CIRCADIAN CURTAIN WALL

ADVOCATING INTEGRATED DESIGN

John Neary AIA LEED AP, HOK Facades
Elliot Glassman AIA NCARB LEED AP CPHD,
WSP Built Ecology

INTRO

John Neary, HOK Facades

Facades architect at HOK, Frank Seta & Associates and Arup. Project Designer, focus on envelope and special structures at Gensler, Perkins Eastman, Pei Cobb Freed & Partners. My interest in the building enclosure is a basis for advocating integration of the conceptual and technical aspects of design. MArch Rice University. BA Vassar College. AIA, LEED AP, NCARB Certified.

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Elliot Glassman, WSP Built Ecology

Associate and high performance building consultant. Expertise in daylighting, passive design, and using computational design for building performance optimization. Masters of Design Studies in Sustainable Design from the Harvard Graduate School of Design. BArch from New Jersey Institute of Technology. Licensed Architect, LEED AP, NCARB Certified, and Certified Passive House Designer.

Elliot J. Glassman, AIA, NCARB, LEED BD+C, CPHD
Associate
Technical Principal
Built Ecology

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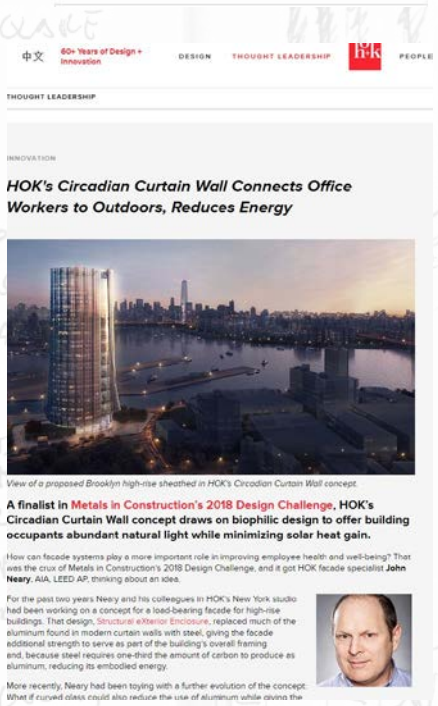
Project Team

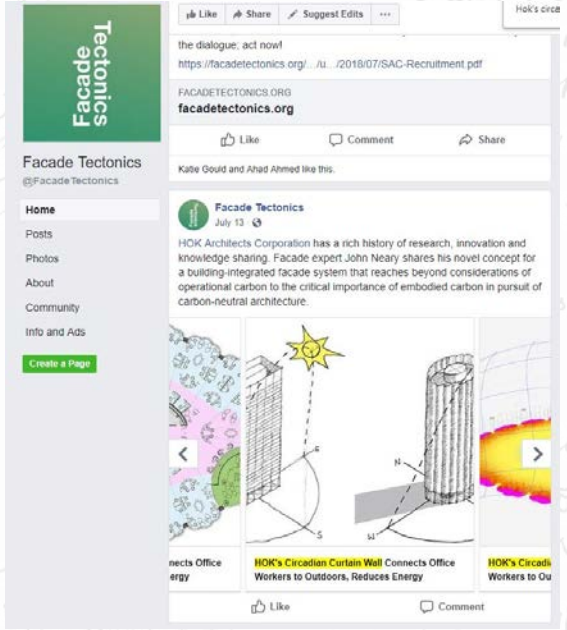
John Neary, HOK Façade Architecture
Michael Miller, HOK
Zhenhuan Xu, HOK
Blake Kurasek, HOK
Marie Achabalun, HOK
Mario Claussnitzer, HOK Façade Engineering
Matt Breidenthal, HOK Structural Engineering

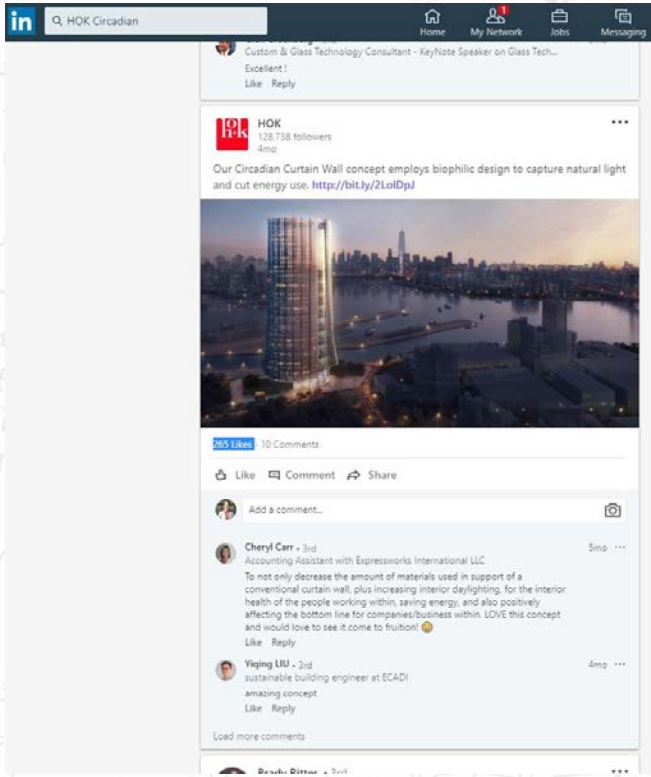
Matthew Payne, WSP Built Ecology
Elliot Glassman, WSP Built Ecology

with extra help from:
Apoorv Goyal, Sustainability Specialist at HOK
Victoria Ereskina, Facade designer at HOK

MEDIA COVERAGE





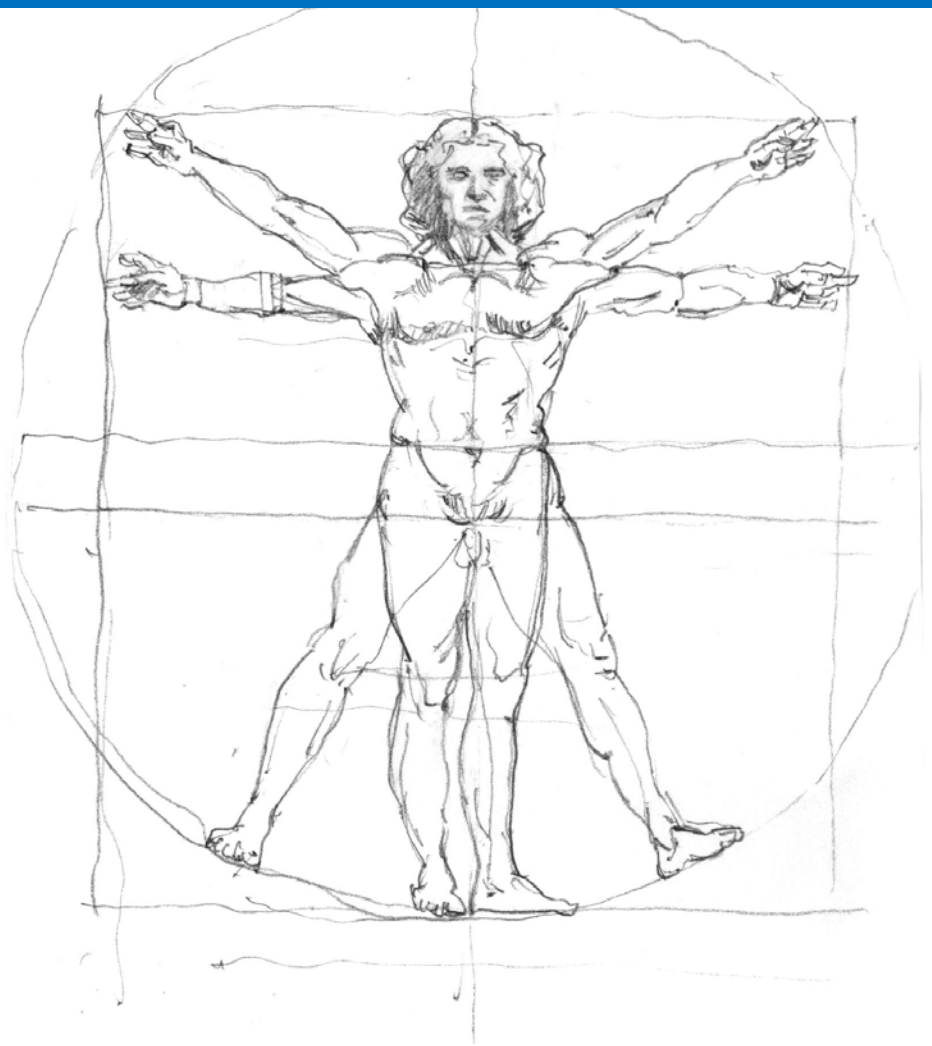


PRINCIPLES

Wellness

Connections between:

- Mind and Body
- Emotional and Intellectual
- Functional and Formal
- Quantitative and Qualitative
- Environmental and architectural:
- Thermal, texture, air, water, light, sound.
- Interior and exterior



Integrated Design

Connections between:

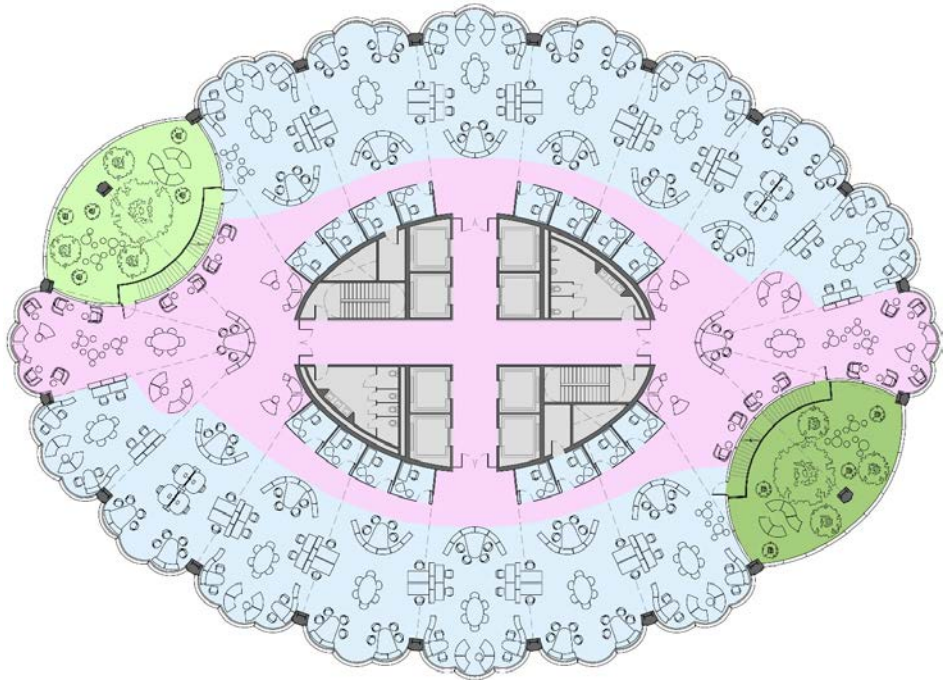
- Form and Performance
- Aesthetic and Technical aspects of Architecture
- Form and Spatial Order
- Elimination of unnecessary material
- Following natural principles of structure

Through our proposal, we are advocating integration of aesthetic, experience-related objectives and the technical, performance-related objectives in design.

Organic Design

Connections between:

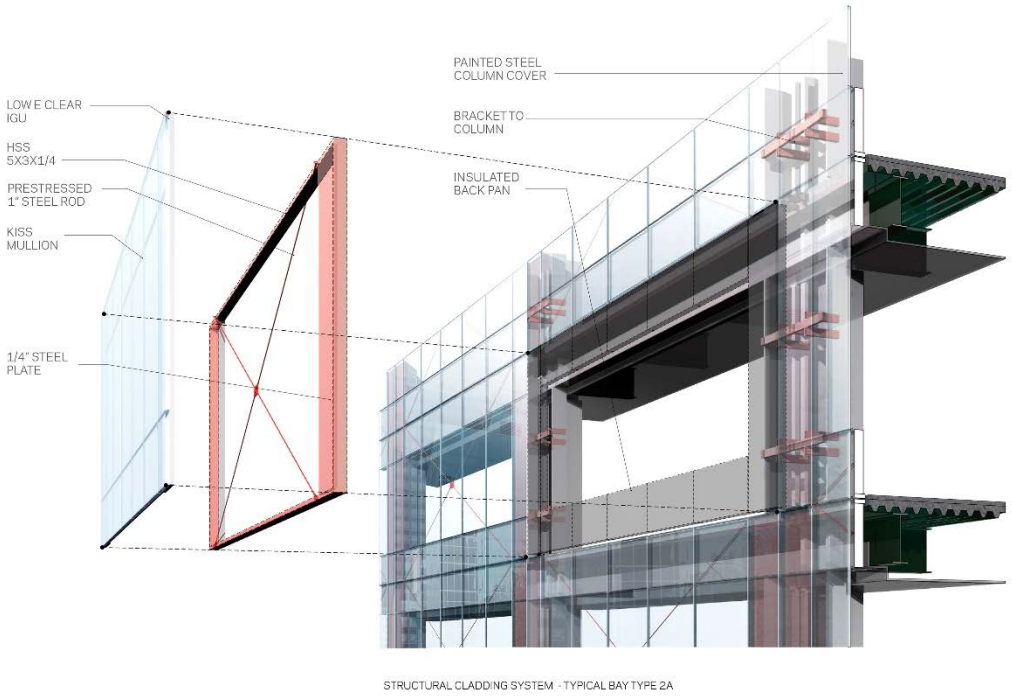
- Architecture and Nature
- Building and Human Scale
- Themes that define early modernist work from Sullivan and Wright to the Bauhaus and Mies.
- The shading and articulation of the floor plate design resulted in a biomorphic lobed geometry that resembles an organic form.



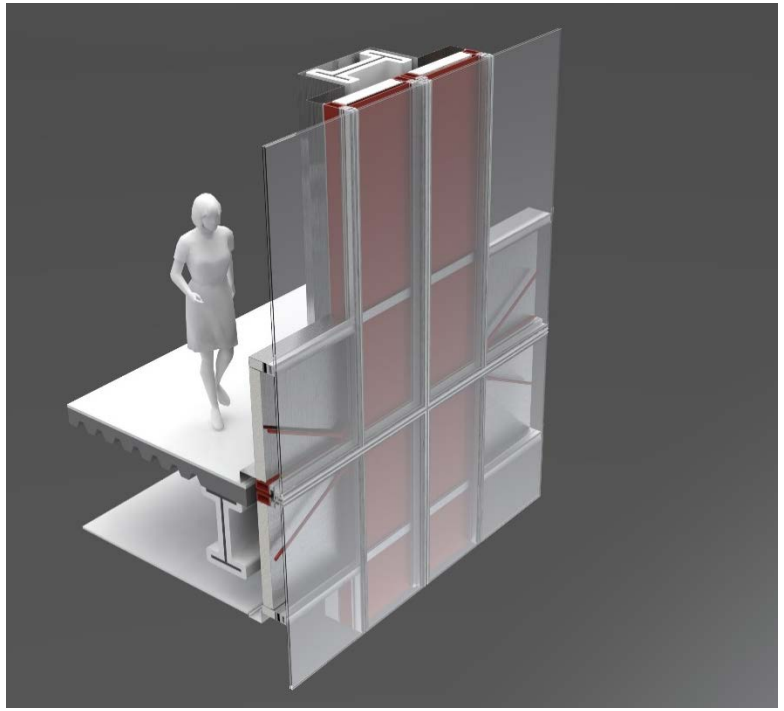
Structural eXterior Enclosure
2017 Metals In Construction Competition-
Reimagine Structure
Finalist

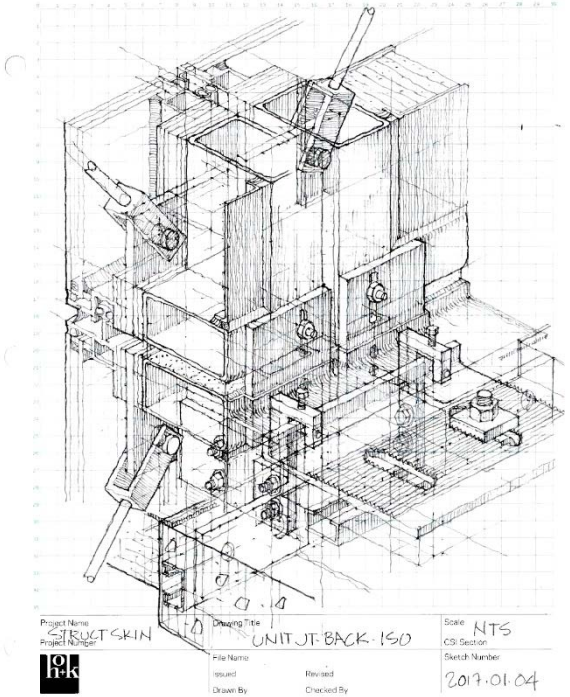
- Mega-panel steel frame with diagonal bracing contributes wind-stiffness to the primary structure.
- Mullions are minimized by bracing glazing against diagonals
- Embodied CO2 is reduced in frame and cladding

CURRENT



STRUCTURAL CLADDING SYSTEM - TYPICAL BAY TYPE 2A





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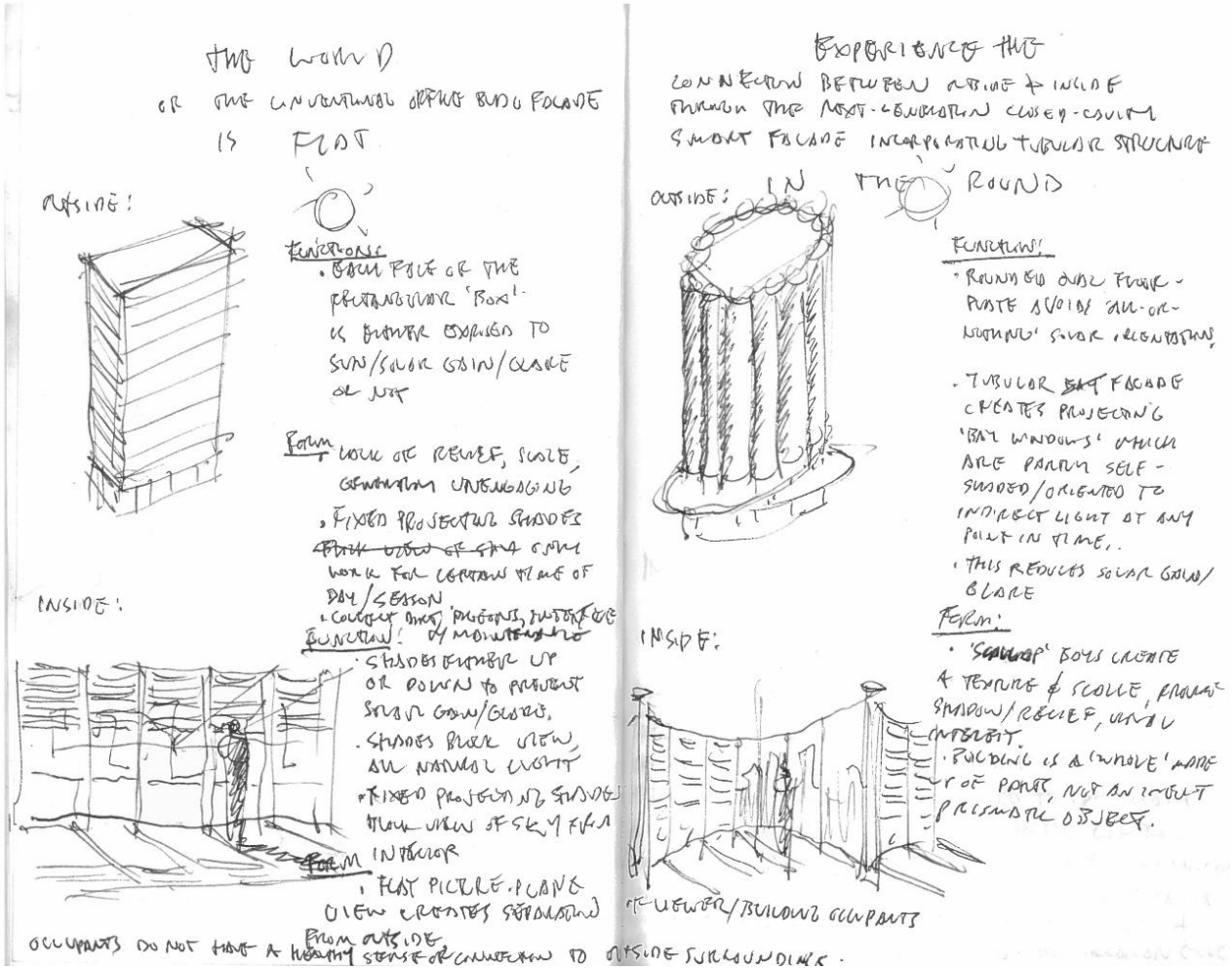
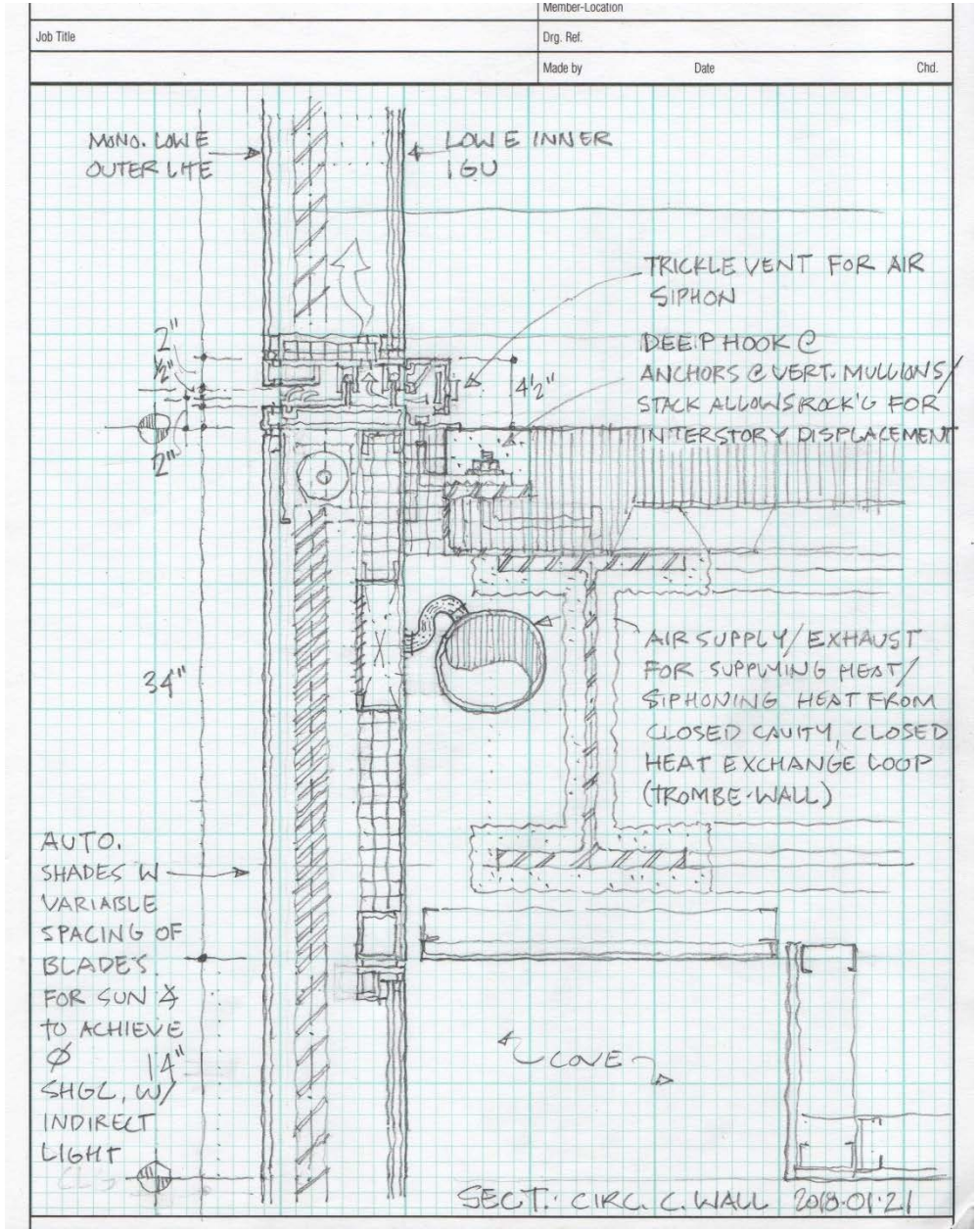


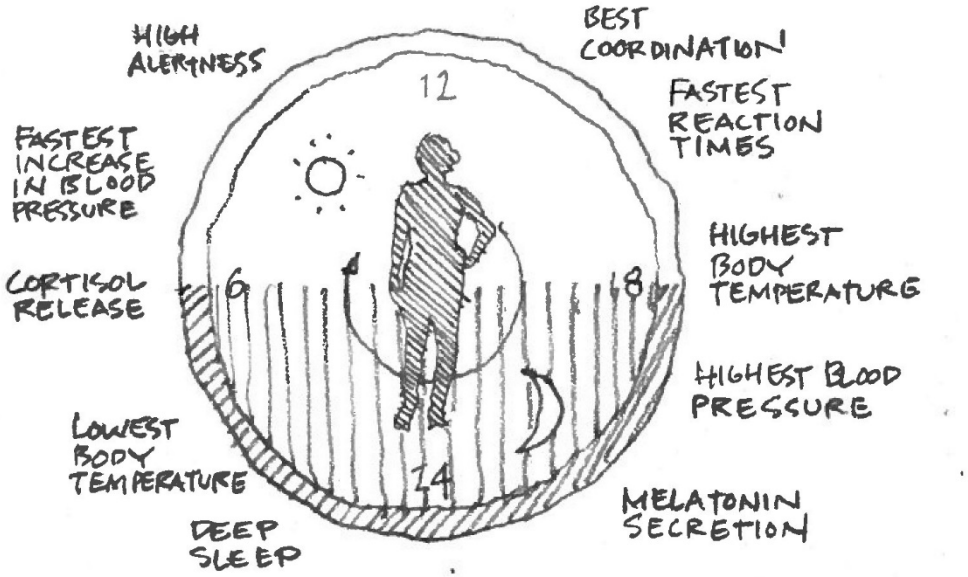


HOK Facades Group

Advocacy of integrating aesthetic/experiential and performance/technical aspects of design throughout the process.

CIRCADIAN CURTAIN WALL

The *Metals in Construction* magazine 2018 Design Challenge is a competition to generate ideas for a facade system that can play a major role in enhancing employee health and well-being. This ideas competition is based on the philosophy that the 21st century facade needs to be adaptive and responsive to human needs, especially in the workplace. With researchers probing beyond workplace aesthetics to examine holistic factors, we are learning that air and water quality, thermal control, and especially visual access to outdoor environments can directly improve employee well-being.



"Life on Earth is adapted to the rotation of our planet. For many years we have known that living organisms, including humans, have an internal biological clock that helps them anticipate and adapt to the regular rhythm of the day"

source: www.nobelprize.org

Circadian Rhythm

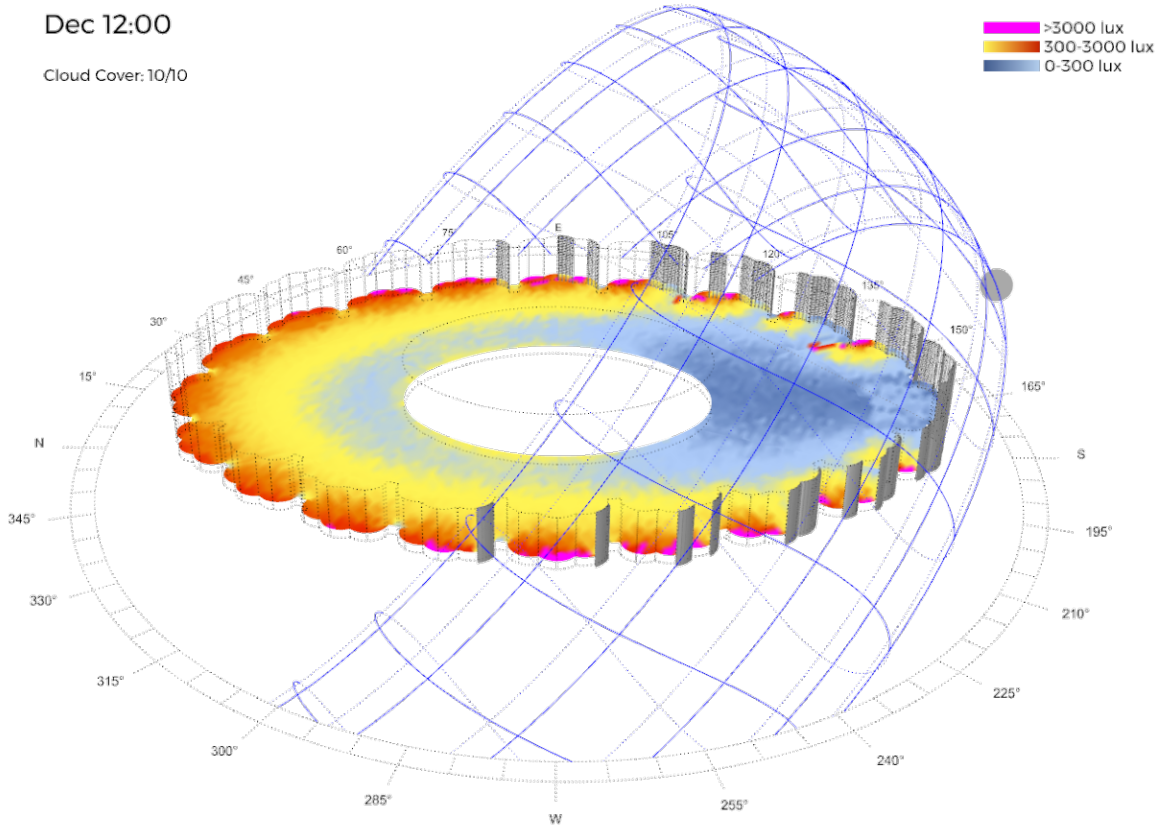
The cycle/circle of Life

- The 2017 Nobel Prize in Medicine was awarded for research into the science of Circadian Rhythm.
- A critical subject for defining how buildings relate to environment.

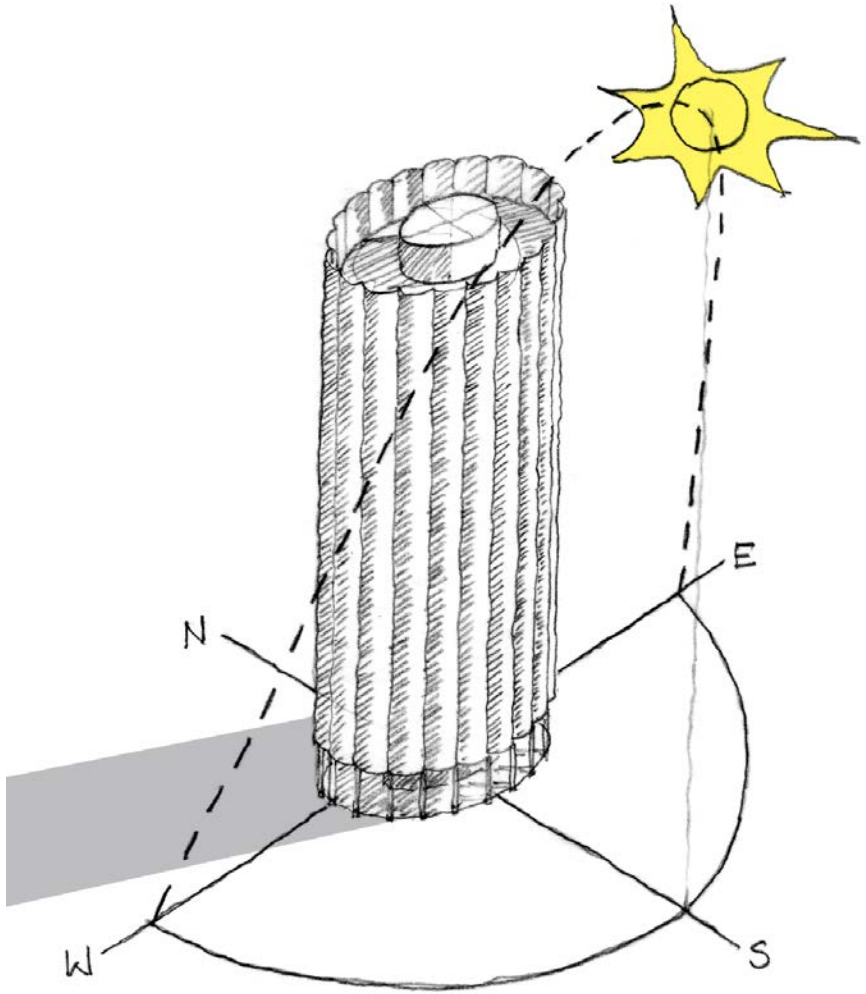
CURRENT

"Research shows that to a large extent employee well-being is a result of connecting the occupants of spaces within a building with the world outside."

source: www. metalsinconstruction.org/design-brief/



Solar exposure– North-South orientation

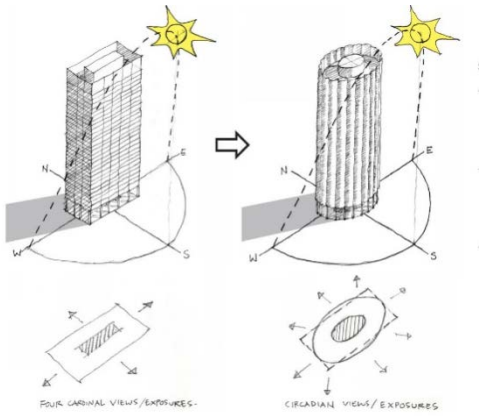


Arc of the Sun– study of West-East orientation

Symbol of Time

The symbol, the essence, of the circadian, daily cycle is the arc of the sun across the sky-- the yin-and-yang of day followed by night.

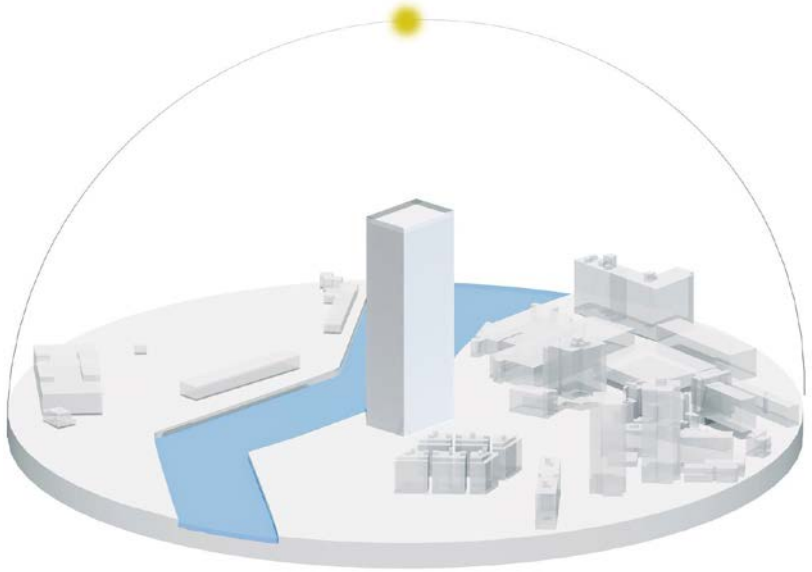

12'
15'

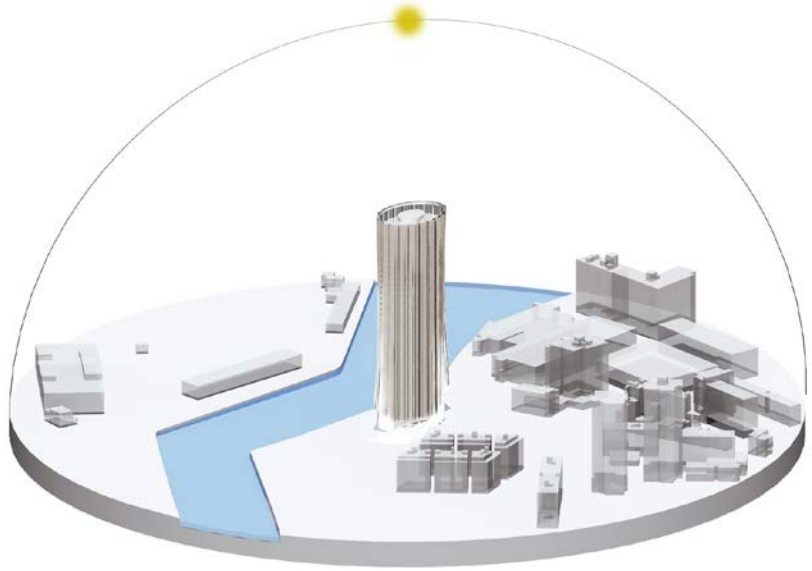


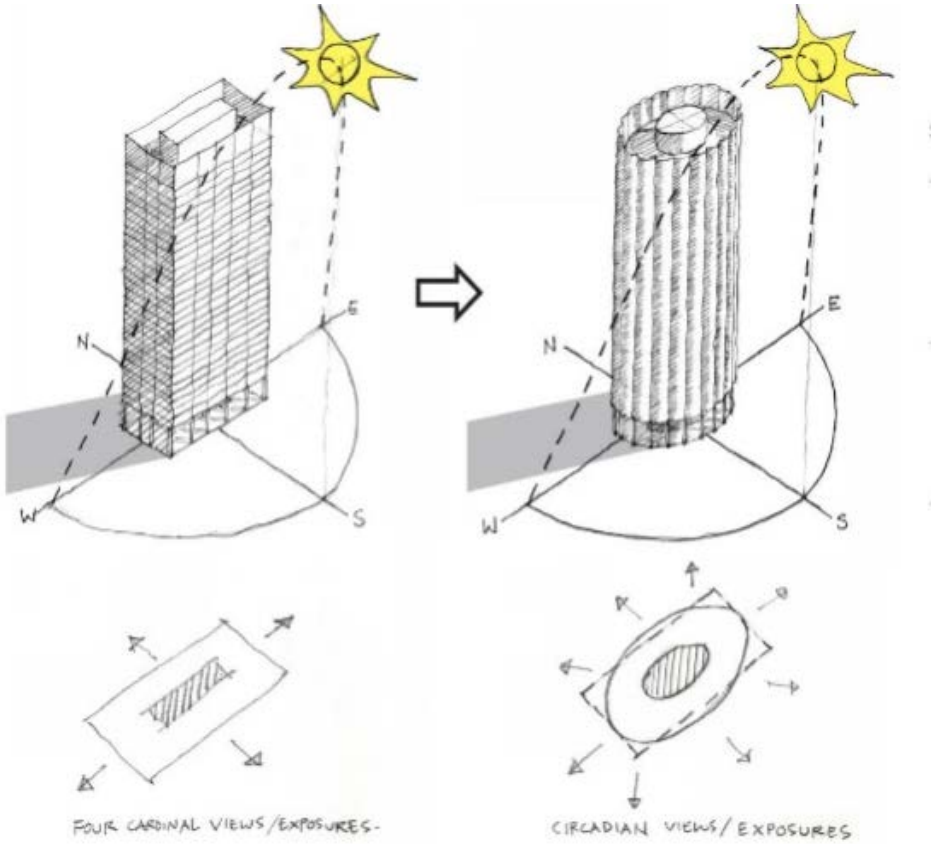
Circadian Rhythm

The fine-grain fluting of the Circadian façade produces a constantly changing pattern of light and shade.

The conventional rectangular building's facades are either in direct sun or in shade, essentially. The building is visually static from the outside.







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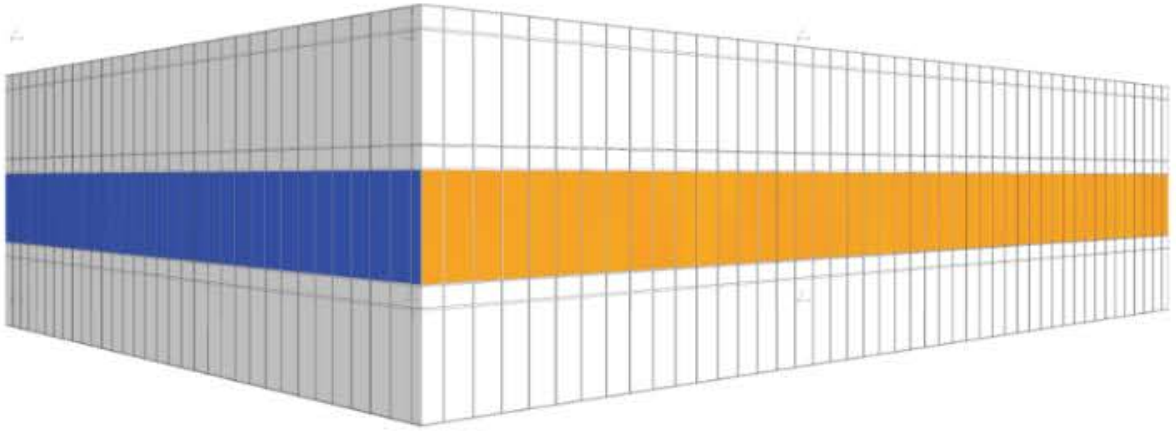


Aug 21
11:00-12:00

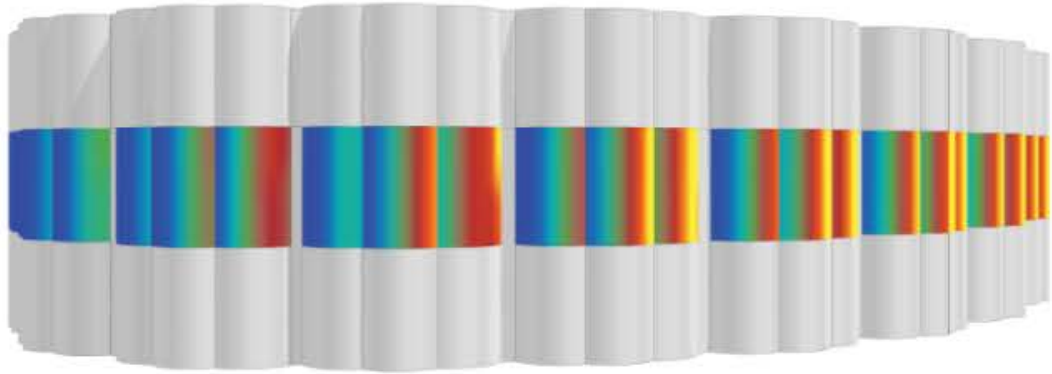
Average Irradiance: 255 W/m²
Total Irradiance: 173,343 W

N

Solar Irradiance
W/m²

500

0



Aug 21
11:00-12:00

Average Irradiance: 234 W/m²
Total Irradiance: 168,325 W

N

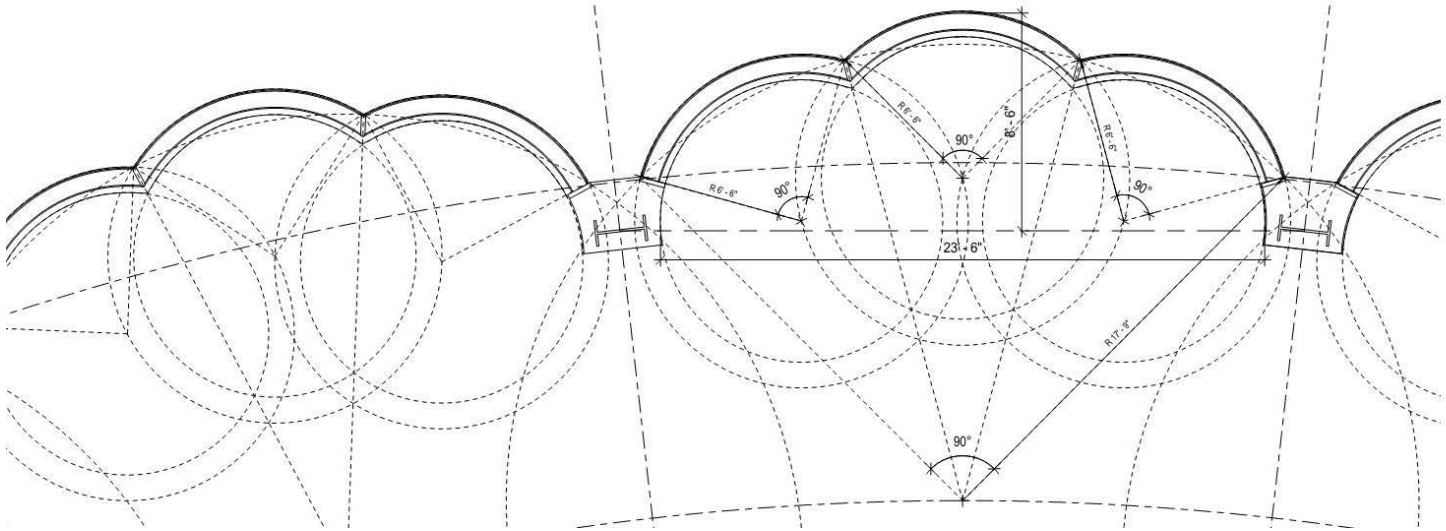
Solar Irradiance
W/m²

500

0


RELIANCE BLDG
2017.12.02
- Modelled, Deep Surface
- Engages, projects into
surrounding Space.

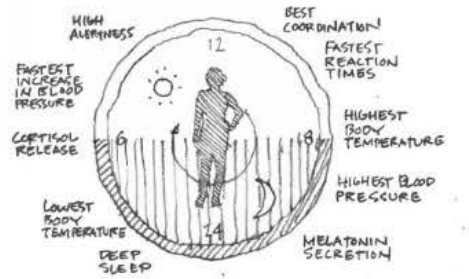

SPACE | 7


R6'-6"
90°
8'-6"
R6'-6"
90°
R6'-6"
90°
23'-6"
R17'-9"
90°

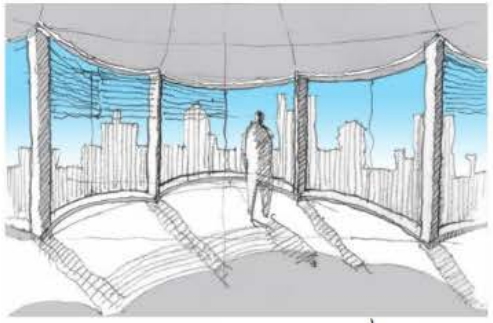
CIRCADIAN CURTAIN WALL

OLD/ FLAT **VS.** **NEW/ ROUND**

Circadian, latin *circa* + dies *day*



source: www.nobelprize.org

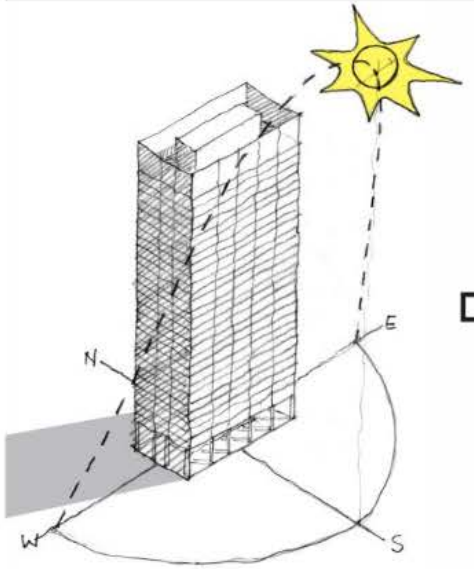


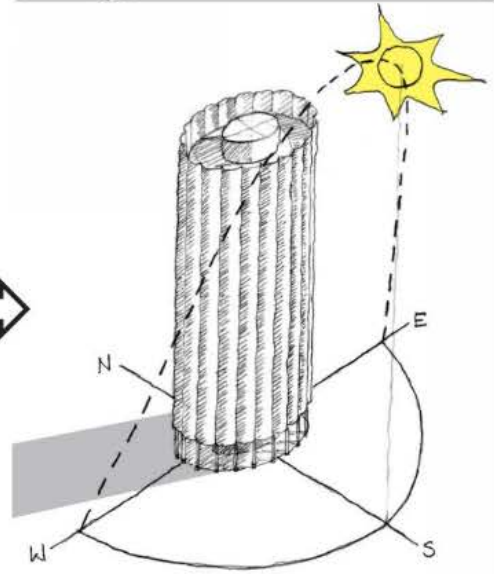
"Life on Earth is adapted to the rotation of our planet. For many years we have known that living organisms, including humans, have an internal biological clock that helps them anticipate and adapt to the regular rhythm of the day"

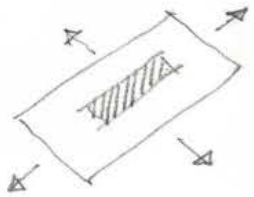
source: www.nobelprize.org

PROBLEM:

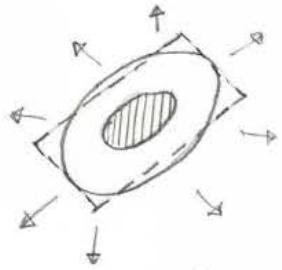
- Flat 'picture plane' view creates a separation between inside and outside, and limited field of view.
- Base case building is 120' x 180'. The program calls for 30 floors. Surface area is 270k sf.
- At any moment, the box is 50% self-shaded, but faces receiving direct sun require complete shading to control solar gain and glare.







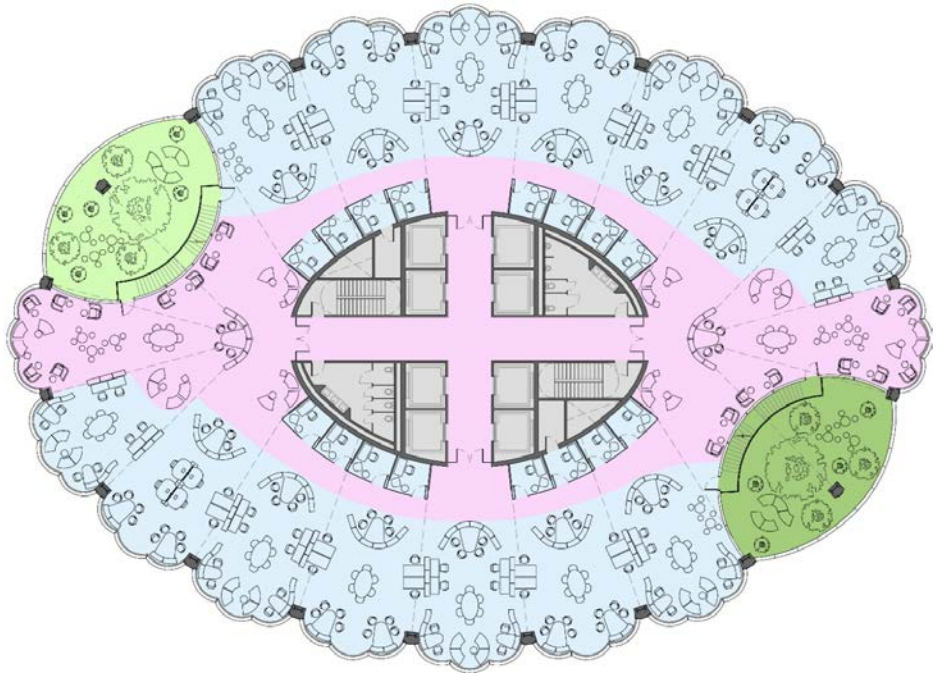
FOUR CARDINAL VIEWS/EXPOSURES

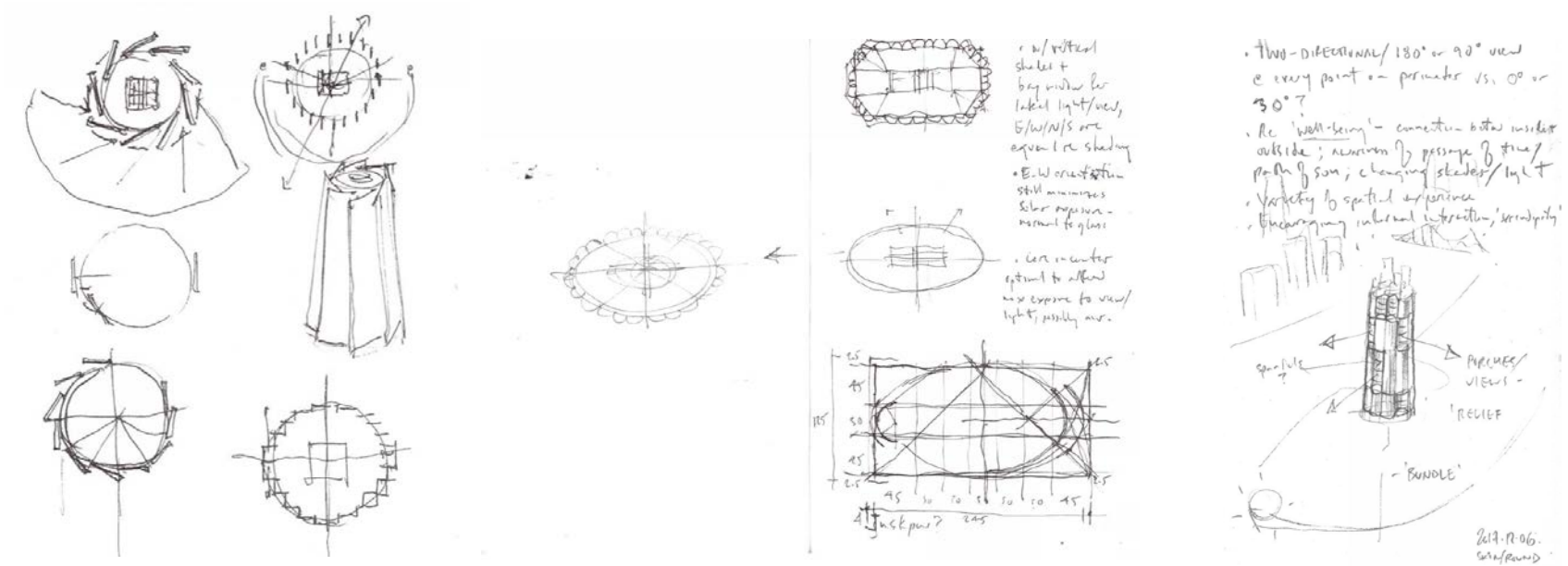


CIRCADIAN VIEWS/ EXPOSURES

SOLUTION:

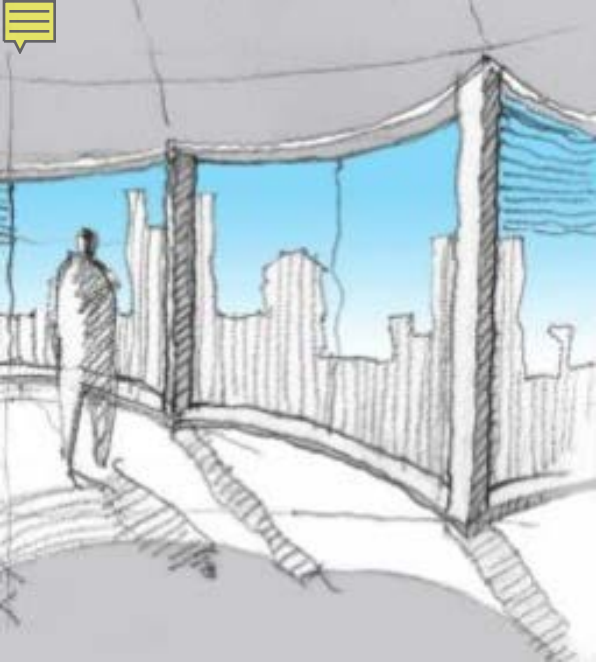
- Projecting bay windows create feeling of connection between inside and outside.
- Circadian Tower floor plate is ovoid with 153' x 212' limiting dimensions. Surface area is almost 290k sf.
- Curved bay windows are self-shading, creating shadow and relief on the building surface. At any moment, the tower is approximately 75% self-shaded. In each bay some glass may be unshaded to allow view and natural light without heat gain and glare.

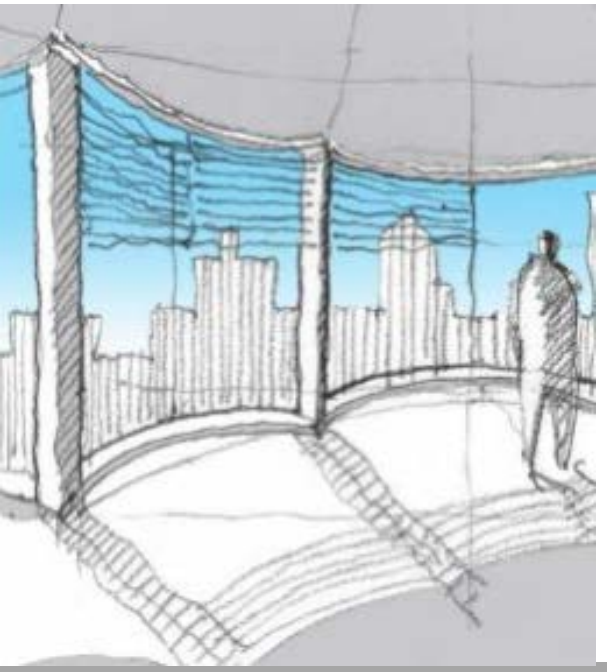


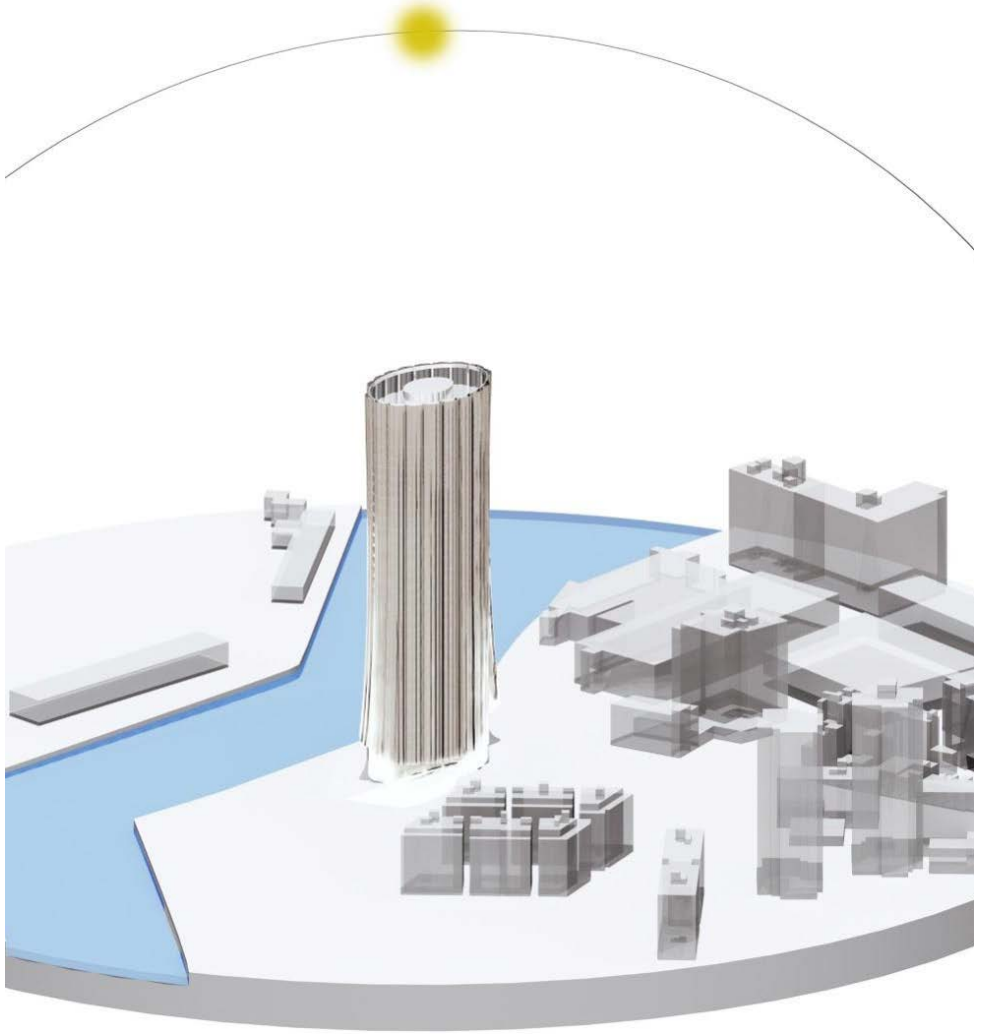


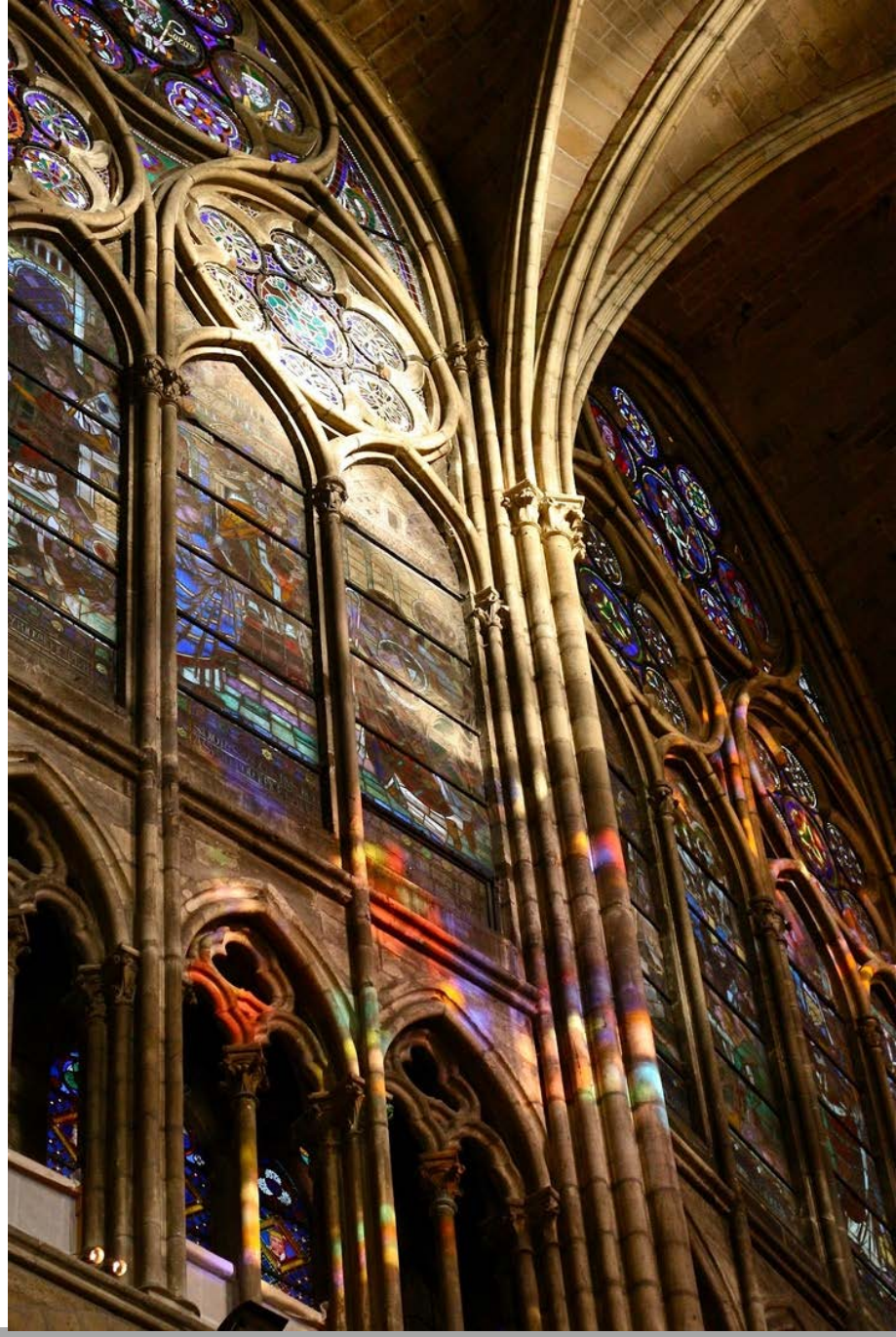
Development of the circular/rounded floor plate with petals or lobes creating a shaded facade.

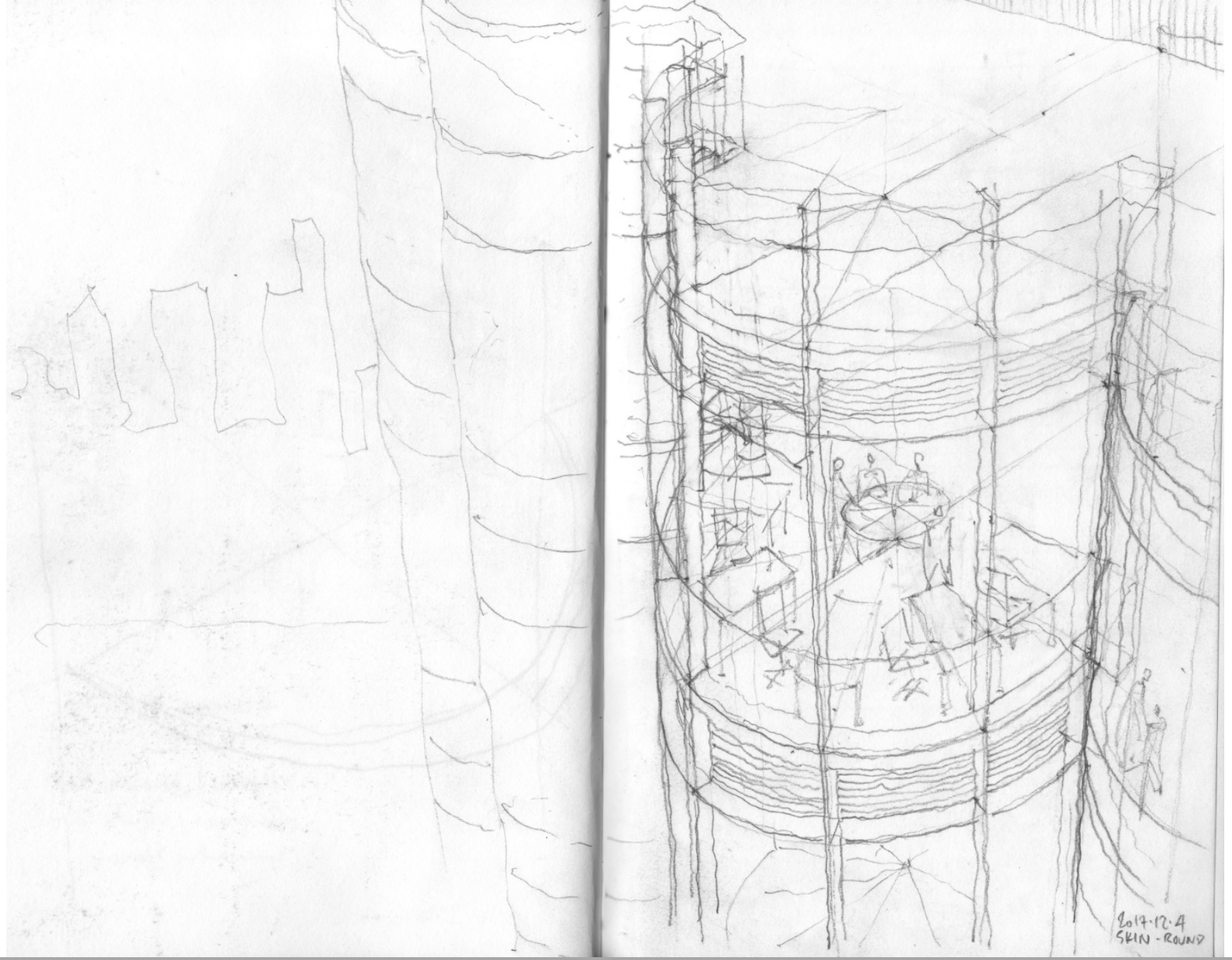

Sullivan - Wright - Corner Window 9.04.17

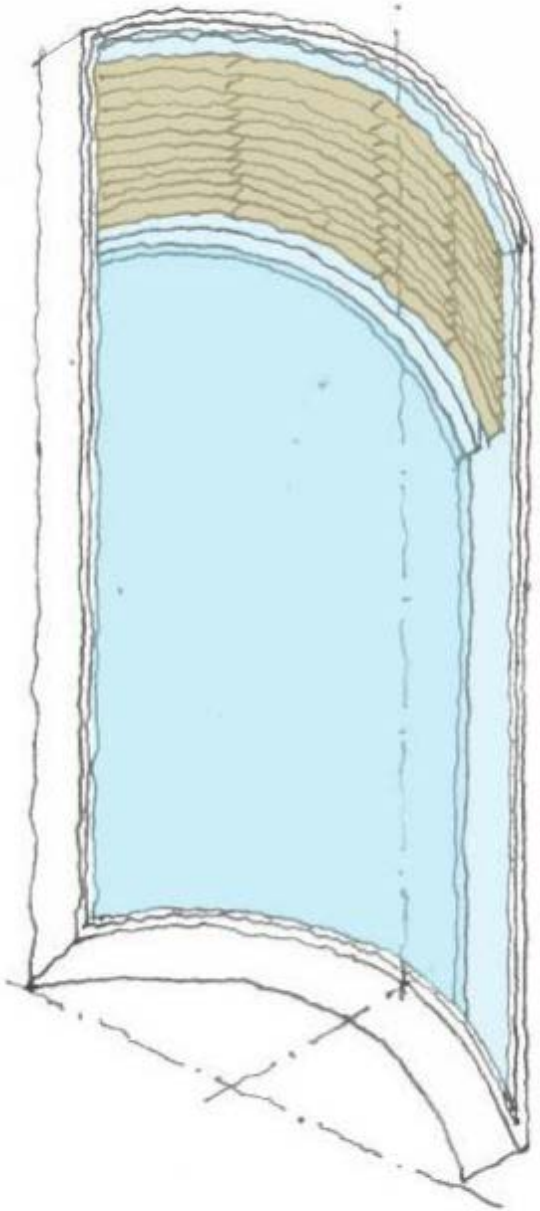


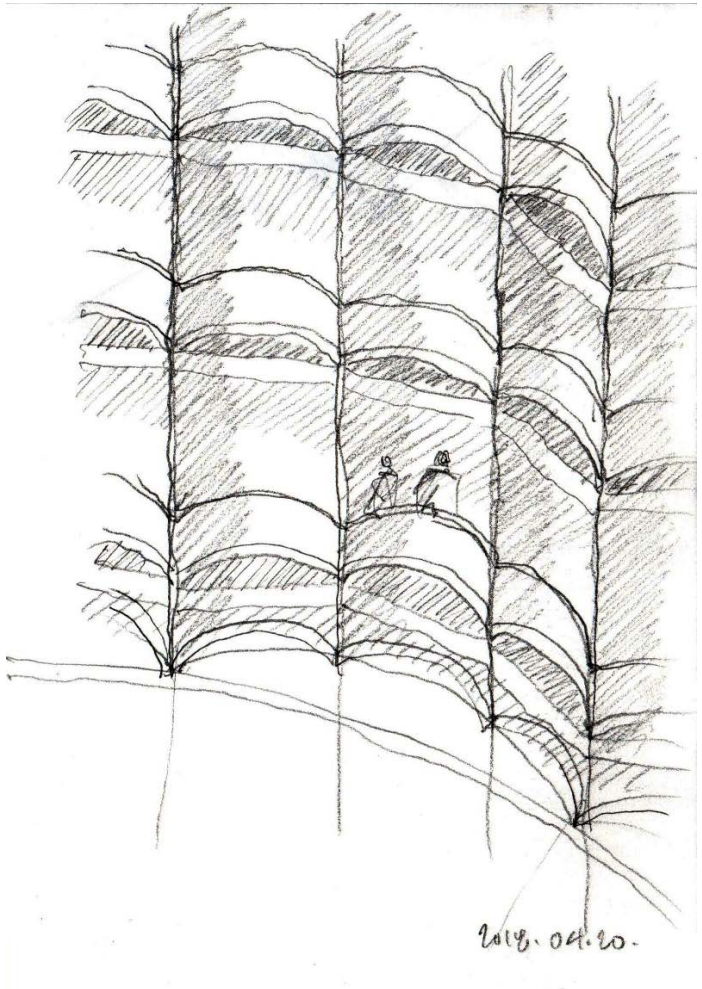




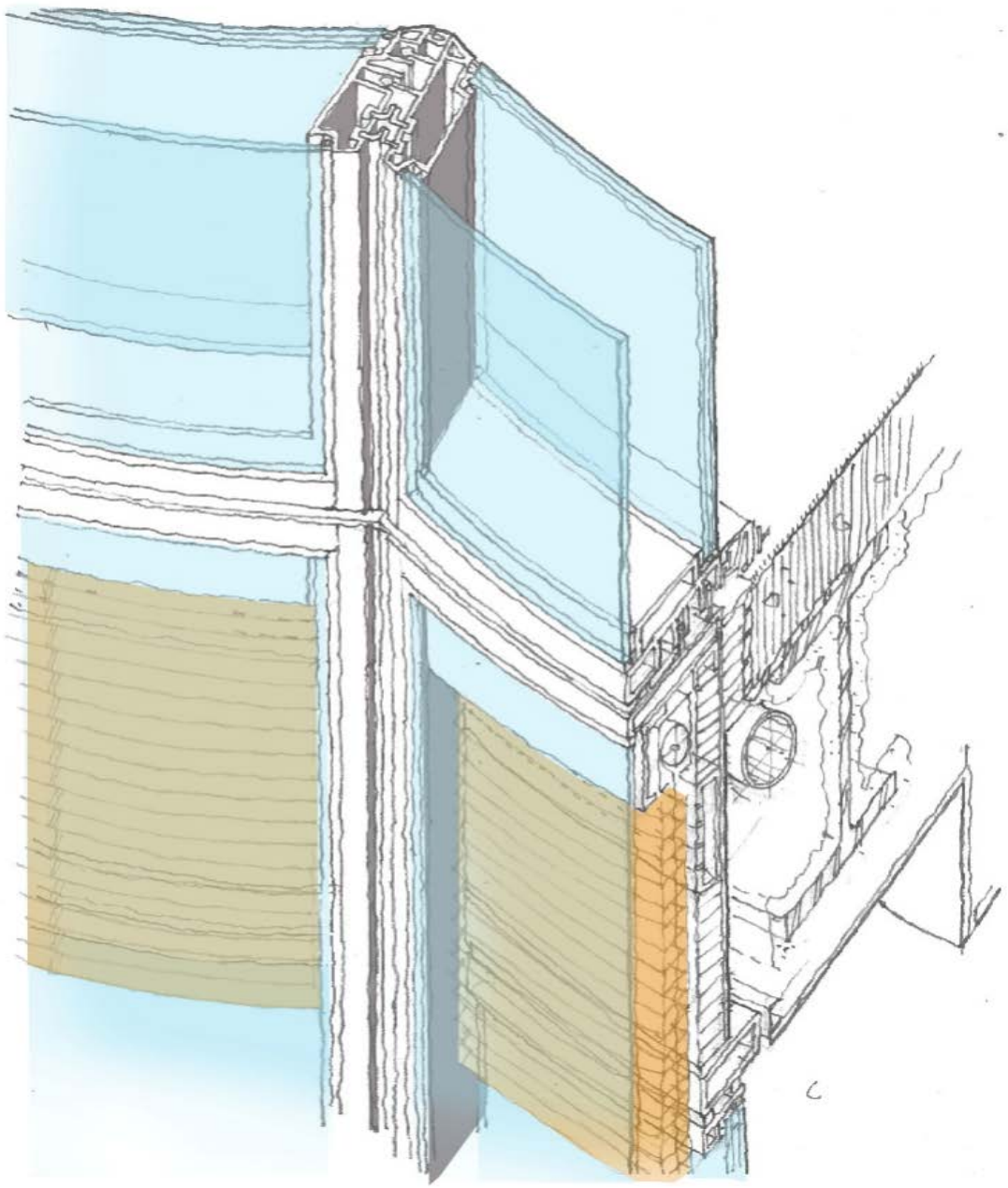



2017·12·4
SKIN - ROUND



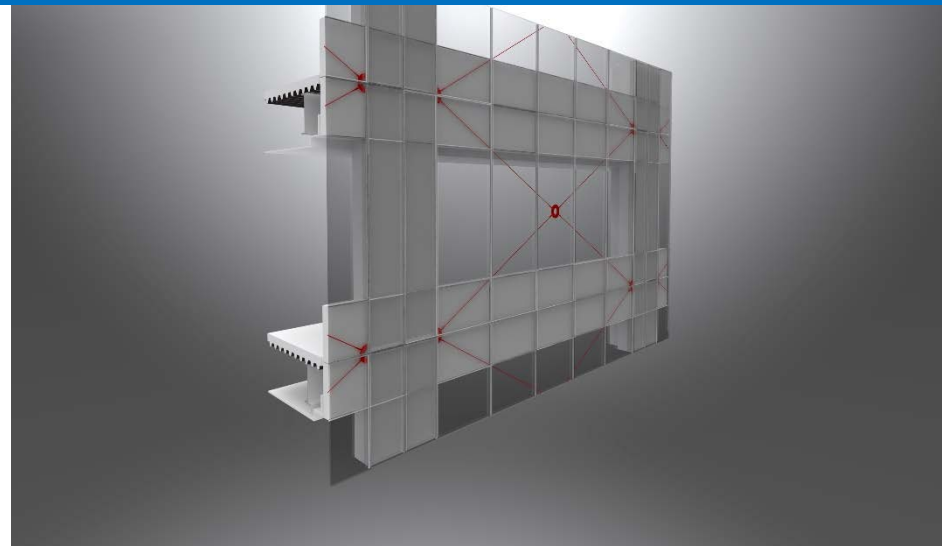


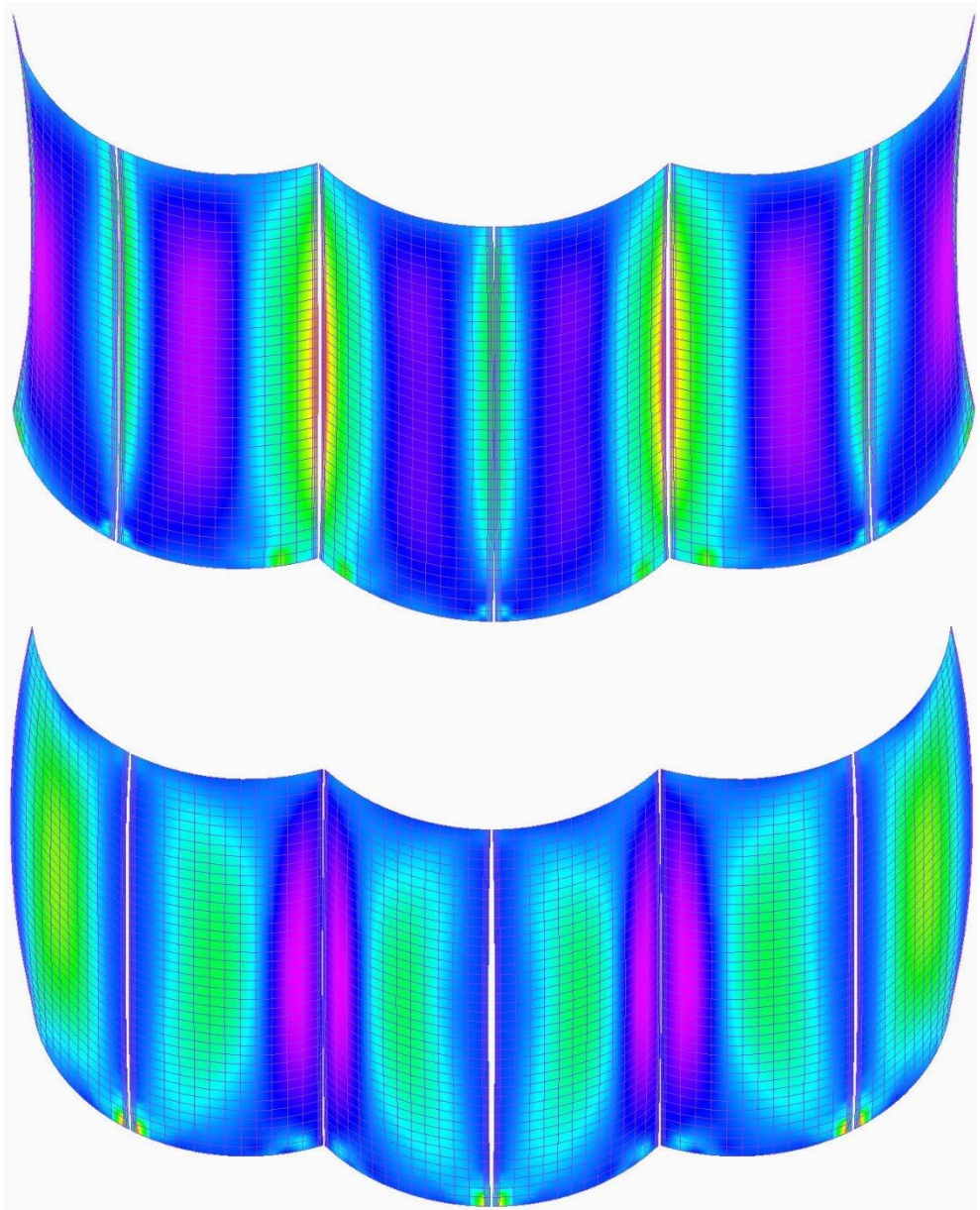
The energy required to operate the shades is much less than can be saved by reducing heat load from sun and from artificial lighting required when shades are down.



The closed cavity protects the automatic shades from dirt and breezes. The supply and return of heated air has practical challenges which explain the absence of this feature in closed cavity systems currently in use, but these seem solvable with development.

EMBODIED ENERGY/ TROMBE WALL HEAT RECYCLING





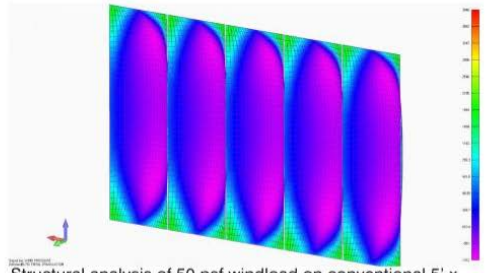
REDUCED EMBODIED ENERGY

Ultimately, Wellness depends on the health and ecology of our environment, and the experiential features of the Circadian facade must be governed by concern for material economy and minimizing embodied energy.

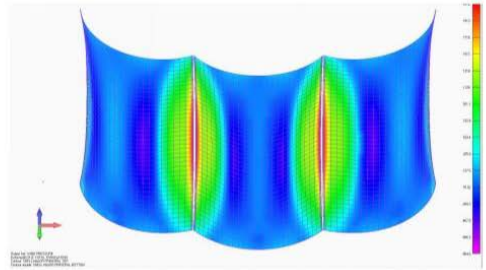
- The conventional curtain wall is made up of 5' wide x floor-height aluminum frames with glass infill. Mullions take wind load to the floors, requiring appr. 5 psf of aluminum.
- The Circadian Curtain Wall curved glass acts as a beam spanning floor-to-floor, leaving the unit frame as a chassis for weather seals, connections to the mechanical systems and firesafing. This tower has a surface area of approximately 300K sf. If aluminum is cut in half by use of the curved glass it saves almost 400 tons of aluminum. This is a significant amount of embodied CO_2 equivalent.
- Structural savings is offset by the curved glass and shading controls and mechanical couplings for the filtered air. But these, combined with the self-shading form of the building generated by the bay-window, effectively eliminate solar gain through the facade, and allow indirect light which reduces heat load and energy use for artificial lighting throughout the day.
- Reduced carbon footprint and connection between the building occupant and the circadian rhythms of shades and lights synced to the time of day all contribute to occupant well-being.

Curved glass acts as a beam, allowing fewer, thinner mullions & savings of 400 tons of aluminum in the tower skin.

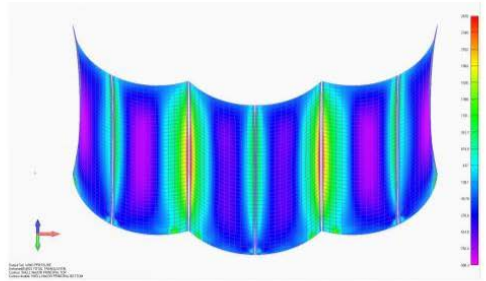
The curved bay windows are self-shading, allowing some shades to be up at all times on most bays and reducing reliance on artificial light.



- Structural analysis of 50 psf windload on conventional 5' x 15' units shows mullions are required to take wind load in order to limit deflection to acceptable maximum.



- Structural analysis of 50 psf windload on 10' x 15' curved lites in Circadian Curtain Wall units shows no mullions are necessary for structural purposes if glass is connected by structural silicone. Aluminum frames are included to provide housing for automated shades, and chassis for anchors and gaskets.



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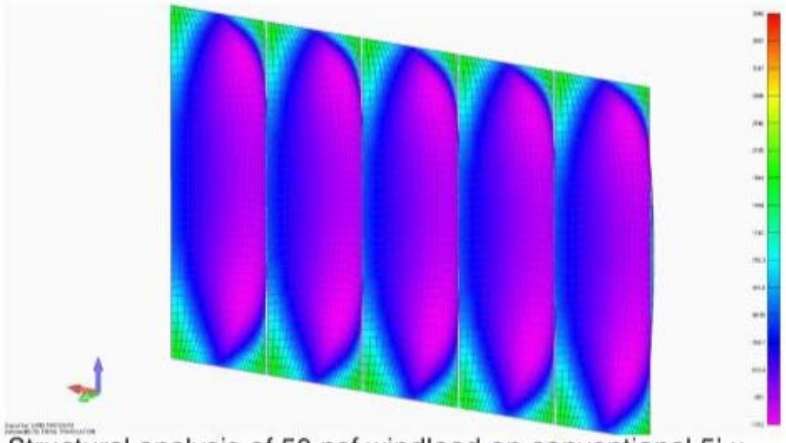
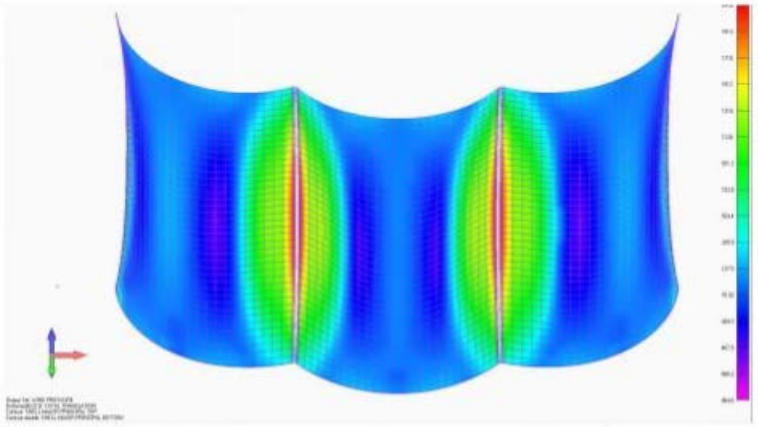
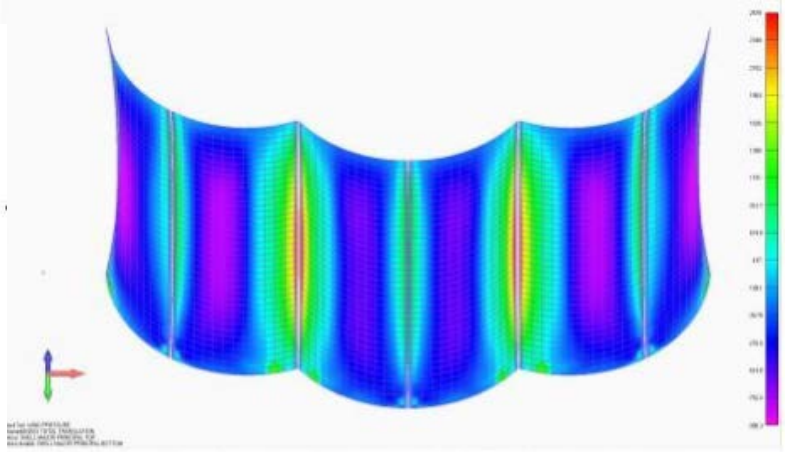
EMBODIED ENERGY/ TROMBE WALL HEAT RECYCLING



Structural analysis of 50 psf windload on conventional 5' x 15' units shows mullions are required to take wind load in order to limit deflection to acceptable maximum.



Structural analysis of 50 psf windload on 10' x 15' curved lites in Circadian Curtain Wall units shows no mullions are necessary for structural purposes if glass is connected by structural silicone. Aluminum frames are included to provide housing for automated shades, and chassis for anchors and gaskets.



Structural analysis of 50 psf windload on 5' x 15' curved lites in Circadian Curtain Wall units shows no mullions are necessary for structural purposes if glass is connected by structural silicone. The smaller glass is more economical, but there are more joints and seals.

The elimination of 50% of the aluminum, offset by the addition of one layer of glass for the laminated lites, adds up to a savings, for approximately 300K sf of skin, of 3,645 tons of embodied CO_2.

Embodied CO_2

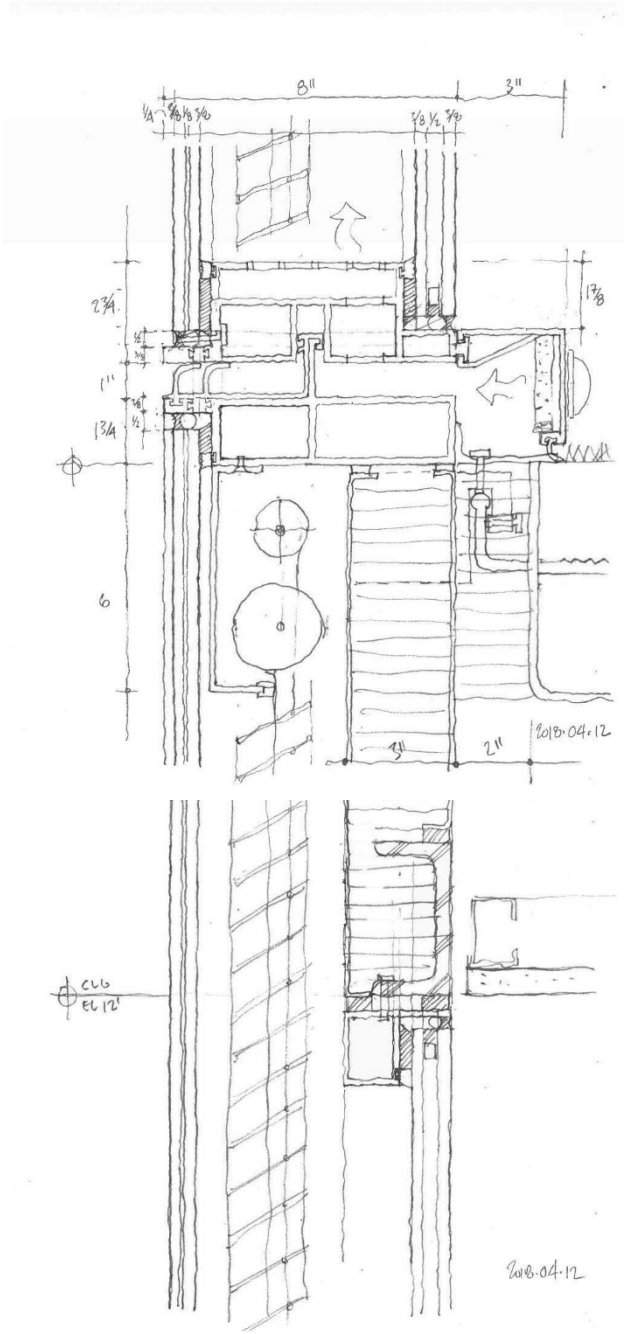
Saving **3,600** tons of embodied CO_2 equals:

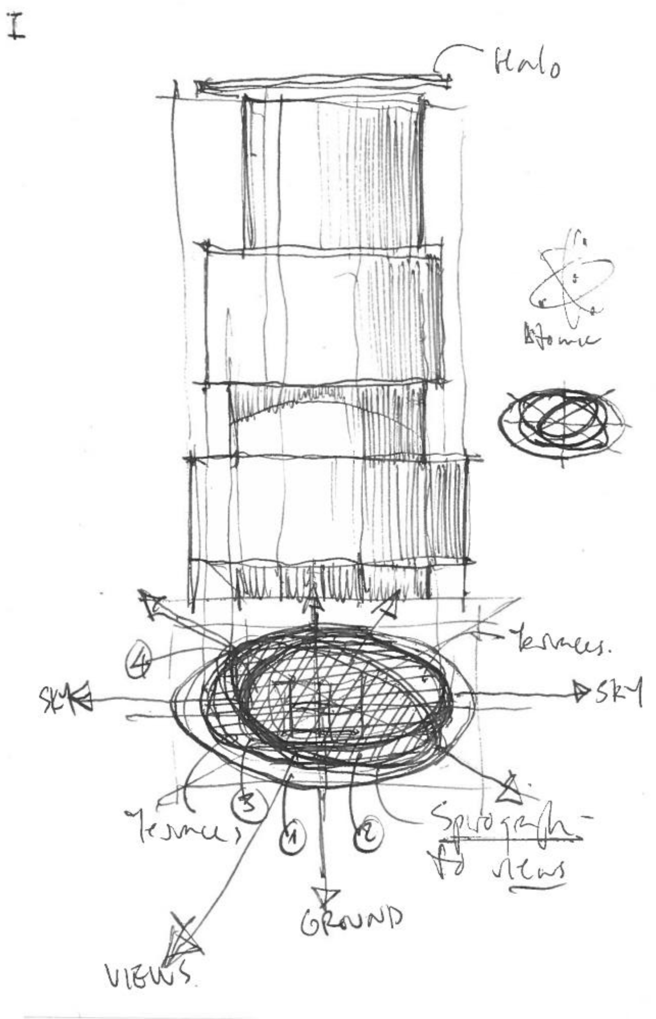
- the output of burning 1260 tons of coal, **enough to heat about 300 homes** for a year
- Taking **760 cars off the road** for a year
- The amount of CO_2 that **17,490 trees** absorb in a year

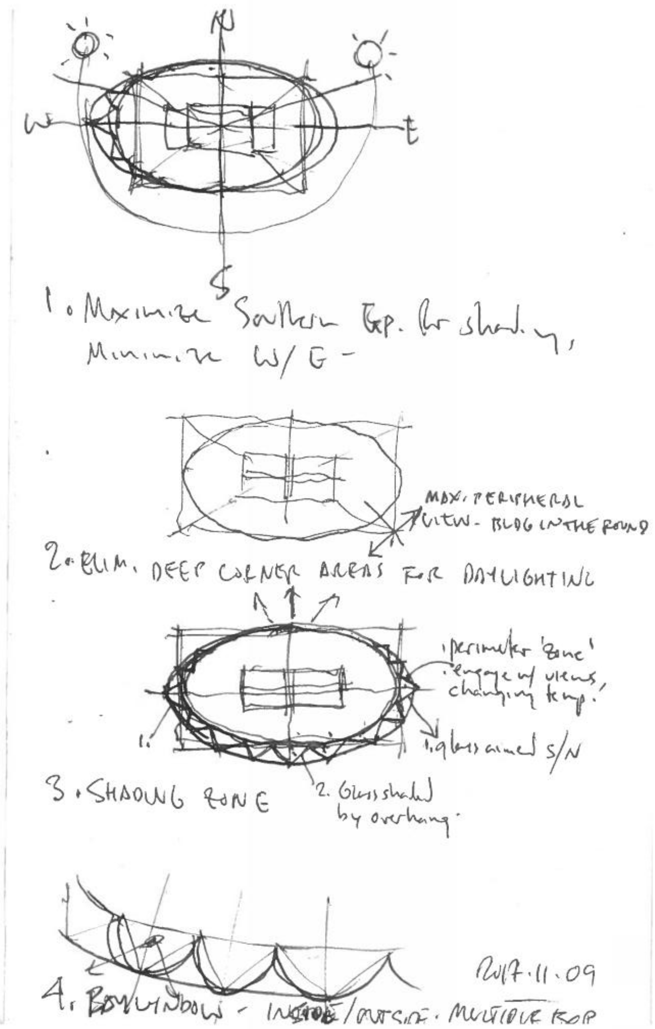
A given square-foot of average exterior then saves approximately 3 pounds of aluminum and costs 3 pounds of glass. On a per-ton basis, Glass costs .9 tons of CO_2 equivalent compared to 9 tons for Aluminum.

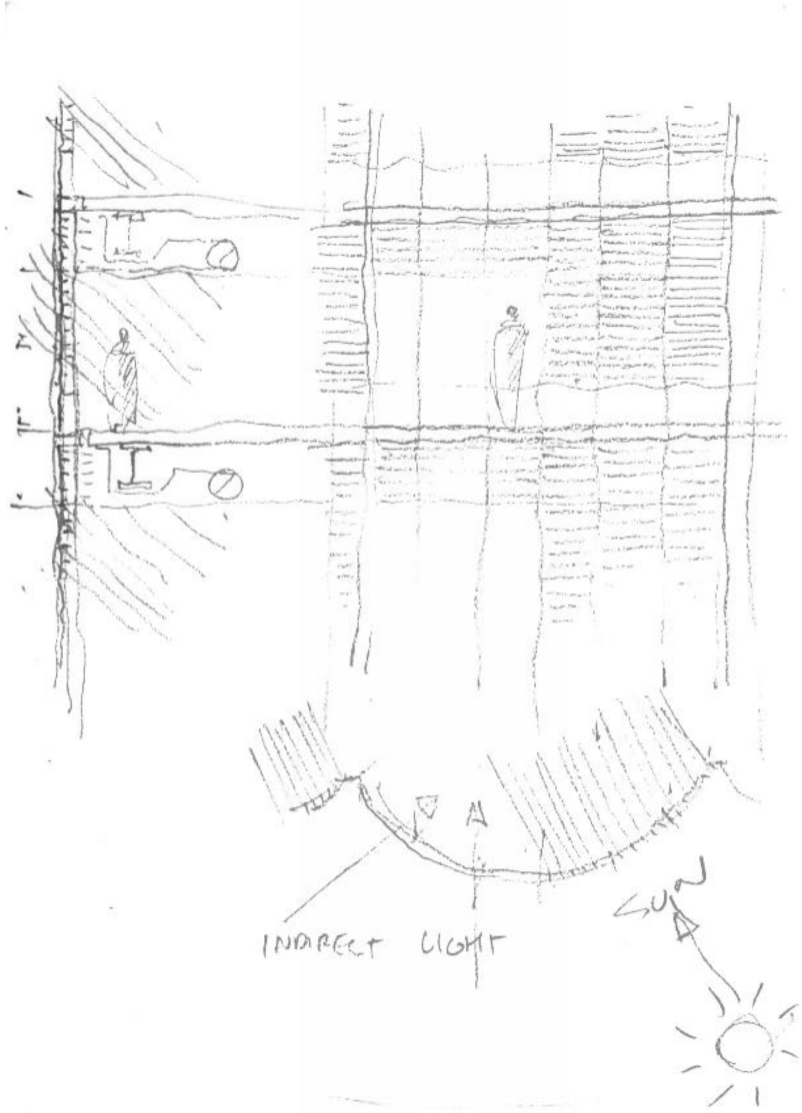
With approximately 300K sf of skin, this tower then could save appr. 3500 tons of embodied energy in CO_2 equivalent compared to the base case building.

(300K x 3 x 9= 8,100,000 lbs CO saved, minus 300K x 3 x .9 = 810,000 lbs CO added, ttl= 7,290,000 lbs CO_2 saved (3,645 tons embodied CO_2). Source- ICE Database, U. of Bath.




Halo
Atomic
Terraces
SKY
SKY
Terraces
Spirograph
views
GROUND
VIEWS


N
W
E
S
2. ELIM. DEEP CORNER AREAS FOR DAYLIGHTING
MAX. PERIPHERAL VIEW - BLDG IN THE ROUND
3. SHADING ZONE
2. Glass shaded by overhang
2017.11.09

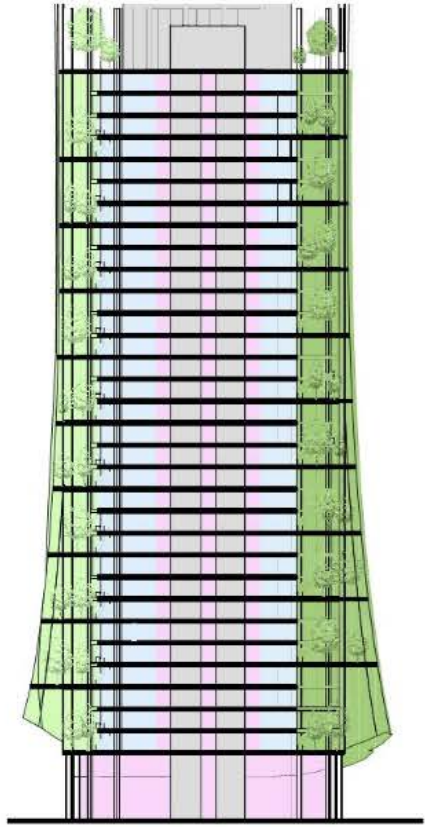

INDIRECT LIGHT
SUN

CIRCADIAN CURTAIN WALL

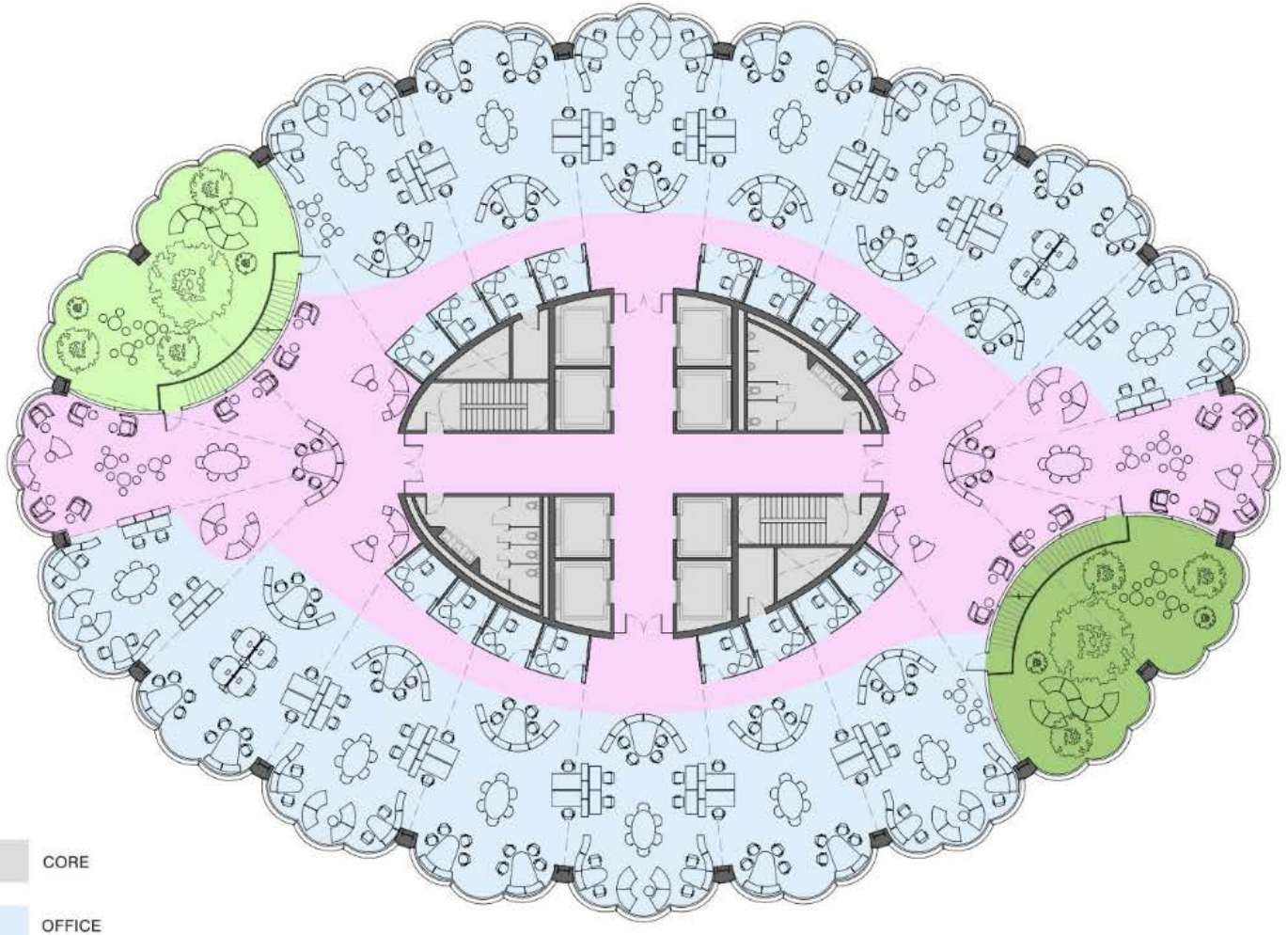
PLAN & SECTION

The 3-lobe cluster defines a space scaled to the most effective group size for creative collaboration. Almost every point on the floor can see the two atria, providing polar orientation.

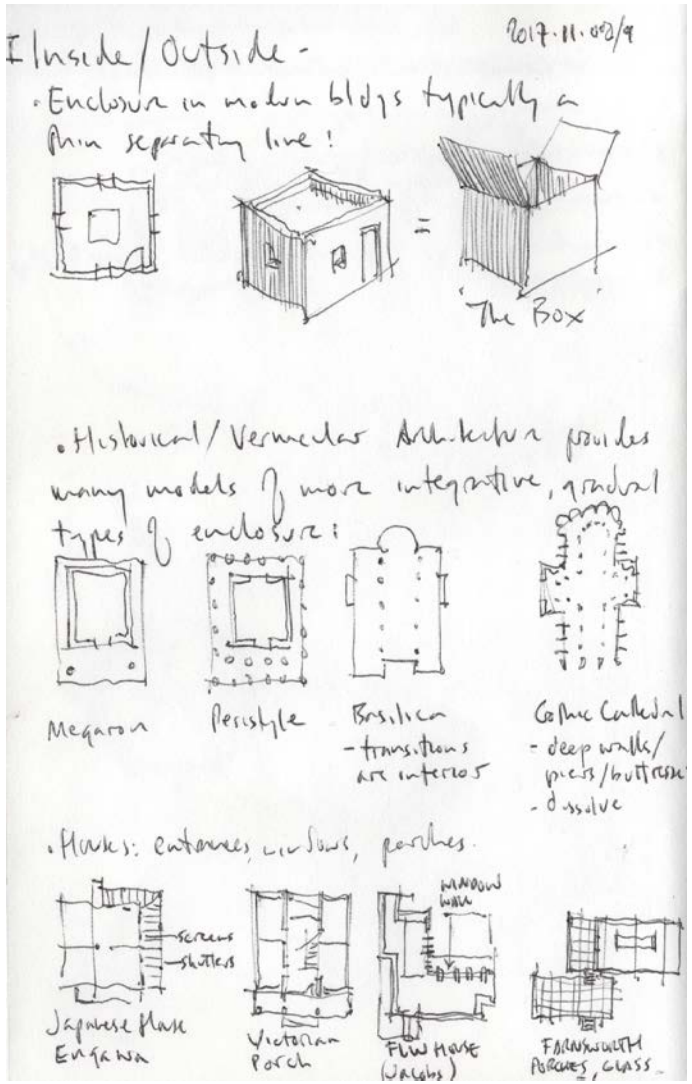
The North and South Atria bring the outside inward. The Atria provide gardens connecting to the roof, with rejuvenating plants, fresh air and water features.



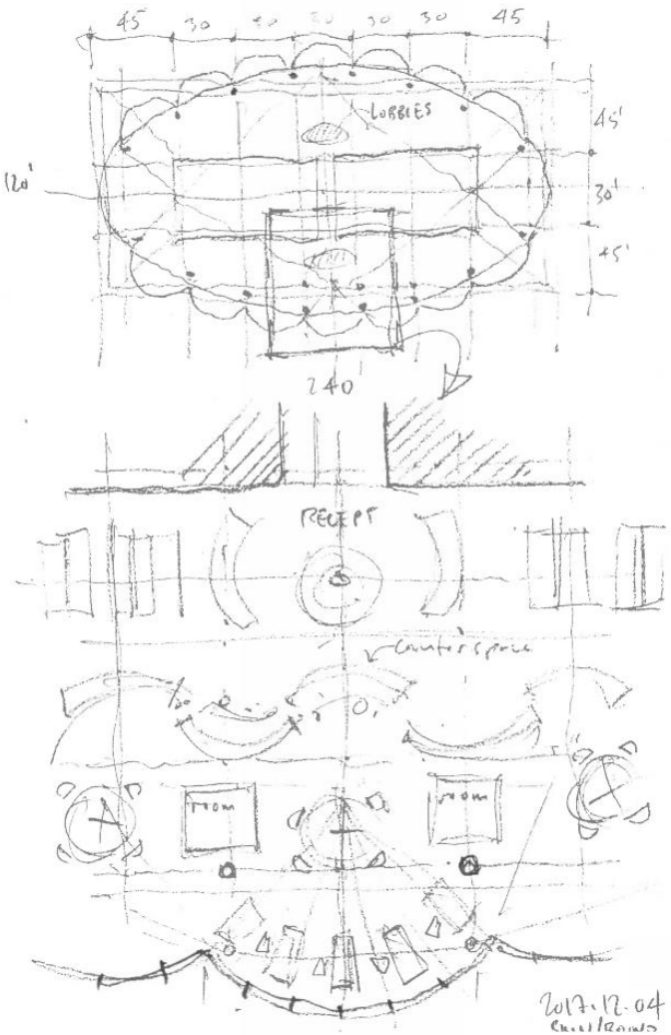
S-N SECTION



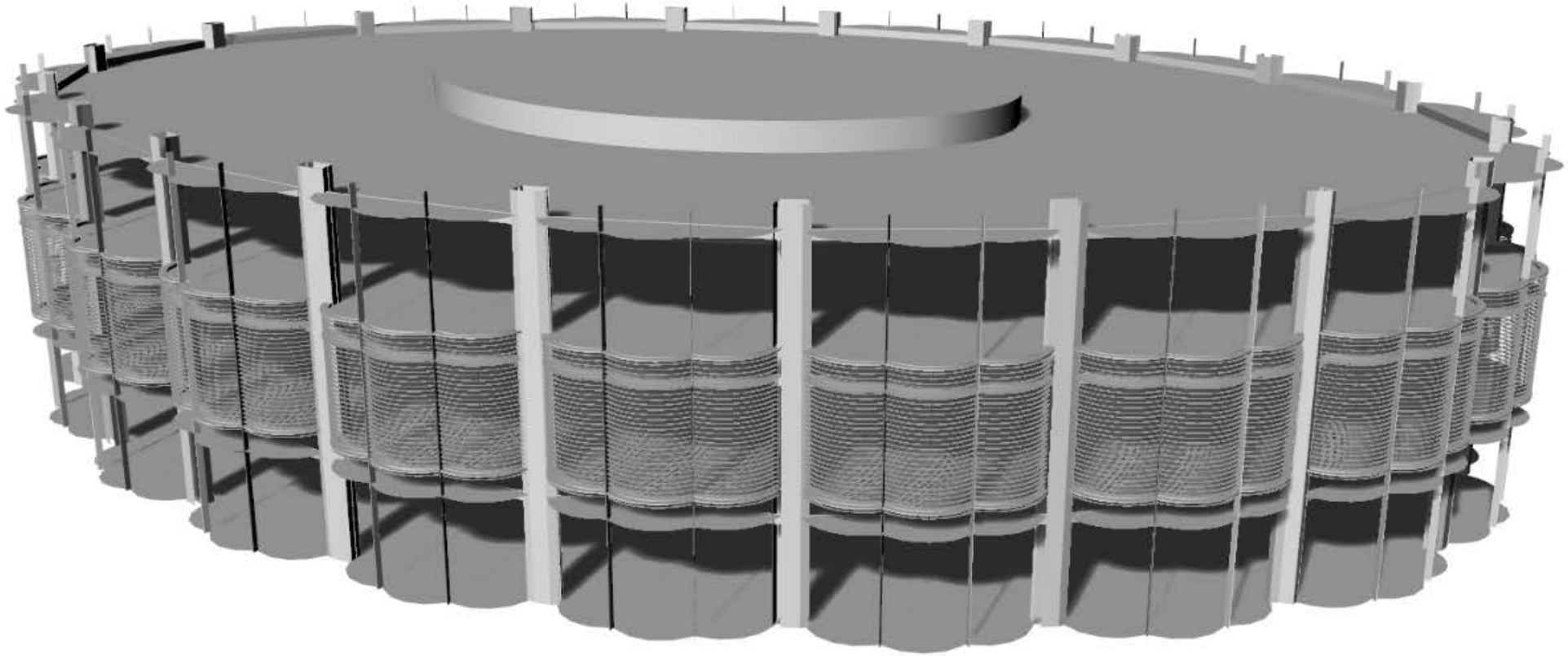
TYPICAL FLOOR PLAN


I Inside / Outside -
2017.11.03/9
• Enclosure in modern bldgs typically a thin separating line!
=
'The Box'
• Historical / Vernacular Architecture provides many models of more integrative, gradual types of enclosure:
Megaron
Peristyle
Basilica
- transitions are interior
Gothic Cathedral
- deep walls/ piers/buttress
- dissolve
• Hooks: entrances, windows, porches
screens
shutters
Japanese Plank Engawa
Victorian Porch
WINDOW WALL
FLW House (Wasmuth)
FARNSWORTH PORCHES, GLASS

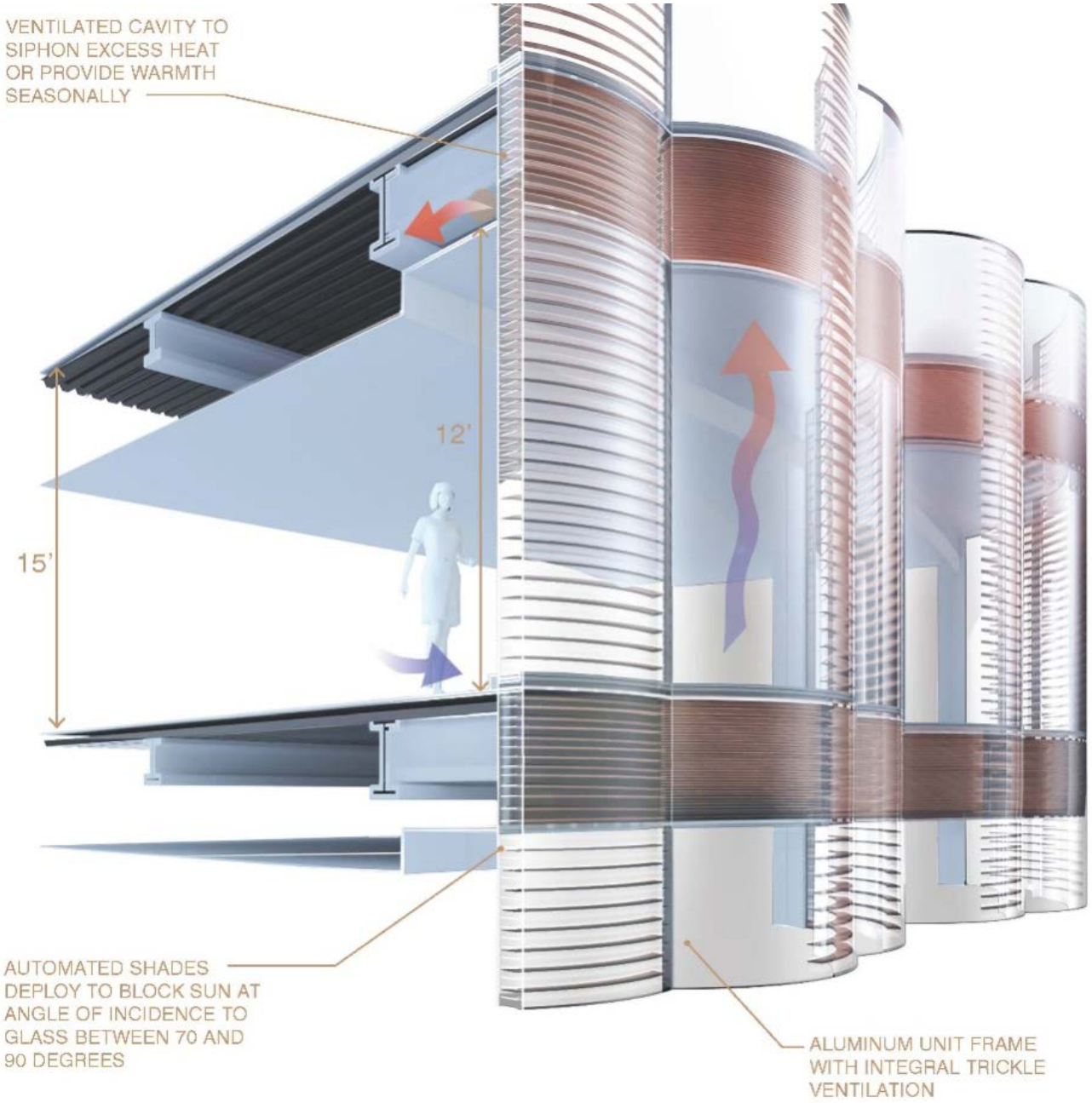

• Conventional FLAT FACADE
• View is defined by the Picture Plane of the Curtain Wall, and by the Mullion
• SHADE EITHER ALL OR NOTHING
• First High Rise buildgs seemed to recognize this, incorporating the BAY WINDOW of the Chicago School
SHADE IS DIRECTIONAL

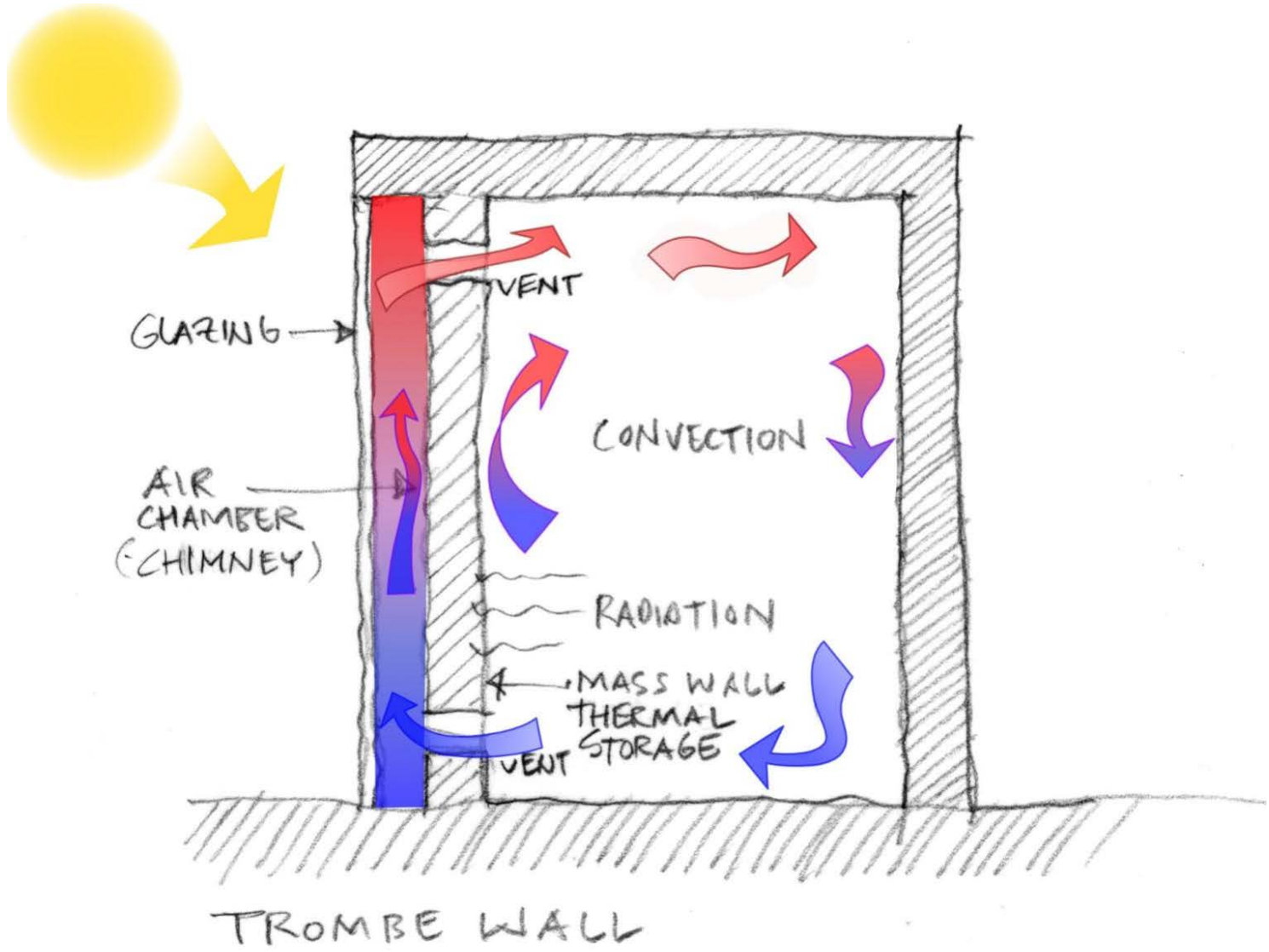

45
30
30
30
30
30
45
LOBBIES
45'
30'
45'
120'
240
RECEPT
counterspace
room
room
2017.12.04

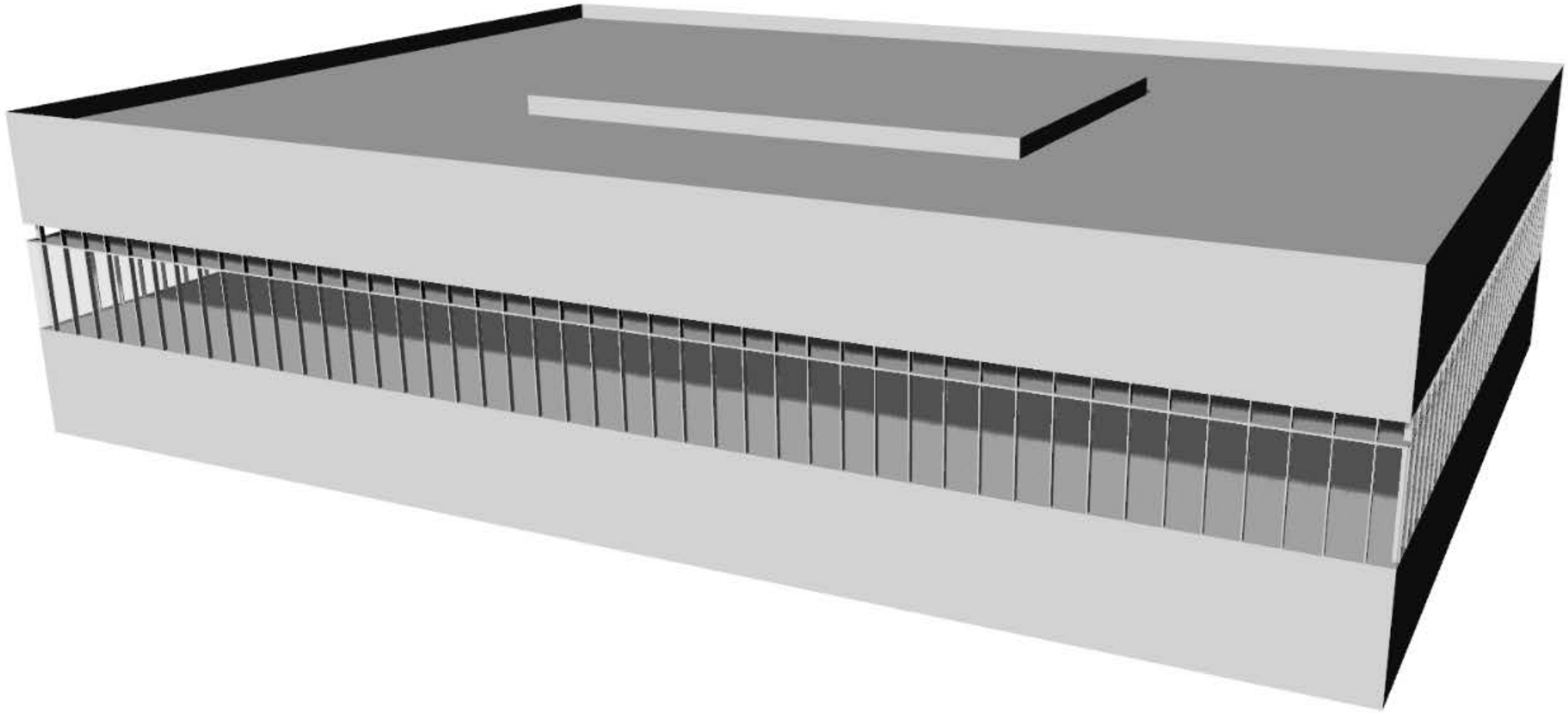
ANALYSIS



Dynamic Shade Operation → Daylight Analysis (Radiance) → Energy Analysis (Energy+)


VENTILATED CAVITY TO SIPHON EXCESS HEAT OR PROVIDE WARMTH SEASONALLY
12'
15'
AUTOMATED SHADES DEPLOY TO BLOCK SUN AT ANGLE OF INCIDENCE TO GLASS BETWEEN 70 AND 90 DEGREES
ALUMINUM UNIT FRAME WITH INTEGRAL TRICKLE VENTILATION


VENT
GLAZING
CONVECTION
AIR
CHAMBER
(CHIMNEY)
RADIATION
MASS WALL
THERMAL
STORAGE
VENT
TROMBE WALL



RHINO

- Model Geometry
- Zoning and Lighting Groups

GRASSHOPPER

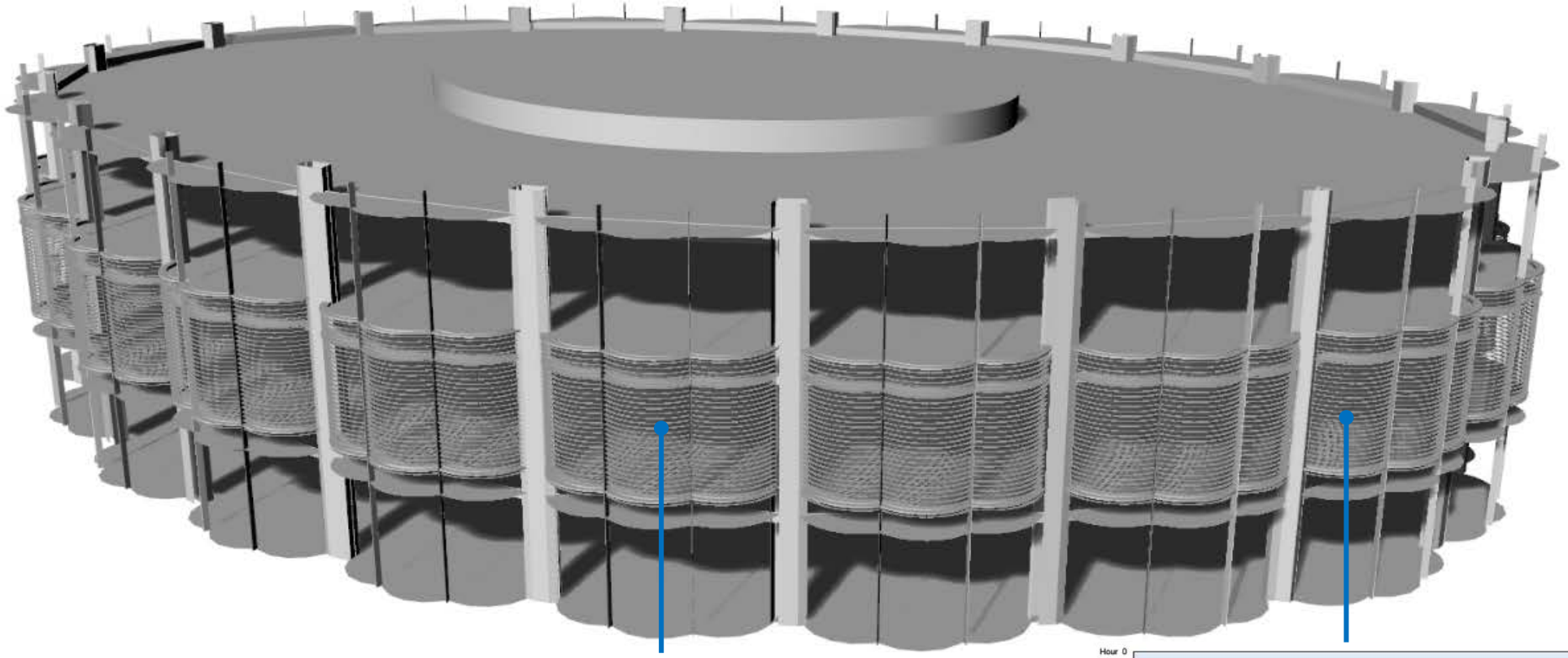
- Thermal and Optical Parameters
- Dynamic Blind Operation
- Post Processing, Results, and Visualization

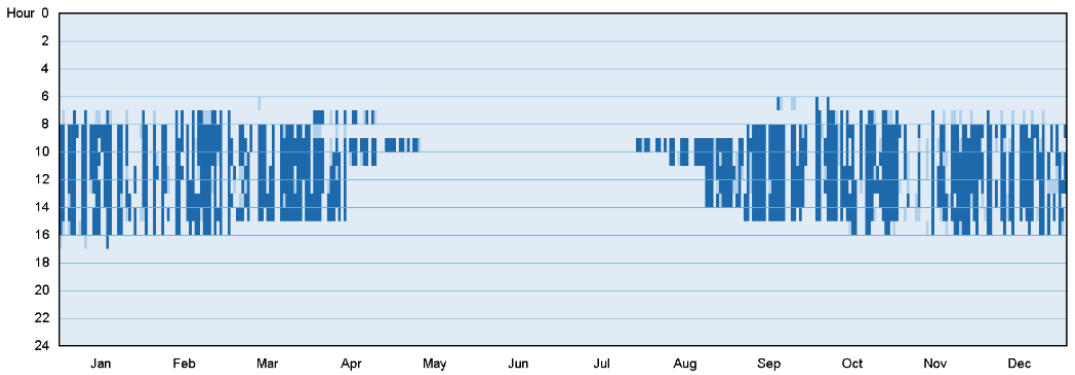
DIVA

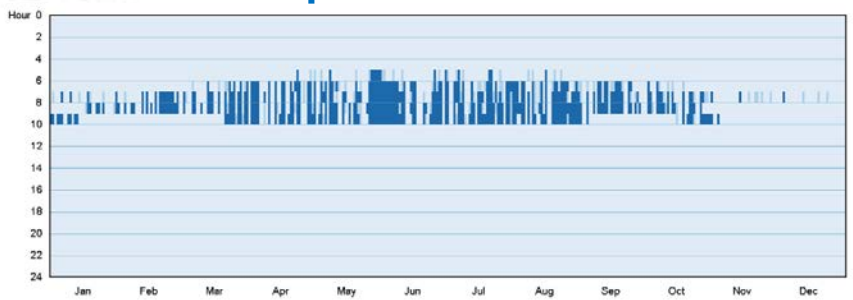
- Annual Daylight Simulation

HONEYBEE

- Energy/Hourly Load Simulation




Hour 0
2
4
6
8
10
12
14
16
18
20
22
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Hour 0
2
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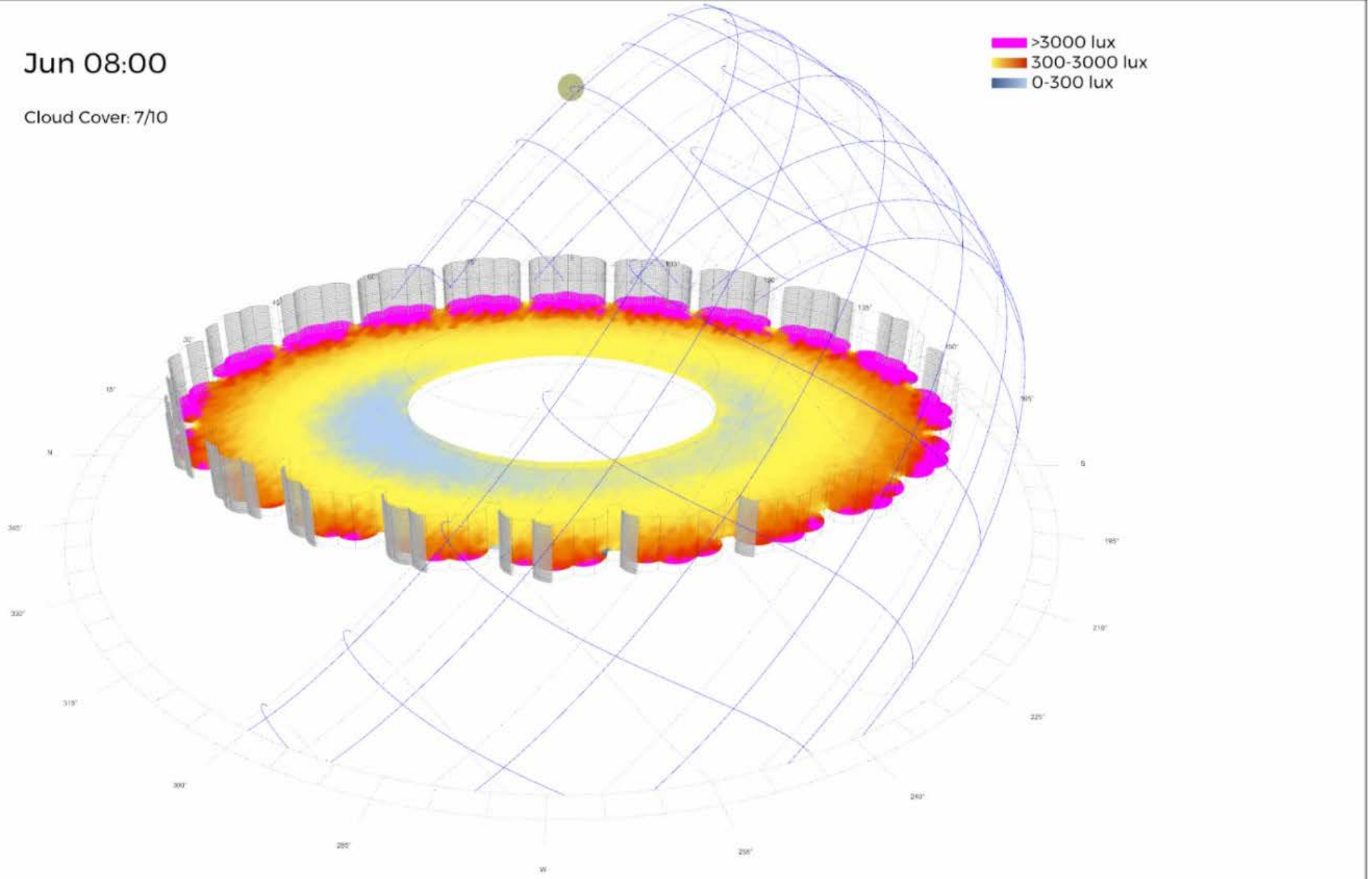
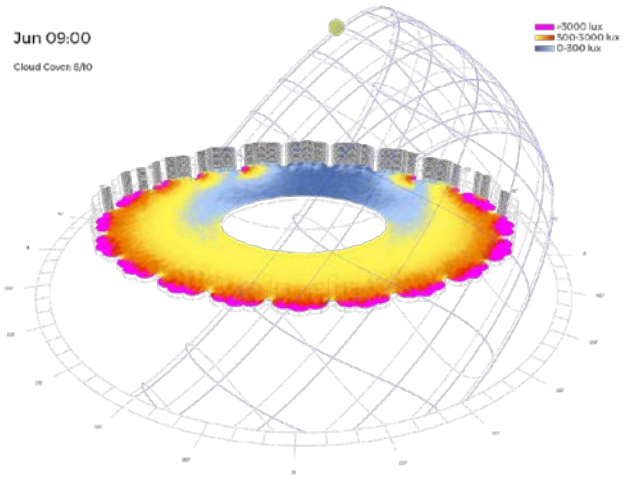
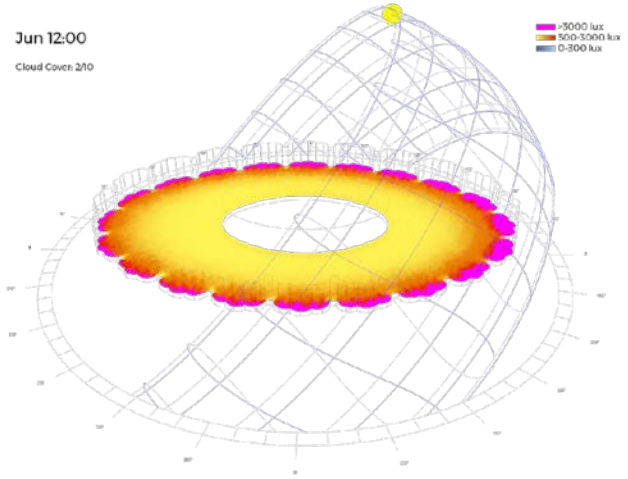
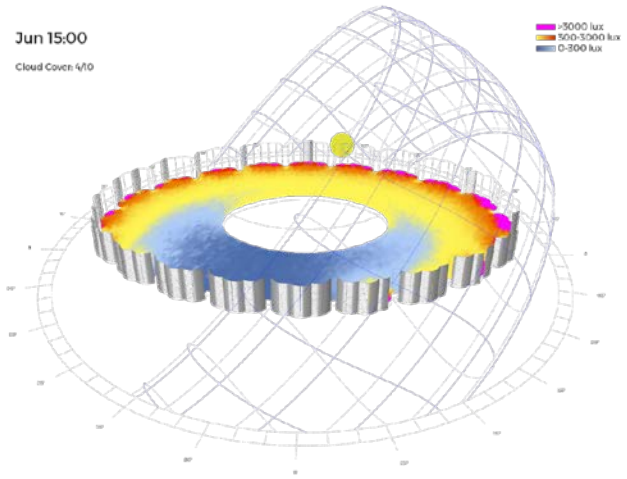
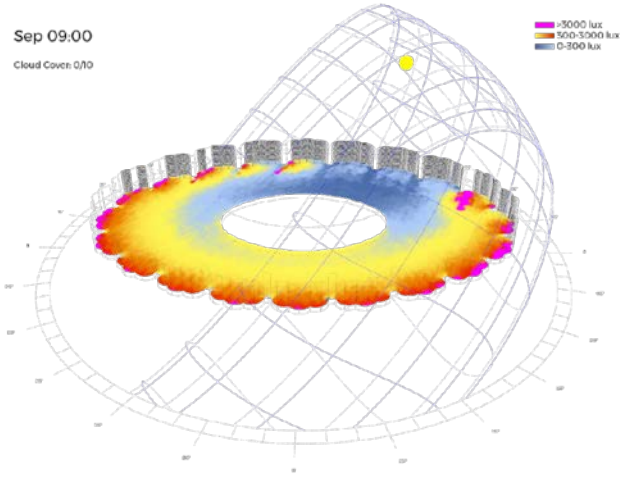
Dec

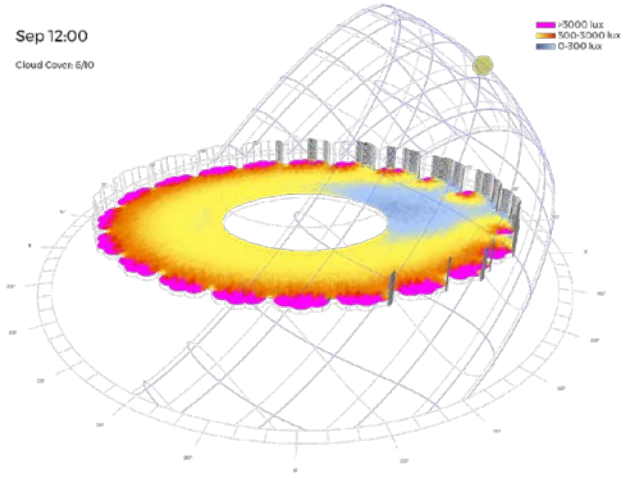

Jun 08:00
Cloud Cover: 7/10
>3000 lux
300-3000 lux
0-300 lux

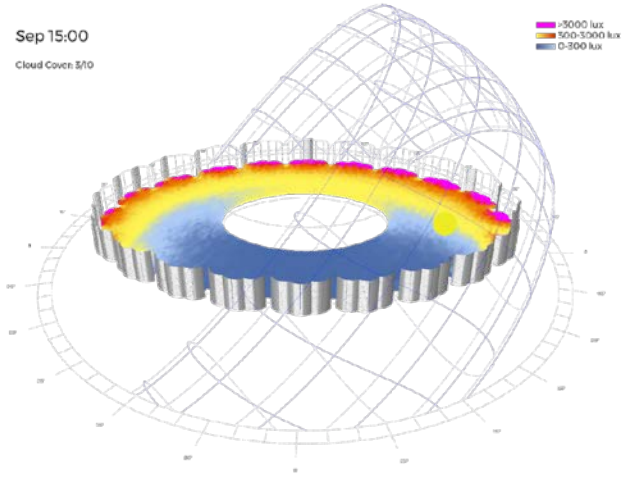

Jun 09:00
Cloud Cover: 6/10
>3000 lux
500-3000 lux
0-300 lux

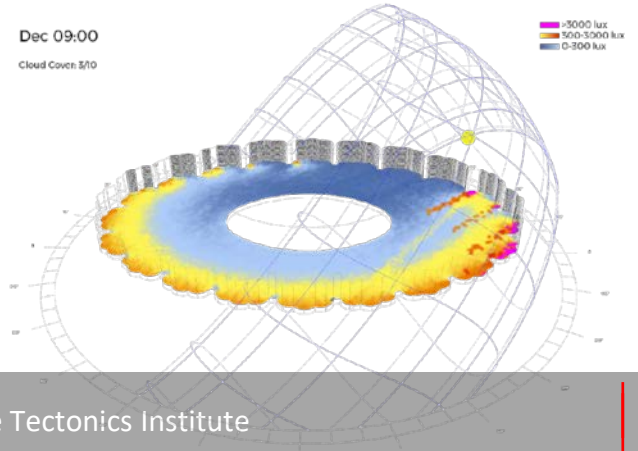

Jun 12:00
Cloud Cover: 2/10
>3000 lux
500-3000 lux
0-300 lux

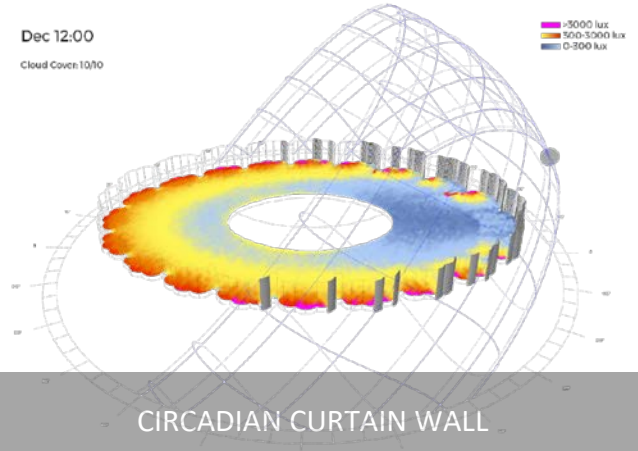

Jun 15:00
Cloud Cover: 4/10
>3000 lux
500-3000 lux
0-300 lux

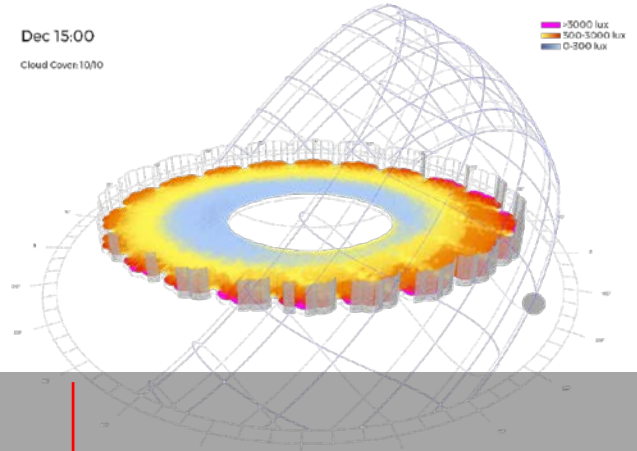

Sep 09:00
Cloud Cover: 0/10
>3000 lux
500-3000 lux
0-300 lux

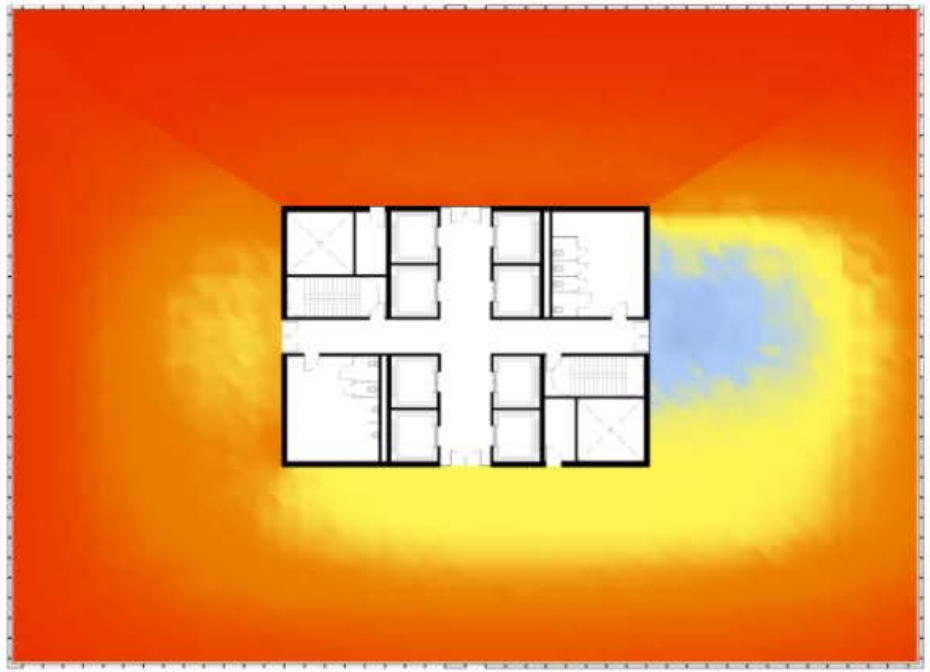

Sep 12:00
Cloud Cover: 6/10
>3000 lux
500-3000 lux
0-300 lux


Sep 15:00
Cloud Cover: 5/10
>3000 lux
500-3000 lux
0-300 lux


Dec 09:00
Cloud Cover: 3/10
>3000 lux
500-3000 lux
0-300 lux


Dec 12:00
Cloud Cover: 10/10
>3000 lux
500-3000 lux
0-300 lux


Dec 15:00
Cloud Cover: 10/10
>3000 lux
500-3000 lux
0-300 lux



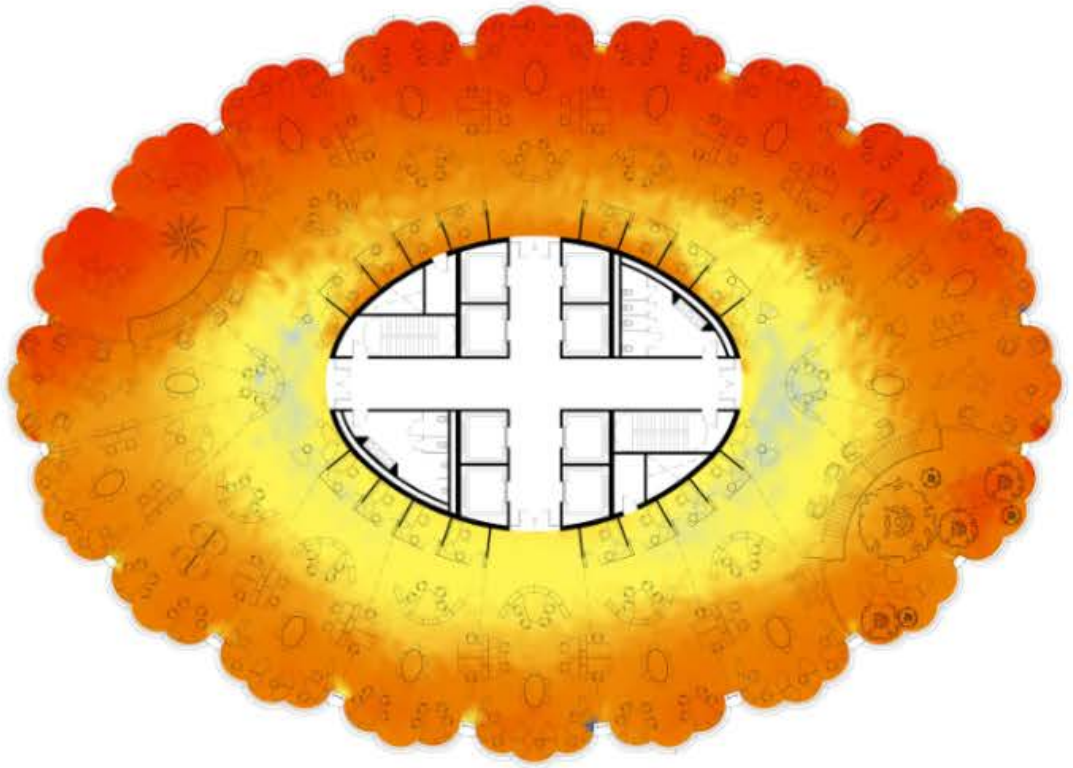
sDA: 88.88%
ASE: 42.2%

N

Daylight Autonomy
>300 lux

100%

0%



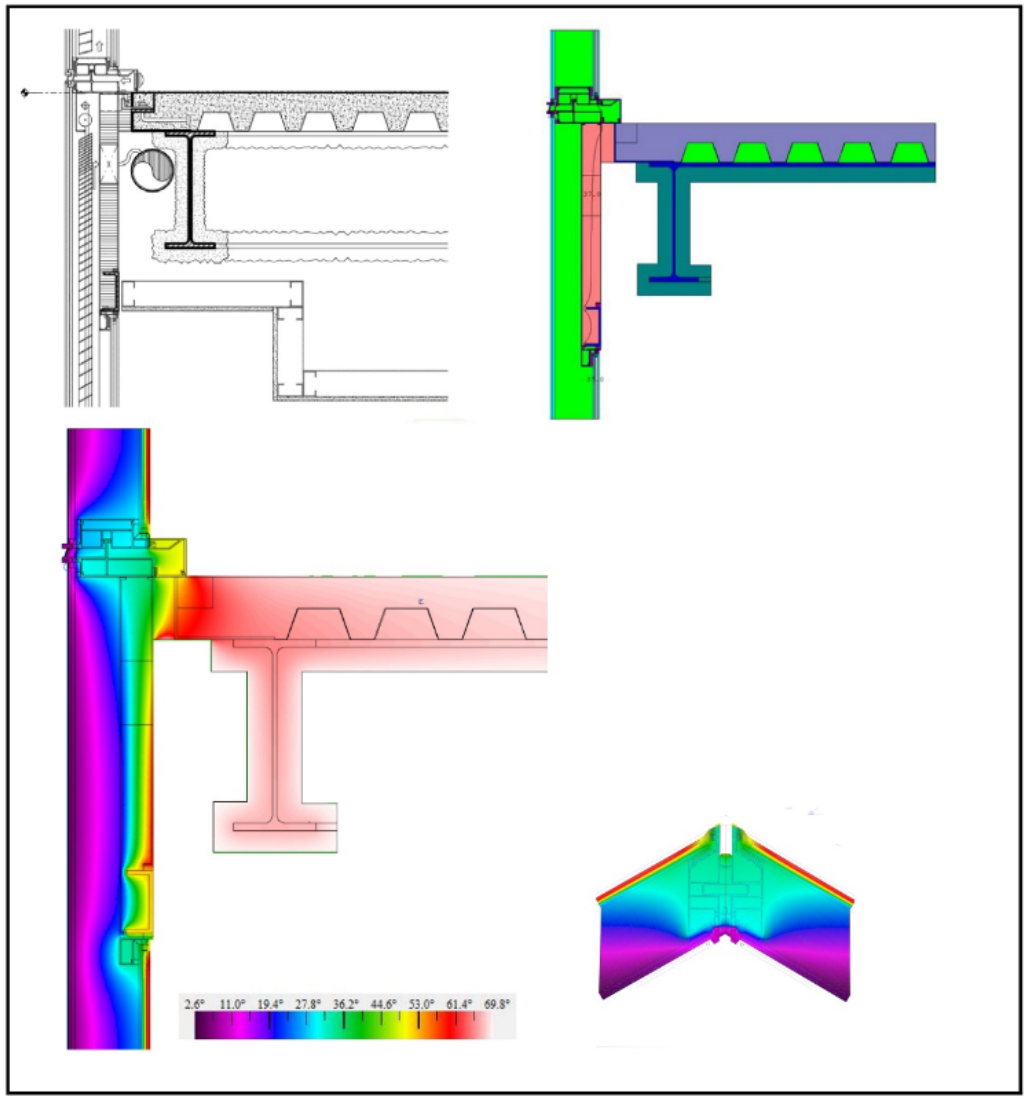
sDA: 89.7%
ASE: N/A (Automatic Blinds)

N

Daylight Autonomy
>300 lux

100%

0%



rtain Wall - Therm Analysis

Material assumptions:

1. Aluminum (Oxidized, Mill Finish) - Aluminum Mullion Sections
2. Steel (Rolled, Ground) - Steel sections
2. Silicone (All silicone fillings, gaskets and structural silicone)
3. Polyethylene (Low Density) - Backer Rod
4. Polyamide with 25% Glass Fiber - Thermal Break
5. Stainless Steel (Buffed) with sillica gel (dessciant) glass spacer.PIB layers at the edges.
6. Mineral Wool - Insulation

Boundary Conditions:

1. NFRC 100-2000 Exterior - All glass exterior and frame exterior (Approx. 0 deg F)
2. Window 7.4 generated Inside U-value film - Glass Interior (70 deg F)

43 Interior Thermally Broken Frame (Convection only) - Frame Interior (70 deg F)

Glass Construction (using Window 7.4):

1/4" (6mm) Solarban 72 on Starphire #2
1/2" (13.2mm) airspace Argon Gas Filled
1/4" (6mm) Starphire

Dew Point:

37 Deg F

Area Calculations			
A	Assembly Height (center line dimensions)	12.00	ft
B	Assembly Width (center line dimensions)	10.00	ft
C	Total Assembly Area (A*B)	120.00	sq.ft
D	Frame Width(Edge of glass to center line)	0.25	ft
E	Vertical Frame Length (A - D)	11.75	ft
F	Horizontal Frame Length (B - D)	9.75	ft
G	Vertical Frame Area (2*E*D)	5.88	sq. ft.
H	Horizontal Frame Area (2*F*D)	4.88	sq. ft.
I	Total Glazing Height (A-2*D)	11.50	ft
J	Total Glazing Width (B-2*D)	9.50	ft
		109.25	
K	Edge of Glass Width	0.21	ft
L	Vertical Edge of Glass Length (I - K)	11.29	ft
M	Horizontal Edge of Glass Length (J - K)	9.29	ft
N	Vertical Edge Area (2*L*K)	4.74	sq. ft.
O	Horizontal Edge Area (2*M*K)	3.90	sq. ft.
P	Core Glass Height (I - 2*K)	11.08	ft
Q	Core Glass Width (J - 2*K)	9.08	ft
R	Core Glass Area(P*Q)	100.61	sq. ft.

U-Value Calculations			
a	Center of Glass	0.24	Btu/hr-ft2-F
b	Vertical Edge of Glass Panel	0.26	Btu/hr-ft2-F
c	Horizontal Edge of Glass Panel	0.25	Btu/hr-ft2-F
d	Vertical Frame	0.45	Btu/hr-ft2-F
e	Horizontal Frame	0.45	Btu/hr-ft2-F

U_Assembly = [(R*a) + {(N*b)+(O*c)} + {(G*d) + (H*e)}] / C

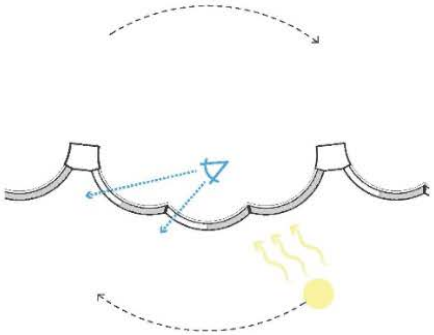
U_Assembly = 0.27 BTU/hr-ft2-F

- Therm model of 10’ wide unit, overall U of .27 is about 25% lower than typical well-performing unitized curtain wall.

16%
ENERGY SAVINGS OVER CONVENTIONAL BASELINE BUILDING WITH FLAT SINGLE LAYER IGU FACADE

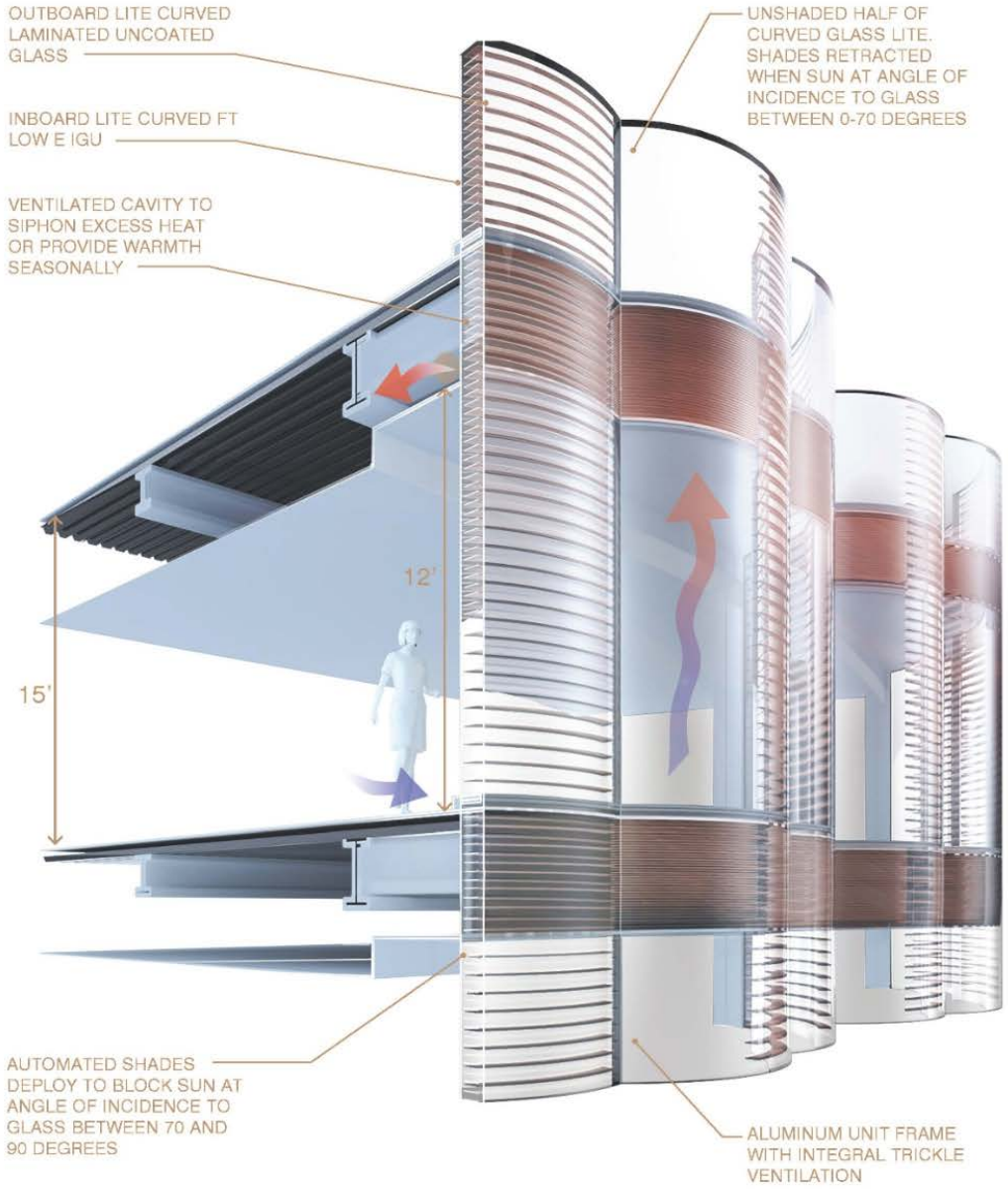
24%
PEAK COOLING LOAD REDUCTION

27%
PEAK HEATING LOAD REDUCTION



PLAN - TYPICAL BAY

SHADES DEPLOY AUTOMATICALLY WITH SUN. CLEAR VISION THROUGH NON-SHADED WINDOWS.

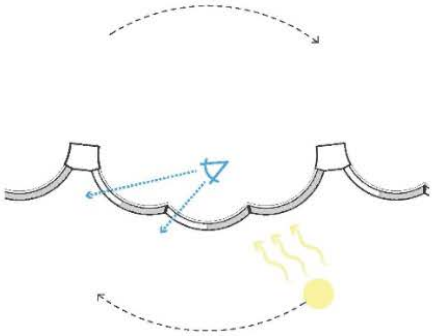


NEXT STEPS

16%
ENERGY SAVINGS OVER CONVENTIONAL BASELINE BUILDING WITH FLAT SINGLE LAYER IGU FACADE

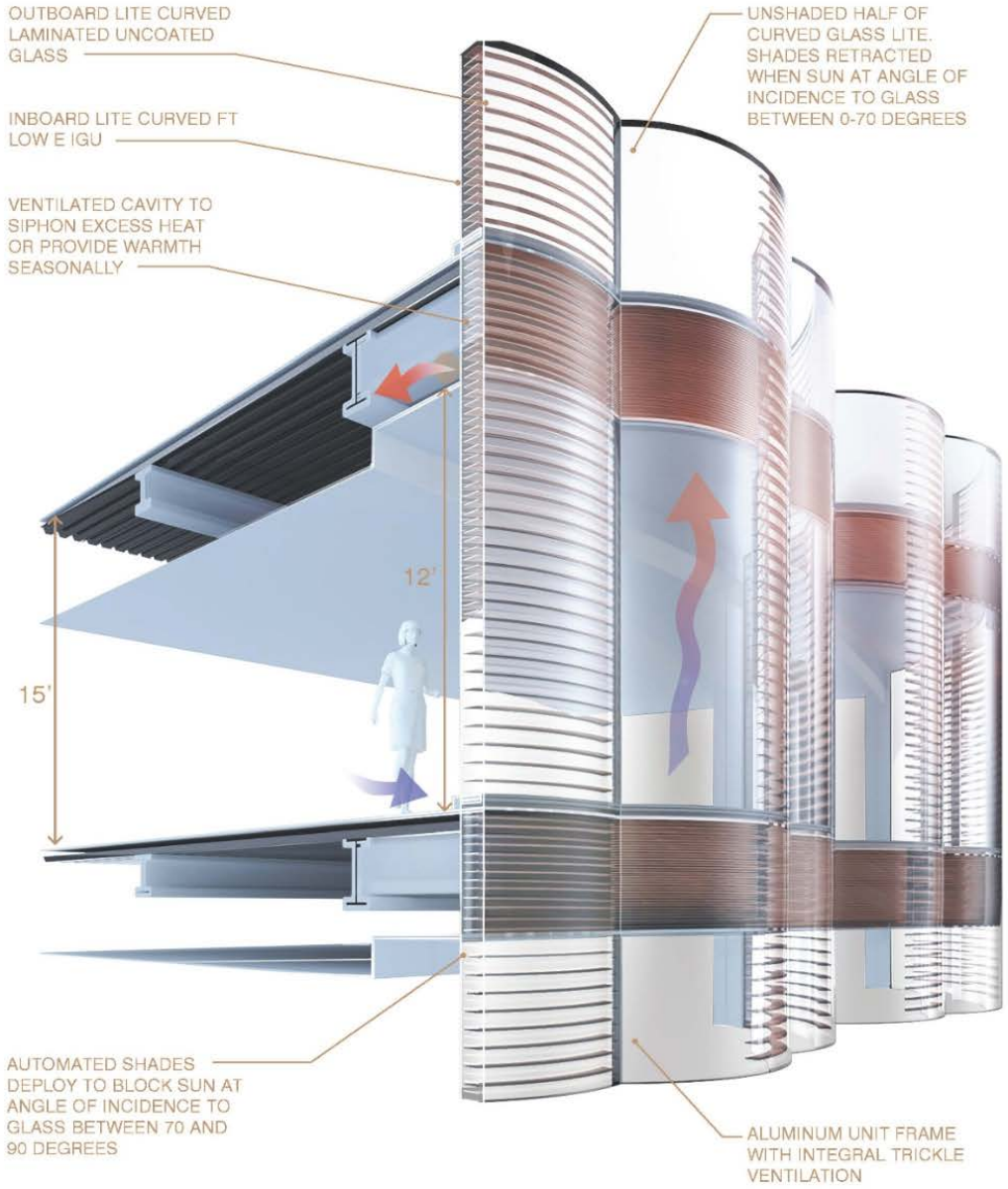
24%
PEAK COOLING LOAD REDUCTION

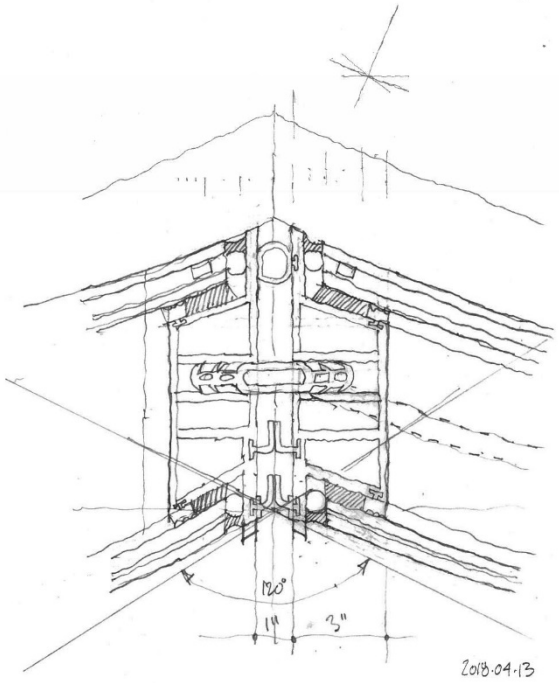
27%
PEAK HEATING LOAD REDUCTION

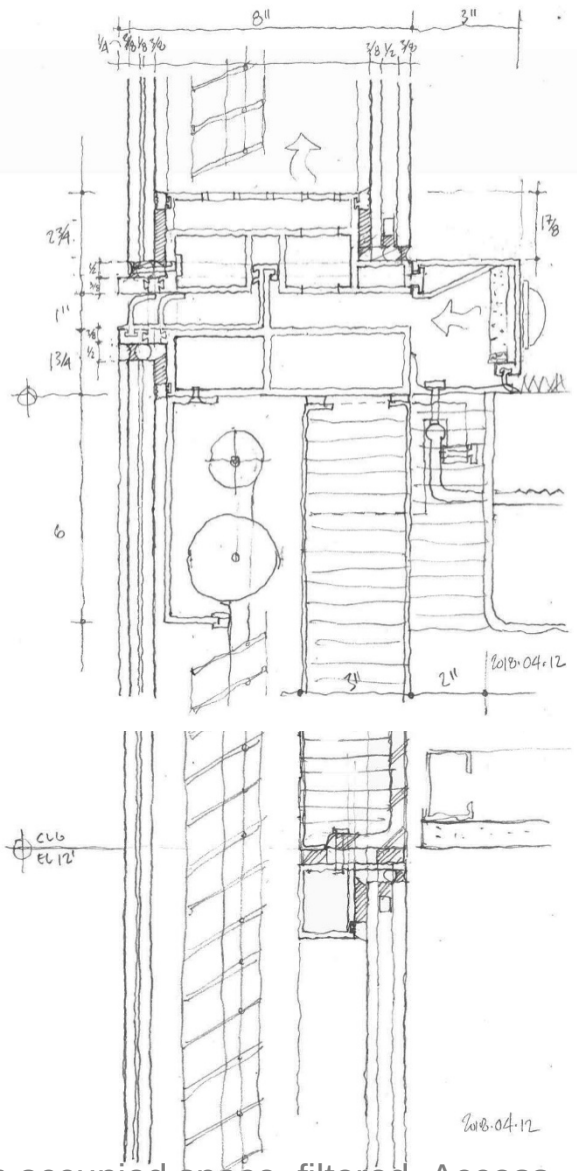


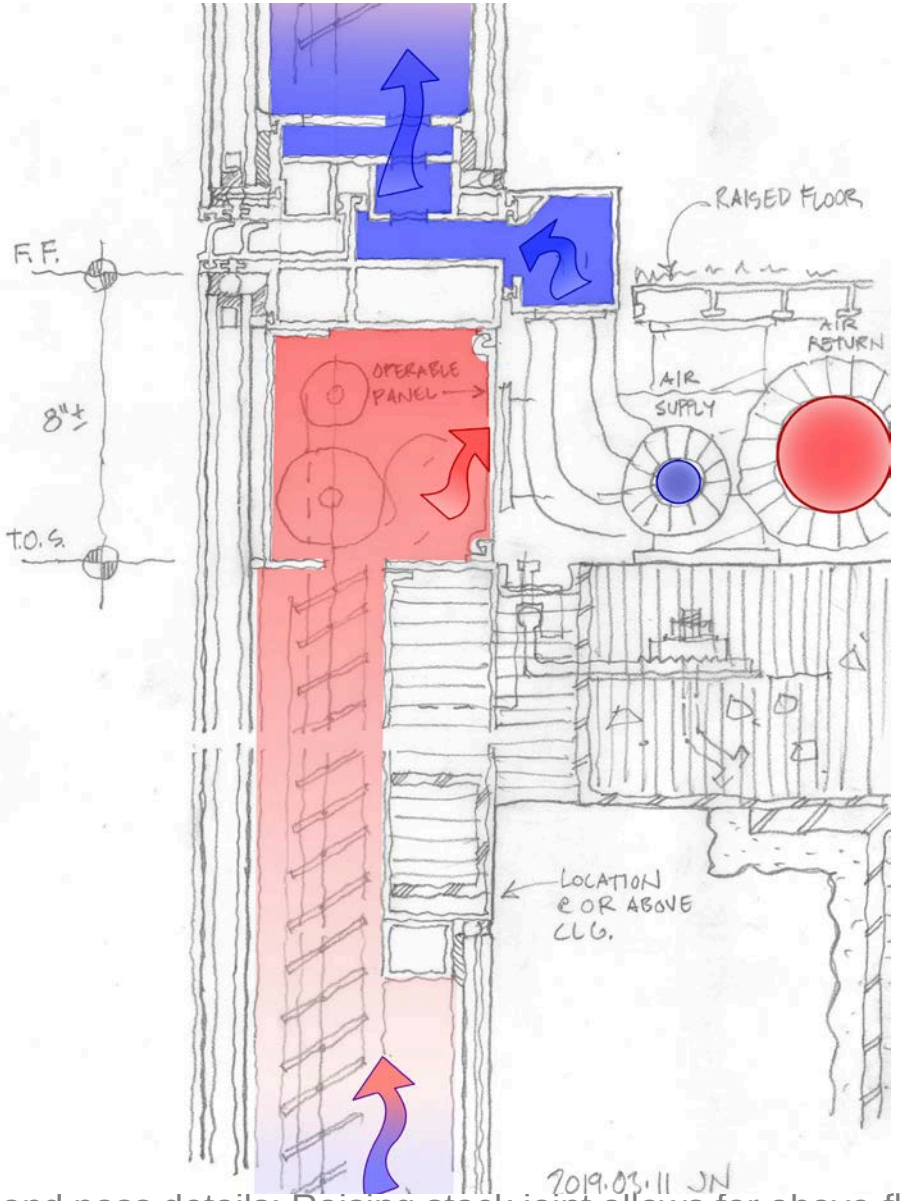
PLAN - TYPICAL BAY

SHADES DEPLOY AUTOMATICALLY WITH SUN. CLEAR VISION THROUGH NON-SHADED WINDOWS.









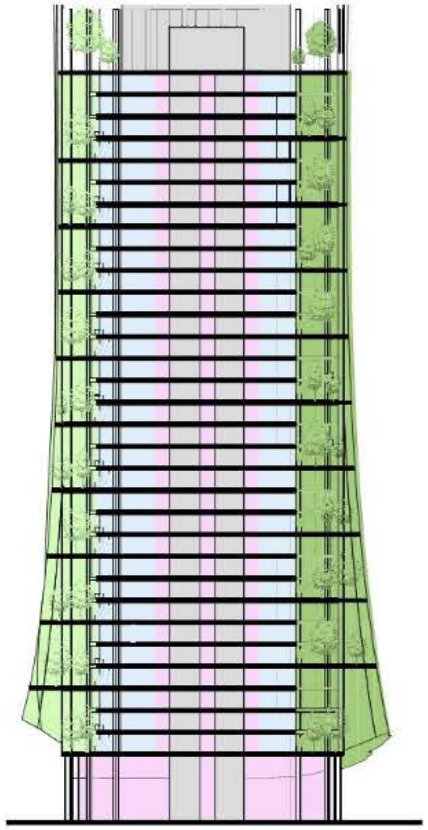
- First pass details: Air circulation from occupied space, filtered. Access to shades an issue.
- Second pass details: Raising stack joint allows for above-floor connections to closed circuit of supply and return air, either in fin-tube-like cover or under raised floor. IGU outboard.

CIRCADIAN CURTAIN WALL

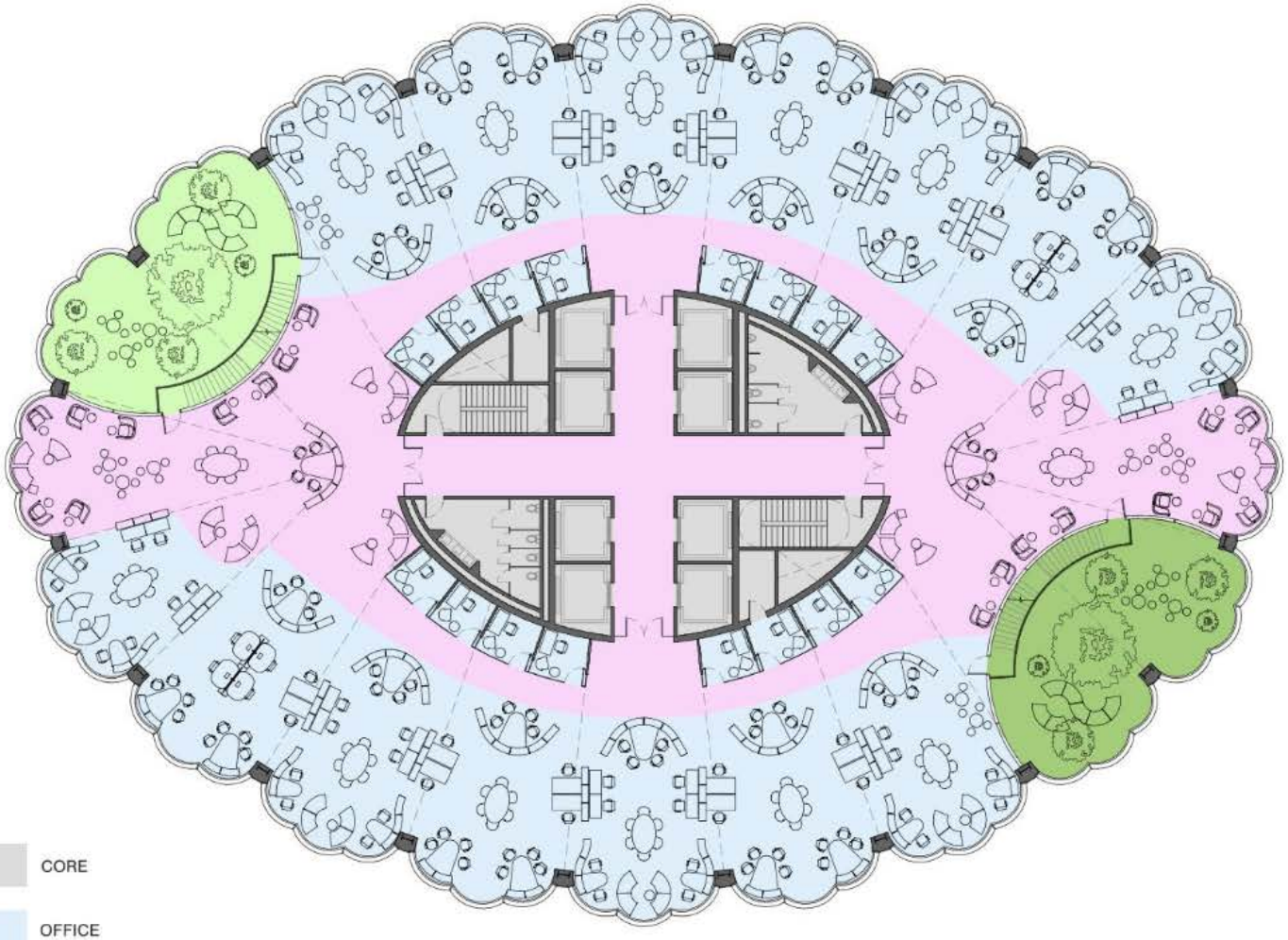
PLAN & SECTION

The 3-lobe cluster defines a space scaled to the most effective group size for creative collaboration. Almost every point on the floor can see the two atria, providing polar orientation.

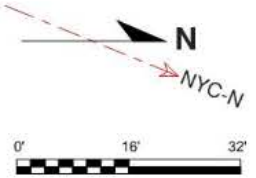
The North and South Atria bring the outside inward. The Atria provide gardens connecting to the roof, with rejuvenating plants, fresh air and water features.

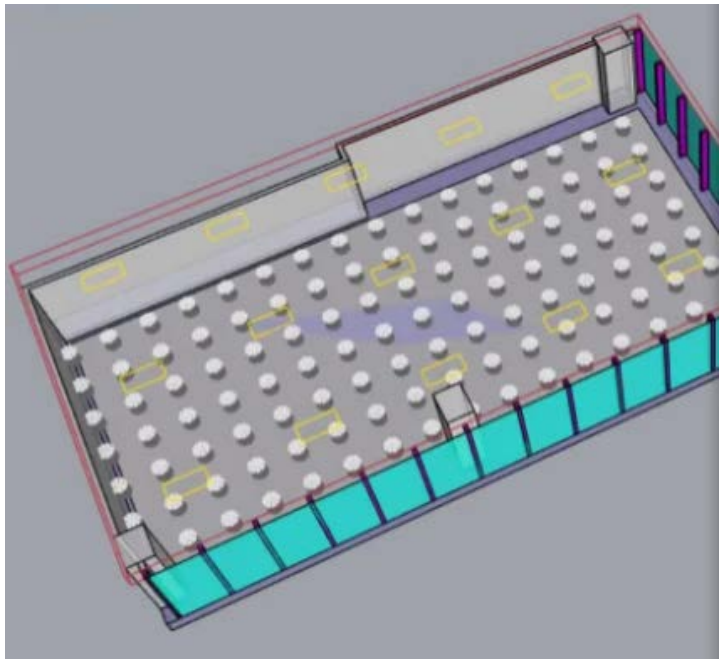


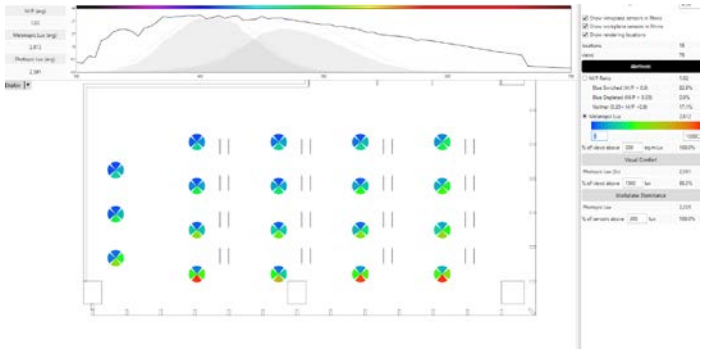
S-N SECTION

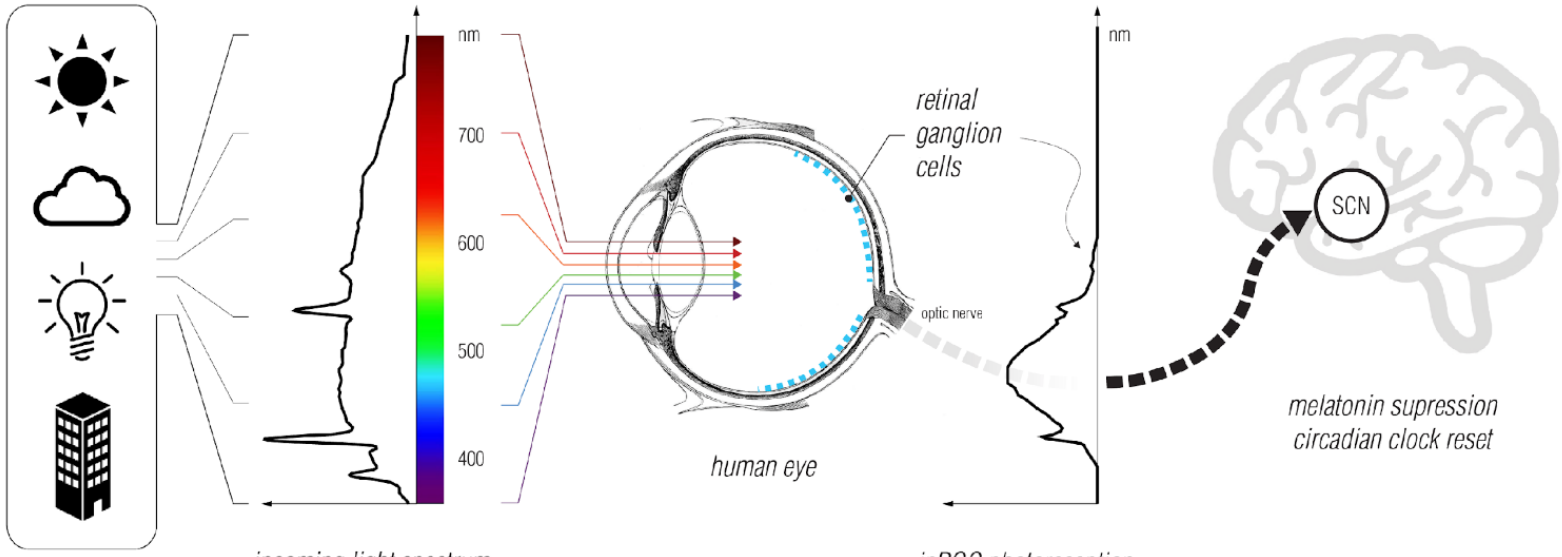


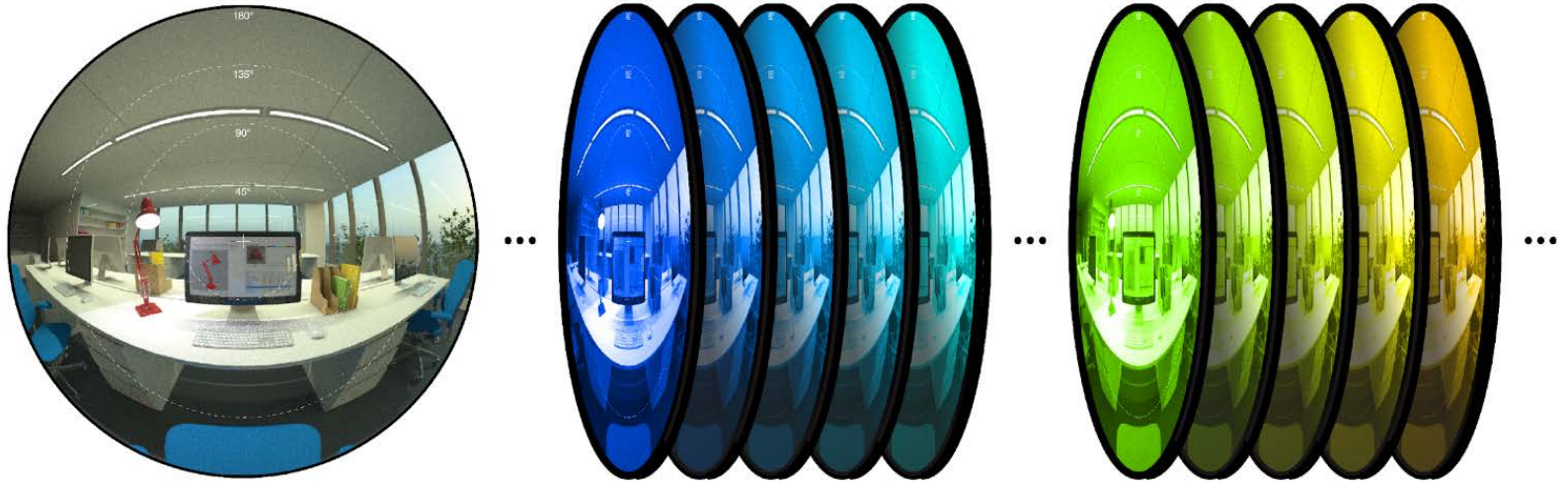
TYPICAL FLOOR PLAN





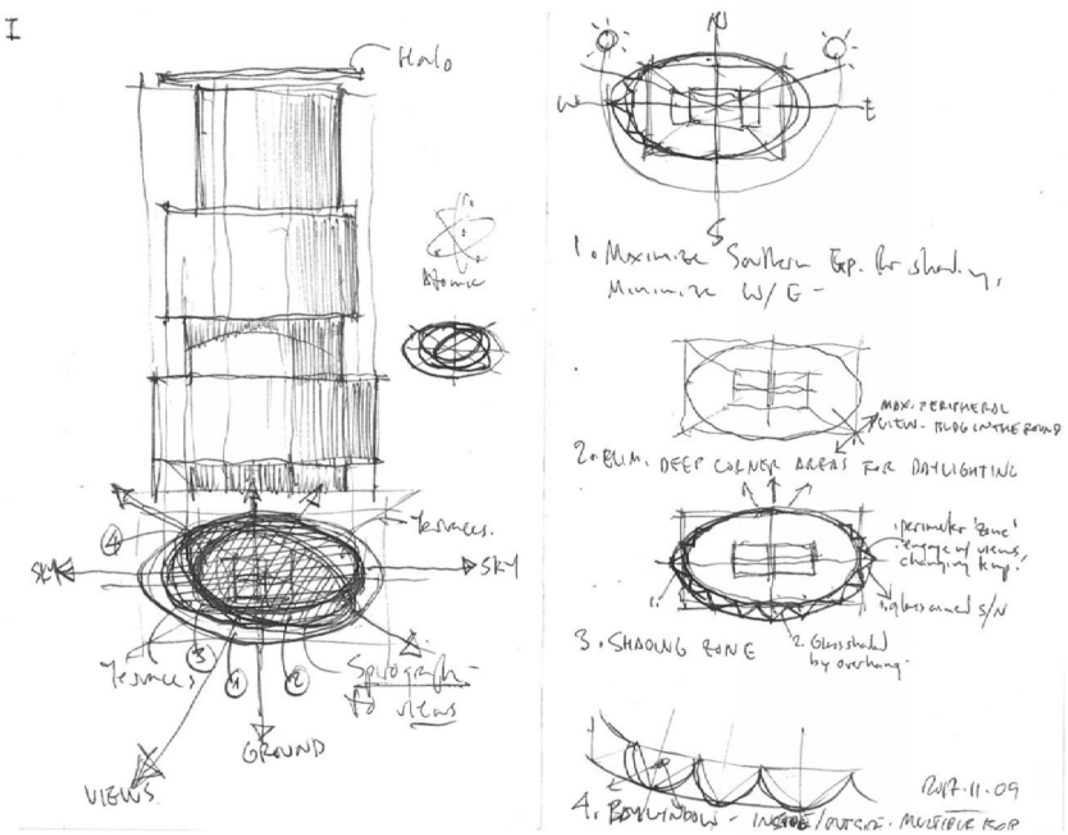


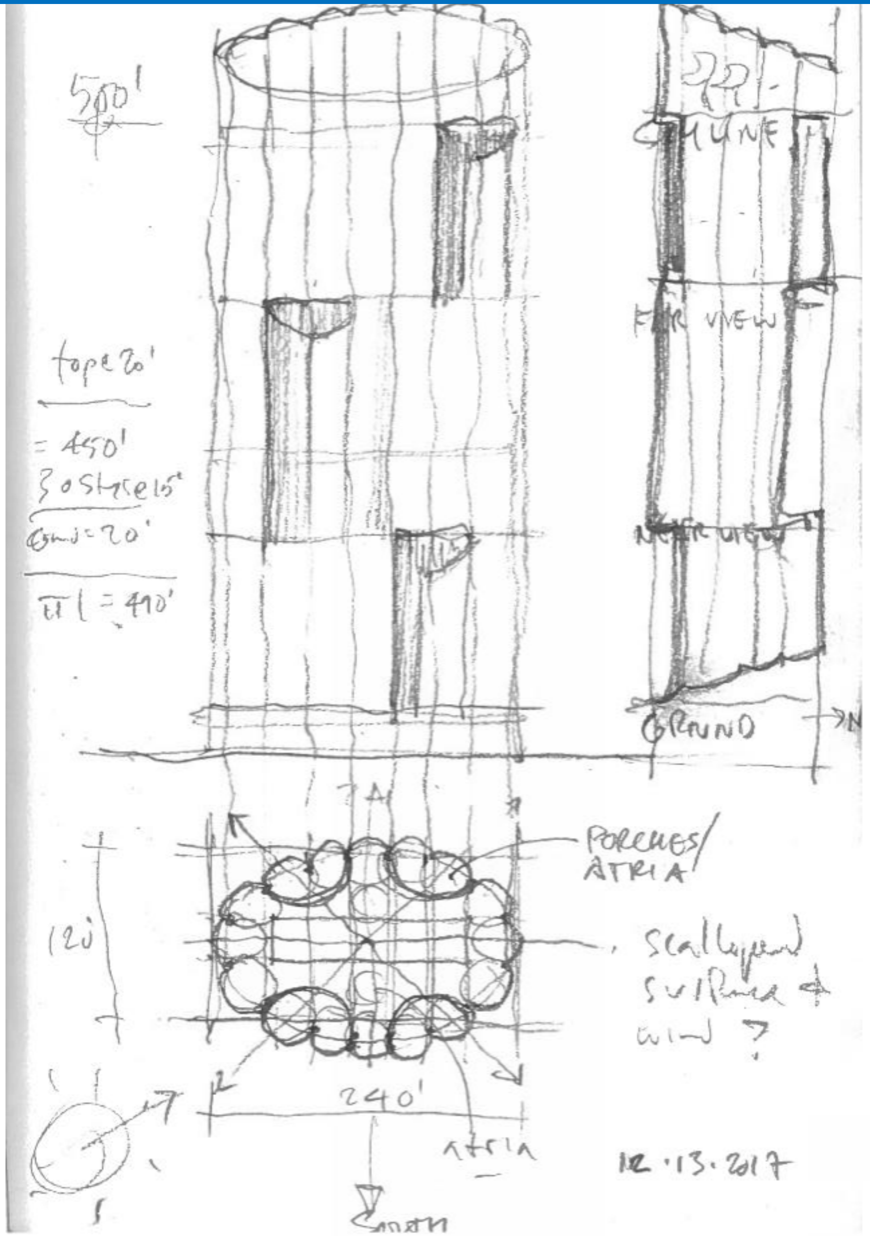


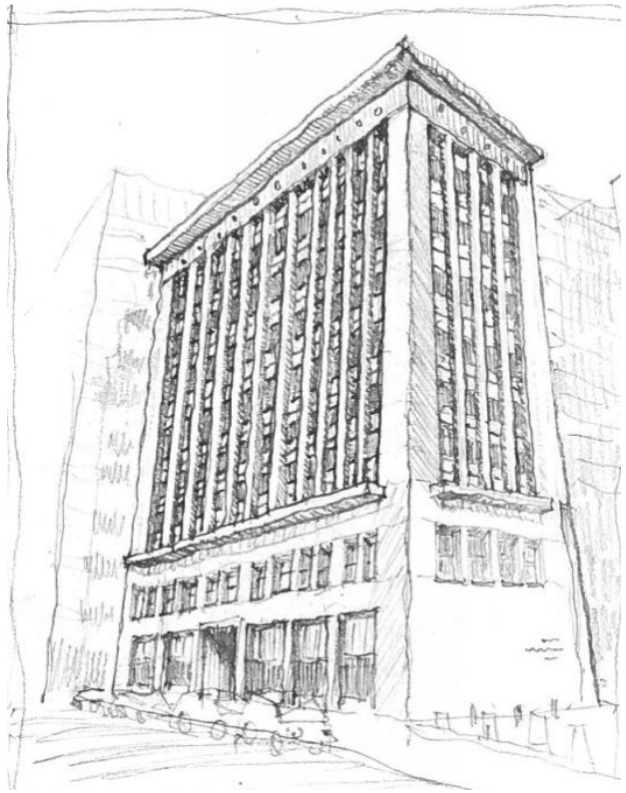


Images Source: Solemma LLC

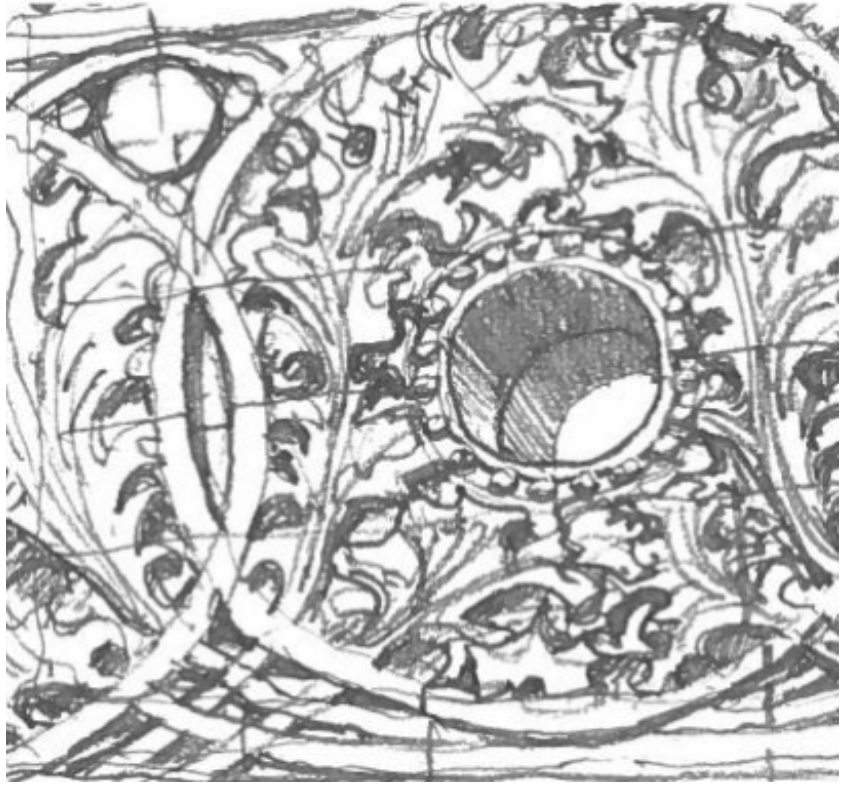
CONCLUSION


Halo
SKY
GROUND
VIEWS
1. Maximize Southern Exp. for shading, Minimize W/E
MAX. PERIPHERAL VIEW - BLDG IN THE ROUND
2. ELIM. DEEP CORNER AREAS FOR DAYLIGHTING
3. SHADING ZONE
2017.11.09


500'
FAR VIEW
NEAR VIEW
GROUND
PORCHES/ ATRIA
120'
240'
12.13.2017



Wainwright Building, L. Sullivan, 1891



Wainwright Building, L. Sullivan, 1891- Detail

Reliance Building, D. Burnham, 1895

VICTOR OLGYAY

IAN McHARG

KEN YEANG

The organic approach to architecture emphasises the relationship of buildings to climate and site, seeking to emulate natural habitat in finding strategies for tempering the extremes of natural conditions.