMAT	Bronze Matte	**GSIL**	Graphite Silver	**RUST**	Rust
BRNZ	Bronze	**GW9002**	Grey White	**SUNG**	Sungold
BSIL	Blade Silver	**HTHR**	Heather	**TW9016**	Traffic White
CVBL	Cove Blue	**JB9005**	Jet Black		
CW9001	Cream	**OBRZ**	Old Bronze		

Options continued on Page 2

LED ETL Listed 5 Year Warranty

CB1904 – UNITY

VISA LIGHTING

Options continued

E DIFFUSER OPTIONS (Select one)

MWAC Matte White Acrylic
● **OLIN** Oyster Linen Acrylic

MWAC

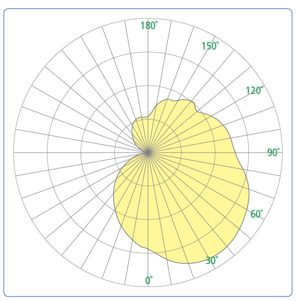

OLIN

F OPTIONS (Multiple Selections Allowed)

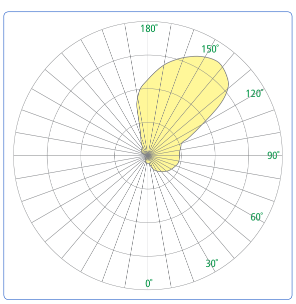
⚠ Option availability may be interdependent with Voltage, Source or Other Options

AMC	Antimicrobial coating (no VOC) for painted surfaces
CH	Pull chain
FUSE	Fluorescent fusing, specify 120V or 277V
NGT	Night light (amber LED), not available with 347V
XPS	Express 10 day shipping. Items marked with a bullet (●) are not available with **XPS**

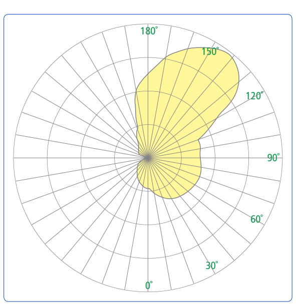
Photometrics



Reading



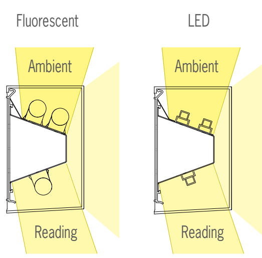
Ambient



Reading and Ambient

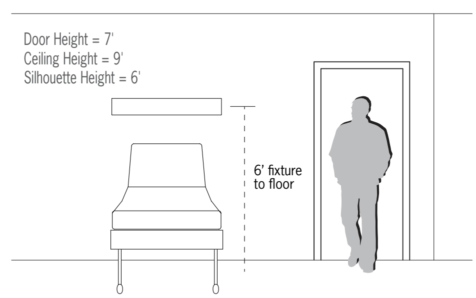
Technical Information

- Modular design for replacement of LED source and power supply
- Fixture tested per LM79 standard (with 3500K white source)
- Amber LED night light option to minimize patient disturbance
- Optional 90+ CRI (delivered lumens reduced by 15%)
- LVPC-DIM switching interface accessory available for pillow speaker/nurse call systems
- Separately switched
- Clear top lens for ambient uplight; bottom lens provides diffuse downlight for reading
- Easy to clean OLIN (oyster linen) Lumicor® acrylic diffuser or matte white acrylic diffuser
- Optional antimicrobial coating (no VOC) for all interior and exterior painted surfaces
- ETL listed for damp locations. Not suited for exterior applications



- Split optic is angled for directional output
- Hammertone reflector

Relative Scale Drawing



ACCESSORY (Order Separately)

LVPC-DIM Oldenburg Electronics low voltage patient control interface (3 load with dimming) requires minimum of one switch per zone (by others), mounts in electrical box (by others)

12in Linear LED Bath Light NI

11141NILED (Brushed Nickel)

Project Name: LCC of Banner Elk / Hall 400 Redesign
Location: Resident's Rooms
Type: L4
Qty: 15
Comments:

Dimensions

Height	4.50"
Width	12.75"

Ordering Information

Product ID	11141NILED
Finish	Brushed Nickel

Dimensions

Extension	4.00"
Height from center of Wall opening	2.25"
Base Backplate	12.00 X 3.00
Weight	1.00 LBS

Photometrics

Kelvin Temperature	3000 K
Color Rendering Index	90

Specifications

Material	Steel
Glass Description	White Etched Polycarbonate

Electrical

Dimmable	Yes
Voltage	120 V

Qualifications

Safety Rated	Damp
Energy Star	Yes
Title 24	Yes
ADA Compliant	Yes
Expected Life Span	45000 Hours
Warranty	www.kichler.com/warranty

Primary Lamping

Light Source	LED
Lamp Included	Integrated
Number of Lights/LEDs	1
Delivered Lumens	640

Kichler
7711 East Pleasant Valley Road
Cleveland, Ohio 44131-8010
Toll free: 866.558.5706 or kichler.com

Notes:
1) Information provided is subject to change without notice. All values are design or typical values when measured under laboratory conditions.
2) Incandescent Equivalent: The incandescent equivalent as presented is an approximate number and is for reference only.

Metalux AP Series

Catalog #		Type
Project		
Comments		Date
Prepared by		

DESCRIPTION

FM series is a versatile LED ceiling or wall mount series which can be used in a broad range of residential and commercial applications. This series provides customers with a high quality luminaire utilizing the latest LED, solid state lighting and electronic driver technology for optimal performance and maximized energy efficiency. With a traditional opal white lens, the FM series produces even, uniform light distribution and ideal choice for offices, corridors, stairways, bedroom, closet and foyers applications where customers are replacing incandescent, circline or compact fluorescent lamps.

FMLED
LED

Wall or Ceiling Mount

ENERGY STAR

SPECIFICATION FEATURES

Construction
Housing consists of die formed steel which is post painted to offer the ideal aesthetics. Diffuser are white opal injection molded acrylic blends offering the ideal light distribution. These lens are offered in three different sizes: 12, 16 and 20 inch models. Lens are attached with easy mount clips.

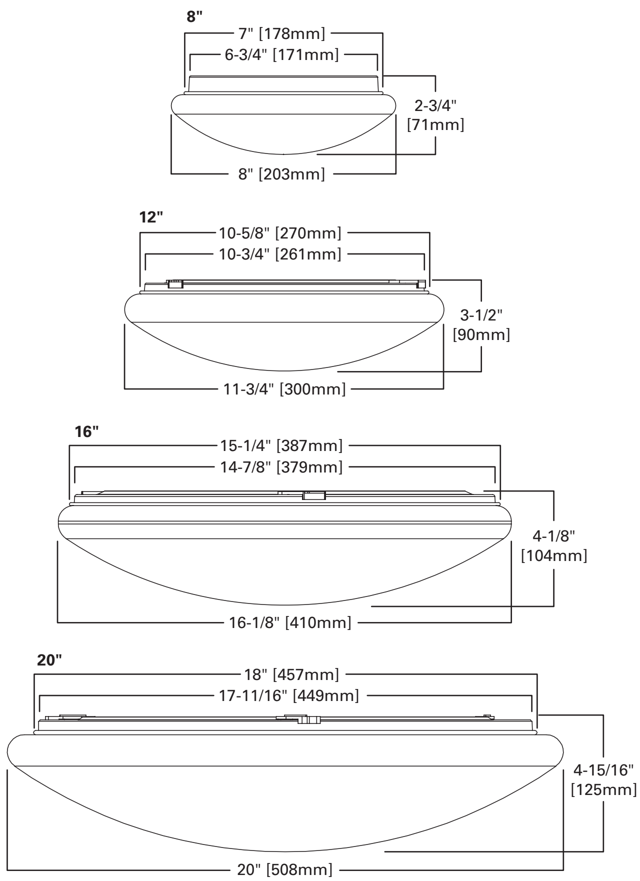
Controls
Equipped standard with non-dimmable electronic drivers which provides extensive energy savings over existing fluorescent lamp options. All drivers are suitable for 120V applications.

Electrical
Long-Life LED system coupled with electrical driver to deliver optimal performance. LEDs are 3000K or4000K with a typical CRI 80. Projected life is 35,000 hours at 70% lumen output.

Shielding
Specially developed LED lens blend allows this product series to offer optimal light out and providing smooth even illumination with no pixilation. Lenses are designed from smooth opal white acrylic and provide 360° uniform light distribution. Lens is securely held in place by swing clips and can be easily removed for installation and maintenance.

Installation
Fixture may be surface (wall or ceiling) mounted.

Compliance
UL/CUL Listed. Energy Star Qualified. Lighting Facts Approved. Suitable for Damp locations.



WATTAGE

Size	3000K	4000K	Watts
8"	577	635	8
12"	1018	1055	14
16"	1707	1975	22
20"	2300	2399	32

EATON
Powering Business Worldwide

ISO SYSTEMS CERTIFIED

ADF142366
2015-08-17 09:45:52

ORDERING INFORMATION

SAMPLE NUMBER: FMLED12WH840PR

Application
FM=Flush Mount

Lamp Type
LED

Fixture Size
8=8"
12=12"
16=16"
20=20"

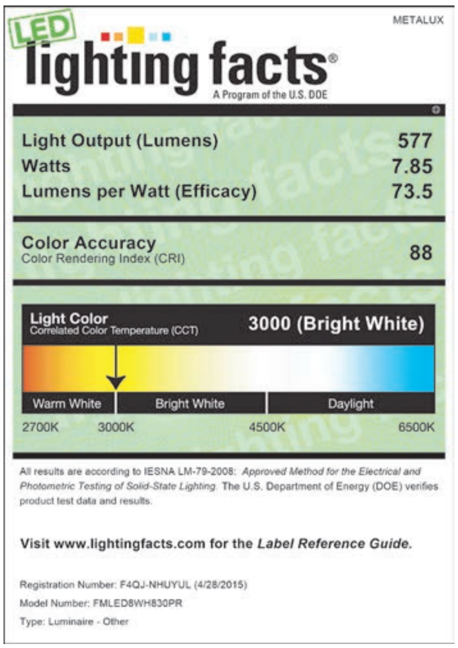
Color
WH=White

CCT
830=3000K
840=4000K

Fixture Shape
PR=Round

Specifications & dimensions subject to change without notice. Consult your Eaton Representative for availability and ordering information.

3000K



LED lighting facts® A Program of the U.S. DOE — METALUX

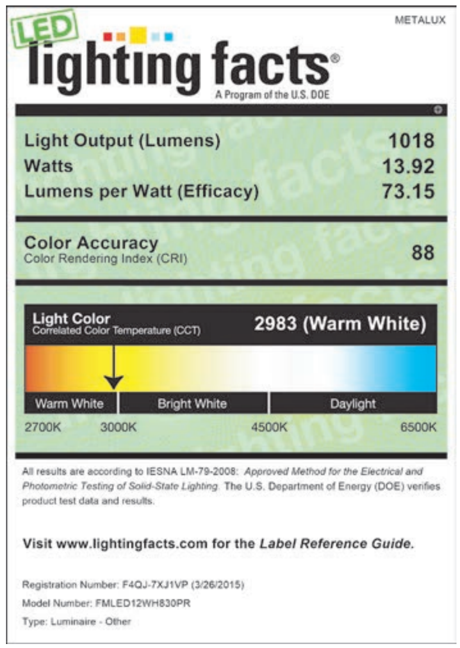
Light Output (Lumens)	577
Watts	7.85
Lumens per Watt (Efficacy)	73.5
Color Accuracy Color Rendering Index (CRI)	88
Light Color Correlated Color Temperature (CCT)	3000 (Bright White)

Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results.

Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: F4QJ-NHUYUL (4/28/2015)
Model Number: FMLED8WH830PR
Type: Luminaire - Other



LED lighting facts® A Program of the U.S. DOE — METALUX

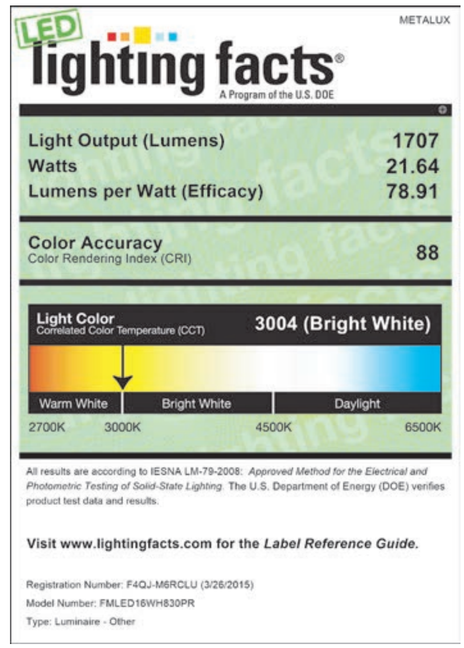
Light Output (Lumens)	1018
Watts	13.92
Lumens per Watt (Efficacy)	73.15
Color Accuracy Color Rendering Index (CRI)	88
Light Color Correlated Color Temperature (CCT)	2983 (Warm White)

Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results.

Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: F4QJ-7XJ1VP (3/26/2015)
Model Number: FMLED12WH830PR
Type: Luminaire - Other



LED lighting facts® A Program of the U.S. DOE — METALUX

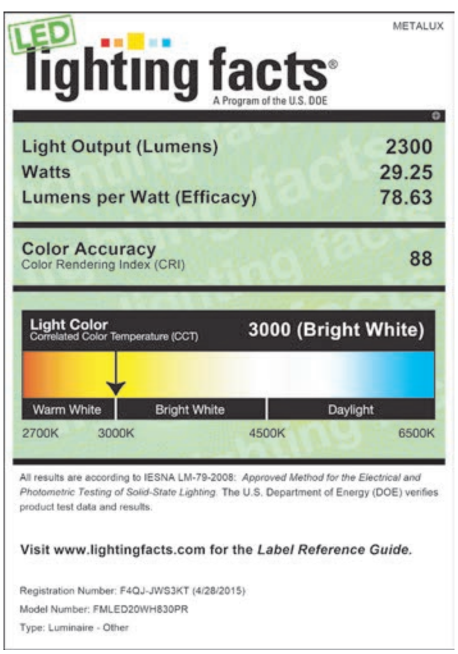
Light Output (Lumens)	1707
Watts	21.64
Lumens per Watt (Efficacy)	78.91
Color Accuracy Color Rendering Index (CRI)	88
Light Color Correlated Color Temperature (CCT)	3004 (Bright White)

Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results.

Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: F4QJ-M6RCLU (3/26/2015)
Model Number: FMLED16WH830PR
Type: Luminaire - Other



LED lighting facts® A Program of the U.S. DOE — METALUX

Light Output (Lumens)	2300
Watts	29.25
Lumens per Watt (Efficacy)	78.63
Color Accuracy Color Rendering Index (CRI)	88
Light Color Correlated Color Temperature (CCT)	3000 (Bright White)

Warm White | Bright White | Daylight
2700K 3000K 4500K 6500K

All results are according to IESNA LM-79-2008: *Approved Method for the Electrical and Photometric Testing of Solid-State Lighting*. The U.S. Department of Energy (DOE) verifies product test data and results.

Visit www.lightingfacts.com for the *Label Reference Guide*.

Registration Number: F4QJ-JWS3KT (4/28/2015)
Model Number: FMLED20WH830PR
Type: Luminaire - Other

SHIPPING DATA

Catalog No.	Individual Wt.	Master Pack
FMLED8	1.0 lbs.	8
FMLED12	1.8 lbs.	4
FMLED16	3.5 lbs.	4
FMLED20	5.55 lbs.	2

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Eaton's Cooper Lighting Business
1121 Highway 74 South
Peachtree City, GA 30269
P: 770-486-4800
www.eaton.com/lighting

CB1900 – UNITY™

VISA LIGHTING

Type: **Project:**

VisaLighting.com/products/Unity

Fill in shaded boxes using information listed below

Order Code:	CB1900		– MVOLT		
	MODEL	A SOURCE	B VOLTAGE	C SHADE OPTION	D OPTION(S)

Incorporating gradual curves along with the soft glow of an illuminated lens and a cleanable fabric, Unity creates a calm and relaxing environment. Providing attractive and holistic solutions for your healthcare lighting needs.

A SOURCE B VOLTAGE

MVOLT fixture accepts 120 through 277 input voltage
LED sources are 83CRI, within 3-step MacAdam and are dimmable 0-10V to 1%

LED Sources	CCT	Delivered Lumens	Power (Watts)	Voltage
• **L30K-L**	3000K	1300	13	**MVOLT**
L35K-L	3500K			
• **L40K-L**	4000K			
• **L30K-H**	3000K	1900	20	
L35K-H	3500K			
• **L40K-H**	4000K	2000		

Fluorescent Sources		Voltage
1TF26	26w triple, 4-pin GX24q-3 base	Select **MVOLT, 120V, 277V** or **347V**
1TF32	32w triple, 4-pin GX24q-4 base	

C SHADE OPTIONS (Select one)

CRMTR Cream Tri-lam Vinyl
• **NATTR** Natural Tri-lam Vinyl
• **WHTTR** White Tri-lam Vinyl

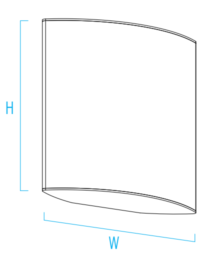
CRMTR **NATTR** **WHTTR**

DIMENSIONS

Depth is measured from wall to front of fixture

W = Width H = Height D = Depth

W	12"	(305 mm)
H	12"	(305 mm)
D	4"	(102 mm)



D OPTIONS (Multiple Selections Allowed)

⚠ Option availability may be interdependent with Voltage, Source or Other Options

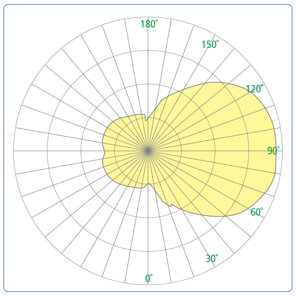
- • **DIM(A)** Advance Mark 10 fluorescent dimming, specify 120V or 277V
- • **DIM(EB)** Lutron H3D EcoSystem digital link fluorescent dimming, TF32 only
- • **DIM(L)** Lutron H3D 3-wire fluorescent dimming, TF32 only
- **FUSE** Fluorescent fusing, specify 120V or 277V
- **NGT** Night light (amber LED), not available with 347V
- **XPS** Express 10 day shipping. Items marked with a bullet (•) are not available with **XPS**

ADA XPS LED ETL Listed 5 Year Warranty

CB1900 – UNITY

VISA LIGHTING

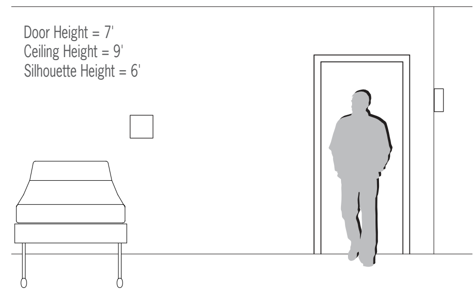
Photometrics



Technical Information

- Modular design for replacement of LED source and power supply
- Amber LED night light option to minimize patient disturbance
- Easy to clean Tri-lam vinyl coated shade with fabric look
- Easy to clean OLIN Lumicor® acrylic diffuser with fabric look
- Antimicrobial housing finish
- ETL listed for damp locations. Not suited for exterior applications

Relative Scale Drawing



Night Light (NGT) Option

CM1974 – SYMMETRY™
Tunable – Recessed

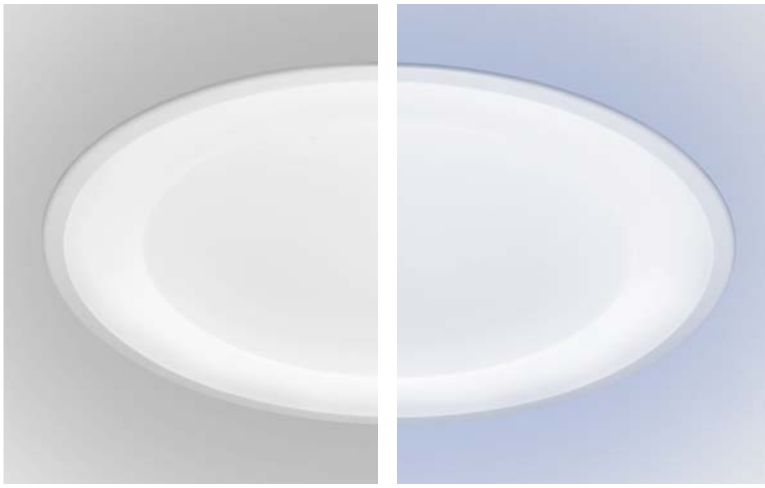
VISA LIGHTING

Type: Project:

VisaLighting.com/products/Symmetry

Fill in shaded boxes using information listed below

Order Code:	CM1974		– MVOLT		
	MODEL	A SOURCE	B VOLTAGE	C LENS FRAME FINISH	D OPTION(S)



The light source in Symmetry has a 1650K-8000K tunable white range and full gamut of saturated color. This 90CRI luminaire is dimmable via 0-10V or DMX-RDM to 1%. The strikingly unique lens is formed in a gentle concave profile with a graceful, shallow dome in the center.

A SOURCE B VOLTAGE

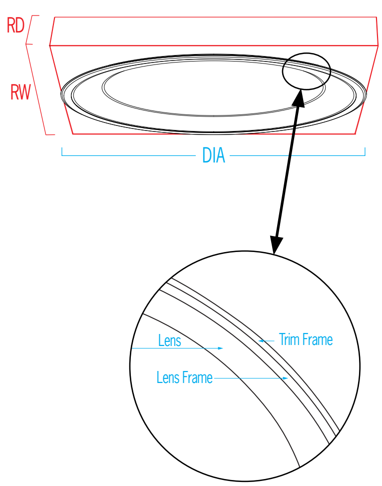
MVOLT fixture accepts 120 through 277 input voltage
Dimmable 0-10V or via DMX controller to 1%
2-step MacAdam across tunable range (2000K-6000K)

Source	Source CCT Range	Max Delivered Lumens	CRI	R9	Max Power (Watts)	Voltage
TUN	1650K	3600	NA	82	68	MVOLT
	2700K	7200	93	99	110	
	3000K	8400	91	94	128	
	3500K	10300	92	91	156	
	4000K	10300	90	93	158	
	5000K	10400	90	77	158	
	6500K	10100	90	76	159	
	8000K	8500	89	70	135	

DIMENSIONS

DIA = Diameter RD = Recessed Depth RW= Recessed Width

DIA	44-1/2"	(1130 mm)
RD	5-7/8"	(149 mm)
RW	44"	(1118 mm)



C LENS FRAME FINISH OPTIONS (Select one)

See page 2 for color chart

Powder Coat Painted Finishes (Standard)

AG7038	Agate Grey	**GLIM**	Glimmer	**PB1035**	Pearl Beige
BMAT	Bronze Matte	**GSIL**	Graphite Silver	**RUST**	Rust
BRNZ	Bronze	**GW9002**	Grey White	**SUNG**	Sungold
BSIL	Blade Silver	**HTHR**	Heather	**TW9016**	Traffic White
CVBL	Cove Blue	**JB9005**	Jet Black		
CW9001	Cream	**OBRZ**	Old Bronze		

Note: Trim Frame is painted white

D OPTIONS (Multiple Selections Allowed)

⚠ Option availability may be interdependent with Voltage, Source or Other Options

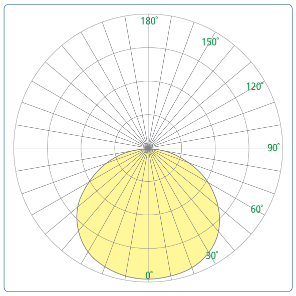
AMC	Antimicrobial coating (no VOC) for painted surface
CP	Chicago Plenum certified
SAF	Sealed Air Flow

LED ETL Listed 5 Year Warranty

CM1974 – SYMMETRY
Tunable – Recessed

VISA LIGHTING

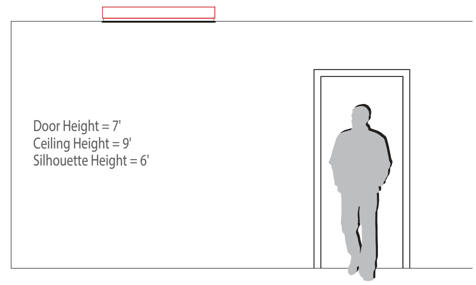
Photometrics



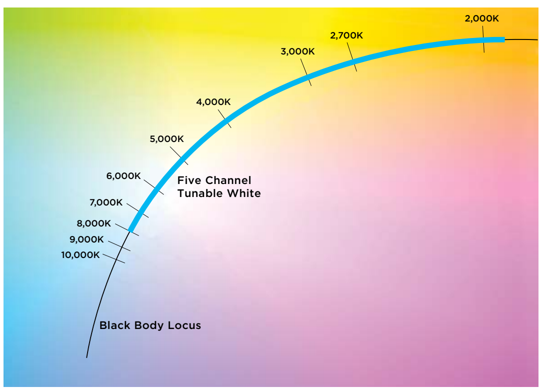
Technical Information

- Integral LED power supplies are located within the housing and accessible from below the ceiling
- Commissioned via an iOS device utilizing BLE
- Suitable for drywall/sheetrock or T-bar grid system
- No VOC powder coat paint
- Optional antimicrobial finishes (no VOC) on all interior and exterior painted surfaces
- ETL listed for indoor locations. Not suited for exterior applications

Relative Scale Drawing



Five-Channel Tunable White LED



5-LED-channel controllable light source system maintains color consistency over a 1650K-8000K range.

Tunable Color Examples

Control Detail

Provided with DMX, Dual 0–10V, and Single 0–10V control capabilities

- **DMX**
  - Compliant with DMX512-A-RDM
  - Separate addresses for:
    - Output (dimming)
    - CCT
    - Color Saturation
    - Hue

    (Color saturation and hue values should be set to zero for blackbody white tuning)
  - DMX addresses may be set using iOS/BLE or through RDM (DMX-RDM controller by others)
- **Dual 0–10V**
  - Independent control of CCT and dimming using two separate 0–10V controllers (by others)
  - Blackbody tuning only, no saturation or hue control
- **Single 0–10V**
  - Preset control using one 0–10V controller (by others) to recall up to five CCT/dim/saturation/hue "scenes" set using iOS commissioning app

Specify color code when ordering. For accurate color matching, individual paint and finish samples are available upon request
For additional information see VisaLighting.com/materials-finishes

Painted Finishes (Standard)

TW9016
Traffic White (RAL9016)

CW9001
Cream (RAL9001)

GW9002
Grey White (RAL9002)

JB9005
Jet Black (RAL9005)

AG7038
Agate Grey (RAL7038)

HTHR
Heather

CVBL
Cove Blue

BSIL
Blade Silver

GSIL
Graphite Silver

GLIM
Glimmer

SUNG
Sungold

BRNZ
Bronze

OBRZ
Old Bronze

BMAT
Bronze Matte

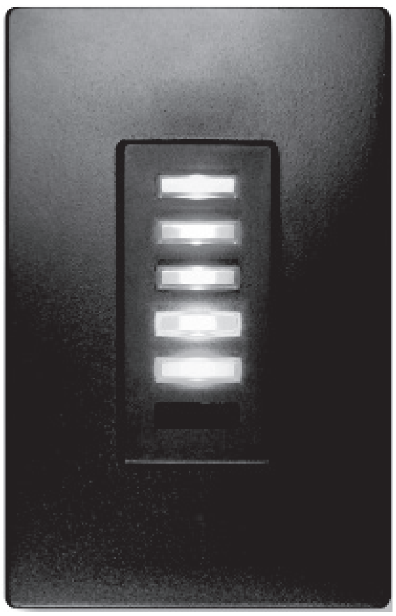
PB1035
Pearl Beige (RAL1035)

RUST
Rust

iLUMIN

ADMX – ArchiDMX – Self-Contained DMX Control Device

Catalog# ADMX-305-W	Prepared by Hazel Chang
Project LCC of Banner Elk /	Date December 2017
Comments Hall 400 Redesign	Type DMX Switch



Overview

ArchiDMX is a completely self-contained device that can control virtually any standard DMX device such as RGB fixtures, moving lights, dimmers, and effects. The ArchiDMX has preset, scene, and show playback features as well as, wireless networking and IR remote control options. ArchiDMX can be programmed by either the ArchiDMX Studio Software or IR Remote. Utilizing the 2.4 GHz wireless option further expedites commissioning as well as allows for linking of multiple stations.

EATON
Powering Business Worldwide

Specifications

Electrical	Supply: 12 Vdc via power supply
	Flash memory for future proof upgradeability
	Variable fade times programmable from .01 seconds to 24 hours per button
	Built-in infrared receiver with learnable remote codes
	Network Communication via DMX
	Using the remote or ArchiDMX Studio Software each button can be individually configured to perform a variety of functions
Mechanical Data	Buttons available with standard or custom engraving
	Suitable for standard single & multi-gang NEMA wall box with decorator style wallplate
	All plastic construction
Environmental Data	Temperature Range: +32°F to +104°F (0°C to +40°C)
	Humidity: 0% - 95% non-condensing
Standards	CE, cULus, CSA, NOM, cETLus

Button Functionality

Using the infrared remote or ArchiDMX Studio Software each button can be configured to perform the following functions:

64 Presets of 512 Channels
Activate
Toggle
Step
Chase
Momentary
Effects

Individual buttons have RGB backlight indicator lights and strong tactile feedback.

The ArchiDMX requires a method of programming. Wireless stations may be programmed by the IR Remote or through the Wireless USB adapter using the free ArchiDMX Studio Software. Stations without wireless capability must be programmed with the IR Remote. When ordering ADMX stations, make certain to select a programming method.

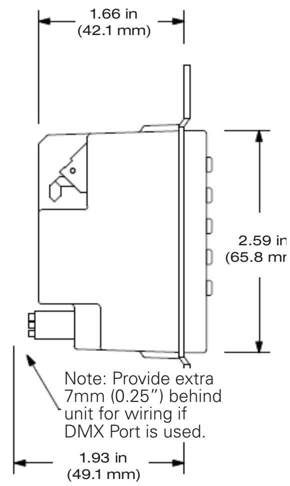
Ordering

Model	Description
ADMX-305-W	Self-Contained, Wireless DMX Control Device - White
ADMX-305-B	Self-Contained, Wireless DMX Control Device - Black
ADMX-305-V	Self-Contained, Wireless DMX Control Device - Ivory
ADMX-315	Portable ArchiDMX Demo Kit
ADMX-IR33	33 Button DMX Programmer Remote
ADMX-USB-STICK	DMX USB Stick
ADMX-12P	DMX 12 VDC Power Supply w/ Pigtails

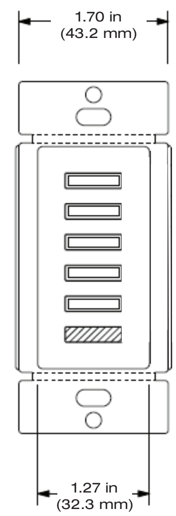
Dimensions

(Inches/mm)

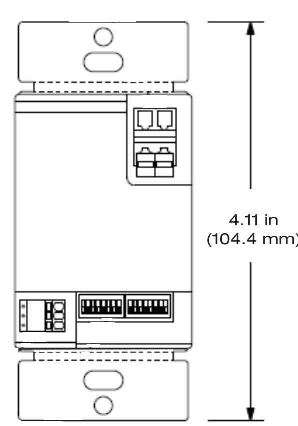
Side View



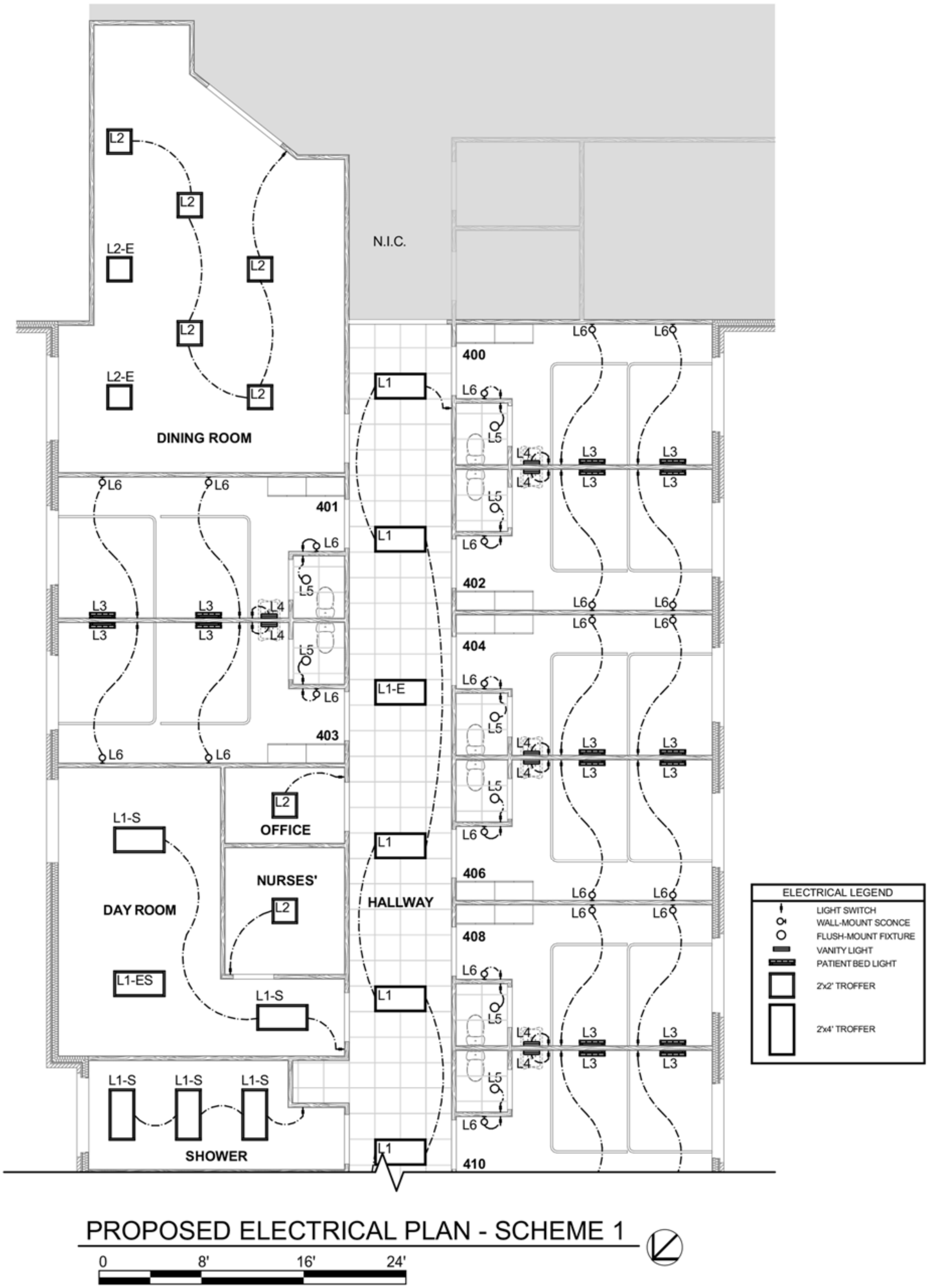
Front View



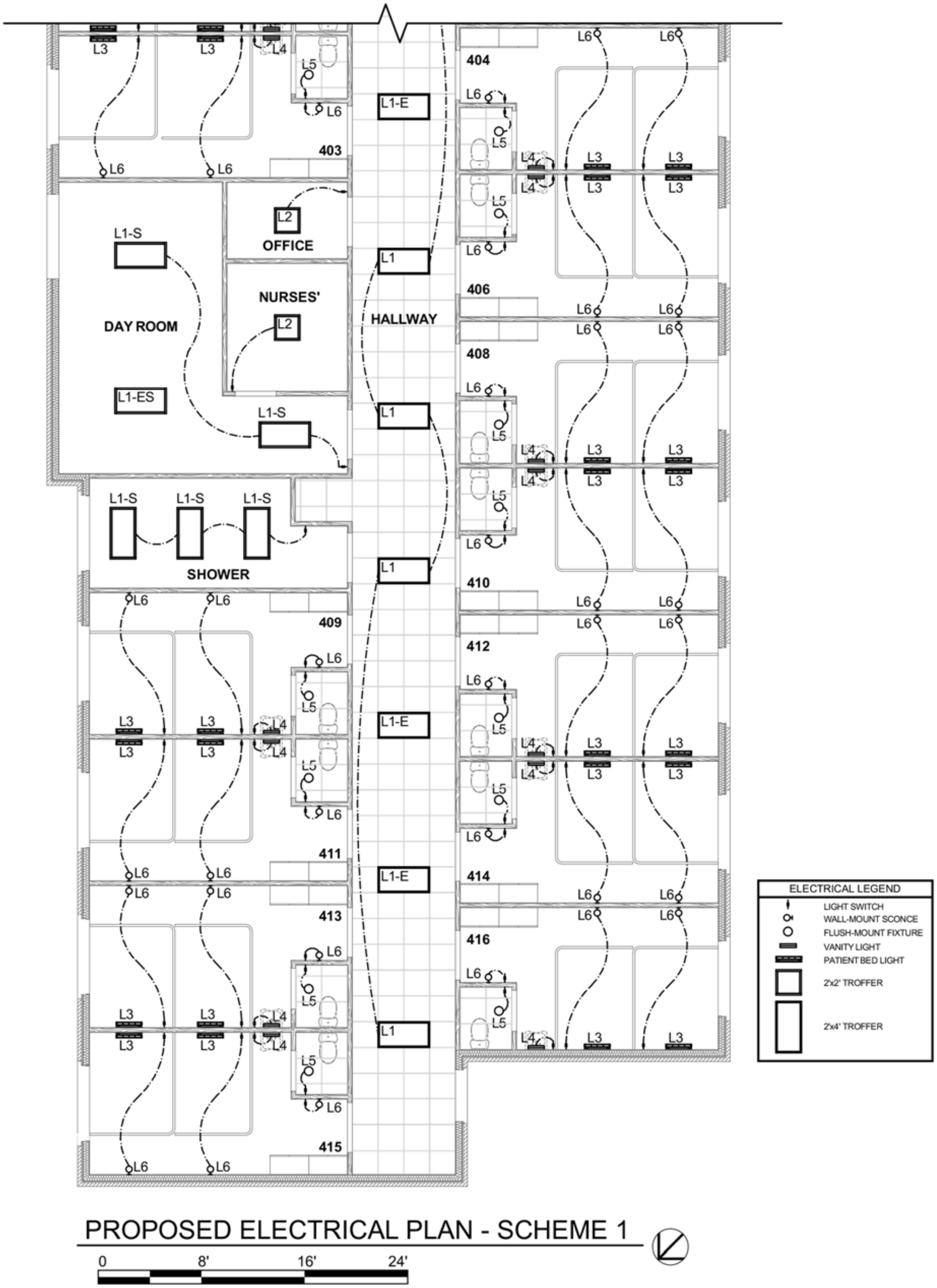
Rear View



Appendix G: Proposed Electrical Plans

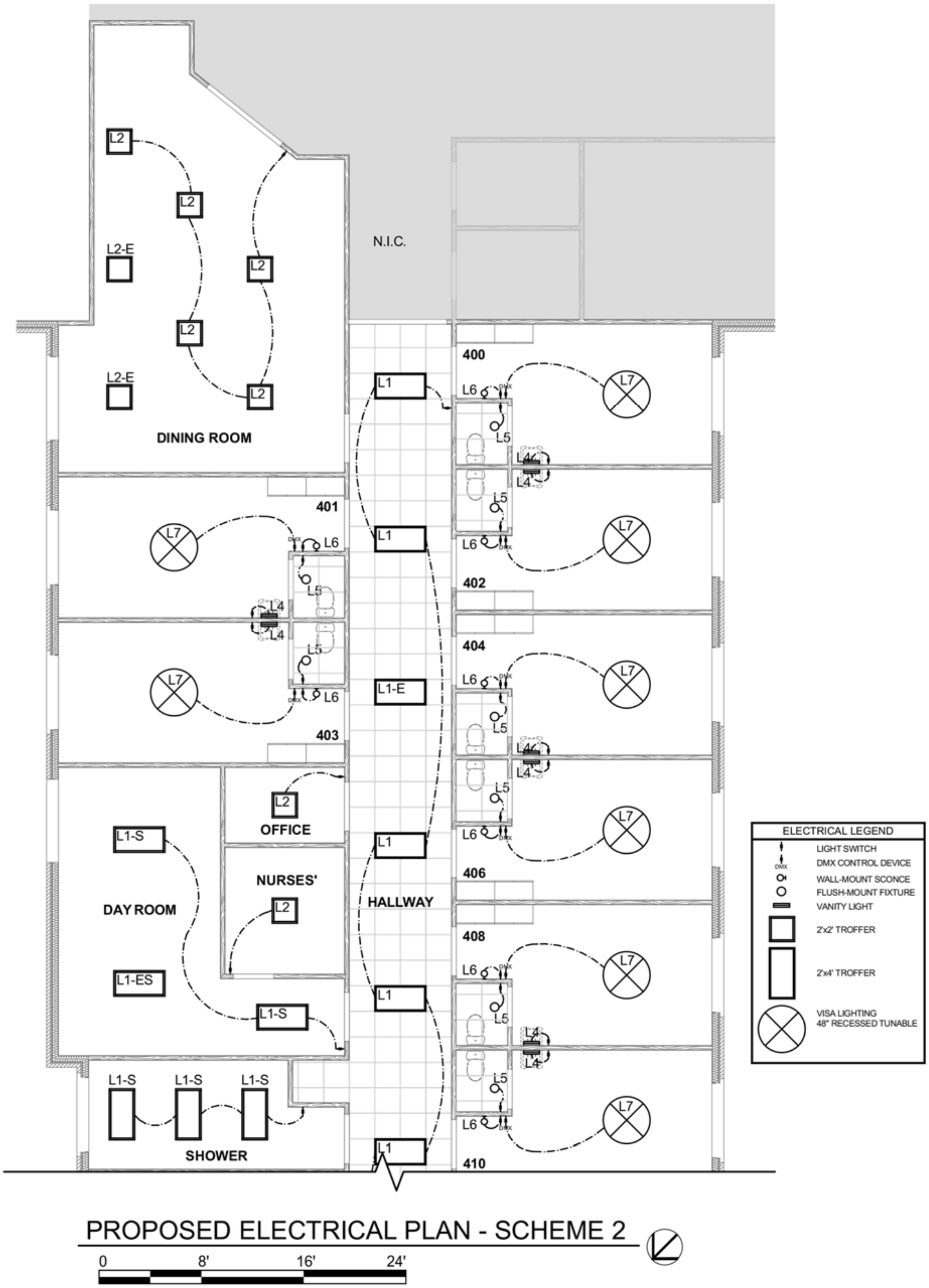


Appendix G: Proposed Electrical Plans cont.

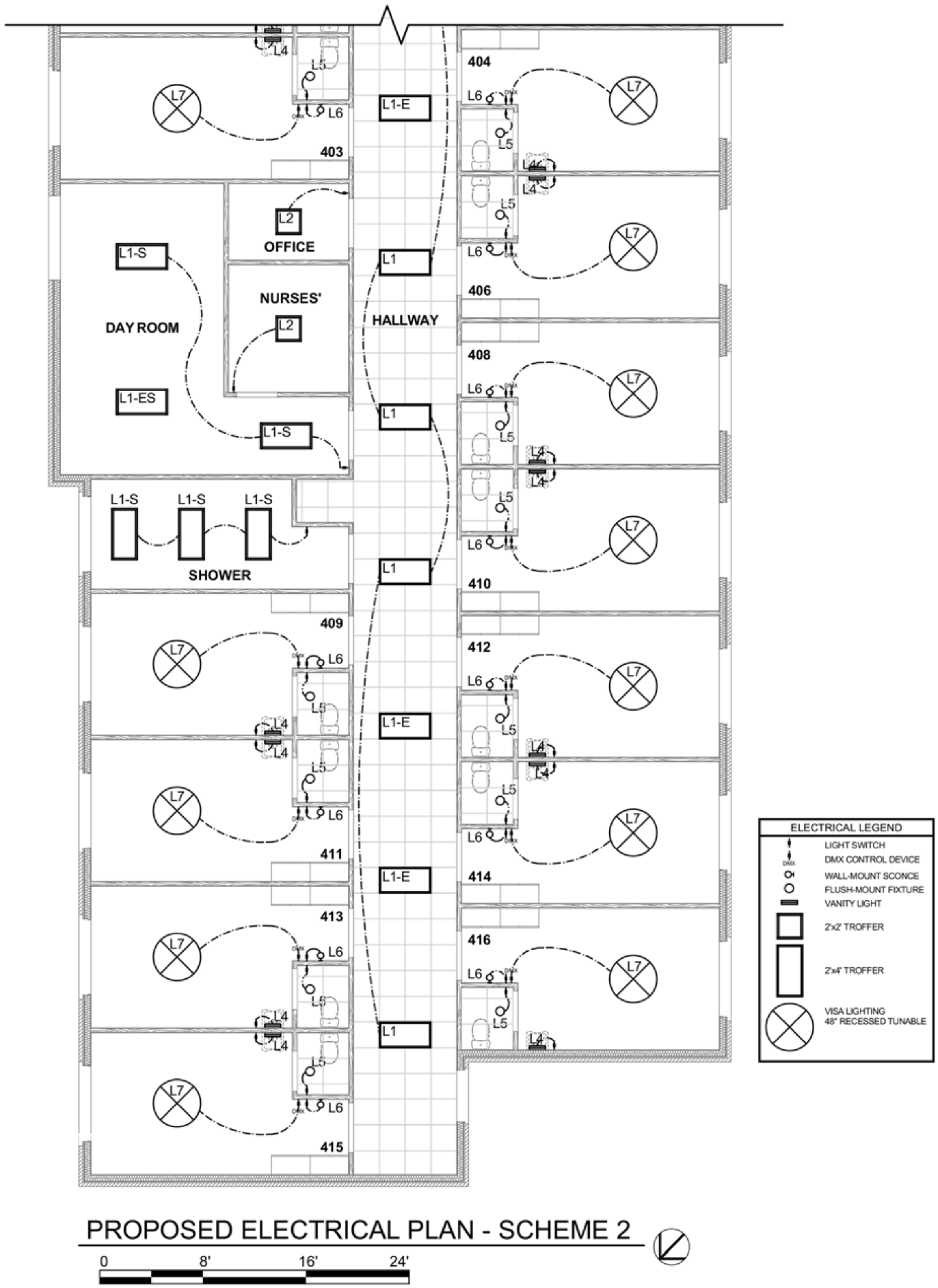


PROPOSED ELECTRICAL PLAN - SCHEME 1

Appendix G: Proposed Electrical Plans cont.



Appendix G: Proposed Electrical Plans cont.



Appendix H: Retrofit Energy and Cost Spreadsheet

Code	Room	Fixture Type	Retrofit Description	Fixture Qty	Hrs of Use Annually	Lamp Qty	Fixture watts existing	Fixture watts proposed	Watts saved by measure
L1	Hallway	Recessed 2x4 fluorescent troffer		6	5840	2	64		
			GEN2 CLARIS LED Retrofit Kits 2'x4' Linear Troffers	6	5840	1		24	240
L1-E(S)	Hallway, day room	Emergency recessed 2x4 fluorescent troffer		4	8760	2	64		
			GEN2 CLARIS LED Retrofit Kits 2'x4' Linear Troffers	4	8760	1		24	160
L1-S	Resident's rooms	Surface-mounted 2x4 fluorescent troffer		30	5840	2	64		
			Remove fixtures	0	5840	0		0	1920
L1-S-Day	Dayroom	Surface-mounted 2x4 fluorescent troffer		2	5110	2	64		
			GEN2 CLARIS LED Retrofit Kits 2'x4' Linear Troffers	2	5110	1		30	68
L1-S-Shower	Central Shower	Surface-mounted 2x4 fluorescent troffer		3	4015	2	64		
			GEN2 CLARIS LED Retrofit Kits 2'x4' Linear Troffers	3	4015	1		24	120
L2	Dining room	Surface-mounted 2x2 fluorescent troffer		5	5110	2	80		
			GEN2 CLARIS LED Retrofit Kits 2'x2' Linear Troffers	5	5110	1		24	280
L2-Office	Private office	Surface-mounted 2x2 fluorescent troffer		1	3650	2	80		
			GEN2 CLARIS LED Retrofit Kits 2'x2' Linear Troffers	1	3650	1		16	64
L2-E	Dining room	Emergency 2x2 fluorescent troffer		3	8760	2	80		
			GEN2 CLARIS LED Retrofit Kits 2'x2' Linear Troffers	3	8760	1		24	168
L3	Resident's rooms	Wall-mounted CFL A-19 lamp bed fixture		30	5840	4	52		
			Visa Lighting Unity 49" Headwall Light	30	5840	1		66	-420
L4	Resident's rooms	Wall-mounted vanity fixture		15	5840	2	26		
			Kichler 12in Linear LED Bath Light NI	15	5840	1		10	240
L5	Bathroom	Ceiling-mounted fixture		15	5840	1	22		
			Metalux AP Series FMLED Ceiling Mount	30	5840	1		8	90
L6	Resident's rooms	(New fixture)		0	5840	0	0		
			Visa Lighting Wall Mounted 12" ADA Sconce	45	5840	1		13	-585
L7	Resident's rooms	(New fixture)		0	5840	0	0		
			Visa Lighting Recessed Symmetry Tunable Light	15	5840	1		127	-1905

Appendix H: Retrofit Energy and Cost Spreadsheet cont.

Code	Total kWh used (or proposed annually)	Total current annual electric cost	Estimated $ cost per fixture	Total estimated $ cost	Annual kWh energy savings	Total Estimated annual energy cost savings	Lighting control existing	Lighting control proposed	Retrofit notes
L1	2242.56	$179.40					Manual switch		
	840.96		$113.00	$678.00	1401.6	$112.13		Dimmer	Price for dimmer not included in study
L1-E(S)	2242.56	$179.40					Manual switch		
	840.96		$113.00	$452.00	1401.6	$112.13			
L1-S	11212.8	$897.02					Manual switch		
	0		$0.00	$0.00	11212.8	$897.02			
L1-S-Day	654.08	$52.33					Manual switch		
	306.6		$113.00	$226.00	347.48	$27.80			
L1-S-Shower	770.88	$61.67					Manual switch		
	289.08		$113.00	$339.00	481.8	$38.54		Occupancy sensor	Price for sensor not included in study
L2	2044	$163.52					Manual switch		
	613.2		$85.00	$425.00	1430.8	$114.46		Occpancy sensor	Price for sensor not included in study
L2-Office	292	$23.36					Manual switch		
	58.4		$85.00	$85.00	233.6	$18.69			
L2-E	2102.4	$168.19					Manual switch		
	630.72		$85.00	$255.00	1471.68	$117.73		Occupancy sensor	Price for sensor not included in study
L3	9110.4	$728.83					Manual switch		
	11563.2		$39.00	$1,170.00	-2452.8	-$196.22		Dimmer	Price for dimmer not included in study
L4	2277.6	$182.21					Manual switch		
	876		$81.00	$1,215.00	1401.6	$112.13			
L5	1927.2	$154.18					Manual switch		
	1401.6		$36.00	$1,080.00	525.6	$42.05		Occupancy sensor	New rewiring for residents' rooms
L6	0	$0.00							
	3416.4		$36.40	$1,638.00	-3416.4	-$273.31		Dimmer	New rewiring for residents' rooms
L7	0	$0.00							
	11125.2		$262.47	$3,937.00	-11125.2	-$890.02		DMX Controller	New rewiring for residents' rooms

Appendix I: System Comparison Calculation Example

Fluorescent 2x4 to LED Retrofit (Type L1)

Parameters	System One (Existing)		System Two (Redesigned)	
Luminaire Type	Recessed '2'x4' Fluorescent Troffers with (2) T8 (L1)		GEN2 CLARIS LED Retrofit 2'x4' Kit	
Number of Lamps/Luminaire	2		1	
Watts per Luminaire	64		24	
Number of Luminaires	6		6	
Operating Hours or FTE	5840		5840	
Initial Costs				
Luminaire Cost	$	-	$	113.00
Lamp Cost	$	3.15	$	-
Labor/Installation Cost (at $28/hr for 0.381 hrs)	$	-	$	10.65
Installed Cost per Luminaire	$	6.30	$	123.65
Total Initial Cost	$	-	$	741.90
Maintenance and Operating Cost				
Electric demand rate ($/kW/mo) *	$	13.77	$	13.77
Peak demand		0.384		0.144
Annual Demand charge	$	63.45	$	23.79
Electric energy rate ($/kWh)	$	0.080	$	0.080
Annual Energy cost	$	179.40	$	67.28
Total Annual Energy Cost	$	242.86	$	91.07
Relamping Method	spot		spot	
Average Rated Lamp Life (Hrs)*		36,000		60,000
Quantity lamps replaced per year		2		0
Hours to replace each lamp		0.06		0
Labor rate to replace lamps	$	20.00	$	20.00
Total Annual Relamping cost	$	8.47	$	-
Hours to clean each luminaire		0.08		0.08
Labor rate to clean luminaires	$	20.00	$	20.00
Cleaning cost per year	$	9.60	$	9.60
Total Annual Maintenance Cost	$	18.07	$	9.60
Total Maintenance and Operating Cost per Year	$	260.92	$	100.67
Difference in Annual M&O Costs			$	160.25

* Electric demand rate would not be used if the account is charged only on energy usage and not demand. This calculation becomes more complicated when demand and/or energy rates are based on time of use. In such instances, software which evaluates usage according to peak rate schedules is valuable, and even necessary for an accurate evaluation.
* Average rated life for most lamps varies depending on the number of on/off cycles. In this case, the rated life for the high lumen T8 lamps is based on 12 hrs of use per start.

Example of Systems Comparison Calculator for (1) Type of Fixture. This Excel spreadsheet file and a blank template can be downloaded at www.hazelchazel.com/lighting-retrofit.

Vita

Hazel Chang was born in 1994 in the outskirts of Kuala Lumpur, Malaysia to John and Janna Chang. At the age of four, she and her family moved to New England where she remained until she was eleven-years-old. Her family returned to Malaysia where she graduated from high school at the age of 16. Chang returned to America to further her education and received her bachelor's degree in Interior Design from Appalachian State University in Spring 2015. After a year of working for Don Duffy Architecture, a custom residential architecture firm in Charlotte, she returned to Appalachian State University to obtain her Masters of Science in Technology with a concentration in Sustainable Design and Construction. During her time at Appalachian, Chang received five scholarships, won seven national and international design competitions, and earned funding for three different research projects, among many other accomplishments. She was awarded her M.S. in December 2017.

Chang's passion for thoughtful design, proper execution, and beautiful structures has led her to a career in design and construction where she continues to push the envelope for better buildings that complement the occupants' specialized needs. She currently resides in Charlotte, NC.