AABC Commissioning Group

AIA Provider Number 50111116

Tunable White Lighting – Minimize Risk During Commissioning and Satisfy Your Client

Course Number: CXENERGY1811

Eric Lind

Lutron Electronics Co., Inc.

April 25, 2018

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Copyright Materials

Course Description

LEDs have provided many new lighting capabilities, but with that have come some challenges. This presentation will discuss how to successfully implement Tunable White lighting on a project, with a brief overview of the technology and the key applications - one such application being tunable white lighting as part of a WELL building. This presentation will educate the audience on the user interfaces needed to make immediate changes and verifications to a lighting control system in order to meet WELL building lighting requirements. It will also cover commissioning/sequence of operations (SoO) requirements.

Learning Objectives

At the end of the this course, participants will be able to:

1. Describe the fundamental categories of spectrum control with LEDs.

2. Analyze the color tuning features of tunable white fixtures.

3. Evaluate the feasibility of meeting a sequence of operations with various fixture types.

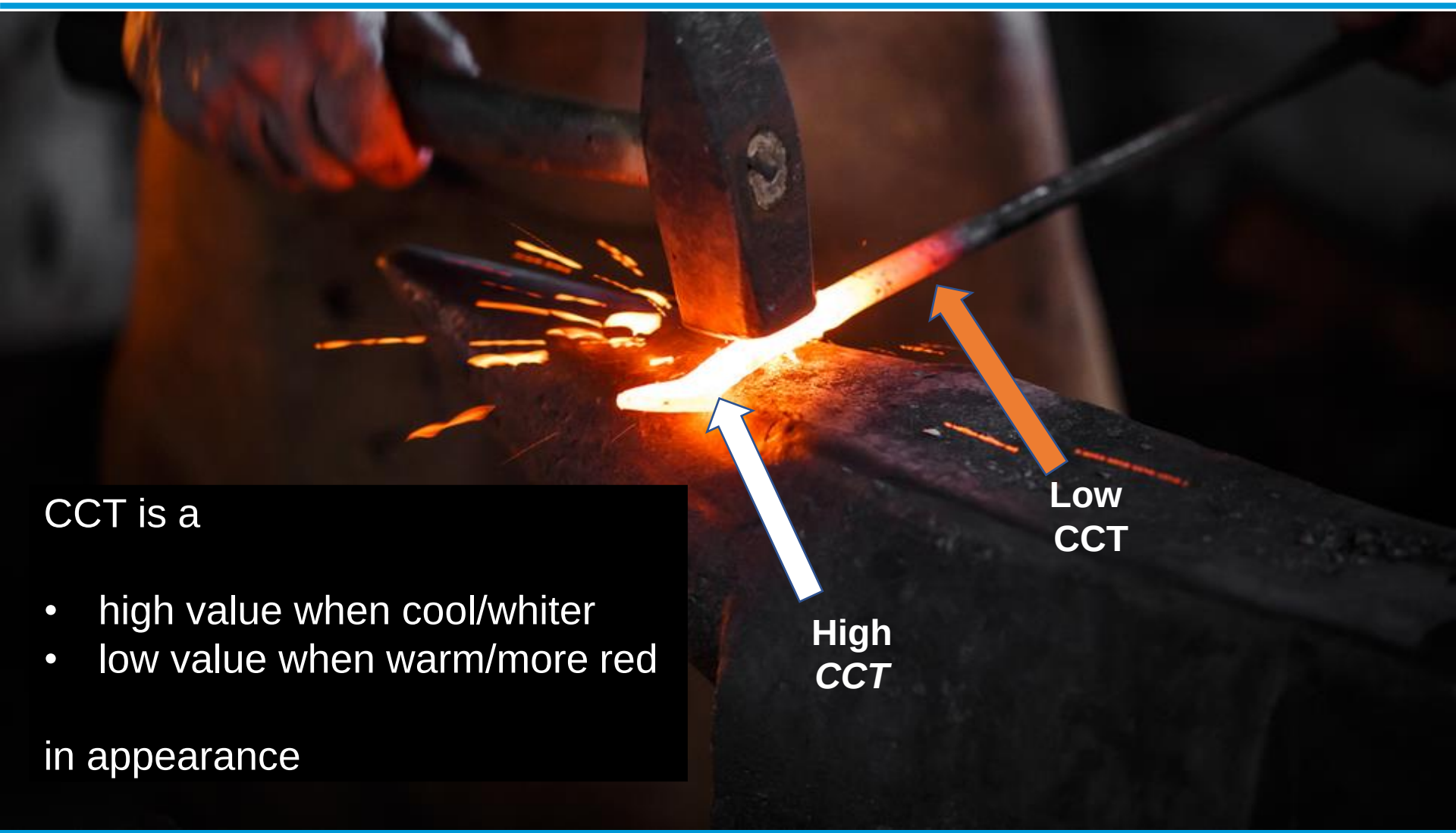
4. Evaluate the commissioning requirements of a lighting system and how to meet WELL building lighting standards.

Topics

- Spectrum control with LEDs
- Color tuning features and considerations
- Sequence of Operations and Commissioning
- Commissioning and WELL

Spectrum Control with LEDs

Correlated Color Temperature (CCT)

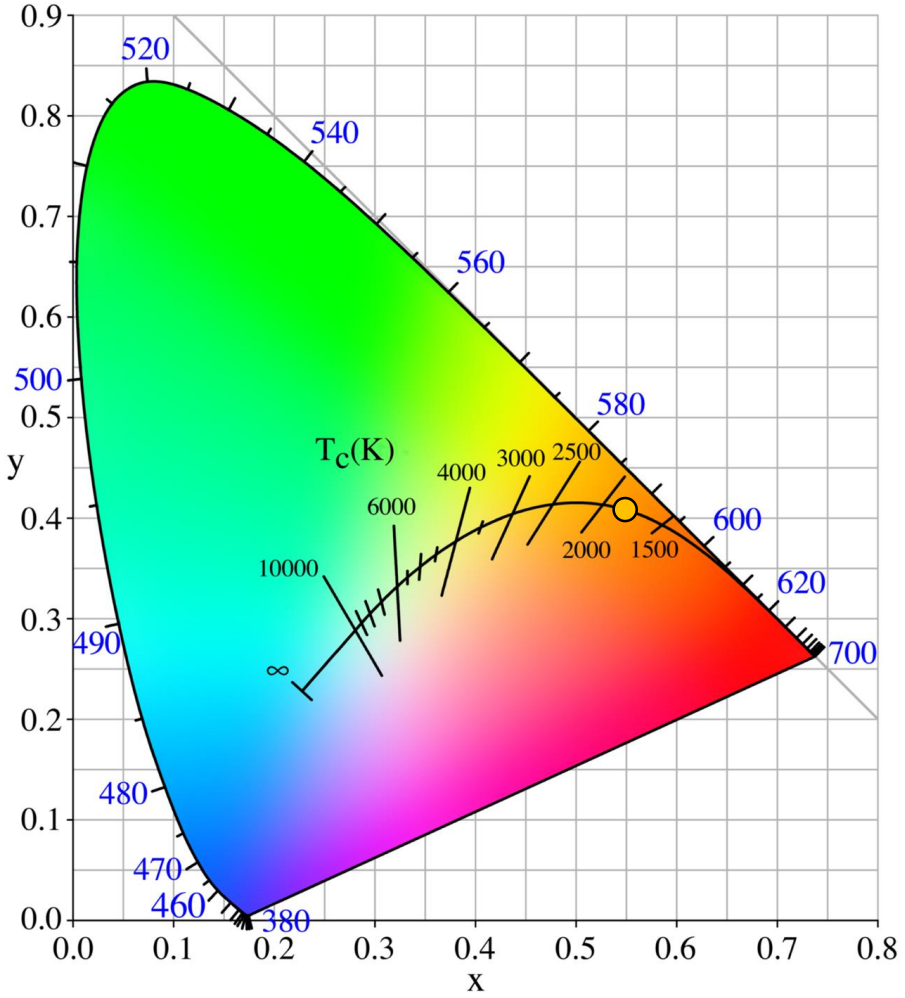


CCT is a

- high value when cool/whiter
- low value when warm/more red

in appearance

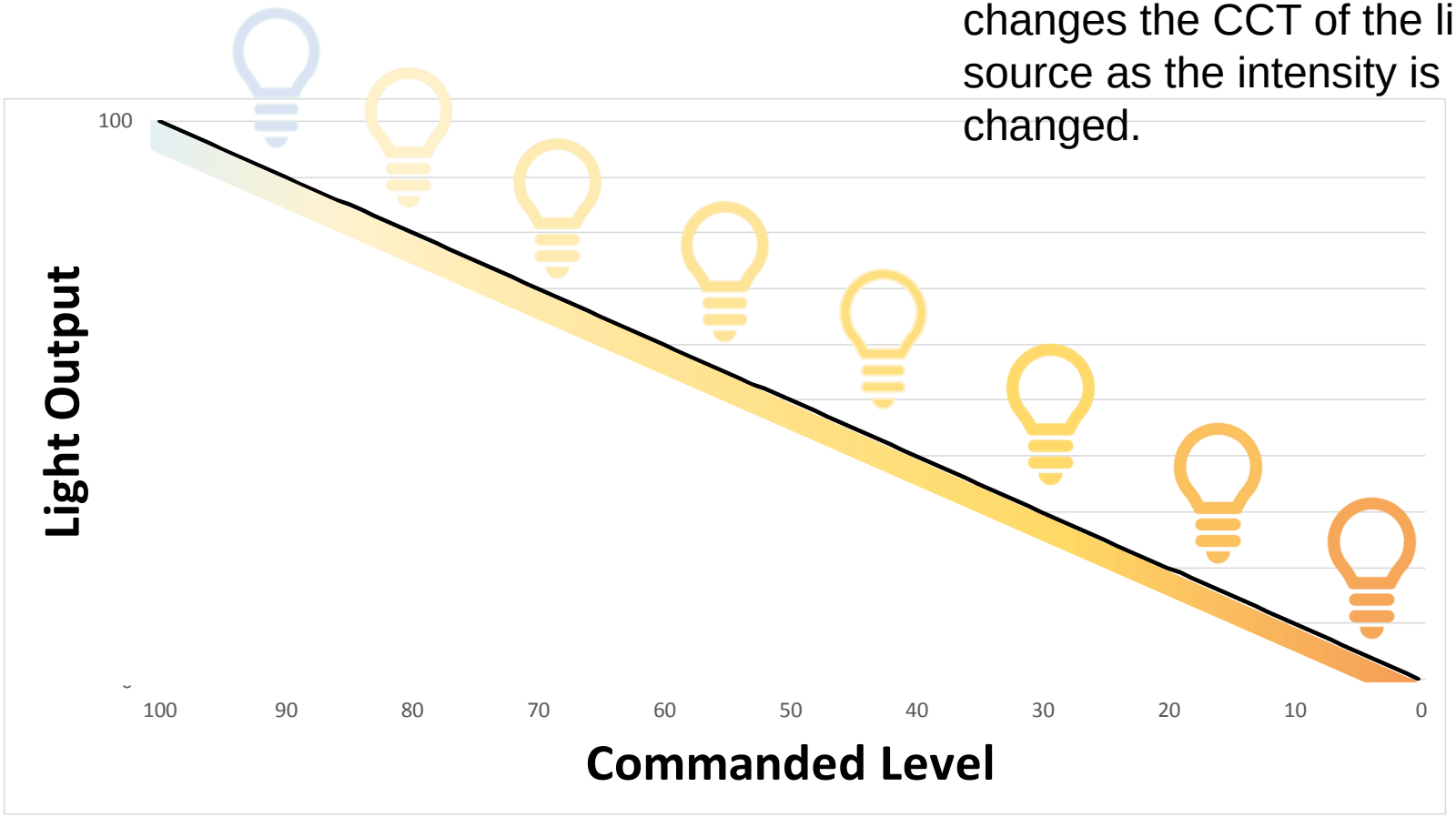
The Chromaticity Diagram



Warm Dimming

Warm Dimming

Warm dimming automatically changes the CCT of the light source as the intensity is changed.



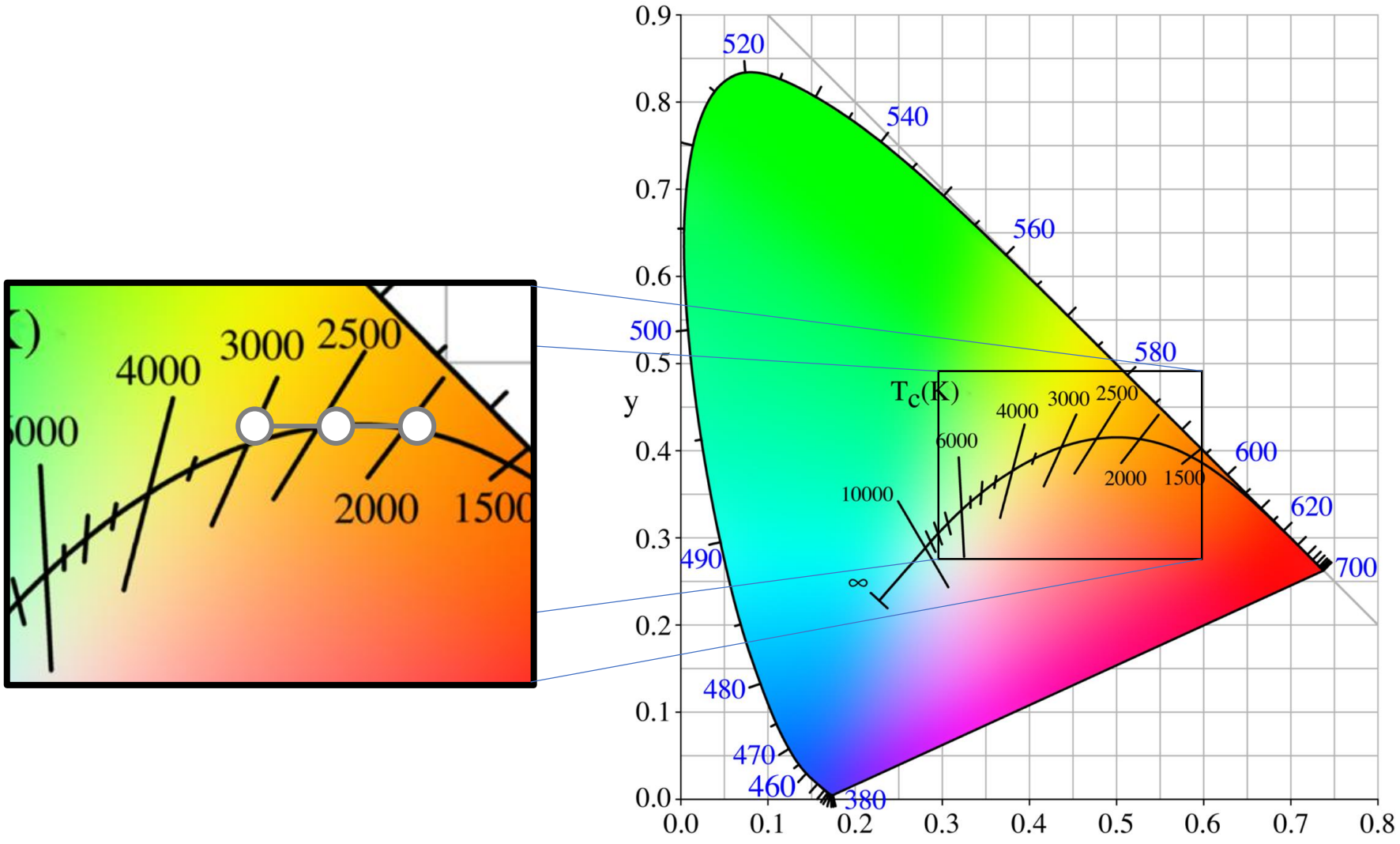
Warm Dimming

Provides incandescent-like experience

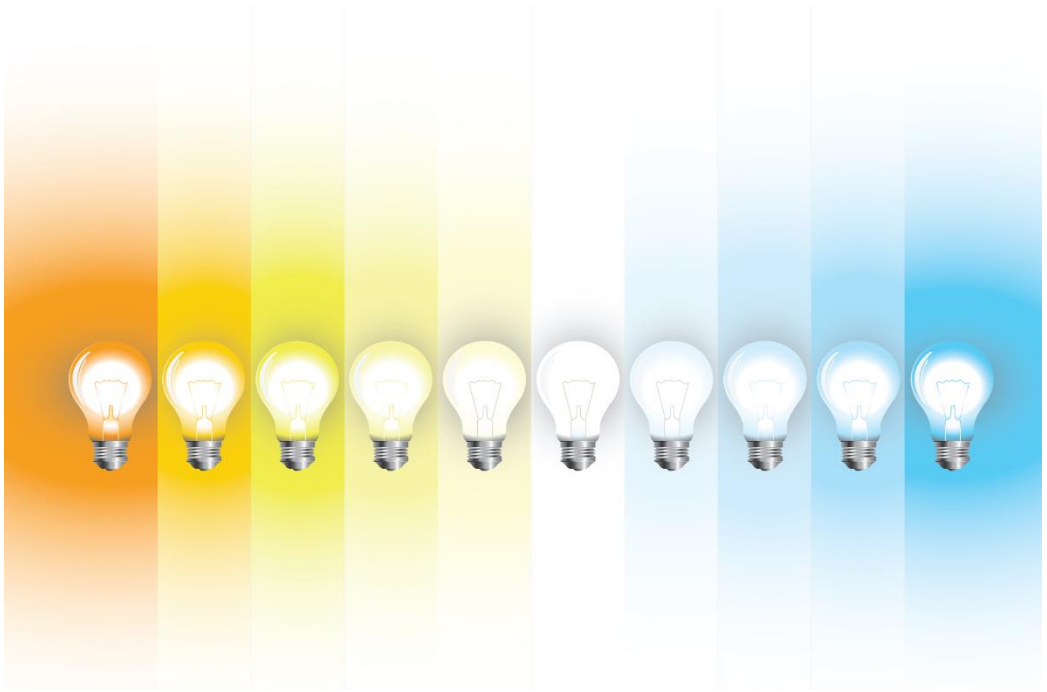
CCT changed automatically by the light source

Controlled by one standard dimmer

How Warm Dimming Works

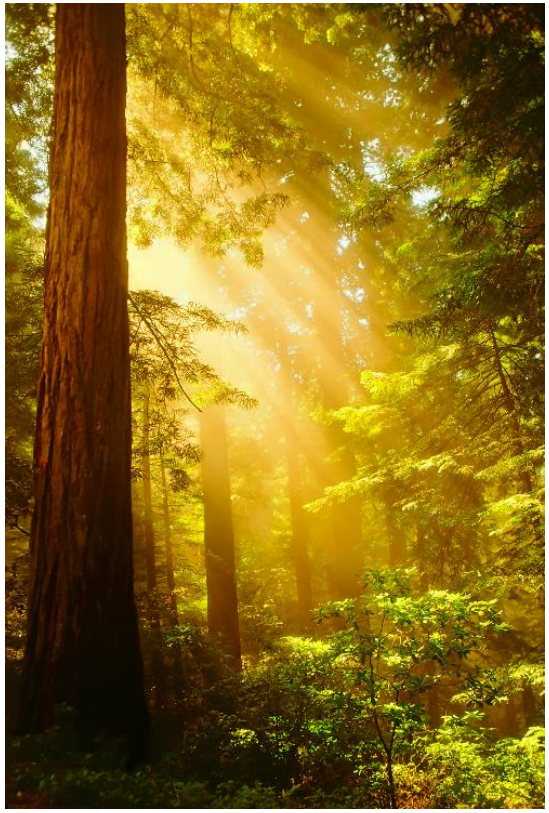


Tunable White



Why use Tunable White?

Mimic Daylight

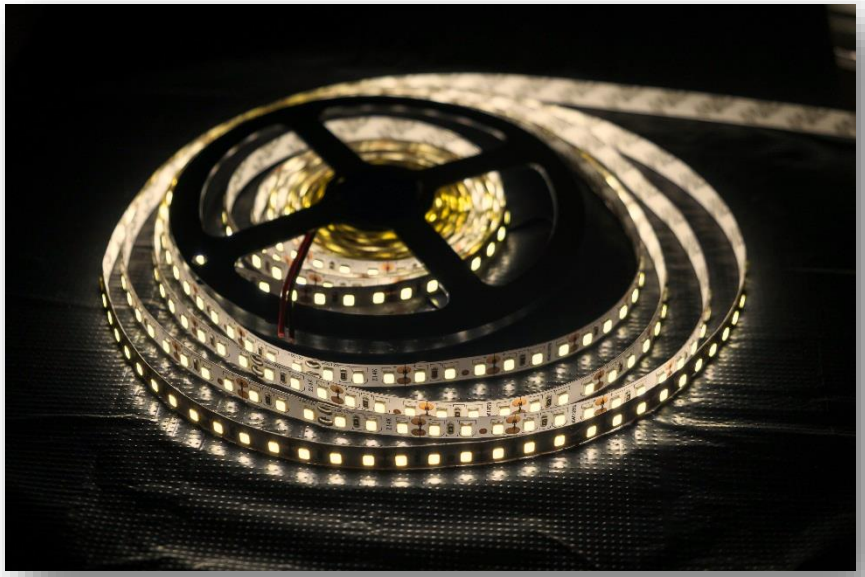


Flexibility of Space

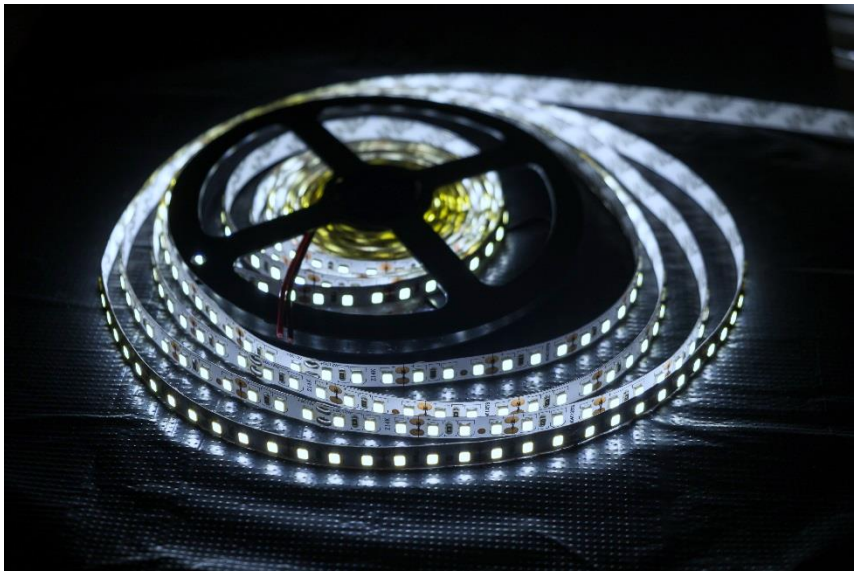
Personal Control

Tunable White:
any CCT at any intensity

Warm



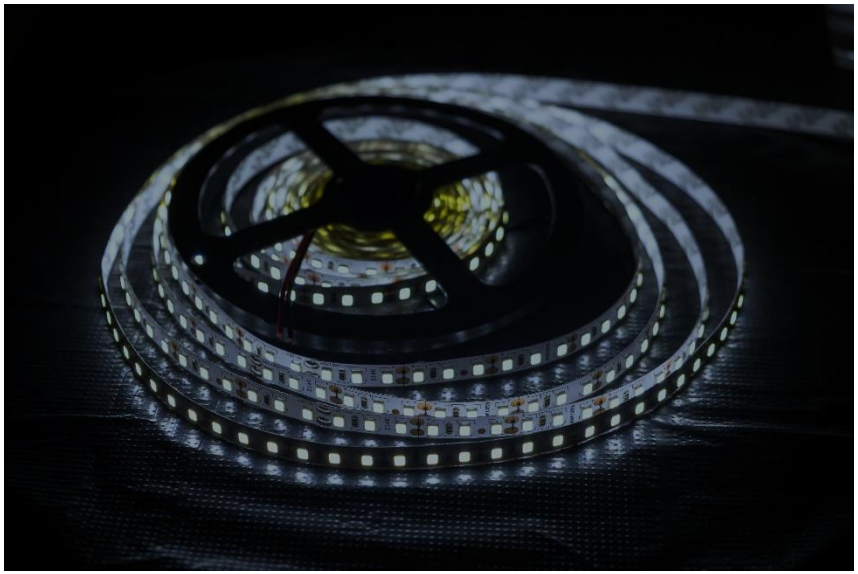
Cool



Tunable White:
any CCT at any intensity

Warm

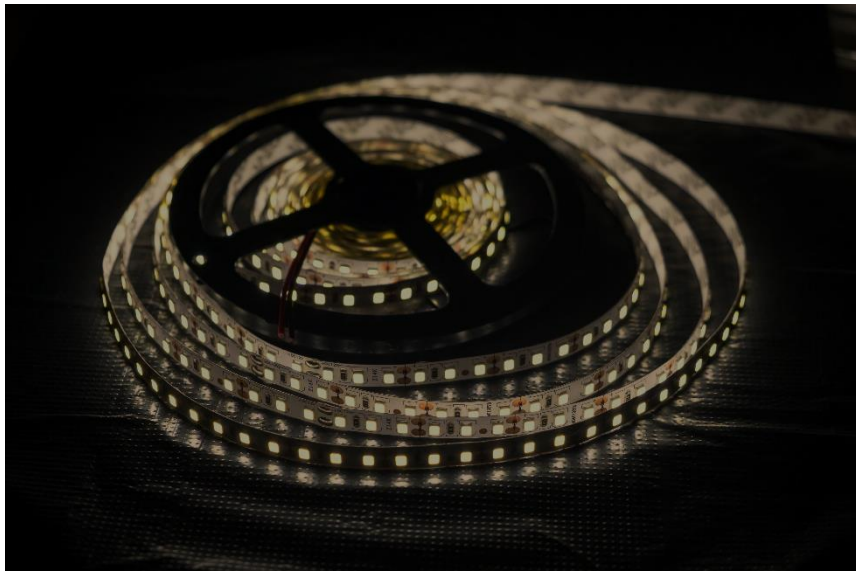
Cool



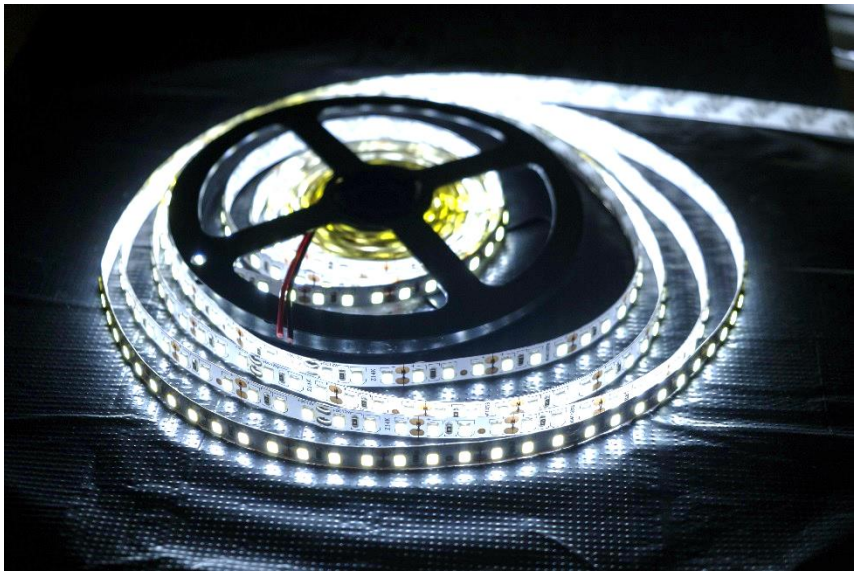
Combined: Warm Output

Tunable White:
any CCT at any intensity

Warm



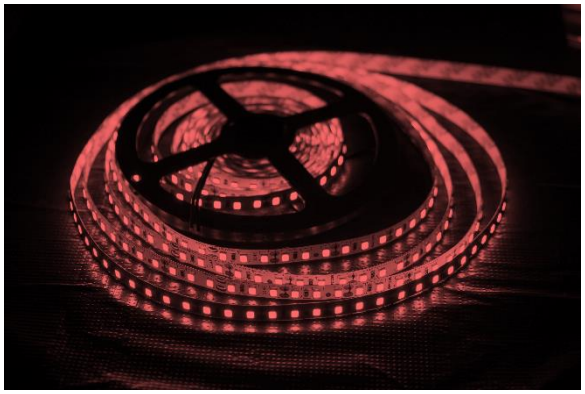
Cool



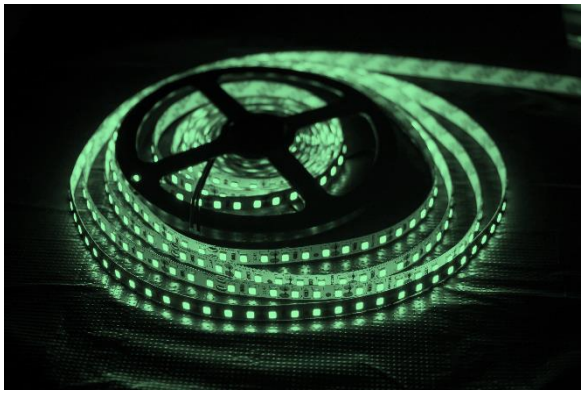
Combined: Cool Output

Tunable White:
any CCT at any intensity

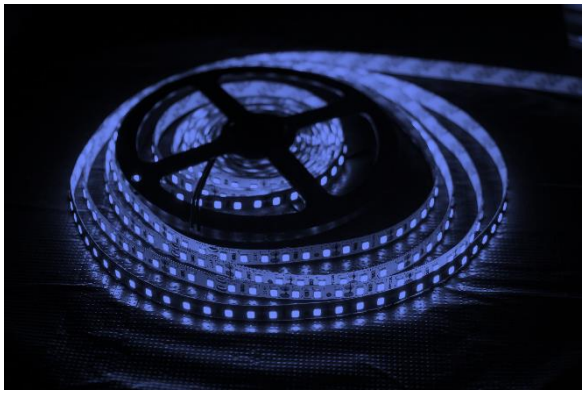
Red



Green



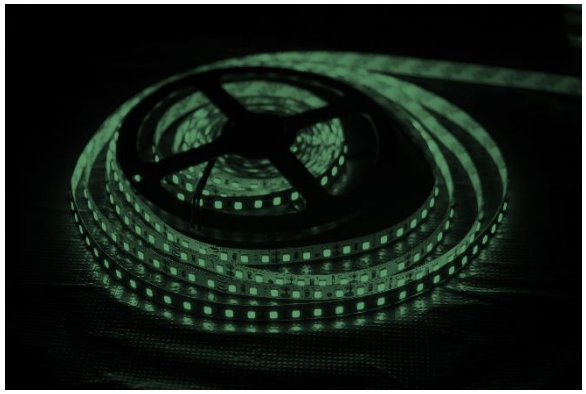
Blue



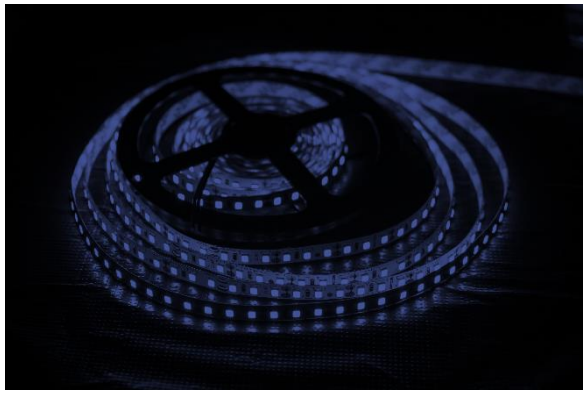
Tunable White:
any CCT at any intensity

Red

Green



Blue

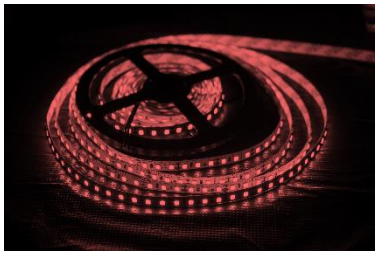


Combined: Warm Output

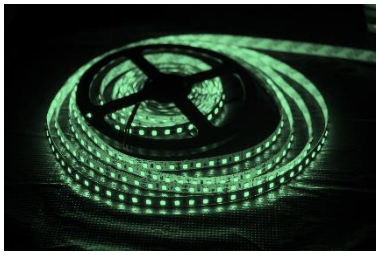
Tunable White:

any CCT at any intensity

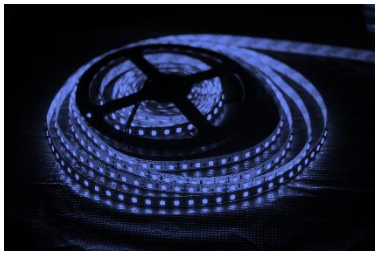
Red



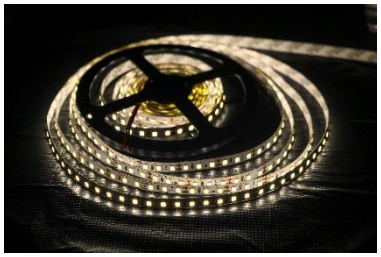
Green



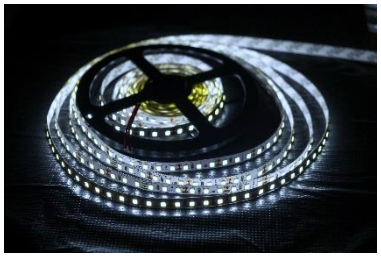
Blue



Warm



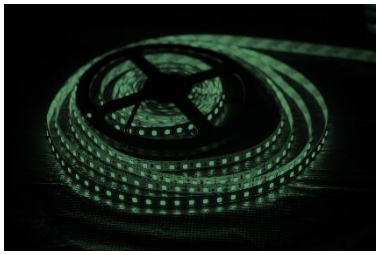
Cool



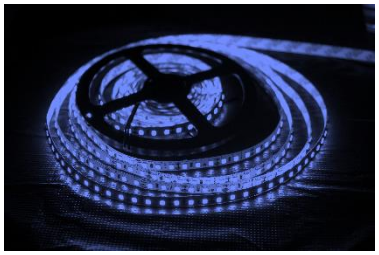
Tunable White:
any CCT at any intensity

Red

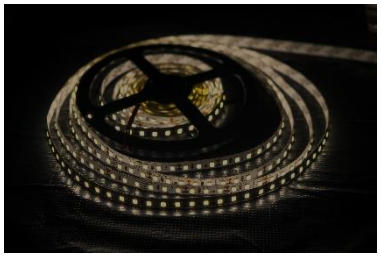
Green



Blue



Warm



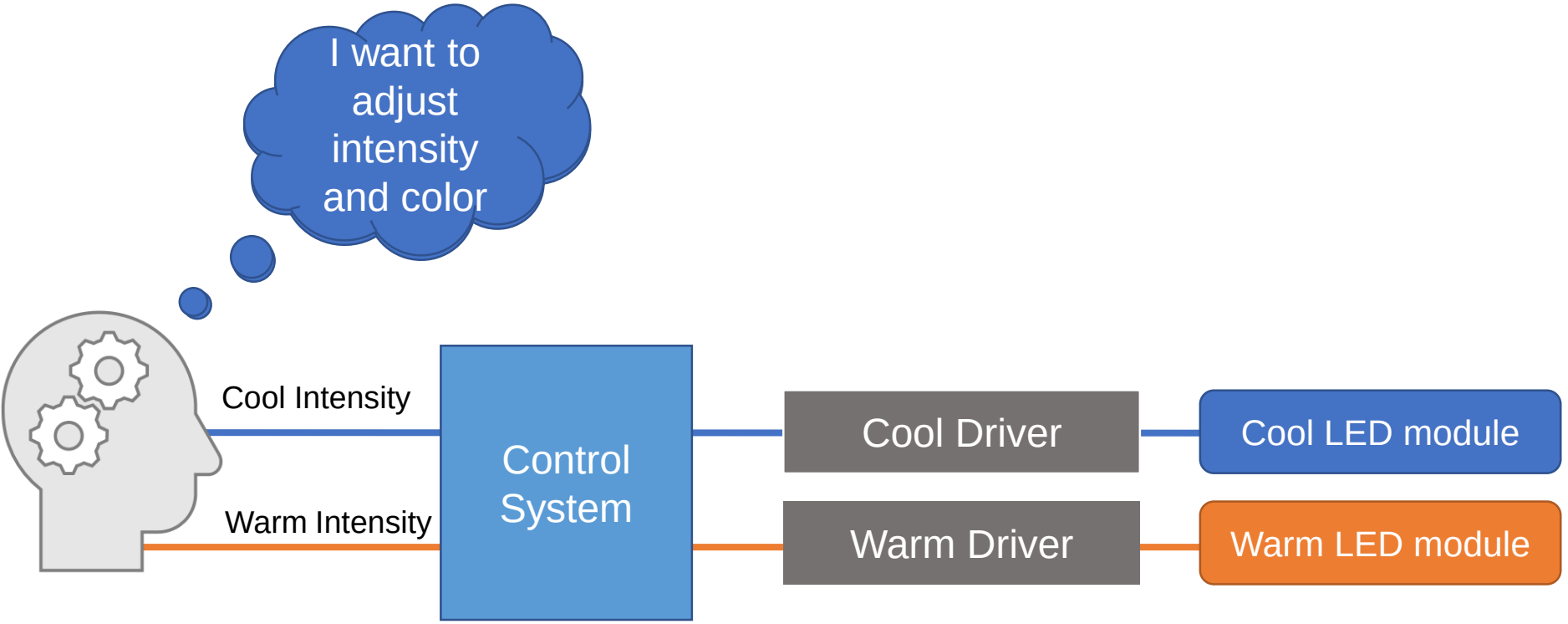
Cool

Combined: Cool Output

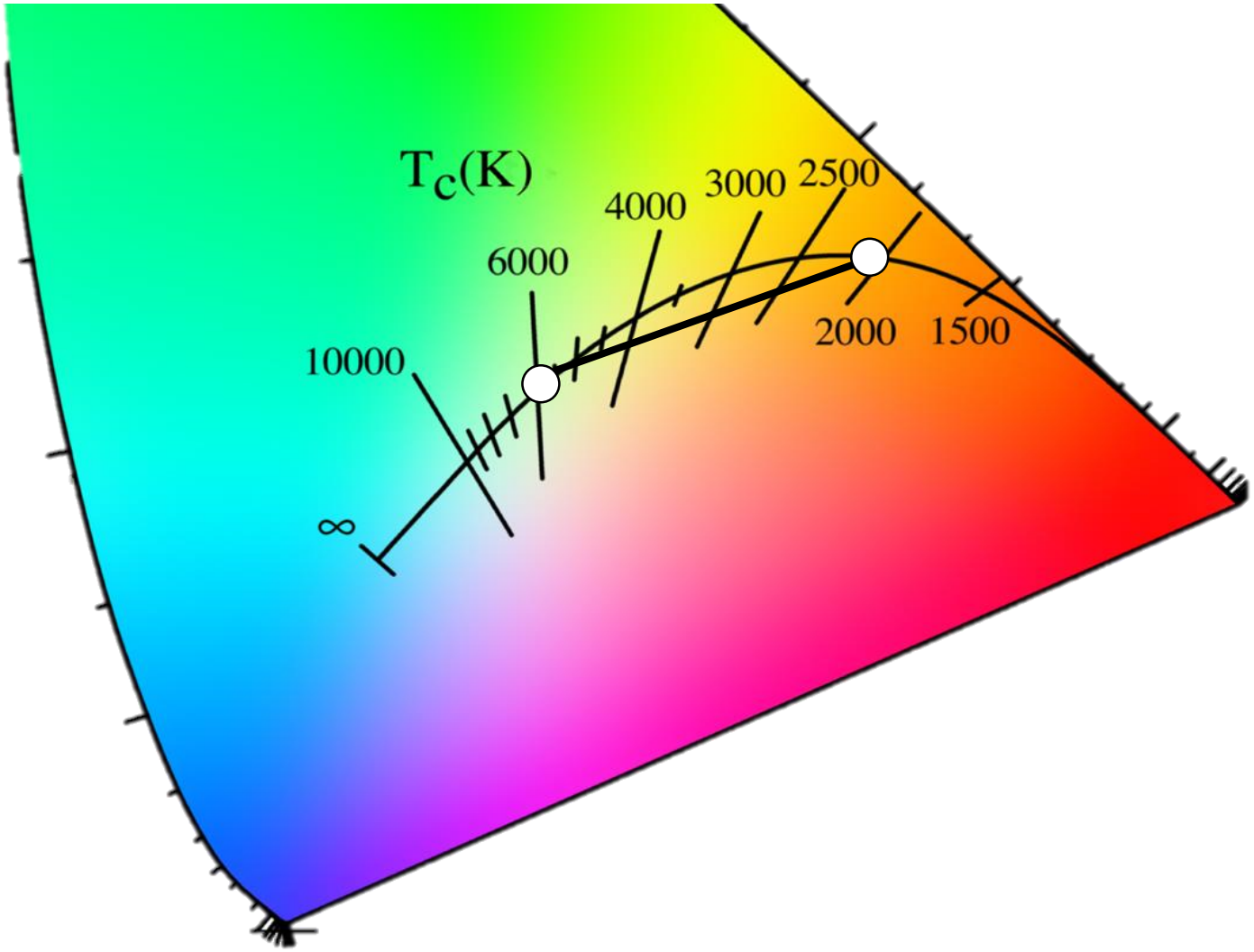
Color Tuning Features and Considerations

- Warm/Cool vs Intensity/Color
- CCT Consistency
- Protocol Selection

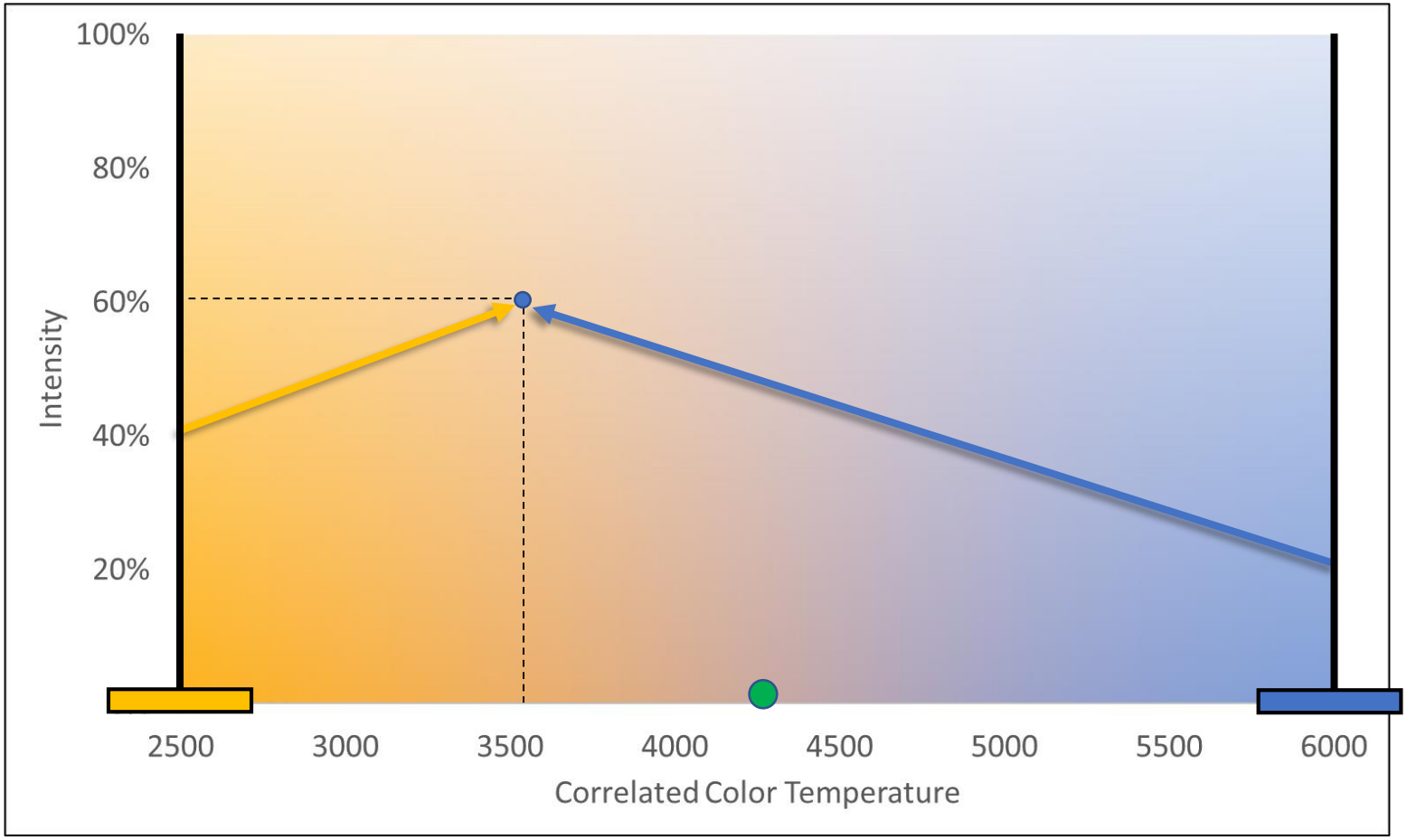
Warm/Cool


I want to adjust intensity and color
Cool Intensity
Warm Intensity
Control System
Cool Driver
Warm Driver
Cool LED module
Warm LED module

Warm/Cool Control:
user does the color mixing

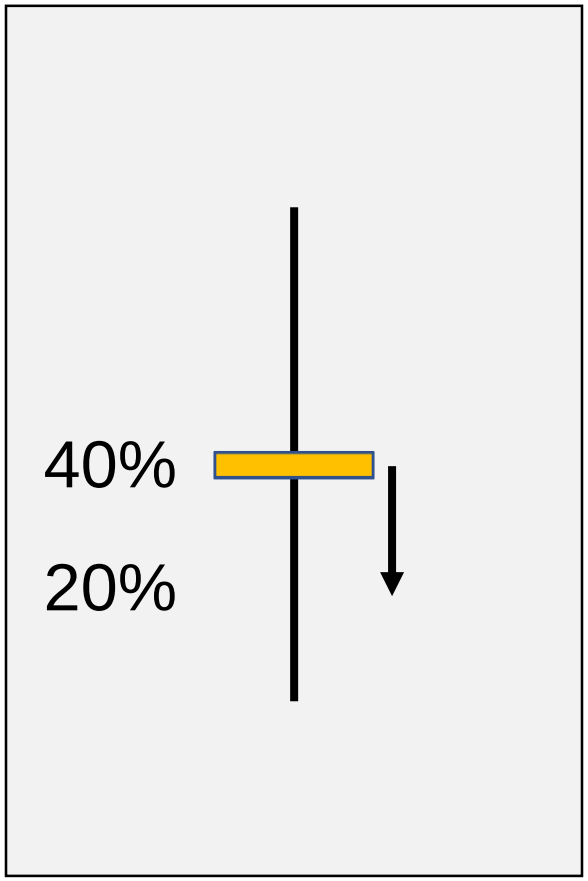


Complications:
tuning intensity of both warm and cool

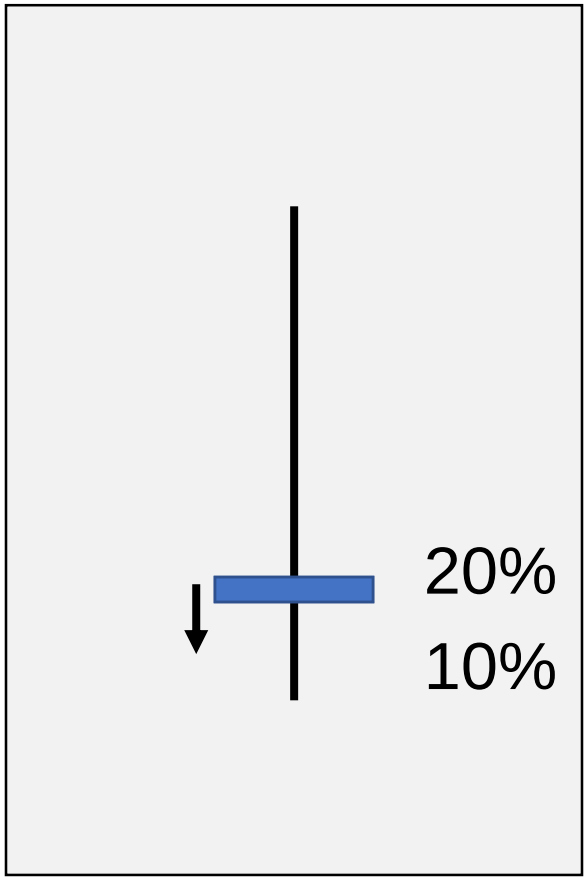


Dimming Warm/Cool Fixtures

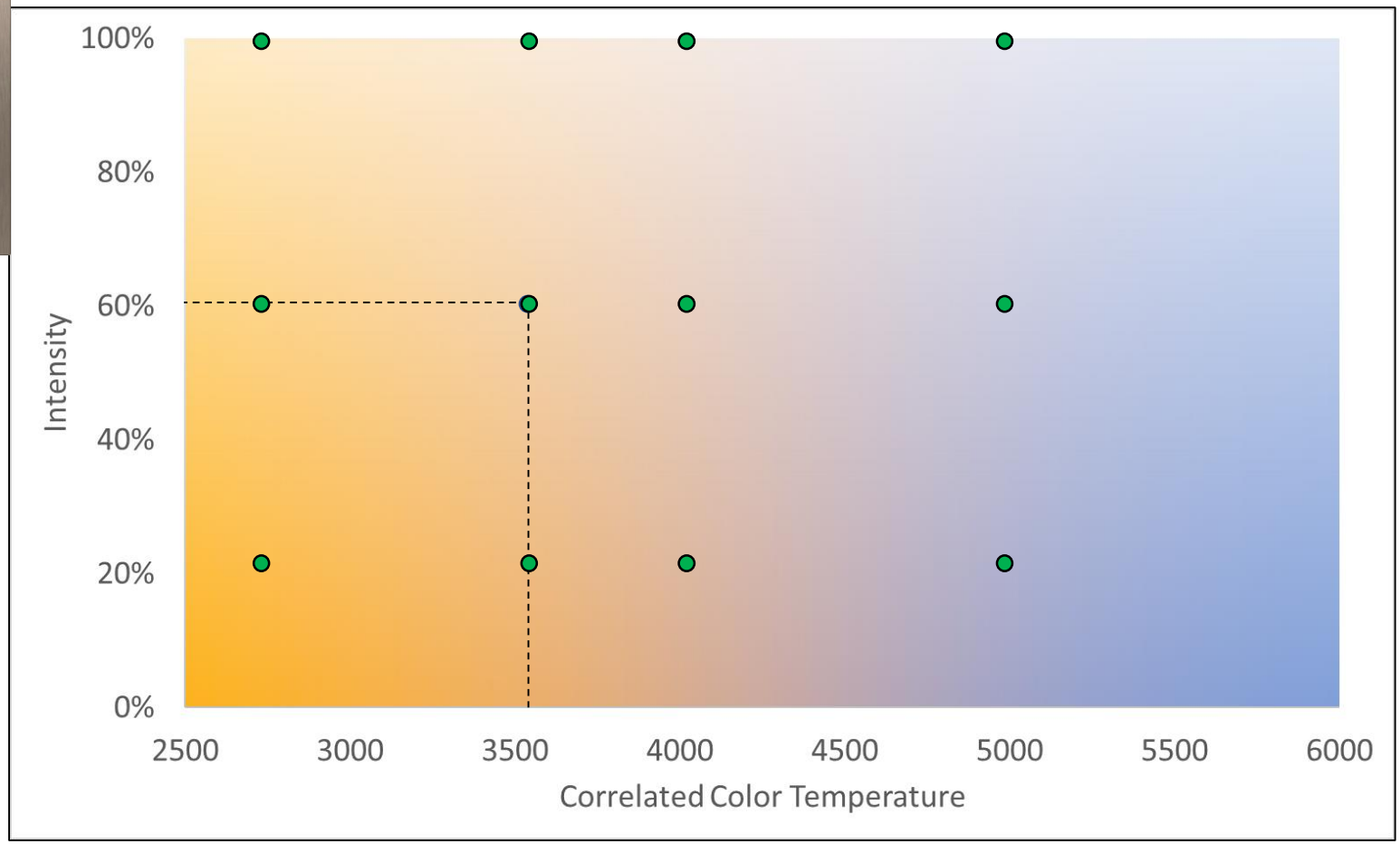
Warm



Cool



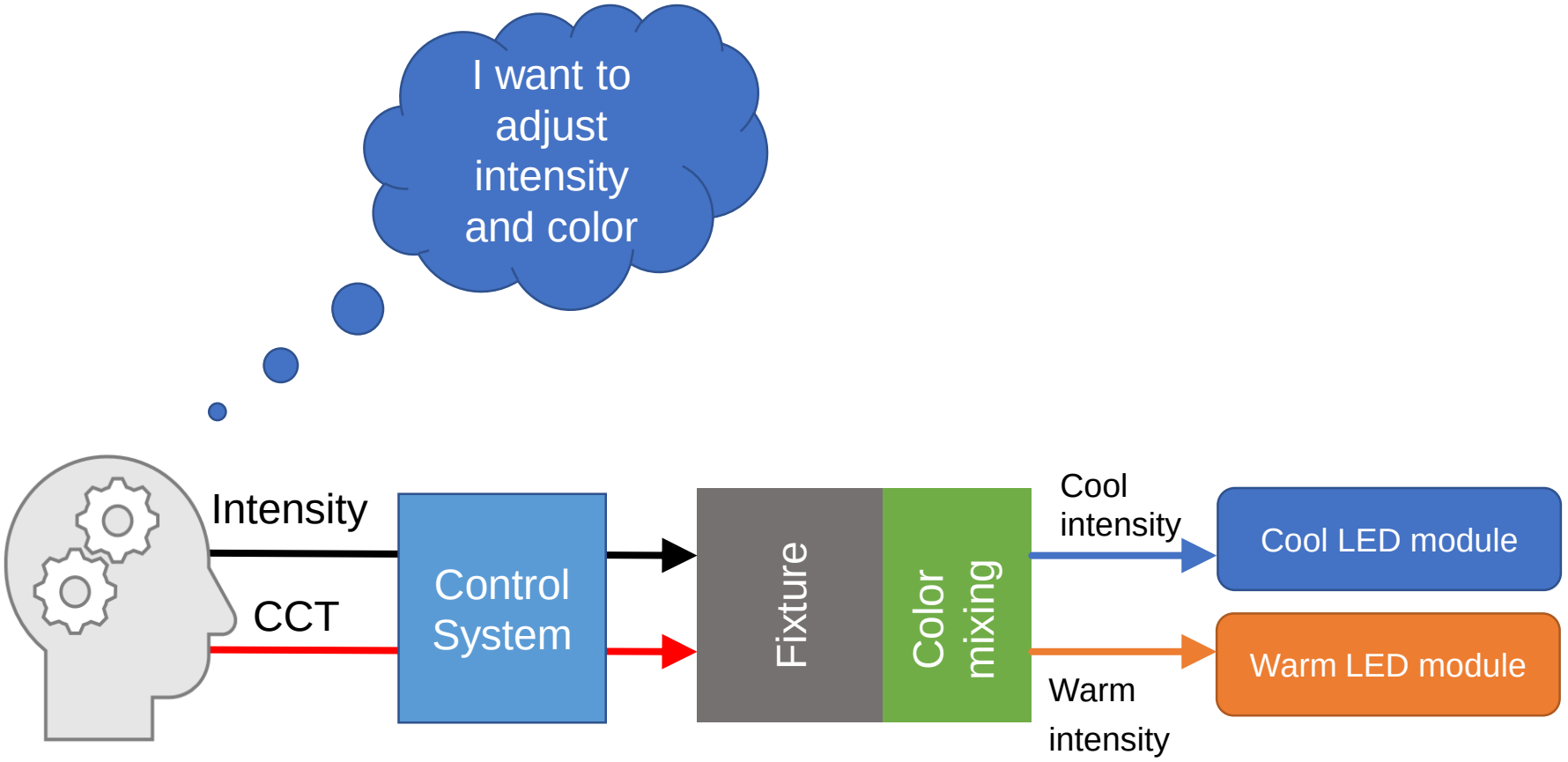
Warm/Cool Control:
additional requirements = additional issues



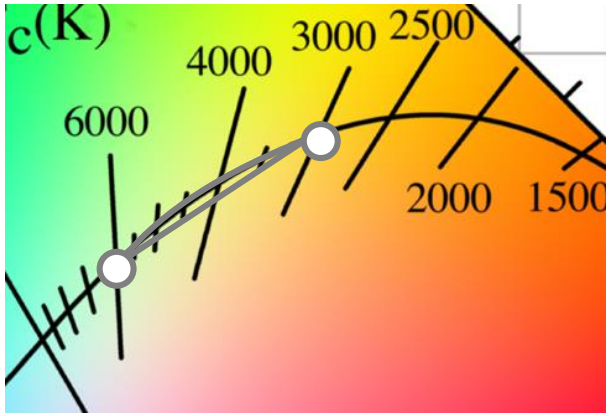
Warm/cool challenges

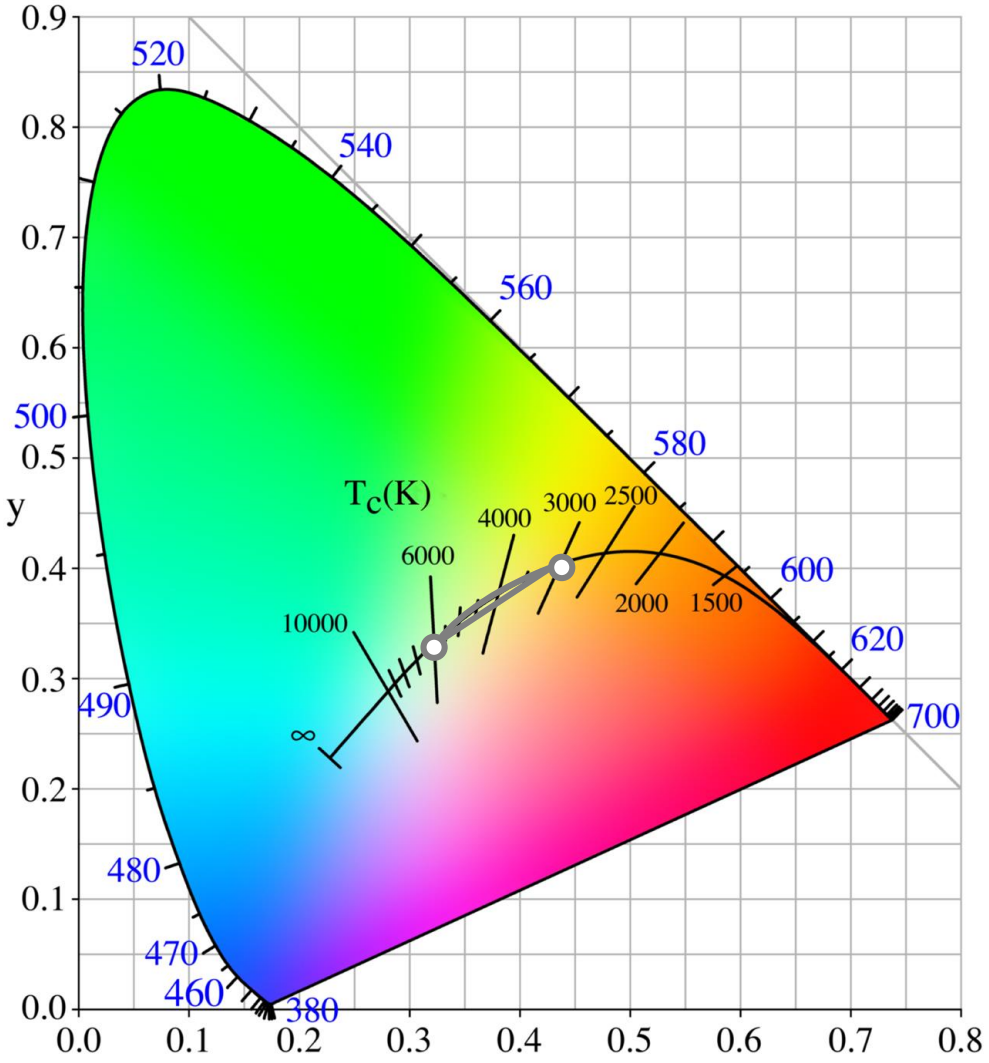
- ✕ User Experience limited to scenes
- ✕ Daylight Dimming is not practical
- ✕ Timeclock control is difficult

Intensity/CCT
straightforward

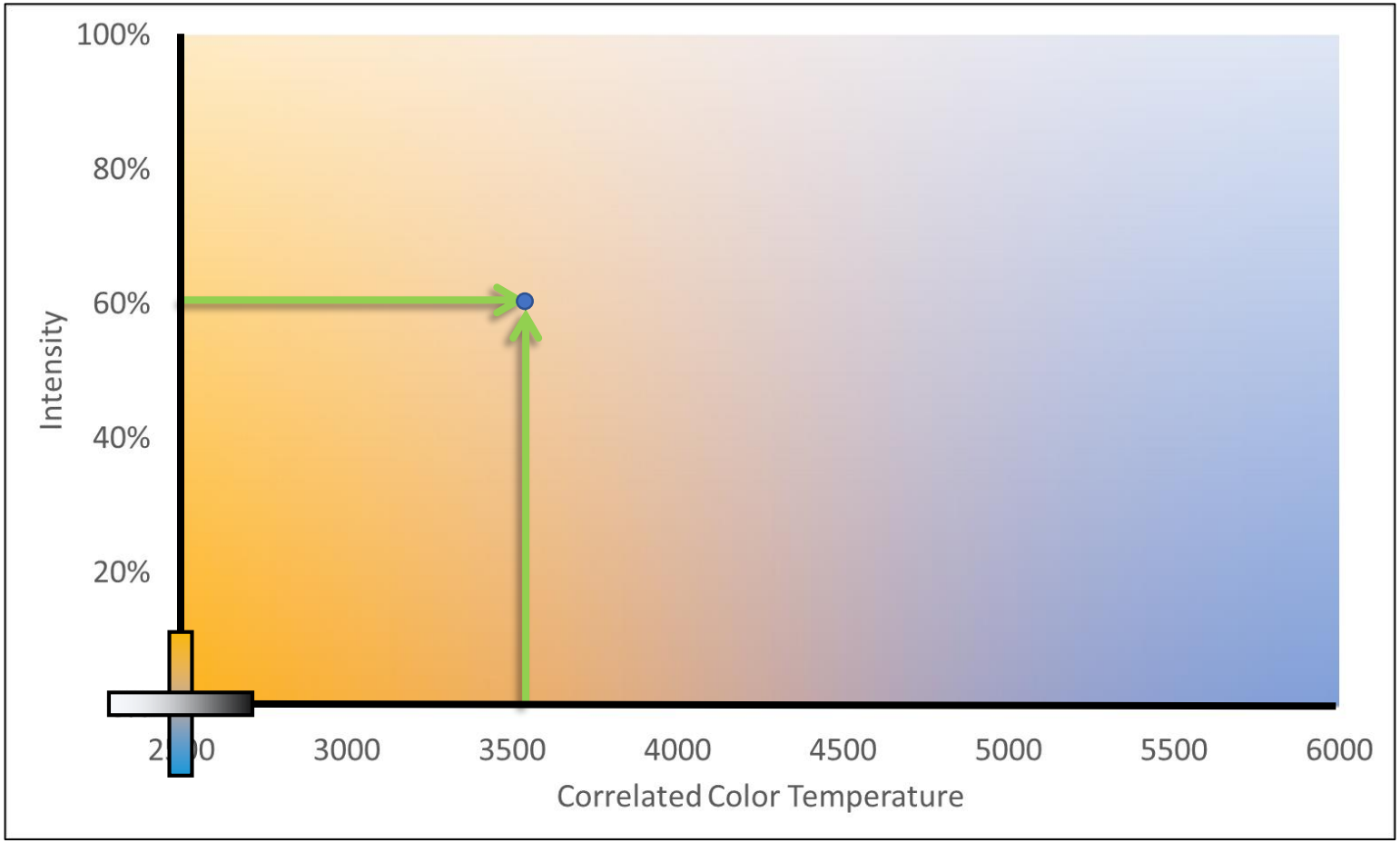


Intensity/CCT control

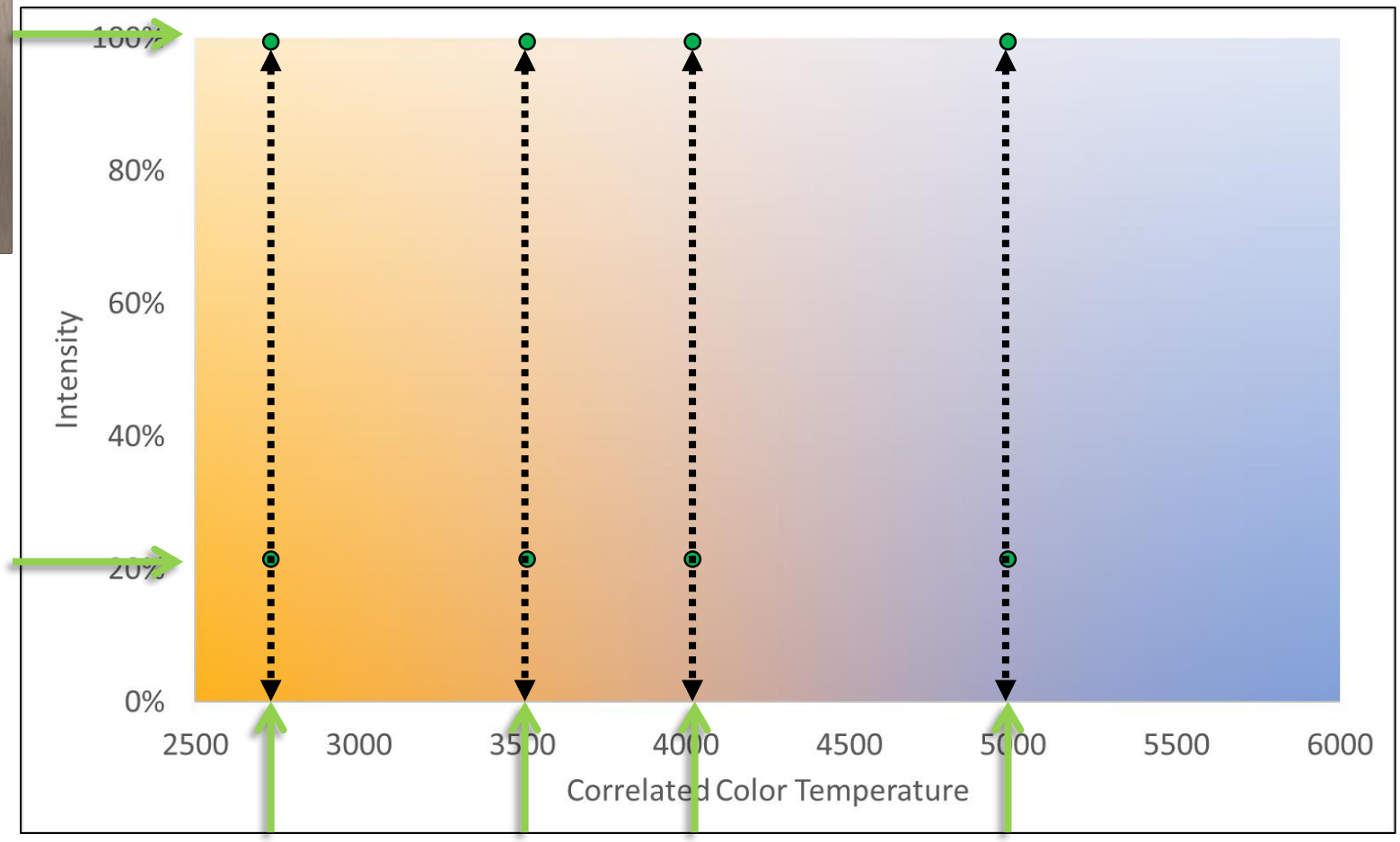




Tunable White with Intensity/CCT Control: a positive user experience.



Simple Programming



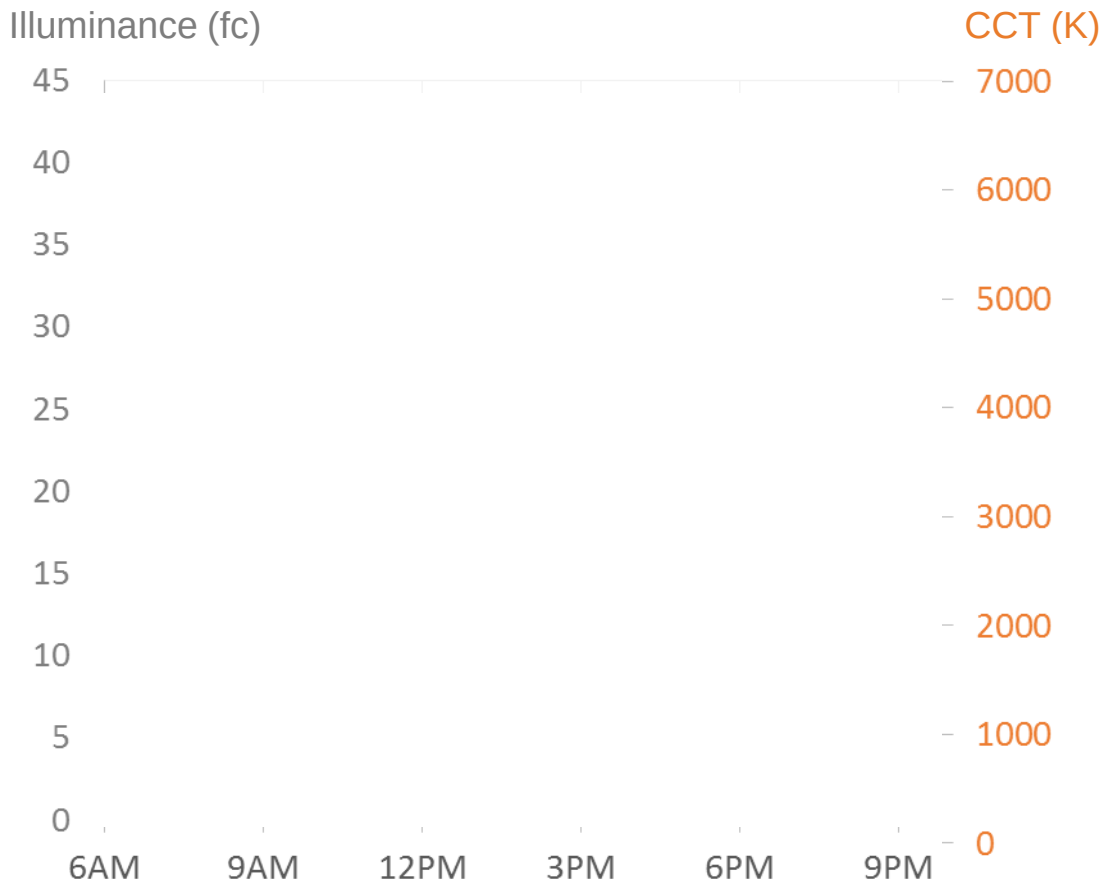
Intensity/CCT Control:
a positive user experience

Independent Control of Intensity/CCT

Daylight dimming is possible

Timeclock

Timeclock with Intensity/CCT Control: a positive user experience.



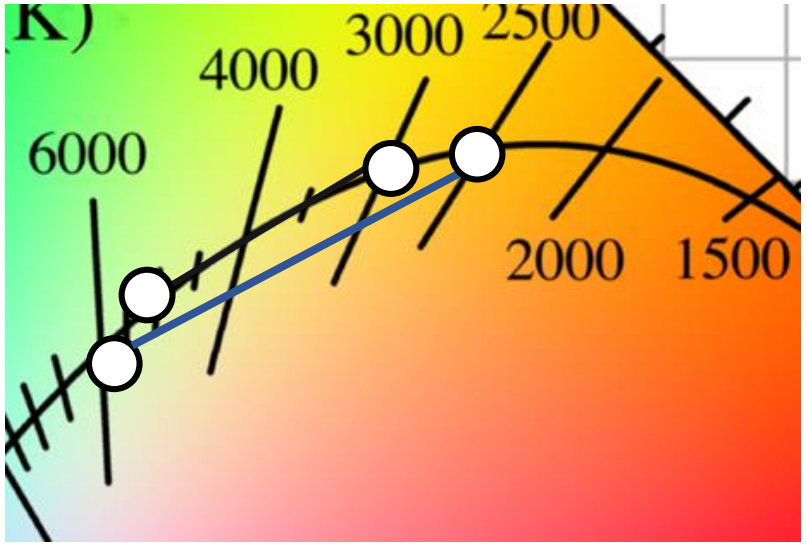
Comparison

Warm/Cool Control	Intensity/CCT
✗ Scenes only, no dimming	✓ Scenes and/or dimming
✗ No daylighting	✓ Daylighting is possible
✗ Timeclock control is difficult	✓ Timeclock control is simple

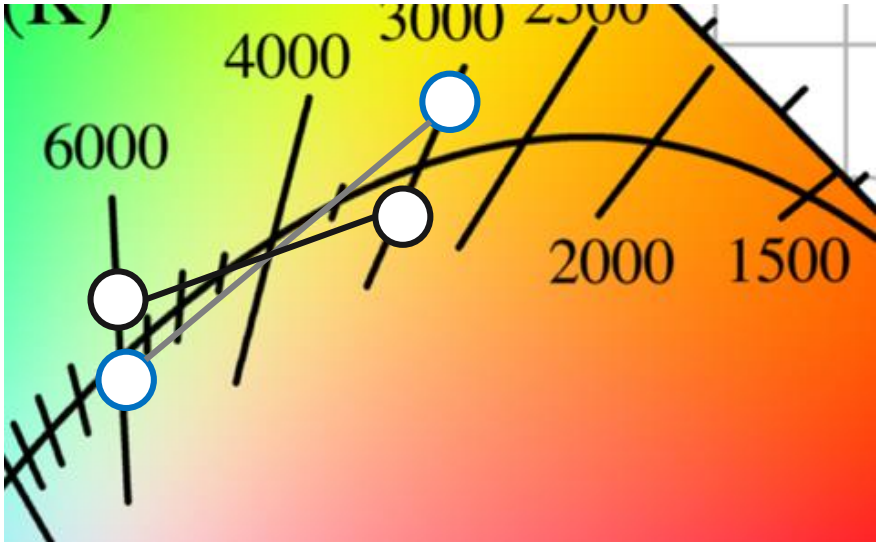
CCT Consistency

CCT Bounds

- ✕ different minimum CCT
- ✕ different maximum CCT
- ✕ different chromaticity coordinates



CCT Consistency



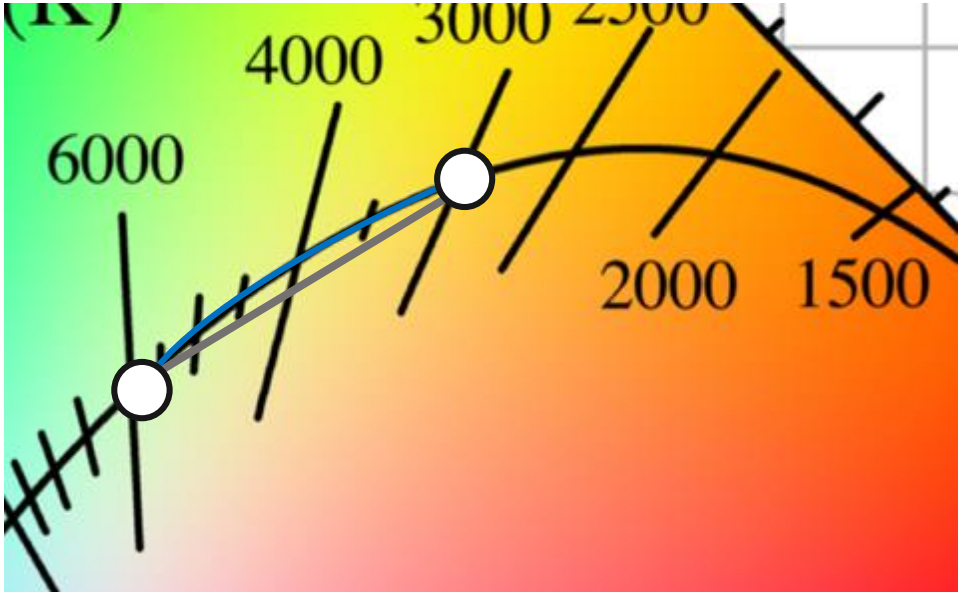
Chromaticity Coordinates

- ✓ same minimum CCT
- ✓ same maximum CCT
- × different chromaticity coordinates

CCT Consistency

Tuning Curves

- ✓ same minimum CCT
- ✓ same maximum CCT
- ✓ same chromaticity coordinates
- × different tuning curves



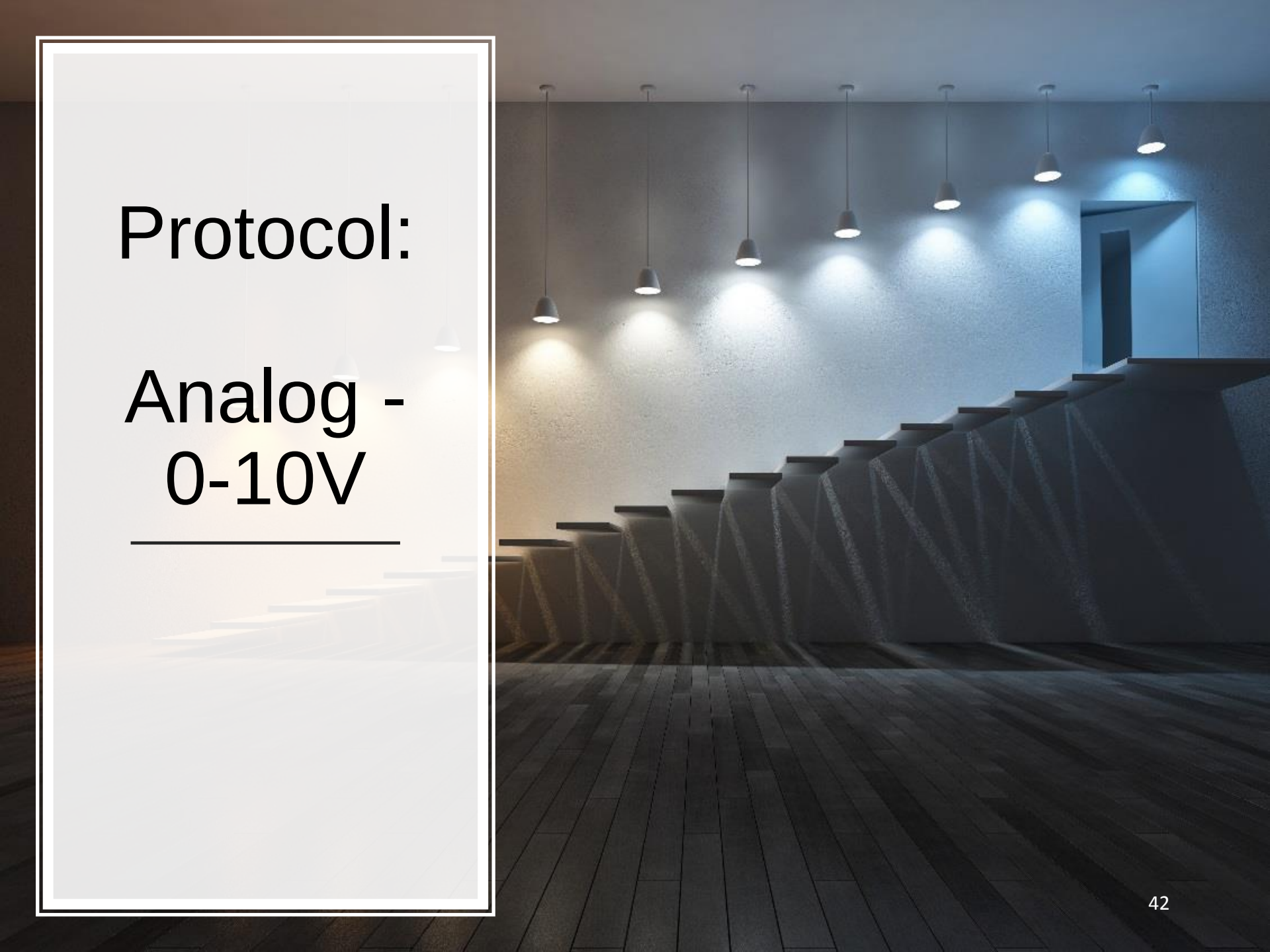
Protocol Selection

The protocol(s) used may not necessarily simplify all of these equally

- Design
- Construction
- Commissioning

It may also have a distinct difference in these:

- First cost
- Installed cost



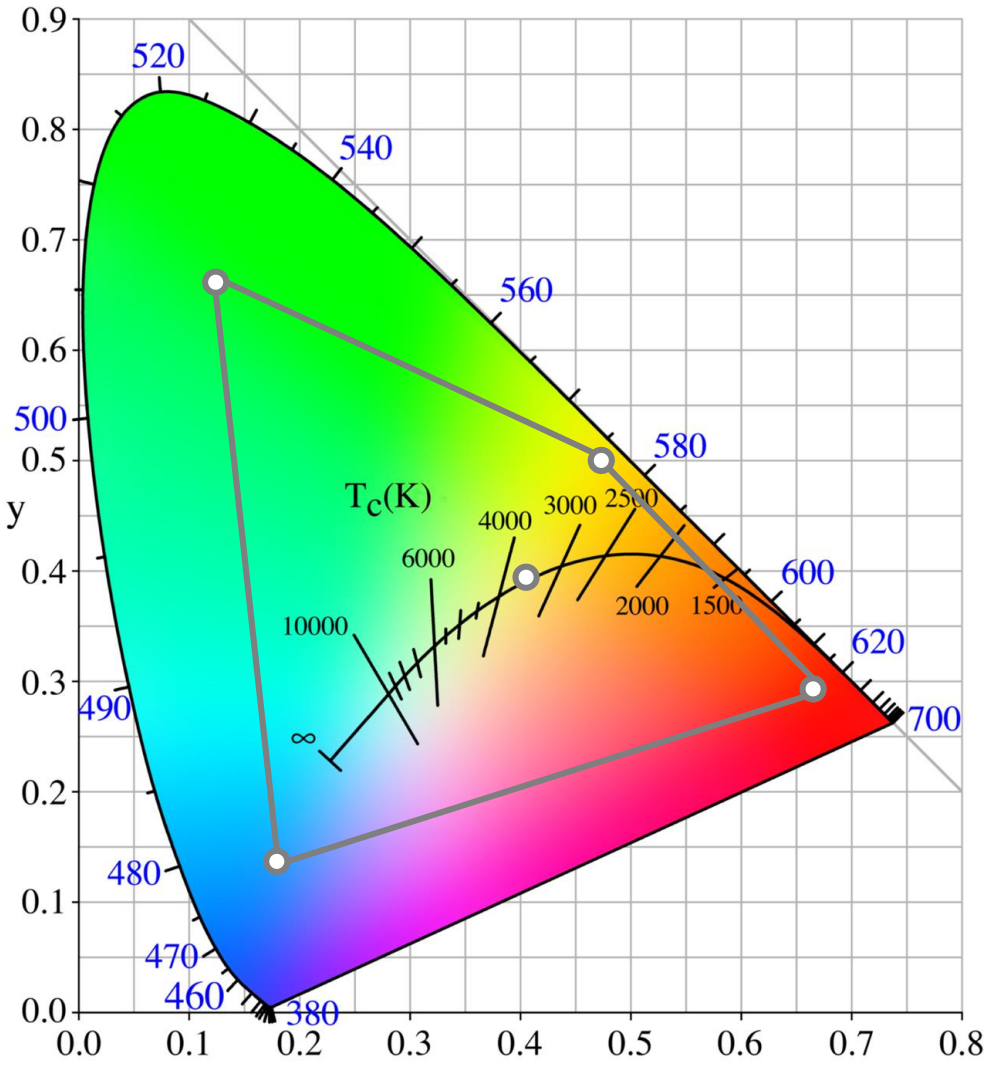
Protocol:

Analog - 0-10V

Protocol – Digital (DALI, DMX, Wireless)

Full spectrum control

ultimate
flexibility
but with
ultimate
complexity



Sequence of Operations (SoO) and Commissioning

Defines how the system operates in detail, establishing the user experience

Defining a good SoO follows the typical architectural design process

Project requirements
- Codes
- Integration needs

Define scenarios
- Interview end users
- Understand tasks and usage for each space
- Develop scenarios that define experiences
- Any special needs?

Evaluate desired lighting control response
- For each scenario
- Consider both user personas and key individual users
- Visualize interactions

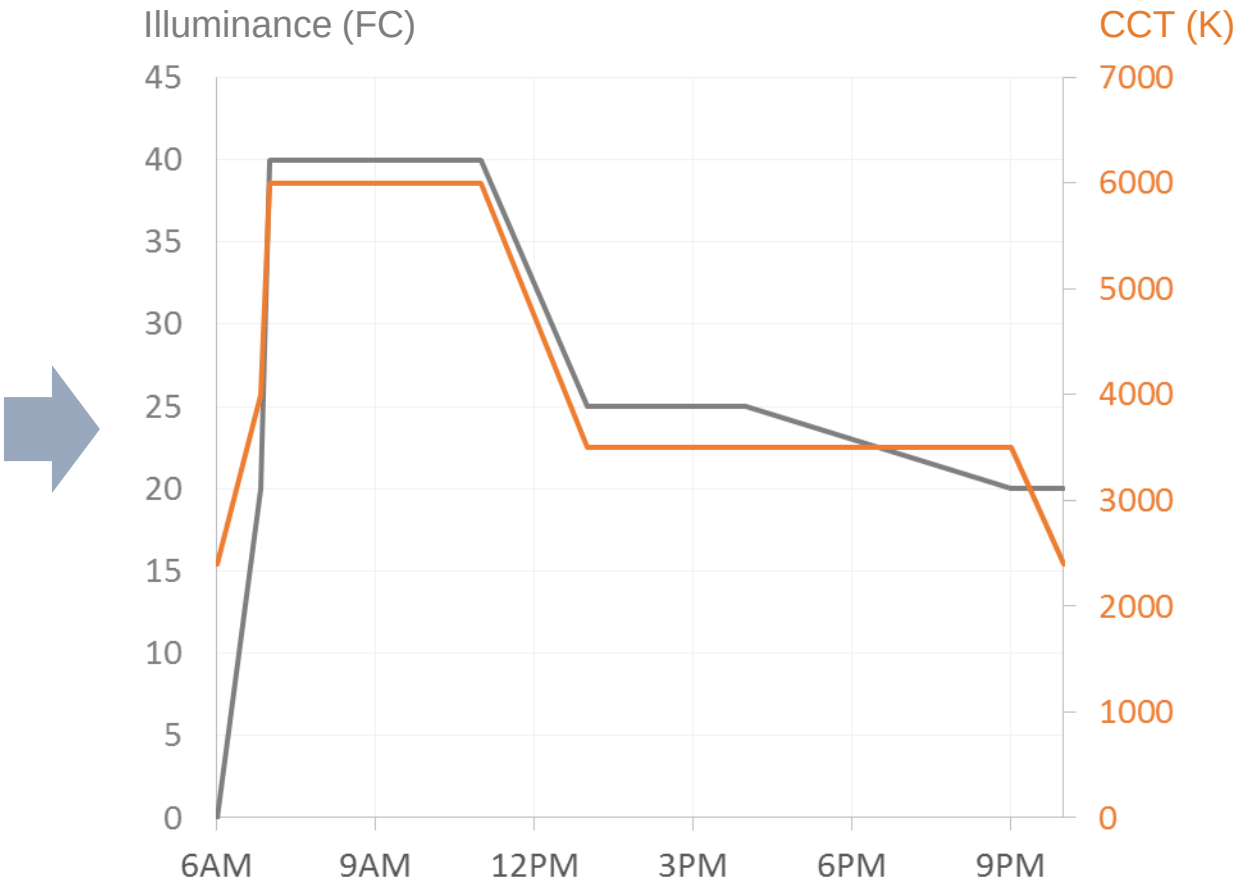
Write the lighting narrative
- For each scenario
- Review with end users

Complete documentation
- Finalize narratives
- Timeclock schedule
- Control locations
- Scene setting schedule
- Floorplan that illustrates SoO categories
- Engraving (if needed)

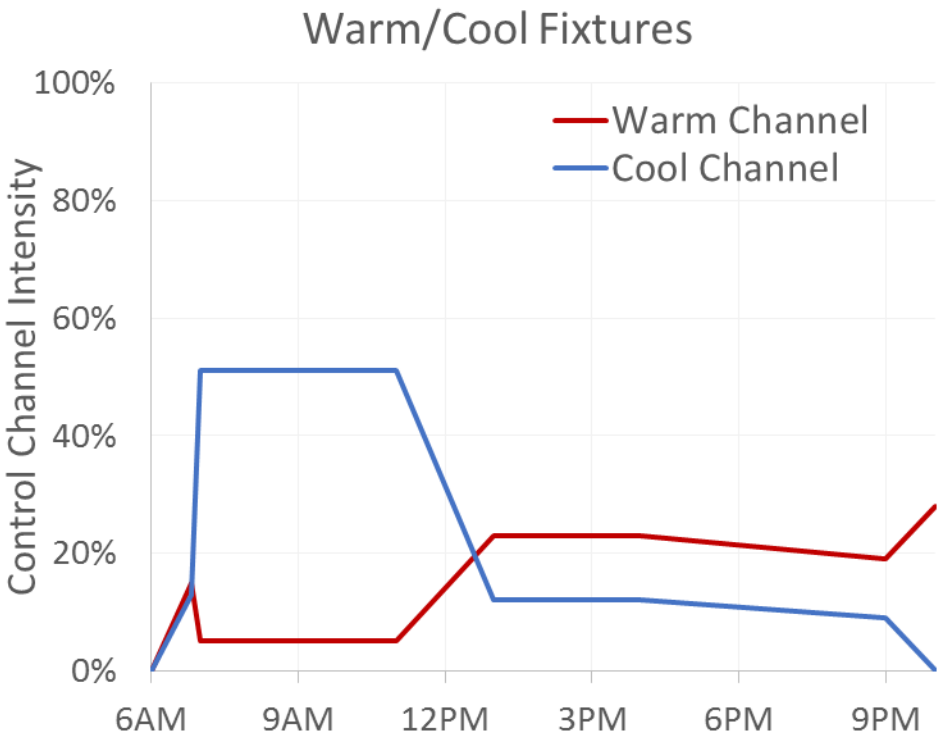
Critical Note: Customized user experience (aka SoO) must be space and user dependent!

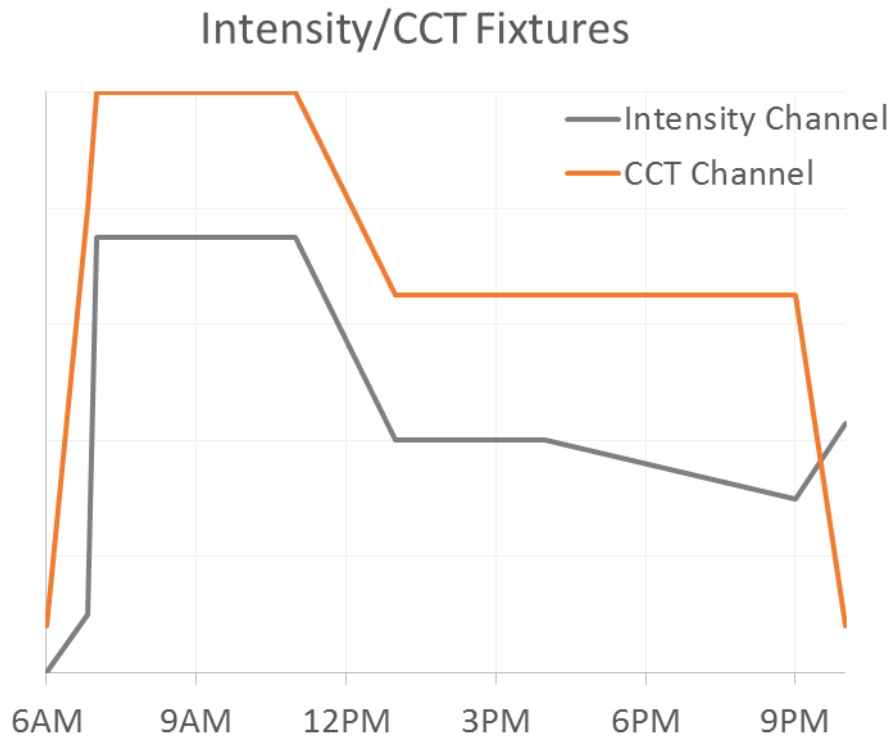
Interpreting the Sequence of Operations: more complex than it may seem

Time	Illuminance (FC)	CCT (K)
6AM	0	2400
6:30AM	20	4000
7AM	40	6000
11AM	40	6000
1PM	25	3500
4PM	25	3500
9PM	20	3500
10PM	20	2400



Interpreting the Sequence of Operations: more complex than it may seem

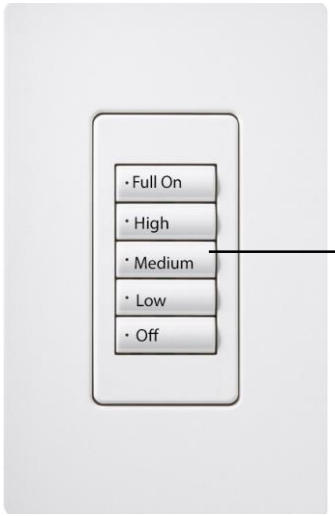


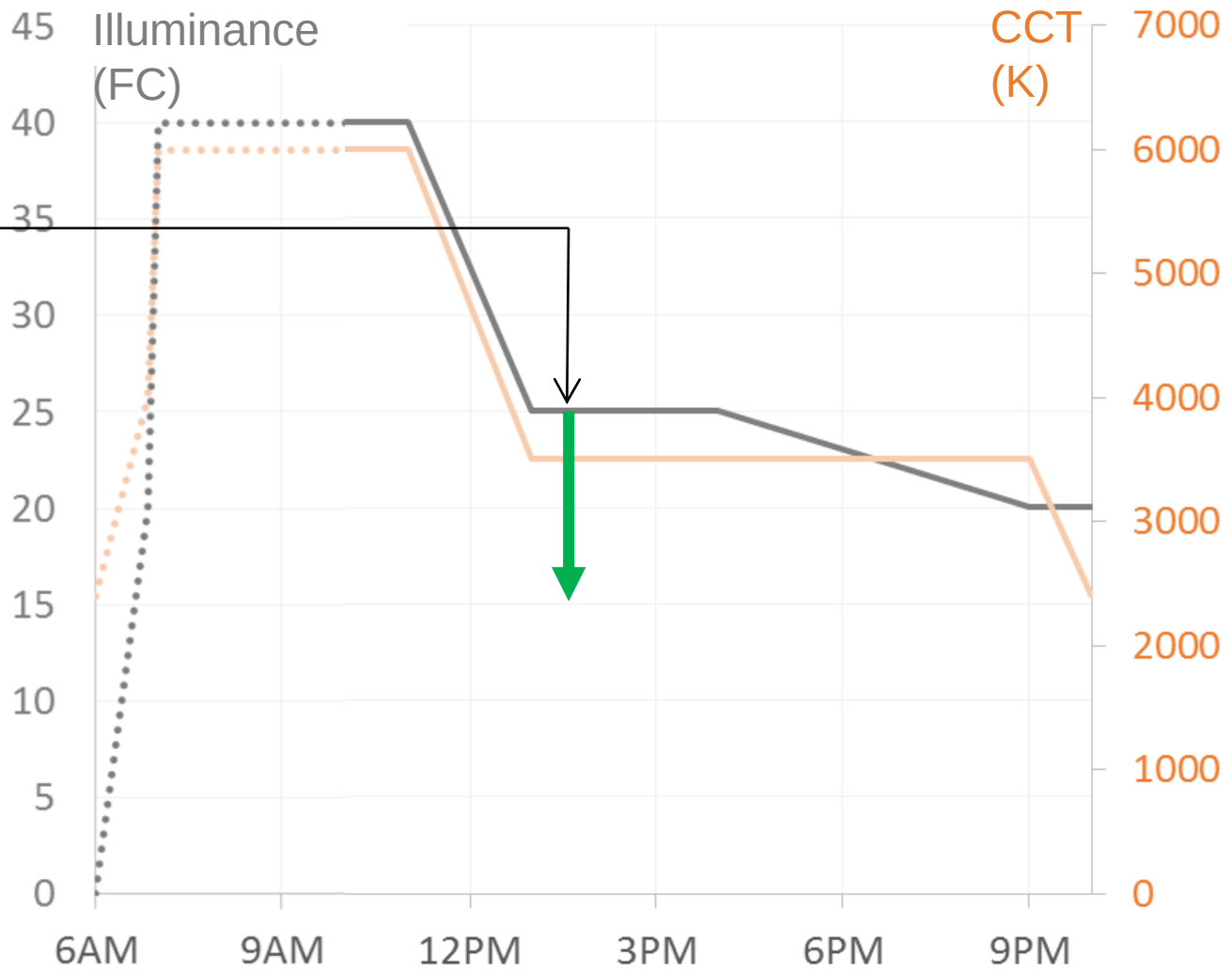


Interpreting the Sequence of Operations

Setting	Output
Full On	100%
High	60%
Medium	35%
Low	5%
Off	0%

Simple Keypad:
complex sequence of operations





Interpreting the Sequence of Operations: more complex than it may seem

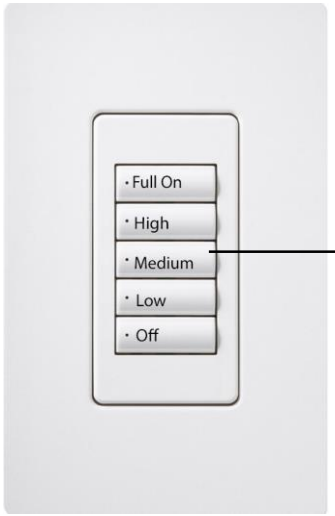
How long does an override last?

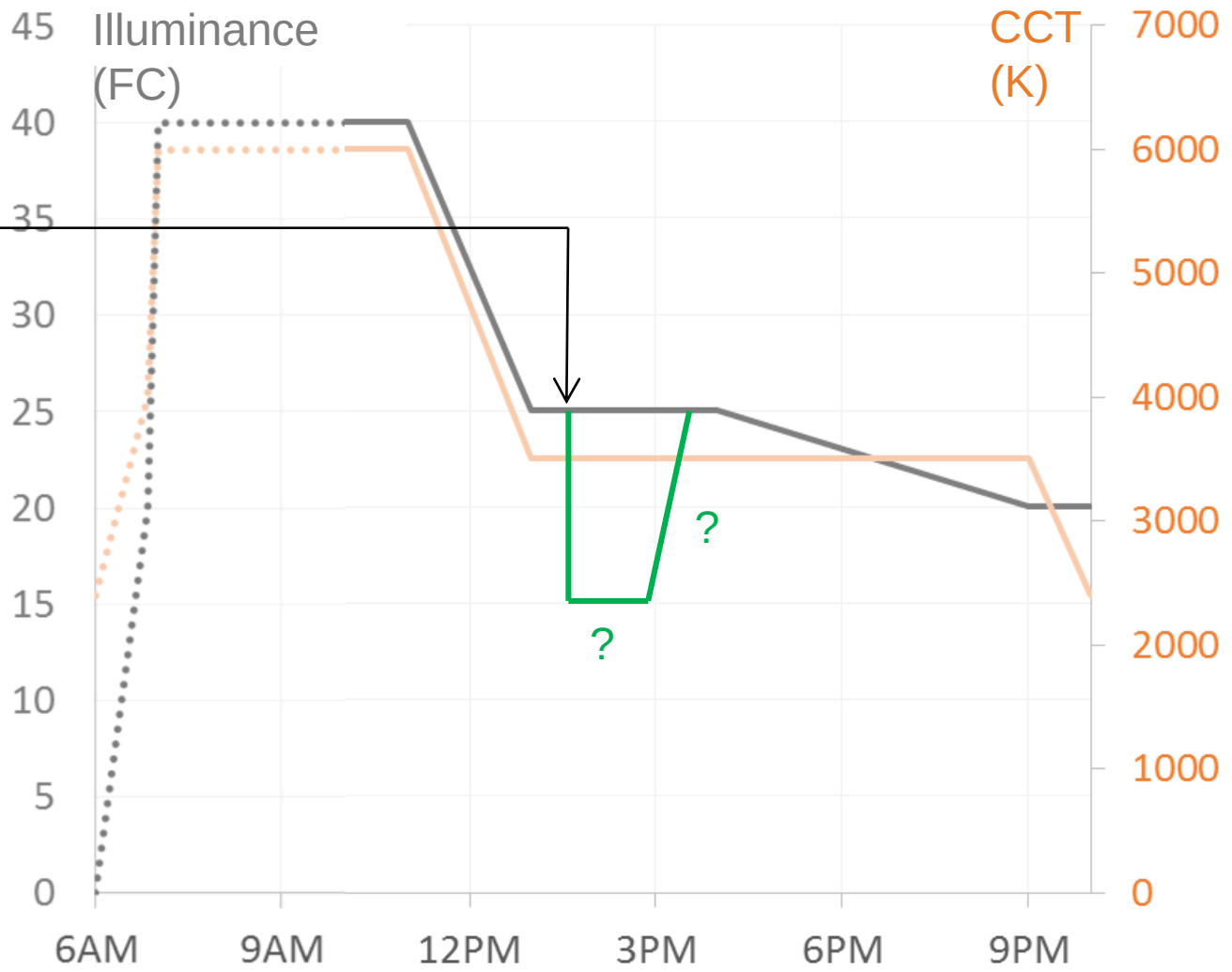
Can a user adjust color or only intensity?

How quickly should the lights return to automation?

1 hour ?
2 hours ?

Programming Considerations





Measurement Techniques

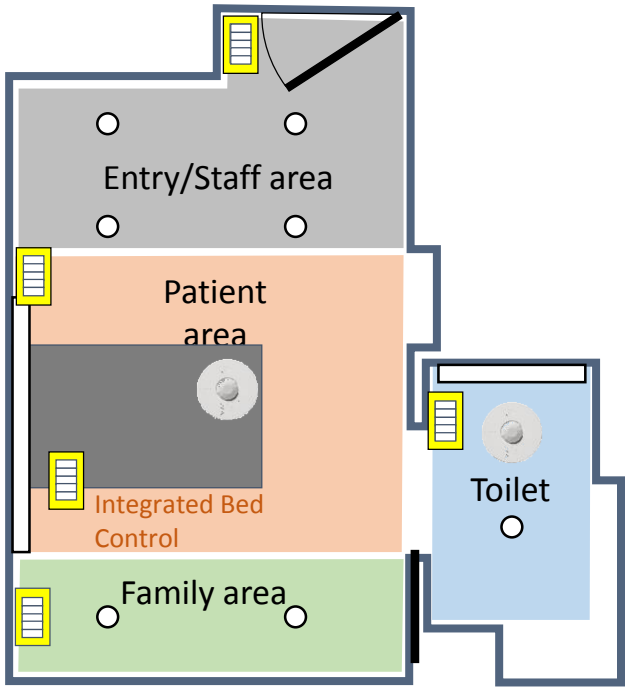
Room Measurement

- Cannot know if the desired CCT can be achieved at the measurement point.
- Each space may have a different source color.
- Requires custom measurements per room.
- Daylight potentially affects readings.

Fixture Measurement

- better confidence that the SoO is achievable with the selected fixture.
- consistent color from fixture to fixture.
- does not require custom measurement per room.
- no affect from daylight.

Spaces with complicated control functionality require deep consideration and detailed documentation



Lighting zones and control locations

Setting	Output
Full On	100%
High	60%
Medium	35%
Low	5%
Off	0%

Engraving and scene settings

Time	Illuminance (FC)	CCT (K)
6AM	0	2400
6:30AM	20	4000
7AM	40	6000
11AM	40	6000
1PM	25	3500
4PM	25	3500
9PM	20	3500
10PM	20	2400

Lighting CCT/Intensity schedule

PATIENT ROOM: Documenting the SoO

Daily Cycle:
- Color temperature and intensity of lights, and the shade position changes throughout the day according to the schedule.
- The fade to the next scheduled intensity and color temperature occurs over 90 sec.
- When manual overrides occur, lights and shades are automatically reverted back to the schedule after 1 hour. The lighting changes occur over a 90 sec. fade.

Entry/Exit (bathroom):
- Upon entry: lights are automatically turned on over a 10 second fade, the intensity and color temperature match the daily cycle.
- Upon exit: all lights are automatically dimmed to off over a 10 second fade.

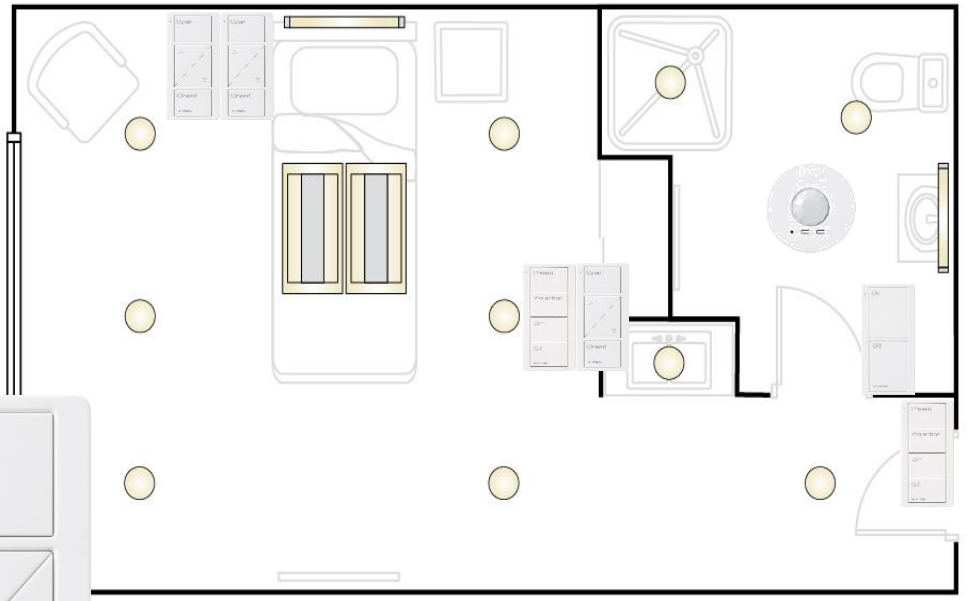
"Exam" Scene:
- All lights are set to 100% and color temperature is set to 5000K.

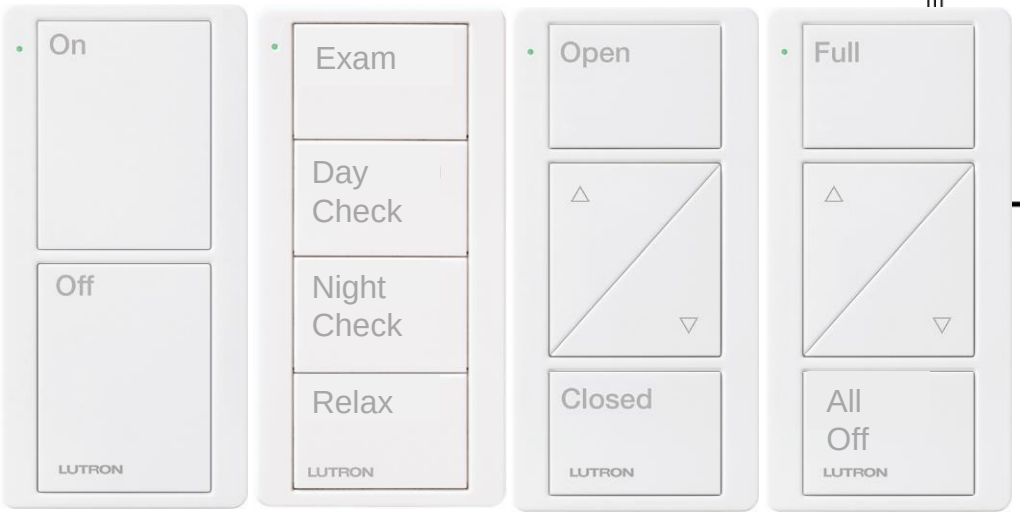
"Day Check" Scene:
- All lights are set to 75% and color temperature continues to follow the daily cycle.

"Night Check" Scene:
- All lights are set to 25% and color temperature continues to follow the daily cycle.

Patient Control (next to bed):
- The light control turns on, raises, and lowers the headboard light.
- The light control turns off all of the lights in the room.
- The shade control can fully open, fully close, raise, or lower the shades.

PATIENT ROOM: Documenting the SoO





There are many tools in the controls toolbox to define the right user experience

- Dimming light levels
- Color temperature (white tuning)
- Scene control
- Control zones
- Daylight zones
- Timeclock scheduling
- Manual ON vs Auto ON
- Partial OFF (when vacant)
- Fade rates for dimming
- Fade rates for white tuning
- Fade rates upon occupancy/vacancy
- Visual communication (e.g. blink warn)
- Modify control based on occupancy
- Modify control based on time of day
- Modify control based on occupancy and time of day

Don’t forget these!

Commissioning and WELL

What is the WELL Building Standard?

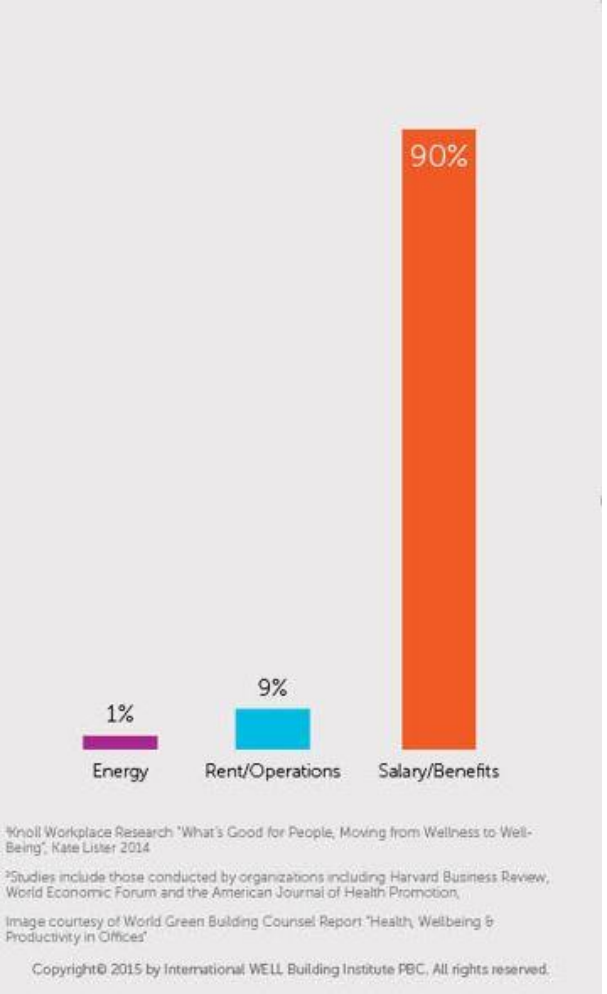
- A performance-based system that measures the impact of the built environment on human health and well-being
- Provides a model for design and construction in integrating health features into the built environment
- Grounded in a body of research and has been peer reviewed by medical experts, designers and building industry practitioners.

Why Well?

Businesses often focus on reducing energy consumption in order to shrink operating costs. Focusing on areas that could impact the health and wellbeing of workers could have a much greater return on investment. As a rule of thumb, businesses spend roughly $3 psf on utilities, $30 psf on rent and $300 psf on people annually.

A 2% energy efficiency improvement would result in savings of $.06 per square foot but a 2% gain in productivity is worth $6 per square foot.

People are typically a business's greatest expense and the biggest opportunity for savings. The WELL Building Standard focuses on people and following the Standard may potentially add measurable value to employee health, well-being and productivity.

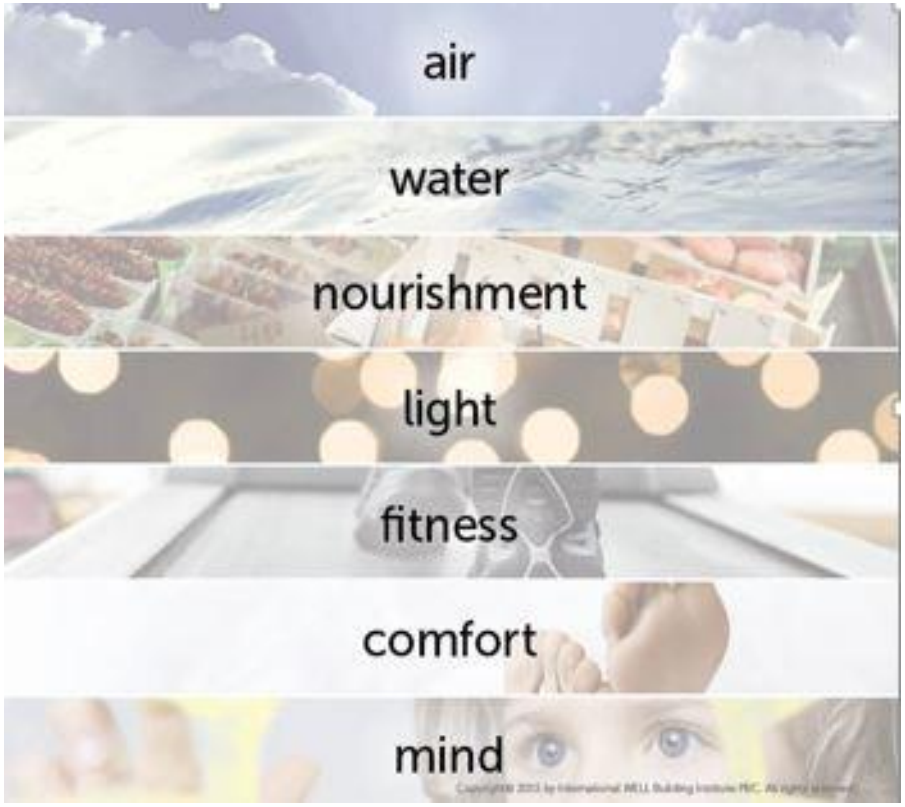


Who manages the WELL Building Standard?

PROJECT TYPES

Structure of the WELL Building Standard

Seven WELL Concept Areas



Goals

Create Optimal Indoor Air Quality to support health and well being of building occupants.

Promote safe and clean water and require the appropriate quality of water for various uses

Require the availability of fresh, wholesome food, limit unhealthy ingredients, and encourage better eating habits

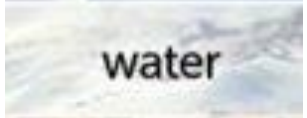
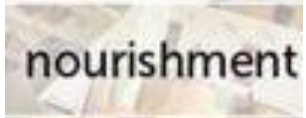
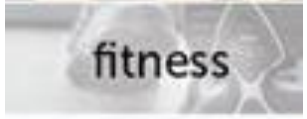
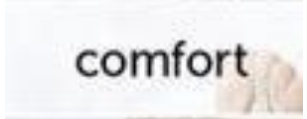
Provide Illumination guidelines to minimize disruption to the body's circadian system, enhance productivity and provide appropriate visual acuity.

Allow for seamless integration of exercise and fitness into everyday life by providing physical feature and components to support and active and healthy lifestyle.

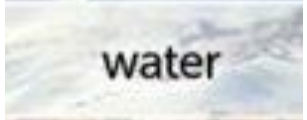
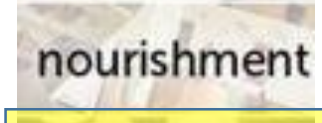
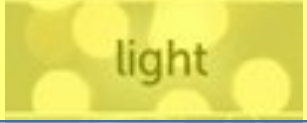
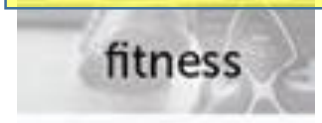
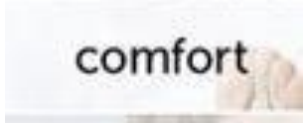
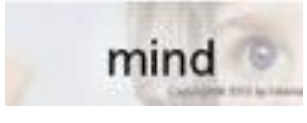
Establish requirements to create a distraction free, productive and comfortable indoor environment.

Require design, technology, and treatment strategies to create a physical environment that optimizes cognitive and emotional health. and altruism

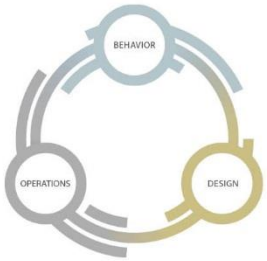
Strategies to Achieve WELL Building Standard Goals

Concept Areas	Strategies
	Filtration - Ventilation - Moisture Control - Construction Protocols -Protection from endogenous pollution
	Water Quality – Filtration - Drinking Water Access
	Access to Healthy Foods - Healthy Portions - Mindful Eating – Food Production - Sanitary Food Prep Areas
	Activity Based Levels – Color Quality - Daylighting – Glare Control – Circadian Design – Visual Acuity
	Interior/Exterior Active Design - Awareness and Habits - Physical Activity Spaces - Activity Based Working
	Thermal – Acoustic – Ergonomic - Olfactory - Accessibility
	Connection to nature – Beauty - Feedback design - Wellness awareness - Adaptable Spaces - Integrative design - Social equity and altruism

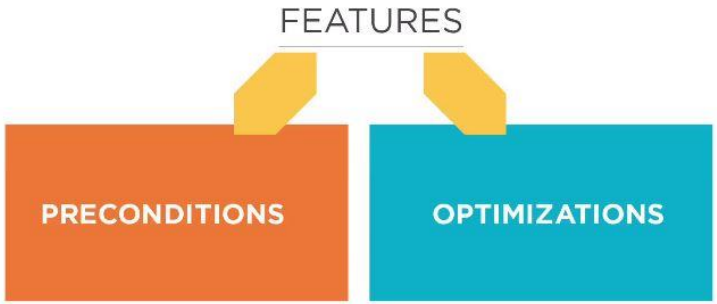
Strategies to Achieve WELL Building Standard Goals

Concept Areas	Strategies
	Filtration - Ventilation - Moisture Control - Construction Protocols -Protection from endogenous pollution
	Water Quality – Filtration - Drinking Water Access
	Access to Healthy Foods - Healthy Portions - Mindful Eating – Food Production - Sanitary Food Prep Areas
	**Activity Based Levels – Color Quality - Daylighting – Glare Control – Circadian Design – Visual Acuity**
	Interior/Exterior Active Design - Awareness and Habits - Physical Activity Spaces - Activity Based Working
	Thermal – Acoustic – Ergonomic - Olfactory - Accessibility
	Connection to nature – Beauty - Feedback design - Wellness awareness - Adaptable Spaces - Integrative design - Social equity and altruism

Structure of the Well Building Standard



WELL Features evaluate ongoing aspects of building performance and occupant behavior to support the operations and maintenance of healthy buildings throughout the building lifecycle.



Projects must meet all Precondition Features across each of the 7 Concepts of the WELL Standard

Silver – Meet All Preconditions

Gold – Meet all Preconditions and 40% of optimizations

Platinum – Meet all Preconditions and at least 80% of optimizations

WELL Certification Process

Light Concept Area

Goals:
Provide illumination guidelines to minimize the disruption to the body's circadian system, enhance productivity and provide appropriate visual acuity. Require specialized lighting systems to increase alertness, enhance occupant experience and promote sleep.

Strategies
Circadian Design
Daylighting
Glare Controls
Color Quality
Activity-based lighting levels
Visual Acuity

WELL Light Features

Feature	Precondition/Optimization
53: Visual Lighting Design	Precondition
54: Circadian Lighting Design	Precondition
55: Electric Light Glare Control	Precondition
56: Solar Glare Control	Precondition
57: Low-Glare Workstation Design	Optimization
58: Color Quality	Optimization
59: Surface Design	Optimization
60: Automated Shading and Dimming Controls	Optimization
61: Right to Light	Optimization
62: Daylight Modeling	Optimization
63: Daylight Fenestration	Optimization

Feature 53: Visual Lighting Design

Part 1: Visual Acuity for Focus - Precondition

Intent: To ensure workers have proper light levels

Key requirements: Maintain at least 20 foot candles at workstation height.

Break large zones into smaller zones.

Provide task lighting if requested.

Verification:

Requires letter of assurance from Architect

Requires Policy Document

Requires Spot Measurement

Feature 53: Visual Lighting Design

Part 2 - Brightness Management Strategies - Precondition

Intent: Maintain a luminance balance to prevent eye strain

Key requirements: (At least 2 of the following)
Maintain brightness contrasts between main rooms and ancillary spaces.

Maintain brightness contrasts between task surfaces and adjacent surfaces.

Maintain brightness contrasts between task surfaces and remote surfaces.

Maintain lighting variety while minimizing dark spots and glare.

Verification: Professional Narrative

Feature 54: Circadian Lighting Design

Part 1: Melanopic Light Intensity for Work Areas - Precondition

Intent: Provide bright, biologically active light to support circadian sleep/wake cycle.

Key requirements: (At least 1 of the following)

For at least 75% of work stations provide at least 200 EML between 9:00am and noon.

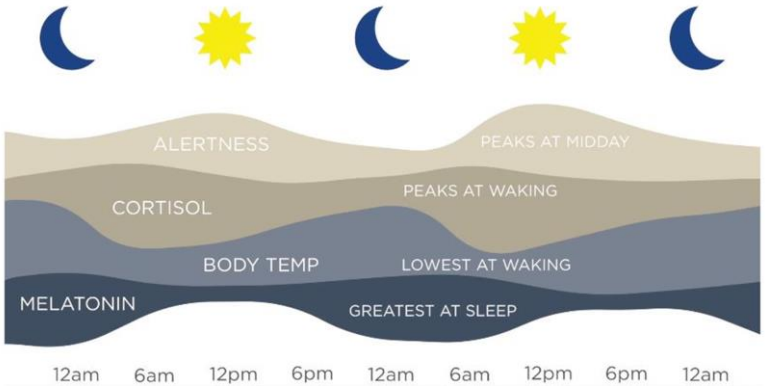
For all workstations maintain at least 150 EML or use IES recommendations for each workstation.

Requirements: Letter of assurance from Architect

On Site spot measurement

Circadian Lighting Emulates the Natural Environment

The eyes detect light and send this information to the brain, triggering the calibration of our 24-hour cycle. Light calibrates the body's biological clock and circadian rhythms direct effects on alertness, mood and cognition



Alignment of our circadian clock is important because it regulates our:

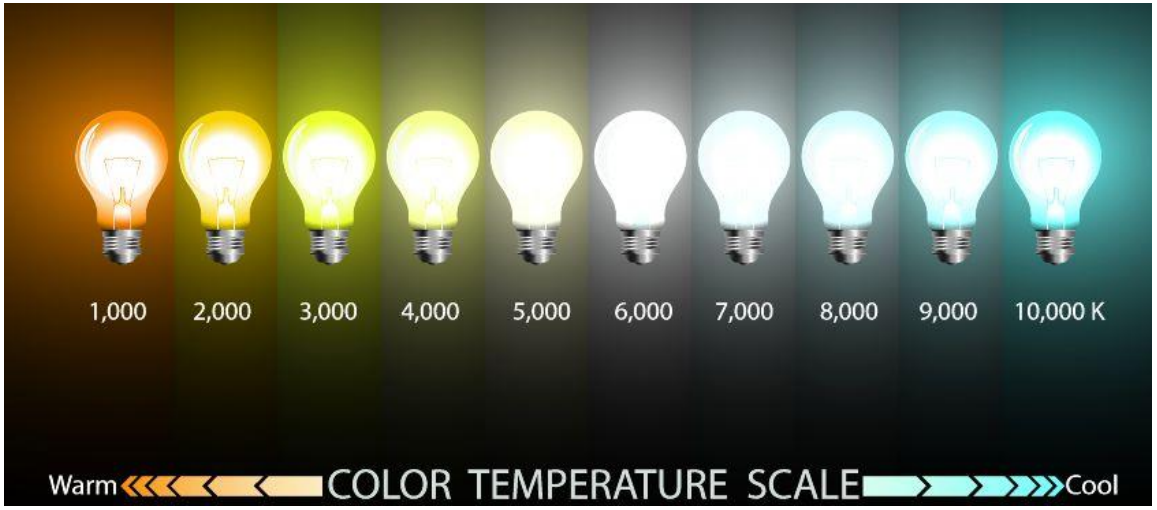
Hormones
Sleep wake cycle
Digestive health
Energy levels
Quality of sleep
And more

Equivalent Melanopic Lux

EML = Measured Lux (L) Multiplied by the Ratio (R) that signifies how biologically active the light source is.
(Blue light is typically more biologically active)

EML = L X R

CCT (K)	Light Source	Ratio
2950	Fluorescent	.43
2700	LED	.45
2800	Incandescent	.54
4000	Fluorescent	.58
4000	LED	.76
6500	Fluorescent	1.02
6500	Daylight	1.1
7500	Fluorescent	1.11



Light Color and Equivalent Melanopic Lux

Lamp: 2950 k
Ratio: .43
Watts: 96
Output @ 100%: 470 Lux

470 X .43 = 202 EML
Lights must be on at 100%
To meet EML requirements.
Watts required = 96

Lamp: 6500 k
Ratio: 1.02
Watts: 96
Output @ 100%: 485 Lux

485 x 1.02 = 495 EML
Dim lights to 41% = 199 Lux
199 x 1.02 = 202 EML @ 41%
Watts Required = 42 Watts

Saves 54 Watts and meets EML requirements.

Why Not use Cool Colored Light Everywhere?

AMBER LENSES TO BLOCK BLUE LIGHT AND IMPROVE SLEEP: A RANDOMIZED TRIAL

Burkhart Kimberly &**Phelps James R.**

Pages 1602-1612 | Received 23 Feb 2009, Accepted 15 Jul 2009, Published online: 23 Dec 2009

http://dx.doi.org/10.3109/07420520903523719

Protective effect of blue-light shield eyewear for adults against light pollution from self-luminous devices used at night

Masahiko Ayaki,Atsuhiko Hattori,Yusuke Maruyama,Masaki Nakano,Michitaka Yoshimura,Momoko Kitazawa, show all

Pages 134-139 | Received 05 Sep 2015, Accepted 09 Nov 2015, Published online: 05 Jan 2016

• http://dx.doi.org/10.3109/07420528.2015.1119158

Wearing blue light-blocking glasses in the evening advances circadian rhythms in the patients with delayed sleep phase disorder: An open-label trial

Yuichi Esaki,Tsuyoshi Kitajima,Yasuhiro Ito,Shigefumi Koike,Yasumi Nakao,Akiko Tsuchiya, show all

Pages 1037-1044 | Received 23 Mar 2016, Accepted 23 May 2016, Published online: 20 Jun 2016

•Download citation

• http://dx.doi.org/10.1080/07420528.2016.1194289

High Sensitivity of the Human Circadian Melatonin Rhythm to Resetting by Short Wavelength Light

Steven W. Lockley George C. Brainard Charles A. Czeisler

The Journal of Clinical Endocrinology & Metabolism, Volume 88, Issue 9, 1 September 2003, Pages 4502–4505, https://doi.org/10.1210/jc.2003-030570

Published:

01 September 2003

High Sensitivity of Human Melatonin, Alertness, Thermoregulation, and Heart Rate to Short Wavelength Light

Christian Cajochen Mirjam Münch Szymon Kobialka Kurt KräuchiRoland Steiner Peter Oelhafen Selim Orgül Anna Wirz-Justice

The Journal of Clinical Endocrinology & Metabolism, Volume 90, Issue 3, 1 March 2005, Pages 1311–1316, https://doi.org/10.1210/jc.2004-0957

Mol Vis. 2016; 22: 61–72.

Published online 2016 Jan 24.

PMCID: PMC4734149

Effects of blue light on the circadian system and eye physiology

Gianluca Tosini,corresponding author1 Ian Ferguson,2 and Kazuo Tsubota3

Feature 55: Electric Light Glare Control

Part 1: Luminaire Shielding and Part 2 Glare Minimization - Precondition

Intent: To reduce glare and minimize eyestrain.

Key requirements:

Part 1: Provide appropriate shielding

Part 2: For seating areas Luminaires more than 53° above the center of view (degrees above horizontal) have luminances less than 8,000 cd/m².

Verification: Letter of assurance from architect.

Feature 58: Color Quality

Color Rendering Index - Optimization

Intent: To accurately portray colors and Enhance occupant comfort

Key requirements:

Color Rendering Index Ra (CRI, average of R1 through R8) of 80 or higher.

Color Rendering Index R9 of 50 or higher

Verification: Letter of Assurance from Architect

Summary

- Projects (and customers) with color tuning requirements are growing rapidly.
- Understand the limitations of the designed/specified system to ensure proper time allocation of your commissioning team
- Define the sequence of operations as early as possible. Be detailed.
- The WELL standard puts an emphasis on lighting and lighting quality. Use that as leverage – even if the building is not following WELL - to drive obtaining the best solution for your clients.


QUESTIONS?

This concludes The American Institute of Architects
Continuing Education Systems Course

Eric Lind

fjlind@Lutron.com