Integrated Design Lab

University of Oregon

Mark Fretz and Siobhan Rockcastle

January 31, 2023

CLASSIFICATION LEVEL: PUBLIC

Achieving non-visual health in the workplace using LLLCs

An adaptive and dynamic view-based approach to
evaluating Equivalent Melanopic Lux under daylit and electric lighting scenarios

Siobhan Rockcastle, Alen Mahić

University of Oregon | Institute for Health in the Built Environment | Energy Studies in Buildings Lab | Baker Lighting Lab

BETTERBRICKS
Powerful Energy Ideas. Delivered by NEEA.

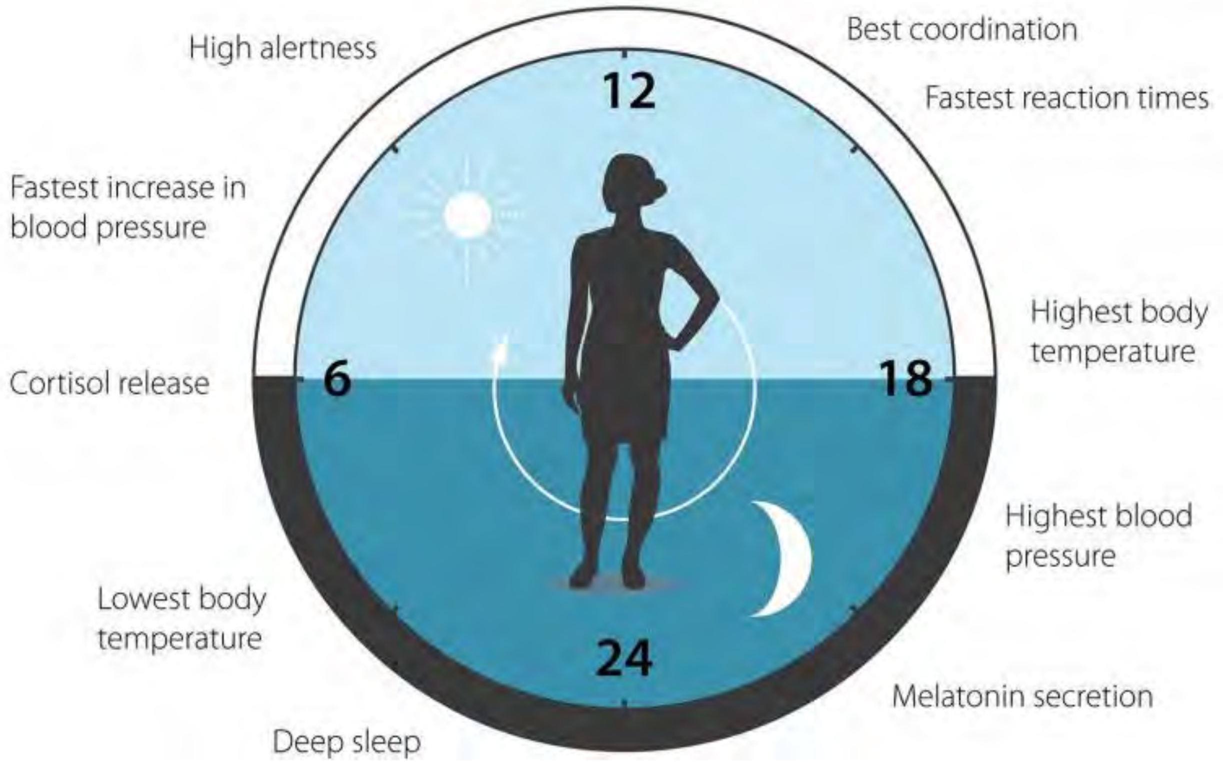
neea

Pacific Northwest
NATIONAL LABORATORY

UNIVERSITY OF
OREGON

Non-Visual Benefits of Light

2017 Nobel Prize in Physiology or Medicine
Jeffrey C. Hall, Michael Rosbash and Michael W. Young



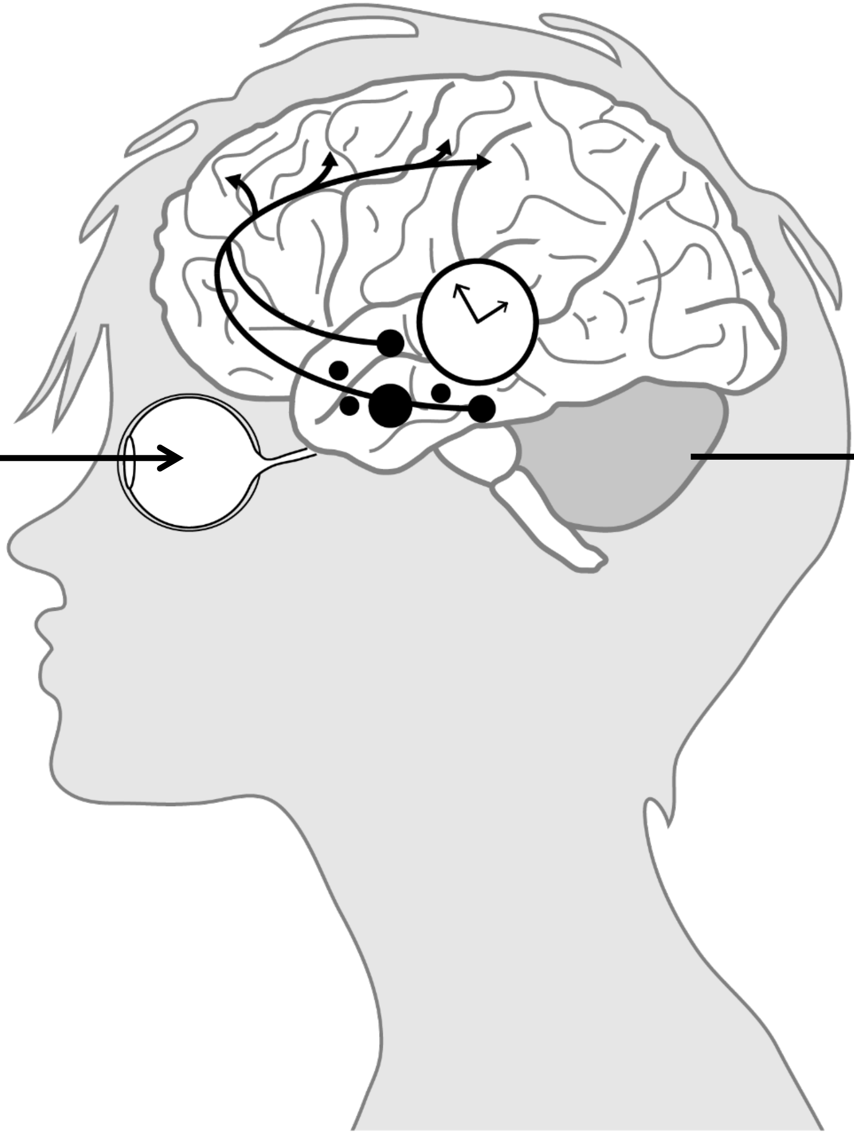
UNIVERSITY OF OREGON

Non-Visual Benefits of Light

Non-Visual Benefits of Light

Light & Dark

Intensity
Wavelength
Duration
Timing
History



Non-visual responses

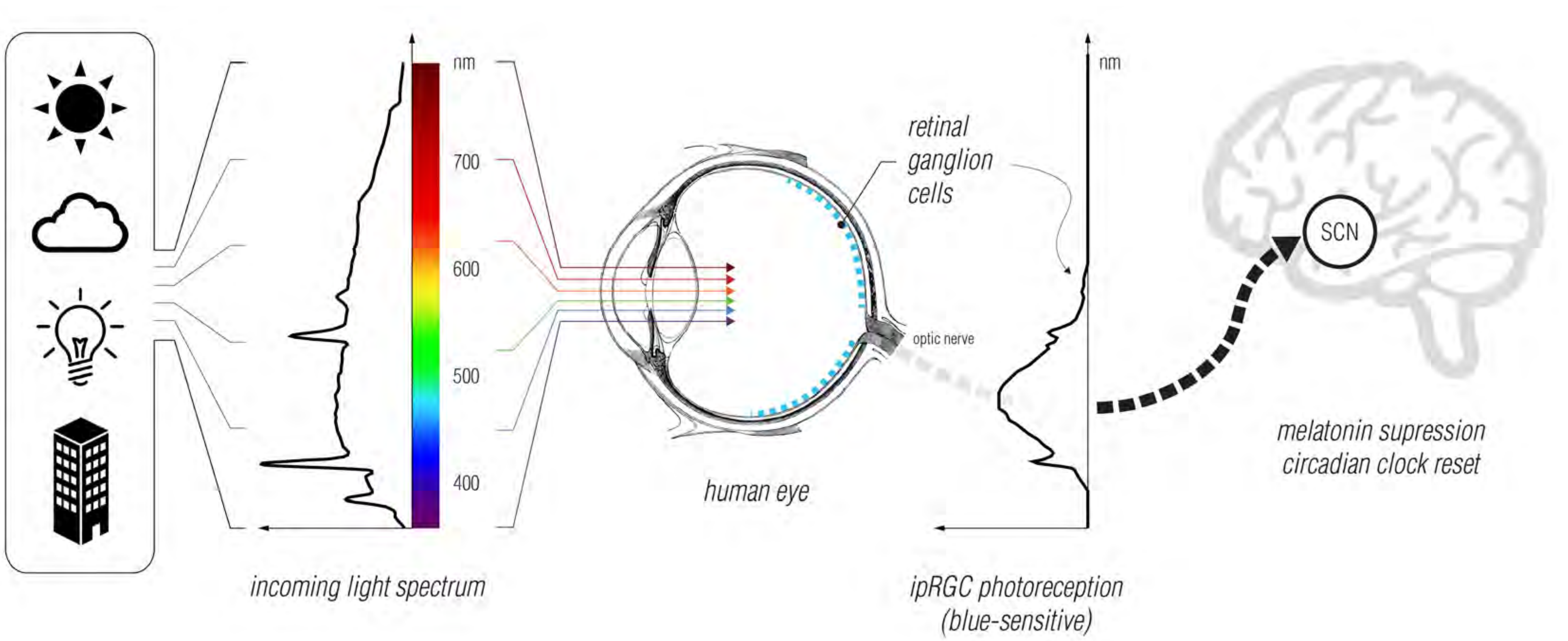
Circadian rhythms

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

Direct effects

- Melatonin suppression
- Pupil constriction
- Subjective alertness
- Performance

Non-Visual Benefits of Light



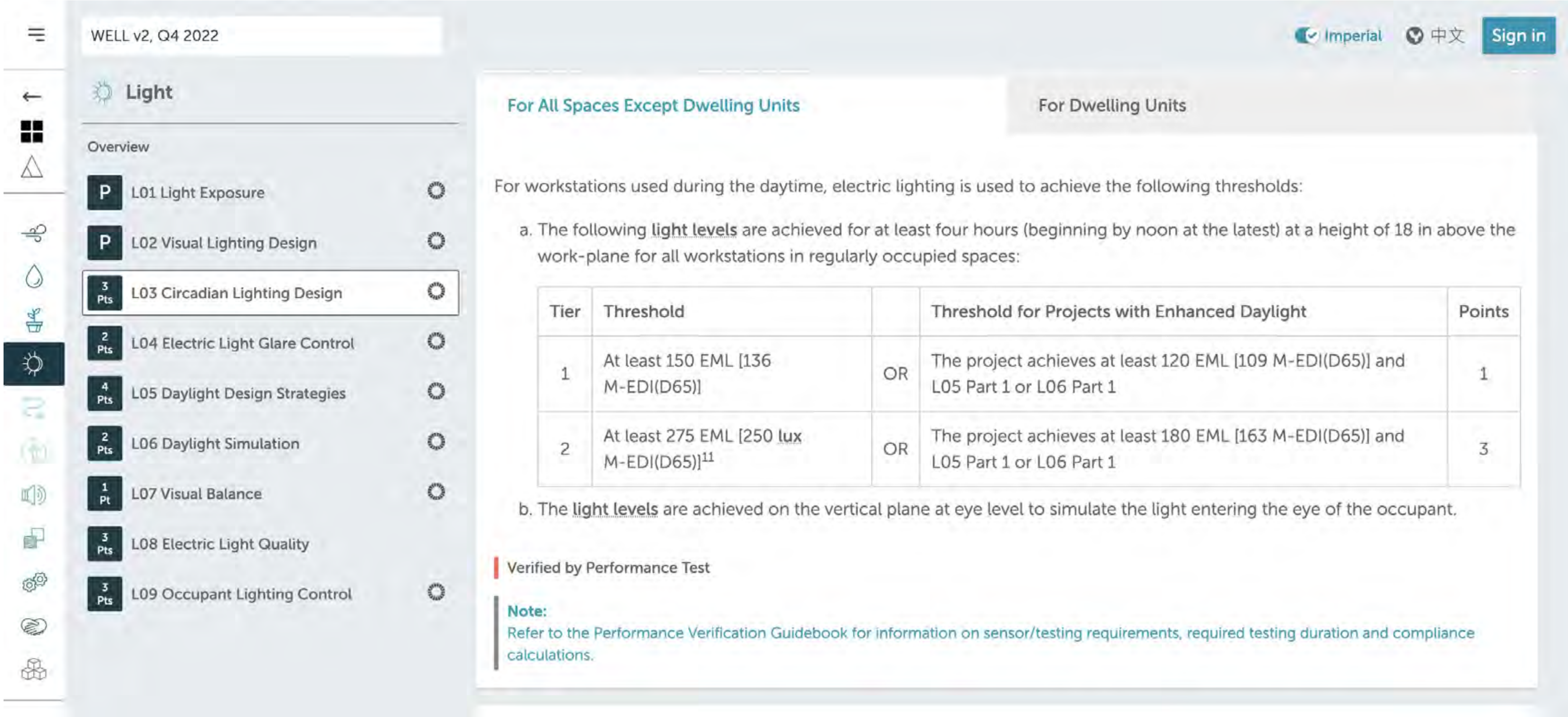
https://www.solemma.com/Alfa.html

UNIVERSITY OF OREGON

Non-Visual Benefits of Light

- **Non-visual health**
  - Eye-level light exposure that entrains our circadian clock
  - Linked to alertness & sleep quality
- **WELL Building Standard**
  - Relies on 4-hours of eye-level light exposure for ALL workstations during occupied hours
  - Prime exposure is in the morning
  - 1-point for 150 EML
  - 3-points for 275 EML

WELL Building Standard – Feature 3, Circadian Lighting Design



WELL v2, Q4 2022

Imperial 中文 Sign in

Light

Overview

- P L01 Light Exposure
- P L02 Visual Lighting Design
- 3 Pts L03 Circadian Lighting Design
- 2 Pts L04 Electric Light Glare Control
- 4 Pts L05 Daylight Design Strategies
- 2 Pts L06 Daylight Simulation
- 1 Pt L07 Visual Balance
- 3 Pts L08 Electric Light Quality
- 3 Pts L09 Occupant Lighting Control

For All Spaces Except Dwelling Units | For Dwelling Units

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 M-EDI(D65)]	OR	The project achieves at least 120 EML [109 M-EDI(D65)] and L05 Part 1 or L06 Part 1	1
2	At least 275 EML [250 lux M-EDI(D65)][11]	OR	The project achieves at least 180 EML [163 M-EDI(D65)] and 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.

Verified by Performance Test

Note:
Refer to the Performance Verification Guidebook for information on sensor/testing requirements, required testing duration and compliance calculations.

https://v2.wellcertified.com/en/wellv2/light/feature/3

Custom Simulation Workflow

Multi-step process that combines:

- Radiance daylighting & electric lighting simulations
- LARK circadian dosing calculation

Radiance and LARK:

- Daylight availability and excessiveness
- Electric lighting integrated using IES files
- Shading operation schedules
- Equivalent Melanopic Lux (EML) levels

Allows us to calculate:

- contribution of daylight and electric light on circadian potential for a series of workstations
- energy required to meet the recommended thresholds using electric lighting
- Compare different control and shading scenarios across the year

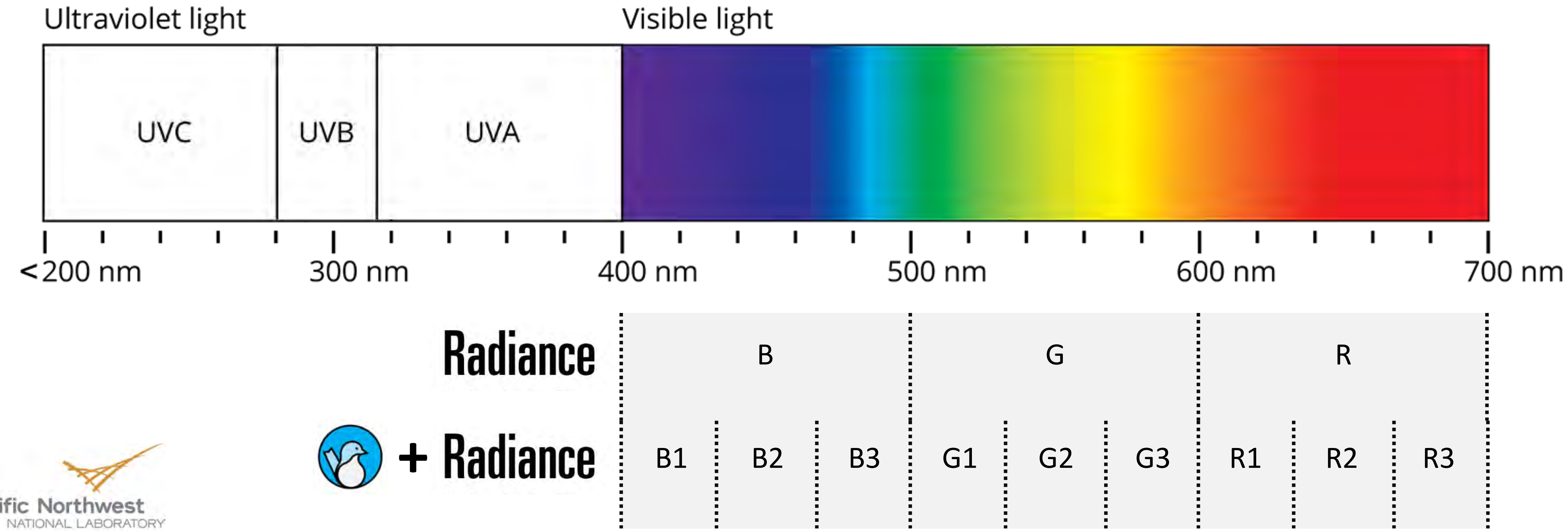
Radiance Synthetic Imaging System

Pacific Northwest NATIONAL LABORATORY

UNIVERSITY OF OREGON

Custom Simulation Workflow

- Increased color resolution via materials and sky definitions:

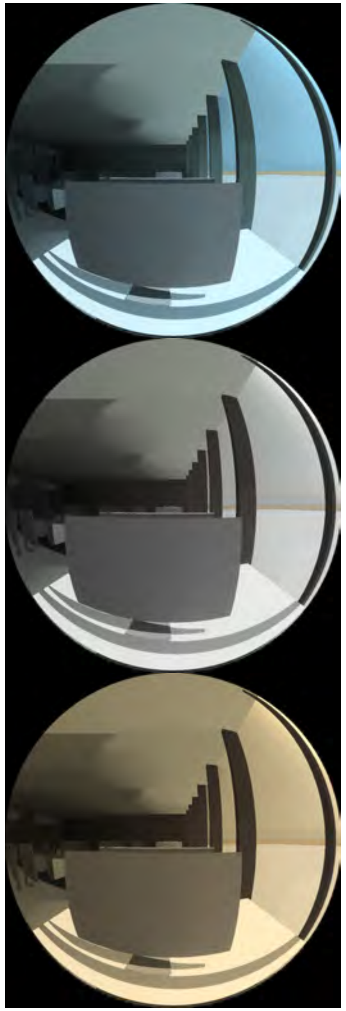


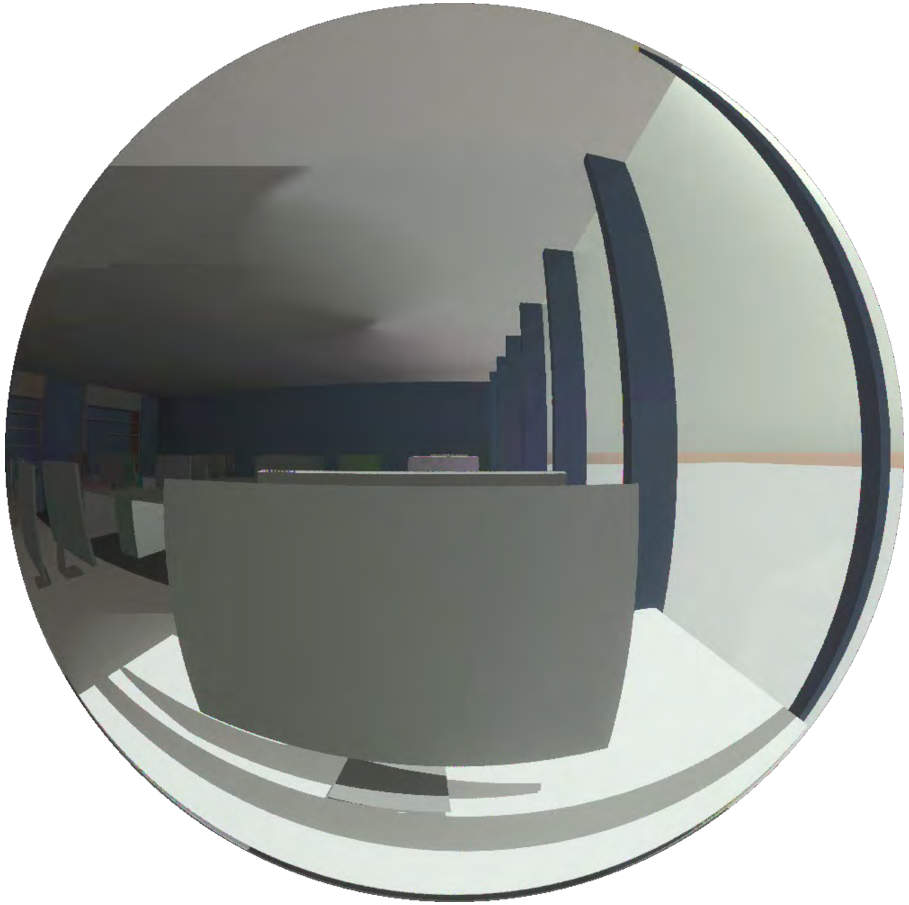
Pacific Northwest NATIONAL LABORATORY

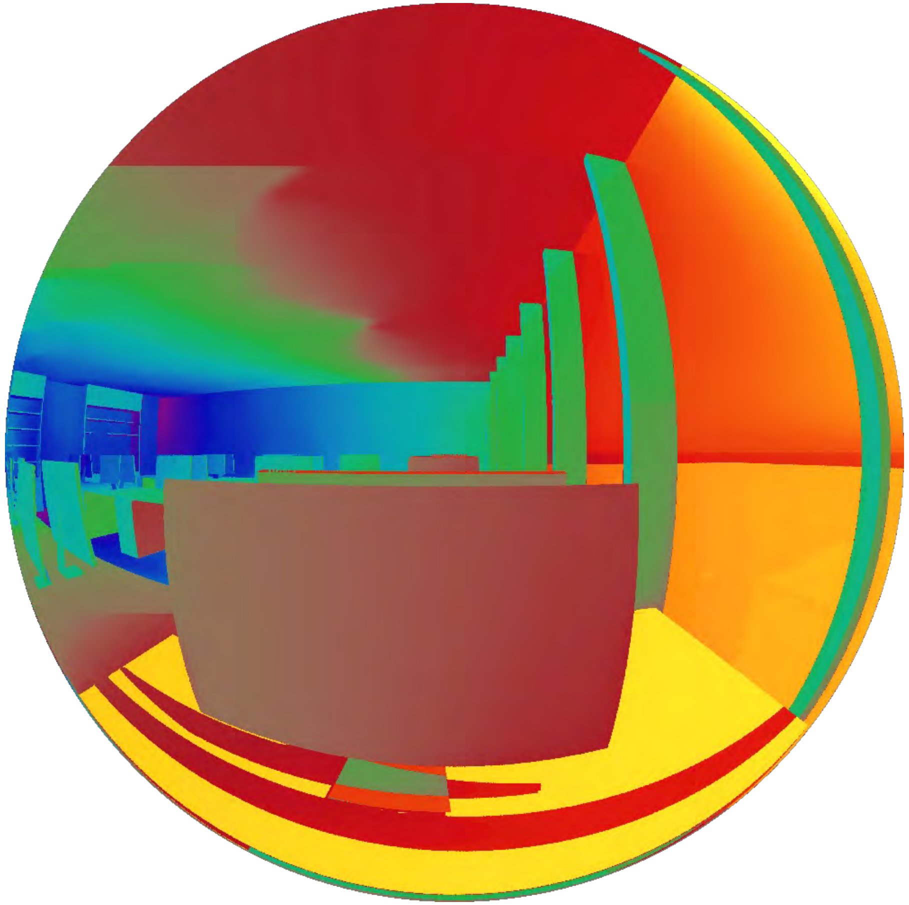
UNIVERSITY OF OREGON

Custom Simulation Workflow

B1
B2
B3
G1
G2
G3
R1
R2
R3







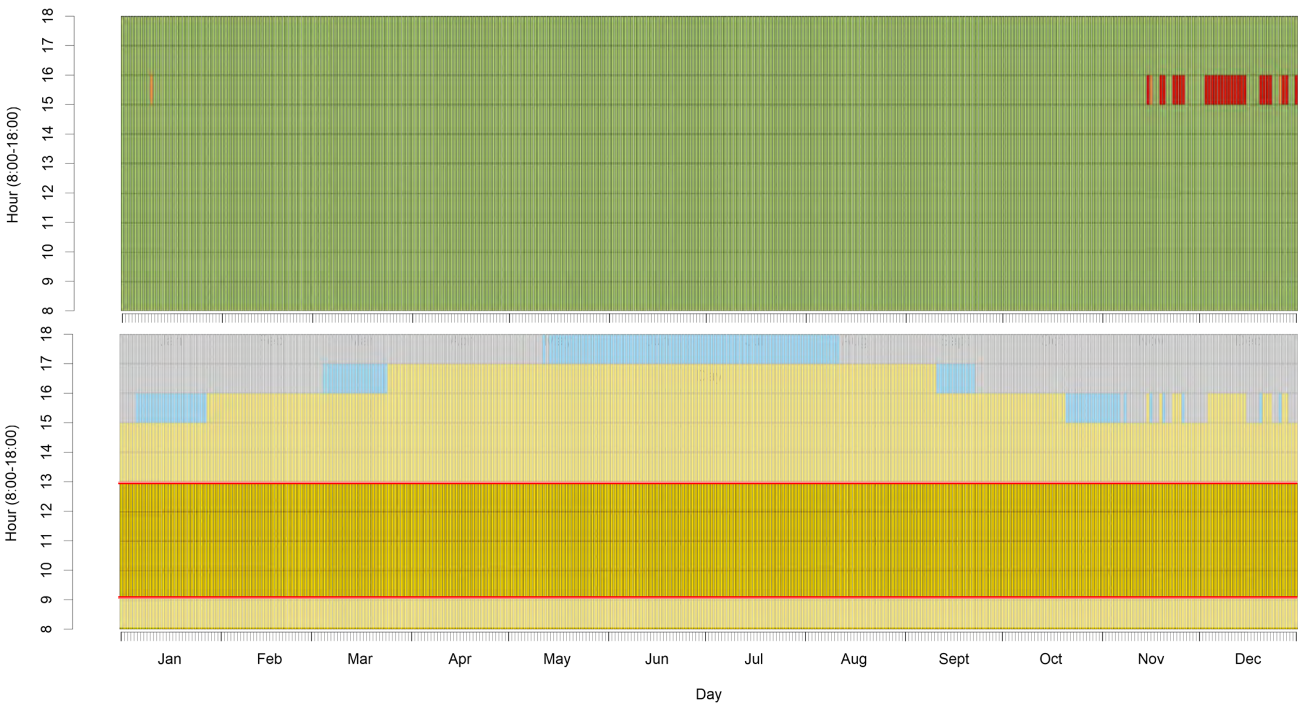
UNIVERSITY OF OREGON

Pacific Northwest NATIONAL LABORATORY

Proof-of-concept

Southwest-facing

CIE Intermediate sky



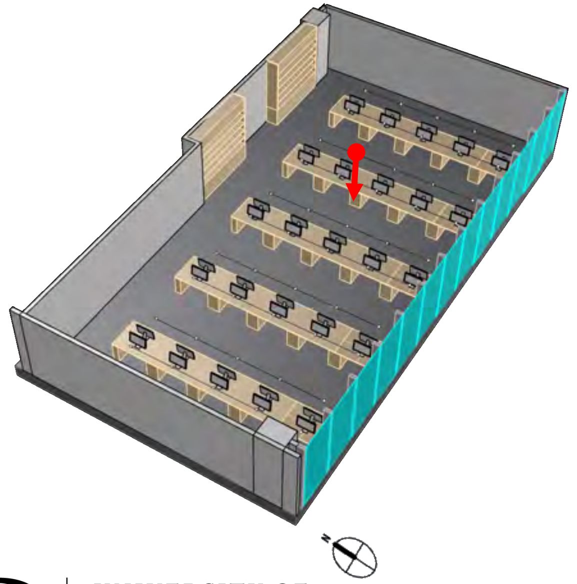
Daylight Glare Probability (DGP)

WELL 2021

150(1pt)

240(2pts)

Electric lighting needed to supplement EML levels



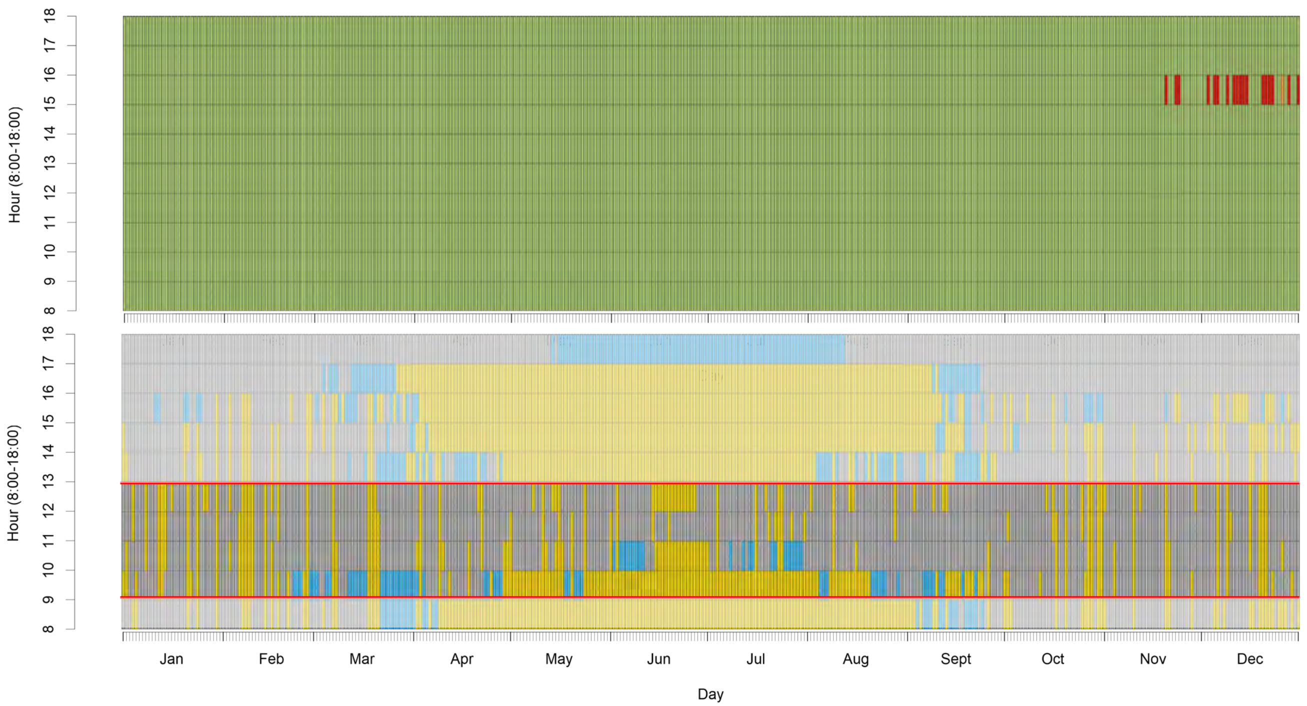
UNIVERSITY OF OREGON

Pacific Northwest NATIONAL LABORATORY

Proof-of-concept

Southwest-facing

CIE Intermediate sky
Operated Shading

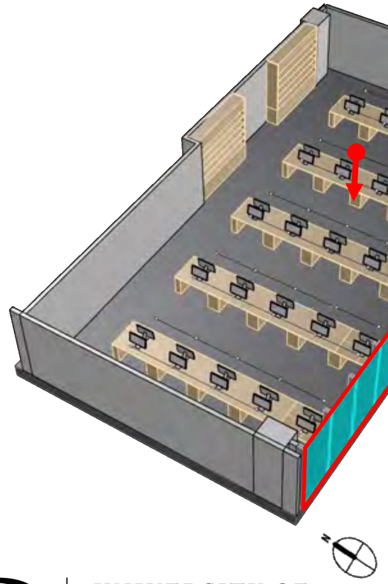


Daylight Glare Probability (DGP)

WELL 2021
150(1pt)
240(2pts)

Gray timestamps indicate instances where supplemental electric lighting is needed to meet 240 m-lux

Electric lighting needed to supplement EML levels



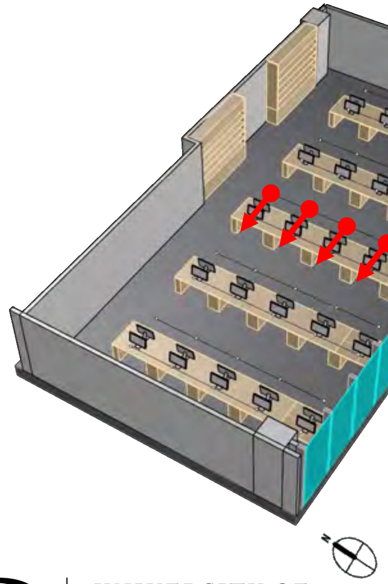
UNIVERSITY OF OREGON

Pacific Northwest NATIONAL LABORATORY

Proof-of-concept

West-facing
TMY3 sky data

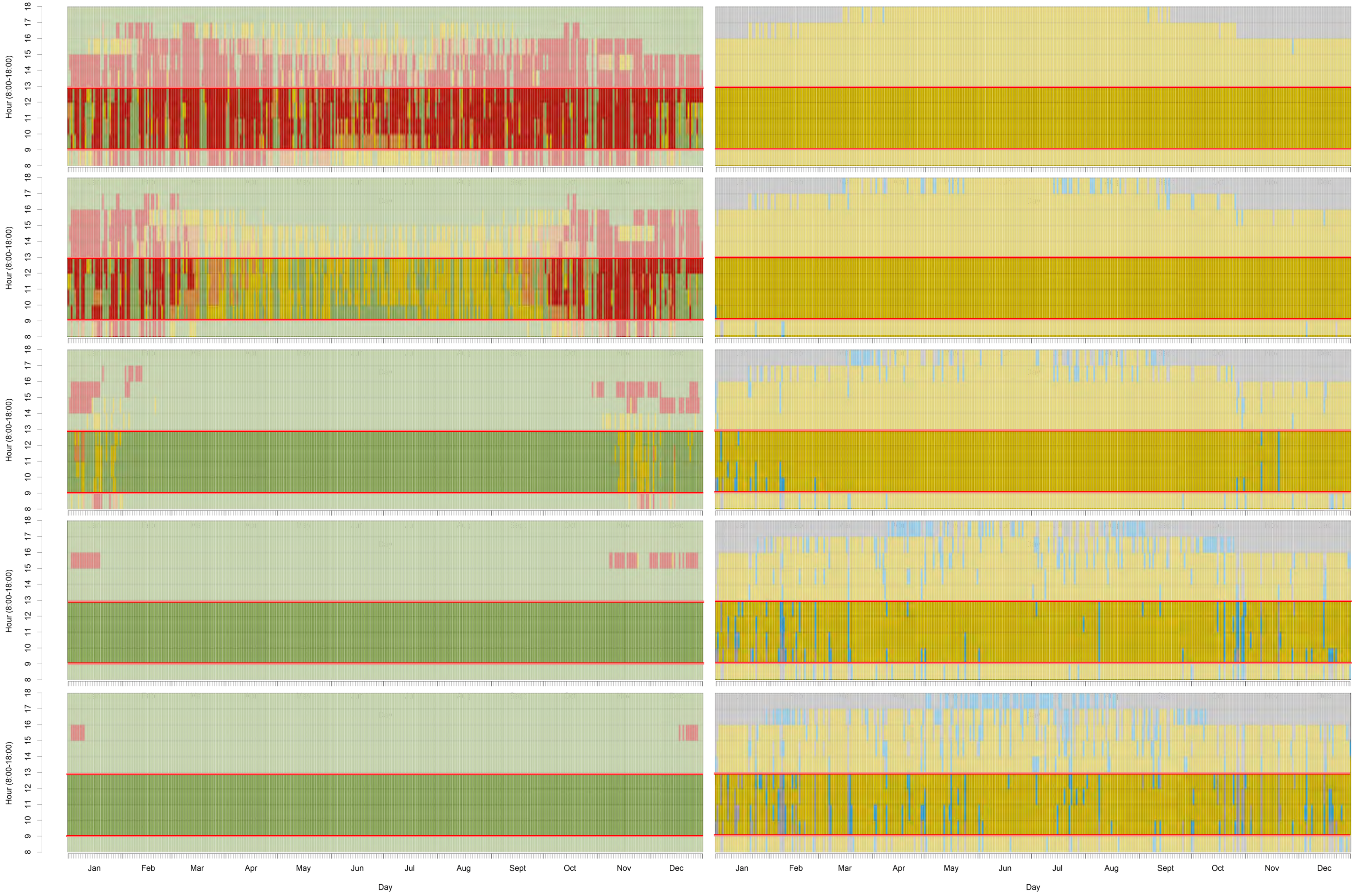
Perimeter



Core

Daylight Glare Probability (DGP<0.4)

WELL 2021 EML (150(1pt) 240(2pts))



Pacific Northwest NATIONAL LABORATORY

UNIVERSITY OF OREGON

Proof-of-concept

with operated shading

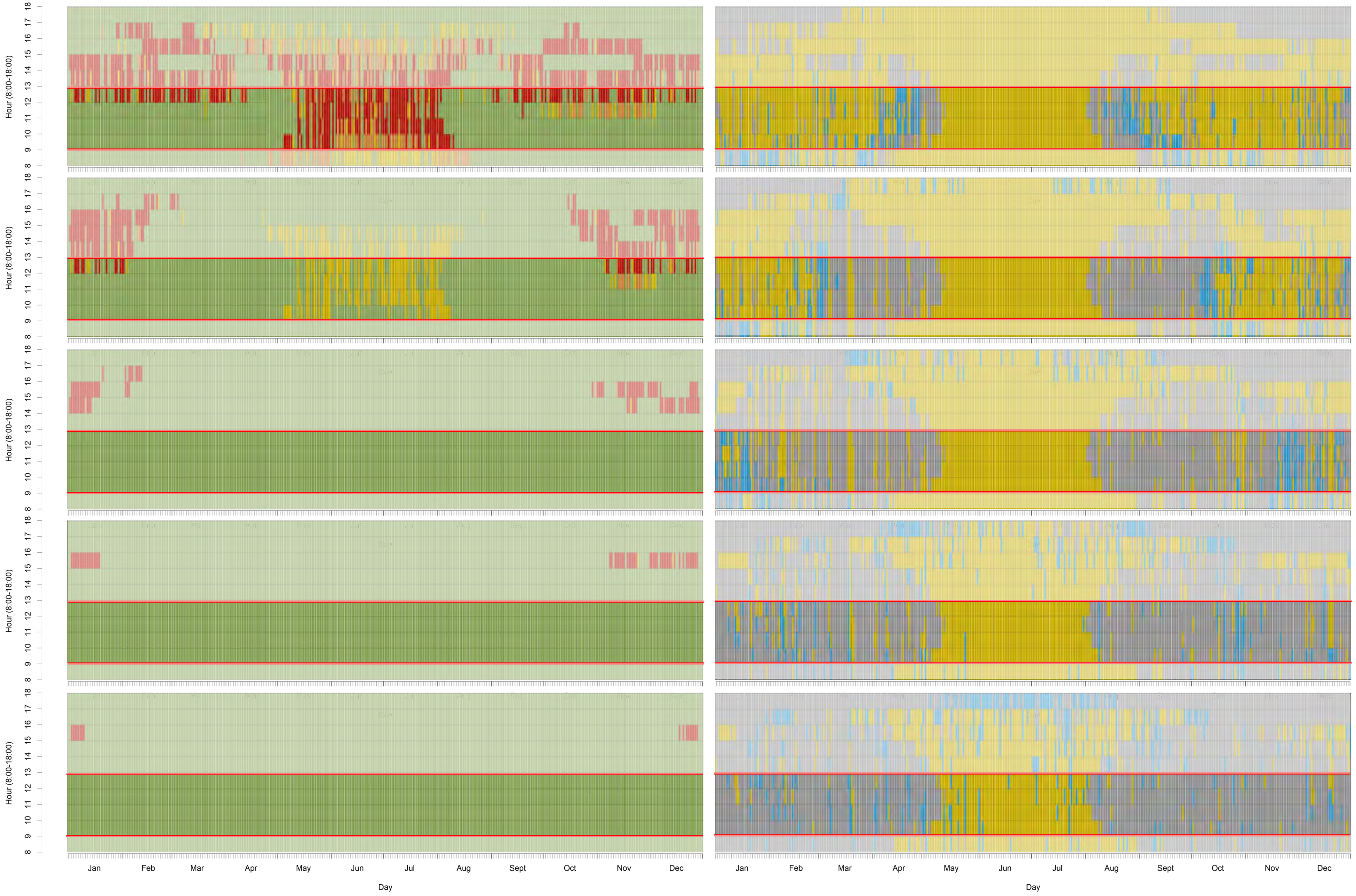
Pacific Northwest NATIONAL LABORATORY

West-facing

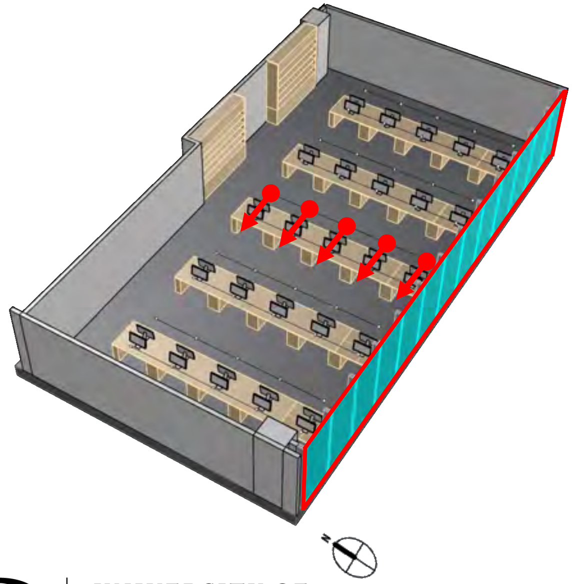
TMY3 sky data

Daylight Glare Probability (DGP<0.4) WELL 2021 EML (150(1pt) 240(2pts))

Perimeter

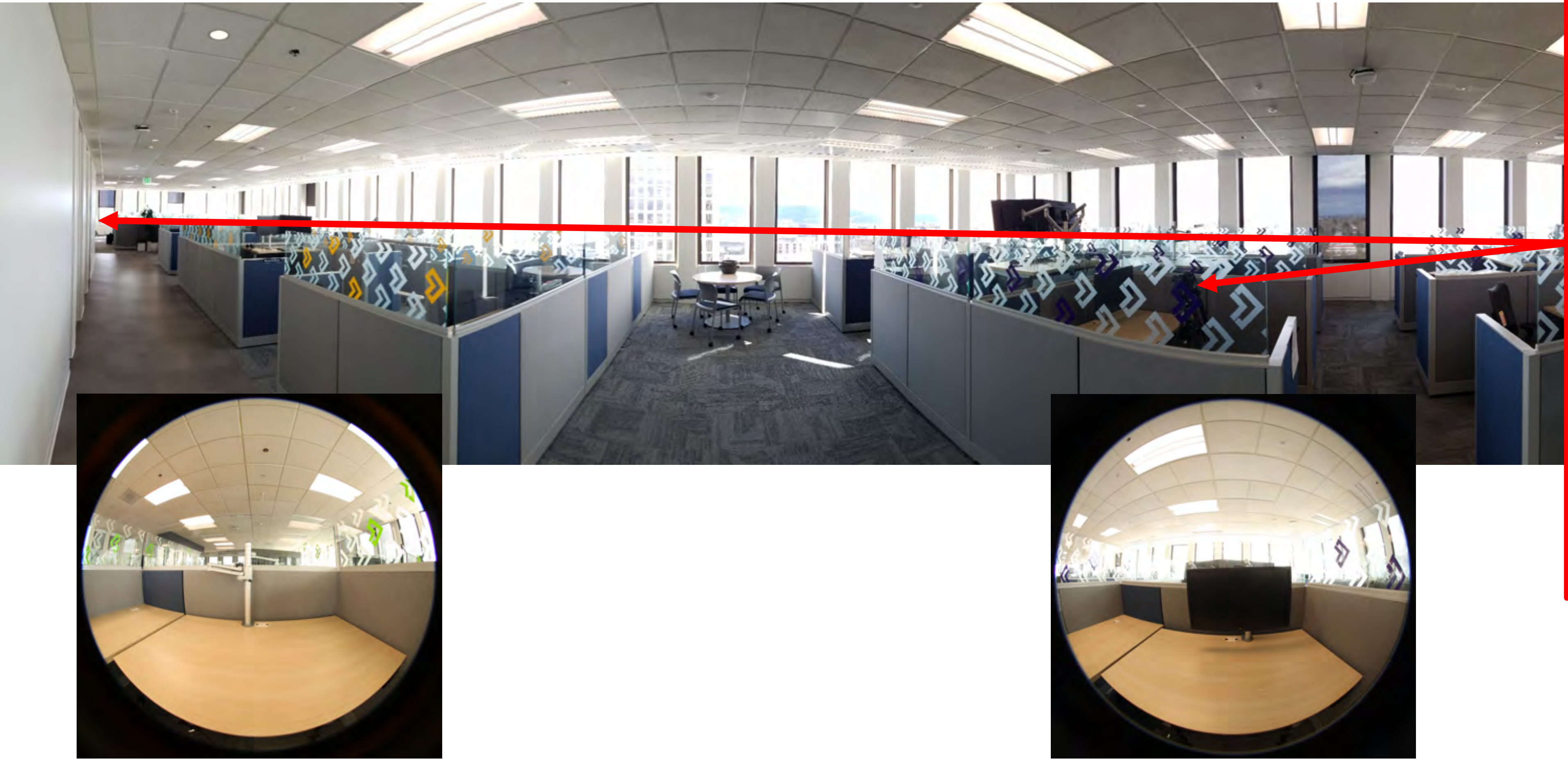


Core

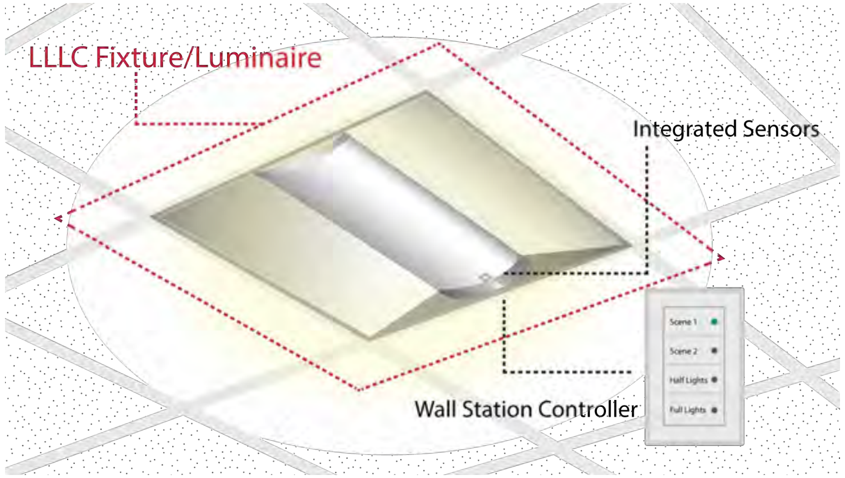


UNIVERSITY OF OREGON

Equipment for Validation at NEEA



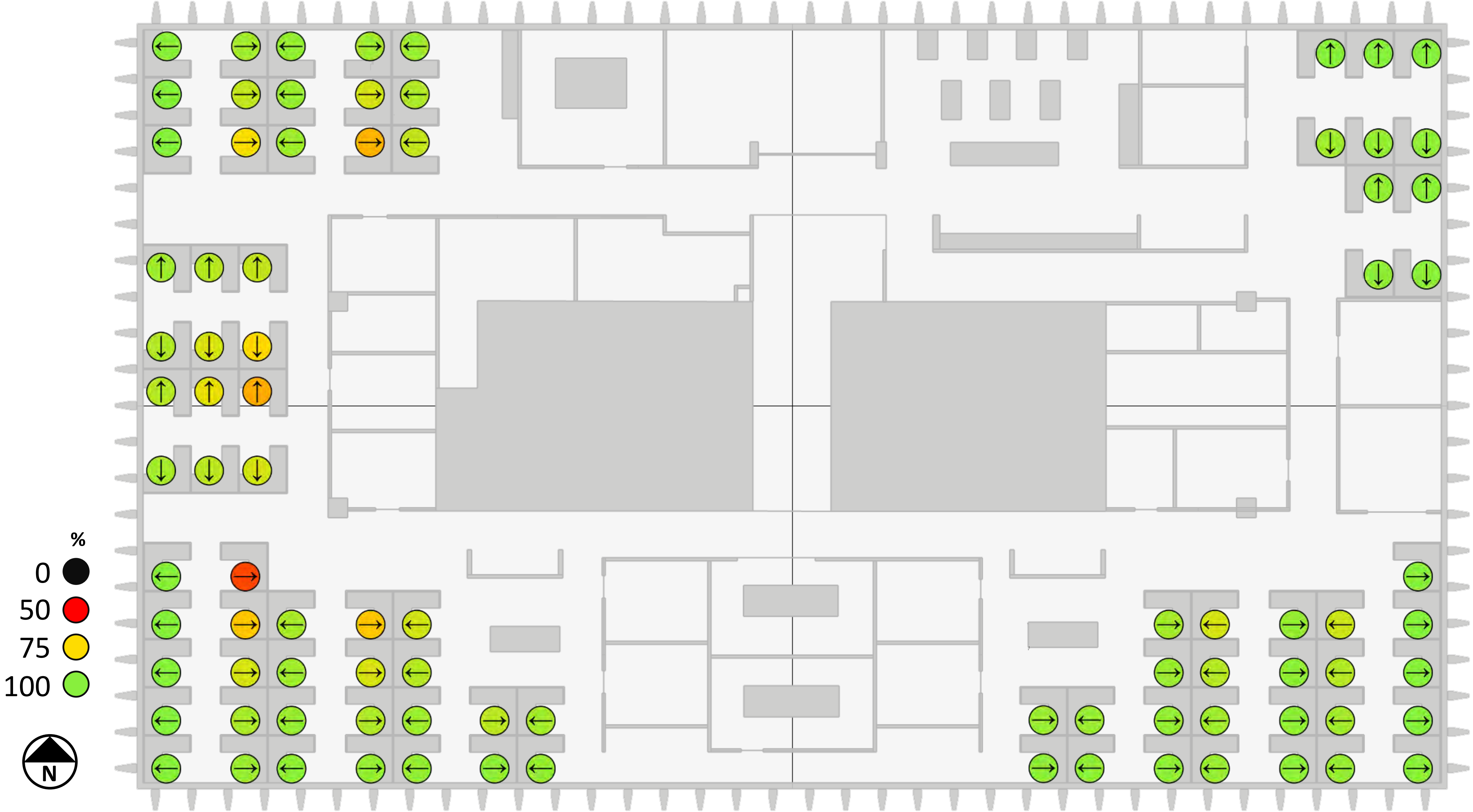
- **NEEA Offices**
  - 88 workstations
  - Seating orientations facing primarily east/west with some north/south
  - 8 zones of LLLC lighting
  - Manual shading systems on perimeter
- **Simulation Set-up**
  - Simulated annual, climate-based EML at eye-level for all workstations
  - Simulated dynamic manual blind use under LM-83 standard
  - Simulated 10-steps of dimming for each zone independently
    - EML dosing under daylight conditions is supplemented using LLLC lighting system
    - Annual energy demand is a result of LLLC needed to supplement eye-level dose



https://idcl.wsu.edu/lllc-curriculum/

UNIVERSITY OF OREGON

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



UNIVERSITY OF OREGON

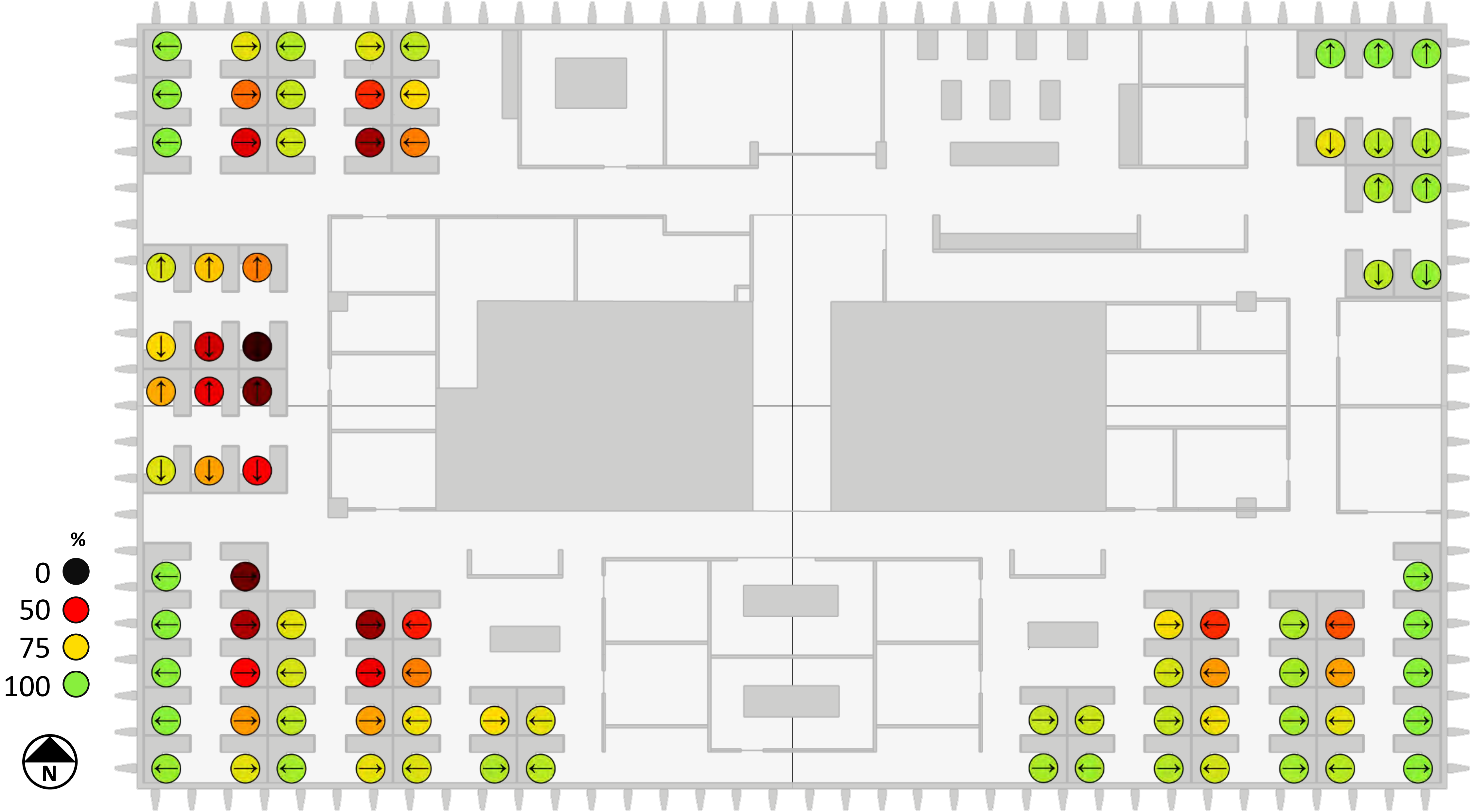
Percent of time of year (9am-1pm) **EML > 150Lux** with daylight only and operated blinds (LM-83, individual window groups)

UNIVERSITY OF OREGON

Percent of time of year (9am-1pm) **EML > 275Lux** with daylight only

UNIVERSITY OF OREGON

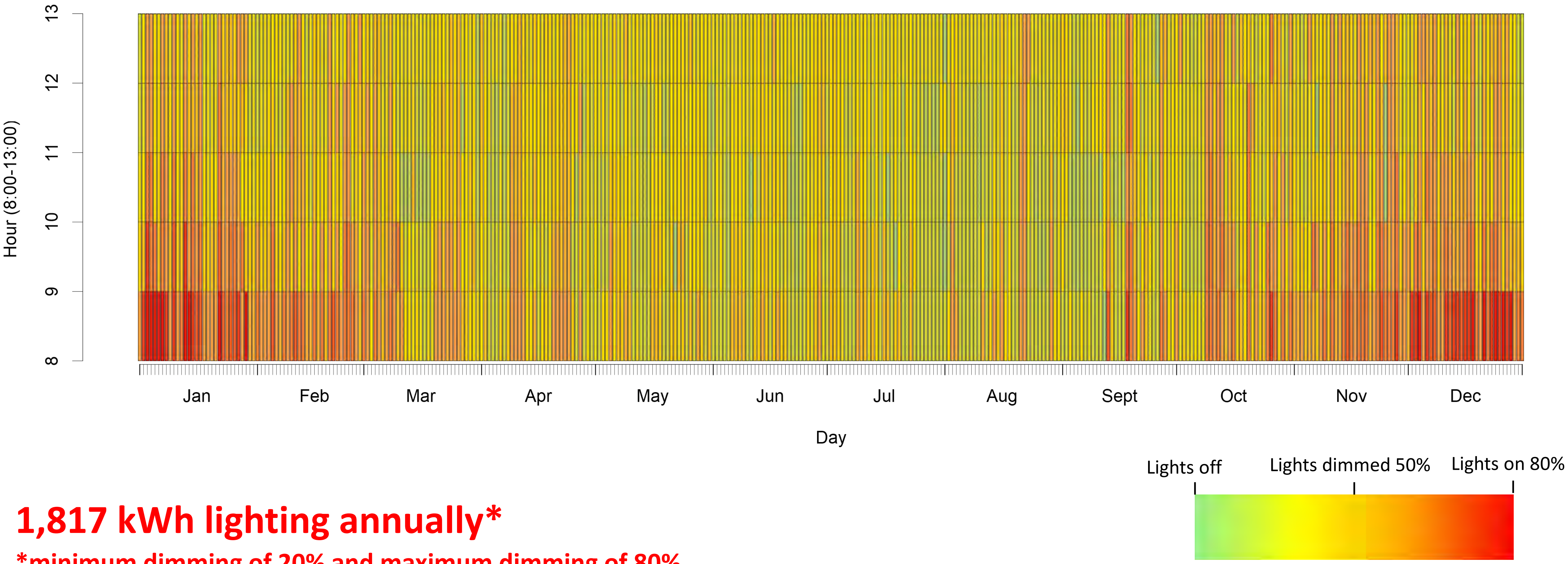
Percent of time of year (9am-1pm) **EML > 275Lux** with daylight only and operated blinds (LM-83, individual window groups)



UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 150 EML

Blinds always open, without task lighting

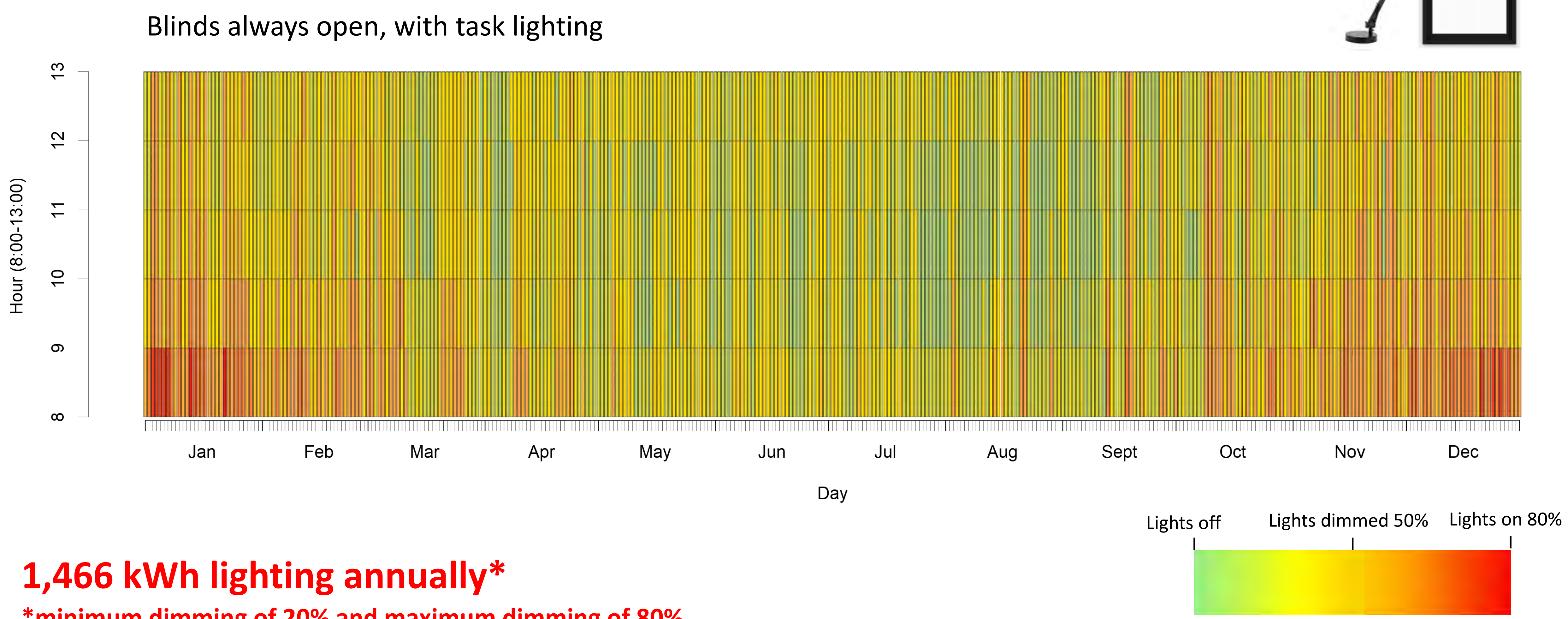


1,817 kWh lighting annually*

***minimum dimming of 20% and maximum dimming of 80%**

UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 150 EML

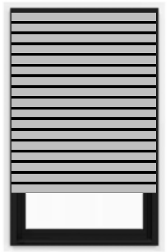


1,466 kWh lighting annually*

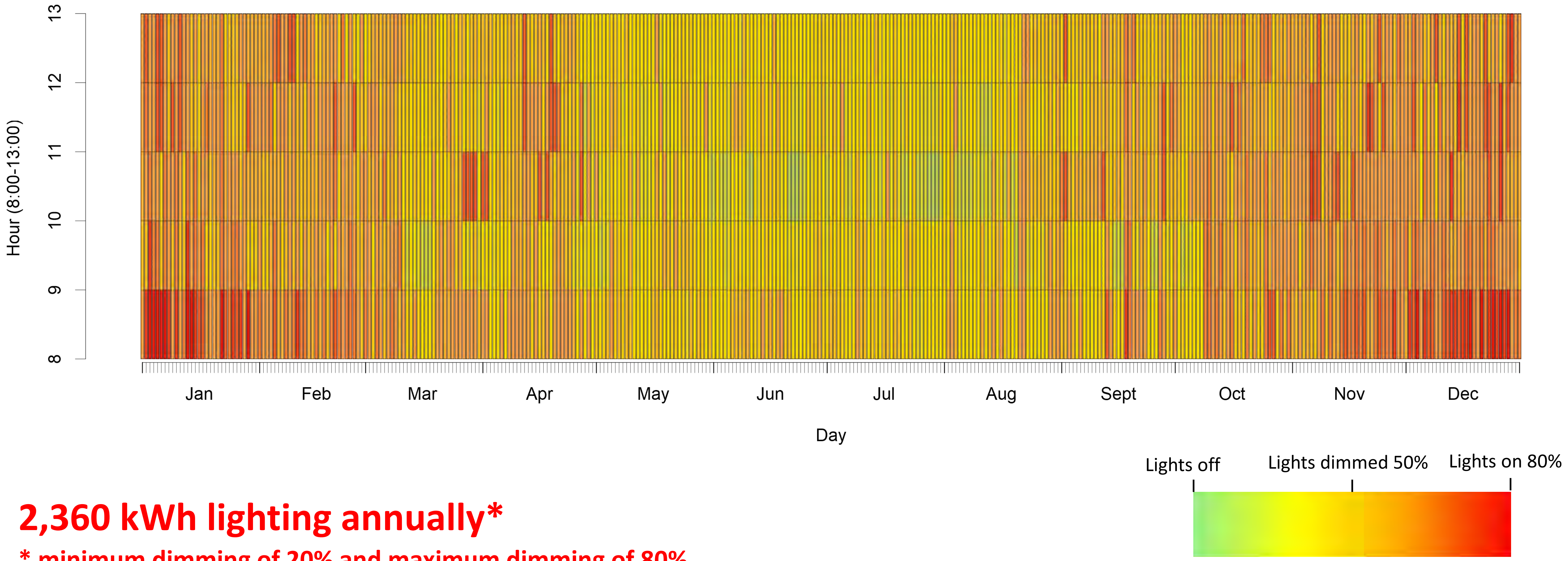
***minimum dimming of 20% and maximum dimming of 80%**

UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 150 EML



Interior window shading operated as per IES-LM-83 manual control algorithm, without task lighting



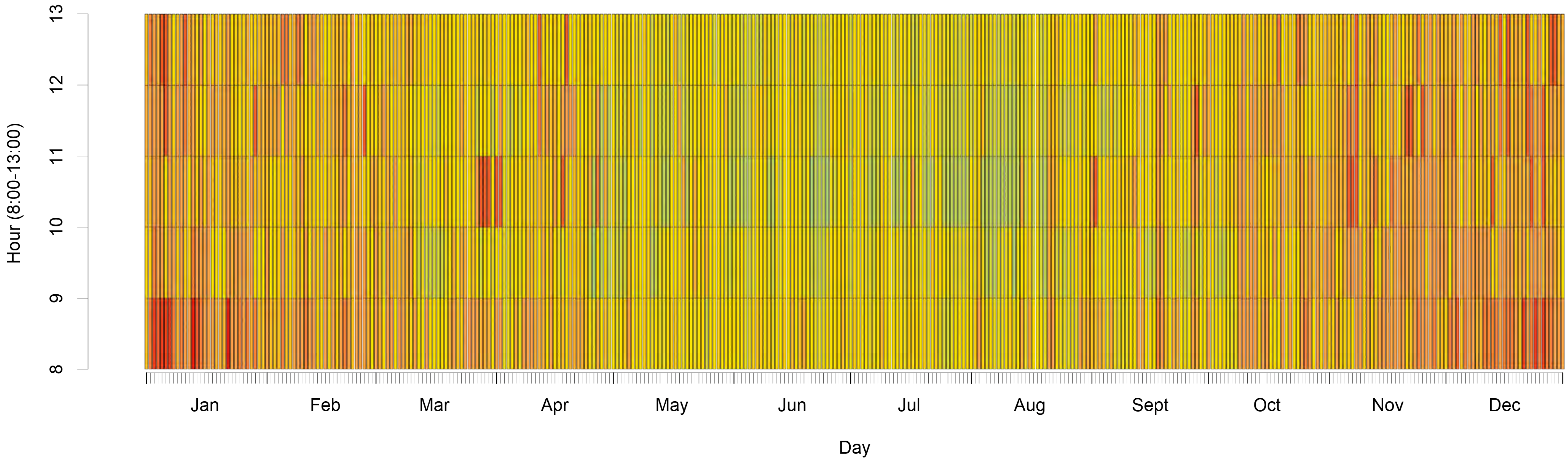
2,360 kWh lighting annually*

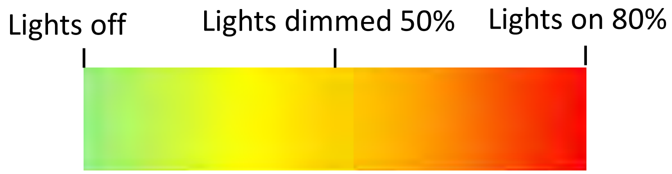
*** minimum dimming of 20% and maximum dimming of 80%**

UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 150 EML

Interior window shading operated as per IES-LM-83 manual control algorithm, with task lighting



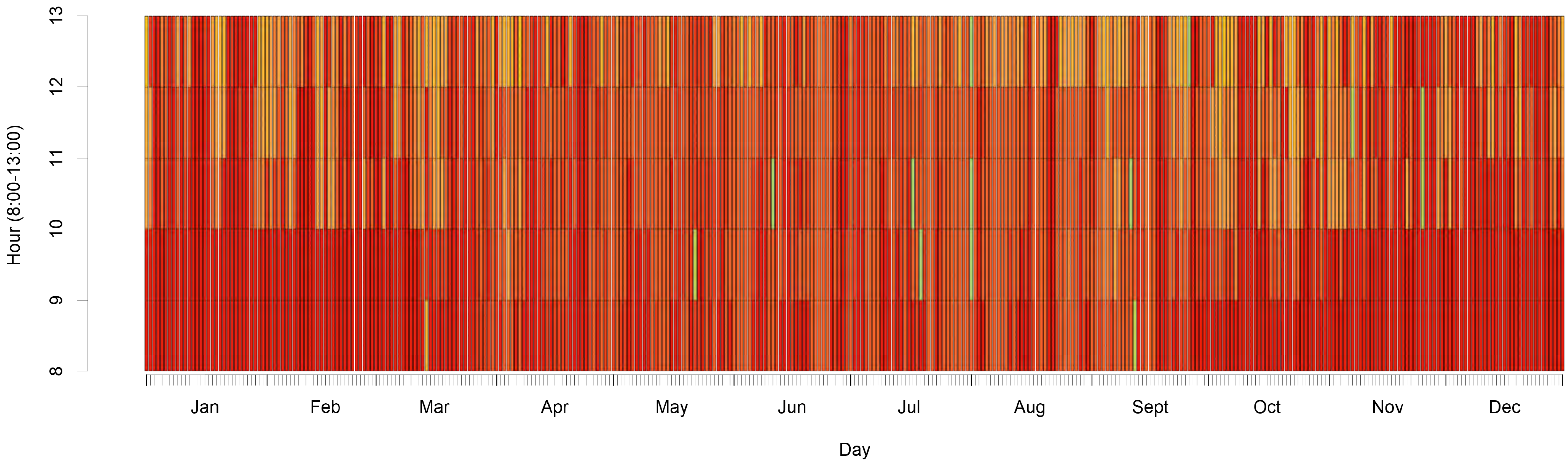


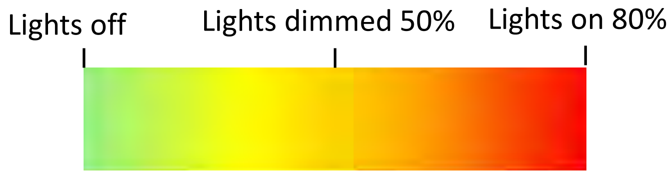
1,968 kWh lighting annually*

*** minimum dimming of 20% and maximum dimming of 80%**

Total wattage/dimming needed to meet 275 EML

Blinds always open without task lighting





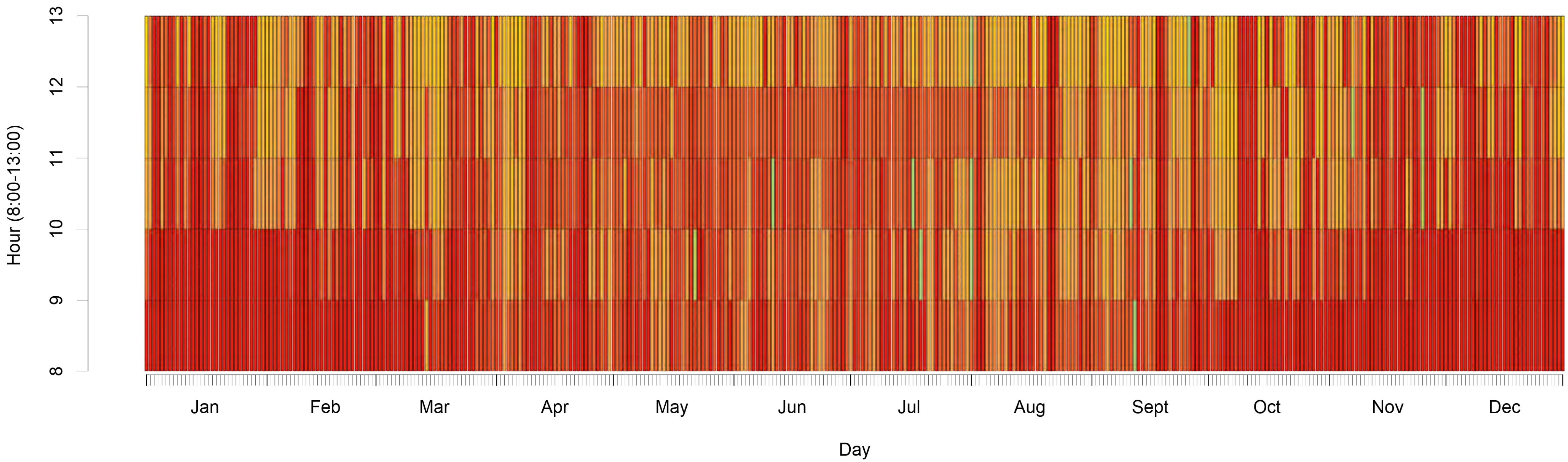
3,857 kWh lighting annually*

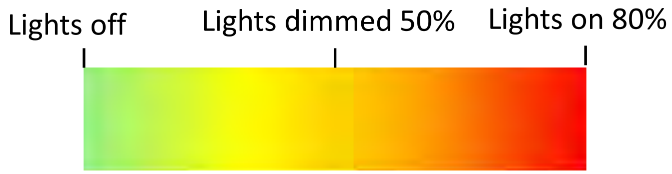
*** minimum dimming of 20% and maximum dimming of 80%**

UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 275 EML

Blinds always open with task lighting

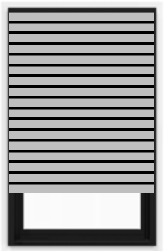




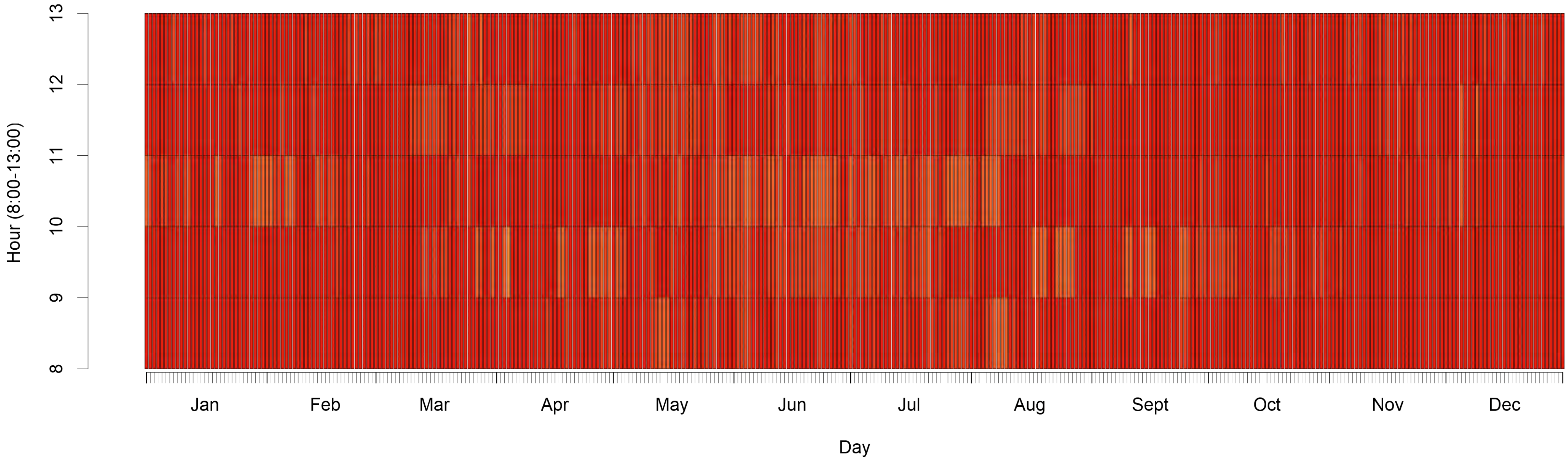
3,619 kWh lighting annually*

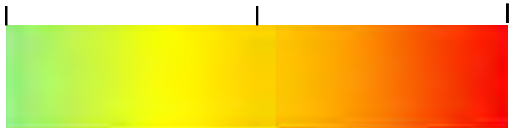
*** minimum dimming of 20% and maximum dimming of 80%**

Total wattage/dimming needed to meet 275 EML



Interior window shading operated as per IES-LM-83 manual control algorithm, without task lighting





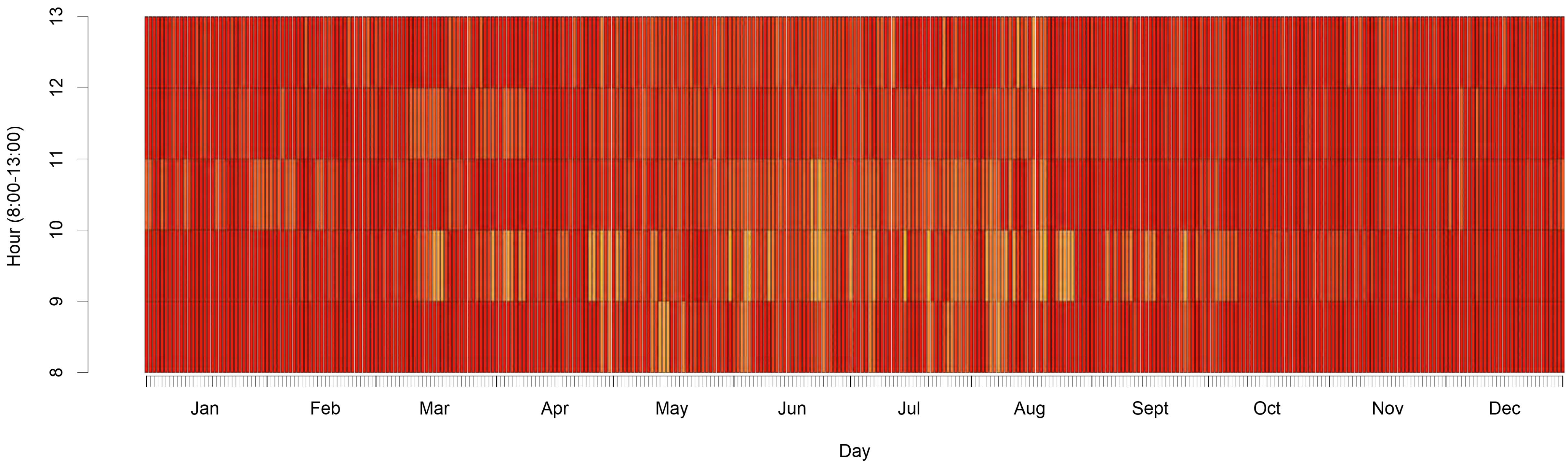
4,223 kWh lighting annually*

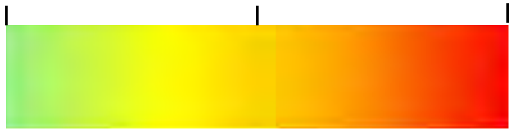
***does not account for continuous dimming at 20% or demand for private office spaces**

UNIVERSITY OF OREGON

Total wattage/dimming needed to meet 275 EML

Interior window shading operated as per IES-LM-83 manual control algorithm, with task lighting



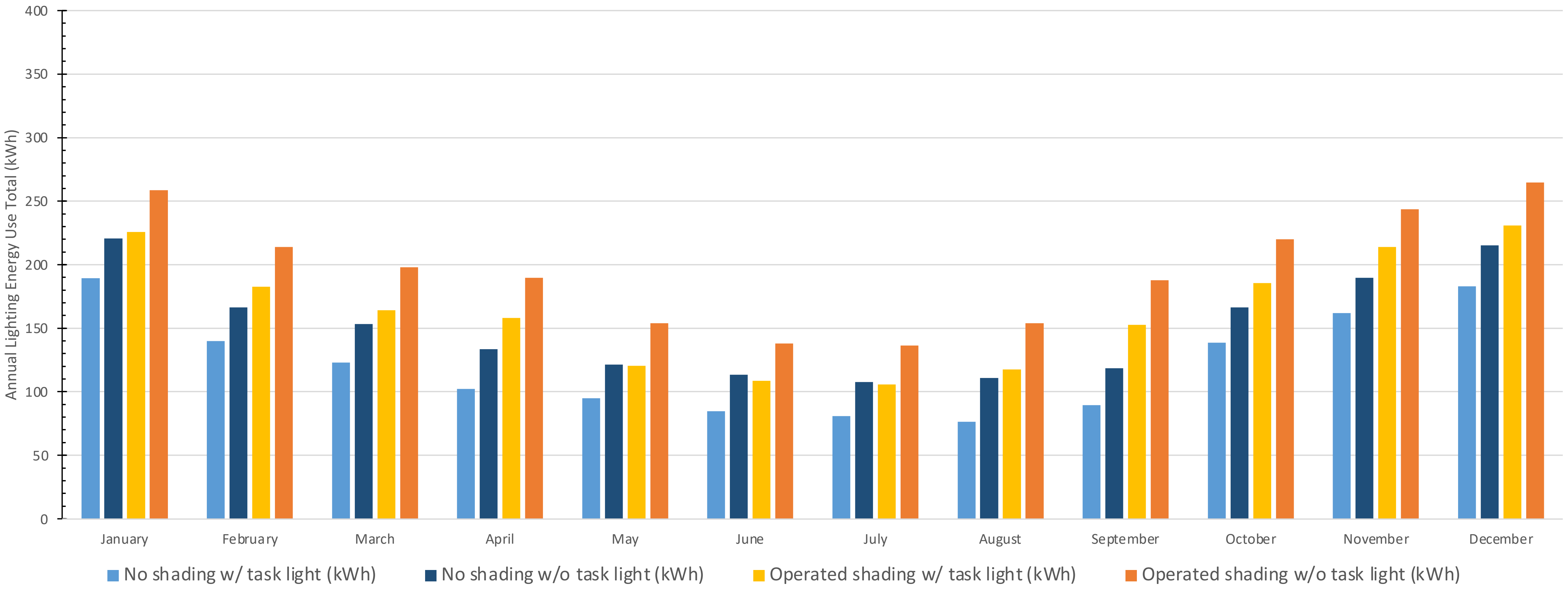


4,133 kWh lighting annually*

***does not account for continuous dimming at 20% or demand for private office spaces**

Monthly Energy Use

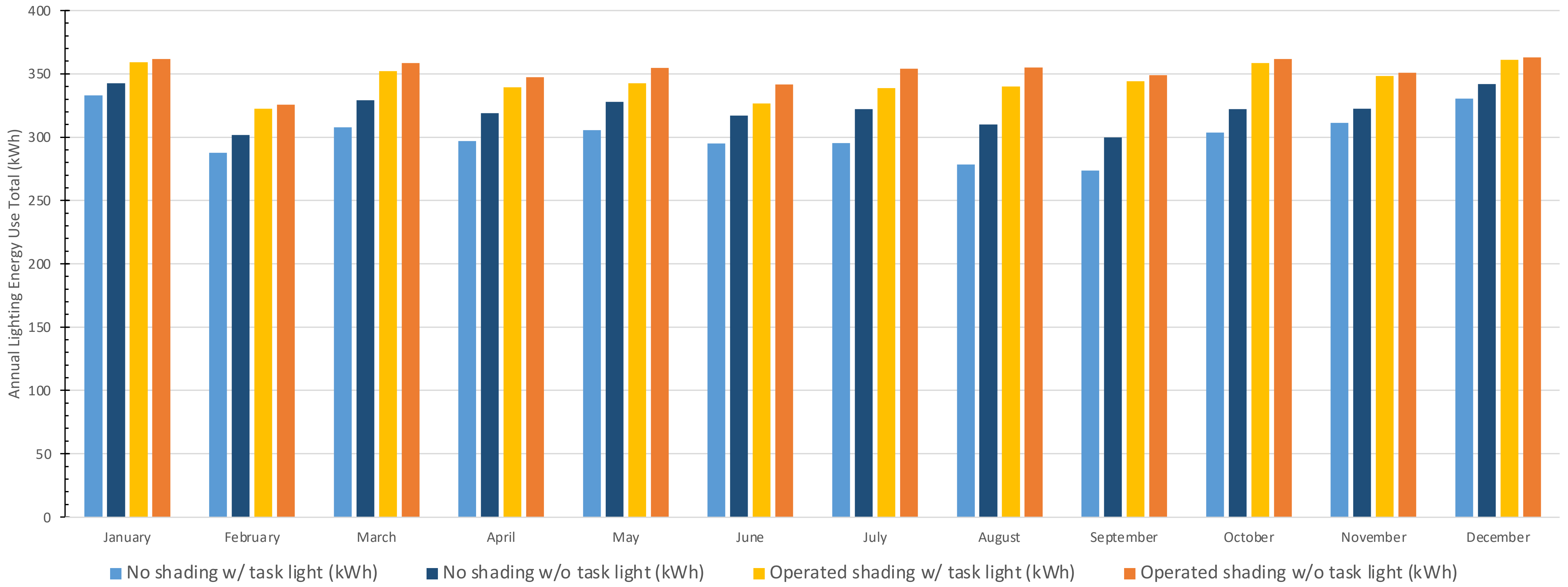
From LLLC lighting system to meet 150EMLux recommendation as per the WELL Standard



UNIVERSITY OF OREGON

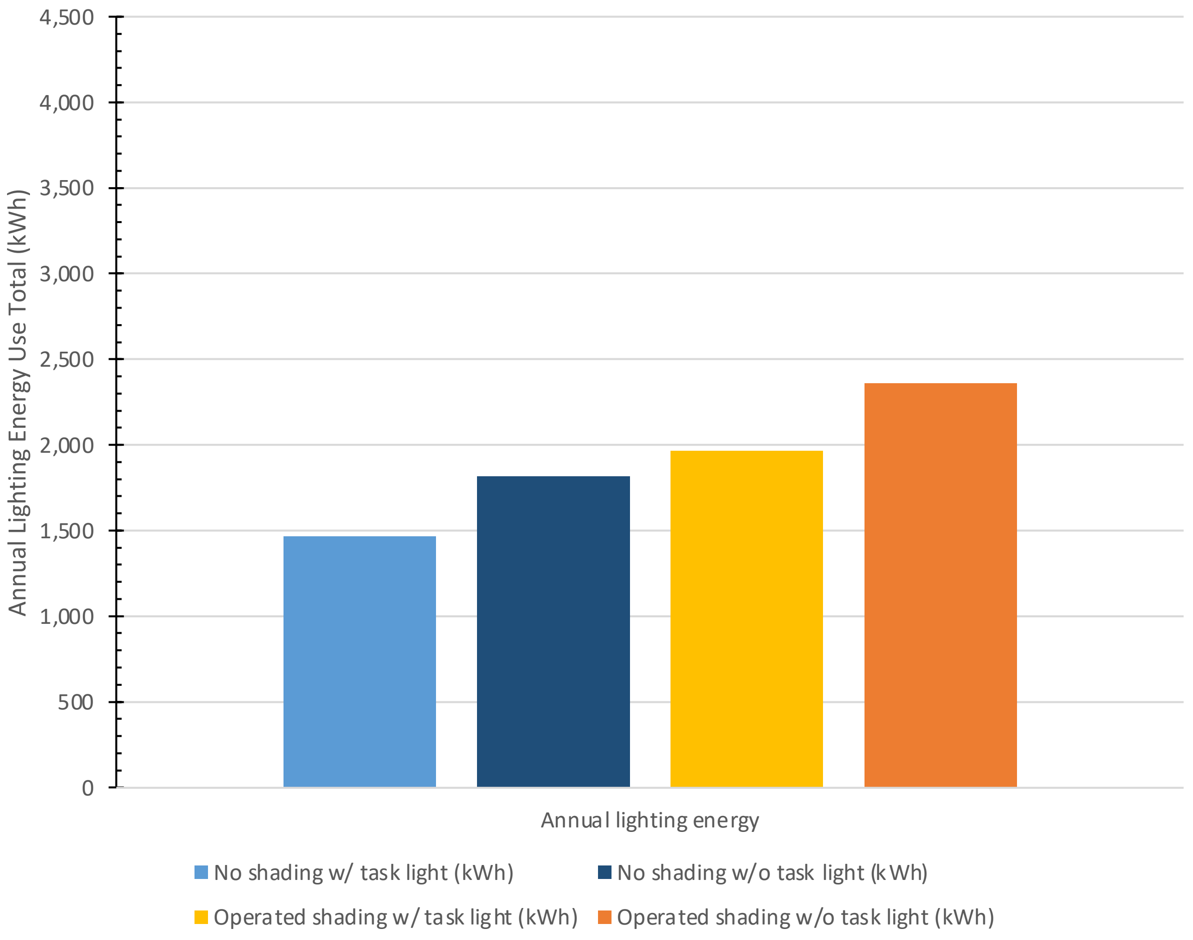
Monthly Energy Use

From LLLC lighting system to meet 275EMLux recommendation as per the WELL Standard

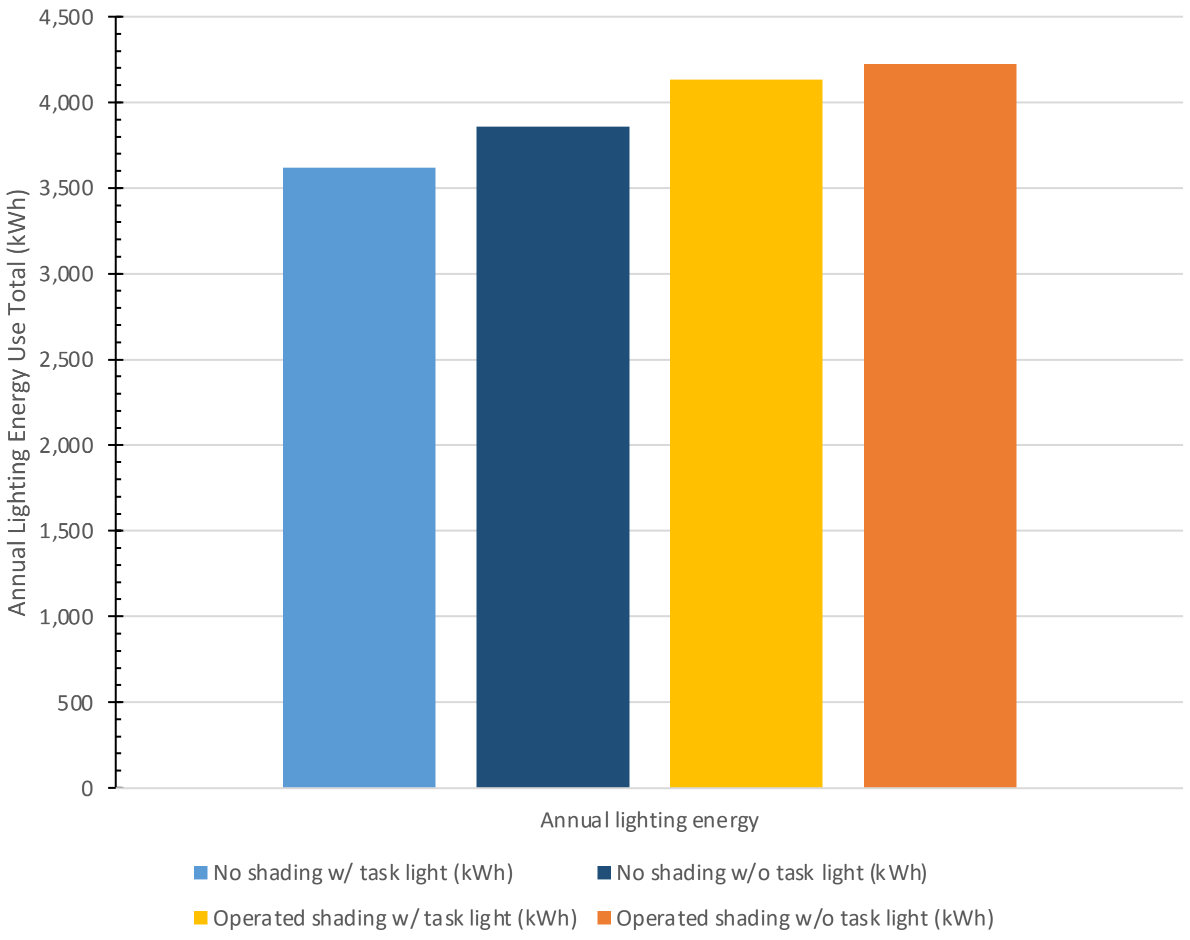


Annual Energy Use

LLLC to meet 150EMLux WELL Standard threshold:

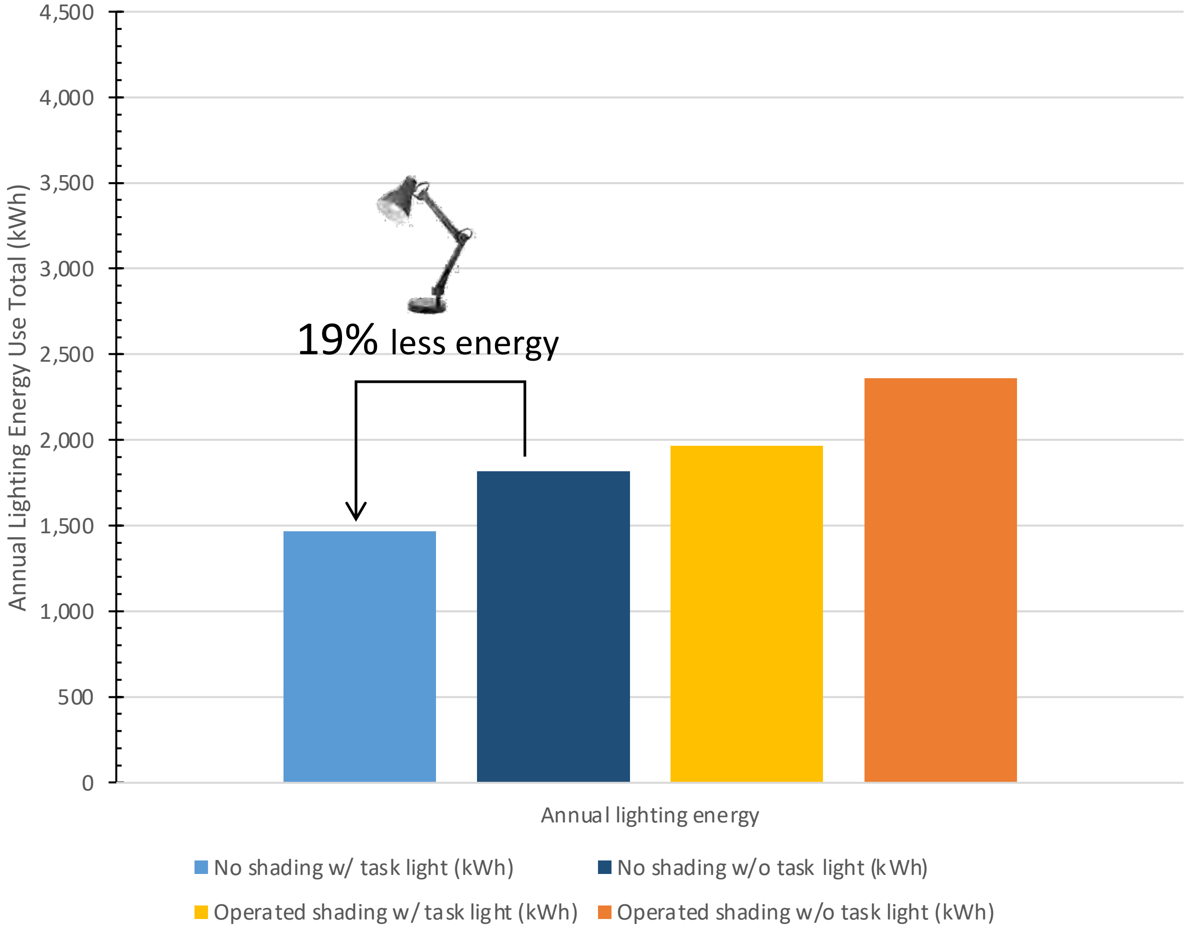


LLLC to meet 275EMLux WELL Standard threshold:

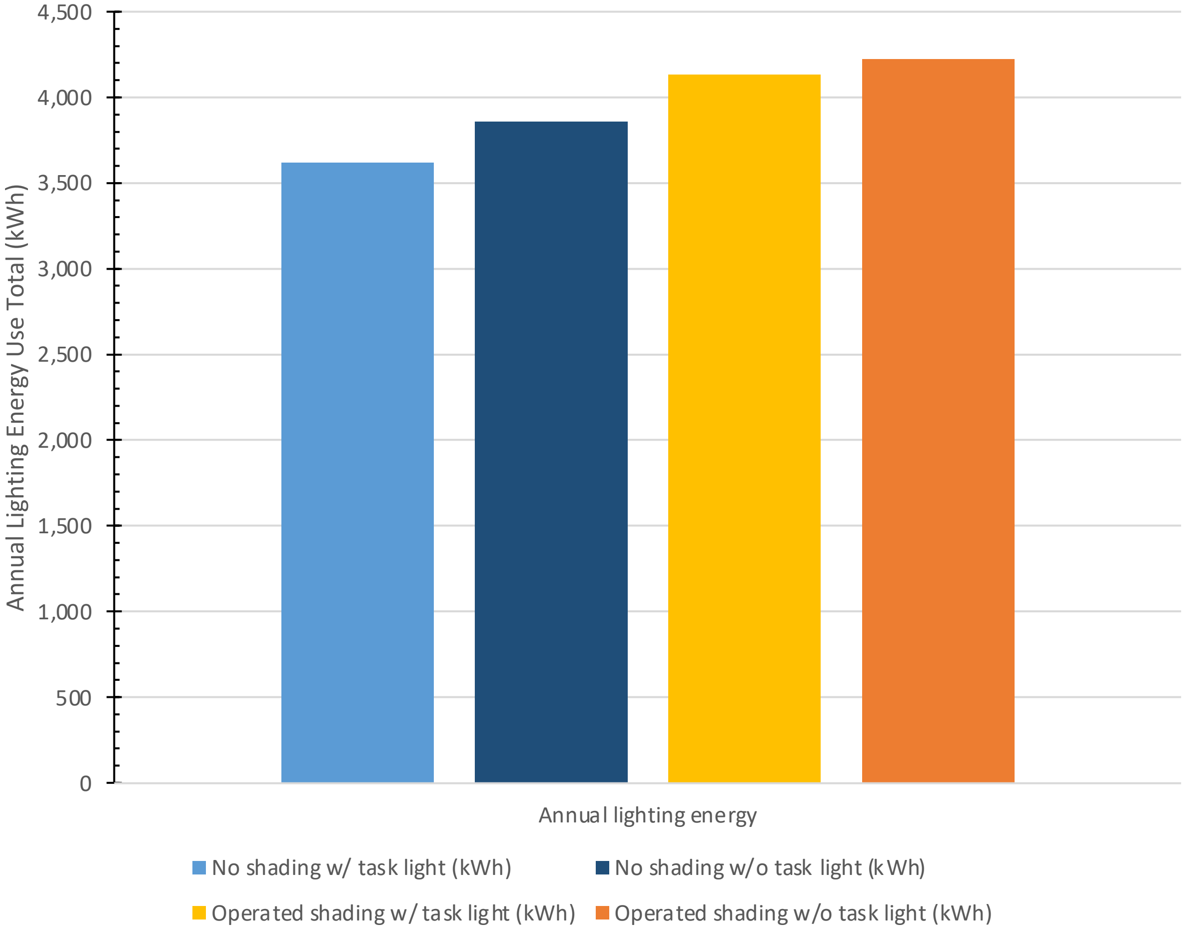


Annual Energy Use

LLLC to meet 150EMLux WELL Standard threshold:

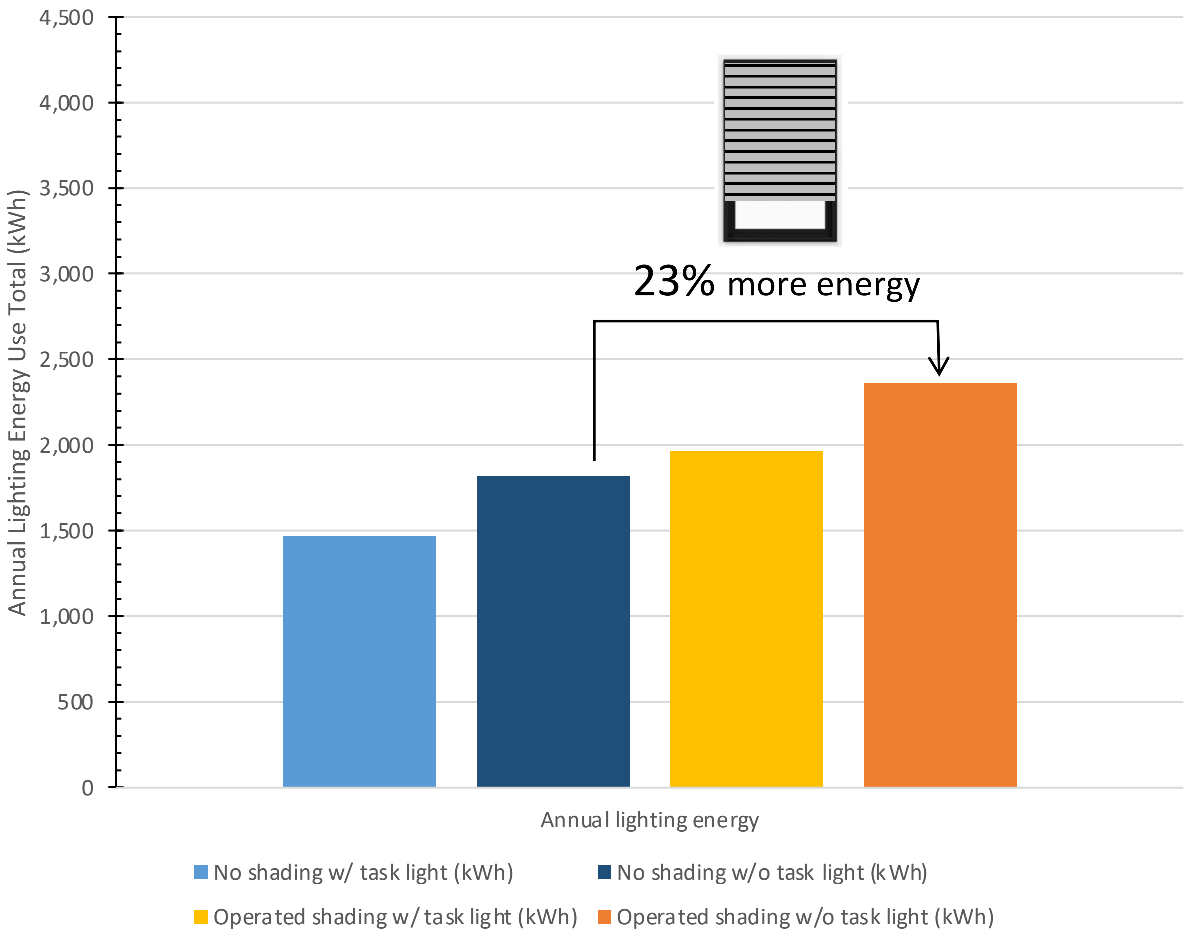


LLLC to meet 275EMLux WELL Standard threshold:

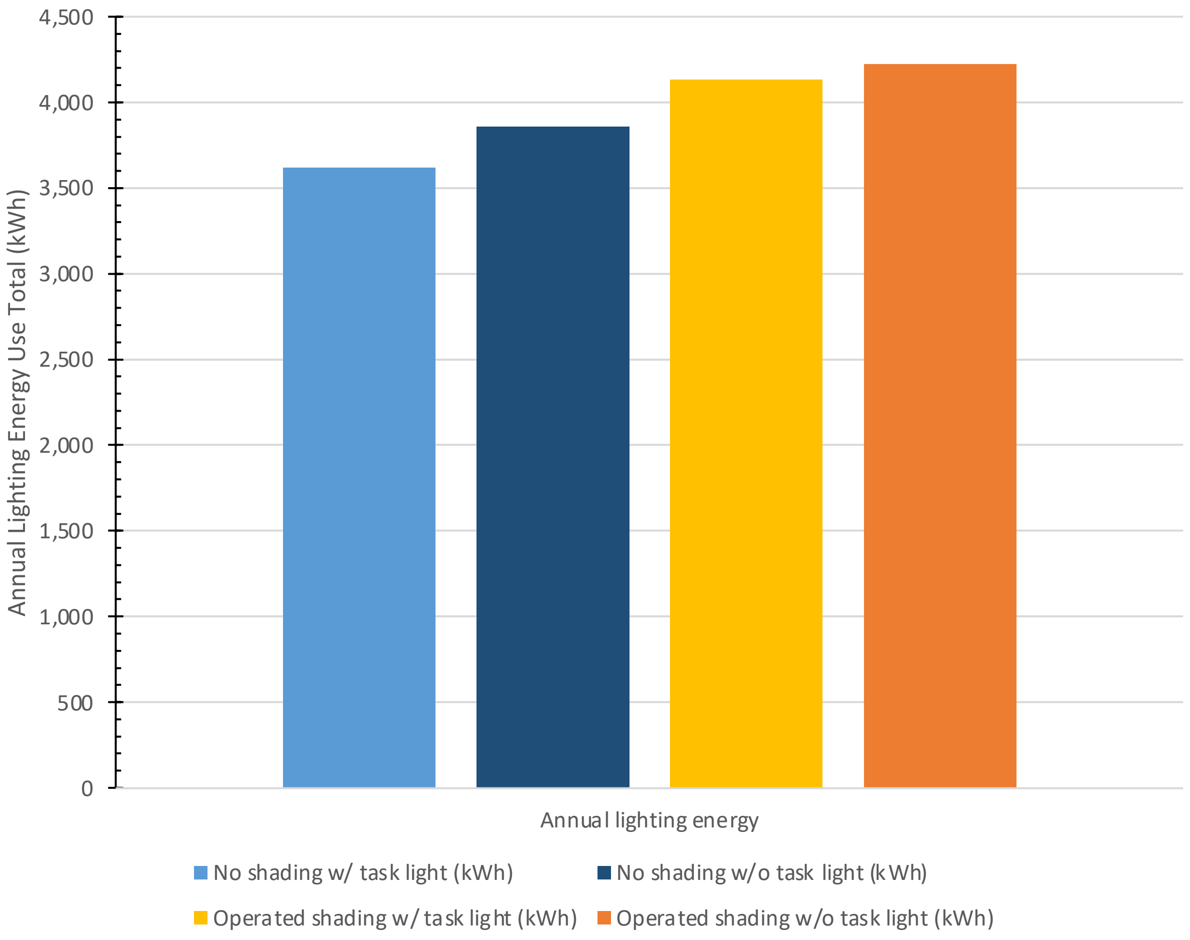


Annual Energy Use

LLLC to meet 150EMLux WELL Standard threshold:

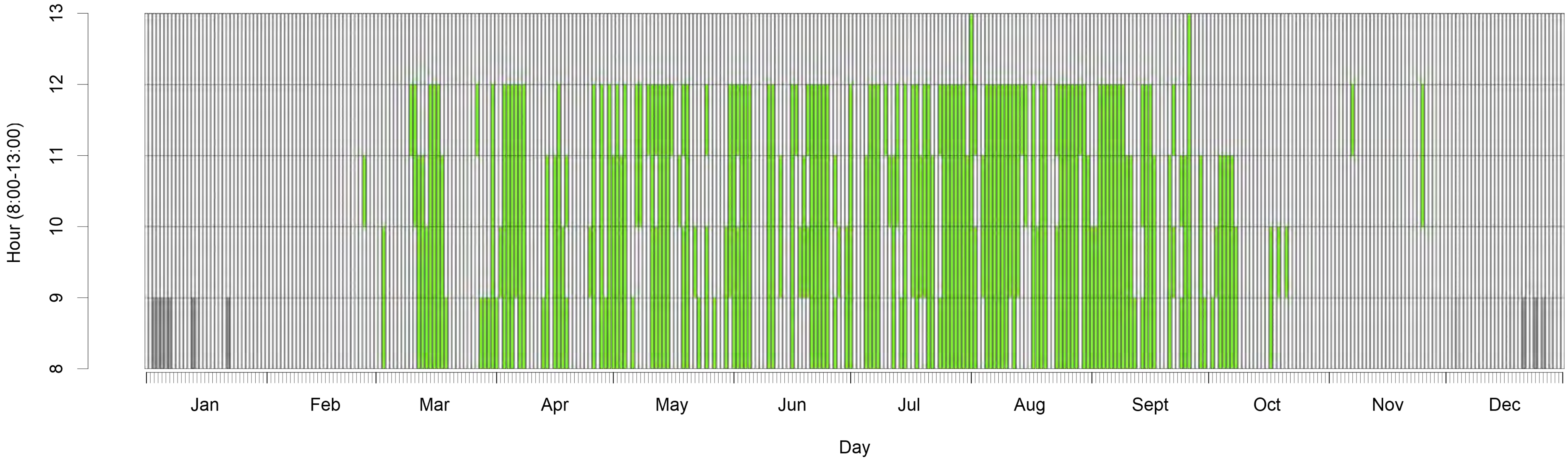


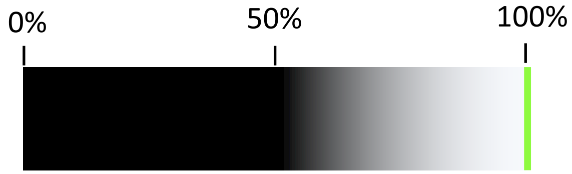
LLLC to meet 275EMLux WELL Standard threshold:



Percent of workstations that meet 150EMLux

Blinds always open without task lighting

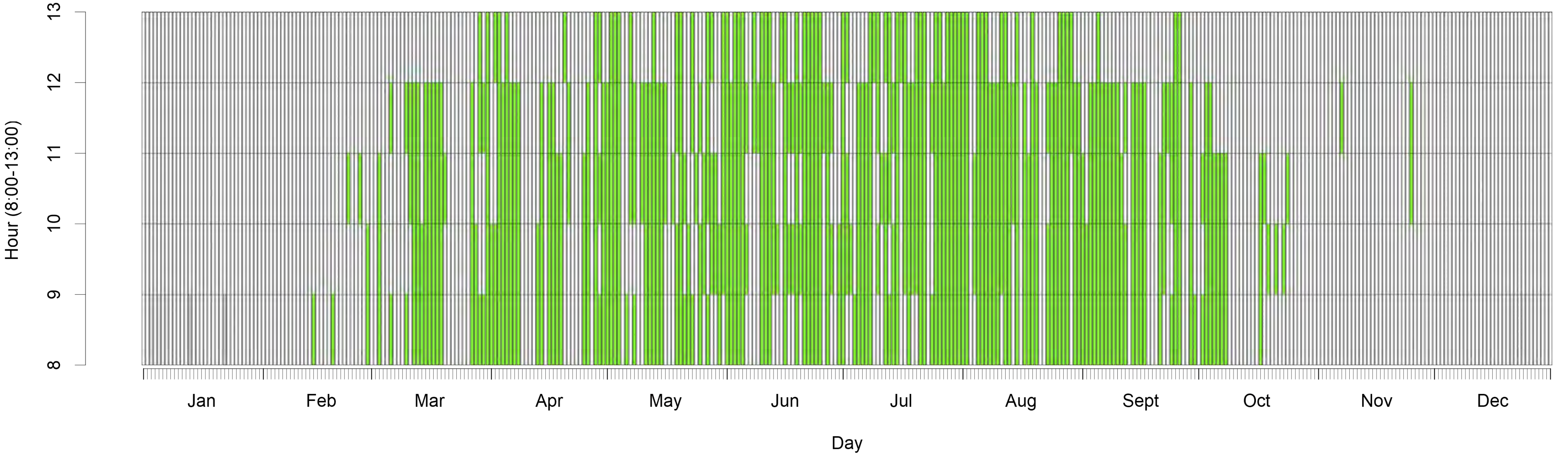


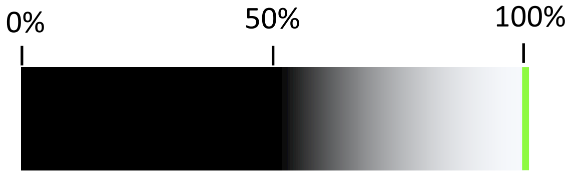


UNIVERSITY OF OREGON

Percent of workstations that meet 150EMLux

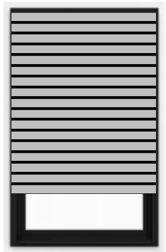
Blinds always open with task lighting



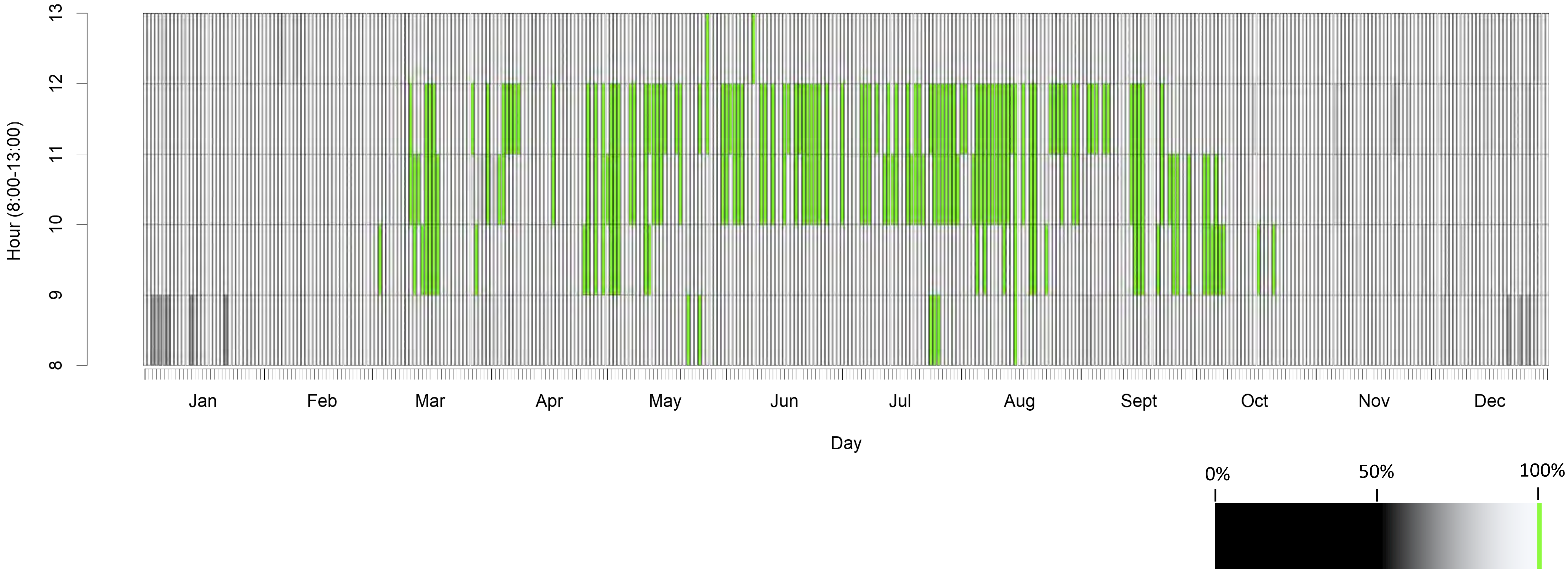


UNIVERSITY OF OREGON

Percent of workstations that meet 150EMLux

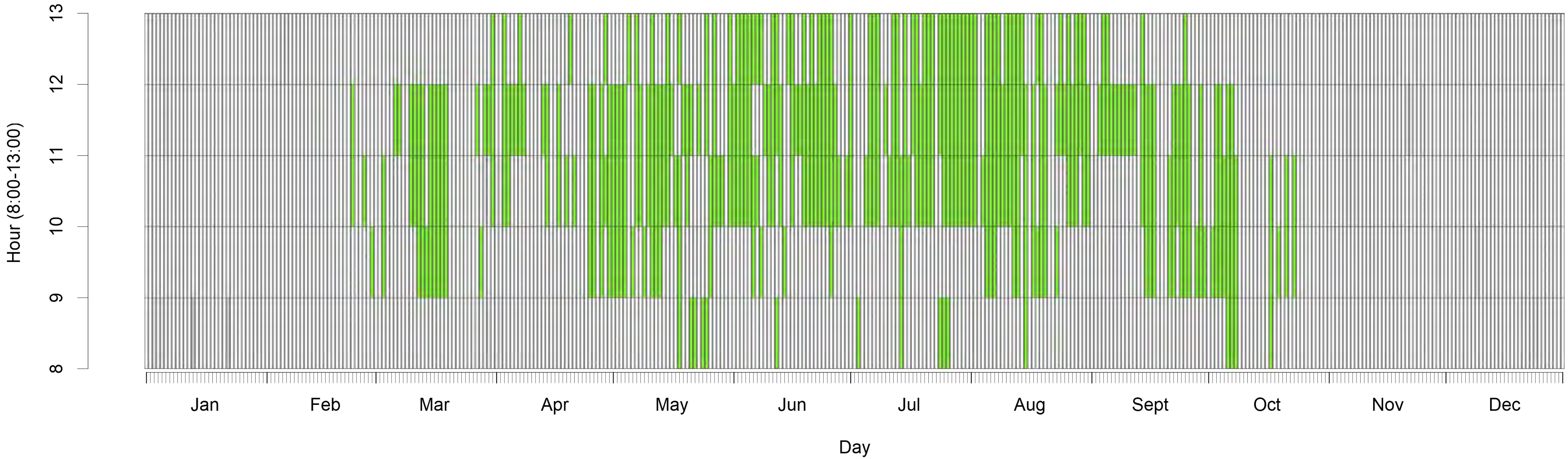


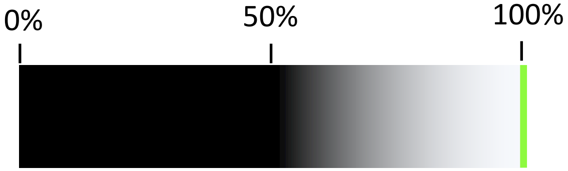
Interior window shading operated as per IES-LM-83 manual control algorithm, without task lighting



Percent of workstations that meet 150EMLux

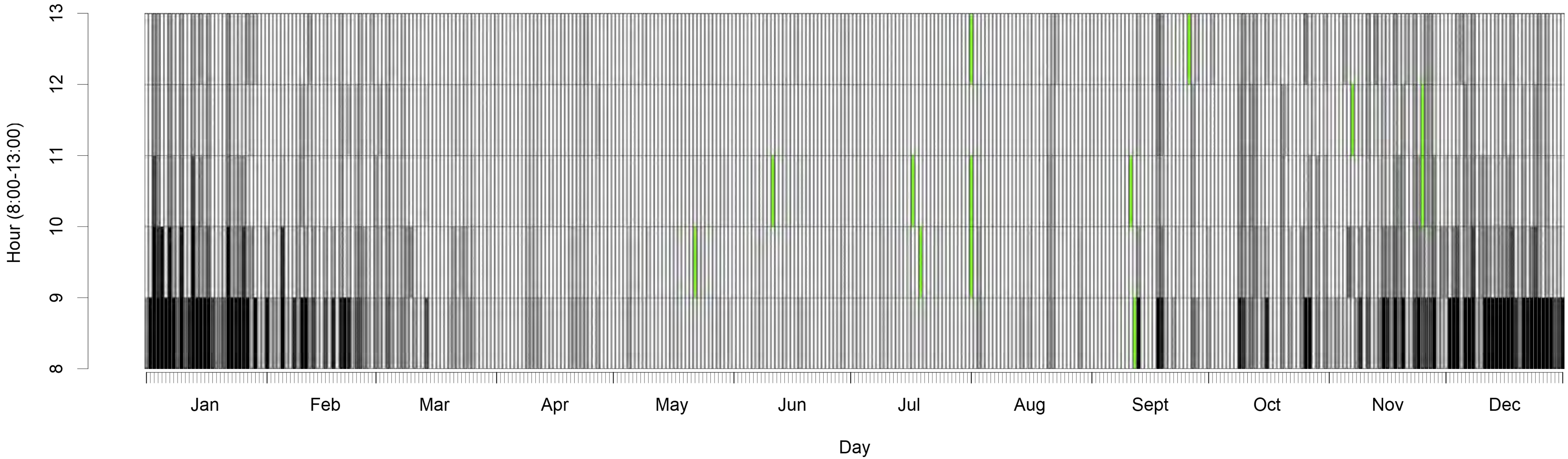
Interior window shading operated as per IES-LM-83 manual control algorithm, with task lighting

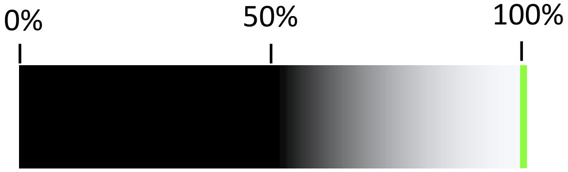




Percent of workstations that meet 275EMLux

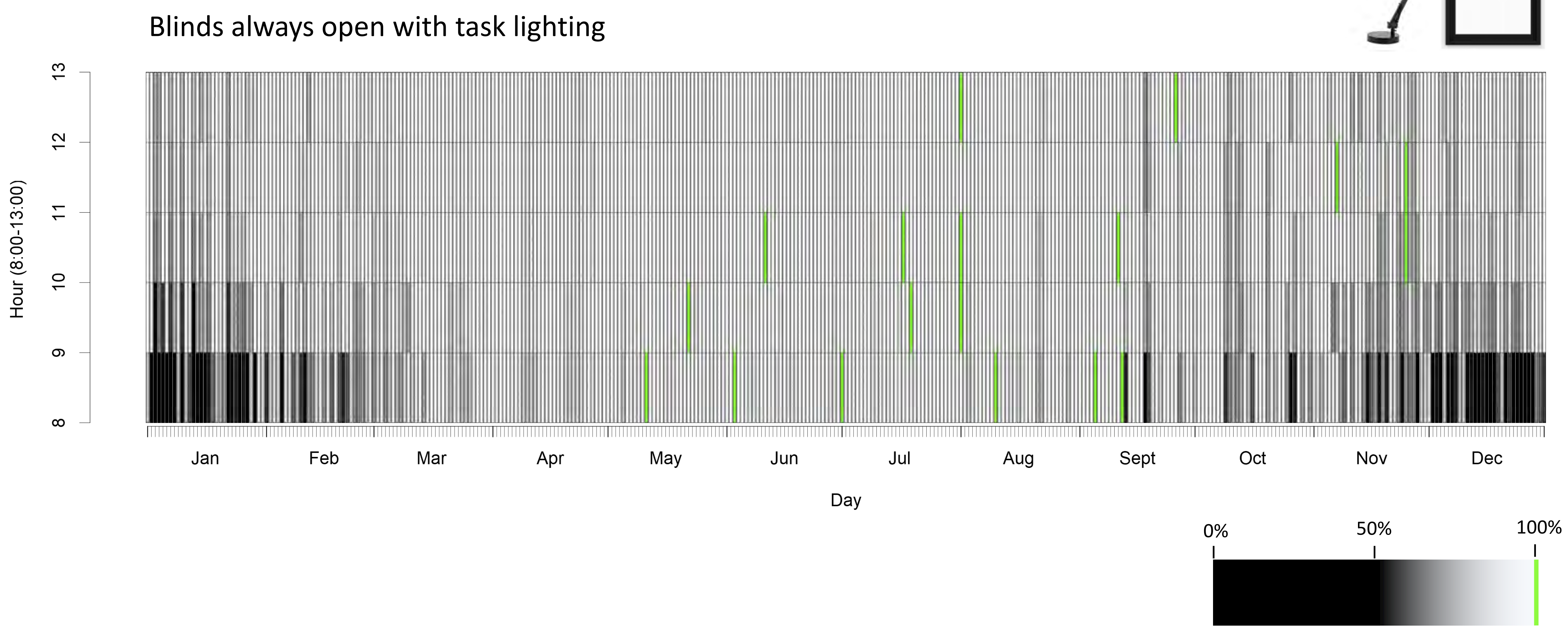
Blinds always open without task lighting



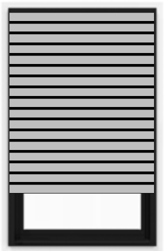


UNIVERSITY OF OREGON

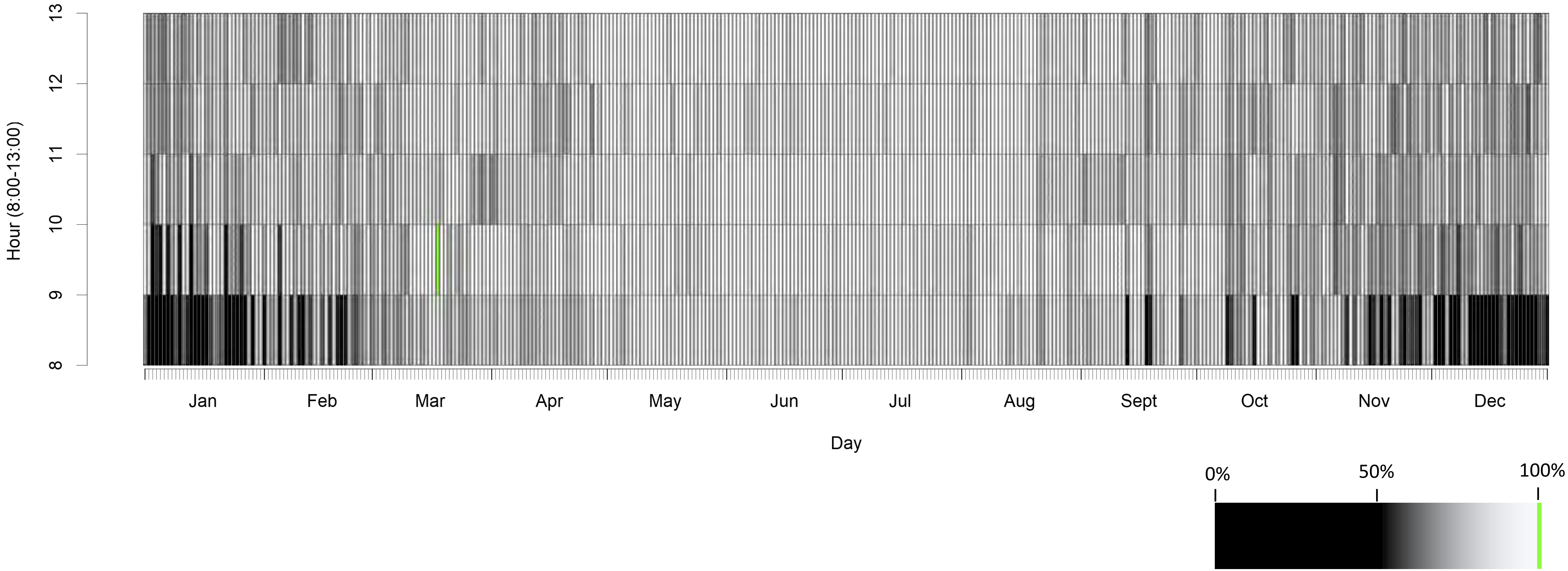
Percent of workstations that meet 275EMLux



Percent of workstations that meet 275EMLux



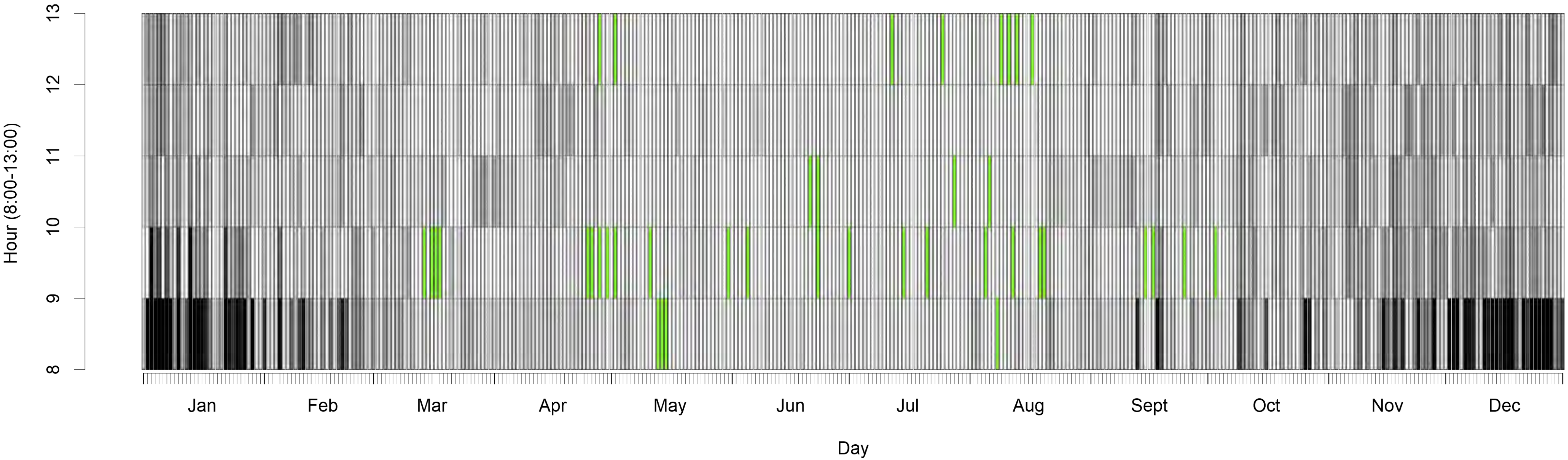
Interior window shading operated as per IES-LM-83 manual control algorithm, without task lighting

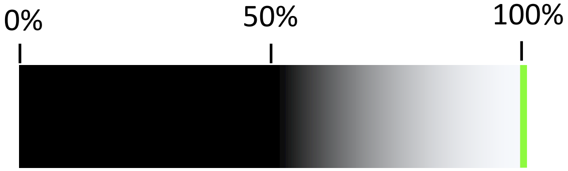


UNIVERSITY OF OREGON

Percent of workstations that meet 275EMLux

Interior window shading operated as per IES-LM-83 manual control algorithm, with task lighting

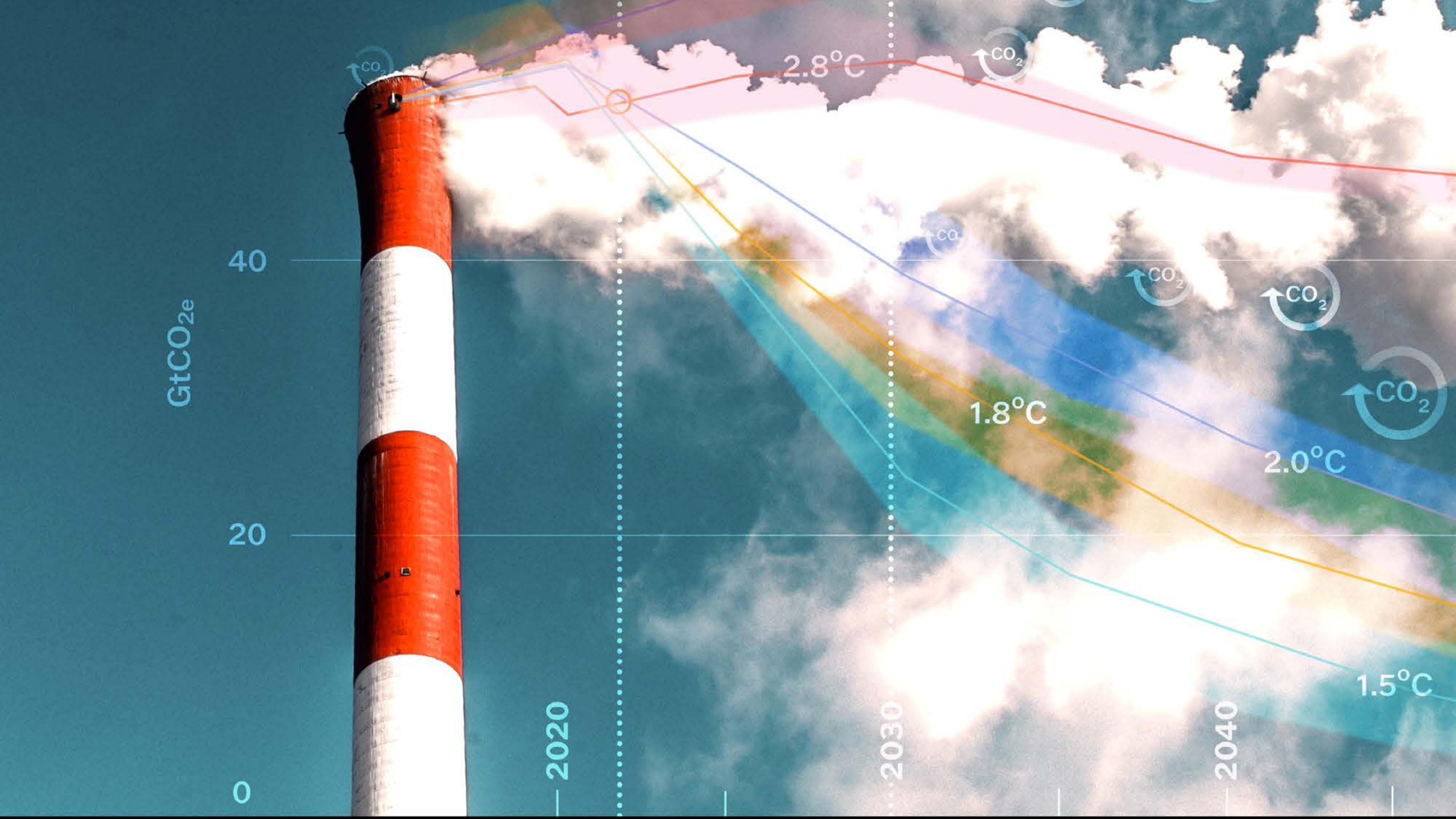




UNIVERSITY OF OREGON

Moving forward

- Based on the WELL standard recommendations, energy use is driven by an algorithm that looks to supplement EML dosing for **ALL** workstations. This means that the **worst offenders are driving up the lighting energy/dimming levels** to satisfy that minority of workstations.
  - CONTROLS MATTER – future work is needed to explore more optimal approaches
- Results are exacerbated by the fact that the lighting fixtures are operated in relatively large groups.
  - BETTER ZONAL CONTROL - Future work could optimize fixture grouping via further simulation of smaller groups (2-3 lighting fixtures/each) to capture potential energy savings
- Future work needed to challenge the implementation recommendations for WELL to balance health and energy savings more holistically
  - FIELD STUDIES NEEDED TO SHAPE STANDARDS



2.8°C
1.8°C
2.0°C
1.5°C
40
20
0
GtCO2e
2020
2030
2040

INSTITUTE FOR HEALTH
IN THE BUILT ENVIRONMENT

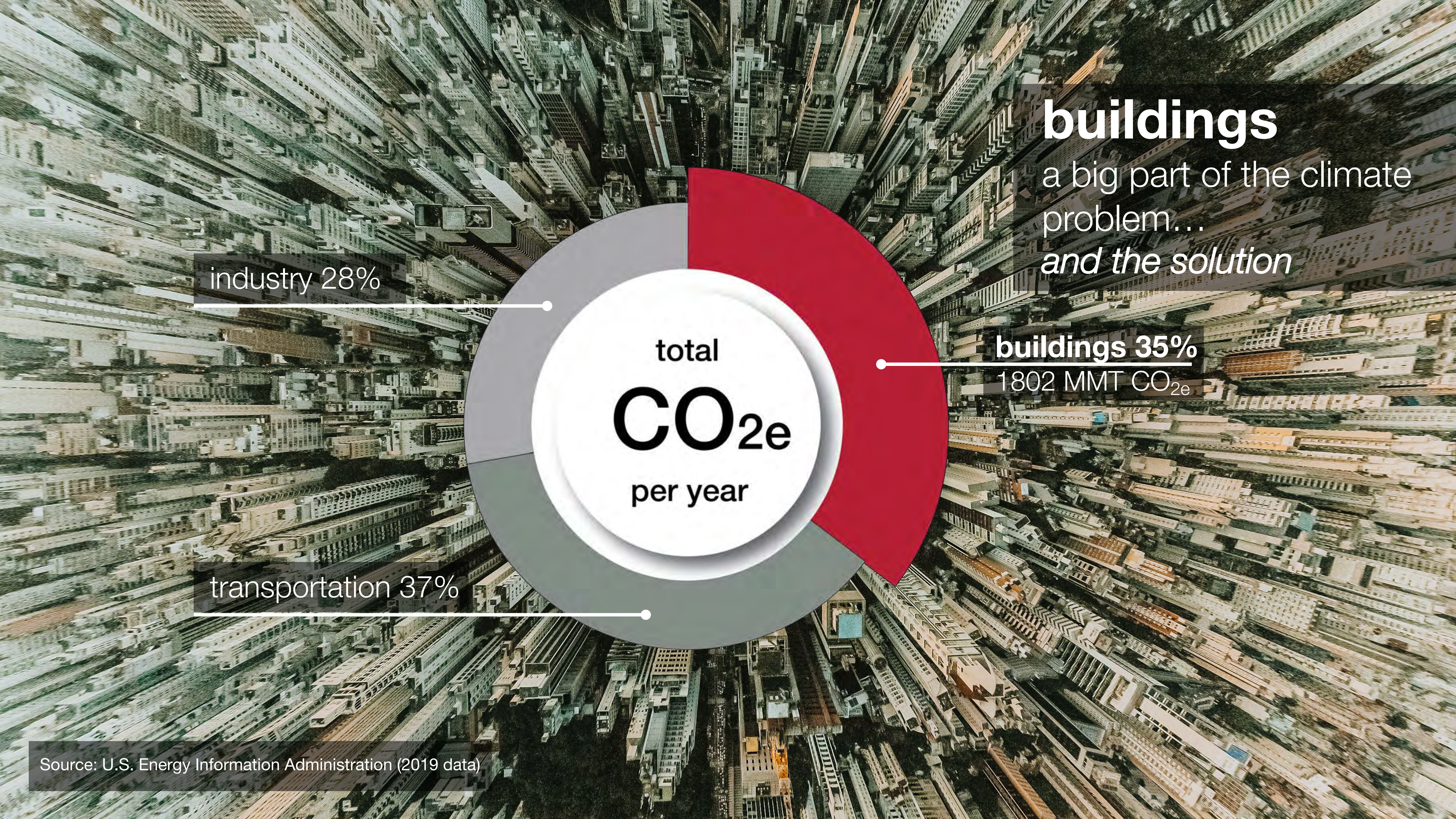
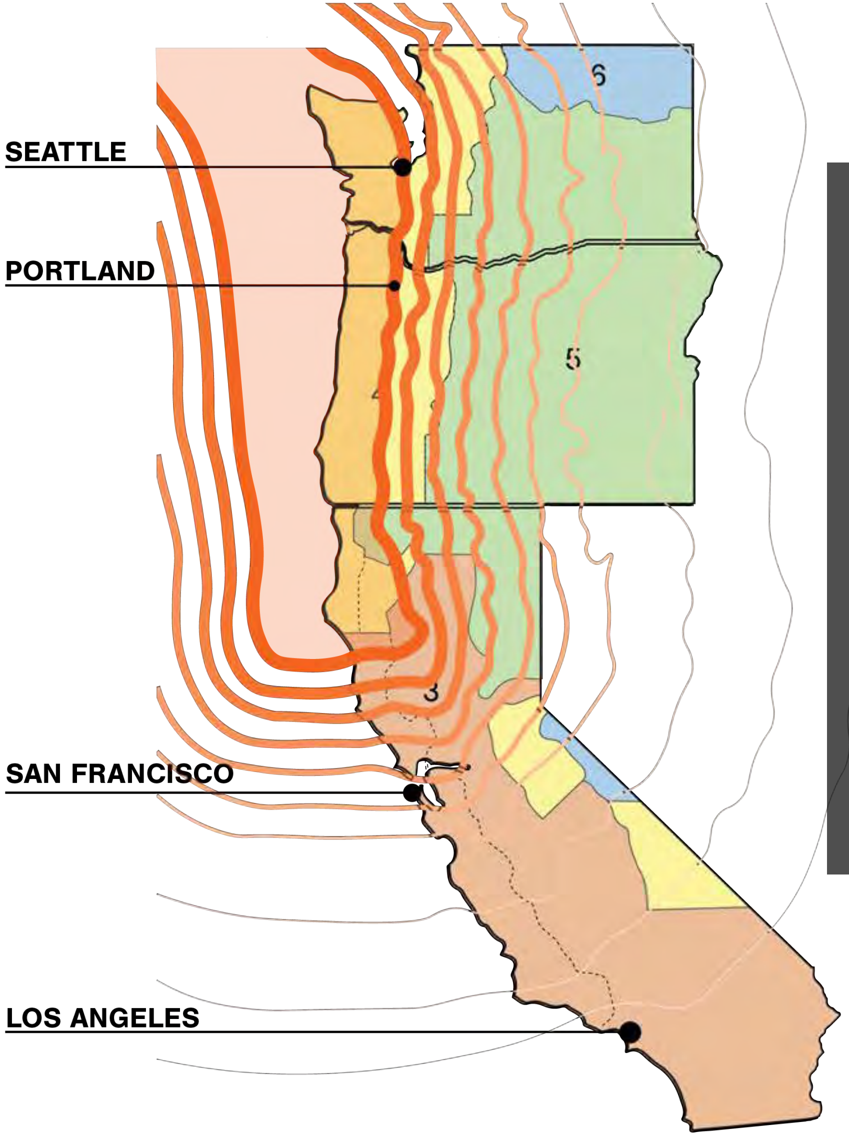

buildings
a big part of the climate problem…
and the solution
industry 28%
total
CO_{2e}
per year
buildings 35%
1802 MMT CO_{2e}
transportation 37%
Source: U.S. Energy Information Administration (2019 data)

IMAGE CREDIT: ENERGIESPRONG.ORG



WARM HUMID, DRY TO WARM MARINE

MIXED HUMID, DRY TO MIXED MARINE

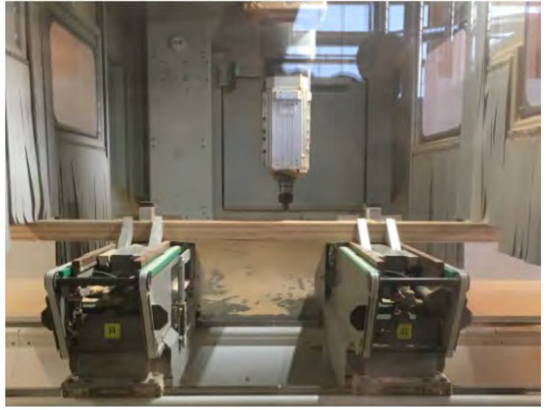
COOL HUMID, DRY, MARINE

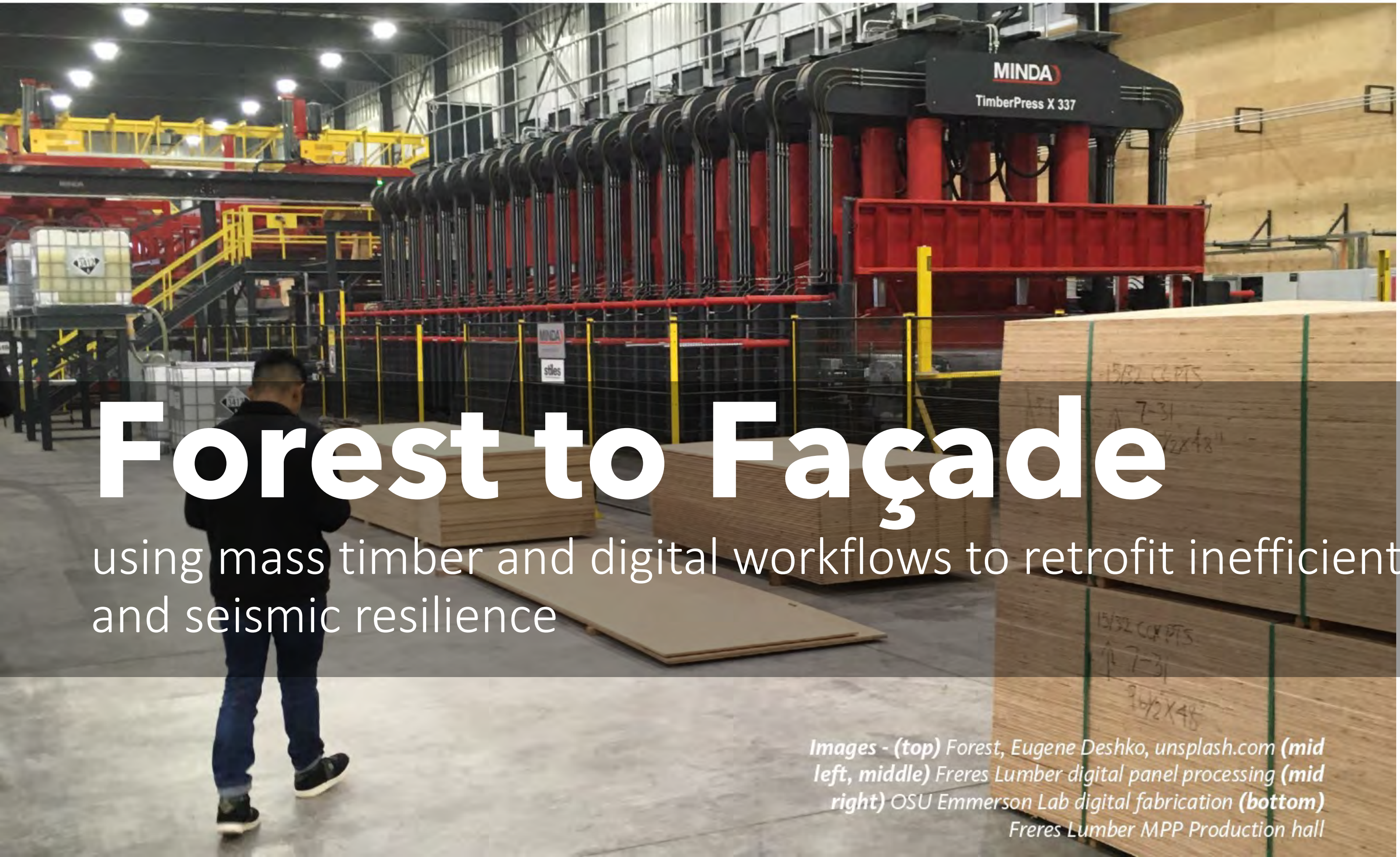
VERY COLD

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 timber and digital workflows to retrofit inefficient 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*

Multifamily Façade Retrofit Project Team

UNIVERSITY OF OREGON

Mark Fretz (PI)
Research Assistant Professor
Institute for Health in the Built Environment
Department of Architecture

Kevin Van Den Wymelenberg (Co-PI)
Professor of Architecture
Director, ESBL
Department of Architecture

Judith Sheine (Co-PI)
Professor of Architecture
Director of Design, TallWood
Department of Architecture

Jason Stenson (Co-PI)
Senior Research Assistant I
ESBL
Department of Architecture

Dale Northcutt
Senior Research Assistant II
ESBL
Department of Architecture

Payton Narancic
Graduate Student Researcher
Department of Architecture

Flynn Casey
Graduate Student Researcher
Department of Architecture

Oregon State University

Andre Barbosa (Co-PI)
Associate Professor
Civil and Construction Engineering

Gustavo Fernando Orozco Orozco
Graduate Student Researcher
Civil and Construction Engineering

TALLWOOD DESIGN INSTITUTE

Phil Mann
Emmerson Lab Technical Manager
TallWood

Mark Gerig
Emmerson Lab Technician
TallWood

Project Support

USDA · FRERES ENGINEERED WOOD · SOPREMA The Building Envelope Company · HAWK RIDGE SYSTEMS · BENSONWOOD · FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE · SIMPSON Strong-Tie · NEW ENERGY WORKS design • build • timberframing • woodworks

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

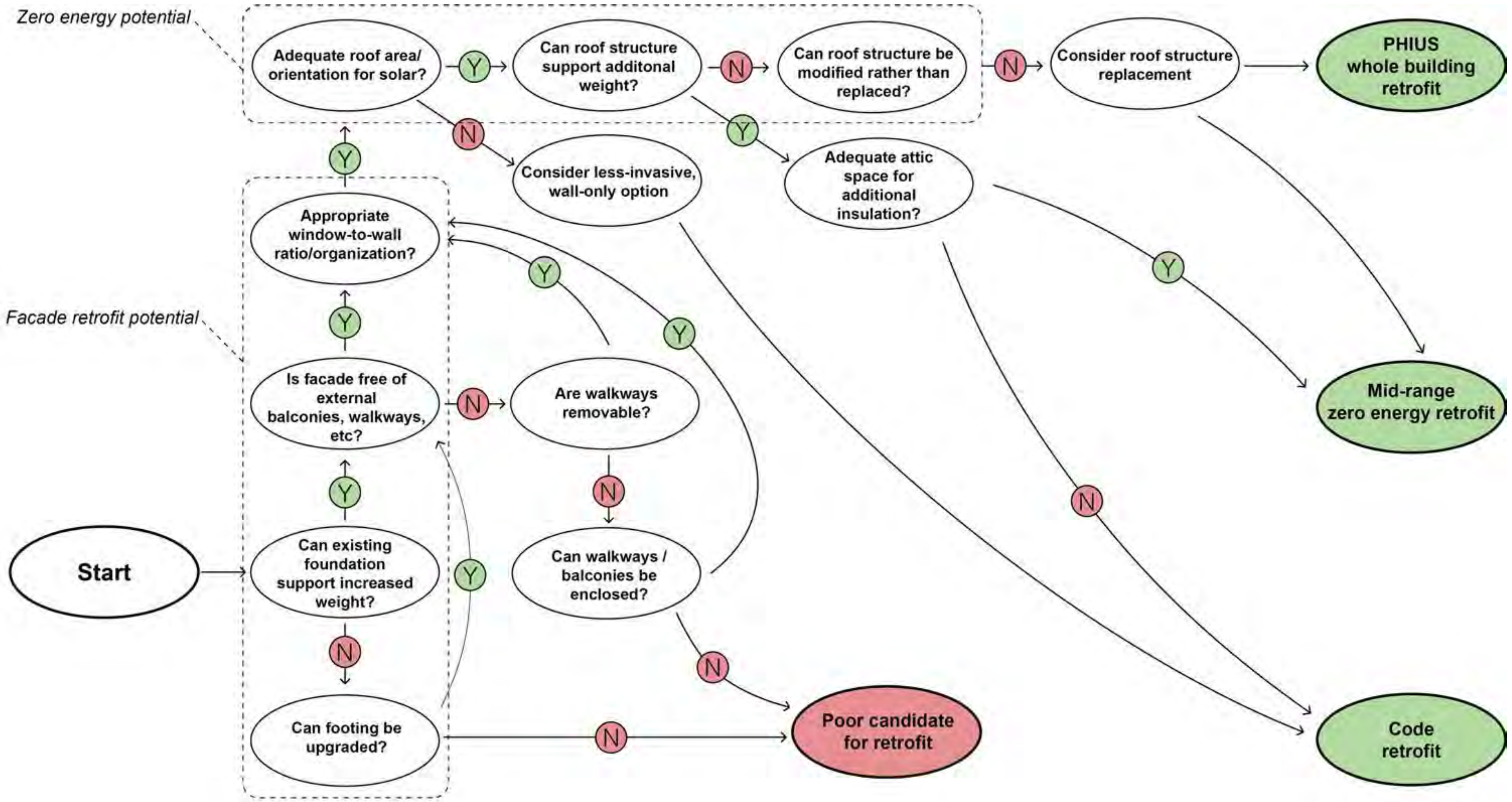
Low-rise multifamily

- 88% of multifamily is 1-3 stories in the PNW
- 1960-1994 before current seismic/energy code
- 64.7% 2x4 construction
- 64% R8-R12 wall Insulation

(Source: NEEA Residential Building Stock Assessment)

How to Retrofit

Is the building a candidate?



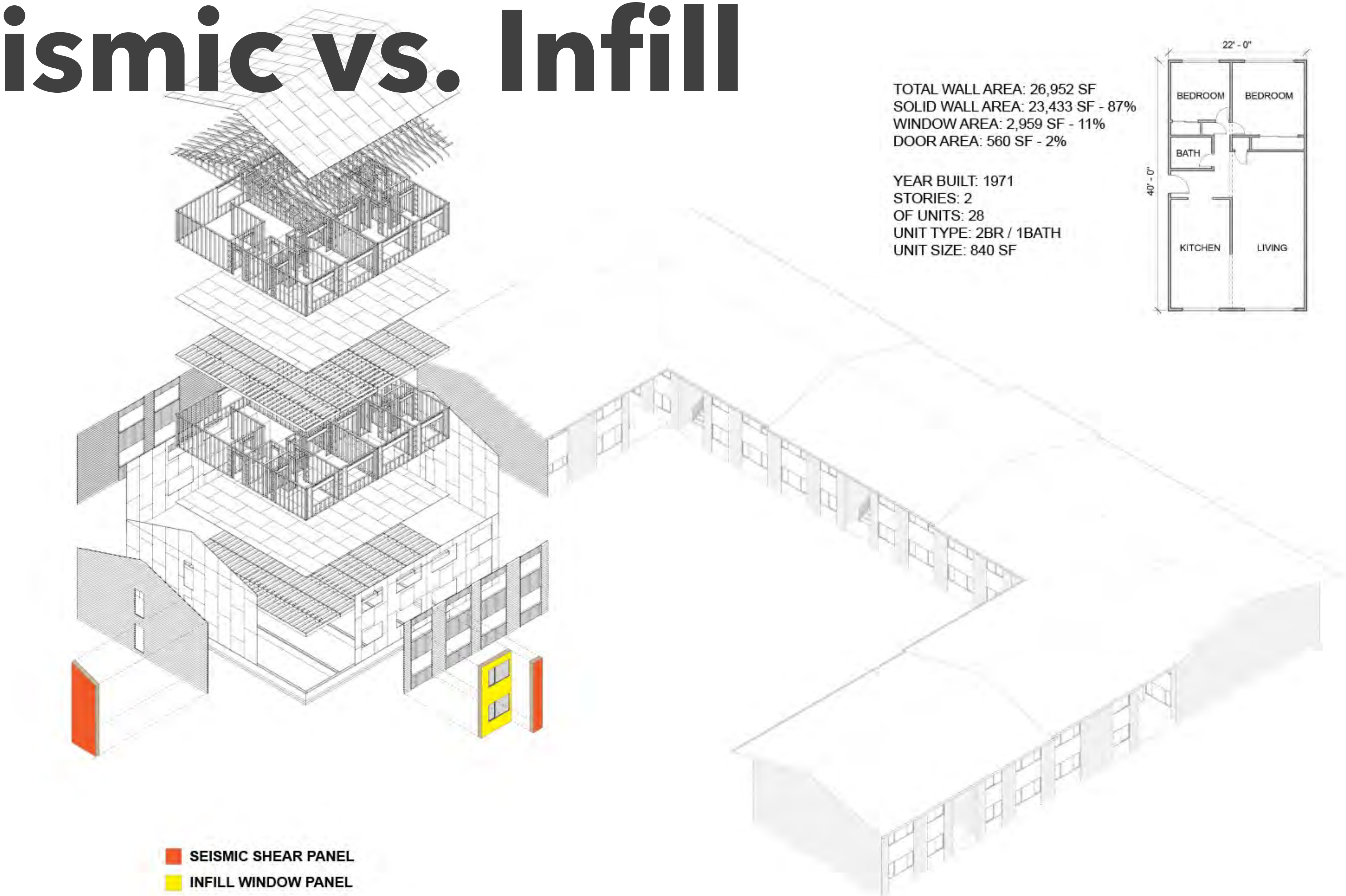
Level of performance?

RETROFIT LEVEL	STANDARD	WALLS	CEILING	FLOOR	WINDOWS	DOORS	AIR INFILTRATION
1 (COMPREHENSIVE)	PHIUS	R-47	R-89	R-51	U-0.16 OR LESS	R-10	0.06 CFM50/FT2 ENVELOPE AREA
2 (MODERATE)	DOE - ZERO ENERGY READY HOME (ZERH)	CZ 4-5: R-20 OR R-13+R-5 CZ 6 R20 +5 or R13+10	CZ 4-6: R-49	CZ 4-6: R-30 SLAB: CZ 4,5 R-10, 2 FT CZ 6 R-10, 4 FT	CZ 4-6: U-0.27 CZ 4C & 5: U-0.30	NR	LESS THAN 3 ACH 50
	ASHRAE 90.2-2018	CZ 4-5: U-0.060 CZ 6: U-0.045	CZ 4-6: U-0.026	(FLOOR) CZ 4-6: U-0.033 (SLAB) CZ 4-5: R-10, 2FT CZ 6: R-10, 4 FT	CZ 4-6: U-0.32	CZ 4-6: U-0.32	CZ 4-6: LESS THAN 3 ACH 50
	NORTHWEST ENERGY EFFICIENCY ALLIANCE (NEEA) ORSC RECOMMENDATIONS	R-21+R-5	R-60	R-38 (FLOOR) R-10 (SLAB)	U-0.24 OR LESS SHGC 0.27	NR	LESS THAN 2 ACH 50
3 (LOW-COST)	OR CODE (2021 ORSC)	R-15 (EXISTING) R-21 (NEW)	(EXISTING) R-21 - R-49 (NEW) R-30 - R-49	(EXISTING) R-25 - R-30 (NEW) R-30 (SLAB EDGE) R-15	U-0.26 OR LESS	U-0.2 WITH <= 2.5 SF GLAZING, U-0.4 WITH >= 2.5 SF GLAZING	LESS THAN 3 ACH 50
	CA CODE (2019) TABLE 150.1-B CAL CZ 1,2,14-16	U-0.051	R-38	(FLOOR) R-19 (SLAB) CAL CZ 1,2,14 - NR; CZ 16 R-7	U-0.30 OR LESS SHGC 0.23 MAX MAX AREA 20% MAX WEST 5%	U-0.20	NR
(NO RETROFIT)	TYPICAL EXISTING CONDITIONS	R-8 - R-12	R-30+	UNINSULATED SLAB	SINGLE PANE ALUMINUM TYPICAL	NR	NR

Seismic vs. Infill

TOTAL WALL AREA: 26,952 SF
SOLID WALL AREA: 23,433 SF - 87%
WINDOW AREA: 2,959 SF - 11%
DOOR AREA: 560 SF - 2%

YEAR BUILT: 1971
STORIES: 2
OF UNITS: 28
UNIT TYPE: 2BR / 1BATH
UNIT SIZE: 840 SF

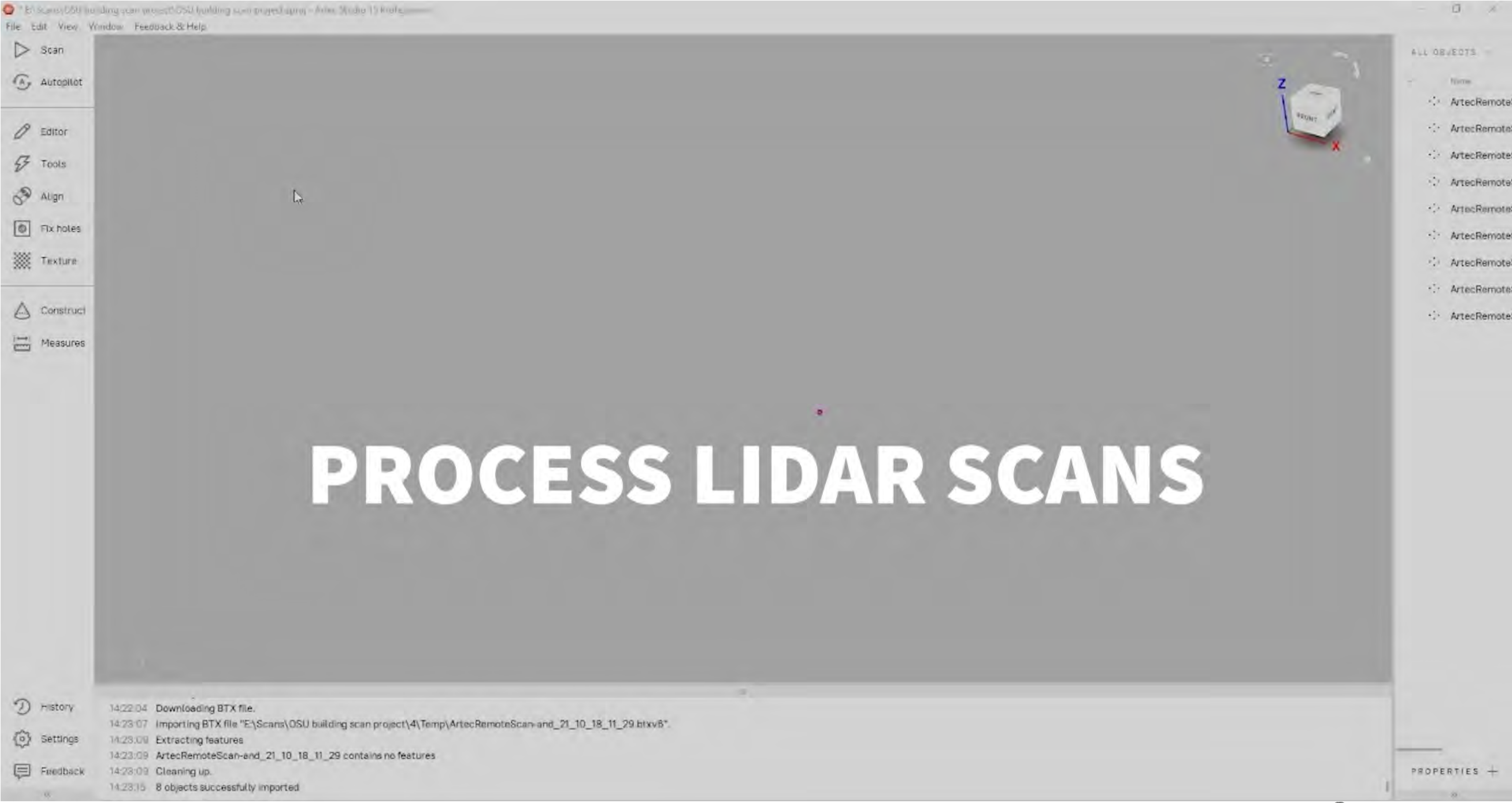


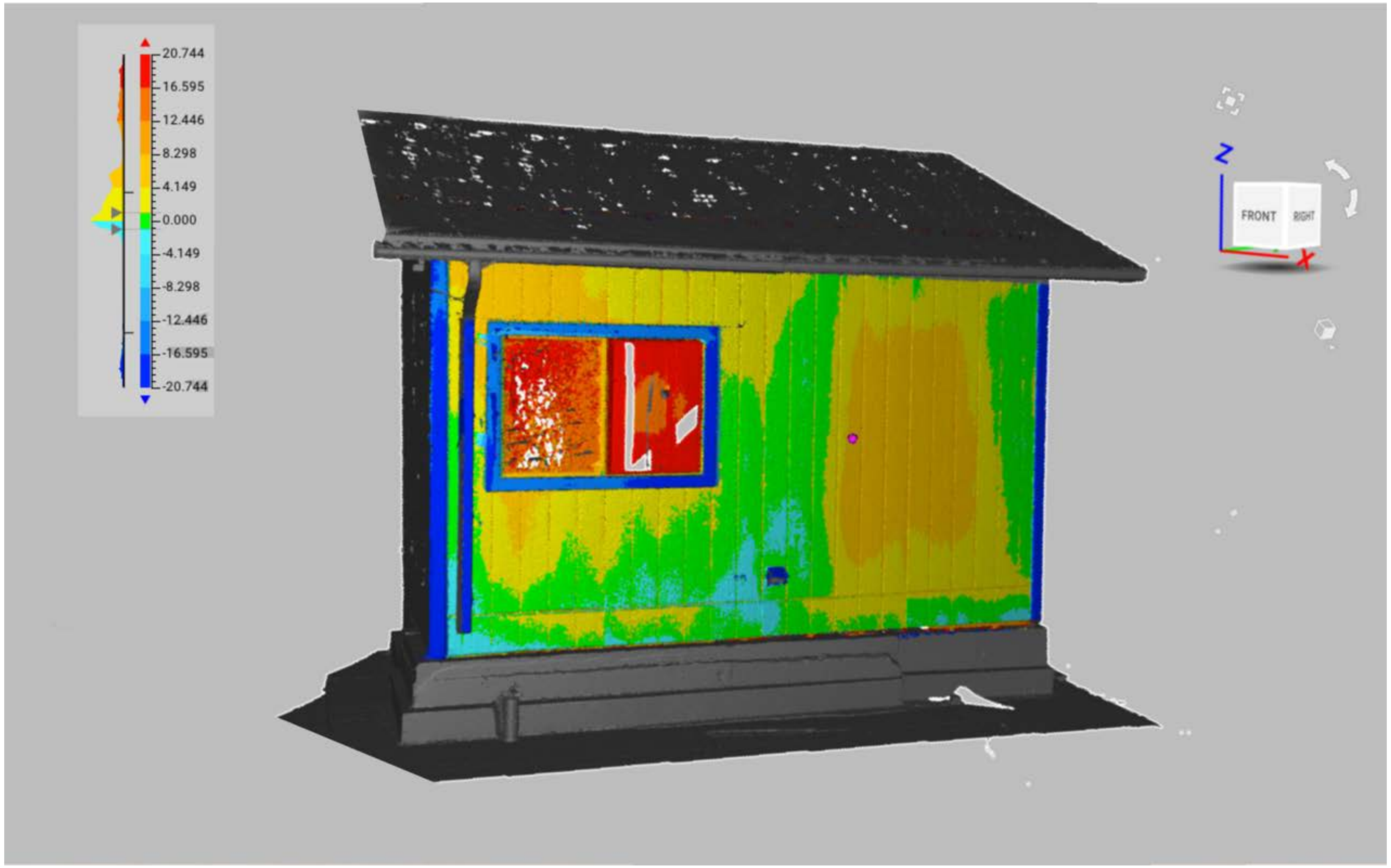
SEISMIC SHEAR PANEL
INFILL WINDOW PANEL

Digital Workflow

SCAN EXISTING BUILDING

PROCESS LIDAR SCANS




20.744
16.595
12.446
8.298
4.149
0.000
-4.149
-8.298
-12.446
-16.595
-20.744
Z
FRONT
RIGHT
X

Fabricate Panels Offsite


STEICO un
rsal dr


SOPREMA


REMOVE EXISTING EAVE

INSTALL 2” MPP TRANSFER JOIST / SPACER

Rig and Fly Panels

MOUNT PREASSEMBLED PANELS

CLOSE PANEL JOINTS

UNIVERSITY OF OREGON

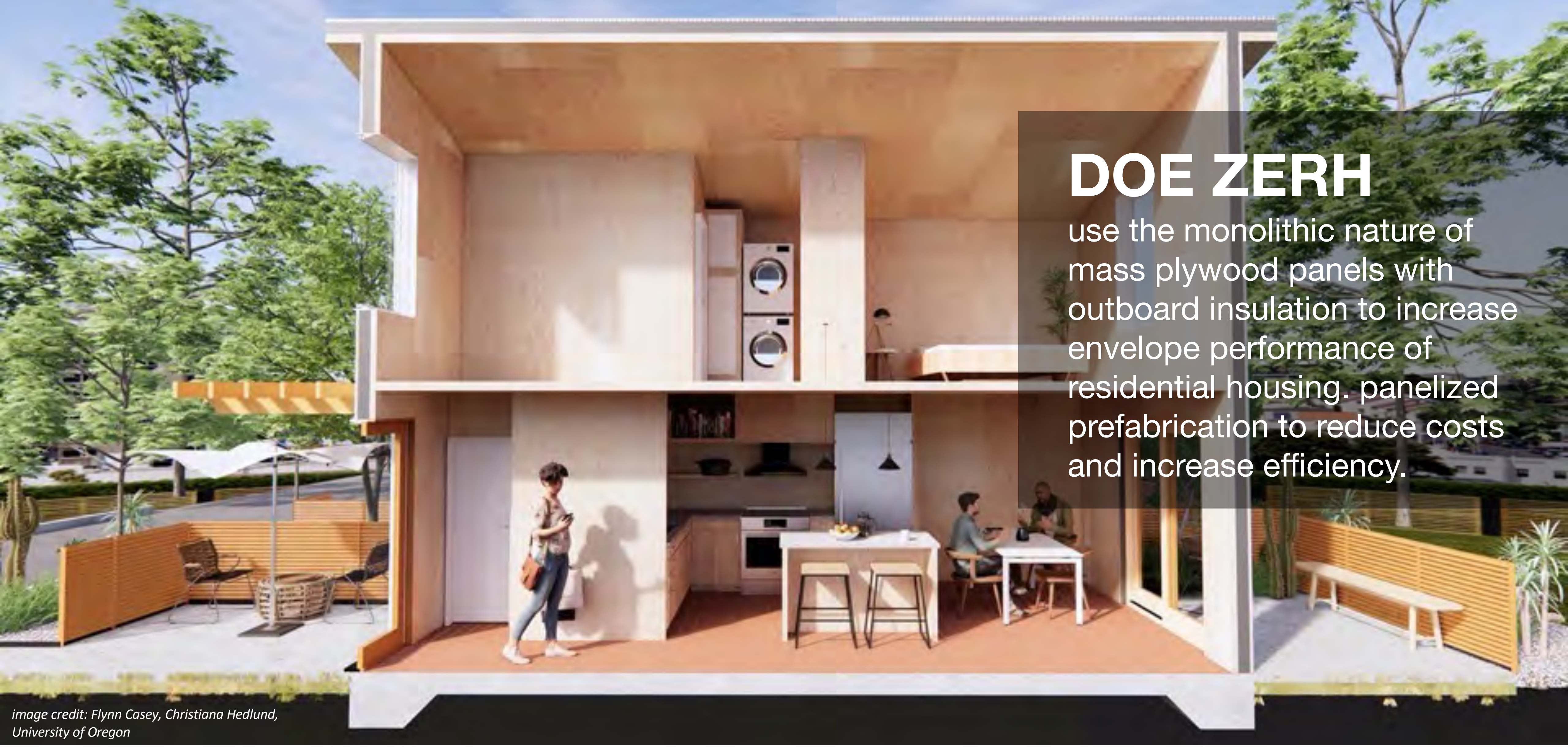
TALLWOOD DESIGN INSTITUTE

Oregon State University

COMPLETE ROOFING

Our case study building...


...revitalized

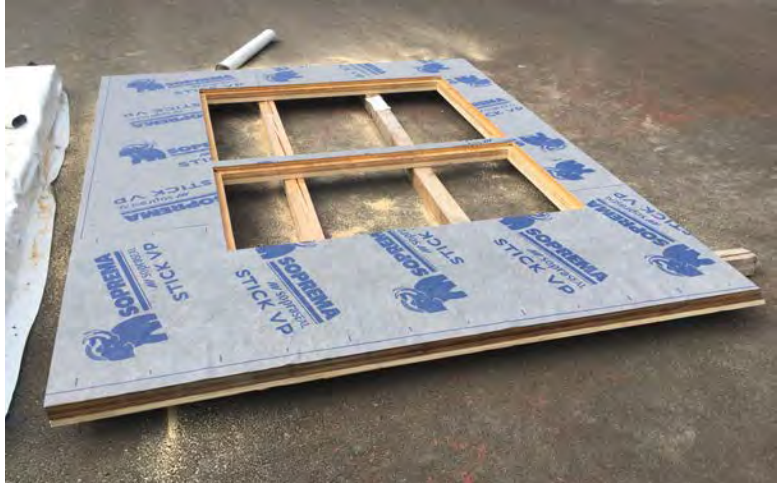


DOE ZERH

use the monolithic nature of mass plywood panels with outboard insulation to increase envelope performance of residential housing. panelized prefabrication to reduce costs and increase efficiency.

image credit: Flynn Casey, Christiana Hedlund, University of Oregon

TALLWOOD DESIGN INSTITUTE
UNIVERSITY OF OREGON
Oregon State University
Home Work
SWINERTON
TIMBERLAB
Freres LUMBER CO., INC.
EnergyTrust of Oregon
PROUD GROUND


SOPREMA
STICK VP


SOPREMA
STICK VP



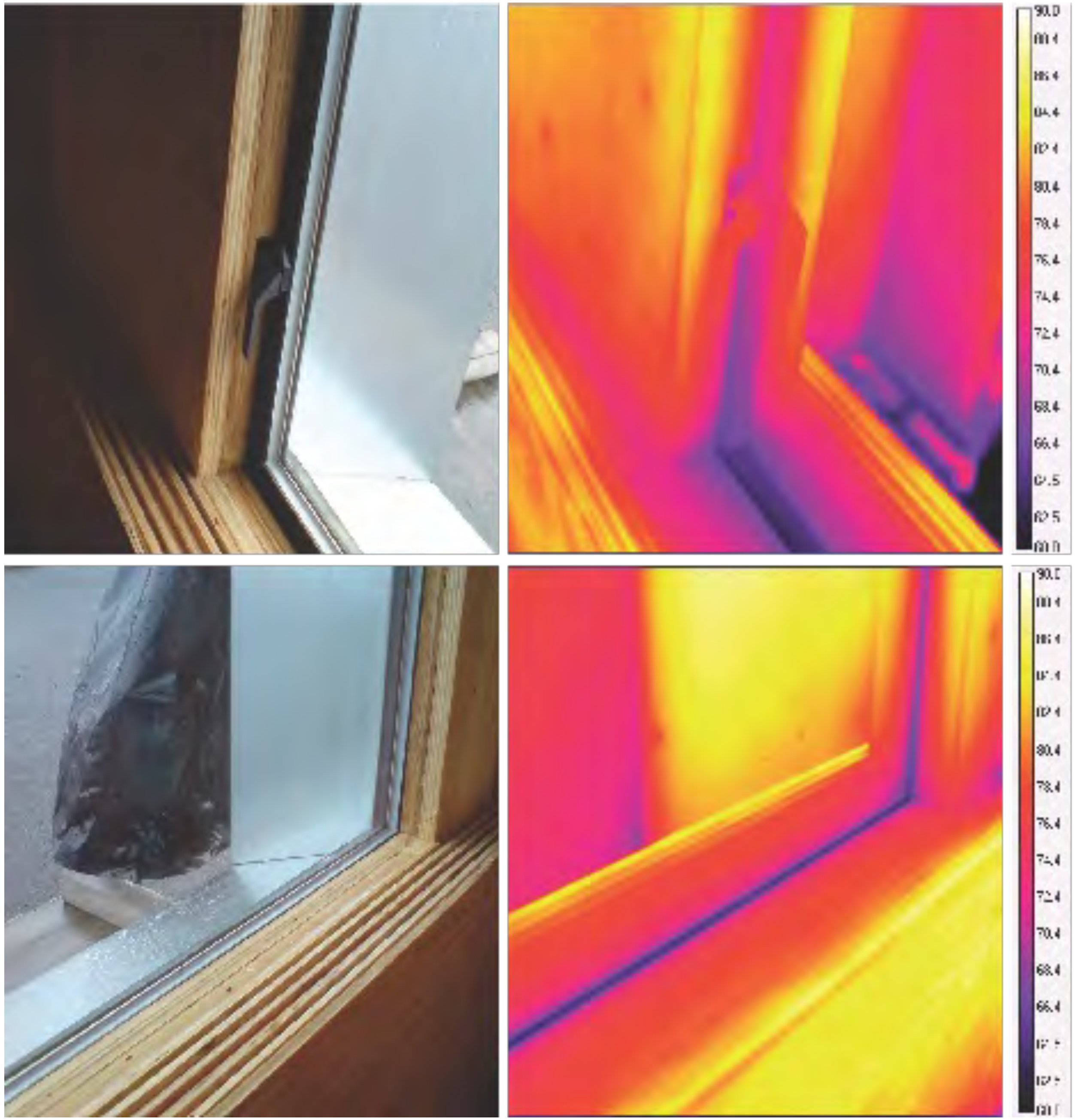



image credit: Flynn Casey, University of Oregon

Questions?

(mfretz@uoregon.edu)