BUILDINGENERGY BOSTON

Daylight Quality in Net Zero Buildings: A Pathway to High Performance Learning Environments

Juan Guarin (Perkins Eastman Architects)
Dan Arons (Perkins Eastman Architects)
Christine Vöhringer (Perkins Eastman Architects)
Christoph Reinhart (Massachusetts Institute of Technology)

Curated by Richard Lo (Kaplan Thompson Architects)

Northeast Sustainable Energy Association (NESEA)
February 28, 2022

PERKINS EASTMAN

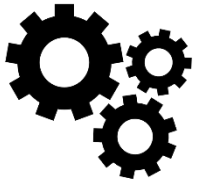
High Quality Daylight in Net Zero Buildings: A Pathway to High Performance Learning Environments

POLL SETUP

POLL: WHAT IS YOUR BACKGROUND?


ARCHITECT?


BUILDING OWNER?


ENGINEER?


BUILDING OPERATOR?


CONTRACTOR?


PUBLIC SECTOR?


OTHER?


PRODUCT REP?

POLL RESULTS: WHAT IS YOUR BACKGROUND?

THE VALUE OF DAYLIGHT

WHY IS IT SO IMPORTANT TO INCORPORATE DAYLIGHT IN OUR DESIGNS?

THE HEALTH AND WELLNESS VALUE OF DAYLIGHT

Source: Health Benefits of Sunlight, Select Health

BOOSTS VITAMIN D

HEIGHTENS PRODUCTIVITY

BENEFITS MENTAL HEALTH

REDUCES VISUAL STRESS

SUPPORTS SLEEP

INCREASES IMMUNE SYSTEM

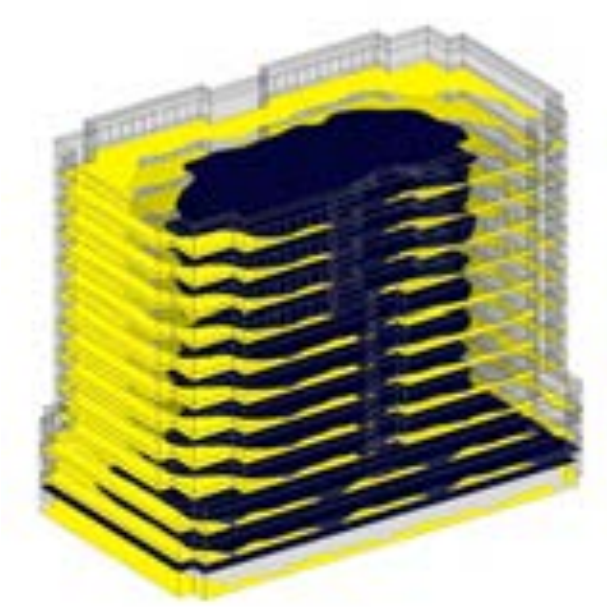
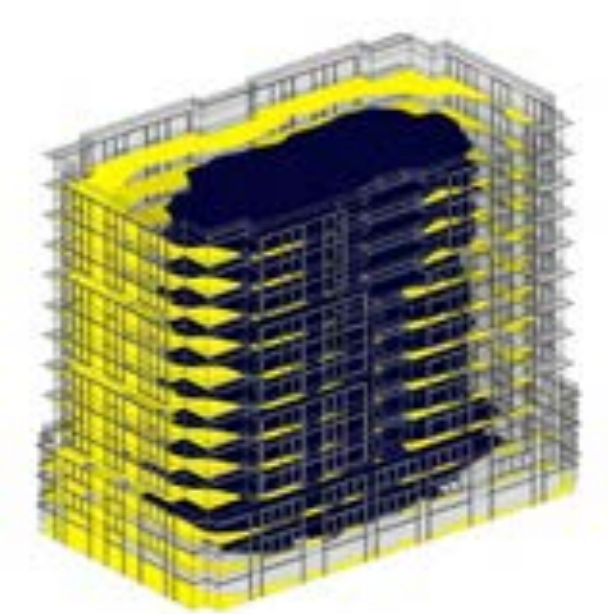
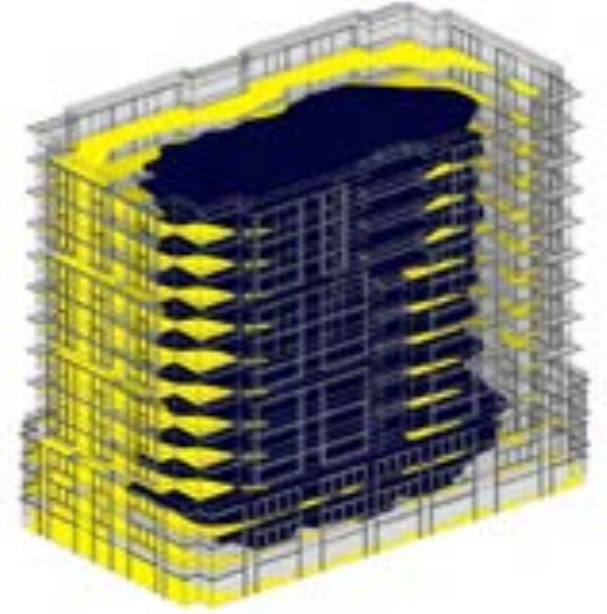
THE VALUE OF DAYLIGHT IN EDUCATIONAL SPACES

SCHOOLS WITH ACCESS TO DAYLIGHT IMPROVED:

- Test performance by **26%**[*1]
- Reading Speed by **23%**[*2]
- Student learning by **21%**[*3]
- Absenteeism by **70%**[*4]
- **46** more minutes of sleep per night[*5]

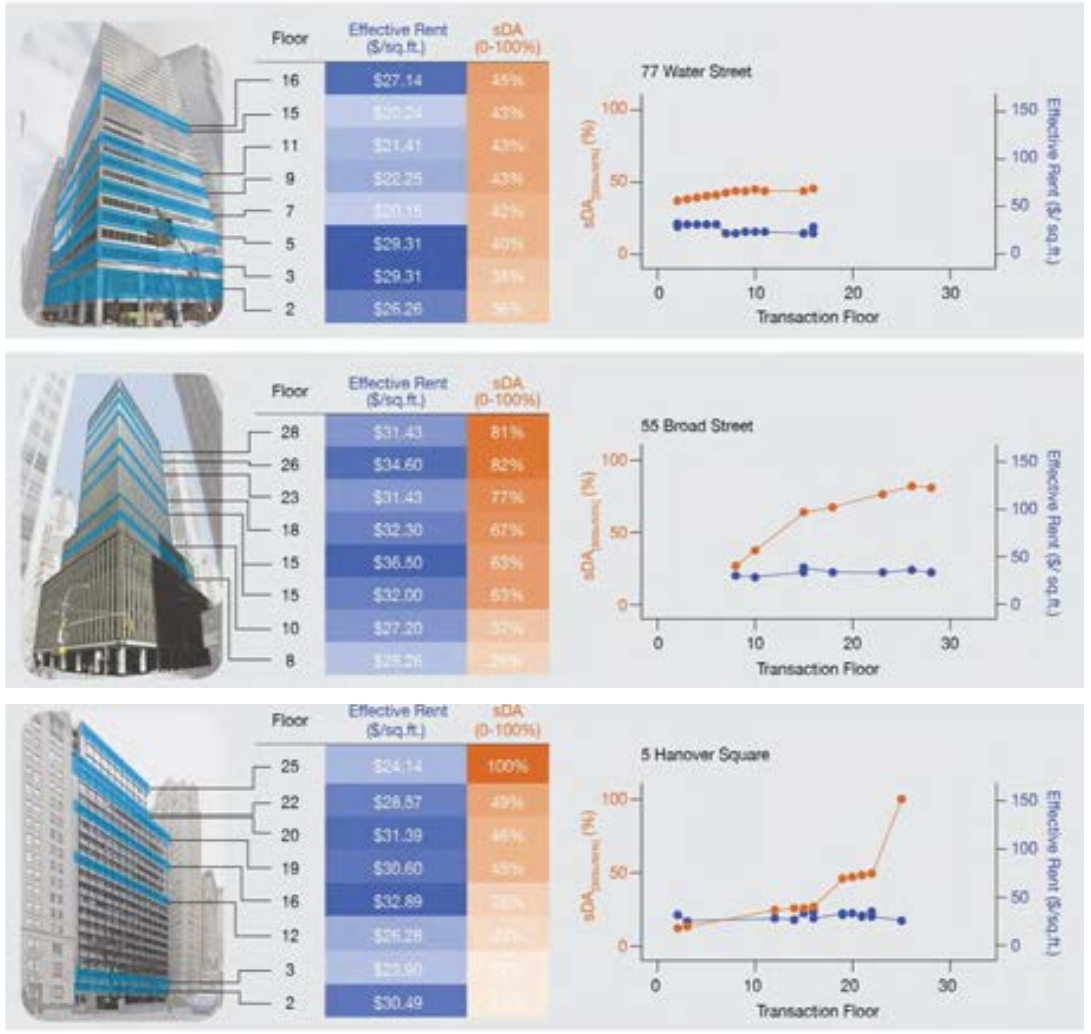
1*: The Benefits of Daylighting. Northwest Energy Efficiency Alliance
2*: (1999, August) Heschong Mahone Group, Daylighting In Schools An Investigation Into The Relationship Between Daylighting and Human Performance
3*: (2009, June). Boulder School Installs Daylighting Device. The Daily Journal, McGraw-Hill Construction
4*: Katz, G. (2006, October). Greening America's Schools. The U.S. Green Building Counci
5*: Interdepartmental Neuroscience, Northwestern University, Impact of Workplace Daylight Exposure on Sleep, Physical Activity, and Quality of Life

THE ENERGY VALUE OF DAYLIGHT

	BASELINE	12'' SHADES	24'' SHADES
			
DAYLIGHT :	58%	60% (2% MORE DAYLIGHT)	63% (5% MORE DAYLIGHT)
GLARE:	26%	20% (6% LESS GLARE)	14% (12% LESS GLARE)
ENERGY:	32 kbtu/sf/yr	30 kbtu/sf/yr (3% LESS ENERGY)	29 kbtu/sf/yr (5% LESS ENERGY)

THE ECONOMICAL VALUE OF DAYLIGHT

There is a 5 to 6% premium for daylight in office rent prices



Source: Irmak Turan, Andrea Chegut, Daniel Finka, Christoph Reinhart, (2019, November), The value of daylight in office spaces

THE REGULATORY VALUE OF DAYLIGHT

INCREASED WINDOW-TO-WALL RATIO:

IECC 2018 ALLOWS FOR 40% WINDOW-TO-WALL RATIO IF DAYLIGHT SENSORS ARE INSTALLED

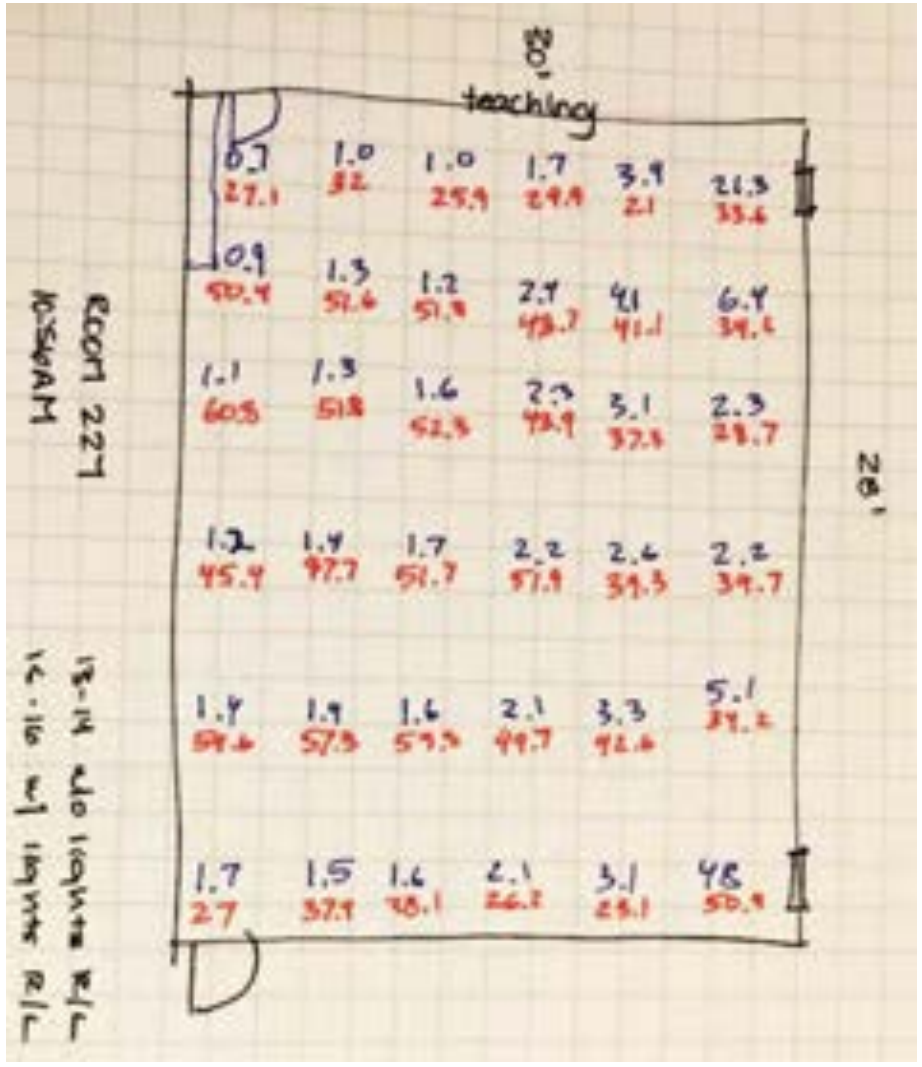
DAYLIGHT SENSORS:

IECC 2018 REQUIRES DAYLIGHT SENSORS FOR DAYLIT SPACES WITH >150 WATTS OF ELECTRIC LIGHT

Source: International Energy Conservation Code 2018

INTERNAL RESEARCH

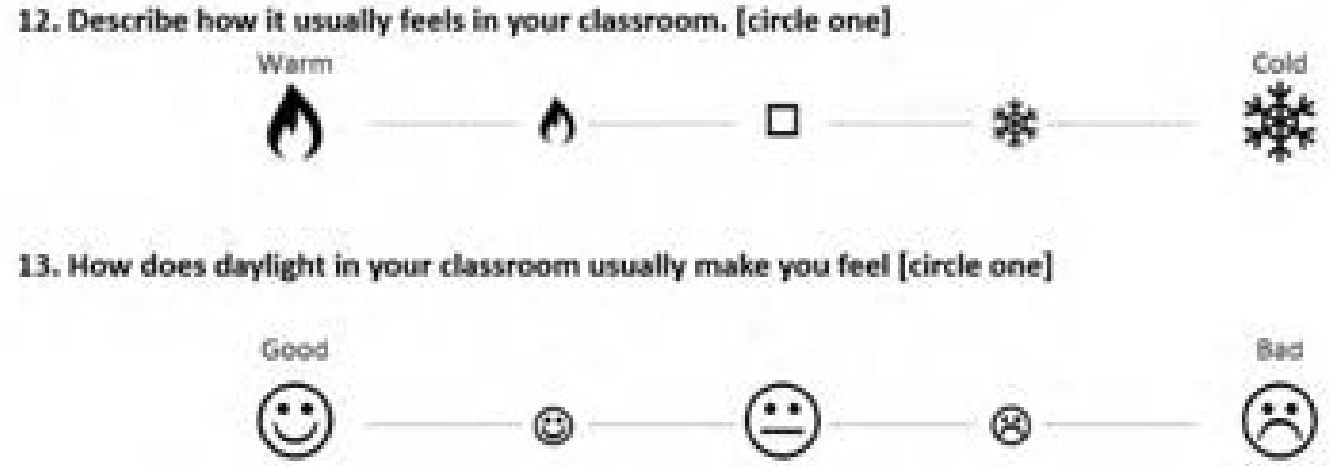
MEASURING DAYLIGHT LEVELS



Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants

UNDERSTANDING DAYLIGHT PERCEPTION

SURVEYS FOR STAFF, TEACHERS, AND STUDENTS



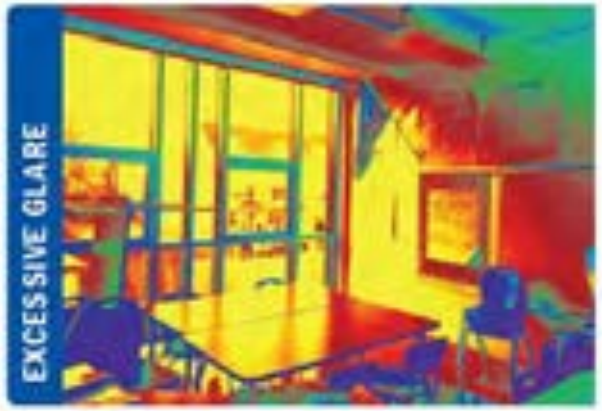
Source: Perkins Eastman, (November 2018), Investing In Our Future: Staff and Teachers Survey Results

Source: Perkins Eastman, (November 2018), Investing In Our Future: Elementary School Survey Results

VISUALIZING DAYLIGHT LEVELS

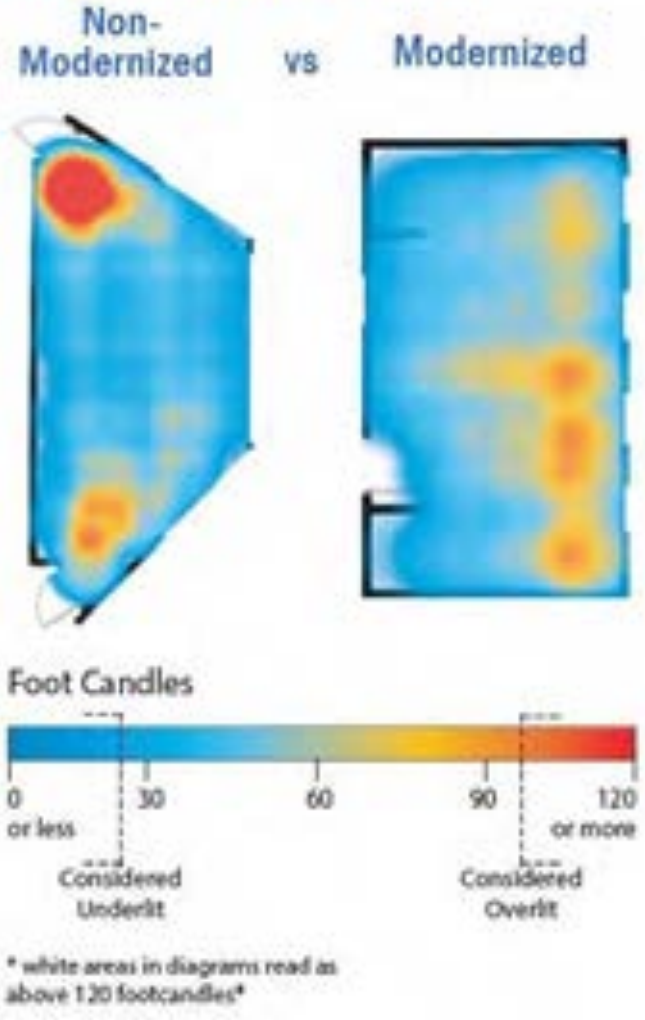
GLARE IMAGING

Non-Modernized

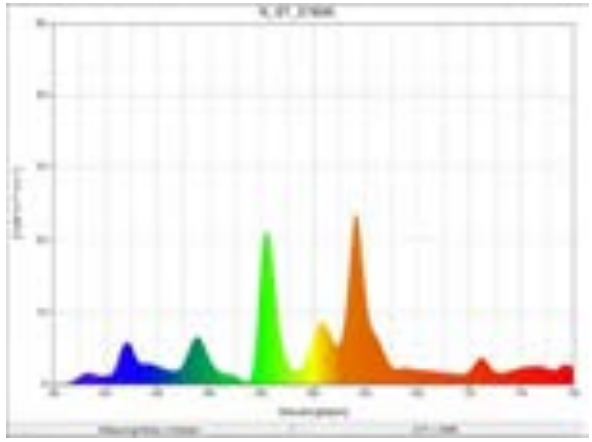


Modernized

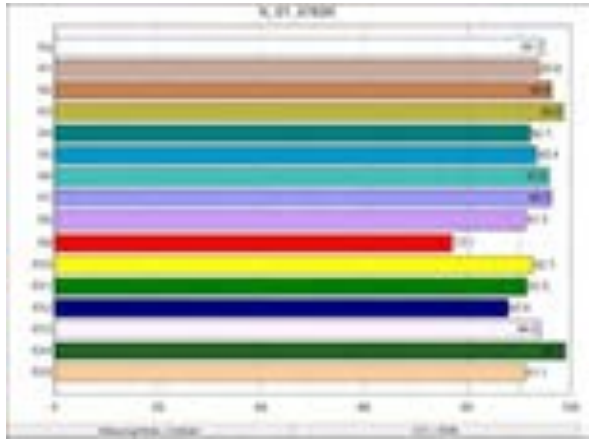
DAYLIGHT DISTRIBUTION



SPECTRAL DISTRIBUTION

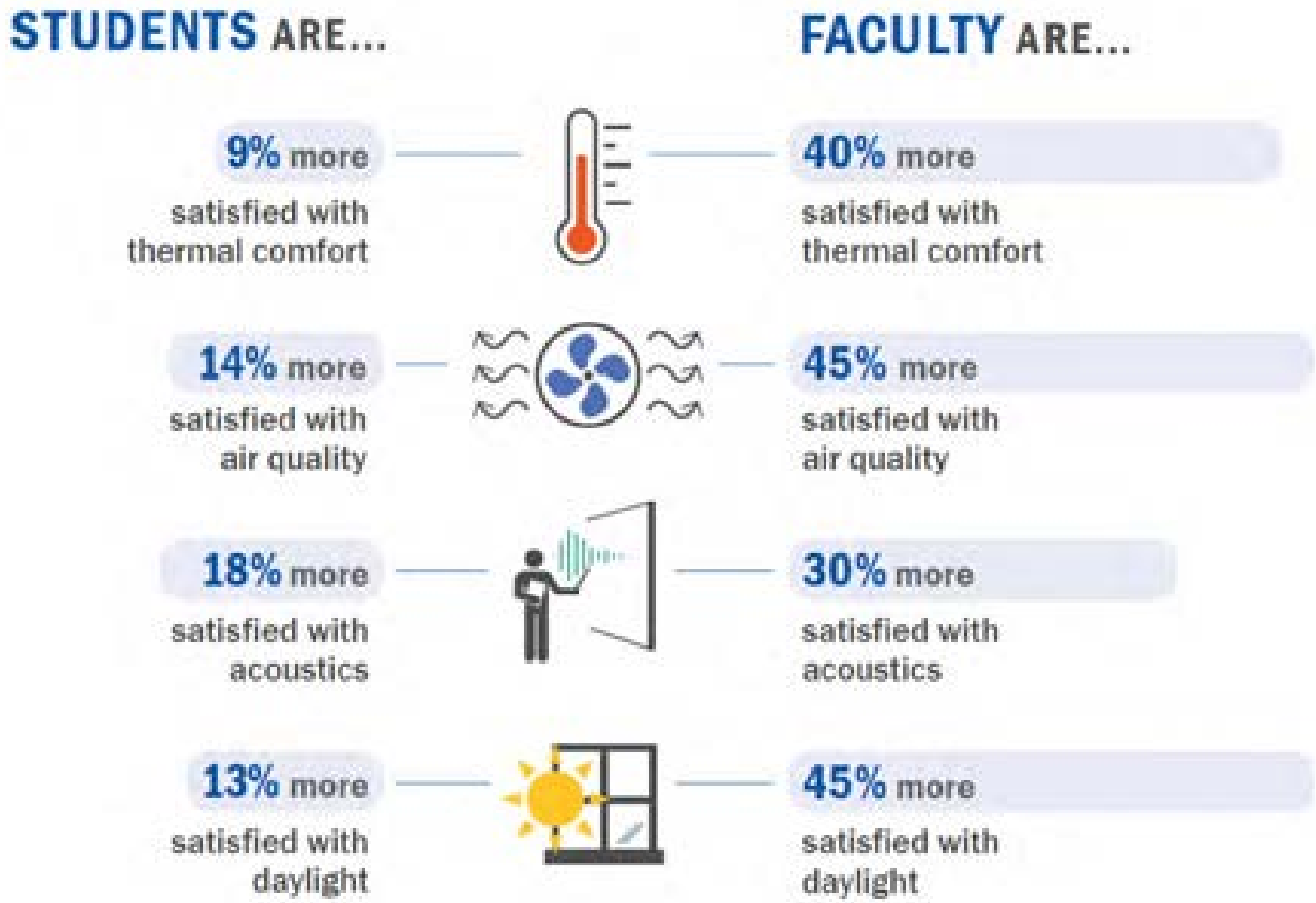


COLOR RENDERING



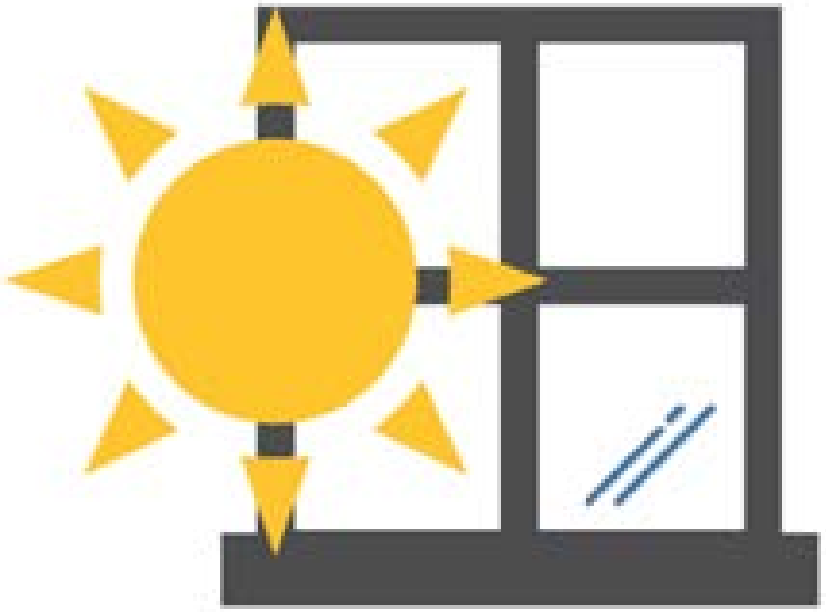
Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants

WHAT DOES THE DATA MEAN?



Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants

RESEARCH: CORRELATIONS



Good Daylight

=

Faculty Satisfaction

Better student attendance,
enrollment,
and fewer nurse visits

Improved Boundary rate,
Less Crime,
and Higher Enrollment Rates

Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants

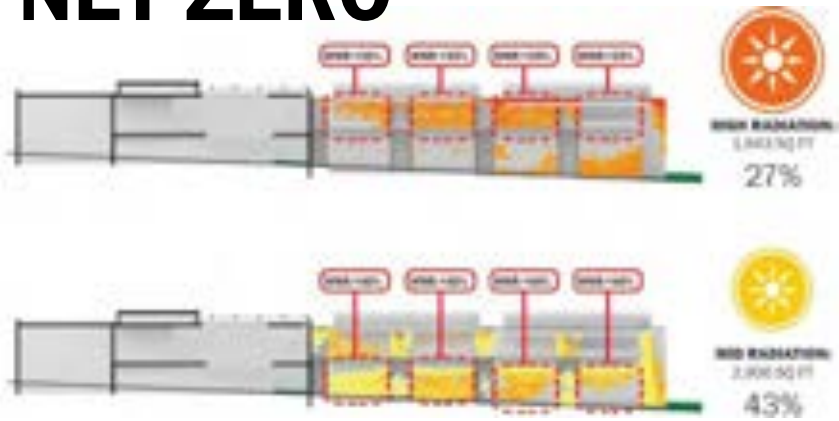
APPLYING THE KNOWLEDGE

RULES OF THUMB FOR DAYLIGHT AND NET ZERO

SHADING

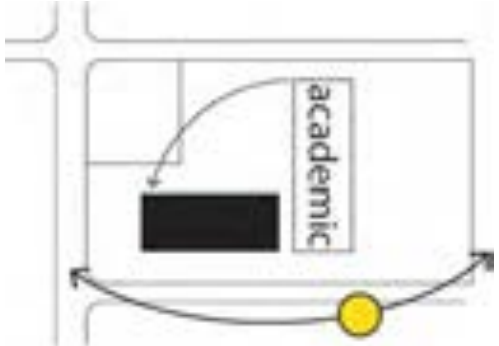
- ✓ Control Solar Angles from the Equinoxes
- ✓ Horizontal shades on south facades
- ✓ Vertical shades effective when rotated >20°
- ✓ Provide 30%-40% perforation to allow for views

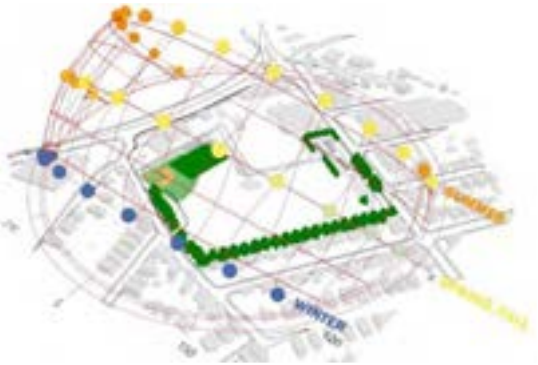
WINDOW TO WALL RATIO



- ✓ Overall Window to Wall Ratio: <30-35%
- ✓ South Window to Wall Ratio: <40%
- ✓ North Window to Wall Ratio: <30%
- ✓ East/West Window to Wall Ratio: <20%

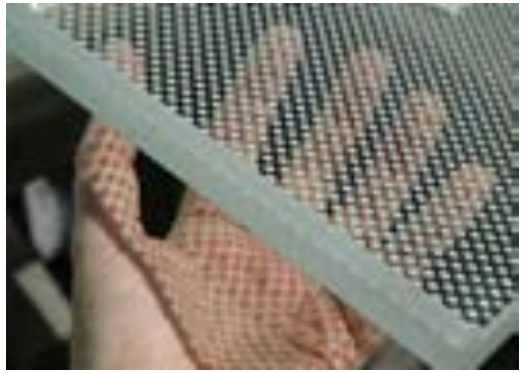
ORIENTATION





- ✓ Building shape with a narrow floor plate
- ✓ Elongate building in the east-west direction
- ✓ north and south sides of the building more open
- ✓ Large floor plates can use atriums or courtyards

GLAZING



- ✓ High VLT (Visible Light Transmittance) for good Daylight
- ✓ Low U-Factor for low thermal bridging
- ✓ Different SHGC (Solar Heat Gain Coefficient) for different facades
- ✓ Fritting not effective and causes visual stress

POLL: WHICH OF THESE BUILDINGS HAS A WINDOW-TO-WALL RATIO OF MORE THAN 40%?

A

Skaggs Pharmacy Research Building,
NBBJ
University of Utah, Salt Lake City

B

Ministry of Urban Development
Sauerbruch Hutton
Hamburg, Germany,

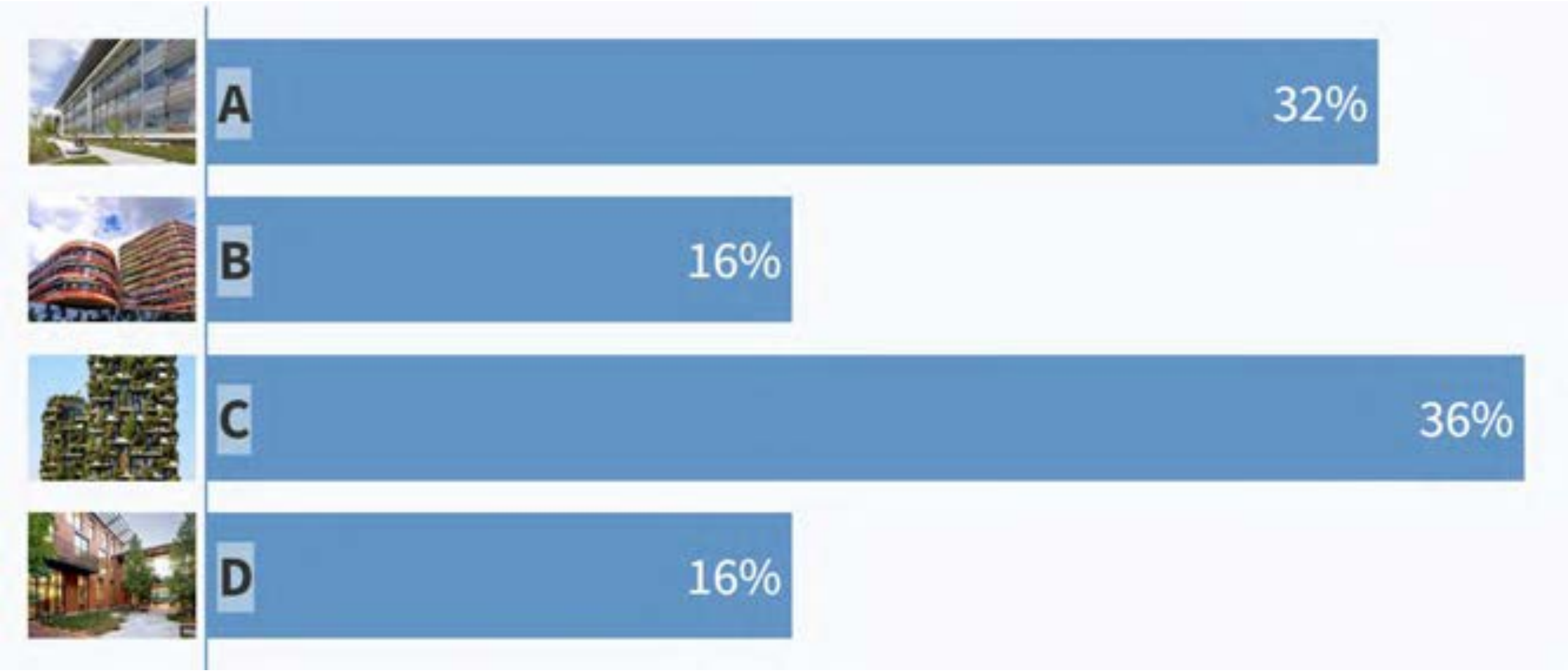
C

Bosco Verticale Apartments
Stefano Boeri Architetti,
Milan, Italy

D

David & Lucile Packard Foundation
EHDD
Los Altos, California

POLL RESULTS: WHICH OF THESE BUILDINGS HAS A WINDOW-TO-WALL RATIO OF MORE THAN 40%?



POLL: WHICH OF THESE BUILDINGS HAS A WINDOW-TO-WALL RATIO OF MORE THAN 40%?

A

Skaggs Pharmacy Research Building,
NBBJ
University of Utah, Salt Lake City

35%
WWR

B

Ministry of Urban Development
Sauerbruch Hutton
Hamburg, Germany,

26%
WWR

C

Bosco Verticale Apartments
Stefano Boeri Architetti,
Milan, Italy

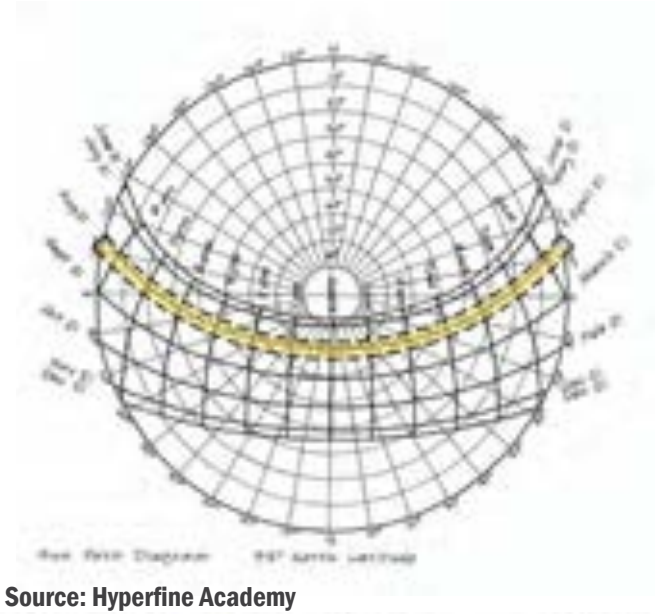
32%
WWR

D

David & Lucile Packard Foundation
EHDD
Los Altos, California

28%
WWR

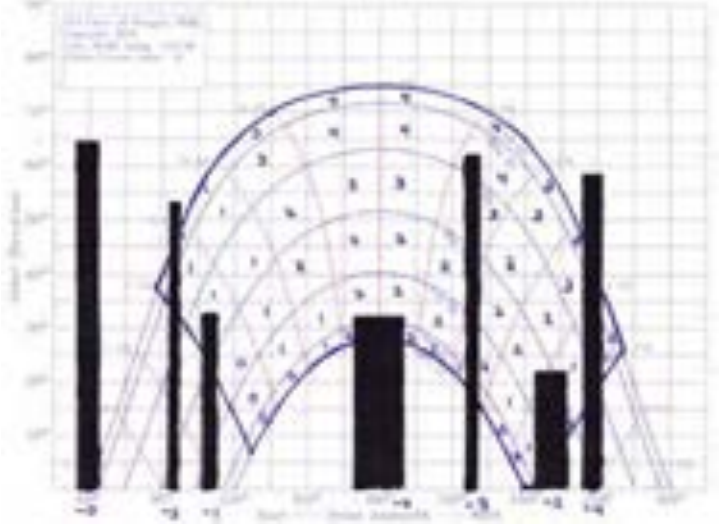
ANALOG MODELING



Source: Hyperfine Academy

Source: Heliotec Equipamentos Didaticos

Source: Personal Data Base

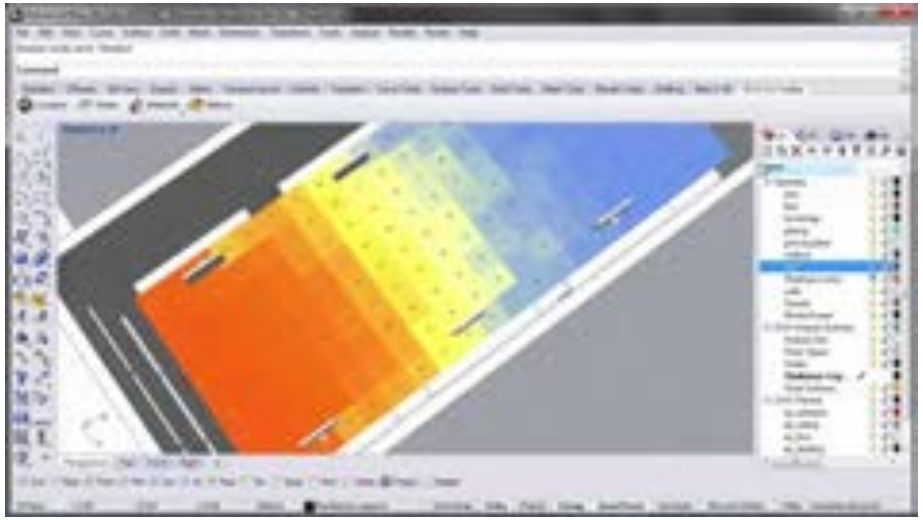


Source: The Solar Planner

Source: Personal Data Base

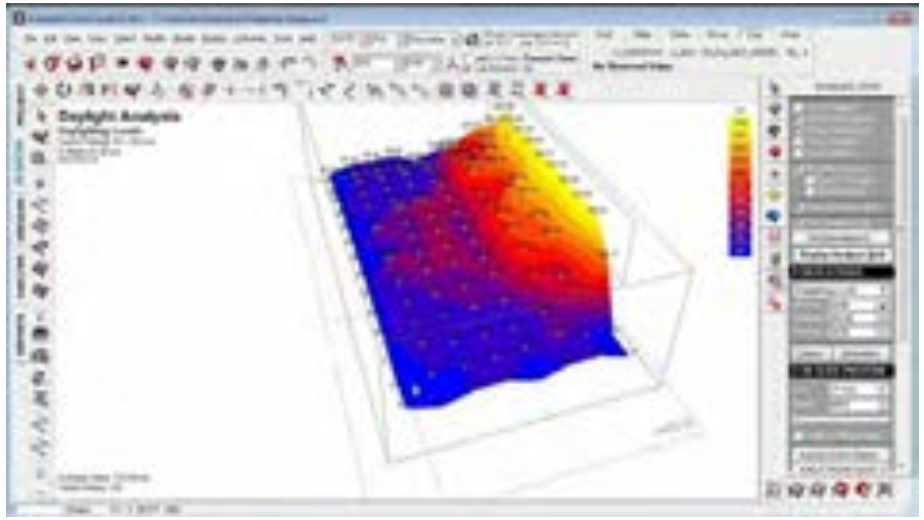
EARLY STAGES OF DAYLIGHT MODELING

DIVA



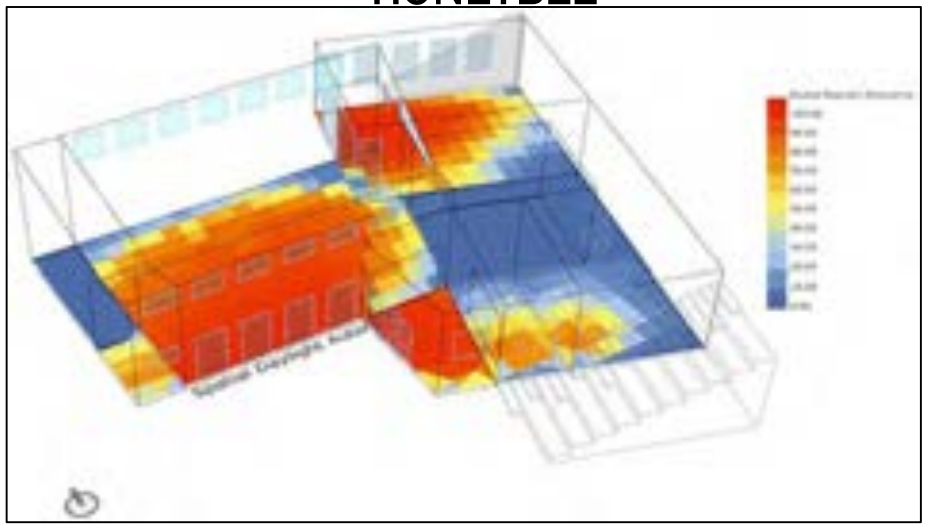
Source: DIVA Tutorial, MIT Sustainable Design Lab

ECOTECT



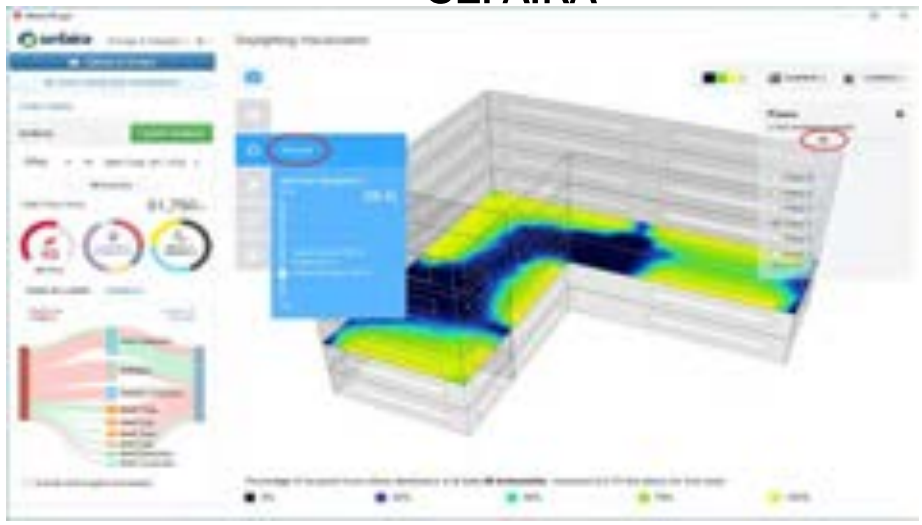
Source: Quantitative Daylighting Analysis in Ecotect, NEWBIM

HONEYBEE



Source: Daylight Analysis as Design Tool, Binghamton University

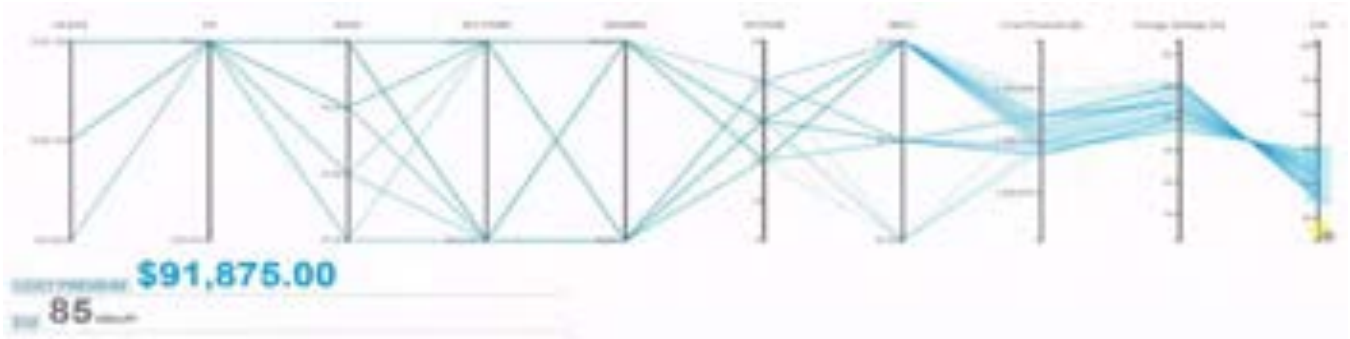
SEFAIRA



Source: Producing Daylighting Graphics and Reports, Sefaira

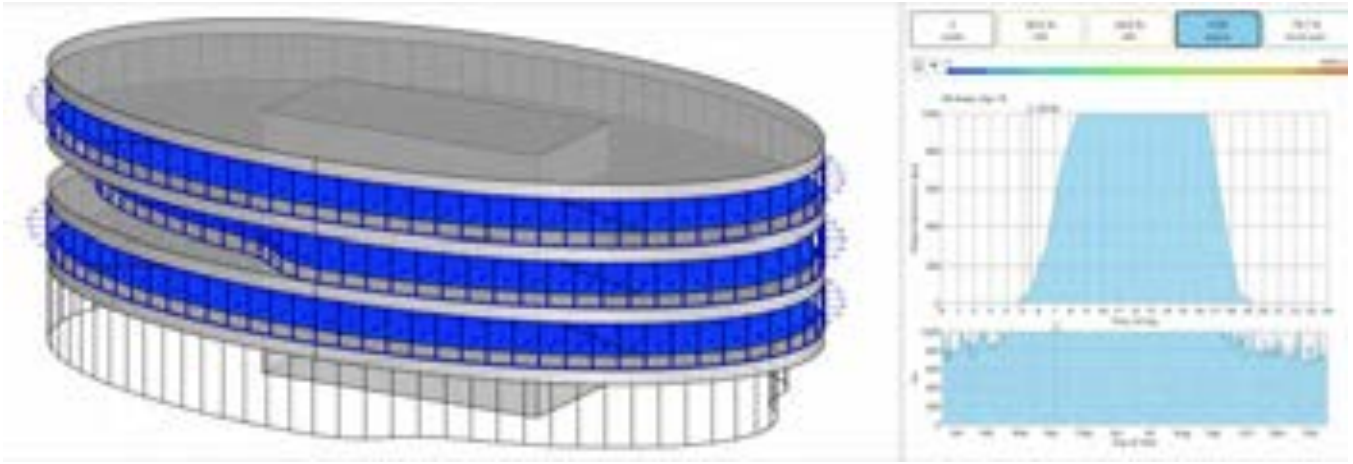
TOOLS THAT MAKE OUR LIFE EASIER

COVE TOOL



Source: COVE Tool

CLIMATE STUDIO

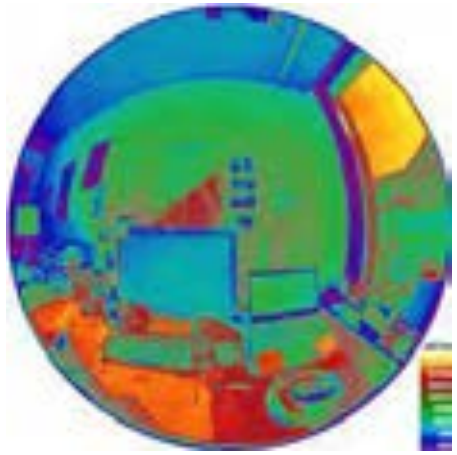


Source: Climate Studio, Solemma

NEW TECHNOLOGIES, NEW TRENDS

14 Patterns of Biophilic Design - Terrapin Bright Green

ohsuriya - Fotolia



Architecture et Climat | October 2019

INTERNATIONAL WELL BUILDING INSTITUTE™

International WELL Building Institute

Halio Smart Tinting Glass

METRICS

SDA
Spatial Daylight Autonomy

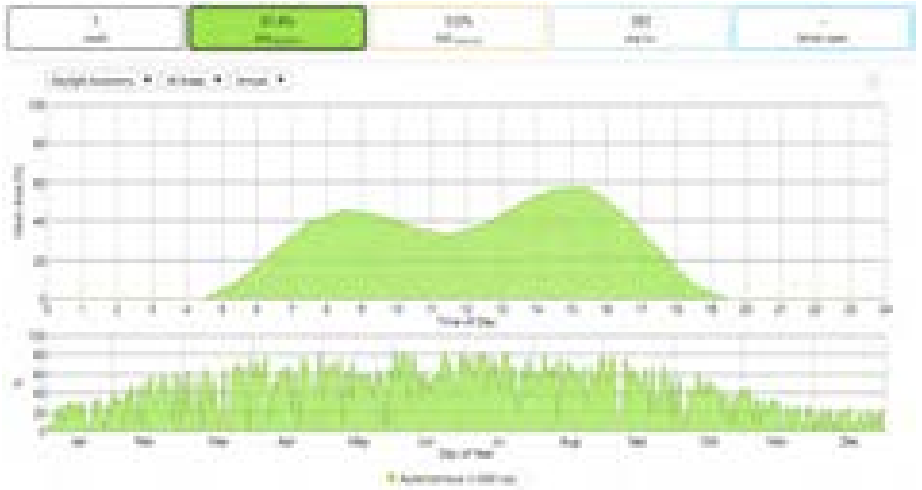
ADF
Average Daylight Factor

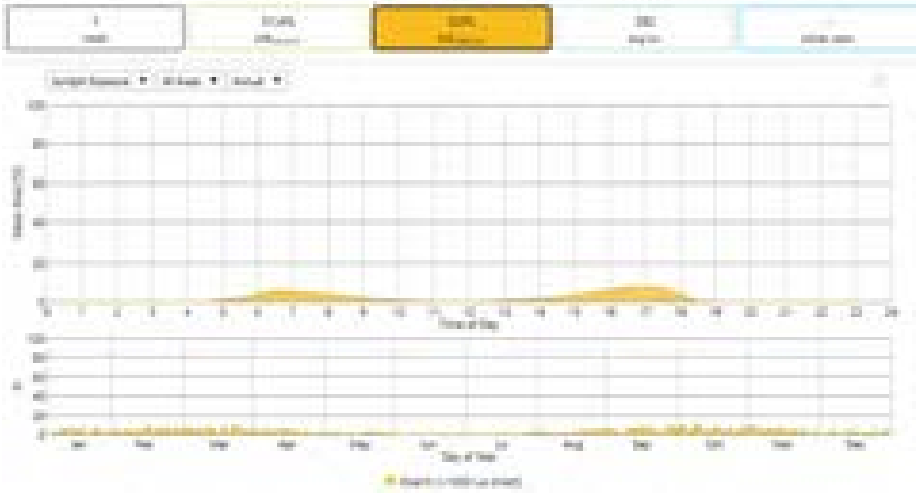
ASE
Annual Solar Exposure

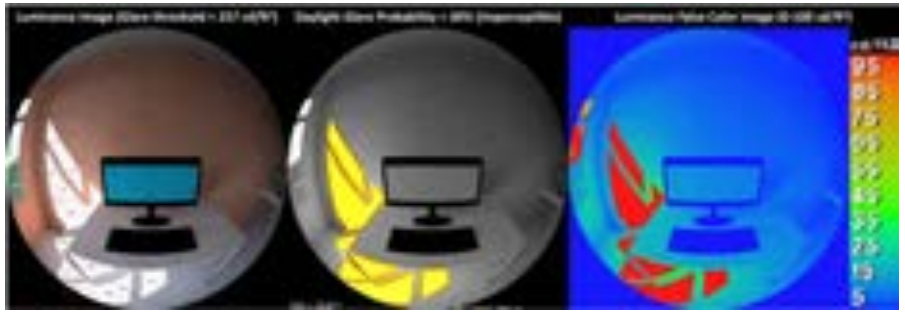
DGP
Direct Glare Potential

UDI
Useful Daylight Illuminance

EUI
Energy Use Intensity

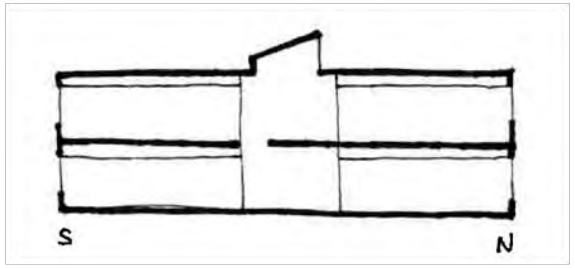




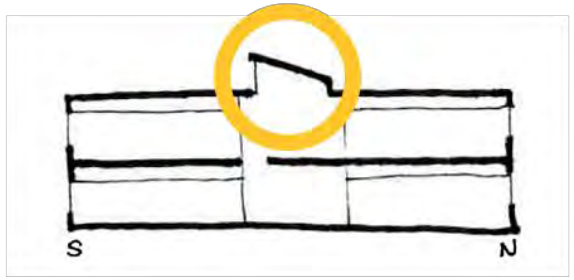


Climate Studio, Solemma

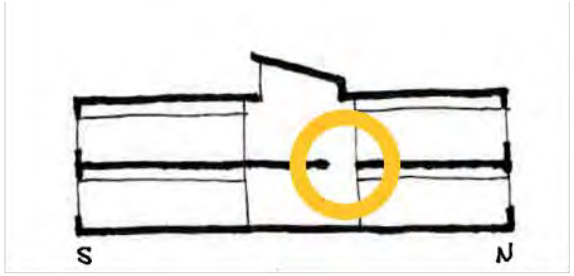
DESIGN STRATEGIES OVER TIME



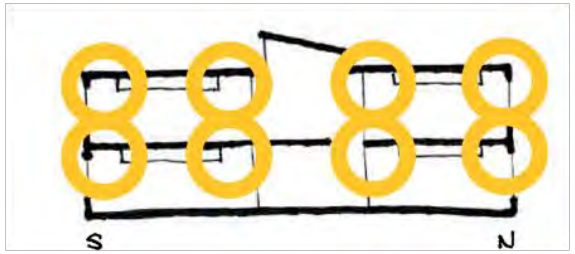
BASELINE



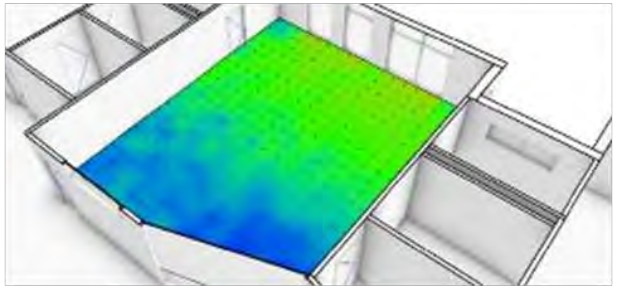
SOUTH FACING CLERESTORY

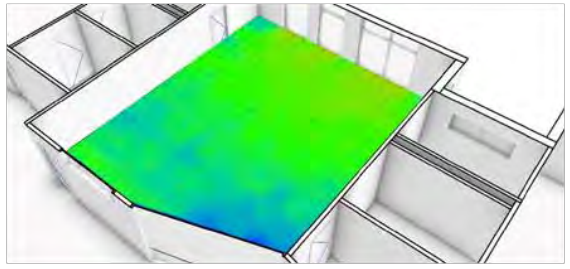


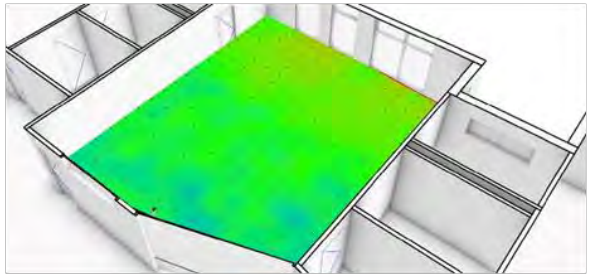
NORTH LIGHT WELLS

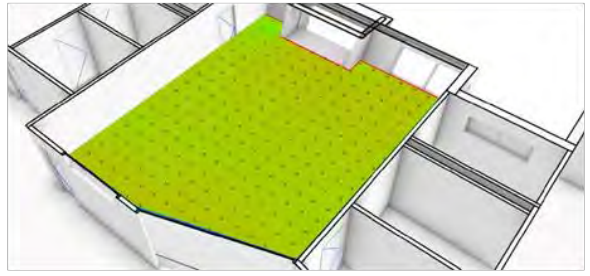


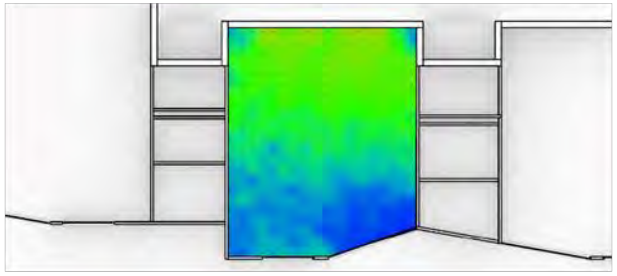
RECESSED CEILINGS + NOOKS

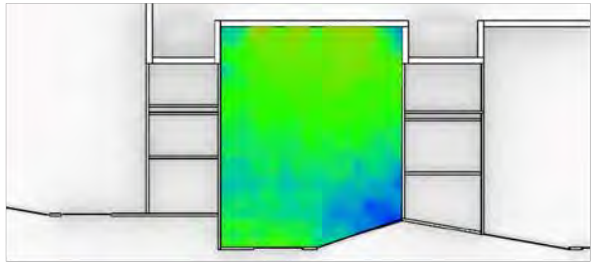


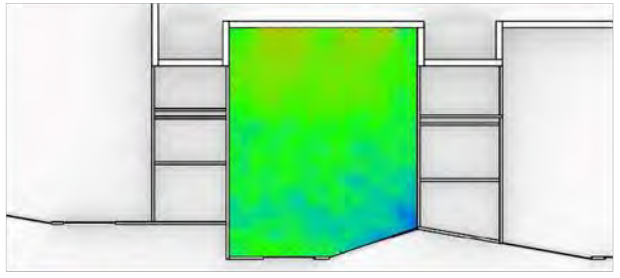


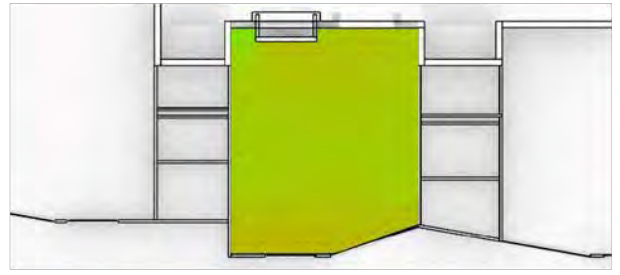












DAYLIGHT (SDA): 17%
GLARE (ASE): 0%
WINDOW RATIO: 25%

DAYLIGHT (SDA): 29%
GLARE (ASE): 0%
WINDOW RATIO: 25%

DAYLIGHT (SDA): 40%
GLARE (ASE): 1%
WINDOW RATIO: 25%

DAYLIGHT (SDA): 62%
GLARE (ASE): 3%
WINDOW RATIO: 25%

THIS IS WHAT A 25% WWR SPACE LOOKS LIKE

John Lewis Elementary School, Perkins Eastman

APPLYING THE KNOWLEDGE TO OUR PROJECTS

JOHN LEWIS ELEMENTARY SCHOOL

DAYLIGHT	78%
GLARE	4%
EUI	22 kbtu/sf/yr
WWR	25%

BANNEKER HIGH SCHOOL

DAYLIGHT	66%
GLARE	3%
EUI	19 kbtu/sf/yr
WWR	30%

C.W. HARRIS ELEMENTARY SCHOOL

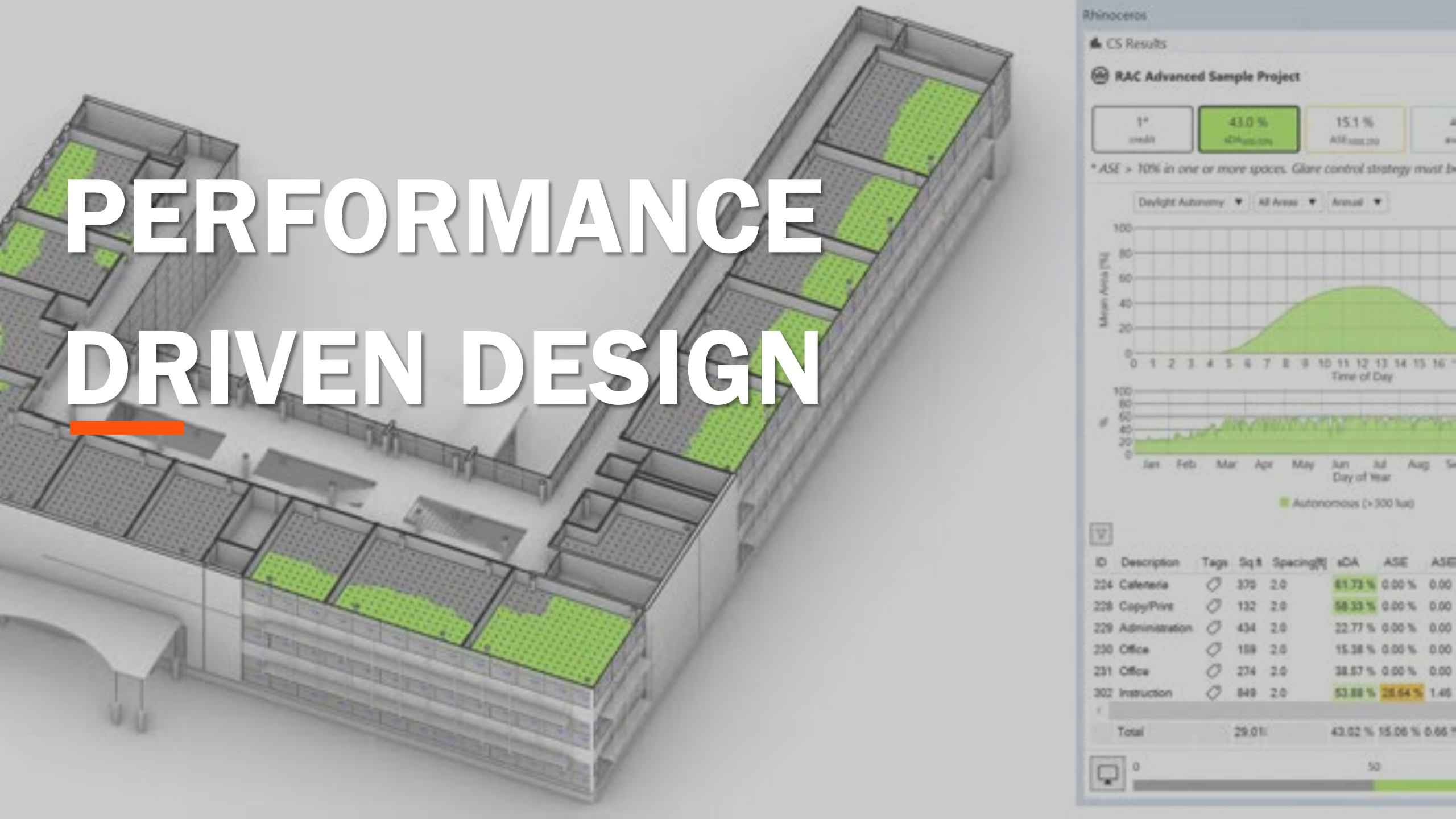
DAYLIGHT	78%
GLARE	4%
EUI	28 kbtu/sf/yr
WWR	25%

MARTIN LUTHER KING SCHOOL

DAYLIGHT	66%
GLARE	3%
EUI	21 kbtu/sf/yr
WWR	30%

Perkins Eastman, 2021

PERFORMANCE DRIVEN DESIGN



SOLEMMA


A Jakubiec


C Reinhart


J Niemasz


D Chang


J Sargent


T Dogan

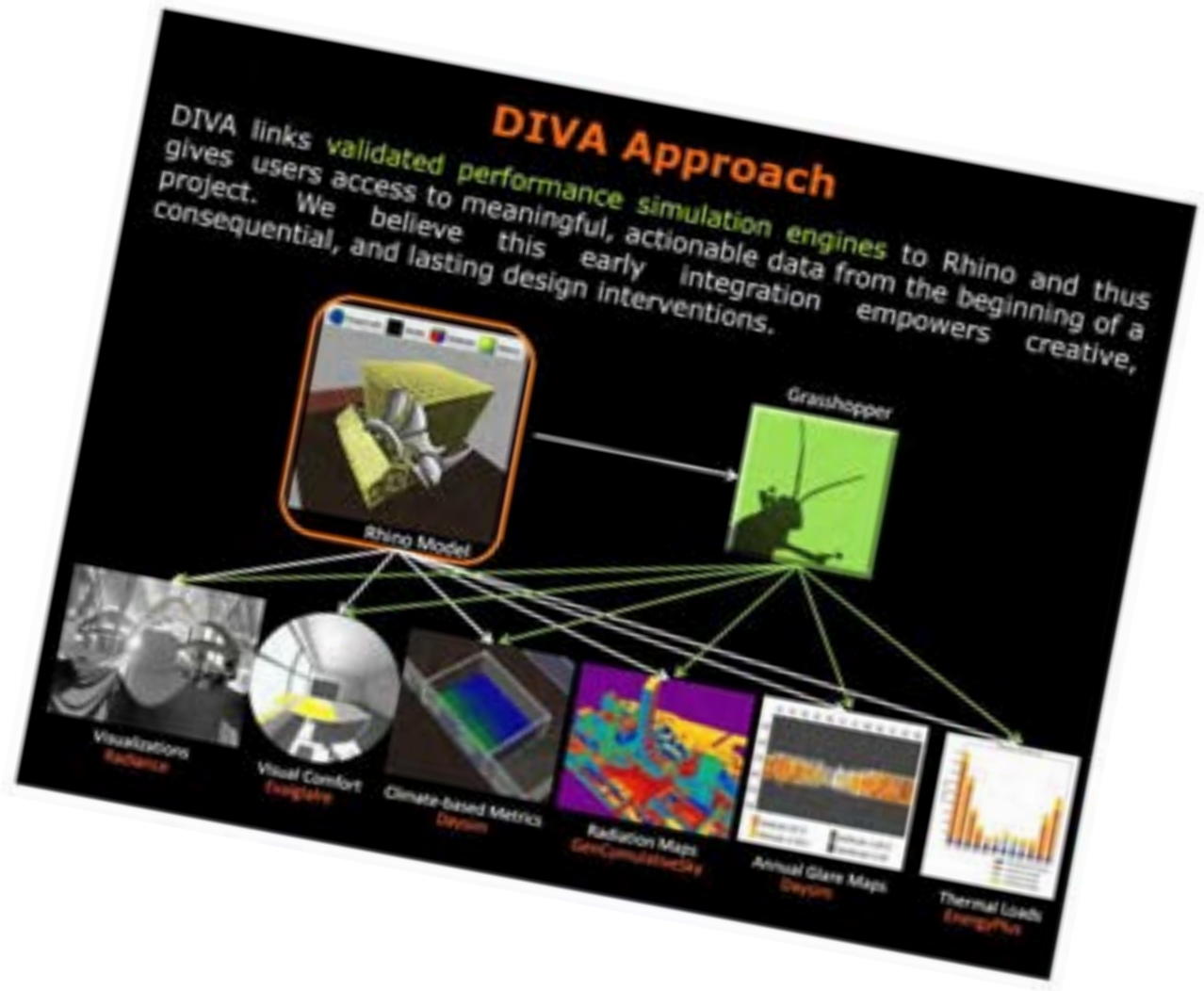

V Lialios-Bouwman

UNIVERSITY OF TORONTO

Cornell University

2012 INITIAL CONCEPT

COMBINING DESIGN AND ENVIRONMENTAL MODELING

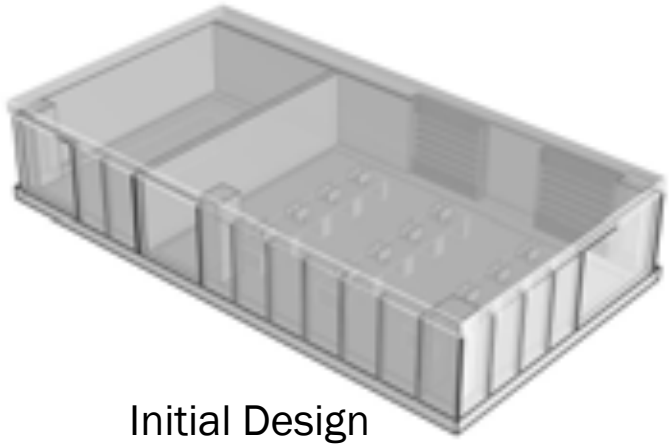


"Building performance simulation is no longer just a good idea for some architectural practices; it is an essential part of building design and delivery." AIA 2019

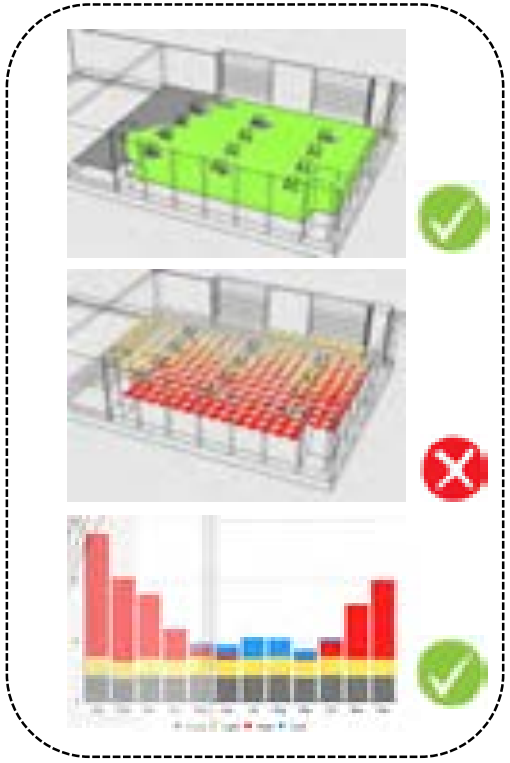
URL: content.aia.org › default › files › Energy_Design_Modeling_Guide_v4

ClimateStudio

ENVIRONMENTAL PERFORMANCE ANALYSIS IN DESIGN



Initial Design



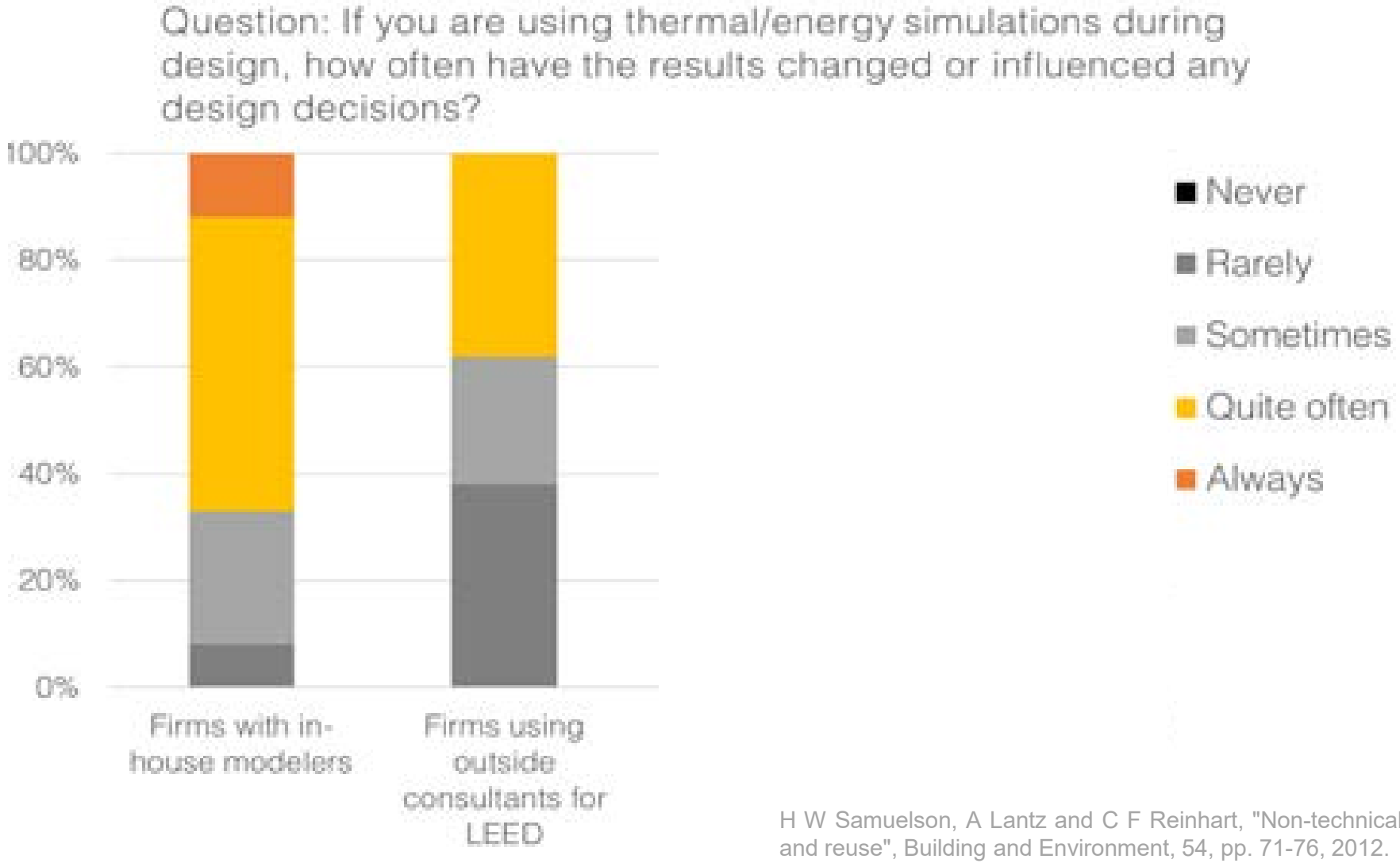
Environmental Analysis

Revised Design

How often does that happen?

TWO SURVEYS

2011 AND 2018

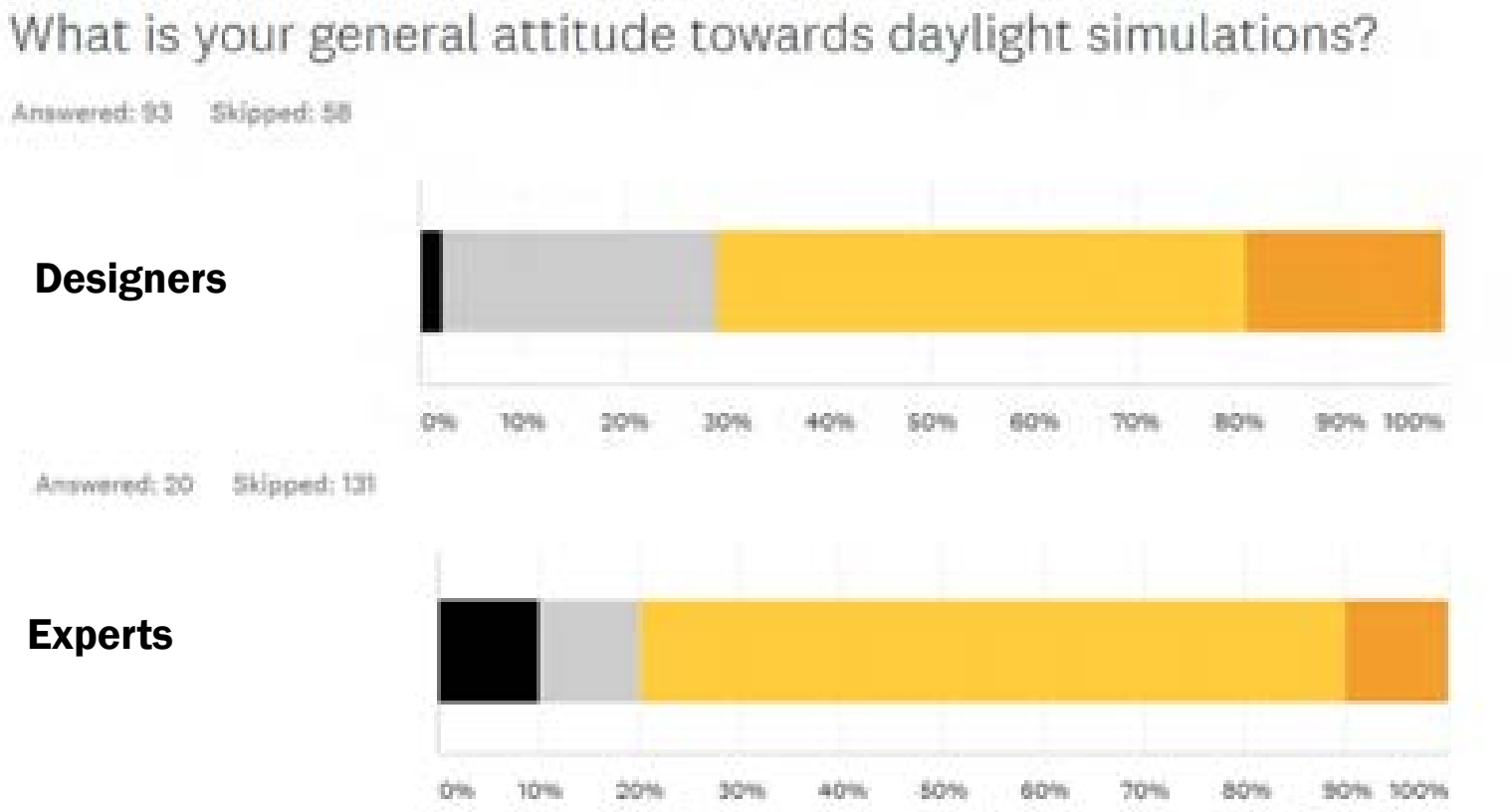


H W Samuelson, A Lantz and C F Reinhart, "Non-technical barriers to energy model sharing and reuse", Building and Environment, 54, pp. 71-76, 2012.

Is there an interest in change?

DAYLIGHTING

ATTITUDE TOWARDS SIMULATIONS



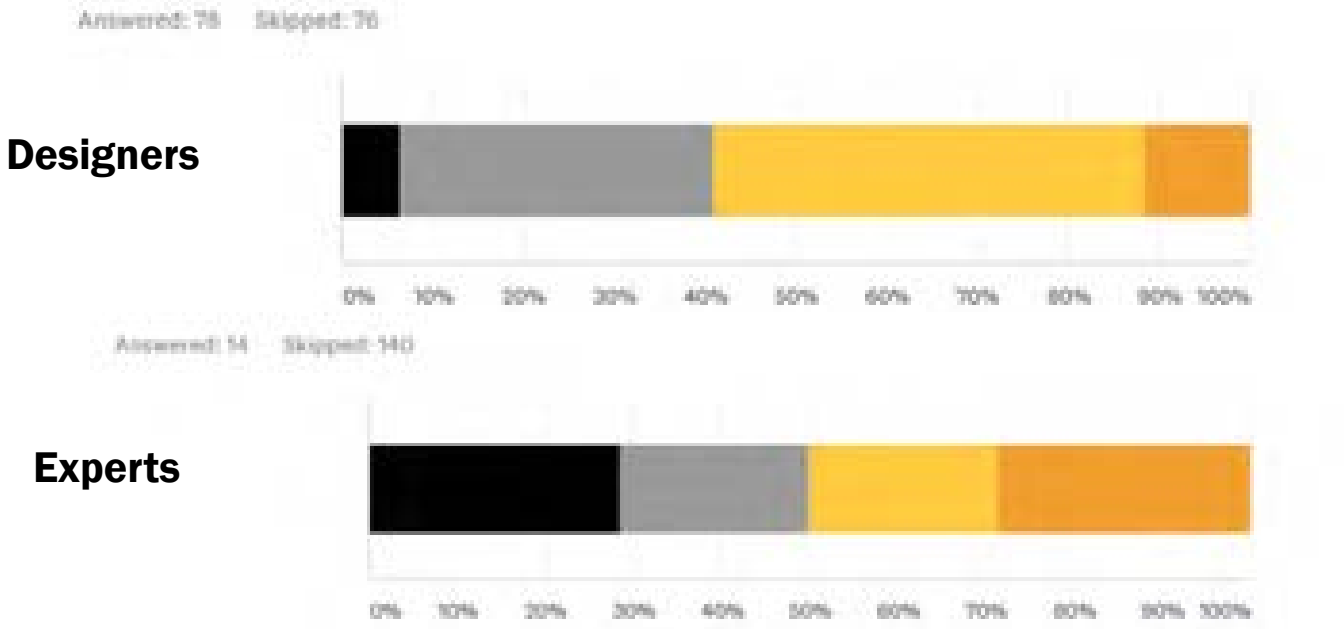
- I have not seen a case in which this type of analysis has helped us to design a better building.
- I appreciate insight gained from daylight simulations provided during design reviews by our sustainability consultants.
- I highly value insight gained from daylight simulations and believe that some of the simulations should be conducted by designers, if adequate training is provided.
- I highly value insight gained from daylight simulations and already use them during design.

- ❑ Positive attitude throughout.
- ❑ Broad consensus regarding interest into training designers in the use of simulations.

THERMAL

ATTITUDE TOWARDS SIMULATIONS

What is your general attitude towards thermal/energy simulations?



- I have not seen a case in which this type of analysis has helped us to design a better building.
- I appreciate insight gained from daylight simulations provided during design reviews by our sustainability consultants.
- I highly value insight gained from daylight simulations and believe that some of the simulations should be conducted by designers, if adequate training is provided.
- I highly value insight gained from daylight simulations and already use them during design.

❑ Less clear mandate to introduce designers to energy modeling

Is there an interest in change?

Yes, and we have to act now!

PRODUCT ADVISORY GROUP

PRODUCT ADVISORY GROUP

- ❑ Monthly calls
- ❑ Present new concept ideas
- ❑ Share test installers
- ❑ Survey and respond to member interests

KEY FEATURES

Fast and accurate

Progressive path tracing

Easy to use

Built for the real world

Database only includes measured/ real world materials

https://www.solemma.com/climatestudio

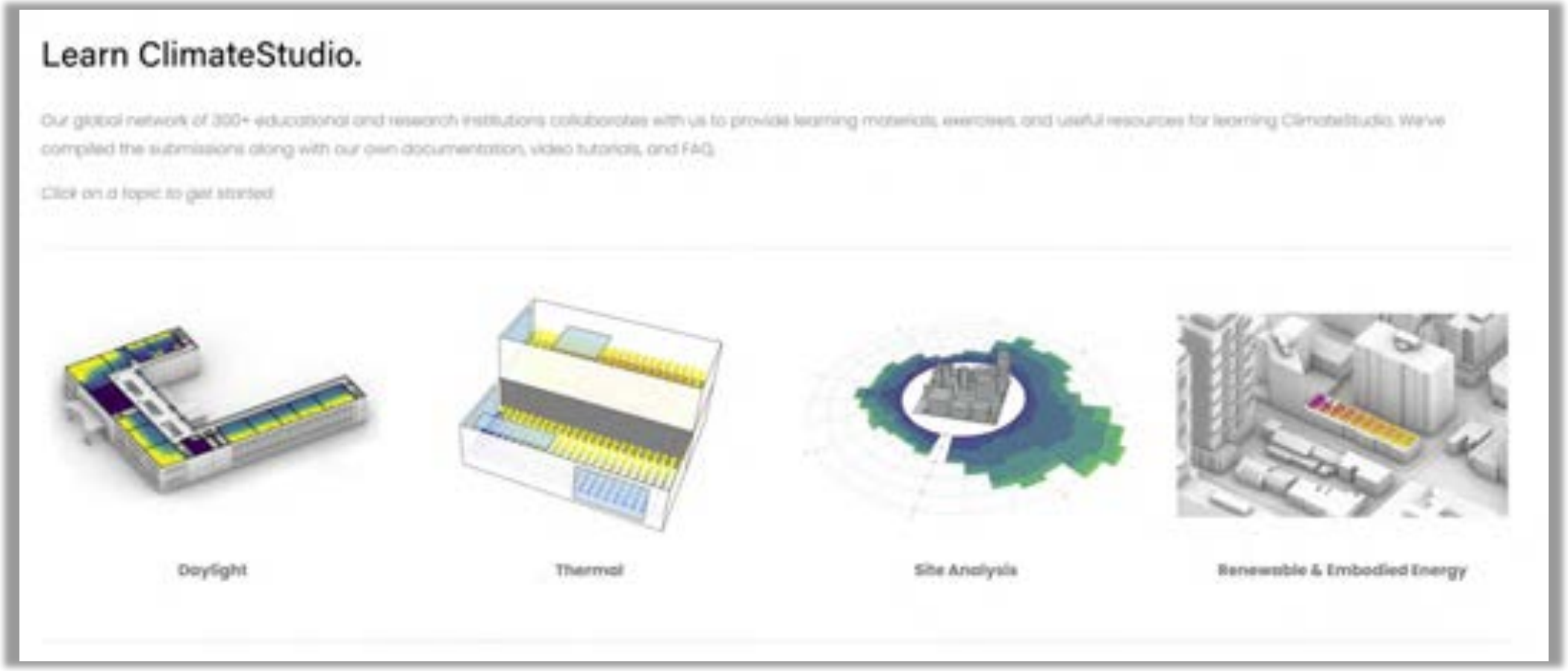
IMPACT ON EDUCATION

- ❑ >370 educational ambassadors at school of architecture worldwide

ClimateStudio IN NIGERIA

Courage (Dzidula) Kpodo teaching CS at Kwame Nkrumah University of Science and Technology

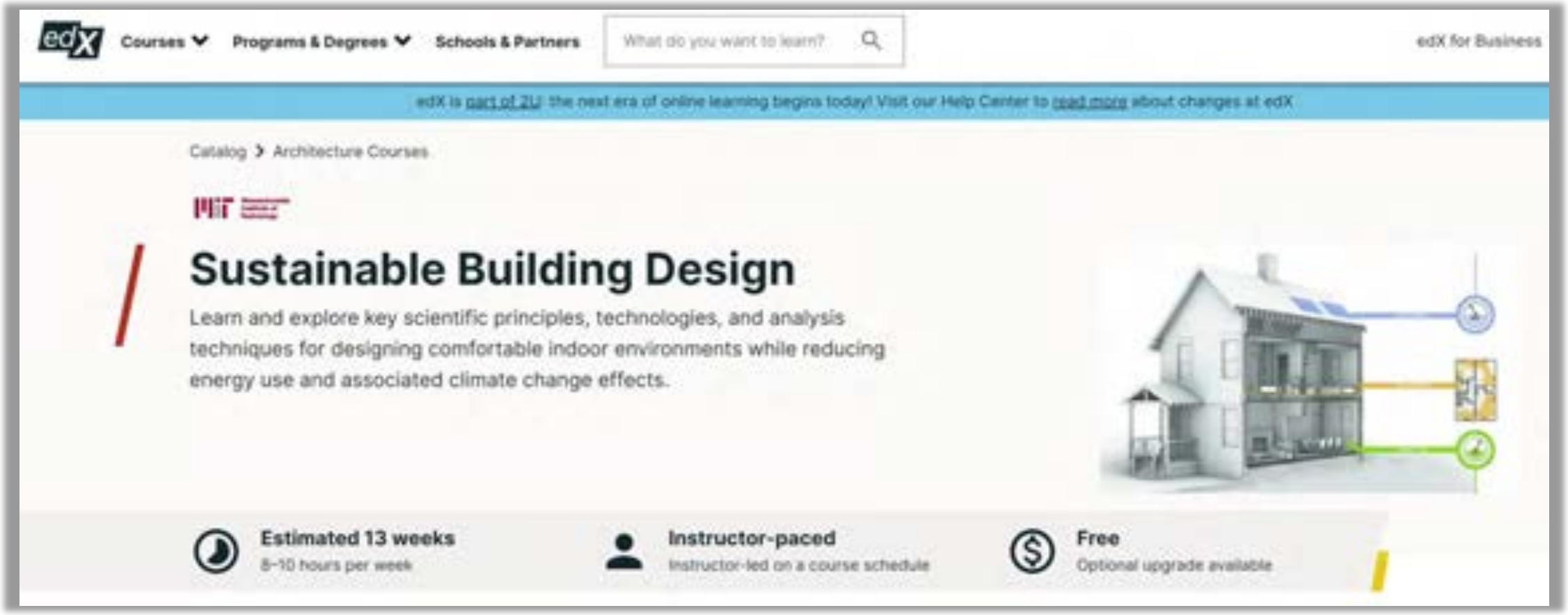
CHALLENGE - TRAINING A GLOBAL WORKFORCE



- How to train designers how to correctly interpret and react to environmental performance results

https://www.solemma.com/learn

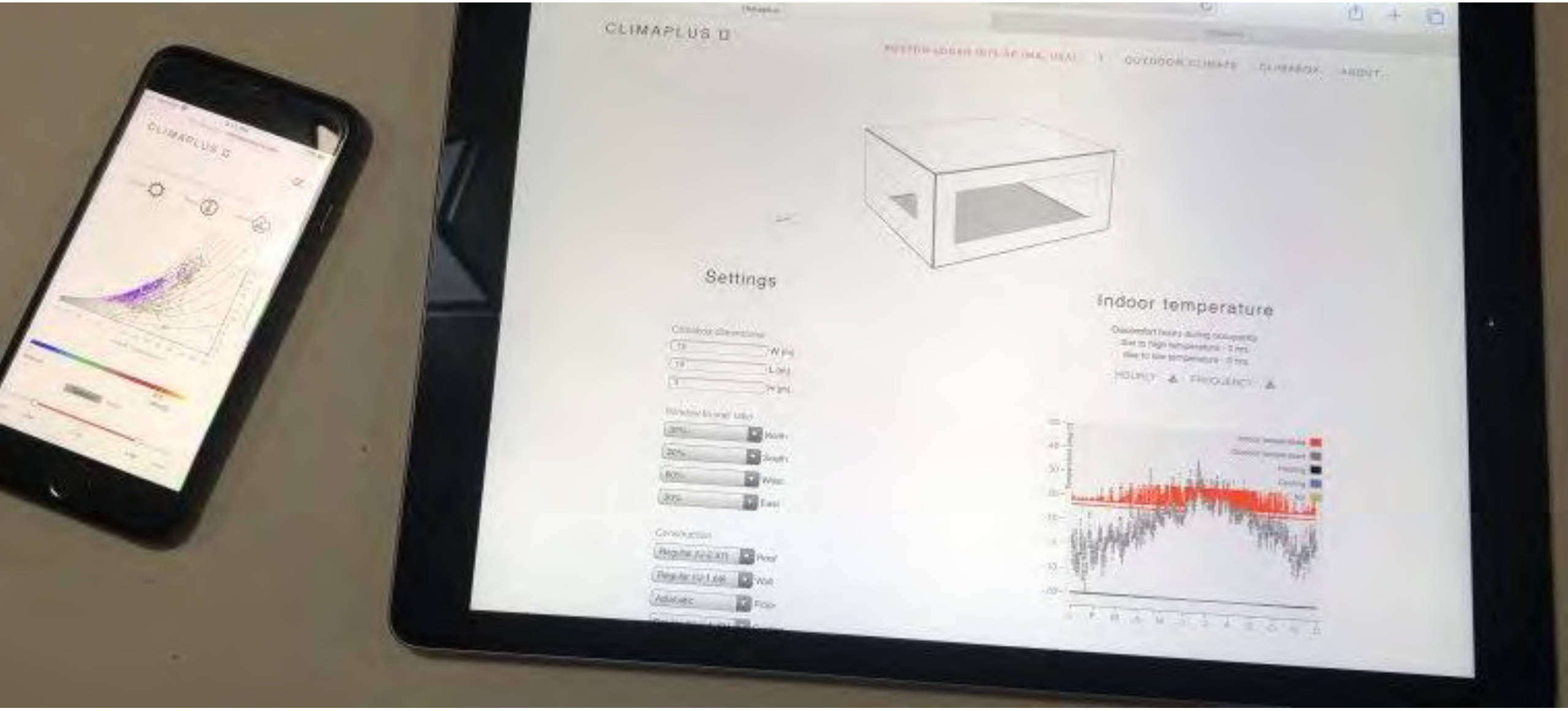
CHALLENGE - TRAINING A GLOBAL WORKFORCE



- ❑ > 40,000 learners and counting…

https://www.solemma.com/learn

CHALLENGE – ACCESS TO ALL



DAYLIGHT STORIES

PERKINS EASTMAN

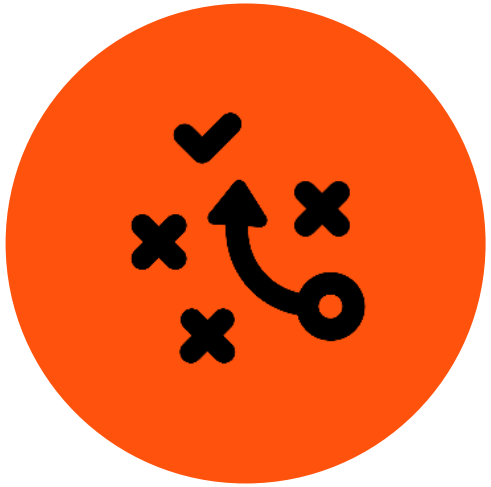
Human by Design

TMVL Proposal, Foot Print Schematic Plan, 2020

DAYLIGHT STORIES

DAYLIGHT APPLICATION IN EDUCATION CASES

Renovation vs. New Construction



Iterative Workflow

Design Exercise and Rules of Thumb

Community Participation

Conclusion and Next Steps

TOBIN VASSAL LANE MONTESSORI SCHOOL

CAMBRIDGE

TMVL Project proposal, School Entrance, Perkins Eastman 2020

TMVL Feasibility Study, Google Earth Image, 2019

SITE – EXISTING BIRD'S EYE VIEW

TMVL Feasibility Study, Google Earth Image, 2019

WASTE MATERIAL

APPROXIMATE AREA

Overlay on Parcel Map - Approximate Boundary of Former Clay Pit/Edge of Waste

Graphic overlay Source: Presentation by CDM Smith, 2-6-19 (slide #15)

BRICKYARDS

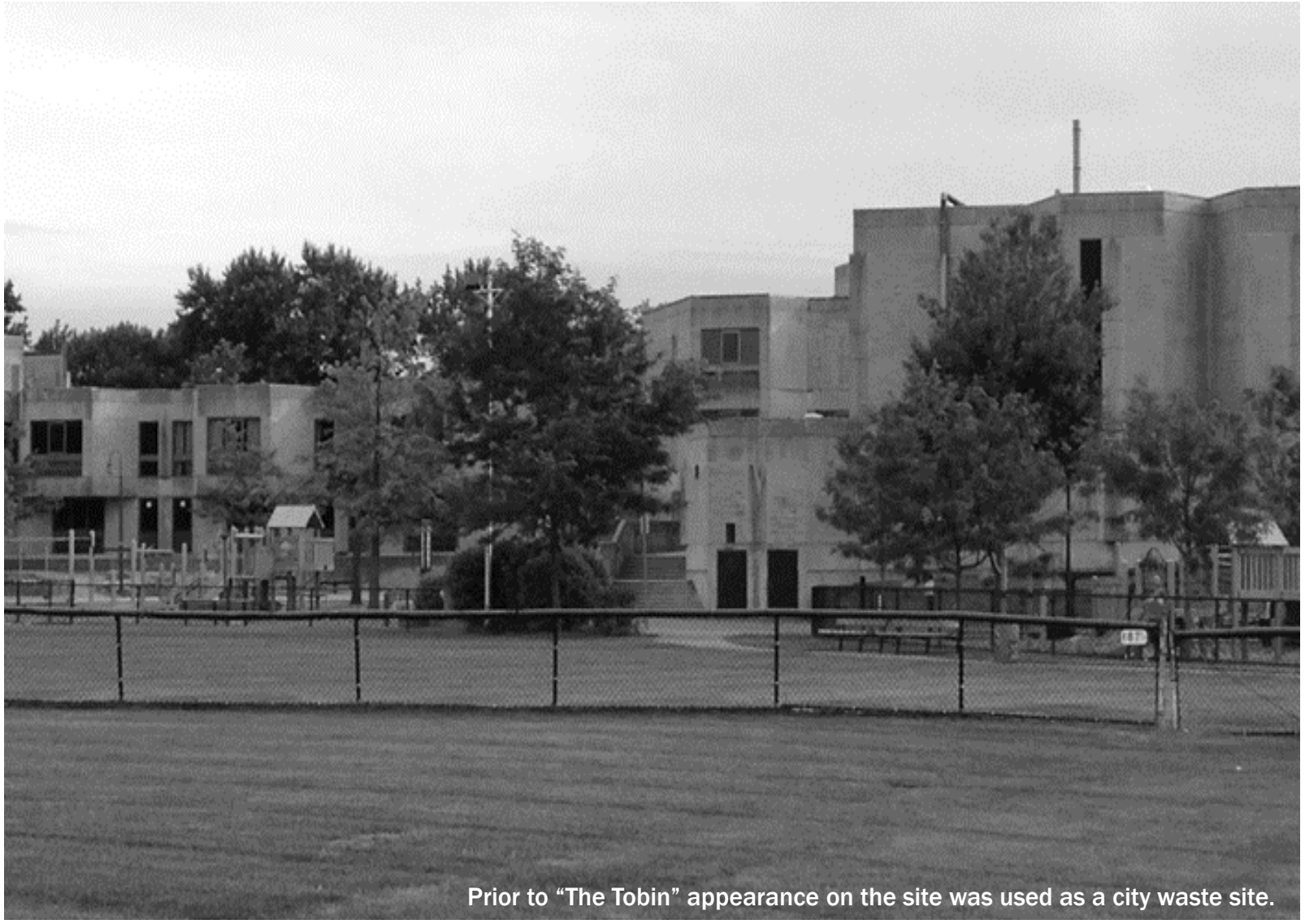
The site could have looked like this around the turn of the century. Drying brick sheds dotted the low-lying, clay-covered landscape. The site was industrialized during the discovery of clay deposits.

Cambridge, Fresh Pond Illustrative image of Llay Quarry. Down: Ballast brick, Perkins Eastman 2020

1950-1972

TMVL Feasibility Study, Google Earth Image, 2019

OVERVIEW



Prior to “The Tobin” appearance on the site was used as a city waste site.

TMVL Existing Building Plan and Photos

INTEGRATED APPROACH

ENERGY METERING

MAXIMIZE ON-SITE RENEWABLE

LOW-FLOW PLUMBING FIXTURES & HEAT PUMPS

EMBODIED CARBON

ZERO ON-SITE GREENHOUSE GAS EMMISSION

ON-SITE STORMWATER MANAGEMENT

LOW ENERGY LED LIGHTING

SOLAR SHADING

EDUCATION

LEED GOLD

HYBRID STRUCTURAL SYSTEM

HIGH-PERFORMANCE BUILDING ENVELOPE

LOW-CARBON IMPACT MATERIALS

ENERGY RECOVERY SYSTEMS

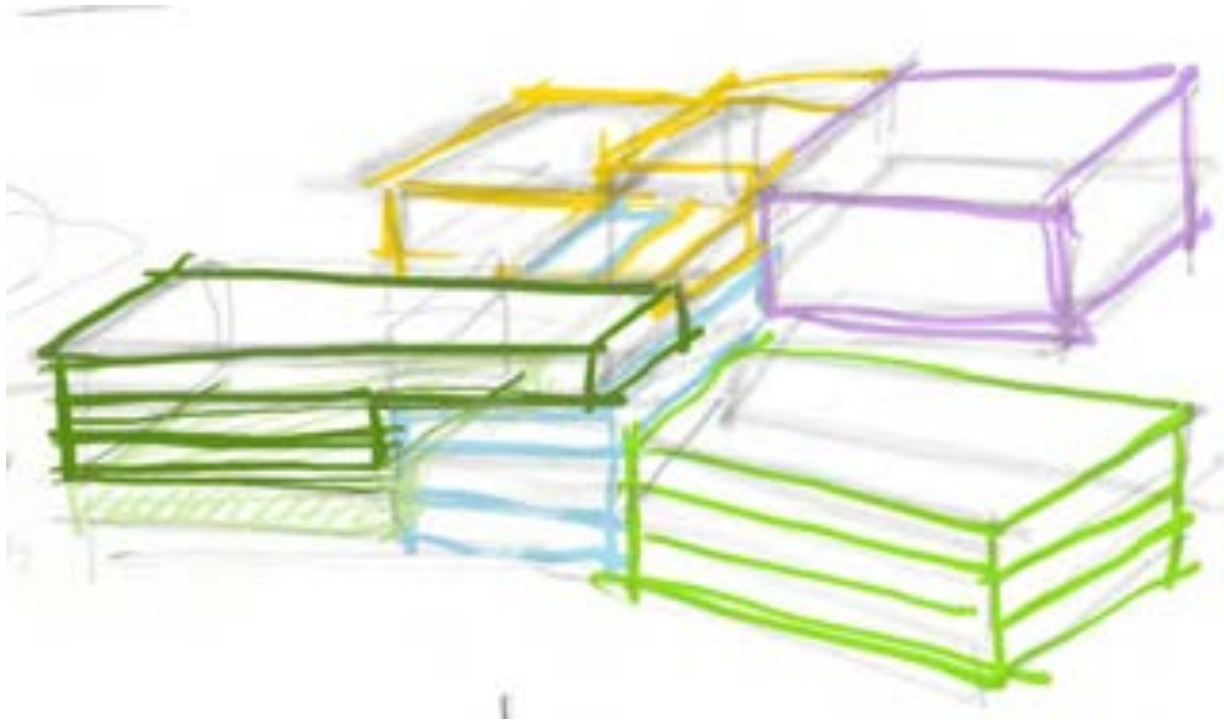
PROGRAM FIT

MONTESSORI PHILOSOPHY

TMVL Feasibility Study; 1st Image: School and students. End and 3rd Image: Montessori method and materials for learning Perkins Eastman, 2019

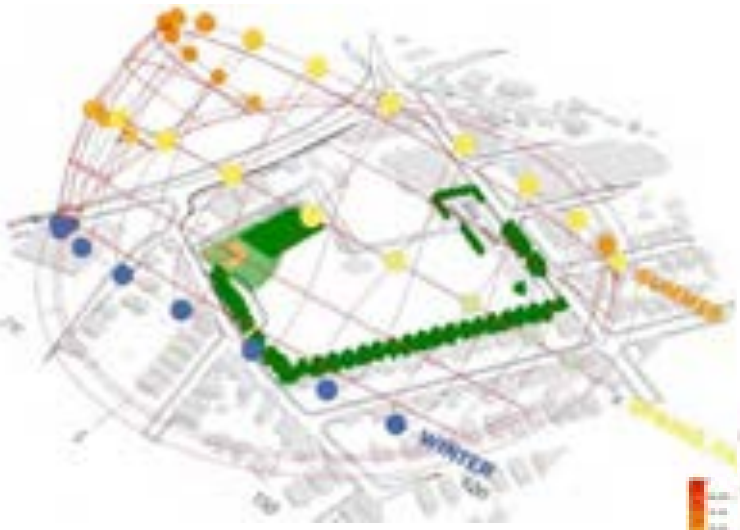
ECOREGIONS INTEGRATION

DESIGN CONCEPT

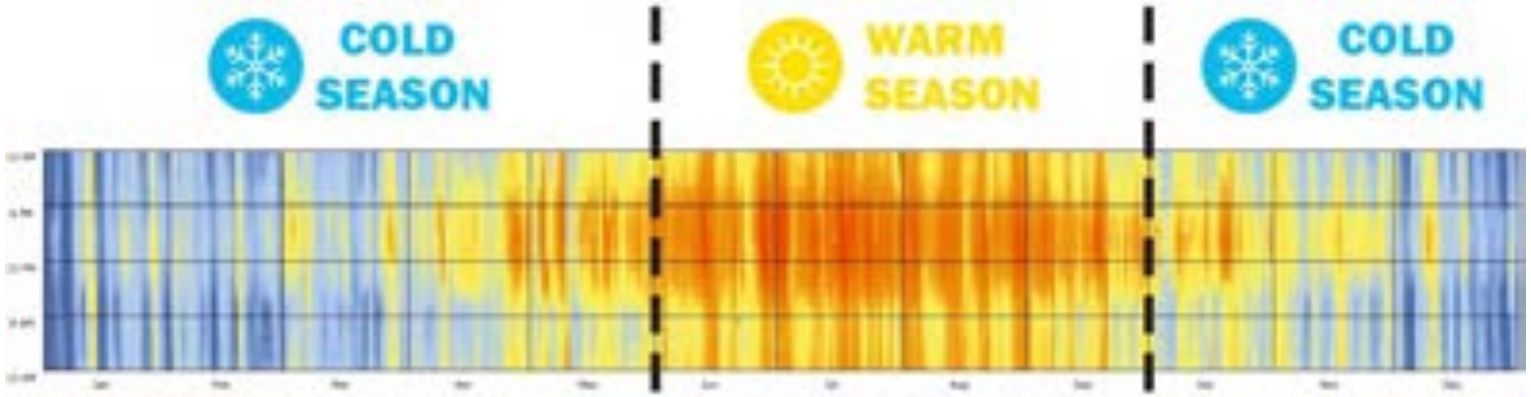


Perkins Eastman 2020

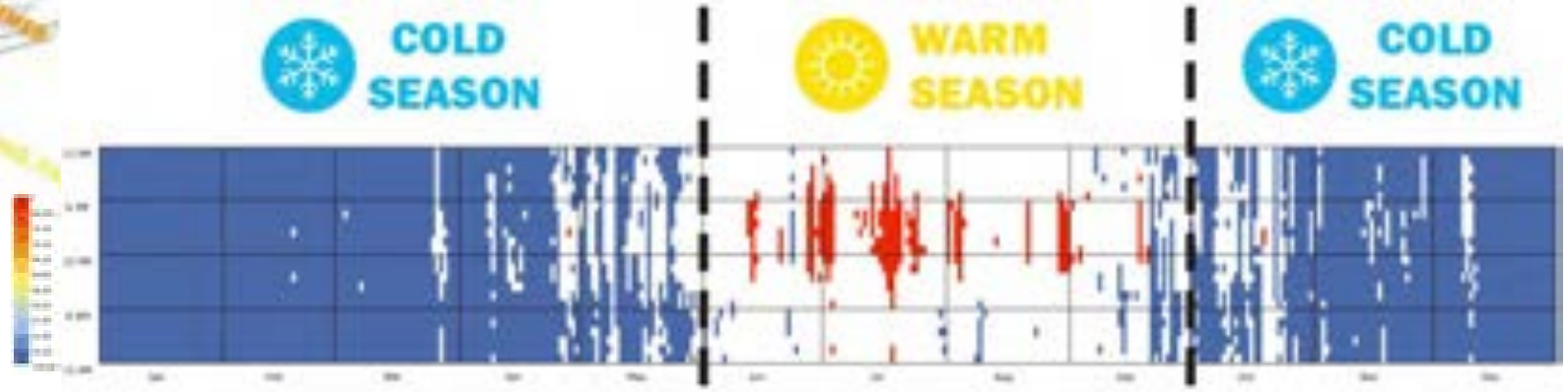
CLIMATE ANALYSIS



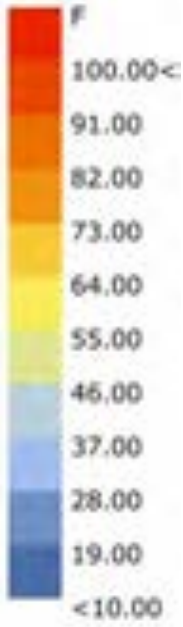
(1 OCT - 31 MAY) (1 OCT - 31 MAY) (1 JUN - 30 SEPT)



Yearly Temperature Chart



Yearly Thermal Comfort Chart

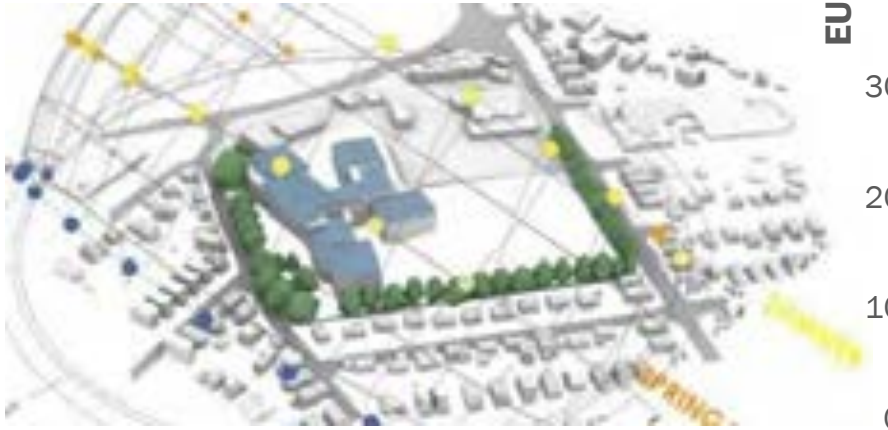


HEAT STRESS
COMFORT
COLD STRESS

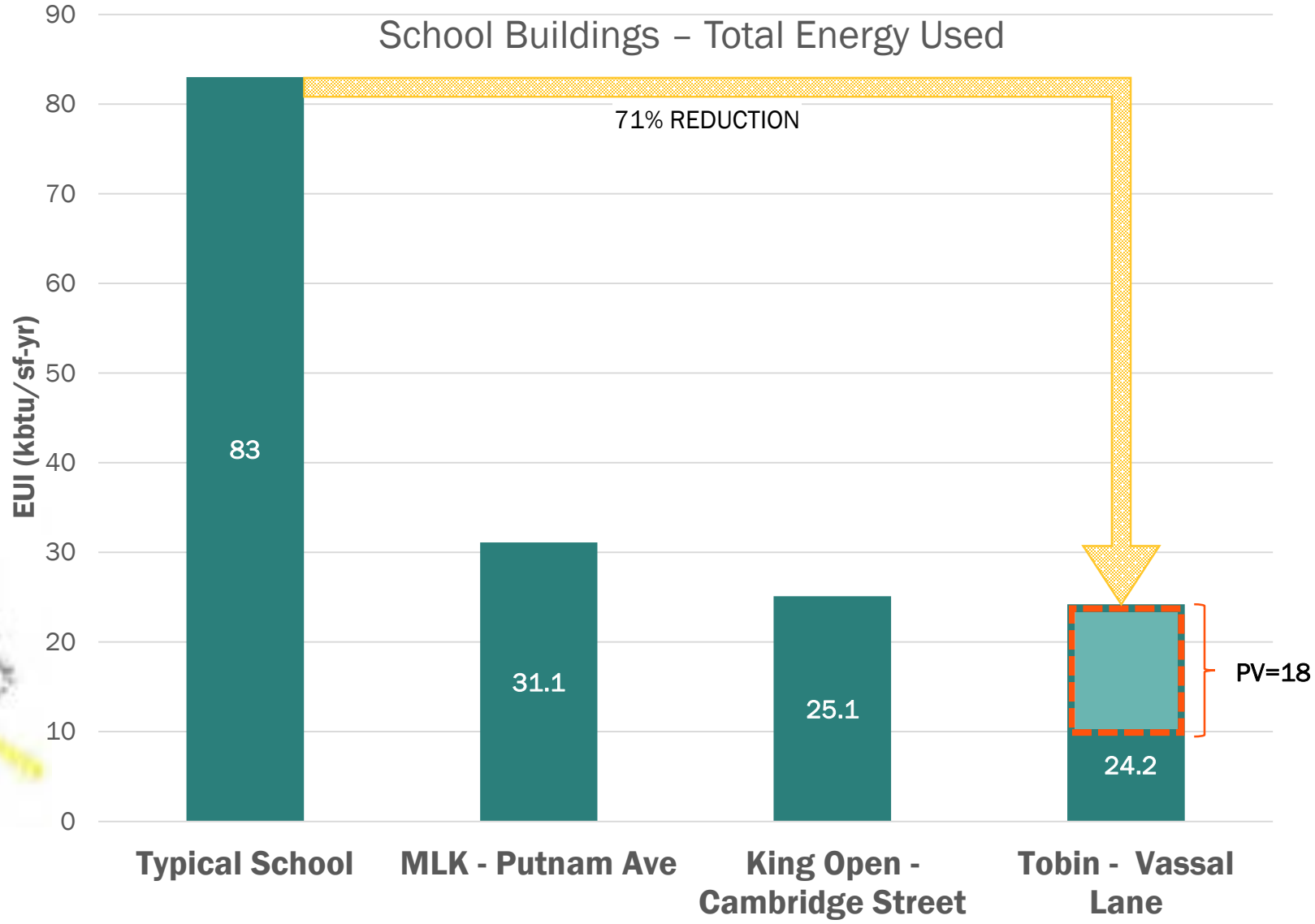
Perkins Eastman 2020

A HIGH PERFORMANCE BUILDING

1. Maximally Efficient -- Low Energy Use Intensity (EUI)
2. All-electric systems
3. Renewable energy



PASSIVE INTELLIGENCE



TMVL, Perkins Eastman 2020

DAYLIGHT STORIES

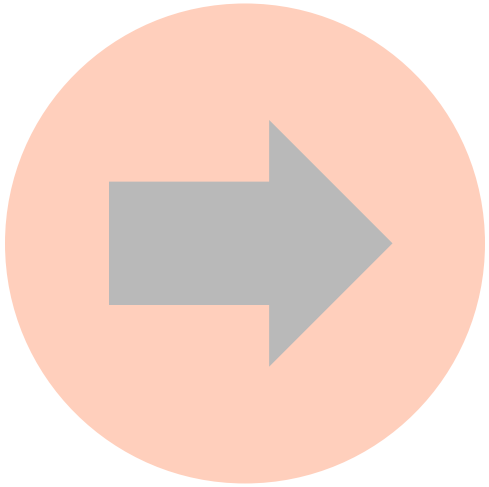
KEEPING THE EXISTING SCHOOL OR BUILDING A NEW ONE?

Renovation vs. New Construction

Iterative Workflow

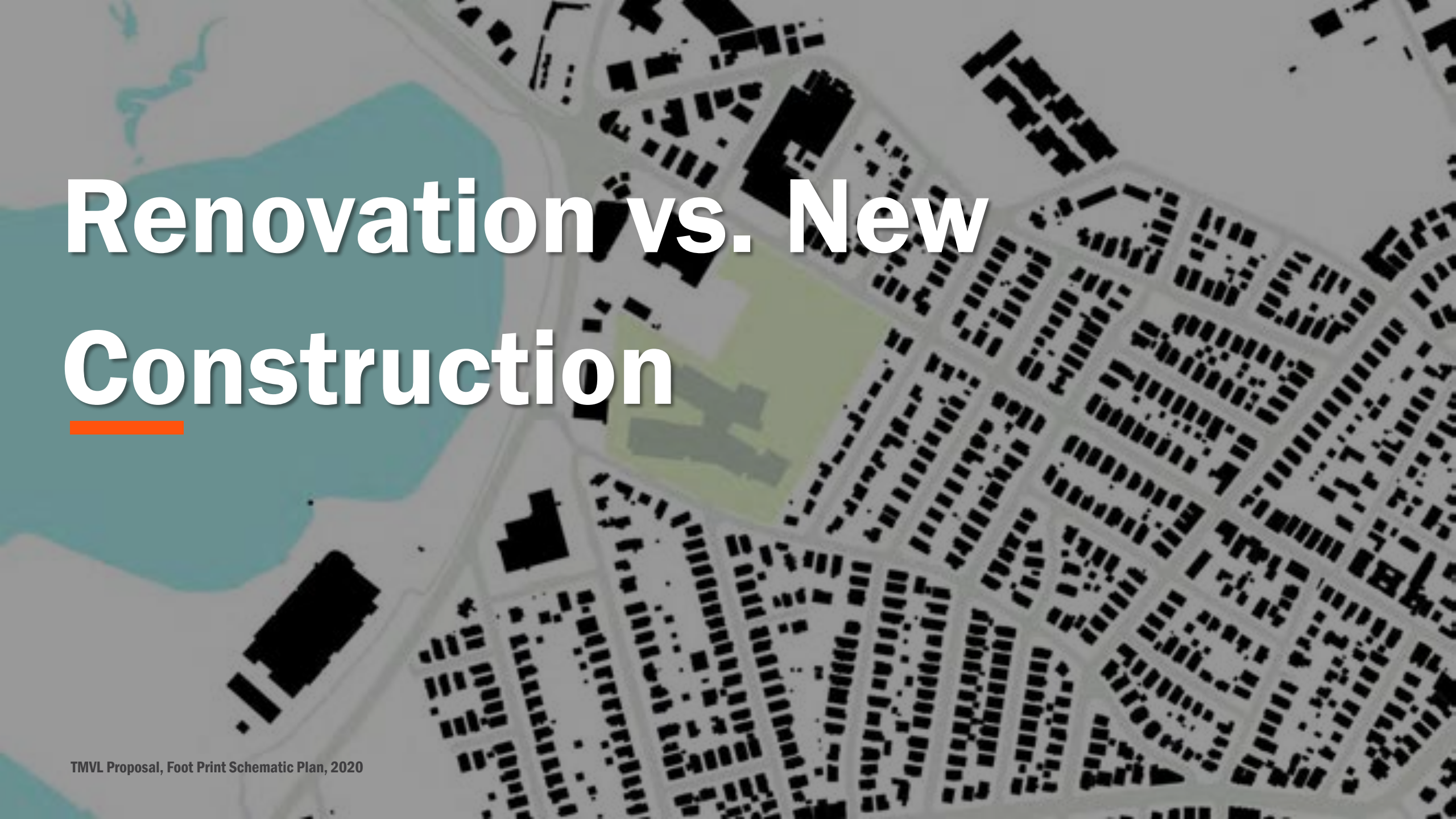
Design Exercise and Rules of Thumb

Community



Conclusion and Next Steps

Renovation vs. New Construction



TMVL Proposal, Foot Print Schematic Plan, 2020

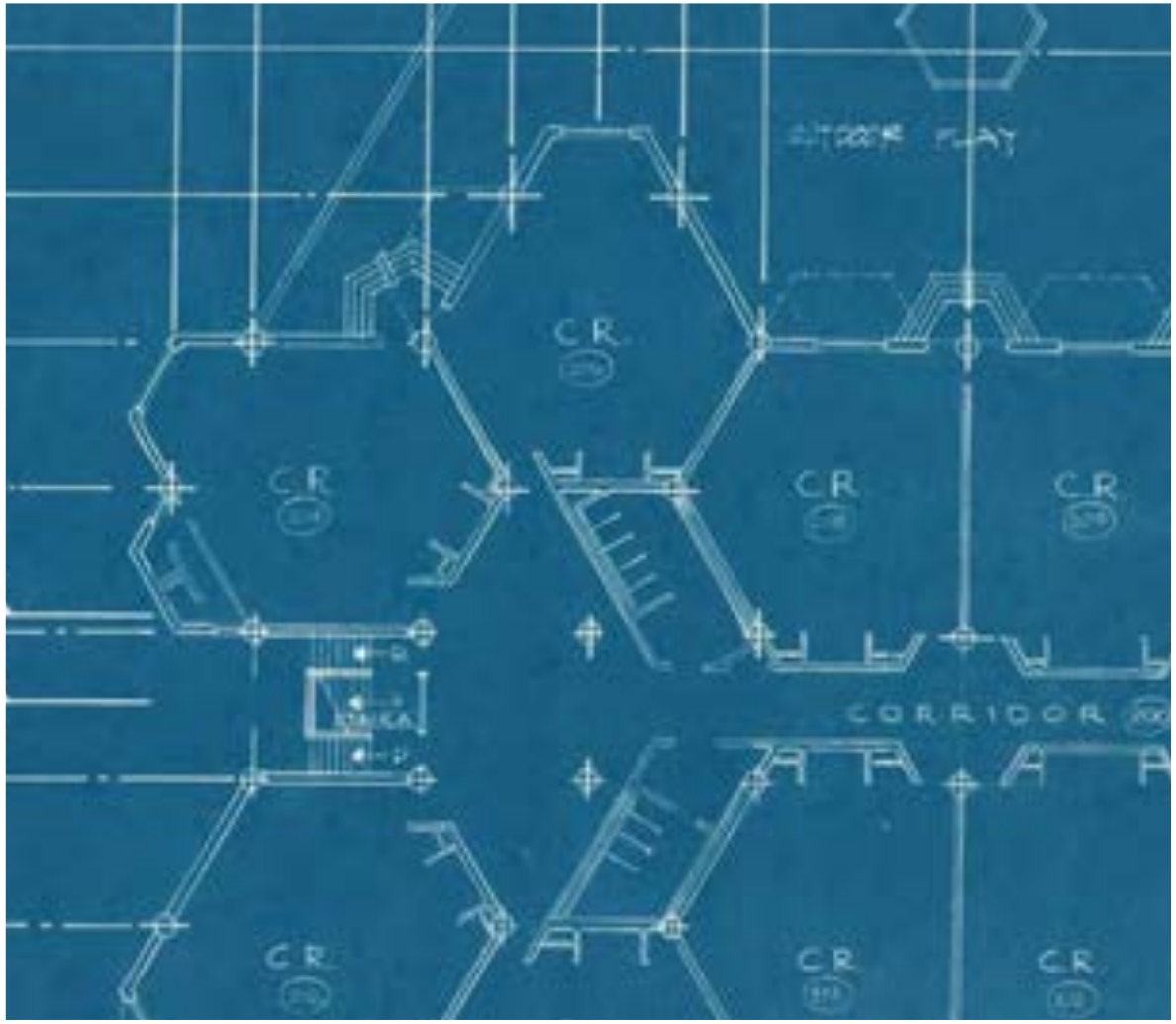
EXISTING CONDITIONS - EXTERIOR

A BUILDING BEYOND ITS USEFUL LIFE

TMVL Existing Building Photos, Perkins Eastman 2019

EXISTING BUILDING CLASSROOMS

POTENTIAL FOR DAYLIGHT



TMVL Existing Building Plan and Photos, Pietro Belluschi

SITE COMPLEXITY AND PROPOSAL

PRE AND POST CONSTRUCTION COMPARISION

Perkins Eastman 2020

RENOVATION VS. NEW CONSTRUCTION

NEW DESIGNS AND EXISTING BUILDING

OPTION 1: RENOVATION

OPTION 2: NEIGHBORHOODS

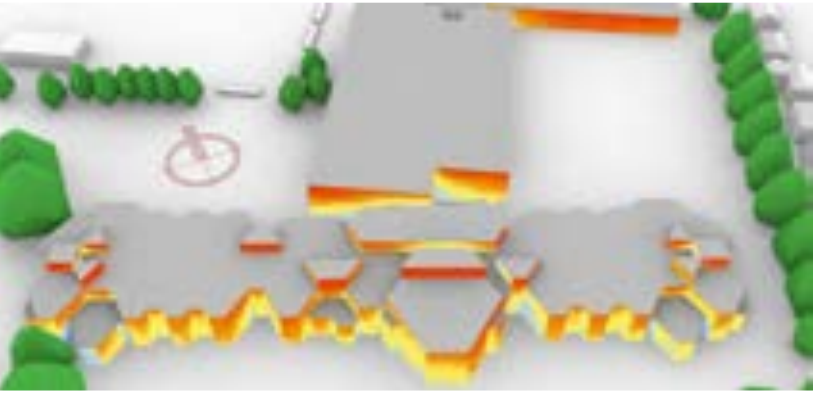
OPTION 3: GRAND COURT

Perkins Eastman 2020

ENVELOPE ANALYSIS

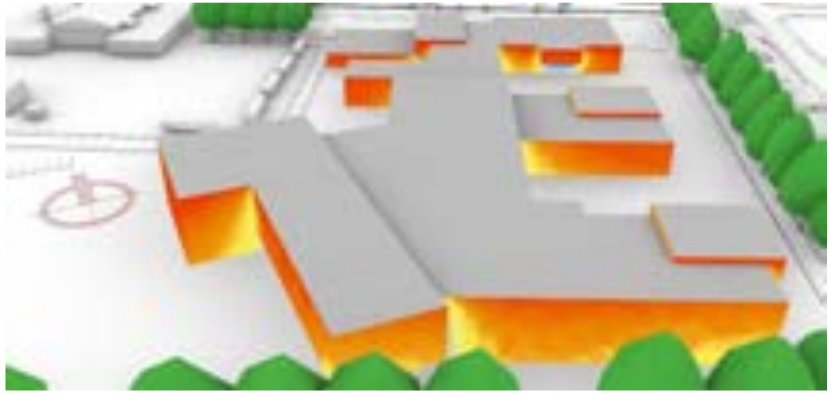
SCENARIOS COMPARISION

OPTION 1: RENOVATION



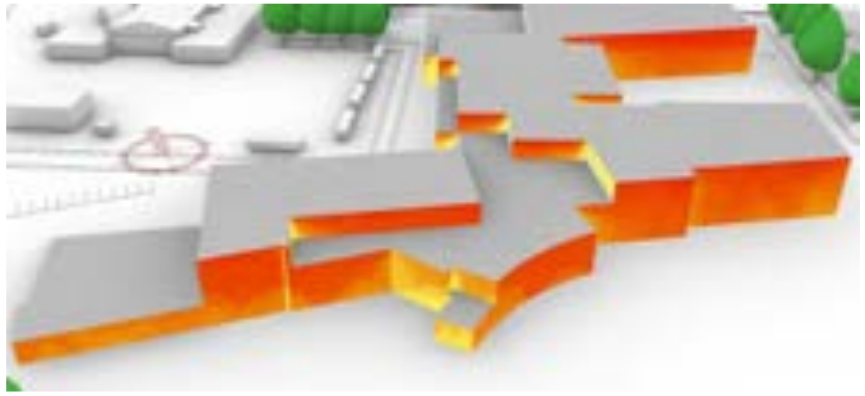
BASELINE:
EXISTING BUILDING

OPTION 2: NEIGHBORHOODS



9% LESS SUMMER SOLAR RADIATION
12% MORE WINTER SOLAR RADIATION
26% LESS ENVELOPE AREA

OPTION 3: GRAND COURT

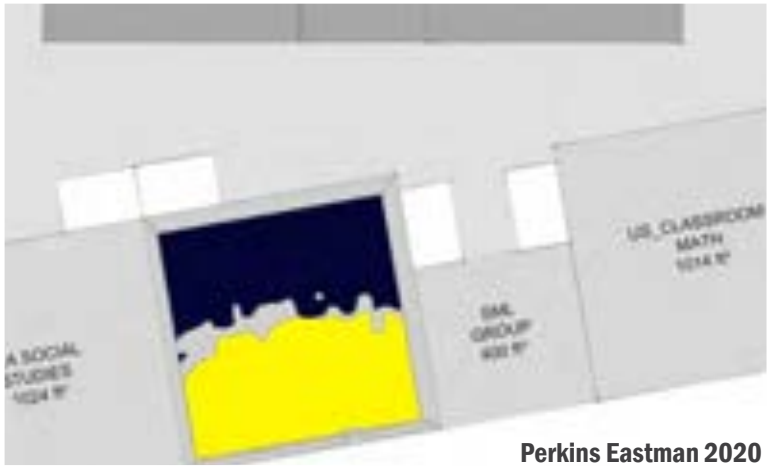


7% LESS SUMMER SOLAR RADIATION
15% MORE WINTER SOLAR RADIATION
24% LESS ENVELOPE AREA

Perkins Eastman 2020

ENERGY AND DAYLIGHT

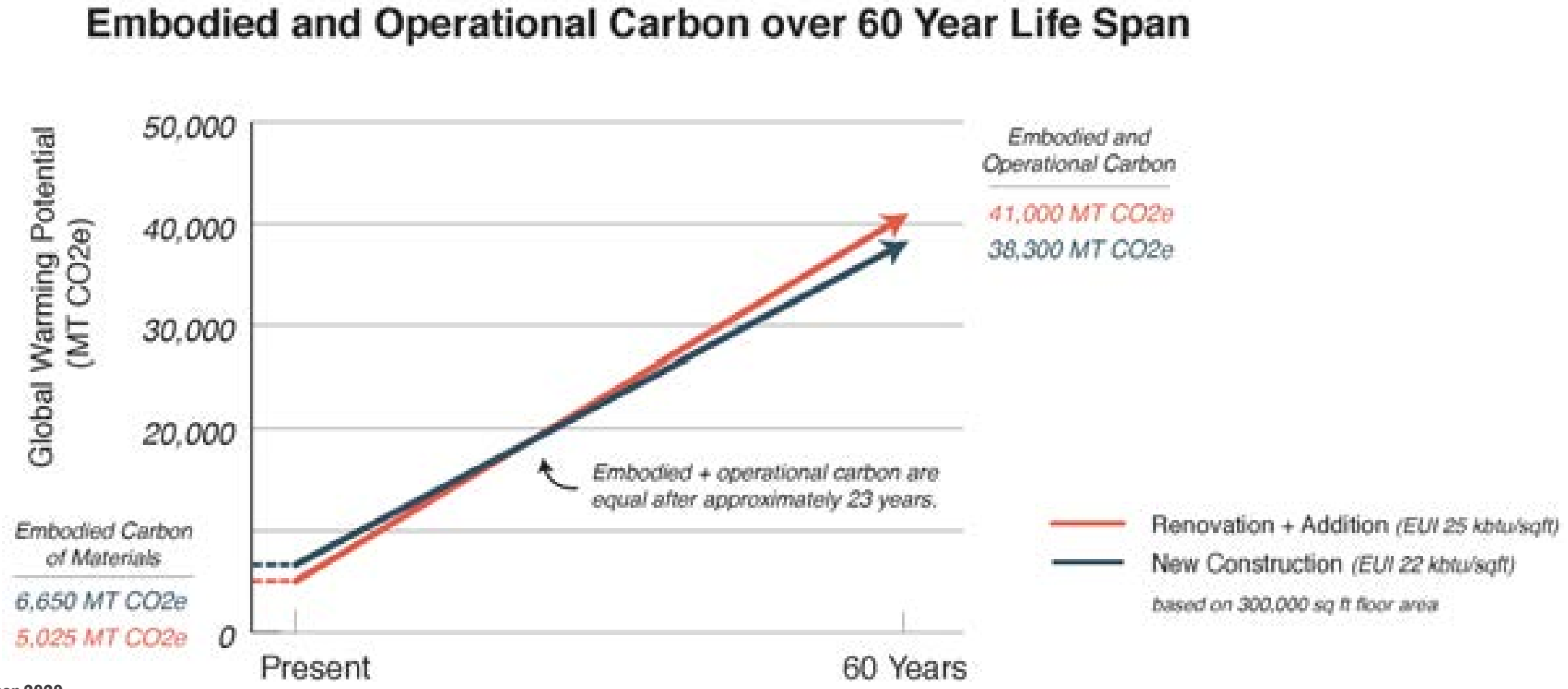
DAYLIGHT SHOEBOX ANALYSIS FOR CLASSROOMS

	OPTION 1: EXISTING BUILDING RENO. + ADDITION BASELINE	OPTION 2: NEIGHBORHOODS	OPTION 3: GRAND COURT
			
SDA >75%	21%	45% +24%	53% +32%
ASE <10%	13%	16% +3%	15% +2%
EUI <25 KBTU/SF/YR	EUI: 54	EUI: 49 -9%	EUI: 47 -13%

Perkins Eastman 2020

TO KEEP OR NOT TO KEEP?

RENOVATION/ADDITION VS. NEW CONSTRUCTION



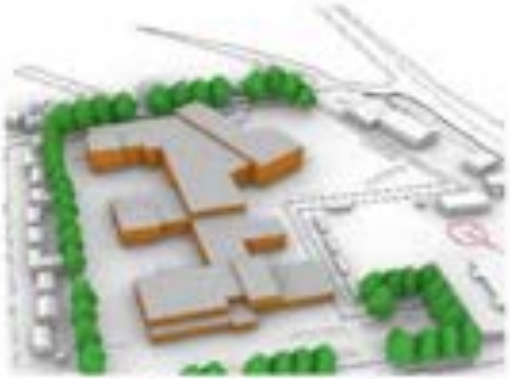
Perkins Eastman 2020

NET ZERO POTENTIAL

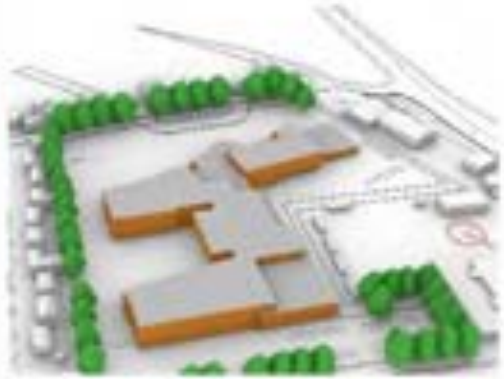
LEGEND
Category Performance

- BEST
- BETTER
- GOOD

RENOVATION



NEIGHBORHOODS



GRAND COURT

	RENOVATION	NEIGHBORHOODS	GRAND COURT
Passive Heating Potential	○	◐	●
Passive Cooling Potential	○	●	◐
PV Generation Potential	○	◐	●
Outdoor Thermal Comfort	◐	○	●
Interior Daylight Performance	○	◐	●
Annual Energy Use	○	◐	●
Compact Building	○	◐	●
Embodied+Operational Carbon	○	◐	●

Perkins Eastman 2020

DAYLIGHT STORIES

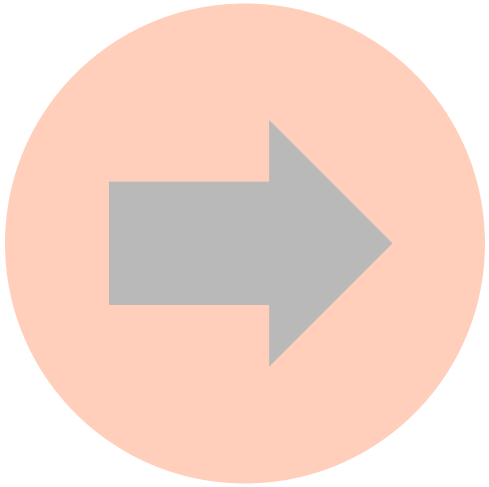
ITERATIONS FOR DAYLIGHT DESIGN

Renovation vs. New Construction

Iterative Workflow

Design Exercise and Rules of Thumb

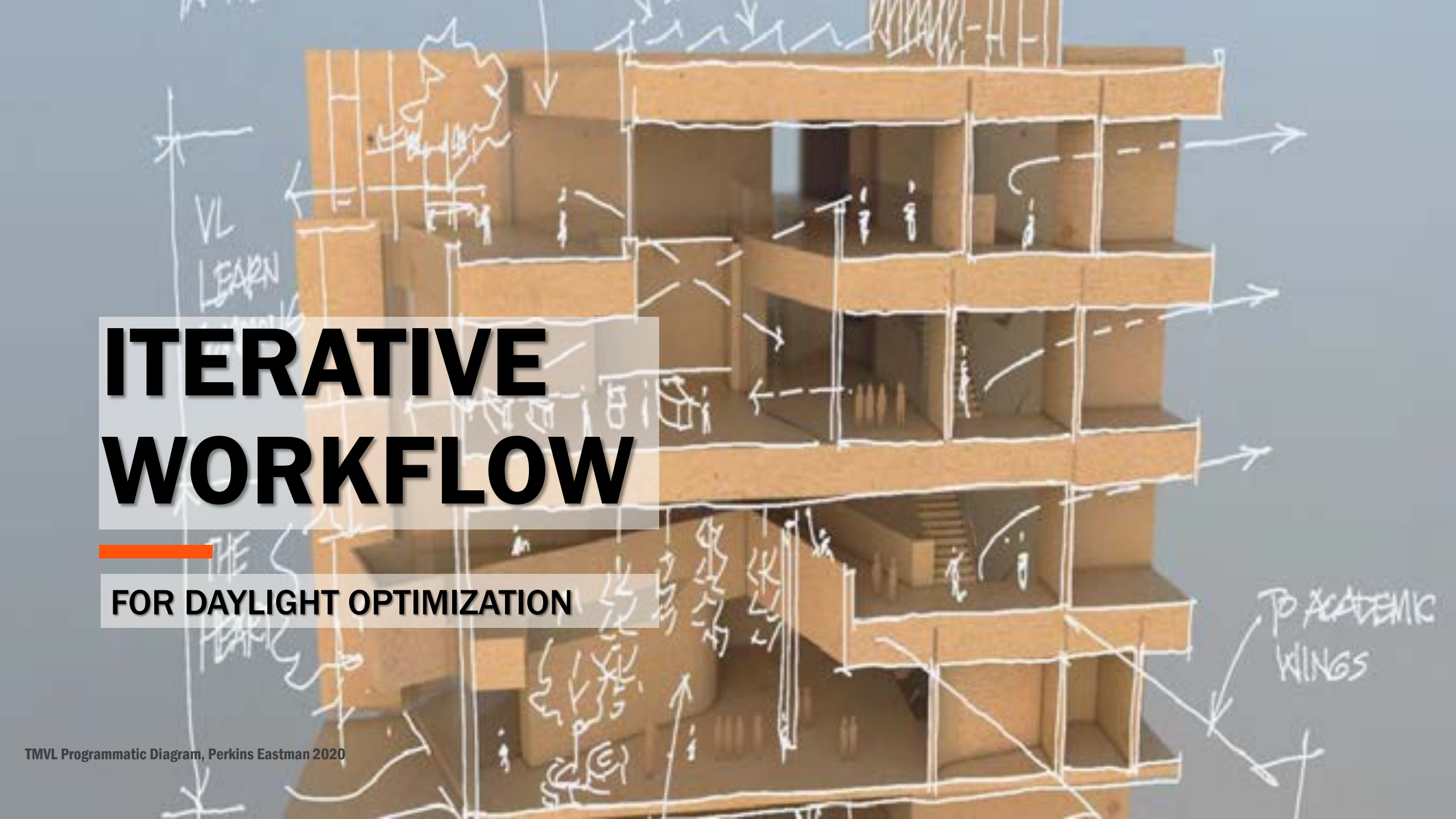
Community Participation



Conclusion and Next Steps

ITERATIVE WORKFLOW

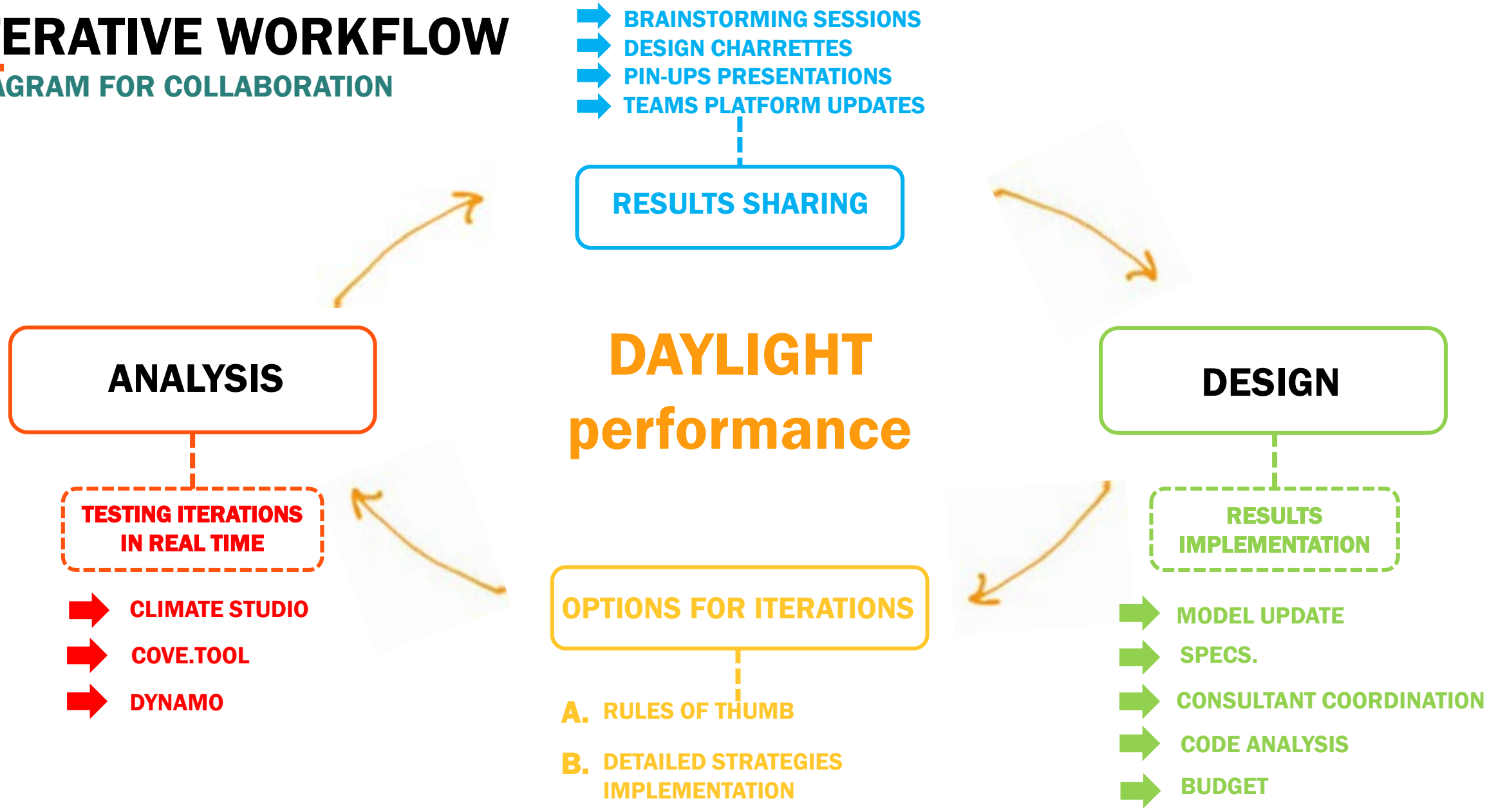
FOR DAYLIGHT OPTIMIZATION



TMVL Programmatic Diagram, Perkins Eastman 2020

ITERATIVE WORKFLOW

DIAGRAM FOR COLLABORATION



Perkins Eastman 2022

TEAM COLLABORATION

COLLABORATIVE WORKFLOW

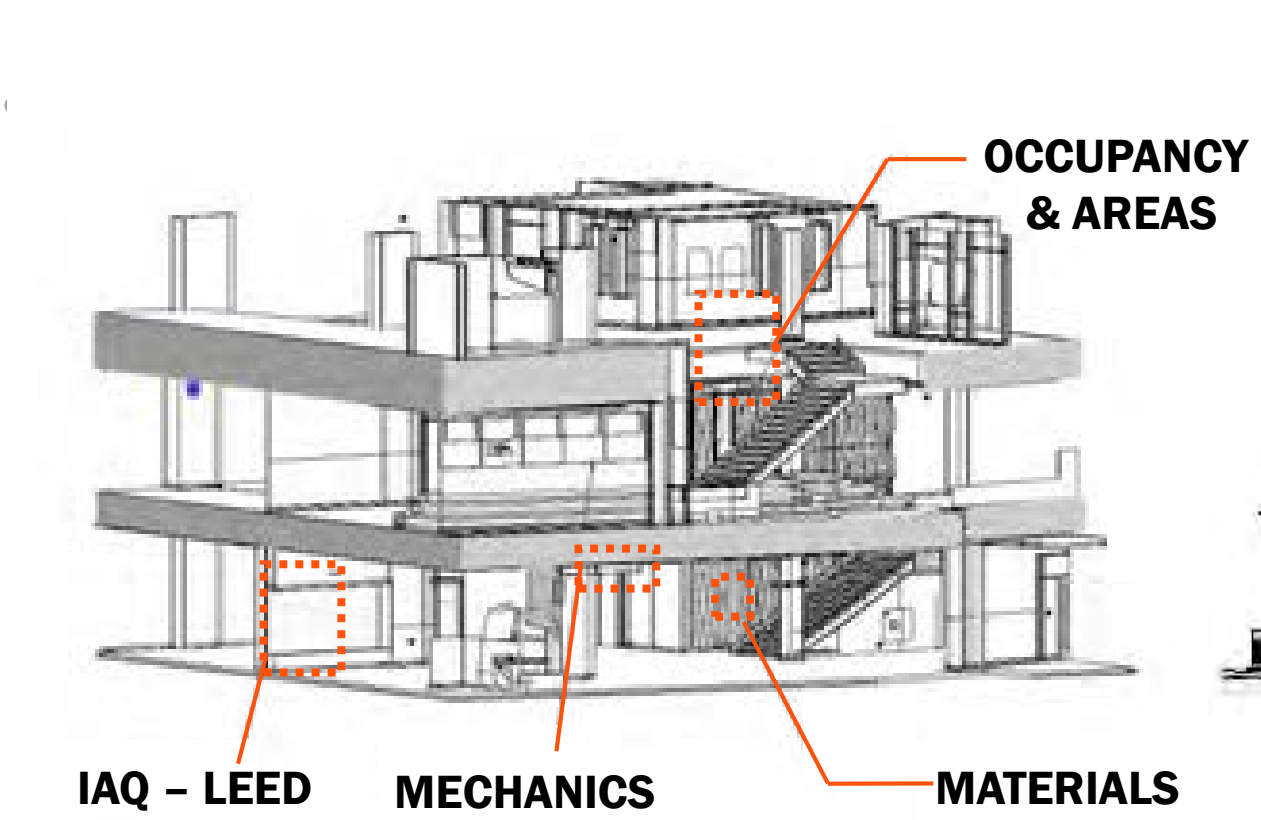


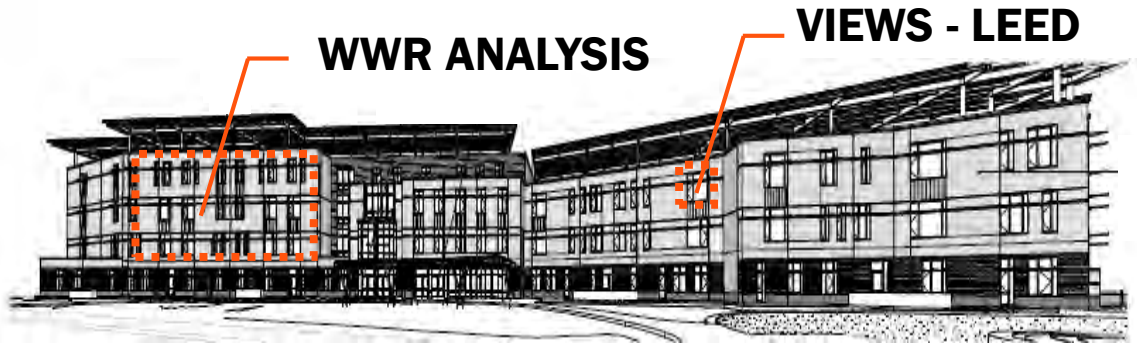



TMVL Photographic archive with Community meetings, Team design Pin-Ups, Users Focus groups Charrettes, Performance analysis meetings over Teams platform

BIM REAL-TIME DATA

WHERE ALL THE DATA LIVES

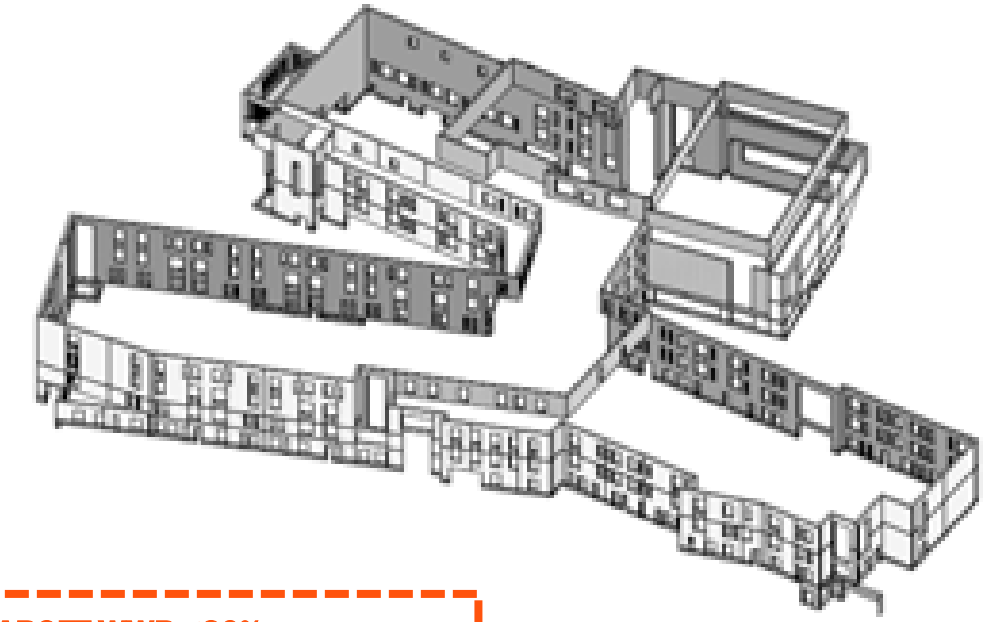




TMVL Interface on COVE.TOOL Platform for WWR analysis, 2022.

WINDOW TO WALL RATIO BASELINE

WHERE WE STARTED



TARGET WWR <30%

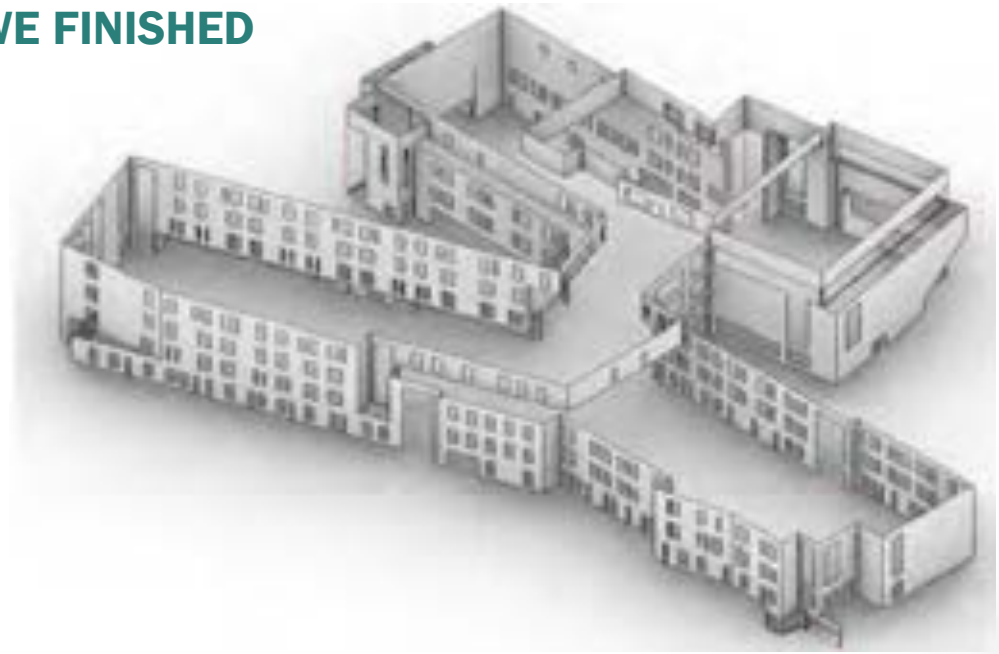
BASELINE WWR: 23%

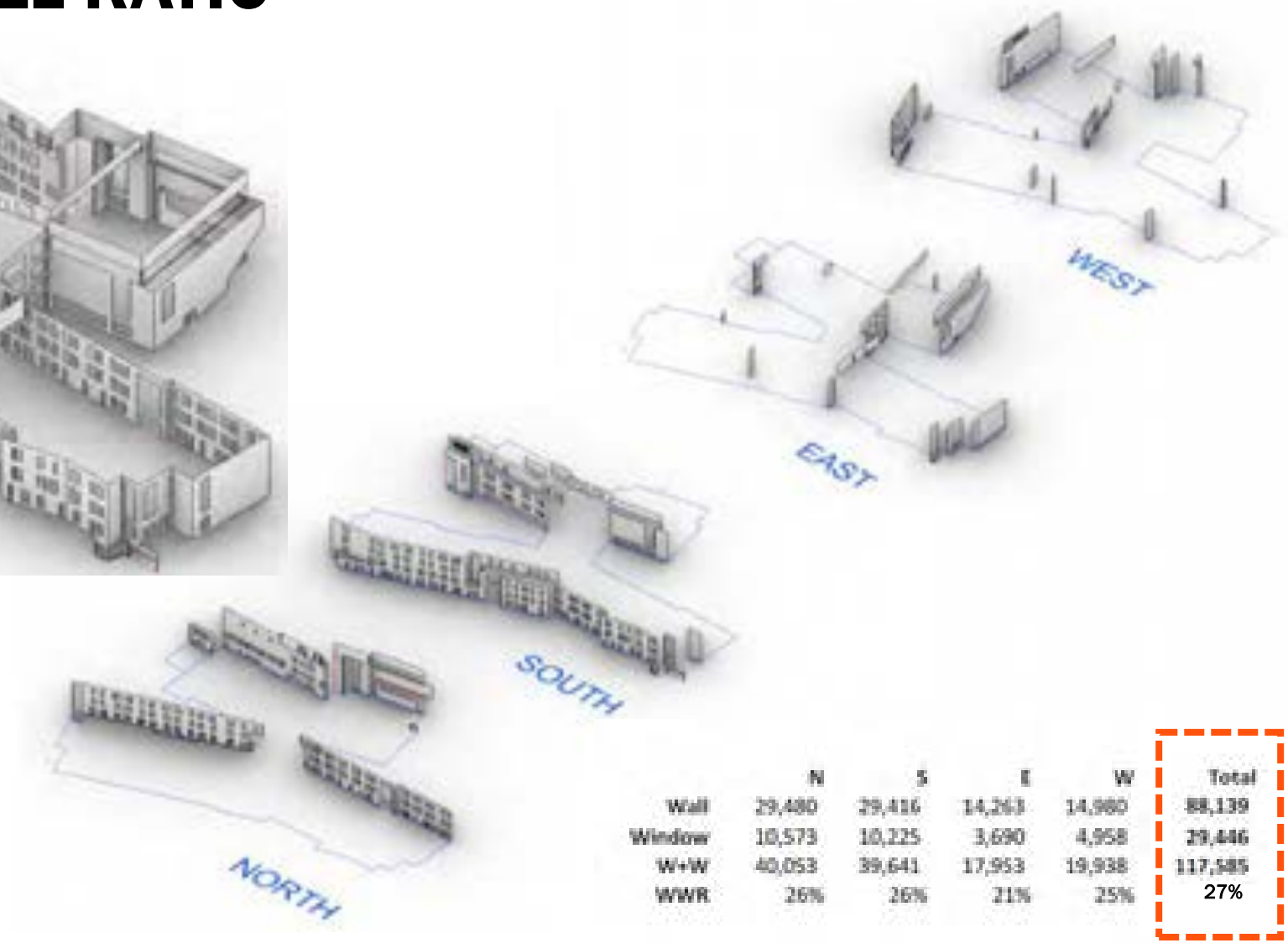
	N	NE	E	SE	S	SW	W	NW	Total
Wall	14,675	15,272	8,634	5,758	14,375	15,448	7,480	7,798	89,440
window	5,145	4,459	2,585	706	4,837	4,603	3,080	617	26,032
W+W	19,820	19,731	11,219	6,464	19,212	20,051	10,560	8,415	115,472
WWR	26%	23%	23%	11%	25%	23%	29%	7%	23%

TMVL Interface on COVE.TOOL Platform for WWR analysis, 2020.

FINAL WINDOW TO WALL RATIO

WHERE WE FINISHED





TARGET WWR <30%

FINAL WWR: 27%

	N	S	E	W	Total
Wall	29,480	29,416	14,263	14,980	88,139
Window	10,573	10,225	3,690	4,958	29,446
W+W	40,053	39,641	17,953	19,938	117,585
WWR	26%	26%	21%	25%	27%

TMVL Interface on COVE.TOOL Platform for WWR analysis, 2022.

BIM MODEL: DIGGING DEEPER

LABELING OCCUPANCY AREAS

NOT REGULARLY OCCUPIED

REGULARLY OCCUPIED – SINGLE USER

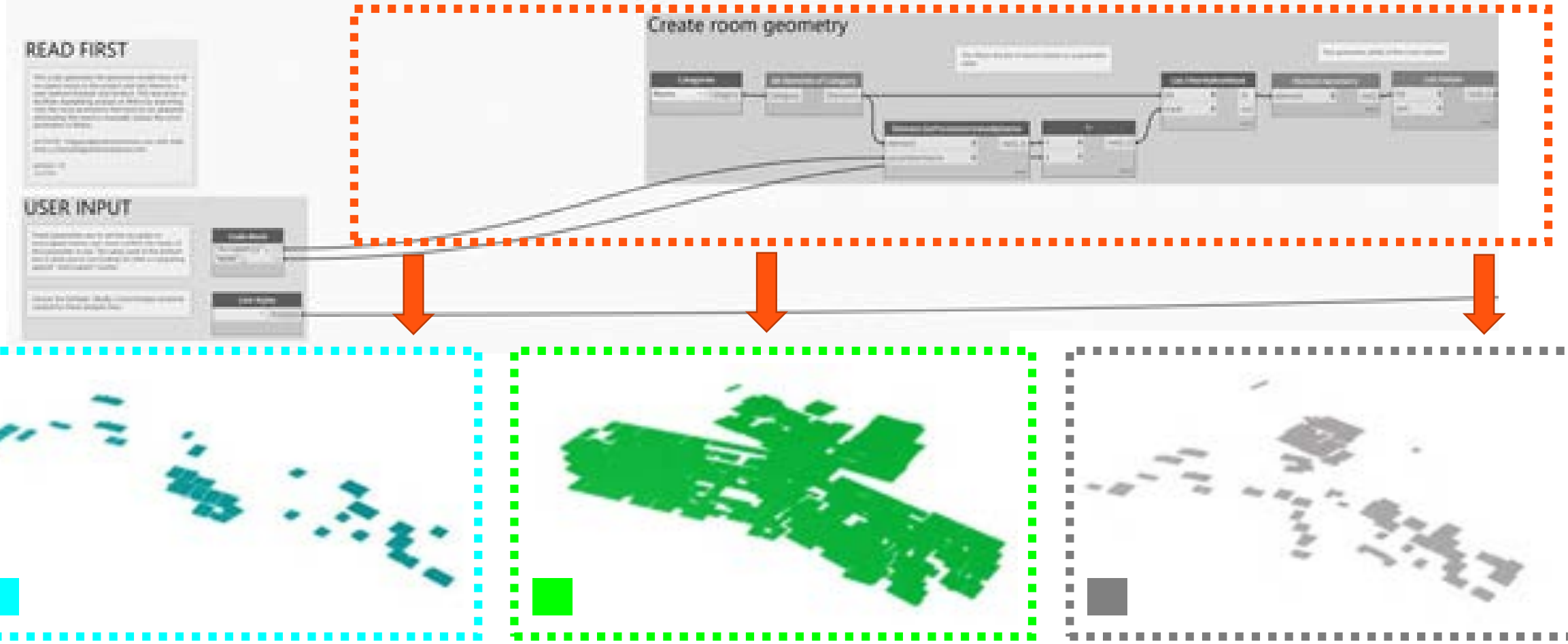
REGULARLY OCCUPIED – MULTI-USER

TMVL Interface on Revit for “Occupied Areas” Graphic Analysis, Perkins Eastman 2022.

AREAS AND ANALYSIS

A SCRIPT THAT EXTRACTS THE INFORMATION

TMVL interface Image on Climate Studio + Rhino/Dynamo for “Occupied Areas” Exporting Operation, Perkins Eastman 2022.



SINGLE AND MULTI USER REGULARLY OCCUPIED SPACES

NONREGULARLY OCCUPIED SPACES

FINE-TUNING

MATERIALS SETUP AND ANALYSIS FOR EDUCATION

DAYLIGHT

TARGET SDA: >75%

GLARE

TARGET ASE: <10%

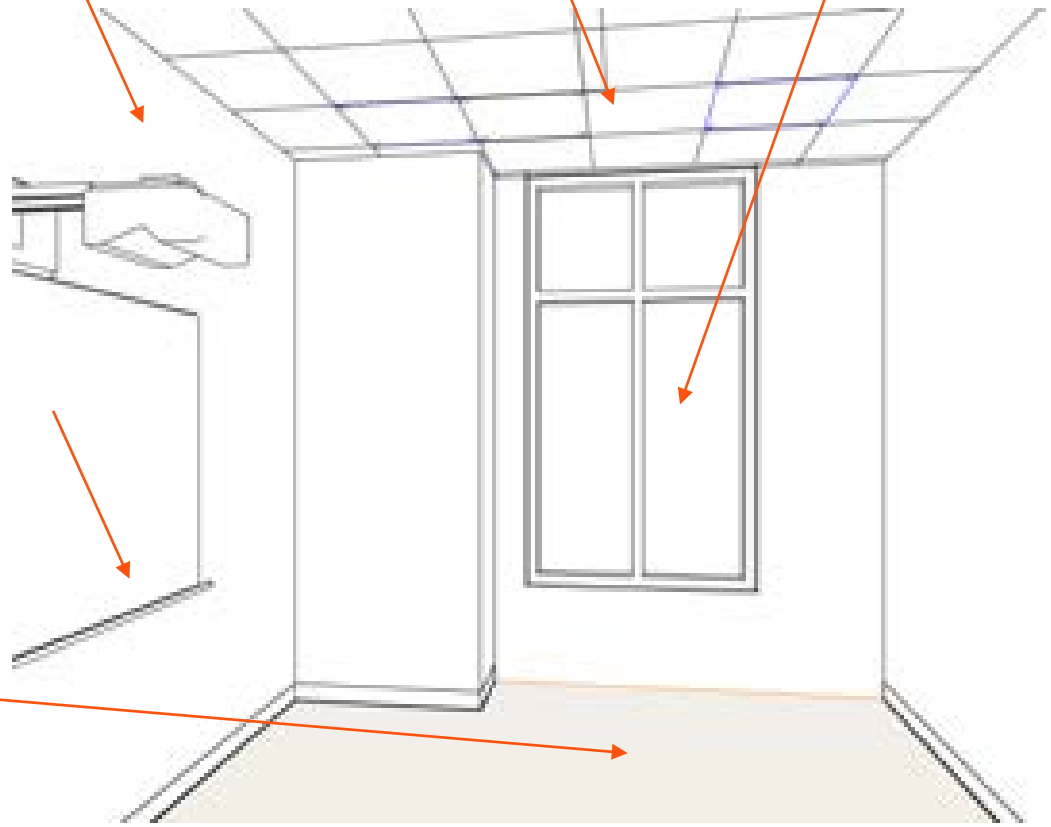
IDEAL REFLECTANCE

- Ceiling – 80-90%
- Walls – 40-60%
- Floors – 30-50%
- Furnishings – 30-50%

WALL MATERIAL:
MACBETH NEUTRAL
60% REFLECTANCE

CEILING:
ACT
85% REFLECTANCE

WINDOW:
SOLAR BLUE
55% VLT



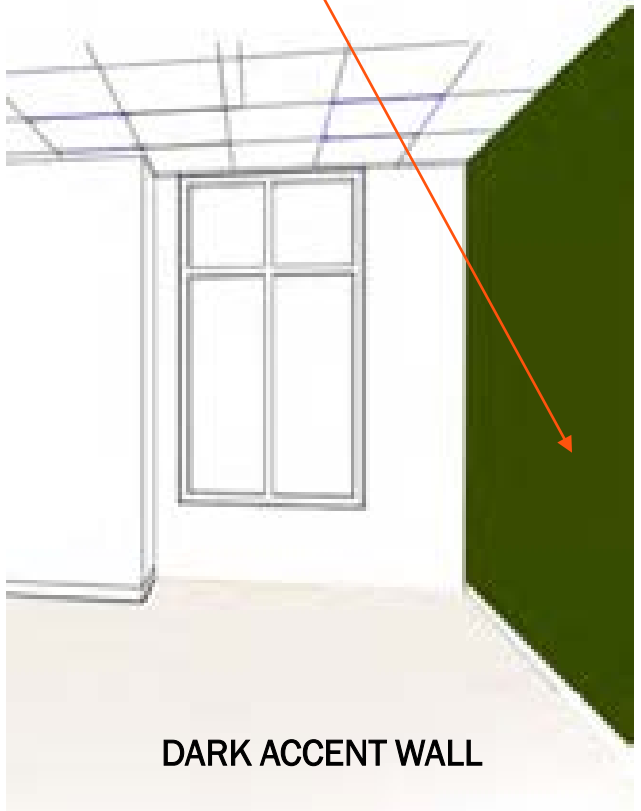
FLOOR:
BEIGE FLOOR
49% REFLECTANCE

TMVL Reflectance and Color Studio on Climate Studio, Perkins Eastman 2022.

SURFACE REFLECTANCE

MATERIALS ANALYSIS

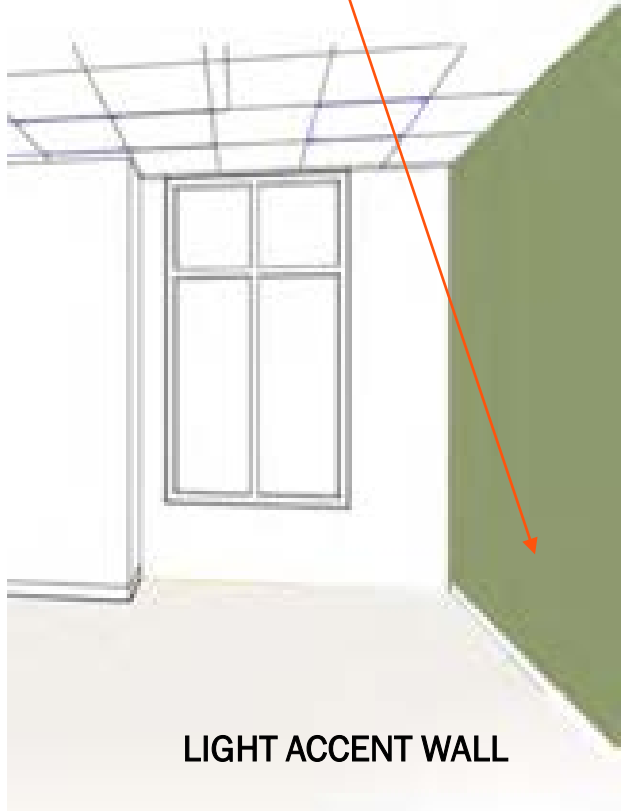
WALL 1:
MACBETH GREEN 22% REFLECTANCE



DARK ACCENT WALL

45% 3%

WALL 2:
DUPONT PALE GREEN 62% REFLECTANCE



LIGHT ACCENT WALL

64% 4%

DAYLIGHT
SDA >75%

GLARE
ASE <10%

Left: Sherwin Williams Suburban Modern Paint Palette 2020. Right: TMVL Reflectance and Color Studio on Climate Studio, Perkins Eastman 2022.

DAYLIGHT STORIES

DESIGN EXERCISES AND RULES OF THUMB

Renovation vs. New Construction

Iterative Workflow

Design Exercise and Rules of Thumb

Community Participation

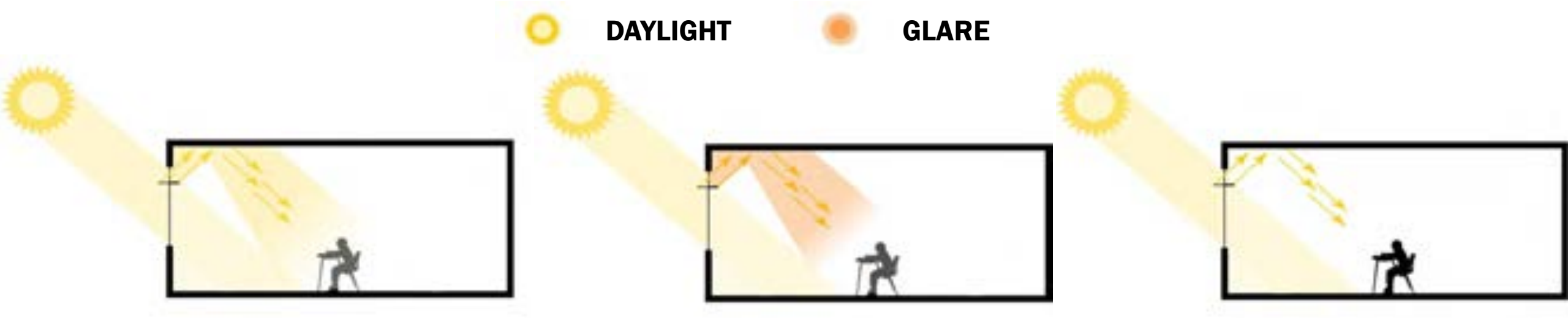
Conclusion and Next Steps

DAYLIGHT

PRECONCEPTIONS AND IDEAS ABOUT DAYLIGHT RESPONSIVENESS & SHADING OPTIMIZATION

Typical Façade – View at VLUS Entrance, PE 2021

POLL: WHAT DO YOU THINK WILL BE THE EFFECT OF ADDING LIGHTSHELVES TO THIS PROJECT?

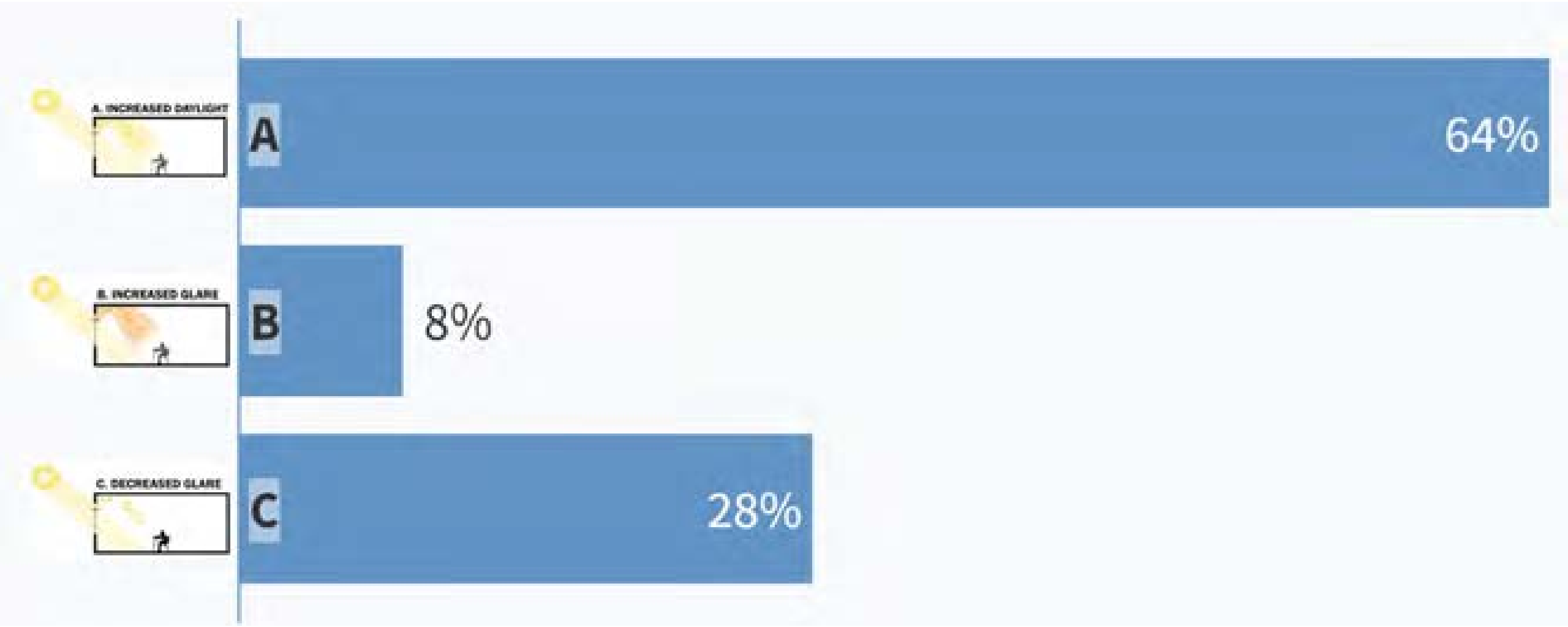


A.
INCREASED DAYLIGHT

B.
INCREASED GLARE

C.
DECREASED GLARE

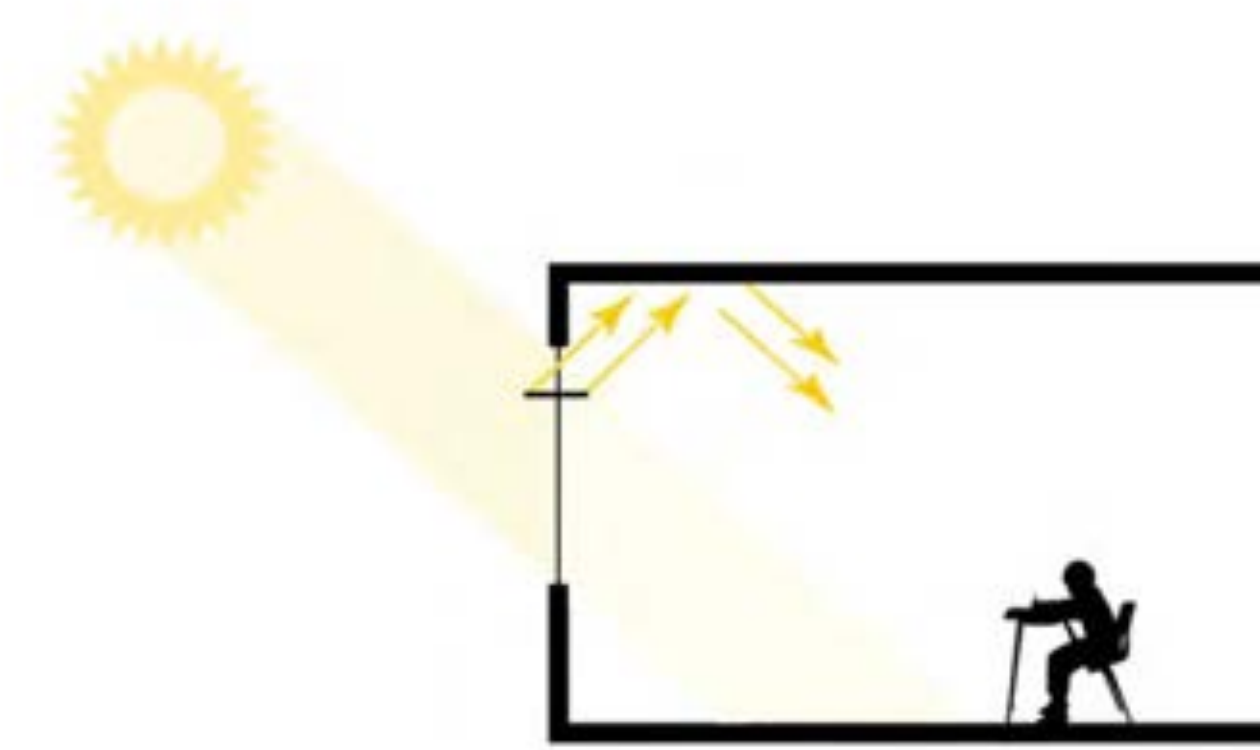
POLL RESULTS: WHAT DO YOU THINK WILL BE THE EFFECT OF ADDING LIGHTSHELVES TO THIS PROJECT?



DOUBLE CHECKING THE RULES OF THUMB

LIGHT SHELVES POTENTIAL

"LIGHT SHELVES HELP REFLECT DAYLIGHT"



Perkins Eastman 2022.

CLAIMS ABOUT LIGHTSHELVES

MANUFACTURES INFORMATION

Source: Thurston Elementary School, **Mahlum Architects Inc.**

Source: PHIPPS Center for Sustainable Landscapes, The Design Alliance Architects

Daylight Penetration

Makes it possible for daylight to penetrate the space up to 2.5 to 4 times the distance between the floor and the top of the window.

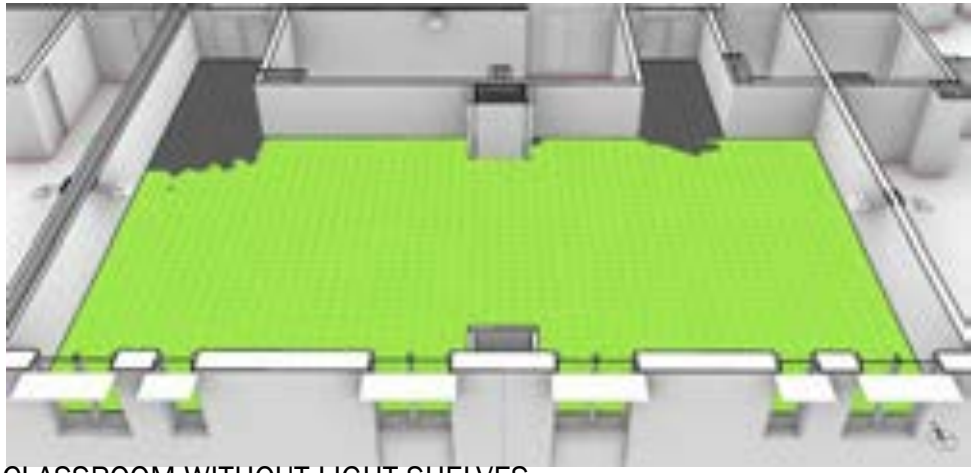
Source: CS Interior Lightshelves, Construction Specialties

Intermediate light shelves eliminate direct sunlight on critical task areas located near a solar glazed window (facing the equator), and reflect sunlight to the ceiling where it is evenly redistributed. Light shelves can extend the depth of side daylighting to 2.5 times the height of the glazed opening.

Source: Intermediate Light Shelves, 2030 Palette

LIGHT SHELVES ON THE SOUTH FACADE

FIRST ANALYSIS: WITH AND WITHOUT LIGHT SHELVES



CLASSROOM WITHOUT LIGHT SHELVES

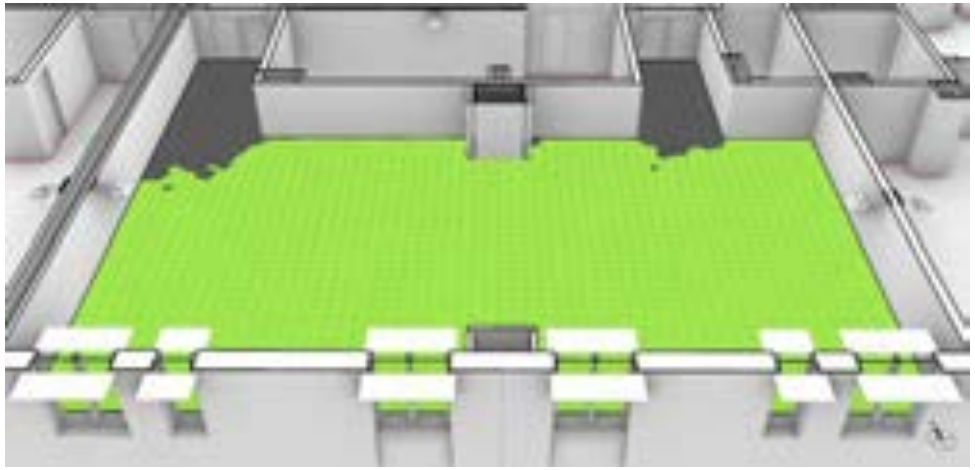
DAYLIGHT: 83%

GLARE: 5%

Perkins Eastman 2022

DAYLIGHT
SDA >75%

GLARE
ASE <10%



CLASSROOM WITH LIGHT SHELVES

DAYLIGHT: 80%

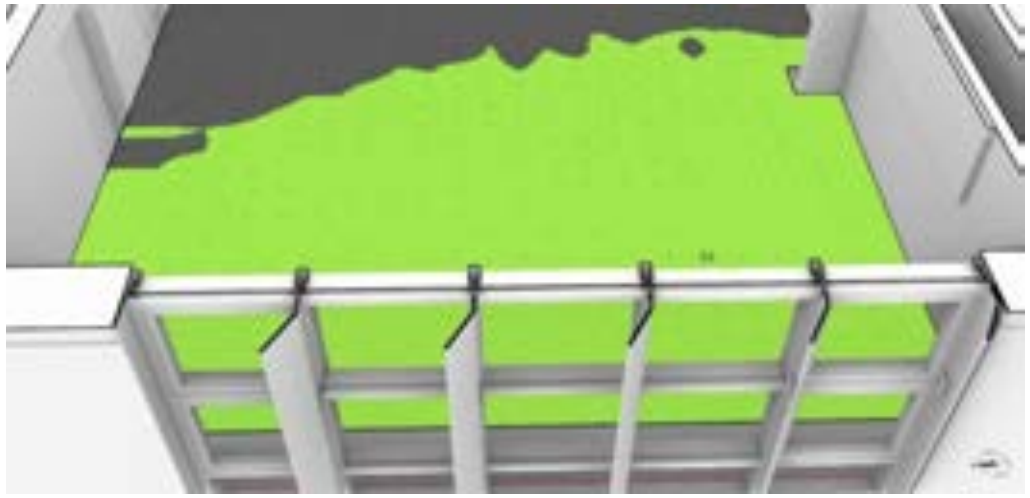
GLARE: 4%

-3%

-1%

LIGHT SHELVES ON THE WEST/EAST FACADE

SECOND ANALYSIS: WITH AND WITHOUT LIGHT SHELVES



CLASSROOM WITHOUT LIGHT SHELVES

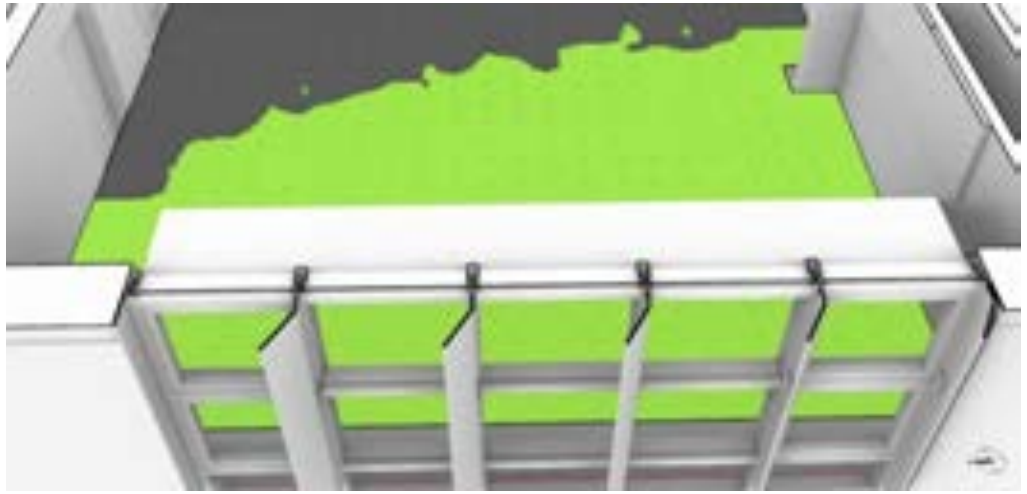
DAYLIGHT: 69%

GLARE: 6%

Perkins Eastman 2022

DAYLIGHT
SDA >75%

GLARE
ASE <10%



CLASSROOM WITH LIGHT SHELVES

DAYLIGHT: 66%

GLARE: 4%

-3%

-2%

LIGHT SHELVES IN THIS CASE WERE...

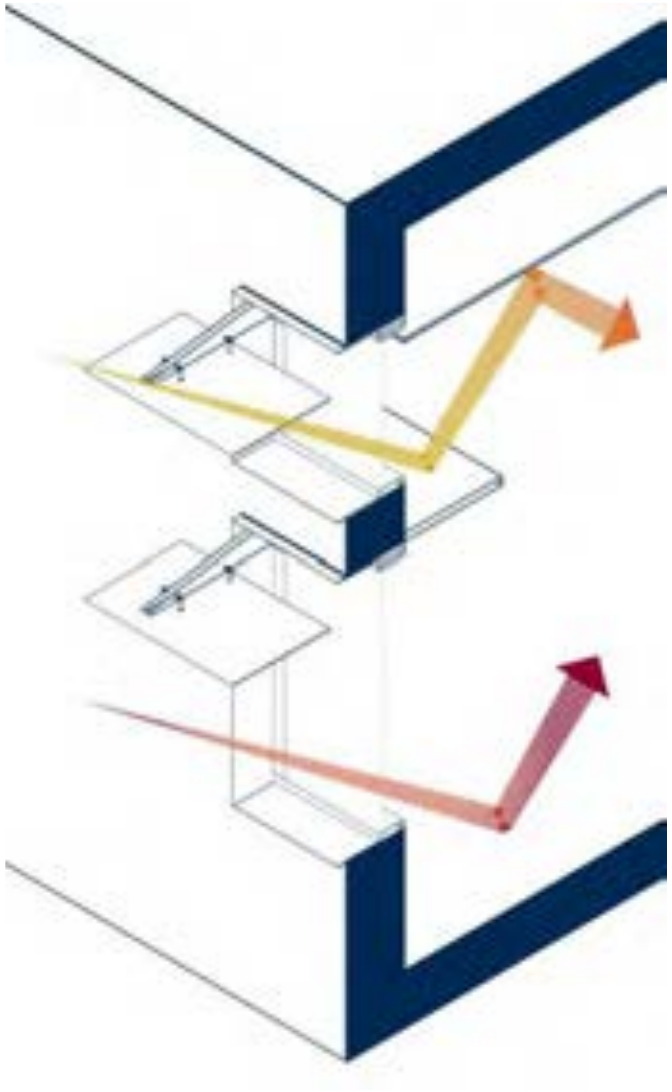
LIGHT SHELVES IMPACT

Reducing
Daylight Autonomy

Increasing
Budget

Increasing
Embodied Carbon

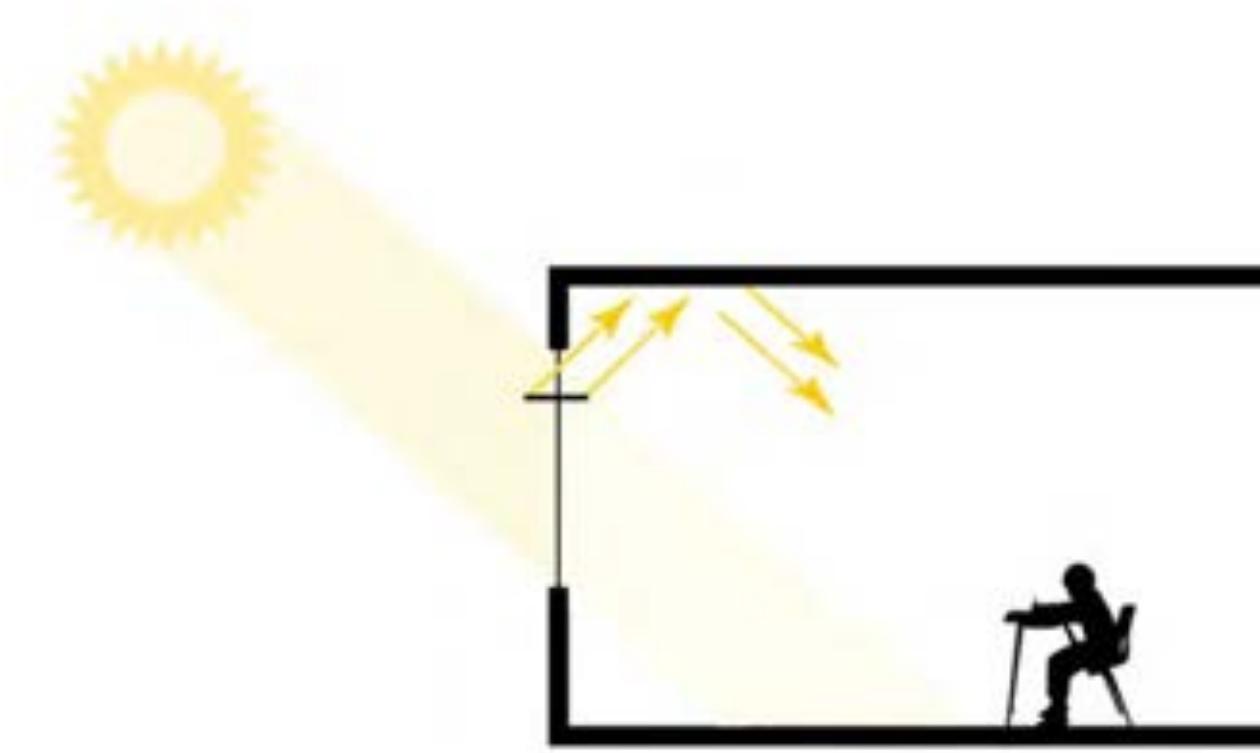
Reducing
Glare



DOUBLE CHECKING THE RULES OF THUMB

YES, BUT...

"LIGHT SHELVES ARE GOOD FOR REFLECTING DAYLIGHT"

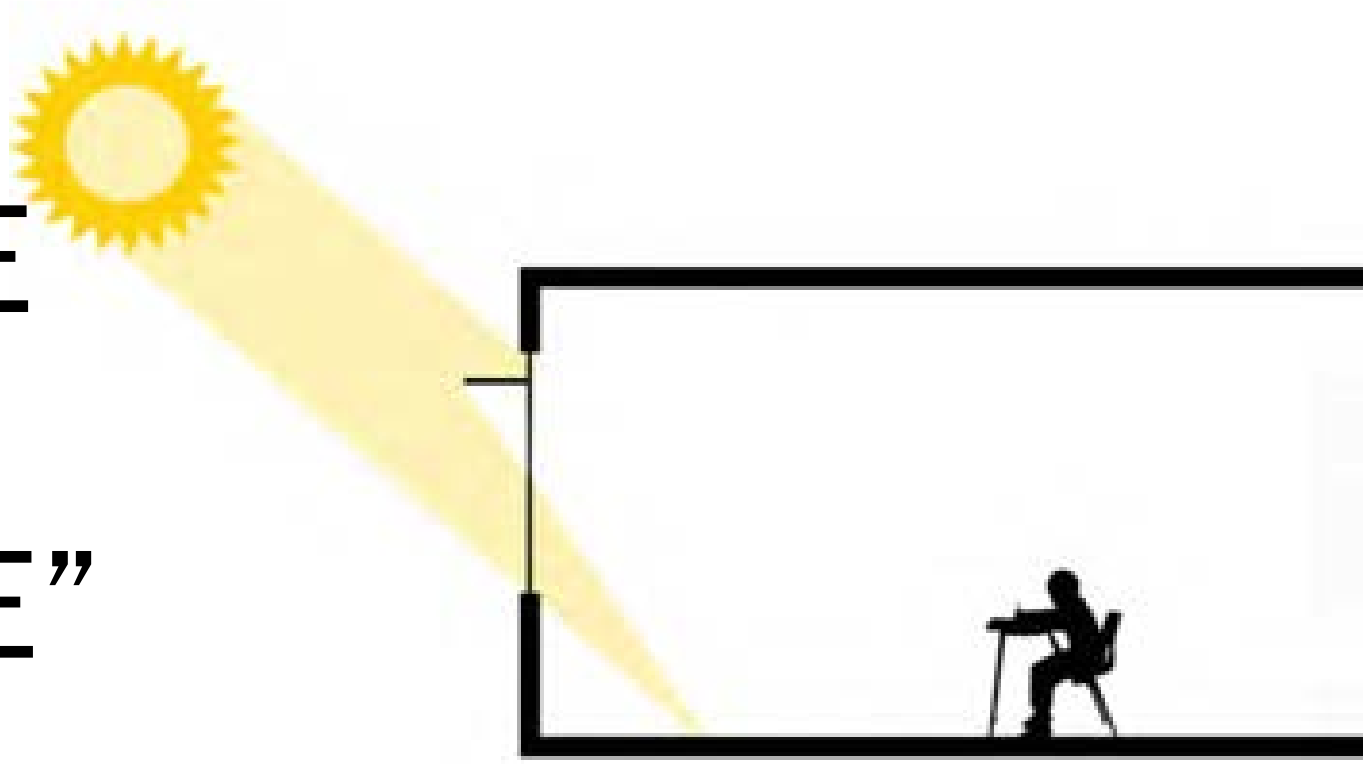


YES BUT, DURING VERY SPECIFIC TIMES OF THE YEAR

Perkins Eastman 2022.

DOUBLE CHECKING THE RULES OF THUMB

"THE MORE SHADING, THE BETTER THE PERFORMANCE"



Perkins Eastman 2022.

RULES OF THUMB FOR SHADING

LATITUDE RULE OF THUMB FOR SHADING DEPTH

-1/4 the height of the opening at 28°- 32° Latitude
-1/3 the height of the opening at 36°- 40° Latitude
-1/2 the height of the opening at 44°- 56° Latitude

Source: Solar Shading, 2030 Palette

SOLAR ANGLE RULE OF THUMB FOR SHADING DEPTH

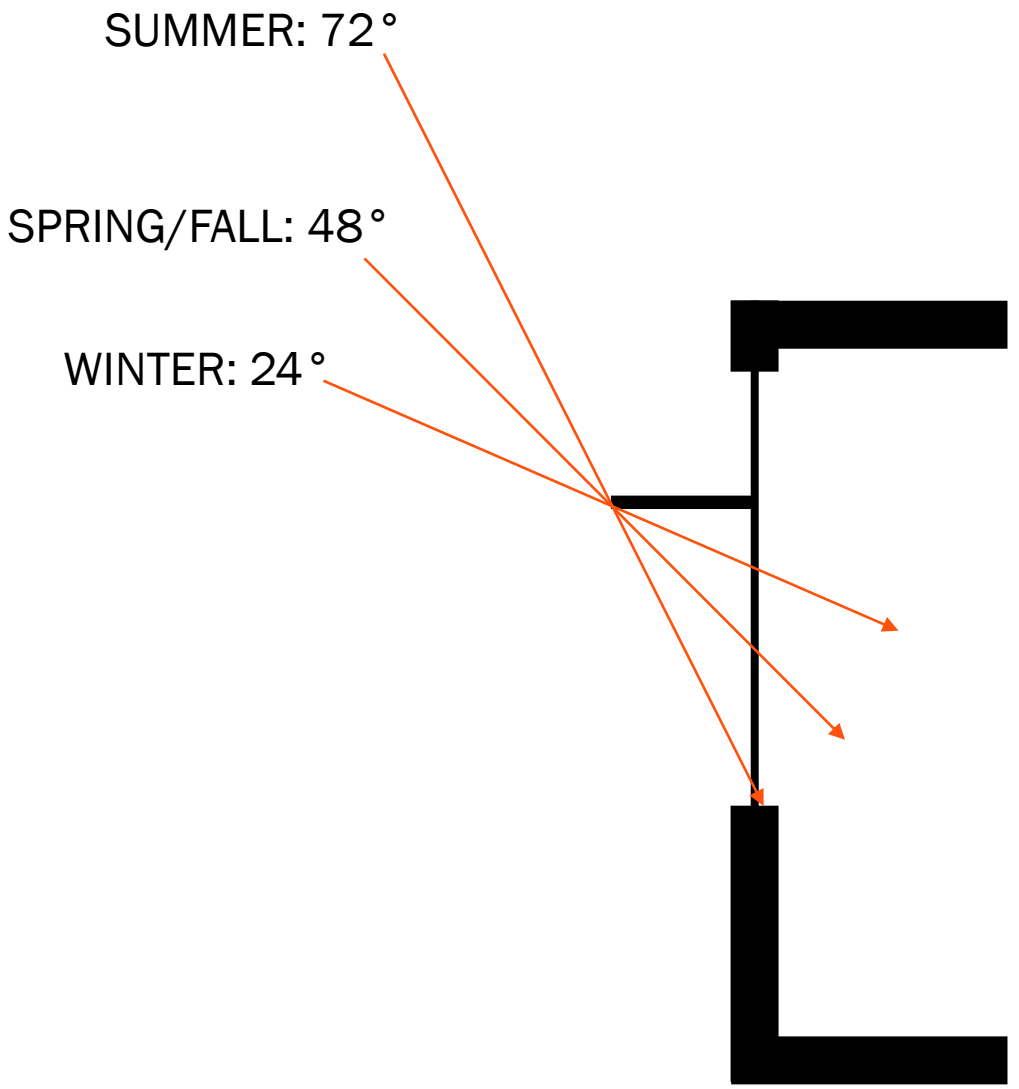
The rule of thumb is that you need to block the solar angles for the Summer solstice and the Equinoxes. This will protect you from unwanted solar heat gains during the hot season of the year; and allow for passive heating in the winter.

Source: The Carbon Neutral Design Project, AIA, 2012

SOLAR ANGLE FOR CAMBRIDGE, MA

Jan	Feb	Mar	Apr	May	Jun
32°	40°	48°	56°	64°	72°
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
64°	56°	48°	40°	32°	24°

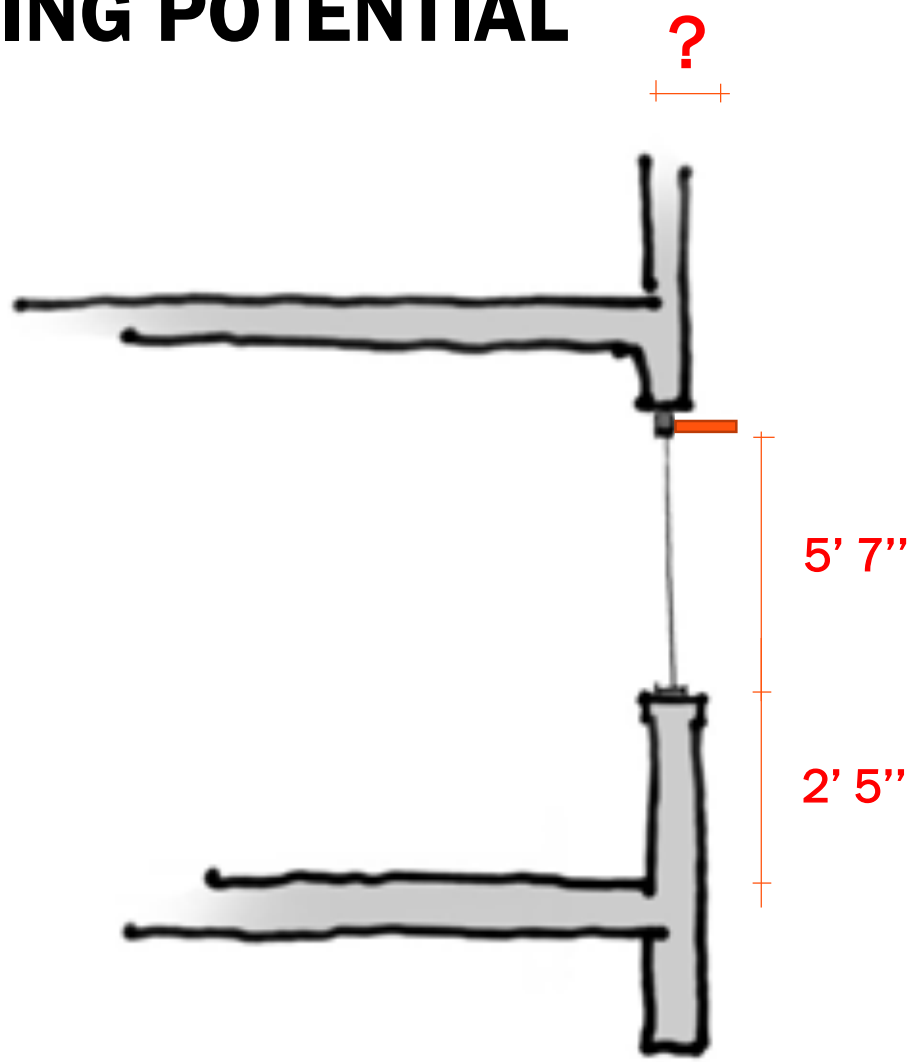
Source: Solar Angle Calculator, Solar Electricity Handbook, 2019



Perkins Eastman 2019

HORIZONTAL SHADING POTENTIAL

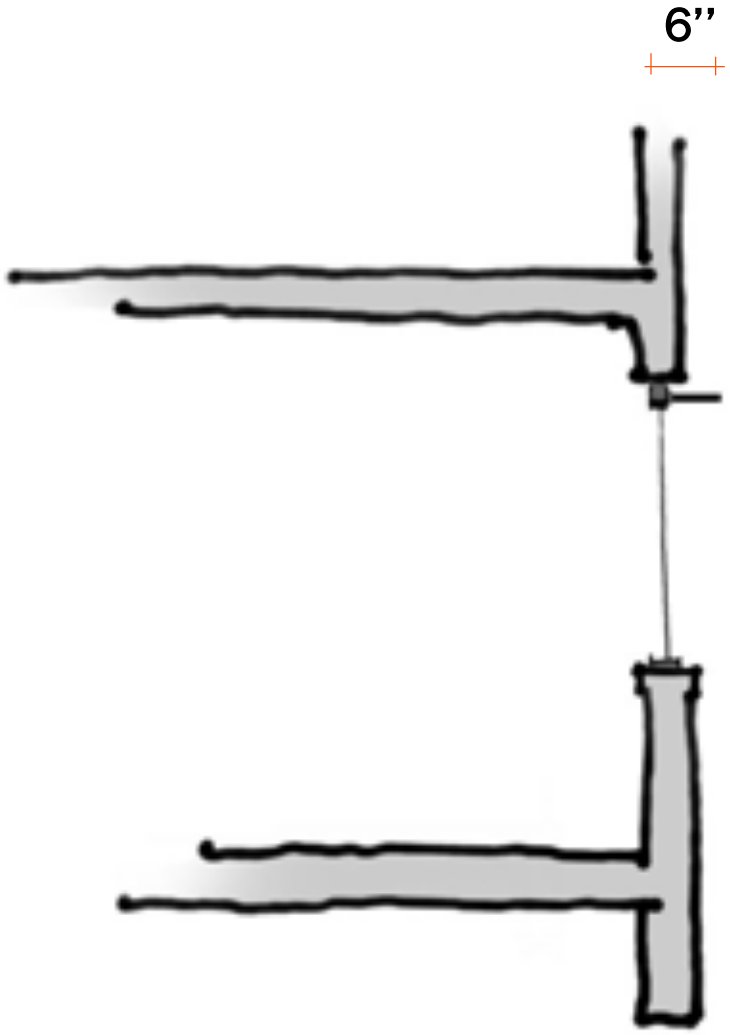
DEPTH DEFINITION



Perkins Eastman 2021.

1st ITERATION

6’’ DEPTH



DAYLIGHT (SDA): 77.5%

GLARE (ASE): 7.8%

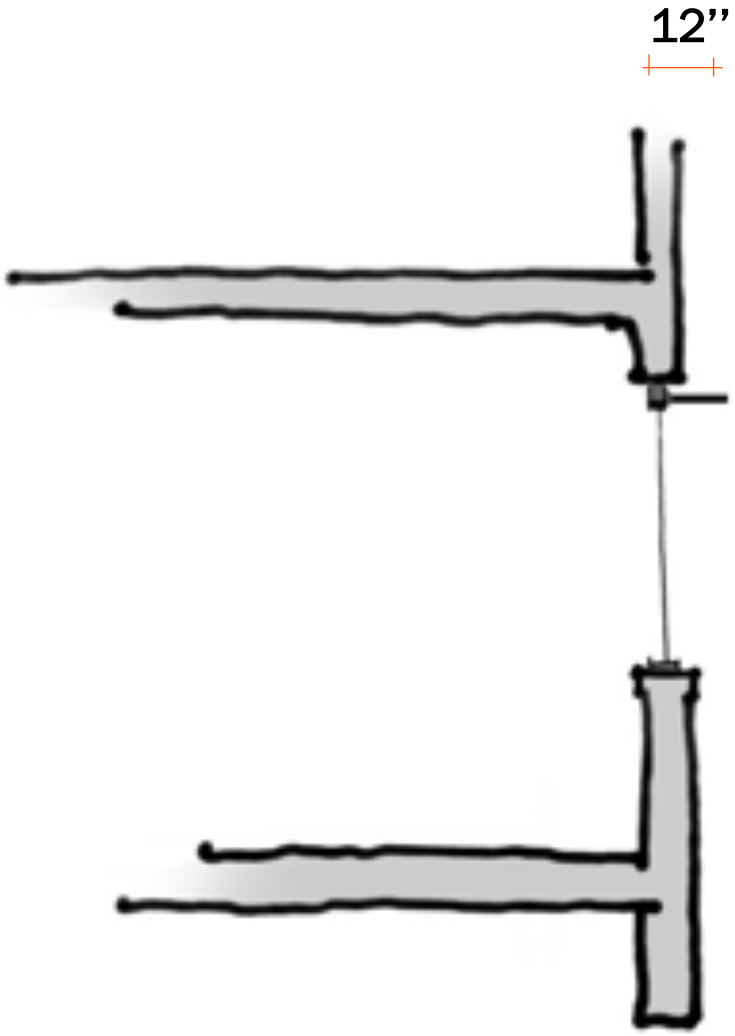
EUI: 33.7 KBTU/SF/ YR

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

2ND ITERATION

12'' DEPTH



DAYLIGHT (SDA): 76.4%
(1.13% WORSE)

GLARE (ASE): 7.7%
(0.1 % BETTER)

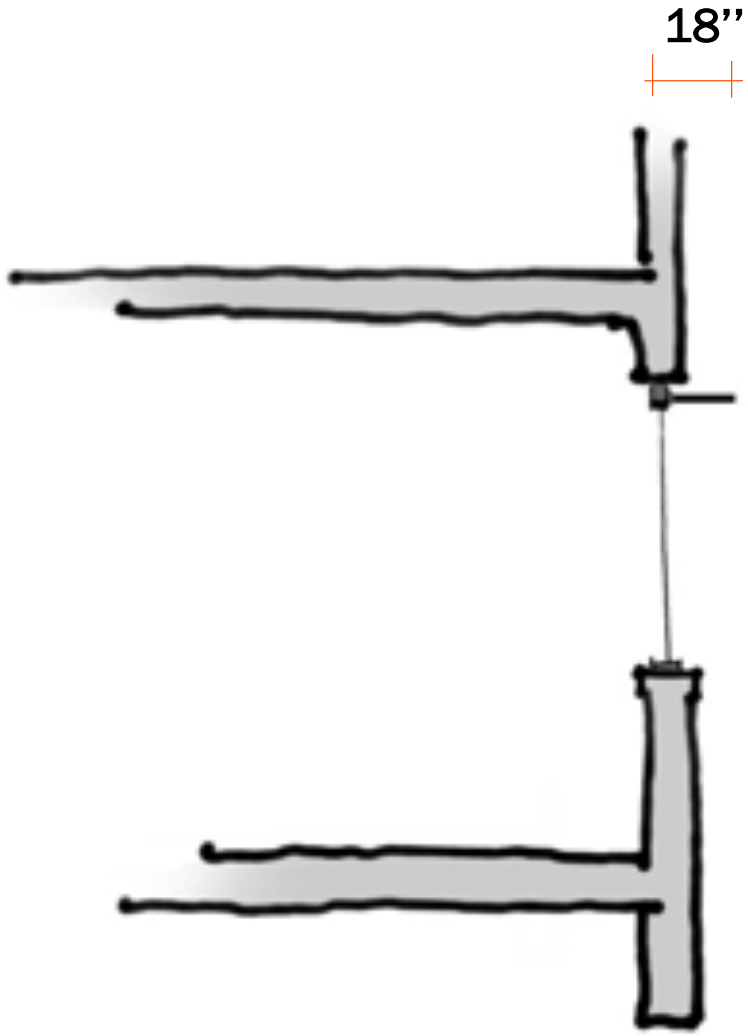
EUI: 33.6 KBTU/SF/ YR
(0.1 % BETTER)

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

3RD ITERATION

18'' DEPTH



DAYLIGHT (SDA): 76%
(1.5% WORSE)

GLARE (ASE): 7.1%
(0.68 % BETTER)

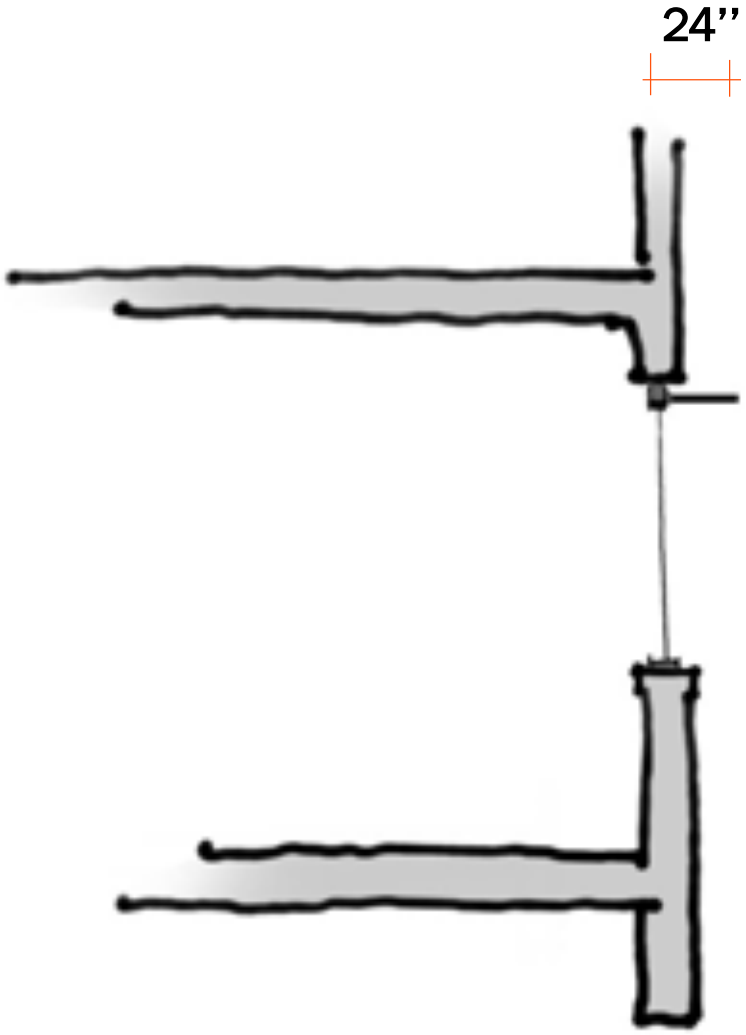
EUI: 33.5 KBTU/SF/ YR
(0.2 % BETTER)

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

4TH ITERATION

24'' DEPTH



DAYLIGHT (SDA): 75.2%
(2.3% WORSE)

GLARE (ASE): 6.7%
(1.1 % BETTER)

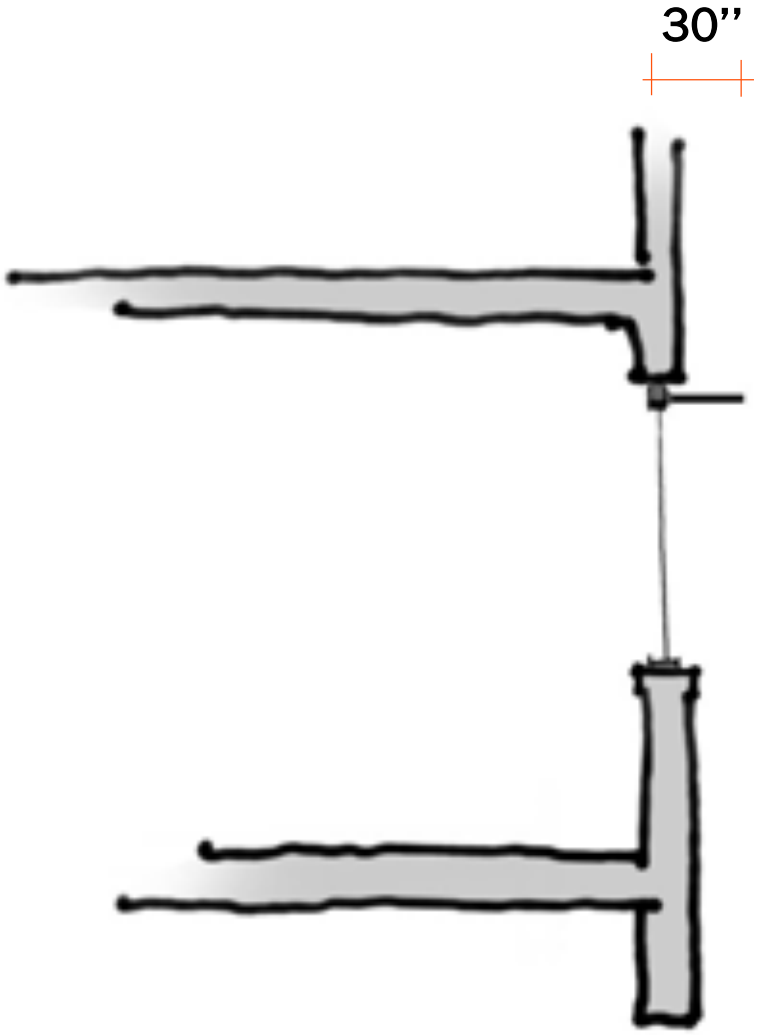
EUI: 33.7 KBTU/SF/ YR
(same as baseline)

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

5TH ITERATION

30'' DEPTH



DAYLIGHT (SDA): 75.1%
(2.4% WORSE)

GLARE (ASE): 6.5%
(1.27 % BETTER)

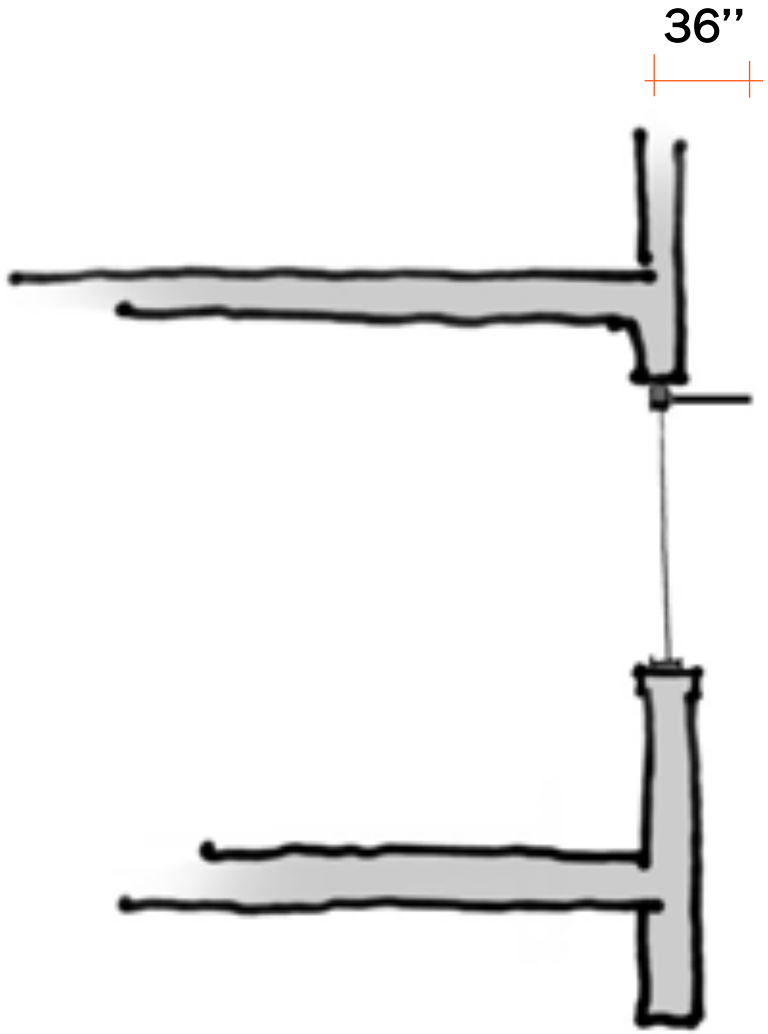
EUI: 33.8 KBTU/SF/ YR
(0.1% WORSE)

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

6TH ITERATION

36'' DEPTH



DAYLIGHT (SDA): 74.9%
(2.63% WORSE)

GLARE (ASE): 6.3%
(1.43 % BETTER)

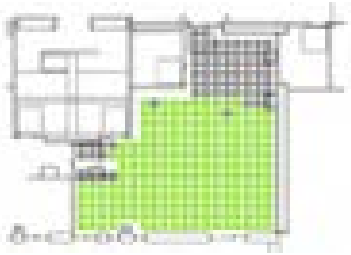
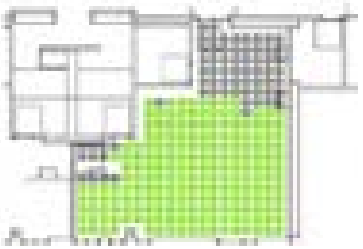
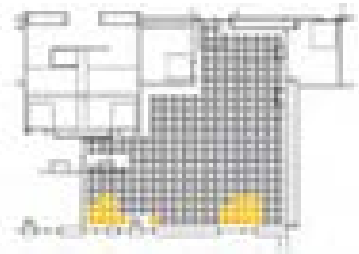
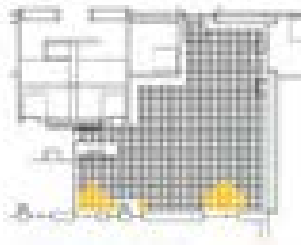
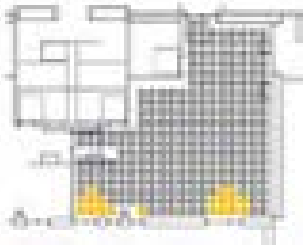
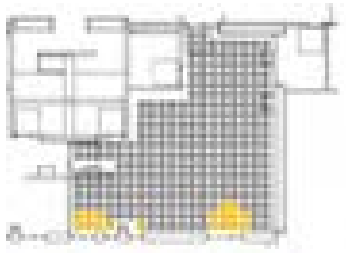
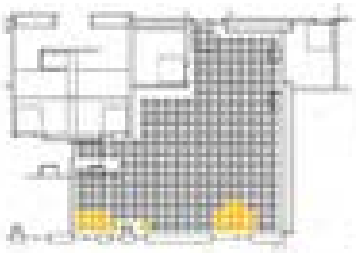
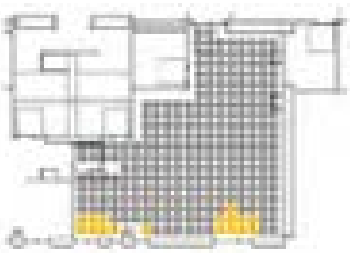
EUI: 39.9 KBTU/SF/ YR
(6.2% WORSE)

Perkins Eastman 2021.

ENERGY	DAYLIGHT	GLARE
EUI <25 KBTU/SF/YR	SDA >75%	ASE <10%

CLIMATE STUDIO OUTPUTS

GRAPHIC PLANS

	6'' DEEP SHADES	12'' DEEP SHADES	18'' DEEP SHADES	24'' DEEP SHADES	30'' DEEP SHADES	36'' DEEP SHADES
SDA						
	77.5%	76.4%	76%	75.2%	75.1%	74.9%
ASE						
	7.8%	7.7%	7.1%	6.7%	6.5%	6.3%

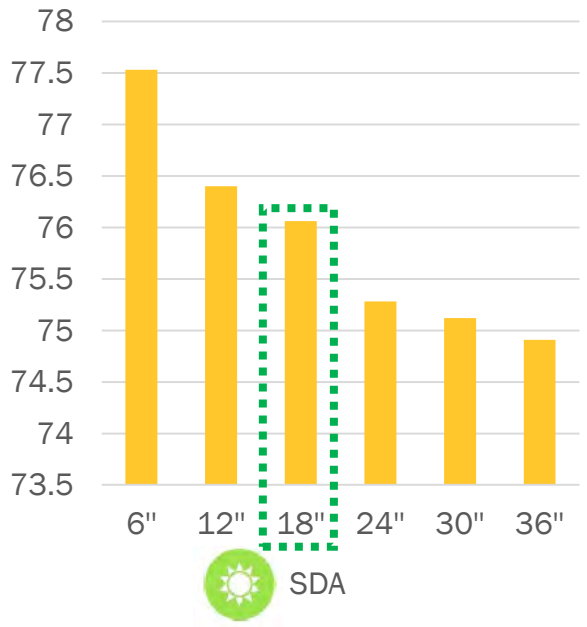
Perkins Eastman 2021.

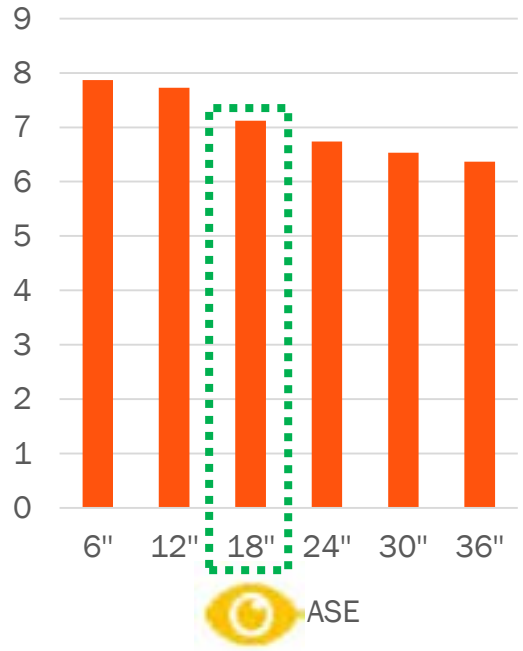
BREAKING DOWN THE DATA

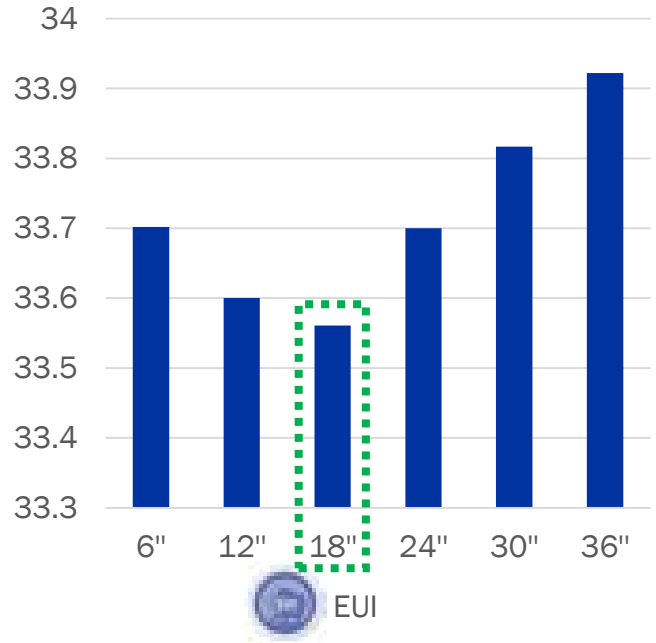
ENERGY
EUI <25 KBTU/SF/YR

DAYLIGHT
SDA >75%

GLARE
ASE <10%

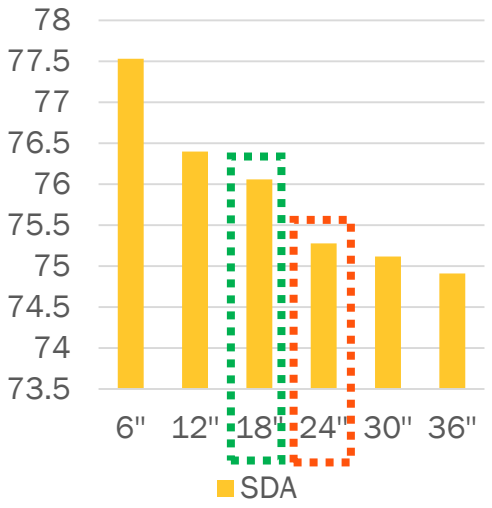


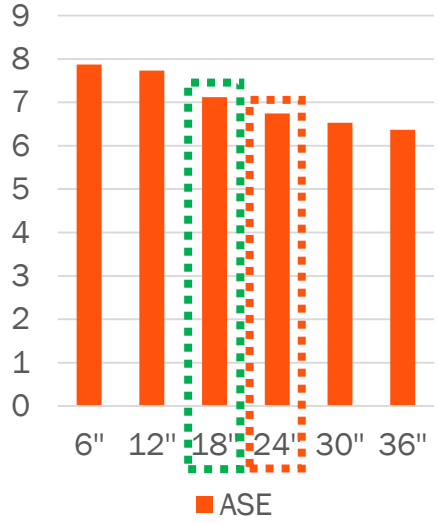


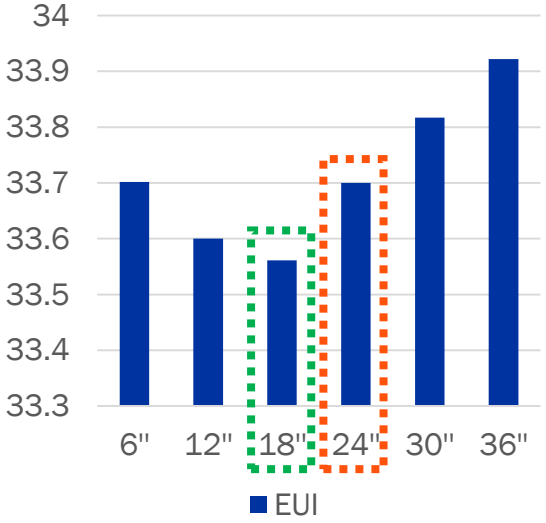


Perkins Eastman 2021.

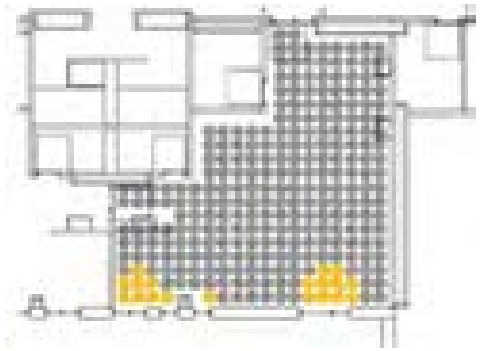
BREAKING DOWN THE DATA







DAYLIGHT (SDA): 76%
(1.5% WORSE)



GLARE (ASE): 7.1%
(1% BETTER)

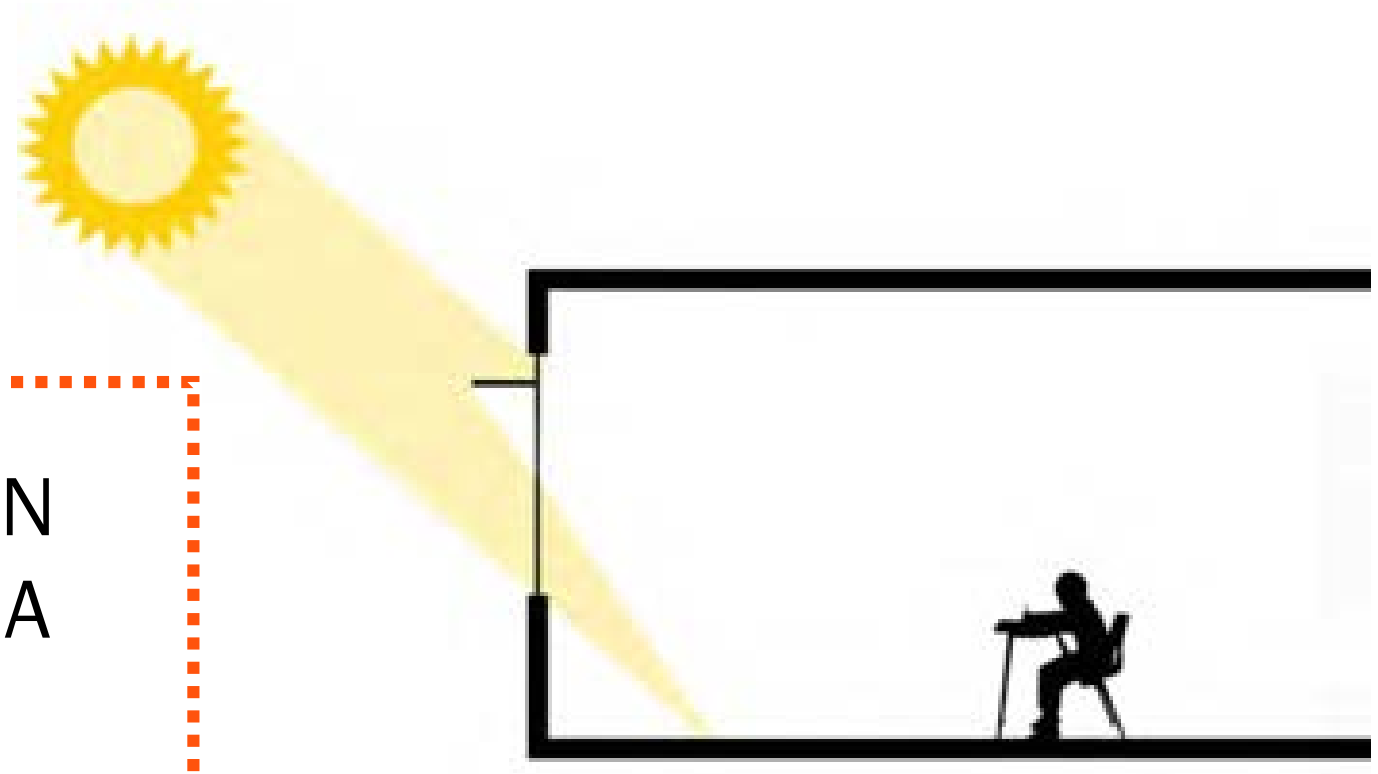
EUI: 33.702 KBTU/SF/ YR
(0.2 % BETTER)

Perkins Eastman 2021.

DOUBLE CHECKING THE RULES OF THUMB

YES, BUT...

"THE DEEPER THE SHADING, THE BETTER THE PERFORMANCE"

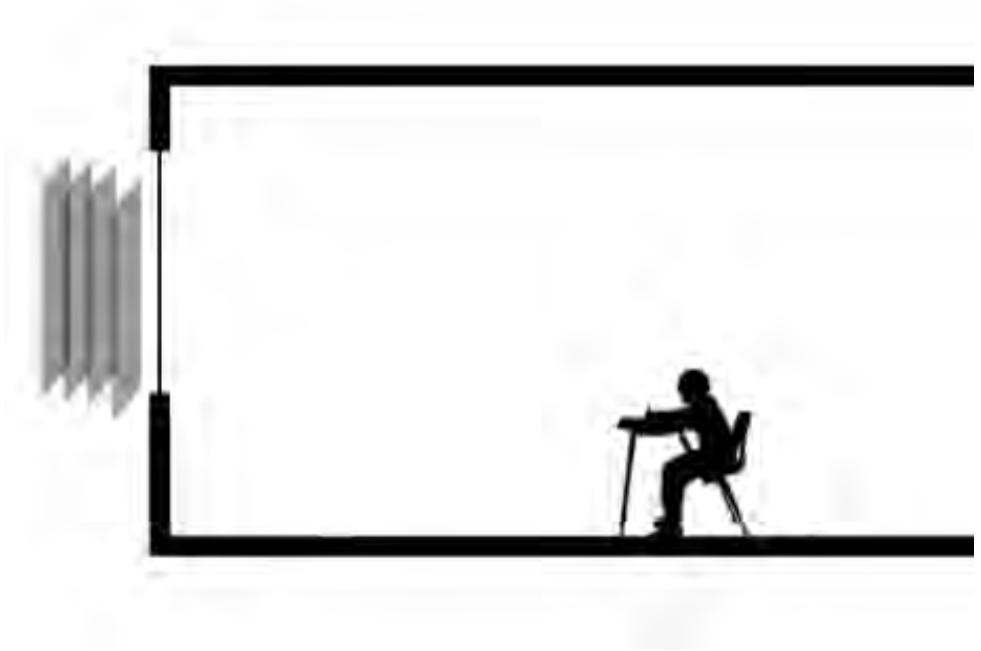


<u>YES BUT,</u> UNTIL A CERTAIN DEPTH, AFTER THERE IS A BIG CHANCE IT WILL BECOME DETRIMENTAL

Perkins Eastman 2022.

DOUBLE CHECKING THE RULES OF THUMB

"VERTICAL SHADING WORKS BETTER ON EAST/WEST FACADES"



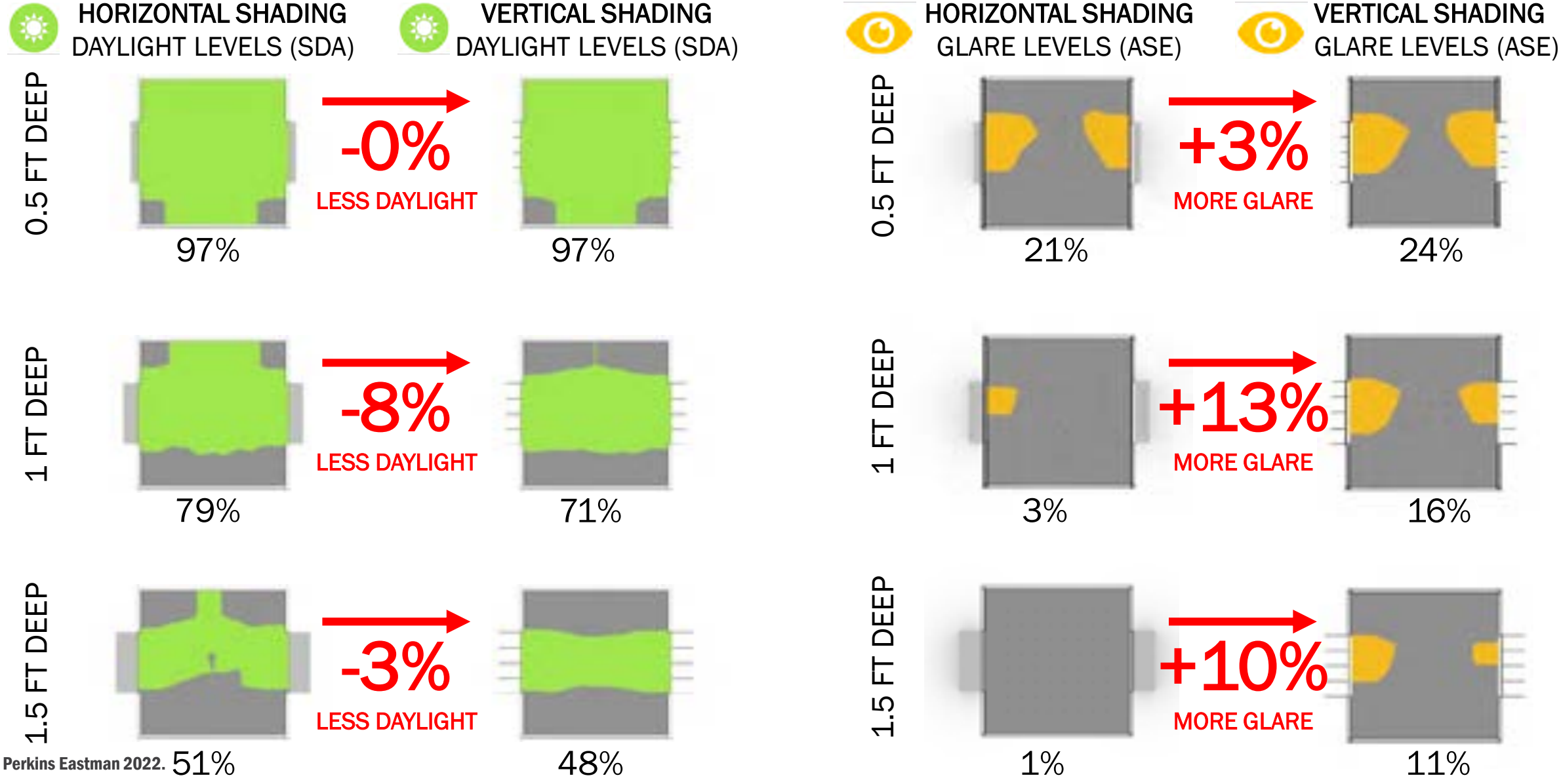
Perkins Eastman 2022.

EAST/WEST-FACING VERTICAL SHADING

DOES VERTICAL SHADING WORK FOR EAST AND WEST FACADES?

Benjamin Banneker High School, Perkins Eastman DC 2022

VERTICAL VS HORIZONTAL SHADING



Perkins Eastman 2022.

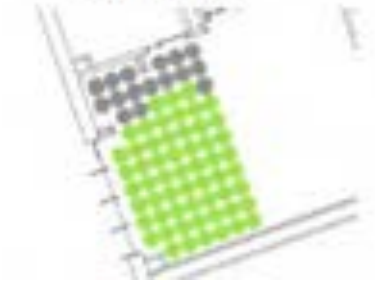
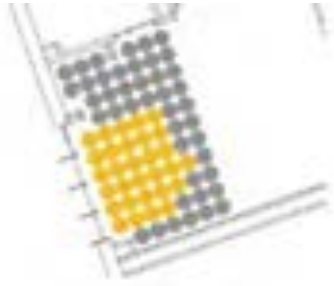
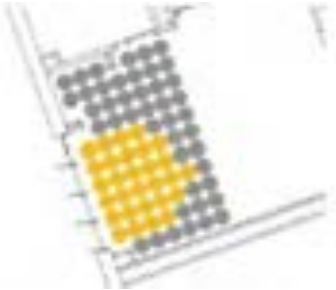
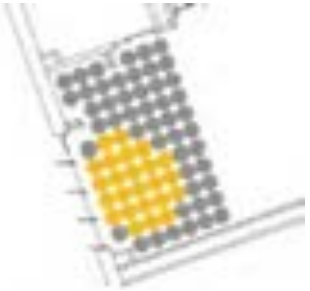
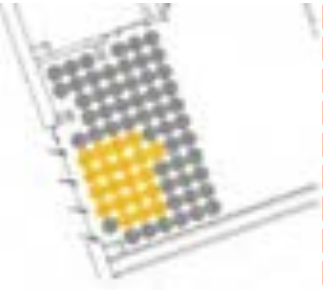
ITERATIVE APPROACH

DAYLIGHT

TARGET SDA >75%

GLARE

TARGET ASE <10%

NON-ROTATED SHADES	10° ROTATED SHADES	20° ROTATED SHADES	30° ROTATED SHADES
			
78%	72% -6%	68% -10%	66% -12%
			
41%	40% -1%	32% -9%	25% -16%

Perkins Eastman 2021.

WHAT ABOUT THE VIEWS?

30%-40% PERFORATION PATTERN
WILL BLOCK SOLAR RADIATION AND ALLOW OR VIEWS

Benjamin Banneker High School, Perkins Eastman DC, Perkins Eastman 2022

SHADING DOESN'T NEED TO BE UGLY

Benjamin Banneker High School, Perkins Eastman DC

Martin Luther King School, Perkins Eastman

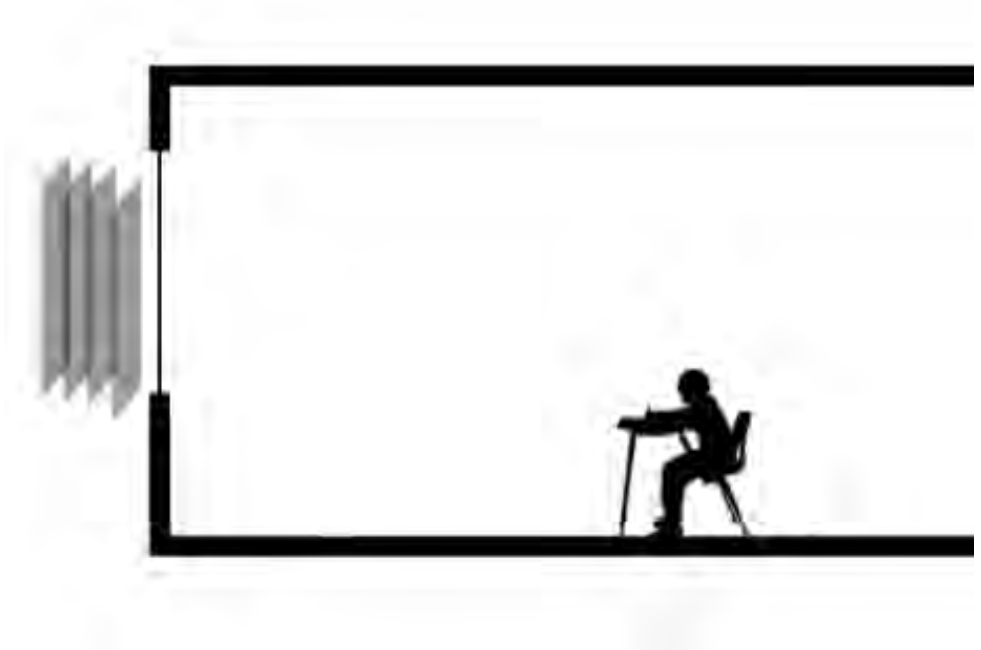
Perkins Eastman 2022.

DOUBLE CHECKING THE RULES OF THUMB

YES, BUT...

"VERTICAL SHADING WORKS BETTER ON EAST/WEST FACADES"

YES BUT, WILL PROBABLY NEED TO BE TILTED AND PERFORATED FOR BETTER PERFORMANCE AND VIEWS



Perkins Eastman 2022.

DAYLIGHT STORIES

COMMUNITY IN DAYLIGHT DESIGN DECISIONS

Renovation vs. New Construction

Iterative Workflow

Design Exercise and Rules of Thumb

Community Participation

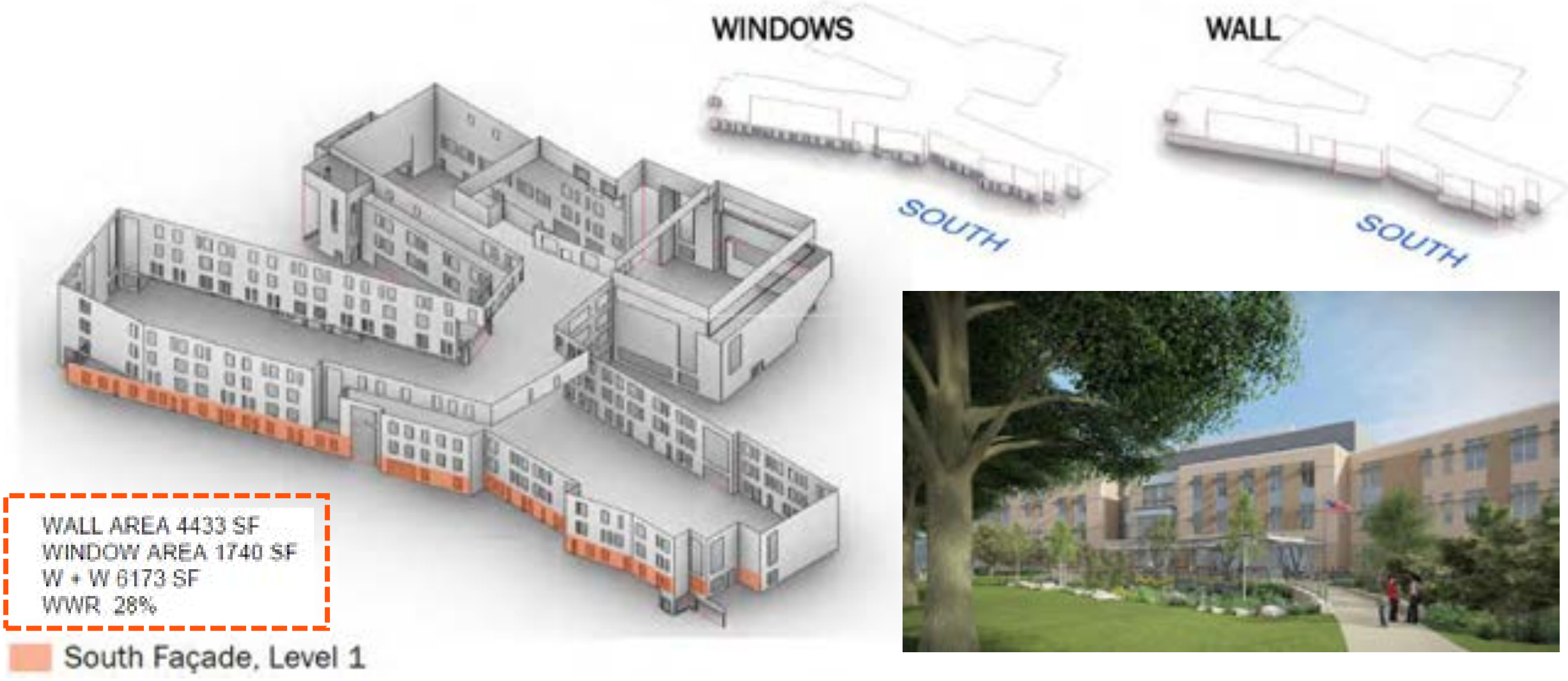
Conclusion and Next Steps

COMMUNITY & GLASSY FACADES

TMVL Visioning meeting, Perkins Eastman 2020

WINDOW TO WALL RATIO –1ST FLOOR

SOUTH LOOKING FACADE



TMVL WWR Analysis on COVE. Tool, Perkins Eastman 2020

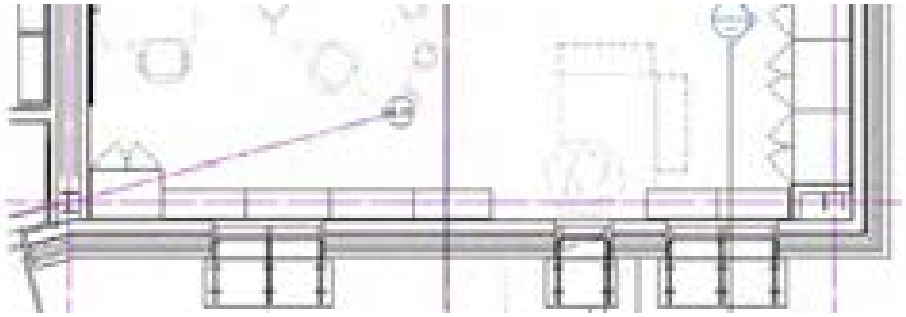
SOUTH FAÇADE CURRENT DESIGN PERFORMANCE

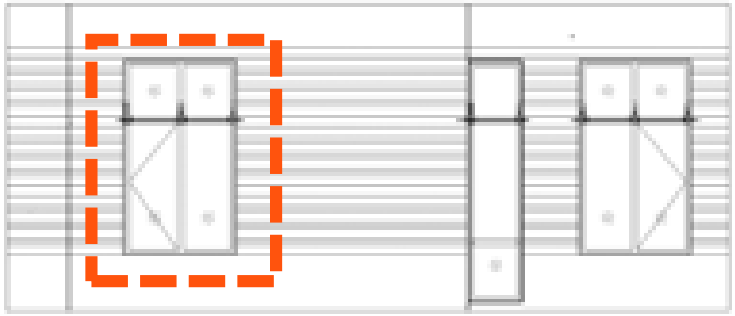
(28% GLAZING) LEVEL 1 SOUTH FACING CLASSROOM

TMVL, Perkins Eastman 2020

SOUTH FAÇADE CURRENT DESIGN PERFORMANCE

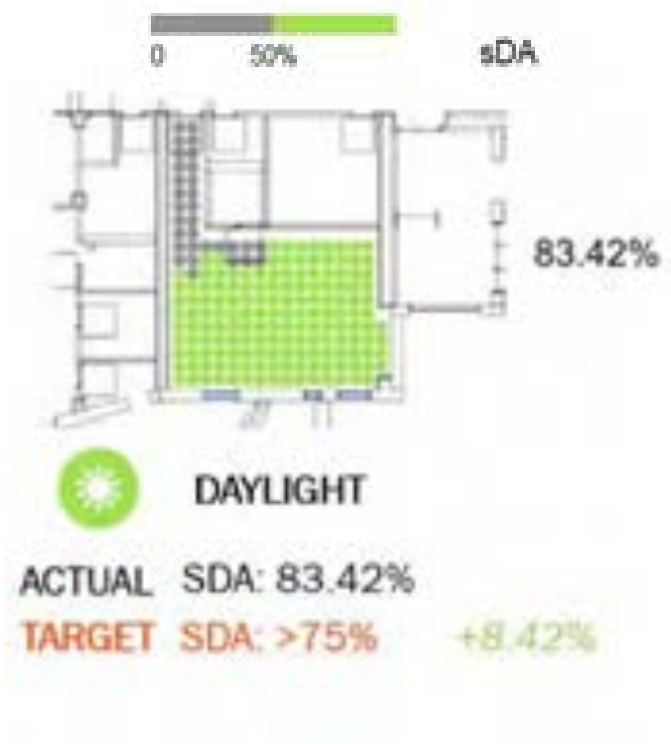
(28% GLAZING) LEVEL 1 SOUTH FACING CLASSROOM





MODULE FOR EVALUATION

DAYLIGHT



GLARE

TMVL, Perkins Eastman 2020

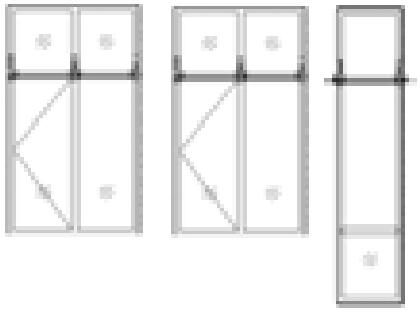
1ST ITERATION ANALYSIS

28% WINDOW TO WALL RATIO

ENERGY
EUI <25 KBTU/SF/YR

DAYLIGHT
SDA >75%

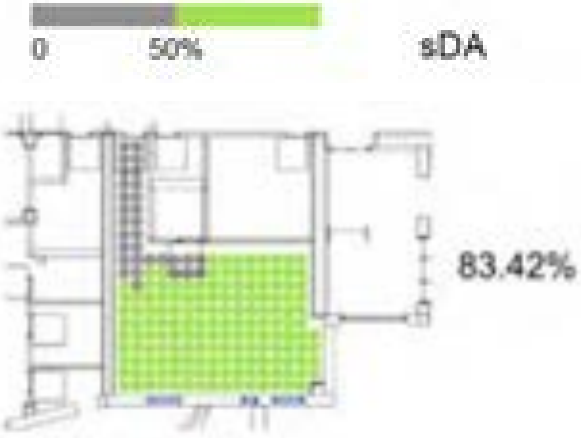
GLARE
ASE <10%



EUI: 22 KBTU/SF/YR

WWR: 28%

DAYLIGHT



TARGET SDA >75%

83.42% AS BASELINE SDA

GLARE

TARGET ASE < 10%

5.35 AS BASELINE GLARE

TMVL, Perkins Eastman 2020

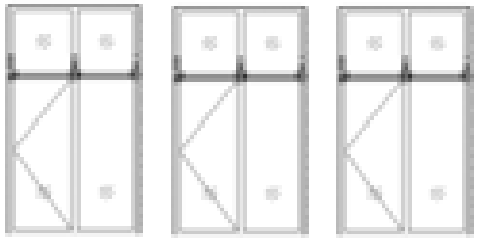
2ND ITERATION ANALYSIS

34% WINDOW TO WALL RATIO

ENERGY
EUI <25 KBTU/SF/YR

DAYLIGHT
SDA >75%

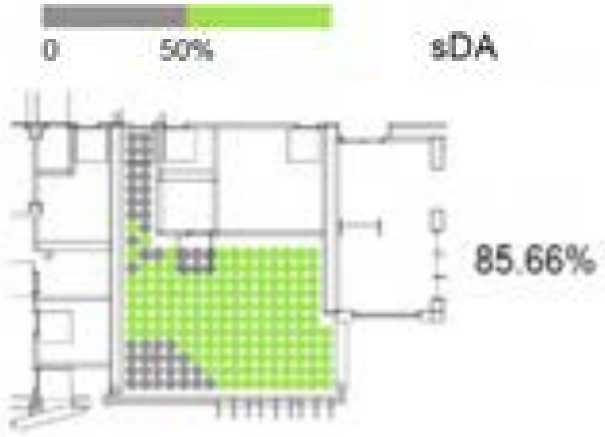
GLARE
ASE <10%



EUI: 24 KBTU/SF/YR

WWR: 34%

DAYLIGHT



TARGET SDA >75%
+ 2.24%

GLARE

TARGET ASE < 10%
+ 3.21%

TMVL, Perkins Eastman 2020

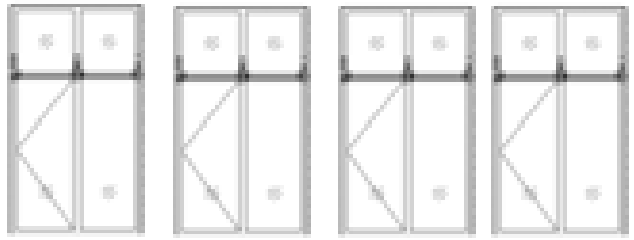
3RD ITERATION ANALYSIS

45% WINDOW TO WALL RATIO

ENERGY
EUI <25 KBTU/SF/YR

DAYLIGHT
SDA >75%

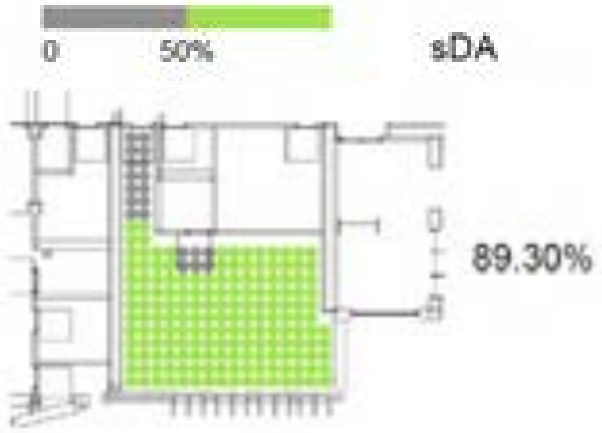
GLARE
ASE <10%



EUI: 27 KBTU/SF/YR

WWR: 45%

DAYLIGHT



TARGET SDA >75%

+ 5.88%

GLARE

TARGET ASE < 10%

+14.92%

TMVL, Perkins Eastman 2020

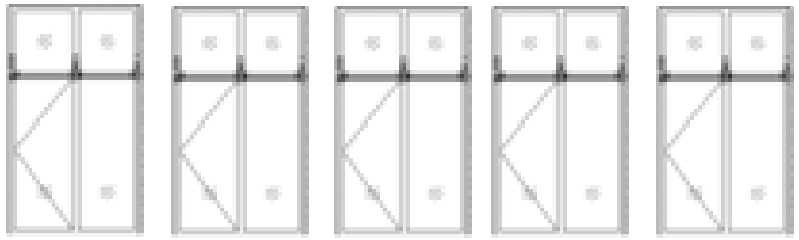
4TH ITERATION ANALYSIS

56% WINDOW TO WALL RATIO

ENERGY
EUI <25 KBTU/SF/YR

DAYLIGHT
SDA >75%

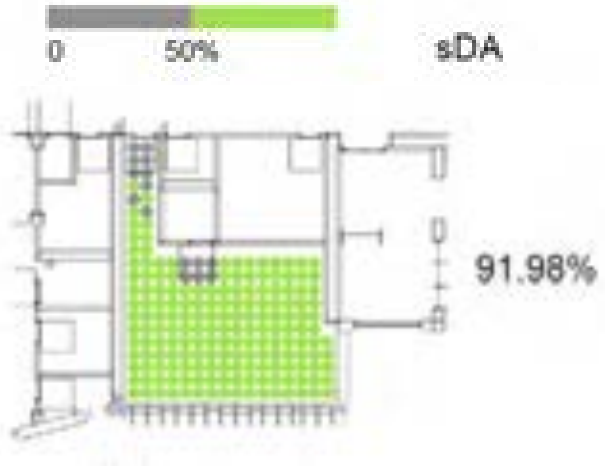
GLARE
ASE <10%



EUI: 32 KBTU/SF/YR

WWR: 56%

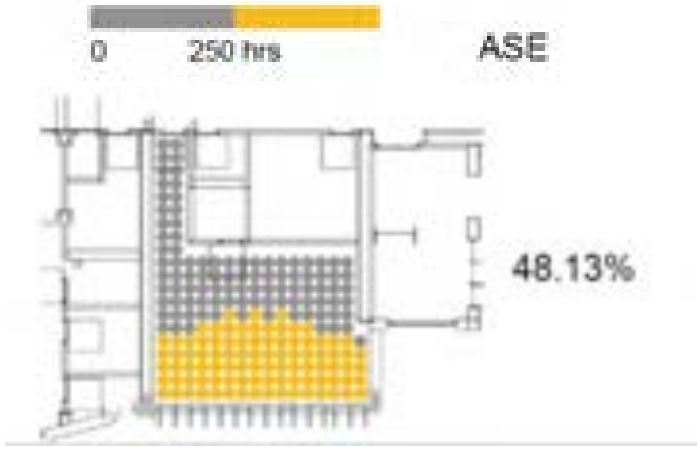
DAYLIGHT



TARGET SDA >75%

+ 8.56%

GLARE



TARGET ASE < 10%

+42.78%

TMVL, Perkins Eastman 2020

SOUTH FAÇADE DAYLIGHT PERFORMANCE ANALYSIS

TAKE OUTS FOR DECISIONS

28% WWR:	83%	5%	22 KBTU/SF/YR
34% WWR:	86%	9%	24 KBTU/SF/YR
45% WWR:	89%	20%	27 KBTU/SF/YR
56% WWR:	92%	48%	32 KBTU/SF/YR

GLARE
ASE <10%

DAYLIGHT
SDA >75%

ENERGY
EUI <25 KBTU/SF/YR

TMVL Community Meeting, Perkins Eastman 2020

COMMUNITY & AUDITORIUM WINDOWS

TMVL Auditorium Daylight Studies, Perkins Eastman 2021

LIGHT LEVELS IN TYPICAL SPACES

WWR PERFORMANCE RESULTS

Egress & Parking
1 fc

Corridors
10-20 fc

Classrooms
30-50 fc

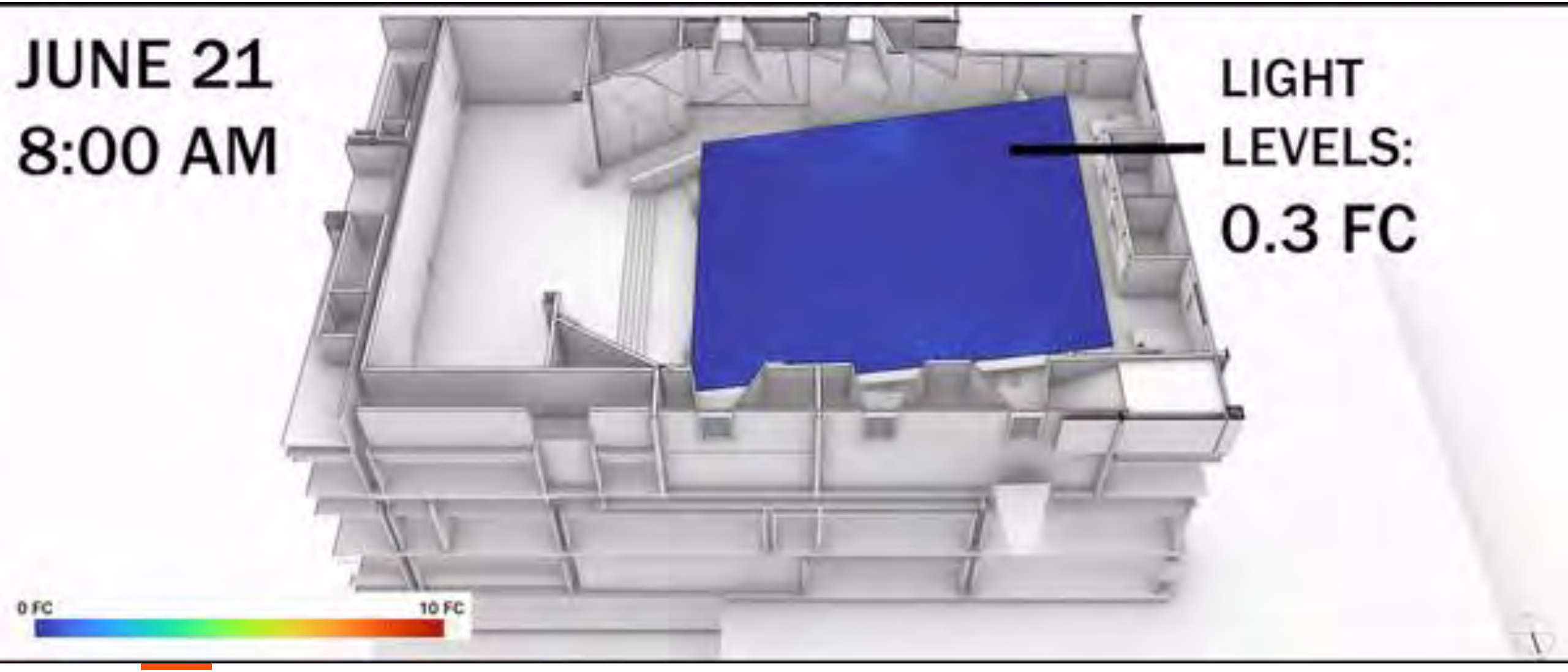
Gyms
40-60 fc

Lobby
50-70 fc

Exteriors
Up to 10000 fc

Auditorium
1.1 fc

TMVL FC Example Images, Perkins Eastman 2021



Auditorium Yearly Daylight Levels in foot-candles

June 21 - 8am, 10am, 12pm, 2pm, 6pm

Mar./Sept. 21 - 8am, 10am, 12pm, 2pm, 6pm

Dec 21 - 8am, 10am, 12pm, 2pm, 6pm

TMVL Auditorium Daylight Study Simulation Animation from Climate Studio, Perkins Eastman 2021

TMVL Auditorium Daylight Studies, Perkins Eastman 2021

OPEN WINDOWS

CLOSED WINDOWS – STAGE LIGHTING

DAYLIGHT STORIES

WHAT'S NEXT?

Renovation vs. New Construction

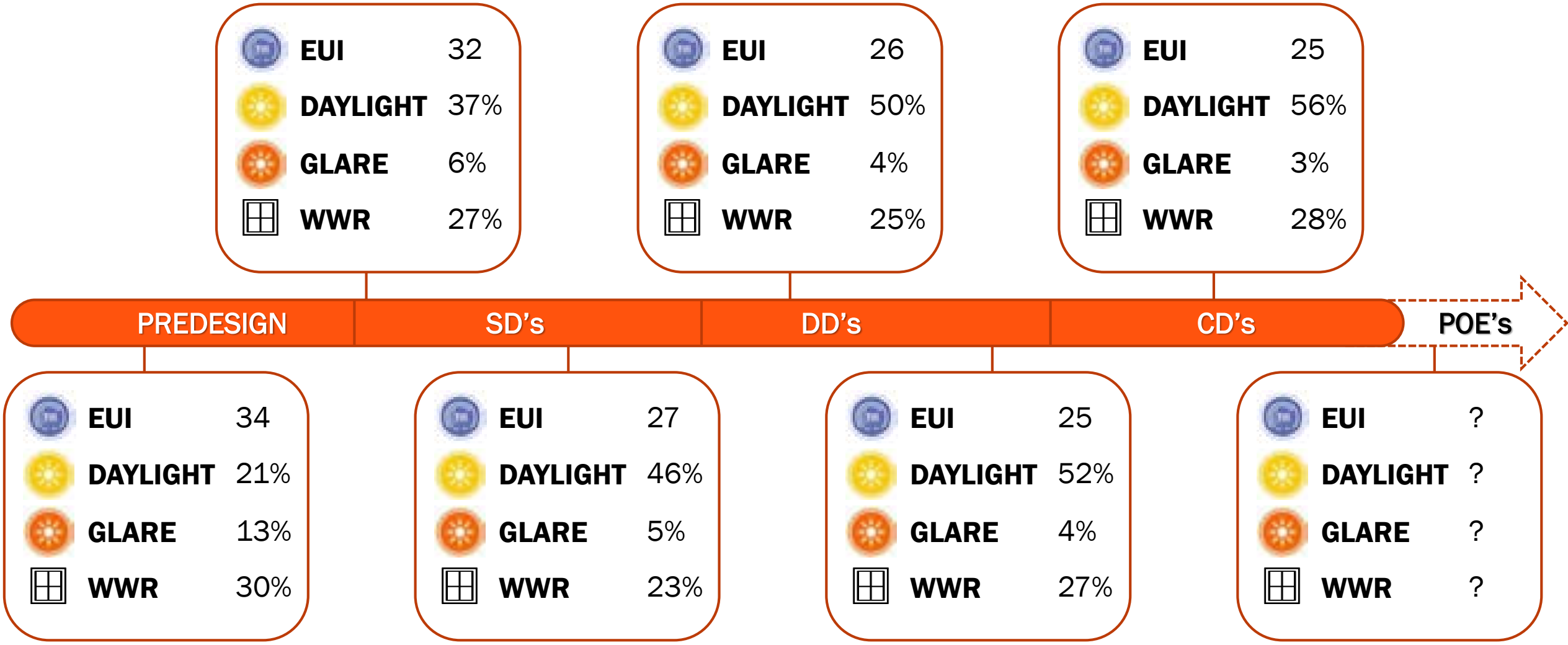
Iterative Workflow

Design Exercise and Rules of Thumb

Community Participation

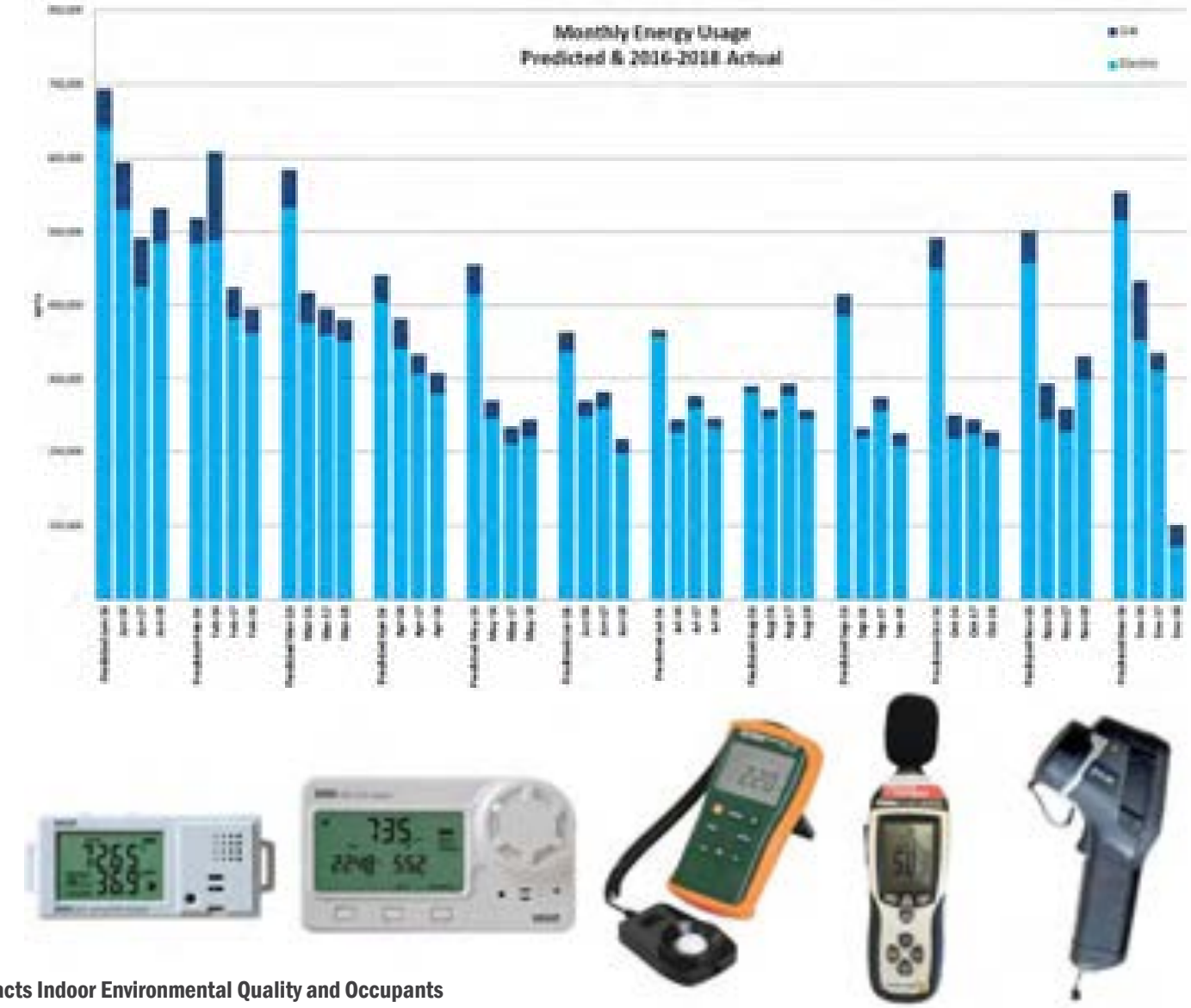
Conclusion and Next Steps

TIMELINE OF THE PROJECT



REAL TIME DATA MEASUREMENTS

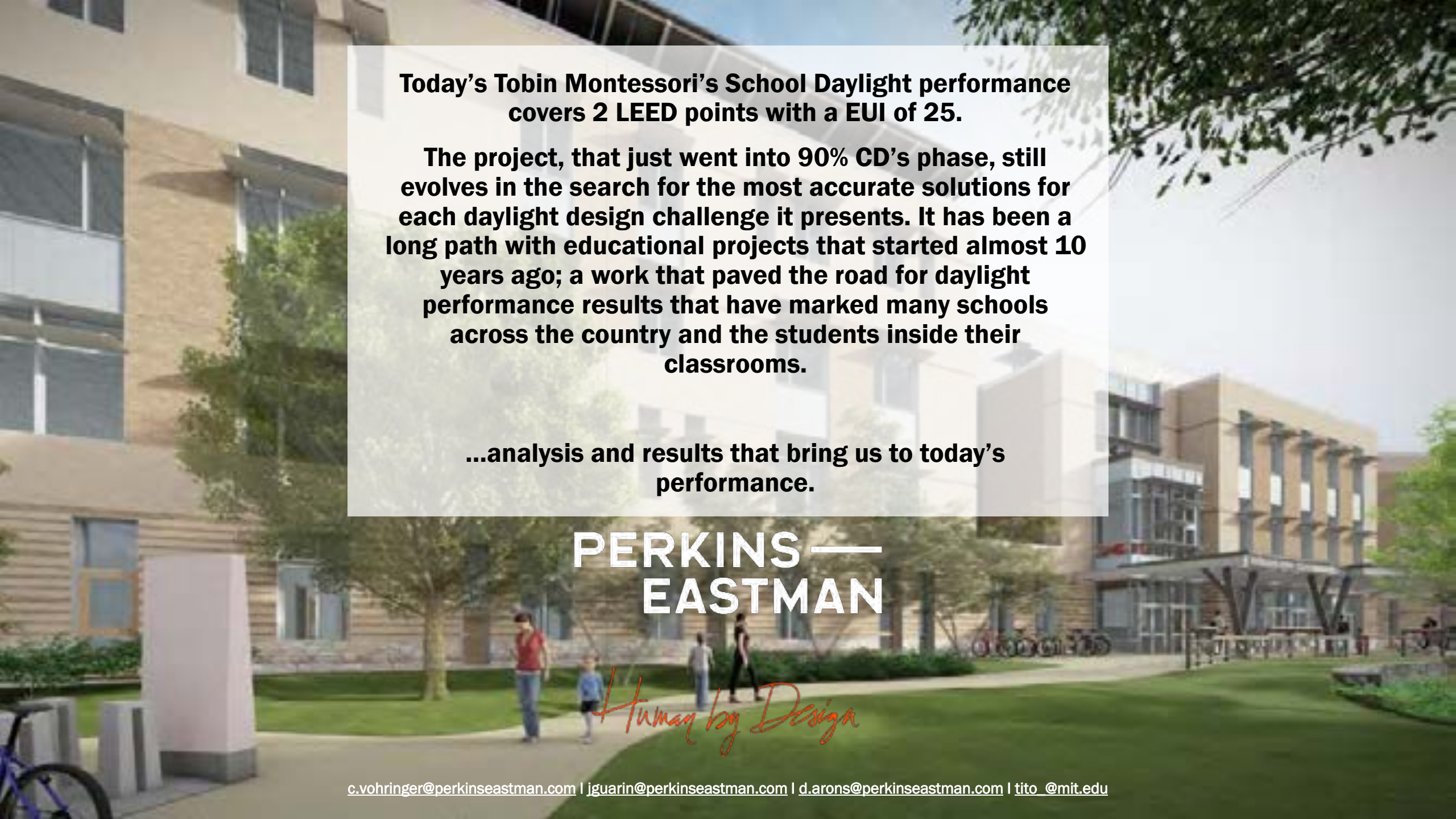
- On-Going Commissioning
- Post-Occupancy Evaluations
  - Daylight
  - Thermal Comfort
  - Acoustics
  - Air quality
- Data Tracking
  - Energy Usage
  - Water Usage



Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants

PERFORMANCE DRIVEN DESIGN CONCLUSION

- ❑ Environmental performance analysis tools are widely available for architects to use *in situ* during design.
- ❑ Designers are ready to use these tools, especially for daylighting.
- ❑ A remaining challenge is to ensure that designers understand what different simulation results mean and to develop a feeling as to what constitutes a “good result”.



Today's Tobin Montessori's School Daylight performance covers 2 LEED points with a EUI of 25.

The project, that just went into 90% CD's phase, still evolves in the search for the most accurate solutions for each daylight design challenge it presents. It has been a long path with educational projects that started almost 10 years ago; a work that paved the road for daylight performance results that have marked many schools across the country and the students inside their classrooms.

...analysis and results that bring us to today's performance.

PERKINS EASTMAN

Human by Design

c.vohringer@perkinseastman.com | jguarin@perkinseastman.com | d.arons@perkinseastman.com | tito_@mit.edu

c.vohringer@perkinseastman.com | jguarin@perkinseastman.com | d.arons@perkinseastman.com | tito_@mit.edu