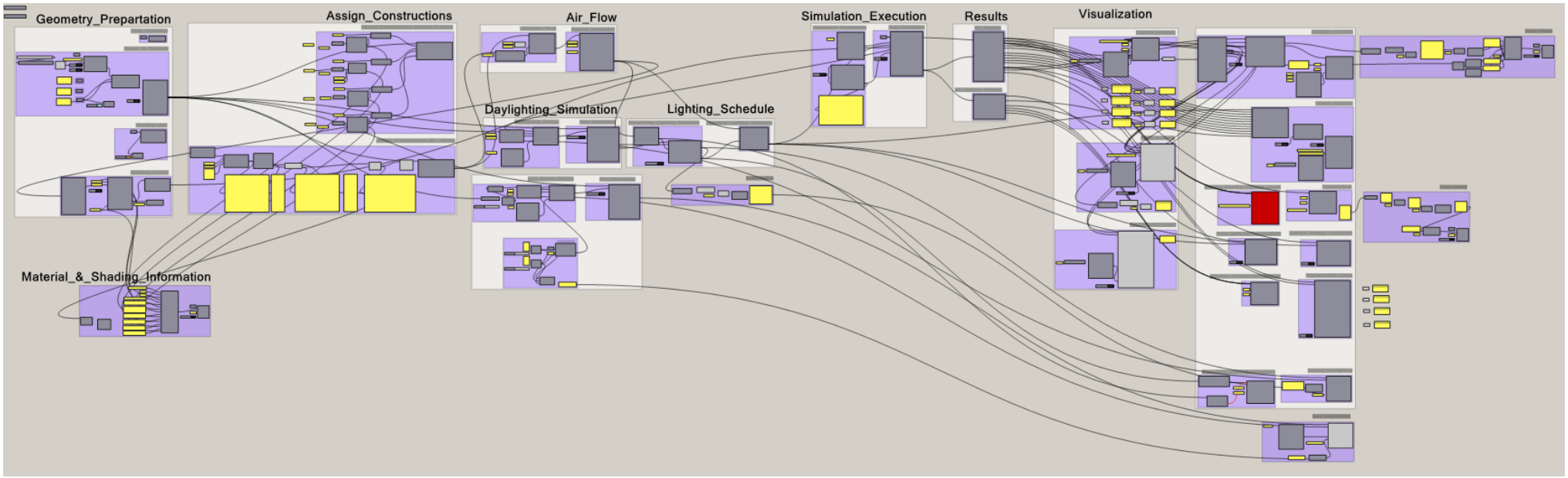
Comfortable, Comfortable, yet, Uncomfortable

Final Project
DREAM ROOM in Philadelphia

ARCH 753 _ Building Performance Simulation | Prof. Mostapha Sadeghipour Roudsari | Student Name: Bosung Jeon



Contents

Sequence of the Simulations

Step 1. Prepare Geometry for the simulations

Assign Construction Properties of the Geometry

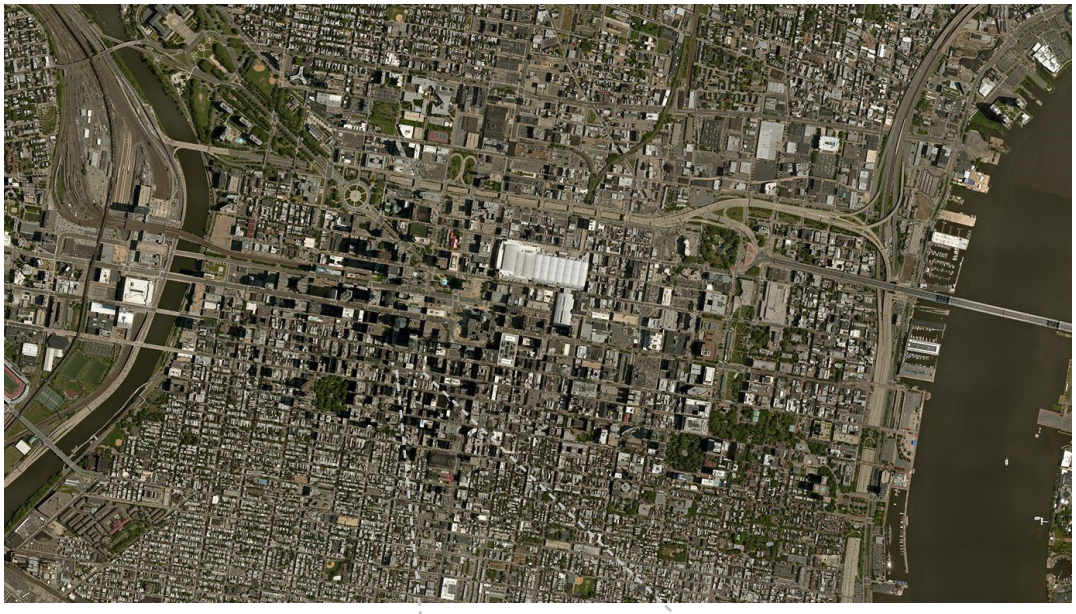
Apply Air Flow Properties And the Effect of Daylighting

Step 2. Execute Simulations

Step 3. Post Process with Proper Visualization Methods

Part 1. Climate Analysis

Center City of Philadelphia



Target Site: 1600 Chestnut Street

N

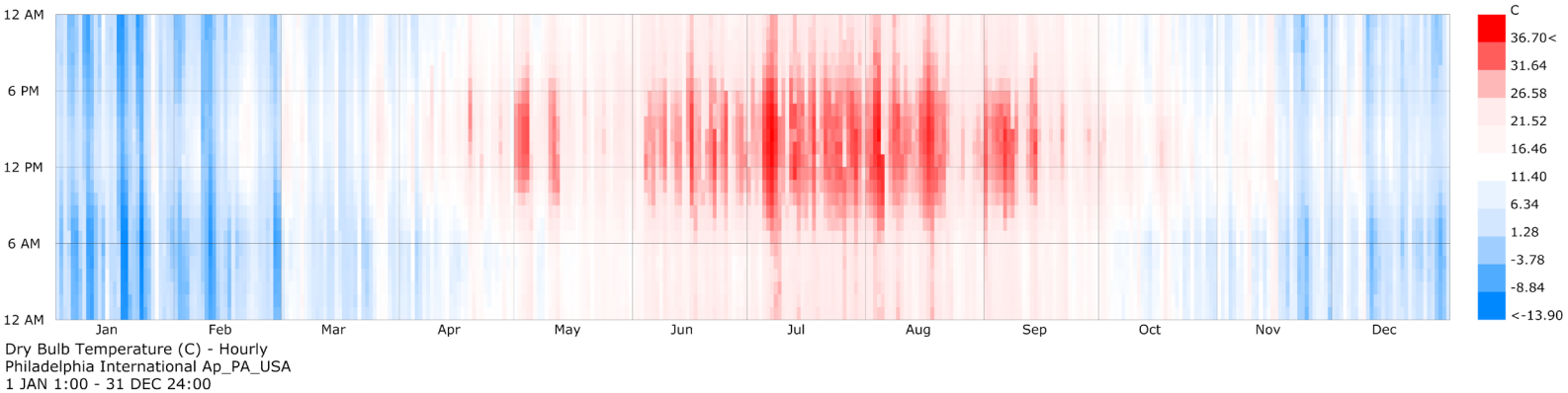
PROVIDED GENERAL INFORMATION OF THE CITY

City: Philadelphia, PA

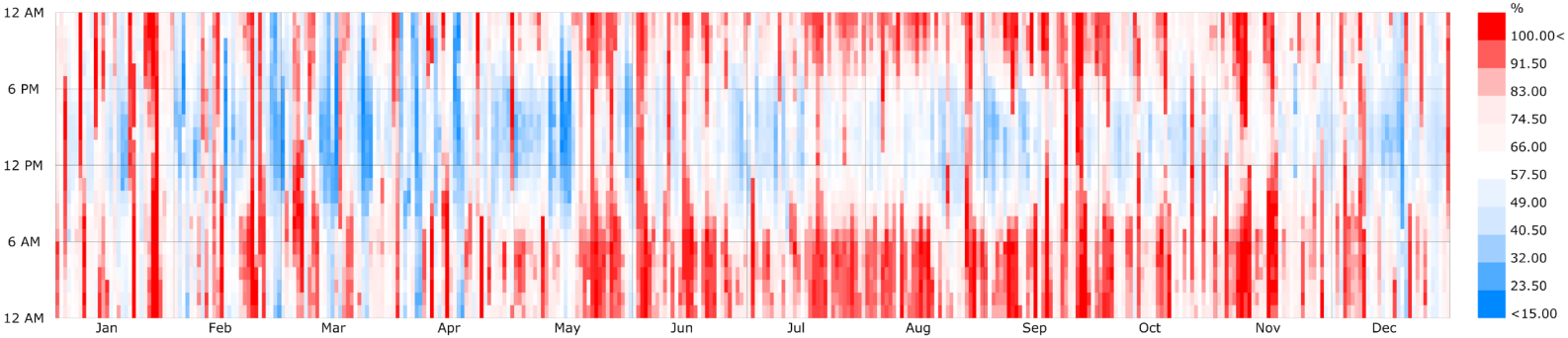
Latitude: 39.8683

Longitude: -75.2311

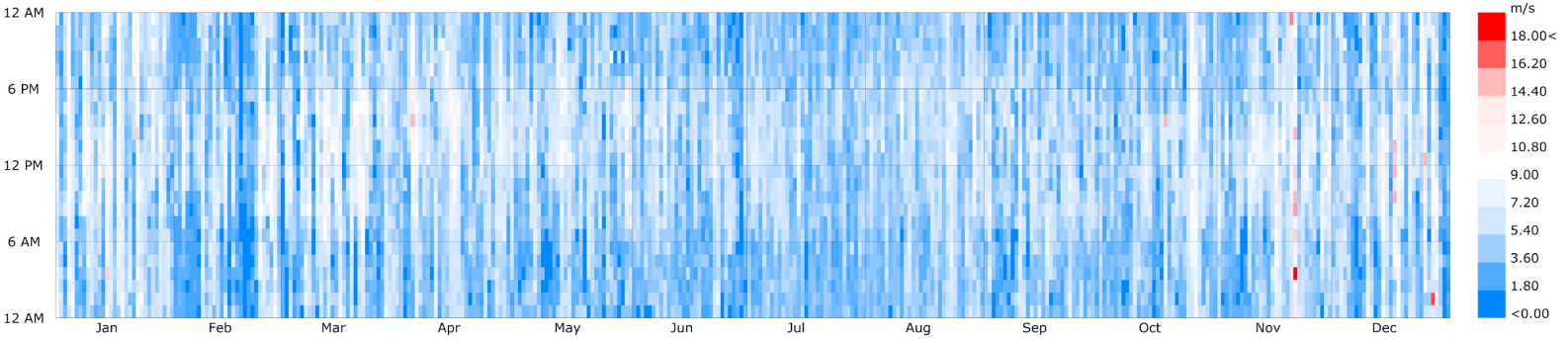
Climate:
According to the Köppen climate classification, Philadelphia falls under the northern periphery of the humid subtropical climate zone (Köppen Cfa),[71] whereas according to the Trewartha climate classification, the city has a temperate maritime climate (Do).[72] Summers are typically hot and muggy, fall and spring are generally mild, and winter is cold. (Wikipedia)



Dry Bulb Temperature (C) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



Relative Humidity (%) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



Wind Speed (m/s) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

SIMULATED GENERAL CLIMATE ANALYSIS

City: Philadelphia, PA

Latitude: 39.8683

Longitude: -75.2311

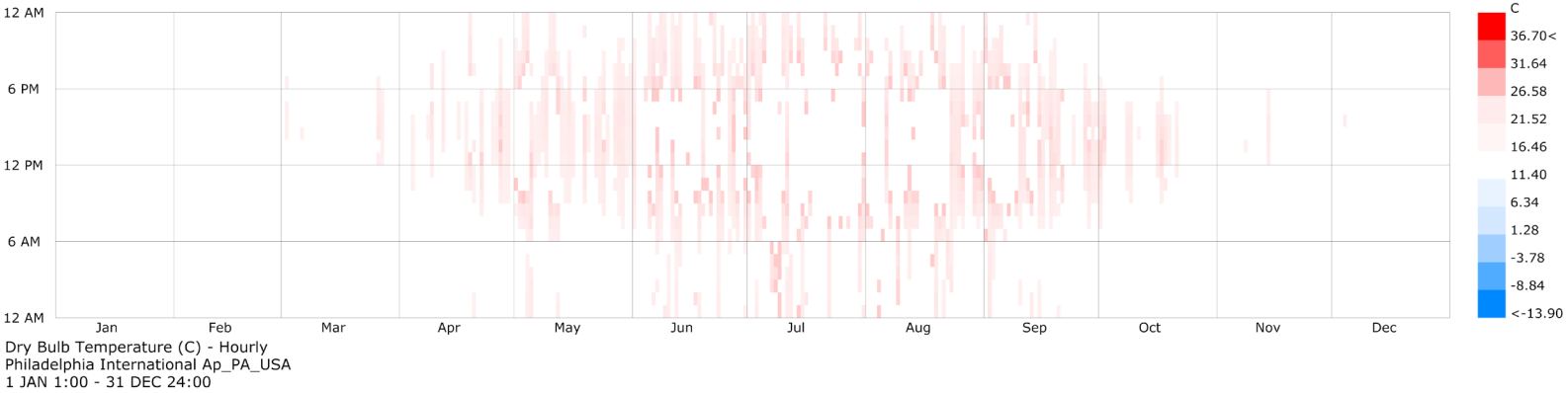
Climate:

Outdoor air temperatures in Summer and in Winter is drastically different, so strategy for dealing with it is necessary.

Relative humidity is generally high in nighttime, and it is relatively low in daytime.

According to calculation, average wind speed is 4.17 m/s , and, wind speed is from 0 to 10 usually, which would not much troublesome comparing to temperature issue.

Drastic Temperature in Summer and Winter. High Humidity in Nighttime.



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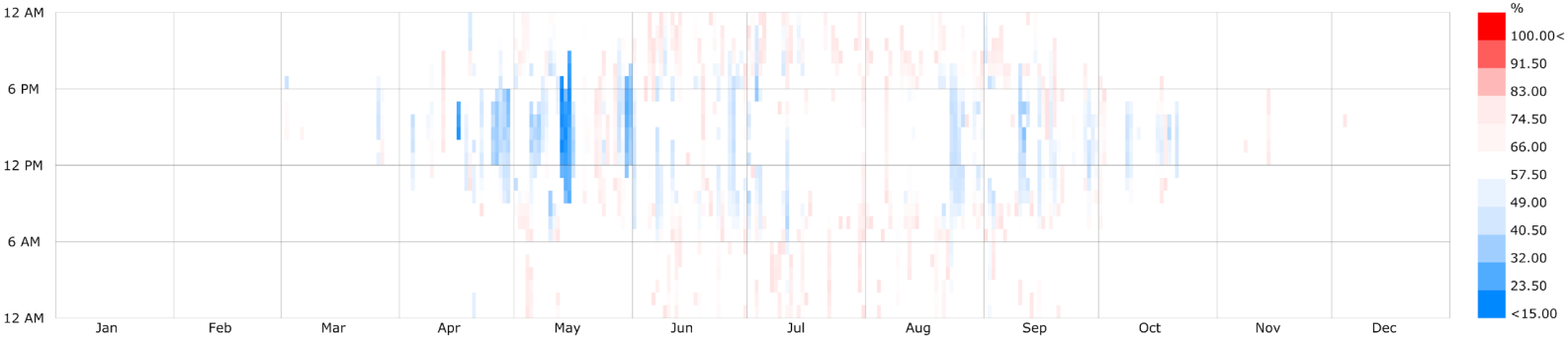
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



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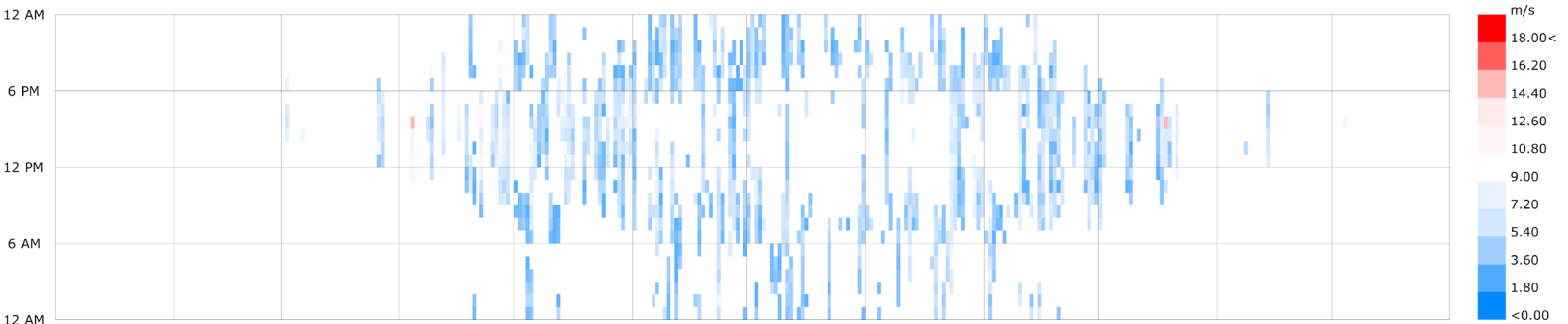


Wind Speed (m/s) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

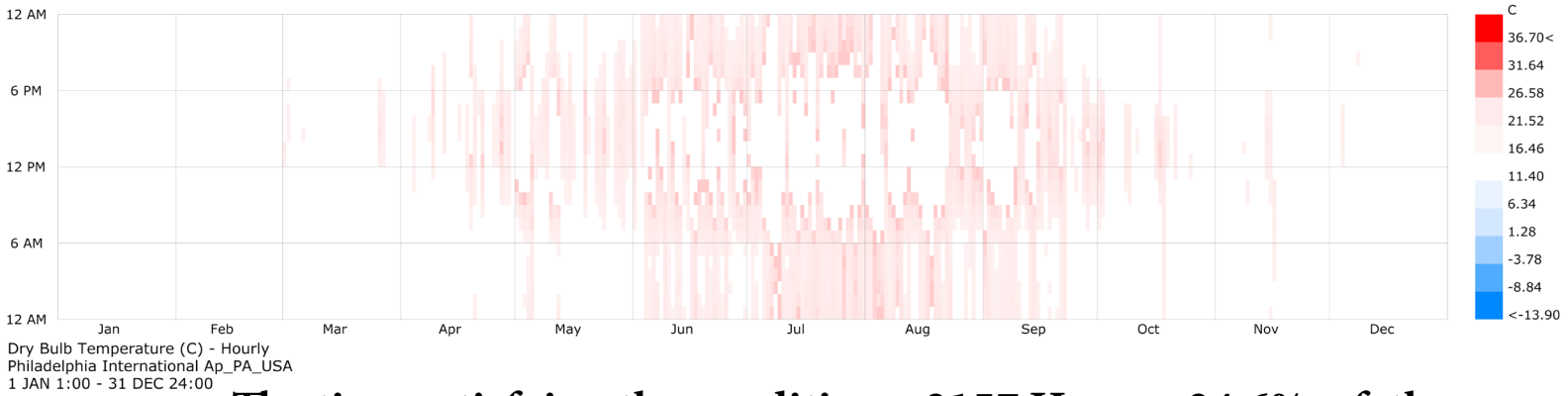
The time satisfying the conditions: 1228 Hours, 14.0% of the year

CLIMATE ANALYSIS IN CONDITIONAL SITUATION

Conditional situation was identified in a simulation. The conditions are that when temperature is between 18 and 26 Celsius, that when relative humidity is less than 80%, and when wind speed is more than 2m/s.

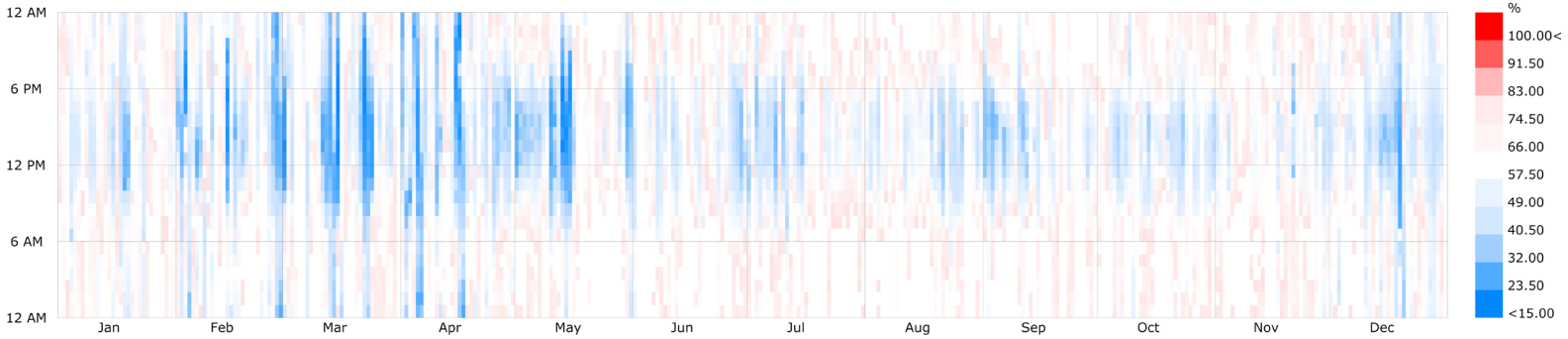
In the charts, comfortable time in terms of air temperature, relative humidity, and wind speed is only 14% now. It is generally in the daytime of Spring and Fall and in the nighttime of Summer.

Daytime in Spring and Fall and Nighttime in Summer are comfortable.



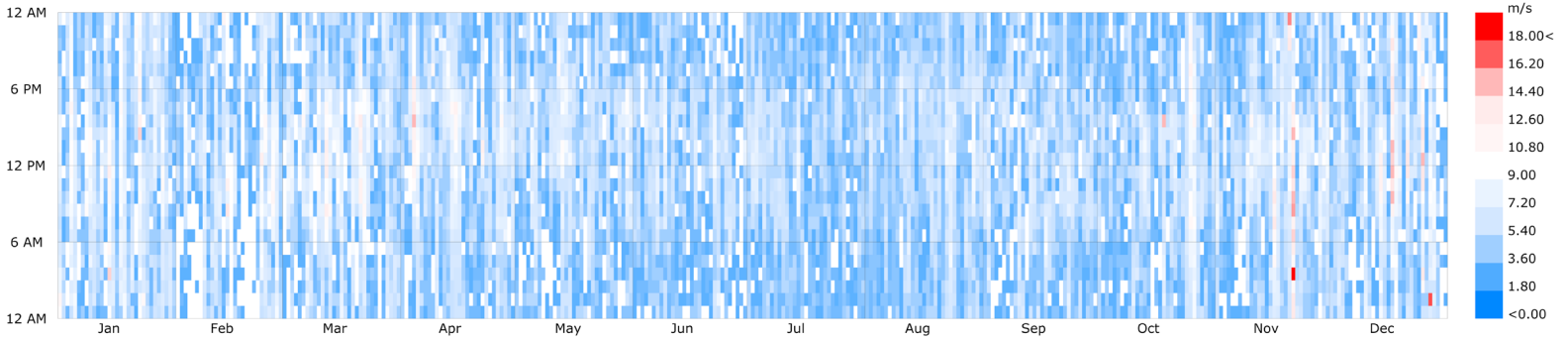
Dry Bulb Temperature (C) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

The time satisfying the conditions: 2157 Hours, 24.6% of the year



Relative Humidity (%) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

The time satisfying the conditions: 6078 Hours, 69.3% of the year



Wind Speed (m/s) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

The time satisfying the conditions: 7993 Hours, 91.2% of the year

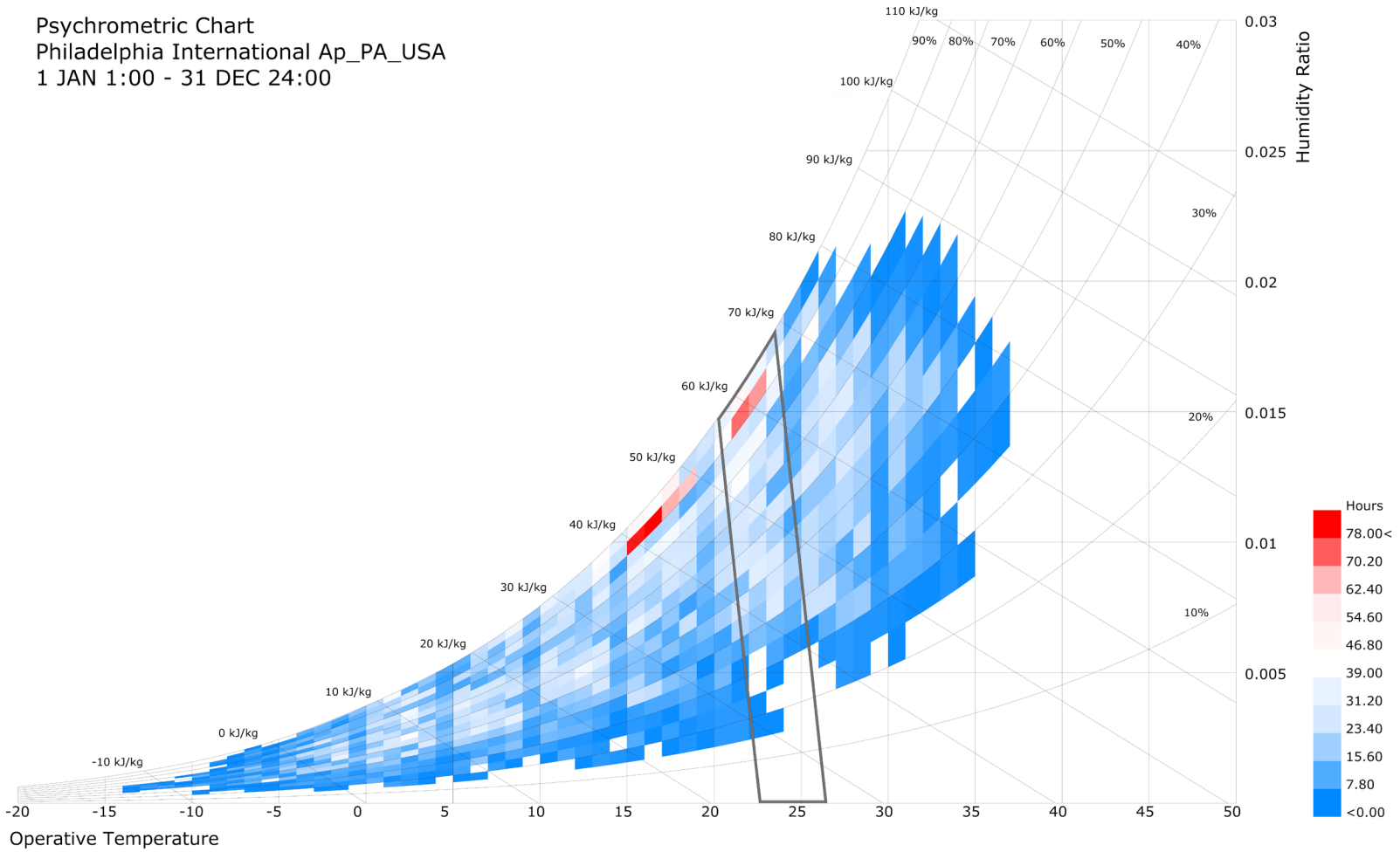
CLIMATE ANALYSIS IN CONDITIONAL SITUATION

Specifically, if it is examined separately, temperature is most problematic, relative humidity is comfortable in 70% of the year, and wind is almost always comfortable.

Thus, major issue would be focused on temperature so far here.

Temperature is the most problematic issue among the three.

CLIMATE ANALYSIS USING PSYCHOMETRIC CHART



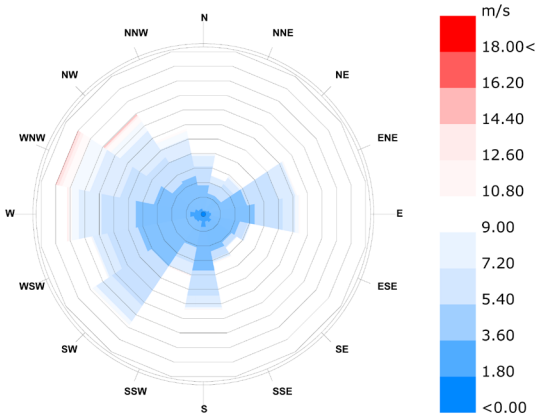
By analysis of the psychometric chart, the wide range of temperature and relatively high humidity lead to total comfort percentage of mere 12.1% of the year.

To manage these issues, ventilation of the room could be helpful, so another analysis concerning wind condition is necessary.

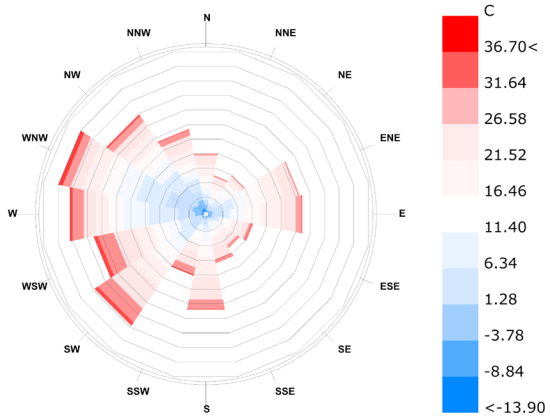
Ventilation is also important because of high humidity.

Total Comfort Percentage: 12.1% of the year

CLIMATE ANALYSIS
OF WIND-ROSE



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 1.0%. = 90 hours.



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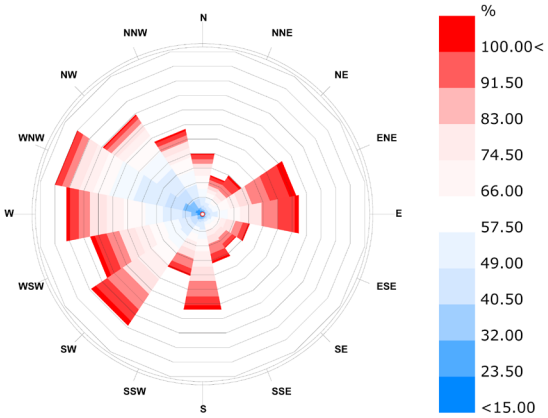
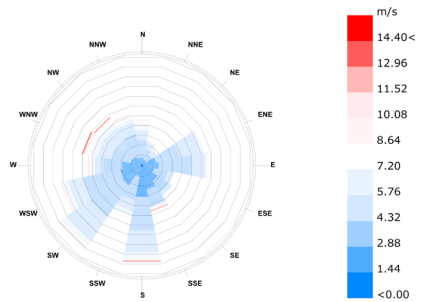


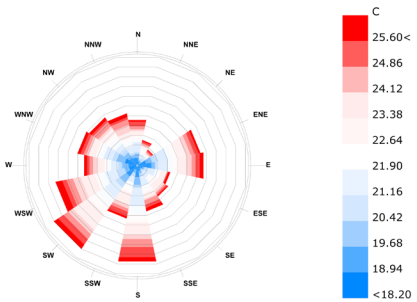
Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Relative Humidity (%)
Calm for 2.81% of the time = 246 hours.
Each closed polyline shows frequency of 1.0%. = 90 hours.

It seems that proper wind for natural ventilation comes from the West.

According to the simulation, wind comes from the West and the East more than the others. Also, considering the temperatures and humidity, proper wind for natural ventilation seems to come from the West. Yet, it is not guaranteed and, more specific analysis is necessary.



Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.46% of the time = 40 hours.
Each closed polyline shows frequency of 0.3%. = 23 hours.
... ...
Conditional Selection Applied:
18 < Dry Bulb Temperature < 26
2095.0 hours of total 8760.0 hours (23.92%).



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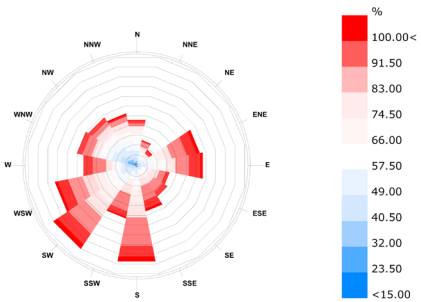

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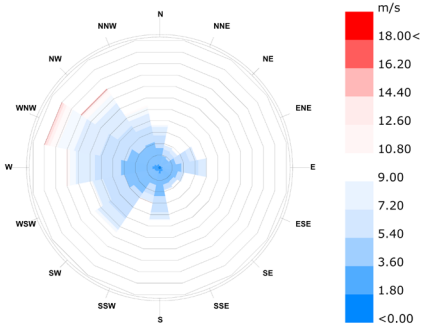
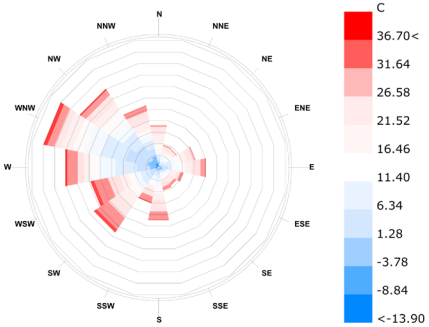
Temperature Condition



Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 1.43% of the time = 125 hours.
Each closed polyline shows frequency of 0.9%. = 79 hours.
... ...
Conditional Selection Applied:
Relative Humidity < 80
5865.0 hours of total 8760.0 hours (66.95%).



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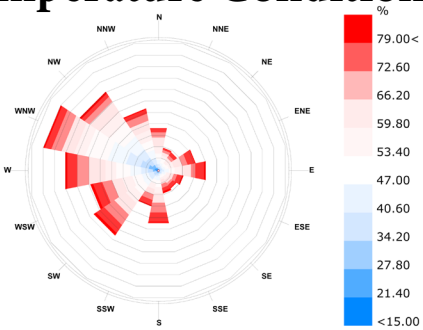

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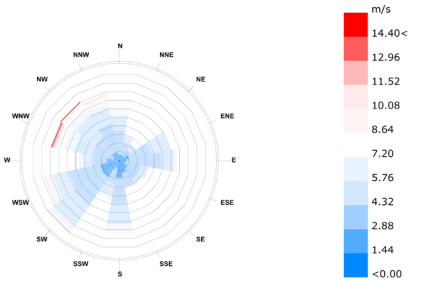
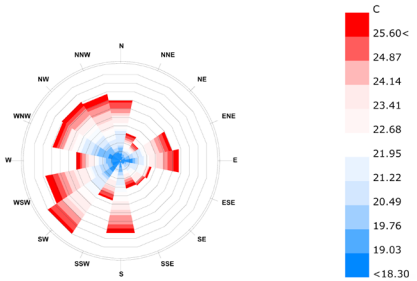
Humidity Condition



Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.18% of the time = 16 hours.
Each closed polyline shows frequency of 0.1%. = 12 hours.
... ...
Conditional Selection Applied:
18 < Dry Bulb Temperature < 26
and Relative Humidity < 80
1253.0 hours of total 8760.0 hours (14.30%).



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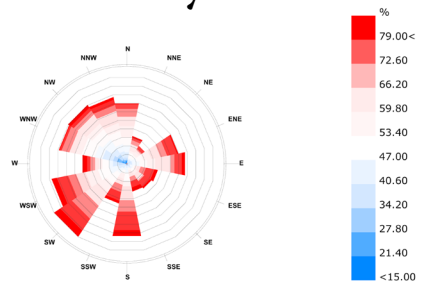

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Temperature & Humidity Condition

CLIMATE ANALYSIS OF WIND-ROSE WITH CONDITIONS

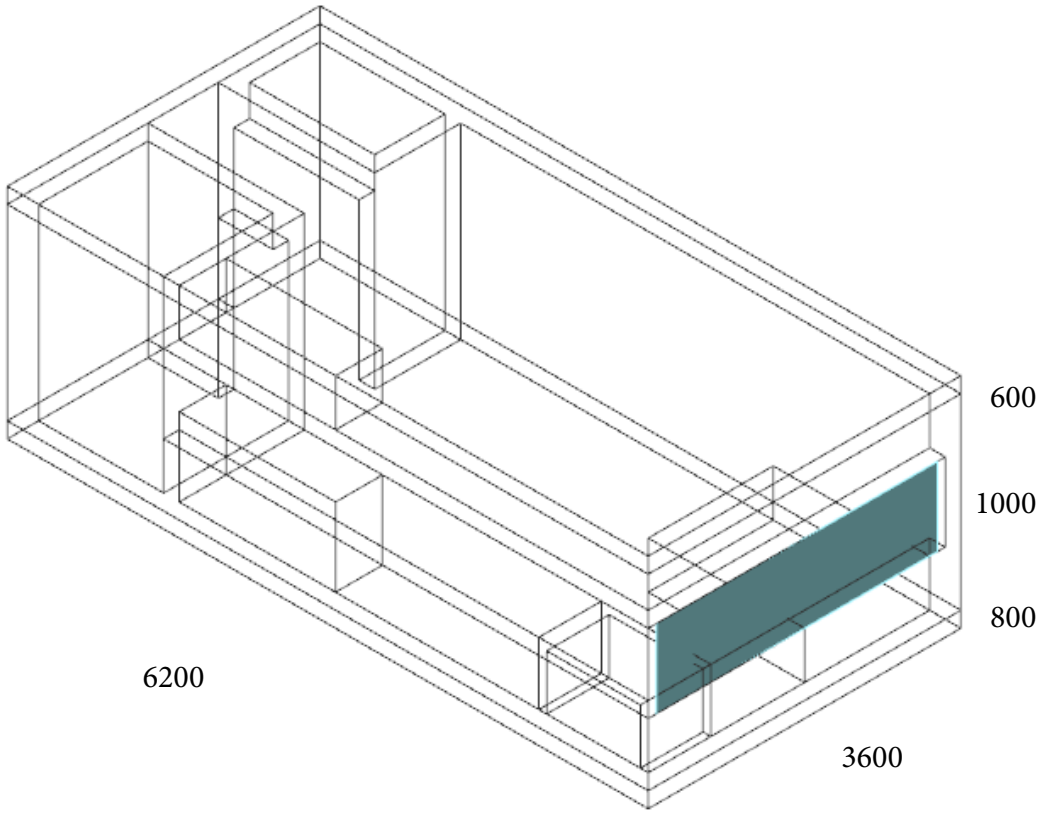
Simulations show that the wind with the temperature between 18 to 26 Celsius mostly comes from the South and Southwest, which is different of the general wind's case.

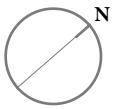
Humid air comes from Northwest mostly.

Comfortable air comes from South and Southwest, so those orientations would be proper for natural ventilation. Yet, humid air comes from the Northwest that should be avoided somehow.

Comfortable air comes from South and Southwest. Humid air comes from Northwest.

Part 2. Base-case Assessment





BASE GEOMETRY OF CURRENT CONDITION

Base geometry in target site is like this. Proportion of it is long width and window is located at the middle of the East.

ENVIRONMENTAL PARAMETERS

Building Program: Midrise APT

Infiltration Rate per Area:
0.000667 m3/s-m2

Number of People per Area:
0.041332 = 1 person / 24.2 m2

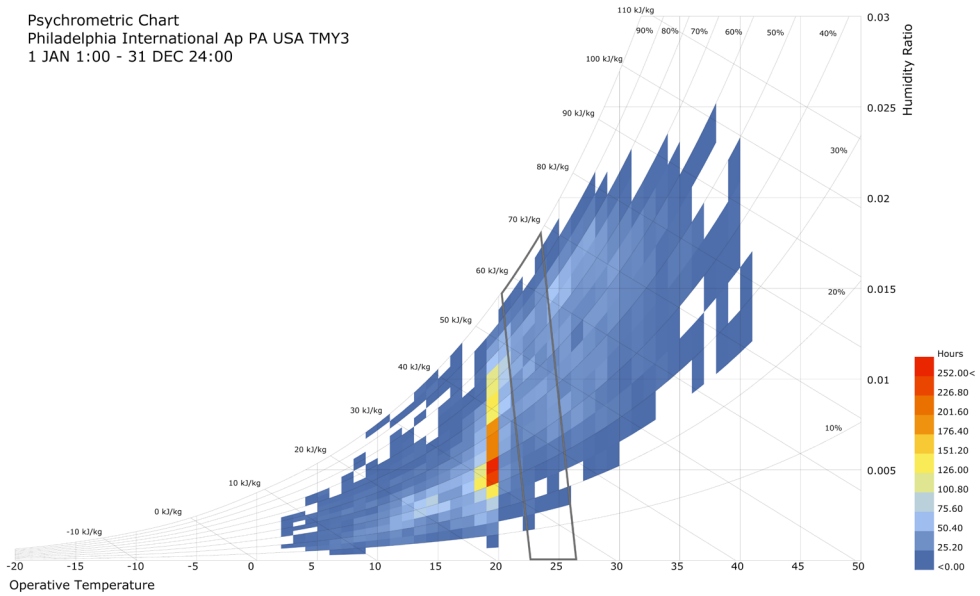
Ventilation Type:
Window Natural Ventilation

Minimum Indoor Temperature for Natural Ventilation: 20 C

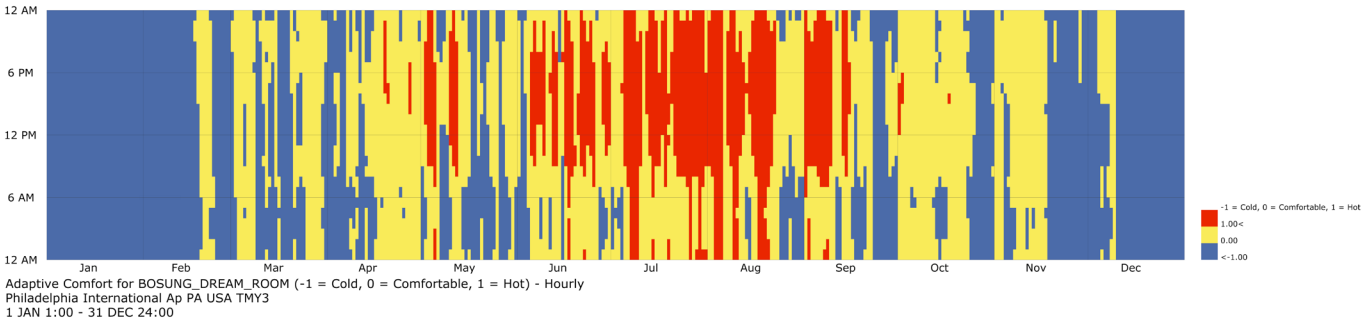
Maximum Outdoor Temperature for Natural Ventilation: 28 C

CONSTRUCTION PARAMETERS

ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall Mass Climatezone 4 (1.54)
Window: ExtWindow Metal Climatezone 4-6 (0.32)
Floor: ExtRoof Metal Climatezone 2-5 (3.06)
Floor: AtticeFloor Climatezone 2-7 (6.33)

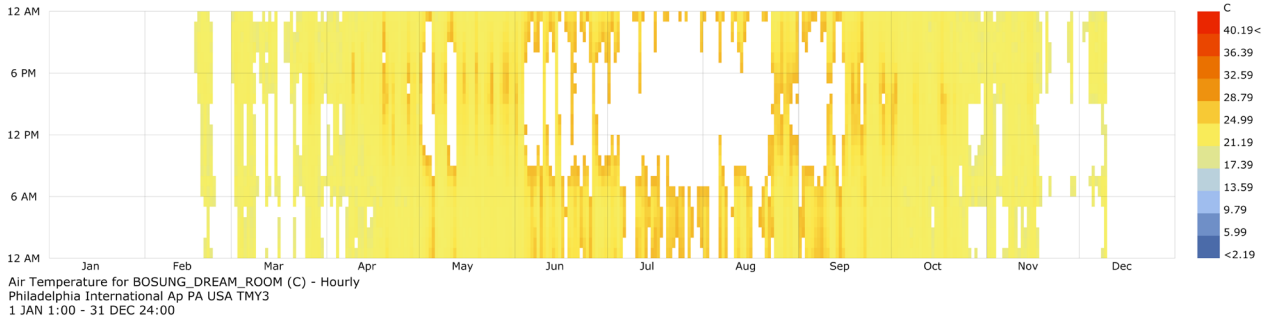


Total Comfort Percentage: 12.1% of the year



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

Annual Total Comfortable Time: 42 %
Percent of Hot: 14 %
Percent of Cold: 43 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 53%

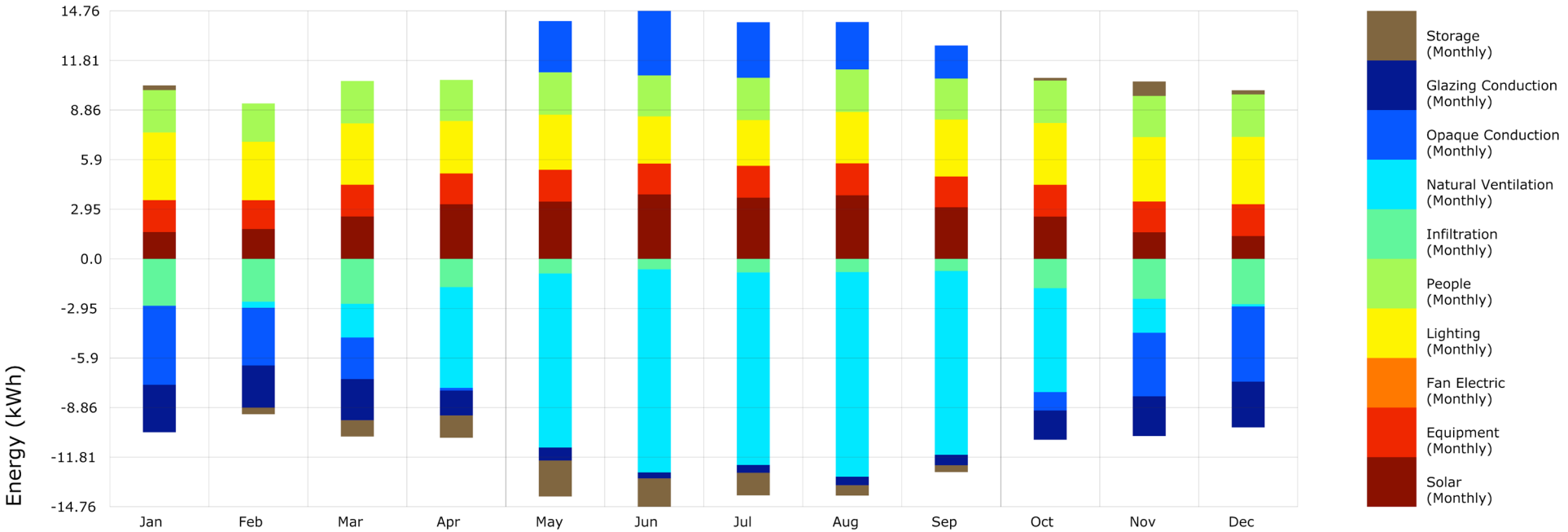
COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

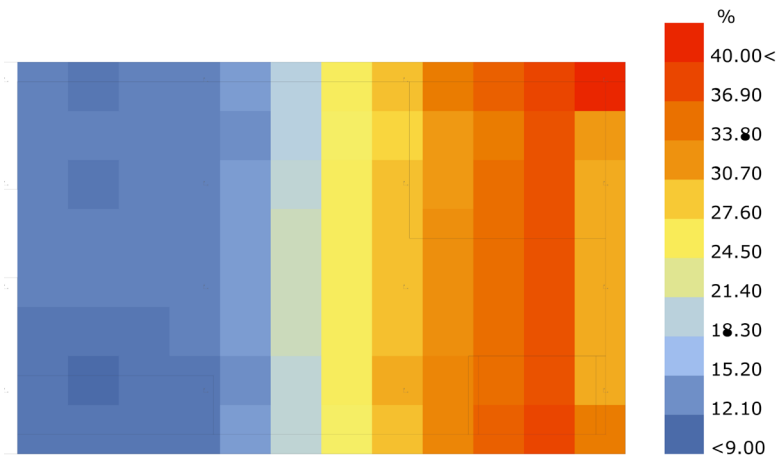
Interestingly, total comfort time of basic simulation is same as that of outdoor comfort in psychometric chart analysis. The value is quite low and need to have a proper strategy to improve this situation.

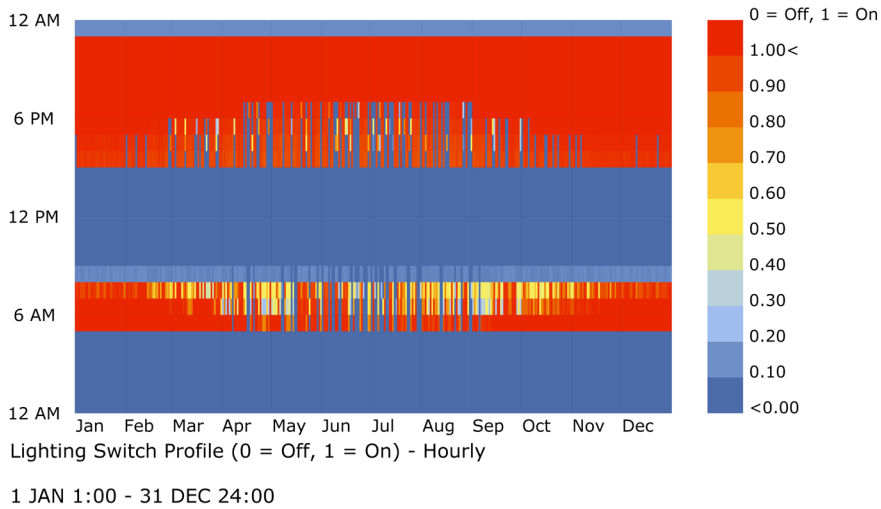
In psychometric chart, much time is located in lower temperature than comfort polygon. Also, in adaptive comfort chart, between uncomfortable times, cold hours are more than hot ones.

Moreover, indoor air temperature chart indicates that it is almost uncomfortable in winter time.

Between uncomfortable hours, cold ones are more.







The reason for cold times are analyzed. Above all, solar heat gain in winter is much low. Simultaneously, daylight autonomy of the West side of the room is poor because there is a window only in the East side. Due to poor daylight, in even Summer time, electric light is used frequently.

Both of solar heat gain and daylight comfort are problem now.

Base-case Assessment Summary:

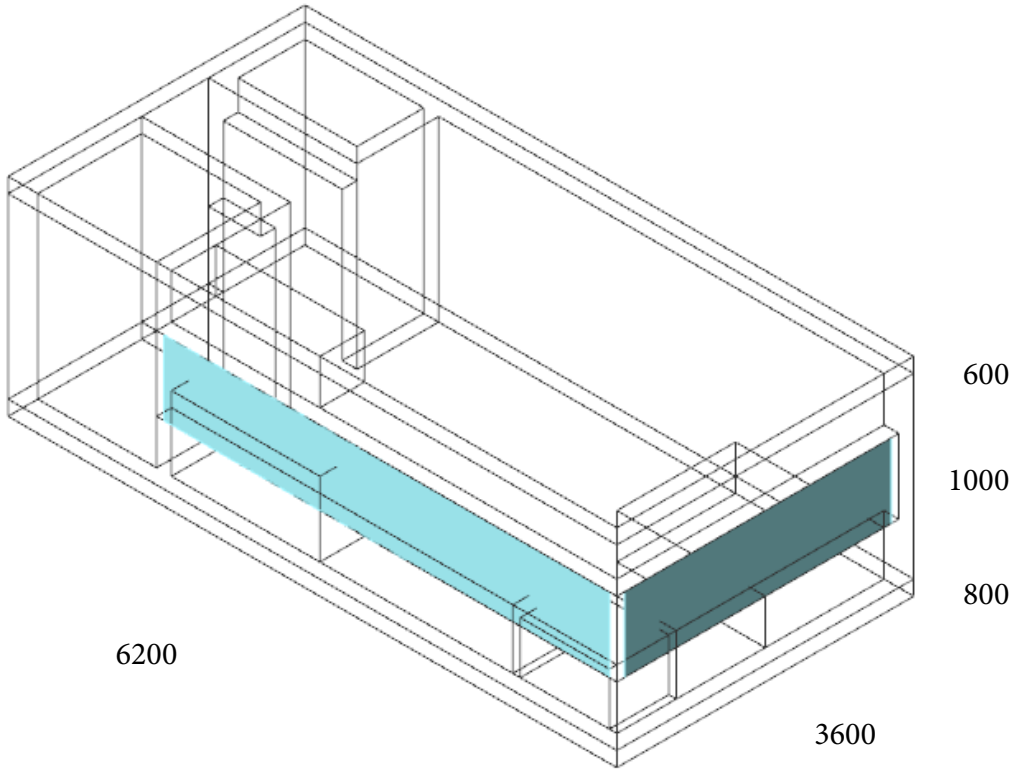
Most of uncomfortable time is because of cold more than hot. Solar heat gain and daylight comfort are not good simultaneously, because there is a window only facing the East.

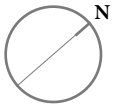
Next Strategy:
Increasing glazing in the proper orientation

Part 3. Design Iterations to Deal with the Current Issues

ADDING A SOUTH WINDOW

Based on the base-case assessment, it is necessary to add a window with the South orientation.





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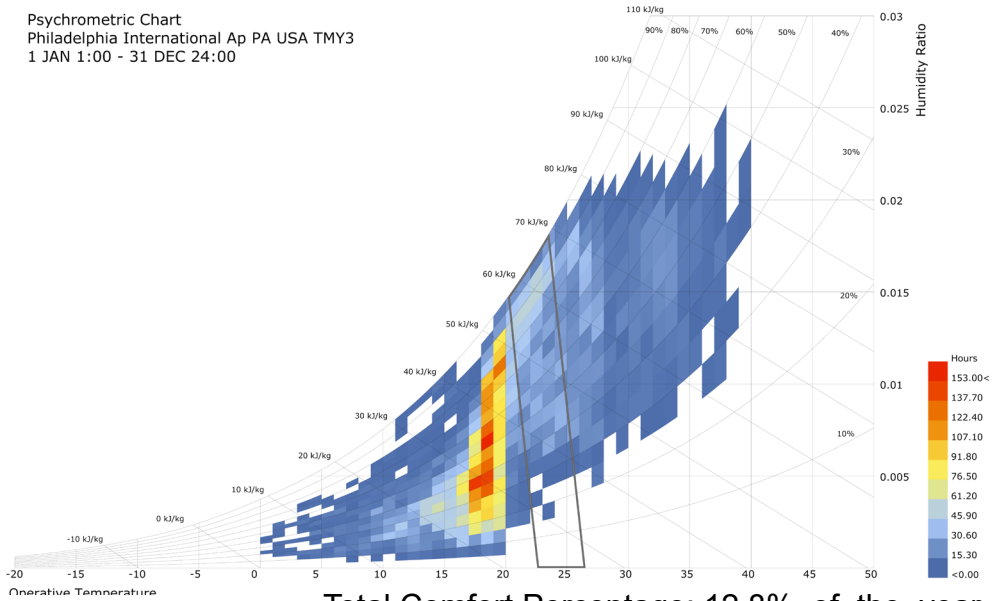
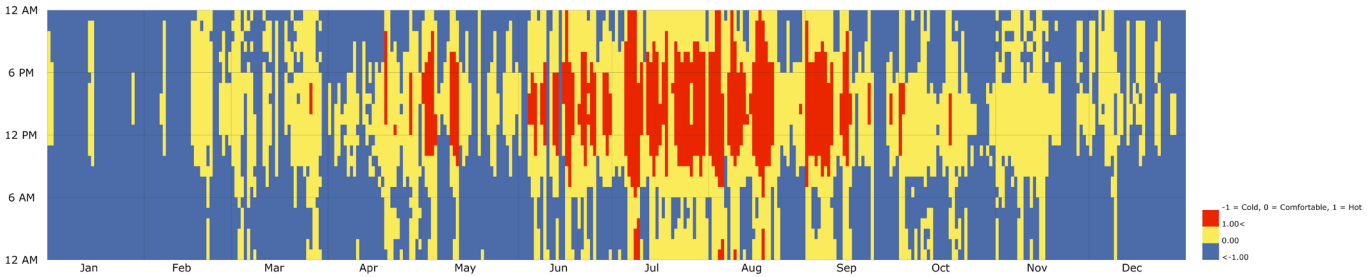
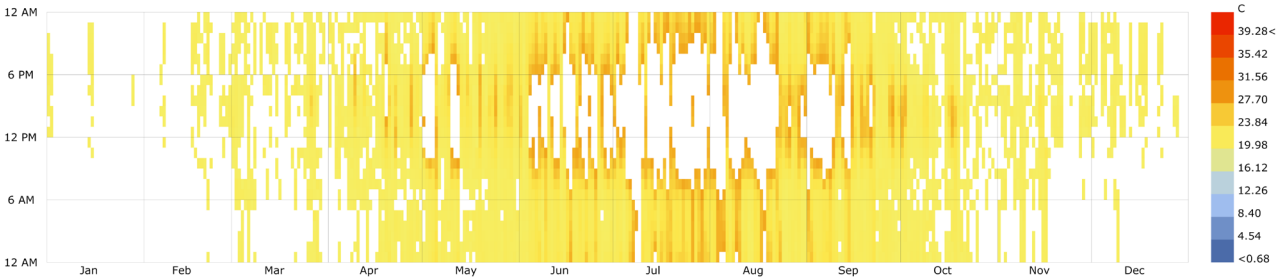


Total Comfort Percentage: 12.8% of the year



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

Annual Total Comfortable Time: 37 %
Percent of Hot: 10 %
Percent of Cold: 53 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

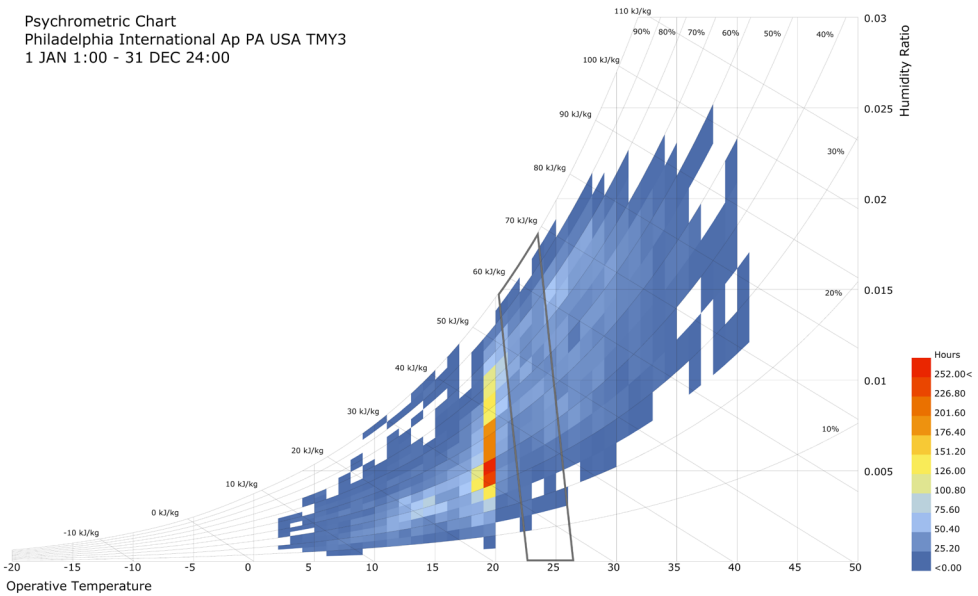
Percentage of Temperature between 18 and 26: 52%

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage increased, even if it's not much. However, only with this, it is difficult to say that the number of cold hours decreased.

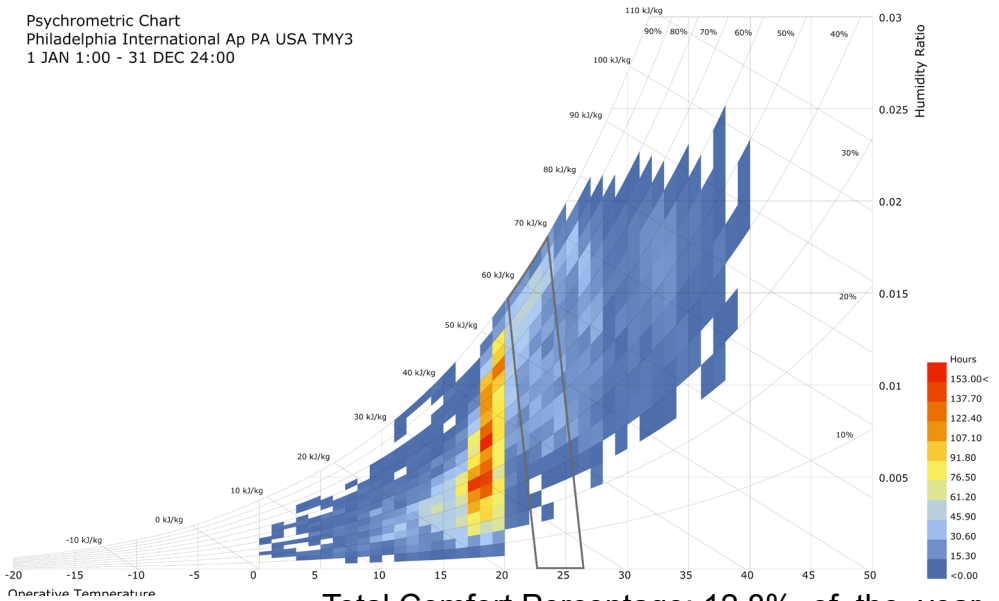
If I see the adaptive comfort charts and comfortable temperature graphs, percent of cold hour increased, which is opposite to expectation. Yet, rather, hot hours decreased.

Total comfort slightly changed.
Cold hours increased opposite to expectation.
Hot hours increased.



Total Comfort Percentage: 12.1% of the year

Only East Glazing



Total Comfort Percentage: 12.8% of the year

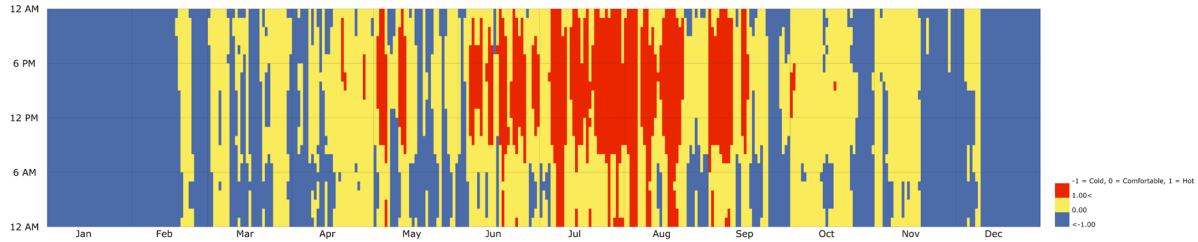
East & South Glazing

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage increased, even if it's not much. However, only with this, it is difficult to say that the number of cold hours decreased.

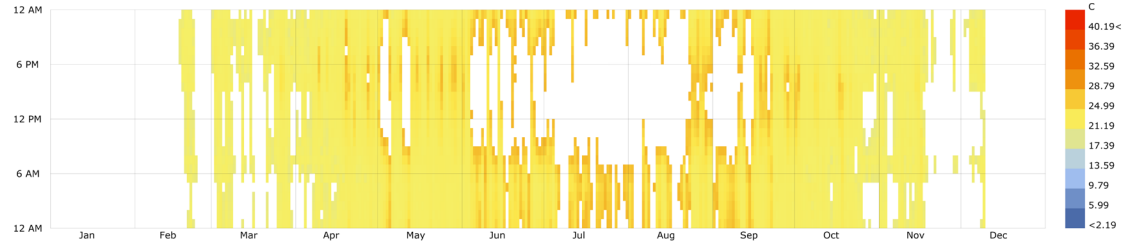
If I see the adaptive comfort charts and comfortable temperature graphs, percent of cold hour increased, which is opposite to expectation. Yet, rather, hot hours decreased.

Total Comfort:
12.1% to 12.8%



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

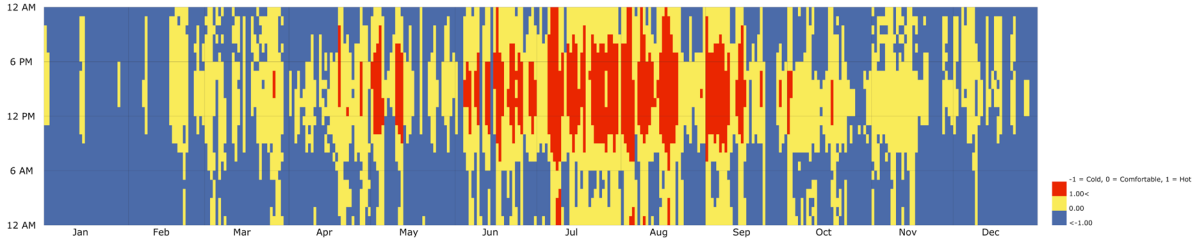
Annual Total Comfortable Time: 42 %
Percent of Hot: 14 %
Percent of Cold: 43 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

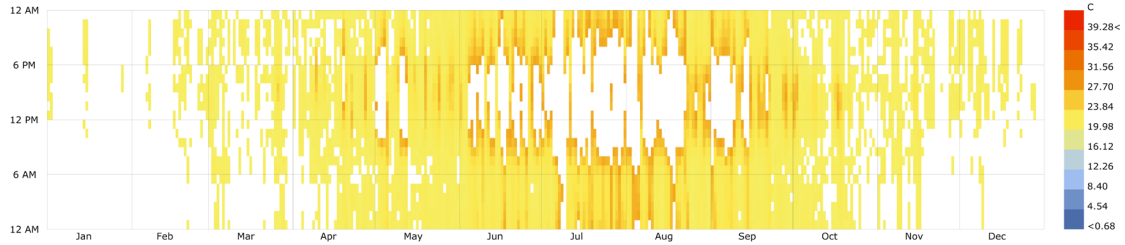
Percentage of Temperature between 18 and 26: 53%

Only East Glazing



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

Annual Total Comfortable Time: 37 %
Percent of Hot: 10 %
Percent of Cold: 53 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 52%

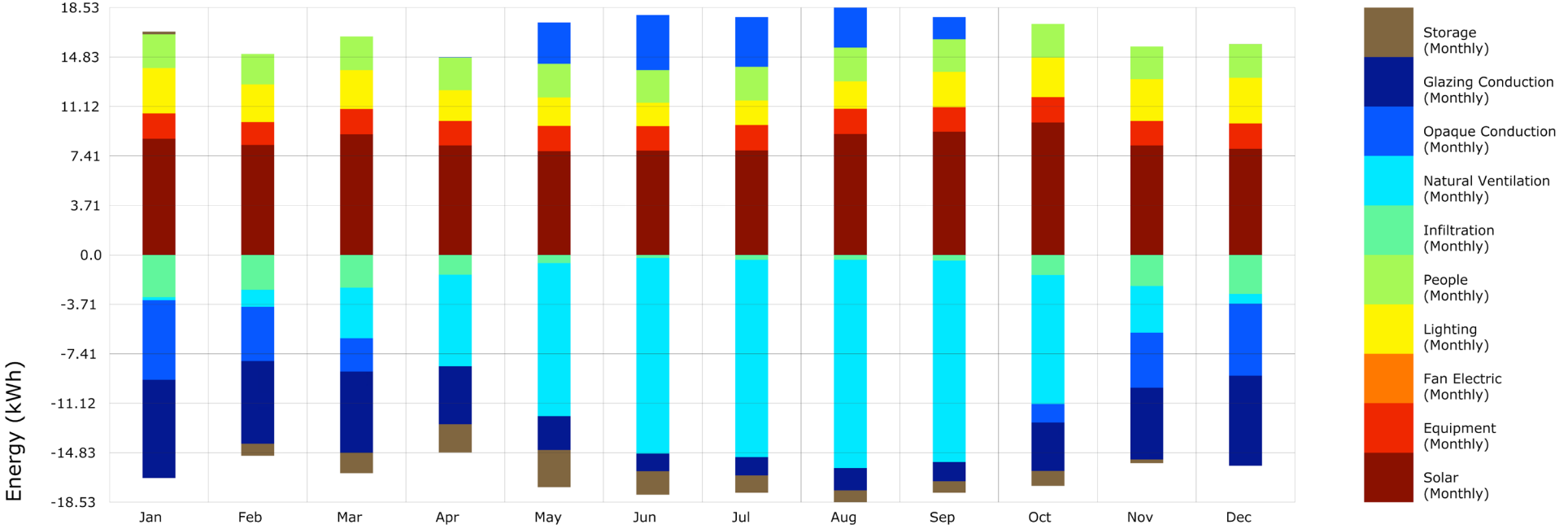
East & South Glazing

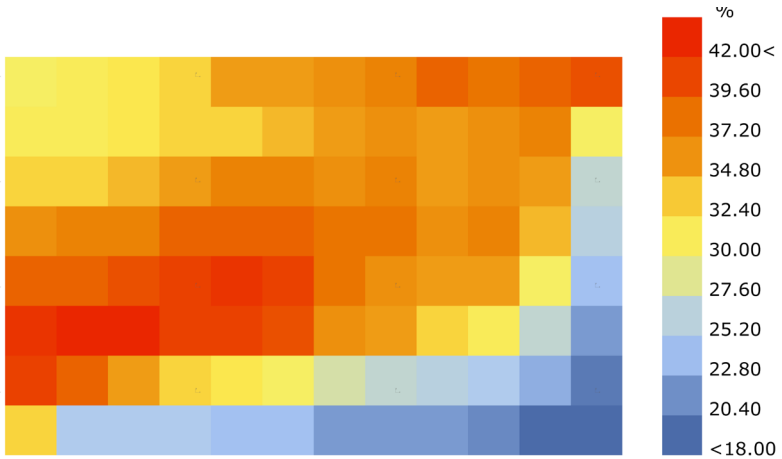
COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage increased, even if it's not much. However, only with this, it is difficult to say that the number of cold hours decreased.

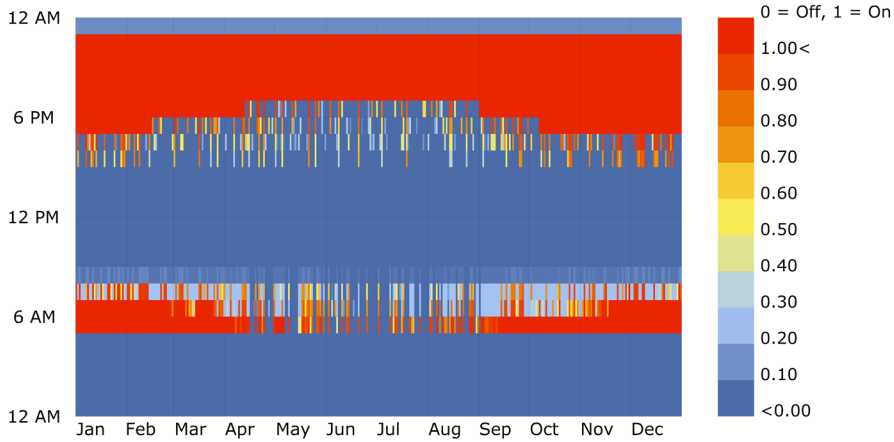
If I see the adaptive comfort charts and comfortable temperature graphs, percent of cold hour increased, which is opposite to expectation. Yet, rather, hot hours decreased.

Cold hours: 43% to 53%
Hot hours: 14% to 10%





Daylight Autonomy
UDI 100 ~ 2000 lux



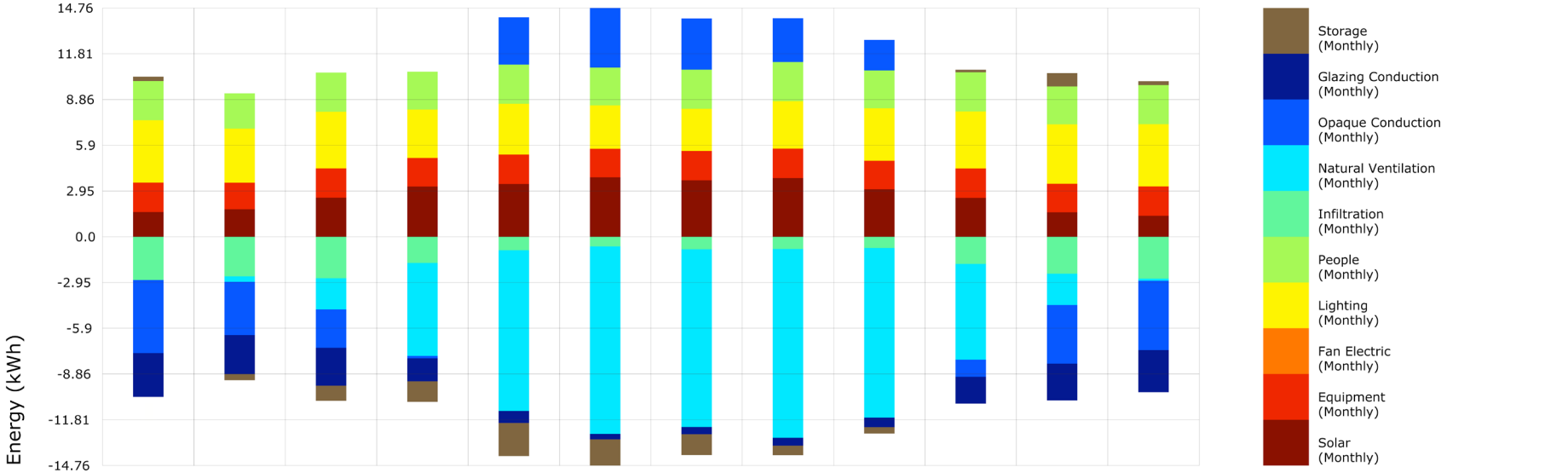
Lighting Switch Profile (0 = Off, 1 = On) - Hourly

1 JAN 1:00 - 31 DEC 24:00

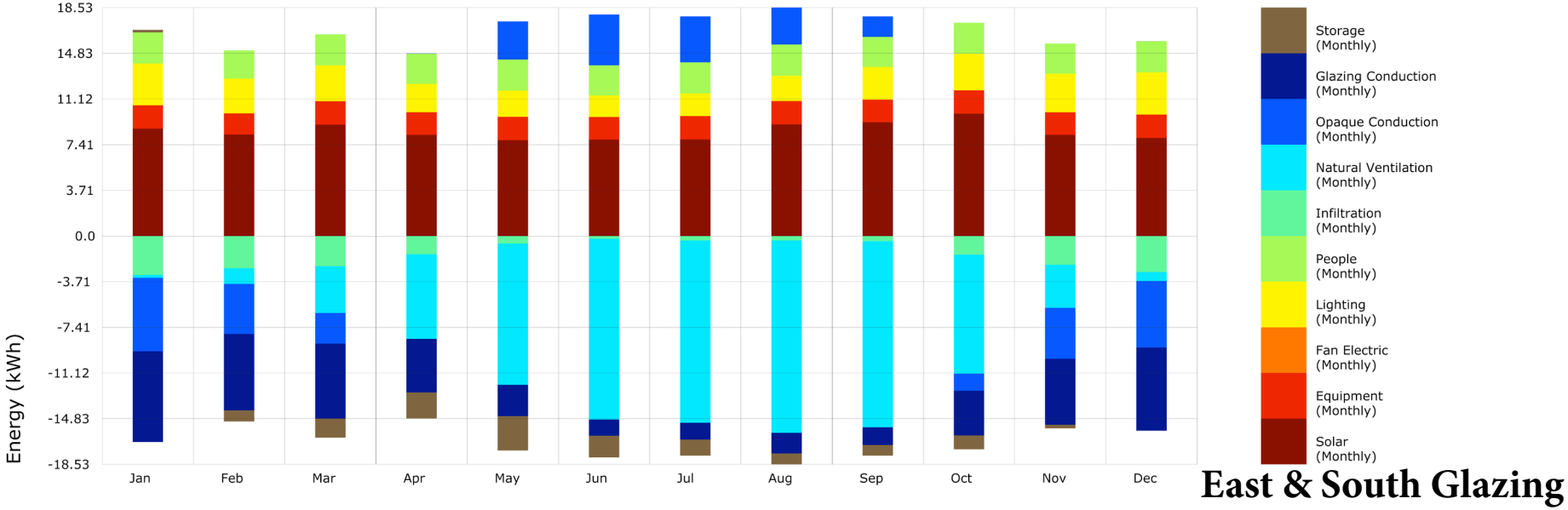
Average of the Whole Space: 32 %

In energy balance chart, energy gain from solar heat takes better balance; in Summer it gets less than in Winter. Also, energy consumed from electric light become less. Yet, because of more glazing, energy loss through glazing in winter increased. Daylighting comfort improved by 10%, and, electric light using hours become much less than before.

Energies concerning solar heat and electric light improved, and glazing got worse. Daylighting comfort become better, and electric light usage decreased.



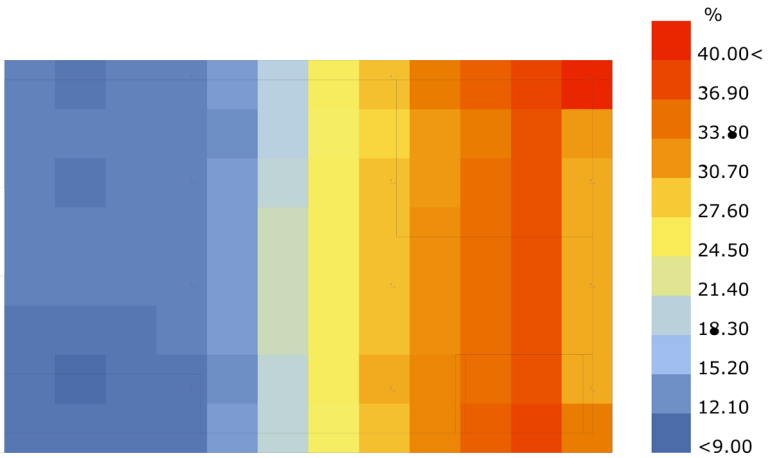
Only East Glazing



East & South Glazing

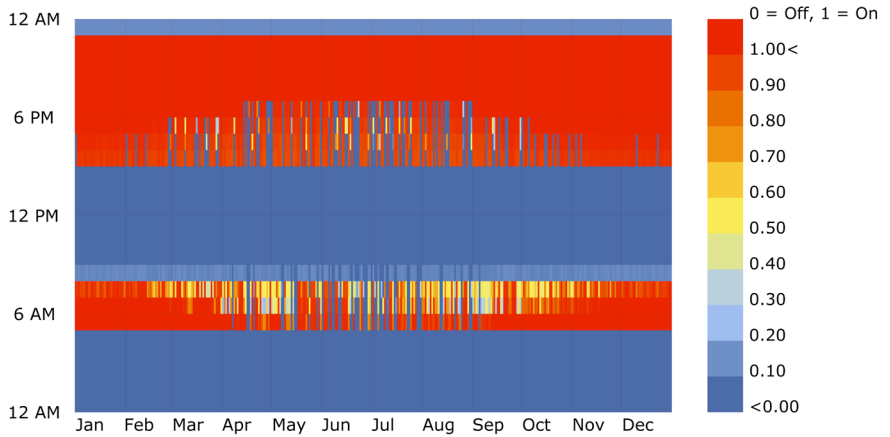
In energy balance chart, energy gain from solar heat takes better balance; in Summer it gets less than in Winter. Also, energy consumed from electric light become less. Yet, because of more glazing, energy loss through glazing in winter increased. Daylighting comfort improved by 10%, and, electric light using hours become much less than before.

Energies concerning solar heat and electric light improved, and glazing got worse.



Daylight Autonomy
UDI 100 ~ 2000 lux

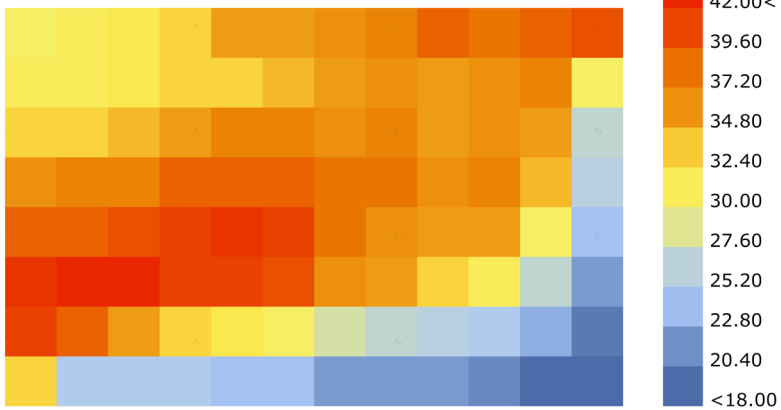
Average of the Whole Space: 22 %



Lighting Switch Profile (0 = Off, 1 = On) - Hourly

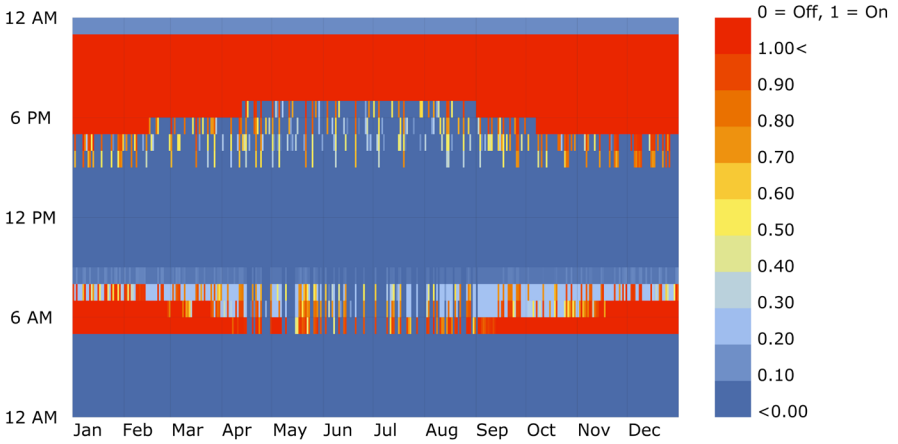
1 JAN 1:00 - 31 DEC 24:00

Only East Glazing



Daylight Autonomy
UDI 100 ~ 2000 lux

Average of the Whole Space: 32 %



Lighting Switch Profile (0 = Off, 1 = On) - Hourly

1 JAN 1:00 - 31 DEC 24:00

East & South Glazing

In energy balance chart, energy gain from solar heat takes better balance; in Summer it gets less than in Winter. Also, energy consumed from electric light become less. Yet, because of more glazing, energy loss through glazing in winter increased. Daylighting comfort improved by 10%, and, electric light using hours become much less than before.

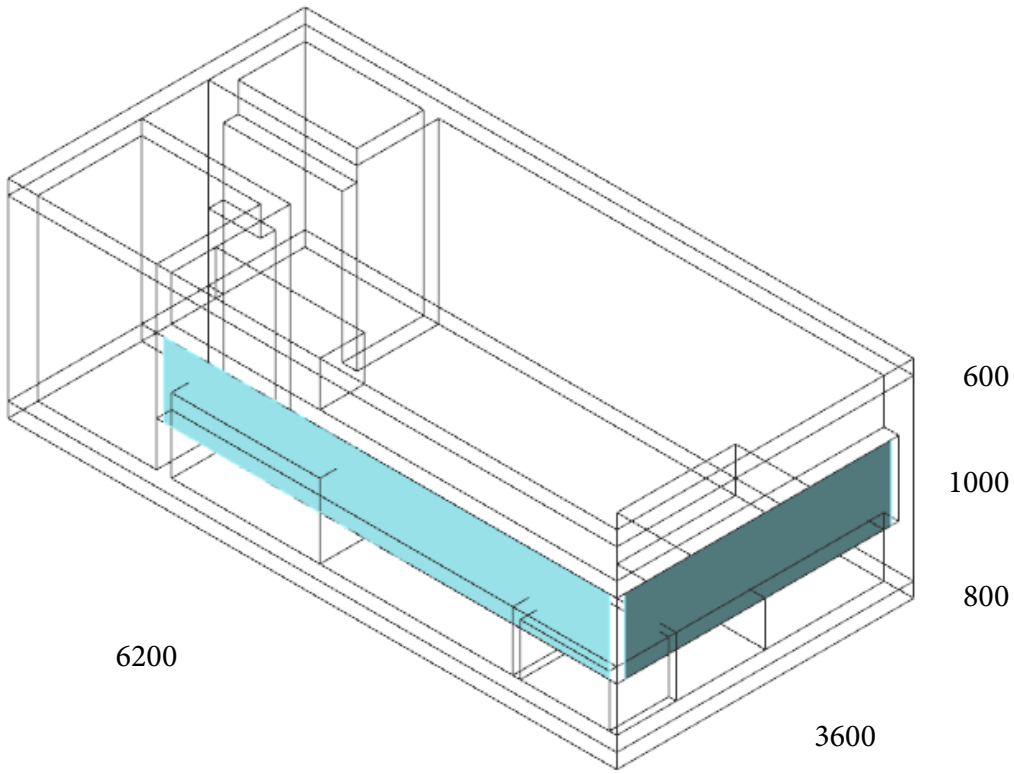
Daylighting comfort: 22% to 32%, and electric light usage decreased.

Adding South glazing Summary:

It become colder.
Energies concerning solar heat and electric light improved,
and glazing got worse.
Daylighting comfort become better, and electric light usage decreased.

Next Strategy:

To solve the colder issue and energy loss from glazings,
construction properties will be changed.



CHANGING CONSTRUCTION PROPERTIES

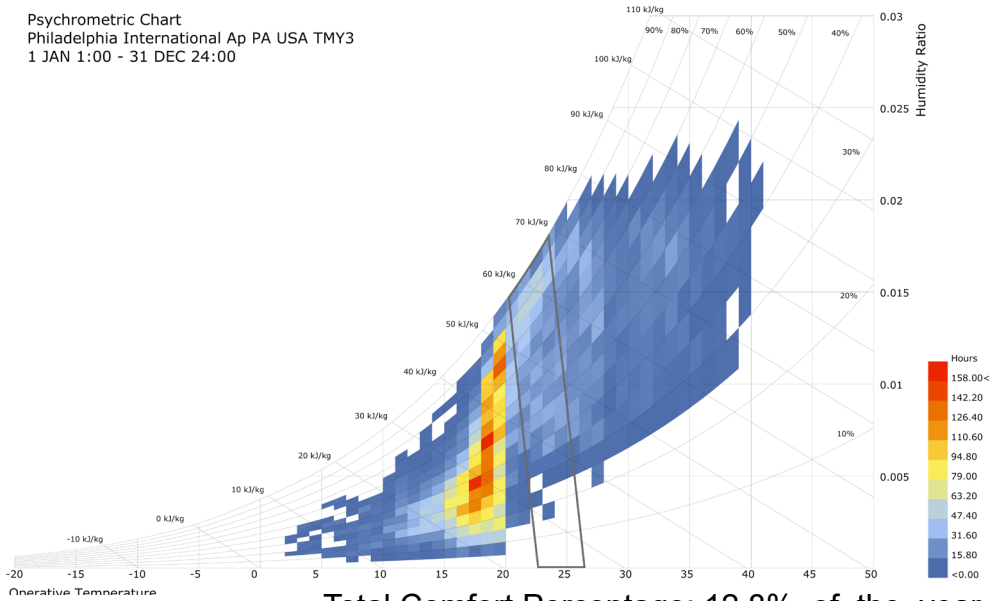
Based on the former simulation, it is necessary to improve R-Value of the construction materials.

FORMER CONSTRUCTION PARAMETERS

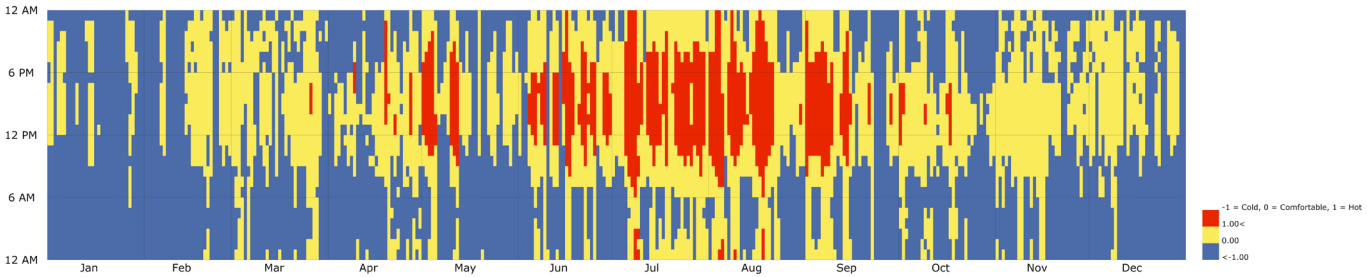
ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall Mass Climatezone 4 (**1.54**)
Window: ExtWindow Metal Climatezone 4-6 (**0.32**)
Floor: ExtRoof Metal Climatezone 2-5 (**3.06**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

CHANGED CONSTRUCTION PARAMETERS

ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall STeelframe Climatezone Alt-Res 2-6 (**2.60**)
Window: ExtWindow NonMetal Climate zone 4 (**0.44**)
Floor: ExtRoof Iead Climatezone 2-8 (**3.53**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

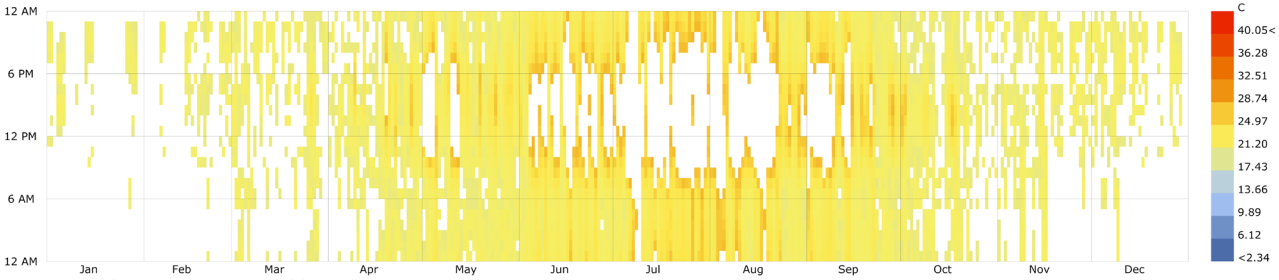


Total Comfort Percentage: 12.8% of the year



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

Annual Total Comfortable Time: 39 %
Percent of Hot: 10 %
Percent of Cold: 51 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 53%

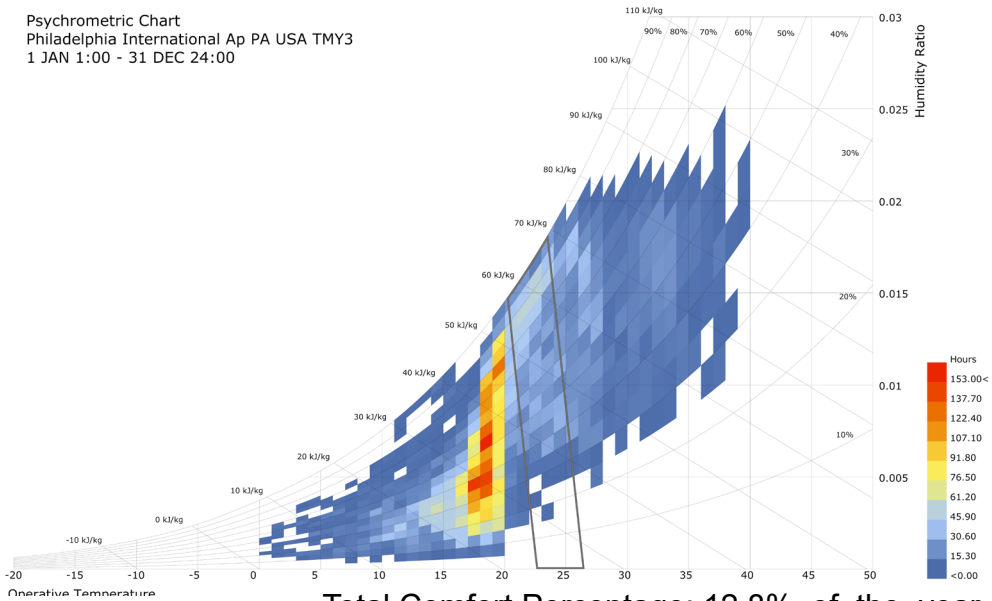
COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage didn't changed but cold hours decreased as expected.

Also, Comfortable hours increased, and cold hours decreased.

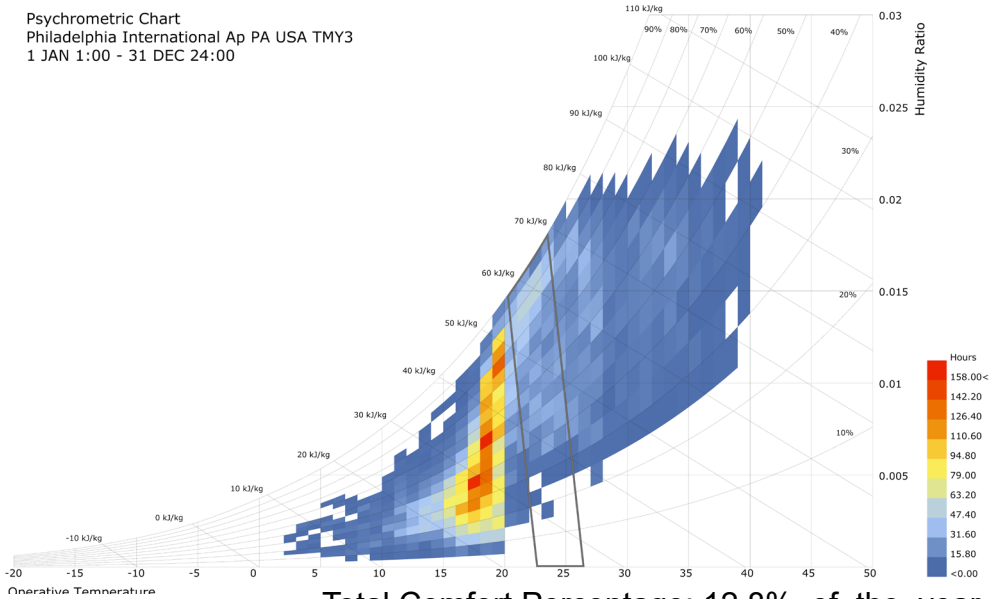
However, still cold hours are many.

Cold hours decreased, yet, still many.



Total Comfort Percentage: 12.8% of the year

Before



Total Comfort Percentage: 12.8% of the year

Construction Properties Changed

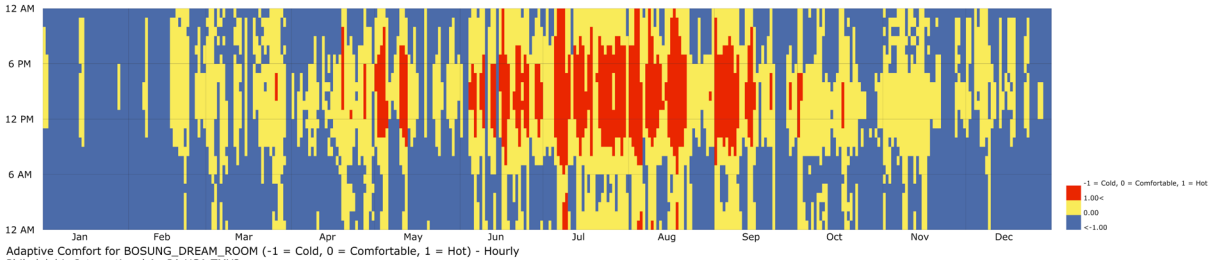
COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage didn't changed but cold hours decreased as expected.

Also, Comfortable hours increased, and cold hours decreased.

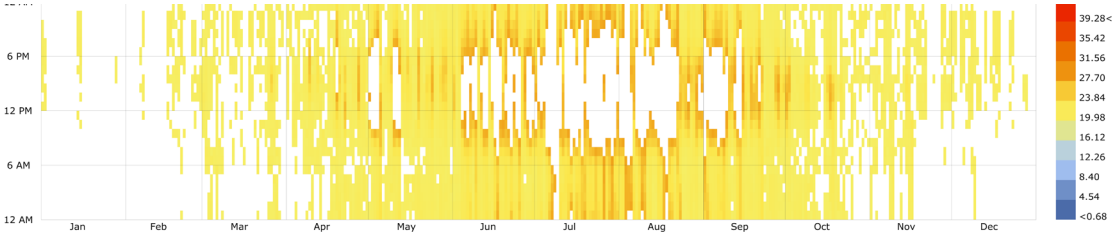
However, still cold hours are many.

Cold hours decreased.



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

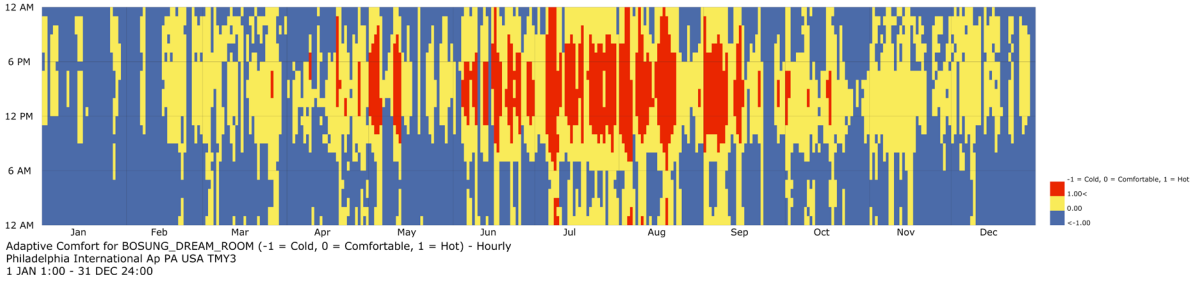
Annual Total Comfortable Time: 37 %
Percent of Hot: 10 %
Percent of Cold: 53 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

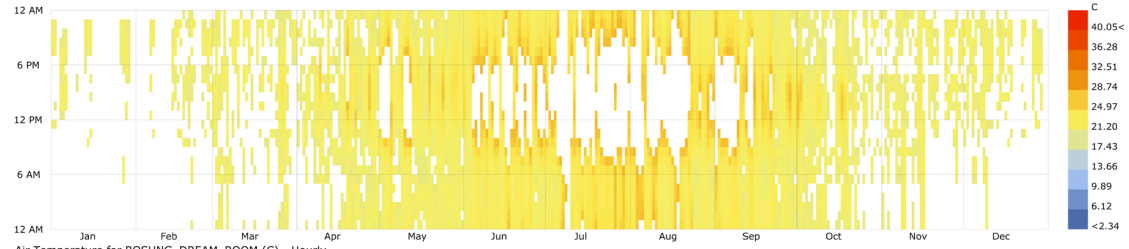
Percentage of Temperature between 18 and 26: 52%

Before



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

Annual Total Comfortable Time: 39 %
Percent of Hot: 10 %
Percent of Cold: 51 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 53%

Construction Properties Changed

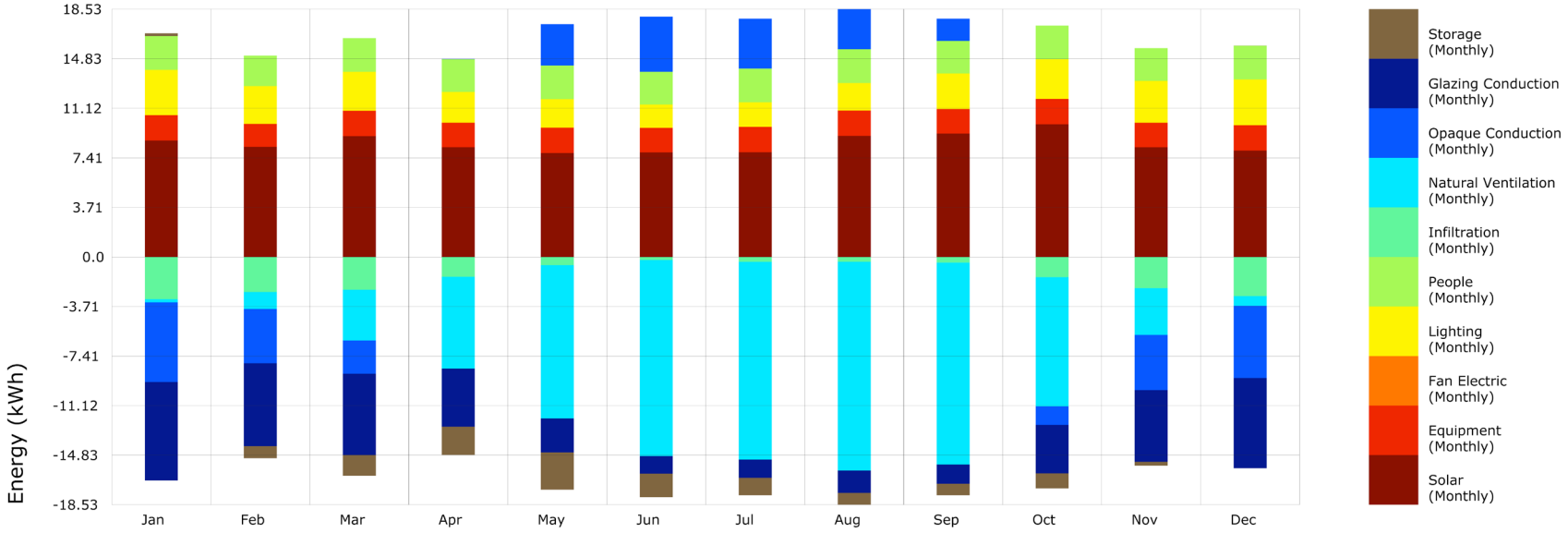
COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage didn't changed but cold hours decreased as expected.

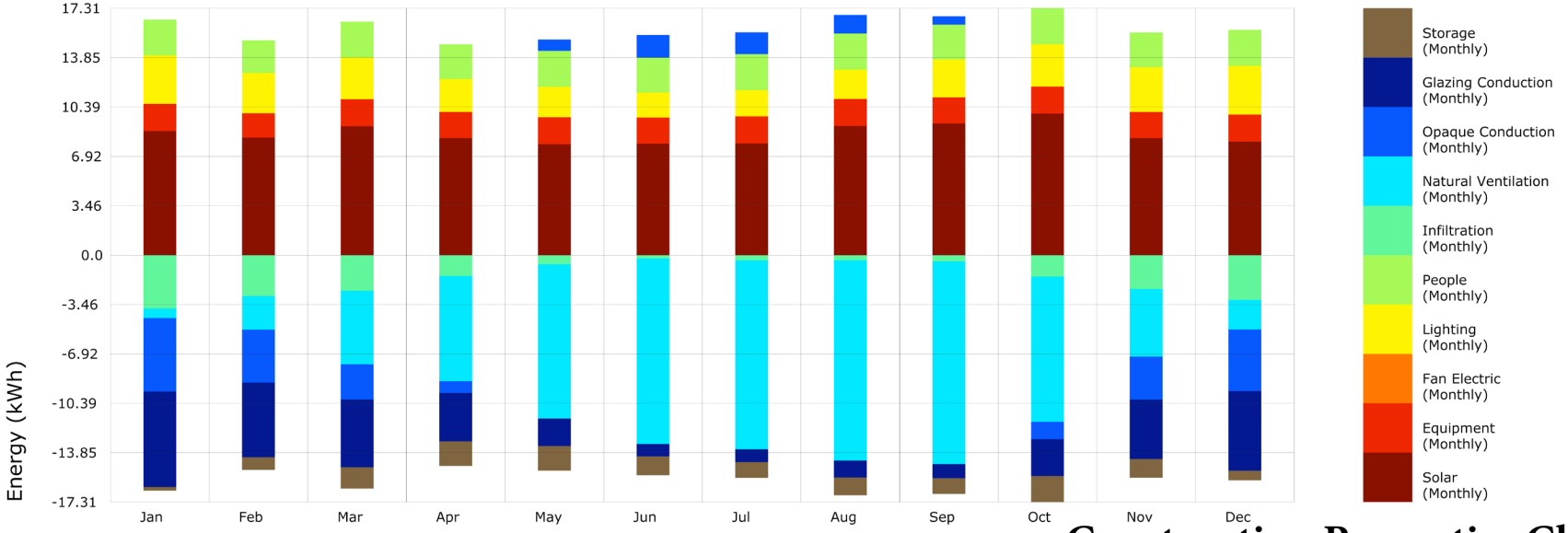
Also, Comfortable hours increased, and cold hours decreased.

However, still cold hours are many.

Cold hours: 53% to 51%
Hot hours: 10% to 10%



Before



Construction Properties Changed

In energy balance chart, energy issue from construction is better, still need to be improved more.

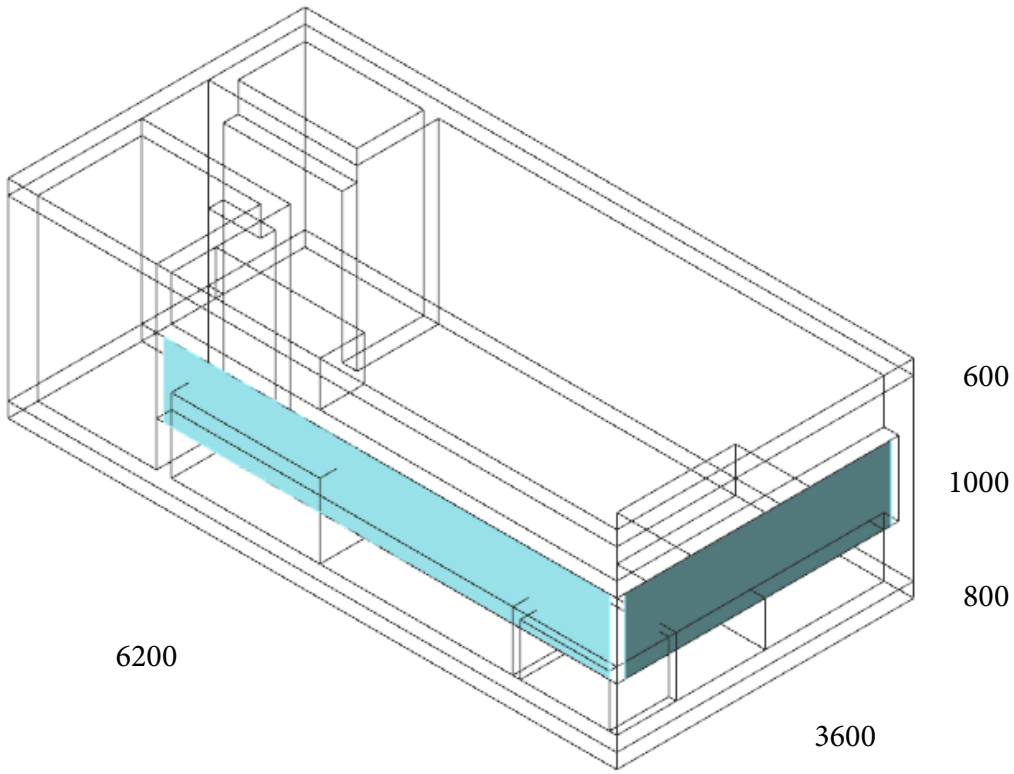
Energy issue from construction is better, still need to be improved more.

Changing Construction Summary:

Cold hour decreased, and construction issue improved in energy balance.

Next Strategy:

Increase R-Value of the construction materials more.



CHANGING CONSTRUCTION PROPERTIES

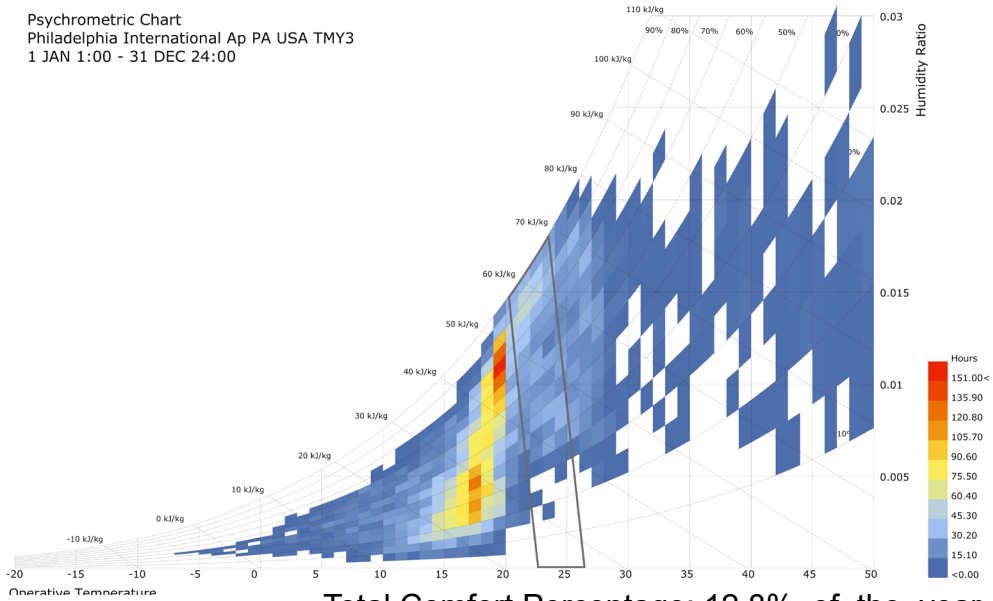
Based on the former simulation, it is necessary to improve R-Value of the construction materials.

FORMER CONSTRUCTION PARAMETERS

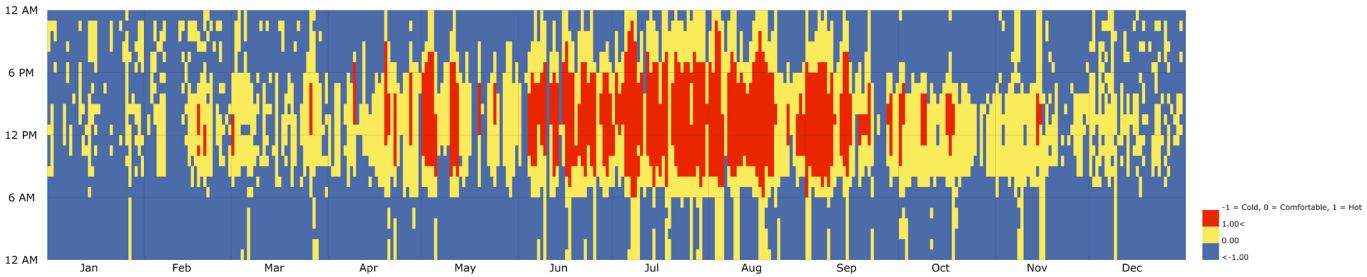
ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall STeelframe Climatezone Alt-Res 2-6 (**2.60**)
Window: ExtWindow NonMetal Climate zone 4 (**0.44**)
Floor: ExtRoof Iead Climatezone 2-8 (**3.53**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

CHANGED CONSTRUCTION PARAMETERS

ASHRAE 90.1-2010 (R-Value)
Wall: (**3.52**)
Window: U-Value, Triple pane argon fiiled glazing (**0.56**)
Floor: (**7.04**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

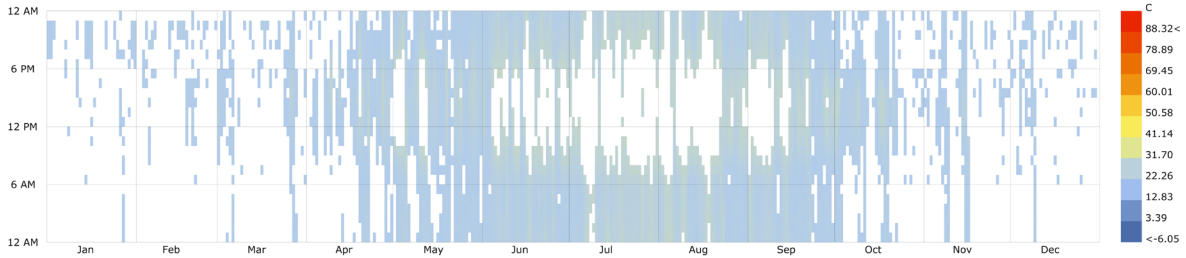


Total Comfort Percentage: 12.8% of the year



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

Annual Total Comfortable Time: 30 %
Percent of Hot: 12 %
Percent of Cold: 58 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 44%

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

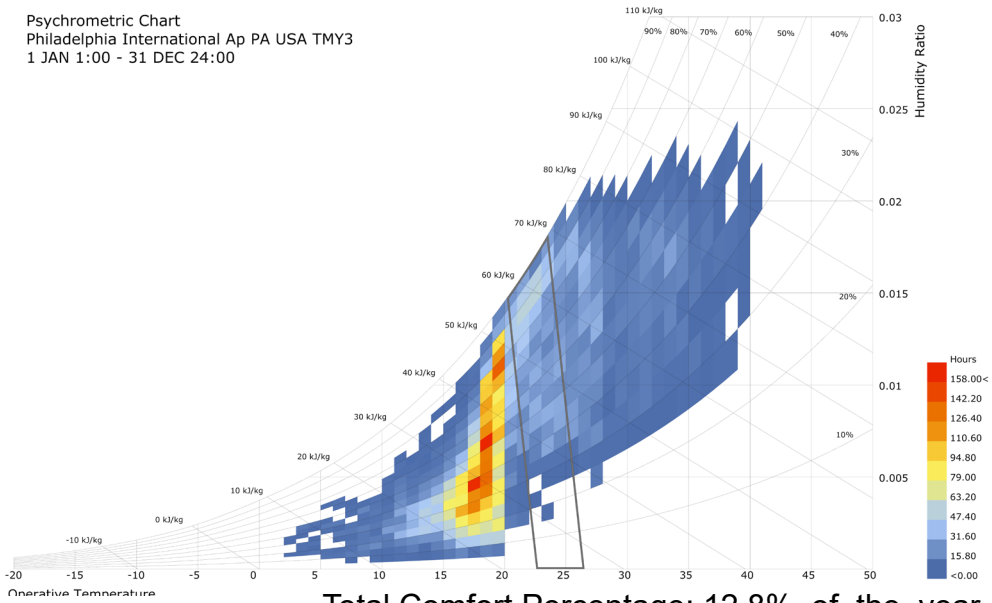
In the psychometric charts, it shows that total comfort percentage didn't changed but hot hours increased not as expected.

Also, Comfortable hours decreased, and cold hours increased.

There should be proper R-Value.

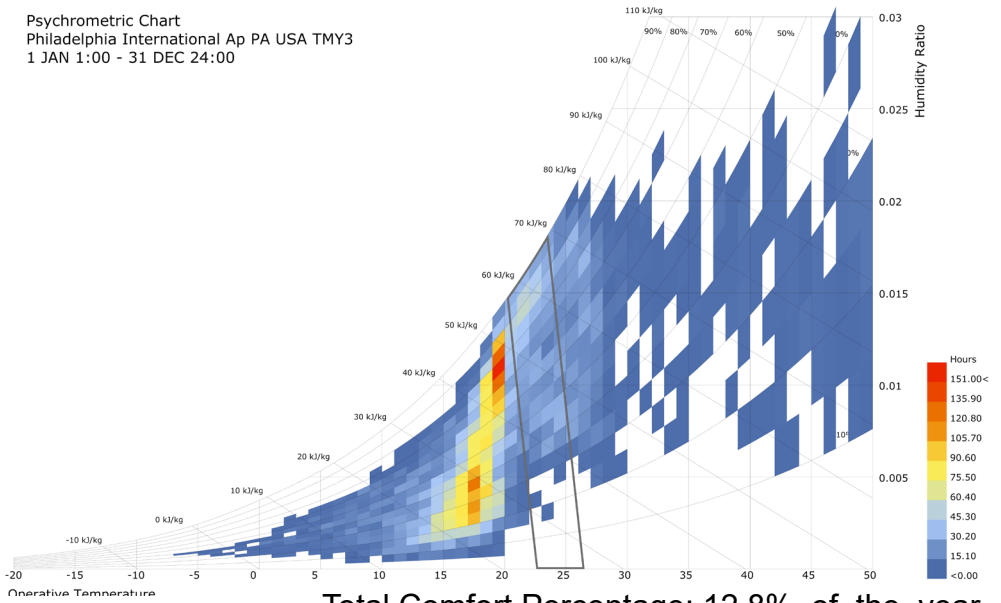
And to deal with the hot hours, another method should be considered. There's limitation only by changing construction properties. Thus, louvers will be applied.

There should be proper R-Value.



Total Comfort Percentage: 12.8% of the year

Before



Total Comfort Percentage: 12.8% of the year

Construction Properties Changed

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

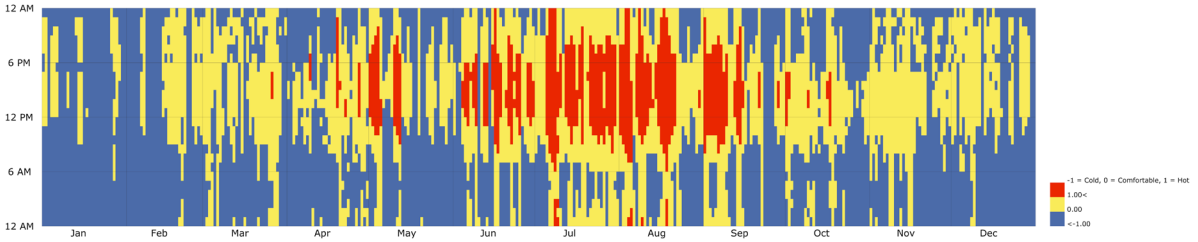
In the psychometric charts, it shows that total comfort percentage didn't changed but hot hours increased not as expected.

Also, Comfortable hours decreased, and cold hours increased.

There should be proper R-Value.

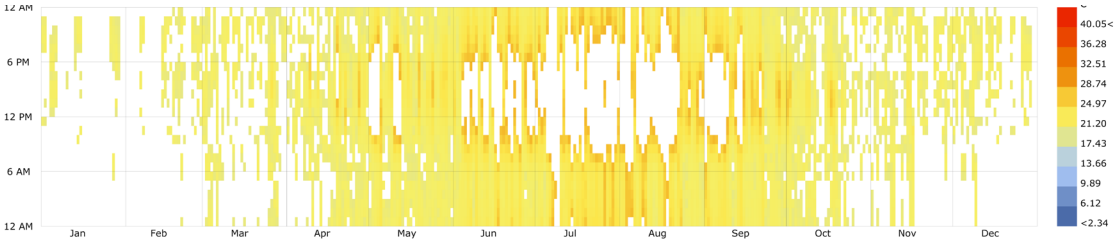
And to deal with the hot hours, another method should be considered. There's limitation only by changing construction properties. Thus, louvers will be applied.

Hot hours increased.



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

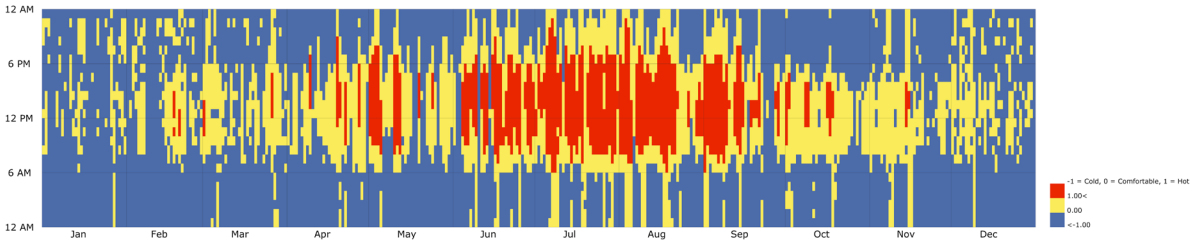
Annual Total Comfortable Time: 39 %
Percent of Hot: 10 %
Percent of Cold: 51 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

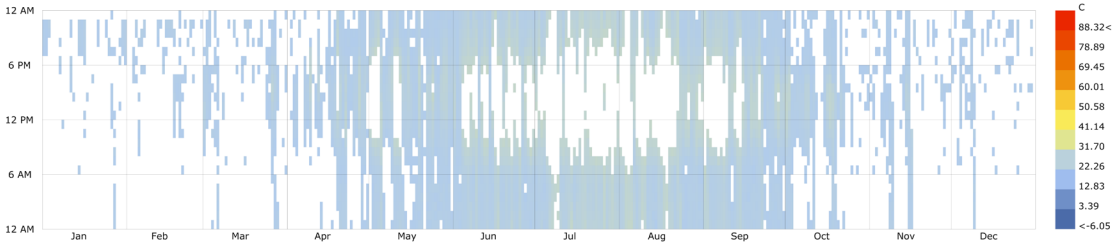
Percentage of Temperature between 18 and 26: 53%

Before



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

Annual Total Comfortable Time: 30 %
Percent of Hot: 12 %
Percent of Cold: 58 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 44%

Construction Properties Changed

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

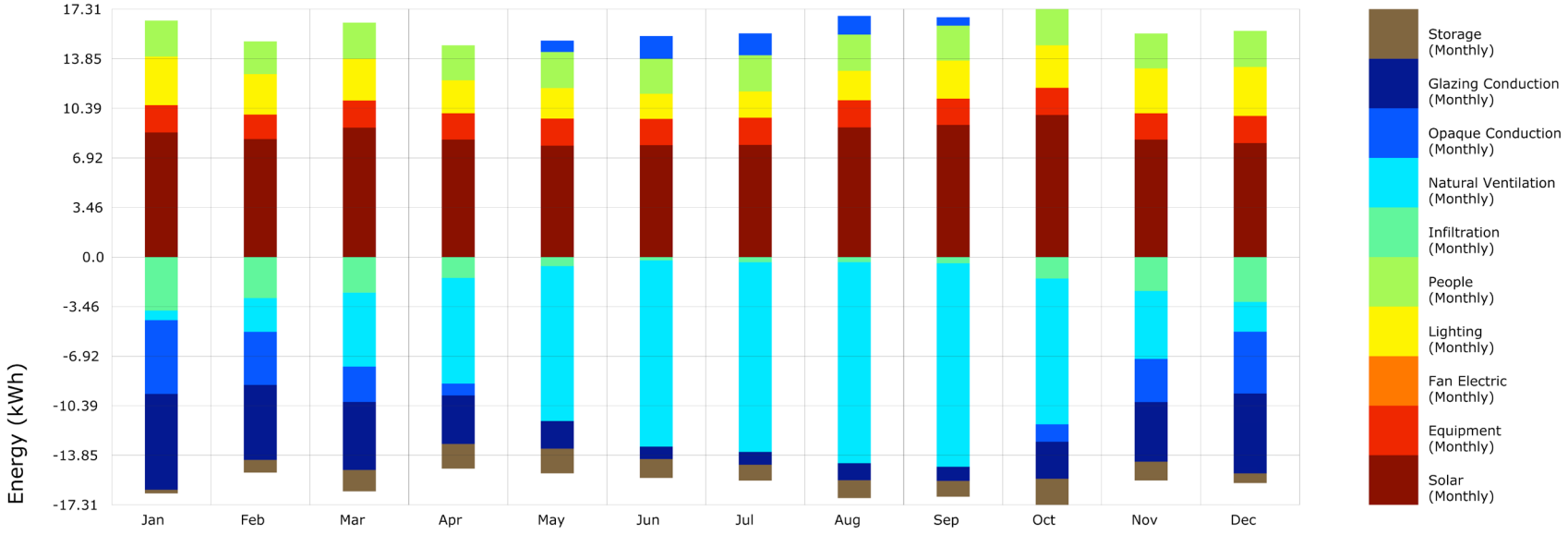
In the psychometric charts, it shows that total comfort percentage didn't changed but hot hours increased not as expected.

Also, Comfortable hours decreased, and cold hours increased.

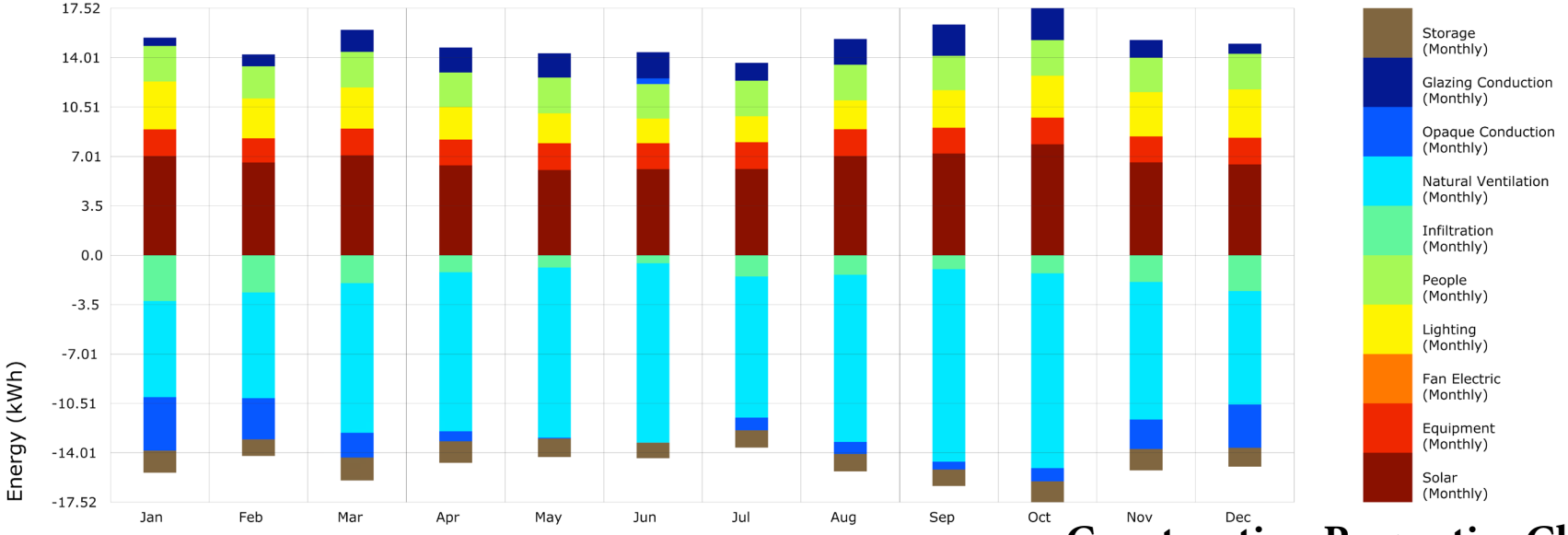
There should be proper R-Value.

And to deal with the hot hours, another method should be considered. There's limitation only by changing construction properties. Thus, louvers will be applied.

There should be proper R-Value.



Before



Construction Properties Changed

In energy balance chart, distinctive change is the only glazing conduction and natural ventilation.

Only glazing conduction and natural ventilation changed drastically.

Changing Construction More Summary:

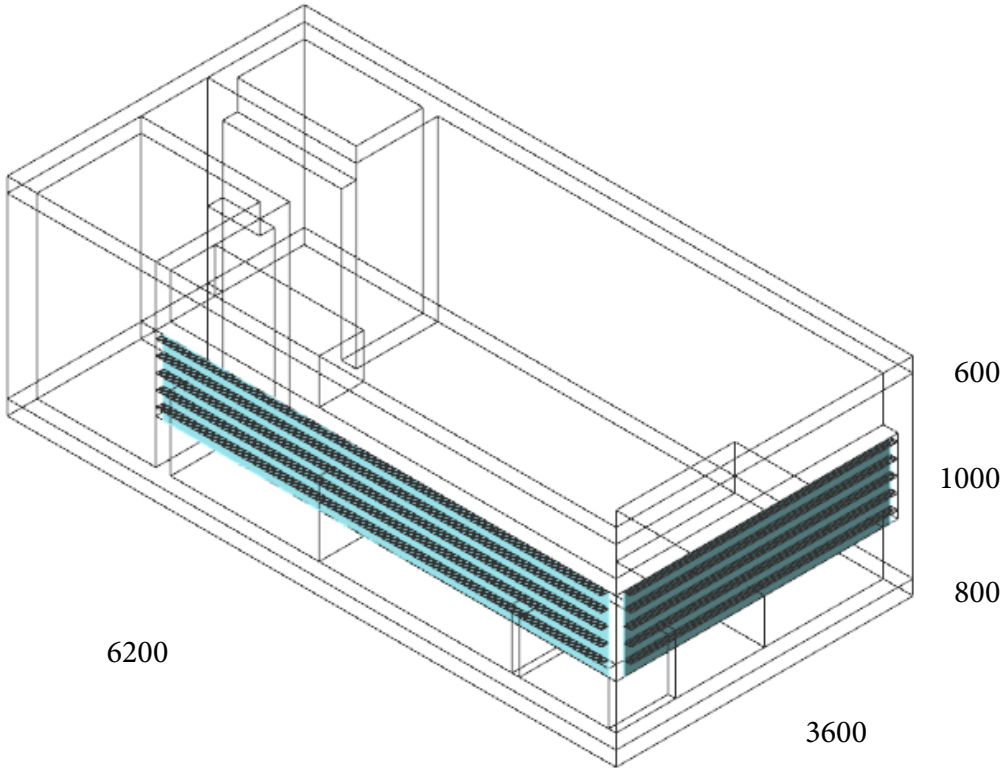
Too high R-Value also has problem. There should be proper value.

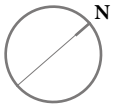
Next Strategy:

Finding better R-Value and applying louver system to deal with the hot hours.

APPLYING LOUVER SYSTEM

Based on the former simulation, it is necessary to apply louver system for managing hot hours due to intense sun radiation.





CHANGED CONSTRUCTION PARAMETERS

ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall STeelframe Climatezone Alt-Res 2-6 (**2.60**)
Window: ExtWindow NonMetal Climate zone 4 (**0.44**)
Floor: ExtRoof Iead Climatezone 2-8 (**3.53**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

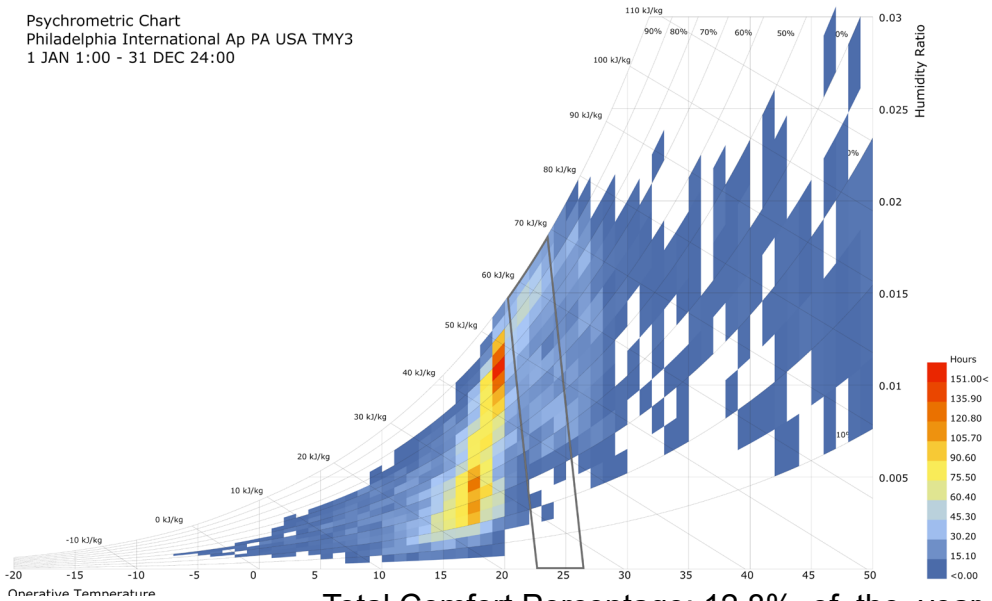
LOUVER SYSTEM INFORMATION

Type of Louvers: East Horizontal
South Horizontal

Number of Louvers: **5**

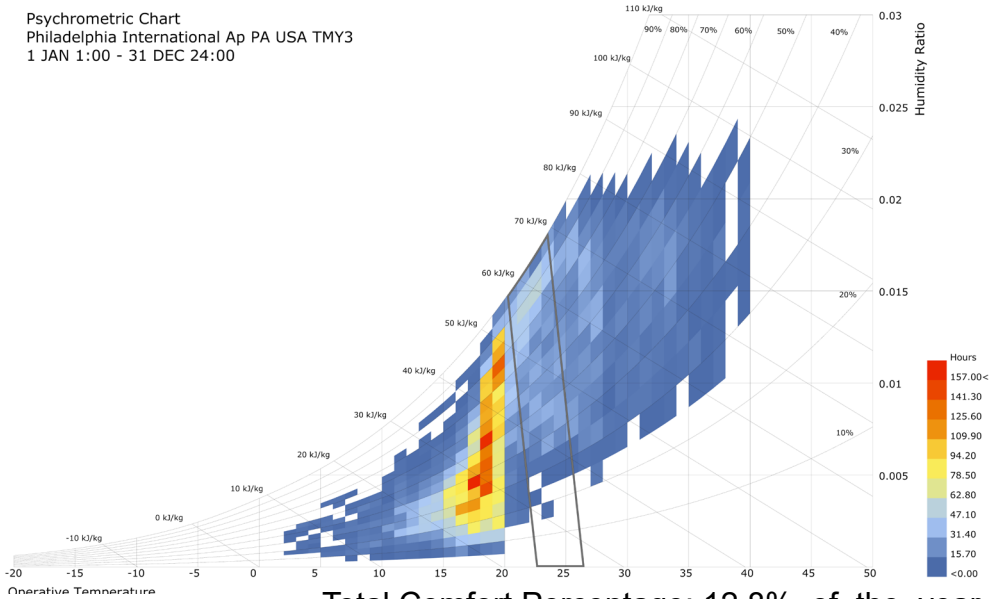
Depth of Louvers: **10cm**

Angle of Louvers: **0**



Total Comfort Percentage: 12.8% of the year

Before



Total Comfort Percentage: 12.8% of the year

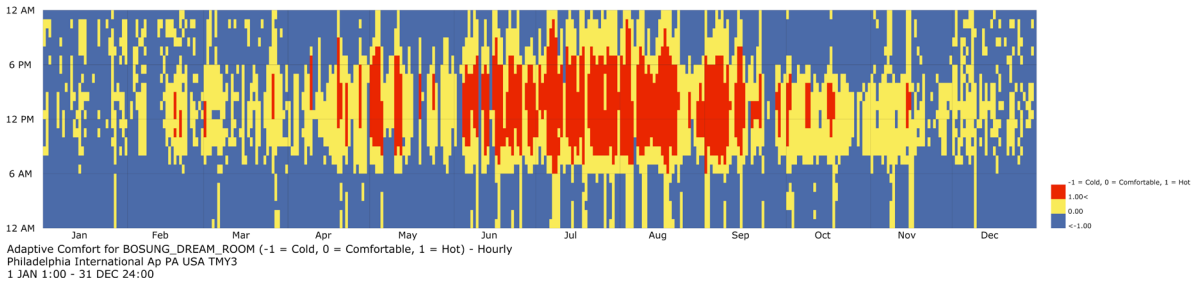
Louver System Applied

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, it shows that total comfort percentage didn't changed but hot and cold hours decreased, and it become stable overall.

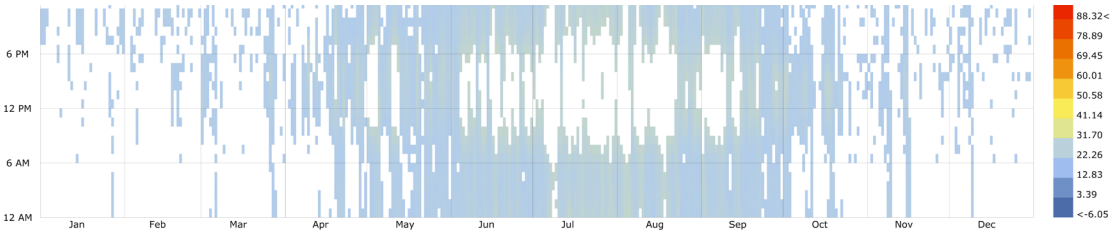
Also, Comfortable hours increased, and both of hot and cold hours decreased.

Overall, it become stable.



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

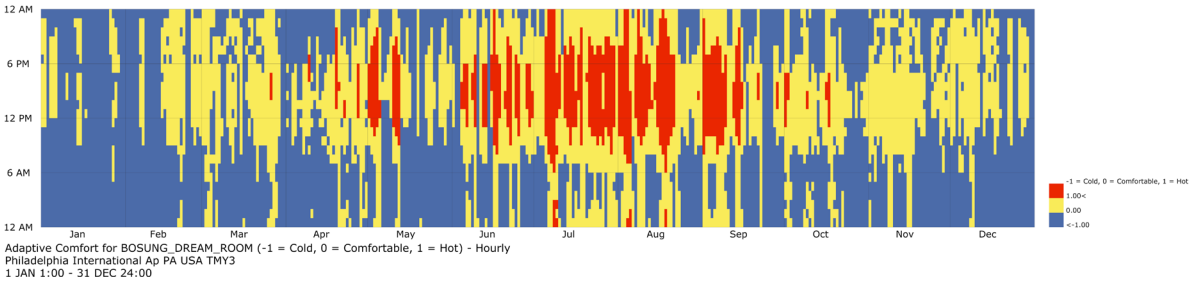
Annual Total Comfortable Time: 30 %
Percent of Hot: 12 %
Percent of Cold: 58 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

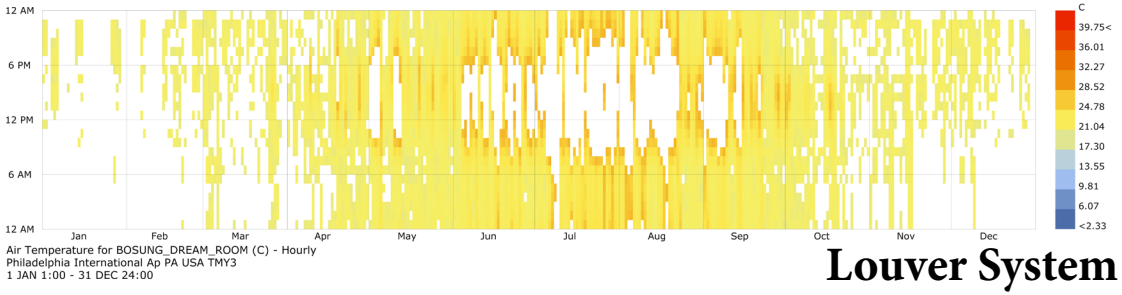
Percentage of Temperature between 18 and 26: 44%

Before



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

Annual Total Comfortable Time: 39 %
Percent of Hot: 9 %
Percent of Cold: 52 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 53%

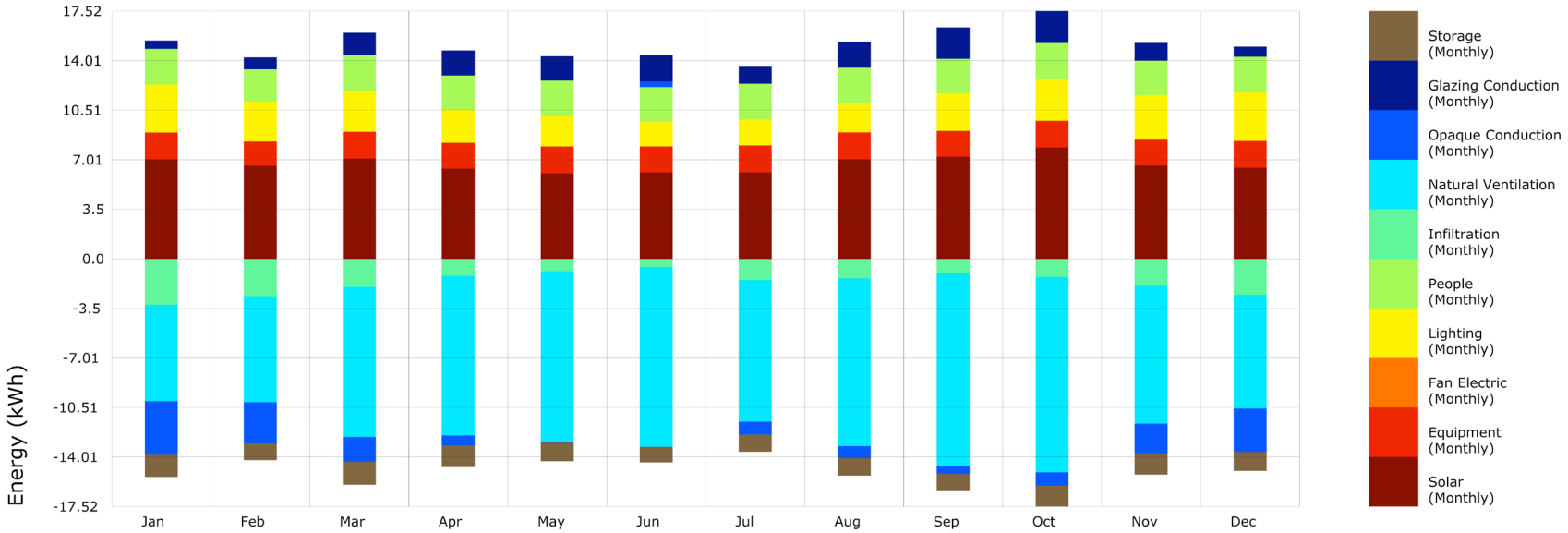
Louver System Applied

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

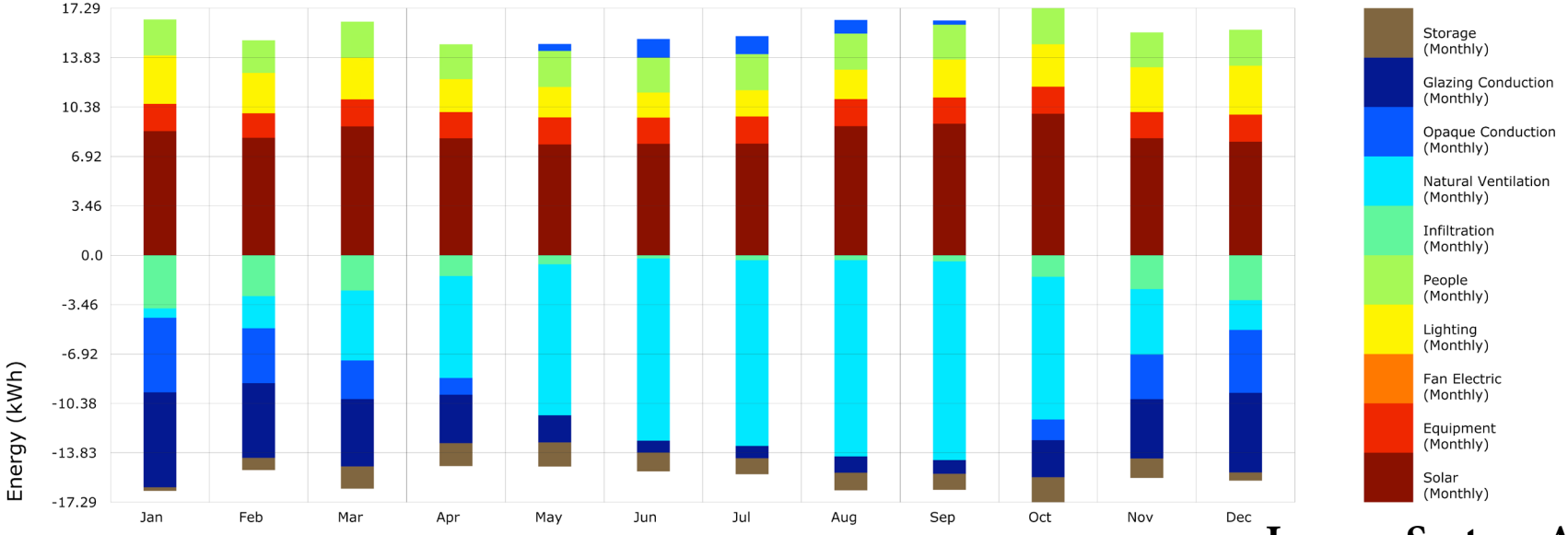
In the psychometric charts, it shows that total comfort percentage didn't changed but hot and cold hours decreased, and it become stable overall.

Also, Comfortable hours increased, and both of hot and cold hours decreased.

Both of hot and cold hours improved.



Before



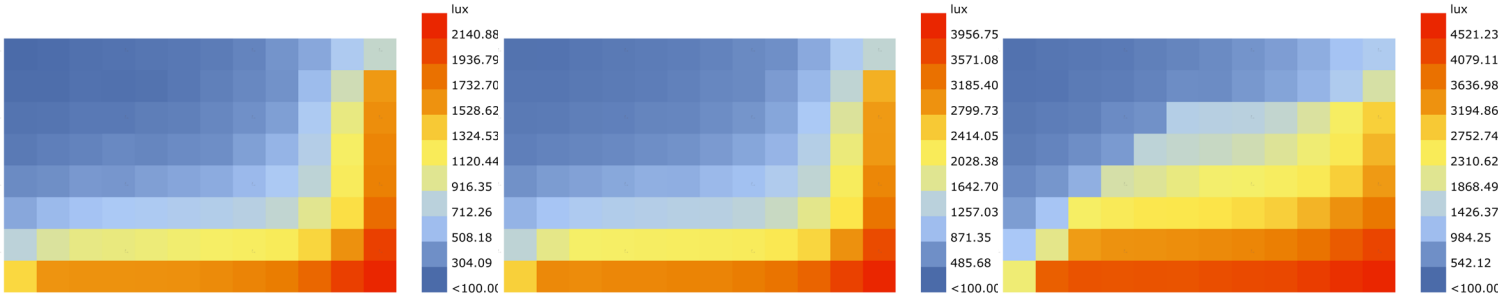
Louver System Applied

Energy gain from glazing decreased and loss increased. Also, Energy loss from natural ventilation in Winter decreased, and increased in Summer increased

To find specific strategy, grid-based simulation is done next.

21 Mar 09:00 **21 Mar 12:00** **21 Mar 15:00**

21 Jun 09:00 **21 Jun 12:00** **21 Jun 15:00**



21 Dec 09:00 **21 Dec 12:00** **21 Dec 15:00**

GRID-BASED DAYLIGHT SIMULATION

Daylight is too intense in East side in the morning and in South side at noon and in the afternoon.

Thus, the number and depth of louvers are not enough. Also, South and East louver system would be different, this is because one side is comfortable yet, the other side is opposite in the morning and the afternoon.

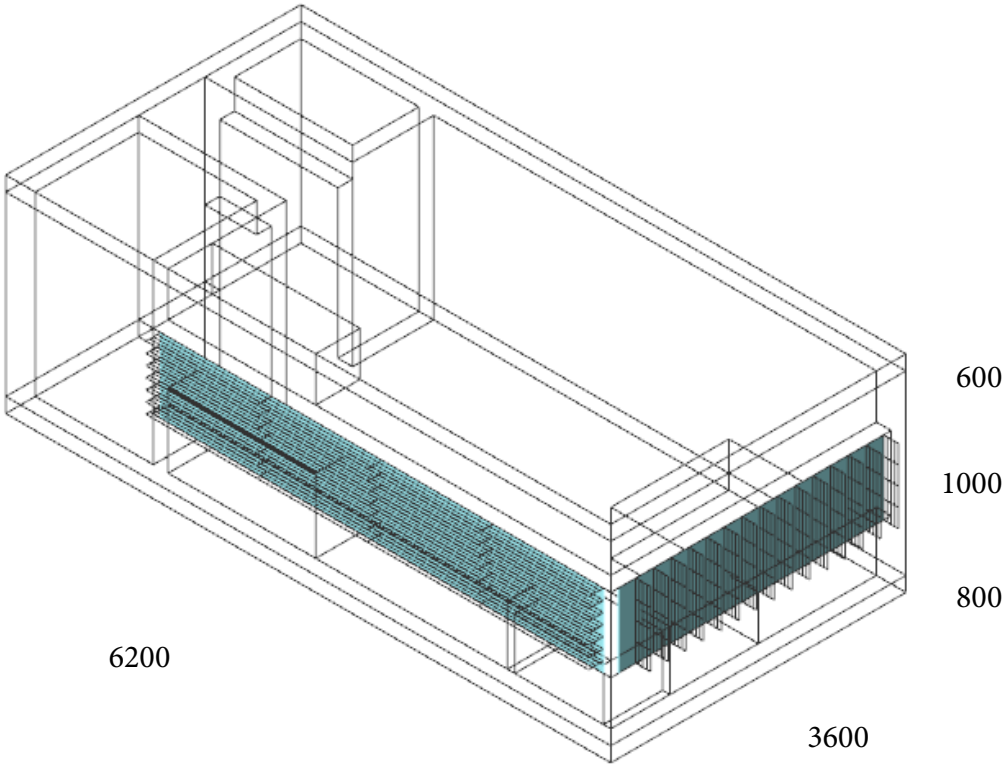
Different system should be applied in different orientations.

Applying Louver System Summary:

**In terms of energy issue, it become more stable overall,
and both of hot and cold hours decreased.
However, based on grid-based daylight simulation,
South and East glazing should have different systems.**

Next Strategy:

Considering sun angles, different louver systems are needed.



APPLYING DIFFERENT LOUVER SYSTEM

Based on the former simulation, it is necessary to apply different louver systems for dealing with conflicting situations of in the morning and in the afternoon.

LOUVER SYSTEM INFORMATION

East Vertical

Number of Louvers: **15**

Depth of Louvers: **20cm**

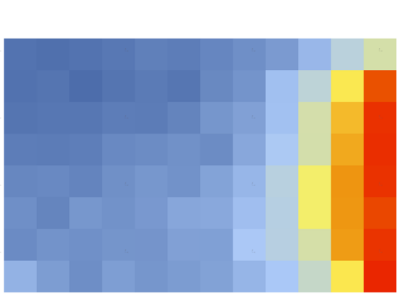
Angle of Louvers: **0**

South Horizontal

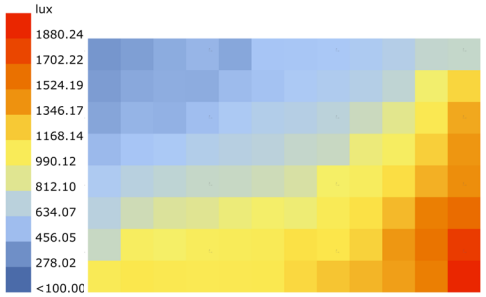
Number of Louvers: **7**

Depth of Louvers: **20cm**

Angle of Louvers: **0**



21 Mar 09:00



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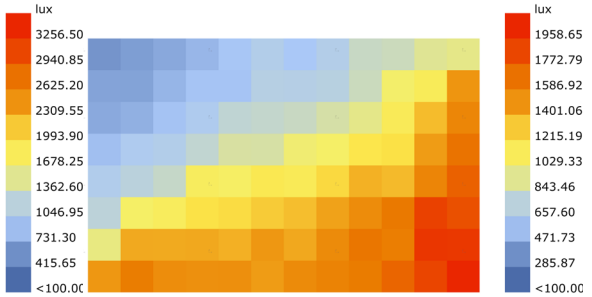
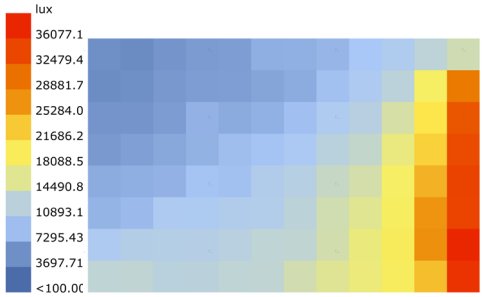


21 Mar 15:00

21 Jun 09:00



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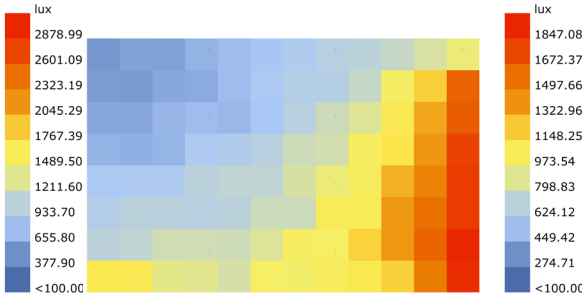

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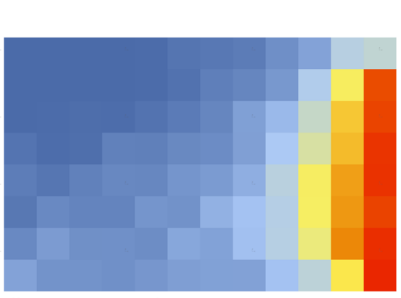

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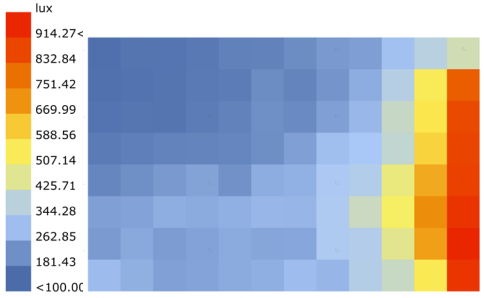

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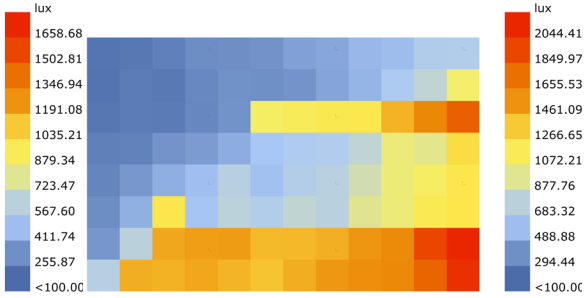


21 Dec 15:00

GRID-BASED DAYLIGHT SIMULATION

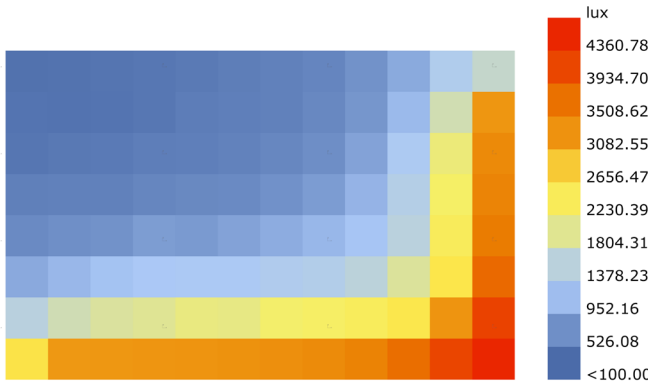
After applying different louver systems on the East and the South glazings, overall daylight become between 600 lux 2000 lux. At noon in Spring and Fall, only near the Southeast corner is over 3000 lux . Also, only in the morning in the Summer, right next to the East glazing, daylight is quite intense, but with more louver components, it would harm the useful daylight.

Except few issues that are acceptable, overall daylight become good in terms of intensity and distribution.

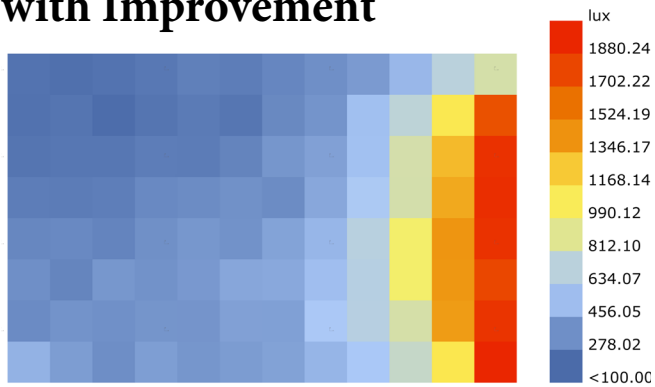
With Same Louver System for Both Orientations

With Different Systems for Each Orientation with Improvement

21 Mar 09:00

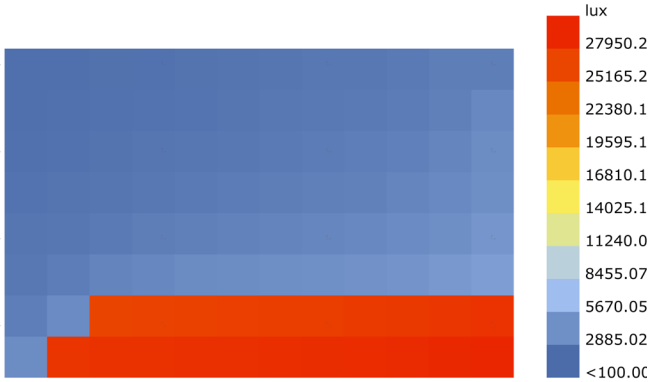


Illuminance Simulation
21 MAR 9:00

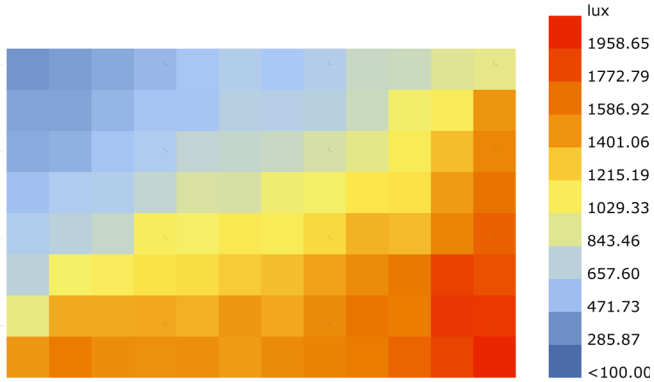


Illuminance Simulation
21 MAR 9:00

21 Mar 15:00



Illuminance Simulation
21 MAR 15:00



Illuminance Simulation
21 MAR 15:00

THE MOMENTS CHANGED MOST EFFECTIVELY

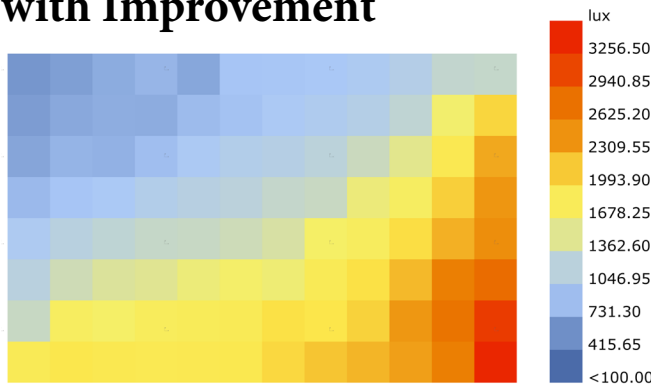
In the morning in Spring and Fall when sun is low at the East, daylight near the window was quite intense. However, after applying the different system, the highest illuminace in the morning is just 1880 lux, and mostly well daylighted except the very deep corner of the Northwest. Also, In the afternoon in the same seasons, daylight is much uncomfortable near the South glazing. However, after the system changed, overall daylight is nicely comfortable and distribution of it is good; even the very deep corner attain more than 200 lux daylight.

With Same Louver System for Both Orientations

With Different Systems for Each Orientation with Improvement

21 Mar 12:00

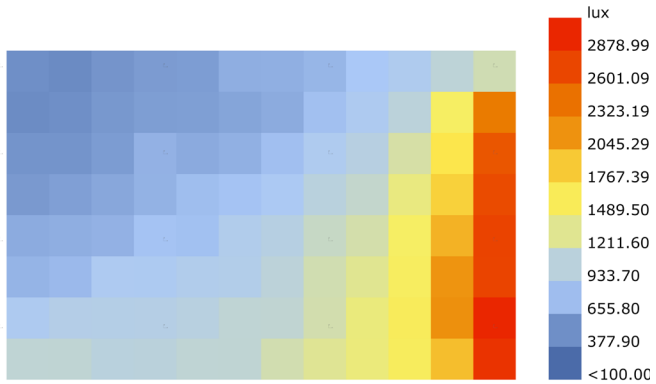
Illuminance Simulation
21 MAR 12:00



Illuminance Simulation
21 MAR 12:00

21 Jun 12:00

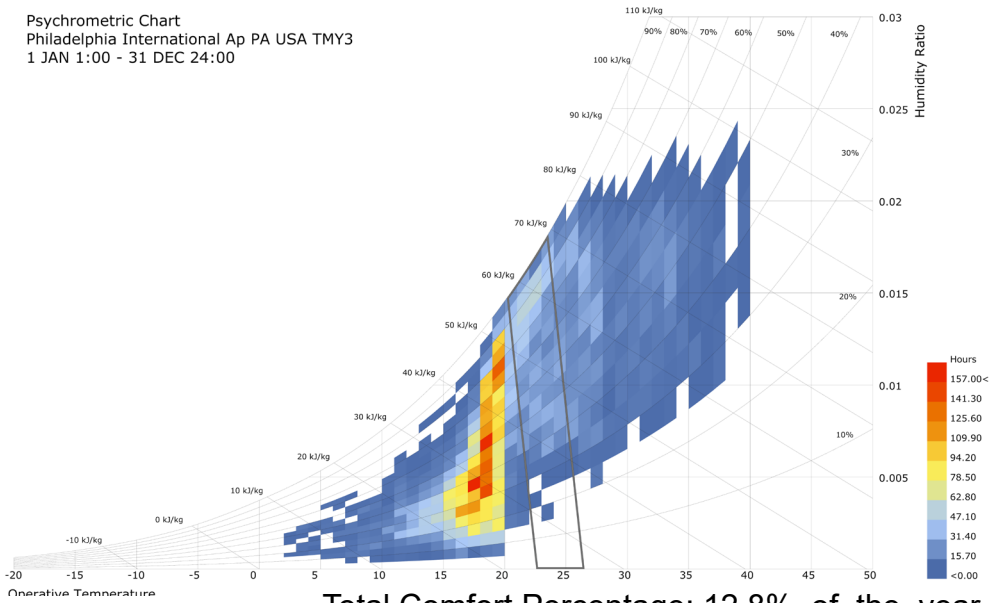
Illuminance Simulation
21 JUN 12:00



Illuminance Simulation
21 JUN 12:00

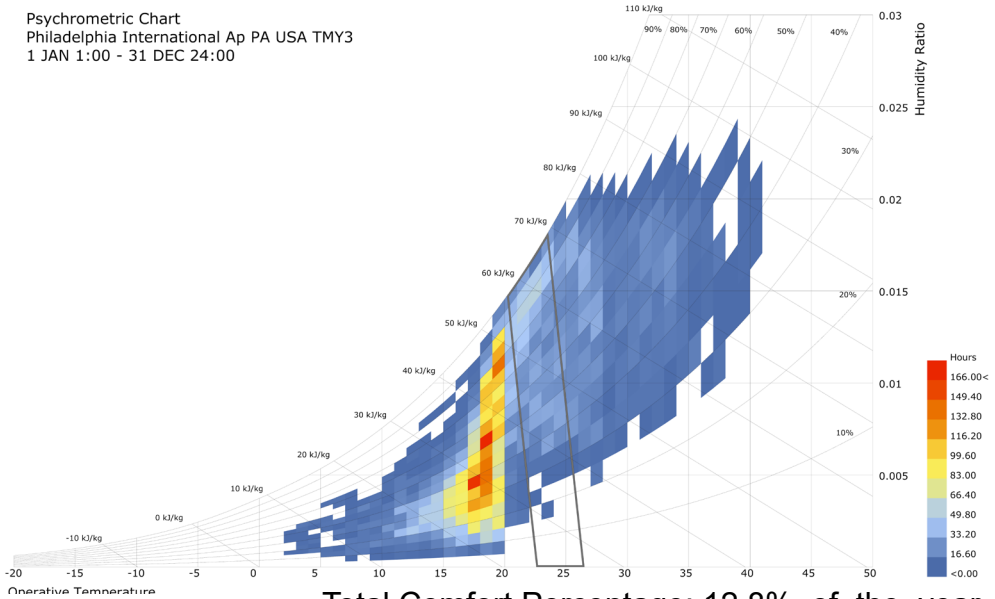
THE MOMENTS CHANGED MOST EFFECTIVELY

At noon in Spring, Summer, and Fall when sun is high, daylight is so strong near the glazings, especially the South orientation. After applying the improved system, it is around 1600 lux in Spring and Fall, and it is about 1200 lux in Summer in the South area of the room. In the East side, due to the daylight comfort of the other times, it was proper not to reduce the daylight more. Yet, right next to the window is just about 3000 lux, and overall East side is around 1500 lux, I think it's acceptable.



Total Comfort Percentage: 12.8% of the year

Before



Total Comfort Percentage: 12.8% of the year

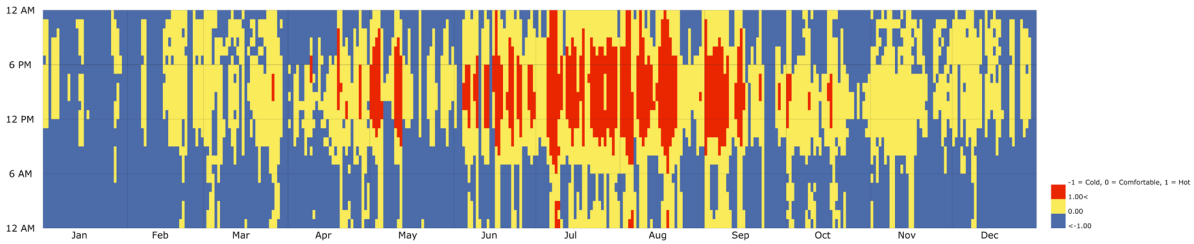
Different Louver System Applied

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

In the psychometric charts, total comfortable hours changed little, however, there distribution converged near the comfort polygon more than before.

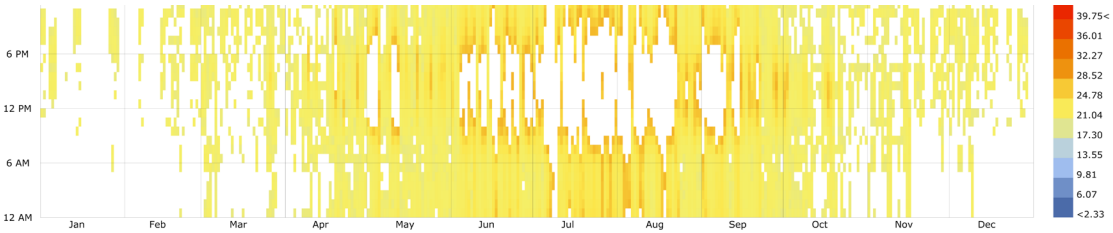
Adaptive comfort chart and indoor comfortable temperature chart show that, indoor quality become better, but it's not much.

Distribution of comfortable hours converged more to the comfort polygon.



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

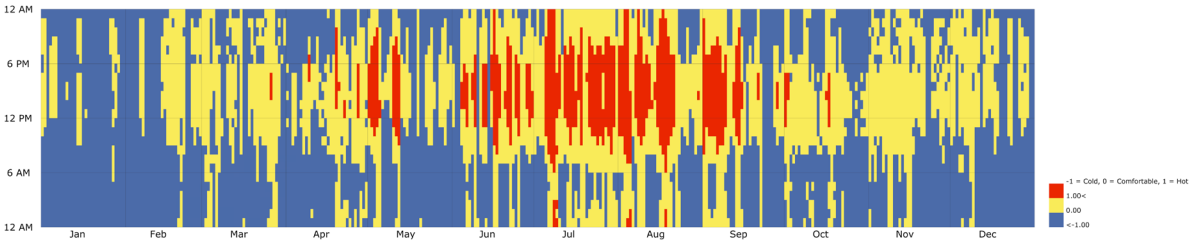
Annual Total Comfortable Time: 39 %
Percent of Hot: 9 %
Percent of Cold: 52 %



Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 53%

Before



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

Annual Total Comfortable Time: 39 %
Percent of Hot: 9 %
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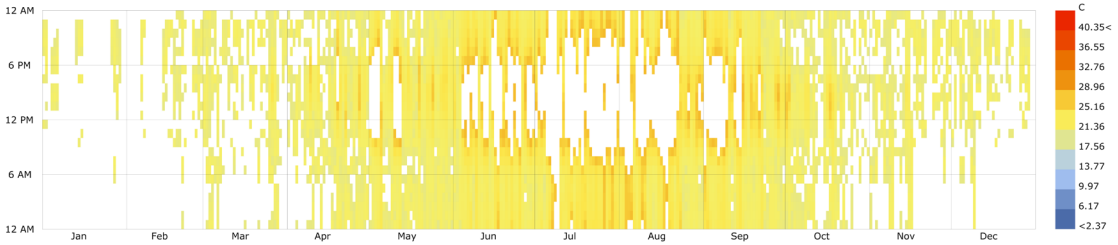


Air Temperature for BOSUNG_DREAM_ROOM (C) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Percentage of Temperature between 18 and 26: 54%

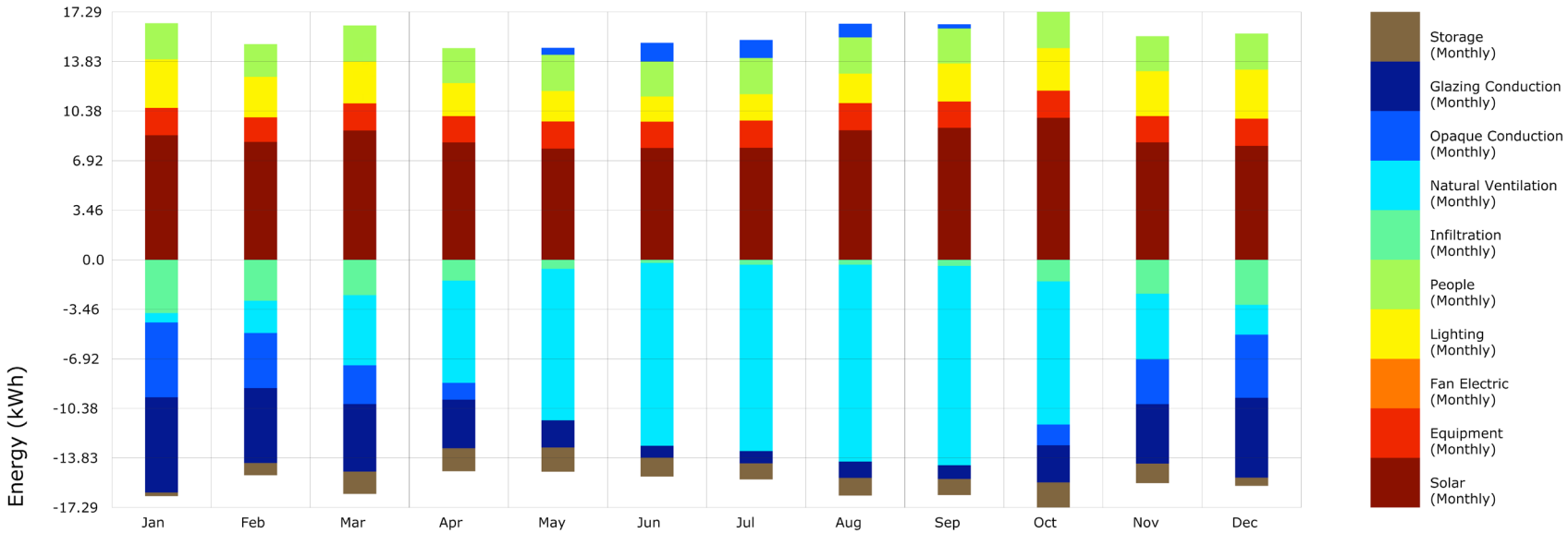
Different Louver System Applied

COMFORTABLE TIME AND ENERGY BALANCE ANALYSIS

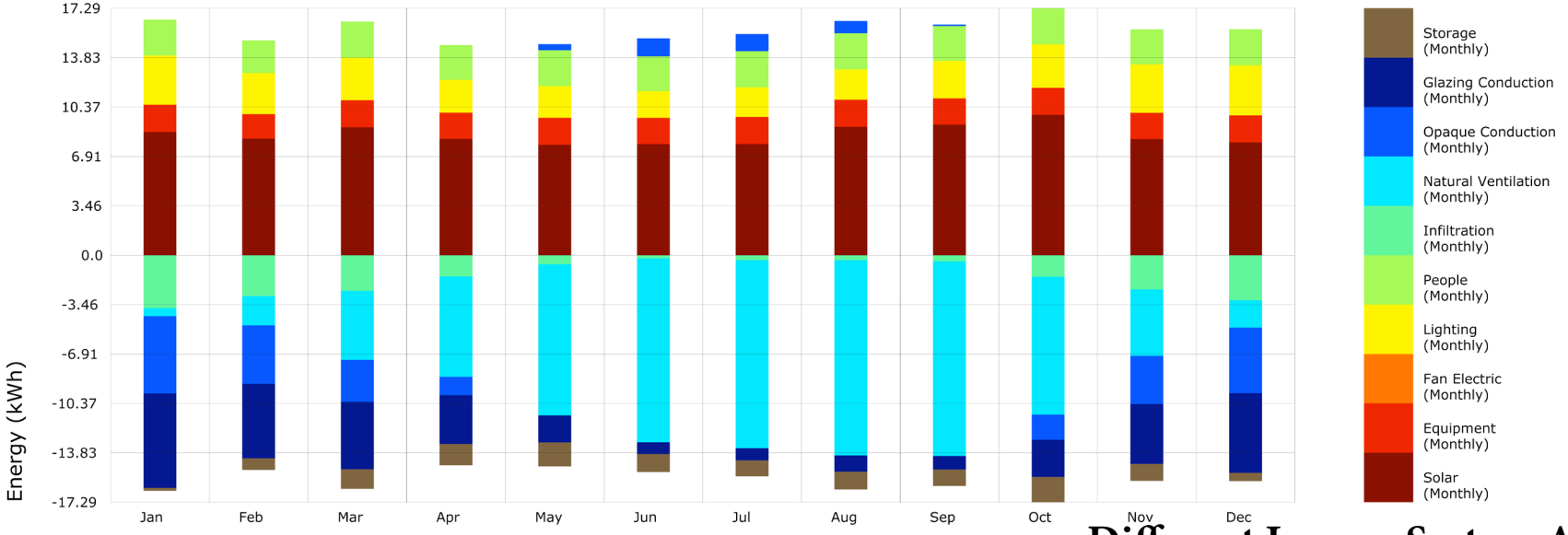
In the psychometric charts, total comfortable hours changed little, however, there distribution converged near the comfort polygon more than before.

Adaptive comfort chart and indoor comfortable temperature chart show that, indoor quality become better, but it's not much.

Both of hot and cold hours improved little.



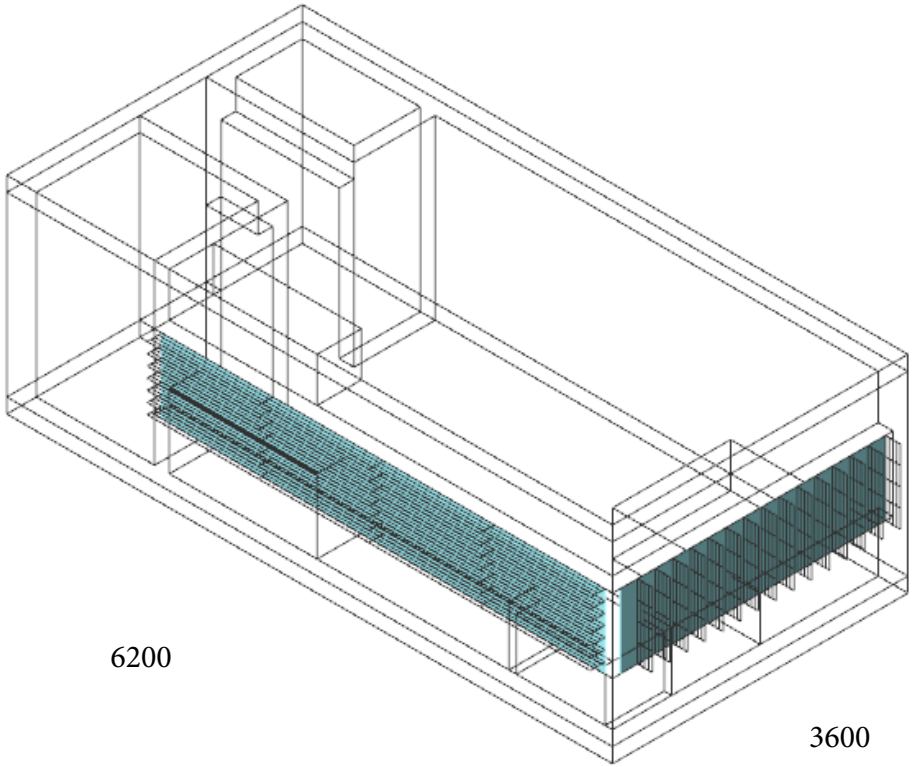
Before



Different Louver System Applied

Energy Balance changed little.

Part 4. Final Design Assessment & Conclusion



LOUVER SYSTEM INFORMATION

East Vertical

Number of Louvers: **15**

Depth of Louvers: **20cm**

Angle of Louvers: **0**

South Horizontal

Number of Louvers: **7**

Depth of Louvers: **20cm**

Angle of Louvers: **0**

CHANGED CONSTRUCTION PARAMETERS

ASHRAE 90.1-2010 (R-Value)
Wall: ExtWall STeelframe Climatezone Alt-Res 2-6 (**2.60**)
Window: ExtWindow NonMetal Climate zone 4 (**0.44**)
Floor: ExtRoof Iead Climatezone 2-8 (**3.53**)
Floor: AtticeFloor Climatezone 2-7 (**6.33**)

ENVIRONMENTAL PARAMETERS

Building Program: **Midrise APT**

Infiltration Rate per Area: **0.000667** m3/s-m2

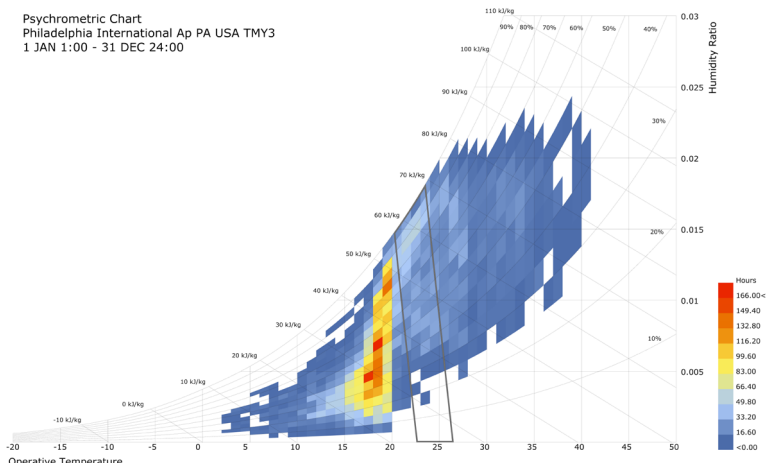
Number of People per Area: **0.041332** = 1 person / 24.2 m2

Ventilation Type: **Window Natural Ventilation**

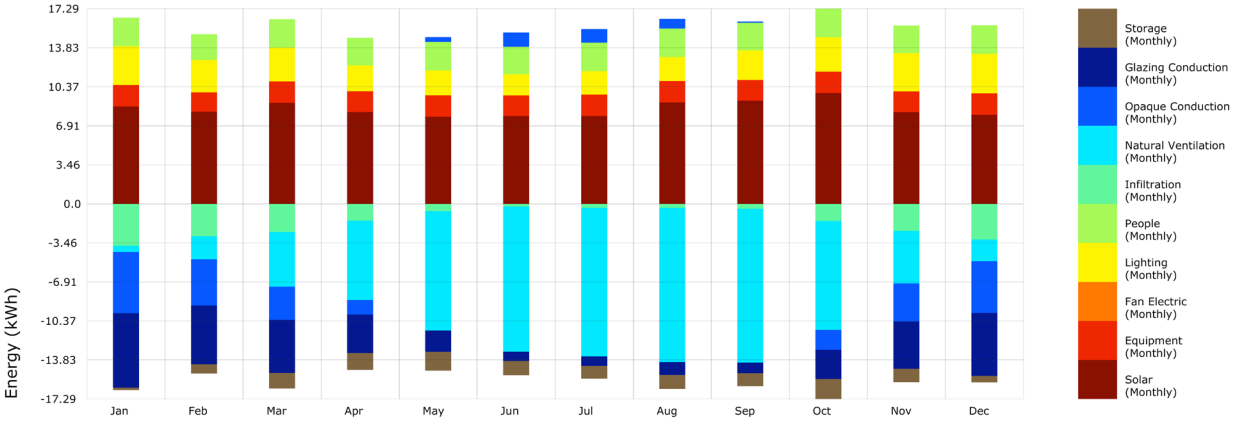
Minimum Indoor Temperature for Natural Ventilation: **20 C**

Maximum Outdoor Temperature for Natural Ventilation: **28 C**

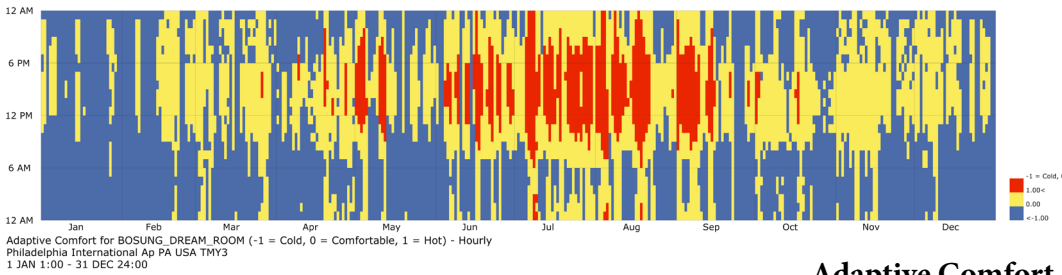
PERFORMANCE OF THE FINAL DESIGN



Psychometric Chart



Energy Balance

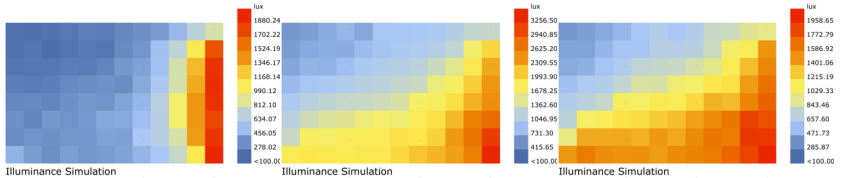


Adaptive Comfort

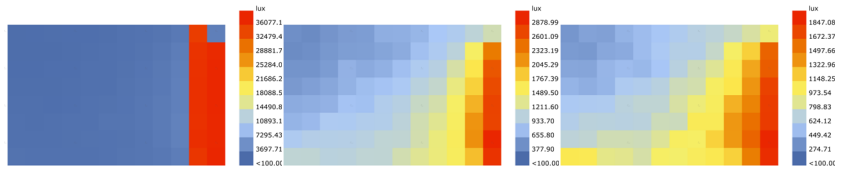
Annual Total Comfortable Time: 39 %
Percent of Hot: 9 %
Percent of Cold: 52 %

Percentage of Temperature between 18 and 26: 54%

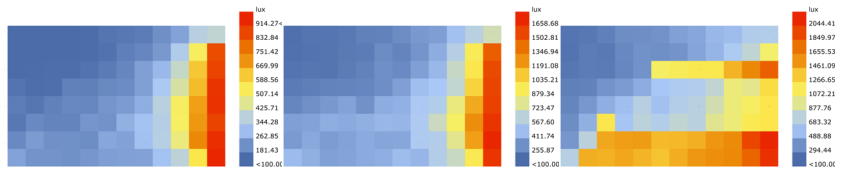
Comfortable Indoor Temperature



21 Mar 09:00 **21 Mar 12:00** **21 Mar 15:00**



21 Jun 09:00 **21 Jun 12:00** **21 Jun 15:00**



21 Dec 09:00 **21 Dec 12:00** **21 Dec 15:00**

Daylight

Conclusion:

In terms of adaptive comfort, the final design achieves indoor comfort of 39% of the year. Also, comfortable indoor temperature time is 54% of the year. Regarding daylighting, mostly it is in the range of UDI 100 to 2000 lux.

There are three reasons the design cannot achieve more adaptive comfort. First, in the morning in Winter, there's no source of generating heat without air conditioning. Second, in the afternoon in Summer, there's limitation of eliminating extra heat only by natural ventilation. Also, if the louver system blocks more sun radiance, it would decrease beneficial daylight. Lastly, R-Value has a balance point, so too low or high value is harm the performance.

In conclusion, there is a balance in the parameters affecting building performance. For instance, glazing brings daylight into a space. However, at the same time, there's both of loss and gain of energy from solar radiance through it. Also, the movement of Sun is dynamic, thus, unless a louver system is kinetic, it can be beneficial at some points and vise versa.