J/M²

Jeeeun Lee | Mingbo Peng | Shinyi Kwan
Spring 2016 | ARCH 708 MEBD Design Studio
PennDesign | University of Pennsylvania

1 SITE & CLIMATE

Natural Boundary & Resources

// About New Orleans
// Neighborhood
// Climate
// Challenges

2 ENV_DEVELOPMENTS

Environmental Challenges

3 ARCH_ PERFORMANCE

Architectural Challenges

NEW ORLEANS

Early 19c Urban Growth Contour

2016

1920

1862

1849

1798

urban growth
1798 - 2016

NEW ORLEANS

Intersection of Growth Contour & Stable Ground

2016

1920

1862

1849

1798

urban growth
1798 - 2016

floodwater depths

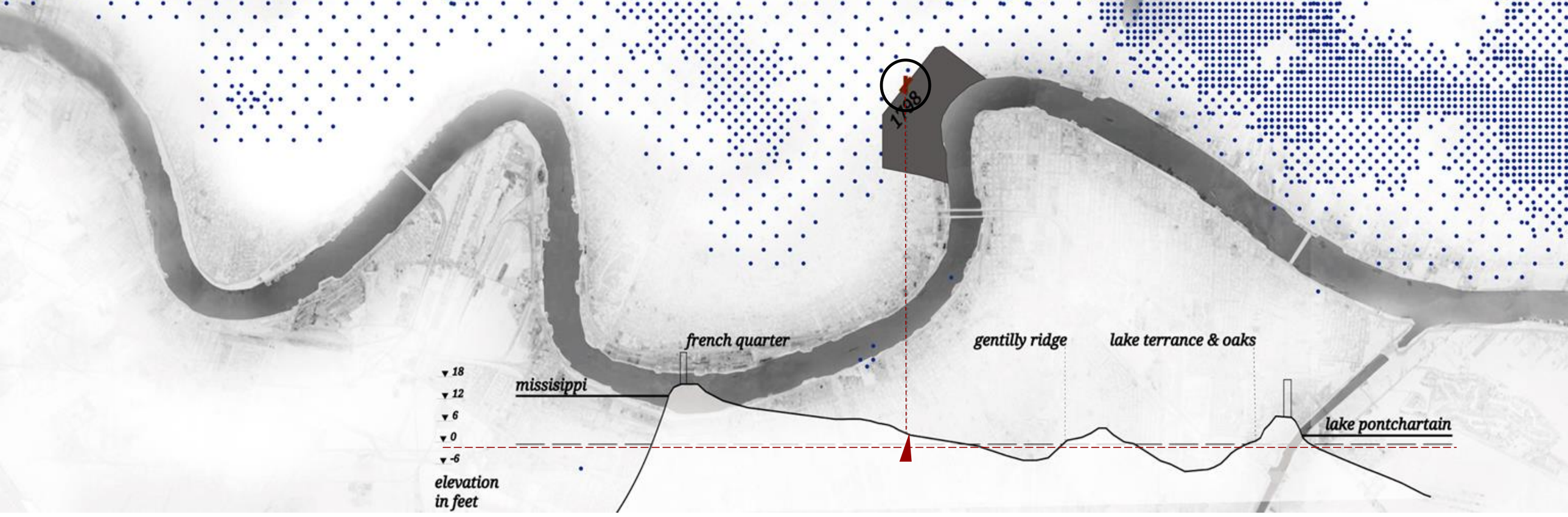
1-2 feet

3-4 feet

5-6 feet

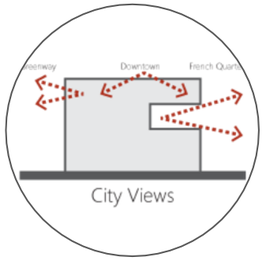
NEW ORLEANS

Site Location- North French quarter



FRENCH QUARTER

Surroundings



Site

The Lafitte Greenway Project

Project has transformed city's the most historic transportation corridors, formerly a canal and then a railroad, into a linear park.

The Greenway includes a 12-foot asphalt path for cyclists and pedestrians, more than 500 shade trees, and LED energy-efficient lighting along the entire trail.

French Quarter

The Mississippi River

Mercedes-Benz Superdome

Downtown New Orleans

FRENCH QUARTER

Location of Festival events

Site

New Orleans Jazz And Heritage Festival
Voodoo Music Experience
Bayou Boogaloo

New World Rhythms Festival
Crescent City Classic - road race

Zurich Classic

Spring Fiesta
The Great French Market
Creole Tomato Festival

Dirty Linen Night
Ponderosa Stomp

French Quarter Festival
Satchmo Summerfest
Christmas New Orleans Style

Wine And Food Experience

White Linen

Allstate Sugar Bowl

Art For Arts' Sake

Essence Music Festival

FRENCH QUARTER

Location of Leisure Spaces

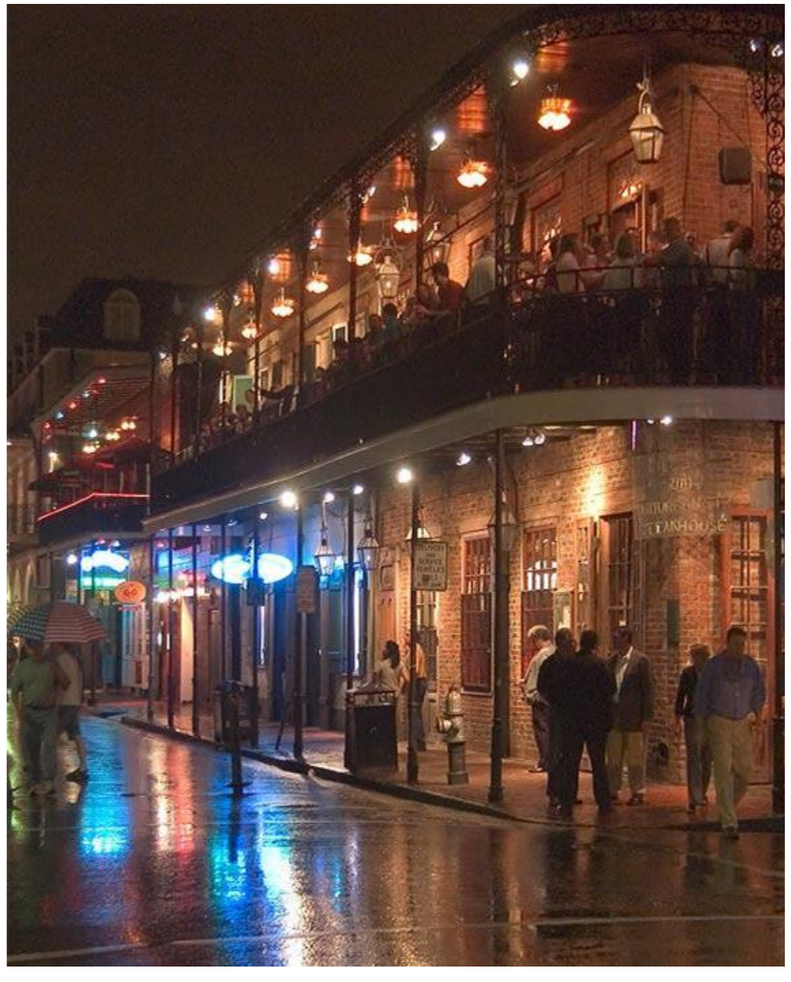
Site

Bar & Restaurant

Art Gallery

FRENCH QUARTER

Atmosphere- Bars, Street Performance & Festival



CLIMATE CONDITIONS

Outdoor Comfort

The most of 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.

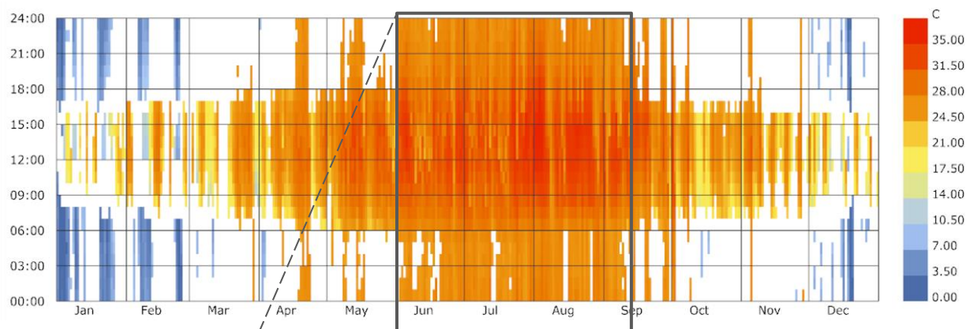
The **Relative Humidity** during **summer daytimes** is around **50%** which evaporative cooling strategy is possible.

47%

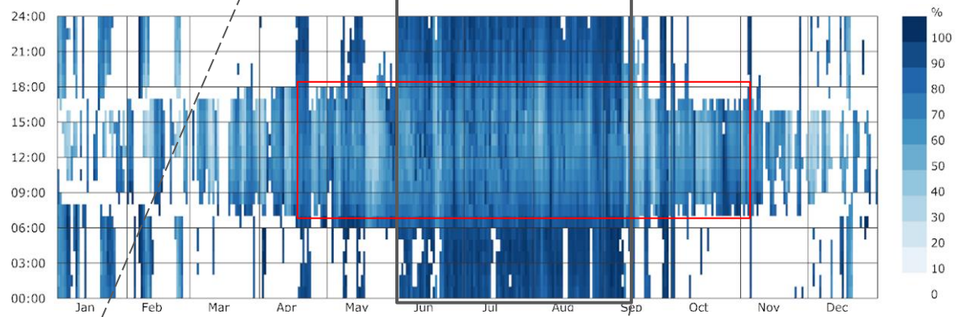
Annual Hours Comfort
Unshaded Condition

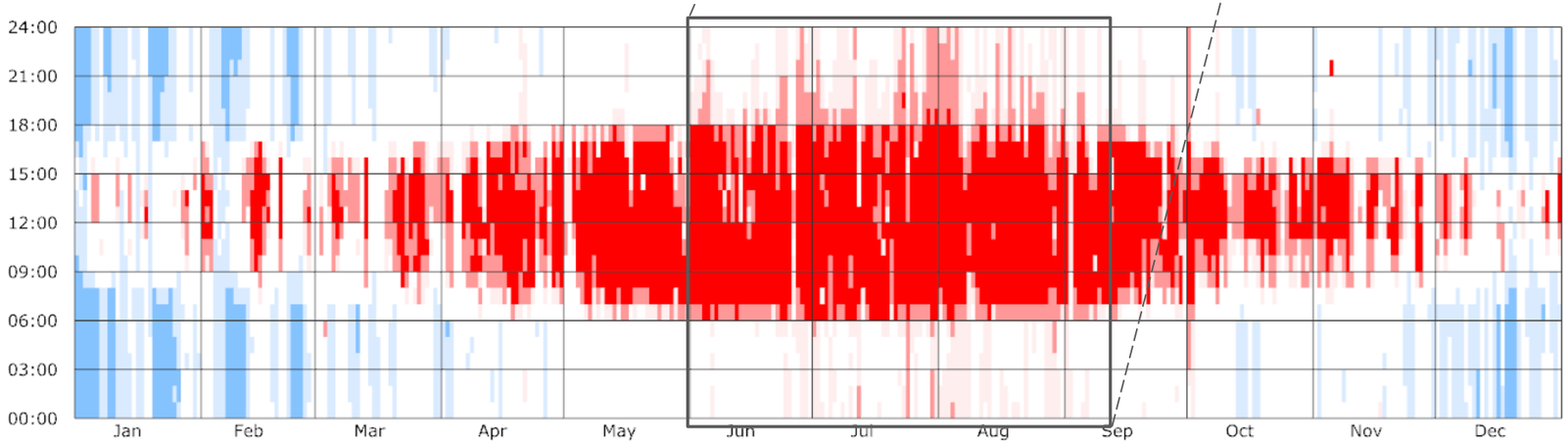
- Extreme Heat
- Hot
- Warm
- **Comfort**
- Cool
- Cold
- Extreme Cold

Temperature



Relative Humidity



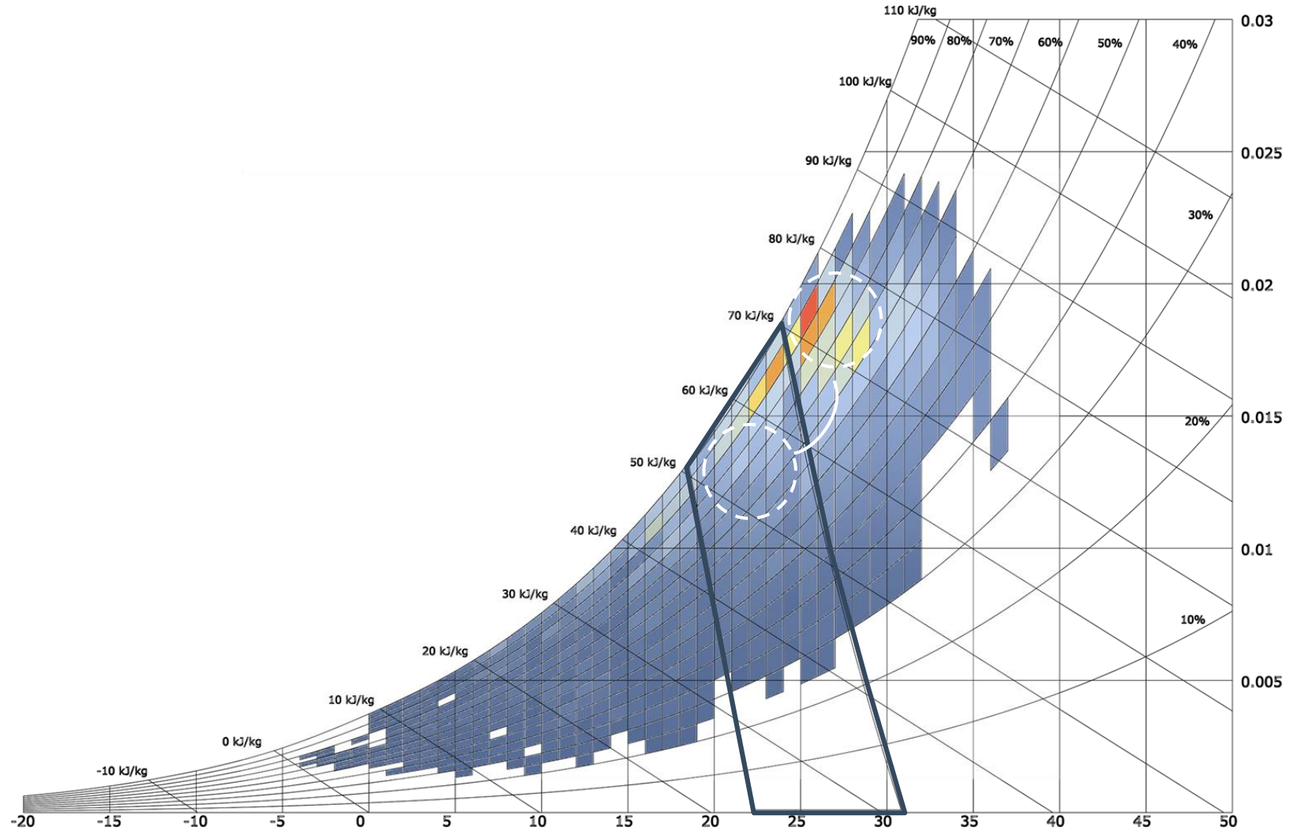


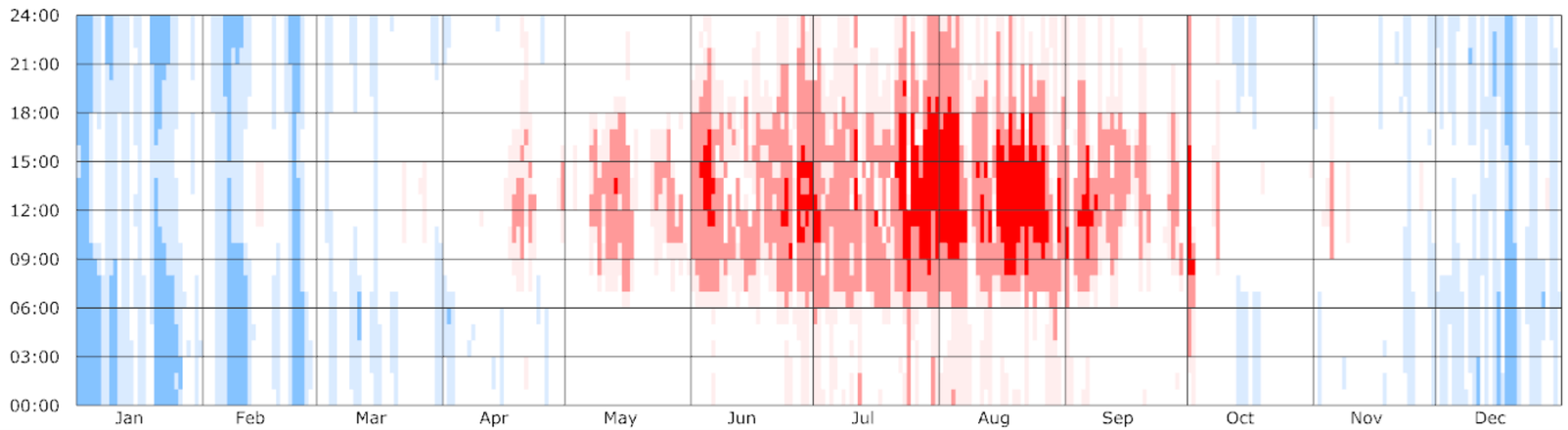
CLIMATE CONDITIONS

Outdoor Comfort of Shaded Condition

Psychrometric Chart suggests that majority of hours are out of outdoor comfort zone.

In order to bring the uncomfortable hours into the comfort zone, enough **cooling strategy** need to be applied to drop temperature around **5°C.**





57%

Annual Hours Comfort
Shaded Condition

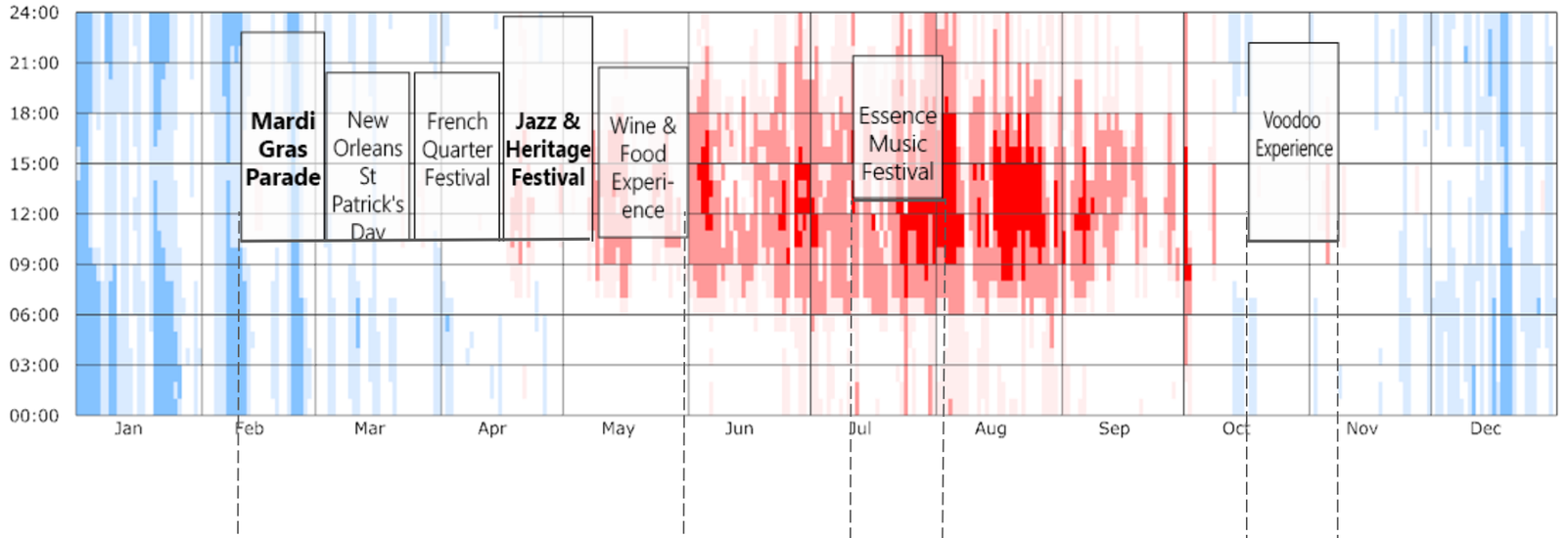
- Extreme Heat
- Hot
- Warm
- **Comfort**
- Cool
- Cold
- Extreme Cold

CLIMATE CONDITIONS

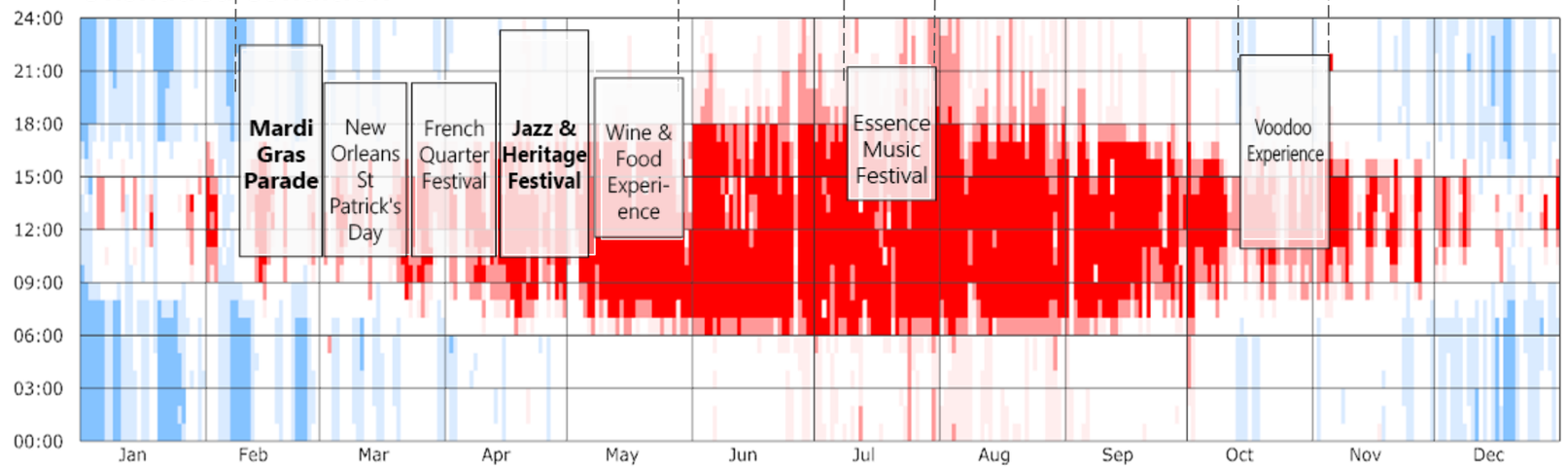
Outdoor Comfort & Festival Events

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.

Annual Hours Comfort
Shaded Condition

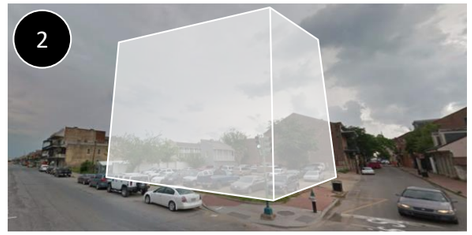


Annual Hours Comfort
Unshaded Condition



NEIGHBORHOOD

Surroundings



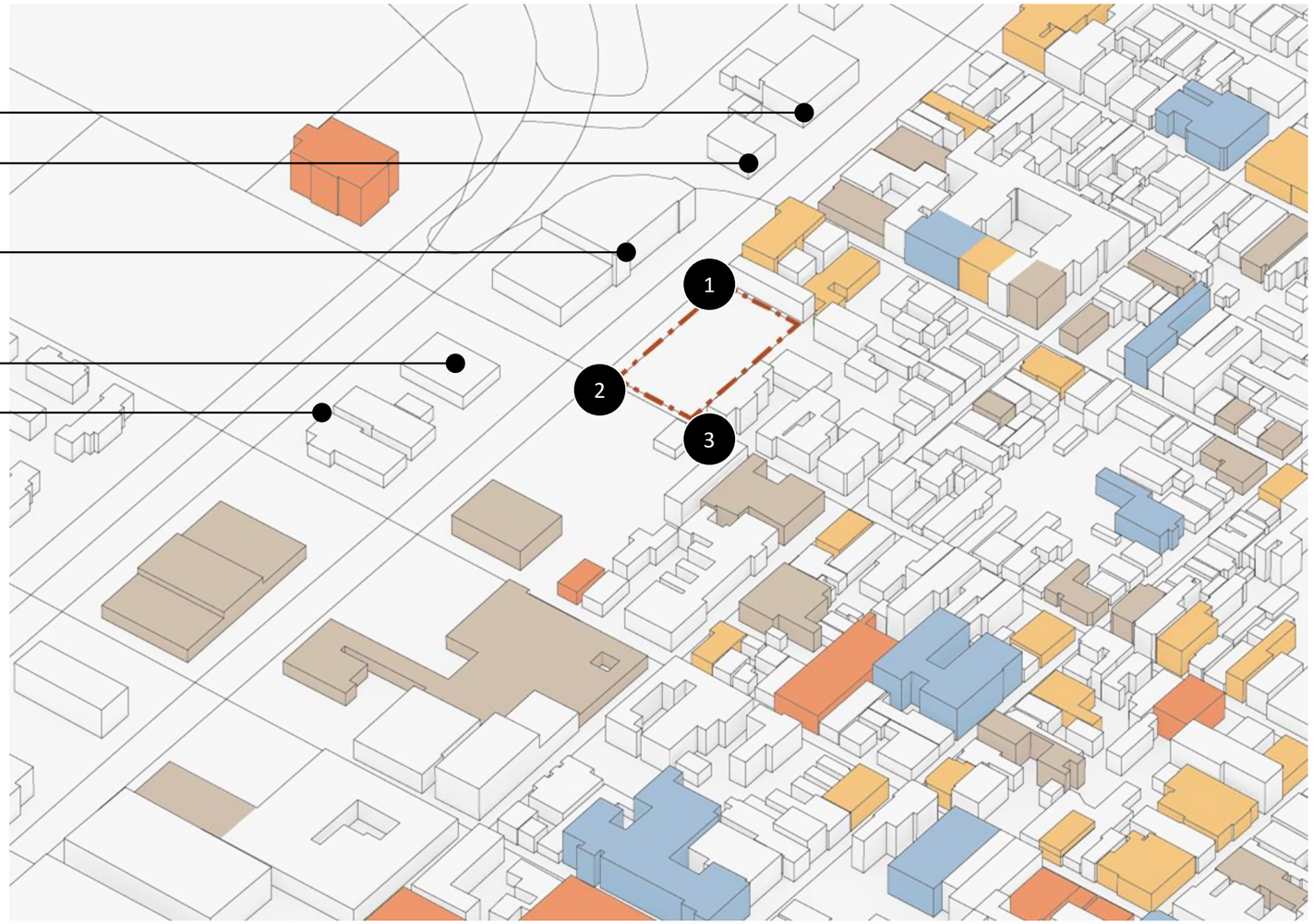
Covenant house

Basin St. Station

Louisiana Department of Health and Hospital

Police Department

Gas Station



BAR / CAFE / RESTAURANT

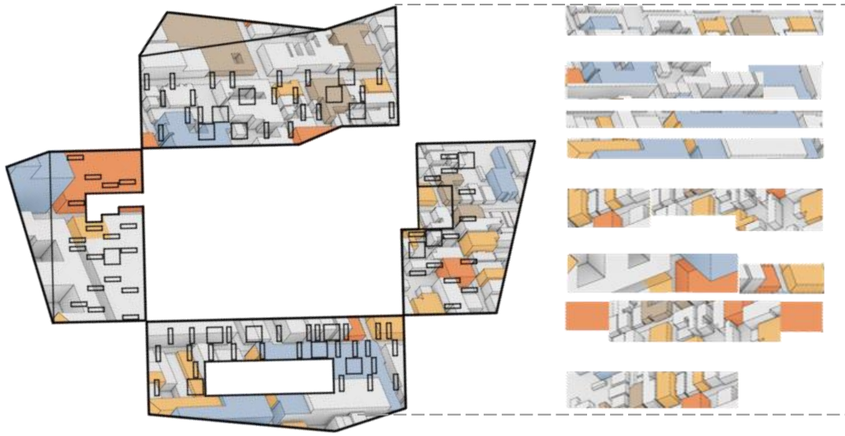
MUSEUM / ART GALLERY

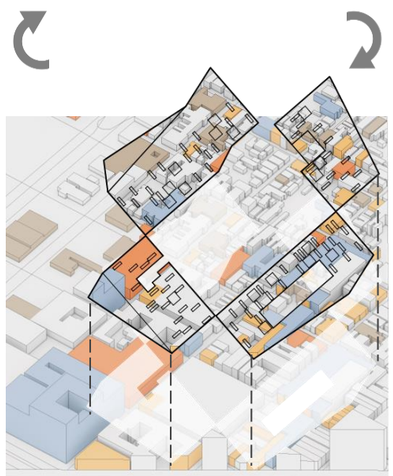
HOTEL

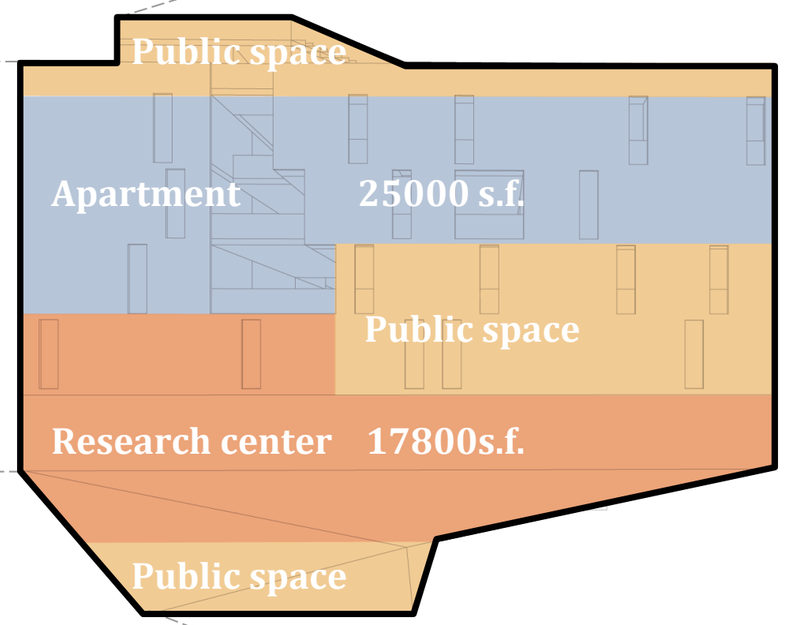
STORE / SERVICE

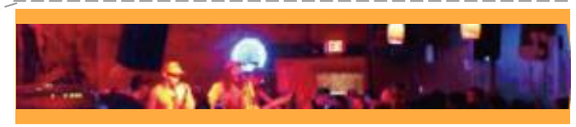
INITIAL PROGRAM

Verticalize Surrounding Programs









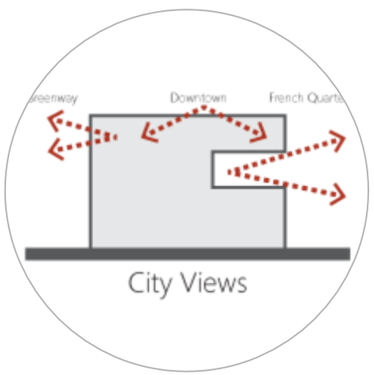
Bar at roof garden

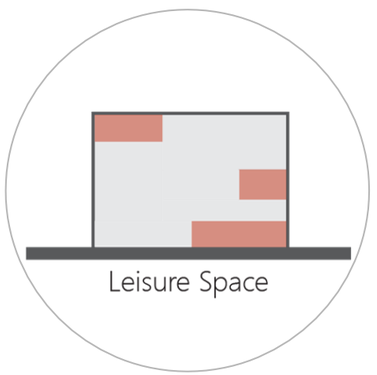
Lookout to French quarter

Outdoors for festival events

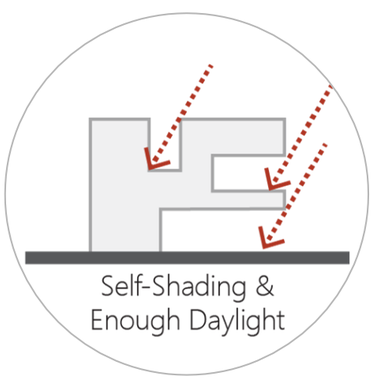
DESIGN CONCEPT

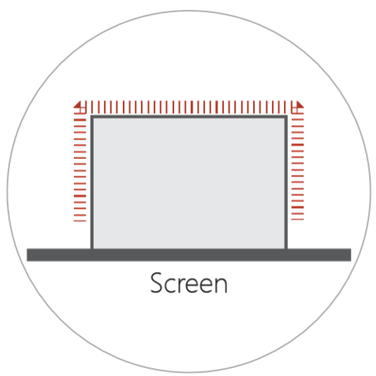
Urban Approaches

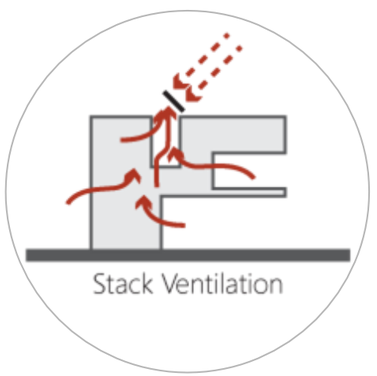




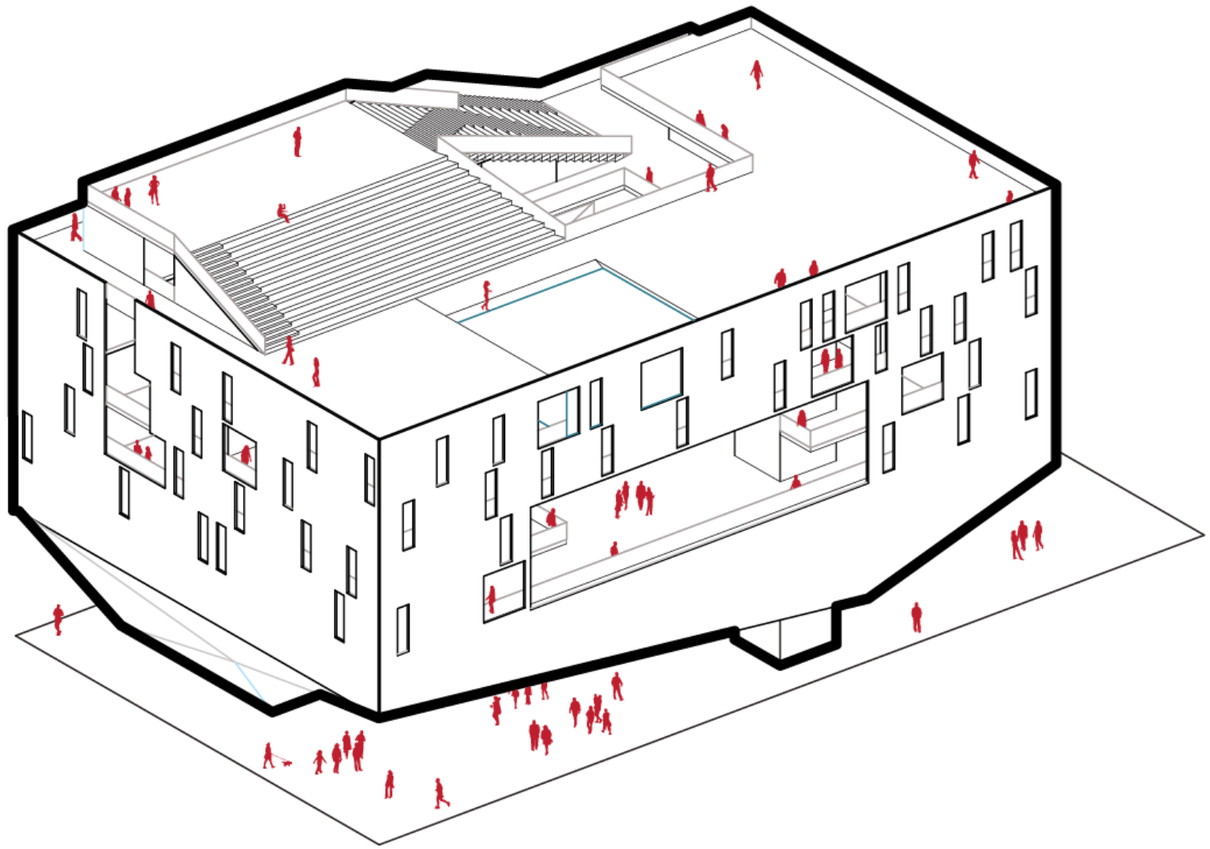
Environmental Approaches

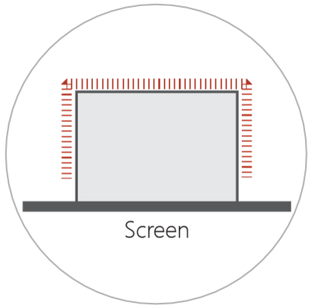


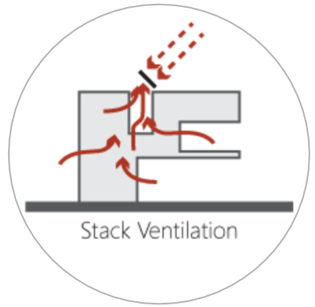


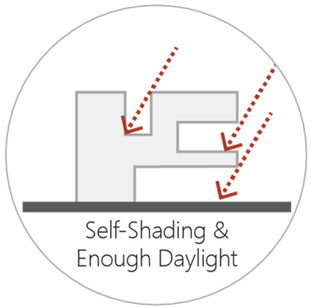


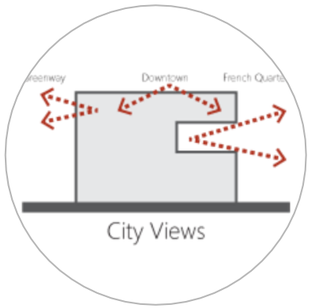
DESIGN CONCEPT

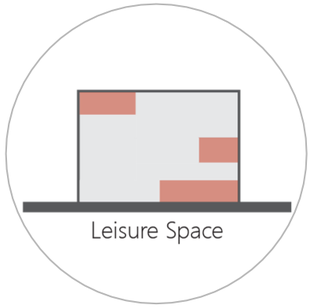












1 SITE & CLIMATE

Natural Boundary & Resources

2 ENV_DEVELOPMENTS

Environmental Challenges

// Outdoor Self-Shading

Mass Exploration

// Balcony

Shading for Indoor Environment

// Screen

// Evaporative Cooling

3 ARCH_ PERFORMANCE

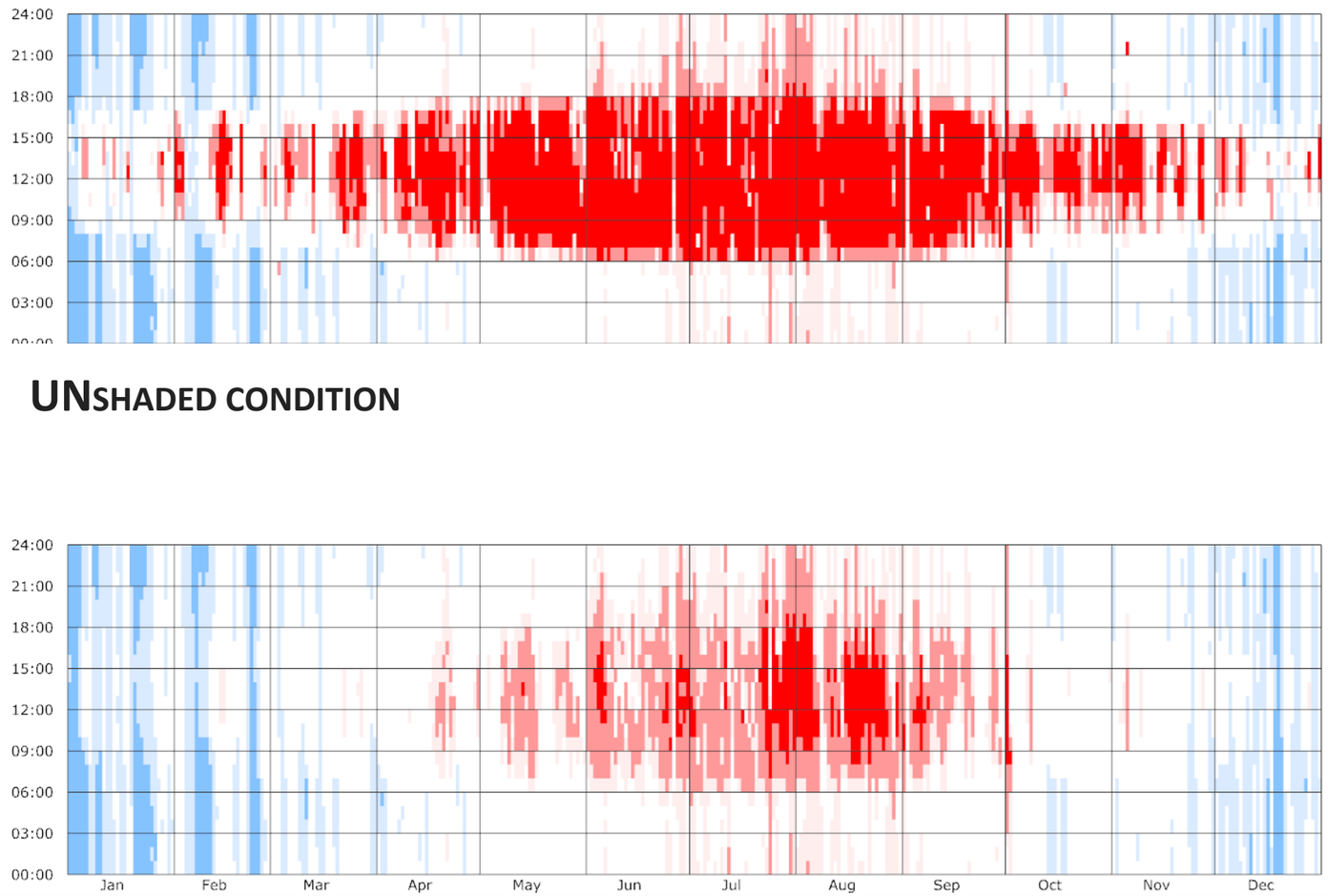
Architectural Challenges

CHALLENGES

Climate Recap

47%

Annual Hours Comfort
Unshaded Condition



UNSHADED CONDITION

57%

Annual Hours Comfort
Shaded Condition

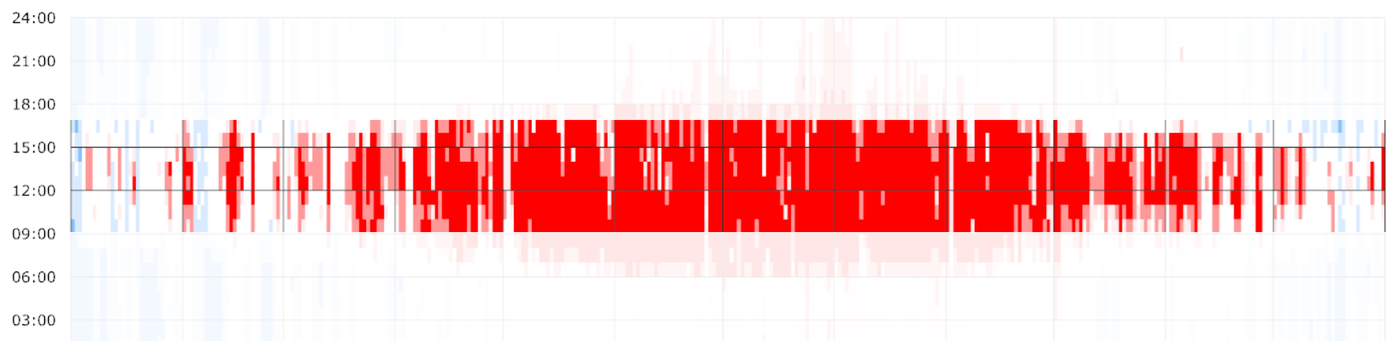
SHADED CONDITION

CHALLENGES

Climate Recap - Daytime

26%

Working Hours Comfort
Unshaded Condition

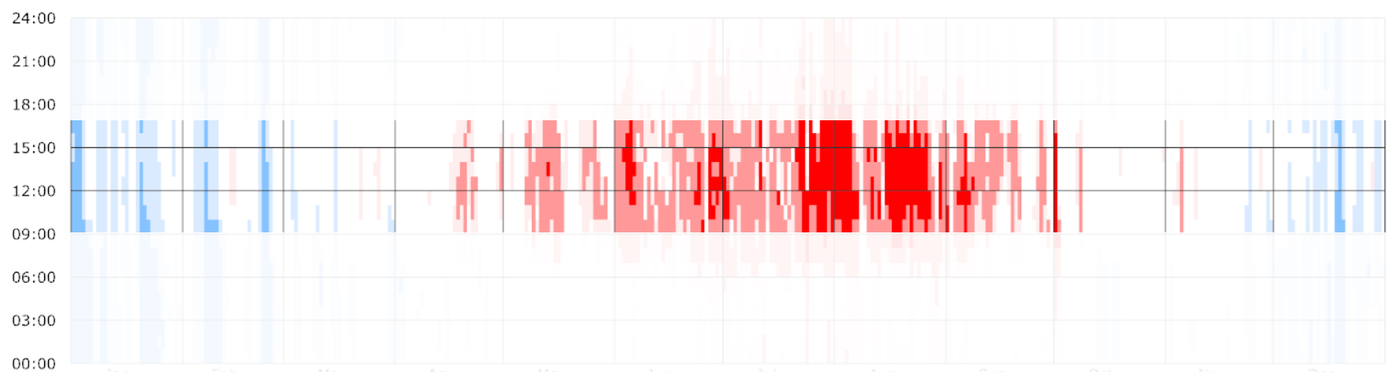


UNSHADED CONDITION (9AM - 5PM)

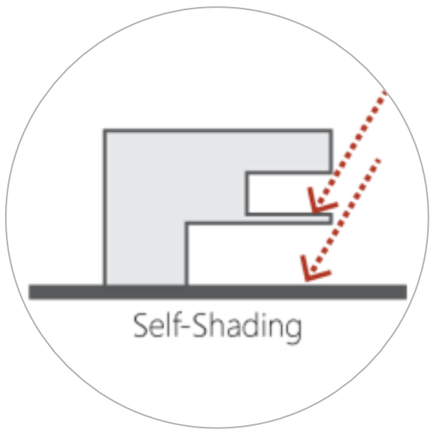
24% = 12 WEEKS

50%

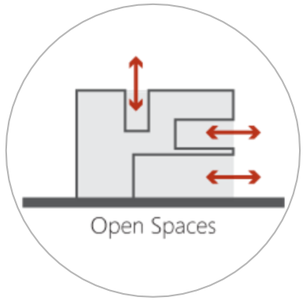
Working Hours Comfort
Shaded Condition



SHADED CONDITION (9AM - 5PM)


Self-Shading

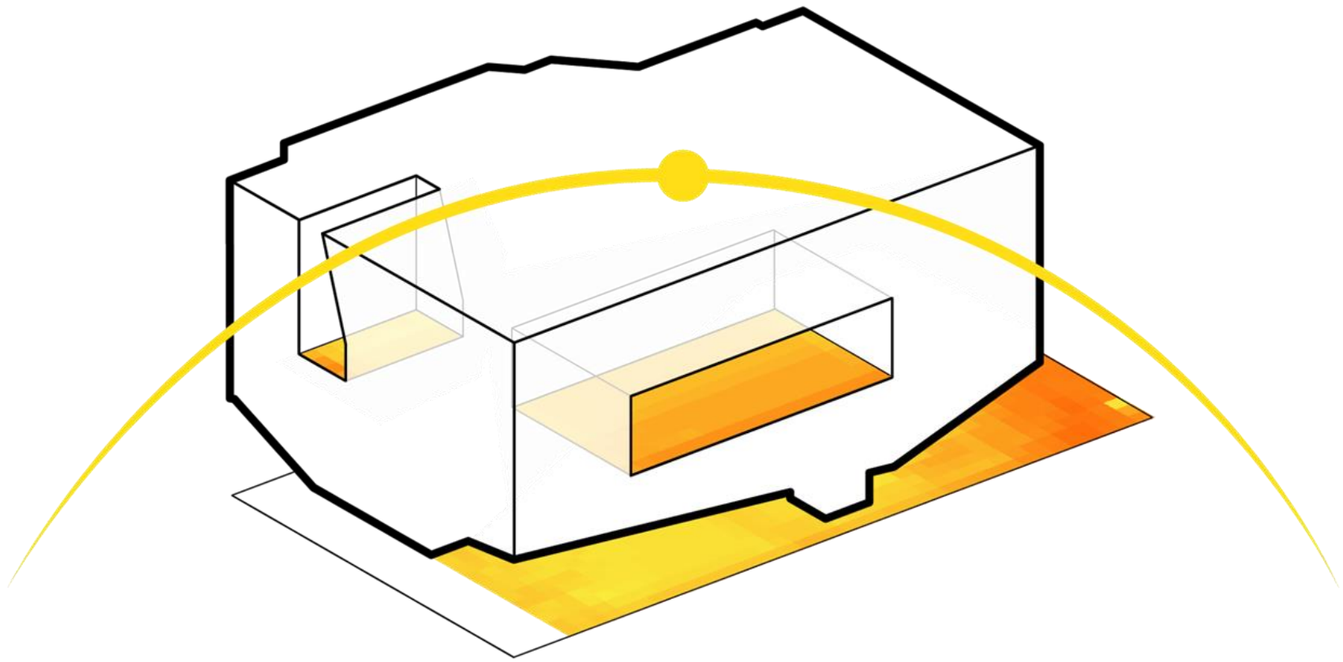

Open for Festival


Open Spaces


Outdoor Privacy

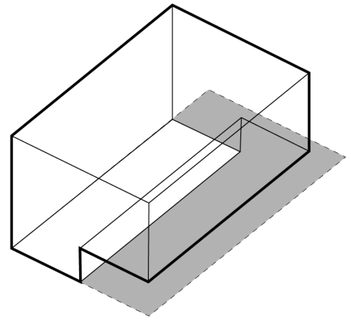
STUDY OF SELF-SHADING

Massing Exploration



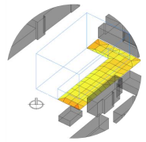
Annual Comfort % (UTCI)

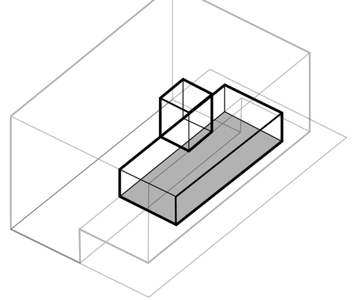
57% 47%



STEP 1

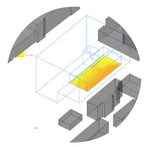
Ground Level - The City Stages

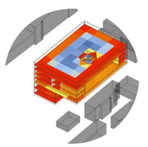


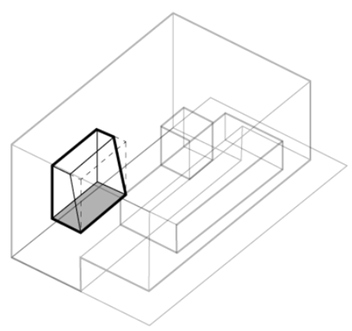


STEP 2

Middle Level - The City Balcony

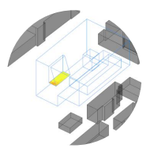


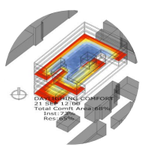




STEP 3

Upper Level - The City Window





THE BEST CASE

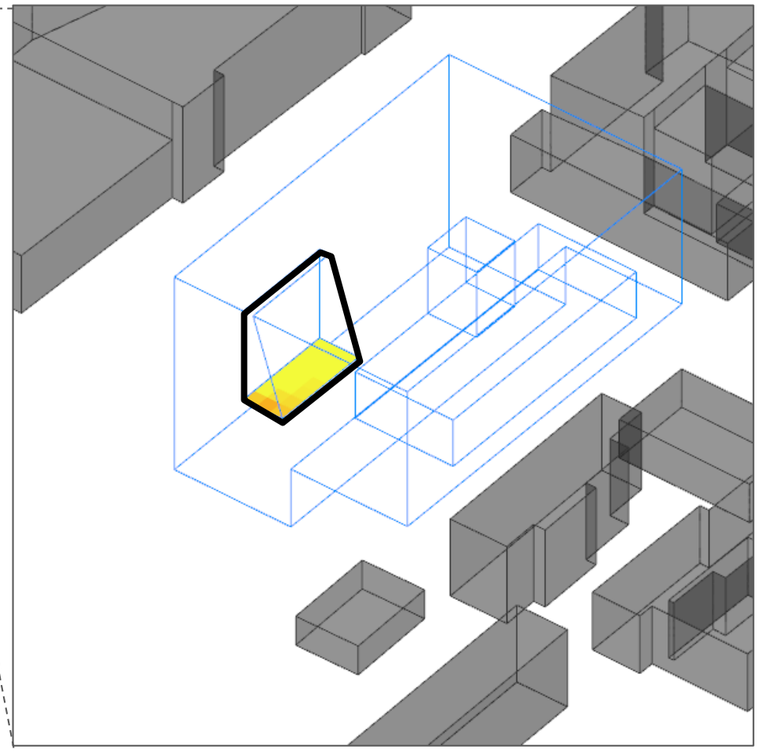
Thermal & Daylight Comfort

THERMAL COMFORT

Within Top 3 of all Cases

57%

55.8%



53%

Thermal comfort range of all cases

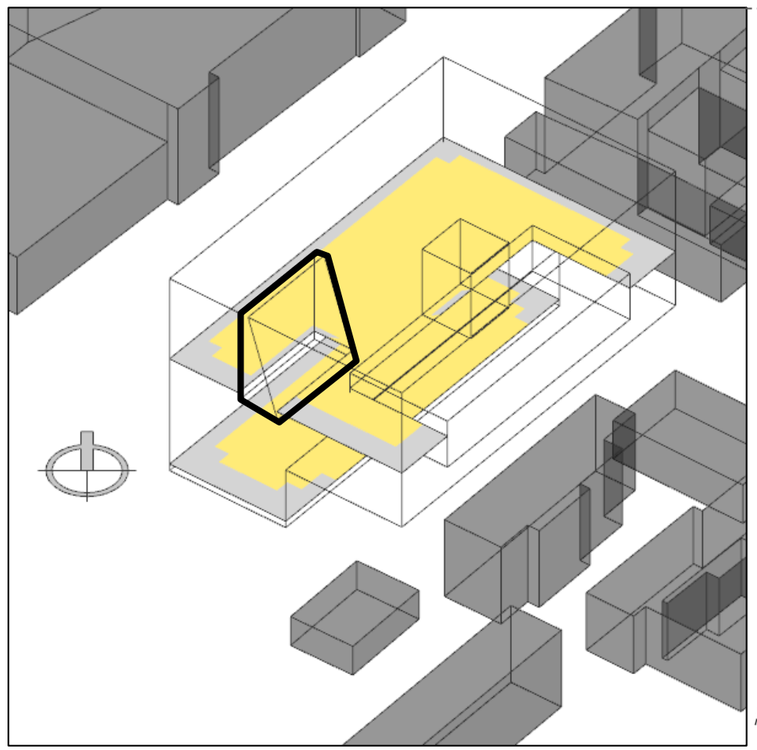
Natural Limitation

47%

DAYLIGHT DISTRIBUTION

Within Top 5 of all Cases

68%



59%

Daylight comfort range of all cases

UTCI

57% 47%

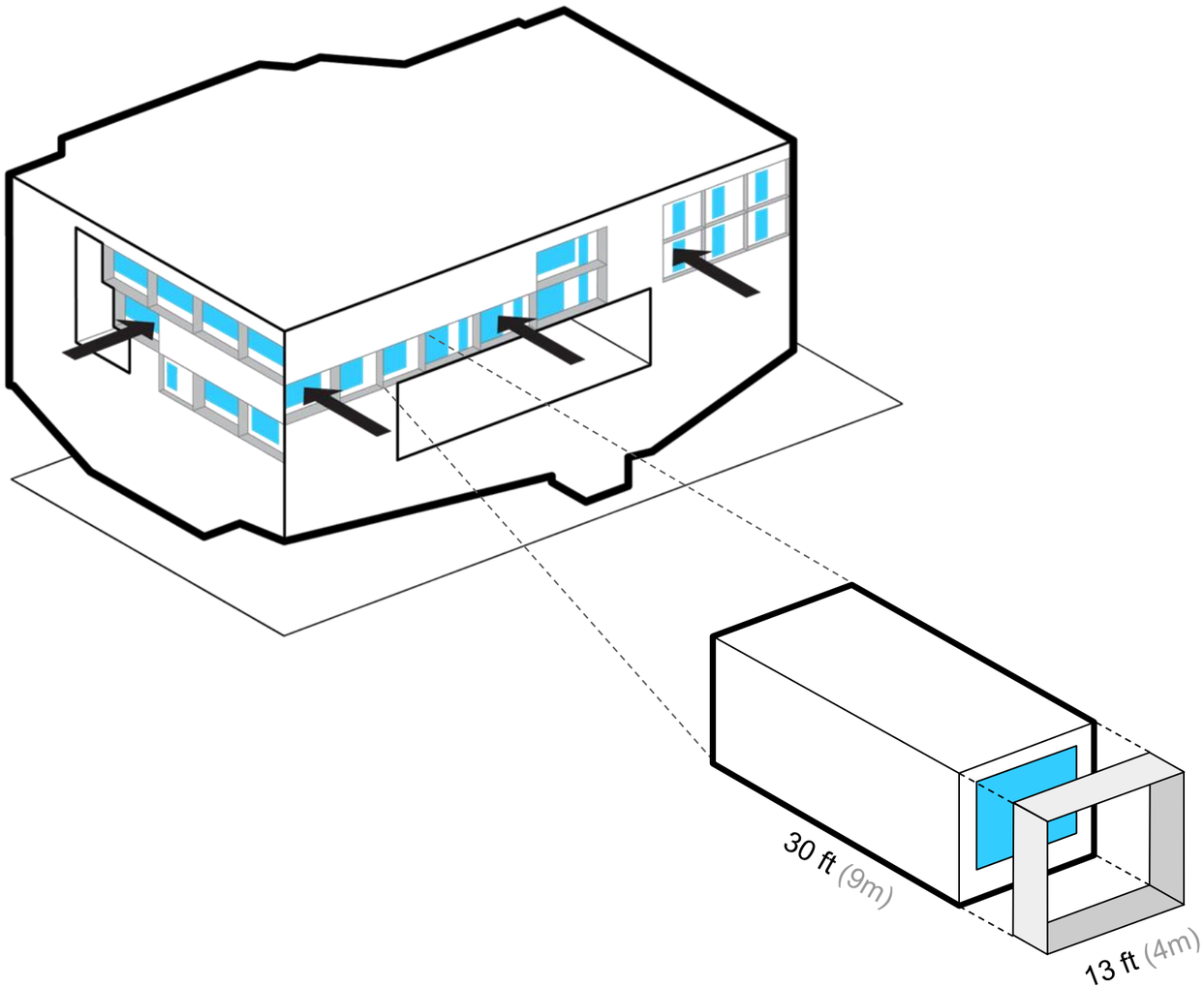
Annual Comfort % hour

Not in Useful Daylight Range

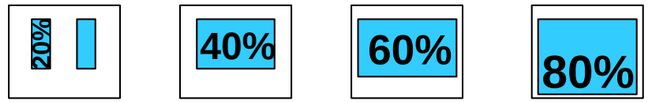
Within Useful Daylight Range

STUDY OF BALCONY

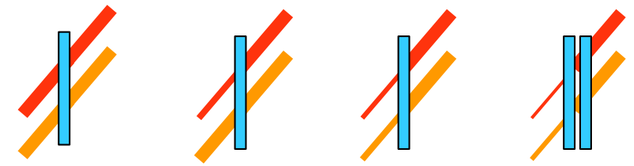
Shadings for Indoor Environment



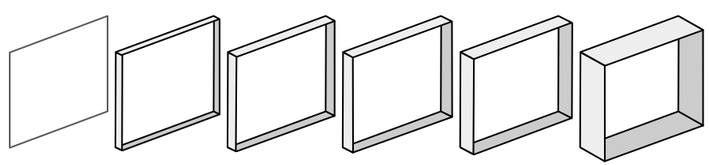
1 **GLAZING RATIO**



2 **GLAZING TYPE**

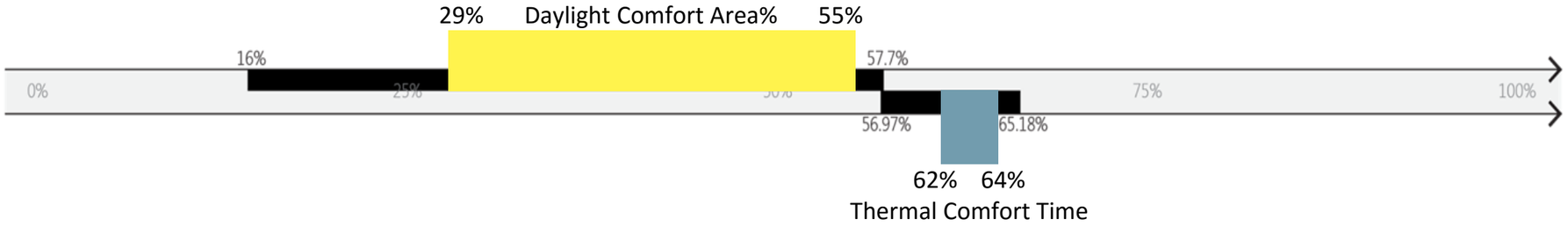


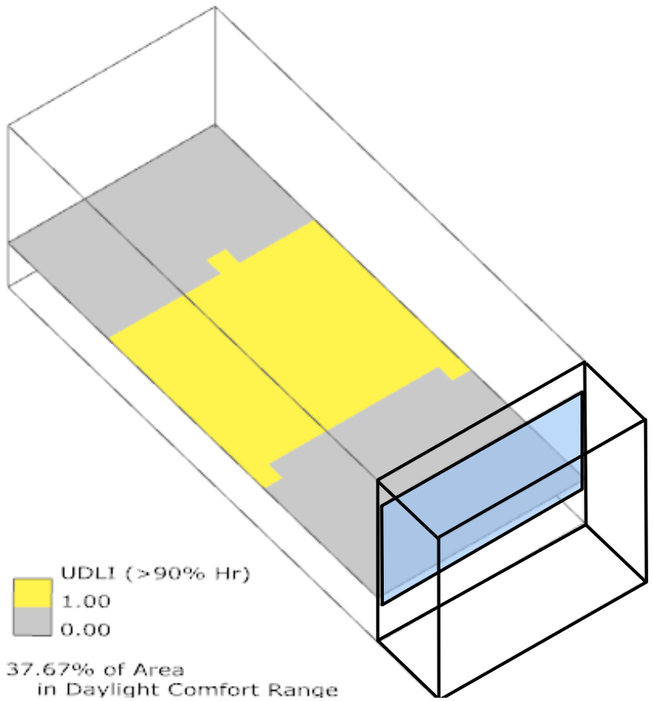
3 **SHADING DEPTH**



UNIT PROTOTYPE

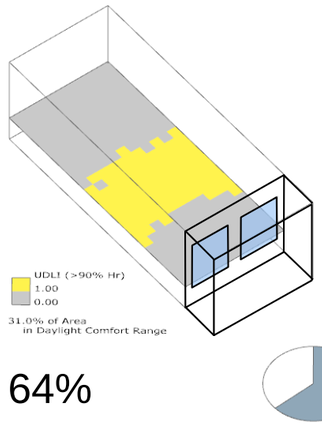
Glz_Ratio & Glz_Type & Shading



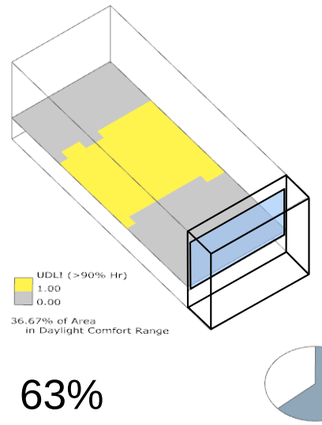


64%

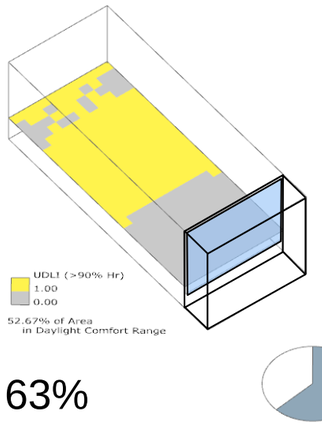
Annual Hours in
Adaptive Comfort



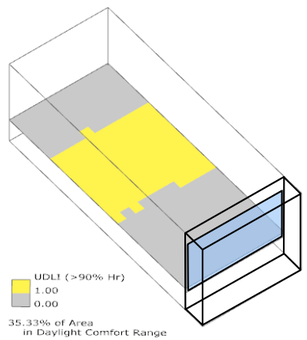
64%



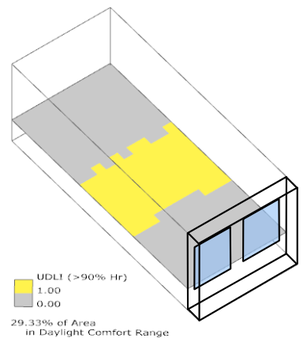
63%



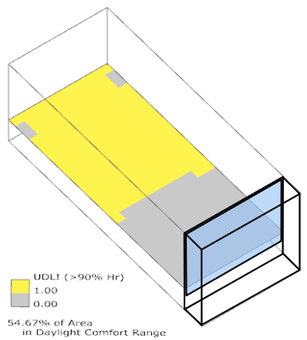
63%



63%



62%

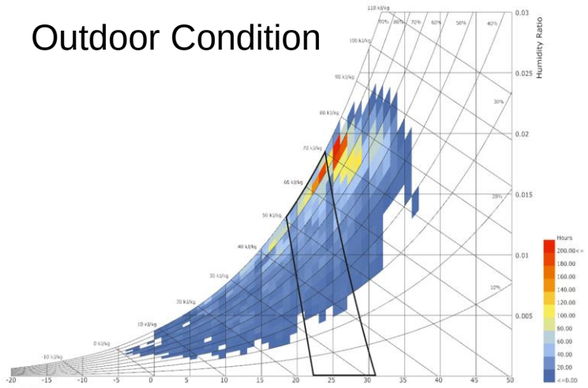


62%

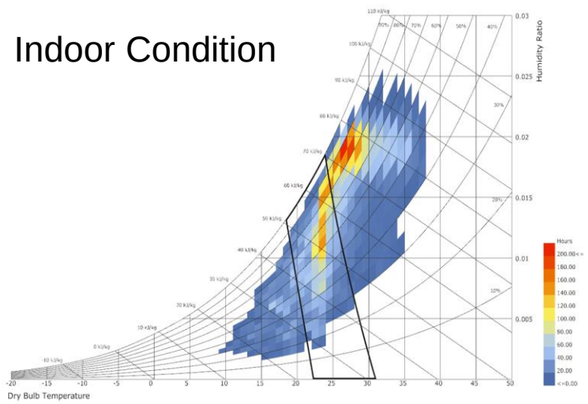
PSYCHROMETRIC CHART

Outdoor & Indoor Condition

Outdoor Condition



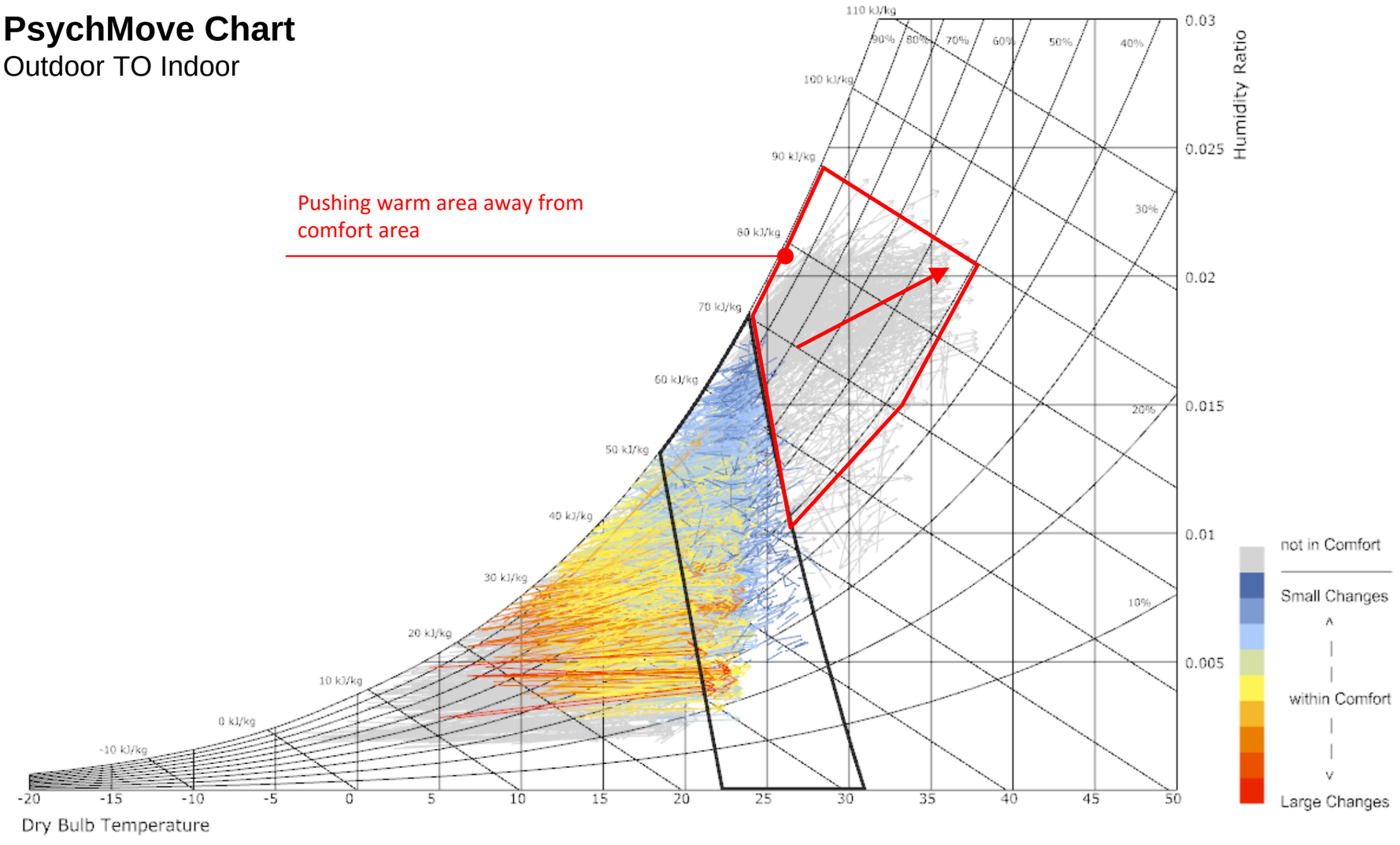
Indoor Condition



PsychMove Chart

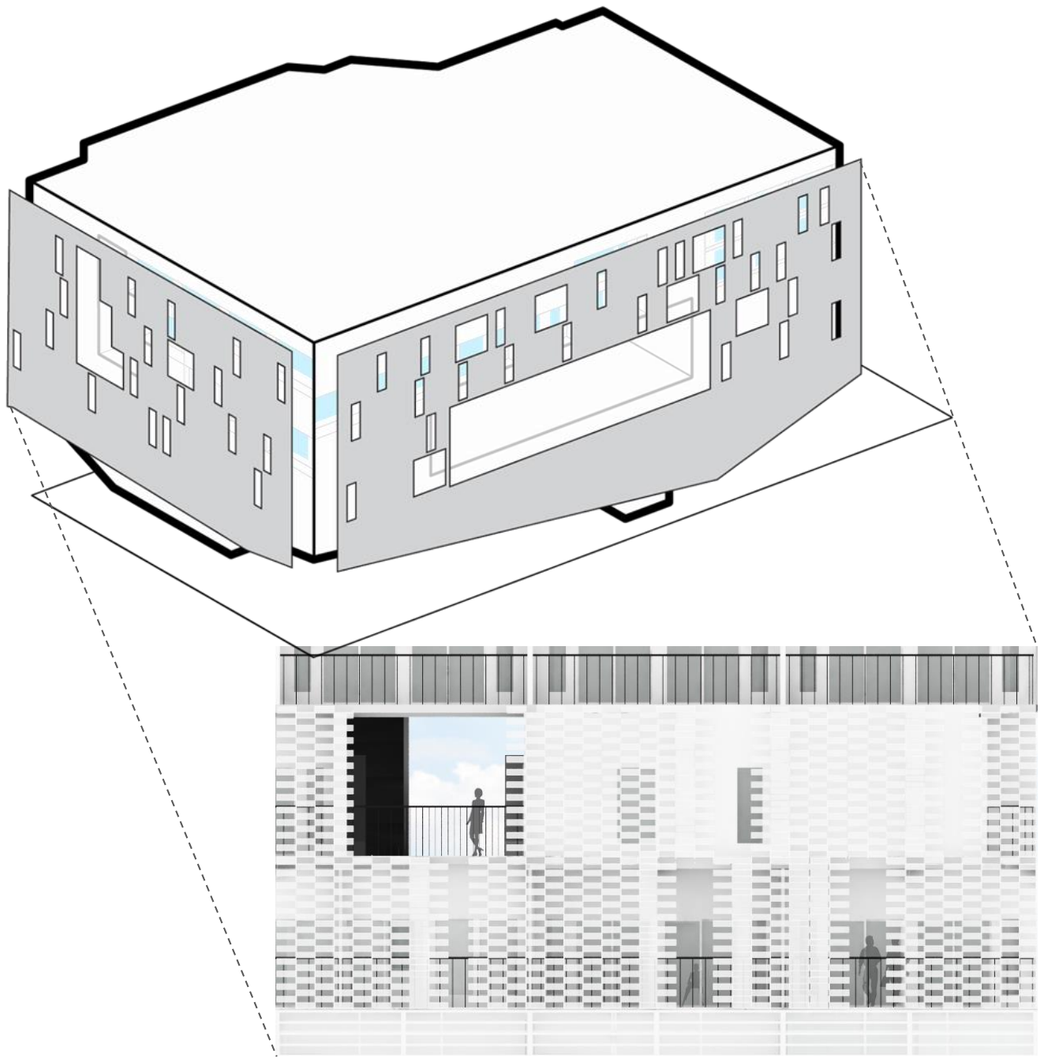
Outdoor TO Indoor

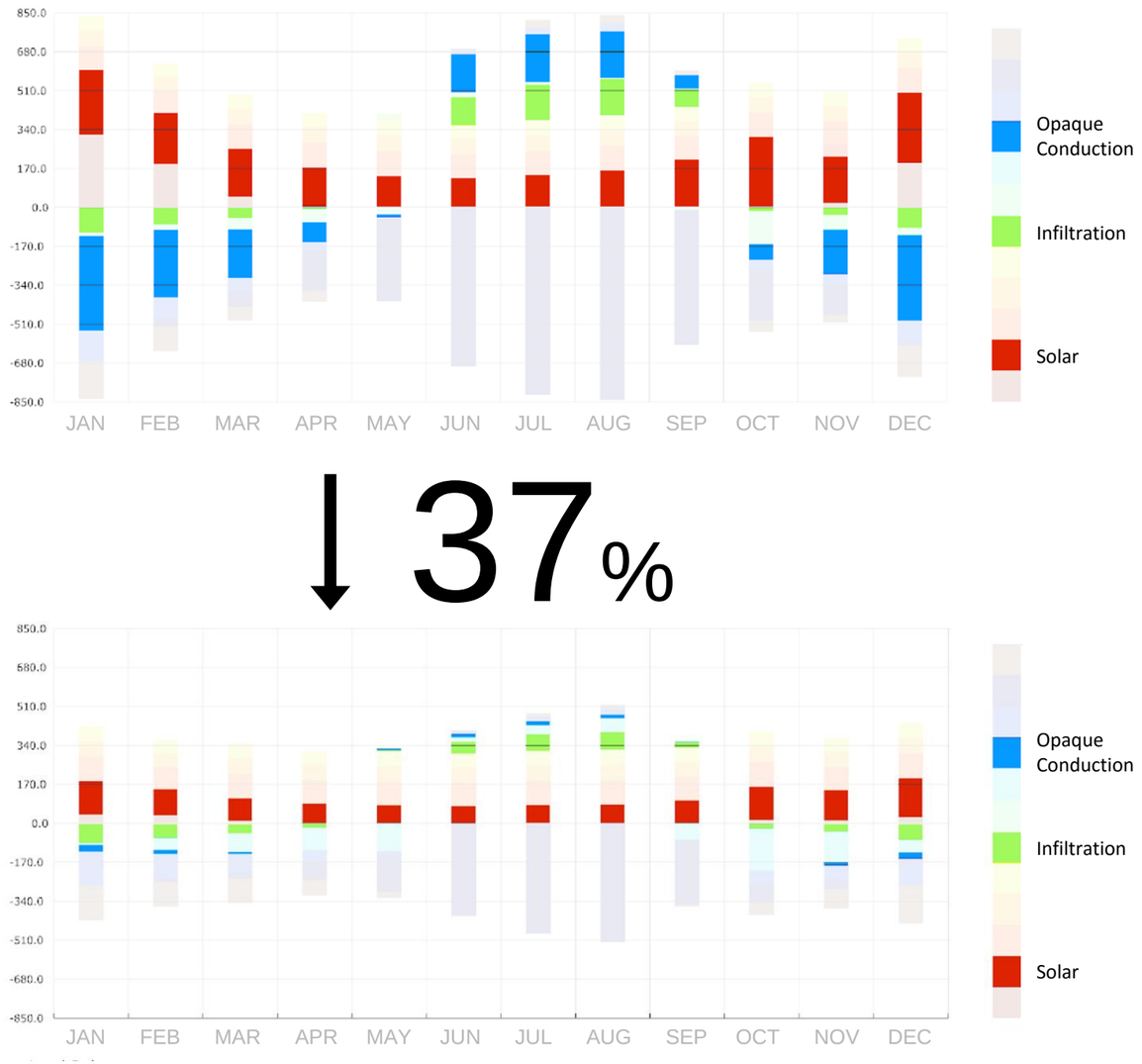
Pushing warm area away from comfort area



NEW SCREEN

Shading & Opaque Material Adjustment





37%

INDOOR ADAPTIVE COMFORT

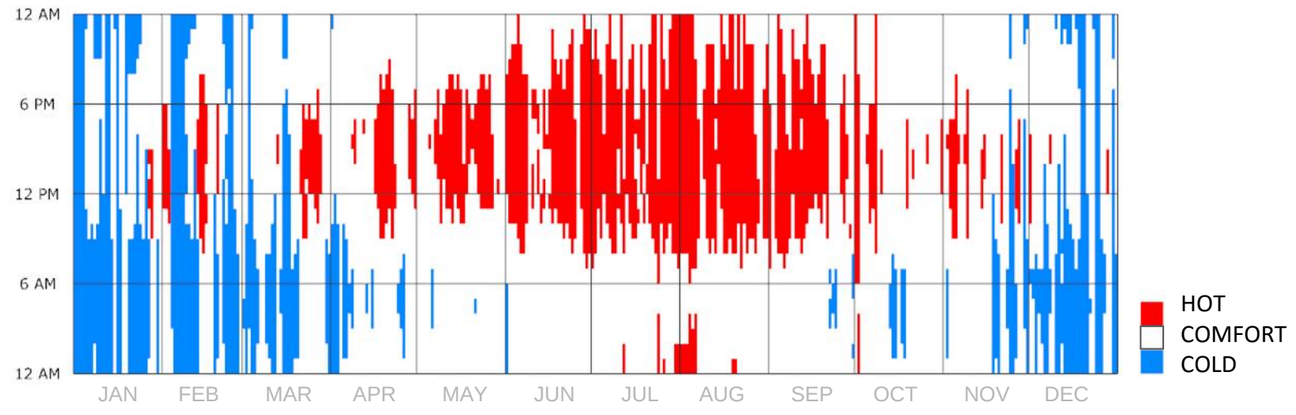
Material & Screen Adjustment

BEFORE

Adaptive Comfort

64%

Of Annual hours

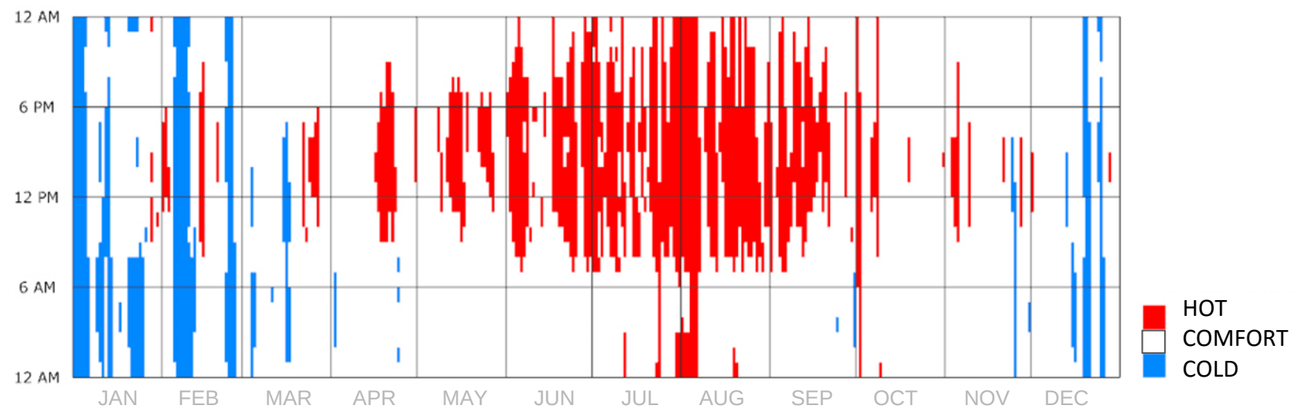


AFTER

Adaptive Comfort

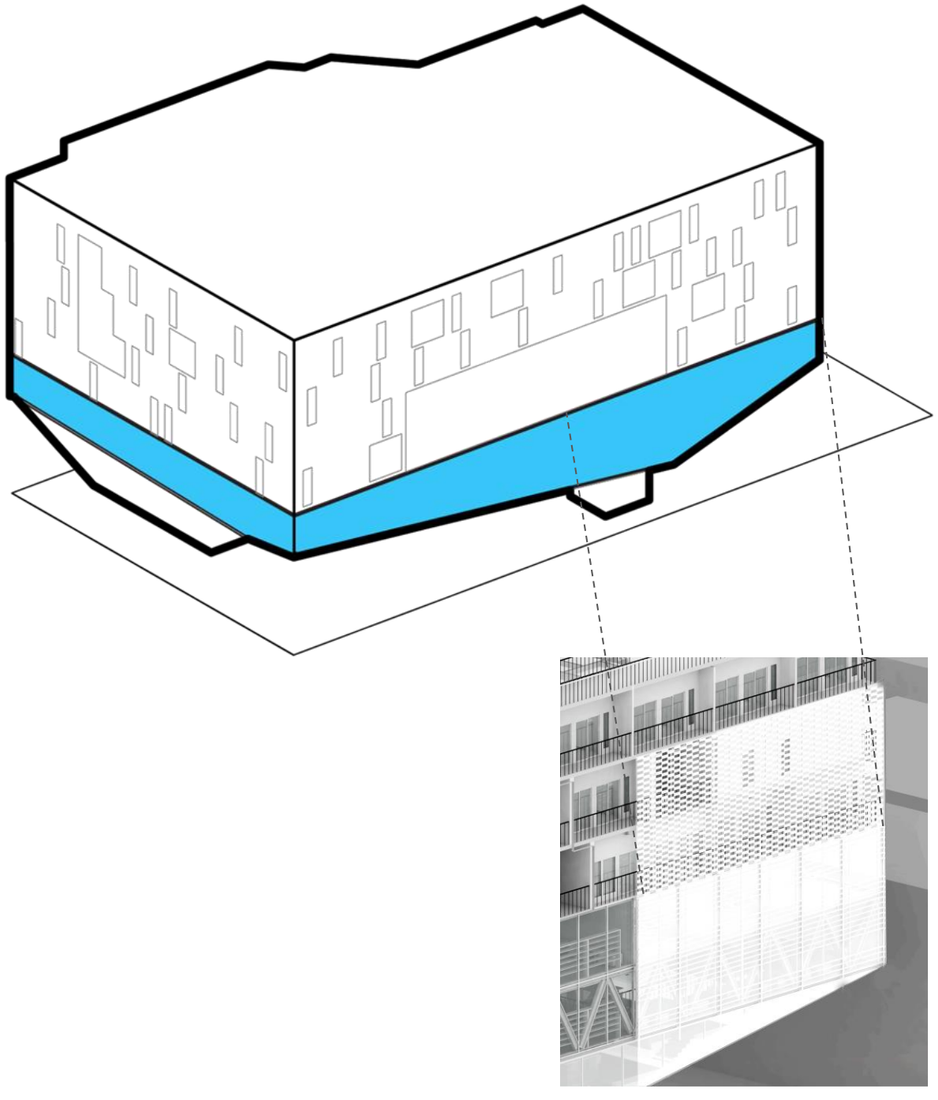
75%

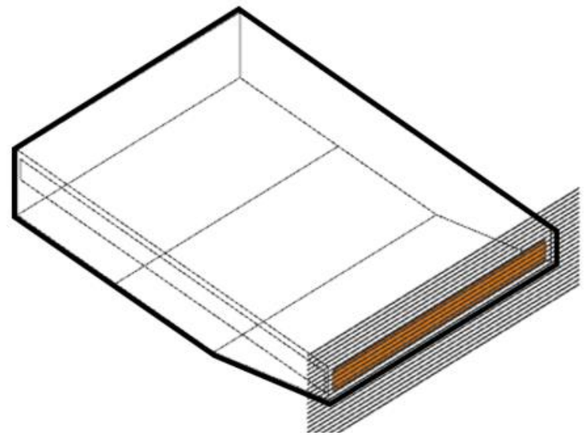
Of Annual hours



EVAPORATIVE COOLING

Outer Surface Cooling

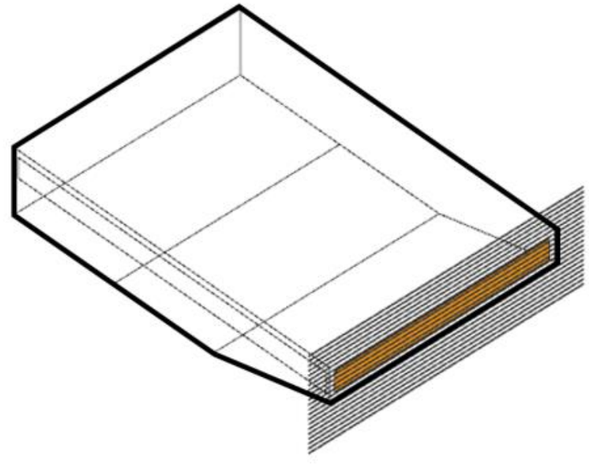




Base case

34.6 °C (94 °F)

Outer Surface Temperature



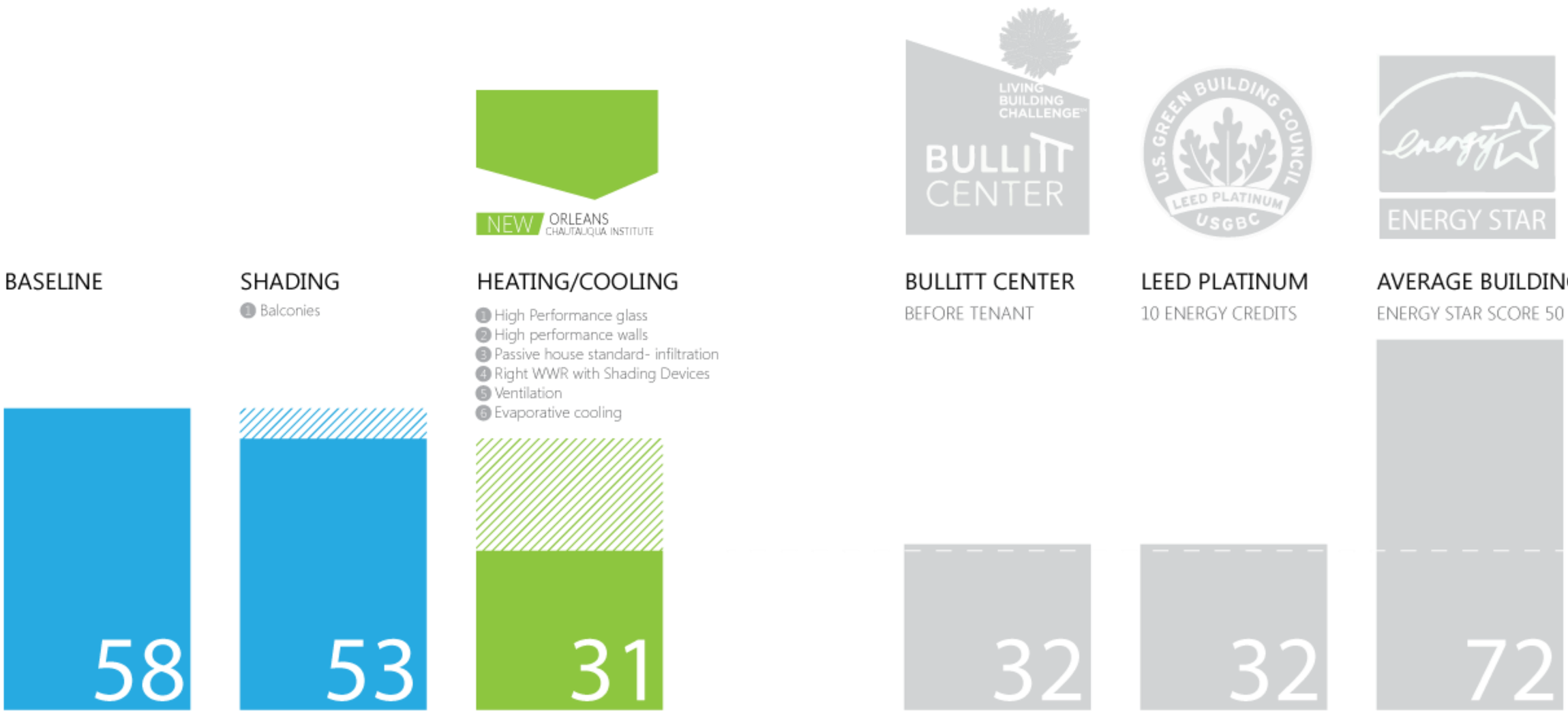
Evaporative Cooling

31.9 °C (89 °F)

Outer Surface Temperature

ENERGY USAGE INTENSITY

EUI Comparison

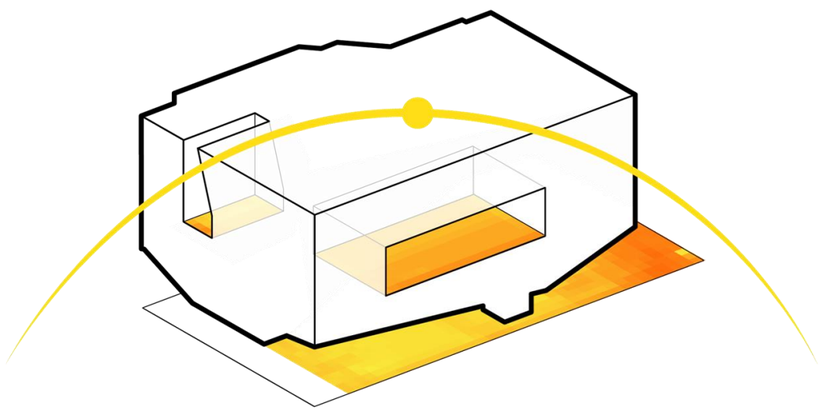


ENVIRONMENTAL APPROACHES

Summary

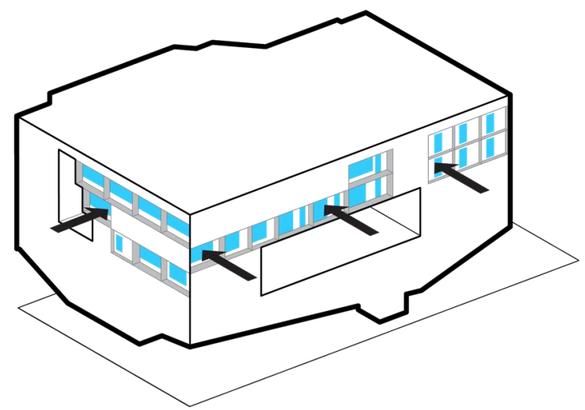
1

OUTDOOR SELF-SHADING



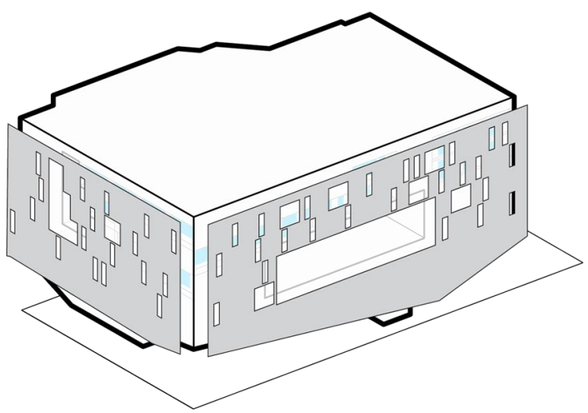
2

INDOOR BALCONIES



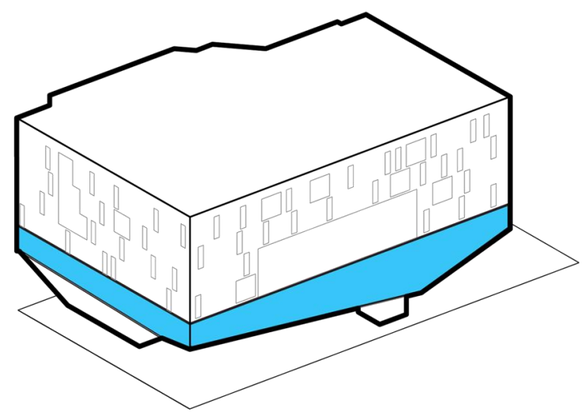
3

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

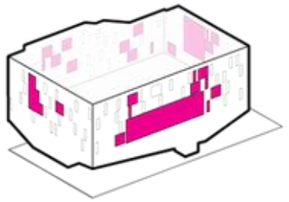
// Outdoor Space

Music + City views + Roof

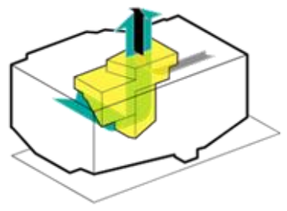
// Details

Shading + Evaporative Cooling + Green

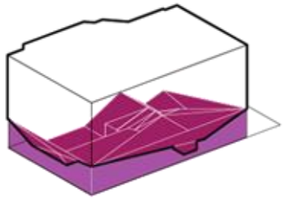
ARCHITECTURAL FEATURES



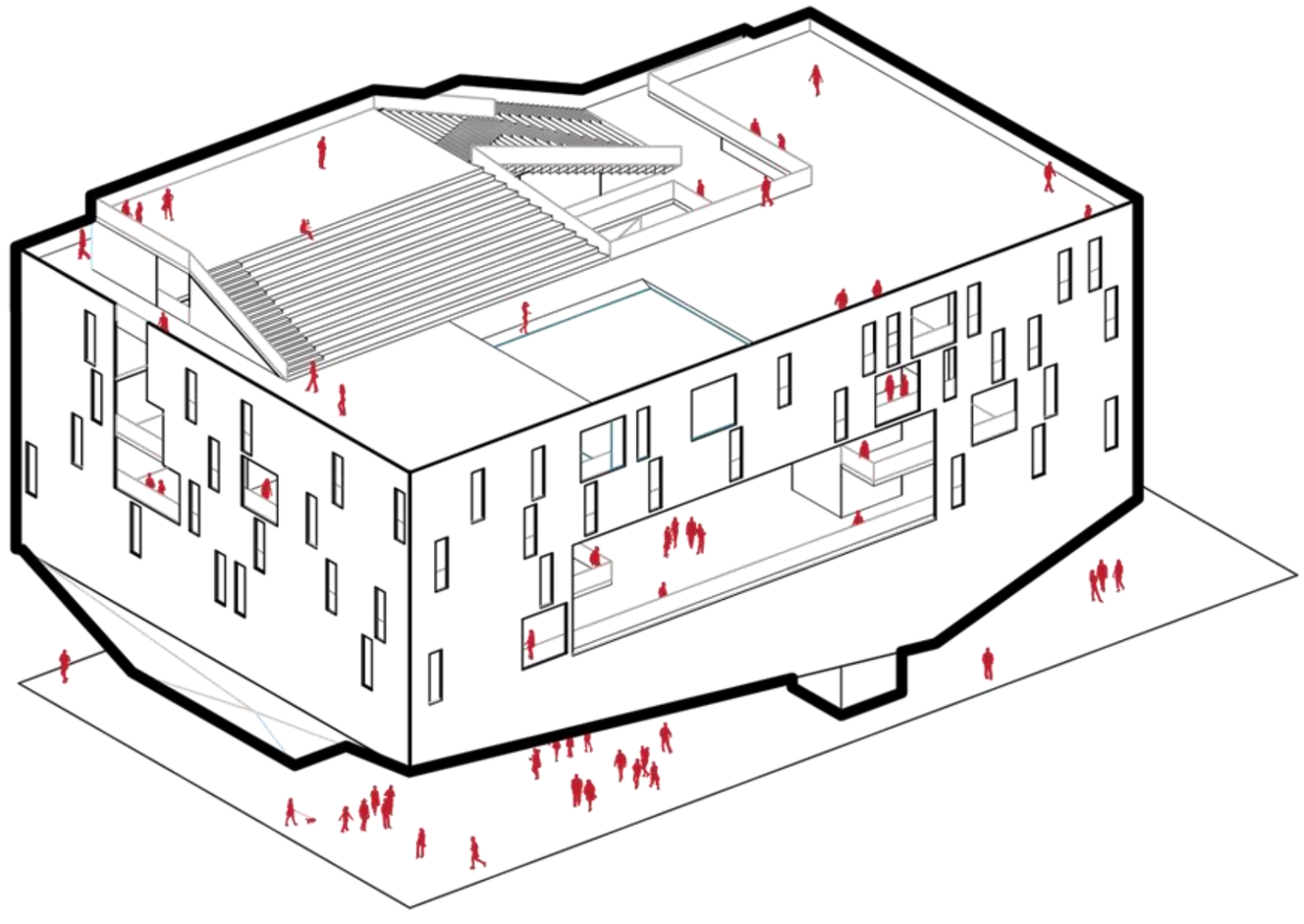
PUBLIC OPENINGS

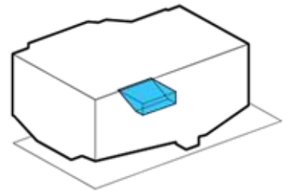


CENTRAL ATRIUM

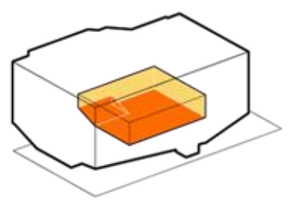


FESTIVAL STAGE

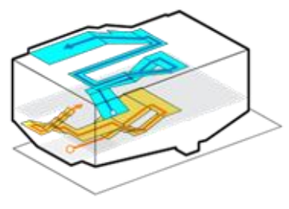




SWIMMING POOL



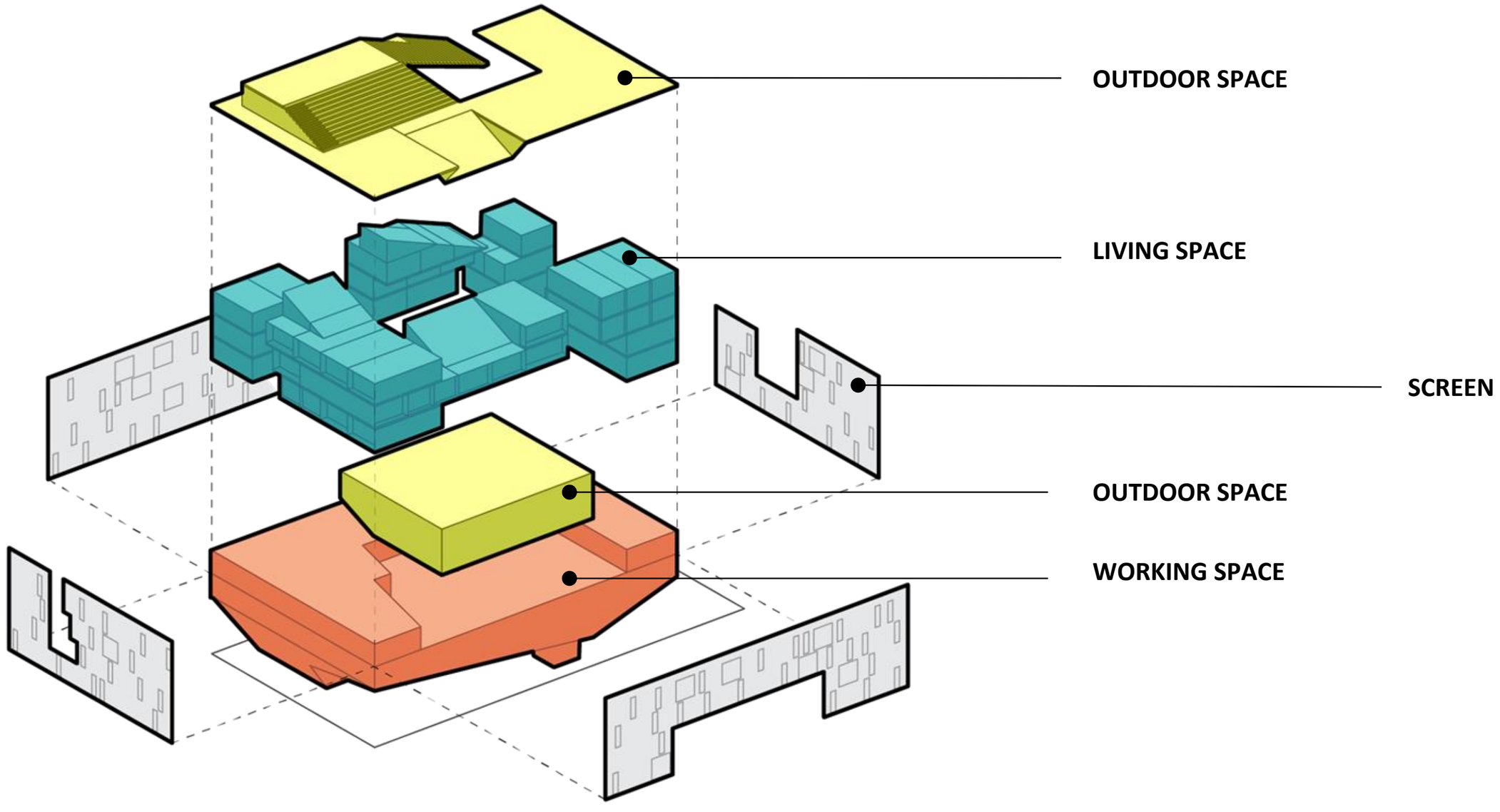
CITY BALCONY



IRRESISTIBLE STAIRS

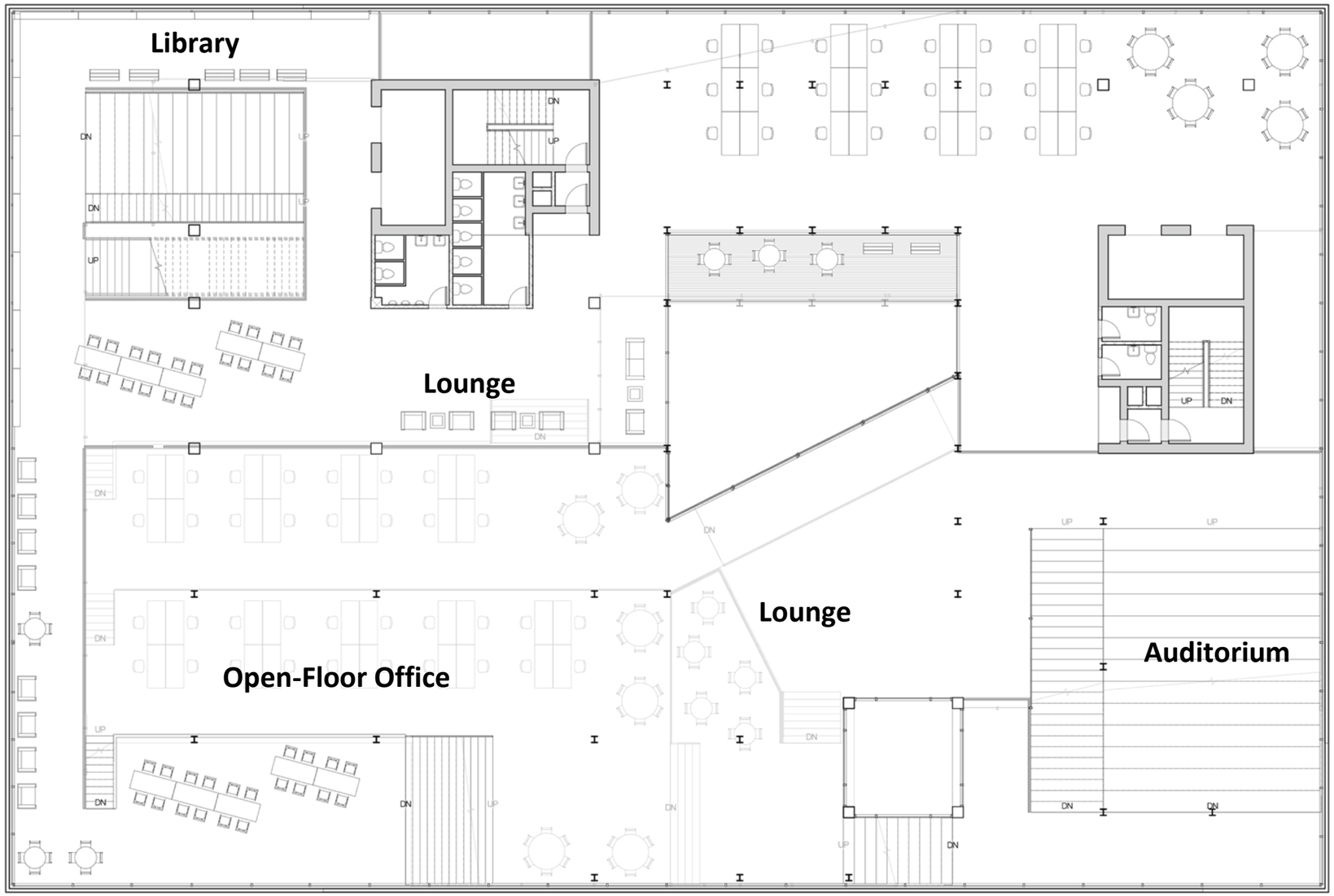
ARCH_PERFORMANCE

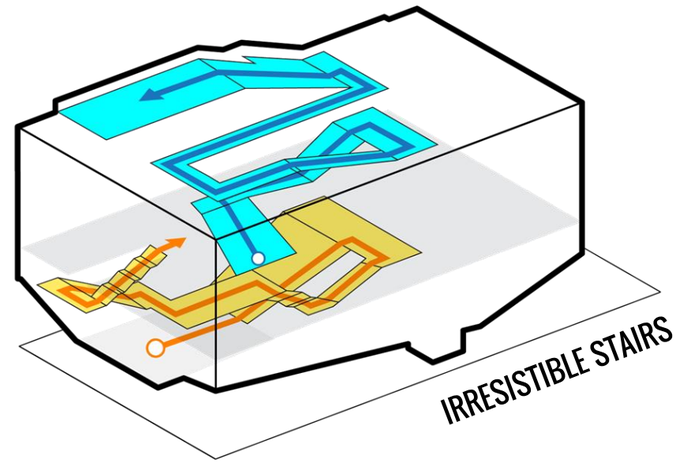
Architectural Challenges



WORKING SPACE

Open-Floor Office



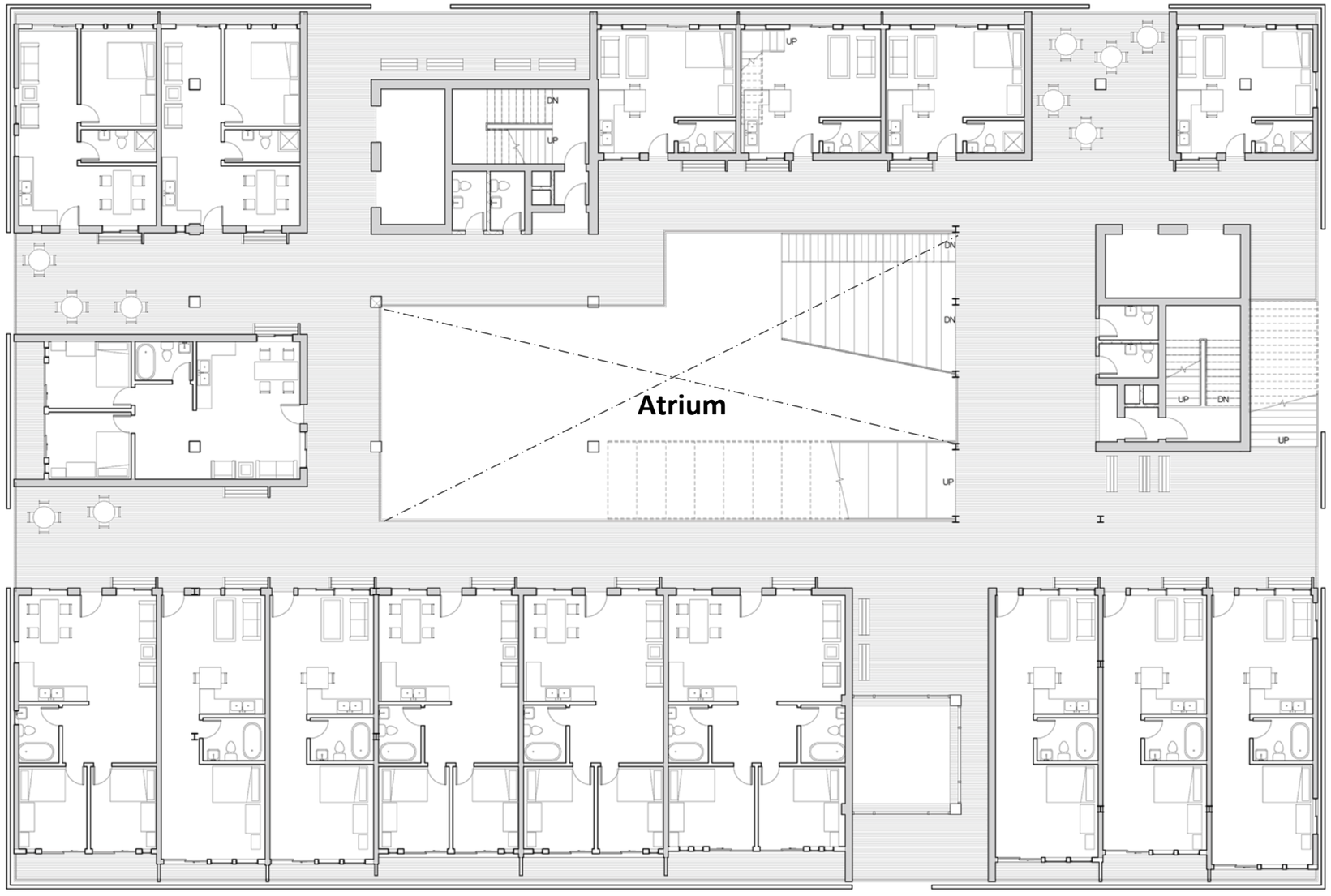


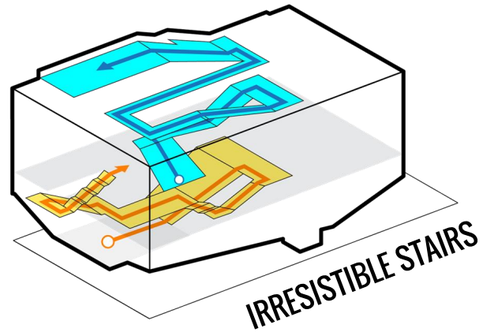
WORKING SPACE

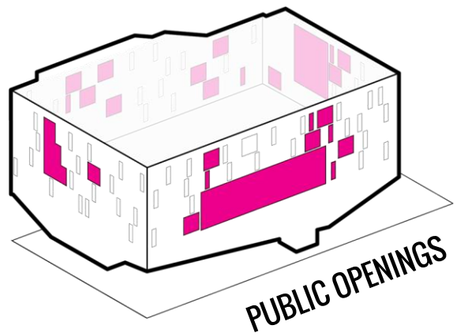
Open-Floor Office

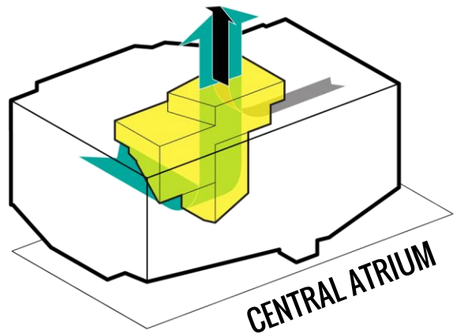
LIVING SPACE

Atrium







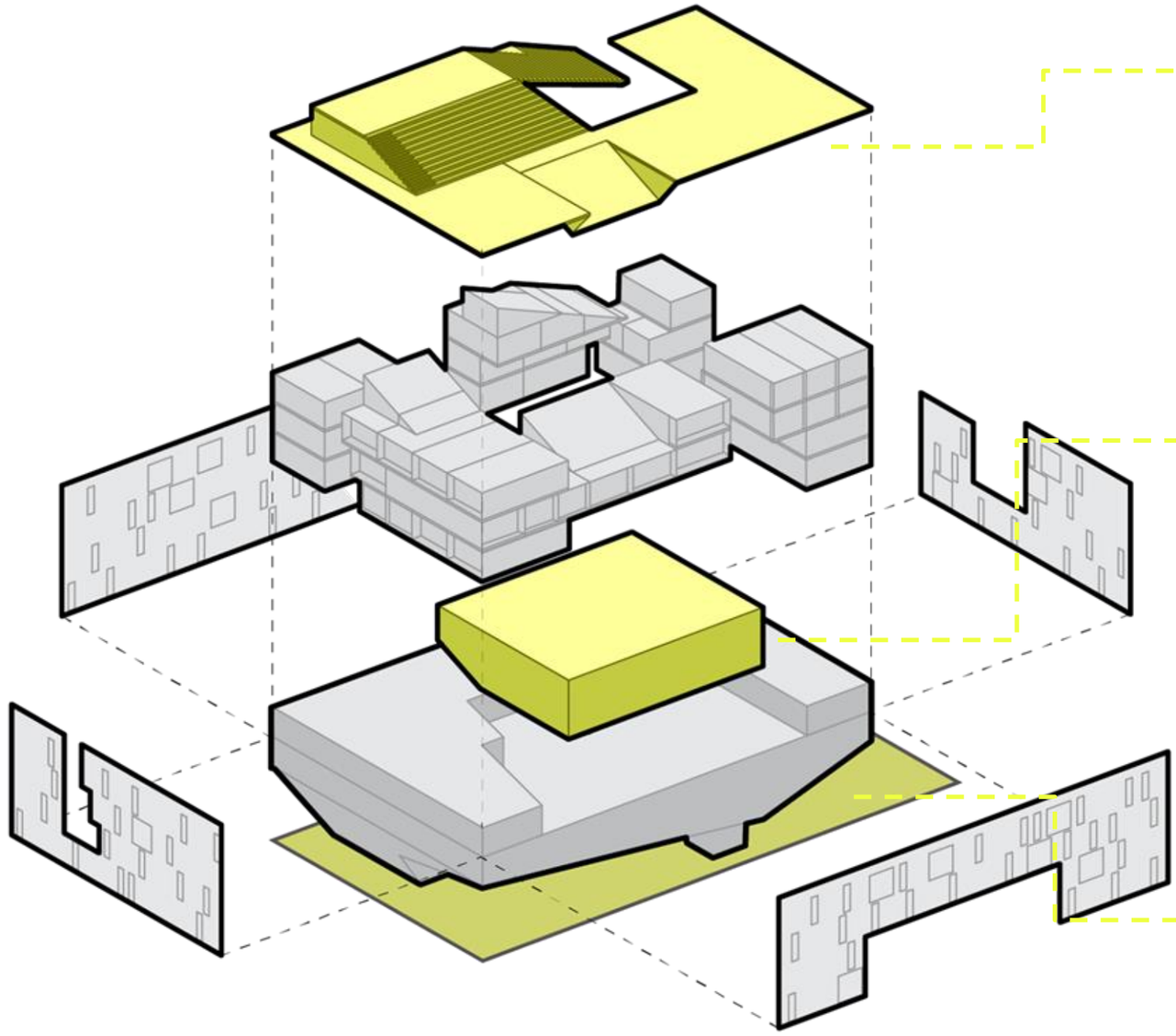


LIVING SPACE

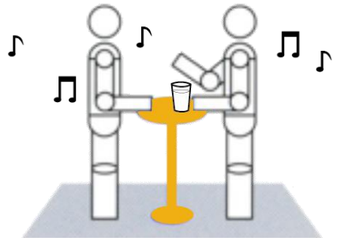
Atrium

OUTDOOR SPACE

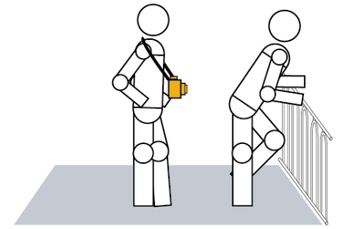
Music Performance



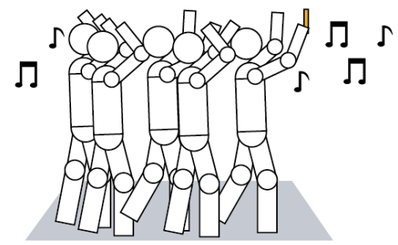
BAR ON THE ROOF



LOOK OUT
THE FRENCH QUARTER



OUTDOOR SPACE
FOR FESTIVALS

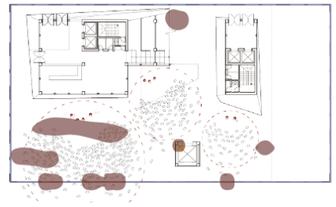


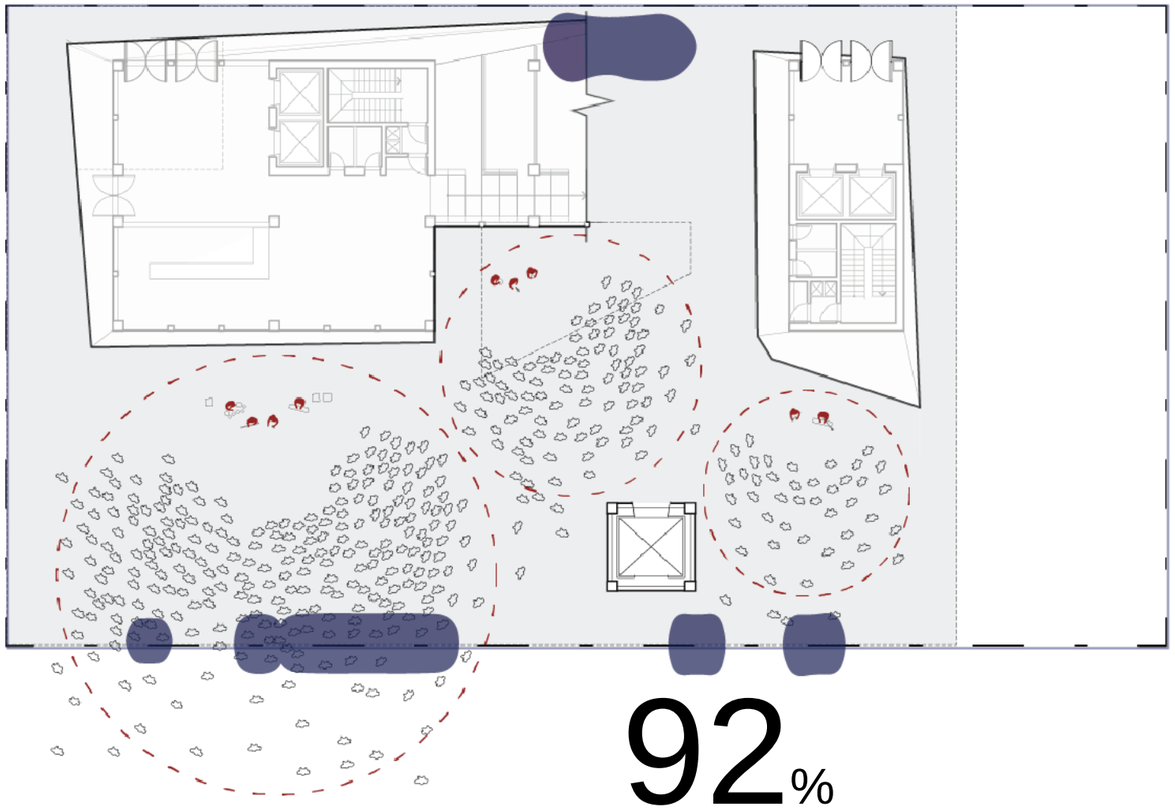
OUTDOOR SPACE

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%.

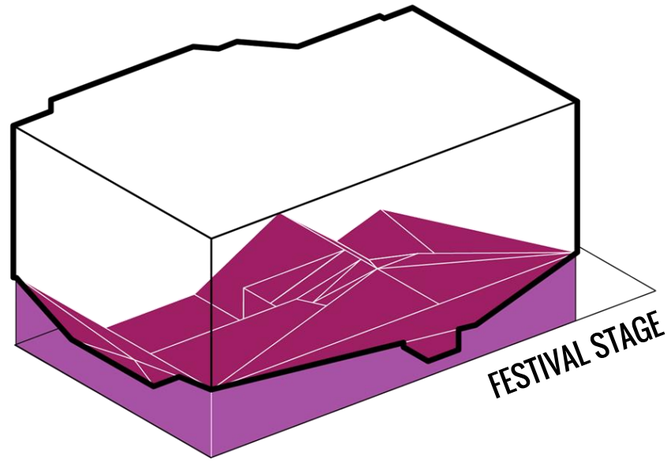
85%

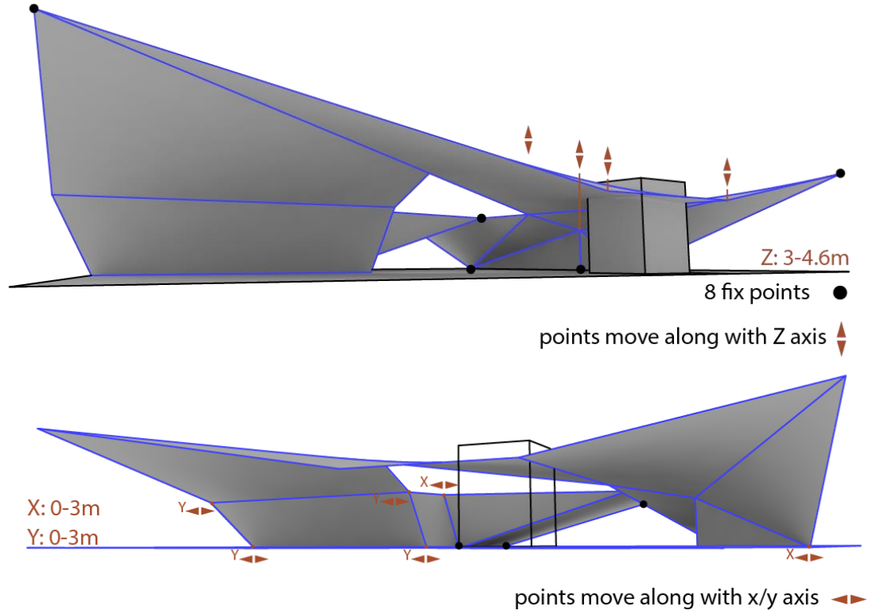


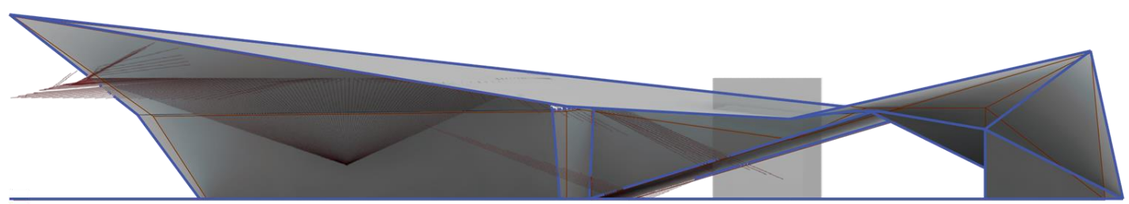


92%

Area have good acoustic performance





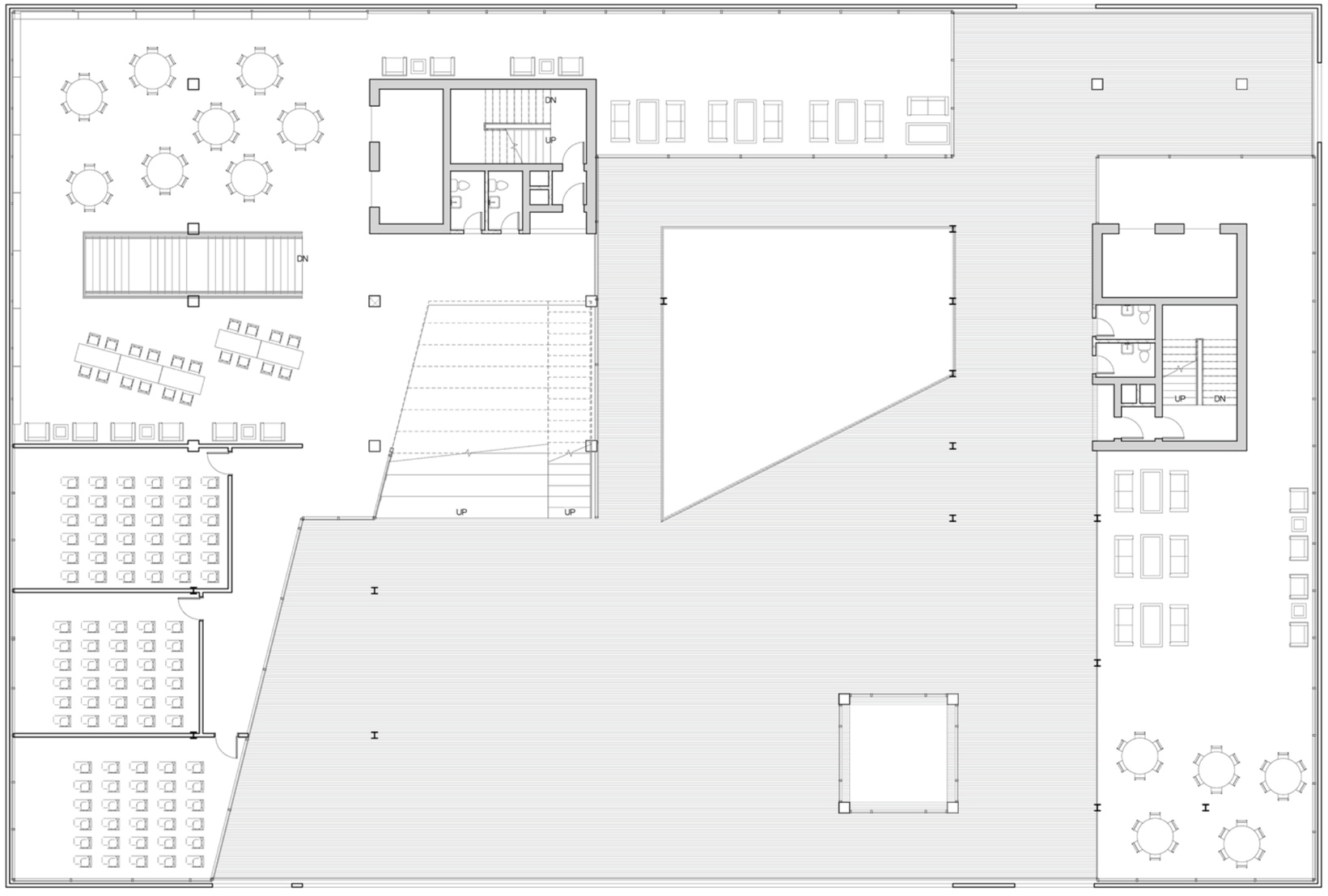


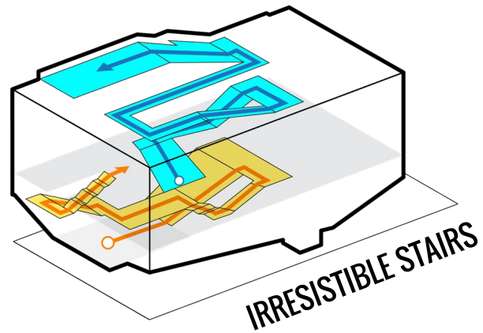
OUTDOOR SPACE

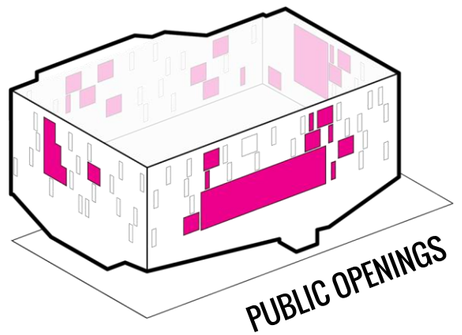
Music Performance

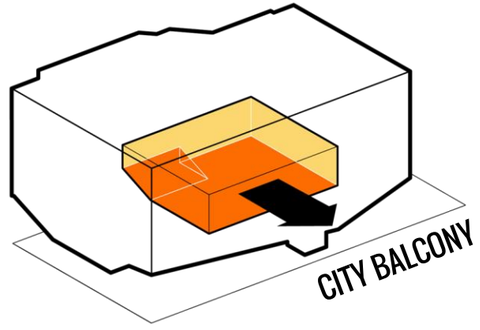
OUTDOOR SPACE

City Balcony







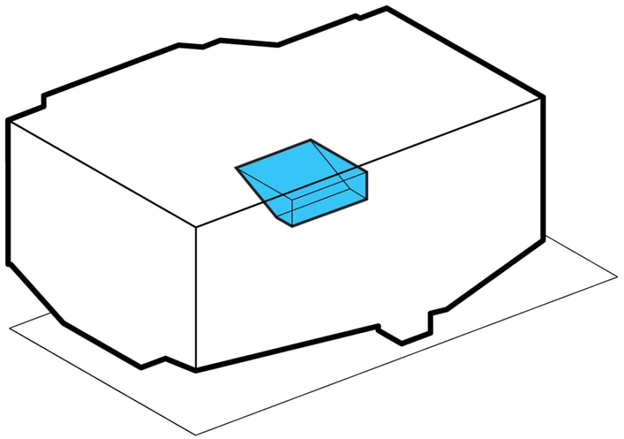


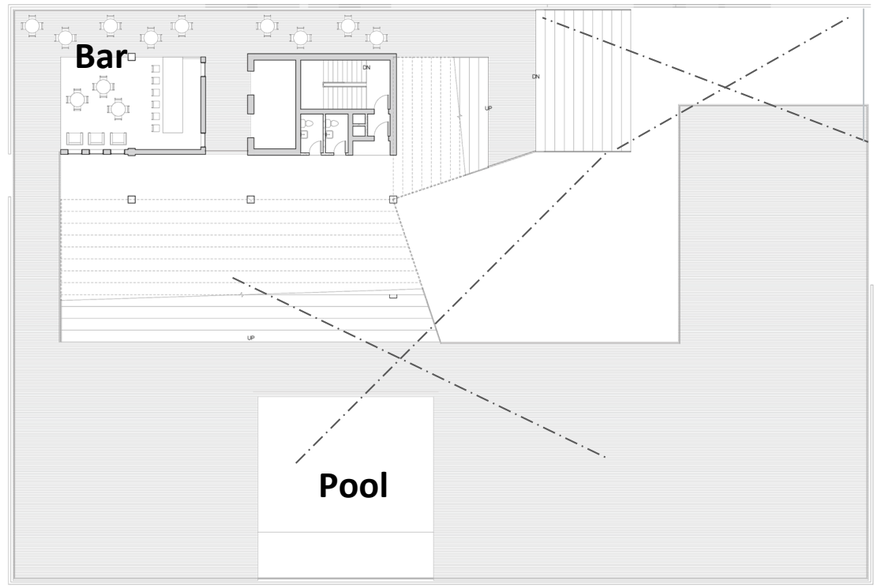
OUTDOOR SPACE

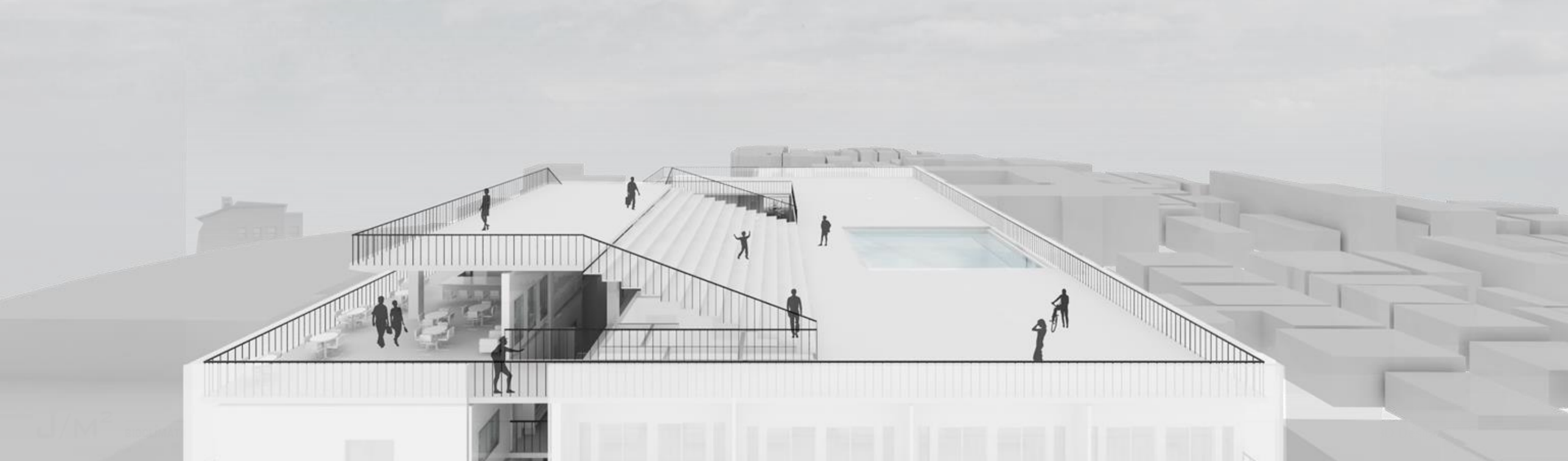
City Balcony

OUTDOOR SPACE

Roof

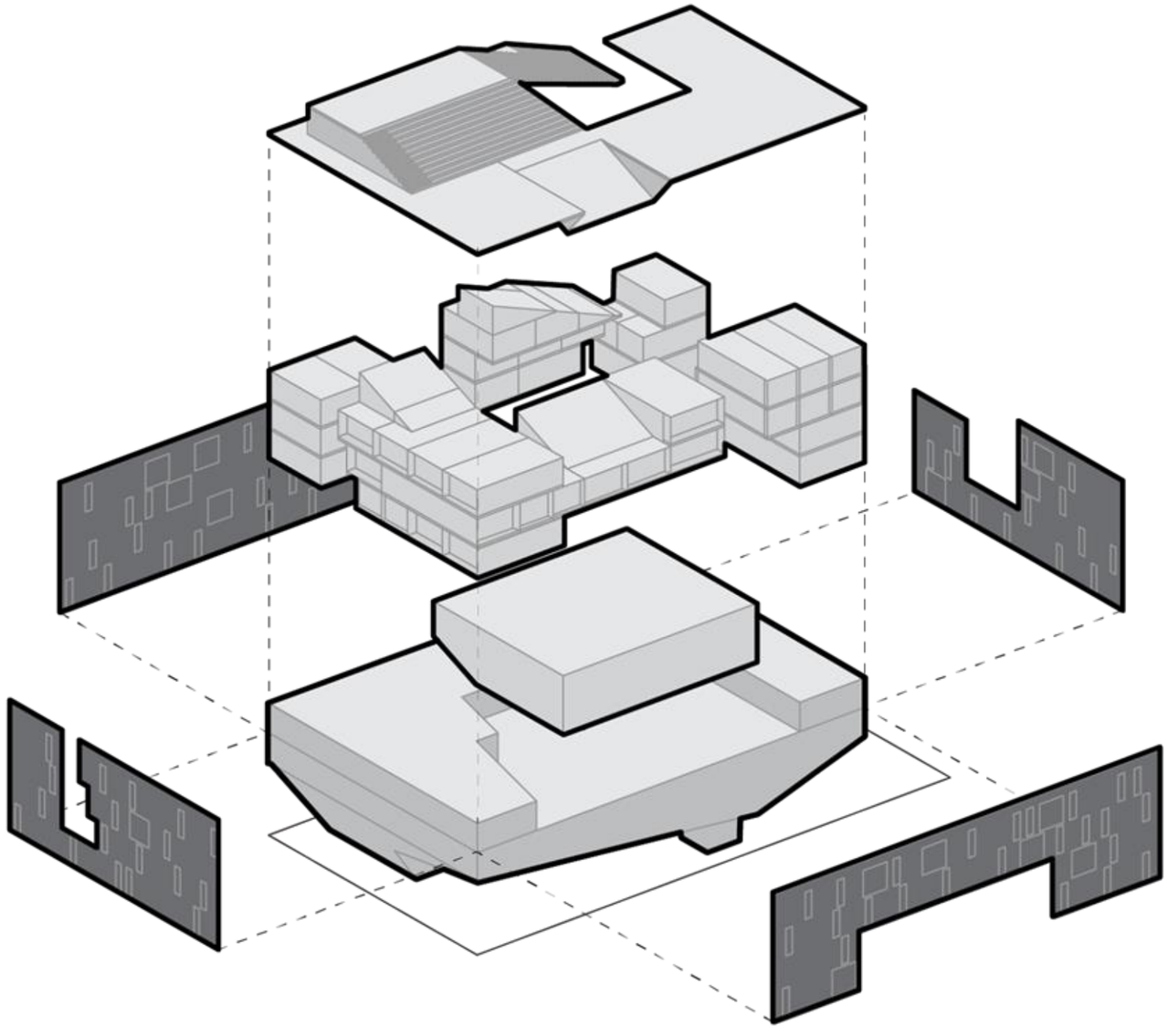




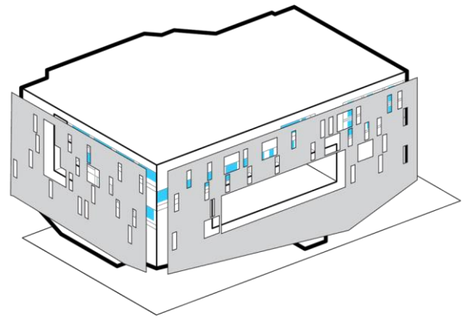


ARCH_PERFORMANCE

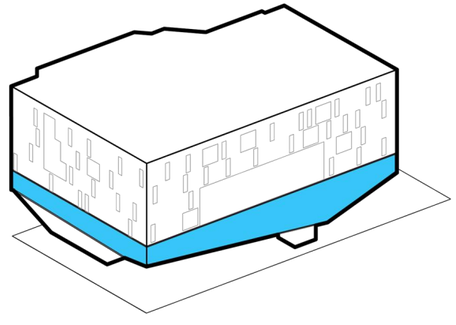
Architectural Challenges_Screen



BALCONIES
WITH SCREEN

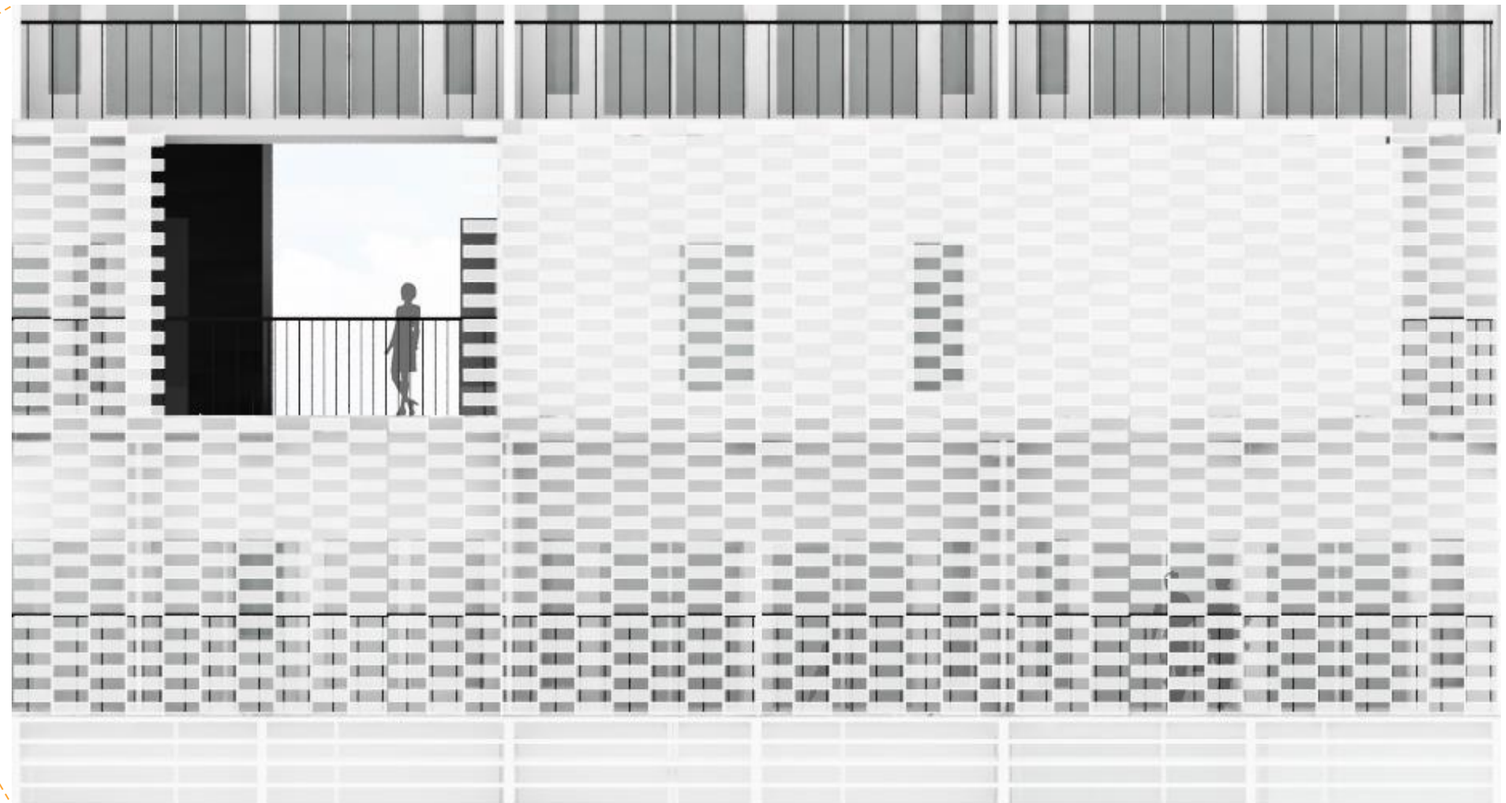


EXTERIOR
EVAPORATIVE COOLING



SCREEN

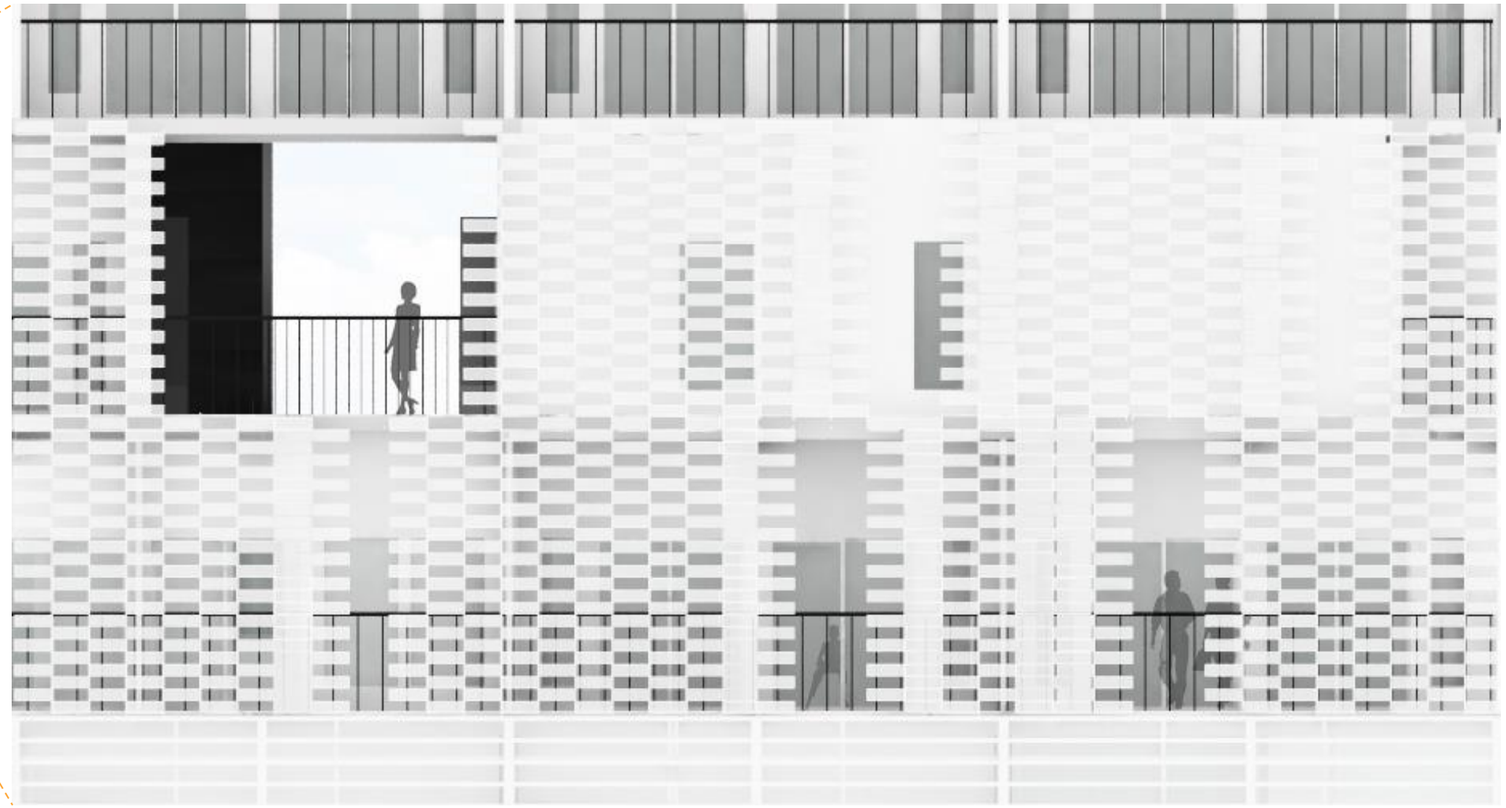
South-East Elevation



Living Space**; Sliding Shading**
Working Space**; Evaporative Cooling**

SCREEN

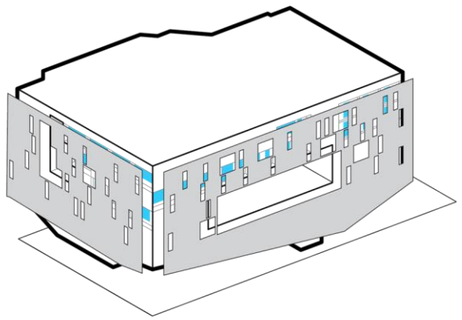
South-East Elevation

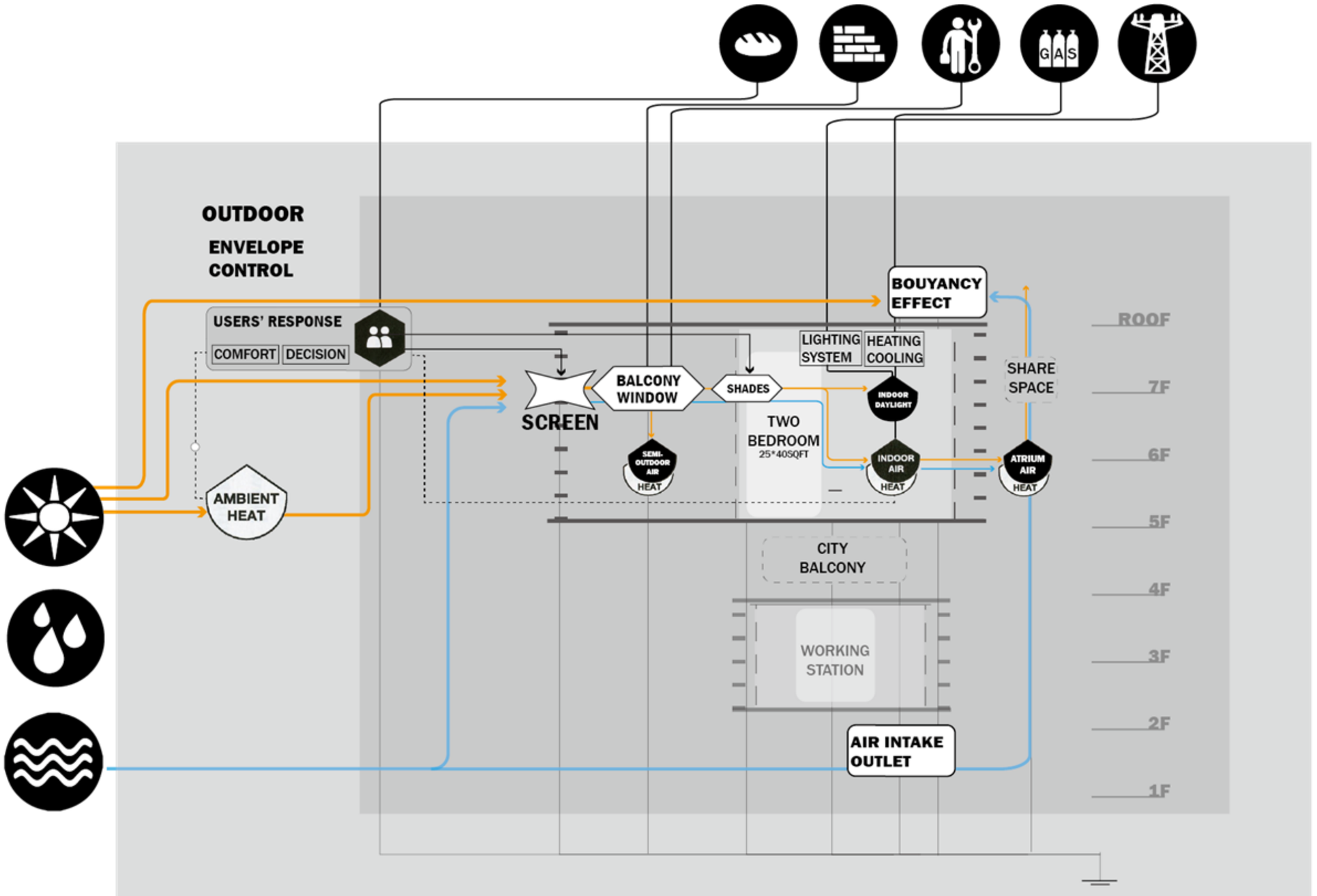


Living Space**; Sliding Shading**
Working Space**; Evaporative Cooling**

SCREEN

Emergy Diagram

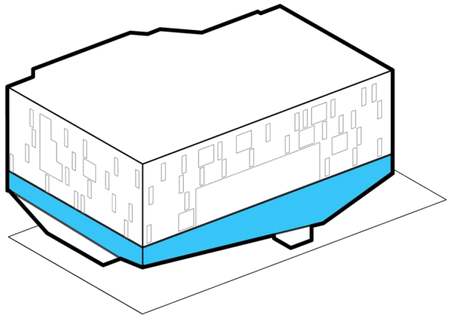


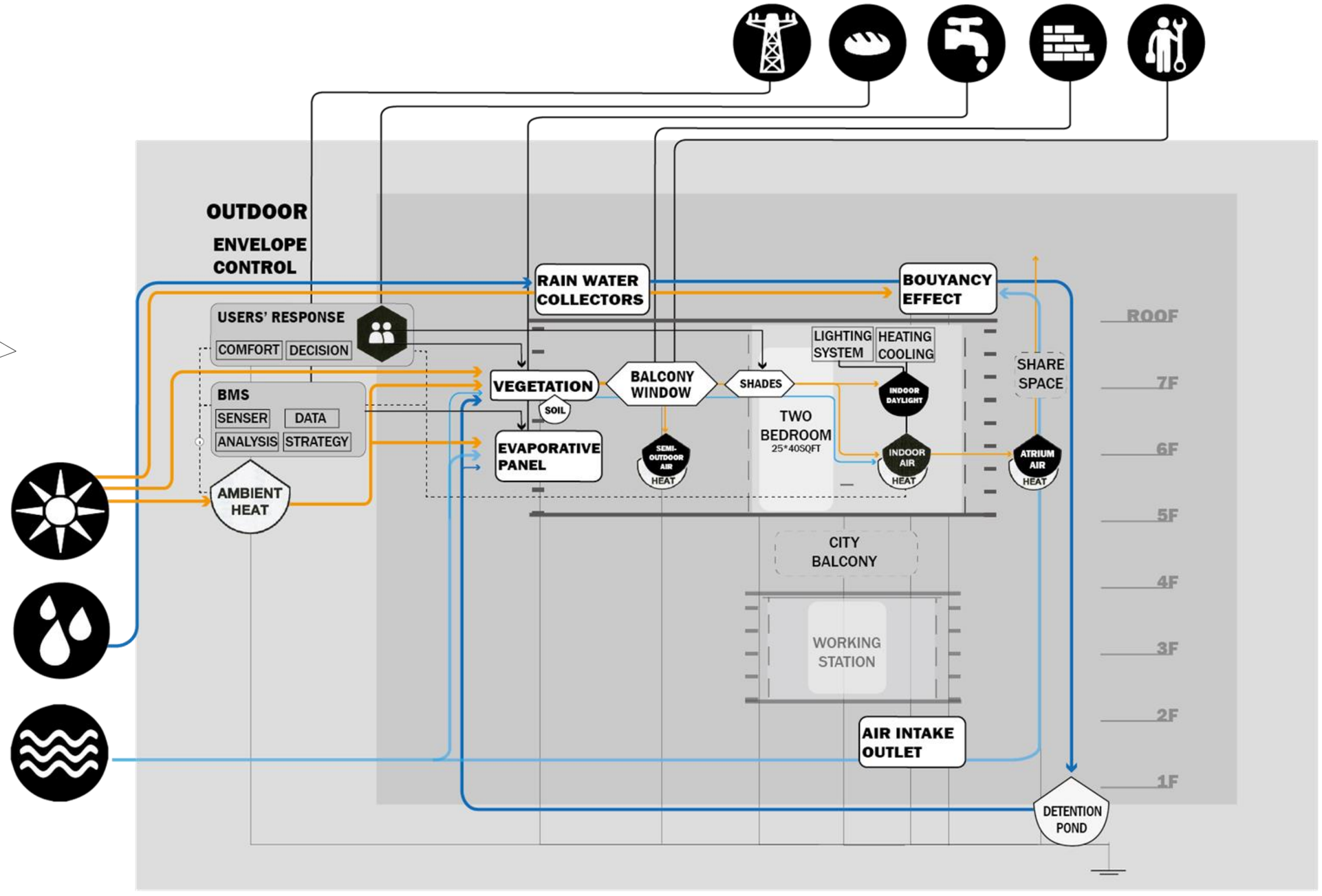


SCREEN

Exterior Evaporative cooling

Emergy Diagram





THANK YOU

J/M^2

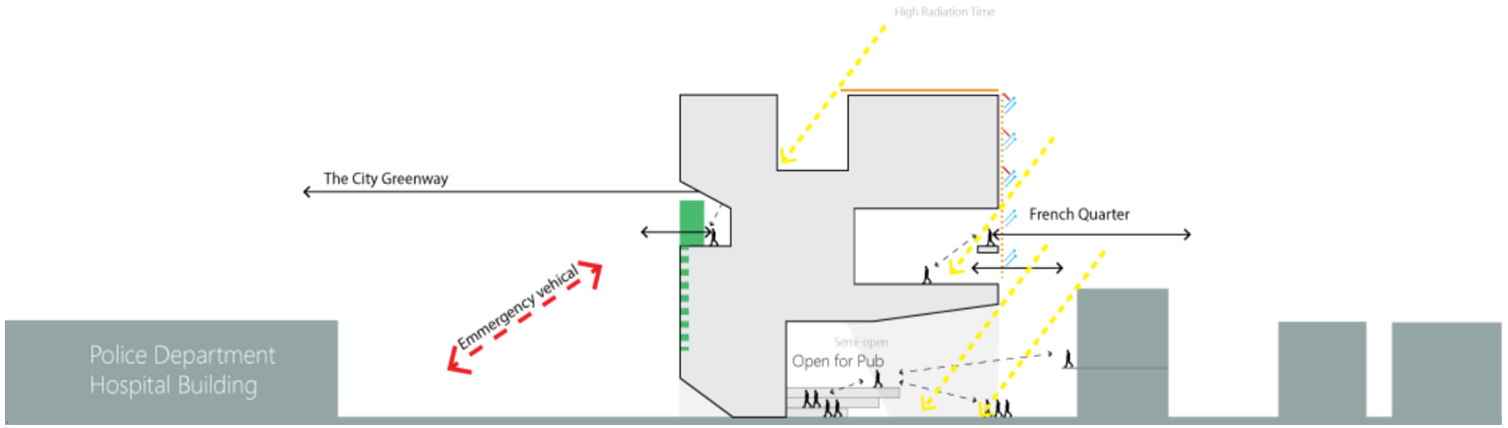
APPENDIX

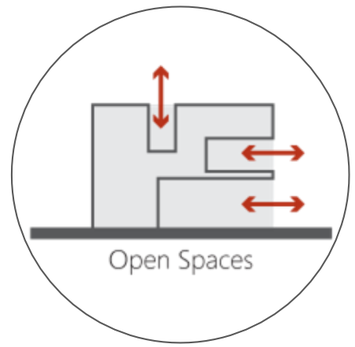
1 SITE & CLIMATE

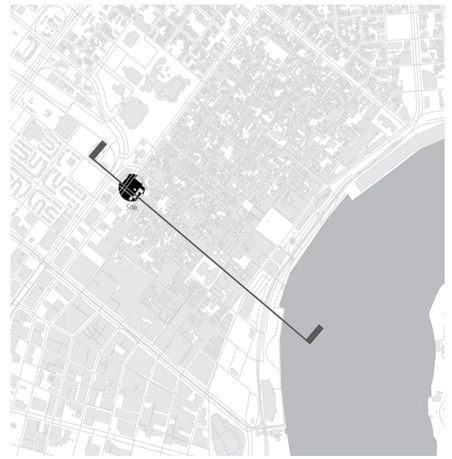
Natural Boundary & Resources

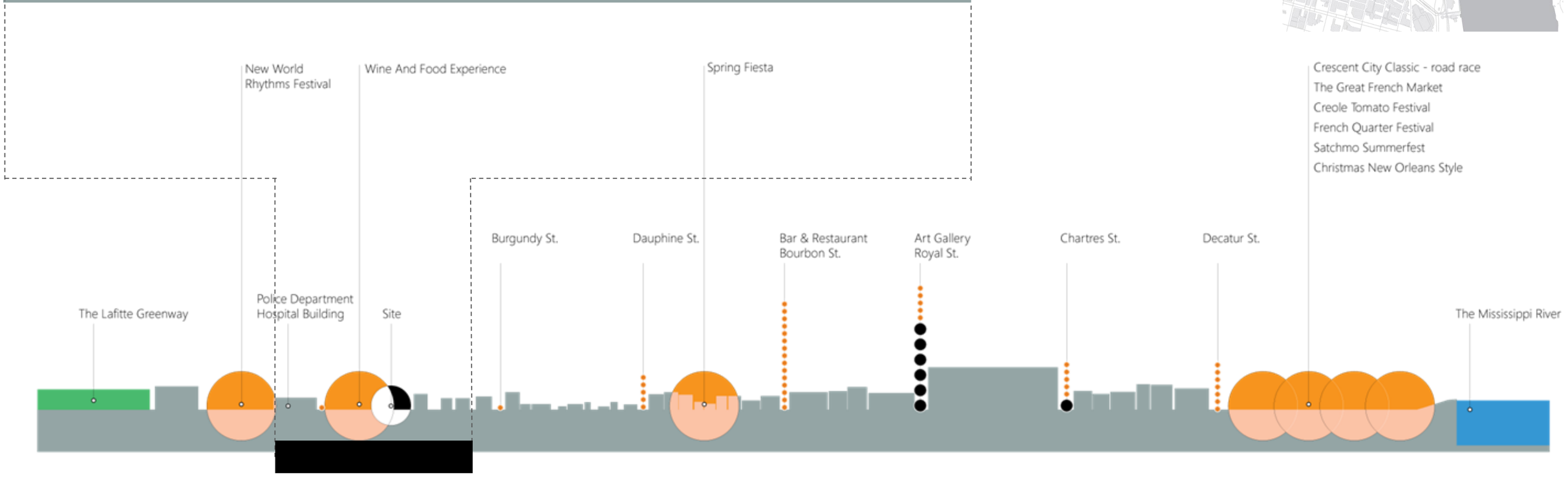
NEIGHBORHOOD

Site Respondence



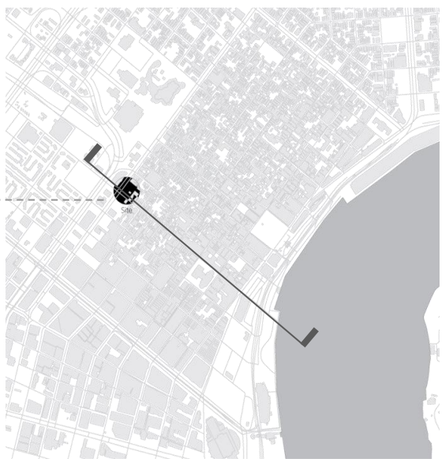


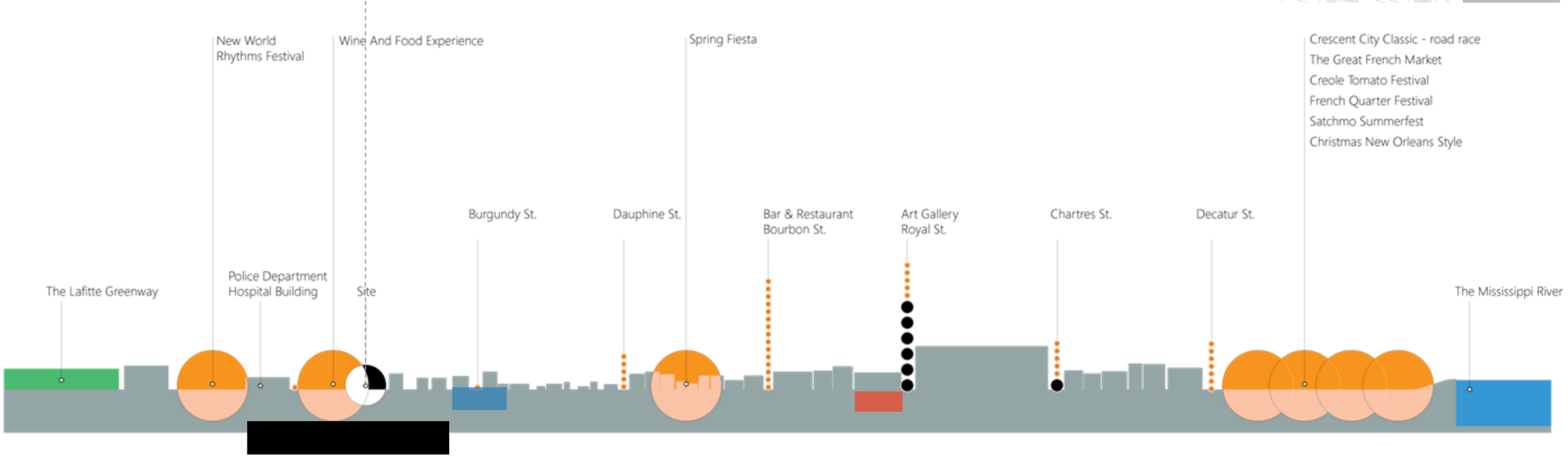




NEIGHBORHOOD

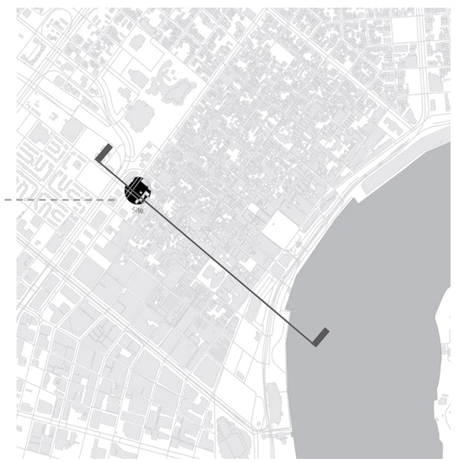
Surrounding Programs

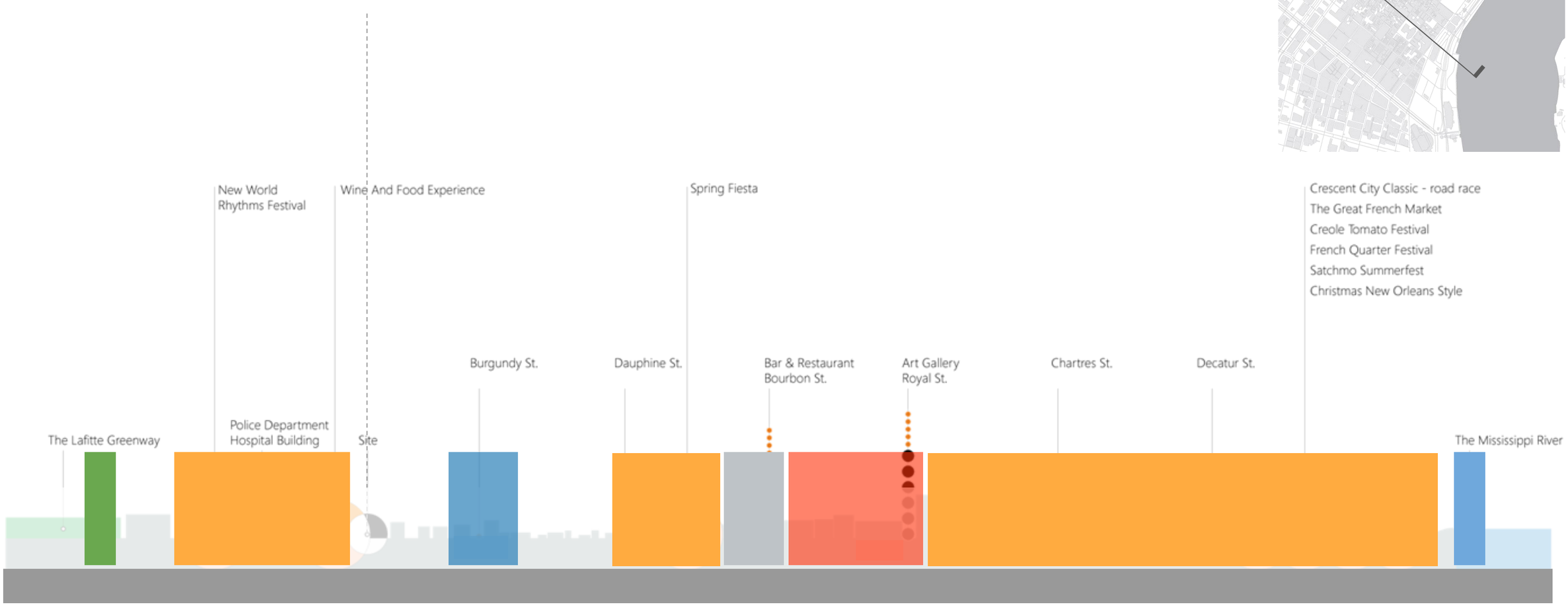




NEIGHBORHOOD

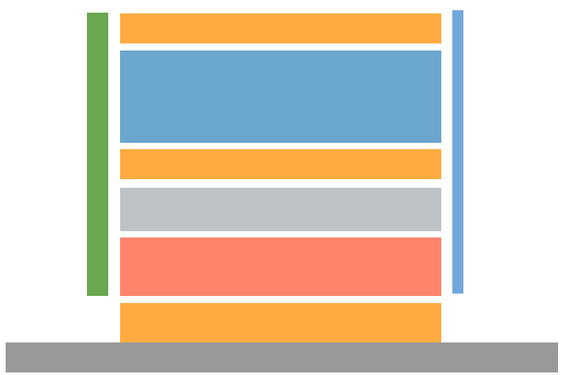
Surrounding Programs

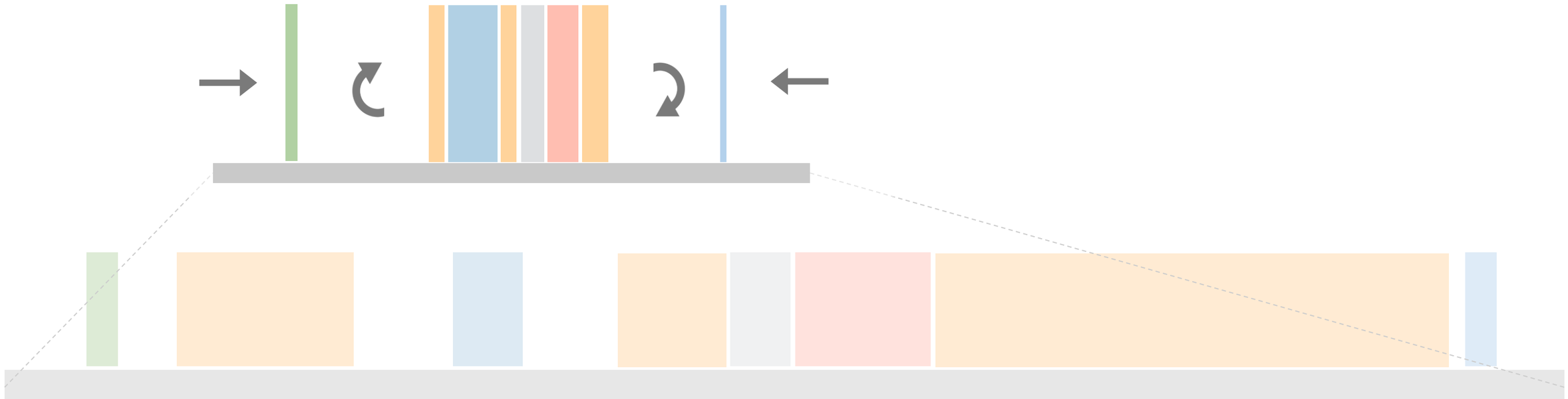




NEIGHBORHOOD

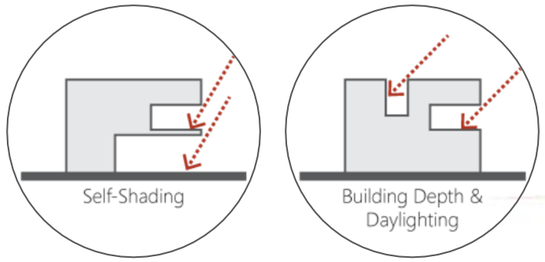
Verticalize Surrounding Programs





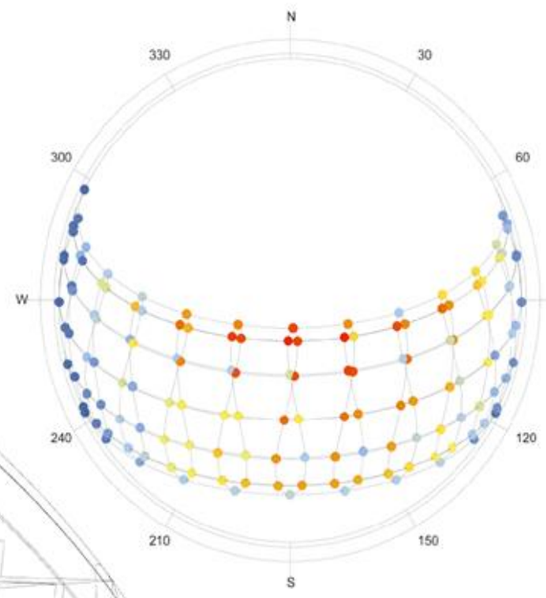
CLIMATE PARAMETERS

Sun Position & Radiation



Latitude 29.9500 °N

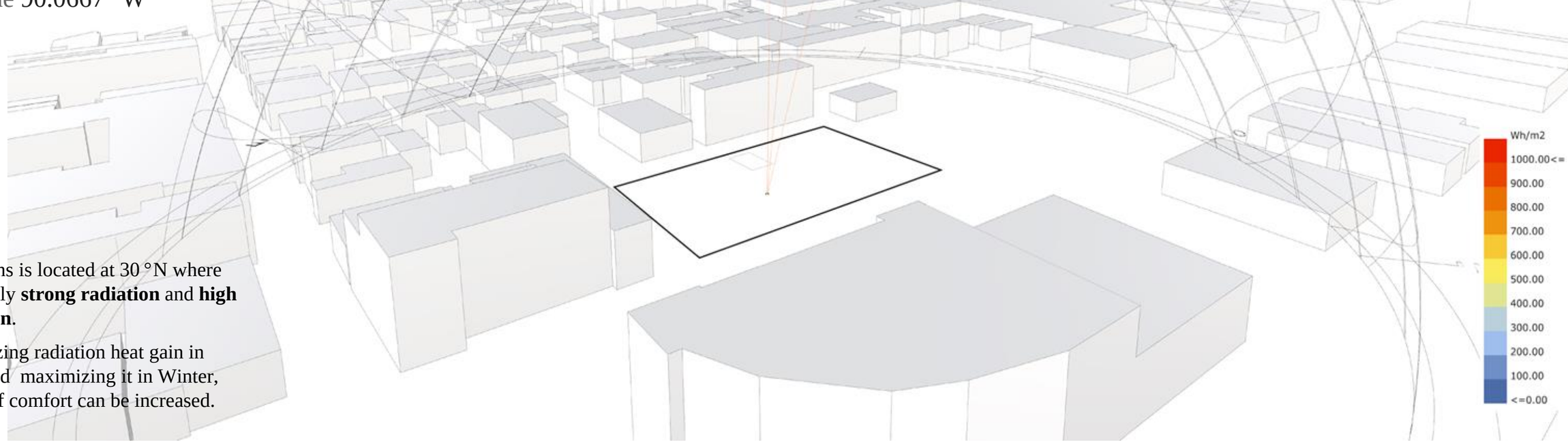
Longitude 90.0667 °W



Summer [895 Wh/m2]

Spring [549 Wh/m2]

Winter [333 Wh/m2]



New Orleans is located at 30 °N where has relatively **strong radiation** and **high sun position**.

By minimizing radiation heat gain in Summer and maximizing it in Winter, the hours of comfort can be increased.

CLIMATE PARAMETERS

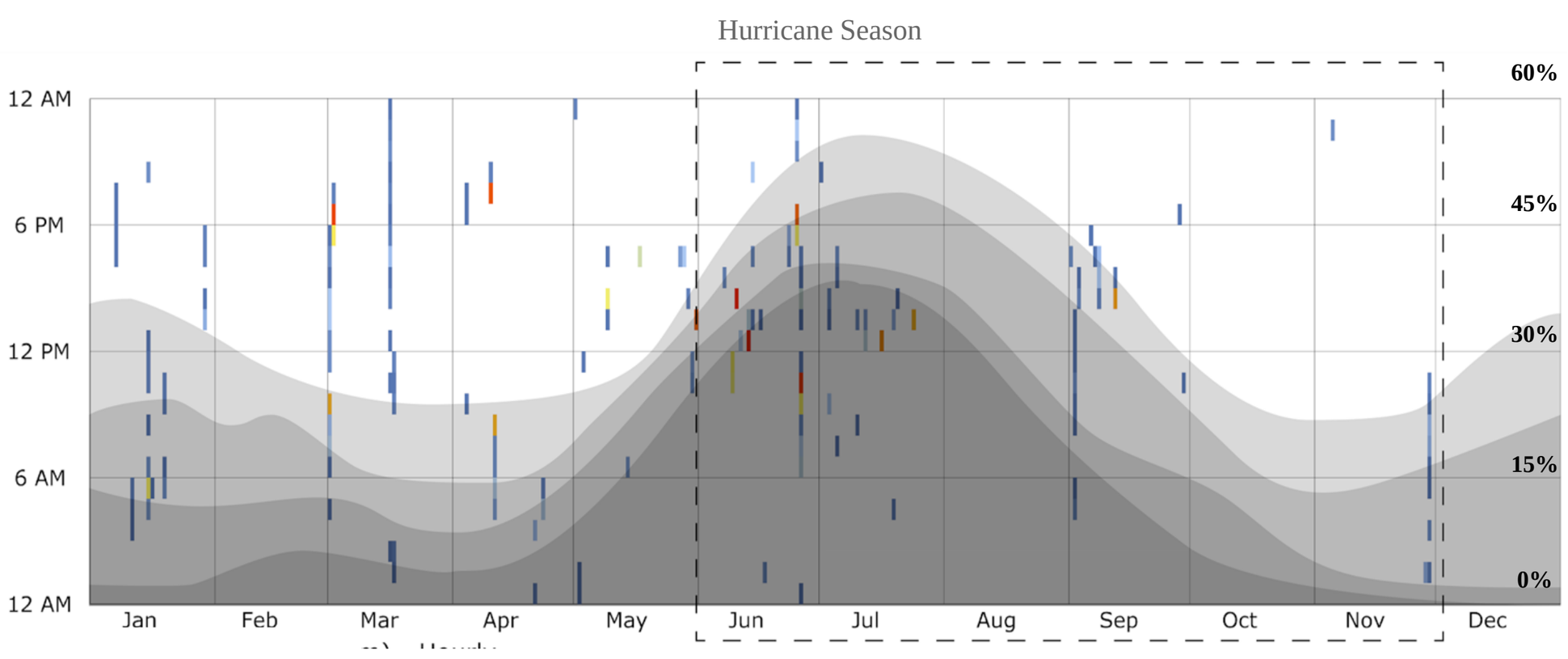
Precipitation

Chance of Precipitation

- Light Rain
- Moderate Rain
- Heavy Rain
- Thunderstorms

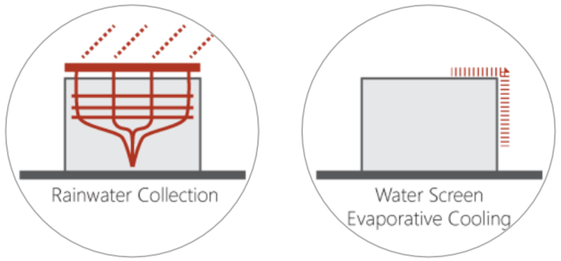
Depth of Precipitation

- 30.0 [mm]
- 25.0
- 20.0
- 15.0
- 10.0
- 5.0
- 0.0



CLIMATE PARAMETERS

Evaporative Cooling

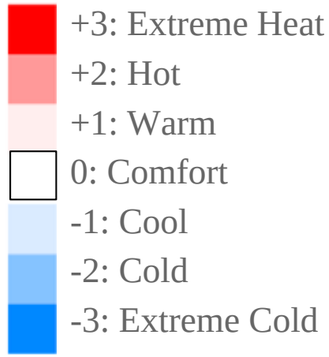


Uncomfort Months and Rain season

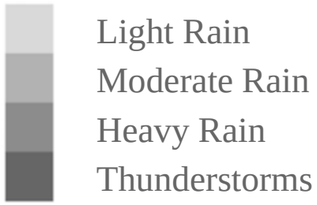
In our weather condition studies, the uncomfortable months (ex June to September) overlap with the heavy rain season.

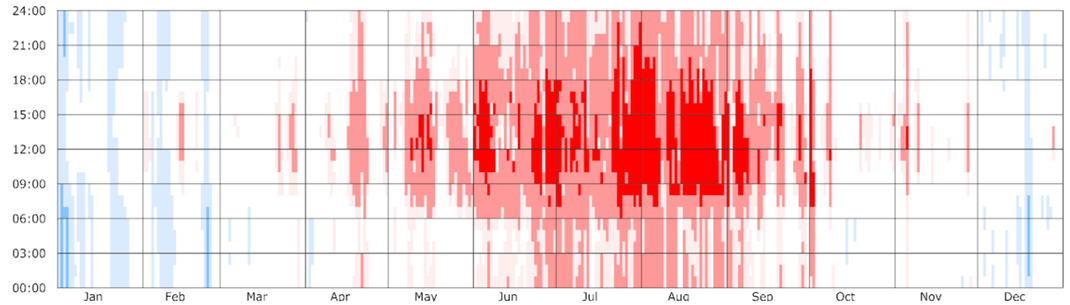
Using Rainwater for Evaporative Cooling during Hot Months

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.

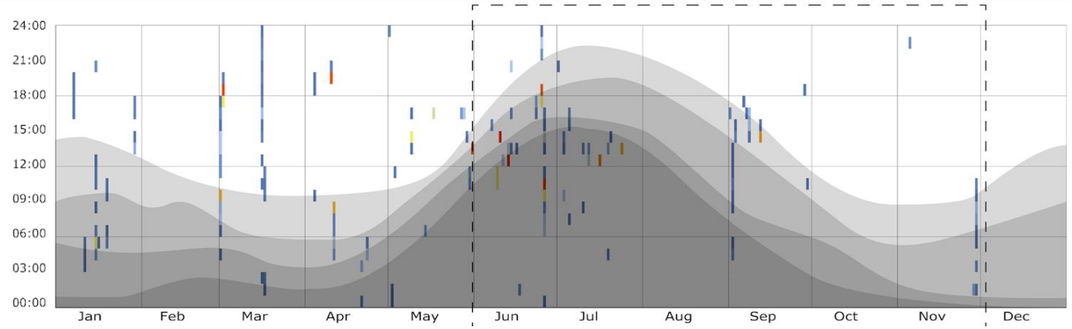


Chance of Precipitation

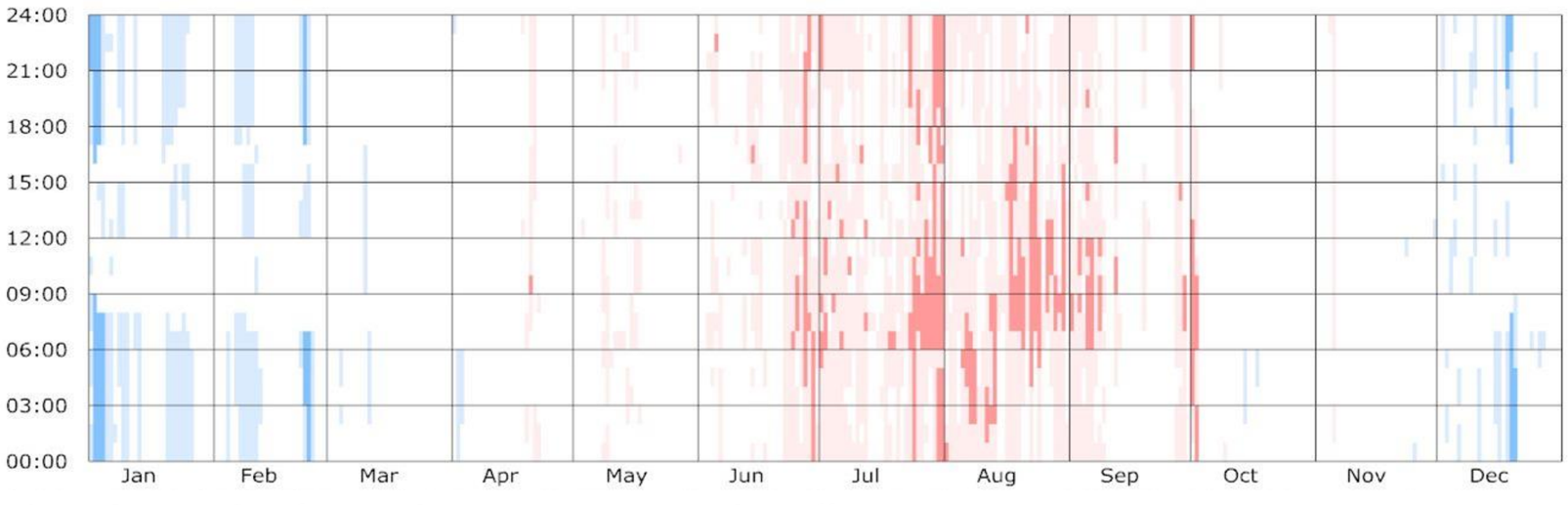




Annual Hours Comfort - Shaded Condition



Precipitation



Annual Hours Comfort - with max evaporative cooling effect

APPENDIX

2 CONCEPT DEVELOPMENTS

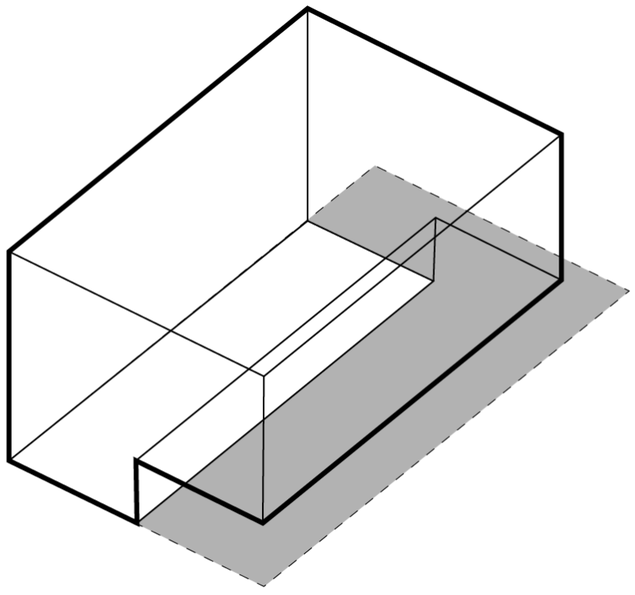
Environmental Challenges

STUDY OF SELF-SHADING

Outdoor Comfort

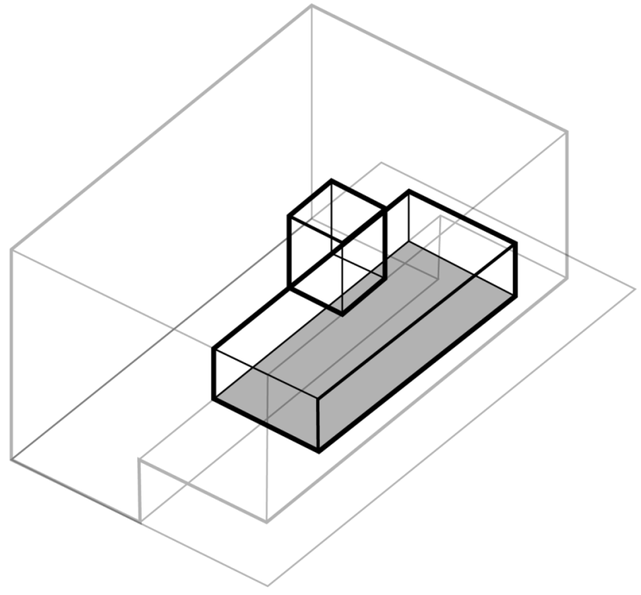
STEP 1

Ground Level - The City Stages



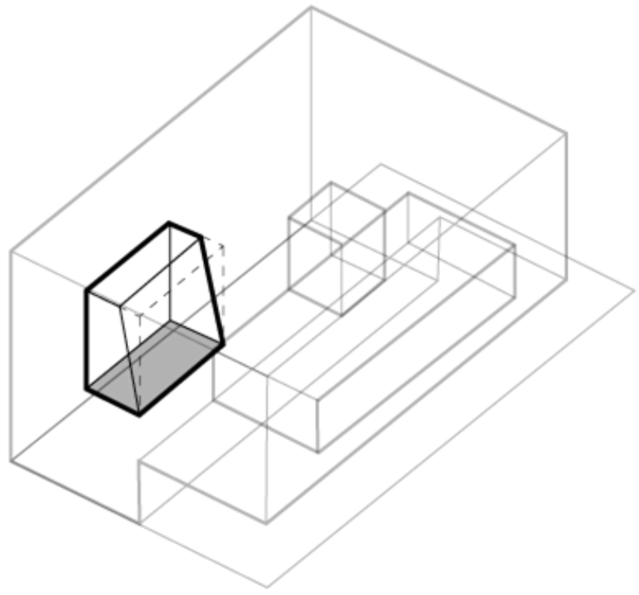
STEP 2

Middle Level - The City Balcony



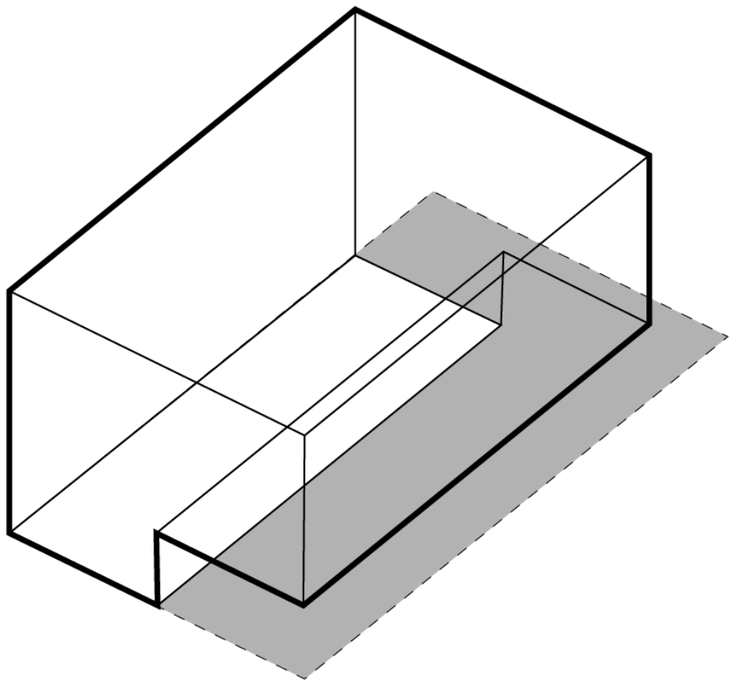
STEP 3

Upper Level - The City Window

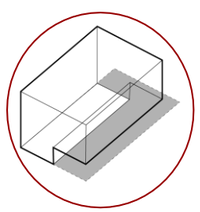


STUDY OF SELF-SHADING

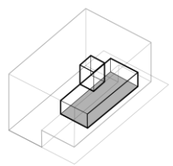
Step 1



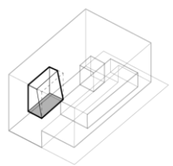
STEP 1



STEP 2

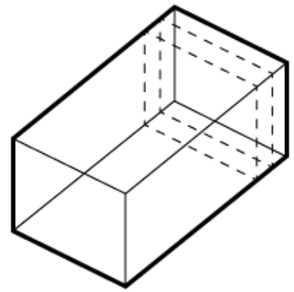


STEP 3



Solid & Void Combinations

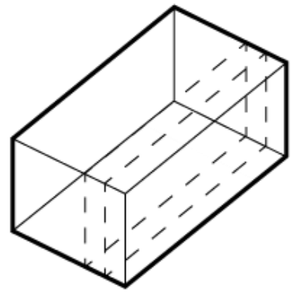
3



Solid_X

140 / 180 / 220

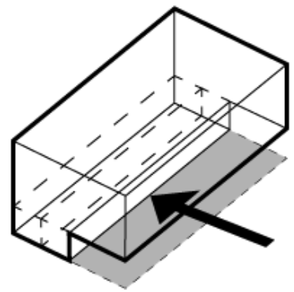
3



Solid_Y

80 / 100 / 120

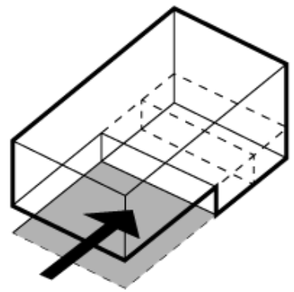
3



Void_x

50% / 75% / 100%

3



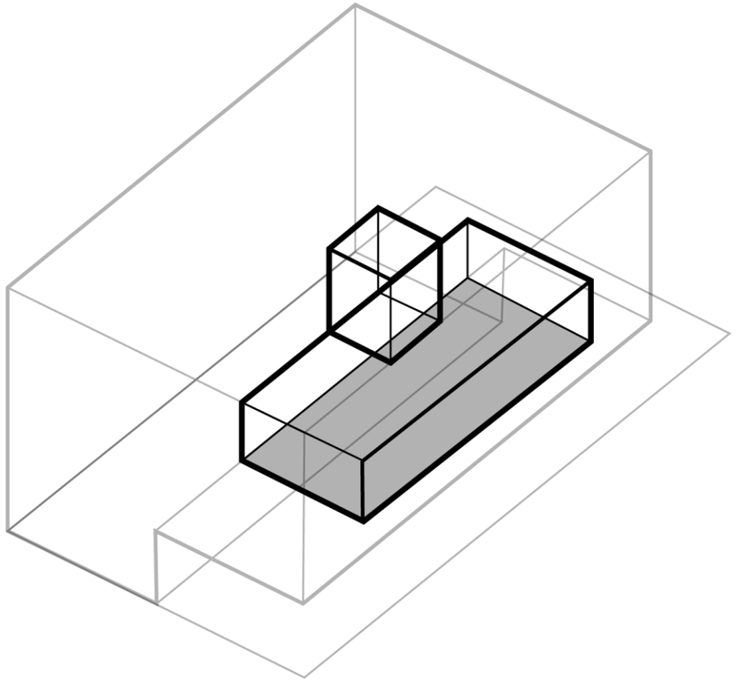
Void_y

50% / 75% / 100%

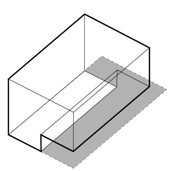
CASE#: 3X3X3X3=**81**

STUDY OF SELF-SHADING

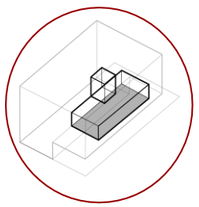
Step 2



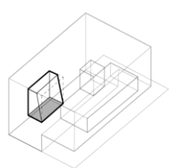
STEP 1



STEP 2



STEP 3



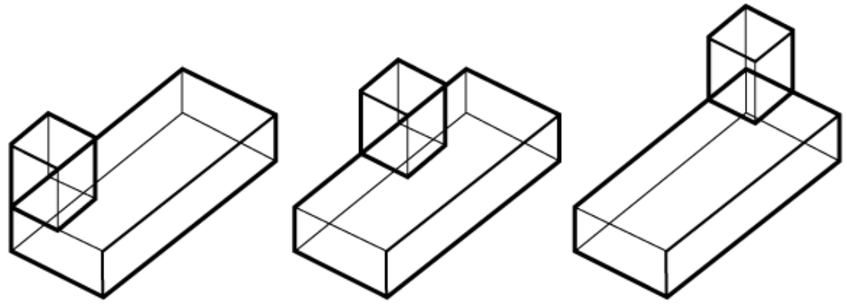
Voids Combinations

3

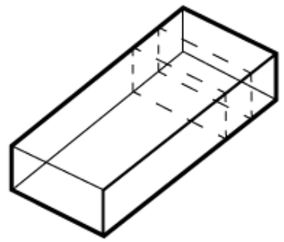
Void2_xx 80 / 100 / 120

Void2_yy 30 / 40 / 50

3



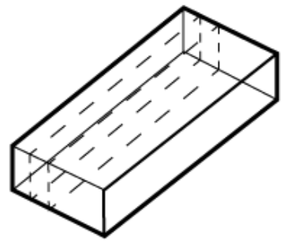
3



Void1_XX

20 / 25 / 30

3



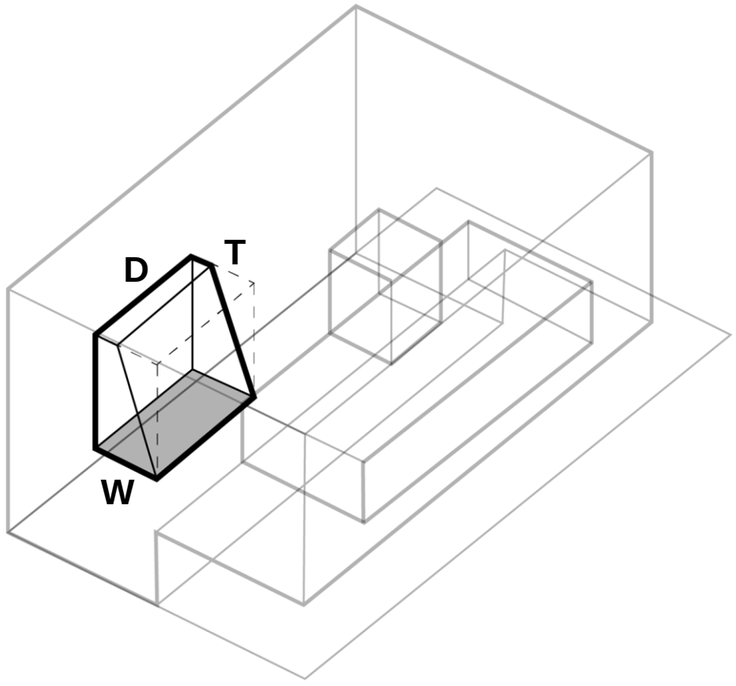
Void1_YY

20 / 25 / 30

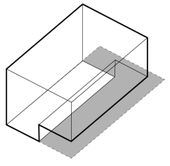
CASE#: 3X3X3X3=**81**

STUDY OF SELF-SHADING

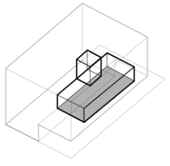
Step 3



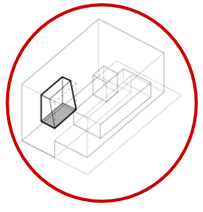
STEP 1



STEP 2

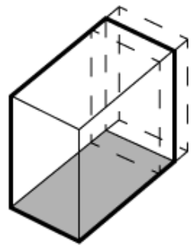


STEP 3



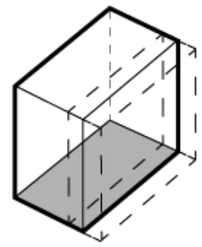
VOIDS DIMENSIONS

3



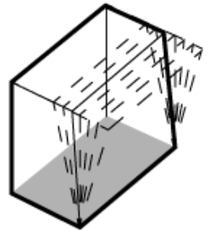
Depth:
40 / 50 / 60

3



Width:
20 / 30 / 40

7



Tilt:
-15 / -10 / -5 / 0 / +5 / +10 / +15

TOTAL TESTED CASE #: 3X3X7= **63**

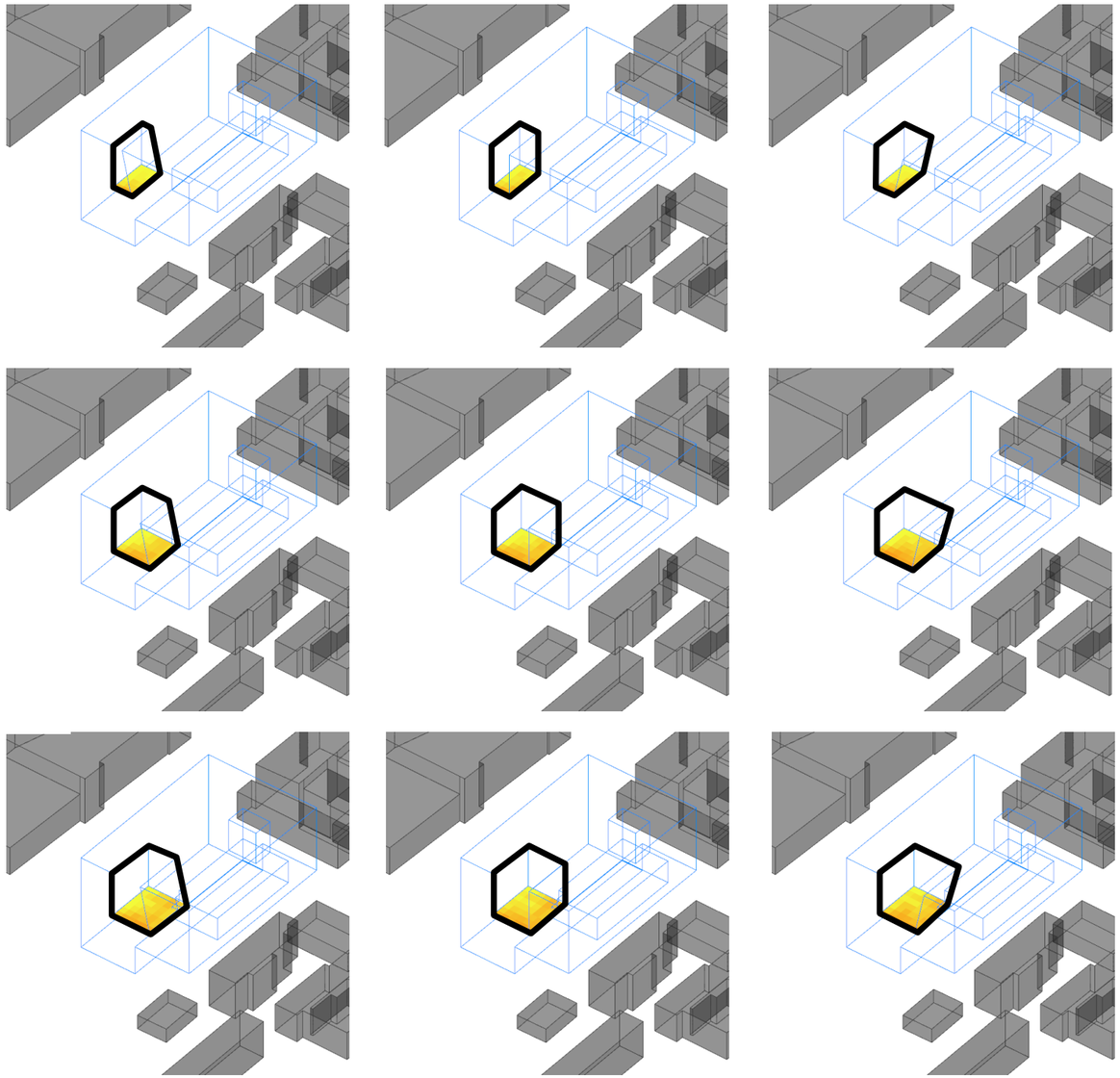
THERMAL COMFORT

% of annual hours

57%
4643 hrs

47%
3679 hrs

Annual Comfort %

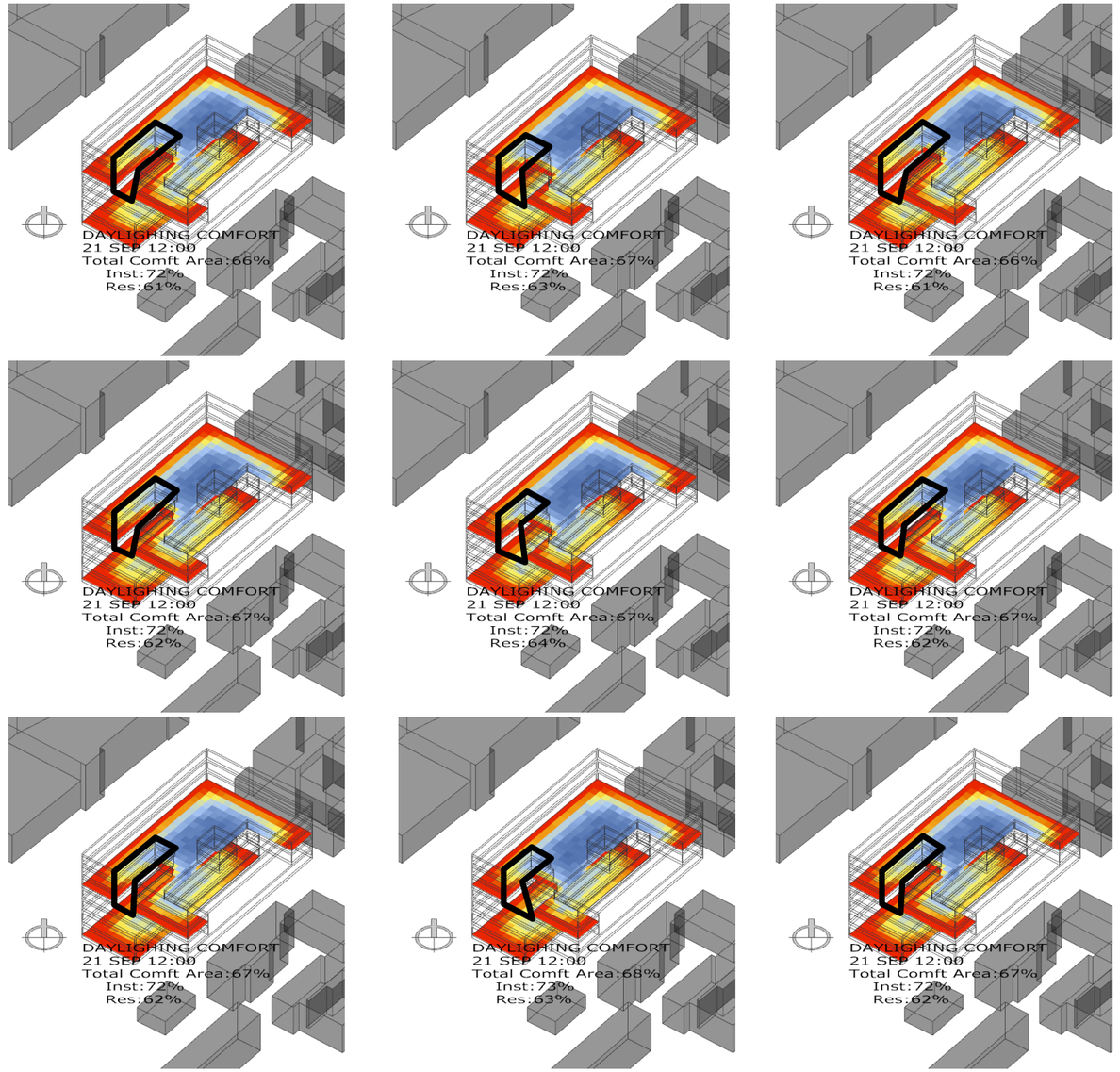


DAYLIGHT DISTRIBUTION

% of Area

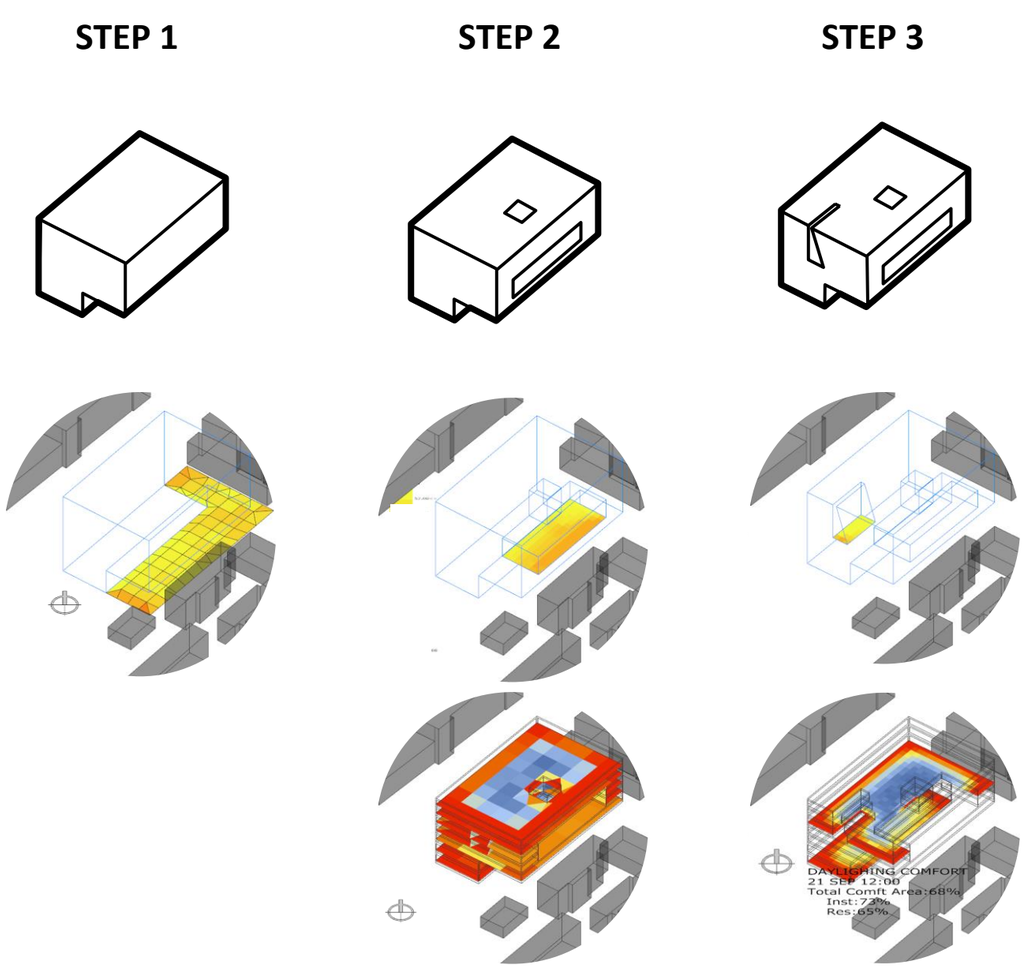
2000 100

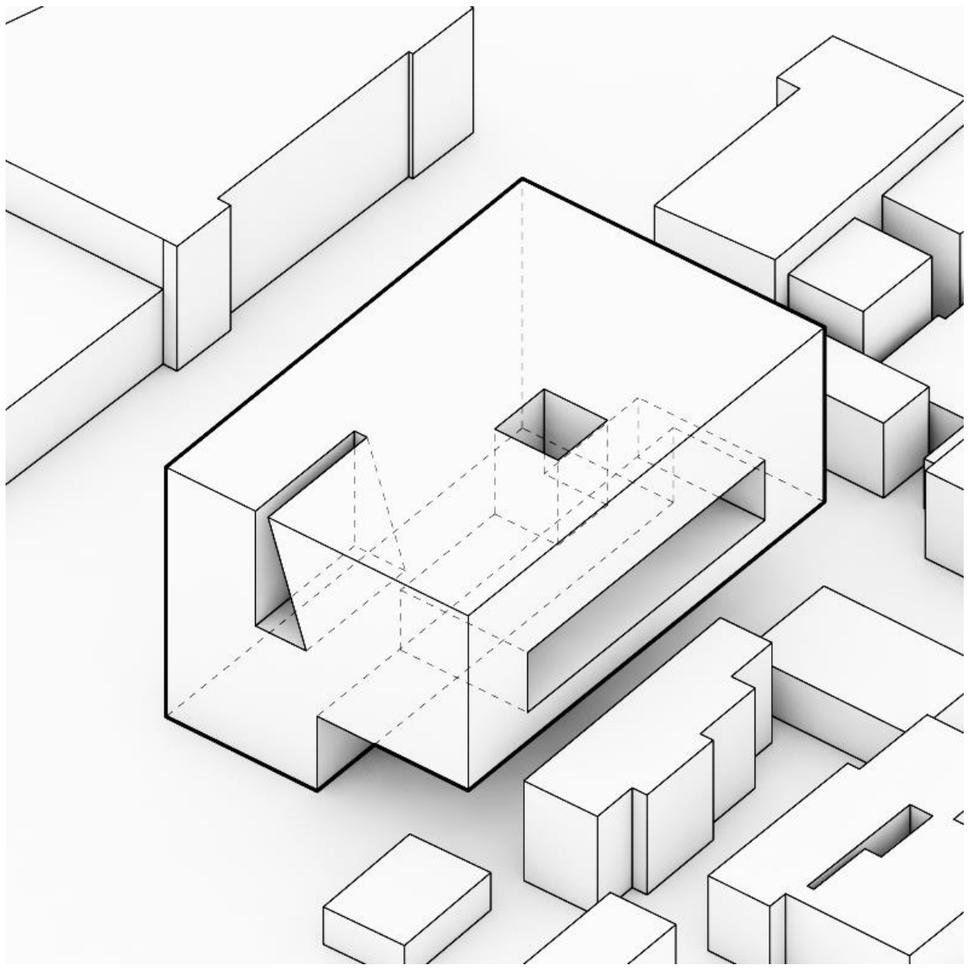
Useful Daylight Range (lux)



STUDY OF SELF-SHADING

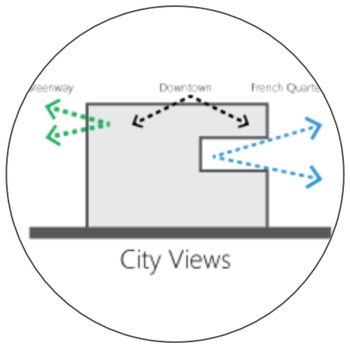
Exploration Summary

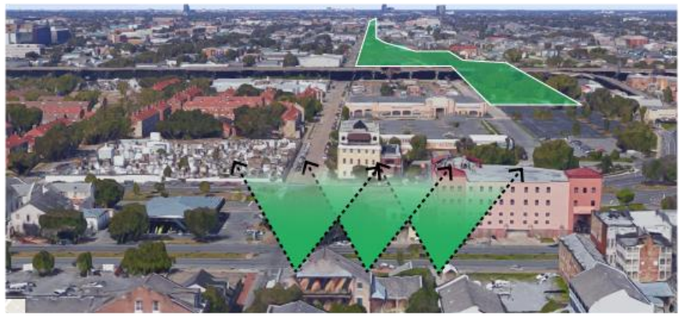


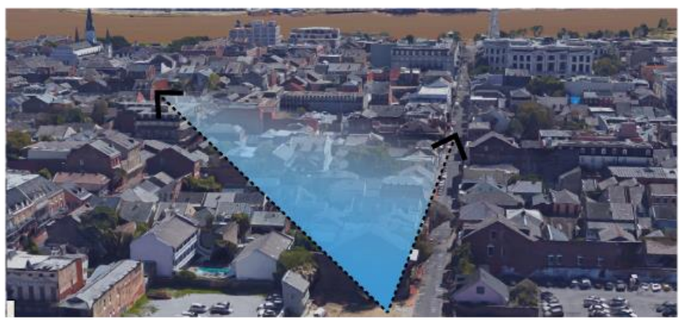


STUDY OF SELF-SHADING

Views

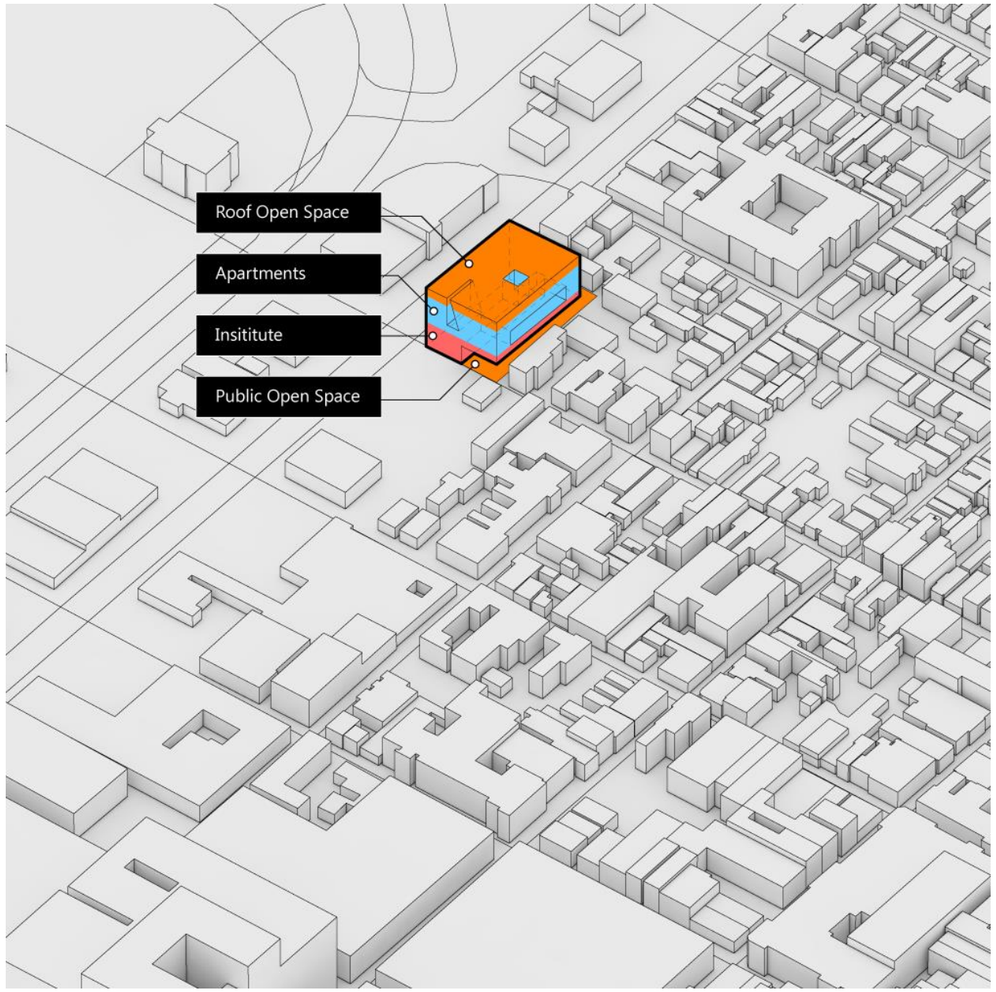


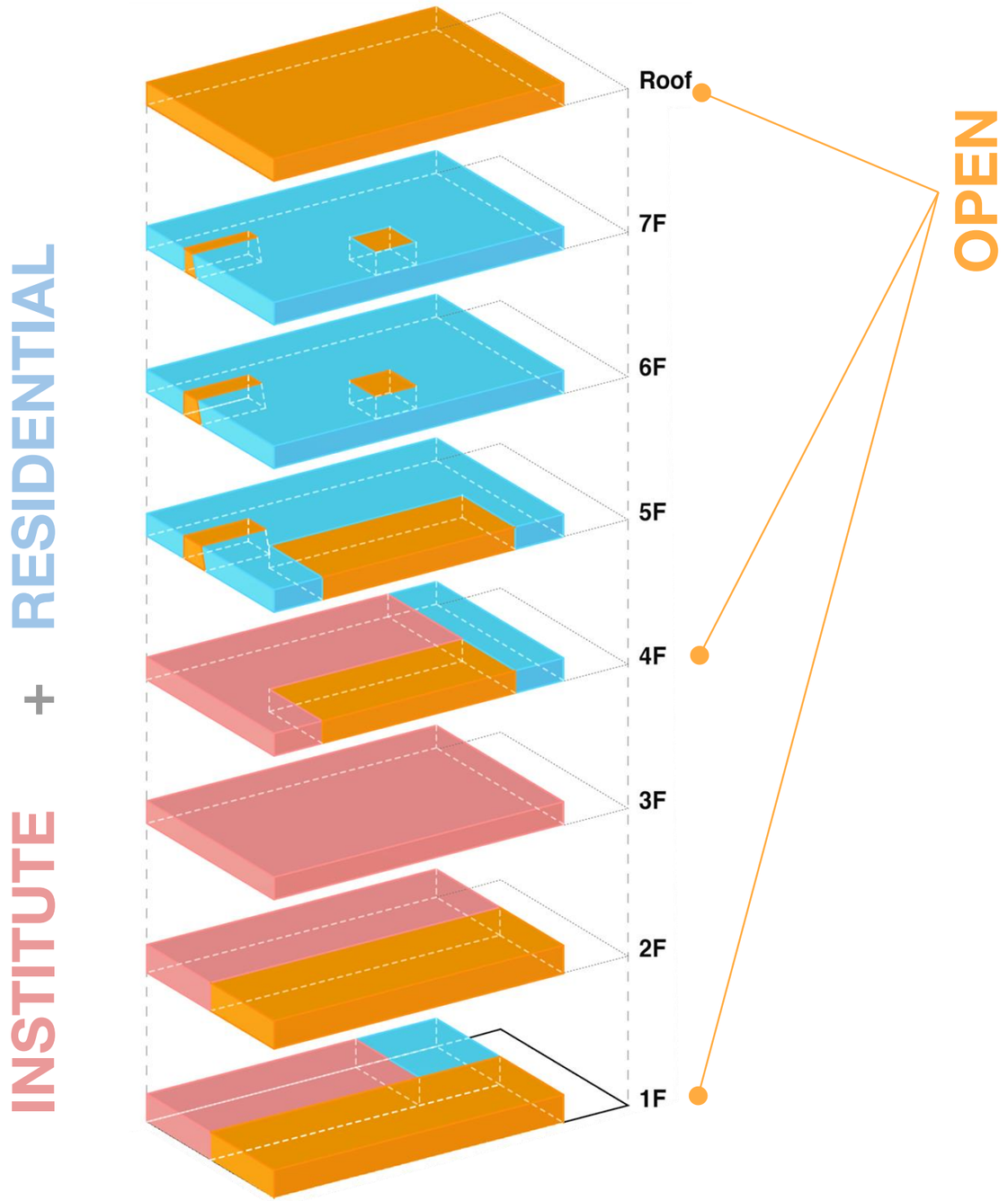




STUDY OF SELF-SHADING

Zoning

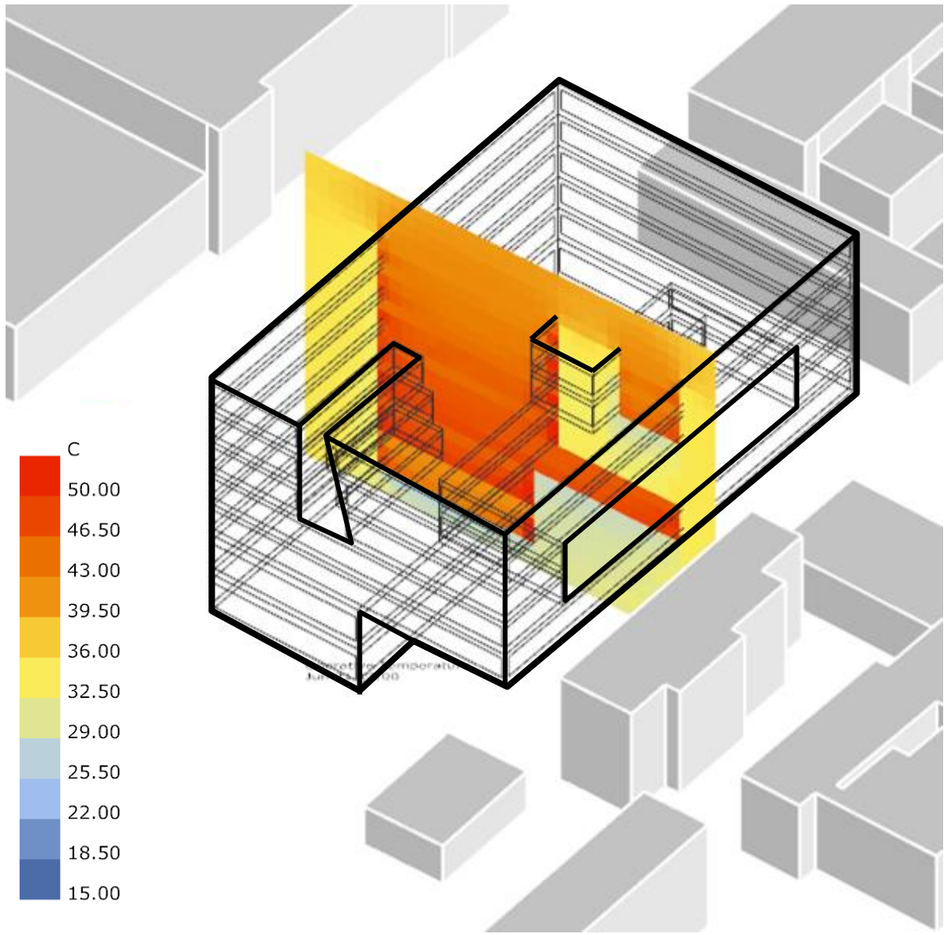


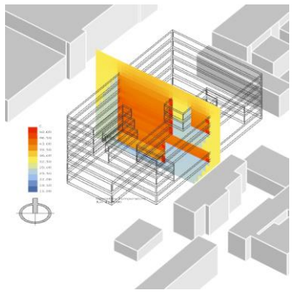
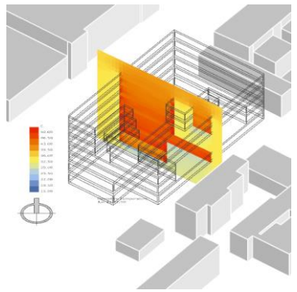
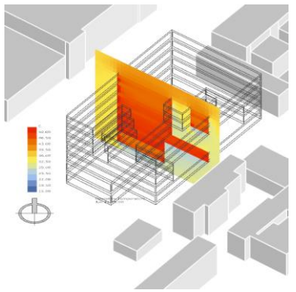
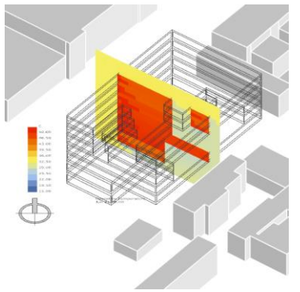
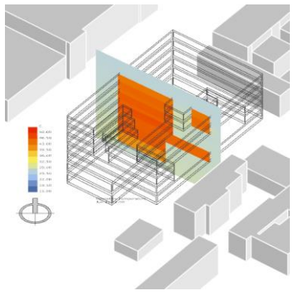
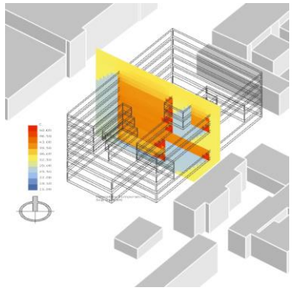
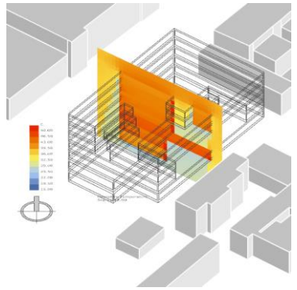
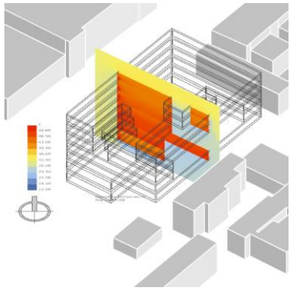
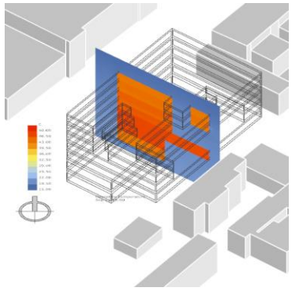
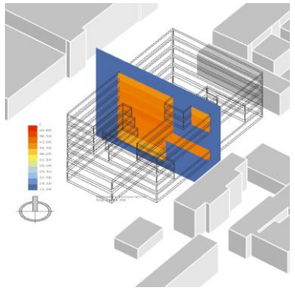
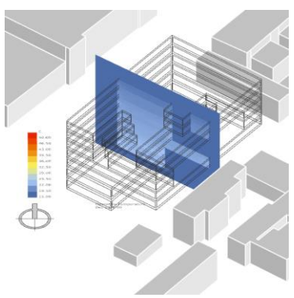
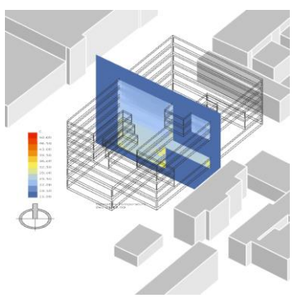
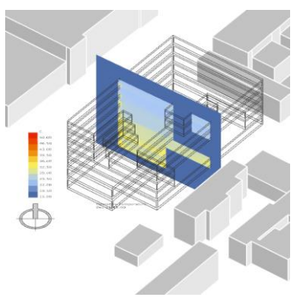
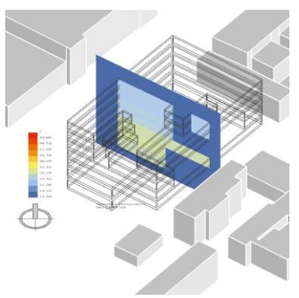
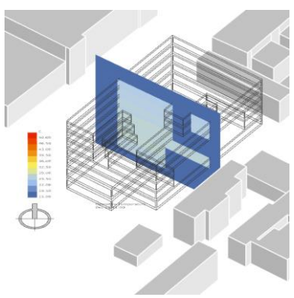


COMFORT SECTION

Indoor: Adaptive
Outdoor: UTCI

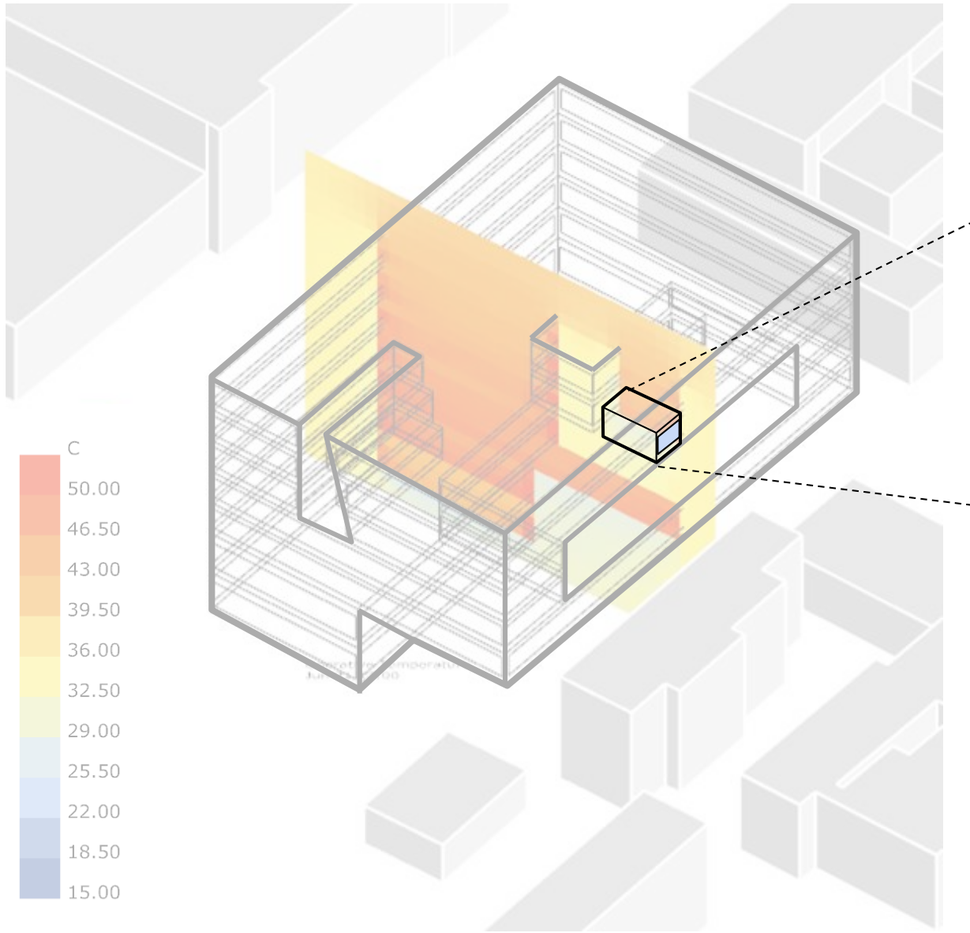
JUNE 21st 12 PM

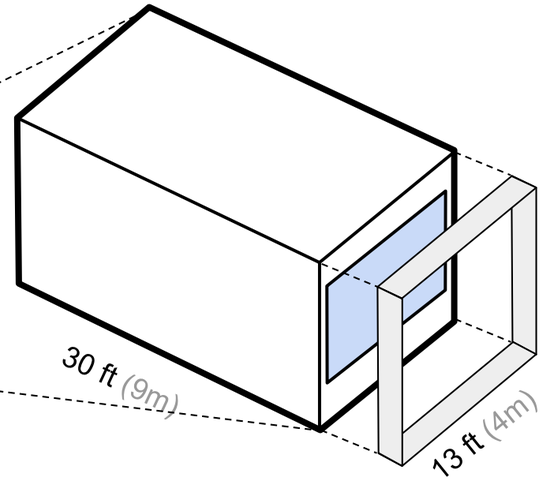


	9 AM	12 PM	3 PM	6 PM	9 PM
JUN. 21st					
SEP. 21st					
DEC. 21st					

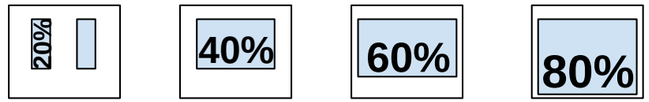
CHALLENGES FROM INTERIOR

Glz_Ratio & Glz_Type & Shading

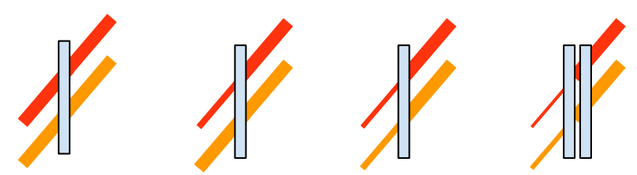




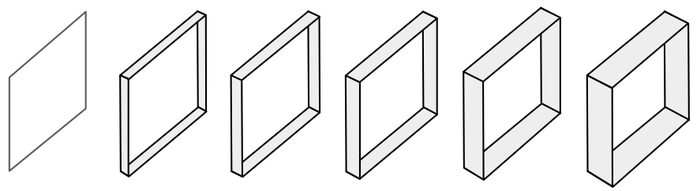
1 **GLAZING RATIO**



2 **GLAZING TYPE**

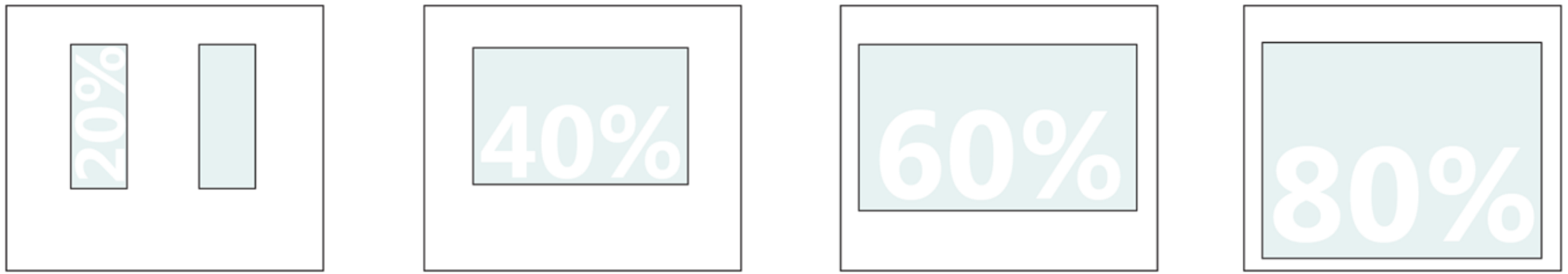


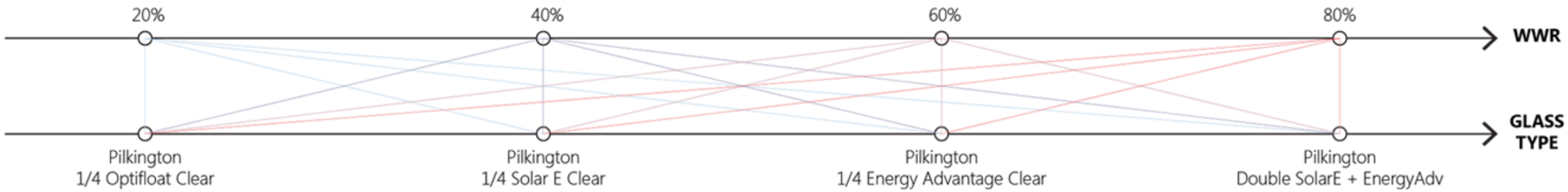
3 **SHADING DEPTH**

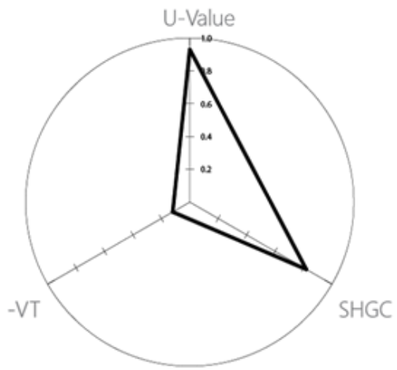


STUDY OF BALCONY

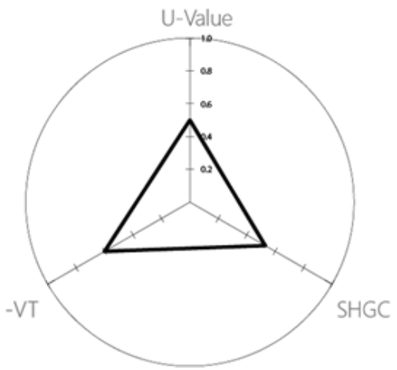
Glazing Ratio & Types



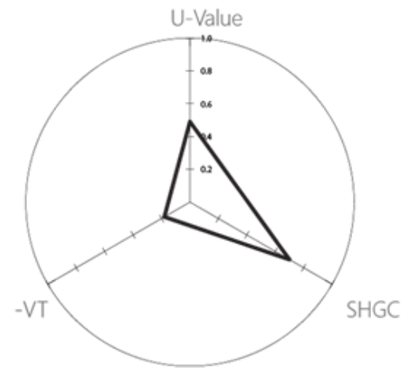




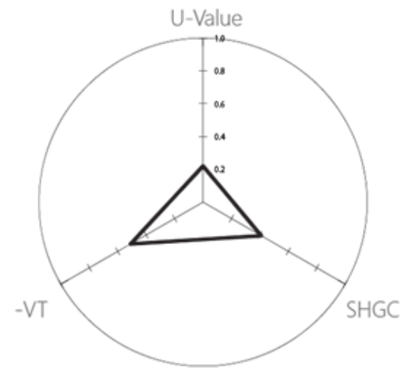
U-Value: 0.93 | SHGC: 0.82 | VT: 0.88



U-Value: 0.5 | SHGC: 0.53 | VT: 0.6



U-Value: 0.49 | SHGC: 0.7 | VT: 0.82



U-Value: 0.22 | SHGC: 0.41 | VT: 0.49

STUDY OF BALCONY

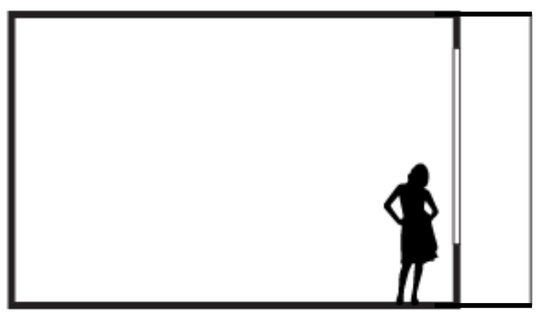
Shading Depth

Daylighting oriented

Deep unit \\ Flat Facade \\ Light shelve

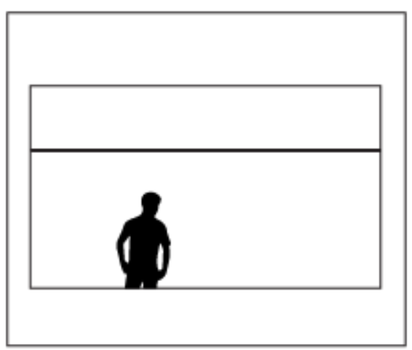
Energy balanced

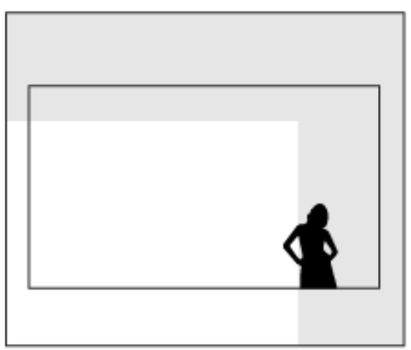
medium size unit \\ shading

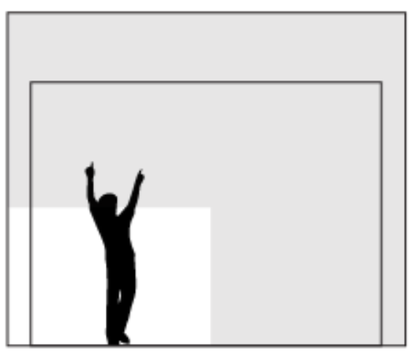


Solar heat controlled

Small unit \\ balcony

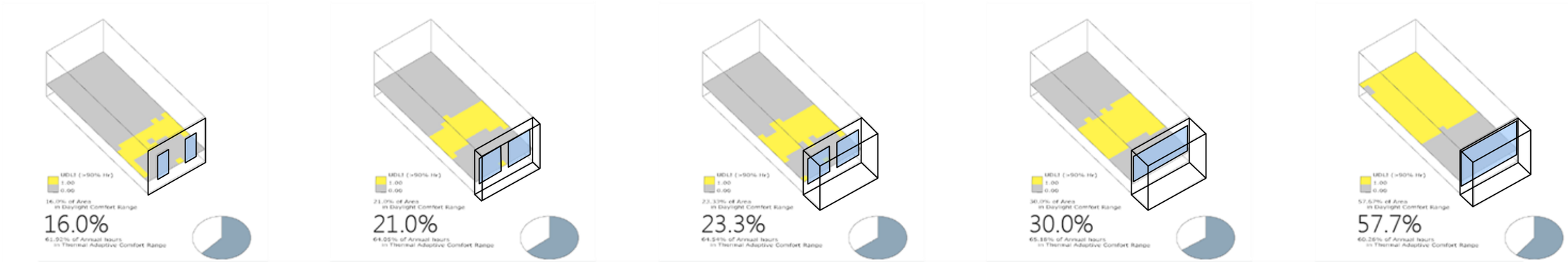






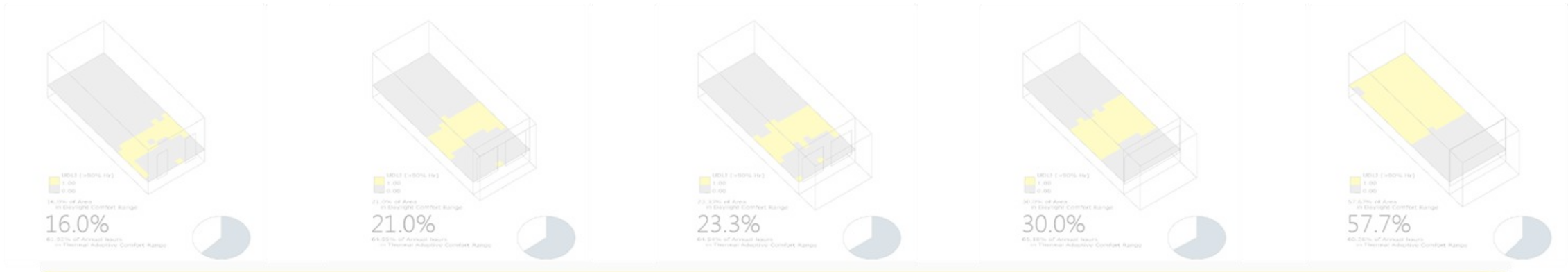
CHALLENGES FROM INTERIOR

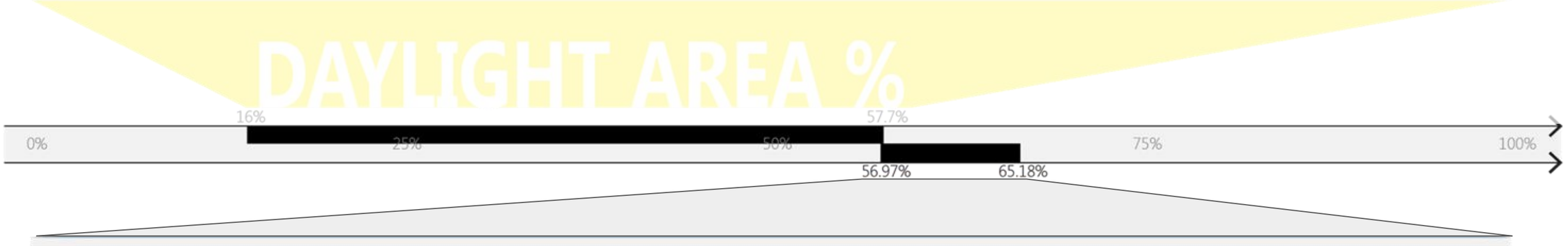
Glz_Ratio & Glz_Type & Shading

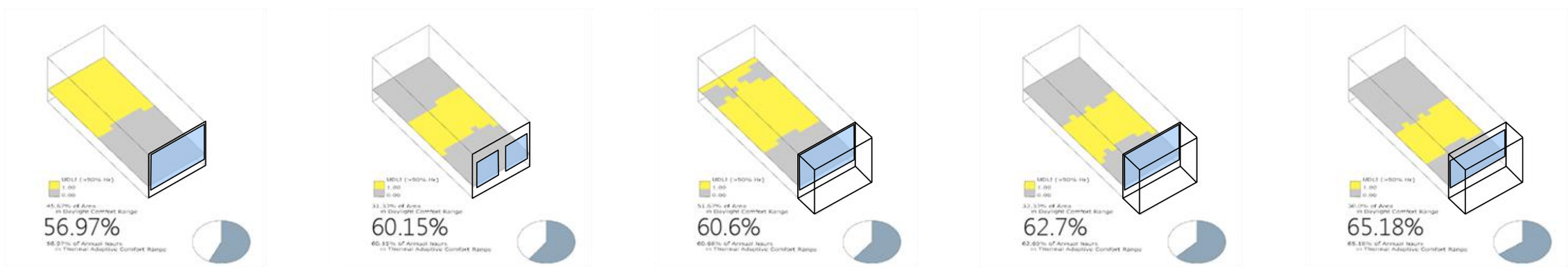


CHALLENGES FROM INTERIOR

Glz_Ratio & Glz_Type & Shading

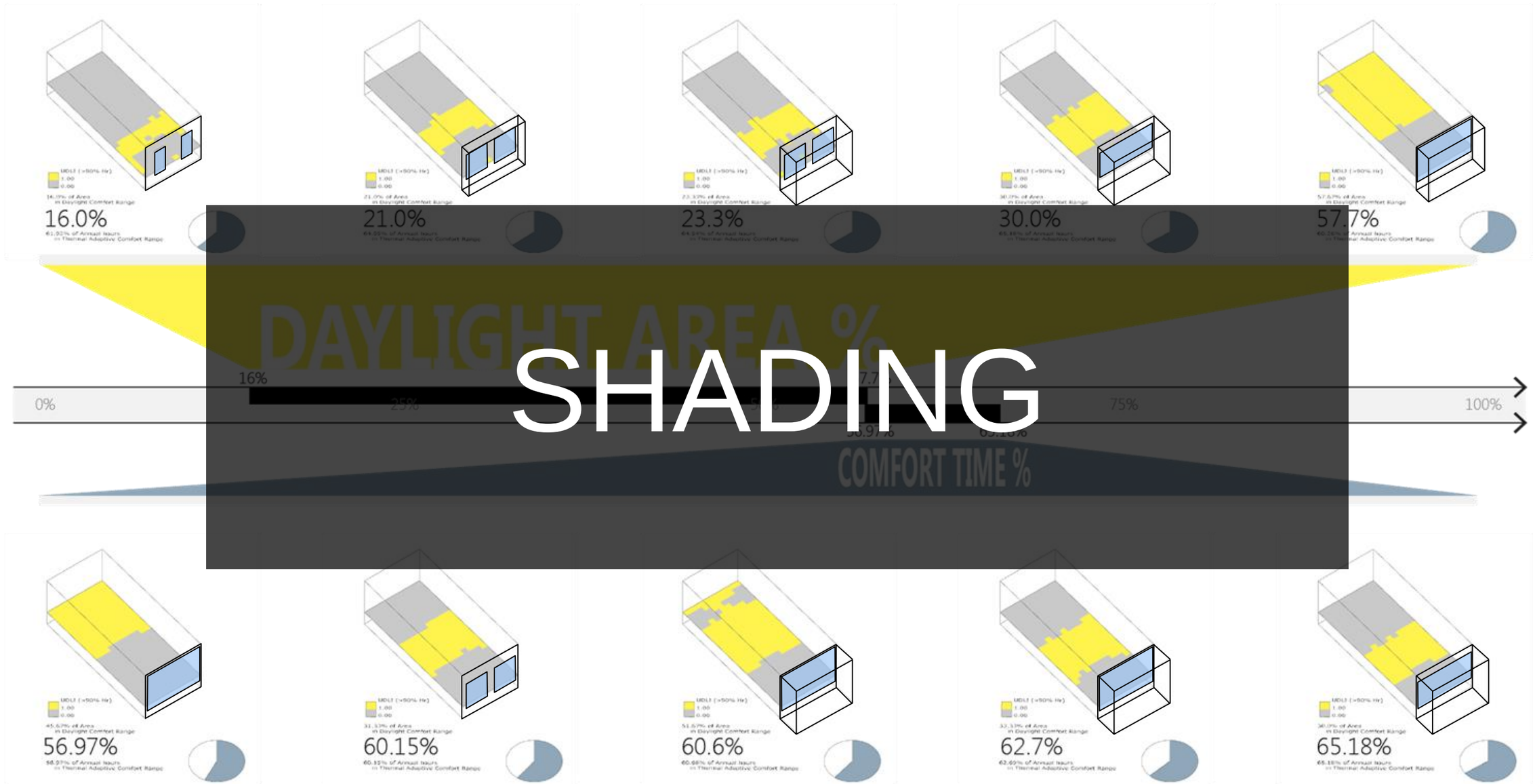






CHALLENGES FROM INTERIOR

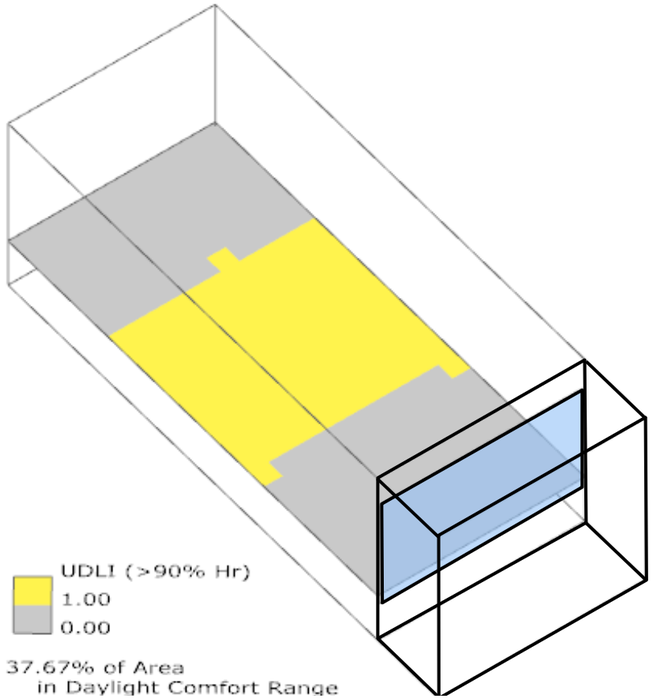
Glz_Ratio & Glz_Type & Shading



SHADING

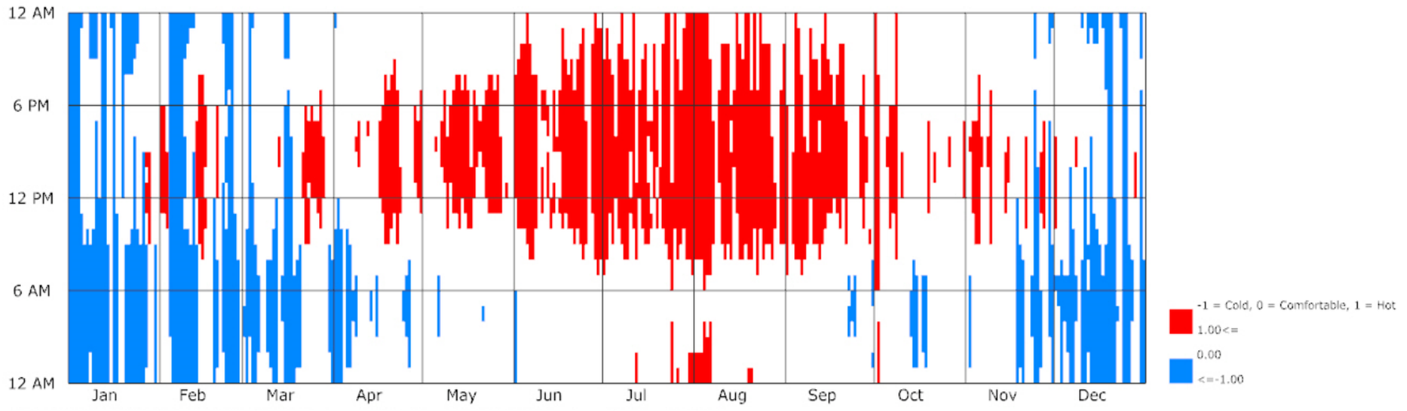
PROTOTYPES

Annual Data Spectrum

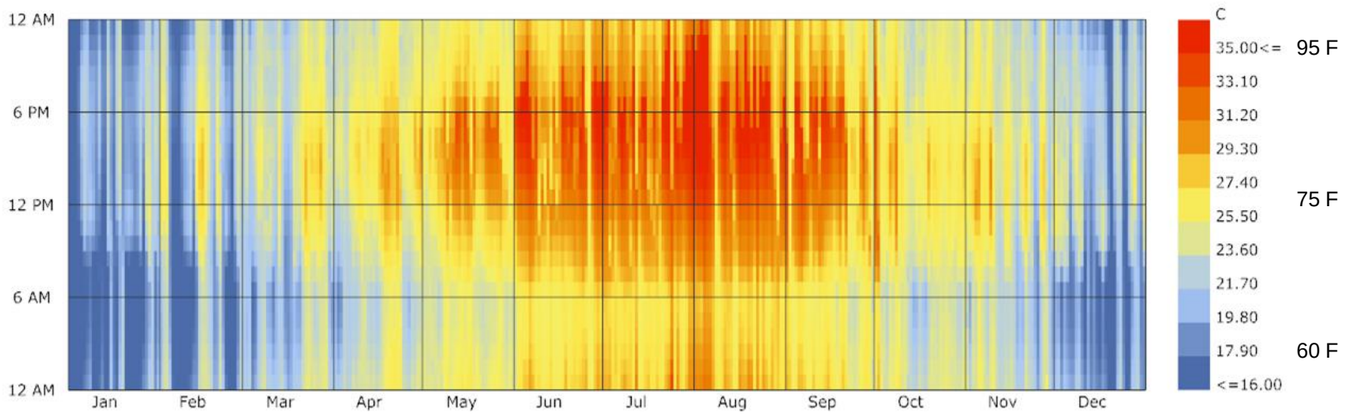


64%

Annual Hours in
Adaptive Comfort



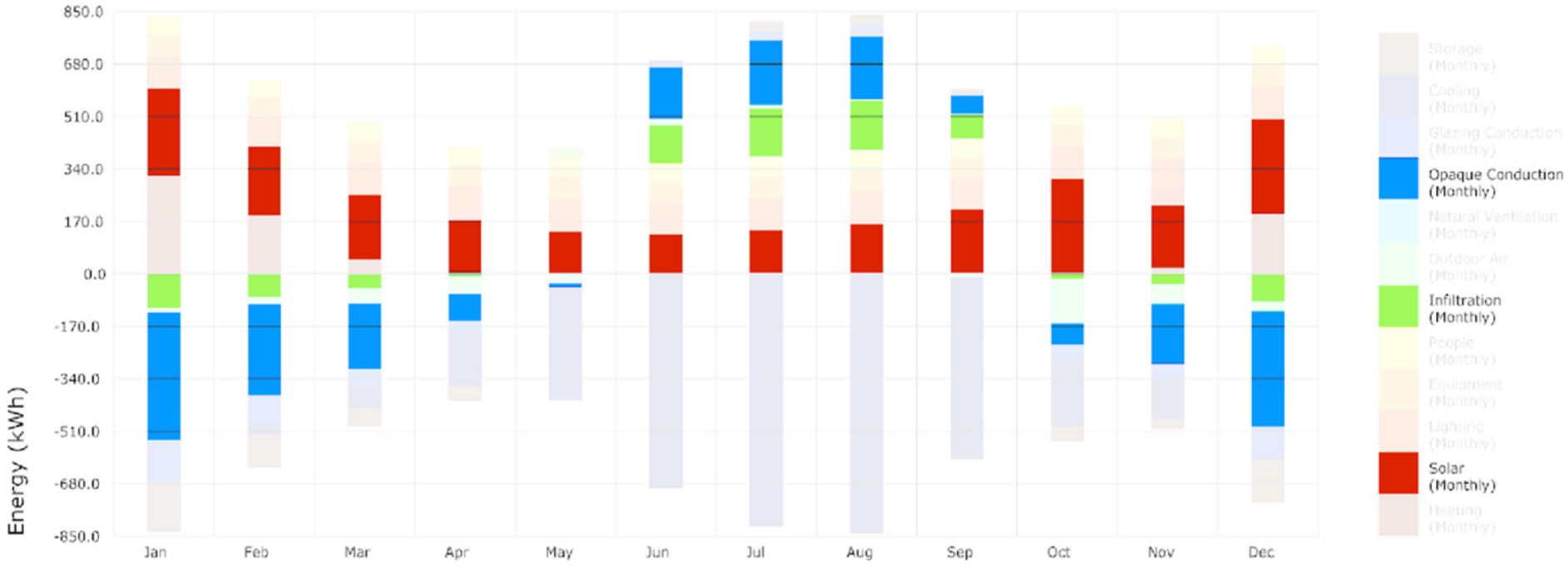
Adaptive Comfort: 64%



Operative Temperature

ENERGY BALANCE (LOAD)

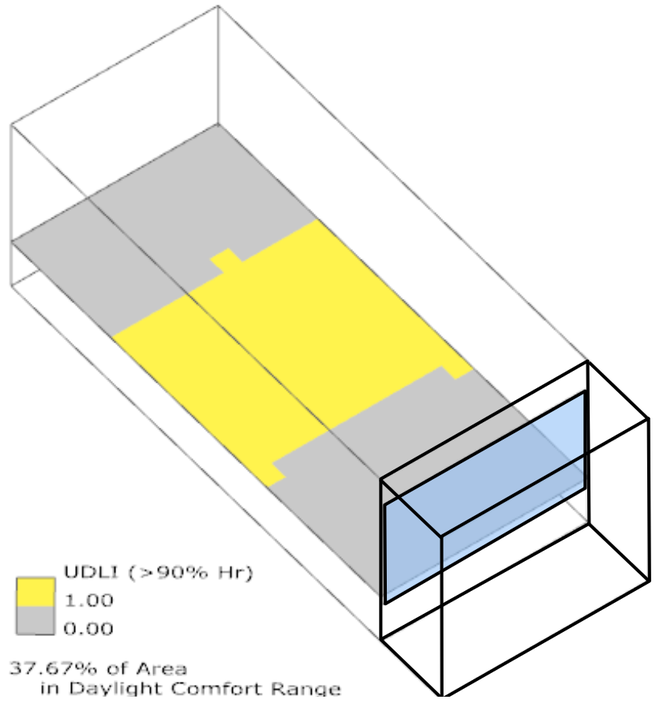
Solar Radiation & Infiltration & Wall Conduction



Room Energy Balance

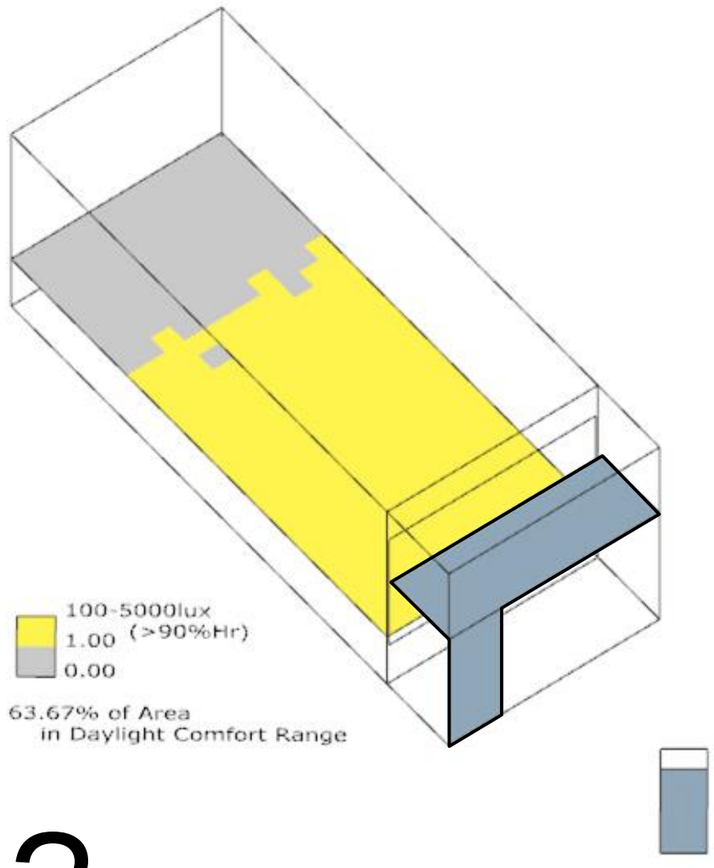
STUDY OF SCREEN

Overall



64%

Annual Hours in
Adaptive Comfort



? %

Annual Hours in
Adaptive Comfort

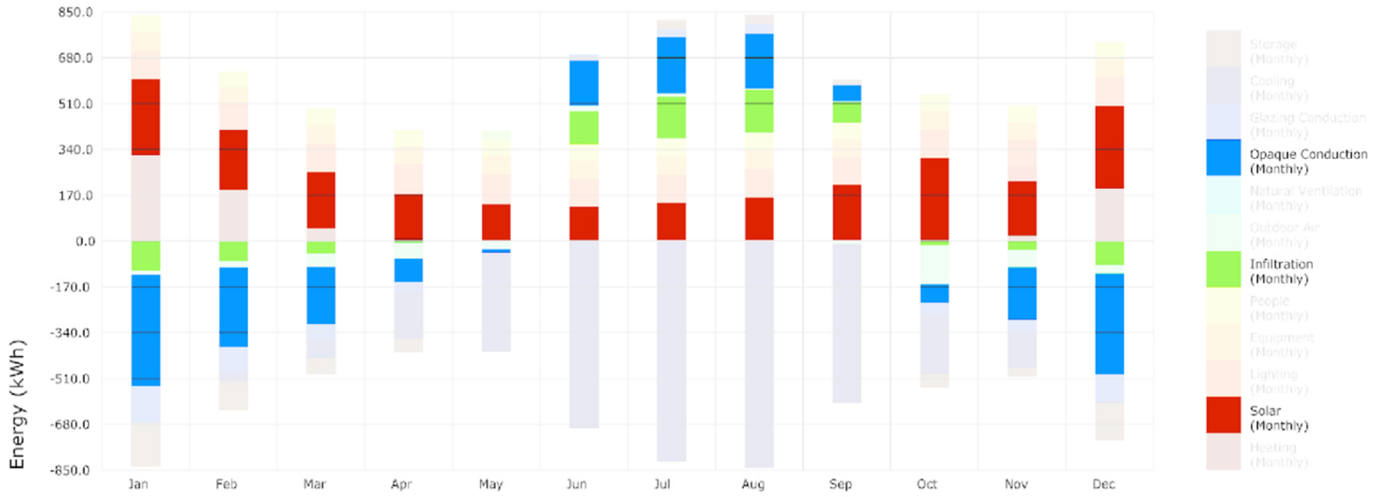
ENERGY BALANCE (LOAD)

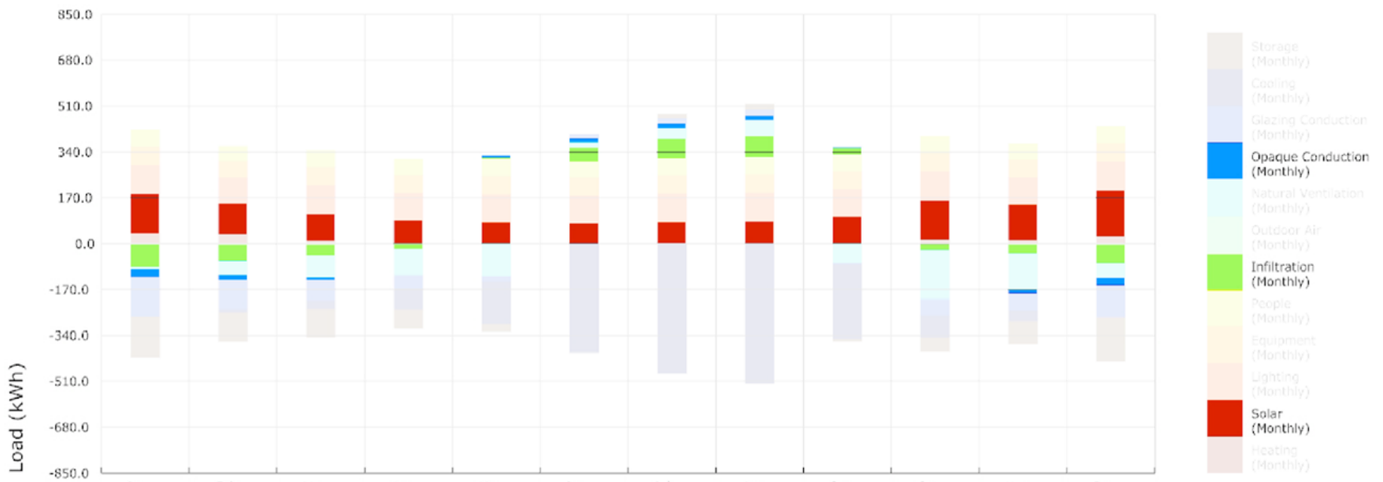
Screen Adjustment

Before 4722 kWh
41 kBtu/sqft

37%

After 2965 kWh
26 kBtu/sqft





Room Load Balance

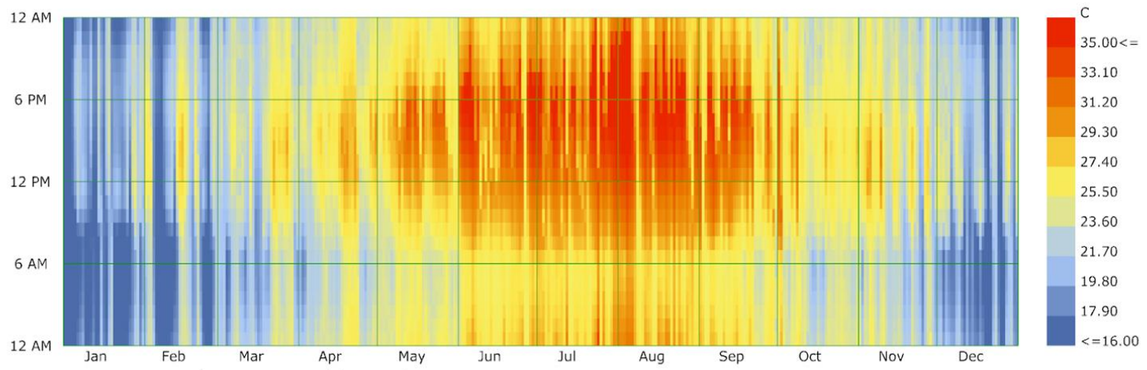
OPERATIVE TEMPERATURE

Air Flow Impact

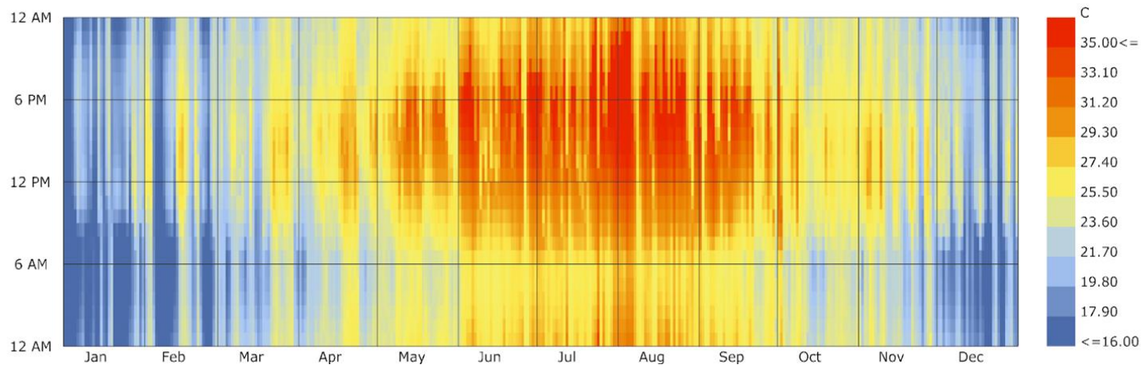
Natural

Mechanical

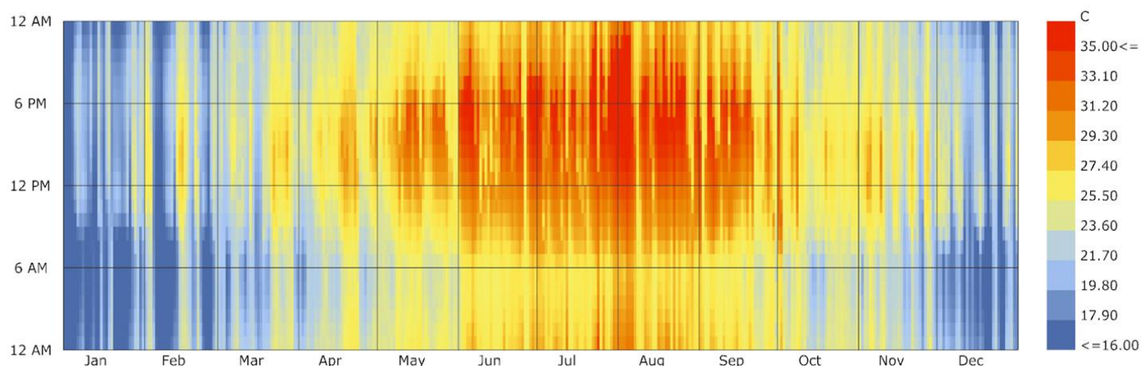
0.1 m/s



0.3 m/s



0.6 m/s

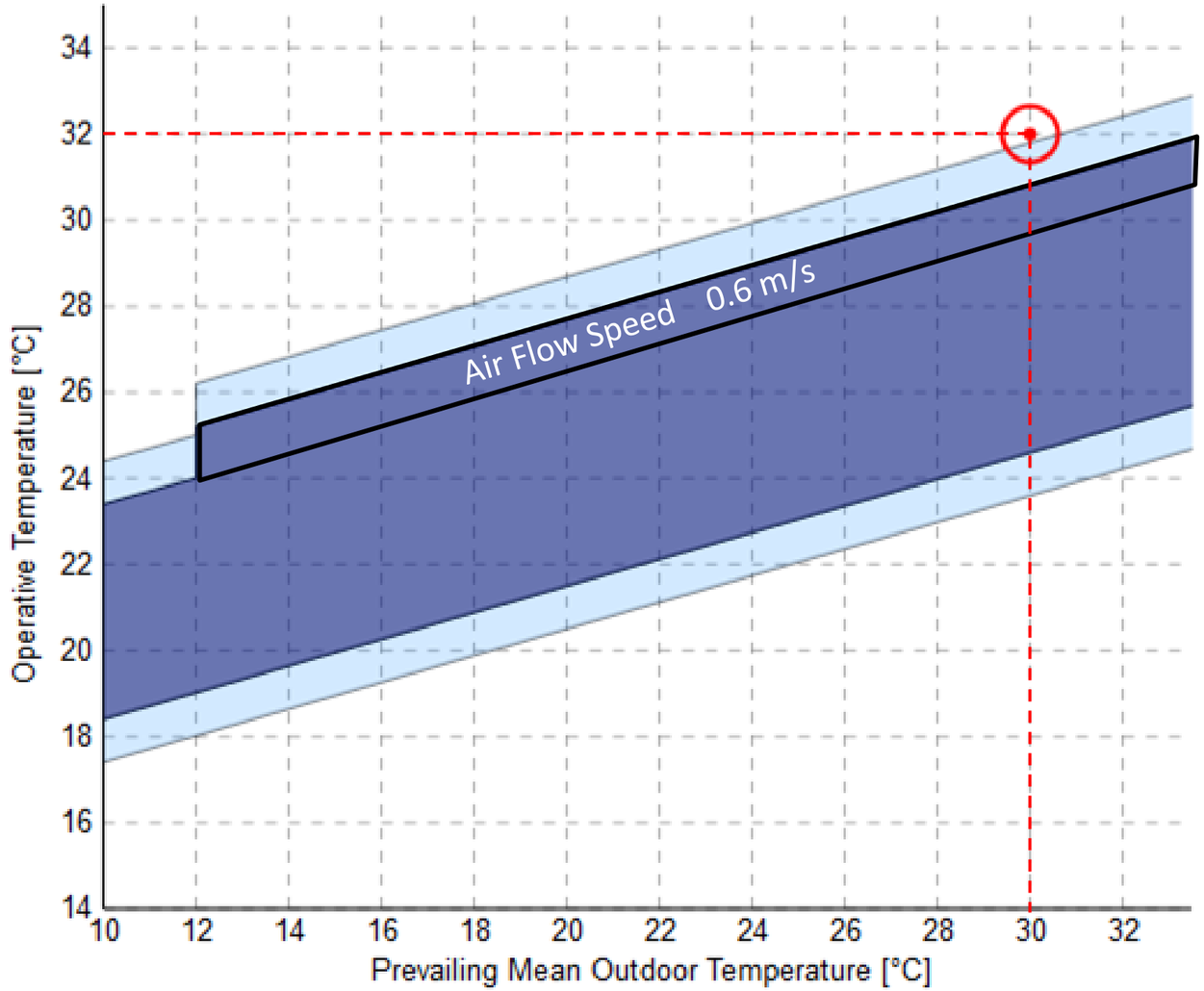


OPERATIVE TEMPERATURE

Air Flow Impact

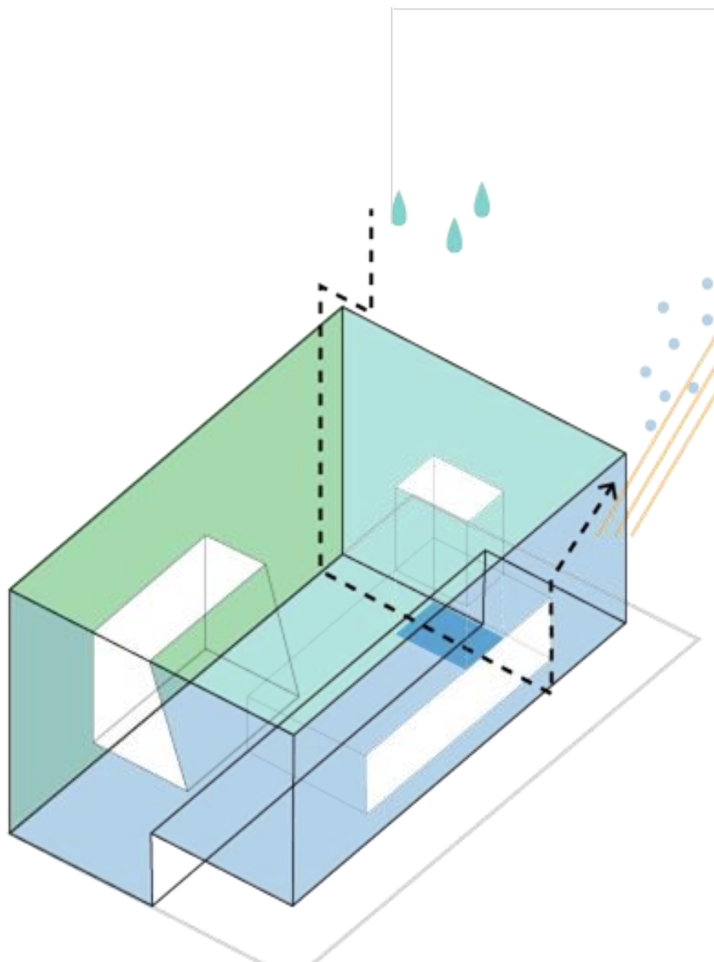
Natural

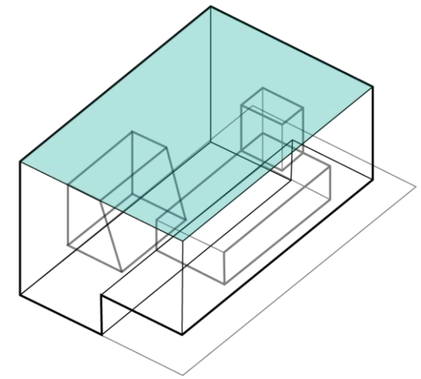
Mechanical



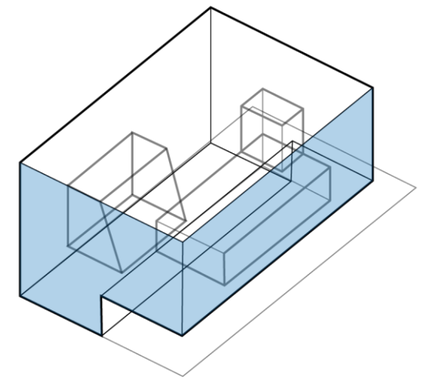
WATER SYSTEM

Elements

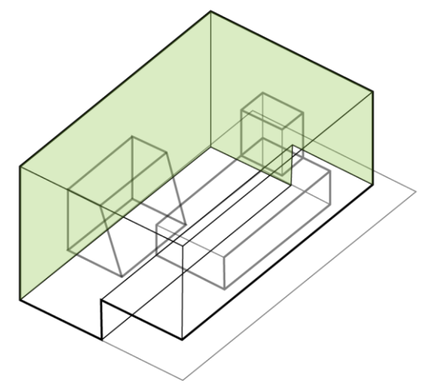




Roof



Blue Screen

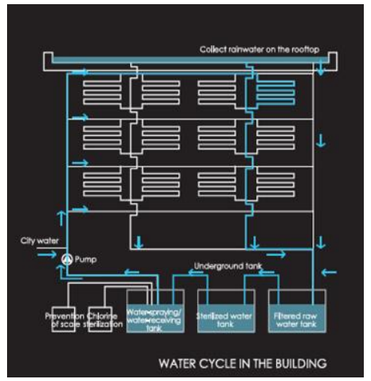


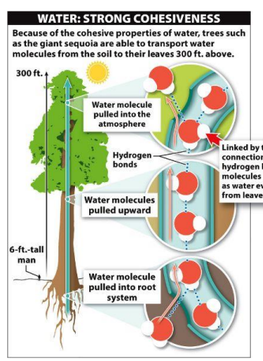
Green Wall

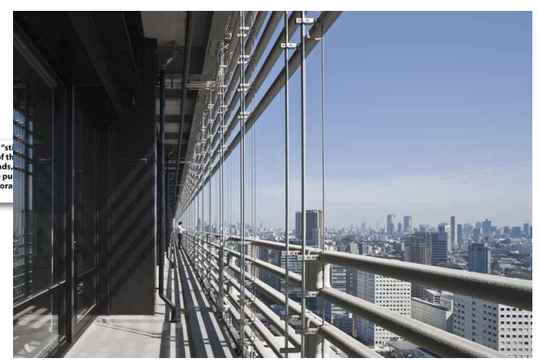
Average Collectable Water Volume per day **308** ft³/day

46 person/day

Pipes on Sony's Osaki Home Entertainment HQ release water to **cool the building's facade** by up to **12.6**°C and the **surrounding** air by **2-3°C**.



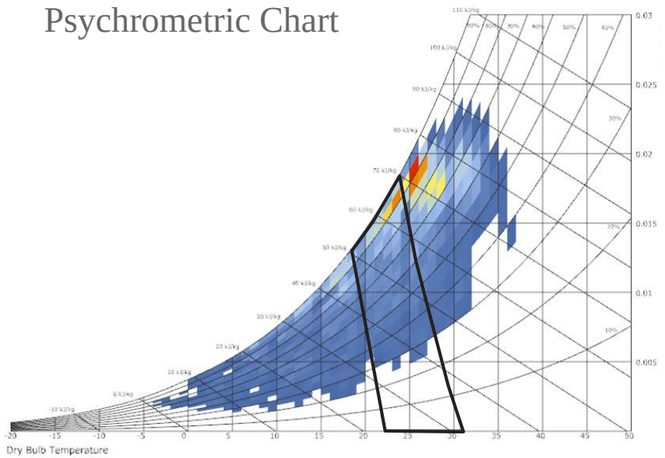




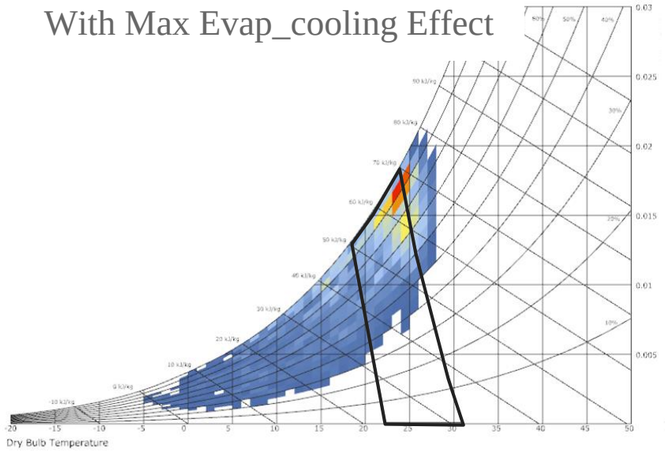
POTENTIAL OF EVAPORATIVE COOLING

Wet Bulb Temperature

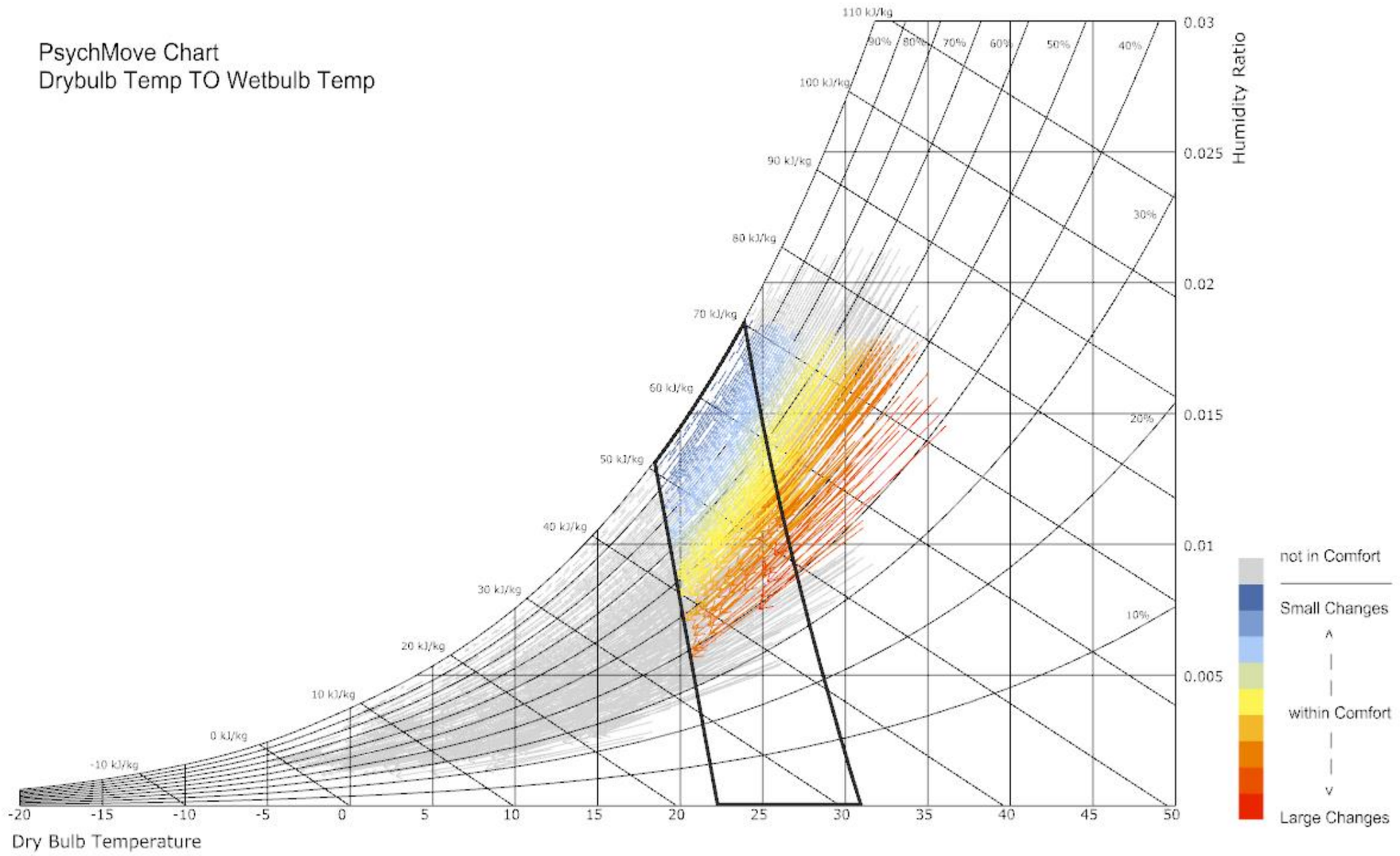
Psychrometric Chart



With Max Evap_cooling Effect

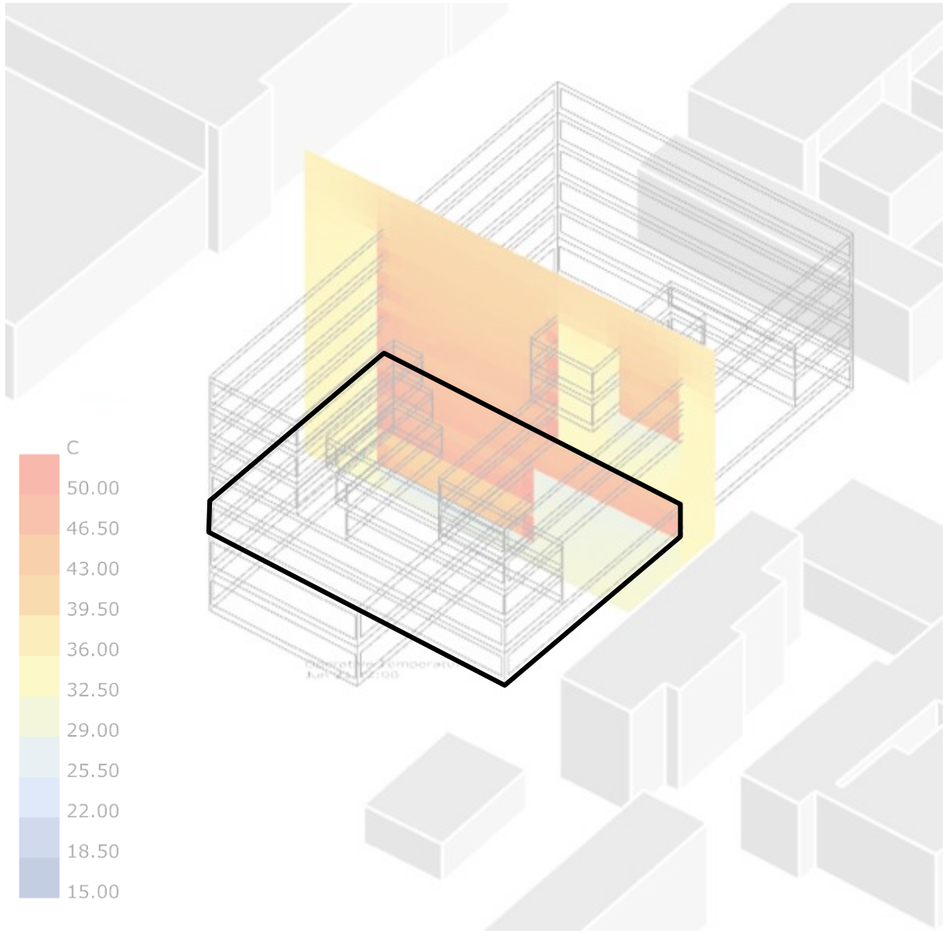


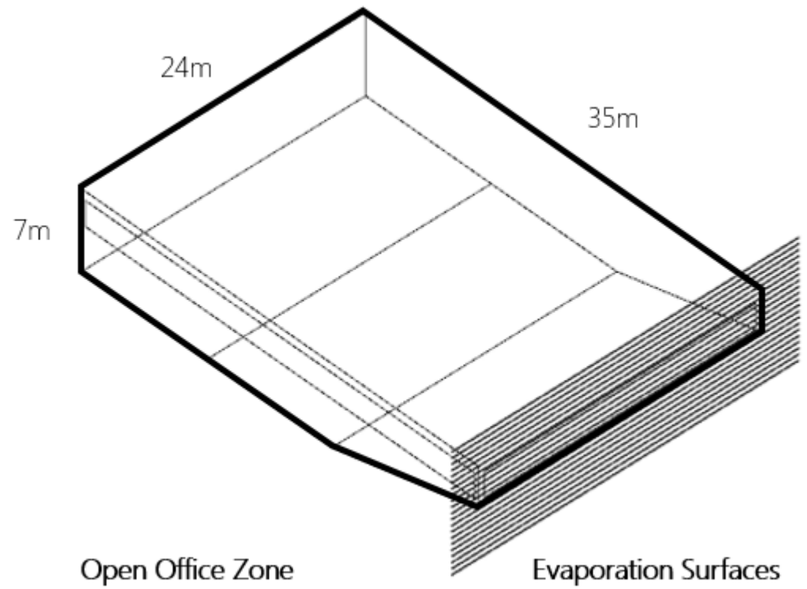
PsychMove Chart
Drybulb Temp TO Wetbulb Temp



POTENTIAL OF EVAPORATIVE COOLING

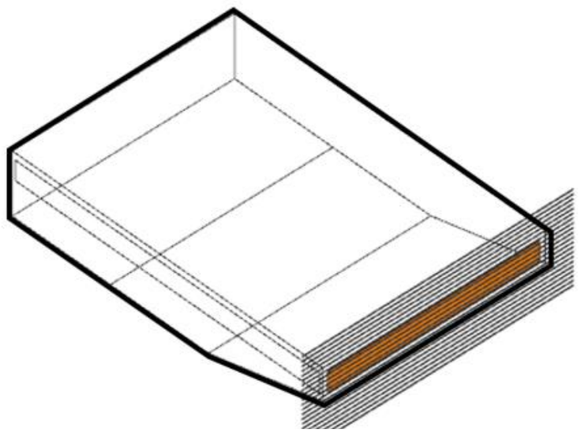
Testing Model





POTENTIAL OF EVAPORATIVE COOLING

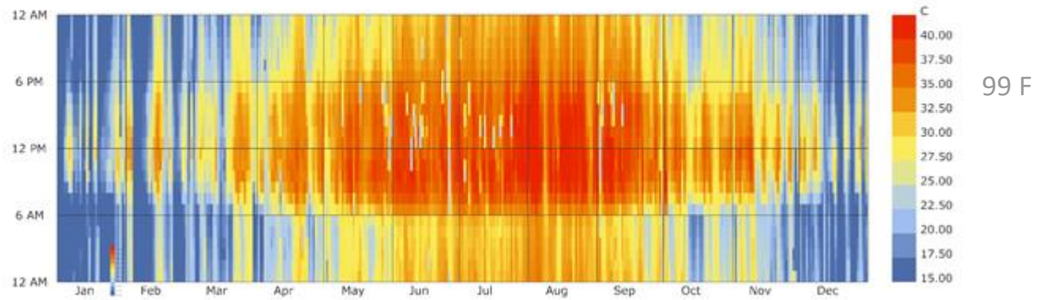
Surface Temperature



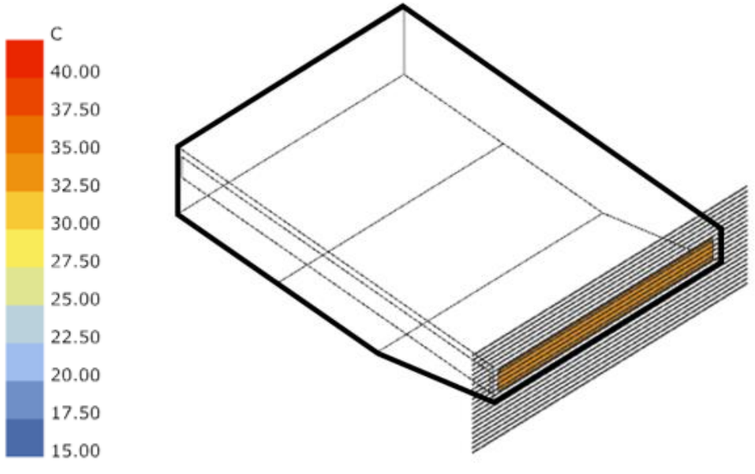
Base case

34.6 °C (94 °F)

Outer Surface Temperature



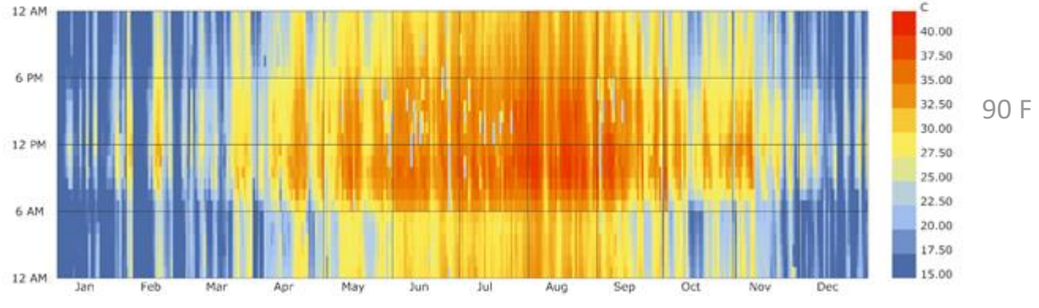
Outer Surface Temperature of Test Windows Surface
Annual Hourly Data - **Base case**



Evaporative Cooling

31.9 °C (89 °F)

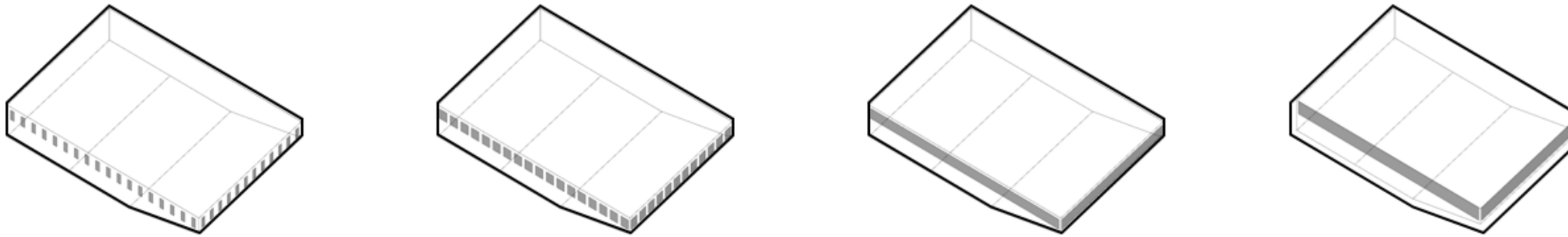
Outer Surface Temperature



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

STUDY OF OFFICE ZONE

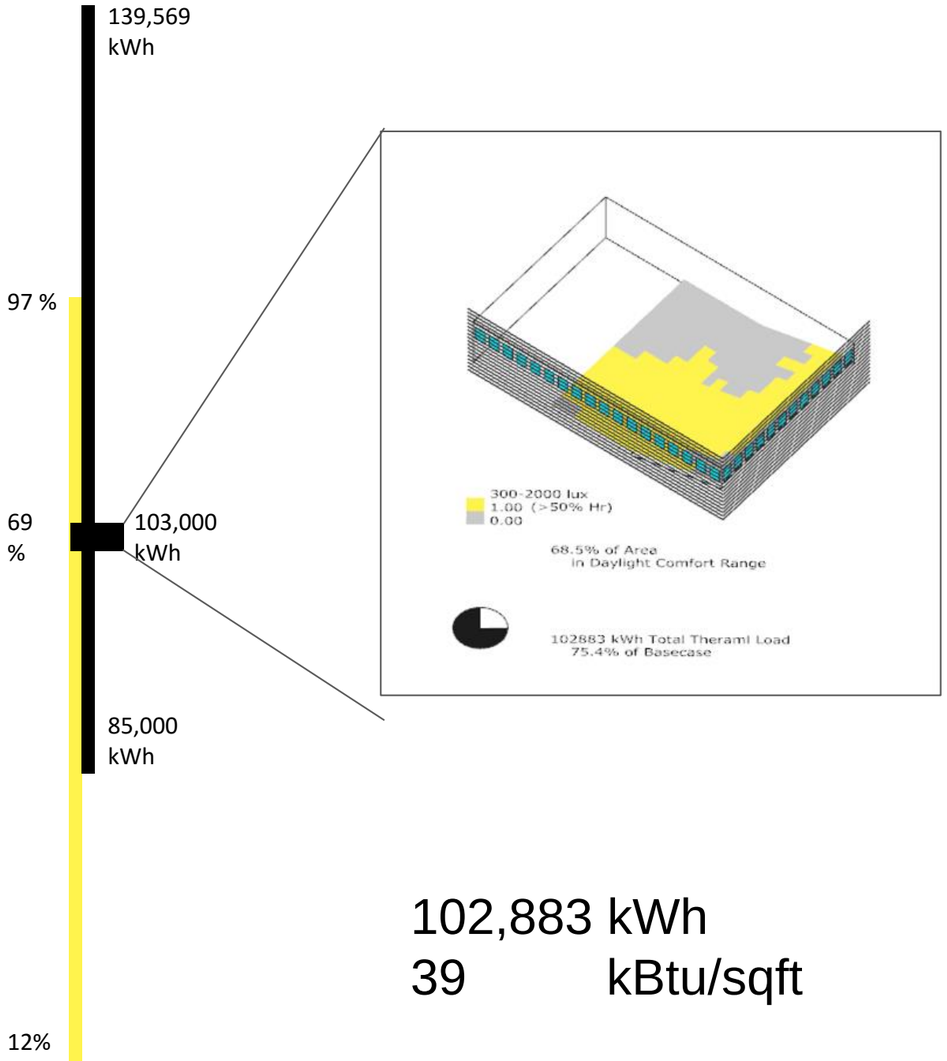
Glazing Ratio

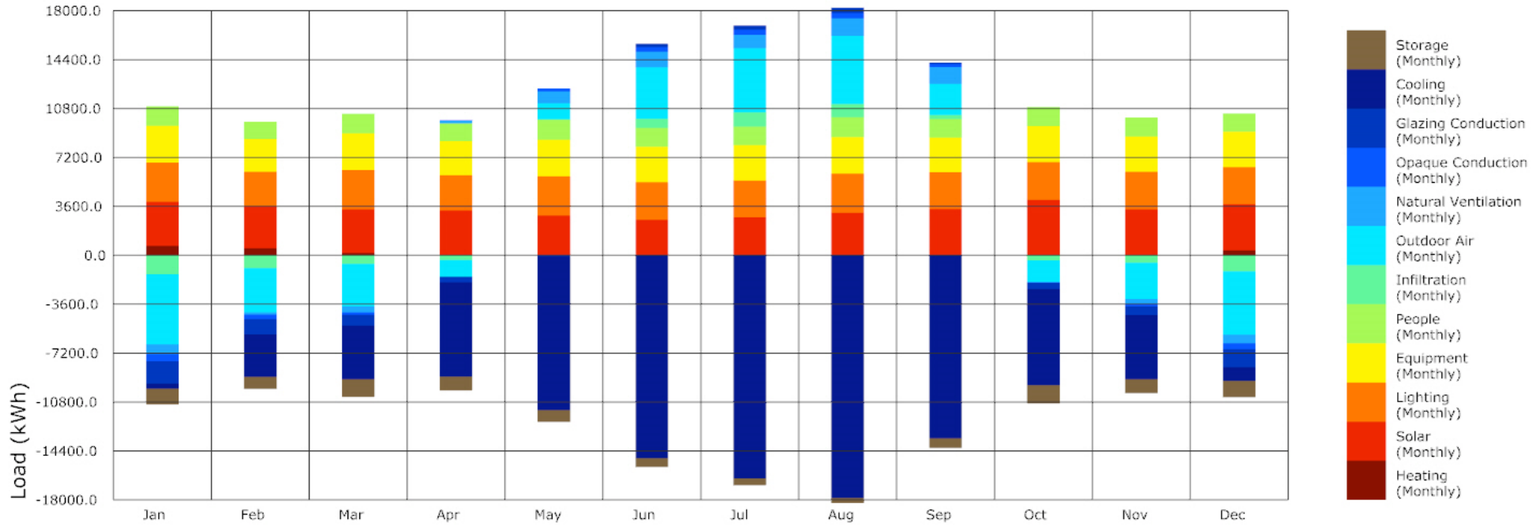


Window-Wall ratio ranges from 20% to 80%, in which 10% increasement of each step, to test the right range for this specific open office.

STUDY OF OFFICE ZONE

Shading Devices





Room Load Balance

102,883 kWh
39 kBtu/sqft

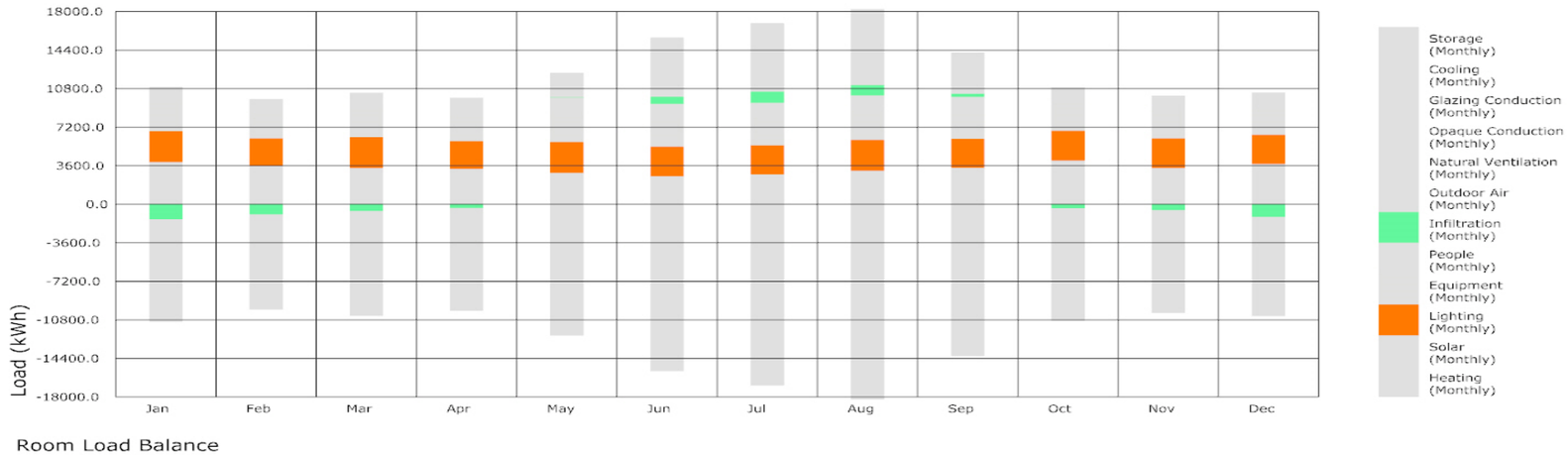
STUDY OF OFFICE ZONE

Energy Loads

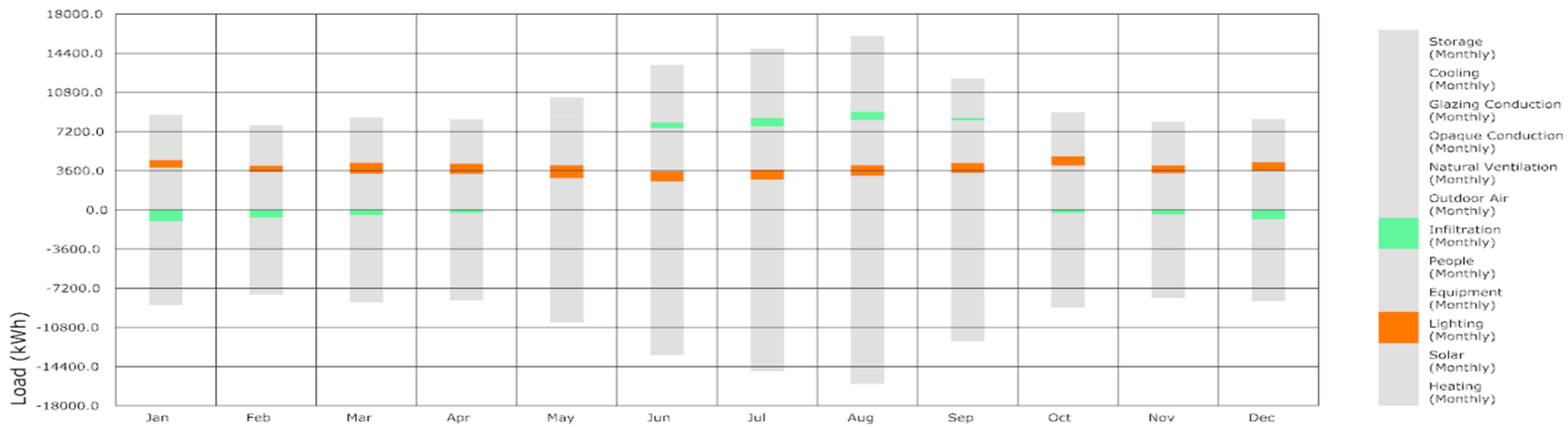
Before	102,883	kWh
	39	kBtu/sqft

16.7%

After	85,688	kWh
	33	kBtu/sqft



Room Load Balance



Room Load Balance

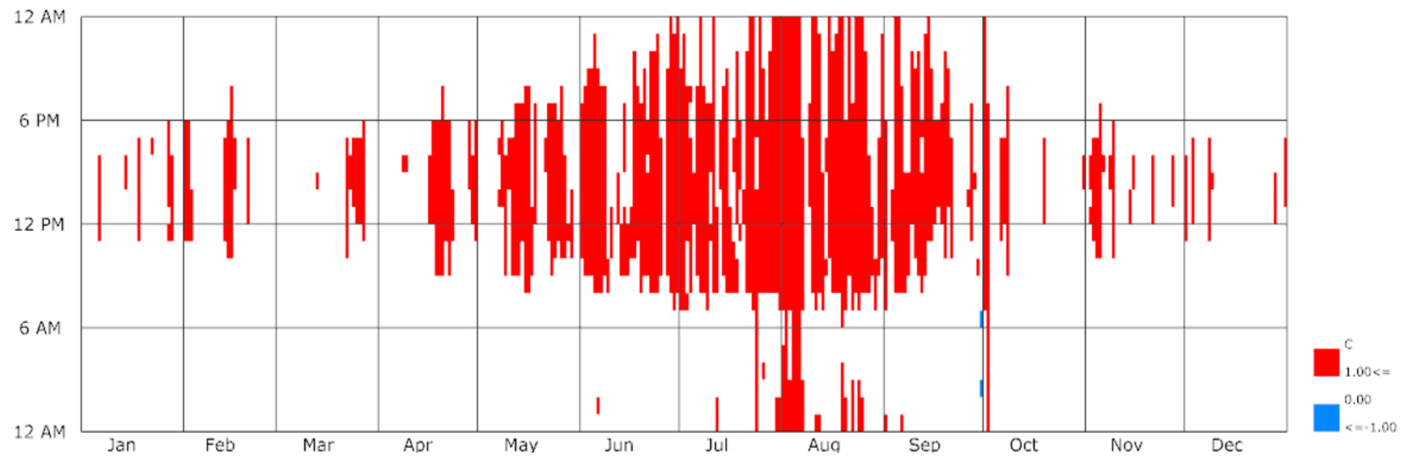
STUDY OF OFFICE ZONE

Adaptive Comfort

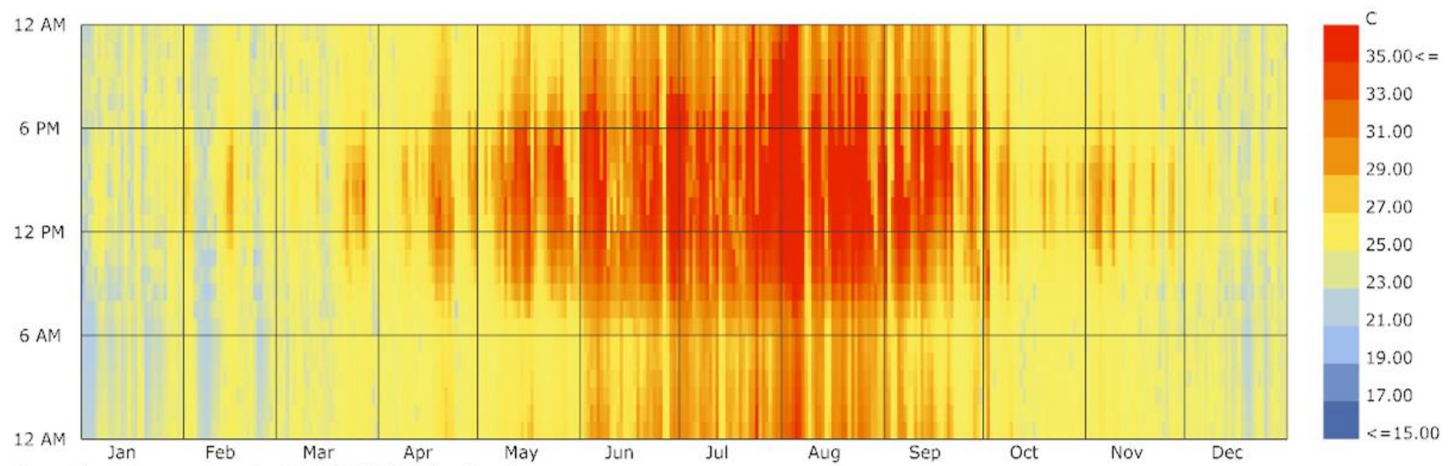
Adaptive Comfort

68%

Of Annual hours



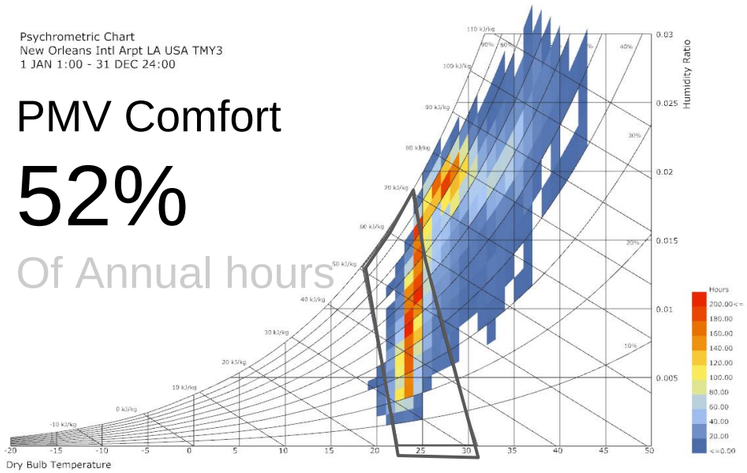
Operative Temperature

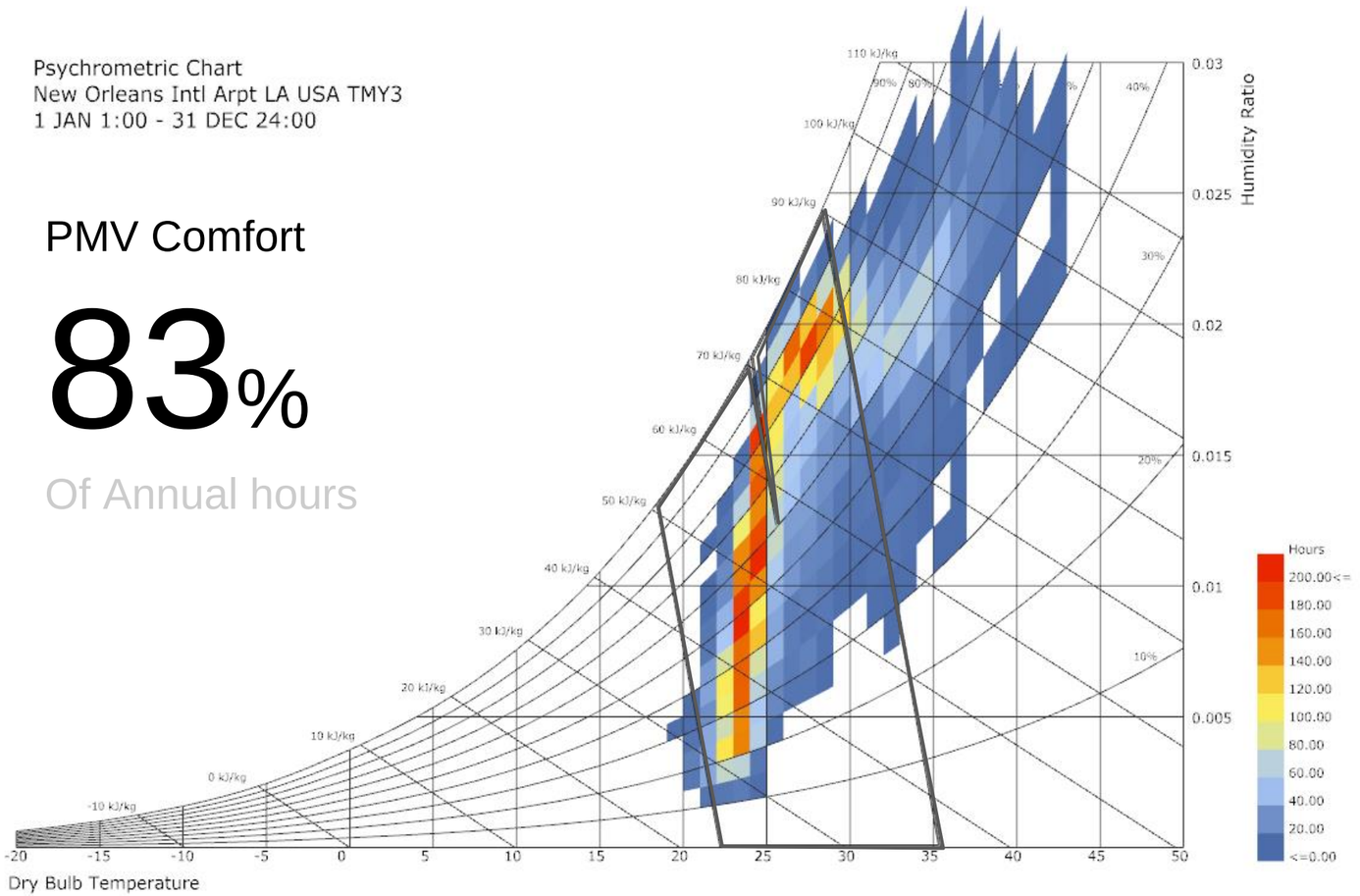


Operative Temperature for NEWOFFICE (C) - Hourly
New Orleans Intl Arpt LA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

STUDY OF OFFICE ZONE

PMV Comfort

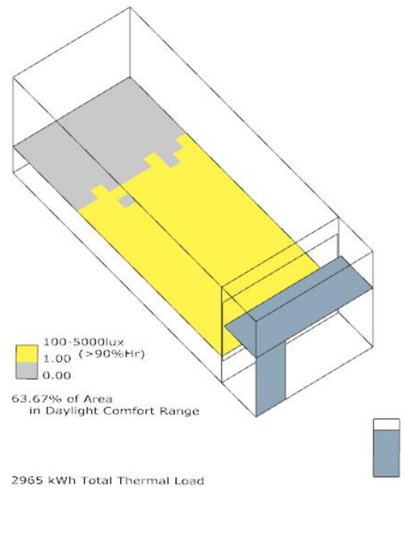




Active Occupant (with T-Shirt)

SUMMARY

Apartment & Open Office

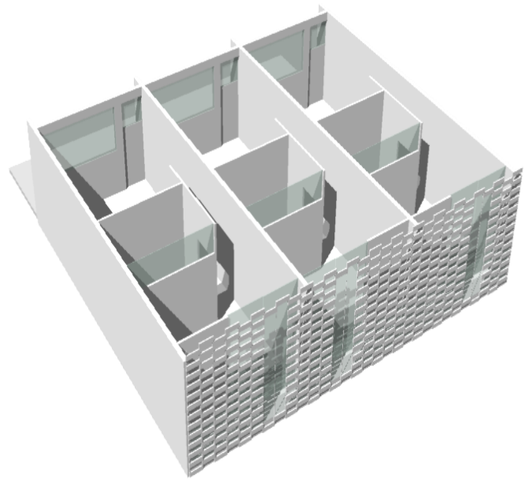


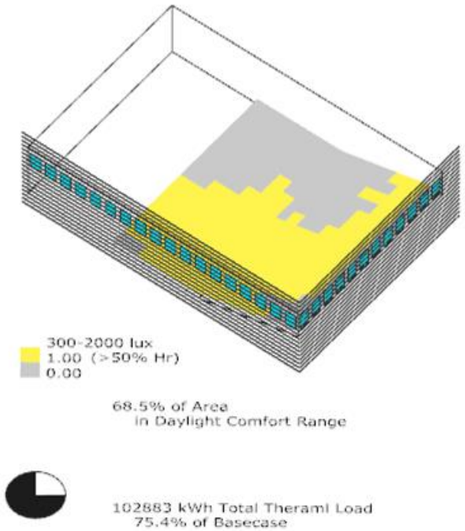
Adaptive Comfort

75%

Of Annual hours

LOAD 26 kBtu/sqft



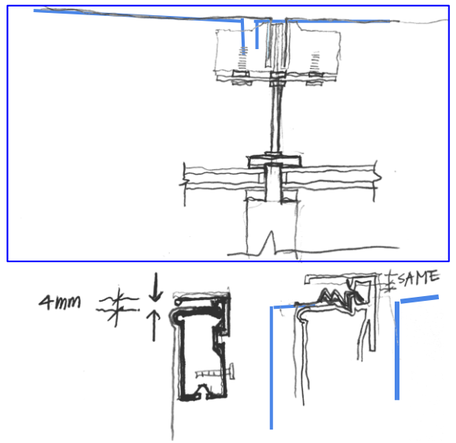


Adaptive Comfort

68%

Of Annual hours

LOAD 33 kBtu/sqft



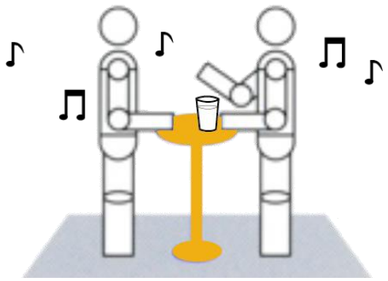
APPENDIX

3 ARCH_ PERFORMANCE

Architectural Challenges

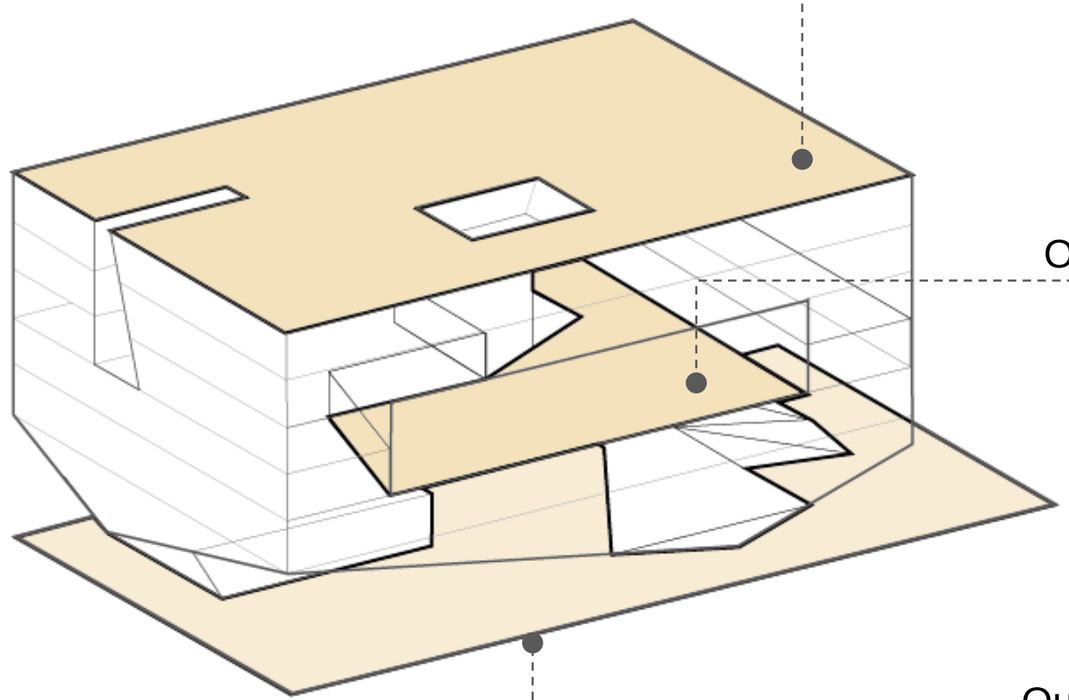
OPENSPACE

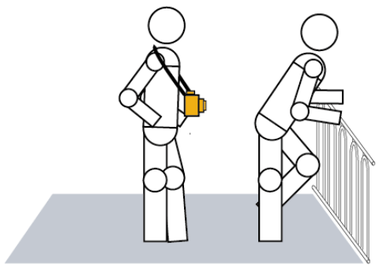
New Orleans



Roof garden & Bar

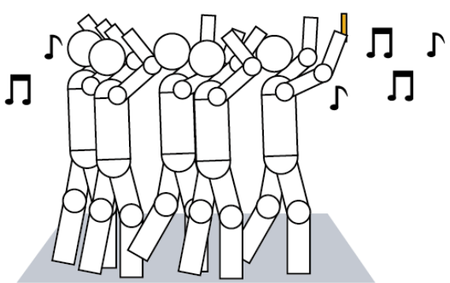
Roof





Outlook to French Quarter

4F

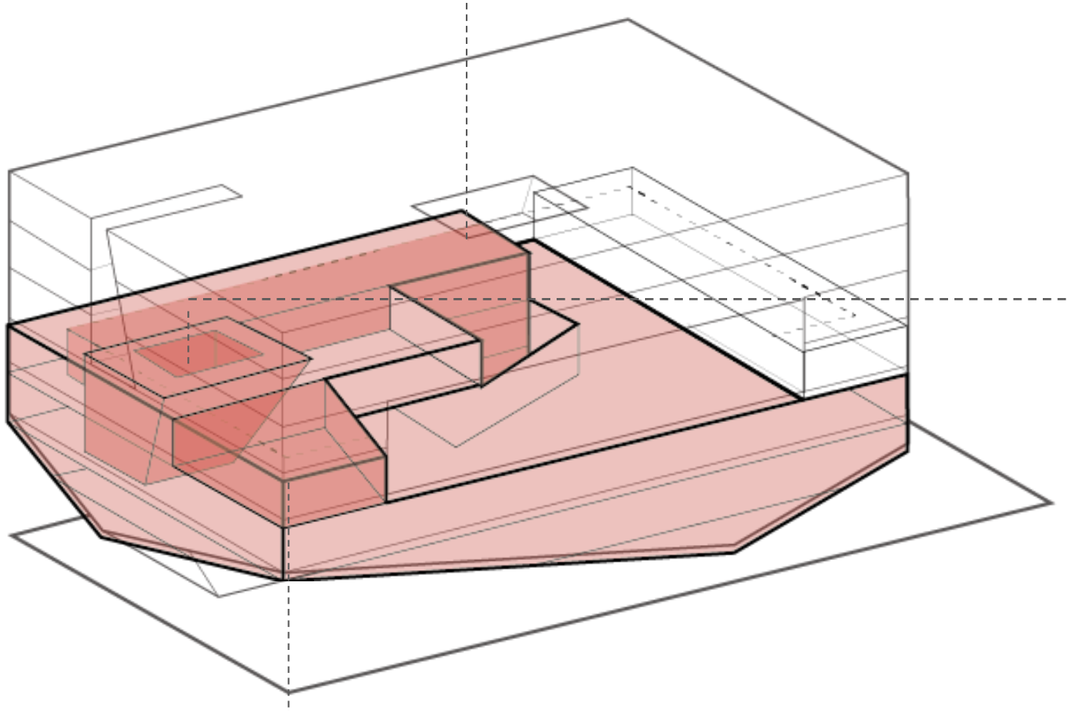


Outdoors for festival events

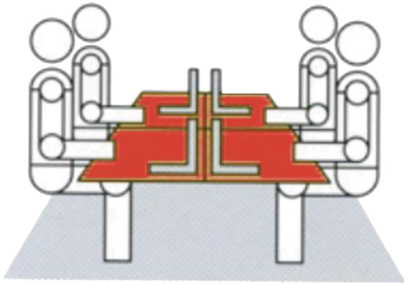
Ground floor

OPENOFFICE

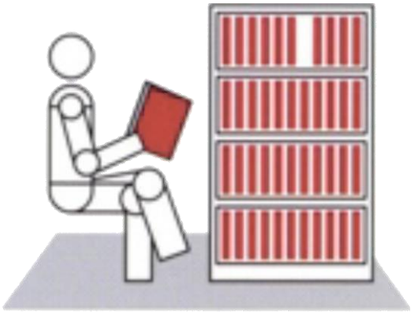
Institute



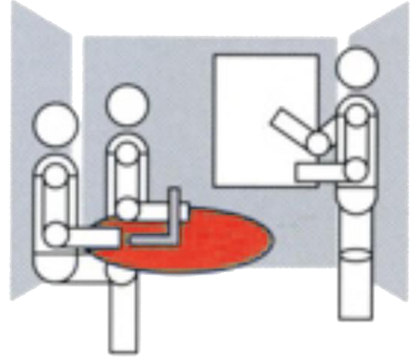
Openoffice



Public Library

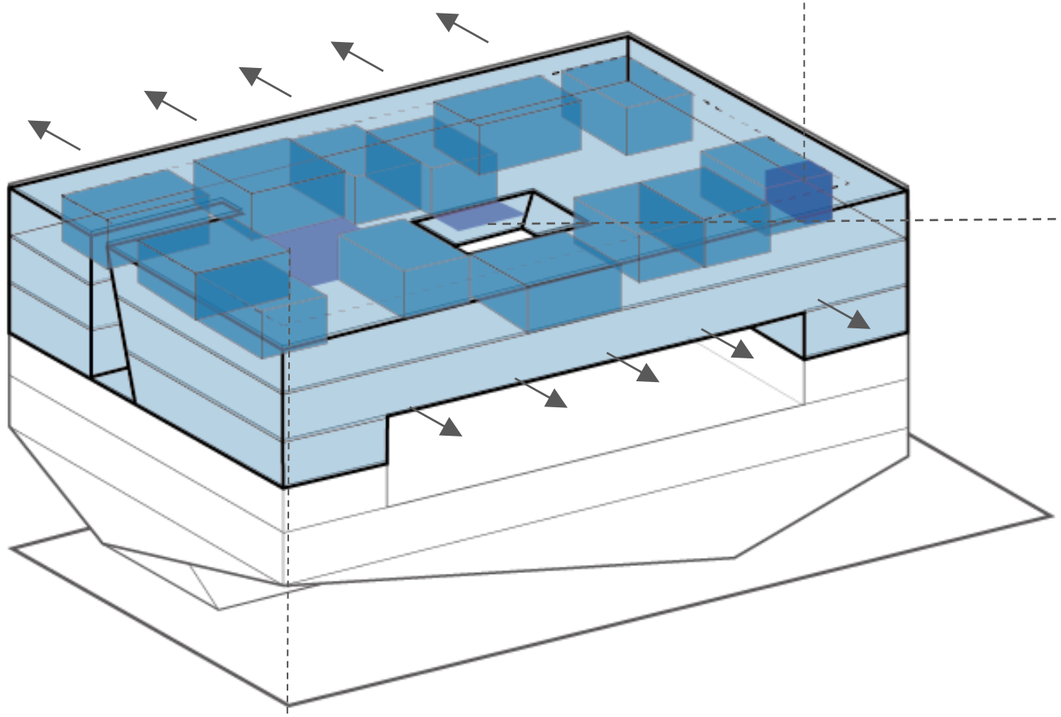


Classroom

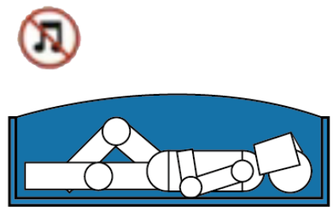


OPENSPACE

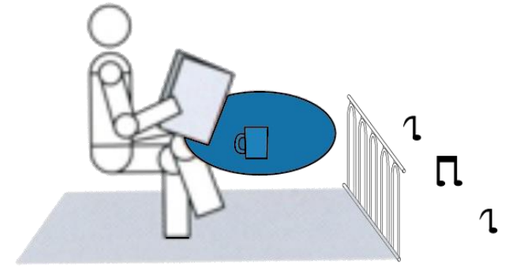
Residential Space



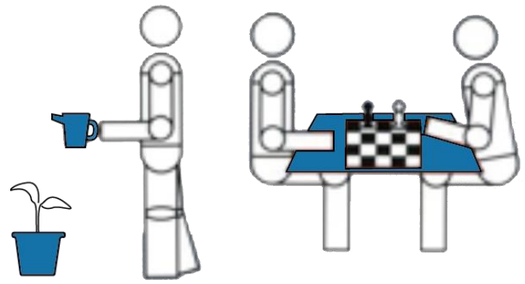
Quiet private space



Individual balcony

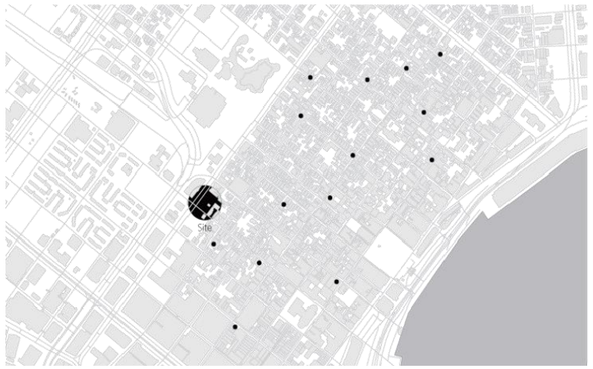


Share space

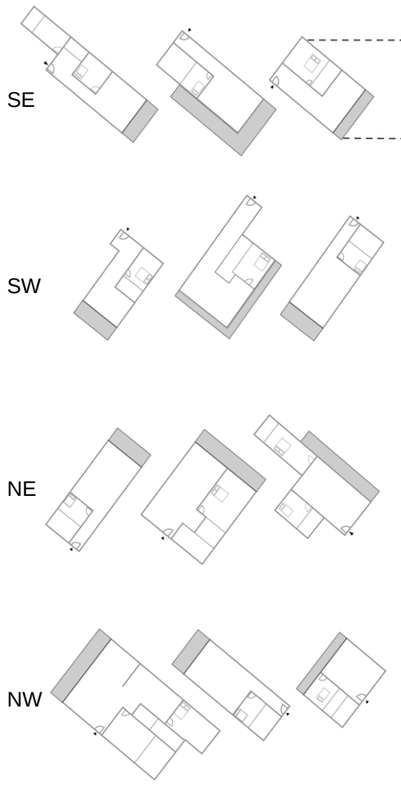


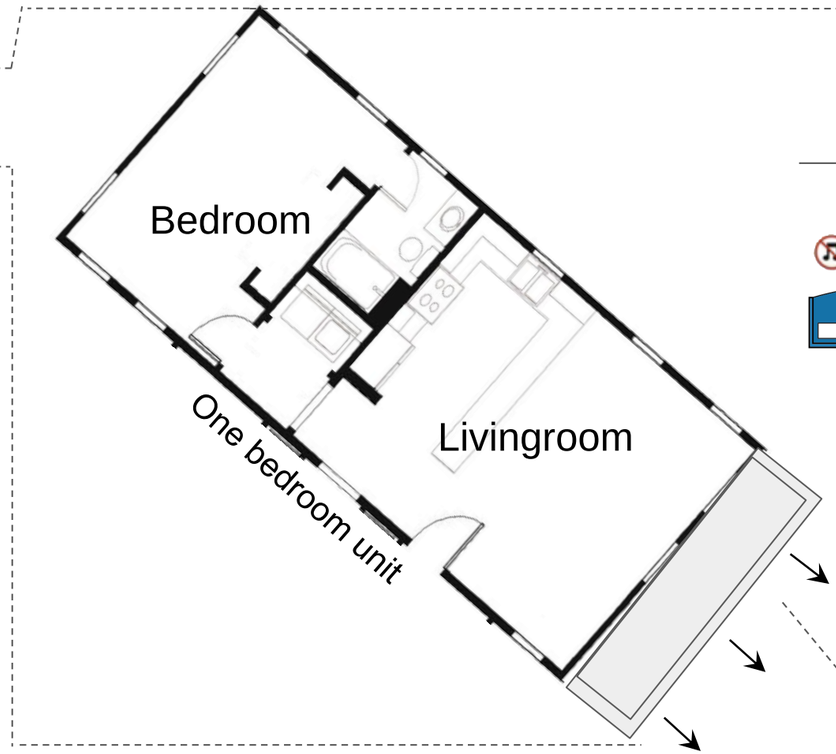
RESIDENTIAL

Unit Study

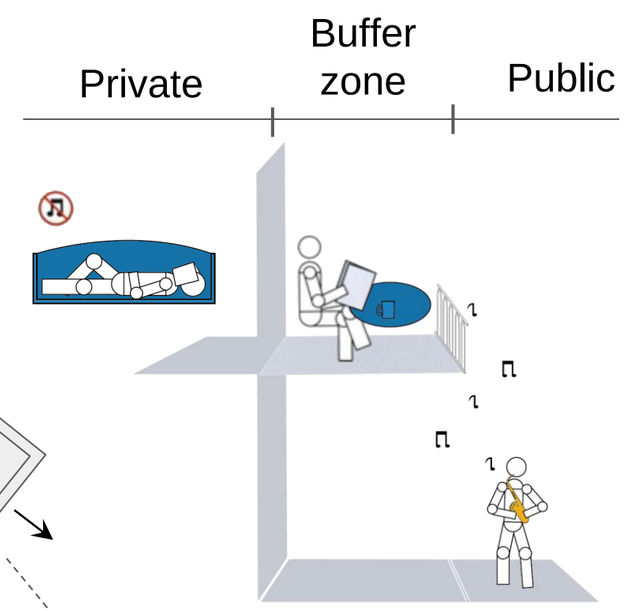


Balcony Direction

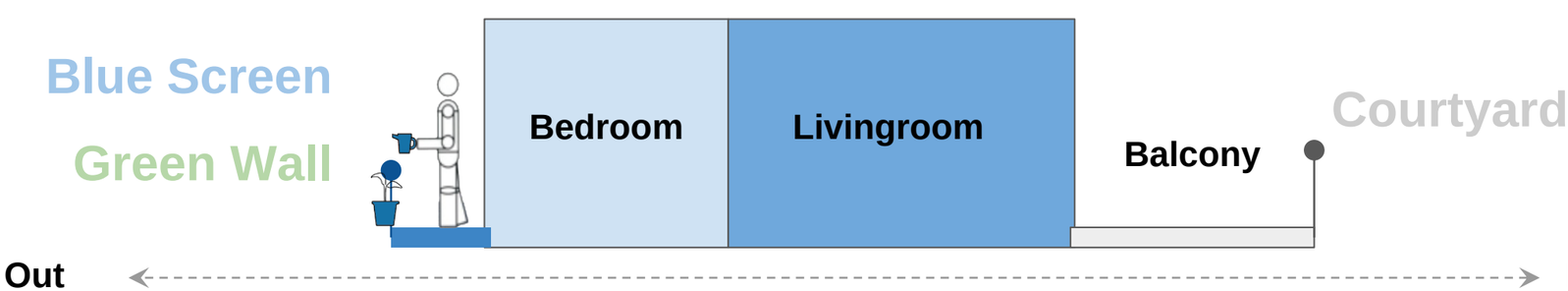




Quiet Private space



View out & buffer zone



APPENDIX

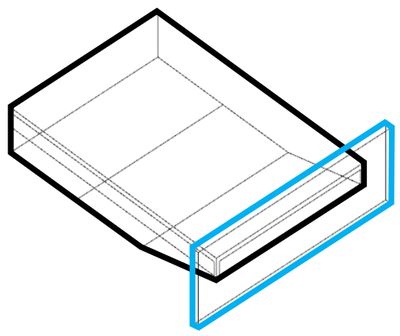
4 EVAPORATIVE COOLING

Simulation Research

SIMULATION MEANS

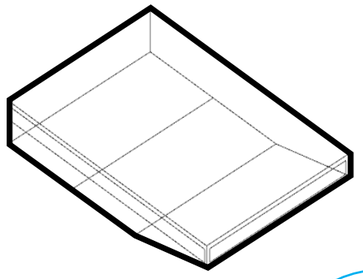
1

EnergyPlus
ZoneCoolTower:Shower



2

Wet bulb Temperature



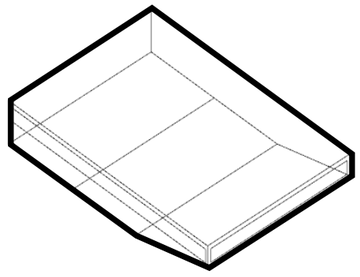
EPW

Wet Bulb Temperature
-
Dry Bulb Temperature

x 0.6

3

Evaporative Rate Equation



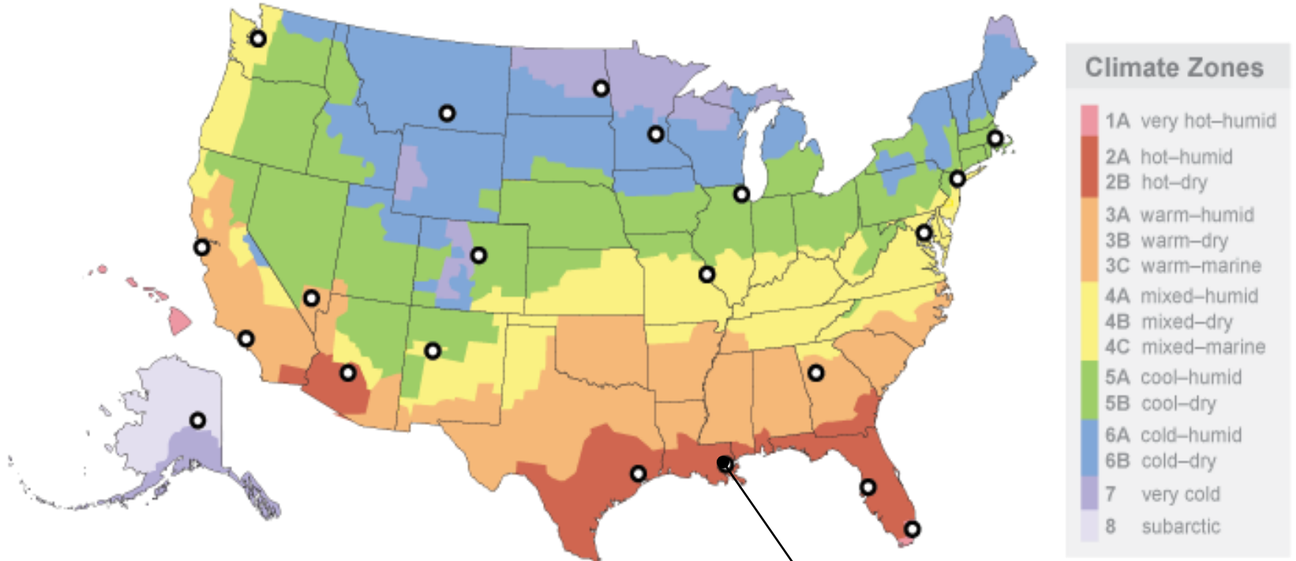
EPW

New Air Temperature

CLIMATE ZONE

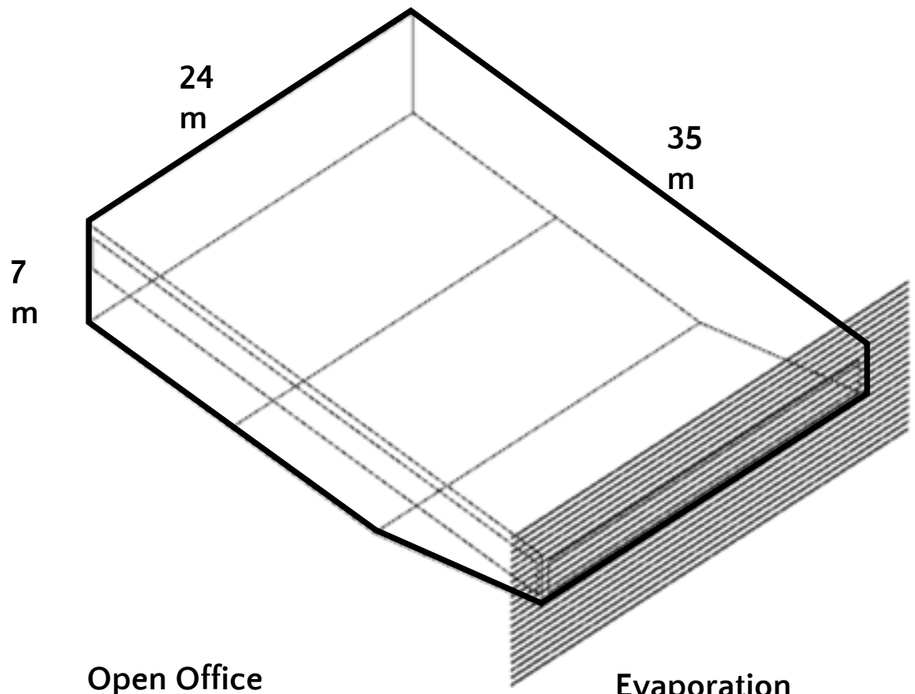
Site Climate & Simulation Data Source

WEATHER DATA:	USA_LA_New.Orleans.Intl.AP.722310_T MY3
LATITUDE:	30
LONGITUDE:	-90.25
CDD:	1280 Degree days
HDD:	741 Degree days
CLIMATE ZONE:	2A
CHARACTERISTIC:	hot-humid



BUILDING INFORMATION

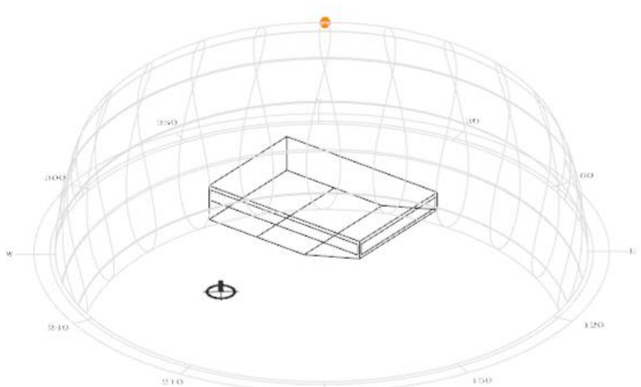
Dimension and EnergyPlus Settings



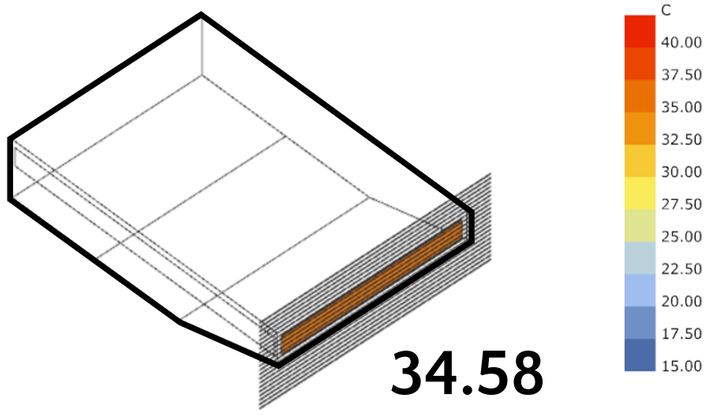

```
BuildingSurface:Detailed,
    newOffice_Srf_4,    !- Name
    ROOF,    !- Surface Type
    Exterior Roof,    !- Construction Name
    newOffice,    !- Zone Name
    Adiabatic,    !- Outside Boundary
Condition
    ,    !- Outside Boundary Condition Object
    NoSun,    !- Sun Exposure
    NoWind,    !- 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

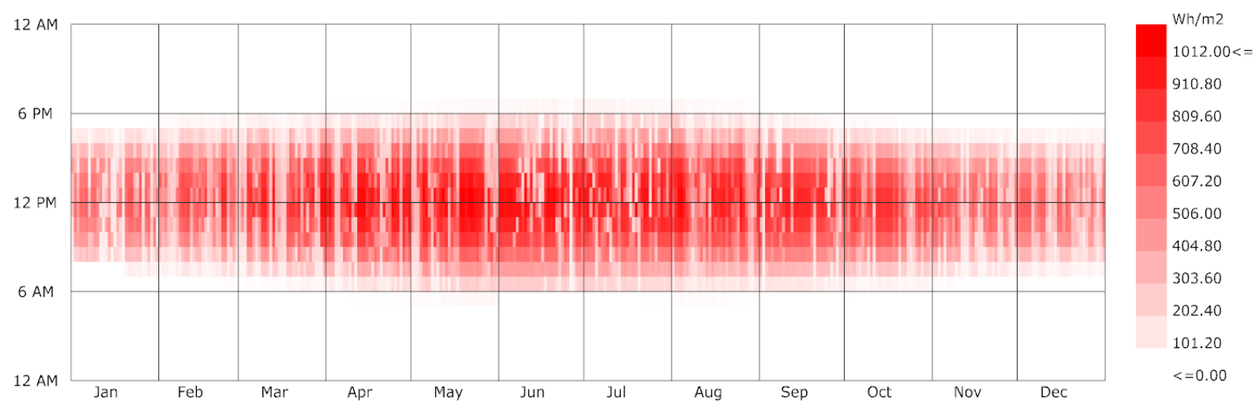
Base Case



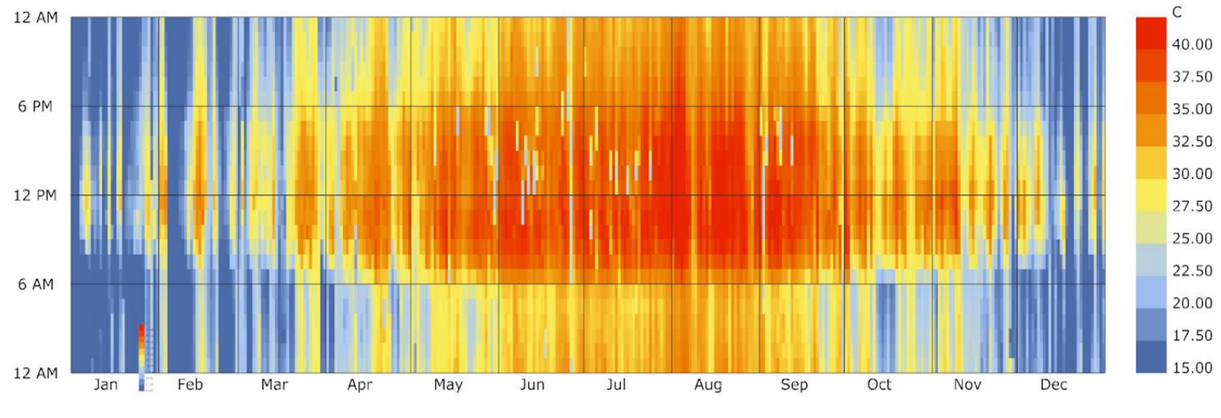
Test Building Orientation & Sun Position @ Jun 21st 12 PM



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



Global Horizontal Radiation
Annual Hourly Data

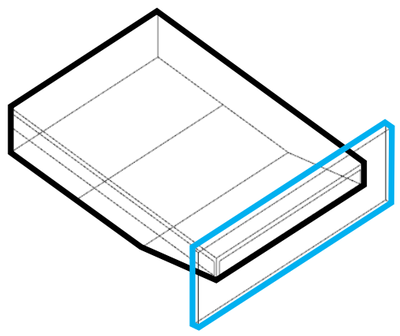


Outer Surface Temperature of Test Windows Surface
Annual Hourly Data

SIMULATION MEANS

1

EnergyPlus
ZoneCoolTower:Shower



2

Wet bulb Temperature

EPW

Wet Bulb Temperature

–

Dry Bulb Temperature

x 0.6

3

Evaporative Rate Equation

EPW

New Air Temperature

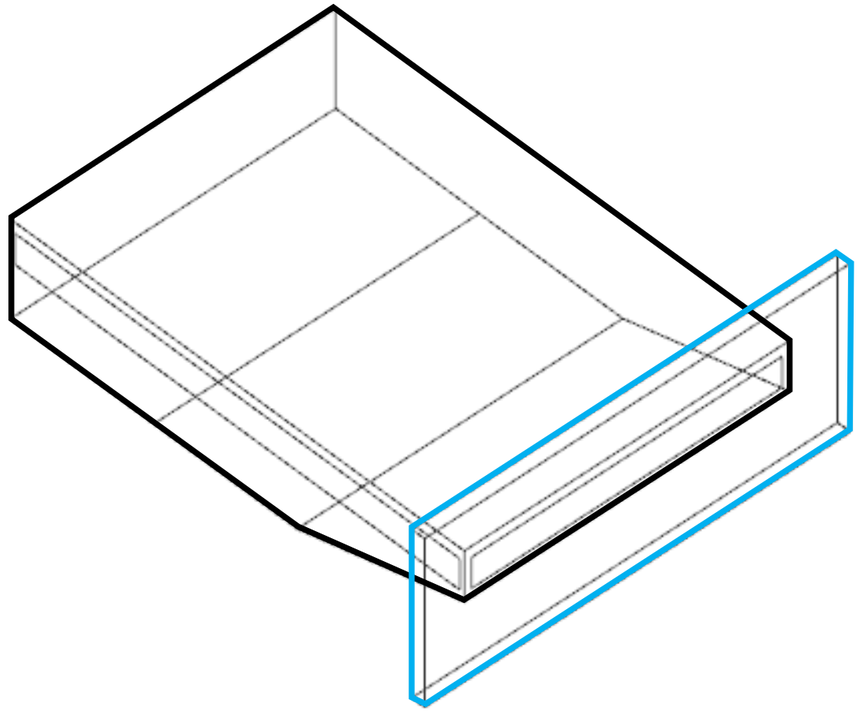
1 ENERGYPLUS EMBED FUNCTION
ZoneCoolTower:Shower

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, *!- 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)
5.0, *!- Effective tower height in m*
1.0, *!- Exit area in m2*
10.0, *!- Maximum supply air volume flow rate in m3/s*
18.0, *!- Minimum indoor temperature to prevent overcooling in C*
0.05, *!- Fraction of Water loss*
0.05, *!- Fraction of flow that goes to outside*
250.0; *!- Rated power consumption in W*

1 ENERGYPLUS EMBED FUNCTION
ZoneCoolTower:Shower



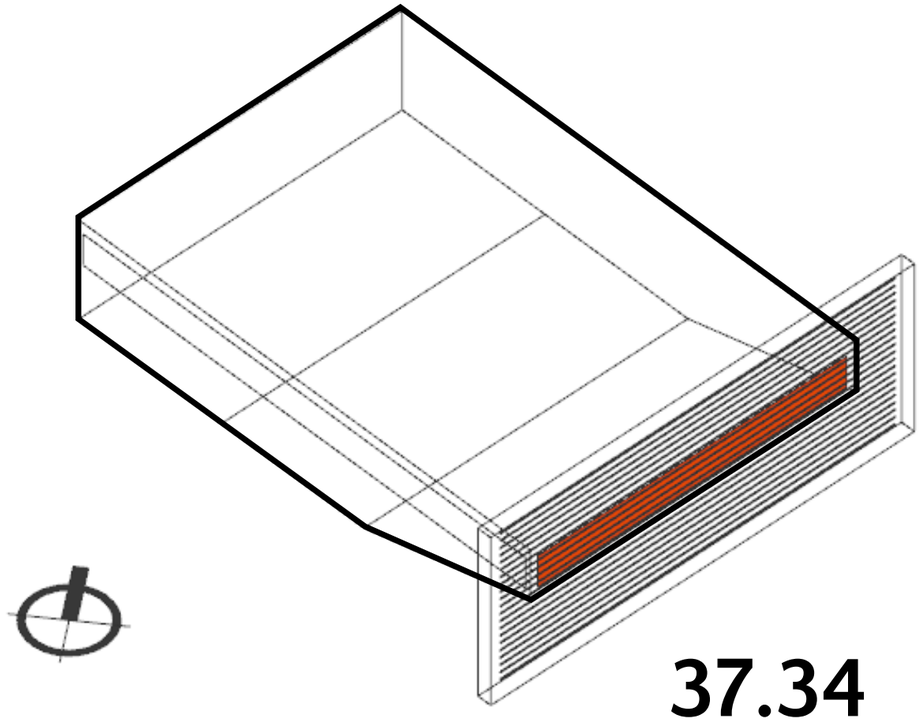
Cooling Zone

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

Air Wall:

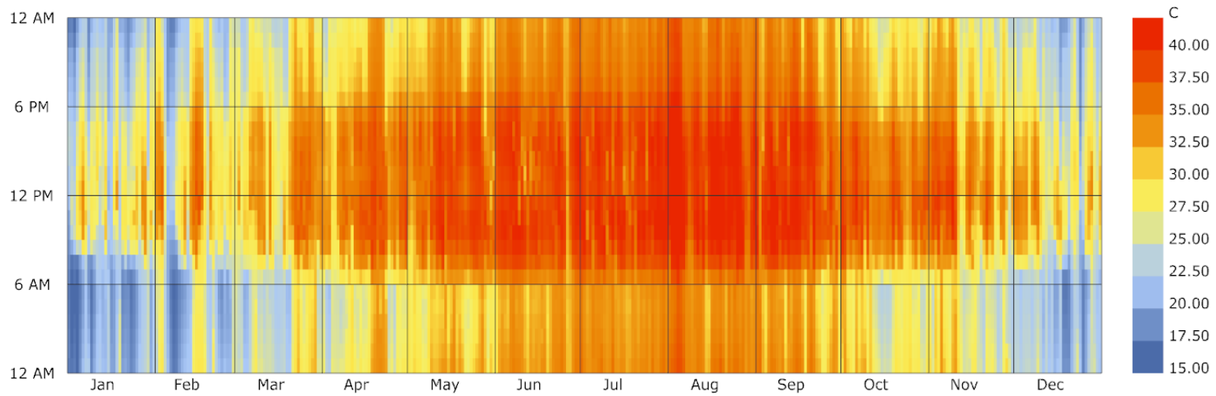
Material	*Material Type*
MediumSmooth	*- Roughness*
0.01	*- Thickness {m}*
0.6	*- Conductivity {W/m-K}*
800	*- Density {kg/m3}*
1000	*- Specific Heat {J/kg-K}*
0.95	*- Thermal Absorptance*
0.7	*- Solar Absorptance*
0.7	*- Visible Absorptance*

1 ENERGYPLUS EMBED FUNCTION
ZoneCoolTower:Shower



37.34
°C

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



Outer Surface Temperature of Test Windows Surface
Annual Hourly Data

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.

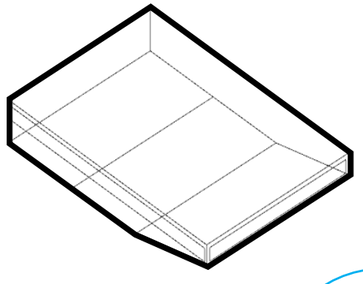
SIMULATION MEANS

1

EnergyPlus
ZoneCoolTower:Shower

2

Wet bulb Temperature



EPW

Wet Bulb Temperature
-
Dry Bulb Temperature

x 0.6

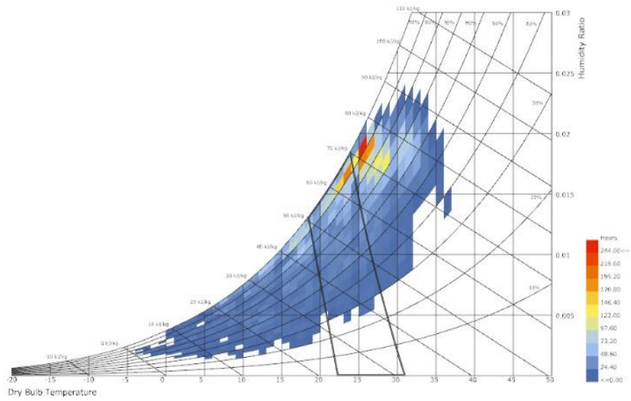
3

Evaporative Rate Equation

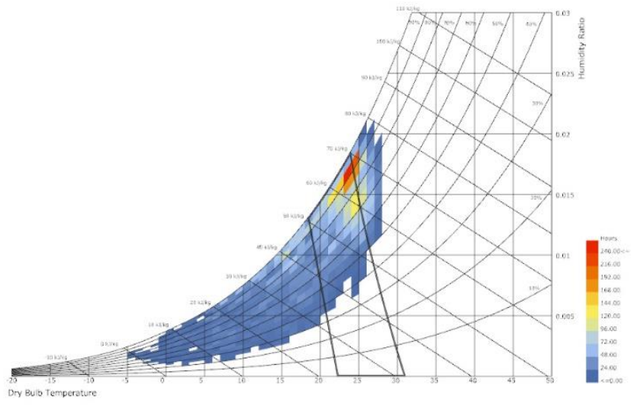
EPW

New Air Temperature

2 WET BULB TEMPERATURE
Generating a new EPW file

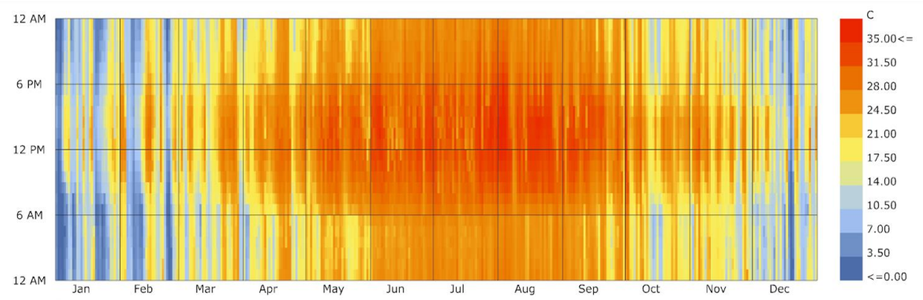


Psychrometric Chart

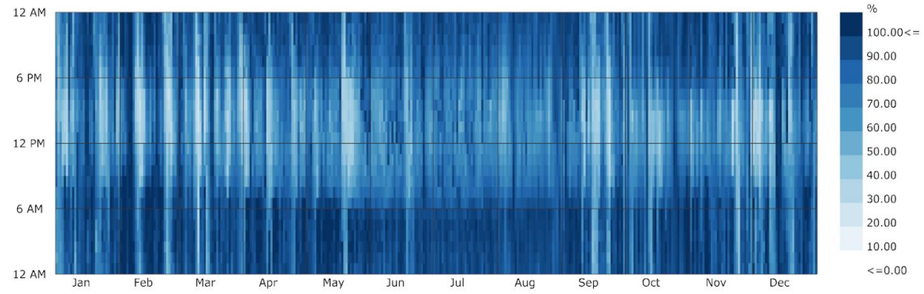


With Max Evaporative Cooling Effect

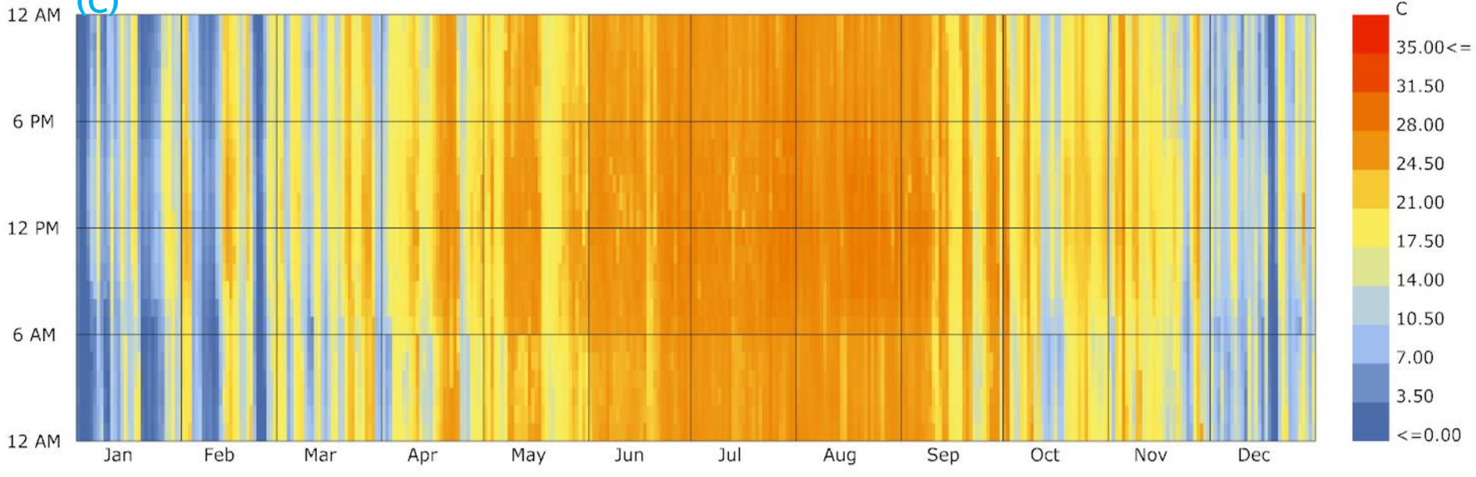
Dry Bulb Temperature (C)



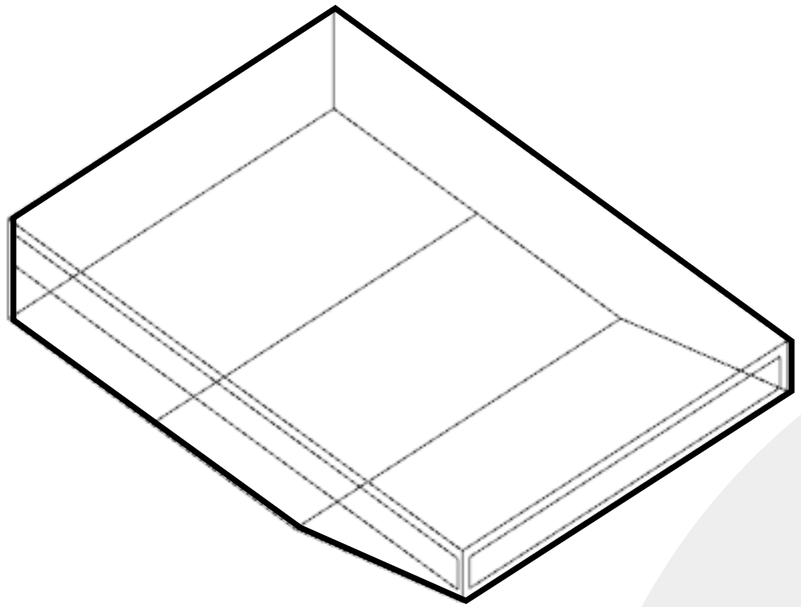
Relative Humidity (%)

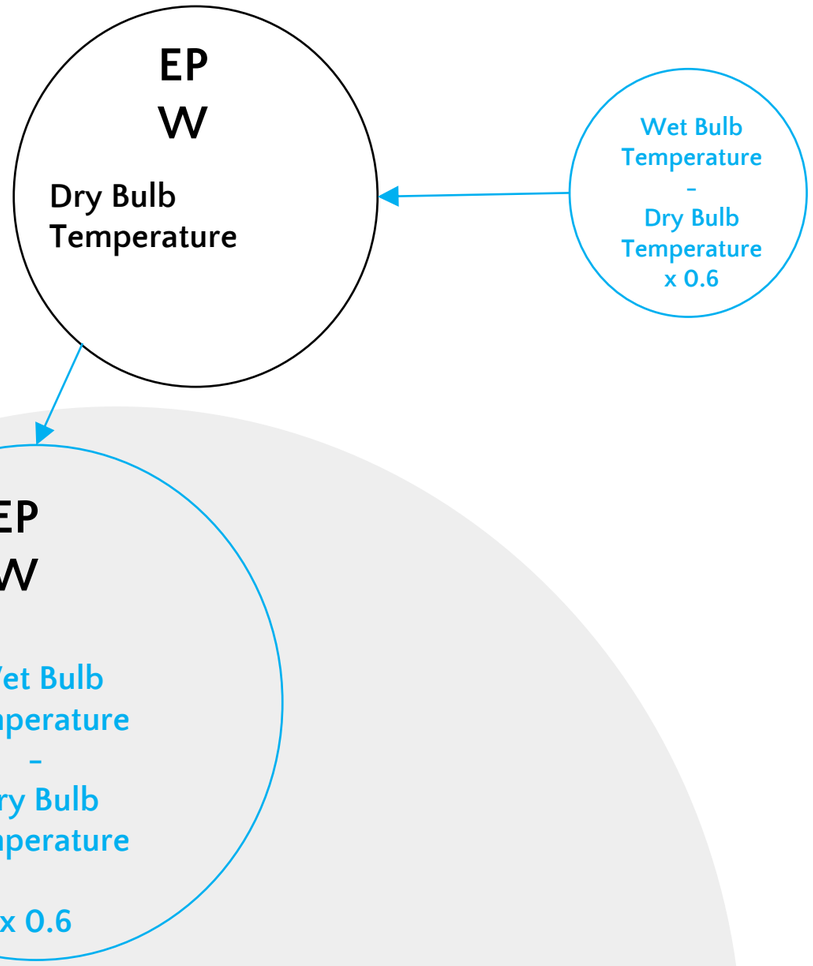


Wet Bulb Temperature (C)

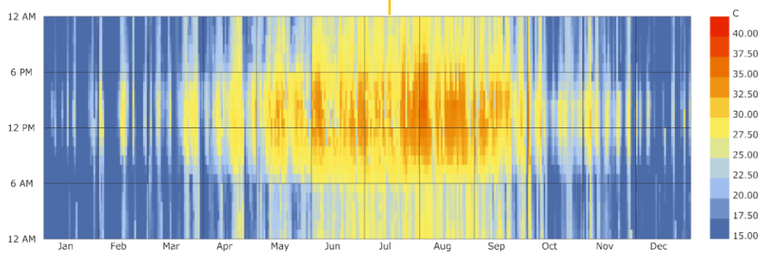


2 WET BULB TEMPERATURE
Generating a new EPW file





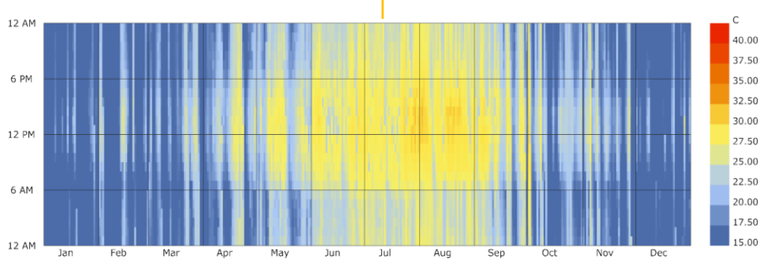
2 WET BULB TEMPERATURE
Generating a new EPW file



Dry Bulb Temperature

Original EPW File

```
0 LOCATION,New Orleans Intl Arpt,LA,USA,TMY3,722310,30.00,-90.25,-6.0,1.0
  DESIGN CONDITIONS,1,Climate Design Data 2009 ASHRAE Handbook,,Heating,1,-0.3,1.9,-8.8,1.8,2.8,-
1 5.9,2.3,5,10.6,13.1,9.4,11.3,4,10,Cooling,8,8.5,34.2,25.6,33.3,25.4,32.5,25.2,27.1,31.5,26.7,31.1,26.3,30.5,3.4,0,25.9,21.3,29.1,25.5,20.8,28.8,25.2,20.3,28.5,85,31.6,83.1,31.1,81.4,30.5,688,Extremes,9
  .2,8.3,7.5,29.2,-3.9,35.8,3.2,1.1,-6.2,36.6,-8.1,37.2,-9.9,37.8,-12.2,38.6
  TYPICAL/EXTREME PERIODS,6,Summer - Week Nearest Max Temperature For Period,Extreme,7/27,8/ 2,Summer - Week Nearest Average Temperature For Period,Typical,8/10,8/16,Winter - Week Nearest Min Temperature
2 For Period,Extreme,1/20,1/26,Winter - Week Nearest Average Temperature For Period,Typical,12/ 8,12/14,Autumn - Week Nearest Average Temperature For Period,Typical,10/20,10/26,Spring - Week Nearest
  Average Temperature For Period,Typical,4/26,5/ 2
  GROUND
3 TEMPERATURES,3,.5,,,,12.99,12.26,13.56,15.58,20.88,24.97,27.72,28.56,27.13,23.96,19.72,15.78,2,,,,15.68,14.38,14.64,15.72,19.26,22.47,25.03,26.40,26.11,24.31,21.39,18.29,4,,,,17.90,16.57,16.27,16.68,18
  .68,20.84,22.82,24.20,24.52,23.74,22.02,19.93
4 HOLIDAYS/DAYLIGHT SAVINGS,No,0,0,0
5 COMMENTS 1,Custom/User Format -- WMO#722310; NREL TMY Data Set (2008); Period of Record 1973-2005 (Generally)
6 COMMENTS 2, -- Ground temps produced with a standard soil diffusivity of 2.3225760E-03 {m**2/day}
7 DATA PERIODS,1,1,Data,Sunday, 1/ 1,12/31
8 2001,1,1,1,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.2,63,102900,0,0,293,0,0,0,0,0,0,0,350,4.1,9,9,14.4,2134,9,999999999,160,0.0710,0,88,0.170,0.0,1.0
9 2001,1,1,2,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-4.4,51,102900,0,0,301,0,0,0,0,0,0,0,360,3.6,10,10,14.4,2134,9,999999999,150,0.0710,0,88,0.170,0.0,1.0
10 2001,1,1,3,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-2.8,58,102800,0,0,294,0,0,0,0,0,0,0,20,6.2,9,9,14.4,2134,9,999999999,139,0.0710,0,88,0.170,0.0,1.0
11 2001,1,1,4,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,20,5.7,10,10,14.4,1280,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
12 2001,1,1,5,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,30,6.7,10,10,14.4,1097,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
13 2001,1,1,6,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-3.3,57,102800,0,0,300,0,0,0,0,0,0,0,50,5.7,10,10,14.4,1981,9,999999999,120,0.0710,0,88,0.170,0.0,1.0
14 2001,1,1,7,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-1.7,66,102900,0,35,302,0,0,0,0,0,0,0,30,5.2,10,10,16.0,1829,9,999999999,110,0.0710,0,88,0.170,0.0,1.0
15 2001,1,1,8,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-2.2,61,103000,138,1415,303,0,0,0,0,0,0,0,20,6.2,10,10,16.0,1128,9,999999999,100,0.0710,0,88,0.170,0.0,1.0
16 2001,1,1,9,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.3,0.6,82,103000,392,1415,301,46,0,46,5487,0,5487,1943,30,5.2,10,10,12.8,1067,9,999999999,89,0.0710,0,88,0.170,0.0,1.0
17 2001,1,1,10,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.3,-0.6,75,103100,603,1415,300,67,0,67,8136,0,8136,3089,30,6.2,10,10,16.0,1189,9,999999999,80,0.0710,0,88,0.170,0.0,1.0
18 2001,1,1,11,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,0.0,73,103100,755,1415,306,82,0,82,10074,0,10074,3989,30,6.2,10,10,16.0,1311,9,999999999,69,0.0710,0,88,0.170,0.0,1.0
19 2001,1,1,12,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,0.0,73,102900,837,1415,306,245,18,234,28105,1560,27179,9784,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
20 2001,1,1,13,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,5.0,0.0,70,102900,843,1415,308,244,12,237,28047,1043,27423,9913,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
21 2001,1,1,14,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,5.6,0.0,67,102900,773,1415,296,219,18,209,25095,1511,24267,8636,40,3.6,8,8,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
22 2001,1,1,15,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,6.7,-0.6,59,102900,632,1415,285,392,506,165,40882,49633,18625,3372,10,3.6,3,3,16.0,77777,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
```

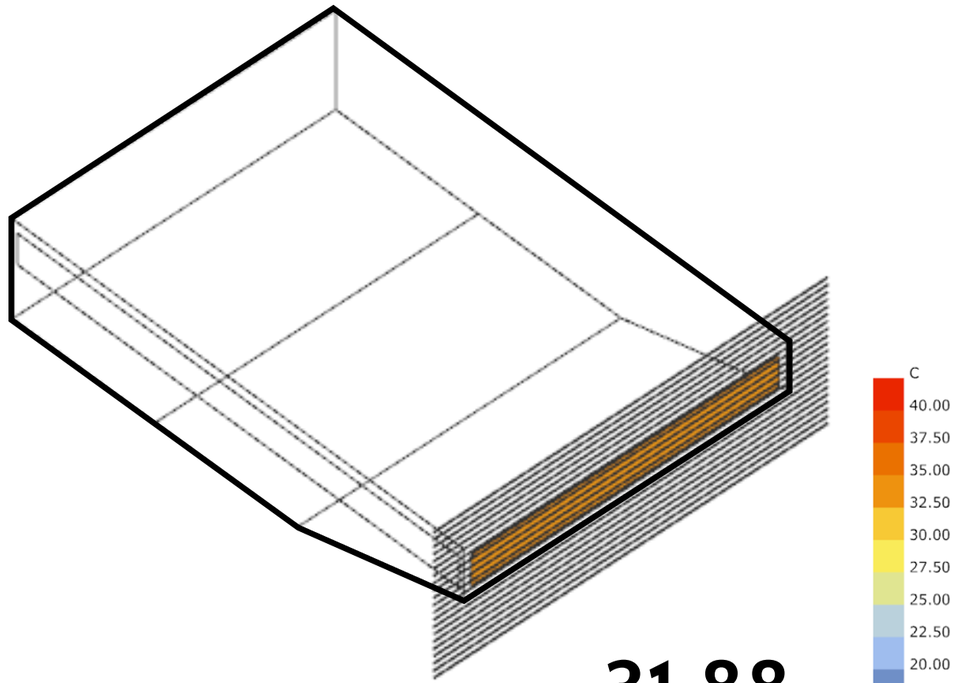


New Dry Bulb Temperature

New EPW File with Dry Bulb Temperature Modified

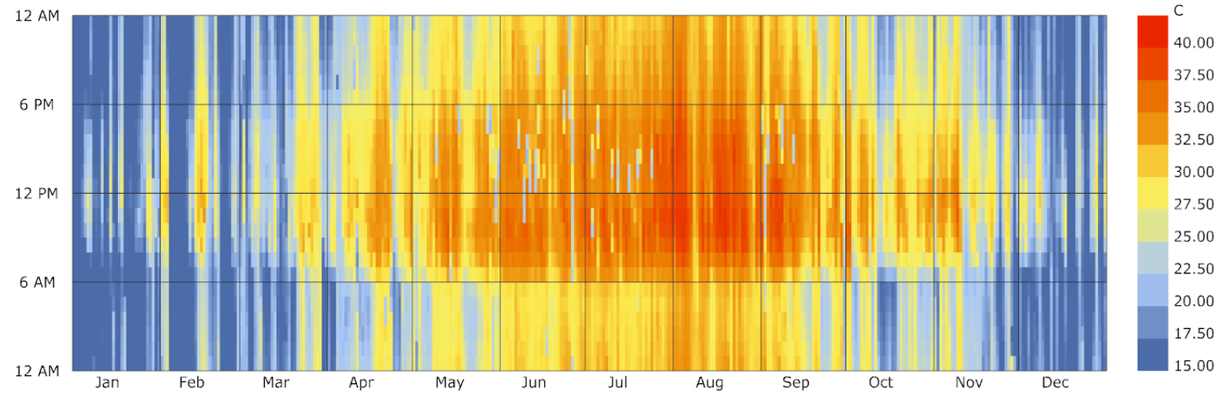
```
0 LOCATION,New Orleans Intl Arpt,LA,USA,TMY3,722310,30.00,-90.25,-6.0,1.0
  DESIGN CONDITIONS,1,Climate Design Data 2009 ASHRAE Handbook,,Heating,1,-0.3,1.9,-8.8,1.8,2.8,-
1 5.9,2.3,5,10.6,13.1,9.4,11.3,4,10,Cooling,8,8.5,34.2,25.6,33.3,25.4,32.5,25.2,27.1,31.5,26.7,31.1,26.3,30.5,3.4,0,25.9,21.3,29.1,25.5,20.8,28.8,25.2,20.3,28.5,85,31.6,83.1,31.1,81.4,30.5,688,Extremes,9
  .2,8.3,7.5,29.2,-3.9,35.8,3.2,1.1,-6.2,36.6,-8.1,37.2,-9.9,37.8,-12.2,38.6
  TYPICAL/EXTREME PERIODS,6,Summer - Week Nearest Max Temperature For Period,Extreme,7/27,8/ 2,Summer - Week Nearest Average Temperature For Period,Typical,8/10,8/16,Winter - Week Nearest Min Temperature
2 For Period,Extreme,1/20,1/26,Winter - Week Nearest Average Temperature For Period,Typical,12/ 8,12/14,Autumn - Week Nearest Average Temperature For Period,Typical,10/20,10/26,Spring - Week Nearest
  Average Temperature For Period,Typical,4/26,5/ 2
  GROUND
3 TEMPERATURES,3,.5,,,,12.99,12.26,13.56,15.58,20.88,24.97,27.72,28.56,27.13,23.96,19.72,15.78,2,,,,15.68,14.38,14.64,15.72,19.26,22.47,25.03,26.40,26.11,24.31,21.39,18.29,4,,,,17.90,16.57,16.27,16.68,18
  .68,20.84,22.82,24.20,24.52,23.74,22.02,19.93
4 HOLIDAYS/DAYLIGHT SAVINGS,No,0,0,0
5 COMMENTS 1,Custom/User Format -- WMO#722310; NREL TMY Data Set (2008); Period of Record 1973-2005 (Generally)
6 COMMENTS 2, -- Ground temps produced with a standard soil diffusivity of 2.3225760E-03 {m**2/day}
7 DATA PERIODS,1,1,Data,Sunday, 1/ 1,12/31
8 2001,1,1,1,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.412,-2.2,63,102900,0,0,293,0,0,0,0,0,0,0,350,4.1,9,9,14.4,2134,9,999999999,160,0.0710,0,88,0.170,0.0,1.0
9 2001,1,1,2,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.36,-4.4,51,102900,0,0,301,0,0,0,0,0,0,0,360,3.6,10,10,14.4,2134,9,999999999,150,0.0710,0,88,0.170,0.0,1.0
10 2001,1,1,3,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.666,-2.8,58,102800,0,0,294,0,0,0,0,0,0,0,20,6.2,9,9,14.4,2134,9,999999999,139,0.0710,0,88,0.170,0.0,1.0
11 2001,1,1,4,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.286,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,20,5.7,10,10,14.4,1280,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
12 2001,1,1,5,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.286,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,30,6.7,10,10,14.4,1097,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
13 2001,1,1,6,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.22,-3.3,57,102800,0,0,300,0,0,0,0,0,0,0,50,5.7,10,10,14.4,1981,9,999999999,120,0.0710,0,88,0.170,0.0,1.0
14 2001,1,1,7,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.538,-1.7,66,102900,0,35,302,0,0,0,0,0,0,0,30,5.2,10,10,16.0,1829,9,999999999,110,0.0710,0,88,0.170,0.0,1.0
15 2001,1,1,8,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.792,-2.2,61,103000,138,1415,303,0,0,0,0,0,0,0,20,6.2,10,10,16.0,1128,9,999999999,100,0.0710,0,88,0.170,0.0,1.0
16 2001,1,1,9,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.604,0.6,82,103000,392,1415,301,46,0,46,5487,0,5487,1943,30,5.2,10,10,12.8,1067,9,999999999,89,0.0710,0,88,0.170,0.0,1.0
17 2001,1,1,10,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,2.334,-0.6,75,103100,603,1415,300,67,0,67,8136,0,8136,3089,30,6.2,10,10,16.0,1189,9,999999999,80,0.0710,0,88,0.170,0.0,1.0
18 2001,1,1,11,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.302,0.0,73,103100,755,1415,306,82,0,82,10074,0,10074,3989,30,6.2,10,10,16.0,1311,9,999999999,69,0.0710,0,88,0.170,0.0,1.0
19 2001,1,1,12,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.302,0.0,73,102900,837,1415,306,245,18,234,28105,1560,27179,9784,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
20 2001,1,1,13,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.746,0.0,70,102900,843,1415,308,244,12,237,28047,1043,27423,9913,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
21 2001,1,1,14,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.178,0.0,67,102900,773,1415,296,219,18,209,25095,1511,24267,8636,40,3.6,8,8,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
22 2001,1,1,15,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.834,-0.6,59,102900,632,1415,285,392,506,165,40882,49633,18625,3372,10,3.6,3,3,16.0,77777,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
```

2 WET BULB TEMPERATURE
Generating a new EPW file



31.88 °C

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



Outer Surface Temperature of Test Windows Surface
Annual Hourly Data

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.

SIMULATION MEANS

1

EnergyPlus
ZoneCoolTower:Shower

2

Wet bulb Temperature

EPW

Wet Bulb Temperature

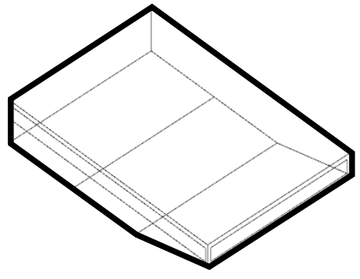
–

Dry Bulb Temperature

x 0.6

3

Evaporative Rate Equation



EPW

New Air Temperature

3 EVAPORATIVE RATE EQUATION
Penman Equation

The Base Evaporation Rate Equation

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

Evaporation from Radiation function

Evaporation from Wind function

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)

= radiation in – $(\text{T} + 237.3)^4$ x Cloudiness% x 4.903×10^{-9}

γ : psychrometric coefficient (kPa/°C)

= 0.0016286·P/λ

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-(2.361×10-3)·T

f_u : wind function

=1+0.536*U

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

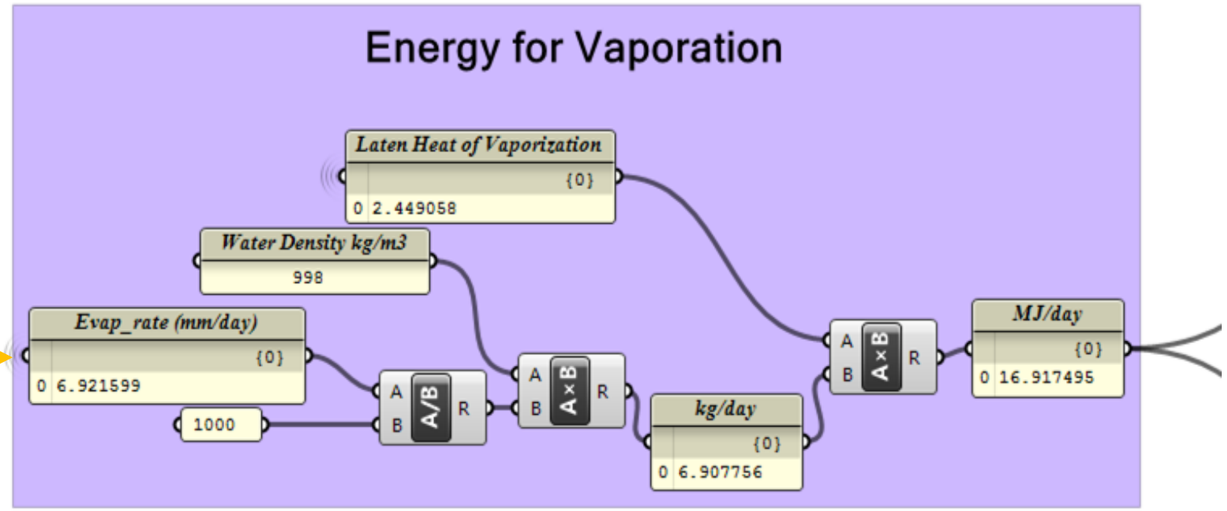
D : vapor pressure deficit (kPa)

= saturation vapor pressure - actual vapor pressure

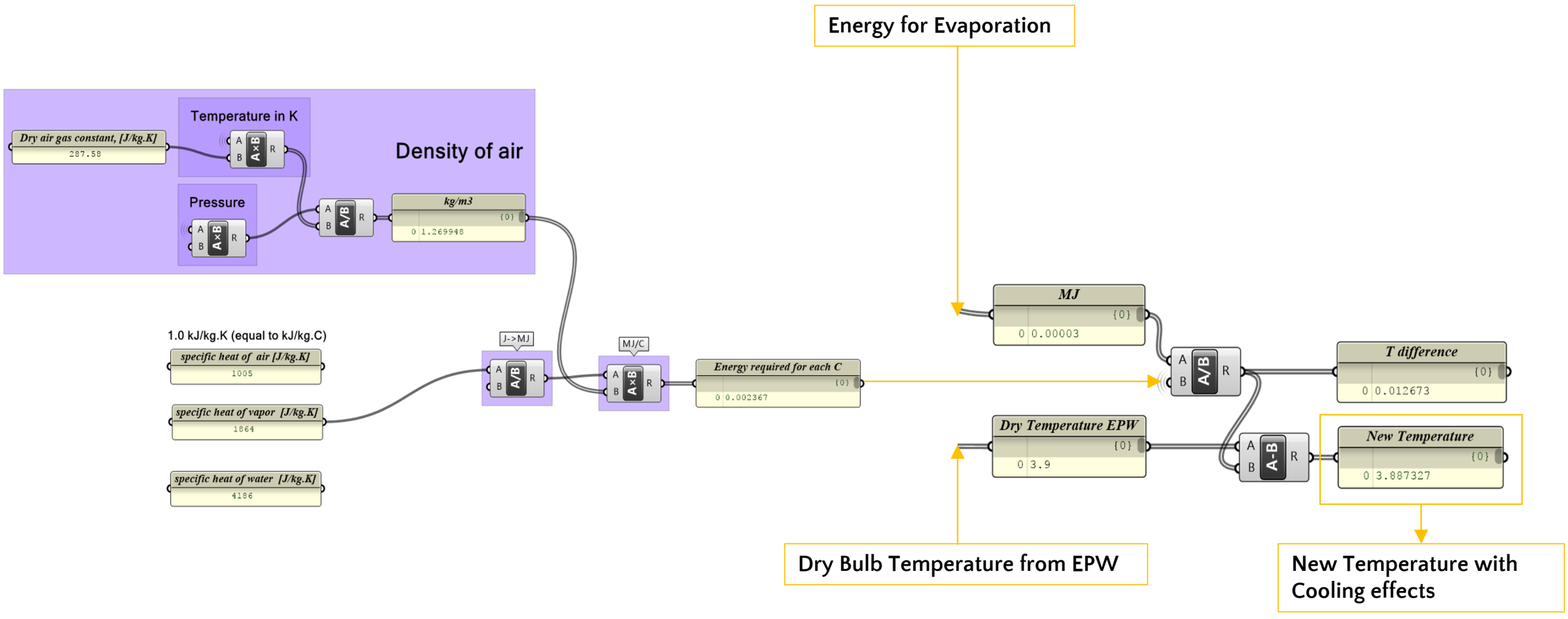
3 EVAPORATIVE RATE EQUATION
New Air Temperature

The Base Evaporation Rate Equation

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

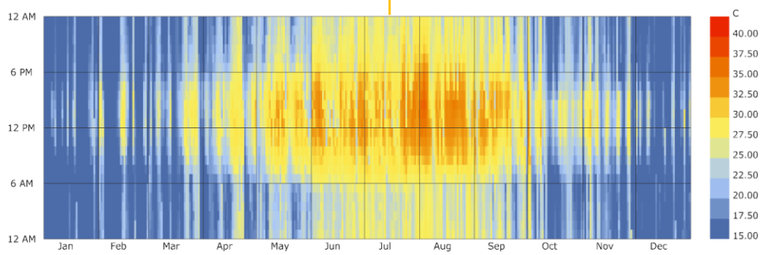


3 EVAPORATIVE RATE EQUATION
New Air Temperature



3 EVAPORATIVE RATE EQUATION

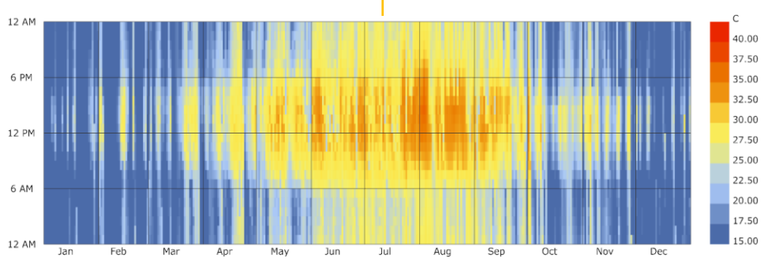
New Air Temperature



Dry Bulb Temperature

Original EPW File

```
0 LOCATION,New Orleans Intl Arpt,LA,USA,TMY3,722310,30.00,-90.25,-6.0,1.0
  DESIGN CONDITIONS,1,Climate Design Data 2009 ASHRAE Handbook,,Heating,1,-0.3,1.9,-8.8,1.8,2.8,-
1 5.9,2.3,5,10.6,13.1,9.4,11.3,4,10,Cooling,8,8.5,34.2,25.6,33.3,25.4,32.5,25.2,27.1,31.5,26.7,31.1,26.3,30.5,3.4,0,25.9,21.3,29.1,25.5,20.8,28.8,25.2,20.3,28.5,85,31.6,83.1,31.1,81.4,30.5,688,Extremes,9
  .2,8.3,7.5,29.2,-3.9,35.8,3.2,1.1,-6.2,36.6,-8.1,37.2,-9.9,37.8,-12.2,38.6
  TYPICAL/EXTREME PERIODS,6,Summer - Week Nearest Max Temperature For Period,Extreme,7/27,8/ 2,Summer - Week Nearest Average Temperature For Period,Typical,8/10,8/16,Winter - Week Nearest Min Temperature
2 For Period,Extreme,1/20,1/26,Winter - Week Nearest Average Temperature For Period,Typical,12/ 8,12/14,Autumn - Week Nearest Average Temperature For Period,Typical,10/20,10/26,Spring - Week Nearest
  Average Temperature For Period,Typical,4/26,5/ 2
  GROUND
3 TEMPERATURES,3,.5,,,,12.99,12.26,13.56,15.58,20.88,24.97,27.72,28.56,27.13,23.96,19.72,15.78,2,,,,15.68,14.38,14.64,15.72,19.26,22.47,25.03,26.40,26.11,24.31,21.39,18.29,4,,,,17.90,16.57,16.27,16.68,18
  .68,20.84,22.82,24.20,24.52,23.74,22.02,19.93
4 HOLIDAYS/DAYLIGHT SAVINGS,No,0,0,0
5 COMMENTS 1,Custom/User Format -- WMO#722310; NREL TMY Data Set (2008); Period of Record 1973-2005 (Generally)
6 COMMENTS 2, -- Ground temps produced with a standard soil diffusivity of 2.3225760E-03 {m**2/day}
7 DATA PERIODS,1,1,Data,Sunday, 1/ 1,12/31
8 2001,1,1,1,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.2,63,102900,0,0,293,0,0,0,0,0,0,0,350,4.1,9,9,14.4,2134,9,999999999,160,0.0710,0,88,0.170,0.0,1.0
9 2001,1,1,2,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-4.4,51,102900,0,0,301,0,0,0,0,0,0,0,360,3.6,10,10,14.4,2134,9,999999999,150,0.0710,0,88,0.170,0.0,1.0
10 2001,1,1,3,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-2.8,58,102800,0,0,294,0,0,0,0,0,0,0,20,6.2,9,9,14.4,2134,9,999999999,139,0.0710,0,88,0.170,0.0,1.0
11 2001,1,1,4,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,20,5.7,10,10,14.4,1280,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
12 2001,1,1,5,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,30,6.7,10,10,14.4,1097,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
13 2001,1,1,6,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-3.3,57,102800,0,0,300,0,0,0,0,0,0,0,50,5.7,10,10,14.4,1981,9,999999999,120,0.0710,0,88,0.170,0.0,1.0
14 2001,1,1,7,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.9,-1.7,66,102900,0,35,302,0,0,0,0,0,0,0,30,5.2,10,10,16.0,1829,9,999999999,110,0.0710,0,88,0.170,0.0,1.0
15 2001,1,1,8,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,-2.2,61,103000,138,1415,303,0,0,0,0,0,0,0,20,6.2,10,10,16.0,1128,9,999999999,100,0.0710,0,88,0.170,0.0,1.0
16 2001,1,1,9,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.3,0.6,82,103000,392,1415,301,46,0,46,5487,0,5487,1943,30,5.2,10,10,12.8,1067,9,999999999,89,0.0710,0,88,0.170,0.0,1.0
17 2001,1,1,10,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.3,-0.6,75,103100,603,1415,300,67,0,67,8136,0,8136,3089,30,6.2,10,10,16.0,1189,9,999999999,80,0.0710,0,88,0.170,0.0,1.0
18 2001,1,1,11,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,0.0,73,103100,755,1415,306,82,0,82,10074,0,10074,3989,30,6.2,10,10,16.0,1311,9,999999999,69,0.0710,0,88,0.170,0.0,1.0
19 2001,1,1,12,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.4,0.0,73,102900,837,1415,306,245,18,234,28105,1560,27179,9784,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
20 2001,1,1,13,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,5.0,0.0,70,102900,843,1415,308,244,12,237,28047,1043,27423,9913,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
21 2001,1,1,14,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,5.6,0.0,67,102900,773,1415,296,219,18,209,25095,1511,24267,8636,40,3.6,8,8,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
22 2001,1,1,15,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,6.7,-0.6,59,102900,632,1415,285,392,506,165,40882,49633,18625,3372,10,3.6,3,3,16.0,77777,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
```



New Dry Bulb Temperature

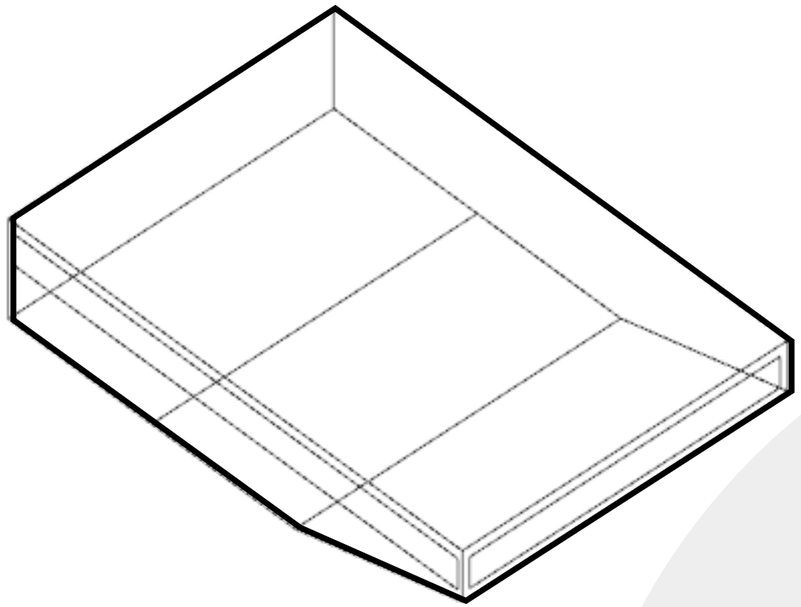
New EPW File with Dry Bulb Temperature Modified

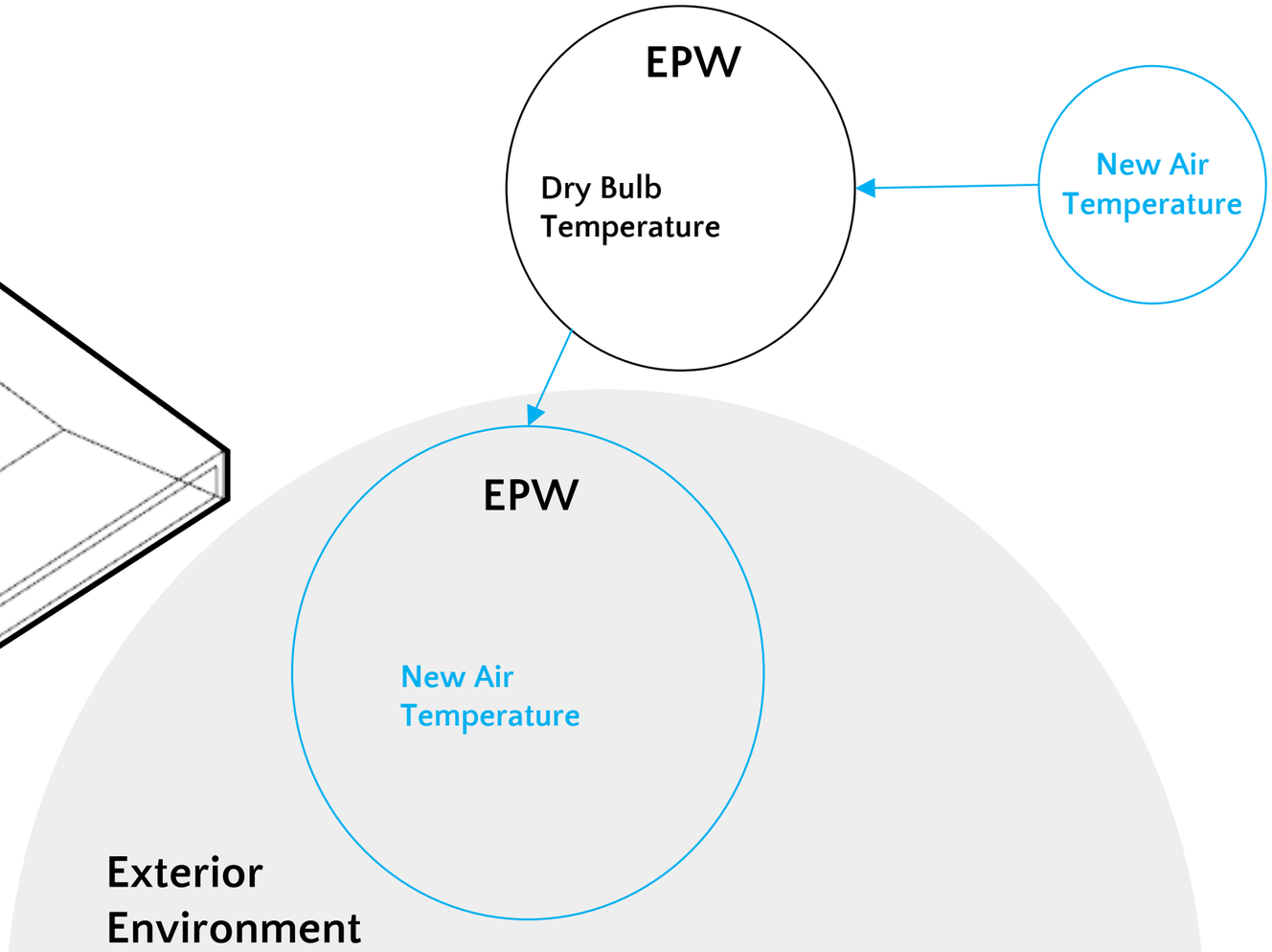
```
0 LOCATION,New Orleans Intl Arpt,LA,USA,TMY3,722310,30.00,-90.25,-6.0,1.0
  DESIGN CONDITIONS,1,Climate Design Data 2009 ASHRAE Handbook,,Heating,1,-0.3,1.9,-8.8,1.8,2.8,-
1 5.9,2.3,5,10.6,13.1,9.4,11.3,4,10,Cooling,8,8.5,34.2,25.6,33.3,25.4,32.5,25.2,27.1,31.5,26.7,31.1,26.3,30.5,3.4,0,25.9,21.3,29.1,25.5,20.8,28.8,25.2,20.3,28.5,85,31.6,83.1,31.1,81.4,30.5,688,Extremes,9
  .2,8.3,7.5,29.2,-3.9,35.8,3.2,1.1,-6.2,36.6,-8.1,37.2,-9.9,37.8,-12.2,38.6
  TYPICAL/EXTREME PERIODS,6,Summer - Week Nearest Max Temperature For Period,Extreme,7/27,8/ 2,Summer - Week Nearest Average Temperature For Period,Typical,8/10,8/16,Winter - Week Nearest Min Temperature
2 For Period,Extreme,1/20,1/26,Winter - Week Nearest Average Temperature For Period,Typical,12/ 8,12/14,Autumn - Week Nearest Average Temperature For Period,Typical,10/20,10/26,Spring - Week Nearest
  Average Temperature For Period,Typical,4/26,5/ 2
  GROUND
3 TEMPERATURES,3,.5,,,,12.99,12.26,13.56,15.58,20.88,24.97,27.72,28.56,27.13,23.96,19.72,15.78,2,,,,15.68,14.38,14.64,15.72,19.26,22.47,25.03,26.40,26.11,24.31,21.39,18.29,4,,,,17.90,16.57,16.27,16.68,18
  .68,20.84,22.82,24.20,24.52,23.74,22.02,19.93
4 HOLIDAYS/DAYLIGHT SAVINGS,No,0,0,0
5 COMMENTS 1,Custom/User Format -- WMO#722310; NREL TMY Data Set (2008); Period of Record 1973-2005 (Generally)
6 COMMENTS 2, -- Ground temps produced with a standard soil diffusivity of 2.3225760E-03 {m**2/day}
7 DATA PERIODS,1,1,Data,Sunday, 1/ 1,12/31
8 2001,1,1,1,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.887146,-2.2,63,102900,0,0,293,0,0,0,0,0,0,0,350,4.1,9,9,14.4,2134,9,999999999,160,0.0710,0,88,0.170,0.0,1.0
9 2001,1,1,2,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.383561,-4.4,51,102900,0,0,301,0,0,0,0,0,0,0,360,3.6,10,10,14.4,2134,9,999999999,150,0.0710,0,88,0.170,0.0,1.0
10 2001,1,1,3,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.37717,-2.8,58,102800,0,0,294,0,0,0,0,0,0,0,20,6.2,9,9,14.4,2134,9,999999999,139,0.0710,0,88,0.170,0.0,1.0
11 2001,1,1,4,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.881104,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,20,5.7,10,10,14.4,1280,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
12 2001,1,1,5,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.877888,-2.8,60,102900,0,0,300,0,0,0,0,0,0,0,30,6.7,10,10,14.4,1097,9,999999999,129,0.0710,0,88,0.170,0.0,1.0
13 2001,1,1,6,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.879279,-3.3,57,102800,0,0,300,0,0,0,0,0,0,0,50,5.7,10,10,14.4,1981,9,999999999,120,0.0710,0,88,0.170,0.0,1.0
14 2001,1,1,7,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.886122,-1.7,66,102900,0,35,302,0,0,0,0,0,0,0,30,5.2,10,10,16.0,1829,9,999999999,110,0.0710,0,88,0.170,0.0,1.0
15 2001,1,1,8,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.379718,-2.2,61,103000,138,1415,303,0,0,0,0,0,0,0,20,6.2,10,10,16.0,1128,9,999999999,100,0.0710,0,88,0.170,0.0,1.0
16 2001,1,1,9,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.295321,0.6,82,103000,392,1415,301,46,0,46,5487,0,5487,1943,30,5.2,10,10,12.8,1067,9,999999999,89,0.0710,0,88,0.170,0.0,1.0
17 2001,1,1,10,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,3.289491,-0.6,75,103100,603,1415,300,67,0,67,8136,0,8136,3089,30,6.2,10,10,16.0,1189,9,999999999,80,0.0710,0,88,0.170,0.0,1.0
18 2001,1,1,11,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.387676,0.0,73,103100,755,1415,306,82,0,82,10074,0,10074,3989,30,6.2,10,10,16.0,1311,9,999999999,69,0.0710,0,88,0.170,0.0,1.0
19 2001,1,1,12,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.387151,0.0,73,102900,837,1415,306,245,18,234,28105,1560,27179,9784,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
20 2001,1,1,13,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,4.98599,0.0,70,102900,843,1415,308,244,12,237,28047,1043,27423,9913,20,5.2,10,10,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
21 2001,1,1,14,0,?9?9?9?9E0?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9?9*9*9?9?9?9,5.586253,0.0,67,102900,773,1415,296,219,18,209,25095,1511,24267,8636,40,3.6,8,8,16.0,1524,9,999999999,60,0.0710,0,88,0.170,0.0,1.0
```

3

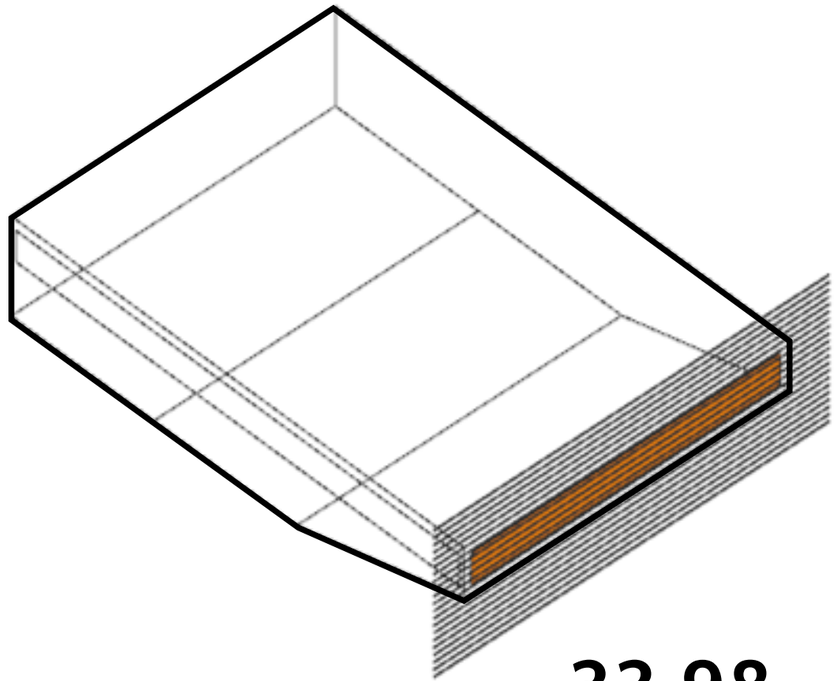
EVAPORATIVE RATE EQUATION

New Air Temperature



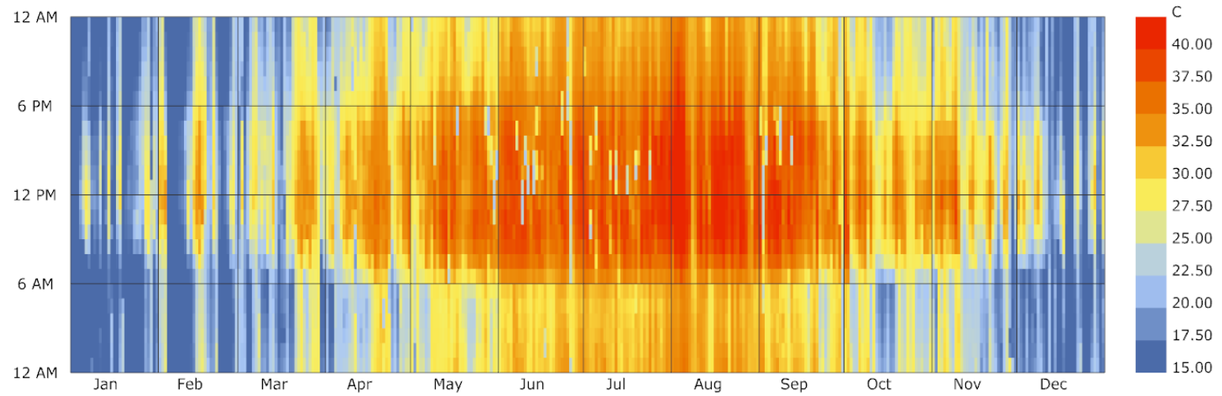


3 EVAPORATIVE RATE EQUATION
New Air Temperature



33.98 °C

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



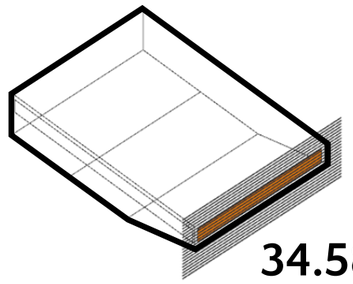
Outer Surface Temperature of Test Windows Surface
Annual Hourly Data

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.

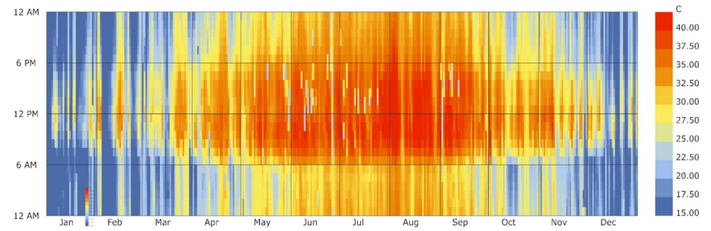
Outer Surface Temperature @ Jun 21st 12 PM

Outer Surface Temperature Annual Hourly Data

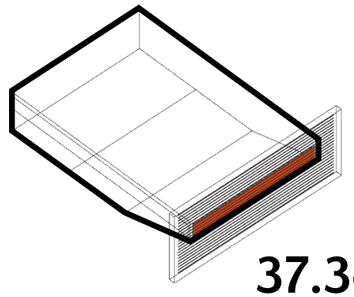
0 Base Case



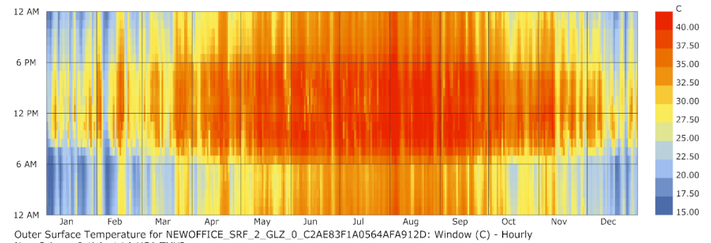
34.58 °C



1 EnergyPlus ZoneCoolTower:Shower

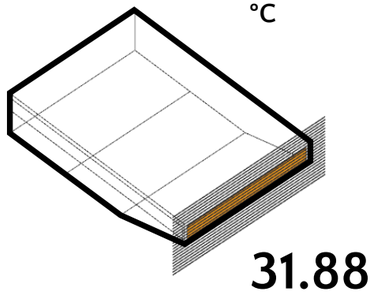


37.34 °C

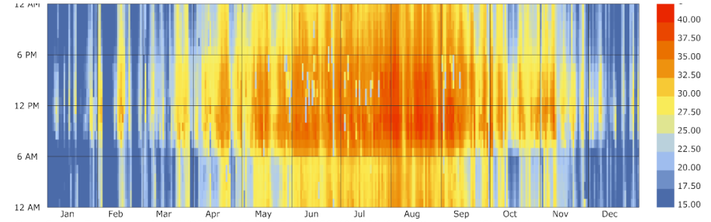


Outer Surface Temperature for NEWOFFICE_SRF_2_GLZ_0_C2AE83F1A0564AFA912D: Window (C) - Hourly
New Orleans Intl Arpt LA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

2 Wet bulb Temperature

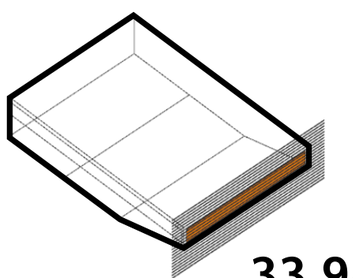


31.88 °C

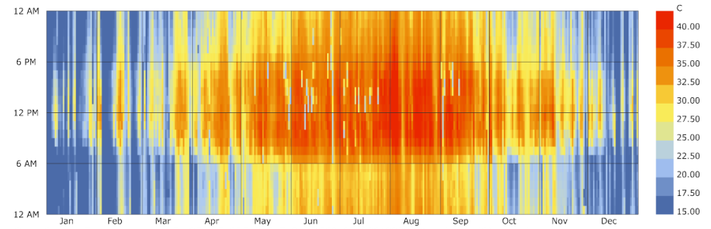


Outer Surface Temperature for NEWOFFICE_SRF_2_GLZ_0_DDC6040E4926490290B1: Window (C) - Hourly
New Orleans Intl Arpt LA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

3 Evaporative Rate Equation



33.98 °C



Outer Surface Temperature for NEWOFFICE_SRF_2_GLZ_0_DDC6040E4926490290B1: Window (C) - Hourly
New Orleans Intl Arpt LA USA TMY3
1 JAN 1:00 - 31 DEC 24:00