

ARCH 753 BUILDING PERFORMANCE SIMULATION  
**THERMAL AND VISUAL COMFORT MAXIMIZATION FOR AN UNCONDITIONED SPACE**  
SILMI FARAH \_MEBD 2017-18

## WORKFLOW

CLIMATE ANALYSIS OF PHILADELPHIA



EXISTING BUILDING EVALUATION



DESIGN PROPOSALS > IMPROVEMENT STEP 1 > IMPROVEMENT STEP 2 > IMPROVEMENT STEP 3 > IMPROVEMENT STEP 4



CONCLUSIVE COMPARISON

# CLIMATE ANALYSIS

PHILADELPHIA COUNTY\_PENNSYLVANIA

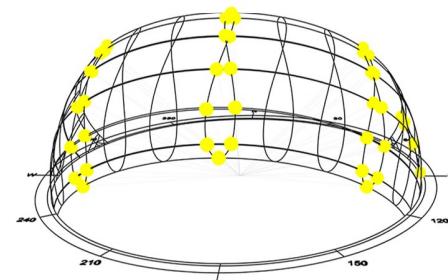
LATITUDE: 39.87 LONGITUDE -75.23 ELEVATION 2.0 CLIMATE ZONE 4



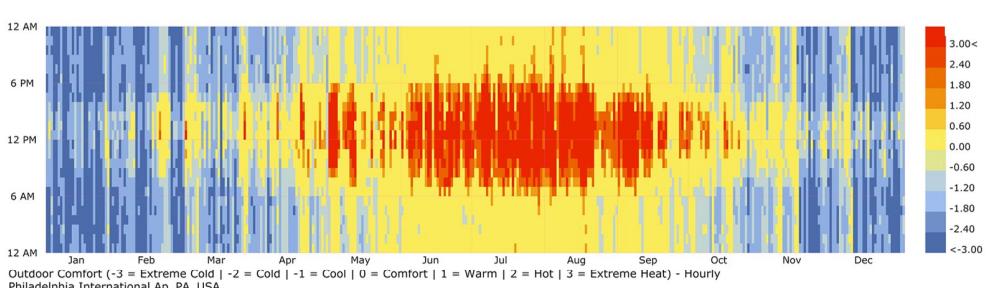
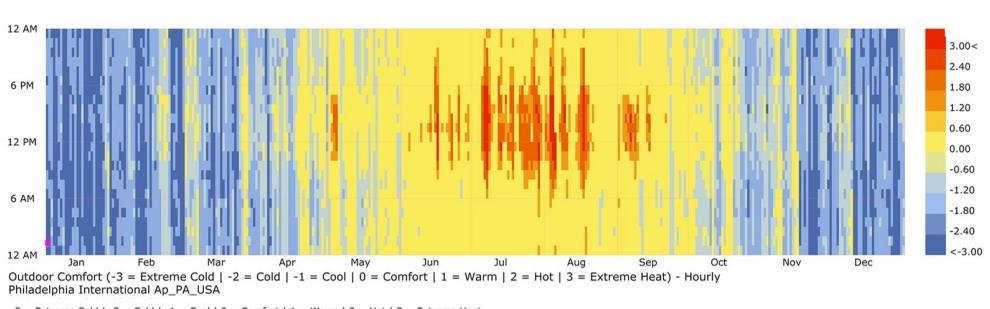
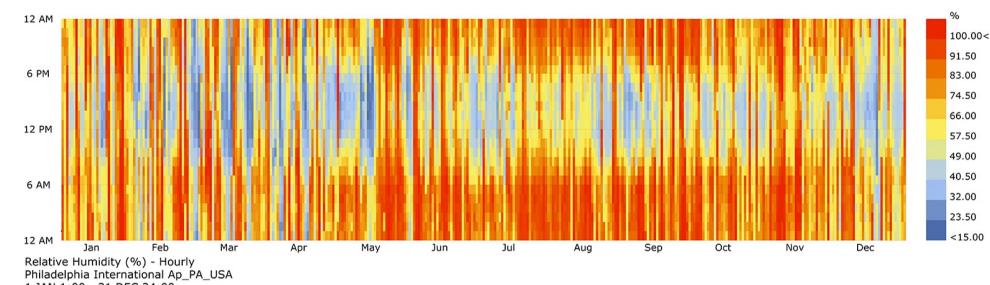
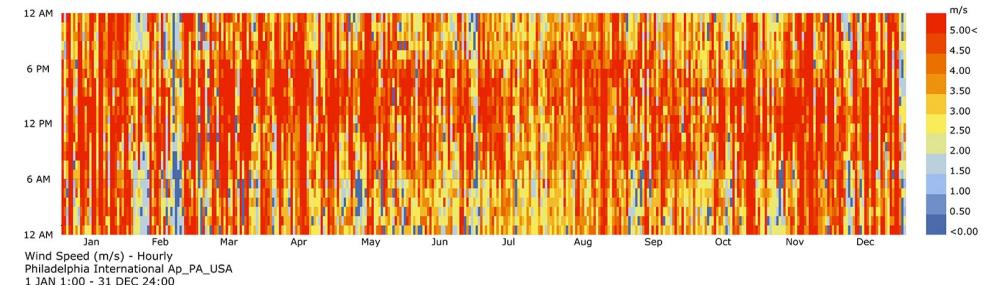
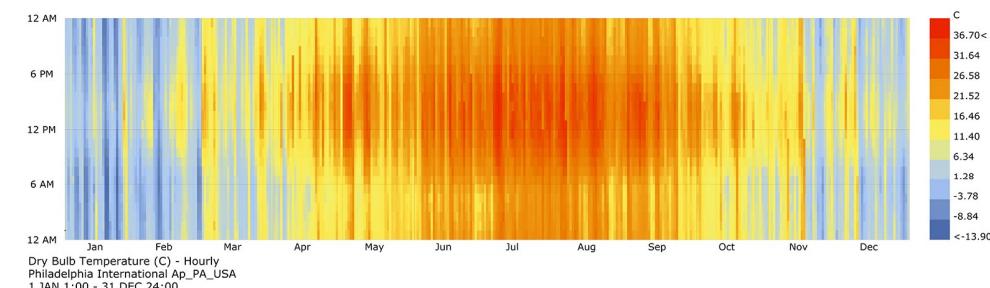
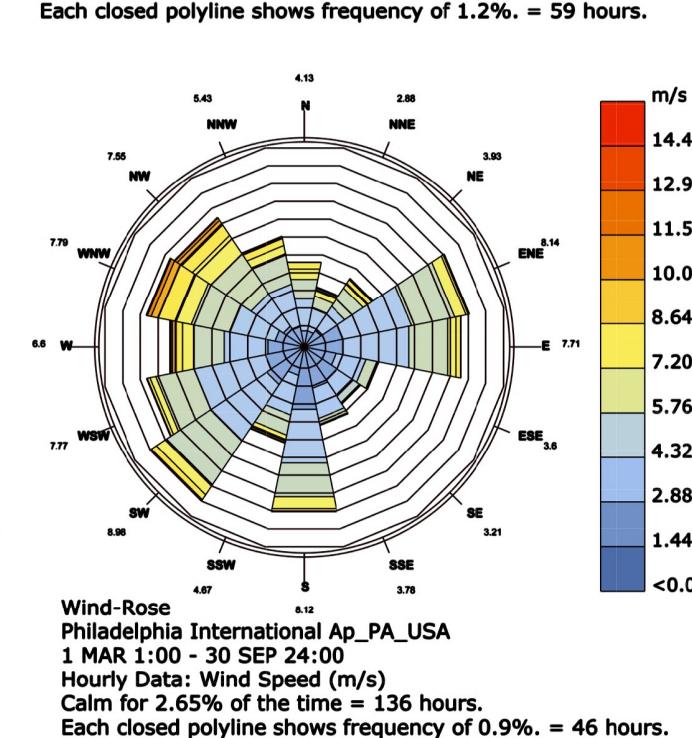
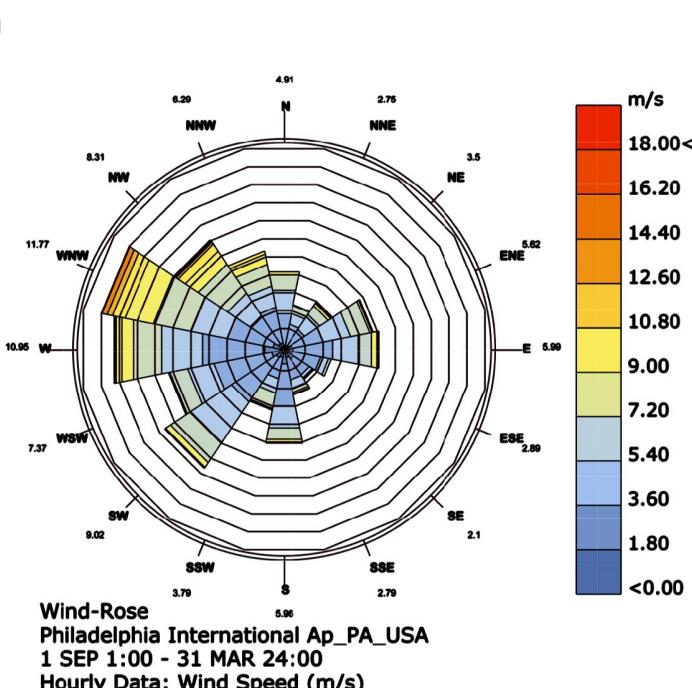
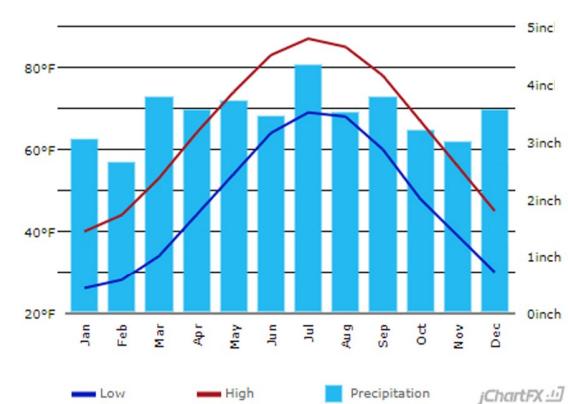
From the wind rose chart it can be seen that in winter the WWW, NW and W side has the highest velocity and frequency. Therefore this side can be closed for direct wind.

But the summer has additional wind rose from WSW SW and S. Therefore, Making openings in these sides would let the summer breeze in. But since from precipitation data, the summer rain rate is quite high so it should have some form of control.

The sun path shows a huge impact on the southern facade throughout the day.



Philadelphia Climate Graph - Pennsylvania Climate Chart



From the annual temperature humidity and airspeed data visualization of Philadelphia, it is seen that the temperature level is above 30c from June to August. Whereas from November to February the temperature below 1c prevails which is another major issue for the design.

The all over wind speed is more than 2.5 m/s most of the time as well which is needed to be controlled by wind direction study of the wind pattern.

Comparatively, lower humidity prevails in the daytime which can be a resource for the summer time.

From the universal thermal climate index calculation with the existing climate data, it is found that the comfortable condition under full shaded surface is nearly 41% while under radiation is 37%

## BASELINE ANALYSIS:

OUR SUBJECT TO IMPROVE IS AN APARTMENT ROOM IN PHILADELPHIA COUNTY IN PENNSYLVANIA. THE ROOM IS USED AS A LIVING+OFFICE PURPOSE. IT IS A RECTANGULAR ROOM WITH AN OPENING AT THE SOUTH FAÇADE.

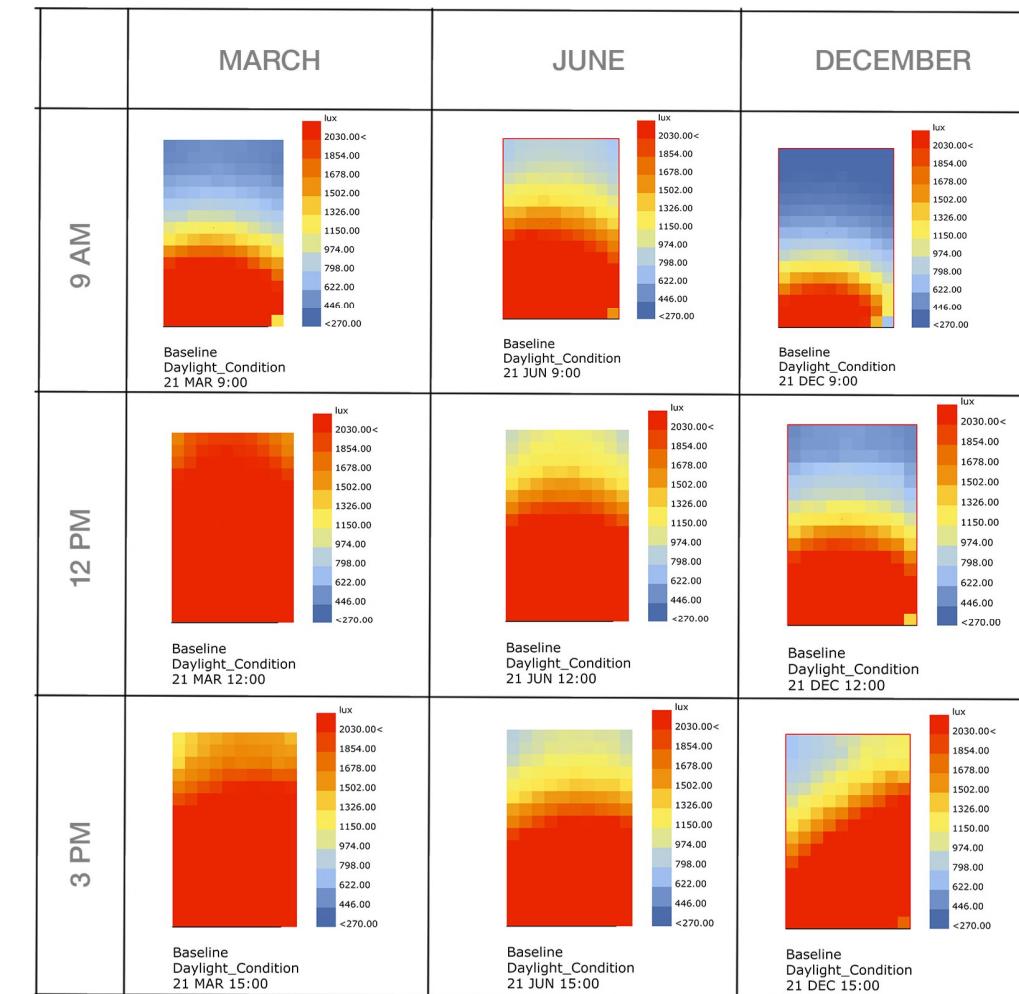
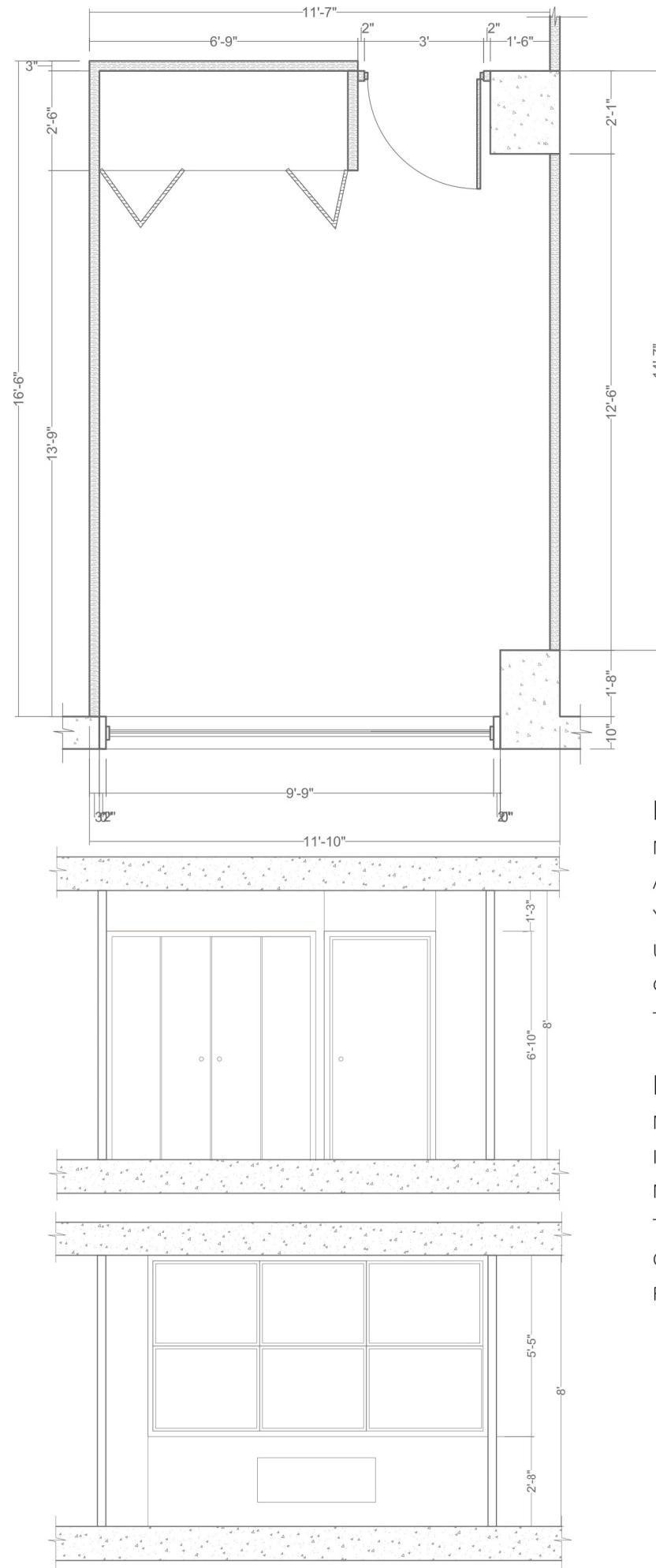
THIS IS THE FAÇADE FACING TOWARDS THE "CITY VIEW".

### STRENGTH:

1. SIMPLE RECTANGULAR FORM THAT HELPS A WELL DISTRIBUTION OF LIGHT WITH PROPER FAÇADE TREATMENT.
2. SOUTHERN FAÇADE PROMOTES INSERTION OF AMPLE DAYLIGHT AND NECESSARY RADIATION IN THE WINTER
3. OTHER SURROUNDING APARTMENTS PROVIDE A GOOD THERMAL MASS AT THREE SIDES OF THE ROOM

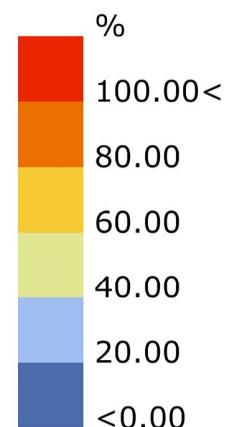
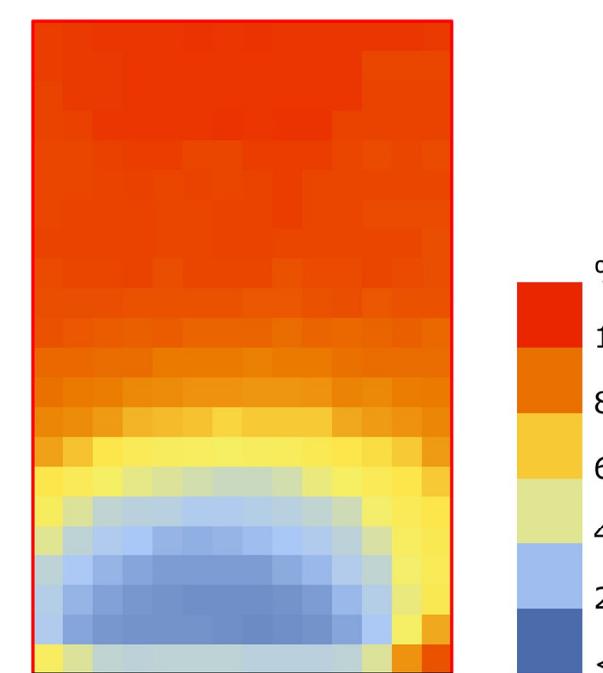
### WEAKNESS:

1. DIVERSE CONTROL NEEDED THROUGHOUT THE YEAR AS THE SUNLIGHT PENETRATES CONSTANTLY IN THE SOUTHERN FAÇADE.
2. DUE TO MAINTAINING THE CITY VIEW FROM THE ROOM THERE IS A DESIGN RESTRICTION OF NOT CHANGING THE POSITION AND ORIENTATION OF THE FAÇADE.



DUE TO HAVING THE LARGE SOUTHERN FAÇADE MORE THAN 50% OF THE SPACE HAVE INTOLERABLE LEVEL OF DAYLIGHTS THROUGHOUT THE YEAR. ON A POSITIVE NOTE THE ANNUAL USEFUL DAYLIGHT ILLUMINANCE SHOWS THE CORNERS ARE NOT UNDERLIT IN 80-100% TIME.

HOWEVER, AFTER DESIGNING THE CONTROL TO MITIGATE THE LIGHTING LEVEL THERE IS AN ISSUE THAT LIGHT MIGHT NOT REACH THE CORNERS OF THE ROOM. THEREFORE, SOME ADDITIONAL STRATEGY IS NEEDED TO BE APPLIED TO CONTROL THE LIGHT BUT ALSO PROVIDE AN UNIFORM DISTRIBUTION THROUGHOUT THE SPACE.

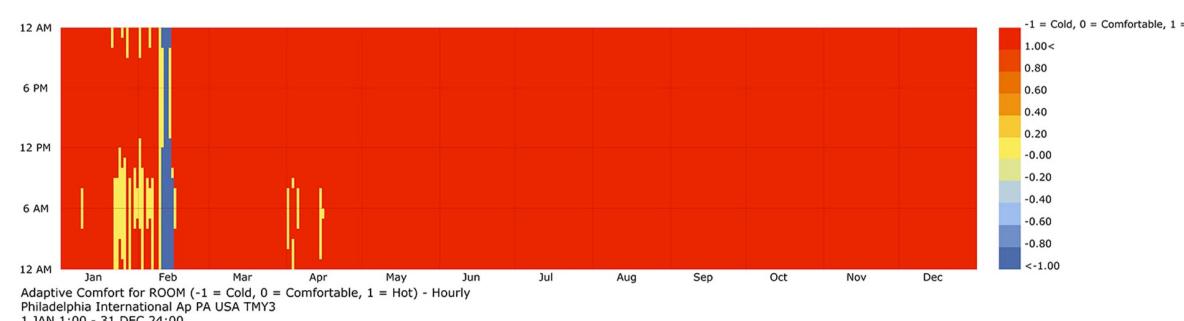
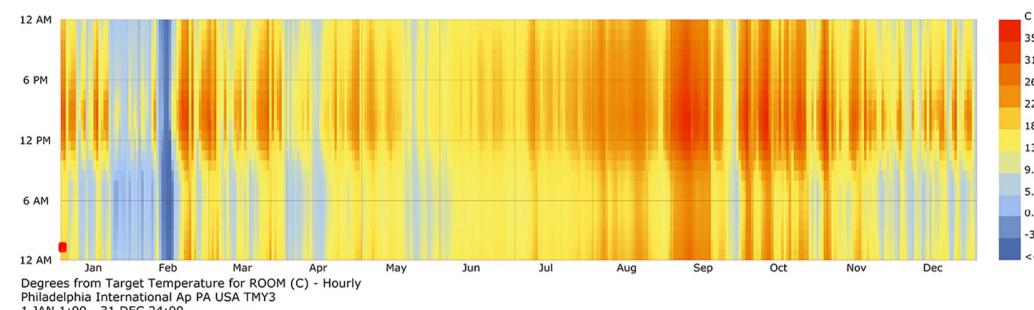
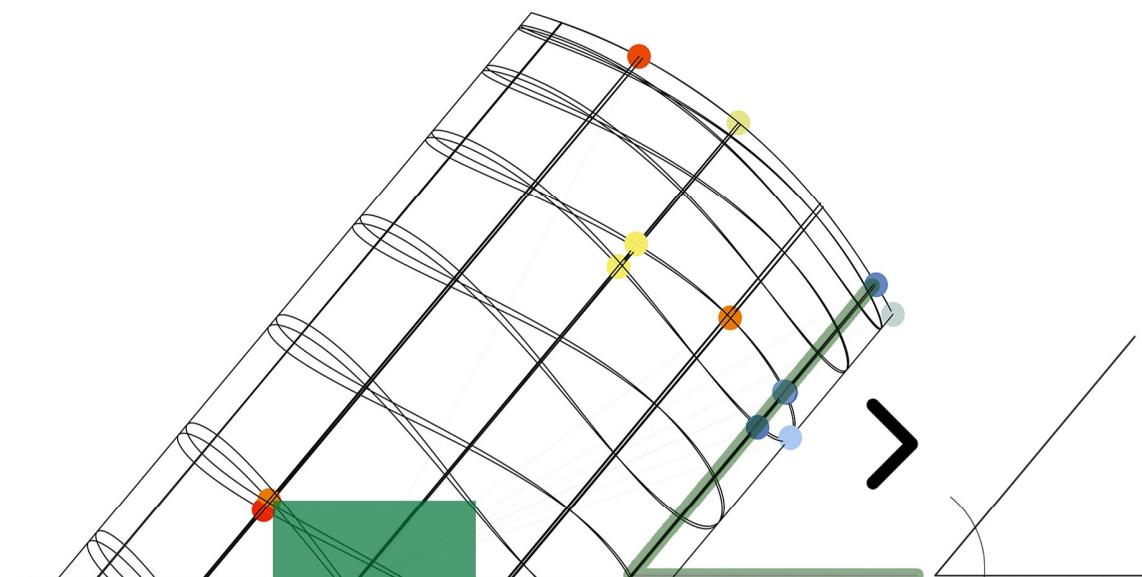
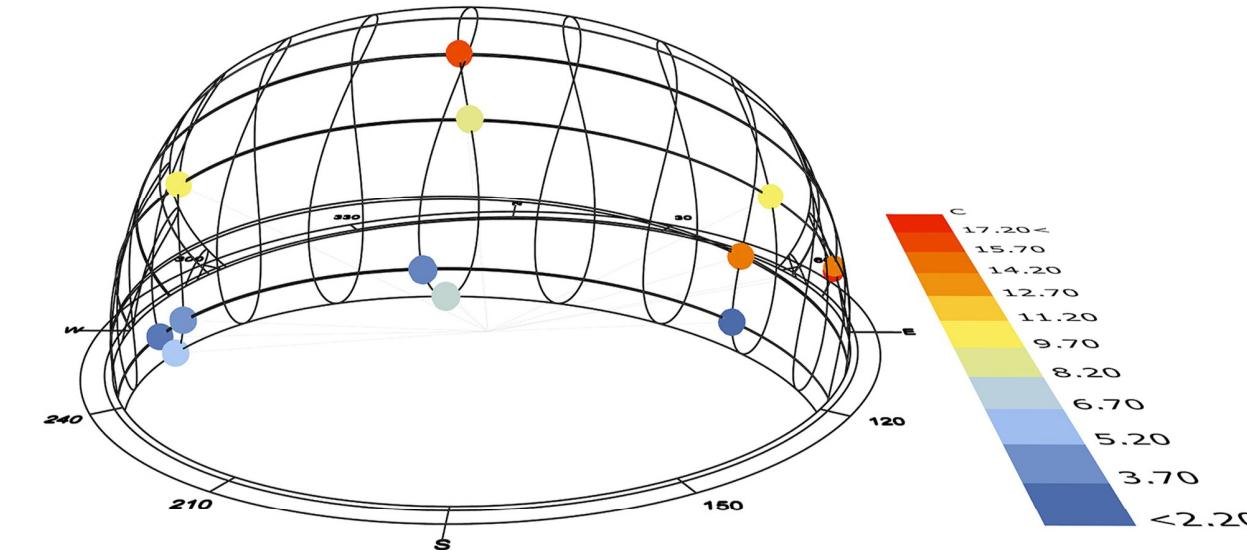


Annual Useful Daylight Illuminance  
Basecase  
Range 100-2000

## BASELINE ANALYSIS:

### SUN ANGLE

TO DETERMINE THE COLD HOURS WHERE THE SUNRADIATION IS NECESSARY IS IDENTIFIED. AN APPROXIMATE CONDITION OF TEMPERATURE UNDER 18C AND RELATIVE HUMIDITY OVER 80% AND WIND SPEED MORE THAN 1 M/S WAS SELECTED UNDER WHICH CONDITION IT IS DEFINITELY COLD AND UNCOMFORTABLE. THE SUN POSITIONS OF MARCH, JUNE, SEPTEMBER AND DECEMBER AT THE TIMES OF 9AM, 12PM AND 3 PM WERE SELECTED AS BASELINES TO STUDY RESULTS. THE RESULTANT DISCOMFORTABLE COLD HOURS SHOW THE MONTH OF NOVEMBER, DECEMBER AND JANUARY IS MORE LIKELY TO BE DISCOMFORTABLE IN WHICH THE SUN ANGLE ARE EQUAL TO OR UNDER 36 DEGREE. THEREFORE THE IF THE SHADING DEPTH AND GAP RATIO IS 10:6 OR THR GAP IS HIGHER IT WILL RECEIVE NECESSARY SUN RADIATION IN DESIRED TIME.



< THERMAL COMFORT CONDITION  
THERMAL COMFORT IS RARELY ACHIEVED IN THE BASELINE CONDITION BOTH IN THE SUMMER AND THE WINTER.

COMFORTABLE TIME PERCENTAGE:  
2.123288 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO HOT:  
96.894977%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO COLD:  
0.981735 %

## MATERIAL IMPROVEMENT

SINCE THE SOUTHERN EXTERIOR FAÇADE IS THE ONE RECEIVING MOST OF THE SOLAR GAIN AND HAVING THE HIGHEST HEAT LOSS A HIGHER R-VALUE MATERIAL OF 0.44 WITH A NONMETAL WINDOW WAS INSTALLED .

THE GLASS IS OF 0.6 VISUAL TRANSMITTANCE

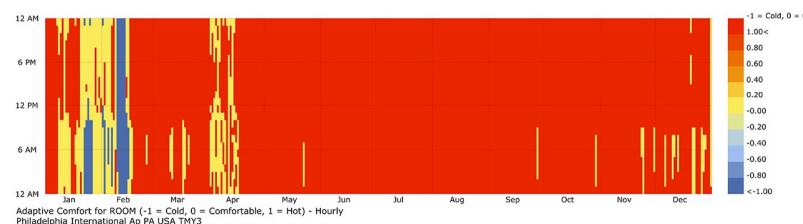
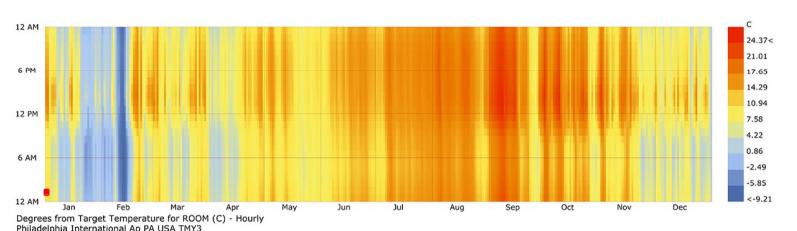
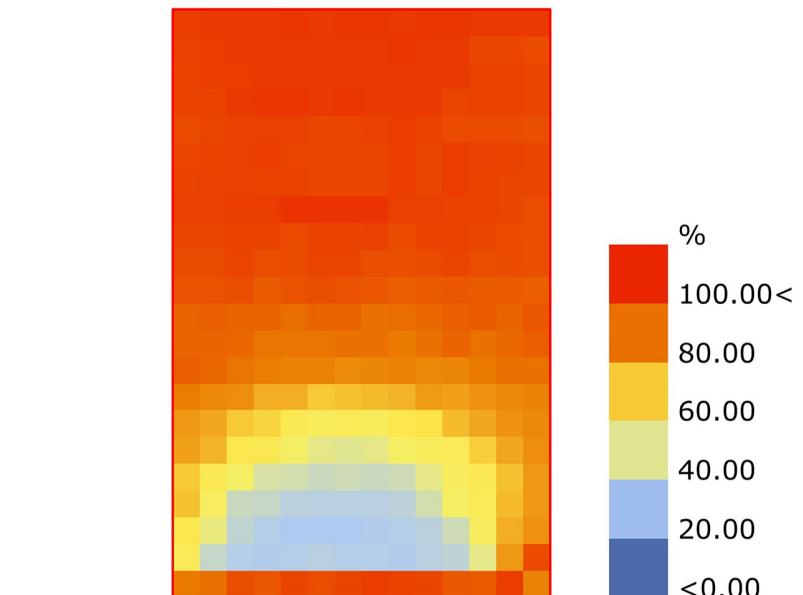
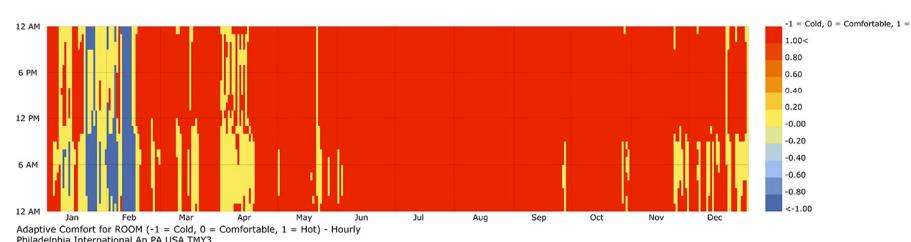
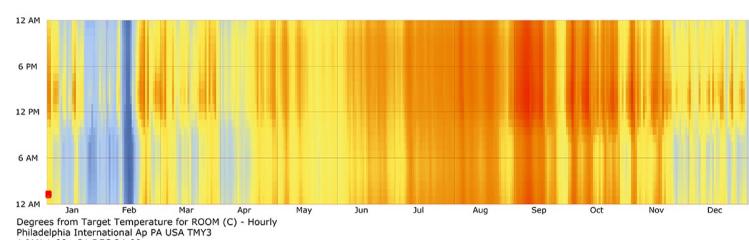
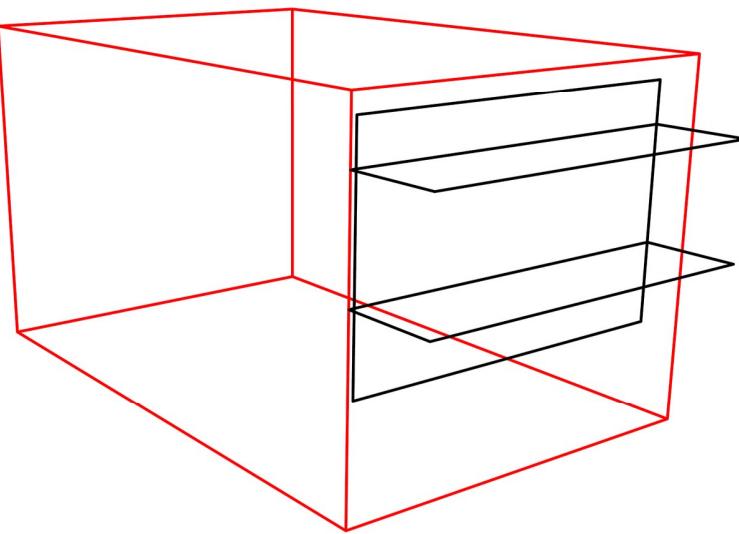
THE REVISED THERMAL COMFORT IS,

**COMFORTABLE TIME PERCENTAGE:**  
9.828767%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO HOT:  
87.705479%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO COLD:  
2.465753%

AS A RESULT, THERE IS A SLIGHT IMPROVEMENT OF ENERGY CONDITION THAN THE BASELINE CONDITION



## DESIGN IMPROVEMENT 1

FROM THE SUN-PATH STUDY, TWO HORIZONTAL SHADING DEVICES CUTTING 36 SOLAR ANGLE WAS INTRODUCED.

FROM THE ANNUAL SUNPATH ANALYSIS IT IS FOUND THAT THE LIGHTING NEAR THE WINDOW IS IMPROVED BY NEARLY 10% STILL 1/3 OF THE AREA IS COMFORTABLE ONLY IN THE 30% TIME OF THE YEAR. THE LAST CORNERS OF THE ROOM IS MAINTAINED WHICH IS A POSITIVE ASPECT TO PRESERVE FOR THE FURTHER STEPS.

**COMFORTABLE TIME PERCENTAGE:**  
10.616438 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO HOT:  
86.79%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO COLD:  
2.59 %

THE THERMAL COMFORT CONDITION DID NOT IMPROVE MUCH BY ADDING THE SHADING DEVICE



## DESIGN IMPROVEMENT 2

IN THE MORNING AND THE EVENING HOURS THE SUNLIGHT CAUSES GLARE AND VISUAL DIFFICULTIES THEREFORE SOME VERTICAL FINS WERE INTRODUCED. SINCE THE HORIZONTAL SHADING WERE MITIGATING THE WINDOWSIDE GLARE MORE HORIZONTAL DEVICES WERE INTRODUCED

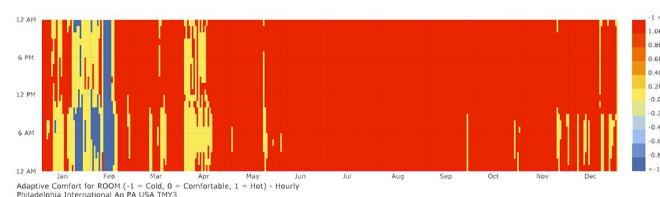
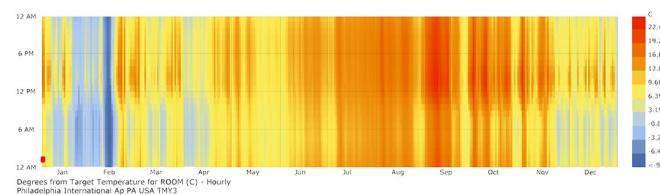
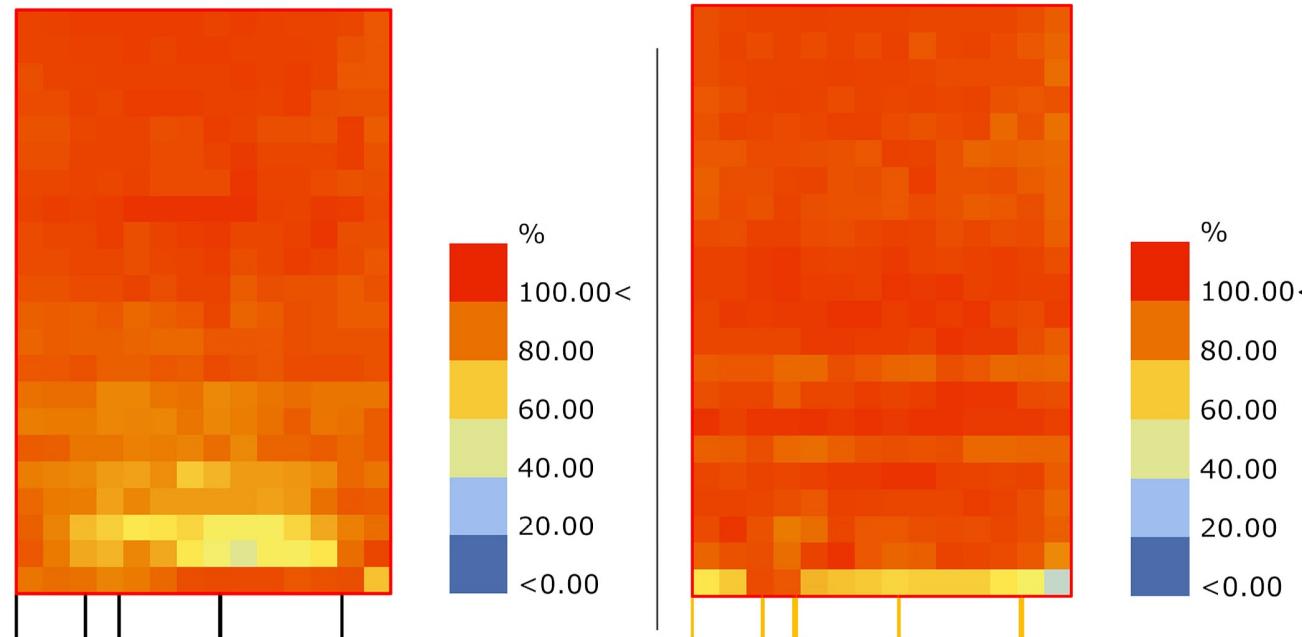
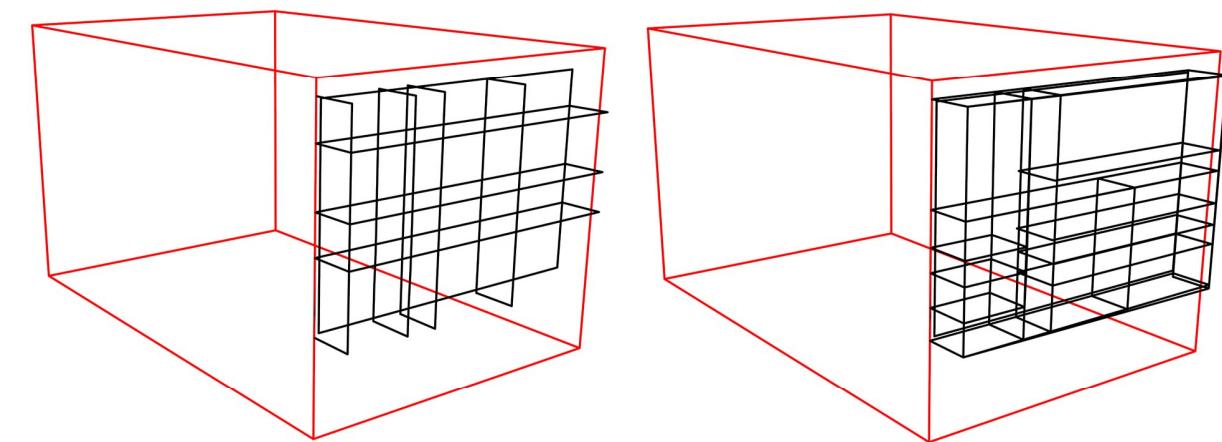
AS A RESULT, THE NEAREST DAYLIGHTING TO THE WINDOW INCREASED TO NEARLY 60-80% TIME COMFORTABLE LIGHTING LEVEL.

THE COMFORT CONDITION IMPROVED BECAUSE OF THE PERCENTAGE OF DISCOMFORT DUE TO HEAT DECREASED

COMFORTABLE TIME PERCENTAGE:  
12.38 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO HOT:  
84.54%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO COLD:  
2.59 %



## DESIGN IMPROVEMENT 3

THE SHADING DEVICE DENSITY IS INCREASED MORE WITH A COUPLE MORE OF TRIAL AND ERROR BASIS. DAYLIGHT IN THE OCCUPANCY HOURS ARE NOW UNIFORMLY DISTRIBUTED ALL OVER THE ROOM. THE MAXIMUM THERMAL EFFICIENCY ACHIEVED JUST BY IMPROVEMENT OF SHADING DEVICES ARE AS FOLLOWS:

COMFORTABLE TIME PERCENTAGE:  
13.73 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO HOT:  
82.4%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE TOO COLD:  
3.84 %



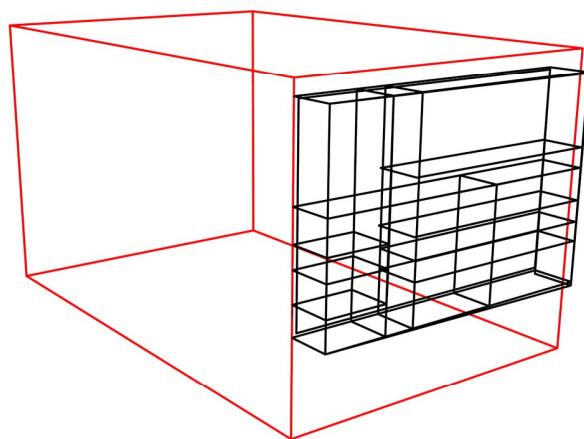
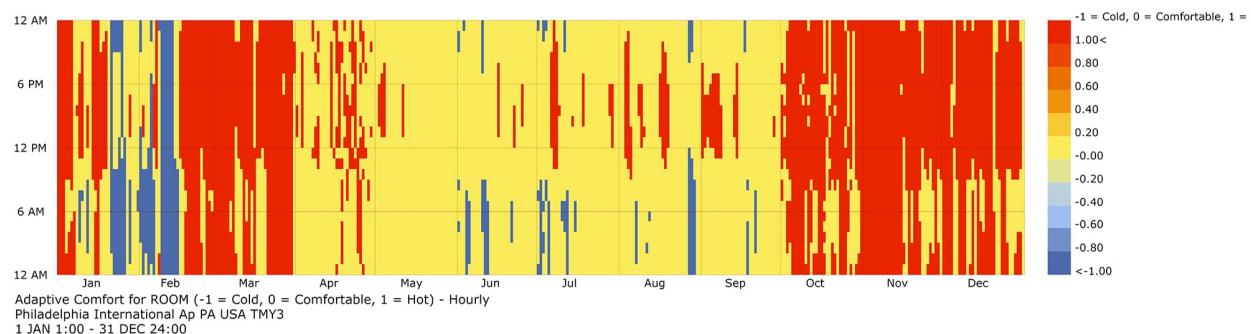
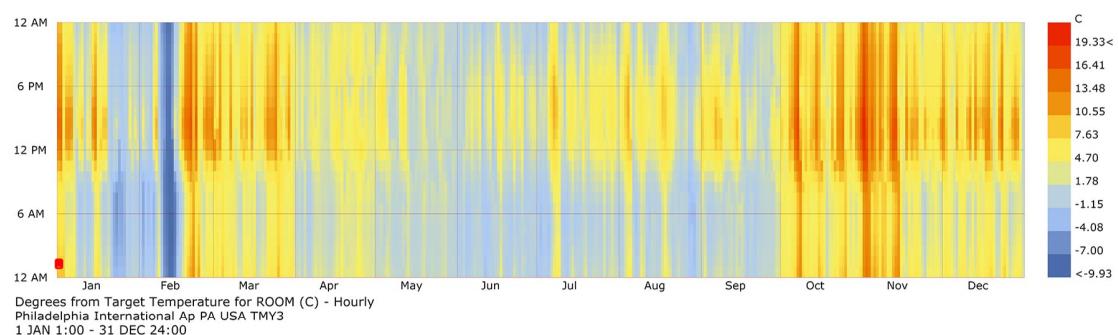
## VENTILATION

After the provisions adding adaptive comfort by natural ventilation the comfort level increased drastically.

COMFORTABLE TIME PERCENTAGE:  
57.1 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE  
TOO HOT:  
37.2%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE  
TOO COLD:  
5.6 %



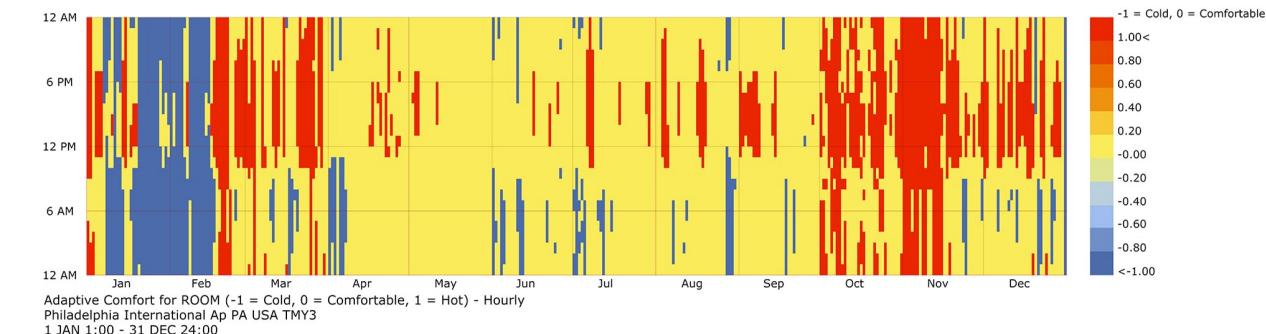
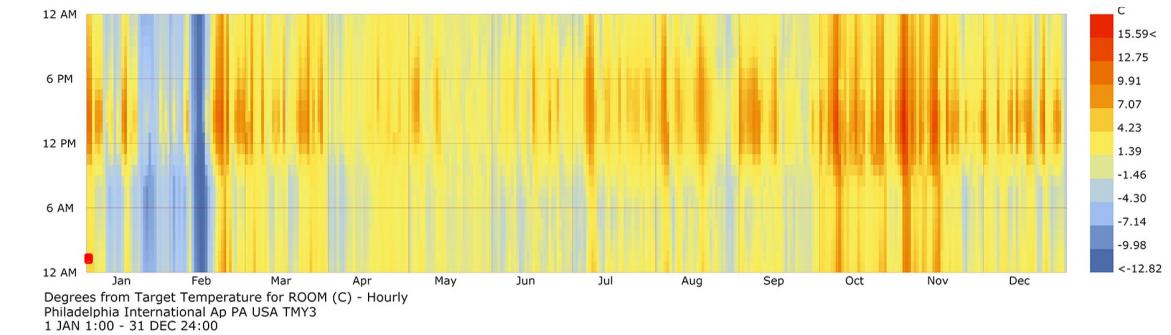
## DETAILED PARAMETERS

MANY PARAMETER LIKE 1 PERSON  
OCCUPANCY WITH LOW ELECTRICITY  
CONSUMPTION.

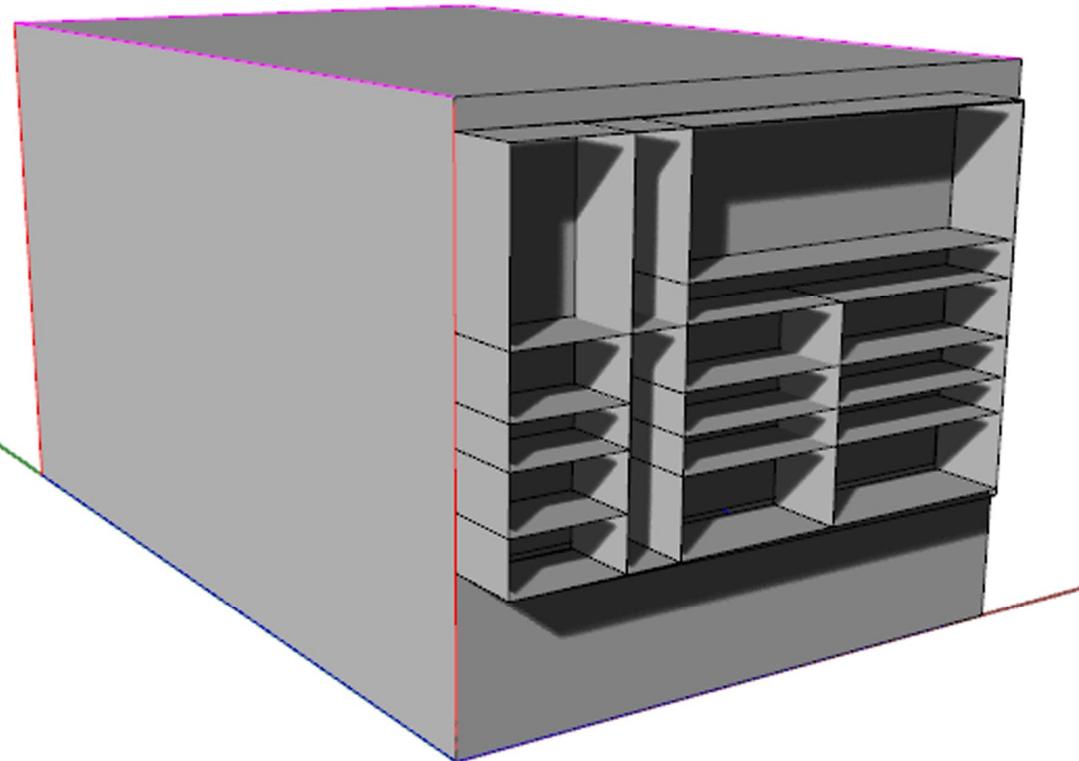
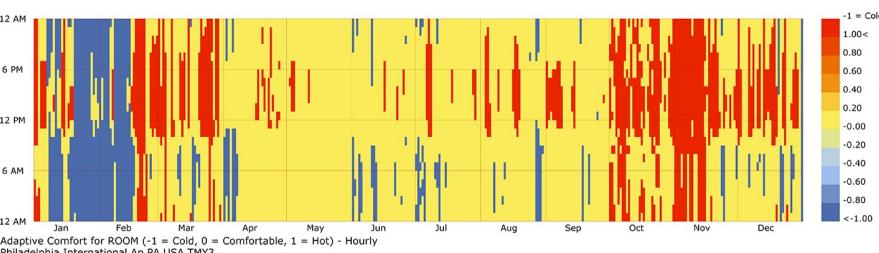
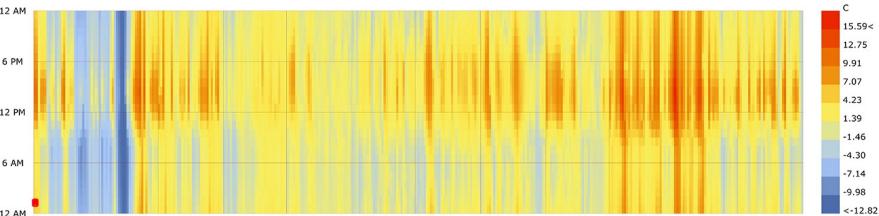
COMFORTABLE TIME PERCENTAGE:  
67.56 %

PERCENTAGE OF TIME WHEN OCCUPANTS ARE  
TOO HOT:  
19.61%

PERCENTAGE OF TIME WHEN OCCUPANTS ARE  
TOO COLD:  
12.81 %



# FINAL DESIGN ACHIEVEMENTS

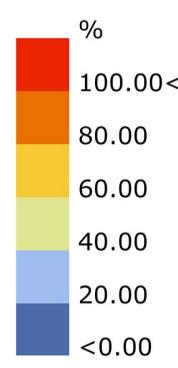


## Thermal Comfort Condition:

### Condition:

By adding the shading surface and ensuring the passive cooling by adding natural ventilation the room actually improved the thermal comfort level 67% of the time.

It could improve more if an hourly basis opening and closing window could be introduced to this design according to the energy model analysis comfort chart.



## Lighting Condition:

The daylighting grid based analysis shows lighting level of 300-2000 lux prevalent in most of the time with an uniform distribution.

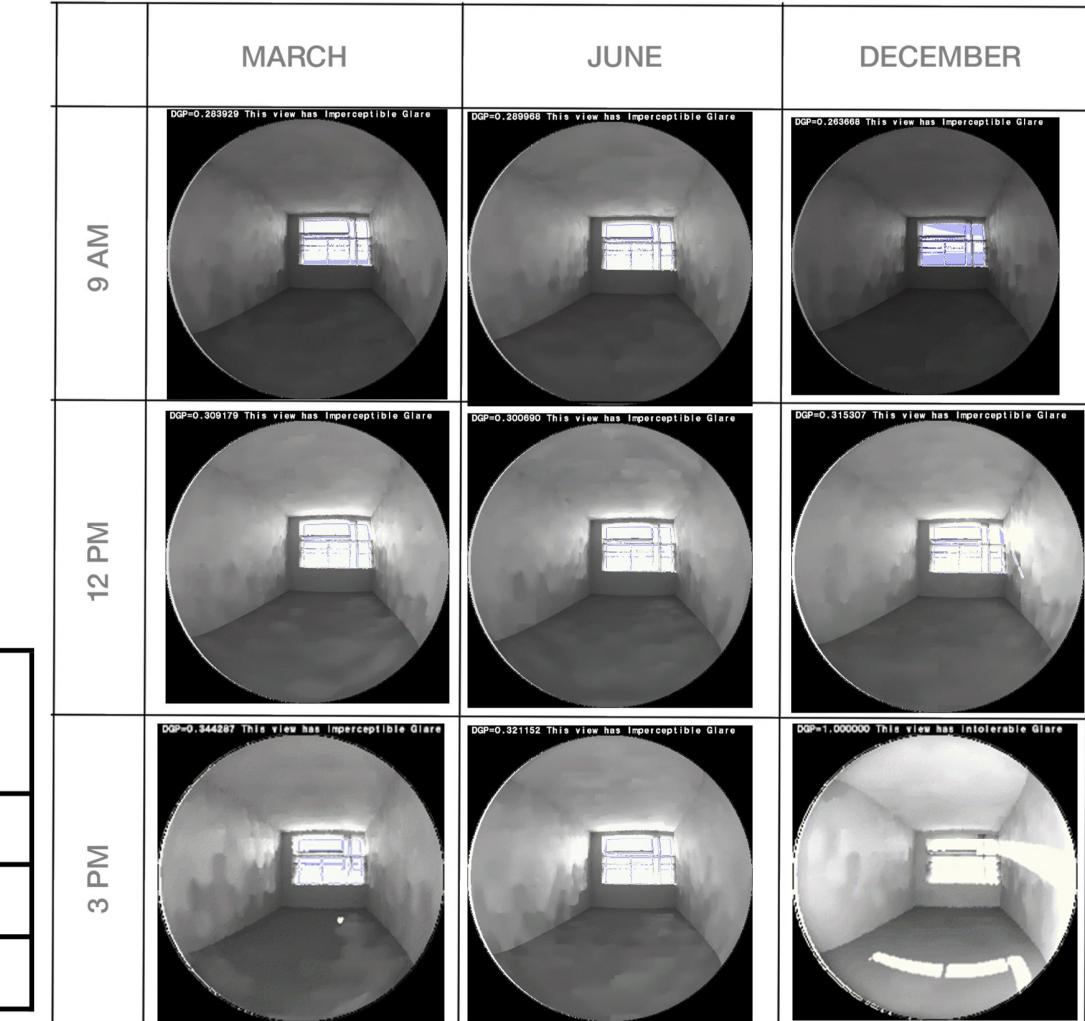
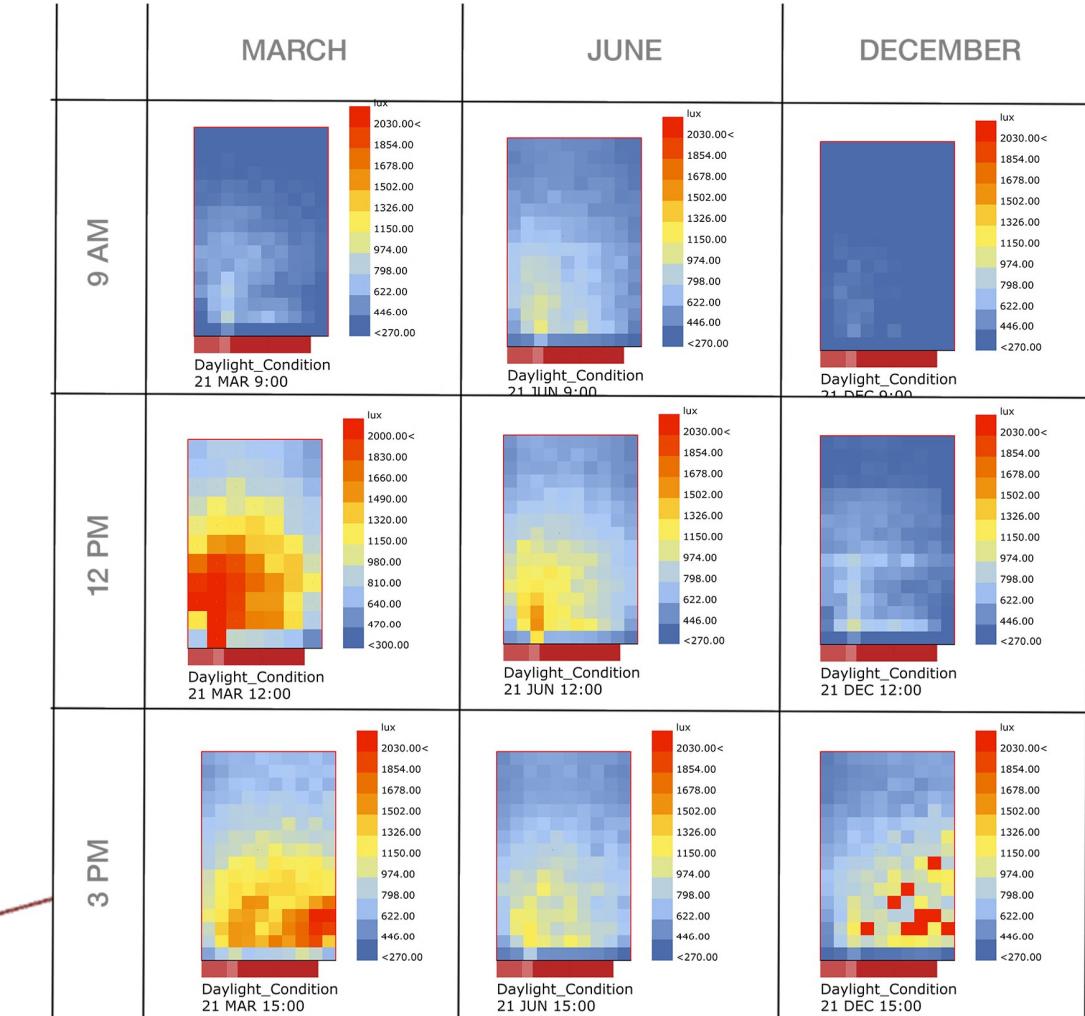
However, around the time December noon there is excessive light which was needed for reduction of cold.

March noon has some room for improvement yet through some refined properties of shading like operable scheduled shading.

## Glare Condition:

The glare level is under 0.34 for almost 80% of the time which is in tolerable level of the whole year.

Just the times around December 12PM to 3PM has direct radiation penetrating inside which could not be solved due to the need of radiation for cold



|                  | Baseline | Improvement |
|------------------|----------|-------------|
| Total Comfort    | 2.12     | 67.56       |
| Cooling Required | 96.89    | 19.61       |
| Heating Required | 0.98     | 12.81       |