Radiance Techniques for Rad Indoor Environments

Seif Eses – Atelier Ten

August 28th, 2024

Case Study 1: Enclosing a Courtyard

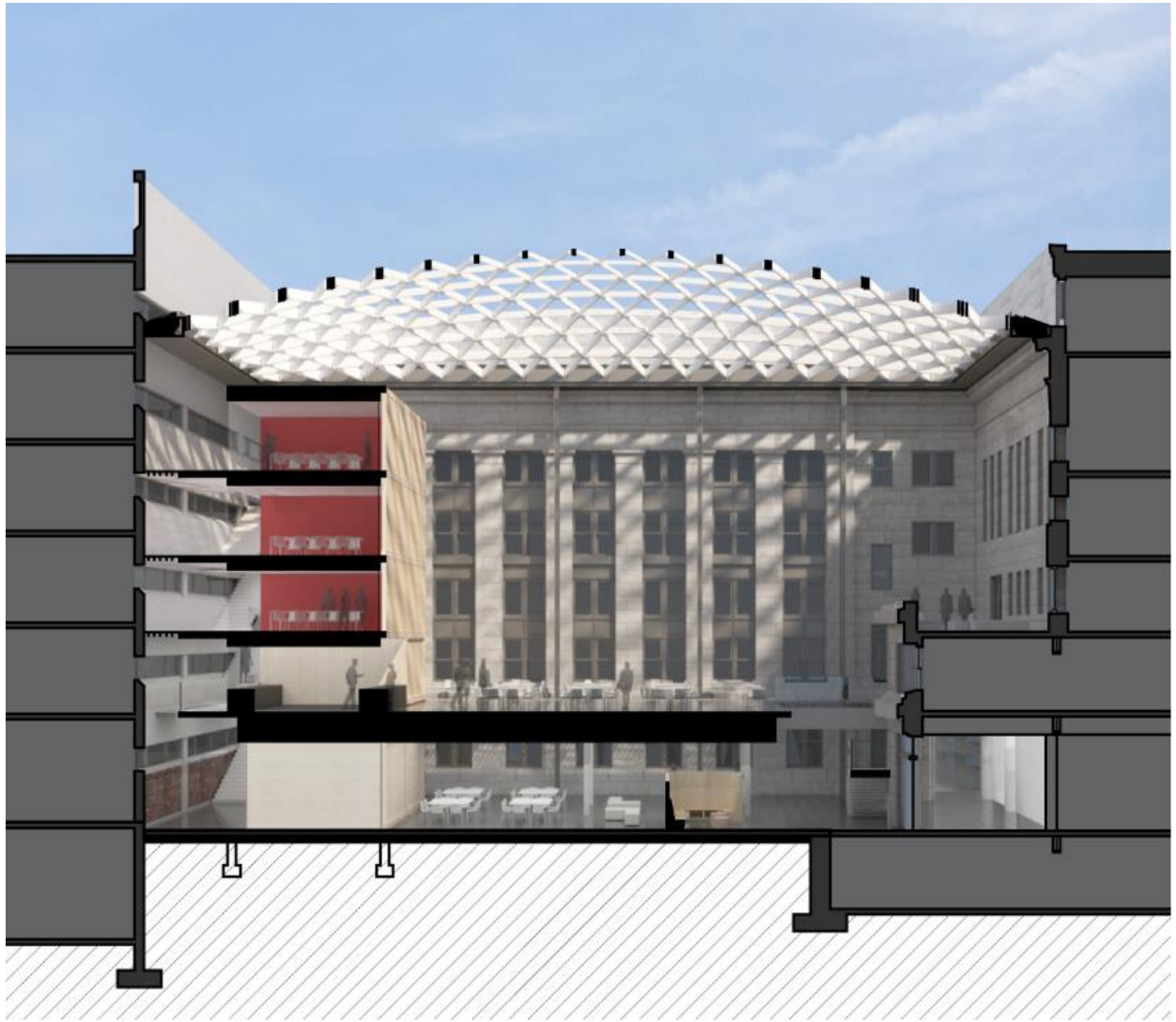
Introduction

Design Problem

Designing a skylight that encloses a multifunctional courtyard space – to be used by students.

Analysis Overview

1. Assess visual comfort for occupants in the courtyard through direct sun and overshadowing studies
2. Assess feasibility of green wall through direct sun and daylight integral studies

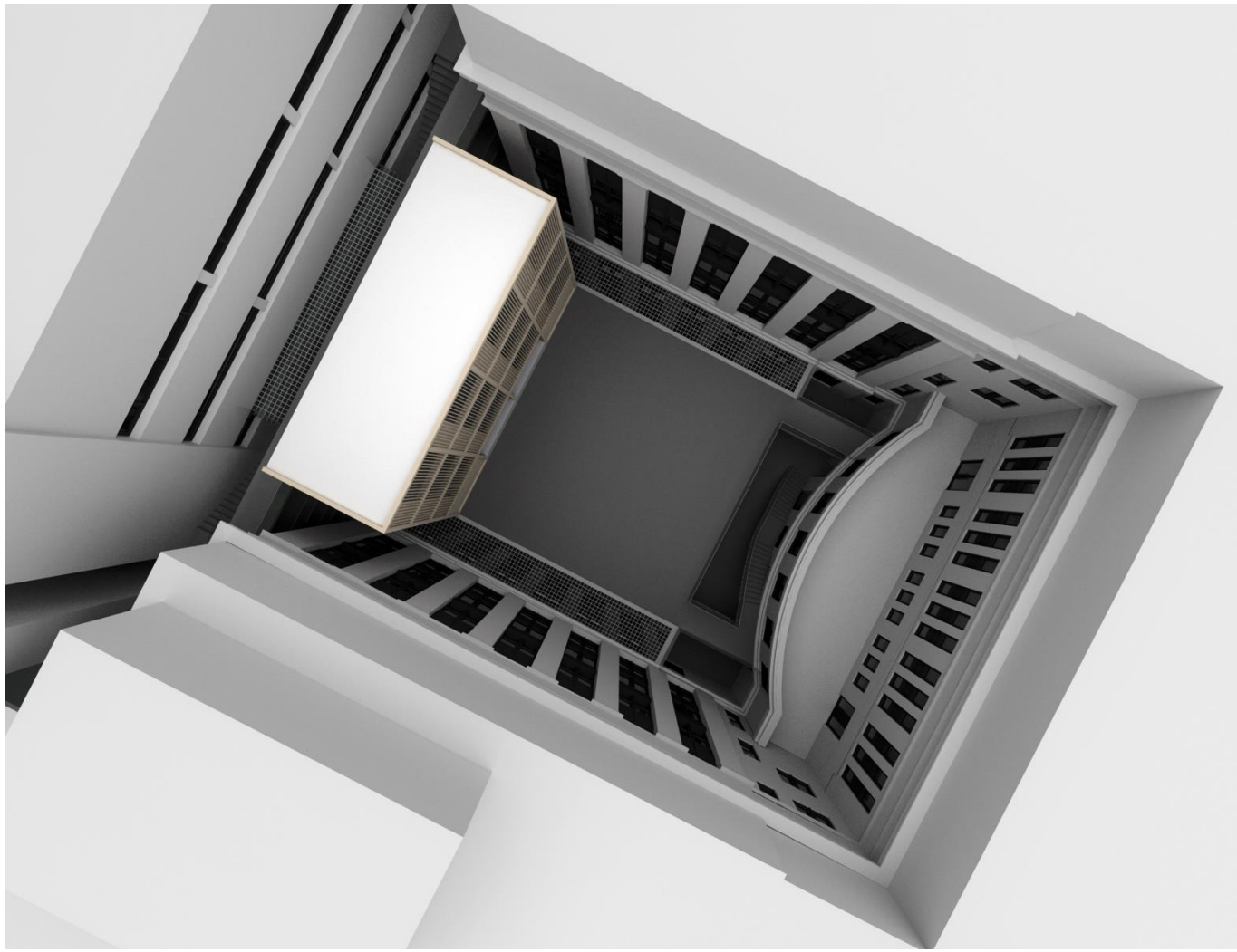


Direct Sun Study

Introduction

Methodology

1. Create a direct sun animation
2. Choose multiples points in the space to study overshadowing
3. Pinpoint times of the year with potential visual discomfort
4. Identify zones on skylight where shading is necessary



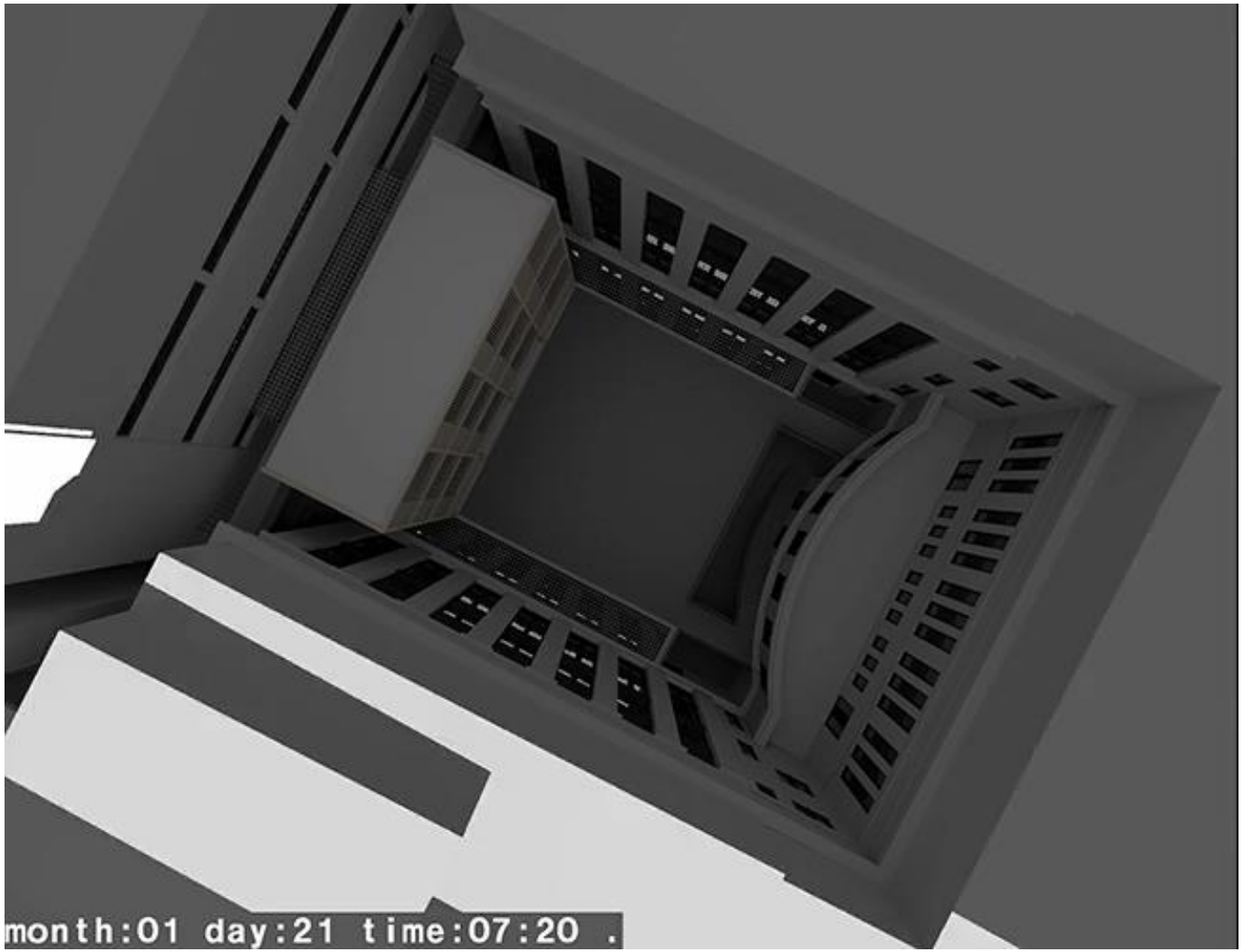
Courtyard Design

Direct Sun Study

Animation

- Atelier Ten studied the direct sun condition in the courtyard on the 21st of every month

- The animation visualizes the direct sun throughout the year

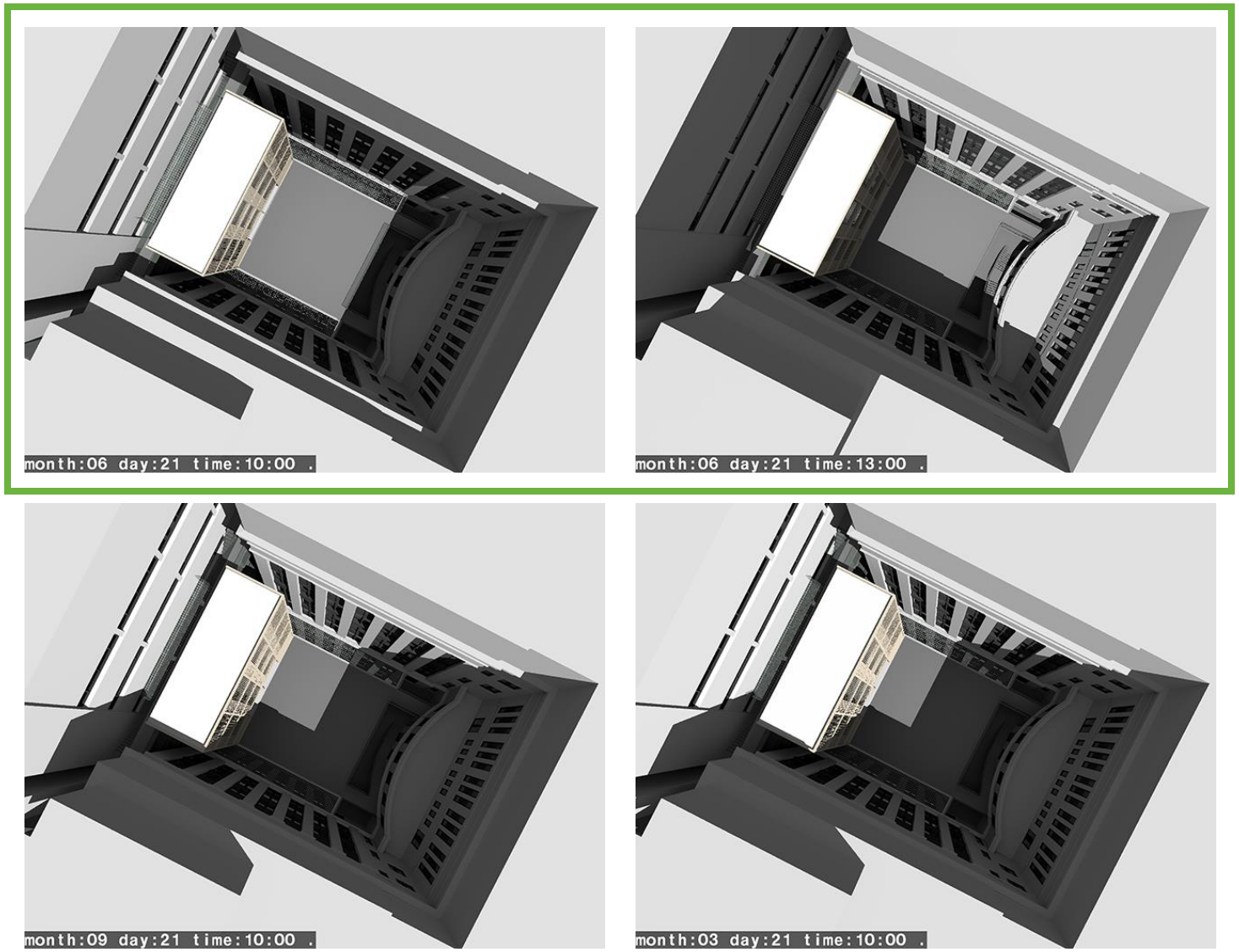


Direct Sun Study

Times of Concern

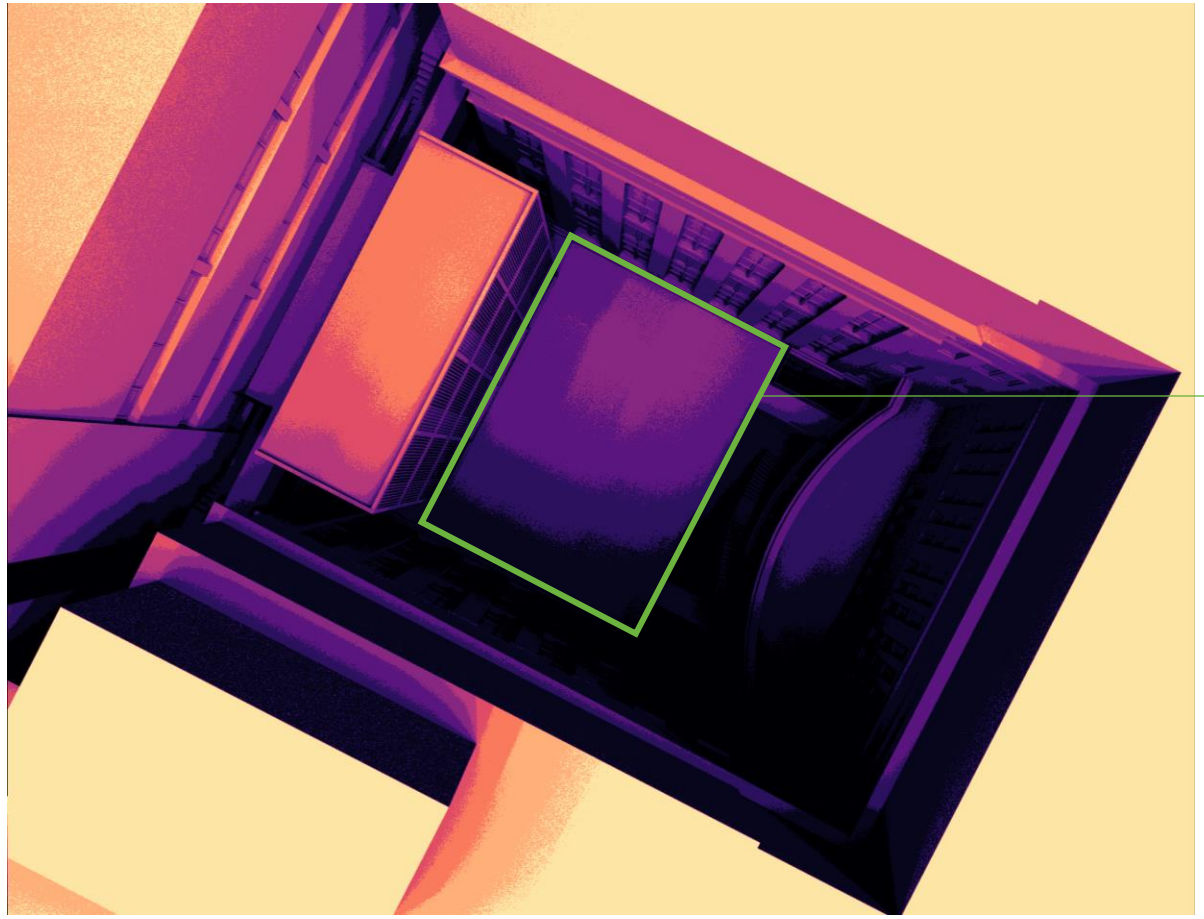
- Times of concern:
  1. Morning to early afternoon hours of the summer
  2. Morning hours of the fall/spring

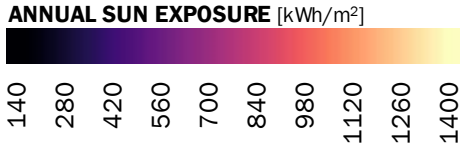
- The **summer hours will cause extreme visual discomfort to occupants** and will require intentional design of the skylight shading system



Direct Sun Study

Annual Sun Exposure



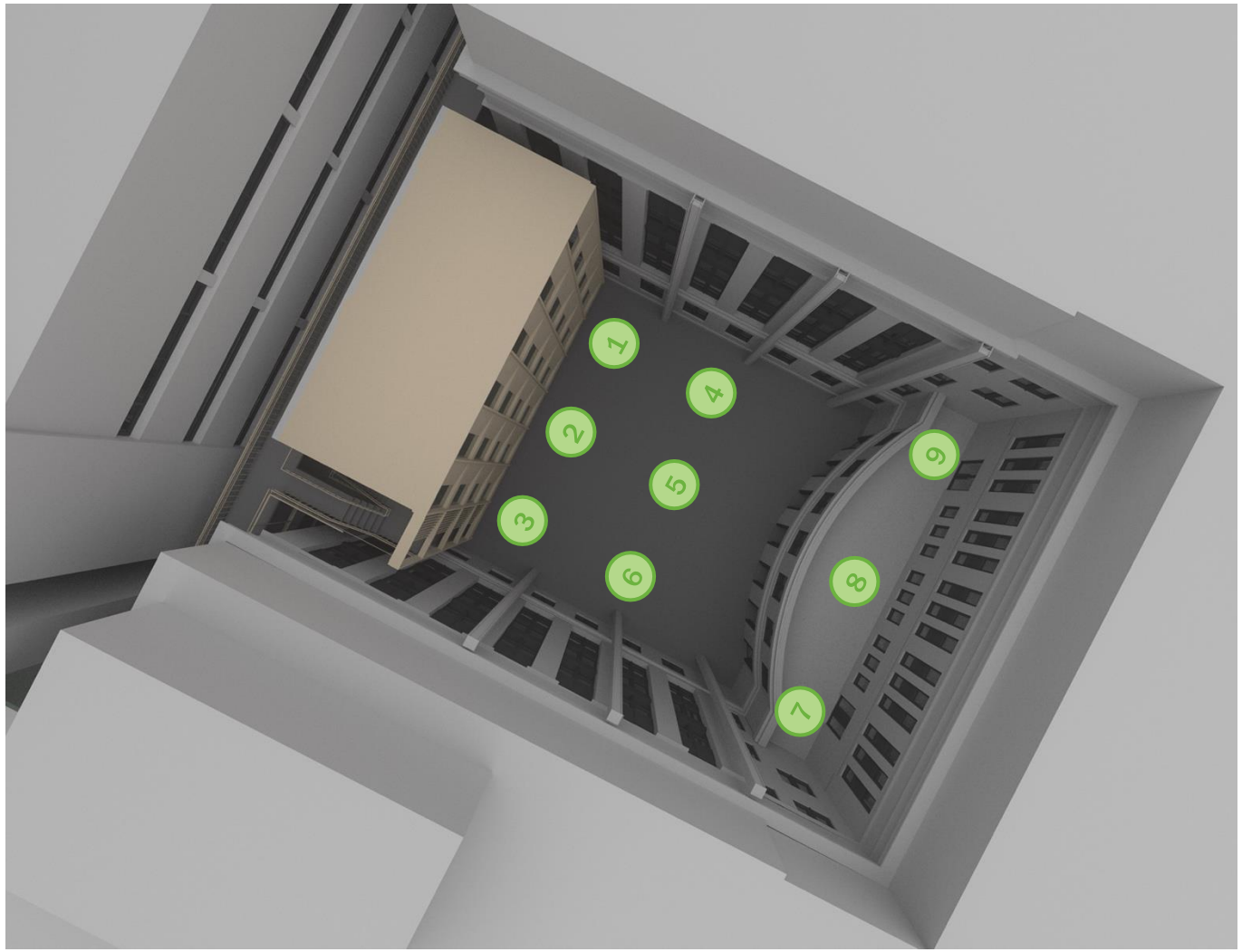


- This annual sun exposure map shows a summary of the zones that are receiving higher levels of direct sun in the courtyard.
  - This will be useful for furniture layout design

Direct Sun Study

Overshadowing

- Nine points across the courtyard and terrace space that potentially can be occupied were chosen
- Overshadowing diagrams were created from each of these points to understand which hours of the year are shaded by the current design and surrounding buildings
- Occupied hours assumed to be 8 AM to 6 PM

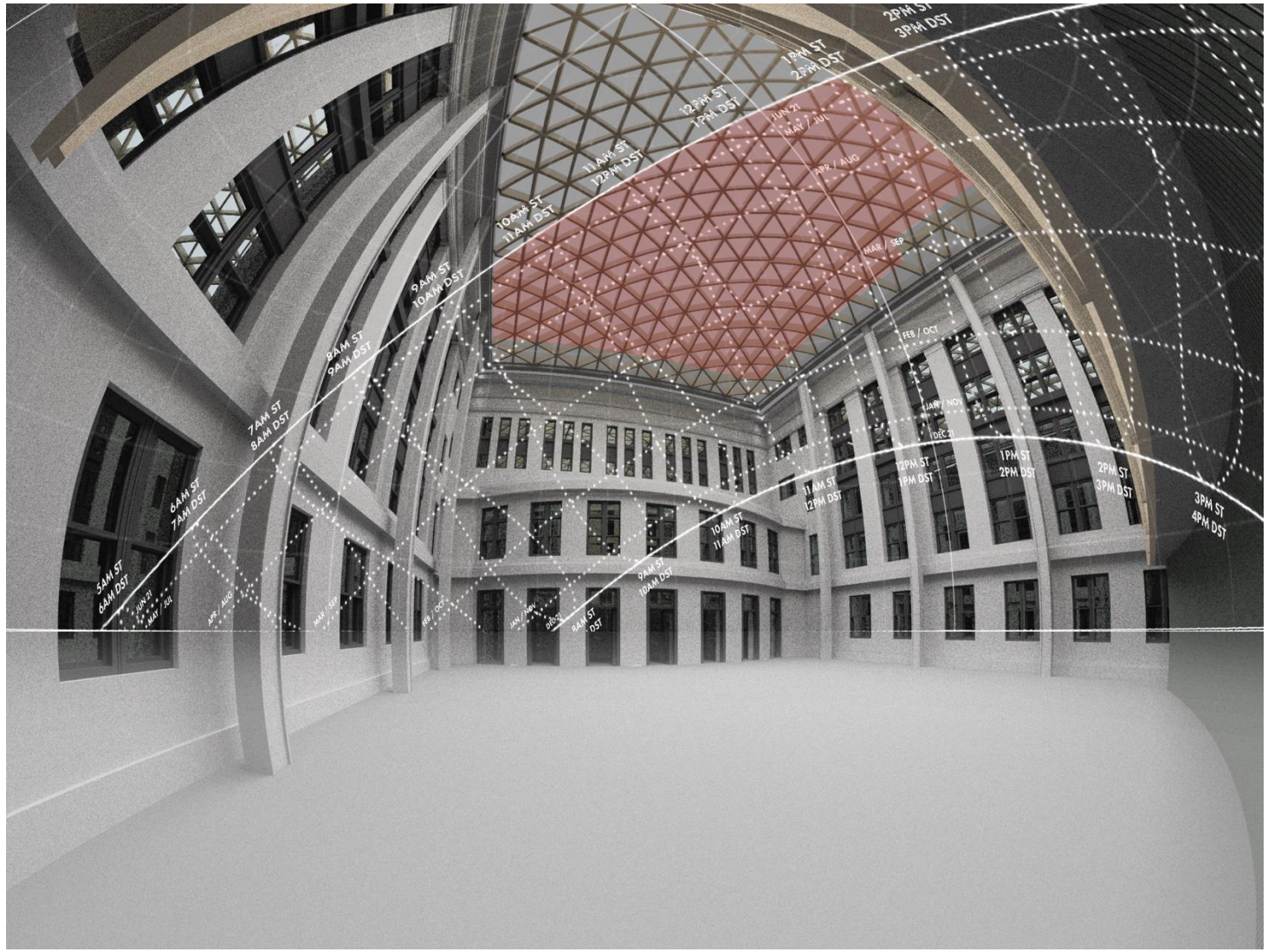


Courtyard Design

Direct Sun Study

Overshadowing – Next to Stack

Area of Concern



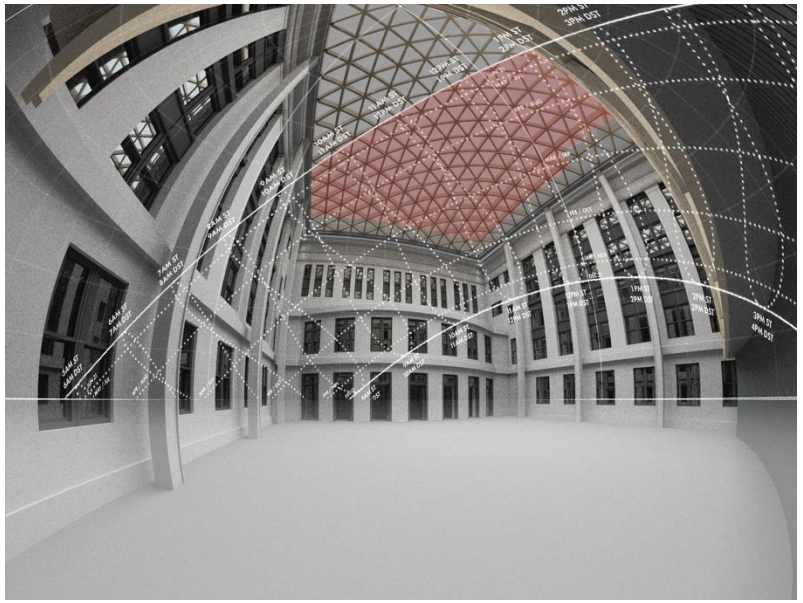
Point 1

- Direct sun from 9:30 AM to 1 PM (3.5 hrs – 35% of occupied hours) from April to August.

Direct Sun Study

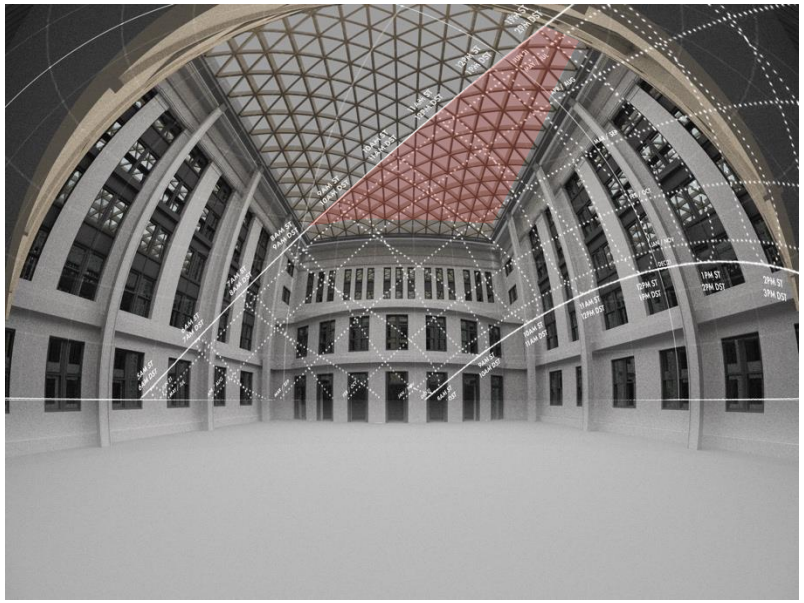
Overshadowing – Next to Stack

Area of Concern



Point 1

- Direct sun from 9:30 AM to 1 PM (3.5 hrs – 35% of occupied hours) from April to August.



Point 2

- Direct sun from 8:30 AM to 1 PM (4.5 hrs – 45% of occupied hours) from April to August.

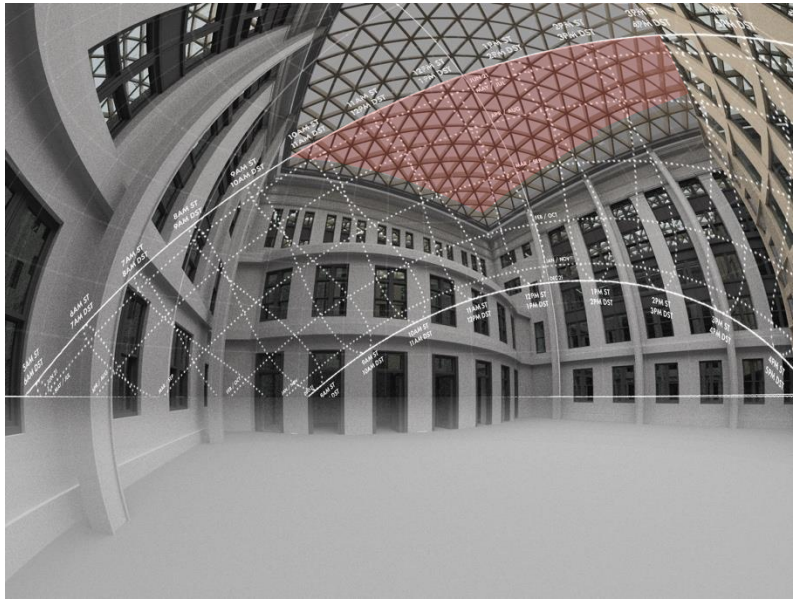
Point 3

- Direct sun from 8:30 AM to 11 AM (2.5 hrs – 25% of occupied hours) during the summer months.

Direct Sun Study

Overshadowing – Middle of Courtyard

Area of Concern



Point 4

- Direct sun from 10 AM to 3 PM (5 hrs – 50% of occupied hours) from April to August.

Point 5

- Direct sun from 9:30 AM to 2 PM (4.5 hrs – 45% of occupied hours) from April to August.

Point 6

- Direct sun from 10 AM to 11 AM (1 hrs – 10% of occupied hours) from May to July.

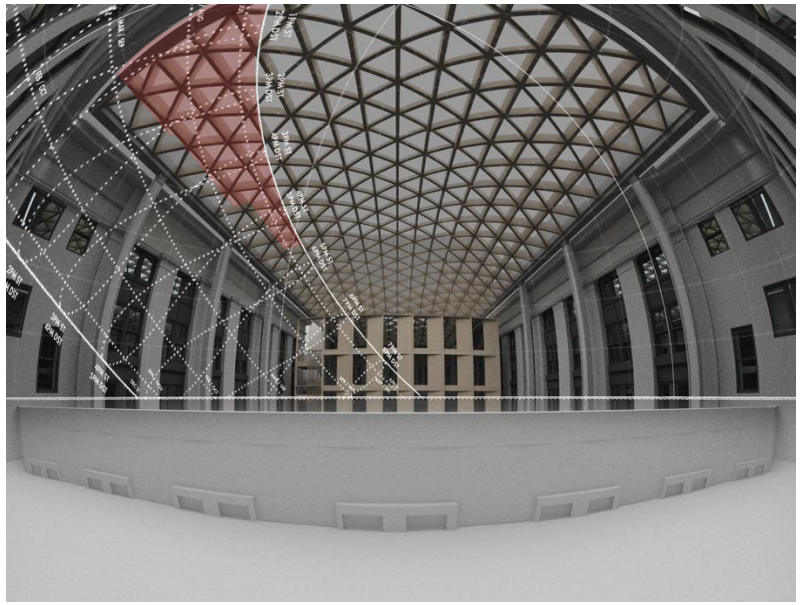
Direct Sun Study

Overshadowing – Terrace

Area of Concern

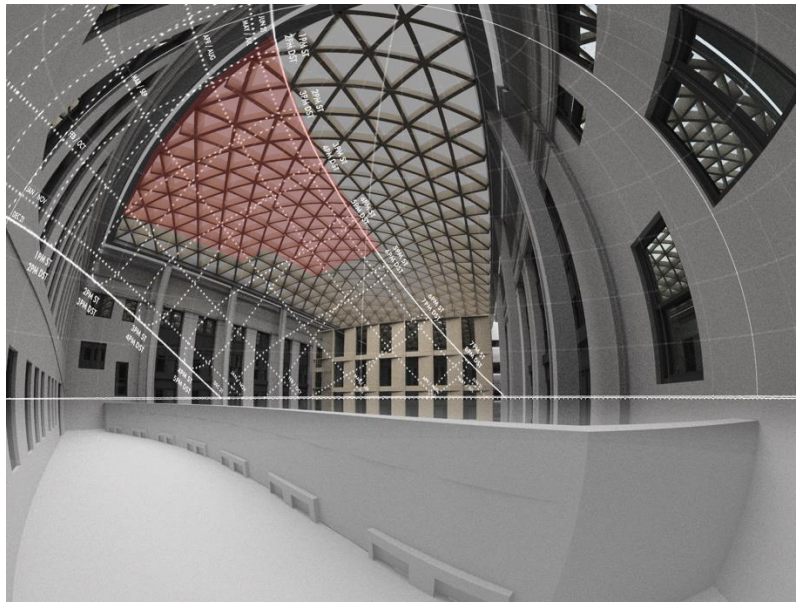
Point 7

- Receives no direct sun.



Point 8

- Direct sun from 12:30 PM to 4:30 PM (4 hrs – 40% of occupied hours) from May to July.



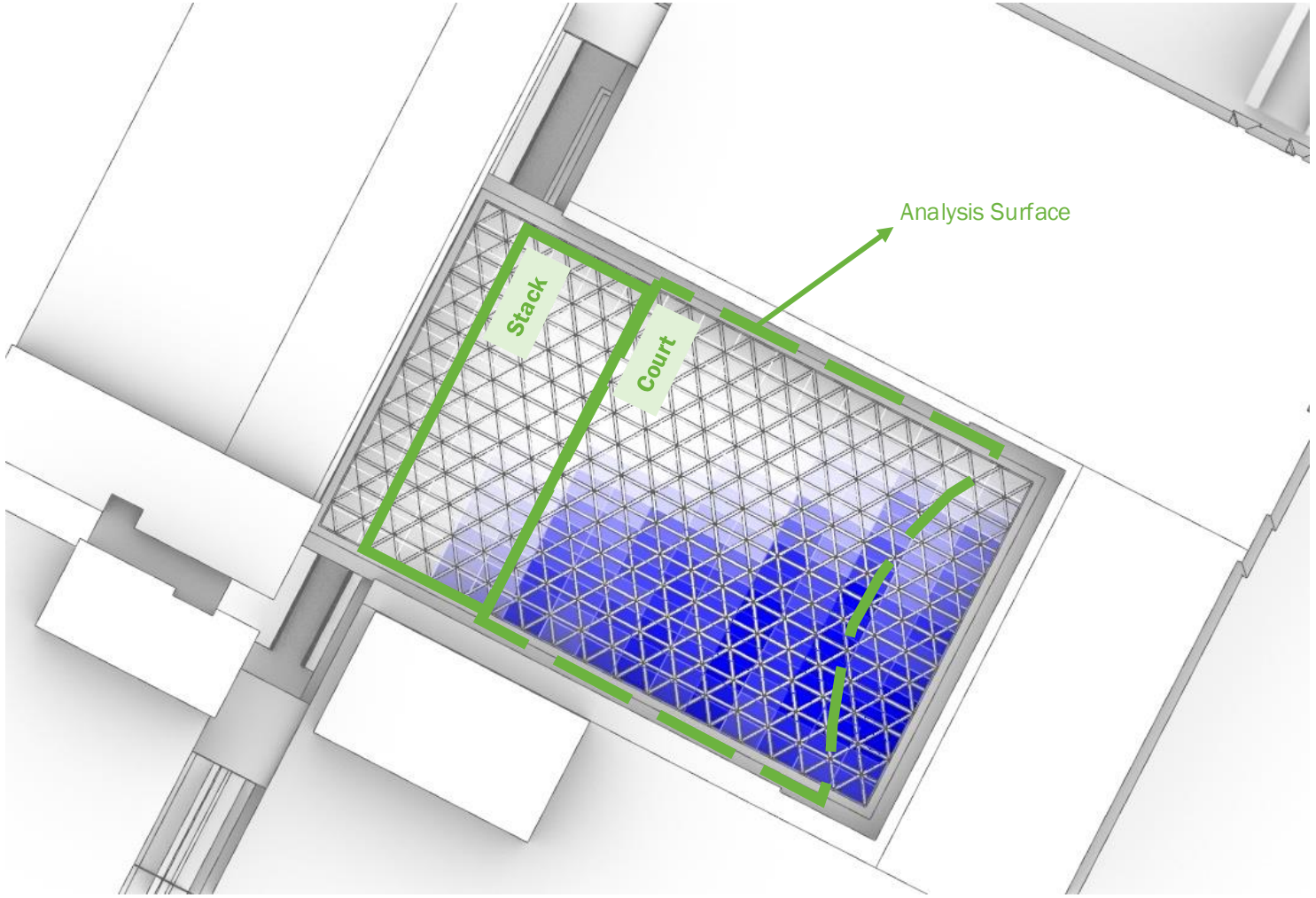
Point 9

- Direct sun from 12:30 PM to 4:40 PM (4 hrs – 40% of occupied hours) from April to August.

Direct Sun Study

Skylight Areas of Concern

- Given the overshadowing conditions, the analysis to the right shows which areas of the skylight are contributing to direct sun encroachment in the space.
- Atelier Ten developed a tool to create a map of which zones are causing the highest level of visual discomfort in the courtyard and potential thermal discomfort.
- The study shows that the SE corner of the façade requires some treatment to avoid visual discomfort. The depth of the glulam elements aid in shading areas of the critical zone.



Critical Glazing Zones for Shading

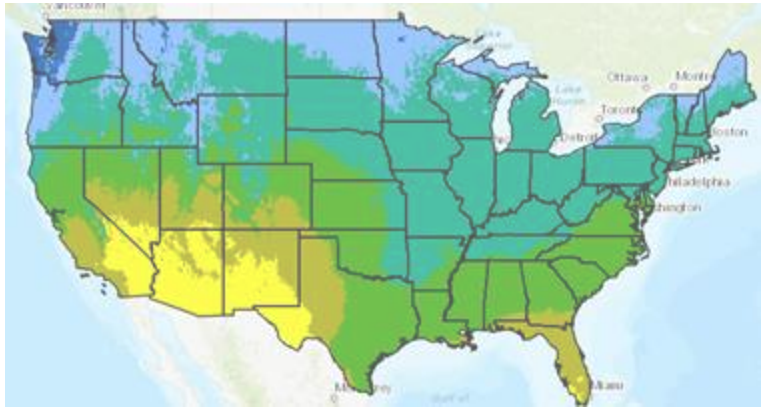
LEAST **MOST**

Outdoor Daily Light Integral (DLI)

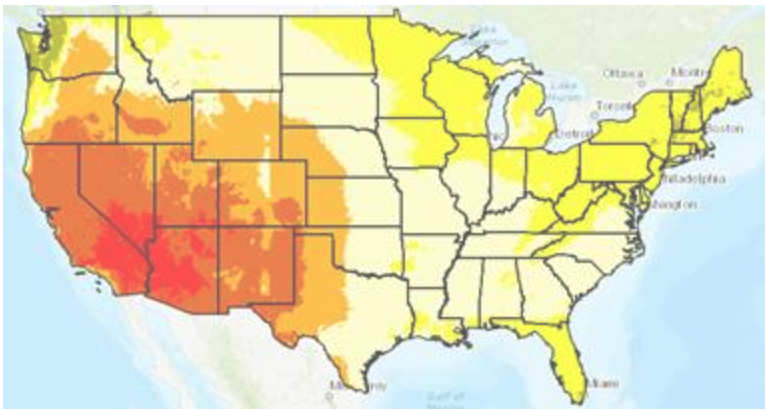
DLI Introduction

Daily Light Integral (DLI) represents the total photosynthetically active radiation accumulated over one day (*mol/m^2/day)* Instead of highlighting DLI for one day, the common application unit of DLI is a monthly average DLI. The monthly average DLI accounts for the variable sky conditions specific to each climate.

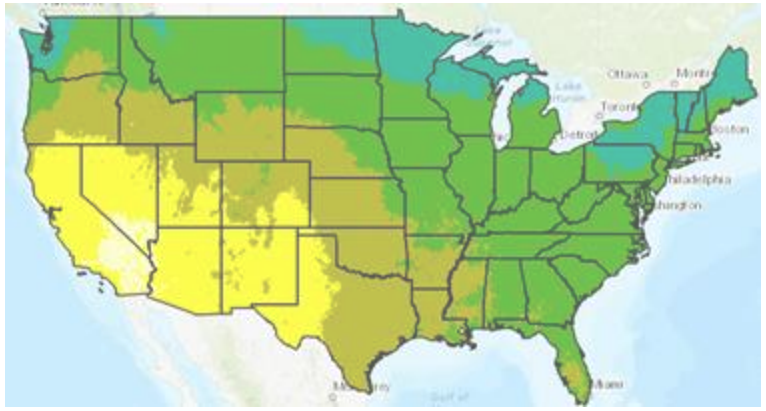
The maps at right show the monthly average outdoor DLI for March, June, September, and December*. This data from Clemson University accounts for typical sky radiation values measured between 1998-2012.



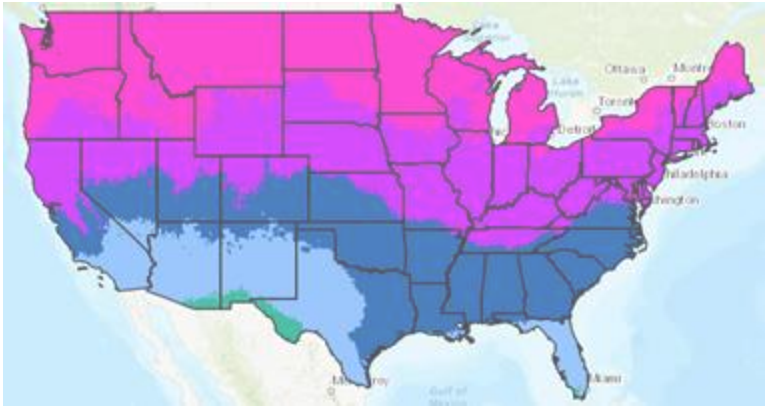
Monthly DLI for March



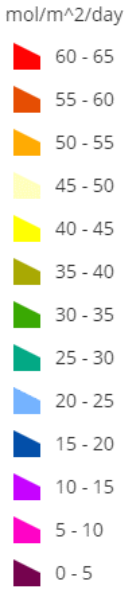
Monthly DLI for June



Monthly DLI for September



Monthly DLI for December



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*reference page: U.S. Daily Light Integral Map by Joanne Logan and James Faust (clemson.edu)
**reference page: \climatewebsite\WMO_Region_4_North_and_Central_America\USA_United_States_of_America (onebuilding.org)

Plant DLI Requirements

Table 2. DLI Requirements for Various Greenhouse Crops

Minimum aceptable quality
Good quality
High quality

1=Requires ample water to perform well at high-light levels.
2=Requires cool or moderate temperatures to perform well at high-light levels.
3=Stock plants perform well under higher light levels than finished plants.

Species	Average Daily Light Integral (Moles/Day)														
	Greenhouse														
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Ferns (Pteris Adiantum)															
Maranta															
Phalaenopsis (orchid)															
Saintpaulia															
Spathiphyllum															
Forced hyacinth															
Forced narcissus															
Forced tulip															
Aglaonema															
Bromeliads															
Caladium													1	1	1
Dieffenbachia															
Dracaena															
Nephrolepsis															
Streptocarpus															
Hosta													1	1	1
Hedera (English ivy)															
Begonia (heimalis)															
Sinningia															
Schlumbergera									2	2	2	2	2	2	2
Cyclamen															
Exacum															
Heuchera															
Coleus (shade)															
Impatiens, New Guinea															
Iris, Dutch (cut flowers)															

- Guides like the one to left will help the landscape architect choose which plants to use in the green wall based on the indoor DLI incident on the surface.
  - Ferns is often used for the green wall

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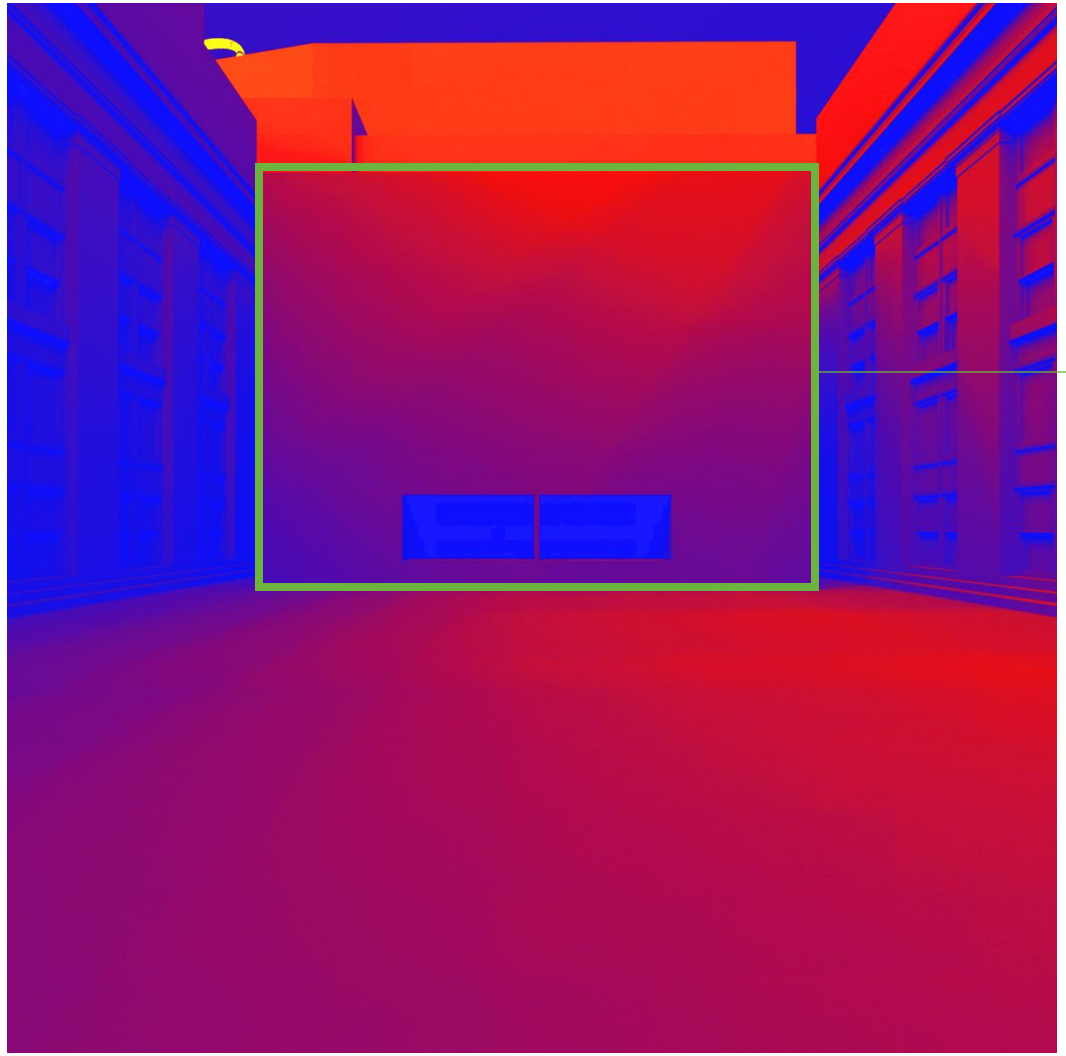
*reference page: https://www.extension.purdue.edu/extmedia/ho/ho-238-w.pdf

Green Wall Study

Daily Light Integral & Annual Sun Exposure Maps



Range of DLI on green wall surface

- Ferns require a minimum DLI of 2 and is high quality with a DLI of 10.

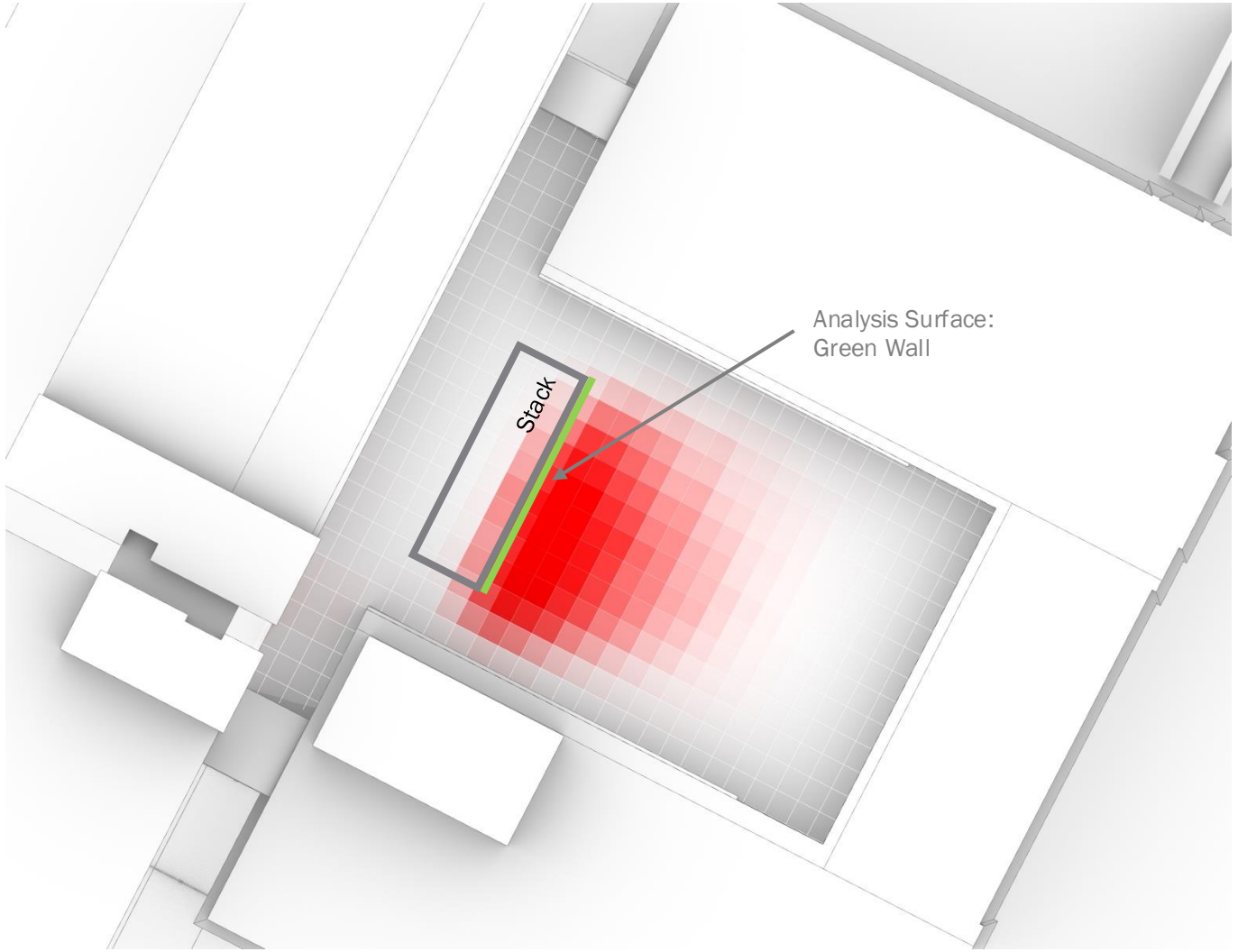
Direct Sun Study – Green Wall

Skylight Shading

- Given the overshadowing conditions, it is useful to understand which areas of the skylight are contributing to direct sun onto the green wall.
- Atelier Ten developed a tool to create a map of which zones are critical for providing the green wall with direct sun. This aligns with the DLI, which reflects direct radiation.
- Based on this study, we recommend that the critical zones are left more open.

Critical Areas of Solar Encroachment

LEAST **MOST**



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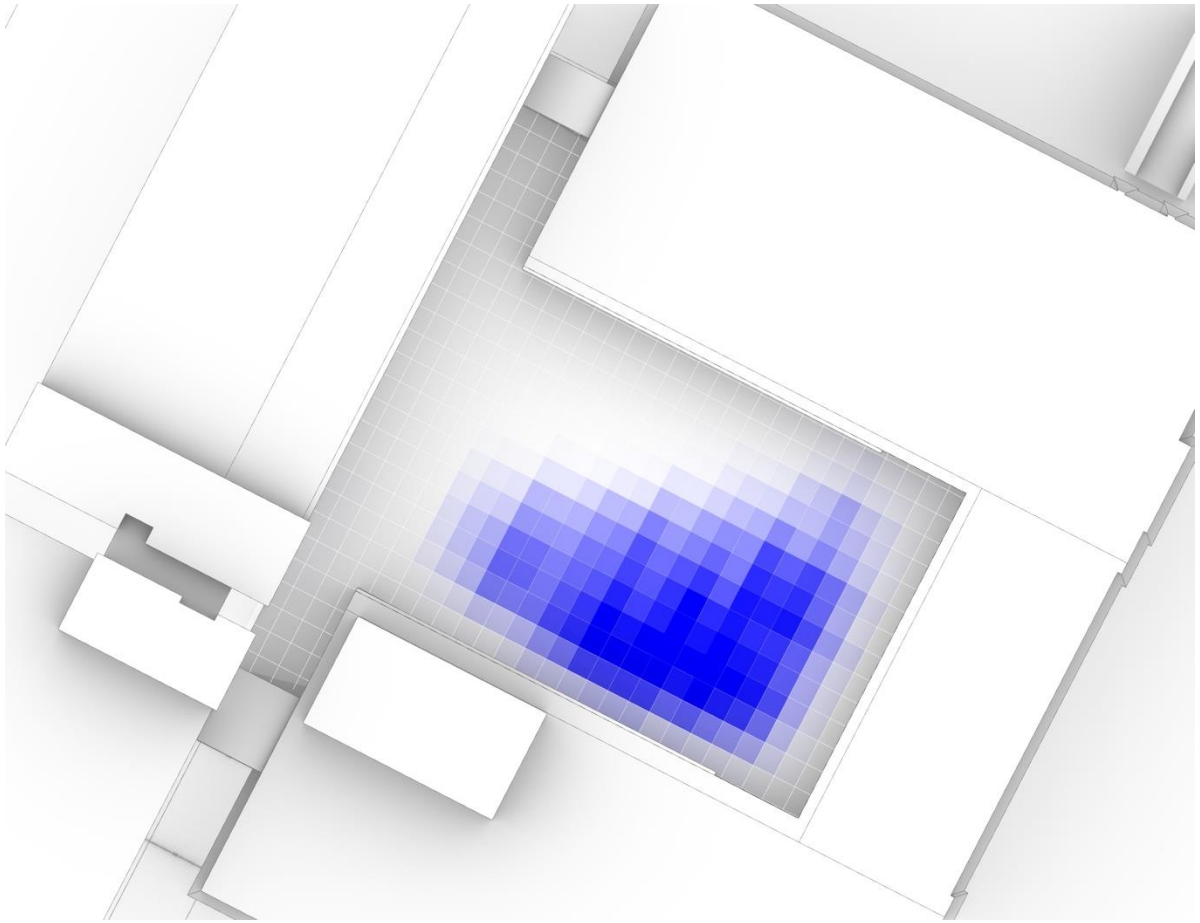
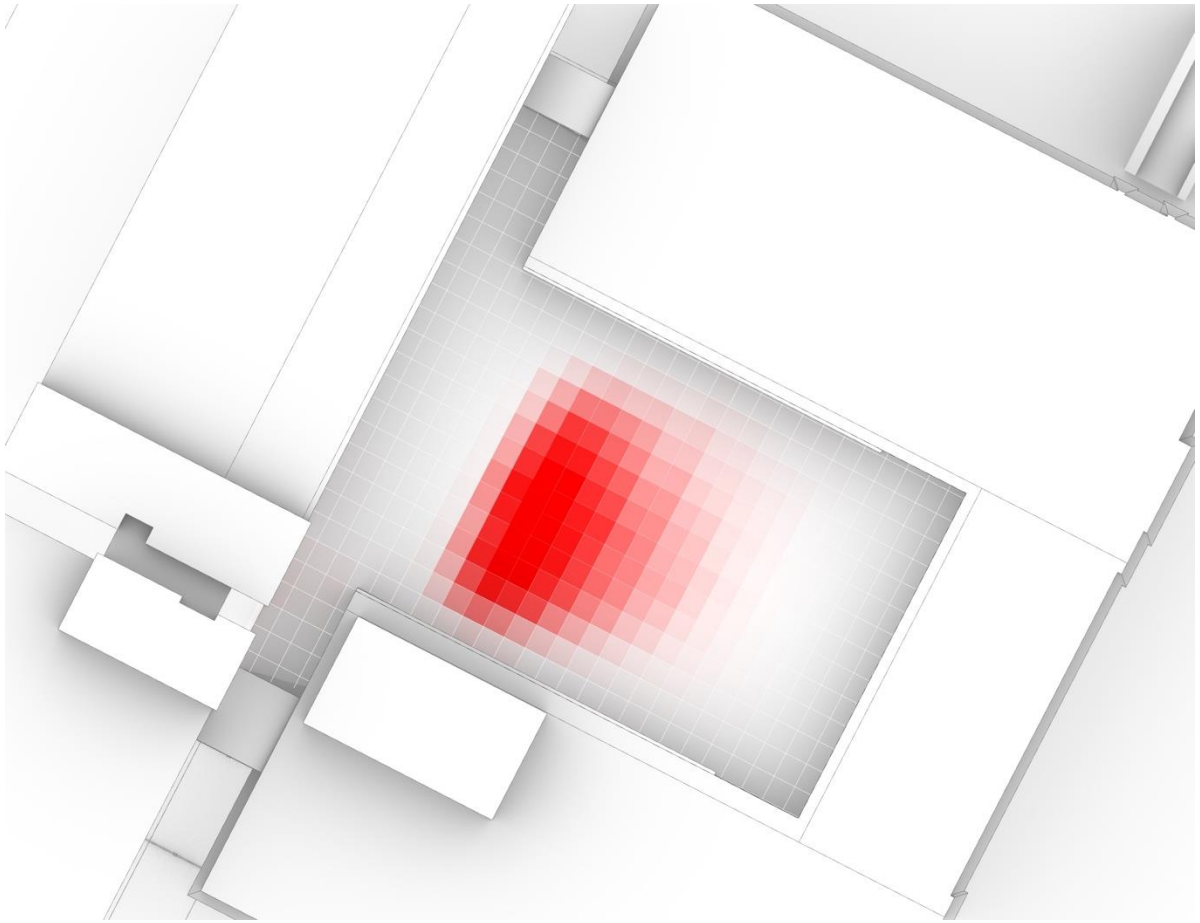
Skylight

Skylight Shading



Courtyard Visual Comfort

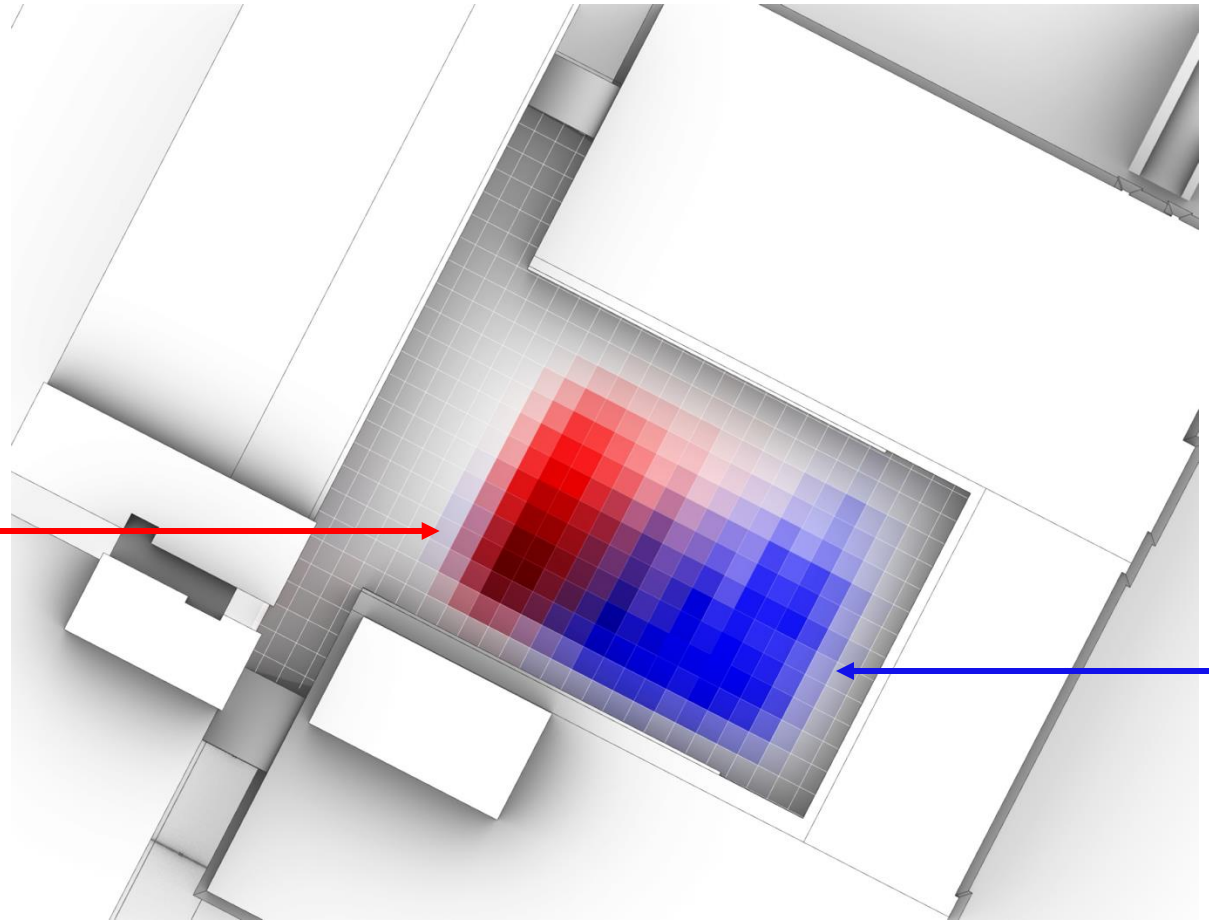


Green Wall Direct Sun

Skylight

Skylight Shading

Zone to leave more open to allow solar encroachment onto the green wall surface.



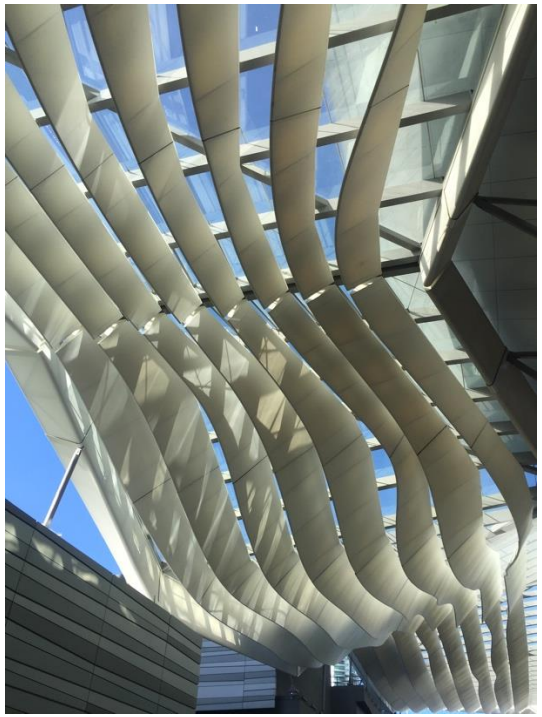
Zone to shade in order to improve visual comfort in the courtyard.

Direct Sun Study

What can we do? – Standard Strategies

Harvard Kennedy School of Government Pavilions

Utilizing frit as glare control

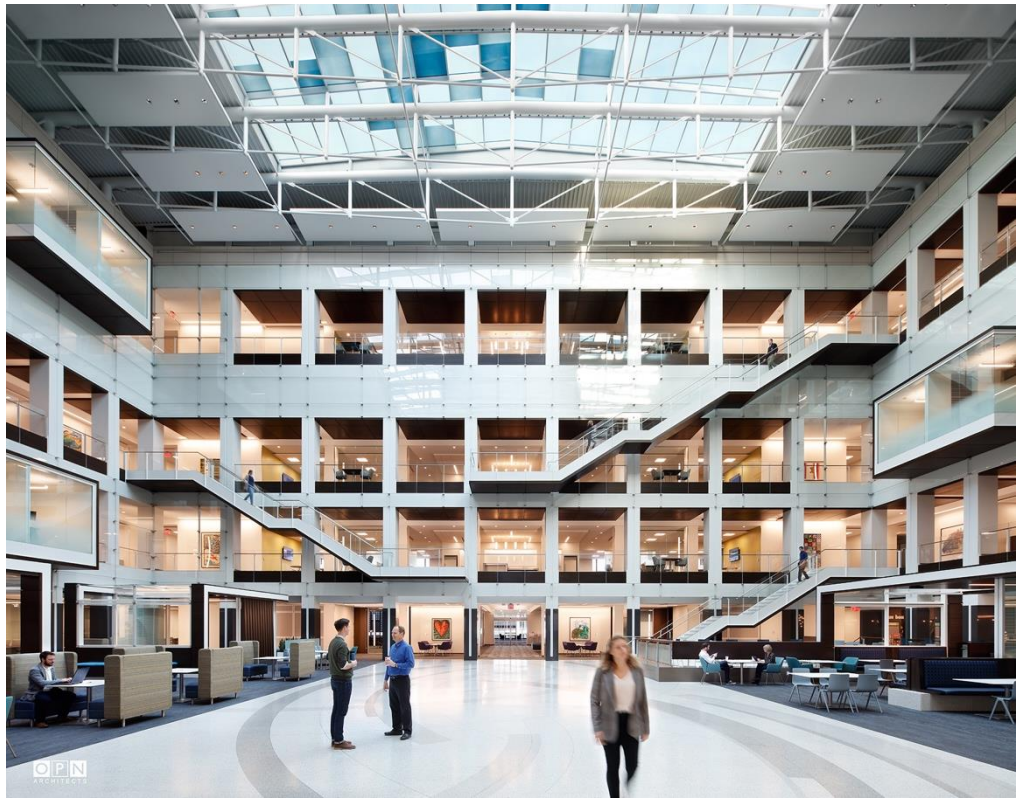


Brickell City Centre

Using sun-screening blades or structural elements as shading

Direct Sun Study

What can we do? – Dynamic Strategies



Principal 711 High Street

Electrochromic Glass

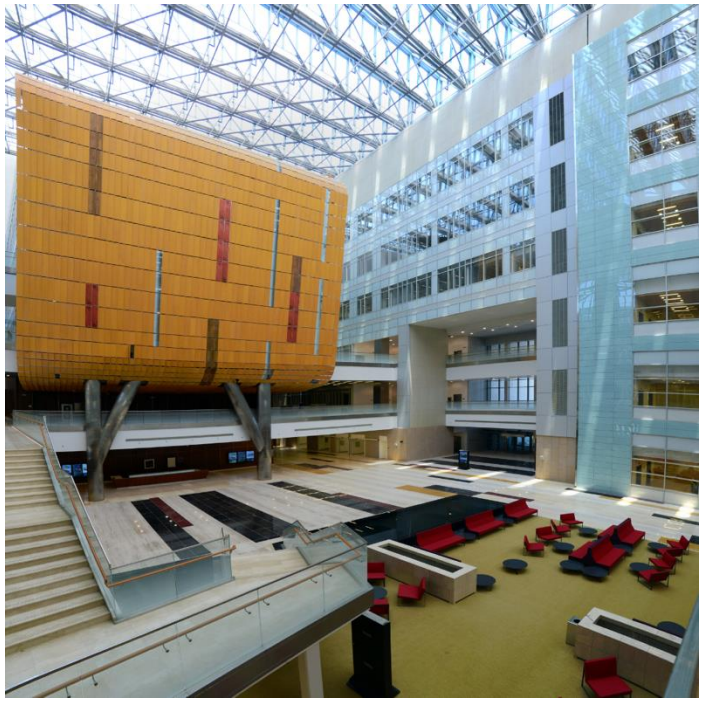
Gardens by the Bay

Dynamic shading

Direct Sun Study

What can we do? – Other Materials

Aerogel



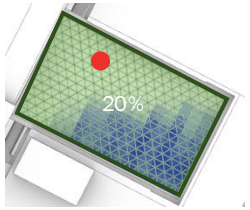
Solera

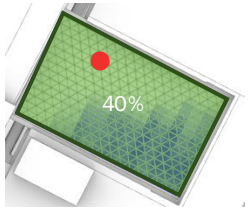
OKALUX

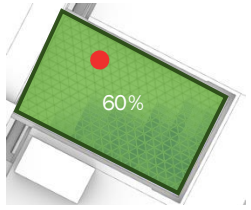
Direct Sun Study

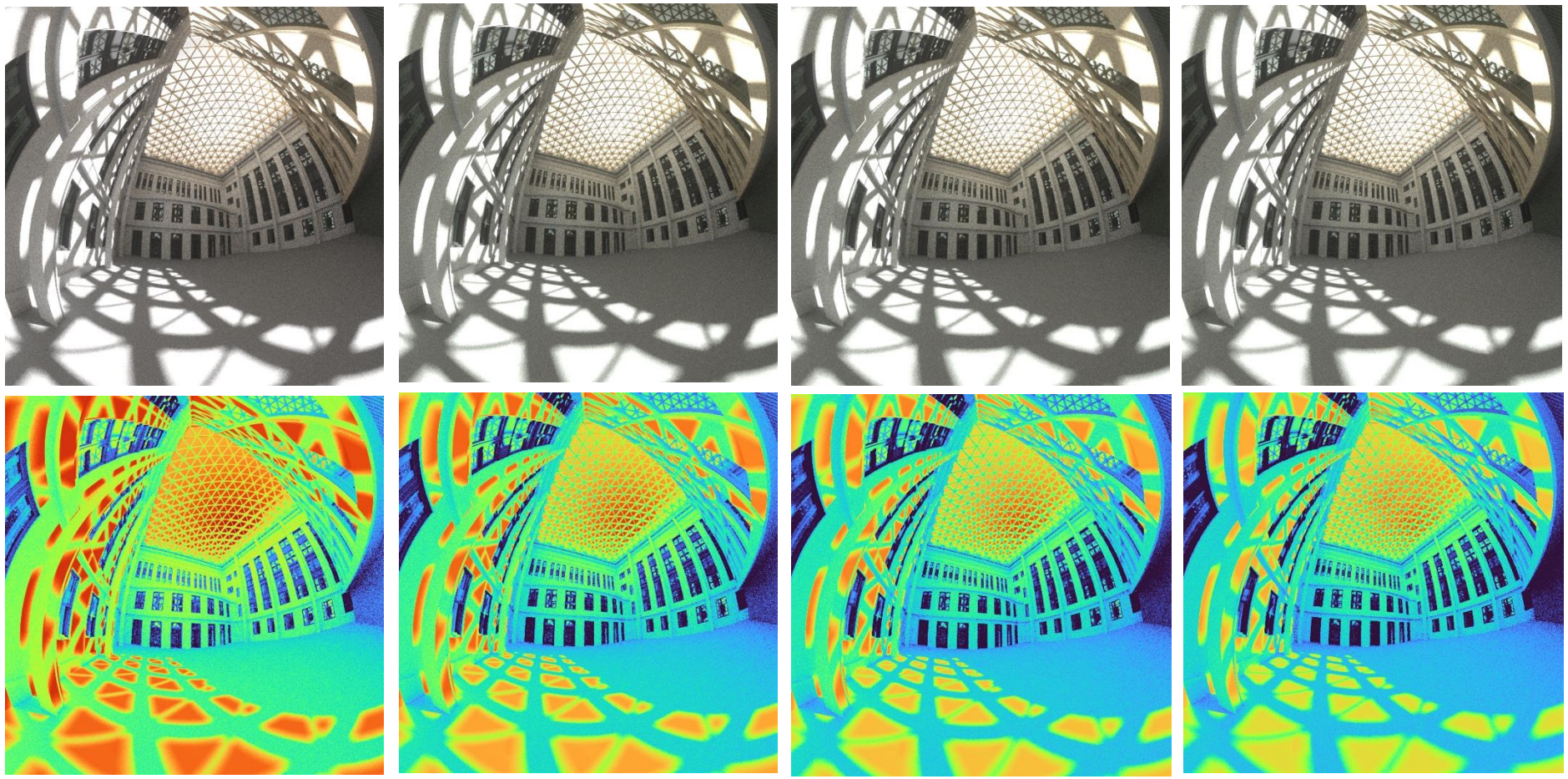
Frit – Mar 21st, 11:30 AM

● = VIEW POINT









Baseline – No Frit

All 20% Frit

All 40% Frit

All 60% Frit

- Although uniform frit reduces the intensity of the bright spots in the field of view, it also reduces the overall brightness of the space.
- Goal is to create a balanced daylit scene, allowing light to enter where desired.

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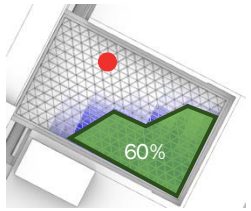
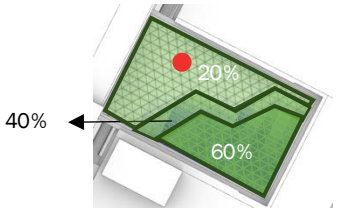
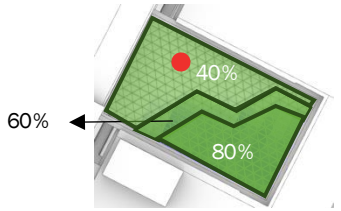
Direct Sun Study

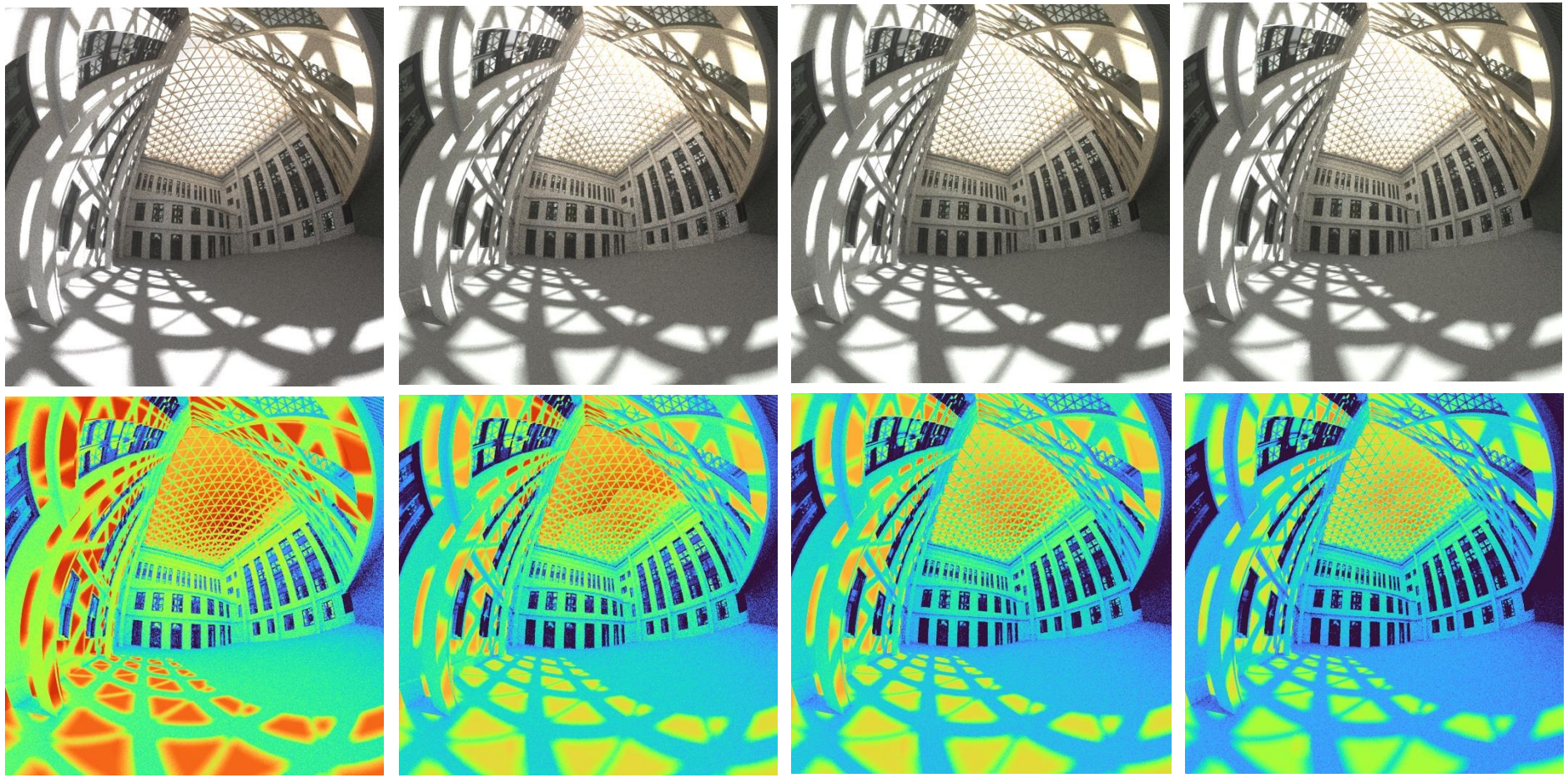
Frit – Mar 21st, 11:30 AM

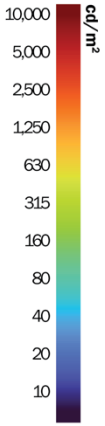
● = VIEW POINT











- Using a gradient frit allows for intentional daylight control, blocking areas of concern and allowing more light elsewhere.

Baseline – No Frit | Partial 60% Frit | Gradient 60-20% Frit | Gradient 80-40% Frit

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Case Study 2: Museum Auditorium

Introduction

Design Problem

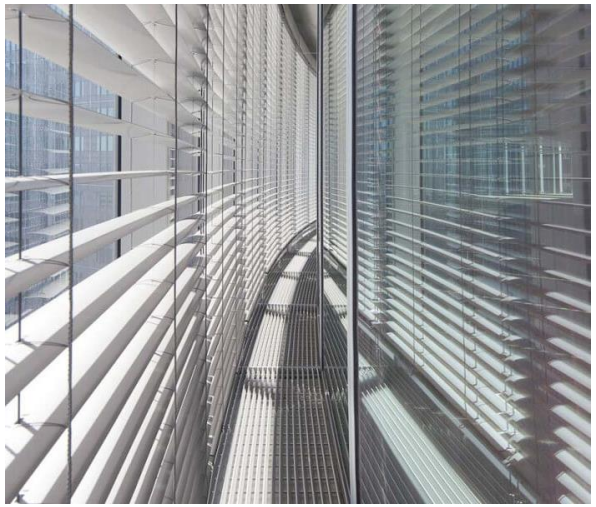
Maintaining open views out of the auditorium whilst providing shading for screen and projector visibility.

Analysis Overview

1. Assess shading options for fully glazed double-skin façade
2. Assess visibility of the screen and projector during times with high daylight exposure

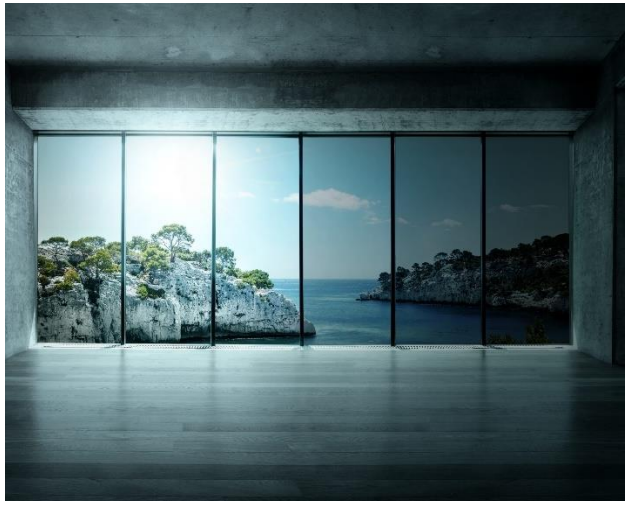
Shading Option Analysis

Fixed Blinds
6’ louvers with 3.6” spacing

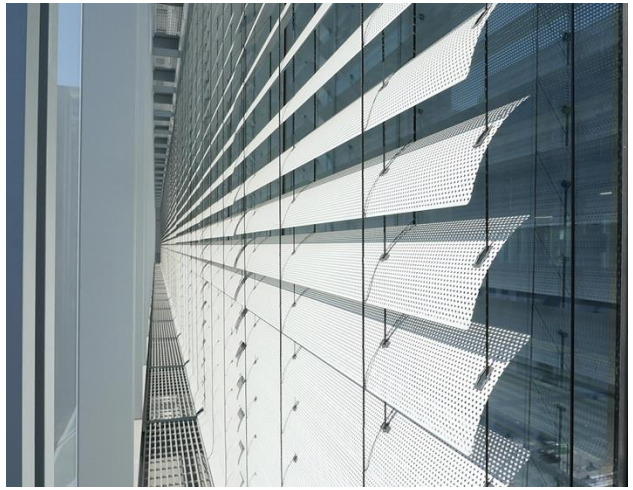


Fabric Shades
3% Medium Gray

Electrochromic Glass
Tvis= 52%/31%/6%/1%



Dynamic Rotating Venetian Blinds
6’ louvers with 4.8” spacing
Can be deployed in 6 positions



Annual Solar Profile Angles

Southwest Facade

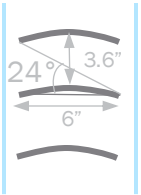
Occupied hours- 9am -5pm

0	PROFILE ANGLE / SECTION SOLAR ENCROACHMENT ANGLE											
	WINTER		SPRING/SUMMER							WINTER/FALL		
Standard Time	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
7:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	74	0	0	0	0	0	0	0	0	0	74	44
8:30 AM	56	85	0	0	0	0	0	0	0	85	56	41
9:00 AM	49	71	88	0	0	0	0	0	88	71	49	39
9:30 AM	45	63	79	0	0	0	0	0	79	63	45	37
10:00 AM	42	57	71	83	0	0	0	83	71	57	42	36
10:30 AM	39	52	65	77	85	87	85	77	65	52	39	34
11:00 AM	37	48	60	72	79	82	79	72	60	48	37	32
11:30 AM	34	45	56	67	75	78	75	67	56	45	34	30
12:00 PM	32	42	53	64	71	74	71	64	53	42	32	28
12:30 PM	30	39	49	60	68	71	68	60	49	39	30	26
1:00 PM	27	36	46	57	64	67	64	57	46	36	27	24
1:30 PM	25	33	43	54	61	65	61	54	43	33	25	21
2:00 PM	22	30	40	51	59	62	59	51	40	30	22	19
2:30 PM	19	27	37	48	56	60	56	48	37	27	19	16
3:00 PM	15	24	34	45	54	58	54	45	34	24	15	12
3:30 PM	12	20	30	42	52	56	52	42	30	20	12	9
4:00 PM	7	15	26	39	49	54	49	39	26	15	7	4
4:30 PM	2	10	21	35	47	52	47	35	21	10	2	0
5:00 PM	0	5	16	31	44	50	44	31	16	5	0	0
5:30 PM	0	0	9	26	41	48	41	26	9	0	0	0
6:00 PM	0	0	0	18	38	47	38	18	0	0	0	0
6:30 PM	0	0	0	7	32	45	32	7	0	0	0	0
7:00 PM	0	0	0	0	19	42	19	0	0	0	0	0

15% occupied hours
require interior supplemental shading

Fixed Blinds
Fabric Shades
Electrochromic Glass
Dynamic Venetian Blinds

24° solar cutoff angle



- Fixed blinds will not be effective in mitigating glare from 2 pm- 4 pm from December through January.
- Supplemental shading will be required for 15% of the year.
- Not recommended.

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Annual Solar Profile Angles & Interior Shade Deployment

Southwest Facade

Occupied hours- 9am -5pm

0	PROFILE ANGLE / SECTION SOLAR ENCROACHMENT ANGLE											
	WINTER		SPRING/SUMMER							WINTER/FALL		
Standard Time	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
7:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	74	0	0	0	0	0	0	0	0	0	74	44
8:30 AM	56	85	0	0	0	0	0	0	0	85	56	41
9:00 AM	49	71	88	0	0	0	0	0	88	71	49	39
9:30 AM	45	63	79	0	0	0	0	0	79	63	45	37
10:00 AM	42	57	71	83	0	0	0	83	71	57	42	36
10:30 AM	39	52	65	77	85	87	85	77	65	52	39	34
11:00 AM	37	48	60	72	79	82	79	72	60	48	37	32
11:30 AM	34	45	56	67	75	78	75	67	56	45	34	30
12:00 PM	32	42	53	64	71	74	71	64	53	42	32	28
12:30 PM	30	39	49	60	68	71	68	60	49	39	30	26
1:00 PM	27	36	46	57	64	67	64	57	46	36	27	24
1:30 PM	25	33	43	54	61	65	61	54	43	33	25	21
2:00 PM	22	30	40	51	59	62	59	51	40	30	22	19
2:30 PM	19	27	37	48	56	60	56	48	37	27	19	16
3:00 PM	15	24	34	45	54	58	54	45	34	24	15	12
3:30 PM	12	20	30	42	52	56	52	42	30	20	12	9
4:00 PM	7	15	26	39	49	54	49	39	26	15	7	4
4:30 PM	2	10	21	35	47	52	47	35	21	10	2	0
5:00 PM	0	5	16	31	44	50	44	31	16	5	0	0
5:30 PM	0	0	9	26	41	48	41	26	9	0	0	0
6:00 PM	0	0	0	18	38	47	38	18	0	0	0	0
6:30 PM	0	0	0	7	32	45	32	7	0	0	0	0
7:00 PM	0	0	0	0	19	42	19	0	0	0	0	0

39% of occupied hours fully closed

28% of occupied hours 75% closed

11% of occupied hours 50% closed

13% of occupied hours 25% closed

9% of occupied hours fully retracted

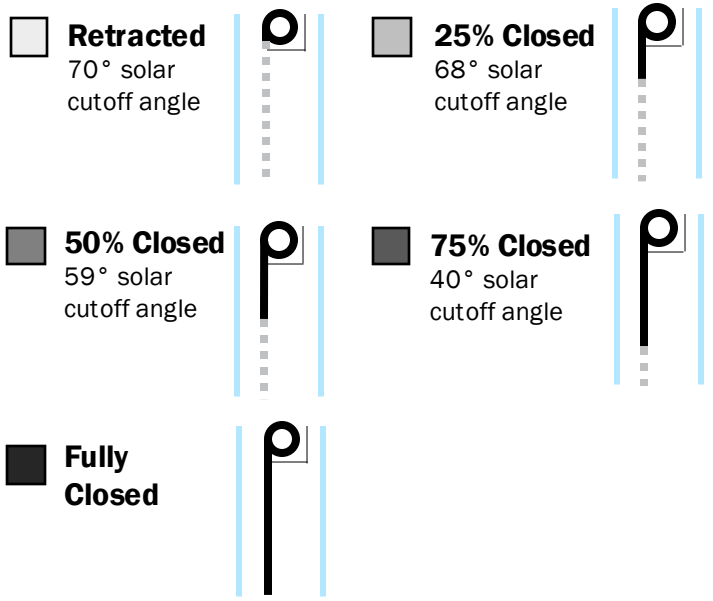
Fixed Blinds

Fabric Shades

Electrochromic Glass

Dynamic Venetian Blinds

Fabric Shade Positions



- Limited views access from 12 pm to 5 pm from March through Sept. & 10 am to 4 pm from Oct. to Feb.
- Not recommended.

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Annual Solar Profile Angles & Dynamic Glass Tint States

Southwest Facade

Occupied hours- 9am -5pm

0	PROFILE ANGLE / SECTION SOLAR ENCROACHMENT ANGLE											
	WINTER		SPRING/SUMMER							WINTER/FALL		
Standard Time	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
7:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	74	0	0	0	0	0	0	0	0	0	74	44
8:30 AM	56	85	0	0	0	0	0	0	0	85	56	41
9:00 AM	49	71	88	0	0	0	0	0	88	71	49	39
9:30 AM	45	63	79	0	0	0	0	0	79	63	45	37
10:00 AM	42	57	71	83	0	0	0	83	71	57	42	36
10:30 AM	39	52	65	77	85	87	85	77	65	52	39	34
11:00 AM	37	48	60	72	79	82	79	72	60	48	37	32
11:30 AM	34	45	56	67	75	78	75	67	56	45	34	30
12:00 PM	32	42	53	64	71	74	71	64	53	42	32	28
12:30 PM	30	39	49	60	68	71	68	60	49	39	30	26
1:00 PM	27	36	46	57	64	67	64	57	46	36	27	24
1:30 PM	25	33	43	54	61	65	61	54	43	33	25	21
2:00 PM	22	30	40	51	59	62	59	51	40	30	22	19
2:30 PM	19	27	37	48	56	60	56	48	37	27	19	16
3:00 PM	15	24	34	45	54	58	54	45	34	24	15	12
3:30 PM	12	20	30	42	52	56	52	42	30	20	12	9
4:00 PM	7	15	26	39	49	54	49	39	26	15	7	4
4:30 PM	2	10	21	35	47	52	47	35	21	10	2	0
5:00 PM	0	5	16	31	44	50	44	31	16	5	0	0
5:30 PM	0	0	9	26	41	48	41	26	9	0	0	0
6:00 PM	0	0	0	18	38	47	38	18	0	0	0	0
6:30 PM	0	0	0	7	32	45	32	7	0	0	0	0
7:00 PM	0	0	0	0	19	42	19	0	0	0	0	0

78% of occupied hours Tint 4

13% of occupied hours Tint 2

8% of occupied hours clear glass

Fixed Blinds

Fabric Shades

Electrochromic Glass

Dynamic Venetian Blinds

Electrochromic Glass Tint States

Tint 1 (Clear Glass)
Tvis=52%, SHGC=0.4

Tint 2
Tvis=31%. SHGC=0.25

Tint 4
Tvis=1%, SHGC=0.09

* Tint 3 (Tvis= 6%, SHGC=0.12) will not be sufficient for glare control.

- Occupants will have obstructed or no views for over 90% of the year when the glass is fully or partially tinted.
- Not recommended

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Annual Solar Profile Angles & Blind Deployment Positions

Southwest Facade

Occupied hours- 9am -5pm

0	PROFILE ANGLE / SECTION SOLAR ENCROACHMENT ANGLE											
	WINTER		SPRING/ SUMMER							WINTER/ FALL		
Standard Time	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7:00 AM	0	0	0	0	0	0	0	0	0	0	0	0
7:30 AM	0	0	0	0	0	0	0	0	0	0	0	0
8:00 AM	74	0	0	0	0	0	0	0	0	0	74	44
8:30 AM	56	85	0	0	0	0	0	0	0	85	56	41
9:00 AM	49	71	88	0	0	0	0	0	88	71	49	39
9:30 AM	45	63	79	0	0	0	0	0	79	63	45	37
10:00 AM	42	57	71	83	0	0	0	83	71	57	42	36
10:30 AM	39	52	65	77	85	87	85	77	65	52	39	34
11:00 AM	37	48	60	72	79	82	79	72	60	48	37	32
11:30 AM	34	45	56	67	75	78	75	67	56	45	34	30
12:00 PM	32	42	53	64	71	74	71	64	53	42	32	28
12:30 PM	30	39	49	60	68	71	68	60	49	39	30	26
1:00 PM	27	36	46	57	64	67	64	57	46	36	27	24
1:30 PM	25	33	43	54	61	65	61	54	43	33	25	21
2:00 PM	22	30	40	51	59	62	59	51	40	30	22	19
2:30 PM	19	27	37	48	56	60	56	48	37	27	19	16
3:00 PM	15	24	34	45	54	58	54	45	34	24	15	12
3:30 PM	12	20	30	42	52	56	52	42	30	20	12	9
4:00 PM	7	15	26	39	49	54	49	39	26	15	7	4
4:30 PM	2	10	21	35	47	52	47	35	21	10	2	0
5:00 PM	0	5	16	31	44	50	44	31	16	5	0	0
5:30 PM	0	0	9	26	41	48	41	26	9	0	0	0
6:00 PM	0	0	0	18	38	47	38	18	0	0	0	0
6:30 PM	0	0	0	7	32	45	32	7	0	0	0	0
7:00 PM	0	0	0	0	19	42	19	0	0	0	0	0

Fixed Blinds

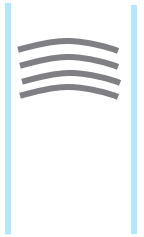
Fabric Shades

Electrochromic Glass

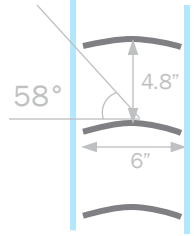
Dynamic Venetian Blinds ✓

6 Blinds Positions

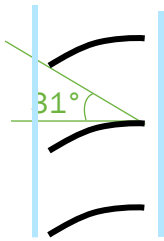
Fully Retracted
No solar cutoff angle



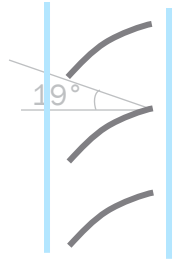
Flat Horizontal
58° cutoff angle



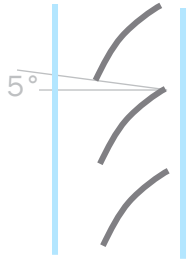
19° Tilt
31° cutoff angle



37°Tilt
19° cutoff angle



56° Tilt
5° cutoff angle



Fully Closed
Total solar cutoff

- Flat horizontal or 19°tilted dynamic blinds can mitigate glare for 67% of the year while preserving views.
- Recommended

1% of occupied hours fully closed

8% of occupied hours 56° Tilt

17% of occupied hours 37° Tilt

41% of occupied hours 19° Tilt

24% of occupied hours flat horizontal

8% of occupied hours fully retracted

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Screen Brightness Analysis

June 21, 9 am clear sky- with Dynamic Blinds (6” louvers with 4.8” spacing)

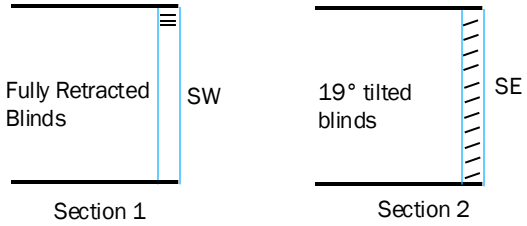
Optimum Daylight

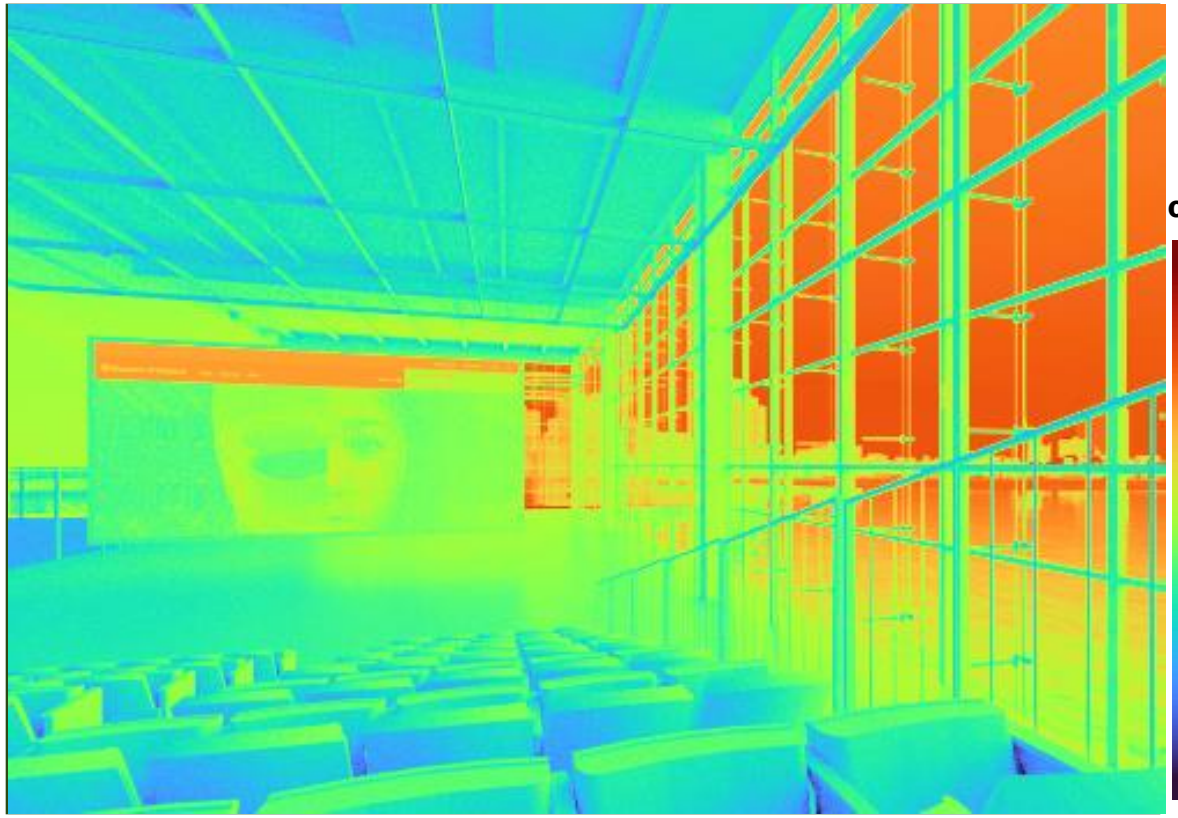
Views

Screen Visibility

Color Rendering

Dynamic blinds **effectively control daylight without any color distortion, while ensuring screen visibility and access to views.**





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Screen Brightness Analysis

October 21, 12pm clear sky- with Dynamic Blinds (6” louvers with 4.8” spacing)

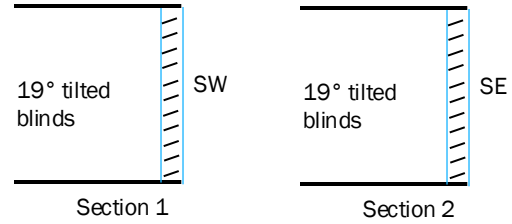
Daylight

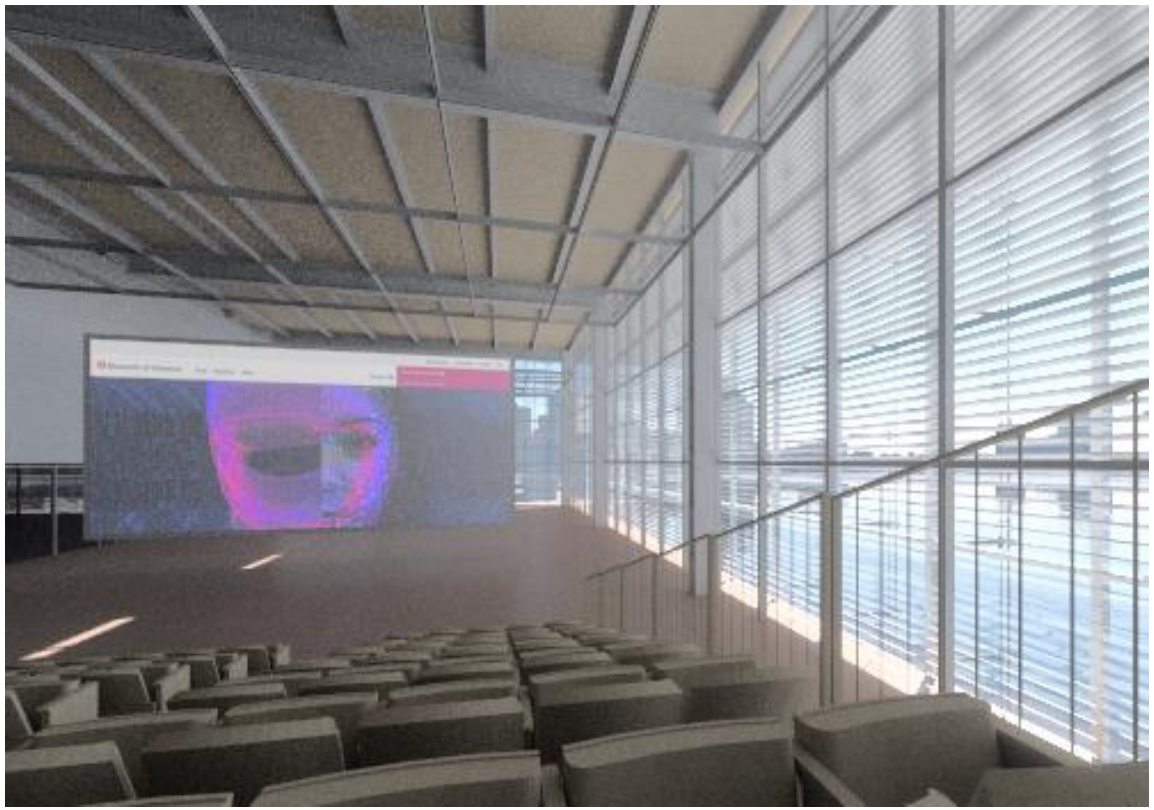
Views

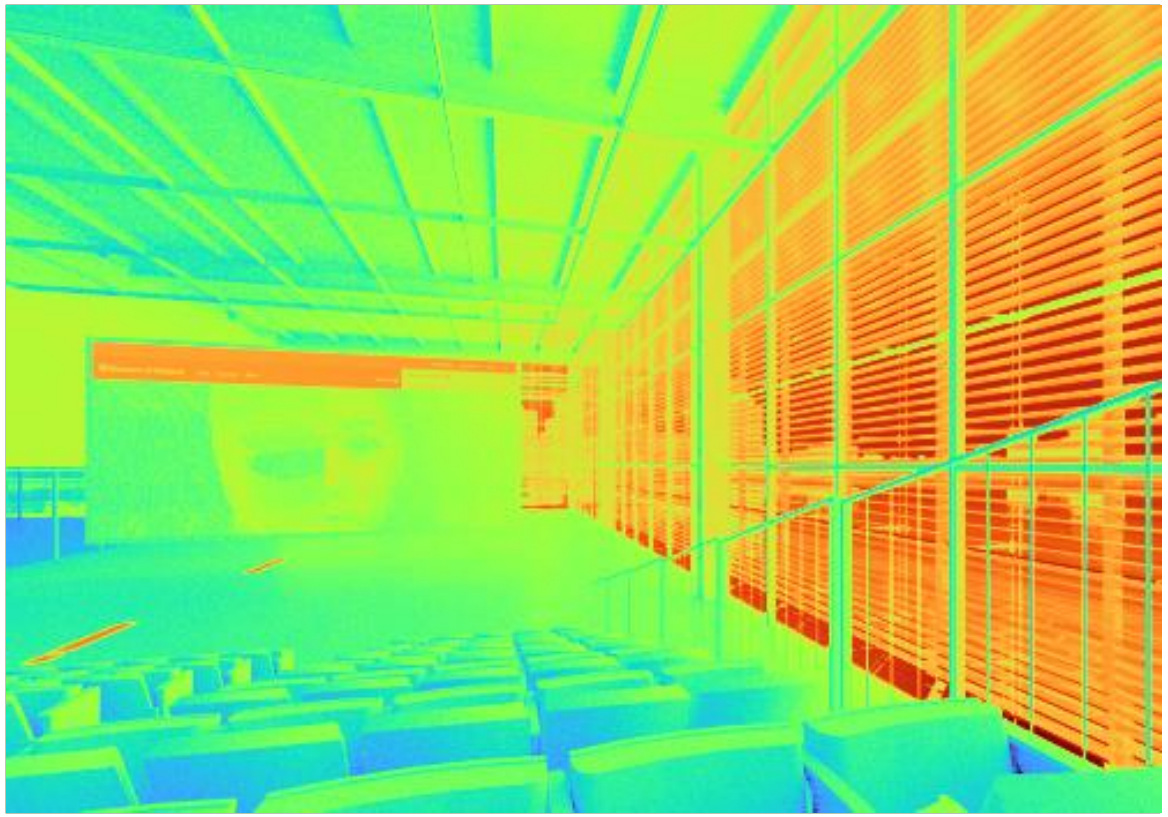
Screen Visibility

Color Rendering

Dynamic blinds **effectively control daylight without any color distortion, while ensuring screen visibility and maintaining some access to views.**







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Screen Brightness Analysis

December 21, 1.30pm clear sky- with Dynamic Blinds

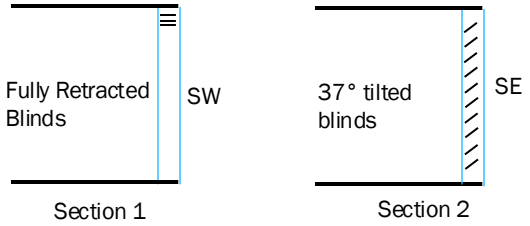
Optimum Daylight

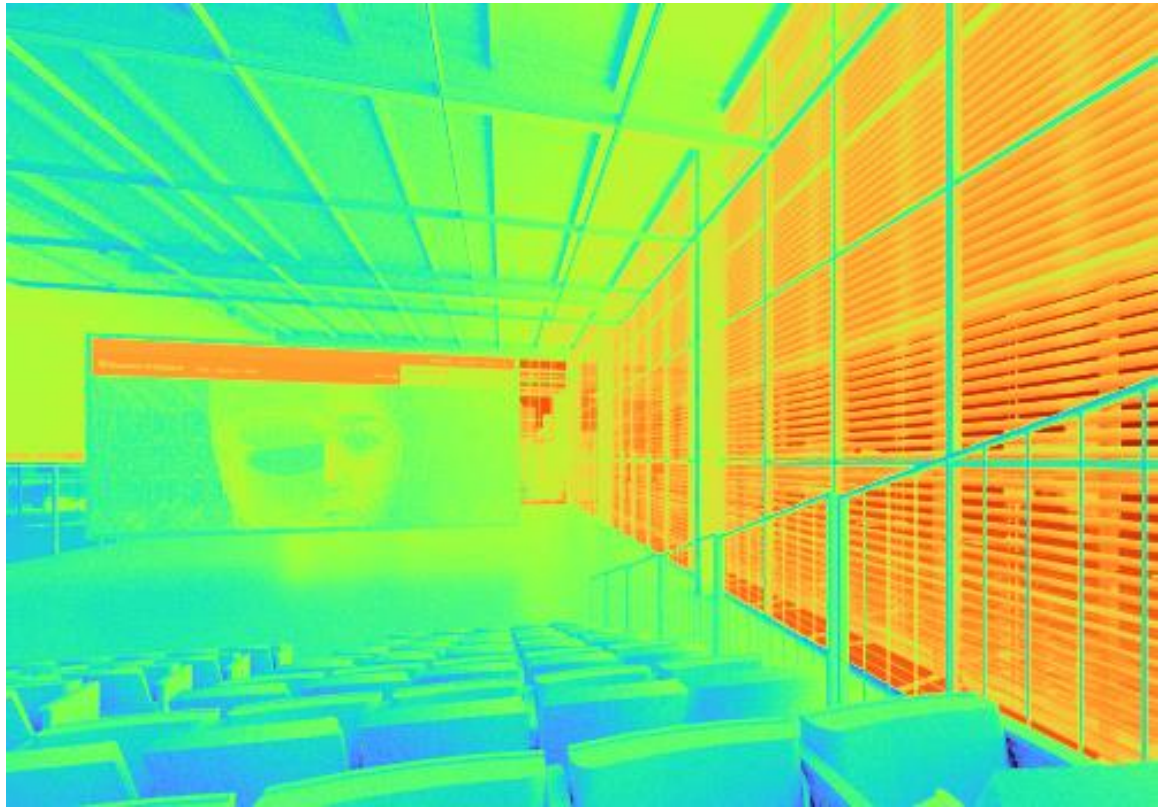
Views

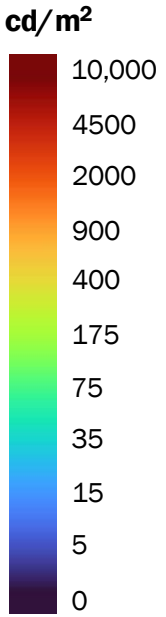
Screen Visibility

Color Rendering

Dynamic blinds **effectively control daylight without any color distortion, while ensuring screen visibility and access to views** and are recommended for the Forum Theater.







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Screen Brightness Analysis

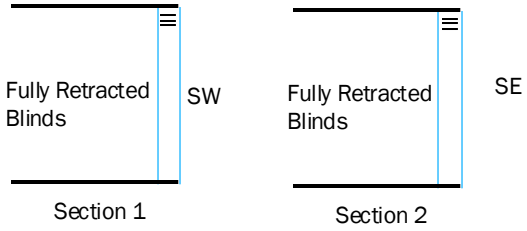
Overcast sky- with Dynamic Blinds (6” louvers with 4.8” spacing)

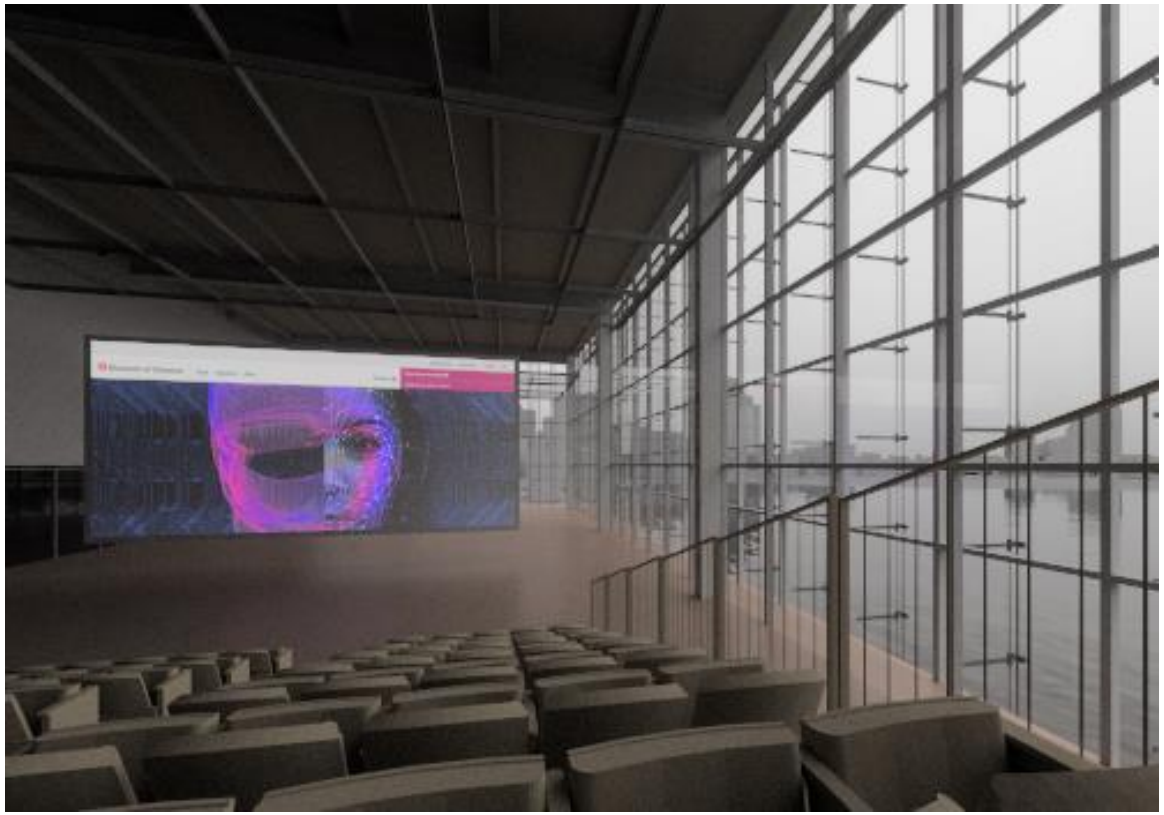
Optimum Daylight

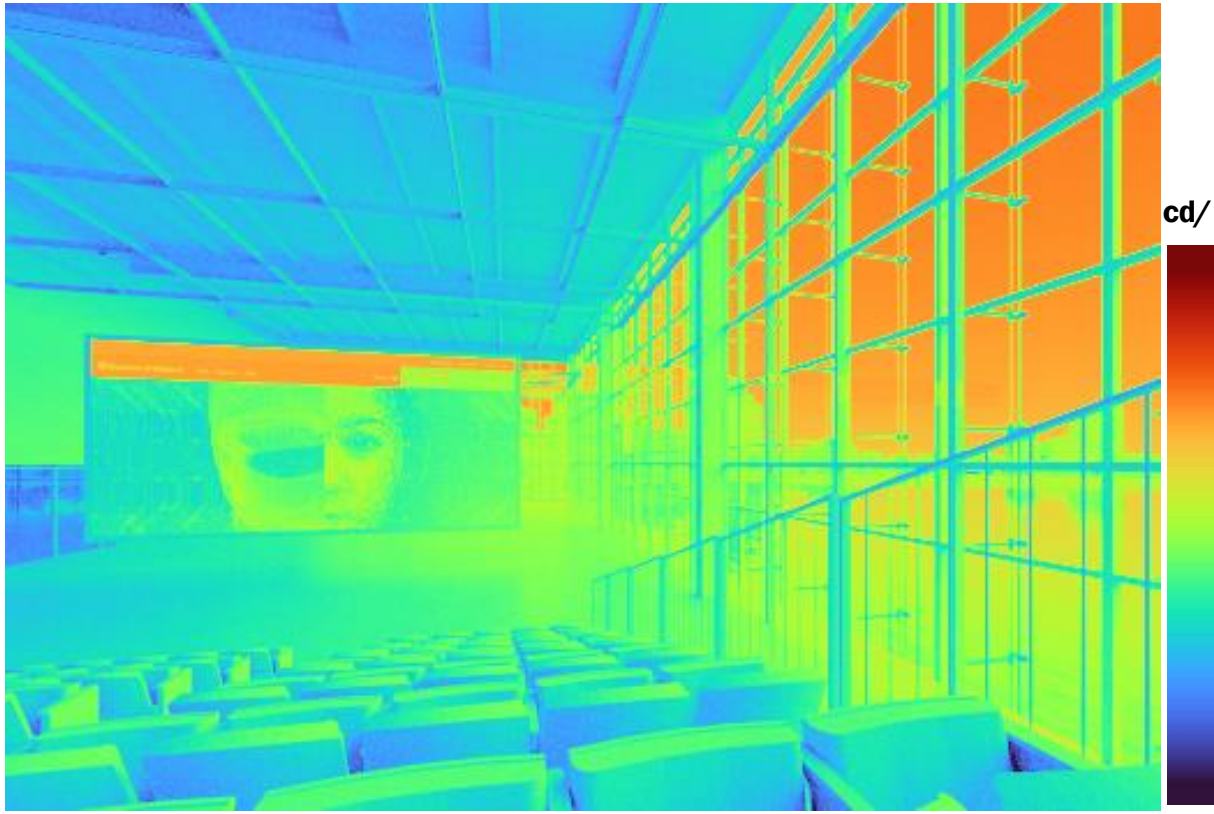
Views

Screen Visibility

Color Rendering







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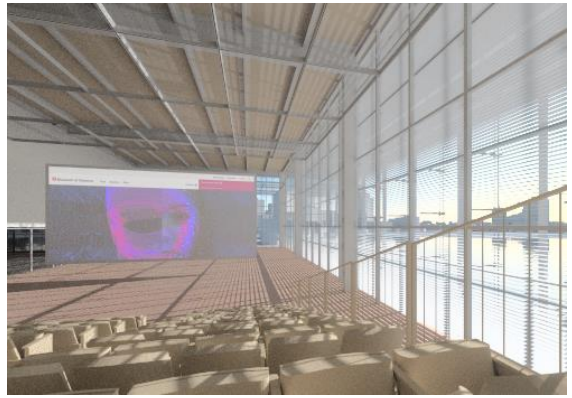
Summary

Dec 21, 1.30pm Clear Sky Conditions

Dynamic blinds effectively control daylight without any color distortion, while ensuring screen visibility and access to views.

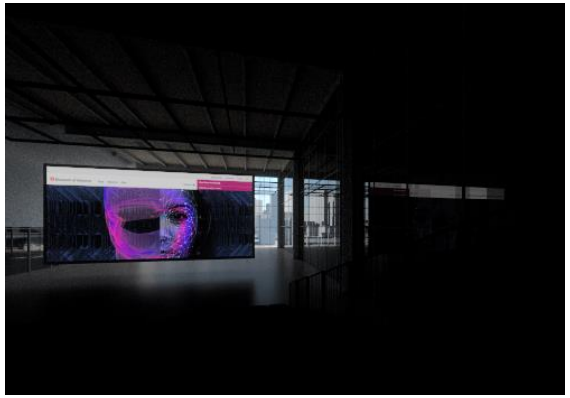
Fixed Blinds

6’ louvers with 3.6” spacing



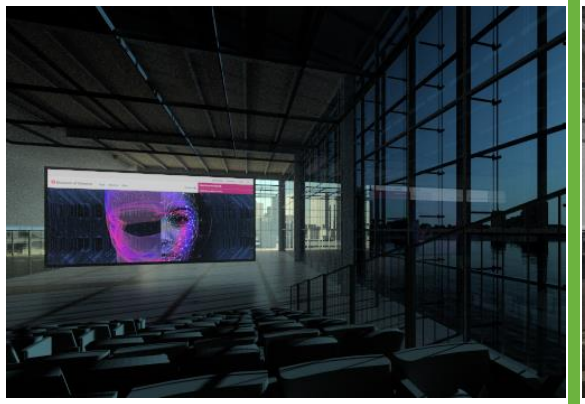
Fabric Shades

3% Medium Gray



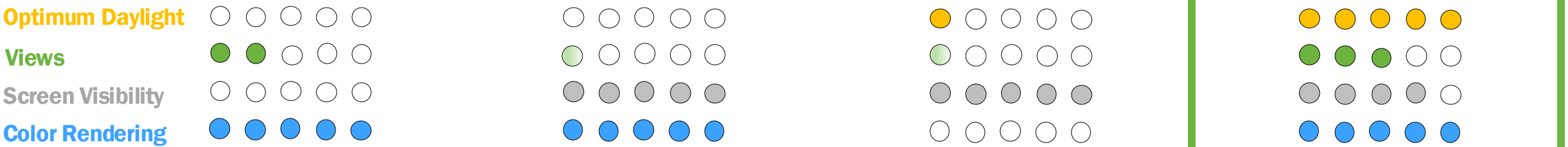
Electrochromic Glass

Tvis= 52%/31%/6%/1%



Dynamic Venetian Blinds

6’ louvers with 4.8” spacing



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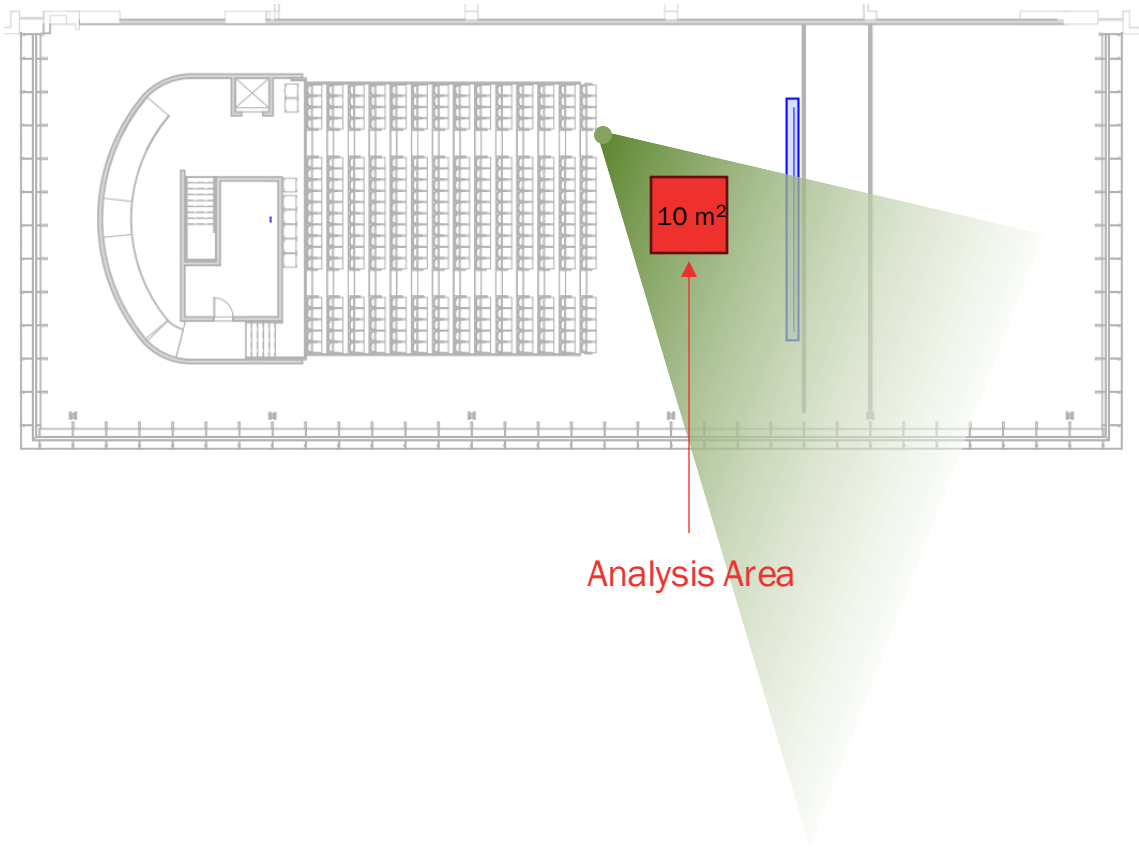
Projector Brightness Analysis

Goal of Analysis

The goal of the study is to help understand **the visibility of projected media onto a Marley mat during the daytime**, as well as to guide the team in selecting a projector with the necessary brightness to alleviate visibility concerns.

Methodology

1. Test a 10 m^2 Marley Mat (Black and Grey) in the analysis area shown. This was chosen to evaluate a realistic location with high ambient light due to its proximity to the façade.
2. Create visualizations during **midday at the open DSF condition**, placing both the glazing and projection in view to evaluate the “worst” visibility risk condition.
    - This is because visibility does not only depend on light levels at the projection surface, but also the contrast of brightness within the field of view.



Projector Brightness Analysis

Visibility Parameter

Effective viewing of projected images on the Marley mat requires high contrast between the display screen and adjacent surfaces, with the brighter surface being the projection. The analysis studies relative luminance of the display mat and its surrounding surfaces under a high level of daylight.

EXAMPLE:
Poor Screen Visibility!
The screen is competing with the brightness from the window.
We want to avoid this scenario.

Projector Brightness Analysis

Projection Assumptions

1. Atelier Ten used Radiance to generate the projector brightness in the Forum Theater.

2. The Projector has a brightness rated at 22,500 lumens.

3. The study assumes a reflectance of 0.35 for the grey Marley mat and 0.05 for the black Marley mat

4. The brightness of the projection was calculated based on the reflectance of the mat, projector lumens, and apex angle of projector based on the assumption below:
   - Height of projector above mat: 20 ft
   - Apex Angle: 75°

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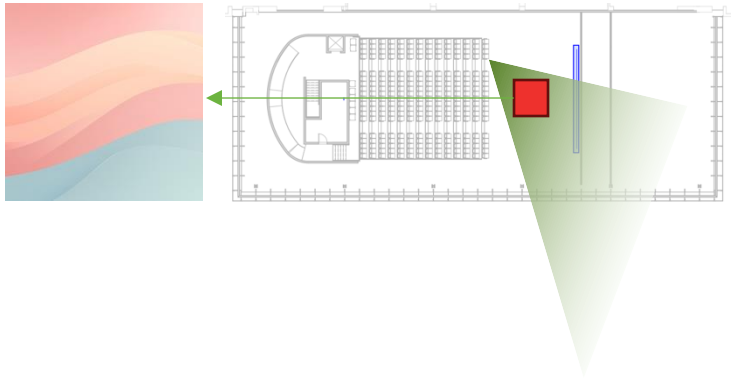
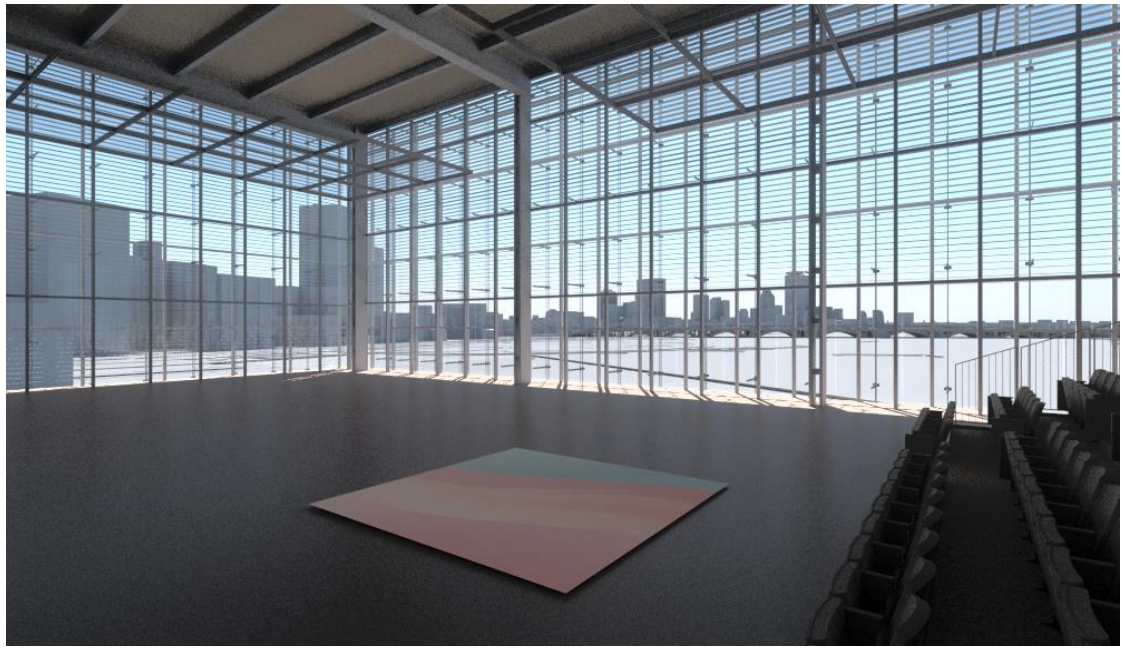
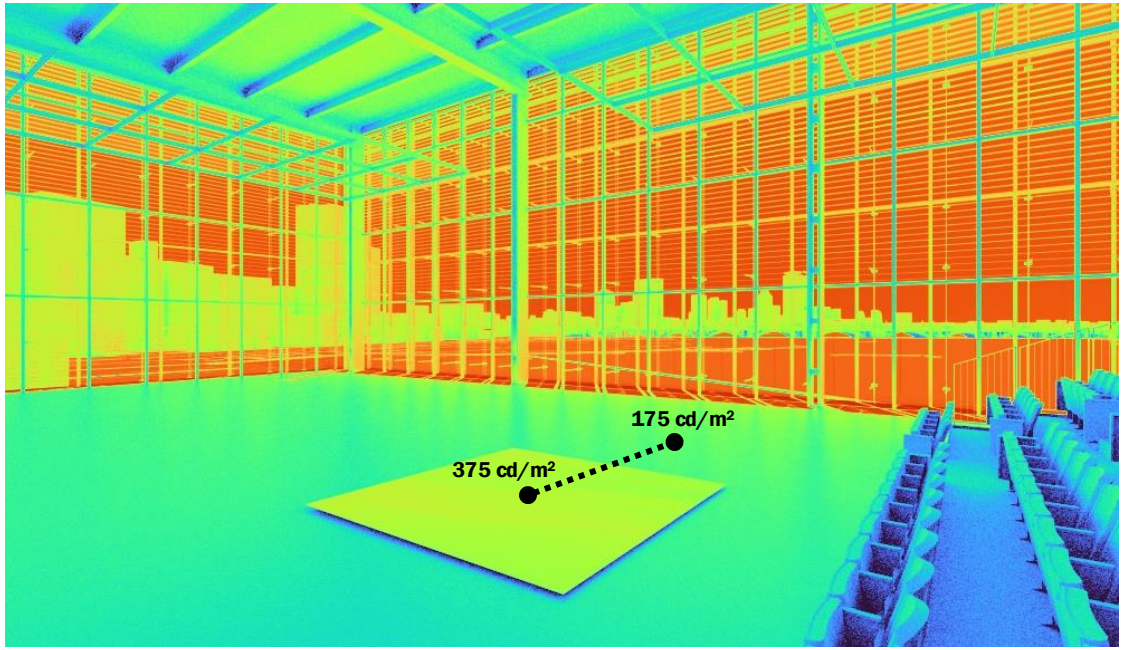
Projector Brightness Analysis

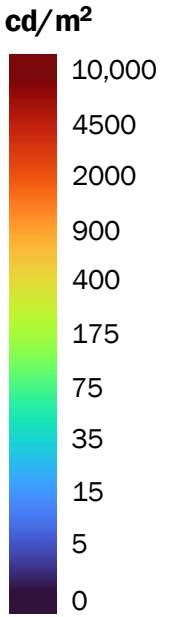
April 21, 12 PM – Grey Marley Mat – 22,500 Lumens Projector



Projection Visibility ● ● ● ○ ○





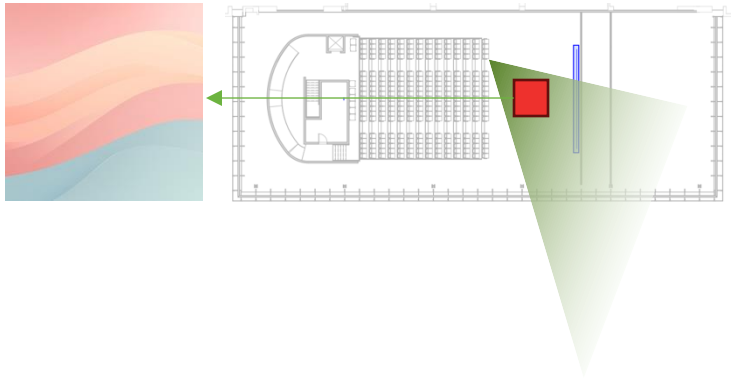


Projection on grey Marley mat has slight compromised visibility during high levels of ambient daylight.

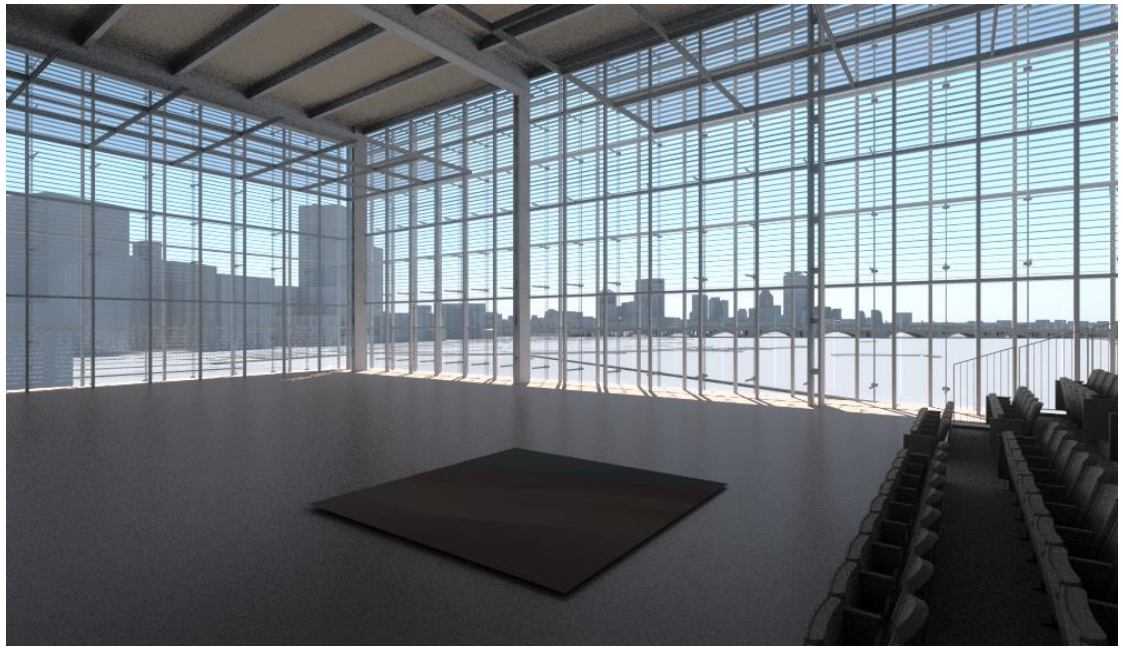
The lack of visibility is mainly due to the lack of contrast in luminance between the projected image and the floor surrounding. The ratio in luminance from image to floor is ~2:1, which is insufficient for optimal visibility.

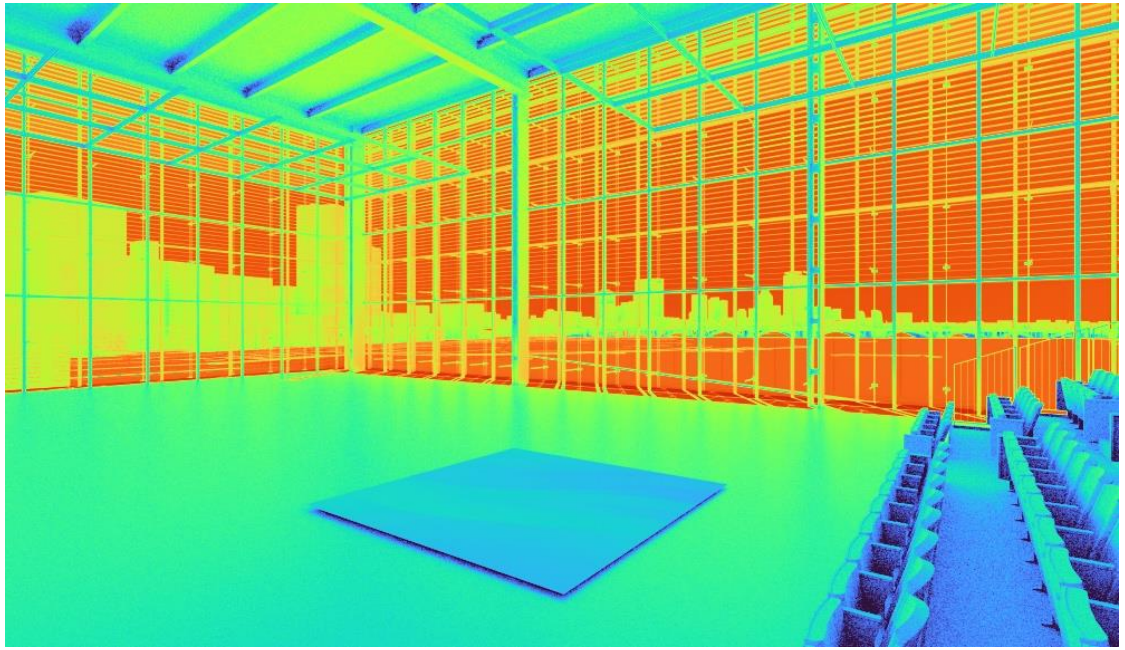
Projector Brightness Analysis

April 21, 12 PM – Black Marley Mat - 22,500 Lumens Projector



Projection Visibility ○ ○ ○ ○ ○





Projection on black Marley mat has total compromised visibility during high levels of ambient daylight.

The lack of visibility is mainly due to low reflectance of the black Marley mat. The higher the reflectance, the higher the brightness of the projected image.

Summary

Factors Influencing Projection Visibility:

1. Reflectance of Marley Mat
    - The higher the reflectance of the mat, the greater the brightness of the projected image

2. Projector Brightness
    - Higher Lumen projectors (40,000 Lumens indicated to the right vs. 22,500 Lumens previously shown) will increase the visibility of the projected image by increasing the brightness of the image and the contrast with the surrounding floor

3. Ambient Light Level at Floor
    - The lower the ambient light level at the floor, the higher the contrast between the projected image and the floor, improving visibility

4. Location of the Marley Mat
    - The study evaluated the “worst” case condition for Marley mat placement in center stage. Positioning the mats further away from the facades will help improve visibility due to lower ambient light levels

Summary

Factors Influencing Projection Visibility:

1. Reflectance of Marley Mat
   - The higher the reflectance of the mat, the greater the brightness of the projected image

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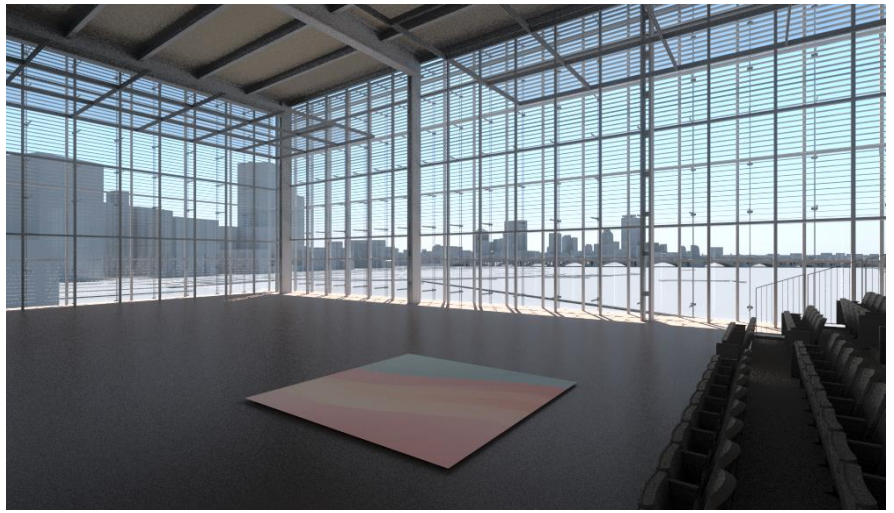
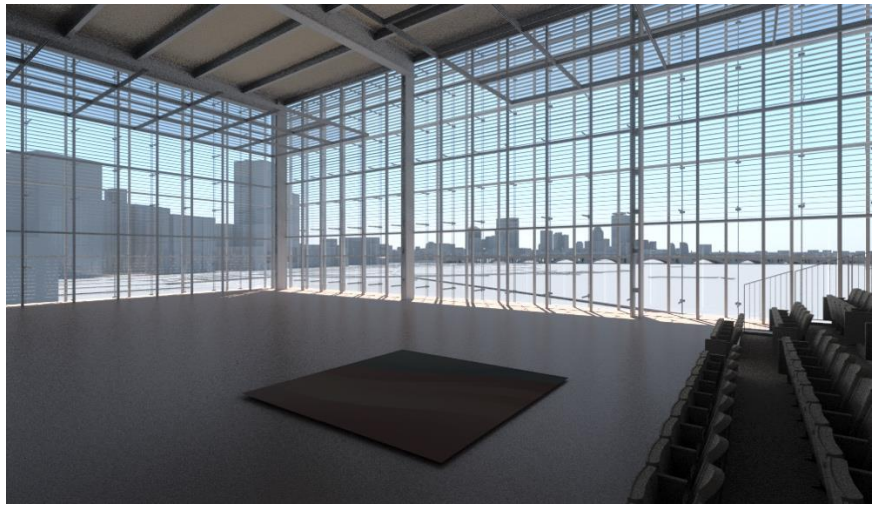
Grey Mat – 0.35 Reflectance



Black Mat – 0.05 Reflectance



Summary

Factors Influencing Projection Visibility:

1. Reflectance of Marley Mat
   - The higher the reflectance of the mat, the greater the brightness of the projected image

2. Projector Brightness
   - Higher Lumen projectors (40,000 Lumens indicated to the right vs. 22,500 Lumens previously shown) will increase the visibility of the projected image by increasing the brightness of the image and the contrast with the surrounding floor

3. Ambient Light Level at Floor
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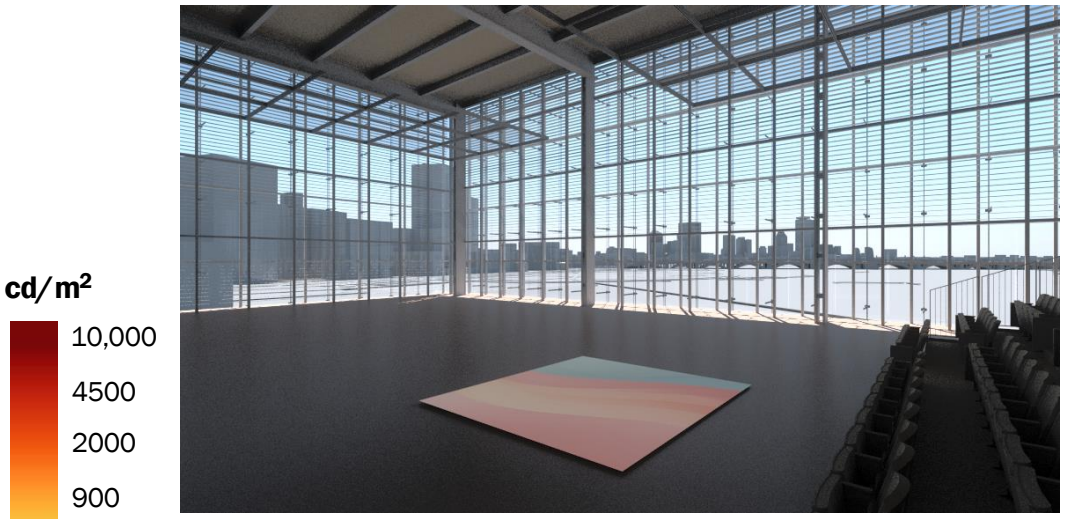
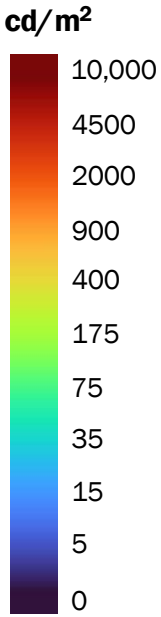
4. Location of the Marley Mat
   - The study evaluated the “worst” case condition for Marley mat placement in center stage. Positioning the mats further away from the facades will help improve visibility due to lower ambient light levels

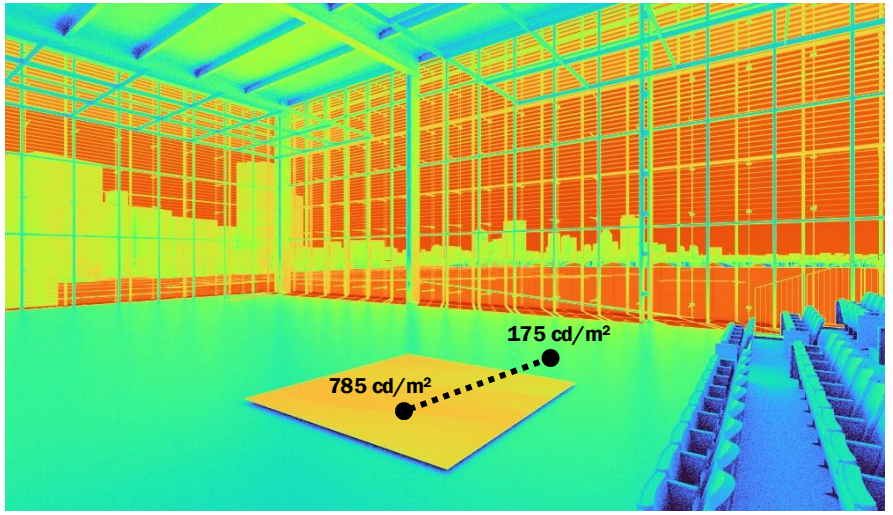
Alternate Projector - 40,000 Lumens

Grey Mat – 0.35 Reflectance





Luminance Ratio – 4.5 : 1



Summary

Factors Influencing Projection Visibility:

1. Reflectance of Marley Mat
   - The higher the reflectance of the mat, the greater the brightness of the projected image

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   - Higher Lumen projectors (40,000 Lumens indicated to the right vs. 22,500 Lumens previously shown) will increase the visibility of the projected image by increasing the brightness of the image and the contrast with the surrounding floor

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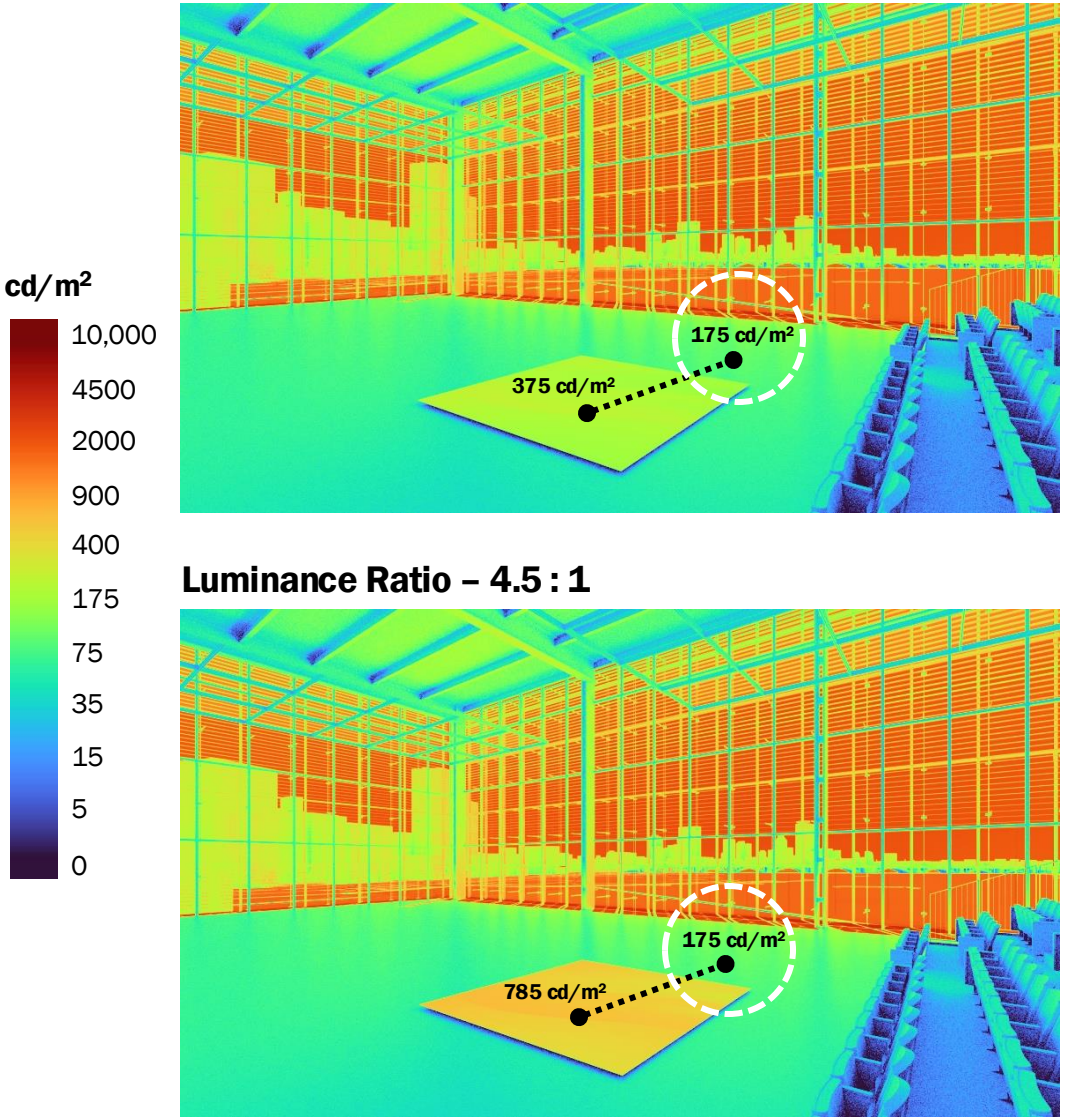
4. Location of the Marley Mat
   - The study evaluated the “worst” case condition for Marley mat placement in center stage. Positioning the mats further away from the facades will help improve visibility due to lower ambient light levels

Luminance Ratio – 2 : 1



Luminance Ratio – 4.5 : 1

Summary

Factors Influencing Projection Visibility:

1. Reflectance of Marley Mat
   - The higher the reflectance of the mat, the greater the brightness of the projected image

2. Projector Brightness
   - Higher Lumen projectors (40,000 Lumens indicated to the right vs. 22,500 Lumens previously shown) will increase the visibility of the projected image by increasing the brightness of the image and the contrast with the surrounding floor

3. Ambient Light Level at Floor
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4. Location of the Marley Mat
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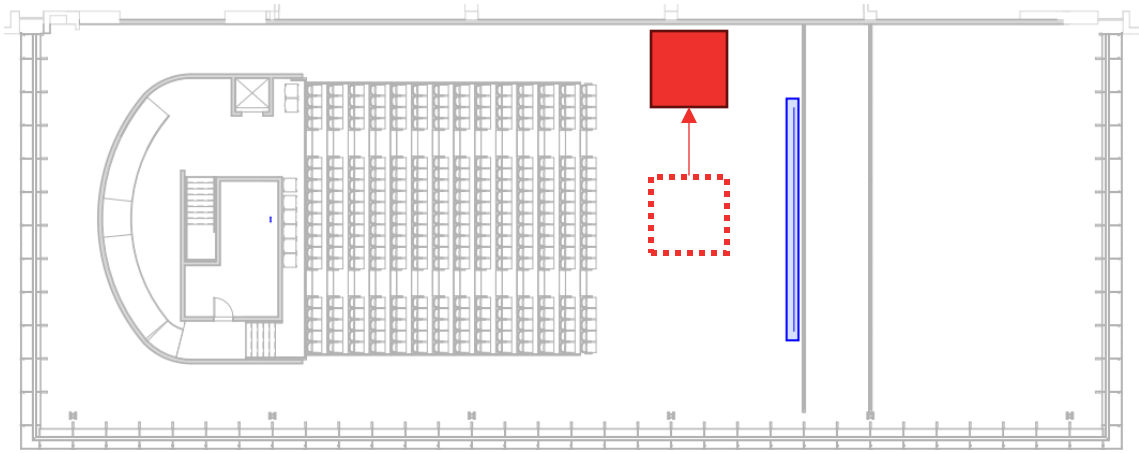


Case Study 3: Theater

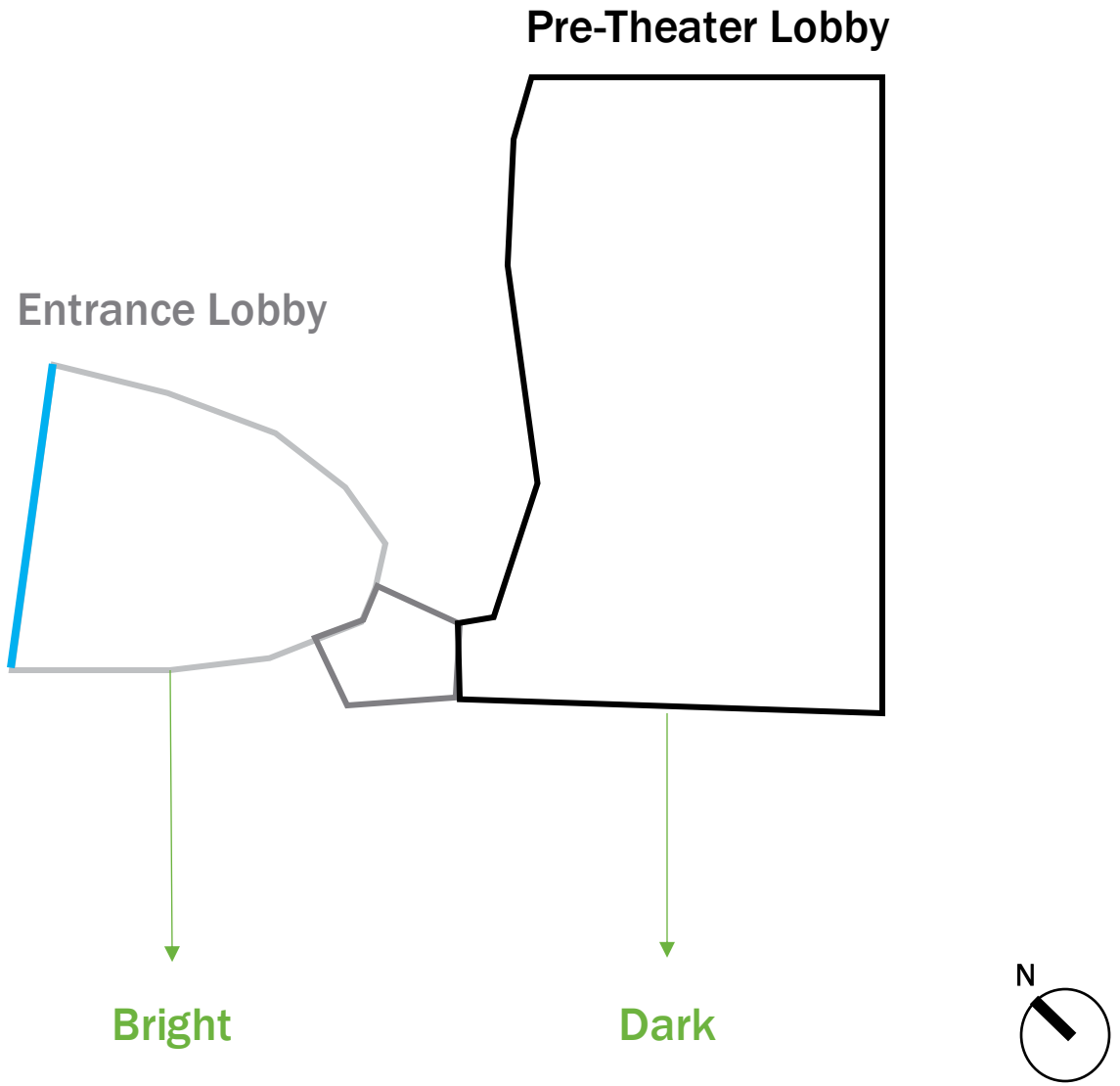
Introduction

Design Problem

Potential visual strain when transitioning from a bright lobby to a dark theater space (and vice versa).

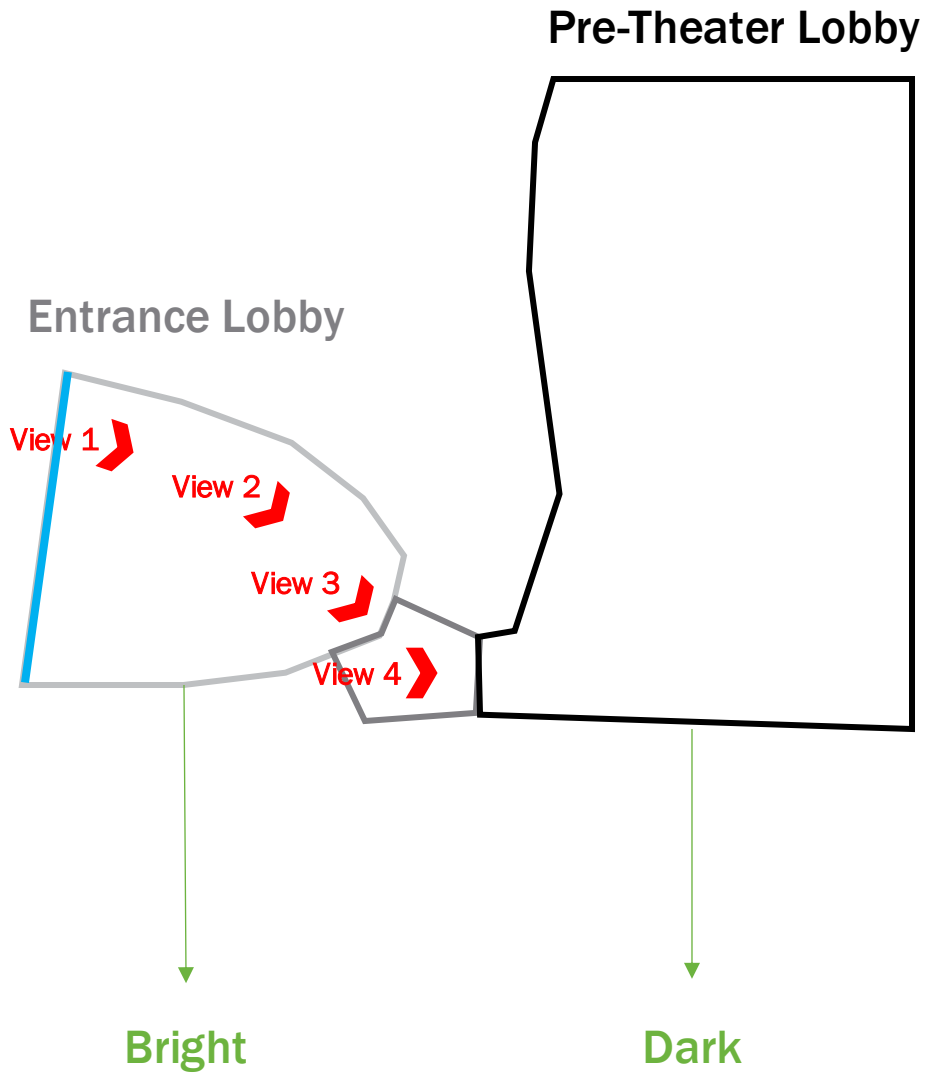
Analysis Overview

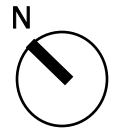
Assess visual discomfort as an occupant's eye adapts to the change in daylight level when walking between the main exterior entrance and the pre-theater lobby vestibule space.



Entrance to Pre-Theater Lobby Transition

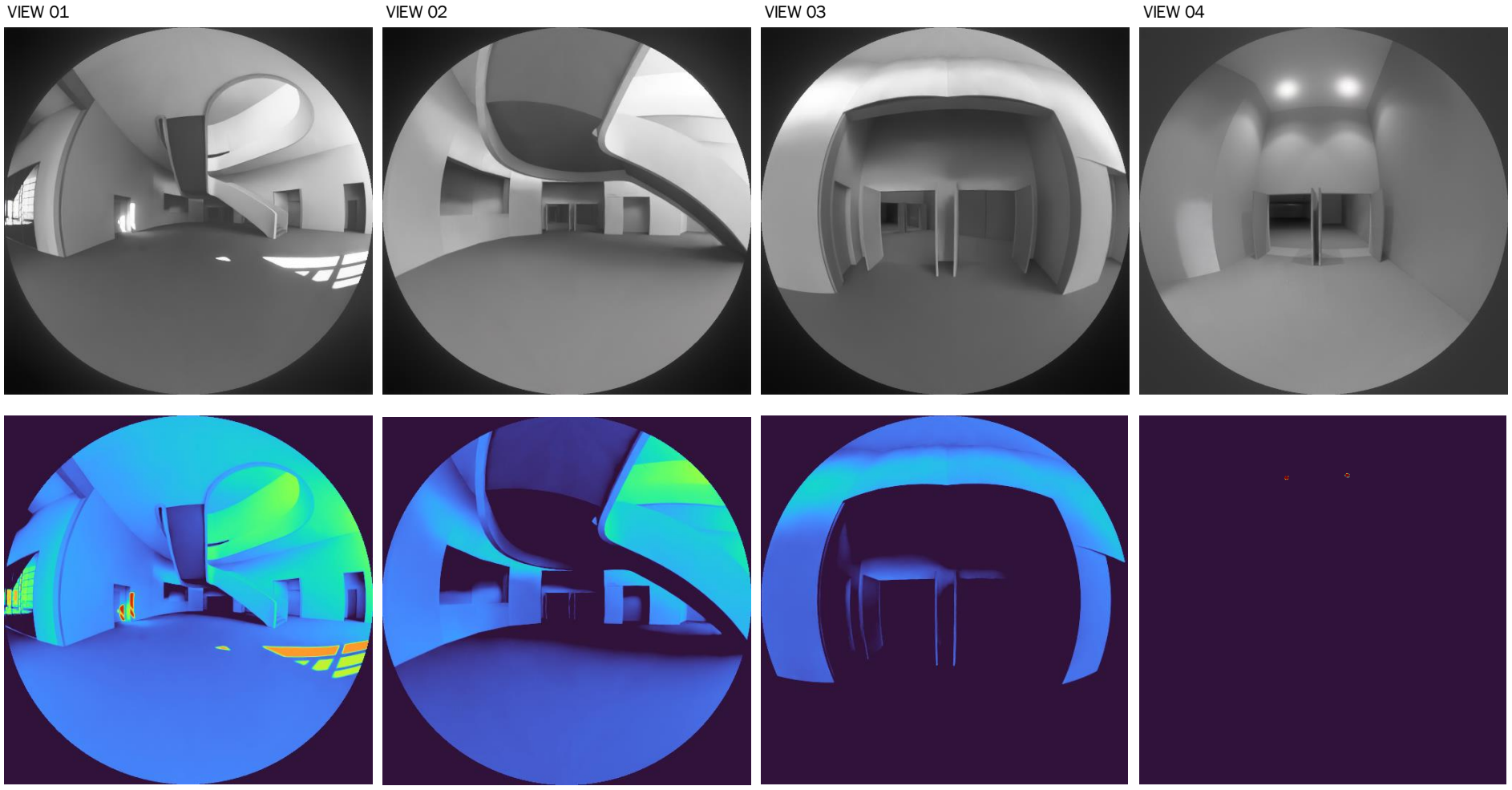
Adjusting from Bright to Dark





Bright to Dark Visual Adaptation – No Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky



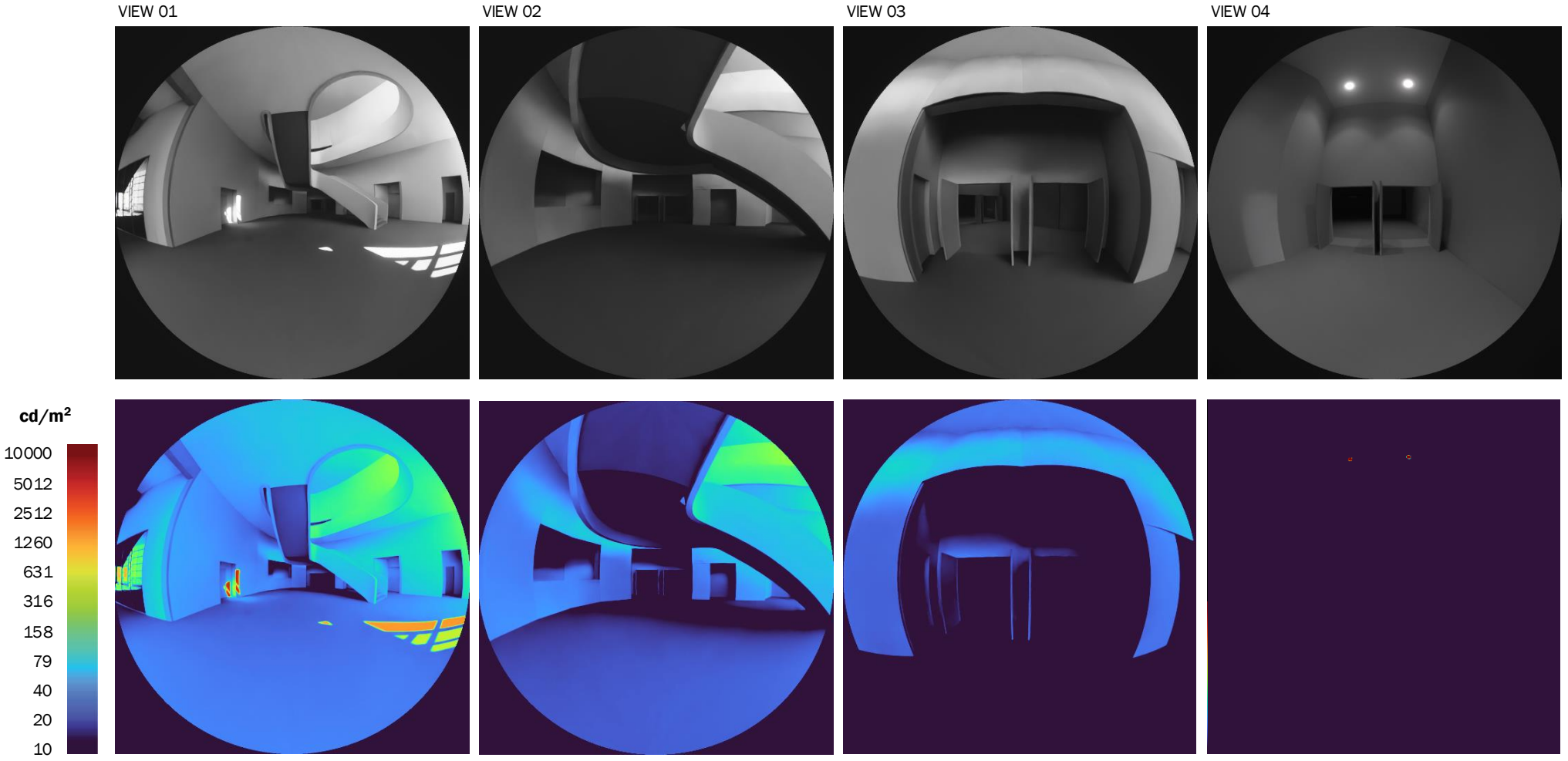
Key Findings

These visualizations represent how the spaces are experienced without accounting for the user's eye adapting when transitioning from View 01 to View 04.

Visual discomfort can still occur without studying this adaptation. However, the more detailed transition study on the next slide represents how the user experiences these spaces most frequently.

Bright to Dark Visual Adaptation – w/ Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky



Overview

The pupil will gradually adjust to adapt to the brightest object in a field of view. In some scenes, areas may appear dim if the eye focuses on the sky or a bright wall. In others, they can be perceptually very dark if the contrast is extreme.

Key Findings

The vestibule seems darker due to the contrast between the surrounding daylit walls and the dark vestibule walls. The dark stair bottom creates more visual contrast as the user approaches the vestibule, delaying when the eye can adjust. Once in front of the vestibule (View 03), the user can slowly adapt to the darker space.

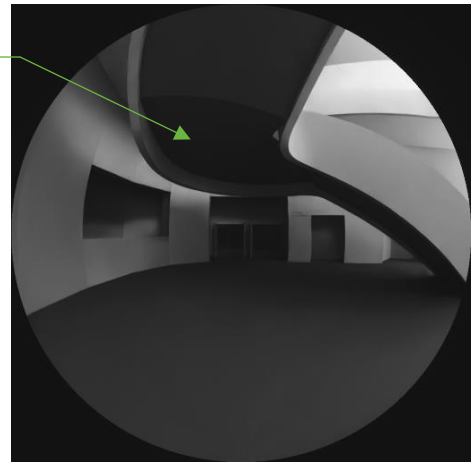
Bright to Dark Visual Adaptation – w/ Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky

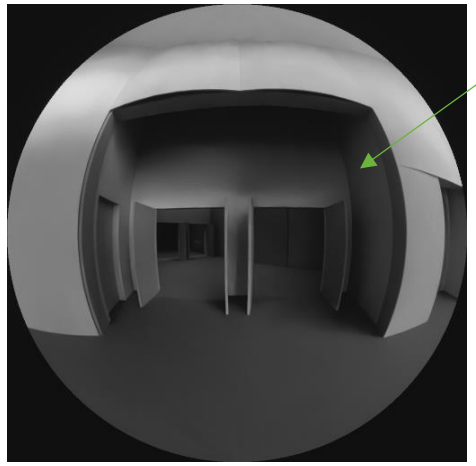
Stair Bottom Recommendation:

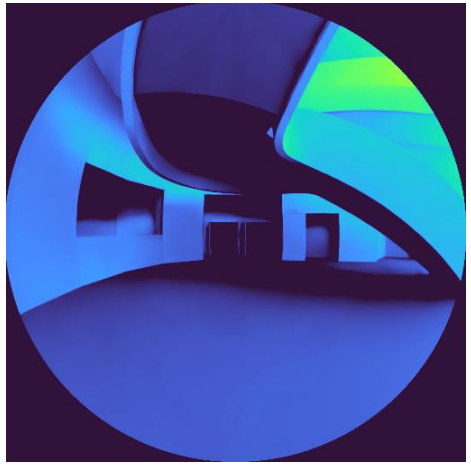
A brighter or luminous stair bottom would reduce the contrast between vertical surfaces and create a more comfortable eye adaptation. We recommend a finish with a Light Reflectance Value (LRV) of 50-60 for the stair bottom.

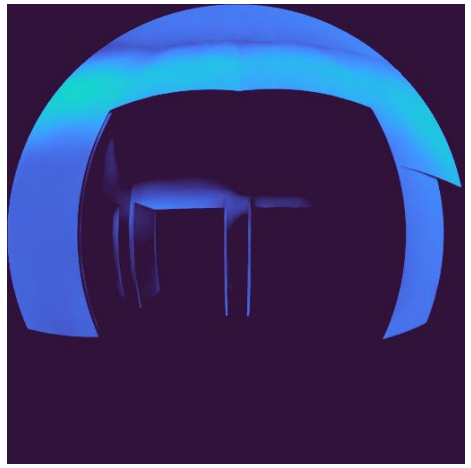
VIEW 02



VIEW 03







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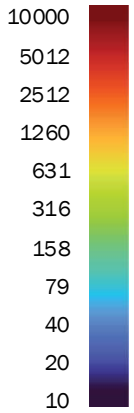
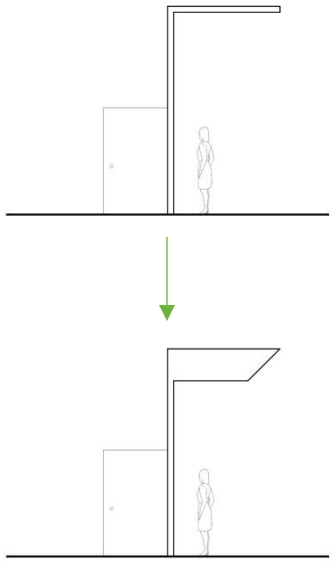


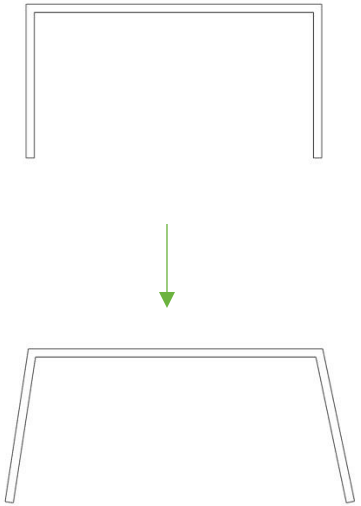
Vestibule Space Recommendations:

Brighter vertical surfaces in the vestibule reduce the contrast with the surrounding walls, helping the user adjust to the darker space faster. We recommend a finish with an LRV of 70-80 for the vestibule surfaces.

Chamfering the edges of the vestibule entrance creates light gradient edges, brightening the space (See diagrams below).



Chamfer Section



Chamfer Plan

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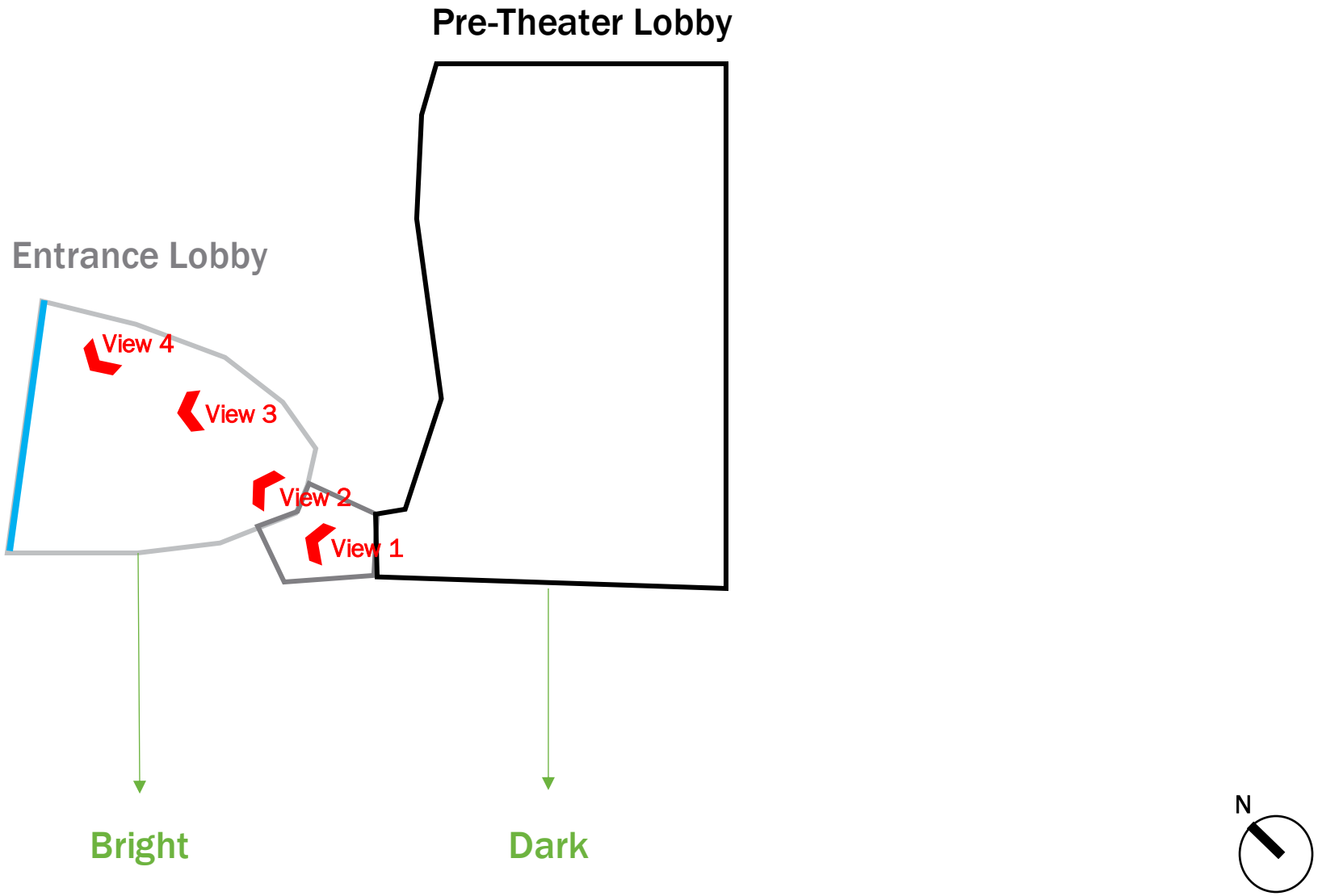
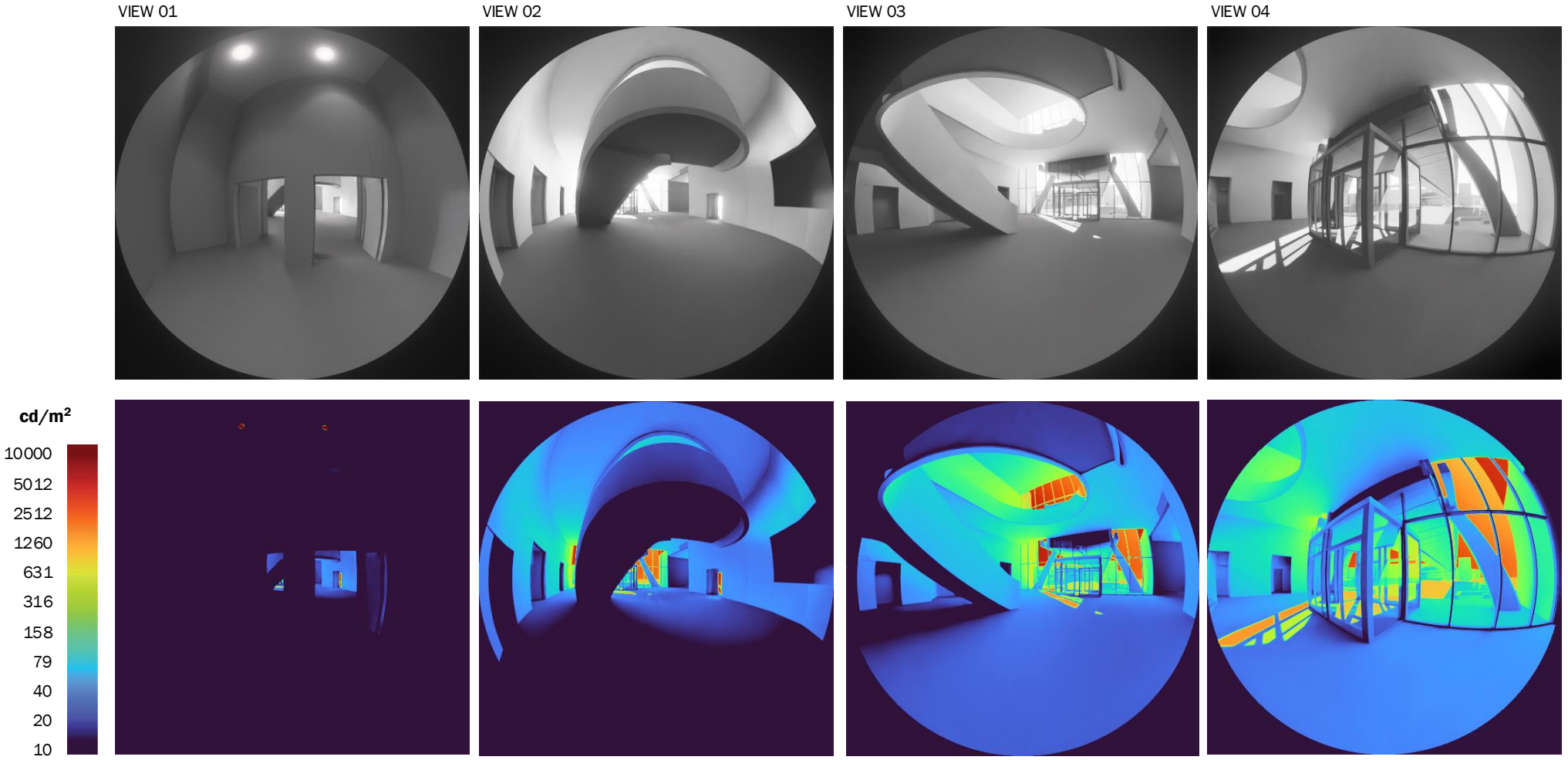
Pre-Theater Lobby to Entrance Transition

Adjusting from Dark to Bright



Dark to Bright Visual Adaptation - No Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky



Overview

Glare is the general phenomenon when the dynamic range of brightness the human eye can decode at once is exceeded, causing visual discomfort.

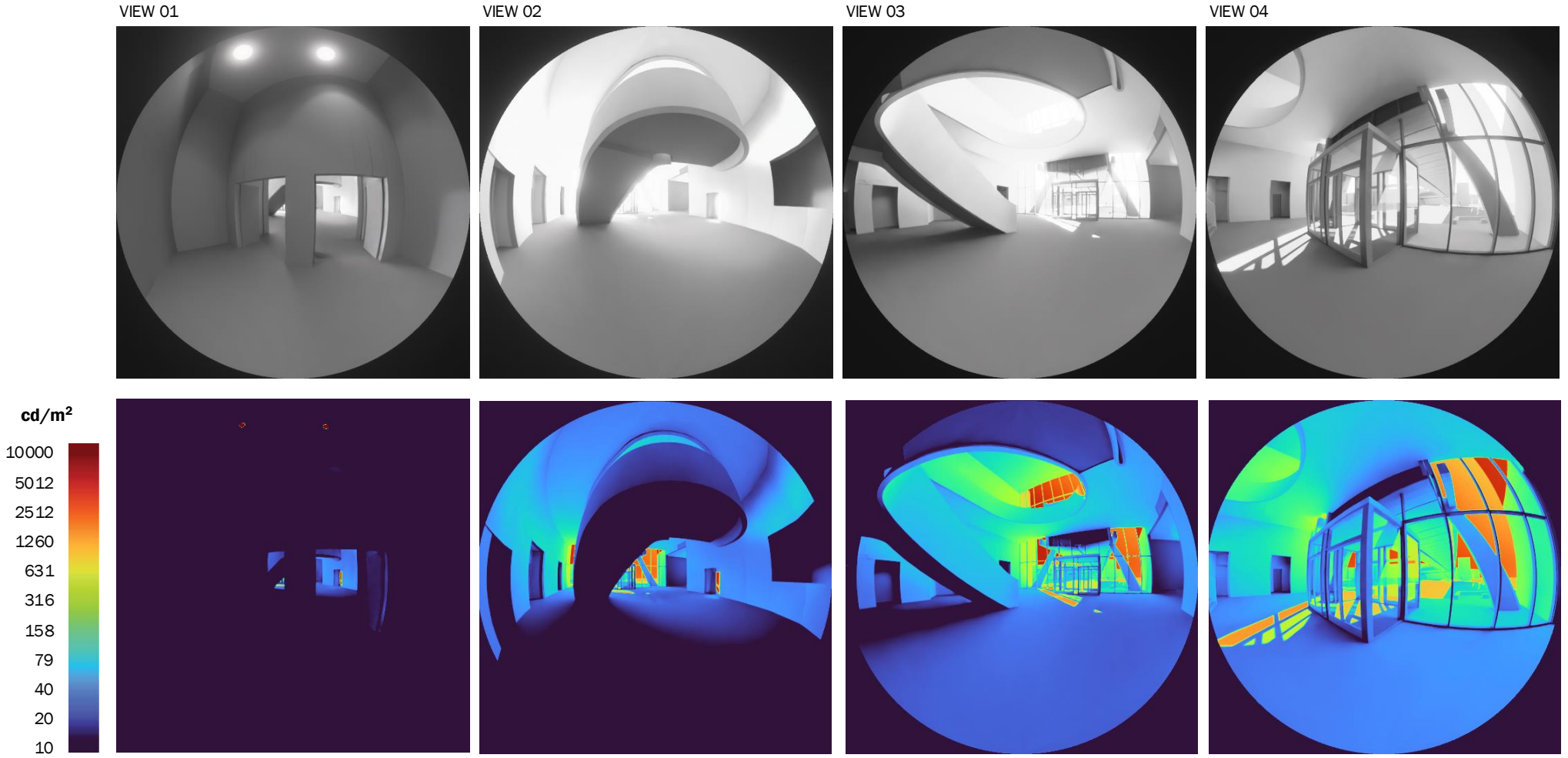
Key Findings

These visualizations represent how the spaces are experienced without accounting for the user's eye adapting when transitioning from View 01 to View 04.

Visual discomfort is already an issue in this space, even before the eye adaptation is accounted for.

Dark to Bright Visual Adaptation – w/Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky



Overview

As an occupant's gaze focuses on more local dim objects to set pupillary adaptation, bright objects within the field of view can become uncomfortable or intolerable.

Key Findings

Transitioning from the vestibule to the building entrance, there is significant visual discomfort due to glare from the bright glazing compared to the dark vestibule walls and stair bottom. This stark contrast elongates the time needed for the eye to adapt to the brighter space.

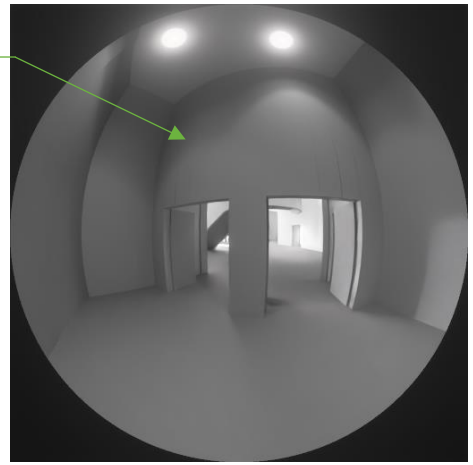
Dark to Bright Visual Adaptation – w/Eye Adaption

Summer Equinox, 4:00pm, Clear Sunny Sky

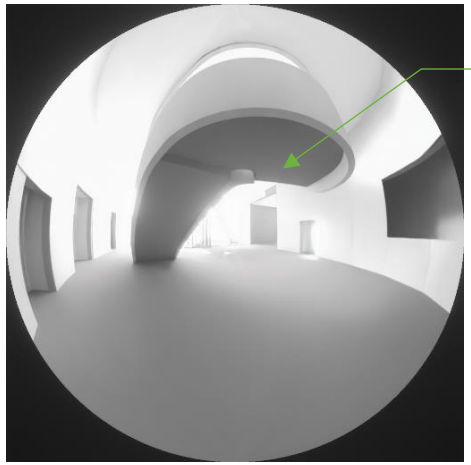
Vestibule Recommendation:

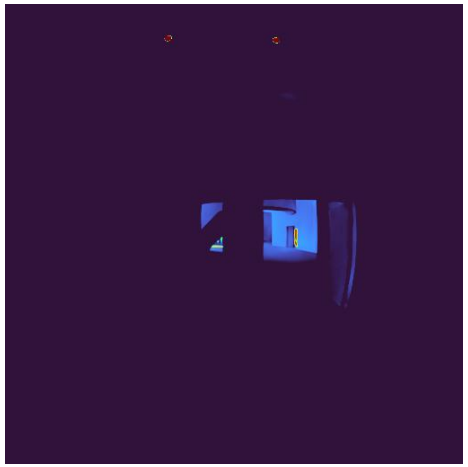
- Brighter vestibule vertical surfaces would reduce the contrast between the vertical surfaces in the field of view, allowing for more comfortable visual adaptation. We recommend a finish with a Light Reflectance Value (LRV) of 70-80 for the vestibule surfaces.

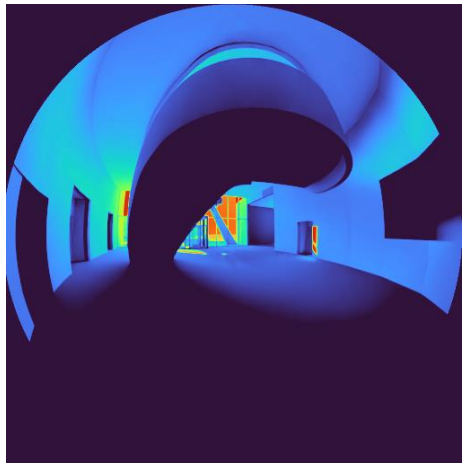
VIEW 01



VIEW 02

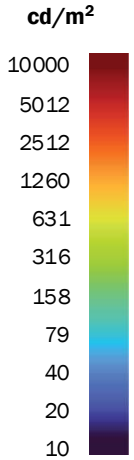




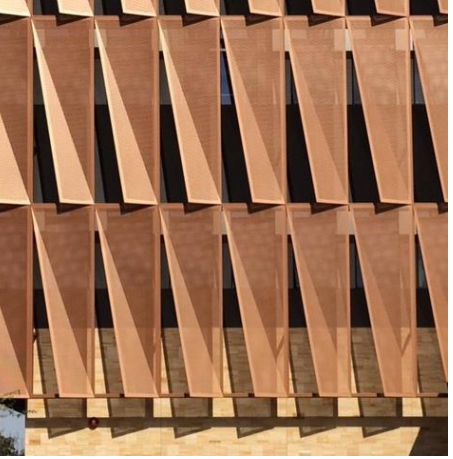


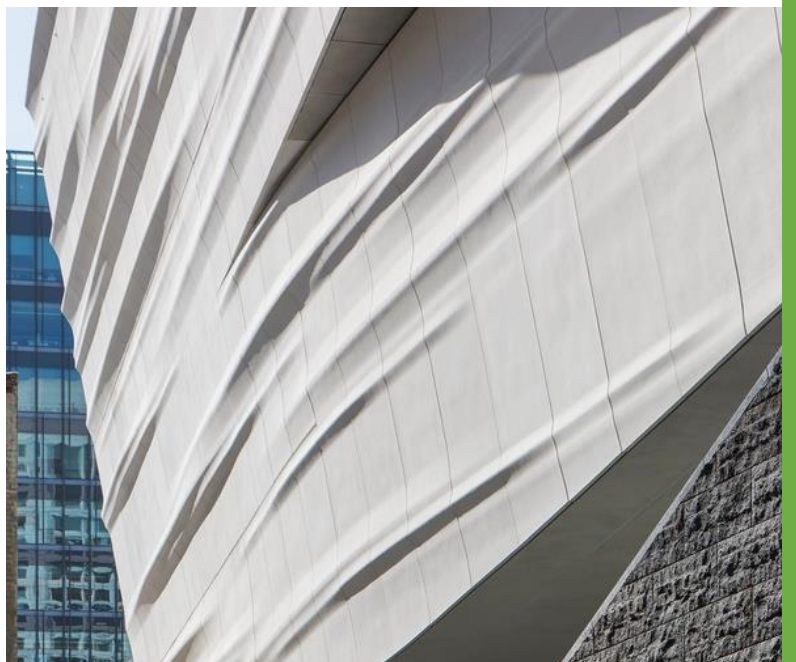
Stair Bottom Recommendation:

- A brighter or luminous stair bottom would reduce the contrast between the stairs and the bright façade glazing, lessening visual discomfort. We recommend a finish with an LRV of 50-60 for the stair bottom.



Questions?





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