Designers Light Forum

Lighting Quality Metrics for Products and Projects

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

Learning Objectives

At the end of the this course, participants will have a better understanding of:

1. What quality-of-light metrics are available in the industry both at the product and project level

2. How quality-of-light metrics are applied to benefit the lighting design process

3. The limitation of metrics, and when they should be supplemented by other, qualitative and observational design strategies

4. How metrics can differ between being applied at the luminaire, lighting system or lighting project level

TABLE OF CONTENTS

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PHASES: TYPICAL LIGHTING PROJECT

PROGRAMMING

user needs and preferences
psychological needs
circadian / biological needs
visual task
quantity/quality of lighting
glare and visual comfort
architectural features
daylighting
color and color rendering
flexibility of function
controls requirements
security
budget
efficiency/efficacy
environmental impact
operating cost
maintenance
energy and resources
building/ electrical codes

SCHEMATIC DESIGN

user needs and preferences
psychological needs
circadian / biological needs
visual task

SAME AS Programming *plus*:

TASKS:
mockups
preliminary budget
concepts presentation

maintenance
energy and resources
building/ electrical codes

DESIGN DEVELOPMENT

user needs and preferences
psychological needs
circadian / biological needs
visual task

SAME AS Programming *plus*:

coordination with bldg systems
coordination with furniture
product availability check

TASKS:
develop details
luminaire selection
lighting and controls plan

maintenance
energy and resources
building/ electrical codes

CONSTRUCTION DOCUMENTATION

coordinate with architecture
electric/ daylighting controls
check for function changes
finalize controls design
check budget
verify maintenance
check energy code compliance
check bldg/elec code compliance
coordinate with bldg systems
coordinate with furniture/built-ins
check product availability

TASKS:
controls schedule/specs
detail drawings
lighting schedule/specs
lighting and controls plan

BID

TASKS:
clarification for contractors

CONSTRUCTION

TASKS:
submittal review
construction observation
field problem coordination
project punch list
final adjustments

EVALUATION

post occupancy evaluation

TASKS:
Asses if project meets objectives
Takes notes to help inform future design projects

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LIGHTING QUALITY METRICS FOR **PROJECTS** AND PRODUCTS

Quality-of-Light at the installation level requires:

Quality Luminaires

Quality layout and design

(including finishes and materials)

Quality installation and integration

Commissioning and aiming

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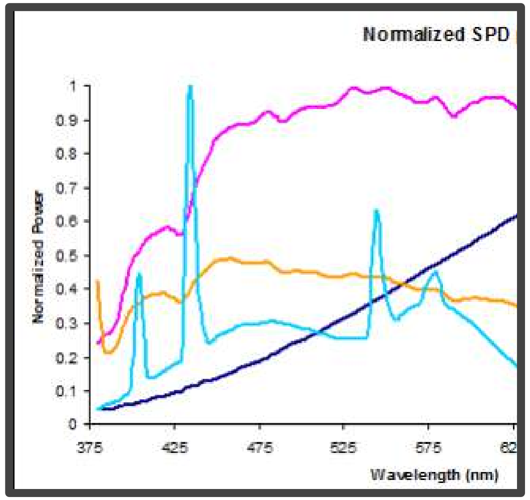
LIGHTING QUALITY METRICS FOR **PROJECTS** AND PRODUCTS

Quality in finished projects is often accomplished using:

Good communication with client, reps, contractors, etc
(renderings, BID clarifications)

Simulation / Design software



Software adding spectral distribution information has been developed

Targeted mock-ups
(testing pre-selected options)

Image credits:
https://lightinganalysts.com/software-products/agi32/overview/
Kate Sweater

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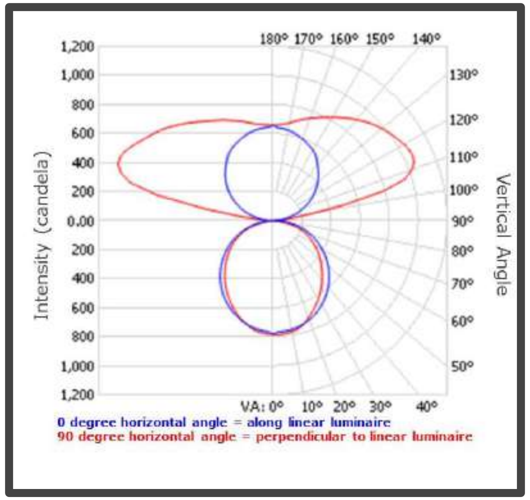
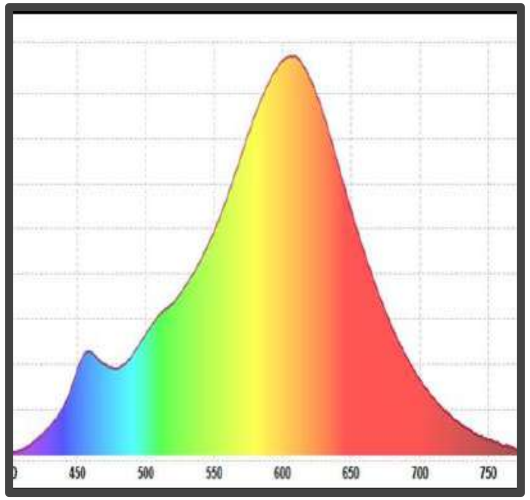
LIGHTING QUALITY METRICS FOR PROJECTS AND **PRODUCTS**

The information is obtained by measuring:





Photometric distribution

- .ies file

Photometric distribution

- goniophotometer

Spectral power distribution

- integrating sphere

Spectral power distribution

- .spdx file

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LIGHTING QUALITY METRICS FOR PROJECTS AND **PRODUCTS**

Quality-of-Light metrics characterize luminaire properties, including:

Color Quality
- color of light
- color rendering

Optical Light Distribution

Glare

Alertness / Circadian Effects

Image credits:
Don Slater, NightTime Design
Ute Besenecker

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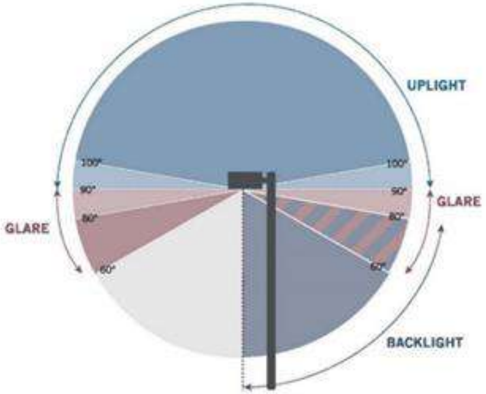
LIGHTING QUALITY METRICS

Definitions and Examples

DISTRIBUTION

- Uniformity and contrast ratios
- Polar plot, beam angle and field angle
- BUG rating (Backlight, Uplight and Glare) defines the distribution from a luminaire within three primary solid angles: forward-, back-, and up-light.



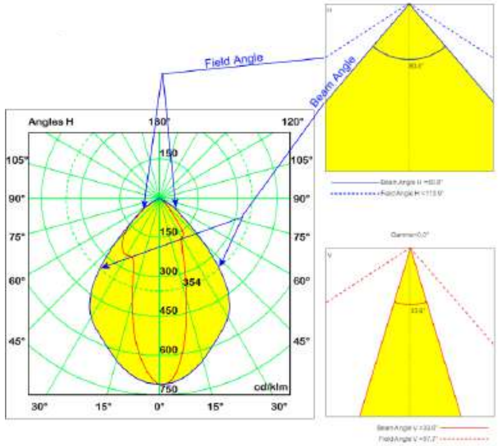


Image credits:
DOE's Overview of Fitted Target Efficacy (FTE), 2009
California Lighting technology Center, UC Davis
https://ransenlightingandcolor.blogspot.com/2016/11/how-to-calculate-beam-angle-field-angle.html

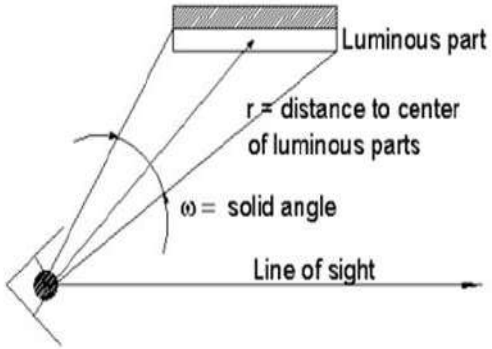
LIGHTING QUALITY METRICS

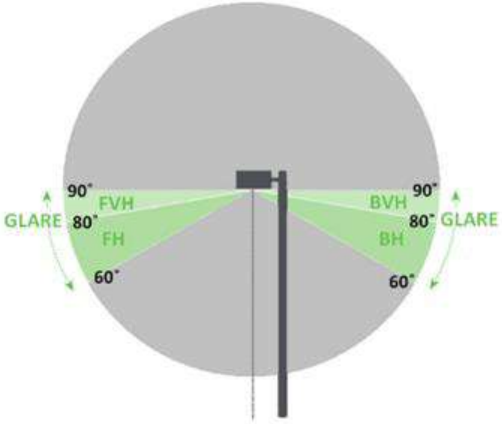
Definitions and Examples

GLARE

- Discomfort glare factors:
    - luminance of the source
    - source size
    - illuminance and luminance of the surround / background
    - distance / position in the field of view

- UGR is an indoor discomfort glare likelihood assessment method.
- UGR tables are based on pre-set room definitions and summarize different room reflectances and geometries.





Reflectances:											
Ceiling (cavity)		0.7	0.7	0.5	0.5	0.5	0.7	0.7	0.5	0.5	0.5
Wall		0.5	0.3	0.5	0.3	0.3	0.5	0.3	0.5	0.3	0.3
Reference plane		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Room Dimensions		Viewed crosswise					Viewed endwise				
X=2H	Y=2H	8.9	10.5	9.3	10.8	11.1	10.7	12.2	11.0	12.5	12.9
	3H	10.5	11.9	10.8	12.2	12.6	12.4	13.8	12.8	14.2	14.5
	4H	11.0	12.3	11.4	12.6	13.0	13.1	14.5	13.5	14.8	15.2
	6H	11.5	12.7	11.9	13.1	13.5	13.6	14.8	14.0	15.2	15.6
	8H	11.7	12.9	12.2	13.3	13.7	13.8	14.9	14.2	15.3	15.7
	12H	12.0	13.2	12.5	13.5	14.0	13.8	15.0	14.3	15.3	15.8
4H	2H	9.6	11.0	10.0	11.3	11.7	11.0	12.4	11.4	12.7	13.1
	3H	11.4	12.5	11.8	12.9	13.3	13.0	14.1	13.4	14.5	14.9
	4H	12.0	13.0	12.4	13.4	13.9	13.9	14.9	14.3	15.3	15.7
	6H	12.7	13.5	13.1	14.0	14.4	14.5	15.4	15.0	15.8	16.3
	8H	13.0	13.8	13.5	14.2	14.7	14.7	15.5	15.2	16.0	16.4
	12H	13.4	14.1	13.8	14.6	15.0	14.8	15.6	15.3	16.0	16.5
8H	4H	12.4	13.2	12.8	13.6	14.1	14.0	14.8	14.5	15.3	15.8
	6H	13.2	13.8	13.7	14.3	14.8	14.8	15.4	15.3	15.9	16.4
	8H	13.6	14.2	14.1	14.7	15.2	15.0	15.6	15.5	16.1	16.6
	12H	14.1	14.7	14.6	15.1	15.7	15.2	15.7	15.7	16.2	16.8
12H	4H	12.4	13.1	12.9	13.6	14.1	14.0	14.8	14.5	15.2	15.7
	6H	13.2	13.8	13.8	14.3	14.8	14.8	15.4	15.3	15.9	16.4
	8H	13.7	14.3	14.3	14.8	15.3	15.1	15.6	15.6	16.1	16.7

Image credits:
https://docs.agi32.com/AGi32/Content/adding_calculation_points/Calculations_UGR_Concepts.htm
California Lighting technology Center, UC Davis

LIGHTING QUALITY METRICS

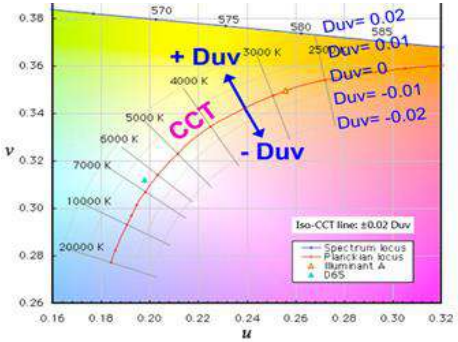
Definitions and Examples

COLOR OF LIGHT

- Correlated Color Temperature (CCT)
- Chromaticity
- *D*uv+ indicates a chromaticity above the BBL, on the green side, *D*uv- below, on the pink/purple side

COLOR RENDERING

- Effect of an illuminant on the color appearance of objects (in comparison to a reference illuminant)
- Common Metrics: Fidelity index, Gamut index, Red rendering



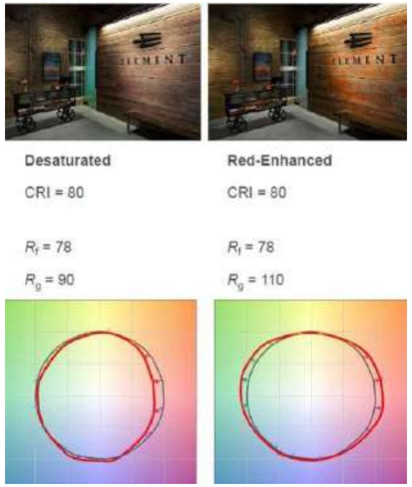


Image credits:
Don Slater, NightTime Design
http://www.asensetek.com/knowledge-duv/
DOE/IES 2015, Understanding and Applying TM-30-15

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LIGHTING QUALITY METRICS

Definitions and Examples

We are frequently using metrics (whether we realize it or not)

Metrics are used when selecting fixtures for:

- ➔ circadian/biological needs
- ➔ visual task
- ➔ glare or visual comfort
- ➔ color or color rendering
- ➔ controls requirements
- ➔ efficiency/ efficacy
- ➔ energy resources
- ➔ meeting bldg/electrical codes
- ➔ lumen maintenance

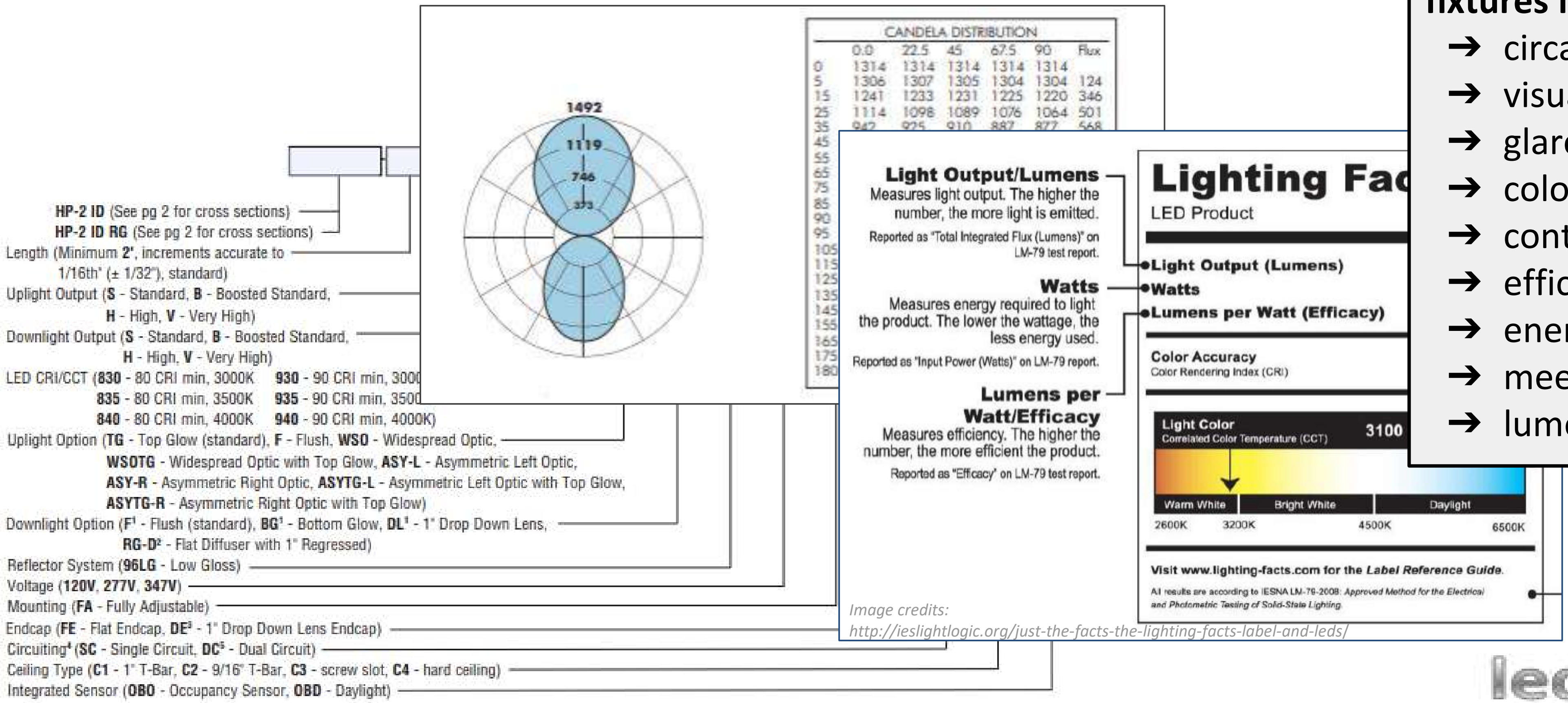

Image credits: http://ieslightlogic.org/just-the-facts-the-lighting-facts-label-and-leds/

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APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Image credits: Finished lighting installation of pathway lighting at Baker Hall, Dartmouth College. Firm: LTLDA, lead designer Kate Sweater

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Design Criteria

Distribution	Fixtures should allow for a variety of distributions and light-outputs, for flexibility in future installations - and to allow for greatest uniformity
Distribution	Fixtures had to be full cut-off to reduce sky glow
Glare	Fixtures should be non-glary
Color of Light	Fixtures should match in color temperature for consistency across campus
Color Rendering	Fixtures to allow for excellent recognition of people and objects at night
Sensitivity to Environment	Lighting levels needed to meet task criteria while maintaining low lighting levels to respect the rural setting
Controllability	Fixtures had to be dimmable to work with controls system
Aesthetics	Fixtures should match aesthetically to previously selected pedestrian standard fixtures

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Distribution / Uniformity

Light output uniformity was a priority on this project

Fixture distribution was the key to achieving uniformity

- How do metrics play into fixture selection?
- How did we know the lighting would be uniform?

Image credits: Finished lighting installation of pathway lighting at Baker Hall, Dartmouth College. Firm: LTLDA, lead designer Kate Sweater

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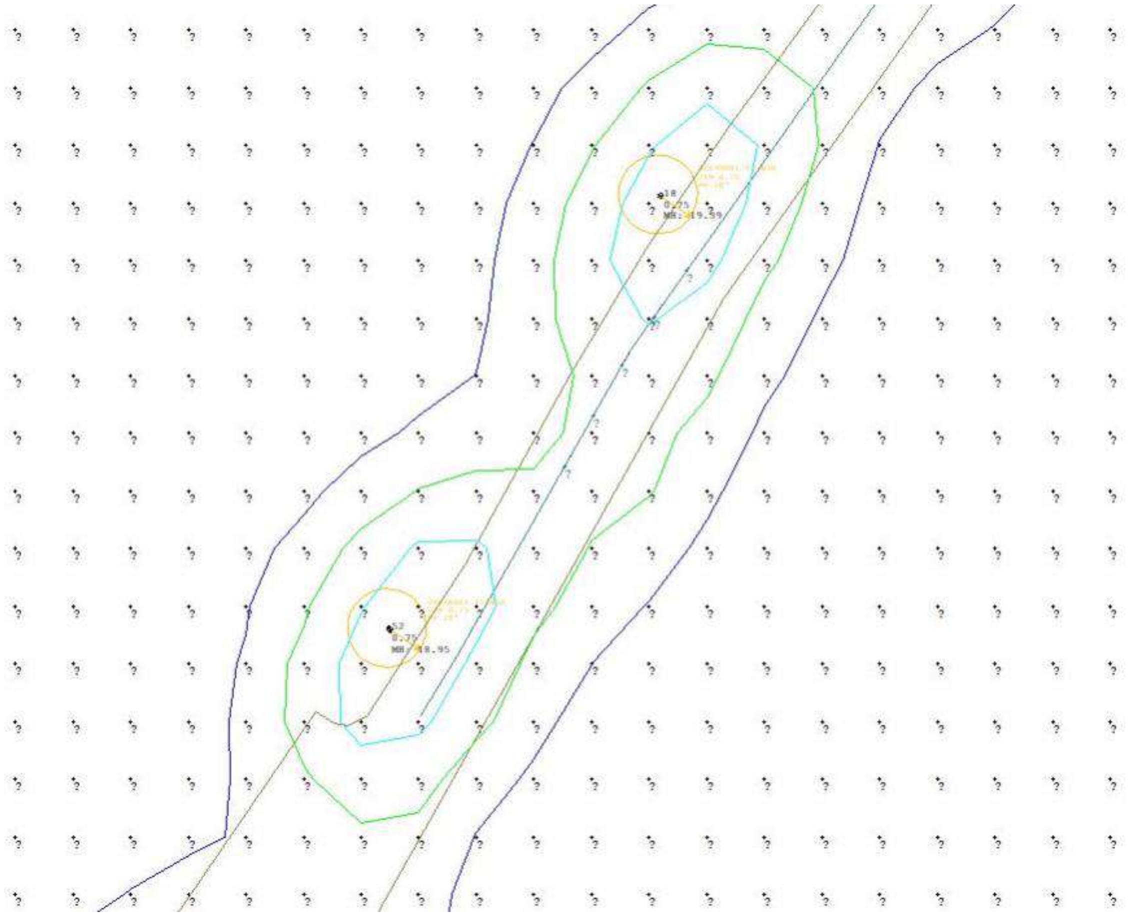
CALCULATION SUMMARY

Draft Illumination Level Recommendations	
Average Maintained Illuminance (horizontal)	0.5 fc
Ave/Min Uniformity	6:1
Average Vertical Illuminance at 6' (for walkways)	not less than 0.5

Estimated Illuminance Values from Photometric Software	
Average Illuminance (horizontal)	0.63 fc
Maximum Illuminance (horizontal)	2.1 fc
Minimum Illuminance (horizontal)	0.2 fc
Ave/Min Uniformity	3.15:1
Average Vertical Illuminance at 6' (along bike path)	1.09 fc



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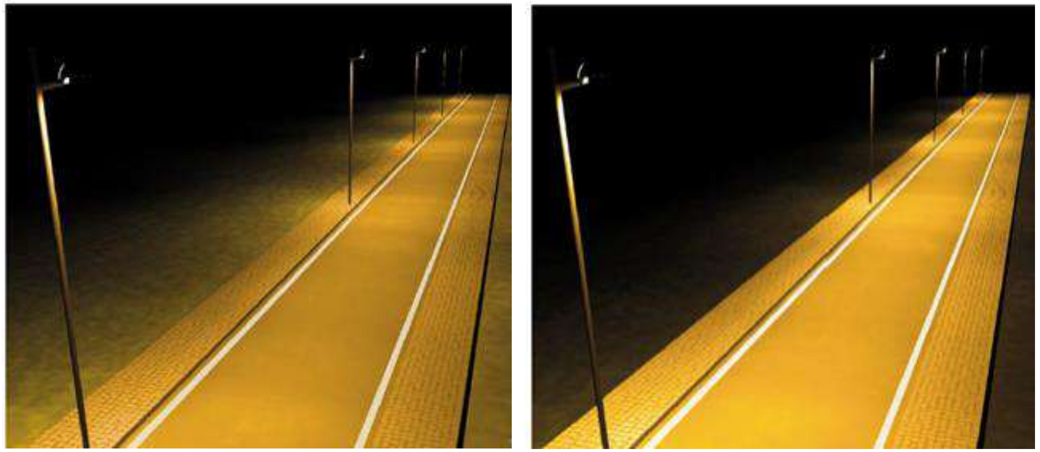

Image credits:
Photo by Kate Sweater
DOE's Overview of Fitted Target Efficacy (FTE), 2009

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APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Distribution / Sky Glow

Minimize sky glow from our fixtures, in consideration of the rural environment

Specify a fixture based on the IESNA* cut-off classifications

- Full Cutoff
- Cutoff
- Semi-cutoff
- Non-cutoff

How do you know which classification your fixture falls into if it is not on the cut sheet?

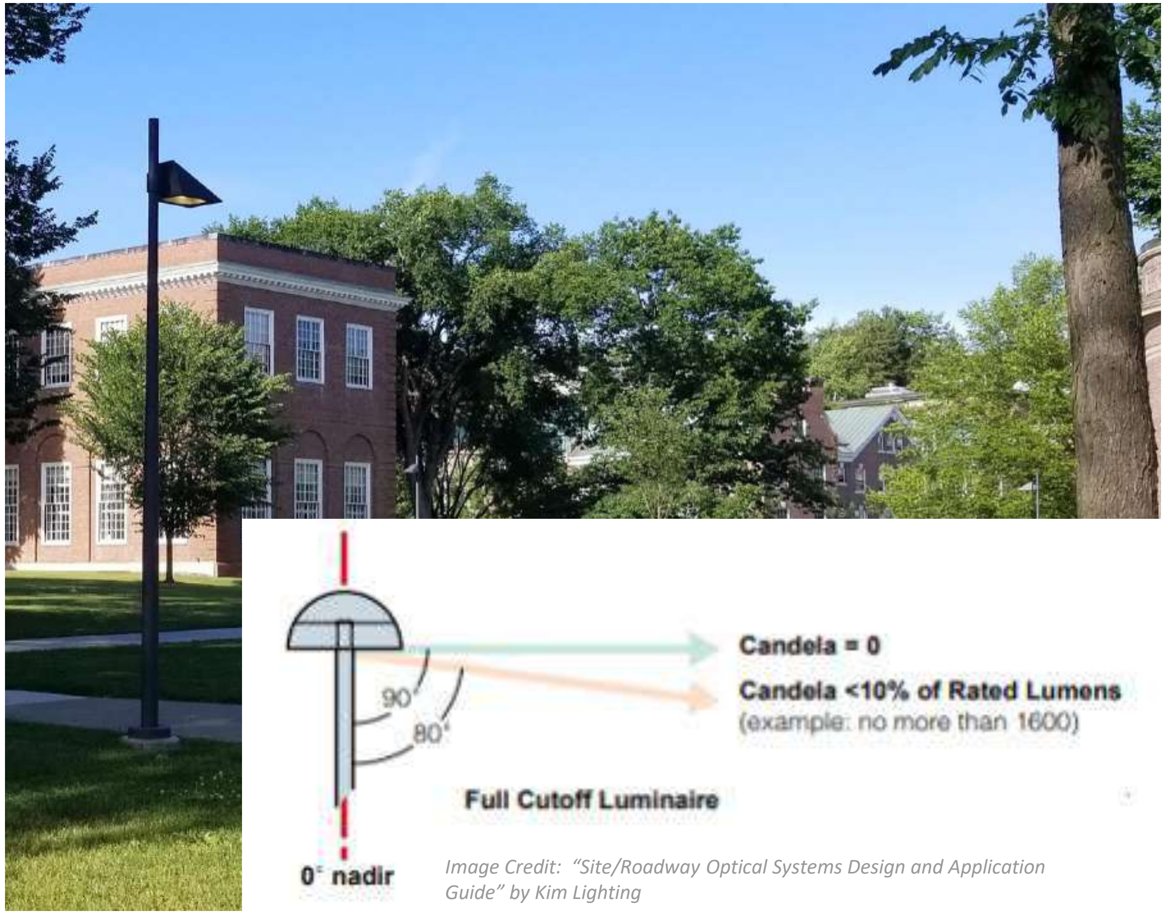

Image Credit: "Site/Roadway Optical Systems Design and Application Guide" by Kim Lighting

Image credits: Finished lighting installation of pathway lighting at Baker Hall, Dartmouth College. Firm: LTLDA, lead designer Kate Sweater

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*Illuminating Engineering Society of North America

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- Cutoff
- Semi-cutoff
- Non-cutoff

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ZONAL LUMEN SUMMARY

Zone	Lumens	%Lamp	%Fixt
0-20	321.92	N.A.	6.00
0-30	763.25	N.A.	14.20
0-40	1442.81	N.A.	26.90
0-60	3428.14	N.A.	63.90
0-80	5319.02	N.A.	99.10
0-90	5365.91	N.A.	100.00
10-90	5288.27	N.A.	98.60
20-40	1120.89	N.A.	20.90
20-50	2043.6	N.A.	38.10
40-70	3085.32	N.A.	57.50
60-80	1890.88	N.A.	35.20
70-80	790.90	N.A.	14.70
80-90	46.89	N.A.	0.90
90-110	0.00	N.A.	0.00
90-120	0.00	N.A.	0.00
90-130	0.00	N.A.	0.00
90-150	0.00	N.A.	0.00
90-180	0.00	N.A.	0.00
110-180	0.00	N.A.	0.00
0-180	5365.91	N.A.	100.00

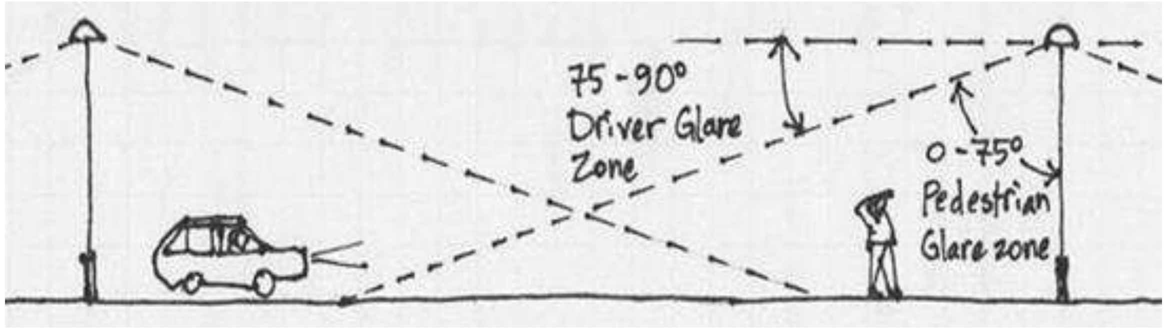
*Illuminating Engineering Society of North America

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Outdoor Glare

Will you know by reading fixture information and metrics if a fixtures will be glary?

- Glary for whom and from what location?
- Do you also need to view the fixture in person?
- What metrics are available?



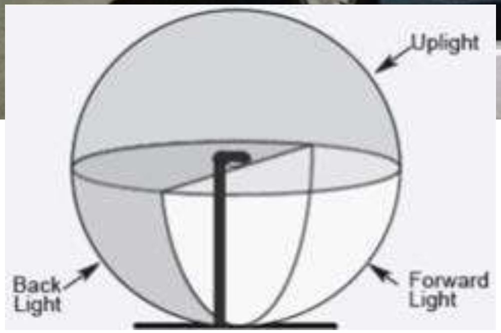


Image credits:
PNNL, Naomi Miller
IES TM-15-11
Kate Sweater

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APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Glare

What can Metrics tell us?

- BUG and Cut-off classifications
- Other Metrics (e.g., DG, UGR,...)

What more do we need to know?

- Illuminance source
- Luminance source

- Illuminance surrounding the source
- Ambient illuminance at source location
- Background luminance

- Angular distance between observer and source, position in the field-of-view

- Source size

Image credits:
Kate Sweater
Ute Besenecker

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Brightness

SPECTRUM

- does play a role in scene brightness (and glare)

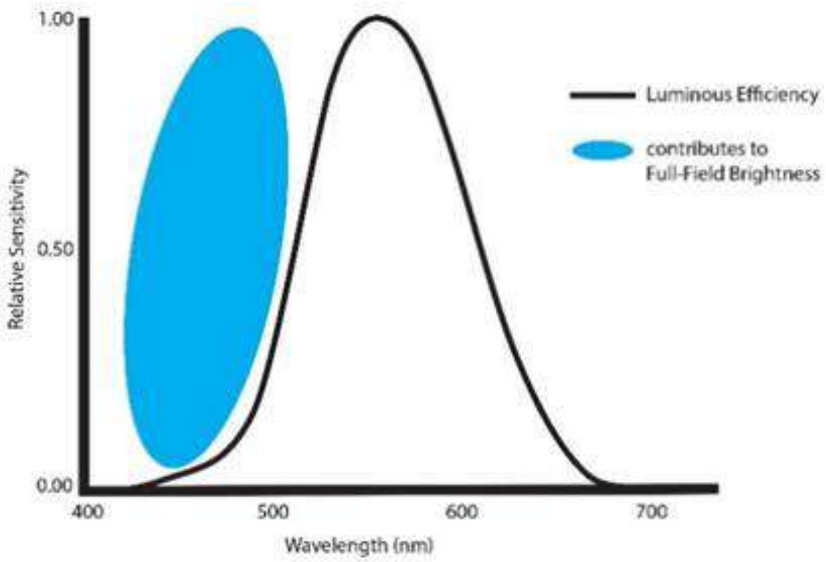

Image credits:
www.ledlite-power.co.uk--LPS-vs-LED
www.wheelshonda.com_xenon-blue-headlights

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Color of Light / CCT

New standard campus fixture needed to match aesthetically with the previously selected standard pedestrian pathway fixture

Fixtures across campus also need to match at nighttime

- Is CCT all we need to know in order to reduce variation in the color of light at night?

Image Credits:
Nantes by night (© Didier Robcis photography)
https://www.lec-expert.com/topics/the-colour-rendering-index-at-the-led-test-bench
Kate Sweater

APPLICATION EXAMPLE: DARTMOUTH COLLEGE

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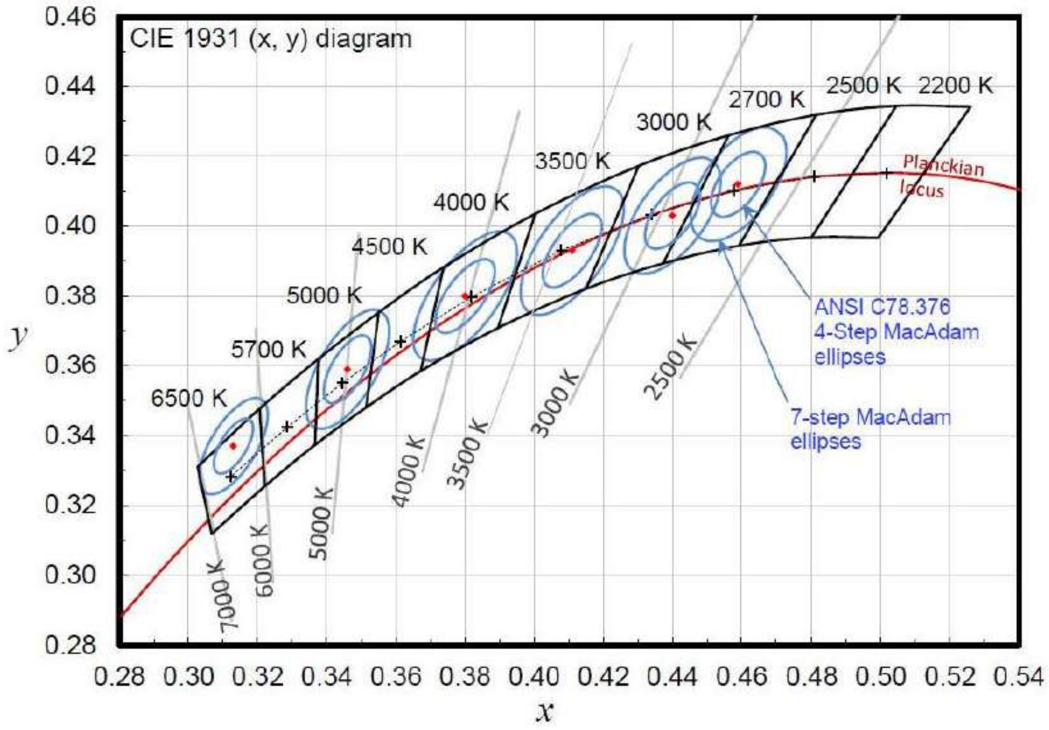

Image credits:
NEMA ANSI C78.377-2017

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APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Color Rendering

Good color rendering allows for better identification of people or objects at night.

- How do we understand how the lighting we are specifying will render the surrounding environment?

- What are some metrics we can use to better understand?

Image credits: Fixtures along a driveway at night. Photo by Kate Sweater

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APPLICATION EXAMPLE: DARTMOUTH COLLEGE

Color Rendering

Good color rendering allows for better identification of people or objects at night.

- How do we understand how the lighting we are specifying will rendering the surrounding environment?

- CRI (Ra)
- TM-30-18 (Rf & Rg)

Image credits:
http://www.lightingservicesinc.com/sites/default/files/_/resources/lsi_tm-30_shedding_new_light_on_color_rendering_1.pdf
https://insights.regencylighting.com/answering-your-questions-on-light-color-and-quality-ask-the-expert-series

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APPLICATION EXAMPLE: OPENING THE EDGE

Color Rendering

Color rendering at night is important both for:

- safety and security (for identification)
- in order to render the color artwork in the environment.

Both fidelity and saturation are important parameters

Image credits: model of Opening the Edge green-space, a project of the Design Trust for Public Space - photo by Kate Sweater. Bird's eye view by Destiny Mata

APPLICATION EXAMPLE: ELECTRIC GARDEN

Color Rendering

Elements in the space feature color saturated *materials* such as

- Blue velour walls
- Marbled floors
- Shag carpeting walls (acoustic)

Or deep *saturated colored lighting*

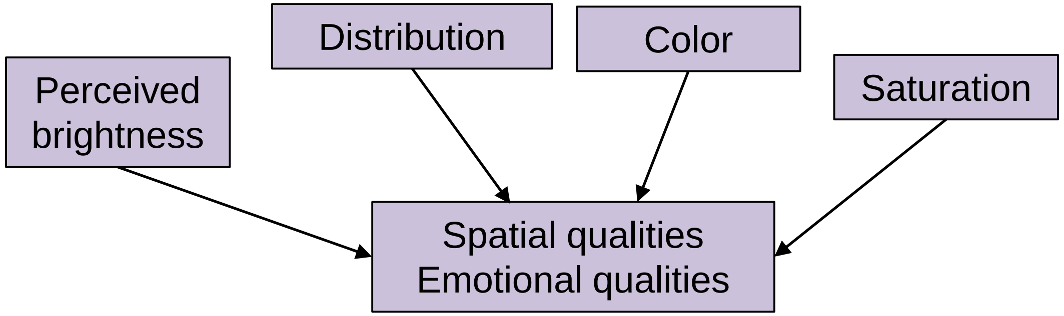
How to select the lighting based on the mood, but also for the required tasks?

Image credits: Electric Garden Recording Studio in Brooklyn NY. Photo by F. Oudeman

APPLICATION EXAMPLE: ELECTRIC GARDEN

Mood and Atmosphere Considerations

- There are no direct metrics
- There are some correlations



METHODS

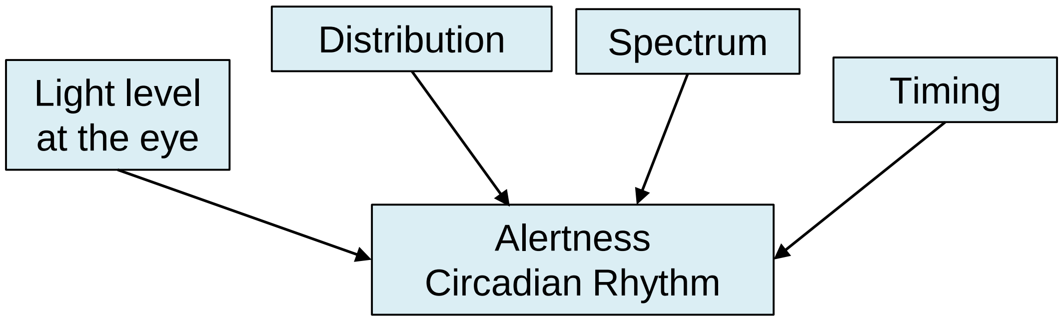
- Use of common associations (e.g. sky-blue, fire-red)
- Use of fixtures and controls that provide desired options

Image credits: Electric Garden Recording Studio in Brooklyn NY. Photo by Ben Kane

APPLICATION EXAMPLE: ELECTRIC GARDEN

Alertness and Circadian Considerations

- There are preliminary metrics (spectrum)
- There are preliminary recommendations



METHODS

- Use of melanopic and circadian stimulus measures
- Use of fixtures and controls that provide desired options

Image credits: Electric Garden Recording Studio in Brooklyn NY. Photo by F. Oudeman

APPLICATION EXAMPLE: ELECTRIC GARDEN

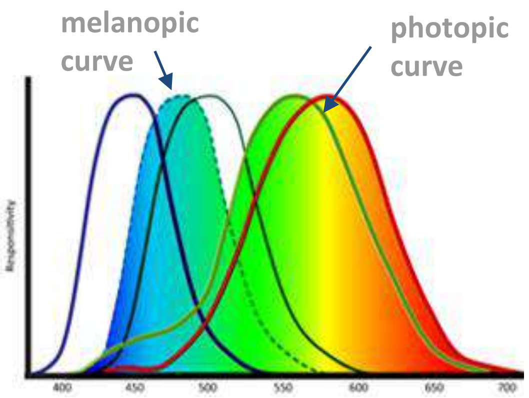
Spectrum and Spectral Tuning

LED spectrum customization

Looking similar with different composition

- Different ability to render color
- Different impact on the non-visual system

EYES' SPECTRAL SENSITIVITIES



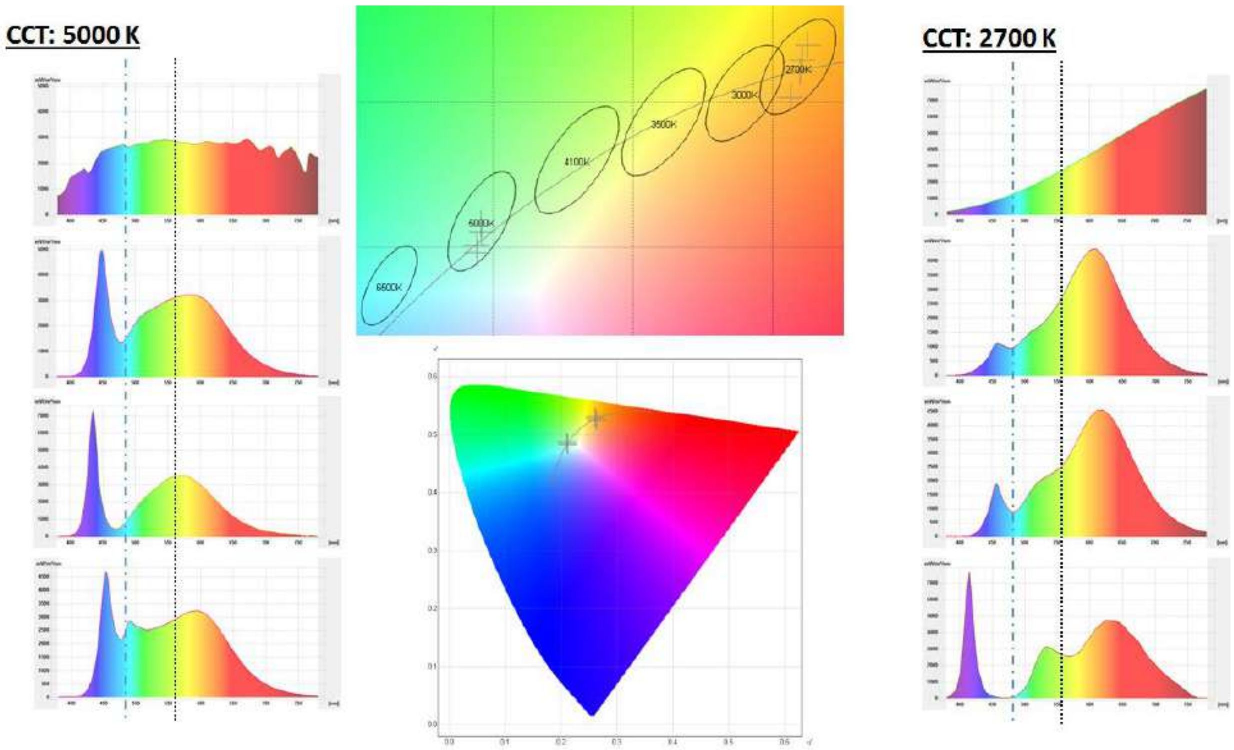


Image credits:
Ute Besenecker

APPLICATION EXAMPLE: ELECTRIC GARDEN

Alertness and Circadian Considerations

METRICS

- Melanopic Flux, Illuminance, and Ratios
- Circadian Stimulus (CS) Calculator

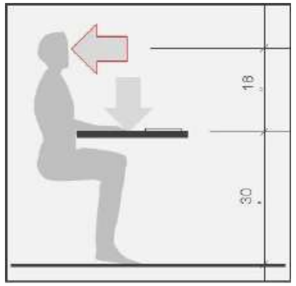
GENERAL RECOMMENDATIONS

Morning/Day/Alerting:

- High melanopic content
- High light level
- High CS

Evening/Night/Relaxing:

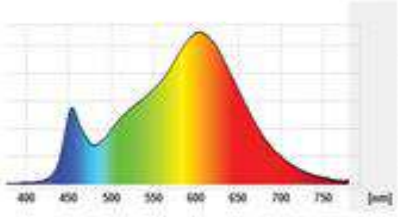
- Low melanopic content
- Low light level
- Low CS



Light at the Eye

IMPACT OF FINISHES

white light white surface



white light yellow surface

white light teal surface

Image credits: http://decordots.com/wp-content/uploads/2013/07/all-white-living-room.-Eco-white-Borge.jpg
Ute Besenecker

APPLICATION EXAMPLE: ELECTRIC GARDEN

Other Considerations

LIGHTING FOR PLANTS

- Plant growth without daylight
- Plant looks (color rendering)

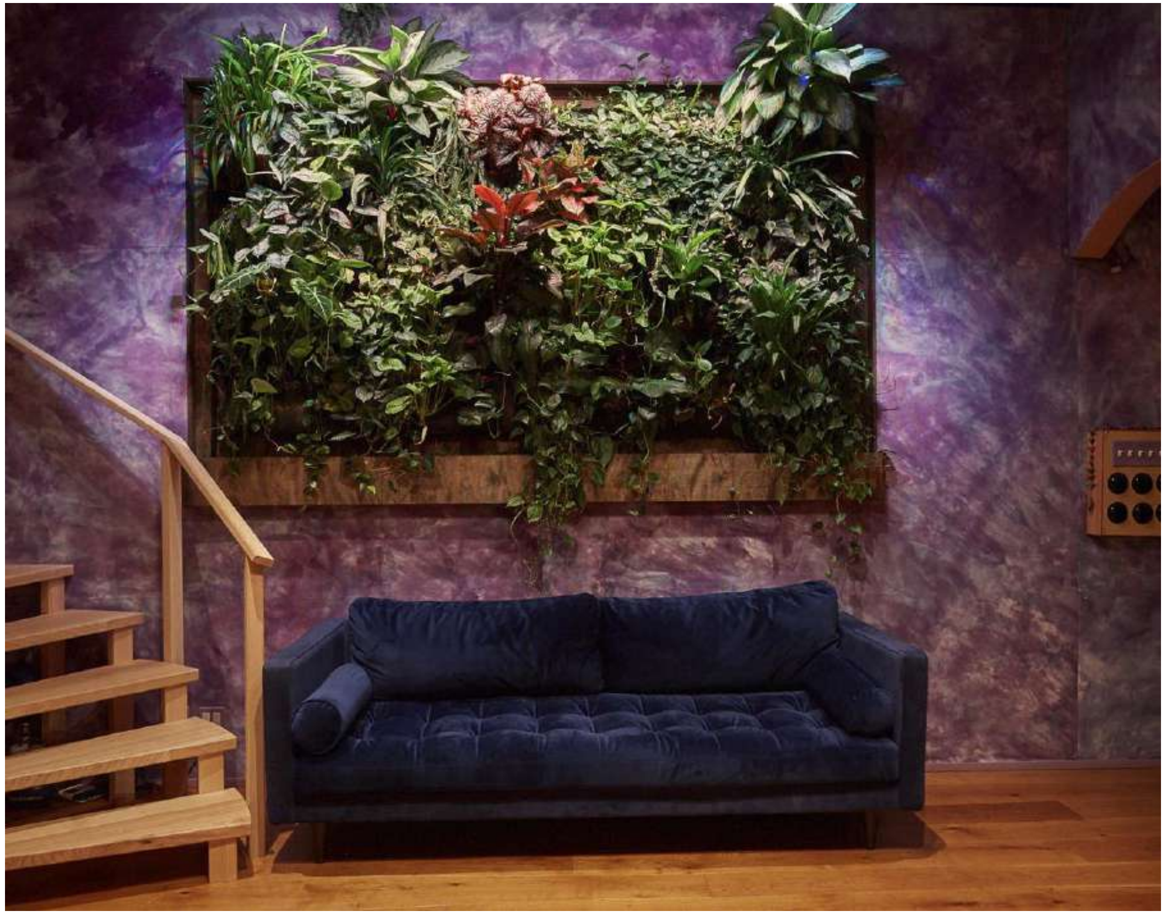


Image Credits: Electric Garden Recording Studio in Brooklyn NY. Photo by Ben Kane

SUMMARY

PRODUCTS

- Measurement files such as .ies or .spdx can help to meet design criteria
- Metrics are being developed and updated all the time
- Software helps us to select fixtures
- Limitations: some design criteria have no metrics

PROJECTS

- Simulations can be performed using measurement files such as .ies or .spdx
- Aiming and commissioning is critical
- Limitations: some design criteria require evaluation of the fixture in the installation environment

Kate

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DISCUSSION & QUESTIONS

Do you have any questions?

Our questions to you:

- What are your strategies for estimating glare on a project?
- Do you have any project examples where metrics played a big role?
- Are there any other metrics you feel we should have discussed?
- How do you determine the best luminaire spacing?

This concludes The American Institute of Architects Continuing Education Systems Course

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