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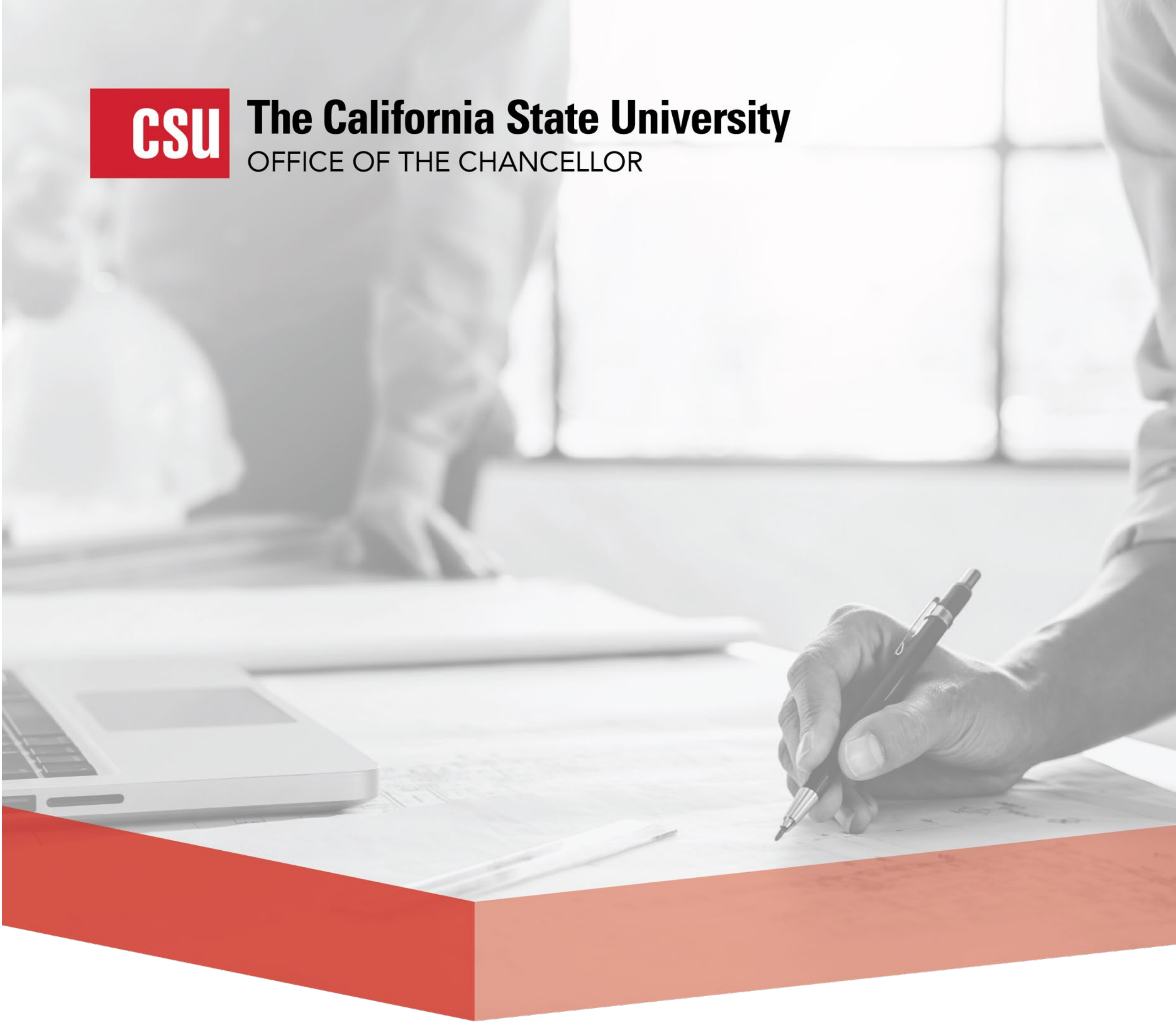

Indoor Lighting Design Guide

Rev: 12/12/18

ACKNOWLEDGEMENT

The California State University (CSU) gratefully acknowledges the effort and work of Jai Agaram, John Andary, Douglas Effenberger, Kent Peterson, Steven Strauss, and Steve Taylor.

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Executive Summary

This document serves as technical guidelines for the California State University system to accomplish its goals in interior lighting design. The following four main sections include design intent, a summary of requirements, and key design considerations.

Section one, *Introduction and General Requirements*, summarizes the qualitative and quantitative requirements introduced by various California legislation. This section provides key terms for lighting as well as applicable codes and regulations to consider in design of all projects in the state of California. Economics play a large role in the design of buildings at CSU campuses. This section ends with a summary of the economics associated with lighting design.

Section two, *Lighting Design Goals*, discusses the general process of lighting design best practices. The key values of lighting design to focus on are visual comfort, aesthetics, usability, appropriate lighting for particular tasks, maintenance, energy use, light levels, uniformity and coordination with architectural features.

Section three, *Lighting Design Strategies*, looks at the different lighting solutions that can incorporate into CSU buildings. This section looks at the different building types and room types to outline good lighting design practices for each type of space and type of user.

Section four, *Lighting Controls Strategies*, outlines different lighting control solutions, again, for different building types and rooms types. This section discusses the benefits to different lighting control solutions based on the users and the needs of each space. This section also looks at the components that go into a lighting control system.

The State of California requires that half of existing state-owned buildings be Zero Net Energy on a square-foot basis by 2025, with all new State buildings and major renovations beginning design after 2025 being constructed as Zero Net Energy facilities. Zero Net Energy facilities are defined as producing as much energy as they consume over the course of a year, when accounted for at the energy generation source. Lighting design plays an important role in achieving a Zero Net Energy building. This guide is intended to provide CSU campuses with useful and practical interior lighting design tools that are up to date as well as cost effective, and is intended to enable a comprehensive approach to indoor lighting design.

LEED and WELL are energy and occupant-based design standards with criteria that focus on improving the built environment. WELL lighting features include visual lighting design, circadian lighting design, electric light glare control, and solar glare control among many others. The targeted design intent of both programs should be consulted when considering any updates to design. Even if the final certifications are not a goal of the projects, credits can still be referenced to improve the overall design of any development.

SECTION 1: Introduction

CSU Policy

The policy driving the improvements in interior lighting design is CSU's desire and alignment with improving energy efficiency and overall quality of the spaces and buildings for the use of staff and students. For an entire facility, the goal is for all CSU buildings to exceed Title-24 (2016 edition) by 20%-30% for new construction and 10%-20% for renovation projects. Additionally, All new buildings must meet or exceed LEED Silver equivalent, and strive to achieve Gold or Platinum. Exceeding Title 24 and building to LEED support CSU's commitment to reducing greenhouse gas (GHG) emissions 80% below 1990 levels.

Maintaining a beautiful, modern, comfortable campus environment is an important factor and must be balanced with cost effective operation and maintenance. These decisions will be made by a comprehensive life cycle cost benefit analysis and not based solely on simple payback.

Definitions

a. Candela – The International System of Units of luminous intensity. One candela is one lumen per steradian.

b. Center Beam Candlepower (CBCP) – The luminous intensity at the center of a beam, expressed in candelas (cd)

c. Coefficient of Utilization (CU) – The ratio of the luminous flux (lumens) received on a plane to the light output (lumens) of the lamps. Coefficient of utilization depends on luminaire efficiency, distribution of light from the luminaire, size and shape of the room, and reflectances of surfaces in the room. Specifiers use the CU to evaluate how effectively a luminaire delivers light to a work plane.

d. Color Rendering – A general expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source (typically the sun).

e. Color Rendering Index (CRI) - A rating index commonly used to represent how well a light source renders the colors of objects that it illuminates. For a CRI value of 100, the maximum value, the colors of objects can be expected to be seen as they would appear under an incandescent or daylight spectrum of the same correlated color temperature (CCT). Sources with CRI values of less than 70 are generally regarded as rendering colors poorly, that is, colors may seem unnatural.

f. Correlated Color Temperature (CCT) – A specification for white light sources used to describe the dominant color tone along the dimension from warm (yellows and reds) to cool (blues) in terms of degrees Kelvin (K). Lamps with a CCT rating below 3200K are usually considered warm sources, whereas those with a CCT above 4000K are considered cool.

g. Demand Response – Short term changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in price, or when electrical grid reliability is jeopardized. For lighting, this may include dimming or shutting off non-essential lighting manually or automatically in response to an automated demand response signal.

h. **Efficacy** – The ratio of the light output of a lamp (lumens) to its active power (watts), expressed as lumens per watt.

i. **Lamp Lumen Depreciation (LLD)** – The reduction in lamp light output that progressively occurs during lamp life.

j. **Lighting Power Density (LPD)** – A measurement of the ratio of electric power used to produce light in a specific area. LPD is determined by dividing the total lighting energy usage in watts by the total area of the space and is measured in watts per square foot.

k. **Lumen (lm)** – A unit measurement of the rate at which a lamp produces light. A lamp's light output rating expresses the total amount of light emitted in all directions per unit time. Ratings of initial light output provided by manufacturers express the total light output after 100 hours of operation.

l. **Luminaire** – A complete lighting unit consisting of a lamp or lamps and the parts designed to distribute the light, to position and protect the lamp(s), and to connect the lamp(s) to the power supply. (Also referred to as lighting fixture).

m. **Lux** – A measurement of illuminance in lumens per square meter. One lux equals 0.093 footcandles.

Utility Incentives

a. Investor Owned Utility (IOU) Qualified LED Product Lists http://caioulightingqpl.com/

    i. Utilities often require lighting products to be prequalified for use in specific applications.

    ii. All new fixtures and components must carry the appropriate designated safety certification label including, but not limited to, Underwriters Laboratories (UL), Electrical Testing Laboratory (ETL), or TUV Rheinland (TUV).

    iii. Installations must be installed in accordance with all applicable local, state, and national codes and ordinances.

b. CSU / IOU Energy Efficiency Partnership Program

    i. CSU, UC, California's four large investor-owned utilities, and LADWP established a partnership in 2004 in order to provide a sustainable and comprehensive energy management program for their campuses.

    ii. Retrofit, monitoring-based commissioning, and training and education are included in the partnership program.

    iii. For more information, visit www.uccsuiouee.org. Utilities offer incentives for verified energy savings which typically accompany lighting retrofits and quality lighting designs.

c. Electric Utility Information

    i. Los Angeles Department of Water and Power (LADWP); www.ladwp.com

    ii. Sacramento Municipal Utility District(SMUD); www.smud.org

    iii. Turlock Irrigation District (TID); www.tid.org

    iv. Imperial Irrigiation District (IID); www.iid.com/

    v. Pacific Gas & Electric (PG&E); www.pge.com

vi. Southern California Edison (SCE); www.sce.com

vii. SDG&E; www.sdge.com

Applicable Codes and Regulations

Indoor lighting and controls must comply with the California Energy Code (CEC), California Code of Regulations Title-24, Part 6 (2016 Edition). The Energy Code contains requirements regarding amount of power used for lighting, lighting controls, light sources, dimming types, automated demand response capabilities, and incorporation of daylight into the lighting control system.

All electrical and lighting installations must comply with the California Electrical Code (CEC), California Code of Regulations Title-24, Part 3, including but not limited to wiring and grounding methods, and luminaire installation requirements.

The California Building Code, California Code of Regulations Title-24, Part 2, contains requirements pertaining to illumination requirements for egress lighting.

The California Green Building Standards Code, California Code of Regulations Title-24, Part 11, contains mandatory and voluntary measures necessary to meet CALGreen building tiers established in the Code. In general, a project must exceed California Energy code requirements by 15% to be considered CALGreen Tier 1, and by 30% to be considered CALGreen Tier 2.

Economic Analysis

For economic analysis of design solutions, there are two main methods; a life cycle cost analysis (LCCA) and a payback analysis. Internal Rate of Return (IRR) and Total Cost of Ownership (TCO) are also acceptable methods of economic analysis. Simple payback analyses are much faster and easier to calculate for retrofits but may leave out information important to decision making on new construction. LCCA is the combination of the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time. Payback tends to be taken as the amount of time energy savings from an updated system will take to make the money back for said update, known as the return on investment (ROI). LCCA can take into account factors such as cost of ownership, span of time across which the costs are realized, and the discount rate applied to those future costs relative to current values. The latter of which is known as net present value. Costs items include initial equipment costs and labor for installation. Ongoing costs include parts replacement, maintenance labor, and for a lighting system, energy usage. The effective useful life is the timespan that should be used for the analysis. Lighting systems can have an effective useful life of 5-20 years, depending on the installation. The discount rate is set by the owner’s typical financing abilities and is usually 5% to 6%. Decisions will be made by a comprehensive life cycle cost benefit analysis and not based solely on simple payback.

Operation and maintenance costs, particularly for high bay lights, should be accounted for in the analysis. In-house labor versus trade labor and contract maintenance can also be a factor. Lighting systems must be maintained by proper cleaning and testing otherwise a number of issues may arise. These include:

- Reduced light output due to dust accumulation and lamp depreciation leading to potentially underlit and therefore unsafe areas.
- Premature failures of lamps, ballasts, drivers or boards that lead to unnecessary replacement costs
- Control system component functionality issues causing suboptimal function, excess energy usage, unsafe

environments, and replacement costs.

SECTION 2:
Lighting Design Goals

Visual comfort is the summation of increased uniformity, reduced glare, and adequate light levels for the specific tasks performed in a space. Reducing glare, especially disability glare, can have positive effects on productivity and increase usability of a space. Glare can be summarized as a brightness ratio between different objects in a space, and should always be designed to meet recommended values based on the purpose of the space. Glare can come directly from luminaires if there is a high output coming from a small source area. Reflected glare can occur from the same source glare bouncing off a glossy object in the space into the occupant's eyes, and should also be avoided. Solar glare comes from poor daylighting design, and is when the sun causes intense bright spots in a space. Contrast ratios between walls, ceilings, and work planes should be appropriately designed to not cause visual discomfort. In work spaces, the lower the uniformity ratio, the better.

The Illuminating Engineering Society (IES) has recommended illuminance values for tasks and space types in the IESNA *The Lighting Handbook Tenth Edition*, and should always be consulted when designing for specific operations. Along with light levels, the IES also calls out uniformity ratios and targeted age groups to assist lighting design goals. Proper lighting design should always be heavily coordinated with interior architectural features to maximize design impact. Architectural features, finishes, furnishings, and equipment in the area should all be considered when designing a lighting solution. When considering a facility for lighting upgrades, both retrofit and redesign options should be analyzed. An example would be a classroom upgrade from recessed 2x4 fluorescent troffers to a two-row pendant mounted linear LED system with integrated digital controls. Initial costs may be higher, but lifetime savings from energy usage may make the upgrade not only feasible, but the best option.

Operation and maintenance costs can be drastically decreased with durable LED fixtures. The L70 rating of a luminaire corresponds to the number of hours that a fixture can operate and still deliver 70% of its initial output. At a minimum, fixtures should have an L70 of 70,000 hours. If the fixtures are on 12 hours a day, this equates to almost 16 years of operation before any maintenance will need to be done, other than periodic cleaning. To help meet energy usage goals, fixtures should have a high efficacy, meaning a large ratio of lumens output per watt consumed. Currently, there are fixtures that achieve over 100 lumens/watt, and efficacy should always be taken into consideration to help achieve design goals. Energy efficiency can be further increased by implementing a lighting controls strategy. California Title 24 lighting controls requirements must be met, and are a great baseline controls design. All projects over 10,000 SF must be automated demand responsive.

SECTION 3:
Lighting Design Strategies

Color

Fixture selection is vital to achieve proper design intent of a space and should be coordinated to align with the aesthetics of the building and campus. Consult with the campus architect regarding campus standards for luminaires and controls. Correlated Color temperature (CCT) will need to be selected based on finishes in the space as well as general design goals. Color temperatures should not be mixed in an individual area, as different whites look mismatched and are not aesthetically pleasing when combined. We recommend CCT values of 3500K for office and classroom settings.

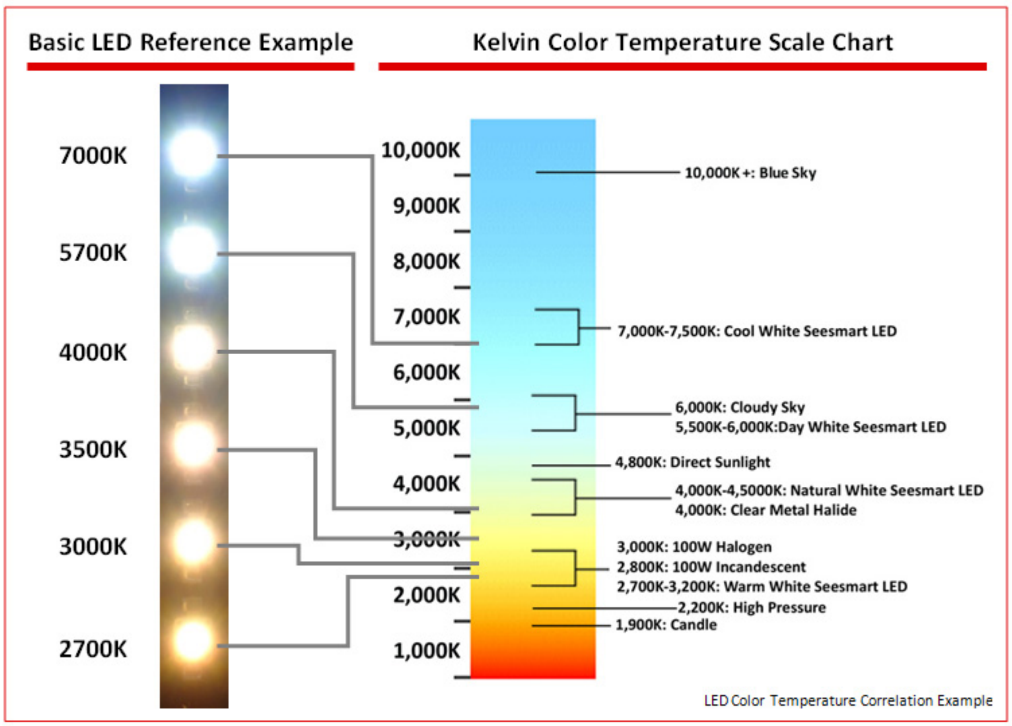


Figure 1: CCT chart

Along with CCT, fixtures should meet color rendering (CRI) criteria as well. The higher the CRI value, the more accurately colors will be rendered in the environment. For example, general offices will perform fine using fixtures with a CRI of 85, but if artwork is going to be accented, high CRI sources of 95+ should be used to properly render the pigments of the art, preventing dulling of the colors.

Tunable white lighting is a newer technology that involves creating a range of CCT values for a fixture to emit by blending a lower CCT LED with a higher CCT LED. Research is still being done to see how health effects of the occupant can be influenced by tuning standard LED diodes. This is not to be confused with Circadian Lighting, as often manufacturers only blend two different CCT LED's, meaning the black body curve of CCT is not maintained, and may not have the same effects on the circadian rhythm of the occupants as a pure black body source like the sun. It does allow to 'future proof' the lighting design and accommodate for interior design and finish changes without needing to alter the lighting design, as well as create the psychological effect of time change if so desired. The controls system will need to be designed accordingly to handle the more complex method of a tunable white system. The main goal here is to create lighting with a full spectrum of color, like daylight.

It is important that any light fixtures considered for a project are able to show the spectrum of light provided by the fixture with a reasonable amount of reds, yellows, greens, and blues represented. Spectral Power Distribution graphs, like the one of sunlight shown above need to be obtained from all lighting manufacturers along with their CCT, CRI, and R9 value. The R9 value is corelated to the value of light within the red spectrum. It is important this value be higher than 40 in order to show skin tones appropriately.

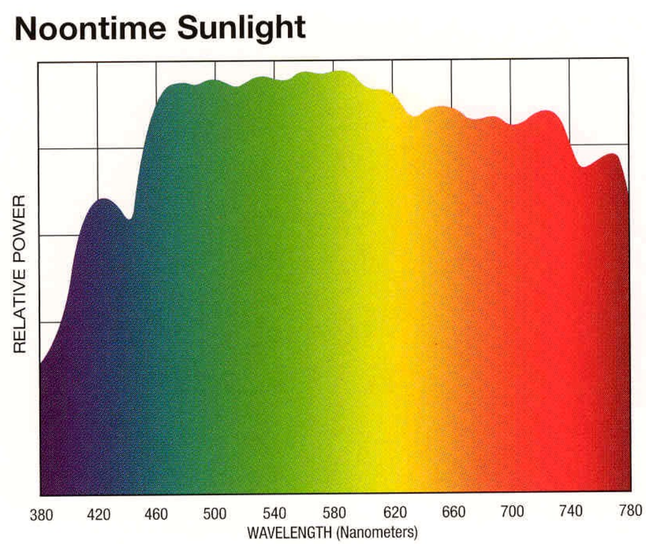


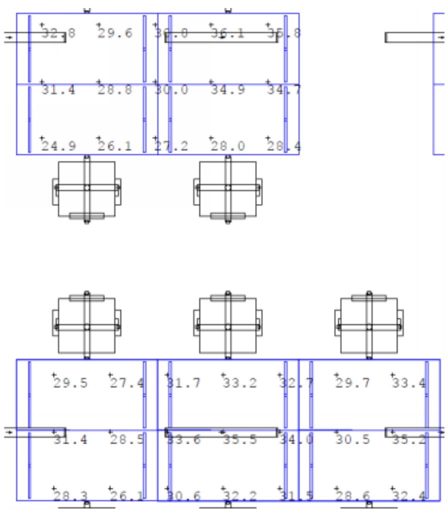
Figure 2: Daylight Spectral Power Distribution Graph

A circadian lighting design can be achieved with a static output LED if the LED has the proper spectral distribution, and can have numerous health benefits. Studies show that people with sleep issues have a greater chance of obesity, increased addiction to nicotine and alcohol consumption, increased risk of cardiovascular disease, and an increased risk of metabolic disease. Circadian lighting can help mitigate those health concerns while also influencing alertness, hormone secretion, cell proliferation, enzyme activity, and more.

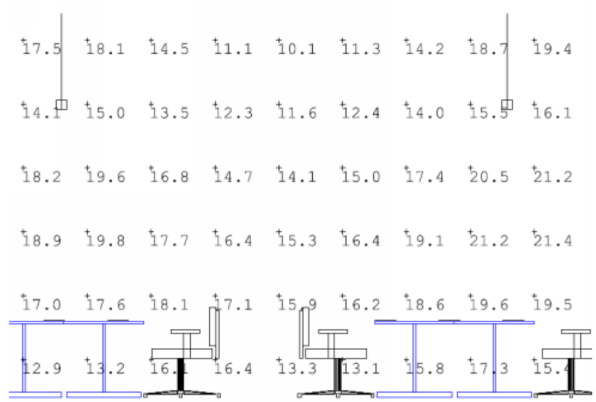
Uniformity

Uniformity in lighting design is the difference between the maximum perceived brightness and the minimum perceived brightness. A low uniformity ratio is an important design technique for all space types on a CSU campus. The following three uniformity guidelines should be followed to maintain uniform spaces for maximum visual comfort for the users.

UNIFORMITY CRITERIA #1 WORKSURFACE VS ADJACENT WALL ILLUMINANCE RATIO		
MUST BE LOWER THAN **15:1 MAX:MIN RATIO**		
BETWEEN WORK SURFACE AND ADJACENT WALL (AVERAGES ASSUMED)		
EXAMPLE:		
WORK SURFACES CALCULATED AVERAGE:	31	fc
ADJACENT WALL CALCULATED AVERAGE:	16.23	fc
CALCULATED WORST CASE RATIO:	2	:1

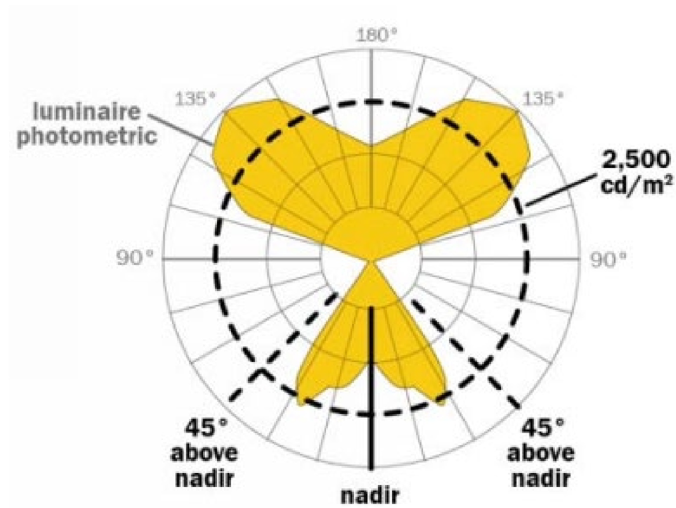


WORK SURFACE CALC @28" A.F.F.
ESTIMATED AVERAGE LIGHT LEVELS=31 F.C



WEST WALL CALC WITH ACCENT LIGHTS
ESTIMATED AVERAGE LIGHT LEVELS=16.23 F.C

UNIFORMITY CRITERIA #2
LOW GLARE LUMINAIRE

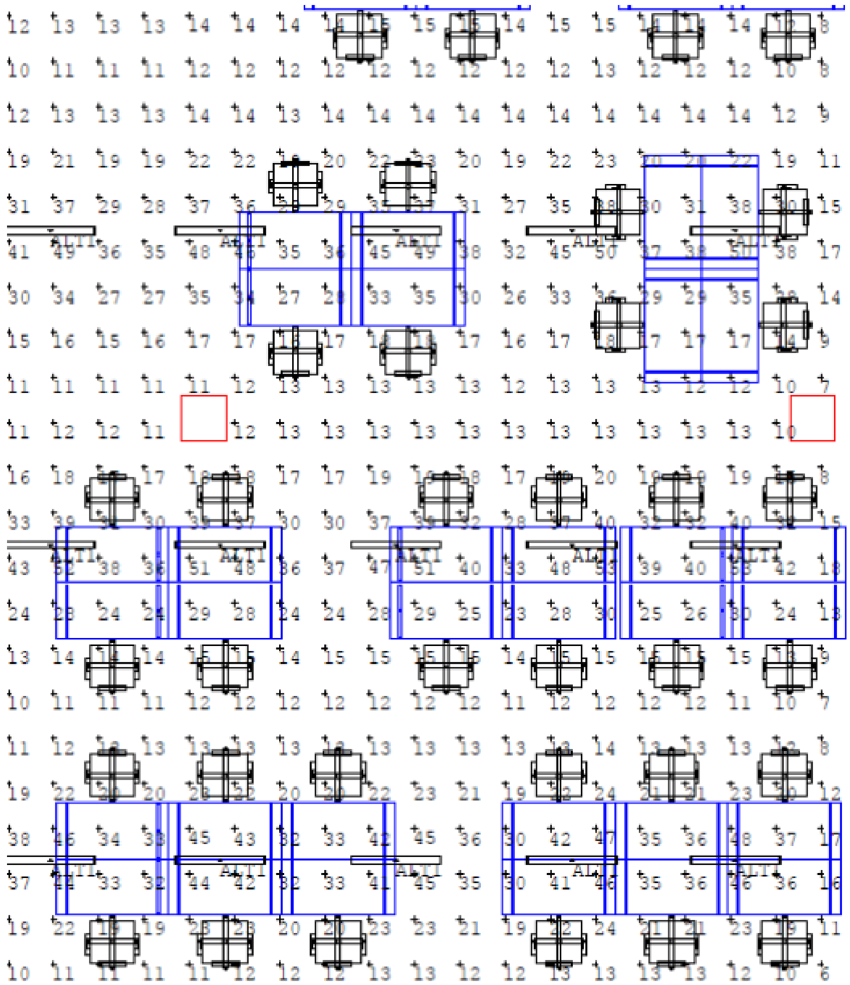


MEETS CRITERIA

LUMINANCE DOES NOT EXCEED 2,500 cd/m²
ABOVE 45° FROM NADIR
VERIFY FIXTURE DOES NOT HAVE A DIRECT VIEW FROM
A REGULARLY OCCUPIED AREA FROM ABOVE

*Wall wash fixtures exempt from criteria.

UNIFORMITY CRITERIA #3 CEILING UNIFORMITY RATIO		
15:1 MAX RATIO		
ON A SINGLE CEILING PLANE		
EXAMPLE		
CALCULATED MAX:	53.4	FC
CALCULATED MIN:	6.2	FC
CALCULATED WORST CASE RATIO:	9	:1



CEILING FOOT CANDLE CALCULATION
ESTIMATED LIGHT LEVELS ON UNDERSIDE OF CEILING SURFACE @12'A.F.F.

Egress

Safety and emergency lighting should always comply with the local jurisdiction and electrical code. Typically, egress paths under emergency lighting need to have an average illumination of 1.0 footcandle (fc) and a minimum of 0.1 fc. This is subject to change.

SECTION 4:
Lighting Control Strategies

See Appendix Table 1 for a typical lighting target and control sequence of operation table.

Classrooms

Tasks: reading, writing, presentation

Recommended Light Levels: 30fc on workplane

Recommended Fixture Types: LED Linear indirect/direct pendants, recessed wall washers

Recommended color properties: 3500K, 80+ CRI, access to daylight or full spectrum LED light

Important lighting factors:

a. Vertical lighting on whiteboards/presentation areas should be at least twice the horizontal light levels at the workplane.
b. Flexible lighting controls and shade controls for different presentation modes
c. Layers of light for different presentation modes, i.e. indirect, direct, and accent.

Figure SEQ Figure * ARABIC 3: Classroom rendering by Lionakis for Mission College in Santa Clara, California

Laboratories

Tasks: writing, detailed work, detailed materials

Recommended Light Levels: 50fc on workplane

Recommended Fixture Types: LED Linear indirect/direct pendants or recessed troffers

Recommended color properties: 3500K, 80+ CRI, access to daylight or full spectrum LED light

Conference Rooms

Tasks: presentation, facial recognition, reading, writing

Recommended Light Levels: 30fc on workplane

Recommended Fixture Types: LED indirect/direct pendants, recessed wall washers

Recommended color properties: 3500K, 80+ CRI, access to daylight or full spectrum LED light

Important lighting factors:

a. Vertical lighting on whiteboards/presentation areas should be at least twice the horizontal light levels at the workplane.

b. Flexible lighting controls and shade controls for different presentation modes

c. 0.1% dimming drivers

Corridors / Stairway

Tasks: circulation

Recommended Light Levels: 15fc on floor

Recommended Fixture Types: LED Linear indirect/direct pendants or recessed troffers

Recommended color properties: 3500K, 80+ CRI

Important lighting factors:

a. Emergency egress light levels 1fc minimum average, unless otherwise noted by local jurisdiction.

b. Vertical illuminance to increase perceived brightness

c. Uniform illuminance

Lobbies

Tasks: circulation, facial recognition, wayfinding

Recommended Light Levels: 20fc on floor

Recommended Fixture Types: LED recessed downlights/wall washers, indirect/direct pendants, decorative pendants

Recommended color properties: 3500K, 80+ CRI

Important lighting factors:

a. Decorative lighting

b. Directional guidance (moth effect- people are drawn towards light)

Office

Tasks: reading, writing, computer work

Recommended Light Levels: ambient lighting 20fc on workplane with additional individual task lighting

Recommended Fixture Types: LED Linear indirect/direct pendants or recessed troffers, wall washers

Recommended color properties: 3500K, 80+ CRI, access to daylight or full spectrum LED light

Important lighting factors:

a. Avoid direct glare from light fixtures. All lighting needs to have 45-degree cutoff
b. Layers of light: indirect and direct
c. Visual comfort: avoid high luminance contrasts between surfaces

LIBRARIES

Tasks: reading, writing, reading vertical stacks

Recommended Light Levels: 30fc on workplane and 30fc vertical on stacks

Recommended Fixture Types: LED recessed downlights/wall washers, linear indirect/direct pendants or recessed troffers, decorative pendants, linear stack luminaires

Recommended color properties: 3500K, 80+ CRI

Important lighting factors:

a. Vertical lighting on stacks should be at least twice the horizontal light levels at the floor.

b. Stack mounted fixtures or fixtures with optics specifically designed to uniformly illuminate stack shelving from

top to bottom.

SECTION 5:
Lighting Control Strategies

Lighting Control Systems

The lighting control system should be compliant with California Title 24 requirements. A building-wide controls system is the best at decreasing energy consumption. It allows for a central computer to control all programs, schedules, zoning, and sensors desired on a space-by-space basis and, depending on the system, can allow for two-way communication for usage reports. This can allow programming to be adjusted based on usage data, which can lead to decreasing energy waste even more.

Room based lighting control is often the best method for renovations that do not encompass entire buildings. This can lead to more components being required per space than the building-wide method, but can still utilize programming, zoning, and sensors to maximize energy savings. Each room will act independently, however, so typically no system wide override will be available.

Typical room profiles include room types such as:

- Classrooms
- Conference Rooms
- Corridors/Stairways/Circulation
- Laboratories
- Lecture Halls
- Libraries
- Lobbies
- Open Offices
- Private Offices
- Restrooms

Wireless control systems are a great solution for multiple scenarios. Renovations where unique architectural designs have construction limitations allow wireless switches and sensors to be installed to minimize install costs. They also allow for flexibility on locations of equipment if future alterations may occur. Wireless control systems can be utilized in both building-wide and room based lighting control systems.

Window shade controls can be installed for added benefit with Title 24 daylighting controls and strategies. When used, a photocell would not only implement dimming of the light fixtures in daylit zones, but also automatically raise and lower shading systems to maximize usable daylight while minimizing energy usage in a space.

For emergency and egress lighting controls, typically a UL924 relay device is implemented. Depending on the system and fixtures used in an area, a relay may be needed on a per fixture basis or a per circuit basis. A UL924 relay allows for normal power to the fixture, but when the emergency system is activated, it automatically switches power to be received from the generator/inverter and the luminaire's driver turns the fixtures on to full output to meet emergency lighting requirements. The relay also takes away the manual override capability of local switching so no one can dim or turn off emergency fixtures until normal power is restored.

- Demand responsive lighting controls are required by Title 24 in particular applications. Demand responsive controls are capable of receing and automatically responding to a demand response signal. Energy Design Resources offeres a comprehensive design brief "Integrating Demand Responsive Capabilities into Facility Design:https://energydesignresources.com/media/17052134/EDR_DesignBriefs_demandresponse.pdf
- Energy Design Resources is funded by California utility customers and administered by Pacific Gas and Electric Company, Sacramento Municipal Utility District, San Diego Gas & Electric, Southern California Edison, and Southern California Gas under the auspices of the California Public Utilities Commission.

Lighting Control Components

Wall dimmers and switches are the main method for the occupant to control the lighting system as they see fit. Depending on the space type, Title 24 will either require dimming capability, or allow a standard switch to be implemented i.e. electrical rooms, storage closets, etc. Dimmers have multiple variations, from one button controlling one zone to multiple buttons controlling multiple zones and/or scenes that can be pre-programmed. Scene control is a great solution for spaces that have multiple needs depending on the time of day or uses that can occur in the same space. Take a large conference room for example. One scene may need to be all lights on for paperwork, another scene may be required for video conferencing, turning one or more zones down or off, and a third scene may be for presentations, where light levels need to vary by distance from a screen.

Occupancy sensors can be either ceiling or wall mounted and can be integrated into the wall switch for certain areas like private bathrooms. Per the current code, occupancy sensors actually behave like vacancy sensors. The lights will not come on automatically when an occupant enters the space, the wall dimmer will need to be activated, but the lights will go off automatically when the occupant leaves the space after a pre-programmed allotted time has gone by where the sensor does not notice a user in the space. There are multiple types of occupancy sensors, including passive infrared, acoustic, and dual technology, which utilizes both types. All variations have their pros and cons, and should be considered carefully before being installed. Occupancy can also be tied to the HVAC system and a CO_2 sensor or other equipment for further control of larger auditoriums and lecture halls.

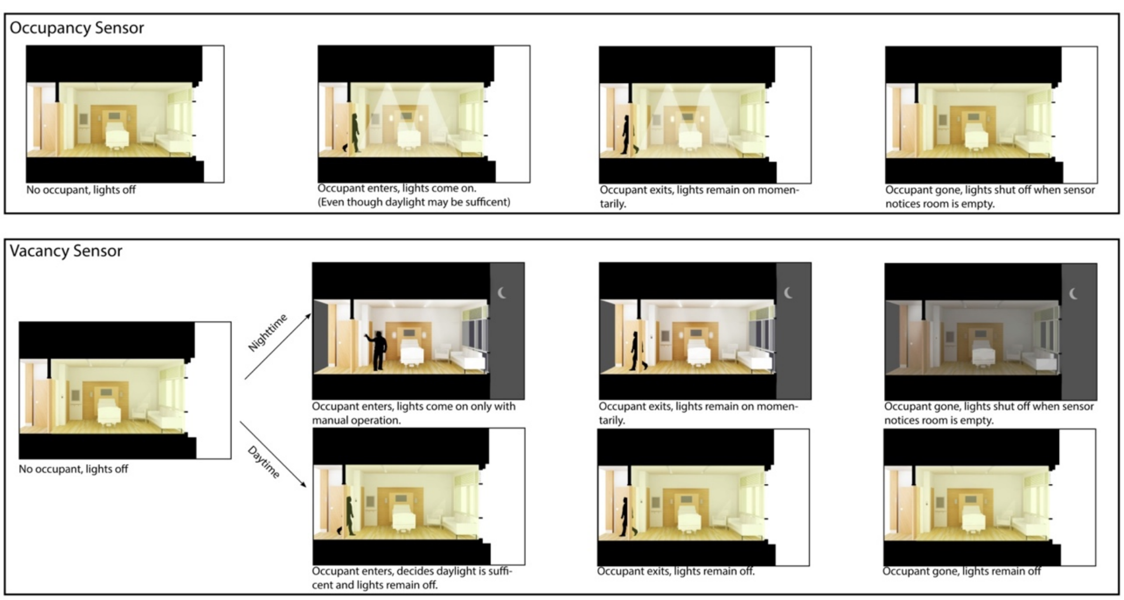


Figure SEQ Figure * ARABIC 4: Occupancy vs. Vacancy Sensor

Photocells are small sensors typically mounted to the ceiling on the boundary between the primary and secondary daylight zones as defined in Title 24. When a certain illuminance threshold is met, they will dim the surrounding fixtures to mitigate energy waste while ensuring adequate light levels are met for the tasks in the area. They can be paired with an automatic shading system for further daylight control, and will make the lights and shades work together to achieve the desired lighting criteria while decreasing energy usage.

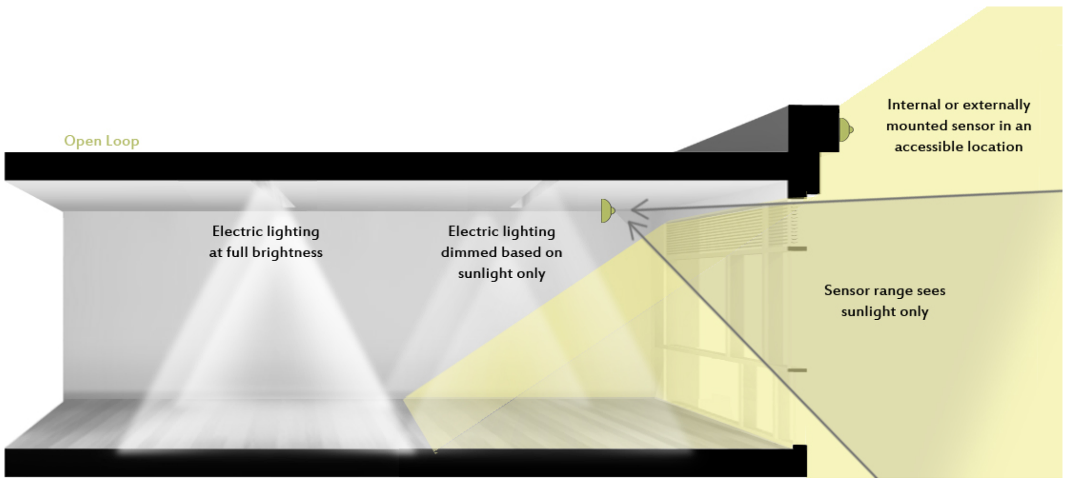


Figure SEQ Figure * ARABIC 5: Open loop daylight sensors work in applications where accuracy is less important, such as hallways, atriums, and open offices with multiple adjacent zones

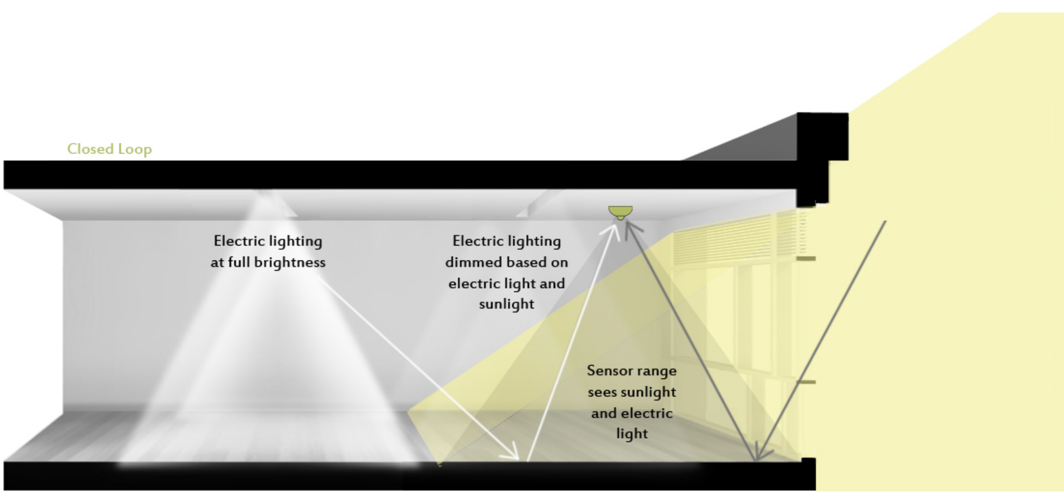


Figure SEQ Figure * ARABIC 6: Closed loop daylight sensors work in applications where a specific target light level must be maintained such as private offices or open offices controlled on 1 zone

Room controllers and main servers are the brains behind all the lighting control operations. Whether a building-wide system or a room-by-room system is used, something needs to understand all the programming protocols, zones, and system components to make the controls system meet code and design intent.

SECTION 6:
Lighting Controls Strategies per Space Type

See Appendix Table 1 for a typical lighting control sequence of operation table.

Classrooms

Components: dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)
b. Secondary daylight zone (if applicable)
c. Front of classroom
d. Back of classroom
e. Whiteboard lighting

Laboratories

Components: dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)
b. Secondary daylight zone (if applicable)
c. General lighting (may need broken up into areas if space is large)
d. Task lighting at specific equipment and/or workstations

Conference Rooms

Components: dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)
b. Secondary daylight zone (if applicable)
c. Direct lighting
d. Indirect lighting
e. Center of room
f. Perimeter of room/presentation lighting

Corridors / Stairway

Components: time clock, dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)

b. Secondary daylight zone (if applicable)

Lobbies

Components: time clock, dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)

b. Secondary daylight zone (if applicable)

c. General lighting (may need broken up into areas if space is large)

d. Accent lighting (may need broken up into areas if space is large or multiple accent types)

Office

Components: dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)

a. Secondary daylight zone (if applicable)

b. General lighting (may need broken up into areas if space is large)

Libraries

Components: dimmers, occupancy sensors, photocells

Zones (Typical):

a. Primary daylight zone (if applicable)

b. Secondary daylight zone (if applicable)

c. General lighting (may need broken up into areas if space is large)

d. Stack Lighting (may need broken up into areas if space is large)

Daylight Control

Daylight control must meet applicable codes and regulations and comply with California Title 24 daylight zoning. Daylight consists of both direct light from the sun and ambient light from the rest of the sky dome. Each façade of a building with face unique daylighting challenges, for as the sun travels along the solar path, it reacts differently with each directional surface. Architectural elements can be incorporated into the building design to further increase usable daylight in a space and minimize energy usage. Usable daylight is daylight that enters the space in a controlled manner and does not cause glare or visual discomfort, but increases illuminance on targeted planes i.e. workplanes, floors, and ceilings. Architectural light shelves, skylights, micro-prismatic films on windows, vertical and horizontal fins, and other methods can drastically increase the amount of usable daylight in a space and/or decrease direct sunlight that causes extreme luminance contrasts and just allow soft skylight into a space.

Daylight control consists of multiple system components. Occupancy sensors, separate dimming for both primary and secondary daylight zones in a space, and a photocell(s) will need to work together. See figures 5 and 6 above for photocell types and different control methods; open vs. closed loop systems and sensors. Fixtures in the primary and secondary daylight zones will have different illuminance thresholds for automatic dimming to engage. An occupancy sensor will ensure that lights in the space will deactivate when not in use and will not allow photocell control to operate when the space is vacant.

SECTION 7:
Appendices

Table 1 TYPICAL LIGHTING CONTROL S.O.O.

TYPICAL LIGHTING CONTROL SEQUENCE OF OPERATION											
	CONTROL TYPE										
	ZONE CONTROL	TARGET ILLUMINANCE	OCCUPANCY SENSOR			DAYLIGHT SENSOR		WALLSTATIONS	UL924 EMERGENCY DEVICES	DEMAND RESPONSE
ROOM TYPE			ON OPERATION	OFF OPERATION	TIMEOUT	ZONE 1	ZONE 2			
CLASSROOM	REFER TO PLANS FOR KEYED ZONING BY LOWERCASE LETTER	30FC	MANUAL ON @ 100% OUTPUT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	ALL ZONES DIMMED VIA 0-10v CONNECTION. REFER TO PLANS FOR KEYED ZONING BY LOWERCASE LETTER	REFER TO PLANS FOR KEYED ZONING BY LOWERCASE LETTER FOR NORMAL OPERATION. 100% OUTPUT UPON LOSS OF NORMAL POWER.	NETWORK ENABLED DEVICES; CONNECTION PROVIDED IN MAIN ELEC ROOM. LIGHTING TO DIM TO 20% OUTPUT UPON RECEIPT OF DEMAND RESPONSE SIGNAL.
LABORATORY		50FC	MANUAL ON @ 100% OUTPUT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR			
PRIVATE OFFICE		20FC	MANUAL ON @ OUTPUT LEVEL ROOM WAS LAST LEFT AT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIGHT ROOMS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR			
CONFERENCE		30FC	MANUAL ON @ OUTPUT LEVEL ROOM WAS LAST LEFT AT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT ROOMS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR			
RECEPTION/LOBBY		20FC	MANUAL ON @ OUTPUT LEVEL ROOM WAS LAST LEFT AT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR			
CORRIDOR		15FC	MANUAL ON @ 100% OUTPUT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	-			
LIBRARY		30RC	MANUAL ON @ 100% OUTPUT	AUTO OCCUPANCY OFF OR MANUAL OFF	5 MIN	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 150% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR	IN DAYLIT AREAS: CONTINUOUSLY DIM FIXTURES WHEN 200% OF TARGET ILLUMINANCE IS MEASURED AT SENSOR			

References

- Energy Design Resources. (2013). Integrating Demand Responsive Capabilities into Facility Design. Retrieved from https://energydesignresources.com/media/17052134/EDR_DesignBriefs_demandresponse.pdf
- Illuminating Engineering Society. (2011). The Lighting Handbook, Tenth Edition, Reference and Application
- California Energy Commission. (2011, February). Time Dependent Valuation of Energy for Developing Building Efficiency Standards. Retrieved from http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf
- California Public Utilities Commission. (2006, April). Renewable Energy Certificates and the California Renewable Portfolio Standard Program. Retrieved from http://docs.cpuc.ca.gov/publishedDocs/published/Report/55606.htm
- Sacramento Municipal Utility District. (2017, October). Company Profile. Retrieved from SMUD: https://www.smud.org/en/about-smud/company-information/company-profile.htm