Thermal and Visual Comfort Maximization

in Mexico City

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ARCH-753-Building Performance Simulation
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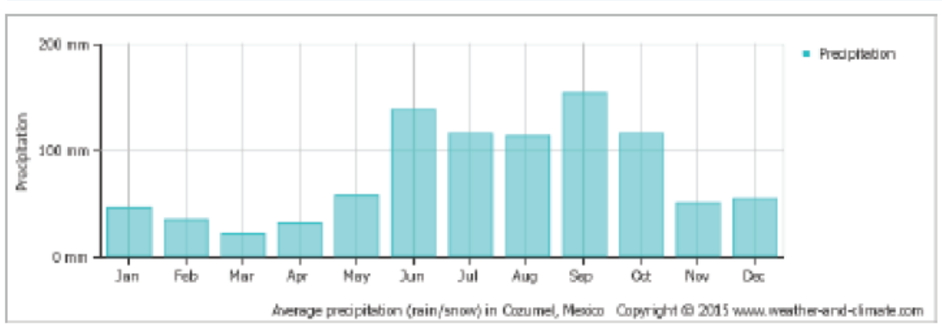


Mexico City

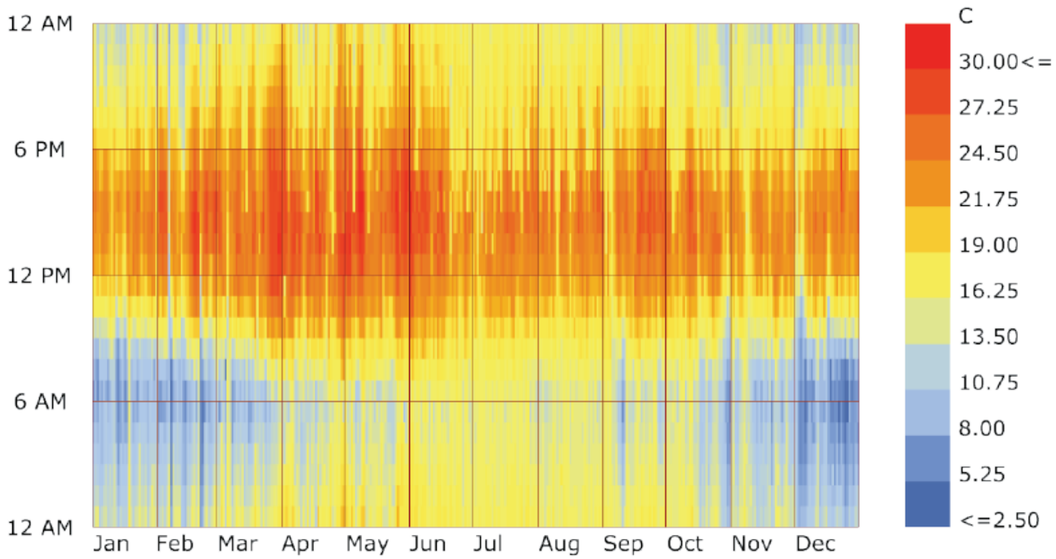
19°26 N, 99°8 W

Elevation 2,250 m (7,380 ft)

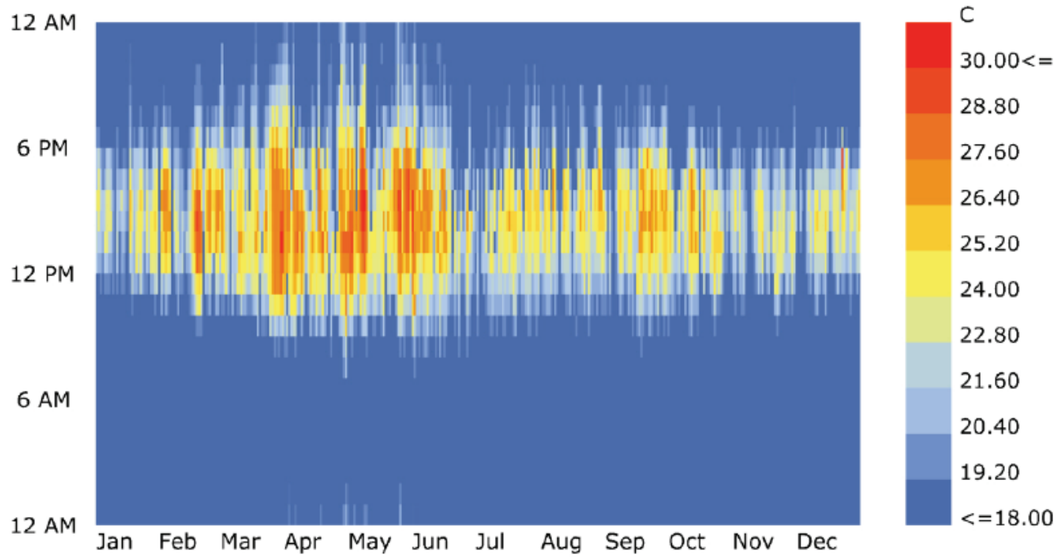
Temperate highland tropical climate with dry winters

is a type of climate characteristic of the highlands inside the tropics of Mexico. Winters are noticeable and dry, and summers can be very rainy. In the tropics, the rainy season is provoked by the tropical air masses and the dry winters by sub tropical high pressure.

Outdoor Temperature



Dry Bulb Temperature (C) - Hourly
MEXICO CITY_MEX
1 JAN 1:00 - 31 DEC 24:00

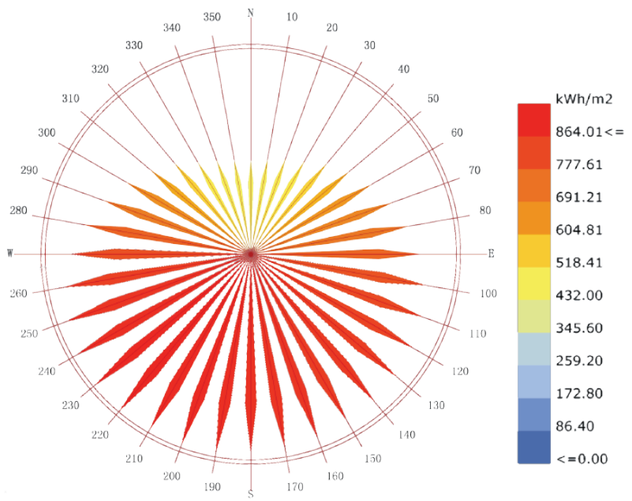


Dry Bulb Temperature (C) - Hourly
MEXICO CITY_MEX
1 JAN 1:00 - 31 DEC 24:00

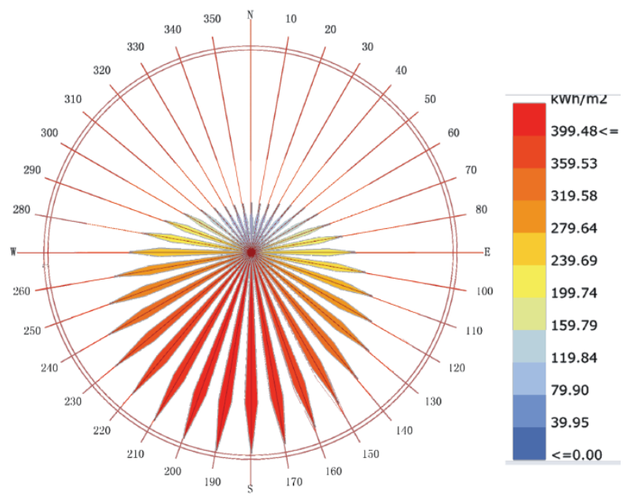
The temperature of outdoor is over all very pleasant during daytime. The temperature at night could also get very low, and that could be resolved with a better insulated evenlope.

Wind Direction and Orientation

Year Round Radiation

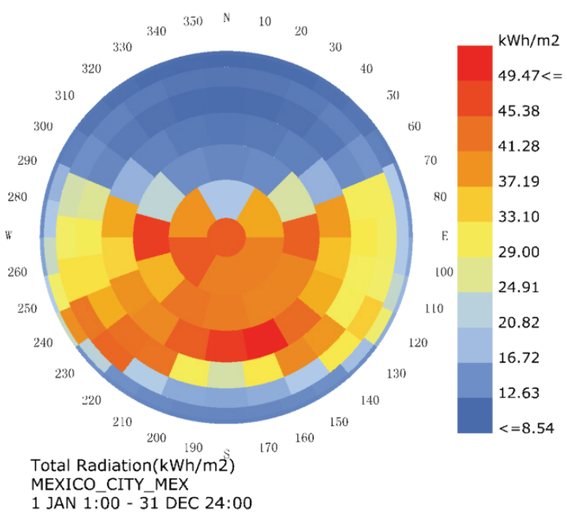


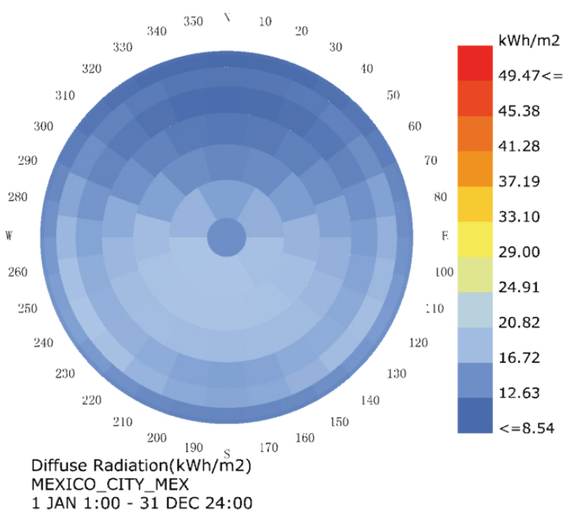
Winter Radiation



As the temperature during night of Mexico city is not very high, presumably solar radiation could be used the heat up the thermal mass especially during winter.
Most of the slar radiation of Mexico City comes from south, while in the winter it's south to south west.

Year Round Solar Radiation Mapping on Skydome





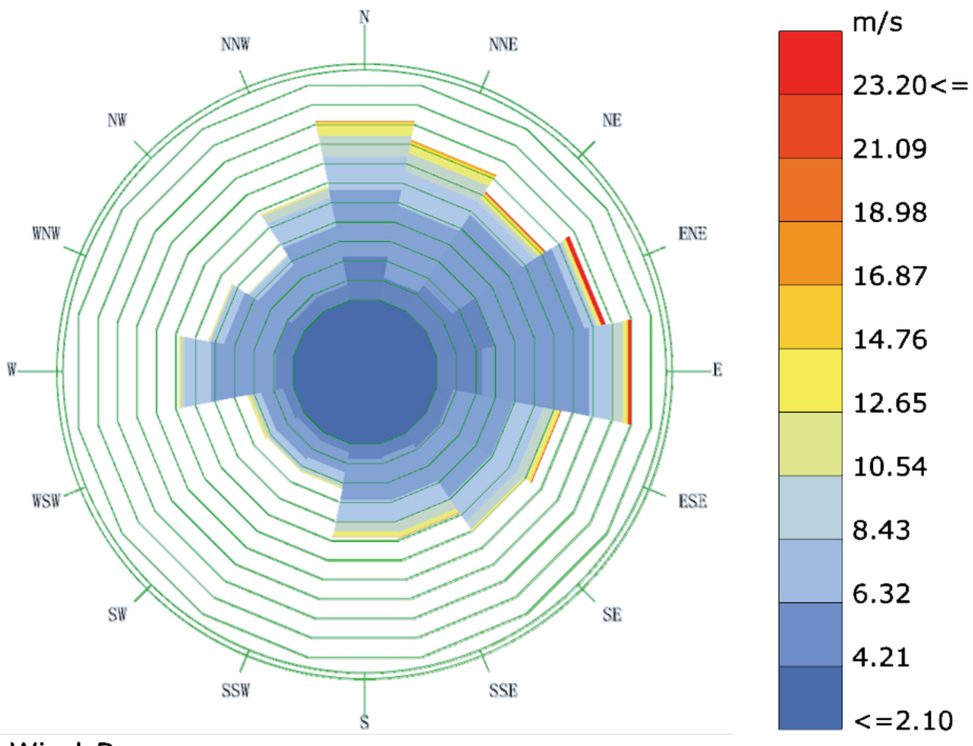
By mapping the solar radiation on sky dome, it's clear to see the the sun angle of Mexico city is high. That leads the design towards a focus on overhang and maybe alternative roof top material.

Wind Direction and Orientation

Natural ventilation uses natural outside air movement and pressure differences to both passively cool and ventilate a building. It can provide and move fresh air without fans. For warm and hot climates, it can help meet a building's cooling loads without using mechanical air conditioning systems. In this design, the preferable orietation is highly related to the wind direction.

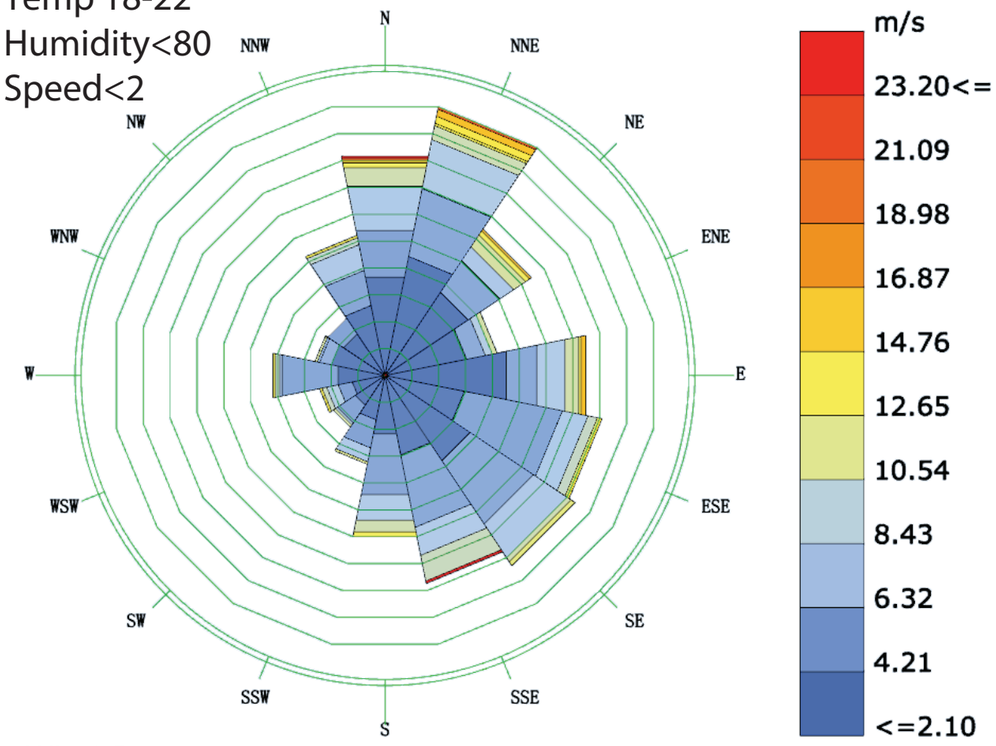
In Mexico City, the preferable wind that could be used for natural ventilation mainly comes from southeast, so it’s better to orient the building towards south east.

Year Round Wind Rose



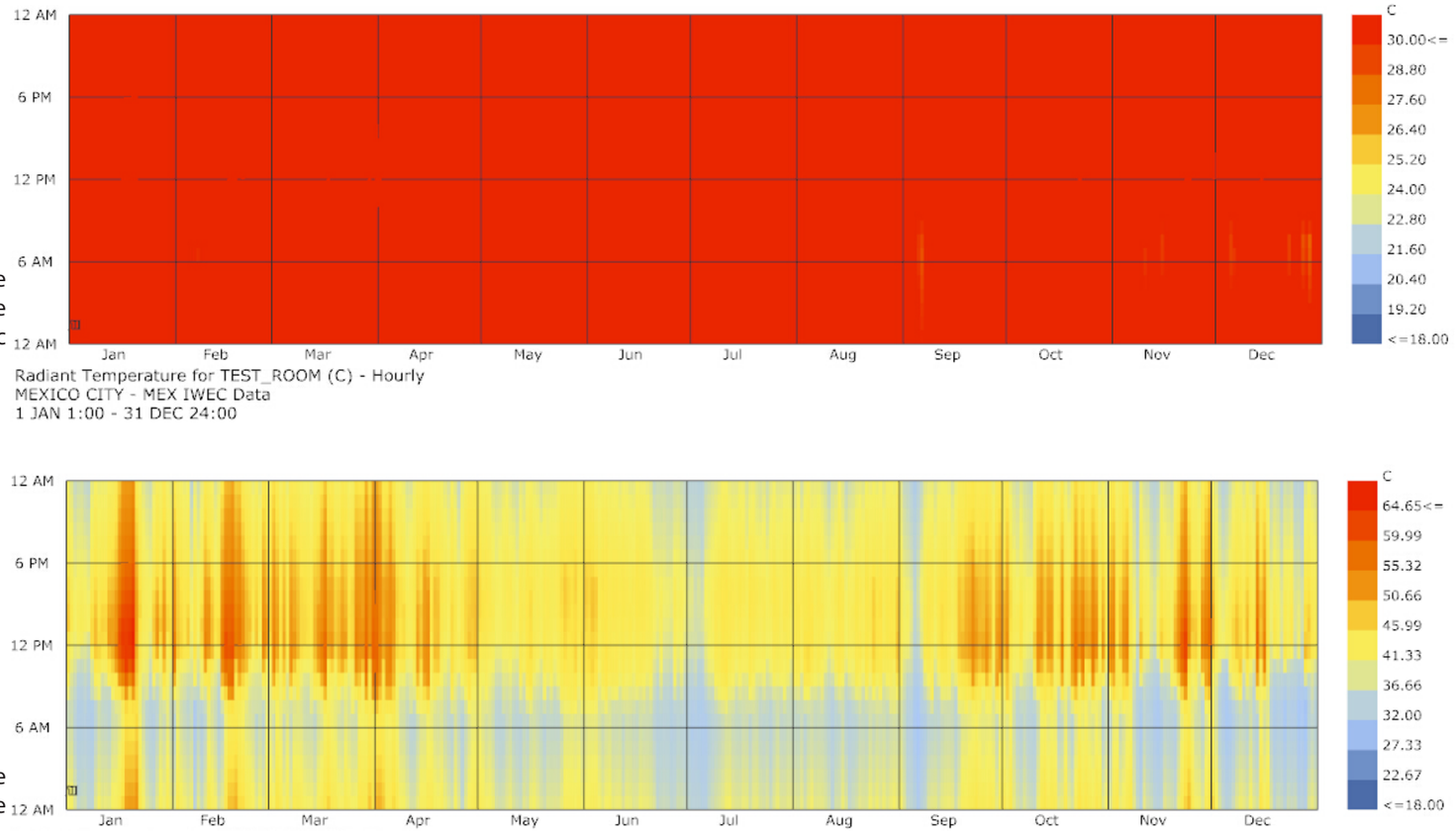
Wind-Rose
MEXICO CITY_MEX
1 JAN 1:00 - 31 DEC 24:00

Preferable Wind Direction
Temp 18-22
Humidity<80
Speed<2



Wind-Rose
MEXICO CITY_MEX
1 JAN 1:00 - 31 DEC 24:00

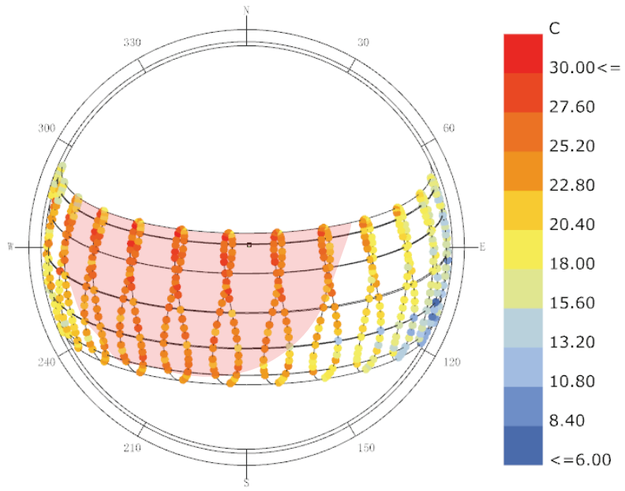
Baseline Case
Indoor Temperature



Baseline Case
Indoor Temperature
High Bound Temperature 30c

Radiant Temperature for TEST_ROOM (C) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

The indoor temperature is overall higher than 30degree

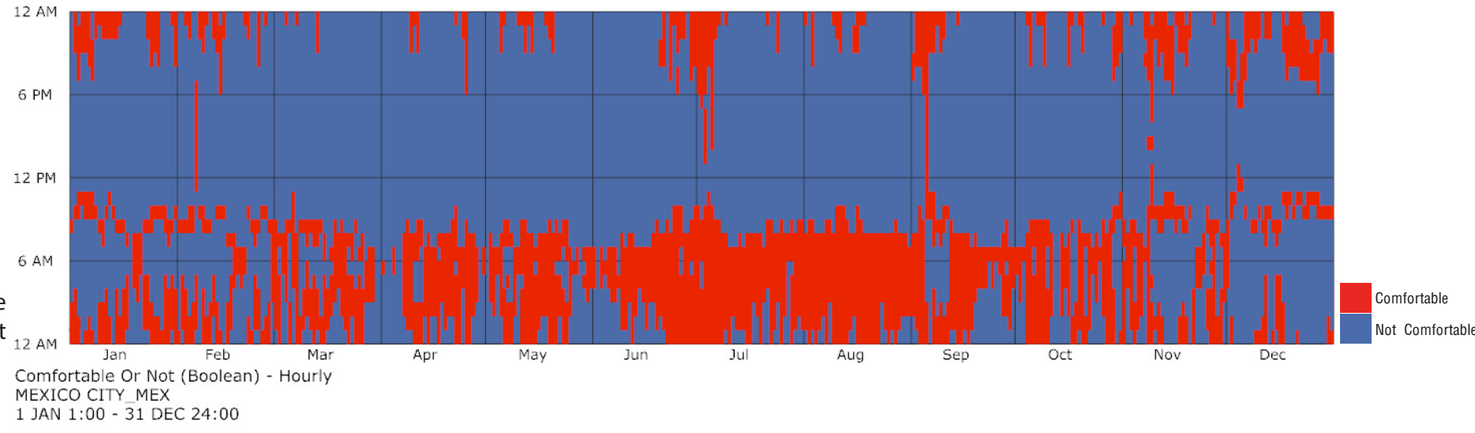


Sun-Path Diagram - Latitude: 19.43
Hourly Data: Dry Bulb Temperature (C)
MEXICO CITY_MEX

Baseline Case
Indoor Temperature

Radiant Temperature for TEST_ROOM (C) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

By putting the sun path with dry bulb temperature and indoor temperature together, it shows that that strongest early noon and early after noon sunlight come from west.



Baseline Case
PMV Comfort

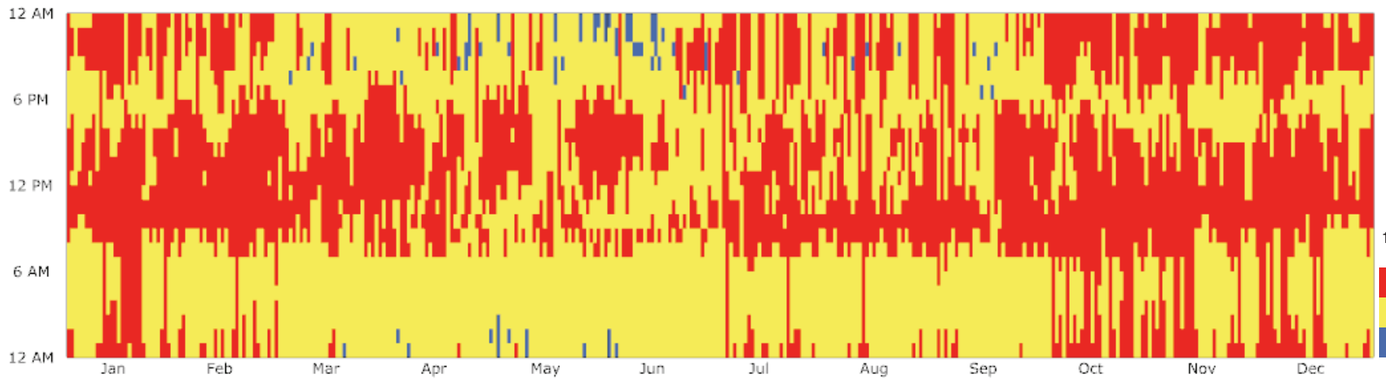
Comfortable Or Not (Boolean) - Hourly
MEXICO CITY_MEX
1 JAN 1:00 - 31 DEC 24:00

According to the PMV Comfort chart, the sumlight during noon is always a problem resulting in an overheated indoor environment

Adding In Base Shading

Baseline Case
with Natural Ventilation
Adaptive Comfort
Percentage of Comfort time

55.388128

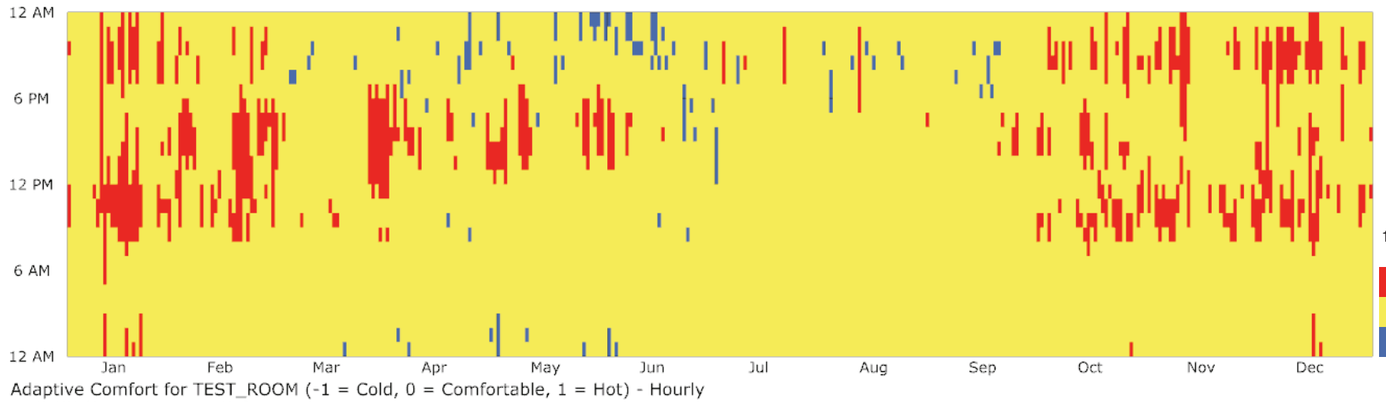


Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

In an unconditioned building natural ventilation would be the first choice to reduce the overheated problem. A min indoor temperature for natural ventilation was set fo 18degree.

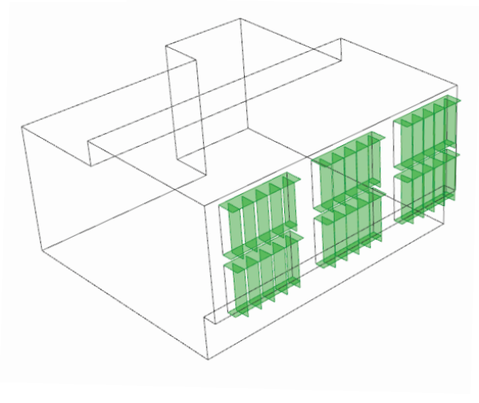
Designed with Shading
Percentage of Comfort time

88.8



Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

With a base shading design, the indoor comfort was dramaticlly improved

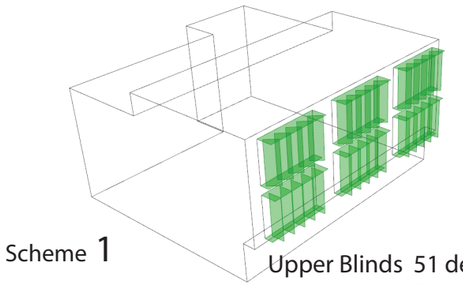


To design a shading with a better vertical fins turning angle. Galapagos was used to test the most effective combination of upper and lower fins.

The turning angle was set between **90-135**(-Blocking **south to southwest** sunlight). And the analysis time was limited from March to May(during which monthes "chunks" of hot hours appear).

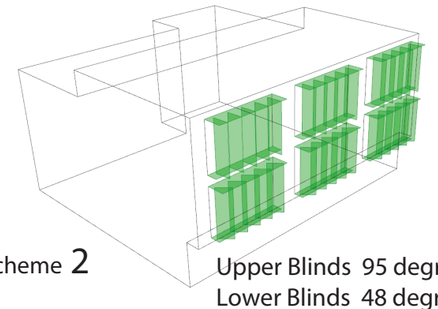
```
Generation 5
{
  Bio-Diversity: 0.726
  Genome[0], Fitness=92.04, Genes [0% · 96% · 0%]
  Genome[1], Fitness=91.48, Genes [2% · 96% · 7%]
  Genome[2], Fitness=91.44, Genes [0% · 96% · 13%]
  Genome[3], Fitness=90.88, Genes [3% · 92% · 11%]
  Genome[4], Fitness=90.51, Genes [2% · 84% · 10%]
  Genome[5], Fitness=90.19, Genes [17% · 96% · 7%]
  Genome[6], Fitness=89.86, Genes [16% · 89% · 13%]
  Genome[7], Fitness=89.17, Genes [14% · 82% · 8%]
  Genome[8], Fitness=88.94, Genes [24% · 12% · 23%]
  Genome[9], Fitness=88.94, Genes [18% · 87% · 10%]
  Genome[10], Fitness=88.80, Genes [18% · 84% · 9%]
  Genome[11], Fitness=88.75, Genes [30% · 9% · 12%]
```

Parameter: Turning Angle of Blinds
Fitness: Total Comfort Hour from **March to May**
Result: 1.Upper Blinds 95 degree 2.Upper Blinds 51 degree
Lower Blinds 48 degree Lower Blinds 91 degree



Scheme 1

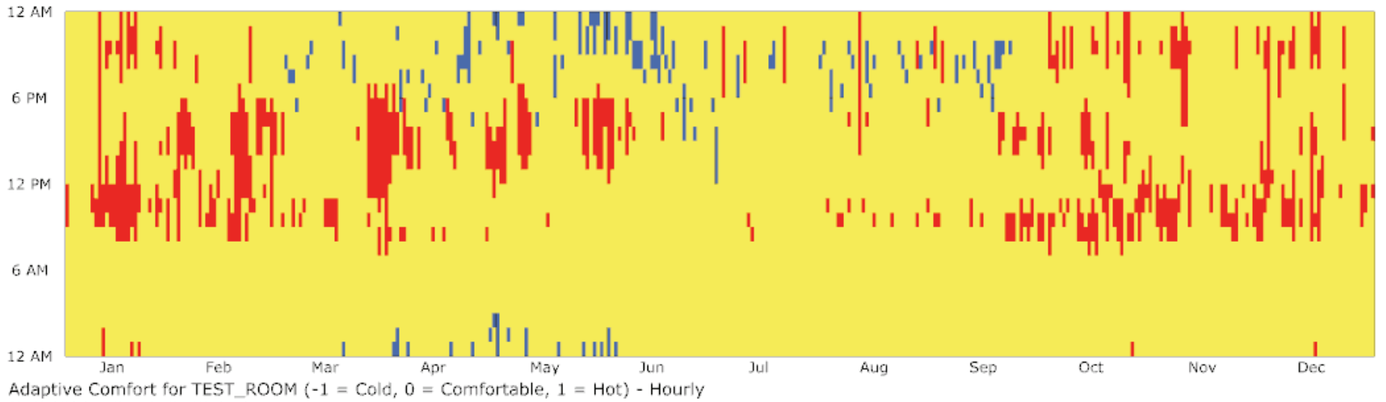
Upper Blinds 51 degree
Lower Blinds 91 degree



Scheme 2

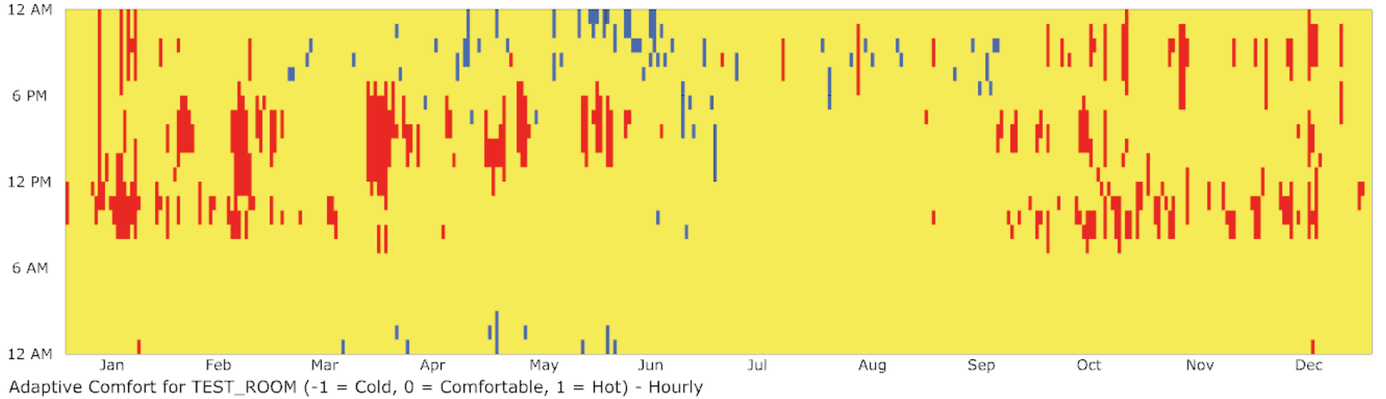
Upper Blinds 95 degree
Lower Blinds 48 degree

Result (Adaptive Comfort)



Scheme 1

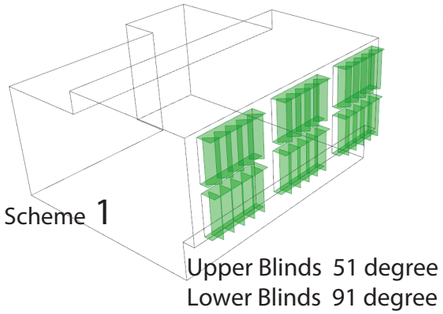
Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00



Scheme 2

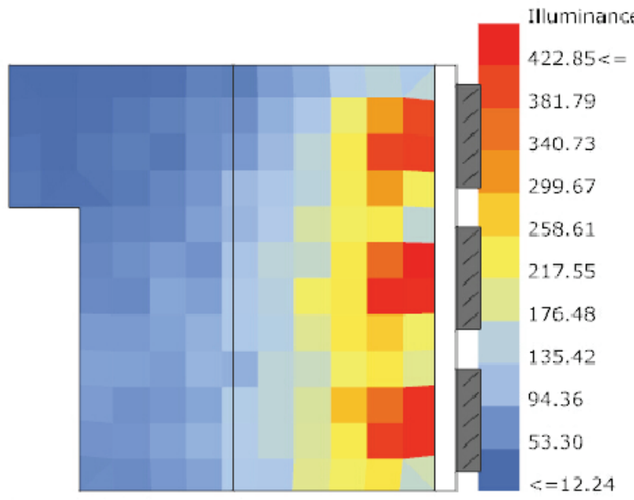
Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

As daylighting is also an important factor to consider, the two schemes were brought into daylighting simulation to see its impact on the indoor illuminance level.
The result is that with upper fins more opened up, the lighting of indoor is more diffused and equally distributed.

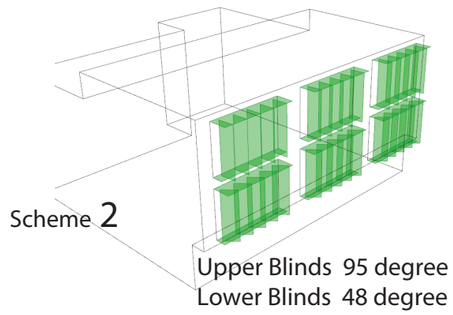


Scheme 1

Upper Blinds 51 degree
Lower Blinds 91 degree

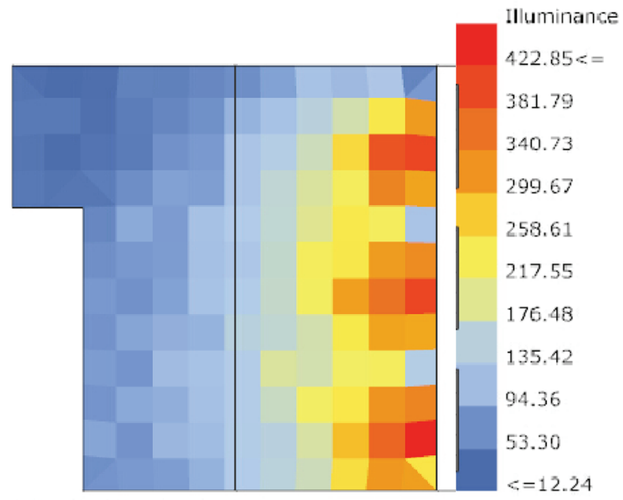


Daylight Analysis
August, 15 8:00 am



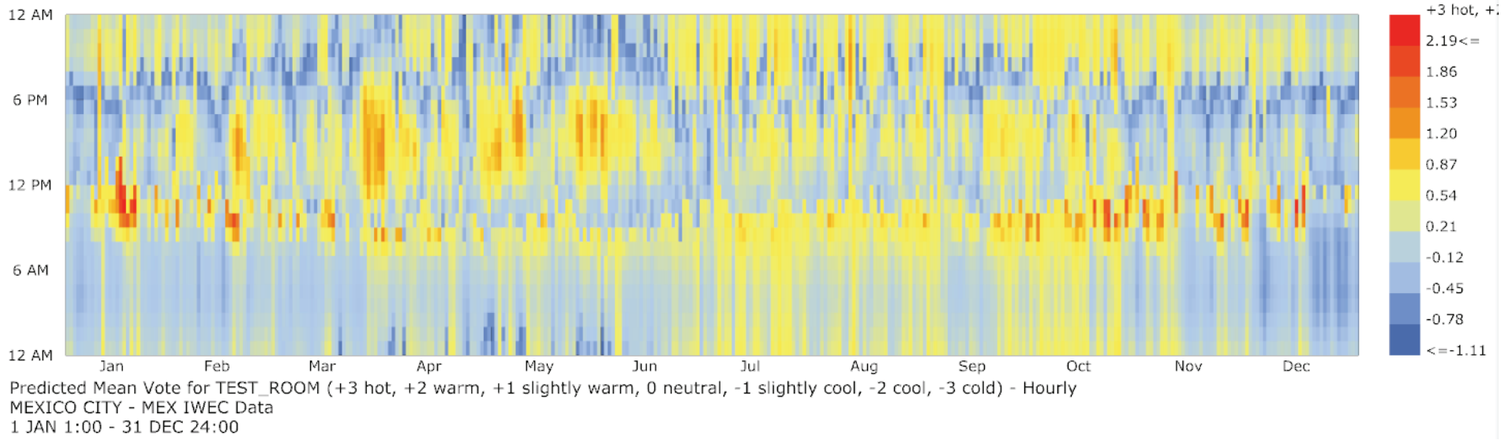
Scheme 2

Upper Blinds 95 degree
Lower Blinds 48 degree

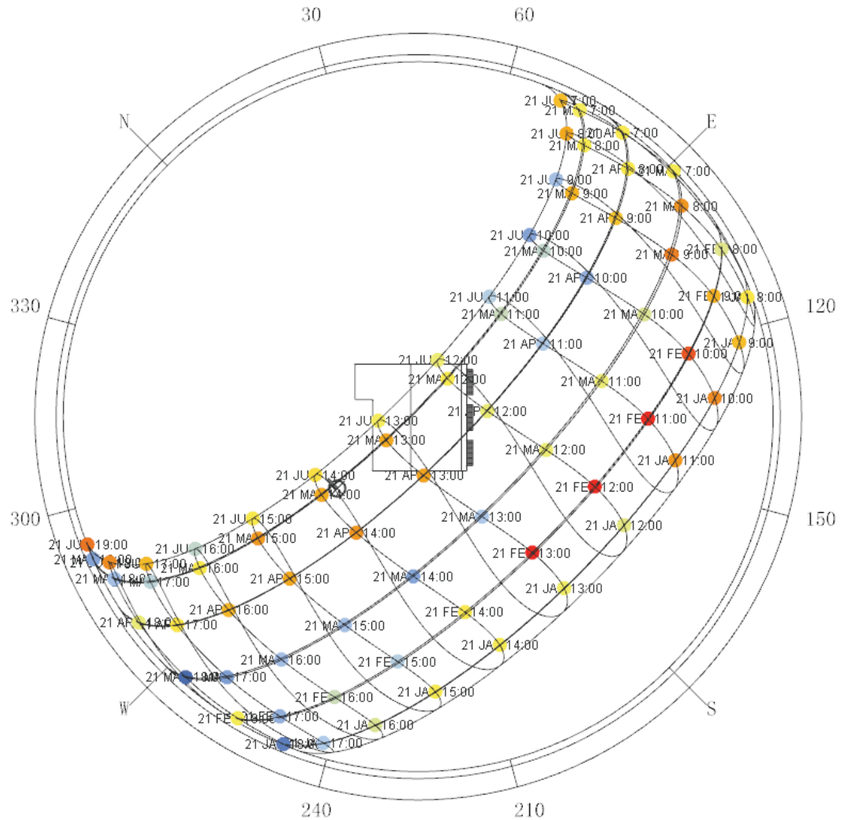


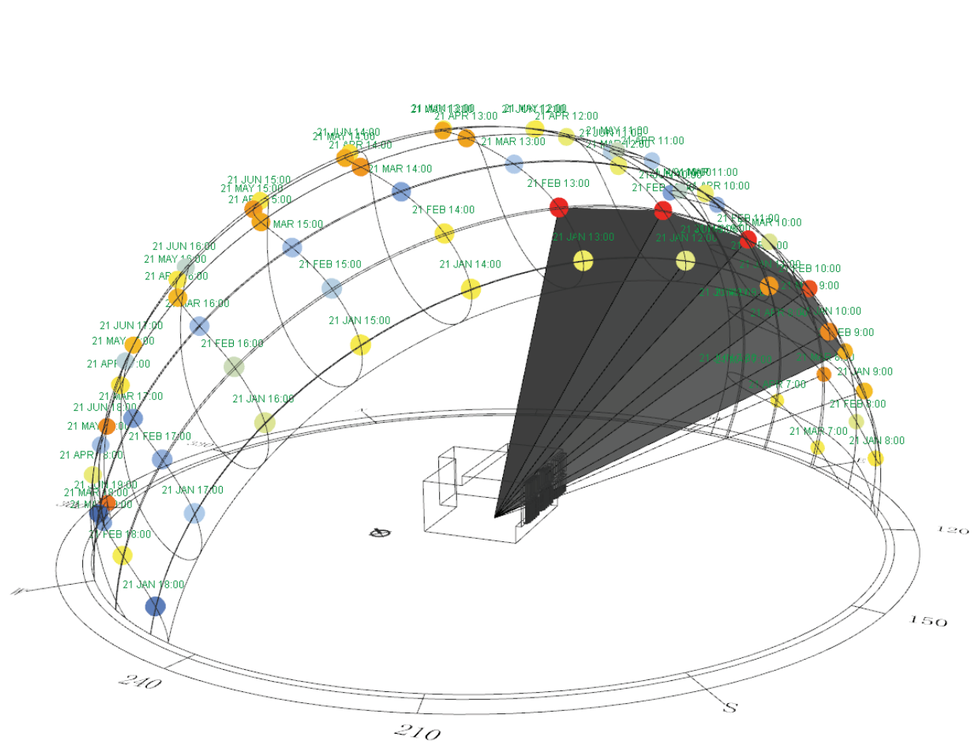
Daylight Analysis
August, 15 8:00 am

Going back to the energy analysis, the focus is to adjust the scheme 2 to better deal with the over heated hours.
In the Sunpath diagram, the sun positions was mapped out with color showing the uncomfortable hours.
The sunlight around early noon is the main problem from October to January(which was not considered during the evolutionary solver test).

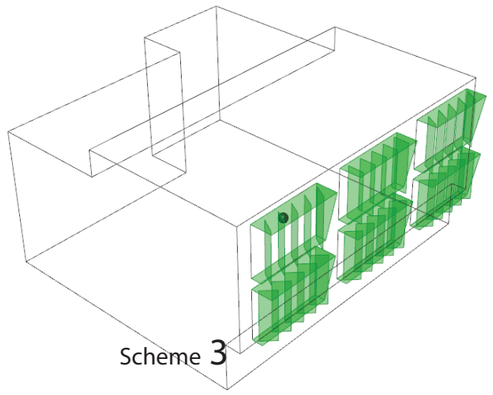


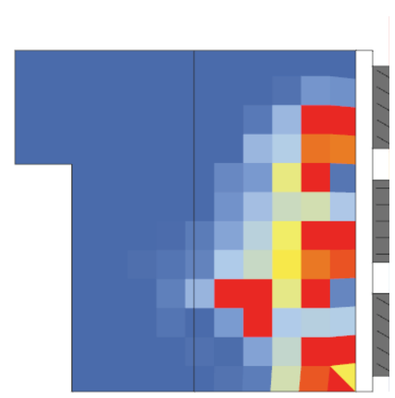
Predicted Mean Vote for TEST_ROOM (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

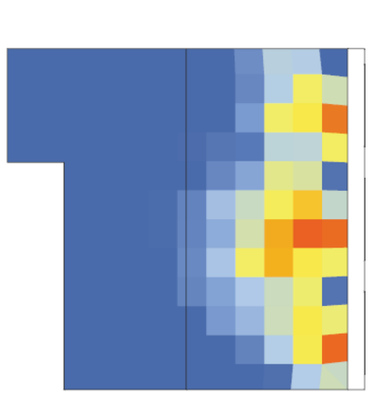


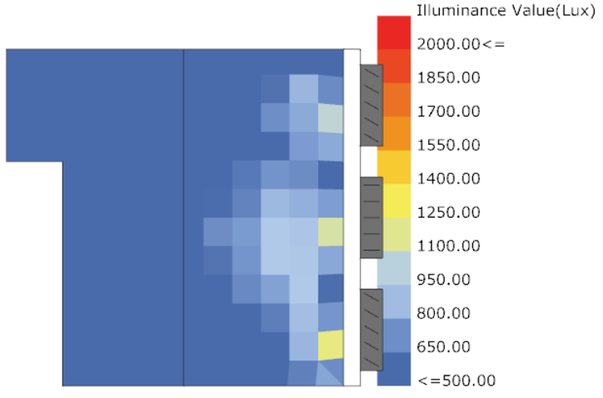


To Deal with the early noon sunlight from east, some of the upper fins were again, turned 90 degree to block the eastern sunlight.



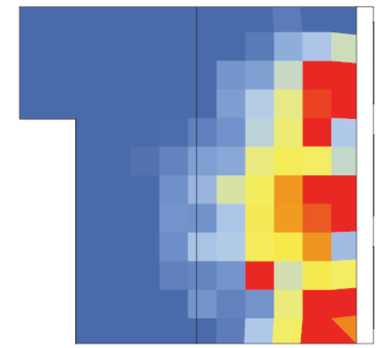

Mar 21 9am

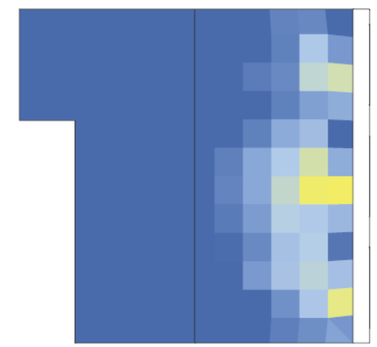

Mar 21 12pm



Mar 21 3pm

Color Dark red represents the space is too bright while the dark blue area shows the area is too dark for reading and working.
Thought the very back of the room is under lit, the area closer to the window is suitbale for working.
The daylighting analysis showed that the morning sunshing are possibly causing visual uncomfort and the space is not lit up enough during afternoon.


Sep 21 9am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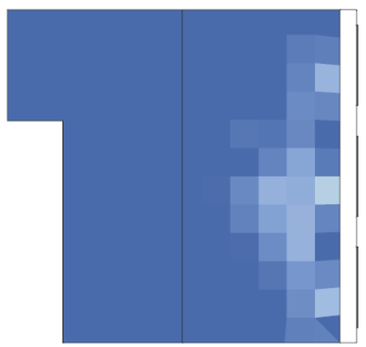
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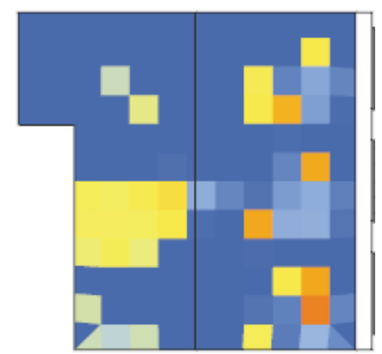
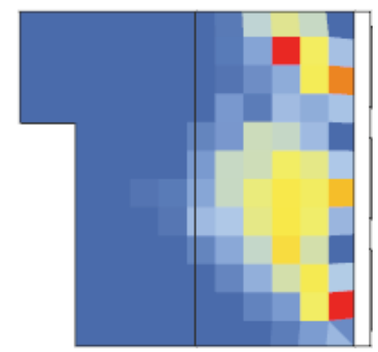
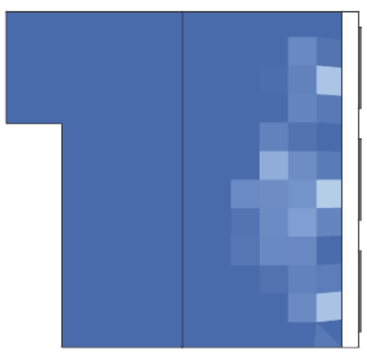

Dec 21 9am


Dec 21 12pm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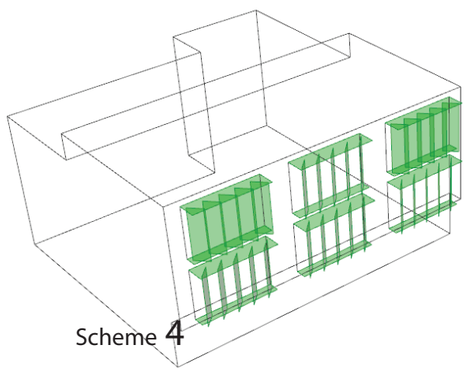
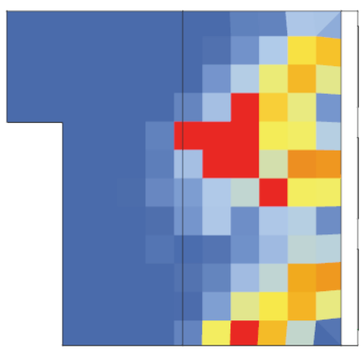
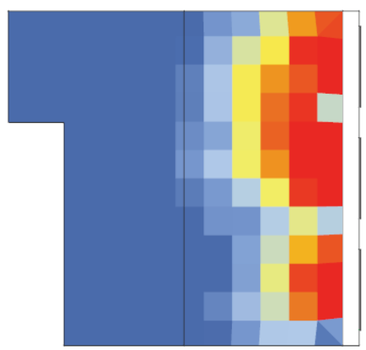


Scheme 4

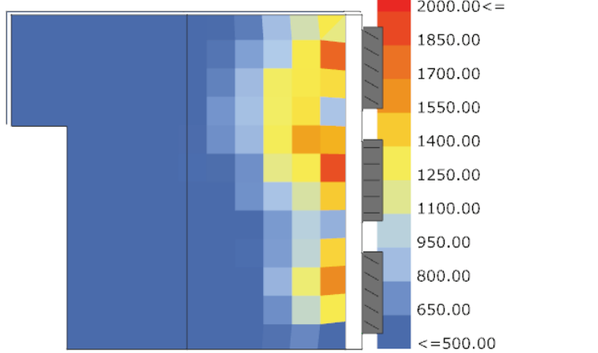
As the lower level windows allows in too much light from east , more of the lower fins are switched and the result is less uncomfortable morning light and brighter interior condition during afternnon. However the sunlight at noon is not blocked properly by the overhang and fins.



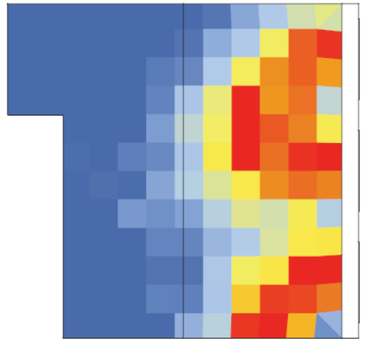
Mar 21 9am



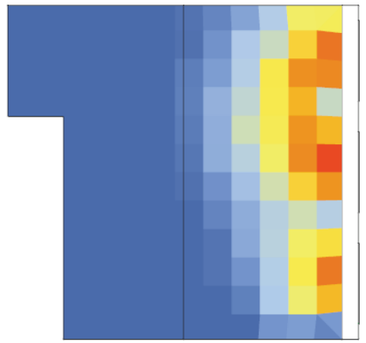
Mar 21 12pm



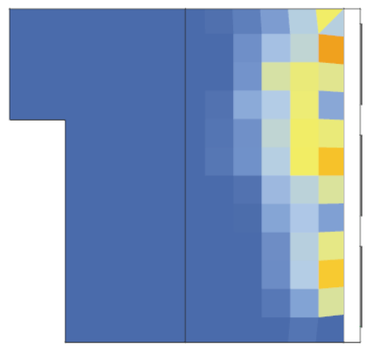
Mar 21 3pm



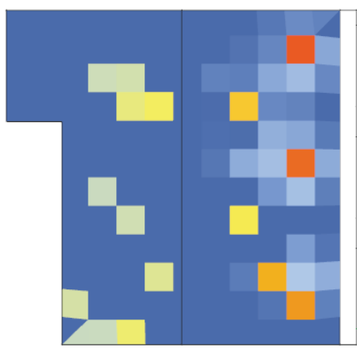
Sep 21 9am



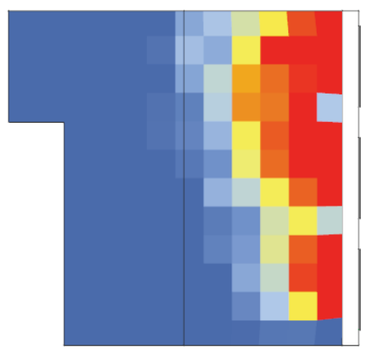
Sep 21 12pm



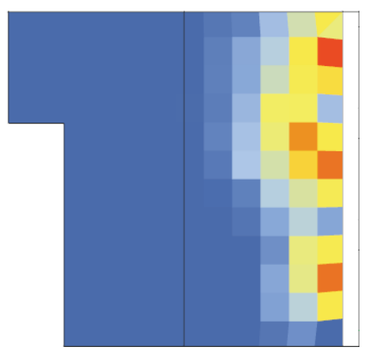
Sep 21 3pm



Dec 21 9am

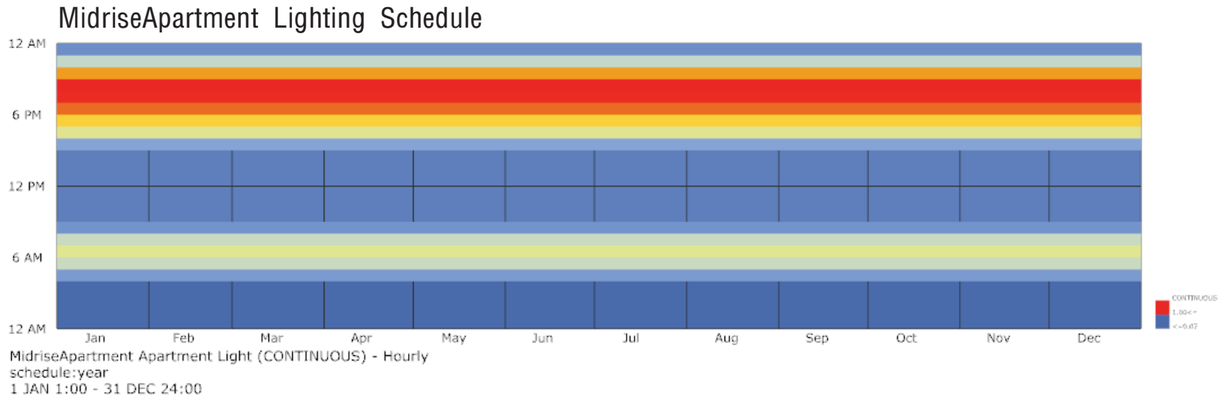


Dec 21 12pm

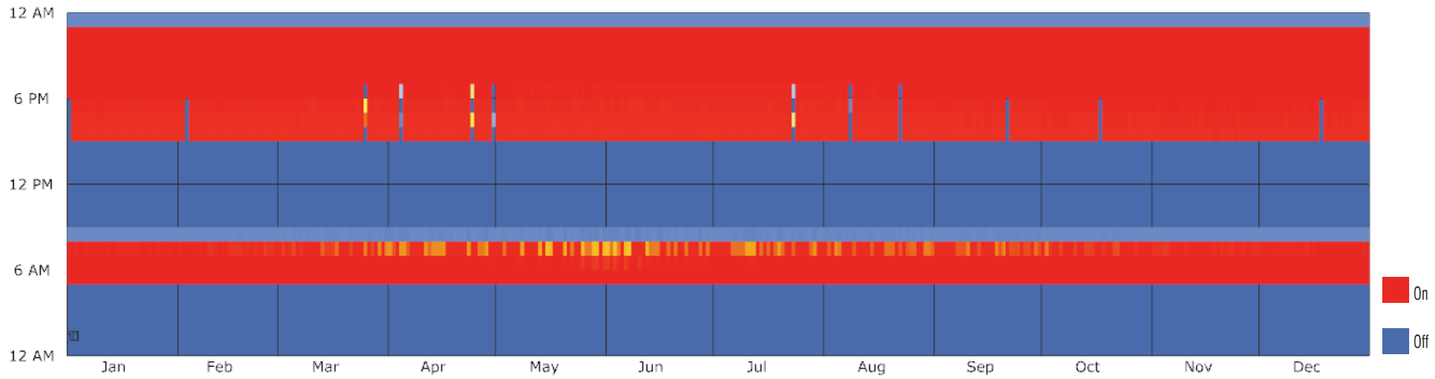


Dec 21 3pm

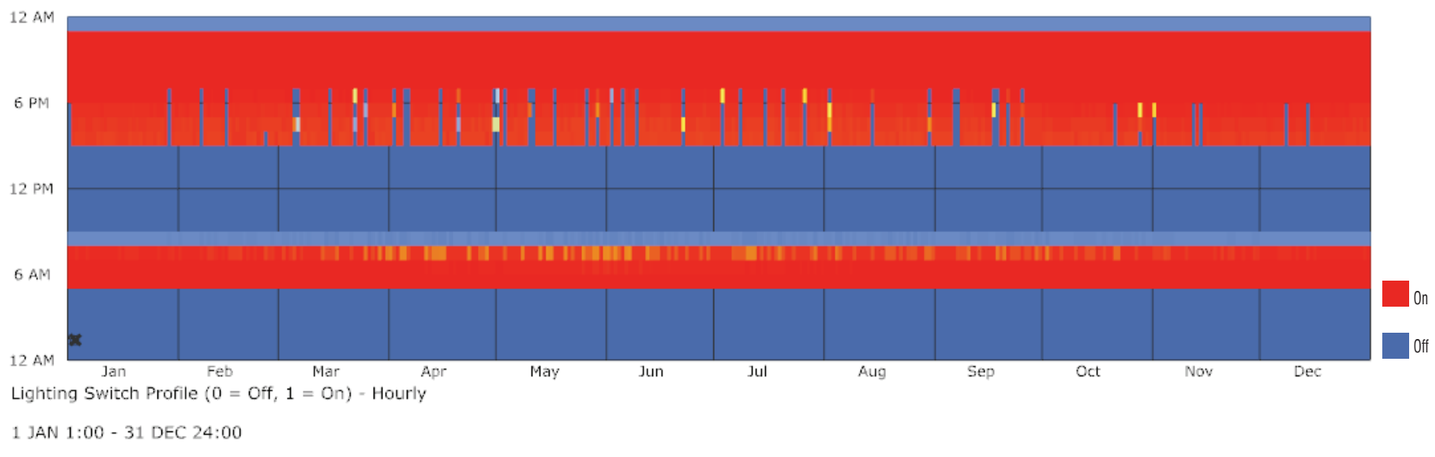
The lighting schedule also shows that Scheme four does better in providing a more visually comfortable room.



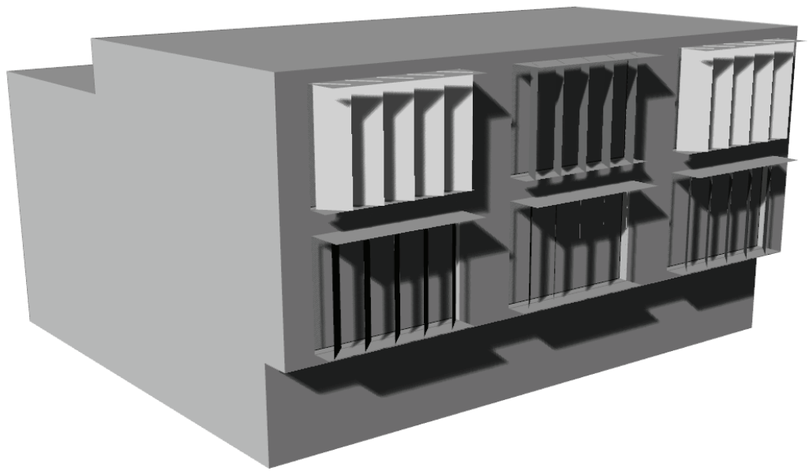
Scheme 3



Scheme 4



Final Design



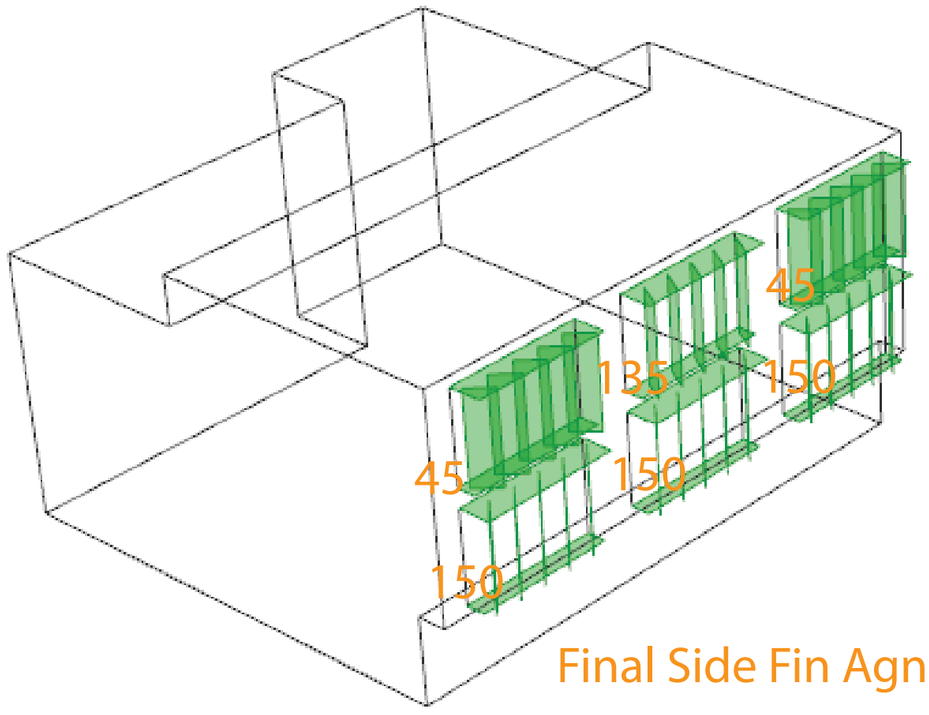
The design process started with the analysis of local climate and suggest an effective passive design scheme (is it possible to be 100% comfortable in your house). Most of the assumptions at the beginning lead the project to the right way. The only thing is that when setting limits fot the genome calaulation, the opening was too narrow (excluding the east sunlight issue too early) and later during the visual comfort analysis the process goes back a little bit.

ClimaGuard 55/27 Performance

ClimaGuard 55/27 is designed to have low solar heat gain and reduce glare in southern climates and waterfront homes. As shown below, it can be used in multiple configurations to meet the needs of many applications.

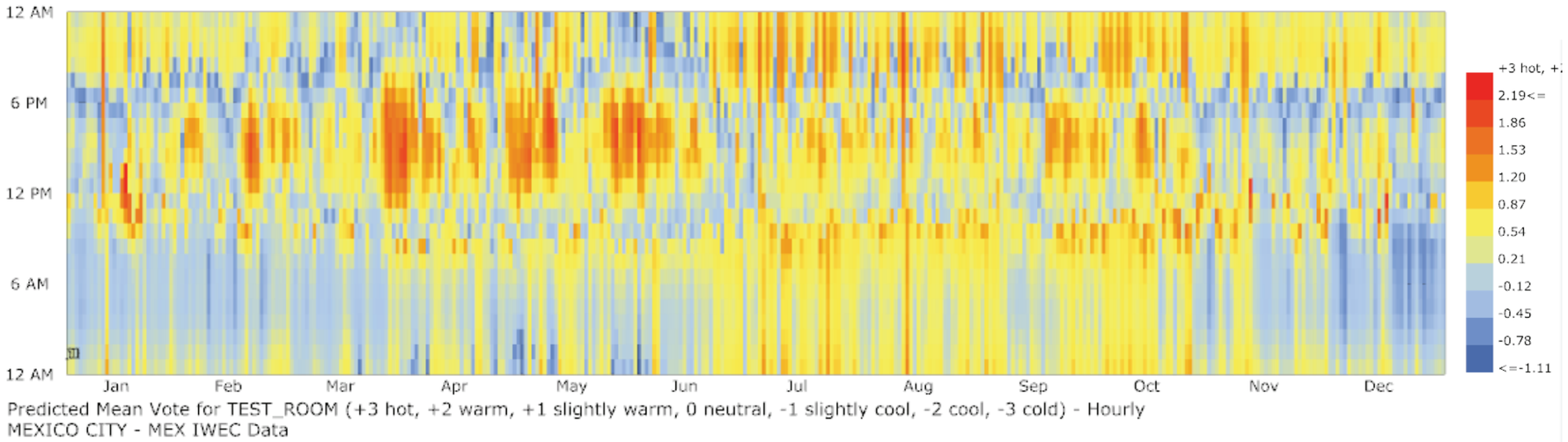
	Visible Light					U-Factor		
Double Glazed	Trans	Reflect Out	Reflect In	UV Trans	SHGC	Argon	Air	ENERGY STAR Zones*
55/27 (#2)	55%	12%	17%	18%	0.275	0.243	0.290	N, NC, SC, S
55/27 (#2) + IS-30 (#4)	55%	12%	16%	18%	0.274	0.211	0.248	N, NC, SC, S
55/27 (#2) + IS-20 (#4)	53%	12%	18%	17%	0.267	0.201	0.236	N, NC, SC, S
Triple Glazed								
55/27 (#2) + 70/36 (#5)	42%	14%	17%	8%	0.240	0.166	0.215	N, NC, SC, S

Window & Glass



Final Side Fin Agnle

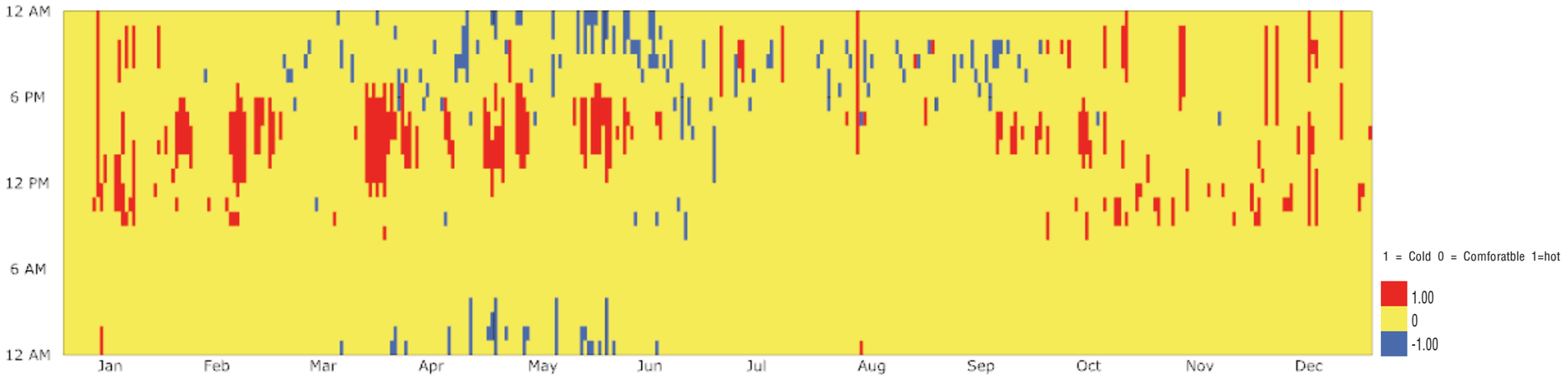
Final Design - Comfor hours



Predicted Mean Vote for TEST_ROOM (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

Comfor Hours: 7013
Percentage of Comfor time: 80.1

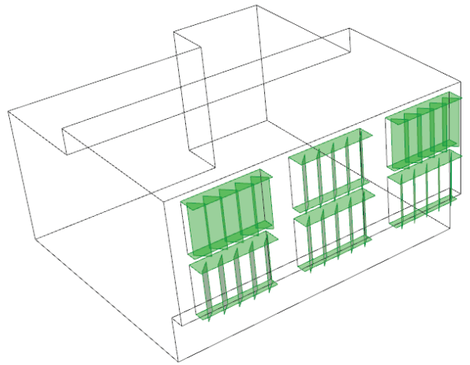
The design achieves 92.1% comfort time, which is a pretty good result. During the dry season the temperature change is very dramatic and make it hard to keep the house constantly comfortable. The main passive design scheme is ventilation and shading.

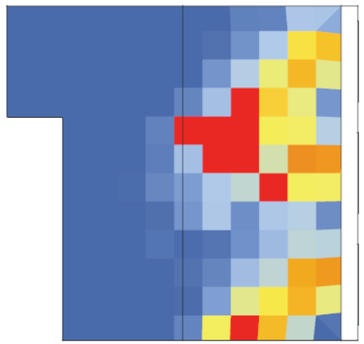


Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
MEXICO CITY - MEX IWEC Data
1 JAN 1:00 - 31 DEC 24:00

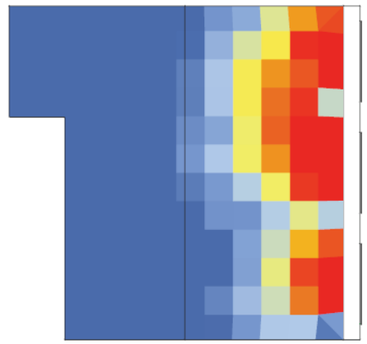
Comfor Hours: 8074
Percentage of Comfor time: 92.1

Final Design - Daylighting Analysis

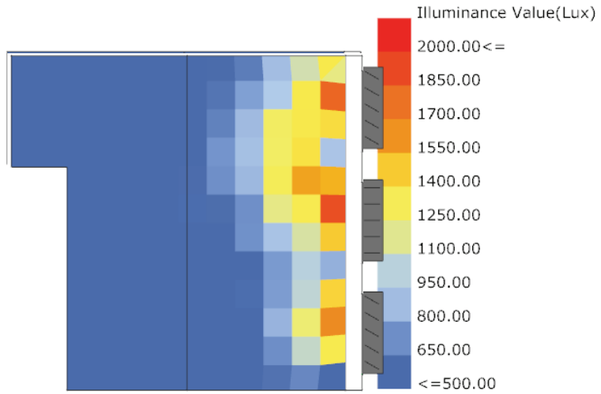




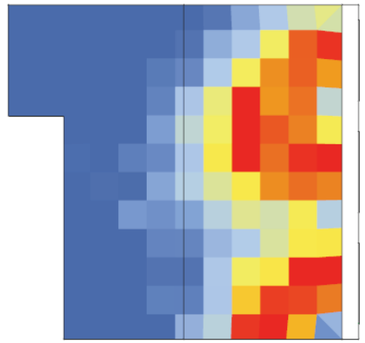
Mar 21 9am



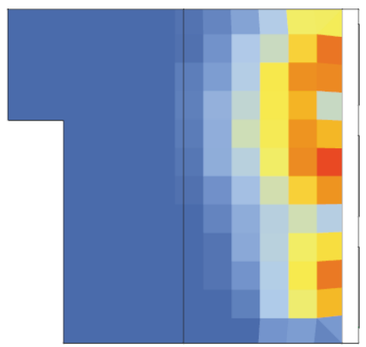
Mar 21 12pm



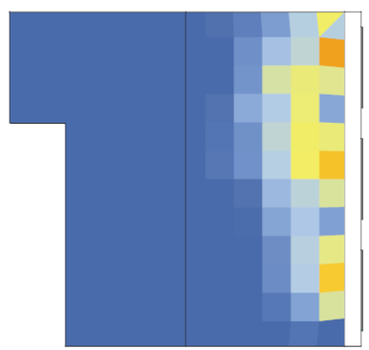
Mar 21 3pm



Sep 21 9am

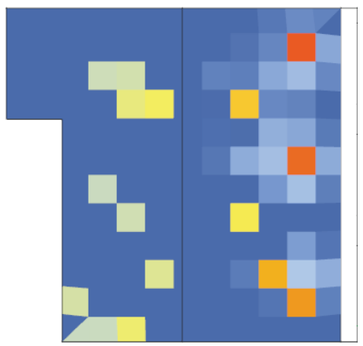


Sep 21 12pm

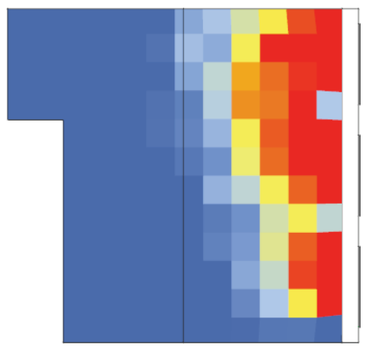


Sep 21 3pm

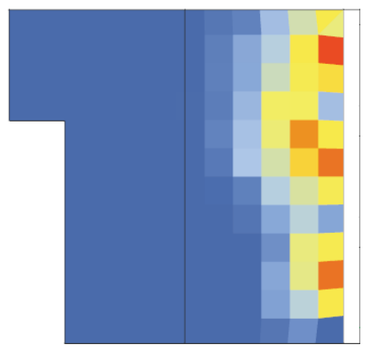
The balance of visual comfort/good daylighting and a more comfortable interior environment is the main discussion of this design. The scheme is to use overhang and vertically divided openings to block the high angle sun as much as possible and use fins to deal with the low angle sun and visual comfort. The result is a more evenly distributed natural light.



Dec 21 9am



Dec 21 12pm



Dec 21 3pm

Final Design - Daylighting And Visual Comfort

From very early morning, there's a very strong light from east,. but the shading did a good job in filtering most of lt.
While the working area is in the back of the room, it is very important that during afternoon there is enough natural light.