



J/M²

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Spring 2016 | ARCH 708 MEBD Design Studio
PennDesign | University of Pennsylvania

1 SITE & CLIMATE

Natural Boundary & Resources

2 ENV_DEVELOPMENTS

Environmental Challenges

3 ARCH_PERFORMANCE

Architectural Challenges

// About New Orleans

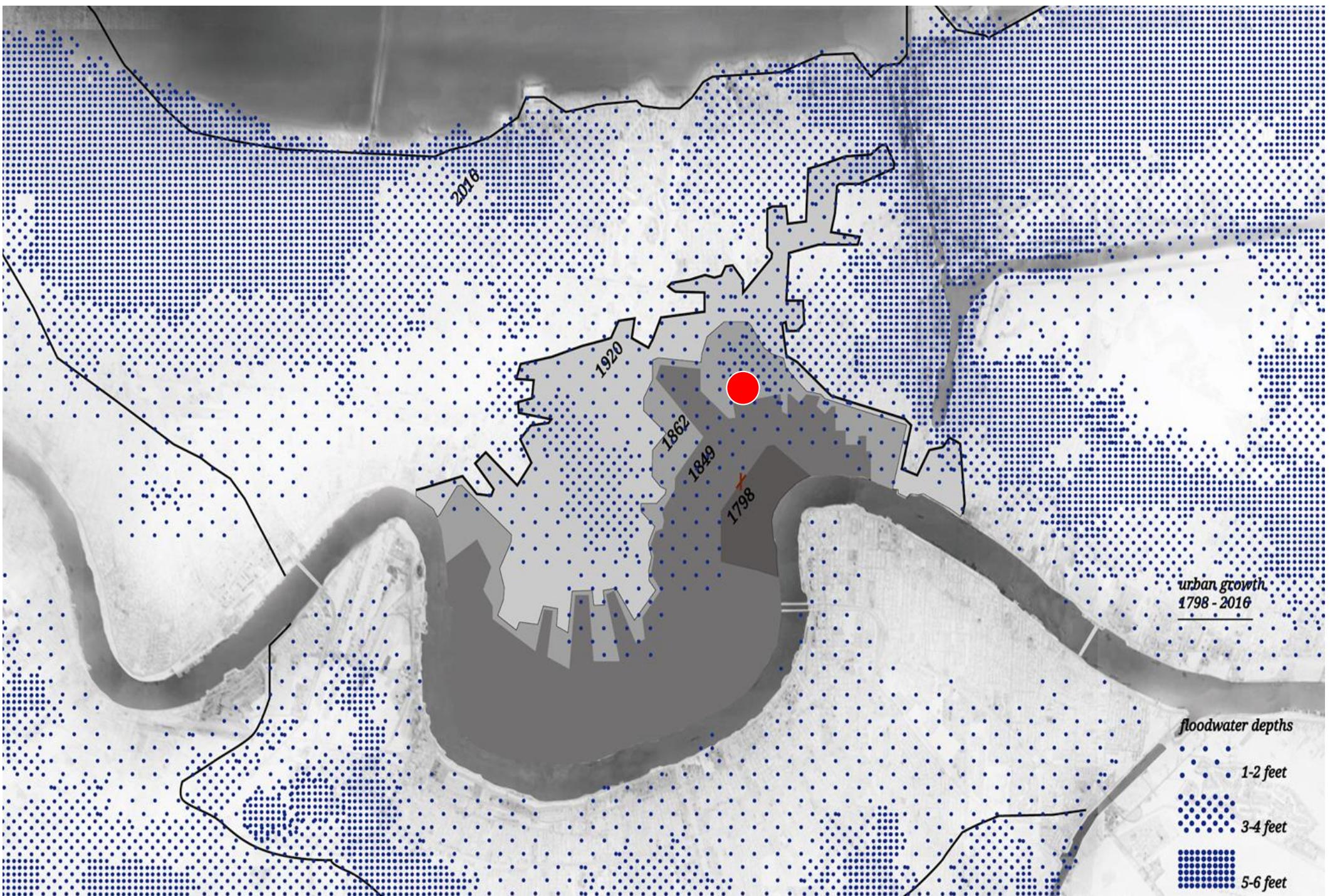
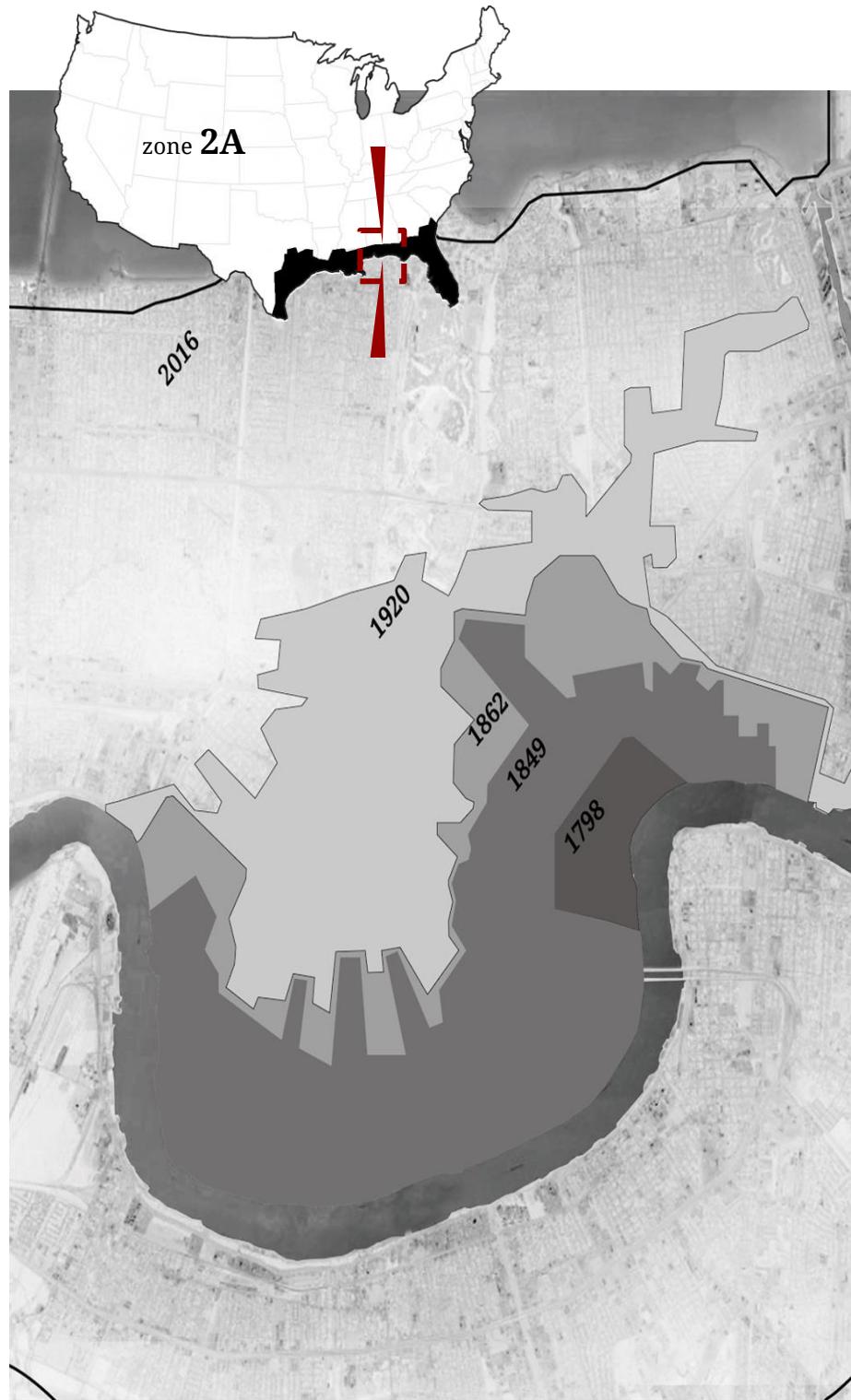
// Neighborhood

// Climate

// Challenges

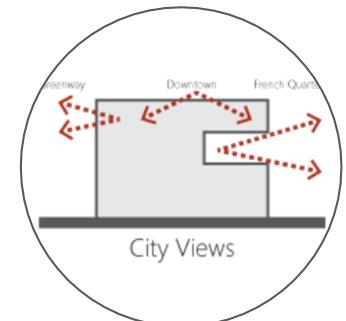
NEW ORLEANS

Early 19c Urban Growth Contour



FRENCH QUARTER

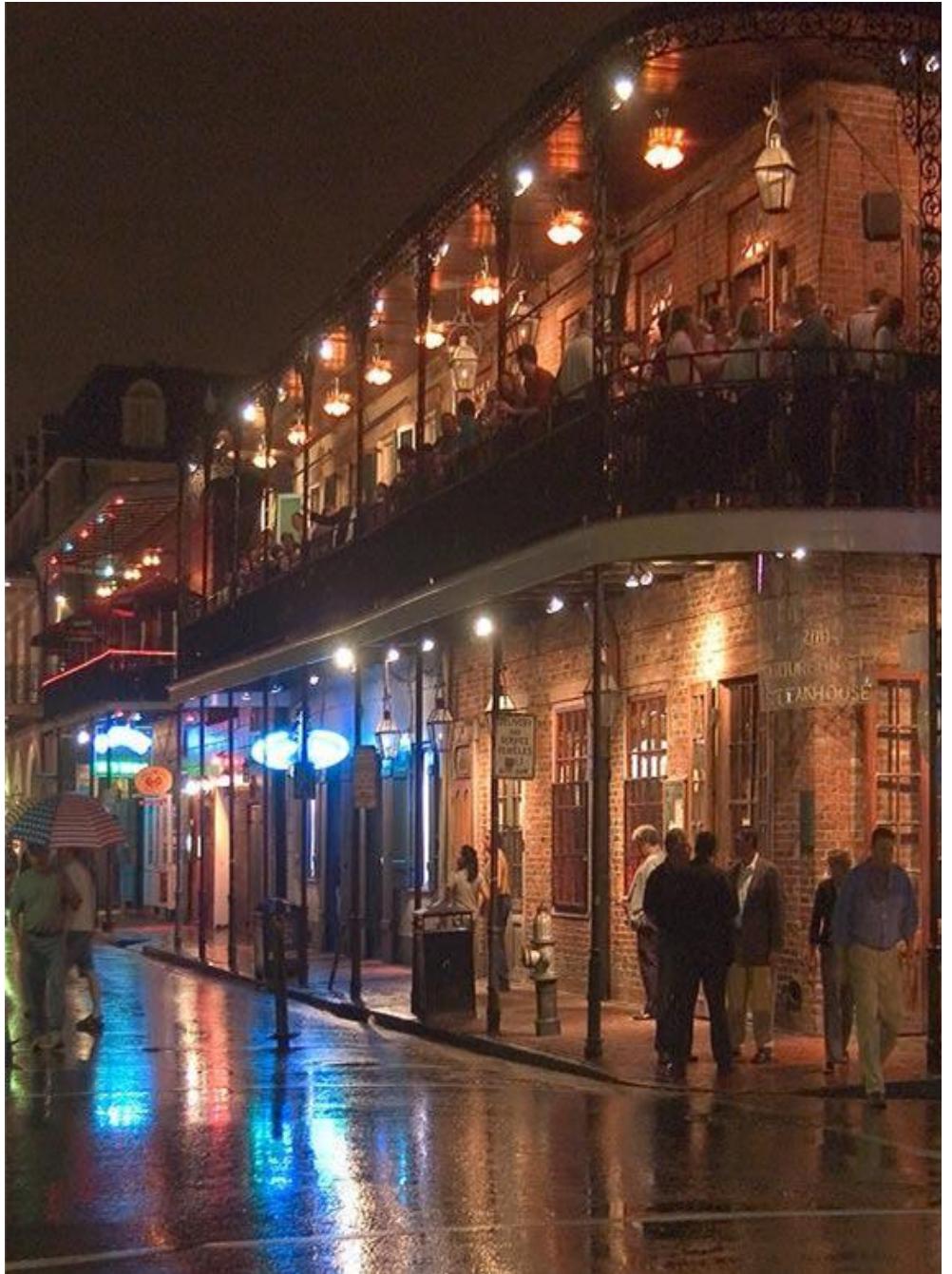
Surroundings



- Orange dot: Bar & Restaurant
- Black dot: Art Gallery
- Orange circle: Festival Location

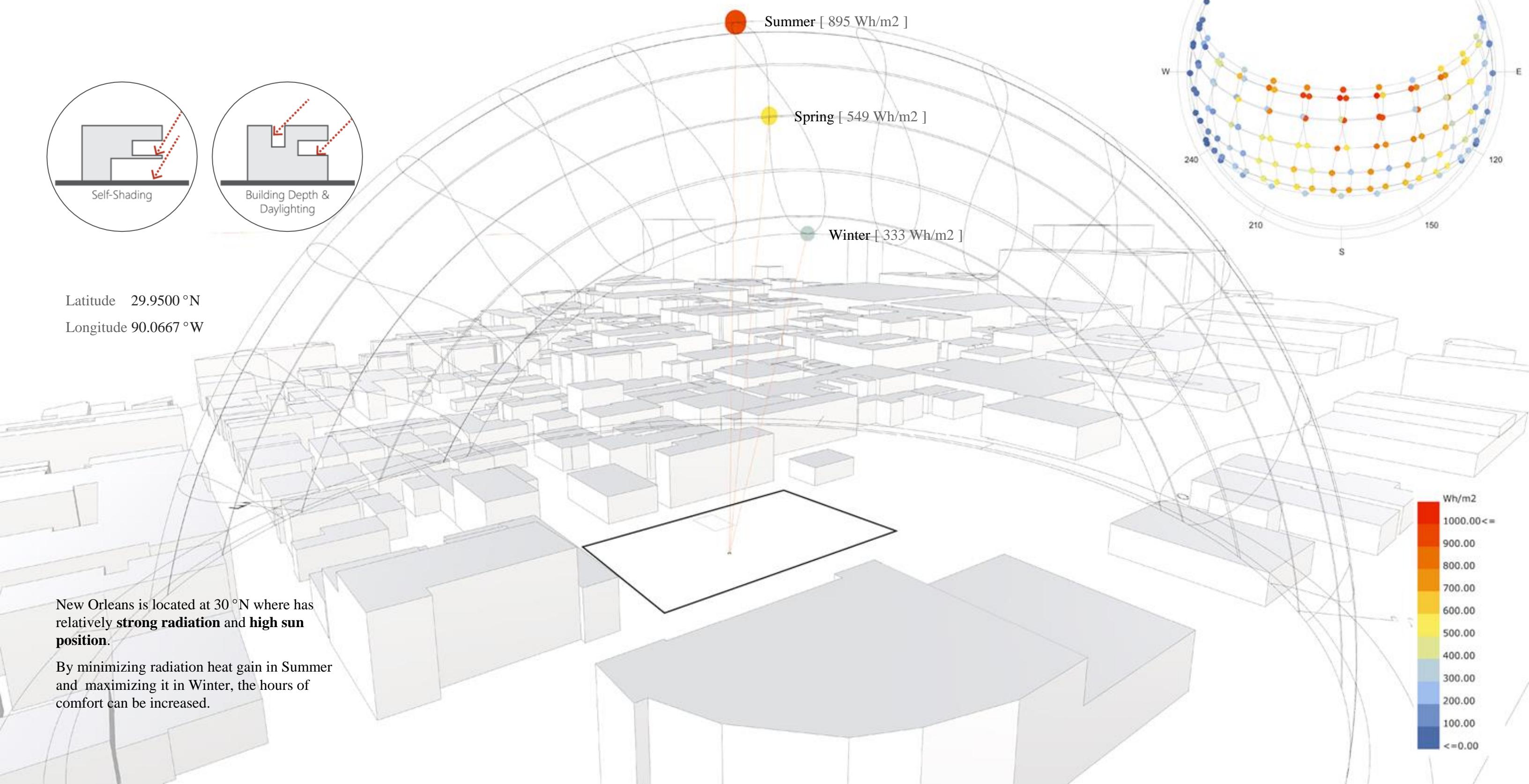
FRENCH QUARTER

Atmosphere- Bars, Street Performance & Festival



CLIMATE PARAMETERS

Sun Position & Radiation



CLIMATE CONDITIONS

Outdoor Comfort

The most uncomfortable hours are placed in Summer, from **June to September**. Also there are much more hours that people feel it's extremely hot rather than cold.

The **Relative Humidity** during **summer daytimes** is around **50%** which evaporative cooling strategy is possible.

47 %

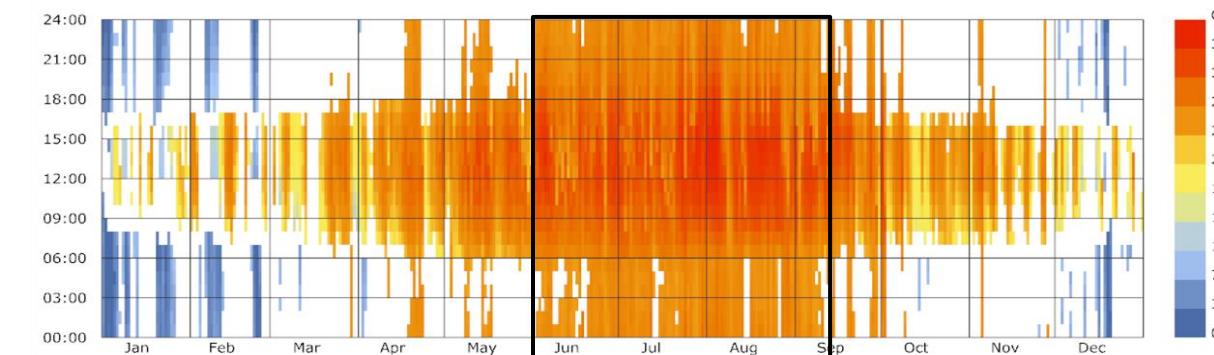
Annual Hours Comfort
Unshaded Condition

- █ Extreme Heat
- █ Hot
- █ Warm
- █ **Comfort**
- █ Cool
- █ Cold
- █ Extreme Cold

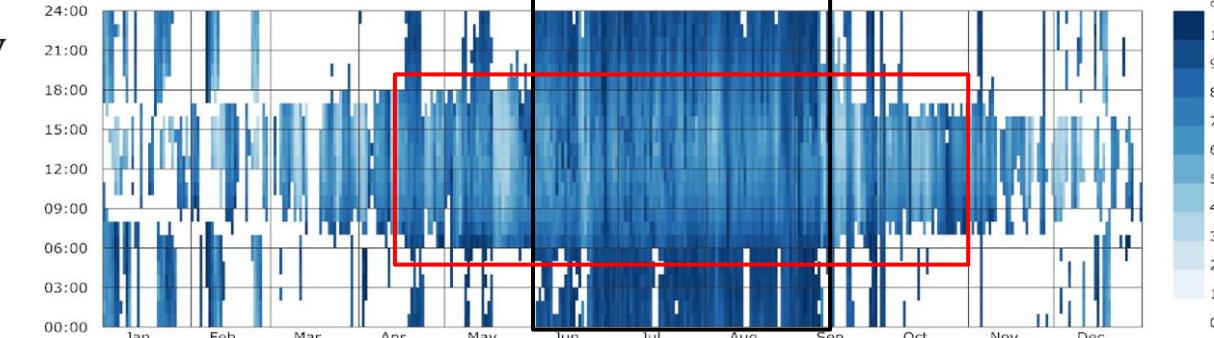
57 %

Annual Hours Comfort
Shaded Condition

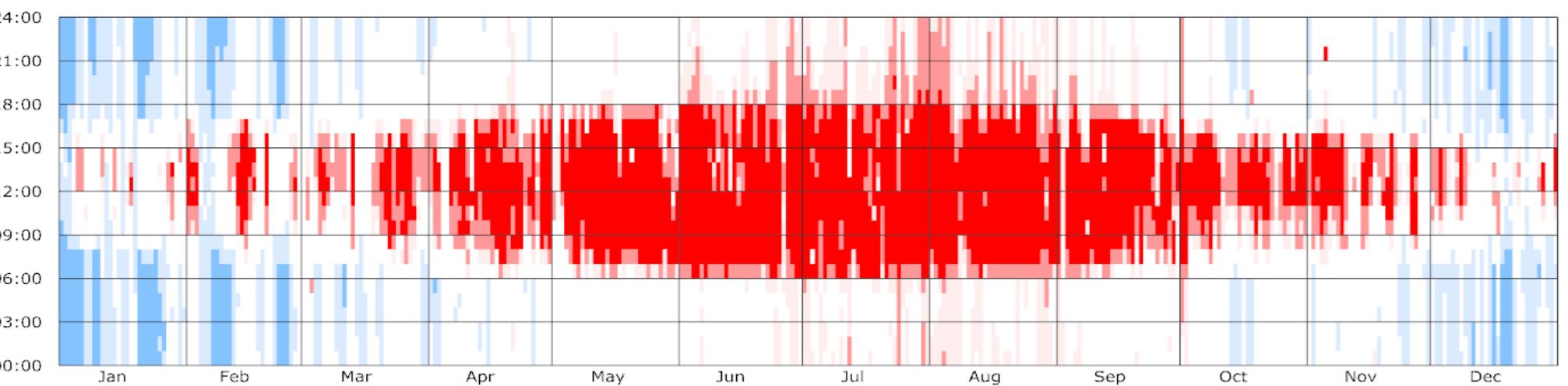
Temperature



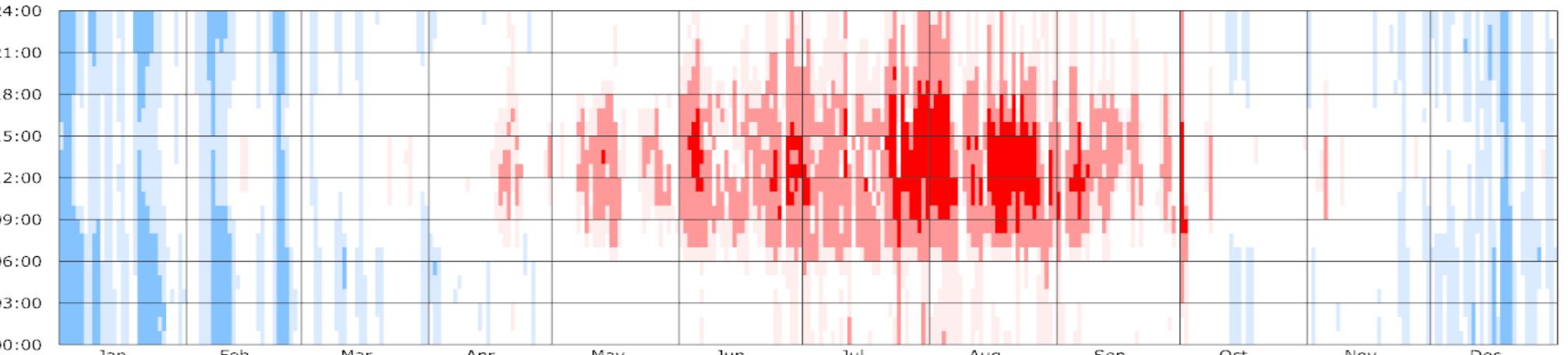
Relative Humidity



Unshaded Condition



Shaded Condition



CLIMATE CONDITIONS

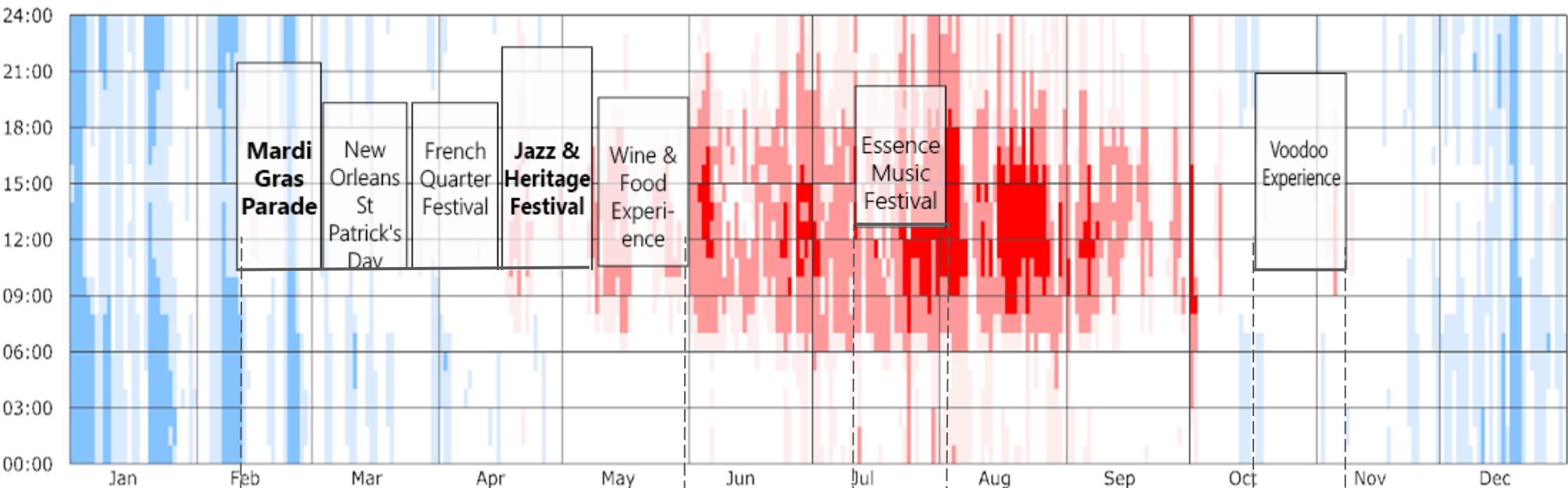
Outdoor Comfort & Festival Events

Most of the festivals are held during February to May when there are more comfort hours in shaded condition. To keep the celebrating atmosphere of New Orleans all year around, providing comfortable outdoor space for summertimes festival events would be critical.

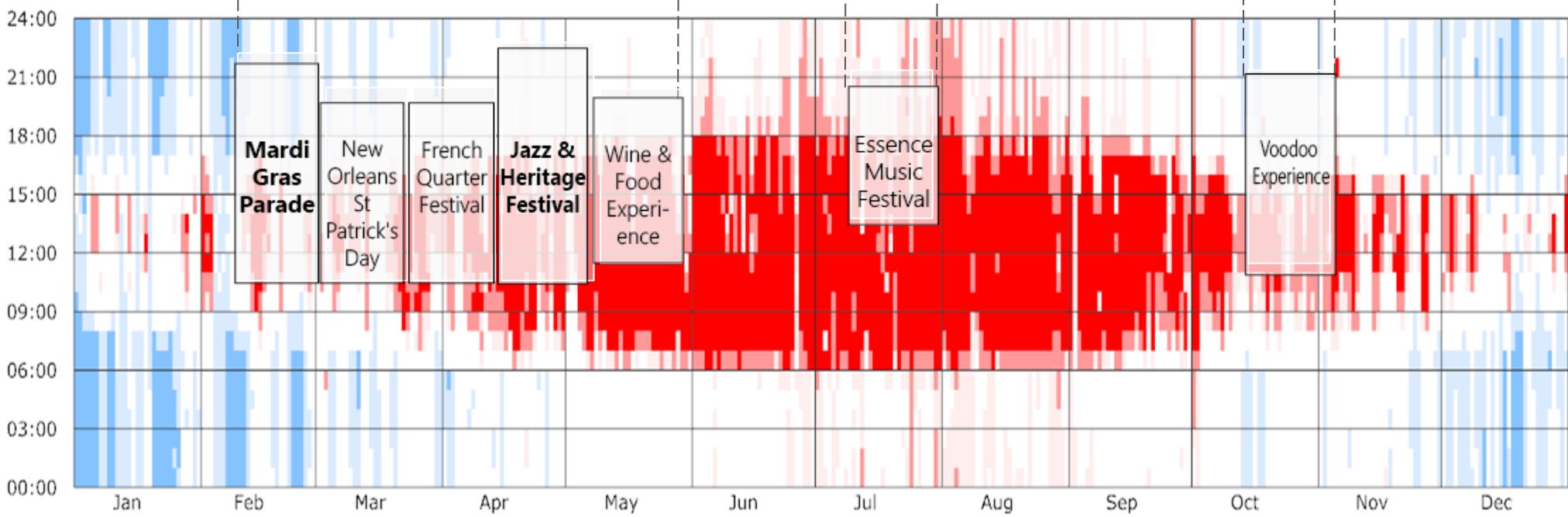


- Extreme Heat
- Hot
- Warm
- Comfort**
- Cool
- Cold
- Extreme Cold

Annual Hours Comfort
Shaded Condition

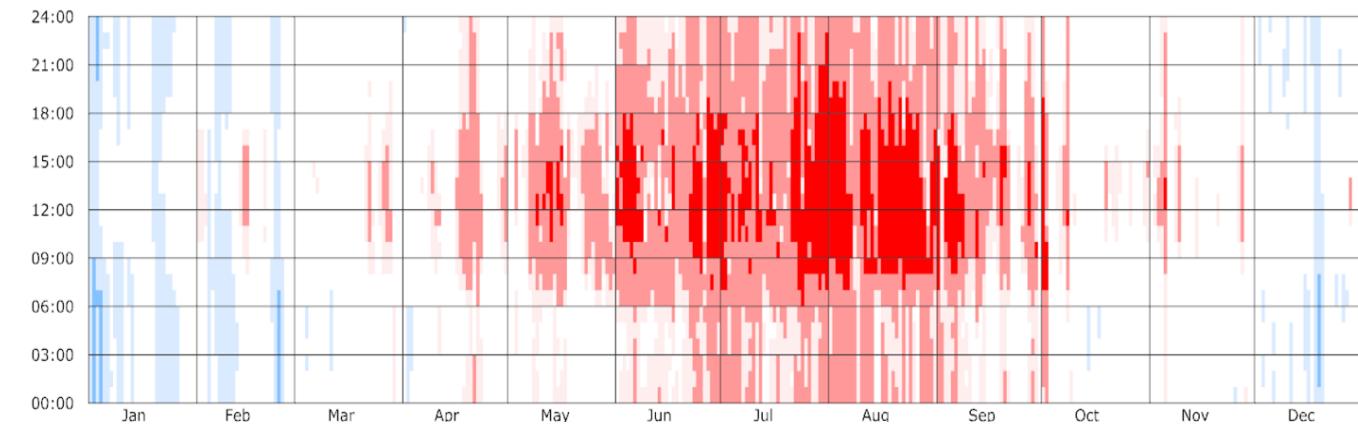
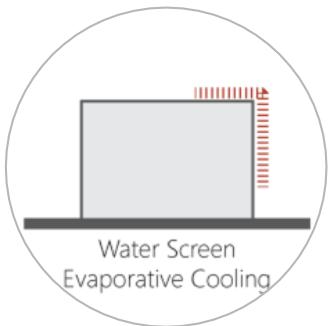


Annual Hours Comfort
Unshaded Condition



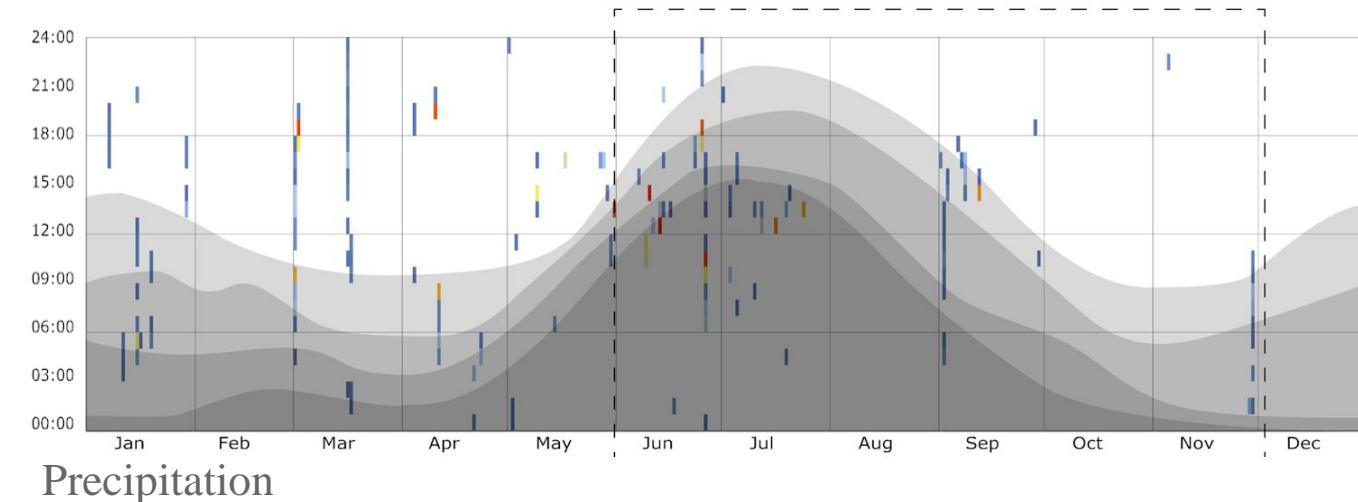
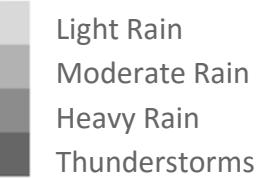
CLIMATE PARAMETERS

Evaporative Cooling



Annual Hours Comfort - Shaded Condition

Chance of Precipitation



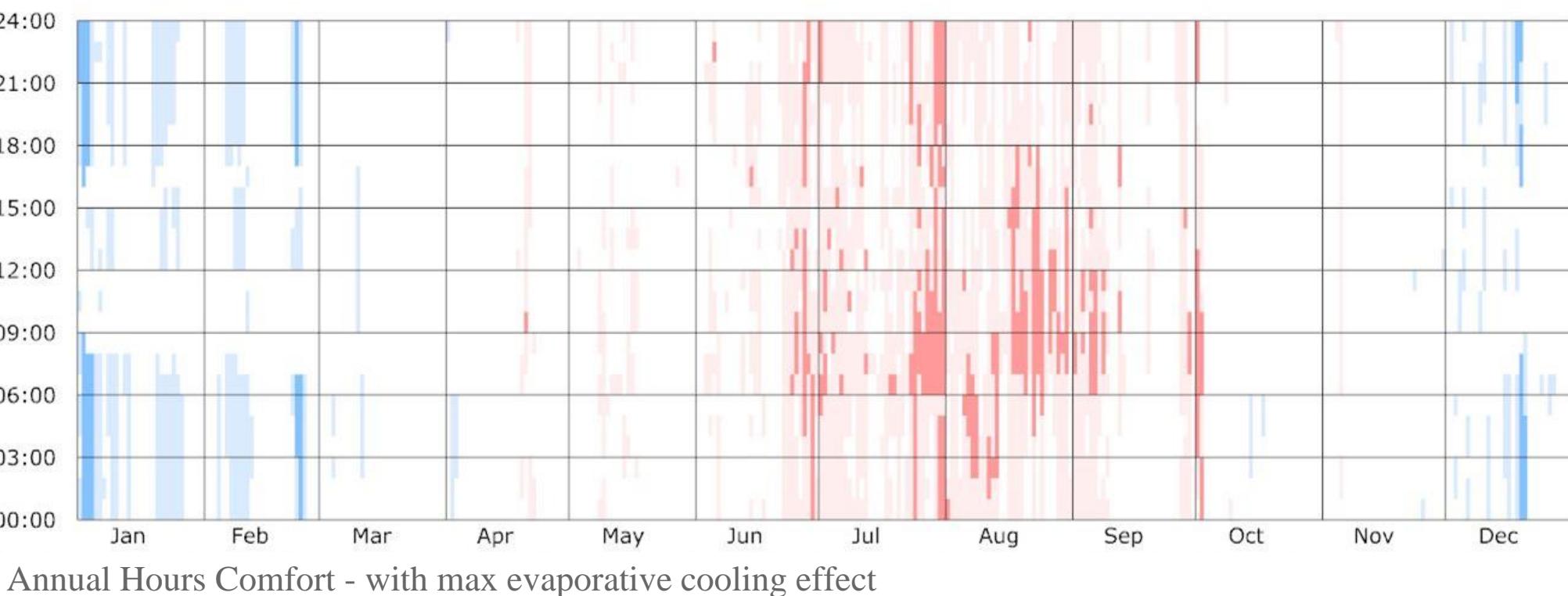
Precipitation

Uncomfortable Months and Rainy Season

In our weather condition studies, the uncomfortable months (ex June to September) overlap with the heavy rain season.

Using Rainwater for Evaporative Cooling during Hot Months

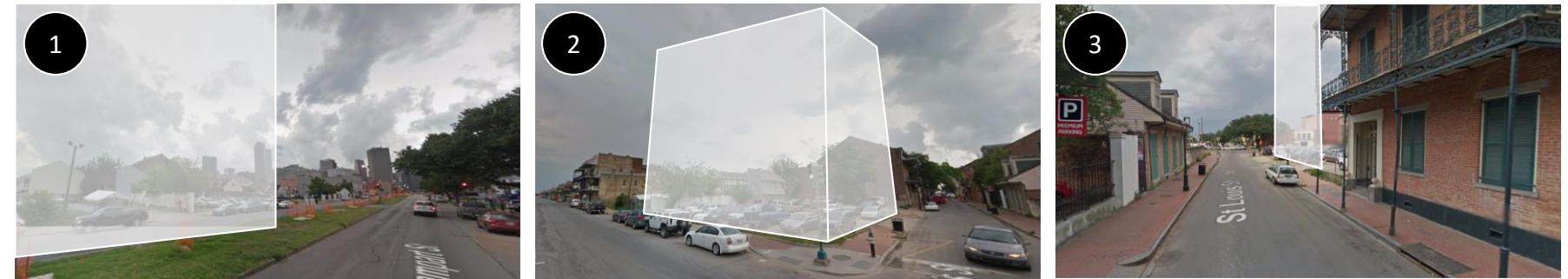
By applying evaporative cooling system in New Orleans, we found that the comfortable hours have increased from 52% to 68%. However it's still warm and hot in summer.



Annual Hours Comfort - with max evaporative cooling effect

NEIGHBORHOOD

Surroundings



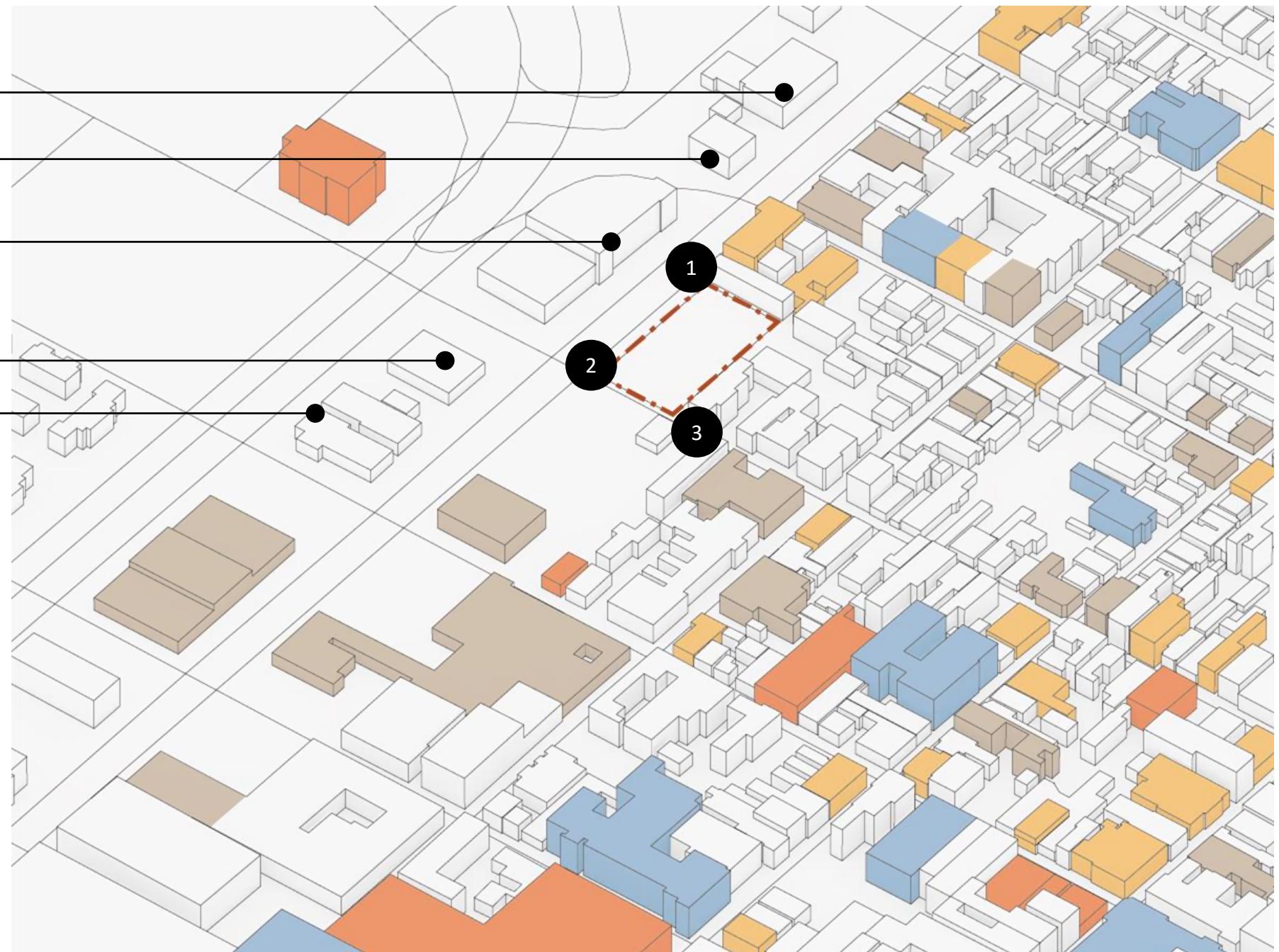
Covenant house

Basin St. Station

**Louisiana Department of Health
and Hospital**

Police Department

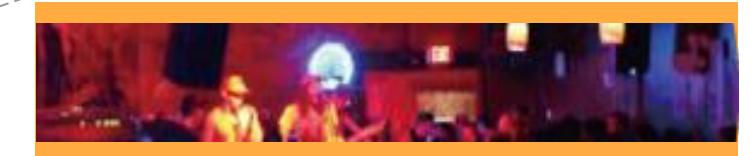
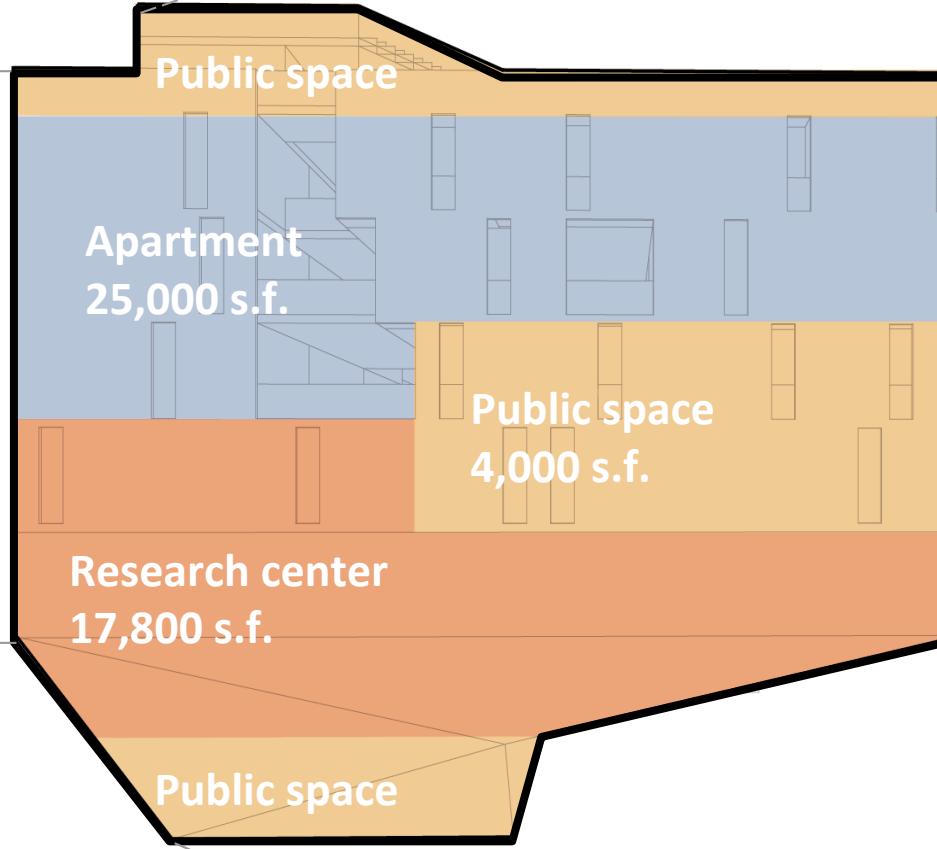
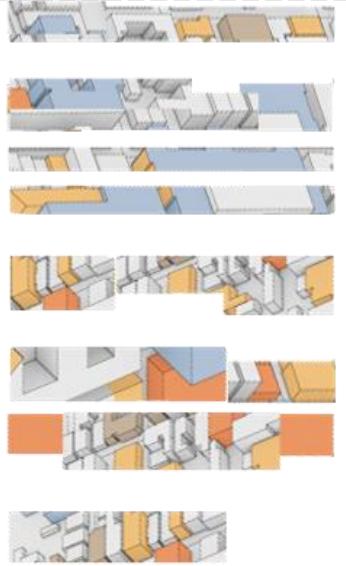
Gas Station



- █ BAR / CAFE / RESTAURANT
- █ MUSEUM / ART GALLERY
- █ HOTEL
- █ STORE / SERVICE

INITIAL PROGRAM

Verticalize Surrounding Programs



Bar at roof garden



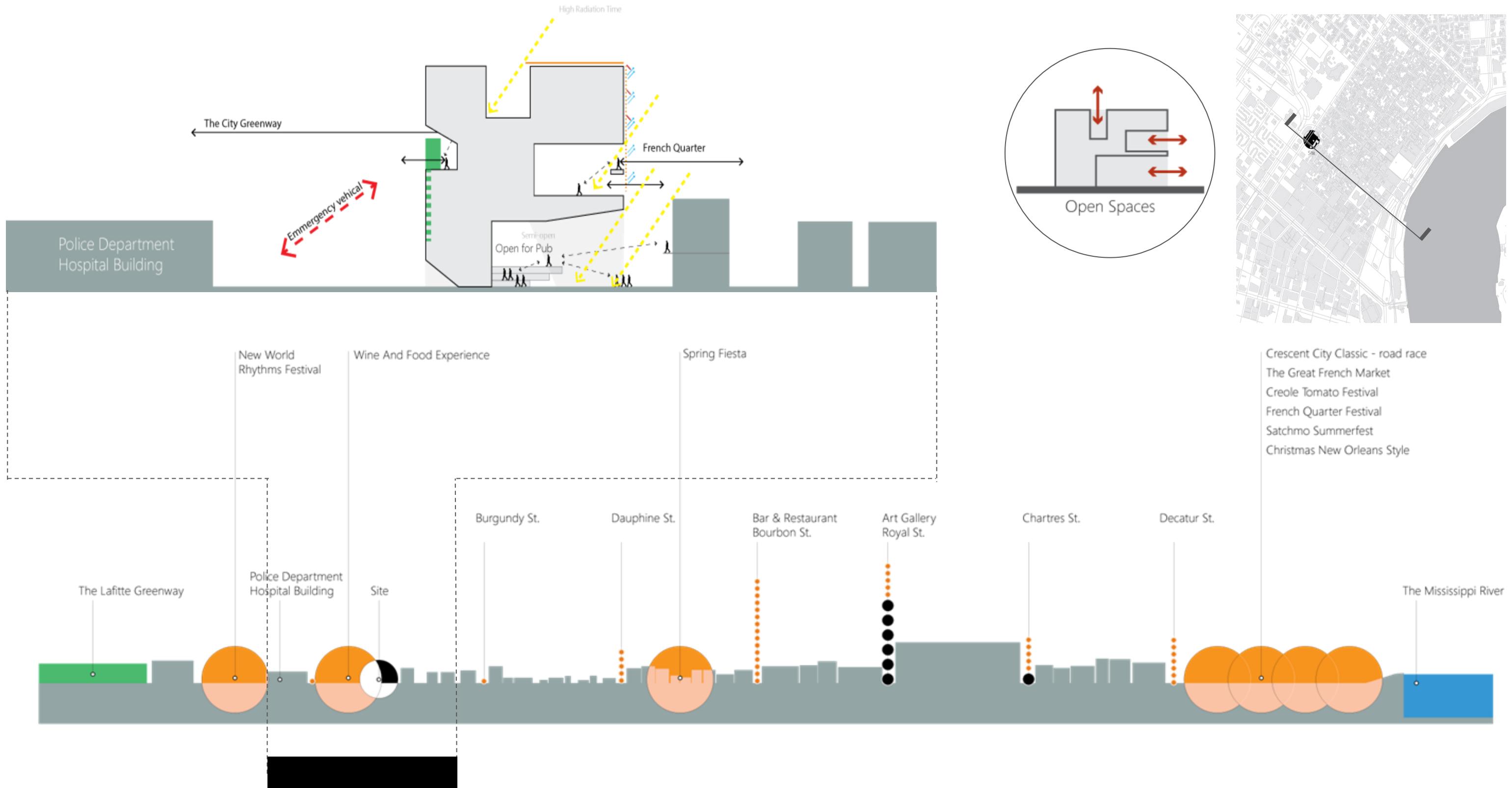
Lookout to French quarter



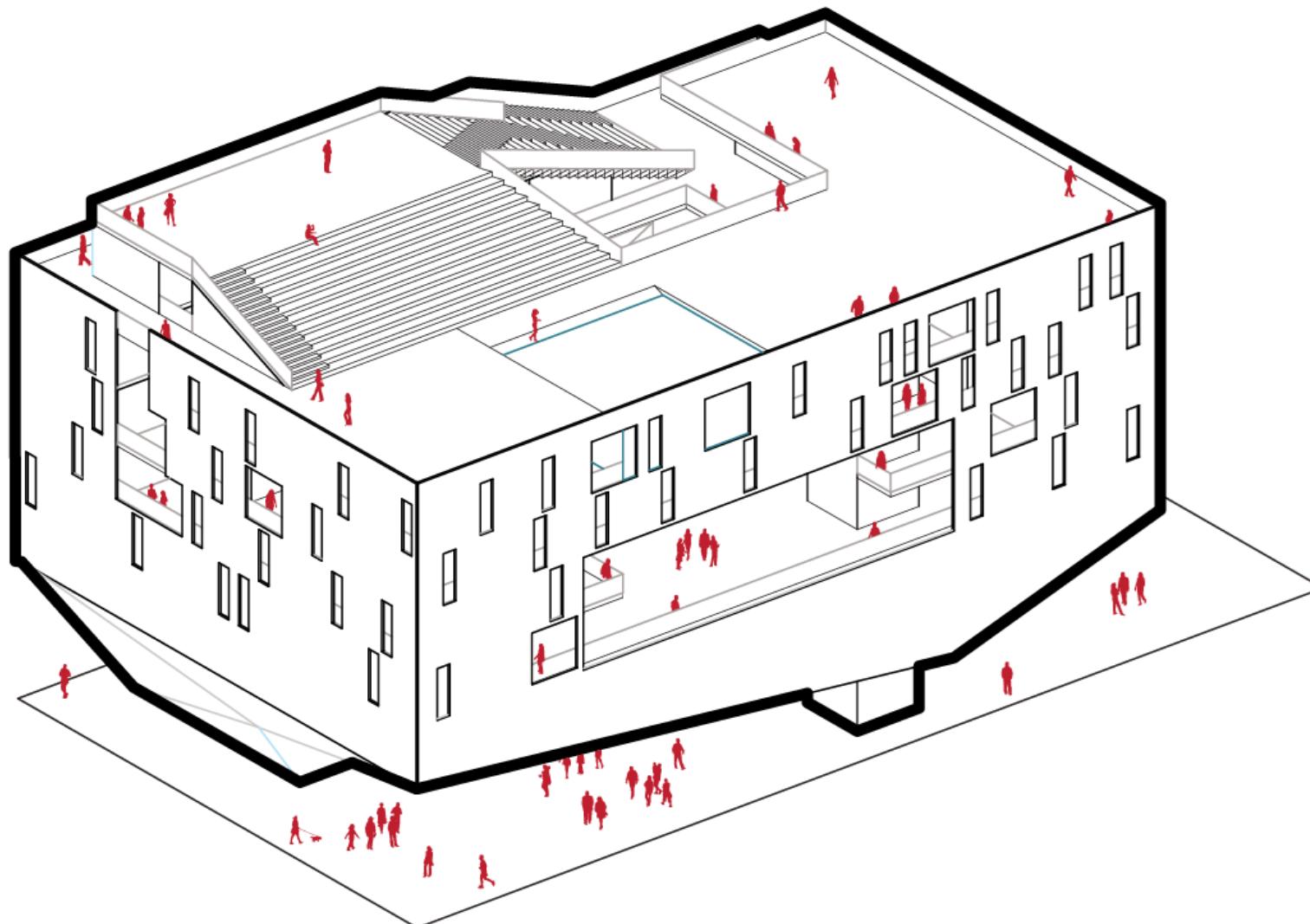
Outdoors for festival events

NEIGHBORHOOD

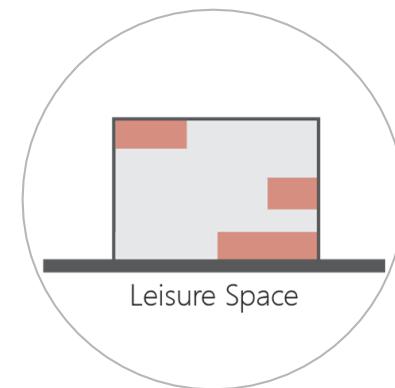
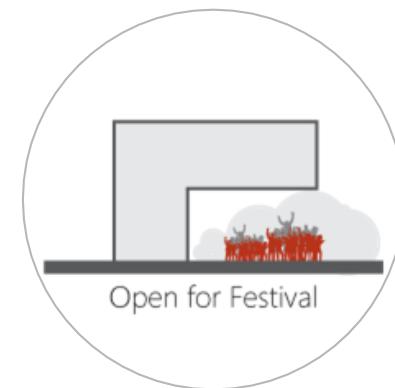
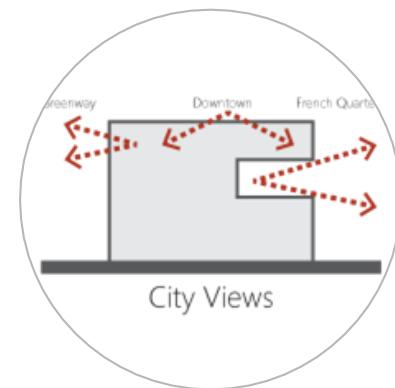
Site Response



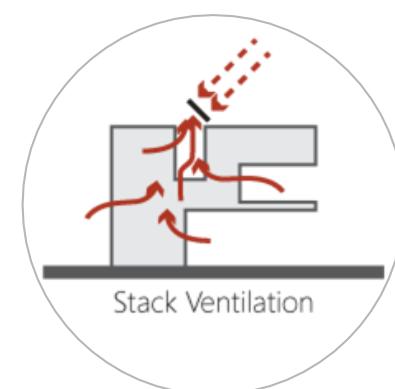
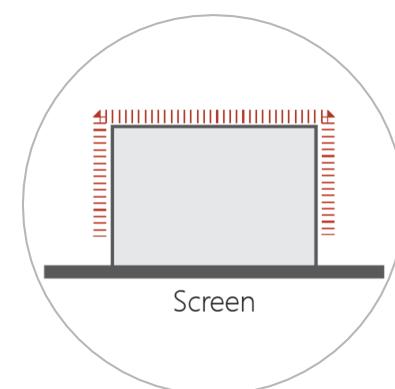
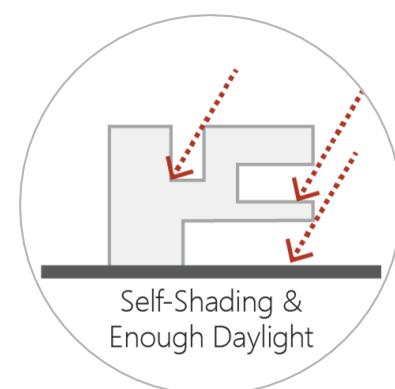
DESIGN CONCEPT



Urban Approaches



Environmental Approaches



1 SITE & CLIMATE

Natural Boundary & Resources

2 ENV_DEVELOPMENTS

Environmental Challenges

3 ARCH_PERFORMANCE

Architectural Challenges

// Outdoor Self-Shading

Mass Exploration

// Balcony

Shading for Indoor Environment

// Screen

// Evaporative Cooling

CHALLENGES

Page Description

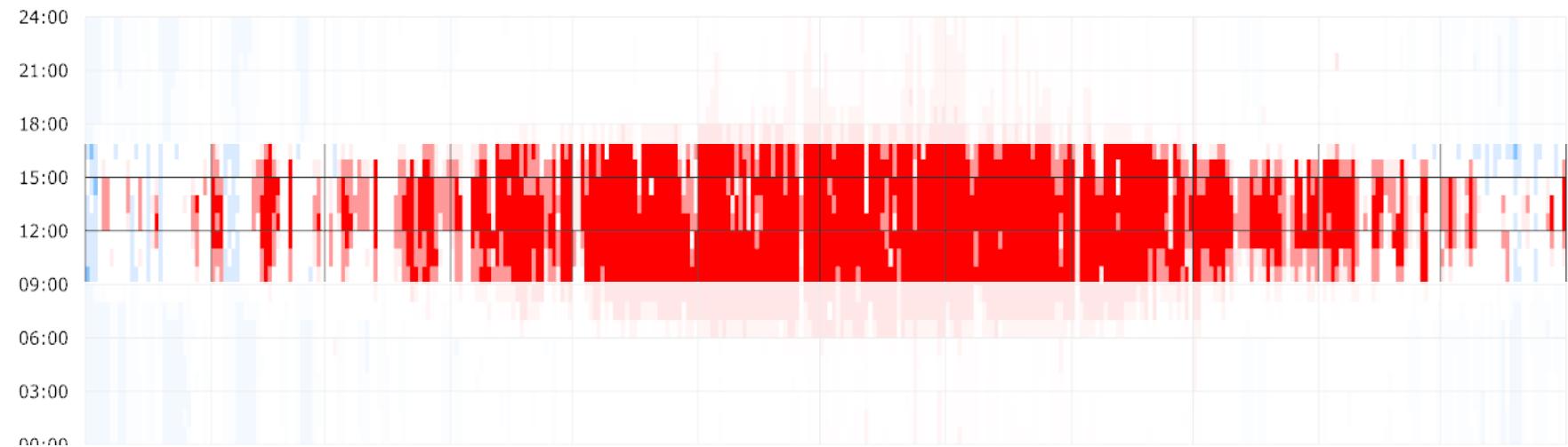
26%

Working Hours Comfort
Unshaded Condition

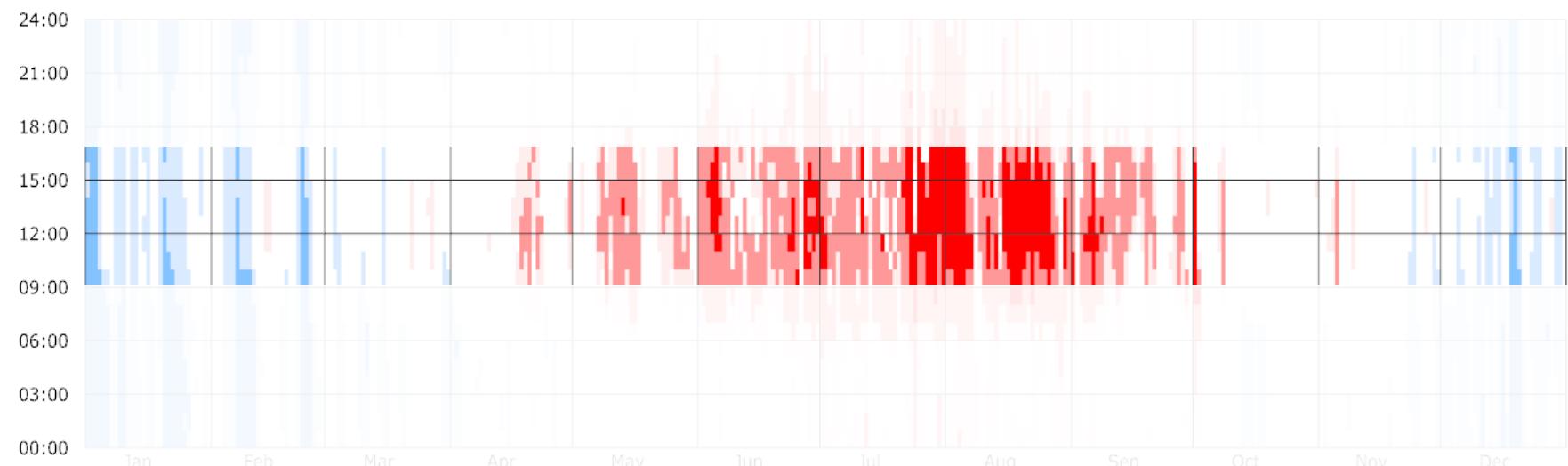
24% = 12 WEEKS

50%

Working Hours Comfort
Shaded Condition



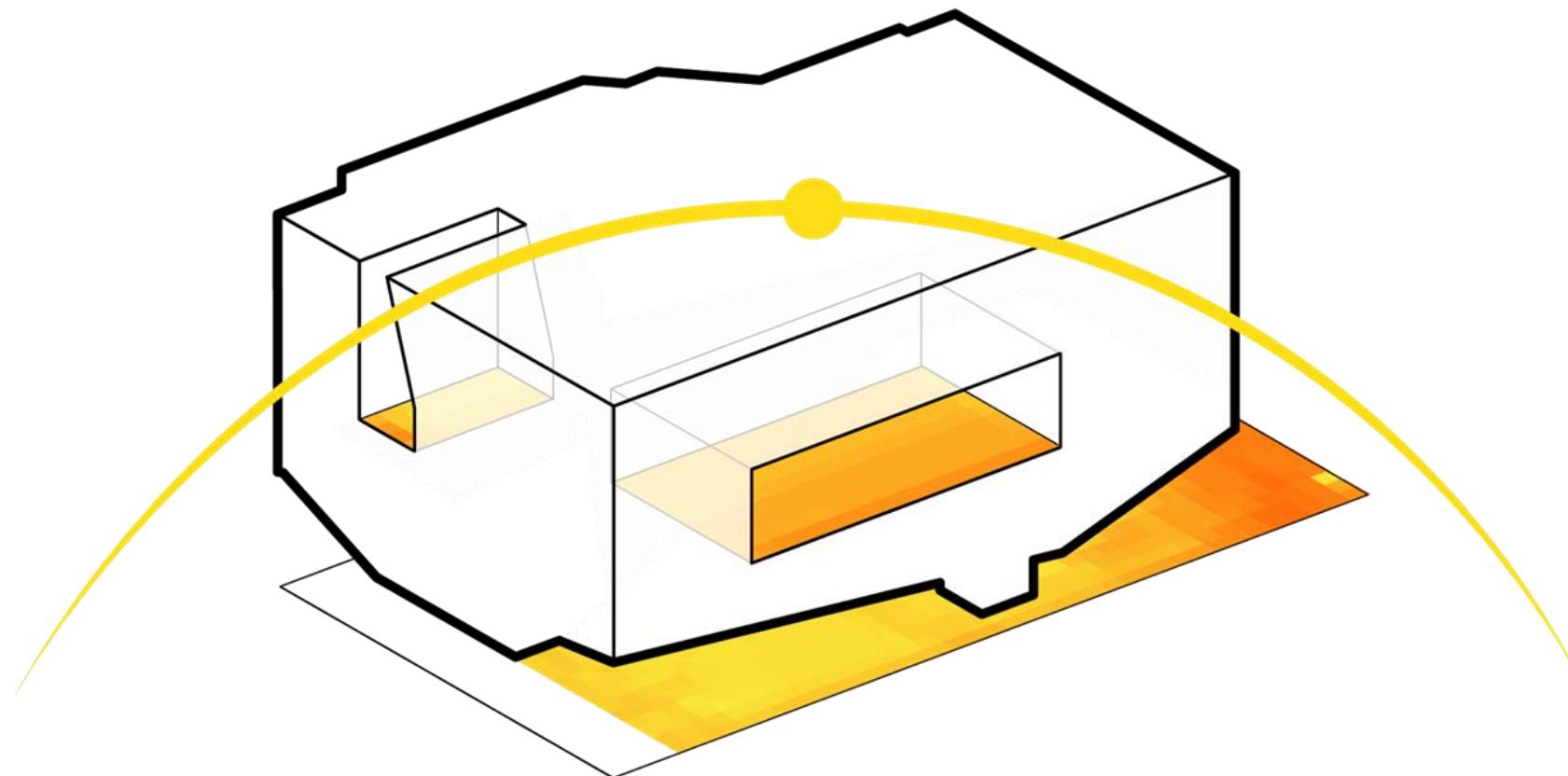
UNSHADED CONDITION (9AM - 5PM)



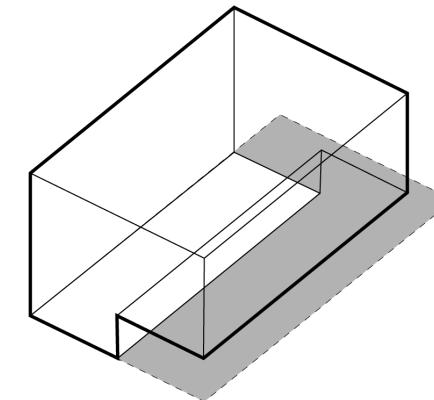
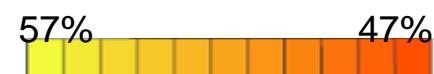
SHADED CONDITION (9AM - 5PM)

STUDY OF SELF-SHADING

Massing Exploration

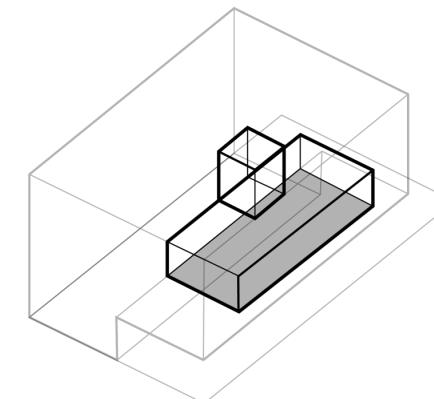
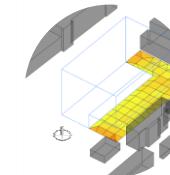


Annual Comfort % (UTCI)



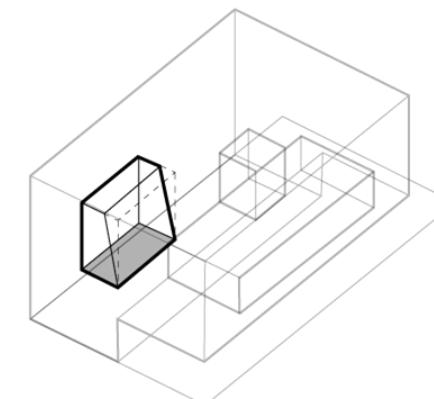
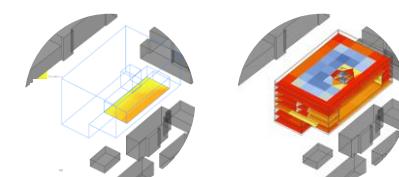
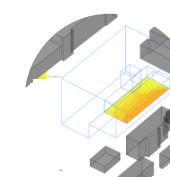
STEP 1

Ground Level - The City Stages



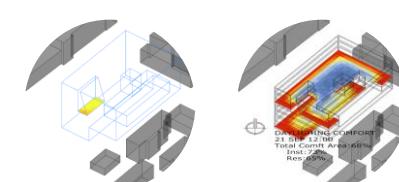
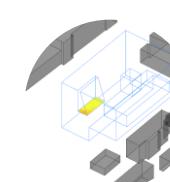
STEP 2

Middle Level - The City Balcony

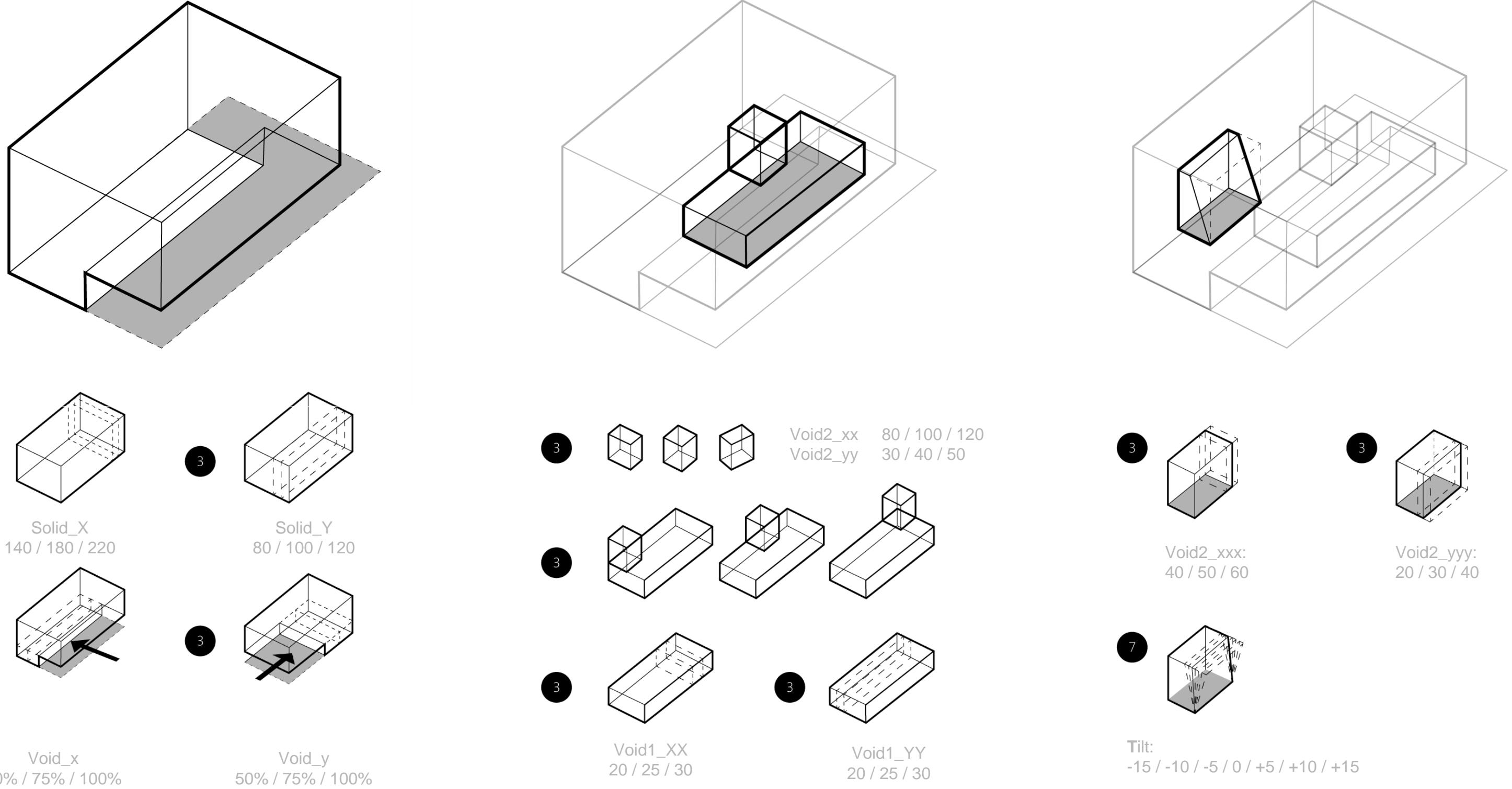


STEP 3

Upper Level - The City Window

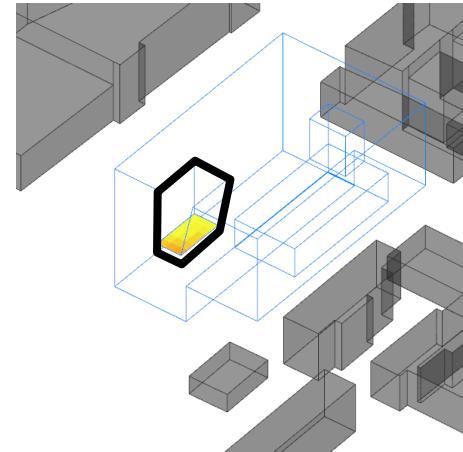
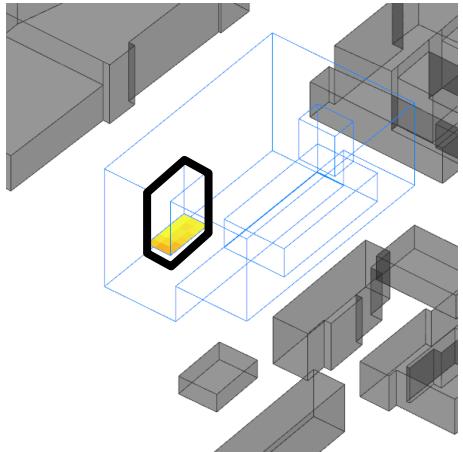
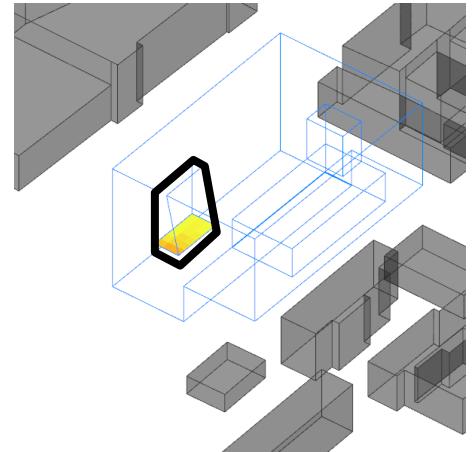
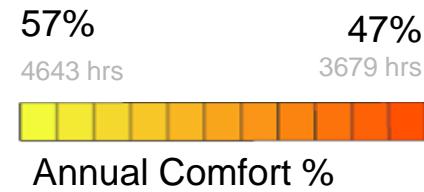


STUDY OF SELF-SHADING



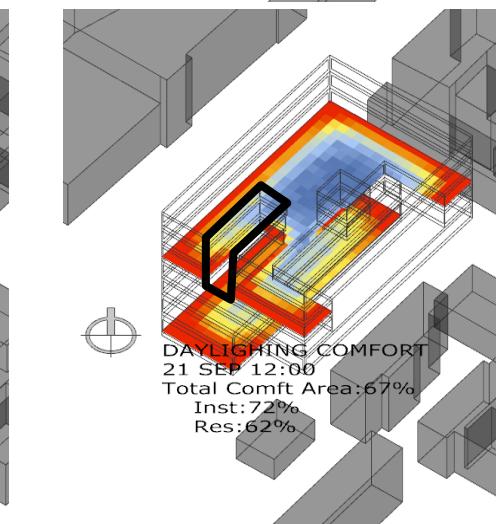
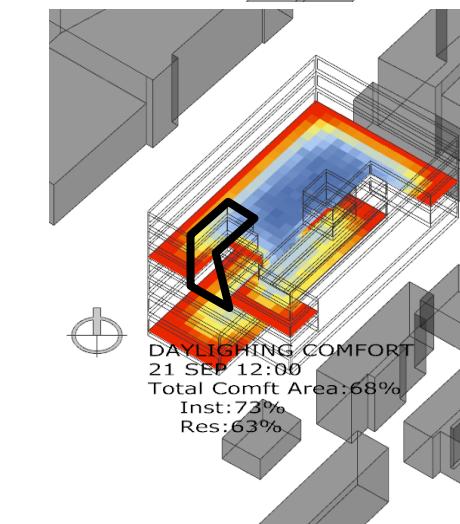
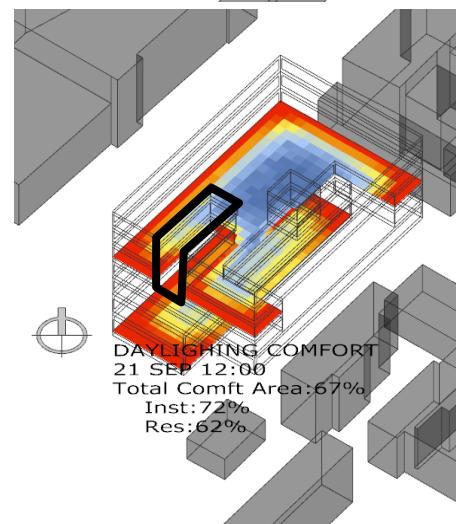
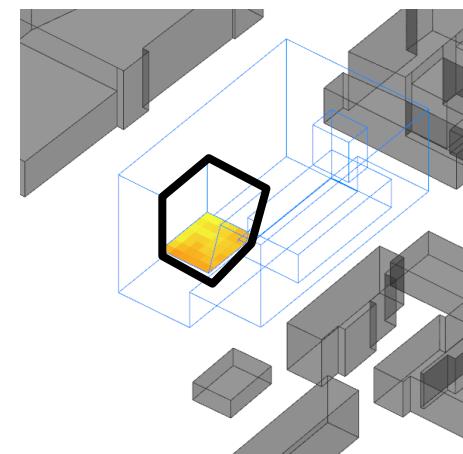
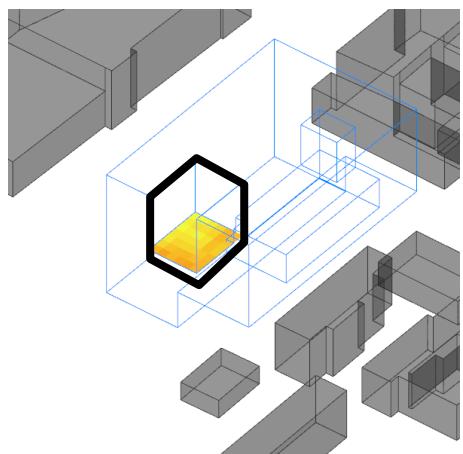
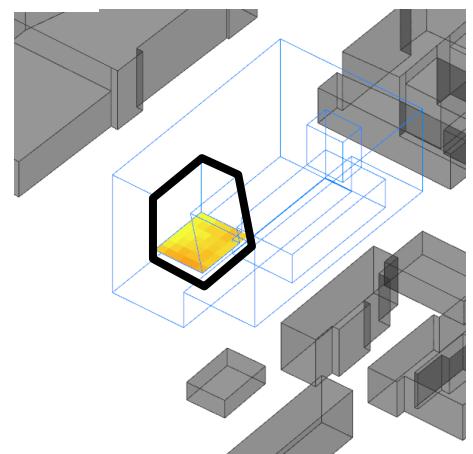
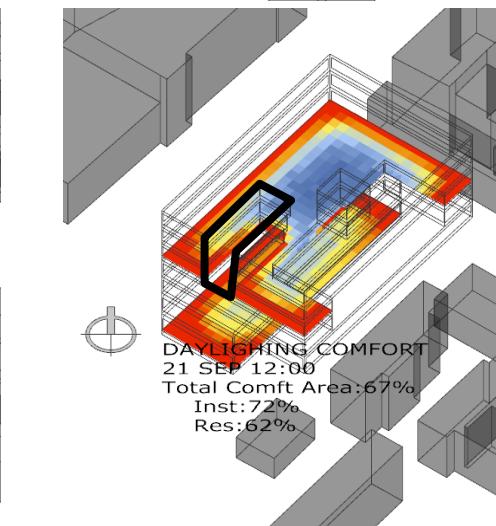
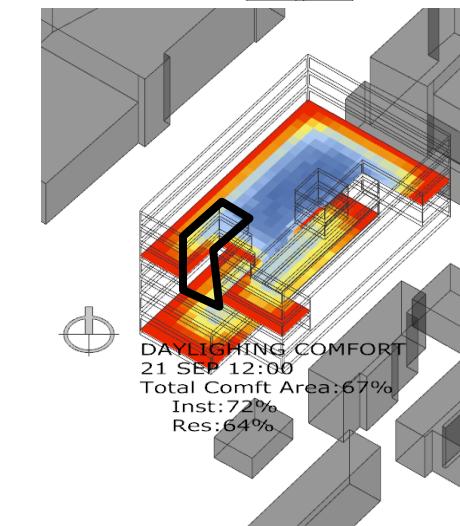
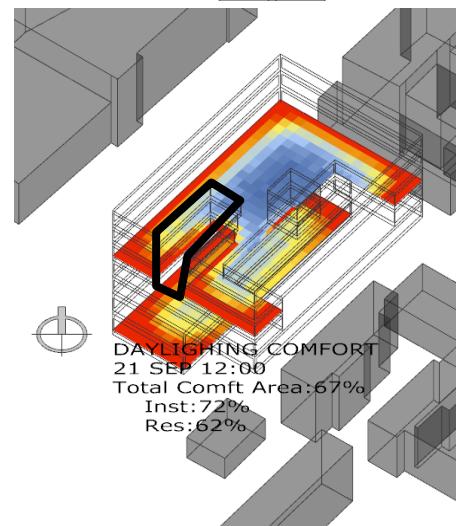
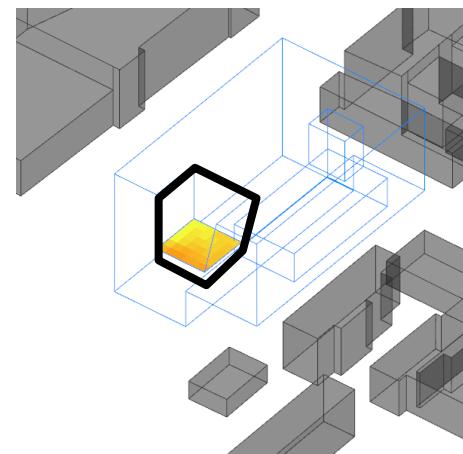
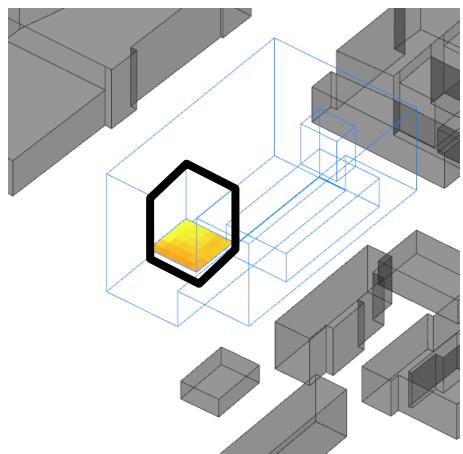
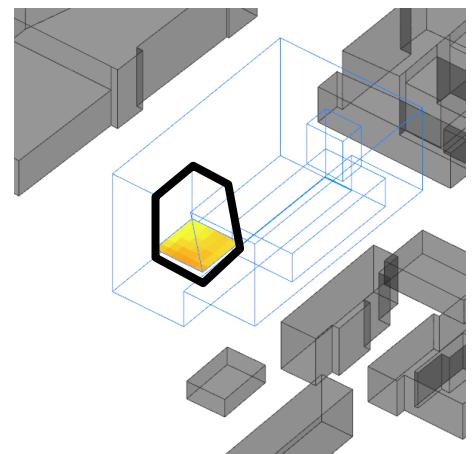
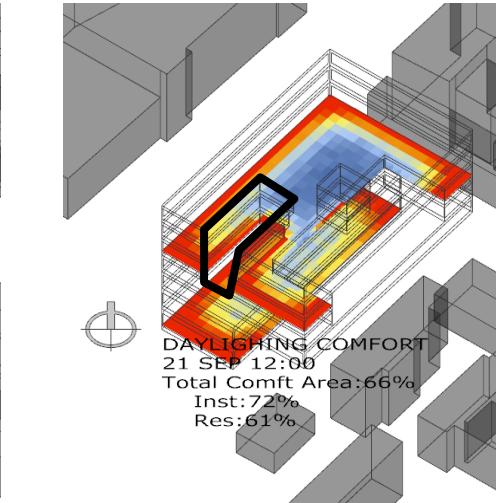
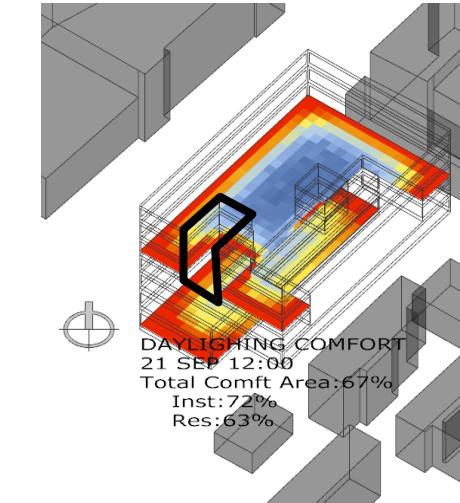
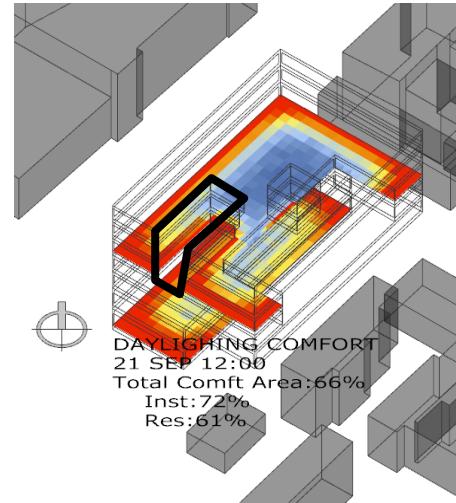
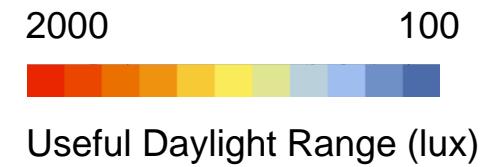
THERMAL COMFORT

% of annual hours



DAYLIGHT DISTRIBUTION

% of Area



THE BEST CASE

Thermal & Daylight Comfort

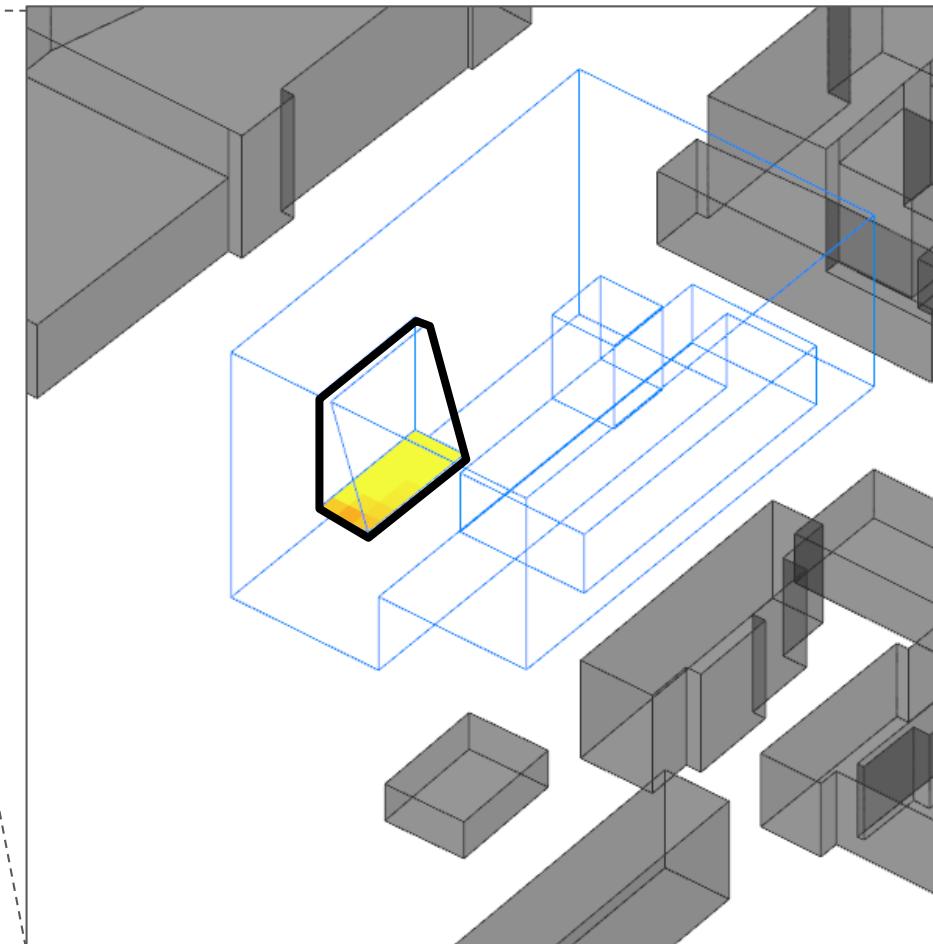
57%

55.8%

THERMAL COMFORT

Within Top 3 of all Cases

Thermal comfort
range of all cases



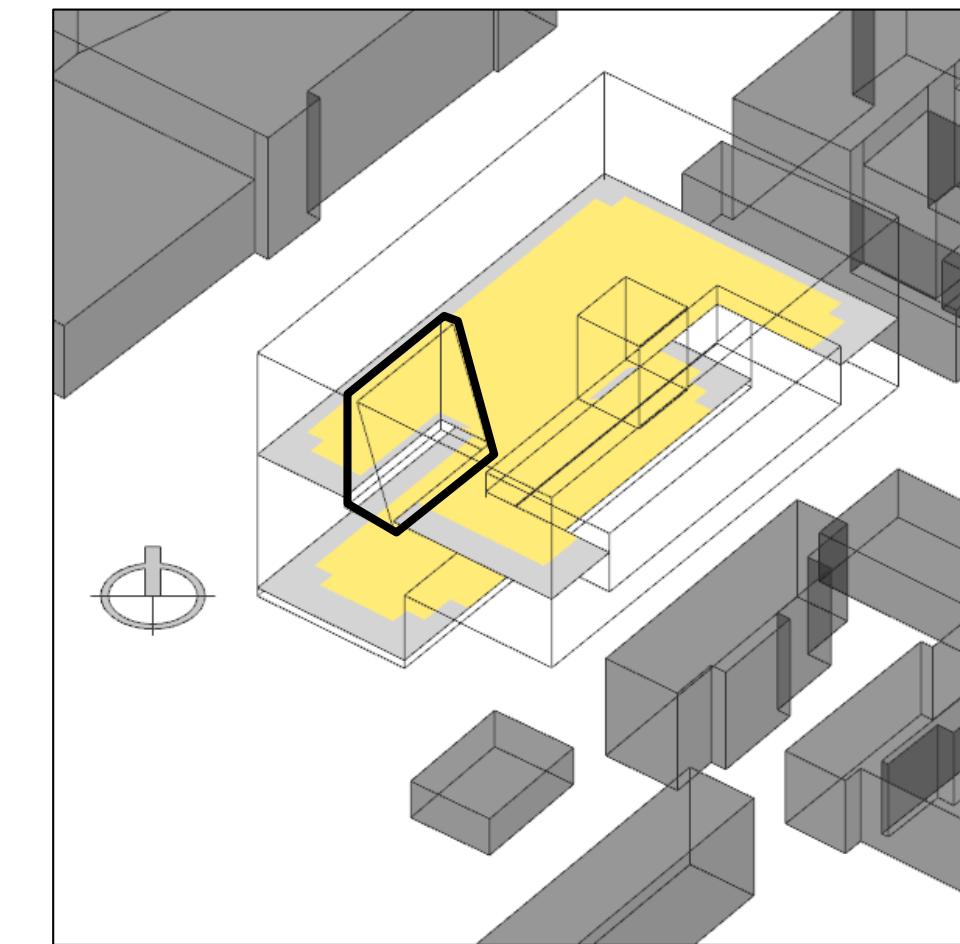
DAYLIGHT DISTRIBUTION

Within Top 5 of all Cases

68%

59%

Daylight comfort
range of all cases



Natural Limitation

100%

UTCI

57%



Annual Comfort % hour



Not in Useful Daylight Range

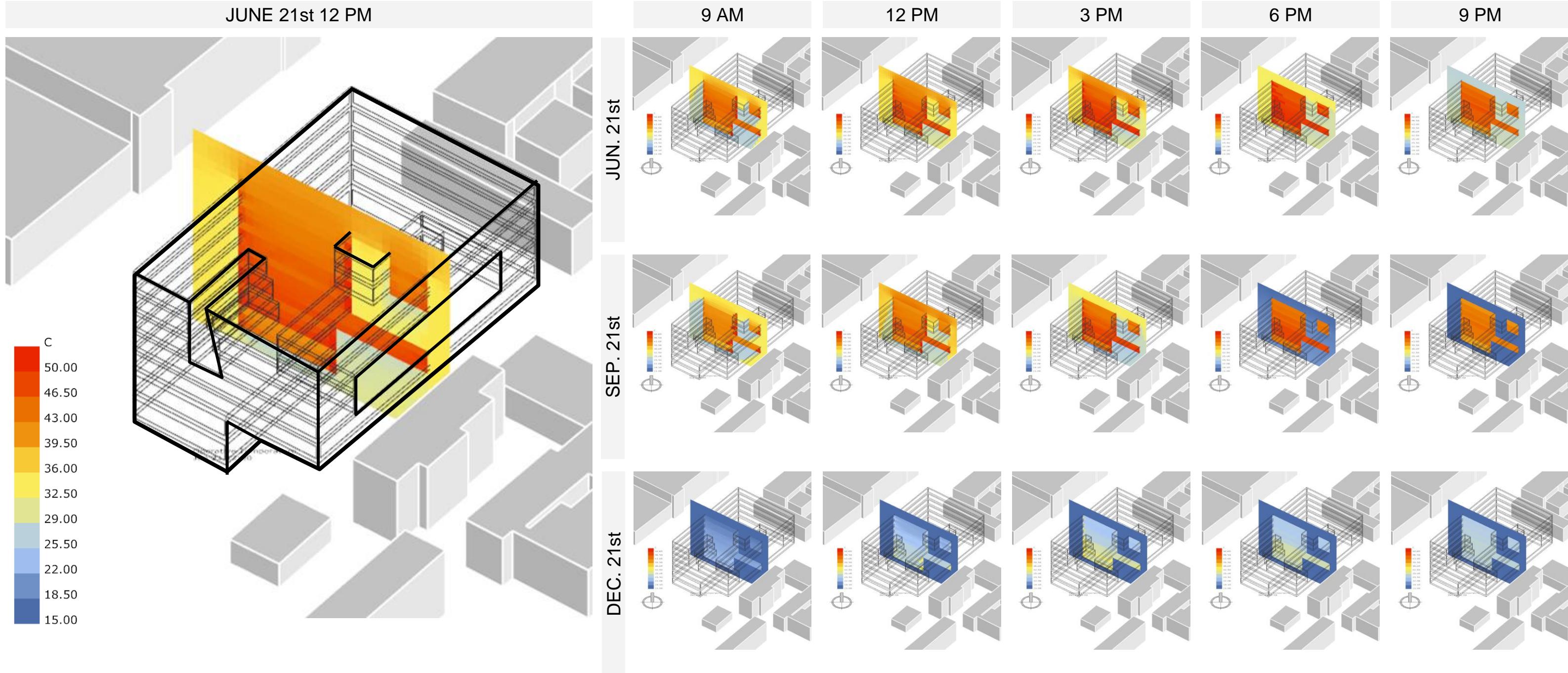


Within Useful Daylight Range

COMFORT SECTION

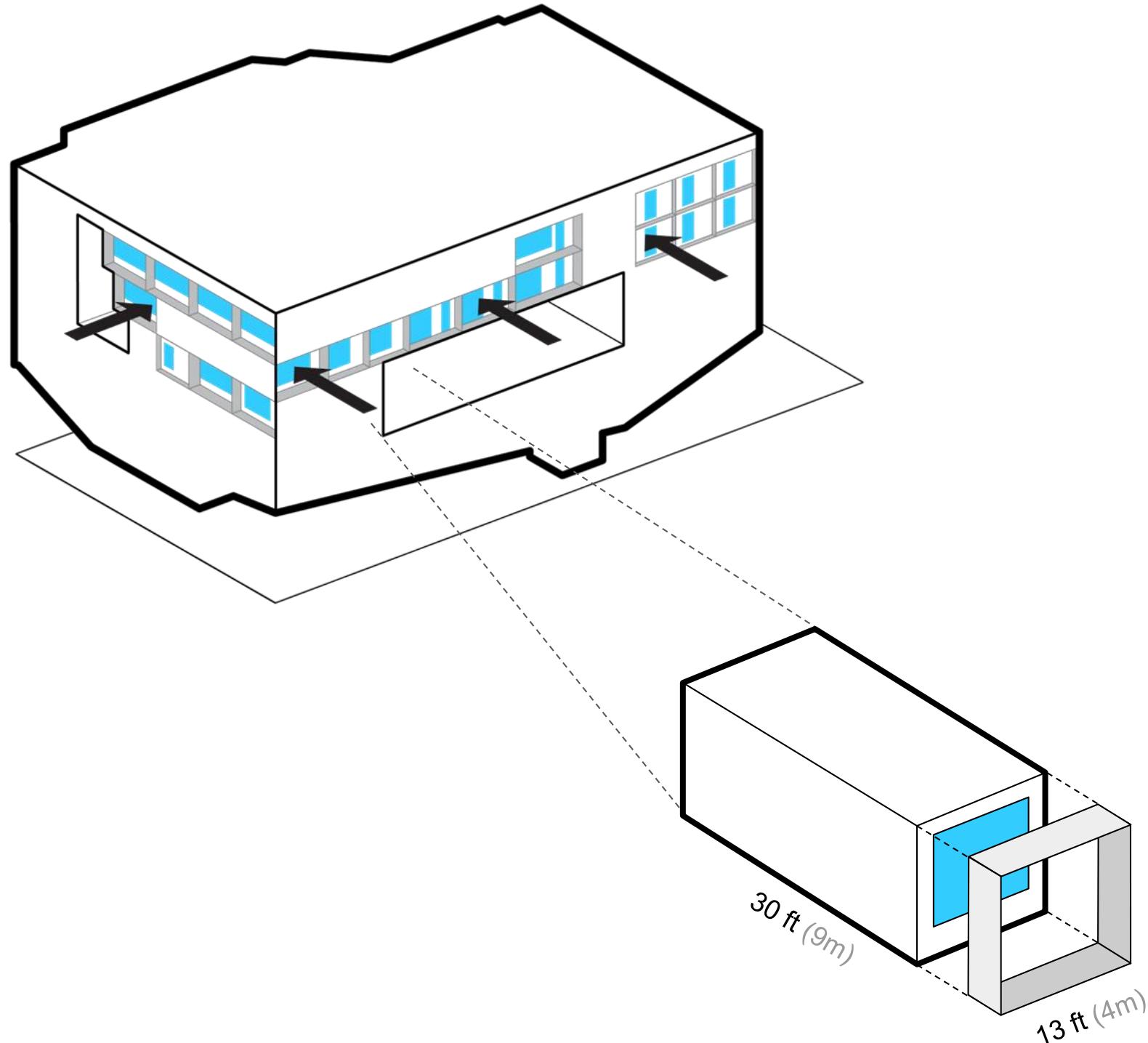
Indoor: Adaptive

Outdoor: UTCI

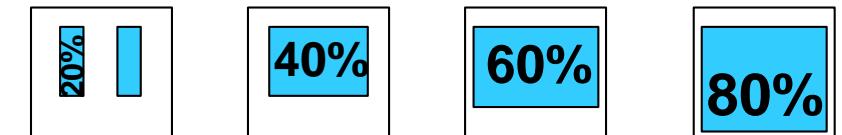


STUDY OF BALCONY

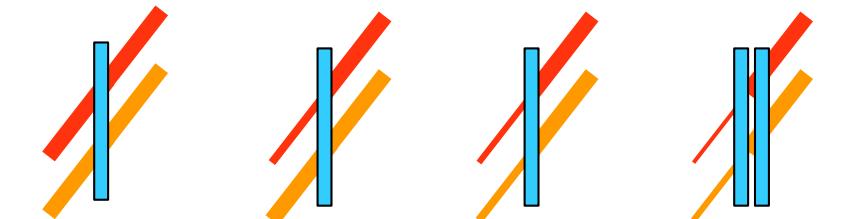
Shadings for Indoor Environment



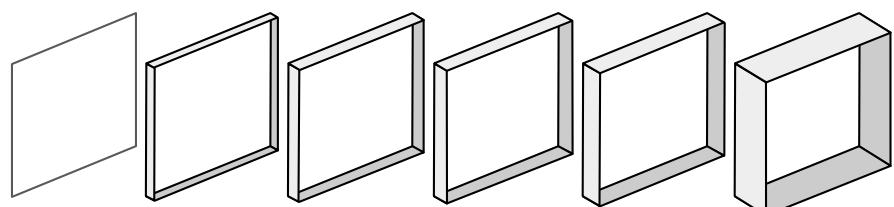
1 GLAZING RATIO



2 GLAZING TYPE

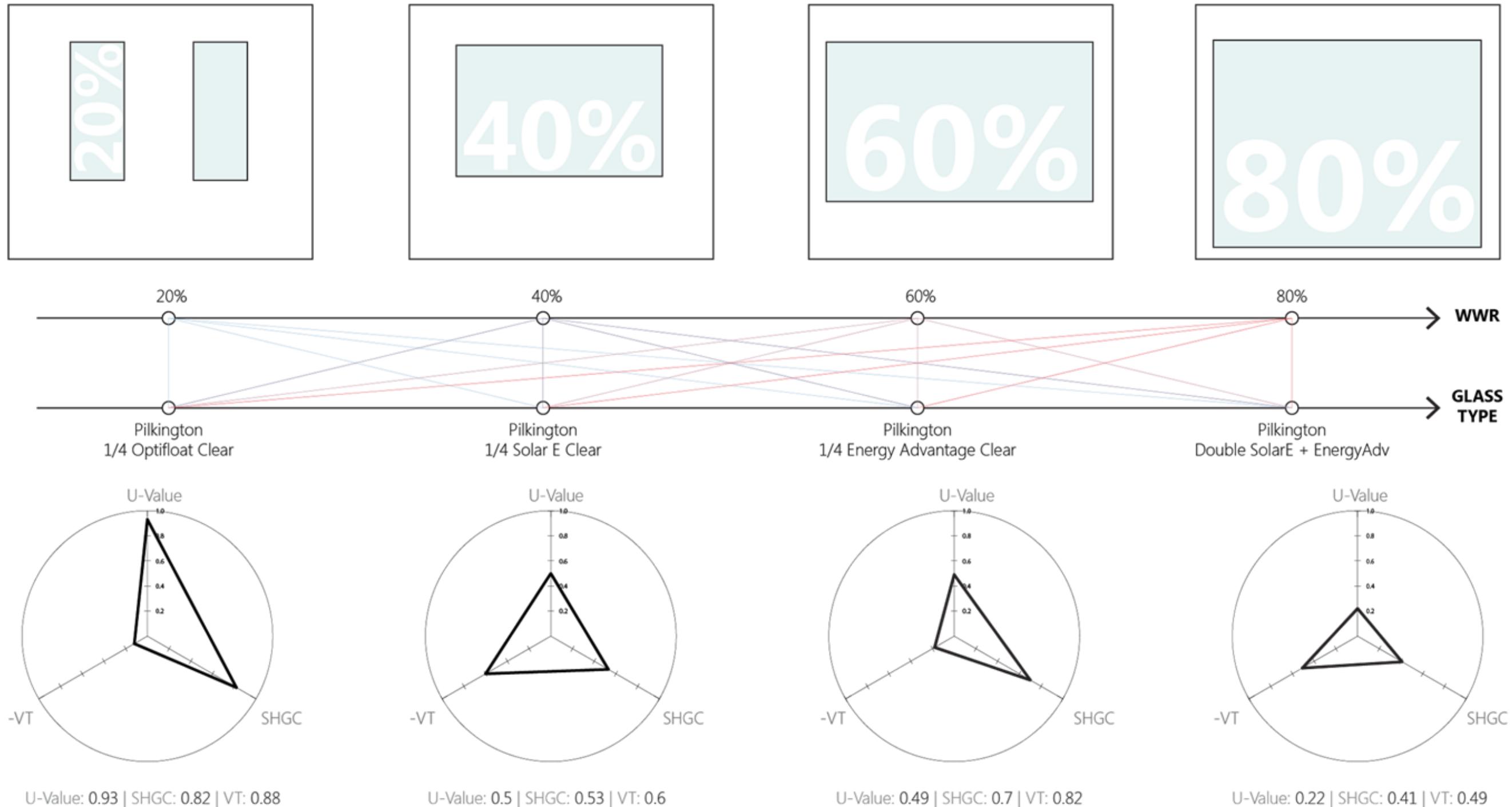


3 SHADING DEPTH



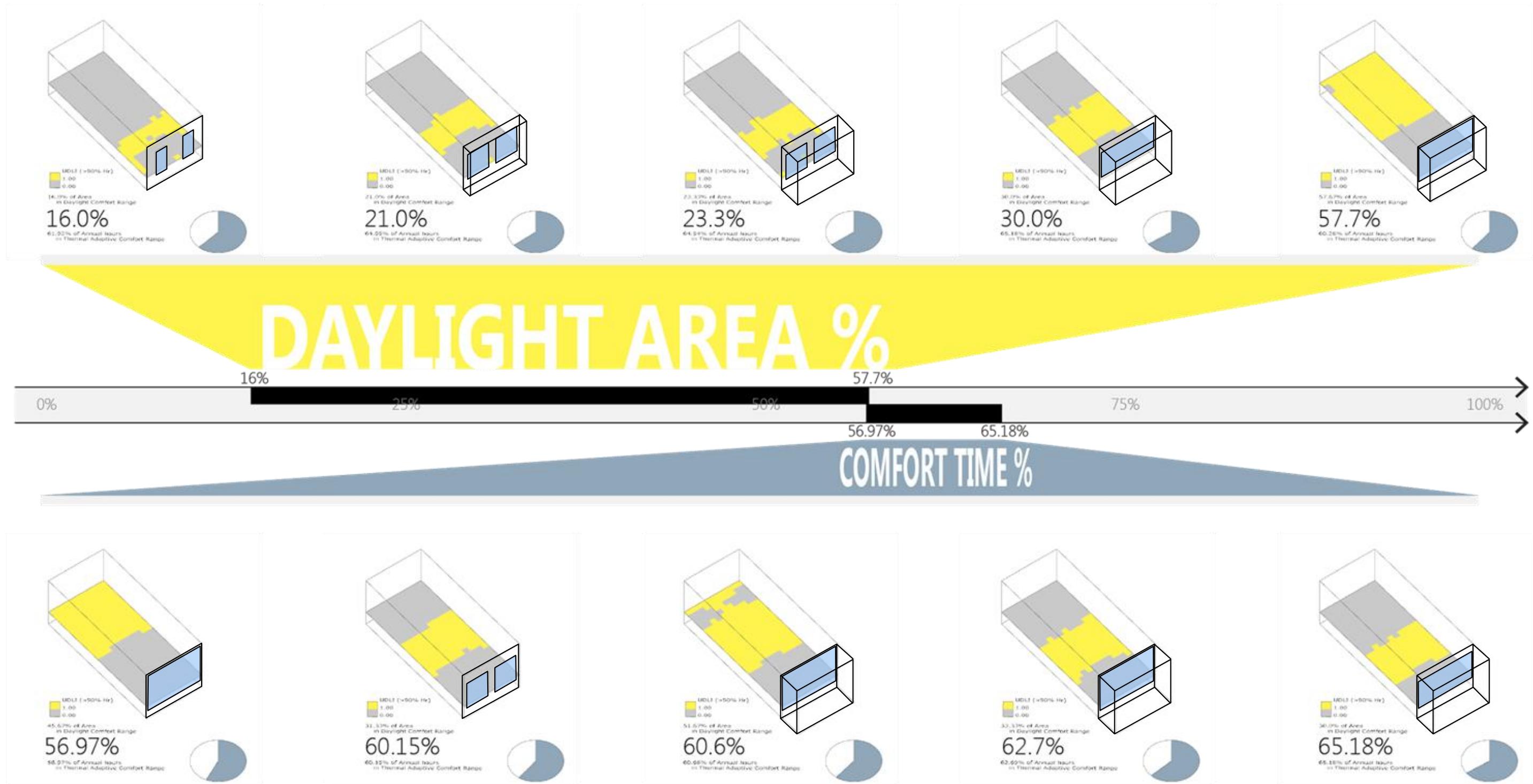
STUDY OF BALCONY

Glazing Ratio & Types



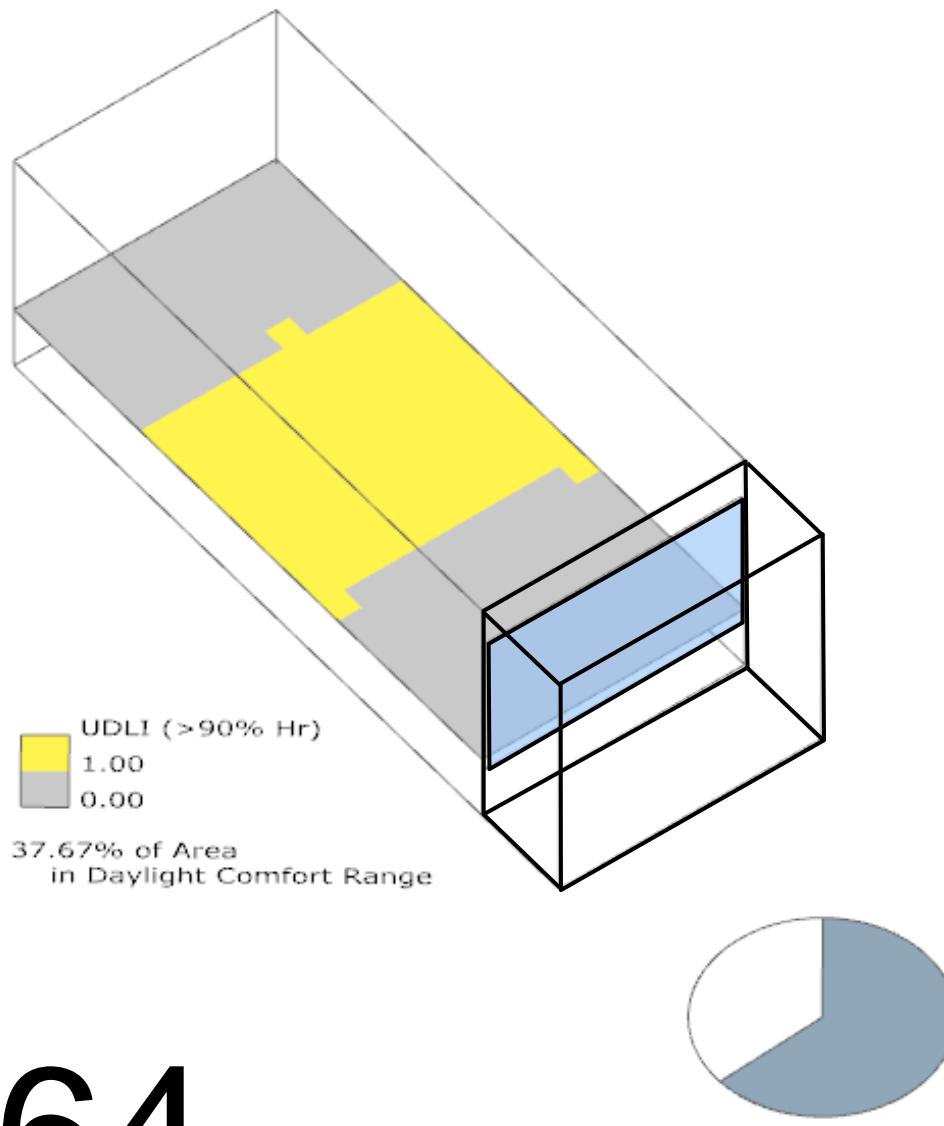
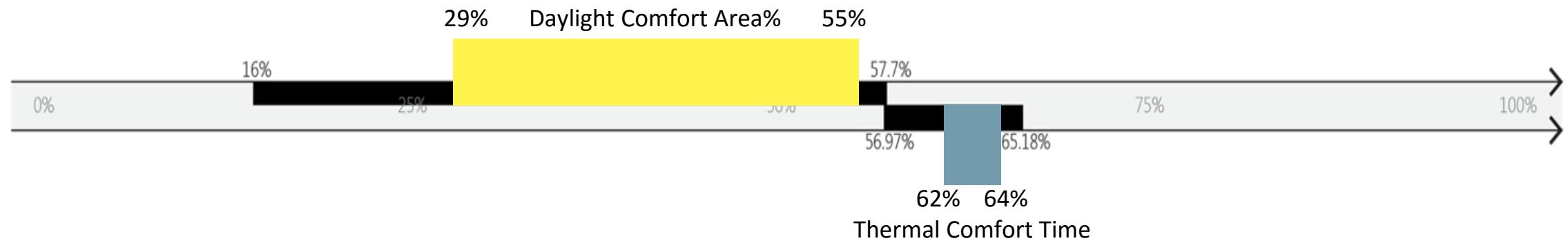
CHALLENGES FROM INTERIOR

Glz_Ratio & Glz_Type & Shading



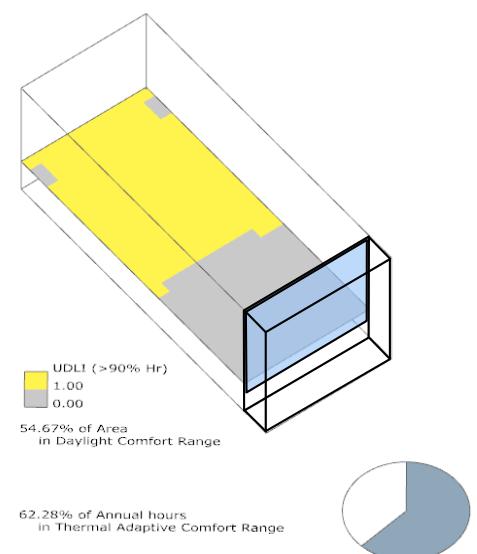
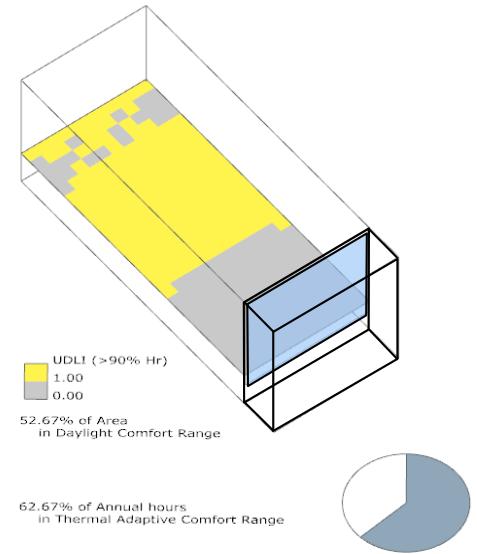
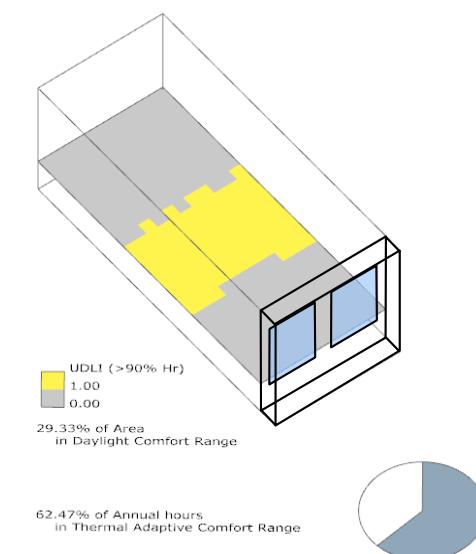
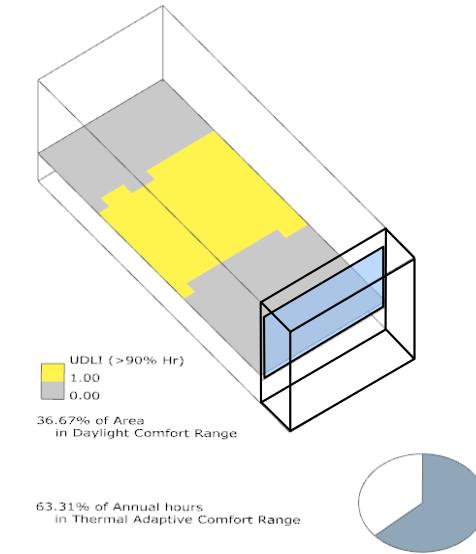
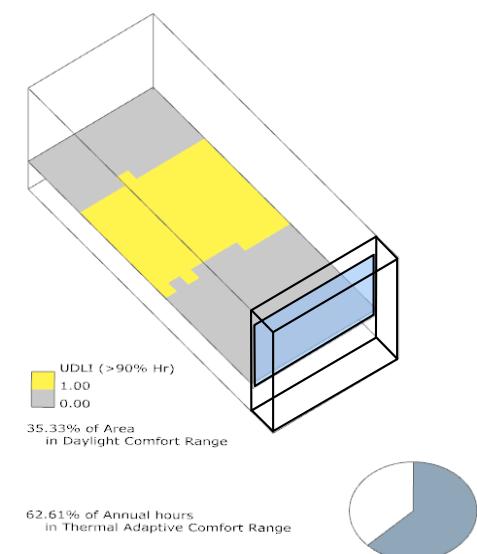
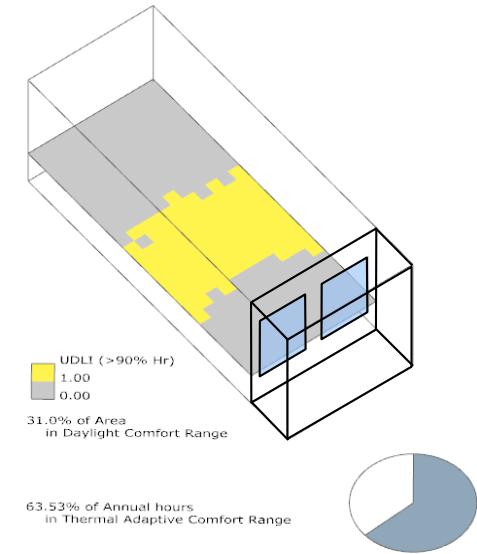
UNIT PROTOTYPE

Glz_Ratio & Glz_Type & Shading



64%

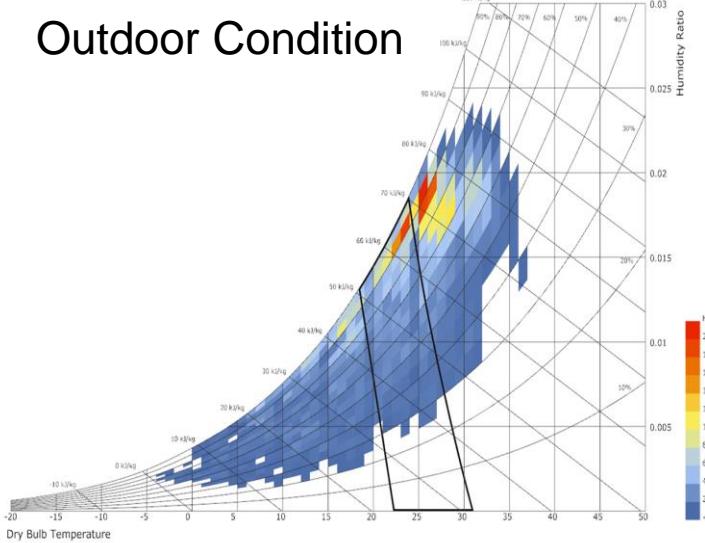
Annual Hours in Adaptive Comfort



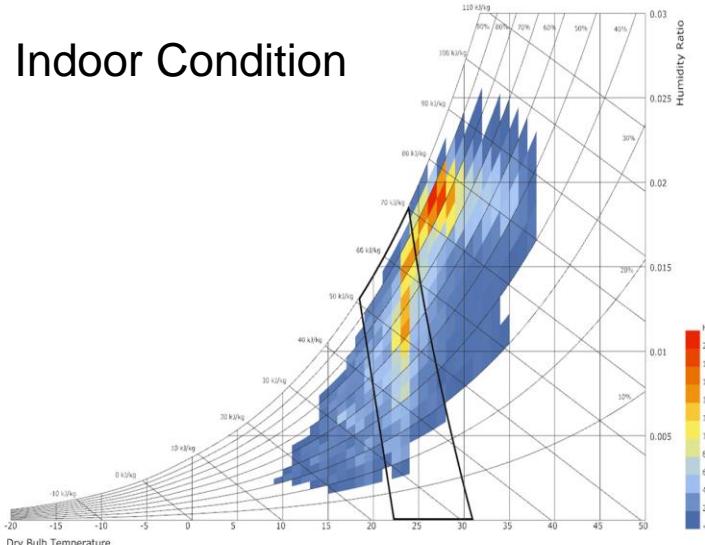
PSYCHROMETRIC CHART

Outdoor & Indoor Condition

Outdoor Condition

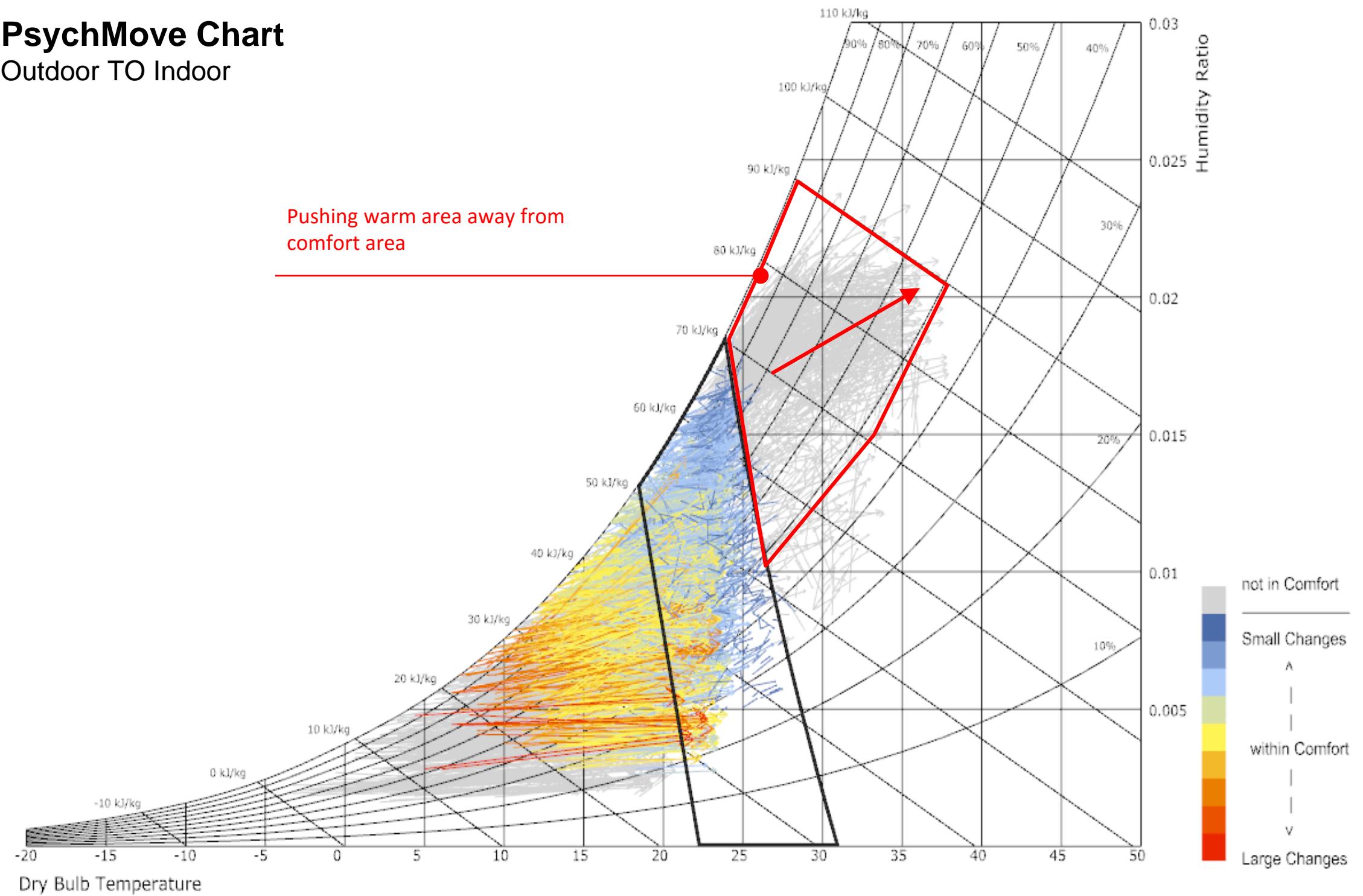


Indoor Condition



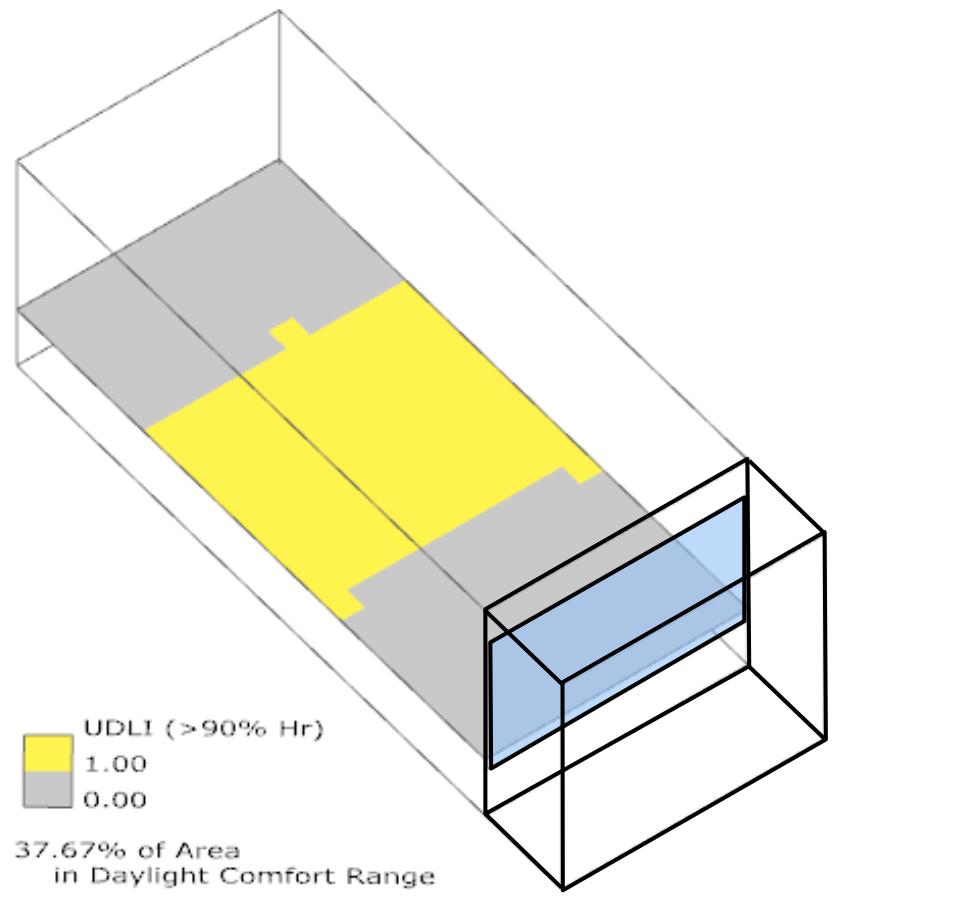
PsychMove Chart Outdoor TO Indoor

Pushing warm area away from comfort area



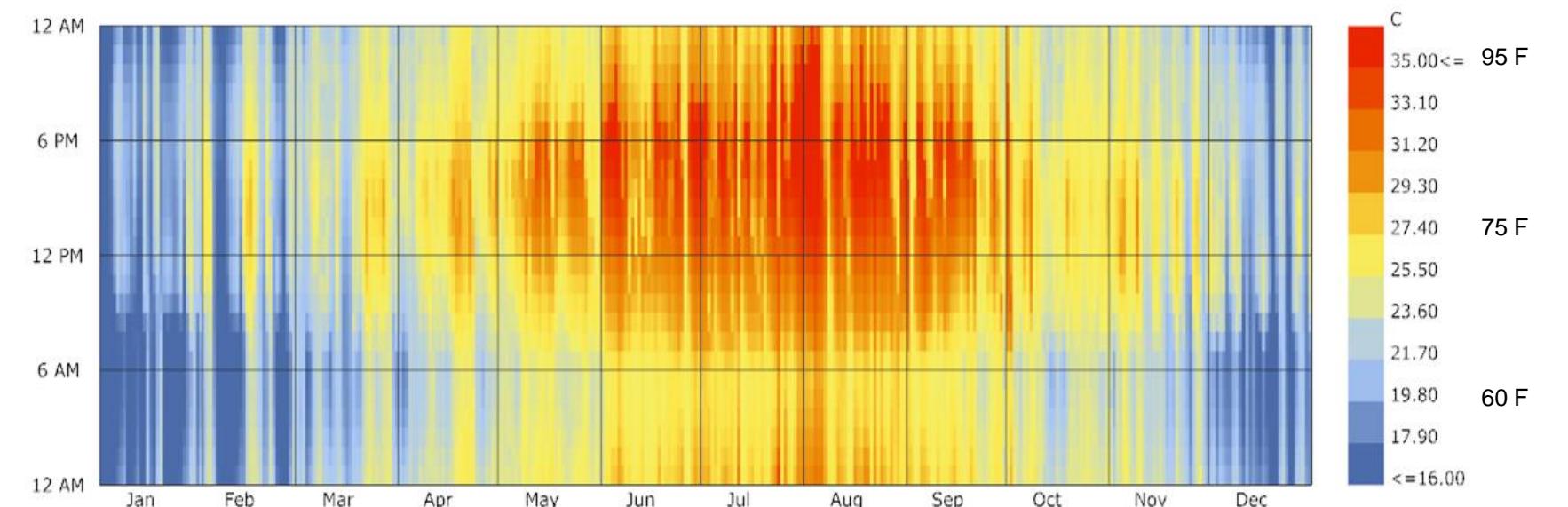
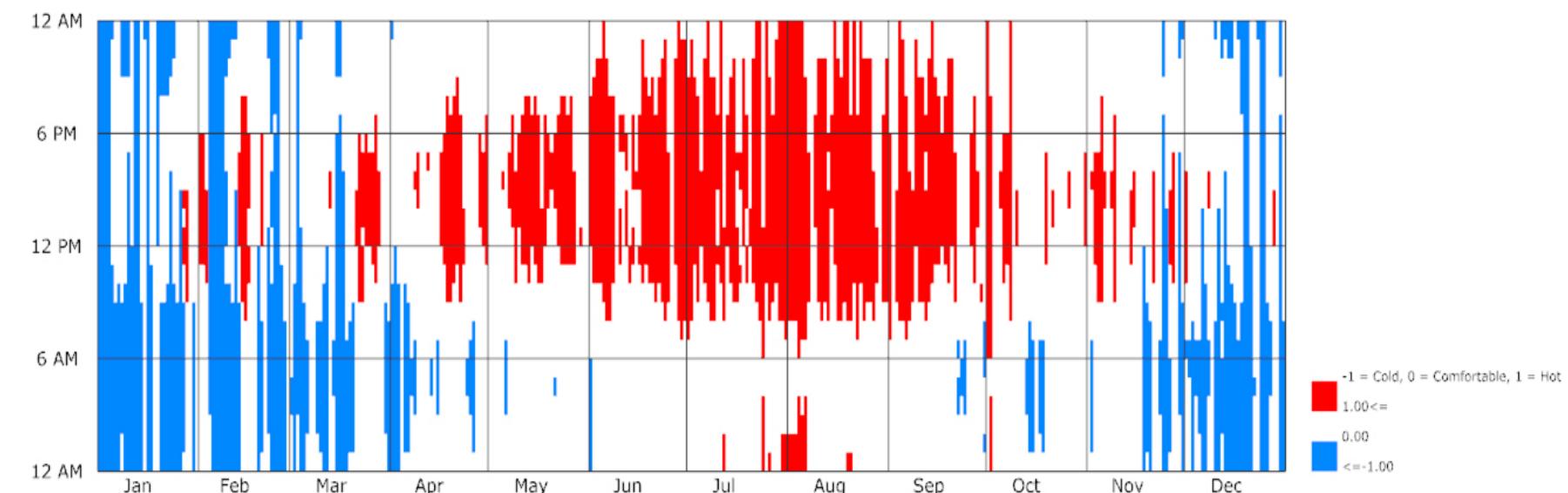
PROTOTYPES

Annual Data Spectrum



64%

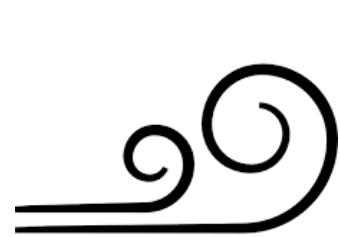
Annual Hours in Adaptive Comfort



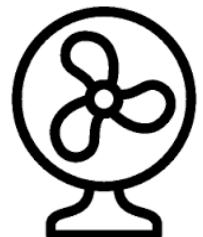
Operative Temperature

OPERATIVE TEMPERATURE

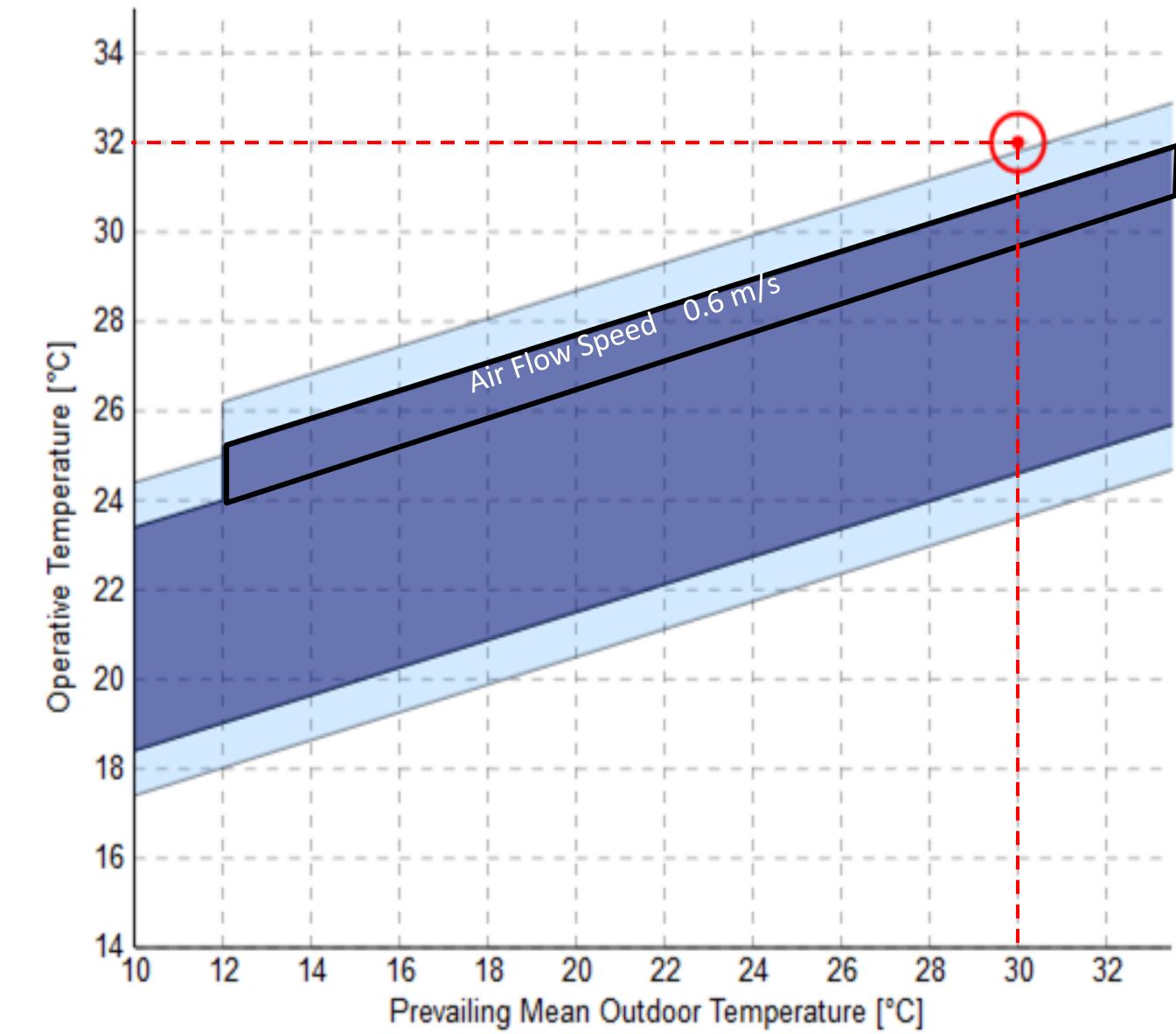
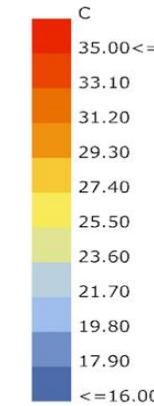
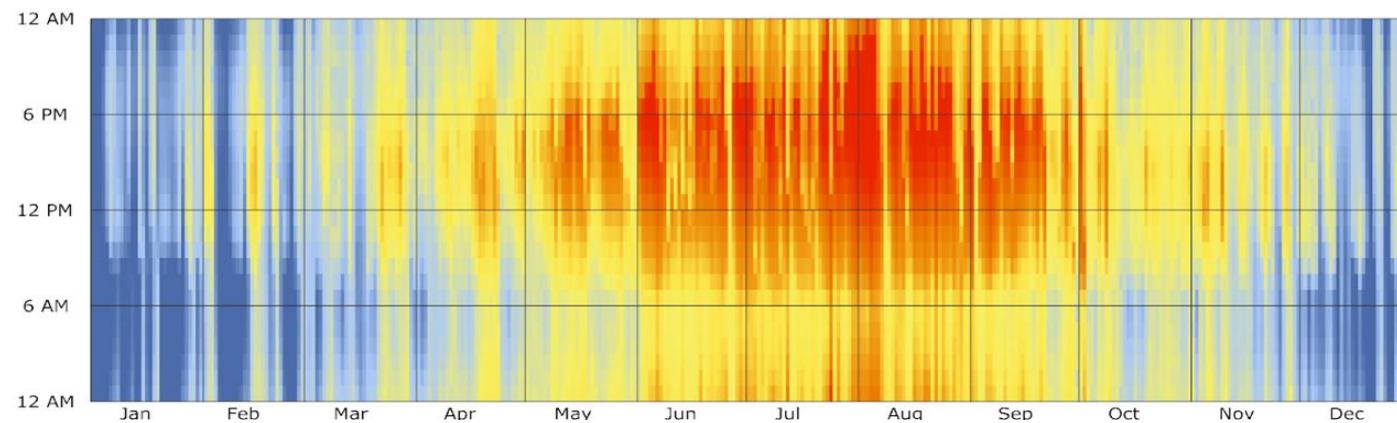
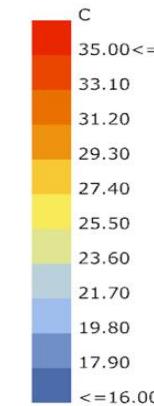
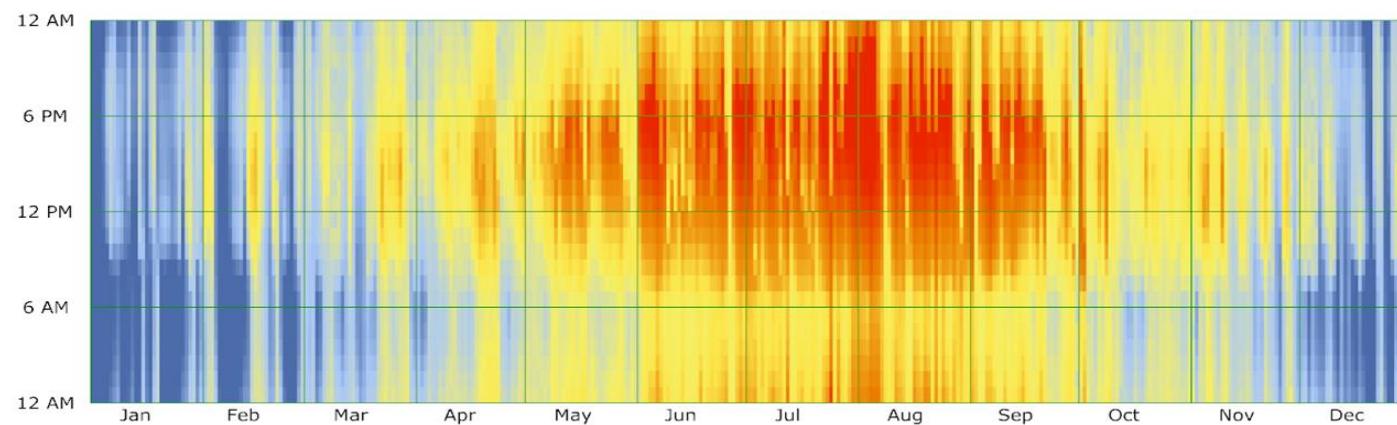
Air Flow Impact



Natural

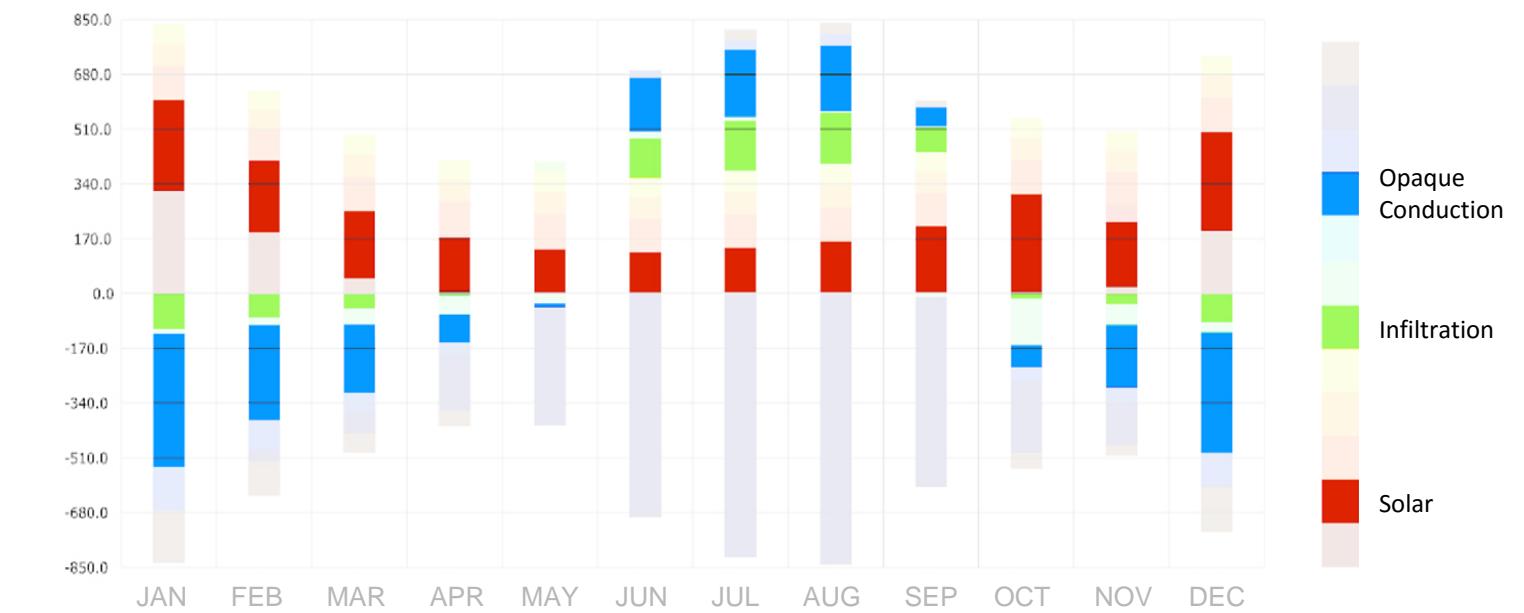
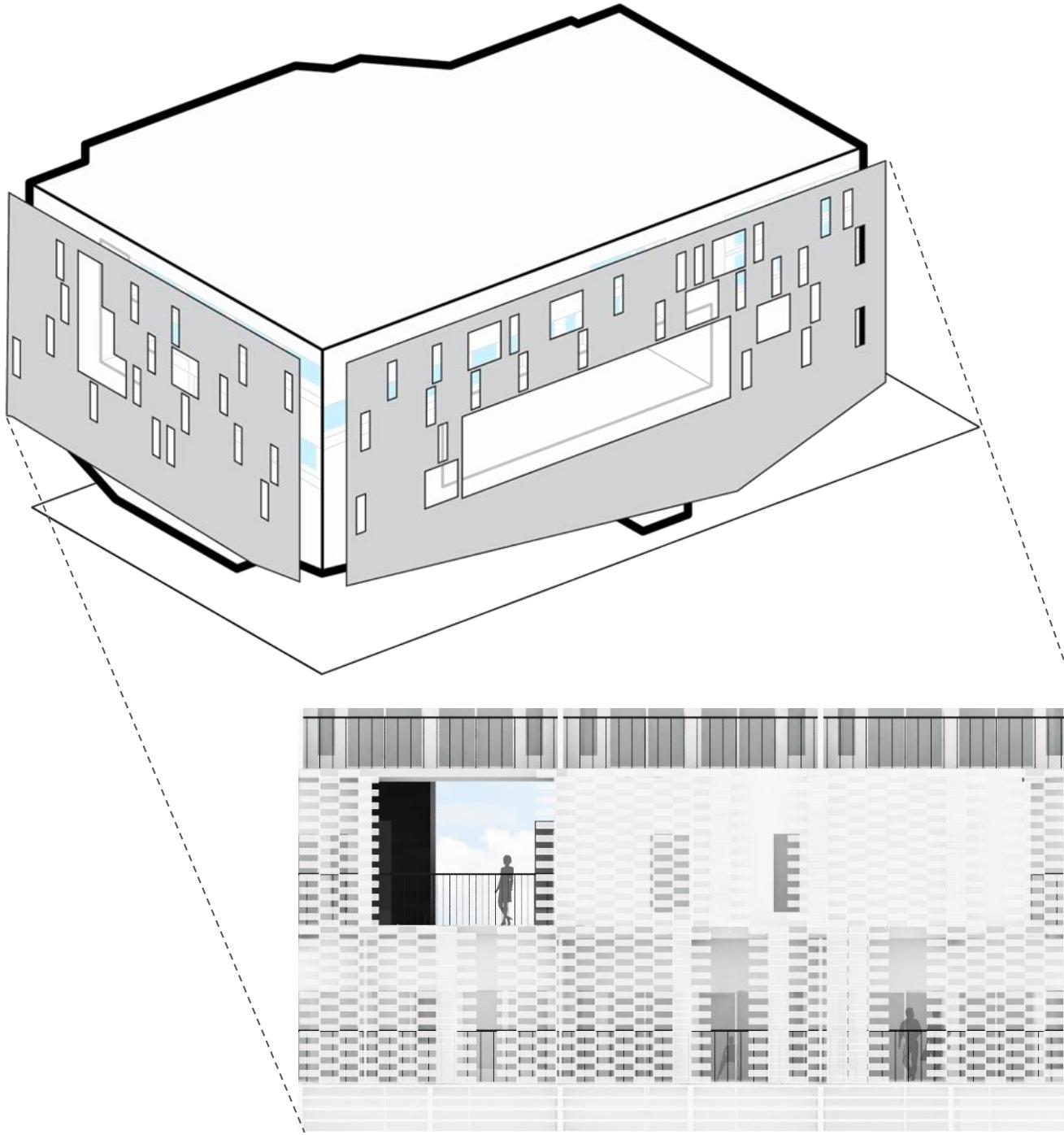


Mechanical



NEW SCREEN

Shading & Opaque Material Adjustment



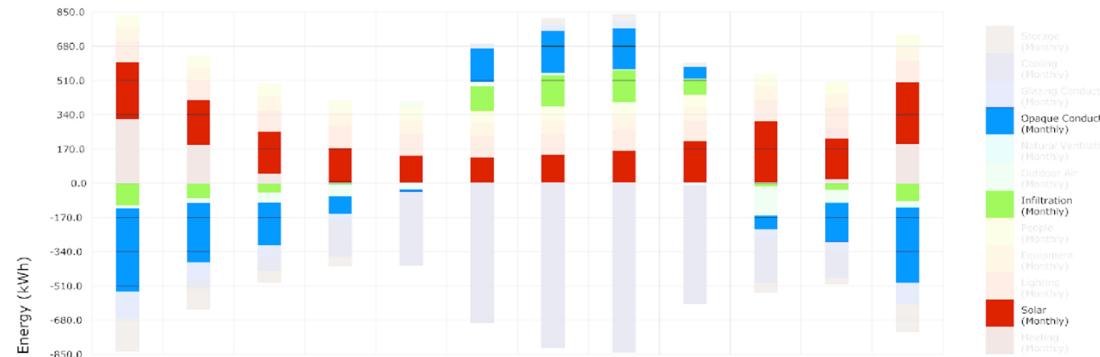
↓ 37 %



ENERGY BALANCE (LOAD)

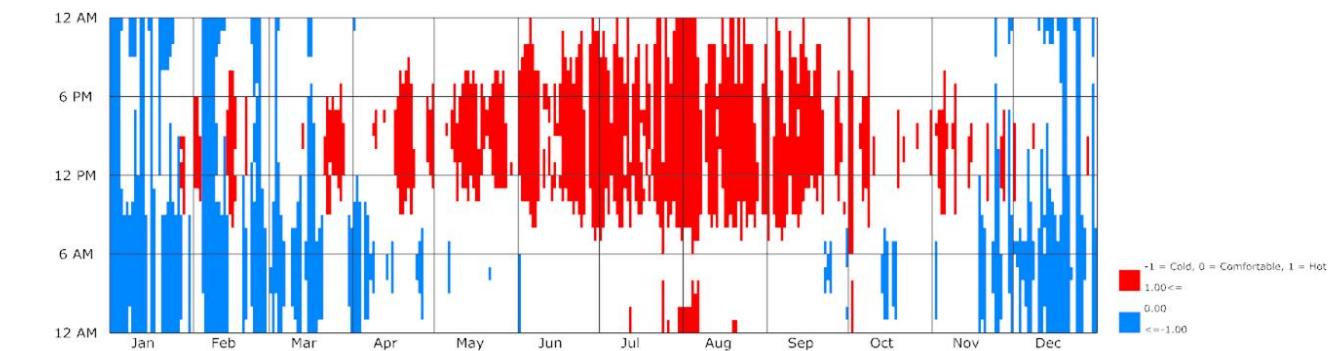
Screen Adjustment

BEFORE



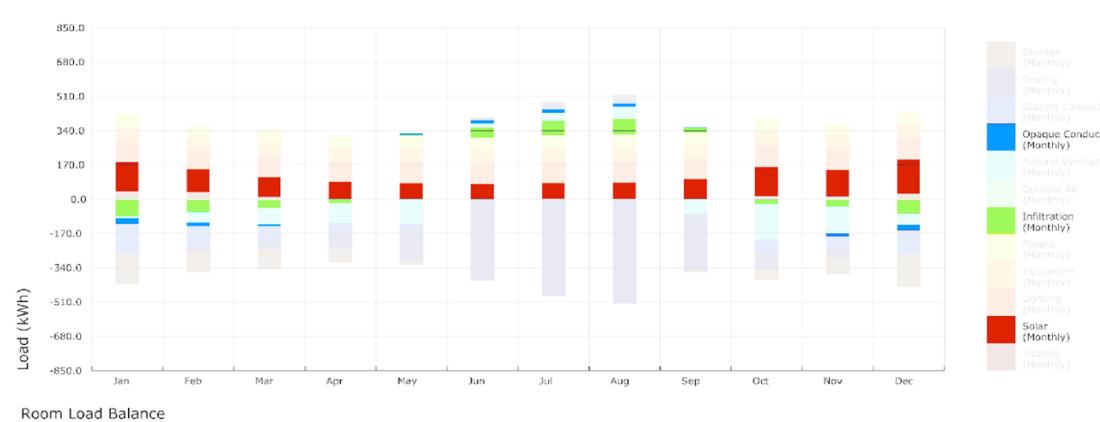
4722 kWh
41 kBtu/sqft

37% REDUCTION

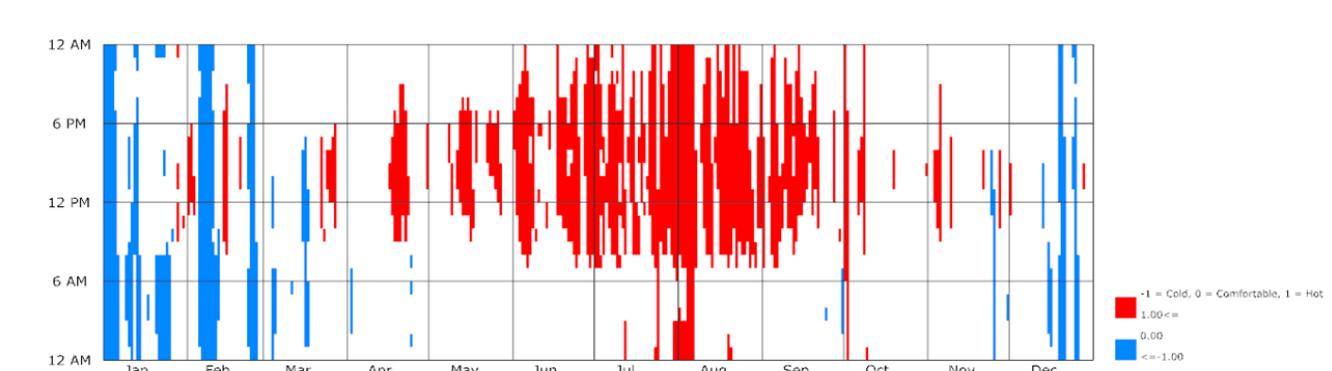


64%
Of Annual hours (Adaptive Comfort)

11% IMPROVEMENT



2965 kWh
26 kBtu/sqft

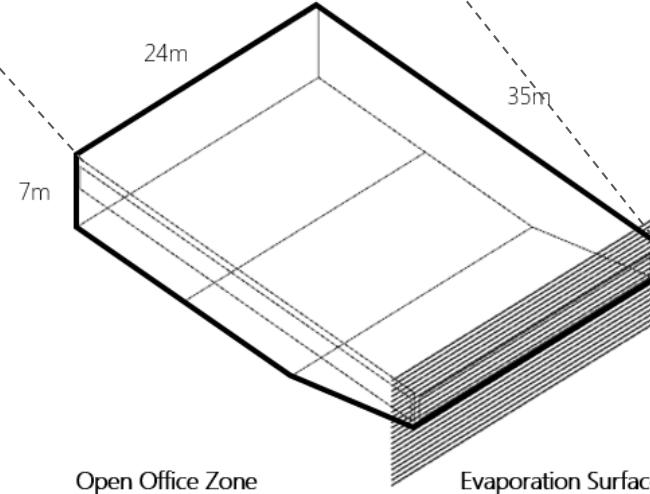
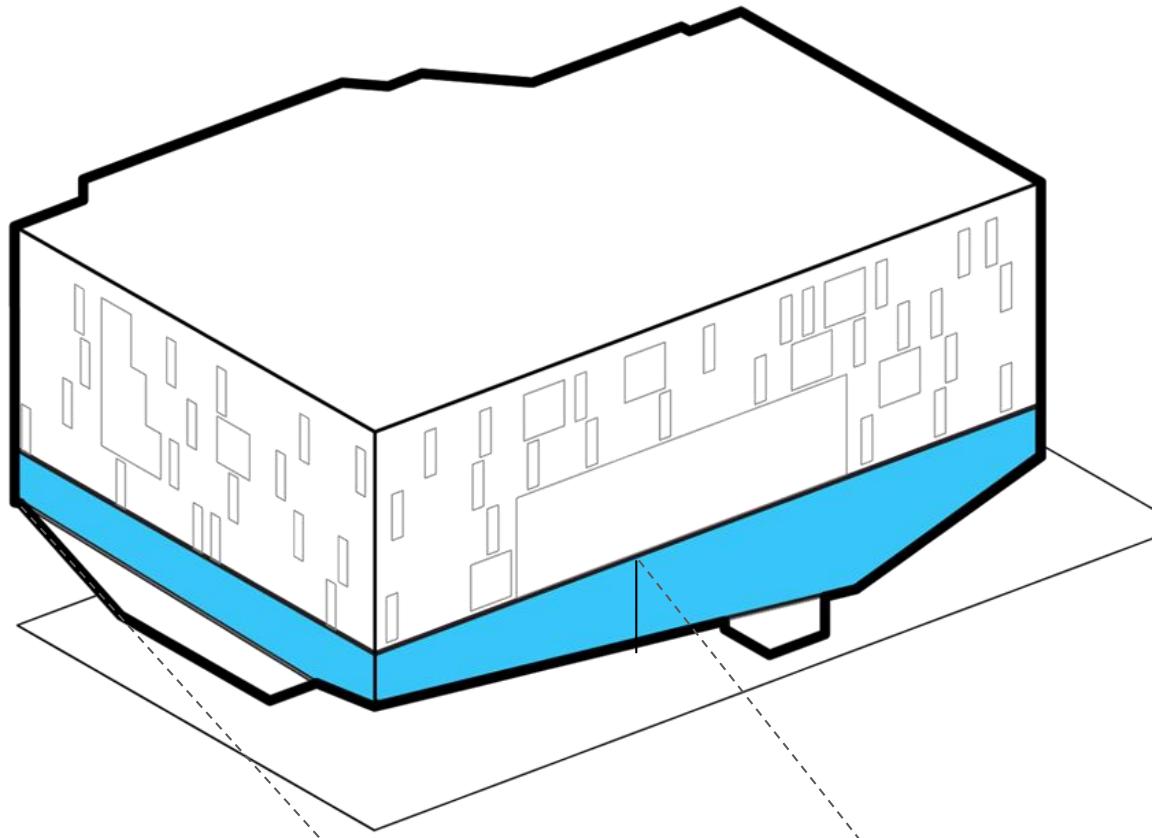


75%
Of Annual hours (Adaptive Comfort)

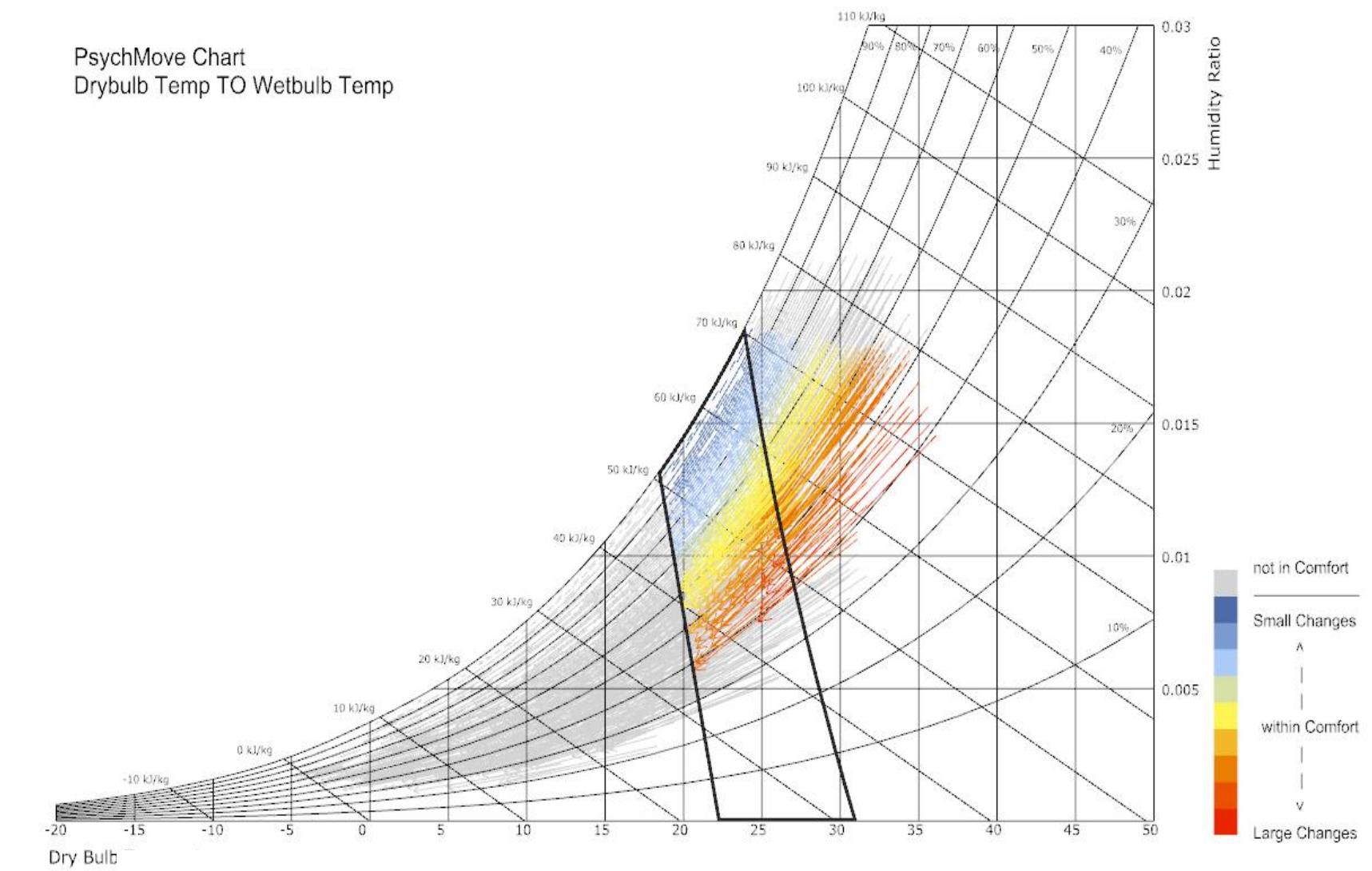
AFTER

EVAPORATIVE COOLING

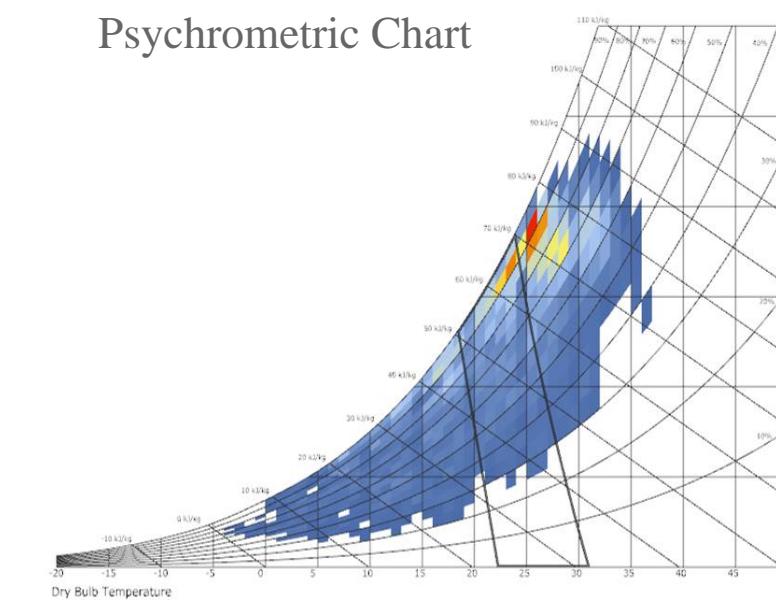
Outer Surface Cooling



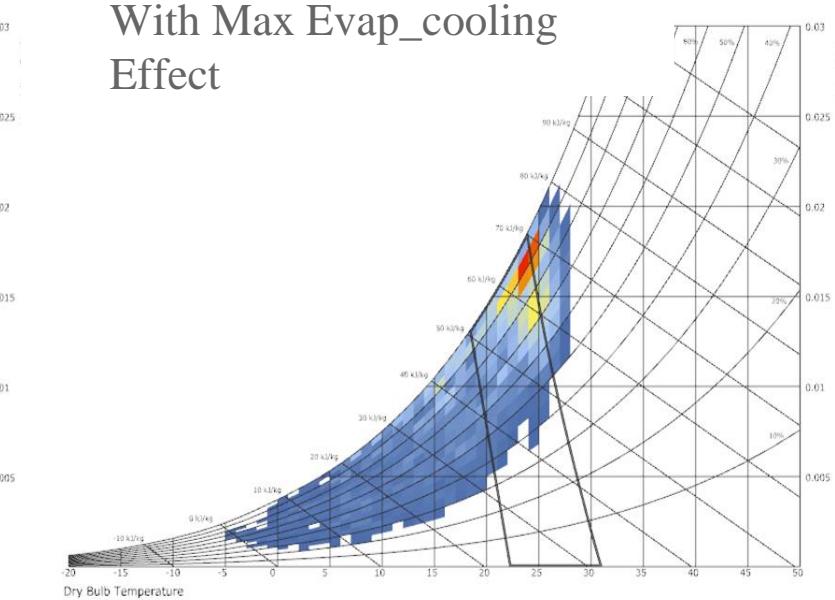
PsychMove Chart
Drybulb Temp TO Wetbulb Temp



Psychrometric Chart

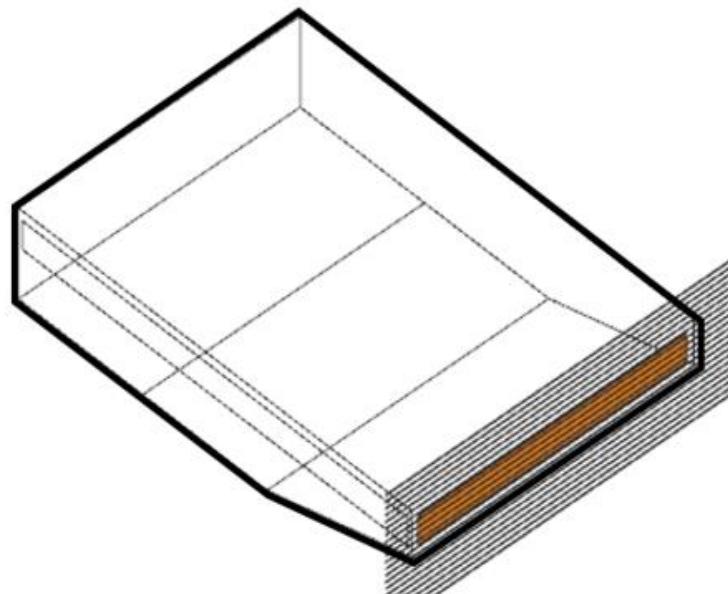


With Max Evap_cooling Effect



POTENTIAL OF EVAPORATIVE COOLING

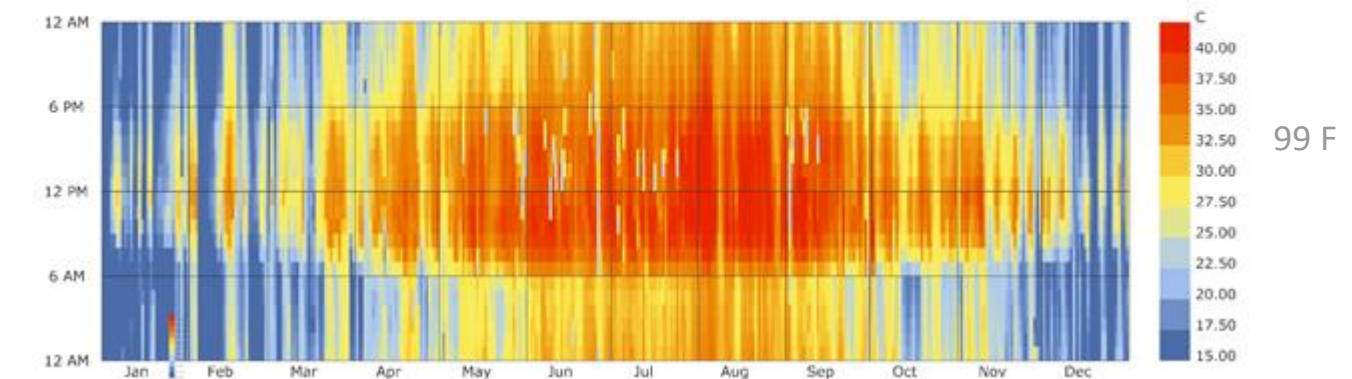
Surface Temperature



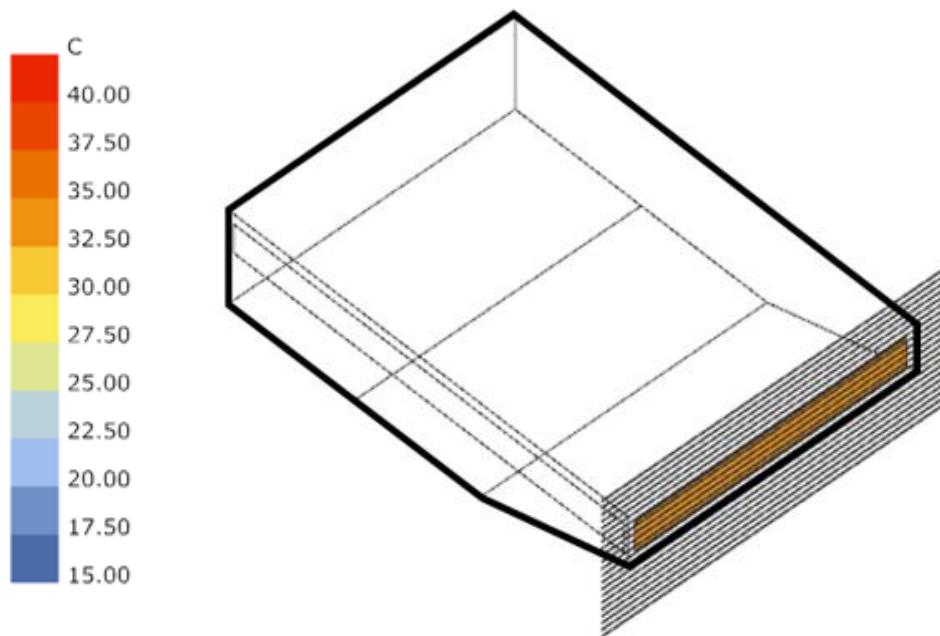
Base case

34.6 °C (94 °F)

Outer Surface Temperature



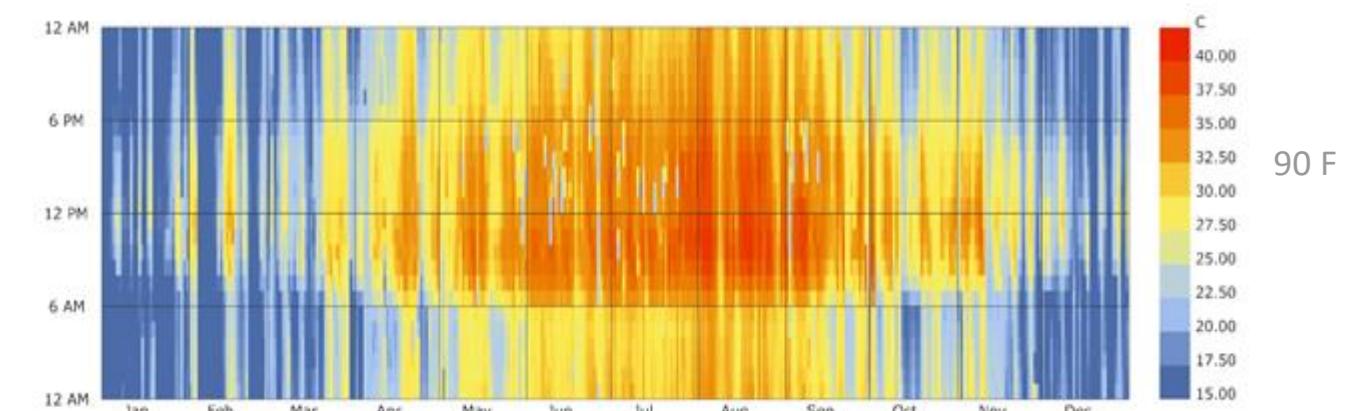
Outer Surface Temperature of Test Windows Surface
Annual Hourly Data - **Base case**



Evaporative Cooling

31.9 °C (89 °F)

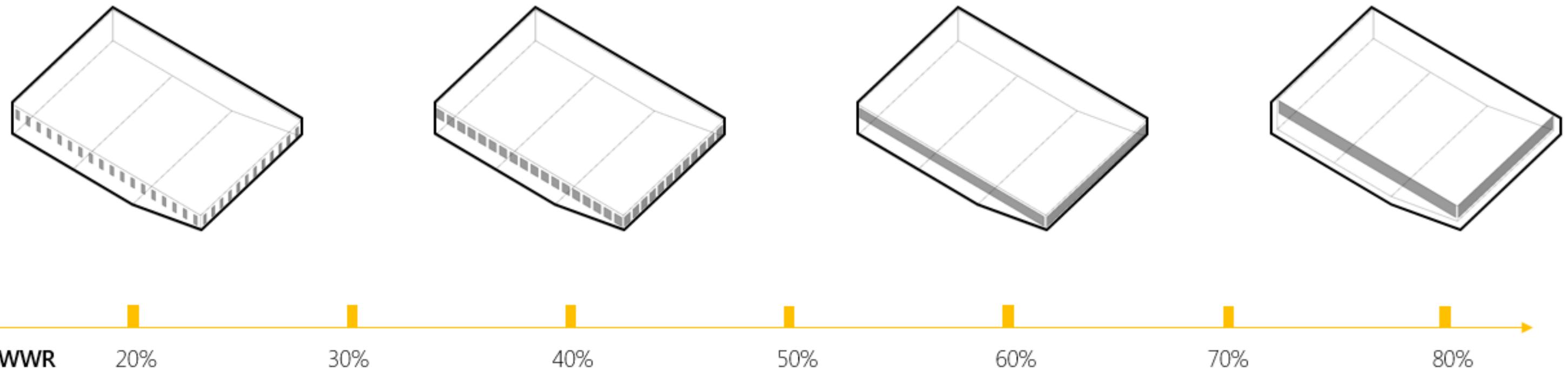
Outer Surface Temperature



Outer Surface Temperature of Test Windows Surface
Annual Hourly Data - **with Evaporative Cooling**

STUDY OF OFFICE ZONE

Glazing Ratio

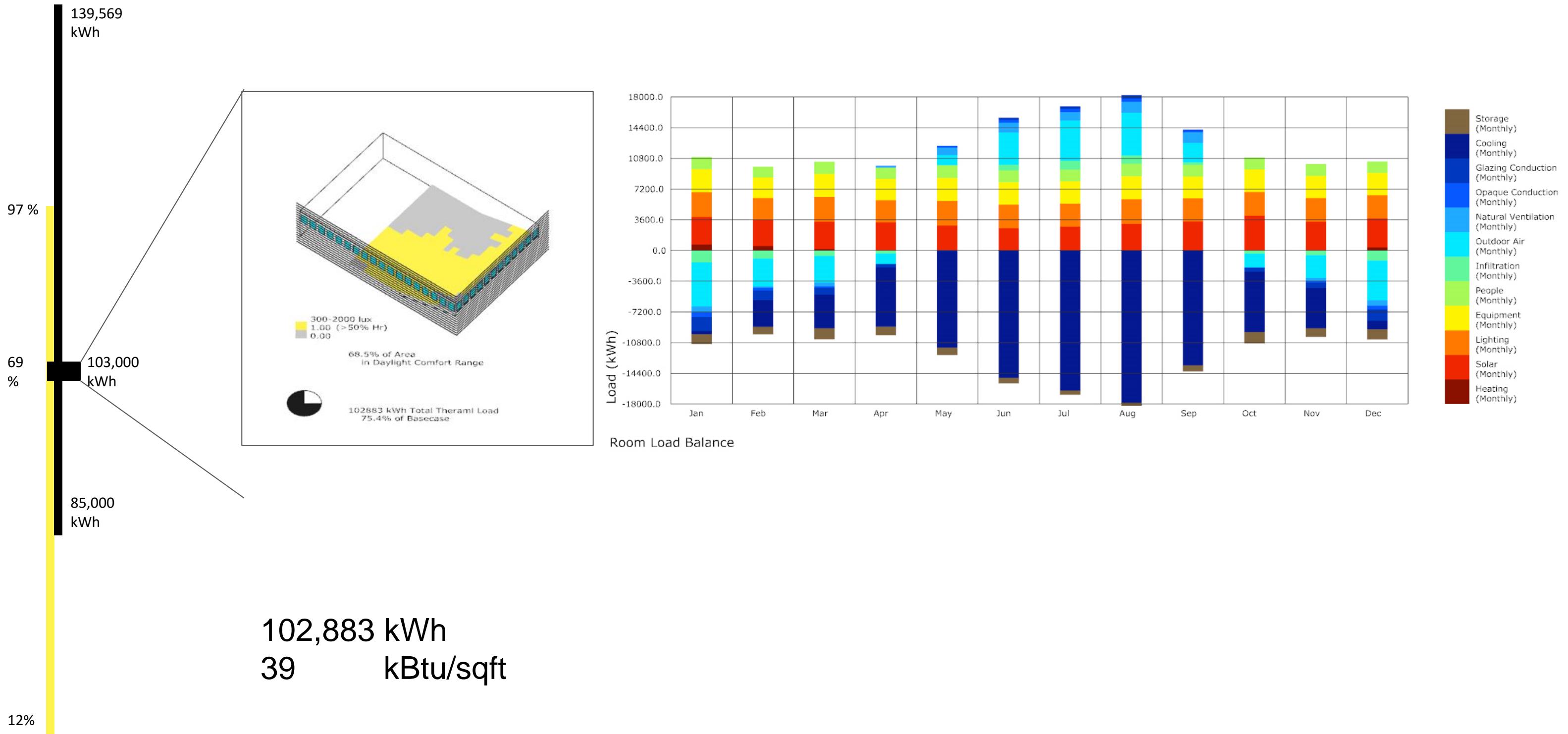


Window-Wall ratio ranges from 20% to 80%, in which 10% increase of each step, to test the right range for this specific open office.

*Construction,
EXTERIOR WINDOW, !- name
Clear 3mm. !- - Layer 1*

STUDY OF OFFICE ZONE

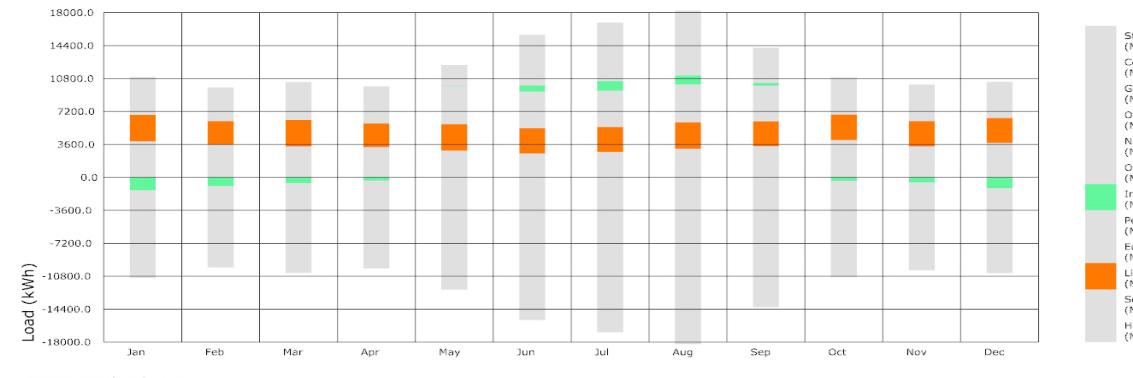
Shading Devices



STUDY OF OFFICE ZONE

Energy Loads

BEFORE

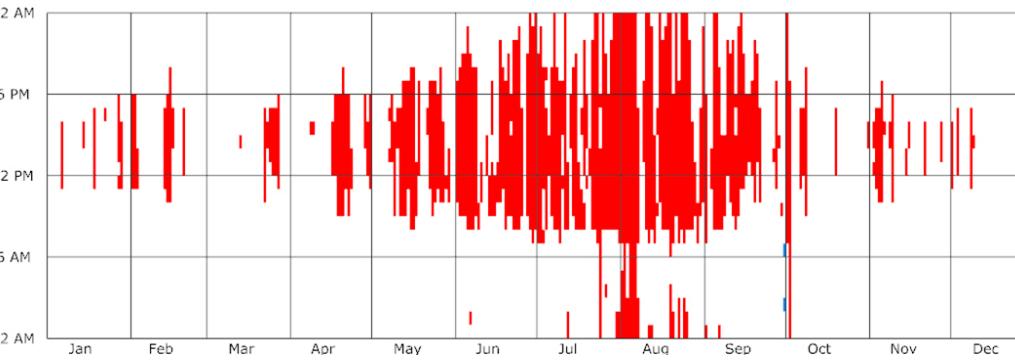
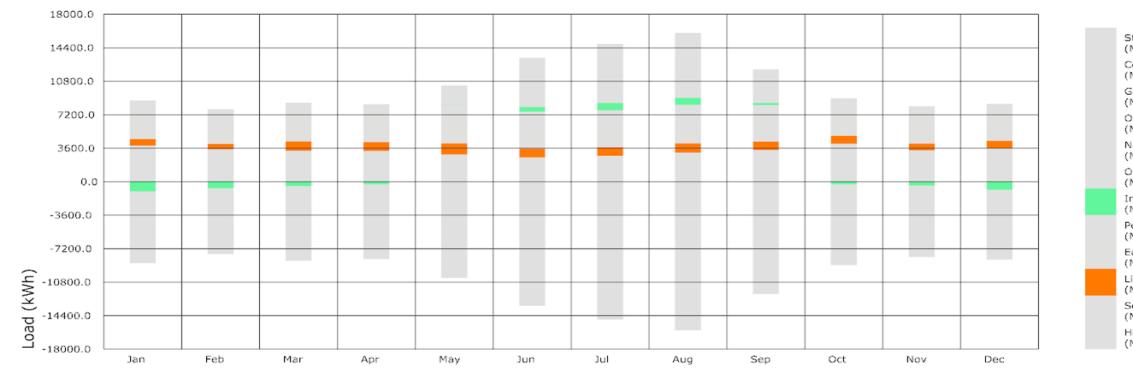


102,883 kWh
39 kBtu/sqft

85,688 kWh
33 kBtu/sqft

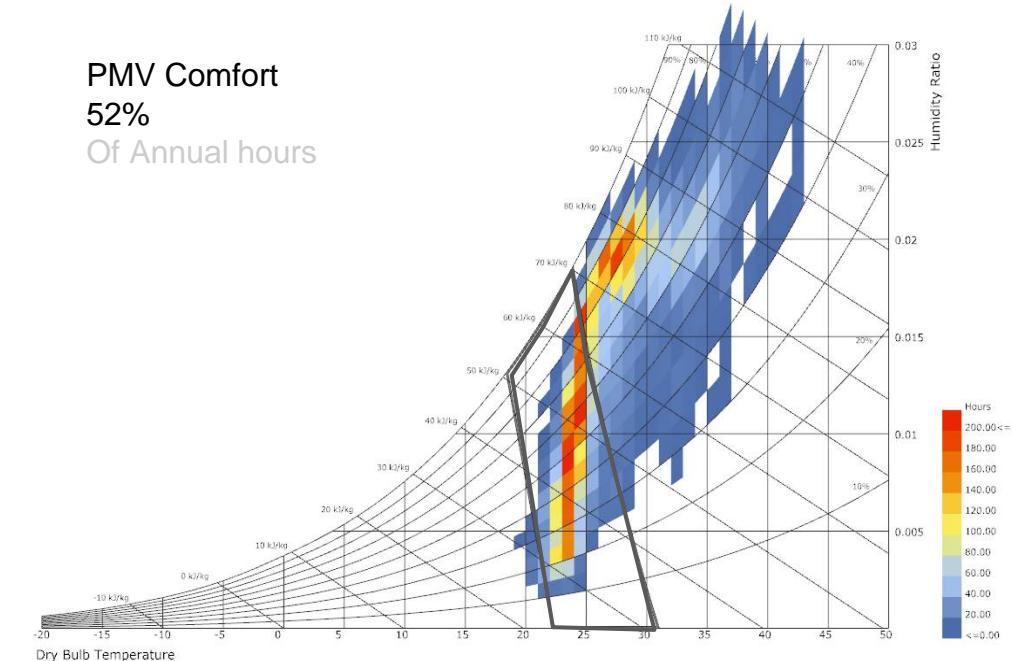
↓ 16.7 %

AFTER

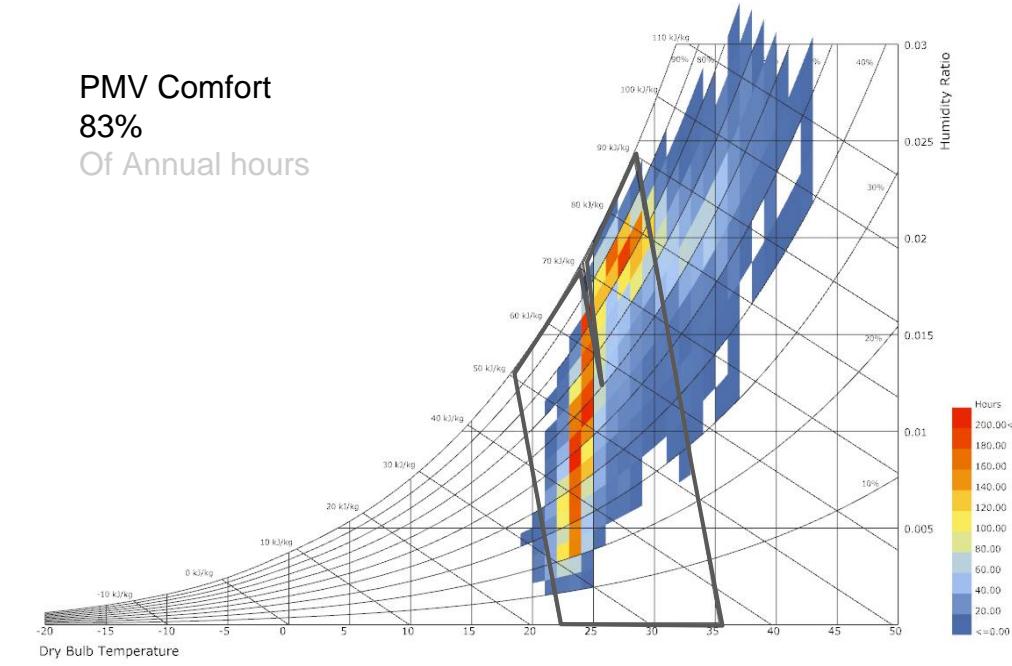


68%
Of Annual hours (Adaptive Comfort)

PMV Comfort
52%
Of Annual hours

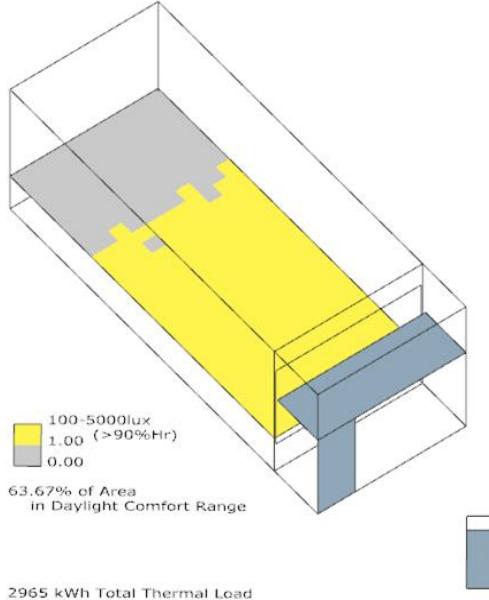


PMV Comfort
83%
Of Annual hours



SUMMARY

Apartment & Open Office



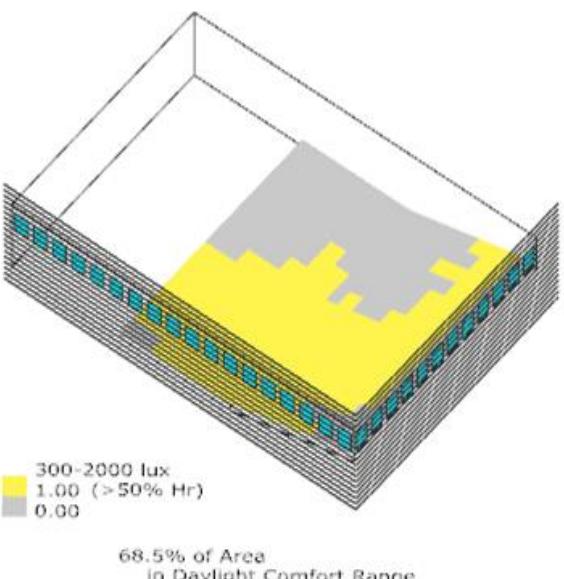
Adaptive Comfort

75%

Of Annual hours

LOAD

26 kBtu/sqft



Adaptive Comfort

68%

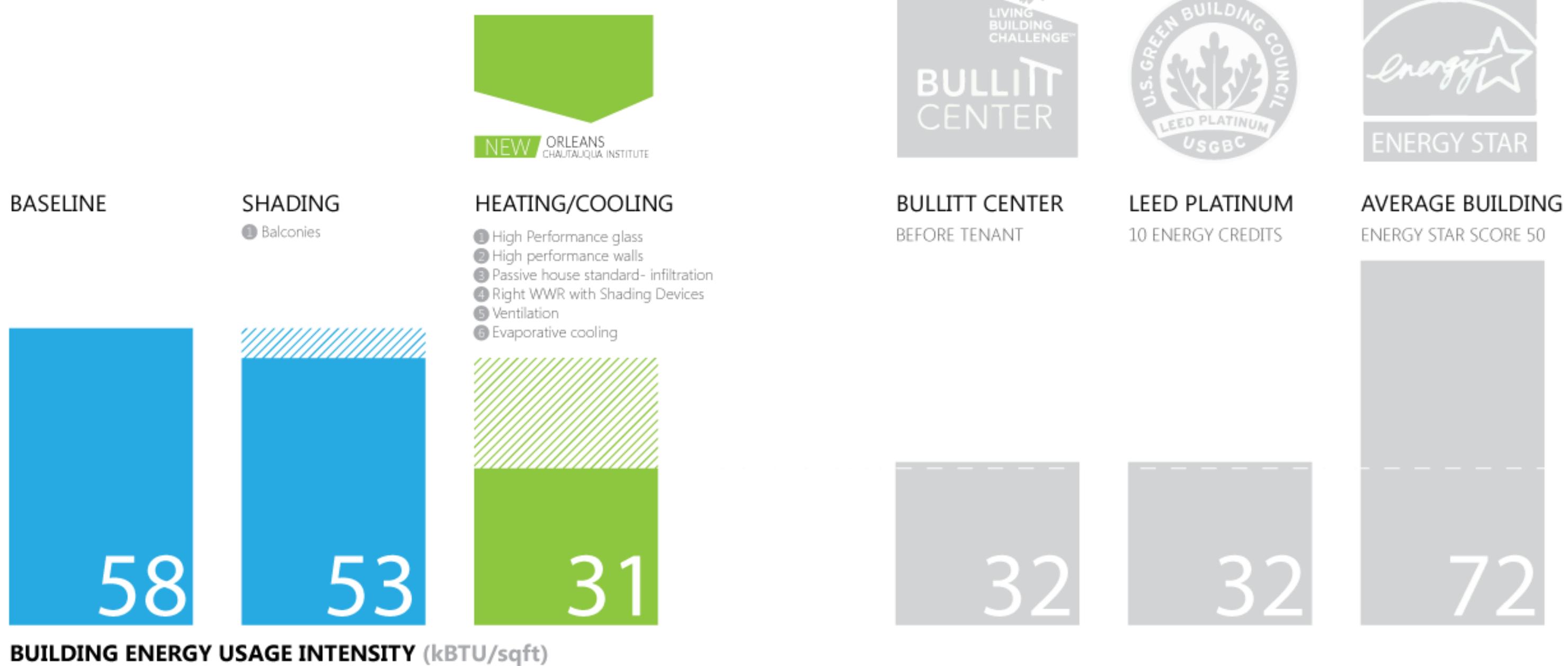
Of Annual hours

LOAD

33 kBtu/sqft

ENERGY USAGE INTENSITY

EUI Comparison

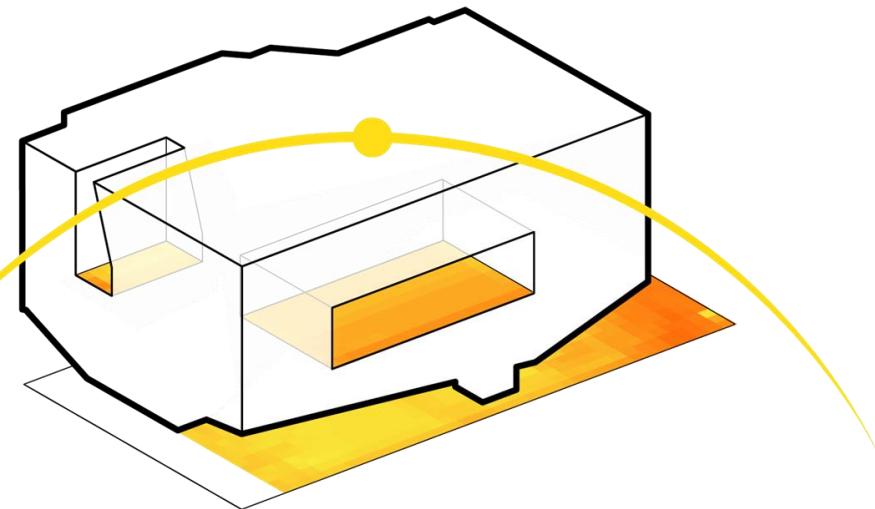


ENVIRONMENTAL APPROACHES

Summary

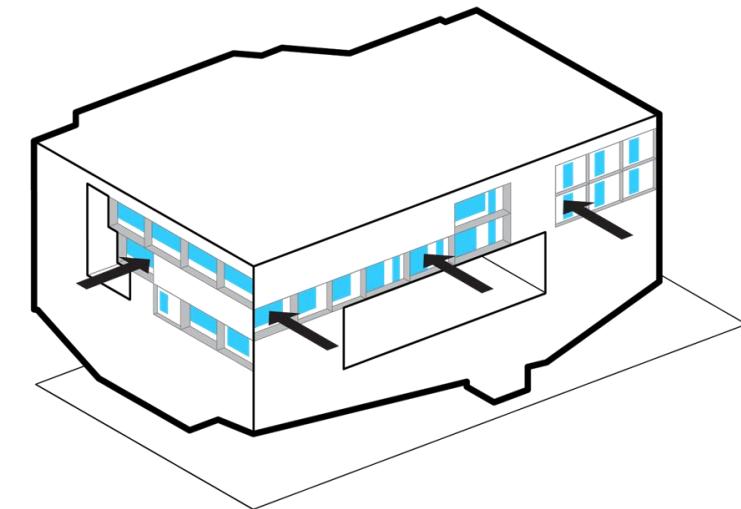
1

OUTDOOR
SELF-SHADING



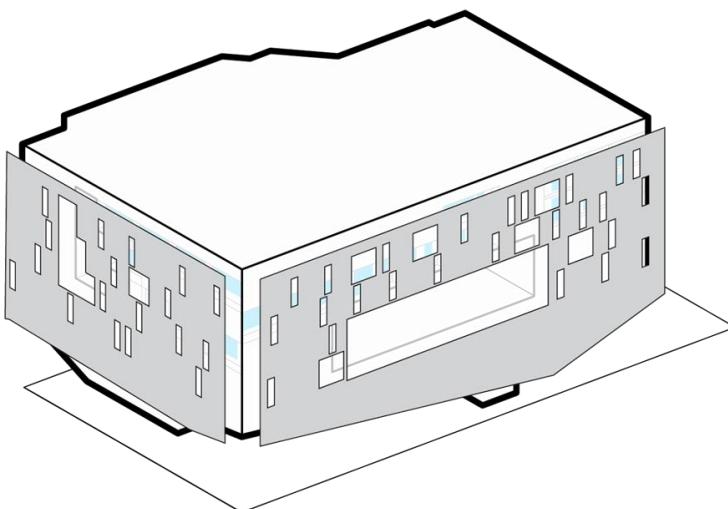
2

INDOOR
BALCONIES



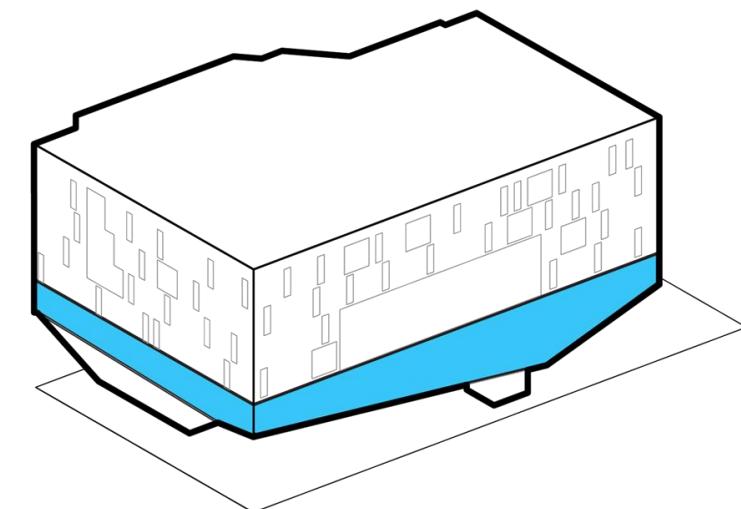
3

BUILDING
SCREEN



4

EXTERIOR
EVAPORATIVE COOLING



1 SITE & CLIMATE

Natural Boundary & Resources

2 ENV_DEVELOPMENTS

Environmental Challenges

3 ARCH_PERFORMANCE

Architectural Challenges

// Working Space

Open-Floor Office + Cooling Pipes + Shading

// Living Space

Residential Units + Atrium + Double Facade

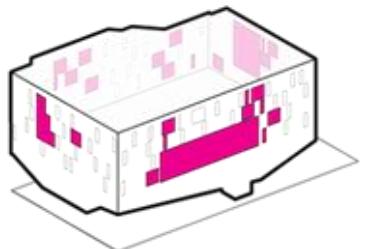
// Outdoor Space

Music + City views + Roof

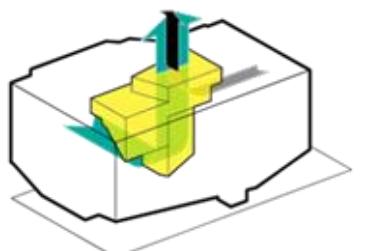
// Details

Shading + Evaporative Cooling + Green

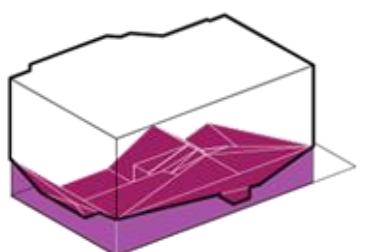
ARCHITECTURAL FEATURES



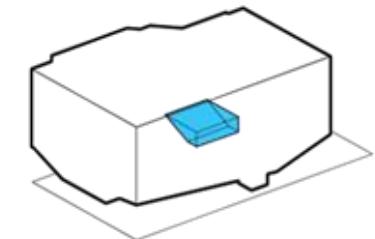
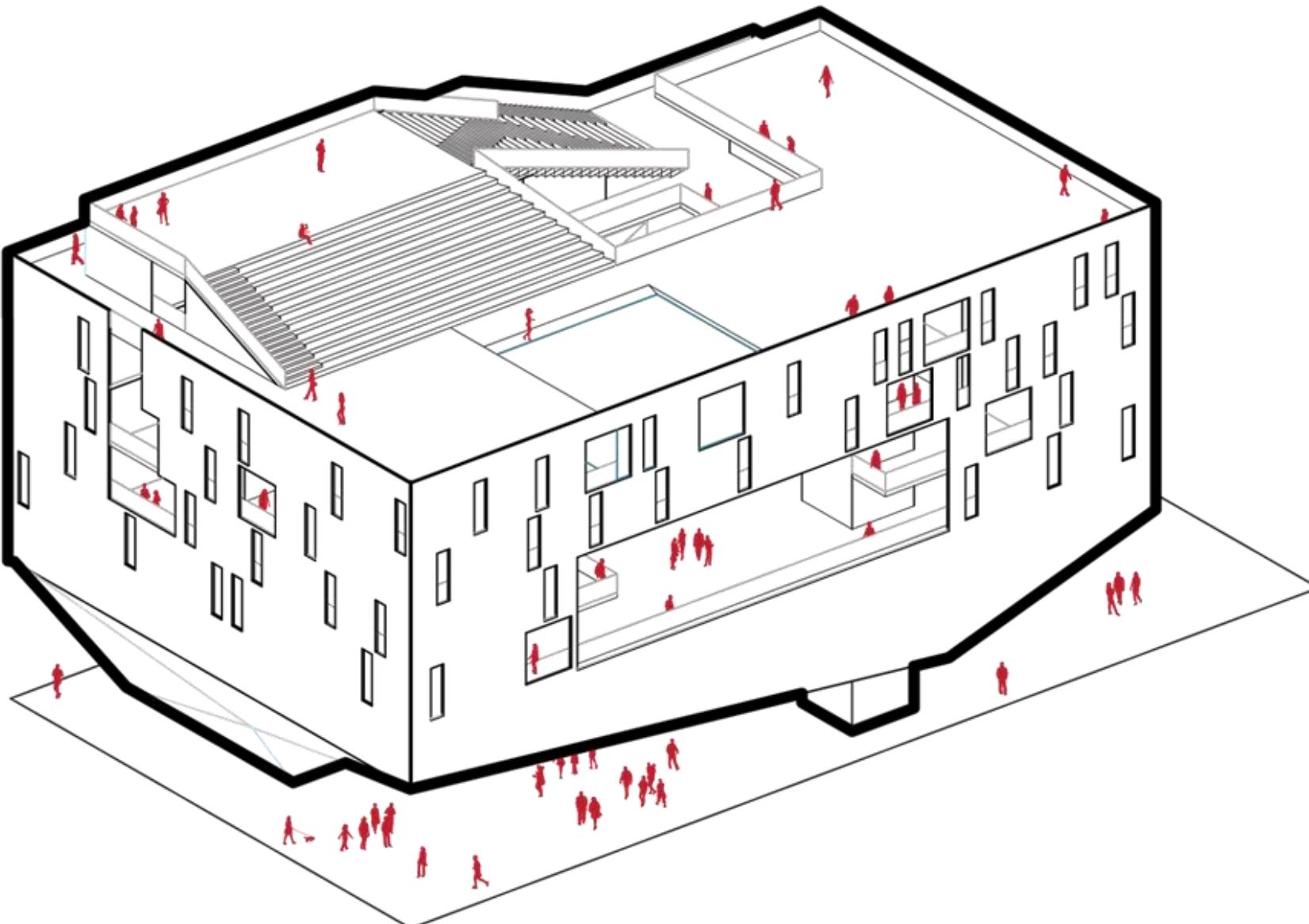
PUBLIC OPENINGS



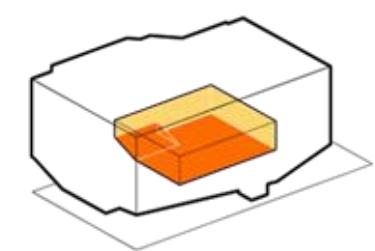
CENTRAL ATRIUM



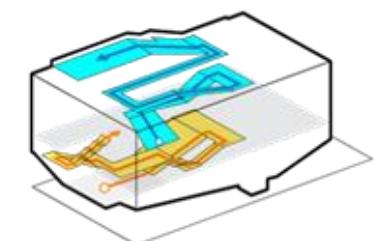
FESTIVAL STAGE



SWIMMING POOL



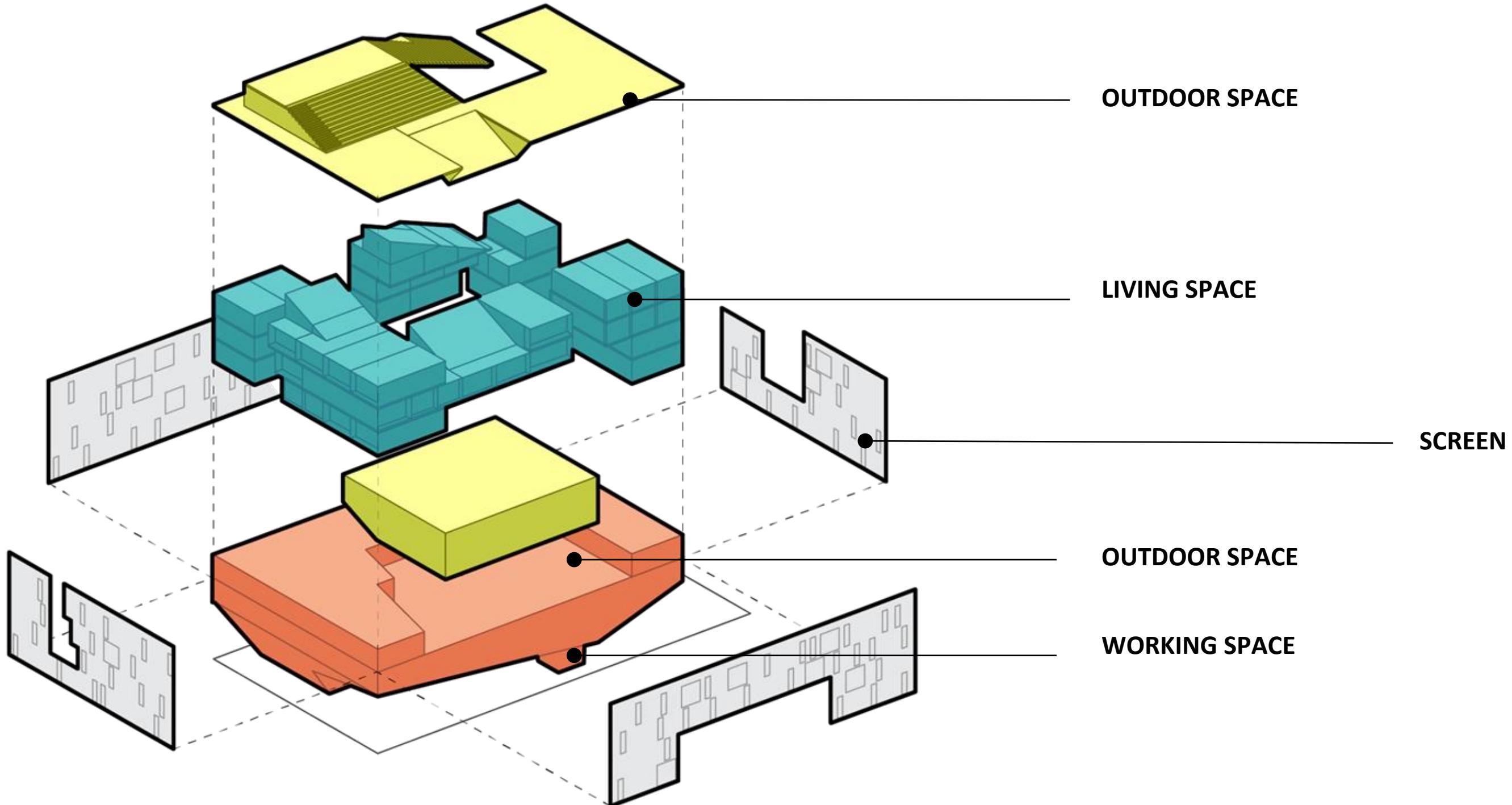
CITY BALCONY



IRRESISTIBLE STAIRS

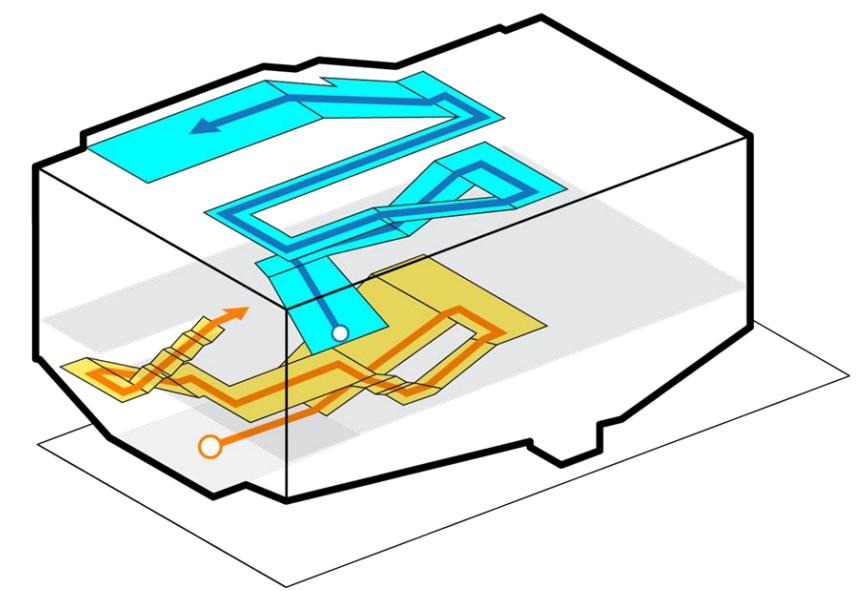
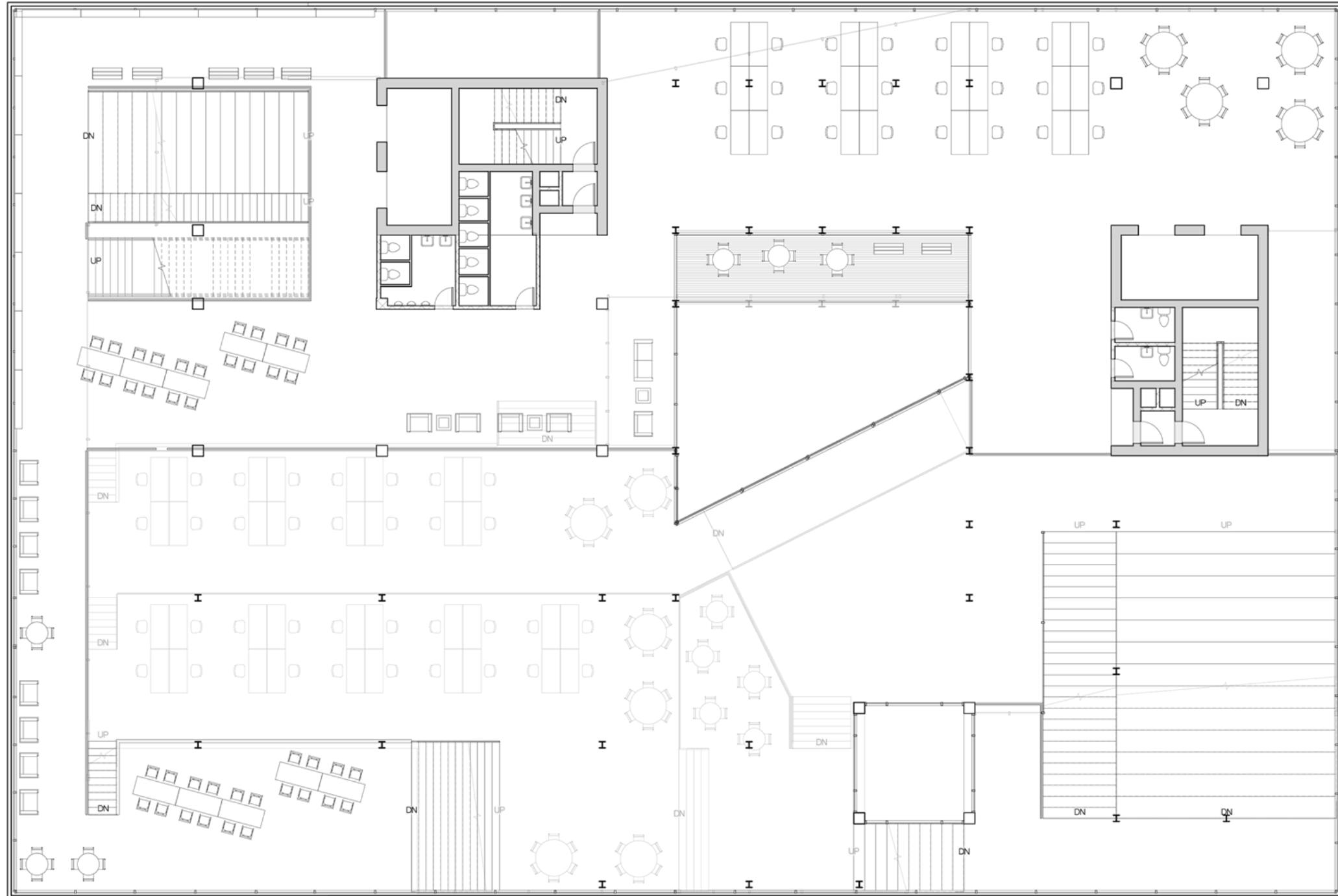
ARCH_PERFORMANCE

Architectural Challenges



WORKING SPACE

Open-Floor Office



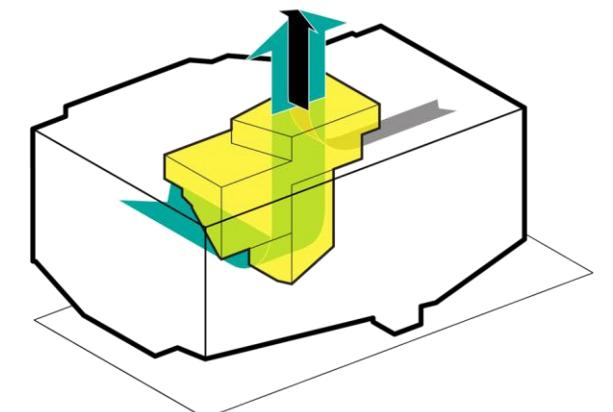
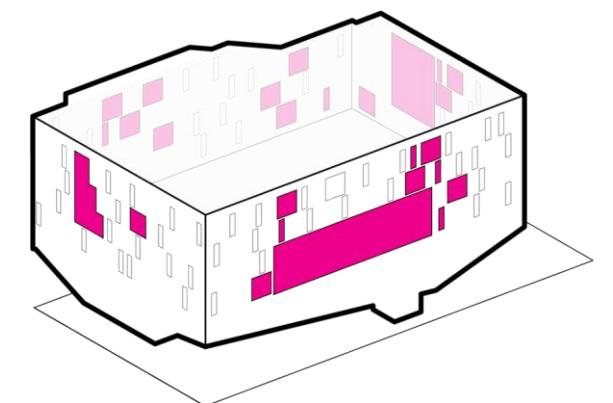
WORKING SPACE

Open-Floor Office



LIVING SPACE

Atrium



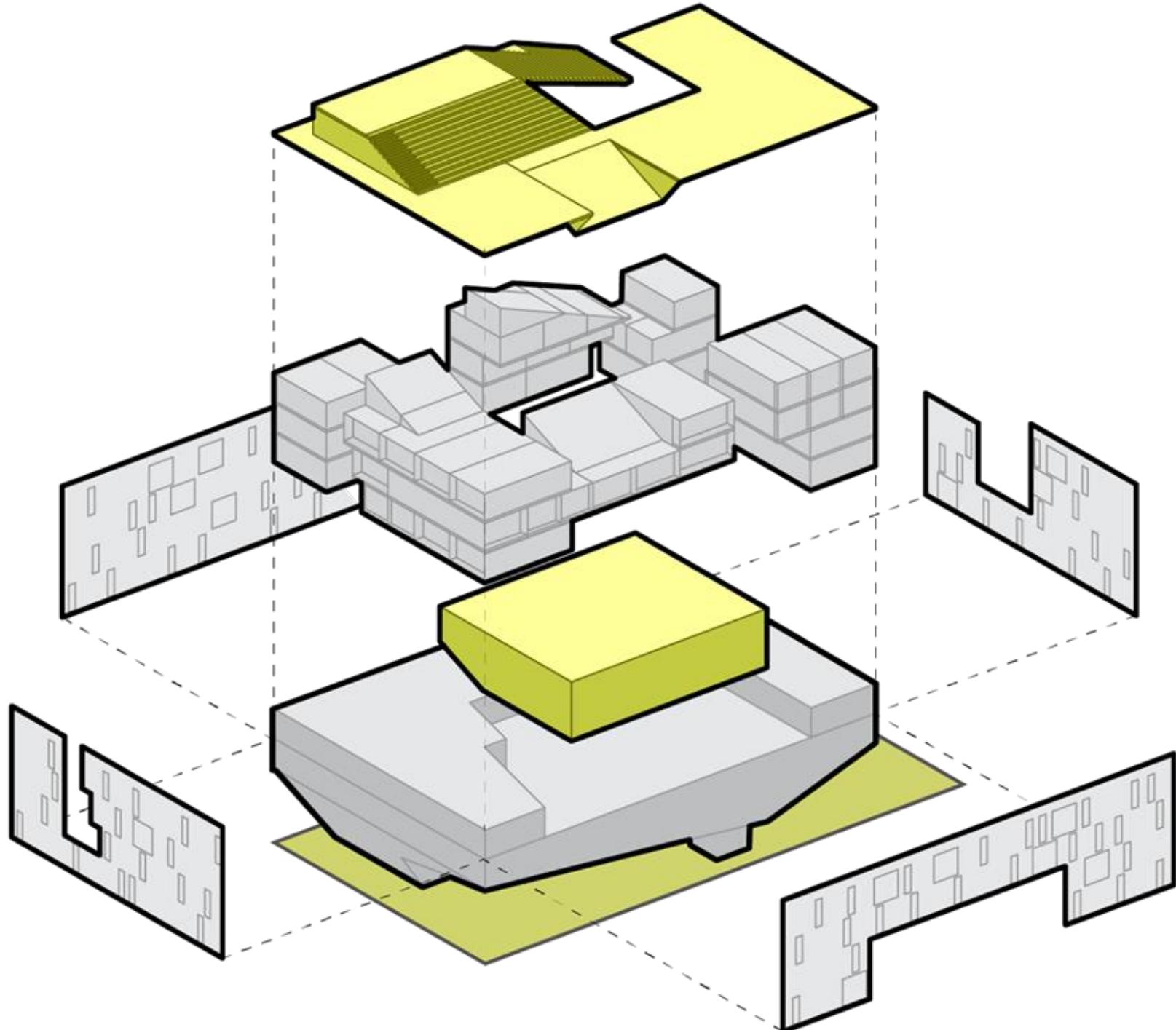
LIVING SPACE

Atrium

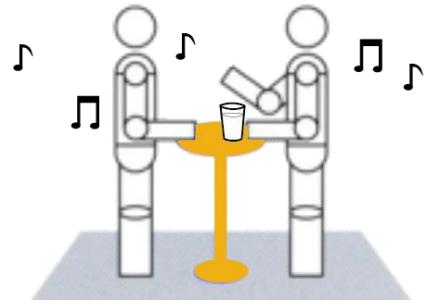


ARCH_PERFORMANCE

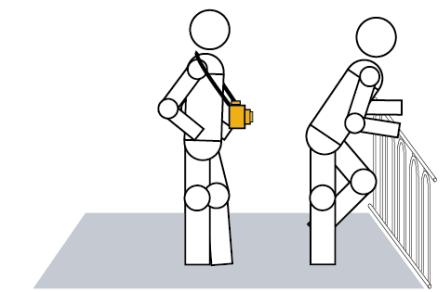
Architectural Challenges



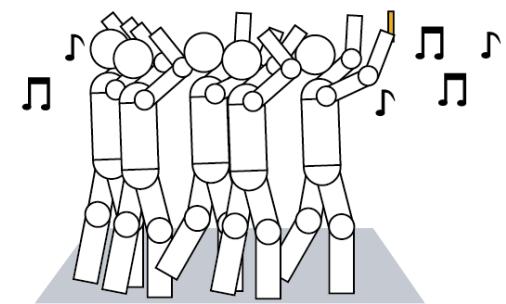
BAR AT ROOF GARDEN



LOOKOUT TO FRENCH QUARTER



**OUTDOORS FOR
FESTIVAL EVENTS**

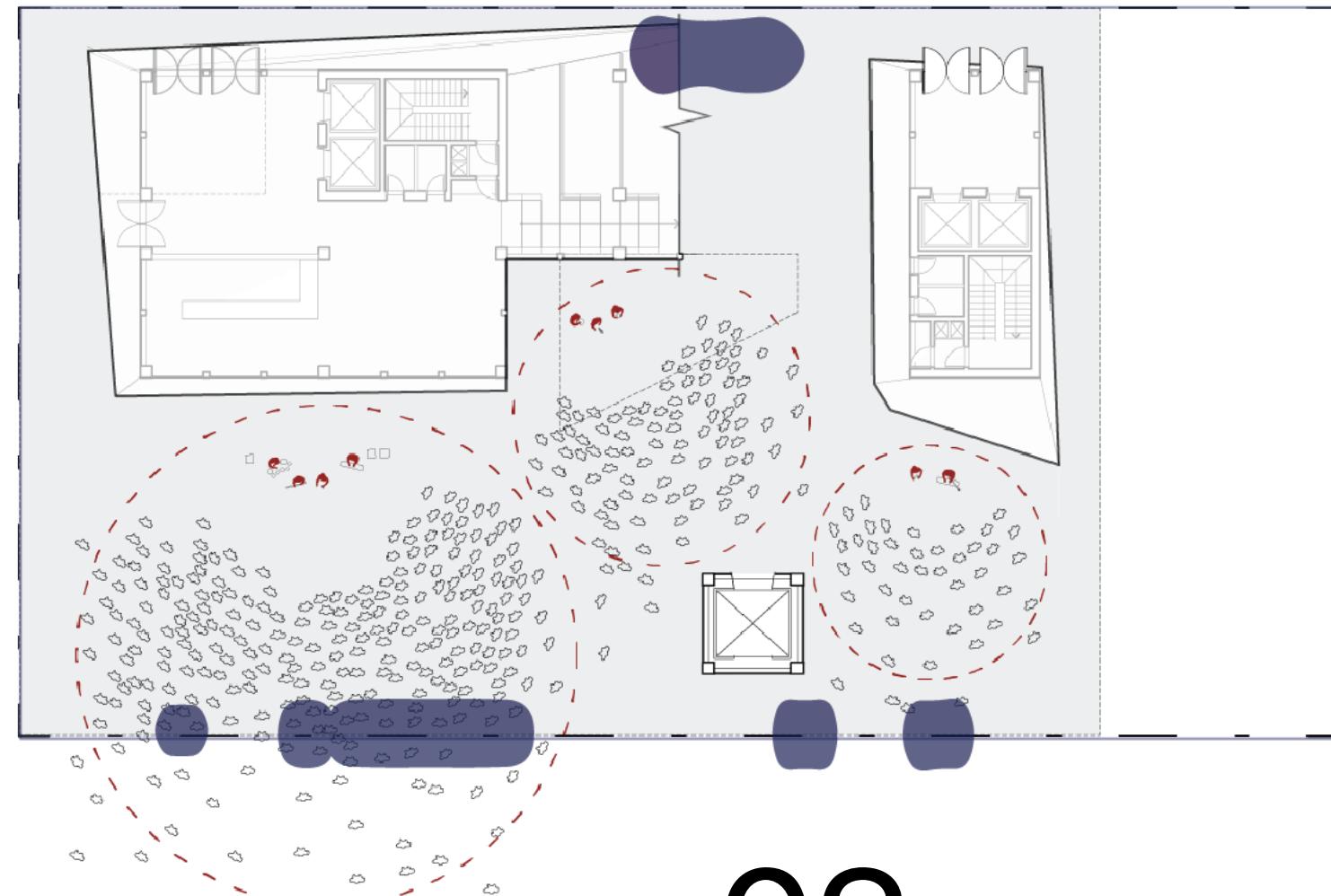
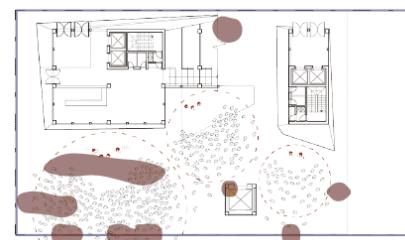


OUTDOOR SPACE

Music Performance

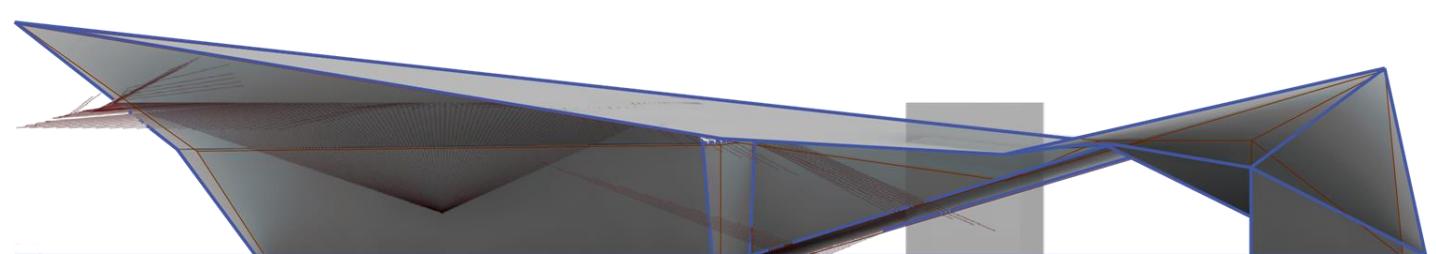
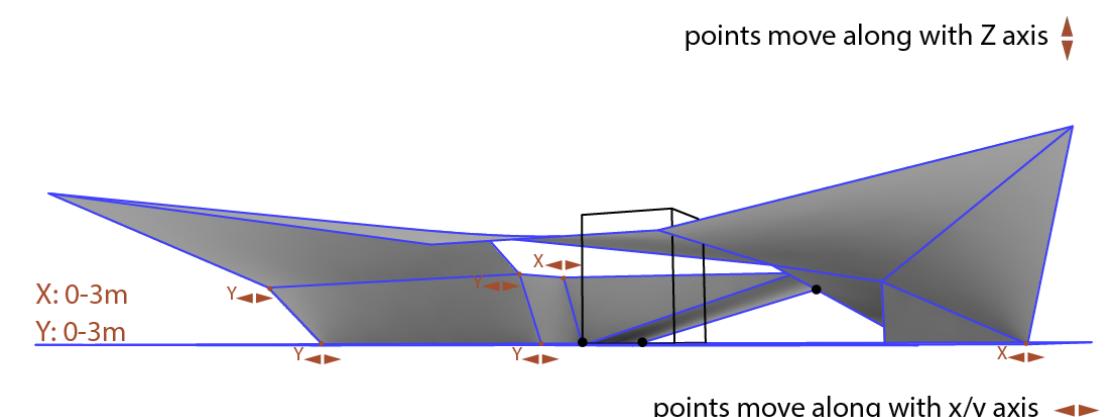
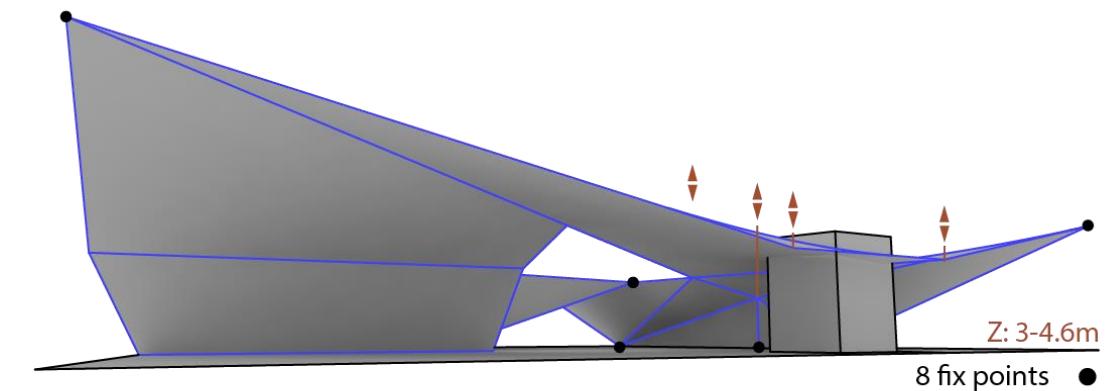
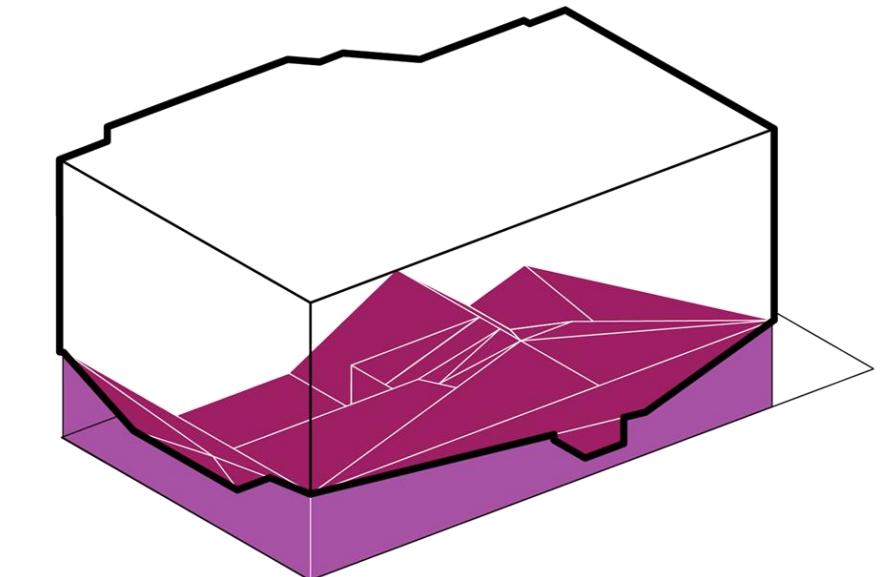
The space area that doesn't have potential echo was originally 85%. By applying adjustable ceiling, the space can be increased up to 92%.

85%



92%

Area have good acoustic performance



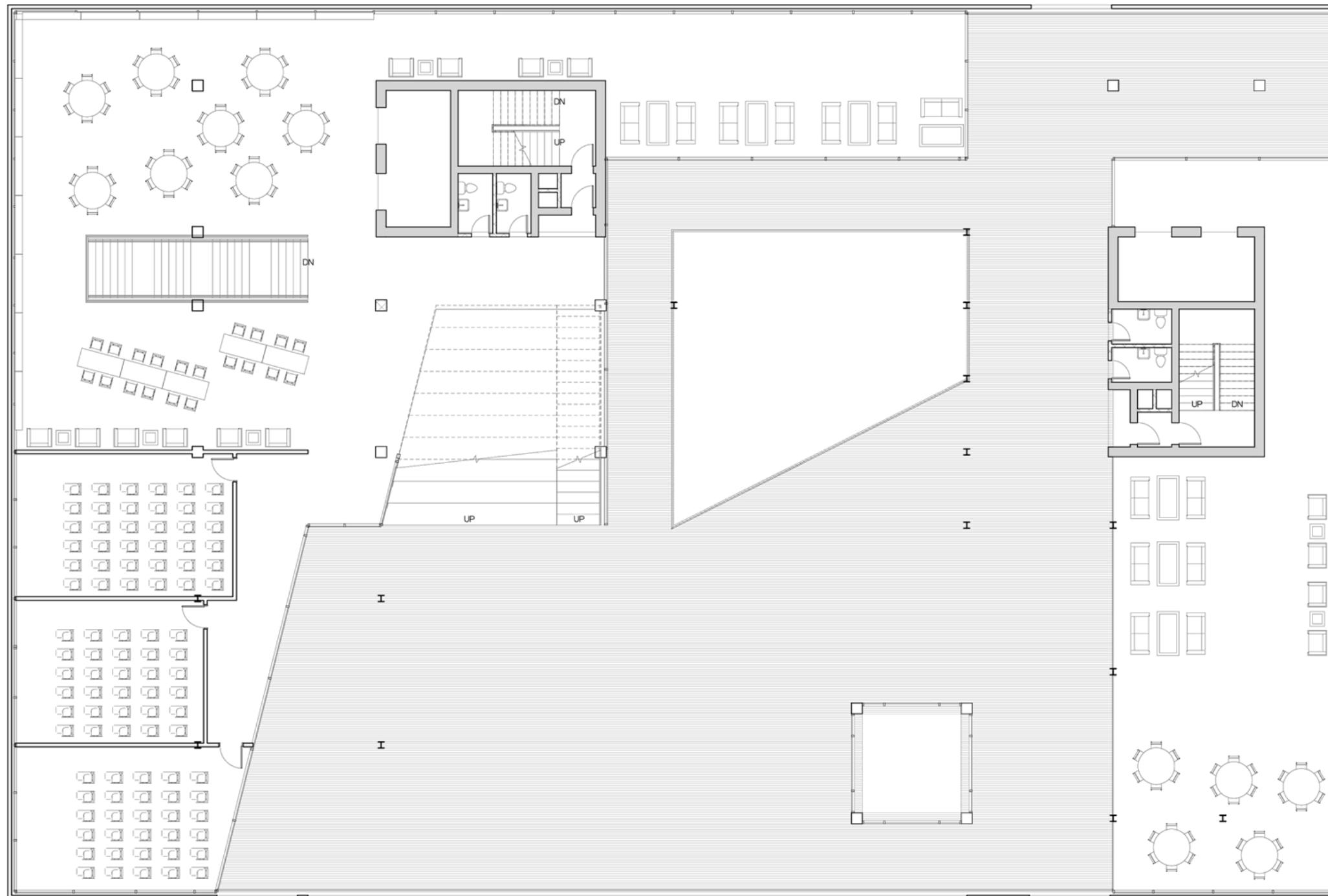
OUTDOOR SPACE

Music Performance

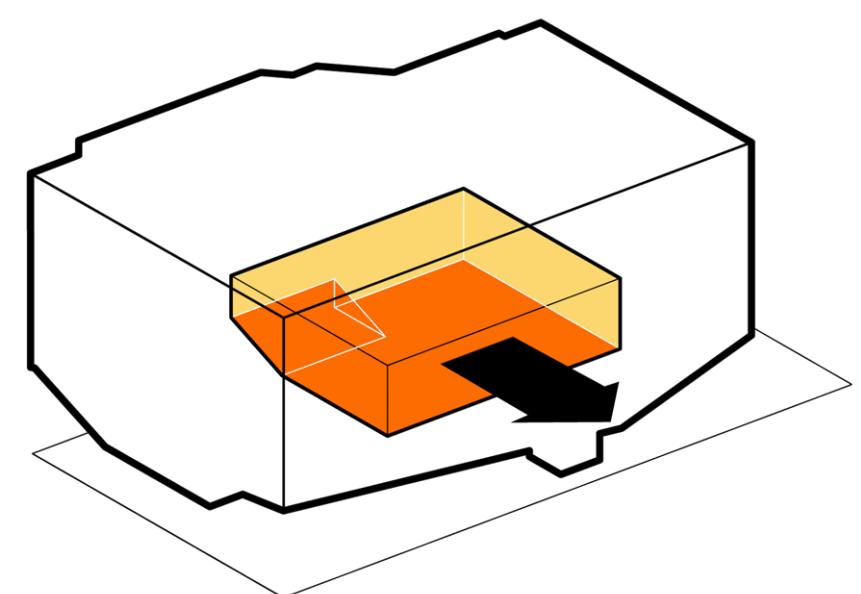


OUTDOOR SPACE

City Balcony



Directing views to French Quarter



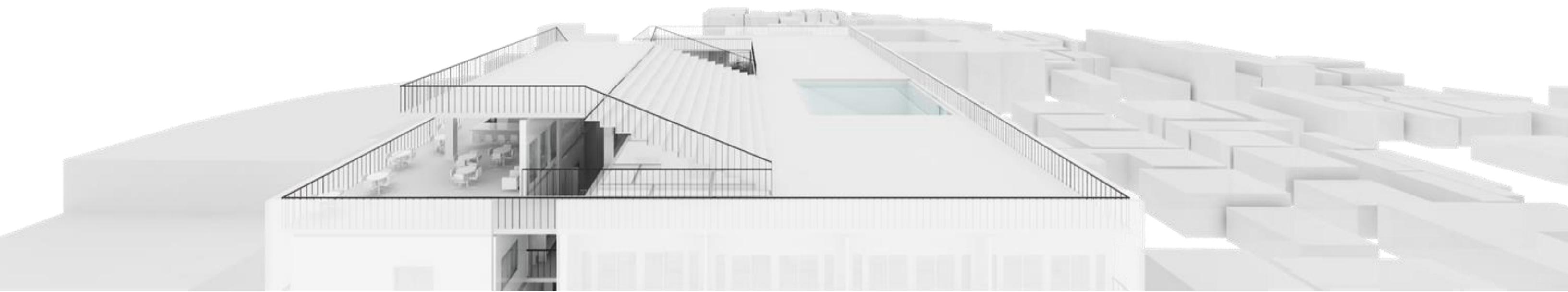
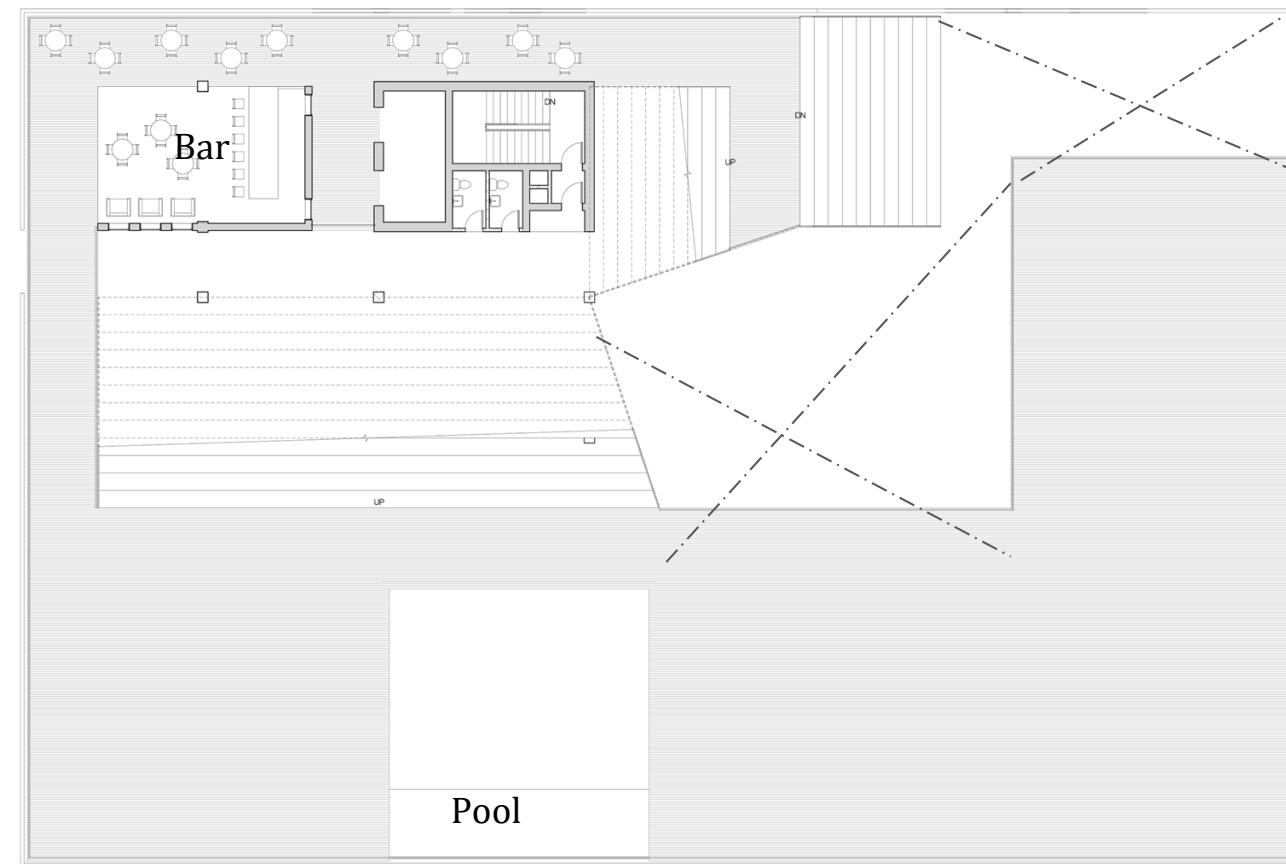
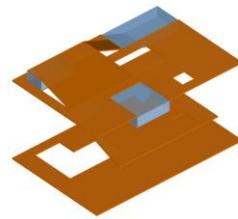
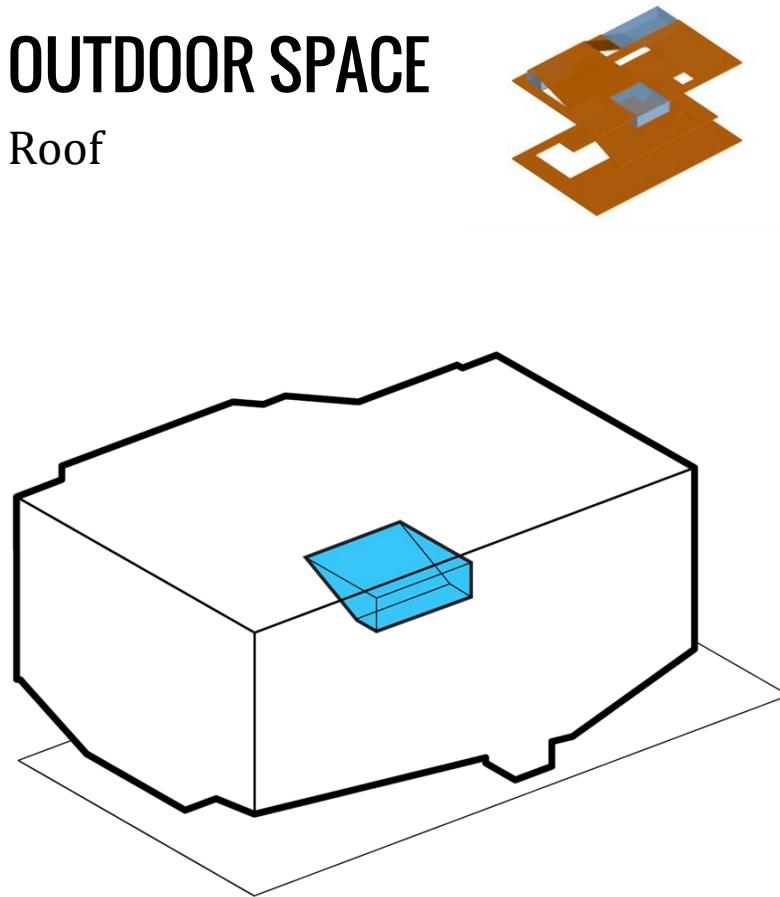
OUTDOOR SPACE

City Balcony



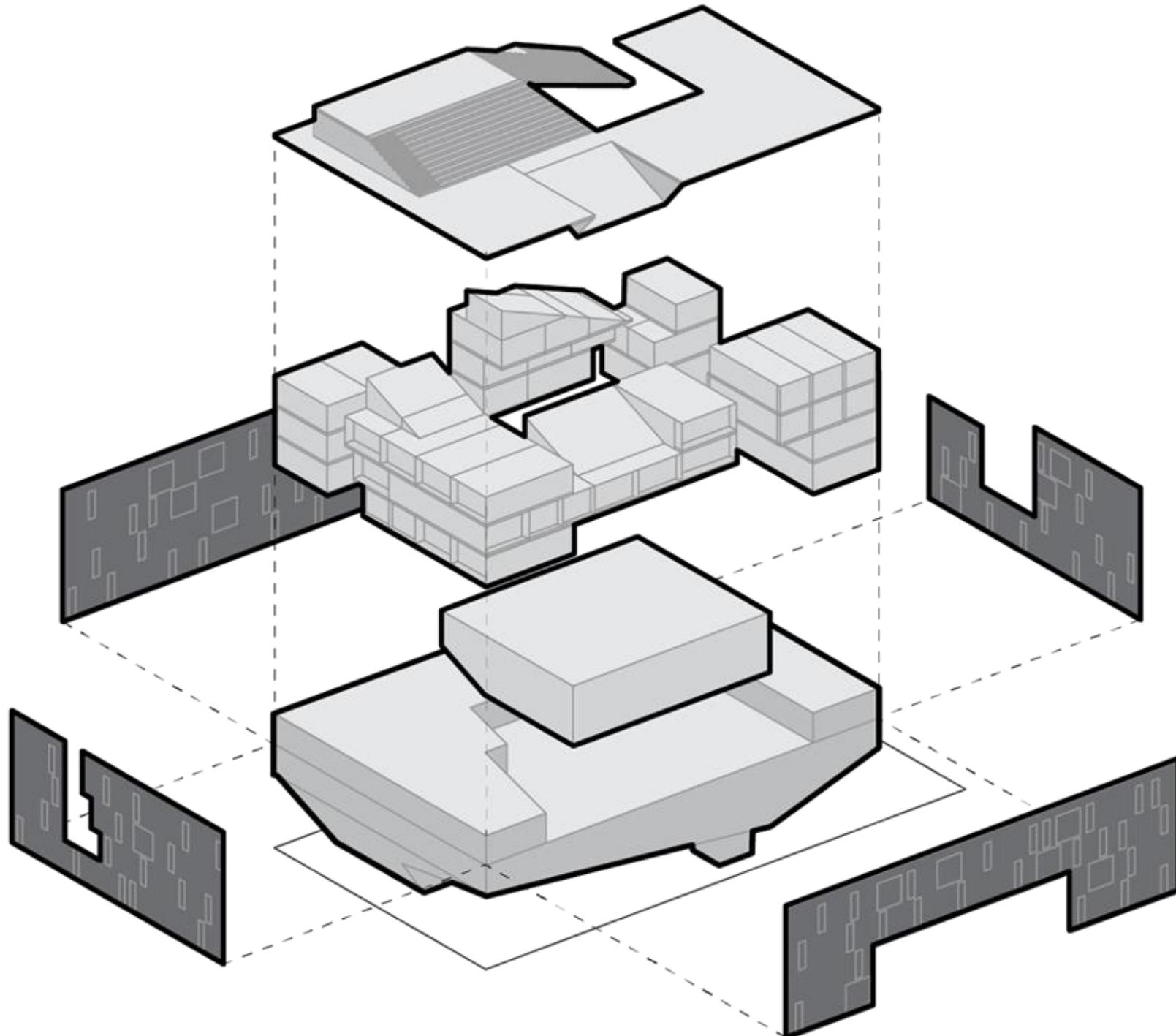
OUTDOOR SPACE

Roof

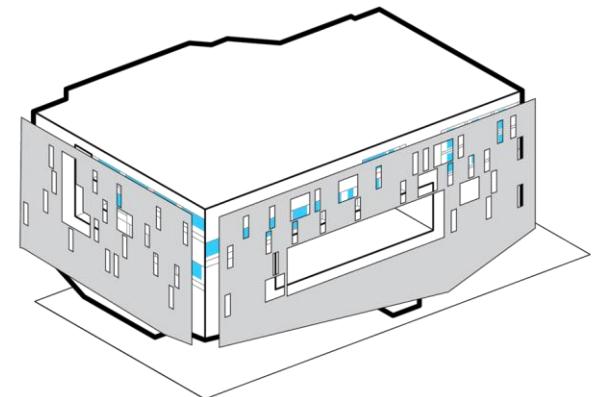


ARCH_PERFORMANCE

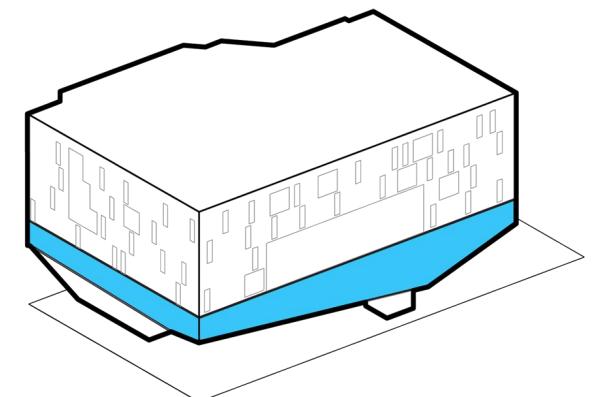
Architectural Challenges_Screen



INDOOR
BALCONIES

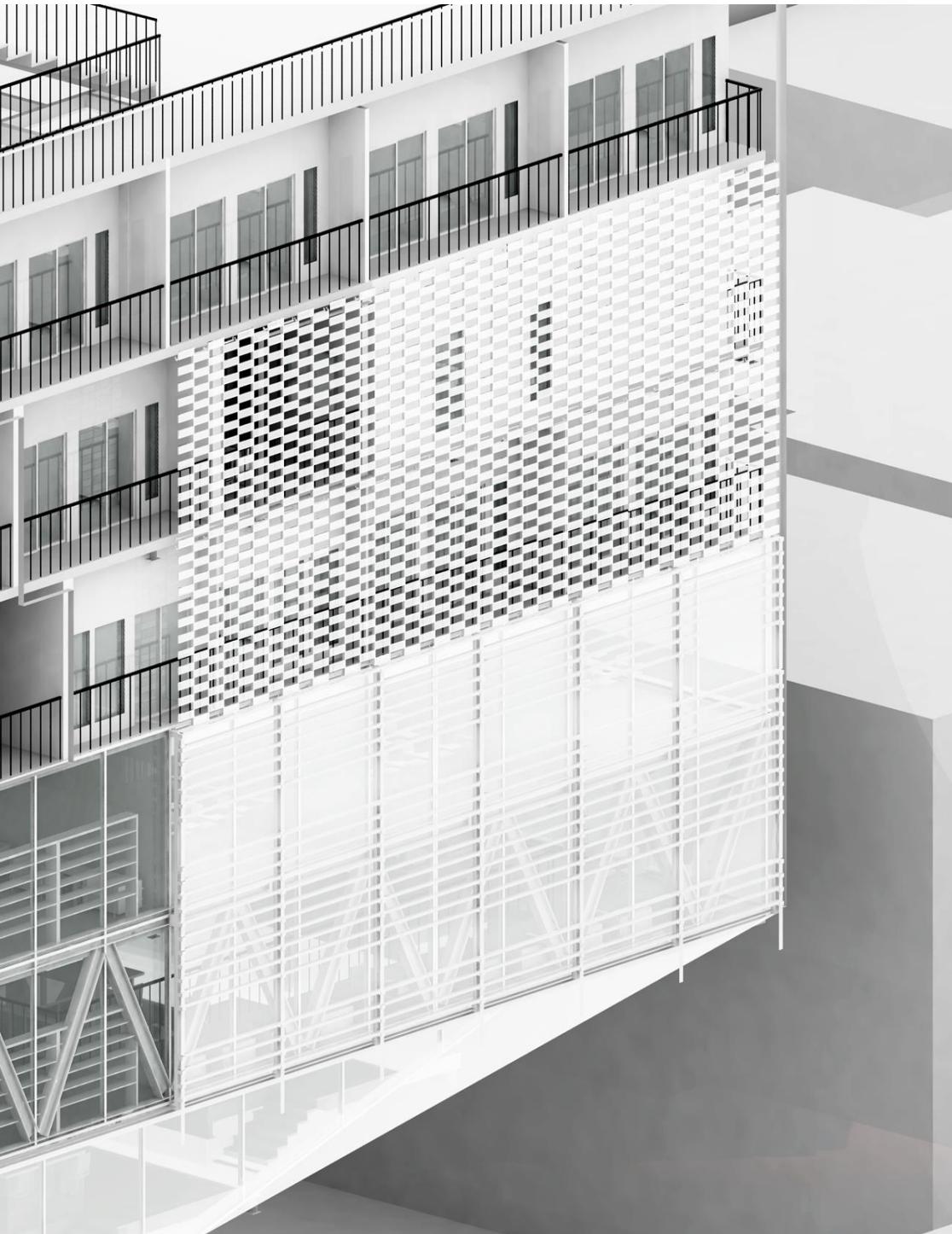


EXTERIOR
EVAPORATIVE COOLING

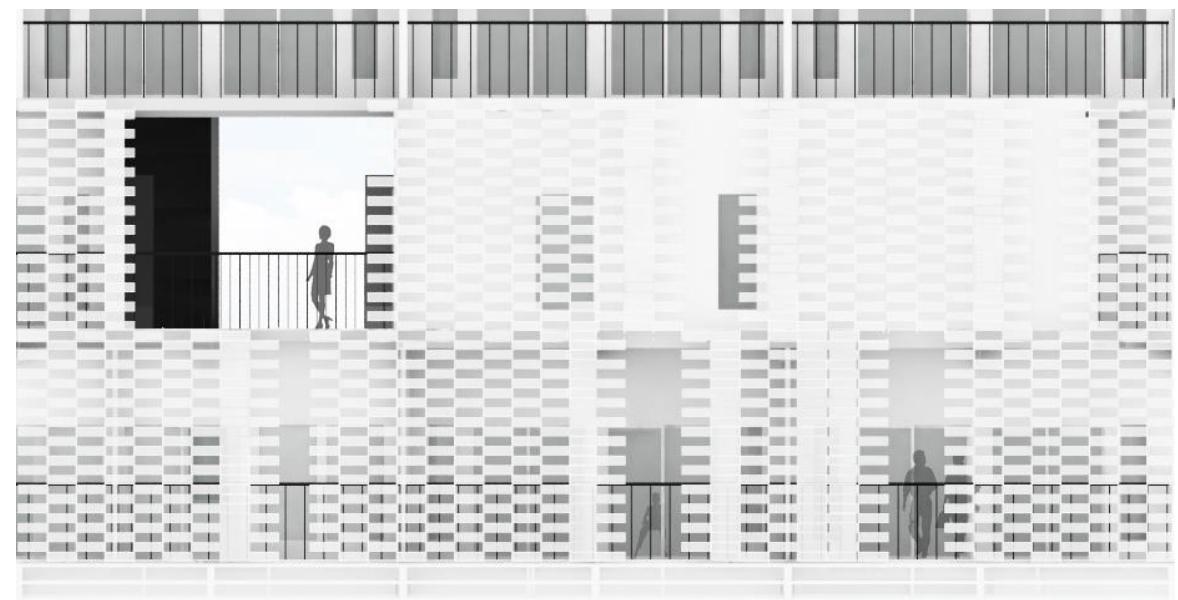
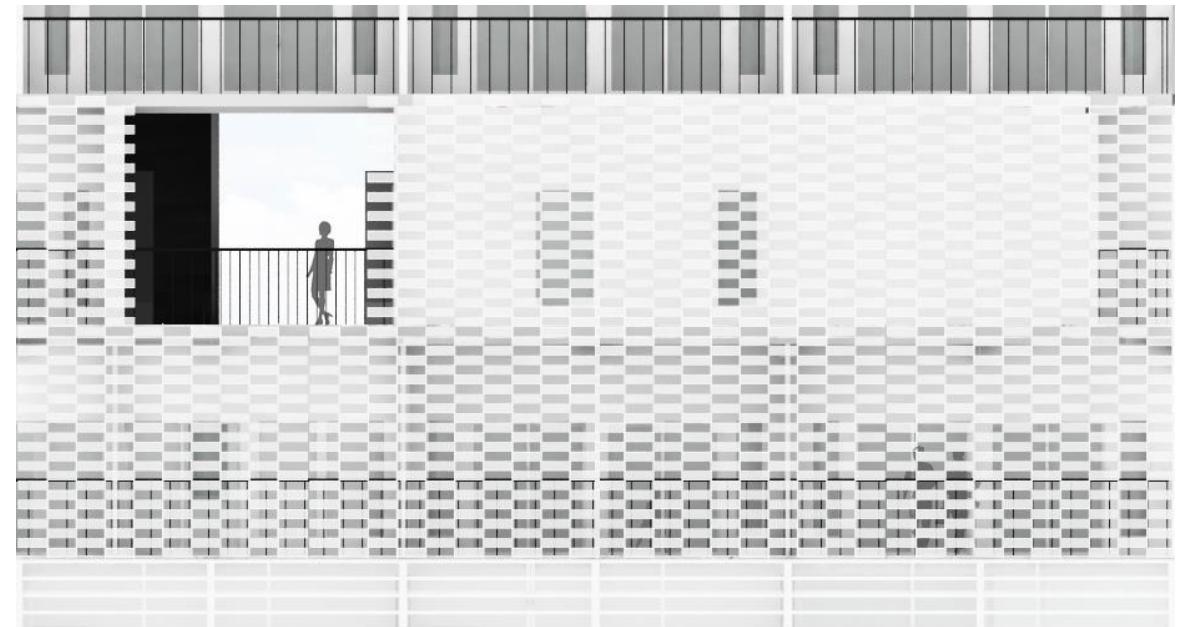


SCREEN

Living Space

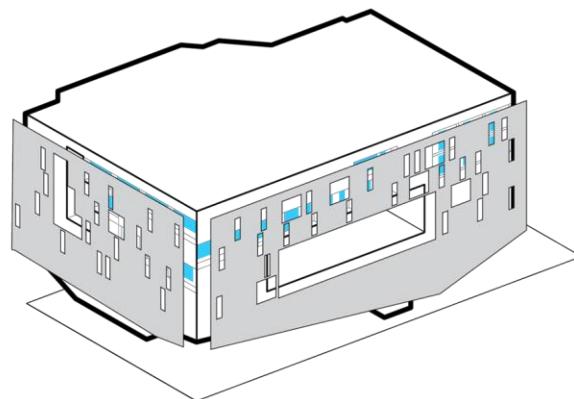


Sliding Shading + Green



SCREEN

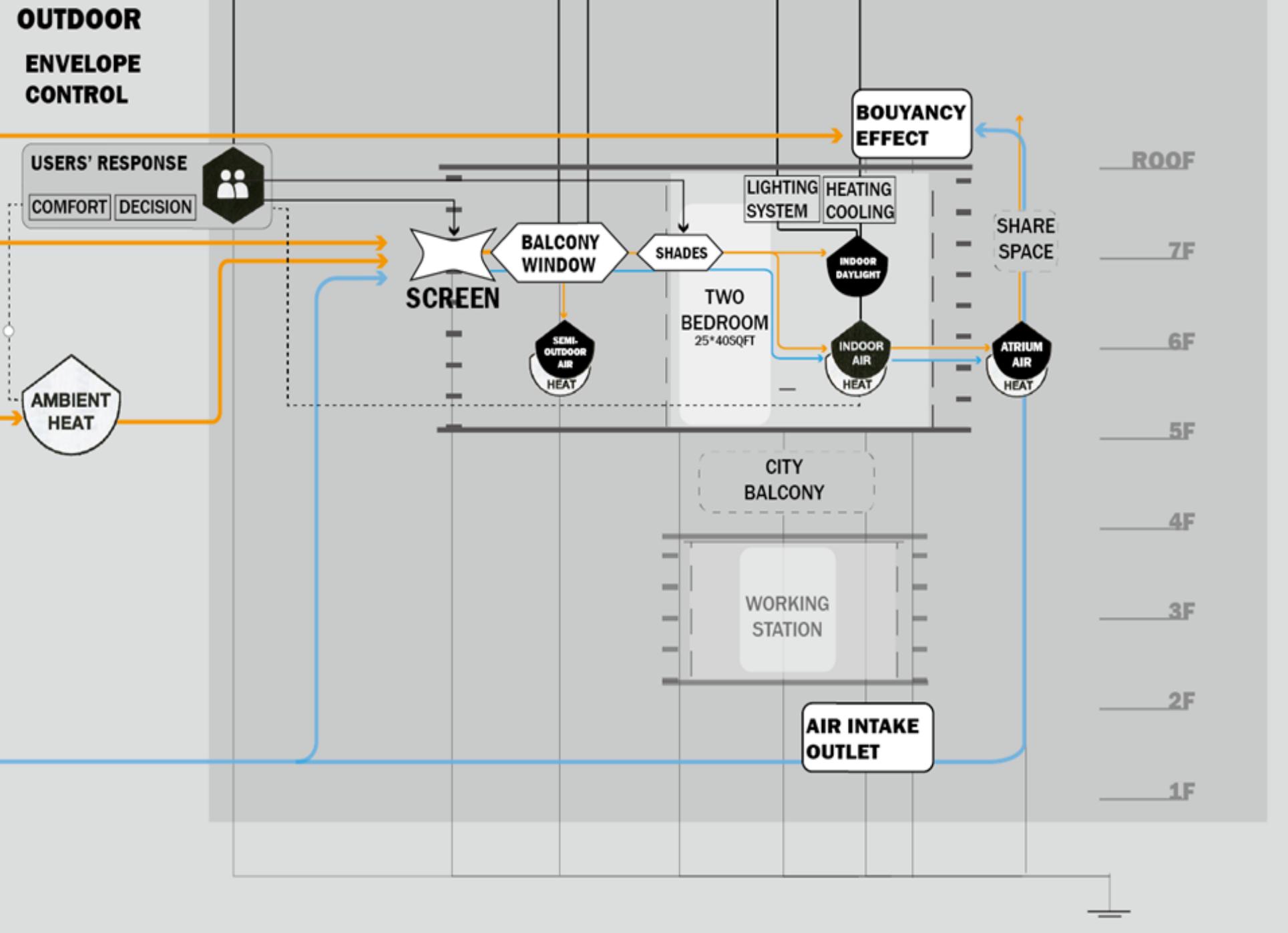
Energy Diagram



OUTDOOR ENVELOPE CONTROL

USERS' RESPONSE
COMFORT DECISION

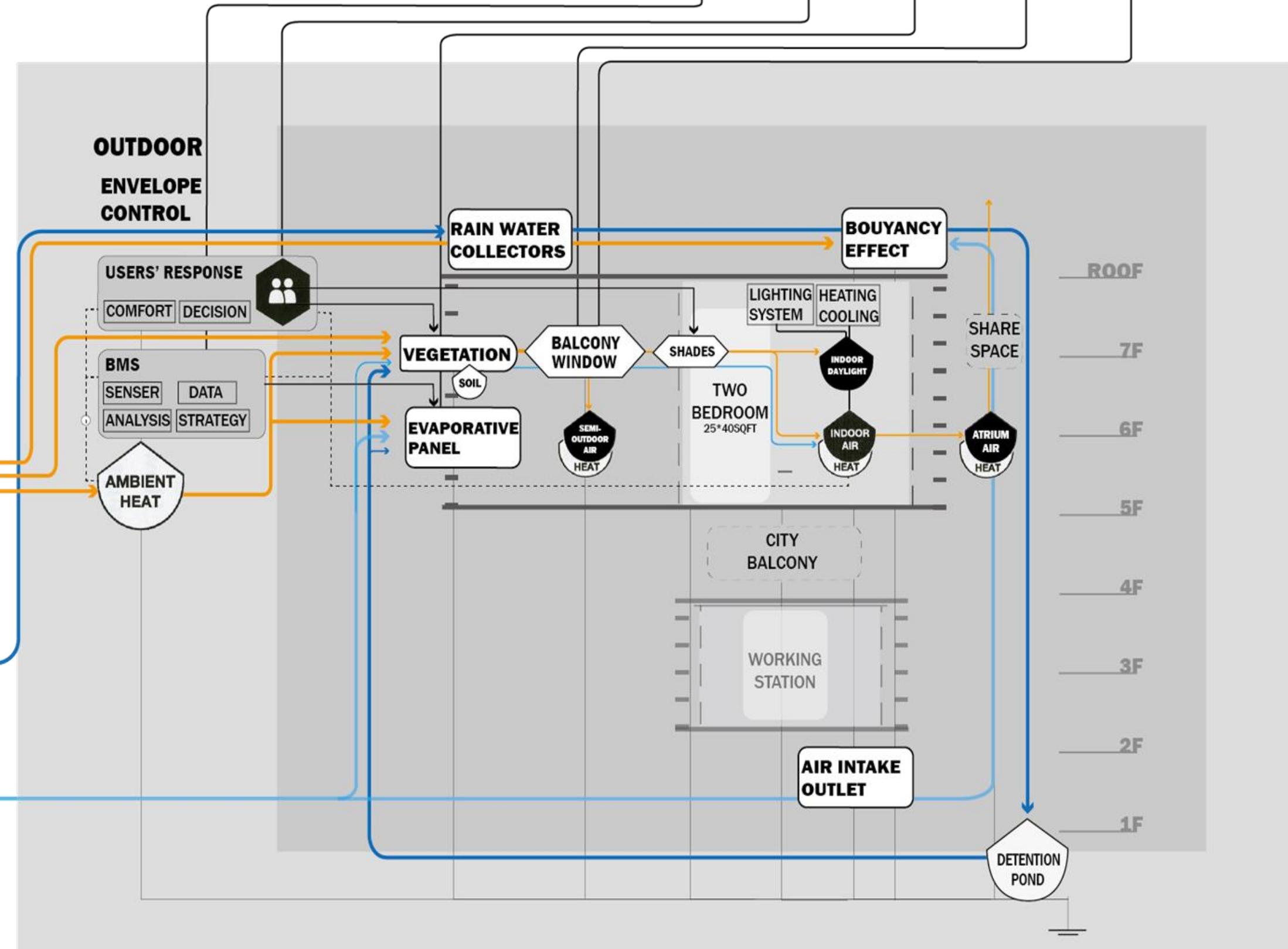
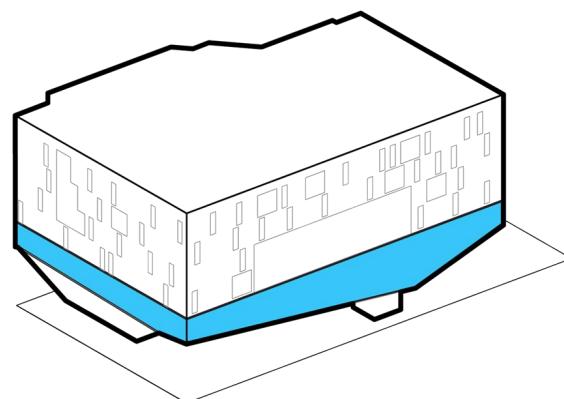
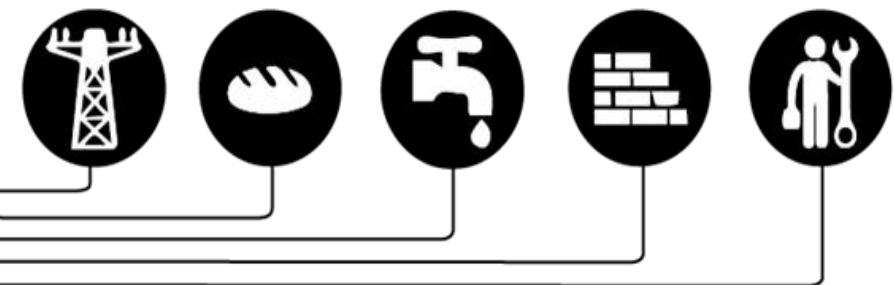
AMBIENT HEAT

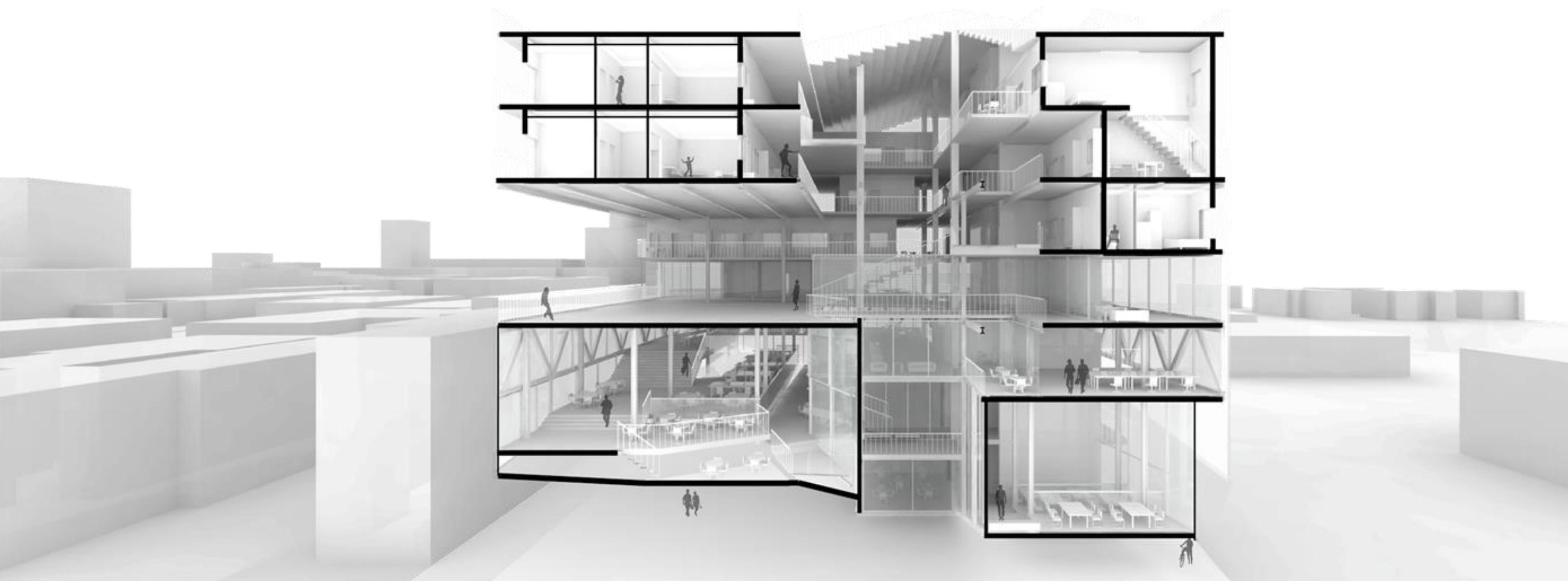


SCREEN

Exterior Evaporative cooling

Energy Diagram





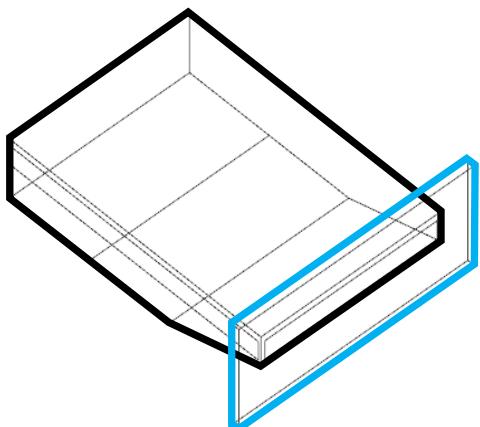


APPENDIX.

EVAPORATIVE COOLING RESEARCH

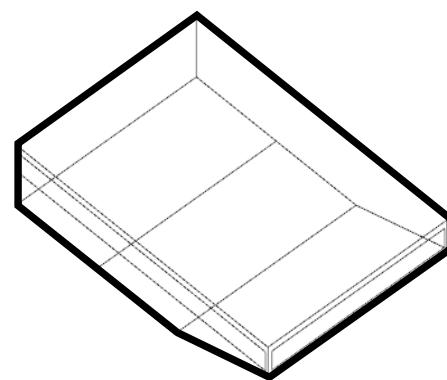
1

EnergyPlus
ZoneCoolTower:Shower



2

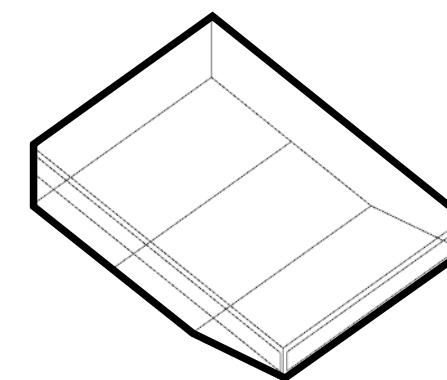
Wet bulb Temperature



$$\text{EPW}$$
$$\frac{\text{Wet Bulb Temperature} - \text{Dry Bulb Temperature}}{x 0.6}$$

3

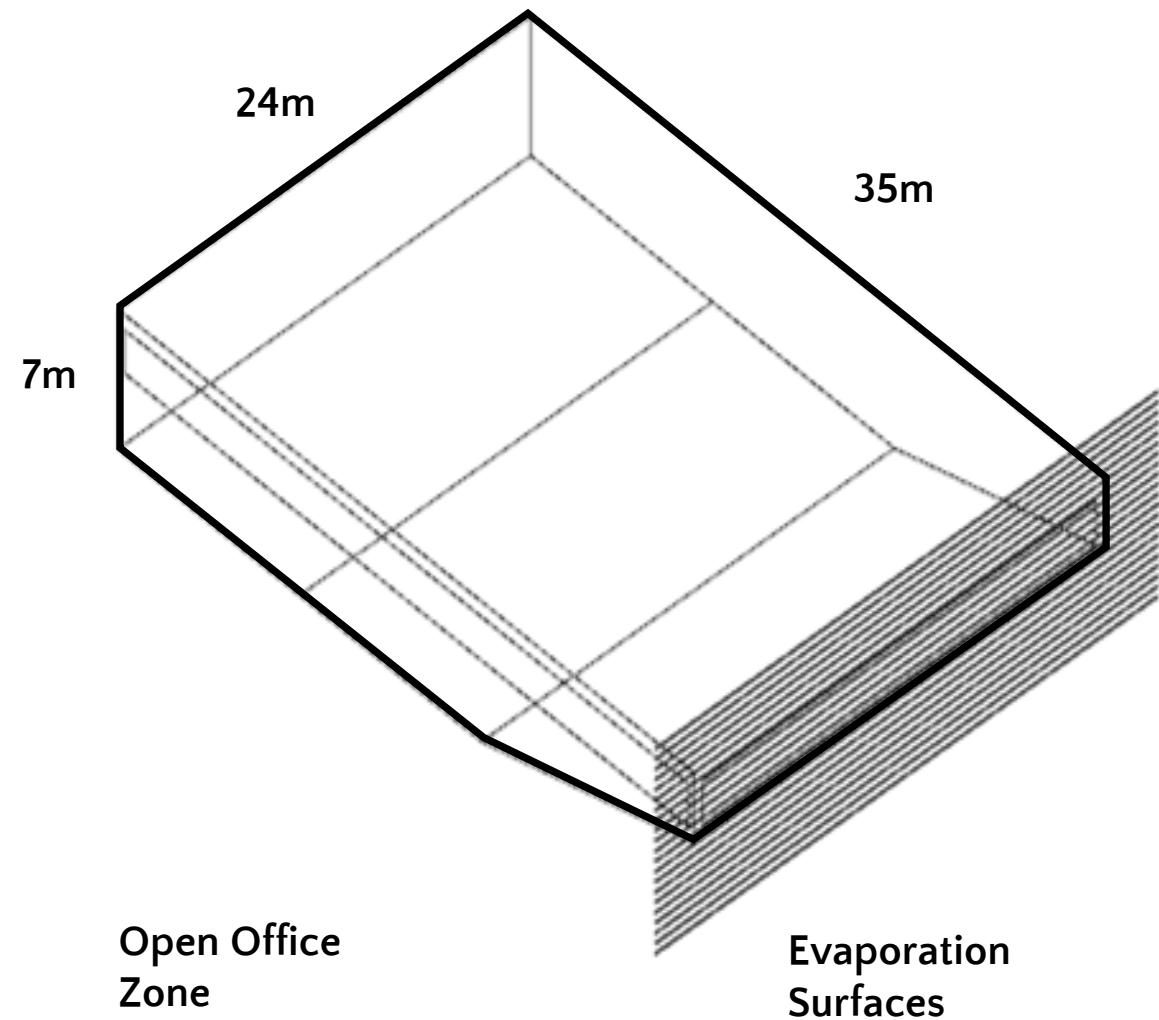
Evaporative Rate Equation



$$\text{EPW}$$
$$\text{New Air Temperature}$$

BUILDING INFORMATION

Dimension and EnergyPlus Settings



BuildingSurface:Detailed,

```
newOffice_Srf_4, !- Name
ROOF, !- Surface Type
Exterior Roof, !- Construction Name
newOffice, !- Zone Name
Adiabatic, !- Outside Boundary
```

Condition

```
, !- Outside Boundary Condition Object
NoSun, !- Sun Exposure
NoWind, !- Wind Exposure
autocalculate, !- View Factor to Ground
```

BuildingSurface:Detailed,

```
newOffice_Srf_7, !- Name
FLOOR, !- Surface Type
Interior Floor, !- Construction Name
newOffice, !- Zone Name
Adiabatic, !- Outside Boundary
```

Condition

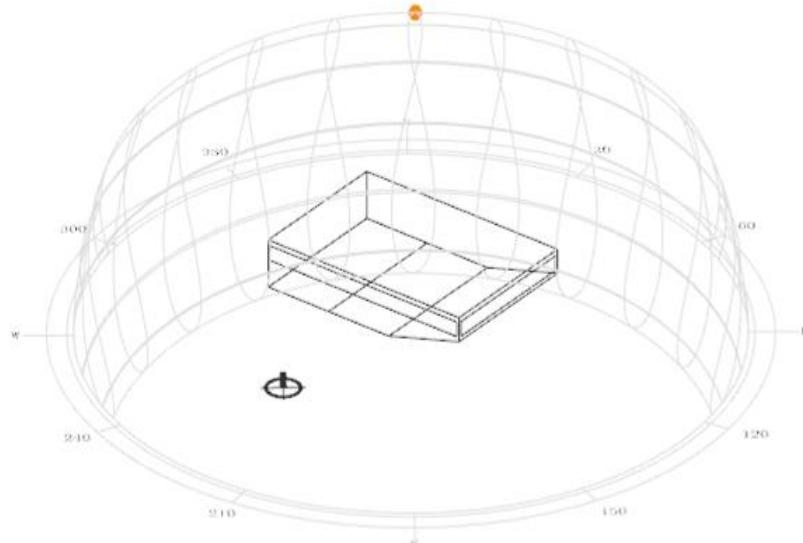
```
, !- Outside Boundary Condition Object
NoSun, !- Sun Exposure
NoWind, !- Wind Exposure
autocalculate, !- View Factor to Ground
```

Construction,

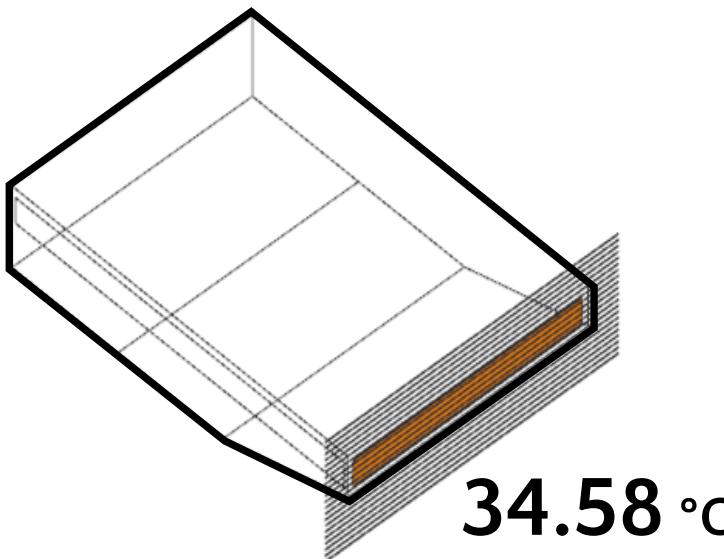
```
EXTERIOR WALL, !- name
M01 100mm brick, !- - Layer 1
M15 200mm heavyweight concrete, !- -
Layer 2
I02 50mm insulation board, !- - Layer 3
F04 Wall air space resistance, !- - Layer 4
G01a 19mm gypsum board; !- - Layer 5
```

BUILDING INFORMATION

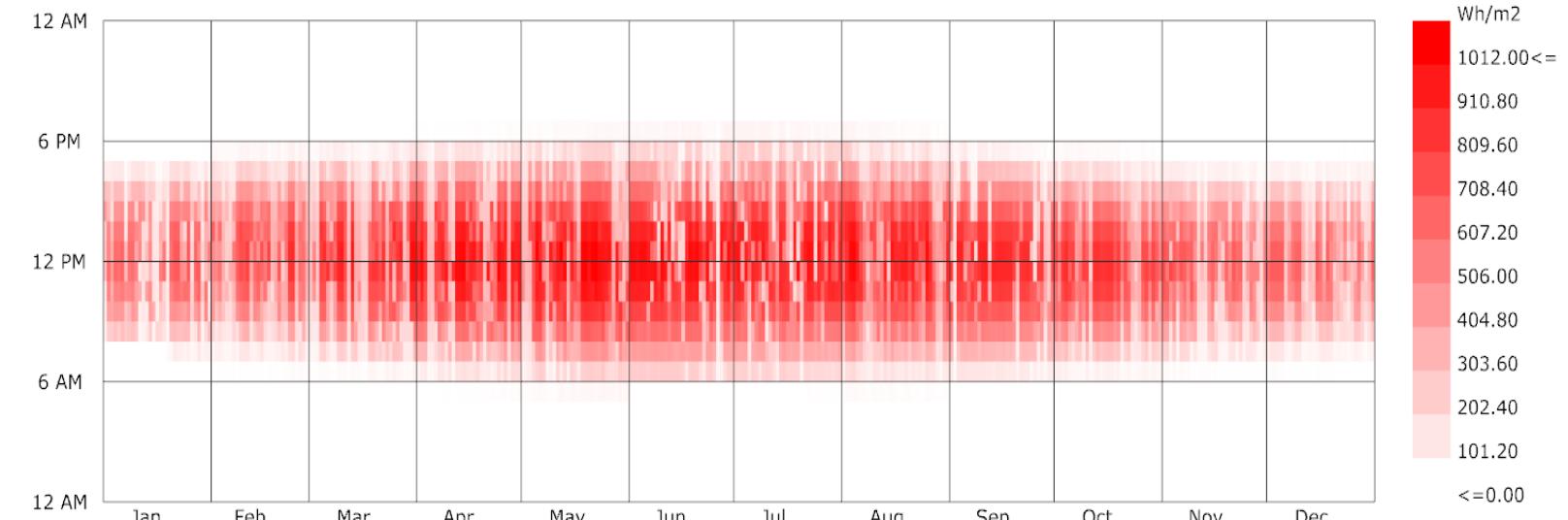
Base Case



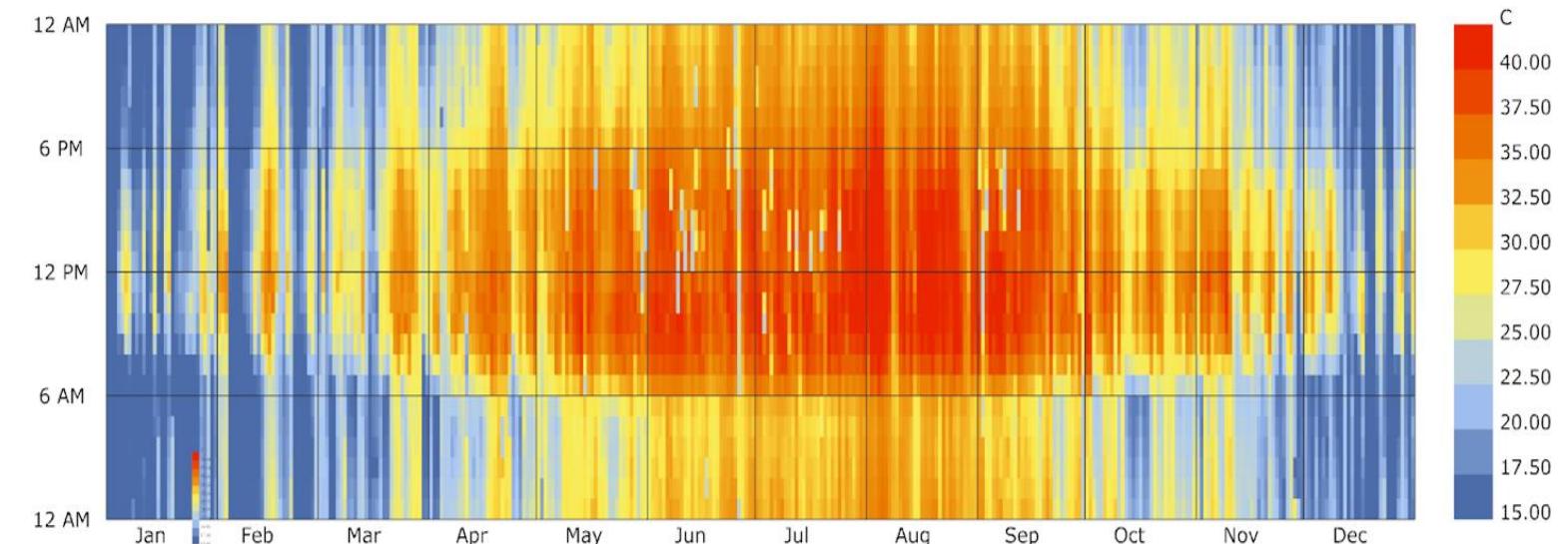
Test Building Orientation & Sun Position @ Jun 21st 12 PM



Outer Surface Temperature of Test Windows Surface @ Jun 21st 12 PM



Global Horizontal Radiation Annual Hourly Data



Outer Surface Temperature of Test Windows Surface Annual Hourly Data

ENERGYPLUS EMBED FUNCTION

ZoneCoolTower:Shower

The first simulation method is to create a cooling zone attached the exterior surface of the office zone, and assign ZoneCoolTower function to the cooling zone to mimic evaporation cooling effect.

ZoneCoolTower:Shower Inputs

```
ZoneCoolTower:Shower
  Cool_Tower_1,
  Cooling_Zone,
  Simple_Vent,
  ,
  WindDrivenFlow,
  0.0005,
  ,
  constant)
  5.0,
  1.0,
  10.0,
  18.0,
  0.05,
  0.05,
  250.0;
```

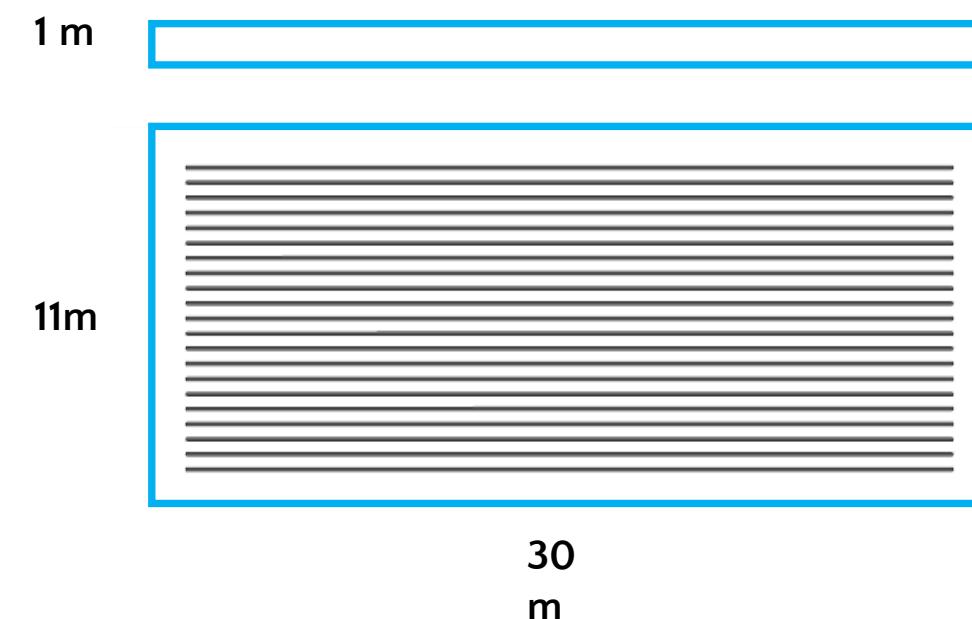
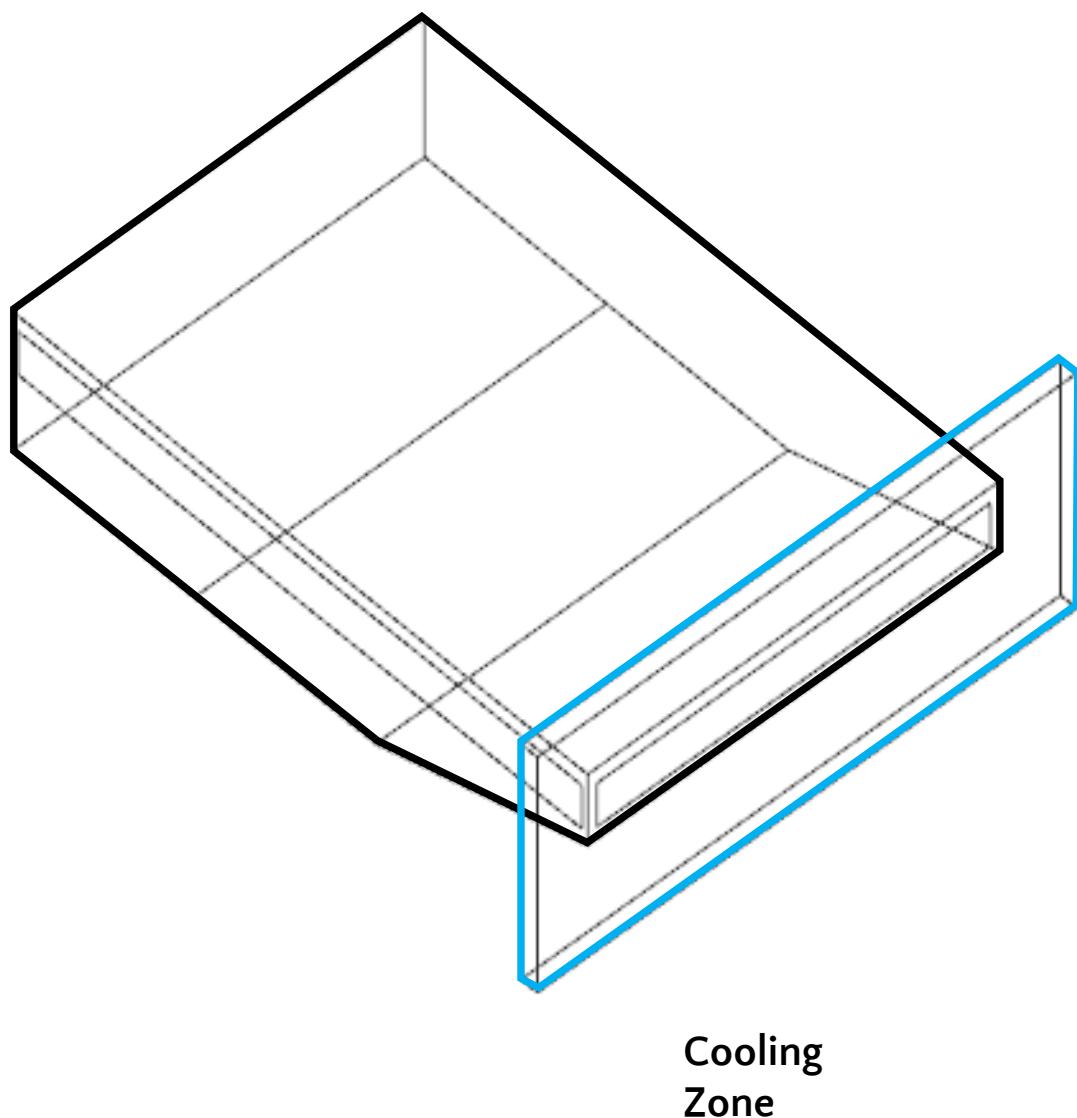
Cool Tower 1, !- Name of cooltowers
Cooling_Zone, !- Zone name
Simple Vent, !- Schedule
, !- Name of water supply storage tanks
WindDrivenFlow, !- Flow control type
0.0005, !- Water flow rate from the spray in m³/s
, !- schedule for flow rate (optional, non-existent means
constant) !- Effective tower height in m
5.0, !- Exit area in m²
1.0, !- Maximum supply air volume flow rate in m³/s
10.0, !- Minimum indoor temperature to prevent overcooling in C
18.0, !- Fraction of Water loss
0.05, !- Fraction of flow that goes to outside
0.05, !- Rated power consumption in W
250.0;

1

ENERGYPLUS EMBED

FUNCTION

ZoneCoolTower:Shower



All surfaces of the cooling zone are assigned “Air Wall” material, except where attached the office’s exterior surface.

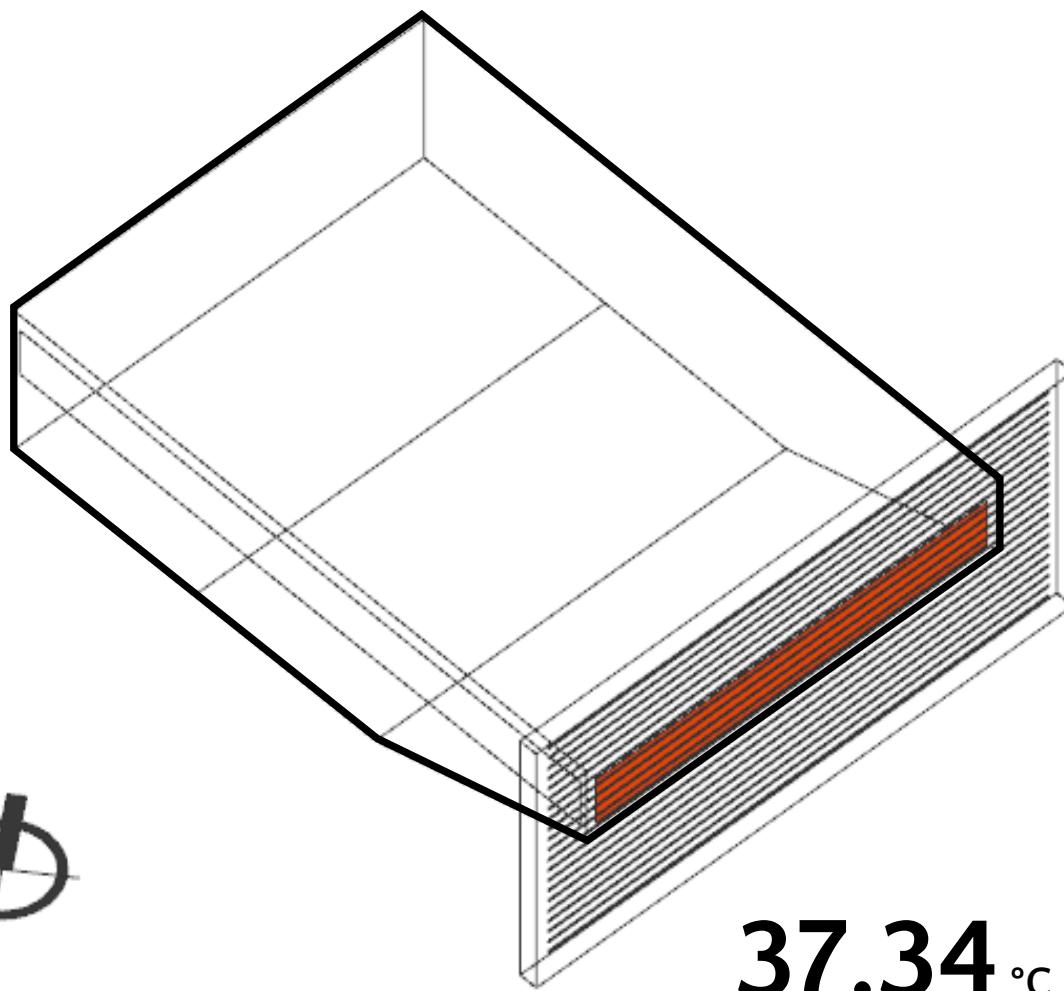
Air Wall:

Material	Material Type
MediumSmooth	- Roughness
0.01	- Thickness {m}
0.6	- Conductivity {W/m-K}
800	- Density {kg/m ³ }
1000	- Specific Heat {J/kg-K}
0.95	- Thermal Absorptance
0.7	- Solar Absorptance
0.7	- Visible Absorptance

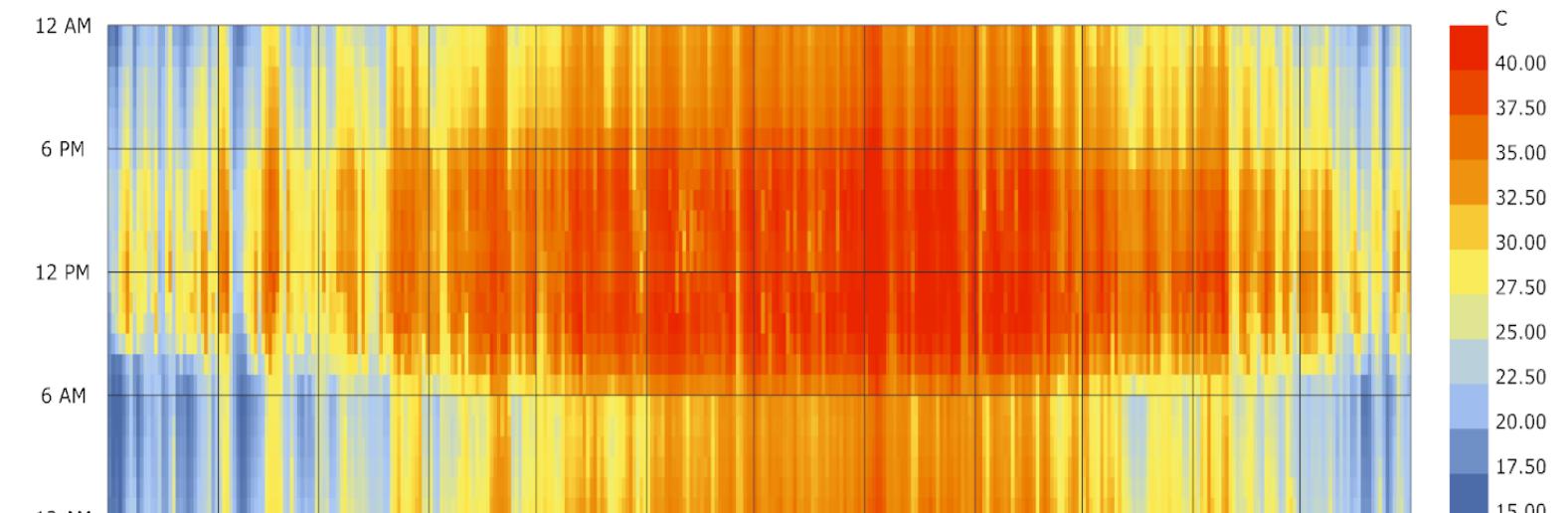
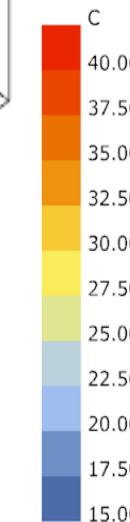
1

ENERGYPLUS EMBED FUNCTION

ZoneCoolTower:Shower



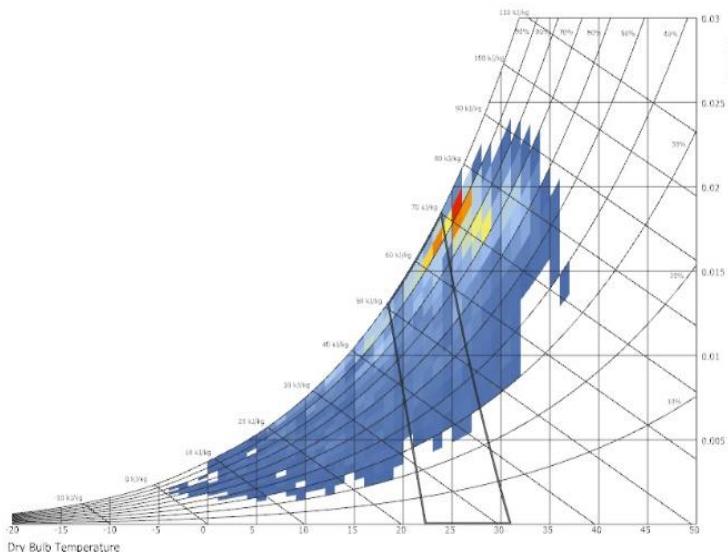
Outer Surface Temperature of Test Windows
Surface
@ Jun 21st 12 PM



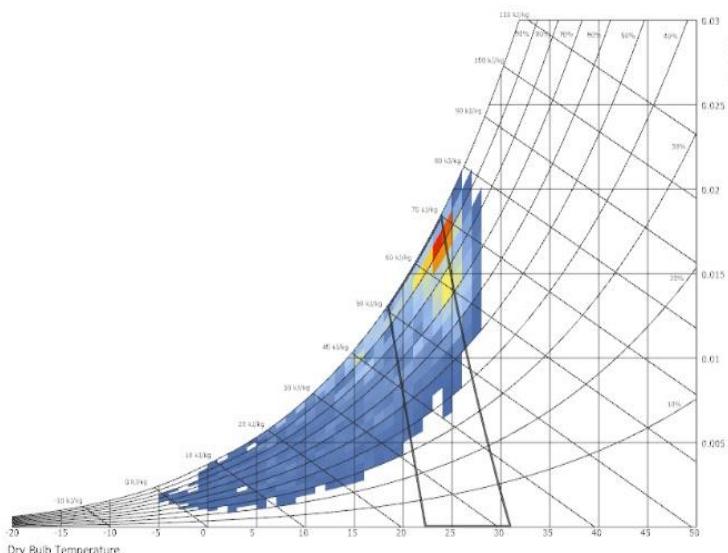
The result from this simulation was surprisingly higher than the base case, which mainly because of the cool zone traps the heat. However, it does have roughly 0.3 °C reduction while applying “ZoneCoolTower:Shower” in simulation.

2

WET BULB TEMPERATURE Generating a new EPW file

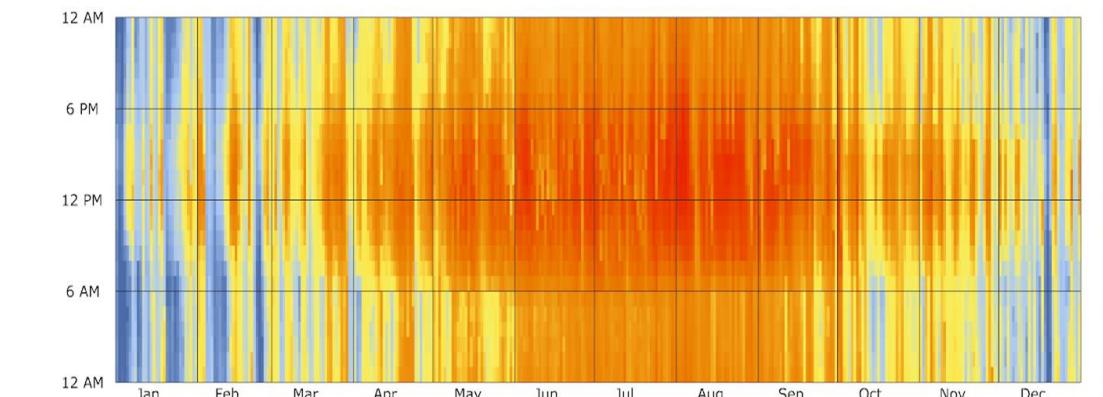


Psychrometric Chart

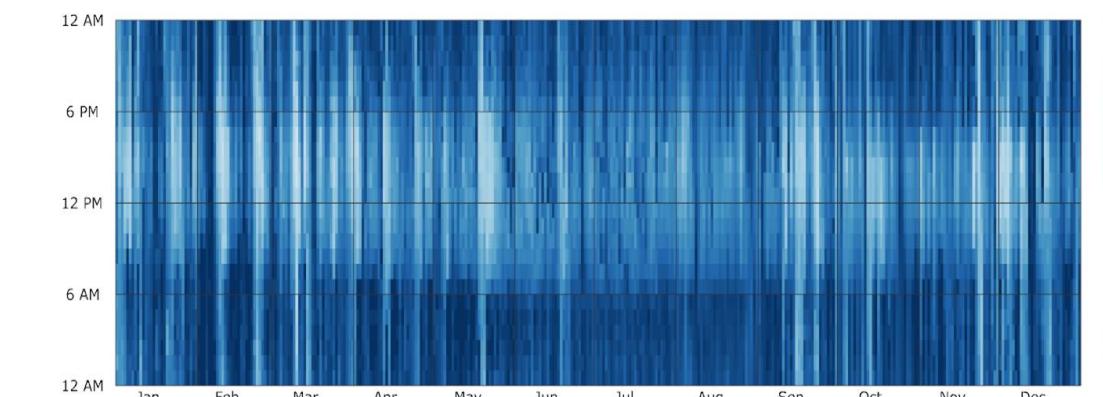


With Max Evaporative Cooling Effect

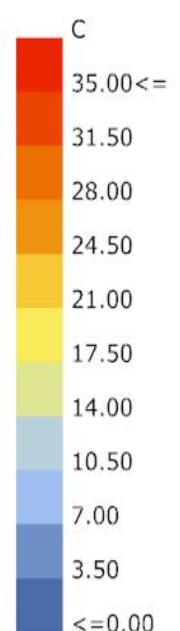
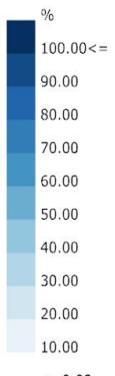
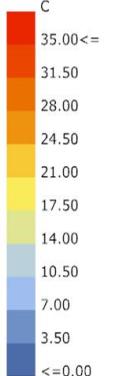
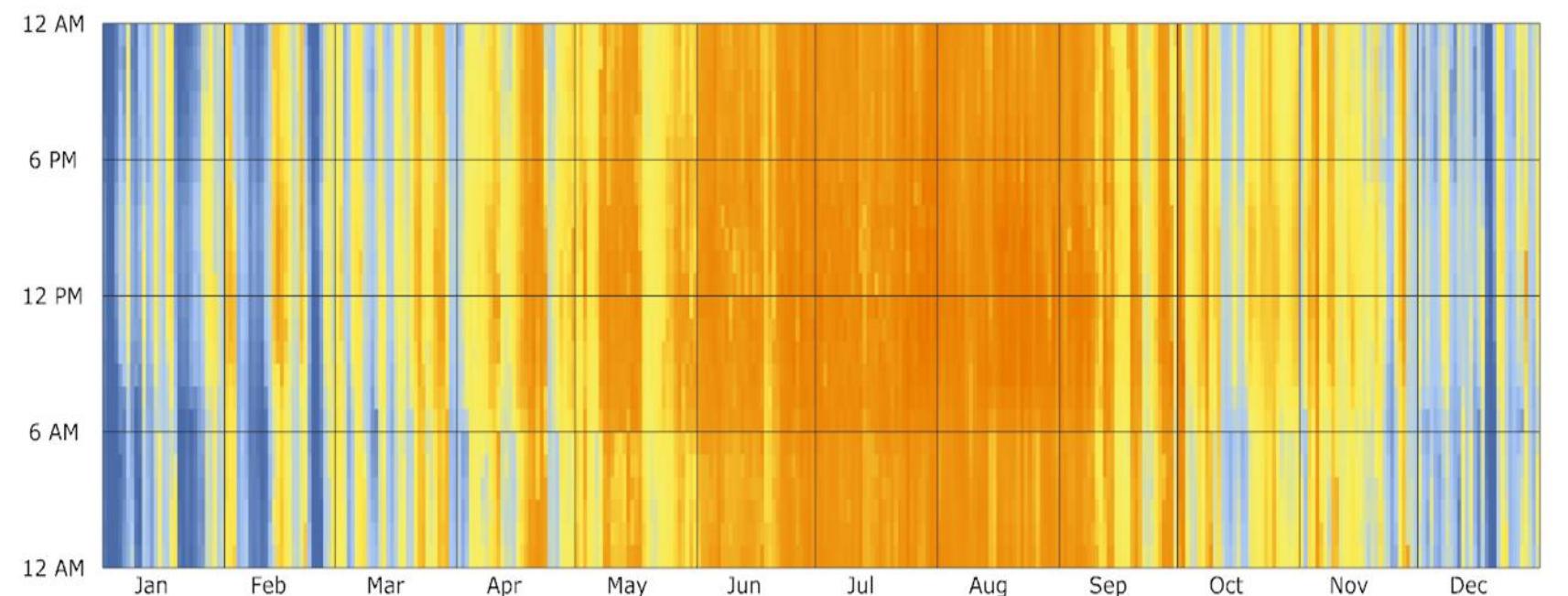
Dry Bulb Temperature (C)



Relative Humidity (%)



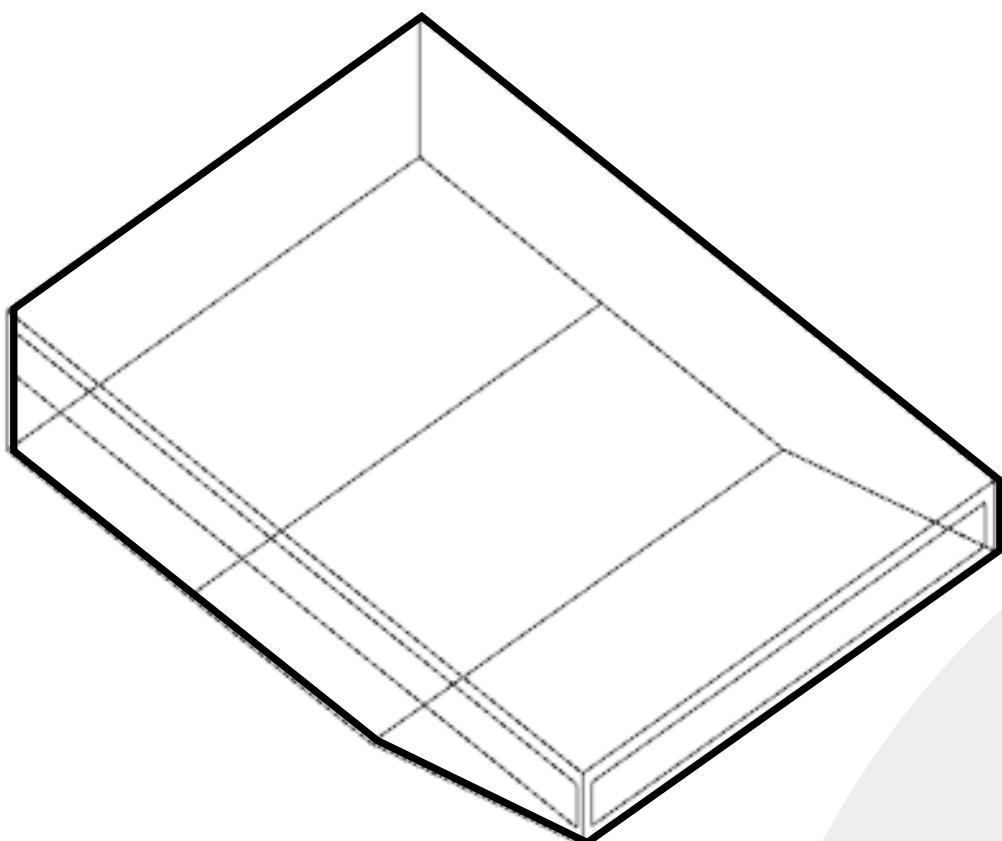
Wet Bulb Temperature (C)



2

WET BULB TEMPERATURE

Generating a new EPW file



EPW

Dry Bulb Temperature

Wet Bulb
Temperature
-
Dry Bulb
Temperature
x 0.6

EPW

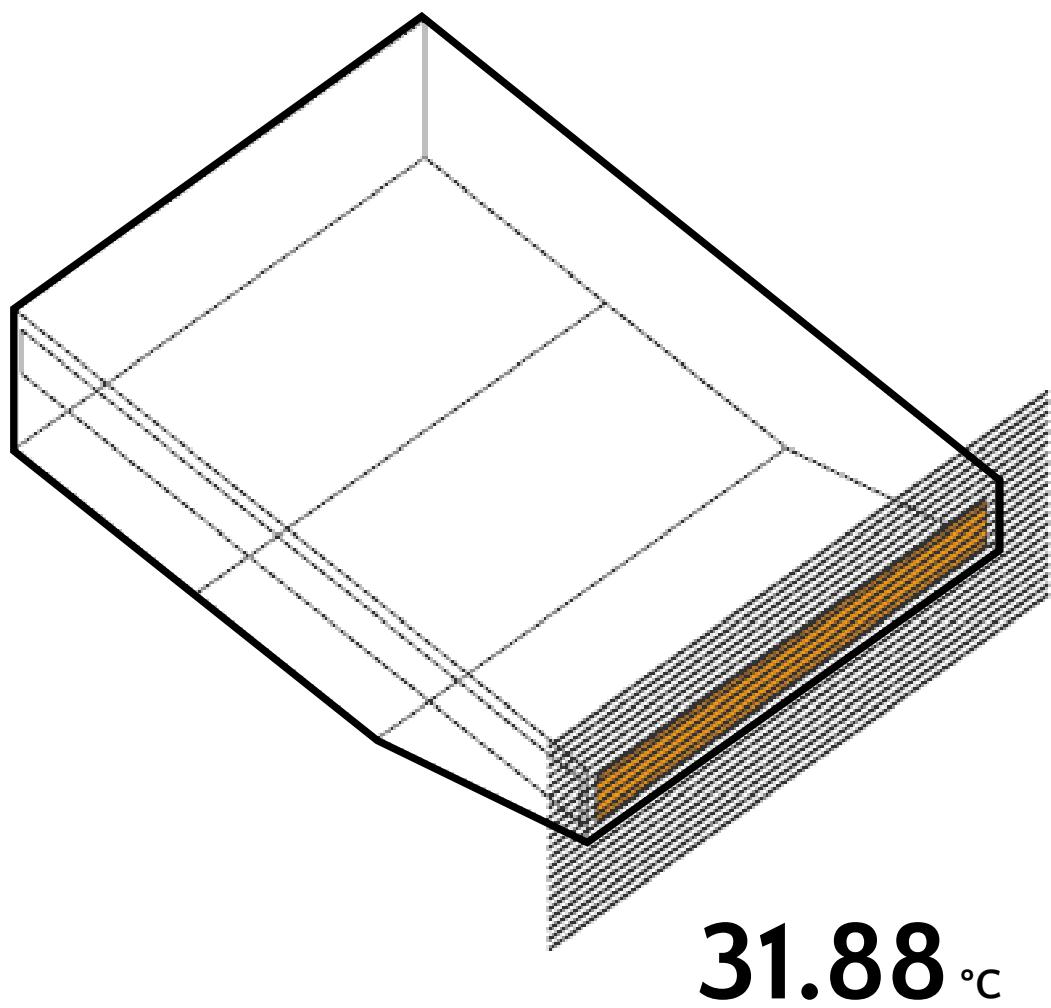
Wet Bulb
Temperature
-
Dry Bulb
Temperature
x 0.6

Exterior
Environment

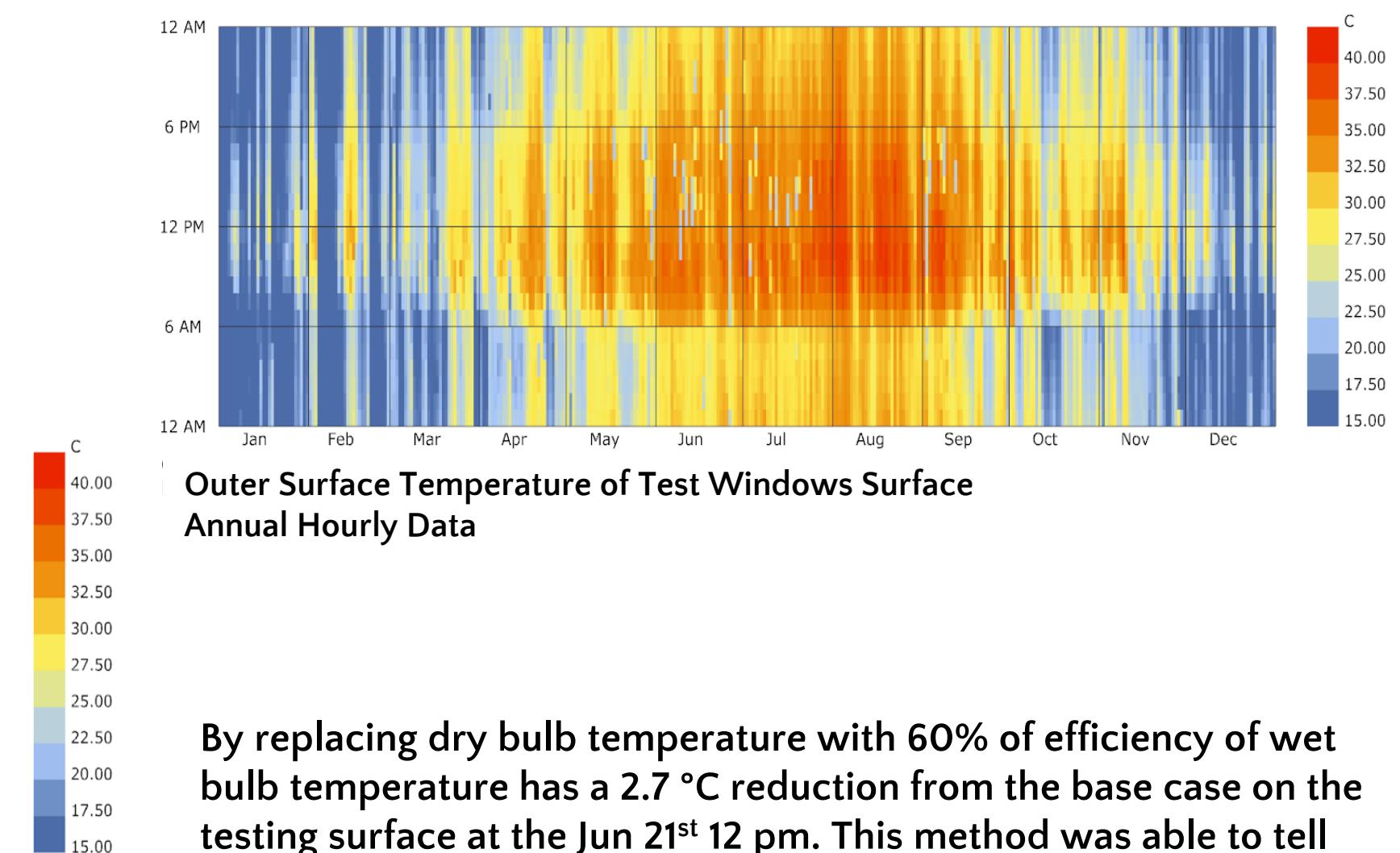
2

WET BULB TEMPERATURE

Generating a new EPW file



Outer Surface Temperature of Test Windows Surface
@ Jun 21st 12 PM



By replacing dry bulb temperature with 60% of efficiency of wet bulb temperature has a 2.7 °C reduction from the base case on the testing surface at the Jun 21st 12 pm. This method was able to tell the best cooling effect from evaporation theoretically.

EVAPORATIVE RATE EQUATION

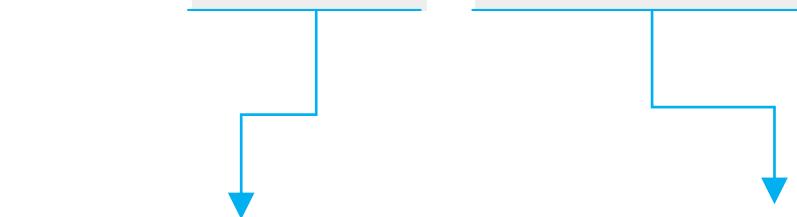
Penman Equation

Δ : slope of the saturation vapor pressure curve (kPa/°C)
 $= \frac{4098 \times \text{saturation vapor pressure}}{(T+237.3)^2}$

R_n : net radiation (MJ/day)
 $= \text{radiation in} - (T + 237.3)^4 \times \text{Cloudiness\%} \times 4.903 \times 10^{-9}$

The Base Evaporation Rate Equation

$$E_{\text{PEN}} = \frac{\Delta}{\Delta+\gamma} \cdot \frac{R_n}{\lambda} + \frac{\gamma}{\Delta+\gamma} \cdot \frac{6.43 \times f_u \times D}{\lambda}$$



Evaporation from
Radiation function

Evaporation from
Wind function

γ : psychrometric coefficient (kPa/°C)
 $= 0.0016286 \cdot P/\lambda$

P : barometric Pressure (kPa)
 $= 101.3 \times [(293 - 0.0065 \times Z)/293]^{5.26}$

Z : elevation of the site (m)

λ : latent heat of vaporization (MJ/kg)
 $= 2.501 - (2.361 \times 10^{-3}) \cdot T$

f_u : wind function
 $= 1 + 0.536 \cdot U$

U : wind speed at 2m (m/s)

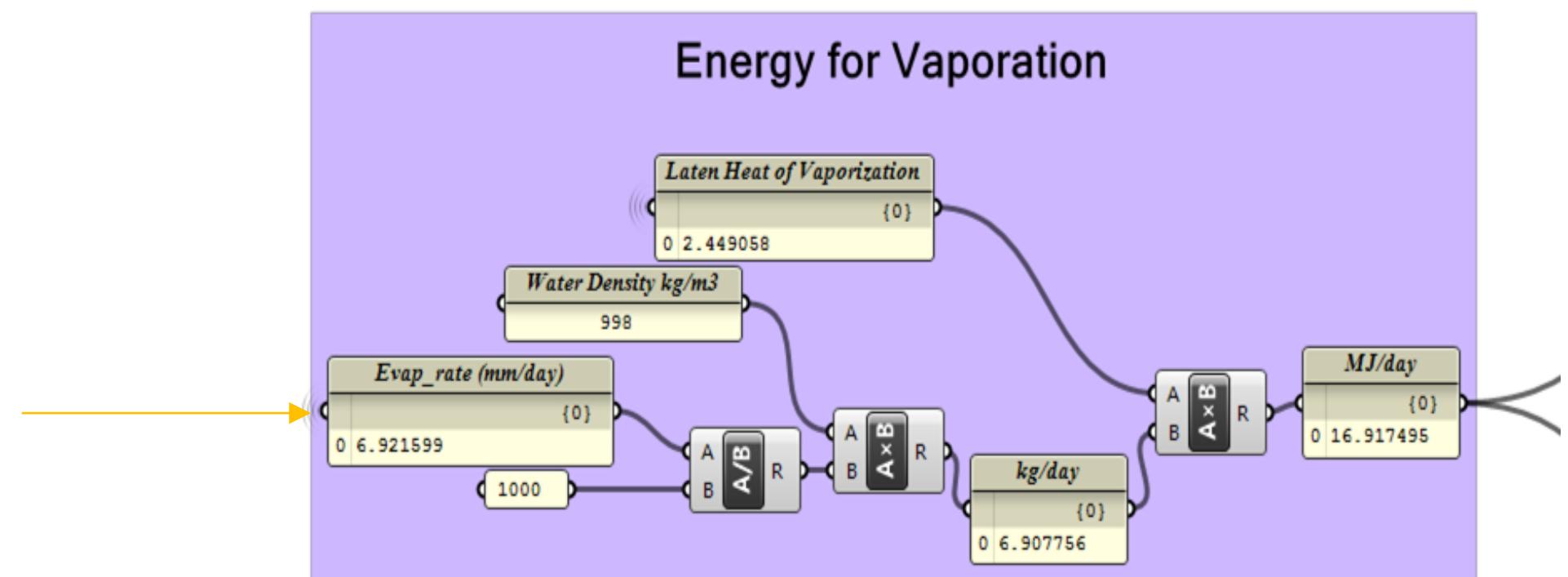
D : vapor pressure deficit (kPa)
 $= \text{saturation vapor pressure} - \text{actual vapor pressure}$

EVAPORATIVE RATE EQUATION

New Air Temperature

The Base Evaporation Rate Equation

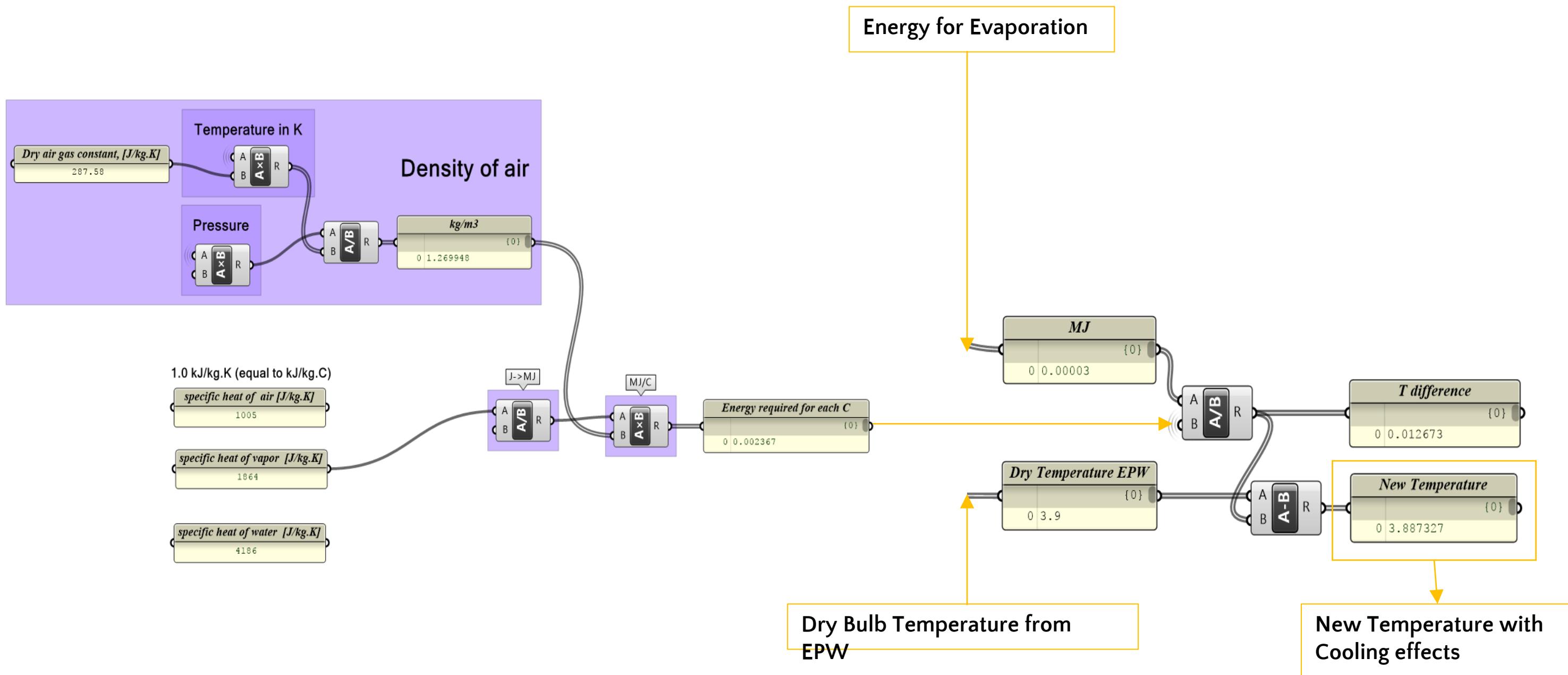
$$E_{PEN} = \frac{\Delta}{\Delta+\gamma} \cdot \frac{R_n}{\lambda} + \frac{\gamma}{\Delta+\gamma} \cdot \frac{6.43 \times f_u \times D}{\lambda}$$



3

EVAPORATIVE RATE EQUATION

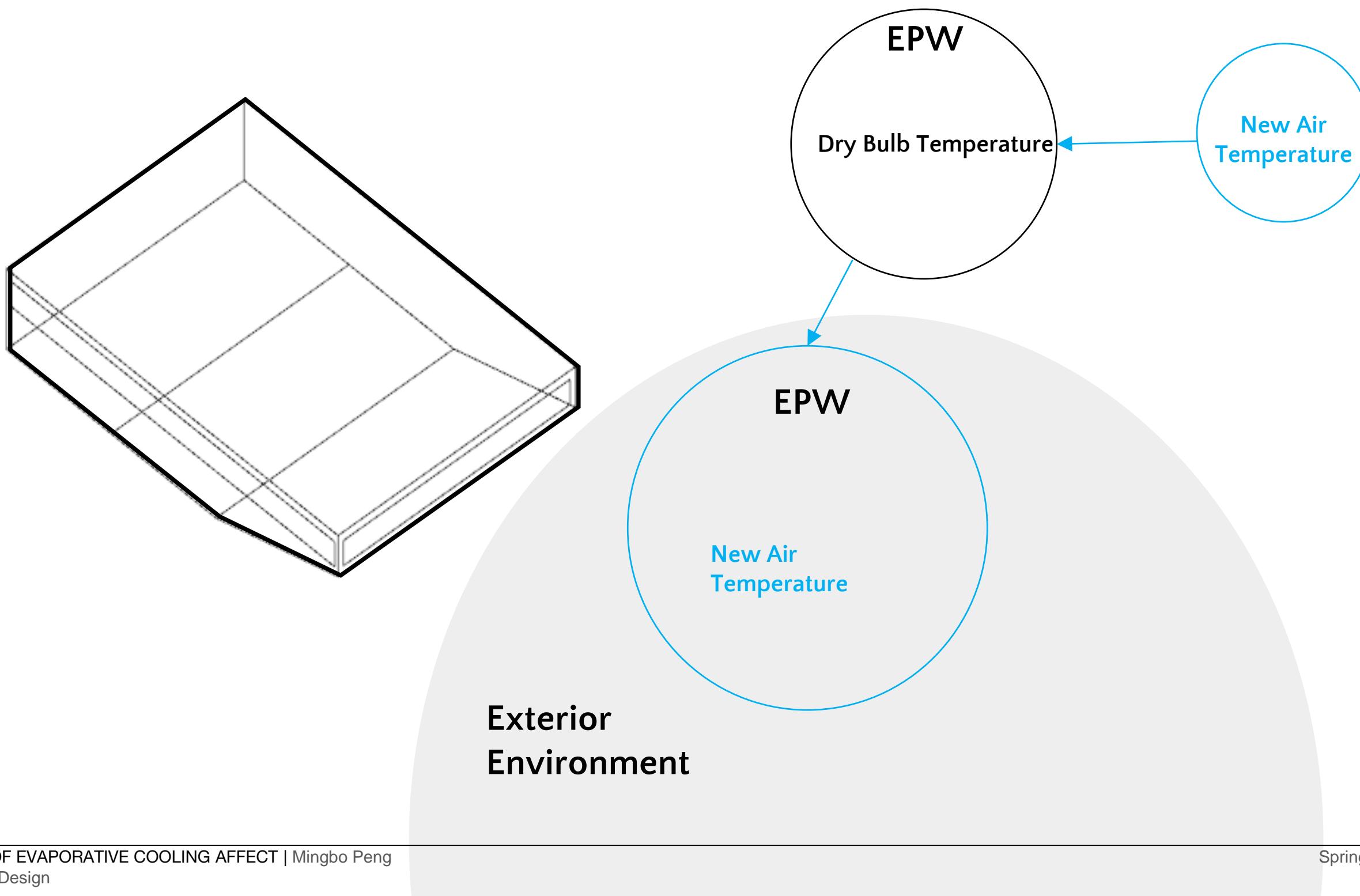
New Air Temperature



3

EVAPORATIVE RATE EQUATION

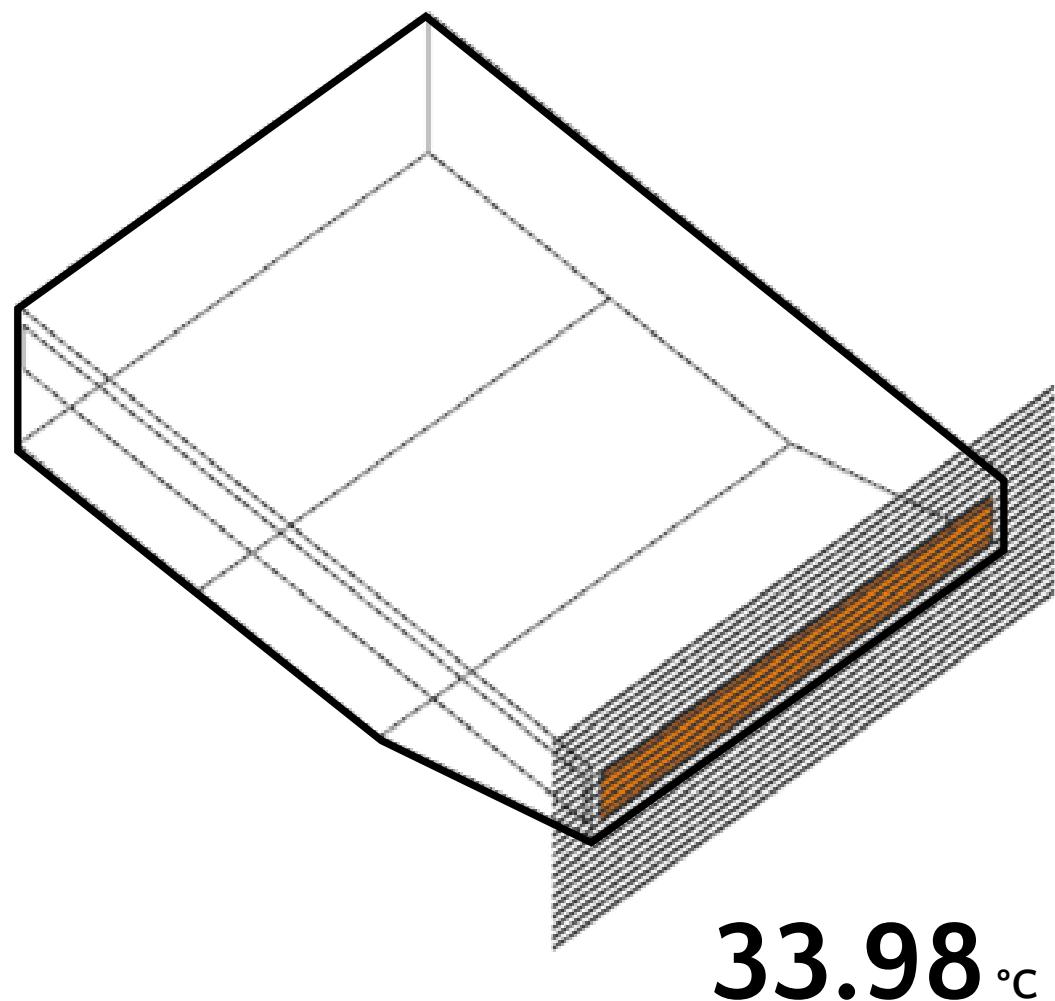
New Air Temperature



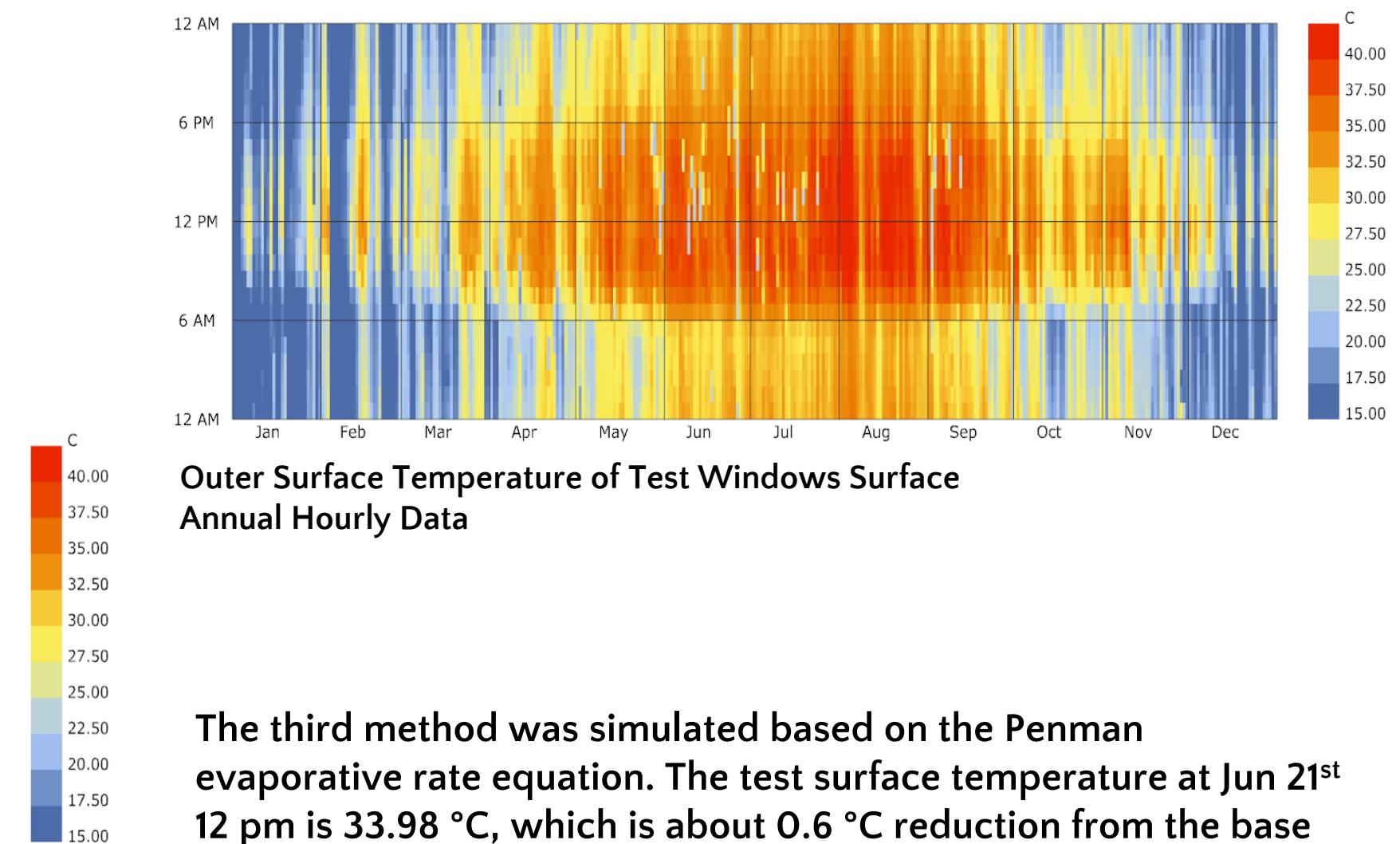
3

EVAPORATIVE RATE EQUATION

New Air Temperature



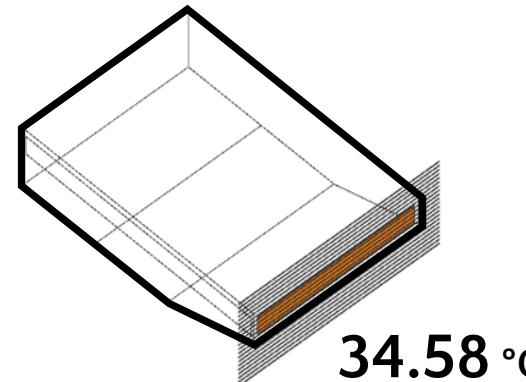
Outer Surface Temperature of Test Windows Surface
@ Jun 21st 12 PM



The third method was simulated based on the Penman evaporative rate equation. The test surface temperature at Jun 21st 12 pm is 33.98 °C, which is about 0.6 °C reduction from the base case.

0

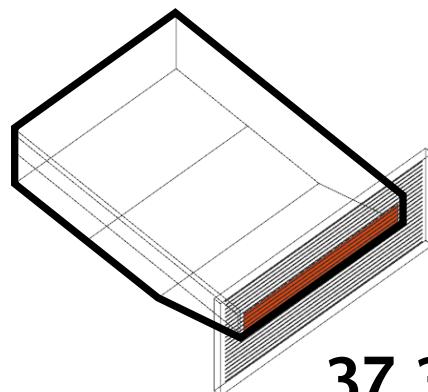
Base Case



34.58 °C

1

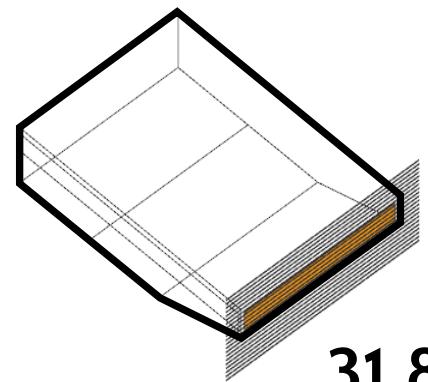
EnergyPlus
ZoneCoolTower:Shower



37.34 °C

2

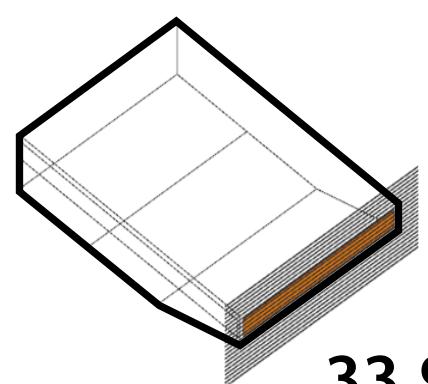
Wet bulb Temperature



31.88 °C

3

Evaporative Rate Equation



33.98 °C

Outer Surface Temperature
@ Jun 21st 12 PM

Outer Surface Temperature
Annual Hourly Data

