

High Performance Architecture Meets Electric Lighting Design

Christoph Reinhart

Screenshot ClimateStudio

DOE Solid State Lighting workshop | Energy Savings from Lighting Application, January 14, 2022





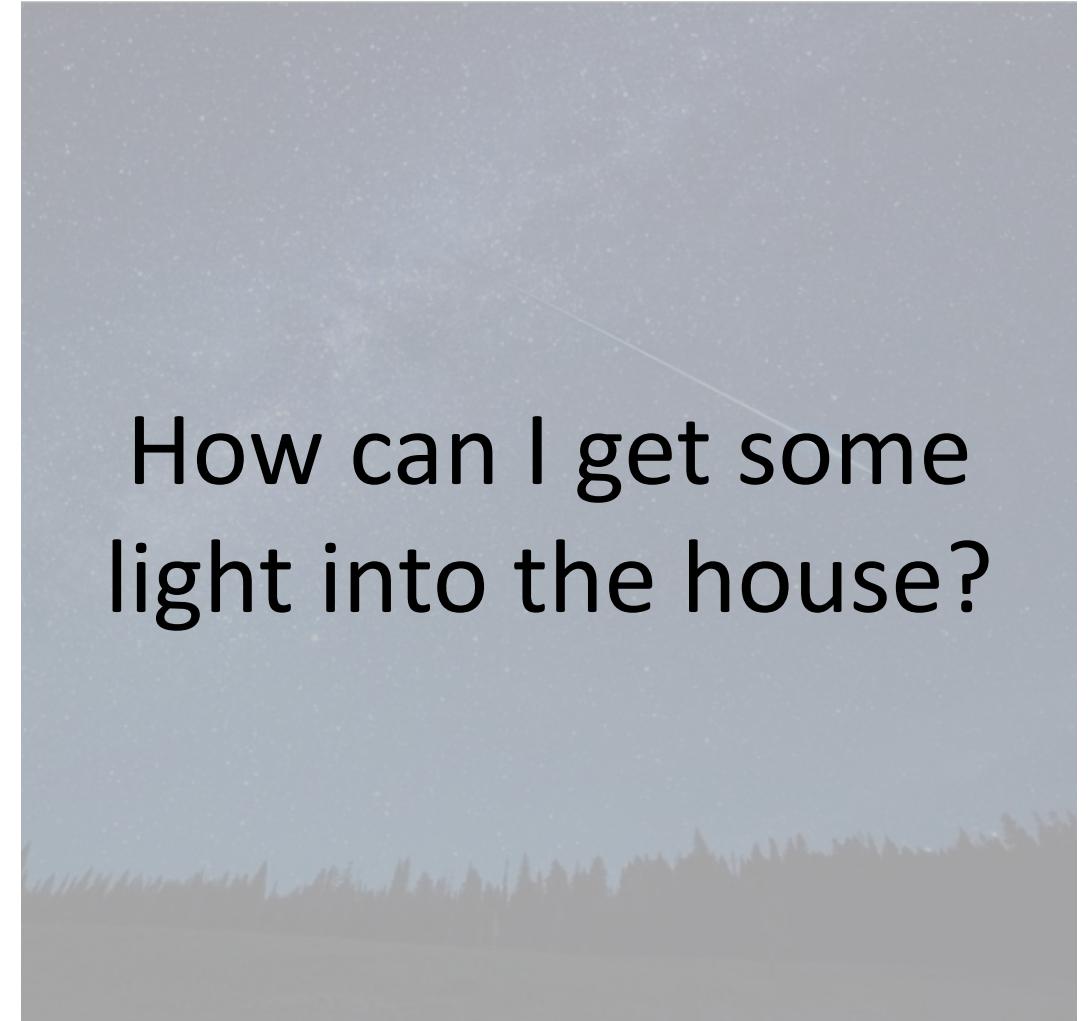
Energy Savings from Lighting Application Efficiency

Lighting energy savings don't just come from source efficiency improvements. More effective optical delivery, **spectral content**, and **intensity control** can have enormous energy impacts and improve the functions of lighting. This panel will cover efforts to understand the LAE energy opportunity, the **modeling tools** necessary for LAE, and real-world implementations that demonstrate the impacts of LAE improvements.

Lighting our life



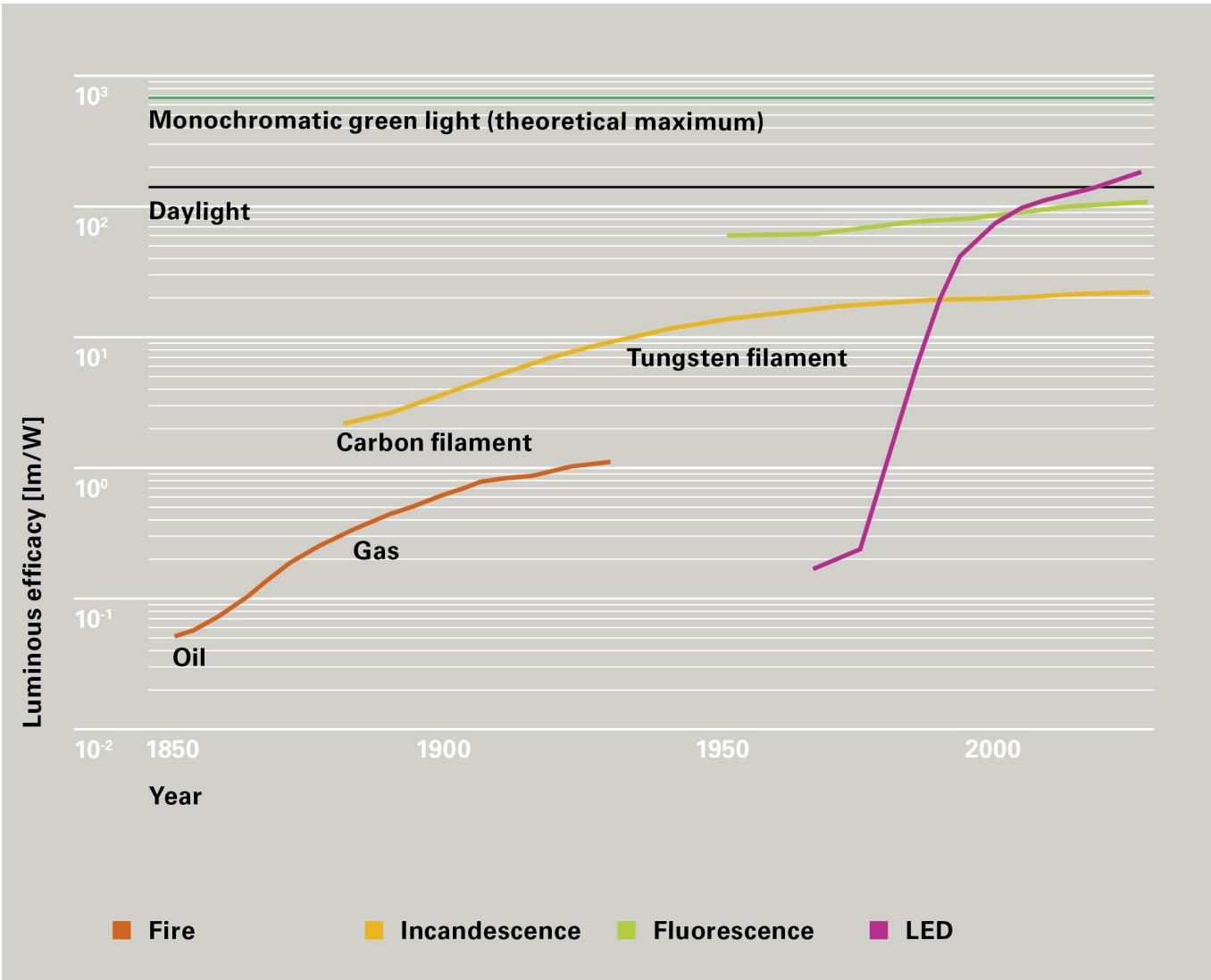
Daytime = Awake



How can I get some
light into the house?

Nighttime = Asleep

170 years of Lighting



We have created an awesome, affordable light source...

... and, we can control its intensity and spectrum



3000K



6500K



9W

A few questions

- ❑ How efficient is the overall, global lighting system?
- ❑ Do we still need to worry about daylighting?
- ❑ How can we best integrate SSL technologies into the architectural design process?

Earth from space at night



- None of these photons ever enter a human eye

How many of these photons are needed?



- Potentially all those that bounce off a surface within the stadium

How many of these photons are needed?



- Only shine light downwards
- Do we really need to keep the whole parking lot opened at night?

Lighting Application Efficiency Guidelines

- ❑ Use controlled/free daylight when available
- ❑ Top up daylight with efficient electric lighting
- ❑ Provide electric lighting in adequate quantities where and when needed

How does this approach look within an architectural/urban design context?

Access to (Day)light in cities

New York Zoning Laws 1916

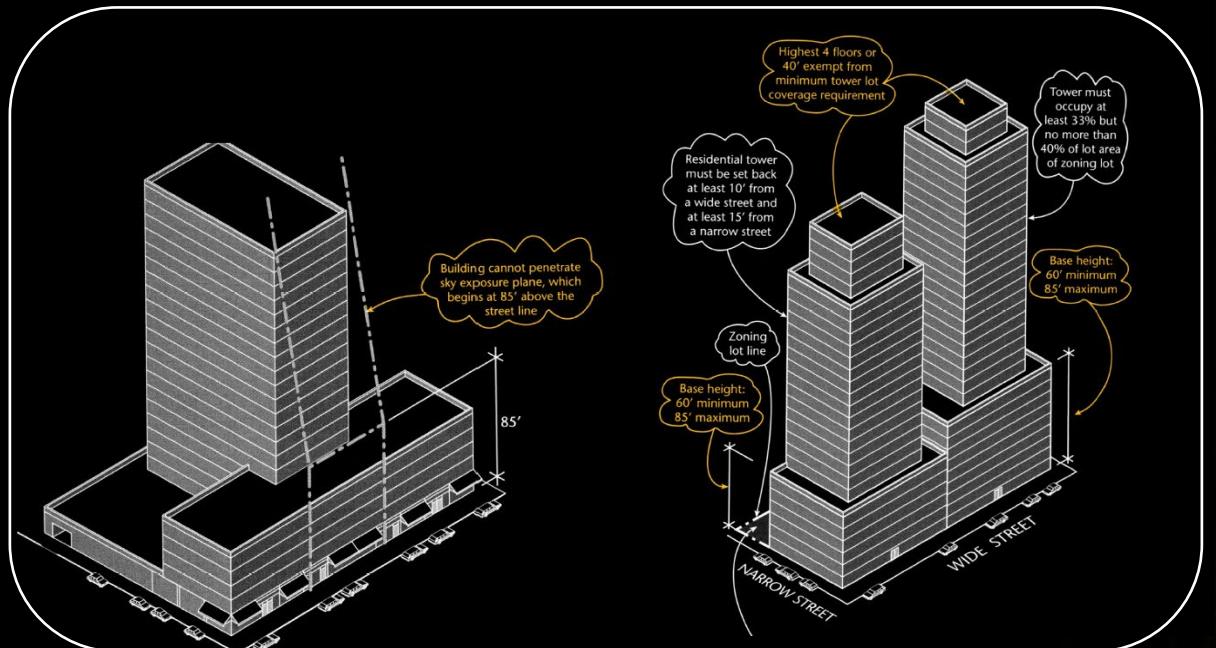
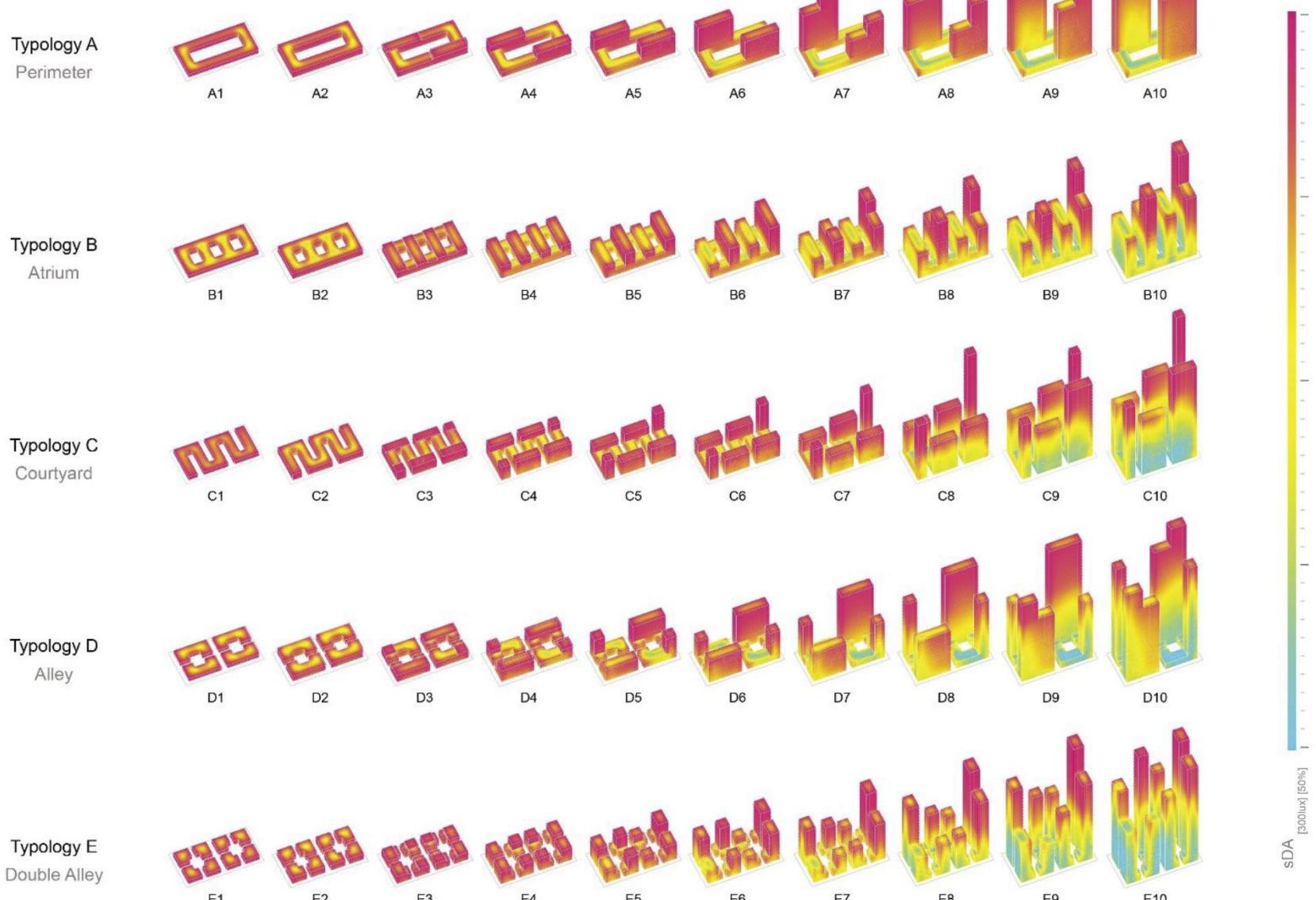
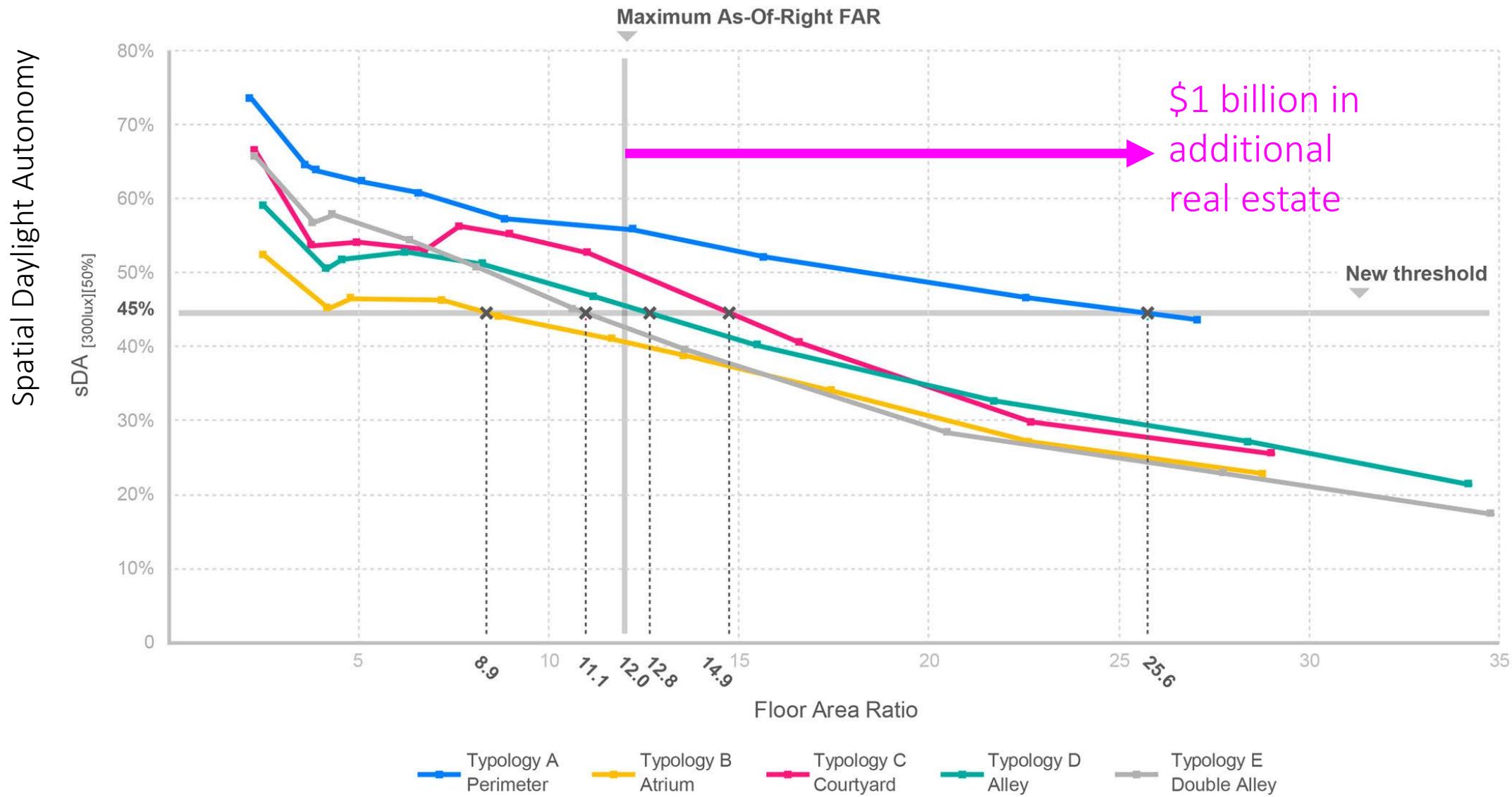


Photo: M Saratsis

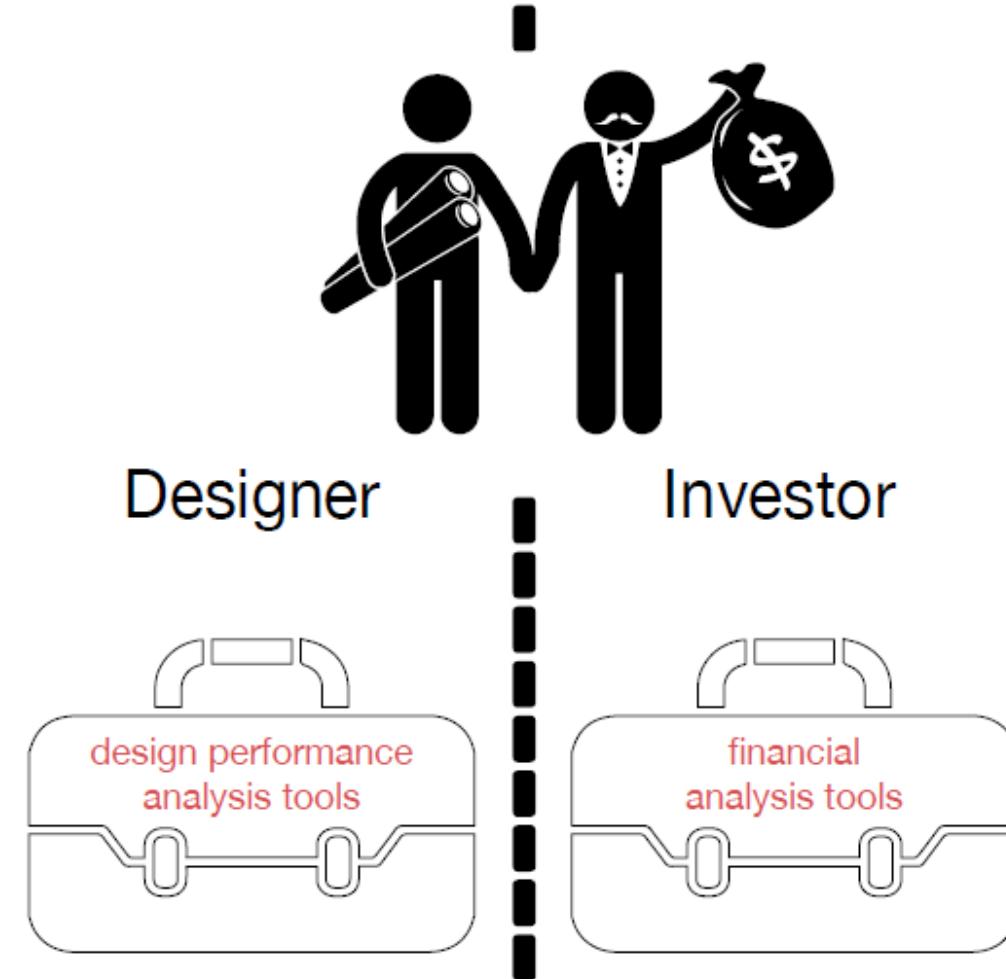
New York Zoning Revisited



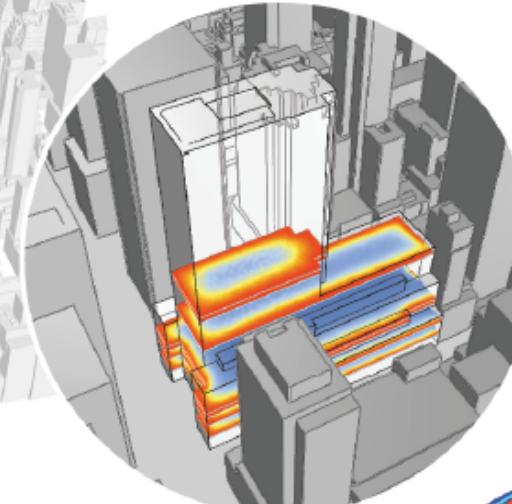
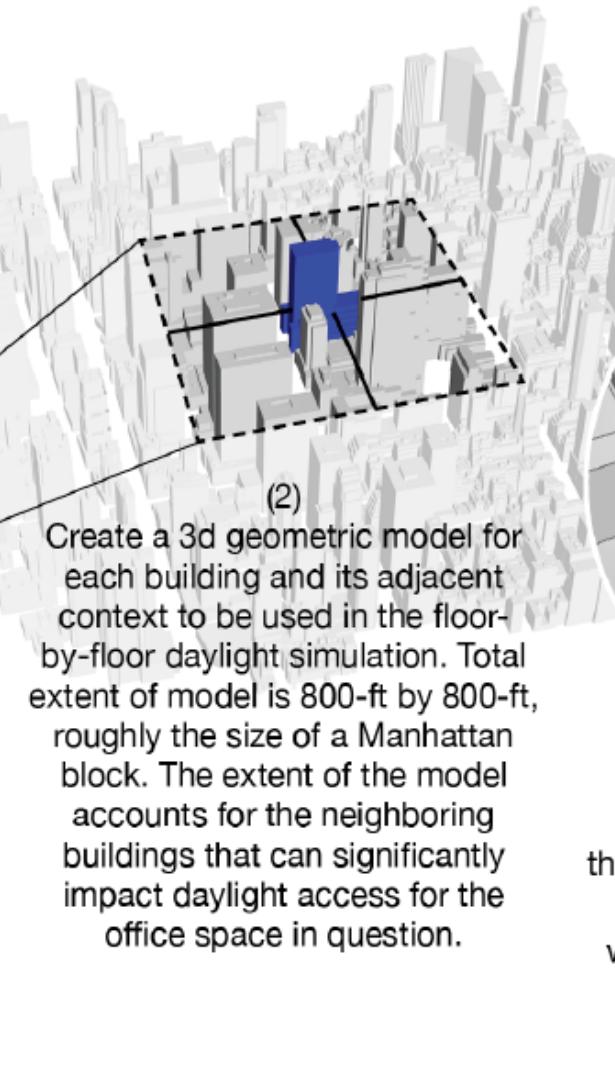
LM83/LEED vs zoning regulations



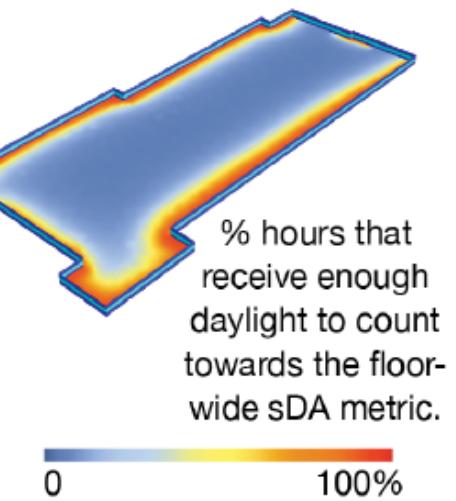
How do we overcome the conflict between carbon emissions and economics?



The Financial Value of Daylight



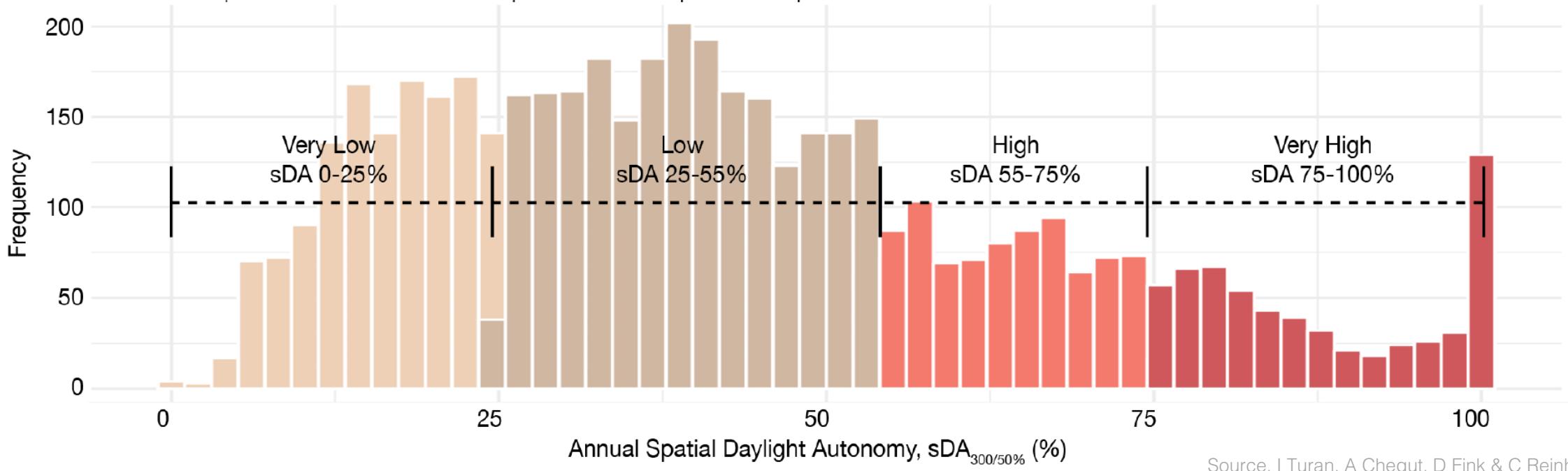
Simulate hourly illuminance through each floor plate of interest individually. Calculate floor-wide Spatial Daylight Autonomy (sDA_{300/50%}) based on annual illuminance values.



Daylight Availability in Manhattan

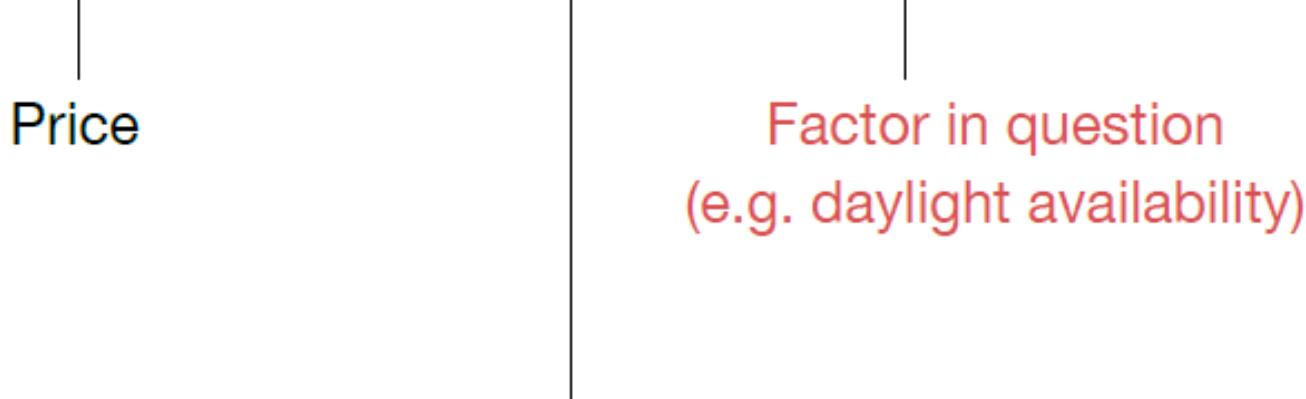
Distribution of Spatial Daylight Autonomy (sDA_{300/50%}) for the 5,154 Floors in the Sample

Mean: 43% | Standard Deviation: 23% | Median: 39% | Min: 0% | Max: 100%



Hedonic Pricing Model

$$\log P_i = \alpha + \beta X_i + \delta g_i + \varepsilon_i$$

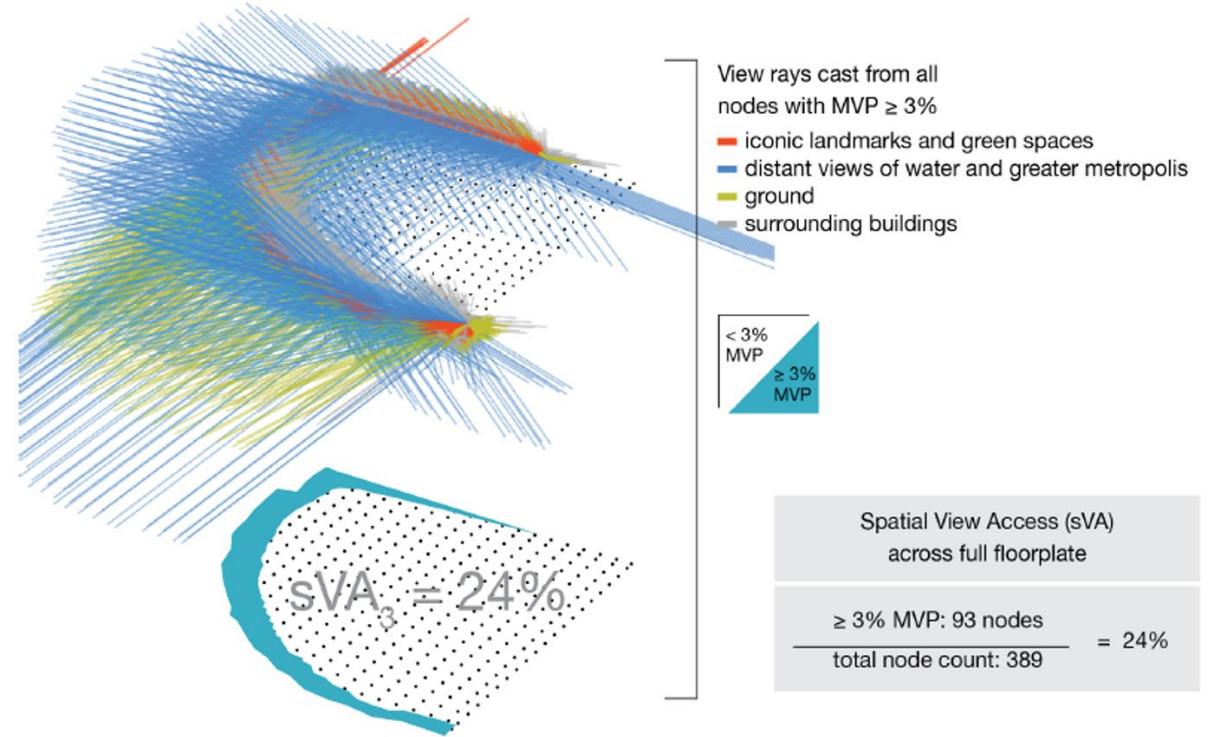
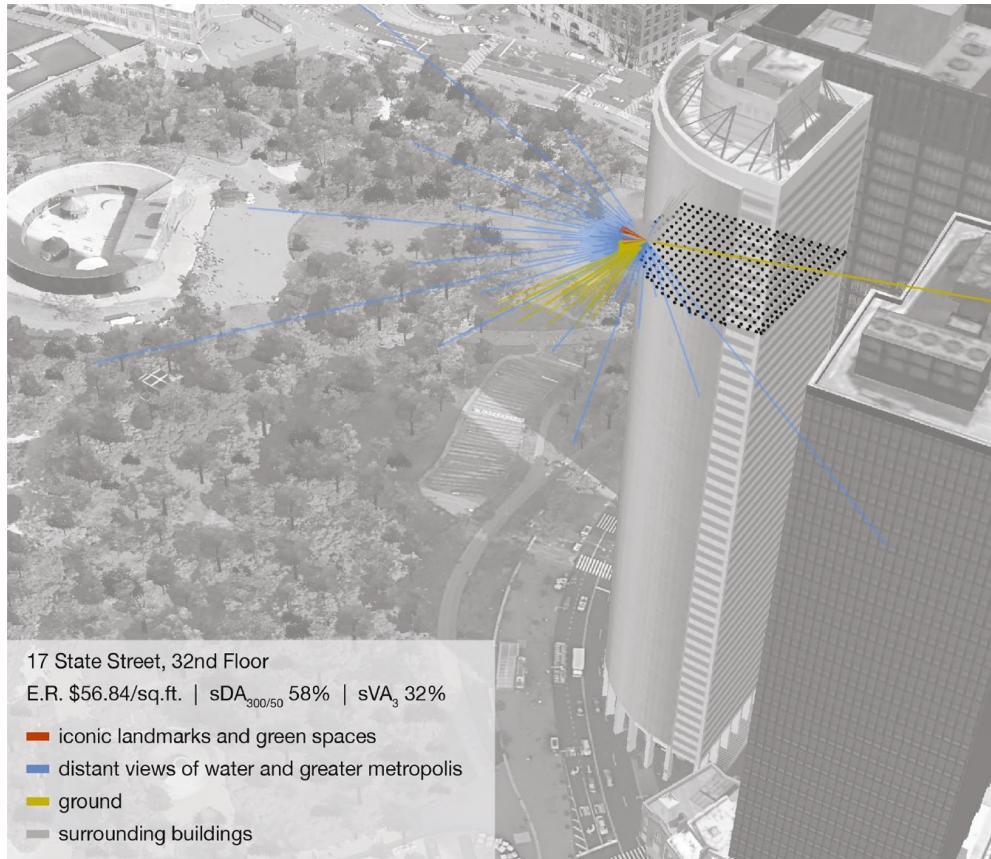


Hedonic characteristics include:

property type; age; building class; number of floors;
renovations; amenities; transportation accessibility;
investor type

- Spaces with access to high amounts of daylight (sDA> 55%) have a **5 to 6% value premium** over occupied spaces with low amounts of daylight (sDA<55%)

Spatial View Access



- Spaces with high access to views (10% and above $sVA_3\%$) have a **6% premium** over spaces with low access to views (less than 10% $sVA_3\%$)
- The combined value of spaces with *both* high daylight and view access, similarly, is **6%**, indicating that the impact of daylight and views together is significant but is not additive.
- Hight relevant result since **rent/mortgage is typical 10 x higher** than energy costs

The role of electric lighting in net zero building design

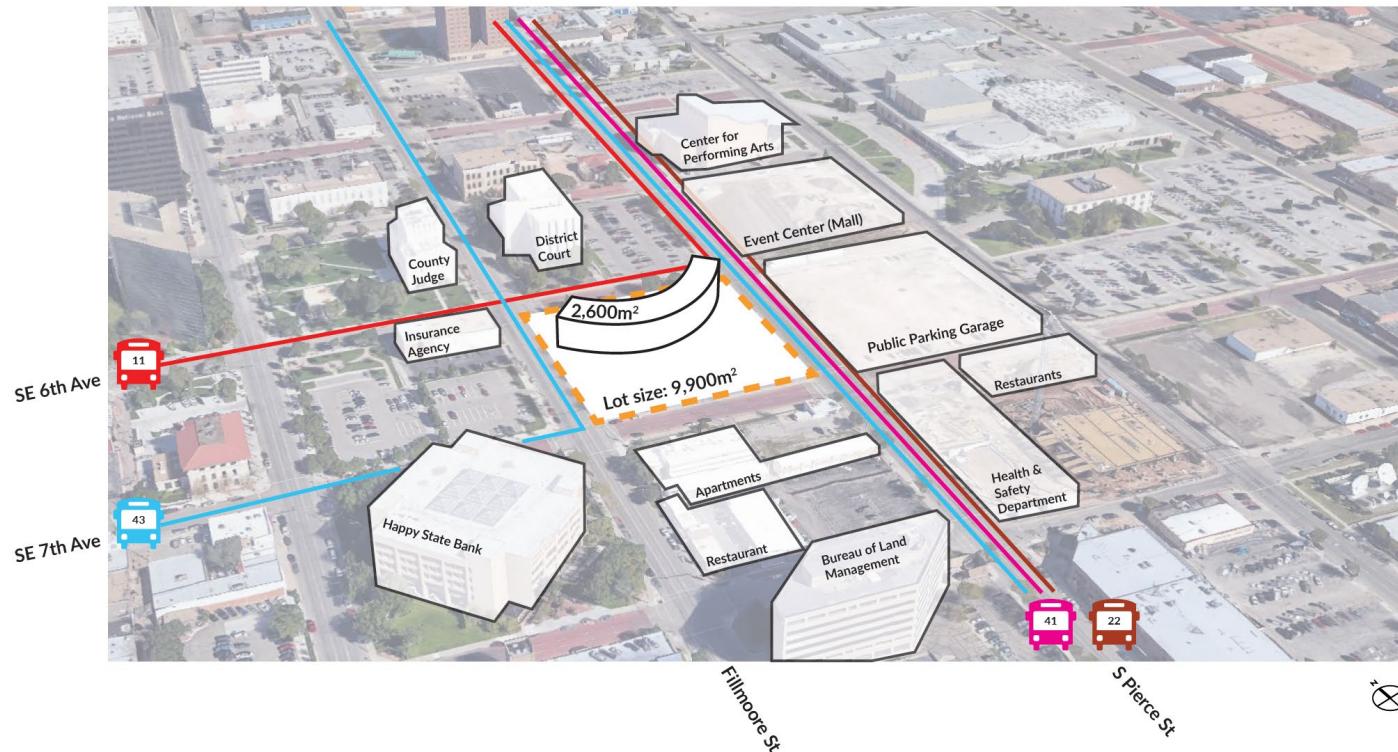
Eight Steps Towards Net-Zero Ready Design

1. Site Selection & EUI Target Finding
2. Climate Analysis
3. Daylight Massing
4. Façade Design
5. Glare
6. Electric Lighting
7. EUI Study
8. Photovoltaics

1 Site Selection & EUI Target Finding

Walkscore

State: Texas
City: Amarillo
Address: SE 6th Ave, Amarillo, TX 79101



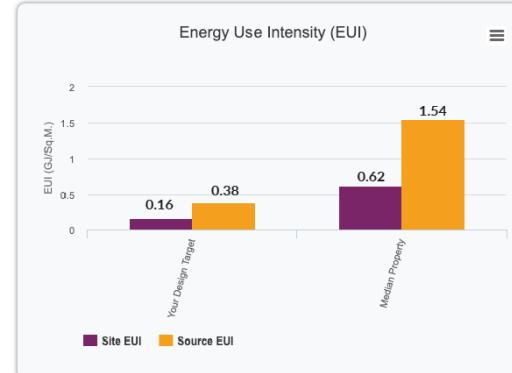
Energy Star

Portfolio Manager – Target Finder

EUI target

Site EUI
44.4kWh/m²

Source EUI
105.5kWh/m²

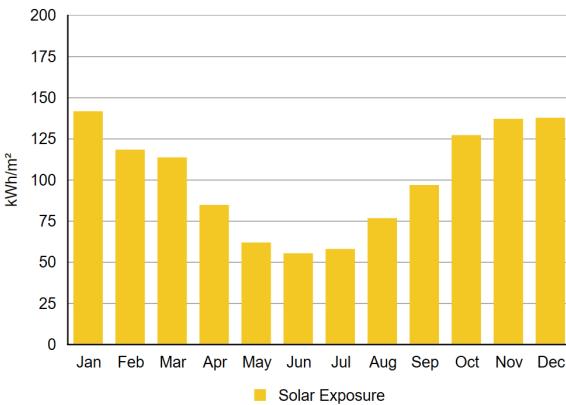


1 building
Medium sized office in 4B climate zone

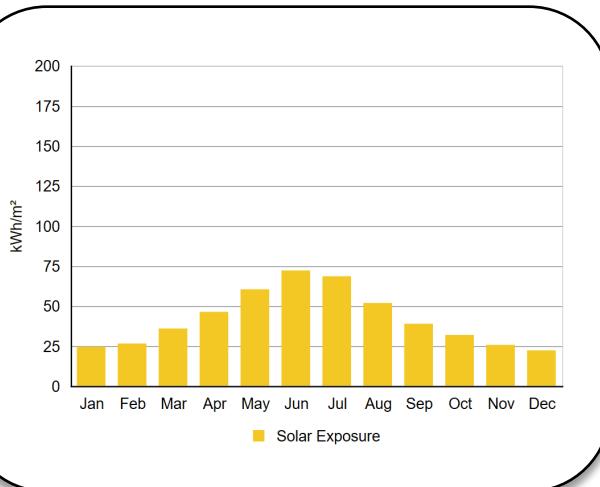
Benchmark
Lower energy use than of comparable buildings in the U.S.

2 Climate Analysis

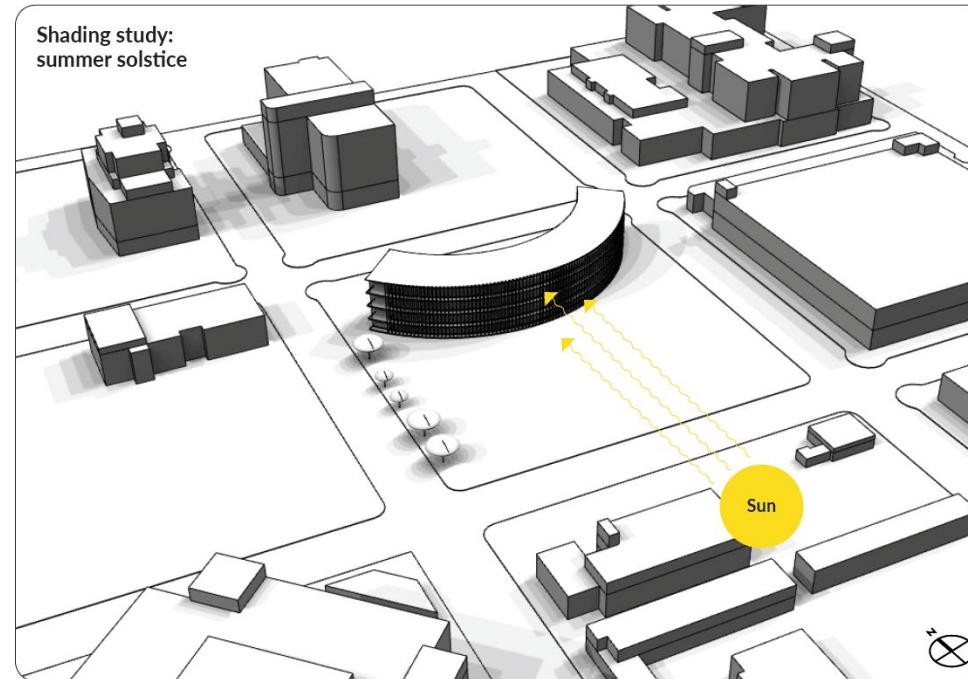
Month radiation South façade



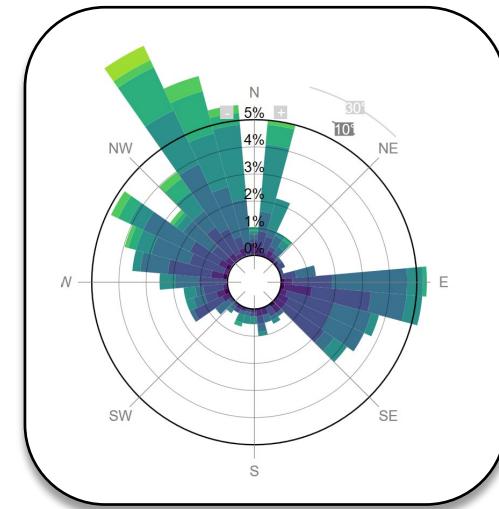
Month radiation North façade



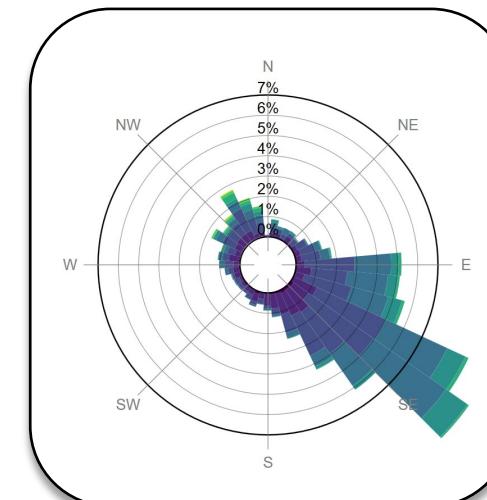
Shading study: summer solstice



Cold NW winds

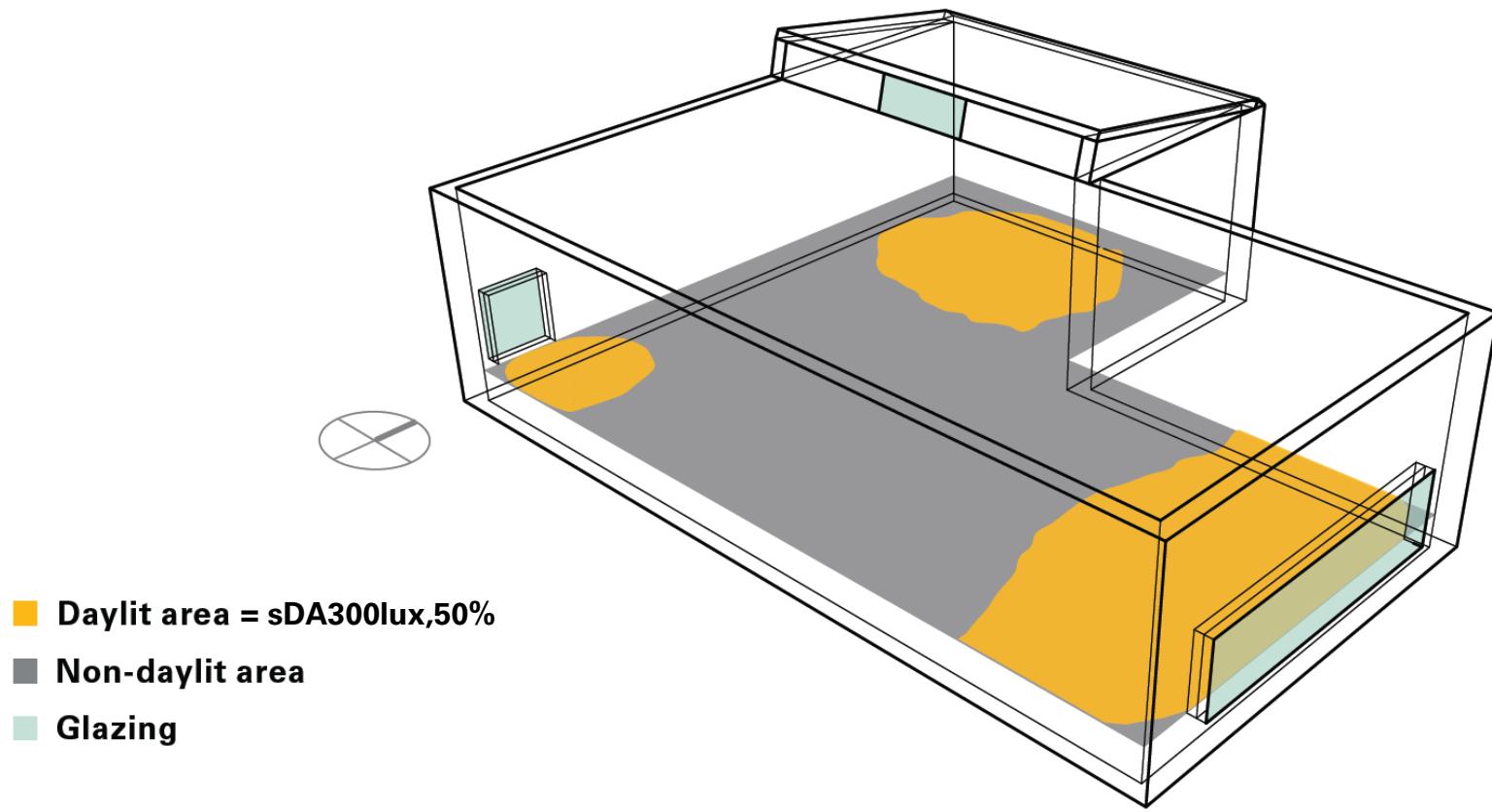


Comfortable SE winds



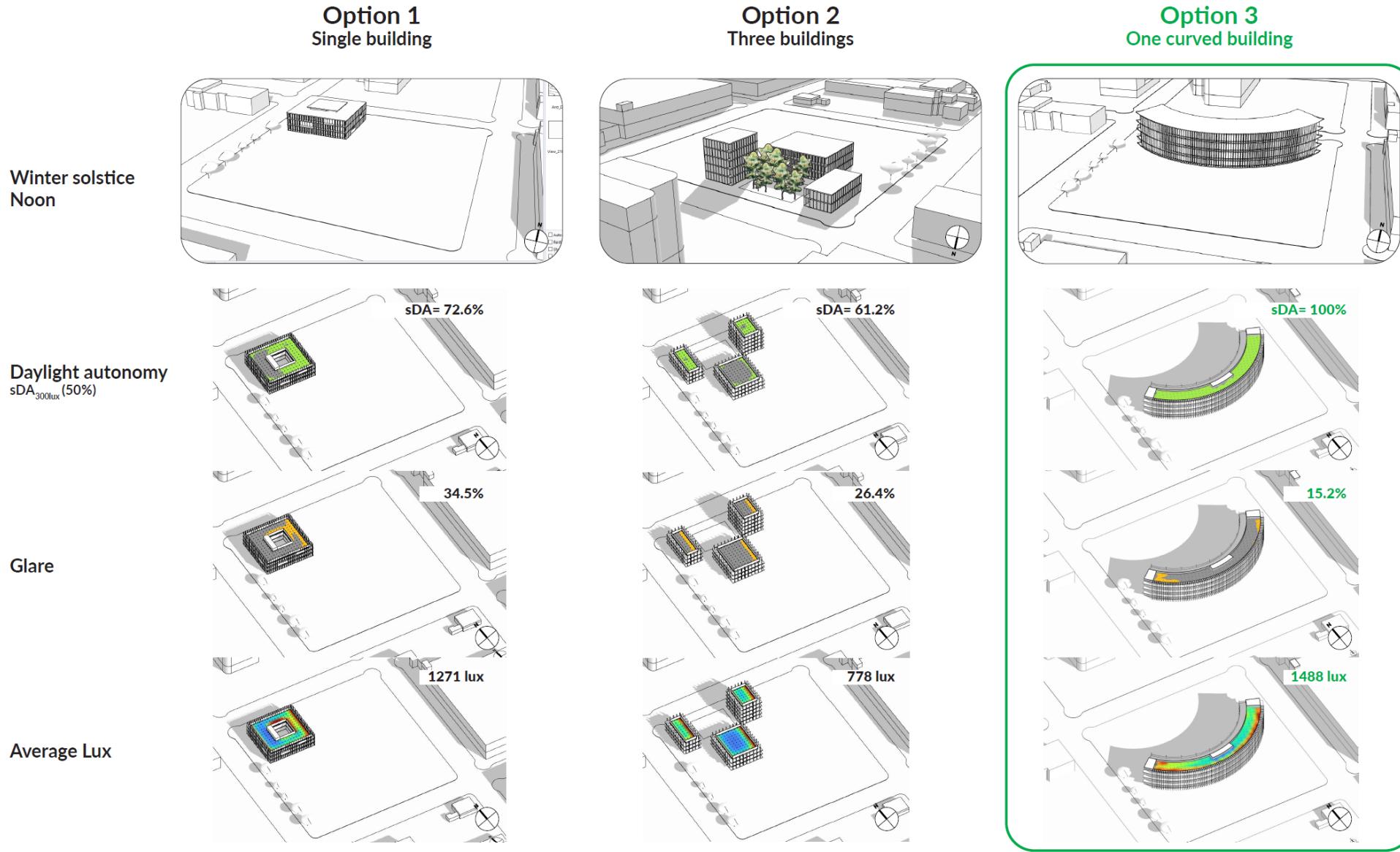
- ❑ Main idea: Look south to maximize winter solar gains and SE comfort winds

3 Daylight Massing | Spatial Daylight Autonomy

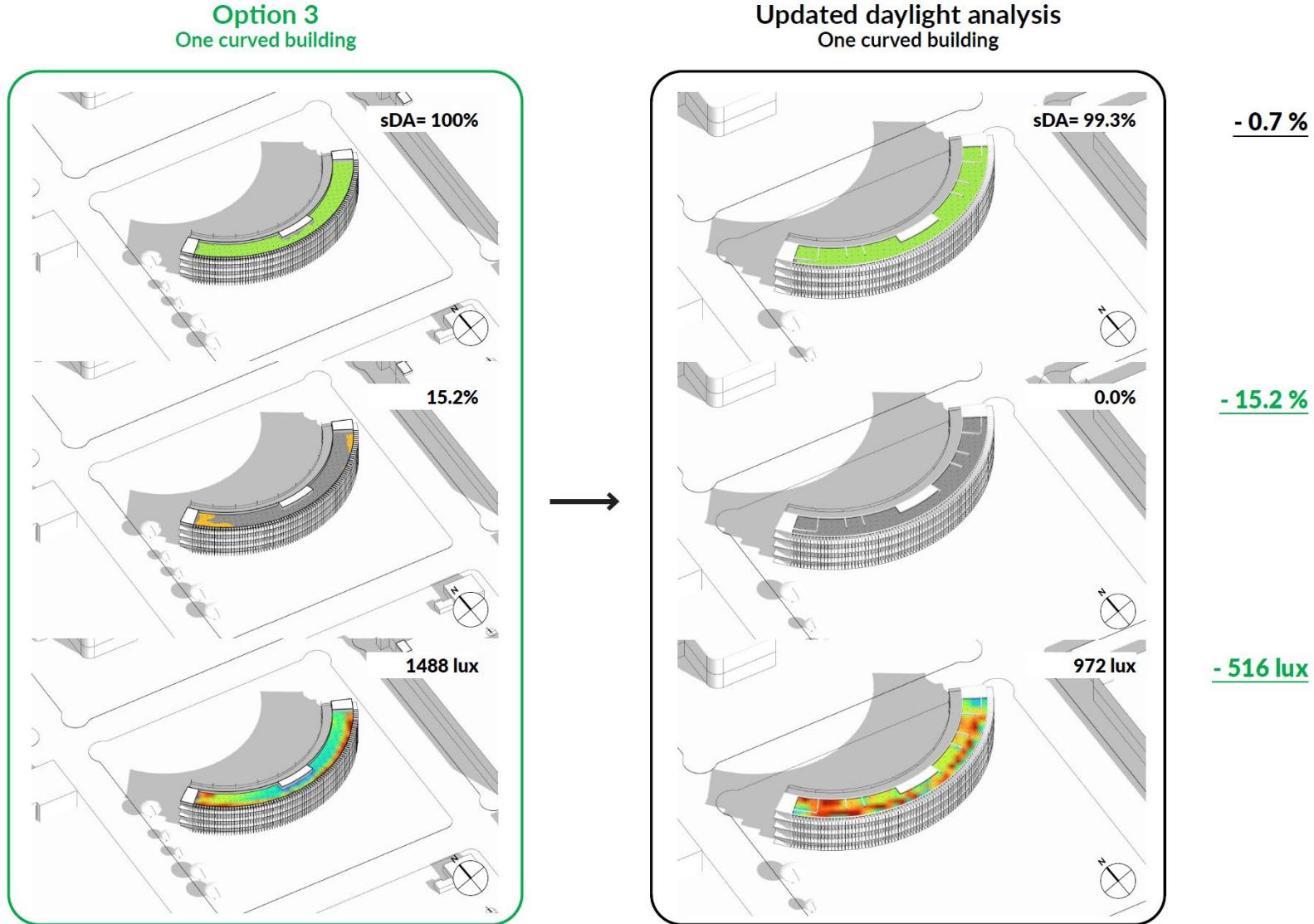


- Daylight autonomy (DA) is a daylight availability metric that corresponds to the percentage of the occupied time when the target illuminance at a point in a space is met by daylight.
- sDA_{300lx, 50%} means that 300lux are met by daylight 50% of the occupied time

3 Daylight Massing



4 Façade Design



Optimized vertical shades

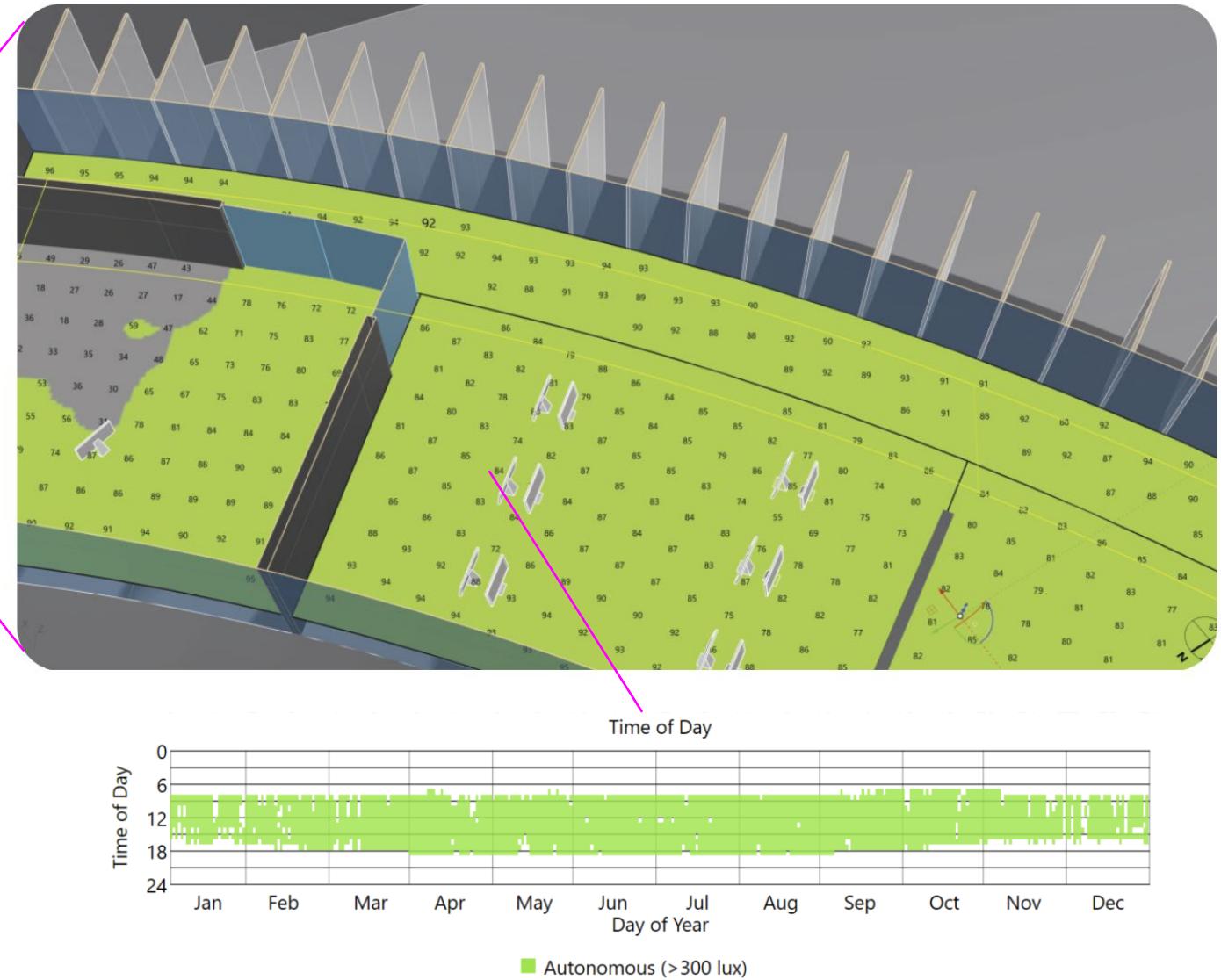
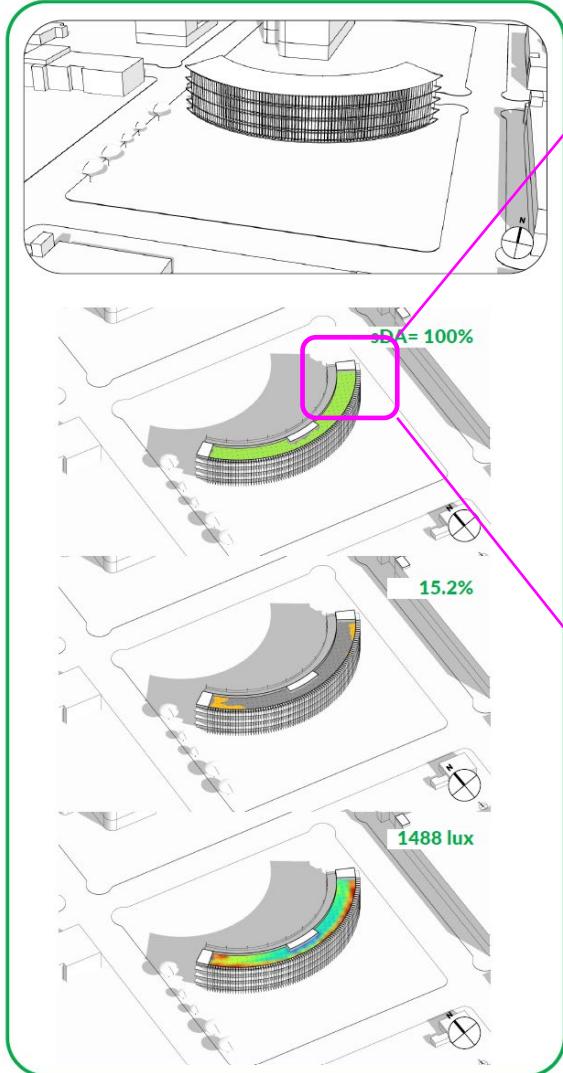
3 Daylight Massing – Zoom In

Winter solstice
Noon

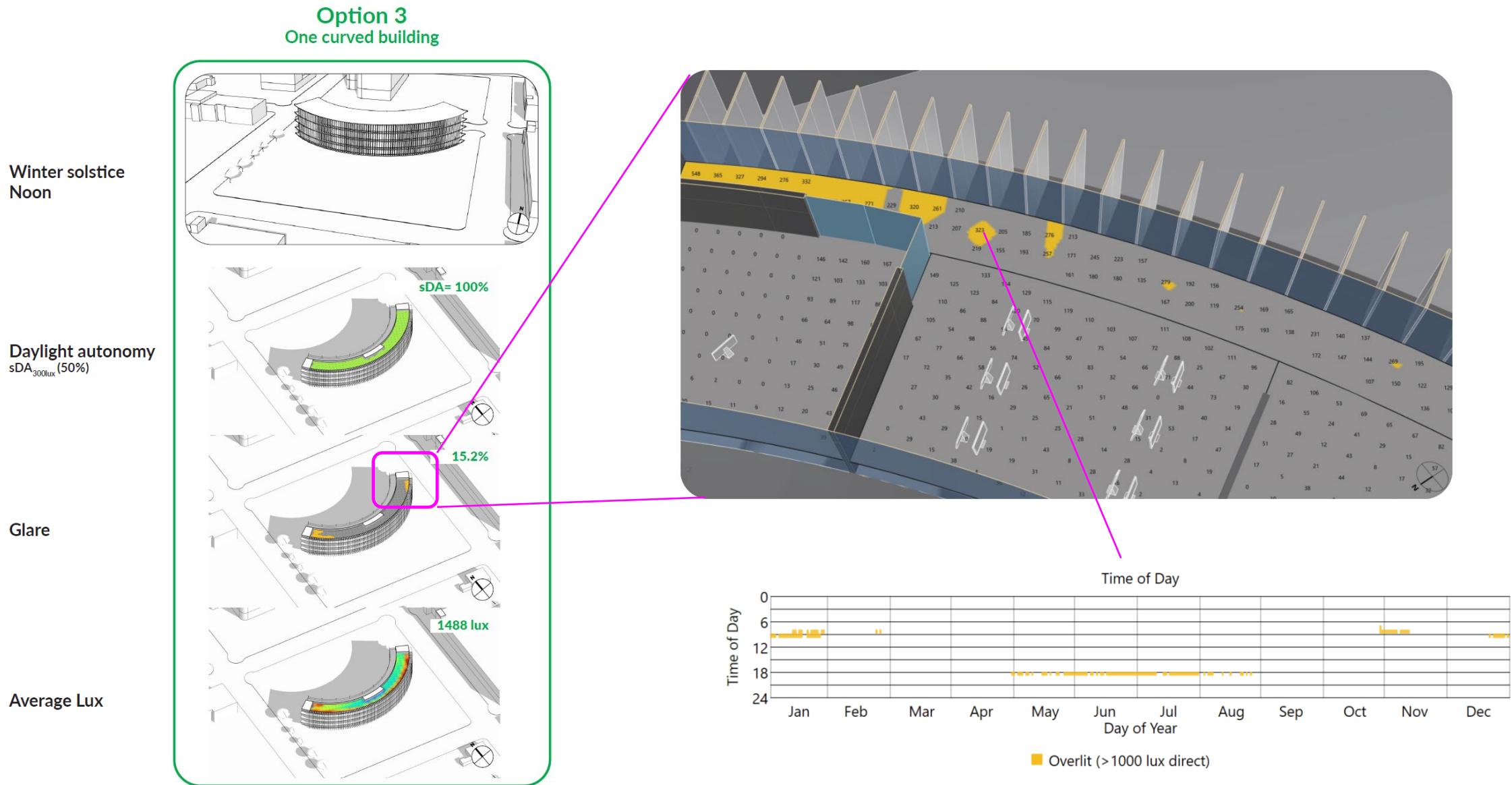
Daylight autonomy
 $sDA_{300\text{lux}} (50\%)$

Glare

Average Lux



3 Daylight Massing – Zoom In



5 Glare Analysis | Daylight Glare Probability

- ❑ A glare index is a numerical evaluation of high dynamic range images using a mathematical formula.
- ❑ Daylight glare probability (DGP) is becoming increasingly widely used. DGP was developed based on HDR photography measurements combined with human subject evaluations.
- ❑ DGP reacts to scene properties, overall brightness and contrast in the field of view.

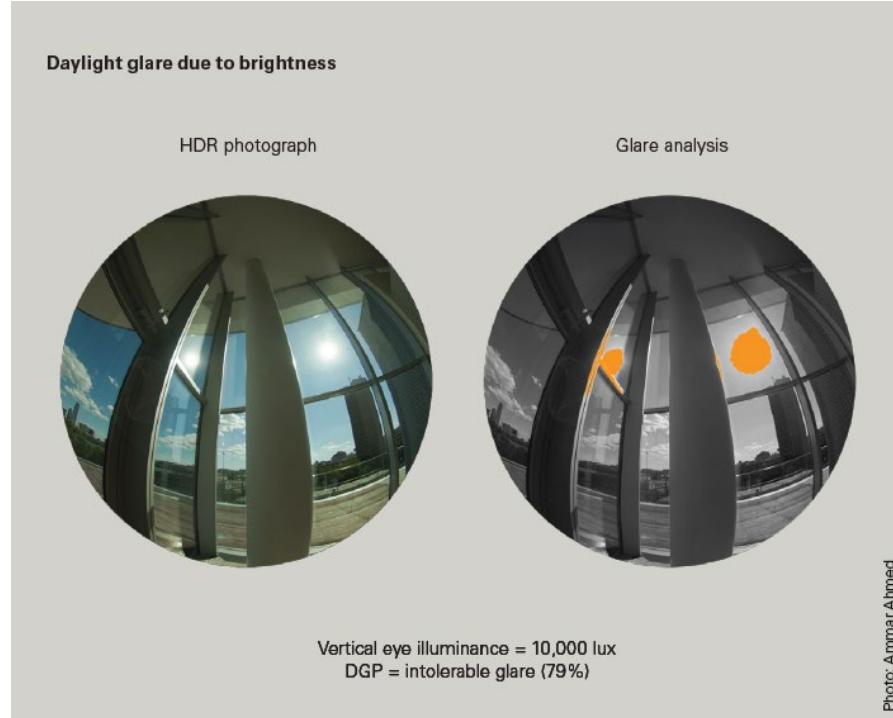
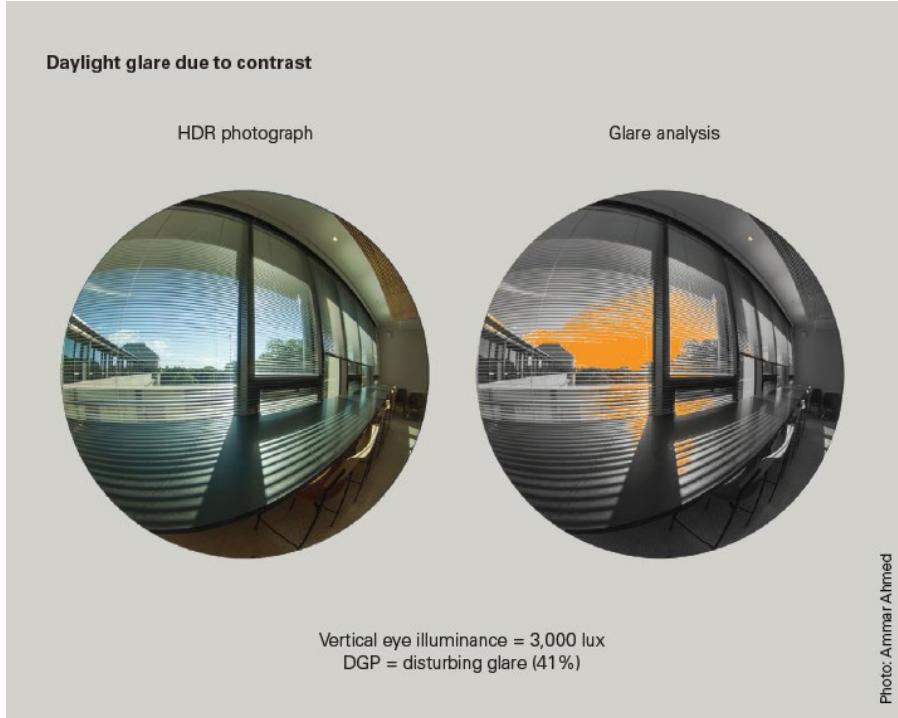
$$\text{DGP} = 5.87 \times 10^{-5} \times E_v + 9.18 \times 10^{-2} \log \left(1 + \sum_{i=1}^n \frac{L_i^2 \times \omega_i}{E_v^{1.87} \times P_i^2} \right) + 0.16$$



- Results are interpreted as falling into one out of four categories.

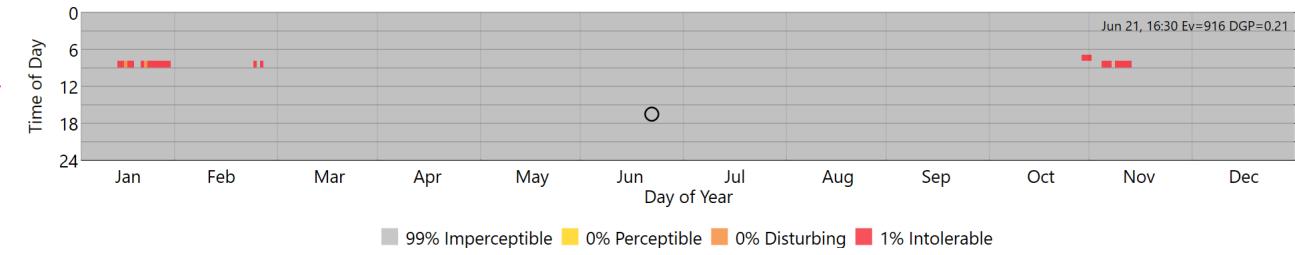
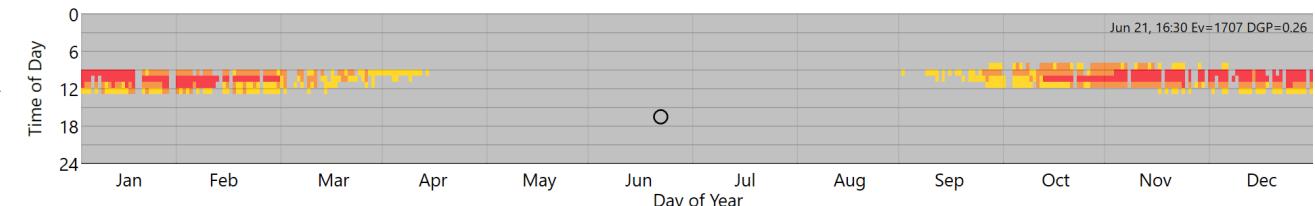
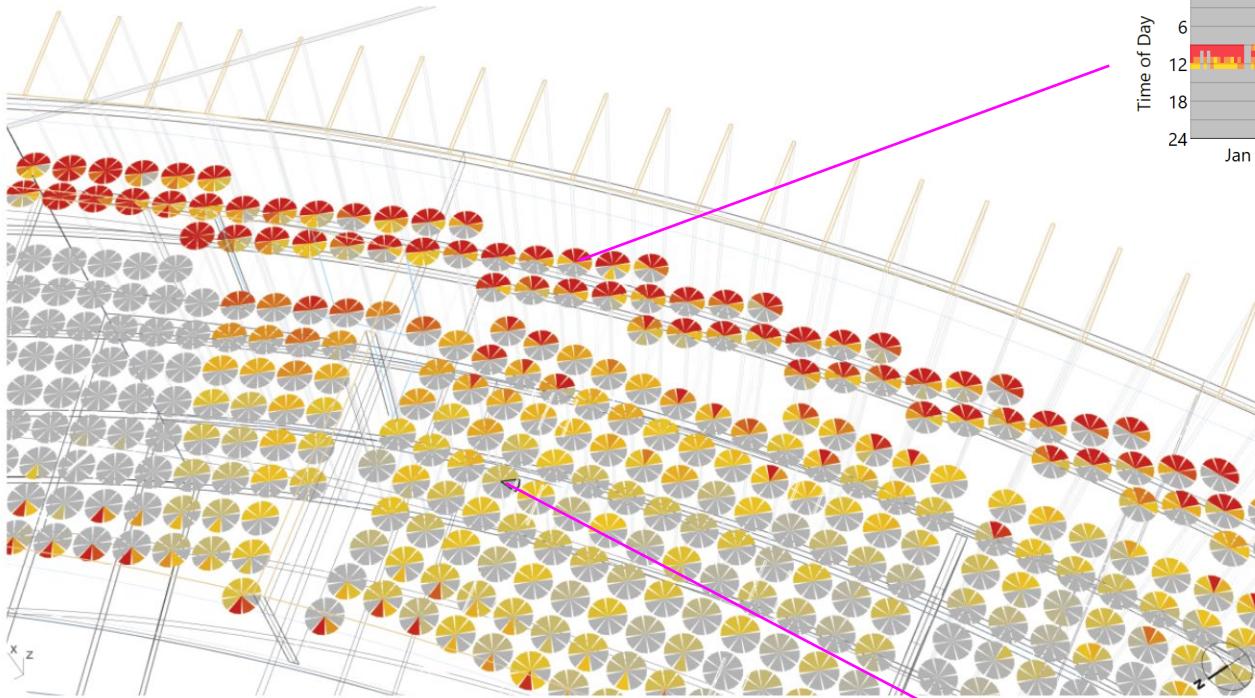
Imperceptible glare	Perceptible glare	Disturbing glare	Intolerable glare
DGP \leq 35%	35% $<$ DGP \leq 40%	40% $<$ DGP \leq 45%	45% $<$ DGP

5 Glare Analysis



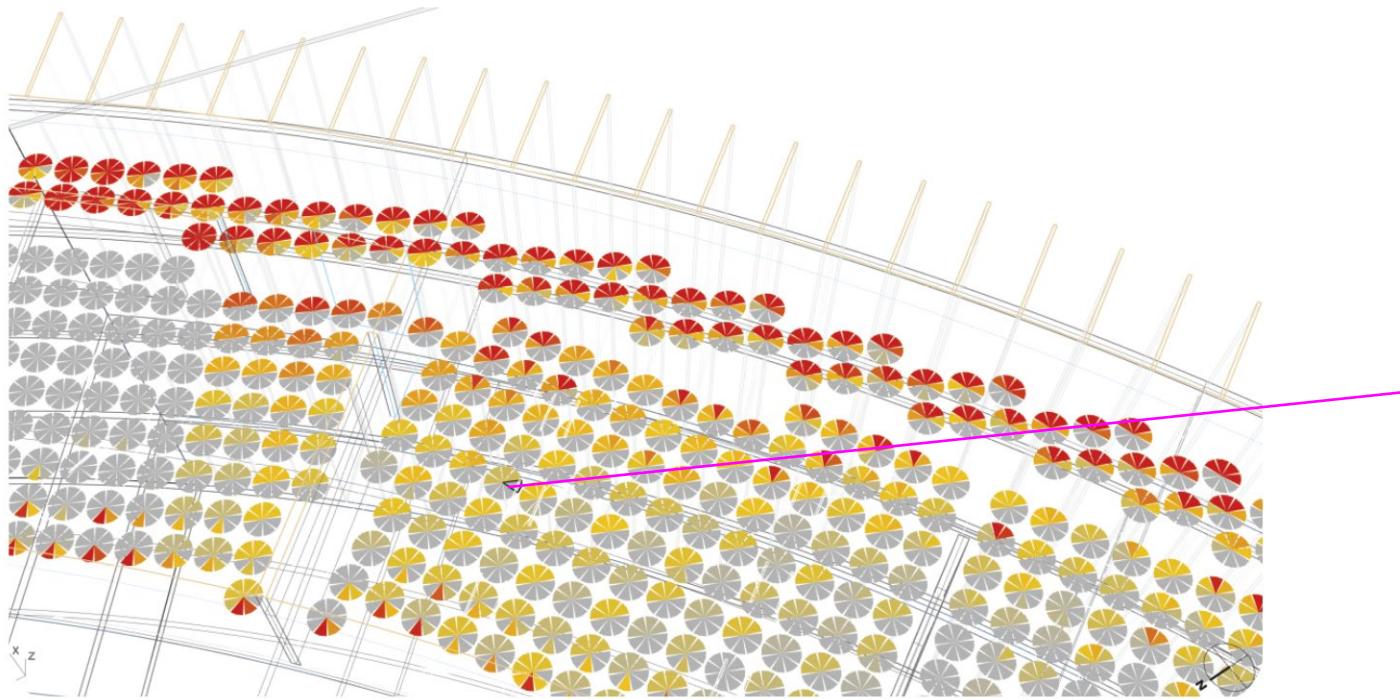
Imperceptible glare	Perceptible glare	Disturbing glare	Intolerable glare
$DGP \leq 35\%$	$35\% < DGP \leq 40\%$	$40\% < DGP \leq 45\%$	$45\% < DGP$

5 Glare Analysis



- ❑ Each slice corresponds to a give view direction within the scene
- ❑ The color of the slice depends on how often a spectator may experience discomfort glare throughout the year.

5 Glare Analysis



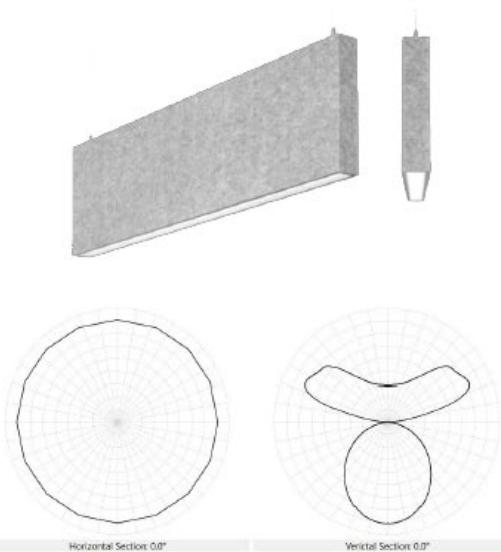
Hemispheric glare map
December 22nd at 8:30am



6 Electric Lighting Design | List of Luminaires

Workspaces

50.2 W



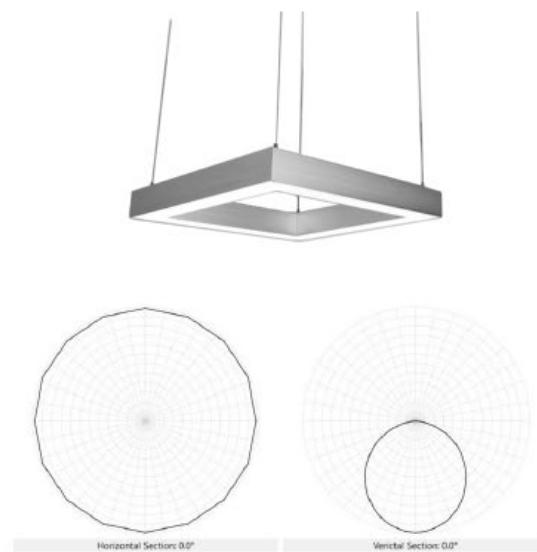
Focal Point:
Seem 1 Acoustic, Direct/Indirect LED,
Batwing/Regress Lens

5200 lm/ 4 ft. length

3500K

Circulation Space

30.8 W



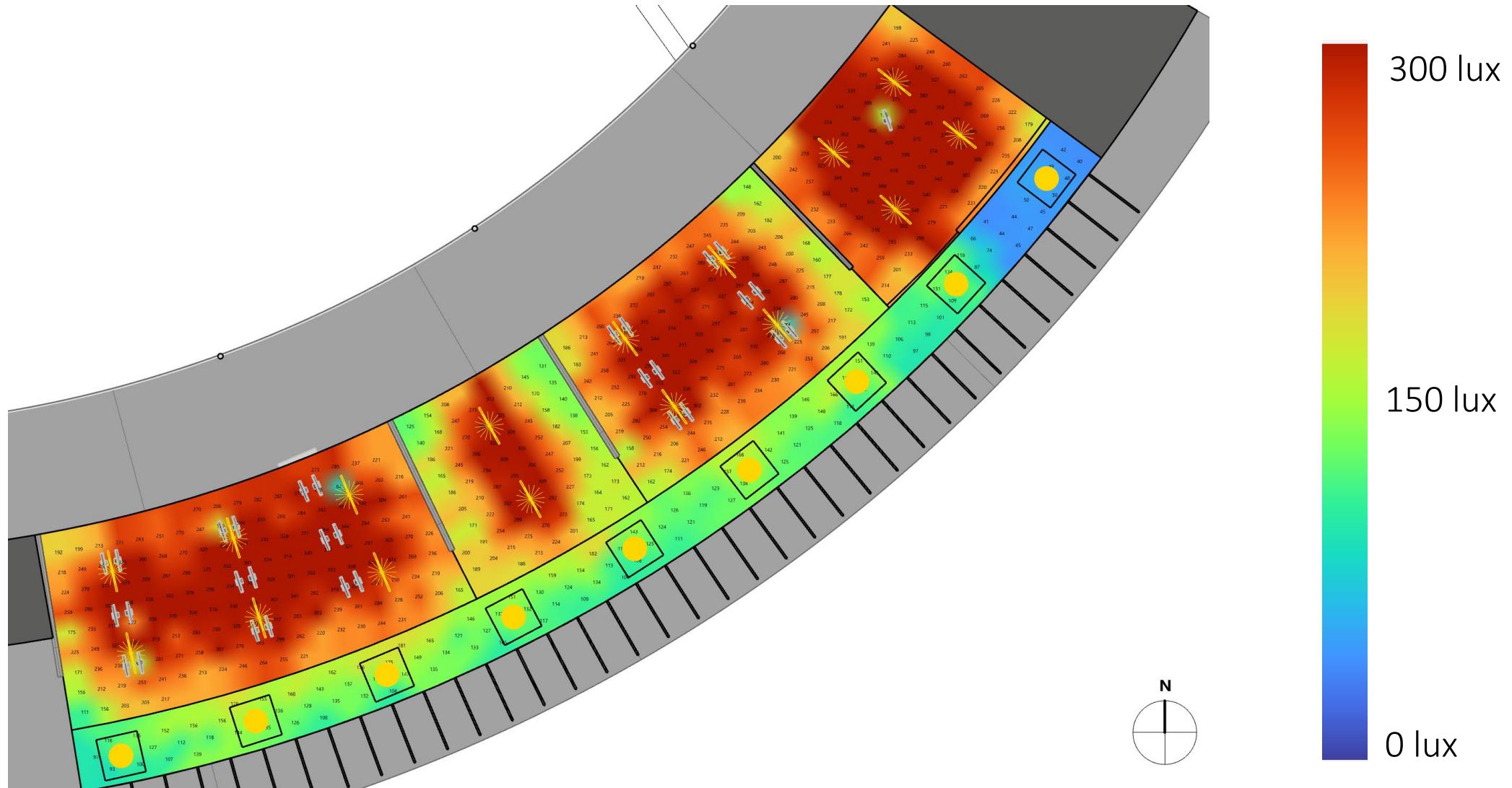
Signify:
TruGrooves Shapes,
Suspended Direct LED

1500 lm/ 2 ft. x 2 ft.

3500K

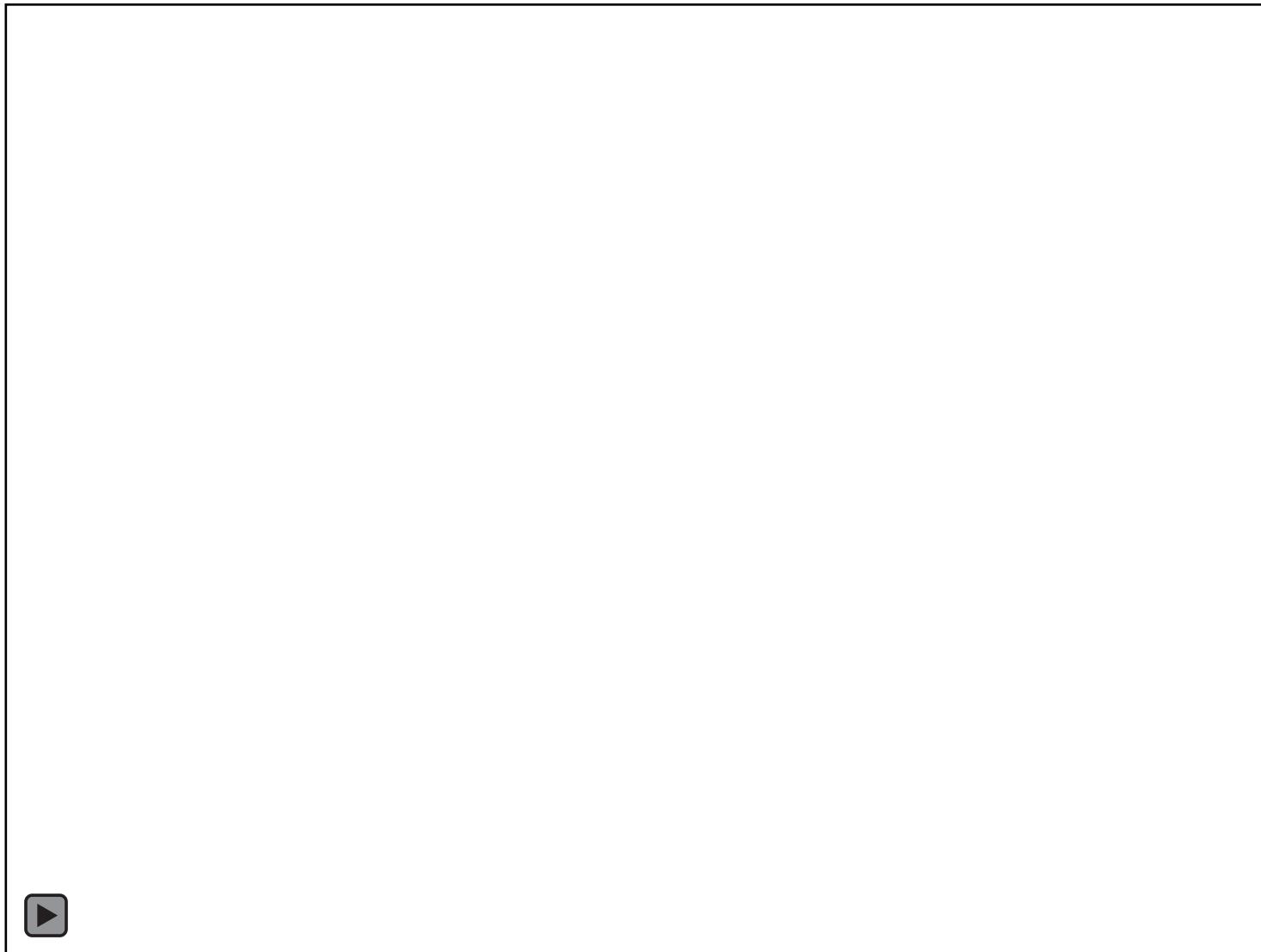
- ☐ Two luminaire types for workspaces (target = 300lux) and corridor (Target 150lux)

6 Electric Lighting Design in 2 dimensions



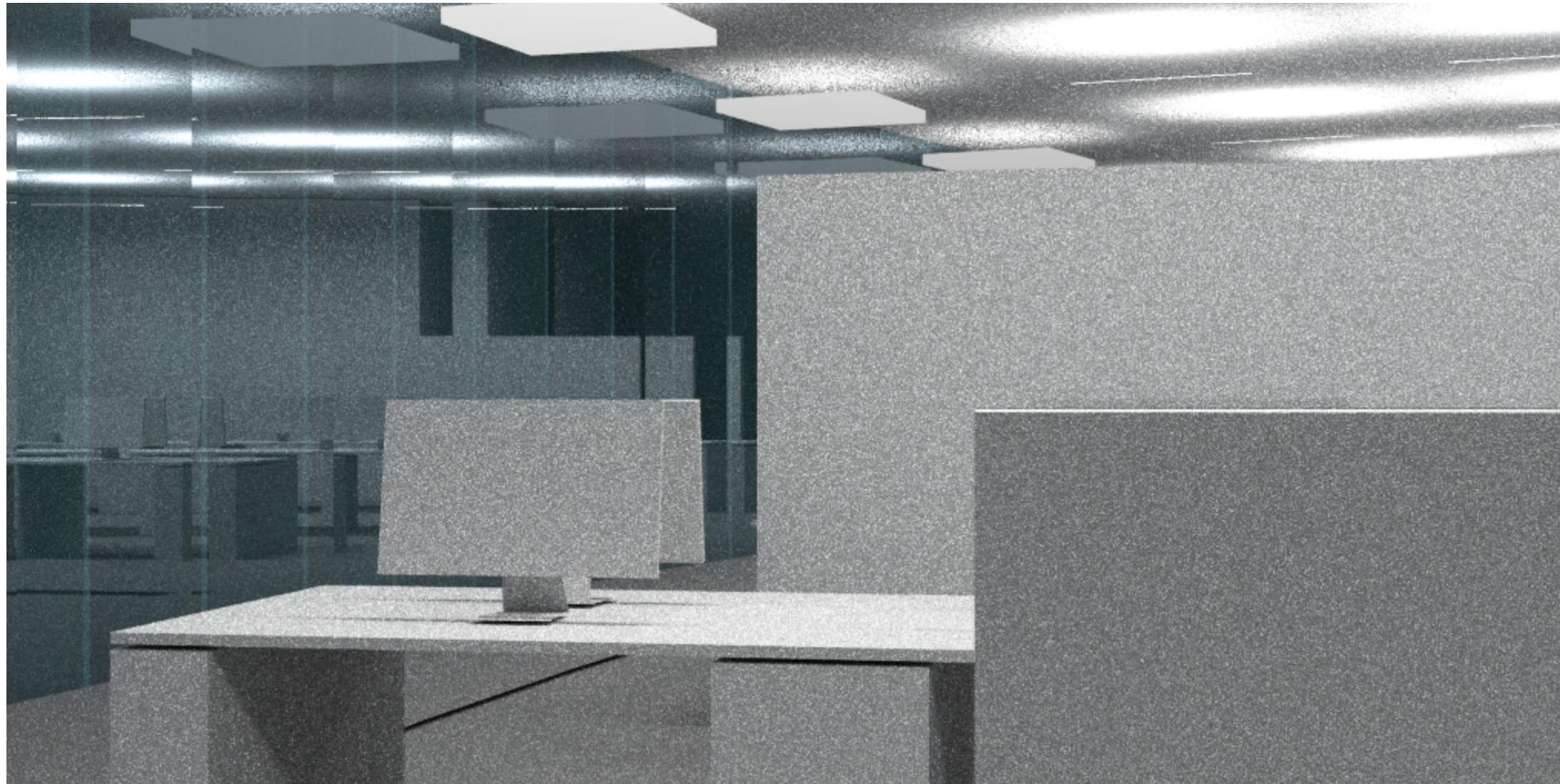
- Two luminaire types for workspace (target = 300lux) and corridor (Target 150lux)

6 Electric Lighting Design in 2 dimensions



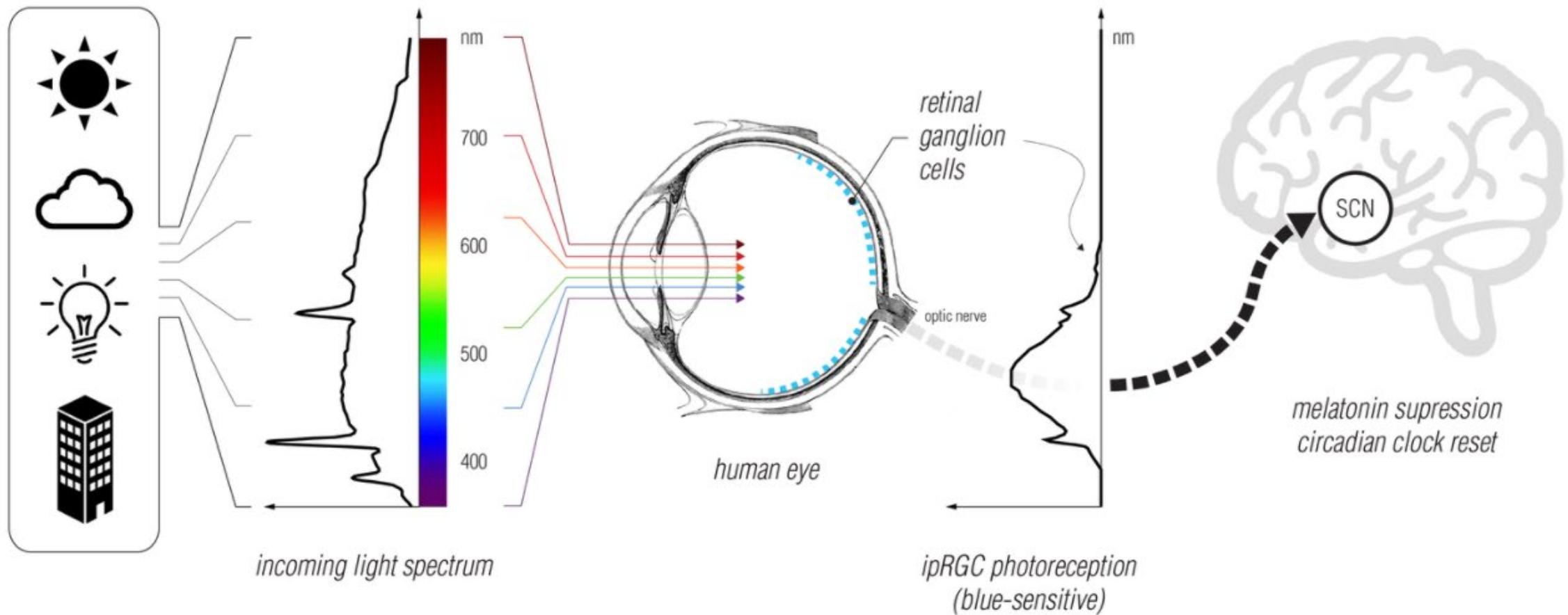
Parametric design to optimize spacing

6 Electric Lighting Design in 3 dimensions



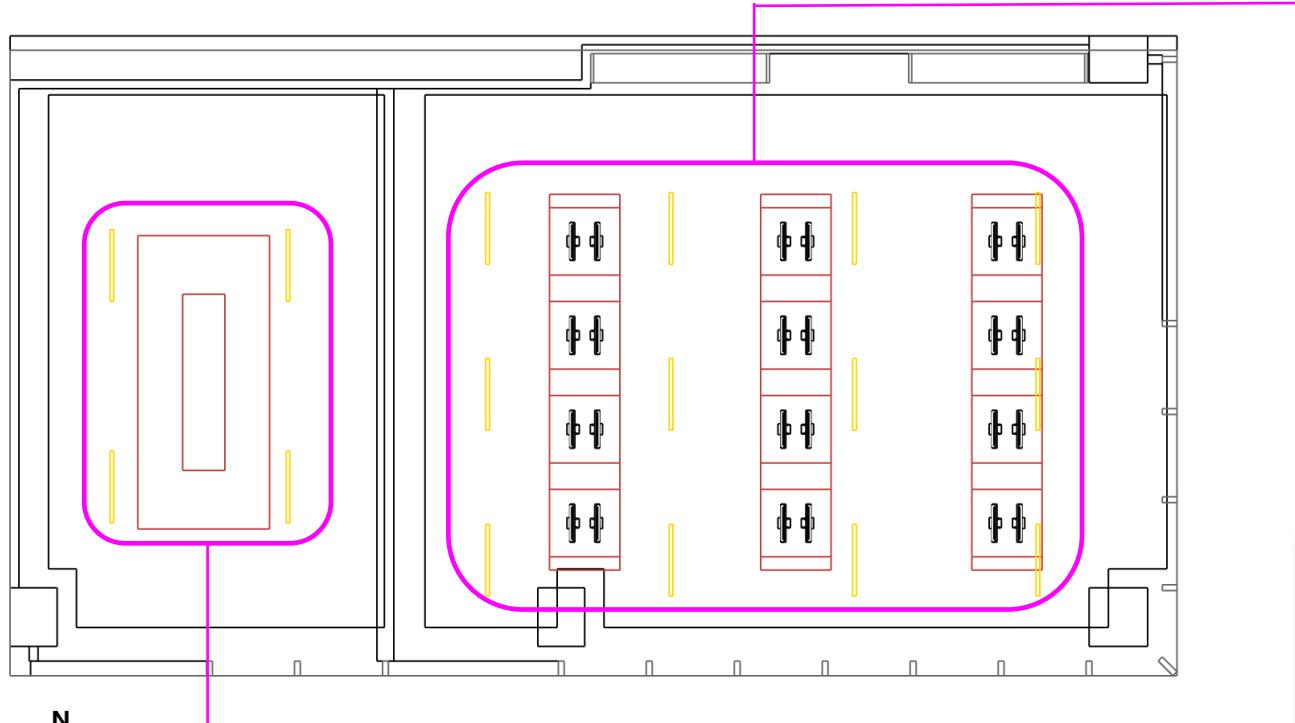
□ Dan Weissman (Lam Partners): “Simulation as a proxy for experience.”

6 Electric Lighting Design For Health

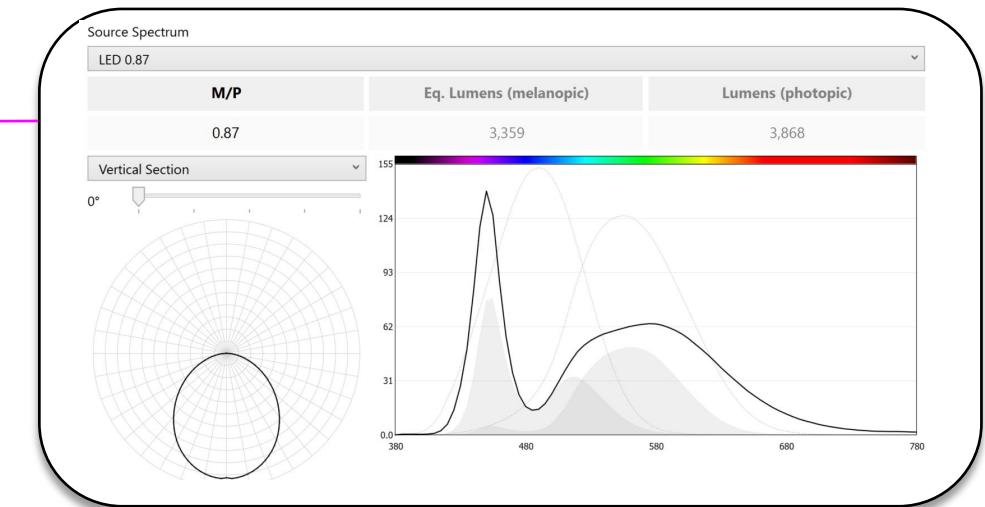


- 81 color channel simulations using ALFA

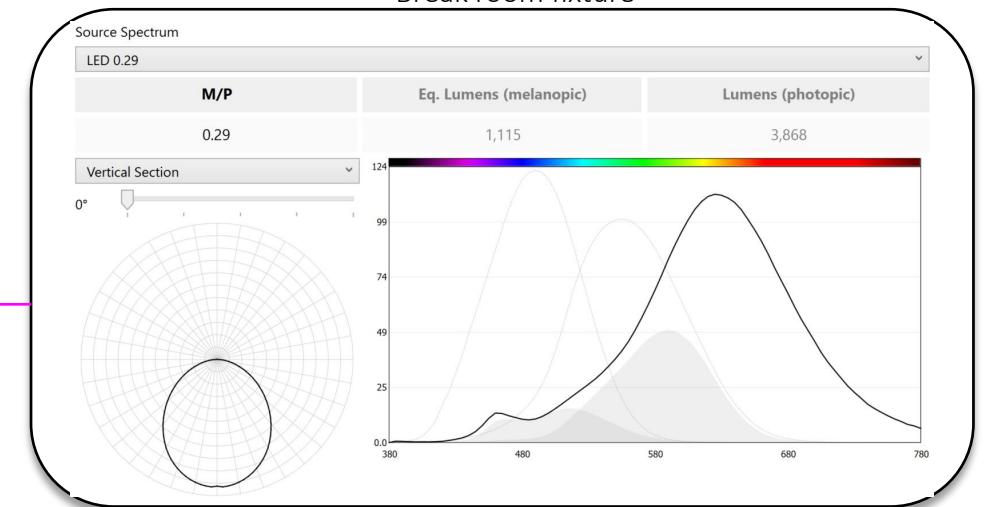
6 Electric Lighting Design For Health



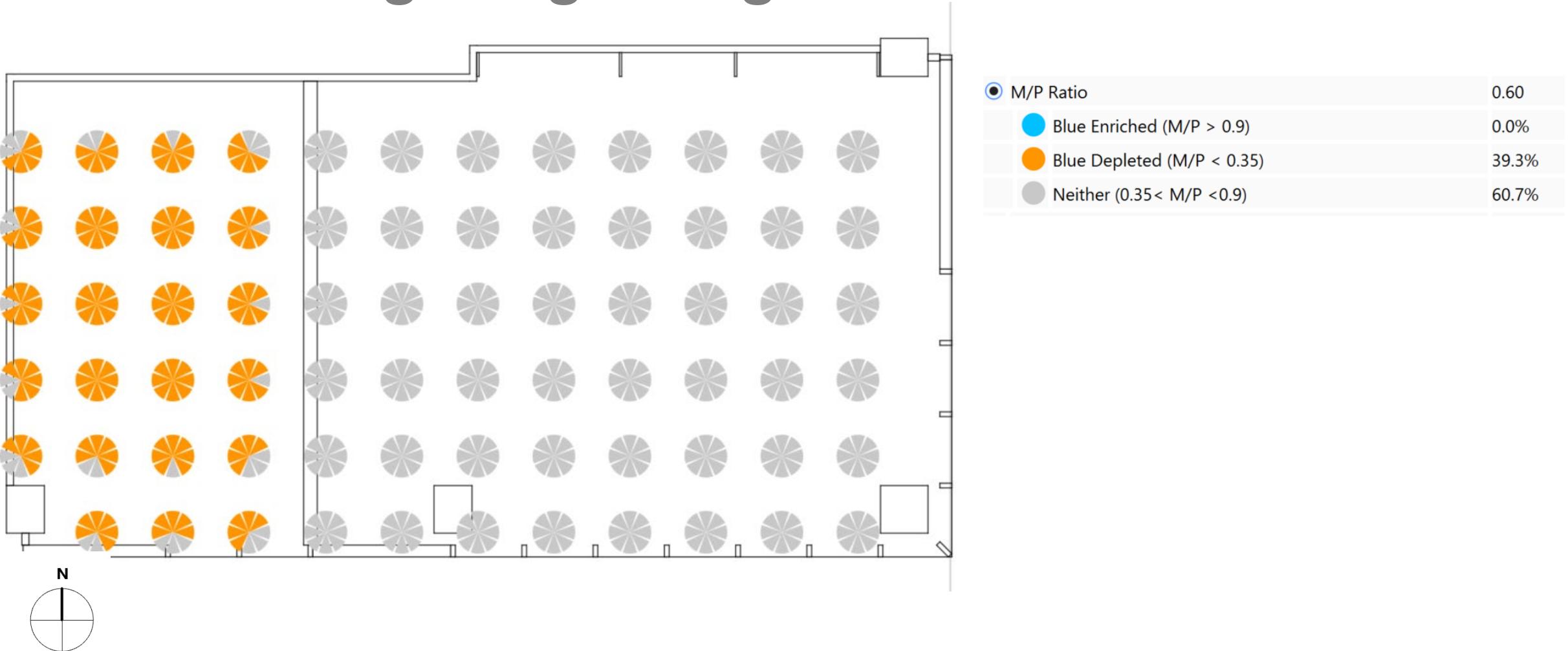
Open Office fixture



Break room fixture

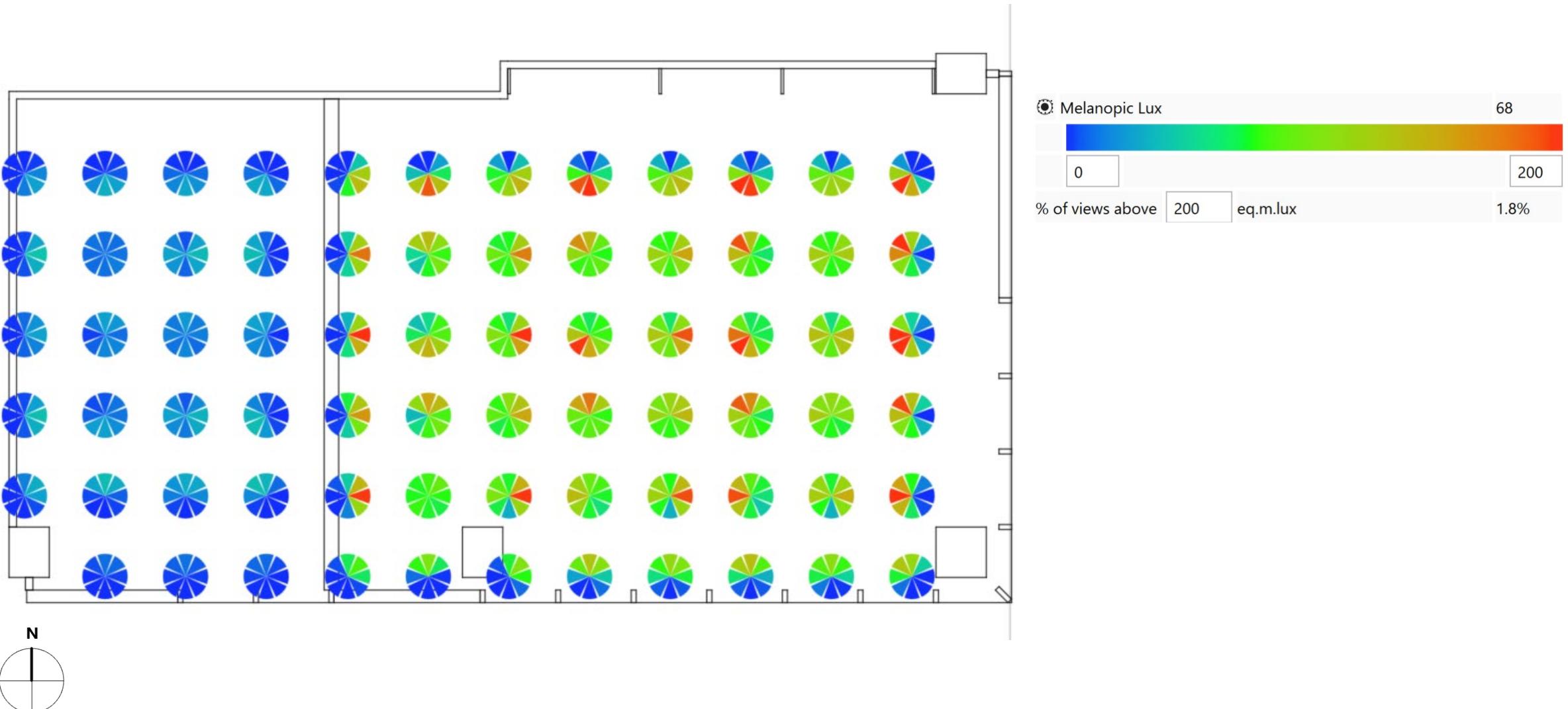


6 Electric Lighting Design For Health

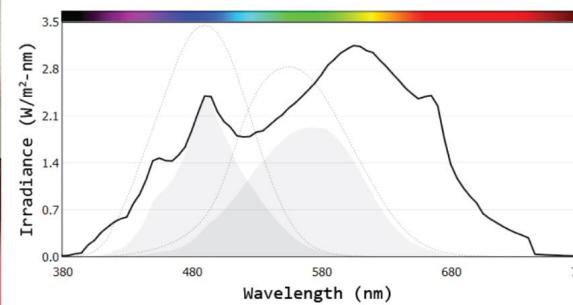
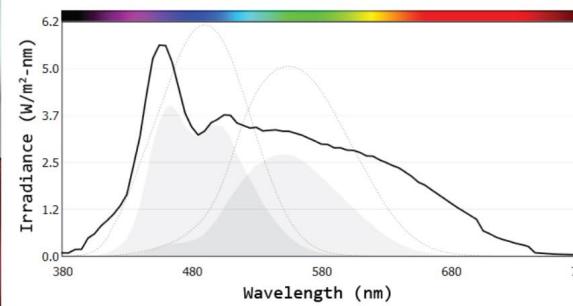


□ Warm break room, neutral working area

6 Electric Lighting Design For Health

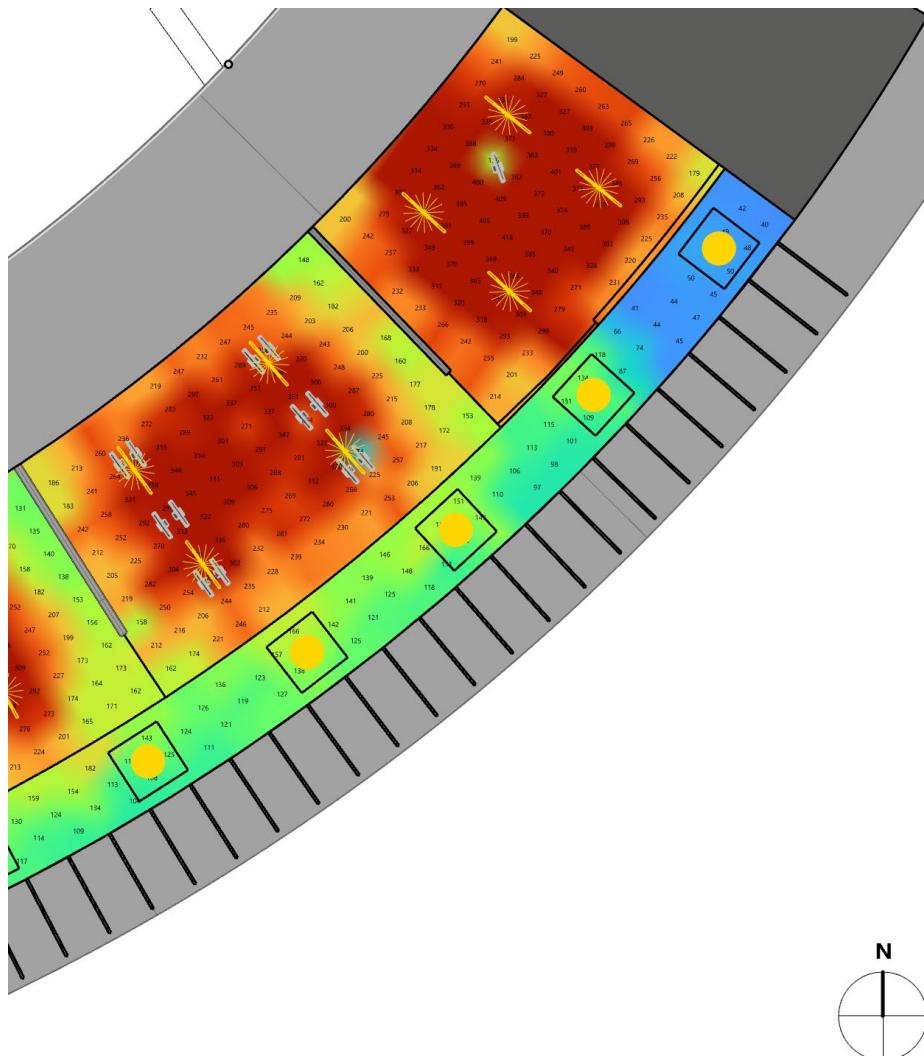


6 Electric Lighting Design For Health



- ☐ Rendering for different spectral distributions

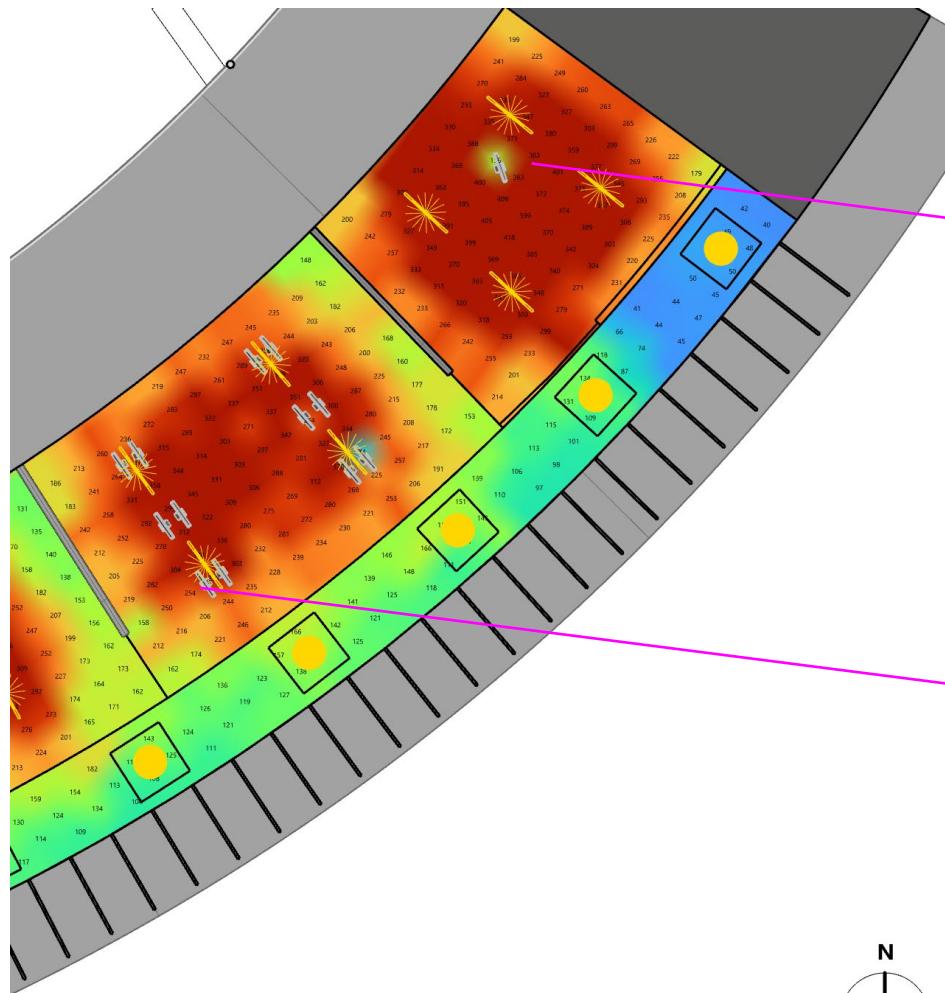
6 Electric Lighting Design | Schedules



IES/ASHRAE 90.1 – 30kWh/m²yr

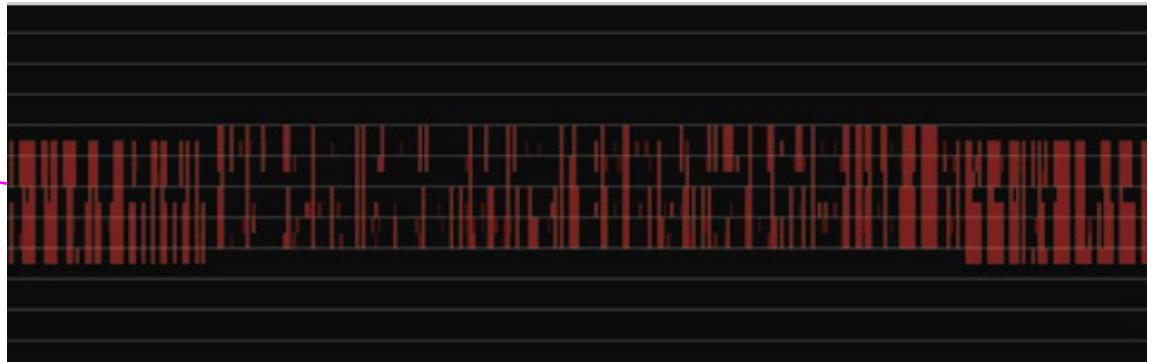
Default ASHRAE schedules very high

6 Electric Lighting Design | Schedules

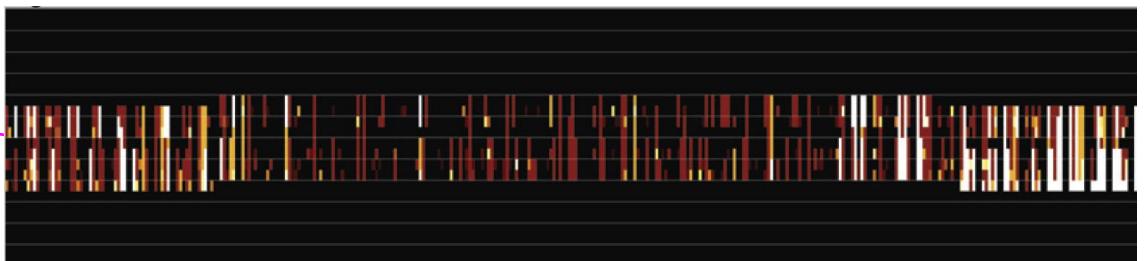


Occupant behavior models

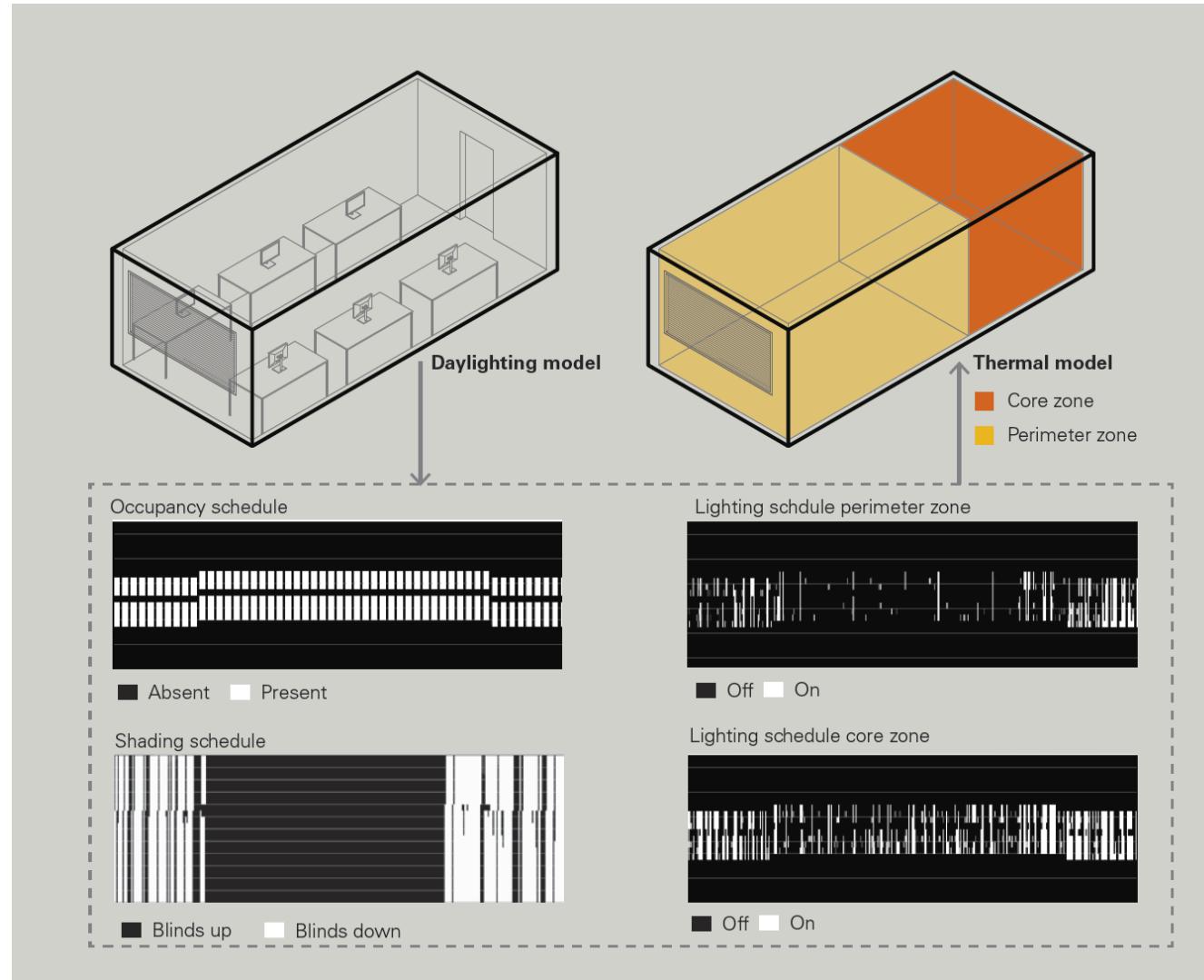
Core zone – 10kWh/m²yr



Perimeter zone – 4kWh/m²yr

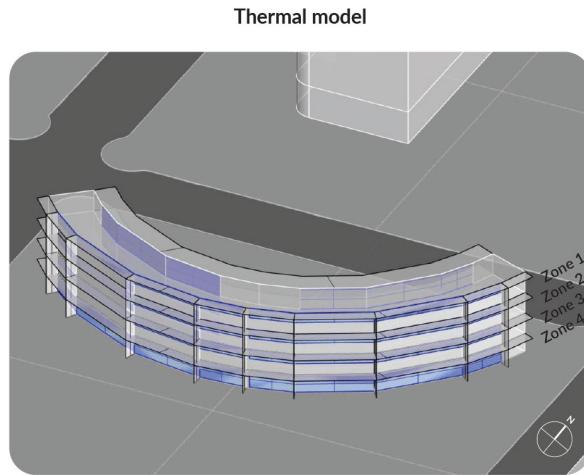


Transition Lighting to Therma Model

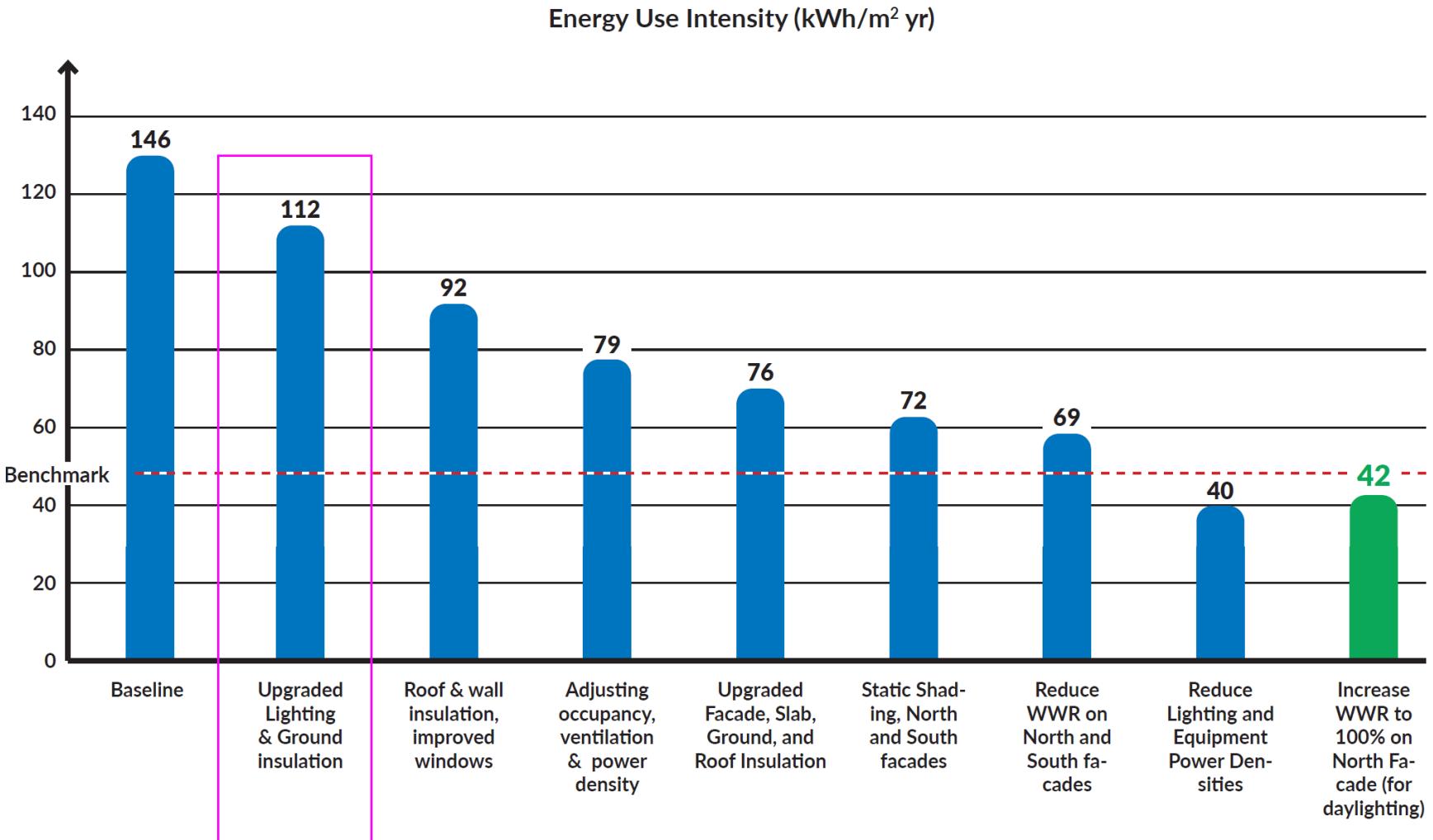
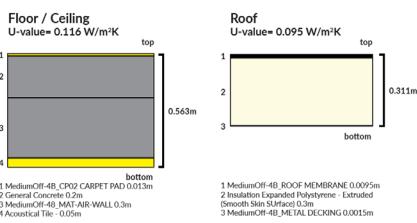
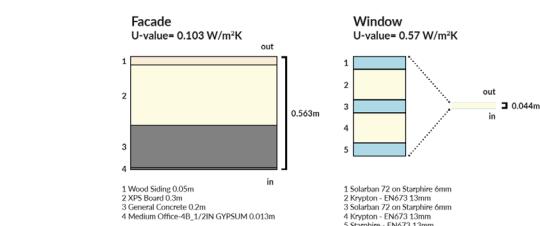


□ Lighting Power Density 4.4 W/m²

7 EUI Study

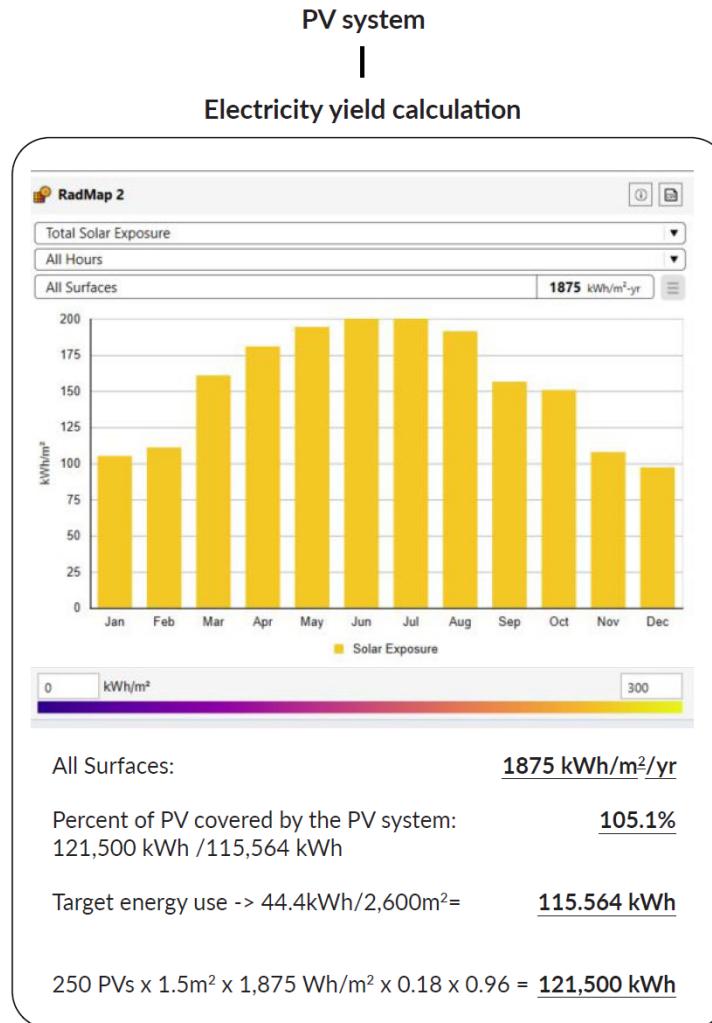


Legend: Window (blue) Zones (grey)



Electric Lighting

8 Getting to Net Zero

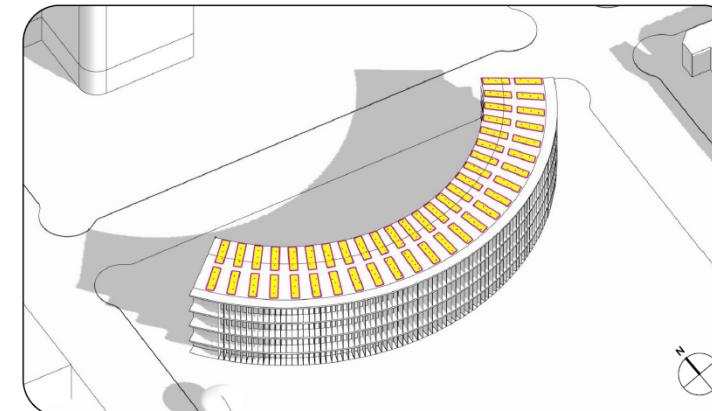


Financial Analysis

Installation costs: (250 panels x 294 W _p /panel x \$US 2.77/W _p **)	<u>\$US 203,595</u>
Federal tax break*: (\$US 203,595 x 0.26)	<u>\$US 52,935</u>
Total installation cost after taxes:	<u>\$US 150,660</u>
Annual revenue/savings through PV system: (121,500 kWh/yr x \$US 0.22)	<u>\$US 26,730</u>
Payback time: (\$US 150,660 / \$US 26,730/yr)	<u>5.6 years</u>

* 26% Federal Investment Tax Credit (ITC) for Amarillo TX

** As of December 2020



- ☐ Matching energy demand with PV yield

A few questions

- ❑ How efficient is the overall, global lighting system?

For outside applications there seems to be a strong focus on light source vs. design and control.

- ❑ Do we still need daylighting?

Yes, for health purposes but also as a financial driver for projects.

- ❑ How can we best integrate SSL technologies into the architectural design process?

Innovative , easy to use simulation tools that foster collaboration with the larger design team

Thank You

