Room Study

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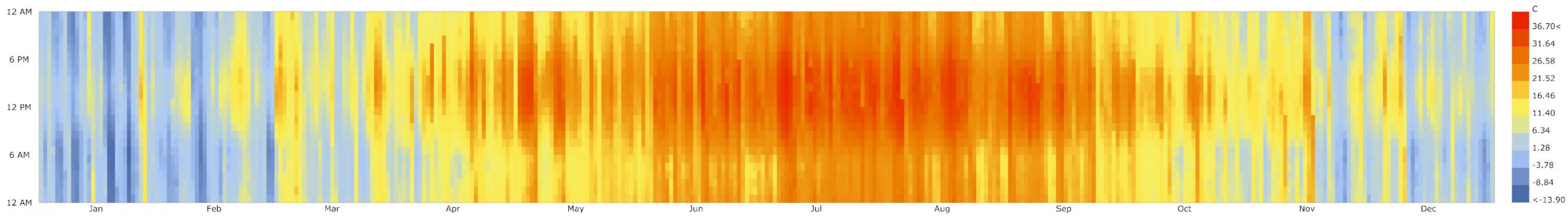
Contents

Weather

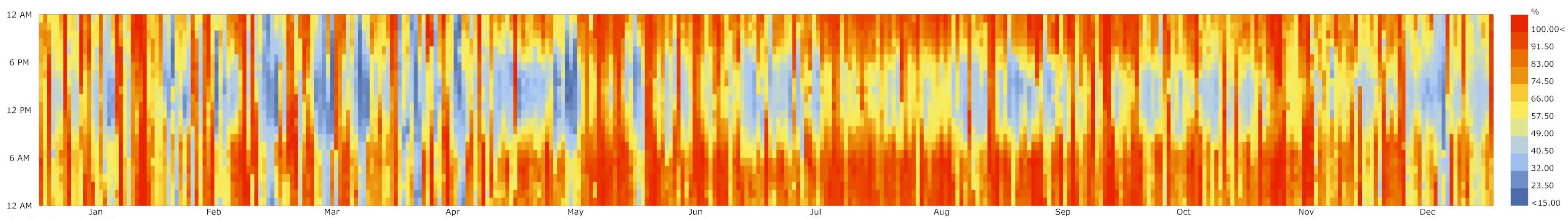
Located around the middle of the eastern seaboard of the US, Philadelphia has a highly variable environment. The graphs below and on the following page help paint a picture of this environment and the difficulties it poses for designing comfortable spaces.

The first graph below depicts the dry bulb temperatures throughout the year. As can be seen, the summer in Philadelphia reaches high temperatures which are very uncomfortable and temperatures in the winter which not terrible, are not suited for proper human living. Further by looking at this with the graph below showing the relative humidity, it become apparent as to why Philadelphia can be so uncomfortable. The large amount of humidity in the summer amplifies the heat already present make it even more uncomfortable. Additionally, the presence of some humidity in the winter also exacerbates the feeling of cold.

With the knowledge of these two pieces alone points to the importance of reducing additionally heating in the summer while increasing any possible heat intake in the summer. The impacts of temp and humidity can be seen in the UTCI graph on the next page as well.

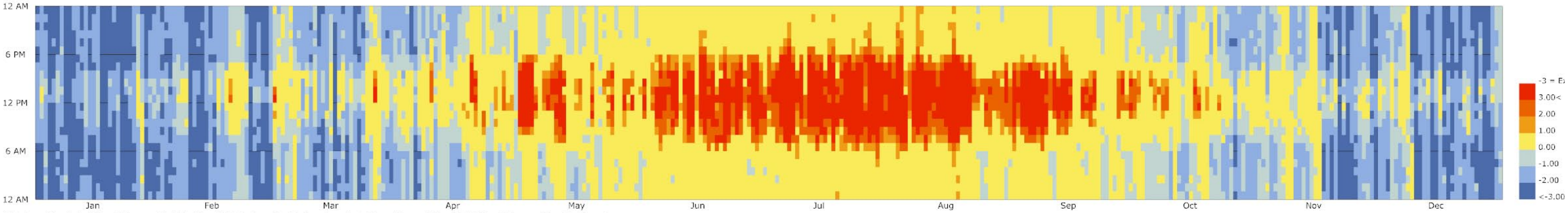


Dry Bulb Temperature (C) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

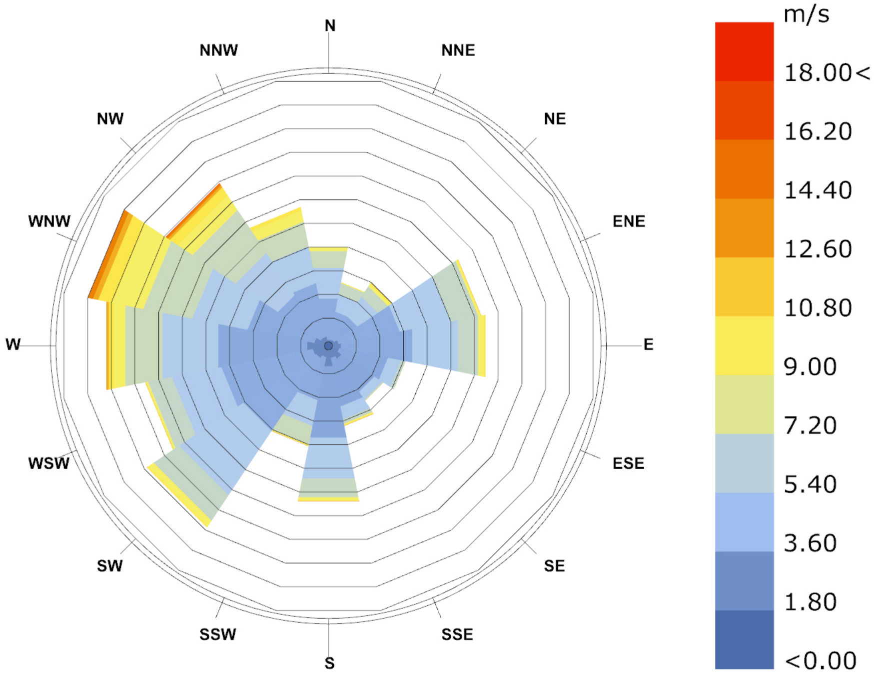


Relative Humidity (%) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00

Weather



Outdoor Comfort (-3 = Extreme Cold | -2 = Cold | -1 = Cool | 0 = Comfort | 1 = Warm | 2 = Hot | 3 = Extreme Heat) - Hourly
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



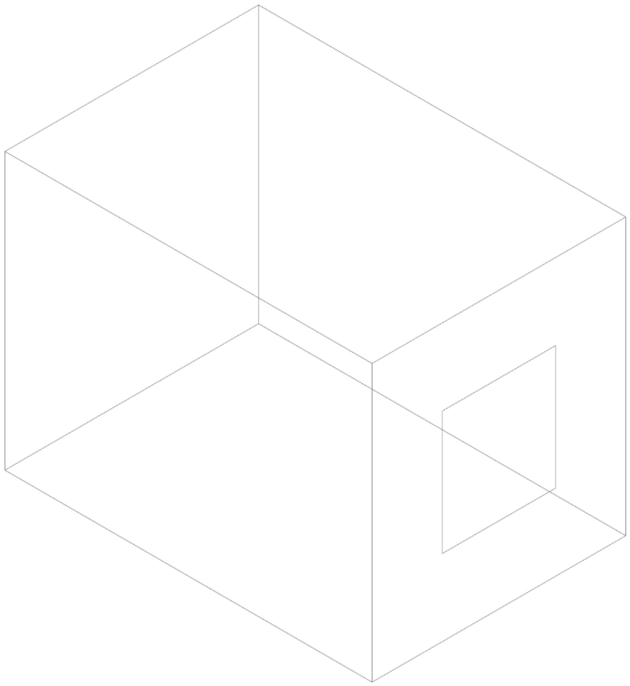
Wind-Rose
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.81% of the time = 246 hours.
Each closed polyline shows frequency of 1.0%. = 90 hours.

As can be seen to the left, Philadelphia also has a good deal of wind. With both the fastest and most insistent winds coming from WNW, this plays less of a role in the room which will be analyzed further in this report. However, these speeds, especially as they occur in winter can cause further discomfort.

All of these readings along with the impact of the sun can be seen in the UTCI chart above. This chart measures the levels of comfort for a person outside. With the heat in the summer and the cold in the winter, much of the year is uncomfortable. As a total, the climate is only comfortable for 37% of the year with the rest falling under either cold or heat stress.

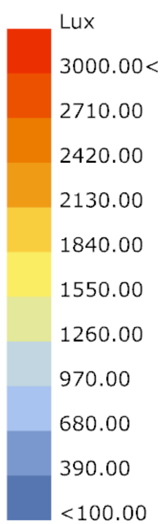
Overall, Philadelphia provides challenges that would not be seen in a more constant climate. The room which will be analyzed needs to be protected from the sun and heat in the summer while using it in the winter. Further these needs must be accompanied with comfortable daylighting. These aspects together should provide a space which needs less energy.

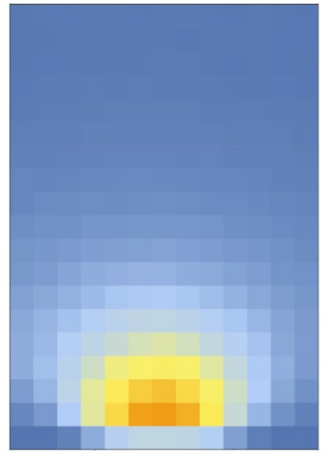
Base Room

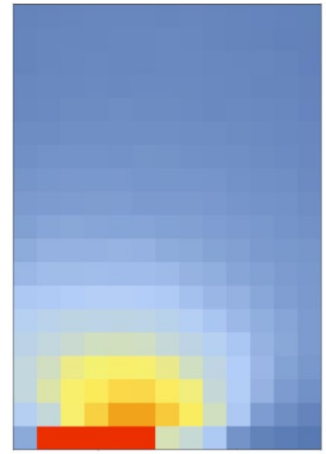


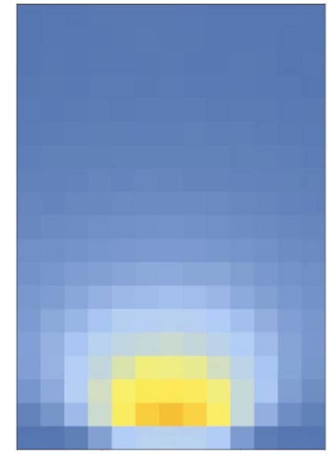
The room depicted above is a small room on the second floor of an apartment building in Philadelphia. This bedroom is south facing with a relatively large window. Built in the early 1900s, this building has not seen a great deal of renovations apart from the cosmetic. Without the data which is provided here and the following pages, the room is highly susceptible to exterior conditions. This is largely due to the window, its age and lack of proper seal. However, as it is part of a larger building, exterior conditions only effect the south wall which is, therefore, what this report will focus on.

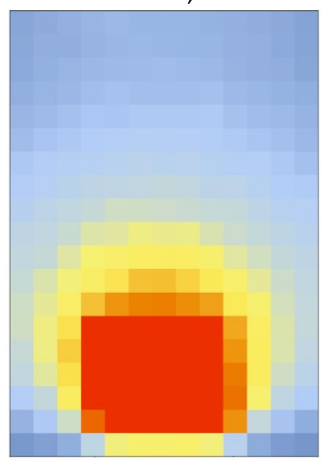
To the right can be seen a daylight analysis. As the room is deep and narrow but does have a large window, there is excessive daylighting near the wall and little to none deeper into the room.

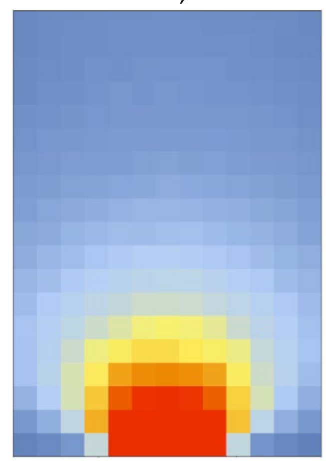



March 21, 9AM


June 21, 9AM


December 21, 9AM


March 21, 12PM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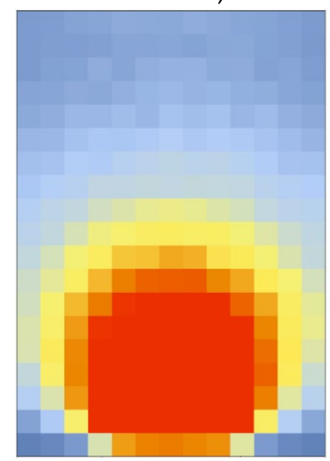
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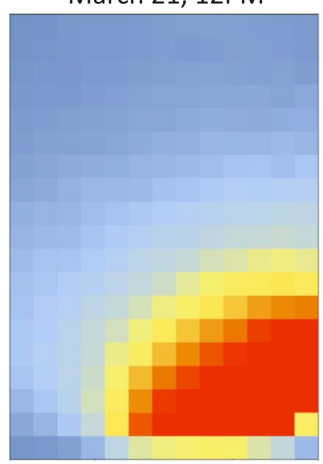
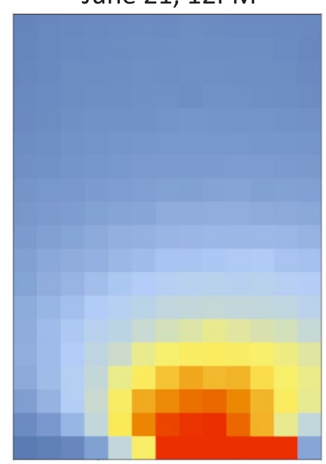
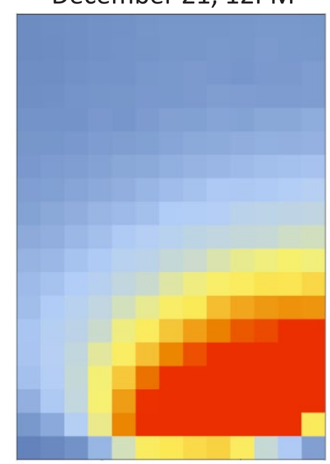

March 21, 3PM

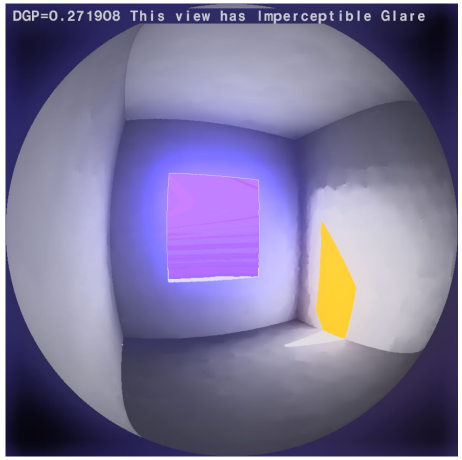

June 21, 3PM


December 21, 3PM

Base Room

Perhaps surprising, only one of the tested times appears to result in uncomfortable glare. Noon of December 21st seems to be the harmful period of time. This makes sense as the sun is low enough to reach well into the space. However, this does not seem to be a large issue as the space is currently a bedroom and not used during the day. Still, it is important, where possible, to make space as flexible as possible.

On the following page, the energy balance and adaptive comfort can be seen. The energy need for this room is not super high. At a total of 852kWh (52 kWh/ m^2) the energy use for this rooms is not terrible, however there is clear room for improvement. In particular, the need for cooling seem very high. This can and will be dealt with in the following report.



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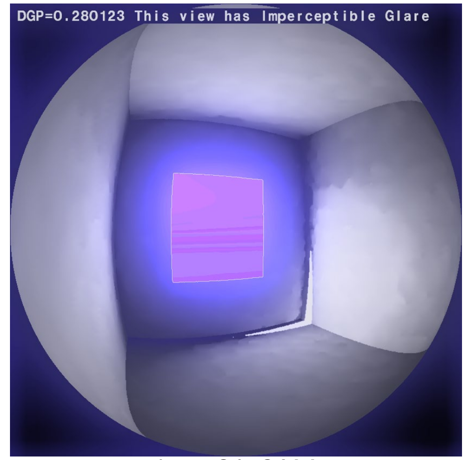

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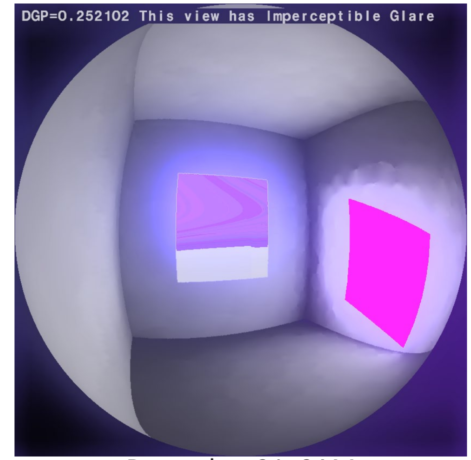
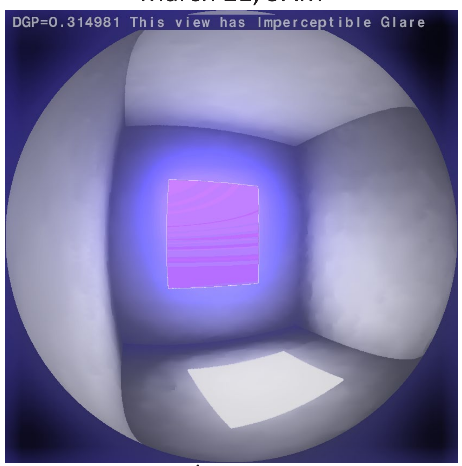


December 21, 9AM



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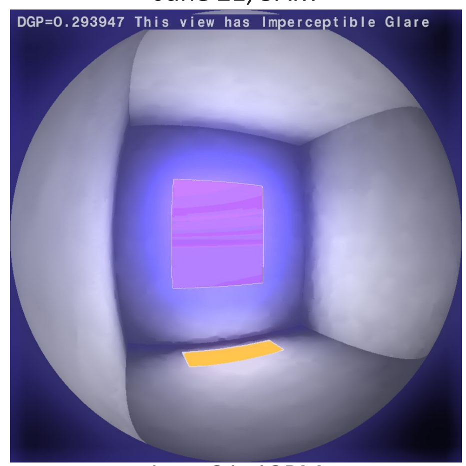

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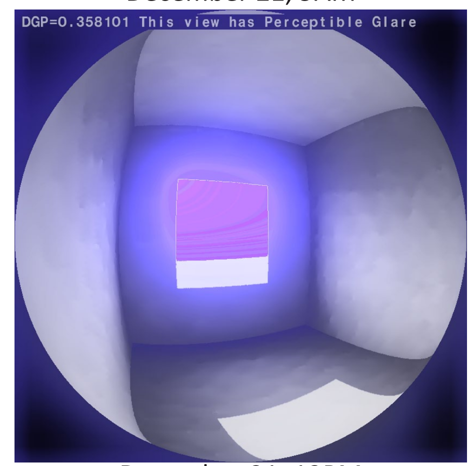
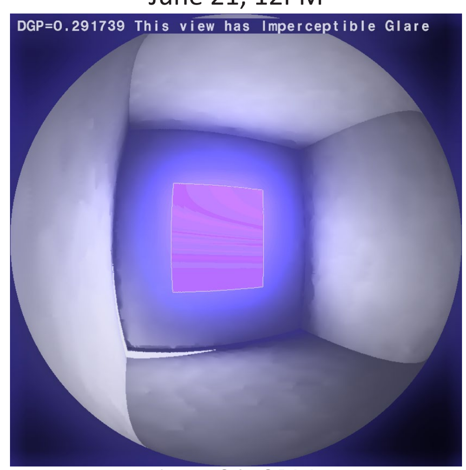


December 21, 12PM

March 21, 3PM



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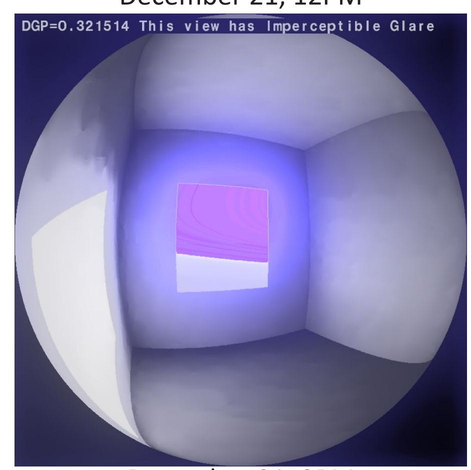
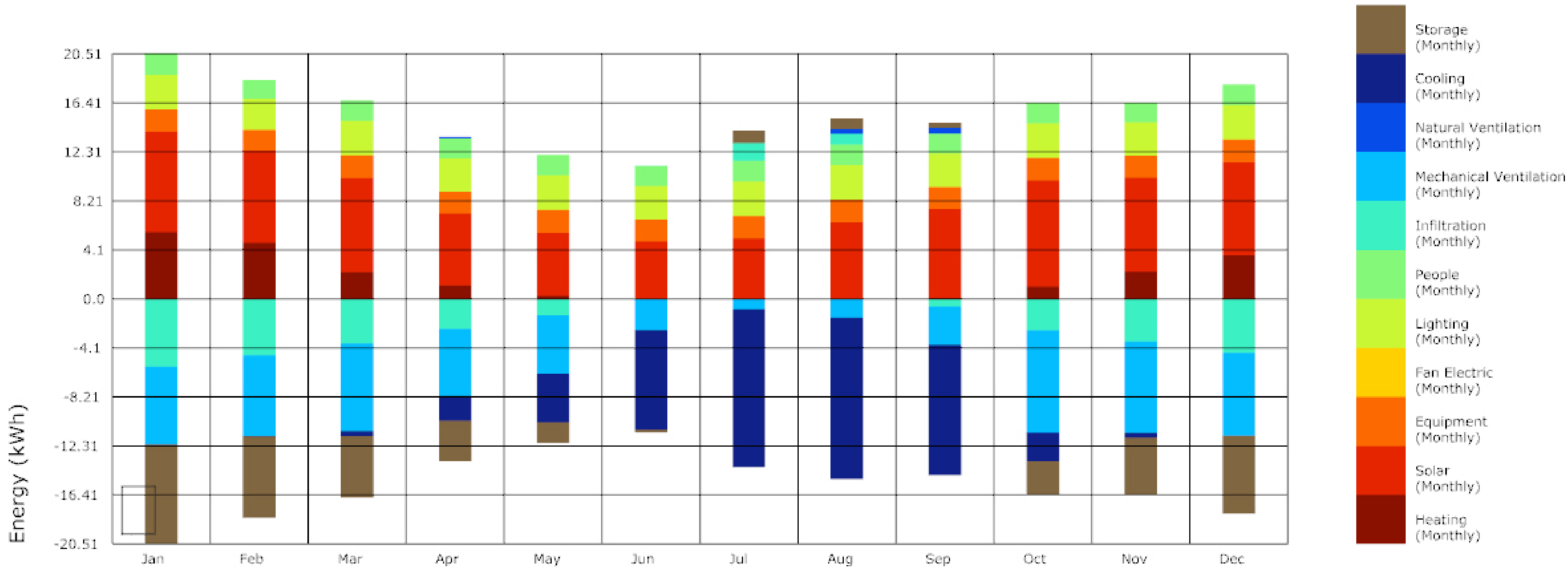
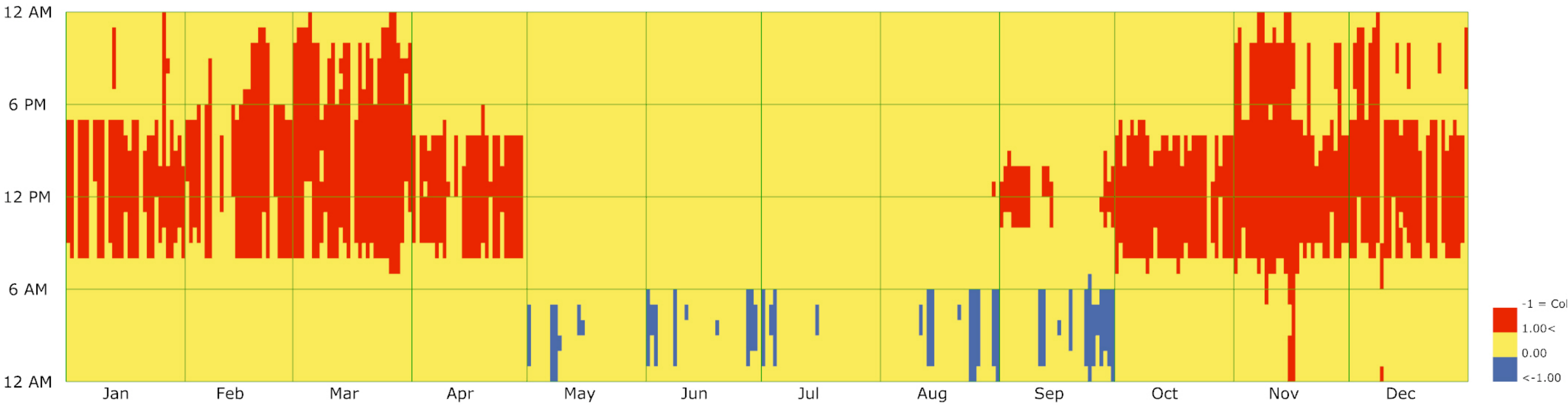


December 21, 3PM

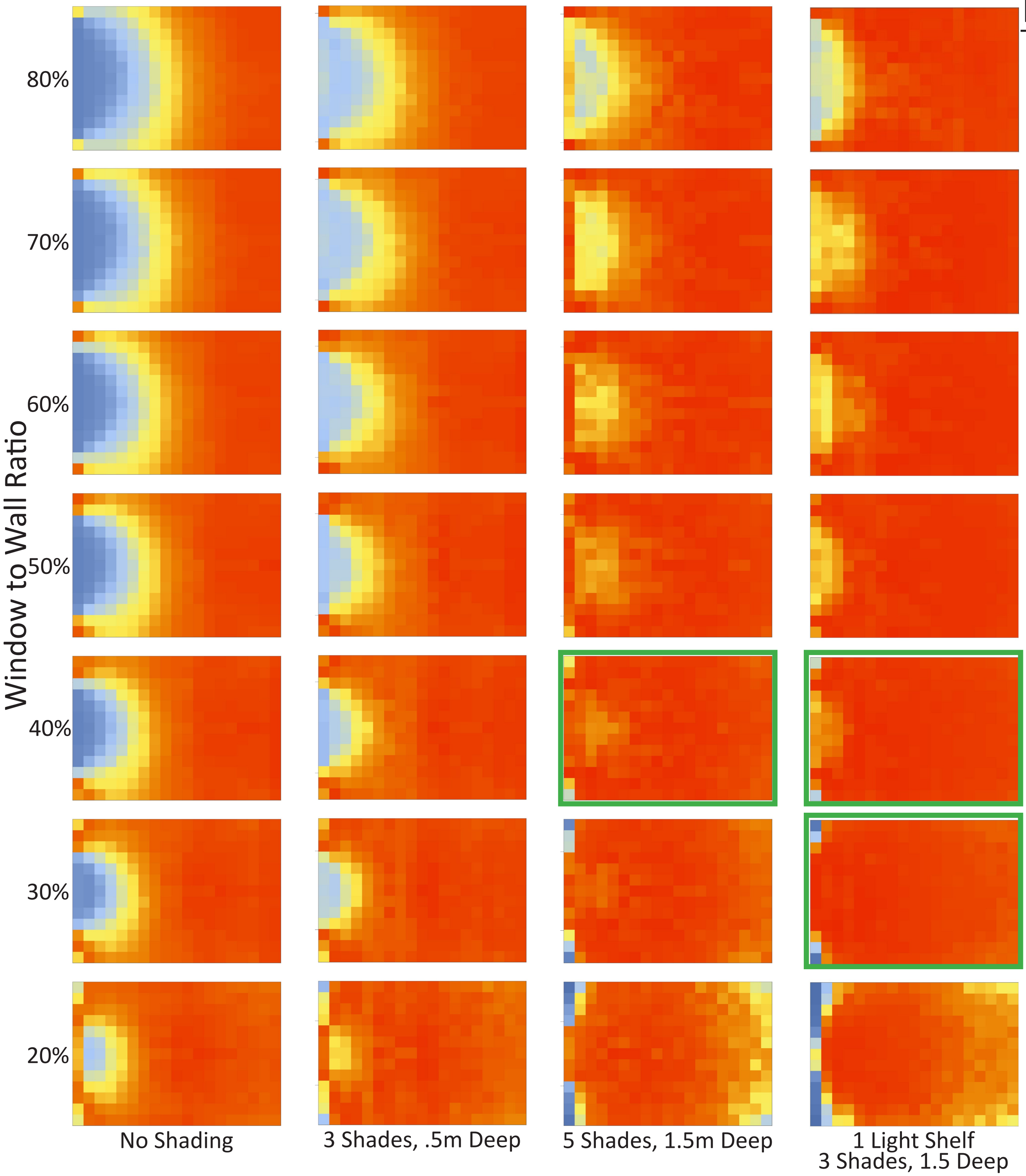
Base Room





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

Matrix of Possibilities



As a baseline measure, all of the results to the left represent a higher level of construction than seen in the base. This building is old and is in dire need of reduced ventilation rates, higher insulation and a better window. Sine 4 of the walls are interior, these were not effected by the change. However, the south brick wall saw an additional layer of rigid insulation added, bringing the R-value to 26, a new low-e, argon filled window construction and a reduced leakiness.

After these changes were applied, the room was run through a basic set of changes to identify the options which would be best to pursue further.

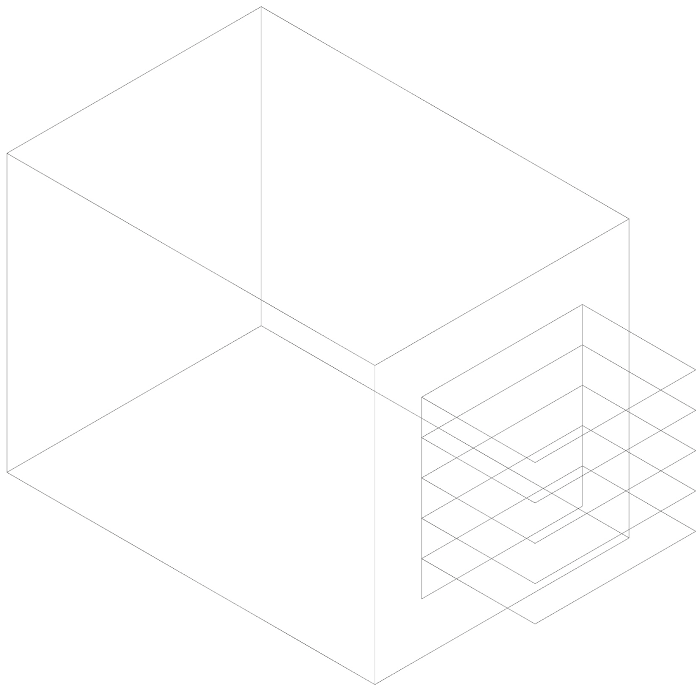
The images to the left show the Annual Daylight Analysis. It is clear that the largest issue across the length of a year is the intensity of the sun near the window. The shading options in the right three columns seek to try and rectify this issue.

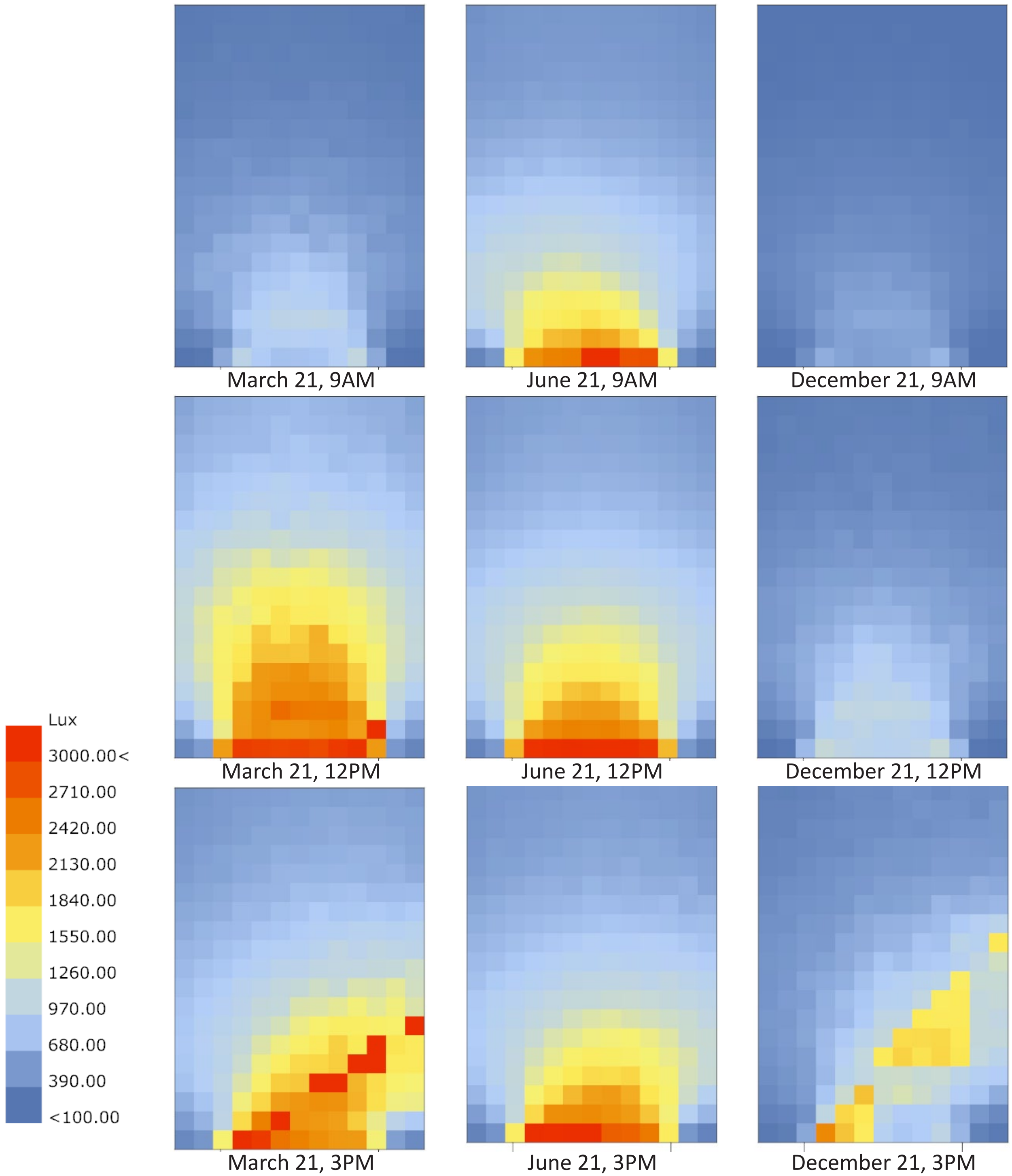
On the following page energy balance charts can be seen for the same scenarios. By running these two graphics, it is possible to get both a little understanding of daylighting and the energy needs. While neither provides an extensive understanding, it is possible to see trends and pick some to test further.

Those which will be looked at more closely have been highlighted. While they do not necessarily perform the best at either, they are selected for their performance in both of the tests.


Window to Wall Ratio
80%
70%
60%
50%
40%
30%
20%
No Shading
3 Shades, .5m Deep
5 Shades, 1.5m Deep
1 Light Shelf
3 Shades, 1.5 Deep

Option 1





Option 1 represents the room with a slightly larger window and shading devices. In this proposal, the window to wall ratio is increased to 40%. Additionally 5 highly reflective shades are added at even intervals to both block light and bounce some further back into the room. Since the largest issue with light shown in the matrix was the excess of light near the window itself it is important to try and reduce that radiation. Further the reflectivity should help bounce some light further into this long room.

However, there are clearly still some issues with too much light and darker spots, especially during the early morning. However, this does show a marked improvement over the base situation.

Option 1

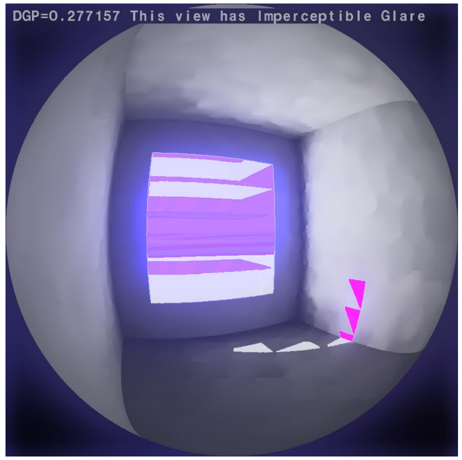
Generally this room is successful with the reduction of glare apart from midday on December 21st. So while this room may not always be well lit it is at least comfortable and may be more comfortable at lower light levels without this contrast.

On the next page the Energy Balance and the Adaptive Comfort charts can be seen.

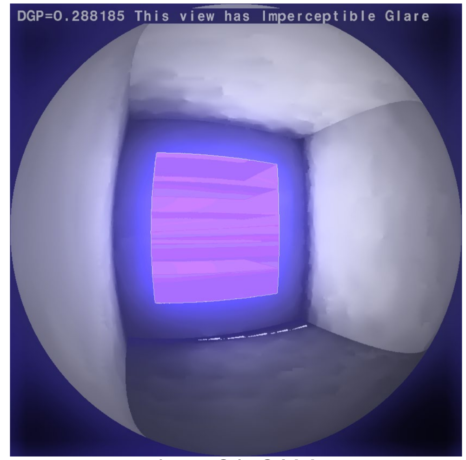
The Energy Balance shows a marked improvement from the base model. This proposal results in a need for 730 kWh a year (44 kWh/ m^2).

However, the adaptive comfort still shows periods of time when an occupant would not be comfortable. As is expected, heating and cooling is still needed to make this space livable for the entirety of the year.

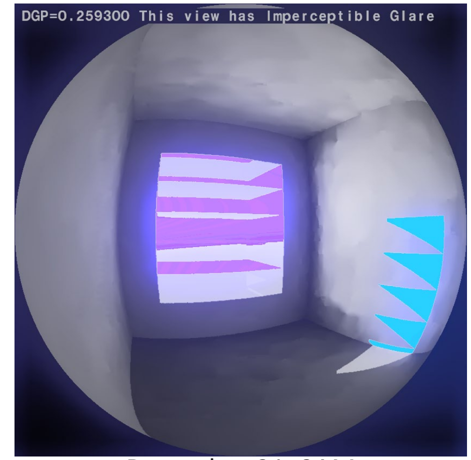
Overall, this option does pretty well with the energy reduction while allowing in more light but not producing glare. However, light still does not enter deeply into this room resulting in more lighting needed.



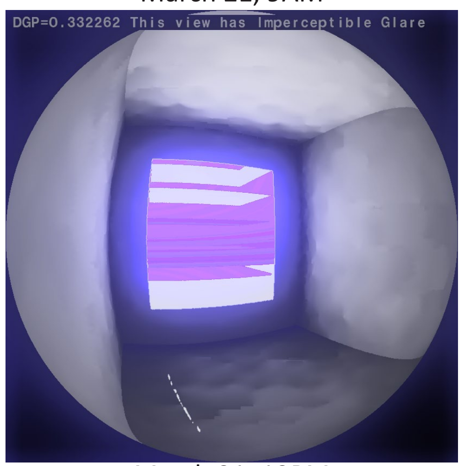
March 21, 9AM



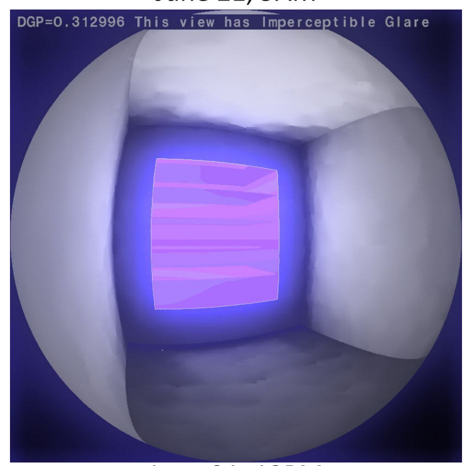
June 21, 9AM



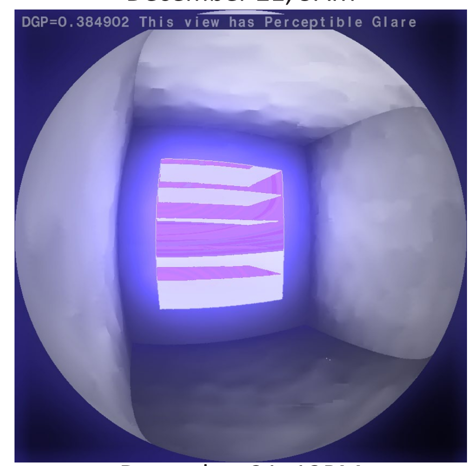
December 21, 9AM



March 21, 12PM

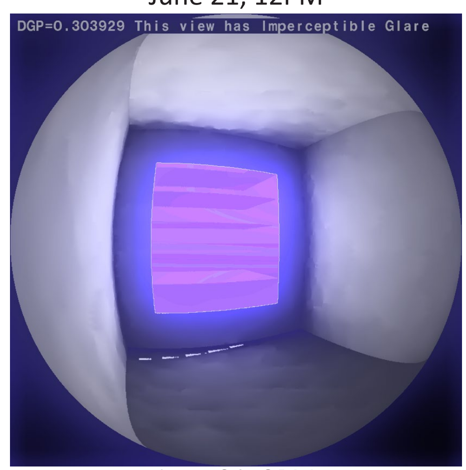


June 21, 12PM



December 21, 12PM

March 21, 3PM



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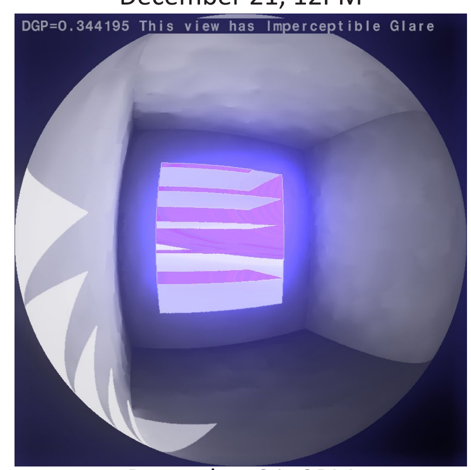
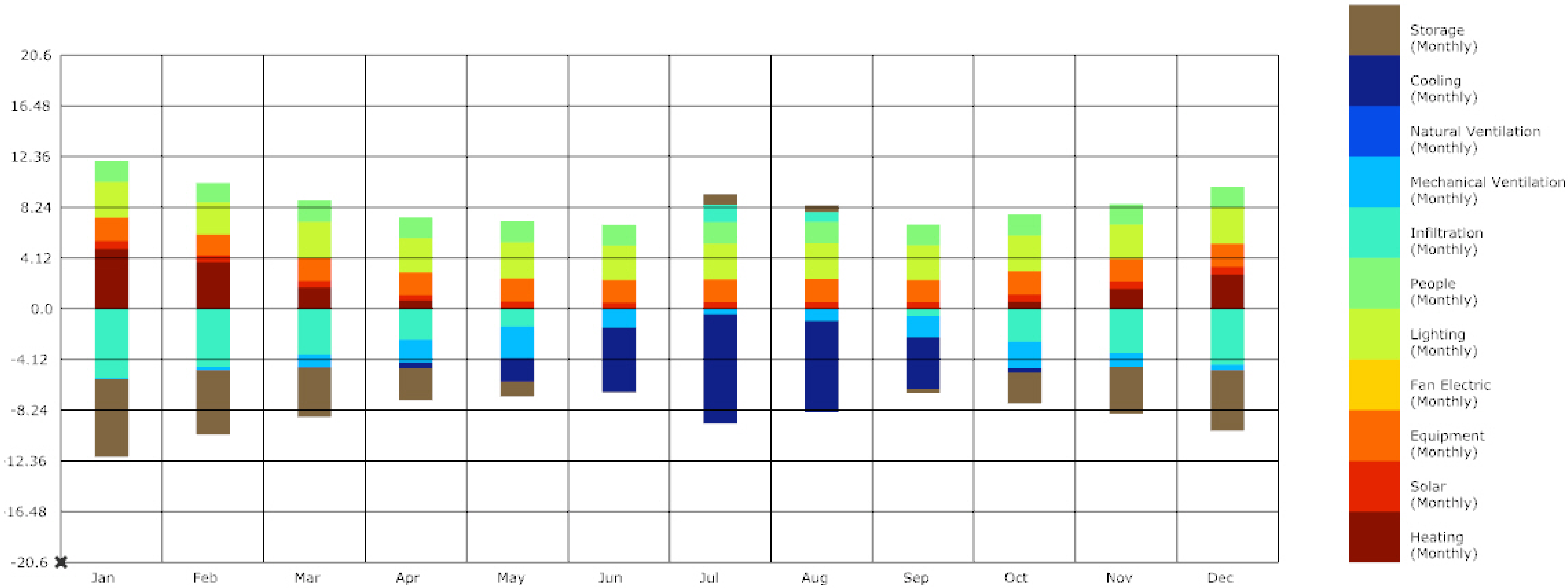
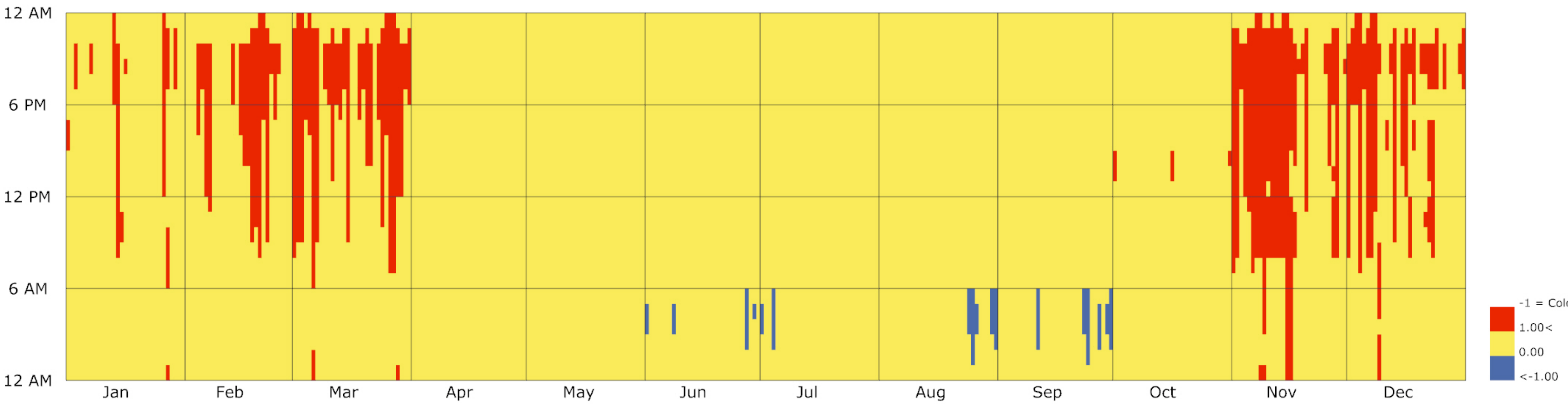


December 21, 3PM

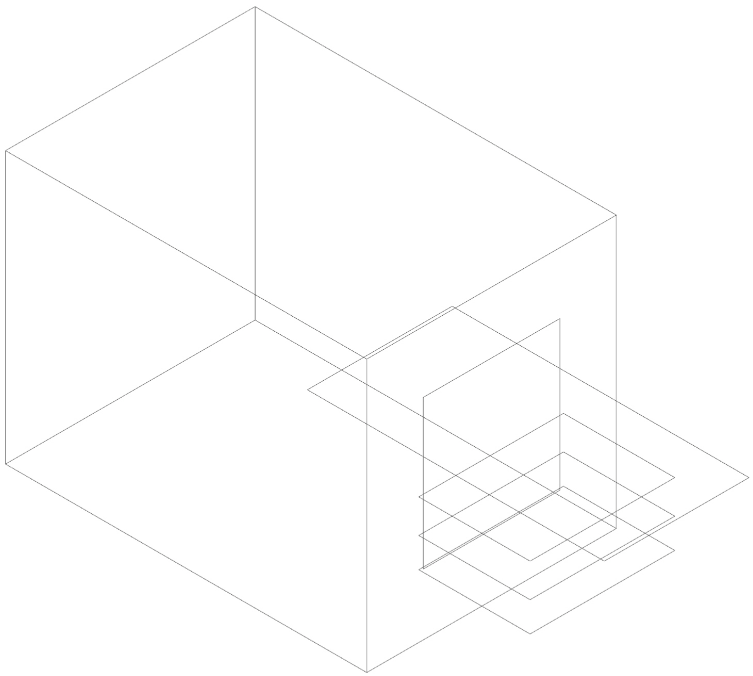
Option 1





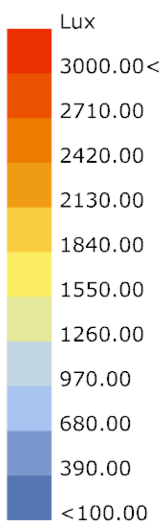
Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

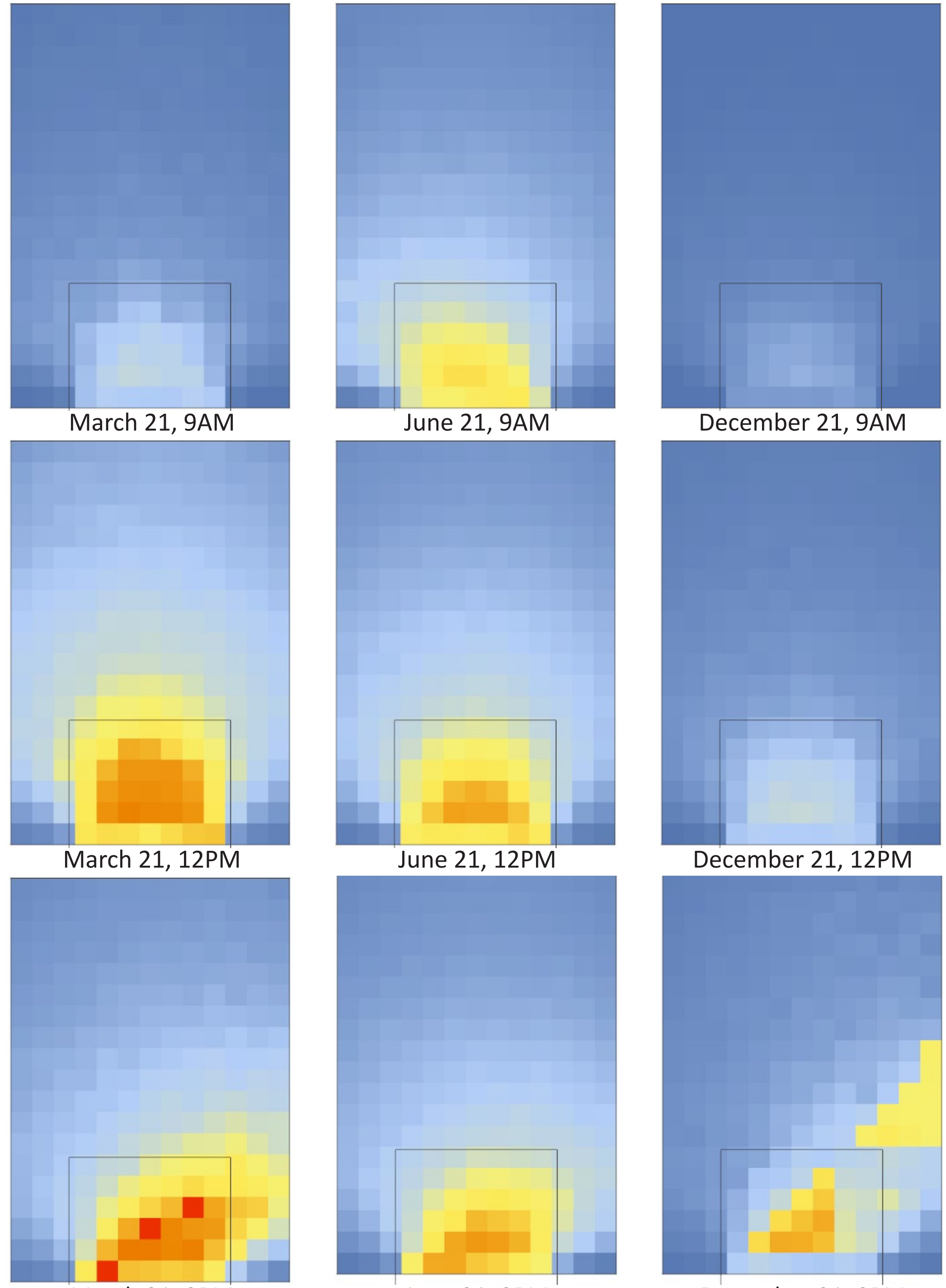
Option 2



Option 2 represents the room with a barely larger window, a light shelf and 3 shading devices. In this proposal, the window to wall ratio is increased to 30%. Additionally 3 highly reflective shades and 1 light shelf are added at even intervals to both block light and bounce some further back into the room. Since the largest issue with light shown in the matrix was the excess of light near the window itself it is important to try and reduce that radiation. Further the reflectivity should help bounce some light further into this long room.

This proposal does a better job of moving light further into the space. While there are still some hots spots at the window, the overall benefit for the depth of the room during many hours makes a little intense sunlight worth it.





March 21, 9AM
June 21, 9AM
December 21, 9AM
March 21, 12PM
June 21, 12PM
December 21, 12PM
March 21, 3PM
June 21, 3PM
December 21, 3PM

Option 2

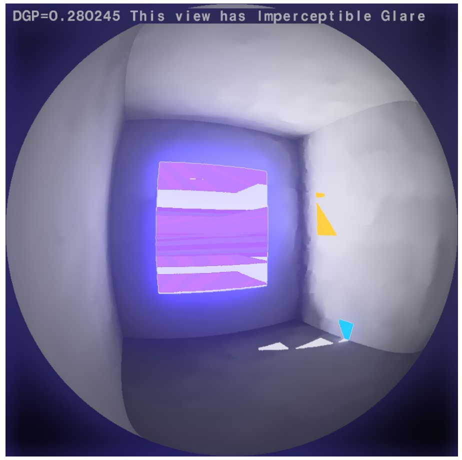
Generally this room is successful with the reduction of glare. However, midday of December 21st does depict the issue of disturbing glare. Still, there is an overall greater brightness in the room shown through the images to the right

On the next page the Energy Balance and the Adaptive Comfort charts can be seen.

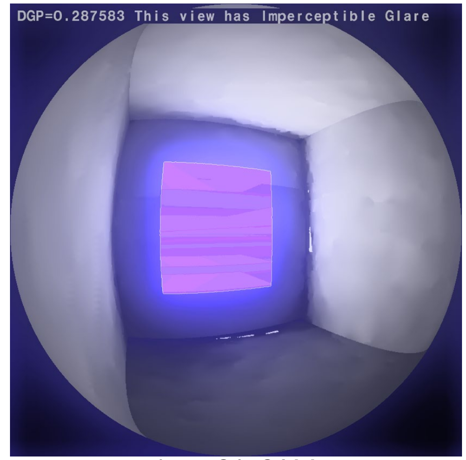
The Energy Balance shows decent improvement from the base model. This proposal results in a need for 701 kWh a year (42.8 kWh/ m^2).

However, the adaptive comfort shows higher periods of time when an occupant would not be comfortable as compared to option 1. As is expected, heating and cooling is still needed to make this space livable for the entirety of the year.

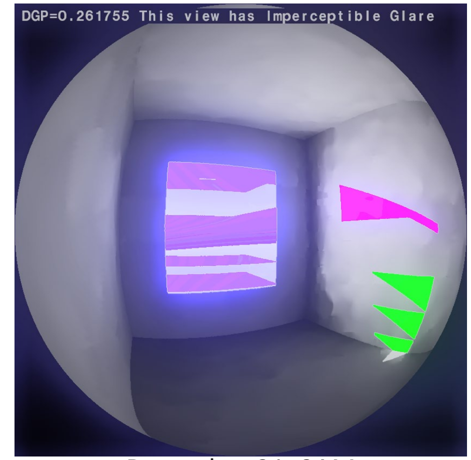
Overall, this option does well with the energy reduction while allowing in more light with some glare. However, light enters more deeply into this room although some lighting would still be needed, task dependent.



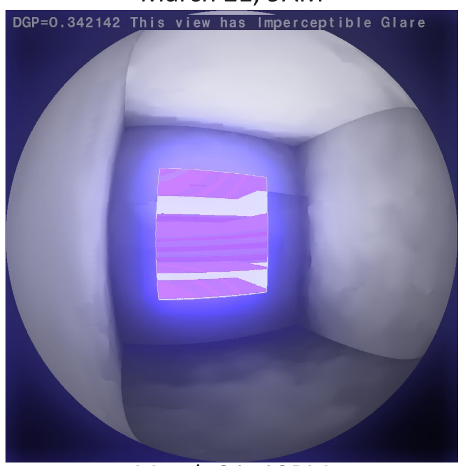
March 21, 9AM



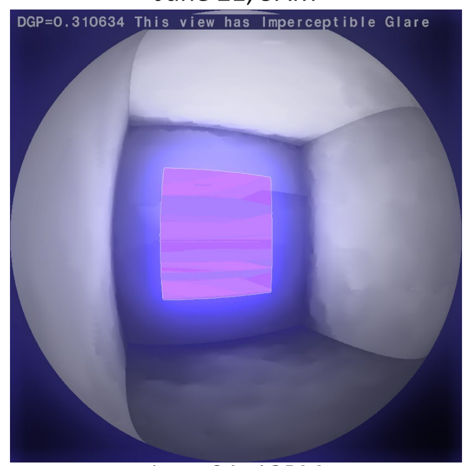
June 21, 9AM



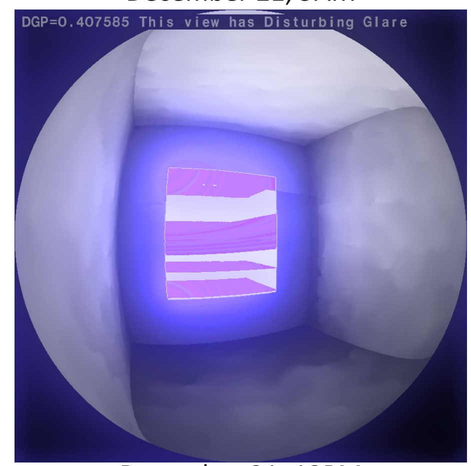
December 21, 9AM



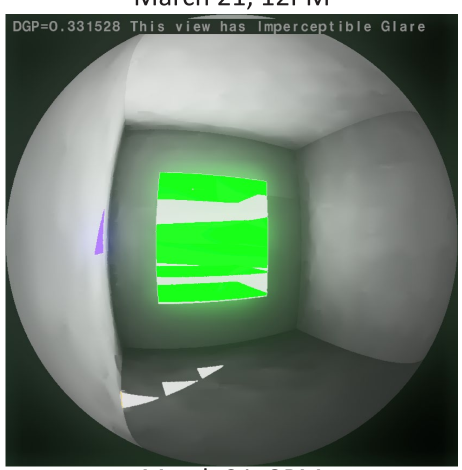
March 21, 12PM



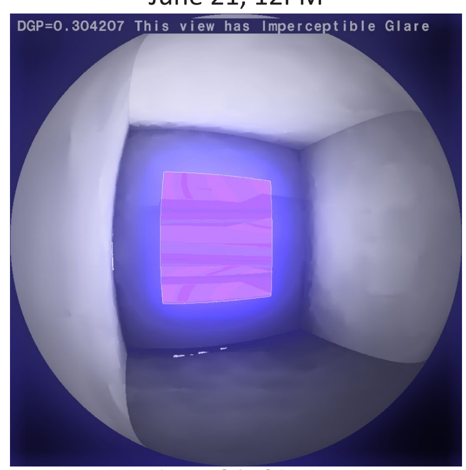
June 21, 12PM



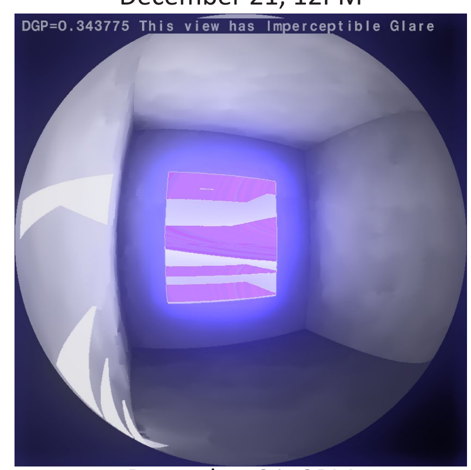
December 21, 12PM



March 21, 3PM

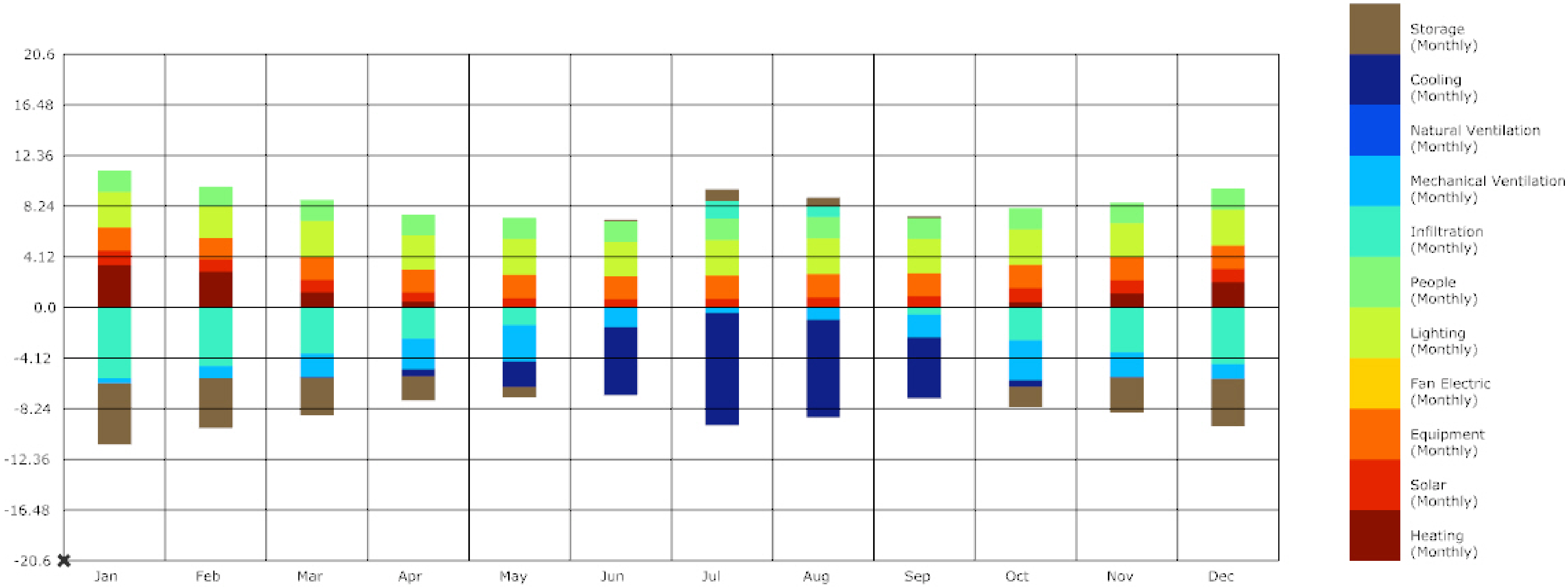


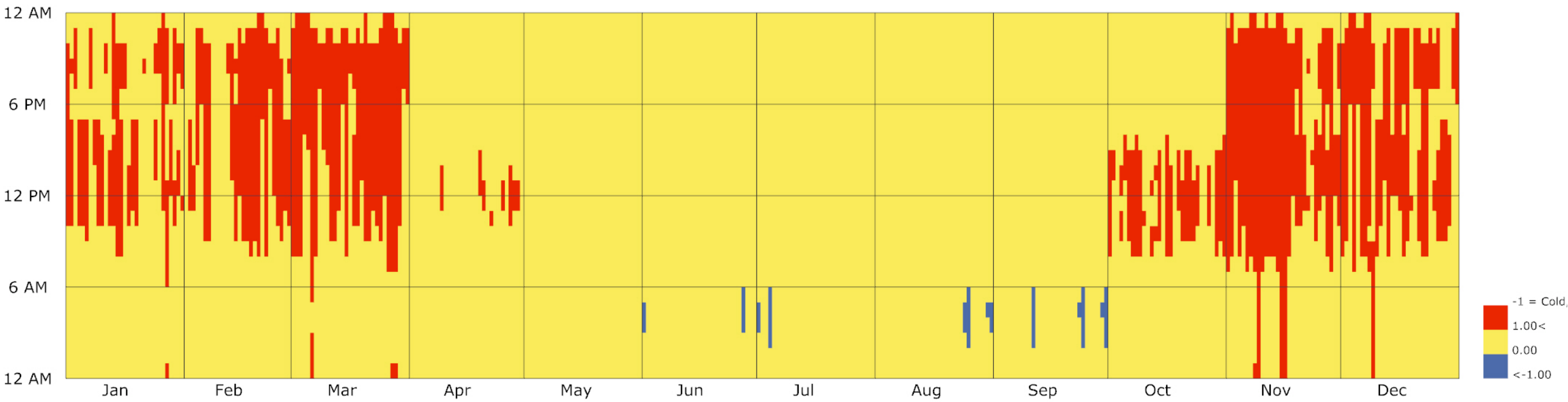
June 21, 3PM



December 21, 3PM

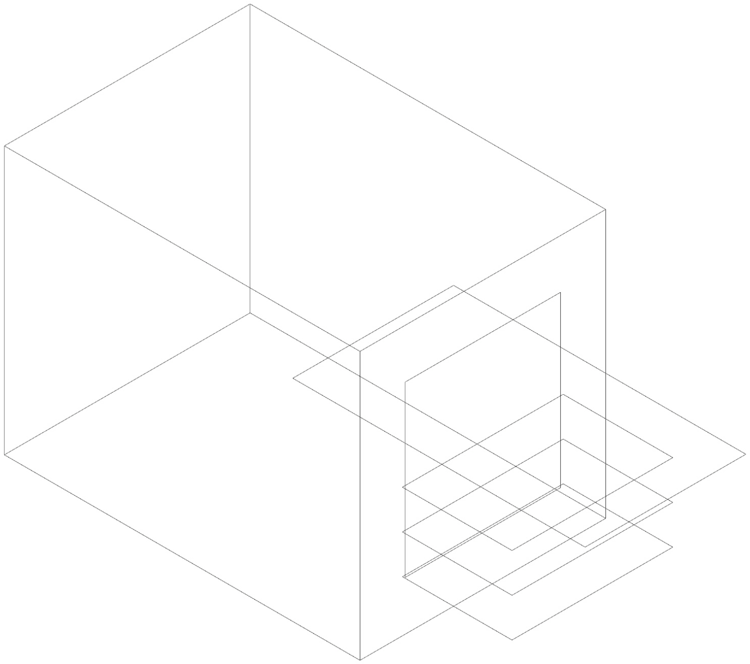
Option 2

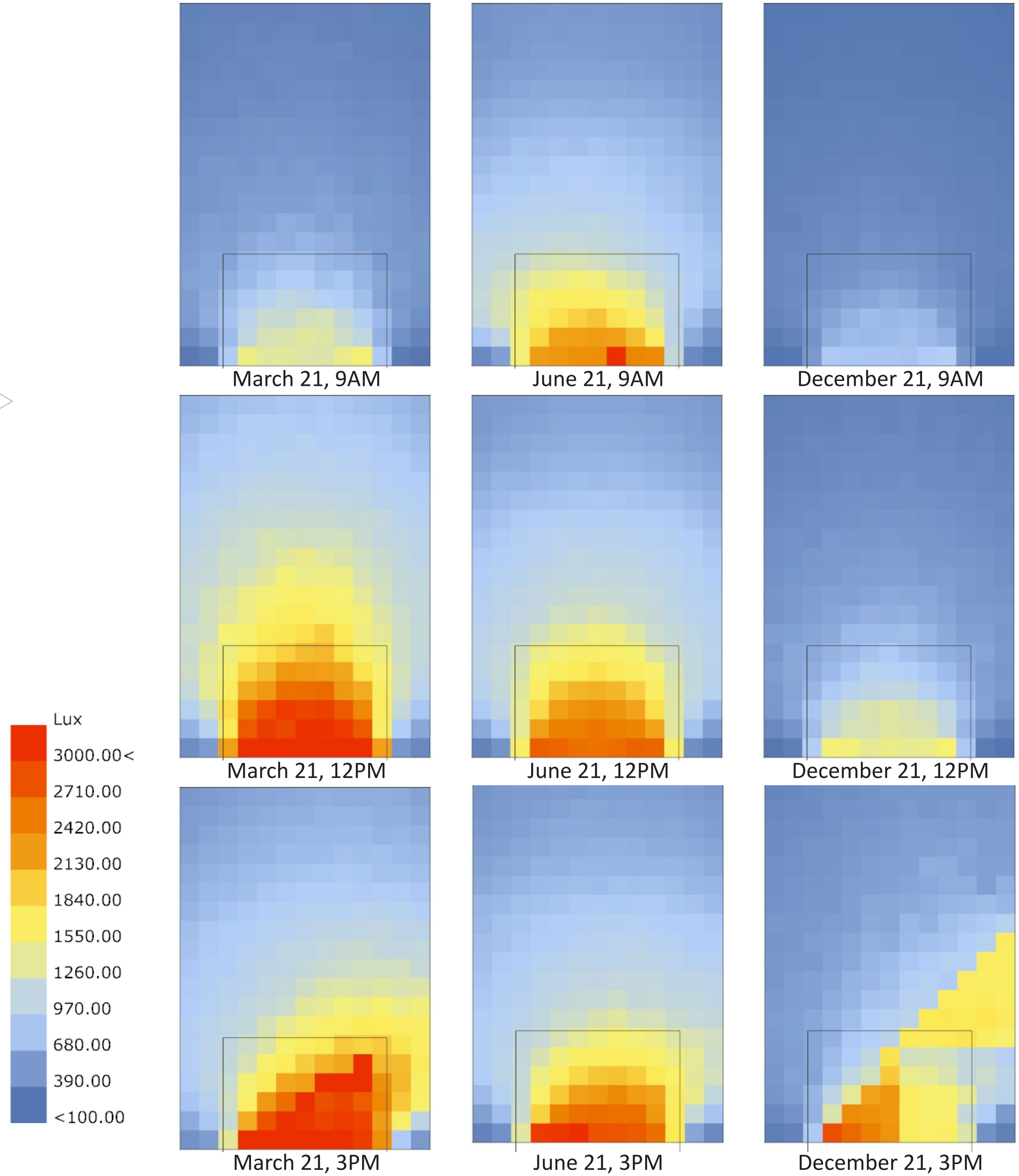




Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Option 3





Option 3 represents the room with a slightly larger window, a light shelf and 3 shading devices. In this proposal, the window to wall ratio is increased to 40%. Additionally 3 highly reflective shades and 1 light shelf are added at even intervals to both block light and bounce some further back into the room. Since the largest issue with light shown in the matrix was the excess of light near the window itself it is important to try and reduce that radiation. Further the reflectivity should help bounce some light further into this long room.

While this proposal does the best at bringing light further into the space, is also creates intense areas by the window which have too much sunlight. One option would be to not actively occupy this area. Another would be to perhaps reduce the reflectivity on the bottom of the shading devices to lessen the bounce down.

Option 3

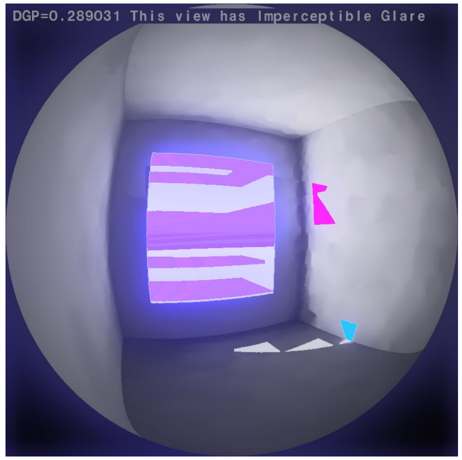
This room is not nearly as successful when dealing with glare. Out of the 9 times where glare is measured 4 have either disturbing or perceptible glare. These leads to the belief that this would not be the best space for working and would be uncomfortable

On the next page the Energy Balance and the Adaptive Comfort charts can be seen.

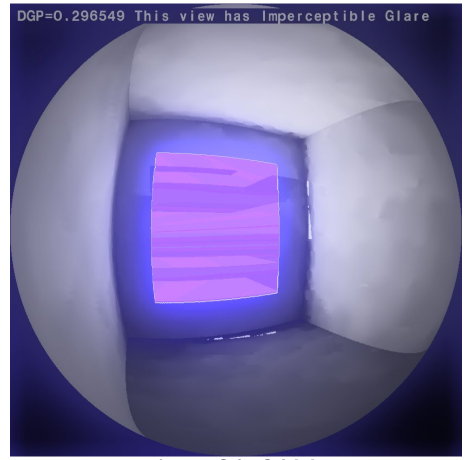
The Energy Balance shows some improvement from the base model. This proposal results in a need for 759 kWh a year (46kWh/ m^2).

Additionally, the adaptive comfort shows higher periods of time when an occupant would not be comfortable as compared to option 1 and 2. As is expected, heating and cooling is still needed to make this space livable for the entirety of the year.

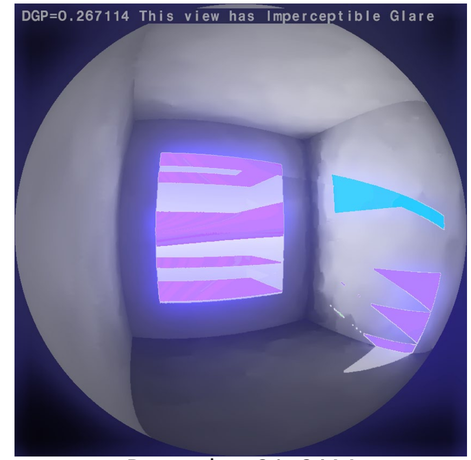
Overall, this option does not do quite as well with the energy reduction and bringing in light. However, it does show some improvements over the base model.



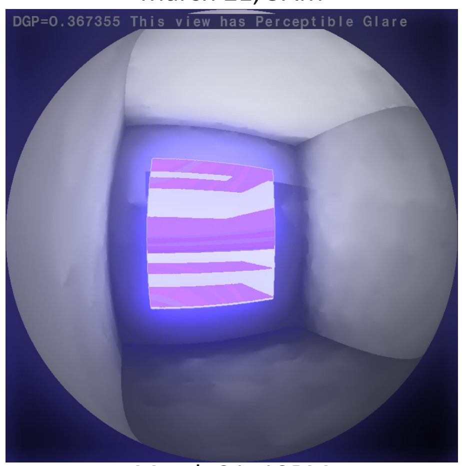
March 21, 9AM



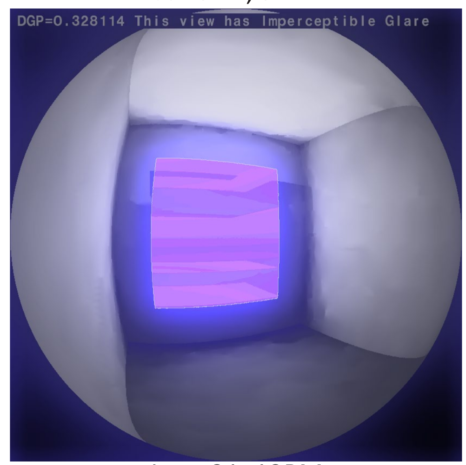
June 21, 9AM



December 21, 9AM



March 21, 12PM



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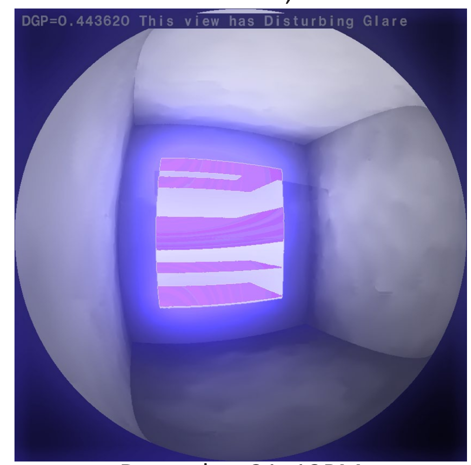


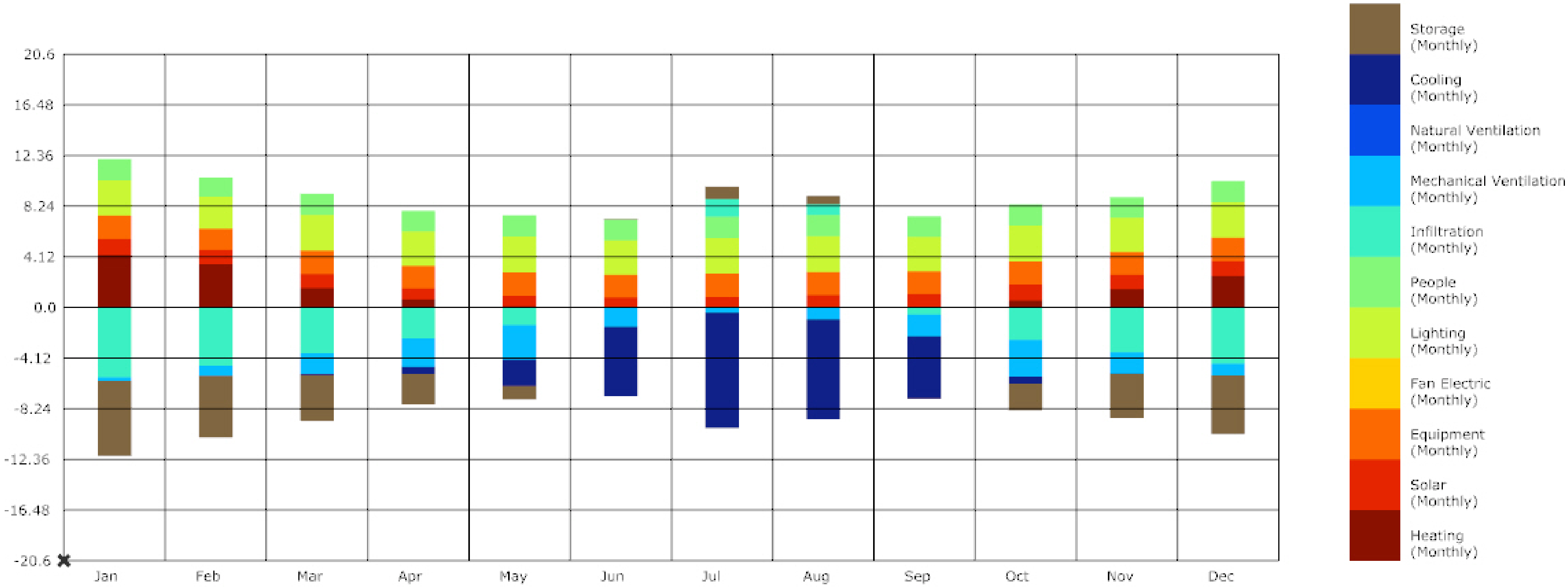
December 21, 12PM

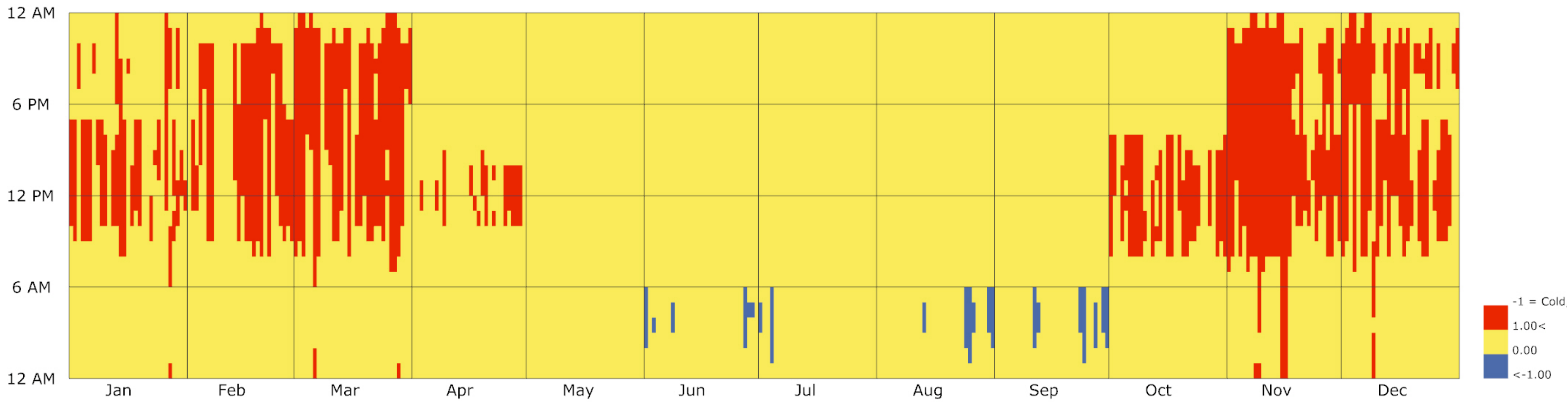
March 21, 3PM

June 21, 3PM

December 21, 3PM

Option 3





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

Conclusion

In conclusion, the second option would provide the best overall benefit out of those researched further. This option with a single light shelf with 3 shading devices and 40% glazing area provides the best improvement over the base study. Overall, there is a reduction of 8kWh / m^2, an increase in window size and greater light brought into the space. However, this solution does not solve all issues nor take into account every aspect.

One way to further this study would be to start adjusting the materiality of the lightshelf and shading devices. While mirroring is important on the top, the mirroring on the bottom of the surfaces is contributing to the hot spots of sunlight right in front of the window.

There are other ways which could also help this room which have not been calculated here. One would be to simply introduce operable shading inside the window to help with the reduction of glare in the winter. Another would be to use evaporative cooling outside of the window to help cool the air being brought in during the summer months and hopefully reduce the need for air conditioning. If this room was not restricted on 5 side other options would be to introduce light through a skylight, and increase the ability of ventilation with a second operable opening.

Overall, this solution does not ‘fix’ all of the issues with this room, however, it makes a strong changes to the current room which overall is helpful. Further studies could of course be made by altering materials and playing with this solution on a minute level.