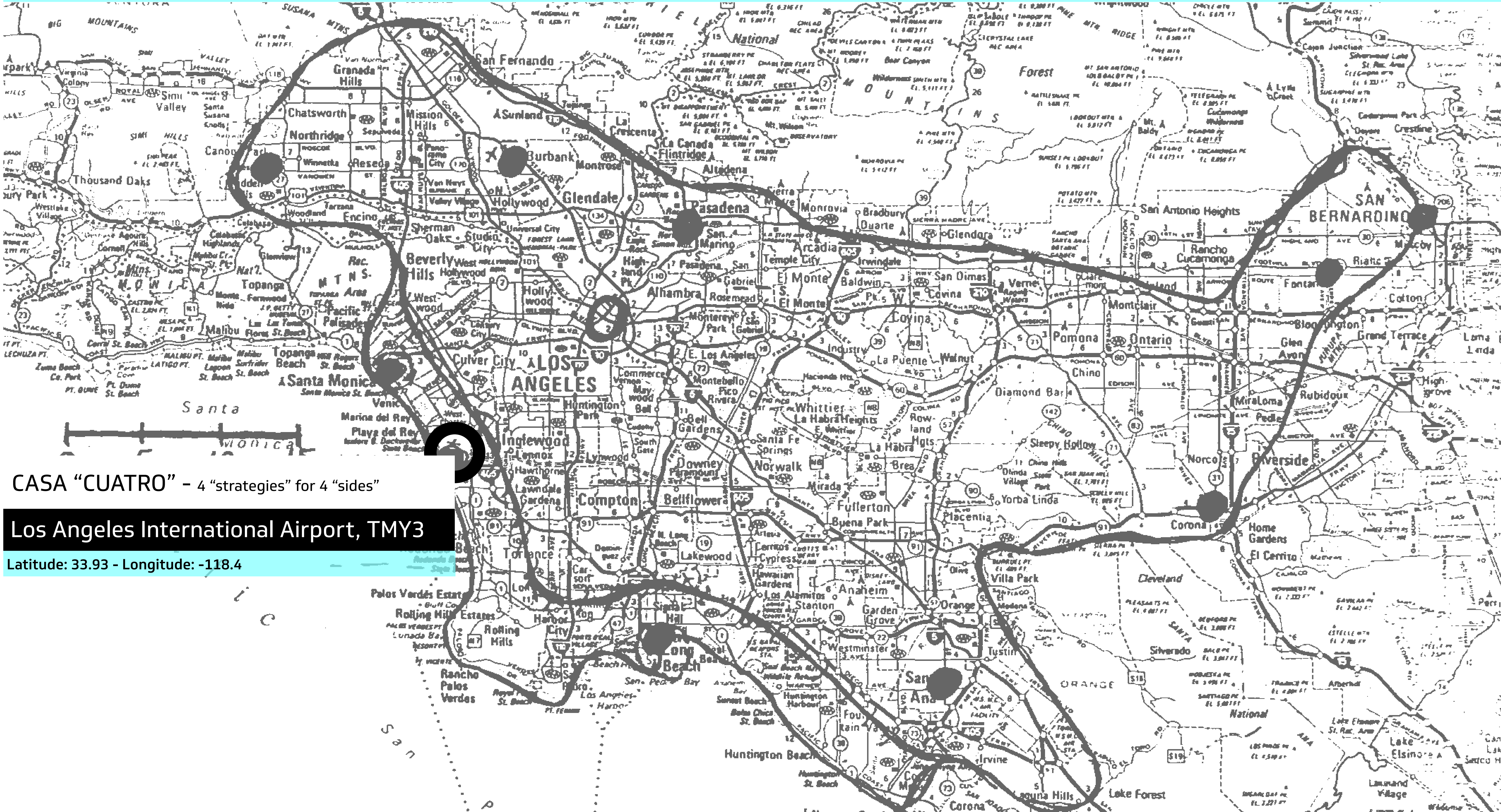
Thermal and Visual Comfor Maximization of an Uncontidioned Space - Los Angeles, CA



CASA “CUATRO” - 4 “strategies” for 4 “sides”

Los Angeles International Airport, TMY3

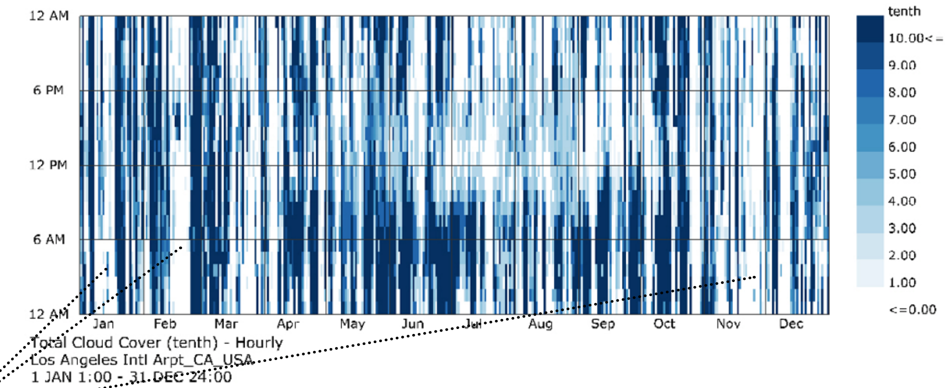
Latitude: 33.93 - Longitude: -118.4

0.0 Climate Assessment

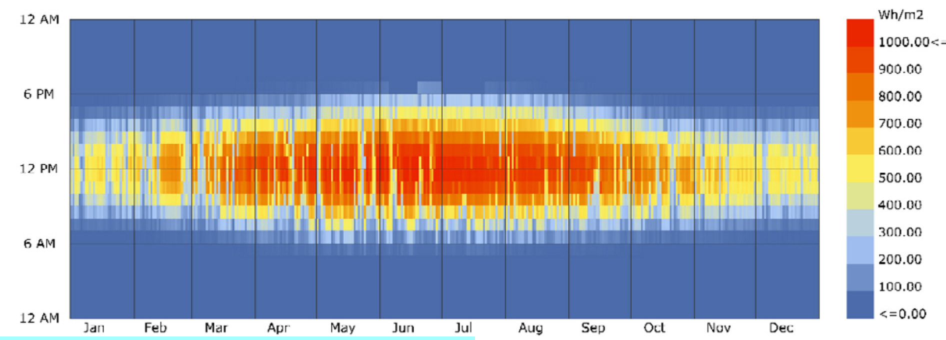
0.1 Background

The Los Angeles metropolitan area weather is characterized by stability year round. The climate is classified as Mediterranean, with dry and warm summers and winter rainy season. Another aspect to take into account is the typical phenomenon of microclimate, the reason why the temperatures of inland areas and coastal areas can significantly vary.

The presence of the ocean tends to depress summer maximums, therefore the cooling demand increases toward the east.

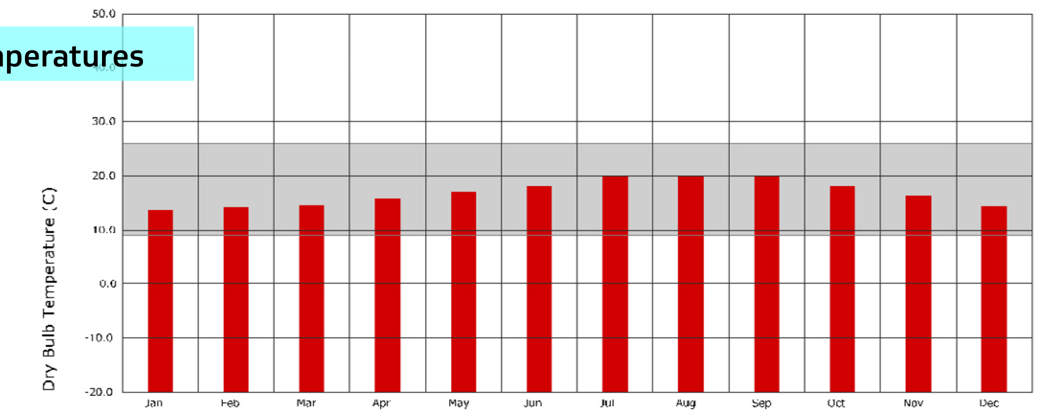


Winter clear sun can lead to colder days (mornings)

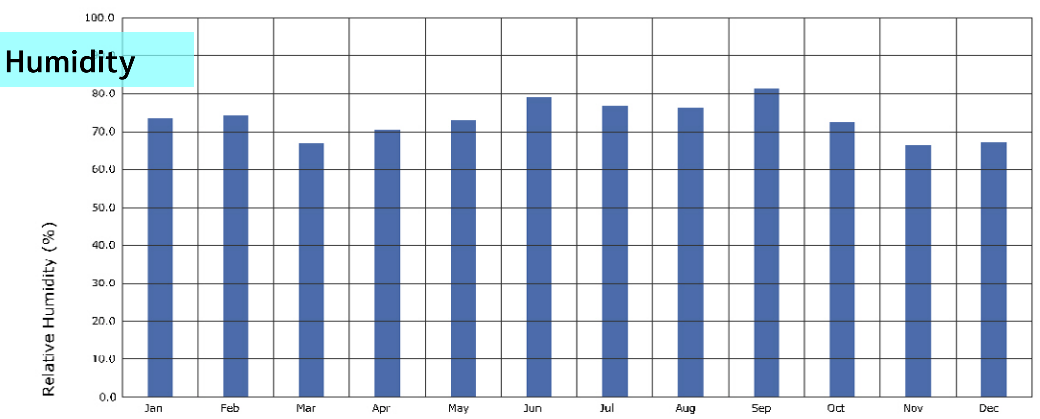


Global Horizontal Radiation (hourly) - kWh/m2

Mild temperatures



Relative Humidity



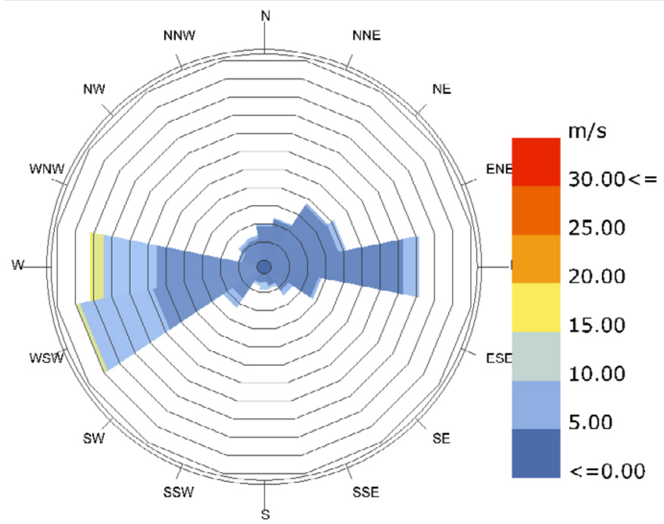
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	95 (35)	95 (35)	99 (37)	106 (41)	103 (39)	112 (44)	109 (43)	106 (41)	113 (45)	108 (42)	100 (38)	92 (33)	113 (45)
Average high °F (°C)	68.2 (20.1)	68.6 (20.3)	70.2 (21.2)	72.7 (22.6)	74.5 (23.6)	78.1 (25.6)	83.1 (28.4)	84.4 (29.1)	83.1 (28.4)	78.5 (25.8)	72.8 (22.7)	67.7 (19.8)	75.2 (24)
Daily mean °F (°C)	58.0 (14.4)	58.9 (14.9)	60.6 (15.9)	63.1 (17.3)	65.8 (18.8)	69.2 (20.7)	73.3 (22.9)	74.3 (23.5)	73.1 (22.8)	68.6 (20.3)	62.4 (16.9)	57.6 (14.2)	65.4 (18.6)
Average low °F (°C)	47.8 (8.8)	49.3 (9.6)	51.0 (10.6)	53.5 (11.9)	57.1 (13.9)	60.3 (15.7)	63.6 (17.6)	64.1 (17.8)	63.1 (17.3)	58.7 (14.8)	52.0 (11.1)	47.5 (8.6)	55.7 (13.2)
Record low °F (°C)	28 (−2)	28 (−2)	31 (−1)	36 (2)	40 (4)	46 (8)	49 (9)	49 (9)	44 (7)	40 (4)	34 (1)	30 (−1)	28 (−2)
Average rainfall inches (mm)	3.12 (79.2)	3.80 (96.5)	2.43 (61.7)	0.91 (23.1)	0.26 (6.6)	0.09 (2.3)	0.01 (0.3)	0.04 (1)	0.24 (6.1)	0.66 (16.8)	1.04 (26.4)	2.33 (59.2)	14.93 (379.2)
Average rainy days (≥ 0.01 in)	6.1	6.4	5.5	3.2	1.3	0.6	0.3	0.3	1.0	2.5	3.3	5.2	35.7
Mean monthly sunshine hours	225.3	222.5	267.0	303.5	276.2	275.8	364.1	349.5	278.5	255.1	217.3	219.4	3,254.2
Percent possible sunshine	71	72	72	78	64	64	83	84	75	73	70	71	73

Source: NOAA (sun 1961–1977)[1][2][3]

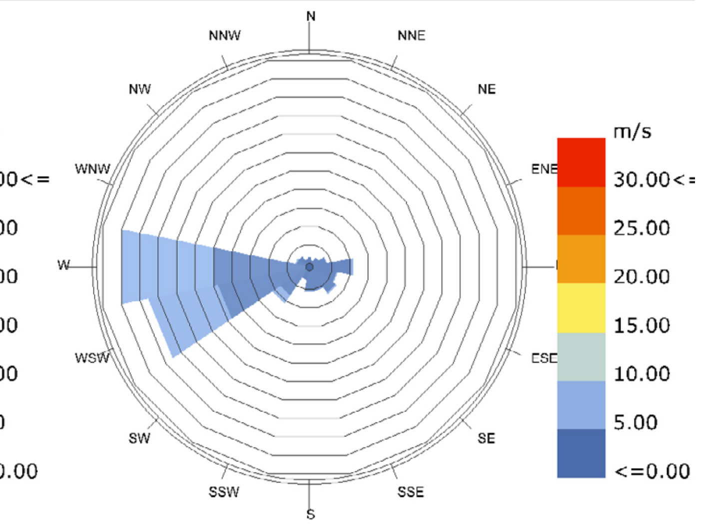
0.0 Climate Assessment

0.2 Design Implications

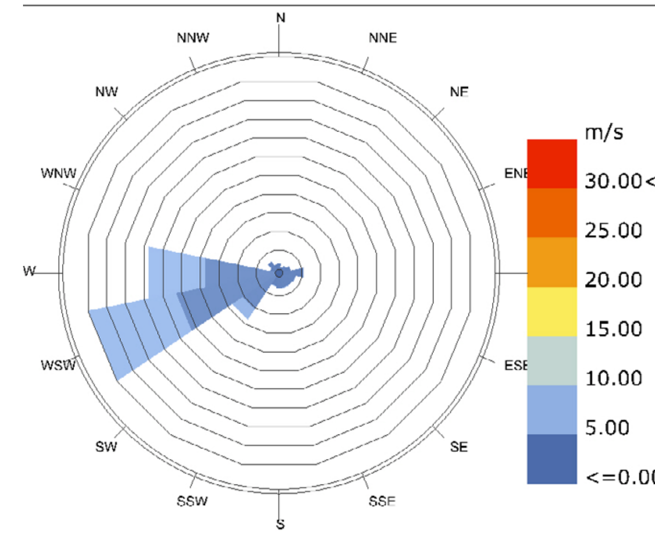
The benign climate promotes interior temparature stability,. To promote comfort and energy efficiency the design shall follow the following strategies: good exposure, solar gain (coupled with good shading), and natural ventilation.



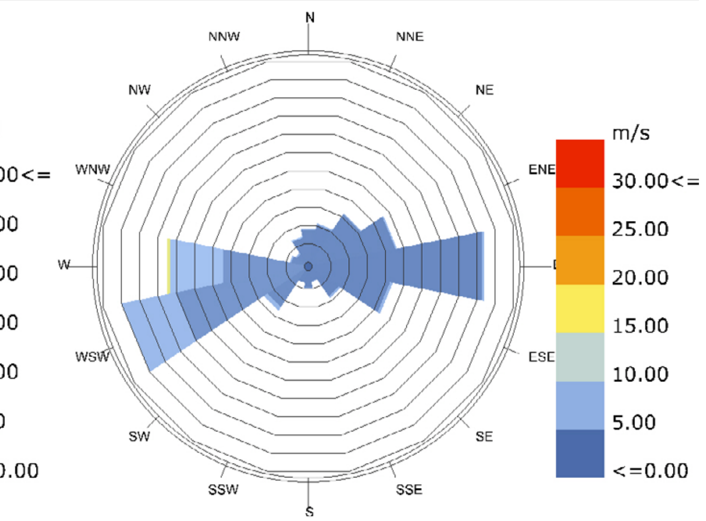
Wind-Rose
Los Angeles Intl Arpt_CA_USA
1 JAN 1:00 - 31 MAR 24:00
Hourly Data: Wind Speed (m/s)
Calm for 10.46% of the time = 226 hours.
Each closed polyline shows frequency of 1.7%. = 36 hours



Wind-Rose
Los Angeles Intl Arpt_CA_USA
1 APR 1:00 - 30 JUN 24:00
Hourly Data: Wind Speed (m/s)
Calm for 9.11% of the time = 199 hours.
Each closed polyline shows frequency of 2.9%. = 62 hou

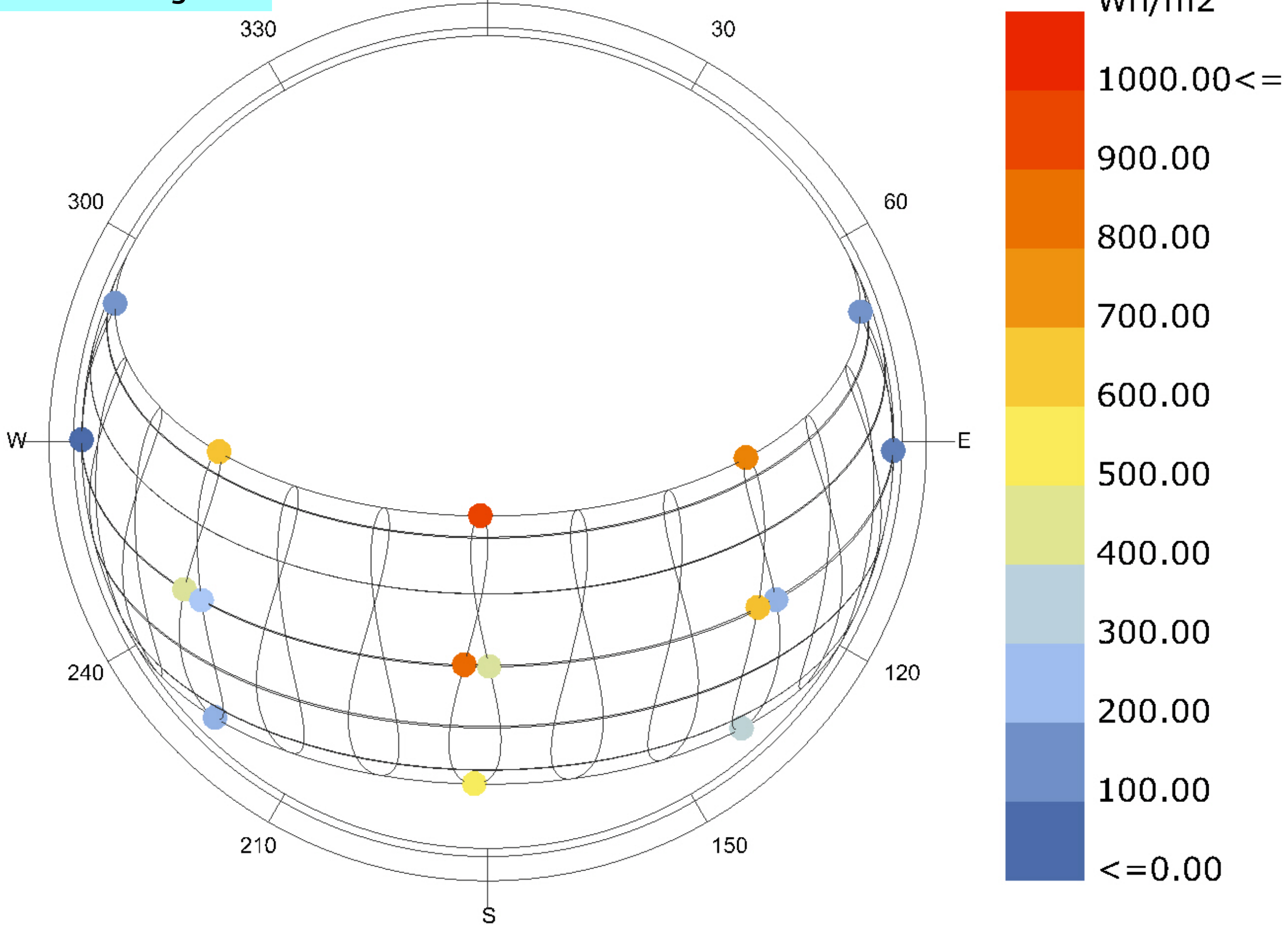


Wind-Rose
Los Angeles Intl Arpt_CA_USA
1 JUL 1:00 - 30 SEP 24:00
Hourly Data: Wind Speed (m/s)
Calm for 11.23% of the time = 248 hours.
Each closed polyline shows frequency of 3.4%. = 75 hours.

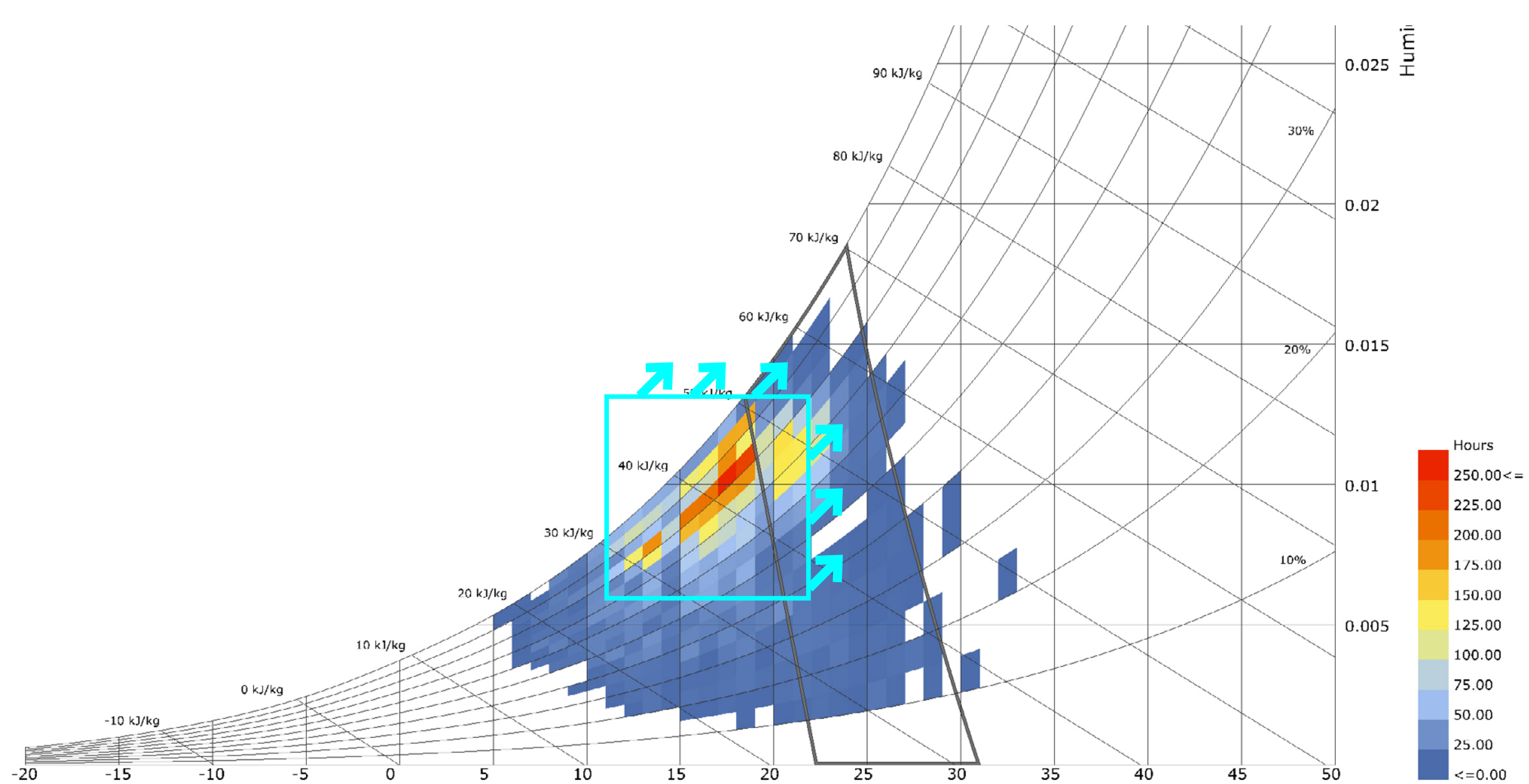


Wind-Rose
Los Angeles Intl Arpt_CA_USA
1 OCT 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 6.25% of the time = 138 hours.
Each closed polyline shows frequency of 1.8%. = 38 hour

Sun Path Diagram



Psychrometric Chart



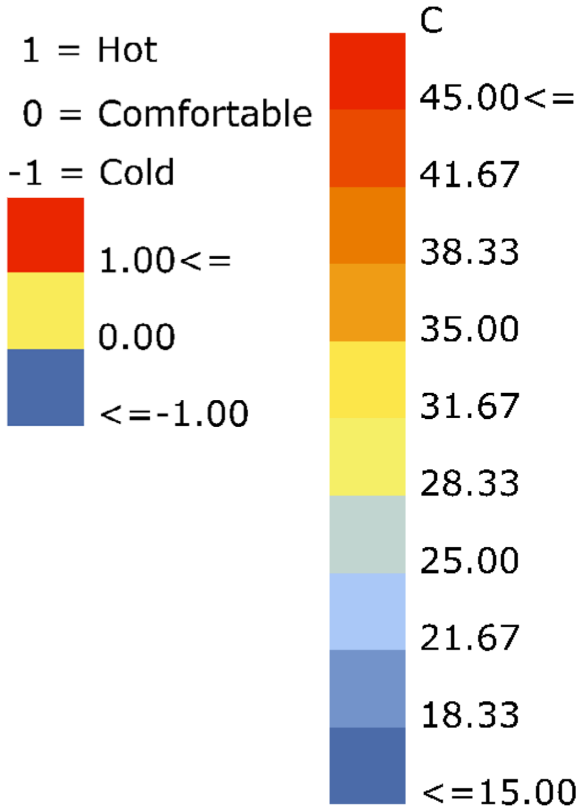
1.0 Baseline

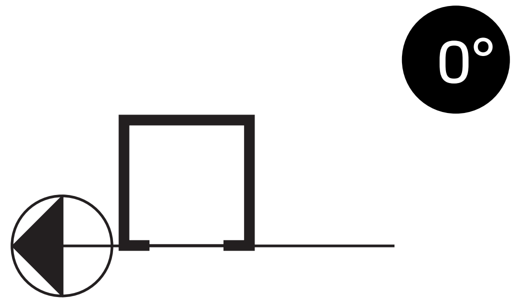
1.0 Orientation - no glazing

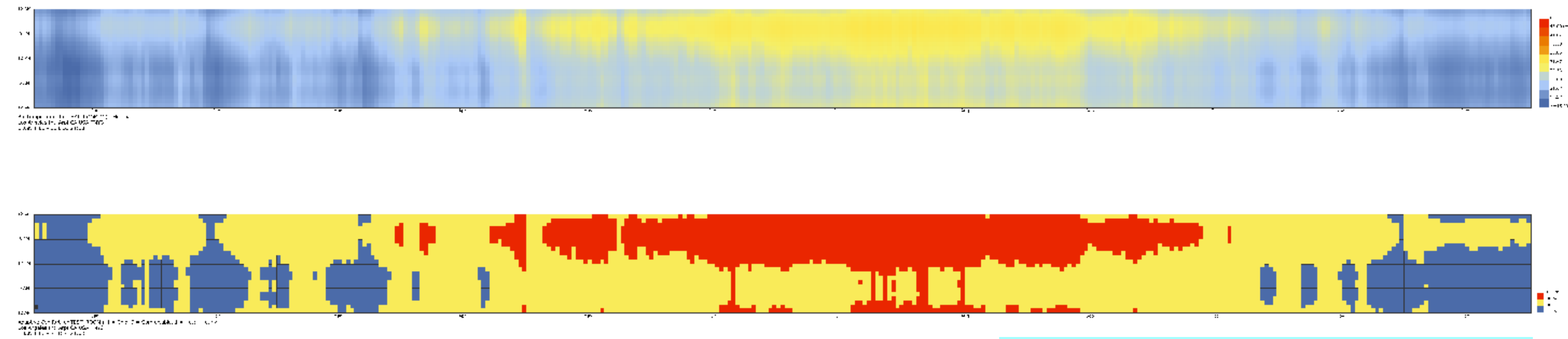
The baseline conditions for the building are considered with no materials applied to the construction, no shading, and no glass.

The reported data show the adaptive comfort of the occupants related to the indoor space air temperature, in 3 different orientation.

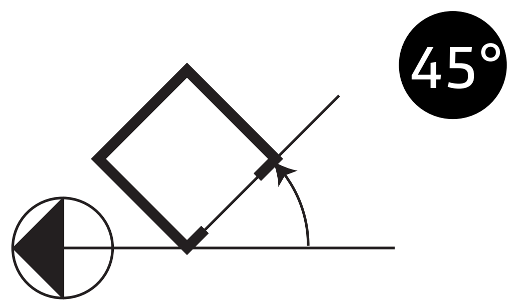
The ATC does not differs significantly.

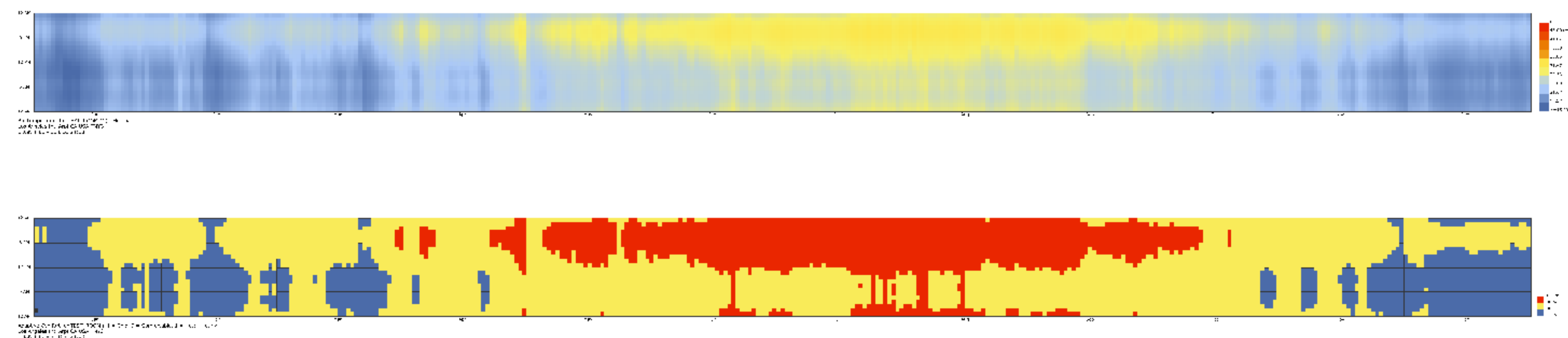




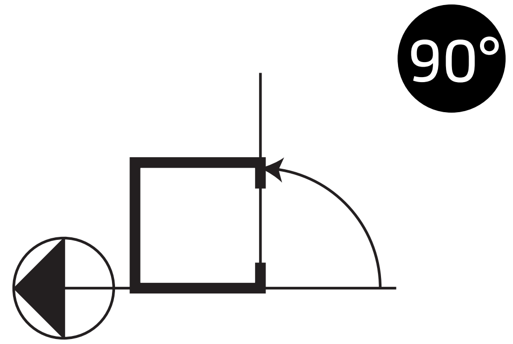


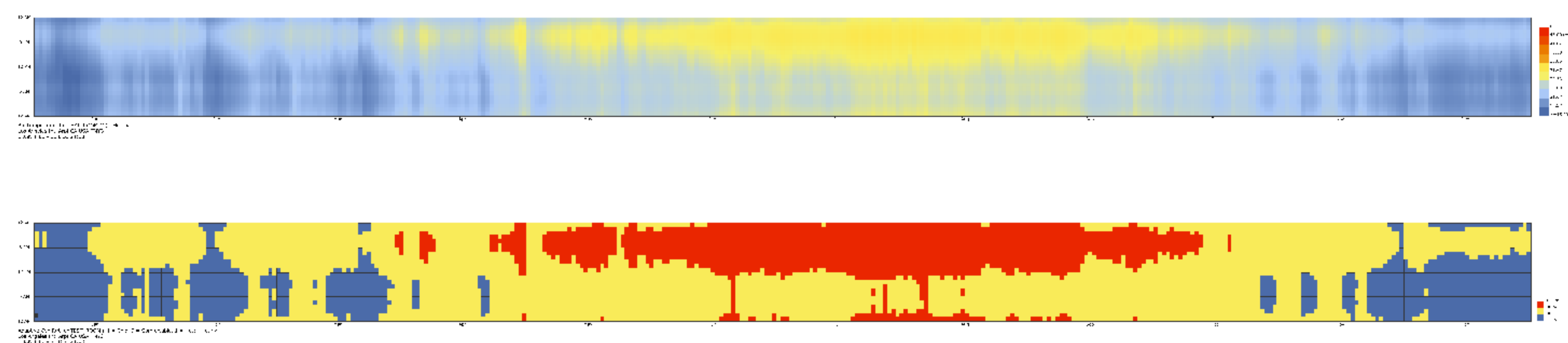
Adaptive Thermal Comfort = 58.8 %





Adaptive Thermal Comfort = 56.2 %





Adaptive Thermal Comfort = 57.8 %

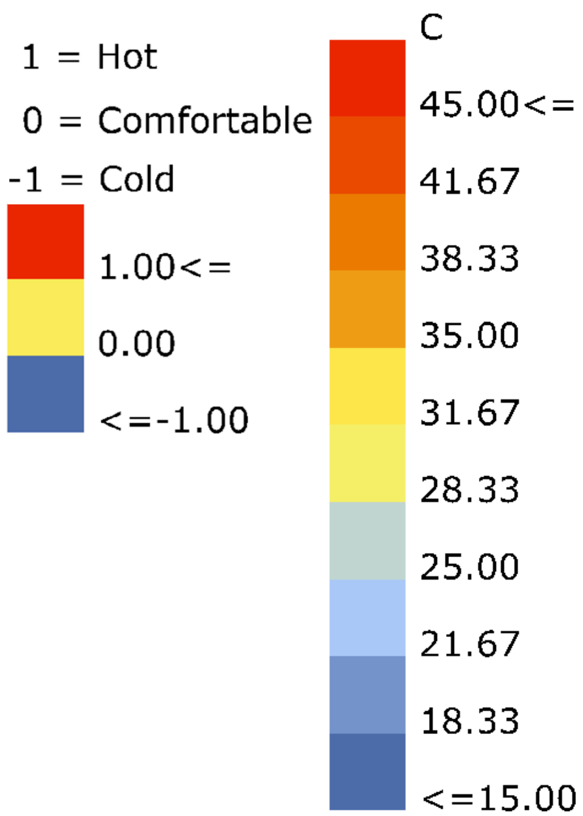
1.0 Baseline

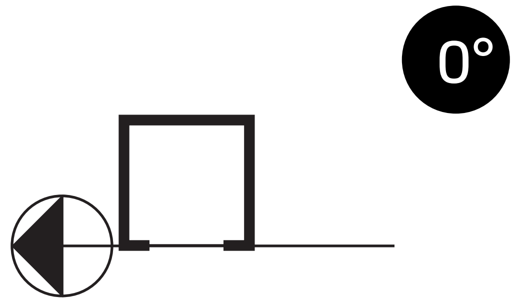
1.1 Orientation - whole glazed south facade

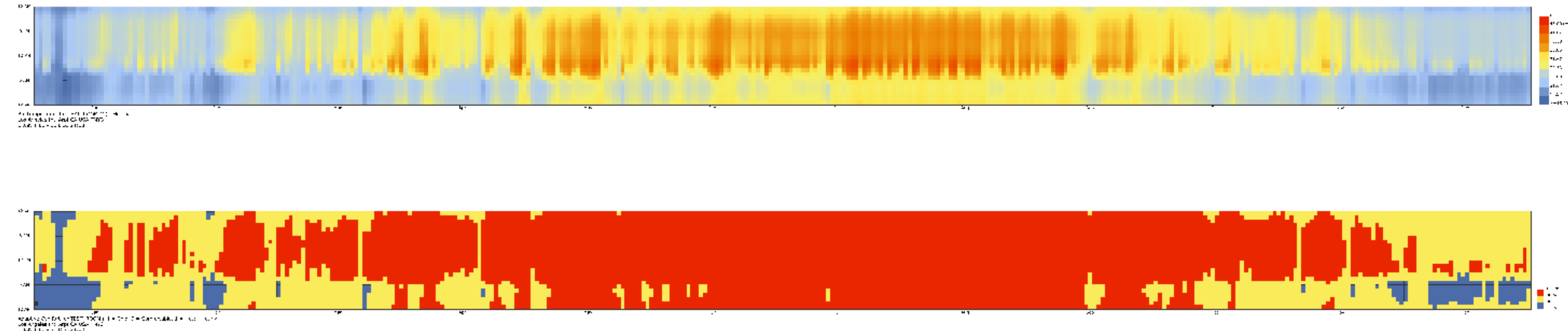
Considering a whole glazed faced, mainly south oriented, ATC greatly decreases compared to baseline conditions.

Accordingly, indoor air temperature significantly increase, from a max avarage of 28-30°C for the baseline (no glaze) to 38-43°C for the glazed solution.

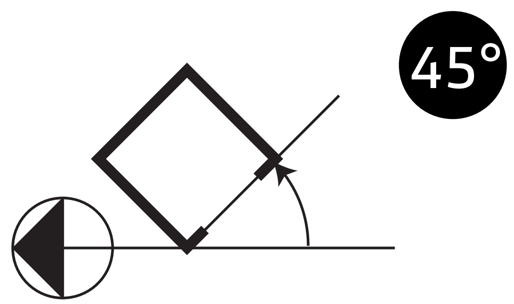
It is important to reach avarage high temperatures throughout the whole year to warm the indoor space, and then consider passive strategies to prevent overheating.

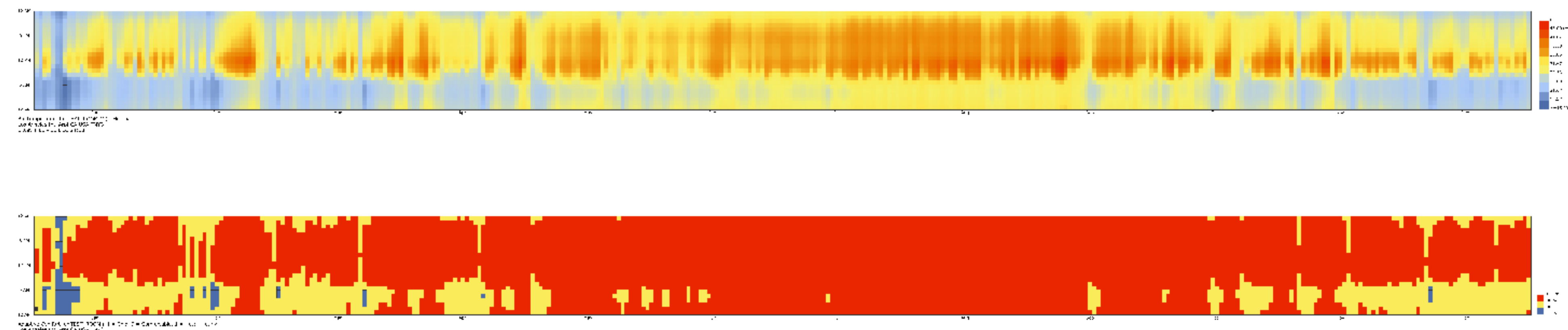






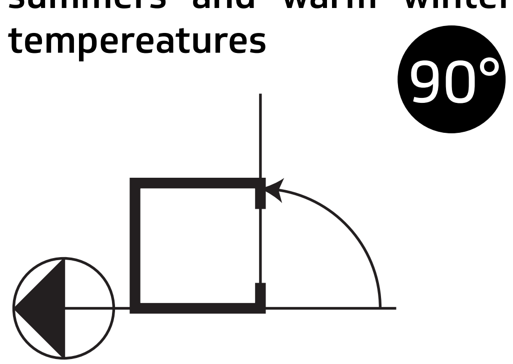
Adaptive Thermal Comfort = 29.4 %

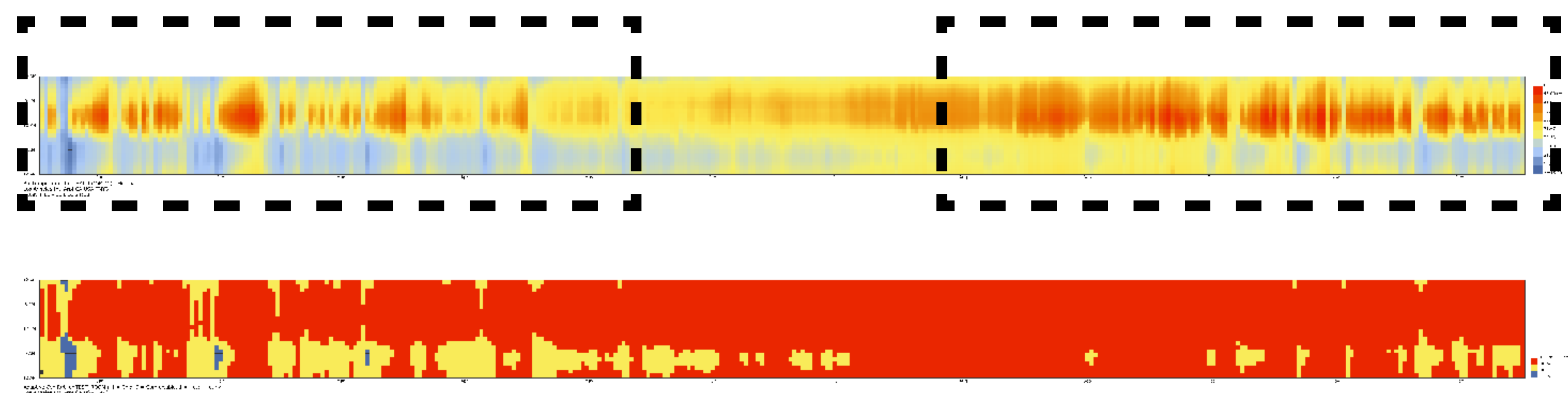




Adaptive Thermal Comfort = 18.8 %

For the indoor comfort, this is the most interesting solution because it provides milder summers and warm winter tempereatures





Adaptive Thermal Comfort = 15.5 %

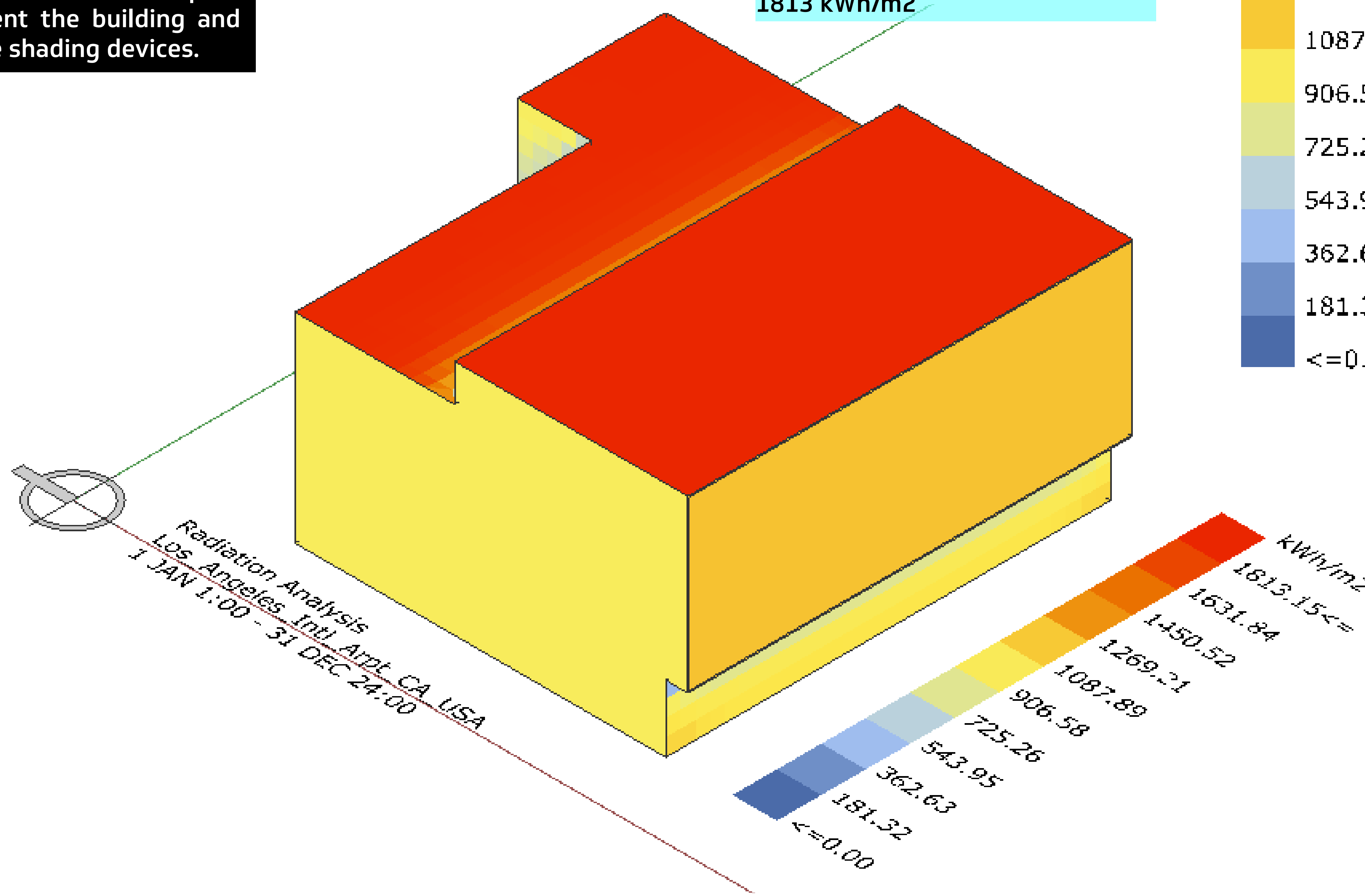
1.0 Baseline

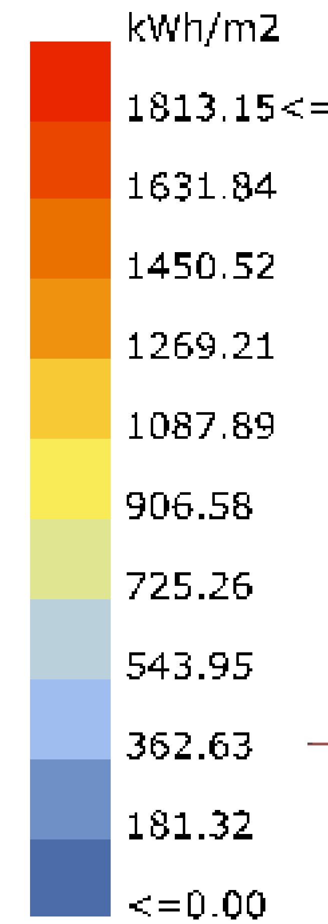
1.2 Solar Radiation

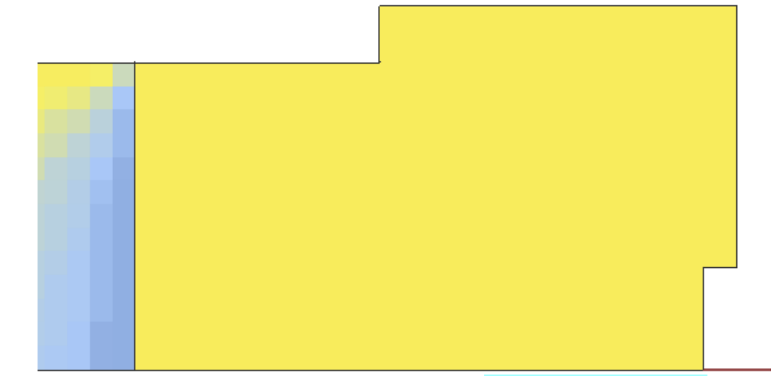
Solar radiation equates to the heat that effects the buidling horizontal and vertical surfaces.

Based on the climate, understanding the significance of solar radiation will help to mass, orient the building and design the shading devices.

The roof is the more significant surface in terms of insolation, the energy accumulated per year is 1813 kWh/m2

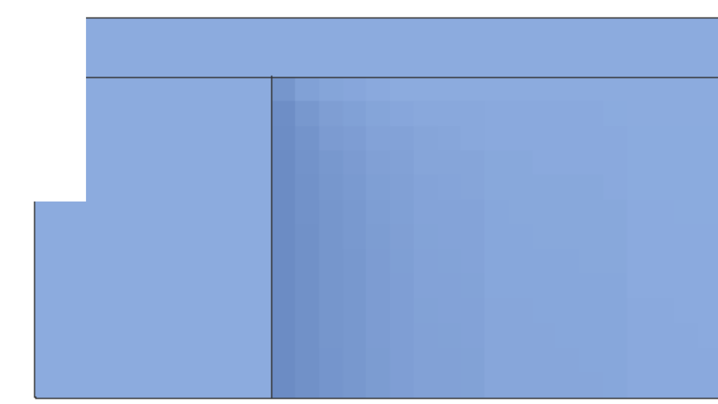




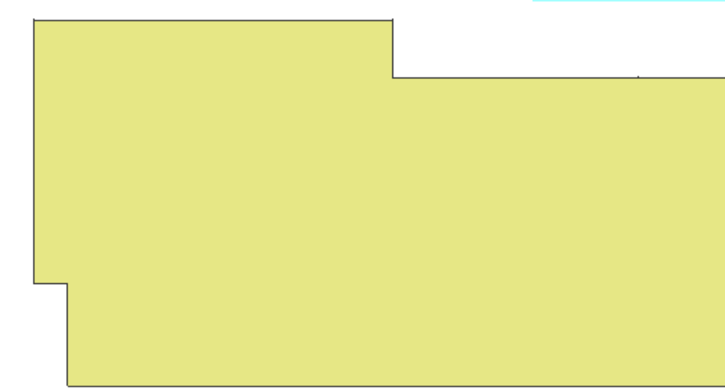


WEST FACADE 906 kWh/m2

SOUTH FACADE 1087 kWh/m2



NORTH FACADE 362 kWh/m2



EAST FACADE 725 kWh/m2

2.0 Buidling Envelope

2.0 Thermal Mass

Introducing thermal mass to the exterior walls, percetage of comfortable time rises to 24 %.

Temperatures stay quiete uniform but a little milder than before: thermal mass helps the building envelope to protect the room from high temperature.

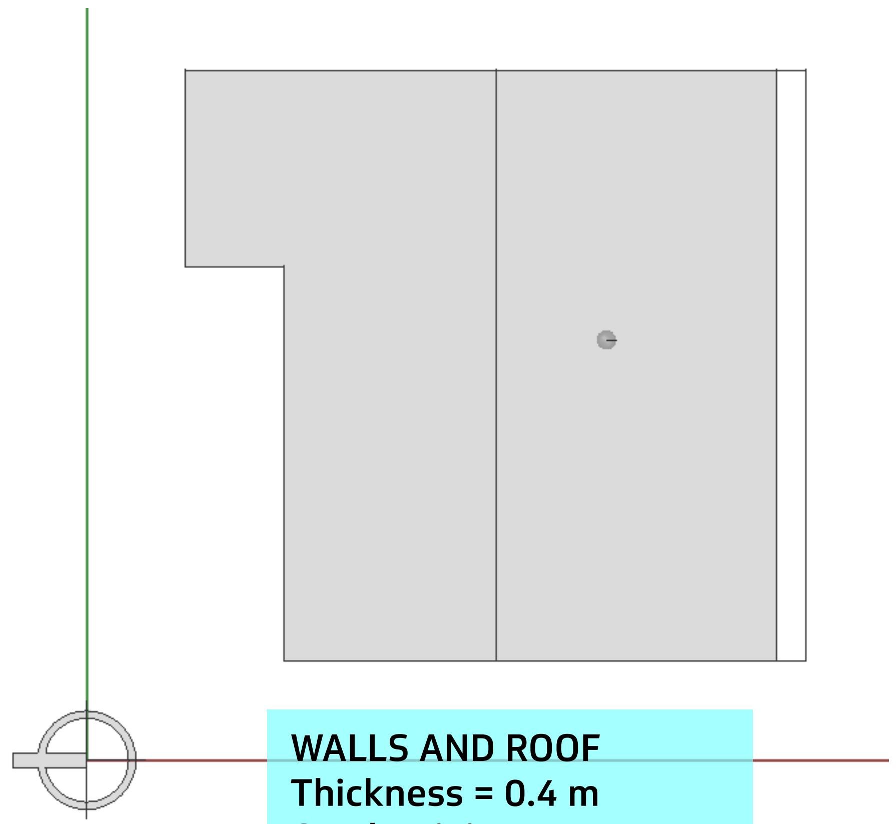
Indoor max temperatures are expected around noon from September to mid November.

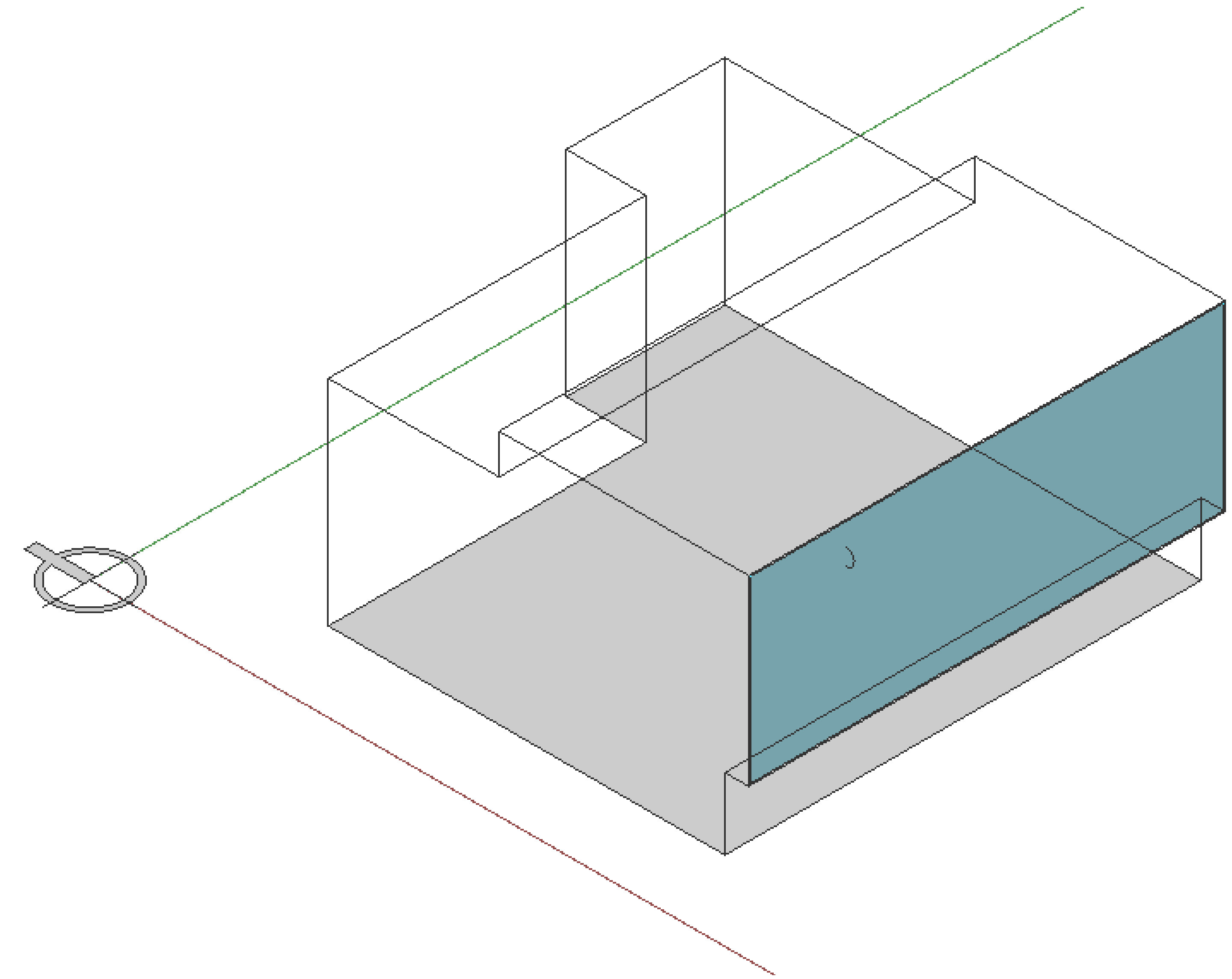
Cold days are estimated at the beginning of January.

1 = Hot
0 = Comfortable
-1 = Cold

1.00<=
0.00
<=-1.00

C
45.00<=
41.67
38.33
35.00
31.67
28.33
25.00
21.67
18.33
<=15.00

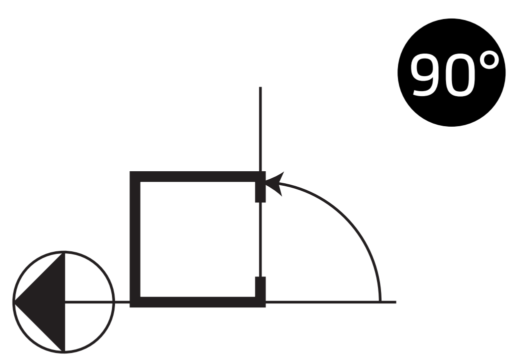


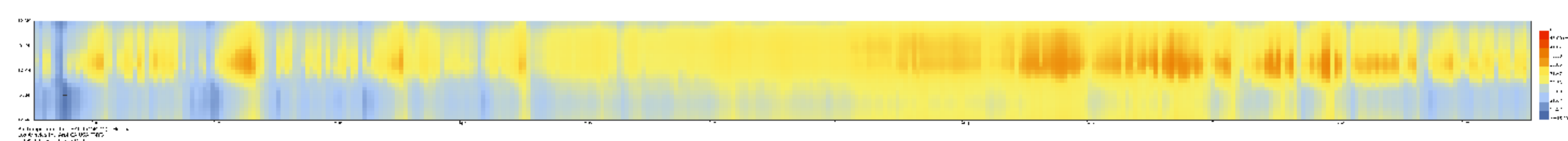


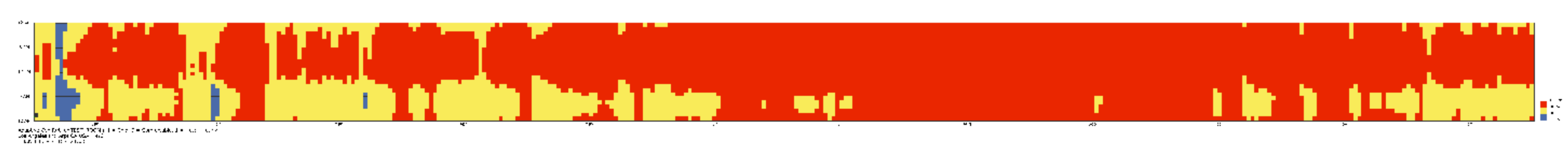
WALLS AND ROOF
Thickness = 0.4 m
Conductivity = 0.6 W/mK
Density = 2000 kg/m3
Specific Heat = 835 J/kgK

GLASS
Conductivity = 0.3 W/mK
SHGC = 0.4
VT = 0.3

Adaptive Thermal Comfort = 24.2 %





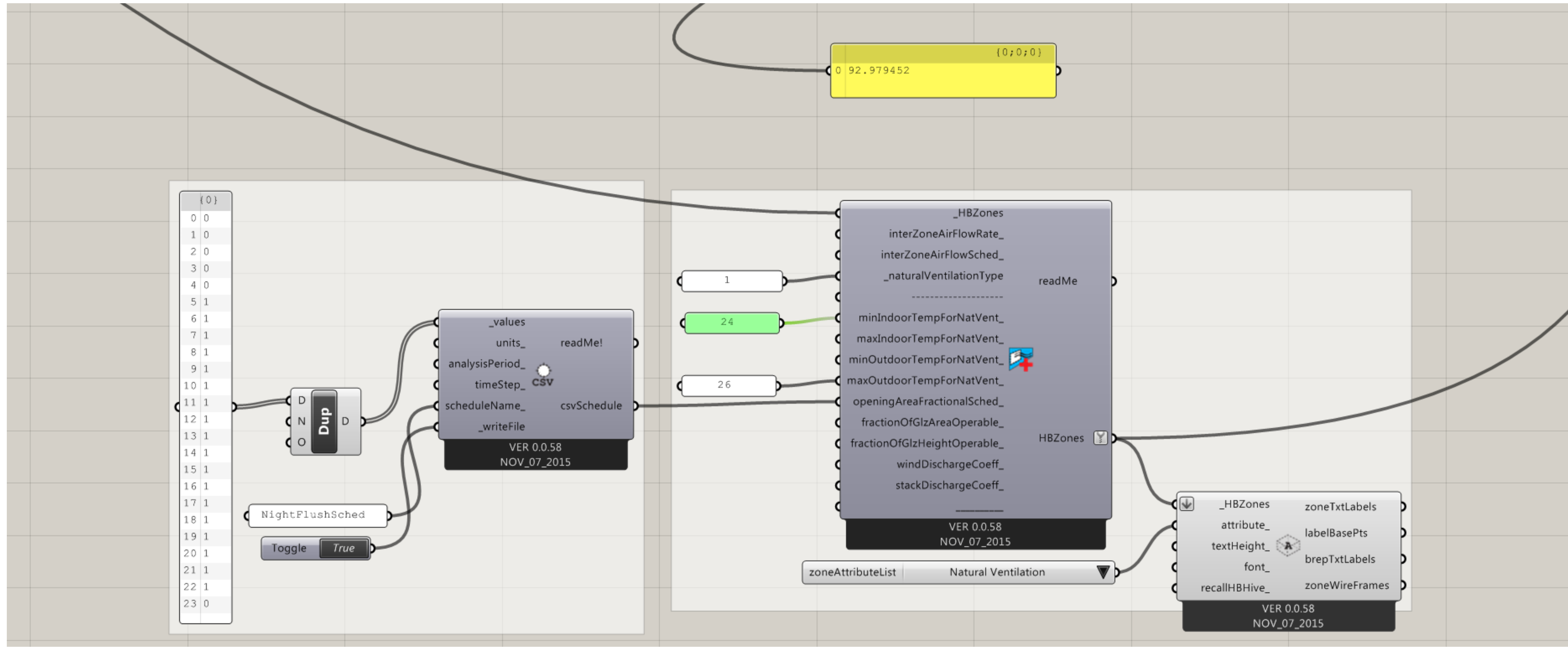


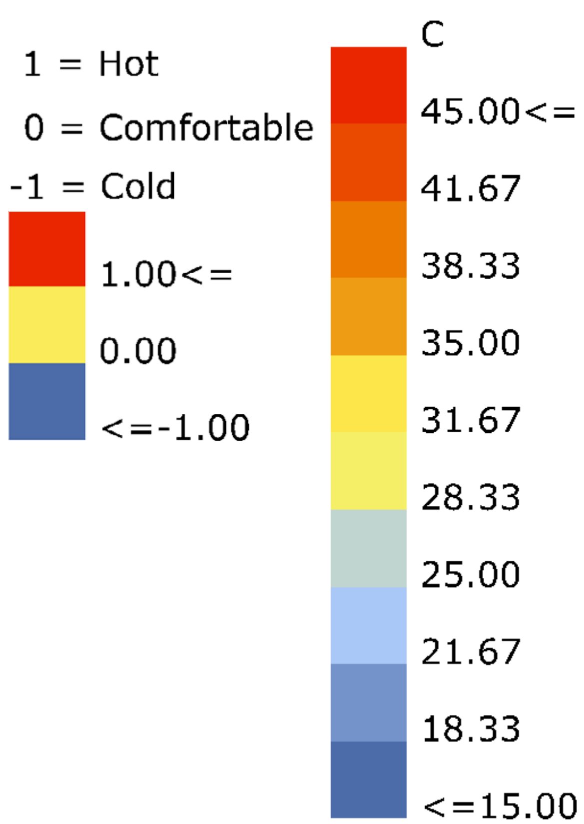
3.0 Natural Ventilation

Natural ventilation provide a great improvement to indoor temperature and comfort, helping cooling down the highest peak of the day.

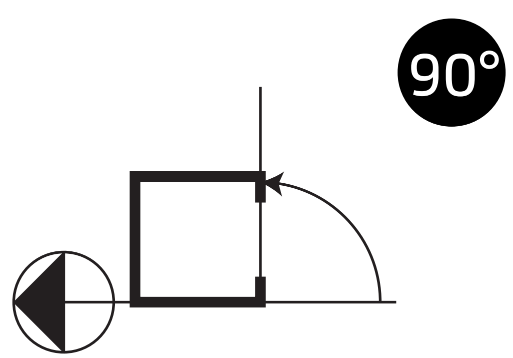
Introducing natural ventilation, and adjusting the hours of operation of the windows, percetage of comfortable time rises to 90.9 %, while temperatures get down of around 5-10 °C.

During the day, indoor temp are now in a mild range of 22°C to 28°C.

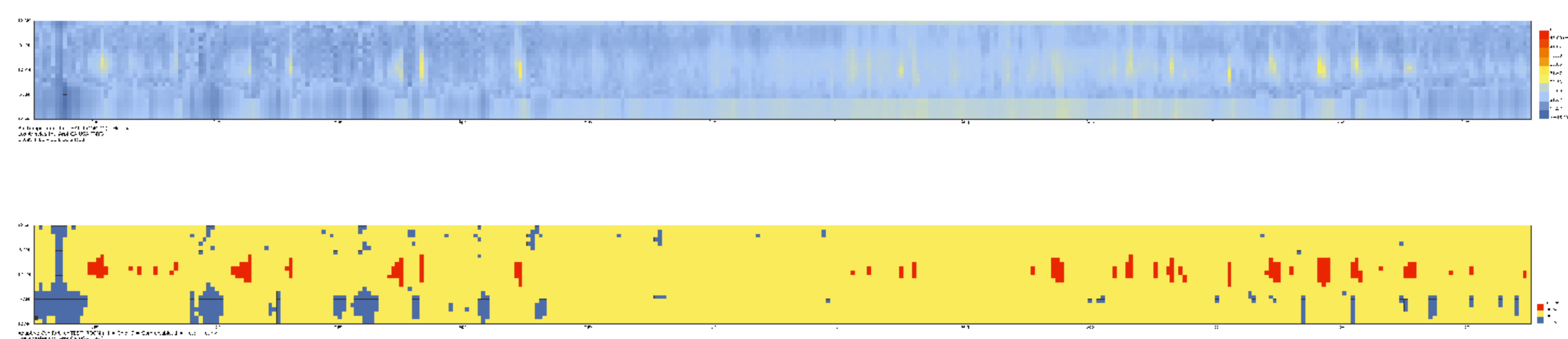




The minimum indoor temperature at which to ventilate is set to 24 °C.
The minumum outdoor temperature at which to ventilate is set to 26 °C.



Adaptive Thermal Comfort = 90.9 %



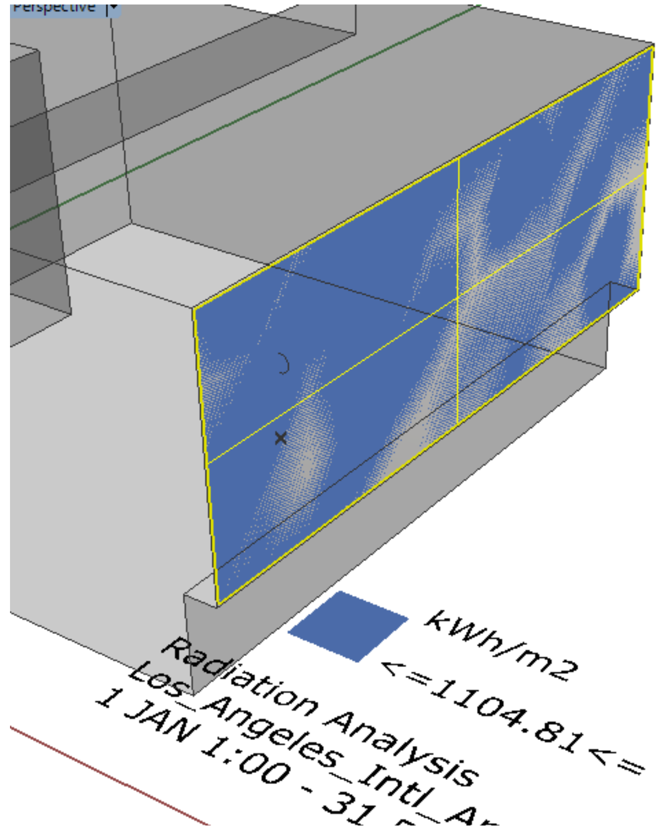
4.0 Shade

4.0 Glaze shading

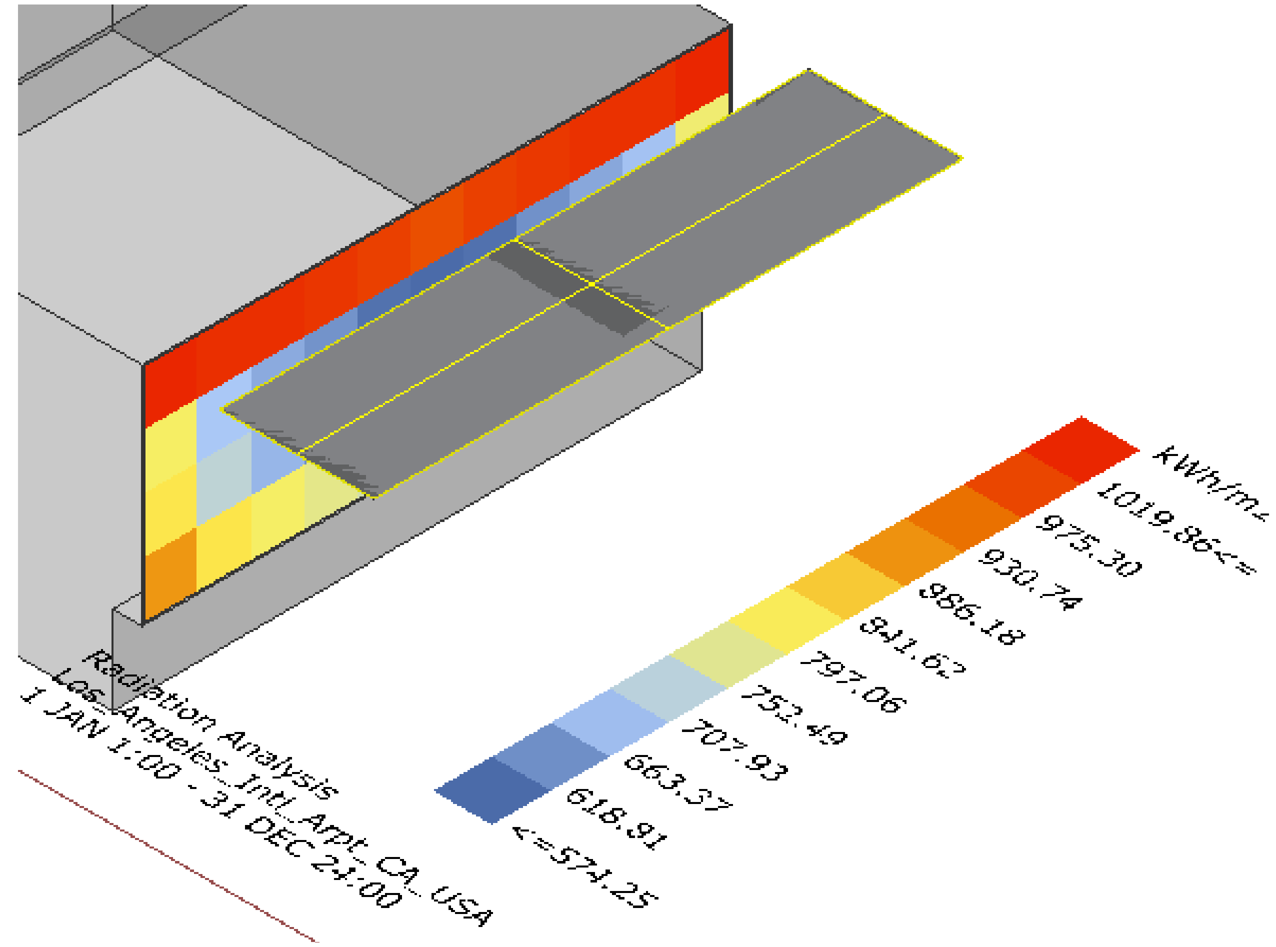
Anlyzing the solar radiation and the sun path I expolred several design configuration of shading devices.

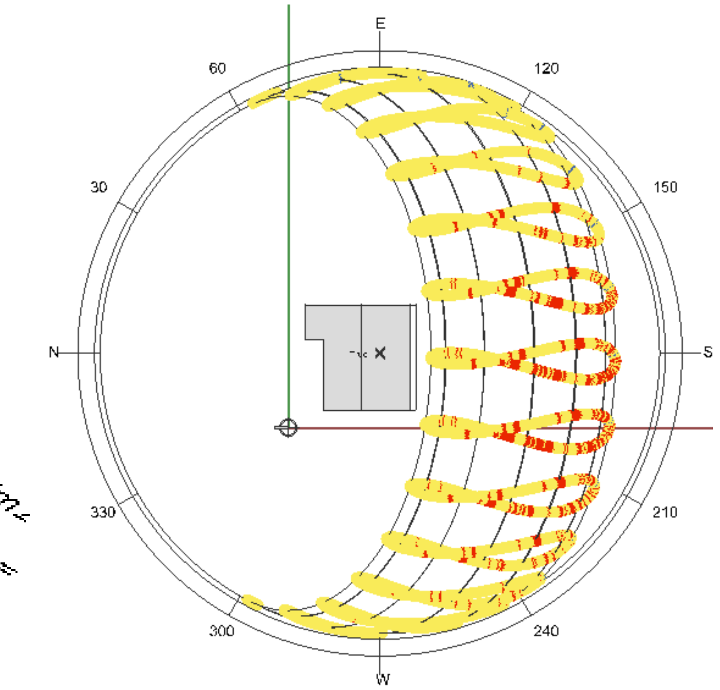
From a simple overhang, to a more complex system of louvers, the results were not as effective as expected.

Sun radiation is very helpful throughout the year, even if It occasionally produces overheating during the hottest part of the day.



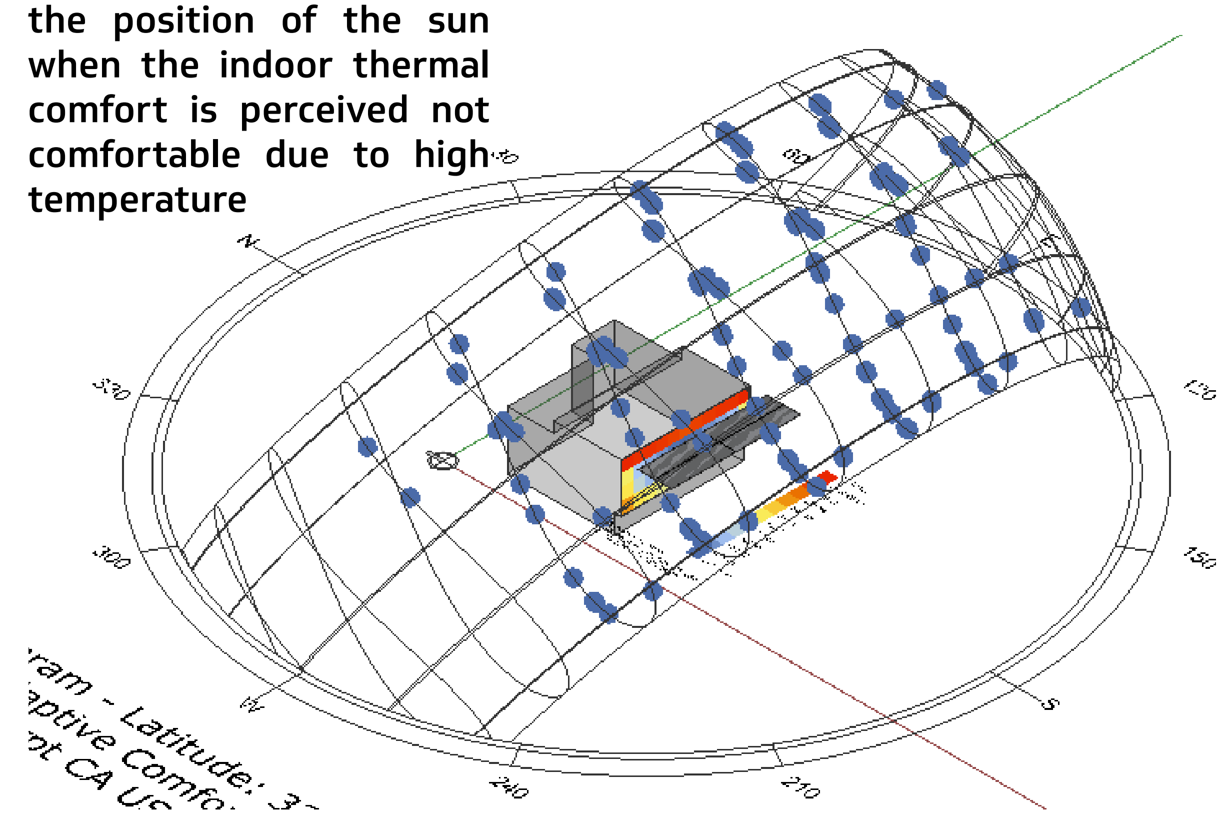
The south glazed facade gets a high amount of solar radiation, but the glass is also less effective to retain heat loss during night.





Not comfortable (too hot) ATC conditions are concentrated from during the central part of the day (noon-afternoon).

The blue dots show the position of the sun when the indoor thermal comfort is perceived not comfortable due to high temperature



4.0 Shade

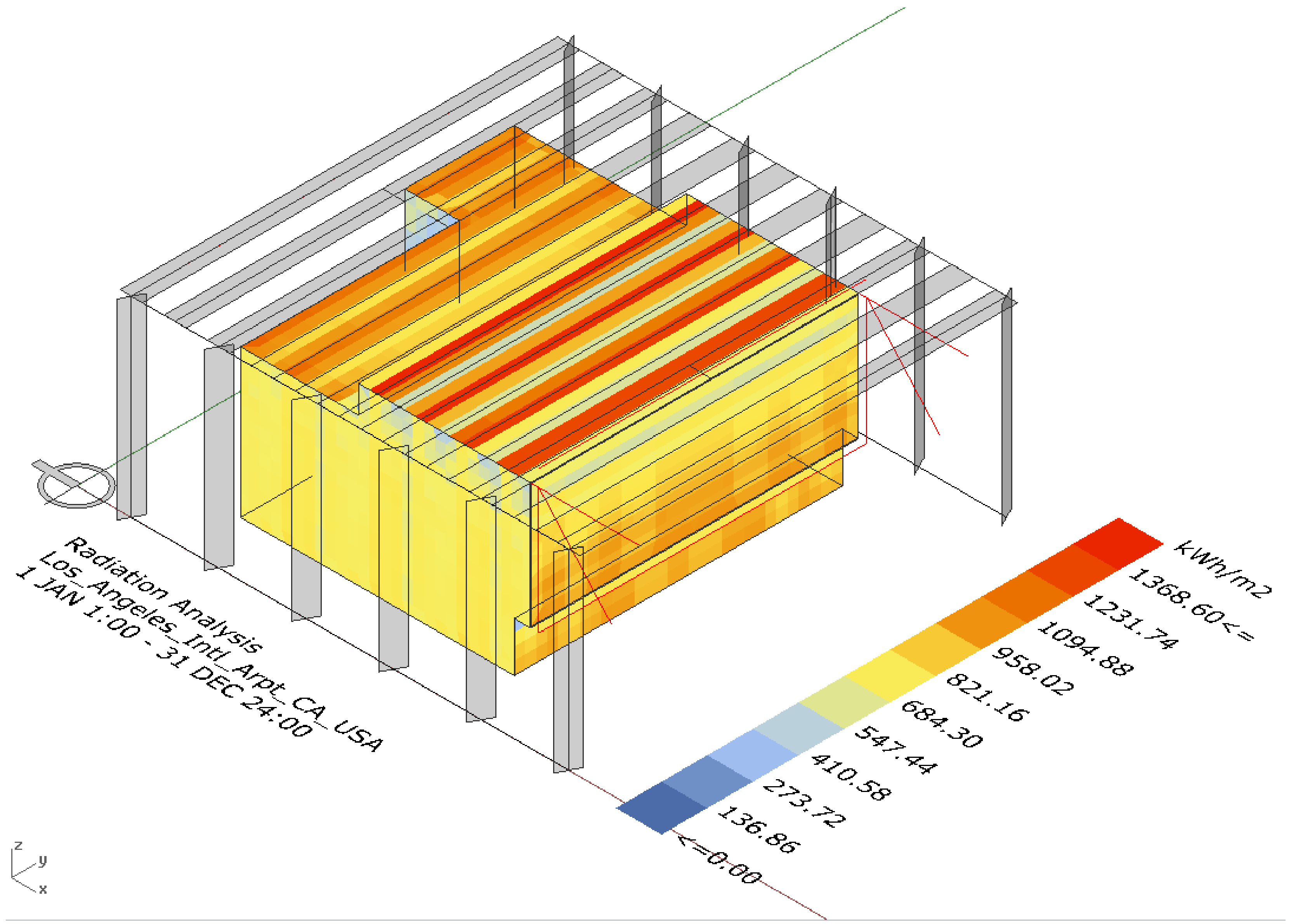
4.1 Parametric Louvers

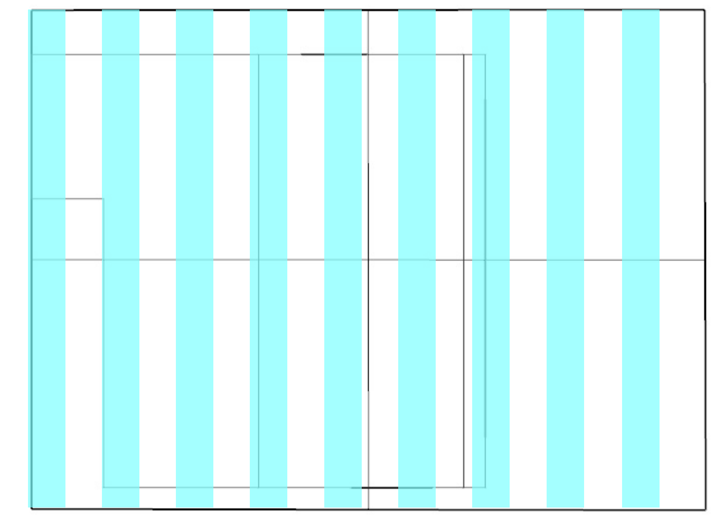
The designed GH definition allows to manage the settings of the shading devices (number of fins,angle, width) to optimize shading performance obtaining immediate energy simulation results.

The horizontal devices were added to protect the flat roof from excessive solar radiation, although allowing part of the radiation to still heat the surface.

The vertical fins help protecting the hot summer sun during the afternoon, when it is lower and hits the facade from the West side.

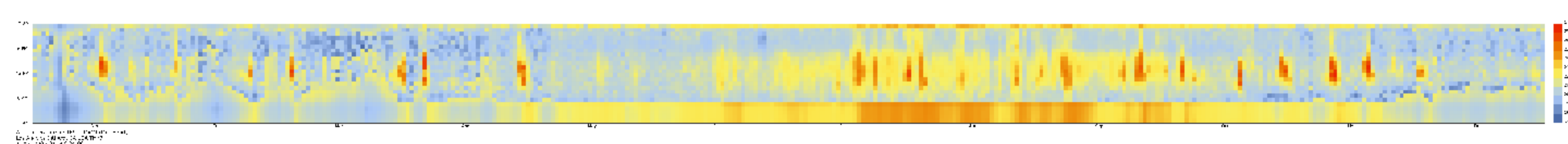
Vertical louvers are not really effective in terms of indoor thermal comfort, while the horizontal shade of the roof (50% shade of the roof) positively increased ATC.

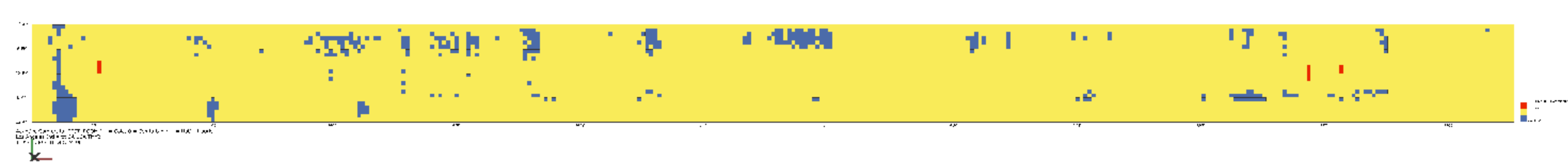




50% coverage of the roof by horizontal louvers

Adaptive Thermal Comfort = 94.9 %





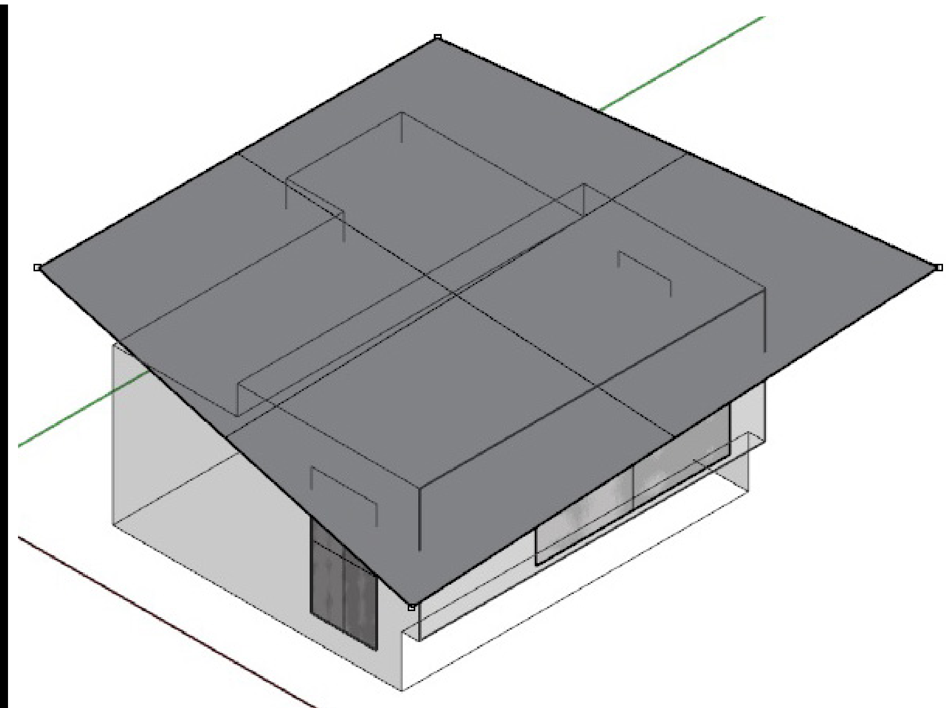
4.0 Shade

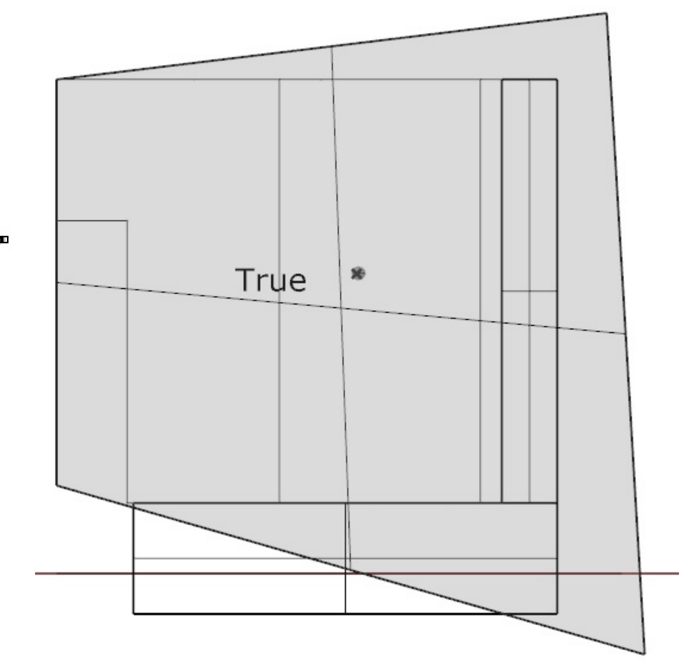
4.2 Windows Design

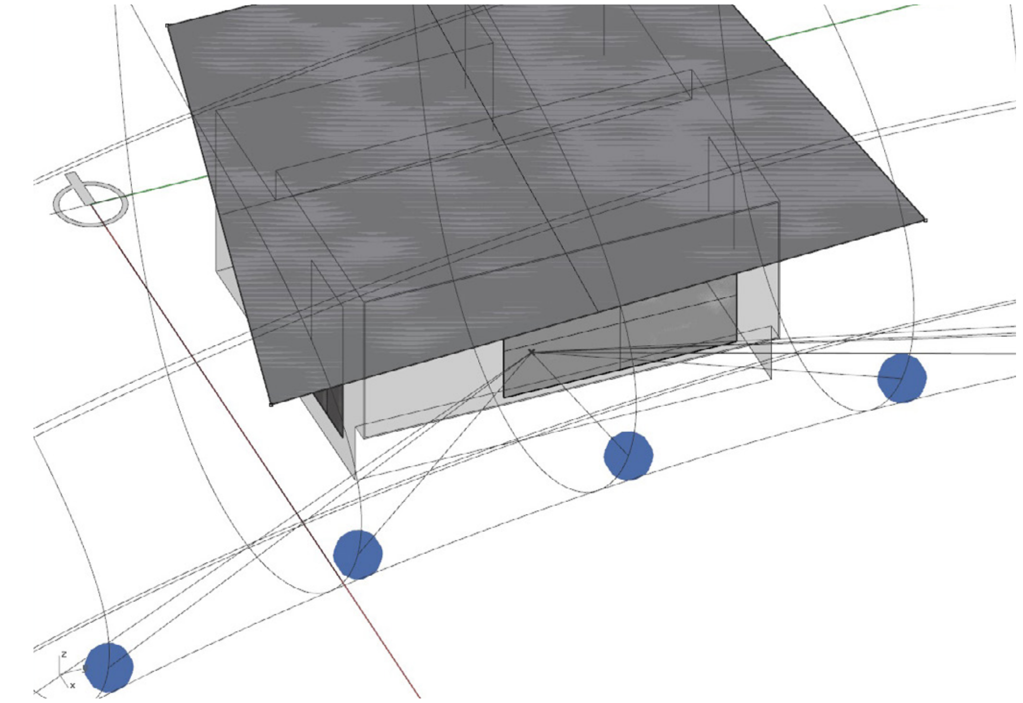
To further increase thermal comfort and reduce overheat, several combination of glazing have been investigated.

The south glaze is very important to provide heat throughout the year.

The east glaze allow the morning sun to heat up the indoor space. Similarly, the window on the west facade let the afternoon sun in.

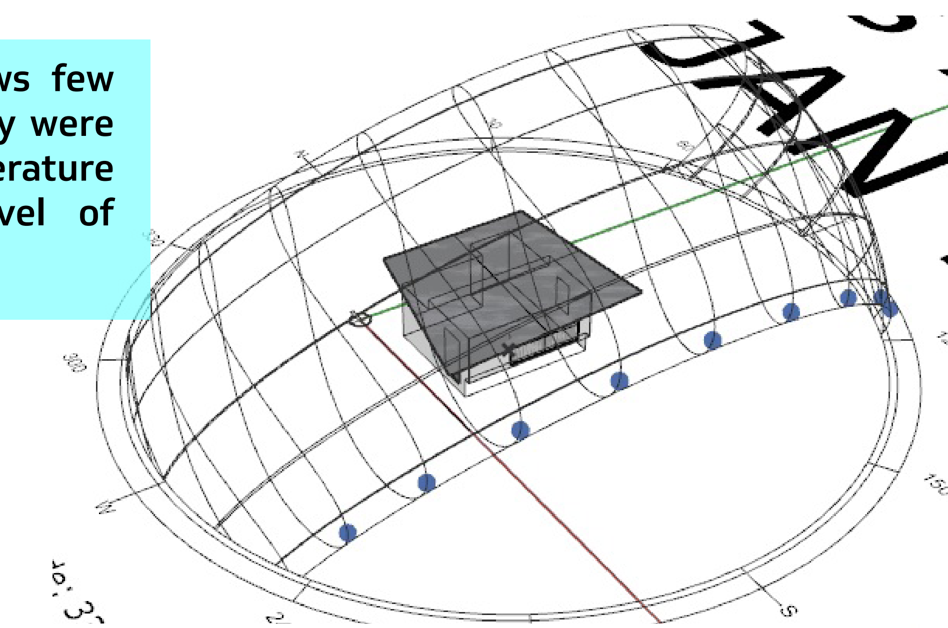






Any alteration of the geometry of the horizontal shading surface did not signifivantly increased thermal comfort

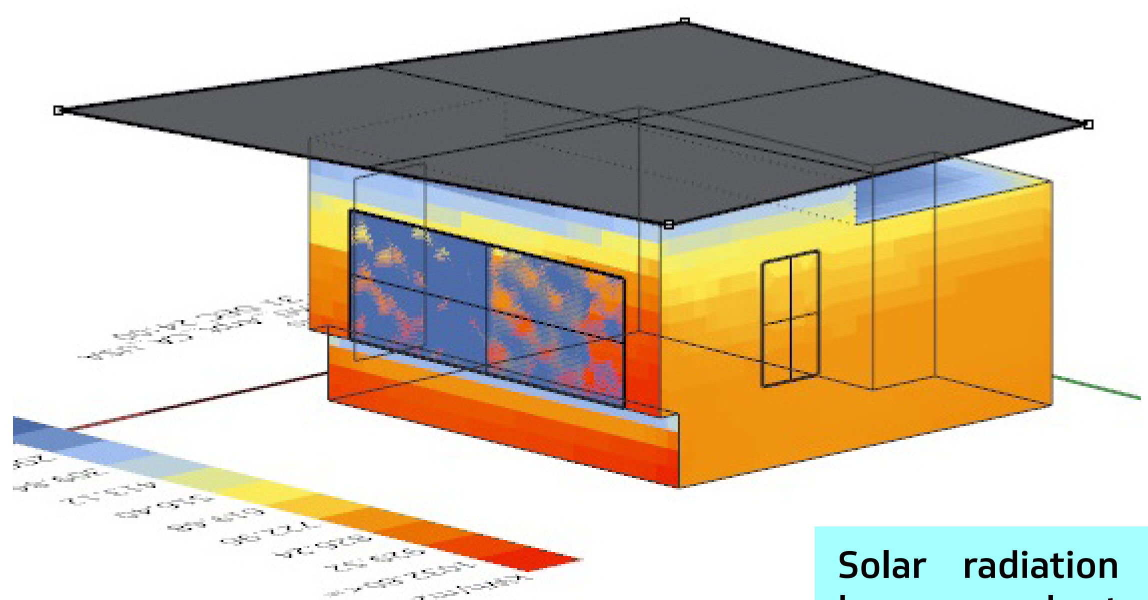
The sun path shows few cold days in January were the indoor temperature fall under the level of comfort



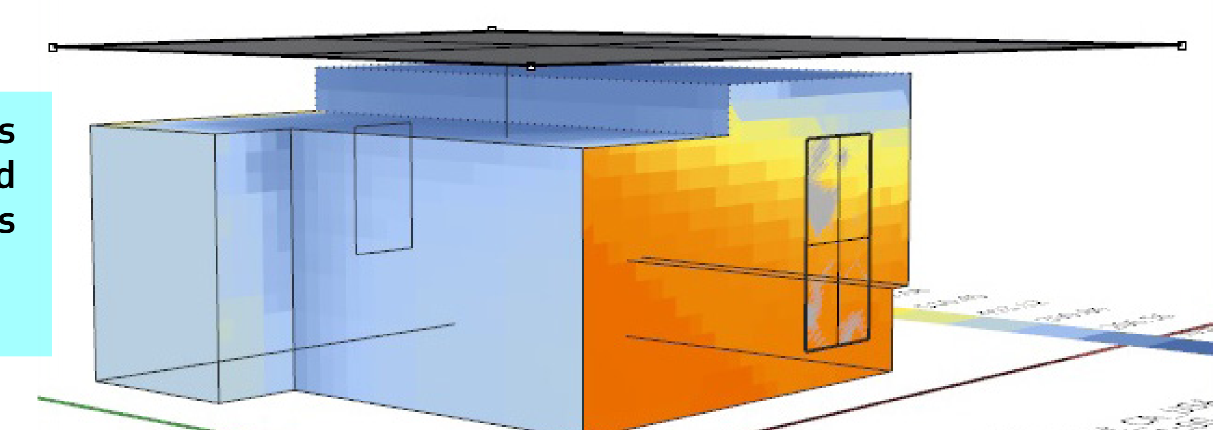
4.3 Roof Shade Optimization

Having in mind not only energy efficiency and comfort, but also construction needs and PV panels installations (high annual solar radiation) I preferred to further investigate a simple flat shading devices for the roof.

Also, several different solution did not significantly increased thermal comfort.



Solar radiation analysis has been used to understand shading incidence on facades and winodws.



5.0 Further Improvements

5.2 More Thermal Mass

To further increase thermal comfort, warm the space during winter while reducing overheat, it has been necessary to increase the thermal mass of the exterior walls and roof.

Some attempts were also made with the flooring material, but did not produce interesting results.

DESIGN 1
Thickness = 0.4 m
Conductivity = 0.6 W/mK
Density = 2000 kg/m3
Specific Heat = 835 J/kgK

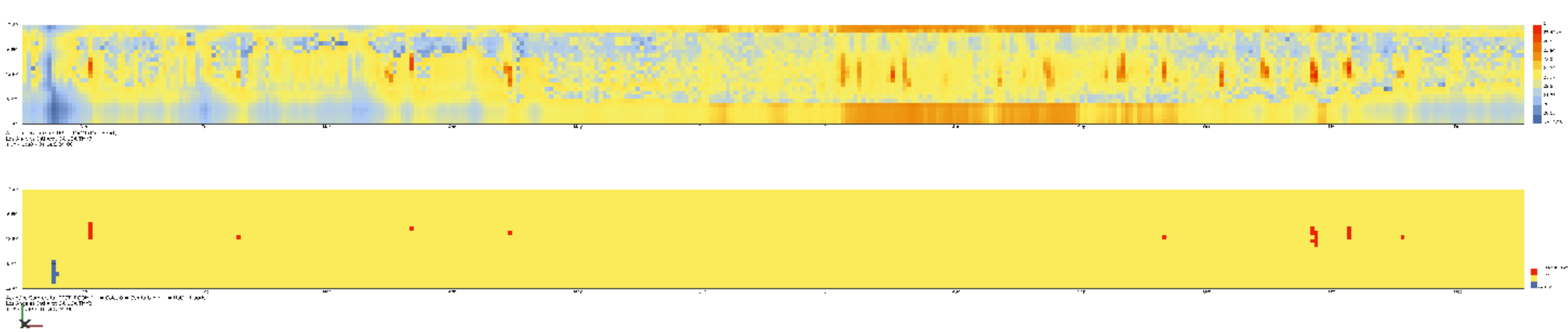
DESIGN 2
Thickness = 0.4 m
Conductivity = 0.3 W/mK
Density = 2000 kg/m3
Specific Heat = 835 J/kgK

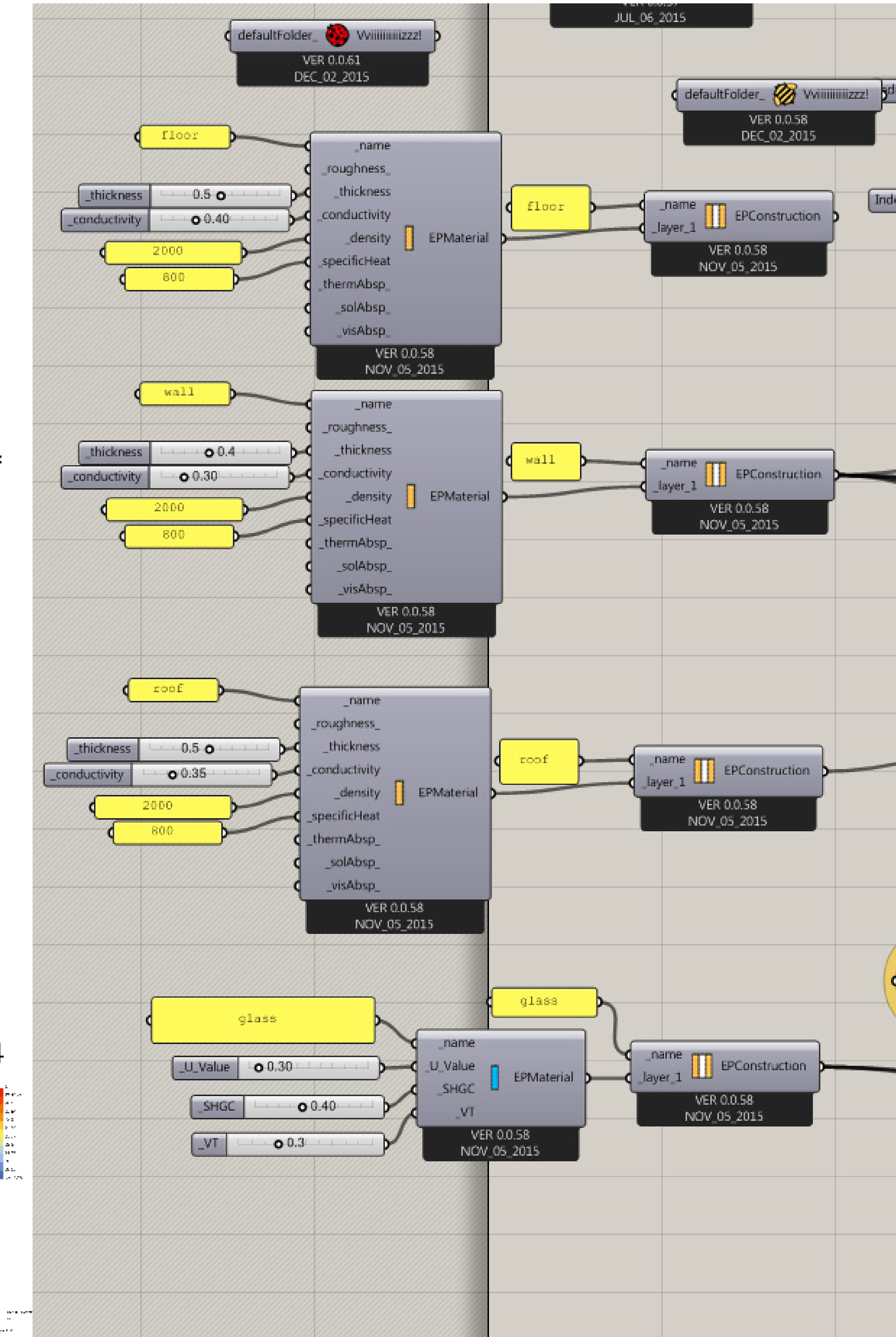
C
27.69<=
26.82
25.94
25.06
24.19
23.31
22.44
21.56
20.69
19.81
<=18.94

1 = Hot
0 = Comfortable
-1 = Cold
1.00<=
0.00
<=-1.00

the maximum ATC level the design could reach

Adaptive Thermal Comfort = 99.7 %



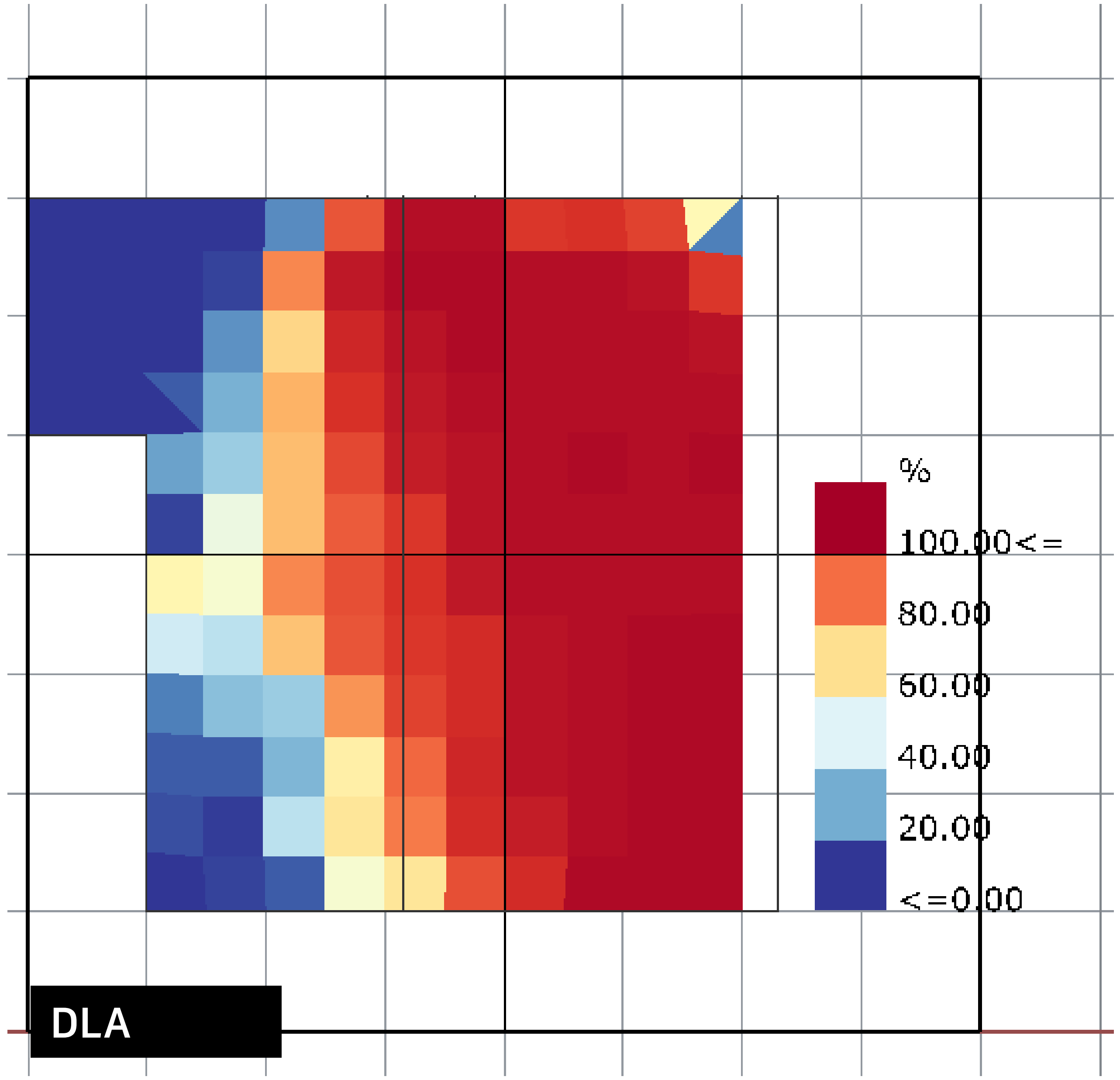


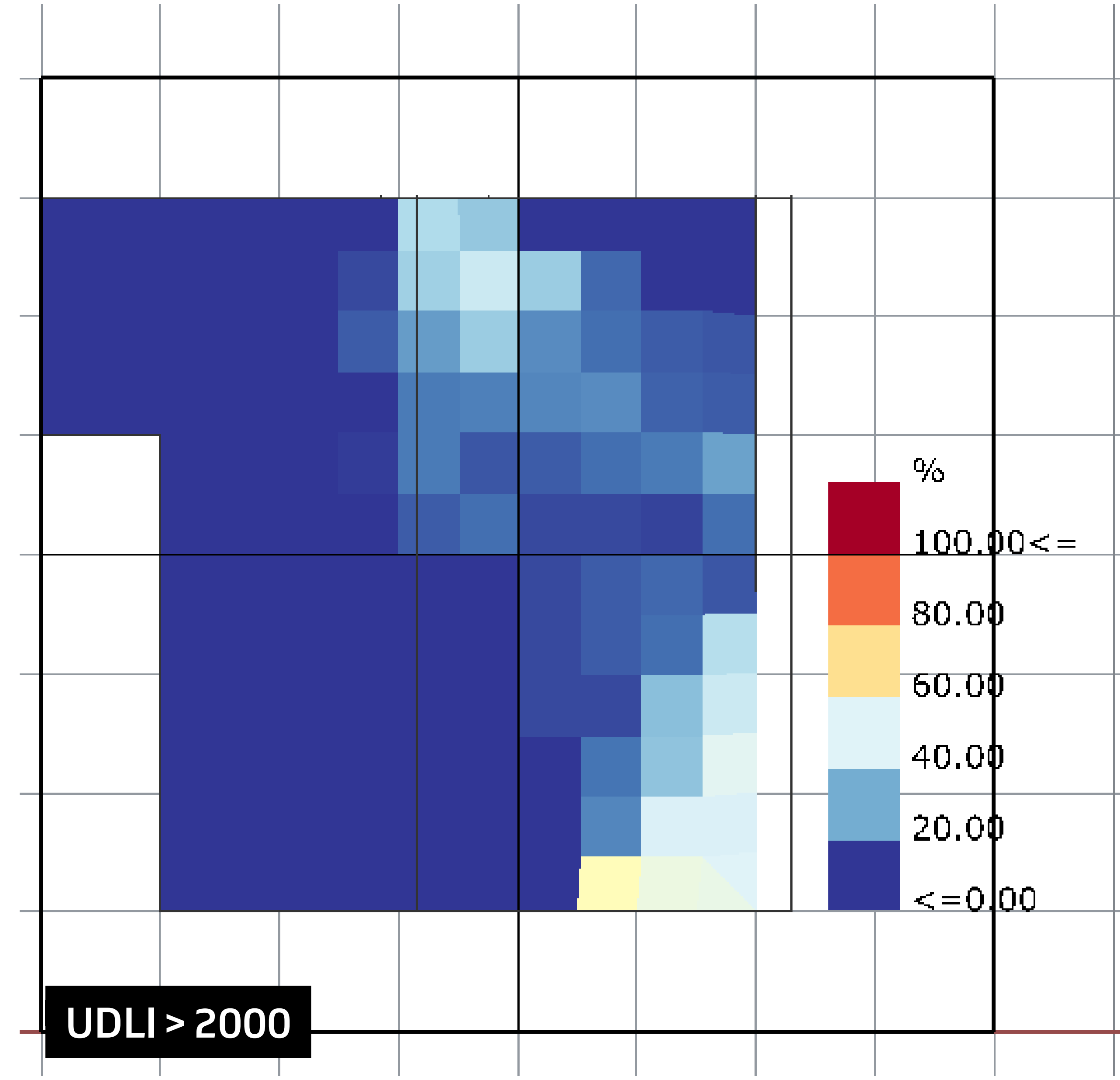
6.0 Annual Daylight and Glare Analysis

6.1 sDA

The Spatial Daylight Autonomy is the percent of analysis points across the analysis area that meet the DLA Illuminance Thresholds values, set to 300 lux for LEED, for at least 50% of the analysis period.

The measured sDA percentage is 67.65%.



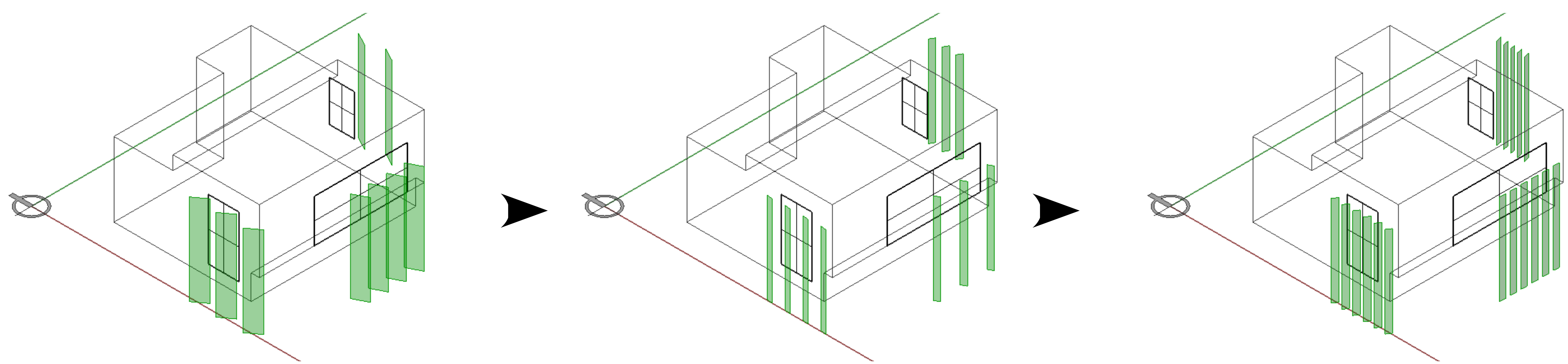


to protect the indoor space from glare the design involved vertical louvers

Parametric Louvers Design

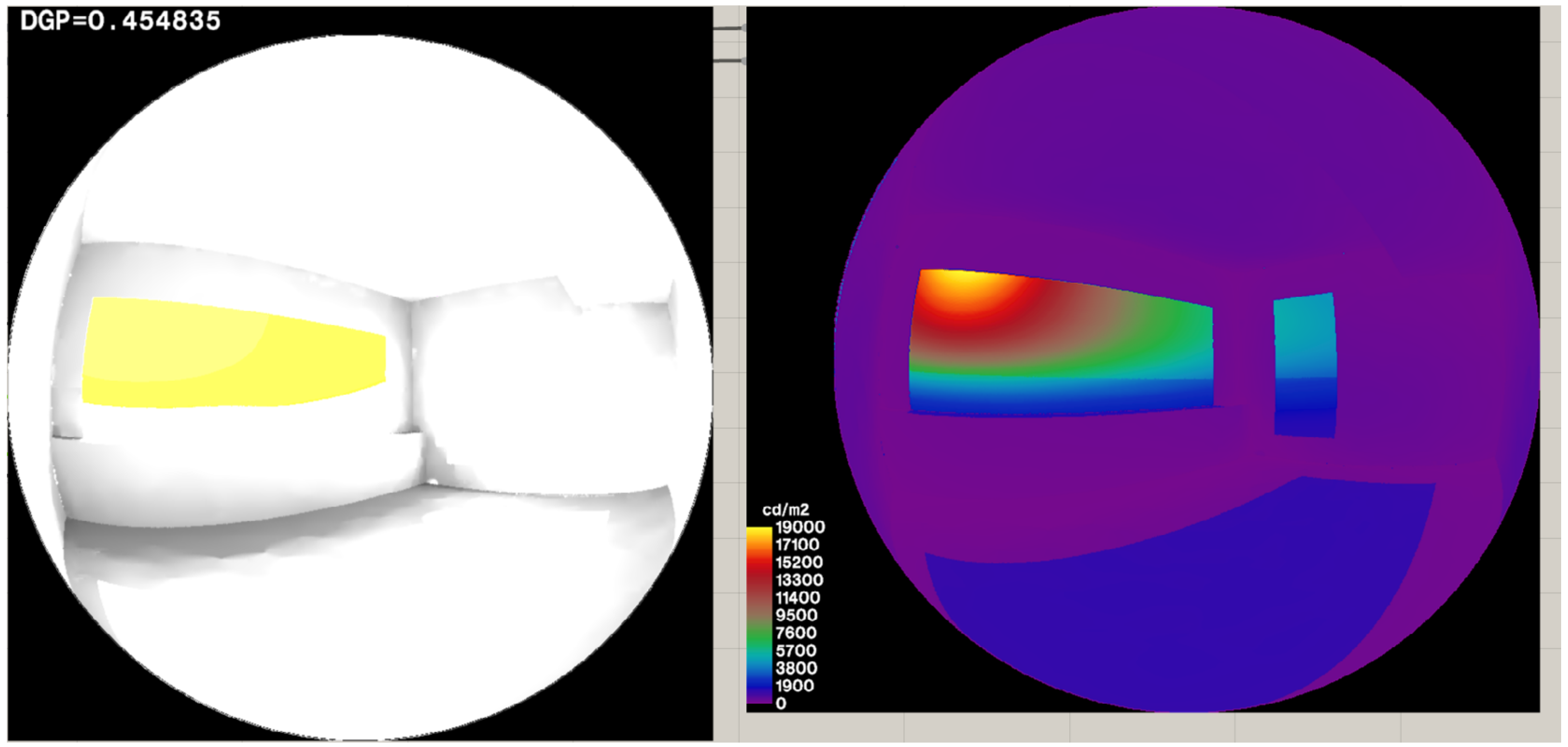
To optimize the design, the GH definition allows to manage the settings of the shading devices:

- number of fins
- angle
- width



6.0 Annual Daylight and Glare Analysis

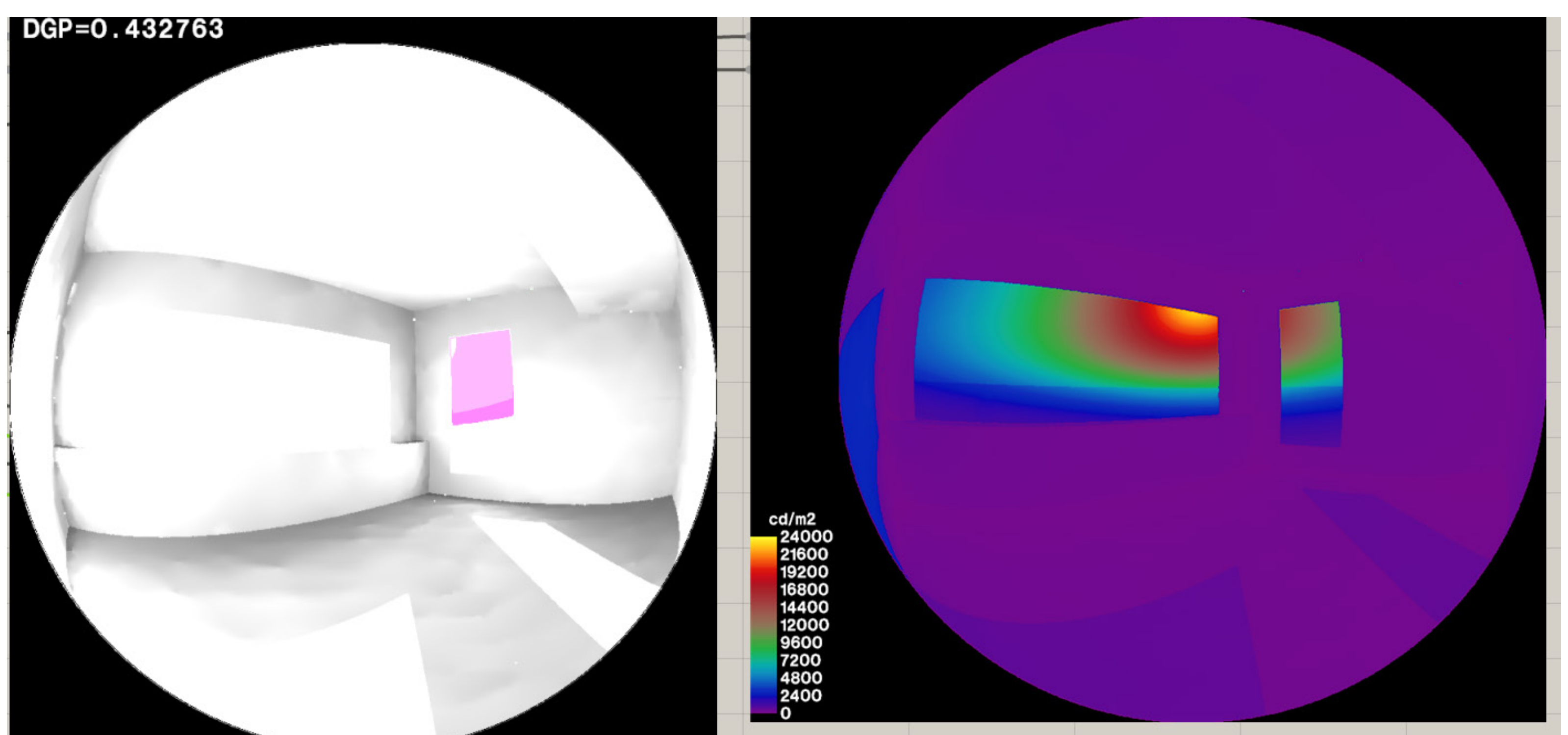
6.2 Glare Analysis - Quick assessment



DEC

12 PM ➤ DGP = 0.4548 ➤ DGP > 0.45 , DISTURBING GLARE, there is high probability of glare

<u>The design of louvers has been implemented to provide more glare protection</u>



15 PM ➤ DGP = 0.4327 ➤ DGP > 0.40 , PERCEPTIBLE GLARE, there is some probability of glare

6.0 Annual Daylight and Glare Analysis

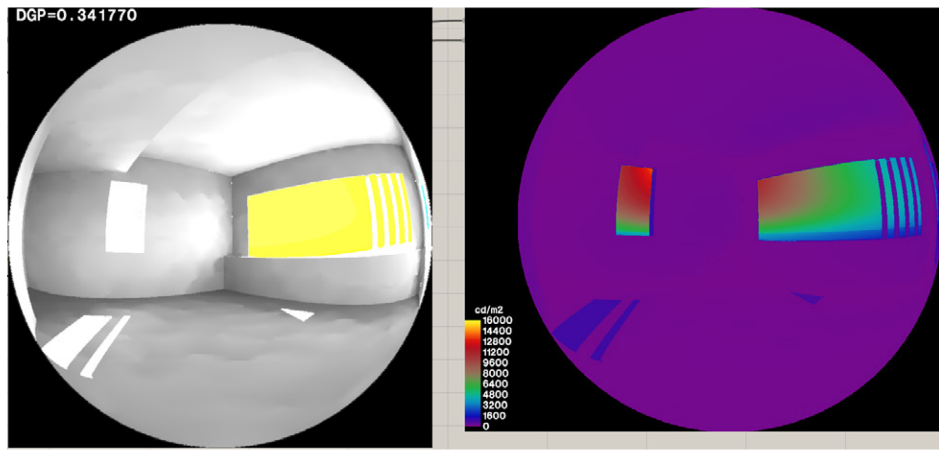
6.3 Glare Analysis - With louvers

DGP > 0.40 , PERCEPTIBLE GLARE, some glare probability still remains

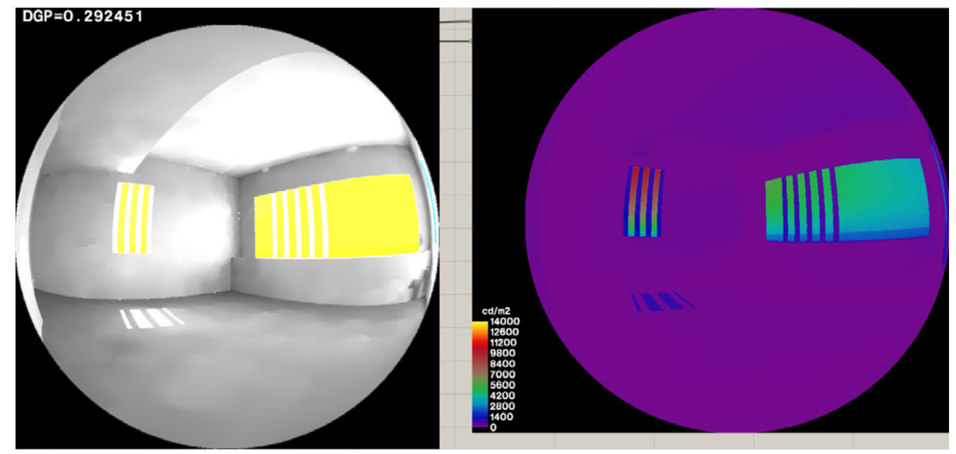
MARCH | JUNE | DEC

9 AM

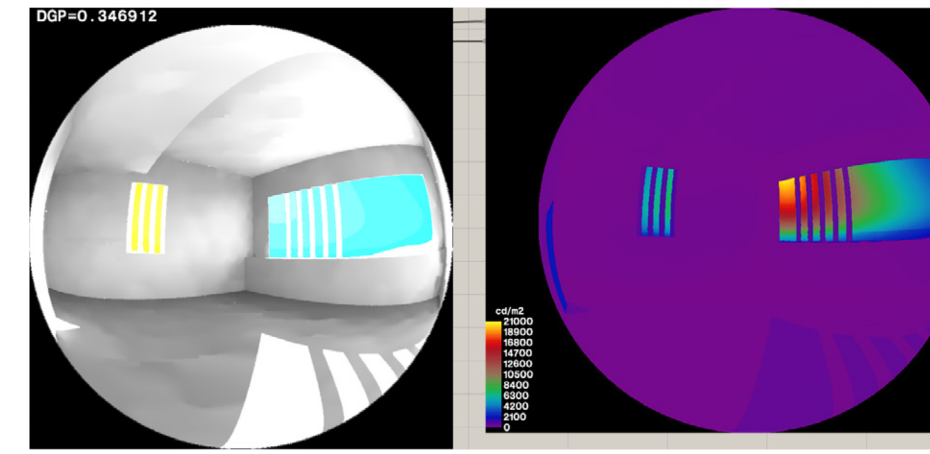
DGP = 0.3417



DGP = 0.2924

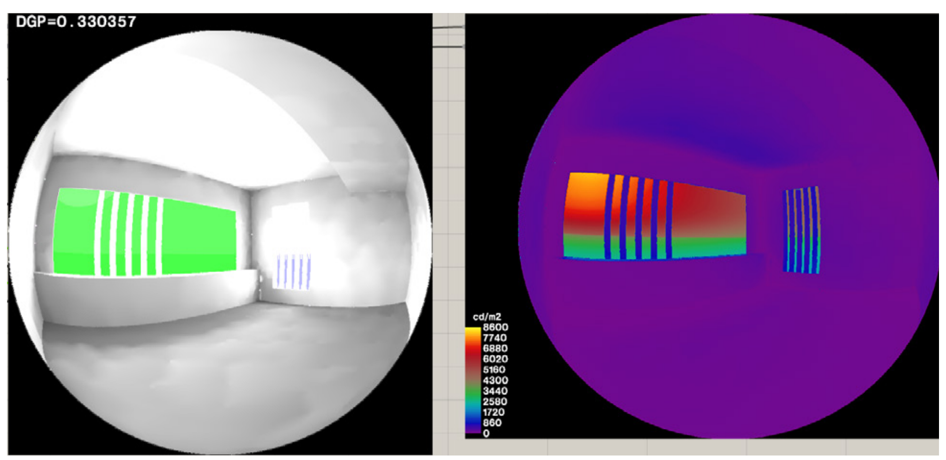


DGP = 0.3469

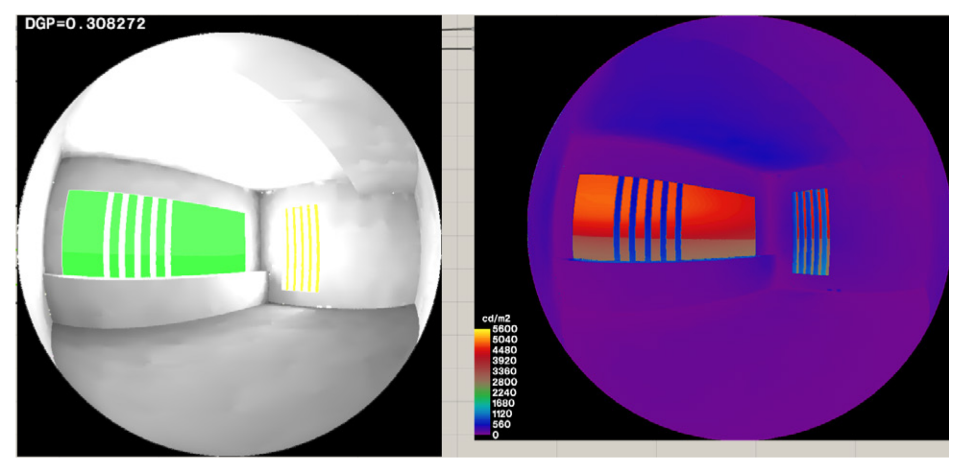


12 PM

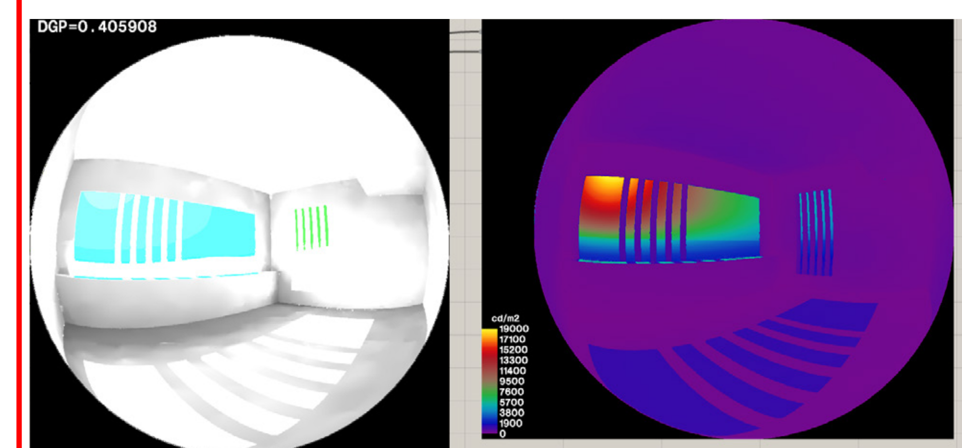
DGP = 0.3303



DGP = 0.2924

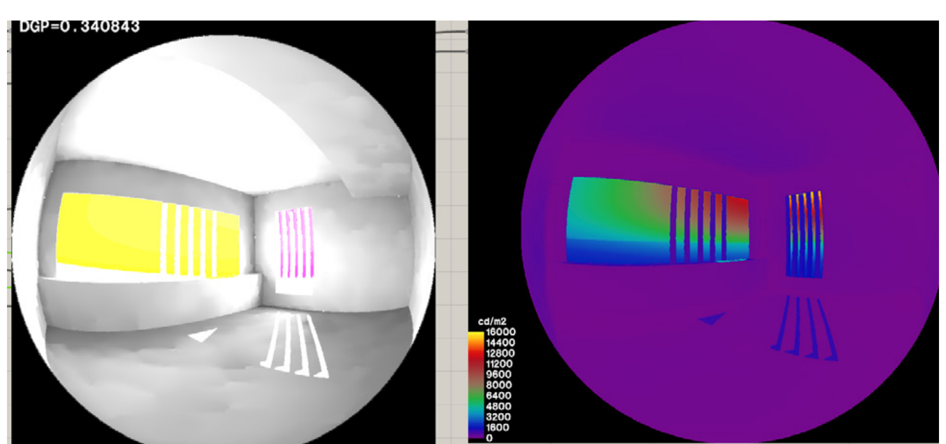


DGP = 0.4059

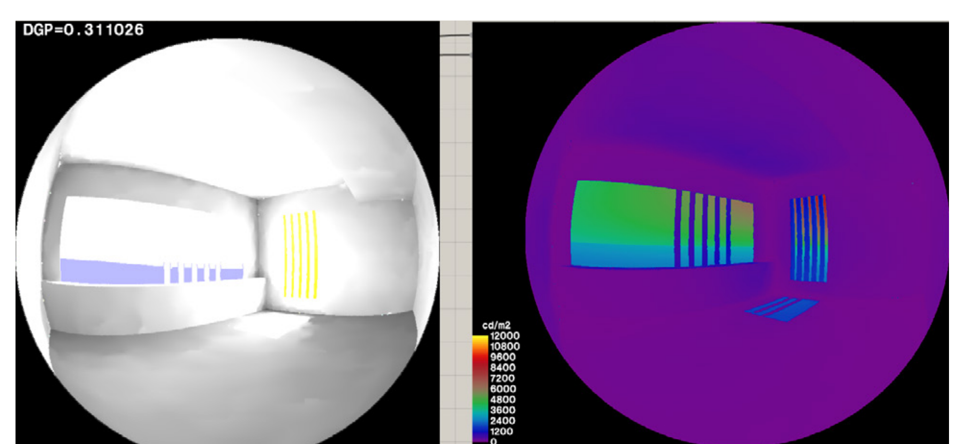


15 PM

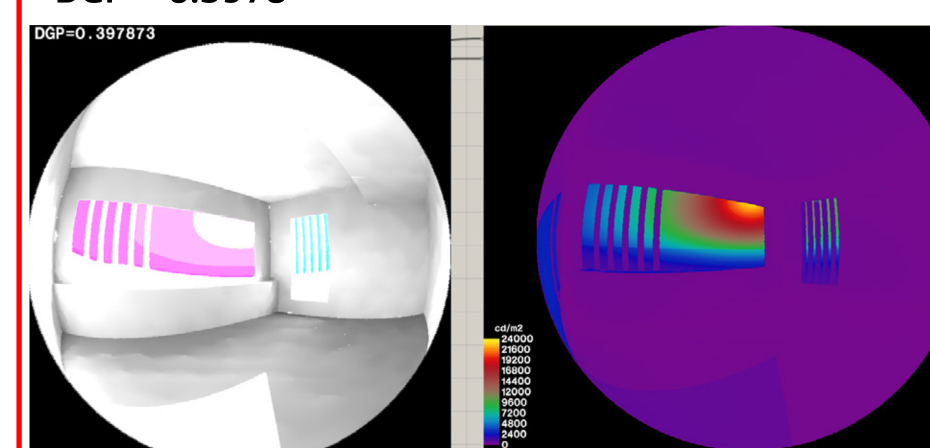
DGP = 0.3408



DGP = 0.2924

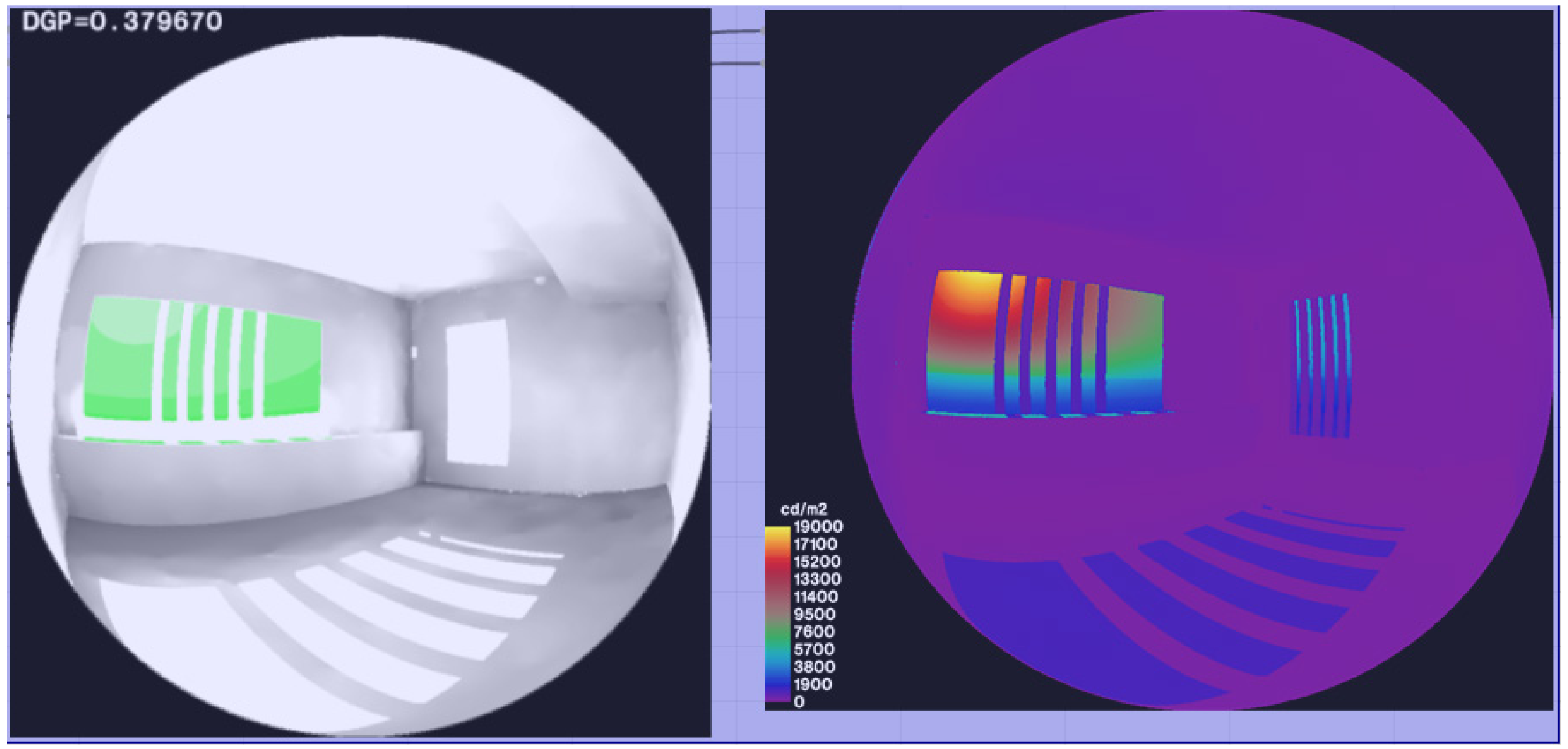


DGP = 0.3978



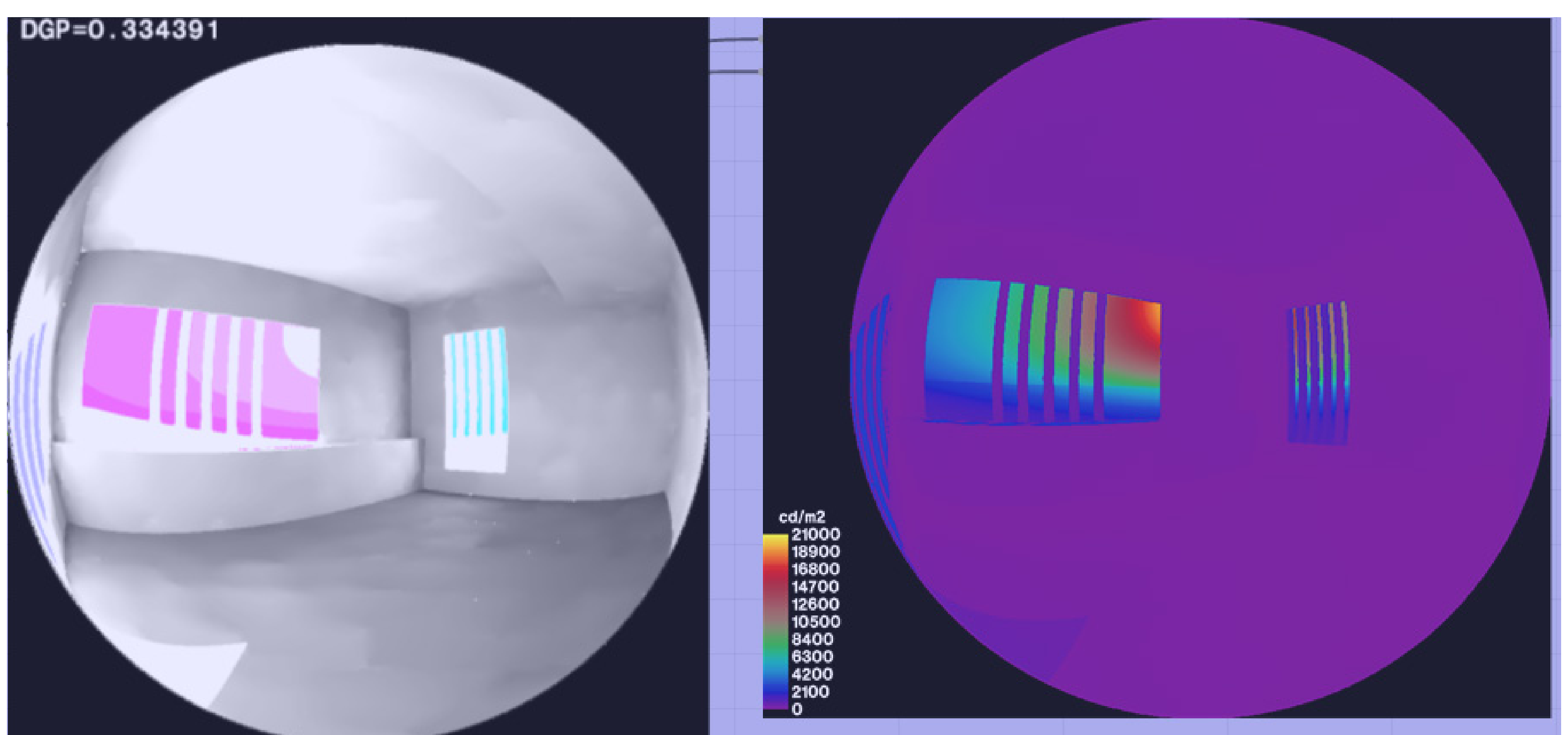
6.0 Annual Daylight and Glare Analysis

6.4 Glare Analysis - South Glaze Reduction



DEC

12 PM ➤ DGP = 0.3796



<u>The louvers has provide the necessary screen to reduce glare probability</u>

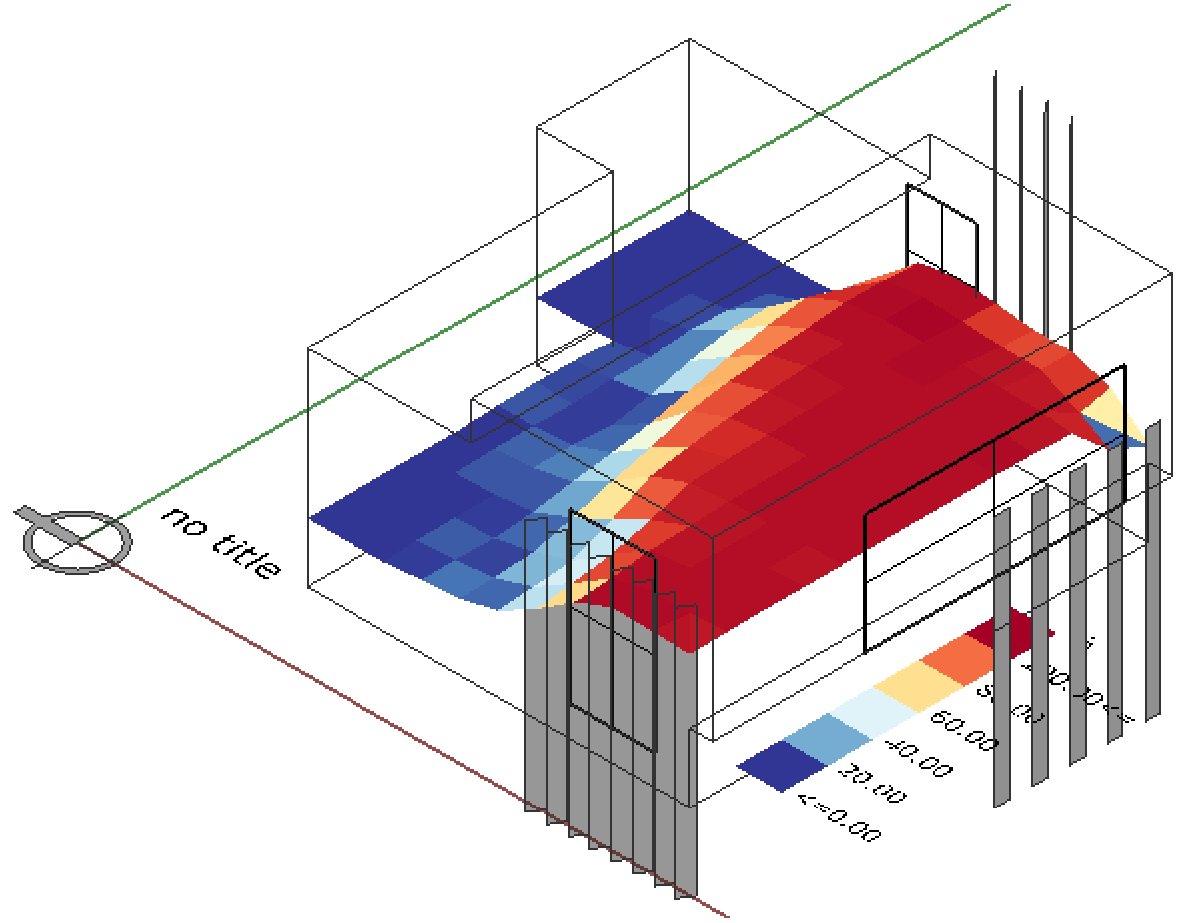
15 PM ➤ DGP = 0.3343

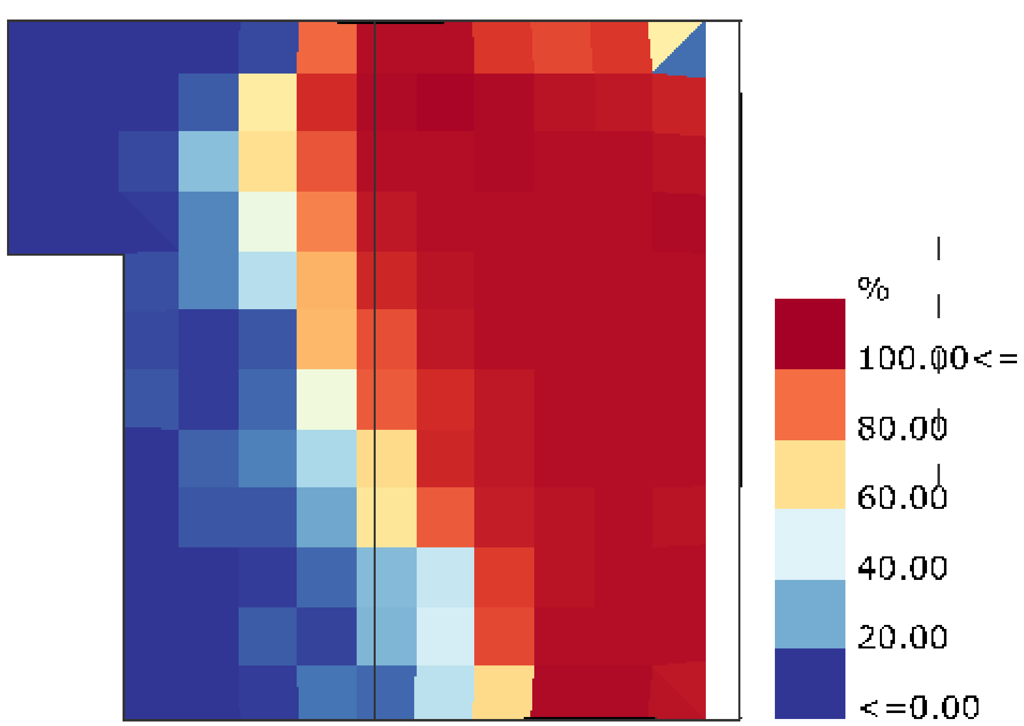
6.0 Annual Daylight and Glare Analysis

6.3 Final sDA

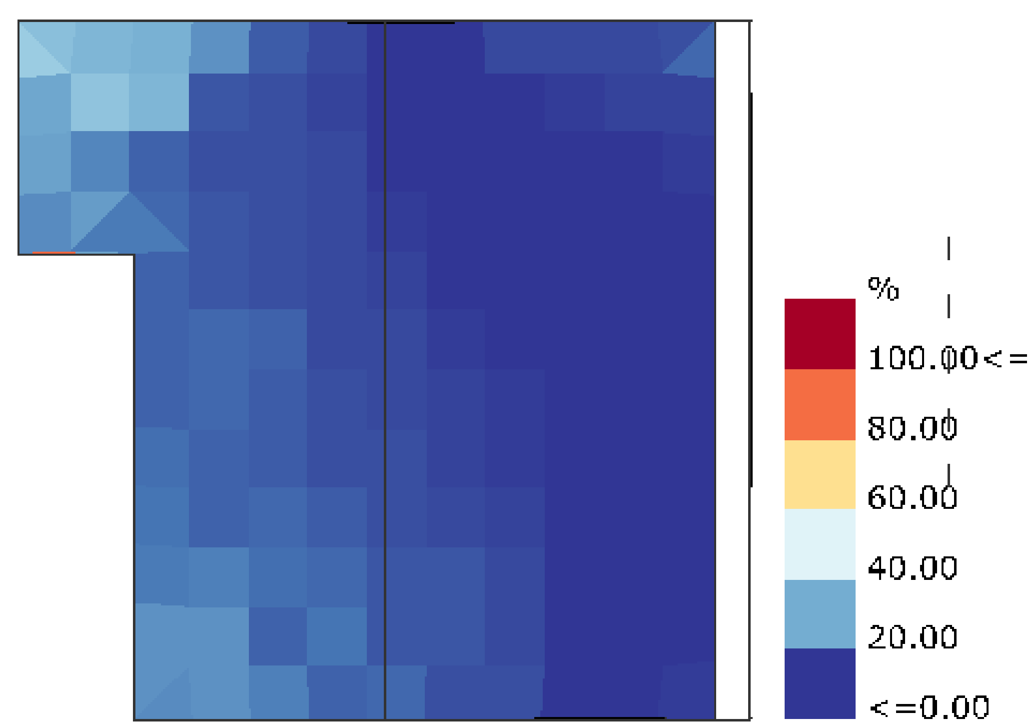
The final sDA percentage is 55.15%.

Glare areas have been reduced by vertical louvers and a slightly smaller glaze on the south facade.

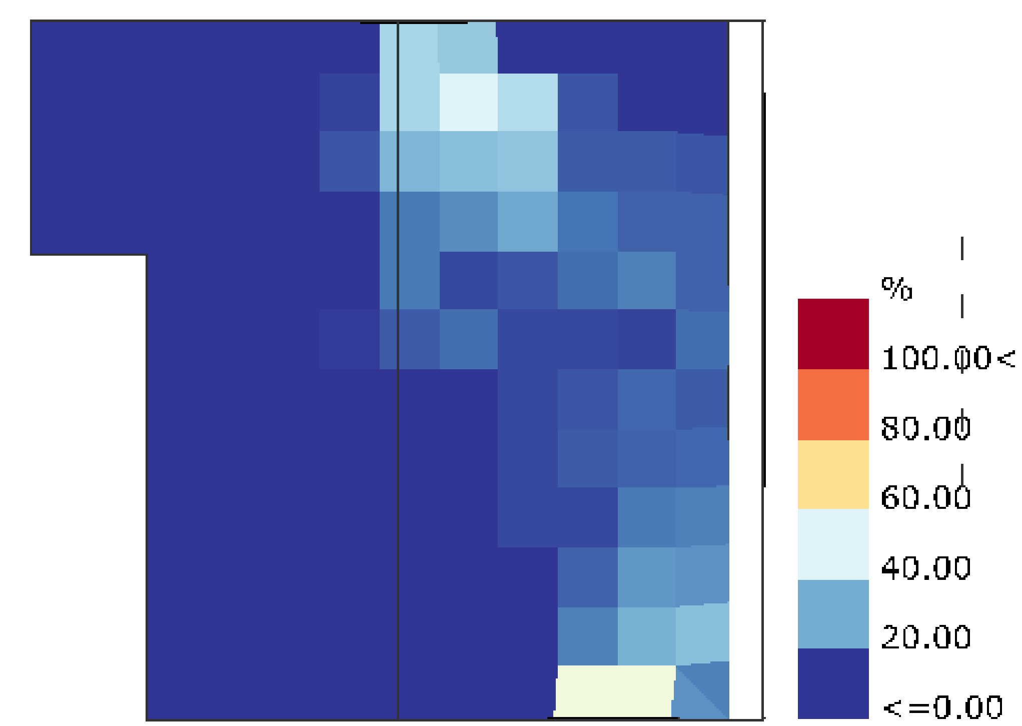




DLA



UDLI < 100



UDLI > 2000

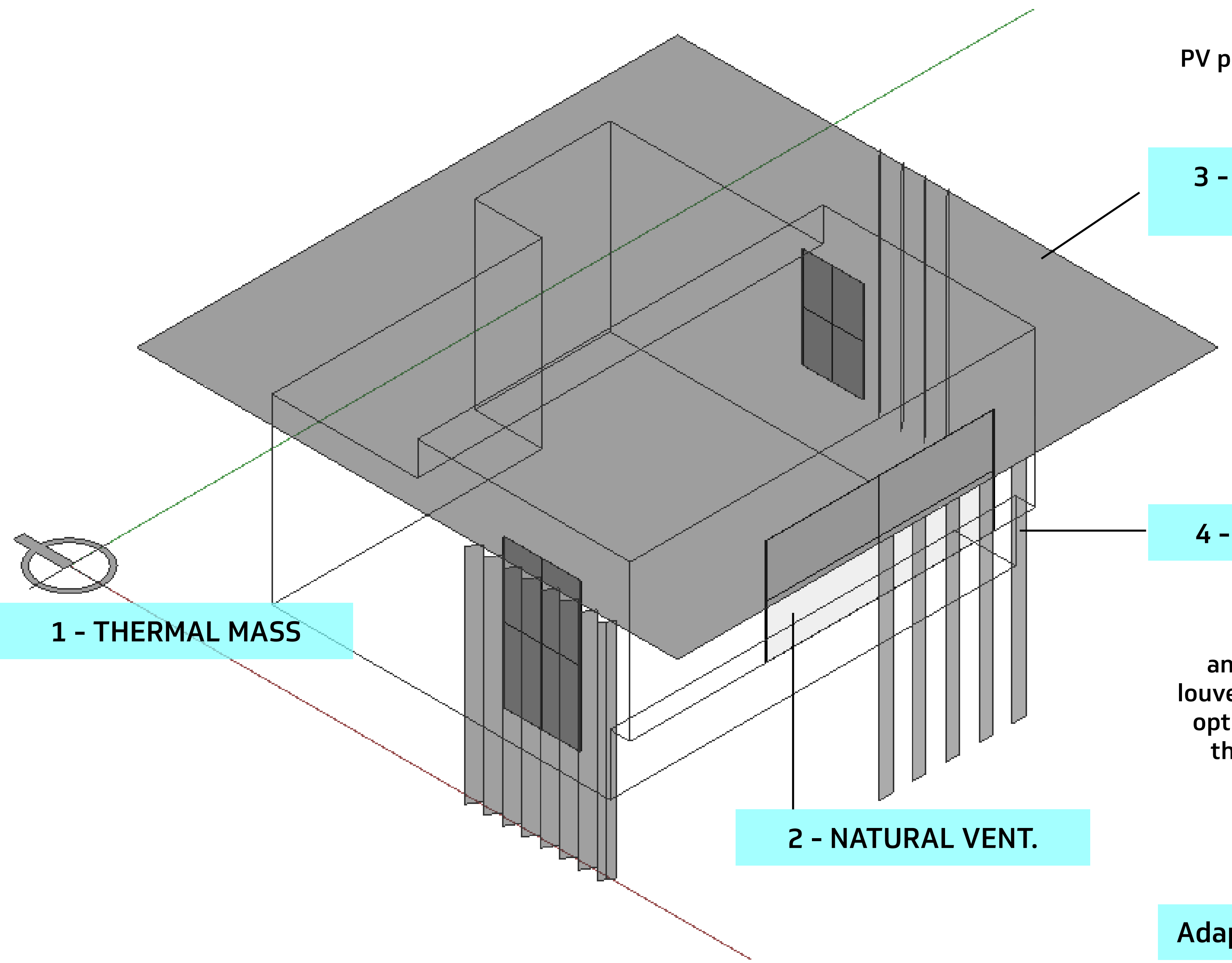
7.0 Final Adaptive Comfort Assessment

Conclusion

The final ATC percentage is 96.6%.

From the baseline the increment is not great, natural ventilation and thermal mass provide most of the benefits in terms of thermal comfort.

Shade and louvers help the daylight of the building, preventing the indoor space from excessive glare.



Adaptive Thermal Comfort = 96.6 %