

Fall 2016

Arch 753 Building Performance Simulation

## **THERMAL AND VISUAL COMFORT**

2144 Kater Street  
Philadelphia, PA 19146

Natasha Sanjaya

# CLIMATE ZONE

2144 Kater Street  
Philadelphia, PA 19146

*Weather Data:*

*Latitude:* 39.87

*Longitude:* -75.23

*Köppen Climate Zone:* Cfb - warm temperature, fully humid, warm summer

*Climate Zone:* 4A - mixed humid

*Cooling Degree Days (CDD):* 265.675

*Heating Degree Days (HDD):* 2754.125

## Main Köppen-Geiger Climate Classes for US counties

updated with CRU TS 2.1 temperature and VASClimo v1.1 precipitation data 1951 to 2000

|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |    |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| Af  | Am  | As  | Aw  | BWk | BWh | BSk | BSh | Cfa | Cfb | Cfc | Csa | Csb | Csc | Cwa |    |
| Cwb | Cwc | Dfa | Dfb | Dfc | Dfd | Dsa | Dsb | Dsc | Dsd | Dwa | Dwb | Dwc | Dwd | EF  | ET |

### Main climates

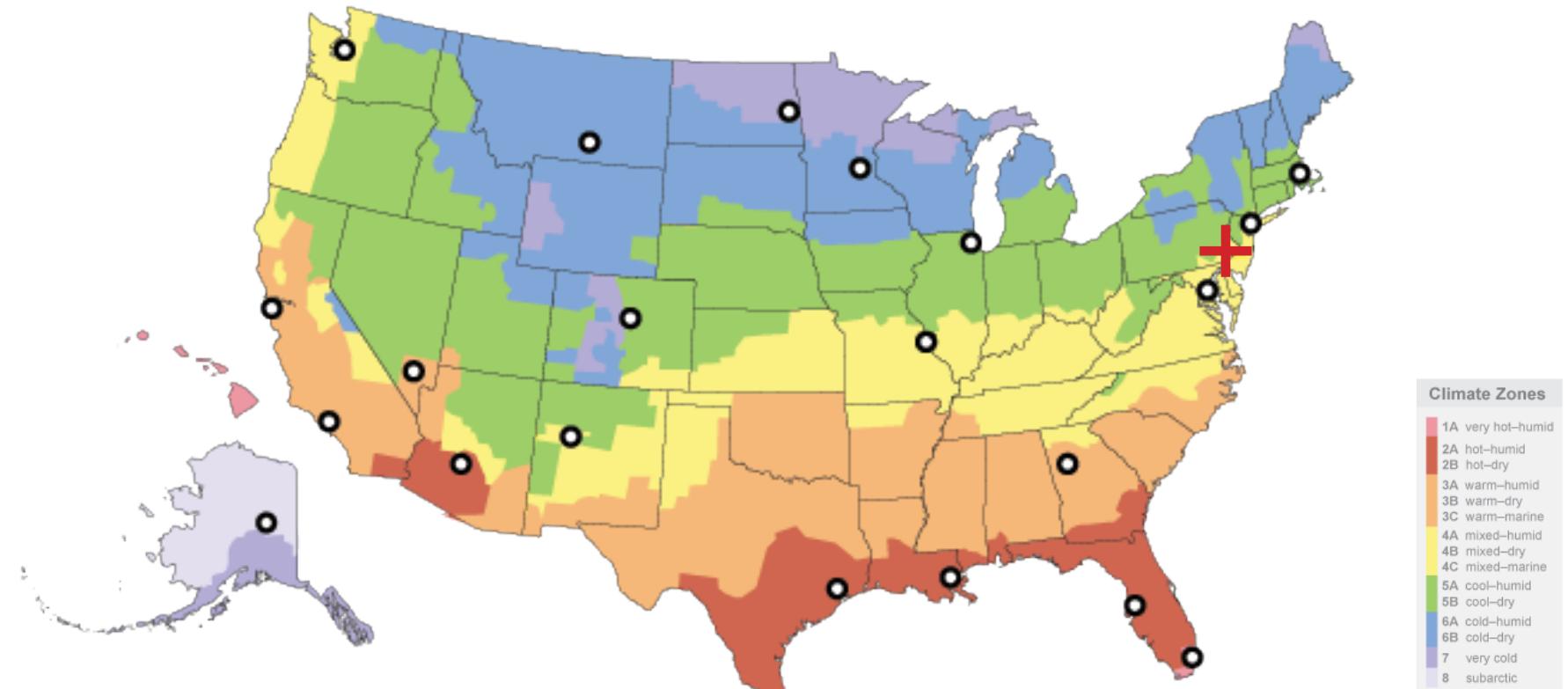
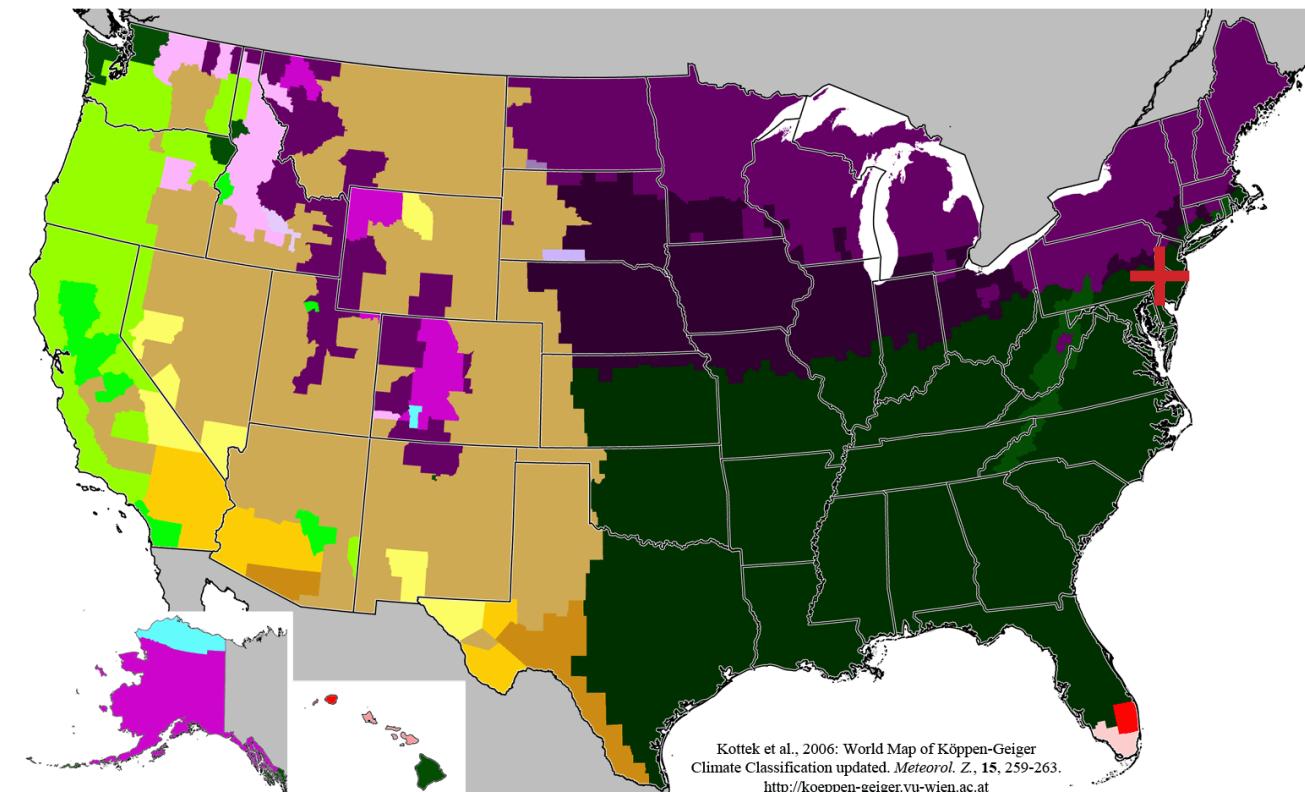
|                   |
|-------------------|
| A: equatorial     |
| B: arid           |
| C: warm temperate |
| D: snow           |
| E: polar          |

### Precipitation

|                |
|----------------|
| W: desert      |
| S: steppe      |
| f: fully humid |
| s: summer dry  |
| w: winter dry  |
| m: monsoonal   |

### Temperature

|                          |          |
|--------------------------|----------|
| h: hot arid              | F: polar |
| k: cold arid             | T: polar |
| a: hot summer            |          |
| b: warm summer           |          |
| c: cool summer           |          |
| d: extremely continental |          |

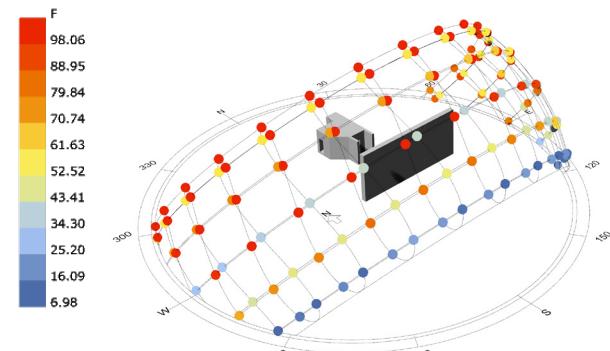
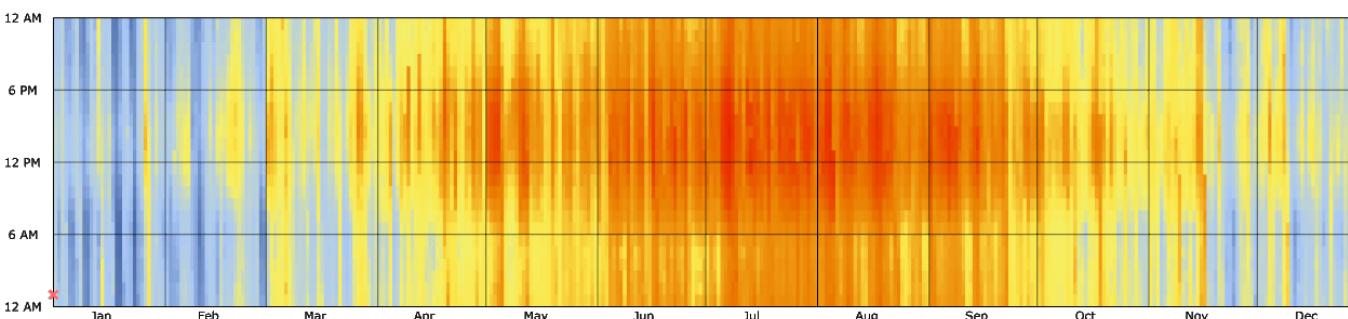


# ENVIRONMENTAL FACTORS

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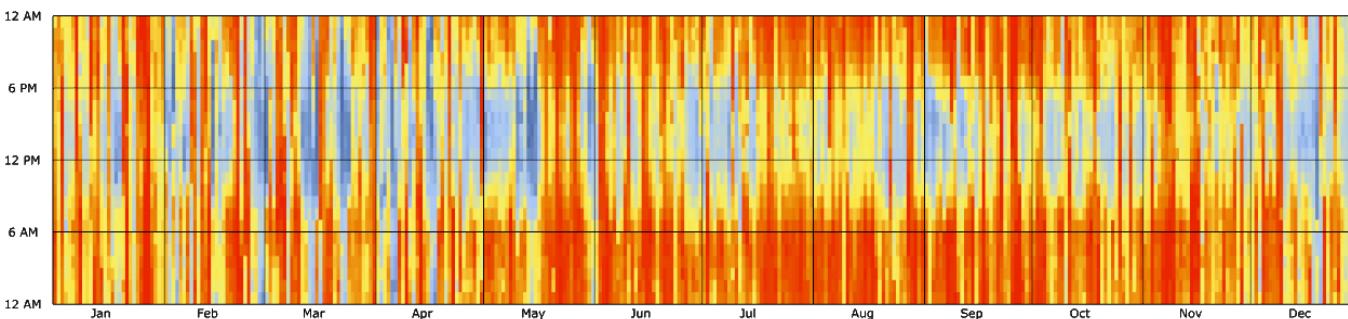
## Dry Bulb Temperature (°F)

Temperature High: 6.98°F (36.9°C)  
Temperature Low: 98.06°F (-13.9°C)



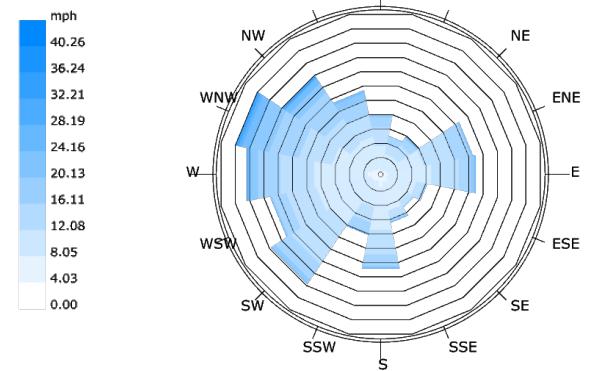
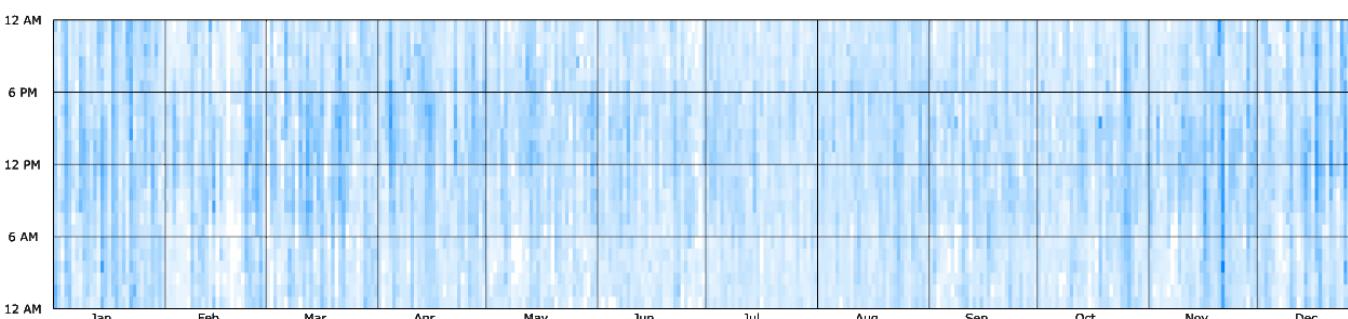
## Relative Humidity (%)

Comfortable ( $20 < x < 80$ ): 70%



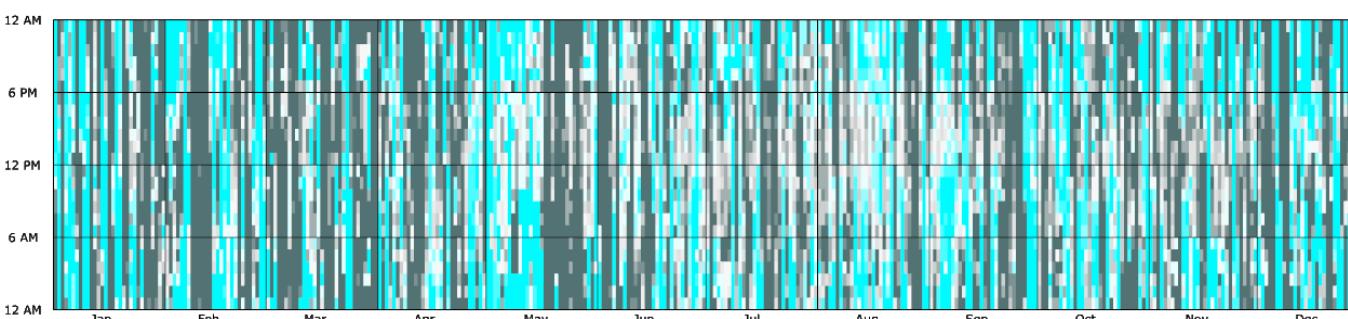
## Wind Speed (mph)

Prevailing Wind Direction: WNW, W, NW, SW  
Speed High: 40.26 mph (18 m/s)  
Speed Low: 0 - 1.79 mph (0 - 1 m/s)



## Sky Cover (%)

Clear (0 - 1/10th): 26.4%  
Scattered (2/10th-5/10th): 18.6%  
Broken (6/10th-9/10th): 20.4%  
Overcast (fully covered): 34.6%



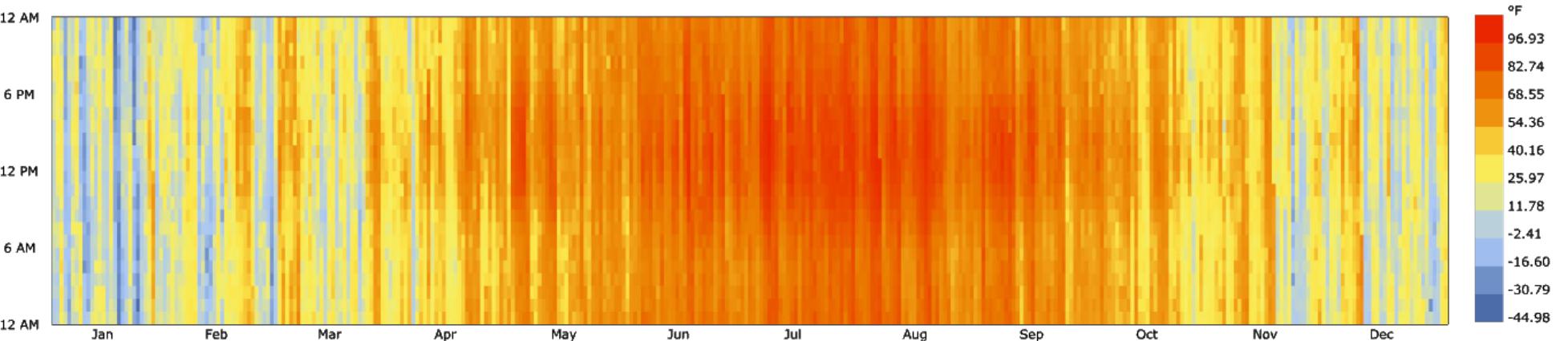
# OUTDOOR COMFORT

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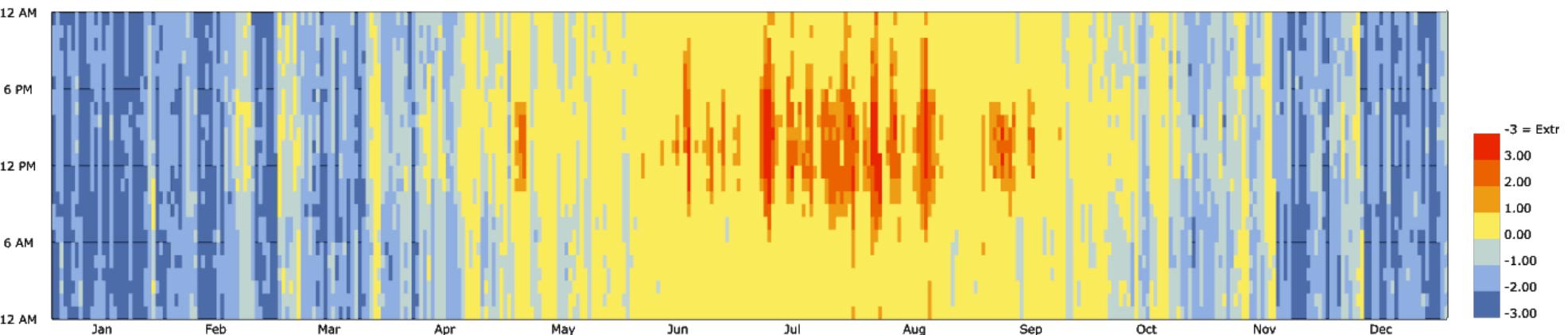
## Universal Temperature Comfort Index (UTCI)

UTCI is the "feels like" temperature, taking into account radiant temperature, relative humidity, and wind speed.

Comfortable = 48.2 - 78.8 °F (9 - 26°C)

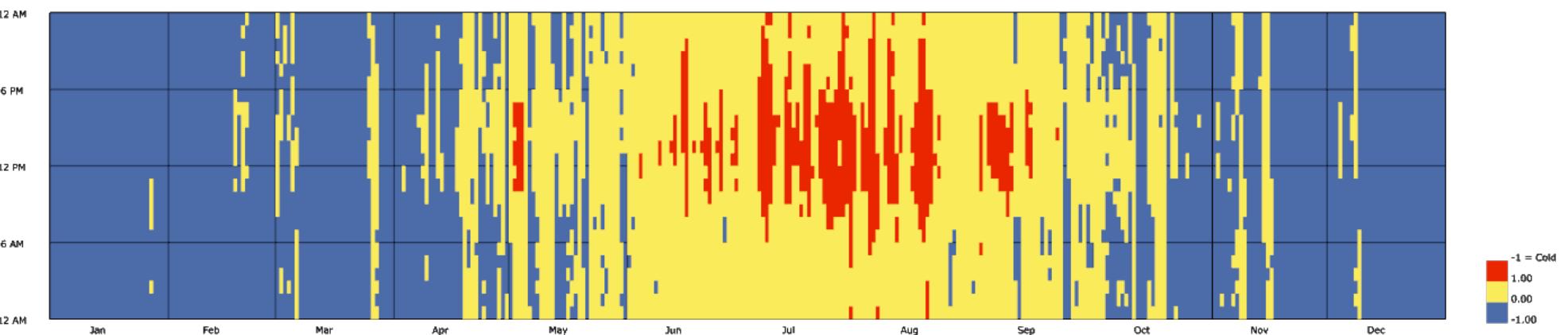


## Condition of Person



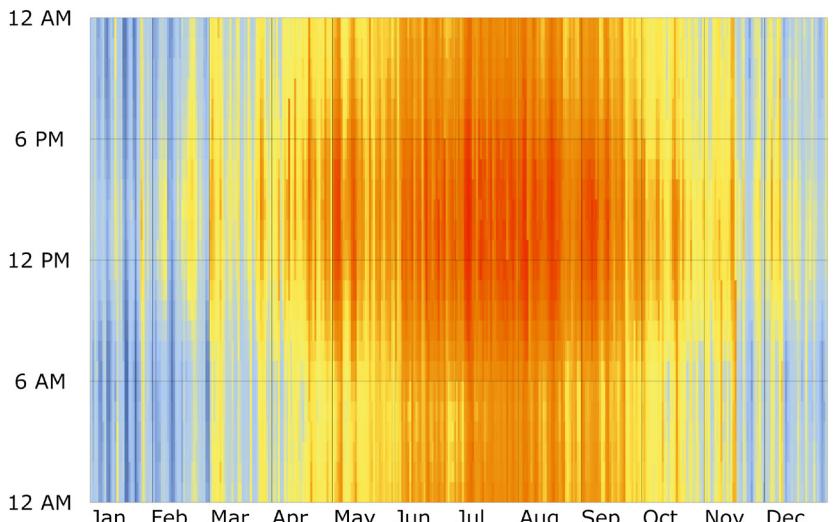
## Thermal + Cold Stress

*Percent Comfortable* 41.3%

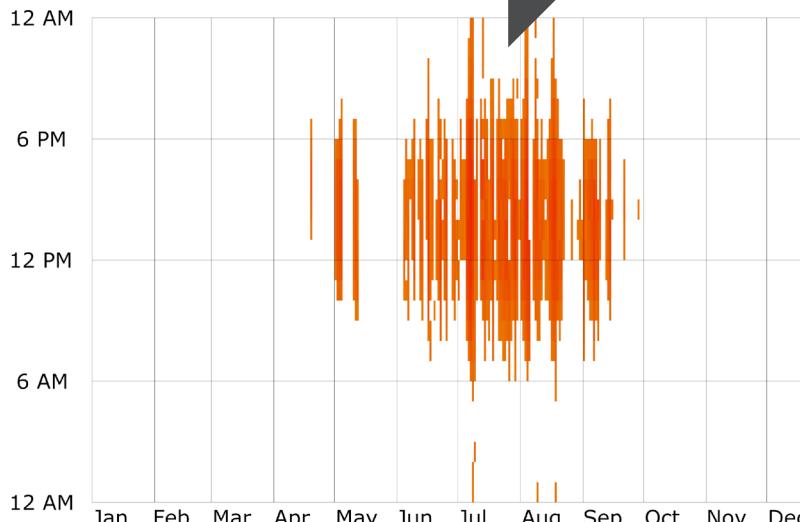


# IDEAL VENTILATION CONDITION

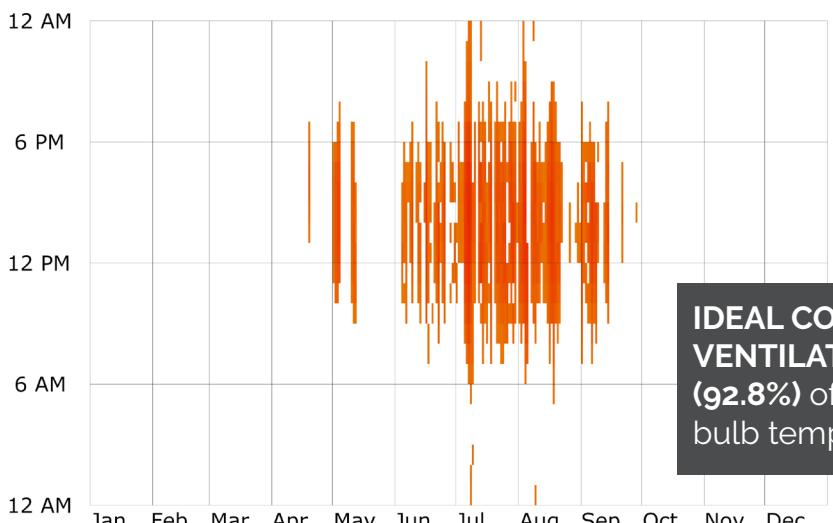
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Dry Bulb Temperature for All Times of the Year



Dry Bulb Temperature is **above 26°C** for **894 hours** (10.2%) of the year. This can cause heat stress without methods of cooling.

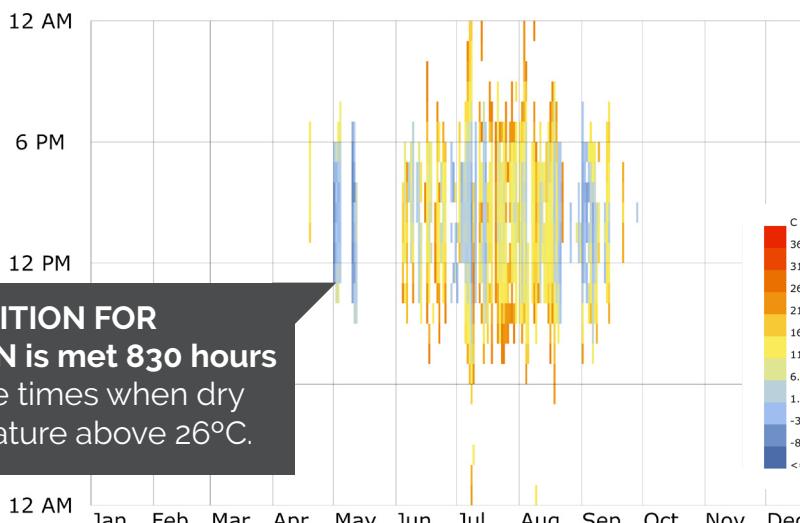


## IDEAL CONDITION FOR VENTILATION

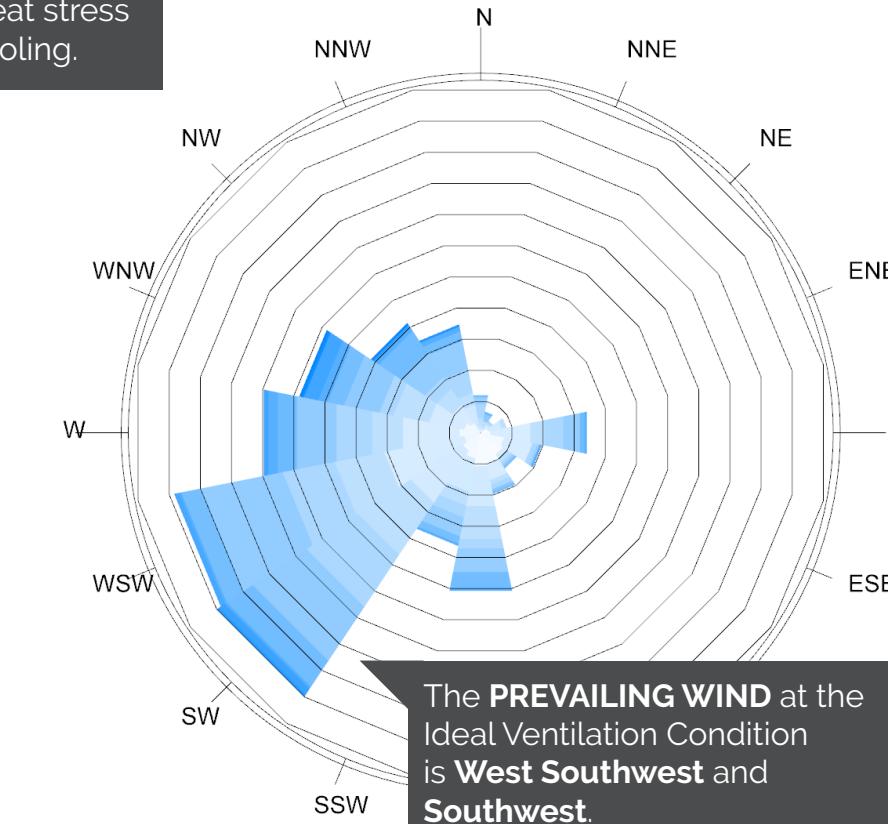
is indicated by the following parameters:

Humidity:  $20\% > H > 80\%$

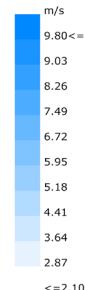
Wind Speed:  $2 \text{ m/s} > v > 10 \text{ m/s}$



**IDEAL CONDITION FOR VENTILATION** is met 830 hours (92.8%) of the times when dry bulb temperature above 26°C.



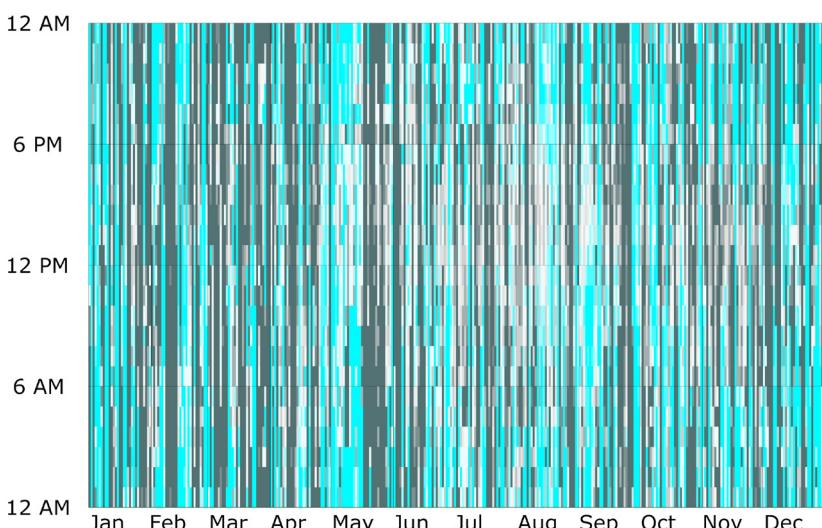
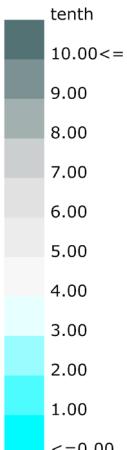
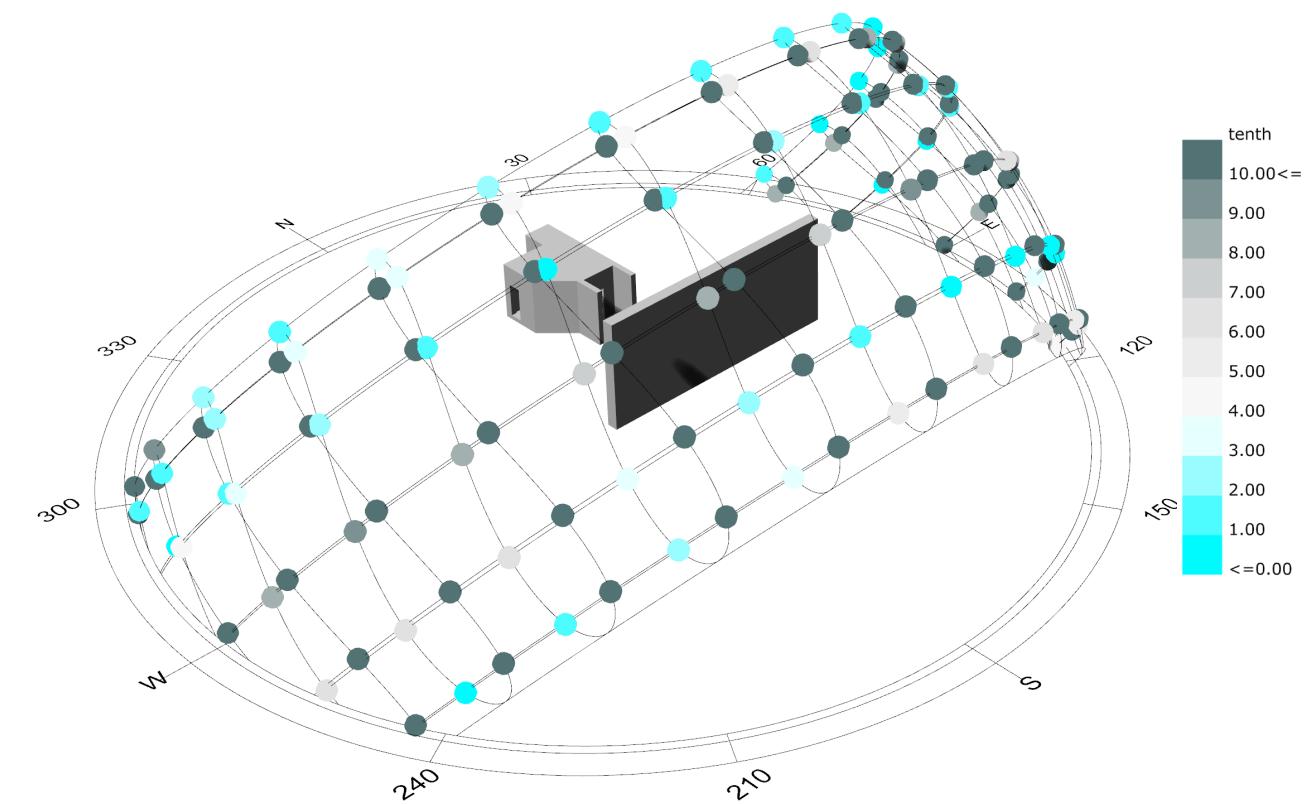
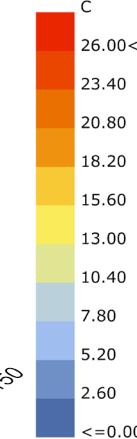
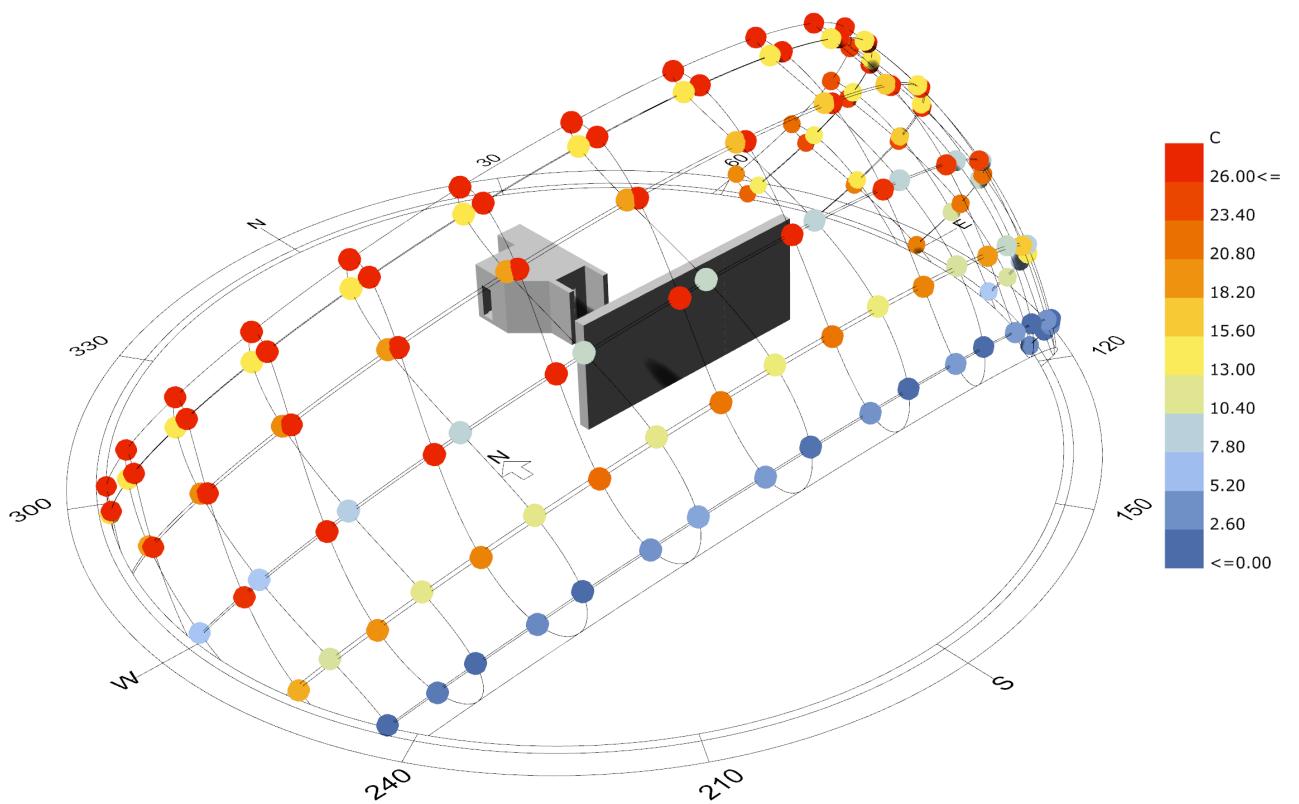
Wind-Rose  
Philadelphia International Ap\_PA\_USA  
1 JAN 1:00 - 31 DEC 24:00  
Hourly Data: Wind Speed (m/s)  
Calm for 0.00% of the time = 0 hours.  
Each closed polyline shows frequency of 0.2%. = 13 hours.  
...     ...     ...  
Conditional Selection Applied:  
Dry Bulb Temperature > 26  
and 20 < Relative Humidity < 80  
and 2 < Wind Speed < 10  
804.0 hours of total 8760.0 hours (9.18%).



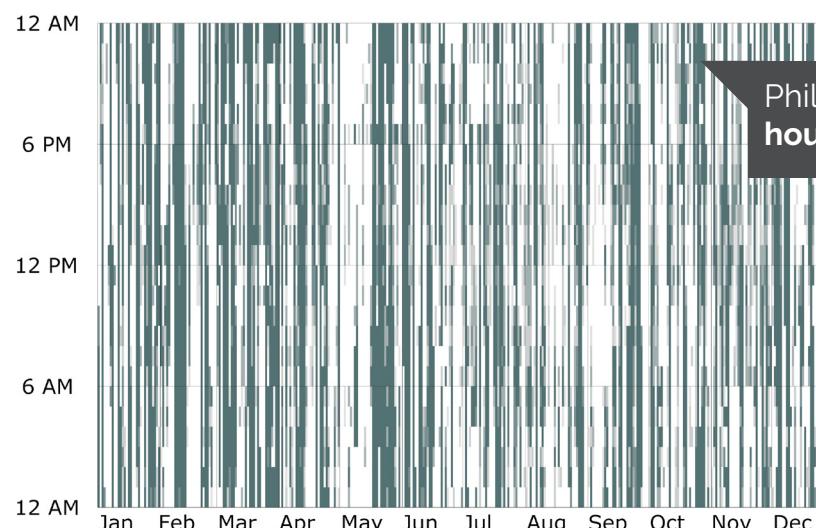
Operable windows are needed on the roof as a flush skylight or a series of vertical clerestory windows facing north or east to assist in cross ventilation and stack effect to flush out the heat from the room.

# DAYLIGHTING CONDITION

2144 Kater Street  
Philadelphia, PA 19146



Sky Cover for All Times of the Year



Cloudy Hours (24-Hours)

Philadelphia is **cloudy for 4816 hours (54.9%)** of the year.

Cloudy days in Philadelphia makes up 54.9% of the year and is evenly distributed throughout, though with more frequency during the winter and fall. The surrounding context of the room is shading the sun during the winter hours even on a clear day. The high sun angle also prevents much light from entering the room during the summer time except for the morning hours.

The **DAYLIGHTING GOAL** is to let more light into the room throughout the year, especially during the winter hours, without increasing heat gain.

# DESIGN PROBLEMS & APPROACH

2144 Kater Street  
Philadelphia, PA 19146

## PROBLEMS

### Daylighting

Could be better lit, especially in the winter time. The size and positioning of the window, in addition to the context of the room prevents adequate light to enter the room. The light that does come into the room is concentrated.

### Temperature

Too hot in the summer, not warm enough in the winter  
Room is situated right above the kitchen. Air vent is situated on the bottom of the eastern wall. Hot air seeps up through the floors since the house is really old and nothing is well sealed (cracks everywhere), but the vent doesn't seem to deliver/distribute air well.

### Lack of Ventilation

Room can feel stuffy in the summer time

## APPROACH

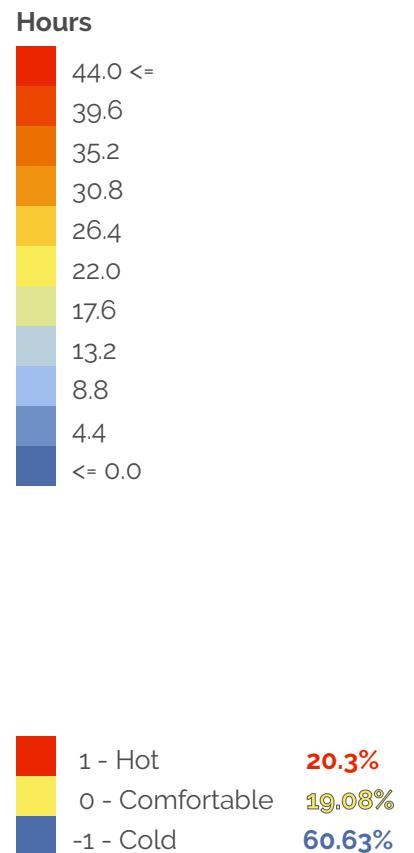
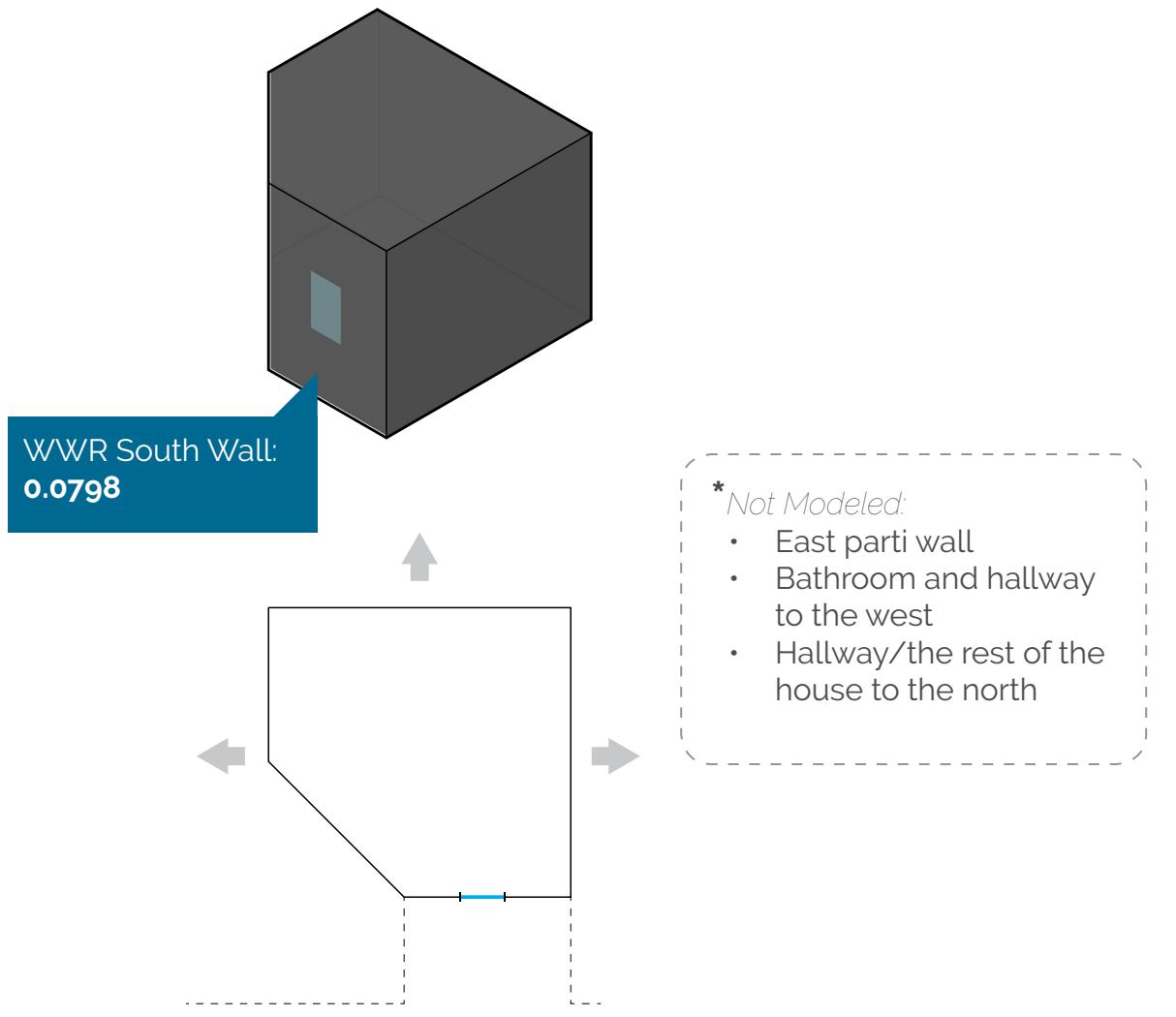
Enlarging the existing window, specifically increasing the vertical dimension to clear the shading context, will allow more light to enter the room during the winter time while still shading the summer sun. This way, we avoid additional solar heat gain. Horizontal louvers can be added to fine tune the amount of light entering the room. Another possible solution is to add a north-facing skylight to allow indirect sunlight to come in.

Considering the context and the size of the window, solar heat gain transmitted through the window is minimal. The low window-to-wall ratio provides a generous amount of mass to absorb heat (to cool the building in the summer time and release heat in the winter time). Providing additional windows to facilitate natural ventilation during optimal times of the year will help flush out heat. Ideal ventilation conditions (as described in the page prior) occurs 830 hours of the year (9.5% of the year). However, even when the temperature is lower, windows can be opened to increase fresh air flow without severely lowering the interior temperature to create discomfort.

A construction / material solution is to improve insulation/seal everything up and to relocate the vent to the top of the wall so that it's not obstructed.

# COMFORT ANALYSIS | BASE 8% WINDOW

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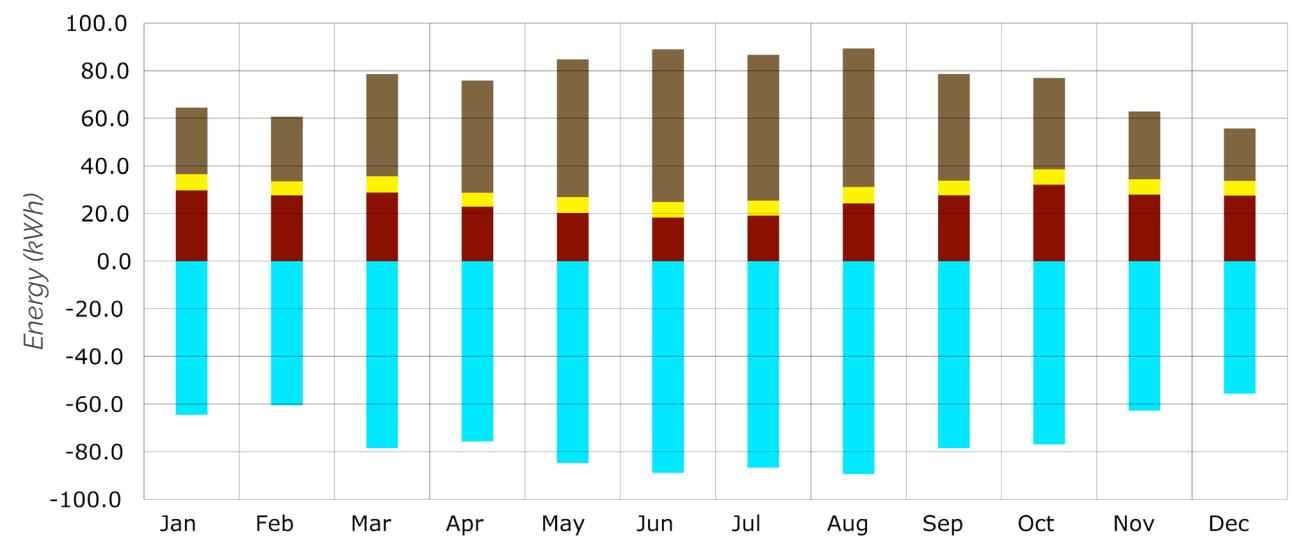
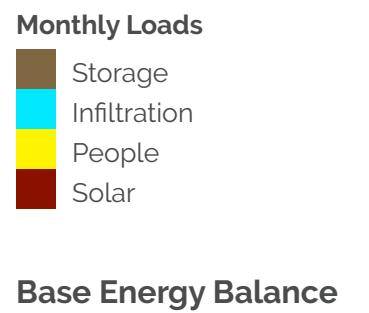
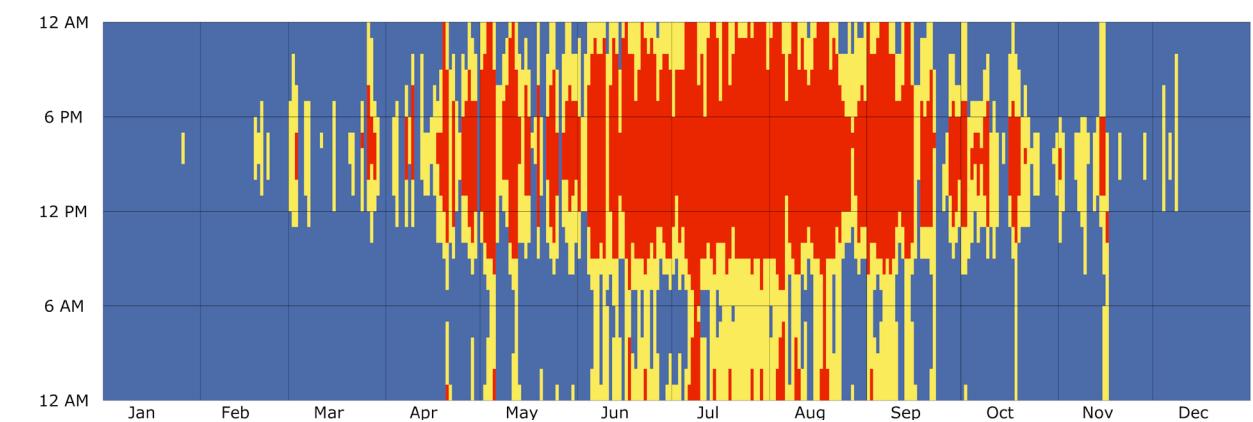
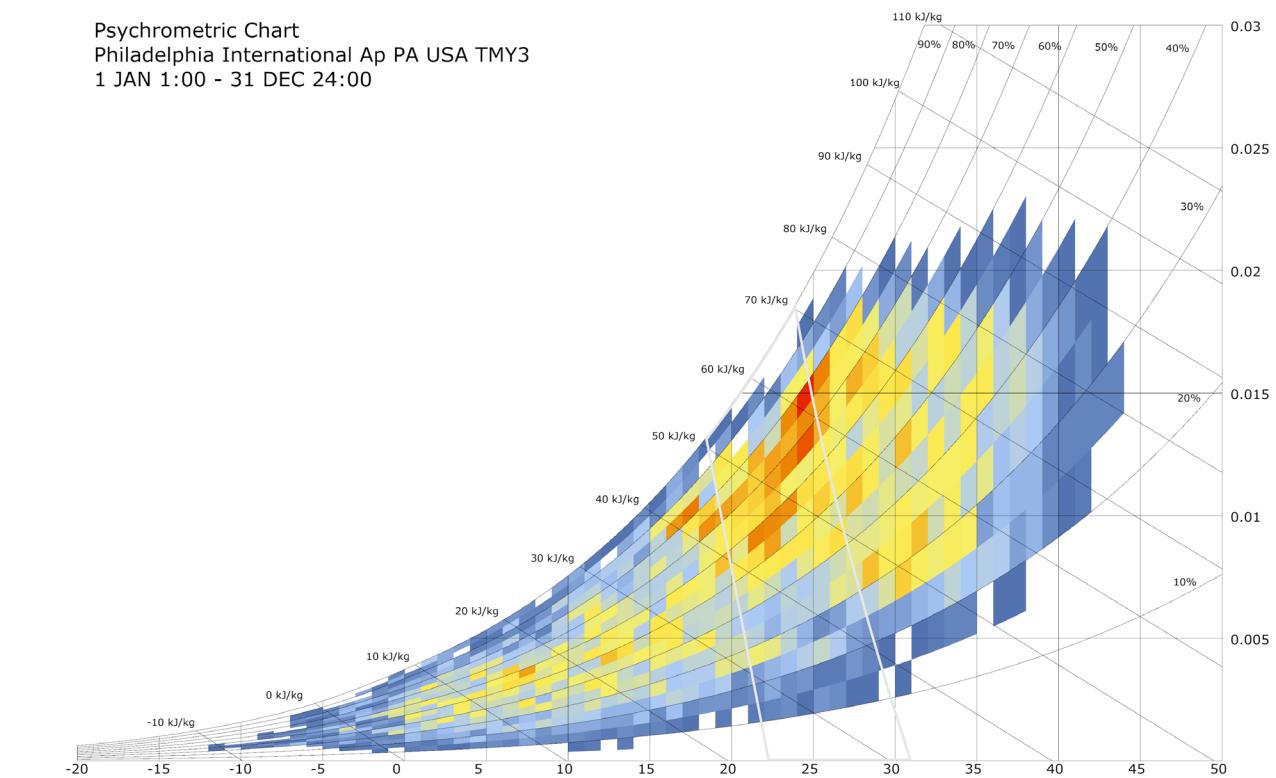


**ANNUALLY** this room is **comfortable only for 19% of the time**. The majority of the year (61%), the room is too cold. The simulation result is largely due to energy loss from infiltration, which, in the simplification of the modeling\*, is presenting behaviour of a room situated as a singular entity in the round.

To reduce energy loss due to infiltration, the adjacent rooms can be added to the model or the wall construction can be adjusted. Solar gain can be increased in the winter time by increasing the WWR ratio on the south wall to increase comfort in the winter months but shading devices must be employed to reduce summer heat gain (as seen in the Adaptive Comfort chart).

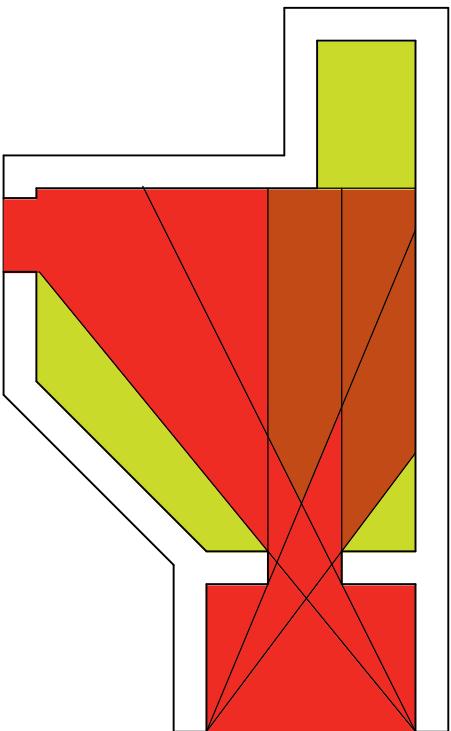
This model also is not taking account the internal loads of an office, although the single occupancy should not produce high internal load that will contribute to heating up the space.

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

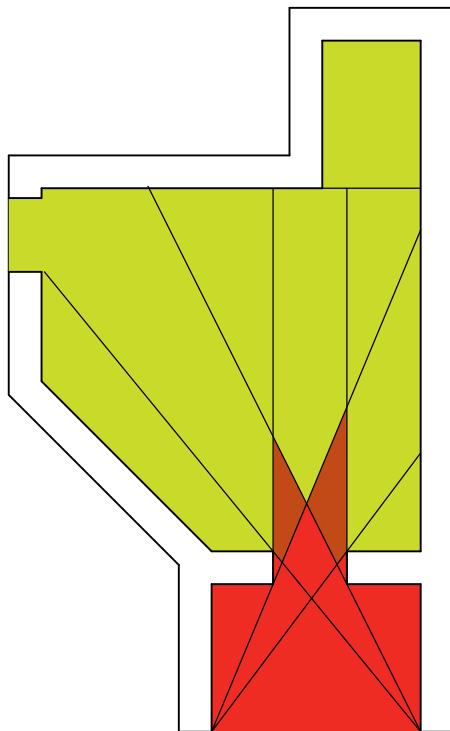


# DAYLIGHTING | BASE 8% WINDOW

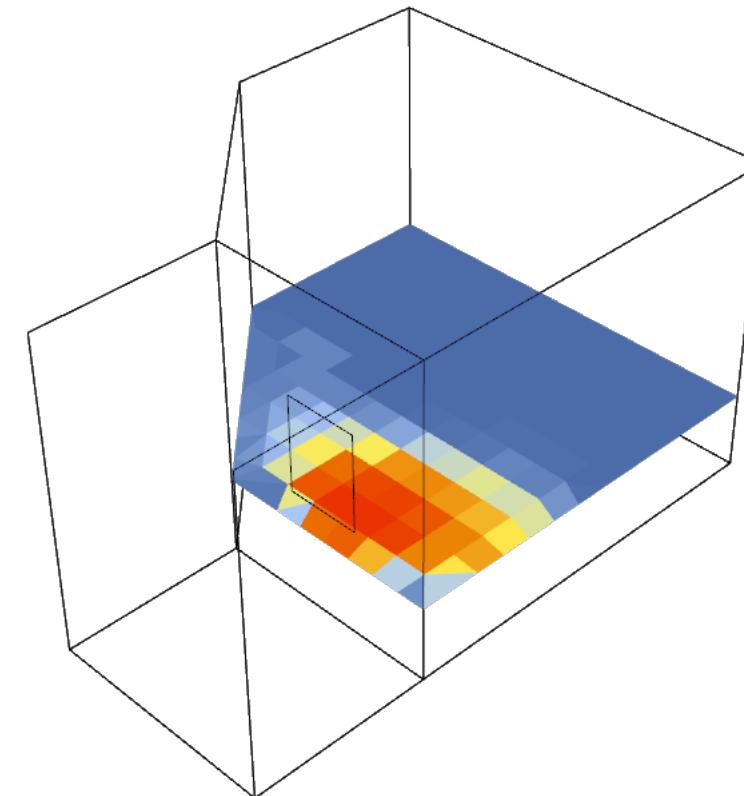
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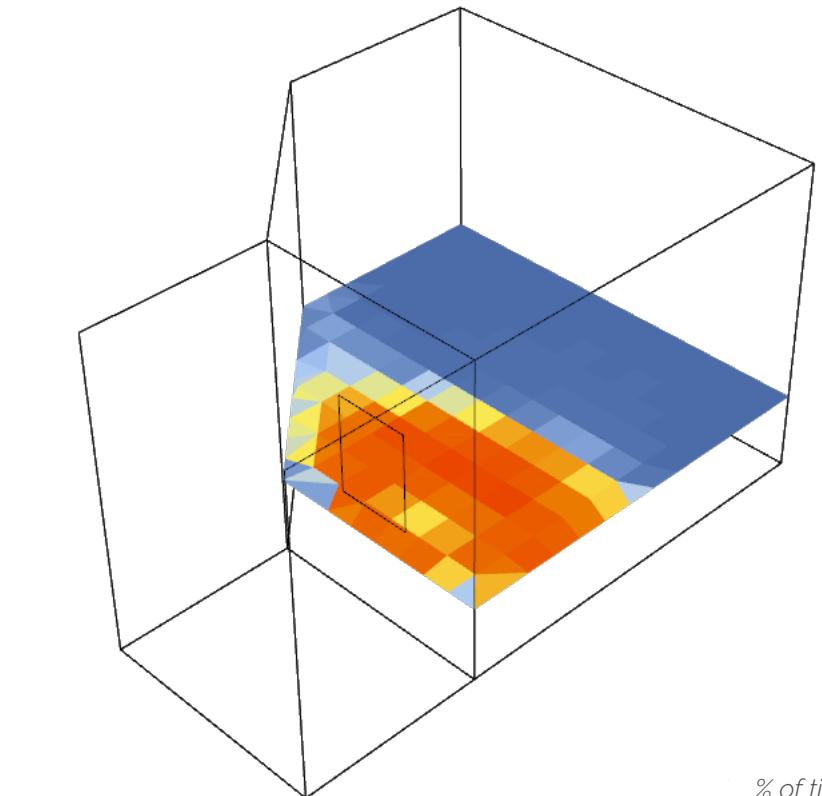
*Based on Perception  
Summer Solstice*



*Based on Analysis  
Summer Solstice*



**Daylight Autonomy (DLA)**  
300+ lux



**Useful Daylight Illuminance (UDLI)**  
100 - 2000 lux

**Qualitative Light Assessment  
Relative to Areas Within**

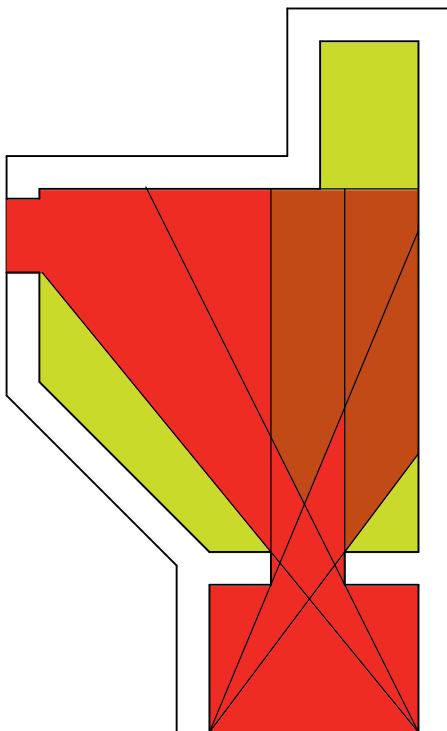
Good  
Ok  
Bad

As perceived, a concentrated area of the room directly in front of the window receives adequate daylight.

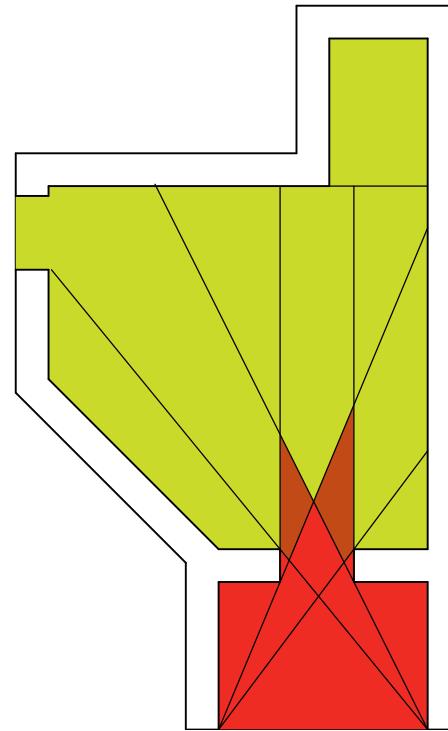
% of time  
100  
90  
80  
70  
60  
50  
40  
30  
20  
10  
0

# DAYLIGHTING | BASE 8% WINDOW

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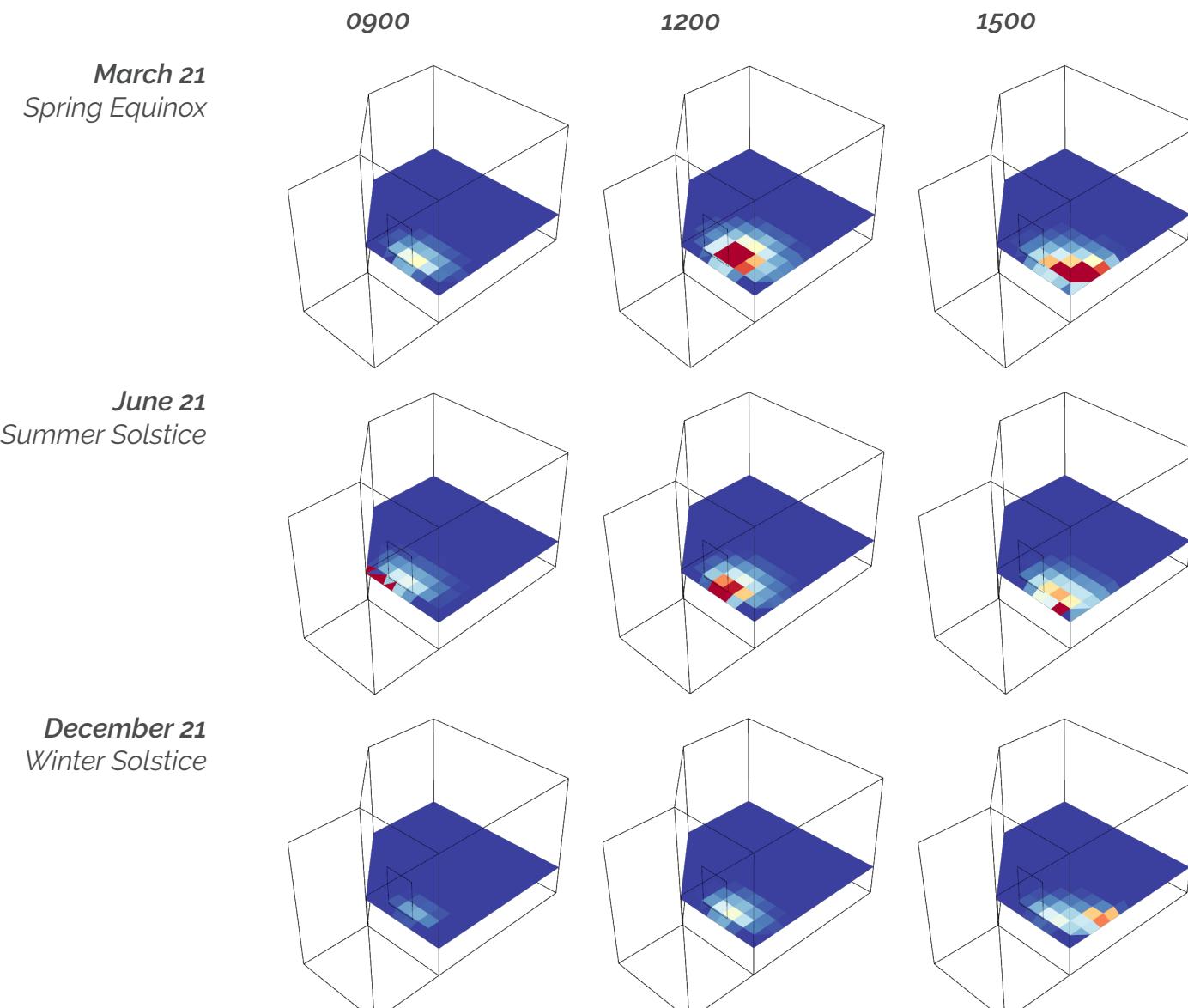
*Based on Perception*  
Summer Solstice



*Based on Analysis*  
Summer Solstice

**Qualitative Light Assessment**  
*Relative to Areas Within*

Good  
Ok  
Bad



*March 21*  
Spring Equinox

*June 21*  
Summer Solstice

*December 21*  
Winter Solstice

**Quantitative Light Assessment**  
(Illuminance)

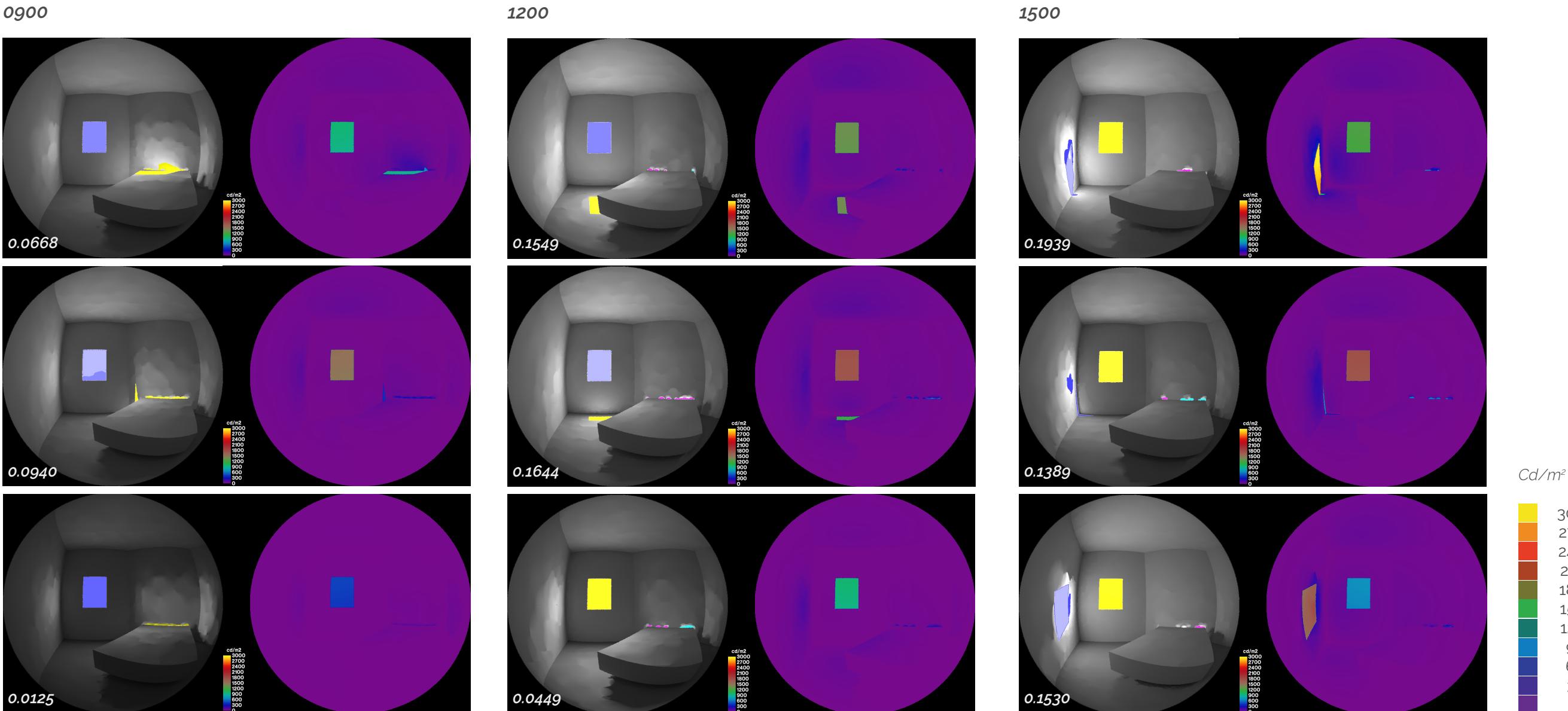
Much of the room receives 200 lux of light and below.

lux

|         |
|---------|
| 2000 => |
| 1800    |
| 1600    |
| 1400    |
| 1200    |
| 1000    |
| 800     |
| 600     |
| 400     |
| <= 200  |

# GLARE | BASE 8% WINDOW

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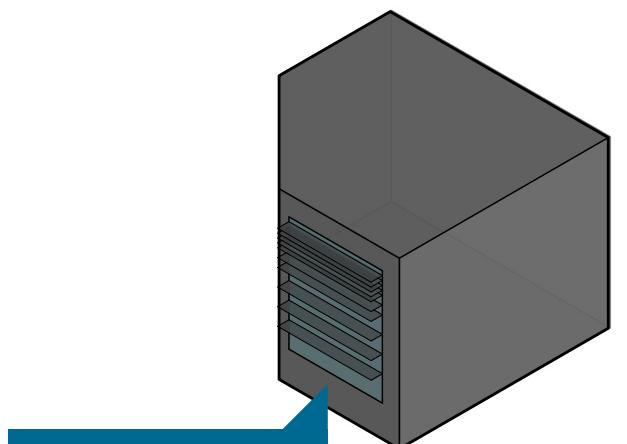


**Daylight Glare Probability (DGP)**  
*Imperceptible Glare [0.35 > DGP]*  
*Perceptible Glare [0.4 > DGP >= 0.35]*  
*Disturbing Glare [0.45 > DGP >= 0.4]*  
*Intolerable Glare [DGP >= 0.45]*

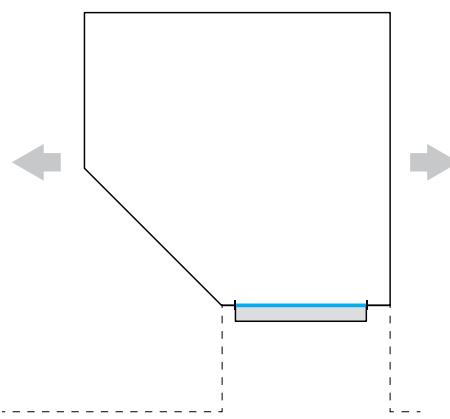
Very little glare occurs in the room due to external obstructions that prevent much light from entering the room.

# GLARE | ITERATION 01 - 54% WINDOW + LOUVERS

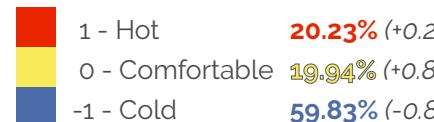
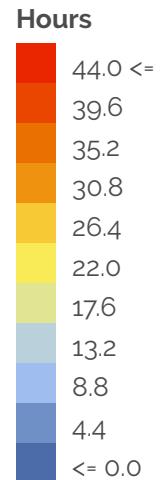
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WWR South Wall:  
**0.539**

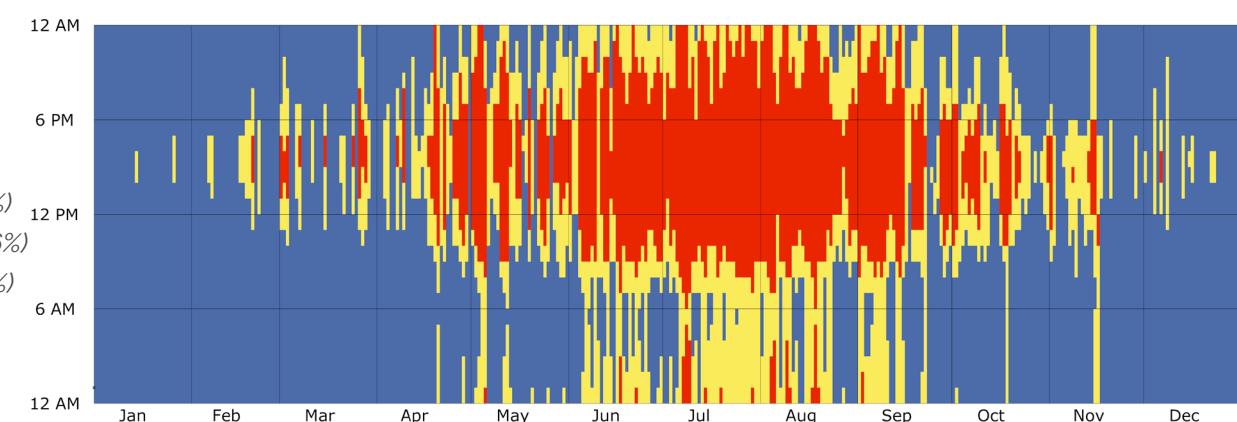
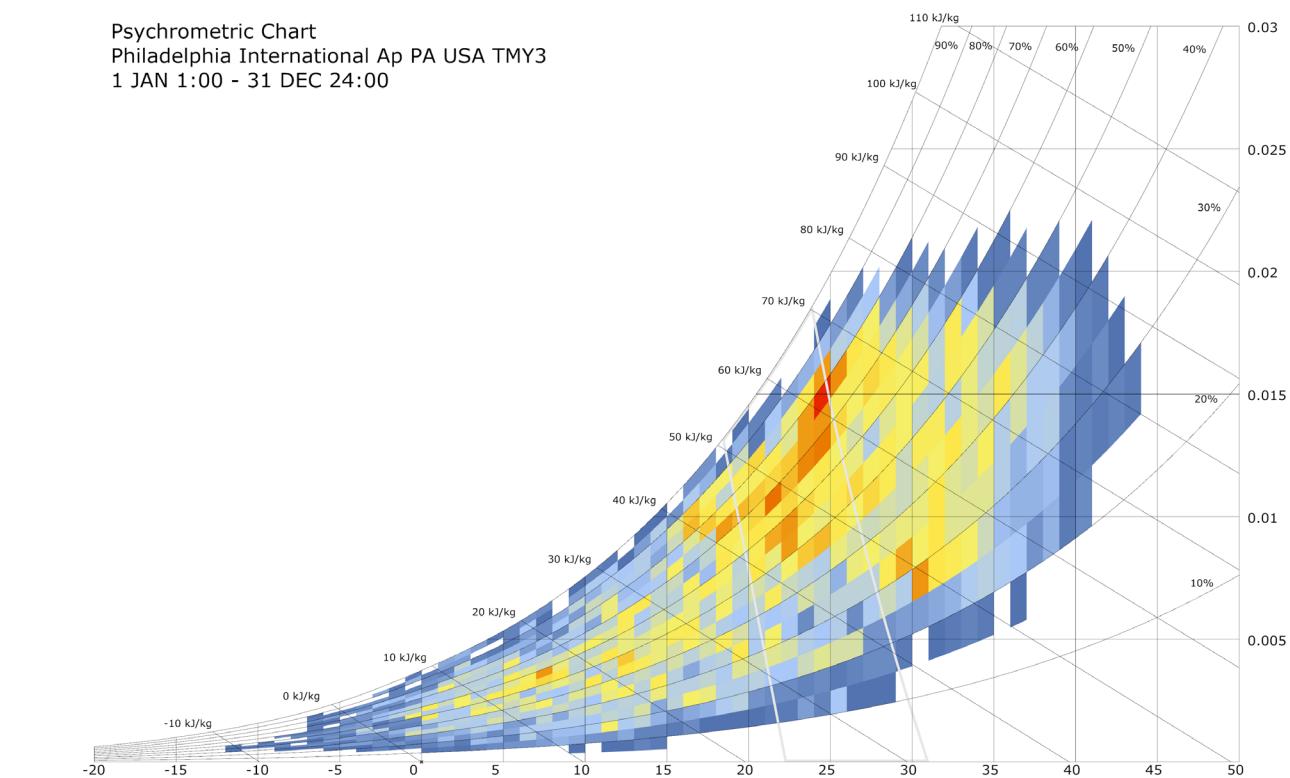


- \* Not Modeled:
  - East parti wall
  - Bathroom and hallway to the west
  - Hallway/the rest of the house to the north



**Adaptive Comfort**

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

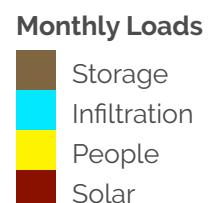


## THE ADJUSTMENT INCREASED THE ANNUAL COMFORT

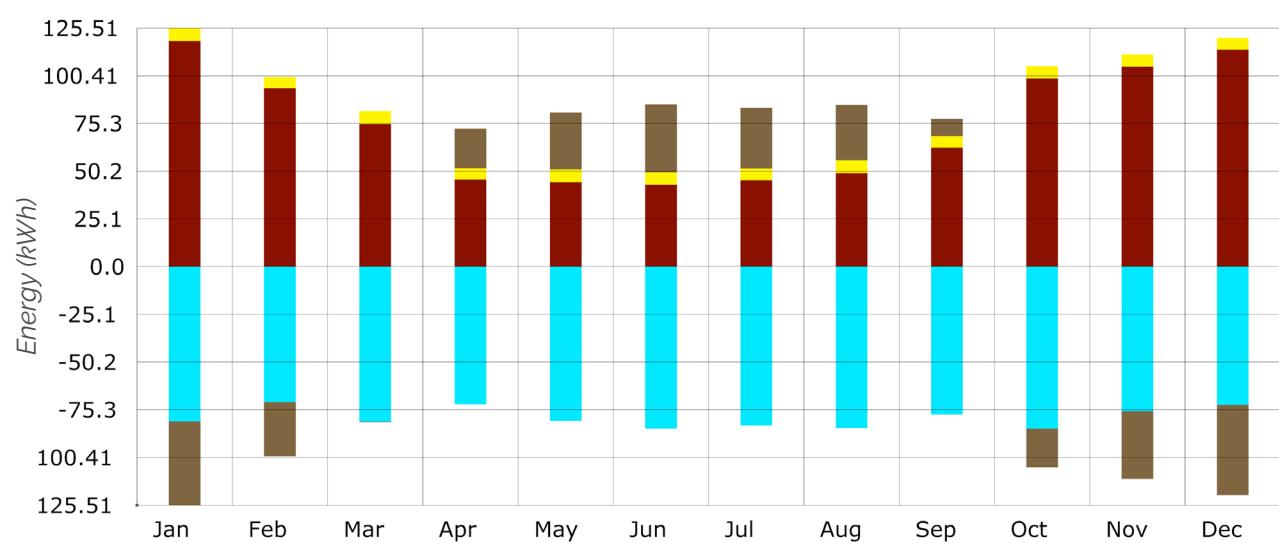
by 0.89% to nearly 20% of the year. The amount of discomfort due to the cold is significant compared to the discomfort due to heat.

It became a priority to reduce discomfort due to the cold while maintaining (or increasing) the amount of comfortable days. The increase in glazing surface reduced energy loads in storage during the winter months. Energy loss due to infiltration increased by approximately 15 kWh but it is diminished as a trade off with an increase in solar heat gain (5-folds increase) in the winter months.

Adjustable internal shading can be applied to reduce solar heat gain the the summer months during the days when ventilation is not ideal (low wind speed and/or high humidity levels).

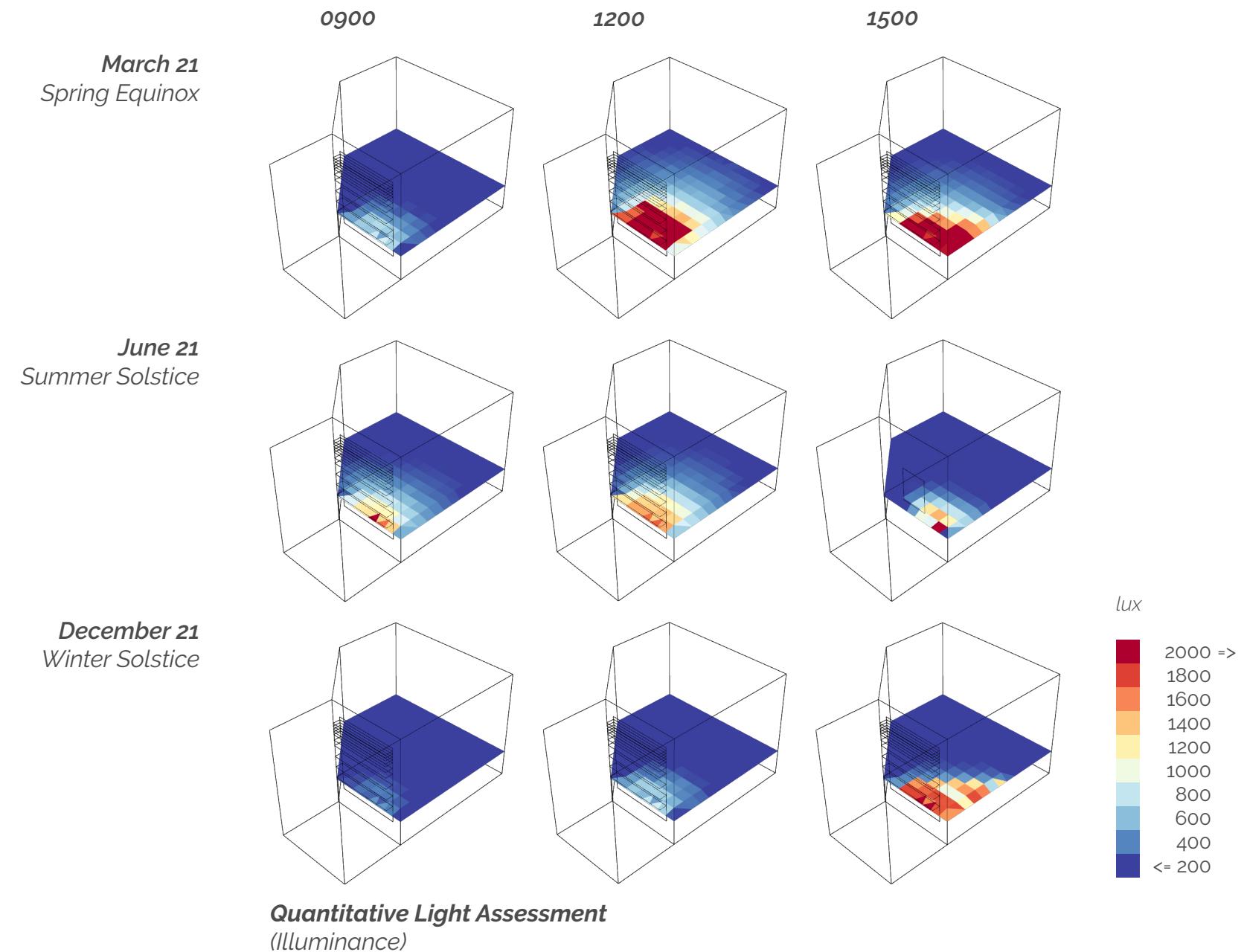
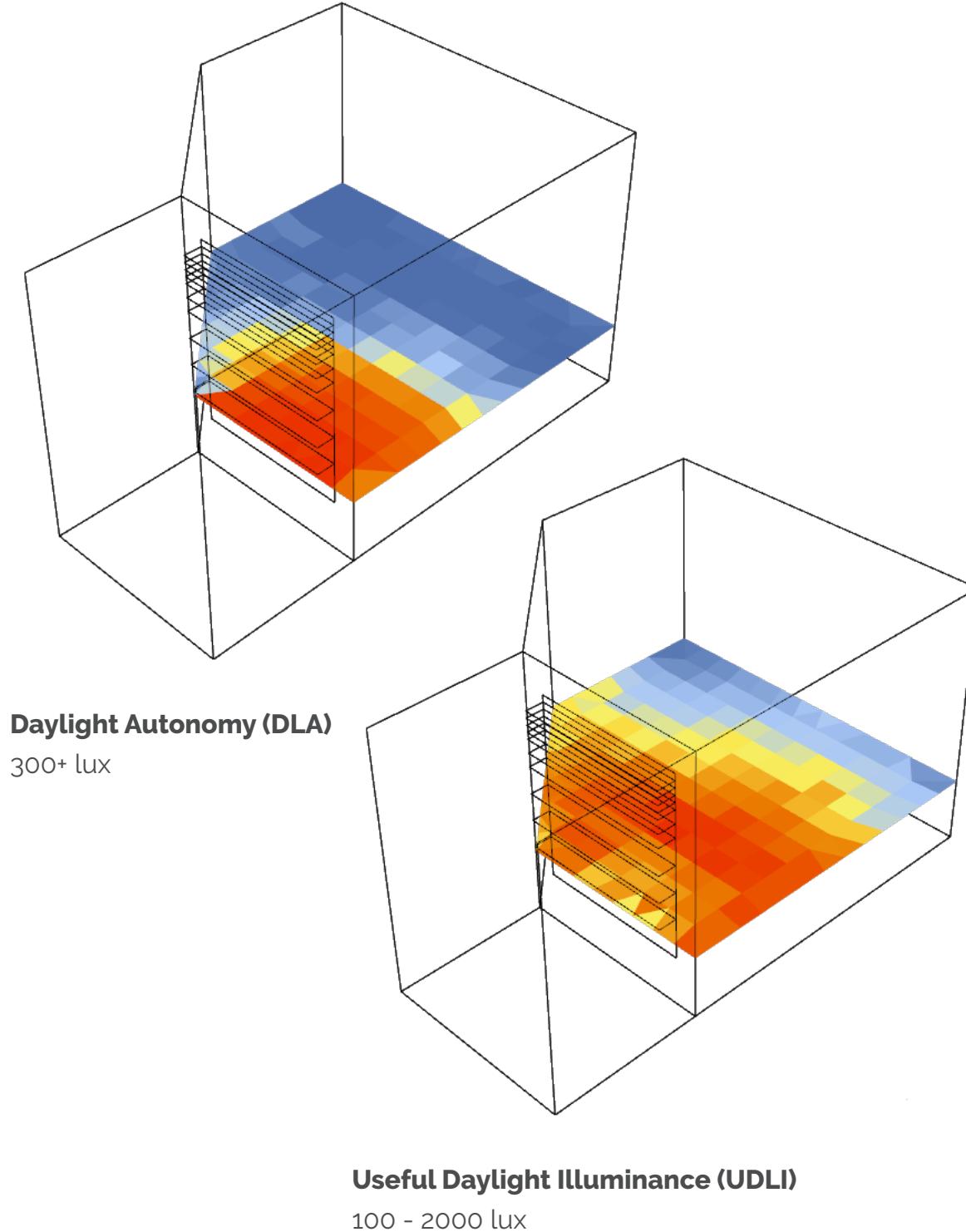


**Base Energy Balance**



# DAYLIGHTING | ITERATION 01 - 54% WINDOW + LOUVERS

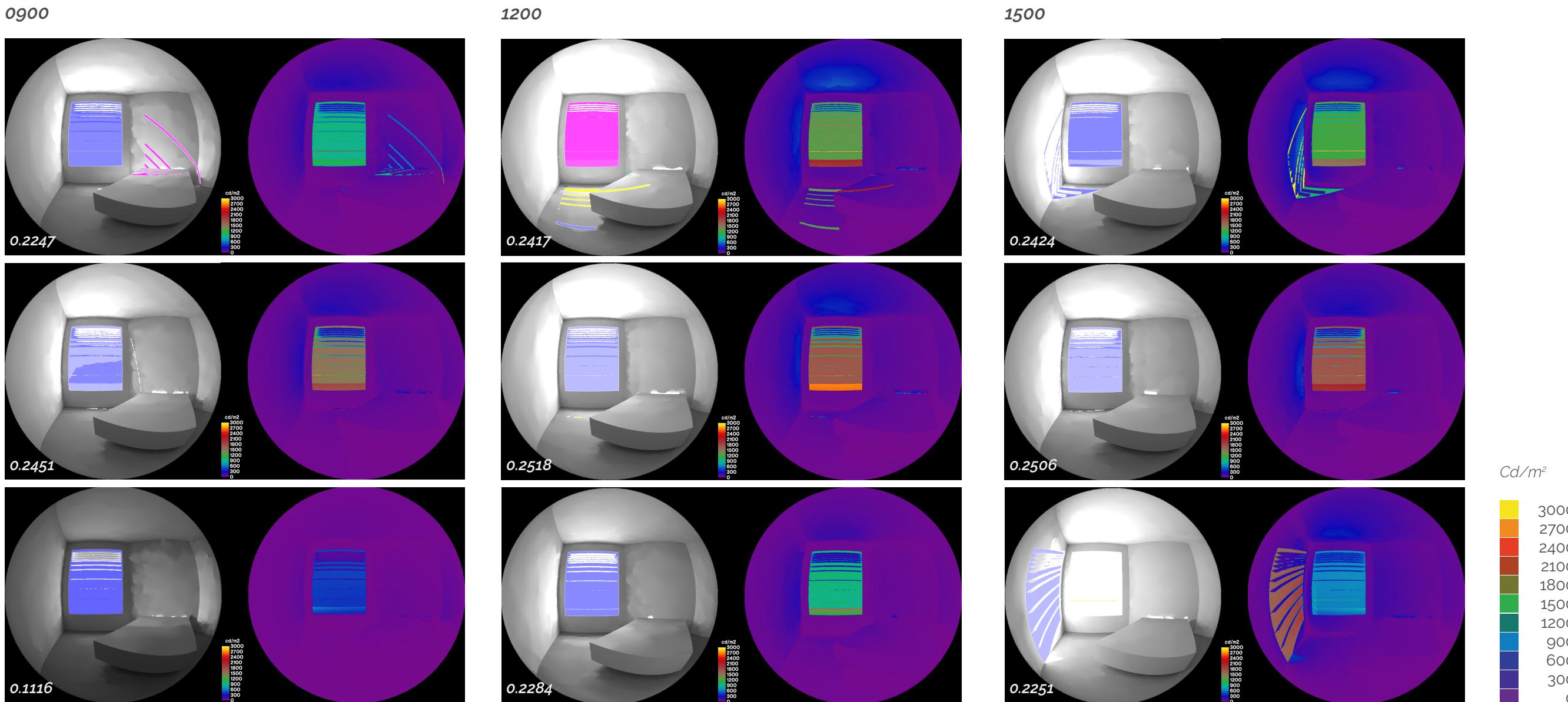
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While the winter condition could be improved, the overall room is receiving more and evenly distributed light throughout.

# GLARE | ITERATION 01 - 54% WINDOW + LOUVERS

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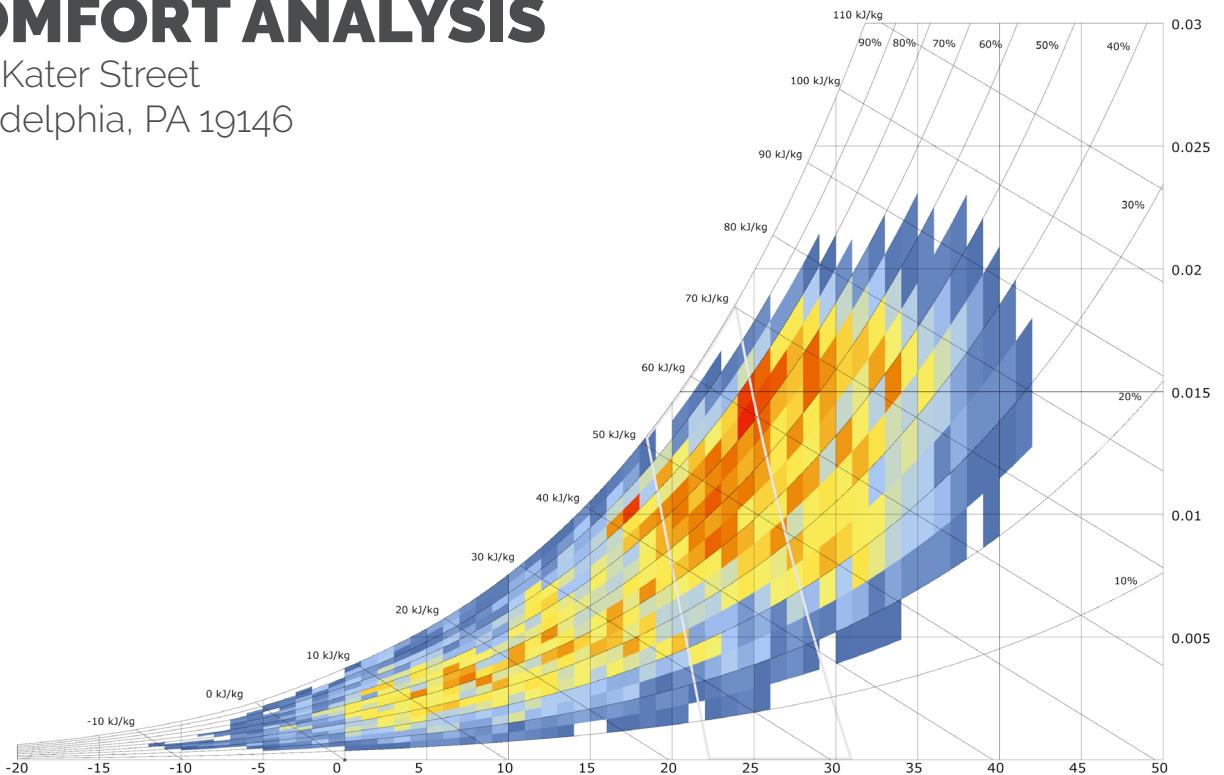


**Daylight Glare Probability (DGP)**  
*Imperceptible Glare [0.35 > DGP]*  
*Perceptible Glare [0.4 > DGP >= 0.35]*  
*Disturbing Glare [0.45 > DGP >= 0.4]*  
*Intolerable Glare [DGP >= 0.45]*

Even with an increase in window size, glare is not a problem in the room. The DGP value is well below the upper limit for Imperceptible Glare throughout the year. The dense upper louvers help reflect light to the ceiling of the room to diffuse the light condition inside. Glare is only occurring sparingly on the floor and western wall in the afternoon.

# COMFORT ANALYSIS

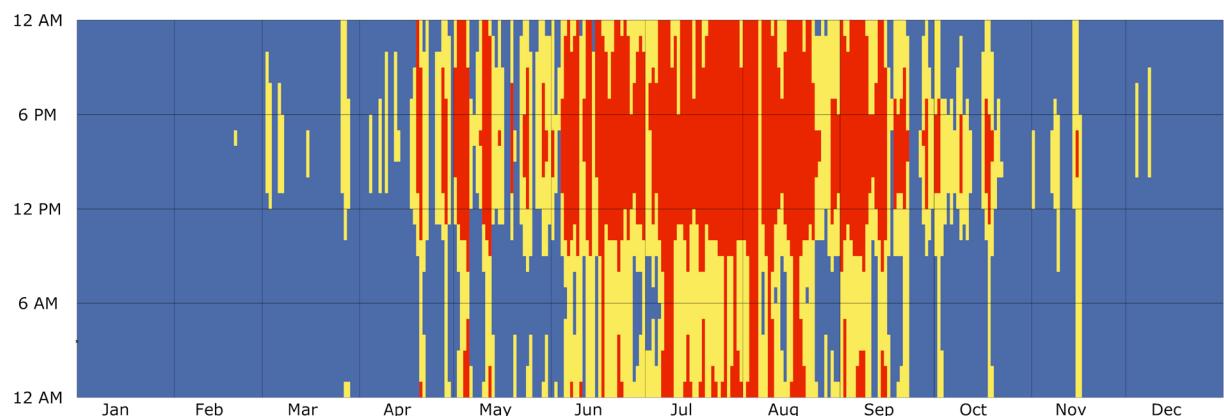
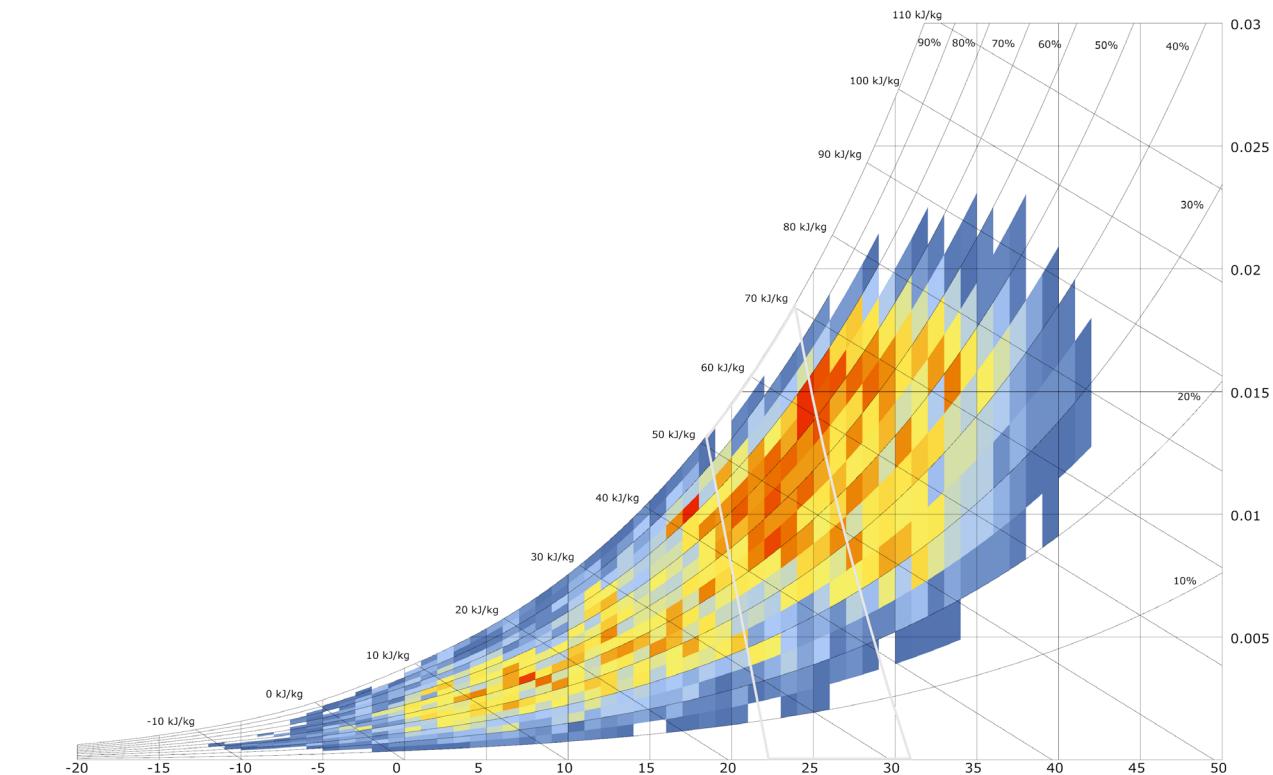
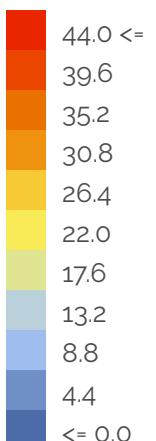
2144 Kater Street  
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## COMPARING

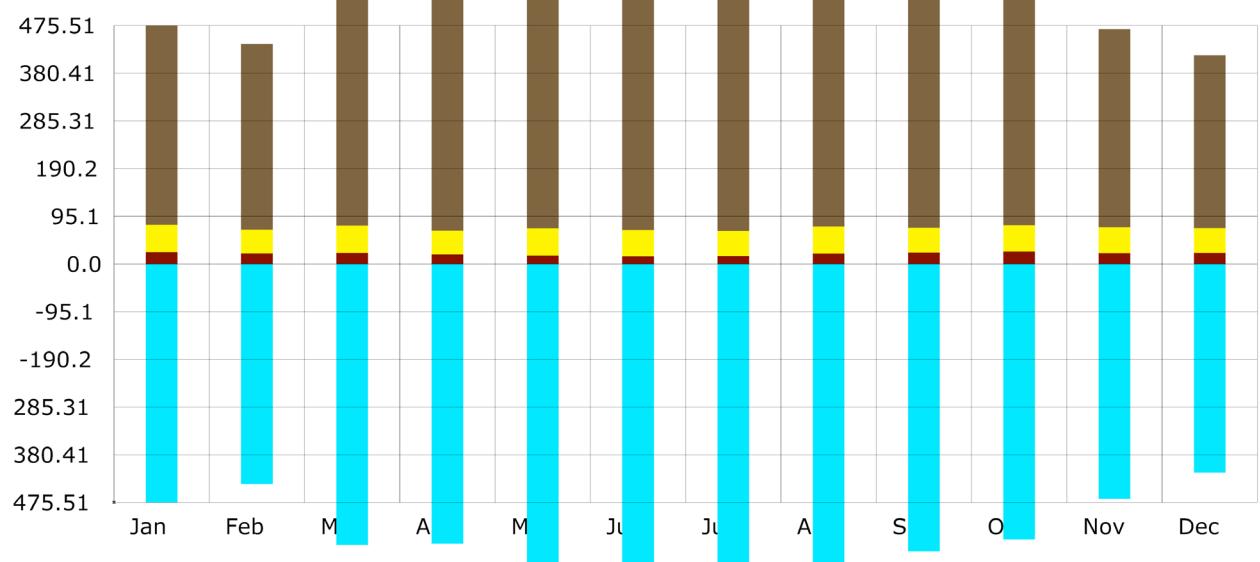
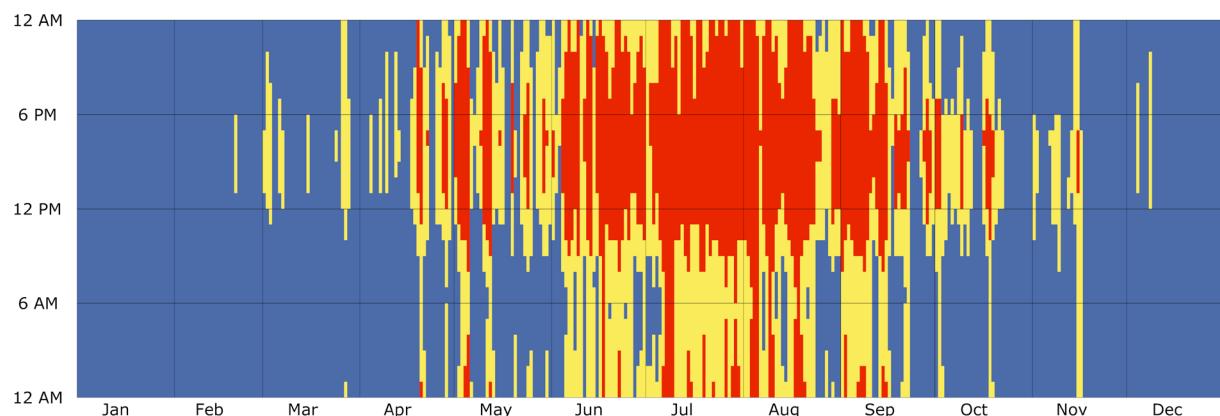
base case with context  
versus altered case with  
context

### Hours

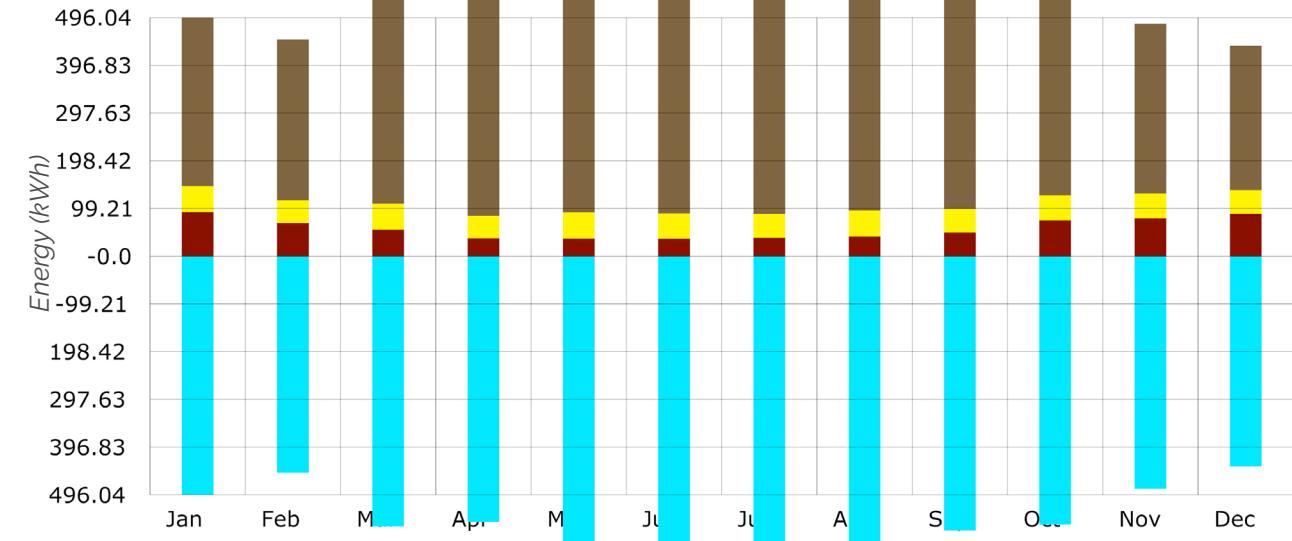


18.38% 17.79% (-0.59%)  
20.88% 21.45% (-0.57%)  
60.74% 60.76% (+0.02%)

## Adaptive Comfort



### Monthly Loads



## Base Energy Balance