What is Ideal Light?

The Office Environment

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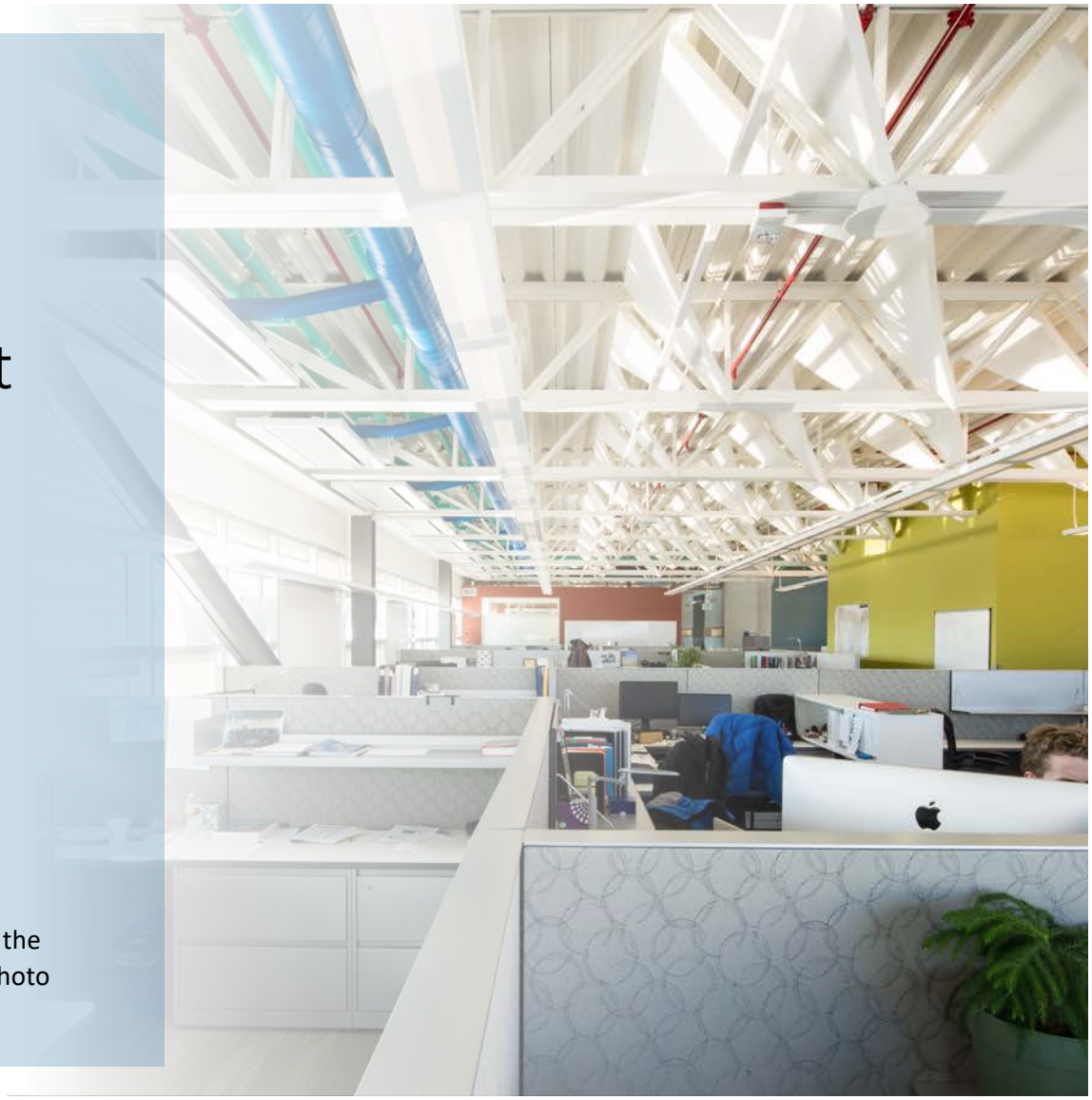


Office space in the Energy Systems Integration Facility at the National Renewable Energy Laboratory in Golden, CO. Photo by Dennis Schroeder / NREL

What is Ideal Light?

Better than that of today!

Office Lighting Design Goals

The Big Picture

Supports human health and wellbeing

- Meets basic needs for tasks and comfort
- Promotes health
- Promotes positive emotion
- Promotes engagement

Supports climate change mitigation and adaptation

- Supports zero energy buildings
- Supports zero carbon communities
- Supports resilient infrastructure

Office Lighting of Today

Common Attributes

Does so using *common* source spectrum and luminaire forms, intensity distribution, and layouts

Supports human health and wellbeing

Meets basic needs for tasks and comfort

Promotes health

Promotes positive emotion

Promotes engagement

Contrast

Glare

Flicker

Supports climate change mitigation and adaptation

Supports zero energy buildings

Supports zero carbon communities

Supports resilient infrastructure

Office Lighting of Today

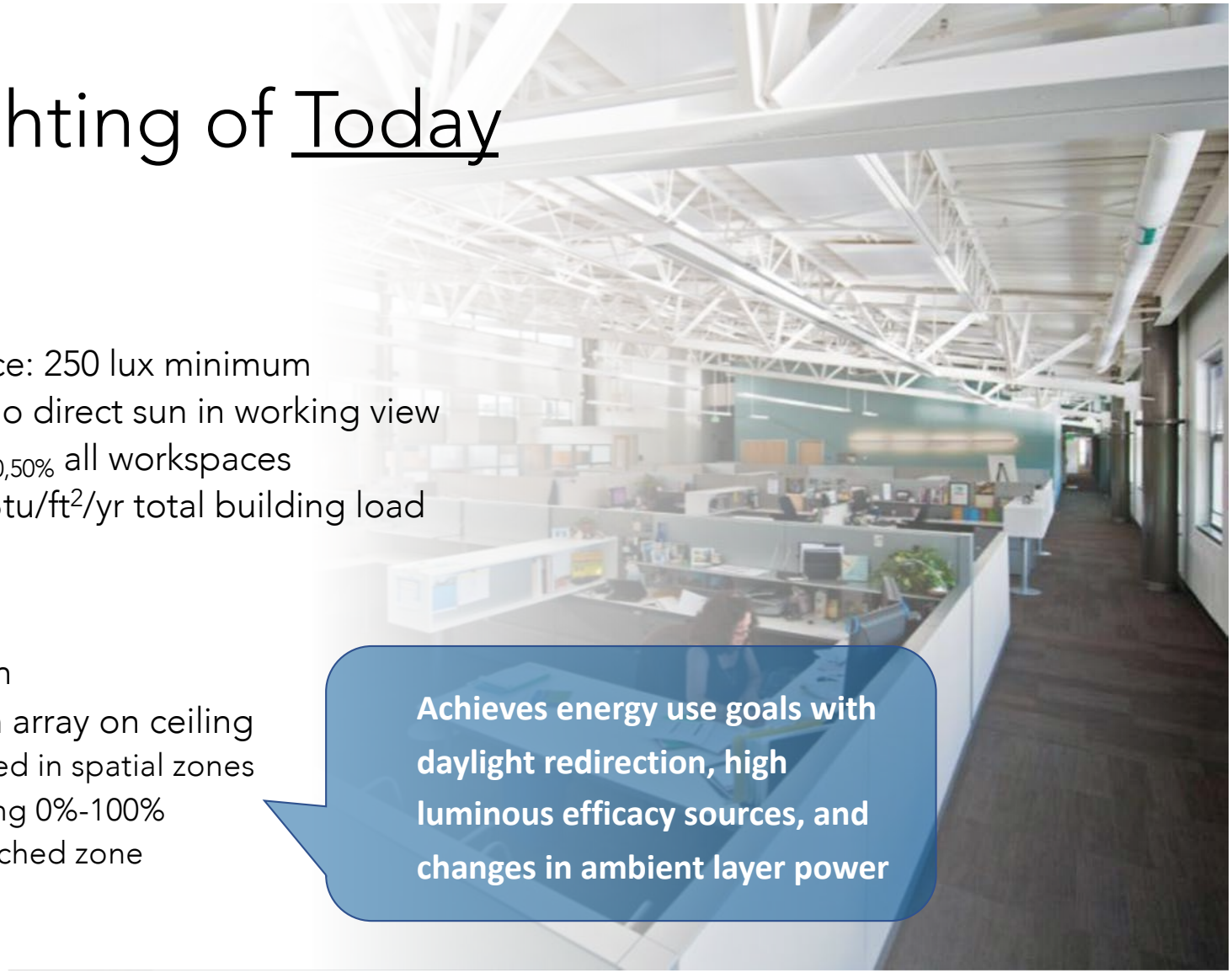
A Solution

Design constraints

- Ambient illuminance: 250 lux minimum
- Glare mitigation: No direct sun in working view
- Daylighting: $sDA_{300,50\%}$ all workspaces
- Energy use: <25 kBtu/ft^2/yr total building load

Design response

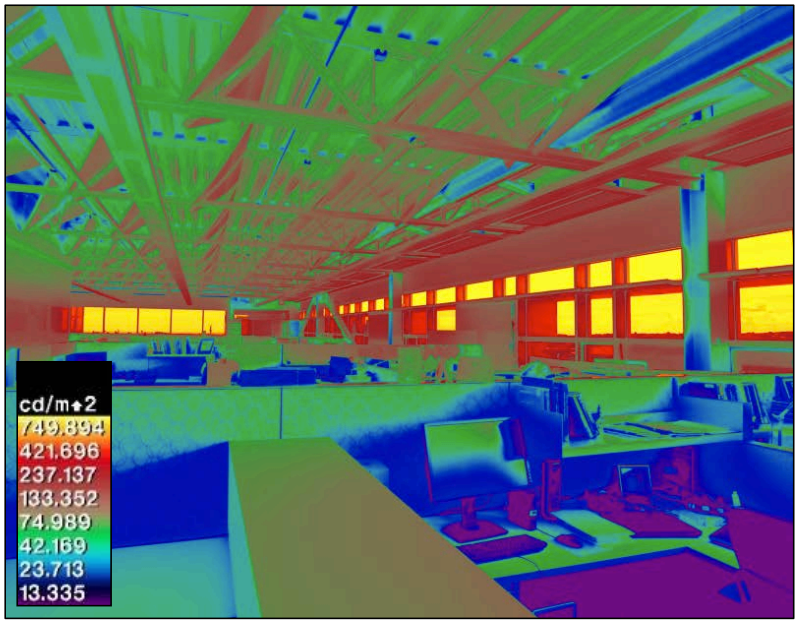
- Daylight redirection
- Layers of light from array on ceiling
  - Ambient, switched in spatial zones
  - Daylight, dimming 0%-100%
  - Wayfinding, switched zone
- Task layer at desks

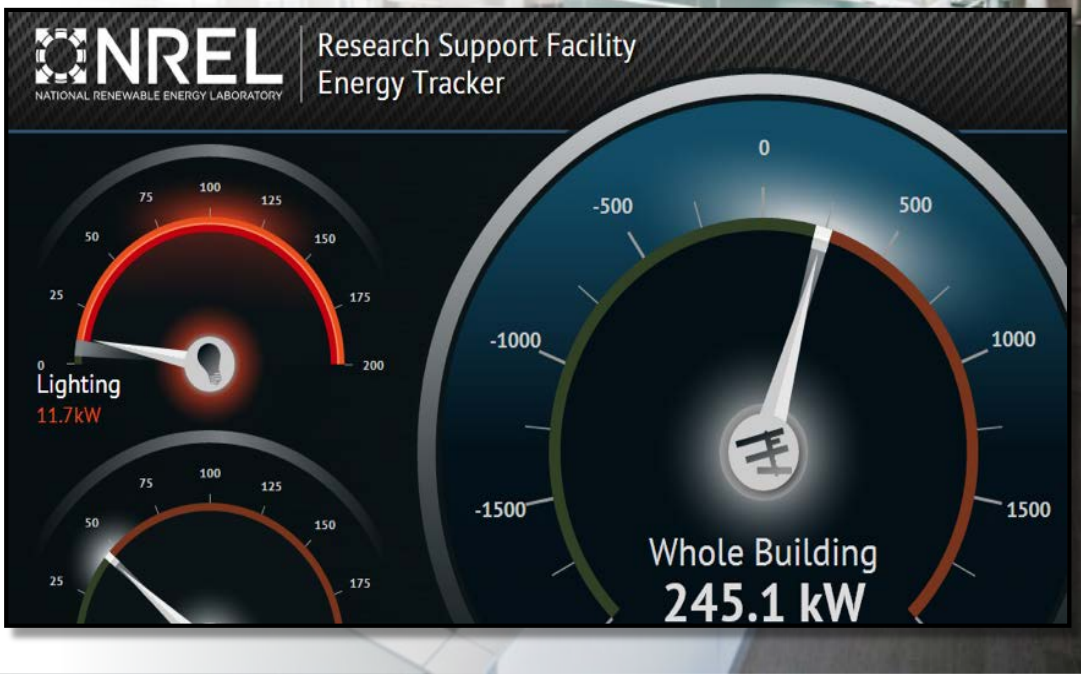


Achieves energy use goals with daylight redirection, high luminous efficacy sources, and changes in ambient layer power

Office Lighting of Today

A Solution





Process Input *Sample*

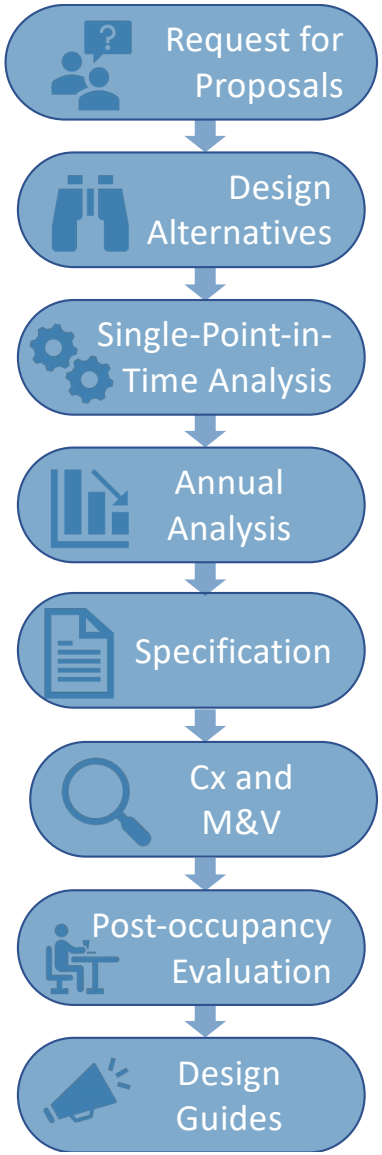
Metrics
LPD, sDA, ASE, EUI, collaboration with designers and energy engineers

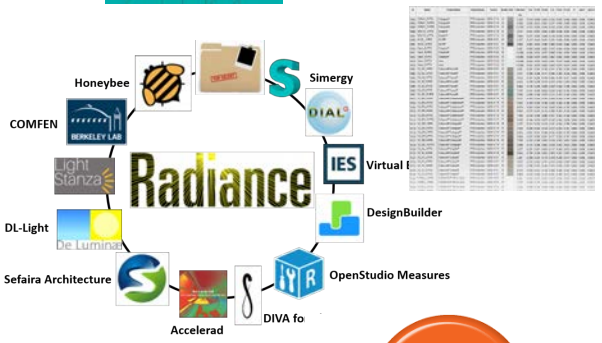
Form, Material
Optical device BSDF, WWR, VLT, avg surface reflectance, collaboration with manufacturers

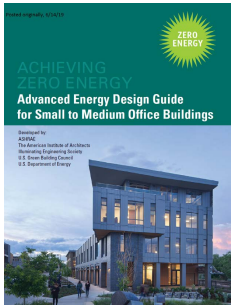
Equipment
Luminous efficacy, intensity distribution, .ies file

Model
1-3 spectral channels, hourly weather, horizontal calc grid, photosensor spatial response, daylighting control algorithm, typical occupant schedule, collaboration with building operators

Evaluation Method
Submetering, occupant survey, HDRI, collaboration with social scientists







Office Lighting of Today

Advanced Energy Design Guide

Table 5-11 (EL7) LED Specifications

Metric	Recommendation (Minimum)
Efficacy	125 LPW
End of life	L70 50,000+ hours
CRI	80+
Fidelity Index and Gamut Area Index	Rf above 85, Rg 90–110
Warranty	5+ years
Dimmable	Specify dimming driver

Table 5-12 (EL8) Interior Lighting Power Densities

Interior Space	LPD, W/ft^2	90.1-2016	90.1-2019 (proposed)
Open-plan office	0.31	0.81	0.67
Private office	0.42	0.93	0.88
Conference room/meeting room	0.77	1.07	0.97
Corridor	0.34	0.66	0.41
Storage area	0.34	0.46	0.38
Restroom	0.51	0.85	0.63
Break room	0.47	0.62	0.59
Electrical/mechanical room	0.42	0.43	0.42
Stairway	0.49	0.58	0.49
Lobby	0.77	1.0	0.84
Other spaces	0.49		
Average building LPD	0.40		

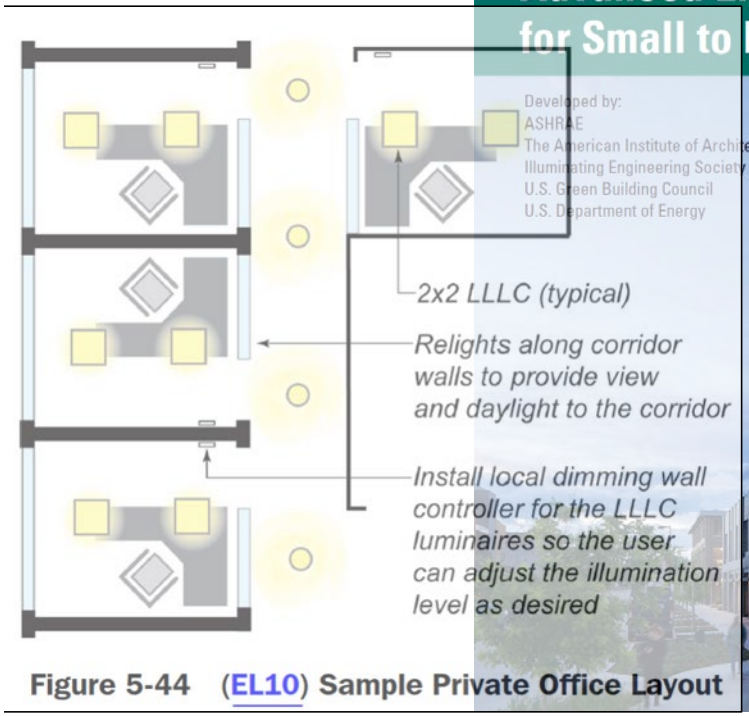
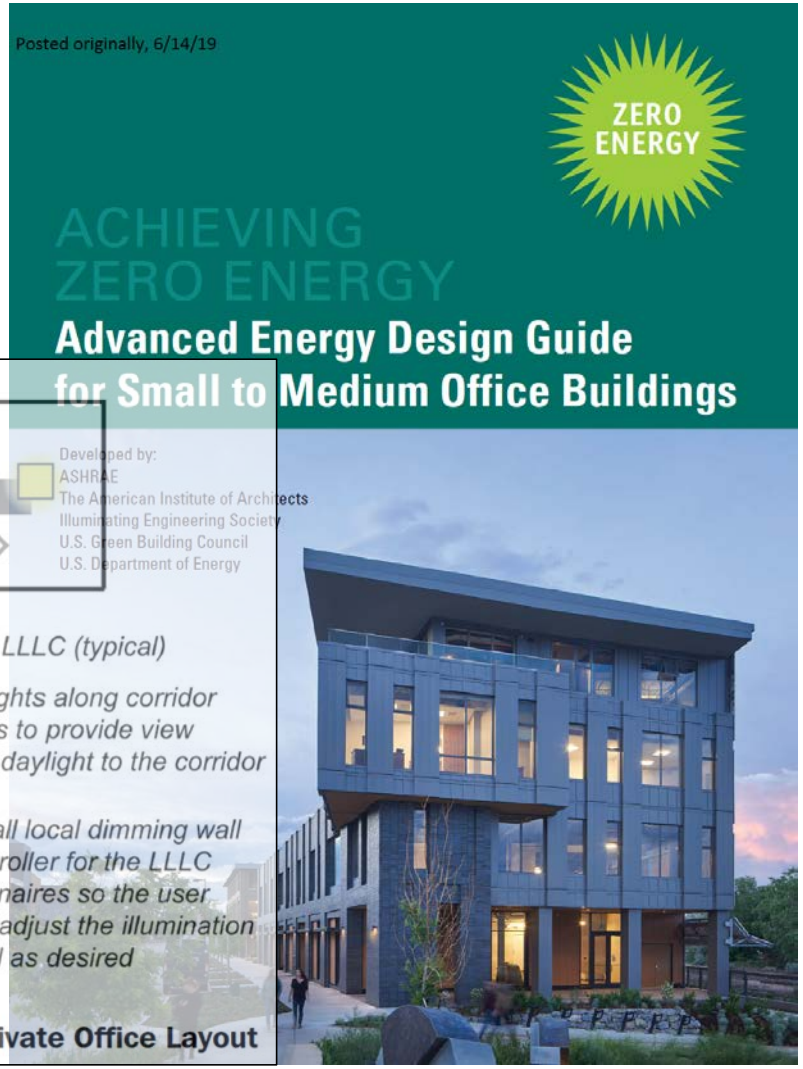


Figure 5-44 (EL10) Sample Private Office Layout



What is Ideal Light?

Zero Energy as Baseline

Office Lighting of Tomorrow

Common Attributes

Supports human health and wellbeing

Meets basic needs for tasks and comfort

Promotes health

Promotes positive emotion

Promotes engagement

Circadian rhythm entrainment and phase shifting

Mood

Alertness

Supports climate change mitigation and adaptation

Supports zero energy buildings

Supports zero carbon communities

Supports resilient infrastructure

Office Lighting of Tomorrow

A Private Office Example, Circadian Lighting

Design constraints

- Ambient illuminance (250 lux), glare mitigation, daylighting, and energy requirements
- AEDG LPD of 0.40 W/ft^2
- Equivalent Melanopic Lux **(EML) of 150** for 100% of working positions for 4 morning hours, per WELL, e.g.
- Circadian Stimulus **(CS) of 0.3** for 2 morning hours, per UL, e.g.

Design response

Can we tweak current design templates to meet circadian lighting goals?

Office Lighting of Tomorrow

Common Attributes

Circadian rhythm entrainment and phase shifting

Needs to do so using *novel* source spectrum and luminaire forms, intensity distribution, and layouts

Supports human health and wellbeing

- Meets basic needs for tasks and comfort
- Promotes health
- Promotes positive emotion
- Promotes engagement

Supports climate change mitigation and adaptation

- Supports zero energy buildings
- Supports zero carbon communities
- Supports resilient infrastructure

Process Input *Sample*

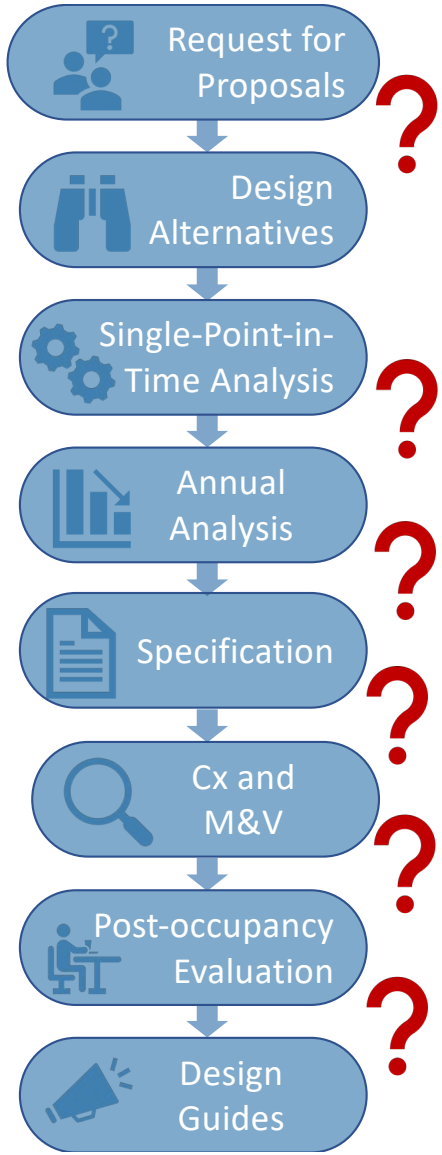
Metrics
LPD, sDA, ASE, EUI, EML, CS, other circadian, collaboration with designers, energy engineers, and physiologists

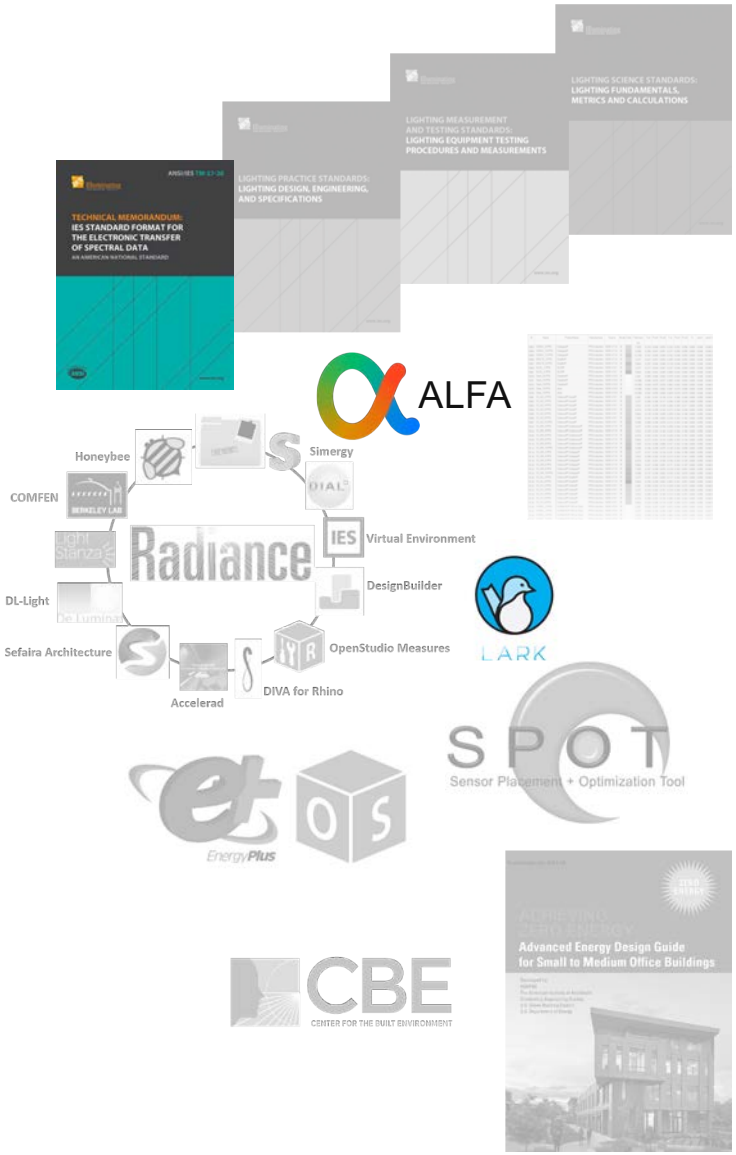
Form, Material
Optical device BSDF, WWR, ~~VLT~~, ~~avg surface reflectance~~, spectral BSDF, collaboration with manufacturers

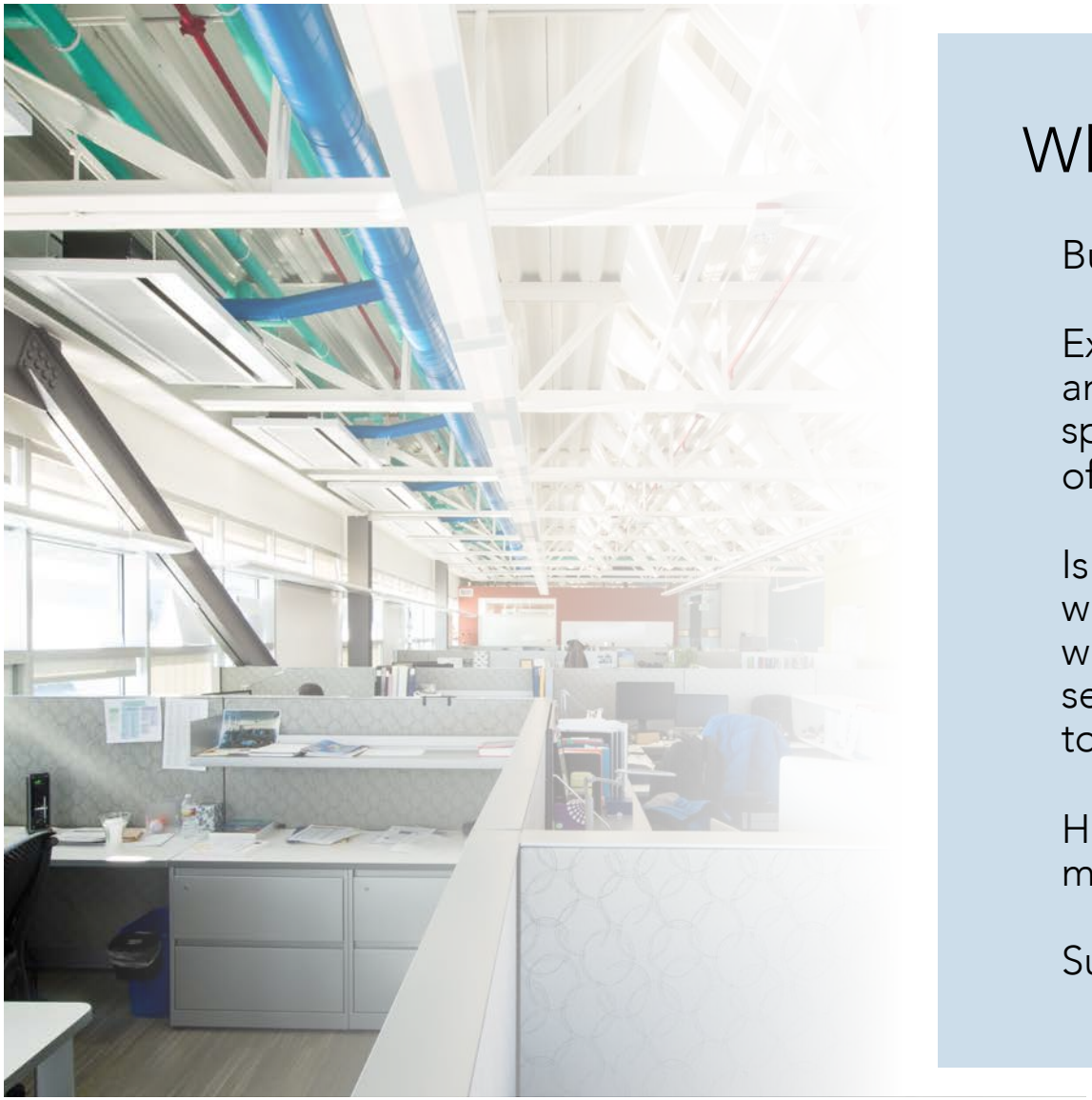
Equipment
Luminous efficacy, intensity distribution, .ies file, SPD file

Model
~~1-3~~ 9-81 spectral channels, hourly weather, horizontal calc grid, vertical calc grid, photosensor spatial and spectral response, daylighting control algorithm, typical occupant schedule, collaboration with building operators

Evaluation Method
Submetering, occupant survey, HDRI, collaboration with social scientists







What is Ideal Light?

Builds on zero energy as a baseline

Explores potential for circadian entrainment and phase shifting using novel spatial and spectral distributions, mounting, and timing of energy use

Is guided in design by appropriate metrics, with ideas sourced from creative individuals who have access to multi-channel source, sensor, and material data, and analysis tools to test ideas

Has its performance predicted in design and measured in operation

Supports sustainable, resilient building goals