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

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Curated by Richard Lo (Kaplan Thompson Architects)

Northeast Sustainable Energy Association (NESEA)
February 28, 2022
High Quality Daylight in Net Zero Buildings: A Pathway to High Performance Learning Environments
POLL: WHAT IS YOUR BACKGROUND?

ARCHITECT?

ENGINEER?

CONTRACTOR?

OTHER?

BUILDING OWNER?

BUILDING OPERATOR?

PUBLIC SECTOR?

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

- Boosts Vitamin D
- Heightens Productivity
- Benefits Mental Health
- Reduces Visual Stress
- Supports Sleep
- Increases Immune System

Source: Health Benefits of Sunlight, Select Health
THE VALUE OF DAYLIGHT IN EDUCATIONAL SPACES

SCHOOLS WITH ACCESS TO DAYLIGHT IMPROVED:

• Test performance by **26%**
• Reading Speed by **23%**
• Student learning by **21%**
• Absenteeism by **70%**
• **46** more minutes of sleep per night

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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
5*: Interdepartmental Neuroscience, Northwestern University, Impact of Workplace Daylight Exposure on Sleep, Physical Activity, and Quality of Life
THE ENERGY VALUE OF DAYLIGHT

BASELINE

DAYLIGHT: 58%

GLARE: 26%

ENERGY: 32 kbtu/sf/yr

12” SHADES

DAYLIGHT: 60%

GLARE: 20%

ENERGY: 30 kbtu/sf/yr

(2% MORE DAYLIGHT)

(6% LESS GLARE)

(3% LESS ENERGY)

24” SHADES

DAYLIGHT: 63%

GLARE: 14%

ENERGY: 29 kbtu/sf/yr

(5% MORE DAYLIGHT)

(12% LESS GLARE)

(5% LESS ENERGY)

Mark Center Analysis, Perkins Eastman
THE ECONOMICAL VALUE OF DAYLIGHT

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

Source: İrmak 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

12. Describe how it usually feels in your classroom. [circle one]
   - Warm
   - Cold

13. How does daylight in your classroom usually make you feel [circle one]
   - Good
   - Bad

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

Source: Perkins Eastman, (November 2018), Investing In Our Future: How School Modernization Impacts Indoor Environmental Quality and Occupants
WHAT DOES THE DATA MEAN?

**STUDENTS ARE...**
- 9% more satisfied with thermal comfort
- 14% more satisfied with air quality
- 18% more satisfied with acoustics
- 13% more satisfied with daylight

**FACULTY ARE...**
- 40% more satisfied with thermal comfort
- 45% more satisfied with air quality
- 30% more satisfied with acoustics
- 45% more satisfied with daylight

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

Good Daylight

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

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

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%

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  B  C  D

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

Ministry of Urban Development Sauerbruch Hutton
Hamburg, Germany,

Bosco Verticale Apartments Stefano Boeri Architetti,
Milan, Italy

David & Lucile Packard Foundation
EHDD
Los Altos, California
POLL RESULTS: WHICH OF THESE BUILDINGS HAS A WINDOW-TO-WALL RATIO OF MORE THAN 40%?

- **A**: 32%
- **B**: 16%
- **C**: 36%
- **D**: 16%
POLL: WHICH OF THESE BUILDINGS HAS A WINDOW-TO-WALL RATIO OF MORE THAN 40%?

A  B  C  D

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

Ministry of Urban Development Sauerbruch Hutton, Hamburg, Germany,

Bosco Verticale Apartments Stefano Boeri Architetti, Milan, Italy

David & Lucile Packard Foundation EHDD, Los Altos, California

35% WWR  26% WWR  32% WWR  28% WWR
ANALOG MODELING
EARLY STAGES OF DAYLIGHT MODELING

DIVA

ECOTECT

HONEYBEE

SEFAIRA

Source: DIVA Tutorial, MIT Sustainable Design Lab

Source: Quantitative Daylighting Analysis in Ecotect, NEWBIM

Source: Daylight Analysis as Design Tool, Binghamton University

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
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
DESIGN STRATEGIES OVER TIME

<table>
<thead>
<tr>
<th>Baseline</th>
<th>South Facing Clerestory</th>
<th>North Light Wells</th>
<th>Recessed Ceilings + Nooks</th>
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<tbody>
<tr>
<td>DAYLIGHT (SDA):</td>
<td></td>
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<tr>
<td>17%</td>
<td></td>
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<td>62%</td>
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<tr>
<td>GLARE (ASE):</td>
<td></td>
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<tr>
<td>0%</td>
<td></td>
<td></td>
<td>3%</td>
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<tr>
<td>WINDOW RATIO:</td>
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<tr>
<td>25%</td>
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<td>25%</td>
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</tbody>
</table>

John Lewis Elementary School, Perkins Eastman
THIS IS WHAT A 25% WWR SPACE LOOKS LIKE
APPLYING THE KNOWLEDGE TO OUR PROJECTS

**John Lewis Elementary School**
- **Daylight:** 78%
- **Glare:** 4%
- **EUI:** 22 kbtu/sf/yr
- **WWR:** 25%

**Baneker 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
HIGH DAYLIGHT QUALITY IN NET ZERO BUILDINGS: A PATHWAY TO HIGH-PERFORMANCE LEARNING ENVIRONMENTS

A Jakubiec  C Reinhart  J Niemasz  D Chang  J Sargent  T Dogan  V Liallos-Bouwman
2012 INITIAL CONCEPT

COMBINING DESIGN AND ENVIRONMENTAL MODELING

DIVA Approach

DIVA links validated performance simulation engines to Rhino and thus gives users access to meaningful, actionable data from the beginning of a project. We believe this early integration empowers creative, consequential, and lasting design interventions.
“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
ClimateStudio

ENVIRONMENTAL PERFORMANCE ANALYSIS IN DESIGN

Initial Design

Environmental Analysis

Revised Design
How often does that happen?
TWO SURVEYS

2011 AND 2018

Question: If you are using thermal/energy simulations during design, how often have the results changed or influenced any design decisions?

Is there an interest in change?
Positive attitude throughout.

Broad consensus regarding interest into training designers in the use of simulations.
HIGH DAYLIGHT QUALITY IN NET ZERO BUILDINGS

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.

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

PERKINS EASTMAN

Snøhetta
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
How to train designers how to correctly interpret and react to environmental performance results
> 40,000 learners and counting...
CHALLENGE – ACCESS TO ALL
DAYLIGHT STORIES
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
SITE – EXISTING BIRD’S EYE VIEW
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.
Prior to “The Tobin” appearance on the site was used as a city waste site.
INTEGRATED APPROACH

- HIGH DAYLIGHT QUALITY IN NET ZERO BUILDINGS
- A PATHWAY TO HIGH-PERFORMANCE LEARNING ENVIRONMENTS

- LOW-CARBON IMPACT MATERIALS
- ZERO ON-SITE GREENHOUSE GAS EMISSION
- LEED GOLD
- HYBRID STRUCTURAL SYSTEM
- HIGH PERFORMANCE BUILDING ENVELOPE
- LOW-FLOW PLUMBING FIXTURES & HEAT PUMPS
- EMBODIED CARBON
- ON-SITE RENEWABLE
- Educación
- RECOVERY SYSTEMS
- ENERGY METERING
- MAXIMIZE ON-SITE RENEWABLE
- LOW ENERGY LED LIGHTING
- STORMWATER MANAGEMENT
- SOLAR SHADING
- SOLAR SHADING
- ENERGY RECOVERY SYSTEMS
- LOW-FLOW PLUMBING FIXTURES & HEAT PUMPS
- EMBODIED CARBON
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

ZONAL
Organized by the zones within Boston basin. Public areas is where they come together.

PLANTS & ANIMALS OF:
TOBIN: ALEGHIS RESERVATION
VASSAL: BURGHILL RESERV.
PRESCHOOL: FRESH POND

EARTH

FIRE: Geology for those zones: clay, volcanic rock, etc.

WATER: Water sources:
FRESH POND, CHARLES RIVER

AIR: Avian species; migration patterns; movement through air.
CLIMATE ANALYSIS

Yearly Temperature Chart

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

Yearly Thermal Comfort Chart

Perkins Eastman 2020
A HIGH PERFORMANCE BUILDING

1. Maximally Efficient -- Low Energy Use Intensity (EUI)
2. All-electric systems
3. Renewable energy
D A Y L I G H T S T O R I E S

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
EXISTING CONDITIONS - EXTERIOR

A BUILDING BEYOND ITS USEFUL LIFE
EXISTING BUILDING CLASSROOMS

POTENTIAL FOR DAYLIGHT

TMVL Existing Building Plan and Photos, Pietro Belluschi
SITE COMPLEXITY AND PROPOSAL

PRE AND POST CONSTRUCTION COMPARISON
RENOVATION VS. NEW CONSTRUCTION
NEW DESIGNS AND EXISTING BUILDING

OPTION 1: RENOVATION
OPTION 2: NEIGHBORHOODS
OPTION 3: GRAND COURT
ENVELOPE ANALYSIS
SCENARIOS COMPARISON

OPTION 1: RENOVATION

**BASELINE:** EXISTING BUILDING

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

OPTION 2: NEIGHBORHOODS

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

OPTION 3: GRAND COURT

Similar information as option 2.
ENERGY AND DAYLIGHT

DAYLIGHT SHOEBOX ANALYSIS FOR CLASSROOMS

OPTION 1: EXISTING BUILDING RENO. + ADDITION
BASELINE

21%

SDA >75%

13%

ASE <10%

EUI: 54

EUI <25 KBTU/SF/YR

OPTION 2: NEIGHBORHOODS

45%

+24%

53%

+32%

16%

+3%

15%

+2%

EUI: 49

EUI: 47

EUI: 47

-9%

-13%

OPTION 3: GRAND COURT

EUI: 54

EUI: 49

EUI: 47

Perkins Eastman 2020
TO KEEP OR NOT TO KEEP?

RENOVATION/ADDITION VS. NEW CONSTRUCTION

Embodied and Operational Carbon over 60 Year Life Span

- Embodied and Operational Carbon
  - Embodied: 41,000 MT CO₂e
  - Operational: 38,300 MT CO₂e

Global Warming Potential (MT CO₂e)

- Embodied Carbon of Materials
  - Present: 6,650 MT CO₂e
  - 60 Years: 5,025 MT CO₂e

- Renovation + Addition (EUI 25 kbtu/sqft)
- New Construction (EUI 22 kbtu/sqft)

Based on 300,000 sq ft floor area

Embodied + operational carbon are equal after approximately 23 years.
# NET ZERO POTENTIAL

<table>
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<tr>
<th>LEGEND</th>
<th>Category Performance</th>
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<tr>
<td><img src="image1.png" alt="Best" /></td>
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<td><img src="image2.png" alt="Better" /></td>
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<tr>
<td><img src="image3.png" alt="Good" /></td>
<td>GOOD</td>
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## RENOVATION
- Passive Heating Potential: ![Good](image4.png)
- Passive Cooling Potential: ![Better](image5.png)
- PV Generation Potential: ![Good](image6.png)
- Outdoor Thermal Comfort: ![Better](image7.png)
- Interior Daylight Performance: ![Better](image8.png)
- Annual Energy Use: ![Better](image9.png)
- Compact Building: ![Better](image10.png)
- Embodied + Operational Carbon: ![Better](image11.png)

## NEIGHBORHOODS
- Passive Heating Potential: ![Better](image12.png)
- Passive Cooling Potential: ![Better](image13.png)
- PV Generation Potential: ![Better](image14.png)
- Outdoor Thermal Comfort: ![Better](image15.png)
- Interior Daylight Performance: ![Better](image16.png)
- Annual Energy Use: ![Better](image17.png)
- Compact Building: ![Better](image18.png)
- Embodied + Operational Carbon: ![Better](image19.png)

## GRAND COURT
- Passive Heating Potential: ![Best](image20.png)
- Passive Cooling Potential: ![Best](image21.png)
- PV Generation Potential: ![Best](image22.png)
- Outdoor Thermal Comfort: ![Best](image23.png)
- Interior Daylight Performance: ![Best](image24.png)
- Annual Energy Use: ![Best](image25.png)
- Compact Building: ![Best](image26.png)
- Embodied + Operational Carbon: ![Best](image27.png)
ITERATIVE WORKFLOW FOR DAYLIGHT OPTIMIZATION
### Iterative Workflow

**Diagram for Collaboration**

**Analysis**
- Testing Iterations in Real Time
  - Climate Studio
  - Cove.Tool
  - Dynamo

**Daylight Performance**
- Options for Iterations
  - Rules of Thumb
  - Detailed Strategies Implementation

**Design**
- Results Implementation
  - Model Update
  - Specs.
  - Consultant Coordination
  - Code Analysis
  - Budget

**Results Sharing**
- Brainstorming Sessions
- Design Charrettes
- Pin-Ups Presentations
- Teams Platform Updates
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.
HIGH DAYLIGHT QUALITY IN NET ZERO BUILDINGS: A PATHWAY TO HIGH-PERFORMANCE LEARNING ENVIRONMENTS

WINDOW TO WALL RATIO BASELINE
WHERE WE STARTED

BASELINE WWR: 23%

TARGET WWR <30%

FINAL WINDOW TO WALL RATIO

WHERE WE FINISHED

TARGET WWR <30%

FINAL WWR: 27%

TMVL Interface on COVE.TOOL Platform for WWR analysis, 2022.
BIM MODEL: DIGGING DEEPER

LABELING OCCUPANCY AREAS

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

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

SDA >75%

ASE <10%

DAYLIGHT

45%

3%

GLARE

WALL 2:
DUPONT PALE GREEN 62% REFLECTANCE

LIGHT ACCENT WALL

64%

4%

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
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?

- **A. Increased Daylight**: 64%
- **B. Increased Glare**: 8%
- **C. Decreased Glare**: 28%
“LIGHT SHELVES HELP REFLECT DAYLIGHT”
CLAIMS ABOUT LIGHTSHELVES

MANUFACTURES INFORMATION

Source: Thurston Elementary School, Mahlum Architects Inc.

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

Source: CS Interior Lightshelves, Construction Specialties

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.

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

CLASSROOM WITH LIGHT SHELVES

DAYLIGHT: 83%
GLARE: 5%

DAYLIGHT: 80%
GLARE: 4%

Perkins Eastman 2022
SECOND ANALYSIS: WITH AND WITHOUT LIGHT SHELVES

CLASSROOM WITHOUT LIGHT SHELVES

DAYLIGHT: 69%
GLARE: 6%

CLASSROOM WITH LIGHT SHELVES

DAYLIGHT: 66%
GLARE: 4%

Perkins Eastman 2022
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
DOUBLE CHECKING THE RULES OF THUMB

“THE MORE SHADING, THE BETTER THE PERFORMANCE”
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

Source: Solar Angle Calculator, Solar Electricity Handbook, 2019

SUMMER: 72°
WINTER: 24°
SPRING/FALL: 48°
HORIZONTAL SHADING POTENTIAL

DEPTH DEFINITION

5' 7"

2' 5"

Perkins Eastman 2021.
1st ITERATION

6” DEPTH

DAYLIGHT (SDA): 77.5%
GLARE (ASE): 7.8%
EUI: 33.7 KBTU/SF/YR

Perkins Eastman 2021.
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)

EUI <25 KBTU/SF/YR
DAYLIGHT SDA >75%
GLARE 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.
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)
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.
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.
CLIMATE STUDIO OUTPUTS

GRAPHIC PLANS

<table>
<thead>
<tr>
<th>SHADE DEPTH</th>
<th>SDA</th>
<th>ASE</th>
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<tbody>
<tr>
<td>6'' SHADES</td>
<td>77.5%</td>
<td>7.8%</td>
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<tr>
<td>12'' SHADES</td>
<td>76.4%</td>
<td>7.7%</td>
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<tr>
<td>18'' SHADES</td>
<td>76%</td>
<td>7.1%</td>
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<tr>
<td>24'' SHADES</td>
<td>75.2%</td>
<td>6.7%</td>
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<tr>
<td>30'' SHADES</td>
<td>75.1%</td>
<td>6.5%</td>
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<tr>
<td>36'' SHADES</td>
<td>74.9%</td>
<td>6.3%</td>
</tr>
</tbody>
</table>
BREAKING DOWN THE DATA

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)
DOUBLE CHECKING THE RULES OF THUMB

YES, BUT...

“THE DEEPER THE SHADING, THE BETTER THE PERFORMANCE”

YES BUT, UNTIL A CERTAIN DEPTH, AFTER THERE IS A BIG CHANCE IT WILL BECOME DETRIMENTAL
DOUBLE CHECKING THE RULES OF THUMB

“VERTICAL SHADING WORKS BETTER ON EAST/WEST FACADES”
EAST/WEST-FACING VERTICAL SHADING

DOES VERTICAL SHADING WORK FOR EAST AND WEST FACADES?
VERTICAL VS HORIZONTAL SHADING

HORIZONTAL SHADING DAYLIGHT LEVELS (SDA)

VERTICAL SHADING DAYLIGHT LEVELS (SDA)

HORIZONTAL SHADING GLARE LEVELS (ASE)

VERTICAL SHADING GLARE LEVELS (ASE)

0.5 FT DEEP

97%  
LESS DAYLIGHT -0%

97%

21%  
MORE GLARE +3%

24%

1 FT DEEP

79%  
LESS DAYLIGHT -8%

71%

3%  
MORE GLARE +13%

16%

1.5 FT DEEP

51%  
LESS DAYLIGHT -3%

48%

1%  
MORE GLARE +10%

11%

Perkins Eastman 2022.
## Iterative Approach

### Target SDA >75%

- Non-Rotated Shades: 78%
- 10° Rotated Shades: 72% (-6%)
- 20° Rotated Shades: 68% (-10%)
- 30° Rotated Shades: 66% (-12%)

### Target ASE <10%

- Non-Rotated Shades: 41% (-1%)
- 10° Rotated Shades: 40% (-9%)
- 20° Rotated Shades: 32% (-9%)
- 30° Rotated Shades: 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
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
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
WINDOW TO WALL RATIO – 1ST FLOOR

SOUTH LOOKING FACADE

WALL AREA 4433 SF
WINDOW AREA 1740 SF
W + W 6173 SF
WWR 28%

South Façade, Level 1

TMVL WWR Analysis on COVE. Tool, Perkins Eastman 2020
SOUTH FAÇADE CURRENT DESIGN PERFORMANCE

(28% GLAZING) LEVEL 1 SOUTH FACING CLASSROOM

DAYLIGHT

GLARE

ACTUAL SDA: 83.42%
TARGET SDA: >75%
+8.42%

ACTUAL
TARGET
ASE: <10%
-4.65%

ASE: 5.35%

TMVL, Perkins Eastman 2020
SOUTH FAÇADE CURRENT DESIGN PERFORMANCE

(28% GLAZING) LEVEL 1 SOUTH FACING CLASSROOM

MODULE FOR EVALUATION

DAYLIGHT
ACTUAL SDA: 83.42%
TARGET SDA: >75%
+8.42%

GLARE
ACTUAL
TARGET
ASE: <10%
-4.65%

ASE: 5.35%
1\textsuperscript{st} ITERATION ANALYSIS

28\% WINDOW TO WALL RATIO

<table>
<thead>
<tr>
<th>ENERGY</th>
<th>DAYLIGHT</th>
<th>GLARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUI &lt;25 KBTU/SF/YR</td>
<td>SDA &gt;75%</td>
<td>ASE &lt;10%</td>
</tr>
</tbody>
</table>

EUI: 22 KBTU/SF/YR

WWR: 28\%

**TARGET SDA >75\%**

83.42\% AS BASELINE SDA

**TARGET ASE < 10\%**

5.35 AS BASELINE GLARE
2ND ITERATION ANALYSIS

34% WINDOW TO WALL RATIO

ENERGY
EUI < 25 KBTU/SF/YR

DAYLIGHT
SDA > 75%
ASE < 10%

GLARE

EUI: 24 KBTU/SF/YR

WWR: 34%

TARGET SDA > 75%
+ 2.24%

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%
- **TARGET SDA**: > 75% + 5.88%
- **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%

**Target SDA >75%**

+ 8.56%

**Target ASE <10%**

+42.78%

TMVL, Perkins Eastman 2020
### SOUTH FAÇADE DAYLIGHT PERFORMANCE ANALYSIS

#### TAKE OUTS FOR DECISIONS

<table>
<thead>
<tr>
<th>WWR</th>
<th>GLARE</th>
<th>DAYLIGHT</th>
<th>ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>28%</td>
<td>83%</td>
<td>5%</td>
<td>22 KBTU/SF/YR</td>
</tr>
<tr>
<td>34%</td>
<td>86%</td>
<td>9%</td>
<td>24 KBTU/SF/YR</td>
</tr>
<tr>
<td>45%</td>
<td>89%</td>
<td>20%</td>
<td>27 KBTU/SF/YR</td>
</tr>
<tr>
<td>56%</td>
<td>92%</td>
<td>48%</td>
<td>32 KBTU/SF/YR</td>
</tr>
</tbody>
</table>

**TMVL Community Meeting, Perkins Eastman 2020**
COMMUNITY & AUDITORIUM WINDOWS
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
HIGH DAYLIGHT QUALITY IN NET ZERO BUILDINGS: A PATHWAY TO HIGH-PERFORMANCE LEARNING ENVIRONMENTS

OPEN WINDOWS

TMVL Auditorium Daylight Studies, Perkins Eastman 2021
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
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