Thermal and Visual Comfort Maximization of an Unconditioned Space

Yunqian Li PennDesign MEBD

ARCH-753 - Building Performance Simulation Fall 2017 - Final Project

Philadelphia Climate Analysis

The location of this unconditioned simple room is in Philadelphia. The weather data used here is collected at the Philadelphia International Airport. (USA_PA_Philadelphia.Intl.AP.724080_TMY3)

According to the Trewartha climate classification, Philadelphia has a mixed humid climate. Summers are typically hot and muggy, fall and spring are generally mild, and winter is cold.

According to the chart shows on the right, the dry-bulb temperature in Philadelphia ranges from -13.9 to 36.7 Celsius degree. The relative humidity ranges from 15% to 100%. Summer and fall are the most humid seasons. The wind speed ranges from 0 to 18 m/s. High speed wind usually happens in winter and spring.

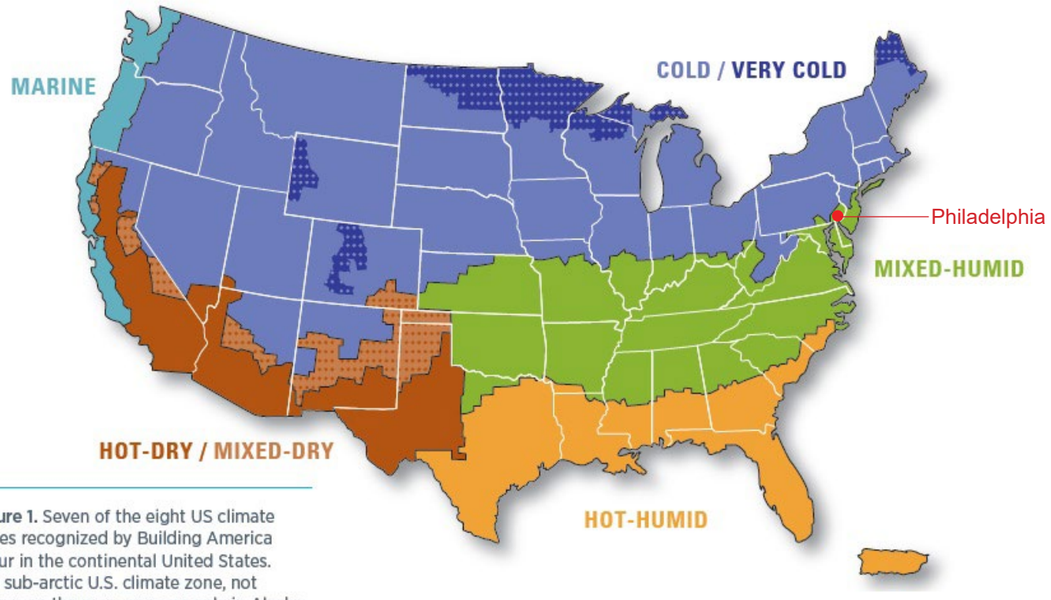
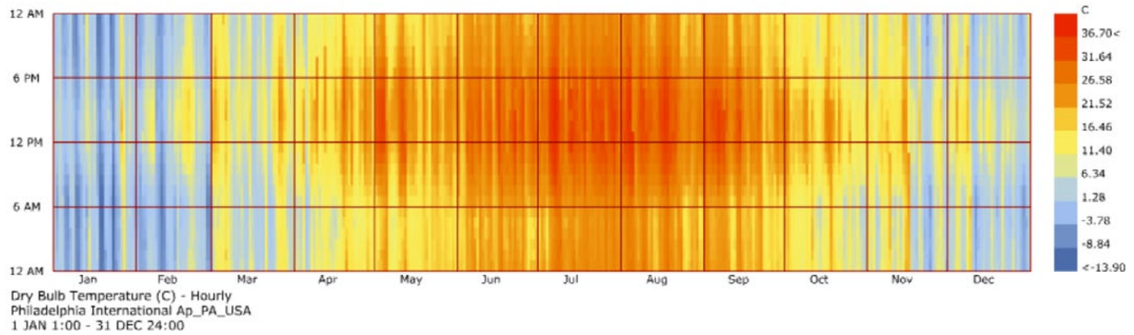
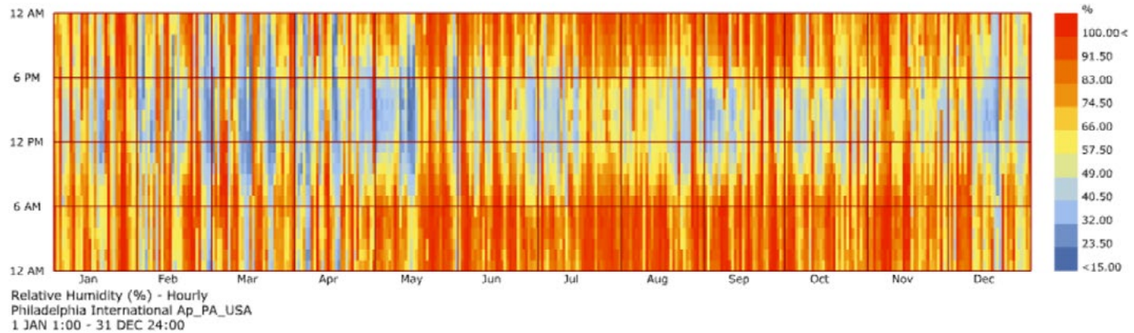
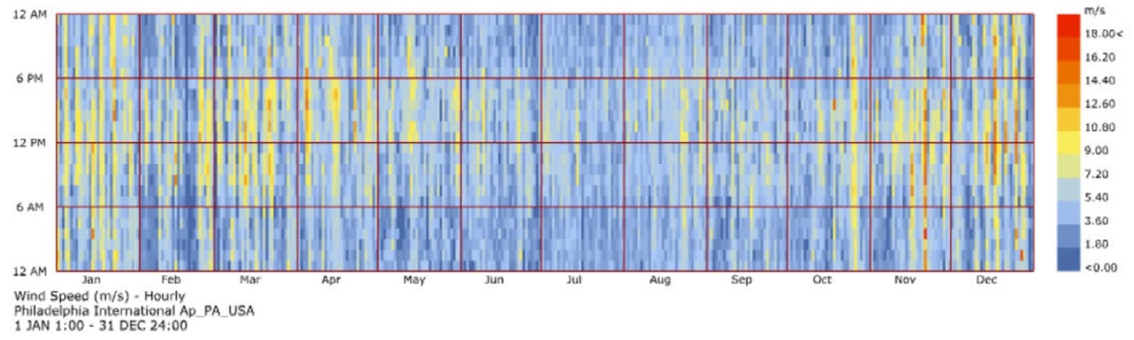


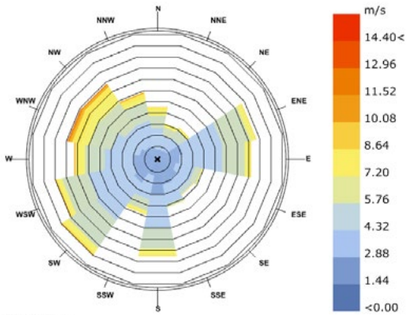
Figure 1. Seven of the eight US climate zones recognized by Building America occur in the continental United States. The sub-arctic U.S. climate zone, not shown on the map, appears only in Alaska.



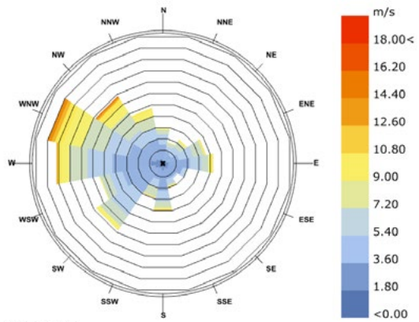




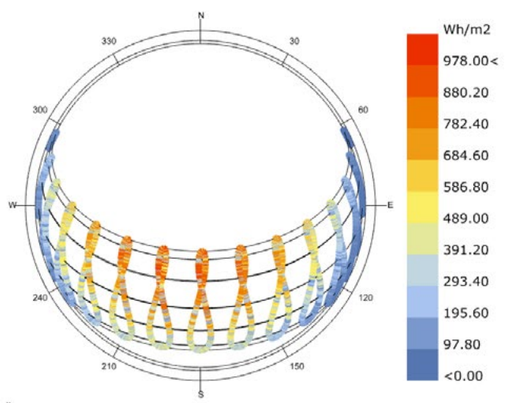
Philadelphia Climate Analysis



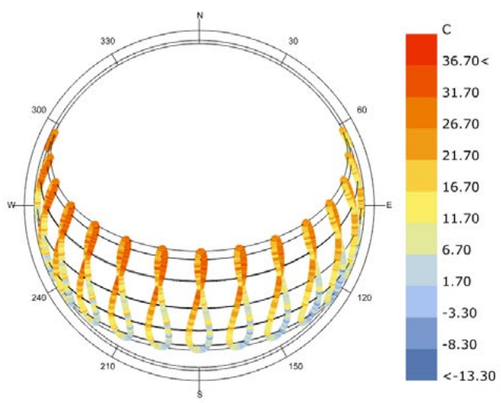
Wind-Rose
Philadelphia International Ap_PA_USA
1 APR 1:00 - 30 SEP 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.12% of the time = 93 hours.
Each closed polyline shows frequency of 0.9%. = 41 hours.



Wind-Rose
Philadelphia International Ap_PA_USA
1 OCT 1:00 - 31 MAR 24:00
Hourly Data: Wind Speed (m/s)
Calm for 3.50% of the time = 153 hours.
Each closed polyline shows frequency of 1.3%. = 58 hours.



Sun-path: Radiation



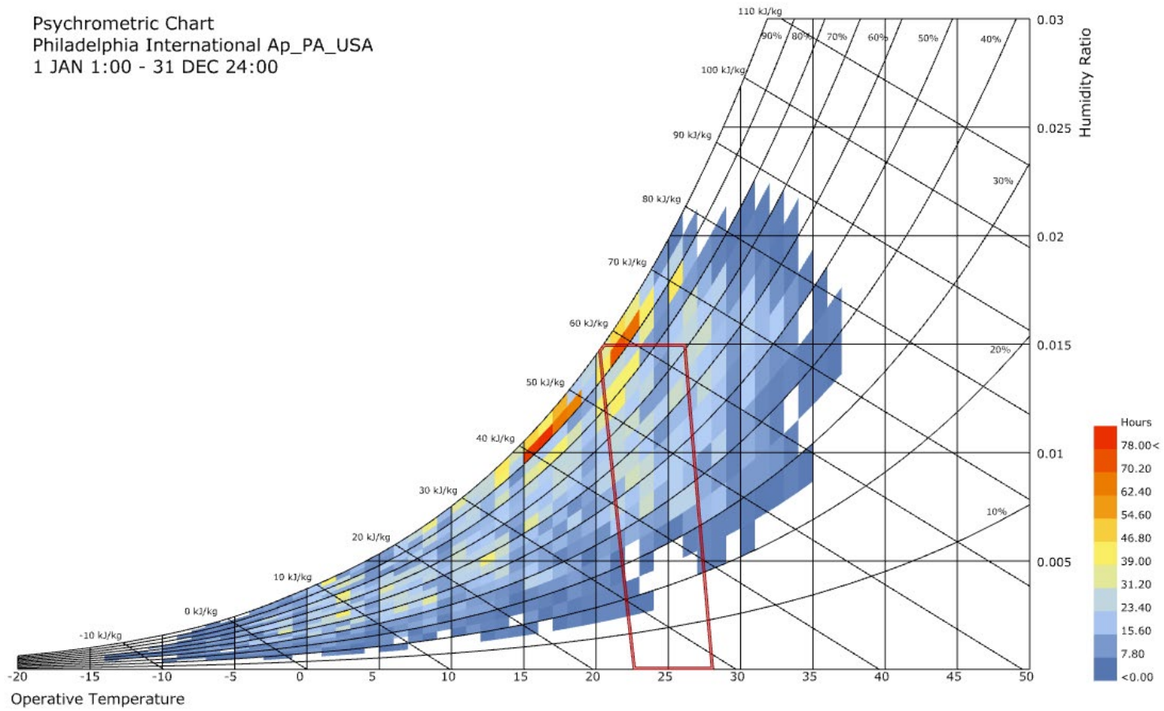
Sun-path: Dry-bulb Temperature

According to the wind-rose on the left, from April to September, most wind comes from Southwest; from October to March, most wind comes from Northwest. In the design warm wind should be introduced and cold wind should be avoided as much as possible.

According to the Sun-path, the most radiation happens at summer noon, from South; the most radiation that happens during high temperature periods is from Southwest. In the design the shade should be de-sign to avoid summer direct radiation from Southwest.

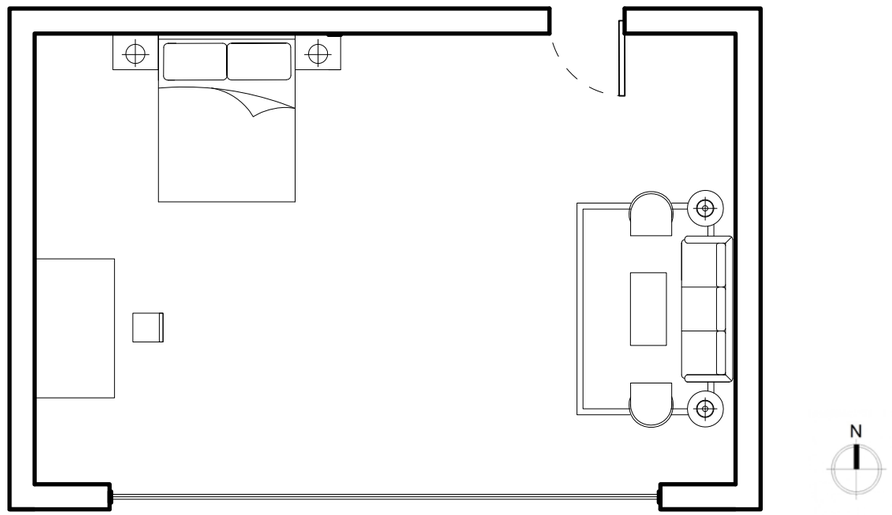
In the psychometric chart, most uncomfortable days drop at low temperature and high relative humid area. Theoretically, the temperature should be increased and the humidity should be reduced inside a room to improve comfortable level.

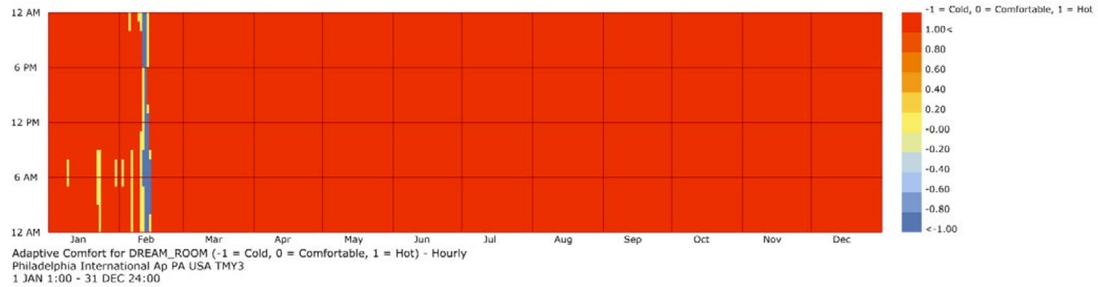
Psychrometric Chart
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



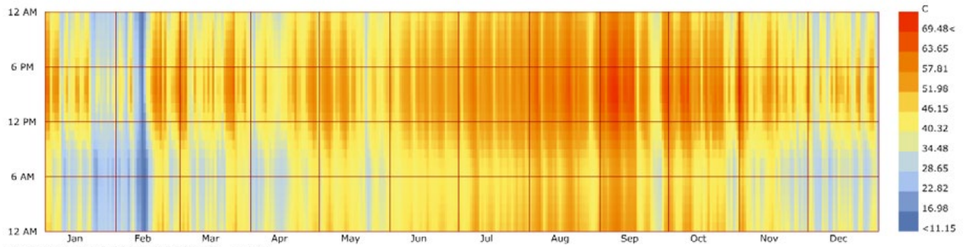
Simple Room Base-case Assessment

Because of the large amount of solar radiation from the huge south facing window, if there isn't any ventilation of cooling system, the room temperature is too high almost the whole year, except some time in February. The humidity level is in a acceptable range during the whole year.

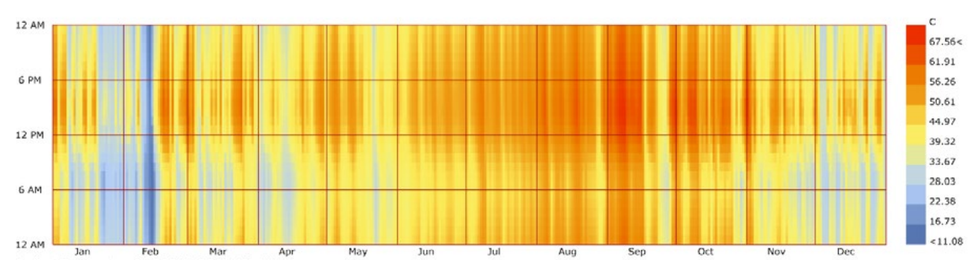




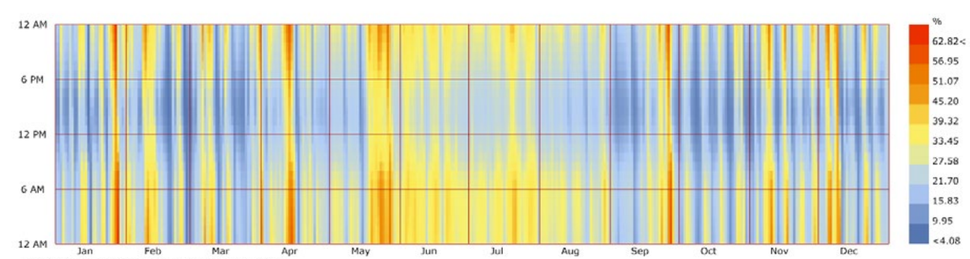
Adaptive Comfort for DREAM_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00



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



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

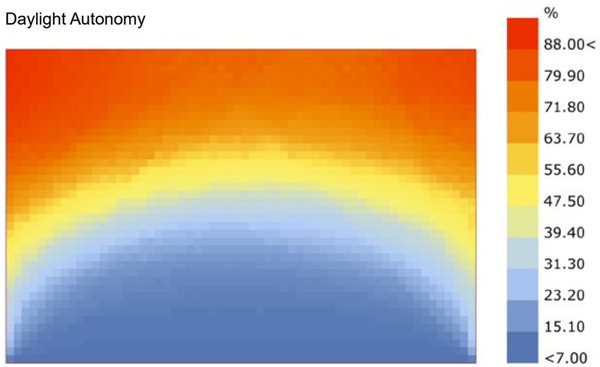


Relative Humidity for DREAM_ROOM (%) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

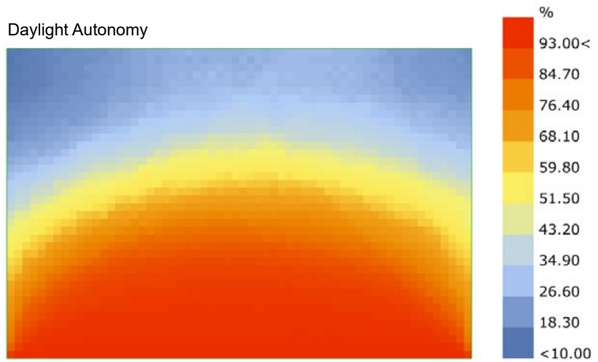
Shading Design

Base Assessment

The illuminance level is too high close to the window, so that the useful daylight is not enough and need to be adjusted.



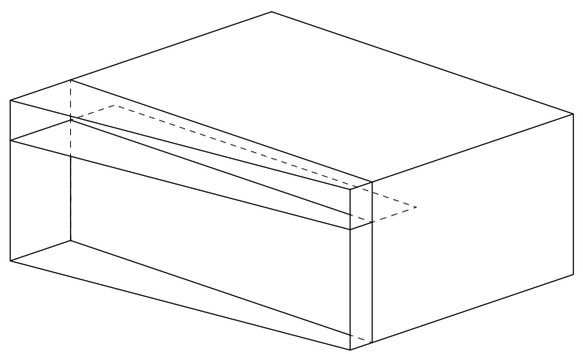
100LUX<UDLI<2000LUX

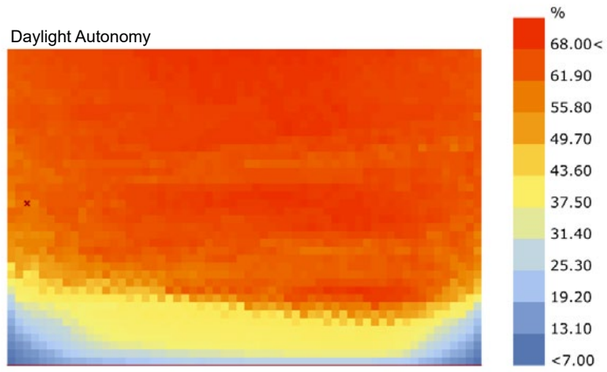


UDLI>2000LUX

First Design

Window glazing rate is 0.5
Light shelve close to the ceiling
Wider shading at the west end

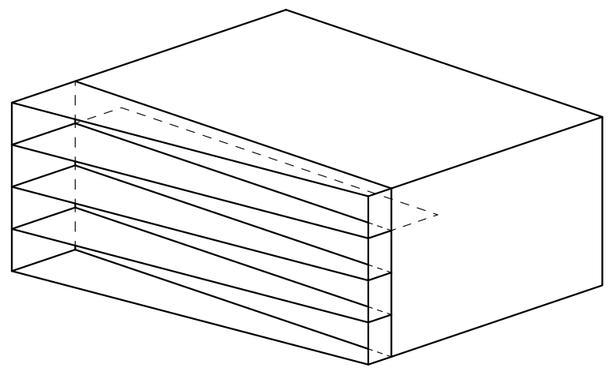


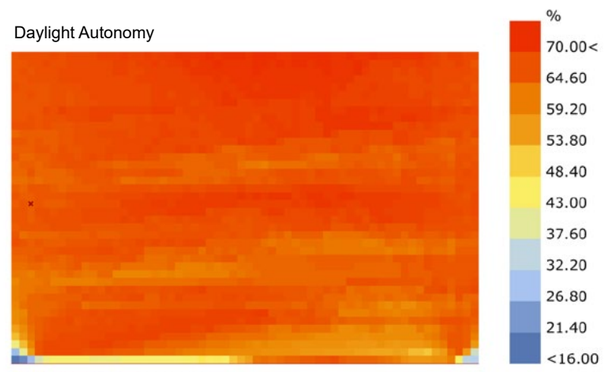


100LUX<UDLI<2000LUX

Second Design

Window glazing rate is 0.8
More shading louvers

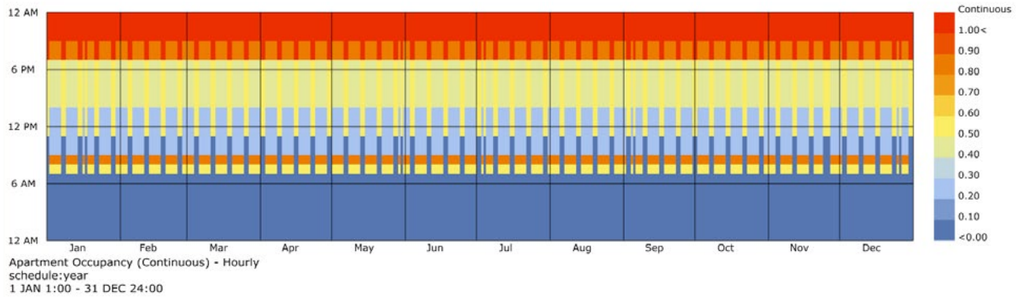


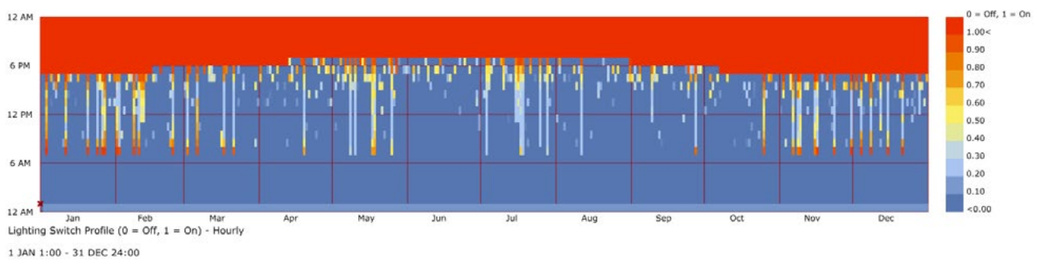


100LUX<UDLI<2000LUX

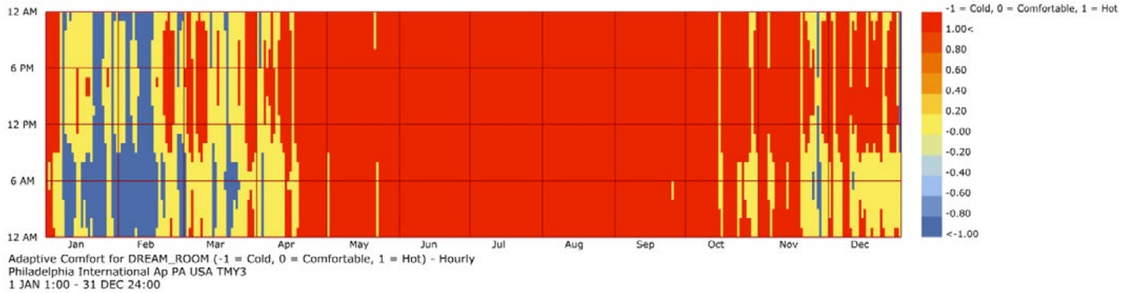
Indoor Comfort: Ventilation

According to my personal daily schedule, I customized a lighting schedule for this simple room. Taking into account of the lighting schedule, I made several adjustments to achieve a better adaptive comfort. By adding shades, the solar radiation drops a lot. By adding fan ventilation, it helps to cool down the room, but it makes the winter days too cold. By changing fan ventilation to natural ventilation, it helps a lot in cooling down the room in summer and keep some heat in winter.

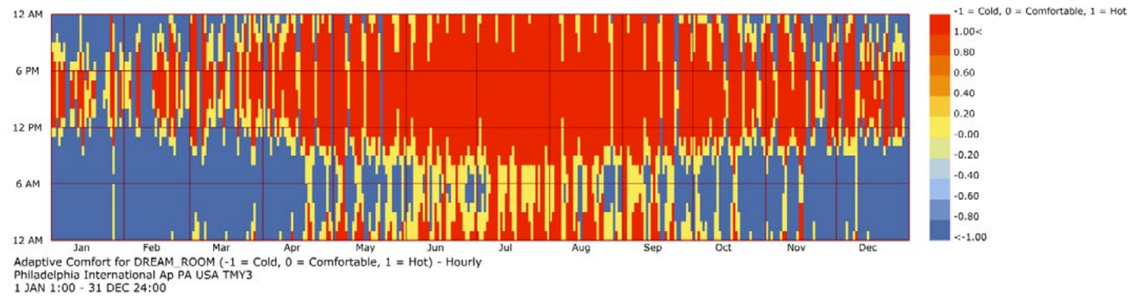




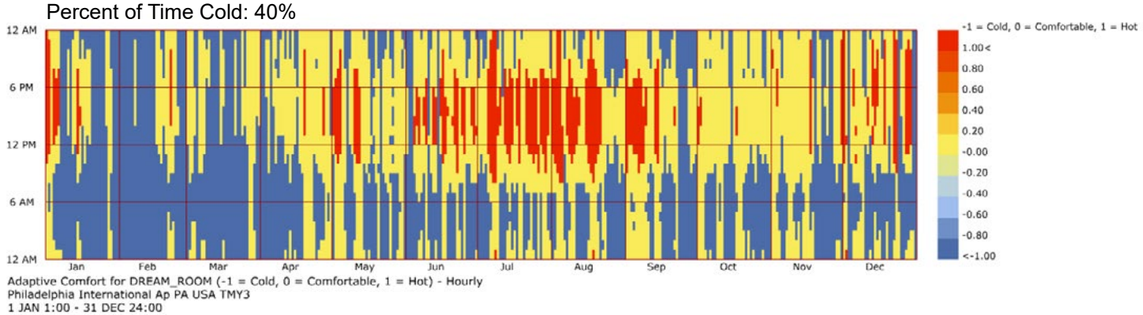
Room with Shading:
Percent of Time Comfortable: 22%
Percent of Time Hot: 67%
Percent of Time Cold: 9%



Fan Driven Ventilation:
Percent of Time Comfortable: 19%
Percent of Time Hot: 43%
Percent of Time Cold: 36%



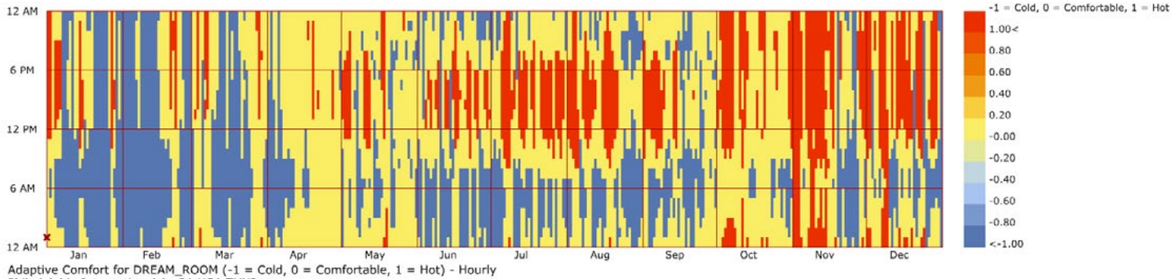
Natural Ventilation:
Percent of Time Comfortable: 44%
Percent of Time Hot: 15%
Percent of Time Cold: 40%

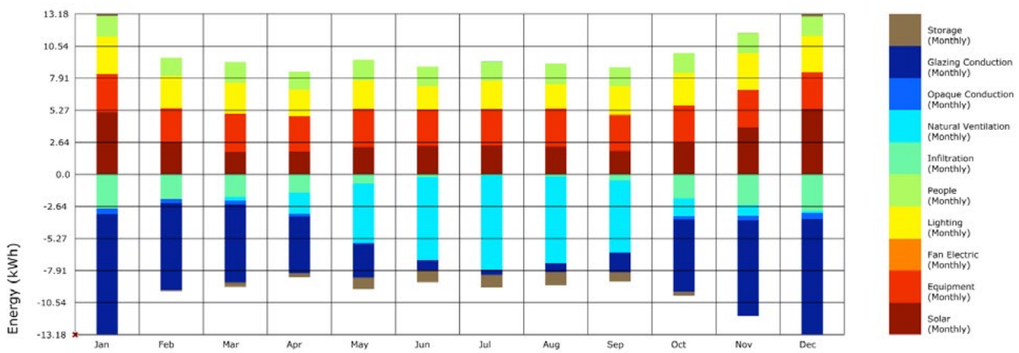


Indoor Comfort: Materials

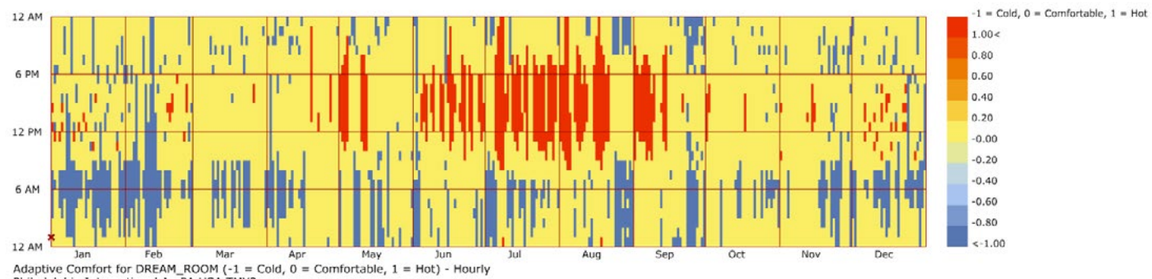
By changing wall materials, it helps lot in keeping the room temperature in a more constant and relatively comfort level. From the energy balance chart on the left, we can see the glazing conduction is in a large amount during winter. So I changed it from a single glazing to low-e double glazing glass, and it helps the room to keep warm in winter.

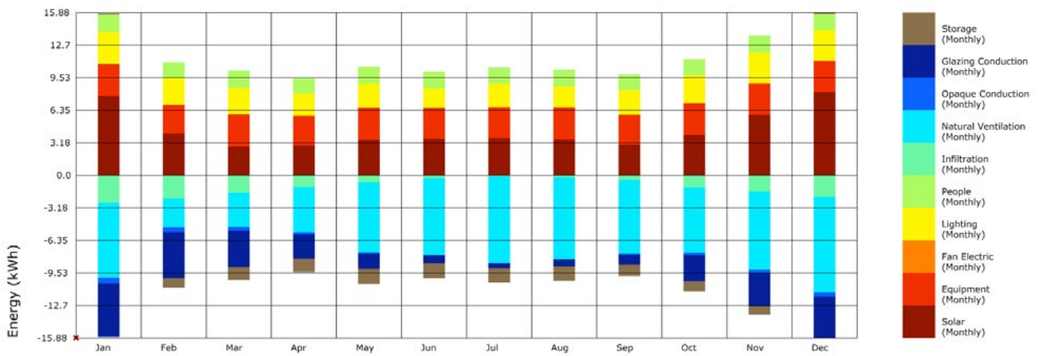
Change Wall Materials:
Percent of Time Comfortable: 51%
Percent of Time Hot: 18%
Percent of Time Cold: 31%





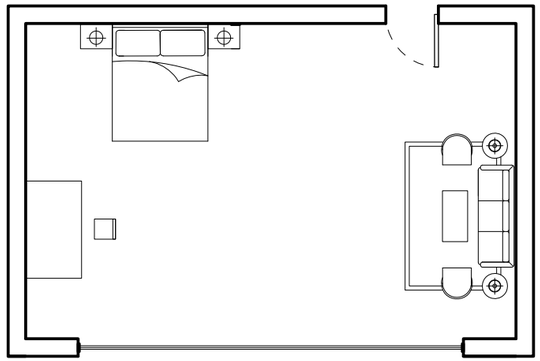
Change Glazing Material: Low-e Double Glazing
Percent of Time Comfortable: 76%
Percent of Time Hot: 8%
Percent of Time Cold: 16%

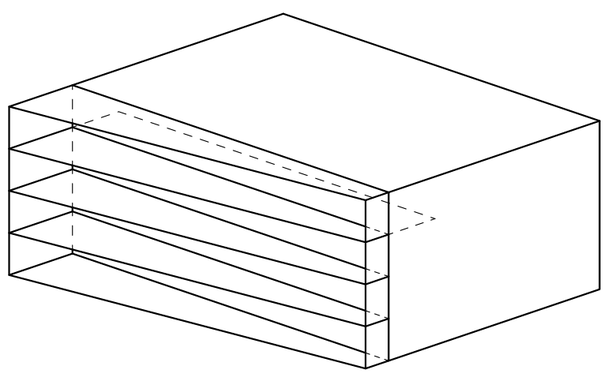


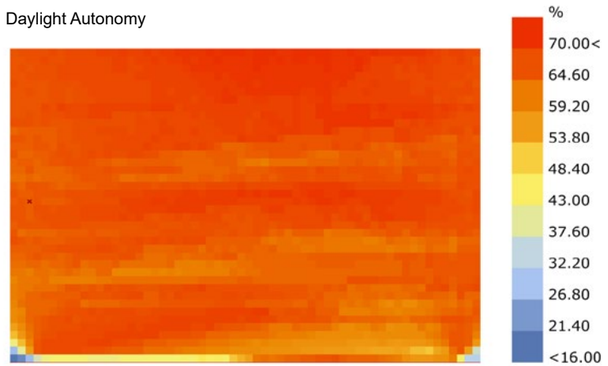


Summary

Through passive design methods, the performance of this unconditioned simple room achieved 76% percentage of indoor thermal comfort and 96% sDA for at least 50% >300lux daylighting. The methods used during the design process includes: adding shading louvers and lighting shelves, adjusting ventilation, changing construction materials.







100LUX<UDLI<2000LUX

Percent of Time Comfortable: 76%
Percent of Time Hot: 8%
Percent of Time Cold: 16%