THERMAL AND VISUAL COMFPORT MAXIMIZATION OF AN UNCONDITIONED SPACE

PHILADELPHIA | PA

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

CLIMATE ANALYSIS
BASE-CASE ASSESSMENT
DISCUSSION AND DESIGN PROPOSALS
FINAL DESIGN ASSESSMENT
CONCLUSIONS

CLIMATE ANALYSIS

Climate Zone

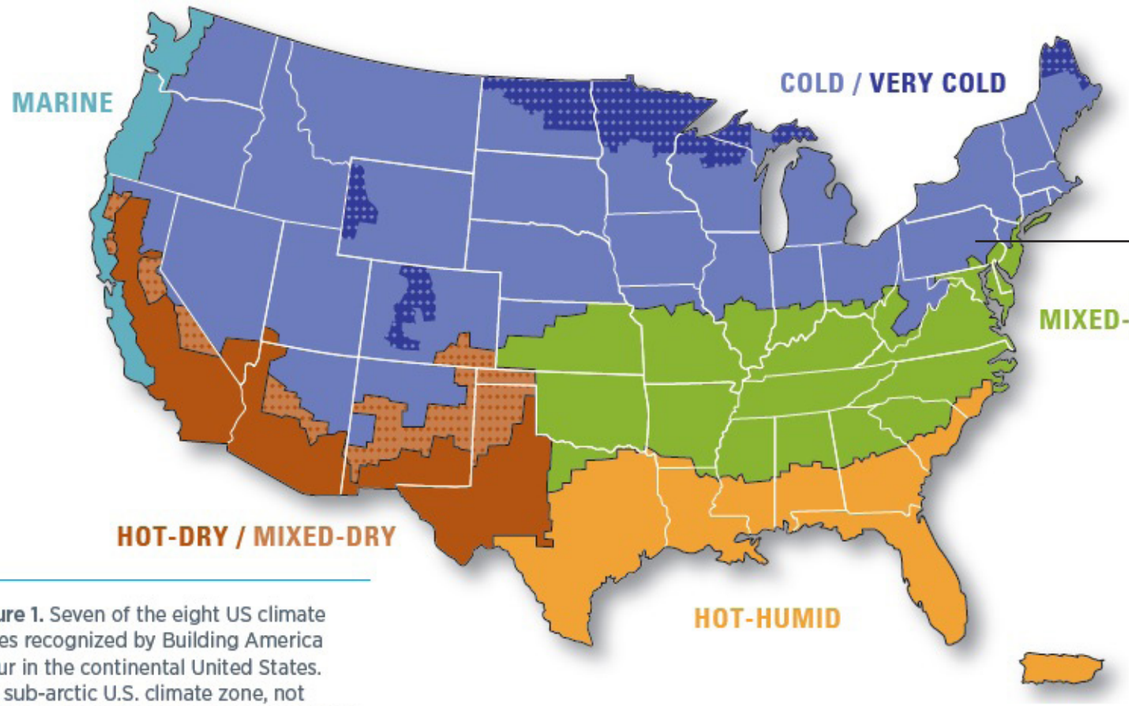
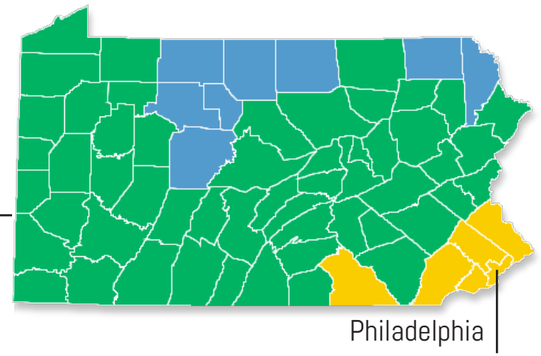


Figure 1. Seven of the eight US climate zones recognized by Building America occur in the continental United States. The sub-arctic U.S. climate zone, not shown on the map, appears only in Alaska.



Climate Zone 4 Minimal Insulation Requirements

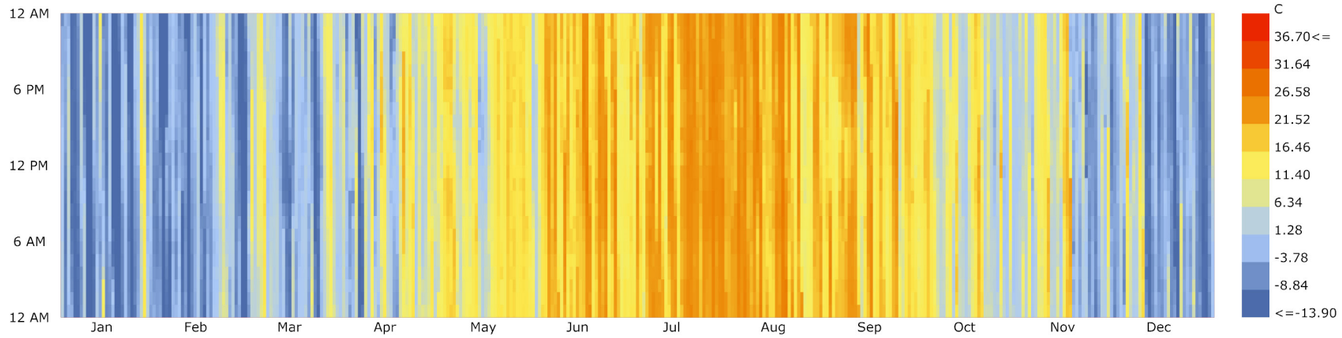
Ceiling R-value	**38**
Wood Frame Wall R-value	**13**
Mass Wall R-value [i]	**5/10**
Floor R-value	**19**
Basement Wall R-value [c]	**10/13**
Slab R-value [d], Depth	**10, 2 ft**
Crawlspace Wall R-value [c]	**10/13**
Fenestration U-Factor [b]	**0.35**
Skylight U-Factor [b]	**0.60**
Glazed fenestration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

Philadelphia Weather Averages

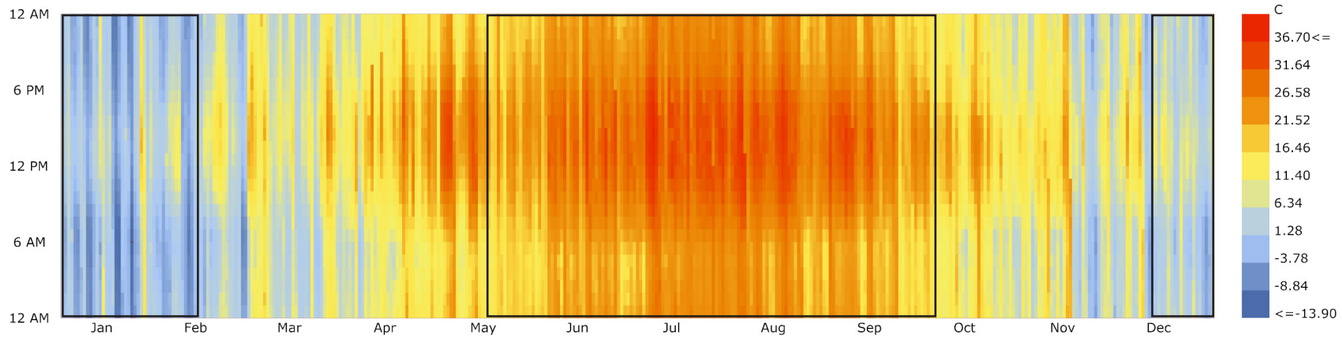
Annual high temperature: 64.7°F
Annual low temperature: 47°F
Average temperature: 55.85°F
Average annual precipitation - rainfall: 4145 inch
Av. annual snowfall: 23 inch

CLIMATE ANALYSIS

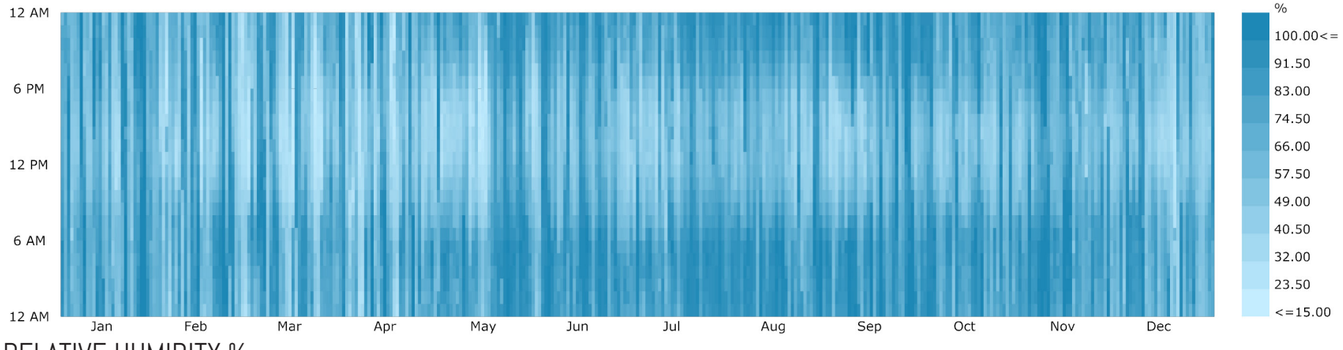
Exterior Factors



DEW POINT TEMPERATURE °C



DRY BULB TEMPERATURE ° °C



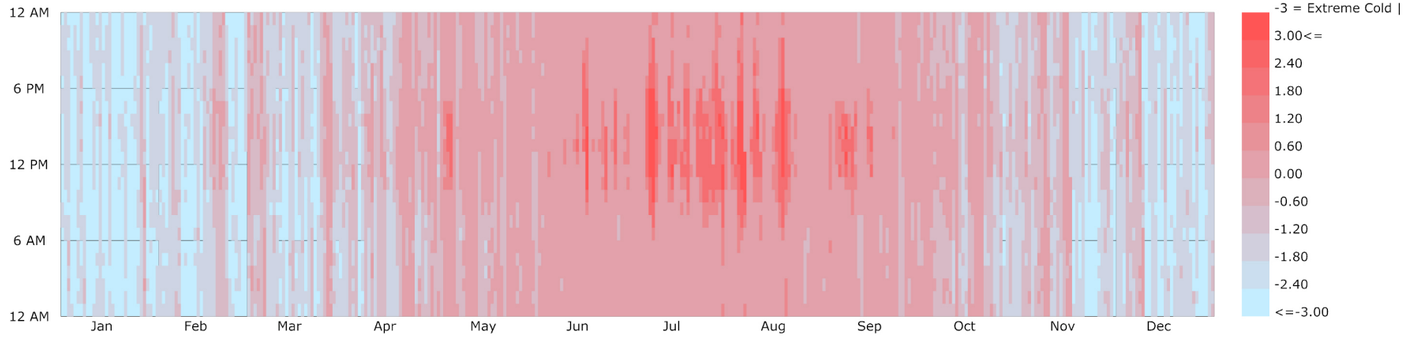
RELATIVE HUMIDITY %

From the dry bulb temperature, dew point temperature and relative humidity percentage data, we should be aware the hot weather from June to August and cold weather from December to February.

Since this project is my apartment room, my occupied hour is almost whole day except the class time. We need to take whole day hours temperature and humidity into consideration.

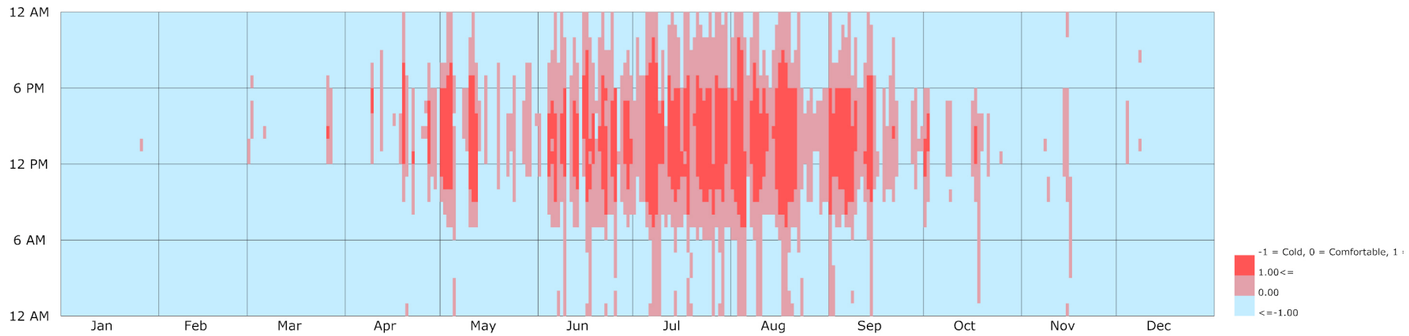
CLIMATE ANALYSIS

UTCI/PSYCHROMETRIC CHART



ANNUAL
41% COMFORTABLE
3% HOT
34% COLD

UTCI



ANNUAL
15% COMFORTABLE
7% HOT
77% COLD

ADAPTIVE COMFORT

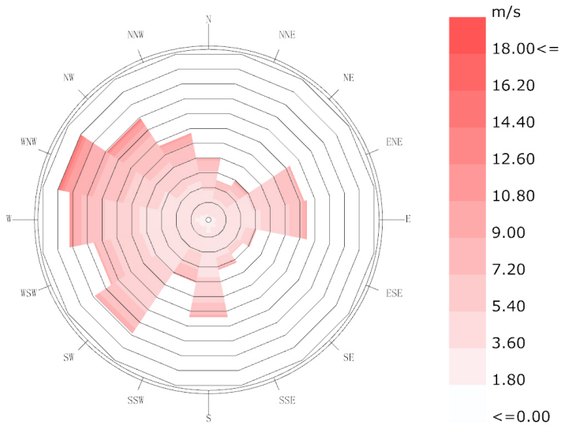
The UTCI is defined as the air temperature (Ta) of the reference condition causing the same model response as actual conditions. UTCI was developed in 2009 by virtue of international co-operation between leading experts in the areas of human thermophysiol- ogy, physiological modelling, meteorology and climatology.

To understand how comfortable it is outdoors, we can use the Universal Thermal Climate Index (UTCI), which is an indicator of “how it feels outside”.

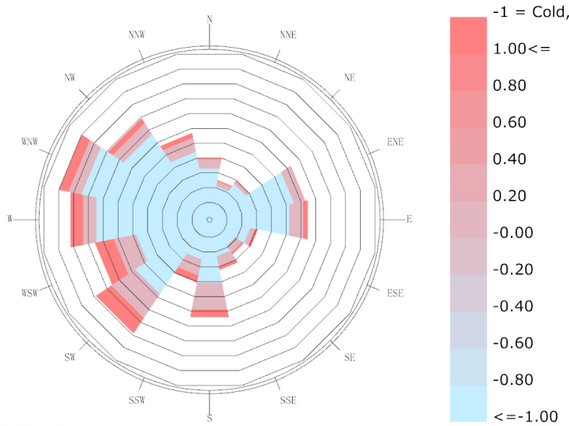
From the UTCI, we can see there is 41% comfortable hours whole year and most of the uncomfortable period is from the cold weather.

CLIMATE ANALYSIS

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.



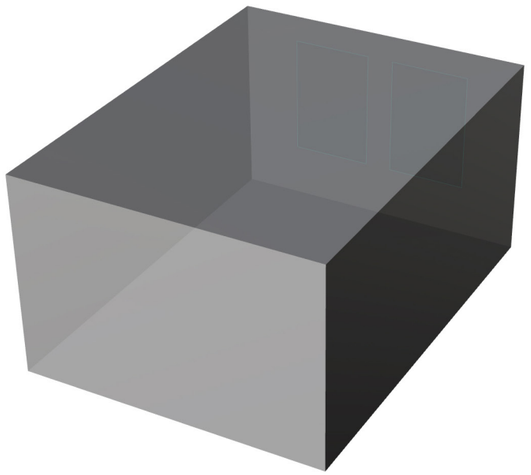
Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Adaptive Comfort (-1 = Cold, 0 = Comfortable, 1 = Hot)
Calm for 2.81% of the time = 246 hours.
Each closed polyline shows frequency of 1.0%. = 90 hours.

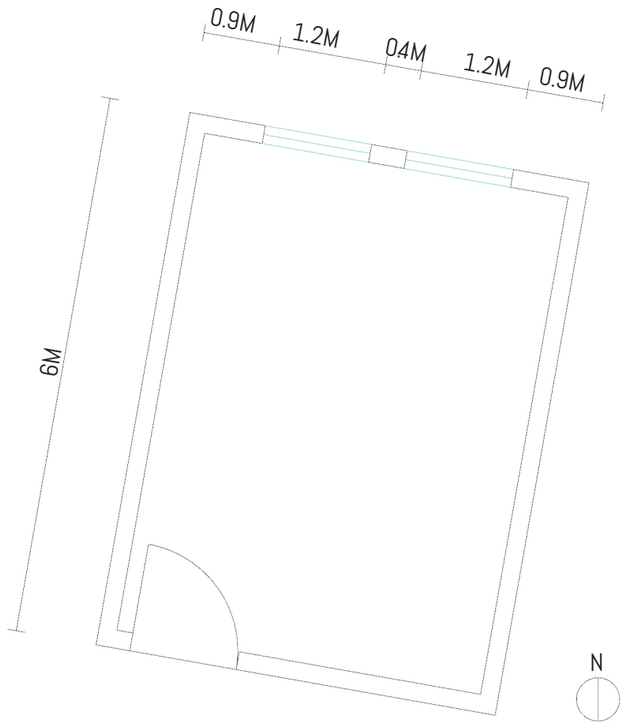
Another important weather factor to simulate is sky wind speeds and direction.

As we can see the picture showed above, philadelphia has larger part of cold wind compared with hot wind. This is one of the reason why Philadelphia has longer uncomfortable time of cold.

BASE-CASE ASSESSMENT

Test Room

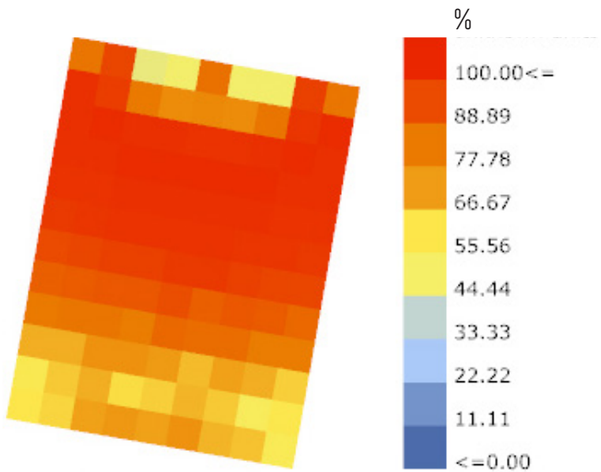




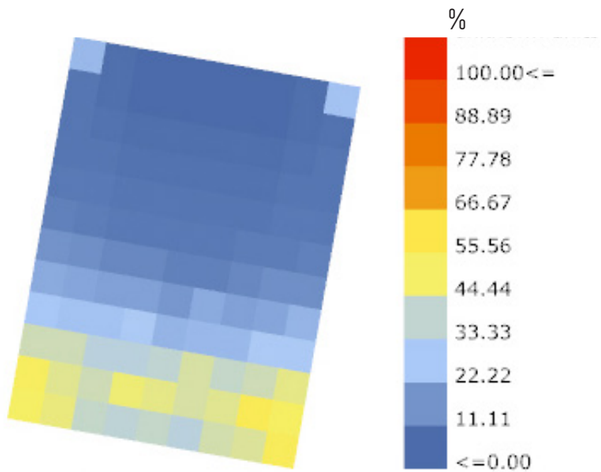
Area: 27 square meter
Orientation: 10 degree from North
Program: Mid-rise apartment
Occupied Hour: Whole day

BASE-CASE ASSESSMENT

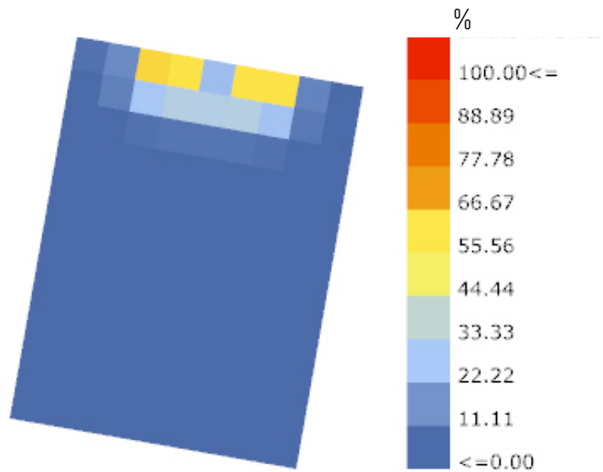
ANNUAL DAYLIGHT ANALYSIS



Useful Daylight (UDLI)
100-2000 LUX



Useful Daylight (UDLI)
<100 LUX



Useful Daylight (UDLI)
>2000 LUX

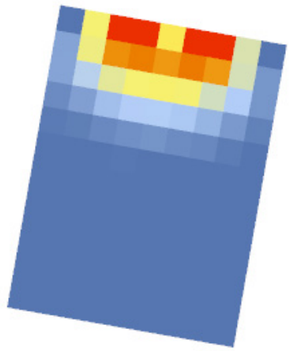
Useful Daylight Illuminance (UDI) is an attempt to integrate the evaluation of daylight level and glare in one scheme. According to Nabil and Mardaljevic [1], UDI is defined as the annual occurrence of illuminances across the work plane that are within a range considered “useful” by occupants.

Basically UDI is a coubling of Daylight Autonomy (DA) and Maximum Daylight Autonomy (maxDA). The current definition of UDI evaluates (e.g. hourly) illuminance levels according to three illuminance ranges: 0-100 lux, 100-2,000 lux and above 2,000 lux. Horizontal illuminance levels between 100 and 2,000 lux - the so-called useful range - are grated full credit whereas levels which fall short of the useful range (<100 lux) and levels which exceeds the useful range (>2,000 lux) are granted no credit.

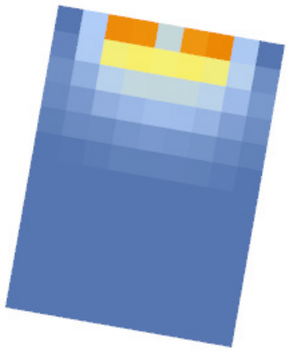
sDA: 42.59%

BASE-CASE ASSESSMENT

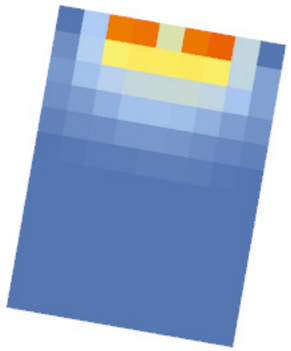
POINT-IN-TIME ILLUMINANCE



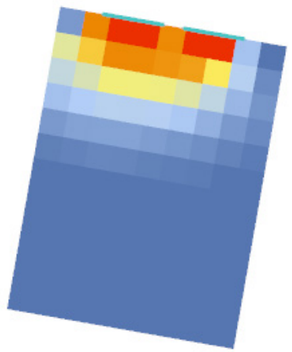
Mar 9AM



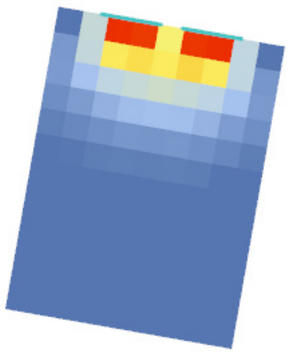
Mar 12AM



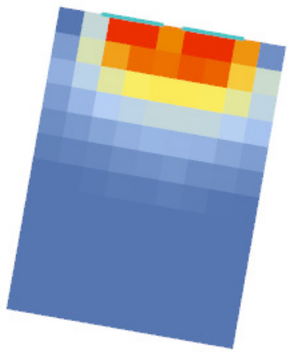
Mar 15PM



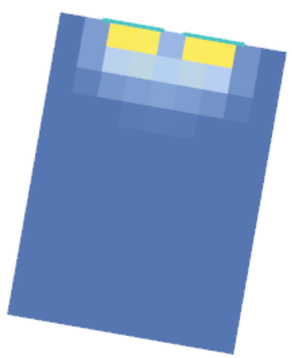
Jun 9AM



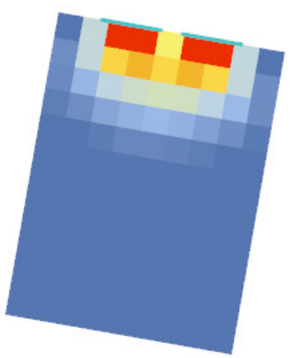
Jun 12AM



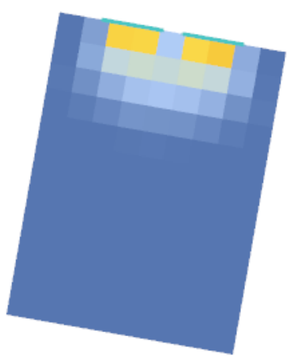
Jun 15PM



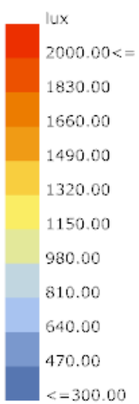
Dec 9AM



Dec 12AM



Dec 15PM

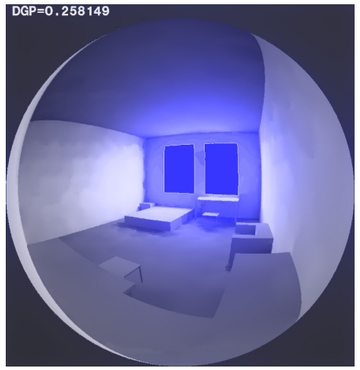


Point-in-Time Simulations helps us to understand how light enters the building at different points in the day and year. I choose March, June, December at 9AM, 12AM and 15PM to simulate.

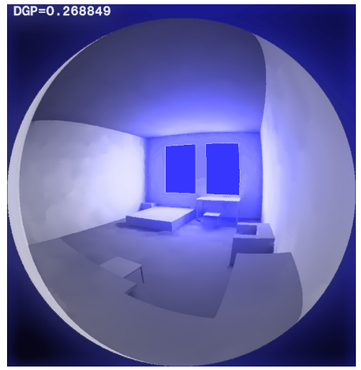
From this simulation we can see, it has more sunlight in the morning of March compared with the noon and afternoon. And during the winter, we have more sunlight at noon compared with moring and afternoon.
During the summer, there is no big difference of sunlight at 9am, 12am and 15pm.

BASE-CASE ASSESSMENT

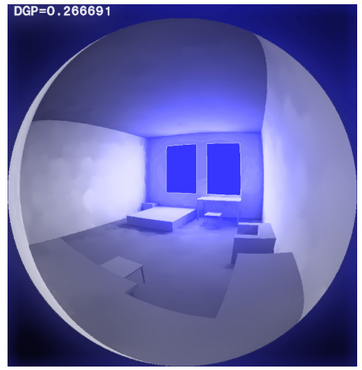
Daylight Glare Probability



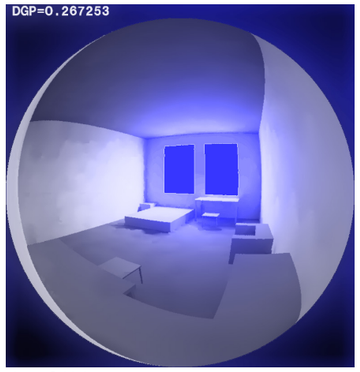
Mar 9AM



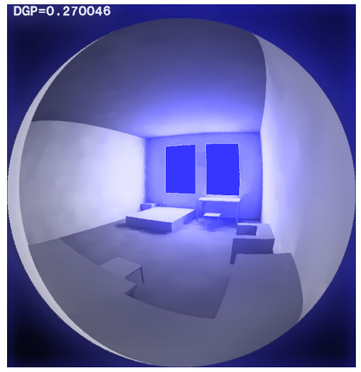
Mar 12AM



Mar 15PM



Jun 9AM



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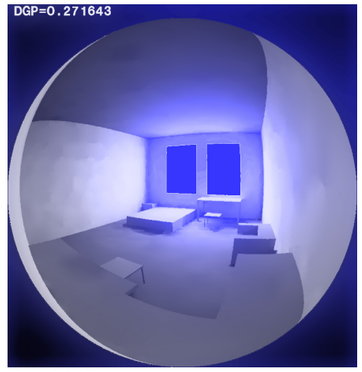
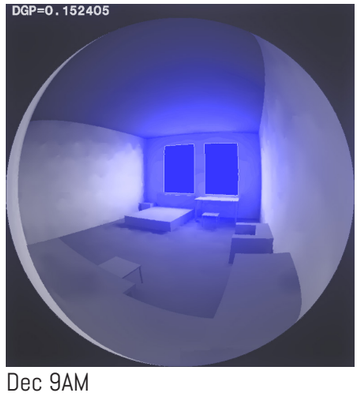
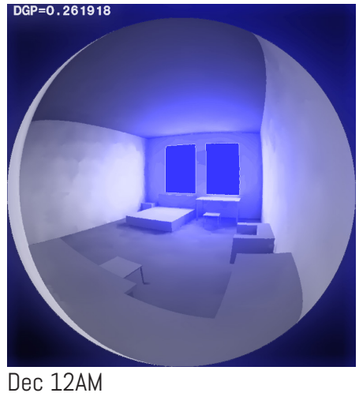


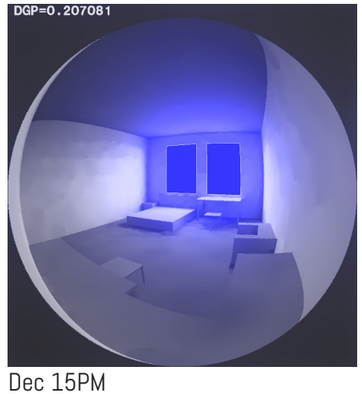
Jun 15PM



Dec 9AM



Dec 12AM



Dec 15PM

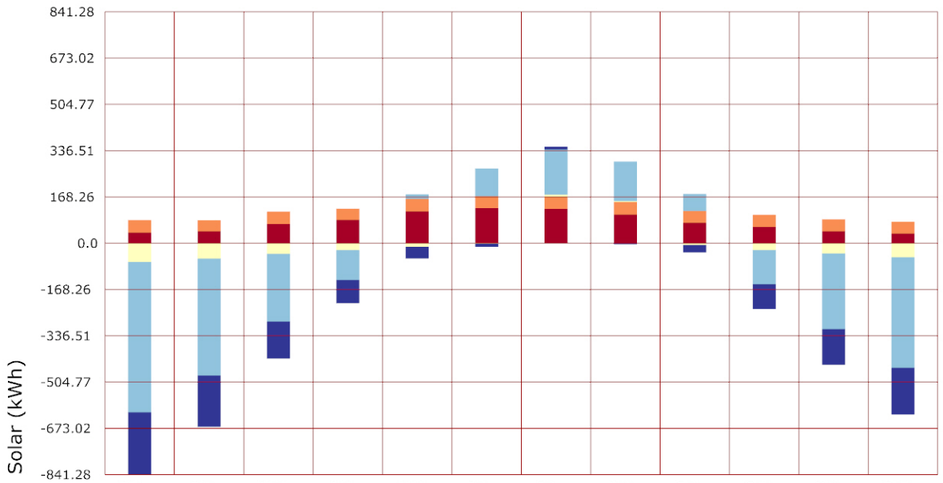
DGP (Daylight Glare Probability) is a metric to predict the appearance of discomfort galre in daylit spaces proposed in 2005 by Jan Wienold and Jens Christoffersen.

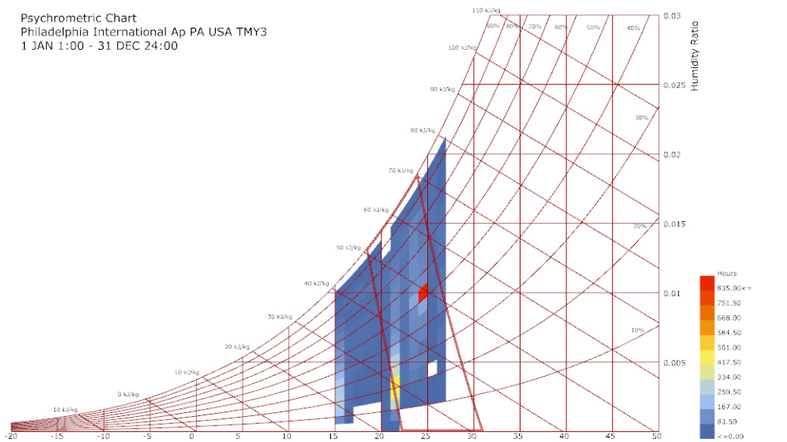
DGP < 0.35 Imperceptible
04 > DGP ≥ 0.35 Perceptible
045 > DGP ≥ 04 Disturbing
DGP ≥ 045 Intolerable

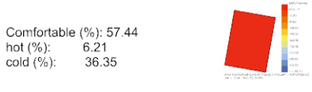
Based on the 9 Point-in-Time analysises for the baseline case, all simulations fall in the imperceptible range. So glare does not seem to be an issue for the baseline case.

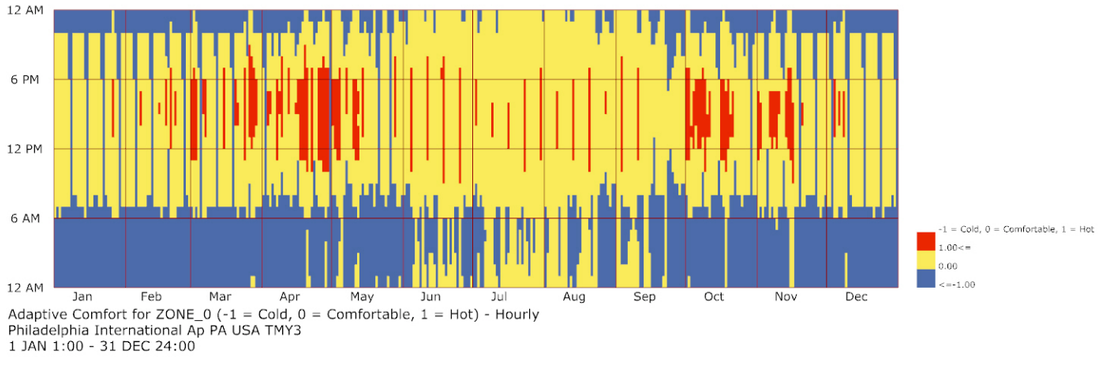
BASE-CASE ASSESSMENT

BASELINE ASSESSMENT : PSYCHROMETRIC COMFORT AND ADAPTIVE COMFORT MODELS









COMFORTABLE: 57.44%

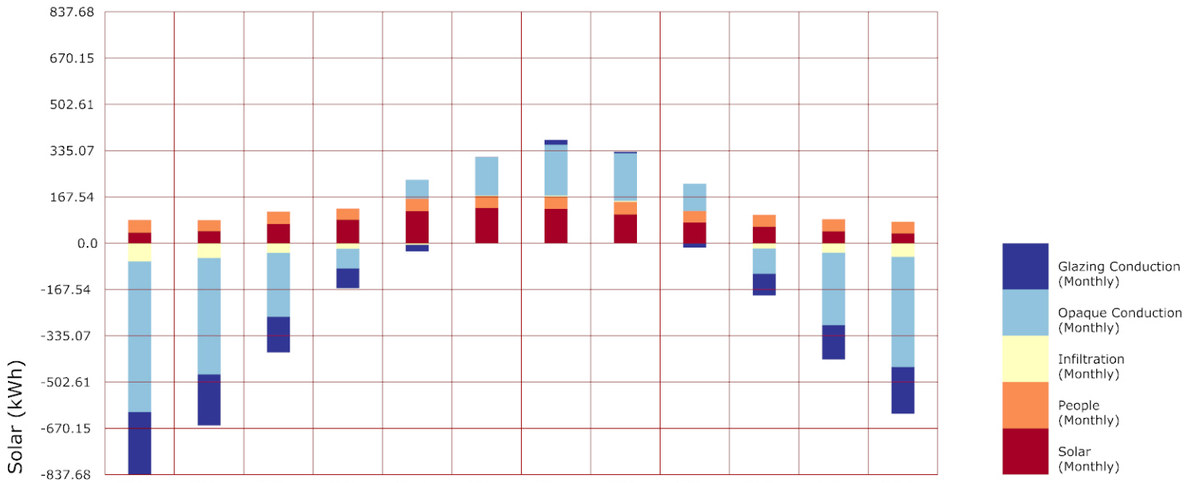
HOT: 6.21%

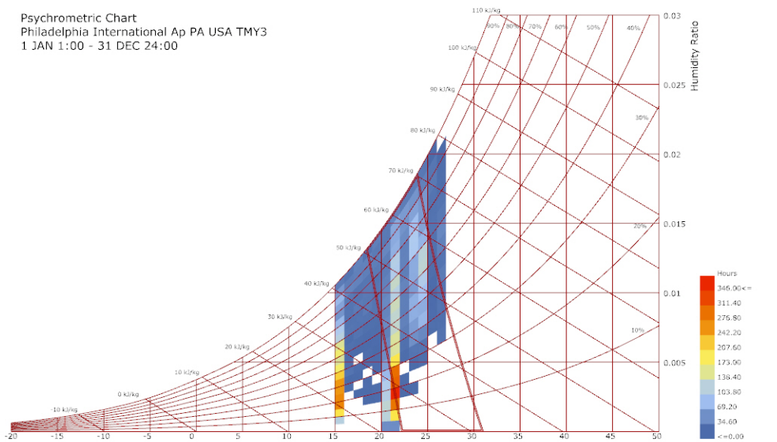
COLD: 36.35%

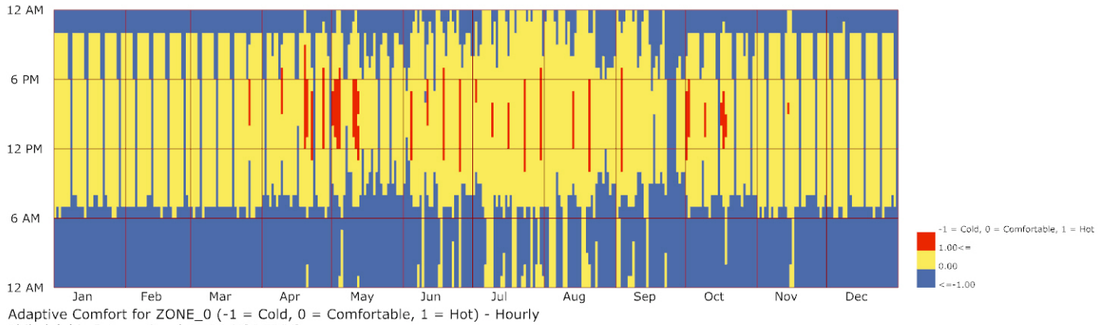
From the simulation of PSY chart and adaptive comfort model, we can see the key uncomfortable problem is from cold feeling. As we can see the energy balance, the most potential strategy is changing the construction materials. Besides the materials, there is two main elements we need to consider when we propose passive strategies: wind and sun. Since the hot uncomfortable hours is smaller compared with cold hours, we need to consider can we gain more solar heat, reduce heat loss or maintain heat while meantime do not increase uncomfortable hot hours?

DISCUSSION AND DESIGN PROPOSAL

ADD NATURAL VENTILATION







COMFORTABLE: 53.31%
HOT: 1.93%
COLD: 44.76%

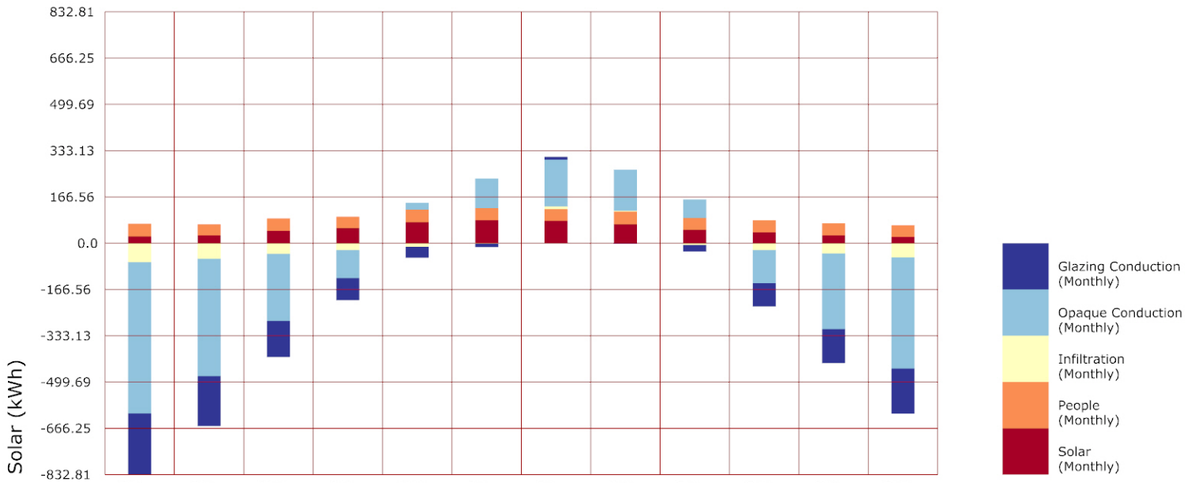
VS

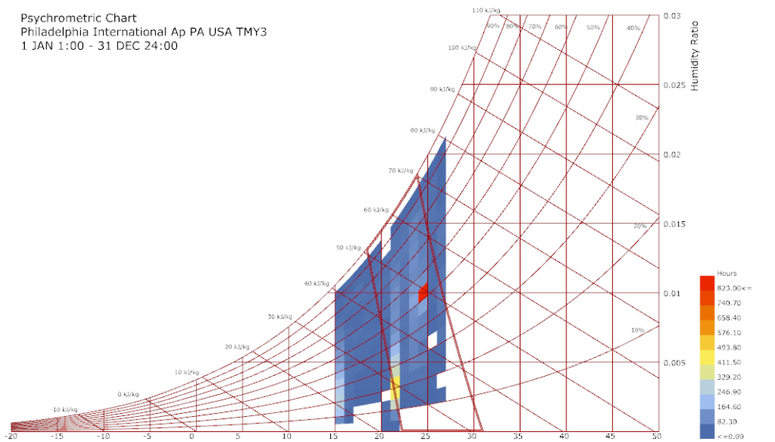
COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

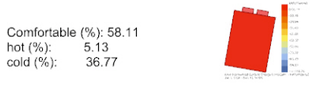
Although the hot hours is decreased after adding natural ventilation, but it increases a lot cold hours. It is not a good strategy.

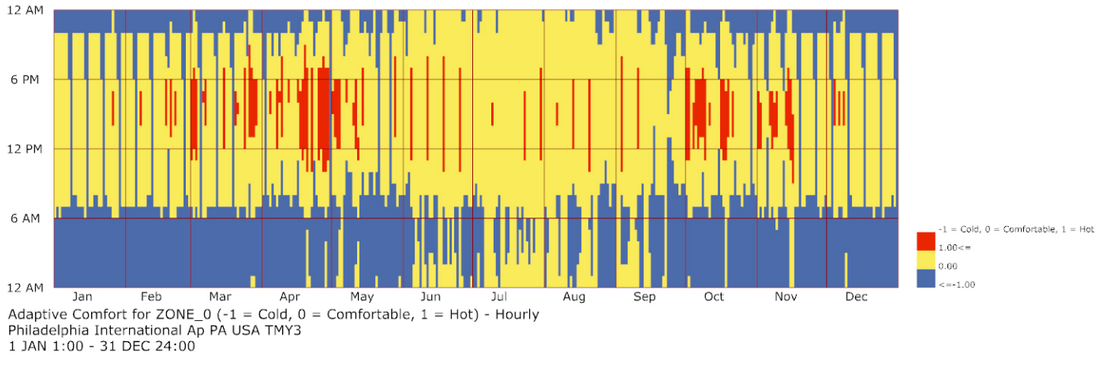
DISCUSSION AND DESIGN PROPOSAL

ADD SHADE









COMFORTABLE: 58.11%
HOT: 5.13%
COLD: 36.77%

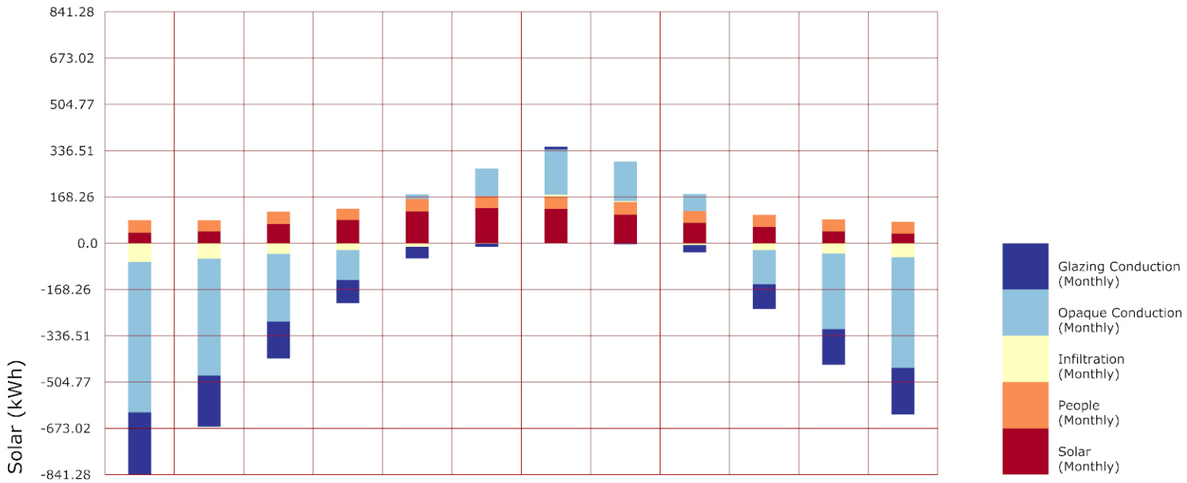
VS

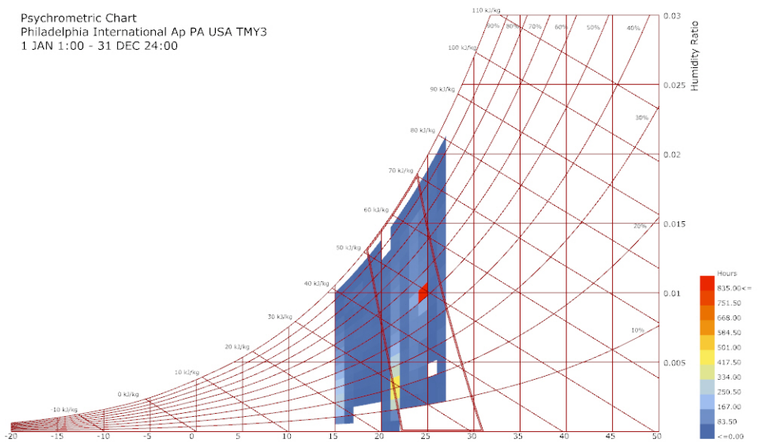
COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

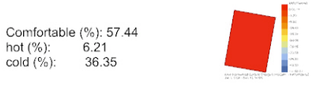
Adding some shades is a good approach to address some of the hot hours meanwhile not change too much for the cold hours. It is a accpetable strategy but not recommended.

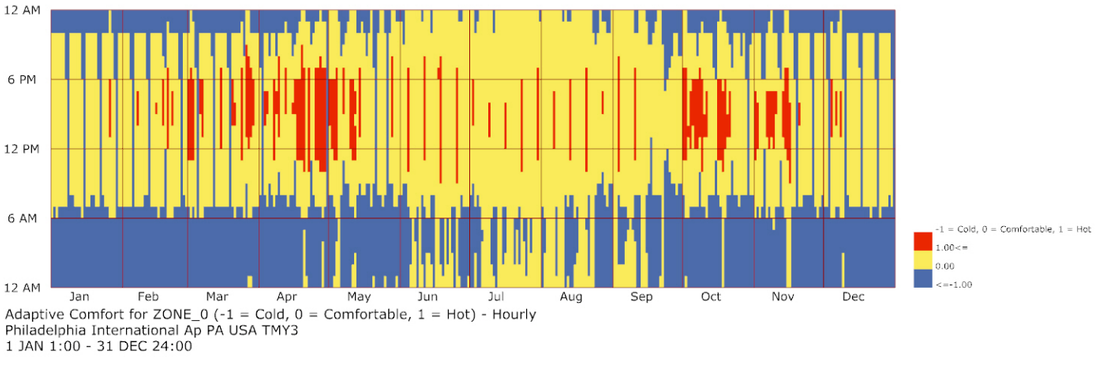
DISCUSSION AND DESIGN PROPOSAL

CHANGE CONSTRUCTION MATERIALS









COMFORTABLE: 66.59%
HOT: 3.89%
COLD: 29.52%

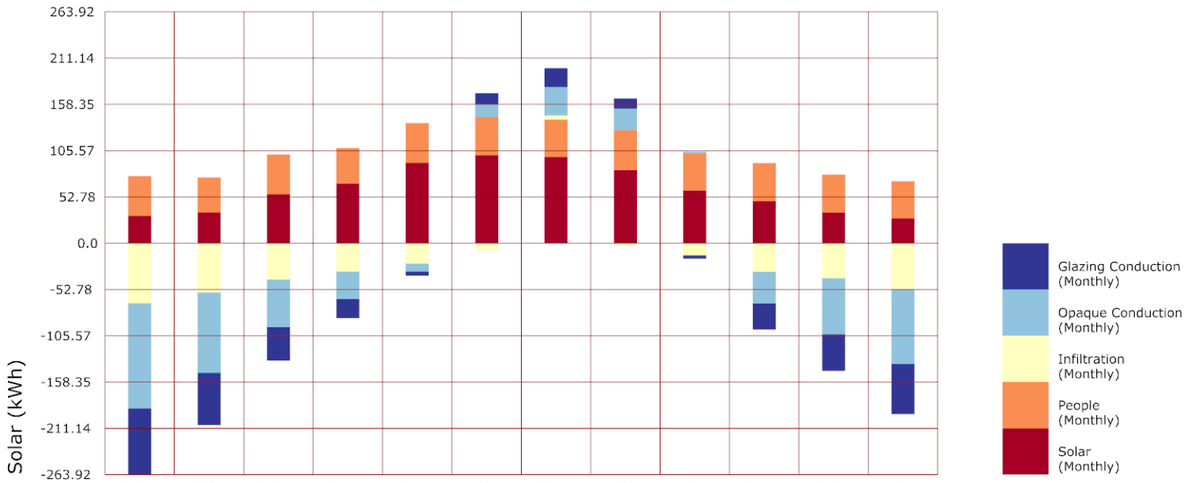
VS

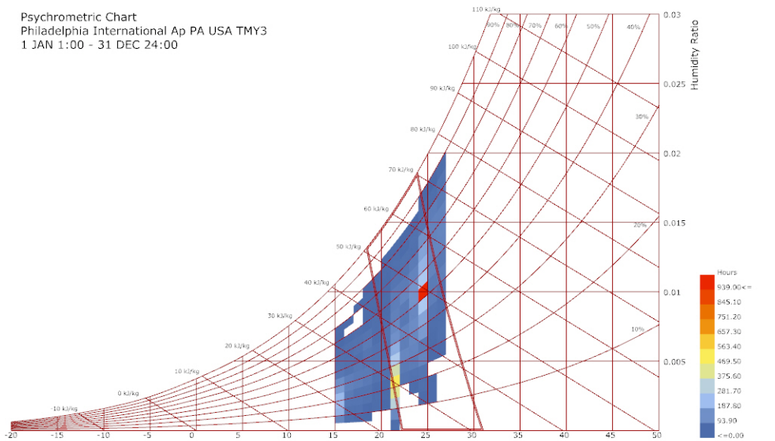
COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

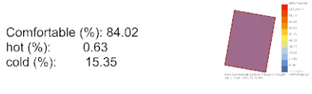
Changing the construction materials is a good approach to reduce hot and cold hours. It is potential and recommended. I changed the wall material from MetalR5.5 to R104 and roof material from Metal R 9.2 to R 14.8.

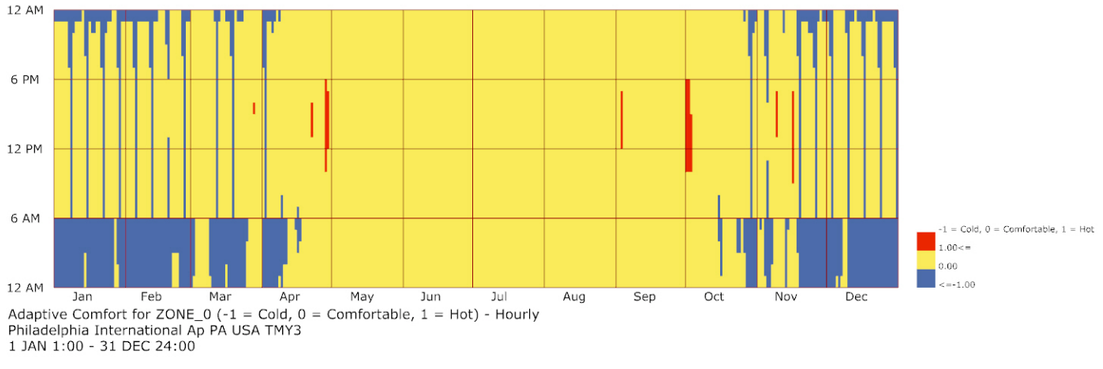
DISCUSSION AND DESIGN PROPOSAL

CHANGE CONSTRUCTION MATERIALS









COMFORTABLE: 73.68%
HOT: 0.81%
COLD: 25.56%

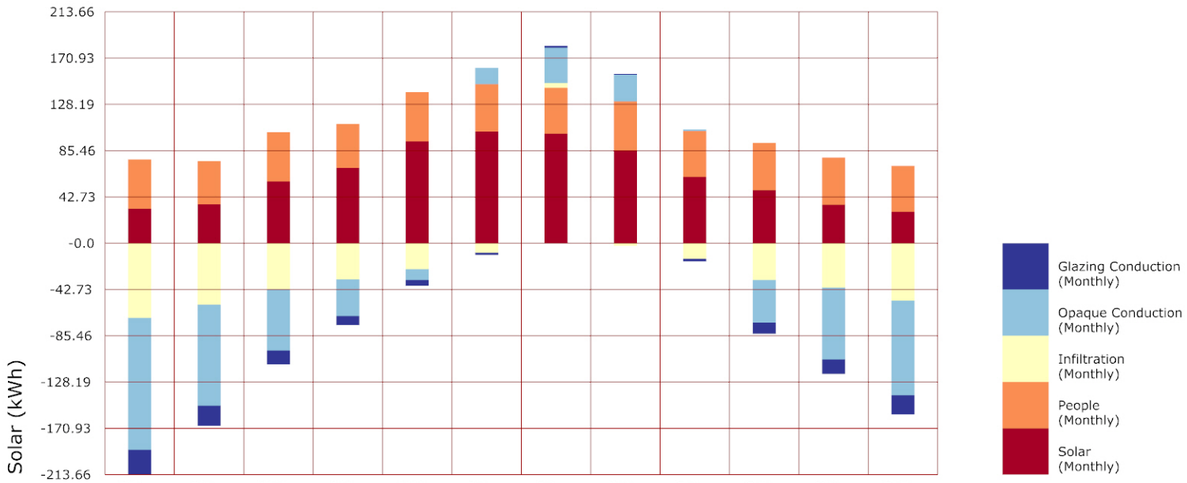
VS

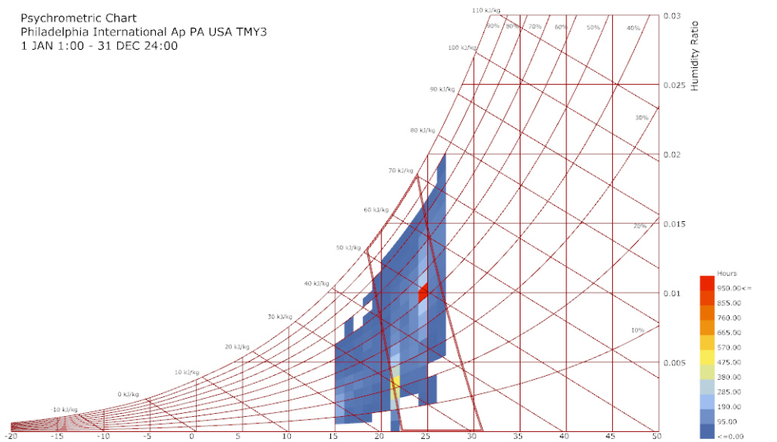
COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

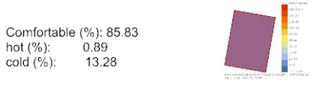
Changing the construction materials is a good approach to reduce hot and cold hours. It is potential and recommended. I changed the wall material from MetalR5.5 to R344 and roof material from Metal R 9.2 to R 344.

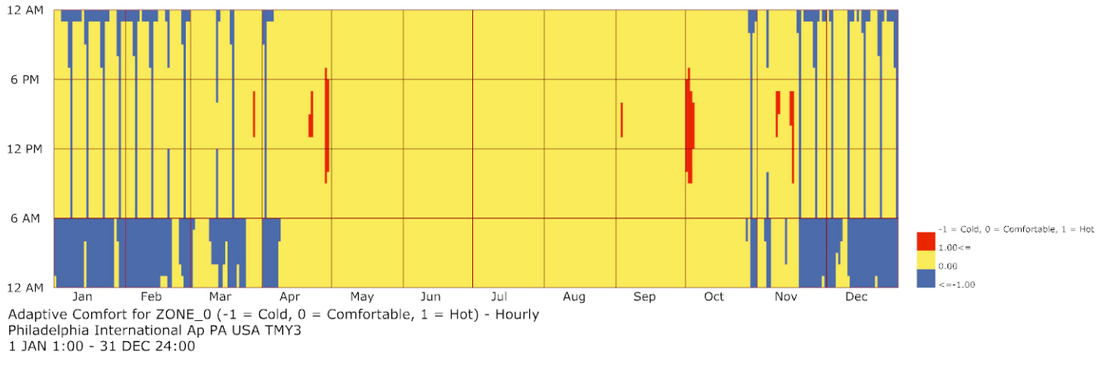
DISCUSSION AND DESIGN PROPOSAL

CHANGE WINDOW GLASS TO LOW-E









COMFORTABLE: 85.83%
HOT: 0.89%
COLD: 13.28%

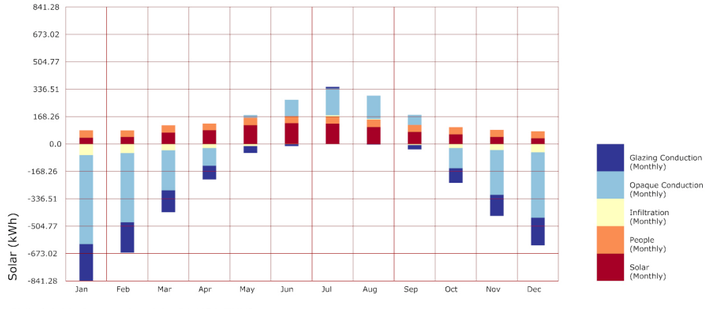
VS

COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

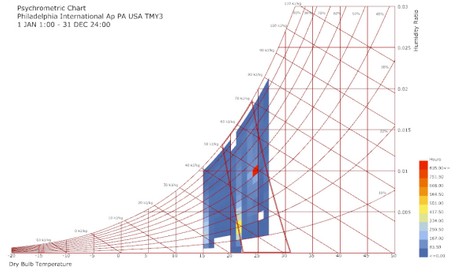
Changing the construction materials is a good approach to reduce hot and cold hours. It is potential and recommended. I changed the wall material from MetalR5.5 to R344, roof material from Metal R 9.2 to R 344 and existing glass to Low E glass..

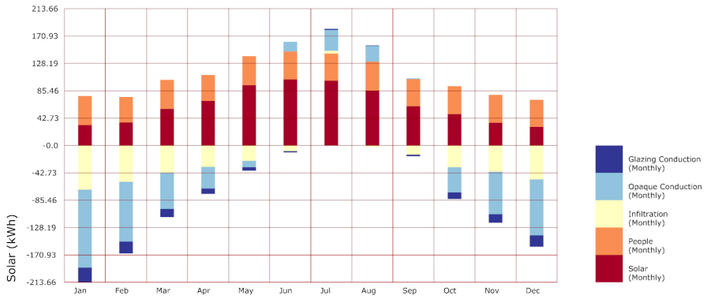
CONCLUSION

SRATEGY

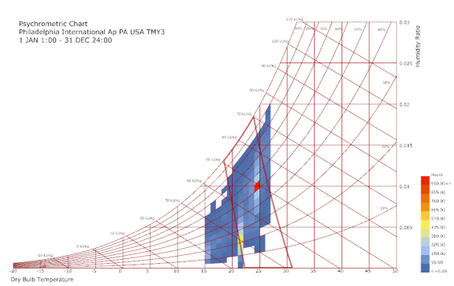


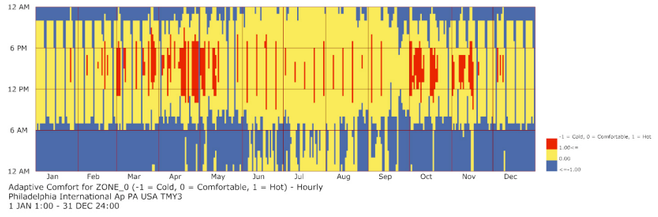
Philadelphia International Ap PA USA TMY3





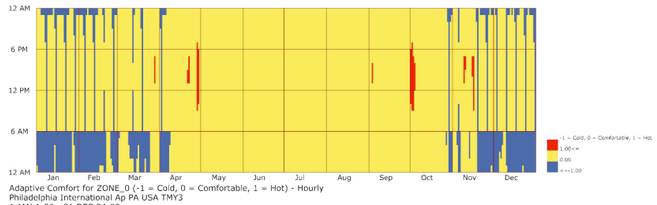
Philadelphia International Ap PA USA TMY3





Adaptive Comfort for ZONE_0 (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Fist Run Result



Adaptive Comfort for ZONE_0 (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Change Materials

COMFORTABLE: 57.44%
HOT: 6.21%
COLD: 36.35%

Fist Run Result

VS

COMFORTABLE: 85.83%
HOT: 0.89%
COLD: 13.28%

Change Materials Result