## 4.1 Illumination

4.1.1: Electric Lighting (1 Credit: Implement 4 of 7)

- Electric lighting is free from glare, but may be uniform or non-uniform in distribution. Resulting brightness ratios should not exceed 40:1 within normal field of view.
- Electric light is dimmed based on available daylight.
- Illumination levels can be adjusted in task areas (such as work stations, dining tables, bedside, etc.).
- Illumination level changes occur gradually between spaces.
- Illumination levels are sufficient based on occupancy and use, and color temperature of lamps should be matched to illumination levels.
- Electric lighting in areas of primary function, workspaces, and toilet and bathing rooms have a color-rendering index of 90 or higher.
- Electric lighting systems are commissioned as per ASHRAE guide.

4.1.2: Electric Lighting Controls (1 Credit: Implement 5 of 6)

- Electric lighting controls are within reach of all people.
- Selected electric lighting controls are labeled to indicate zone controlled.
- Switch plates contrast in color from the surrounding wall.
- Electric lighting controls can be activated by a remote control or voice command.

4.1.3: Daylighting (1 Credit: Implement 4 of 6)

- Daylight is available in all rooms and spaces.
- Daylight levels are managed.
- Shading devices allow occupants to control daylight levels.
- Shading devices reposition automatically based on the time of day and/or year.
- Windows provide views for people of all heights.
- Daylighting systems are commissioned as per ASHRAE guide.

### 1. Overview

Light, as defined by the Illuminating Engineering Society of North America (IESNA), is "radiant energy that is capable of exciting the human retina to create a visual sensation" [3]. Measured in terms of the unit called the *lumen*, light is part of the electromagnetic spectrum and is similar to radio waves and X-rays, but is unique in that its waves are visually perceived [4]. When reflected into our eyes from surrounding objects, light enters the photoreceptors. Electrical signals are transmitted to the brain through the optic nerve, thereby enabling a healthy human eye to perceive color and depth, detect motion, and provide visual acuity [3]. In the absence of light, none of these functions are possible.

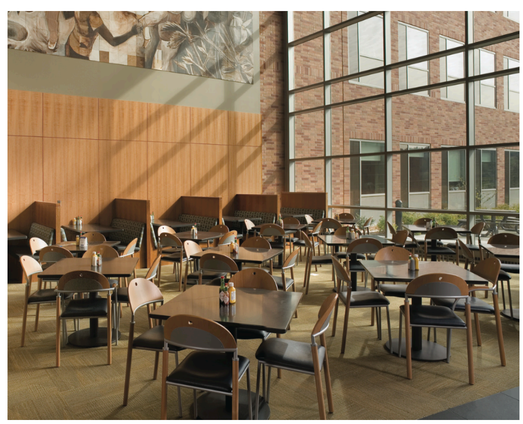

*Figure 1: Full wall, vertical glazing provides daylight to a healthcare facility. Image courtesy of the U.S. Department of Energy*

The Greeks were some of the first masters of maximizing daylight for domestic use through the use of light wells and *toplighting* in their homes (tactics that remain relevant today), and began utilizing pottery, alabaster and wicks for lamp designs in the 7th century BC [5]. It would be another 2500 years before the first electric carbon-arc lamp was developed by sir Humphrey Davy, an English Chemist [5]. Thomas Edison later patented the light bulb that we are most familiar with today, known as the carbon-thread incandescent lamp in 1880, making it available to the public, and ultimately re-defining the indoor environment and lighting market [5]. Nick Holonyak Jr.'s development of the light-emitting diode (LED), in the middle of the 20th century, marked the next significant advancement in illumination. The LED remains one of the most revolutionary developments in the lighting industry on account of its energy efficiency, durability and ability to outlast incandescent bulbs of comparable brightness [6]. The U.S. Department of Energy estimates that by the year 2030, LEDs will make up 75% of all lighting sales, a shift that could decrease energy costs in the United States by up to $30 billion [7].

Research focusing on energy conservation and the visual and non-visual health impacts of lighting, has led to the development and updating of standards, codes and guidelines around lighting systems. One such example is Section 9 of ANSI/ASHRAE/IES Standard 90.1, created by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). This standard provides indoor and outdoor lighting specifications that "establish minimum efficiency requirements of buildings other than low-rise residential buildings" [8]. Specifying daylight and electronic lighting requirements to occupied spaces, 2015 International Code Council, Section 1201, provides basic guidance related to luminance [9]. Additional resources and guidelines for specific populations and uses can be found through the National Institute of Building Science and the Illuminating Engineering Society.

## 2. Issues to Consider

*Visual Impairment / Low Vision:* Low vision can occur from injury, disease or age, and while severity varies, it is defined as vision that can no longer be corrected by eye glasses, contact lenses, medication or surgery [10]. For those suffering from low vision and visual impairments, completing daily tasks can often become difficult. To better promote safety and comfort in the indoor environment, general lighting should be diffused and overall illumination, evenly increased. Additional lighting should be added to hazardous areas such as stairs and access to sufficient, adjustable task lighting provided to further improve the flexibility and usability of lighting systems [11]. Whenever possible placement of windows or light sources at the end of a hallway should be avoided, as these can be the source of glare and place objects in silhouette, making their distance from the viewer difficult to gauge [12]. Material selection should be carefully considered when increasing the overall brightness of the space to avoid severe glare (quantified numerically through Light Reflectance Value (LRV)), which can significantly impede visibility [11]. Fixtures and windows should be covered with diffusers, shades, or blinds to allow for light diffusion, and by selecting matt or non-reflective materials for flooring and furniture, the risk of glare will be reduced [13]. Generally non-diffused, high intensity lighting, also referred to as, "hard light" should be avoided [3]. Hard light creates areas of high glare and contrast and can lead to discomfort and confusion [10].

*Figure 2: LED illuminated hallway, with diffused light to help mitigate glare of high gloss flooring. Image courtesy of IDEA Center*

Transitional spaces, such as hallways, corridors and vestibules should have light continuity with surrounding areas. This will serve to ease the effects of “light adaptation” and “dark adaptation”, both of which occurs when sudden drastic changes in brightness are experienced. Light adaptation occurs when entering a brighter environment, in this condition, the eye tends to adjust rapidly [10]. Whereas dark adaptation, moving from a brighter environment to a darker one, happens much more slowly and the duration of adaptation is often increased in older adults and individuals with impaired vision [10].

Access to lighting controls is vital for individuals with visual impairment or low vision. In addition to visibility through appropriate placement and color contrast with the wall, it is beneficial for strategically placed controls to have occupancy sensors (i.e. motion, infrared or ultrasonic systems) [10]. Entering a completely dark room can lead to an increased risk of injury and confusion. This can be avoided when properly operating sensors activate electrical lights upon occupants entering a room [10].

*Advanced Aging:* As individuals advance in age, their likelihood of visual impairments increase. Although not all impairments are exclusive to the aging population, conditions such as cataracts, macular degeneration, glaucoma and diabetic retinopathy, which can all lead to blindness, are more prevalent within this group [14]. As the human eye ages, parts that were once colorless or transparent, can stiffen and become yellow, which reduces the ability to focus on objects, and adjust focus when transitioning from near to far [11].

Many of the design recommendations for seniors are similar to the strategies used for low or impaired vision, however not all older adults experience changes to their vision in the same way or with the same severity. To avoid a resistance to some of these strategies by older individuals, designers should limit implementation to those that are most beneficial to the end user [14].

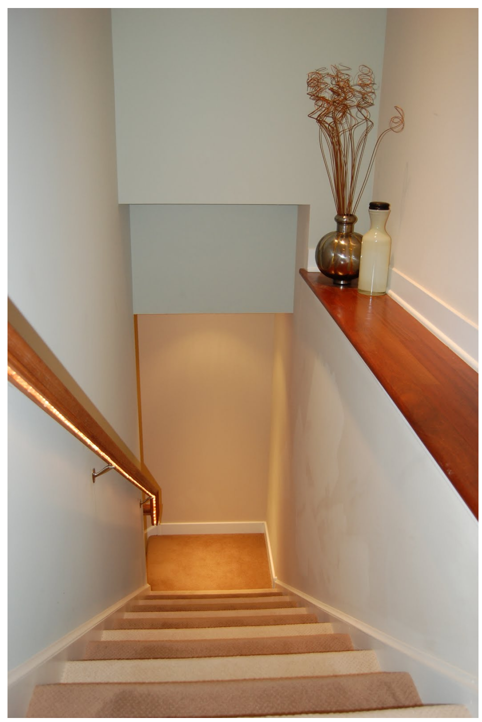

*Figure 3: Alternate colored carpeting on stairs, combined with LED rope lighting beneath handrail help to increase visibility of stairway. Image courtesy of the [LIFEhouse™]*

*Color:* Approximately 8% of males and 0.2% of females are reported to be *protanopic* or have color deficient vision, making it valuable to understand the variable effects that lighting conditions may have on *hues*, *values* and *shades* of color [3]. Photoreceptors in the human eye that are responsible for color recognition, are activated only in the presence of light [3]. While it is impossible to test exactly how individuals perceive color, professionals have developed two basic methods for measurement, the first being *chromaticity*, or color temperature. Color temperature describes the light and the source from which it is emitted [10]. Expressed in degrees Kelvin (K), chromaticity values below 3000 K, represent warm light (reds, oranges and yellows) and values above 4000 K represent cool light (purples, blues and greens) [10]. For further guidance on appropriate illumination levels required to achieve a desired color temperature, refer to *Table 5*. The second method used to assess color, is the *color-rending index* (CRI). CRI measures the amount of variability that a color will appear to have when illuminated with a light source as compared to its perceived color when illuminated with a reference light source [10]. The higher the CRI value of a light source, the more accurately it will represent colors.

Color can be used as a means of increasing visibility when modifications to lighting systems are not possible. Whites and other bright colors help to reflect light and make a room appear brighter [13]. Whereas, the use of contrasting colors can serve as a tactic that aides individuals working in low lighted areas or suffering from visual impairment to differentiate between objects/text of contrasting colors [13]. Legge and Rubin (1989) found that protanopic subjects had a "major reduction in sensitivity to red," and recommended that green or gray be used to increase visibility for these individuals, as well as those with normal or low vision [15].

*Light and Health:* Light has more benefits than just those related to vision, it can promote the length and quality of sleep, alleviate seasonal depression, regulate melatonin, and has a direct relationship to cortical brain activity [10].

Natural light or *full spectrum light* has a major impact on our health and wellbeing. Sunlight is used by our bodies in the production of vitamin D, necessary for bone health, while also synchronizing our bodies with the environment every 24-hours through our circadian rhythm, regulating sleep/wake cycles, temperature control and hormone release [16]. Research suggests that light can be successful in preventing and relieving psychiatric illnesses, such as seasonal affective disorder (SAD) and depression [16]. The Rensselaer Lighting Research Center found that access to daylight through windows and views to the outside environment can actually lead to increases in productivity, learning and even retail sales [17].

*Figure 4: Wall mounted, electric lighting control with occupancy sensor. Image courtesy of the [National Institute of Building Sciences]*

When natural light is not a viable option, artificial, full spectrum light sources can be used to provide some of the non-visual benefits of light (listed above) through daily use [18]. Use of this type of light source has been most significant for individuals suffering from Alzheimer's and dementia, progressive neurodegenerative disorders common in older adults. These disorders can cause individuals to struggle with behavioral symptoms such as nocturnal wandering, agitation and disrupted sleep/wake cycles, contributing to panicked confusion and risk of injury when wandering at night [19]. Studies have shown that light treatments at specific frequencies administered at certain times throughout the day can help to control these adverse effects [20].

The Rensselaer Light Research center developed a circadian stimulus calculator to assist lighting professionals in selecting light sources that increase potential for circadian light exposure and can be accessed for free download here.

*Daylighting, Sustainability and Energy Conservation:* Artificial lighting can account for as much as 40% of the total energy usage in a building [21]. Through simple and inexpensive lighting upgrades, immediate energy reductions can be made without compromising the quality of light [21]. Strategies such as employing daylighting systems, implementation of electric lighting controls, replacing bulbs with those of a lower wattage, or switching out incandescent bulbs with LEDs, all help to limit energy usage.

Whenever available, controlled natural light or *daylighting* systems should be utilized for indoor illumination. Daylight color changes through the day, providing orientation to the passage of time. A successful daylighting system should provide adequate illumination to occupied spaces to perform necessary tasks, while also controlling undesirable effects such as, solar heat gain, glare and harsh shadows [22]. The health benefits that result from utilizing daylighting systems are described above.

One of the most effective ways to improve efficiency of lighting systems is the implementation of electric lighting controls. Traditionally, controls have consisted of an on/off switch, and while energy conservation is possible with this type of control, it is often much less efficient. There are several types of electric lighting controls including: occupancy sensors (infrared, ultrasonic or duel), daylight sensors, clock switches and centralized controls [23]. Selecting the type of electric lighting control for a space should be part of the initial design and should be tailored and calibrated to meet the functional demands of the space and its occupants.

*Subjective Impressions of Lighting:* Other lighting research indicates the perceptual influences that lighting can have on the occupants of a space. Subjective impressions include those related to visual clarity, spaciousness, relaxing versus tense space and impressions of pleasantness, to name a few [1]. See *Figure 6* for lighting conditions associated with specific subjective impressions.

## 3. Related Standards

2016 International Building Code: Section 1205 Lighting specifies the minimum requirements for natural light by defining ratios of glazed area to floor space. Average illumination levels are also provided for spaces and stairways supplied with artificial light. Emergency egress lighting requirements can be found in Section 1008 of the 2016 International Building Code.

ASHRAE Guideline 0-2013: Commissioning Process presents best practices for applying whole-building commissioning to facilities. These practices apply to all phases of new construction and renovation projects. To assist in further understanding of the commissioning process, this guideline outlines the roles and responsibilities of the owner and the commissioning authority.

ANSI/ASHRAE/IES 90.1 Section 9: Energy Standard for Buildings Except Low-Rise Residential Buildings: Lighting is a benchmark for commercial building energy codes in the United States and a key basis for codes and standards by providing the minimum requirements for energy-efficient lighting systems of most buildings, while allowing for quality lighting design based on the latest luminance recommendations from IES.

Illuminating Engineering Society lighting handbook: reference and application reviews all illumination related technologies, applications, and recommendations and is recognized as an industry standard for lighting design. Founded in 1906, the IES is the oldest and largest educational and scientific society in North America devoted to lighting, with membership representation from lighting professionals working in the fields of manufacturing, design, architecture, government, education and retail.

National Institute of Building Sciences: Design Guidelines for the Visual Environment provides background information on commonly diagnosed visual impairments and the impact of these impairments on the visual environment. This resource proposes design recommendations to facilitate equal access through universal design principles.

## 4. Measurement and Verification

The 2015 International Building Code (IBC) specifies that all spaces intended for human occupancy must be provided with illumination, either naturally (i.e. through exterior glazing) or artificially. The IBC also provides minimum illumination values that can be objectively measured. In the case of artificial light, one would sample the lighted space with the use of a light meter, averaging measurements at a specified distance from the floor (in the case of the IBC, the distance from the floor is 3'). While these values provide measureable guidelines for illuminating a space, it is often necessary that the lighting design include adaptations and illumination flexibility to better serve a larger percentage of the population, such as additional task lighting, floor and stair lighting and dimming controls. Once the installation of the lighting system is complete, and after required codes and standards have been met, it is beneficial to conduct a focused post occupancy survey to ensure that the illumination values are satisfactory to the end users [24]. Adjustments can then be made to address any deficiencies discovered.

Additionally, ANSI/ASHRAE/IES Standard 90.1-2013 provides minimum energy efficiency requirements as they relate to IES recommended illumination values. Recognized by both the U.S. Department of Energy and the International Energy Conservation Code, this standard provides allowances for lighting power densities (LPR) for specific building types and common spaces (i.e. living quarters, fire stations, parking lots and restrooms). LPR allowances measure the lighting power of a light source in watts (provided by product manufacturers) per unit of area in an illuminated space [8].

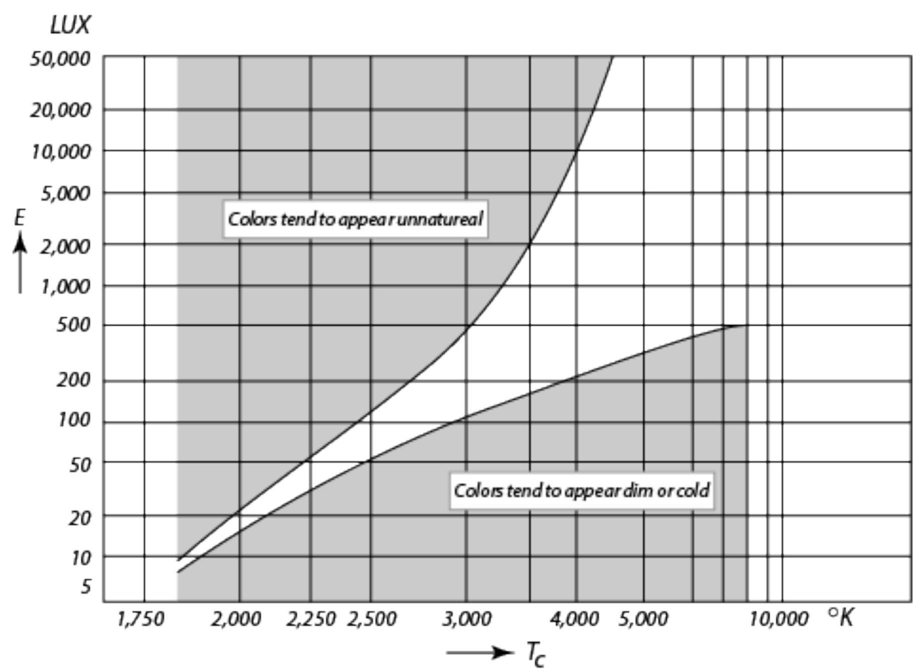


*Figure 5: Table illustrating the relationship of color temperature to illumination level. For every color temperature, there exists a highest and lowest level of illumination at which the illumination is considered "pleasing". Table courtesy of the Phillips Technical Review[2].*

| LIGHTING CONDITIONS | SUBJECTIVE VISUAL IMPRESSION | | | | |
|---|---|---|---|---|---|
| | Clarity | Spaciousness | Relaxation | Intimacy | Pleasantness |
| Brightness as Reinforcement | | X | | | |
| Low Illuminance in area of occupants | | | | X | |
| Warm color temperature light sources | | | X | | X |
| Cool color temperature light sources | X | | | | |
| Perimeter emphasis (wall washers) | X (Some) | X (Uniform) | X (Nonuniform) | X (High Brightness) | X |
| Non-uniform layouts | | | X | X | X |
| Bright, uniform light on horizontal work surfaces | X | X | | | |

*Figure 6: Table illustrating the relationship of lighting characteristics to selected visual impressions. Table adapted from John Flynn's procedures for measuring subjective impressions of lighting [1] by Paul L. Battaglia.*

## 5. Design Considerations

*For 4.1.1, Electric Lighting* (1 Credit: Implement 5 of 6):

*Figure 7: Residential Kitchen lighting design complete with sufficient under-cabinet task lighting, recessed ceiling lighting, and pendent fixtures provide maximum flexibility and illumination for multiple tasks and functions. Image courtesy of the [U.S. Department of Energy]*

- *Electric lighting is even, free from glare, and does not cast distracting shadows.* High contrast shadows and glare can often be distracting, disorienting, or even the cause of temporary blindness for some individuals, specifically those that are visually impaired [10]. Diffusing and distributing light (i.e. providing light that is not incident from any one direction) creates a more evenly lit space that will minimize the harsh effects of direct light, and distracting shadows. Glare can also be controlled through the use of diffused light in coordination with appropriate surface materials (i.e. selecting flat or dull finishes for floors, walls or furniture). The Light Reflectance Value (LRV) identifies reflectance levels of specific surface materials, the lower the percentage assigned, the less light will be reflected back into the environment, therefore producing less glare [10]. For optimal results select finishes with an LRV of values between 25 - 45% [10].

- *Electric light is dimmed based on available daylight.* Electric lighting controls that employ photosensors or light-level sensors are used to automatically control the amount of artificial light supplied to a space depending on how much natural light is present. Photosensor controls should always be used when implementing a daylighting system to ensure maximum efficiency and appropriate luminance [8] [23].

- *Illumination levels can be adjusted in task areas (such as work stations, dining tables, bedside, etc.).* Visual ability and acuity varies from person to person, and while minimum lighting levels are specified in building codes and standards, adjustable task lighting options offer the user a level of flexibility and comfort to best suit their visual needs.

- *Illumination level changes occur gradually between spaces.* Sudden drastic changes in brightness, often occurring in transitional spaces such as hallways, stairwells and vestibules, causes the eye to experience an adjustment condition known as “light” and “dark” adaptation [10]. For some individuals, this adjustment period can cause temporary blindness or limited vision. By implementing dimmable lighting systems in these spaces, the differences in brightness can be minimized through a gradual transition.

- *Illumination levels are sufficient based on occupancy and use, and color temperature of lamps should be matched to illumination levels.* Meeting the standards provided by ANSI/ASHRAE/IES Standard 90.1 and 2015 International Code Council, Section 1201, help to create quality lighting environments because they provide values based on building type/space use. But, occupant feedback should also be considered due to the subjective quality of illumination and its relationship to other design features like color and the reflectance value of surfaces as well as the activities in a particular space. Post occupancy surveys (POS) on lighting quality are a useful tool should be employed to assure that sufficient illumination levels are provided for occupants. Sample surveys can be found at The Center for the Built Environment's Occupant Indoor Environmental Quality Survey) [4]. Additionally, the Lighting Research Center at Rensselaer Polytechnic Institute has developed a basic guide with lighting recommendations for specific room types, which can be accessed here.

- Although not all standards include color requirements for illumination, color has been shown to have an emotional impact on occupants. Designers can refer to *Figure 5* to select appropriate illumination levels to achieve preferred hues and emotional responses.
- *Electric lighting in areas of primary function, workspaces, and toilet and bathing rooms have a color-rendering index of 90 or higher.* Perceived color accuracy impacts the visual environment and can be a contributing factor to occupant comfort [4]. The color-rending index (CRI) of a light source, quantifies its ability to reproduce colors accurately, leading to improvements in visual acuity and the accurate rendering of illuminated objects [4]. The higher the CRI value of a light source, the more successful the light is at rendering color accurately.
- *Electric lighting systems are commissioned as per ASHRAE guide.* According to the Whole Building Design Guide, building commissioning is the professional practice that ensures buildings are delivered according to the Owner's Project Requirements (OPR). The OPR should include visual environment requirements, like conducting focus groups or a survey prior to design, or through an evaluation of lighting quality after lighting system installation is substantially complete. Buildings that are correctly commissioned have fewer change orders, tend to be more energy efficient, and have lower operation and maintenance costs. Commissioning of lighting control systems is of particular importance, as non-commissioned controls can result in greater energy consumption [23]. Commissioning of lighting systems is typically done in accordance with ASHRAE Standard 202-2013, The Commissioning Process for Buildings and Systems, and ASHRAE Guideline 0. As mentioned above, ANSI/ASHRAE/IES Standard 90.1 and the 2015 International Code Council, Section 1201 also contain guidance on lighting power densities, illumination levels, and lighting controls.

*For 4.1.2, Electric Lighting Controls* (1 Credit: Implement 3 of 5):

- *Electric lighting controls are within reach of all people.* Environmental controls are required by the 2010 ADA Standards for Accessible Design to be accessible unless they are intended for use only by service or maintenance personnel. These controls include, but are not limited to, light switches, circuit breakers, duplexes and other convenience receptacles, environmental and appliance controls, plumbing fixture controls, and security and intercom systems.
- *Selected electric lighting controls are labeled to indicate zone controlled.* Identifying various lighting zones in a building helps to better customize function and maximize energy efficiency. Lighting zone classifications include, but are not limited to: space type, space area and available daylighting [8]. By assigning and labeling controls to

specific zones, users can quickly and easily select necessary lighting settings. In locations with multiple switches, organizing switches and dimmers to reflect the locations of the fixtures they control can help building user understand the system. This ergonomic concept is called "spatial mapping."

- *Switch plates contrast in color from the surrounding wall.* Along with being easily accessible, lighting controls should also have a high level of visibility. According to the American Foundation for the Blind, enhancing visual contrast is one of the simplest, most cost effective, modifications one can implement to improve the visibility of objects (i.e., alternate colored steps in figure 2) [25]. Even when individuals have decreased color perception, it is still possible to enhance visibility through the use of contrasting colors. It is recommended that the LRV of two contrasting surfaces (i.e. wall and switch plate) should have a difference of 30 points or more [12].

- *Electric lighting controls can be activated by a remote control or voice command.* Remote and voice activated commands provide users with a wide range of ability levels the opportunity to adjust illumination levels independently. Providing all occupants with control over their visual environment both helps to create optimal illumination while also having a positive impact on occupant mood [4]. It is important to note that in places where people do not move very much, like at workstations where intense computer interaction takes place or in toilet rooms, sensors that rely solely on movement can be annoying, especially if they require significant movement to activate or cannot be adjusted to lengthen the timing cycle.

*4.1.3 Daylighting* (1 Credit: Implement 4 of 6):

- *Daylight is available in all rooms and spaces.* When daylight cannot be sufficiently provided through the use of wall fenestration and glazing, features such as skylights, light shelves or tubular daylight devices are also effective ways to provide daylight to any indoor space [26,27,28,29].

- *Daylight levels are managed.* Controlling natural daylighting systems allows for effective visual and non-visual benefits in the indoor environment, while limiting the adverse effects of natural light such as solar heat gain, excessive glare and distracting shadows. Control strategies such as daylight photosensor electric lighting controls and automatic solar shading should be incorporated into any daylighting system to maximize efficiency and illumination quality [22].

- *Shading devices allow occupants to control daylight levels.* To increase the flexibility of illumination in a space, occupants should be given the ability to manually control the amount of natural light in a space. Automatic lighting controls should be equipped with manual overrides and simple, reachable, features such as blinds, curtains and window shades should be accessible to all occupants.
- *Shading devices reposition automatically based on the time of day and/or year.* When implementing automatic sunshades as a daylight control strategy, it is necessary to calibrate and actively manage control systems upon installation to account for annual variations in sun angle. This will allow for appropriate shading of a space year round [4].

- *Windows provide views for people of all heights.* Research has shown that, "people prefer and place value on window view seats" [30]. By providing windows at various heights and locations, designers can successfully provide widely accessible views to all occupants.

- *Daylighting systems are commissioned as per ASHRAE guide.* Commissioning of a daylighting system is typically done in accordance with ASHRAE Standard 202-2013, The Commissioning Process for Buildings and Systems, and ASHRAE Guideline 0. Considerable amounts of planning is invested in implementing daylighting systems, however too often this effort is not extended when designing electric lighting controls that help to maintain the efficiency and effectiveness of these systems. It is vital that the commissioning and design of the lighting controls also be a part of the overall daylighting system commissioning process [31]. Buildings that are correctly commissioned have fewer change orders, tend to be more energy efficient, and have lower operation and maintenance costs. The 2012 International Energy Conservation Code offers additional guidance on the commissioning of lighting systems.

## 6. Definitions

| | |
|---|---|
| Candelas | Units that measure luminous intensity and describe the flow of light in a given direction [11]. |
| Chromaticity | Defines a color without taking into account its brightness [11]. |
| Daylight | Natural light [11]. |
| Fluorescent Lamp | A low-pressure electric discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light [8]. |
| Hue, Value and Chroma | Used to classify a color in the Munsell System, the most common method of describing colors objectively [11]. |
| Incandescent Lamp | A lamp in which light is produced by a filament heated to incandescence by and electric current [8]. |
| Lighting, decorative | Lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting [8]. |
| Lighting Power Density (LPD) | The maximum lighting power per unit area of a building classification of space function [8] |
| Light Reflectance Value (LRV) | The percentage of light falling on it that is reflected away [10]. |
| Light Source | Anything that emits light directly [11]. |
| Lighting System | A group of luminaires circuited or controlled to perform a specific function [8] |

| | |
|---|---|
| Lumen | Describes luminous flux, the flow of light from a source, i.e. total light output [11]. |
| Luminance | Describes the amount of light flowing in a particular direction from a surface, measured in candelas [11]. |
| Luminous flux, luminous intensity, illuminance and luminance | Terms used to describe the flow of light between surfaces in three-dimensional space. They are the basis for the units of lighting [11]. |
| Photosensor | A device that detects the presence of visible light, infrared (IR) transmission, and/or ultraviolet (UV) energy [8]. |
| Task Lighting | Lighting directed to a specific surface or area that provides illumination for visual tasks [8]. |
| Toplighting | Lighting building interiors with daylight admitted through fenestration, such as skylights and roof monitors, located on roof [5]. |

## 7. References


1. Flynn, John E., Clyde Hendrick, Terry Spencer, and Osyp Martyniuk. 1979. "A guide to methodology procedures for measuring subjective impressions in lighting." *Journal of IES*.
2. Kruithof, A. A. 1941. "Tubular Luminescence Lamps for General Illumination." *Philips Technical Review* 6 (3):65-96.
3. Illuminating Engineering Society. 2011. "The Science of Light " Accessed 6/9/16. http://www.ies.org/lighting/science/index.cfm.
4. Delos Living LLC. 2016. The Well Building Standard. In *v1 with May 2016 Addenda*.
5. Illuminating Engineering Society. 2011. "A Brief History of Lighting." Accessed 6/8/16. http://www.ies.org/lighting/history/.
6. Rensselaer Polytechnic Institute. 2011. "Daylight Dividends." Rensselaer Polytechnic Institute Accessed June 20, 2016. http://www.lrc.rpi.edu/programs/daylighting/dr_productivity.asp.
7. U.S. Department of Energy. 2016. "LED Lighting." [Web Page] Accessed June 20, 2016. http://energy.gov/energysaver/led-lighting.
8. ASHRAE. 2013. ANSI/ASHRAE/IES Standard 90.1-2013. In *Energy Standard for Buildings Except Low-Rise Residential Buildings*.
9. International Code Council. 2015. 2015 International Building Code: Section 1205. In *Lighting*
10. National Institute of Building Science. 2015. Design Guidelines for the Visual Environment. In *Low Vision Design Program*. National Institute of Building Science.
11. Tregenza, Peter, and David Loe. 2014. *The Design of Lighting*. second ed. New York, NY: Routledge.
12. National Disability Authority. Internal Environment and Services. In *Building for Everyone: A Universal Design Approach*.
13. Bakker, Rosemary. 2005. Household Tips for People with Low Vision.
14. Illuminating Engineering Society. 2012. A Vision for the Future: Light + Seniors.
15. Legge, G. E., and G. S. Rubin. 1986. "Contrast Sensitivity Function as a Screening-Test - a Critique." *American Journal of Optometry and Physiological Optics* 63 (4):265-270.
16. Bellia, L., F. Bisegna, and G. Spada. 2011. "Lighting in indoor environments: Visual and non-visual effects of light sources with different spectral power distributions." *Building and Environment* 46 (10):1984-1992 http://dx.doi.org/10.1016/j.buildenv.2011.04.007.
17. Rensselaer Polytechnic Institute. 2016. "Lighting Patterns for Healthy Buildings ". http://lightingpatternsforhealthybuildings.org/content/3.
18. 2016. "Light and Health | Research Programs | LRC." http://www.lrc.rpi.edu/programs/lightHealth/index.asp.
19. Dementia.org. 2015. "How Dementia Affects Sleep Cycles." Accessed 6/17/16. https://www.dementia.org/dementia-affects-circadian-rhythms-and-causes-sleep-disorders.
20. Vitiello, M.V. 2009. Sleep and Circadian Rhythm Disorders in Human Aging and Dementia.
21. National Council on Qualifications for the Lighting Professions. 2016. "NCQLP | Candidate Handbook." Accessed 6/8/16. https://www.ncqlp.org/NCQLP_Handbook.pdf.

22. Ander, Gregg D. 2014. "Daylighting." Accessed 6/14/16. https://www.wbdg.org/resources/daylighting.php?r=promote_health.
23. Nelson, David. 2014. "Electric Lighting Controls." WBDG, Last Modified October 27, 2014 Accessed June 21, 2016. https://www.wbdg.org/resources/electriclighting.php.
24. Brandston, Howard M. 2000. Lighting Design. American Institute of Architects.
25. Blind, Amercian Foundation for the. 2016. "Vision Aware | Contrast and Color." [web page]. Amercian Foundation for the Blind Accessed June 21, 2016. http://www.visionaware.org/info/everyday-living/home-modification-/contrast-and-color/125.
26. Vigener, Nik, and Mark A. Brown. 2006. "Building Envelope Design Guide - Fenestration Systems." [web page]. Whole Building Design Guide, Last Modified March 14, 2006 Accessed June 20, 22016. https://www.wbdg.org/design/env_fenestration.php.
27. Vigener, Nik, and Mark A. Brown. 2012. "Building Envelope Design Guide - Sloped Glazing." [web page]. Whole Building Design Guide, Last Modified June 25, 2012 Accessed June 20, 2016. https://www.wbdg.org/design/env_fenestration_slpglz.php.
28. Whole Buliding Design Guide. 2010. "Strategy: Light Shelf." [web page]. Whole Building Design Guide, Last Modified October 31, 2010 Accessed June 20, 2016. https://www.wbdg.org/ccb/ARMYCOE/COETN/technote02.pdf.
29. Solatube. "Daylighting Systems." [web page]. Solatube Accessed June 20, 2016.
30. Kim, Jong-Jin, and Jean Wineman. 2005. Are Windows and Views Reallly Better? A Quantitative Analysis of the Economic and Psychologic Value of Views. The University of Michigan.
31. Hackel, Scott, and Scott Schuetter. 2013. "Best Practices for Commissioning Automatic Daylighting Controls." *ASHRAE Journal*.