

THERMAL AND VISUAL COMFORT

OPTIMIZING THE POSSIBLE MAXIMUM COMFORT HOURS FOR MY APARTMENT

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Arch 753 Building Performance Simulation
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University of Pennsylvania
School of Design

OVERALL INTRODUCTION

For the final project, the main purpose is to maximum the comfort hours of my apartment.

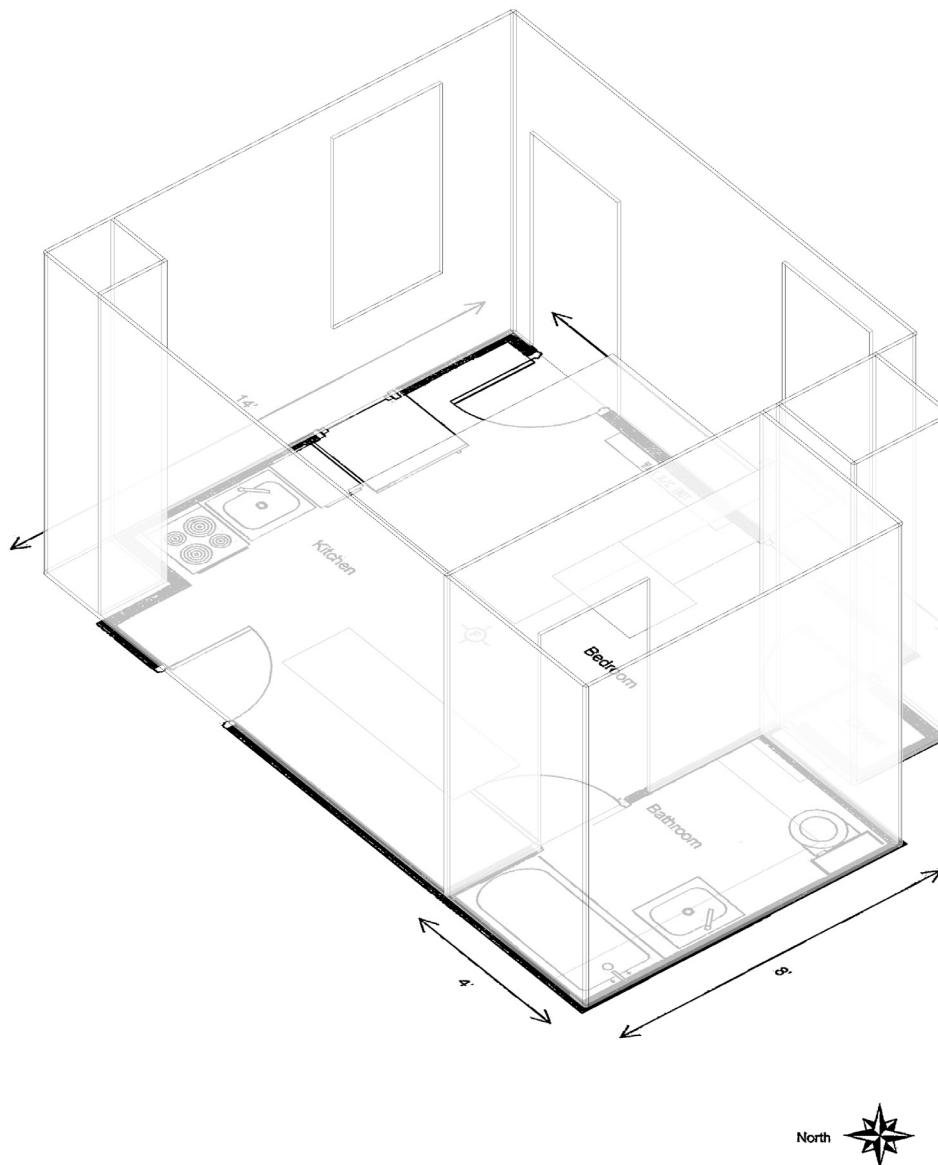
During this semesters, I have learned how to analyze the climate by using Ladybug and Honeybee; how to analyze the Weather Data of 8760 hours; how to design a "dream room" by combining the weather data and passive strategies; what's the definition of Thermal Comfort and how to analyze it and the radiation, annual sunlight hours; how to design a shading system; how to simulate the interior daylight analysis; how to simulate the annual daylight, glareness and Useful Daylight Illuminance; the energy of the apartment.

The Final Project will be coordinated in the following orders:

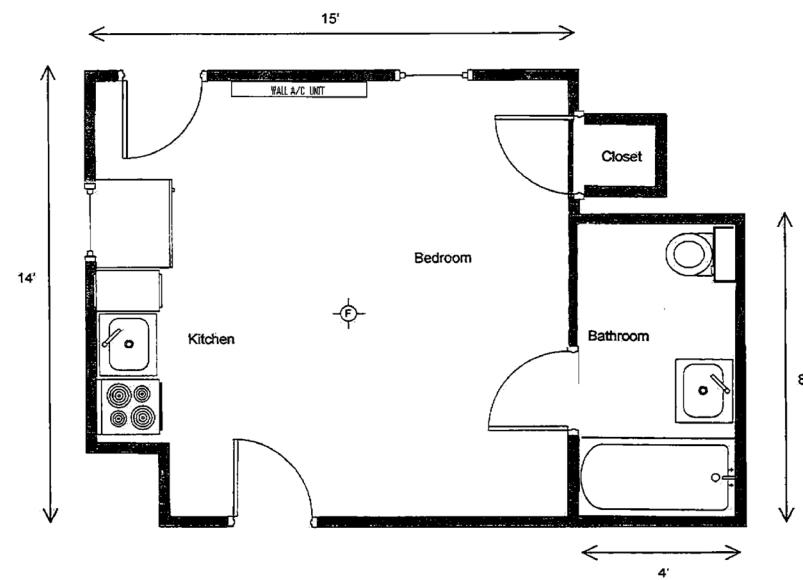
- Introduction of the Apartment and the Site
- City Climate Analysis
- Weather Data Background
- Passive Strategies
- Interior Thermal Comfort Analysis
- Annual Daylight analysis
- Glare Analysis
- UDI Analysis
- Energy Analysis

INTRODUCTION OF THE APARTMENT

MY APARTMENT



My apartment is located at Philadelphia, PA. It is a studio with two small windows facing towards north and east, and two doors facing towards to east and west(corridor). The subjective feeling of living in it is lack of sunlight and freezing cold in winter.



WEATHER DATA ANALYSIS

Climate Analysis

CLIMATE ZONES

WEATHER DATA: USA_PA_Philadelphia.
Intl.AP724080_TMY3

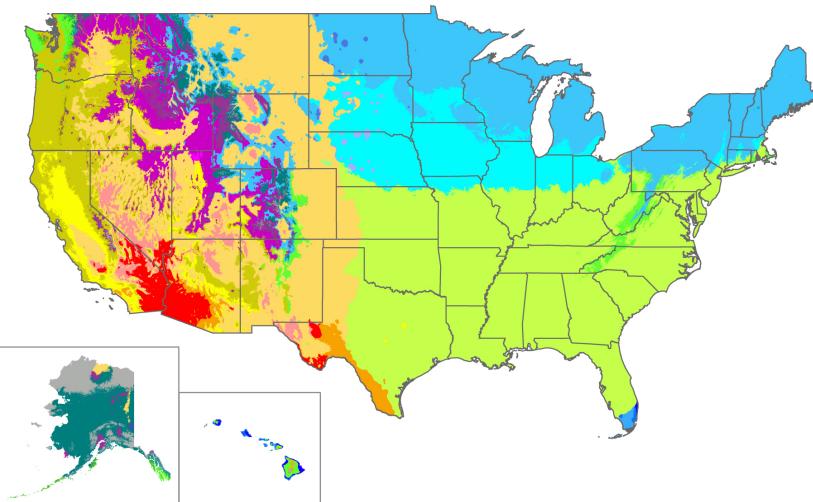
DATA SOURCE: TMV3
LATITUDE: 39.87
LONGITUDE: -75.23

Strong Cold Stress: 1146 hrs
Moderate Cold Stress: 1862 hrs
Slight Cold Stress: 1610 hrs
Comfort: 3616 hrs
Slight Heat Stress: 251 hrs
Moderate Heat Stress: 221 hrs
Strong Heat Stress: 54 hrs

Climate Zone: Zone 4
Ceiling R-value: 38
Wood Frame Wall R-value: 13
Mass Wall R-valueⁱ: 5/10
Floor R-value: 19
Basement Wall R-value^c: 10/13
Slab R-value^d, Depth: 10,2ft
Crawlspacce Wall R-value^c: 10/13
Fenestration U-Factor^b: 0.35
Skylight U-Factor^b: 0.6
Glazed fenestration SHGC^{b,e}: NR

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

Köppen climate types of the United States



Köppen climate type

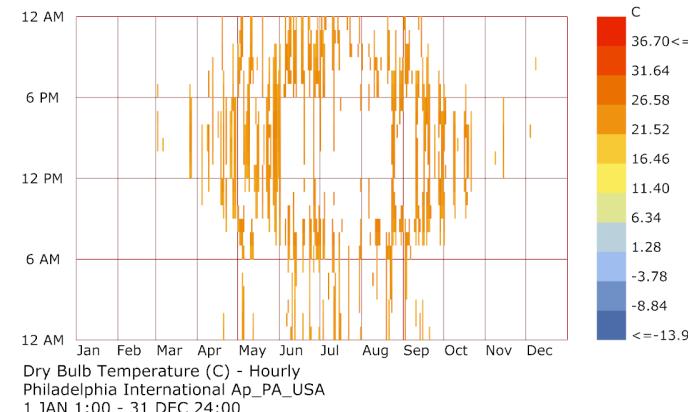
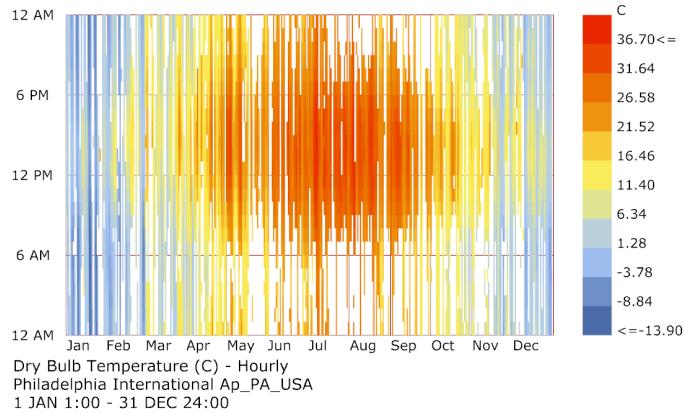
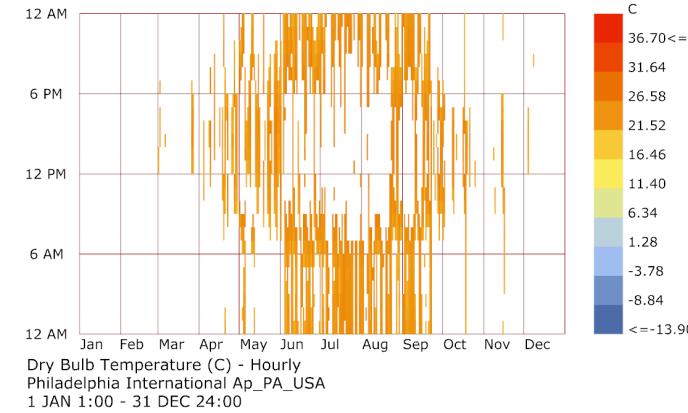
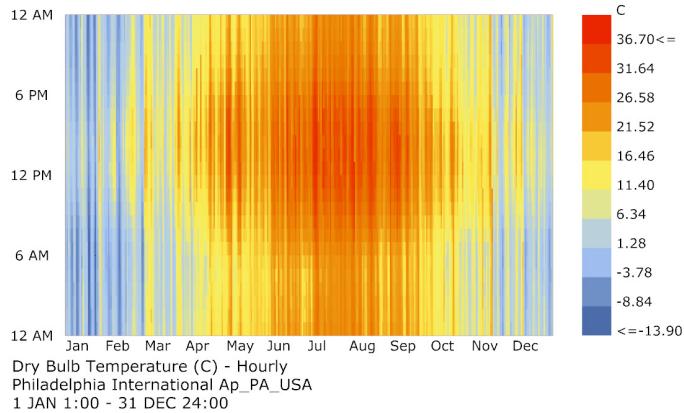
EF (Ice-cap)	Dsb (Warm-summer mediterranean continental)	Csa (Hot-summer mediterrane
ET (Tundra)	Dsa (Hot-summer mediterranean continental)	BSk (Cold semi-arid)
Dfc (Subarctic)	Cfc (Subpolar oceanic)	BSh (Hot semi-arid)
Dfb (Warm-summer humid continental)	Cfb (Oceanic)	BWk (Cold desert)
Dfa (Hot-summer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

*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

https://en.wikipedia.org/wiki/Climate_of_the_United_States

TEMPERATURE ANALYSIS



Relative Humidity

20% - 80%

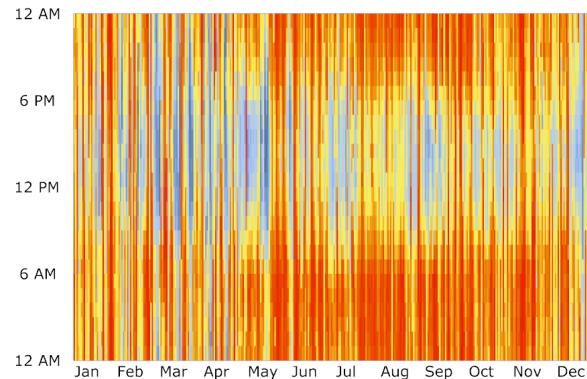
Wind Speed

2M/S - 10M/S

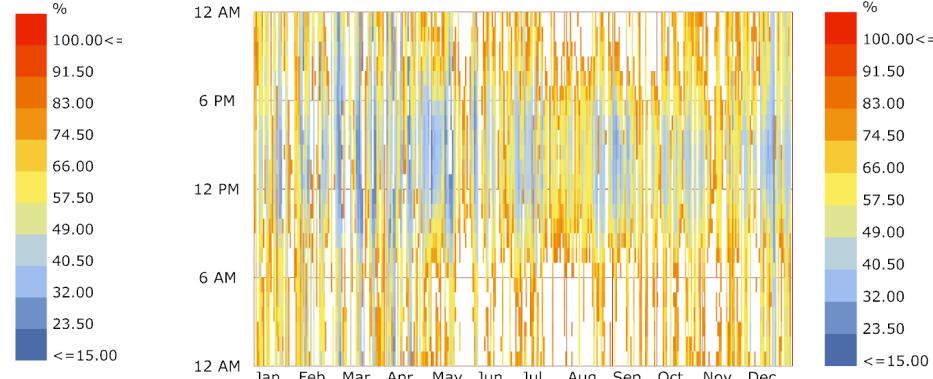
Dry Bulb Average Temperature

21.2°C

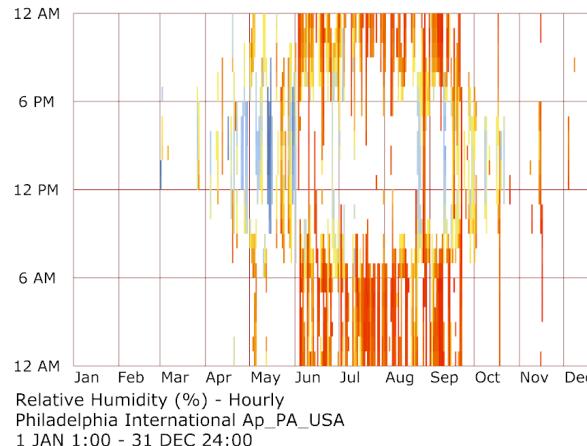
HUMIDITY ANALYSIS



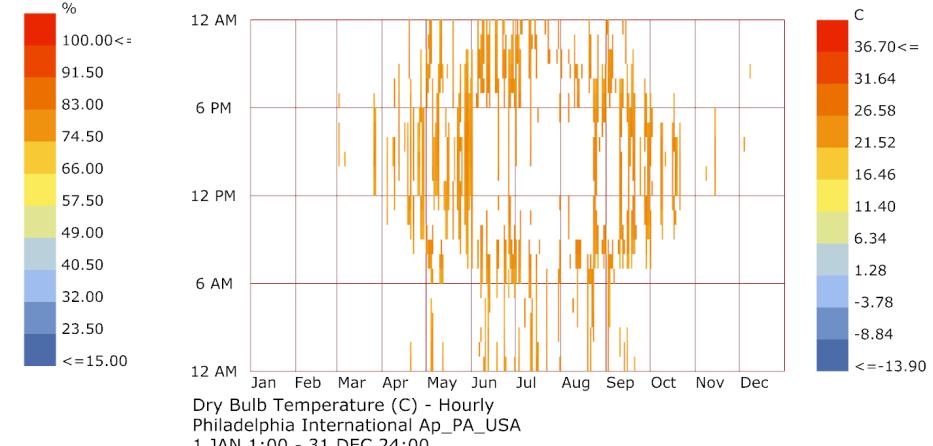
Relative Humidity (%) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



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



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



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

Dry Bulb Temperature

18°C - 24°C

Wind Speed

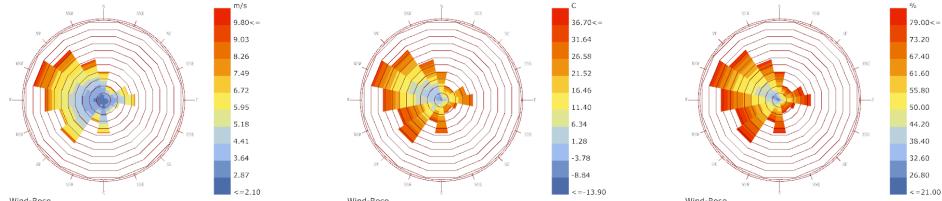
2M/S - 10M/S

Humidity Condition

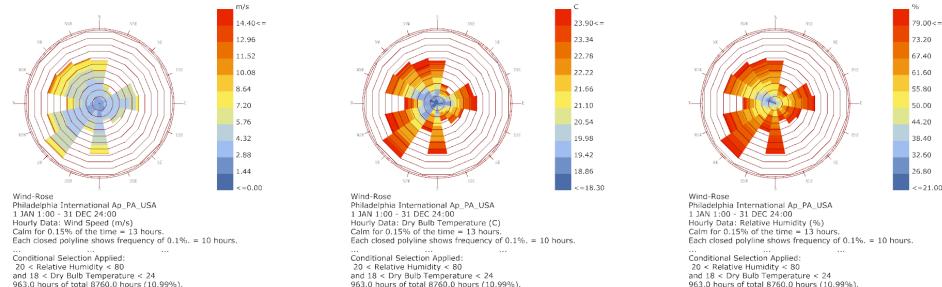
WET

WIND-ROSE ANALYSIS

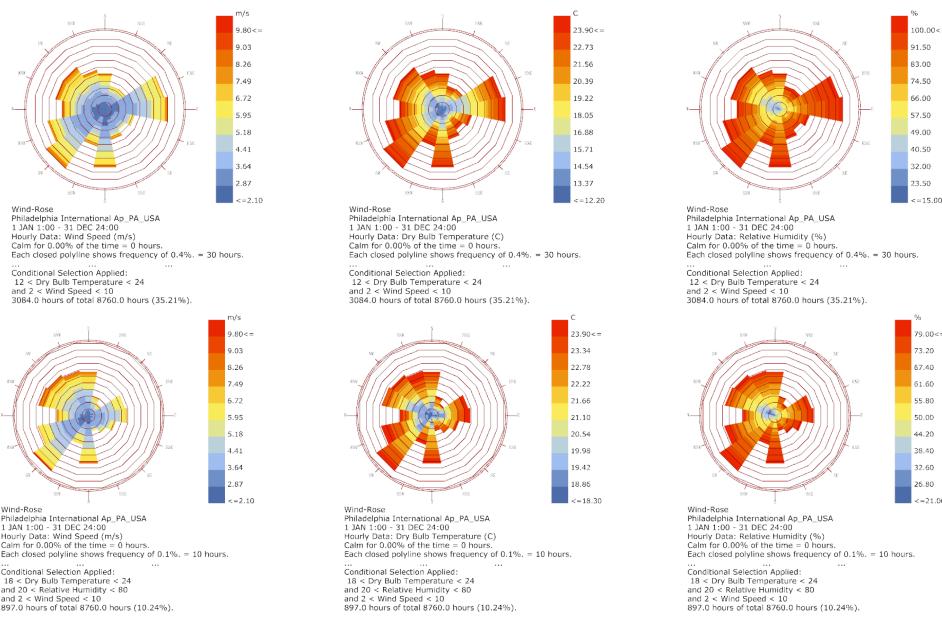
Dry Bulb Temperature
18°C - 24°C



Relative Humidity
20%-80%



Wind Direction
SOUTH-WEST WIND



COMFORT DEFINATION

Dry Bulb Temperature

18°C - 24°C

Relative Humidity

20%-80%

Wind Speed

2M/S - 10M/S

CLIMATE ANALYSIS

Climate Data

Dry Bulb Temperature

18°C - 24°C

Relative Humidity

20%-80%

Dry Bulb Temperature

18°C - 24°C

Wind Speed

2M/S - 10M/S

Relative Humidity

20%-80%

Wind Speed

2M/S - 10M/S

Conditionary Comfort Hour

963/8760 HOURS

Wind Speed is above **8.64m/s**

3084/8760 HOURS

Relative Humidity is above **70%**

5288/8760 HOURS

Dry Bulb Temperature is above **26°C**

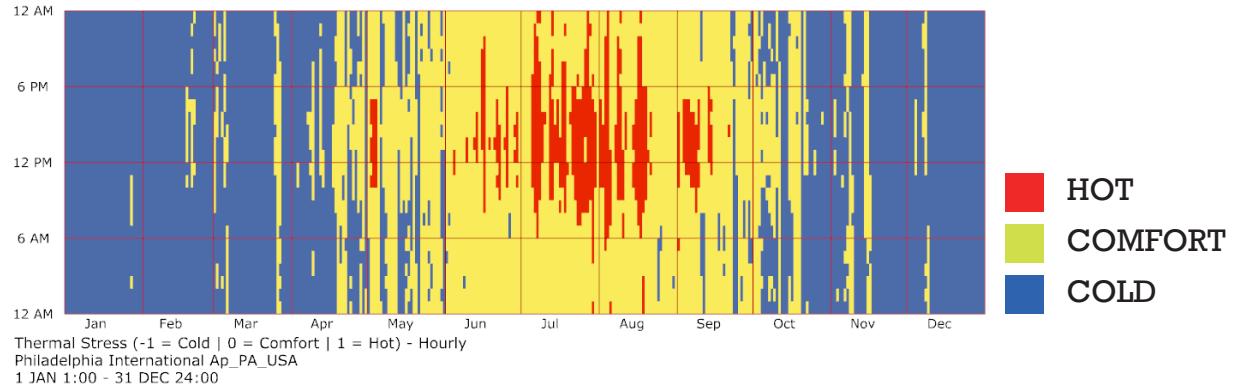
Strategy

WIND SHELTER

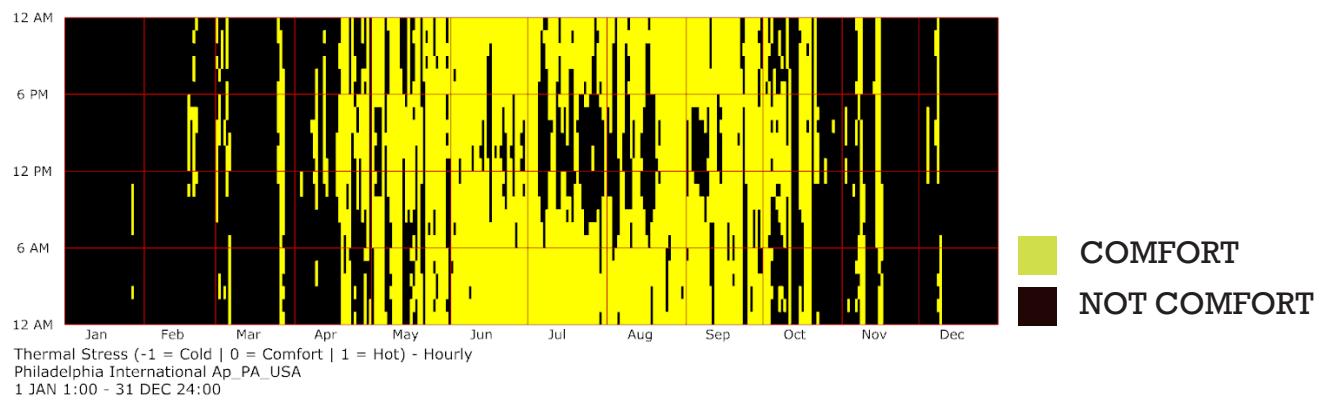
AIR DRYER SYSTEM

COOLING SYSTEM

FULLY SHADED

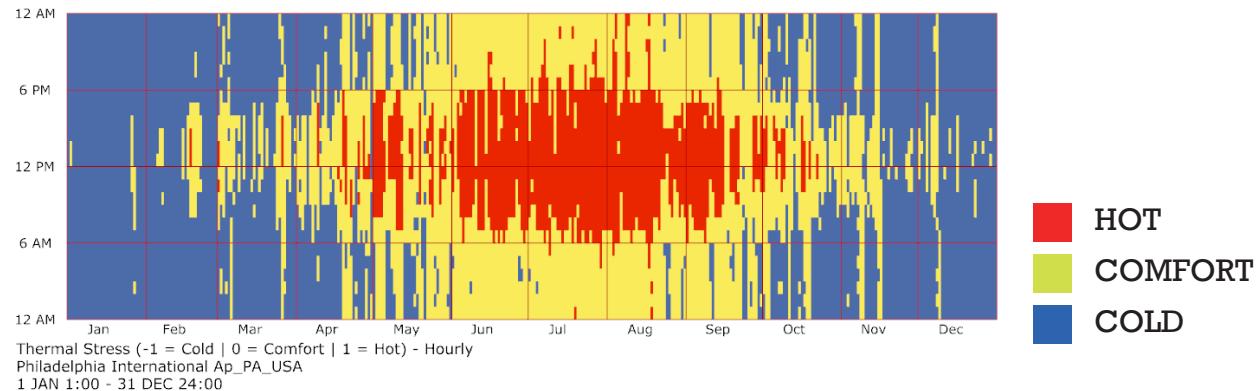


**3616 HRS
COMFORTABLE
OF 8760 HOURS**

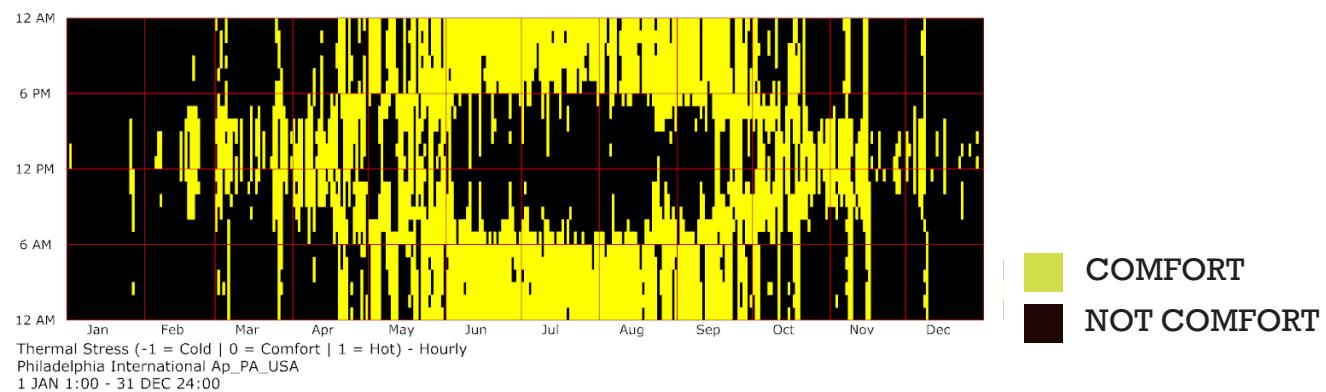


**41.28%
COMFORTABLE
OF 8760 HOURS**

WITH SOLAR RADIATION EFFECT



**3271 HRS
COMFORTABLE
OF 8760 HOURS**



**37.34%
COMFORTABLE
OF 8760 HOURS**

CONCLUSION

According to the weather data, Philadelphia is a comfortable city to live.

If we define the "comfort" as: Dry Bulb Temperature is between 18°C to 24°C, the Relative Humidity is between 20% to 80% and the Wind Speed is between 2m/s to 10m/s, then there are 897 hours of total 8760 hours (10.24%) that can be called "comfortable".

-From the Wind-Rose diagram we can learn that when the Dry Bulb Temperature is between 18°C to 24°C and the Relative Humidity is between 20% to 80%, the best wind speed comes mostly from South-West direction.

-When the Dry Bulb Temperature is between 18°C to 24°C and the Wind Speed is between 2m/s to 10m/s, Philadelphia is always wet. There are 3084 hours of total 8760 hours that both the wind and the temperature is comfortable but the Relative Humidity is always more than 70%.

-When the Relative Humidity is between 20% to 80% and the Wind Speed is between 2m/s to 10m/s, there are 5288 hours of total 8760 hours that both the humidity and the wind is comfortable but the Dry Bulb Temperature is above 26°C which means not comfortable because it's a little bit hot outside.

-When the Relative Humidity is between 20% to 80% and the Temperature is between 18°C to 24°C, there are 963 hours of total 8760 hours that both the humidity and the temperature is comfortable but the wind speed is above 8.64m/s which means not comfortable because the wind is a little bit strong.

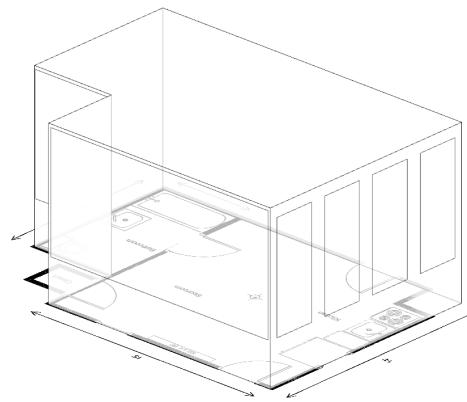
My strategy for having more comfort hours:

- (1) Open the windows from 6am to 6pm in the spring and fall and 8pm to 0am in summer and 8am to 10am in the winter.
- (2) In summer, Philadelphia will be very wet so use air conditioner to dry the air.
- (3) Don't open the South-East window in winter since it's very cold outside and the wind comes mainly from this direction.

BASE-CASE ASSESSMENT

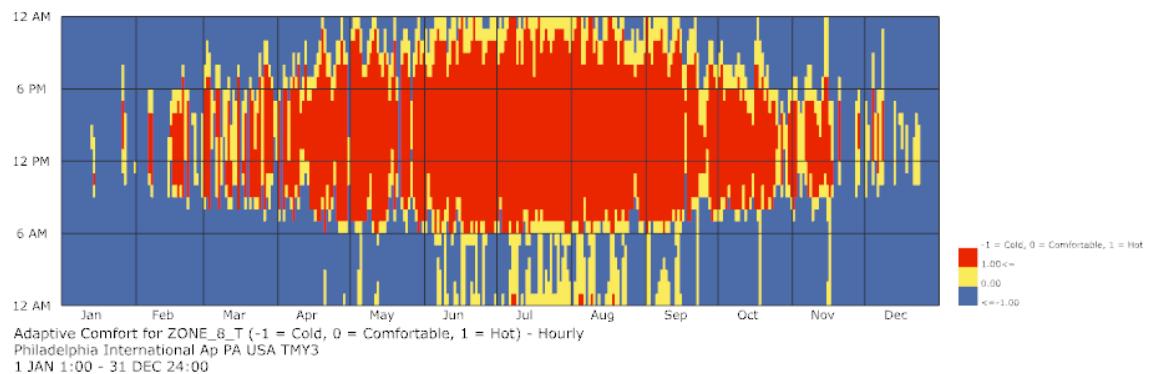
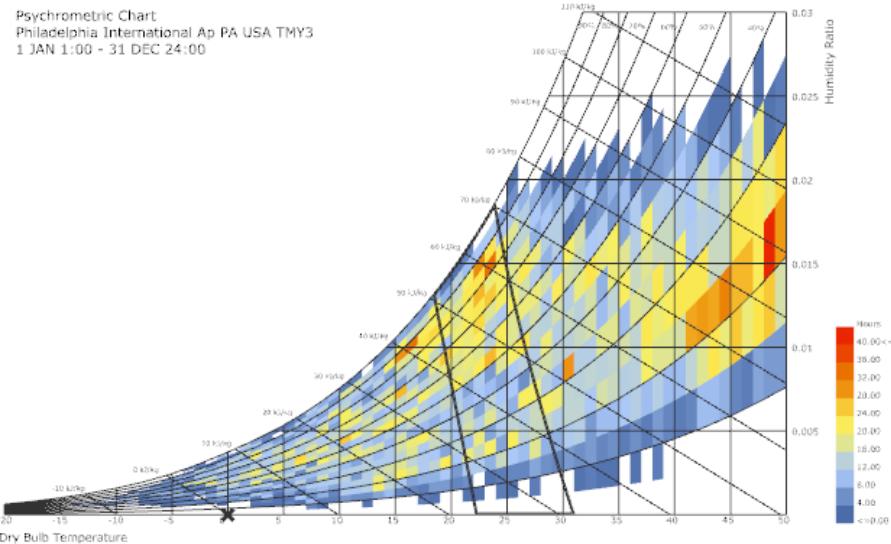
Climate Analysis

INITIAL COMFORT ANALYSIS



The initial data shows that the comfort hours is only 14.28% and most of which comes from the winter because people feel more cold than hot. So my proposal will be:

- (1) Make the north window smaller to prevent cold air.
- (2) Change the orientation to the light.
- (3) Use as thick construction as possible to prevent heat leak.
- (4) Add Blinds to decrease the hot hours.



Comfortable Hours

1251hrs, 14.28%

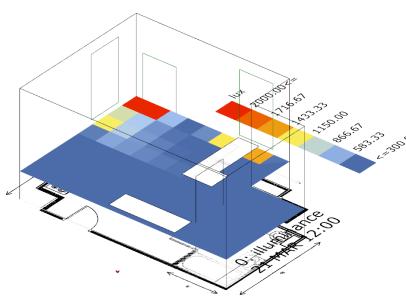
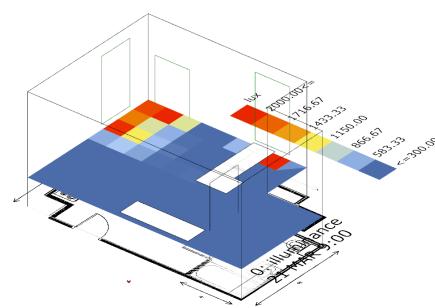
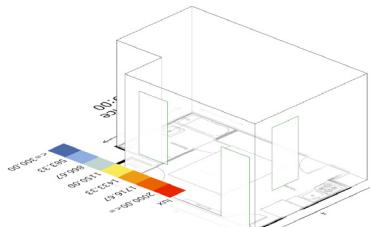
Hot Hours

2908hrs, 33.2%

Cold Hours

4600hrs, 52.52%

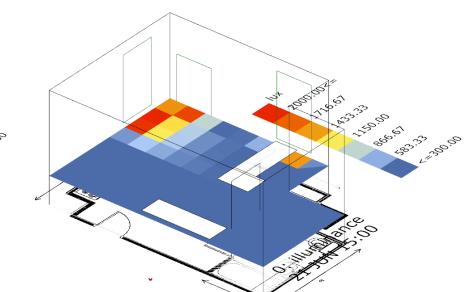
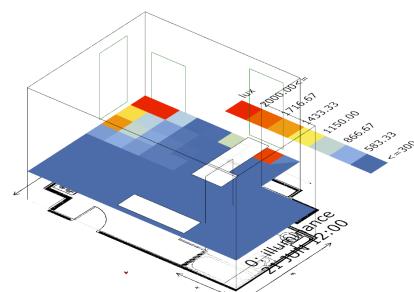
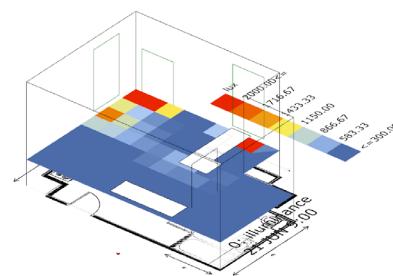
INITIAL DAYLIGHTING



9am Mar 21

12pm Mar 21

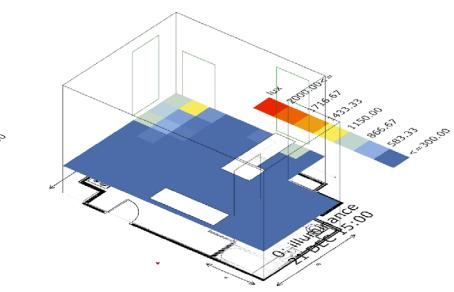
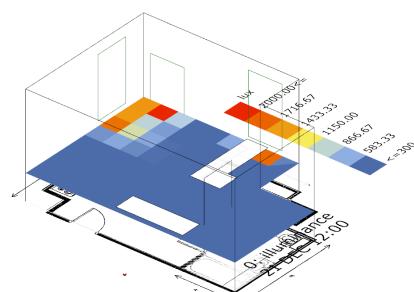
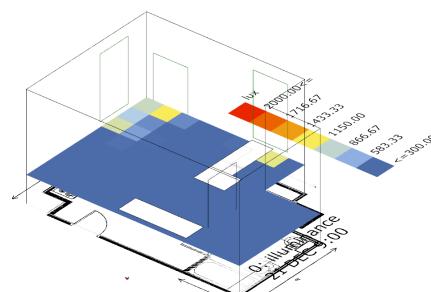
15pm Mar 21



9am Jun 21

12pm Jun 21

15pm Jun 21



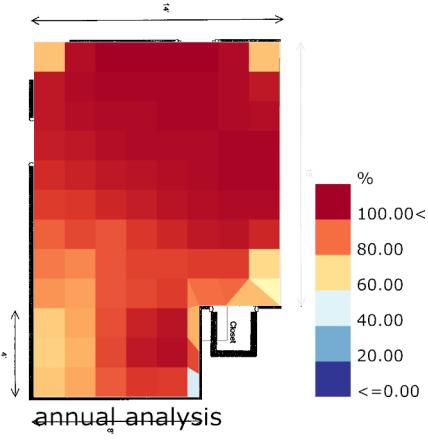
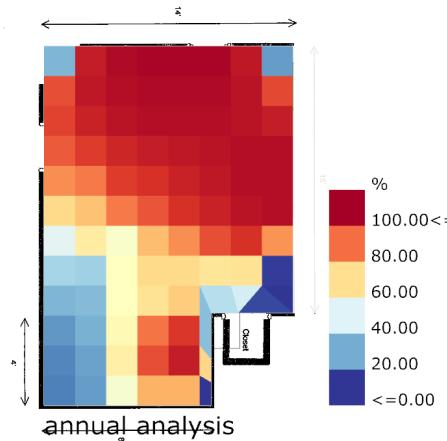
9am Dec 21

12pm Dec 21

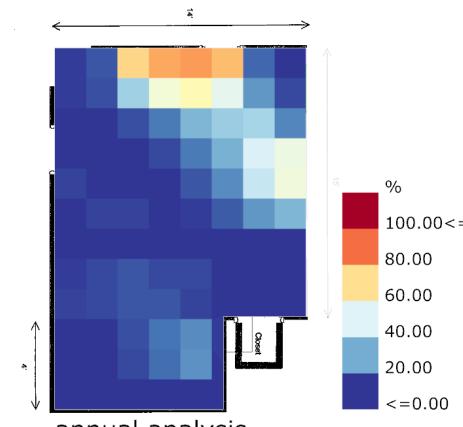
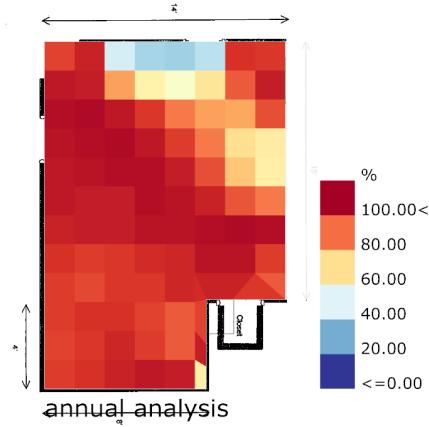
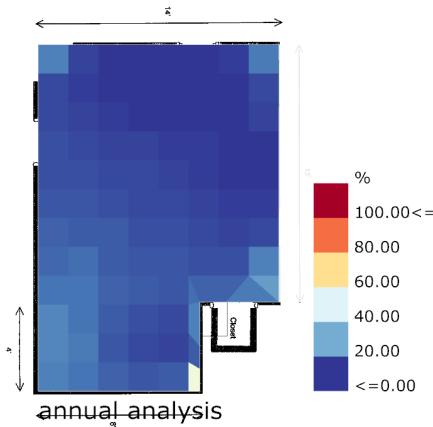
15pm Dec 21

For now, the daylight analysis show that the interior sunshine environment is insufficient. My first proposal is to make the windows' size bigger.

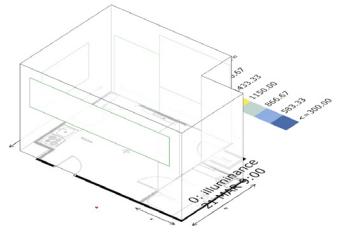
INITIAL DAYLIGHTING



SDA: 75%
300lux 50%

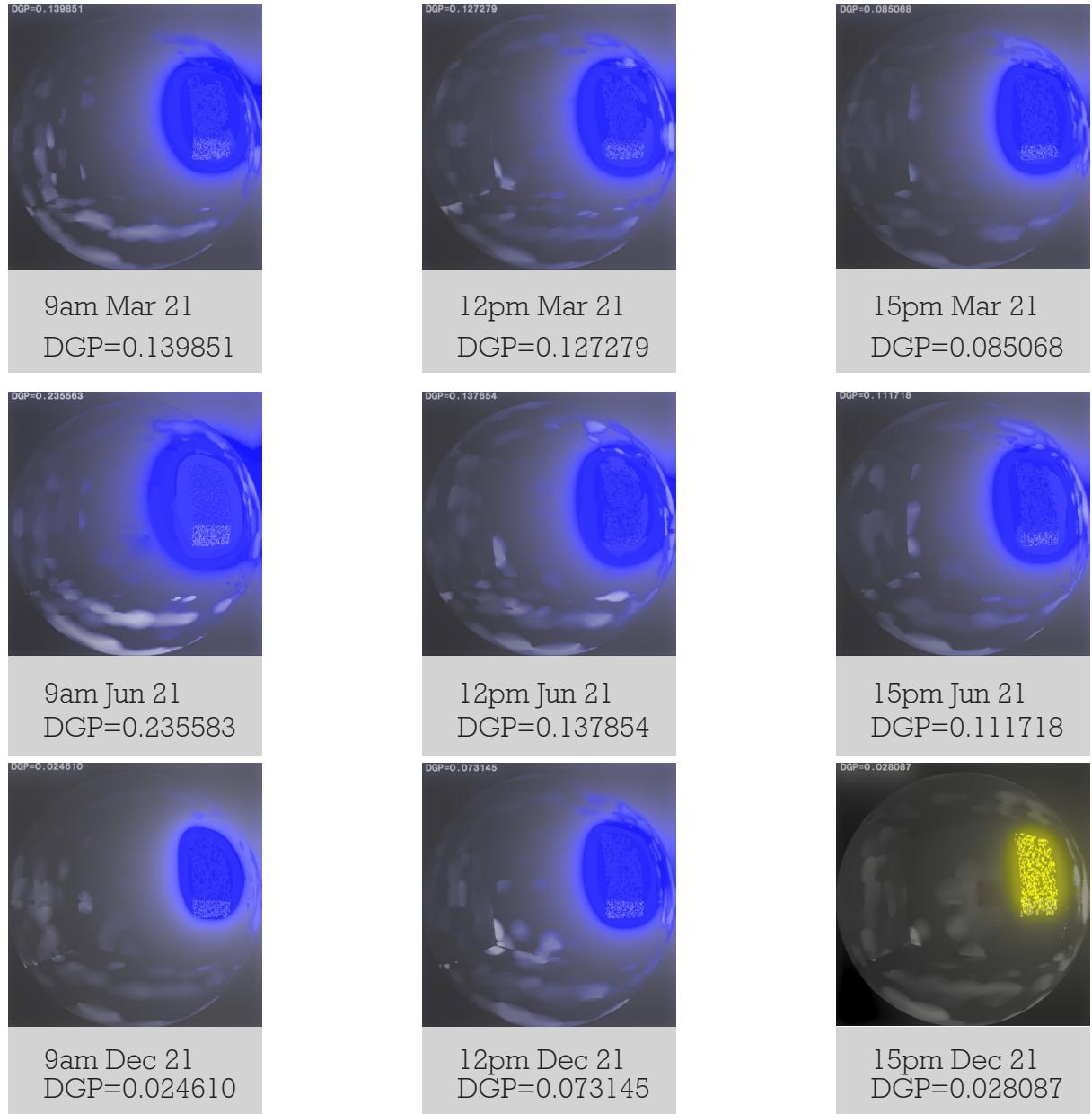


INITIAL GLARE ANALYSIS

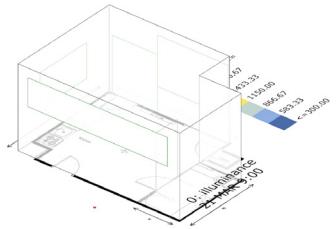


The Glare Analysis runs on the position of my computer, where I probably have a glare issue on my screen. The DGP value should be under 0.35, which means imperceptible.

Even the DGP value from the analysis is quite low, it doesn't mean this is a good "comfortable" situation because my apartment is lack of sunlight. For adding more comfort hours, I have to increase the size of the window and also try to avoid the glare issue.

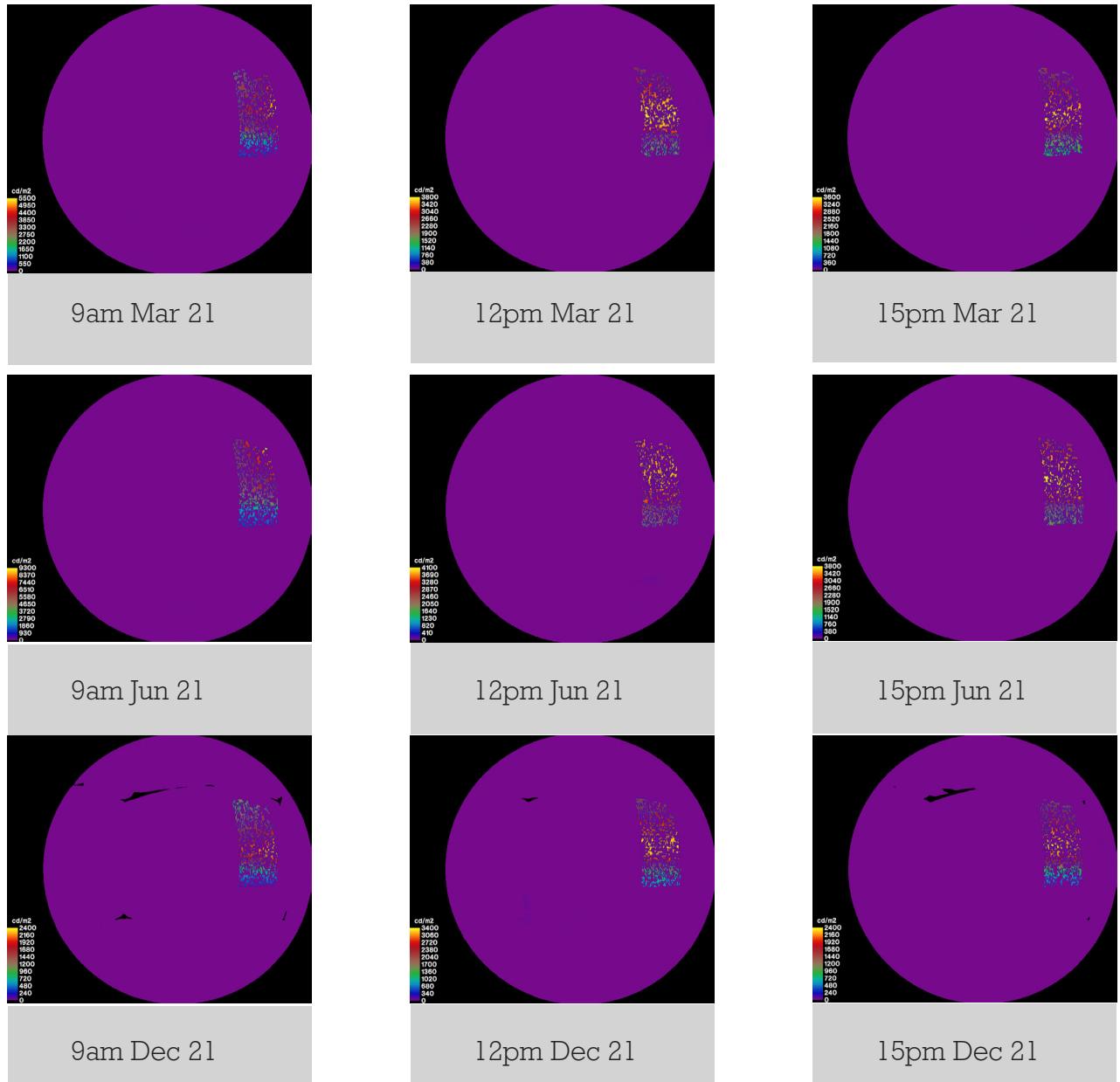


INITIAL GLARE ANALYSIS



The Glare Analysis runs on the position of my computer, where I probably have a glare issue on my screen. The DGP value should be under 0.35, which means imperceptible.

Even the DGP value from the analysis is quite low, it doesn't mean this is a good "comfortable" situation because my apartment is lack of sunlight. For adding more comfort hours, I have to increase the size of the window and also try to avoid the glare issue.



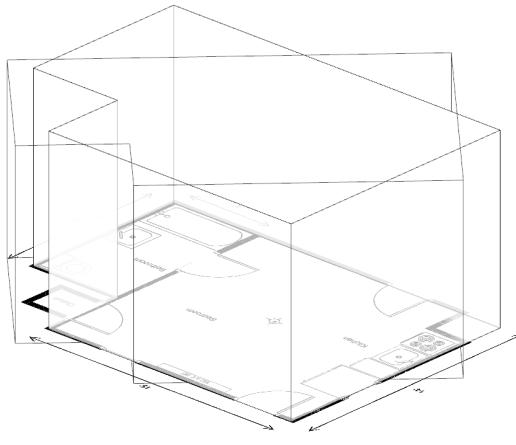
DISCUSSION AND DESIGN PROPOSALS

DESIGN PROPOSALS

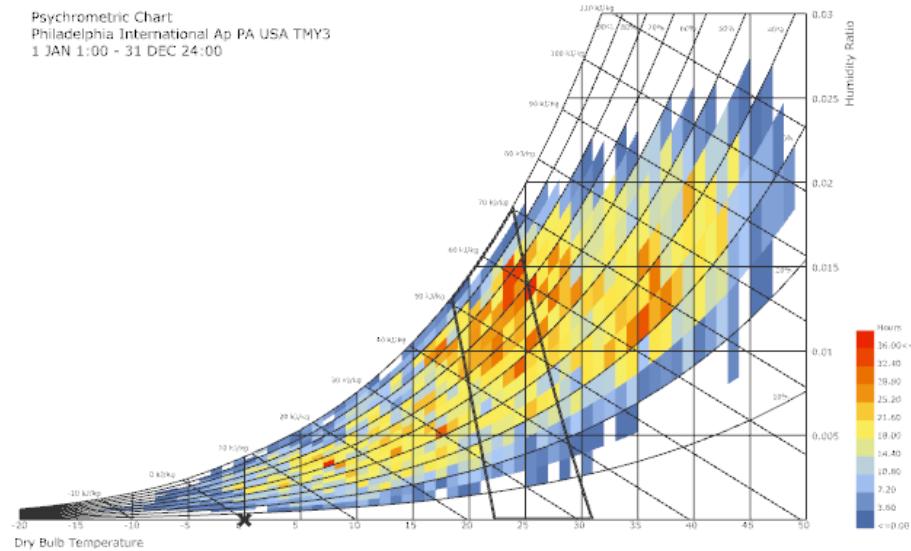
According to the analysis I did with the climate and the apartment, I find that the existing issue with uncomfortable experience is mainly because that the sunlight is terrible in my apartment, and also because Philadelphia is a cold city, the thermal condition in my apartment is not satisfied.

To change the issue and increase the living condition more comfortable, I will be focusing on the following aspects that I learned during this semester. Due to the fact the no heating or cooling system is allowed, my proposal would be to use thicker wall to keep the thermal energy, change the window ratio so that I can get more sunshine inside, change the orientation of the apartment to avoid the glare and get more sunlight.

CHANGE ROTATION

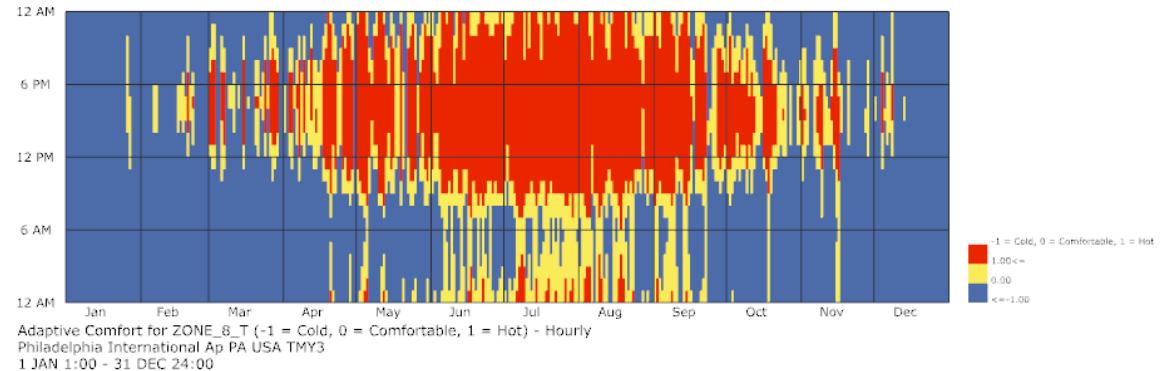


Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Rotation Changed: 45 degree

The comfortable hours decreased. This is because the windows are not facing towards the sun directly. Also, it causes the cold hours increased. Because we gave 0 for window ratio from last step, so the hot hours didn't change because there was no radiation changed.



Comfortable Hours

1519hrs, 17.35%

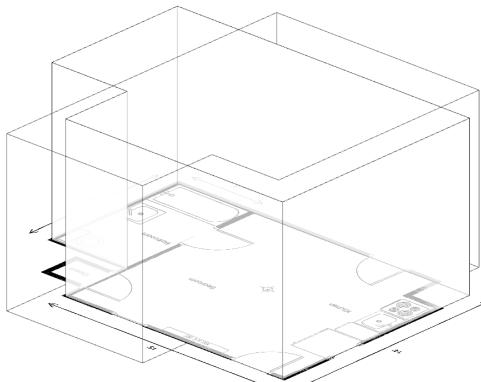
Hot Hours

2266hrs, 25.87%

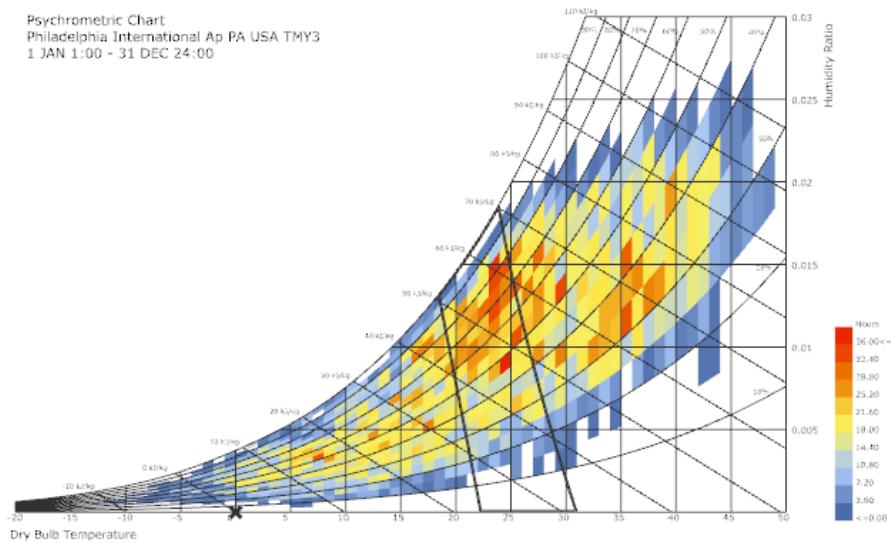
Cold Hours

4974hrs, 56.78%

CHANGE ROTATION

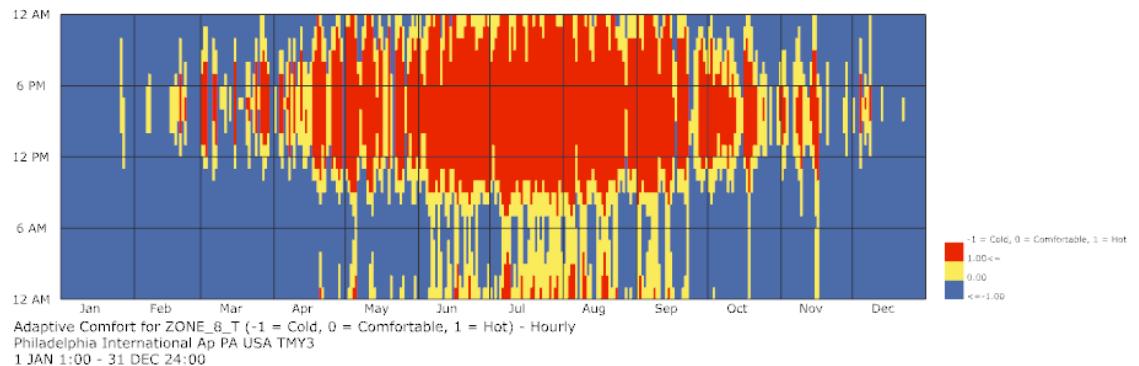


Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Rotation Changed: 90 degree

The comfortable hours decreased. I will keep rotating for testing.



Comfortable Hours

1537hrs, 17.55%

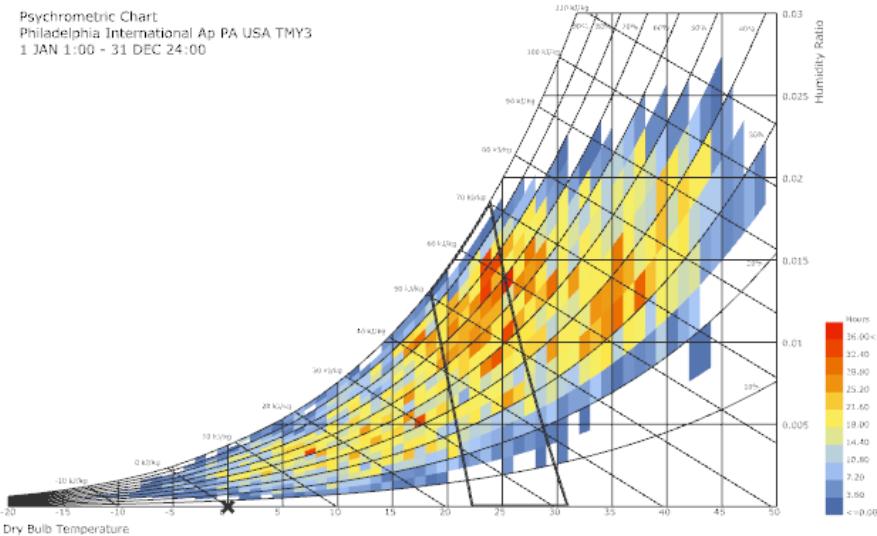
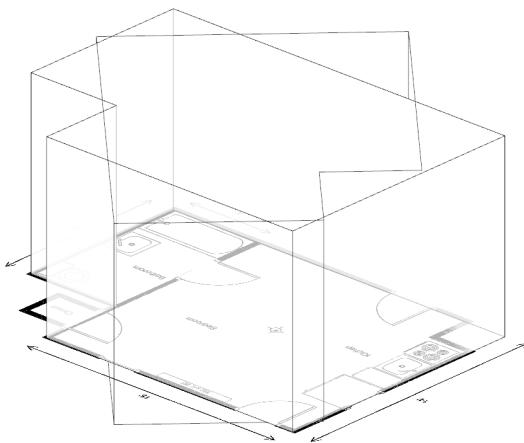
Hot Hours

2240hrs, 25.57%

Cold Hours

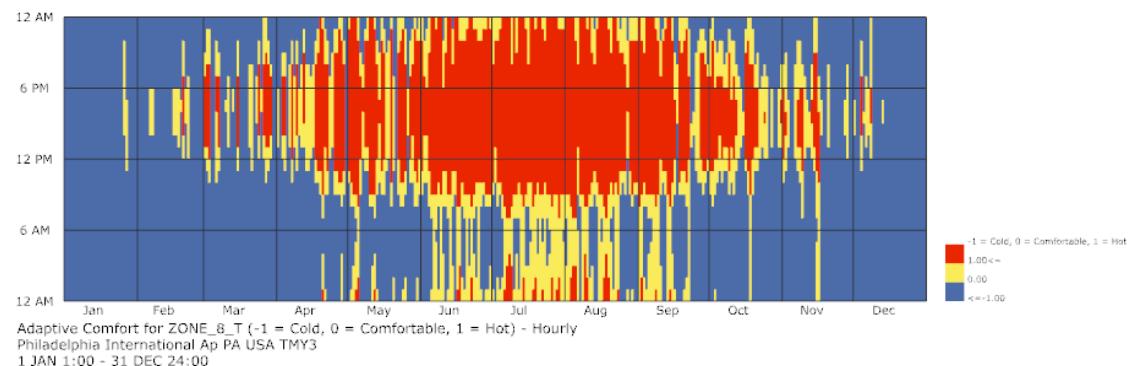
4983hrs, 56.88%

CHANGE ROTATION



Rotation Changed: 135 degree

The comfortable hours decreased. I will keep rotating for testing.



Comfortable Hours

1520hrs, 17.36%

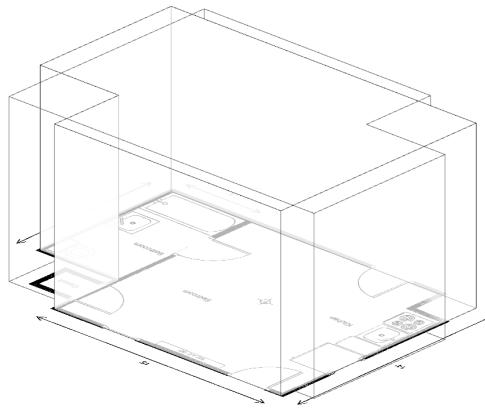
Hot Hours

2252hrs, 25.71%

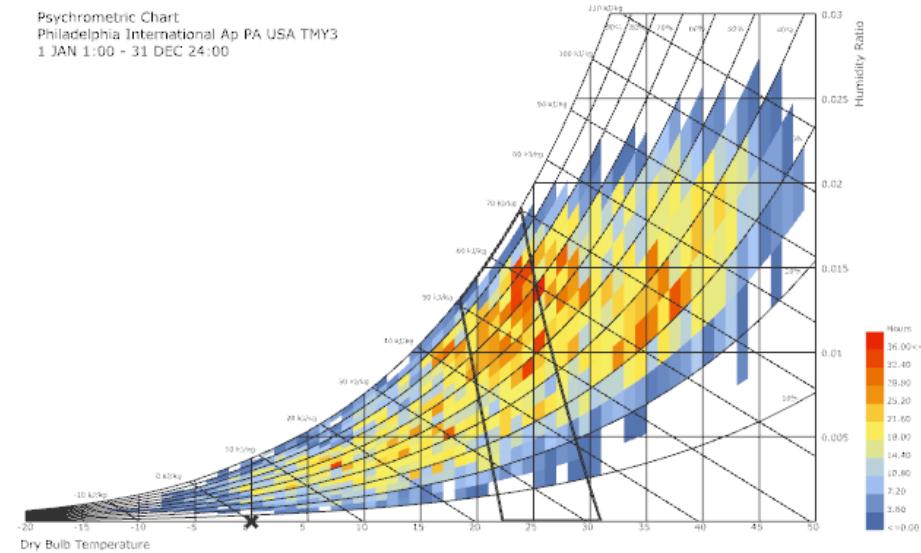
Cold Hours

4987hrs, 56.93%

CHANGE ROTATION

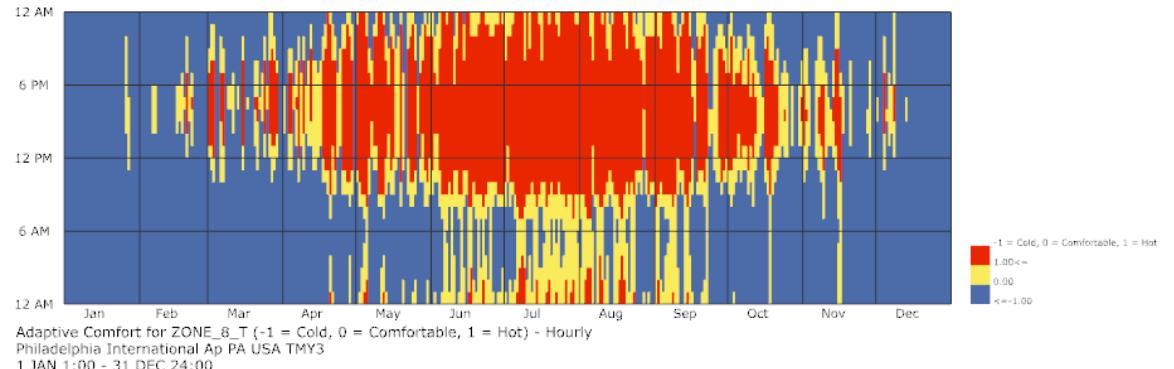


Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Rotation Changed: 180 degree

Comfortable Hours starts to increase and both hot and cold hours start to decrease. Rotating for 180 degree means I'm having two windows facing toward South and West, the best direction in Philadelphia for getting heat from radiation.



Comfortable Hours

1527hrs, 17.44%

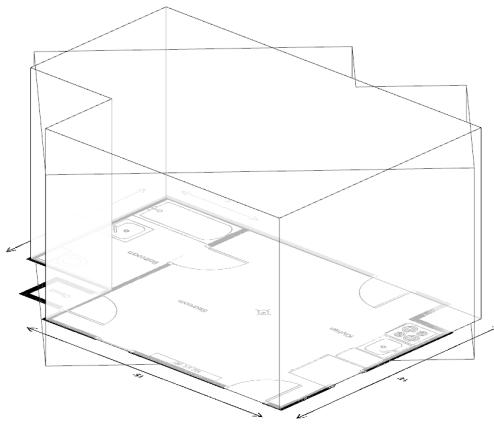
Hot Hours

2262hrs, 25.83%

Cold Hours

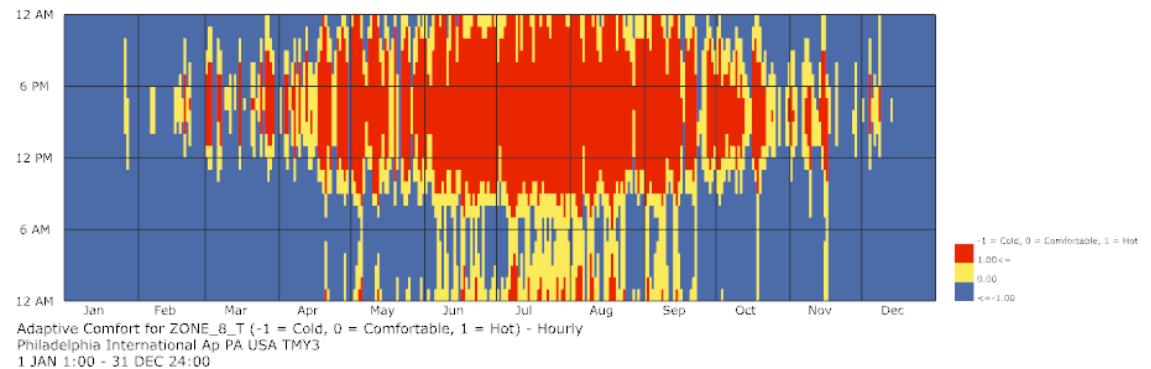
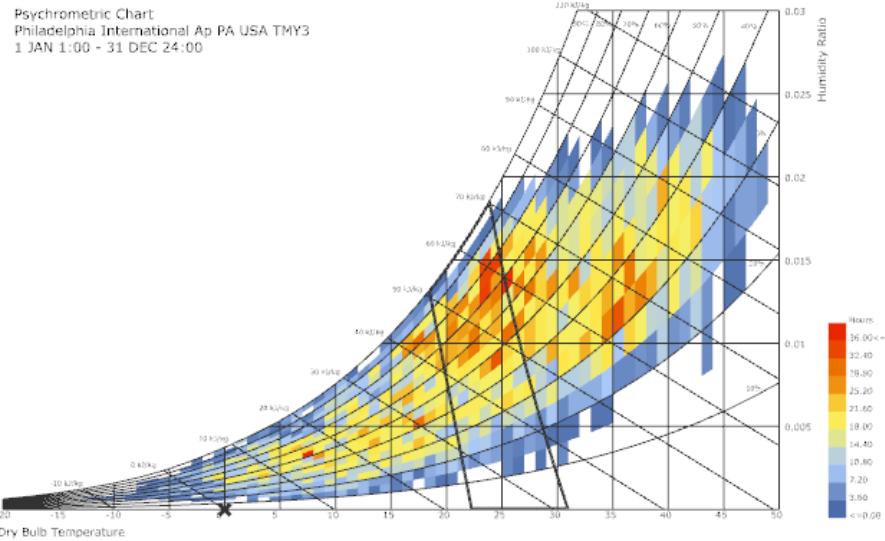
4969hrs, 56.72%

CHANGE ROTATION



Rotation Changed: 225 degree

Once the windows do not face towards the best directions, the comfortable hours start to decrease and hot and cold hours start to increase.



Comfortable Hours

1521hrs, 17.37%

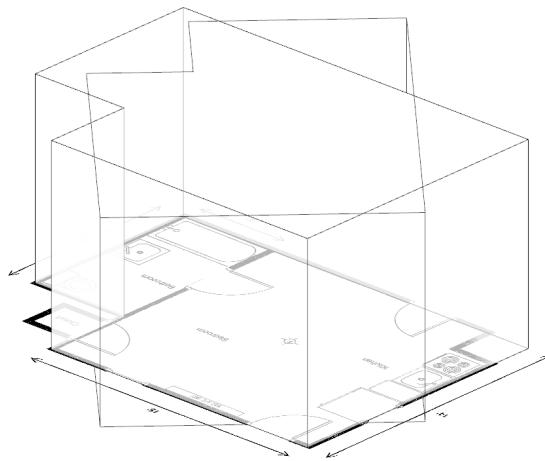
Hot Hours

2267hrs, 25.88%

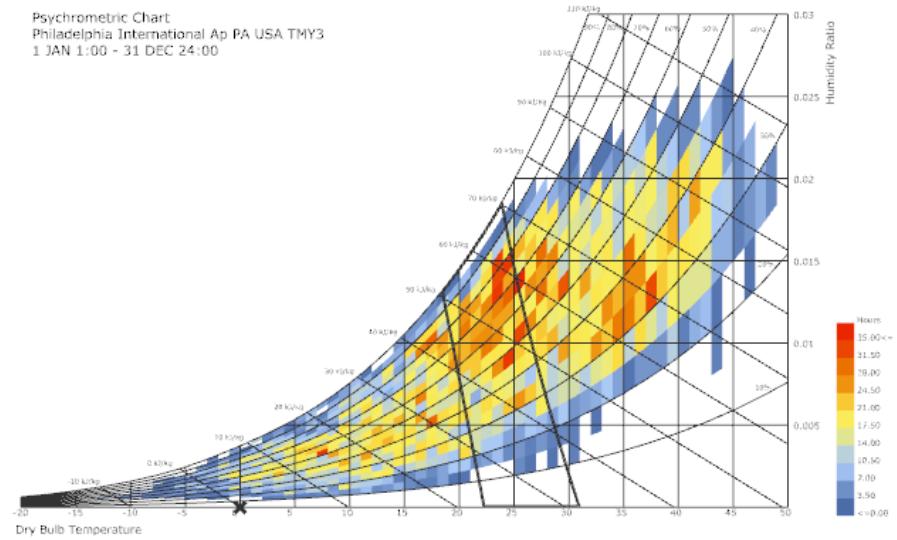
Cold Hours

4971hrs, 56.75%

CHANGE ROTATION

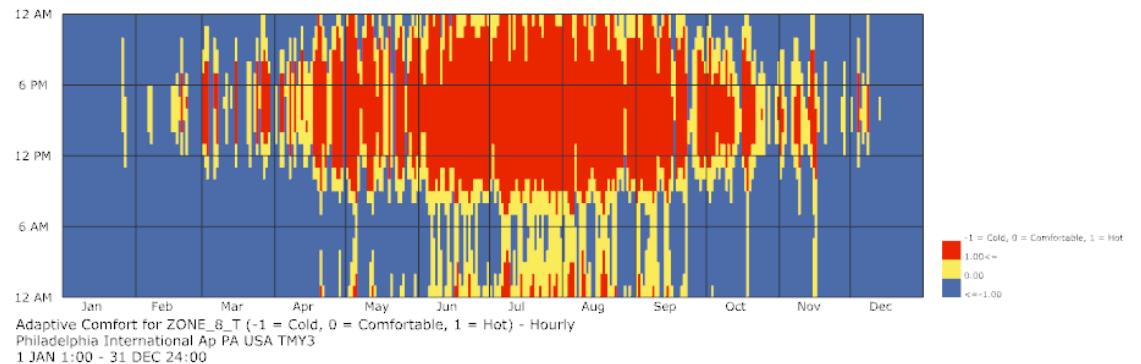


Psychrometric Chart
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



Rotation Changed: 315 degree

Once the windows do not face towards the best directions, the comfortable hours start to decrease and hot and cold hours start to increase.



Comfortable Hours

1523hrs, 17.39%

Hot Hours

2260hrs, 25.8%

Cold Hours

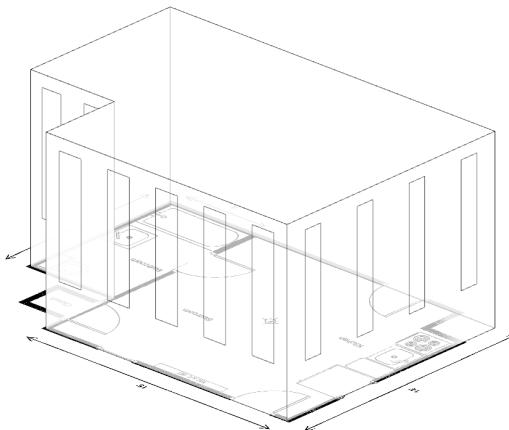
4977hrs, 56.82%

CONCLUSION FOR ROTATION CHANGING

In the above tests, changing orientation is not very useful for increasing the comfort hours. It is true that the orientation can influence the comfort hours slightly; however, because of the initial window ratio is too small as I only have two small windows, the orientation cannot be the crucial factor.

The next step I will change the window ratio for testing.

CHANGE WINDOW RATIO



Rotation:0

Glaze Ratio:

North:0.2

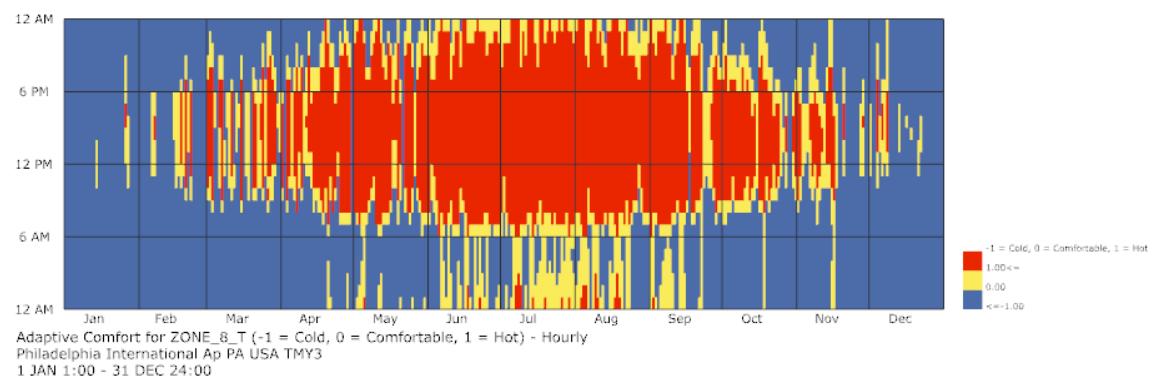
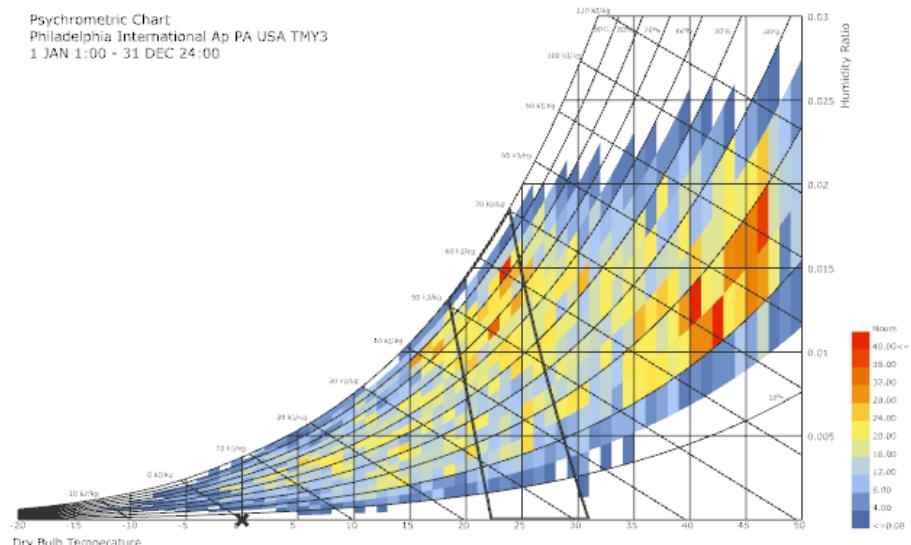
West:0

South:0

East:0.3

For this data, the comfortable hour increased.

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



Comfortable Hours

1377hrs, 15.72%

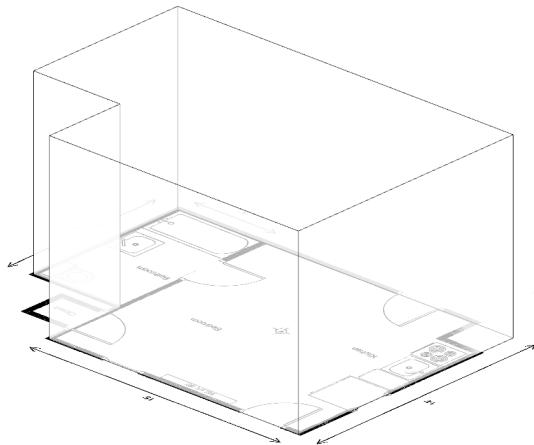
Hot Hours

2775hrs, 31.68%

Cold Hours

4607hrs, 52.6%

CHANGE WINDOW RATIO



Rotation:0

Glaze Ratio:

North:0

South:0

West:0

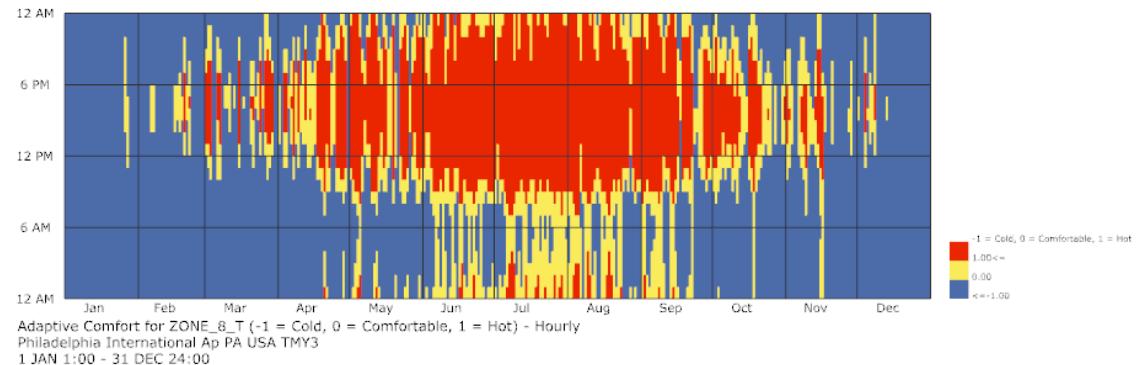
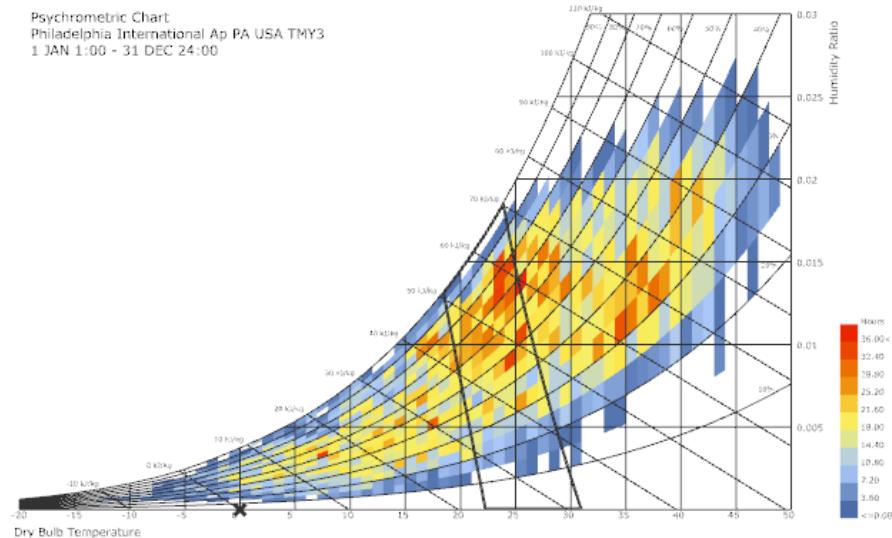
East:0

I tried many possible ratios, however I found 0 window resulted maximum number of comfortable hours. This is absurd in reality. My assumption would be because of the climate in Philadelphia, no window means no heat escapes and no cold comes in. However it also means that I cannot get heat from radiation, this causes the cold hours increased.

Comfortable Hours

1528hrs, 17.45%

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



Hot Hours

2266hrs, 25.87%

Cold Hours

4965hrs, 56.68%

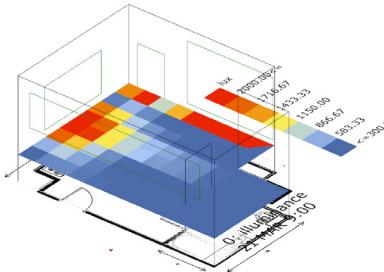
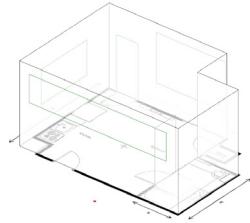
CONCLUSION FOR WINDOW RATIO CHANGING

In the above tests, it is true that changing the window ratio can relatively influence the comfort hours in a more obvious way.

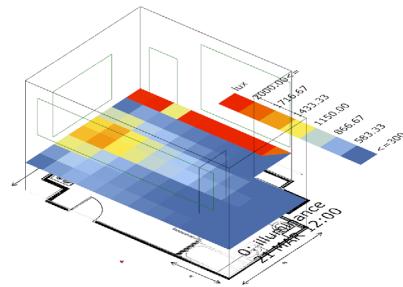
However, it can also bring new issue, like glare, or heat escape.

For next step, I will analyze the glare and run the interior sunlight analysis.

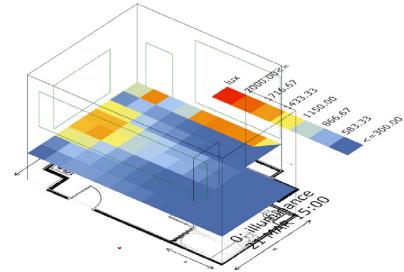
CHANGE NORTH WINDOW'S SIZE



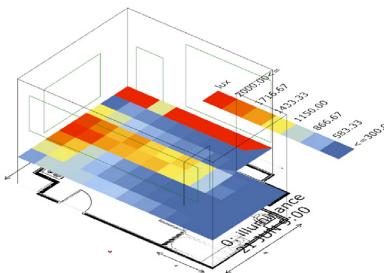
9am Mar 21



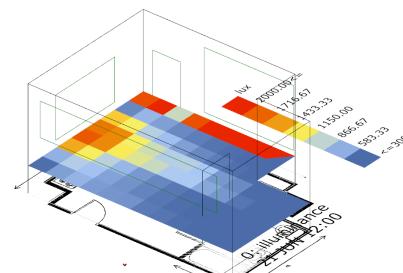
12pm Mar 21



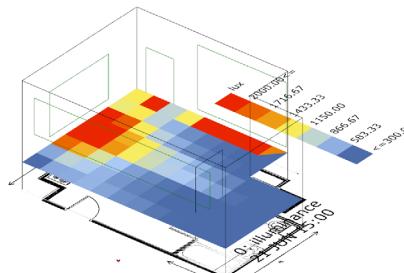
15pm Mar 21



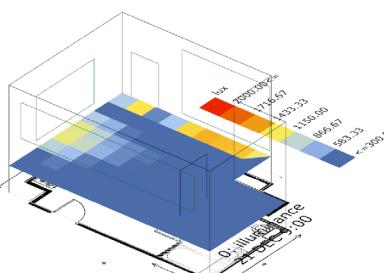
9am Jun 21



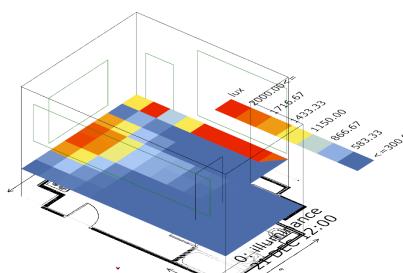
12pm Jun 21



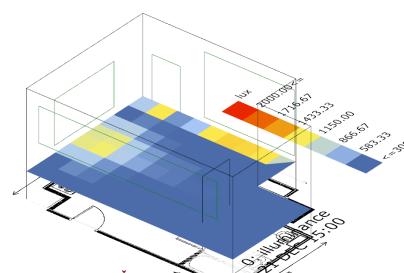
15pm Jun 21



9am Dec 21



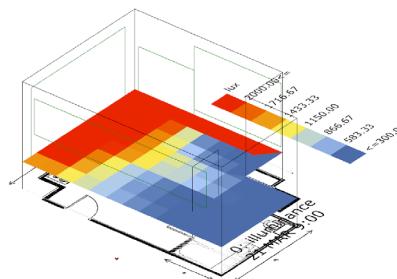
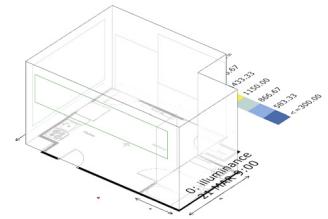
12pm Dec 21



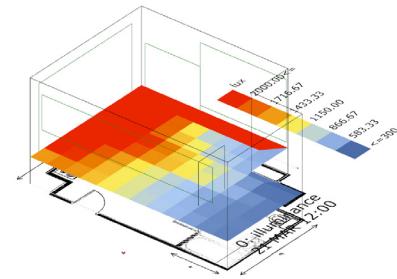
15pm Dec 21

After increasing the size of the north window, the daylight analysis shows that the interior light is getting better. I would like to keep increasing the size of the other windows.

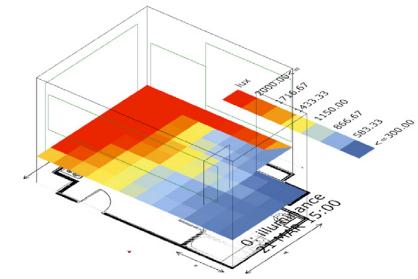
ADD NEW WINDOW



9am Mar 21

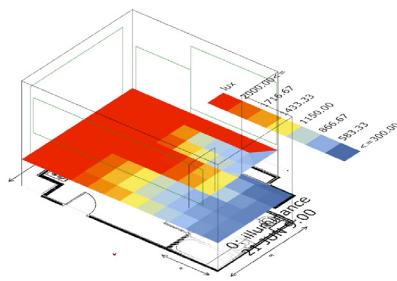


12pm Mar 21

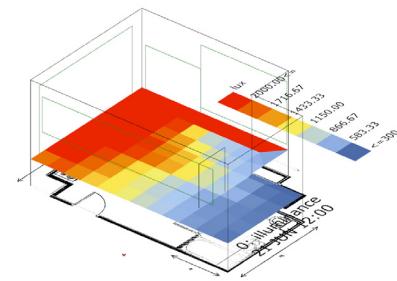


15pm Mar 21

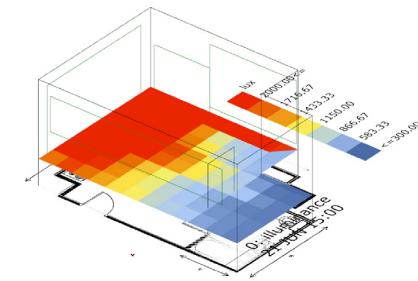
After increasing the size of the door and open it to make it as one of the window when analyzing it, the interior light environment gets better. Also I kept increasing the north window's size and the light now is more than 2000lux. The good thing is the very inside of my apartment get some sunshine in March and June. I also opened a new window on the west wall, it faces to the corridor but not exterior. It helps a little.



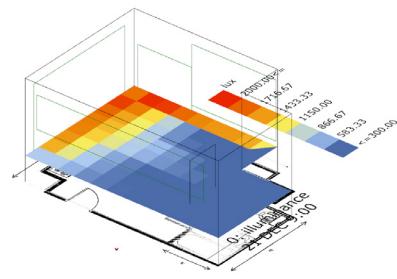
9am Jun 21



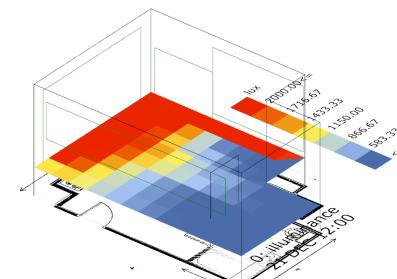
12pm Jun 21



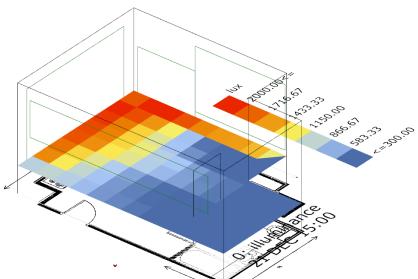
15pm Jun 21



9am Dec 21

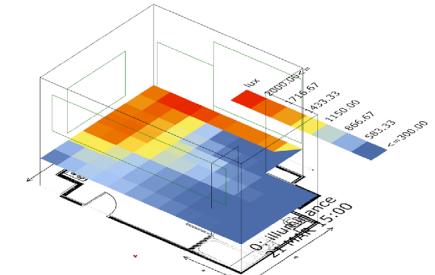
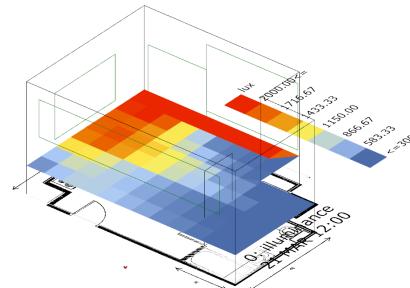
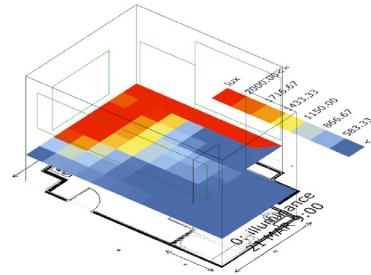
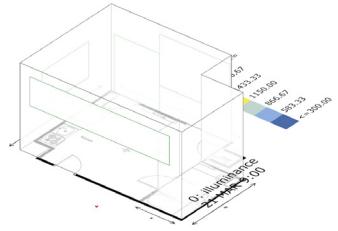


12pm Dec 21



15pm Dec 21

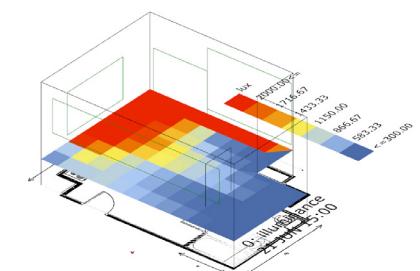
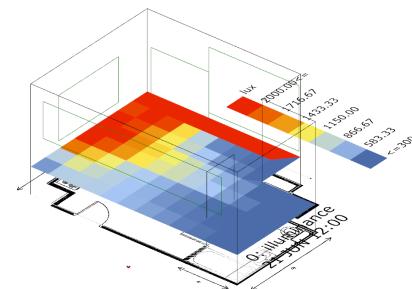
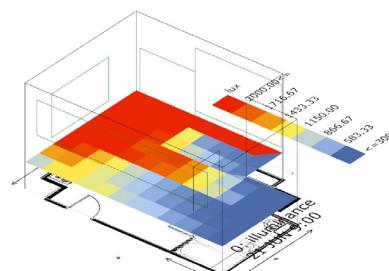
DECREASE THE NORTH WINDOW'S SIZE



9am Mar 21

12pm Mar 21

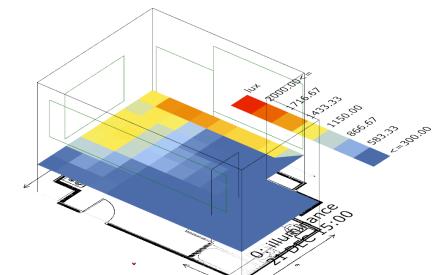
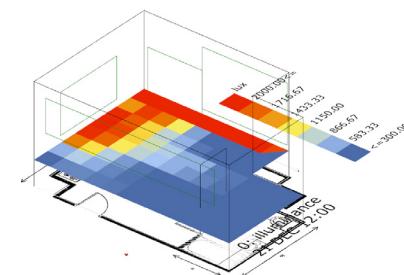
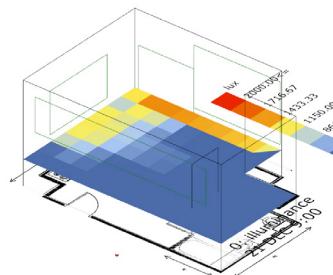
15pm Mar 21



9am Jun 21

12pm Jun 21

15pm Jun 21



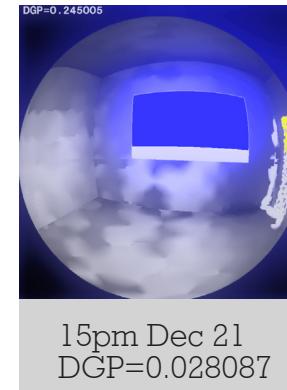
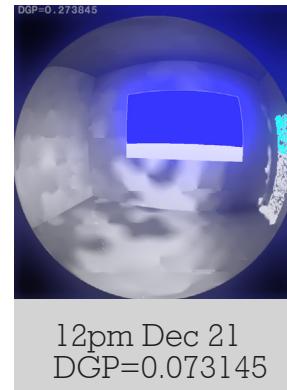
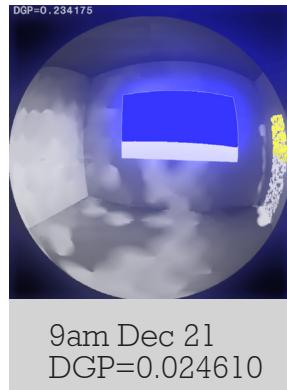
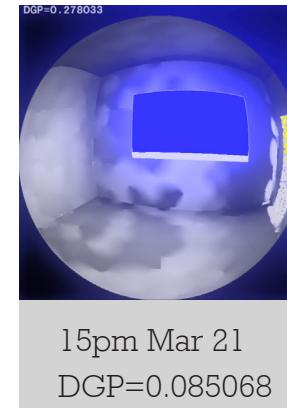
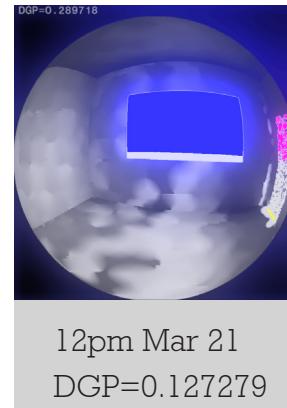
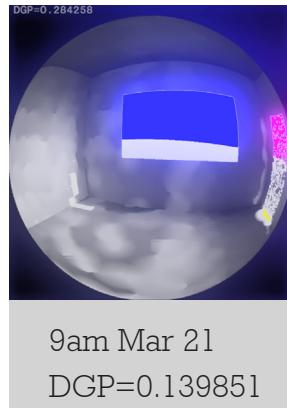
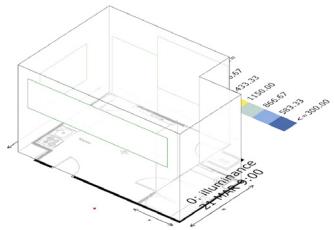
9am Dec 21

12pm Dec 21

15pm Dec 21

According to the former analysis, the light is out of the boundary we set, 2000lux, so I decreased the north window's size. From the analysis now we can see that only in June the sunshine is too much. This range is acceptable for me.

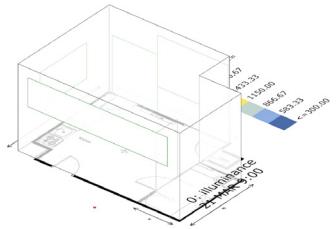
GLARE ANALYSIS



The Glare Analysis runs on the position of my computer, where I probably have a glare issue on my screen. The DGP value should be under 0.35, which means imperceptible.

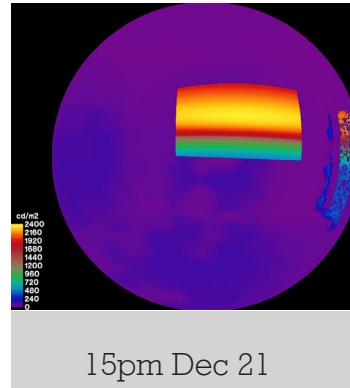
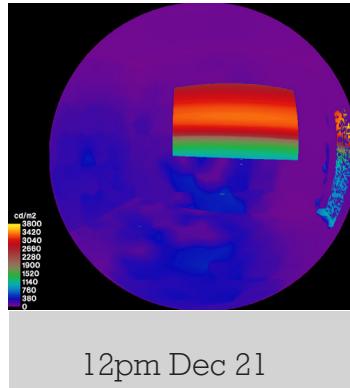
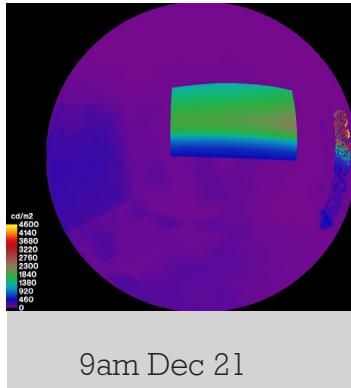
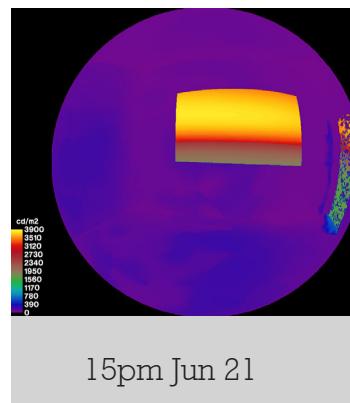
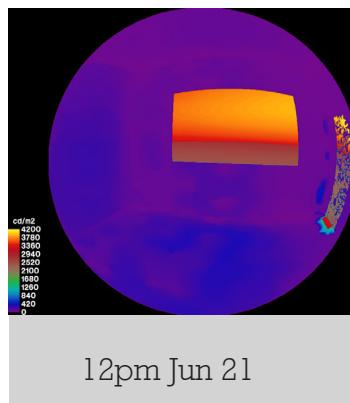
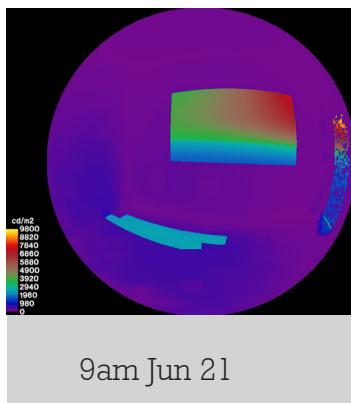
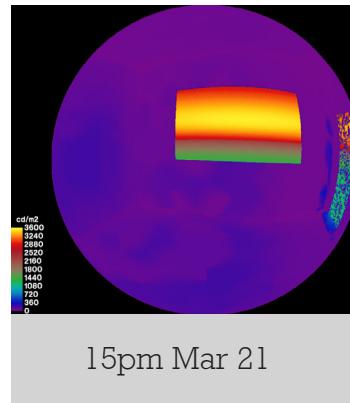
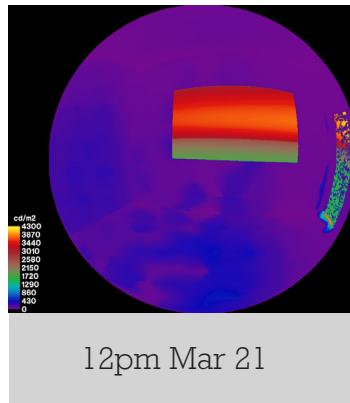
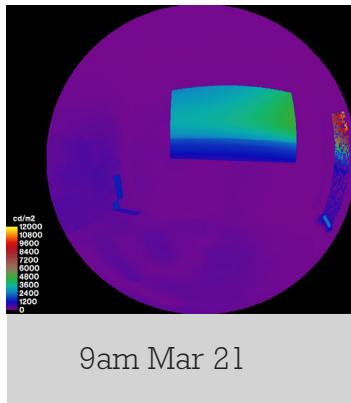
The daylight glare probability(DGP) should under 0.35 to be imperceptible. According to the analysis, the average DGP is under 0.28 which is unperceptible and acceptable for me. The maximum DGP happens at June 21st, 9am, as 0.328985.

GLARE ANALYSIS

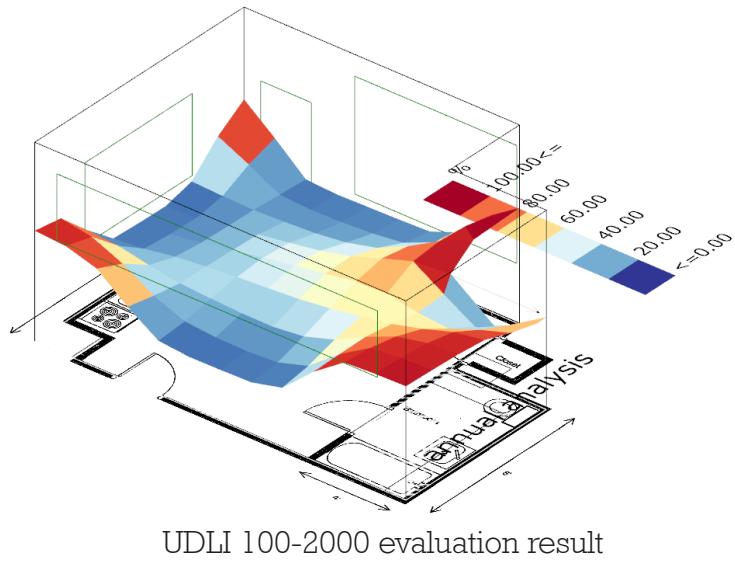


The Glare Analysis runs on the position of my computer, where I probably have a glare issue on my screen. The DGP value should be under 0.35, which means imperceptible.

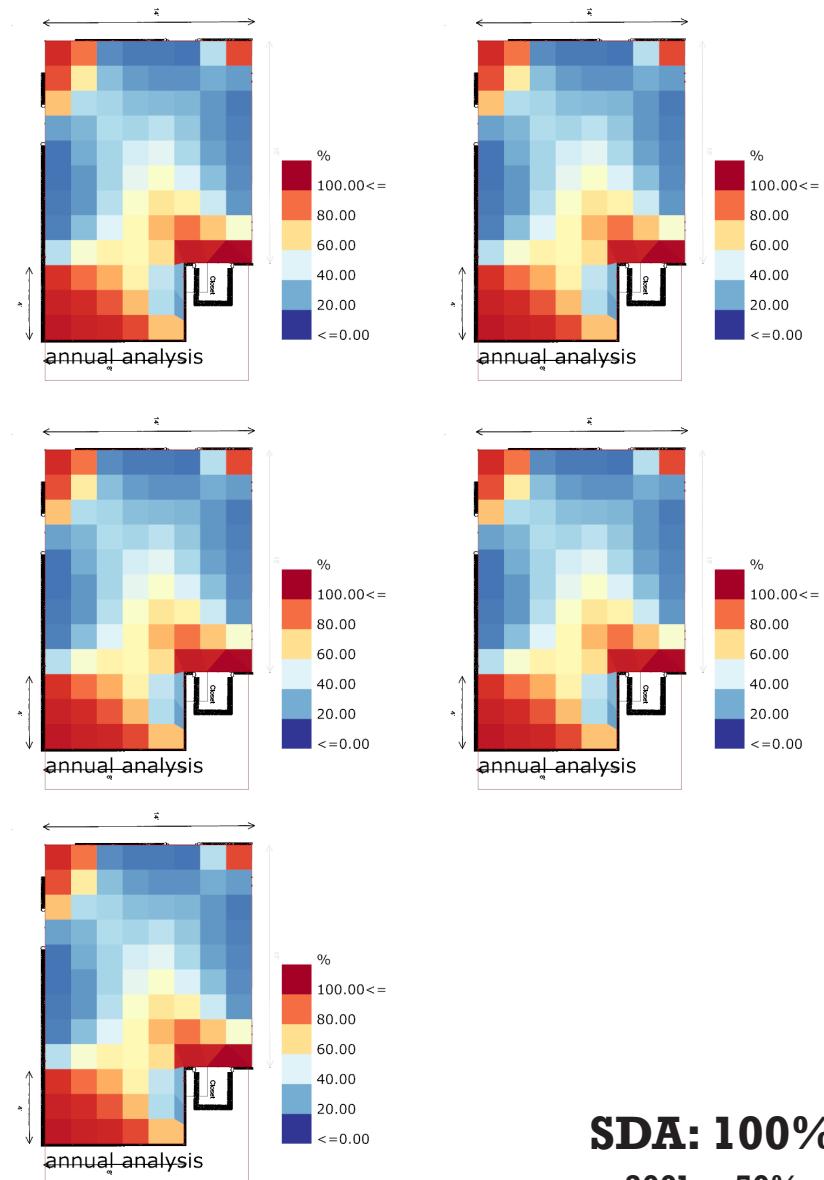
The daylight glare probability(DGP) should under 0.35 to be imperceptible. According to the analysis, the average DGP is under 0.28 which is unperceptible and acceptable for me. The maximum DGP happens at June 21st, 9am, as 0.328985.



ANNUAL DAYLIGHT ANALYSIS: UDI

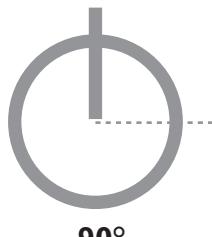


From the Annual Daylight Analysis, we can see that after the improvement, most of the area in the apartment is in good daylight performance. However because of the existing disadvantage of the plan of the apartment, the northwest corner is lack of daylight.



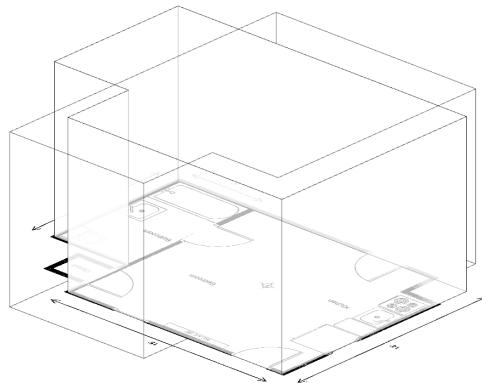
SDA: 100%
300lux 50%

FIRST RUN SUMMARY

	Orientation	Glaze Ratio	Daylighting	Adaptive Comfort
Original	 -90°	North:0.1 West:0.0 South:0 East:0.1	1251hrs, 14.28% Comfortable of 8760 hours	SDA: 75% 300lux 50%
First Run	 90°	North:0.3 West:0.2 South:0.5 East:0.1	1537hrs, 17.55% Comfortable of 8760 hours	SDA: 100% 300lux 50%
Strategies		Construction Material		Ventilation
				Thermal Mass

FINAL DESIGN ASSESSMENT

CHANGE CONSTRUCTION



Exterior Wall [R34.4]

Exterior Window [R1.9, SHGC 0.39]

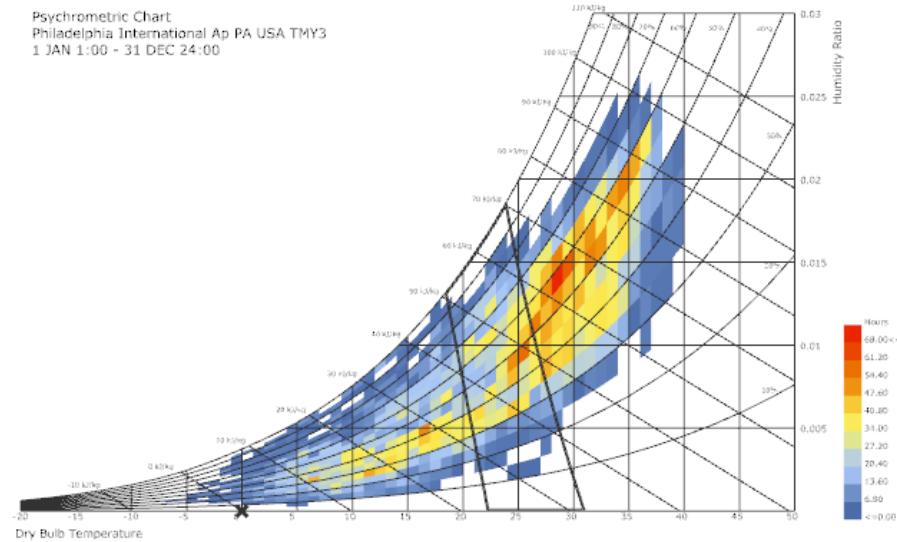
Exterior Roof [R34.4]

Air Change Hour: 2

The main feeling is cold(48.76%), so I choose the thickest wall and window with the biggest resistance value.

Psychrometric Chart

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



12 AM

6 PM

12 PM

6 AM

12 AM

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Adaptive Comfort for ZONE_0_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

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

Comfortable Hours

1873hrs, 21.38%

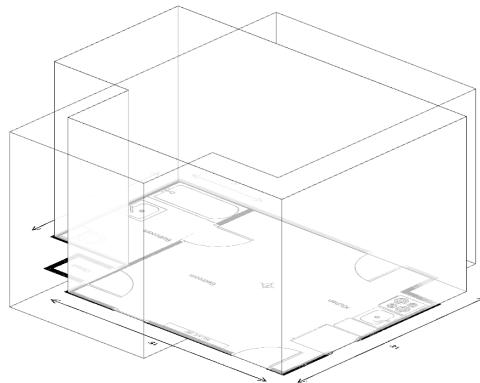
Hot Hours

2612hrs, 29.86%

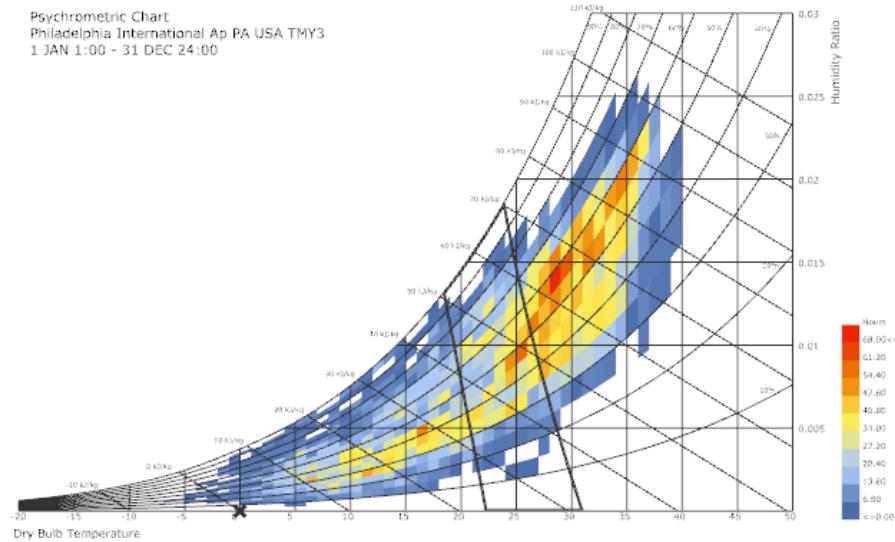
Cold Hours

4271hrs, 48.76%

CHANGE VENTILATION



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



Exterior Wall [R34.4]

Exterior Window [R1.9, SHGC 0.39]

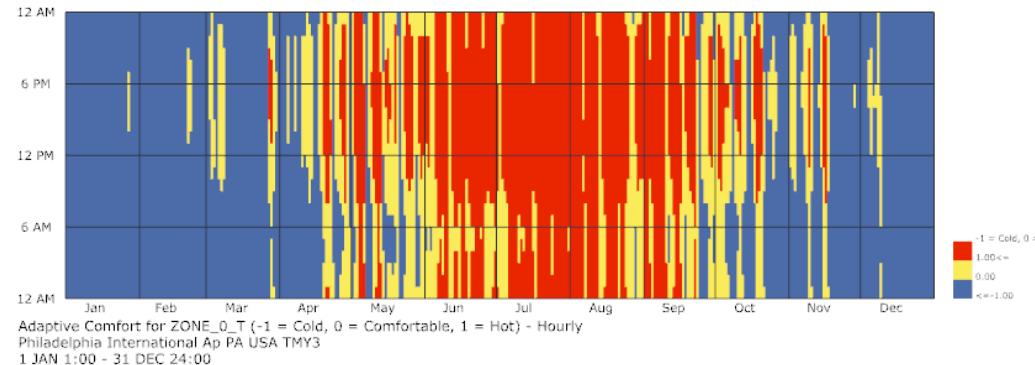
Exterior Roof [R34.4]

Air Change Hour: 0

I changed the Air Change Hour to 0. The comfortable changes from more than 20 percent into 17.4%. The hot hour increased and cold hour decreased dramatically. At this time I thought that maybe the number is better the more comfortable hours I will get.

Comfortable Hours

1524hrs, 17.4%



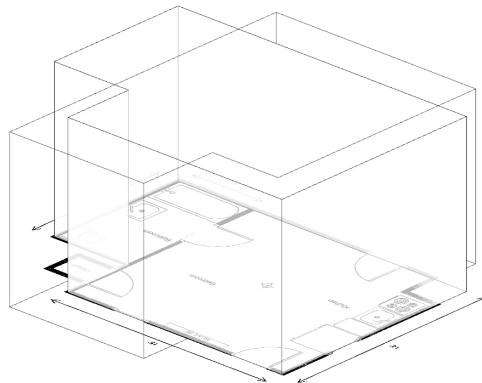
Hot Hours

4876hrs, 55.66%

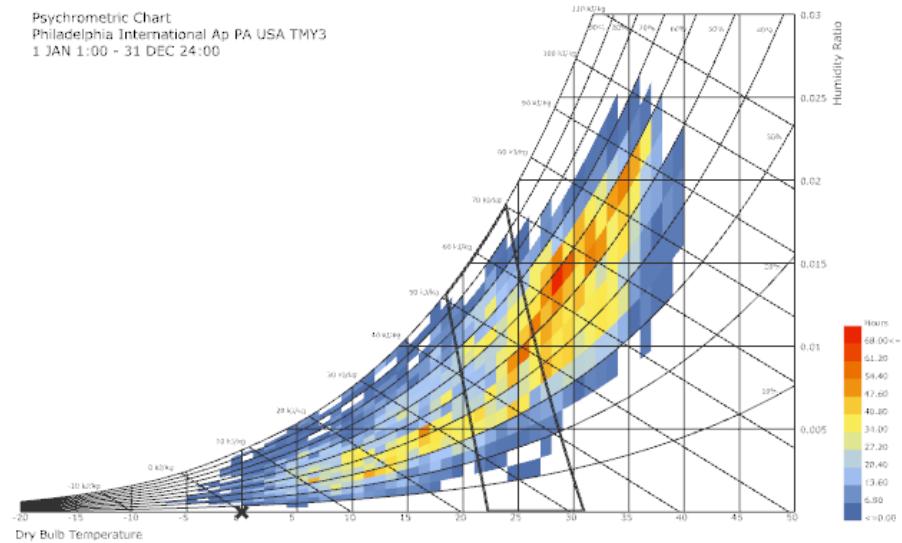
Cold Hours

2359hrs, 26.94%

CHANGE VENTILATION



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



Exterior Wall [R34.4]

Exterior Window [R1.9, SHGC 0.39]

Exterior Roof [R34.4]

Air Change Hour: 10

So I changed the the hour into 10. The comfortable hours increased, and also because of the ventilation the hot hour decreased and the cold hour increased. Since I don't know if this is the biggest possible number. So I tried to make it smaller and let's see what happened.

Comfortable Hours

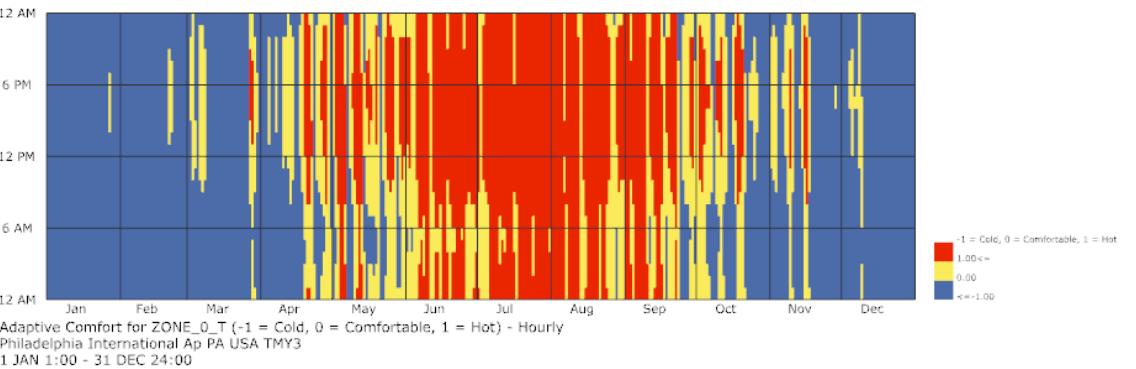
1890hrs, 21.58%

Hot Hours

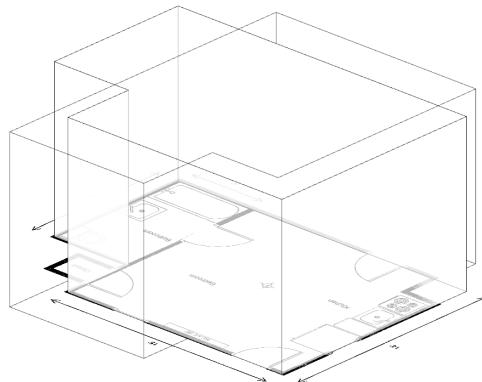
1004hrs, 11.47%

Cold Hours

5264hrs, 66.95%



CHANGE VENTILATION



Exterior Wall [R34.4]

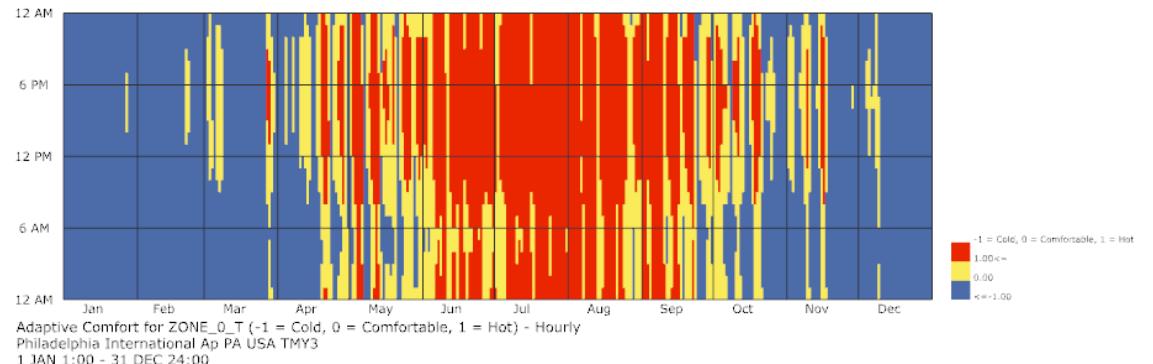
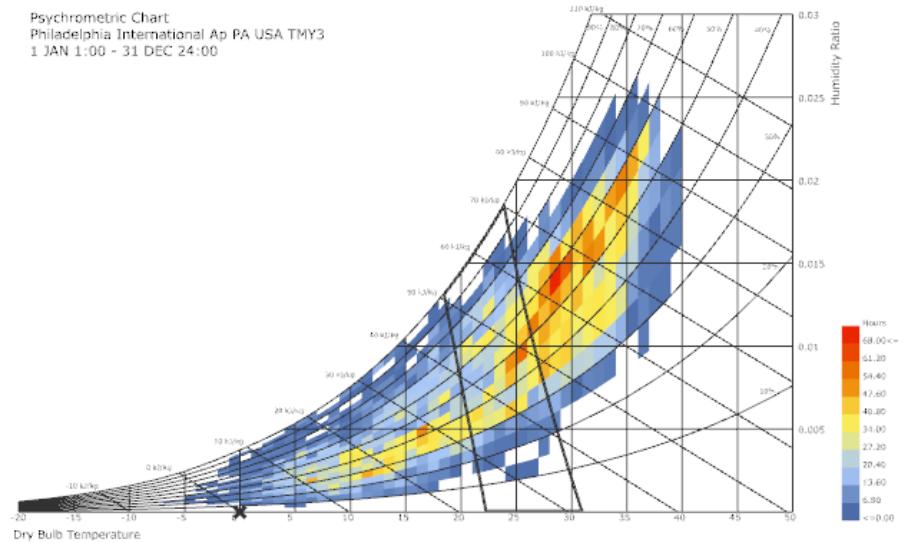
Exterior Window [R1.9, SHGC 0.39]

Exterior Roof [R34.4]

Air Change Hour: 7.5

I made it smaller and surprisingly got more comfortable hours. I kept to narrow it down.

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



Comfortable Hours

1957hrs, 22.34%

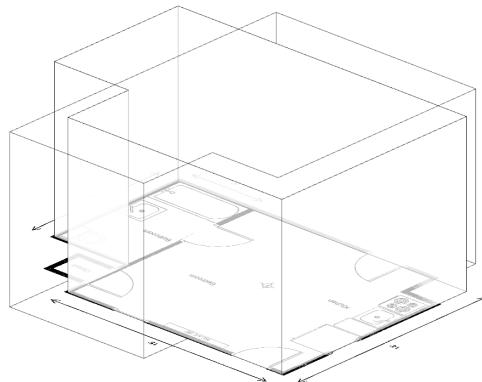
Hot Hours

1158hrs, 13.22%

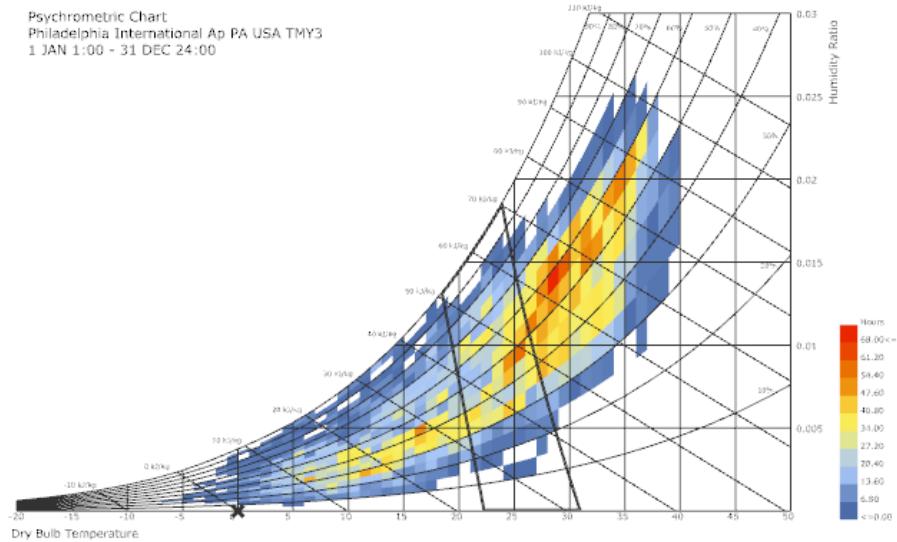
Cold Hours

5644hrs, 64.44%

CHANGE VENTILATION



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



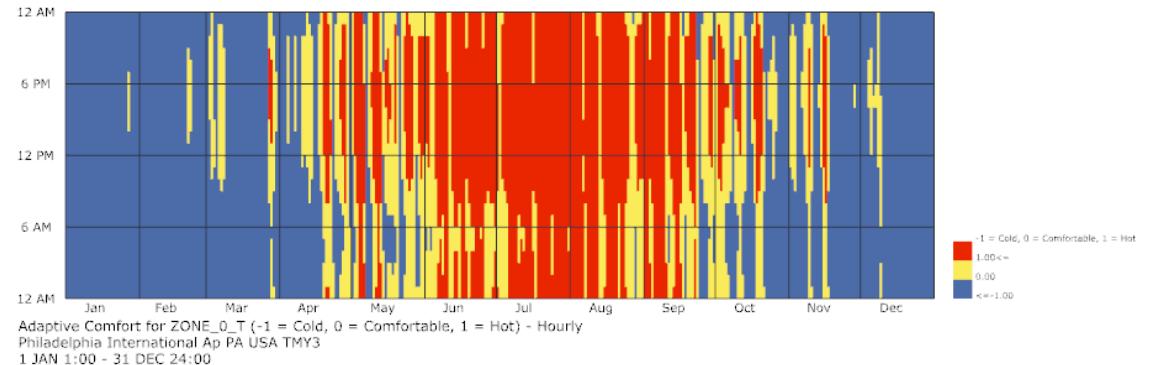
Exterior Wall [R34.4]

Exterior Window [R1.9, SHGC 0.39]

Exterior Roof [R34.4]

Air Change Hour: 5

I found 5 hours is the biggest possible number for me getting the biggest comfortable hours.



Comfortable Hours

2024hrs, 23.11%

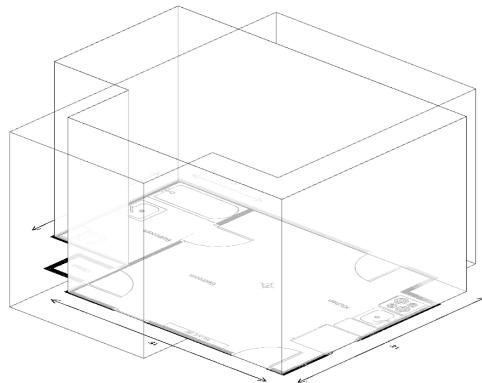
Hot Hours

1448hrs, 16.53%

Cold Hours

5288hrs, 60.37%

CHANGE THERMAL MASS



Exterior Wall [R34.4]

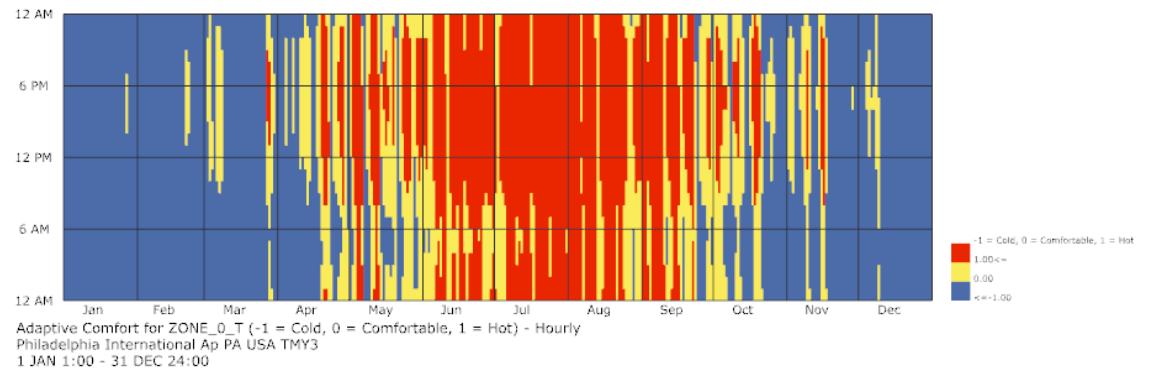
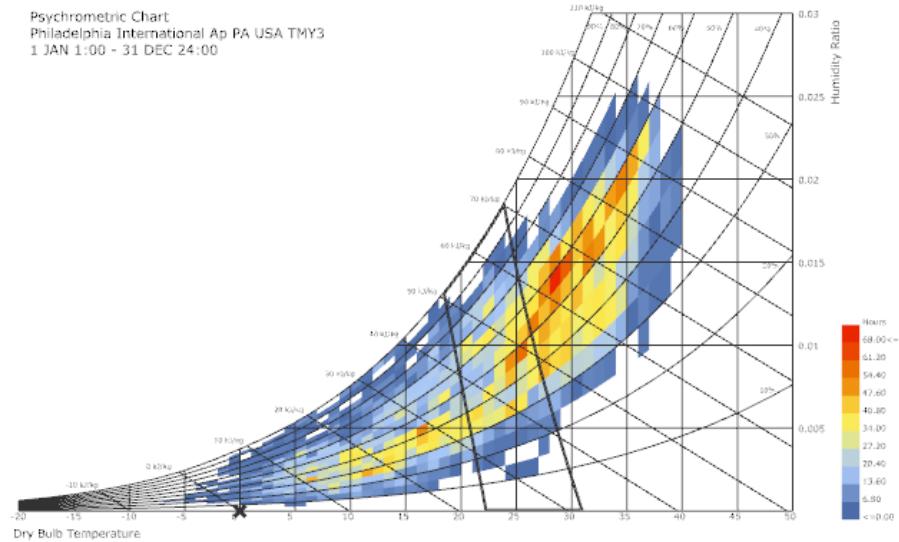
Exterior Window [R1.9, SHGC 0.39]

Exterior Roof [R34.4]

Air Change Hour: 7.5

Thermal Mass: +4 inches concrete

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



Comfortable Hours

2123hrs, 24.24%

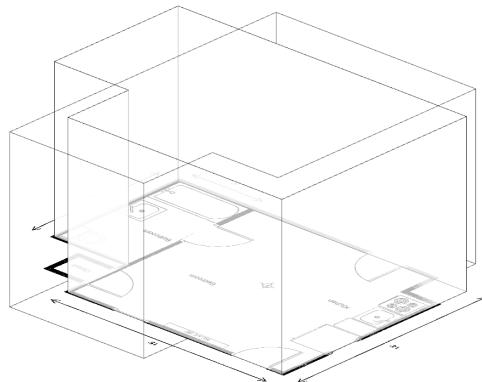
Hot Hours

1367hrs, 15.61%

Cold Hours

5270hrs, 60.16%

CHANGE THERMAL MASS



Exterior Wall [R34.4]

Exterior Window [R1.9, SHGC 0.39]

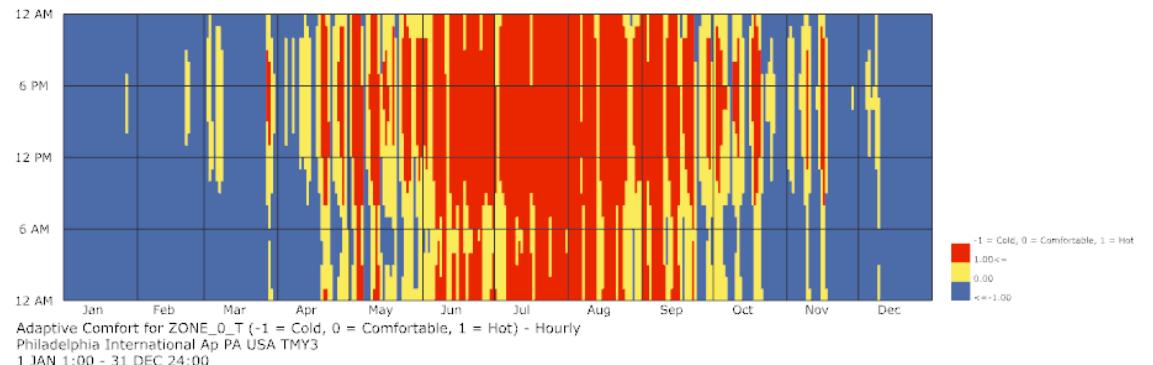
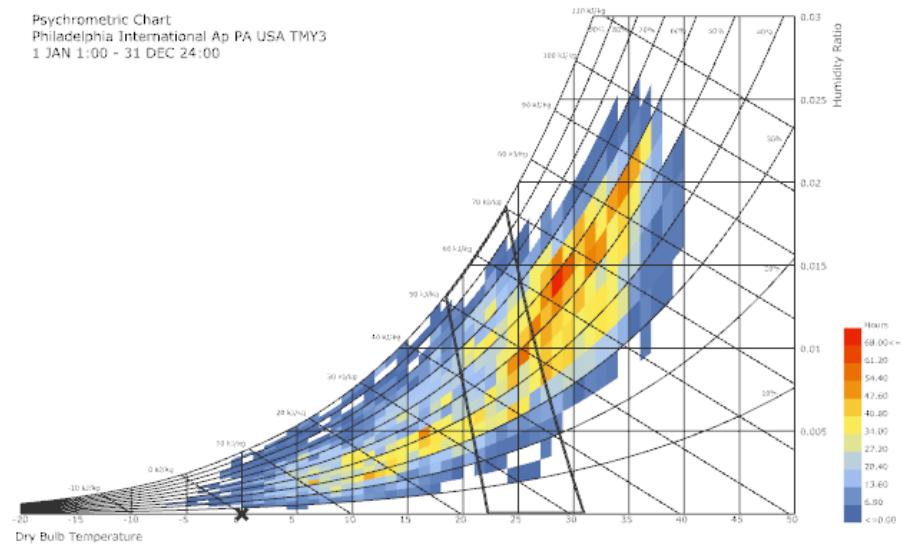
Exterior Roof [R34.4]

Air Change Hour: 7.5

Thermal Mass: +8 inches concrete

The thicker the concrete is, the more comfortable hours I will get.

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



Comfortable Hours

2152hrs, 24.75%

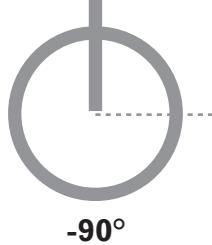
Hot Hours

1338hrs, 15.27%

Cold Hours

5254hrs, 59.98%

FINAL DESIGN SUMMARY

	Orientation	Glaze Ratio	Daylighting	Adaptive Comfort
Original		North:0.1 West:0.0 South:0 East:0.1	1251hrs, 14.28% Comfortable of 8760 hours	SDA: 75% 300lux 50%
First Run		North:0.3 West:0.2 South:0.5 East:0.1	1537hrs, 17.55% Comfortable of 8760 hours	SDA: 100% 300lux 50%
Final Design		Construction List: Exterior Wall [R34.4] Exterior Window [R1.9, SHGC 0.39] Exterior Roof [R34.4]	Ventilation: Air Change Hour: 5	Thermal Mass: +8 inches Concrete
		1873hrs, 21.38%	2024hrs, 23.11%	2152hrs, 24.75%