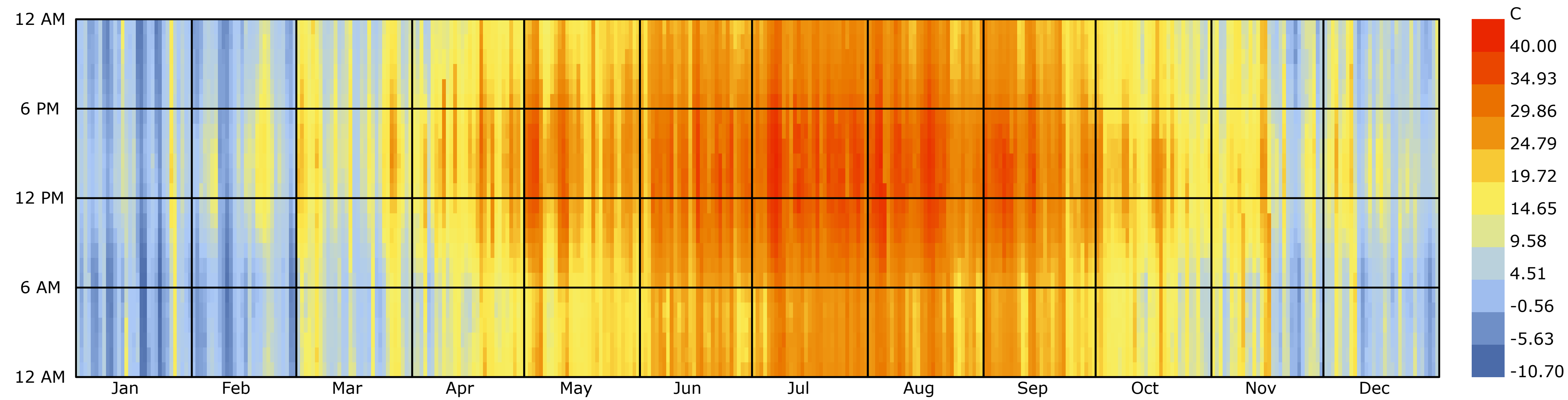
Reinventing the genius in Neutra

The space to be studied in this report is a dormitory room designed by the infamous Richard Neutra firm in 1970. The space is located in Philadelphia, Pennsylvania.

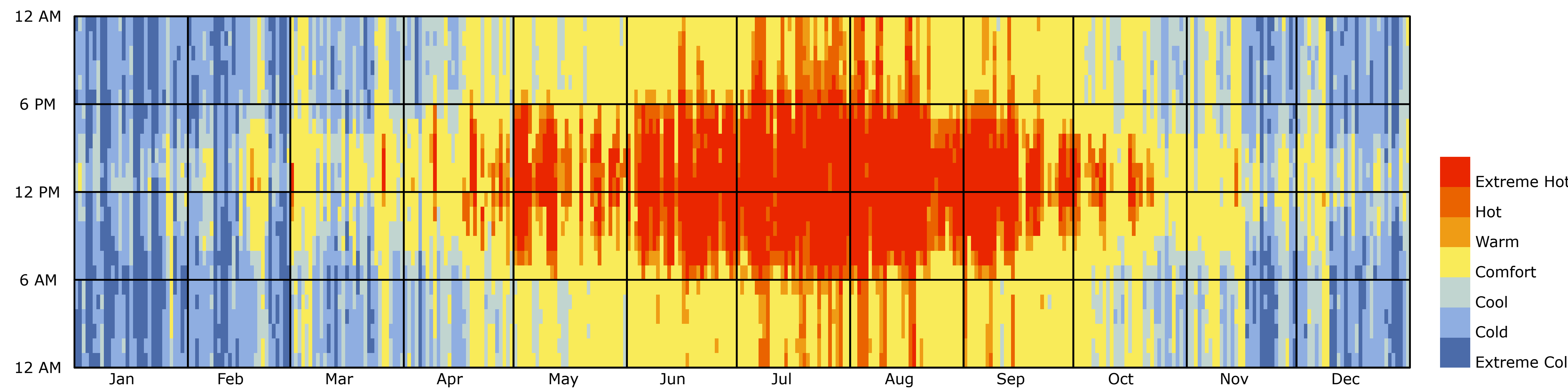
To understand the climate of this locale, a weather file from the Philadelphia International Airport has been interpreted into temperature charts and wind roses. However, one thing to note about this weather file is that it has been modified to account for the effects of climate change until the year 2050.

The dry bulb temperature chart of Philadelphia shows that the city can get fairly warm during the summer, with temperatures up to 40 degrees Celsius, while it can get quite cold in the winter, with temperatures down to -10 degrees Celsius. An outdoor comfort chart on the city demonstrates that it is comfortable outdoors mostly beginning in the second half of April, through May when it starts to be only comfortable in the early morning and evening, until October which is mild throughout, and to the first half of November. The calculation results in outdoor comfort for 36% of the year.

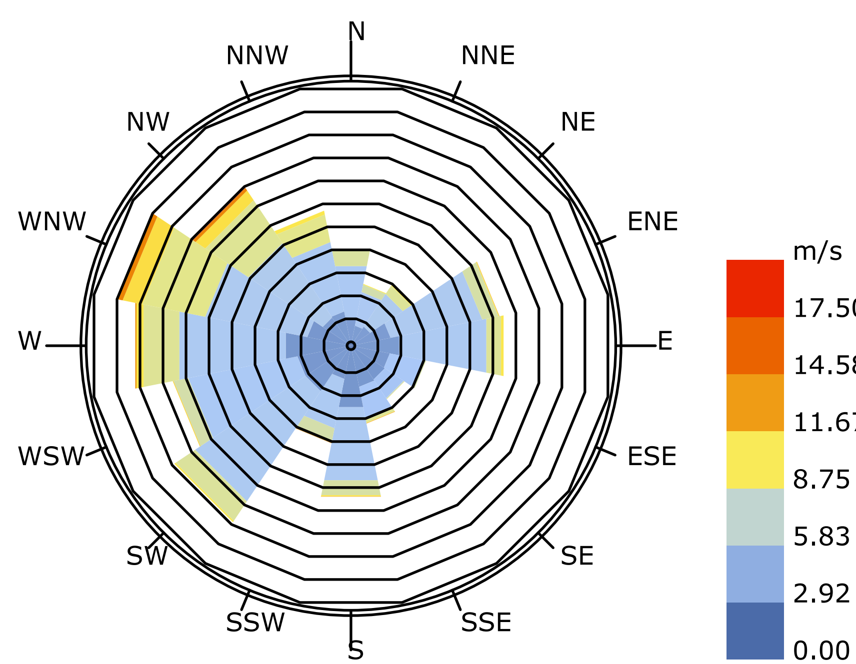
The wind roses show that wind comes predominantly from the west, with the most prominent wind coming from the west northwest direction. A considerable amount of this wind falls within the comfortable range.



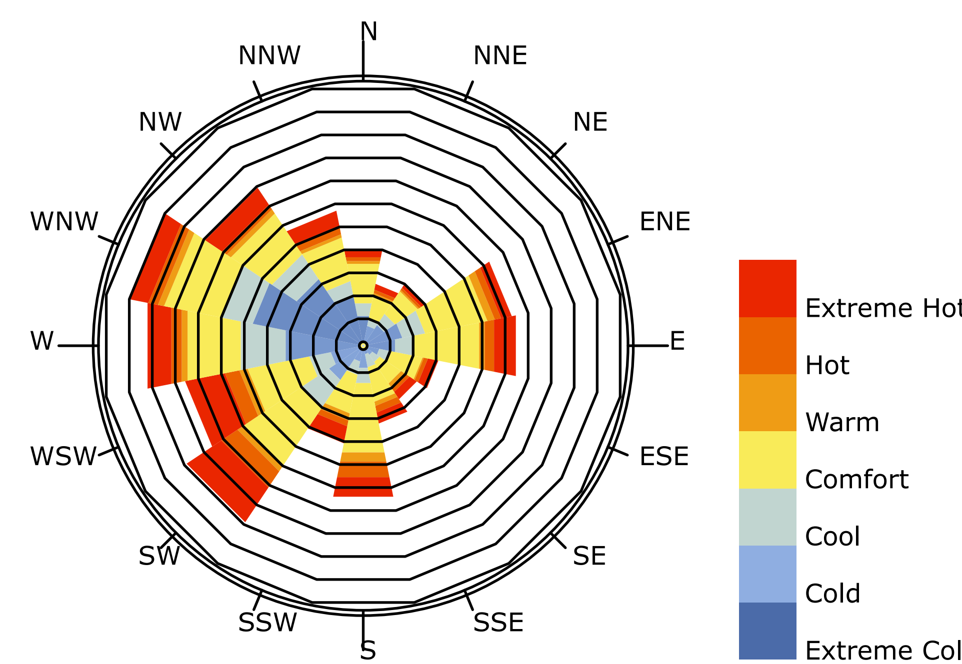
Dry Bulb Temperature (C)



Outdoor Comfort



Hourly Data: Wind Speed (m/s)



Hourly Data: Outdoor Comfort

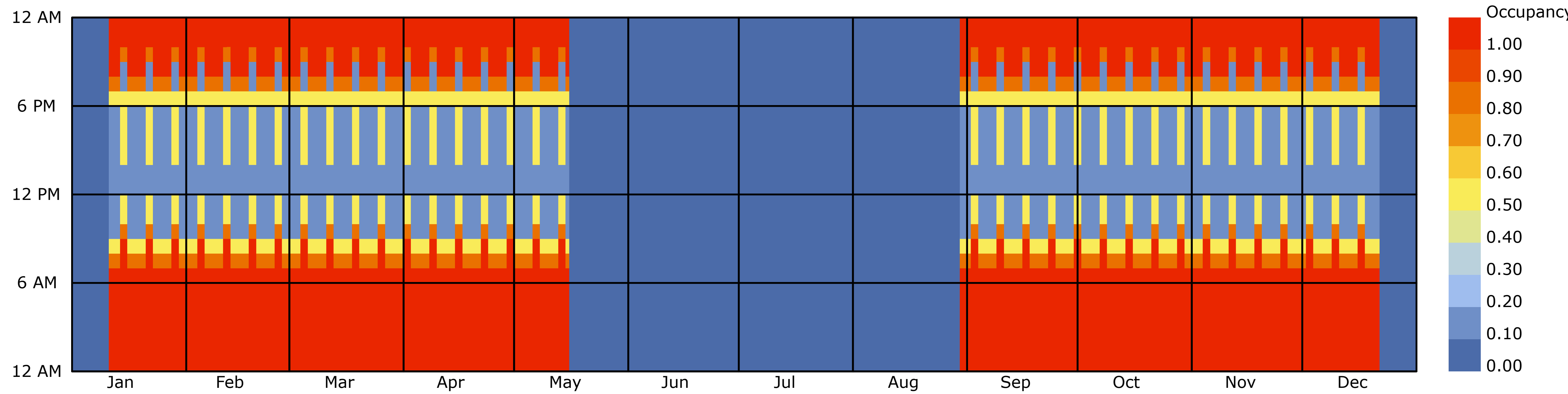
The Goal

Before beginning a base case analysis of the bioclimatic performance of this room, it is necessary to understand the goal of the study here. The goal will be defined as maximizing comfort hours for this space for the entire year.

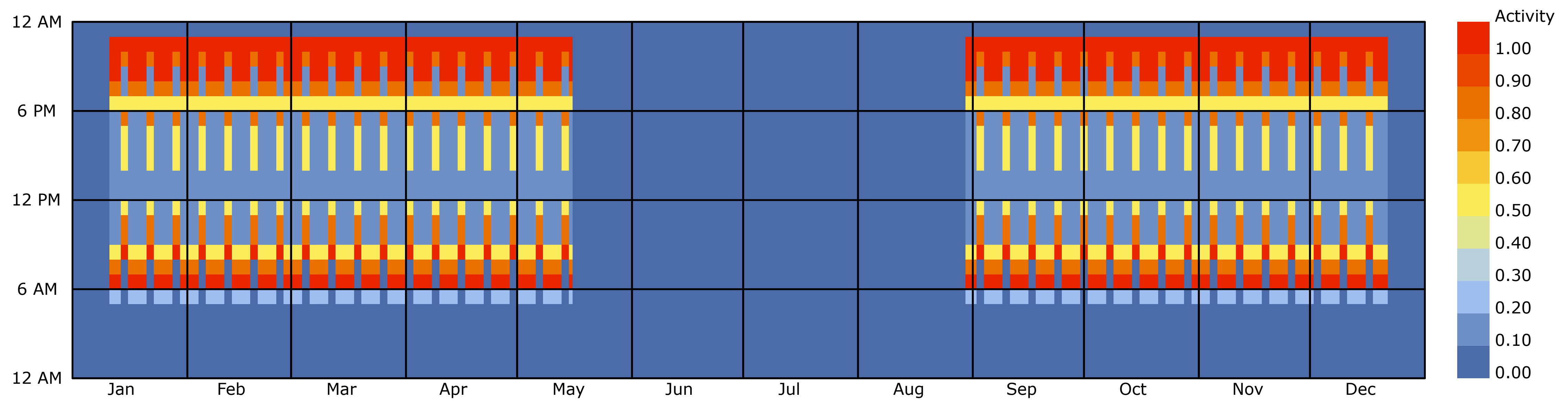
In order to do that, the space must be studied in terms of its yearly schedule. This was completed by creating an occupancy schedule. As the charts on the right show, the space is unoccupied during the summer months from mid-May to the end of August due to summer break. It is also unoccupied in the winter due to winter break. For the time during the school year, the room is generally unoccupied or occupied at a very low rate during the day, and is much more occupied in the evening and through the night. An occupancy activity schedule was also created in order to gather the lighting schedule information for the room.

This schedule has the implication that the room will be unoccupied during the hottest months of Philadelphia, and will be occupied more at a time when it is often cold. This is something to keep in mind when doing the thermal comfort analysis later.

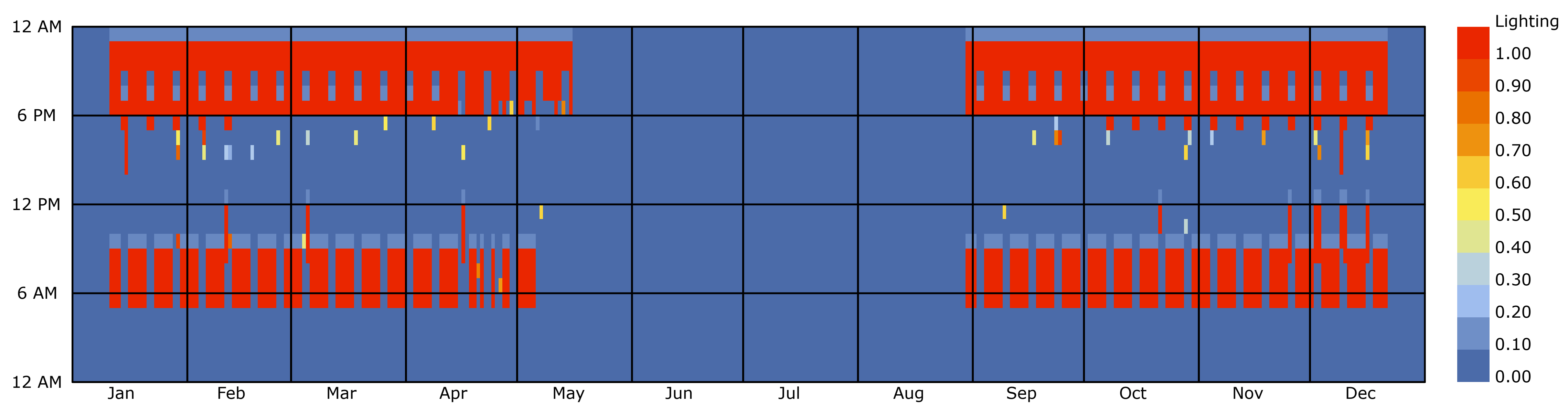
An annual daylight analysis is performed on the room using default materials. This in turn creates the annual lighting profile as shown on the bottom right.



Occupancy Schedule



Occupancy Activity Schedule



Annual Lighting Profile

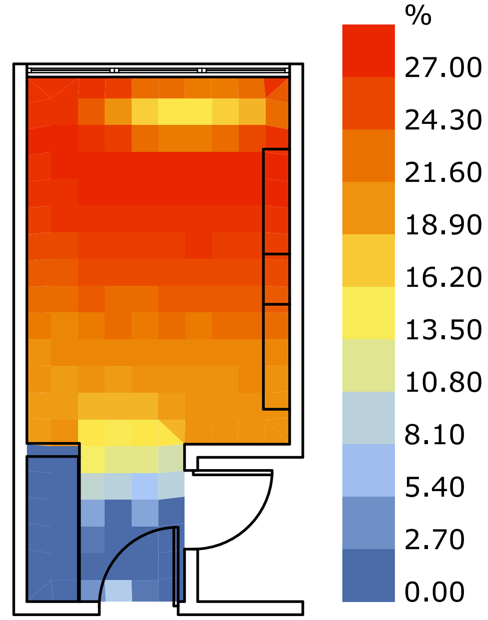
Base-case Analysis

Since the study aims to improve the performance of the room on a yearly basis, the daylight analysis will be an annual one with the metric UDI being used.

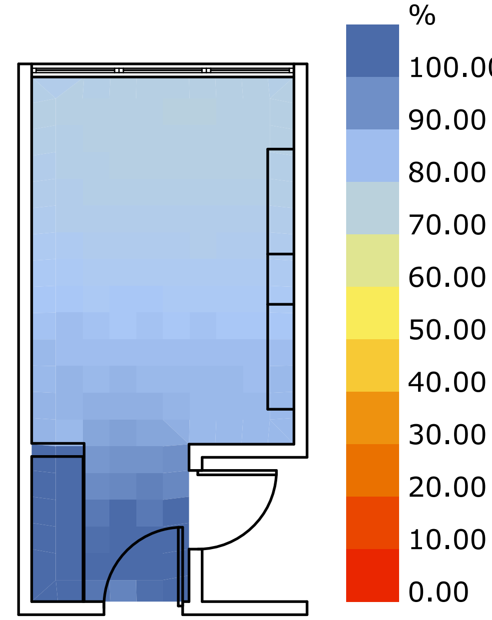
The room is north-facing with three windows on its north wall. All other walls are interior, with an entrance from the south side of the room (and a closet next to the entry door). The working desk surface is located against the middle of the east wall.

The annual daylight analysis reveals that the maximum amount of time this room receives useful daylight between 100-2000 lux is 27%. The part that receives useful daylight for this amount of time is generally the mid-northern part of the room. The working desk surface receives useful daylight for about 24.3% of the time. In order to show how dark the room generally is during the occupied time, the UDI <100 lux analysis is colored according to where the room is dark 100% of the time. This shows that even the northernmost part of the room where the window is located is dark for 70% of the time, presumably due to the occupied time being mostly at night.

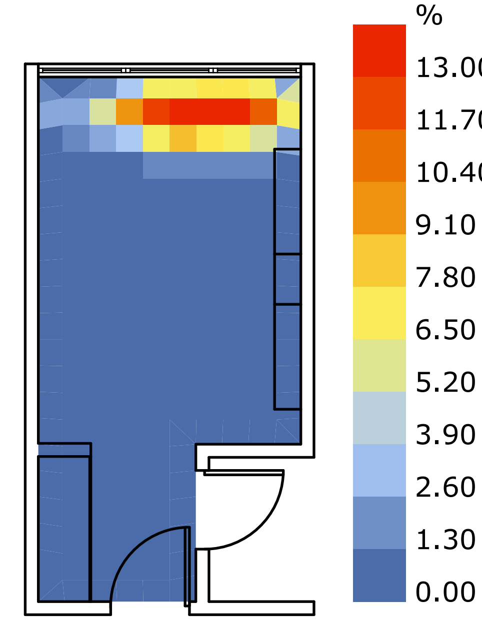
There is a region near the windows where the room receives more than 2000 lux for up to 13% of the time. In order to understand exactly how much more daylight that is, a single point-in-time analysis for June 21 at 3pm is completed, showing that illuminance level reaches about 3800 lux. This is actually still considerably acceptable illuminance levels, meaning that the over-lit part of the room may not be as problematic and it may not be a glare issue at all.



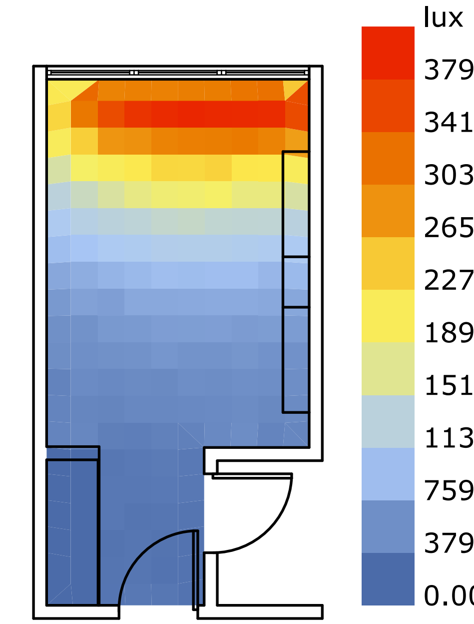
UDI 100<2000lux



UDI<100lux



UDI>2000lux

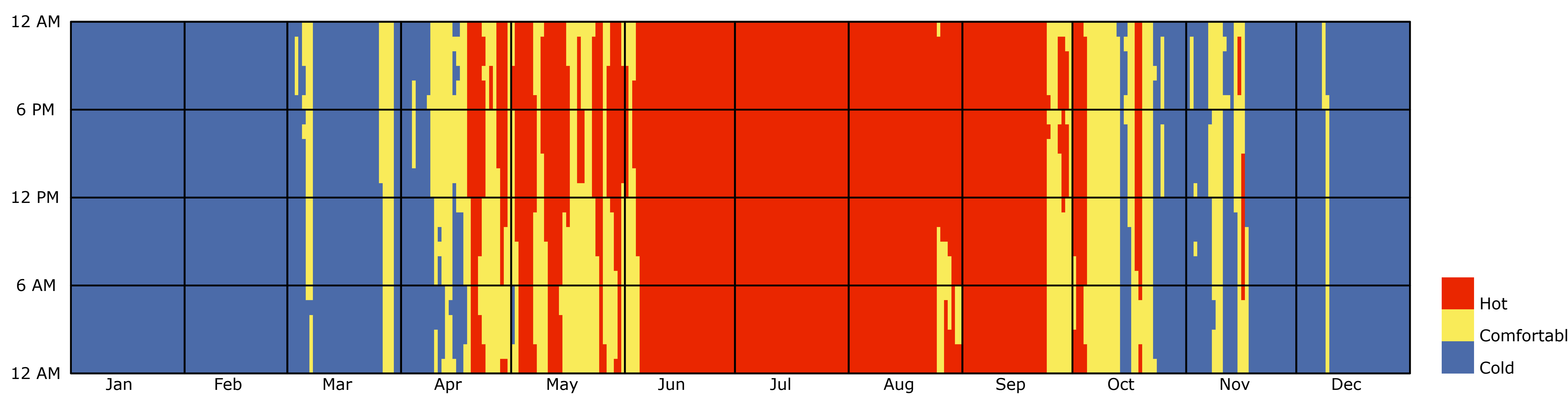


Illuminance

An energy simulation of the room is done using pre-1980 constructions to best simulate the real conditions of the room. All the interior walls and ceiling and floor are set to adiabatic. Given that the room is analyzed as an unconditioned space, the results were then interpreted using the adaptive comfort metric.

The results reveal that the room overheats quite a bit during the summer months from June to September. However, as noted before, the room is unoccupied during the majority of this time, so the heat stress may actually not be such a huge problem here. However, from the months of November until March the room becomes too cold for comfort. Overall, the room is comfortable for 17.9% of the time, with 38.5% of the time being too hot, and 43.7% of the time being too cold.

Comfort: 17.9% Hot: 38.5% Cold: 43.7%



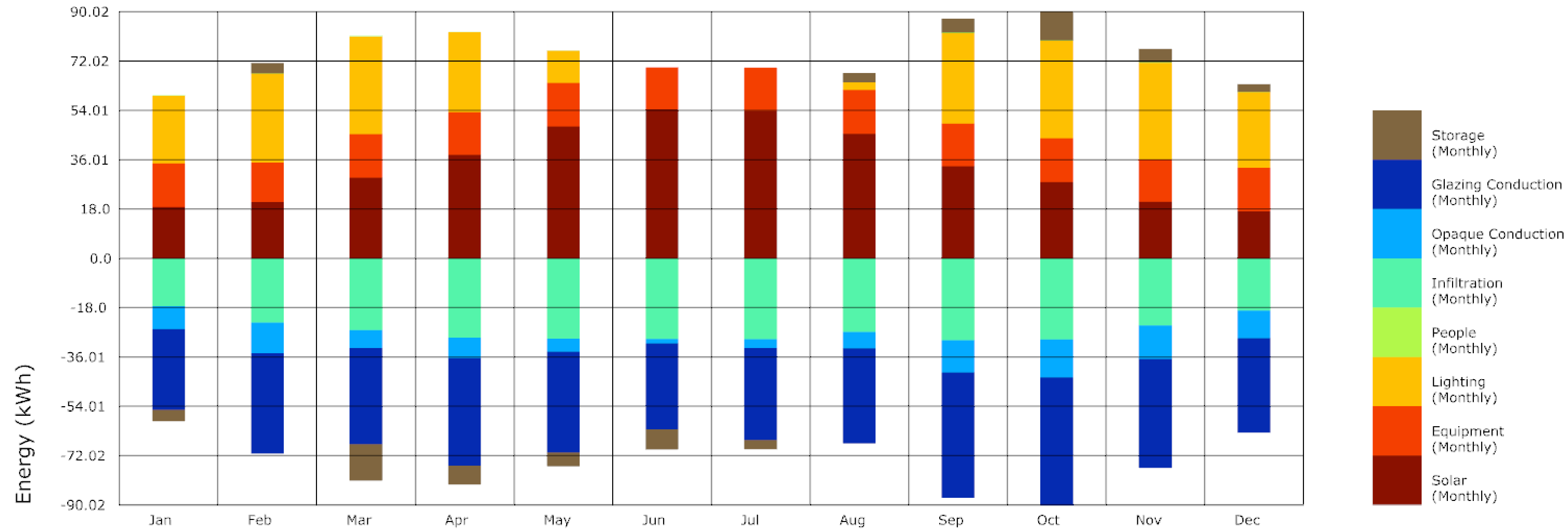
Adaptive Comfort for SANSOM_ROOM

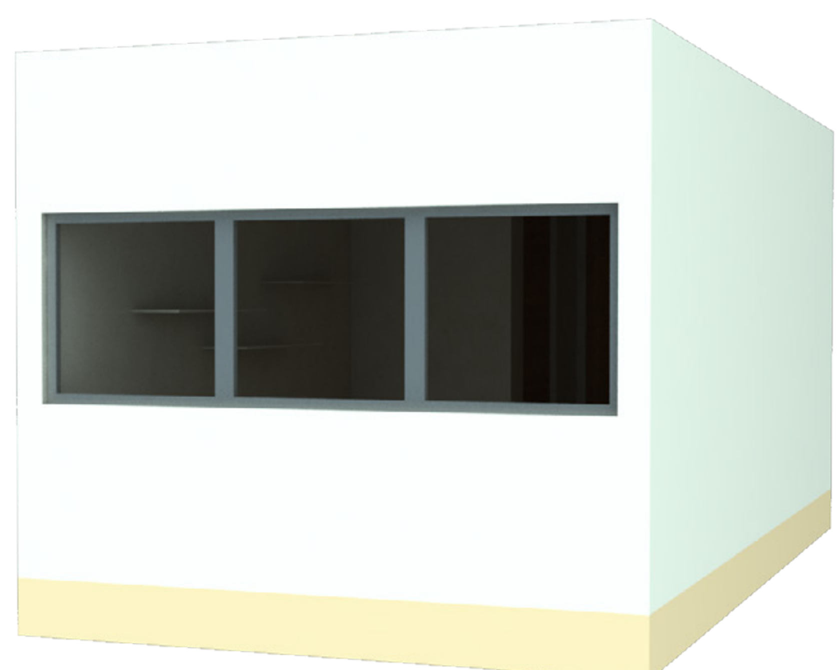
Design Focus

With an energy balance chart, it becomes possible to see the energy flows within the space. As expected, energy gain from the sun is highest during the summer months and lowest during the winter. The gains from lighting is lowest during the summer when the building is unoccupied. What this chart reveals that is interesting are the losses through the conduction of opaque walls and glazing. It becomes apparent that heat loss through the glazing and opaque walls are most problematic in the fall and winter seasons when it is also coldest at the same time.

The implication of this energy balance chart and the energy simulation above is that the design focus of this exercise should really be on the cold season when the building will be occupied the most. In other words, any design proposals should be maximizing the thermal comfort of the room against the cold weather (with the exception of September, which is hot and requires more air flow). The hot weather in the summer is far less of a concern since it won't be occupied, and so the design proposal may even increase thermal comfort against the cold at the expense of having a hotter space in the summer.

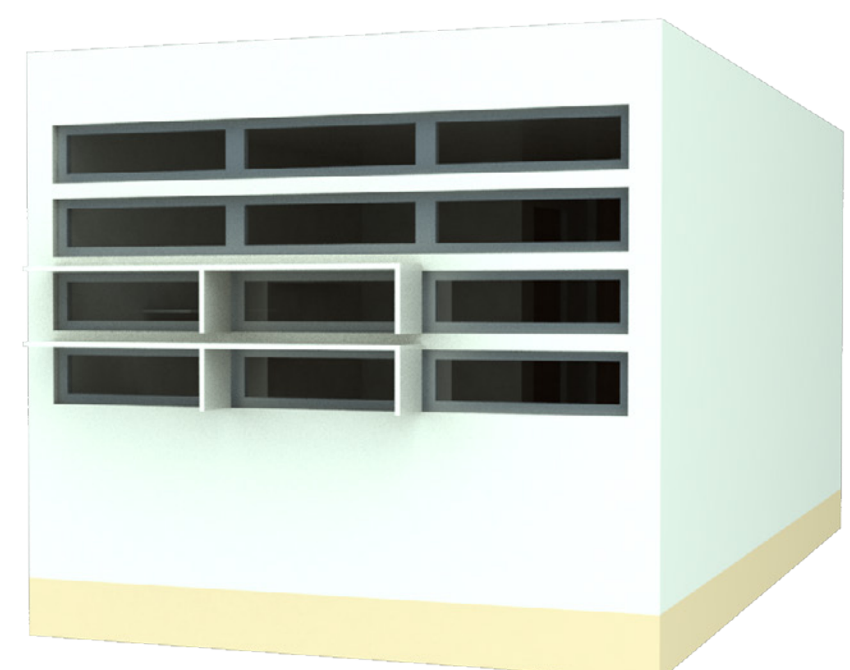
Therefore, the first strategy in a new design proposal is to increase the insulation value of the walls and glazing to protect them from heat loss during the winter. The second strategy will address the hot weather in September by introducing natural airflow (but only for hot temperatures). Finally, the third strategy will address the daylighting needs of the space without sacrificing the thermal comfort of the room.





Strategy 1: increase R-value of walls and windows by constructing custom materials in EnergyPlus

Strategy 2: enable window airflow to cool the space in September



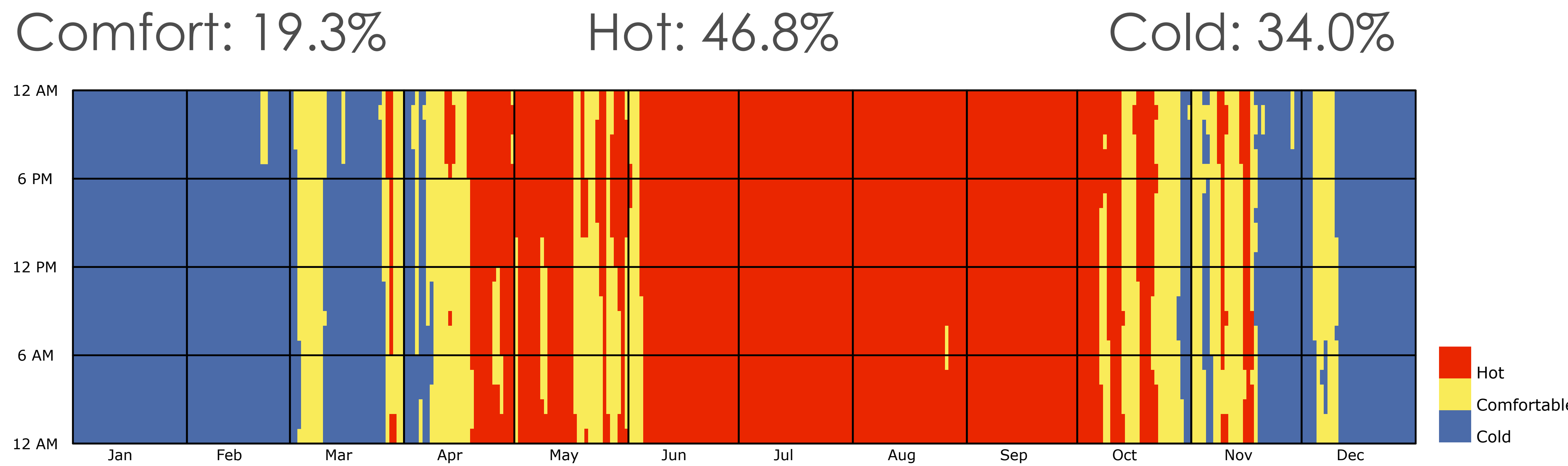
Strategy 3: increase daylight of room without sacrificing thermal comfort by increasing glazing but reducing continuous glazing exposure, and increasing material reflectance of the room. A shading device is also added to reduce over-exposure to sunlight.

Design analysis

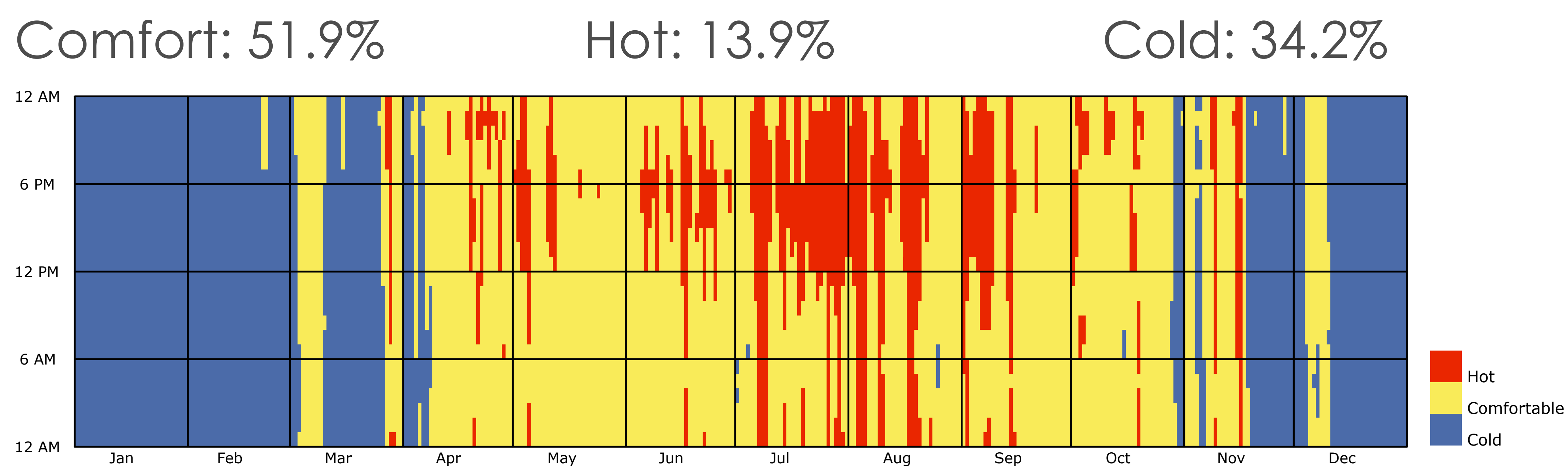
The result of the first design strategy, changing the R-value of EP constructions, is shown on the top right. The changes involved increasing the thickness of the insulation as well as lowering its conductivity (assuming there is a type of material that can achieve better resistance), and changing the window's U-value and SHGC to those of a triple-pane low-e argon-filled window assembly.

As expected, by increasing the insulation, the amount of time the space is too hot increases to nearly 47% of the time. Now all of September and even parts of April and October are too hot. However, the notable improvement is in the cold stress of the space: there is a nearly 10% drop in the amount of time the space is too cold. This is good as it is hard to improve the cold stress of a space while it is easy to relieve heat stress with added airflow.

Now the second strategy is needed to address the times when the room will be occupied and too hot, namely the days in April, May, September, and October when the space becomes hot from its internal gains and increased insulation. To do that, the space is modeled to utilize window airflow when the indoor temperatures get above 24 degrees Celsius, while outdoor temperatures range between 18 to 28 degrees Celsius. The results are shown on the bottom right. The comfort of the room dramatically improved to be above 50% of the time (even though most of that time the room will be unoccupied in the summer). Now it is apparent that April, May, September, and October become acceptably comfortable throughout the day.



Adaptive Comfort for SANSOM_ROOM - improved EP constructions



Adaptive Comfort for SANSOM_ROOM - window airflow

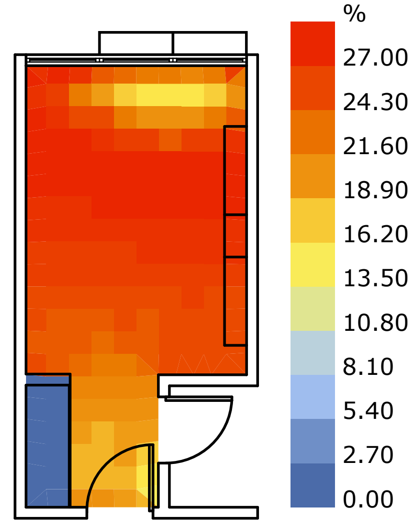
Design analysis

The third strategy involves improving the daylighting of the room without sacrificing the thermal comfort of the room. In order to increase daylighting but minimize glazing exposure, the windows were shrunk and distributed across the top half of the exterior wall. Material reflectance in the room were also increased to 80% for walls, 70% for the ceiling and 50% for the floor.

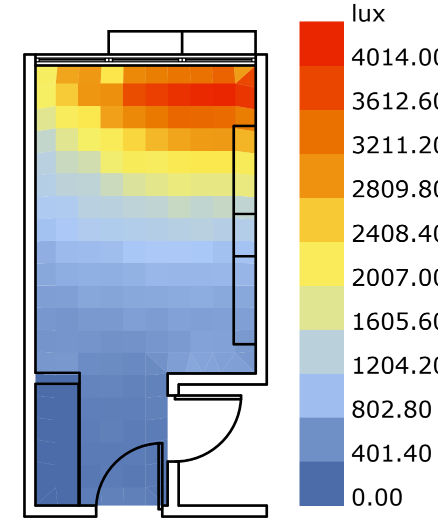
The result of the daylight analysis shows that while the maximum amount of time the rooms receives useful daylight remains the same at 27%, the daylight penetration is deeper into the southern end of the room. Now the main portion of the room excluding the door canal receives useful daylight for at least 24.3% of the time, as compared to the 18.9% of the base case.

The first daylight analysis was done without the shading device, and it reveals that there remains a bright spot under the windows. Once again to understand how much brighter that exactly is, a point-in-time illuminance analysis was done, and it reveals that the bright spot receives about 4000 lux on June 21 at 3pm. This is, again, considerably acceptable levels of sunlight, but for the sake of maximization a daylight simulation was also performed with the shading device. The middle right diagrams show the result of the shading device: the bright spot is eliminated, and now the majority of the room receives useful daylight for at least 24.3% of the time.

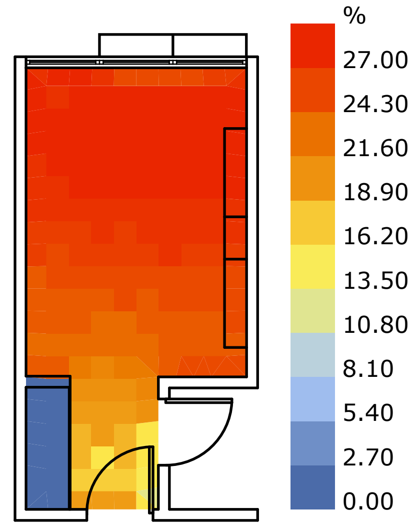
The thermal comfort of this increased glazing design is actually slightly higher than the design with original glazing. However, the cold stress increased by a little bit due to the increased glazing area through which heat loss occurs, as well as perhaps a little too much airflow during comfortable times in August and October.



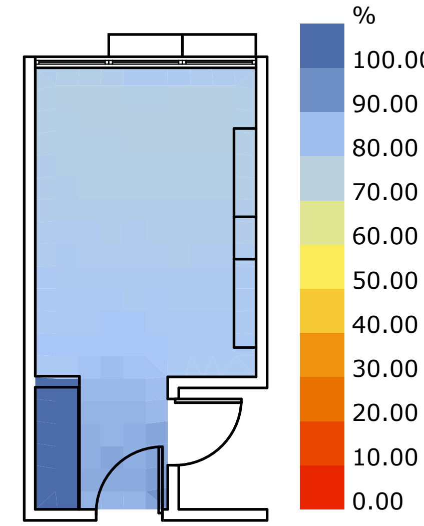
UDI 100<2000lux
Increased glazing, material reflectance
No shading



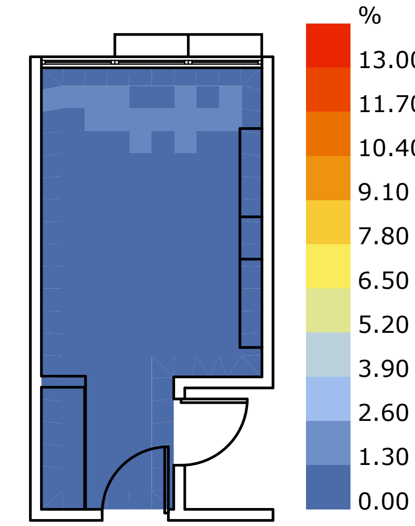
Illuminance



UDI 100<2000lux
Increased glazing, material reflectance
With shading

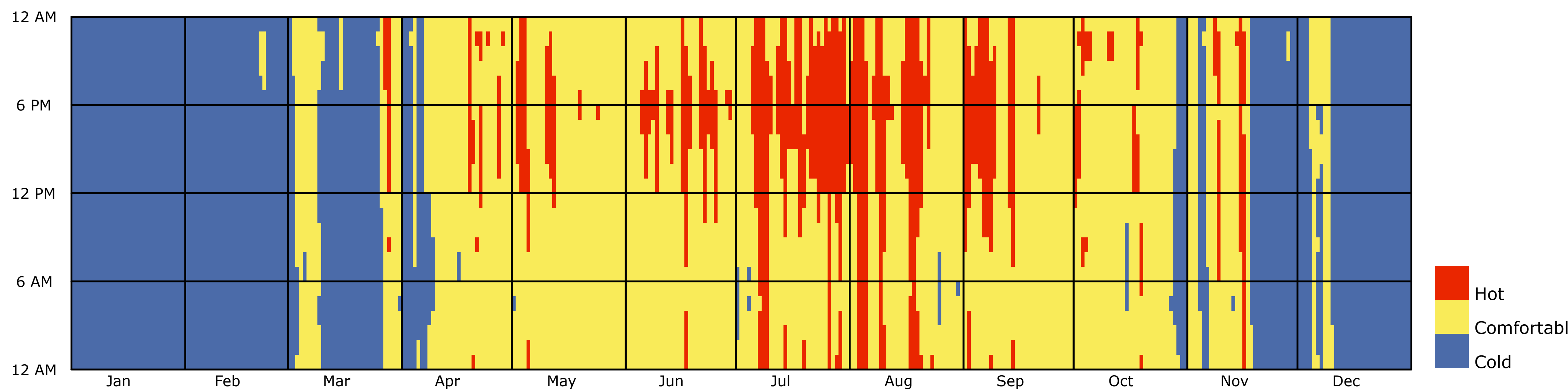


UDI<100lux



UDI>2000lux

Comfort: 52.4% Hot: 12.0% Cold: 35.6%



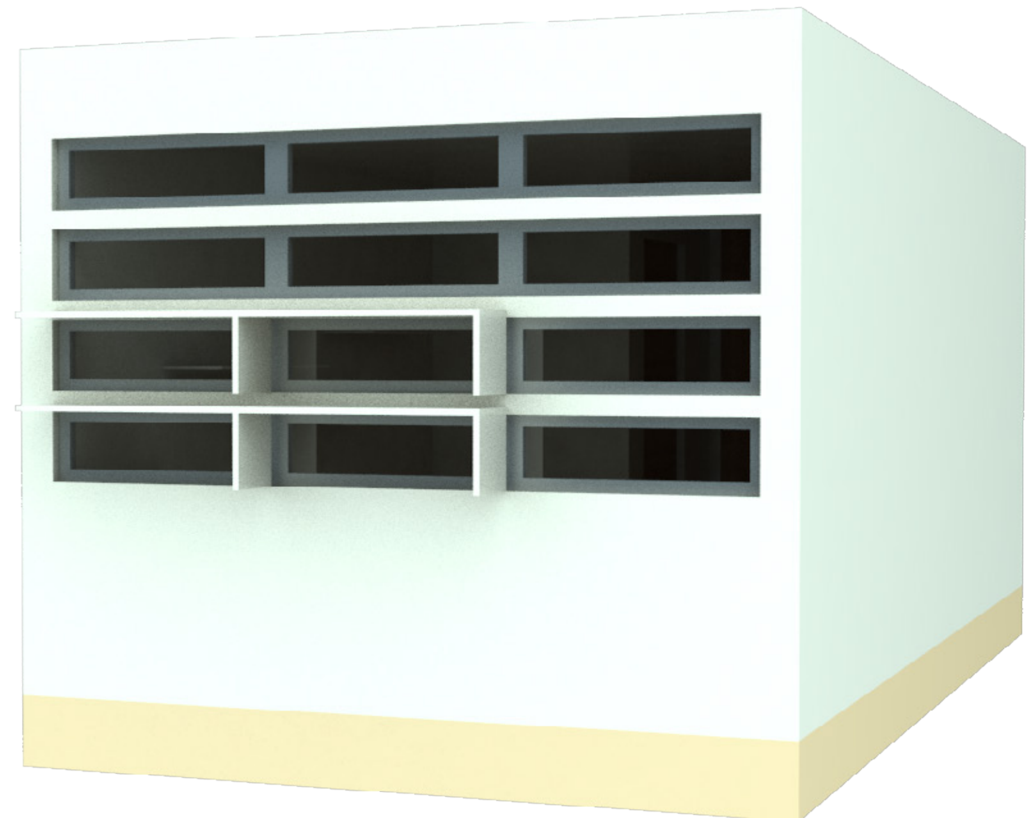
Adaptive Comfort for SANSOM_ROOM - increased daylighting

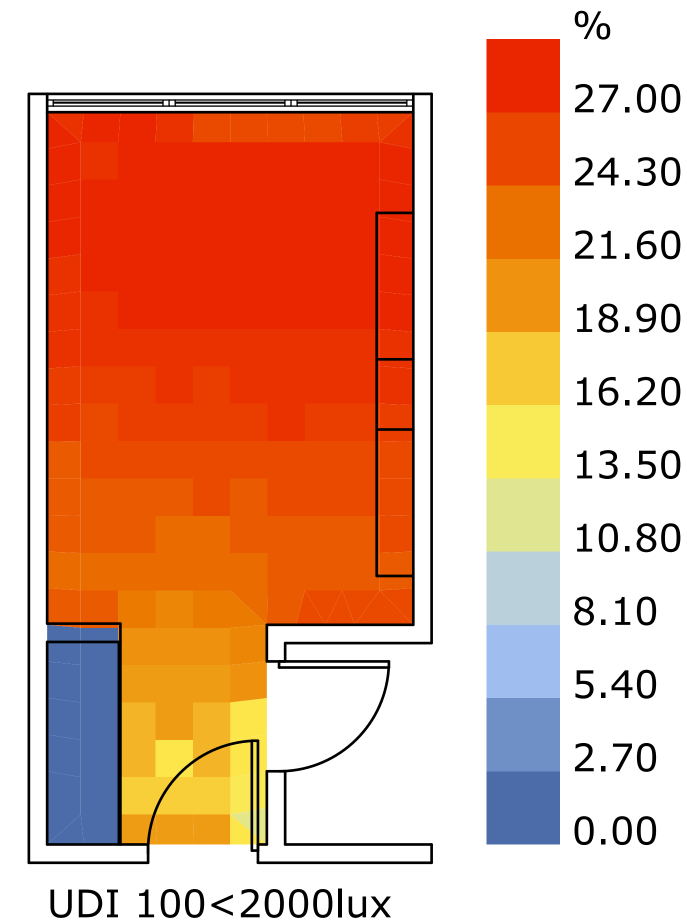
Conclusions

The ultimate finding of this exercise is that the reinvention of this space into an ideally comfortable space has failed. This is largely because unlike with heat stress which can be dealt with by introducing window airflow, it is very difficult to improve the cold stress of the space - because there are very few options other than increasing the insulation value of walls and windows, the amount of time the building is too cold dropped by only 8%. This is not enough considering the amount of time the occupant will spend in this room in the winter. This goes to show how important it is for a building in Philadelphia's cold climate to be well-insulated against heat loss.

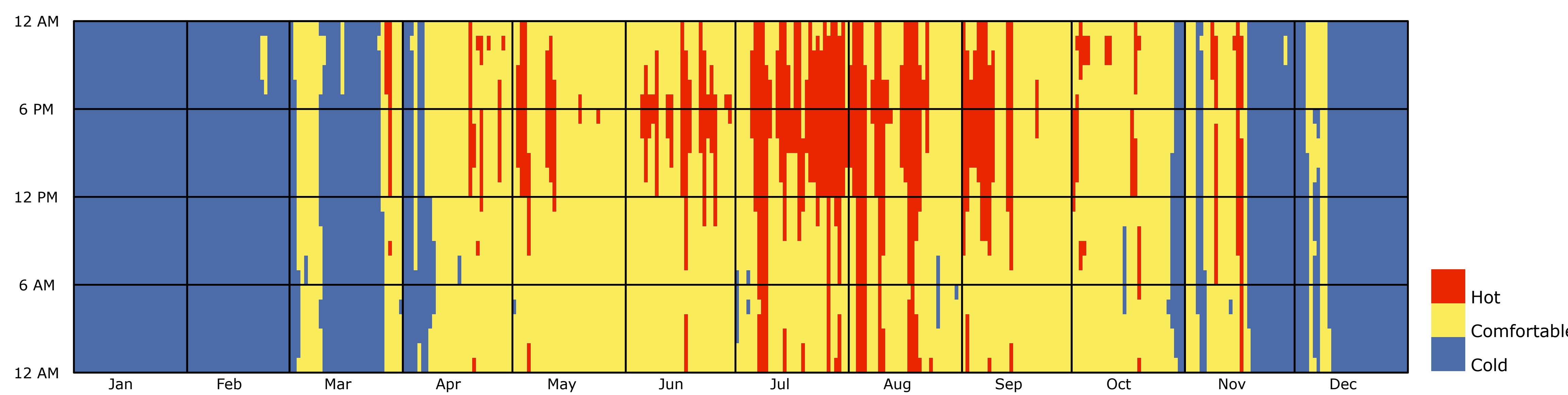
It is possible to achieve comfort for the room for over 50% of the time throughout a year, but some of this improvement may not occur or have meaning at all because it is during a time when the room is unoccupied. What was successfully achieved, however, was comfort for months during the swing seasons - namely in April, September, and October. There is a small amount of heat stress remaining in July and August, mostly because the hot outdoor temperature makes it impractical to use airflow to cool down the space, and the air temperature both indoor and outdoor simply gets too high to have anything be done about it.

In terms of daylighting, the amount of time the room receives useful daylight maximizes at 27%. This low number is due to the fact that the room is most actively occupied during the late afternoon and at night, when the sun is down. Additionally, the fact that the room is north-facing means that it almost never receives direct sunlight, which likely also contributes to the poor thermal performance of the room during the winter.





Comfort: 52.4% Hot: 12.0% Cold: 35.6%



Adaptive Comfort for SANSOM_ROOM - final design