Indoor Comfortness Maximizition Simulation based in Chicago city

Arch 753 | Building Performance Simiulation | Final Assignment
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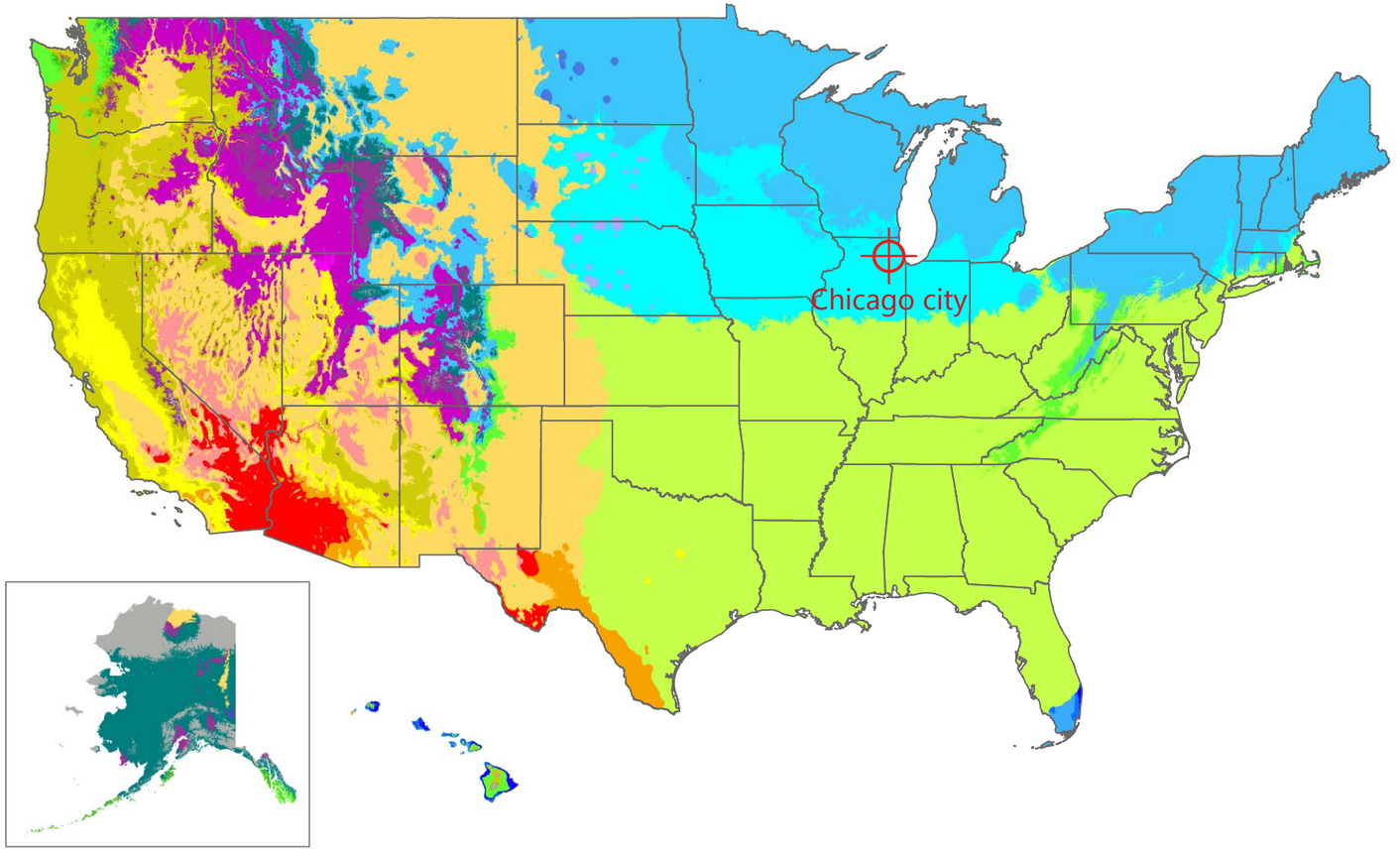
Climate Type of Chicago

Chicago is located in the northeast of U.S. , in the state of Illinois, next to the Michigan river.

The right diagram shows the location of Chicago city and the Köppen climate type of its climate.

Köppen climate classification is one of the most widely used climate classification systems.

The climate of chicago is defined as the **DFA(Hot-summer humid continental)** type, which is typified by large seasonal temperature differences, with warm to hot (and often humid) summers and cold (sometimes severely cold) winters. Precipitation is usually well distributed through the year.



U.S. Köppen Climate Type Map (from wiki)

- *EF (Ice-cap)*
- *ET (Tundra)*
- *Dfc (Subarctic)*
- *Dfb (Warm-summer humid continental)*
- *Dfa (Hot-summer humid continental)*
- *Dwc (Subarctic)*
- *Dwb (Warm-summer humid continental)*
- *Dwa (Hot-summer humid continental)*
- *Dsc (Dry-summer subarctic)*
- *Dsb (Warm-summer mediterranean continental)*
- *Dsa (Hot-summer mediterranean continental)*
- *Cfc (Subpolar oceanic)*
- *Cfb (Oceanic)*
- *Cfa (Humid subtropical)*
- *Cwb (Subtropical highland)*
- *Cwa (Humid subtropical)*
- *Csc (Cold-summer mediterranean)*
- *Csb (Warm-summer mediterranean)*
- *Csa (Hot-summer mediterranean)*
- *BSk (Cold semi-arid)*
- *BSh (Hot semi-arid)*
- *BWk (Cold desert)*
- *BWh (Hot desert)*
- *Aw (Savanna)*
- *Am (Monsoon)*
- *Af (Rainforest)*

**Isotherm used to distinguish temperate (C) and continental (D) climates is -3°C*

Data sources: Köppen types calculated from data from PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu; Outline map from US Census Bureau

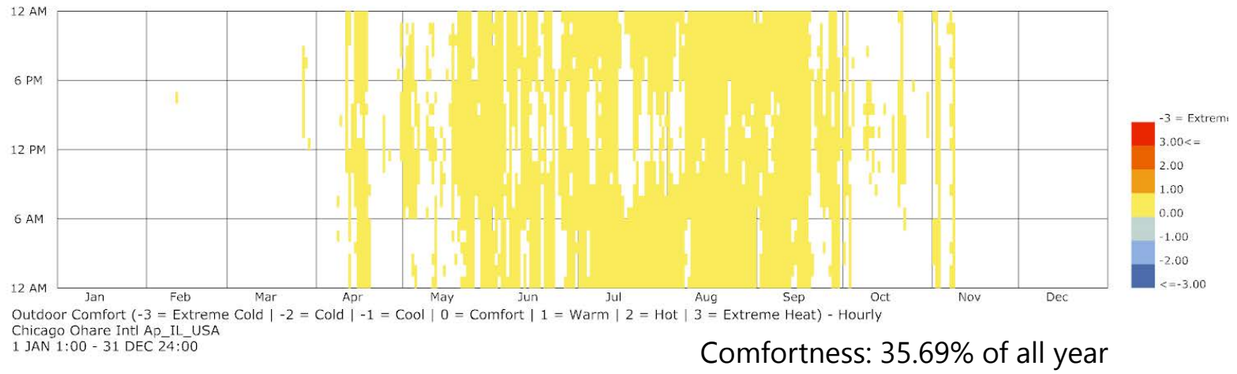
Climate Analysis of Chicago: UTCI

The Universal Thermal Climate Index was set up for all assessments of the outdoor thermal conditions in the major fields of human biometeorology such as public weather service, public health system, precautionary planning, and climate impact research in the health sector. UTCI should become an international standard based on recent scientific progress in human response related thermo-physiological modeling.

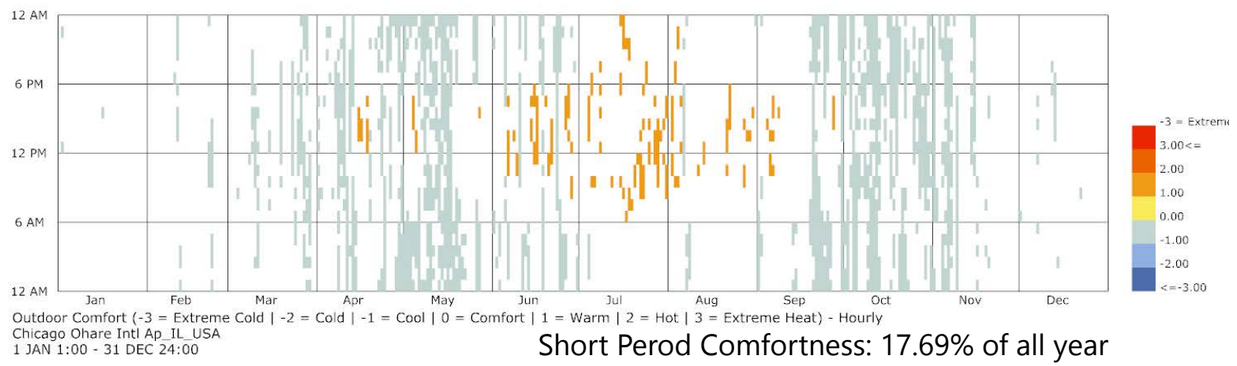
-3 = Extreme Cold | -2 = Cold | -1 = Cool | 0 = Comfort | 1 = Warm | 2 = Hot | 3 = Extreme Hot

From the diagrams on the right, it is obvious that almost all of the uncomfortable time (45.10% of the whole year's period) in a year is caused by cold weather conditions. On the other side, there is only very little uncomfortable time caused by hot weather condition (1.52% of the whole year's period). Most of the comfort time (including short period comfort time) happens summer.

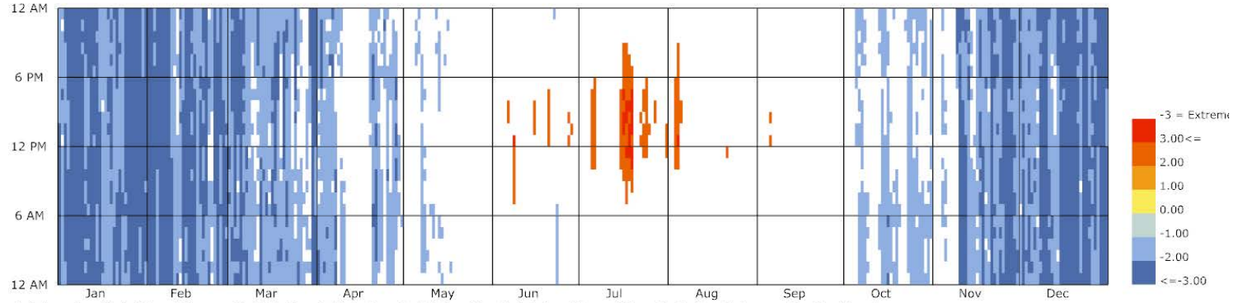
For the building strategy, architect shall put more attention to prevent the cold weather giving the clients of the house bad experience. At the same time, summer is relatively pleasant and there maybe a chance to create the half enclosed space for people to get access to fresh air in summer.



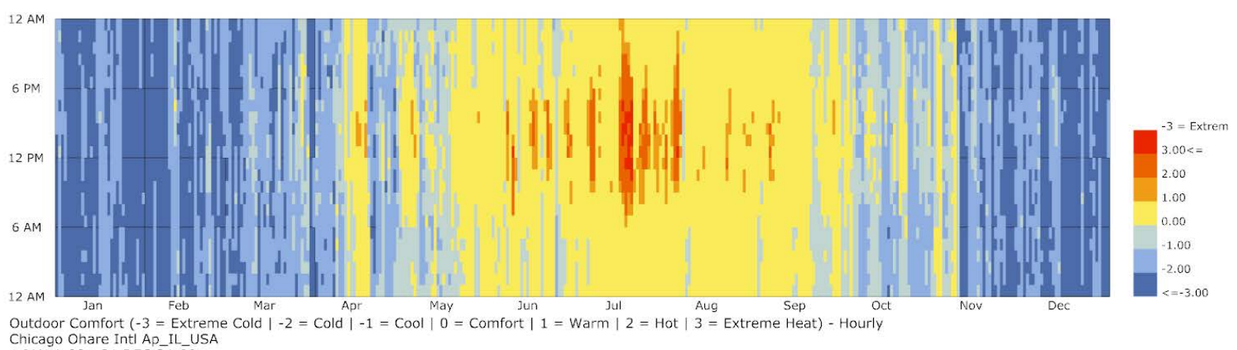
Comfortness: 35.69% of all year



Short Perod Comfortness: 17.69% of all year



Hot Time: 1.52% of all year Cold Time: 45.10% of all

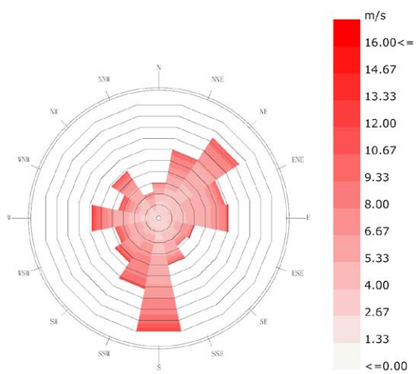


Climate Analysis of Chicago: Wind/Temperature/Humidity

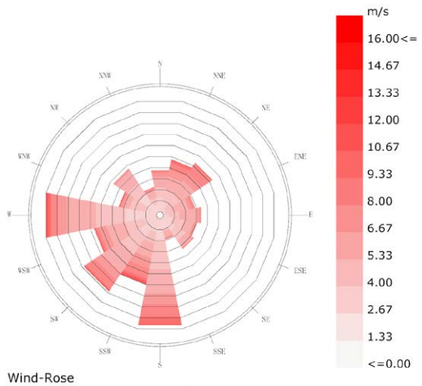
The wind rose diagrams in different seasons show that south and west wind are the main wind for the whole year.
In spring, it seems like most of the wind comes from northeast and south(each more than 10%).
When summer comes, most of the wind comes from the southwest side(including south and west side), taking nearly 50% in total.
Fall and winter show some simularity to have most of their wind coming from west and south. However, it has more wind coming from north west than winter.

During the whole year, noon is always the driest time of the whole day, especially in the spring. And in spring, Relative humidity varies the most in a day. Summer is the most humid season in the whole year. Fall and Winter share some similarities that extreme relative humidity will not appear a lot in most of the days.

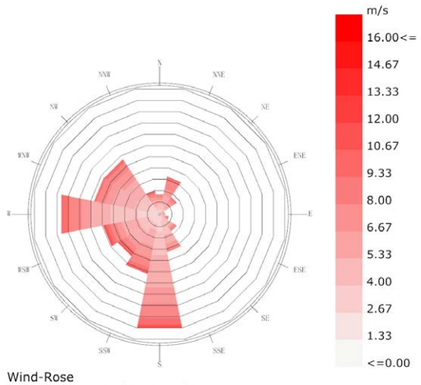
From the diagram, we can know that Chicago has different climates in different seasons. Winter can be very freezing and it has a lot of time to be under freezing point. In summer most of the time it is very hot to be over 20 degrees. Spring and fall share some commons but during the fall time, it is warmer than the spring.



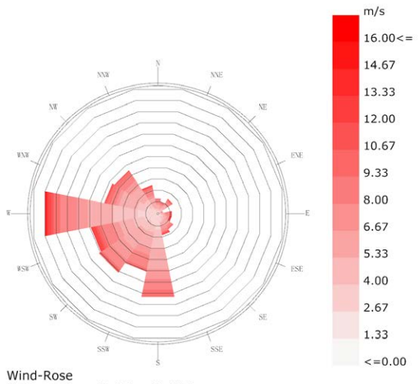
Wind-Rose
Chicago Ohare Intl Ap_IL_USA
21 MAR 1:00 - 22 JUN 24:00
Hourly Data: Wind Speed (m/s)
Calm for 3.72% of the time = 84 hours.
Each closed polyline shows frequency of 1.2%. = 26 hours.



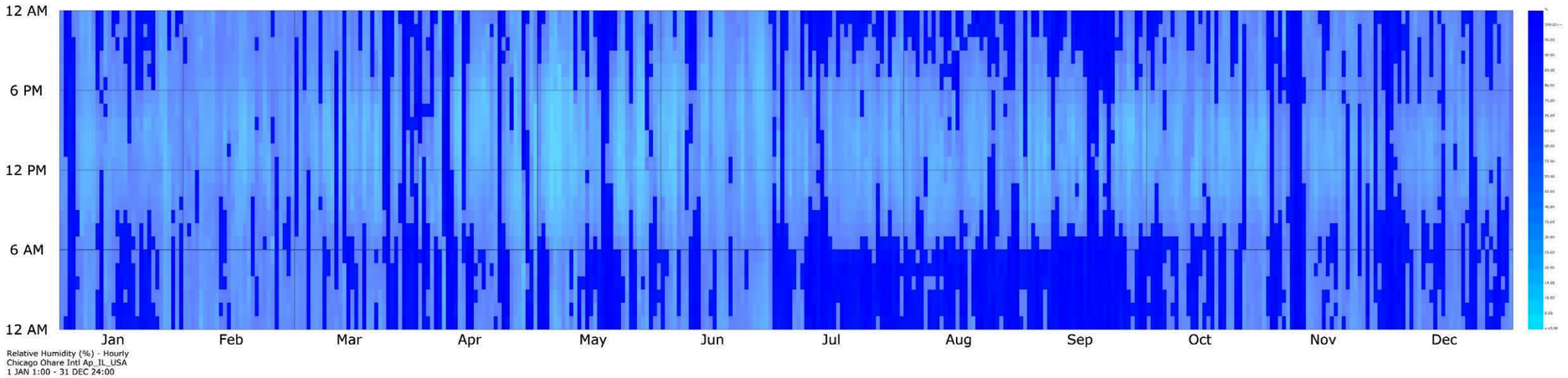
Wind-Rose
Chicago Ohare Intl Ap_IL_USA
21 JUN 1:00 - 21 SEP 24:00
Hourly Data: Wind Speed (m/s)
Calm for 5.73% of the time = 128 hours.
Each closed polyline shows frequency of 1.2%. = 26 hours.



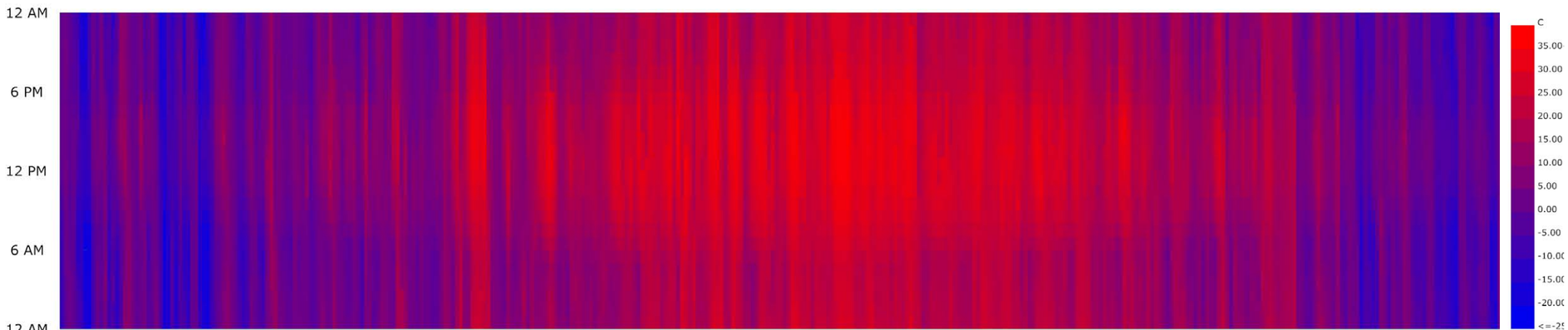
Wind-Rose
Chicago Ohare Intl Ap_IL_USA
21 SEP 1:00 - 21 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.22% of the time = 49 hours.
Each closed polyline shows frequency of 1.6%. = 35 hours.



Wind-Rose
Chicago Ohare Intl Ap_IL_USA
21 DEC 1:00 - 21 MAR 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.20% of the time = 48 hours.
Each closed polyline shows frequency of 1.7%. = 36 hours.



Relative Humidity (%) - Hourly
Chicago Ohare Intl Ap_IL_USA
1 JAN 1:00 - 31 DEC 24:00

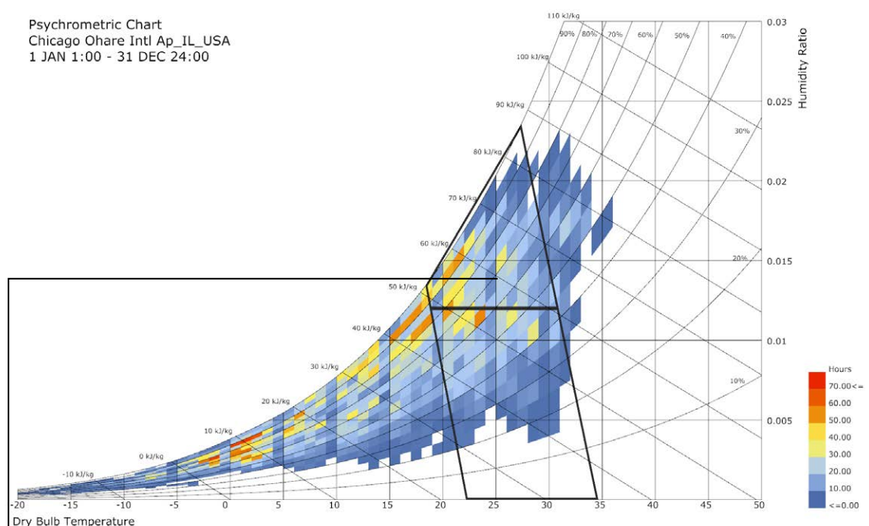


Dry Bulb Temperature (C) - Hourly
Chicago Ohare Intl Ap_IL_USA

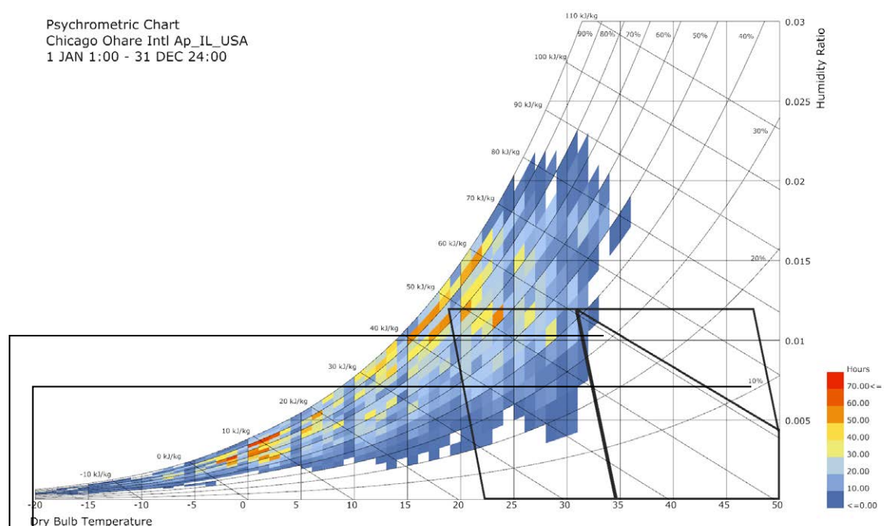
PMV

The PMV/PPD model was developed by P. O. Fanger using heat balance equations and empirical studies about skin temperature to define comfort.

From the diagrams on the right, we can know that only 12.14% of comfort time exists in the whole year without any passive strategy. Among all of the passive strategies, Dehumidification and Internal Heat Gain are the most effective strategies which would increase the comfort time by 12.44% and 17.41% respectively. As a result, I will suggest that buildings which have limited exchange with the exterior should employ Dehumidification and Internal Heat Gain.

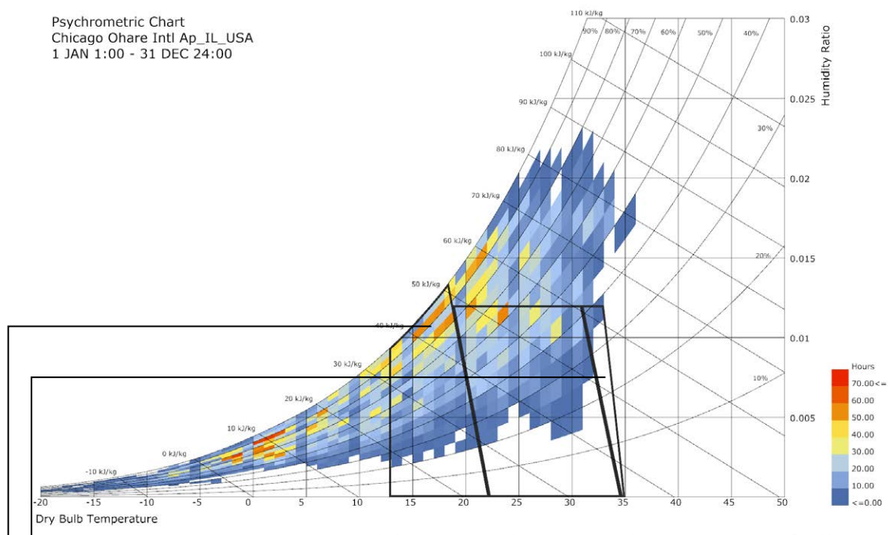


Extra Percentage with Dehumidification Only: 12.44% of all year



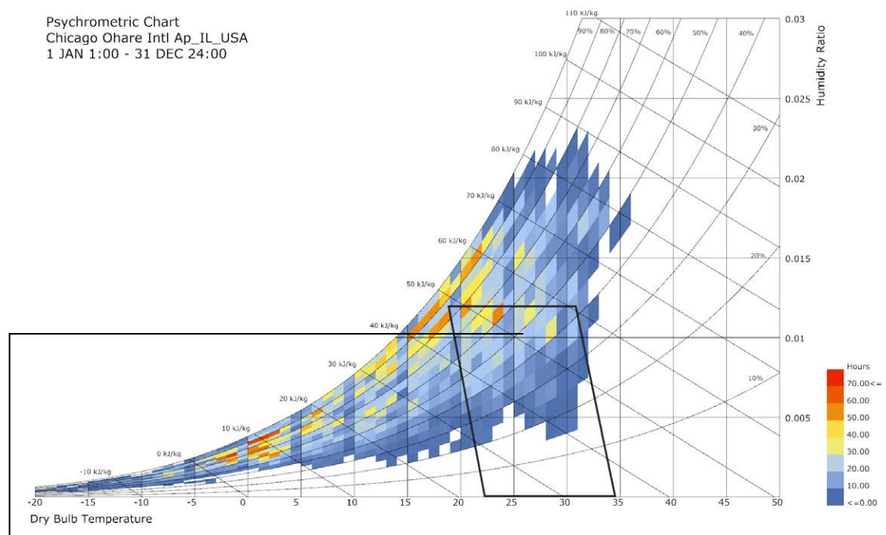
Extra Percentage with Evapourative Cooling: 0.08% of all year

Extra Percentage with Thermal Mass+Night Vent: 0.08% of all year



Extra Percentage with Internal Heat Gain: 17.41% of all year

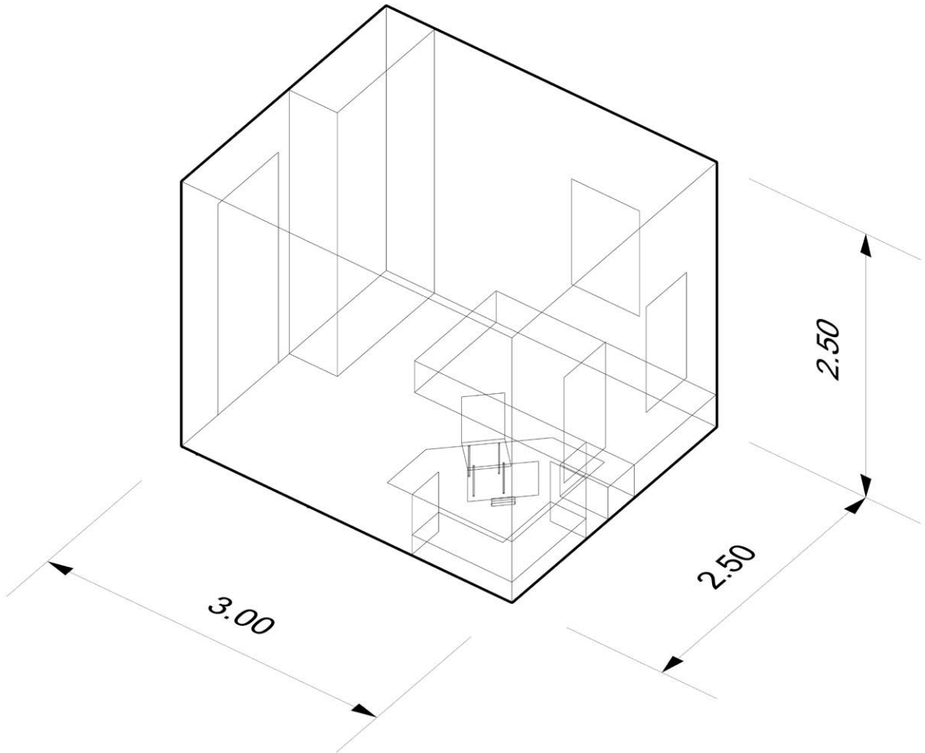
Extra Percentage with Occupant Use of Fans: 0.08% of all year

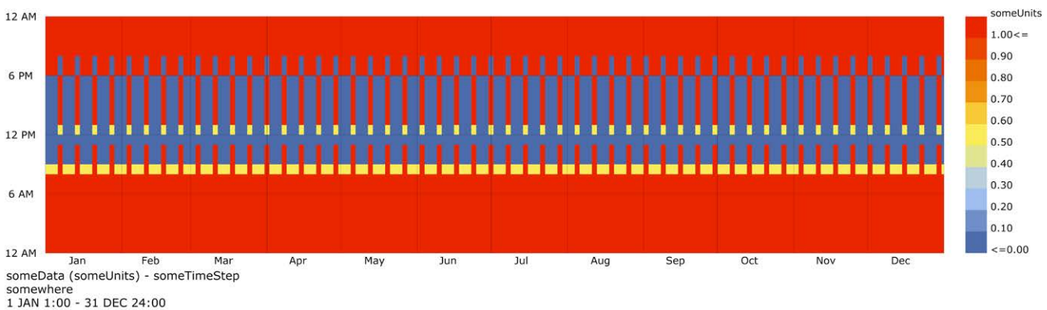


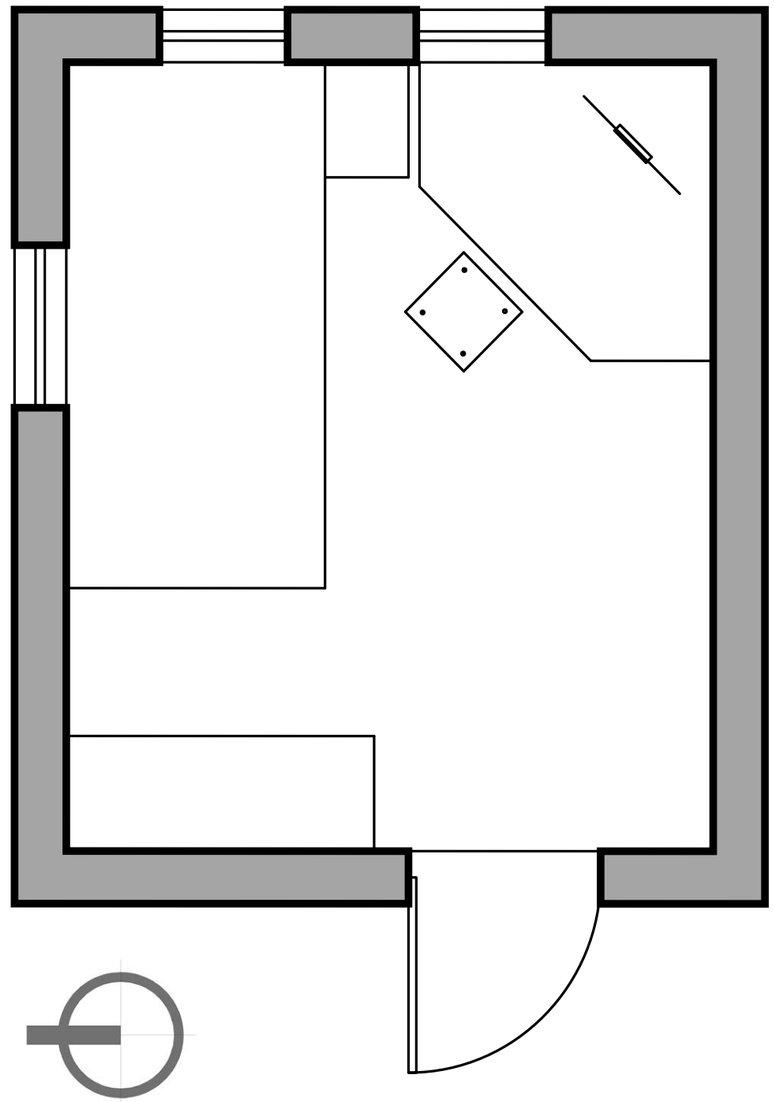
Comfort Percentage without any passive stratagy: 12.12% of all year

Testroom:

The Drawings on the left are the basic information of the test room. The Schedule is defined as a residential schedule to have Mon.-Fri. as work days with the occupation from 6:30p.m. to 8:30 a.m. and Sat.-Sun. as weekends with the 12a.m.-11:30a.m., 12:30-12a.m. occupation.



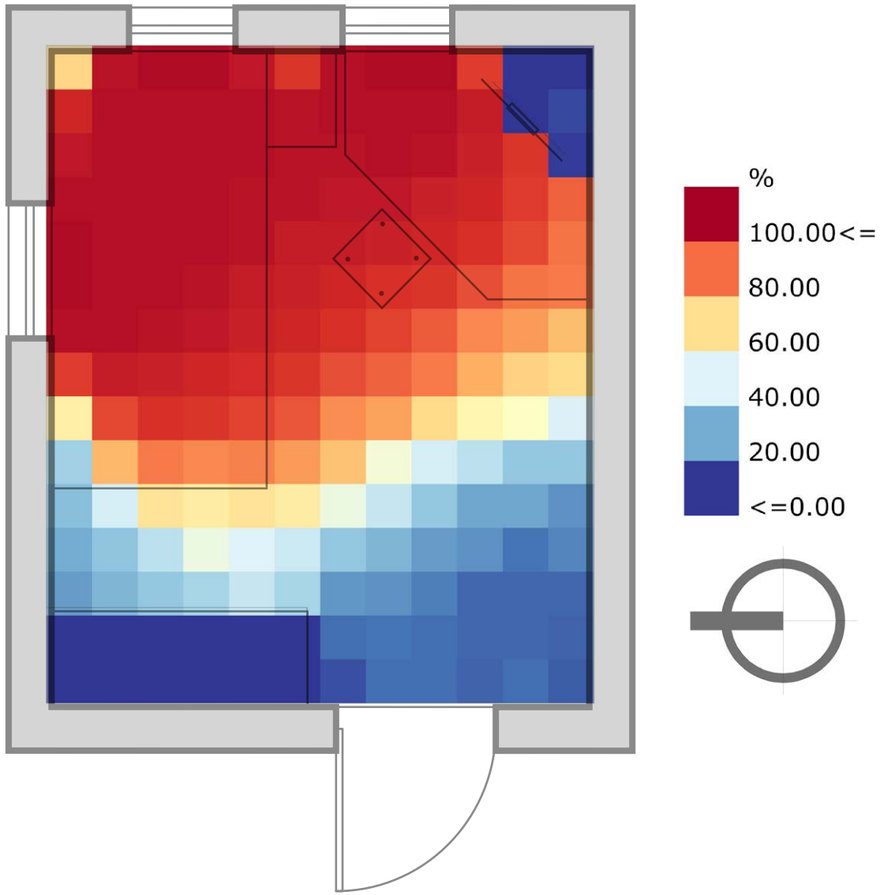




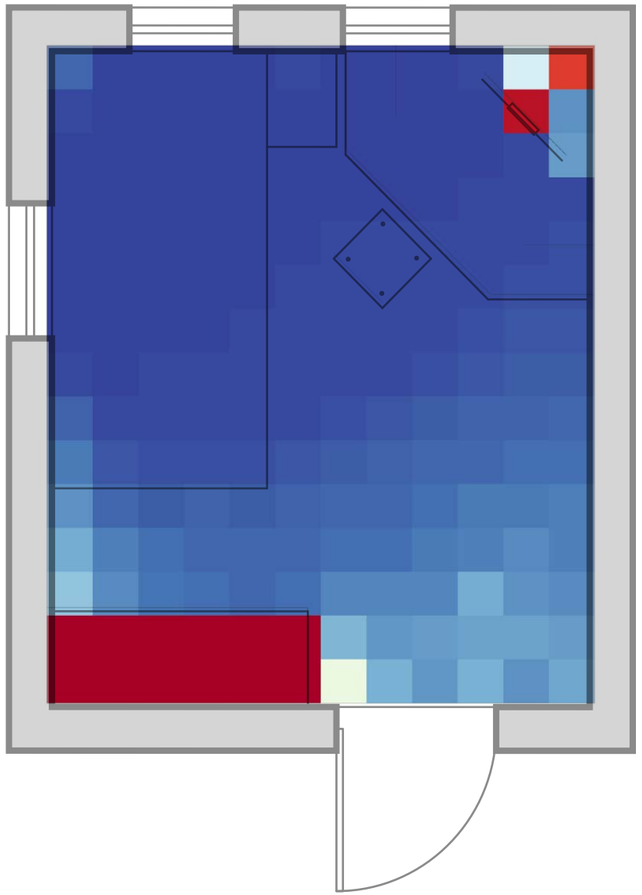
Daylight Base Analysis:

The DLA and UDLI diagrams show that the daylight in the main area where the resident in this room always occupies is good for people (100<UDLI<2000) for almost 60% of the year. The west side of the room is always in the dark because of the depth of the room. The highlight part in the right diagram show that there is potential area for glare issue.

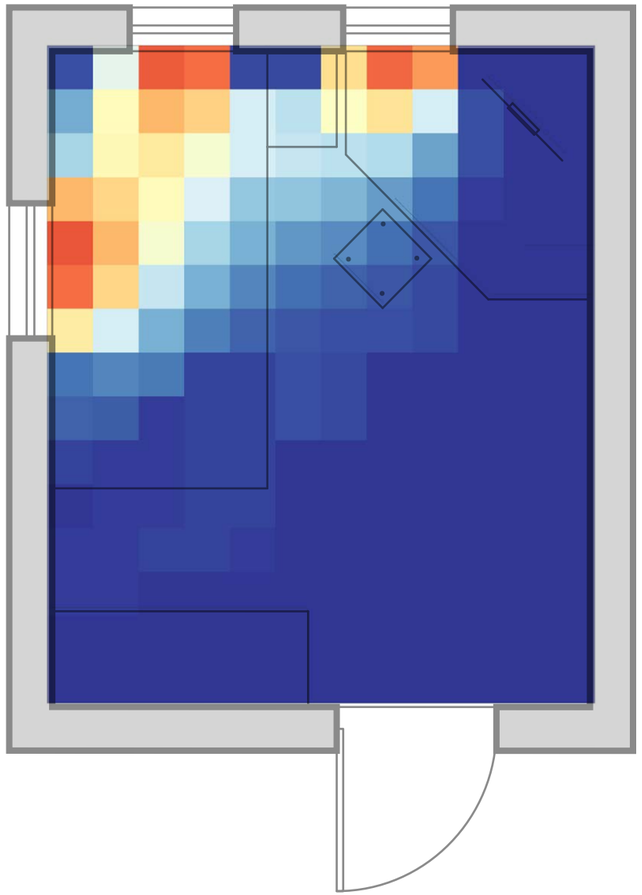
DLA Result
sDA=61.67%



UDLI<100

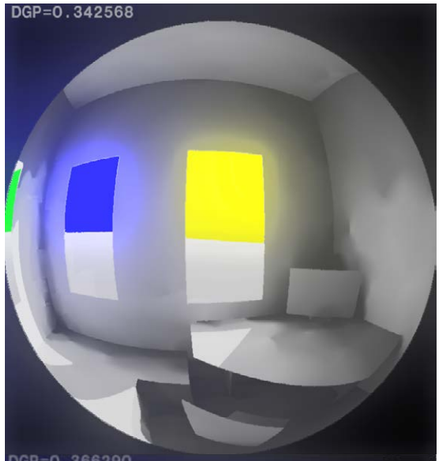
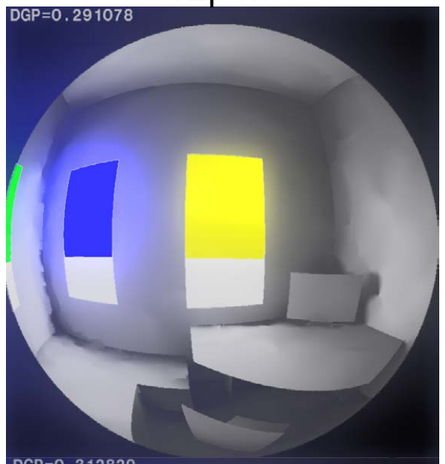
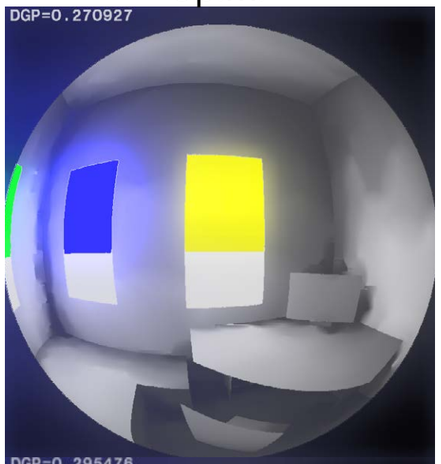
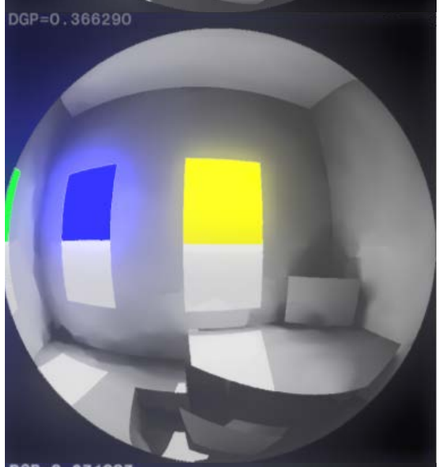
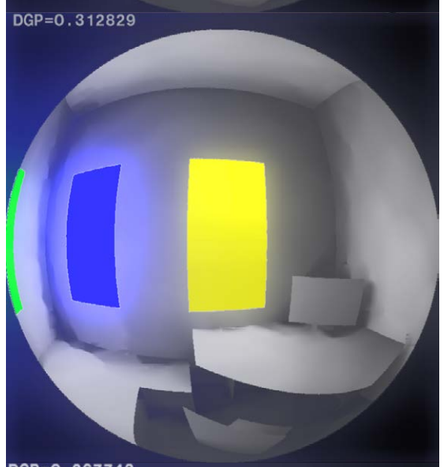
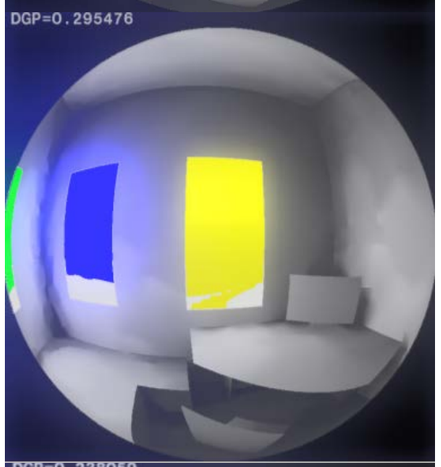
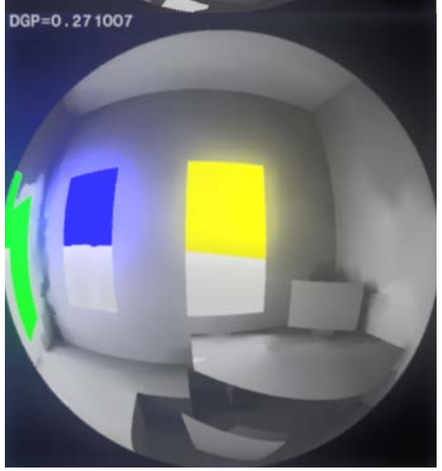
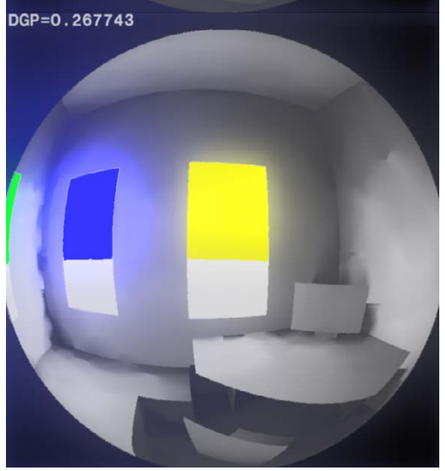
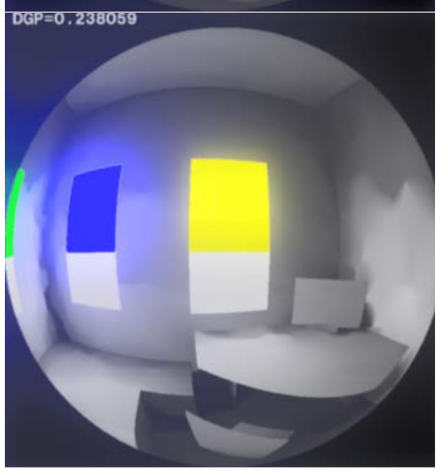


UDLI>2000



Daylight Base Analysis:

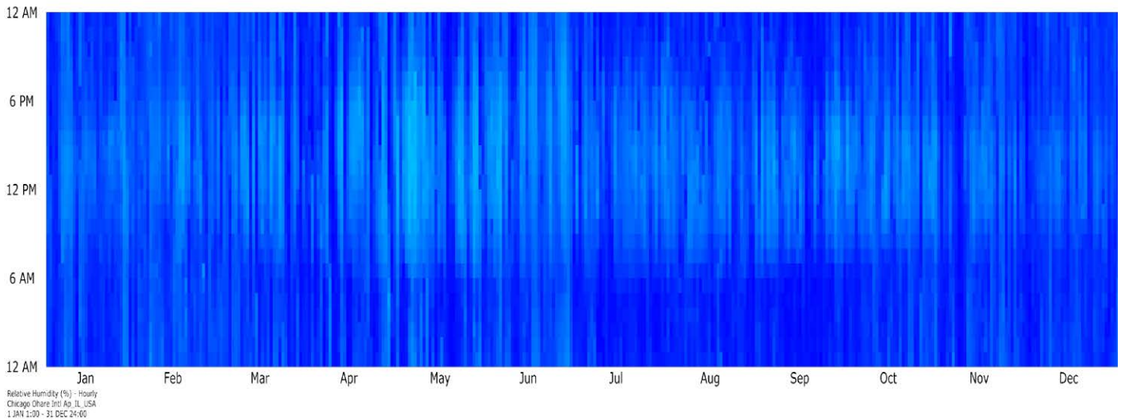
Only the 9a.m. March, 21st 9a.m. June 21st diagram show that there is glare issue at that time. The vertical shedding system may help to solve this problem.

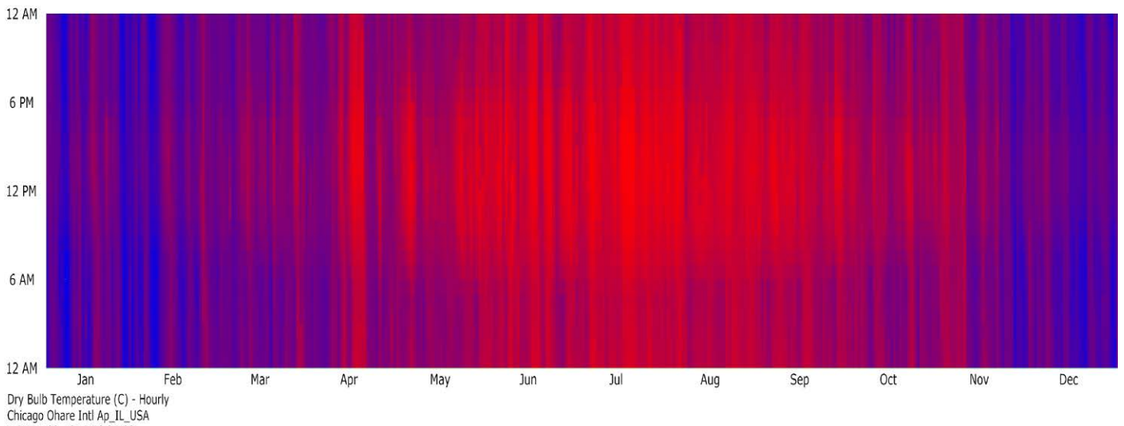
	9a.m.	12p.m.	3p.m.
March 21st			
June 21st			
December21st			

Indoor Temp&Humidity

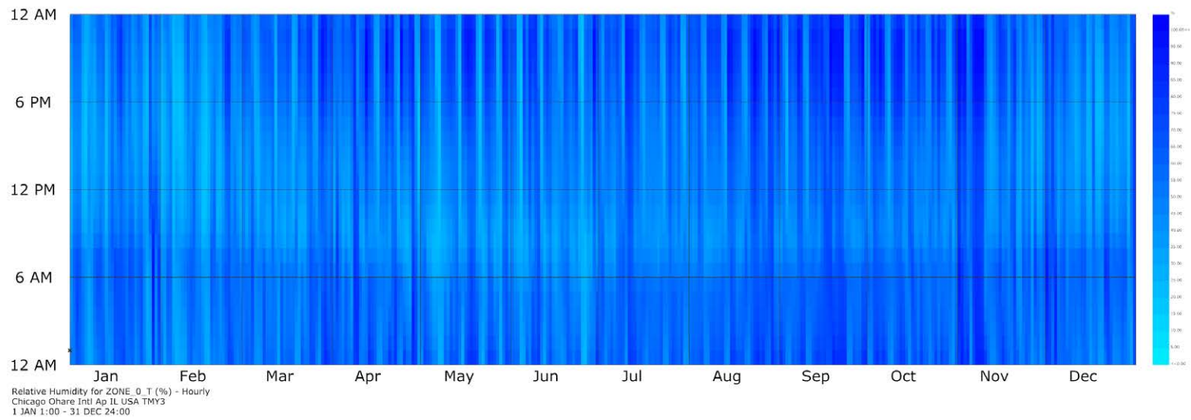
There are extreme temperature in the interior environment, extreme hot in the summer noon and afternoon and extreme cold at night in the winter.

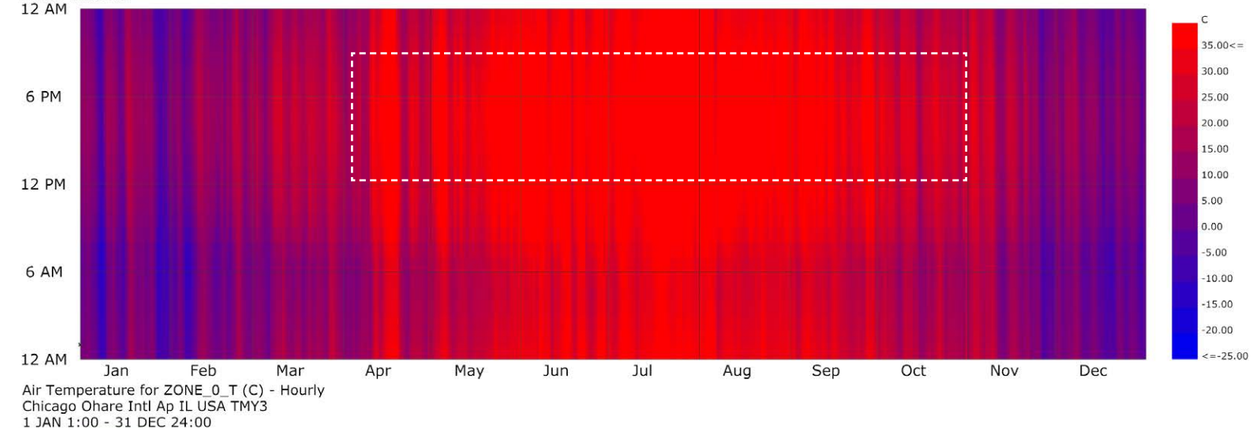
Exterior



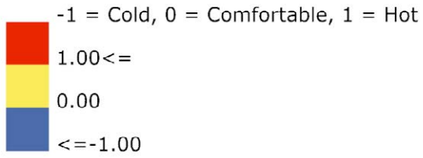


Interior

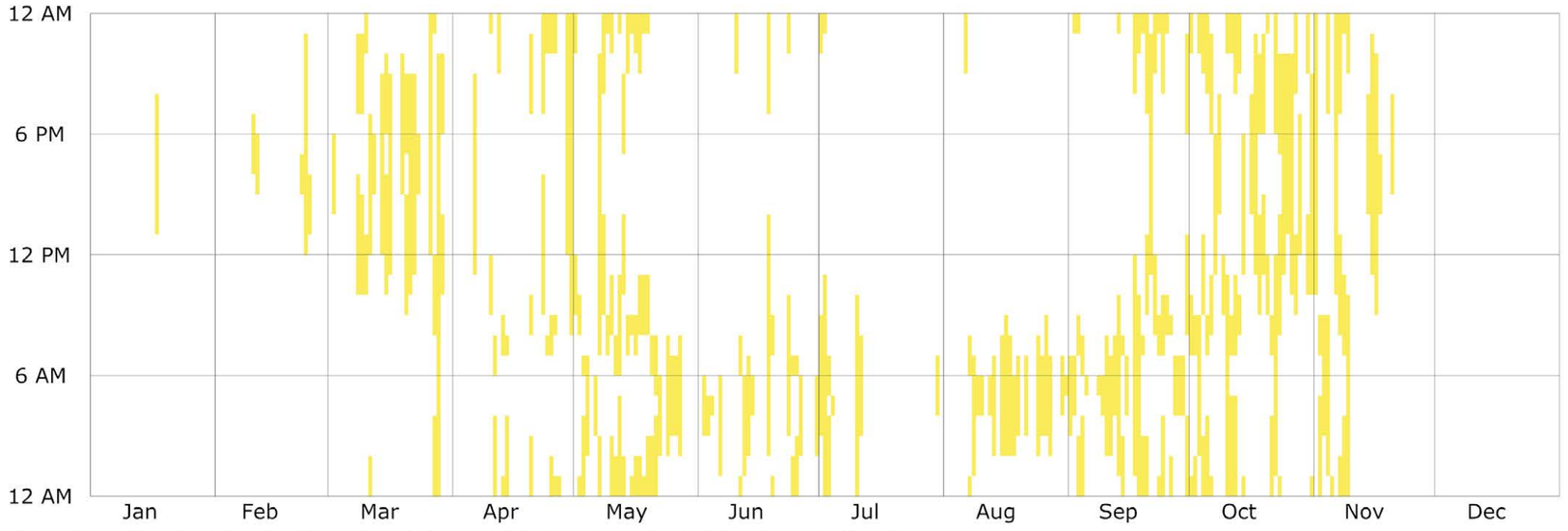




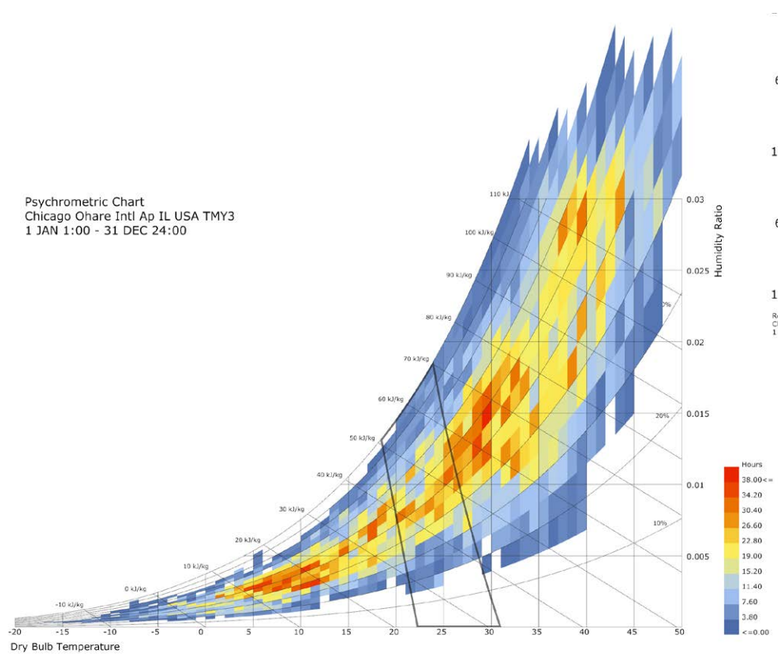
Indoor Comfort

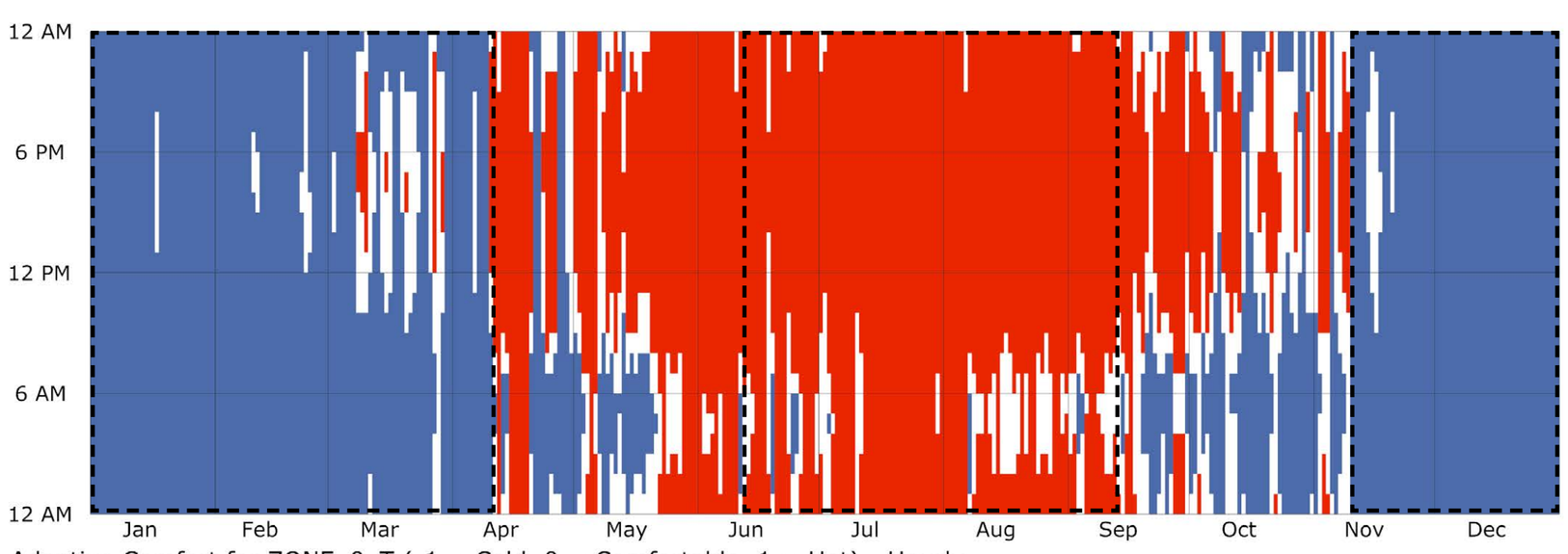


Base test for interior comfort. There are extreme temperature in the interior environment, extreme hot in the summer noon and afternoon and extreme cold at night in the winter.



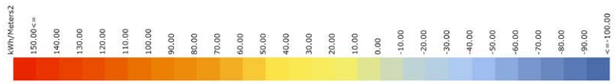
Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Chicago Ohare Intl Ap IL USA TMY3
1 JAN 1:00 - 31 DEC 24:00



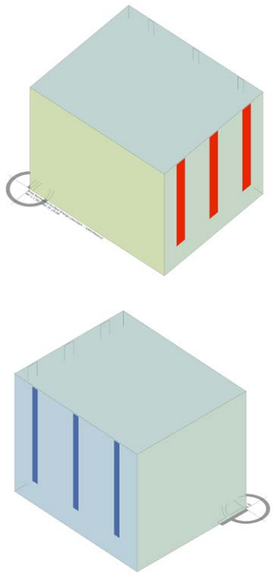


Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Chicago Ohare Intl Ap IL USA TMY3
1 JAN 1:00 - 31 DEC 24:00

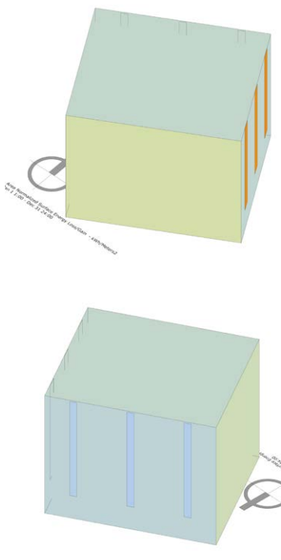
Orientation



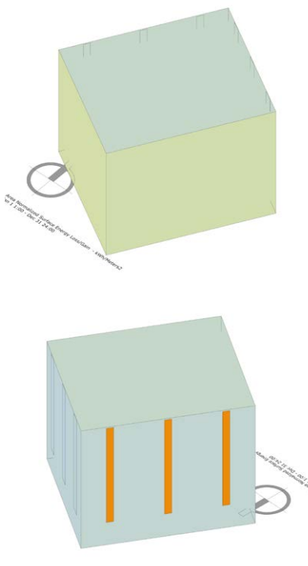
Rotation：0°
Comfortness：13.46%



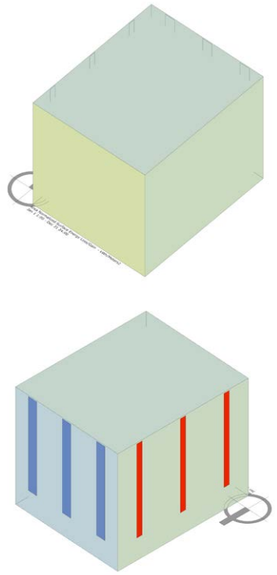
Rotation：30°
Comfortness：13.3%



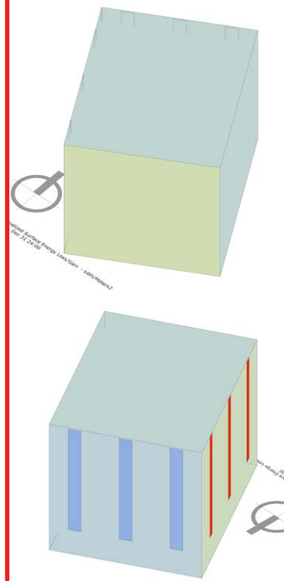
Rotation：60°
Comfortness：13.5%



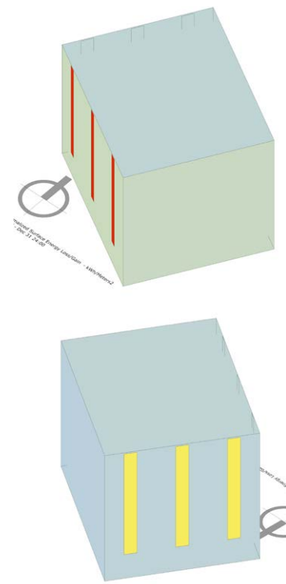
Rotation：90°
Comfortness：14.0%



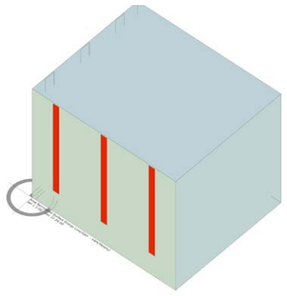
Rotation：120°
Comfortness：13.9%



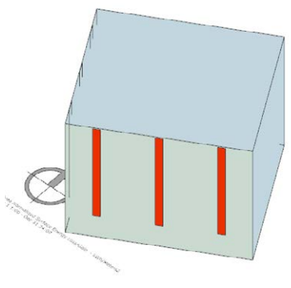
Rotation：150°
Comfortness：13.7%



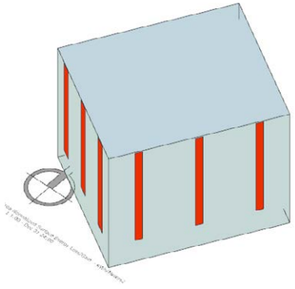
Rotation：180°
Comfortness：13.6%



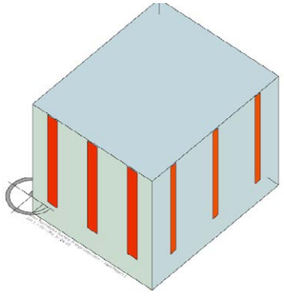
Rotation：210°
Comfortness：12.9%



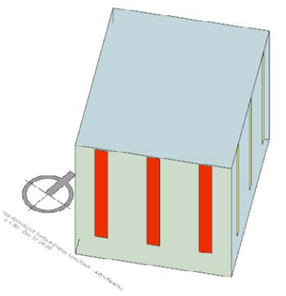
Rotation：240°
Comfortness：13.0%



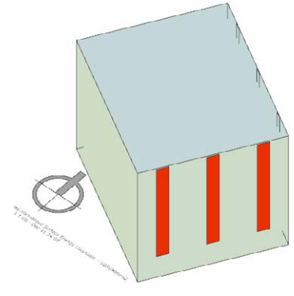
Rotation：270°
Comfortness：13.0%



Rotation：300°
Comfortness：12.8%

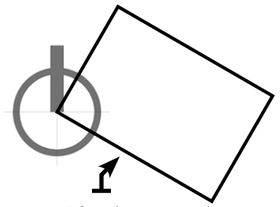


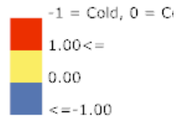
Rotation：330°
Comfortness：13.1%



South Glazing

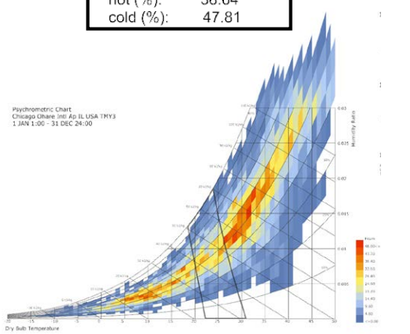
Rotation: 150 degree (has a better angle facing south than 120)
10 iteration for south facade glazing ratio with the other facades 0 glazing
Original Exterior Wall R-value=15 Original Exterior Roof R-value=15

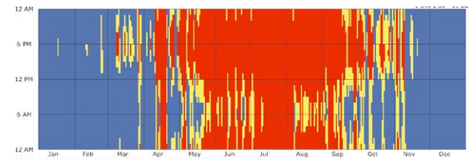




0

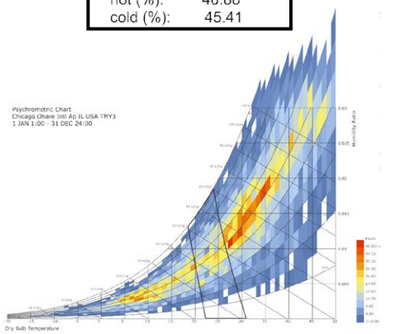
Comfortable (%): 13.55
hot (%): 38.64
cold (%): 47.81

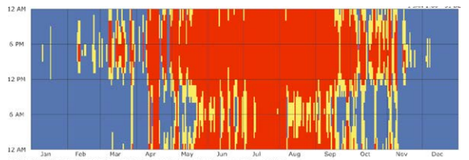




0.1

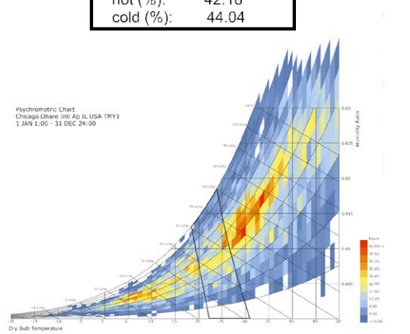
Comfortable (%): 13.71
hot (%): 40.88
cold (%): 45.41

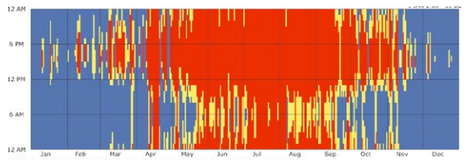




0.2

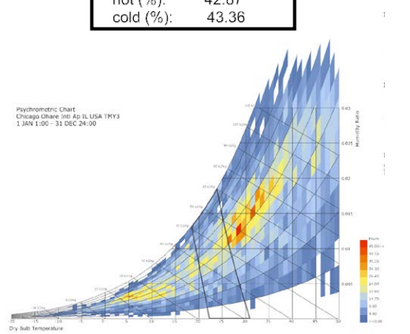
Comfortable (%): 13.78
hot (%): 42.18
cold (%): 44.04

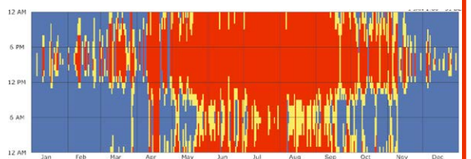




0.3

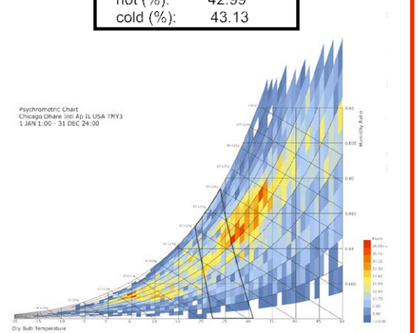
Comfortable (%): 13.78
hot (%): 42.87
cold (%): 43.36



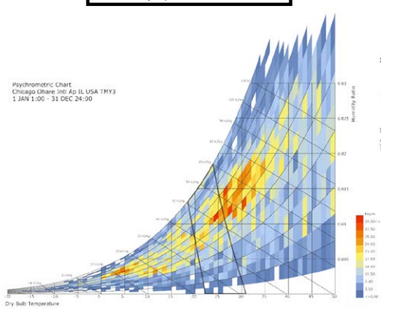


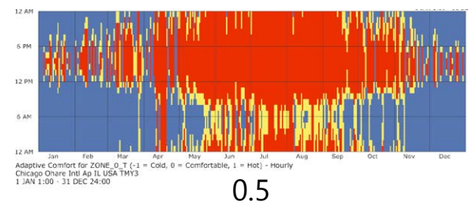
0.4

Comfortable (%): 13.88
hot (%): 42.99
cold (%): 43.13



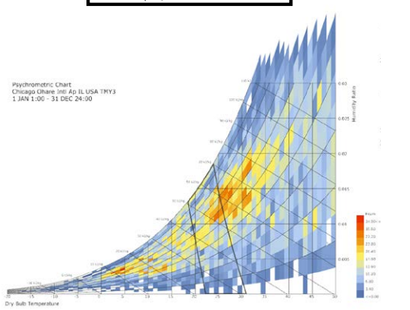
Comfortable (%): 13.8
hot (%): 42.89
cold (%): 43.31

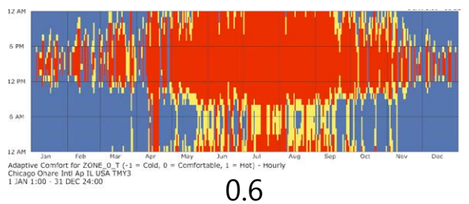




0.5

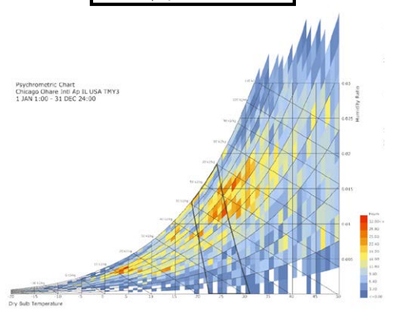
Comfortable (%): 13.79
hot (%): 42.53
cold (%): 43.68

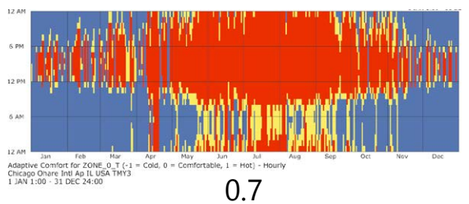




0.6

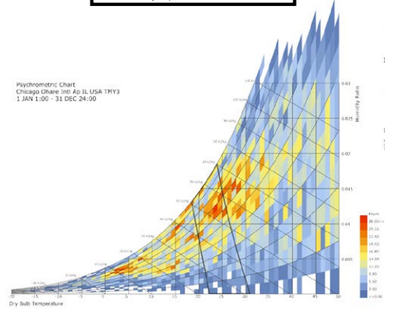
Comfortable (%): 13.7
hot (%): 42.07
cold (%): 44.24

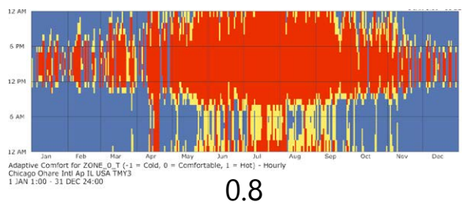




0.7

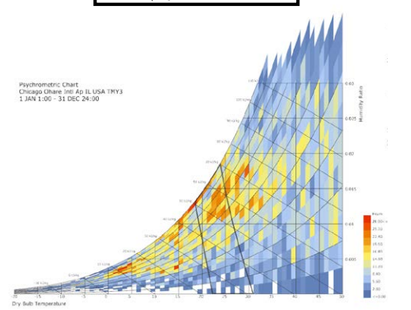
Comfortable (%): 13.5
hot (%): 41.6
cold (%): 44.9

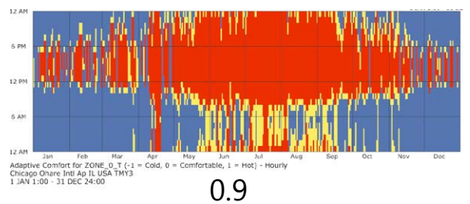




0.8

Comfortable (%): 13.33
hot (%): 40.99
cold (%): 45.67

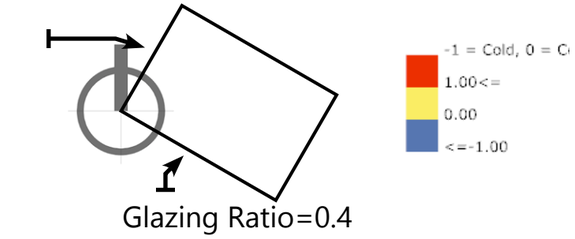




0.9

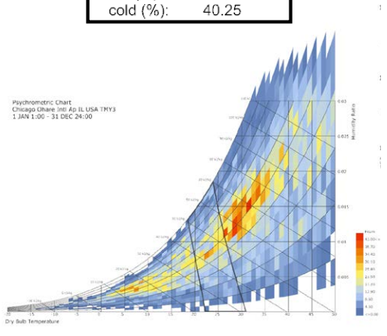
West Glazing

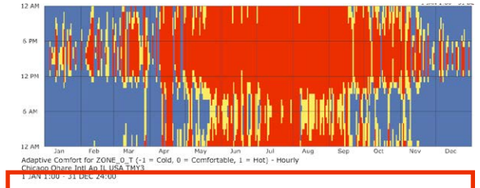
Rotation: 150 degree
10 iteration for west facade glazing ratio with the north and east facades 0 glazing



0

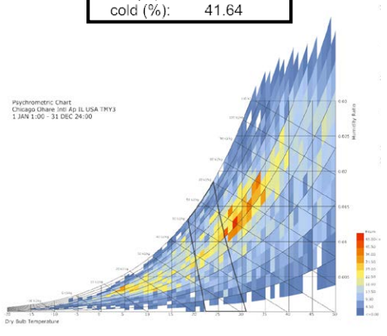
Comfortable (%): 13.82
hot (%): 45.92
cold (%): 40.25

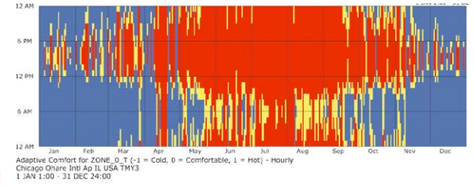




0.1

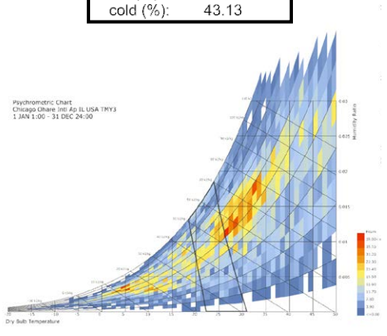
Comfortable (%): 13.81
hot (%): 44.54
cold (%): 41.64

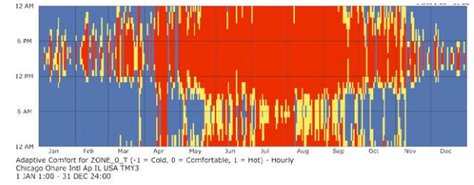




0.2

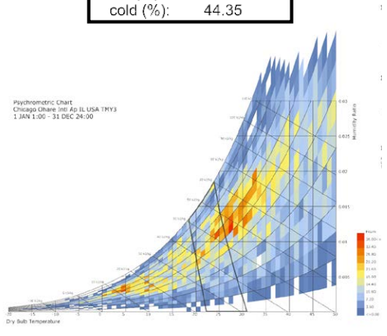
Comfortable (%): 13.88
hot (%): 42.99
cold (%): 43.13

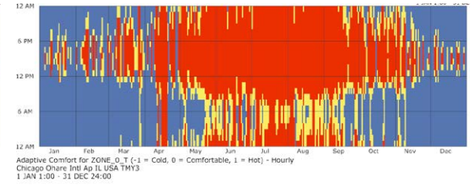




0.3

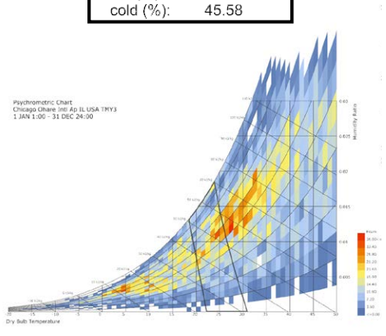
Comfortable (%): 13.97
hot (%): 41.68
cold (%): 44.35

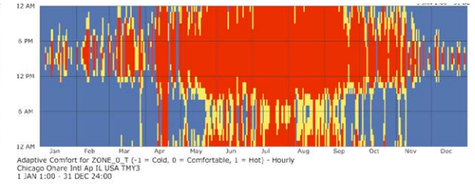




0.4

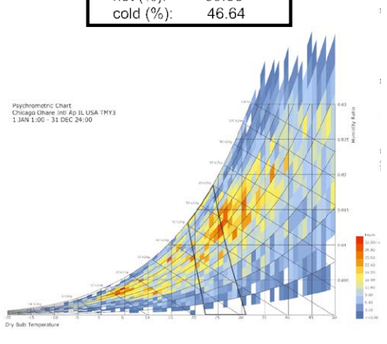
Comfortable (%): 13.87
hot (%): 40.55
cold (%): 45.58

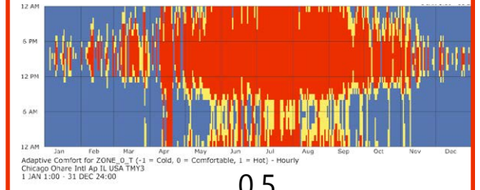




0.5

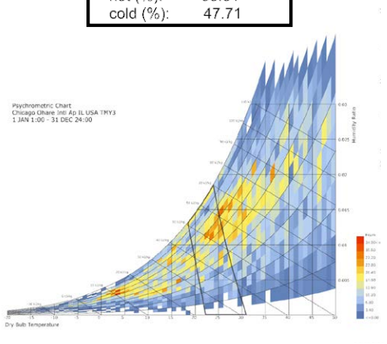
Comfortable (%): 14.0
hot (%): 39.36
cold (%): 46.64

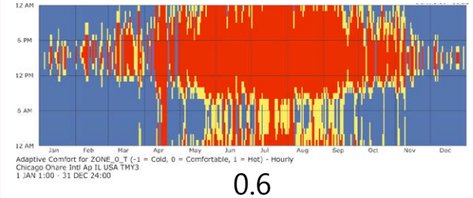




0.6

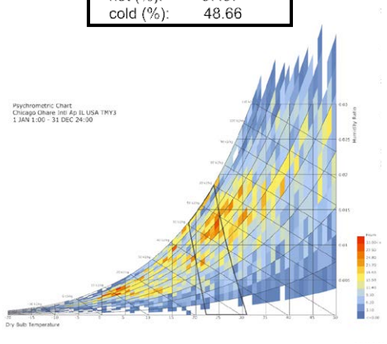
Comfortable (%): 13.98
hot (%): 38.31
cold (%): 47.71

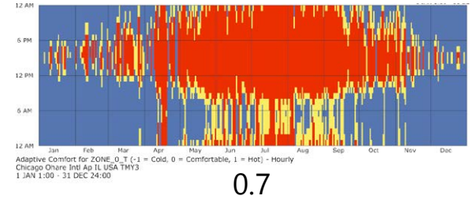




0.7

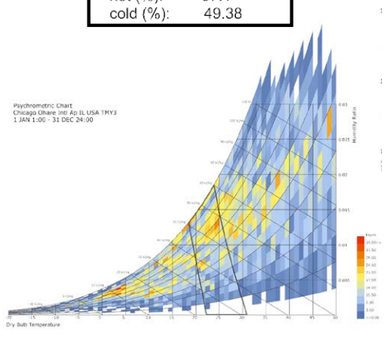
Comfortable (%): 13.77
hot (%): 37.57
cold (%): 48.66

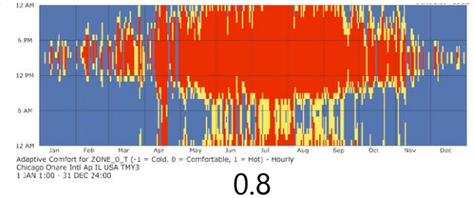




0.8

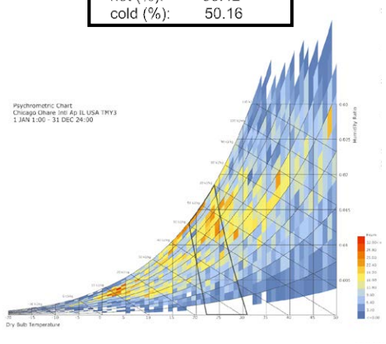
Comfortable (%): 13.52
hot (%): 37.1
cold (%): 49.38

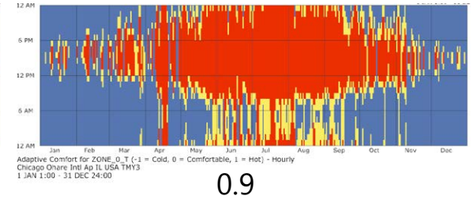




0.9

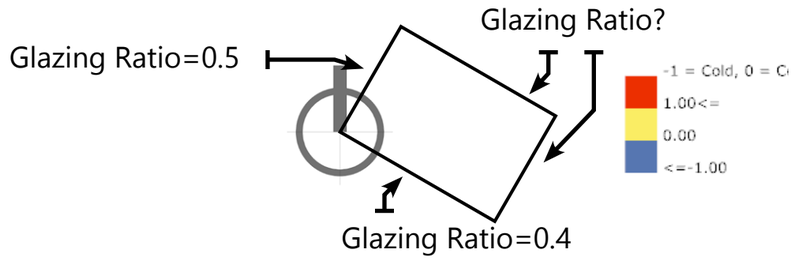
Comfortable (%): 13.42
hot (%): 36.42
cold (%): 50.16





North&East Glazing

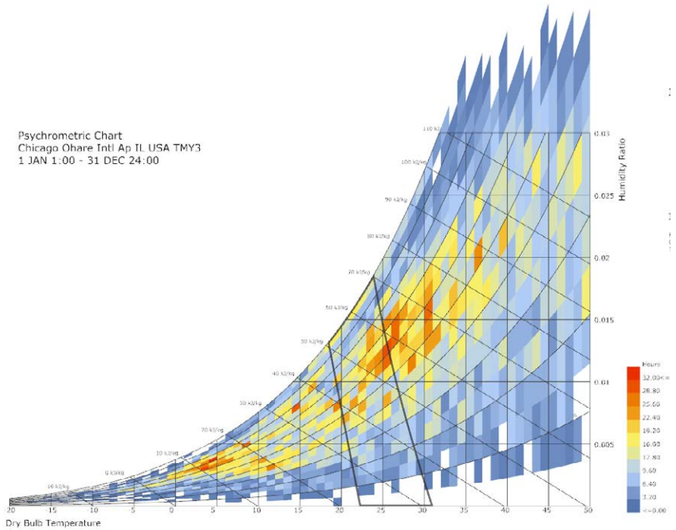
Rotation: 150 degree
The comfortness decreases when the glazing ratio on these 2 facades increases. The best result is no openings on these 2 facades.



	0	0.2	0.4	0.6	0.8
East	Comfortable (%): 14.0 hot (%): 39.36 cold (%): 46.64	Comfortable (%): 13.56 hot (%): 39.63 cold (%): 46.8	Comfortable (%): 13.17 hot (%): 39.39 cold (%): 47.43	Comfortable (%): 12.71 hot (%): 39.13 cold (%): 48.16	Comfortable (%): 12.49 hot (%): 38.49 cold (%): 49.02
North	Comfortable (%): 14.0 hot (%): 39.36 cold (%): 46.64	Comfortable (%): 13.65 hot (%): 37.04 cold (%): 49.3	Comfortable (%): 13.31 hot (%): 35.07 cold (%): 51.62	Comfortable (%): 13.0 hot (%): 33.47 cold (%): 53.53	Comfortable (%): 12.33 hot (%): 32.24 cold (%): 55.43

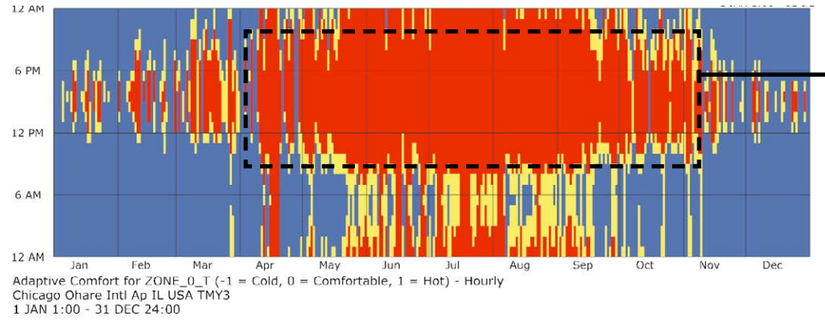
Ventilation

Comfortable (%): 14.0
hot (%): 39.36
cold (%): 46.64

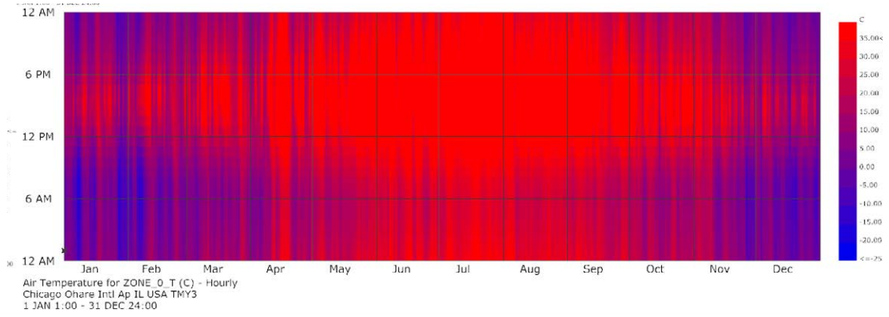


Best Result From Glazing and Orientation Test

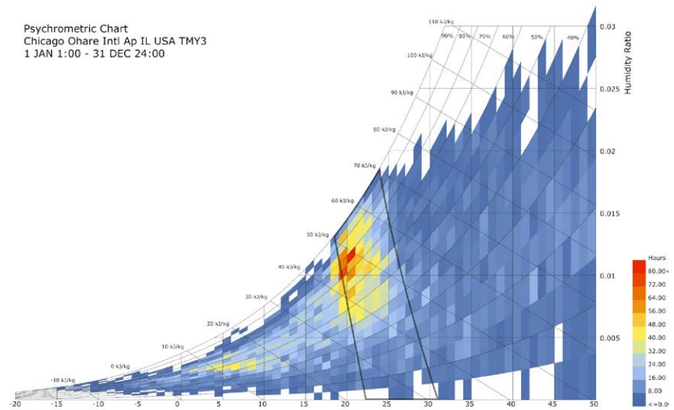
Average Interior Temperature: 17.53°



Hot Condition Tageted Problem

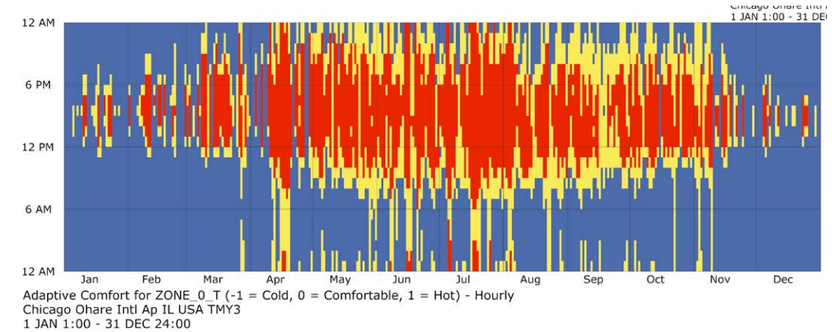


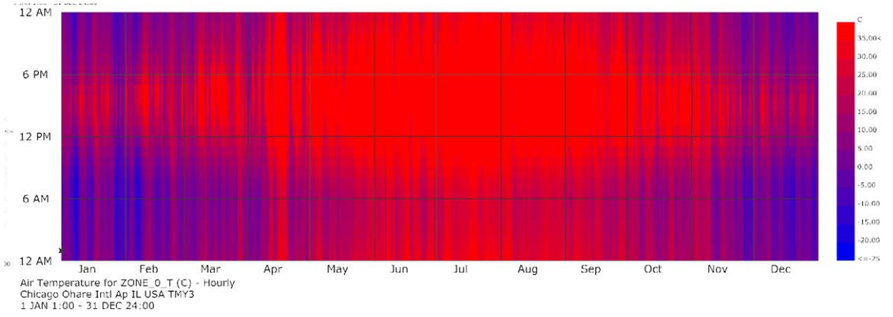
Comfortable (%): 19.93
hot (%): 23.72
cold (%): 56.35



Natrual Ventilation when exterior temperrature is among 18-25° to help improve the hot condition in the afternoon with fewest hot condotion 23.72%

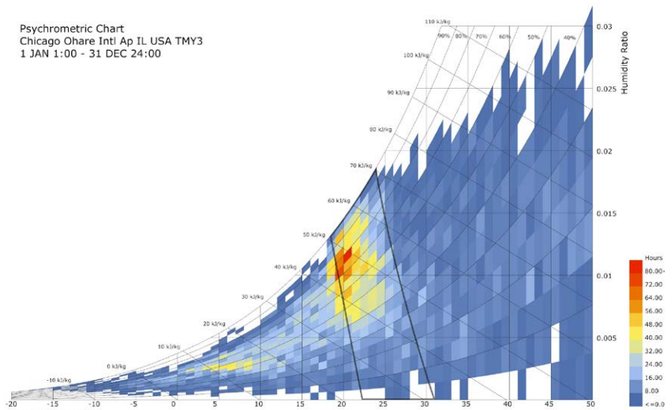
Average Interior Temperature: 18.34°





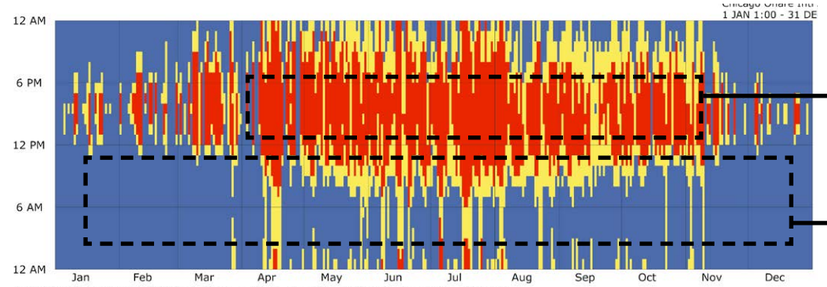
Thermal Mass

Comfortable (%): 19.93
hot (%): 23.72
cold (%): 56.35



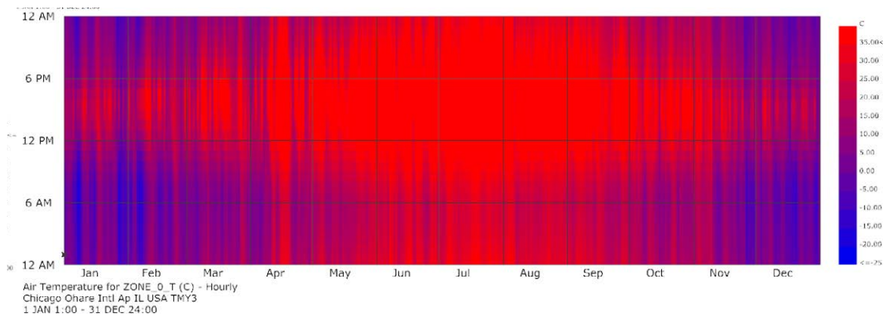
Natrual Ventilation
Result with fewest hot condotion 23.72%

Average Interior Temperature: 18.34°

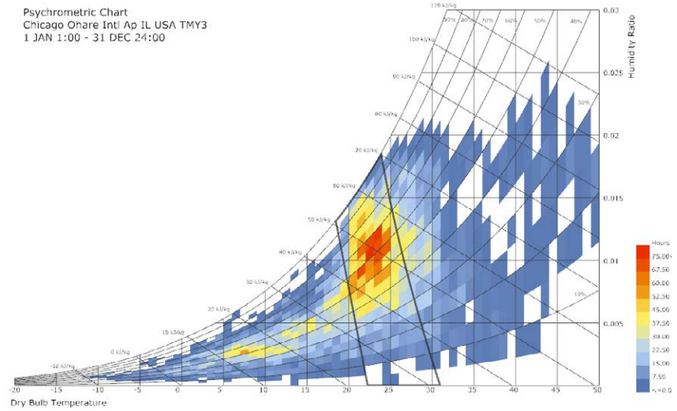


Hot Condition Tageted Problem

Cold Condition Tageted Problem

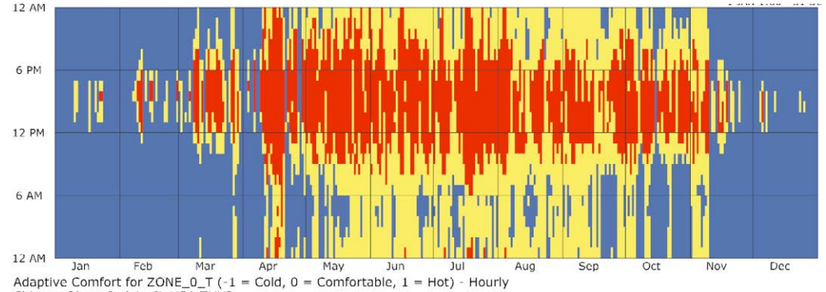


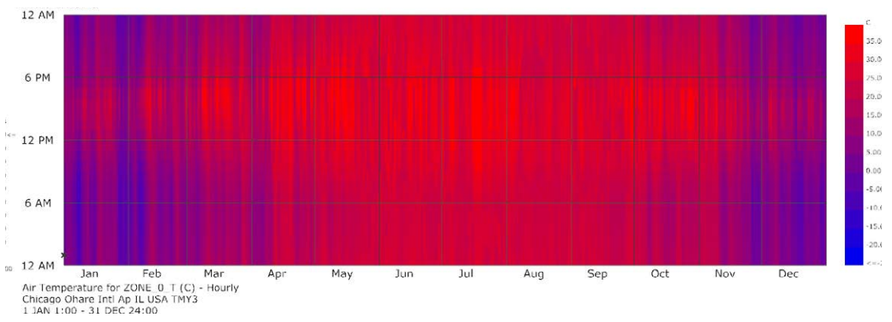
Comfortable (%): 31.42
hot (%): 21.94
cold (%): 46.64



Thermal Mass +8inchs
R-value from 14.3-34.5
readjust the ventilation condition to have exterior temperrature among 19-30° to help improve the hot condition in the afternoon.

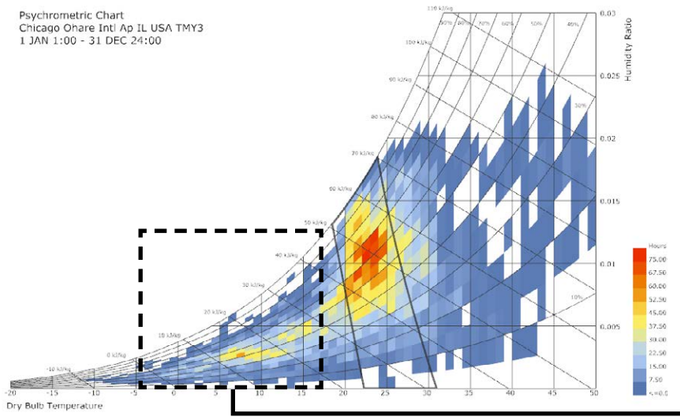
Average Interior Temperature: 18.78°





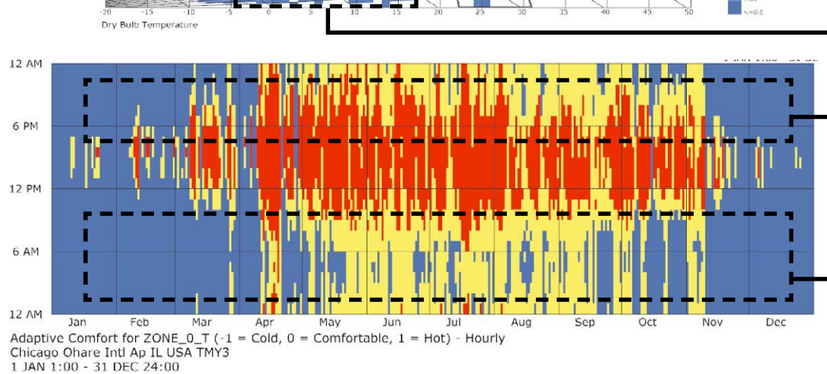
Low E Window

Comfortable (%): 31.42
hot (%): 21.94
cold (%): 46.64



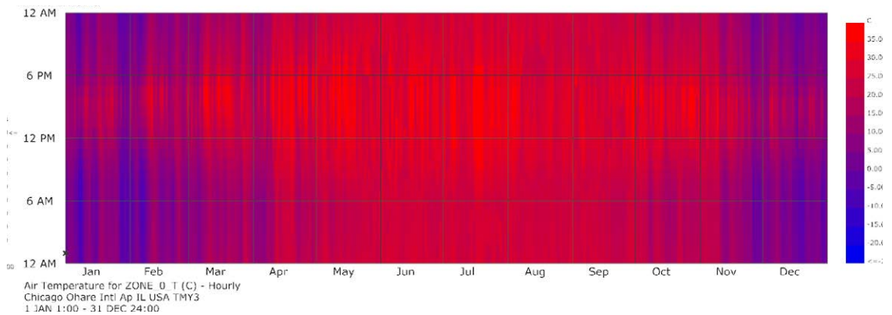
Thermal Mass +8inchs
R-value from 14.3-34.5
ventilation condition: exterior temperature among 19-30° to help improve the hot condition in the afternoon.

Average Interior Temperature: 18.78°

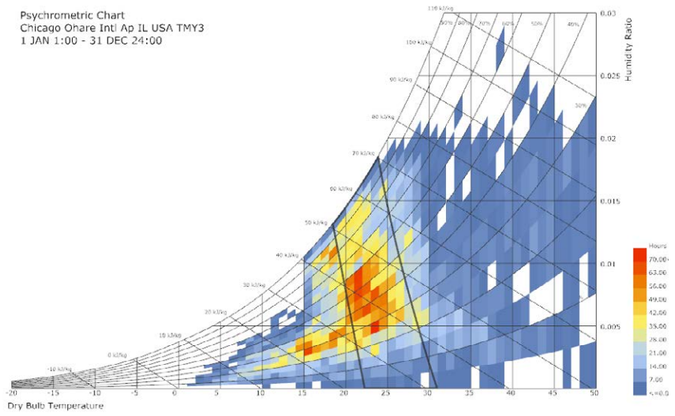


Cold Condition Tageted Problem

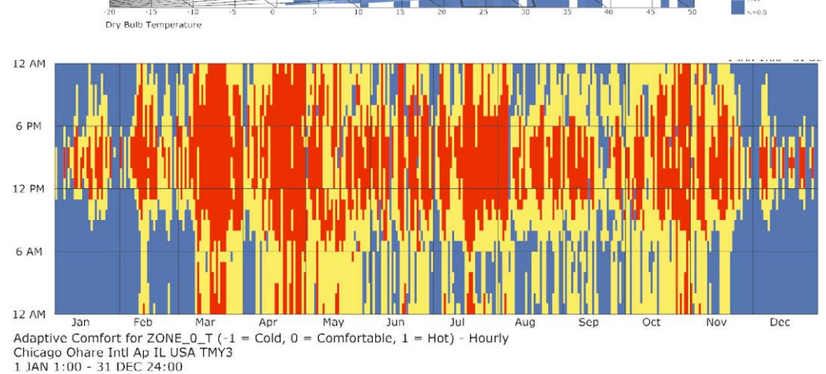
Cold Condition Tageted Problem

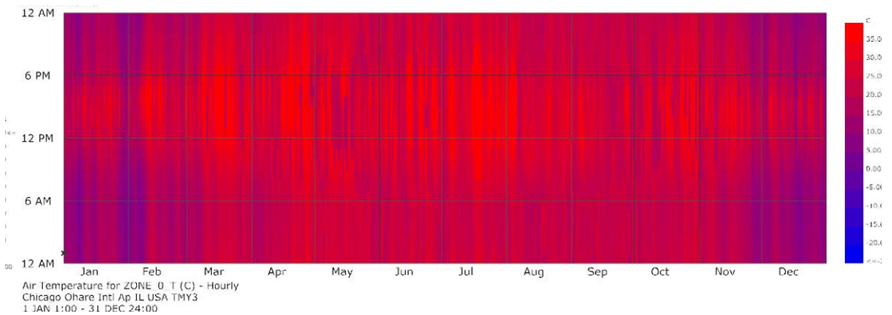


Comfortable (%): 38.68
hot (%): 29.2
cold (%): 32.12



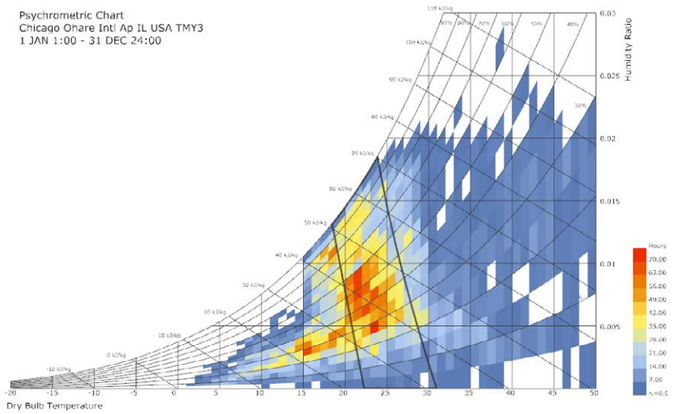
Low-E Window
gives more comfortness from the existing cold condition to centralize the cold time into the comfort zone in the Psy diagram.
readjust the ventilation condition to have exterior temperrature among 15-30° to help improve the hot condition in the afternoon.



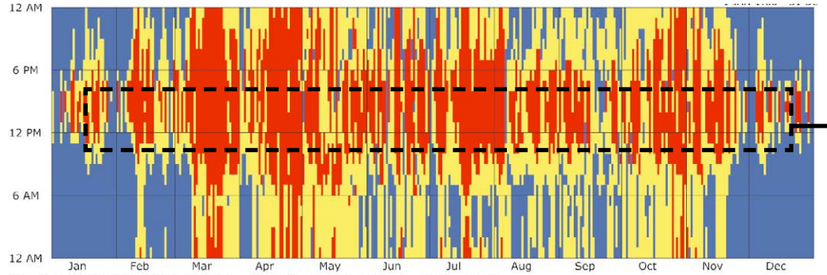


Blinding System

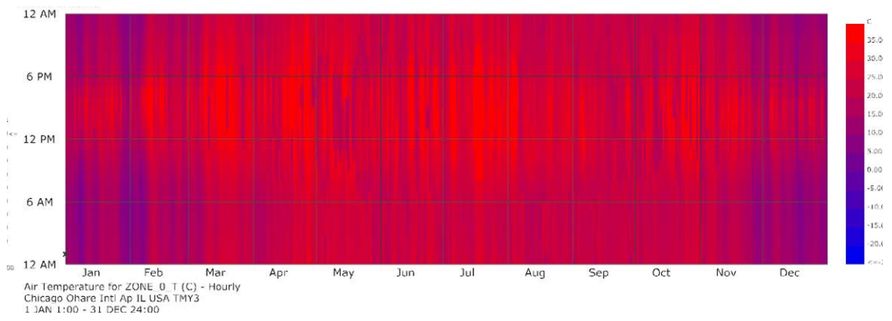
Comfortable (%): 38.68
hot (%): 29.2
cold (%): 32.12



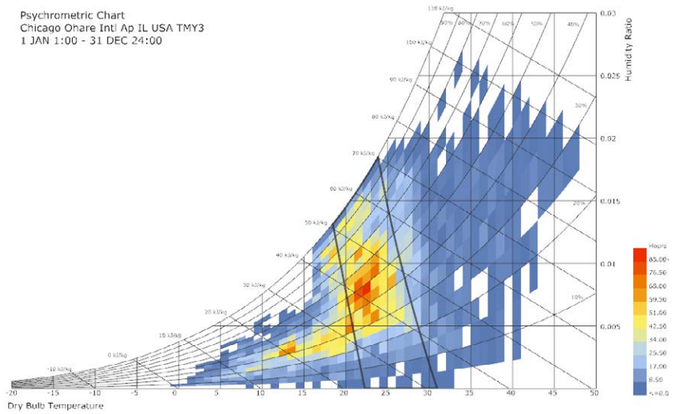
Low-E Window
gives more comfortness from the existing cold condition to centralize the cold time into the comfort zone in the Psy diagram.
readjust the ventilation condition to have exterior temperrature among 15-30° to help improve the hot condition in the afternoon.



Hot Condition Tageted Problem

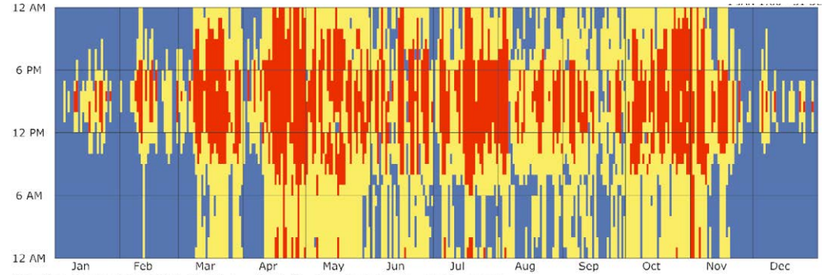


Comfortable (%): 40.84
hot (%): 21.72
cold (%): 37.43

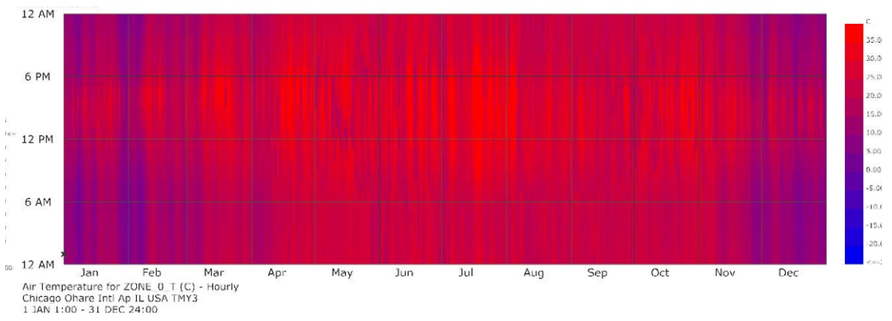


Blinding System
the new blinding system helps to improve some of the hot condision to comfortness.

readjust the ventilation condition to have exterior temperrature among 16-30° to help improve the hot condition in the afternoon.



Average Interior Temperature: 18.96°

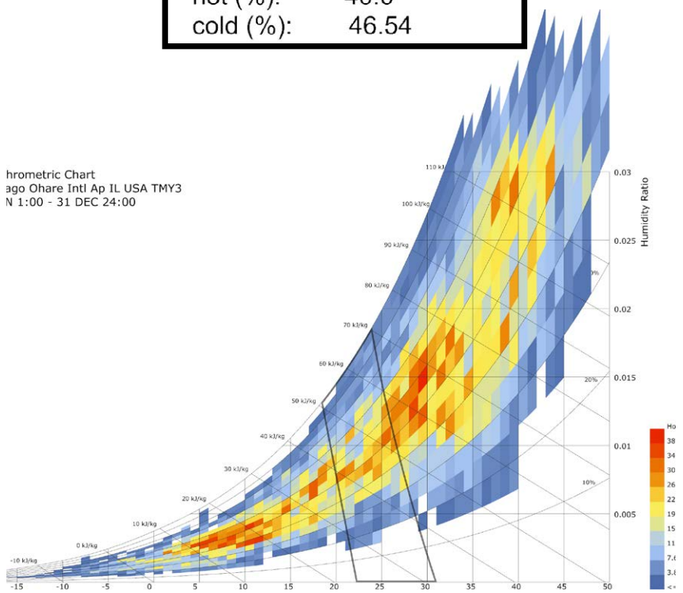


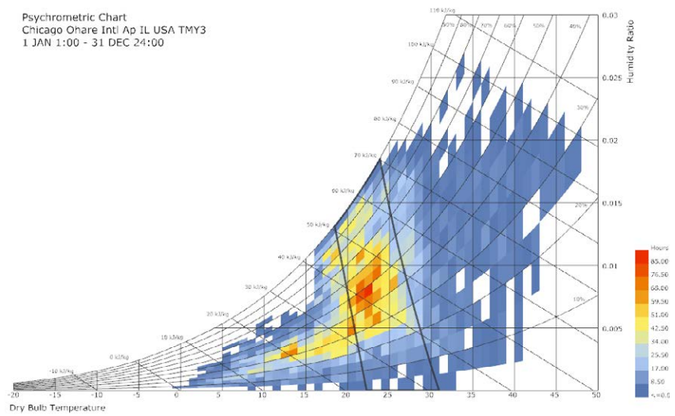
Conclusion

Comfortable (%): 13.46
hot (%): 40.0
cold (%): 46.54

27.38 Improvement

Comfortable (%): 40.84
hot (%): 21.72
cold (%): 37.43





Thermal Mass +8inchs
R-value from 14.3-34.5 12% Improvement
The winter climate in Chicago is severe and suffers from cold condition. Thermal mass strategy helps a lot to improve the cold condition.

Low-E Window 7% Improvement
gives more comfort from the existing cold condition to centralize the cold time into the comfort zone in the PMV diagram.

Natural Ventilation 6% Improvement by its own
when exterior temperature is among 18-25° to help improve the hot condition in the afternoon with fewest hot condition 23.72%, however after adding the thermal mass strategy and readjusting the ventilation condition to have exterior temperature among 16-30°, it helps more than only employing natural ventilation strategy.

Blinding System 2% Improvement
the new blinding system helps to improve some of the hot condition to comfort.

Rotation 1%

Average Interior Temperature: 18.96°