June 25, 2024

Forest to Façade: Commercial Seismic, Daylighting, and Energy Retrofits

NEEA PRODUCT COUNCIL

UNIVERSITY OF OREGON

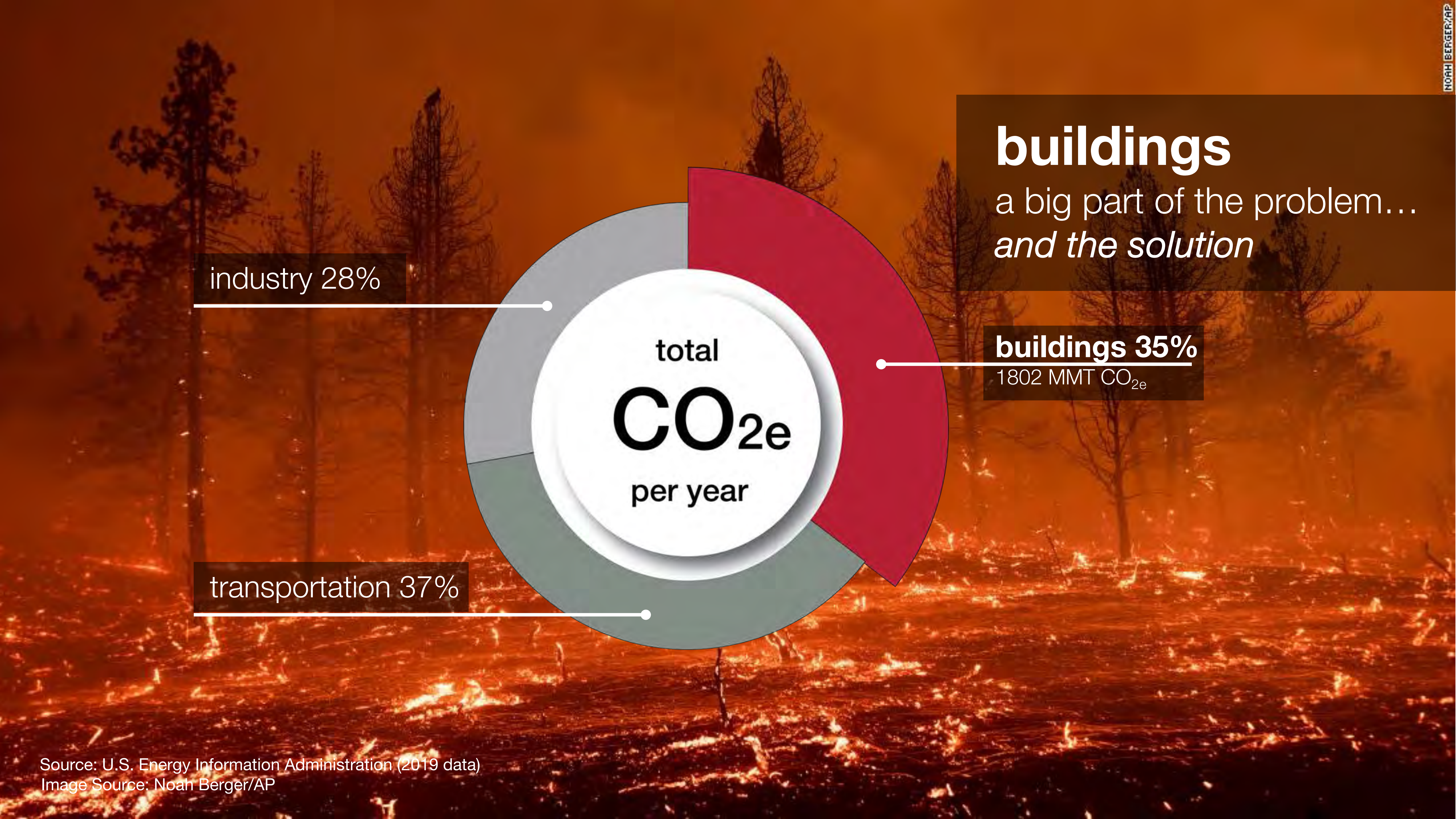
Agenda

- Project overview
- Mass timber seismic and energy retrofits
- Daylight design optimization to improve daylight availability while saving energy

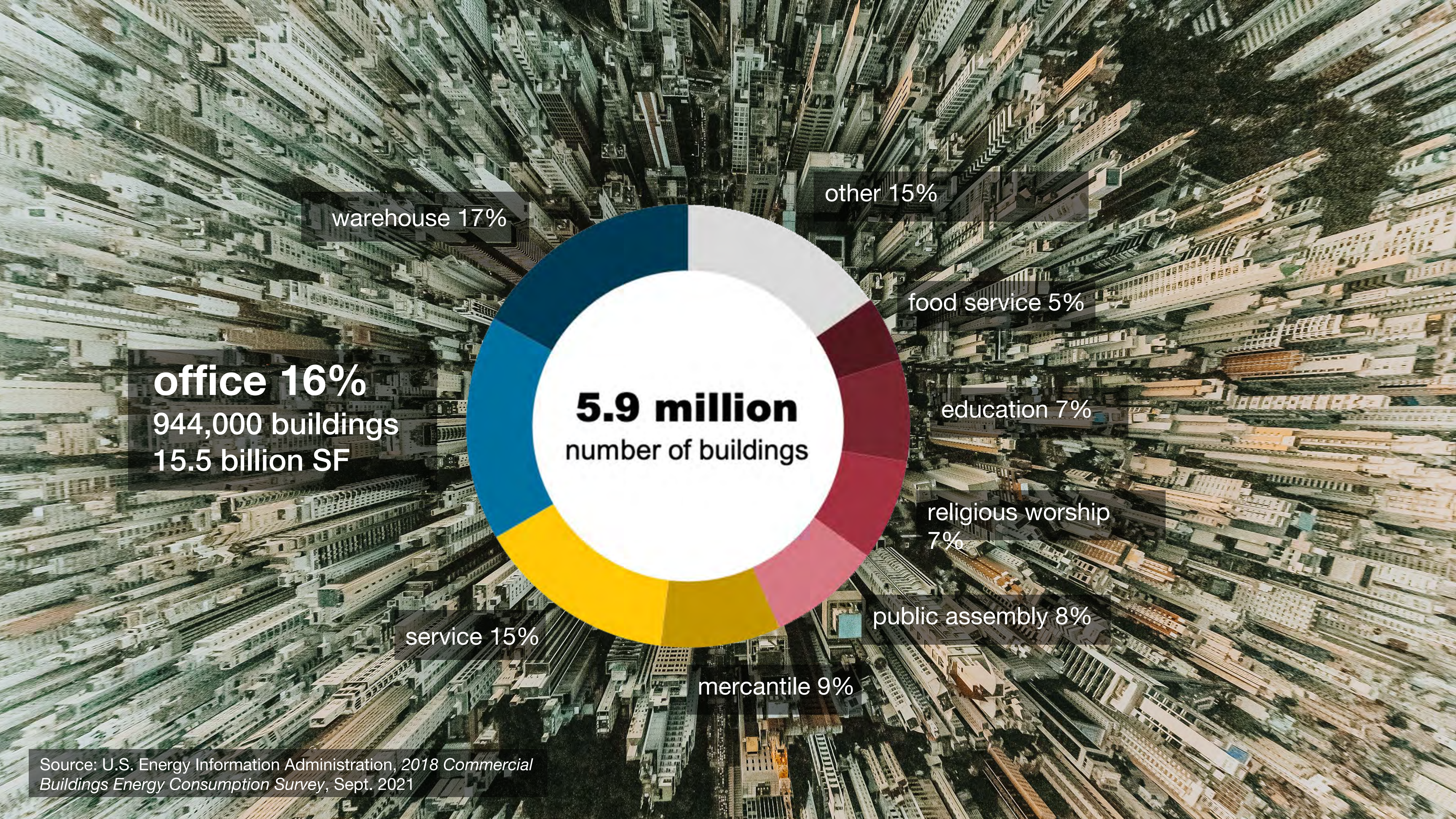
Learning Objectives

- Learn about recent development in mass timber applications to improving commercial seismic and energy performance via existing building retrofits
- Understand the added opportunity to improve daylighting performance, which can affect energy performance, occupant comfort and health
- Discuss effects of daylighting on visual health and potential opportunities for electric lighting and controls upgrades

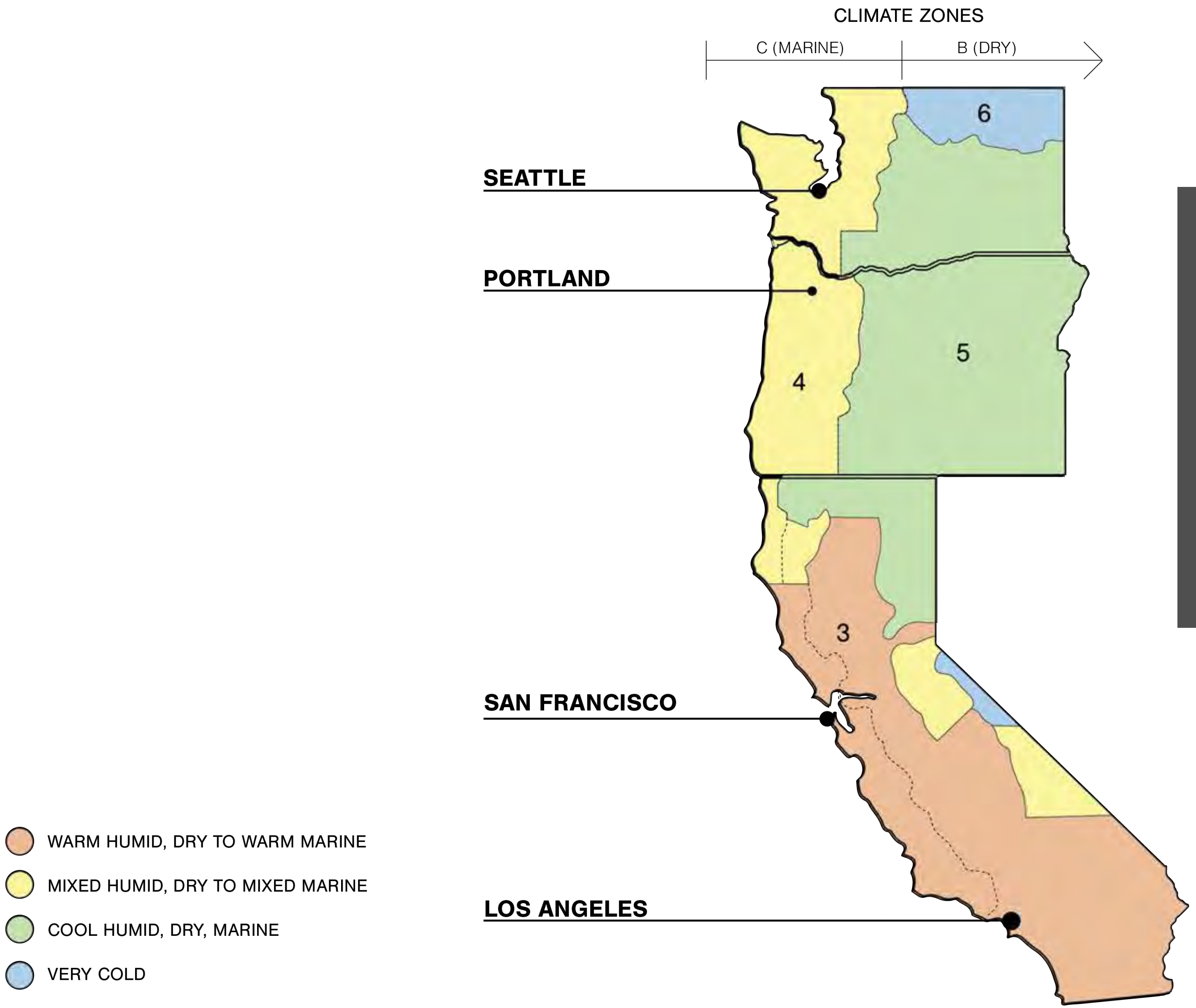
Image Source: Noah Berger/AP



Source: U.S. Energy Information Administration (2019 data)
Image Source: Noah Berger/AP



warehouse 17%
other 15%
food service 5%
office 16%
944,000 buildings
15.5 billion SF
5.9 million
number of buildings
education 7%
religious worship 7%
public assembly 8%
service 15%
mercantile 9%
Source: U.S. Energy Information Administration, *2018 Commercial Buildings Energy Consumption Survey*, Sept. 2021

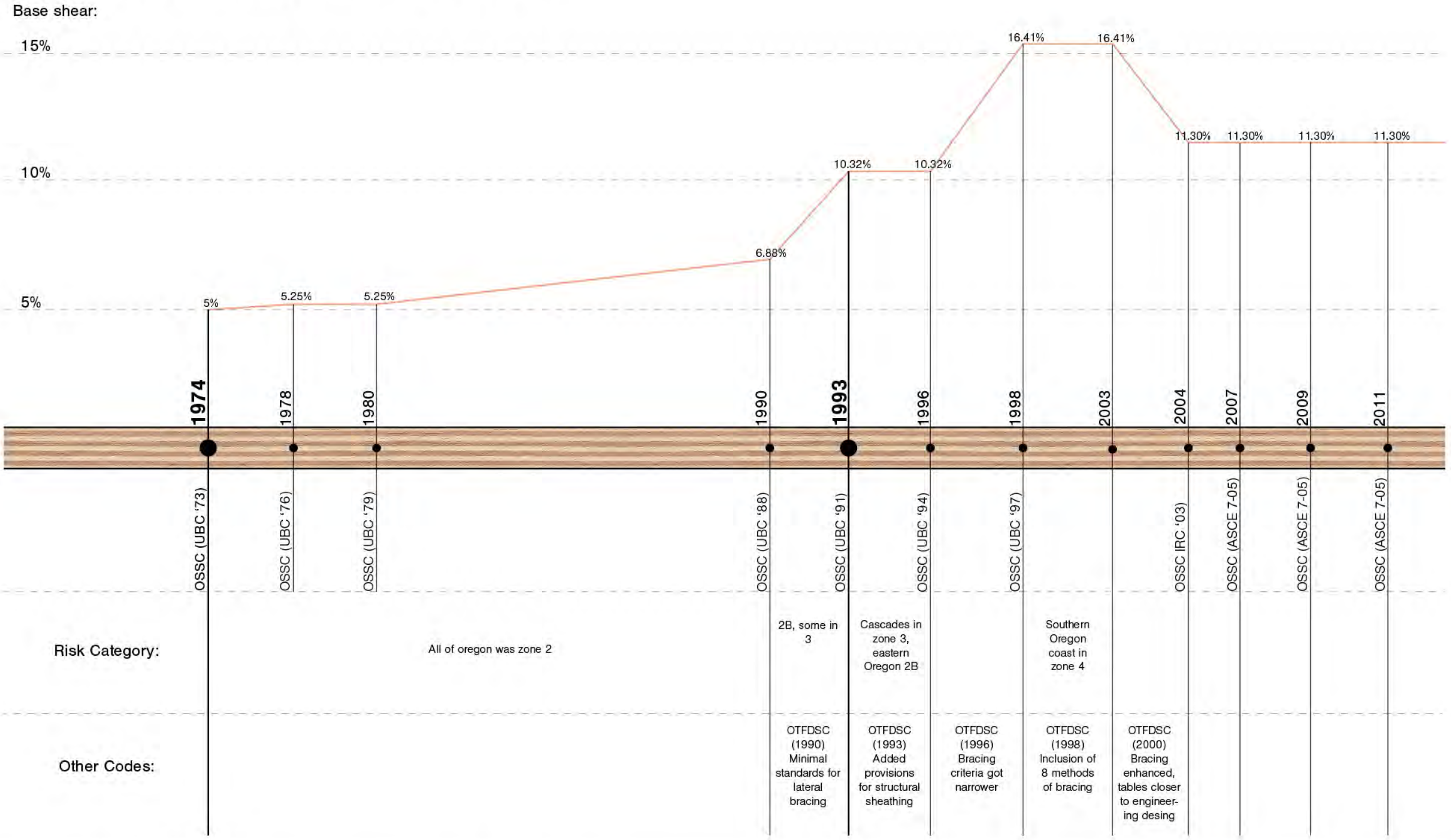


SOURCE: ASHRAE

energy retrofits

areas of climate zones in 4, 5, 6 could especially benefit from increased façade thermal resistance.

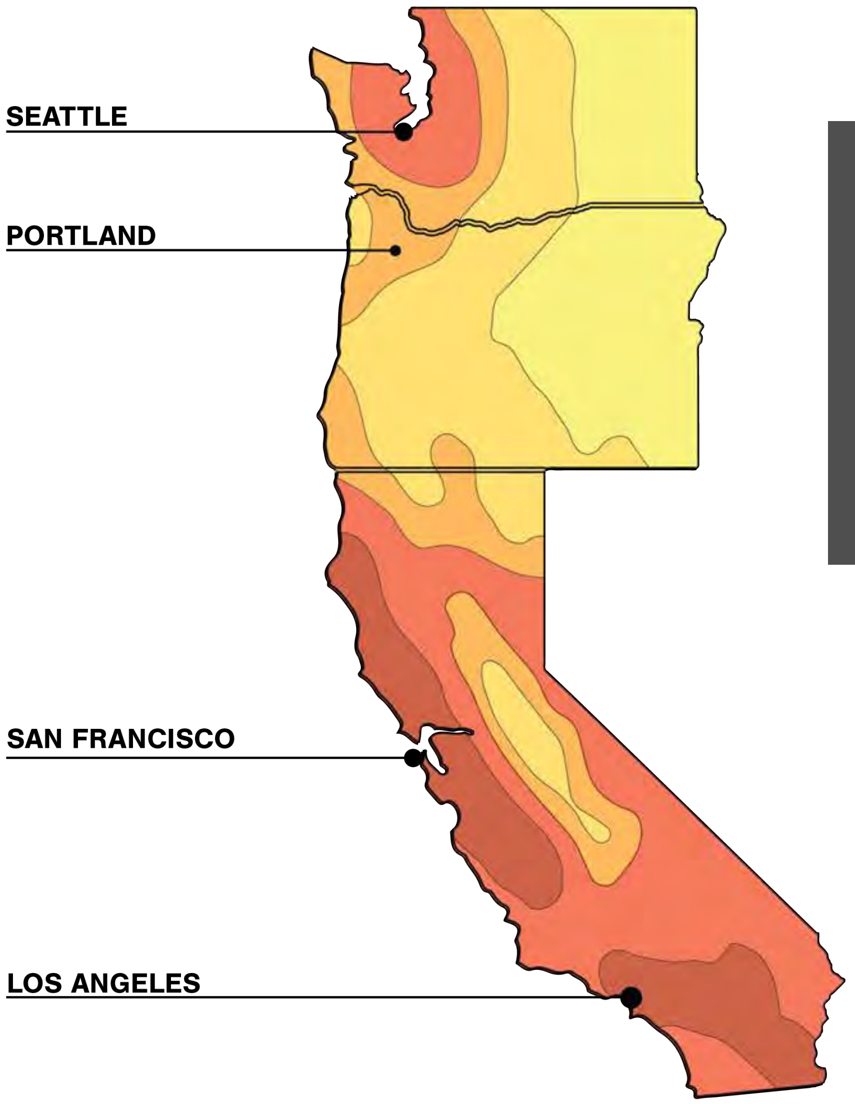
EVOLUTION OF SEISMIC DESIGN STANDARDS



This work is supported by the 2020 Wood Innovations Program grant number 20-DG-11062765-737 from the USDA U.S. Forest Service

seismic retrofits

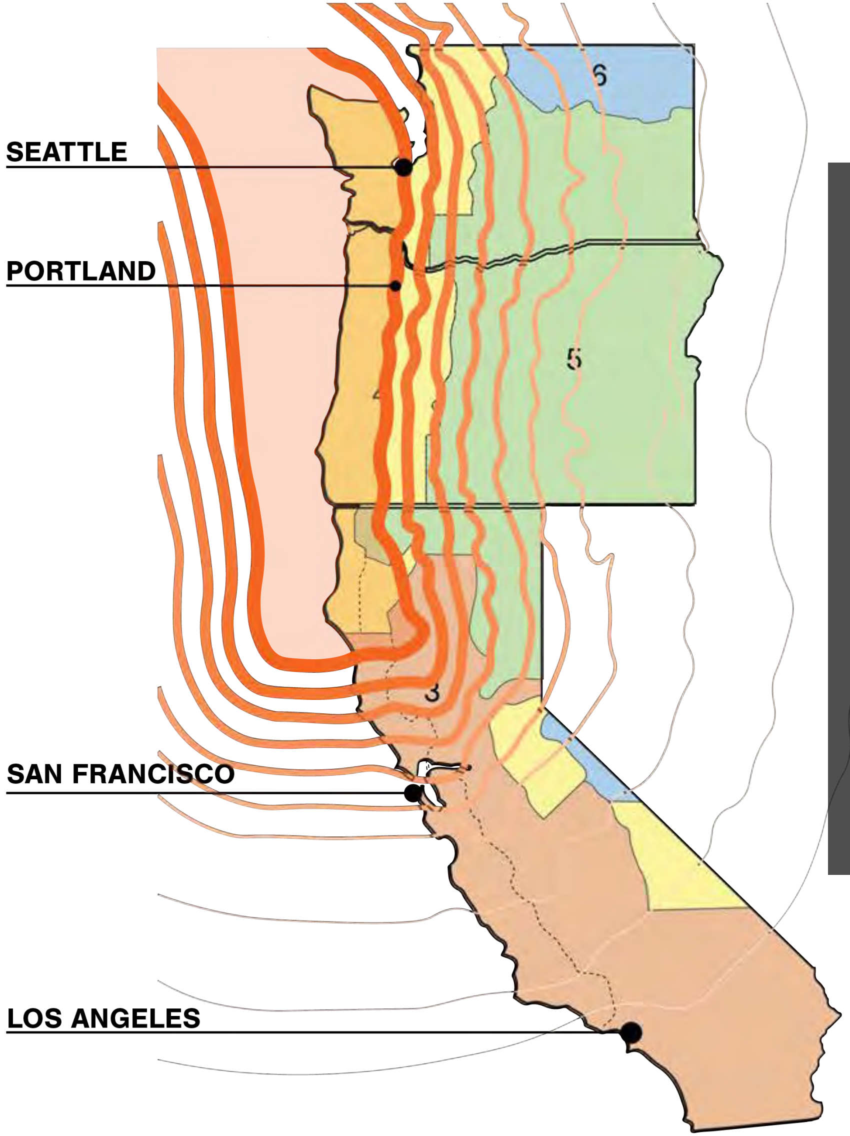
the U.S. West Coast has substantial need to prepare for seismic events



EXPECTED NUMBER OF OCCURANCES

- >250
- >100-250
- >50-100
- >20-50
- >10-20

SOURCE: https://www.usgs.gov/natural-hazards/earthquake-hazards/science/introduction-national-seismic-hazard-maps?qt-science_center_objects=0#qt-science_center_objects

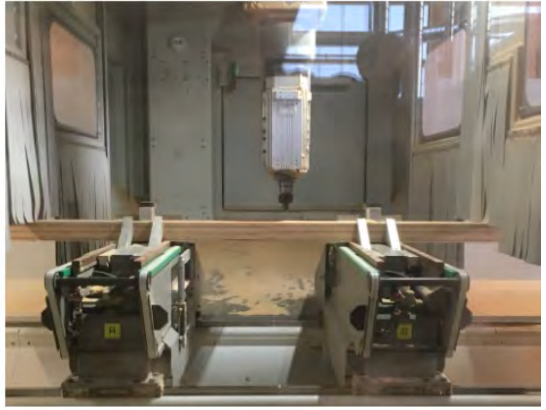


- WARM HUMID, DRY TO WARM MARINE
- MIXED HUMID, DRY TO MIXED MARINE
- COOL HUMID, DRY, MARINE
- VERY COLD

SOURCE: https://earthquake.usgs.gov/scenarios/eventpage/bssc2014cascadia_sub0_m9p34_se/map

energy + seismic retrofits

areas of climate benefitting from increased façade thermal insulation align with areas of Cascadian subduction zone and present a unique opportunity for combining both efforts.



Forest to Façade

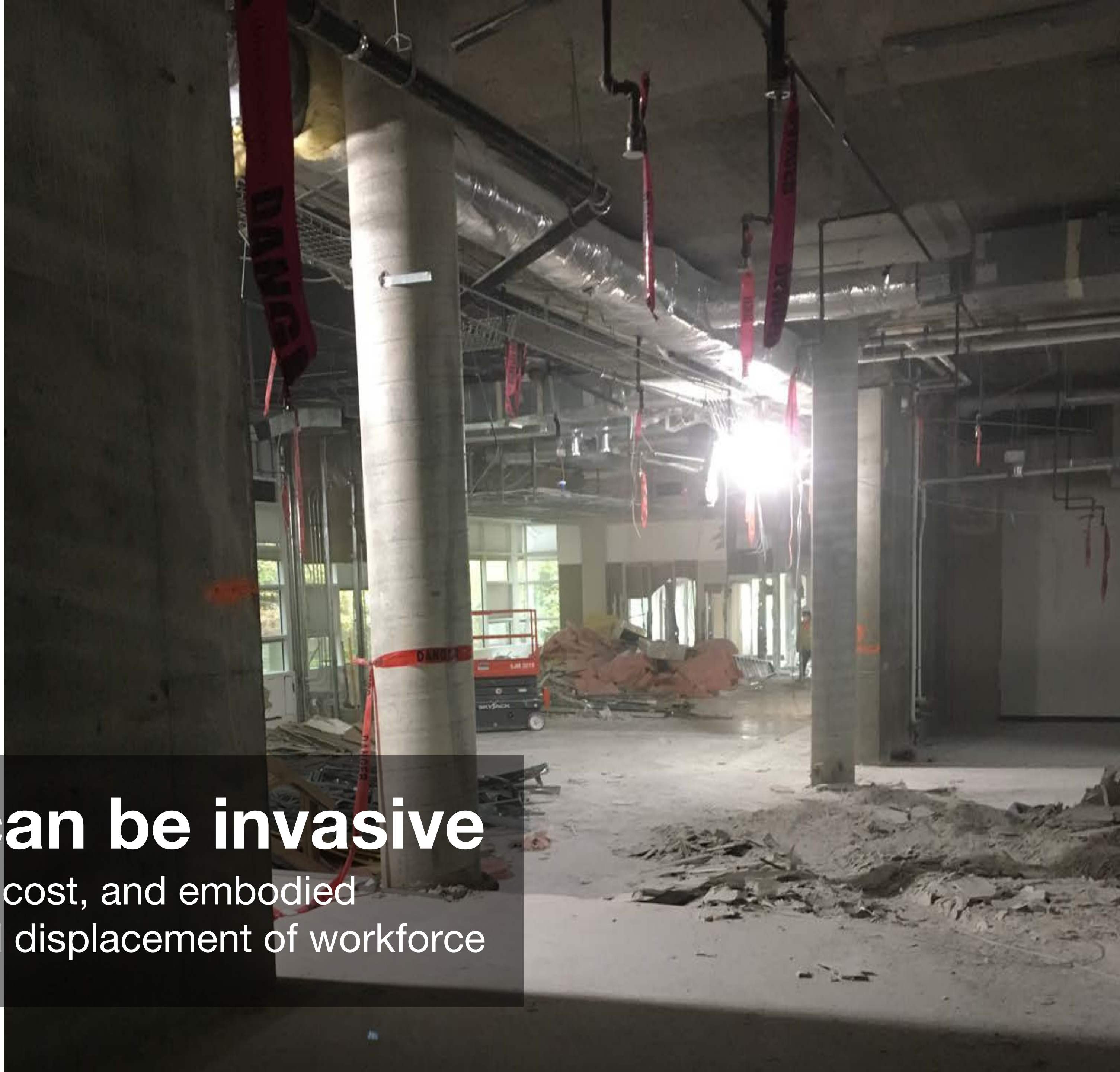
using mass plywood and digital workflows to retrofit low-rise commercial buildings for climate and seismic resilience

Images - (top) Forest, Eugene Deshko, unsplash.com **(mid left, middle)** Freres Lumber digital panel processing **(mid right)** OSU Emmerson Lab digital fabrication **(bottom)** Freres Lumber MPP Production hall

“energiesprong”

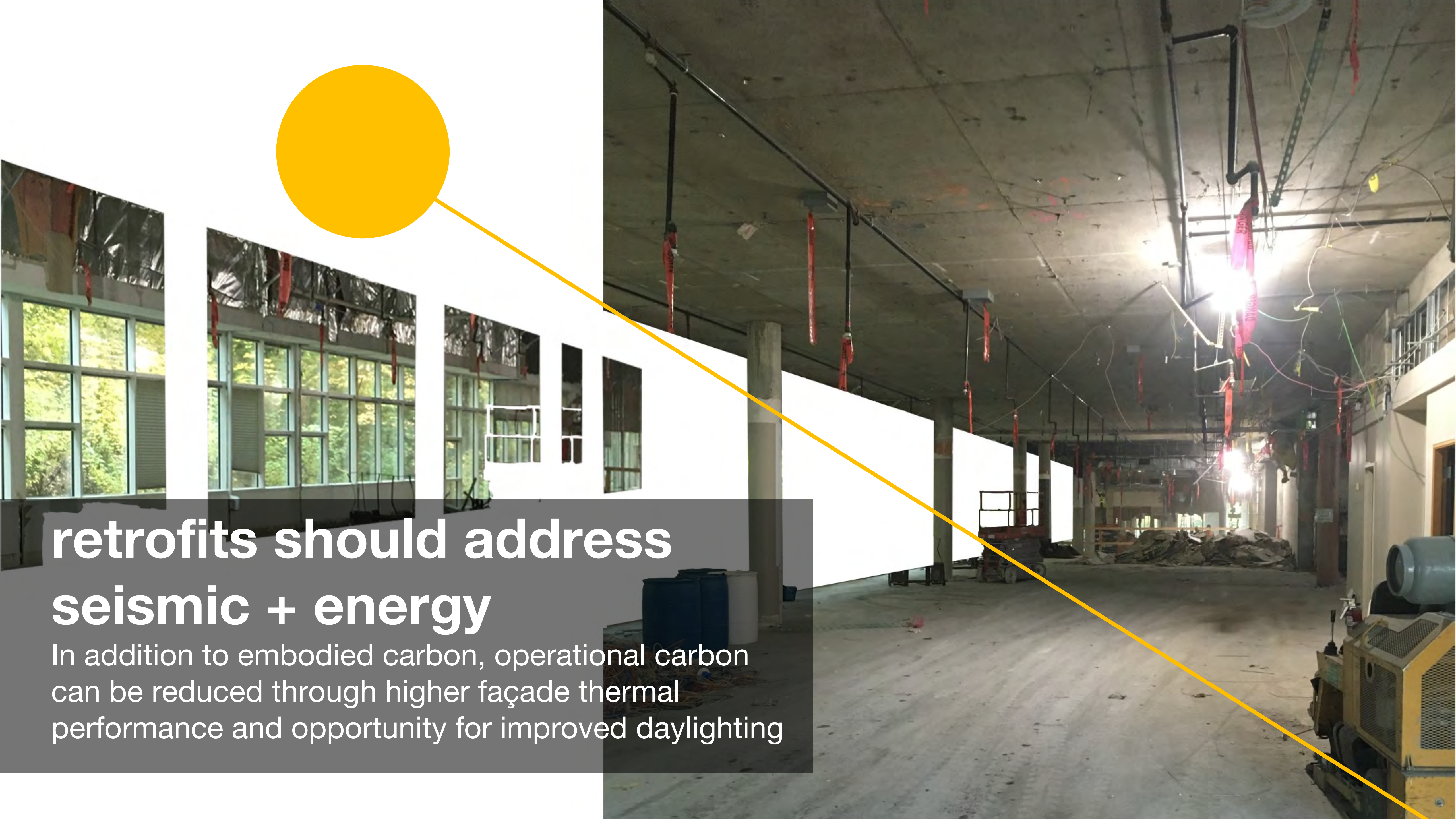
the concept of a leap in energy savings, originated in holland and uses premanufactured facades, created from a building scan, to cover an existing facade. we are developing this in the U.S. using mass timber to reduce energy/emissions of the assembly itself.


Façade Deep Energy + Seismic Retrofit



commercial retrofits can be invasive

leaving behind substantial material waste, cost, and embodied carbon along with business disruption and displacement of workforce



retrofits should address seismic + energy

In addition to embodied carbon, operational carbon can be reduced through higher façade thermal performance and opportunity for improved daylighting

Forest to Façade

developing seismic + energy mass timber commercial façade retrofits

the project

we are using a case study PNW four-story low-rise reference office building to explore seismic upgrade using a mass timber façade-based alternative that also improves energy performance

UNIVERSITY OF OREGON

Oregon State University

SWINERTON

TIMBERLAB

Forest to Façade

developing seismic + energy mass timber
commercial façade retrofits

the project team

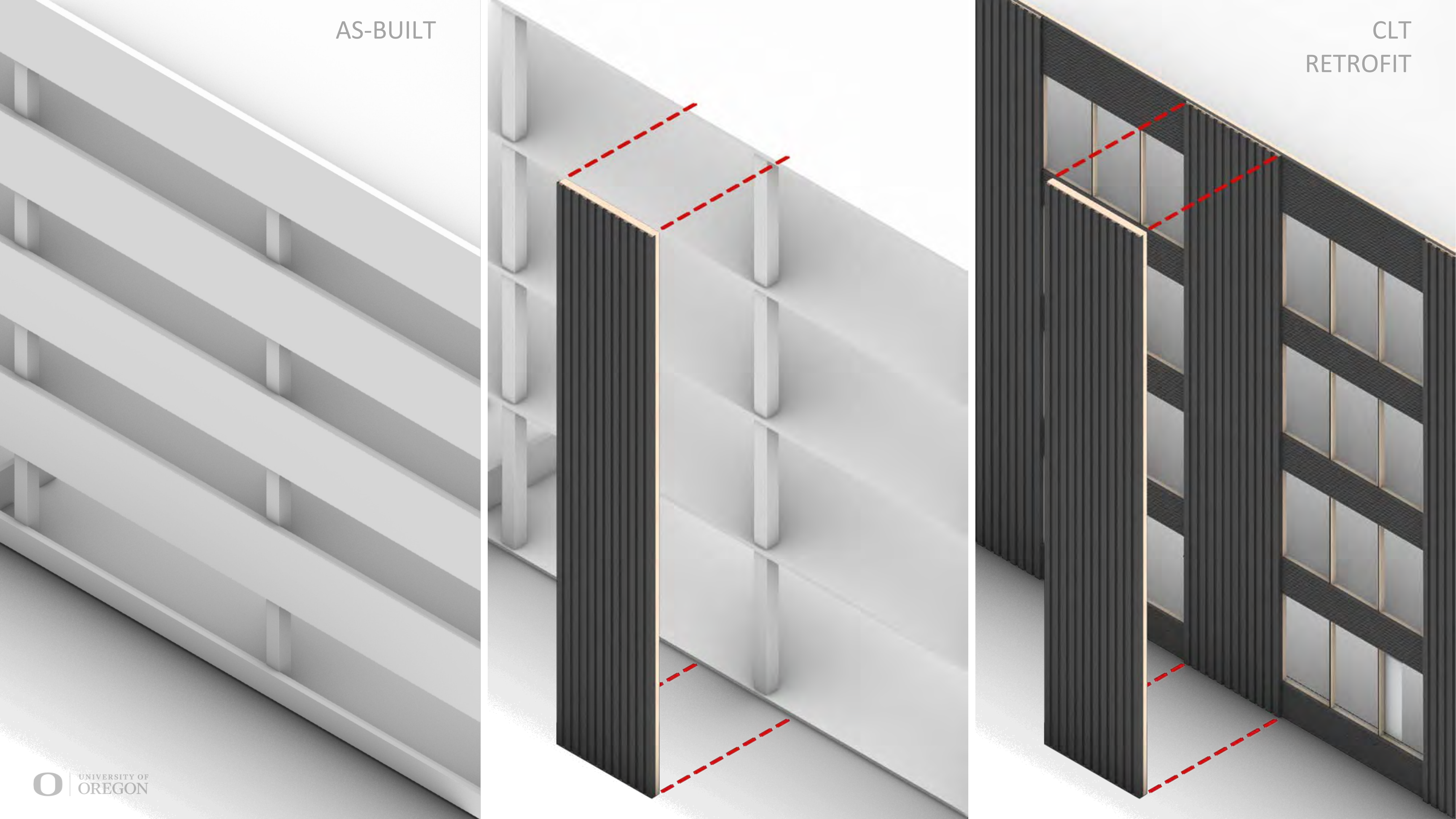
University of Oregon IHBE
Energy Studies in Buildings Lab
Baker Lighting Lab
Mark Fretz (PI), Alen Mahić, Dale Northcutt, Siobhan Rockcastle,
Judith Sheine (Co-PI), Jason Stenson, Daniel Essaides

Oregon State University
Andre Barbosa (Co-PI), Gustavo Fernando Orozco Orozco

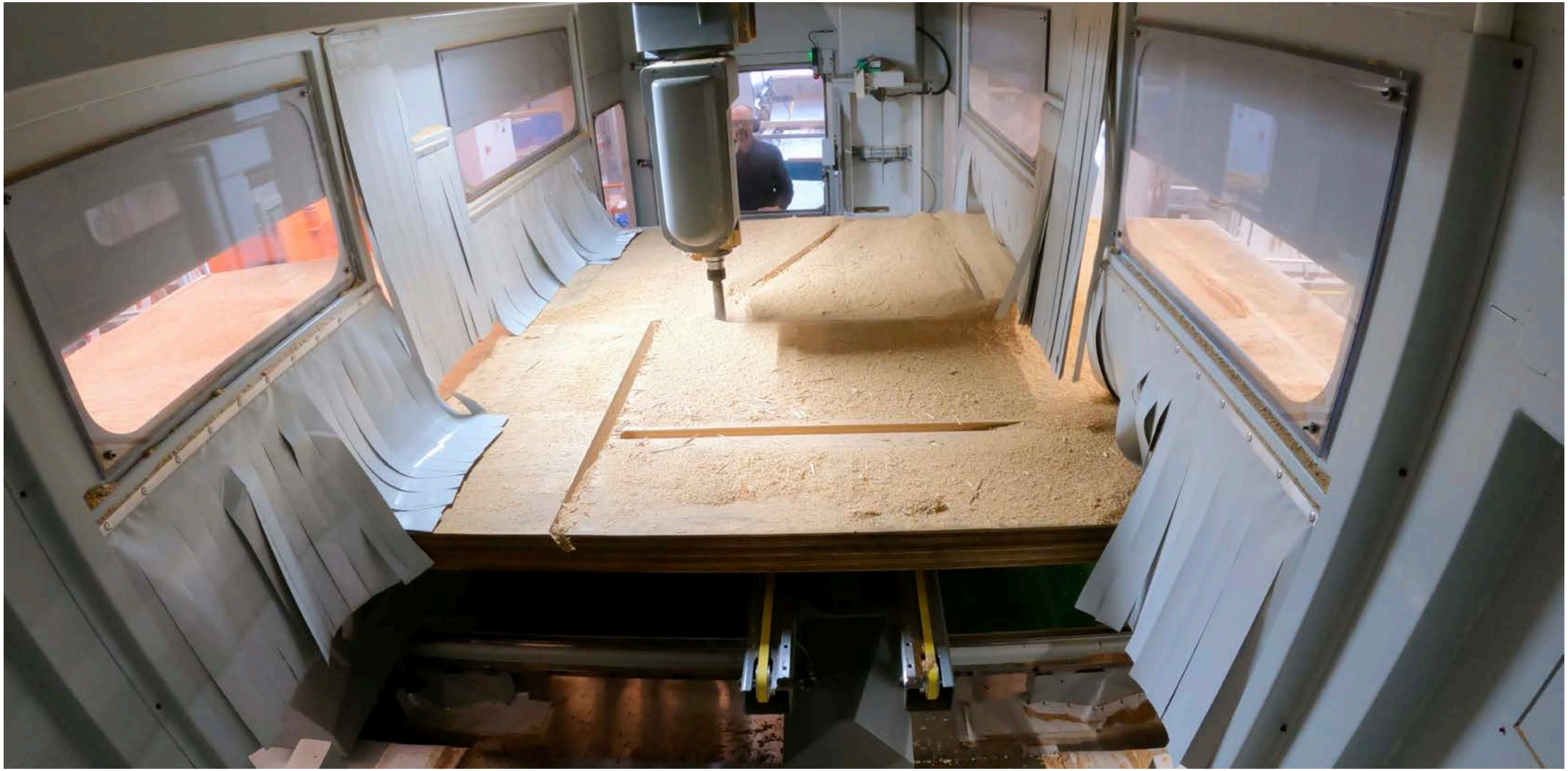
Swinerton / Timberlab
William Silva, Ryan Wasell

Project Goals and Activities

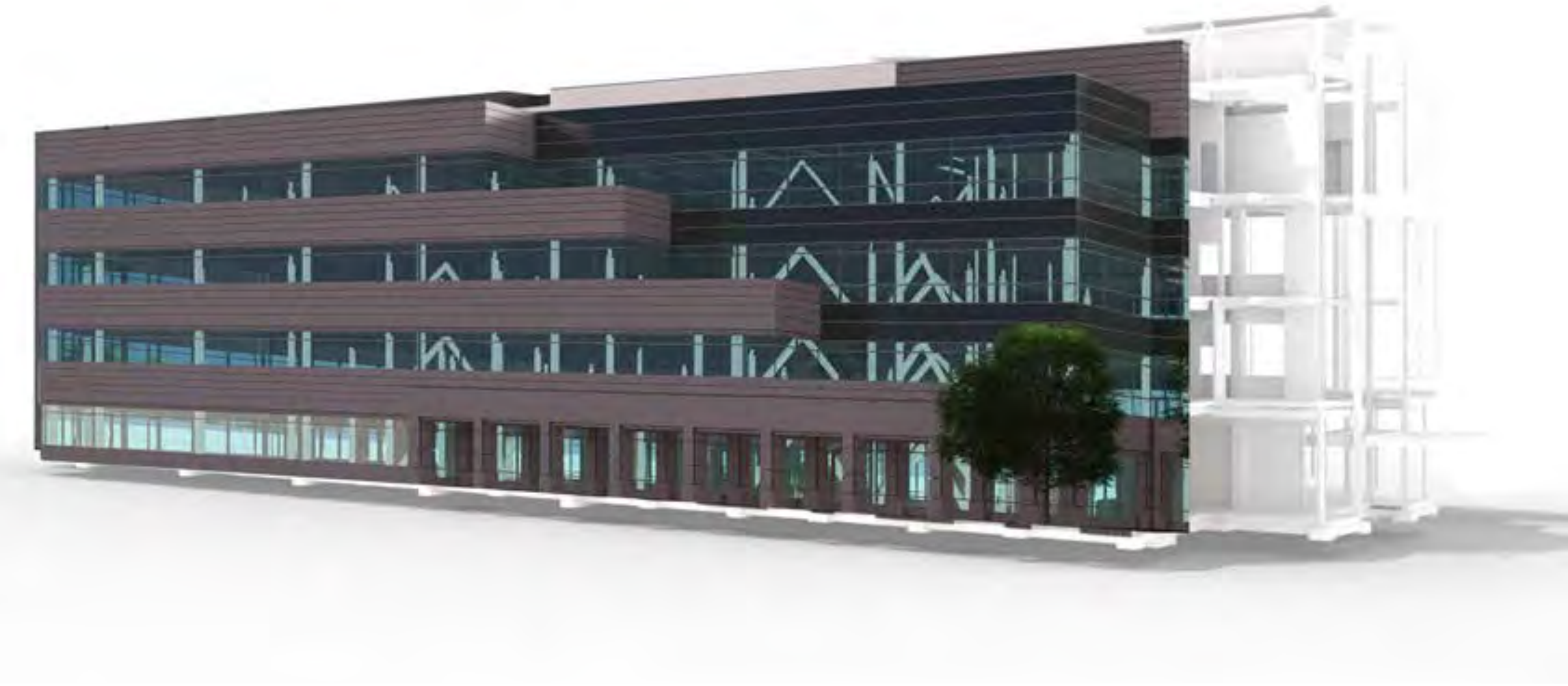
Activity
Goal 1: **Develop a mass timber panel facade retrofit system**
Task 1.1: Building Case Study Development
Task 1.2: Structural Analysis and Sizing
Task 1.3: Energy Performance Analysis of Wall Assembly
Task 1.4: Moisture Analysis of Wall Assembly
Goal 2: **Compare embodied carbon impact**
Task 2.1: Embodied Carbon Analysis of Baseline
Task 2.2: Embodied Carbon Analysis of Proposed Mass Timber Solution
Goal 3: **Provide cost-estimation**
Task 3.1: Cost-Estimation Baseline
Task 3.2: Cost-Estimation Proposal
Goal 4: **Disseminate findings**
Task 4.1: Dissemination


AS-BUILT
CLT
RETROFIT
UNIVERSITY OF
OREGON

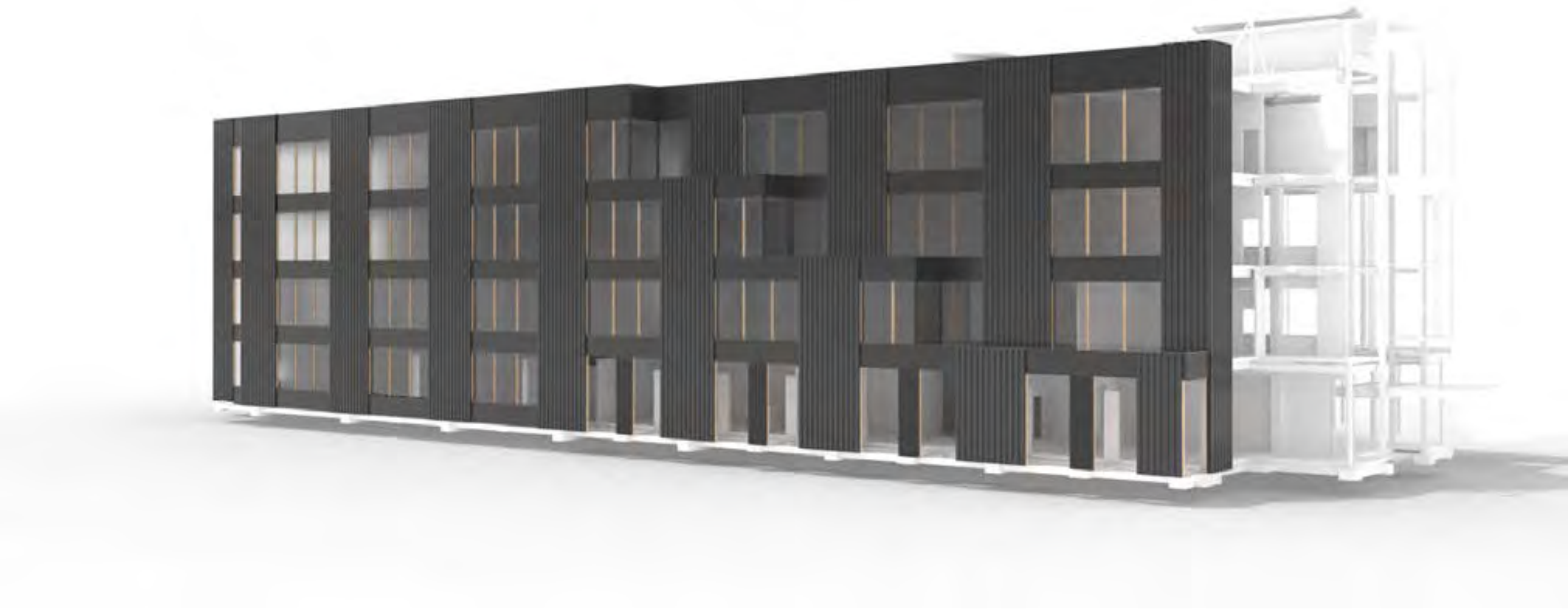
Digital Off-Site Fabrication



Concept: Façade As Built

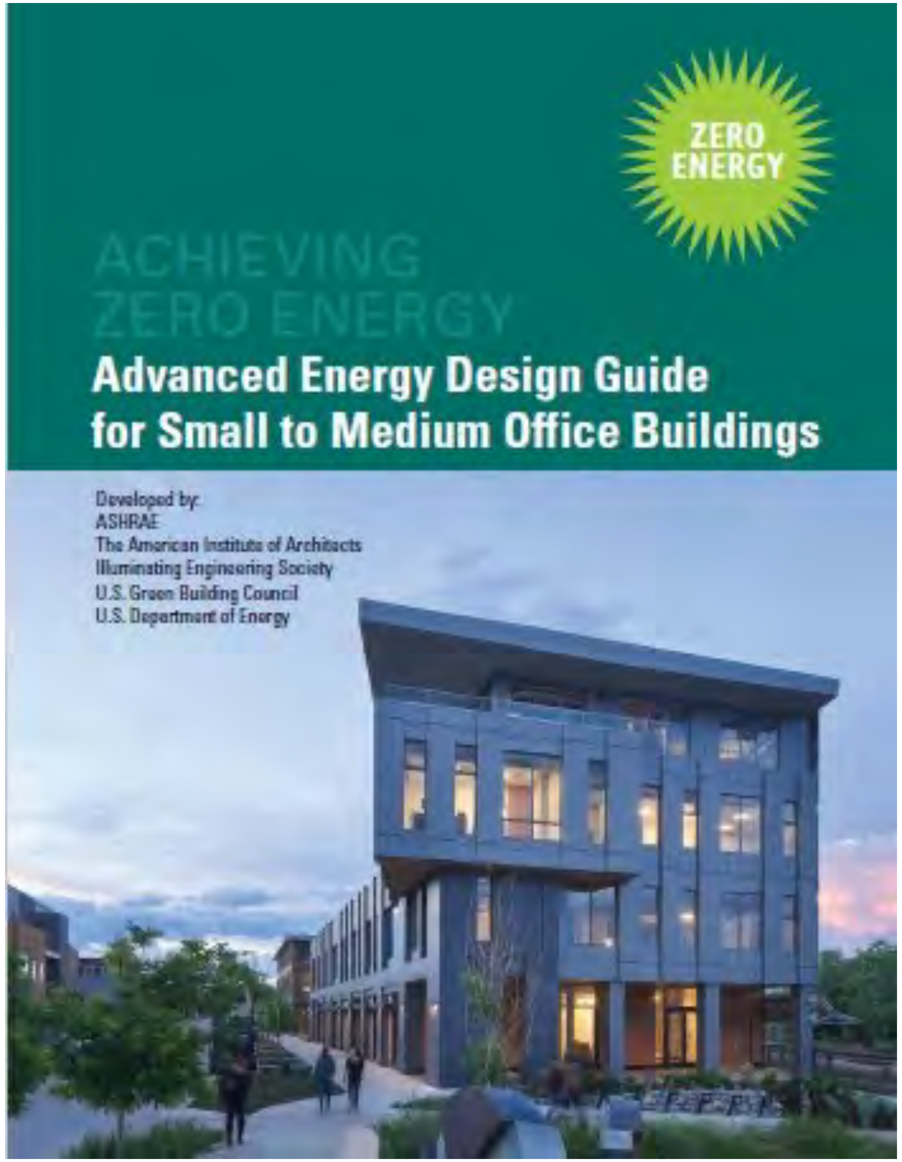


Concept: Façade Retrofit



Vertical
Post-tensioned Rocking
Wall
Lateral Force Resisting
System

Using ASHRAE Achieving Zero Energy Guide to Inform Wall Insulation Levels



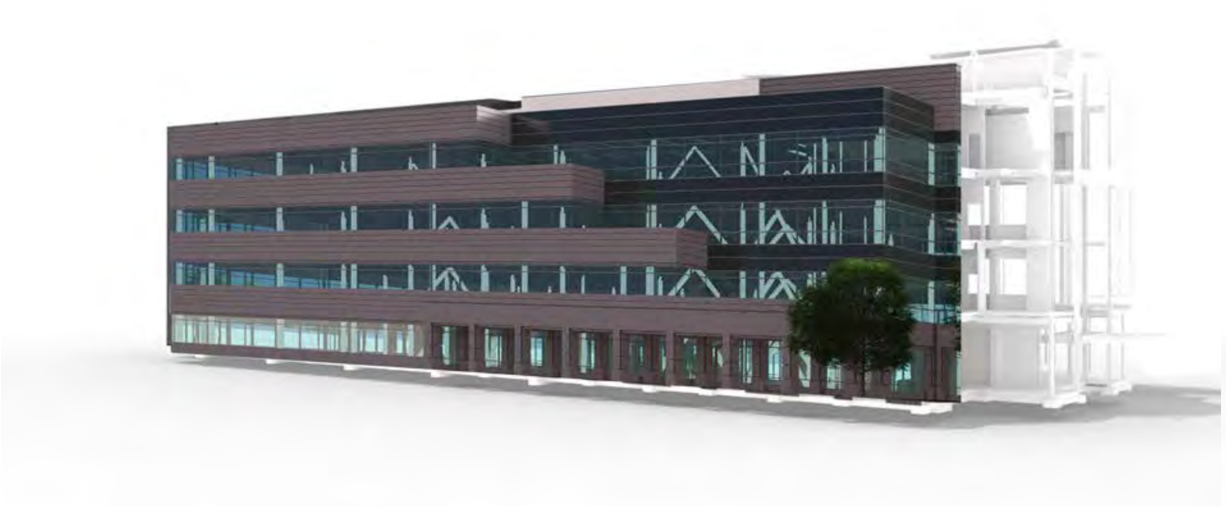
Daylighting performance

Improving visual comfort and health by improving façade daylighting performance

Intro

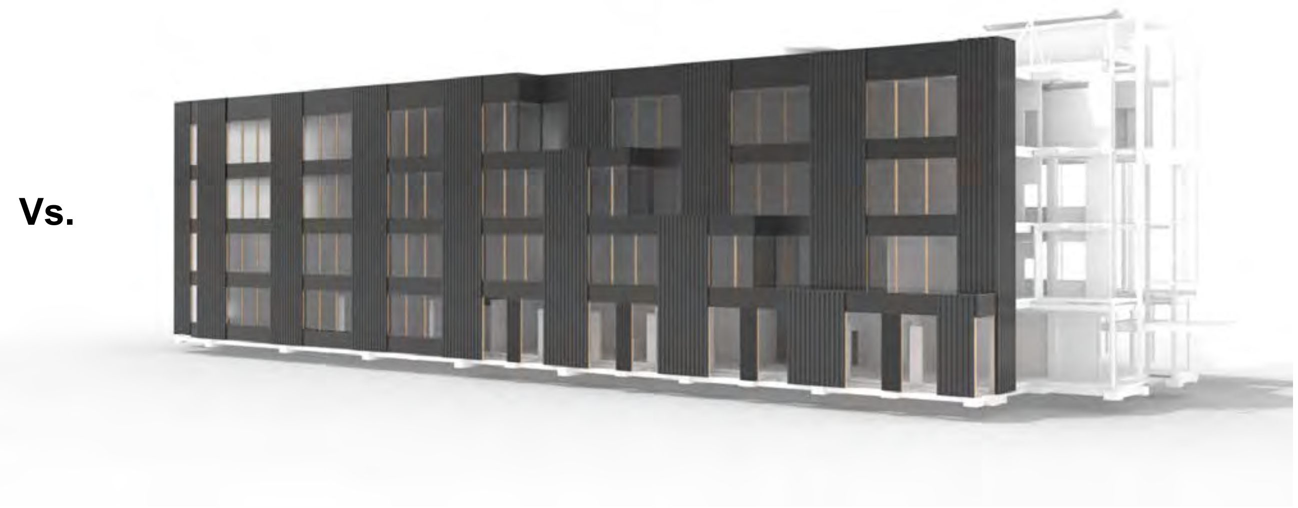
- The Forest to Facades project allowed us to explore the possible co-benefits of seismic upgrades to improve the following daylight conditions:
    - increase daylight availability deeper within the space
    - lower unwanted sunlight exposure through appropriate shading
    - maintain eye-level light exposure levels to promote health
    - decrease glare levels to promote visual comfort

As-Built

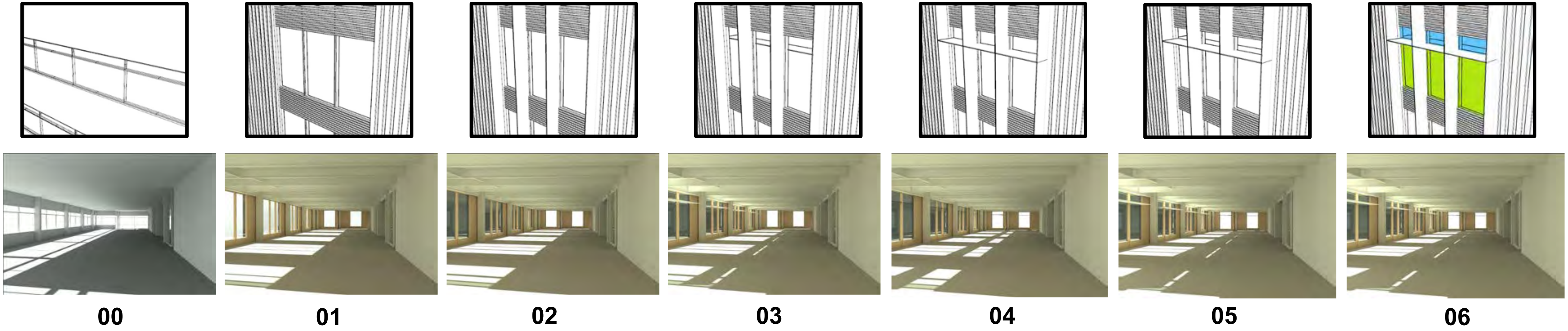


Vs.

Retrofit



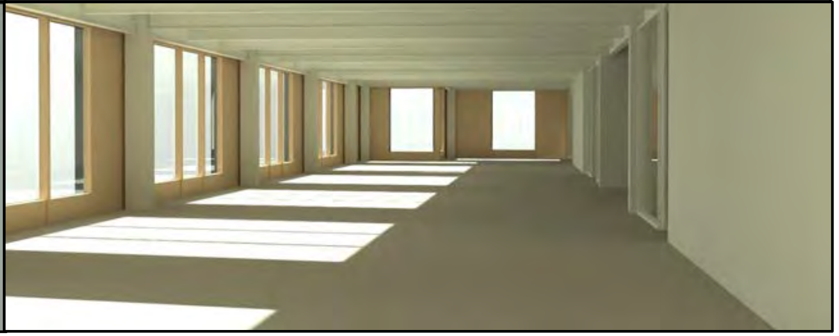
Model conditions



- As-built iterations:
  - 00: Baseline with dropped ceiling
- Retrofit iterations:
  - 01: Baseline
  - 02: Baseline + exterior vertical shading
  - 03: Baseline + exterior vertical shading + interior light shelf
  - 04: Baseline + exterior vertical shading + exterior horizontal shading
  - 05: Baseline + exterior vertical shading + exterior horizontal shading + interior light shelf
  - 06: Baseline + exterior vertical shading + exterior horizontal shading + interior light shelf + clerestory and view window (clerestory is not dynamically shaded)

Materials

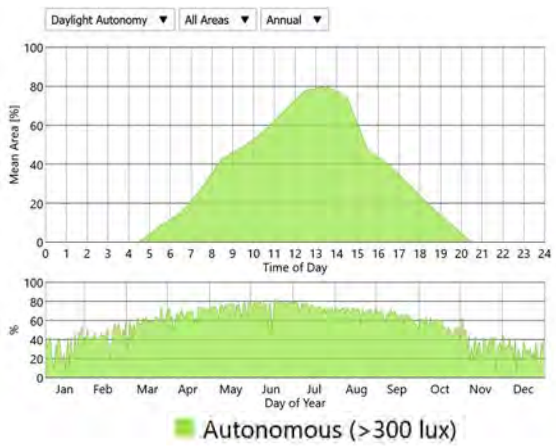
Modeled interior material reflectance/transmissivity:

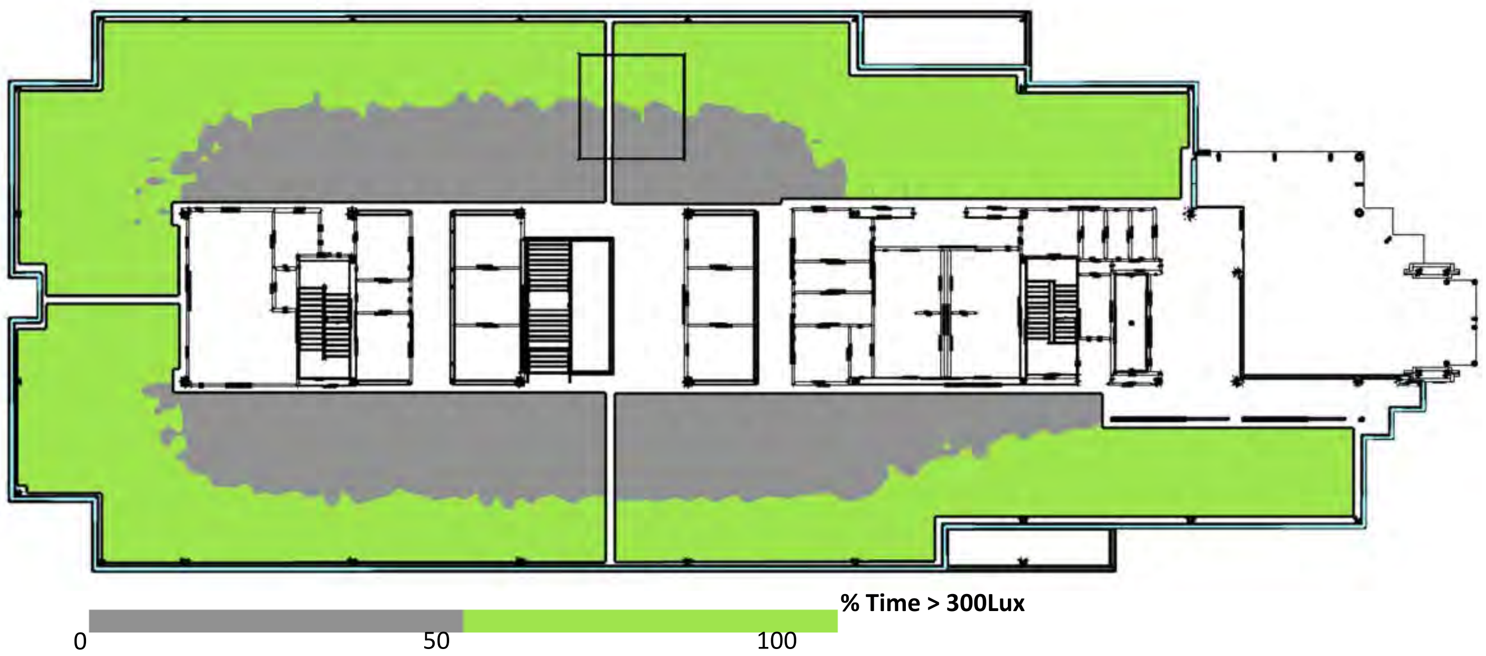
As-built	Retrofit
50% ref. walls 70% ref. ceiling 20% ref. floor 50% VLT glazing	55% ref. perimeter walls (mass timber) 15% ref. exterior metal cladding 70% ref. interior walls 80% ref. ceiling 40% ref floor 70% VLT glazing
	

Glossary

- [sDA] Spatial Daylight Autonomy: Percent of space receiving at least 300 lux for at least 50% of occupied hours. *Calculation includes dynamic shading.*
- [ASE] Annual Sunlight Exposure: Percent of space receiving at least 1000 lux direct sun for at least 250 occupied hours. *Calculation excludes dynamic shading.*
- [UDIa] Useful Daylight Illuminance (autonomous): Averages UDIa across a whole space. UDI differentiates areas that are too dim/failing(<100Lux), supplemental (100-300Lux), acceptable/autonomous(300-3000Lux), and excessively lit(>3000Lux). *Calculation includes dynamic perimeter shading.*
- Avg Lux: Mean workplane illuminance during occupied hours. *Calculation includes dynamic perimeter shading.*
- Occupied hours: Typical time range for office occupancy and our simulations.

63%
sDA 300Lx/50%



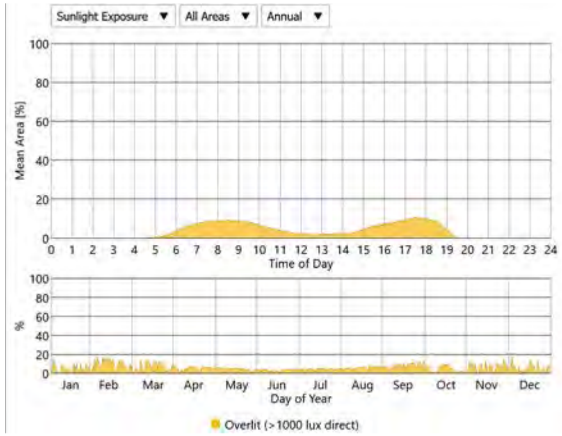


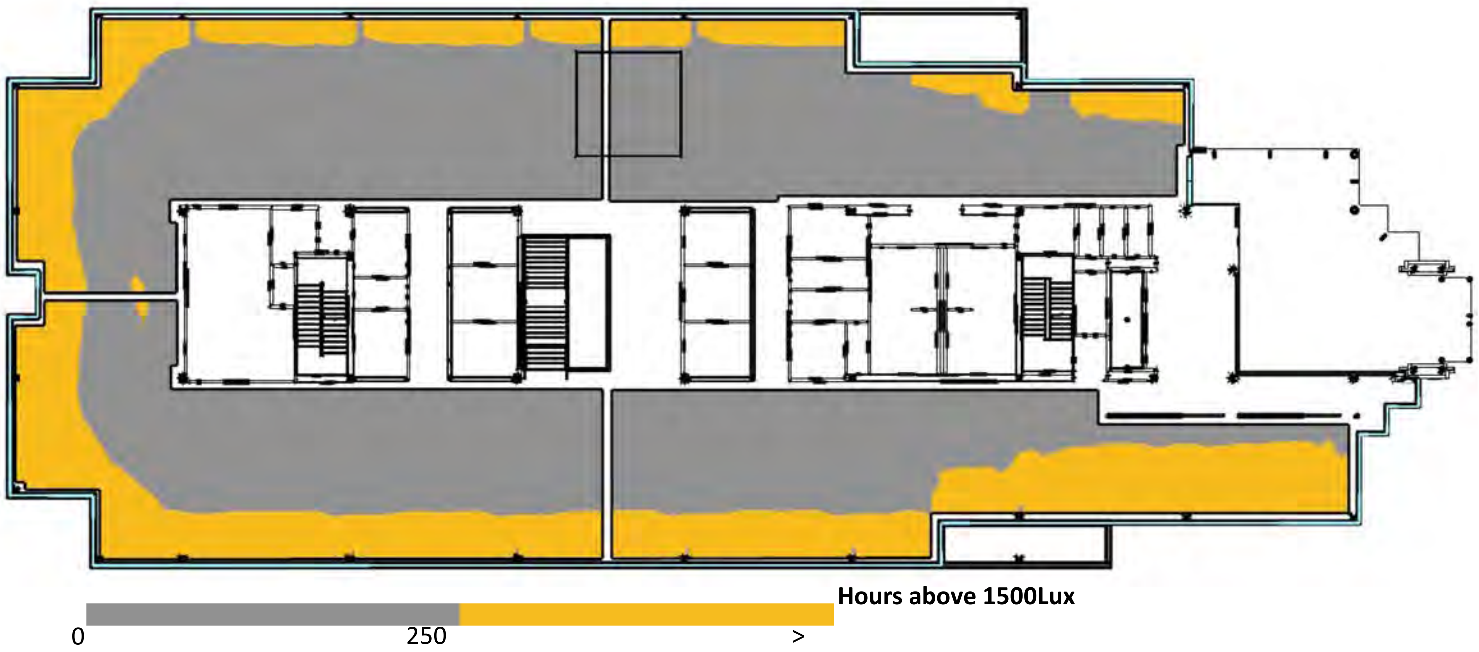
[sDA] Spatial Daylight Autonomy: Percent of space receiving at least 300 lux for at least 50% of occupied hours.

Calculation includes dynamic shading.

28%

ASE 1500Lx/250hr

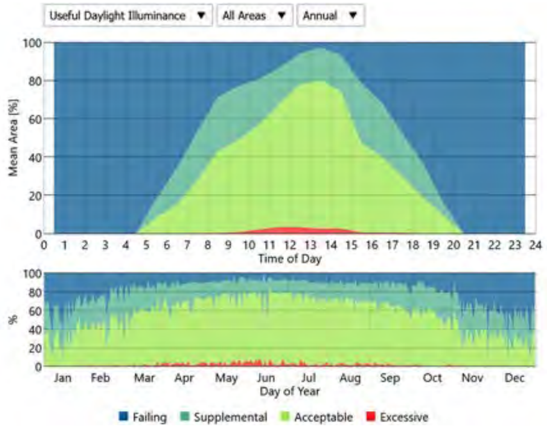


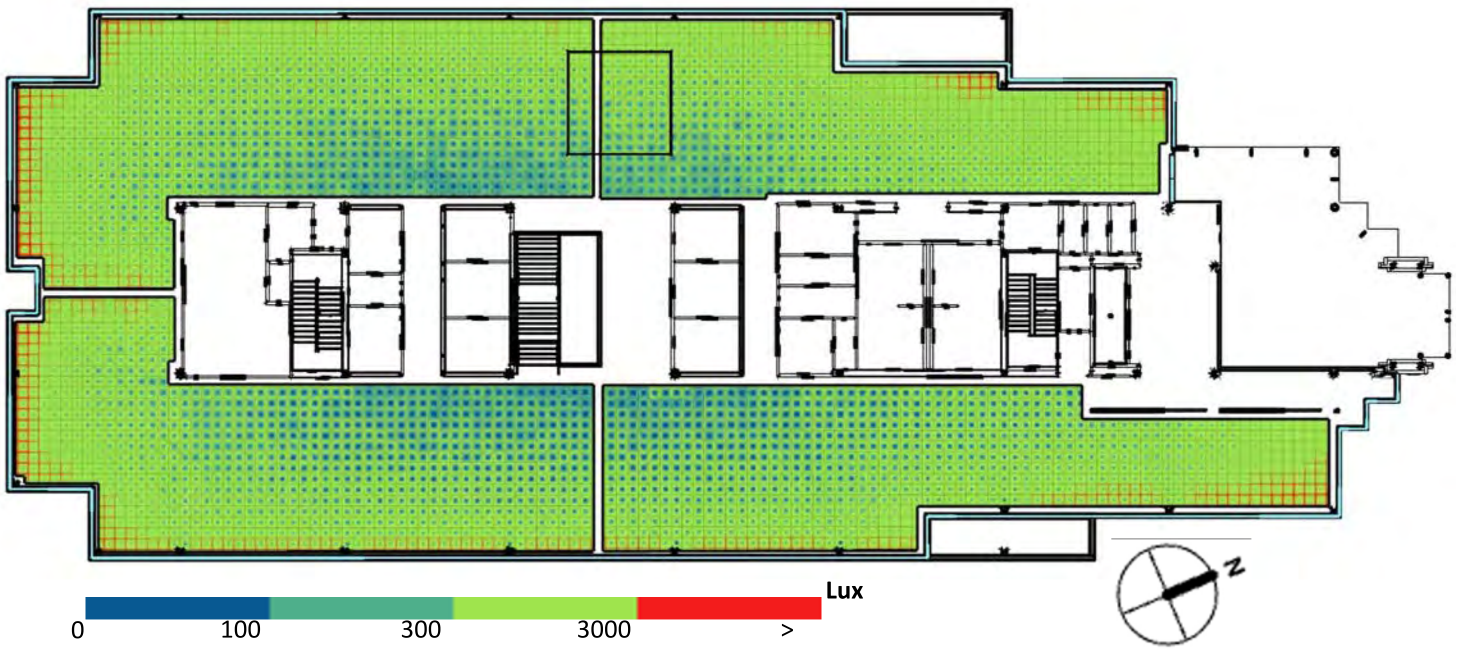


[ASE] Annual Sunlight Exposure: Percent of space receiving at least 1000 lux direct sun for at least 250 occupied hours.

Calculation excludes dynamic shading.

54% Avg. UDIa





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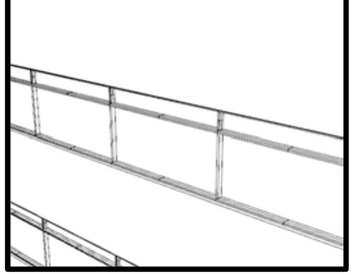
Calculation includes dynamic perimeter shading.



AS-BUILT ANNUAL PERFORMANCE

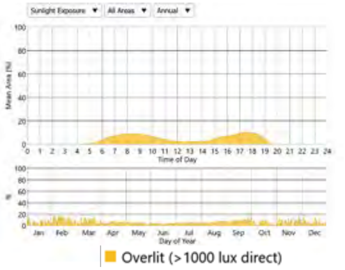
Baseline façade

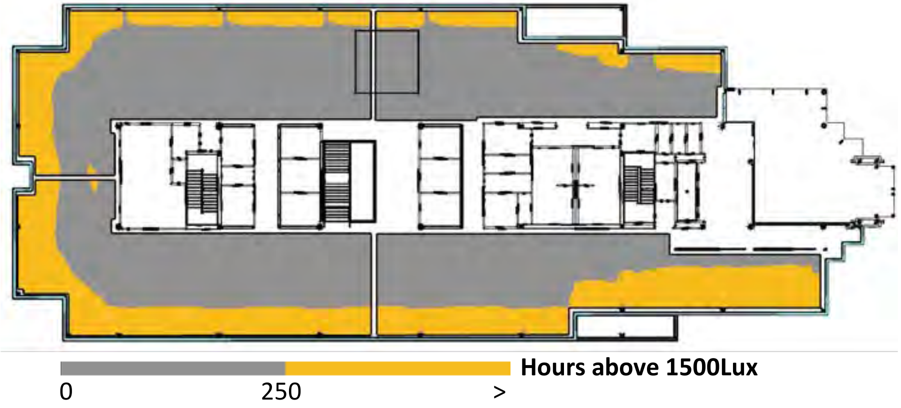
618 average lux

Perimeter shading retracted 80% of occupied hours

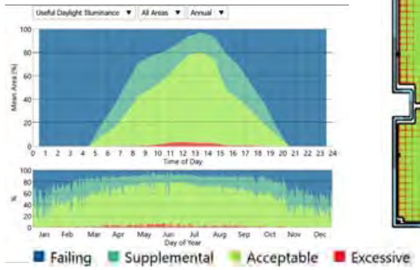
63% sDA 300Lx/50%

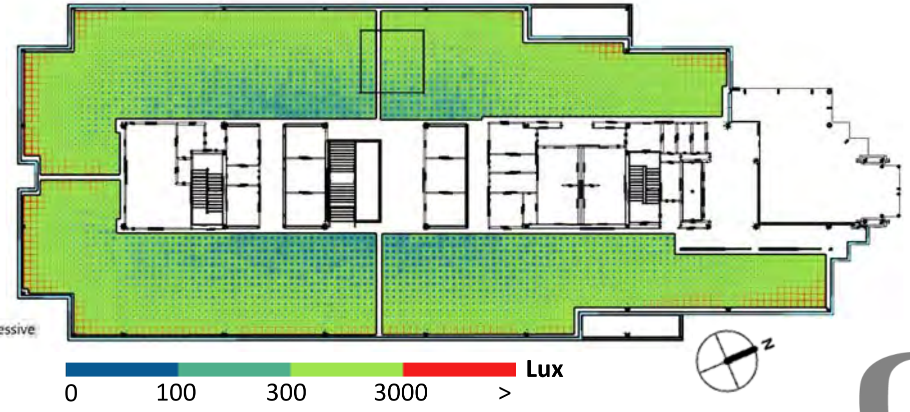
28% ASE 1500Lx/250hr

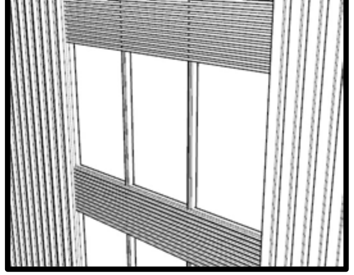




54% Avg. UDIa







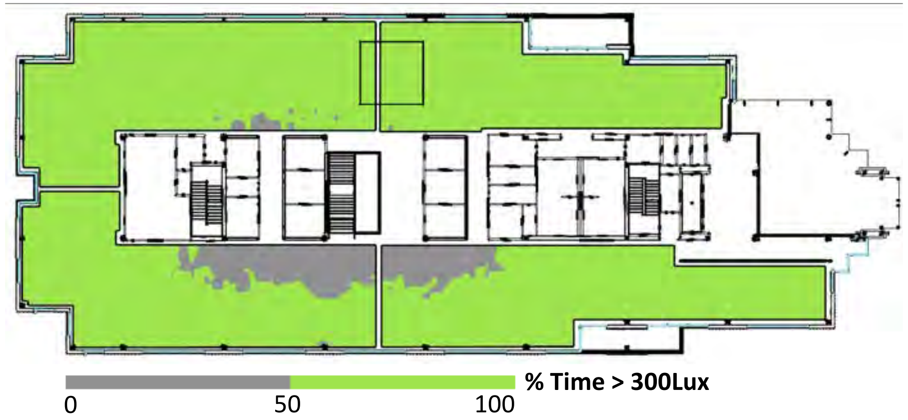
RETROFIT ANNUAL PERFORMANCE

Baseline façade

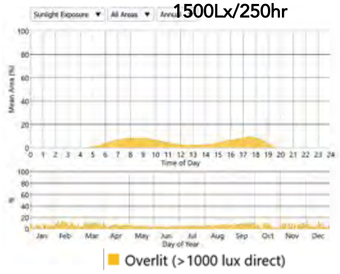
898 average lux

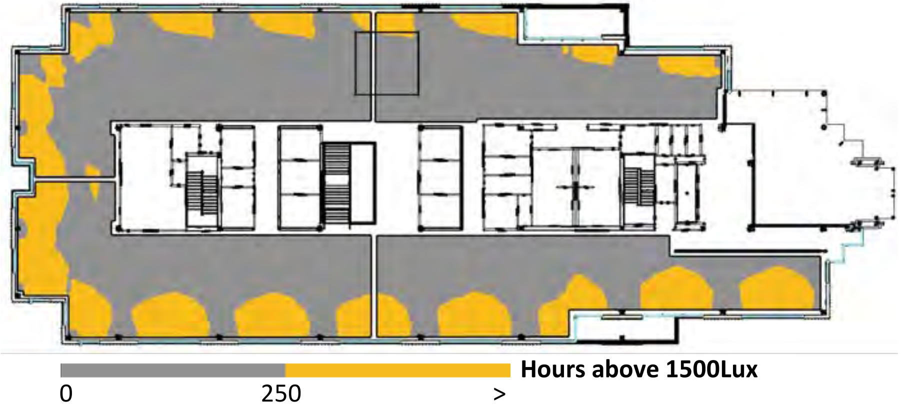
Perimeter shading retracted 76% of occupied hours

91% sDA 300Lx/50%

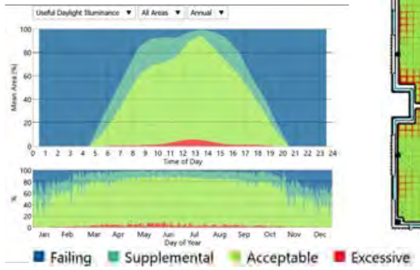


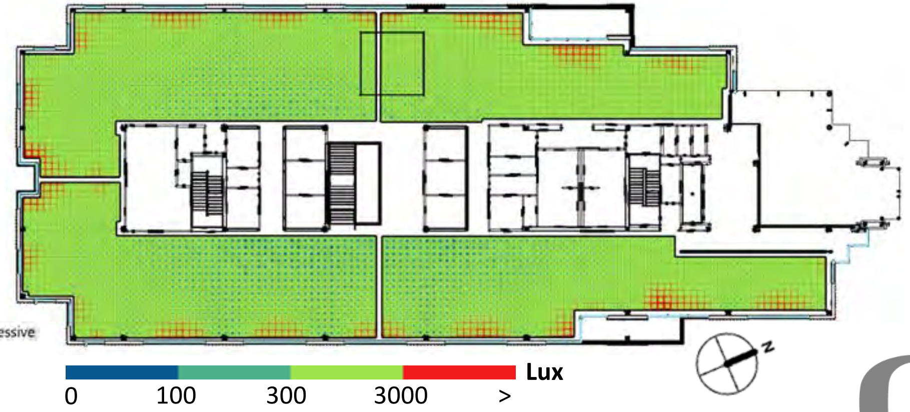
25% ASE 1500Lx/250hr

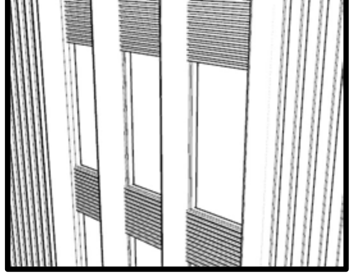




69% Avg. UDIa



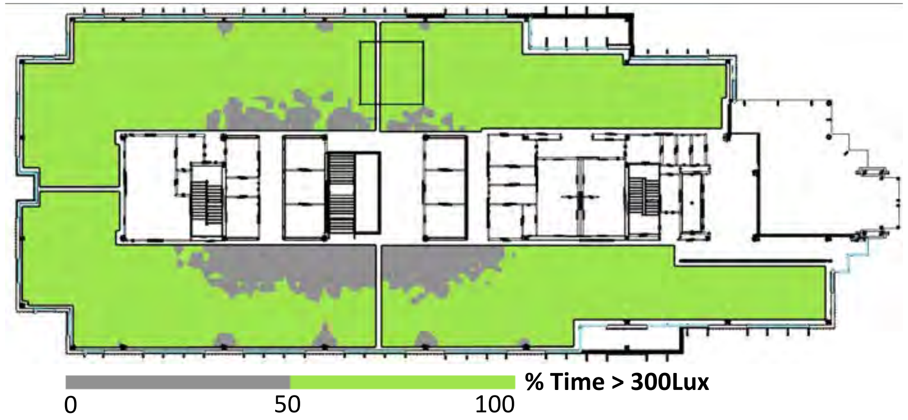




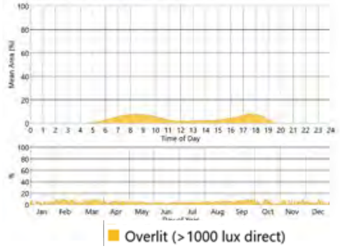
RETROFIT ANNUAL PERFORMANCE

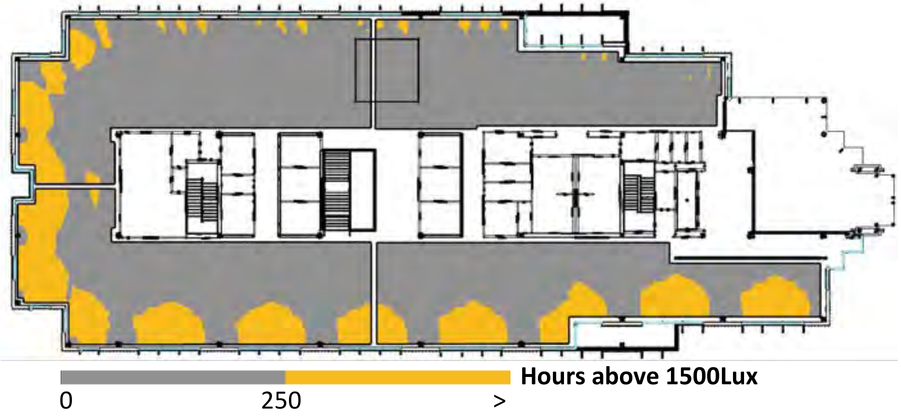
Baseline façade
+exterior vertical shading

87% sDA 300Lx/50%

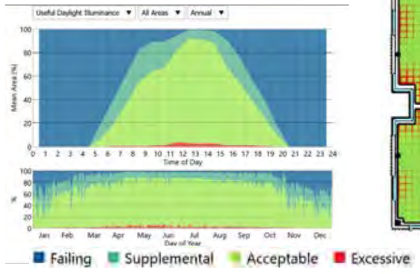


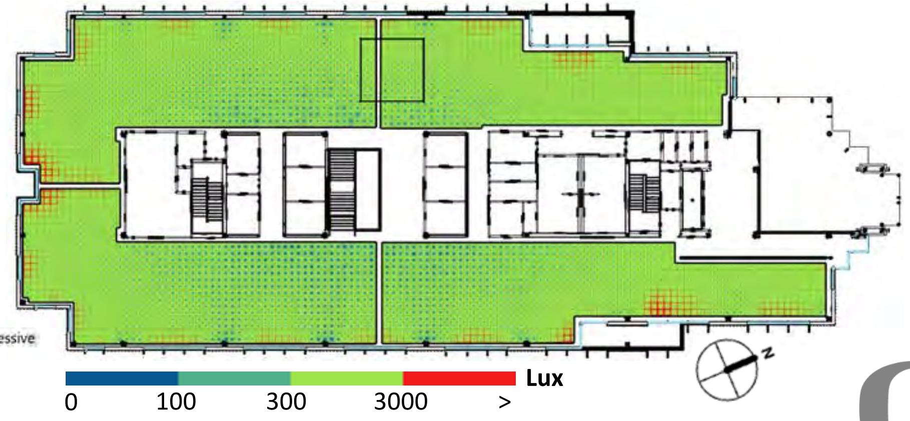
19% ASE 1500Lx/250hr





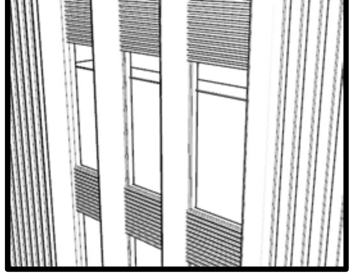
68% Avg. UDIa





791 average lux

Perimeter shading retracted 80% of occupied hours



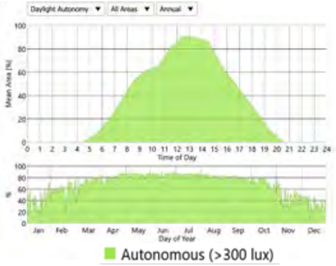
RETROFIT ANNUAL PERFORMANCE

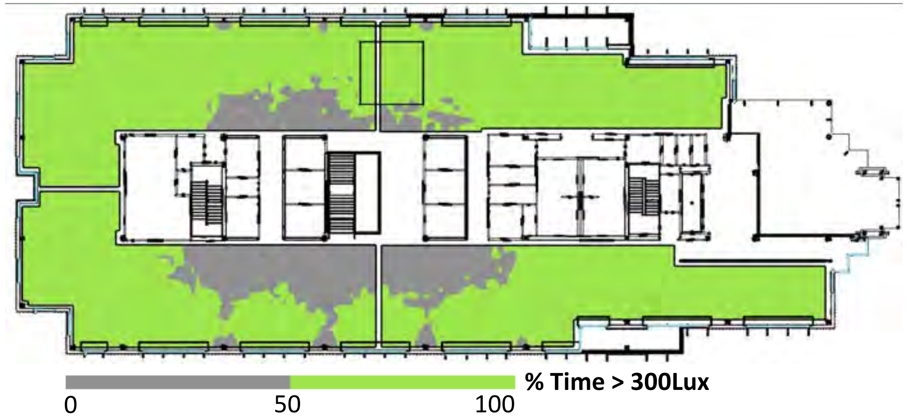
Baseline façade
+exterior vertical shading
+interior light shelf

756 average lux

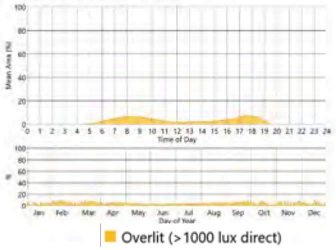
Perimeter shading retracted 81% of occupied hours

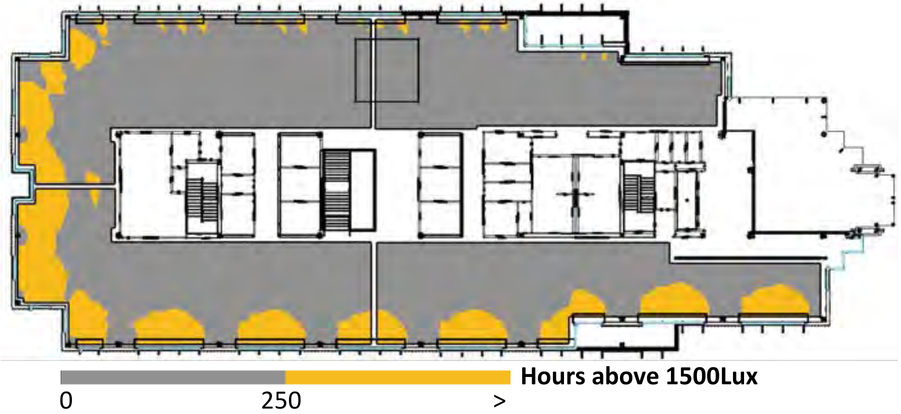
82% sDA 300Lx/50%



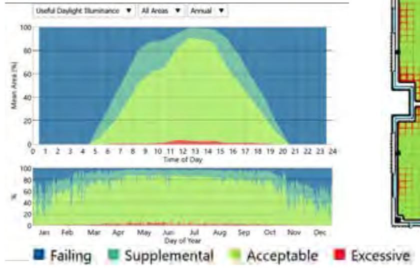


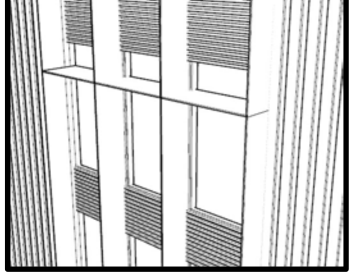
17% ASE 1500Lx/250hr





66% Avg. UDIa





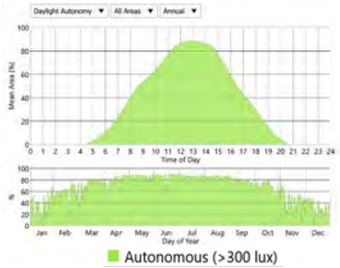
RETROFIT ANNUAL PERFORMANCE

Baseline façade
+exterior vertical shading
+exterior horizontal shading

690 average lux

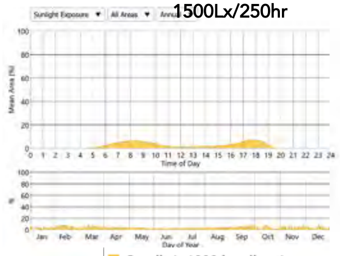
Perimeter shading retracted
83% of occupied hours

85% sDA 300Lx/50%



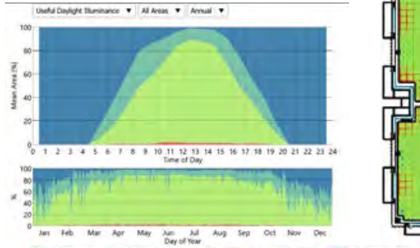
% Time > 300Lux
0 50 100

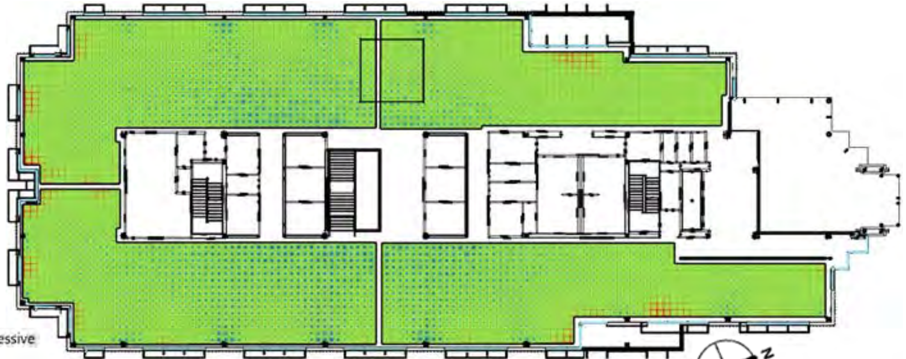
12% ASE
1500Lx/250hr



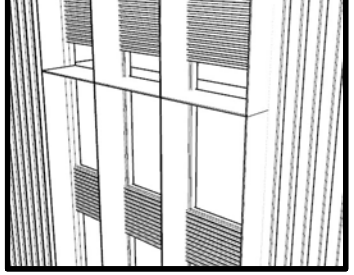
Hours above 1500Lux
0 250 >

66% Avg. UDIa





Lux
0 100 300 3000 >



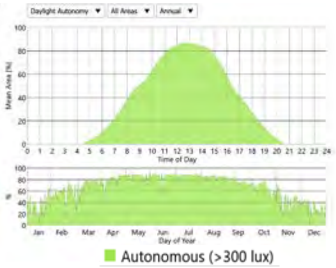
RETROFIT ANNUAL PERFORMANCE

Baseline façade
+exterior vertical shading
+exterior horizontal shading
+interior light shelf

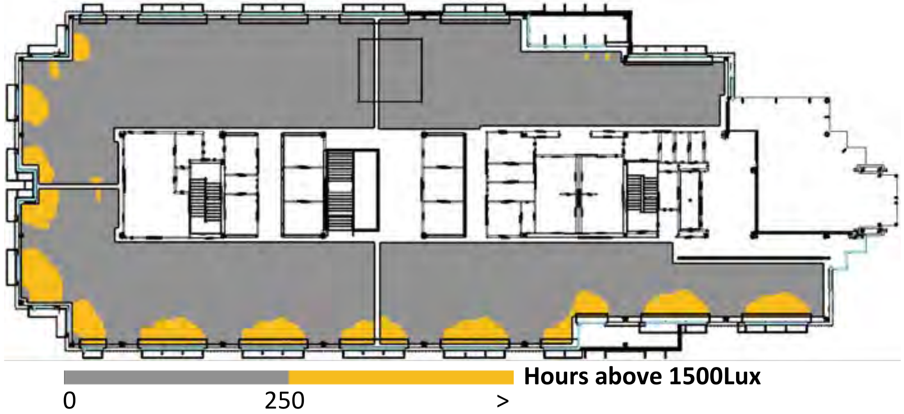
669 average lux

Perimeter shading retracted
85% of occupied hours

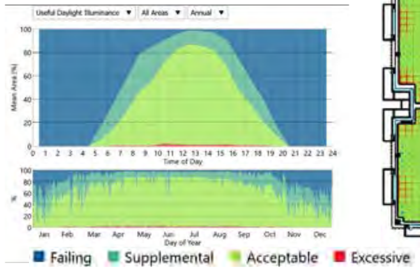
80% sDA 300Lx/50%

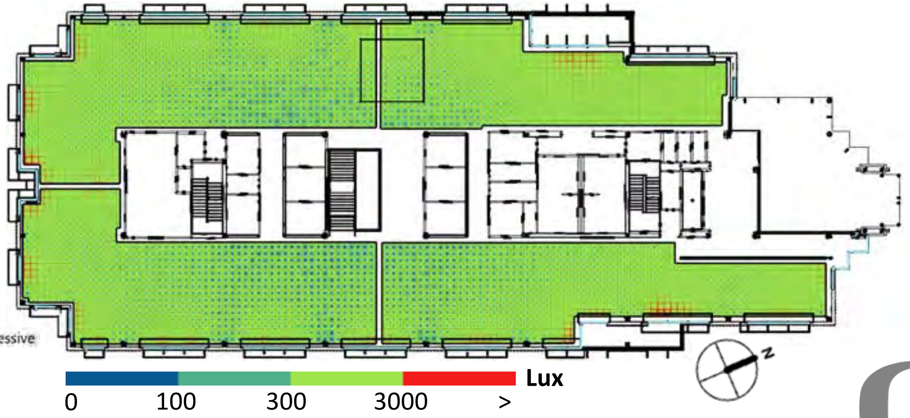


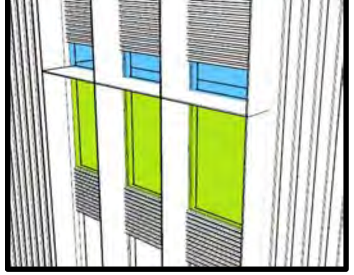
10% ASE 1500Lx/250hr



64% Avg. UDIa







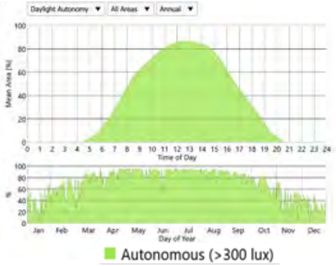
RETROFIT ANNUAL PERFORMANCE

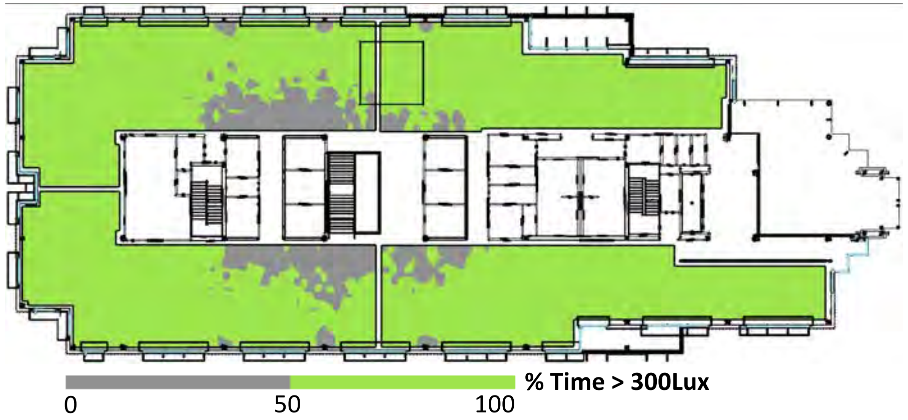
Baseline façade
+exterior vertical shading
+exterior horizontal shading
+interior light shelf
+clerestory and view window

723 average lux

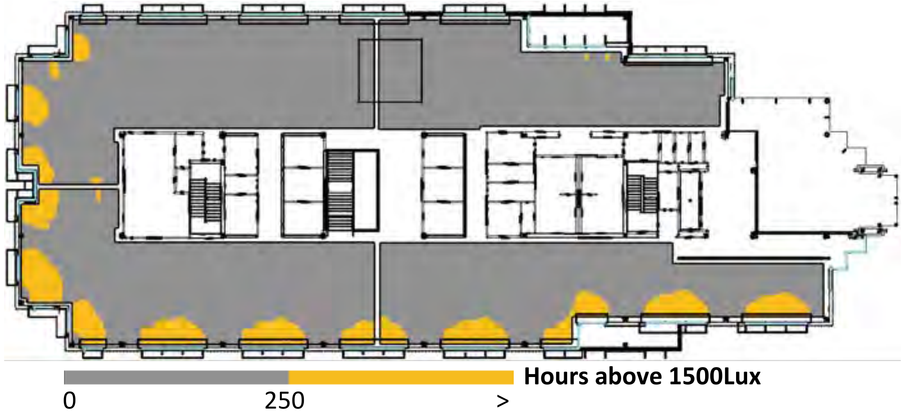
Perimeter shading retracted 85% of occupied hours

89% sDA 300Lx/50%

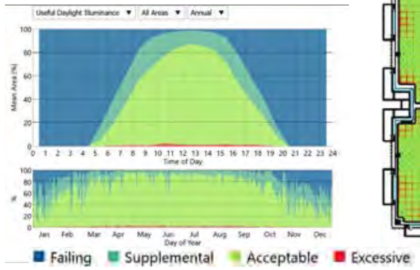


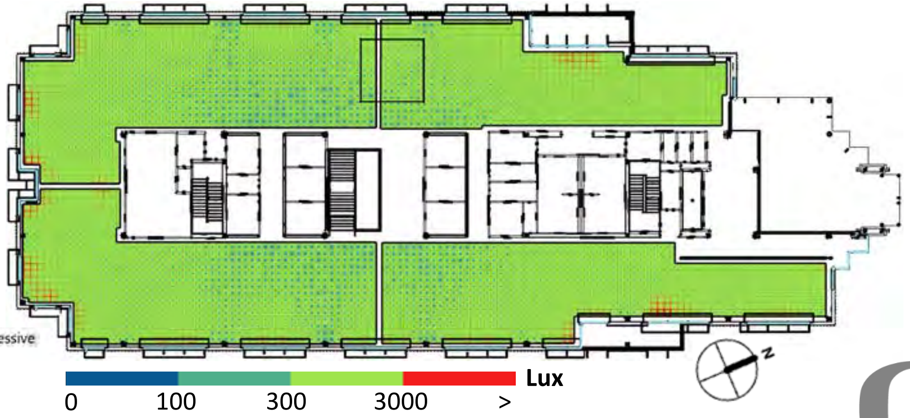


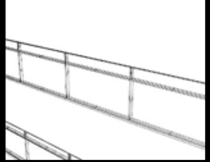
10% ASE 1500Lx/250hr



68% Avg. UDIa



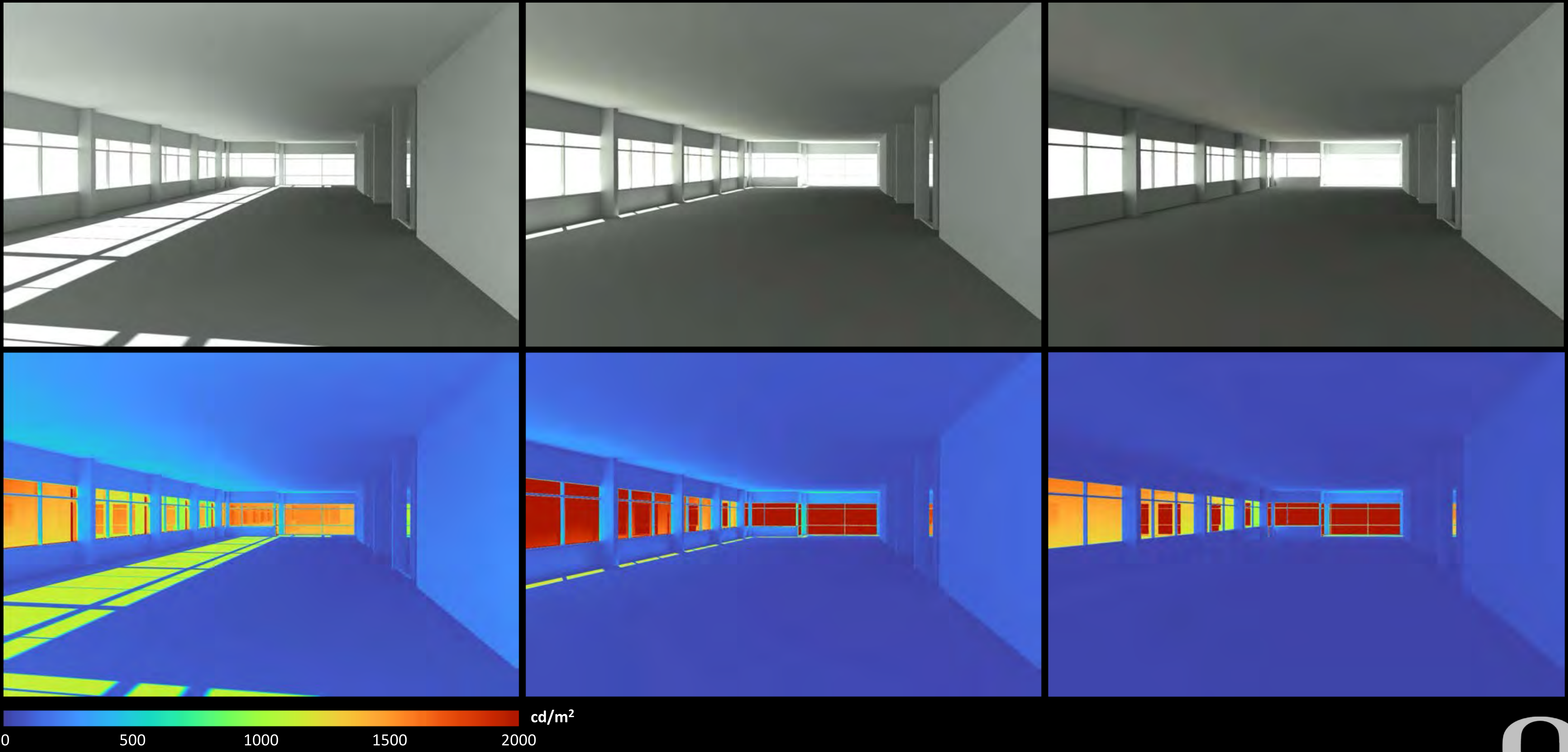


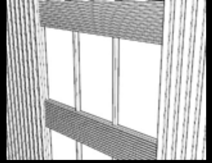


AS-BUILT

September 21st

9:00 | 12:00 | 15:00

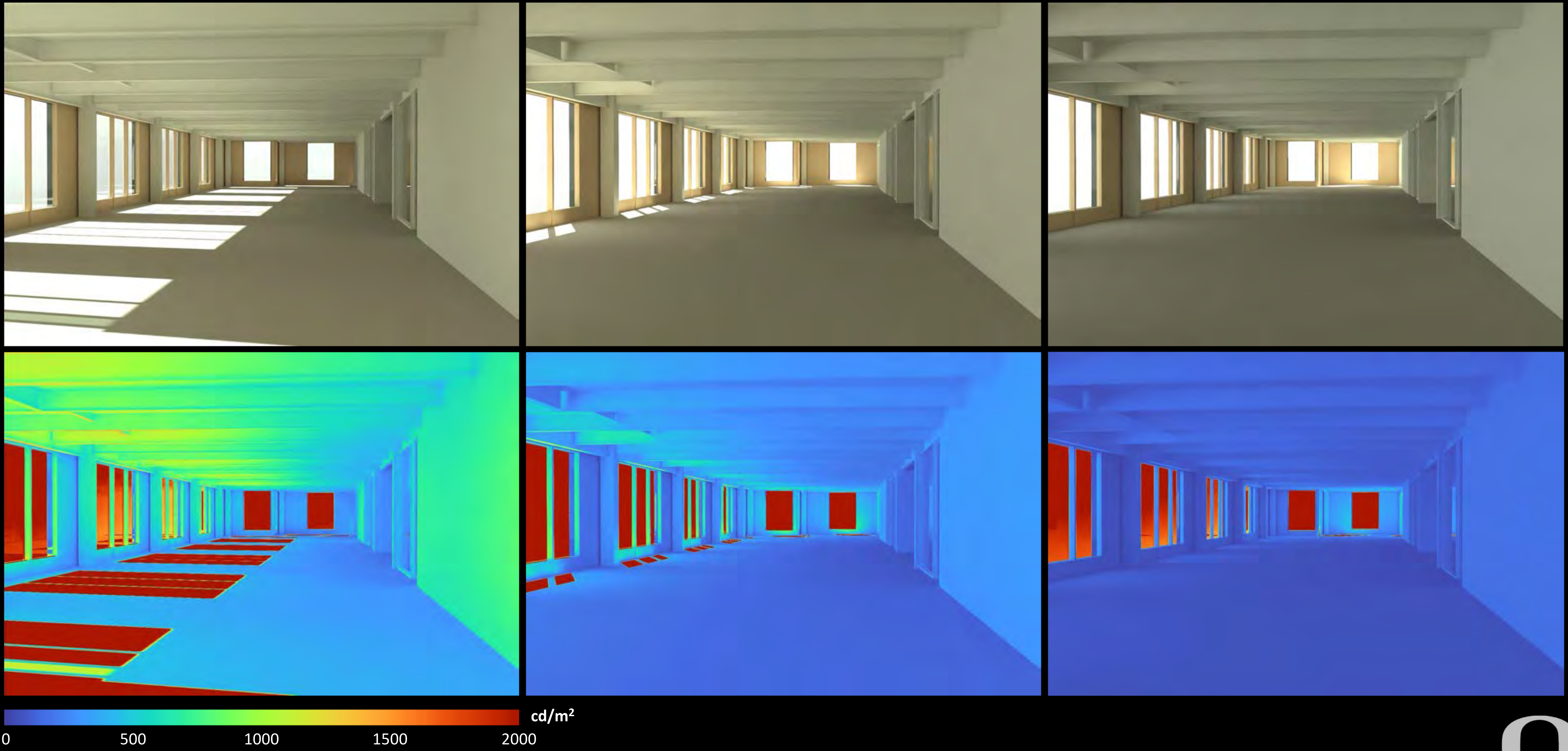


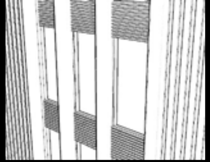


RETROFIT

September 21st

9:00 12:00 15:00

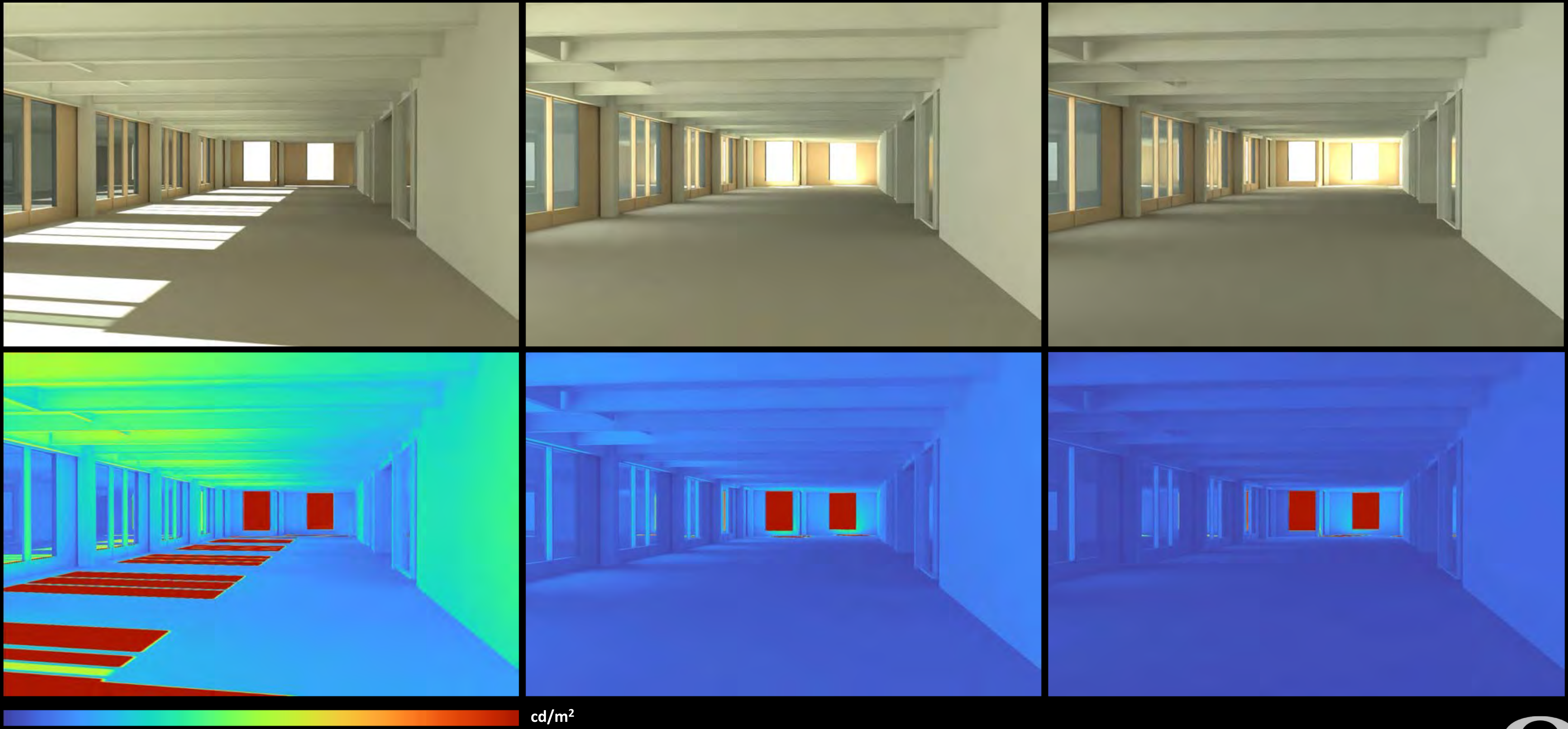


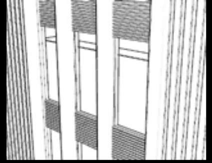


RETROFIT

September 21st

9:00 12:00 15:00

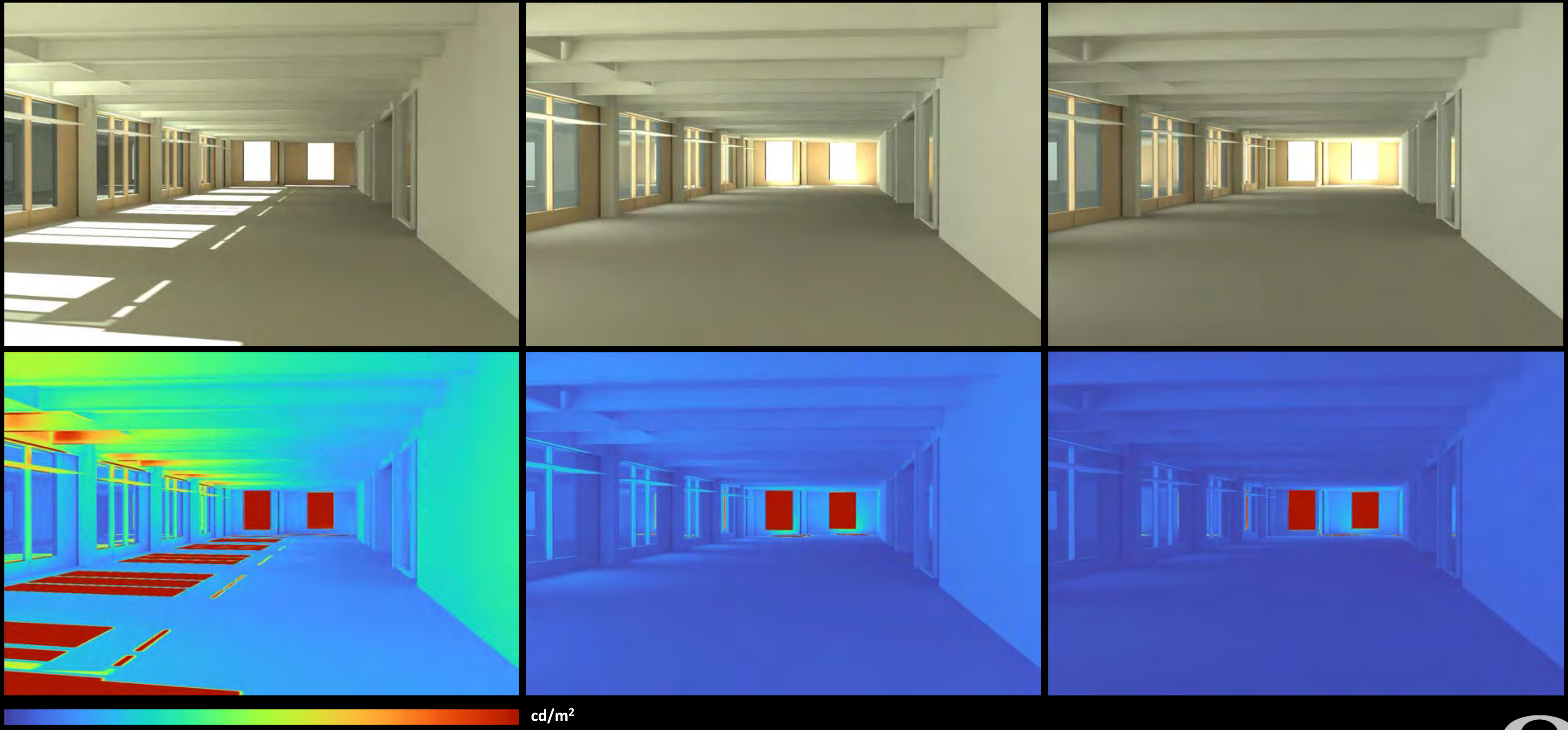


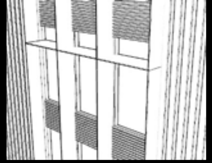


RETROFIT

September 21st

9:00 12:00 15:00

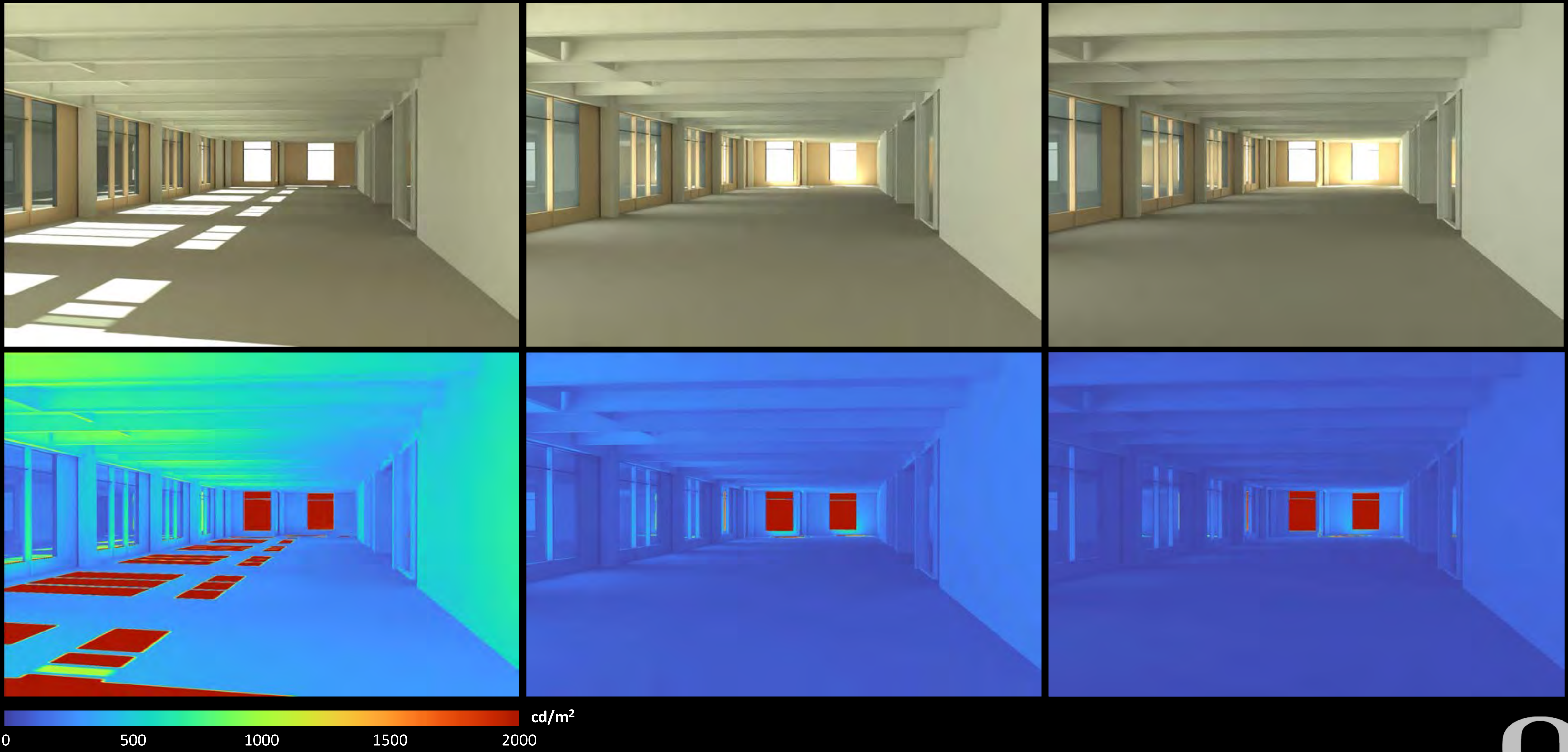


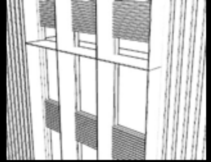


RETROFIT

September 21st

9:00 | 12:00 | 15:00

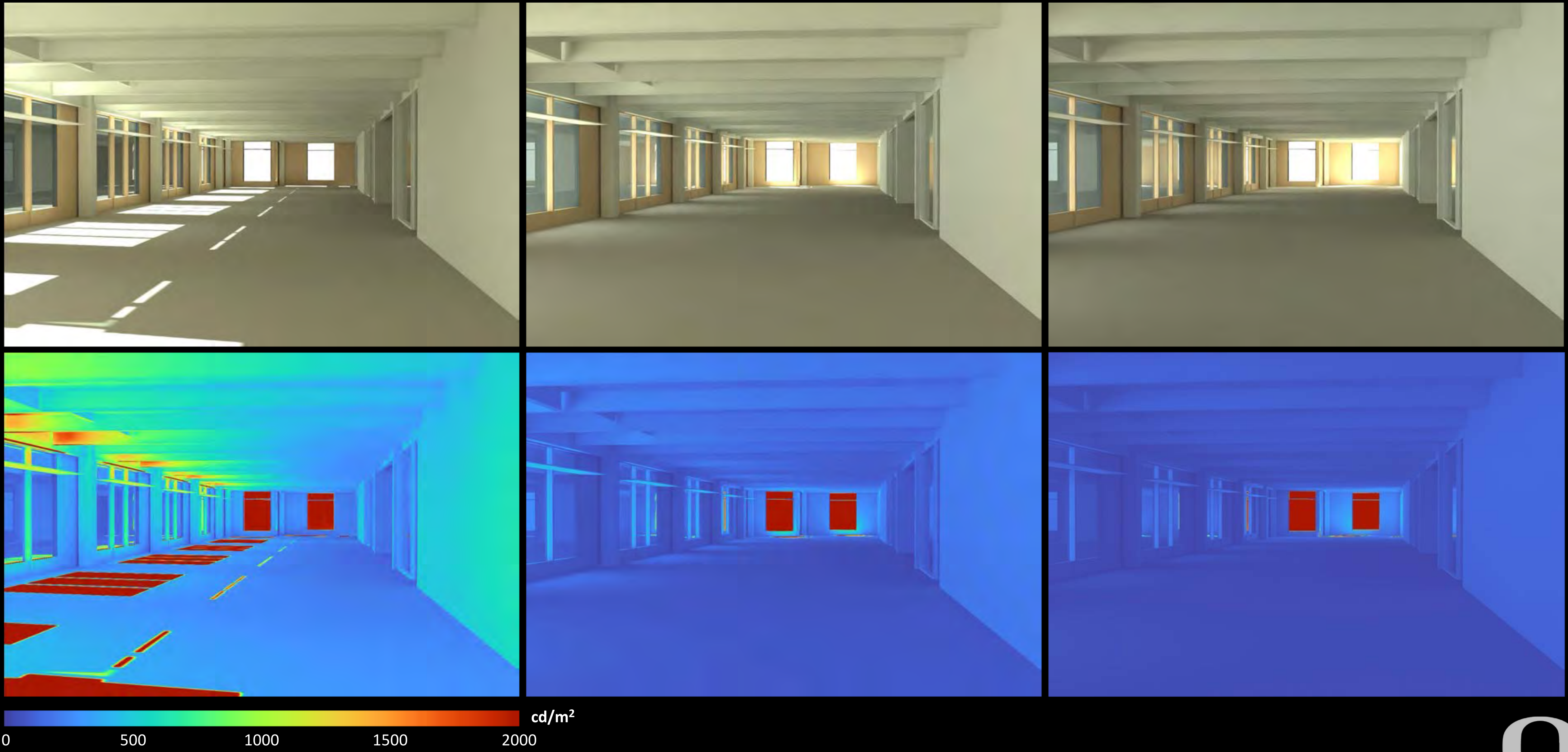


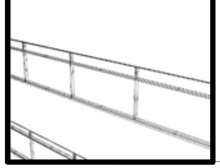


RETROFIT

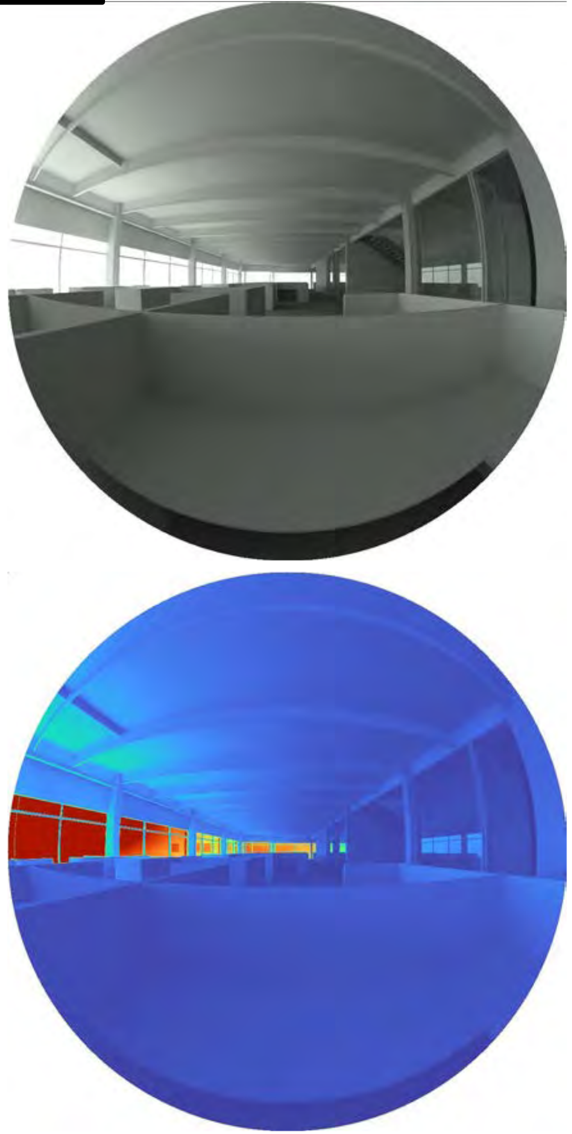
September 21st

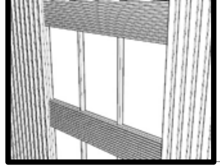
9:00 12:00 15:00



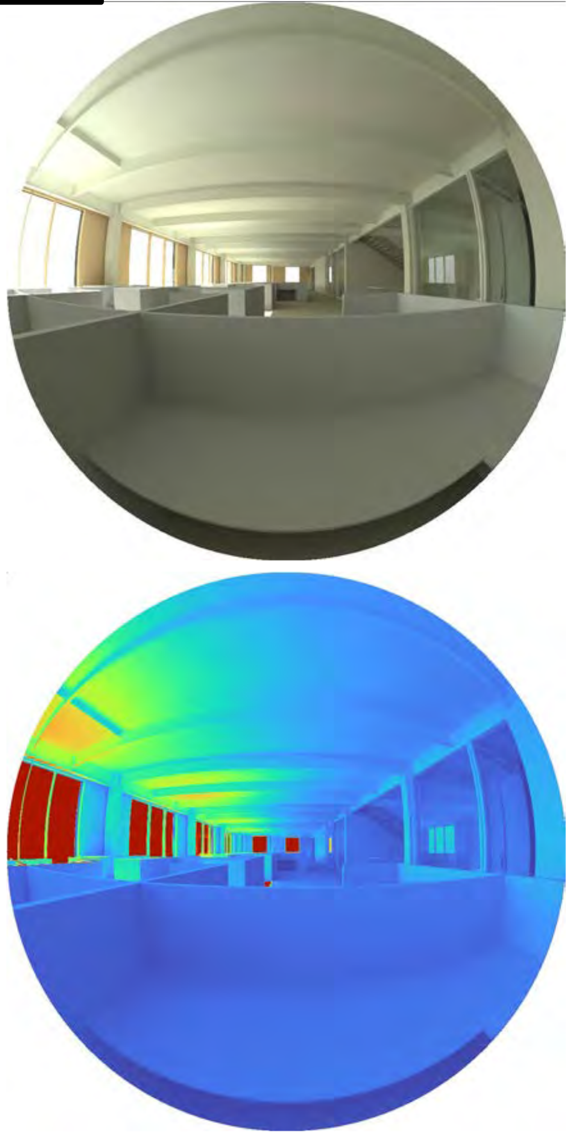


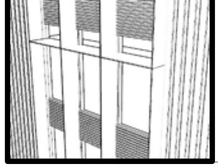
AS-BUILT





RETROFIT





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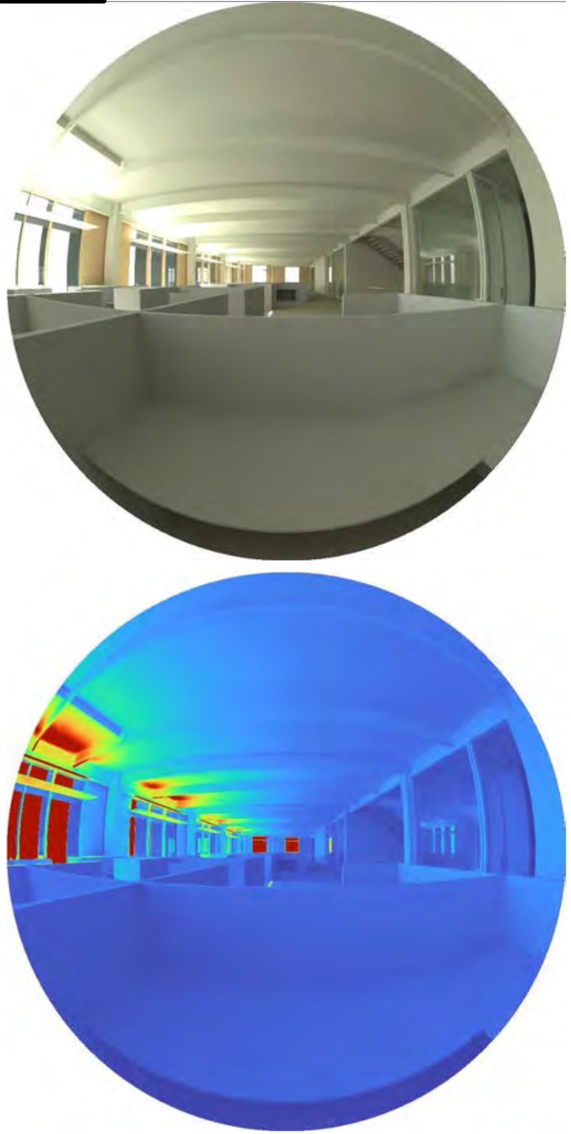
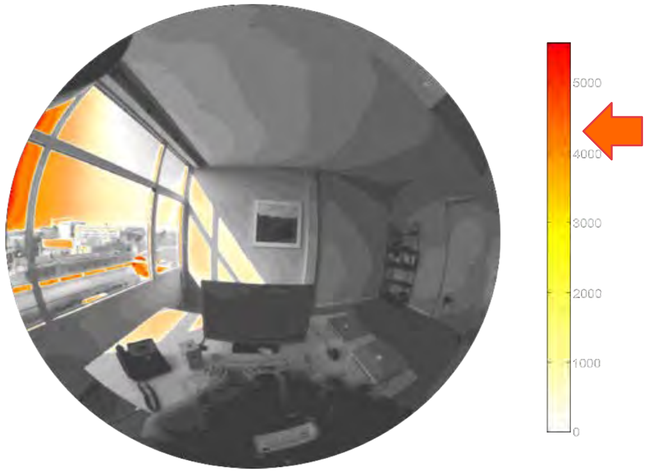


September 21st, 9:00

Glare Risk

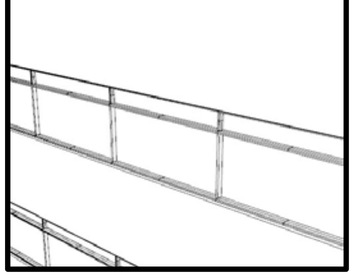
Daylight Glare Probability (DGP)[1]

A percentage of people who are likely to experience glare, with thresholds at 0.40 (disturbing) and 0.45 (intolerable).

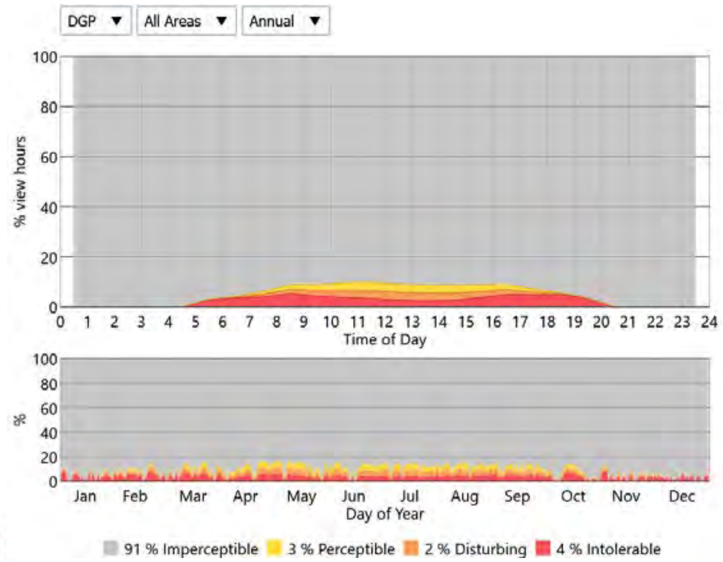


glaring

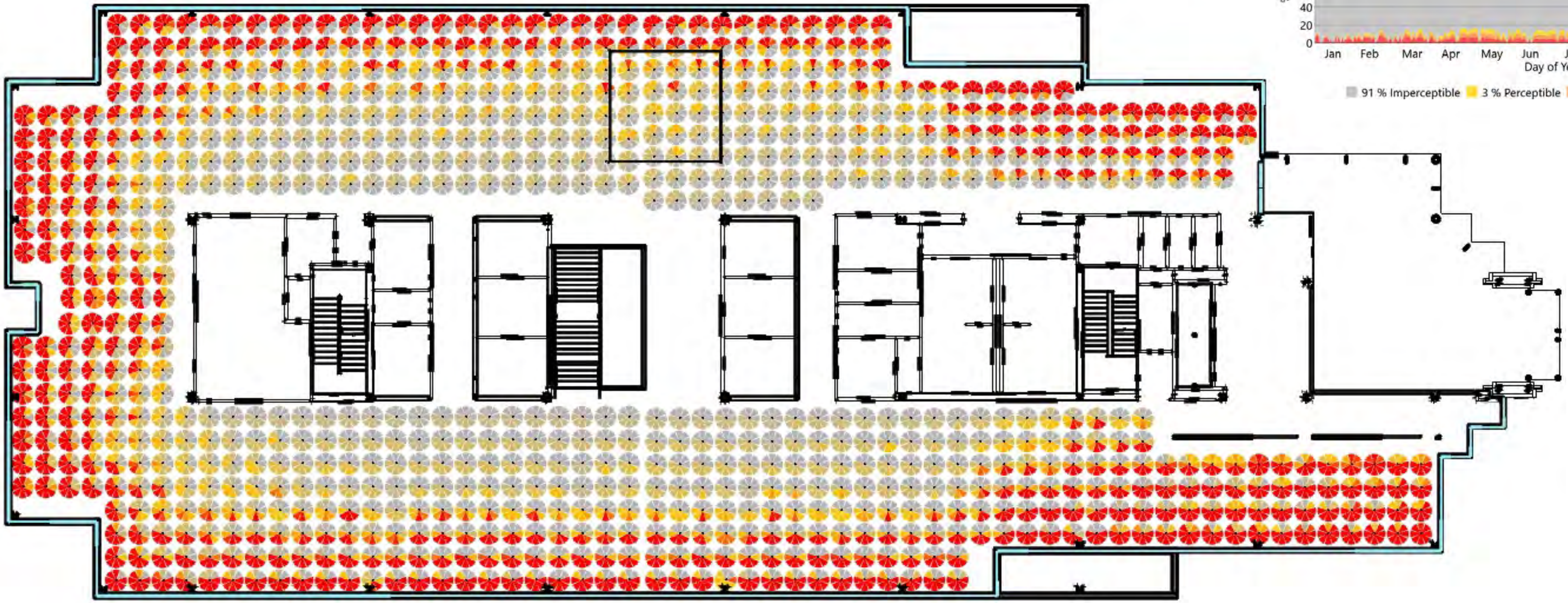
[1] J. Wienold, J. Christoffersen, Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. Energy and Buildings 38(7): 743-757, 2006



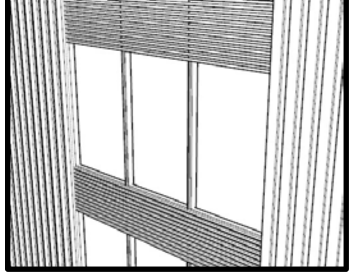
AS-BUILT ANNUAL GLARE



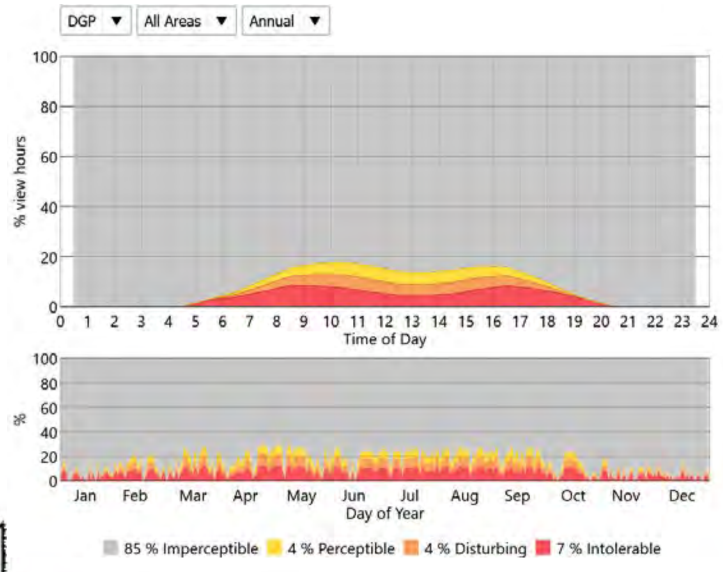
23.8% sDG
(% views with Disturbing Glare >5% of time)



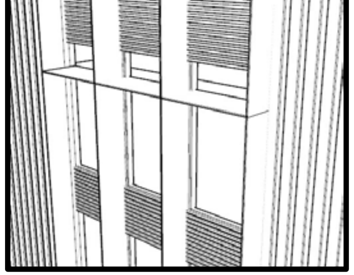
0 — 5 **% Views with disturbing glare >5% of time**



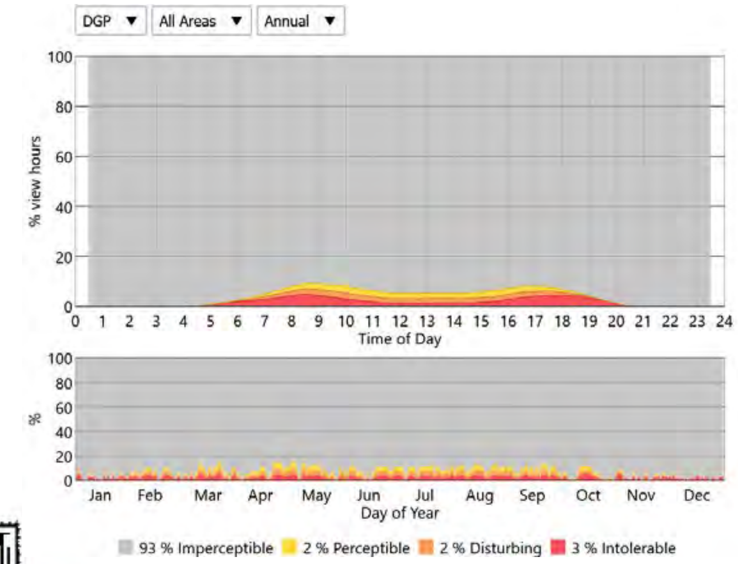
RETROFIT ANNUAL GLARE



50.7% sDG (% views with Disturbing Glare >5% of time)



RETROFIT ANNUAL GLARE



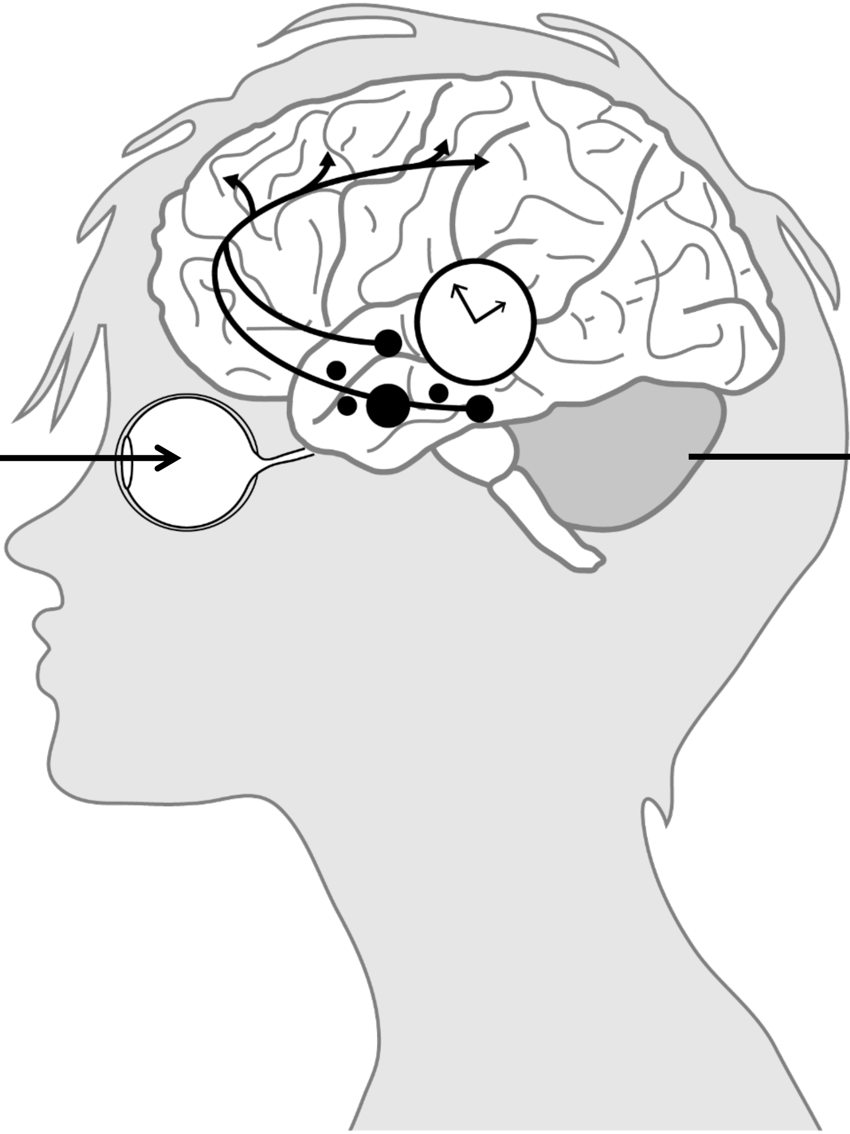
23.0% sDG
(% views with Disturbing Glare >5% of time)

0 — 5 **% Views with disturbing glare >5% of time**

Circadian entrainment

Light & Dark

Intensity
Wavelength
Duration
Timing
History



Non-visual responses

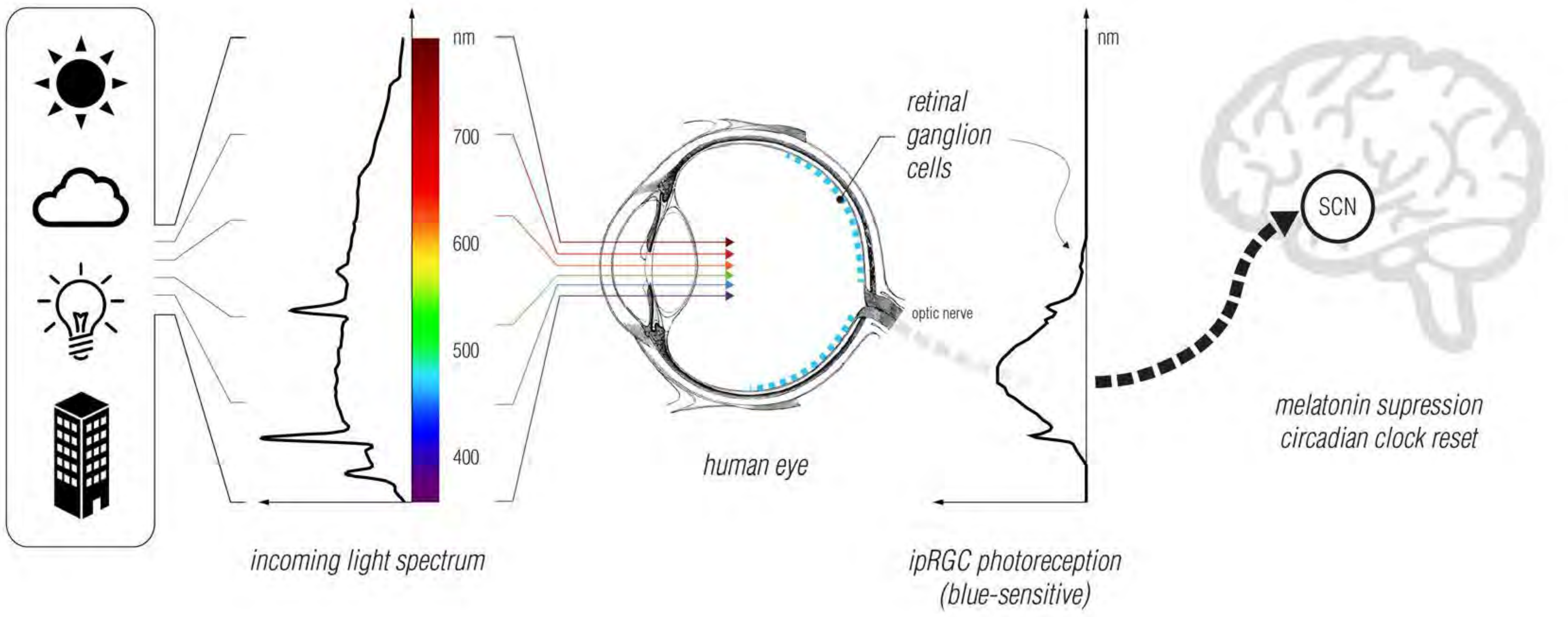
Circadian rhythms

- Sleep and wake
- Hormone secretion
- Body temperature
- Cognitive function

Direct effects

- Melatonin suppression
- Pupil constriction
- Subjective alertness
- Performance

Circadian entrainment



https://www.solemma.com/Alfa.html

Circadian entrainment

Equivalent Melanopic Lux (EML)[1] – WELL Standard

Lux weighted to the melanopic, rather than photopic sensitivity curve

For workstations used during the daytime, electric lighting is used to achieve the following thresholds:

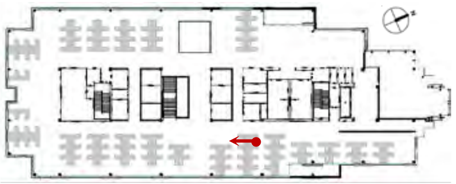
a. The following light levels are achieved for at least four hours (beginning by noon at the latest) at a height of 18 in above the work-plane for all workstations in regularly occupied spaces:

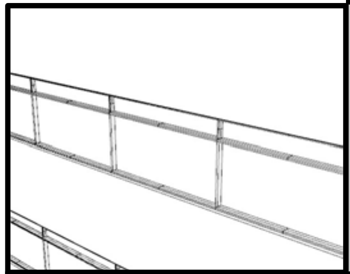
Tier	Threshold		Threshold for Projects with Enhanced Daylight	Points
1	At least 150 EML [136 melanopic EDI]	OR	At least 120 EML [109 melanopic EDI] and either L05 Part 1 or L06 Part 1	1
2	At least 275 EML [250 melanopic EDI][11]	OR	At least 180 EML [163 melanopic EDI] and either L05 Part 1 or L06 Part 1	3

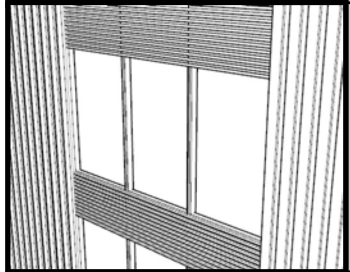
b. The light levels are achieved on the vertical plane at eye level to simulate the light entering the eye of the occupant.

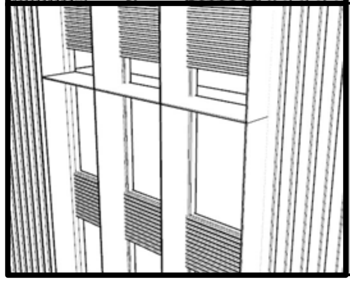
[1]https://standard.wellcertified.com/light/circadian-lighting-design

Circadian performance





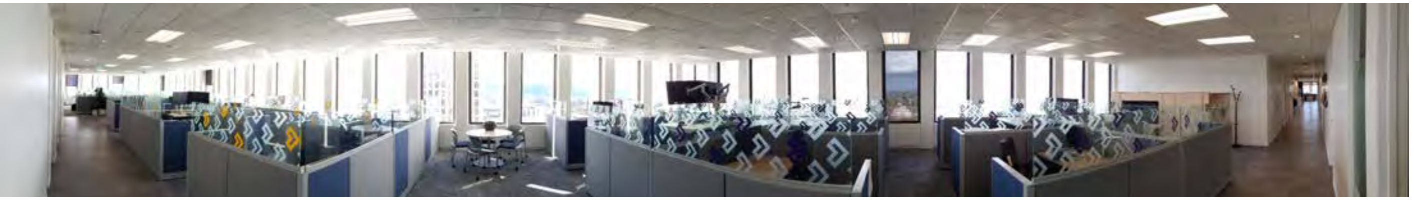




		9am	10am	11am	12am
As-built baseline workstation view	Average Annual Vertical Illuminance (Lux)	534	561	693	660
	% days E_v >= 275 Lux	62%	74%	84%	84%
Retrofit baseline workstation view	Average Annual Vertical Illuminance (Lux)	957	1342	1454	1299
	% days E_v>= 275 Lux	66%	81%	91%	93%
Enhanced retrofit workstation view +exterior shading (vertical and horizontal) +interior light shelf +clerestory and view window	Average Annual Vertical Illuminance (Lux)	866	1008	581	533
	% days E_v >= 275 Lux	69%	74%	83%	82%

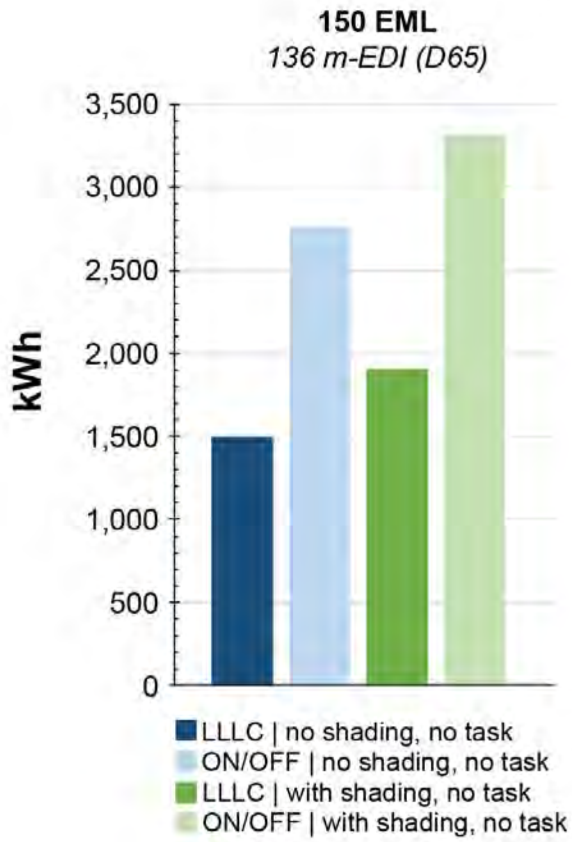
Circadian health and electric lighting

Meeting circadian dosing requirements (WELL Standard)

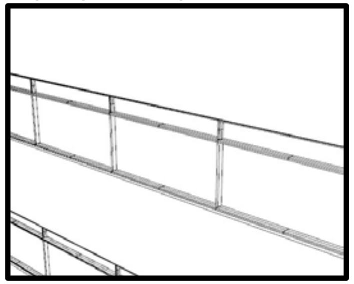


Percent of time of year (9am-1pm) **EML > 150Lux** with daylight only

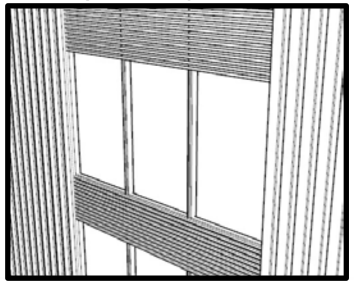
Annual Lighting Energy Use Total (kWh)



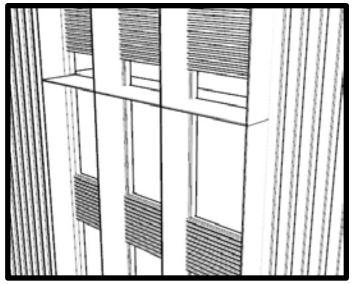
AS-BUILT BASELINE



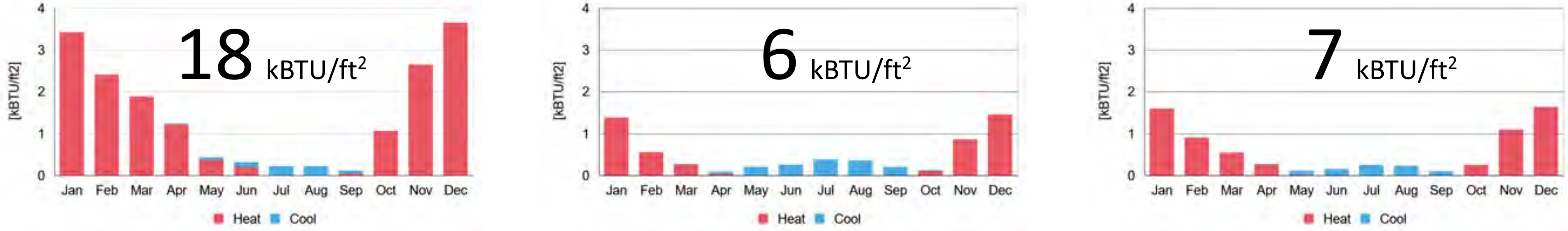
RETROFIT BASELINE



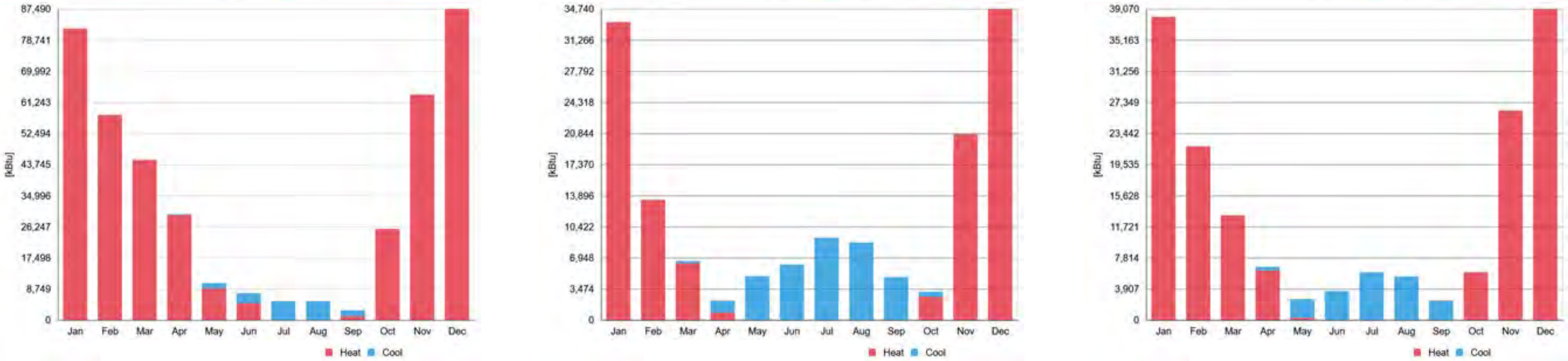
RETROFIT ENHANCED



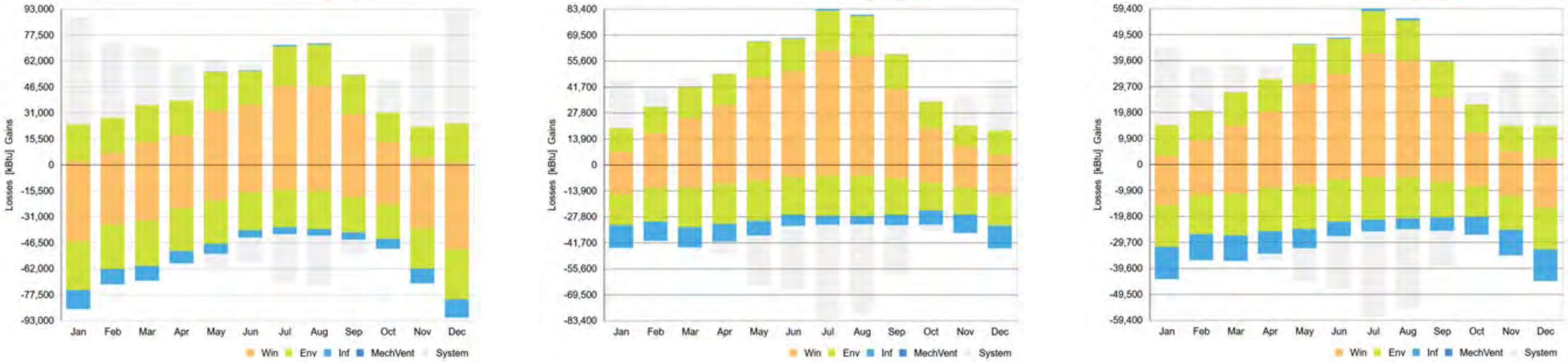
EUI



ENERGY USE



ENERGY FLOWS



Discussion

- Mass plywood and timber products offer a low-carbon solution to improve seismic and climate resilience for commercial buildings
- Façade retrofits can also offer co-benefits like improved thermal performance and daylighting design, which offer energy savings and improved occupant comfort and health
- There is a give-and-take dynamic between maximizing daylight availability, minimizing excessive over-lighting and potential glare, and promoting health. Efficient electric lighting systems and controls can help bridge the gap.

Questions? Discussion?

UNIVERSITY OF OREGON