THERMAL & VISUAL COMFORT OPTIMIZATION OF AN UNCONDITIONED SPACE

Philadelphia, Pa

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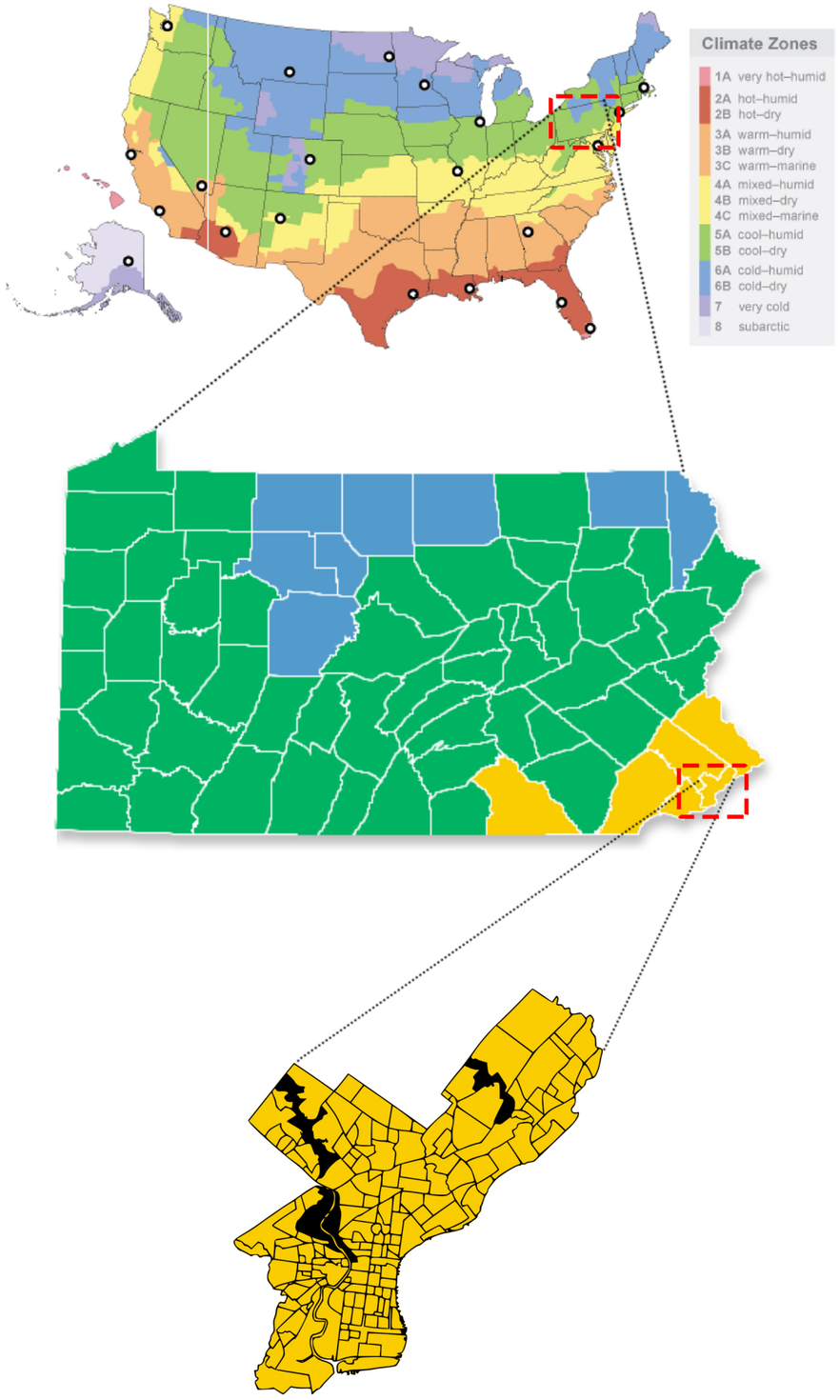
Fall 2016 | ARCH 753 Building Performance Simulation
PennDesign | University of Pennsylvania

Climate analysis

CLIMATE ZONES

WEATHER DATA: Philadelphia International Ap,PA,USA,TMY3,
LATITUDE: 39.87
LONGITUDE: -75.23
CDD: 1235
HDD: 4759
CLIMATE ZONE: 4A
CHARACTERISTIC: MIXED-HUMID

From the climate classification, The heat dregree days of philly is as much as four times than cool dregree days. The design strategy should foucs on the heating efficience and thermal insulation.

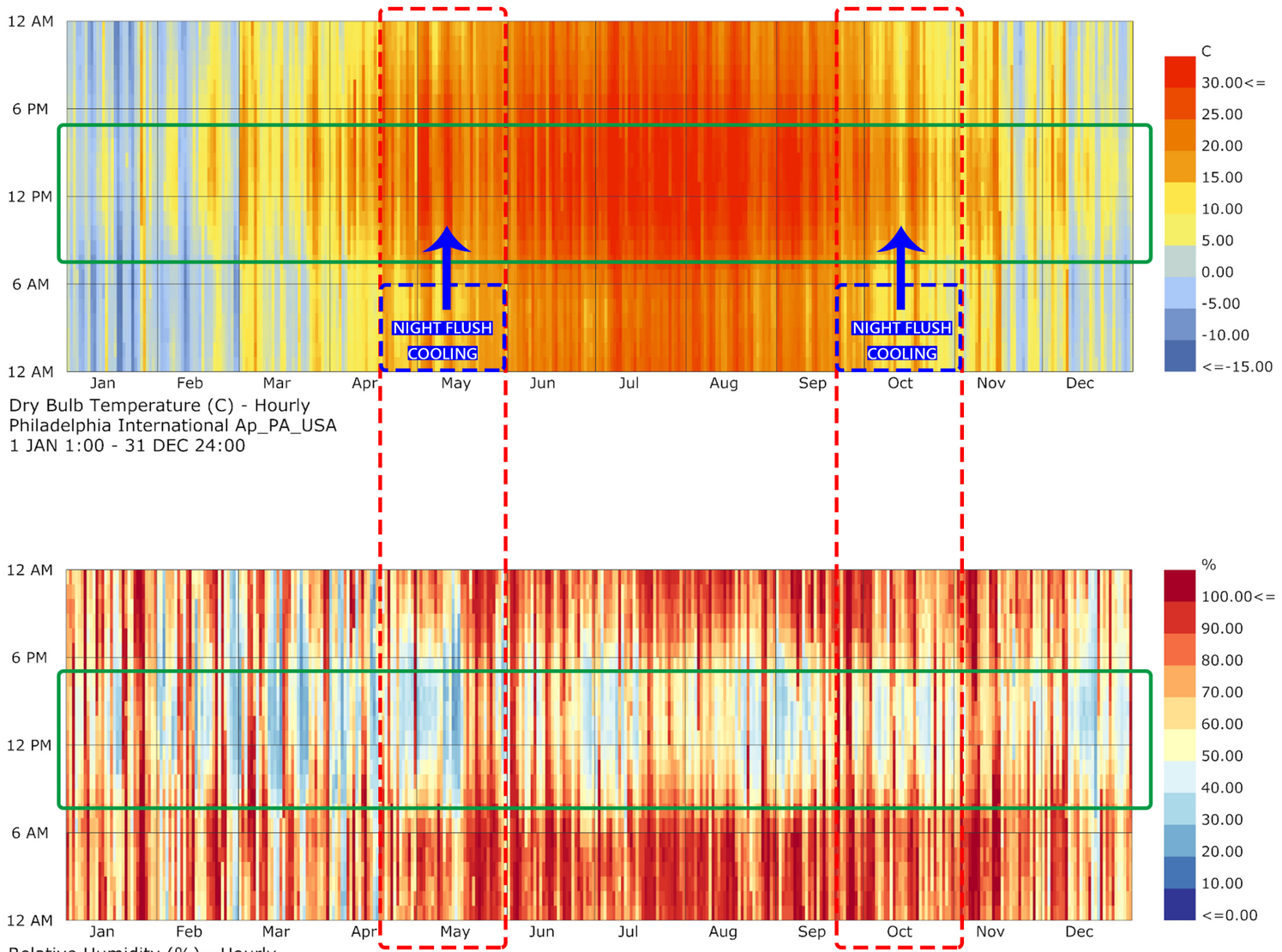


Residential Prescriptive Requirements for Zone 1 (2009 IECC)

Ceiling R-value	**38**
Wood Frame Wall R-value	**13**
Mass Wall R-value [i]	**5/10**
Floor R-value	**19**
Basement Wall R-value [c]	**10/13**
Slab R-value [d], Depth	**10, 2 ft**
Crawlspace Wall R-value [c]	**10/13**
Fenestration U-Factor [b]	**0.35**
Skylight U-Factor [b]	**0.60**
Glazed fenestration SHGC [b, e]	**NR**

https://energycode.pnl.gov/EnergyCodeReqs/?state=Pennsylvania

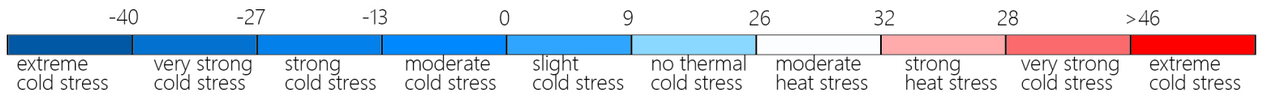
EXTERIOR FACTORS

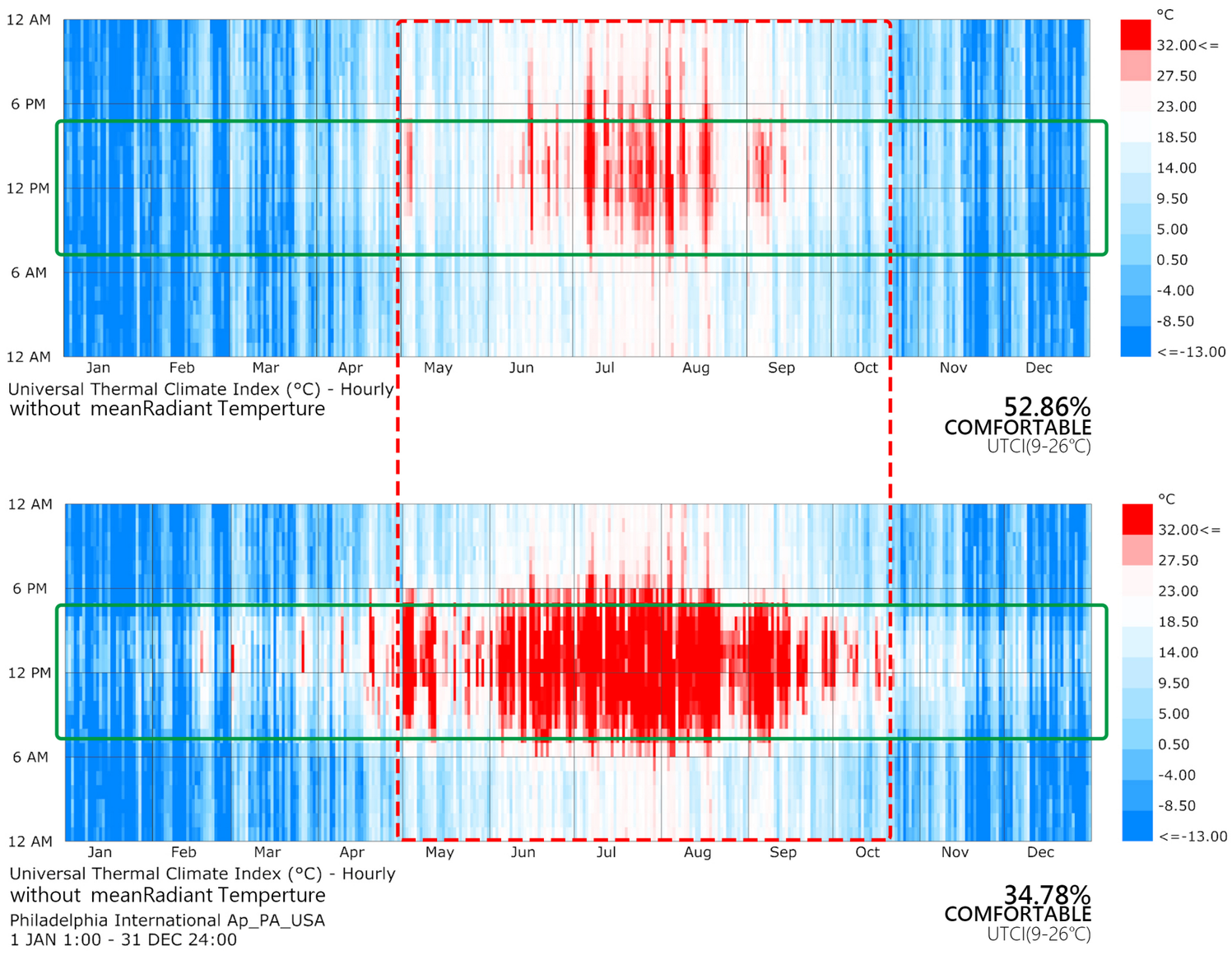


According to the dry bulb temperature chart, the temperature in Philadelphia ranges from -10 to 35degrees Celsius trough out the year, There is wide range difference between Diurnal and Nocturnal temperature during eraly summer and mid autrumn ,which reach up to 10 degrees Celsius. **NIGHT FLUSH COOLING** can be applied to decrease the interior temperature.

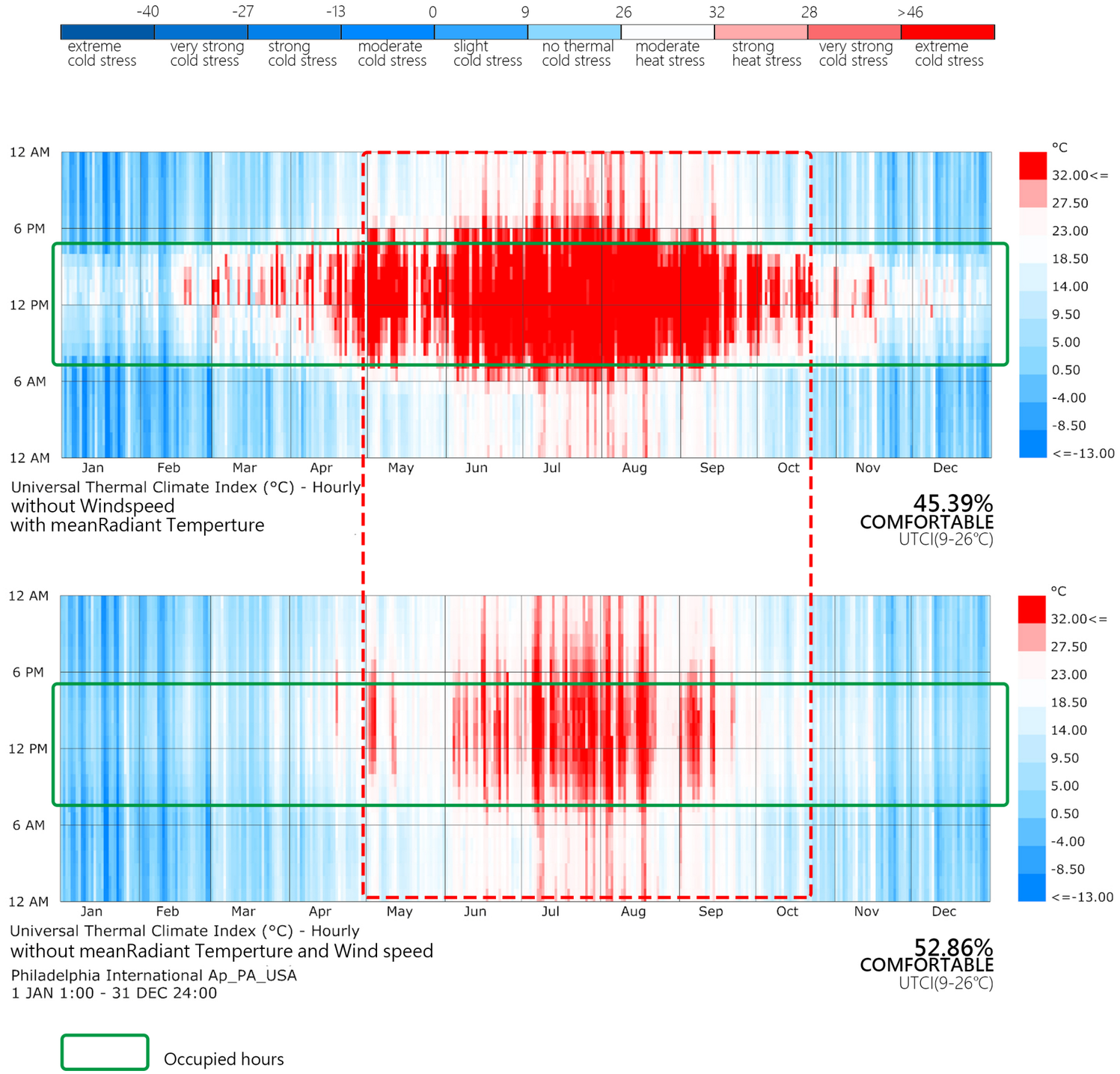
As the relative humidity chart shows, Philadelphia's humidity is moderate. In the occupied hours, the value of relative humidity is in the moderate range.

UTCI (Universial Thermal Climate Index)

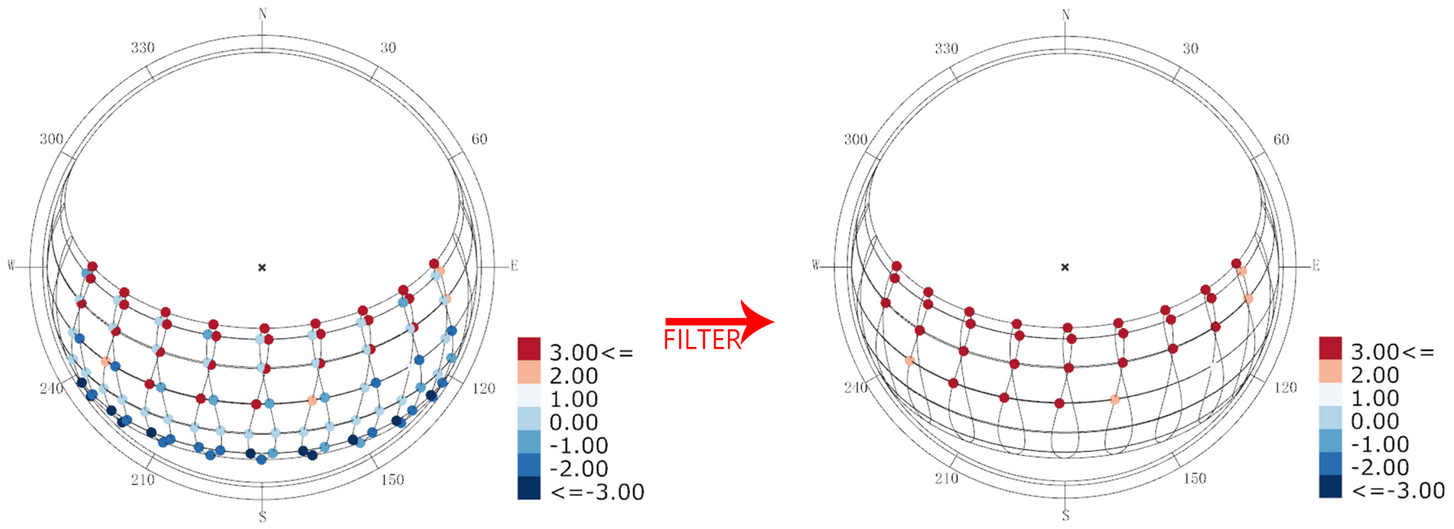




From the UTCI charts, the percentage of comfortable time is 34.78% when considerting MRT and Local Wind, but the comfortable time increses dramatically when it ignore these two factors to 52.86%. Therefore, chosing a suitable orientation and reducing the mean Raidiant may contribute to the increasing of the percentage of comfortable time.



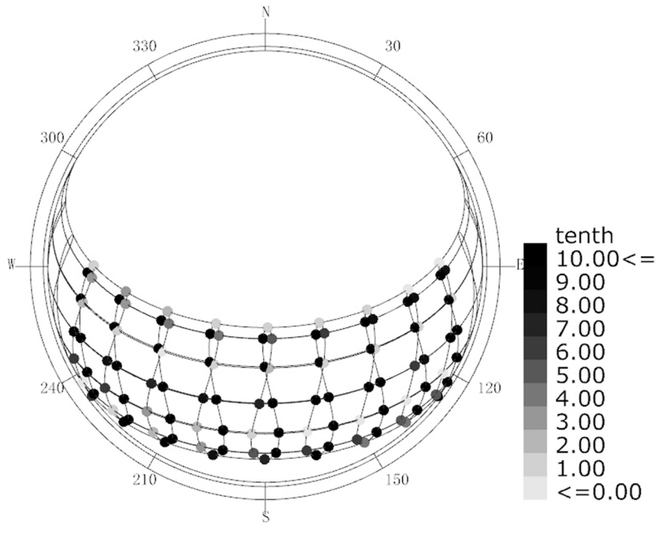
From the UTCI charts, the percentage of comfortable time without windspeed but with MRT is 45.39%, but the comfortable time increses dramatically when it ignore the these two factors to 52.86%. Base on the comparison of these four charts, we could come to a conjecture that the optimal comfortable time may achieve by increase the solar radiant and minimize the ventilation in winter, more over, increase the ventilation and reduce the solar heat gain in summer .



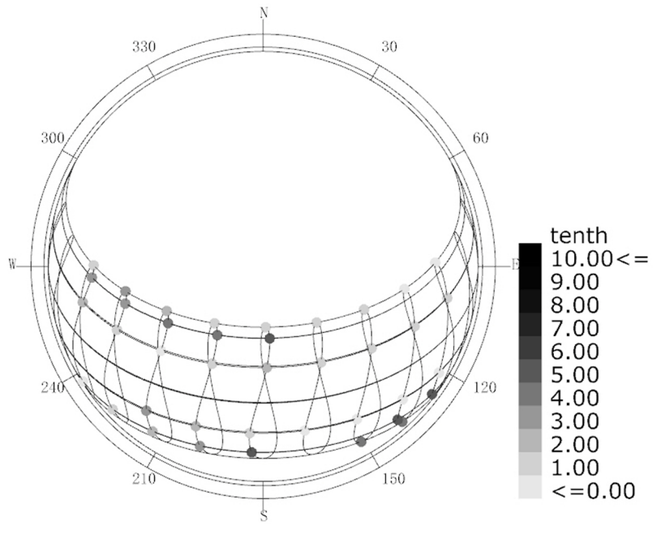
Sun-Path Diagram - Latitude: 39.87

Conditional Selection Applied:
Outdoor Comfort > 0
33.0 hours of total 108.0 sun up hours(30.56%).

Hourly Data: Outdoor Comfort (-3 = Extreme Cold | -2 = Cold | -1 = Cool | 0 = Comfort | 1 = Warm | 2 = Hot | 3 = Extreme Heat)
Philadelphia International Ap_PA_USA



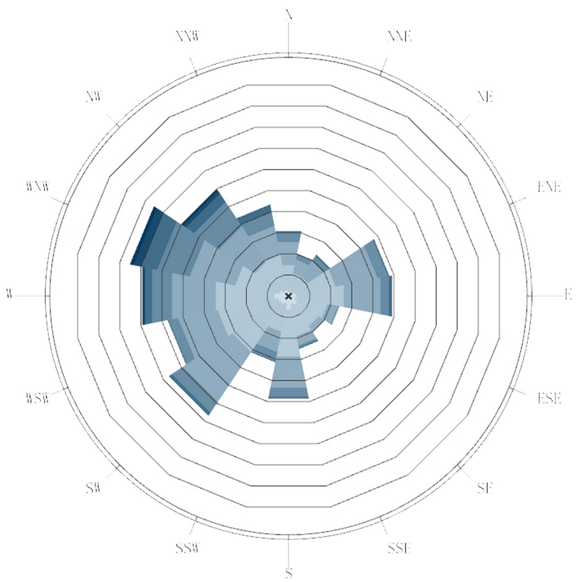
Sun-Path Diagram - Latitude: 39.87
Hourly Data: Total Cloud Cover (tenth)
Philadelphia International Ap_PA_USA



Sun-Path Diagram - Latitude: 39.87
Hourly Data: Total Cloud Cover (tenth)
Philadelphia International Ap_PA_USA
... ...
Conditional Selection Applied:
Total Cloud Cover < 6
39.0 hours of total 108.0 sun up hours(36.11%).

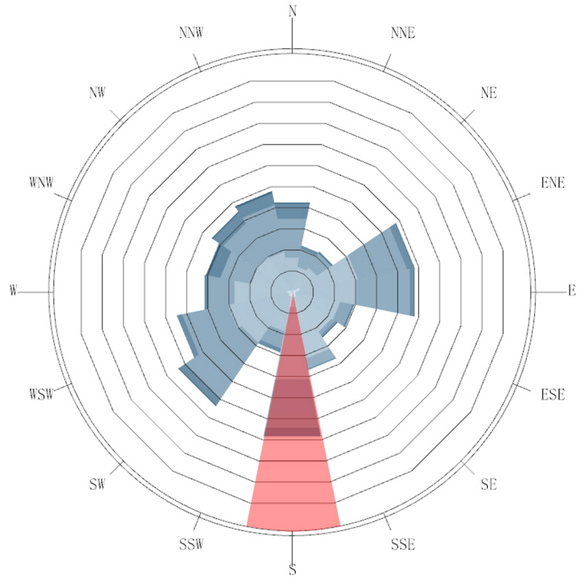
The upward sunpath diagrams show the outdoor comfort situation with the points of occupied time. The other two diagrams show the points of occupied time which cloud cover are fewer than 6. Combined these diagrams, it is reasonable to infer that the form and demension of **shading** should base on over shading the direct sunshine from June to August in order to increase the percentage of comfortable time .

WINDROSE



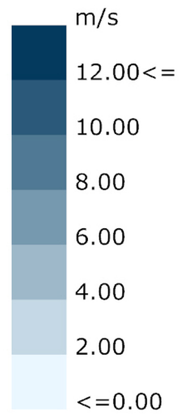
Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.81% of the time = 246 hours.
Each closed polyline shows frequency of 1.4%. = 122 hours.

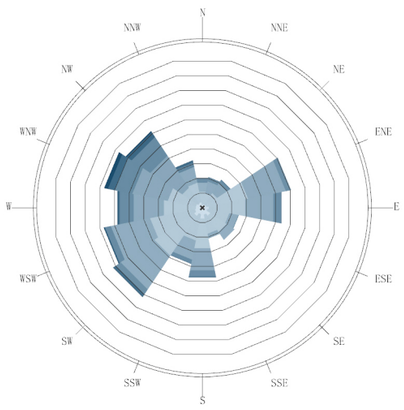
ANNUAL



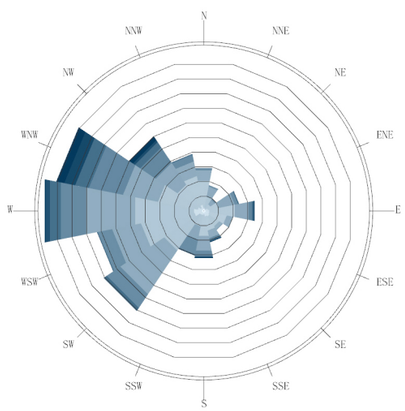
Wind-Rose
Philadelphia International Ap_PA_USA
1 JUL 1:00 - 30 SEP 24:00
Hourly Data: Wind Speed (m/s)
Calm for 1.09% of the time = 24 hours.
Each closed polyline shows frequency of 1.4%. = 30 hours.

SUMMER

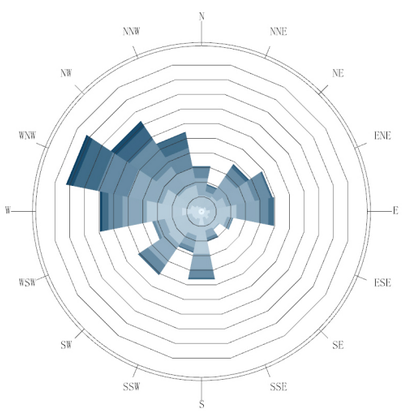




spring



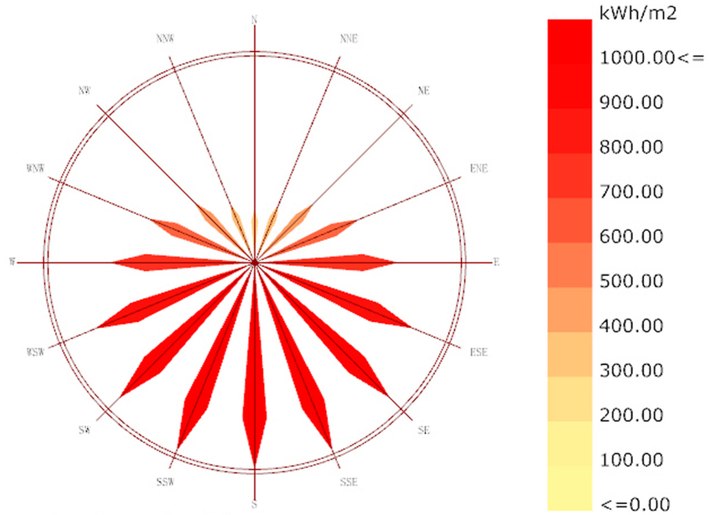
winter



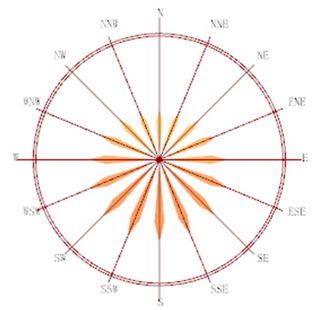
fall

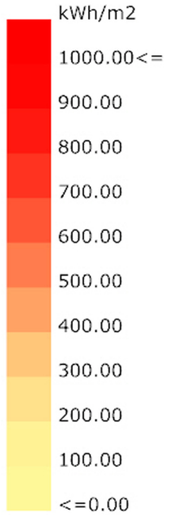
As discussed preceding part of this report, natural ventilation in summer can efficinetly increase the comfort in summer. The preliminary inference can be drawn based on the seasonal windrose that right south could be a better direction since the maximum wind velocity.

RADIATION ROSE

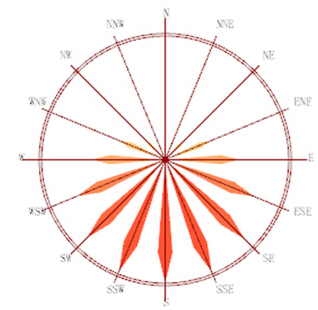


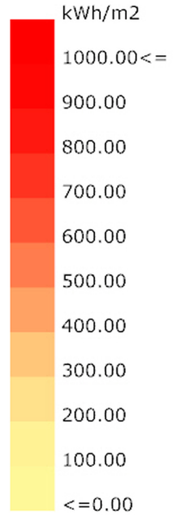
Total Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00





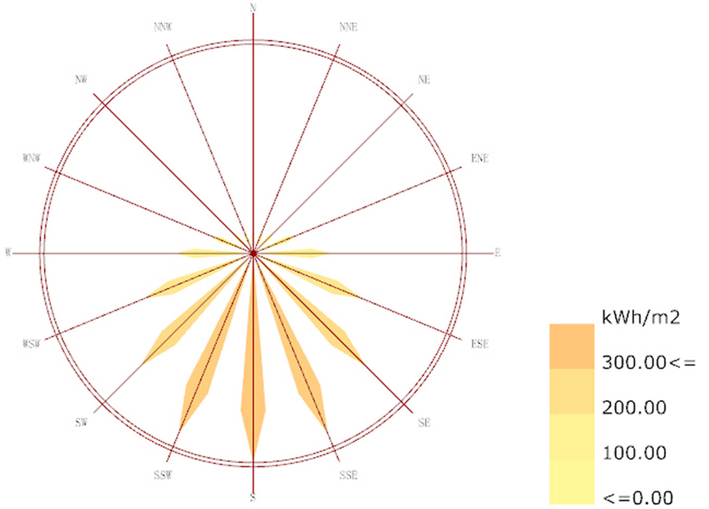
Diffuse Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



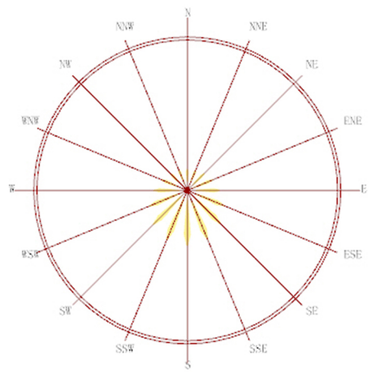


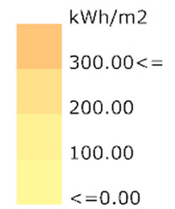
Direct Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

ANNUAL

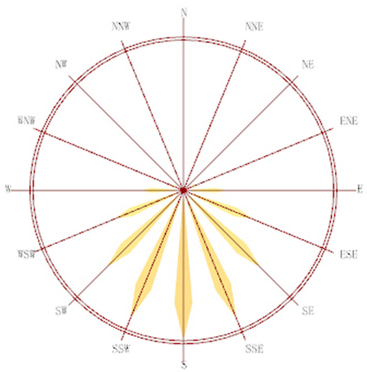


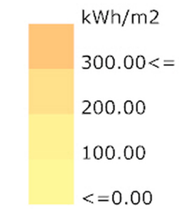
Total Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 NOV 1:00 - 31 JAN 24:00





Diffuse Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 NOV 1:00 - 31 JAN 24:00



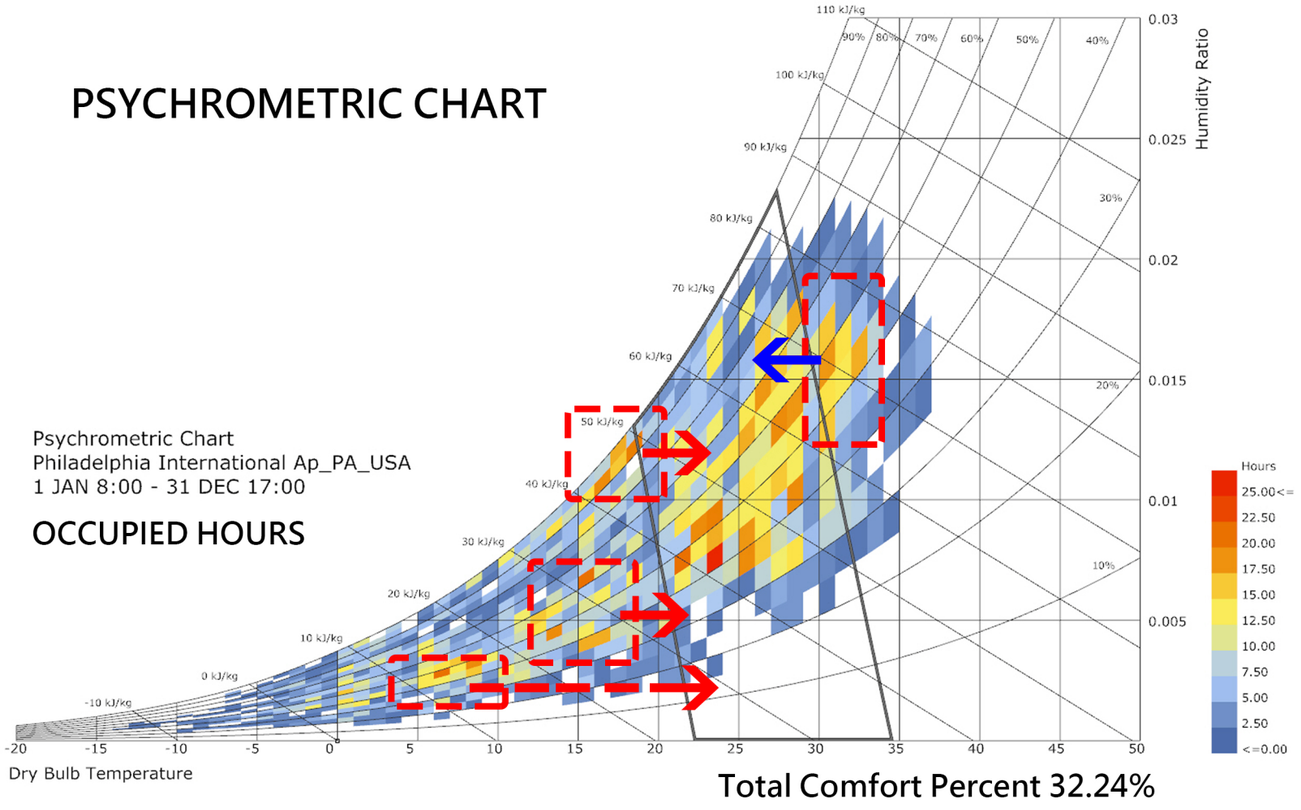


Direct Radiation(kWh/m2)
Philadelphia_International_Ap_PA_USA
1 NOV 1:00 - 31 JAN 24:00

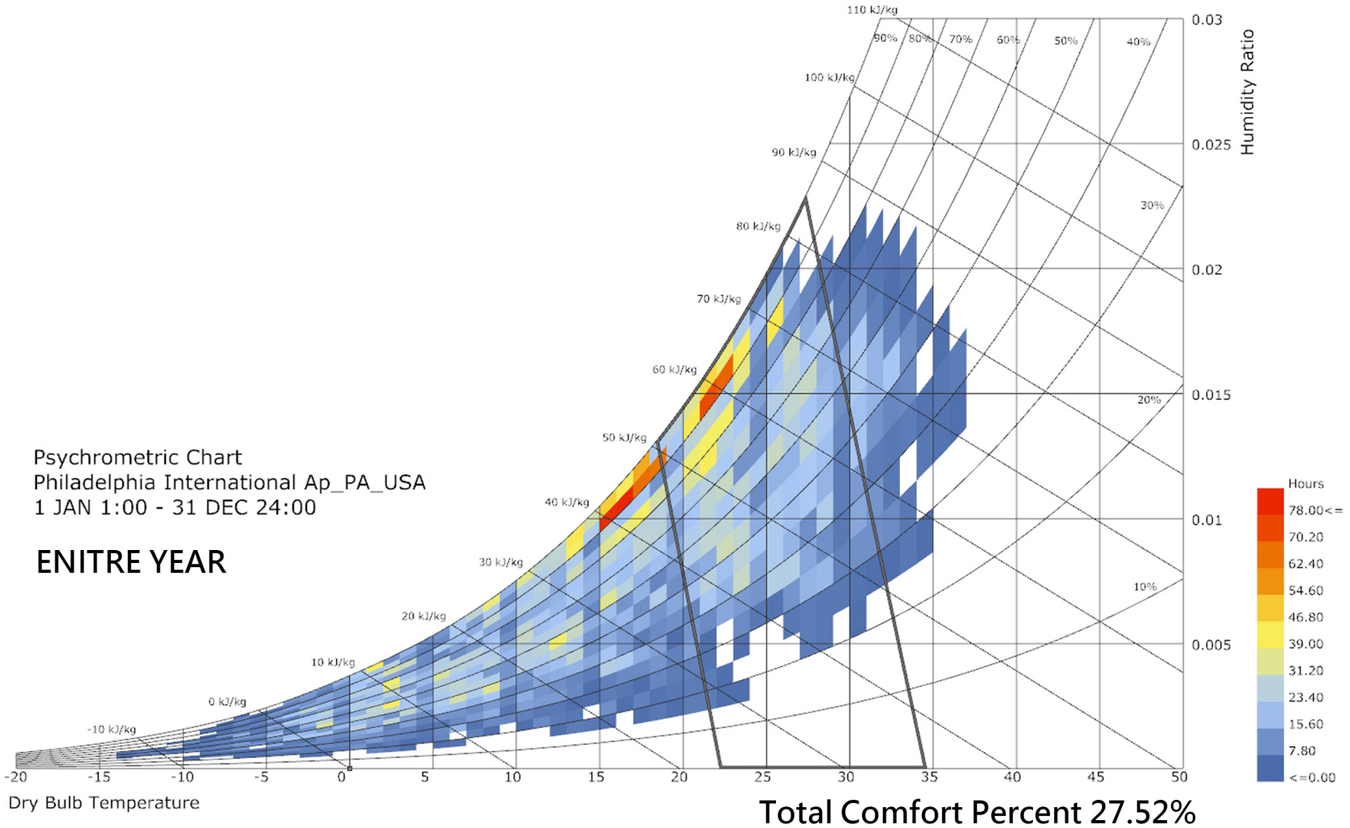
WINTER

As mentioned before, Salor radiation in winter can efficinetly increase the indoor temperature. According to the radiation rose chart in winter, the value of direct radiation is much greater than the diffuse radiation, which means the oriantation of openning should be take into accout. In the light of Direct radiation rose diagram S SSE SSW should be better choices in absorbing the solar radiation.

PSYCHROMETRIC CHART



Total Comfort Percent 32.24%

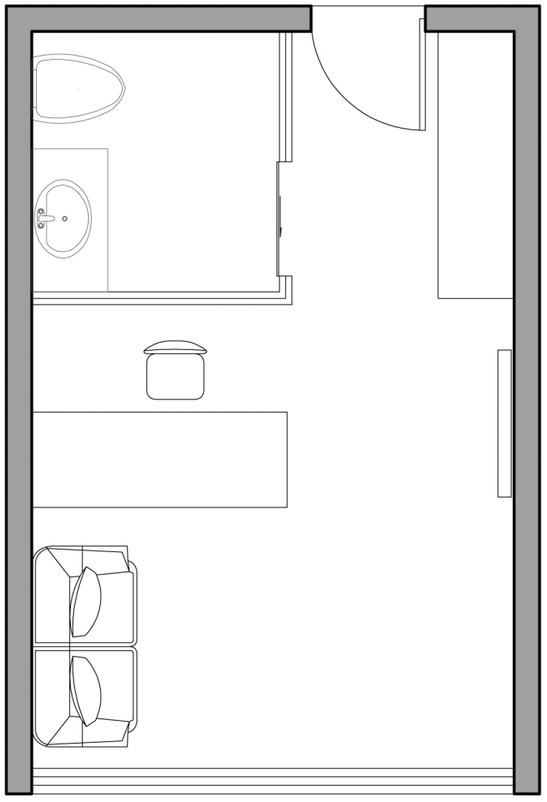


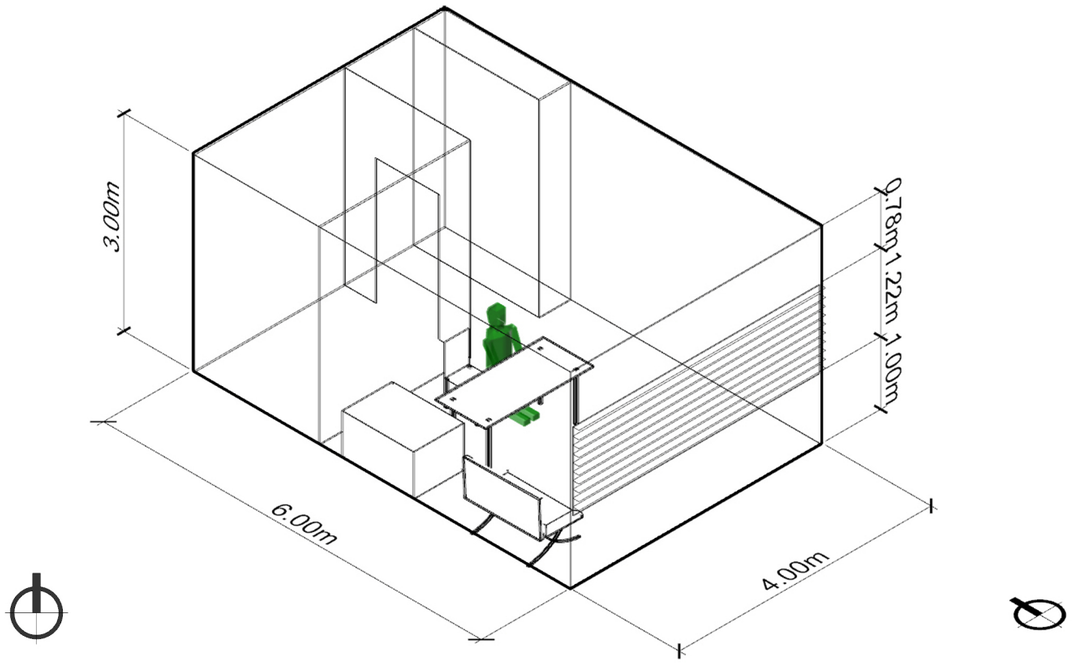
Total Comfort Percent 27.52%

Psychrometric charts show the potential ways to improve the comfort percent time. Unlike chart of the enitre year, occpied chart hours Show greater potential to increase the percentage of comfortable time.

Bace-case assessment

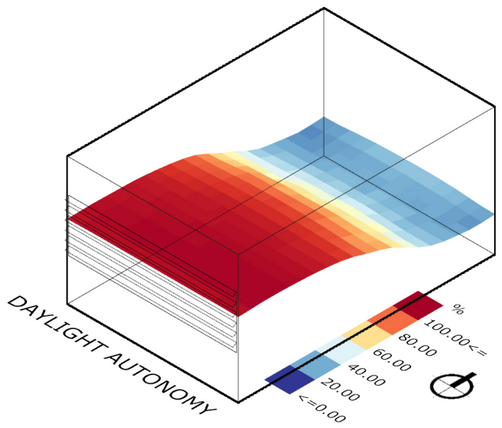
TEST ROOM

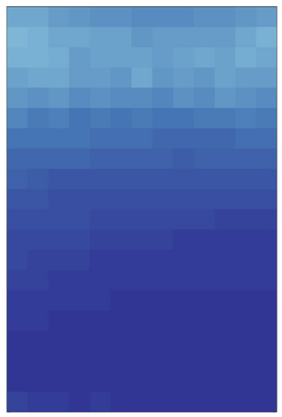




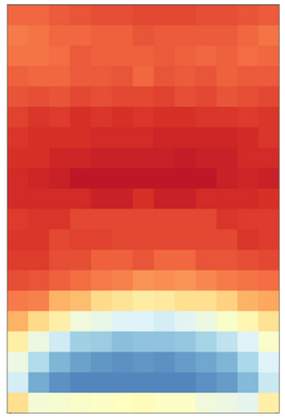
Area: 24㎡
Glazing: 4.6㎡
Orientation: South 0 degree
Program: Midrise SOHO
Occupied Hour: 8am—5pm

TEST ROOM

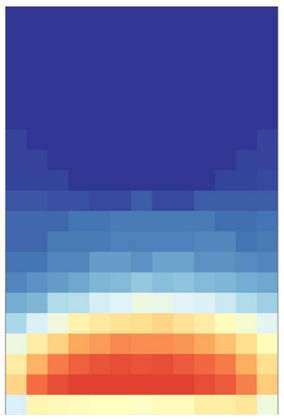




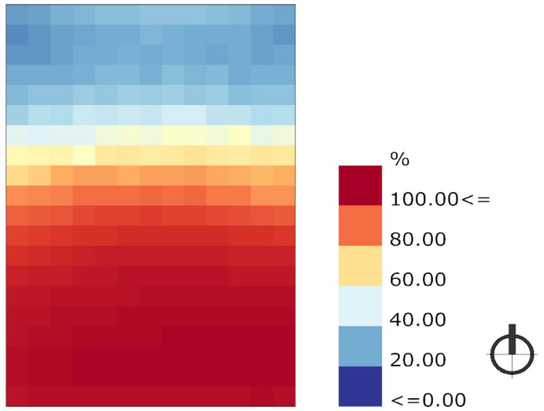
UDLI(<100l ux)



UDLI(100<2000lux)



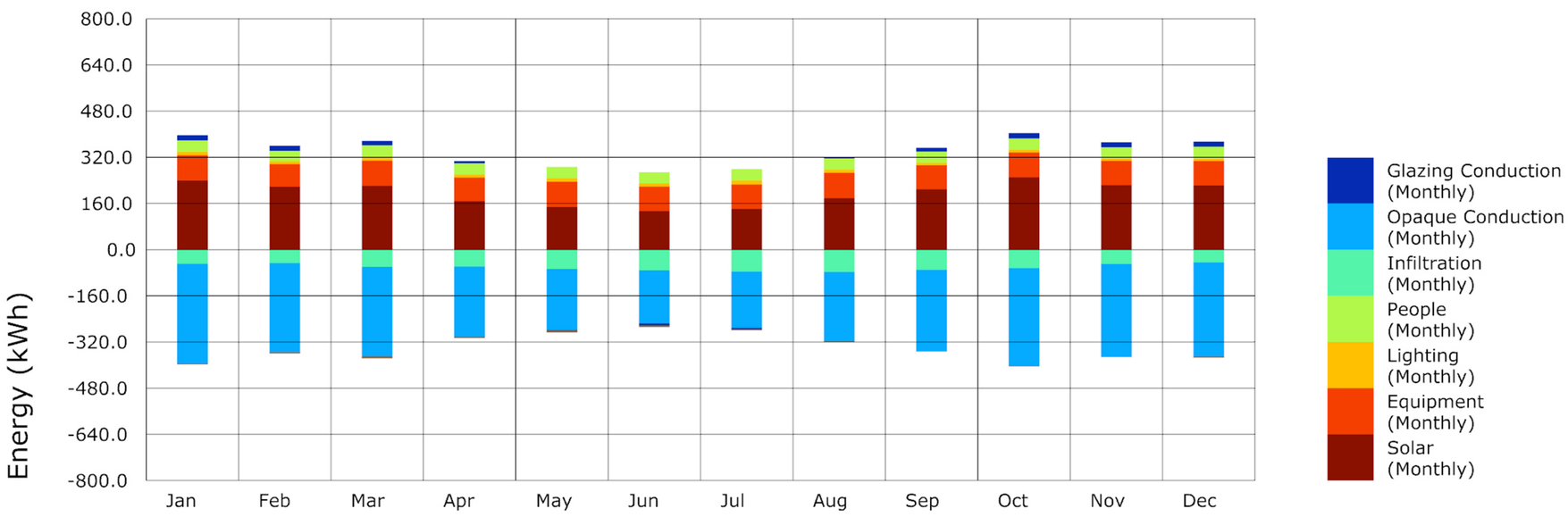
UDLI(>2000lux)



DLA

DAYLIGHT AUTONOMY

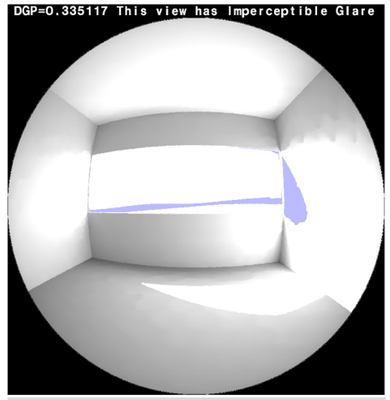
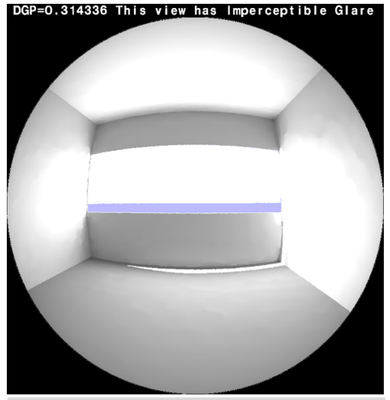
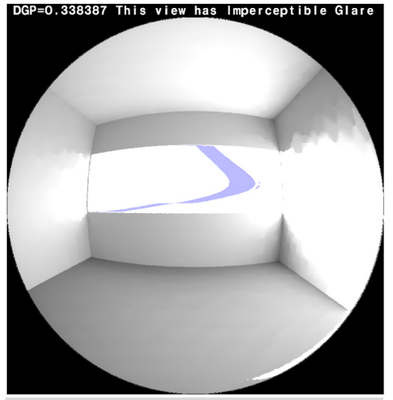
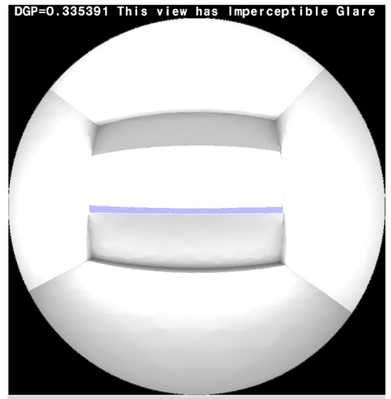
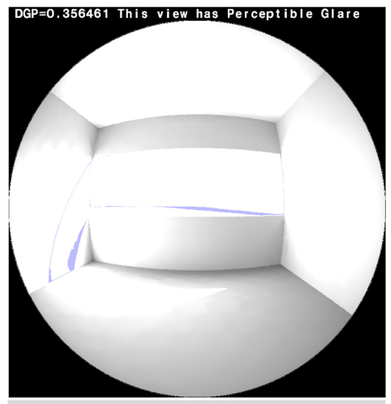
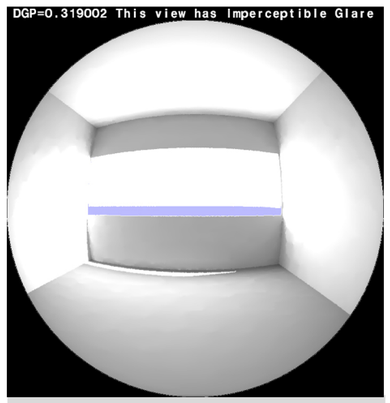
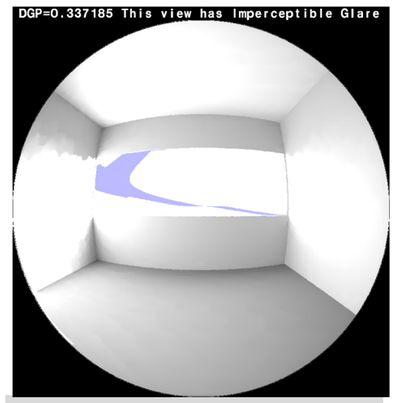
SDA: 64.62%



Apartment Room Energy Balance

Daylight autonomy chart indicates the area which receive 300 lux exceed DLAIllum Thresholds vauue. Energy Balance chart shows the consumption of energy, the iffiltration and opaque conduction accout for the main factor of energy comsue.

GLARE ANALYSIS

	MARCH	JUNE	DECEMBER
9 AM	 DGP: 0.33	 DGP: 0.31	 DGP: 0.34
12 PM	 DGP: 0.41	 DGP: 0.34	 DGP: 0.51
15 PM	 DGP: 0.36	 DGP: 0.33	 DGP: 0.34

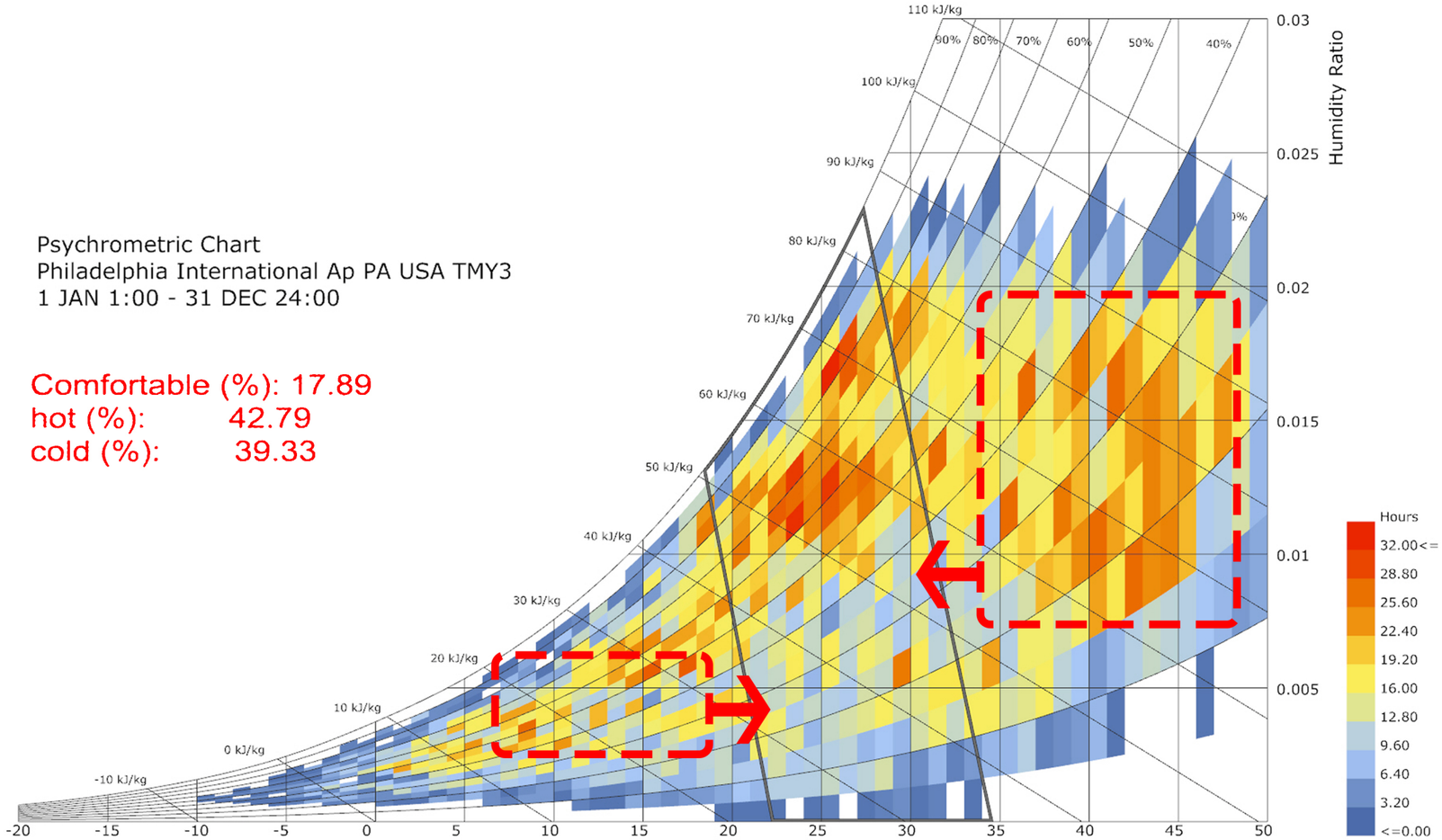
The Daylight Glare Porbability result shows there is Perceptible glare at 15pm of March 21st and at 12PM of March and December.

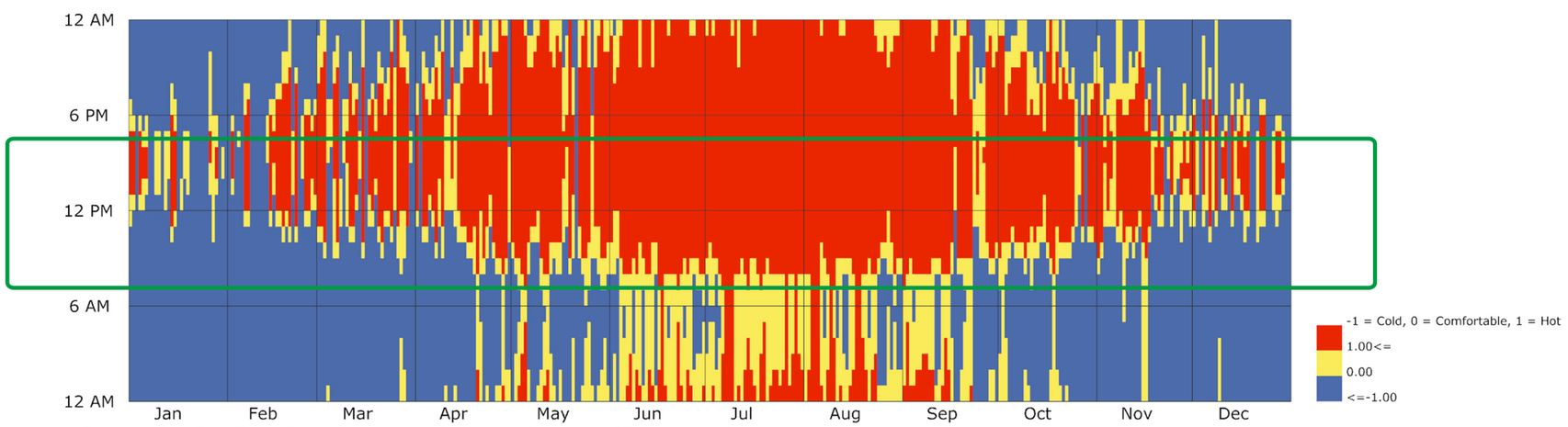
Imperceptible: **<35%**
Perceptible: **35~40%**
Disturbing: **40~45%**
Intolerable: **>45%**

INDOOR COMFORT

Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Comfortable (%): 17.89
hot (%): 42.79
cold (%): 39.33





Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Occupied hours

Adaptive comfort Chart shows hot issue account for the uncomfort situation in most time of the afternoon. And Psychrometric chart indicate the potential the improve the comfort. Base on these two diagrams, the two strategies should be applied to the base case, first one is to optimize the heat insulating performce, the second is to reduce the solar heat gain in afternoon.

Discussion and design proposals

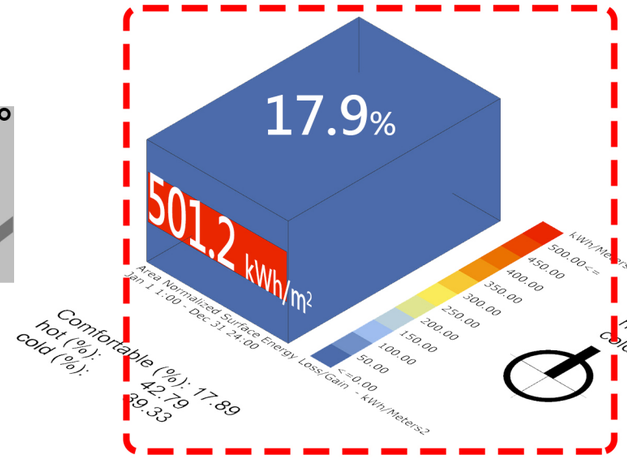
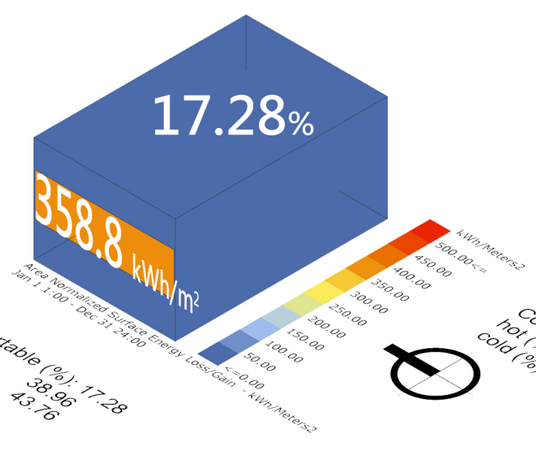
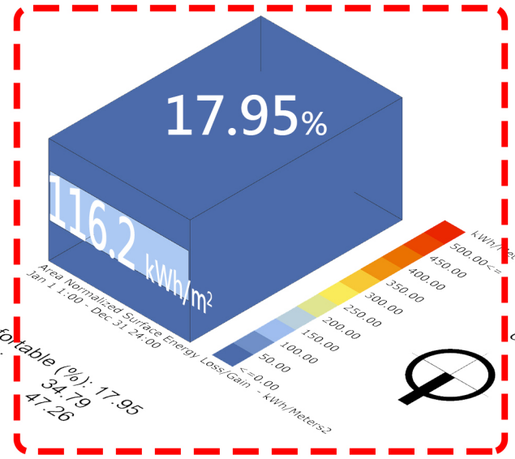
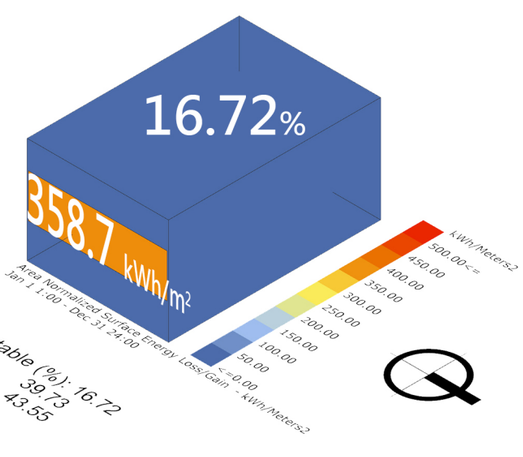
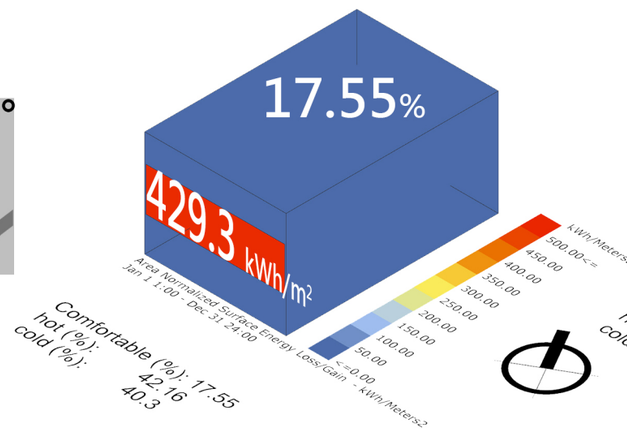
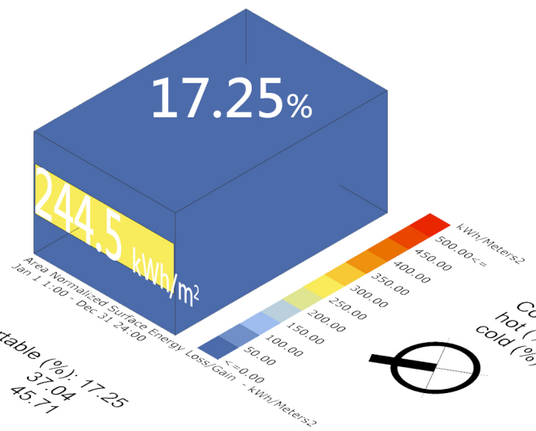
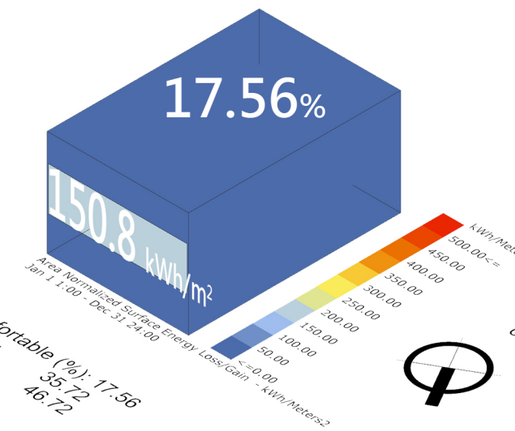
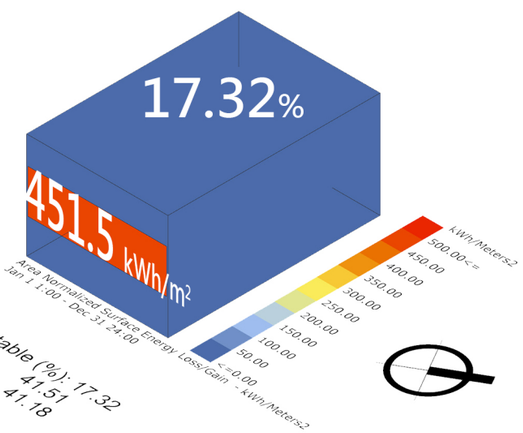
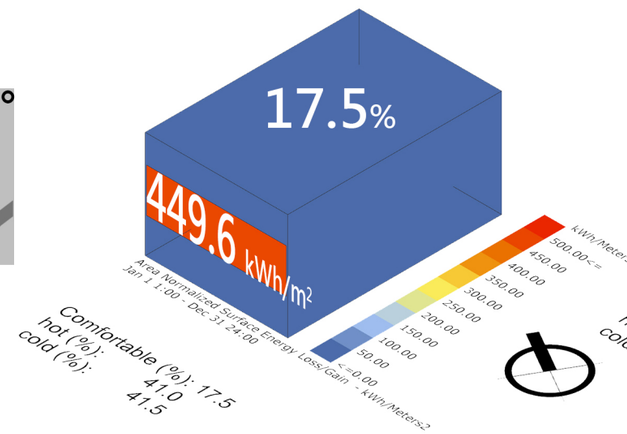
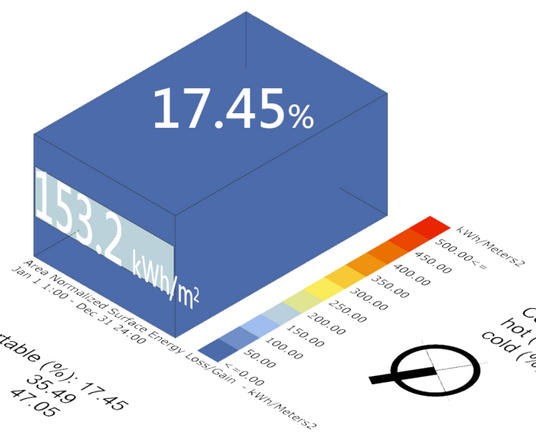
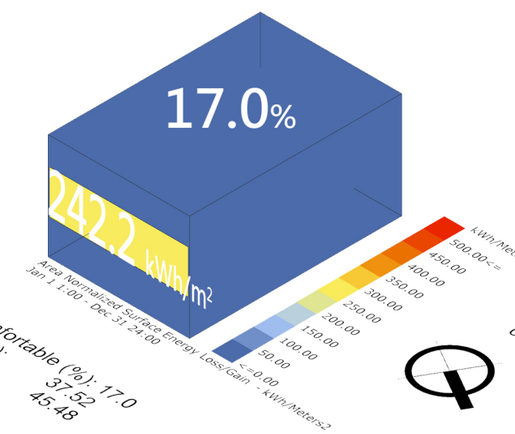
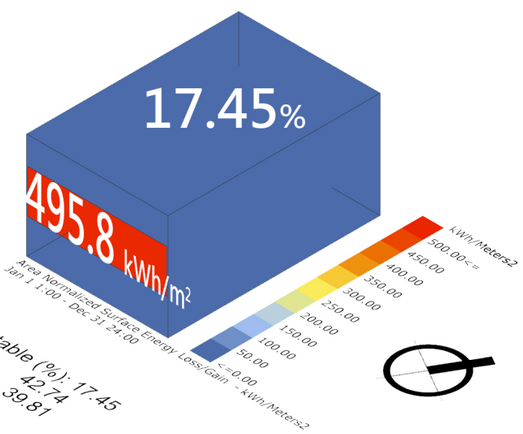
Optimizing Process

BASE CASE

Orientation →	DAYLIGHTING →	VENTILATION →	MATERIAL →	FAN FLOW & LOAD
South	Glazing Ratio: 38% Horizontal blinds: Depth:120mm Width: 3900mm Quantity: 10	Mim Indoor Temperature : 24 ℃ Maxi Outdoor Temperature : 28℃ Equipment Load Per Area : 6 Light Density Per Area : 3 Num of People Per Area : 0.2	Exterior Wall : R 34.3 Exterior Window : R1.9 SHGC 0.39 Exterior Roof : R 34.3 Air Flow : 1 Ground floor EP Construction : 8 inch Concrete	Fan Flow Rate : 3 Fan efficiency : 1 Fan Pressure Rise : 70

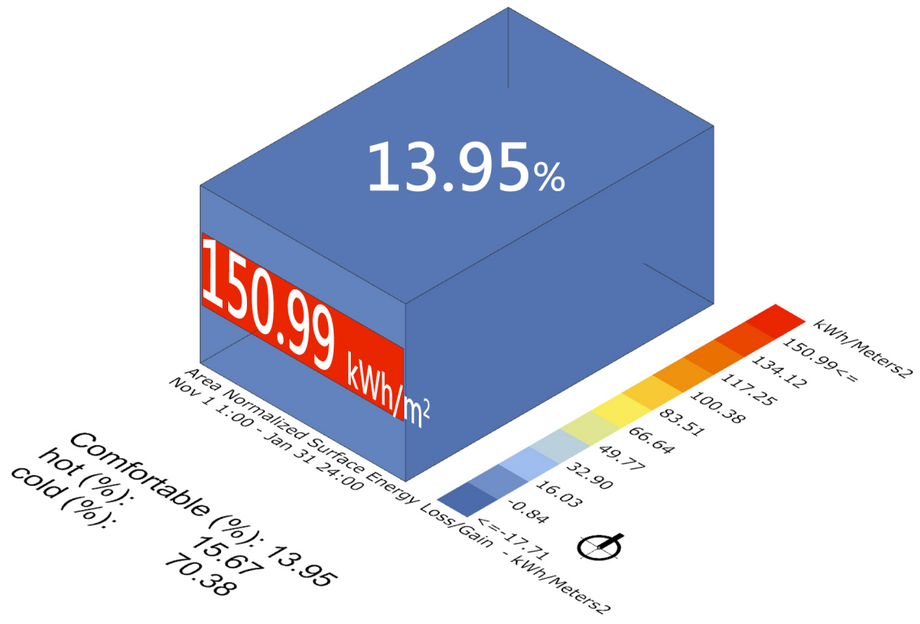
OPTIMISATION

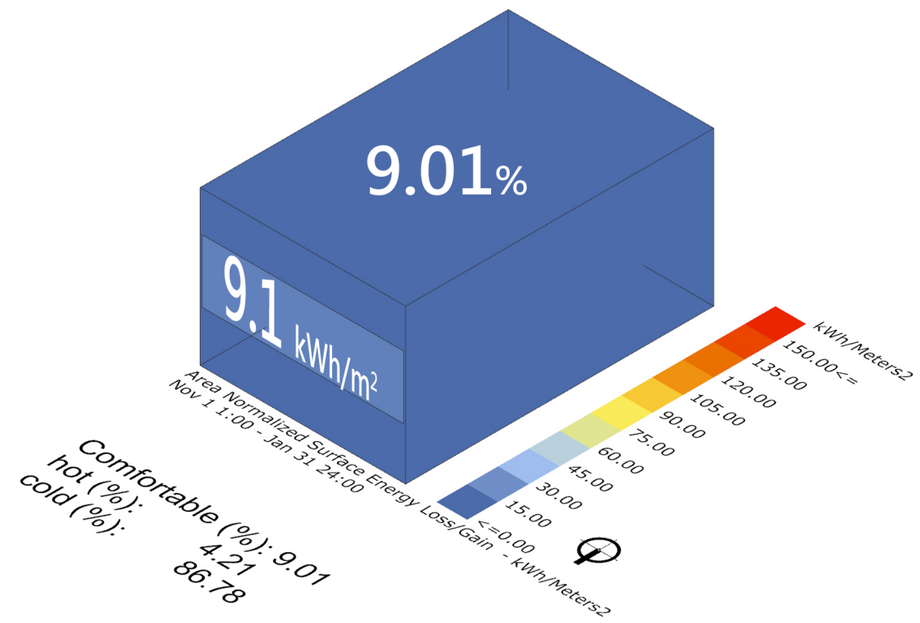
ORIENTATION (EP result of opening & Percentage time of comfort)

	S	E	N	W
0°				
30°				
60°				

Energy simulation with comfort calculation of 12 directions can screen out the best option of the orientation. Base on the charts, **SOUTH** & **NORTH** may be two of the best choice. Next sept will analyze the situation of two options in winter .

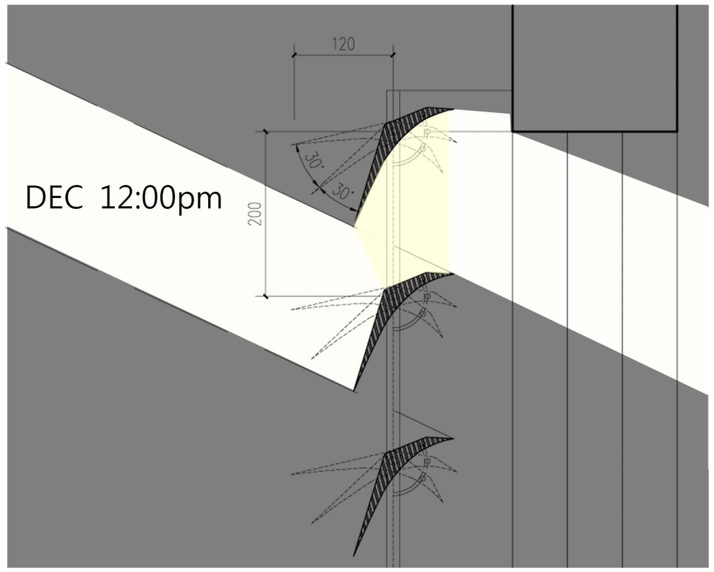
ORIENTATION (EP result of opening & Percentage time of comfort)





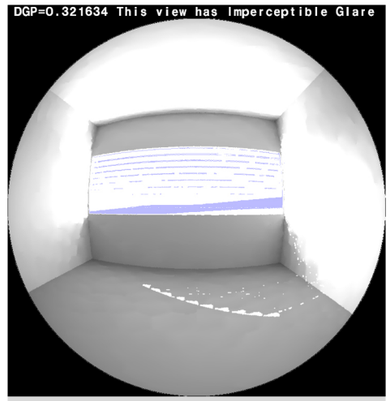
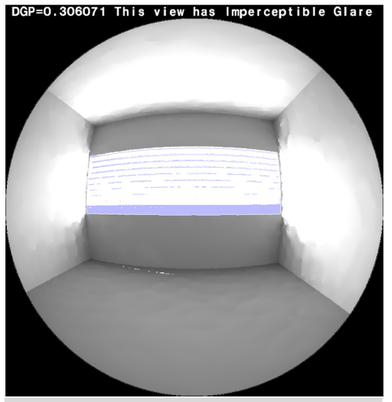
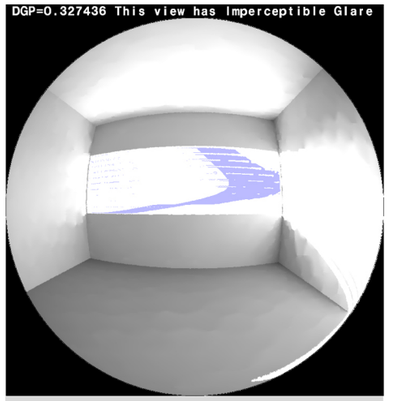
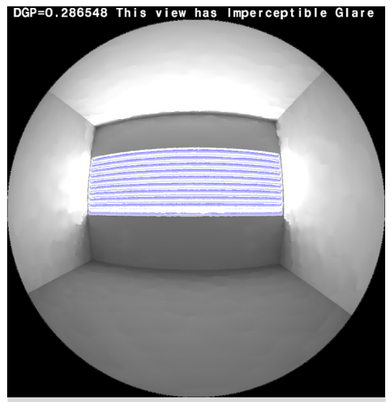
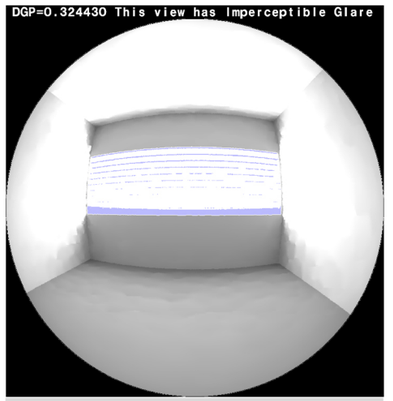
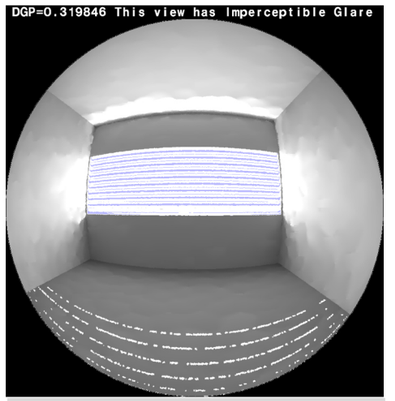
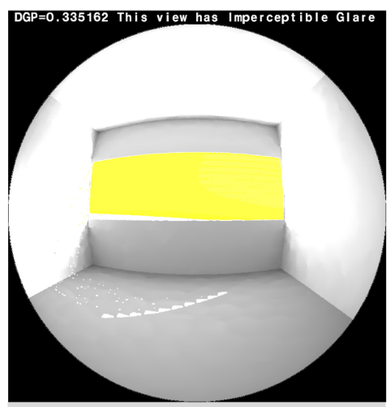
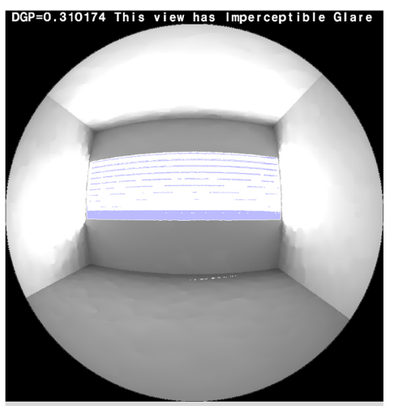
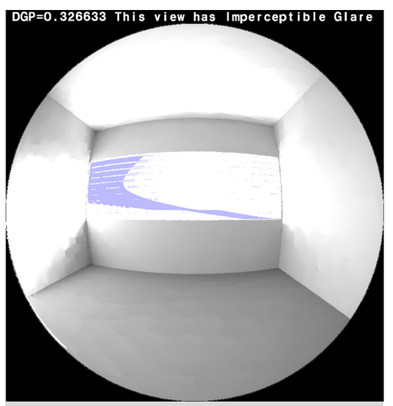
Compared the opening orientation of opposite side in the **winter**, it makes much more sense to locate opening on the **south** orientation since this option not only absorbs more solar radiation but also provide greater value of percentage of comfort.

Sept 1: VISUAL COMFORT



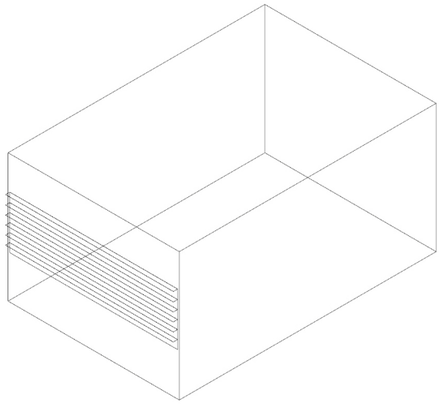
Advanced well design shading device can block the direct sun beam shoot into interior, it can also produce indirected daylight through reflection. This shading device is movable and adaptable so it can adjust its blinds follow the solar azimuth. After installing the shading system, glare may reduce from 0.51 to 0.31 at 12:00 Dec 21st .

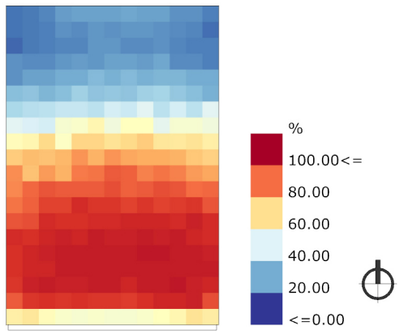
Glazing Ratio: **38%**	Imperceptible: **<35%**
Horizontal blinds:	Perceptible: **35~40%**
Depth : **120mm**	Disturbing: **40~45%**
Width : **3800mm**	Intolerable: **>45%**

	MARCH	JUNE	DECEMBER
9 AM	 DGP: 0.32	 DGP: 0.30	 DGP: 0.33
12 PM	 DGP: 0.29 **(0.41)**	 DGP: 0.32	 DGP: 0.31 **(0.51)**
15 PM	 DGP: 0.34	 DGP: 0.31	 DGP: 0.33

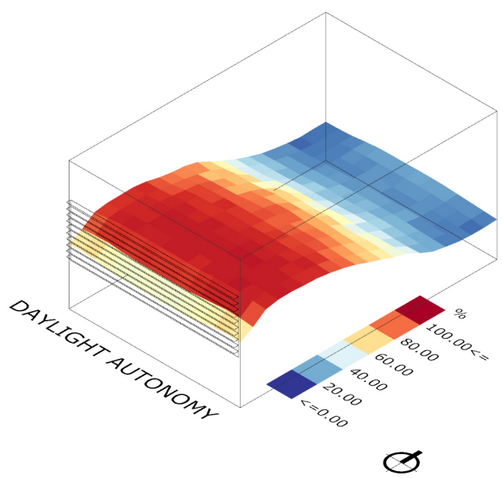
Sept 1 DAYLIGHT AUTONOMY & ADAPTIVE COMFORT

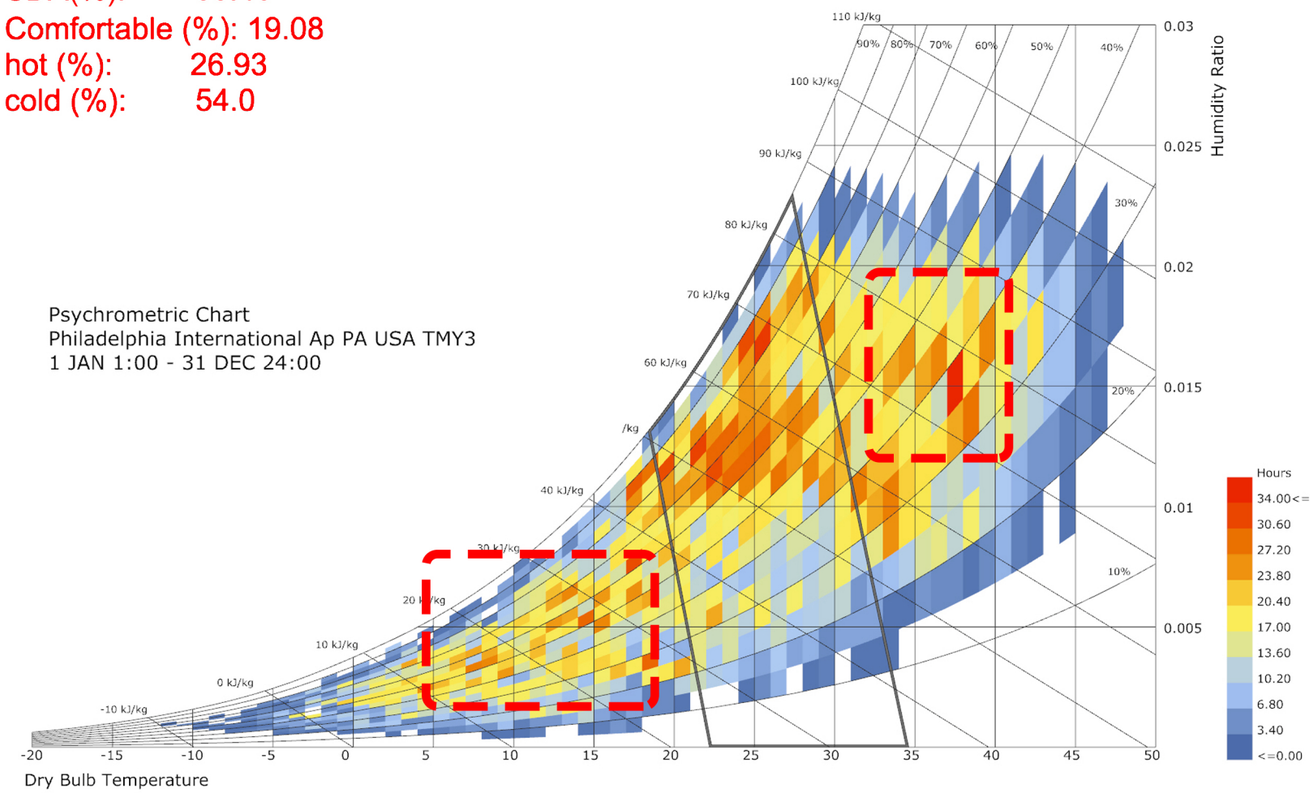
SDA(%): 58.46
Comfortable (%): 19.08
hot (%): 26.93
cold (%): 54.0

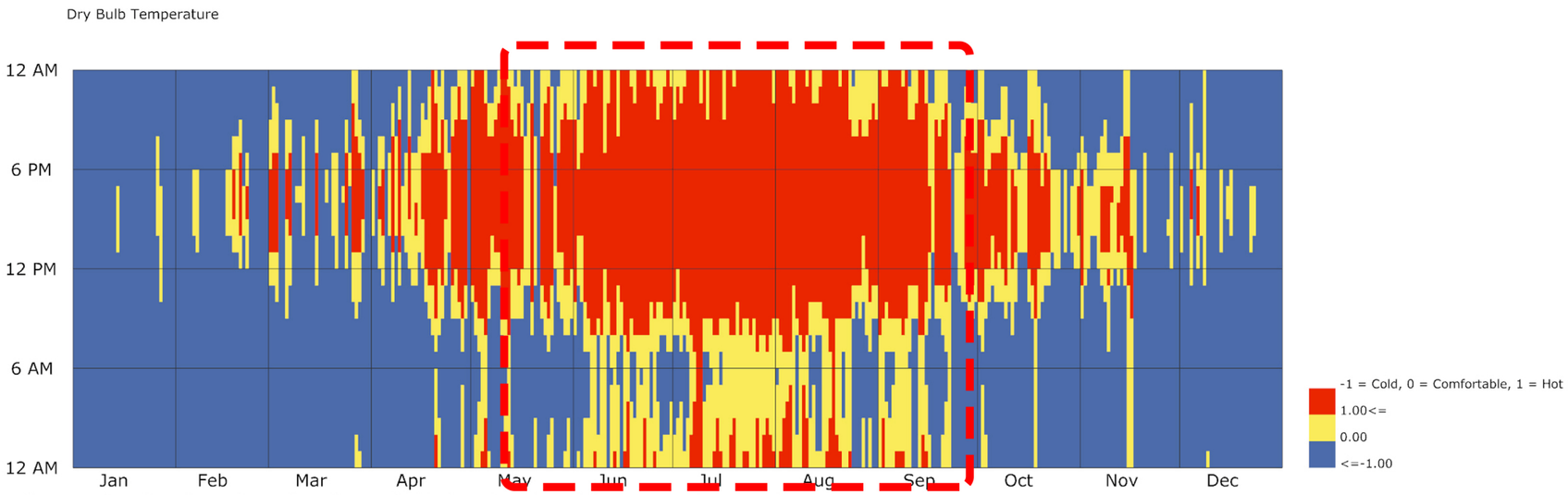




DAYLIGHT AUTONOMY

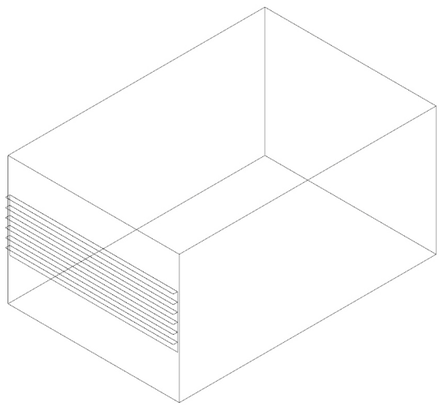




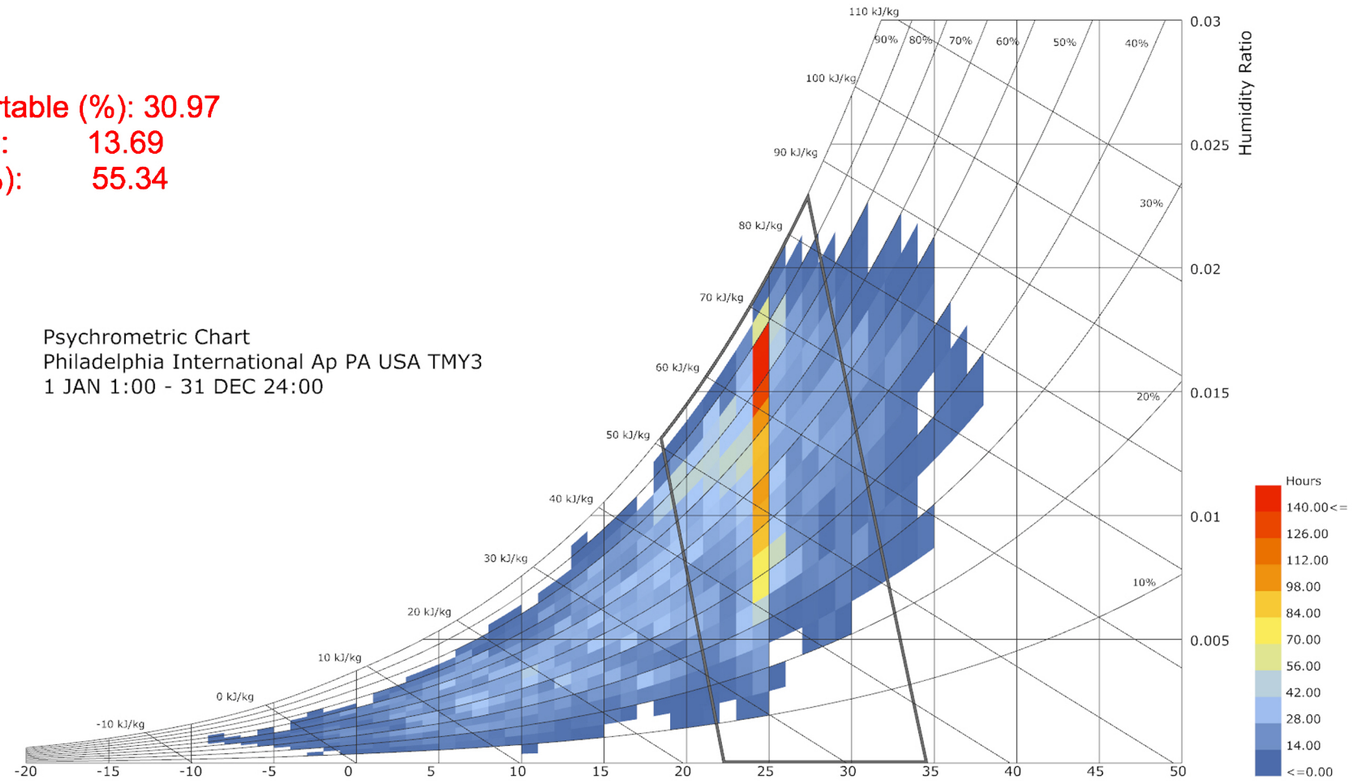


Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Sept 2 VENTILATION

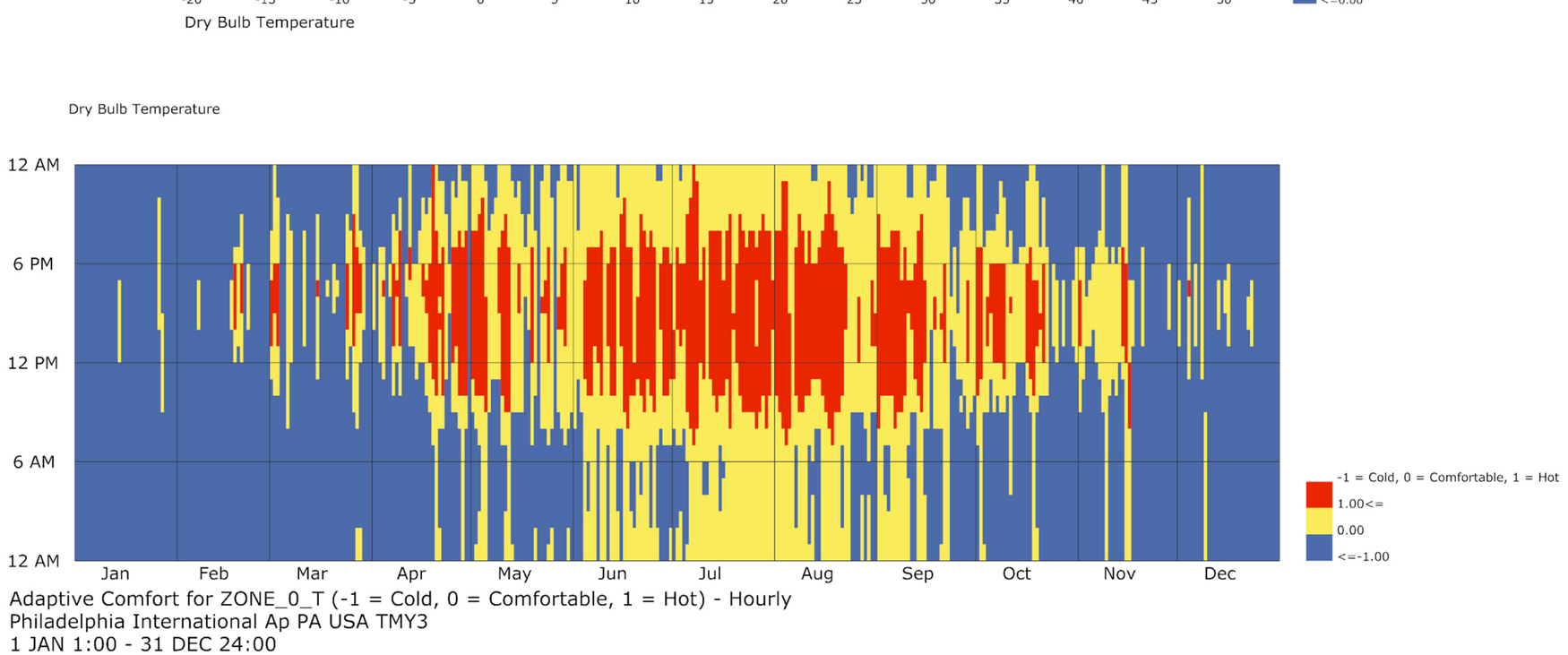


Comfortable (%): 30.97
hot (%): 13.69
cold (%): 55.34

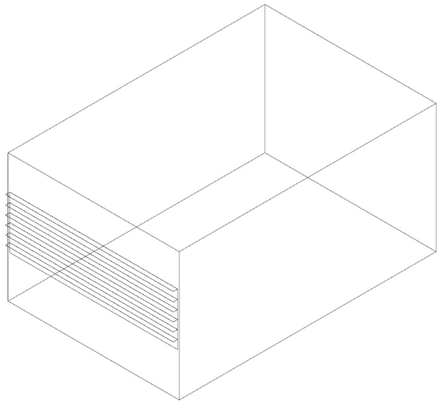


parameters

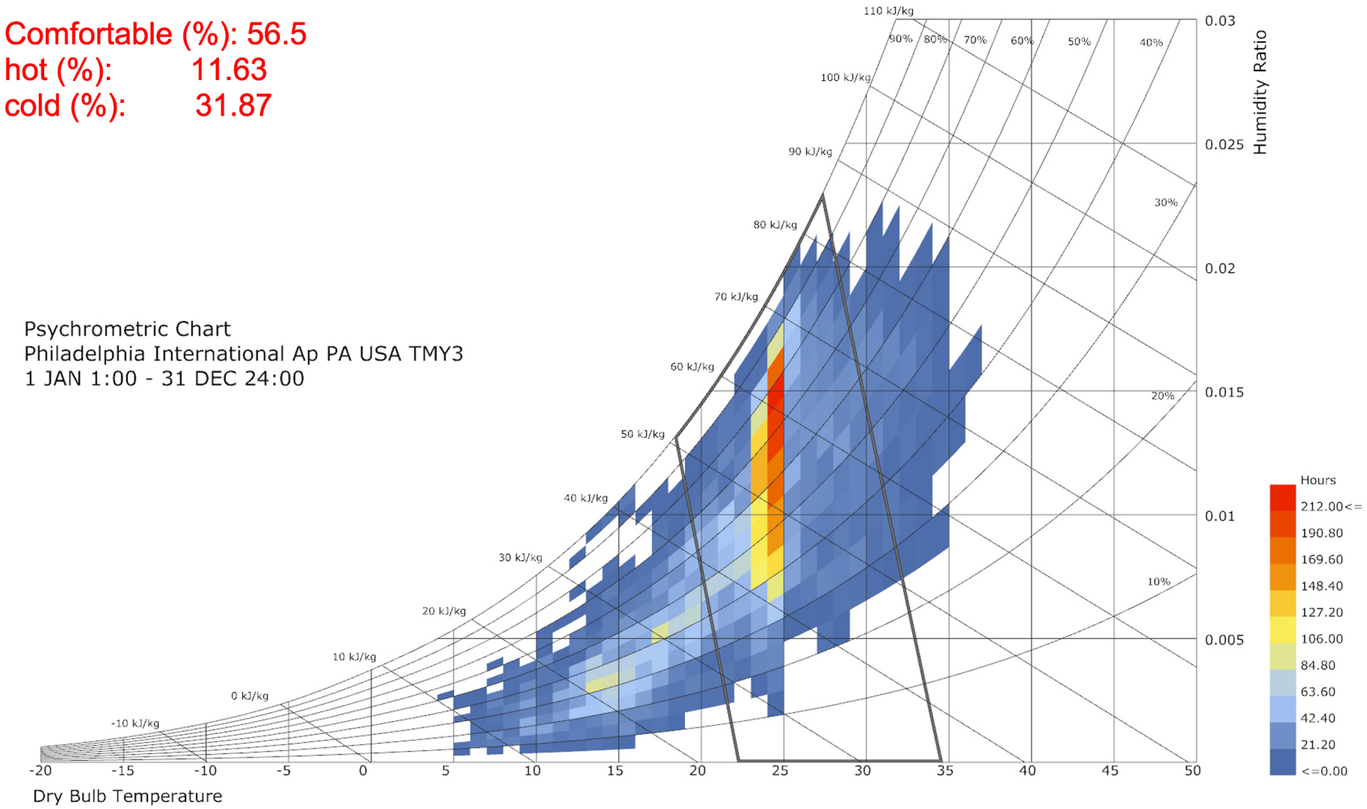
Mim Indoor Temperature :	**24 ℃**
Maxi Outdoor Temperature :	**28℃**
Equipment Load Per Area :	**6**
Light Density Per Area :	**3**
Num of People Per Area :	**0.2**



Sept 3 MATERIAL

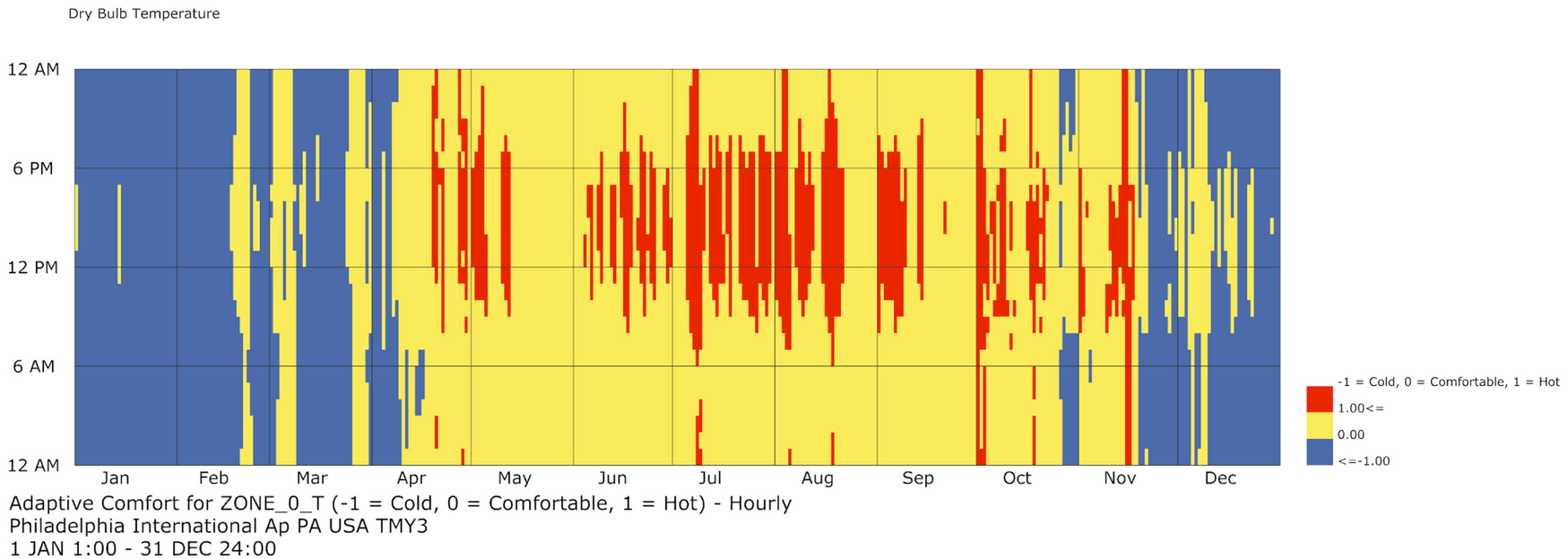


Comfortable (%): 56.5
hot (%): 11.63
cold (%): 31.87



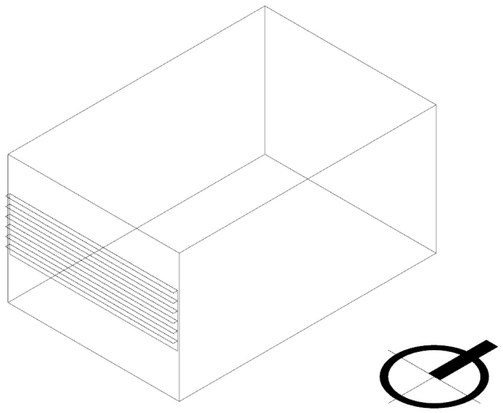
parameters

Exterior Wall :	R 34.3
Exterior Window :	R1.9 SHGC 0.39
Exterior Roof :	R 34.3
Air Flow :	1
Ground floor EP Construction :	8 inch Concrete

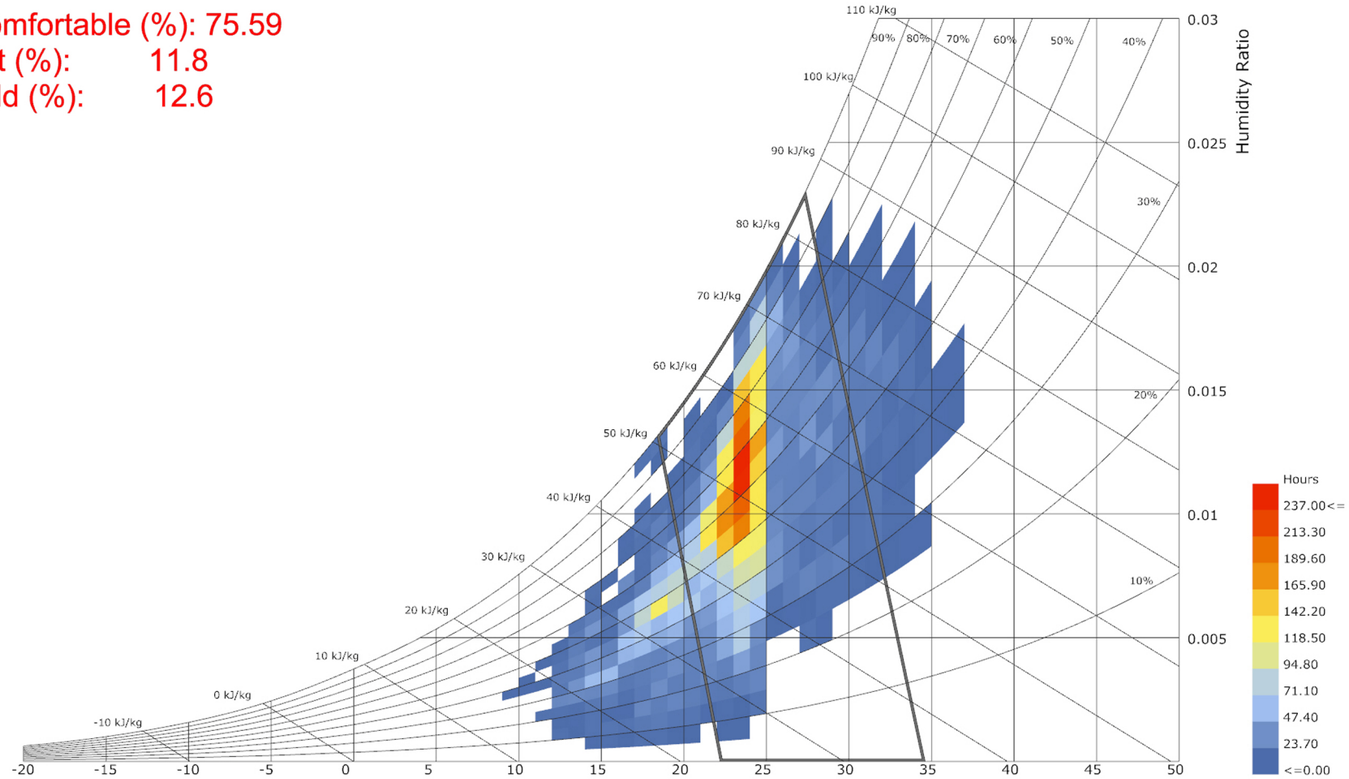


Final design assessment
& Conclusions

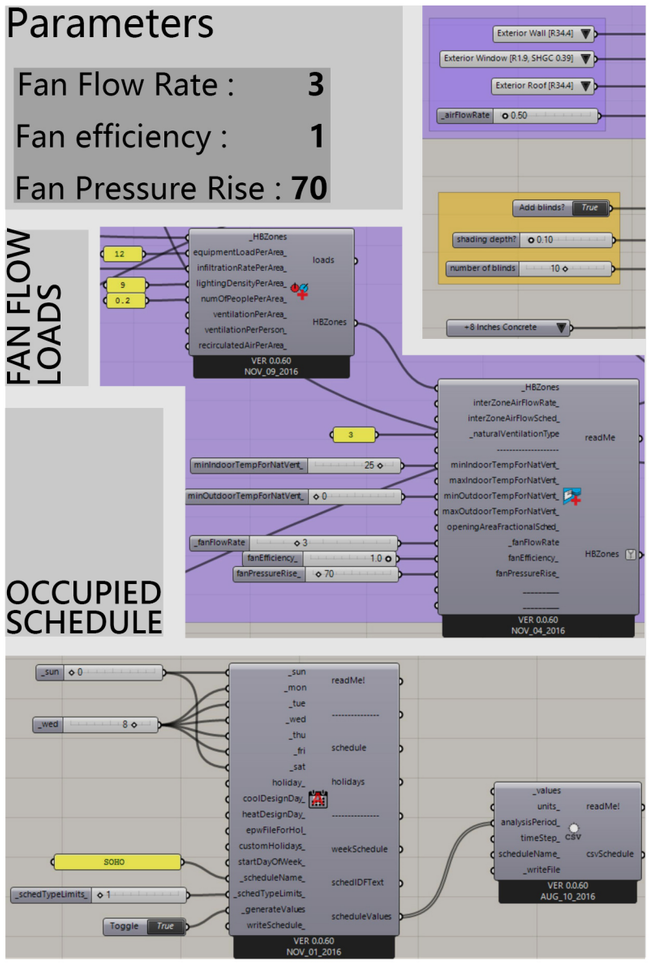
Sept 4 FURTHER IMPROVEMENT

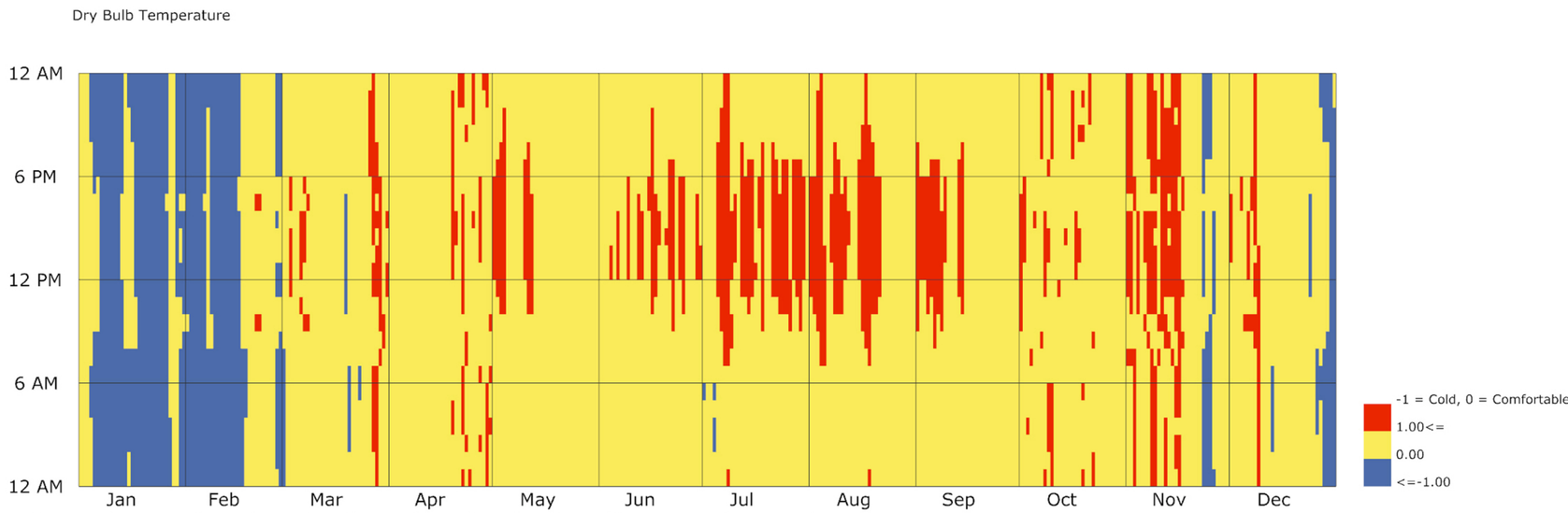


Comfortable (%): 75.59
hot (%): 11.8
cold (%): 12.6



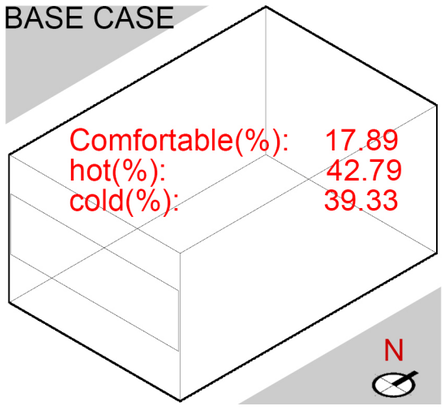
Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

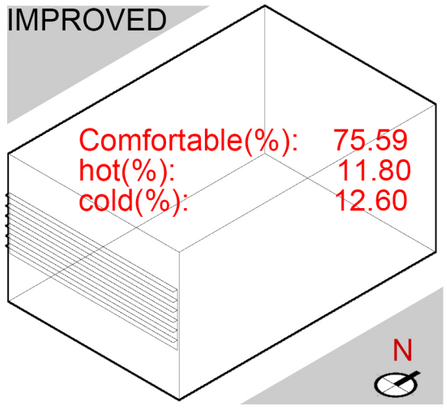


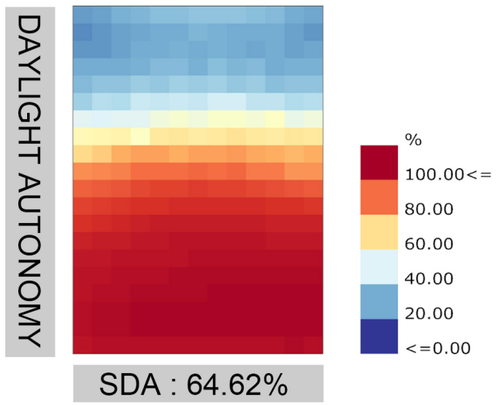


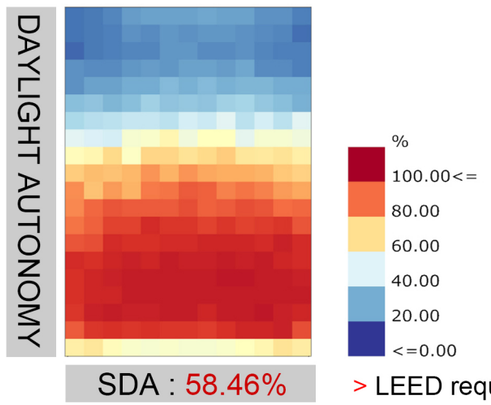
Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

SUMMARY(DAYLIGHTING)

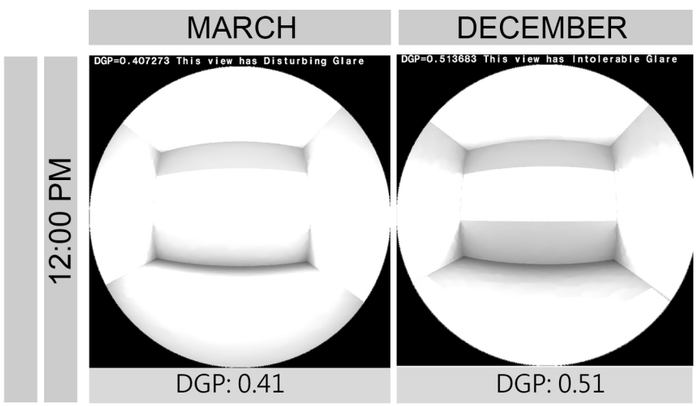


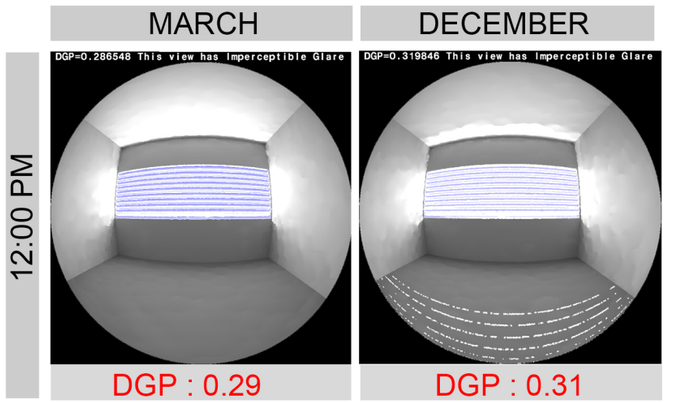






> LEED requirement: 50%



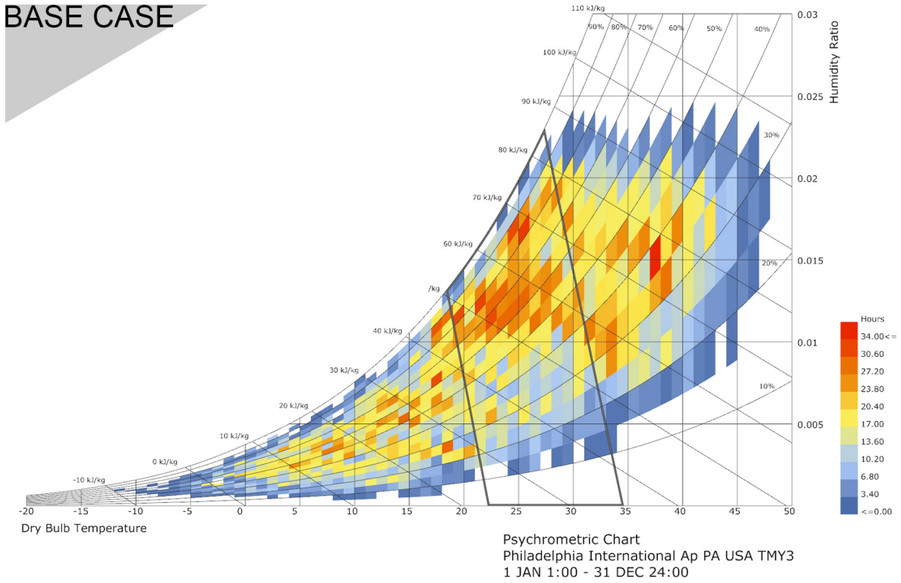


< Imperceptible glare: 35%

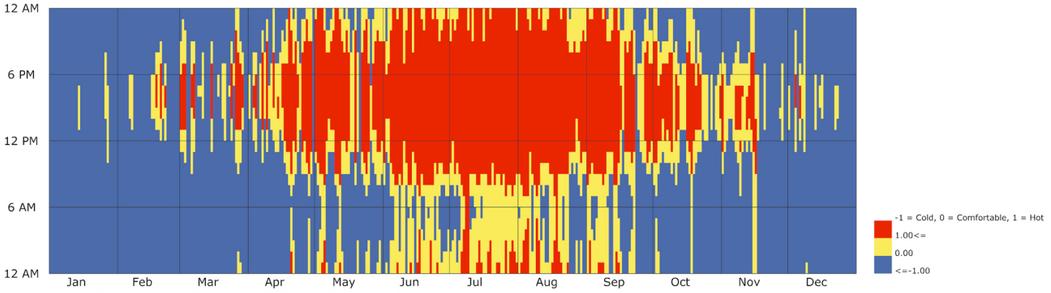
Installing the rotatable blinds can efficiently reduce the DGP (Daylight Glare Probability)，this shading device can also hold the SDA (Spatial Daylight Autonomy) exceeding the LEED standard which requires the DLA llum Thresholds value (300lux)for at least 50%.

SUMMARY(COMFORT & ENERGY)

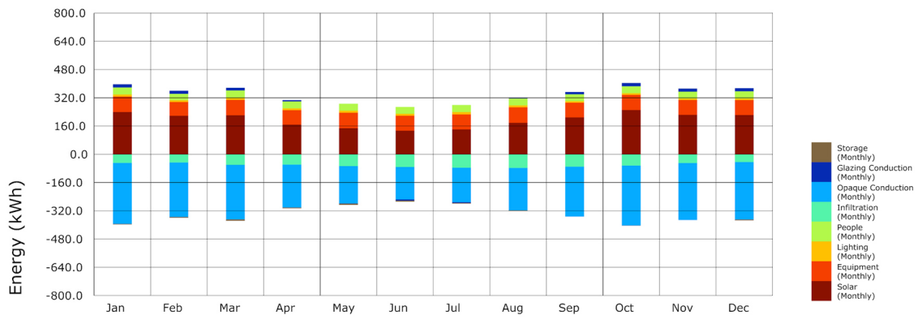
BASE CASE



Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

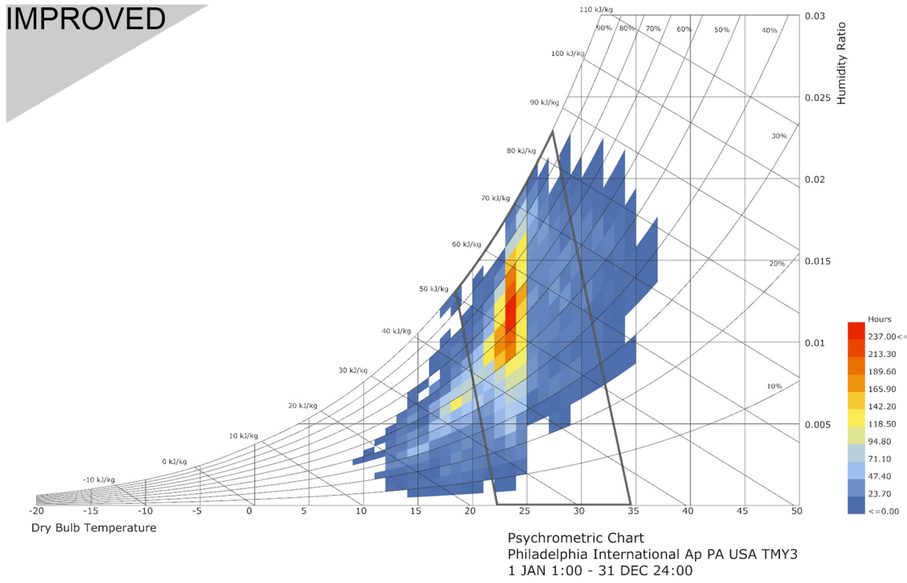


Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

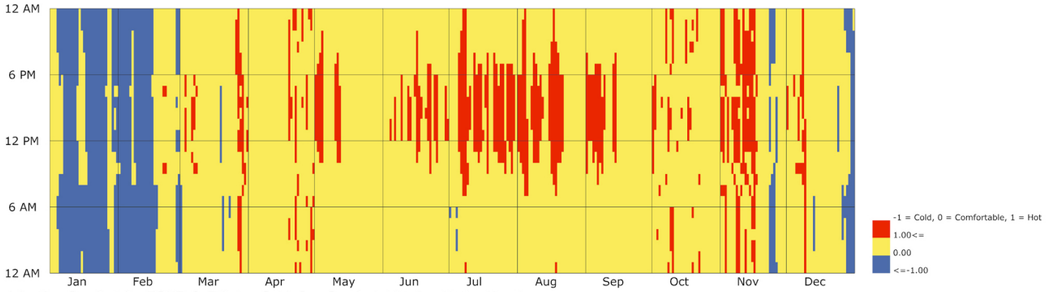


Apartment Room Energy Balance

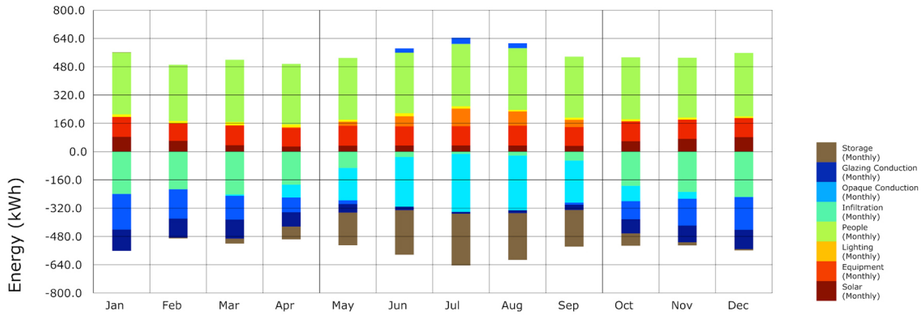
IMPROVED



Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Soho Energy Balance

By improving the natural ventilation, material, and the fan flow, the comfort rate can increase remarkably from 18% to 76%.