Delight Daylight Energy

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University of Idaho – Integrated Design Lab

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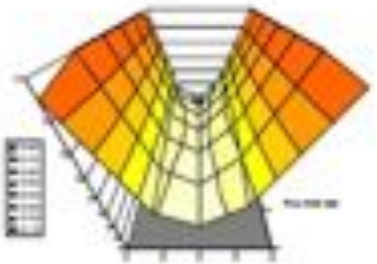
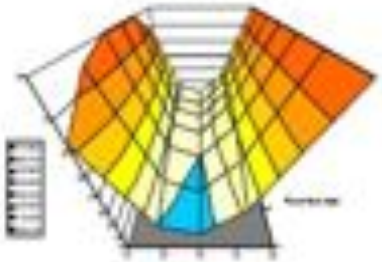
Environmental Services Building
The Miller Hull Partnership

Terry and Thomas Building, Weber+Thompson

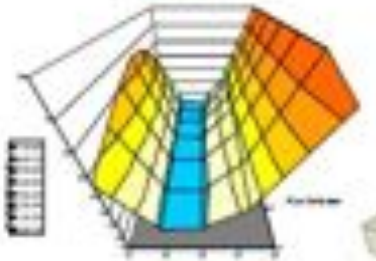
Fourth Floor



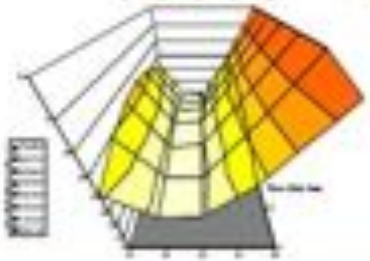
Third Floor



Second Floor



First Floor



Overcast Sky Simulation

Digital Model Image Courtesy of Weber+Thompson

Project: *Terry Ave Office Building*

Architect: *Weber + Thompson* 428 Pontius Ave Suite 200 Seattle, Washington

Daylighting Lab | Seattle

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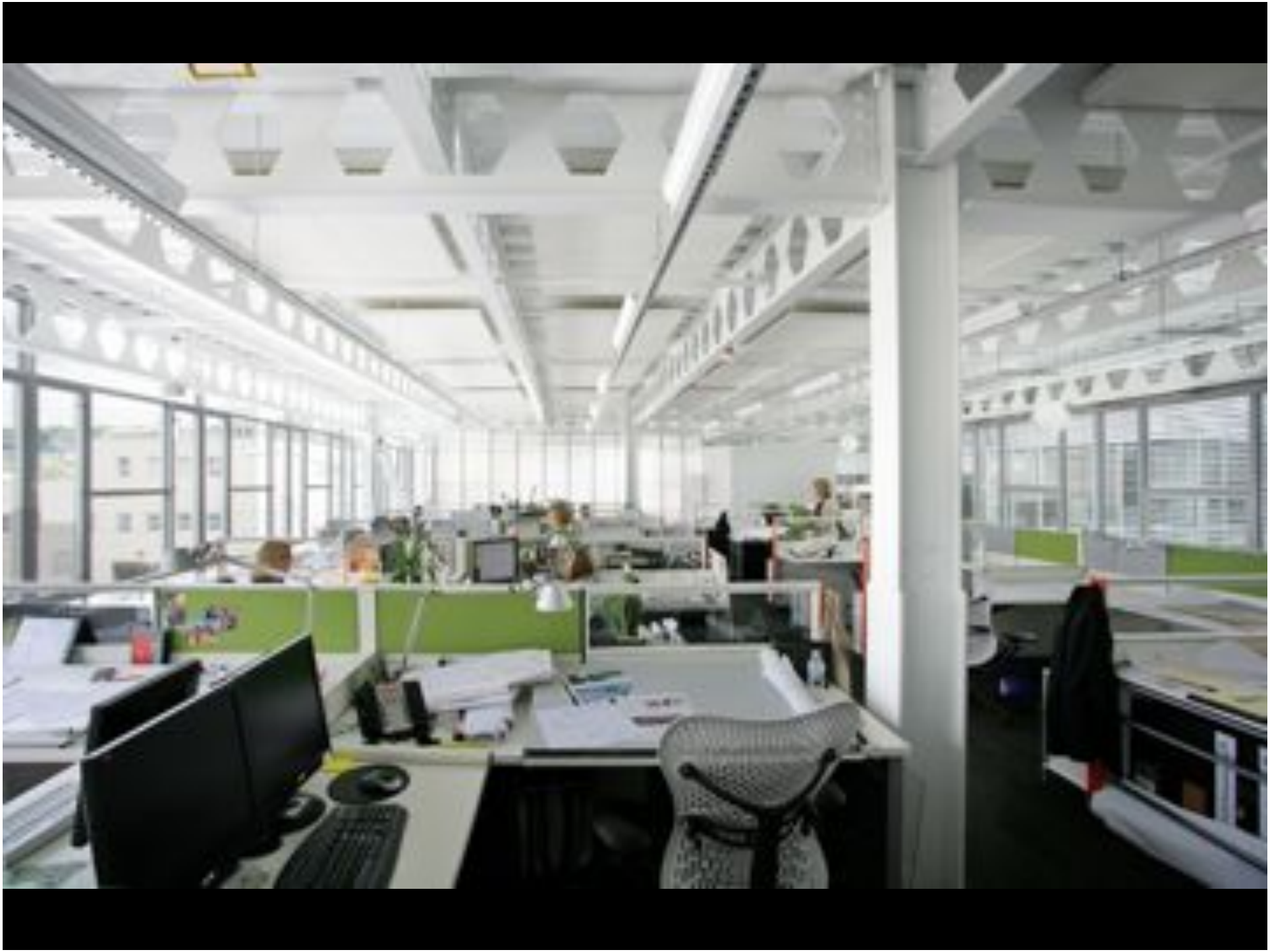
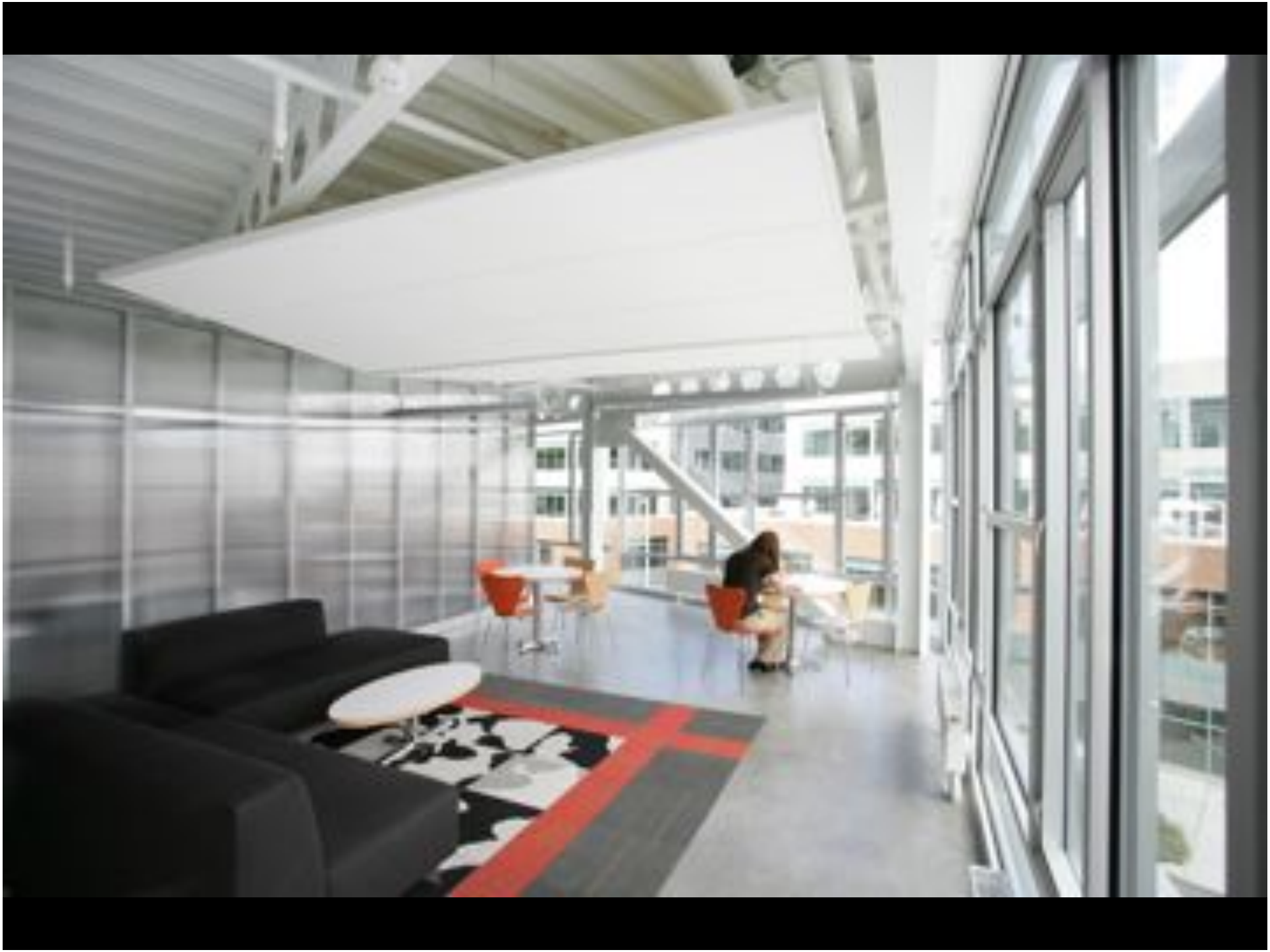
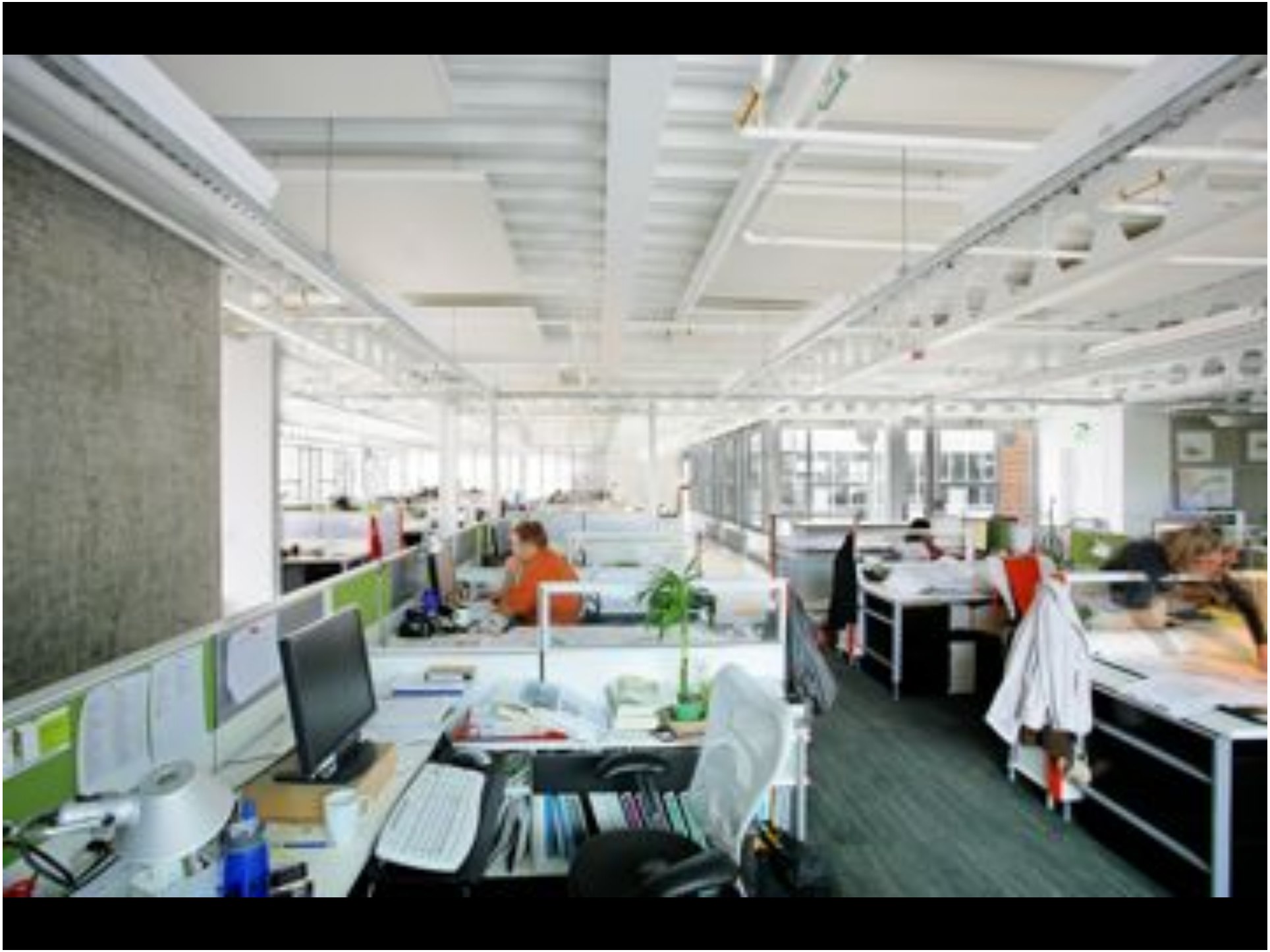
Design EUI :48 kbtu/sf-yr
Measured: 41 kbtu/sf-yr

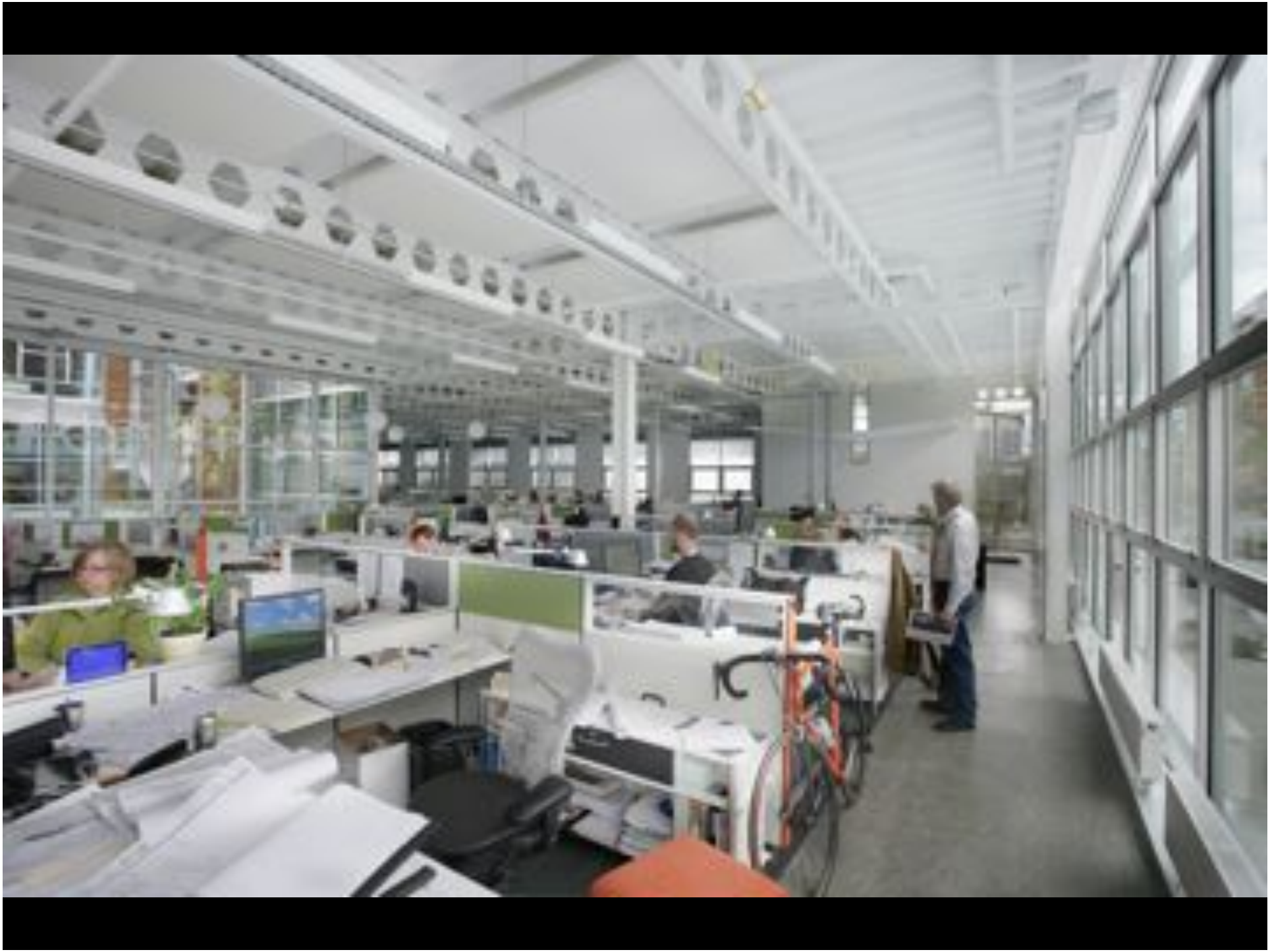
Installed LPD: 0.6 w/sf
Measured LPD: 0.26 w/sf

High Occupant Satisfaction









Daylight Pattern Guide

http://patternguide.advancedbuildings.net/home

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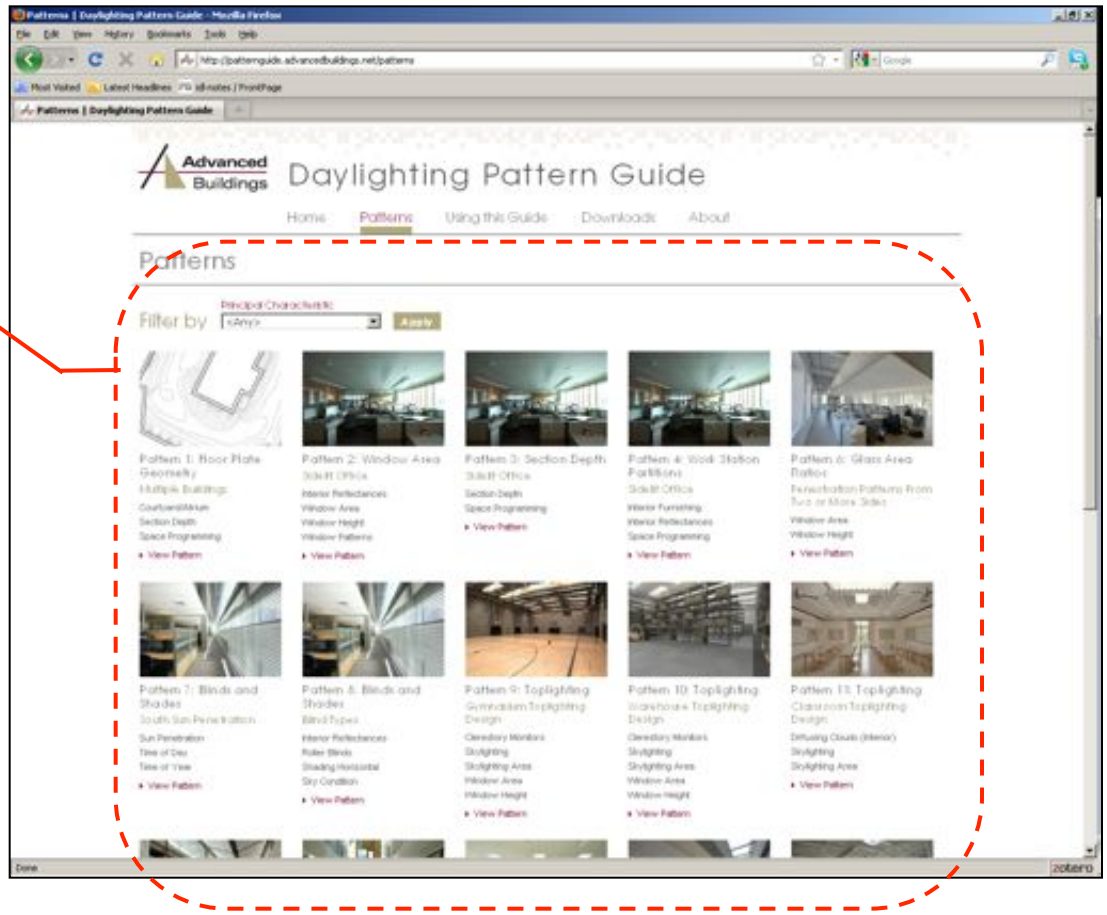
Patterns and Search Page

Table of Contents and Sort Field
Thumbnail images and pattern and sub-pattern descriptions for all or sorted pattern contents.



Daylight Pattern Guide

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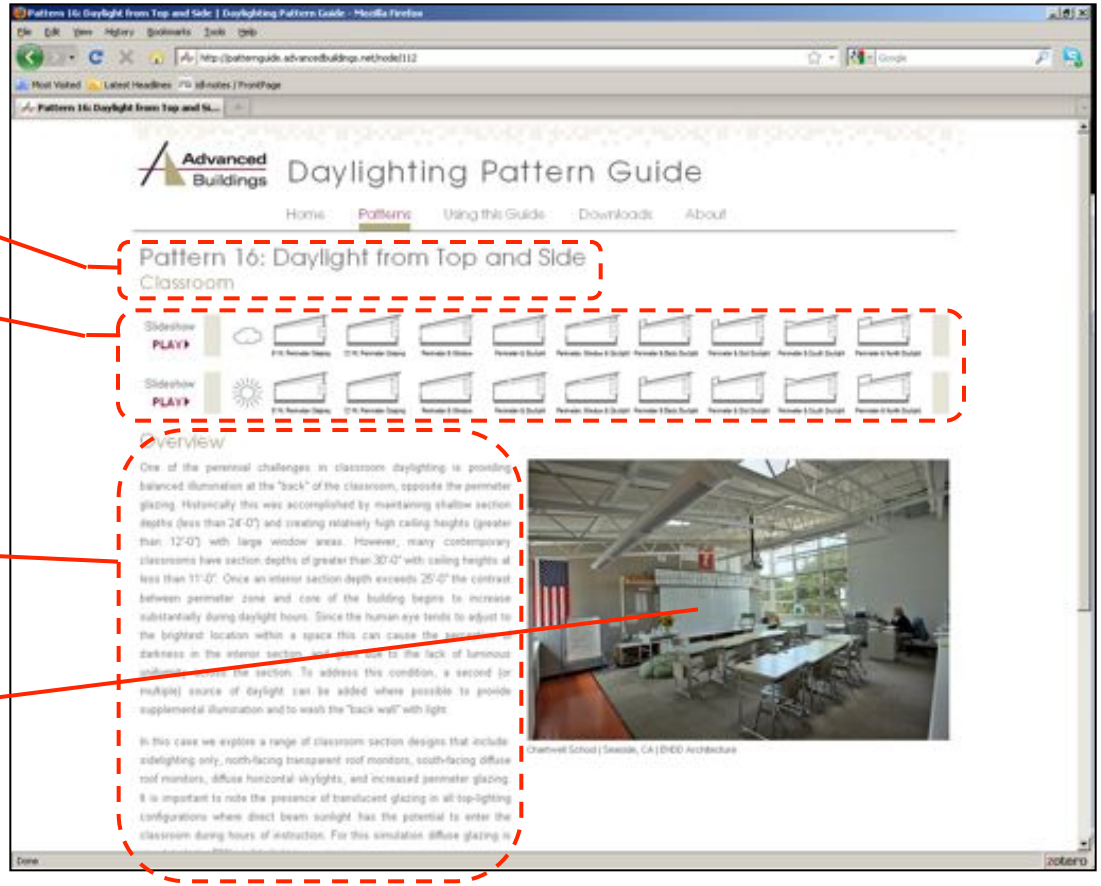
Pattern Overview Page

Pattern Title
Indicates the pattern title and number.

Pattern Overview Filmstrip Overview
Indicates the geometric or temporal variations explored in each pattern and the position of each simulation case within the larger pattern sequence.

Pattern Overview Narrative
Provides overarching design considerations inherent with each daylighting challenge.

HDR Actual Photo
High dynamic range photograph of the physical space



Daylight Pattern Guide

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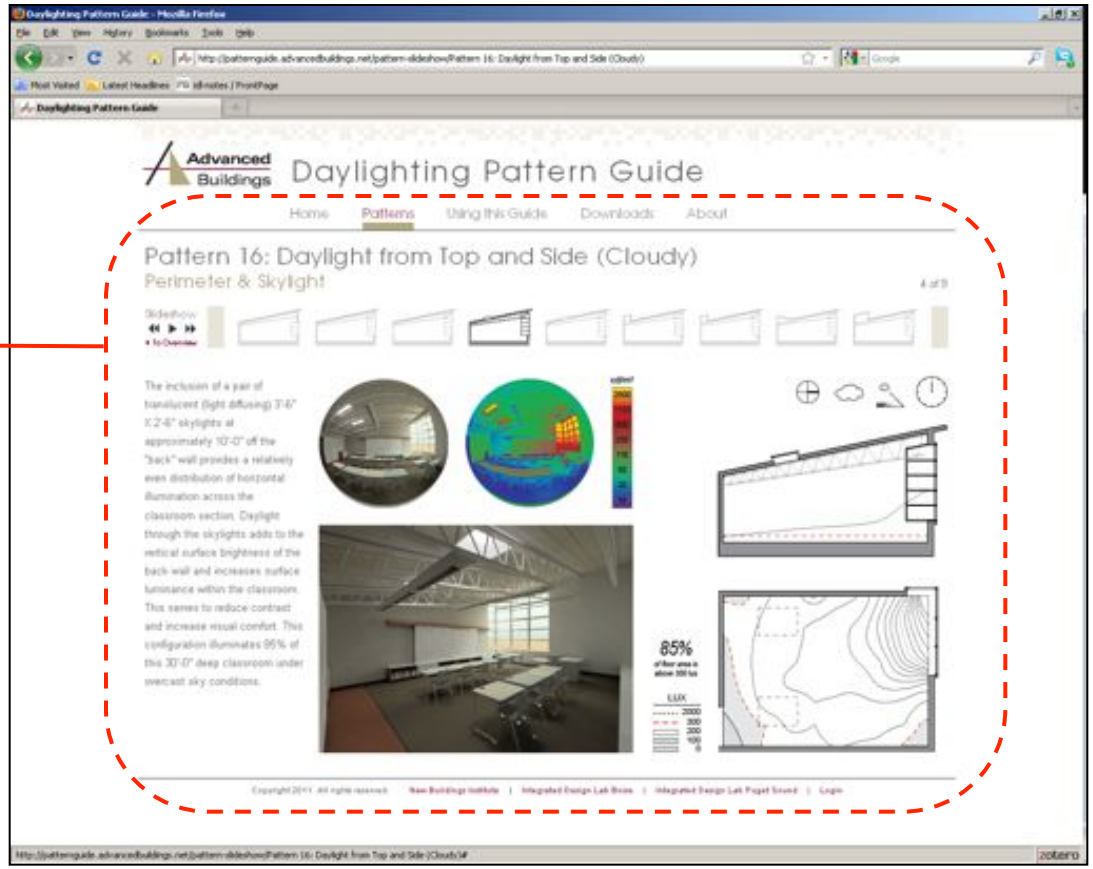
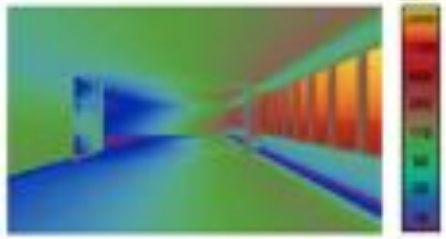
Typical Pattern Page Layout and Common Elements

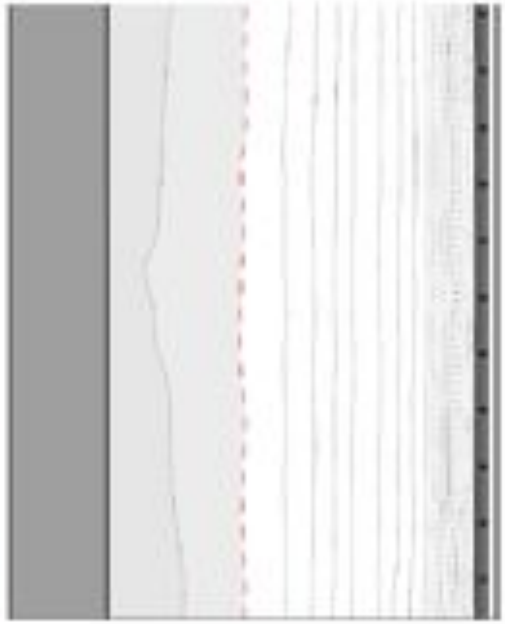


Pattern 5.1: Interior Furniture Layout

Open Volume

A horizontal band of windows at 40 percent of the opaque wall area provides daylight illumination that meets or exceeds commonly accepted minimum daylight illumination criteria at approximately 75 percent of the adjacent 26'-0" deep open office area.

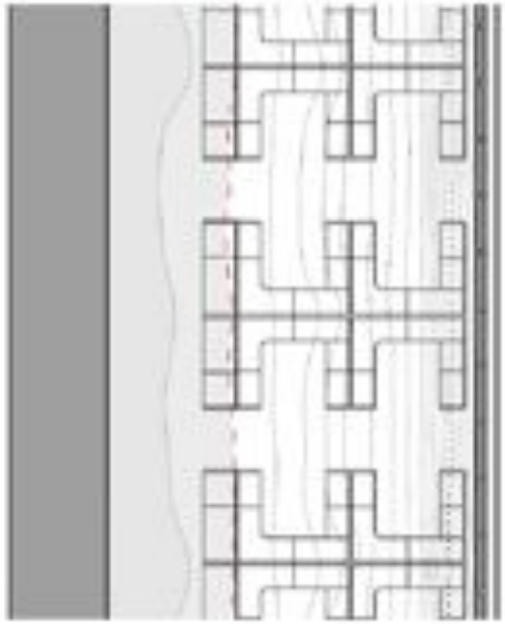




Pattern 5.2: Interior Furniture Layout

Desks Only

The inclusion of "open" desk workstations has limited impact on the daylight distribution across the horizontal workplane. Daylight levels exceed commonly accepted ambient illumination criteria at all areas except at the circulation aisle (at left).



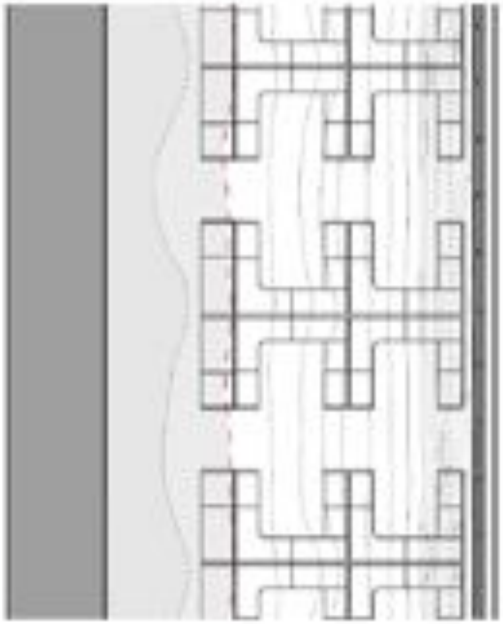
75%

LUX

Pattern 5.3: Interior Furniture Layout

Low Panels

The inclusion of modesty panels below the 30" desk height has virtually no impact on the daylight distribution across the horizontal workplane. Daylight levels exceed commonly accepted ambient illumination criteria at all areas except the circulation aisle (at left).



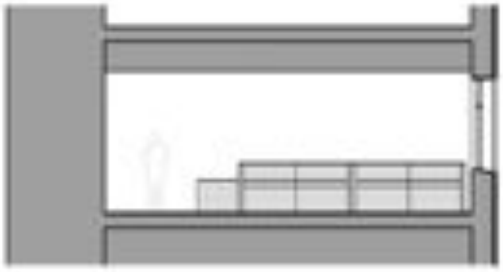
75%

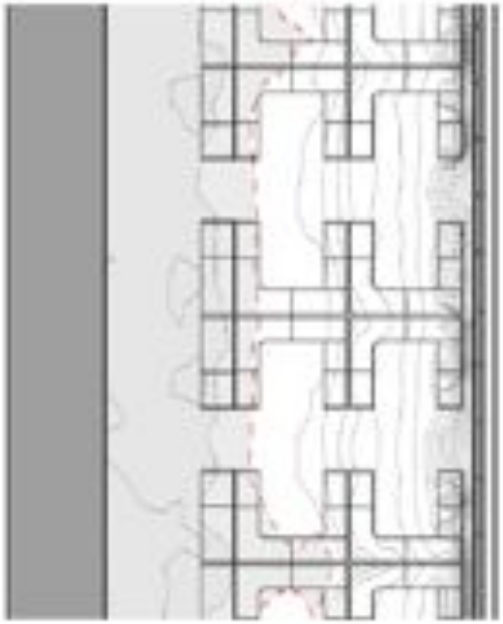
LUX

Pattern 5.4: Interior Furniture Layout

42" Panels

The inclusion of 42" panels begin to create some shadowing at the horizontal workplane. However, ceiling brightness begins to diminish as the reflectance off of the floor and desk surfaces is reduced by the panels. Daylight levels continue to exceed commonly accepted ambient illumination criteria at nearly all workstations.

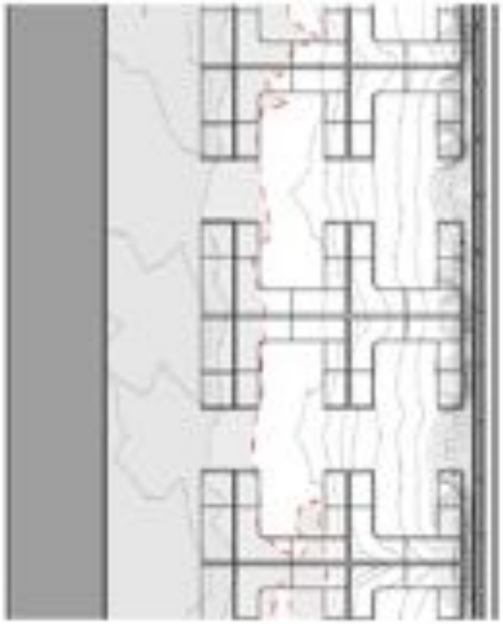




Pattern 5.5: Interior Furniture Layout

42" Panels with Glass Partition (As-Built)

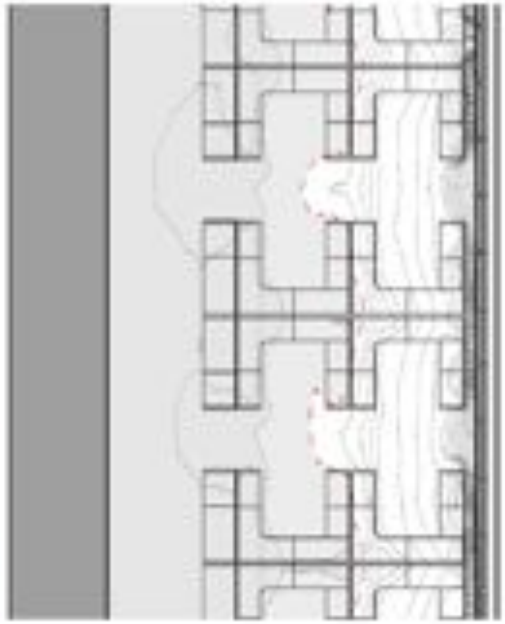
The addition of a glass partition between the aisle an the workstation area increases acoustic privacy while maintaining brightness at the "back" wall (at left). Horizontal daylight levels continue to exceed commonly accepted ambient illumination criteria at nearly all of the workstation areas.



Pattern 5.6: Interior Furniture Layout

42" Panels with 60" Panels Perpendicular to Glazing

The addition of a 60" panel perpendicular to the window wall, increases both visual and acoustic privacy. Though diffuse daylight levels are reduced, views to the exterior remain largely unobstructed. Horizontal daylight levels continue to exceed commonly accepted ambient illumination criteria at 50 percent workstations.



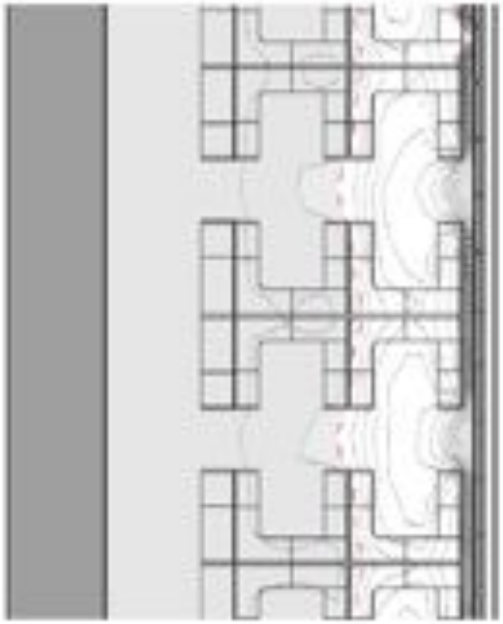
45%

LUX

Pattern 5.7: Interior Furniture Layout

60" Panels

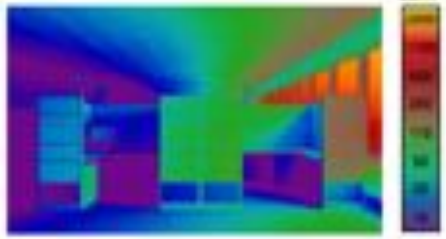
The addition of 60" panels surrounding all workstations substantially reduce daylight levels at the back wall and beyond the workstations directly at the perimeter. Views to the exterior are constrained dramatically at all workstations. Horizontal daylight levels exceed commonly accepted ambient illumination criteria only directly adjacent to the perimeter glazing.

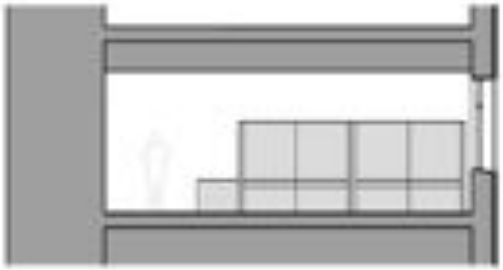


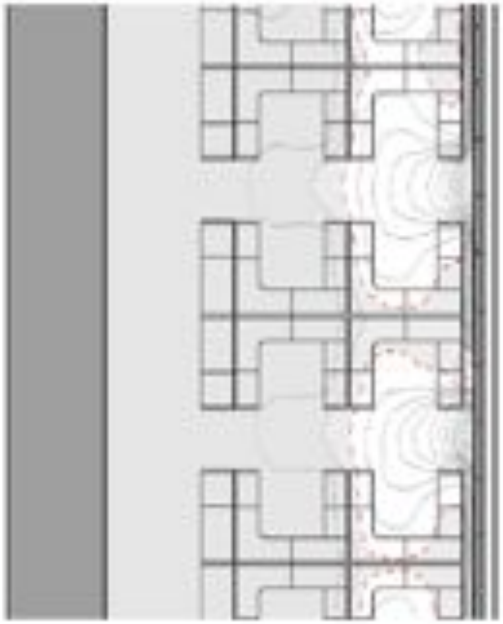
Pattern 5.8: Interior Furniture Layout

72" Panels

72" panels surrounding all workstations reduce daylight levels even further, especially at the back wall. Even the perimeter workstations are marginally daylit. Views to the exterior are constrained dramatically at all workstations. Horizontal daylight levels exceed commonly accepted ambient illumination criteria only at aisle ways directly adjacent to the perimeter glazing.



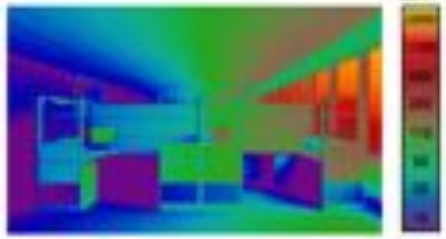


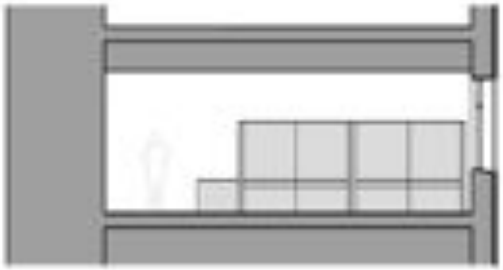


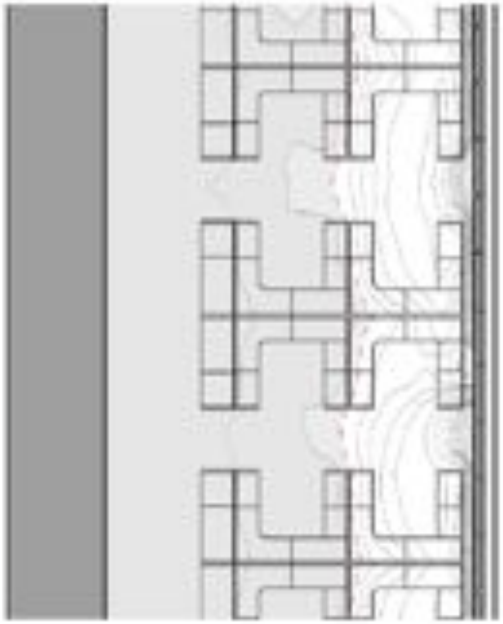
Pattern 5.9: Interior Furniture Layout

72" Panels with Glass Partitions

Changing the materiality of the workstation panels parallel to the glazing to be transparent allows daylight distribution and views despite the 72" panel height. However, horizontal daylight levels exceed commonly accepted ambient illumination criteria only directly adjacent to the perimeter glazing.

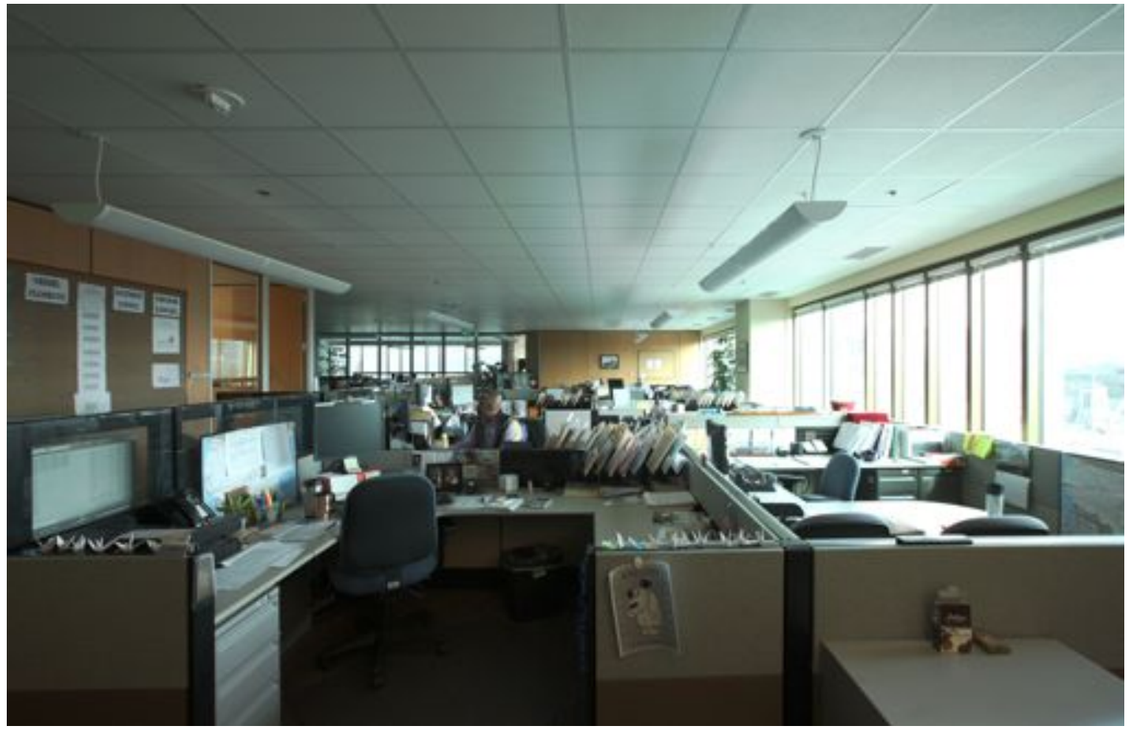






Pattern 3: Section Depth

Daylight from One Side



Banner Bank: Boise, ID

Overview

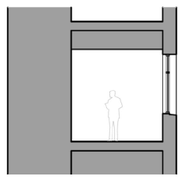
When describing daylight potential in buildings, “section depth” refers to the overall distance between perimeter windows and the innermost wall of an occupied space. In multi-story buildings that are illuminated solely from vertical glazing at the perimeter, the section depth is often the most crucial determinate of whether occupants have access to daylight and views. In general, buildings that exhibit a narrow section depth provide a far higher percentage of daylit area than buildings with deep perimeter to core depths. At common ceiling heights (9’-0” t0 12’-0”), it is nearly impossible to provide effective daylight distribution beyond 25’-0” from a window wall if it is lit exclusively from one side. In contrast, many speculative office buildings are predicated on a minimum 40’-0” “leased span” which implies that the occupied area consists of a 40’-0” minimum section depth, and often a far deeper perimeter to core dimension. This configuration virtually ensures that less than 50 percent of the floor plate will be effectively daylit.

Beyond simple horizontal daylight illuminance on a workplane, the section depth of a space contributes greatly to visual comfort. Specifically, the relationship of the brightness of the perimeter windows to the “back” interior wall is crucial. Since the human eye tends to adjust to the brightest surfaces it’s visual field, a space that is bright at the perimeter, and much darker toward the interior can feel like a cave, even when electrically illuminated at common interior light levels. This “cave effect” is common in buildings with deep section depths, especially when they are over-glazed at the perimeter. Conversely, in spaces with section depths that are not much more than two and a half times deeper than the head height of the perimeter windows, daylight is able to wash the “back” wall, enabling balanced brightness across the building section.

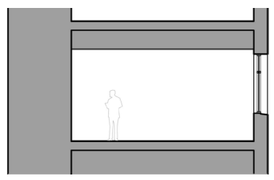
In side-lit buildings, depending on orientation, the perimeter zone can be subject to large fluctuations in illumination and direct sunlight penetration. One approach to managing this is to pull workstations from the perimeter and creates a narrow aisle way where direct sunlight can be present without impacting critical visual task areas. This strategy has been termed creating “glare storage” by some designers.

In short, buildings with a narrower section depth place their occupants in closer proximity to windows and therefore within reach of a potential daylight aperture. This creates greater opportunity for lighting power savings, and more uniformity of daylight illuminance, subsequently increasing the likelihood of visual comfort.

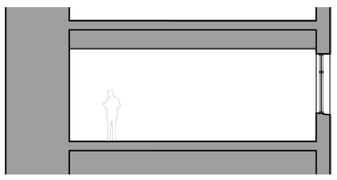
The case study patterns are based on the Banner Bank Building in Boise, ID. It includes a 40% window to exterior wall ratio with a window head height at 9’-6”, a sill height at 3’-0” and a ceiling height at 10’-0”. Interior reflectances are roughly 80%, 50%, and 20% for ceiling, walls, and floors, respectively. The overall section depth in the “as-built” condition is 26’-0”.



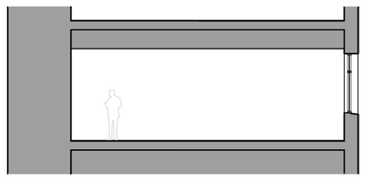
10’-0” Section Depth



20’-0” Section Depth

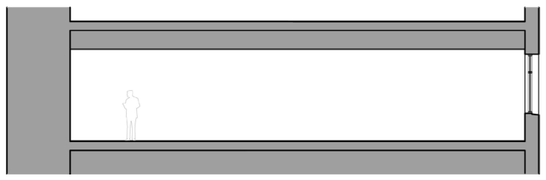


26’-0” Section Depth



30’-0” Section Depth

40’-0” Section Depth

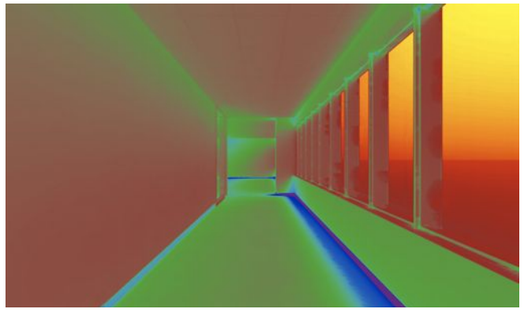


50’-0” Section Depth

3.1: Section Depth

Section Depth of 10’-0”

A 10’-0” section depth represents a common condition in private offices and corridors. In most building configurations, areas within 10ft will receive sufficient daylight illumination to meet ambient lighting goals for the vast majority of daylight hours. Additionally, in most cases where the total section depth is less than 15’-0”, the glazing area could be reduced while maintaining effective daylight illumination.



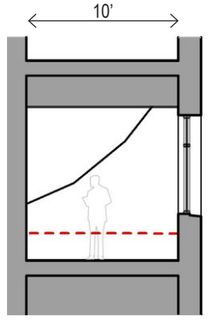
100%

of floor area is above 300 lux

LUX

Horiz. Illum.

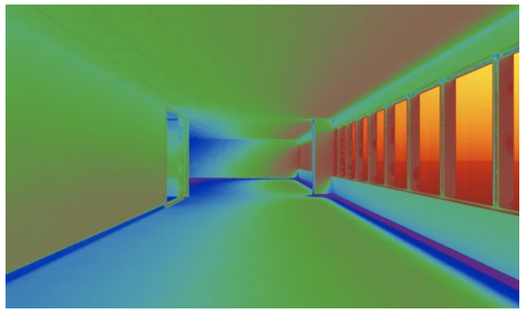
300



3.2: Section Depth

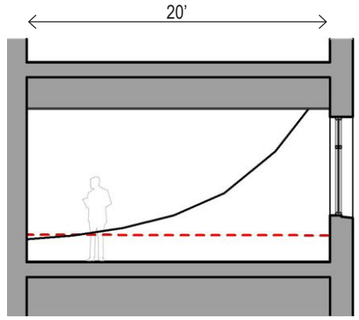
Section Depth of 20’-0”

At 20’-0” deep, the section depth is approximately equivalent to the daylight potential of side lighting at a ceiling height of 10’-0”. The “back” wall (at the left) maintains surface brightness in balance with the brightness of the ceiling and floor luminance. In this configuration horizontal illumination levels meet commonly accepted daylighting criteria for office environments across nearly the entire space, and yields an ideal daylight distribution.



95%
of floor area is above 300 lux

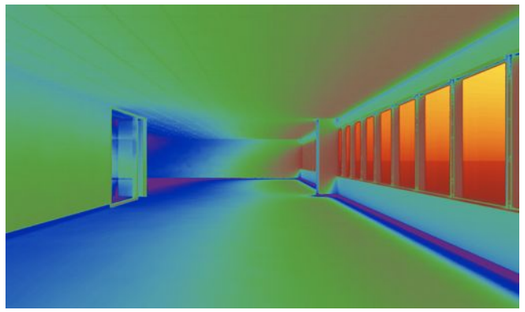
LUX
Horiz. Illum.
300



3.3: Section Depth

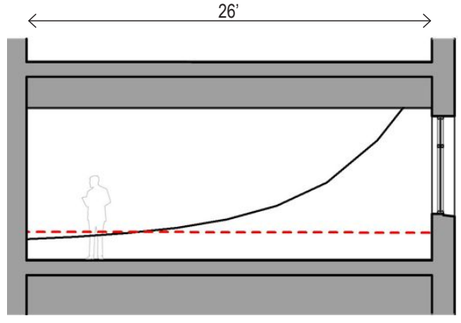
Section Depth of 26’-0” (As Built)

In the “as-built” condition (26’-0” deep), the section depth is approximately equivalent to the daylight potential of side lighting given this ceiling height. The “back” wall (at the left) maintains a balanced surface brightness with the ceiling and floor. With the exception of the aisle way at the back of the section, this configuration yields horizontal illumination levels that meet commonly accepted daylighting criteria for office environments.



85%
of floor area is above 300 lux

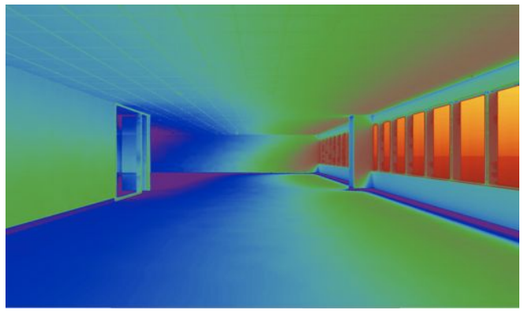
LUX
Horiz. Illum.
300



3.4: Section Depth

Section Depth of 30’-0”

At 30’-0” deep, the perimeter glazing provides effective ambient daylight illumination to approximately two-thirds of the volume. The “back” wall (at the left) begins to lose surface brightness especially in the upper zone. In this configuration horizontal illumination levels meet commonly accepted daylighting criteria for office environments across approximately 80% percent of the floor area.



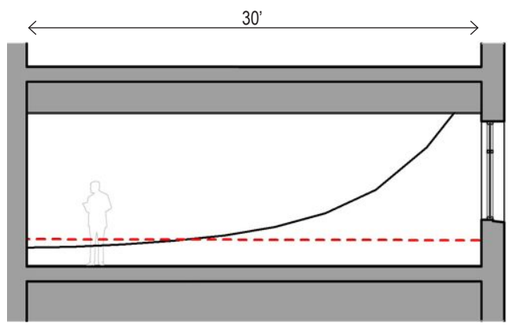
80%

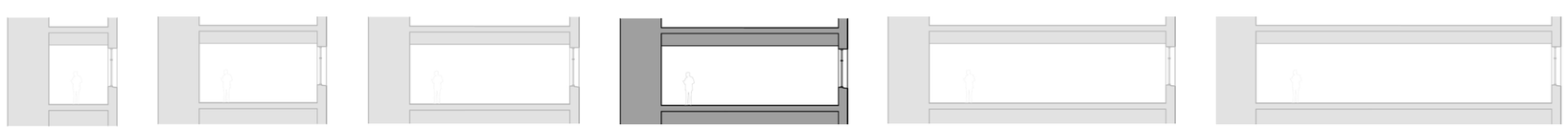
of floor area is above 300 lux

LUX

Horiz. Illum.

300

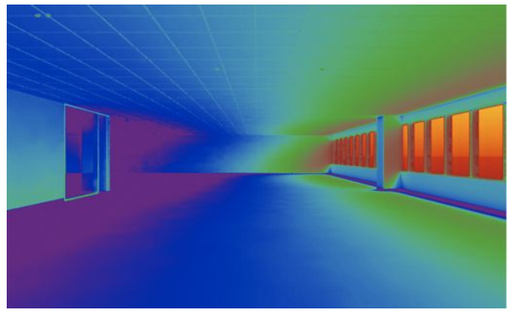




3.5: Section Depth

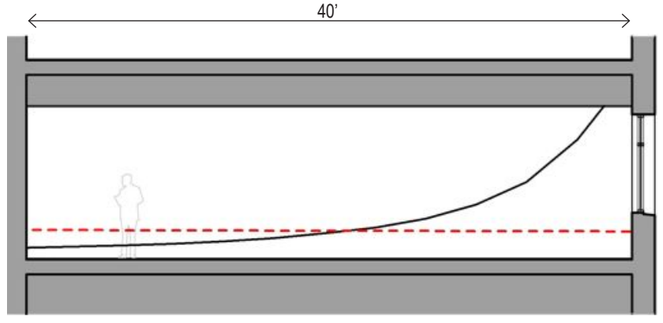
Section Depth of 40’-0”

This configuration represents a common section depth in contemporary open office spaces. At 40’-0” deep the section depth exceeds the daylight potential of side lighting by a factor of 2. Less than half of the office area is daylit. The perimeter area of the open office area is much darker than the majority of the volume. The contrast on the ceiling and vertical surfaces is dramatic, creating the potential for glare. More than half of the office area falls short of commonly accepted minimum daylight illumination criteria.



50%
of floor area is above 300 lux

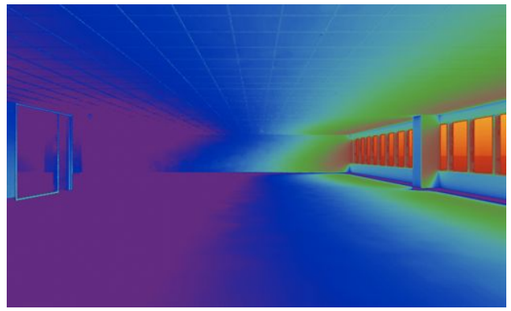
LUX
Horiz. Illum.
300

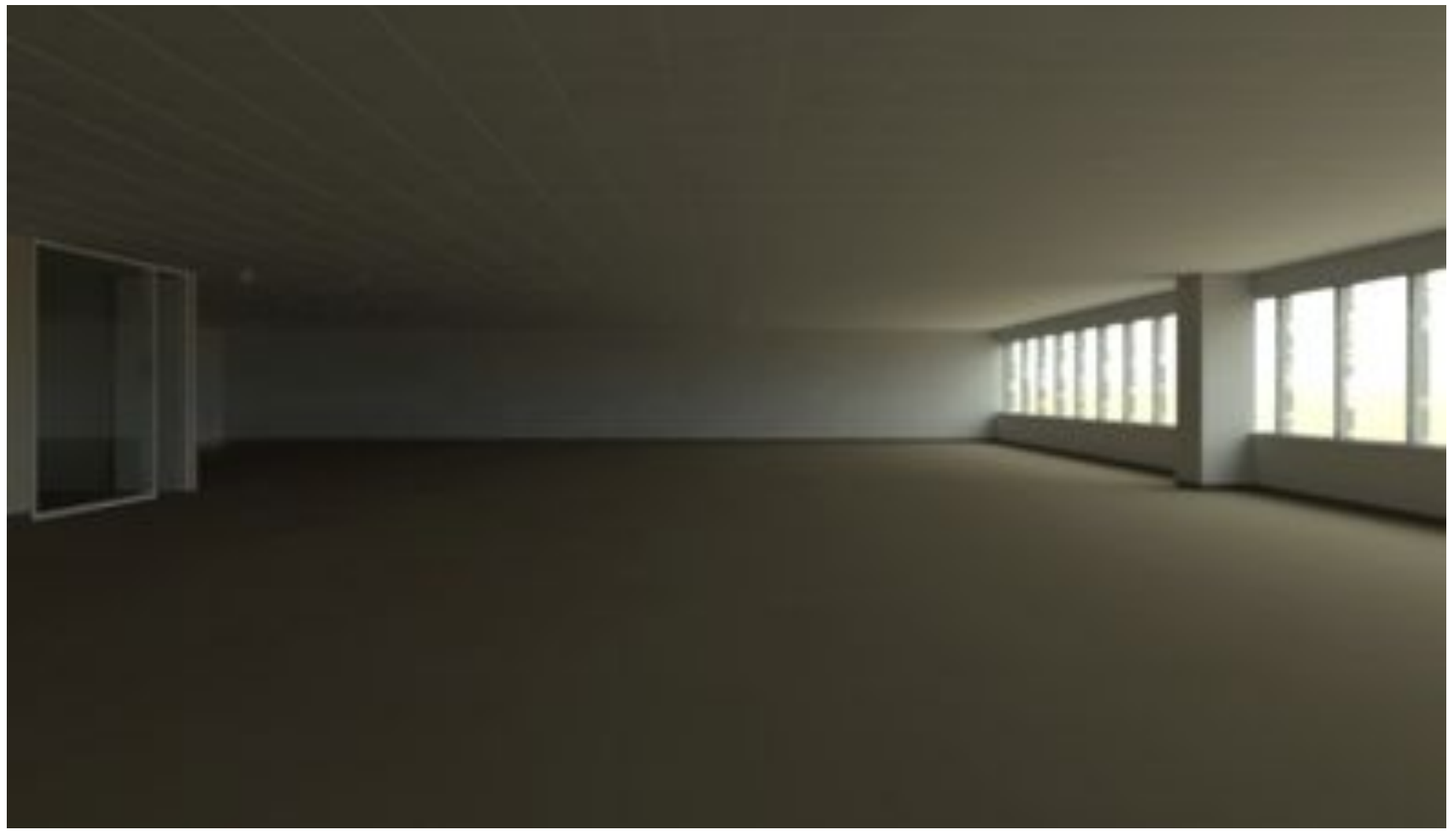


3.6: Section Depth

Section Depth of 50’-0”

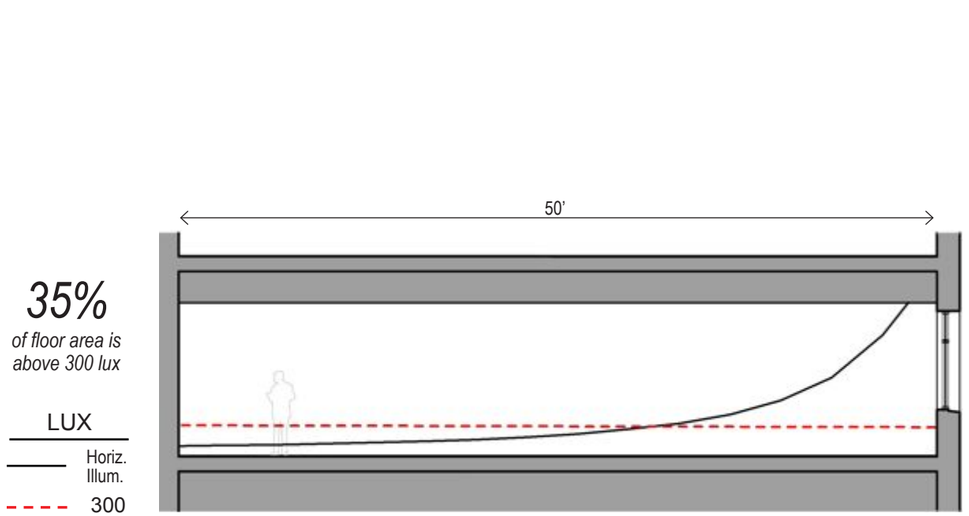
This configuration represents a common section depth in speculative office buildings. At 50’-0” deep the section depth far exceeds the daylight potential of side lighting. The perimeter area of the open office area is substantially darker than the vast majority of the interior volume, creating a “cave-like” effect. The contrast on the ceiling and vertical surfaces is dramatic, creating the potential for glare. Less than 35 percent of the office area meets commonly accepted minimum daylight illumination criteria.

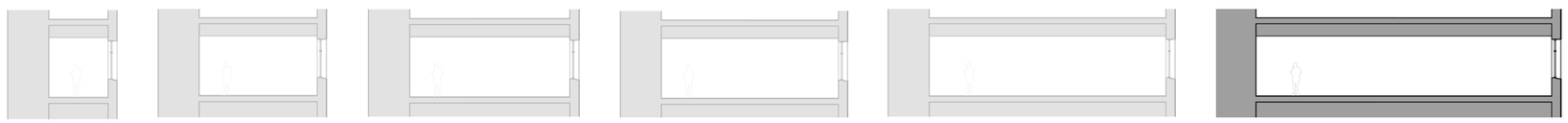




35%

of floor area is above 300 lux

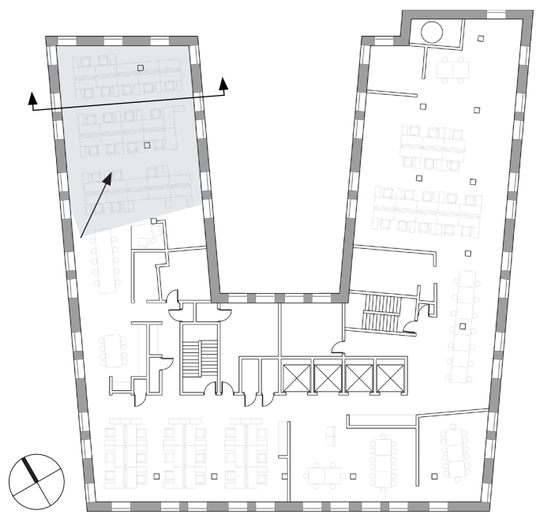




Pattern x: Glass Area Ratios

Fenestration Patterns from 2+ Sides

NBBJ Office: New York, NY



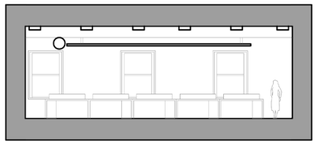
Overview

Successful daylight from the side begins with maintaining a relationship between window head height and section depth. Generally speaking the effective distance of daylight penetration is no more than two times the head height of the perimeter window. In buildings with traditional floor to ceiling heights (~10') this translates to about 20'-0" of section depth that can be daylit from one side. It should be noted that the configuration and size of interior furnishings, and the presence and use patterns of blinds may substantially reduce this distance.

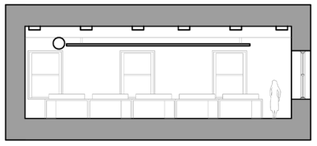
Once an interior section depth exceeds about 25'-0" (assuming traditional ceiling height) the contrast between perimeter zone and core of the building begins to increase substantially during daylight hours. Since the human eye tends to adjust to the brightest location within a space this can cause the perception of darkness in the interior section, and glare due to the lack of luminous uniformity across the section.

There are two primary strategies to address this condition. First, section depths can be kept narrow to ensure both daylight performance and relative uniformity. Alternatively, additional sources of daylight can be added to provide supplemental illumination. In this case additional sources are provided in the form of daylight apertures on multiple sidewalls.

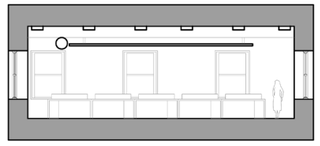
The case study example is the 2 Rector Street building in New York City. This pattern sequence highlights simulations under sunny sky conditions during September at noon with workplane illumination data represented in lux. Typical ambient office lighting criteria range from 300-400 lux and 300 lux was selected as one of the daylighting design criteria examined herein. The percentage of floor area above this value is presented for each permutation.



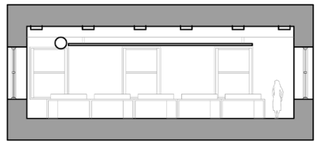
20% Glass Area (1 Side)



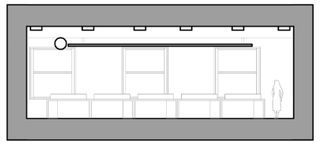
20% Glass Area (2 Sides)



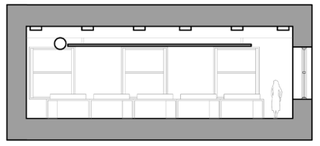
20% Glass Area (3 Sides)



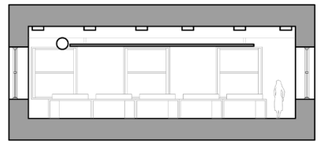
26% Glass Area (3 Sides)
As Designed



30% Glass Area (1 Side)



30% Glass Area (2 Sides)

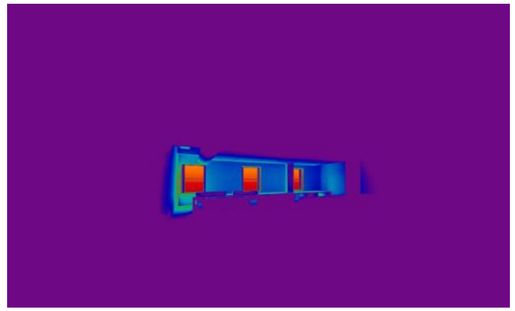


30% Glass Area (3 Sides)

x.1: Fenestration Patterns from 2+ Sides

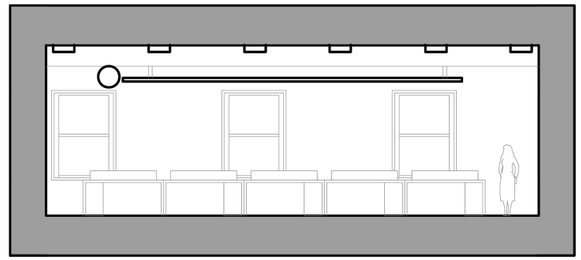
20% Glass Area (1 Side)

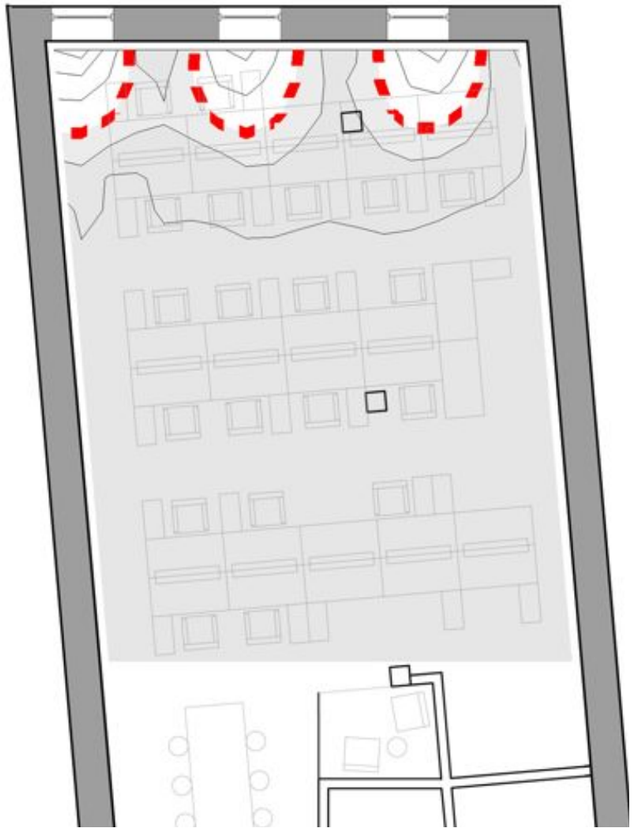
These data illustrate discomfort glare from three perimeter windows comprising 20% of the wall area on the end wall. The daylit zone is restricted to the area within the first 15'-20' from the windows and the majority of the open office space is subject to glare. In a space such as this, blinds would be drawn closed to reduce glare, even on these north-facing windows, much of the time. Approximately 7% of the floor area meets the targeted lighting criteria from daylight alone.



cd/m^2

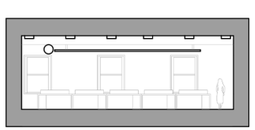
2500
1100
500
250
110
50
20
10

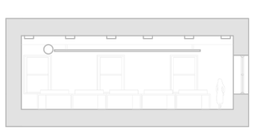


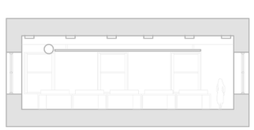


7%
of floor area is above 300 lux

LUX
2000
300
200
100
0



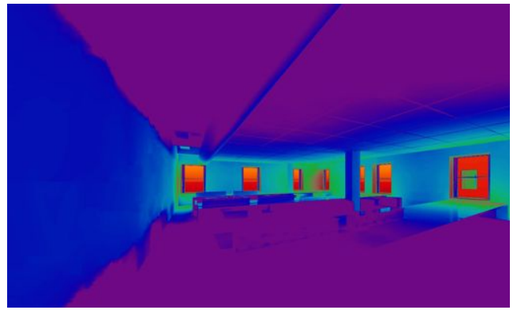


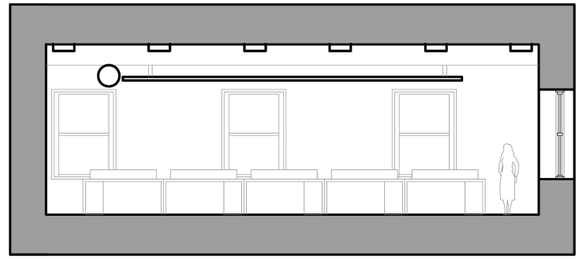


x.2: Fenestration Patterns from 2+ Sides

20% Glass Area (2 Sides)

Windows comprising 20% of the wall area are added to one of the long walls and dramatically reduces the perception of glare experienced. Providing daylight from two directions is an important strategy to create spaces with both functional daylight illumination and with lower contrast. Here, the light from the windows on the long wall can be seen illuminating the third wall opposite it. Approximately 28% of the floor area meets the targeted lighting criteria from daylight alone.





28%

of floor area is above 300 lux

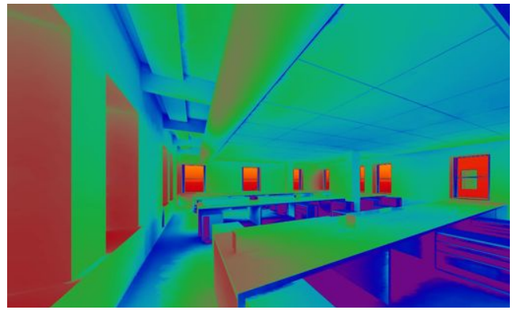
LUX
2000
300
200
100
0

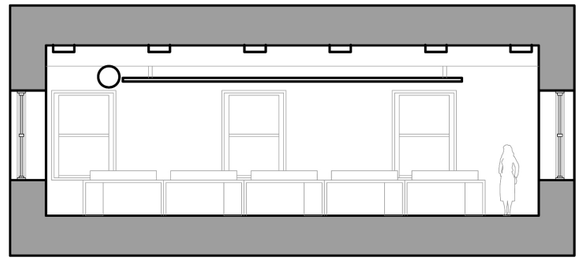
x.3: Fenestration Patterns from 2+ Sides

20% Glass Area (3 Sides)

Windows comprising 20% of the wall area are utilized on all three major walls (N, E, W) within this space. Contrast is reduced because there is light from three sides and walls are painted white to increase inter-reflection. Furthermore, deep window reveals, orientation and building self-shading (atrium at east) serve to minimize direct sun penetration.

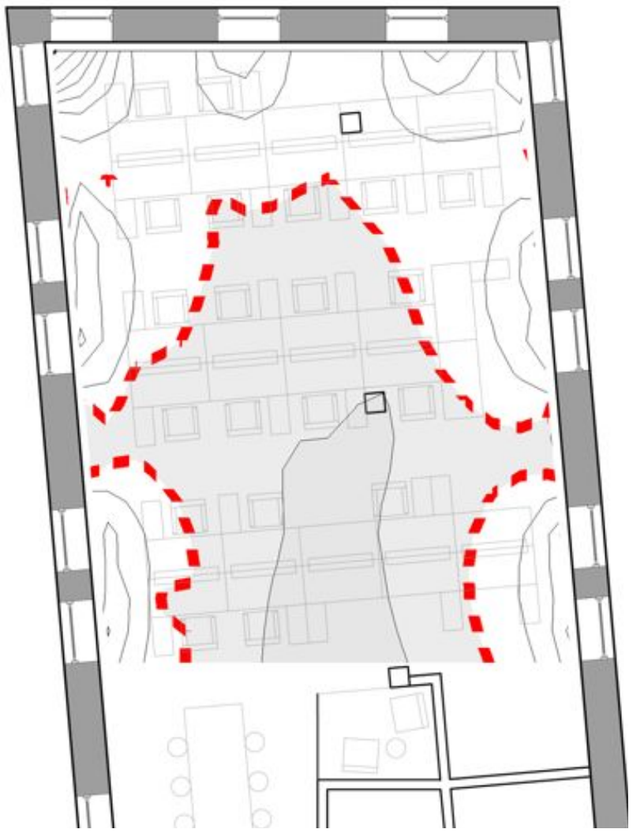
Approximately 53% of the floor area meets the targeted lighting criteria from daylight alone.

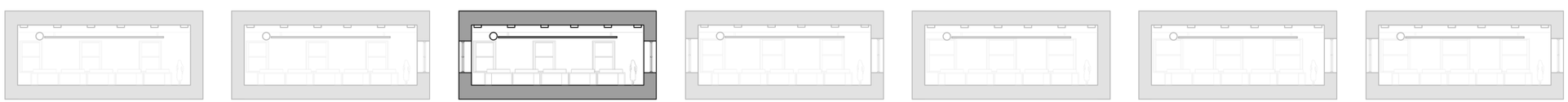




53%
of floor area is above 300 lux

LUX
2000
300
200
100
0

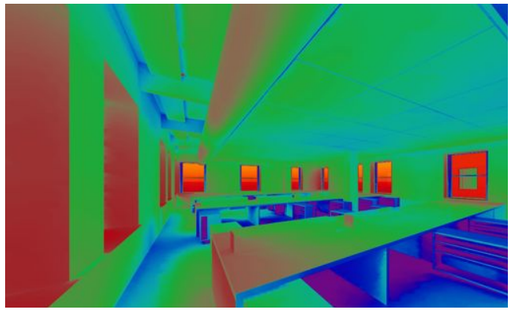


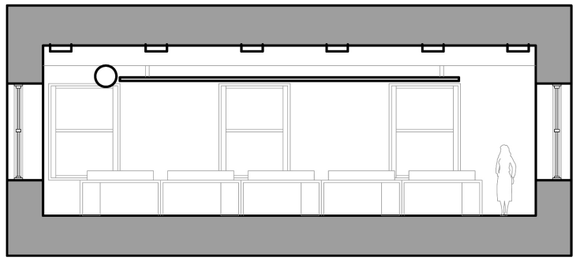


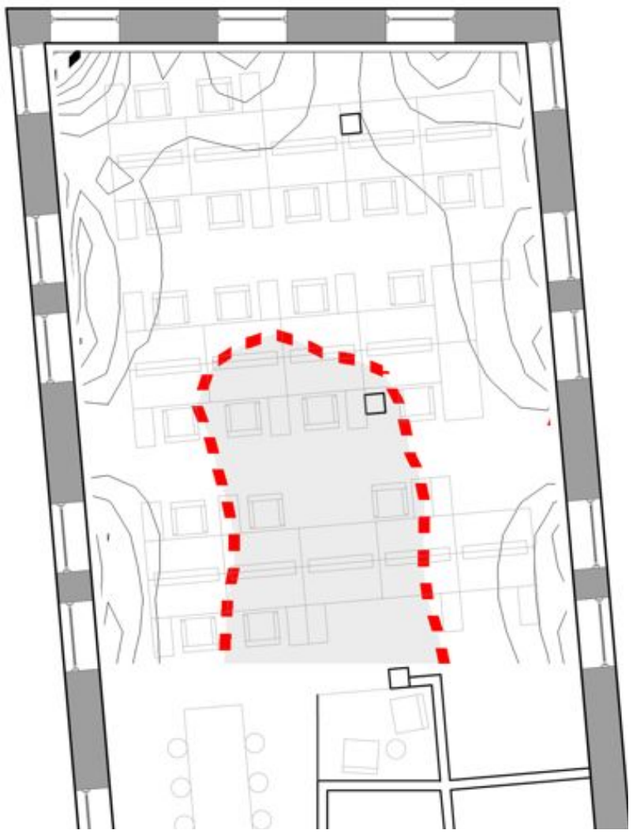
x.4: Fenestration Patterns from 2+ Sides

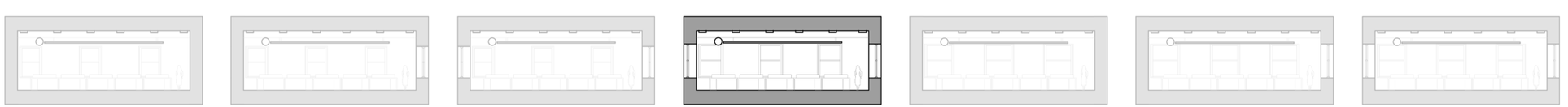
26% Glass Area (3 Sides): As Designed

Windows comprising 26% of the wall area are utilized on all three major walls (N, E, W) within this space. This is the simulation that matches the as designed condition. Contrast is reduced because there is light from three sides and walls are painted white. Deep window reveals, orientation and building self-shading (atrium at east) serve to minimize direct sun penetration. The workstations are pulled back from the perimeter of the space, ensuring windows are considered to be 'owned by all', and also reducing the likelihood of direct sun on work surfaces. Partitions between workstations are essentially eliminated, maintaining free line of sight to both windows and well-illuminated vertical surfaces for all occupants. Approximately 78% of the floor area meets the targeted lighting criteria from daylight alone.





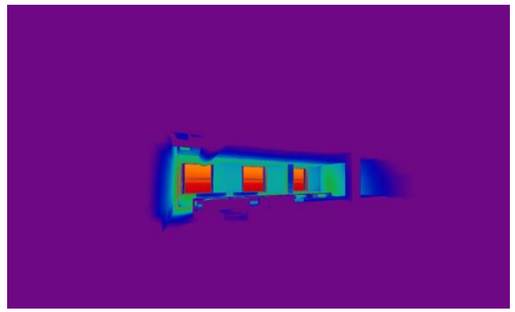


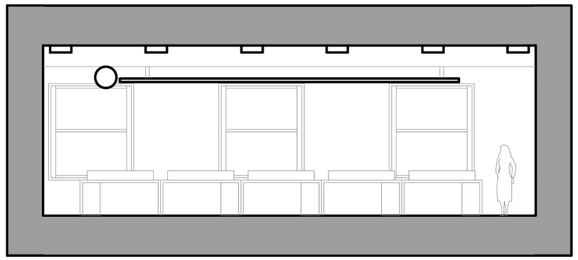


x.5: Fenestration Patterns from 2+ Sides

30% Glass Area (1 Side)

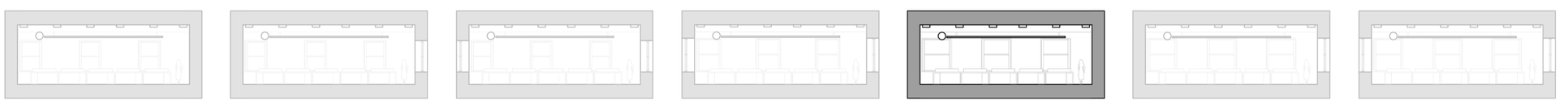
These data illustrate discomfort glare from three perimeter windows comprising 30% of the wall area on the end wall. The daylit zone is restricted to the area within the first 15'-20' from the windows and the majority of the open office space is subject to glare. In a space such as this, blinds would likely be drawn closed to reduce glare, even on these north-facing windows, much of the time. Approximately 16% of the floor area meets the targeted lighting criteria from daylight alone.





16%
of floor area is above 300 lux

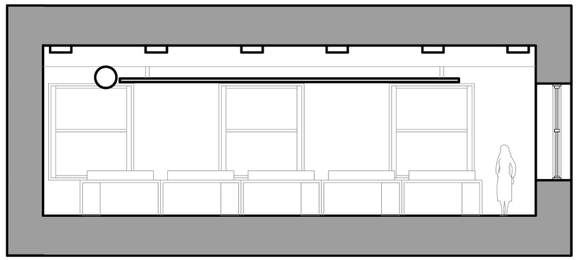
LUX
2000
300
200
100
0

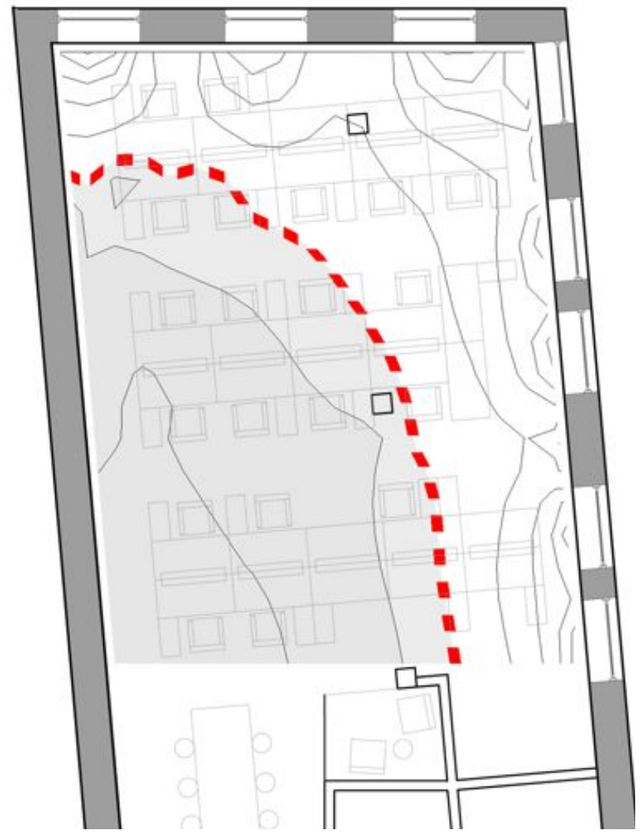


x.6: Fenestration Patterns from 2+ Sides

30% Glass Area (2 Sides)

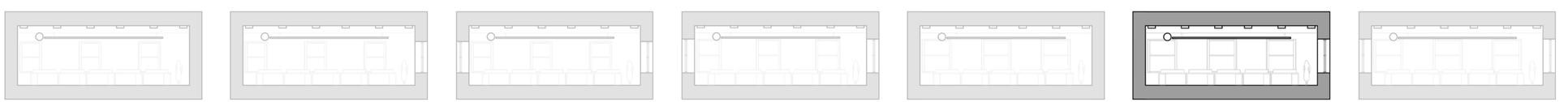
Windows comprising 30% of the wall area are added to one of the long walls and dramatically reduces the perception of glare experienced. Providing daylight from two directions is an important strategy to create spaces with both functional daylight illumination and with lower contrast. Here, the light from the windows on the long wall can be seen illuminating the third wall opposite it. Approximately 51% of the floor area meets the targeted lighting criteria from daylight alone.





51%
of floor area is above 300 lux

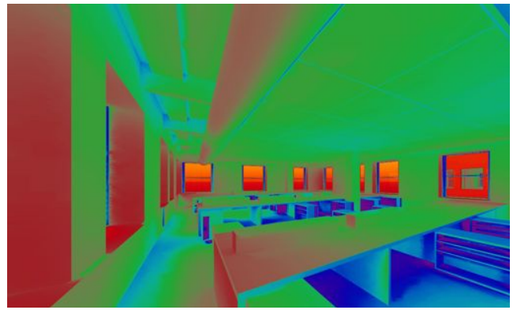
LUX
2000
300
200
100
0

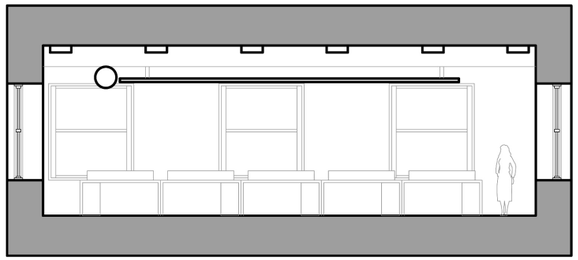


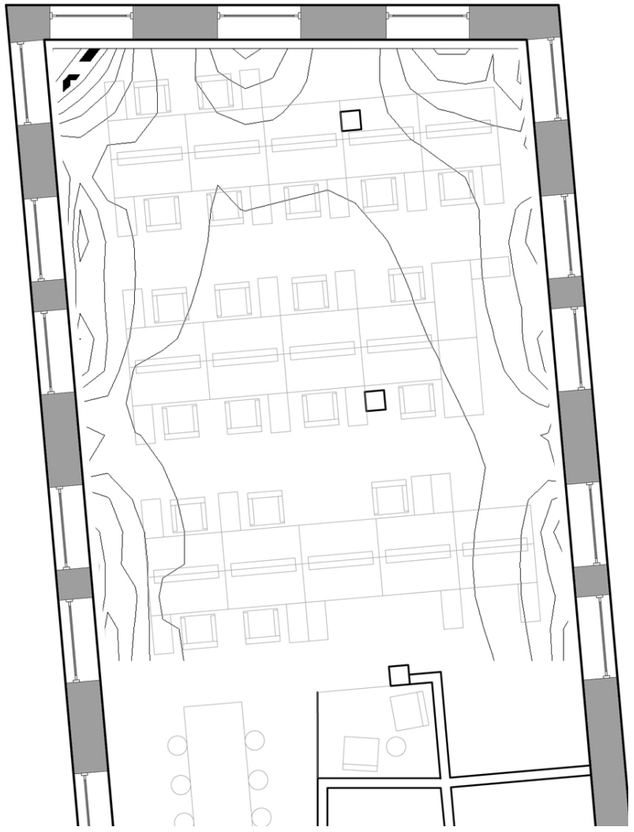
x.7: Fenestration Patterns from 2+ Sides

30% Glass Area (3 Sides)

Windows comprising 30% of the wall area are used on all three major walls (N, E, W) within this space. Contrast is reduced because there is light from three sides and walls are painted white to increase inter-reflection. Furthermore, deep window reveals, orientation and building self-shading (atrium at east) serve to minimize direct sun penetration. The workstations are pulled back from the very edges of the space, ensuring windows are considered to be 'owned by all', and also reduce the likelihood of direct sun on work surfaces. Partitions between workstations are essentially eliminated, maintaining free line of sight to both windows and well-illuminated vertical surfaces for all occupants. Approximately 100% of the floor area meets the targeted lighting criteria from daylight alone.

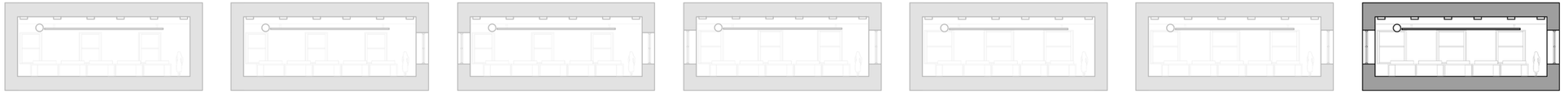




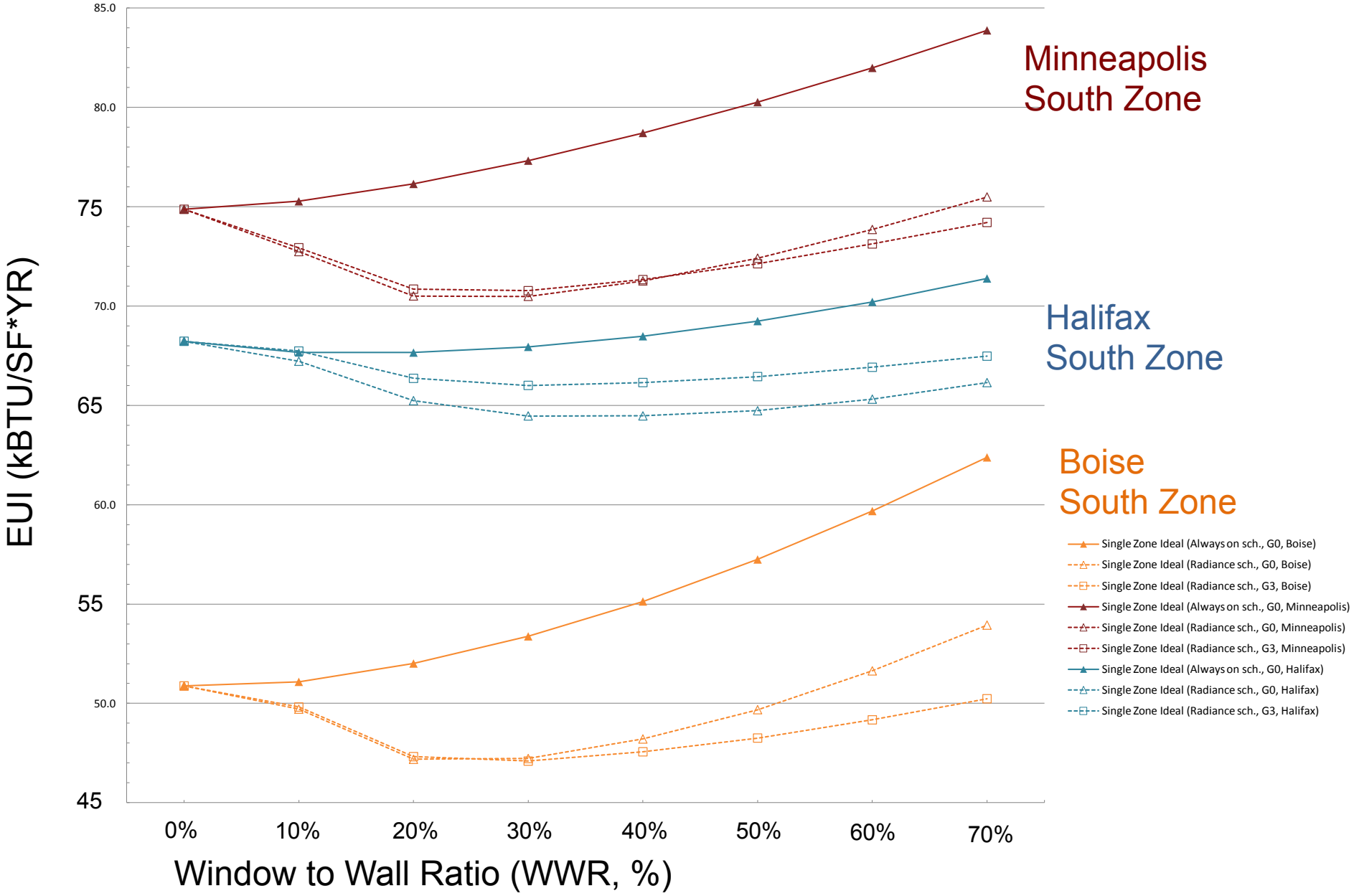


100%
of floor area is above 300 lux

LUX
2000
300
200
100
0



Energy Use w/wo Daylight Harvest



Buildings in USA ~ 75% of all electricity (US-EIA 2008)
Electric Lighting in USA ~ 25% of total electricity in buildings (DOE 2006)
~ 19% of electricity in USA is used for lighting

Laboratory Environment Daylight Harvesting Lighting Energy Savings

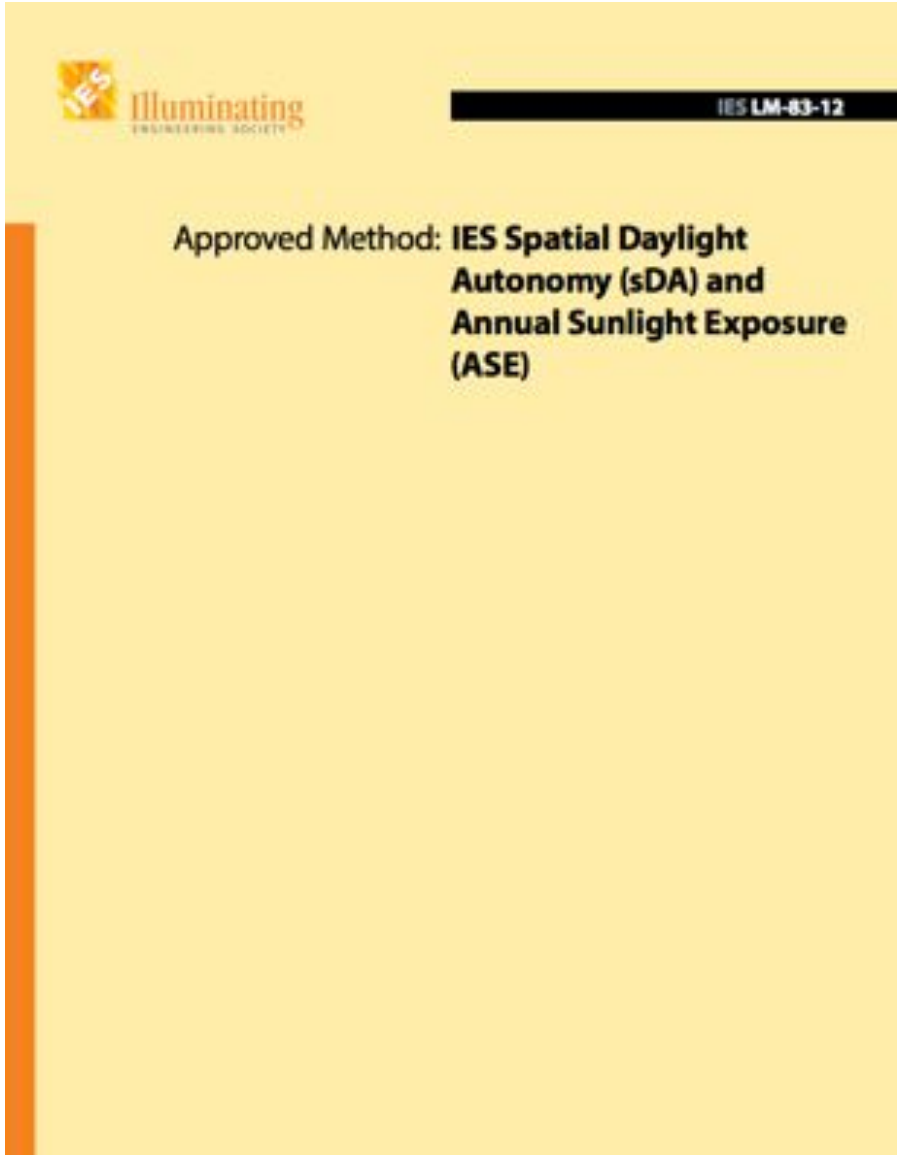
- 45-55 % potential lighting savings from three years worth of illumination data (Littlefair, 2001)
- 60% lighting savings for a dimming system with automated blinds (Roche, 2002)
- 20-23% lighting savings with windows from one side (Lee and Selkowitz, 2006)
- 52-59% with windows on two sides (Lee and Selkowitz, 2006)

Field Study Daylight Harvesting Lighting Energy Savings

- <0% to 156% of predicted savings
  - (Pigg et al. 1996; Jennings et al. 1999; Reinhart & Voss 2003; Moore et al. 2003; McHugh et al. 2004; Heschong et al. 2005; Hackel & Schuetter 2013; Galasiu et al. 2007; Fernandes et al. 2014)
- Savings from Toplit spaces more predictable than sidelit
  - (Heschong et al. 2005; McHugh et al. 2004)
- Recent studies show improvement
  - (Acker & Van Den Wymelenberg 2010; Fernandes et al. 2014)
- but….problems persist (50% realization)
  - (Hackel & Schuetter 2013)

PUBLICATIONS

IES LM-83-12
Approved Method:
IES Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE)



Ash Creek Elementary | Monmouth, OR | BOORA Architects
Photo: Nick Hubof, UI-IDL
Rendering: Nick Hubof, UI-IDL

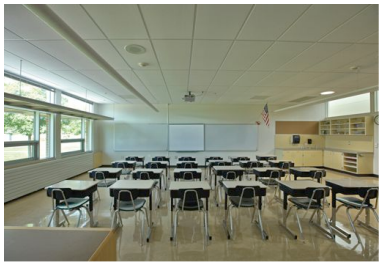
Annual metrics for a classroom model

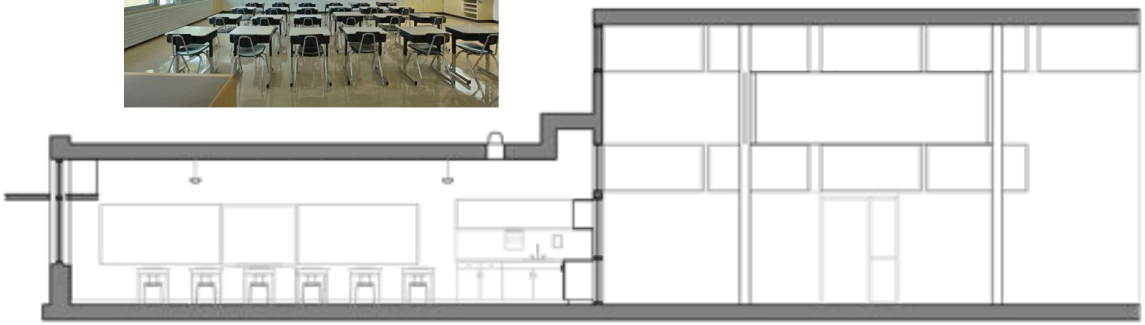
South face.

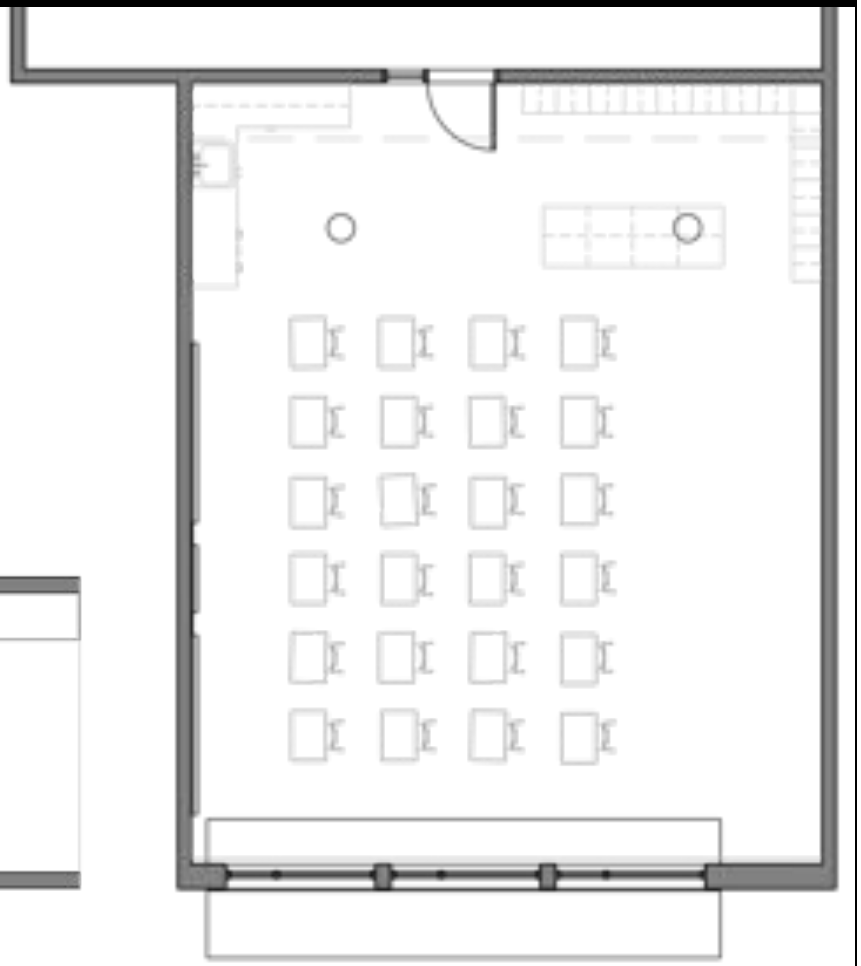
- Run with varied number of window groups.

North re-light.

- Run as a single north-facing window group.





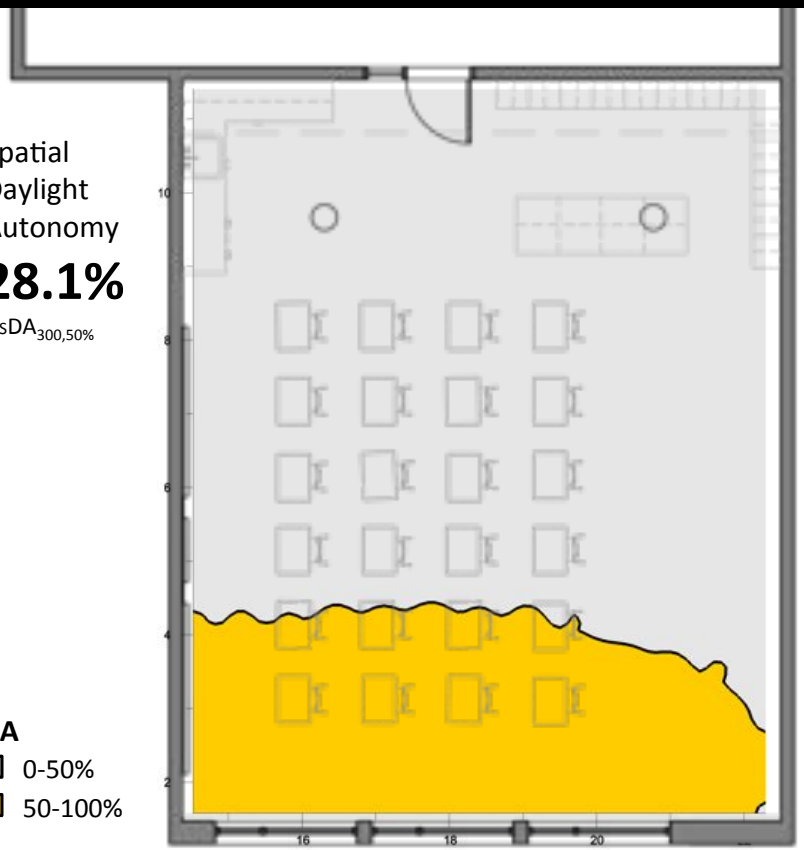


No shading 1 south window group

Spatial
Daylight
Autonomy

28.1%

$sDA_{300,50\%}$



DA
- 0-50%
- 50-100%

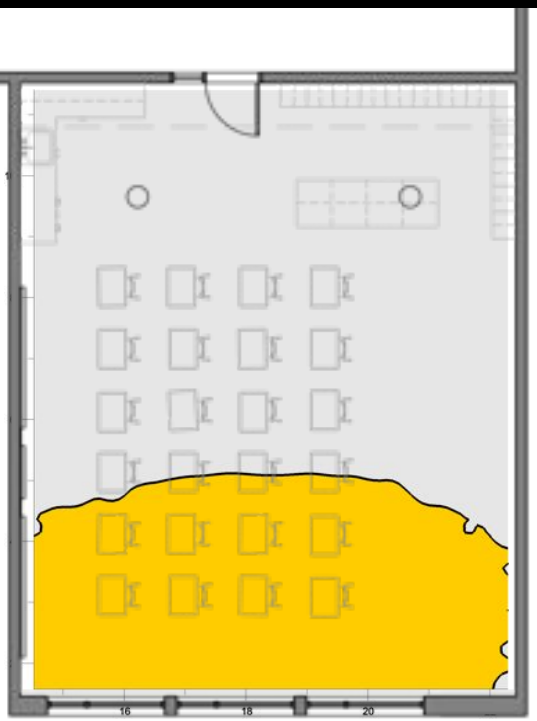
Annual
Sunlight
Exposure

31.3%

$ASE_{1000,250H}$

Average
Hours

669



ASE
- 0-250 hr.
- 250+ hr.

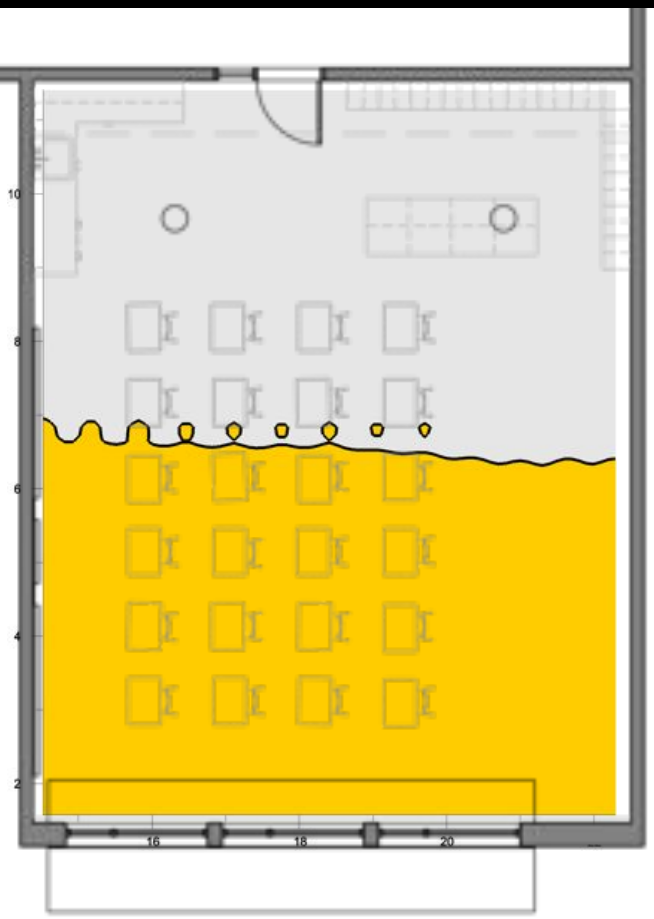
Using LM-83 script v1.0

Shading + light shelf 2 south window groups

Spatial
Daylight
Autonomy

54.3%

$sDA_{300,50\%}$



DA
- 0-50%
- 50-100%

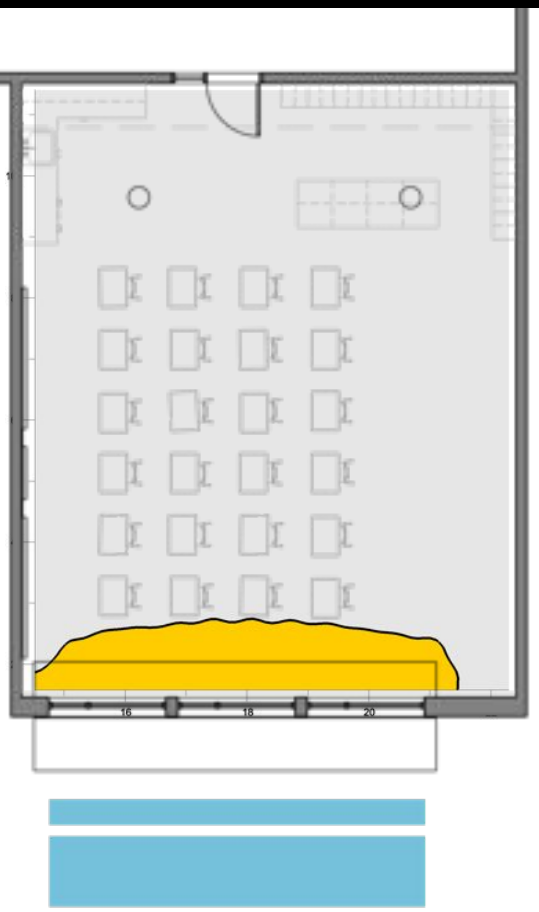
Annual
Sunlight
Exposure

10.1%

$ASE_{1000,250H}$

Average
Hours

604



ASE
- 0-250 hr.
- 250+ hr.

Using LM-83 script v1.0

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Delight Daylight Energy

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