Illuminating Passive Houses

NAPHC September 29, 2017

Keith A. Simon, AIA, CPHC
Building Exterior Solutions,
a division of Terracon,
Adjunct Faculty at the
University of Texas at Austin

What is *daylighting?*

The ***controlled*** distribution of natural light in a space

What is *daylighting?*

NOT:
sunlight

What is *daylighting?*

Can Highly Glazed Building Facades Be Green

by John Straube, BSI-006, 2008


www.GeigerCars.de


SYLVANIA
PHILIPS

DOE Buildings Energy Data Book

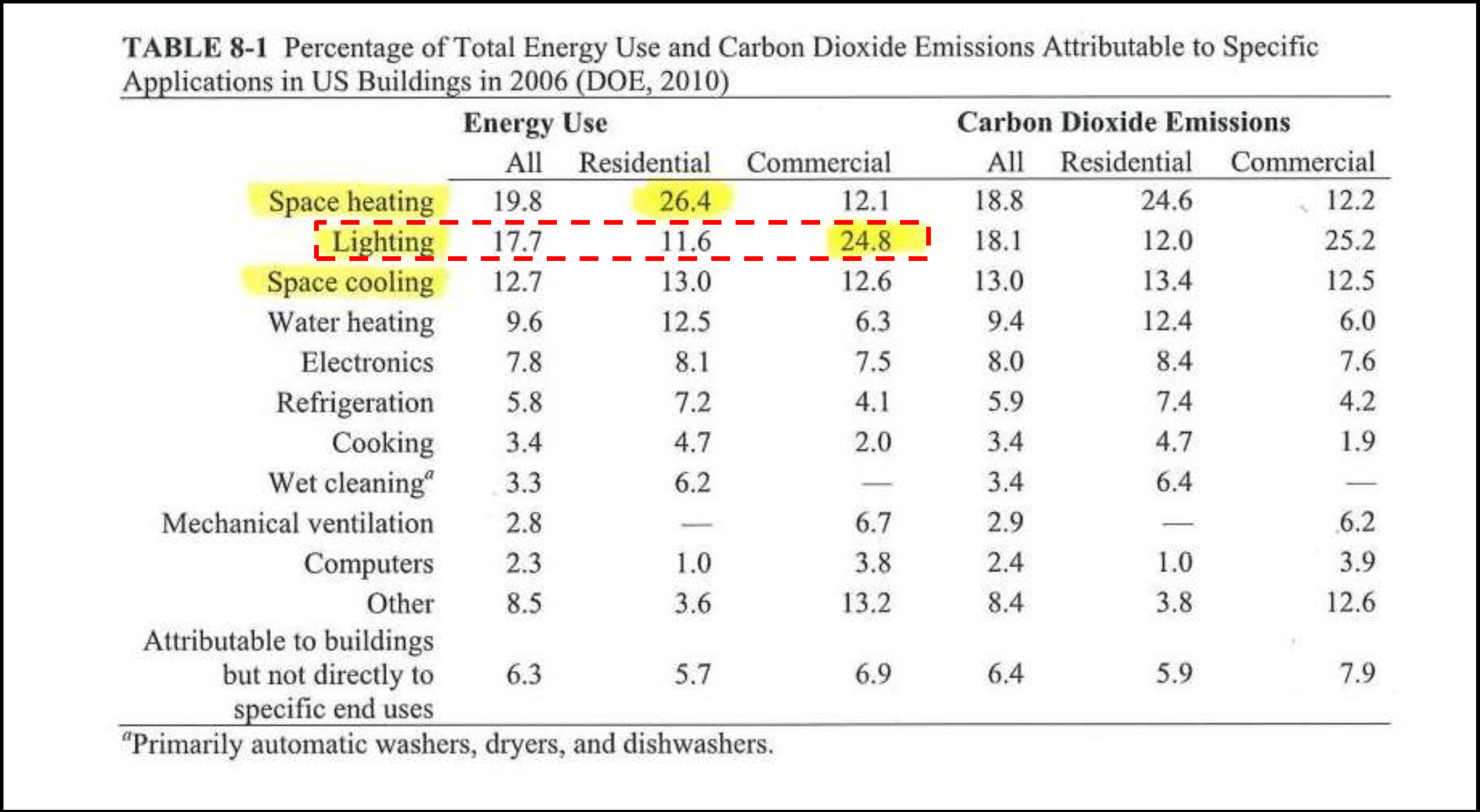


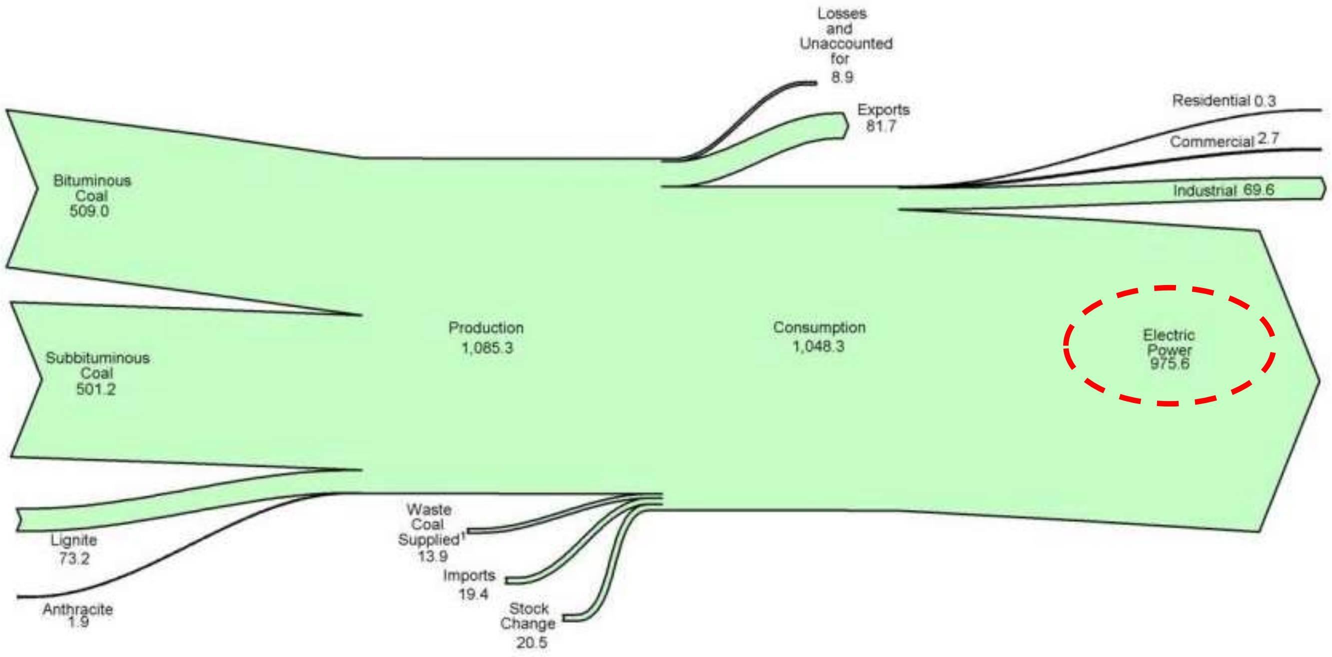
TABLE 8-1 Percentage of Total Energy Use and Carbon Dioxide Emissions Attributable to Specific Applications in US Buildings in 2006 (DOE, 2010)

	Energy Use			**Carbon Dioxide Emissions**		
	All	Residential	Commercial	All	Residential	Commercial
Space heating	19.8	26.4	12.1	18.8	24.6	12.2
Lighting	17.7	11.6	24.8	18.1	12.0	25.2
Space cooling	12.7	13.0	12.6	13.0	13.4	12.5
Water heating	9.6	12.5	6.3	9.4	12.4	6.0
Electronics	7.8	8.1	7.5	8.0	8.4	7.6
Refrigeration	5.8	7.2	4.1	5.9	7.4	4.2
Cooking	3.4	4.7	2.0	3.4	4.7	1.9
Wet cleaning[a]	3.3	6.2	—	3.4	6.4	—
Mechanical ventilation	2.8	—	6.7	2.9	—	6.2
Computers	2.3	1.0	3.8	2.4	1.0	3.9
Other	8.5	3.6	13.2	8.4	3.8	12.6
Attributable to buildings but not directly to specific end uses	6.3	5.7	6.9	6.4	5.9	7.9

[a] Primarily automatic washers, dryers, and dishwashers.

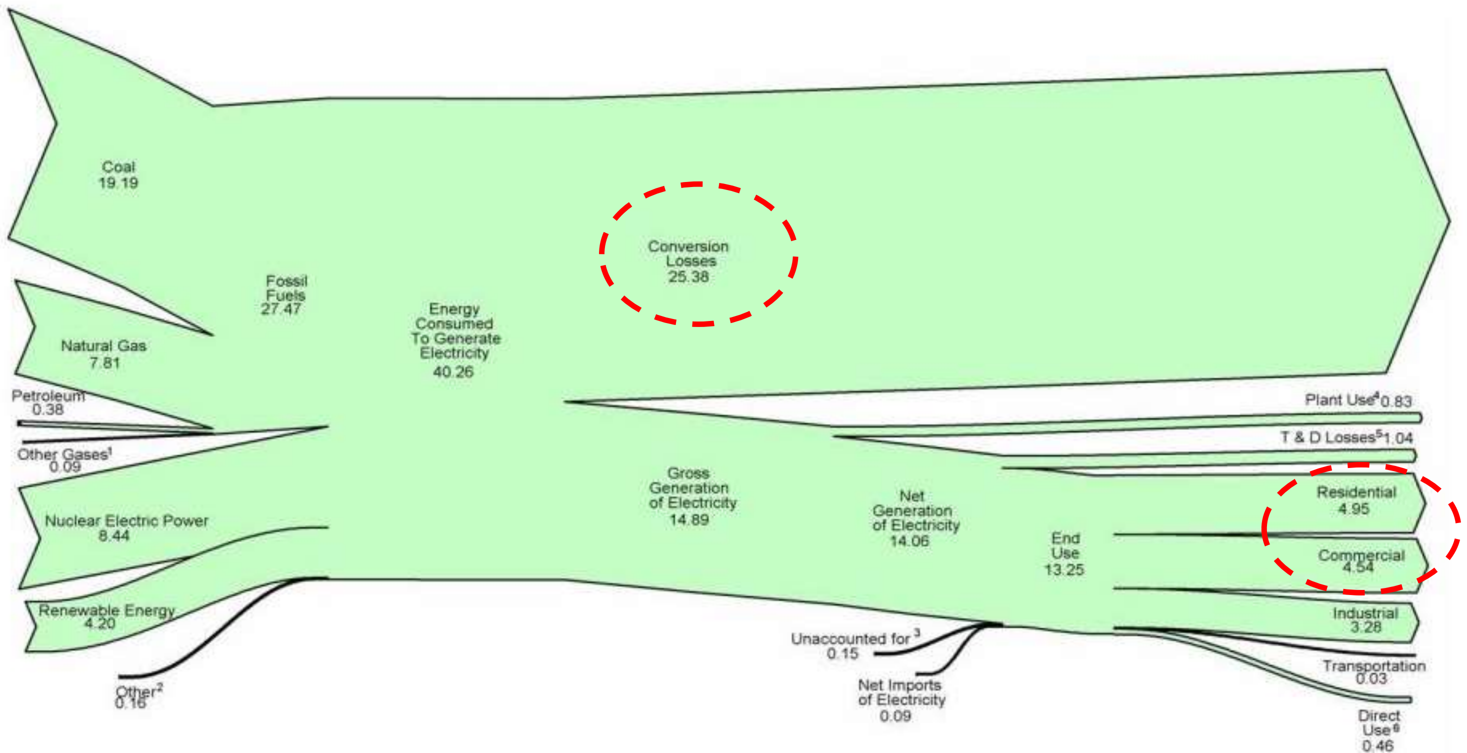
DOE Buildings Energy Data Book

Figure 7.0 **Coal Flow, 2010**
(Million Short Tons)



DOE Buildings Energy Data Book

Figure 8.0 Electricity Flow, 2010
(Quadrillion Btu)



Remember:

=

How “clean” is electricity?

…the electricity grid is primarily fed by fossil fuels (71% on average): with the current power mix, it is reasonable to argue that ***electricity is America’s dirtiest fuel****.*

-John Straube

Why is daylighting so important?

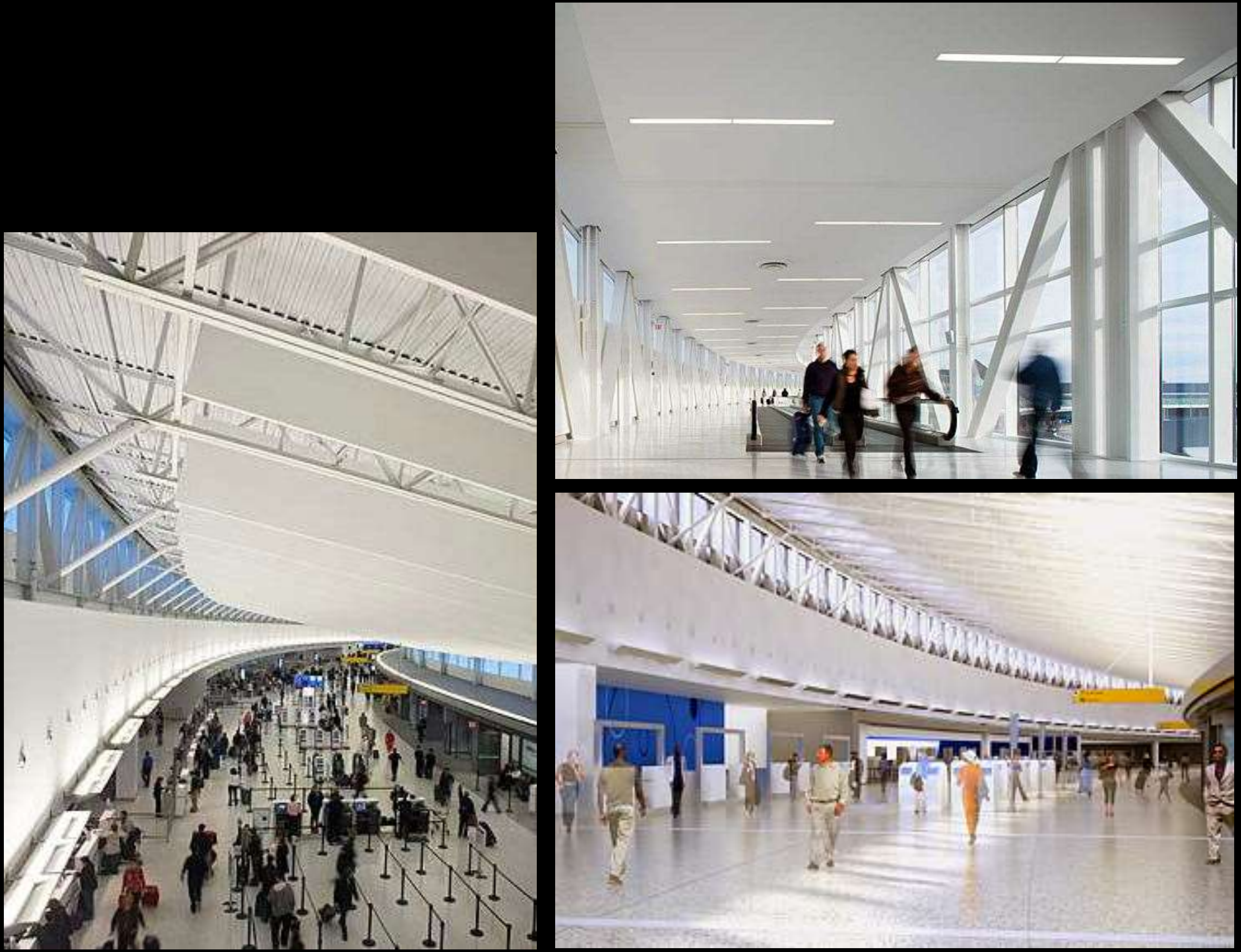
- Energy Efficiency
- Health
- Productivity
- (Almost) Perfect Color Rendering

How does daylighting save electricity?

Rainha Santa Isabel Secondary School/Oficina - Ideias em Linha


Canon
Nikon
ANGING THE WORLD OF
EOSCIENCES

Jet Blue terminal at JFK

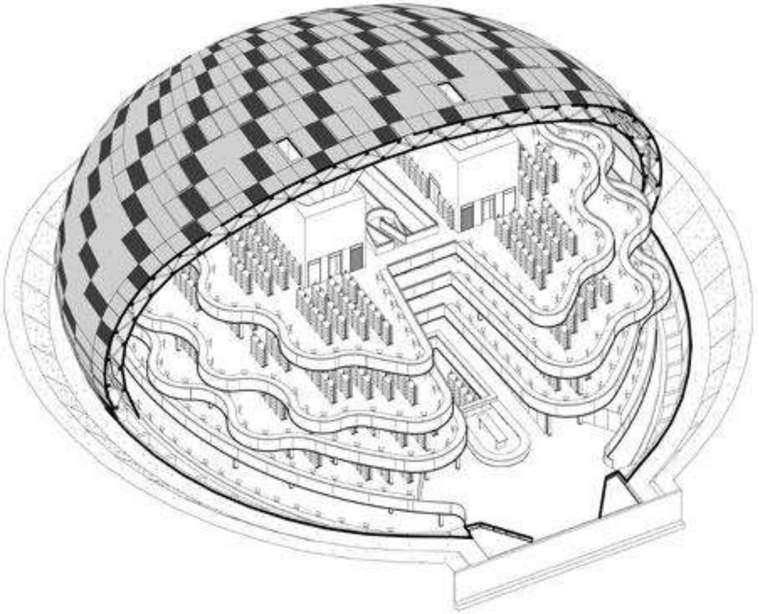


Basic Daylighting Strategies

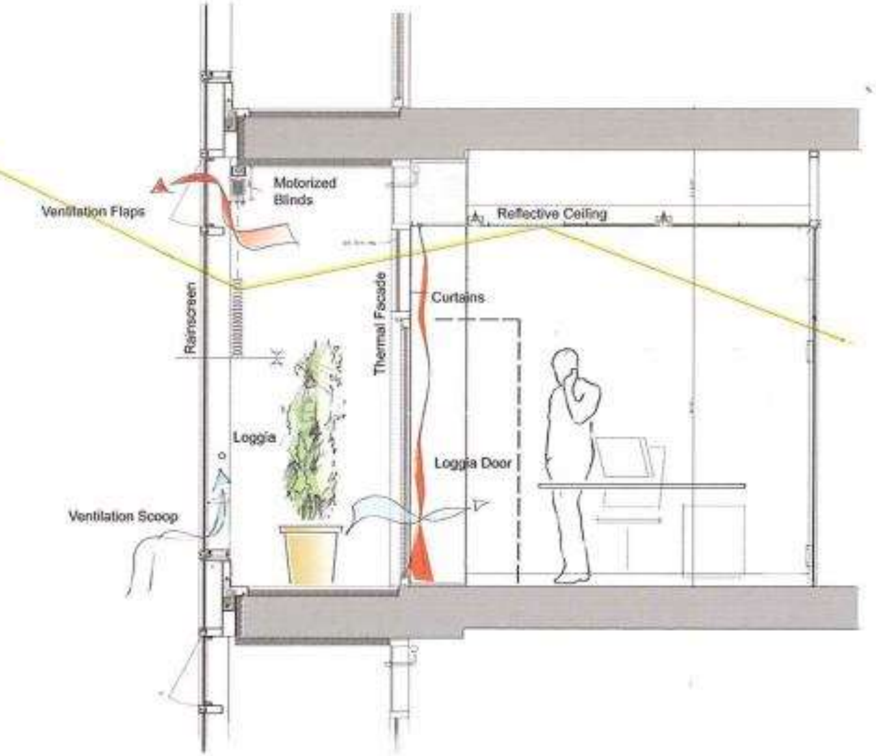
- **Solar Geometry**
- Sidelighting
- Toplighting
- Form
- Programming
- Space Planning
- Surface Reflectances

Solar Geometry

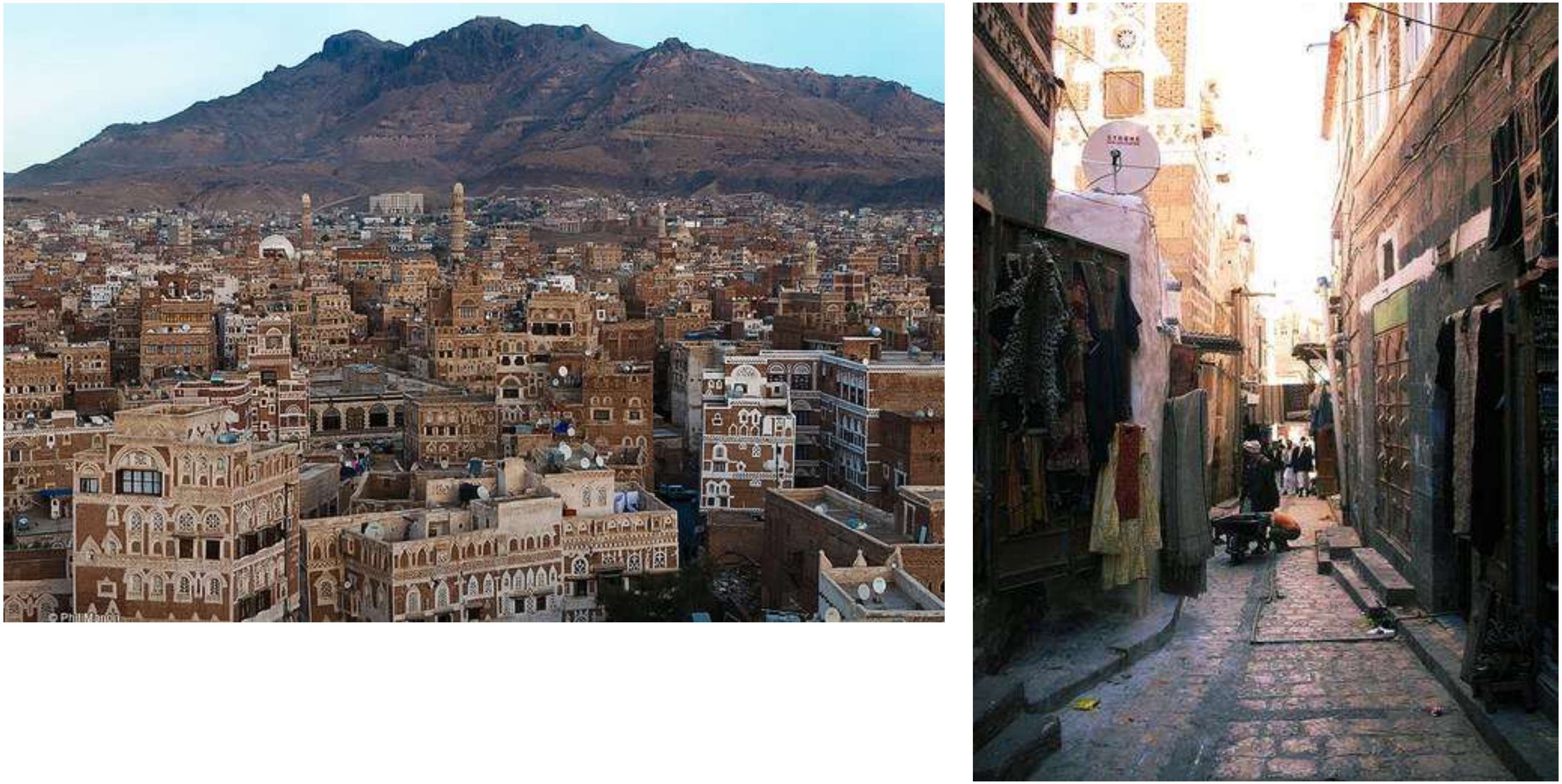
Free University Library, Norman Foster



Genzyme Center, Stefan Behnisch

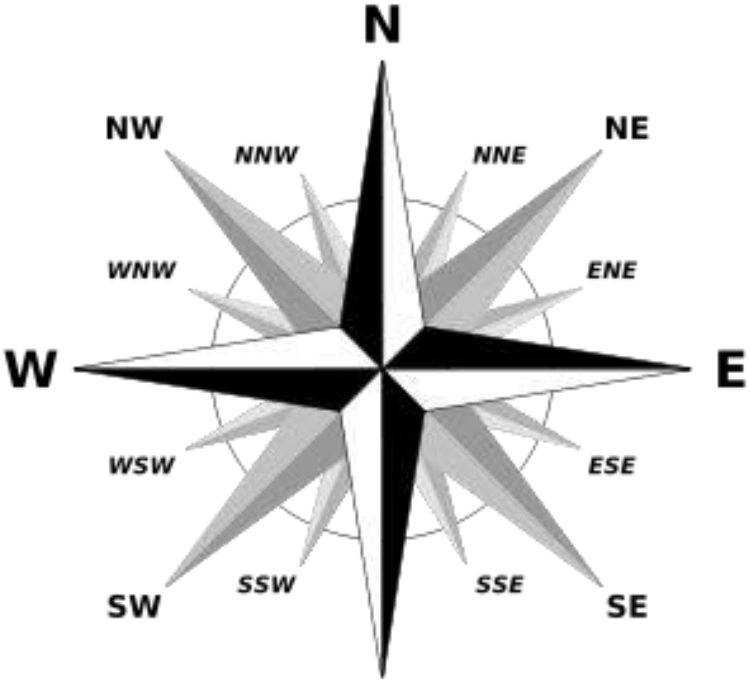


Sana’a, Yemen



Solar Development, Georg Reinberg, Vienna

Southern Orientation



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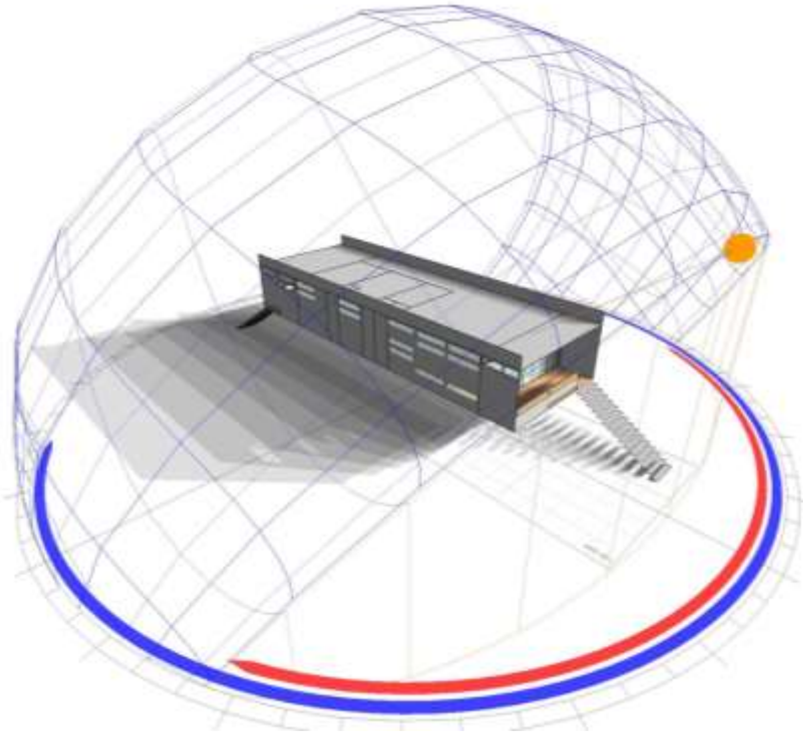
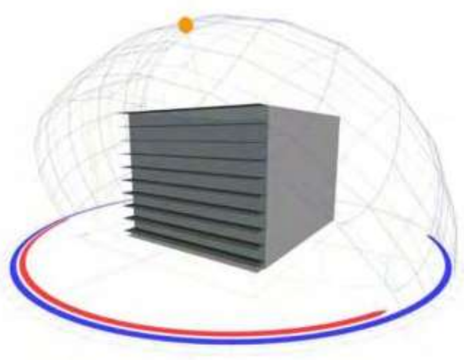
Southern Orientation



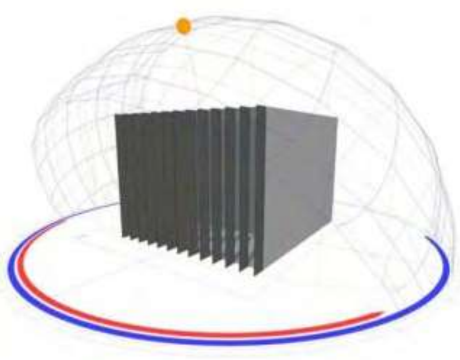
A Pattern Language, Alexander, pattern #128: *Indoor Sunlight*

From UTSoA Facade Thermal Lab:

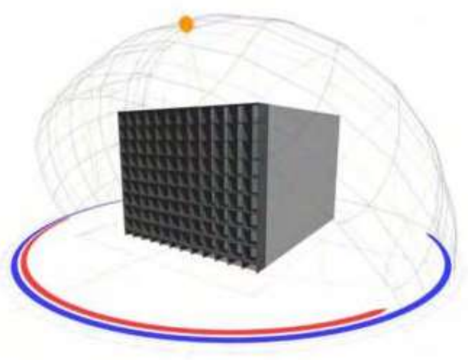
Stefan Bader
Dr. Werner Lang
Professor Matt Fajkus, Thermal Lab Director



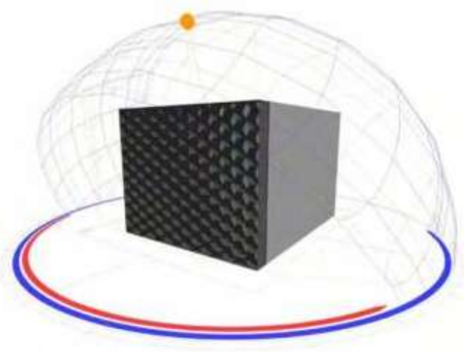
a) Horizontal shading devices



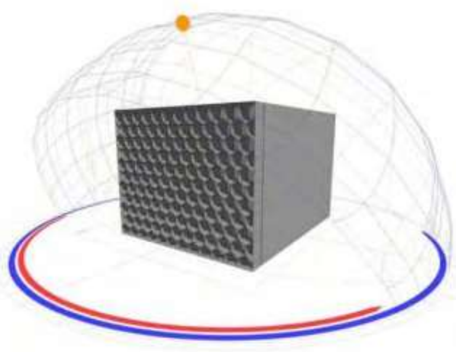
b) Vertical shading devices



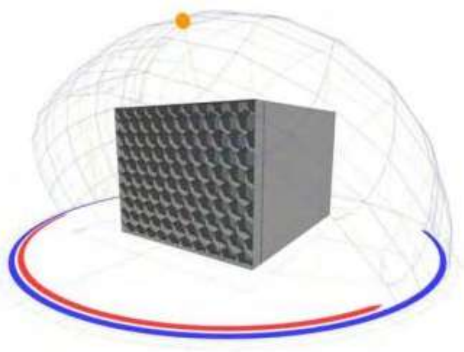
c) Eggcrate shading structure - square



d) Honeycomb shading structure - horizontally oriented

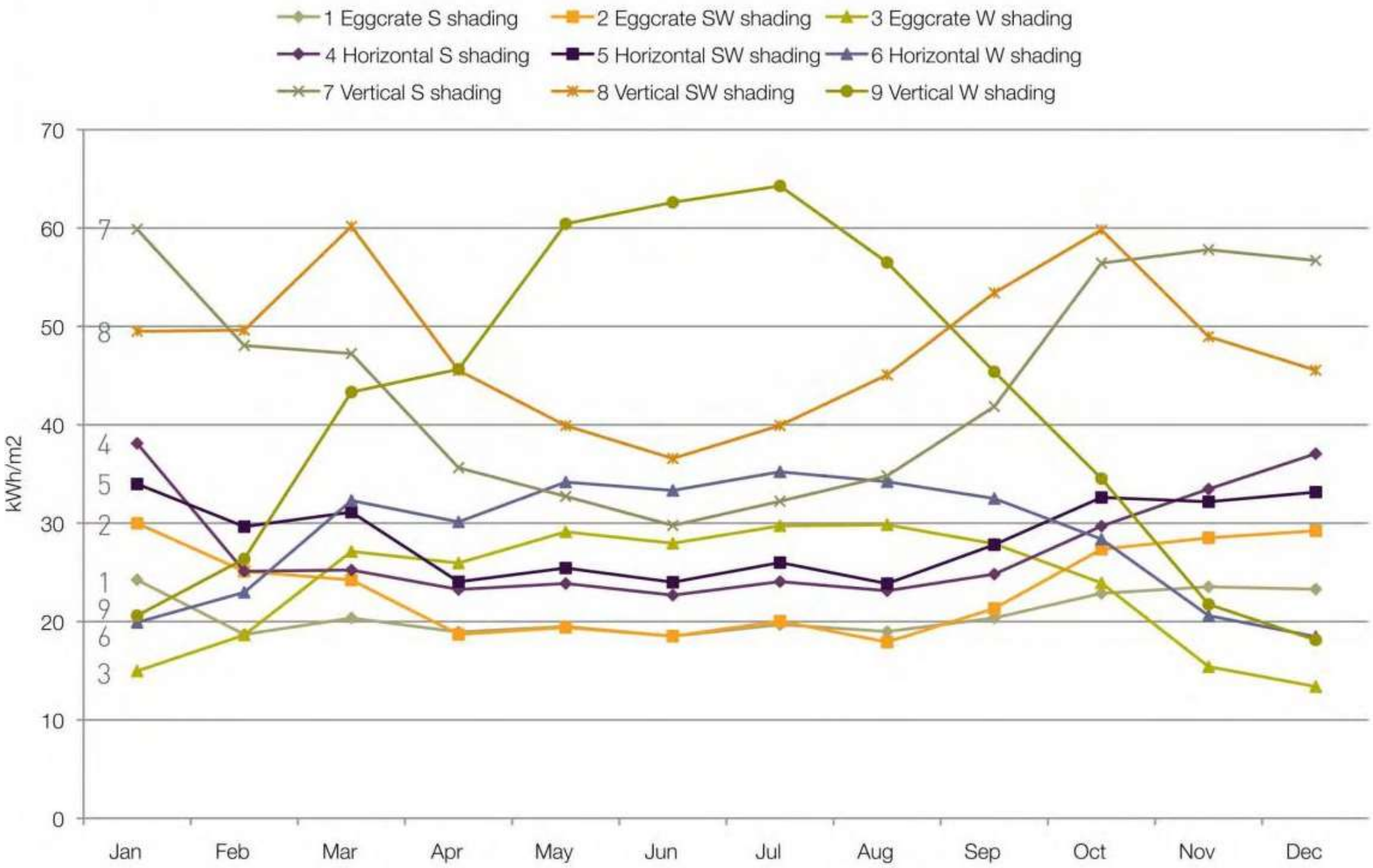


e) Honeycomb shading structure - vertically oriented



f) Honeycomb shading structure - vertically oriented - 4' circumference

From UTSoA Facade Thermal Lab:
Stefan Bader
Dr. Werner Lang
Professor Matt Fajkus, Thermal Lab Director



Monthly solar radiation - comparison of shading structures per orientation (Austin, TX)

Noon
South
Summer

5pm
South
June 5

East

Summer

West, South

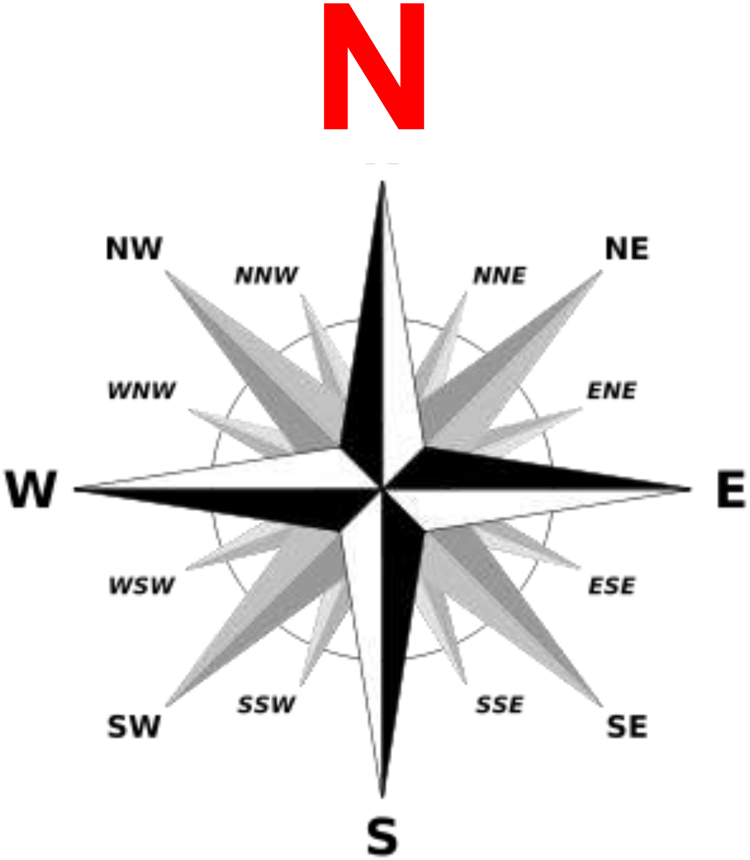
Summer

2:30pm
South
June 17

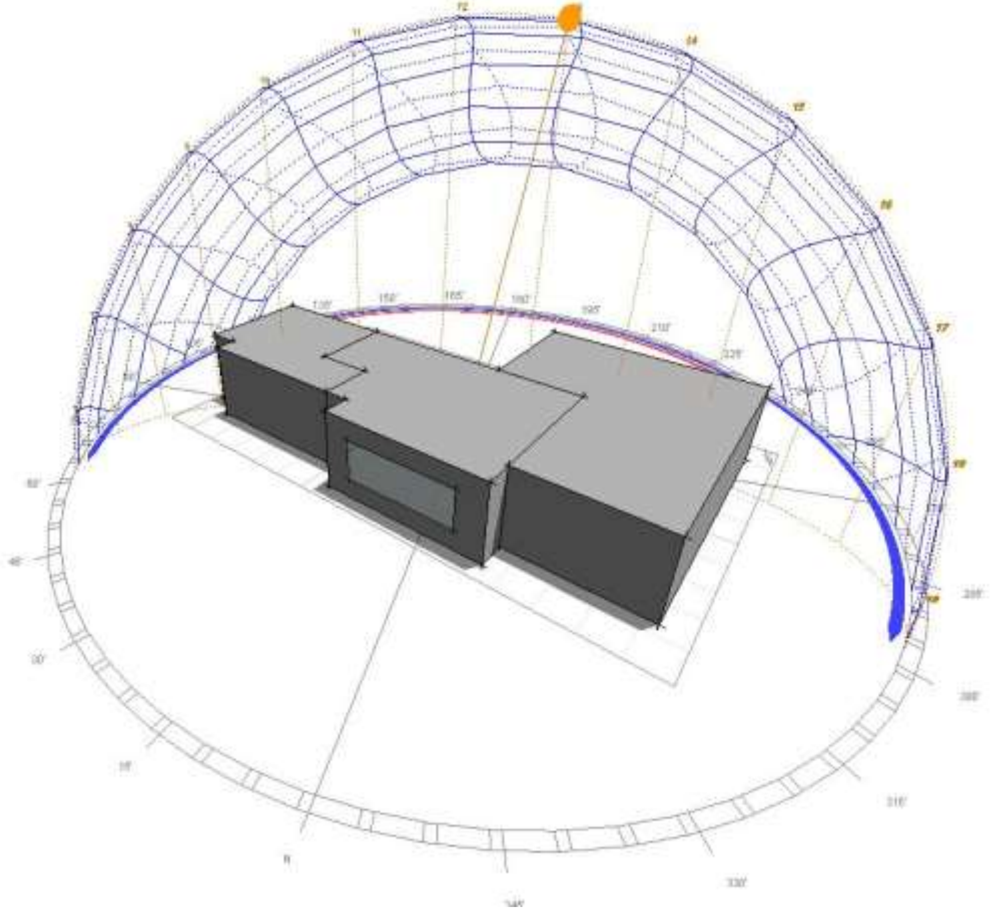
2:30pm
South
June 17

2:30pm
South
June 17

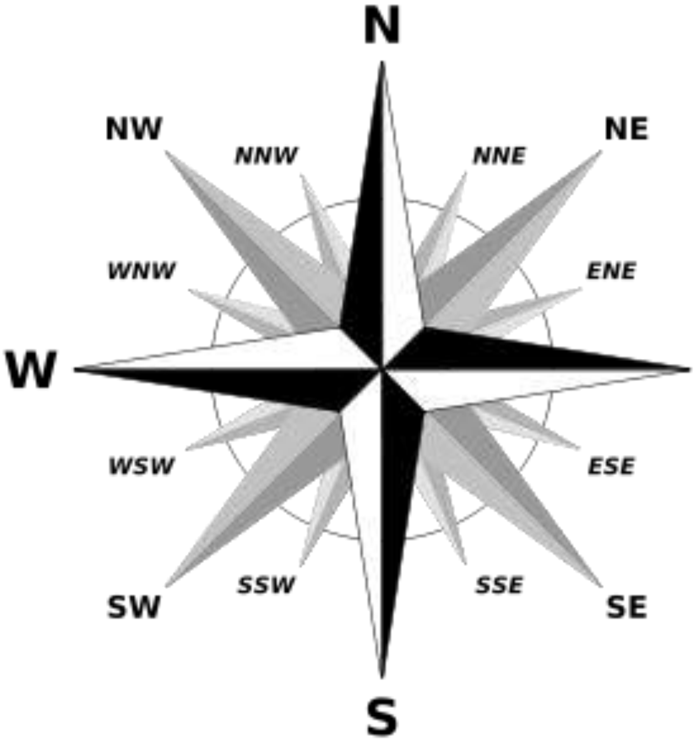
Northern Orientation



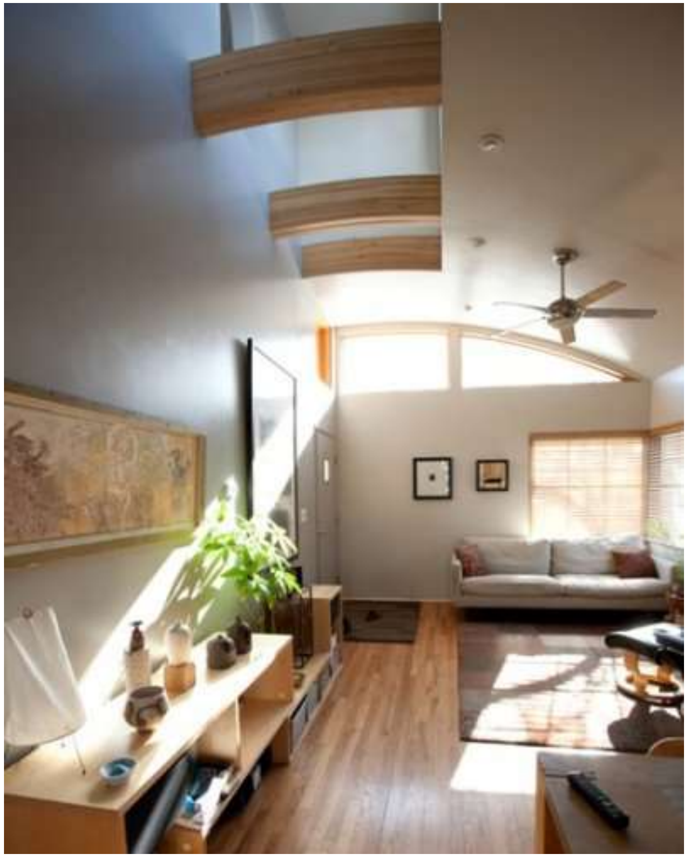
Northern Orientation



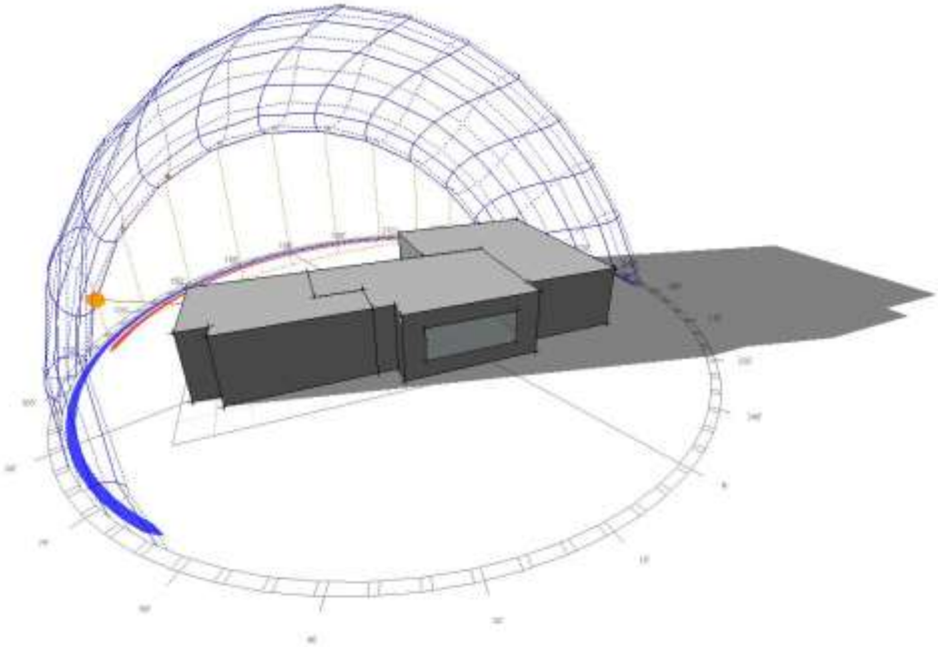
Eastern Orientation



E



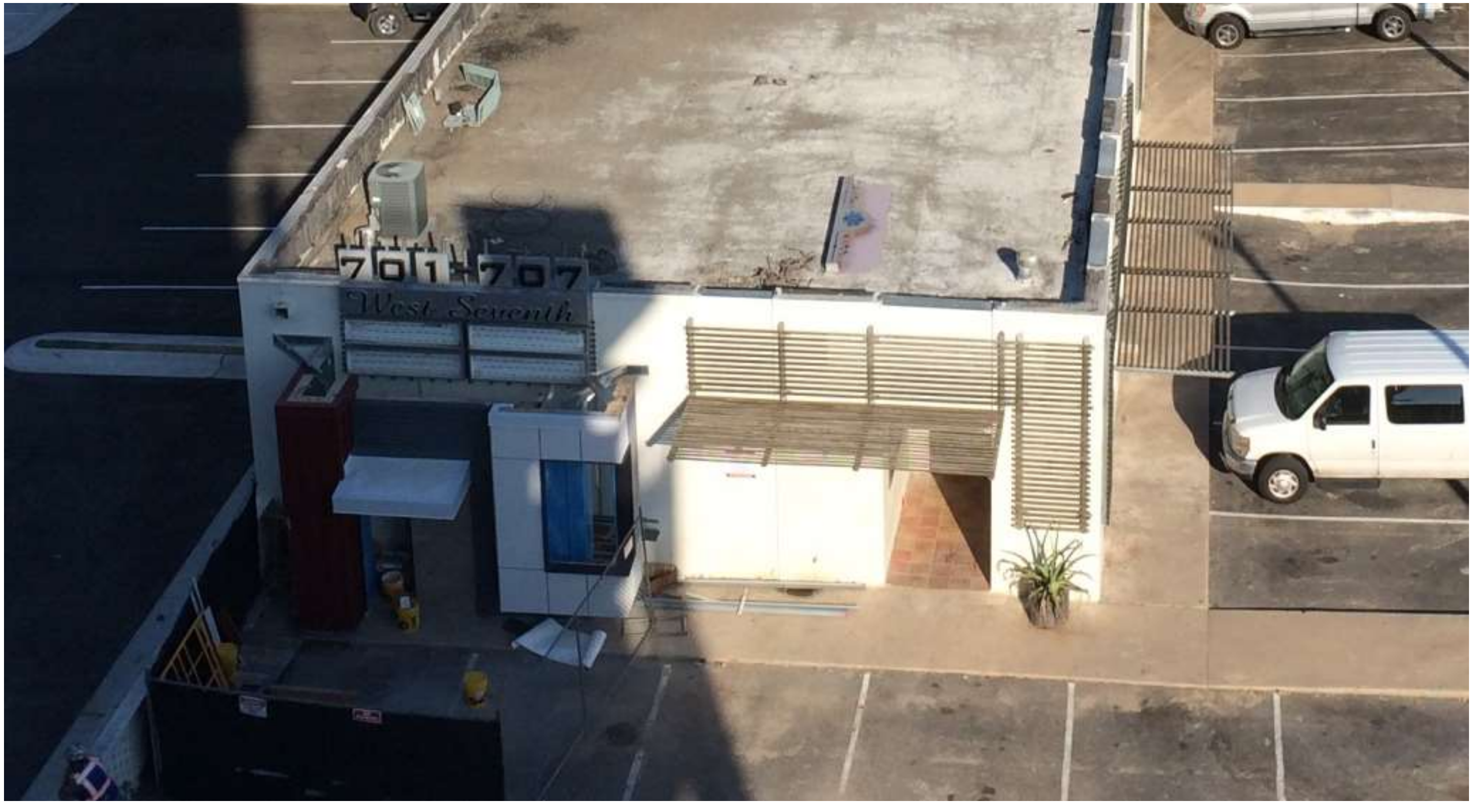
Eastern Orientation



A Pattern Language, Alexander, pattern #138: *Sleeping to the East*

10:00am
East
July 2

9:00 am
East
August 14

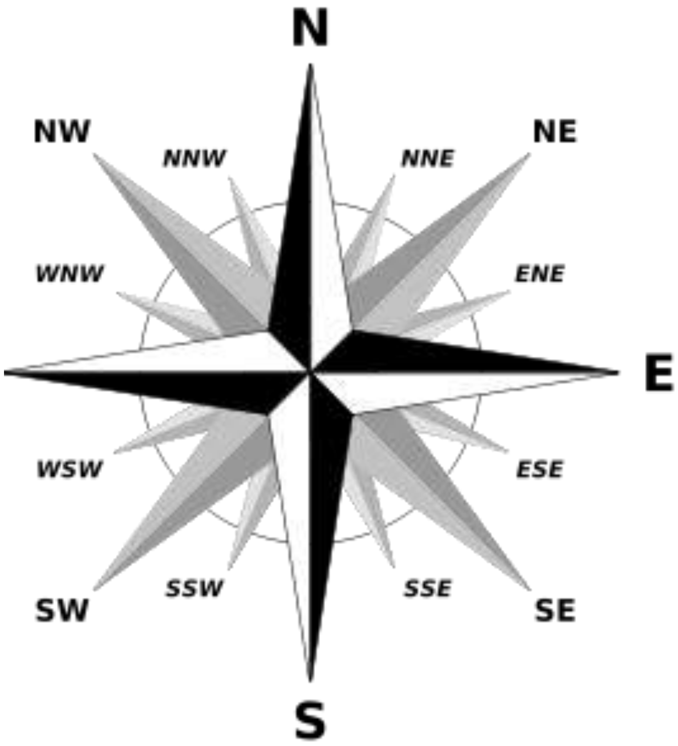


10am, 12pm
East
September 8

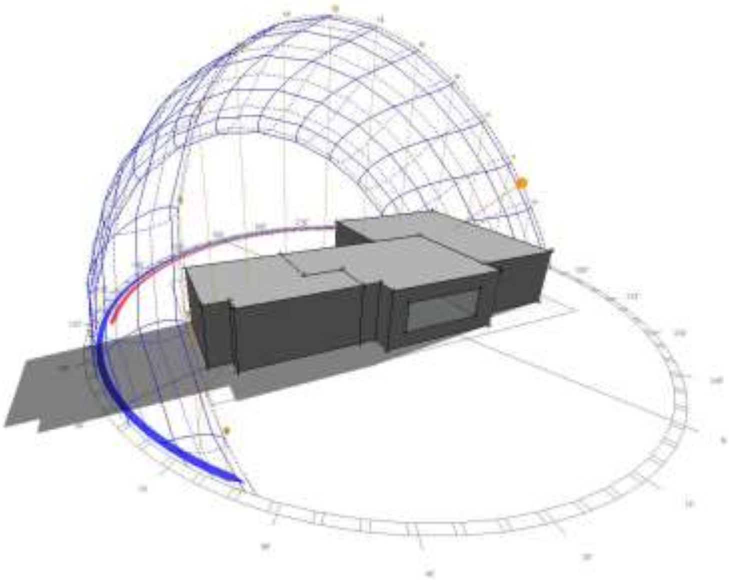
8:45 am
SE
October 17, Austin

Western Orientation

W



Western Orientation

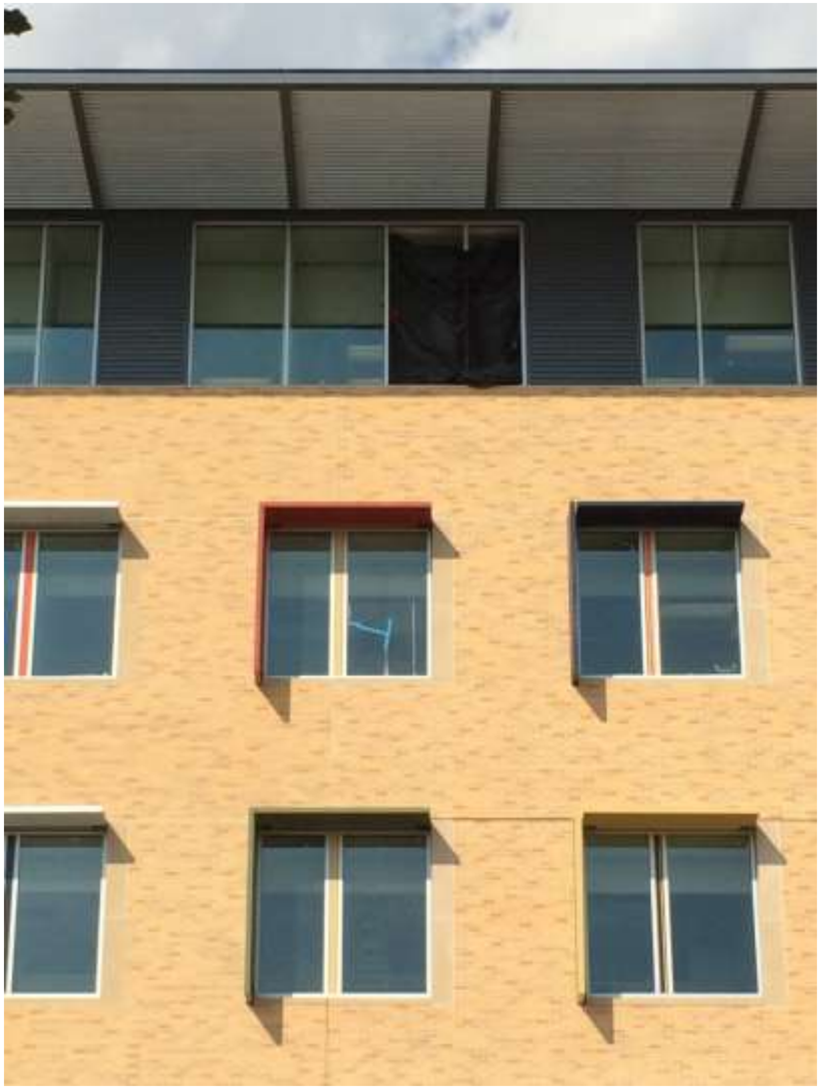


4:15pm
West
August 12

7pm
West
July 12

5:00 pm, Overcast
SE, SW
July 24

5:30 pm
SW
July 24

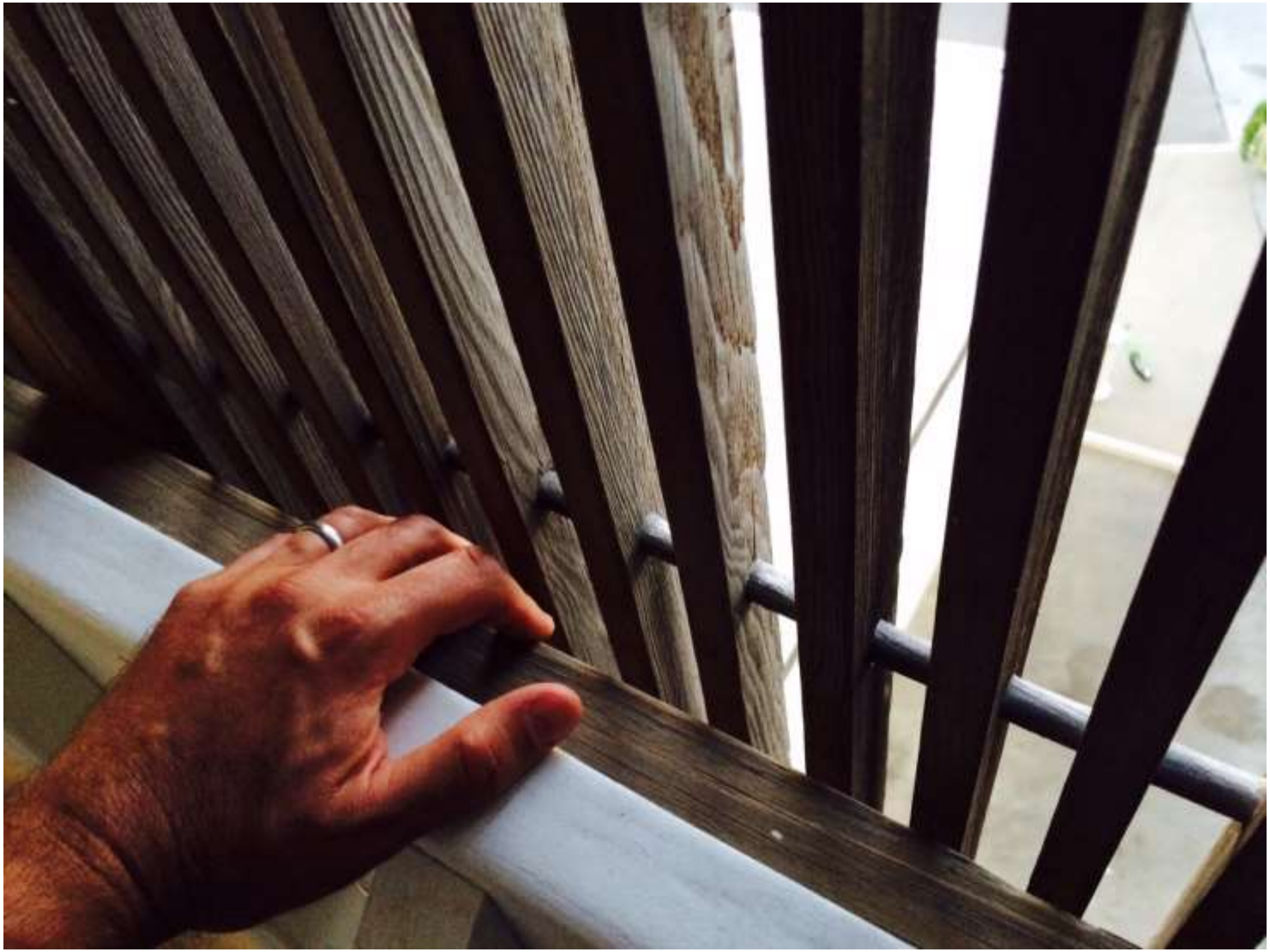


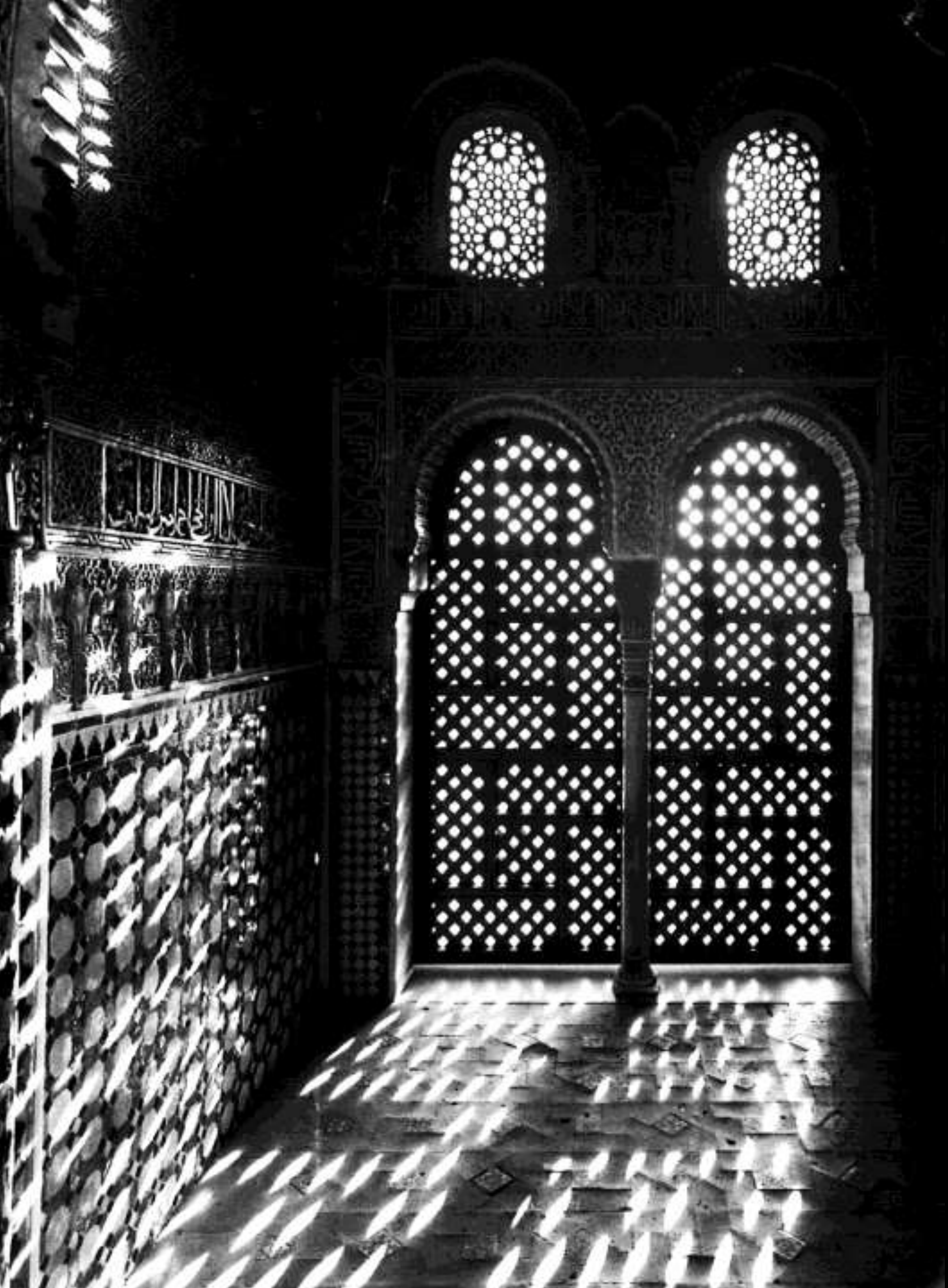
8:00 am
August 4
The Galvestonian – East

The Galvestonian – West Facade

The Galvestonian – West Facade

The Galvestonian – West Facade



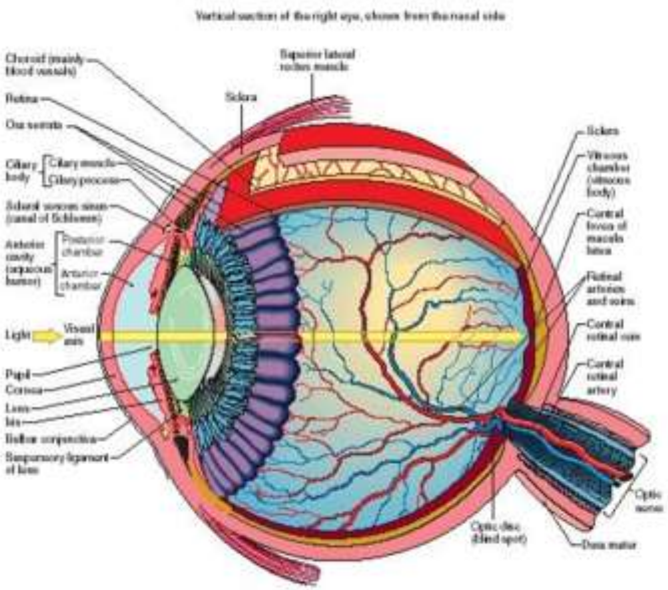


Objectives: Toplighting & Sidelighting

- Solar Geometry
- **Sidelighting**
- **Toplighting**
- Form
- Programming
- Space Planning
- Surface Reflectances

Perception of brightness:

1. **Luminance** of object
2. **Contrast**:
   - Brightness of adjacent objects
   - Luminance Ratios
3. **Biology of Individual**:
   - Health/Age
   - Accommodation
   - Adaptation (time dependent)



Eye Adapts to bright background leaving subject in sillouette, Fuller Moore

Mechanical and Electrical Equipment for Buildings, Kwok/Grondzik

Excessive luminance ratios

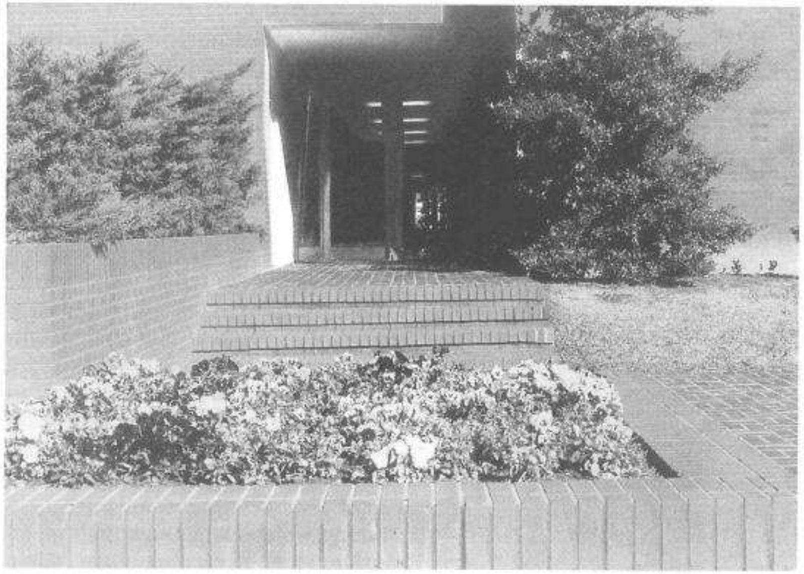
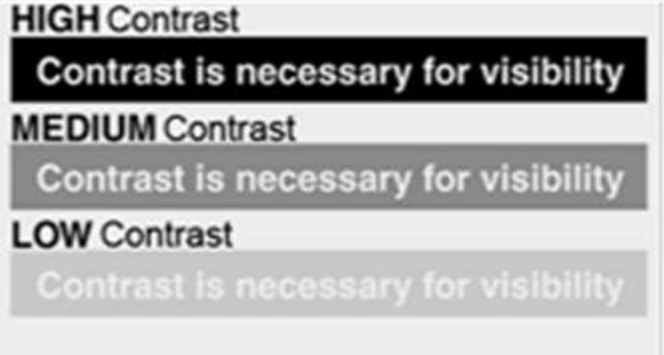


Figure 12.10a In this photograph, the camera was adjusted to correctly expose the high brightness of the exterior. We cannot see indoors because the brightness there is too low compared to the outdoors. This is a problem of excessive brightness ratios.

Figure 12.10b In this photograph, the camera was adjusted to correctly expose the interior. Consequently, we cannot clearly see the outdoor view because it is too bright compared to the interior. This is a problem of excessive brightness ratios.



HIGH Contrast

Contrast is necessary for visibility

MEDIUM Contrast

Contrast is necessary for visibility

LOW Contrast

Contrast is necessary for visibility

Heating, Cooling, Lighting, Lechner, page 417

Light Shelf

- Most effective on south façade
- East and west – must be longer
- Not effective on north

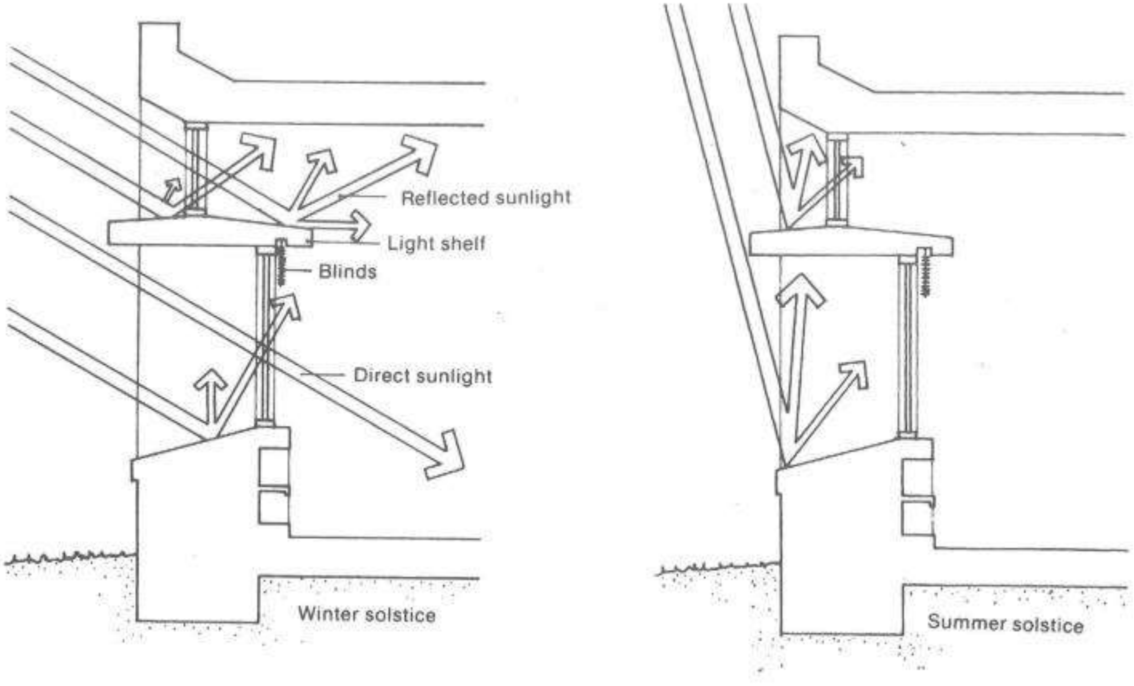


Figure 13.15n Sections through south windows of the Mt. Airy Public Library in North Carolina. More reflected sunlight can enter in the winter than the summer. [From *Passive Solar Journal*, Vol. 3(4). © American Solar Energy Society.]

Light Shelf

Light Shelf

Assessing Light Shelf and Optical Louver Systems in Multi-Story Office Buildings by Using Experimental Methods

Presented at ASES 2011 by Dr. Jianxin Hu, NC State University

Experiments test:

- Light Shelf Top Surfaces
- Partition Materials
- Placement of Partitions
- Ceiling Height
- Comparisons of the Light Shelf & FISCH system

Figure 1: Exterior Image of the Test Cell

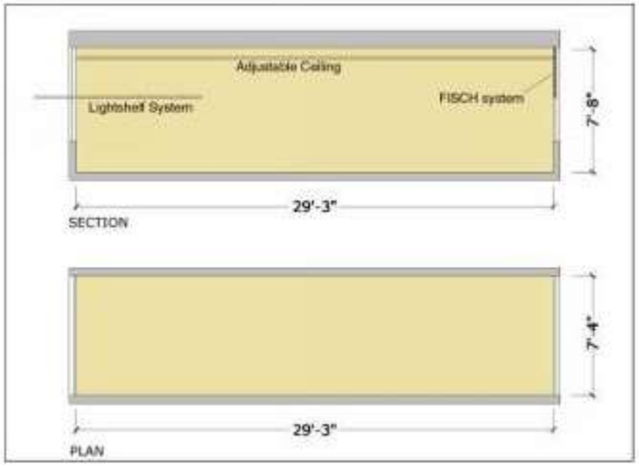


Figure 2: Interior Dimensions of the Test Cell

Mirror

Foil Backing

Glossy White Paint

Ceiling Tile

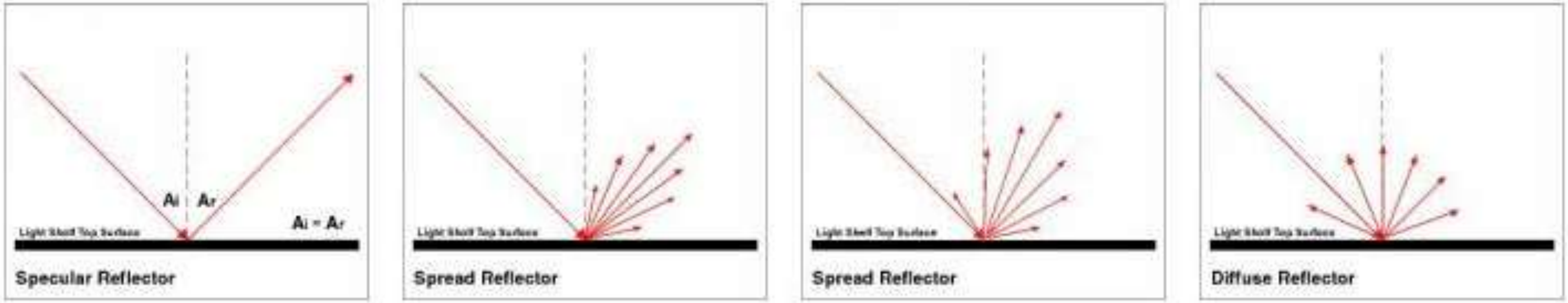


Figure 3: Four Reflectors and Their Optical Properties.

Assessing Light Shelf and Optical Louver Systems in Multi-Story Office Buildings by Using Experimental Methods

Presented at ASES 2011 by Dr. Jianxin Hu, NC State University

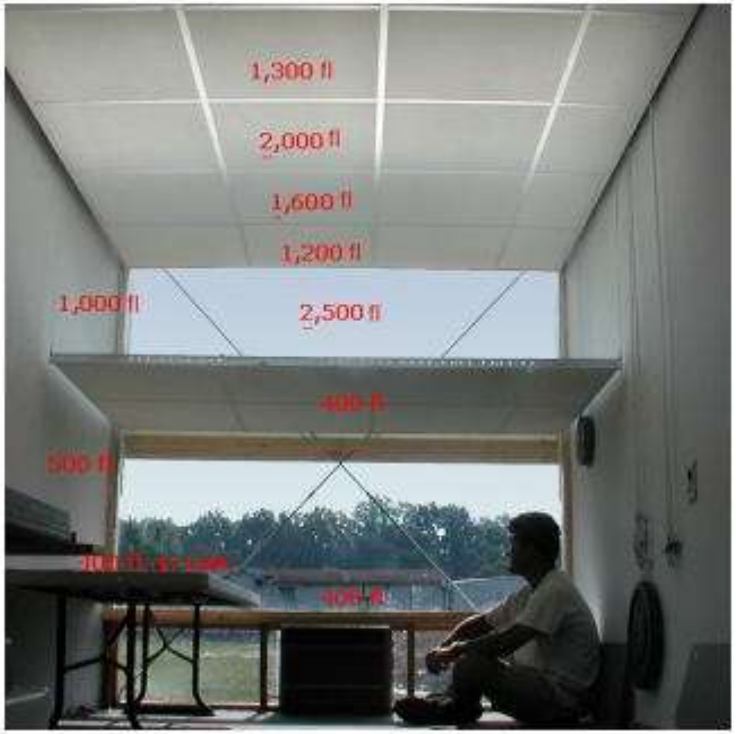


Figure 5: Foil Reflector

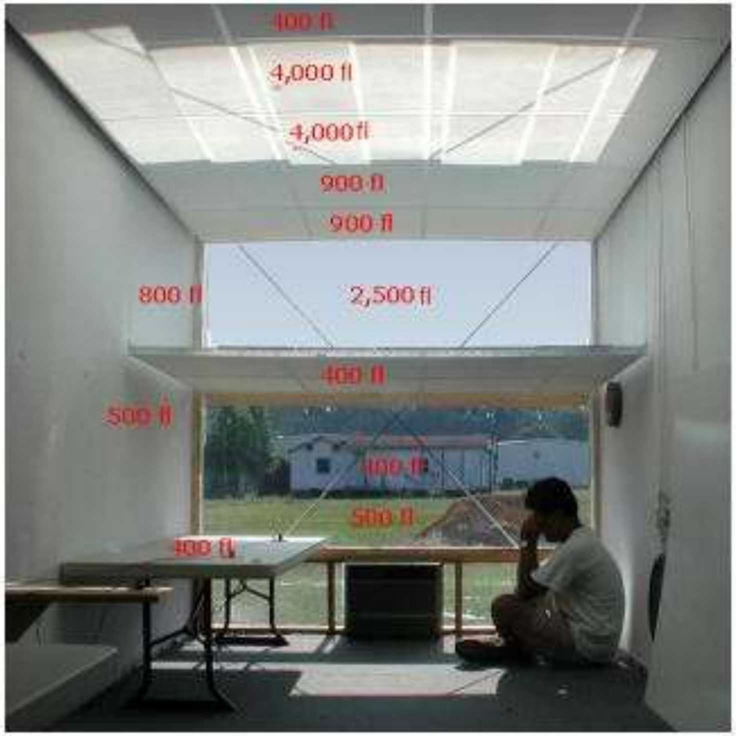
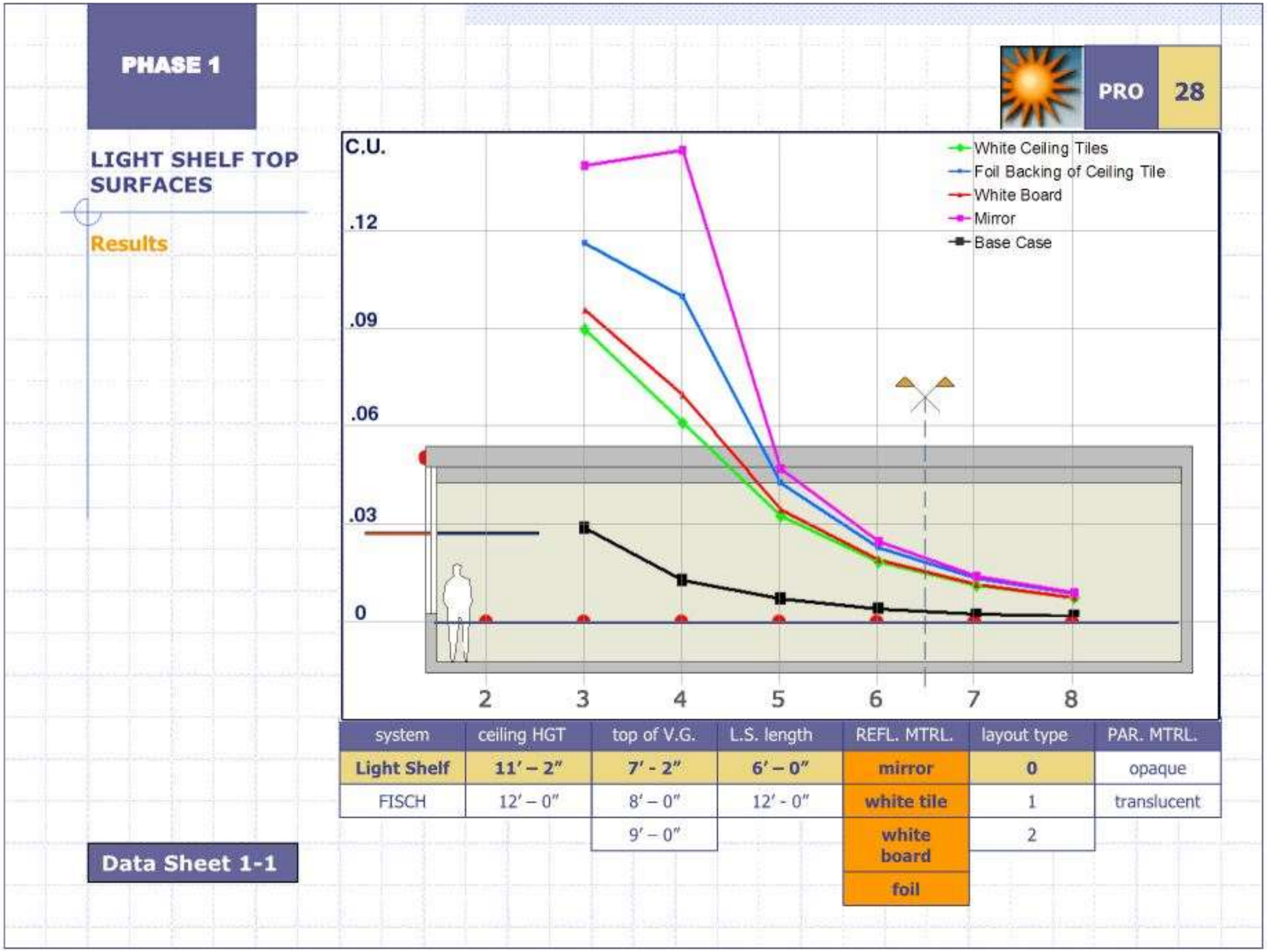


Figure 6: Mirror Reflector

Assessing Light Shelf and Optical Louver Systems in Multi-Story Office Buildings by Using Experimental Methods

Presented at ASES 2011 by Dr. Jianxin Hu, NC State University



PHASE 1

PRO **28**

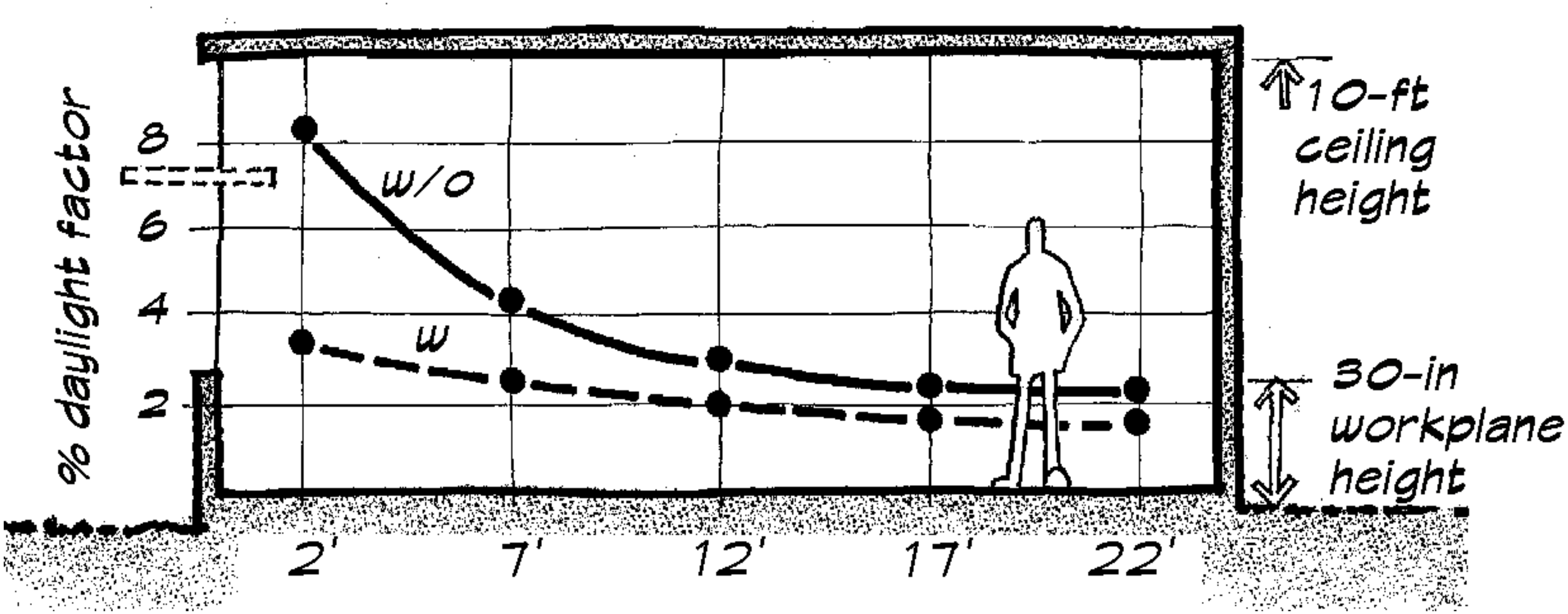
LIGHT SHELF TOP SURFACES

Results

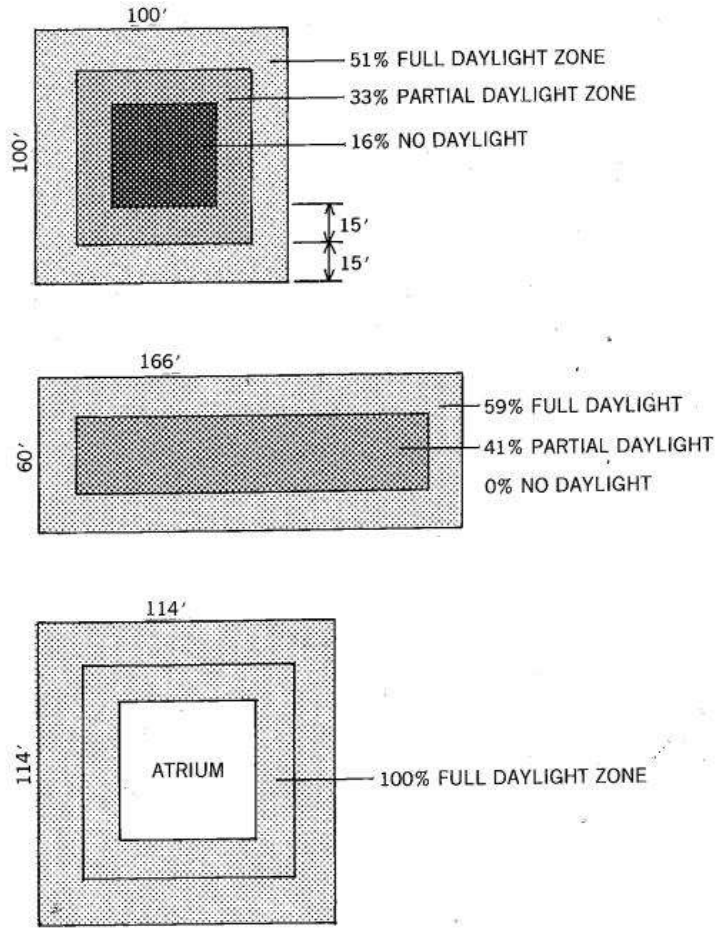
system	ceiling HGT	top of V.G.	L.S. length	REFL. MTRL.	layout type	PAR. MTRL.
Light Shelf	**11′ – 2″**	**7′ - 2″**	**6′ – 0″**	**mirror**	**0**	opaque
FISCH	12′ – 0″	8′ – 0″	12′ - 0″	**white tile**	1	translucent
		9′ – 0″		**white board**	2	
				foil		

Data Sheet 1-1

Environmental Control Systems, Fuller Moore



Building Form



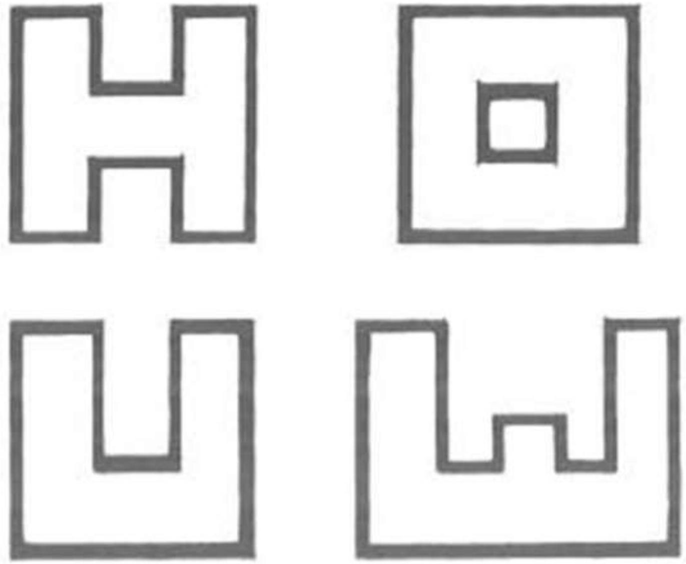


Figure 13.1d These were the common floor plans for large buildings prior to the twentieth century because of the need for light and ventilation.

Lechner p.396

Space Planning

LPD Area - First Floor
Option B - Partially Sloped - Daylight Only

Area:	5735 sf
Total Watts:	5
Light Power Density:	0.001 Watts/sf

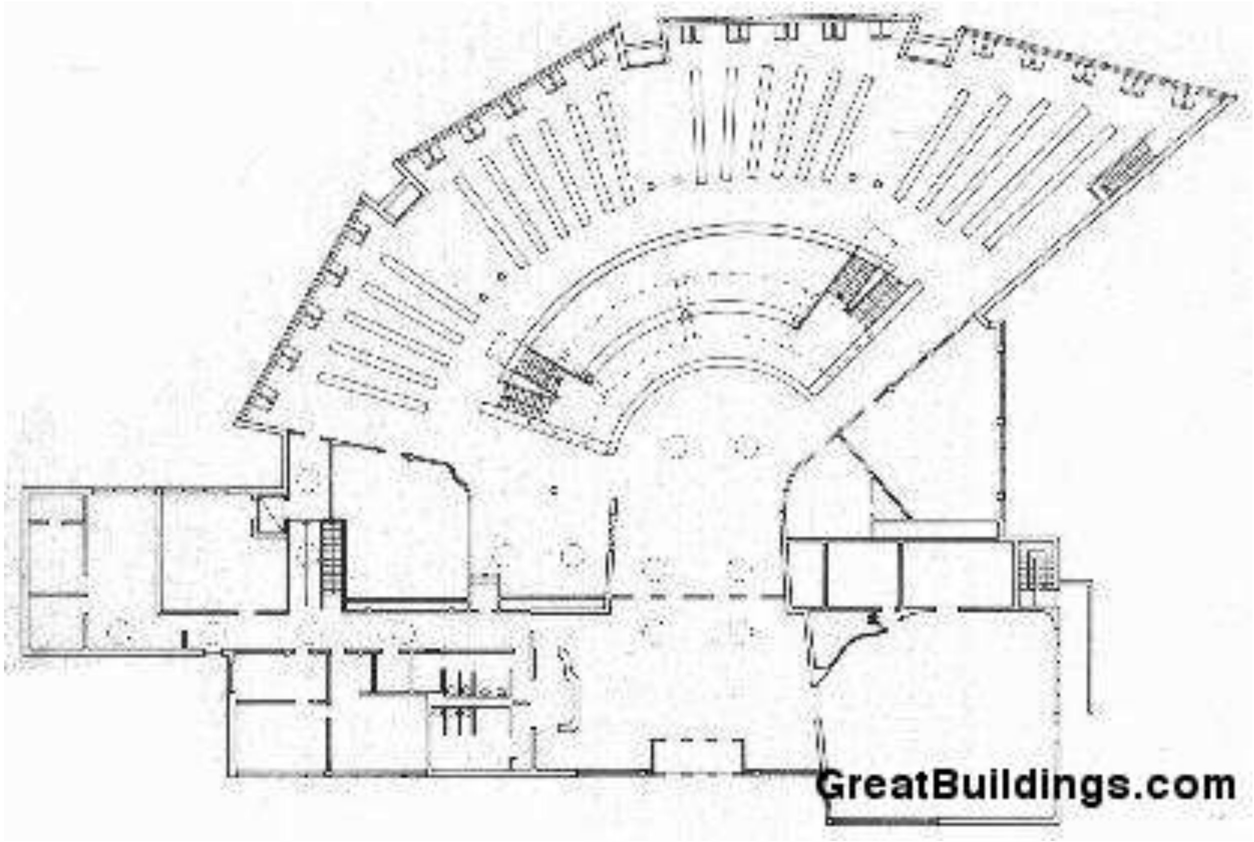
Partially Sloped Ceiling (2707 SF @ 25FC) – 61.5%

CDC Building 107

Option B - Flat Ceiling with Partial Slope

Alvar Aalto Mount Angel

Space Planning: stacks (or desks) perpendicular to windows



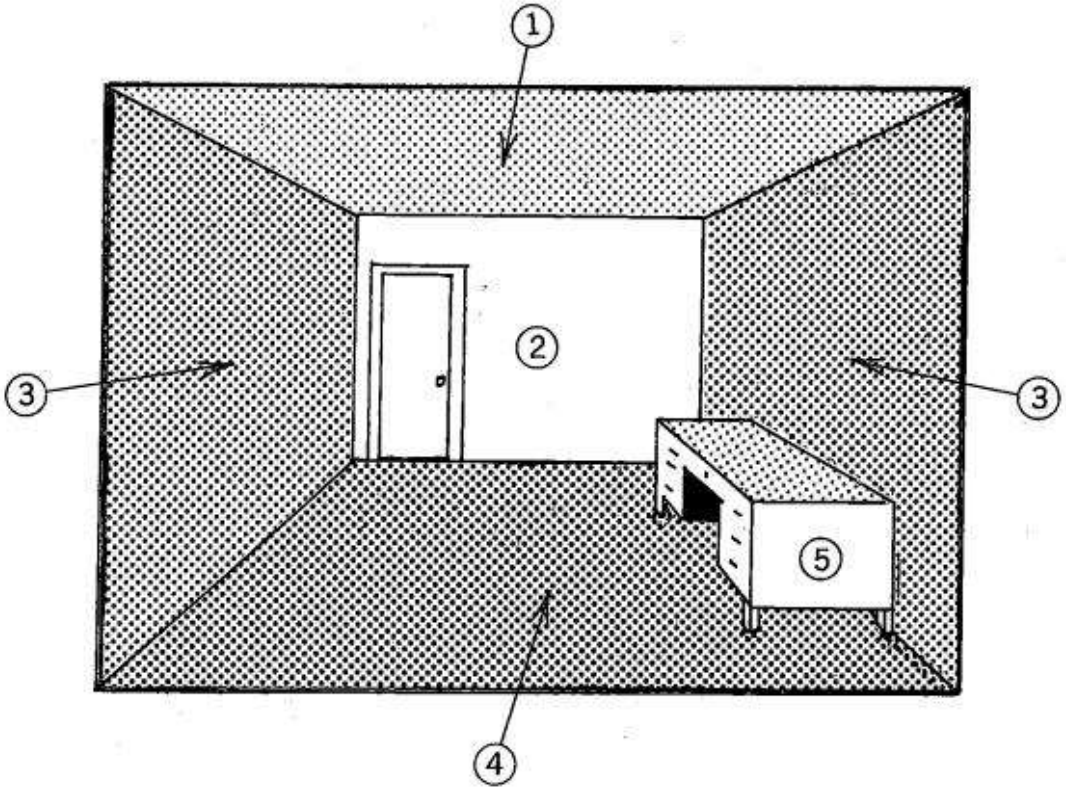
Alvar Aalto Mount Angel

Space Planning: translucent interior partitions

SMP Architects
Space Planning

Color, Surface Reflectances

Heating, Cooling, Lighting, Lechner, page 397



Glazing Selection

U-Factor
U-factor measures how well a window prevents heat from escaping. Ratings generally fall between 0.20 and 1.20. The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.

NFRC
National Fenestration Rating Council
CERTIFIED

World's Best Window Co.

Millennium 2000+
Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS

U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
0.35	**0.32**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S./I-P)
0.51	**0.2**
Condensation Resistance **51**	—

Solar Heat Gain Coefficient
Solar Heat Gain Coefficient (SHGC) is the fraction of incident solar radiation admitted through a window as heat gain, either directly transmitted or absorbed by the glass and then released inward. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat is transmitted.

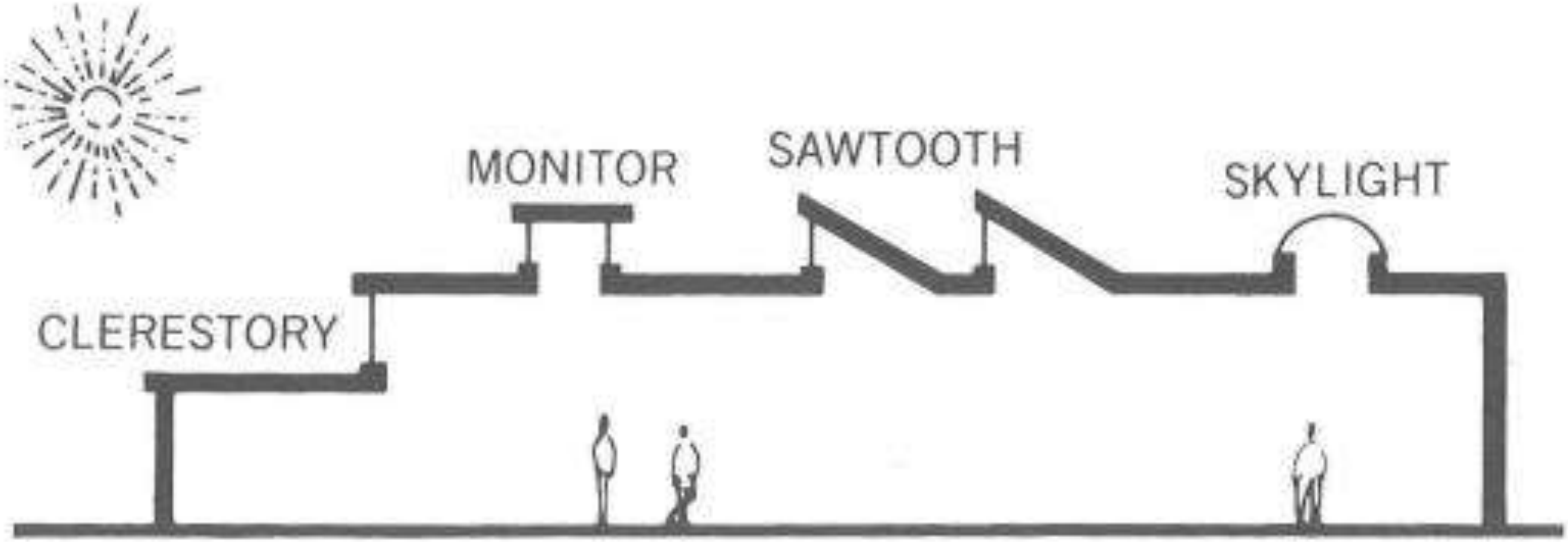
Visible Transmittance
Visible Transmittance (VT) measures how much visible light come through a window, expressed as a number between 0 and 1. The higher the VT, the more light is transmitted.

Air Leakage
Air Leakage (AL) through a window is expressed as the equivalent cubic feet of air passing through a square foot window area (cfm/sq ft). The lower the AL, the less air will pass through cracks in the window assembly.

Condensation Resistance
Condensation Resistance (CR) measures on a scale of 0 to 100 the ability of a window to resist the formation of condensation on the interior surface. The higher the rating, the better the product is at resisting condensation. While this rating cannot predict condensation, it allows consistent product comparisons.

Top Lighting

Heating, Cooling, Lighting, Lechner, page 395



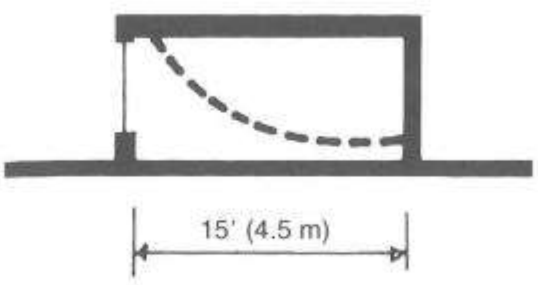
Heating, Cooling, Lighting, Lechner, page 395

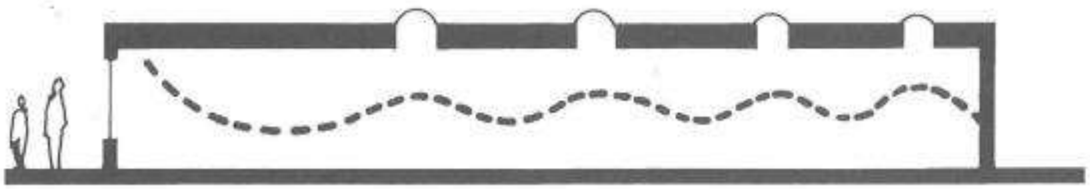
Advantages:

- Potential for uniform illumination over great floor areas
- Receive greater amounts of illumination

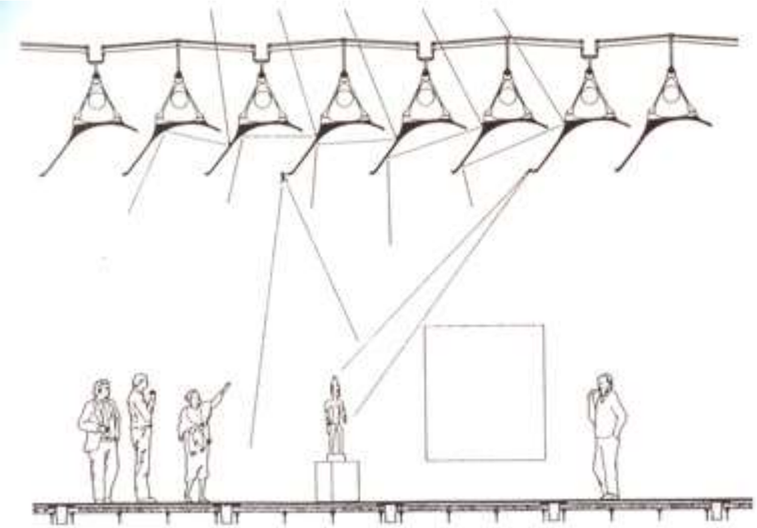
Disadvantages:

- Intensity of light is greater in summer than in winter
- Difficult to utilize other than 1-story buildings or the top floor
- Difficult to shade – therefore try to use vertical glazing on the roof (clerestories, monitors, sawtooths)



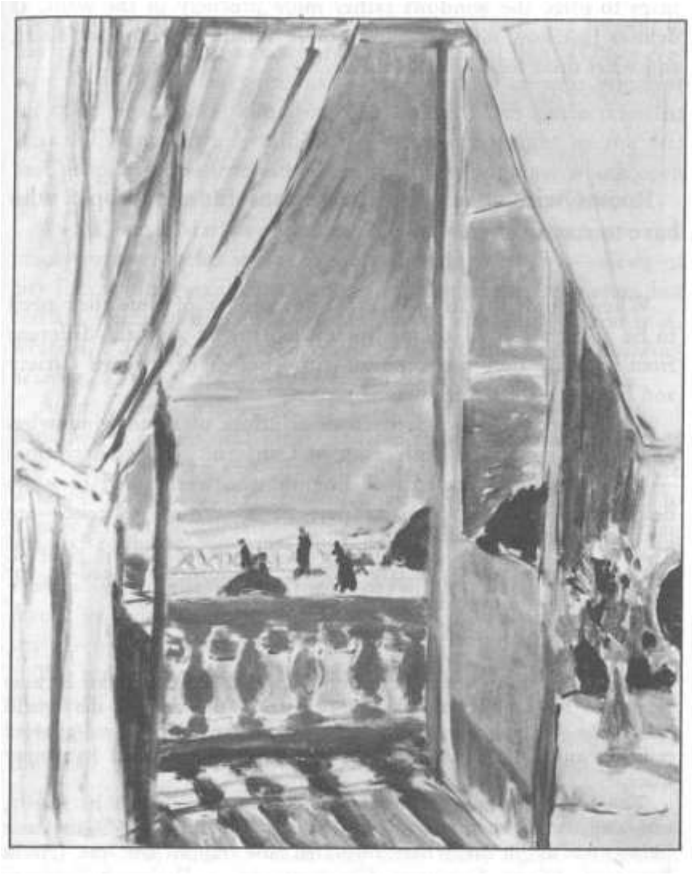


The Menil Museum, Renzo Piano

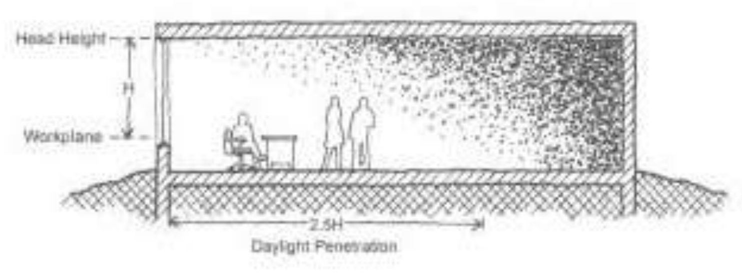


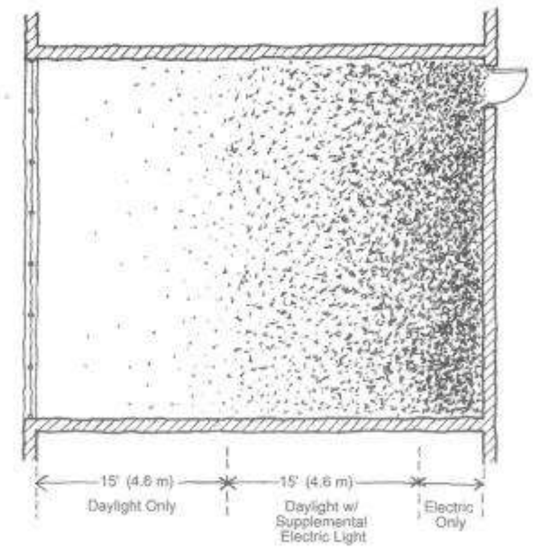
Kahn Kimball

Side Lighting



Grondzik, Walter T.; Kwok, Alison G.; ***The Green Studio Handbook: Environmental Strategies for Schematic Design, 2nd Edition.***
Elsevier, 2011. ISBN-13: 978-0080890524, page 64.





2.5H Rule of Thumb Assumes:

-Clear Glazing
-Overcast Skies
-No major obstructions
-Total window width approximately ½ of perimeter wall

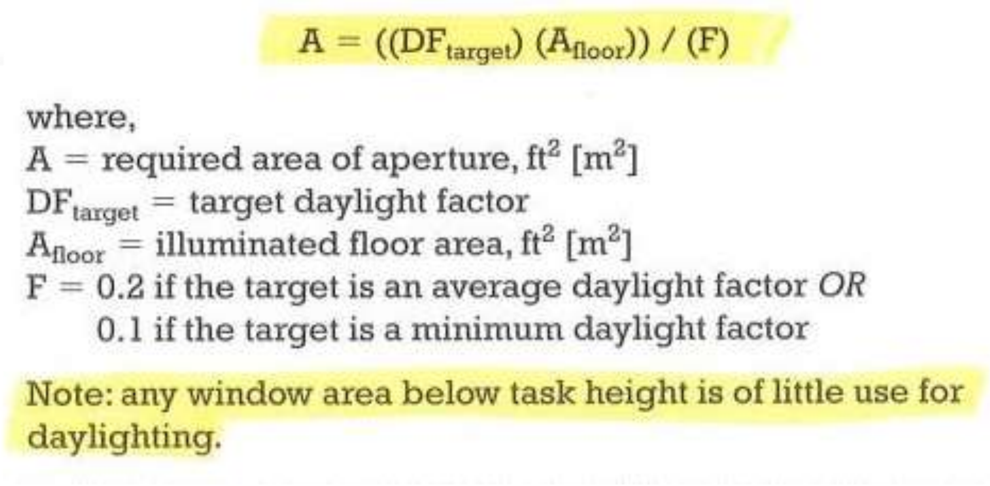
15/30 Rule of Thumb Assumes:

-No assumptions stated
-Very basic guess

Grondzik, Walter T.; Kwok, Alison G.; ***The Green Studio Handbook: Environmental Strategies for Schematic Design, 2nd Edition.***
Elsevier, 2011. ISBN-13: 978-0080890524, page 77.

Calculating Sidelighting Apertures

$$\mathbf{A} = (\mathbf{DF}_{\text{target}})(\mathbf{A}_{\text{floor}}))/(\mathbf{F})$$



$$A = ((DF_{target})\ (A_{floor}))\ /\ (F)$$

where,
A = required area of aperture, ft^2 [m^2]
DF_{target} = target daylight factor
A_{floor} = illuminated floor area, ft^2 [m^2]
F = 0.2 if the target is an average daylight factor *OR*
0.1 if the target is a minimum daylight factor

Note: any window area below task height is of little use for daylighting.

Basics Window Strategies:

From *Heating, Cooling, Lighting* - Lechner

1. Place high on the wall, widely distributed, optimize overall area
2. If possible, place windows on more than one wall
3. Place windows adjacent to interior walls
4. Splay jambs to reduce the contrast between windows and walls
5. Filter daylight
6. Shade windows from excess sunlight in summer
7. Use movable shades
8. Additional Strategies

Heating, Cooling, Lighting, Lechner, page 398

1. Place high on the wall, widely distributed, optimize overall area

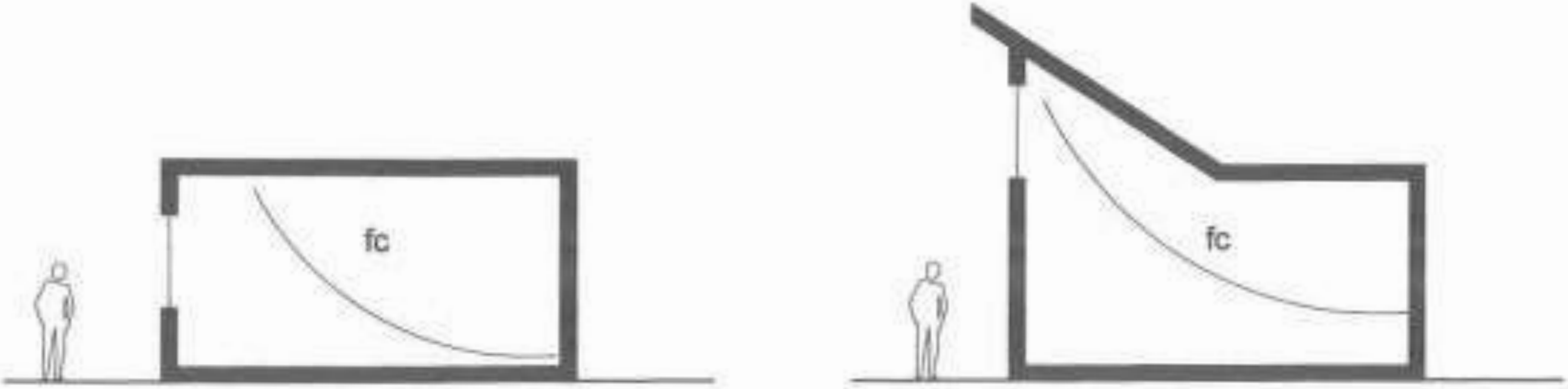
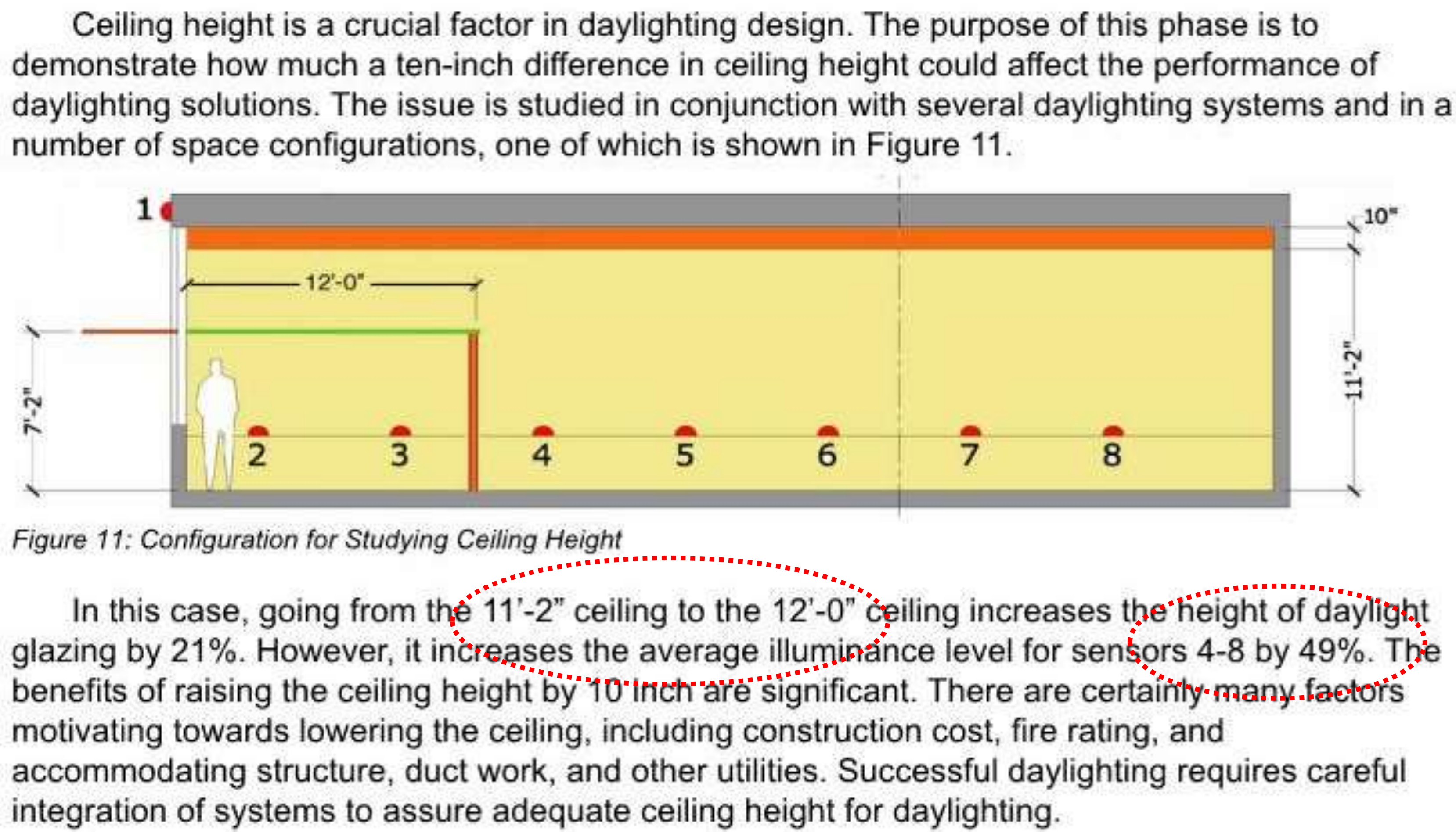


Figure 13.10a Daylight penetration increases with window height.

Assessing Light Shelf and Optical Louver Systems in Multi-Story Office Buildings by Using Experimental Methods

Presented at ASES 2011 by Dr. Jianxin Hu, NC State University

4. Ceiling Height



Ceiling height is a crucial factor in daylighting design. The purpose of this phase is to demonstrate how much a ten-inch difference in ceiling height could affect the performance of daylighting solutions. The issue is studied in conjunction with several daylighting systems and in a number of space configurations, one of which is shown in Figure 11.

Figure 11: Configuration for Studying Ceiling Height

In this case, going from the 11'-2" ceiling to the 12'-0" ceiling increases the height of daylight glazing by 21%. However, it increases the average illuminance level for sensors 4-8 by 49%. The benefits of raising the ceiling height by 10 inch are significant. There are certainly many factors motivating towards lowering the ceiling, including construction cost, fire rating, and accommodating structure, duct work, and other utilities. Successful daylighting requires careful integration of systems to assure adequate ceiling height for daylighting.

Heating, Cooling, Lighting, Lechner, page 398

1. Place high on the wall, widely distributed, optimize overall area

Figure 13.10c Strip or ribbon windows, as seen here in the Maison LaRoche by Le Corbusier, admit uniform light, which is further improved by placing the windows high on the wall. Note that photographic film exaggerates brightness ratios. (Photograph by William Gwin.)

Heading, Cooling, Lighting, Lechner, page 398

1. Place high on the wall, widely distributed, optimize overall area

Heating, Cooling, Lighting, Lechner, page 398

2. If possible, place windows on more than one wall.

Figure 13.10b These plans, with contours of equal illumination, illustrate how light distribution is improved by admitting daylight from more than one point.

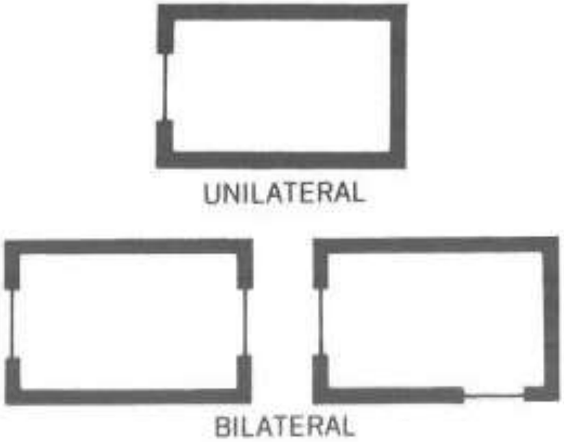
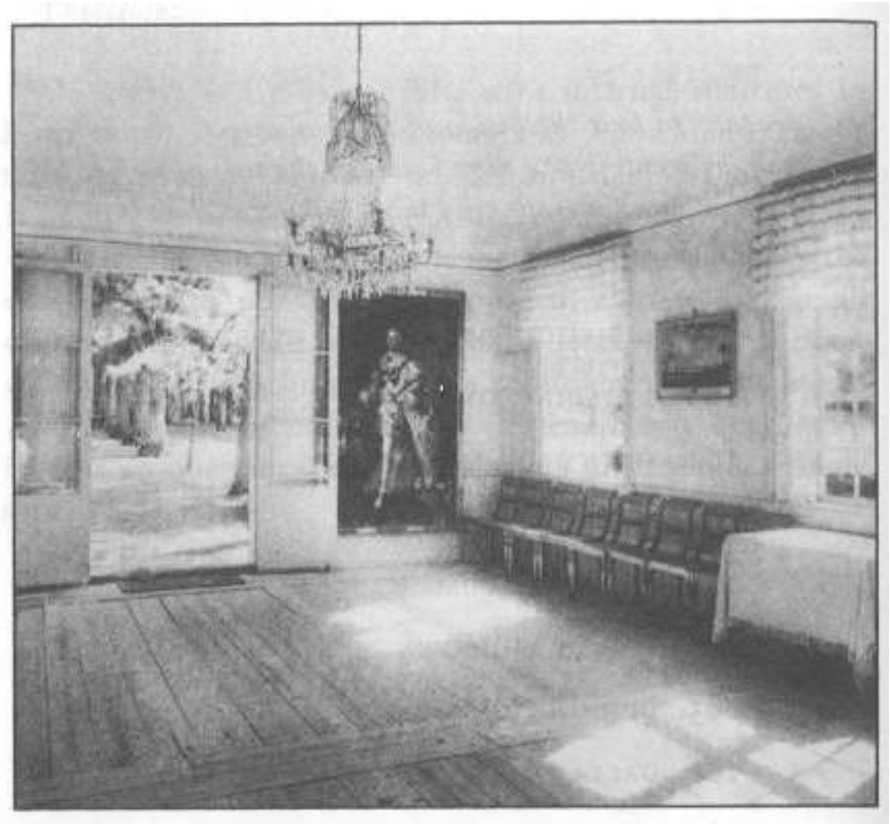


Figure 13.10d Bilateral lighting is usually preferable to unilateral lighting (plan view).

Lady Bird Johnson Wildflower Center

A Pattern Language, Alexander, pattern #159: *Light on Two Sides of Every Room*



Heating, Cooling, Lighting, Lechner, page 399

3. Place windows adjacent to interior walls.

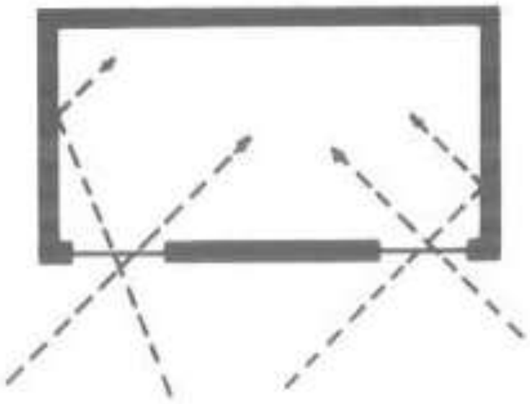


Figure 13.10e Light distribution and quality are improved by the reflection off sidewalls.

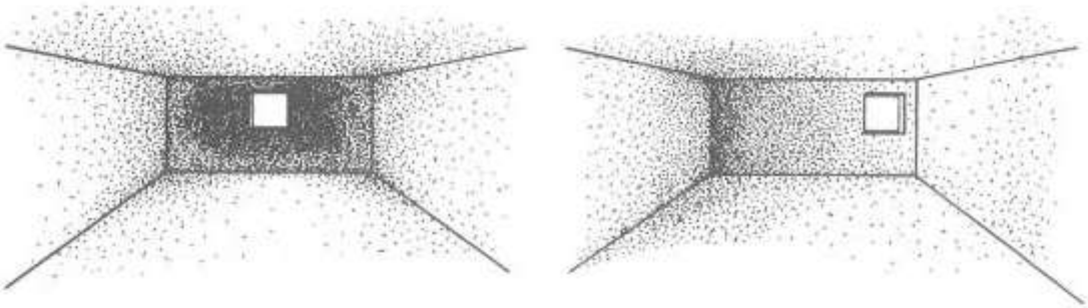


Figure 13.10f The glare from a window next to a sidewall is less severe than that from a window in the middle of a room.

Heating, Cooling, Lighting, Lechner, page 408

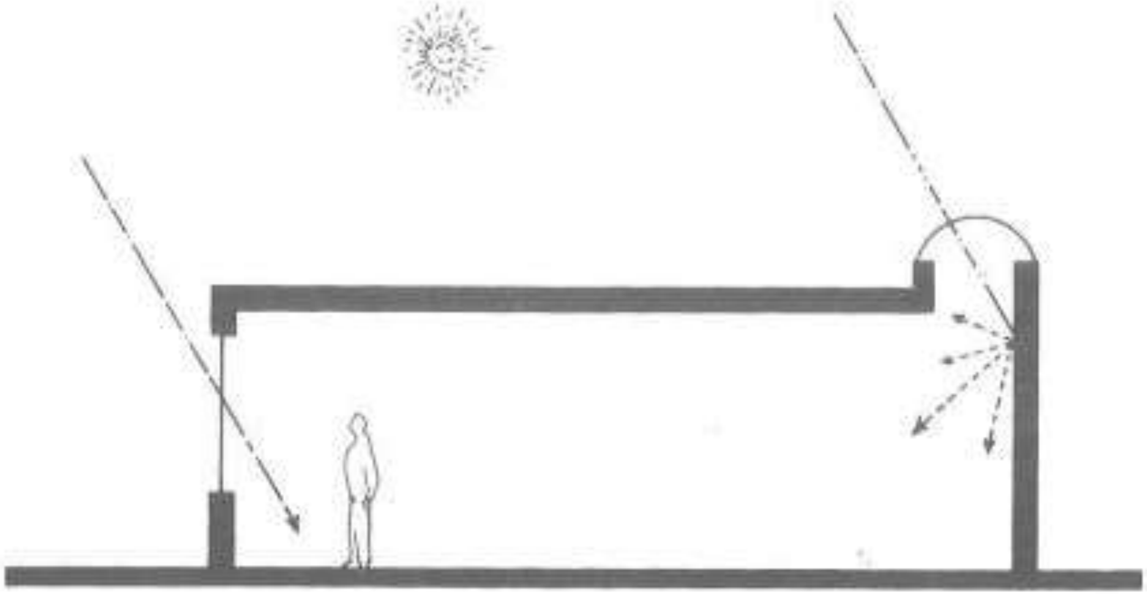


Figure 13.14e Place a skylight in front of a north wall for more uniform lighting and less glare.

Grondzik, Walter T.; Kwok, Alison G.; ***The Green Studio Handbook: Environmental Strategies for Schematic Design, 2nd Edition.***
Elsevier, 2011. ISBN-13: 978-0080890524.

4.72 Multiuse room with toplighting and sidelighting to provide even daylight distribution at the Christopher Center at Valparaiso University, Indiana. © PETER AARON/ESTO

Heating, Cooling, Lighting, Lechner, page 399

4. Splay window surrounds to reduce the contrast between windows and walls as well as increase daylight penetration.

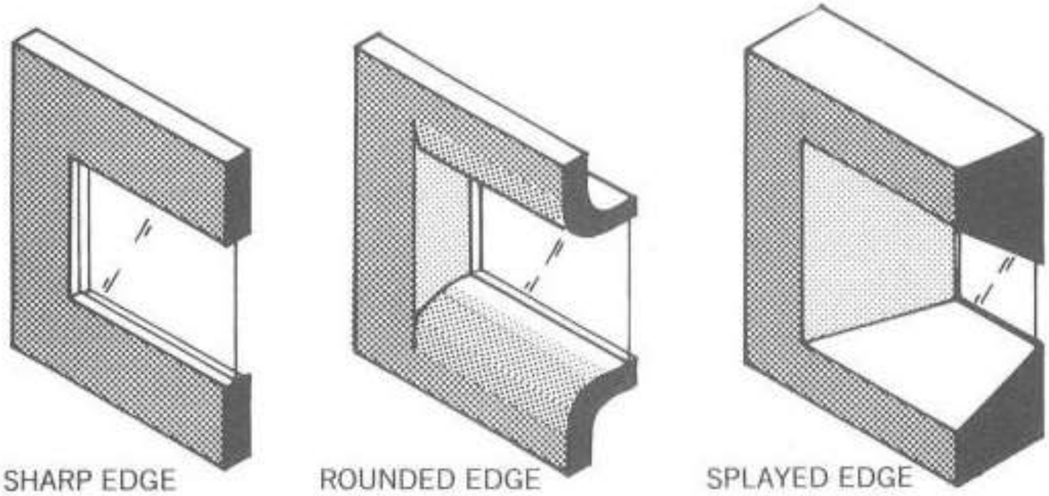

SHARP EDGE ROUNDED EDGE SPLAYED EDGE

Figure 13.10g The excessive contrast between a window and a wall can be reduced by splaying or rounding the inside edges. (After M. D. Egan, *Concepts in Architectural Lighting*.)

Splay Window Surrounds

I am currently working comfortably under daylight at 6.30 PM in a 240 sq ft north-west facing room in a Cornish cottage which has two windows of less than 6 sq ft glass area each with 18" deep splayed reveals in an 8' x 15'6" wall. So the glass area is just under 10% of wall area and 5% of floor area.

With good wishes,
Bill Bordass

Ft. Macon, North Carolina

Splay Window Surrounds

Splay Window Surrounds (same for toplighting)

Figure 13.14c Splayed openings distribute light better and cause less glare than square openings.

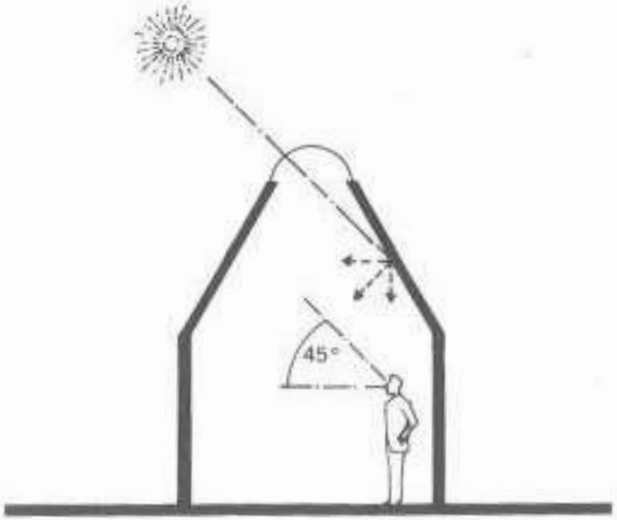
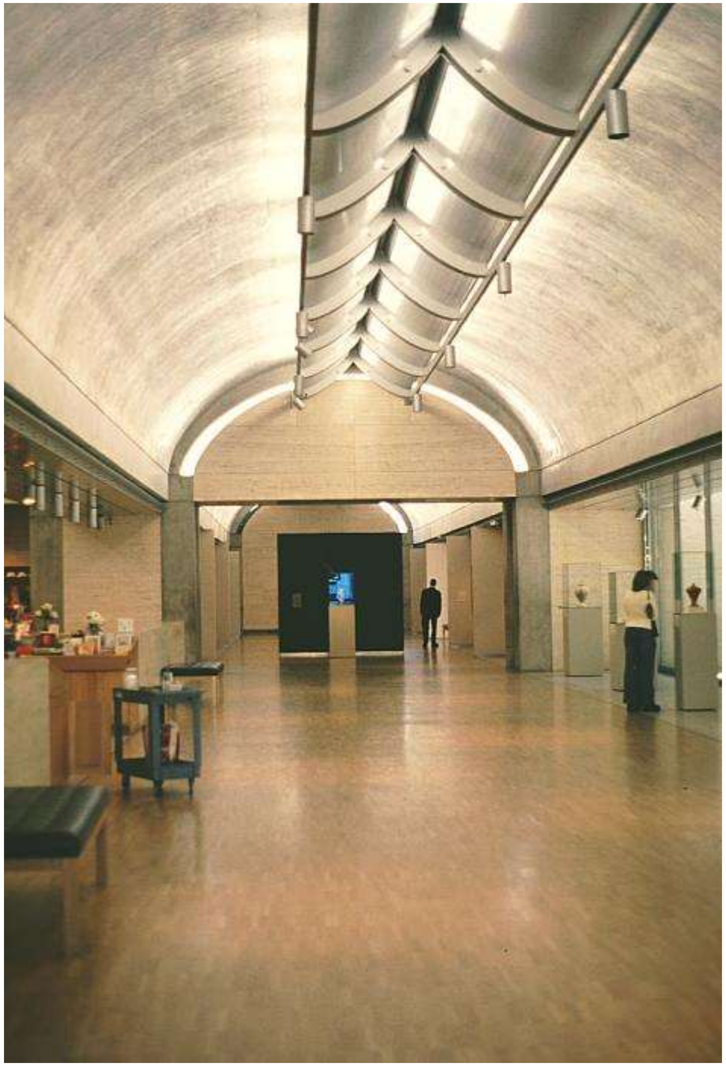


Figure 13.14d In high, narrow rooms, glare is minimal because the high light source is outside the field of view.

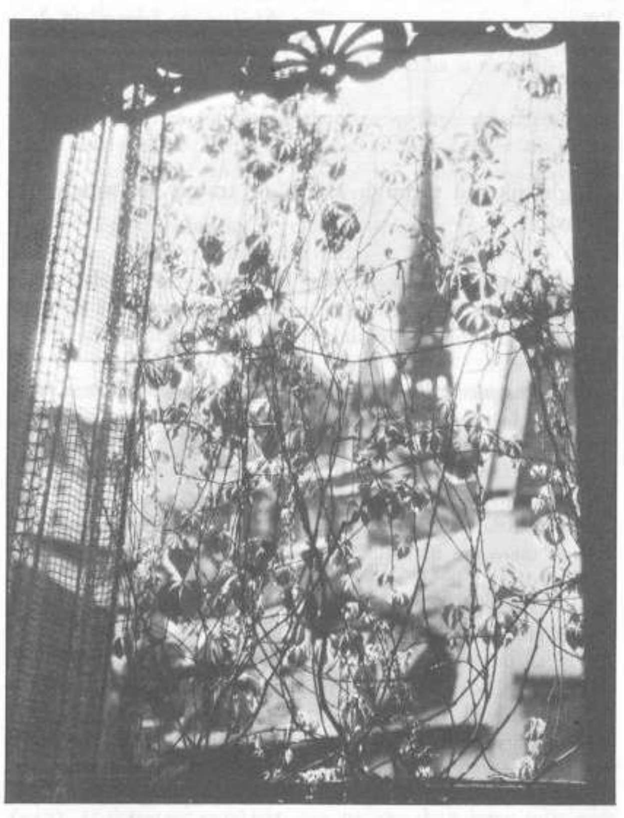
The Kimbell Art Museum - Louis Kahn



Tucson High School - James Benya

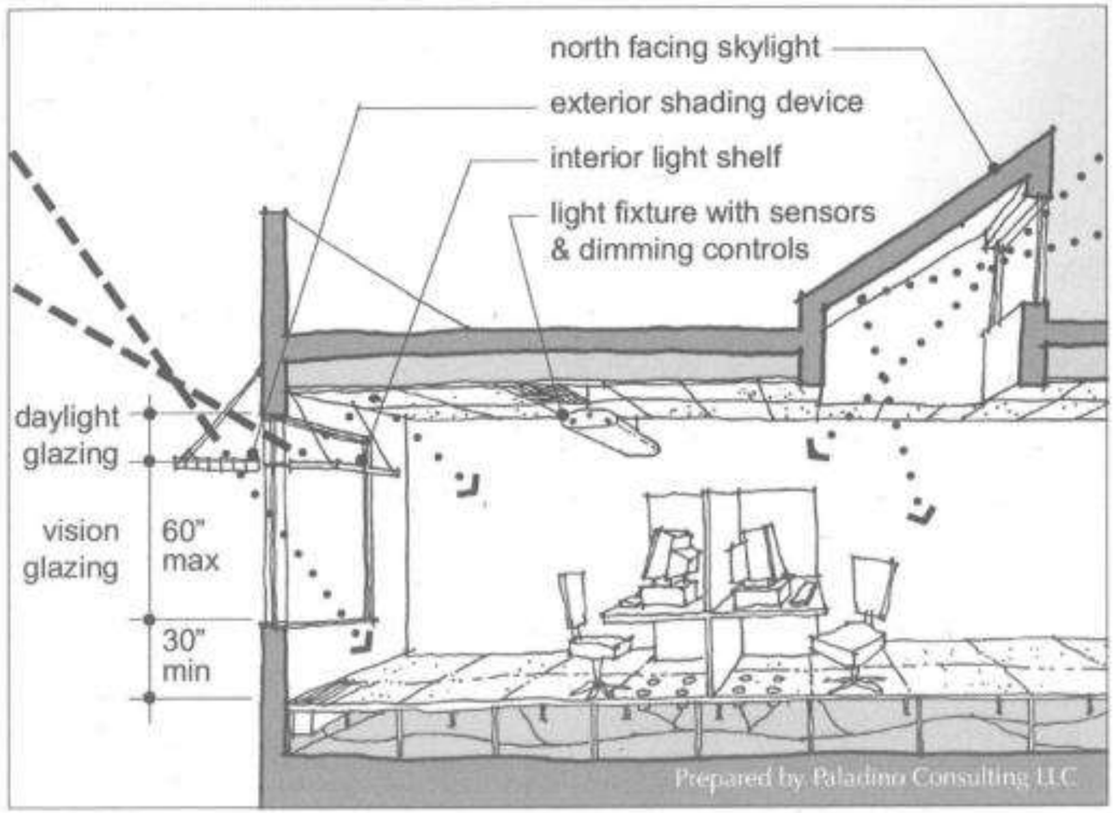
5. Filter Daylight

A Pattern Language, Alexander, pattern #238: *Filtered Light*

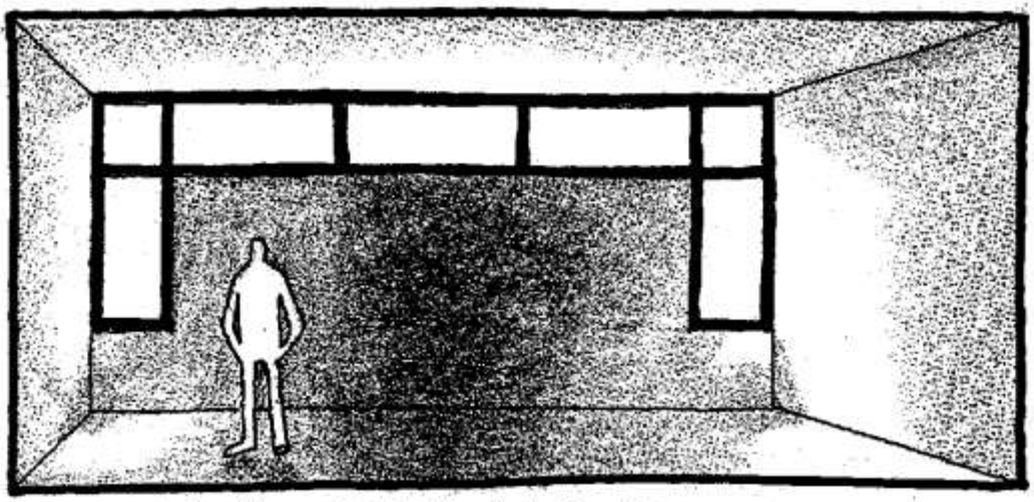


Spicewood Springs Library

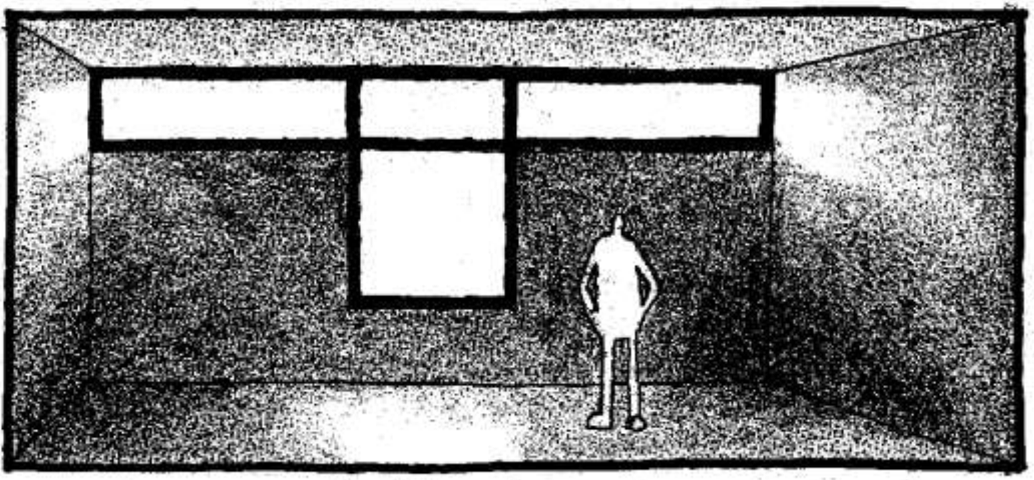
View glazing versus Daylighting



Environmental Control Systems, Fuller Moore



better daylight distribution



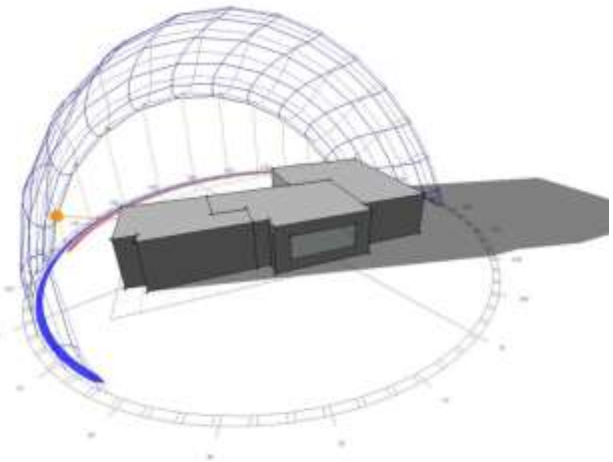
better view

Esherick House, Louis Kahn

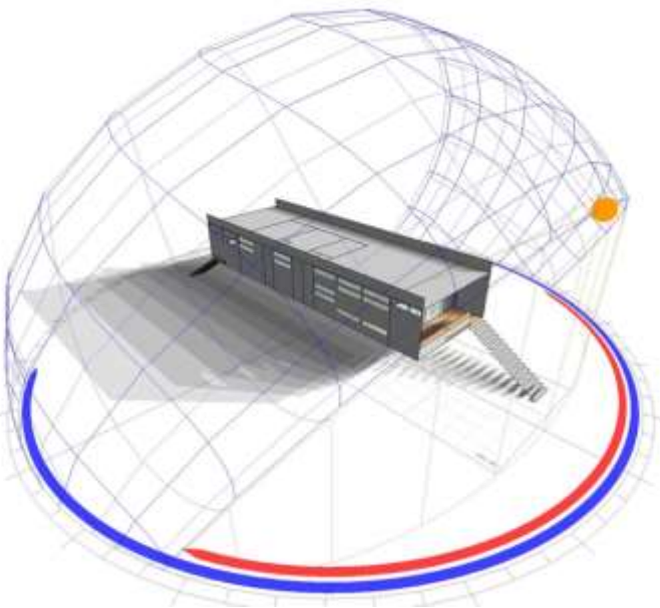
Hyland Park Elementary School

6. Shade Excess Sunlight

E,W



S



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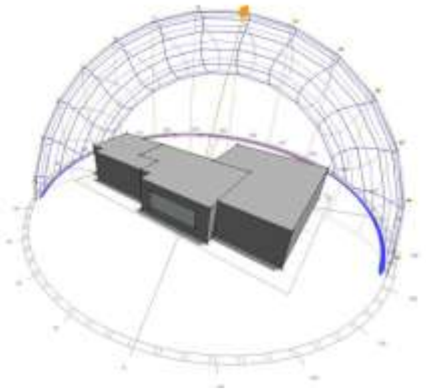


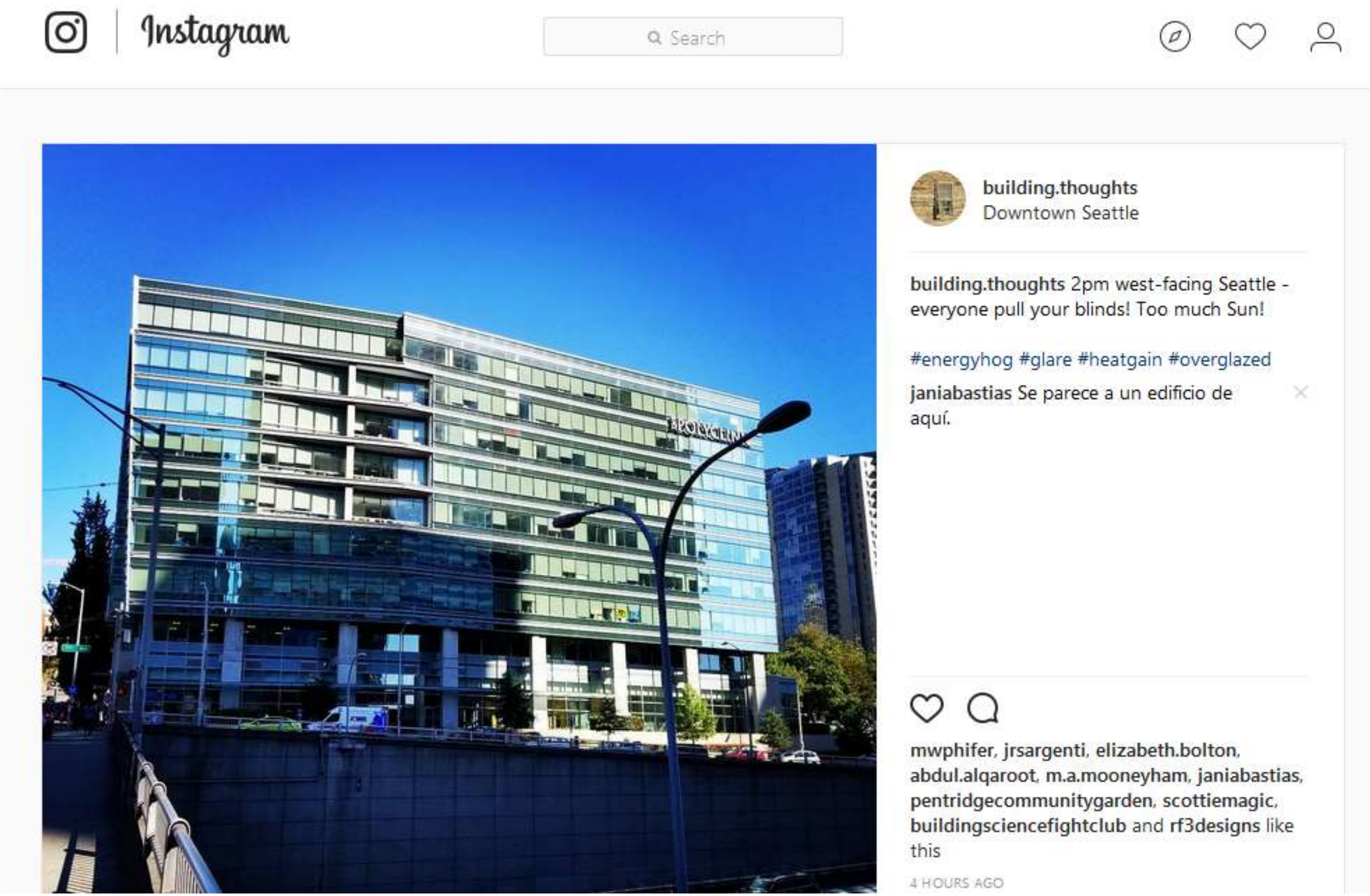
7. Use movable shades

7. Use movable shades:

Venetian Blinds (horizontal slats)

@building.thoughts

Seattle 9/27/17 2pm west-facing



building.thoughts
Downtown Seattle

building.thoughts 2pm west-facing Seattle - everyone pull your blinds! Too much Sun!

#energyhog #glare #heatgain #overglazed

janiabastias Se parece a un edificio de aquí.

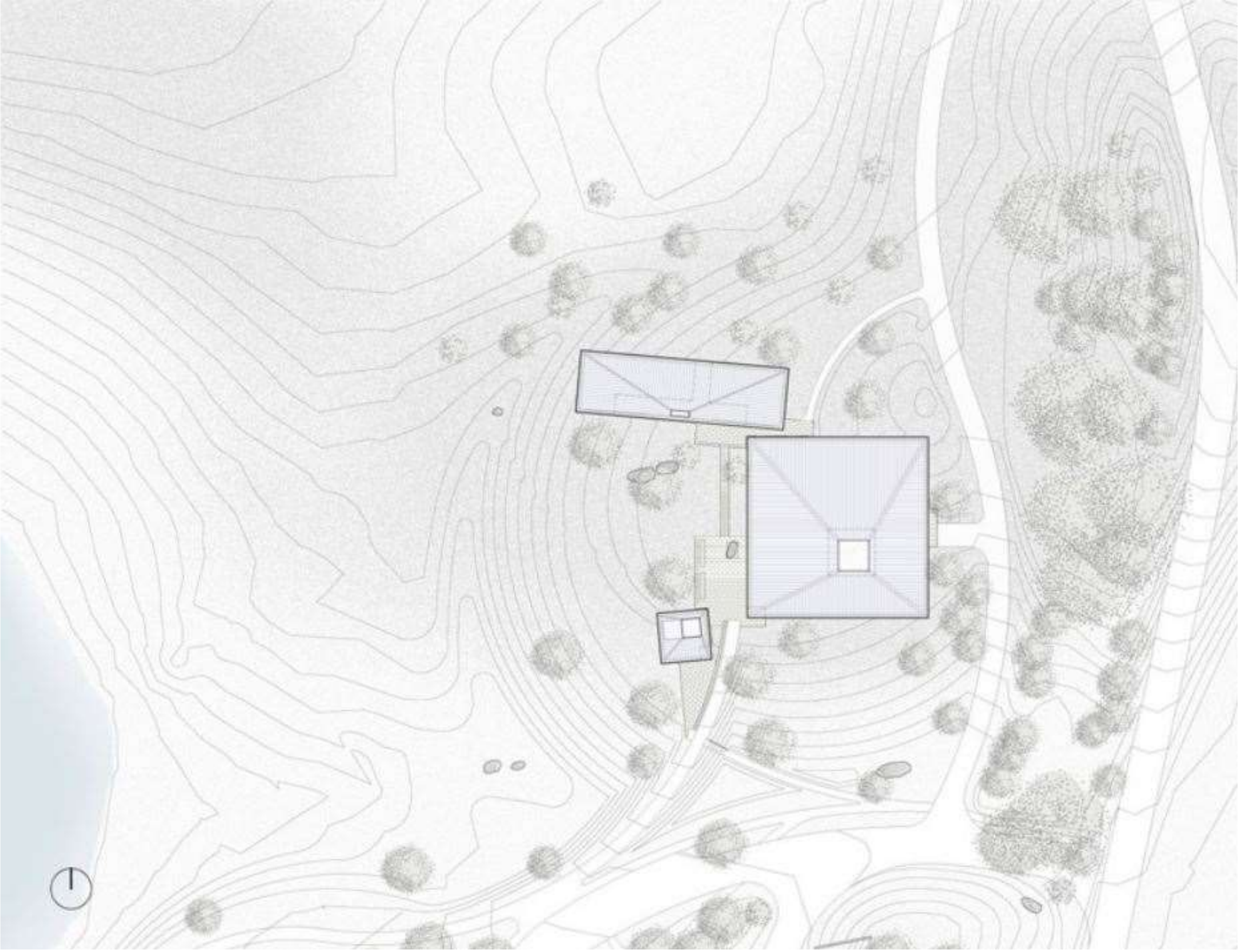
mwphifer, **jrsargenti**, **elizabeth.bolton**, **abdul.alqaroot**, **m.a.mooneyham**, **janiabastias**, **pentridgecommunitygarden**, **scottiemagic**, **buildingsciencefightclub** and **rf3designs** like this

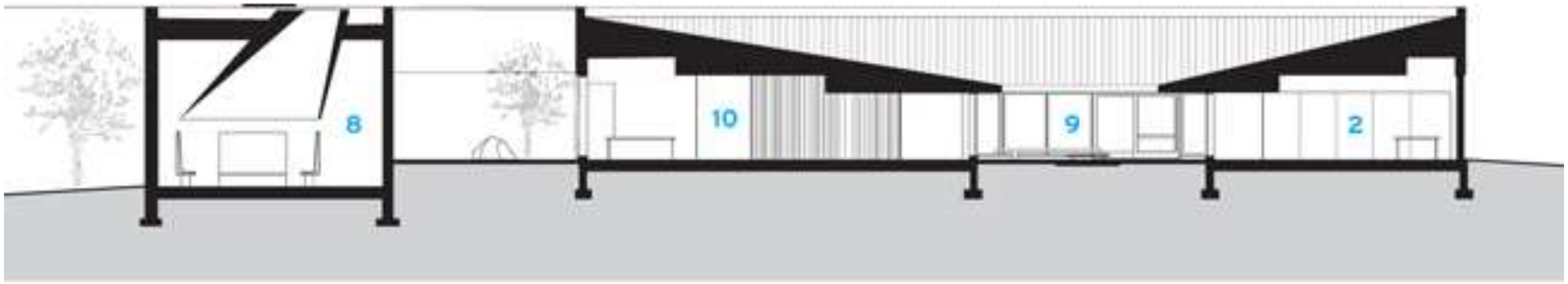
4 HOURS AGO

Is it possible to design a building for daylight only?

Center for Advancement of Public Action, Vermont

Tod Williams Billie Tsien





SECTION A-A

1 ENTRANCE
2 DESIGN LAB
3 FIELDWORK TERM OFFICE
4 FACULTY LOUNGE
5 DIRECTOR'S OFFICE
6 SYMPOSIUM
7 RESIDENCES
8 LENS
9 COURTYARD
10 LOBBY


EGINNING