MELBOURNE, AUSTRALIA

CLIMATE ANALYSIS REPORT

JANKI A VYAS

https://upload.wikimedia.org/wikipedia/commons/f/f7/Melbourne_Docklands_-_Yarras_Edge_-_marina_panorama.jpg

City: **Melbourne**
State: **Victoria**
Country: **Australia**

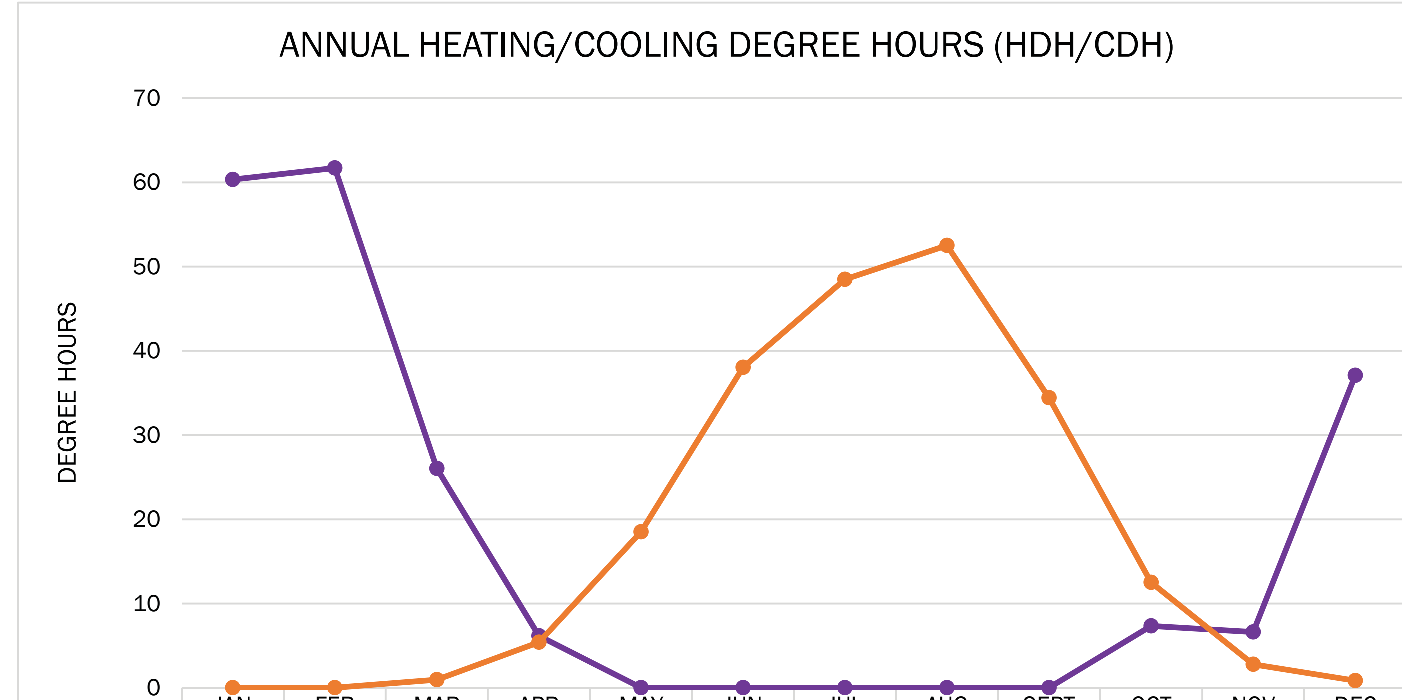
37° 48' S   144° 57' E

Weather File: **AUS_VIC.Melbourne.948680_RMY**

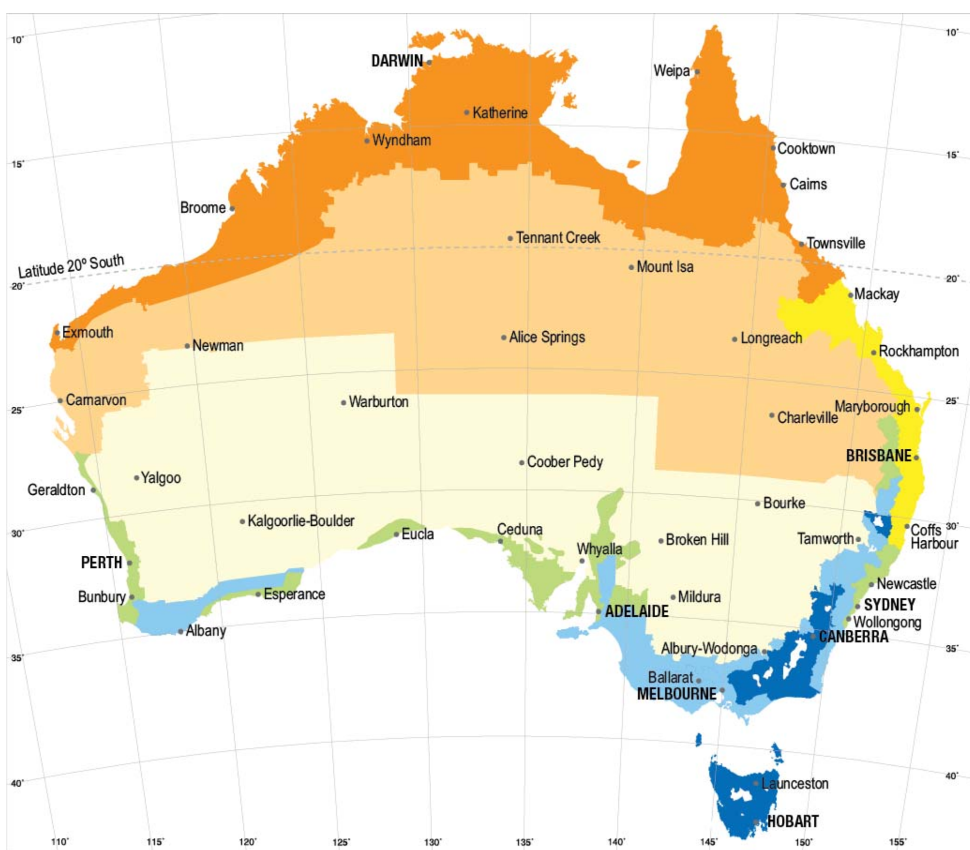
The Cooling Degree Hours (CDH) and Heating Degree Hours (HDH) were calculated using Ladybug for Grasshopper. While Ladybug allows you to custom calculate degree days based on preferred base temperature, it does not allow for consideration of heat from solar gain. Therefore, the base temperatures selected for HDH and CDH are selected intuitively to take into account heating from solar gain:

CDH: 75°F
HDH: 50°F.

The criteria that all comfort hours will be tested to in this report are based on adaptive comfort and fall in the following temperature range : 90°F - 50°F.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
CDH	60.34	61.72	26.04	6.16	0.00	0.00	0.00	0.00	0.00	7.33	6.60	37.08
HDH	0.00	0.00	0.95	5.40	18.50	38.03	48.47	52.52	34.43	12.51	2.79	0.86

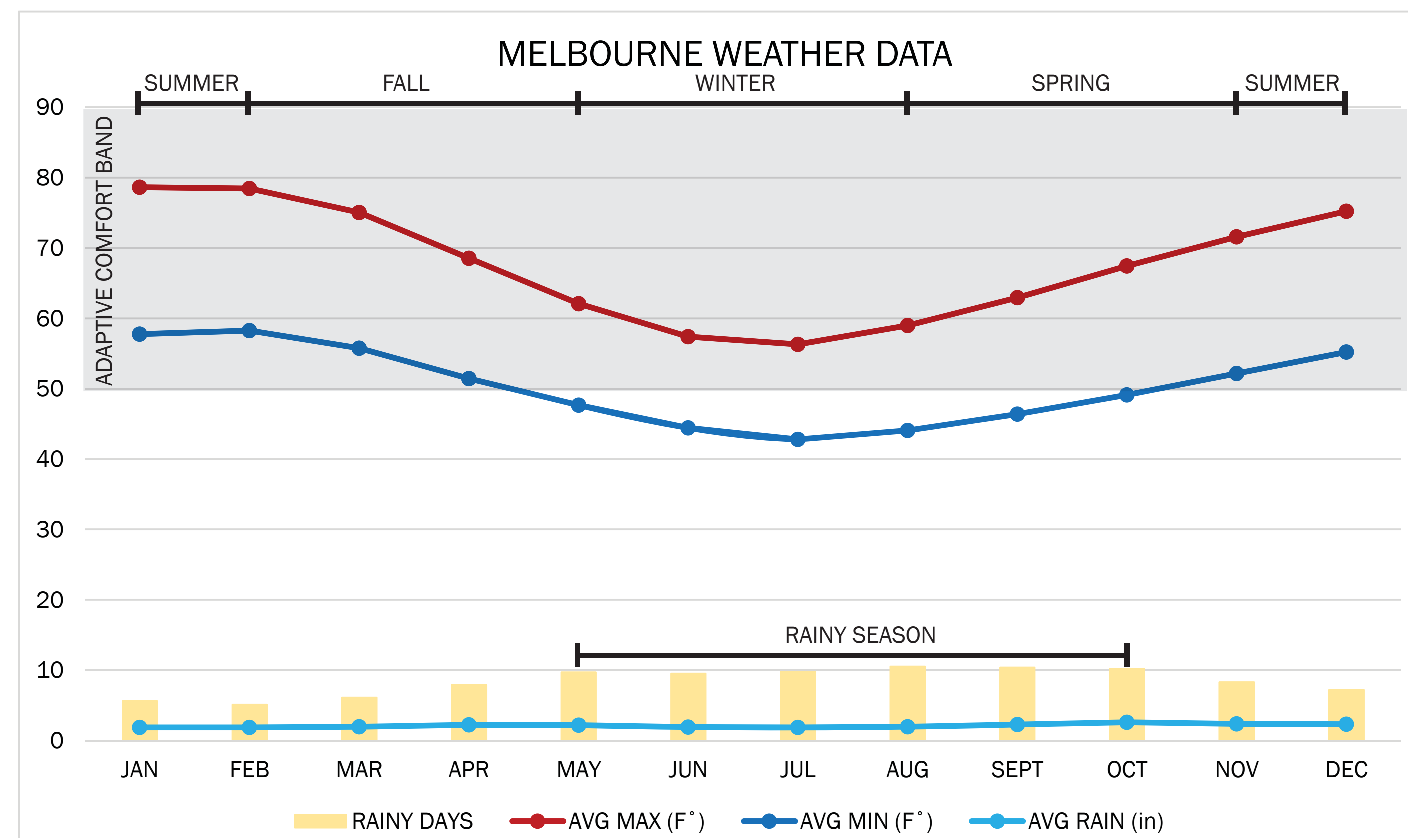


Source: Australian Building Codes Board (Retrieved from: http://www.yourhome.gov.au/passive-design/design-climate)

Melbourne is located in a mild-temperate climate along the southeastern coast of Australia.

Based on meteorological data, rain fall is consistent throughout the year, averaging about 2in a month. The average number of days having precipitation double from May to October.

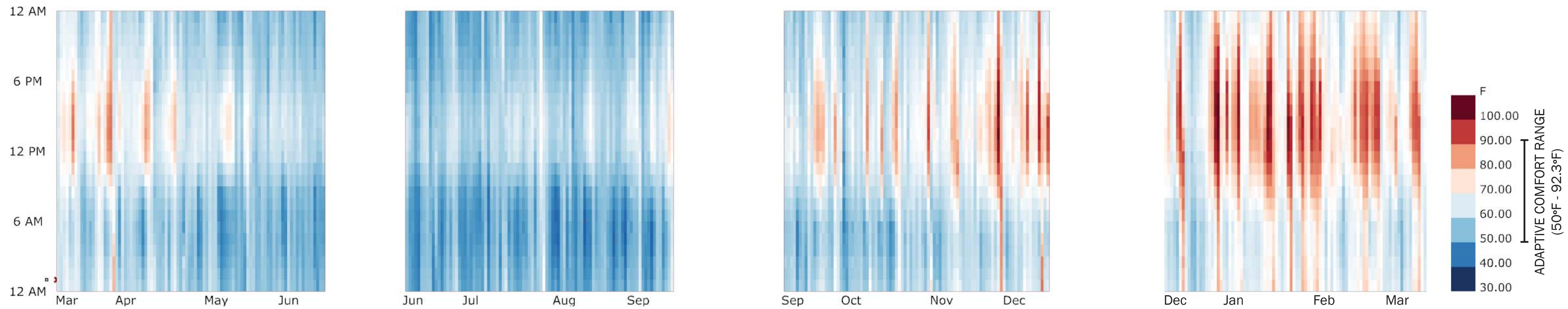
Zone	Description
1	Hot humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine



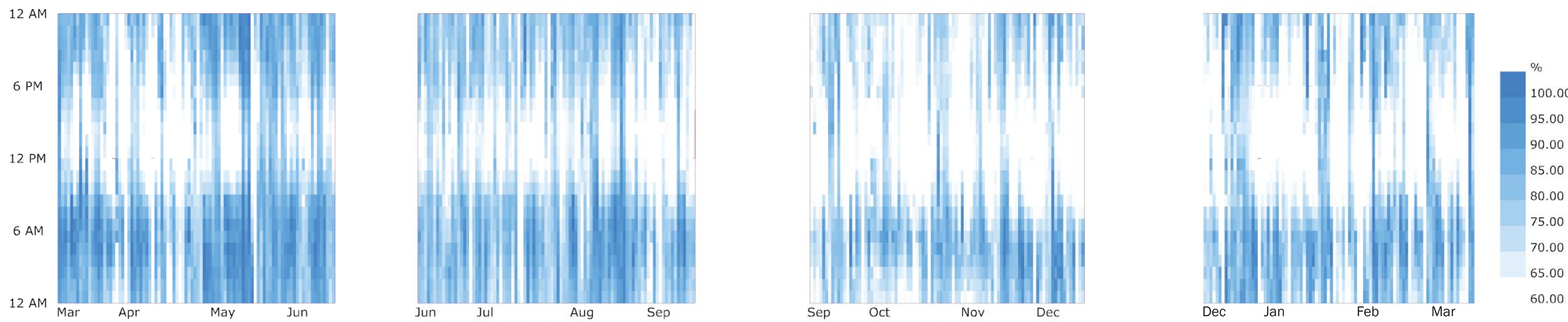
Source: Commonwealth of Australia 2015, Bureau of Meteorology

FOUR DISTINCT SEASONS

FALL	WINTER	SPRING	SUMMER
March 21 - June 20	June 21 - September 20	September 21 - December 20	December 21 - March 20

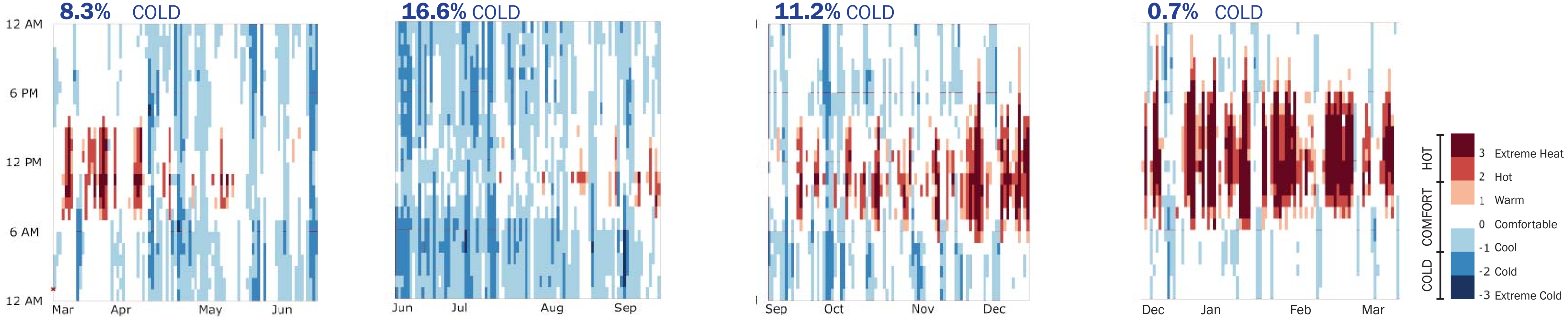


AIR TEMPERATURE



RELATIVE HUMIDITY

FALL	WINTER	SPRING	SUMMER
58% COMFORTABLE	**34.6%** COMFORTABLE	**58.2%** COMFORTABLE	**61.3%** COMFORTABLE
5% HOT	**1%** HOT	**25.4%** HOT	**22.6%** HOT
8.3% COLD	**16.6%** COLD	**11.2%** COLD	**0.7%** COLD



UNIVERSAL THERMAL COMFORT INDEX (UTCI)

There are 4 distinct seasons, **Summer, Winter, Fall and Spring**. It also has a reputation for its changeable weather, often seeing 'four seasons in one day'.

The charts on this and the following page show annual weather data seperated by season to identify weather patterns typical for the year.

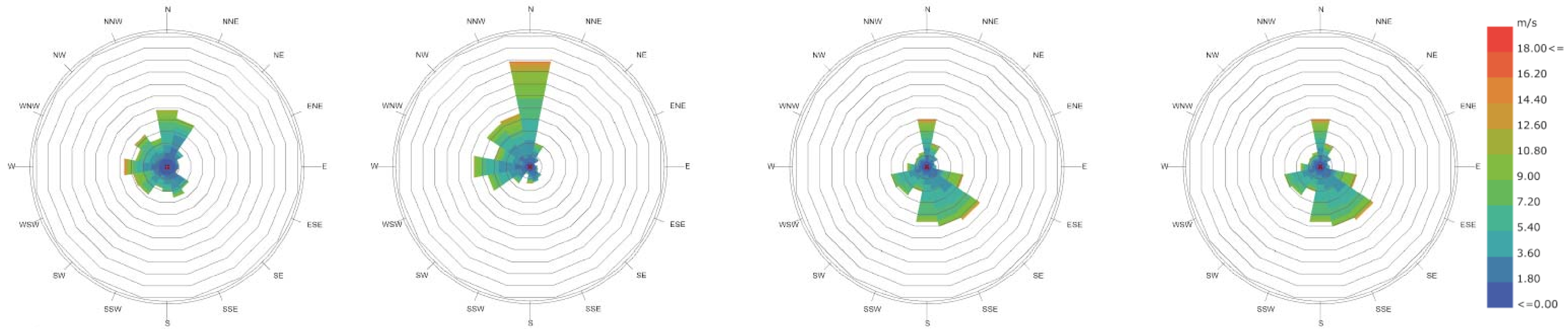
Thermal comfort is a function of multiple factors, such as individual comfort thresholds, air temperature, relative humidity, solar gain, wind speed, etc. Therefore, to design a bioclimatic building it is important to understand how comfortable an individual can be outdoors without any systems or building enclosure first. 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". Per the values generated it is comfortable in Melbourne for about 50% of the year.

This means we need to design for the other 50% when it is not comfortable.

ANNUAL
53% COMFORTABLE
9.9% HOT
7.8% COLD

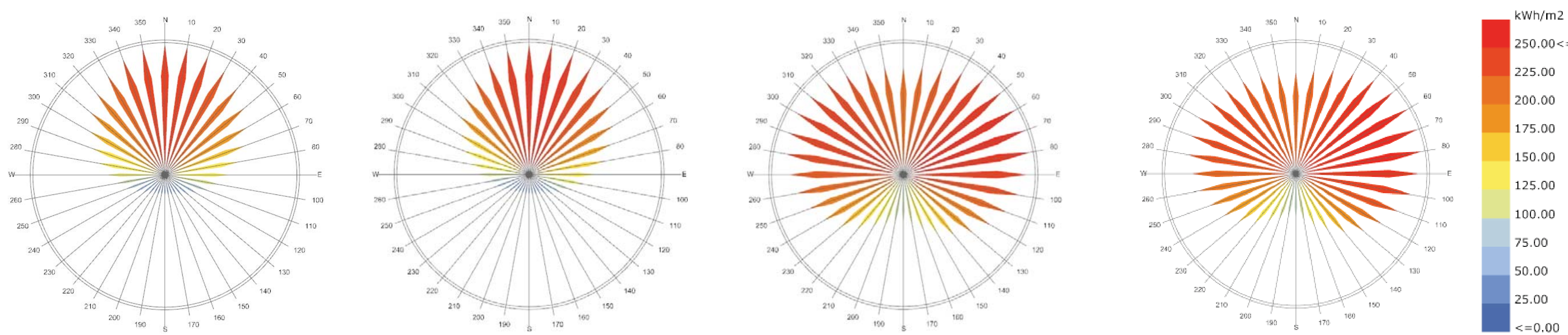
FOUR DISTINCT SEASONS

FALL	WINTER	SPRING	SUMMER
March 21 - June 20	June 21 - September 20	September 21 - December 20	December 21 - March 20

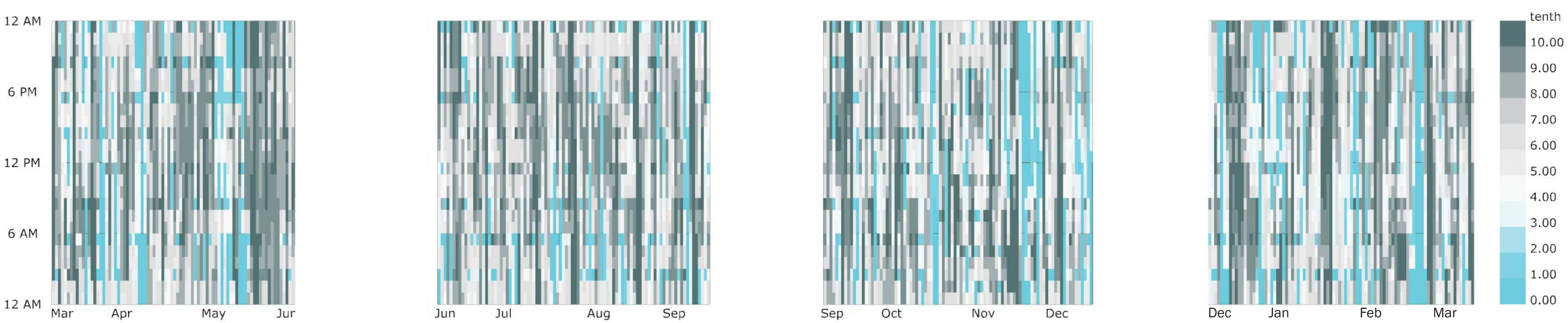


Calm: 26.99% or 596 hours | Calm: 15.22% or 336 hours | Calm: 15.93% or 348 hours | Calm: 16.71% or 361 hours

WIND SPEED + DIRECTION



TOTAL RADIATION



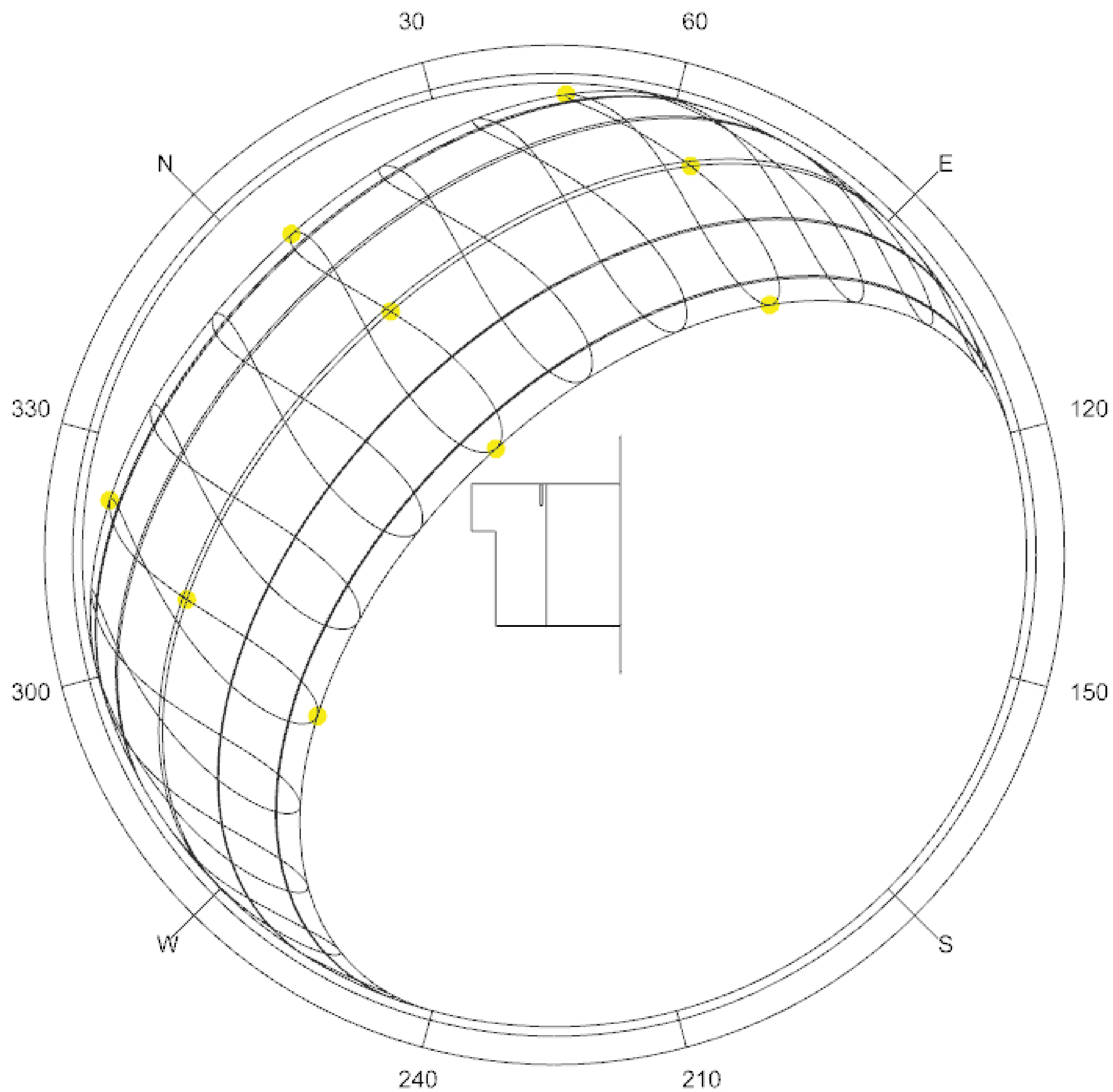
SKY COVER

Another important weather factor to simulate is sky condition, as well as, wind speeds and direction.

WIND SPEEDS
Before using windroses to aid design decisions, it is critical to understand that weather files are generally recorded at airports, which will likely have a very different microclimate from the site for which you are designing a building. Nonetheless, these wind roses can indicate general patterns to expect for the area.

SOLAR RADIATION
Despite the inconsistent sky cover, Melbourne sees an even spread of solar radiation throughout the day in the spring and summer, while the fall and winter sees a more focused sun from the north; coinciding with the high noon sun.

SKY COVER
Sky cover is measured in tenths, with a 10 being cloudy and 1 being clear. There is no clear pattern evident from the sky cover simulations, however, it seems to support the notion that Melbourne sees a range of weather over a course of a day.



BASELINE BUILDING

The baseline building, is a stand-alone residential building simulated using generic walls, floor and ceiling construction, as well as, reflectance values. All surfaces are exposed to the exterior and are capable of losing energy to the outside. There is only glazed facade for daylighting and views, oriented to the south east.

Since Melbourne is in the southern hemisphere, the sun is at its highest point to the north. For the purposes of this study, the building is to be constructed on an open field with no obstructions. The intent is to design a bioclimatic building that does not rely on active systems to maintain thermal comfort for occupants.

Climate studies will be used to attempt a design that achieves 100% thermal comfort.

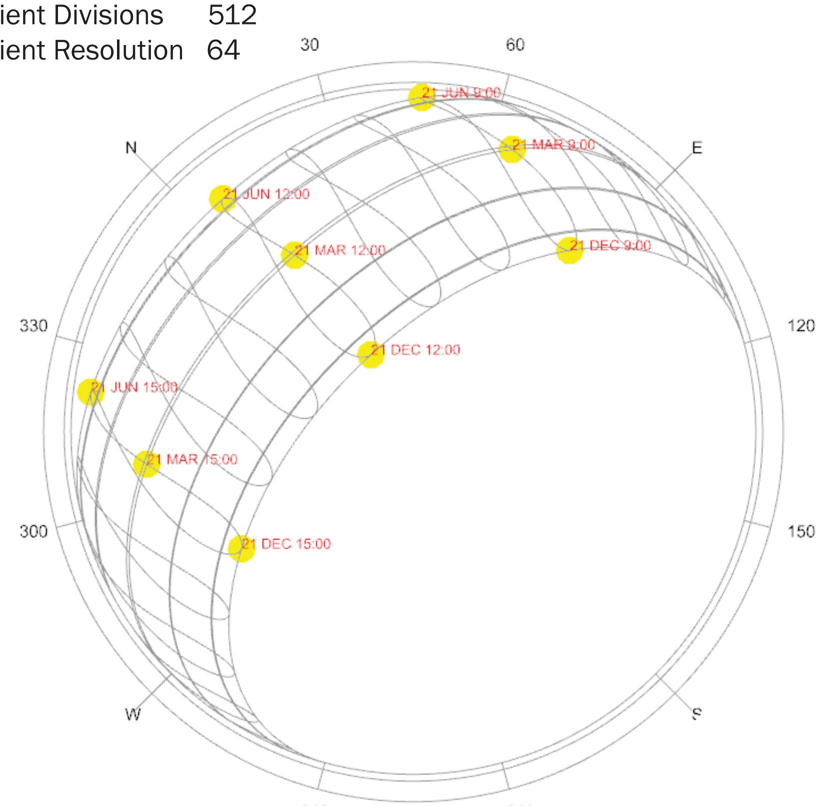
Point-in-Time Simulations such as these, are great to understand how light enters the building at different points in the day and year. Typically the sun is in a very similar position in March and September, so simulations are only run for one of the two months; in this case I chose March. A key factor to remember with Point-in-Time simulations is that they are subject to average weather data available for the specific day and time chosen for the simulation. For Melbourne, according to the weather file, the following sky conditions were relevant for the days simulated:

Date	Cloud Cover (10th)	Avg Temp (F°)
March 21	Cloudy (10)	58°
June 21	Partly Cloudy (7)	52°
December 21	Scattered Clouds (4)	62°

Based on daylight simulations, there is a significant amount of daylight gain due to the highly glazed southeast facade. Upon studying a distribution of solar gain during the early morning hours in the spring and summer hours. The design case will need to find a way to shade the summer / spring sun, while allowing solar gain in the winter months.

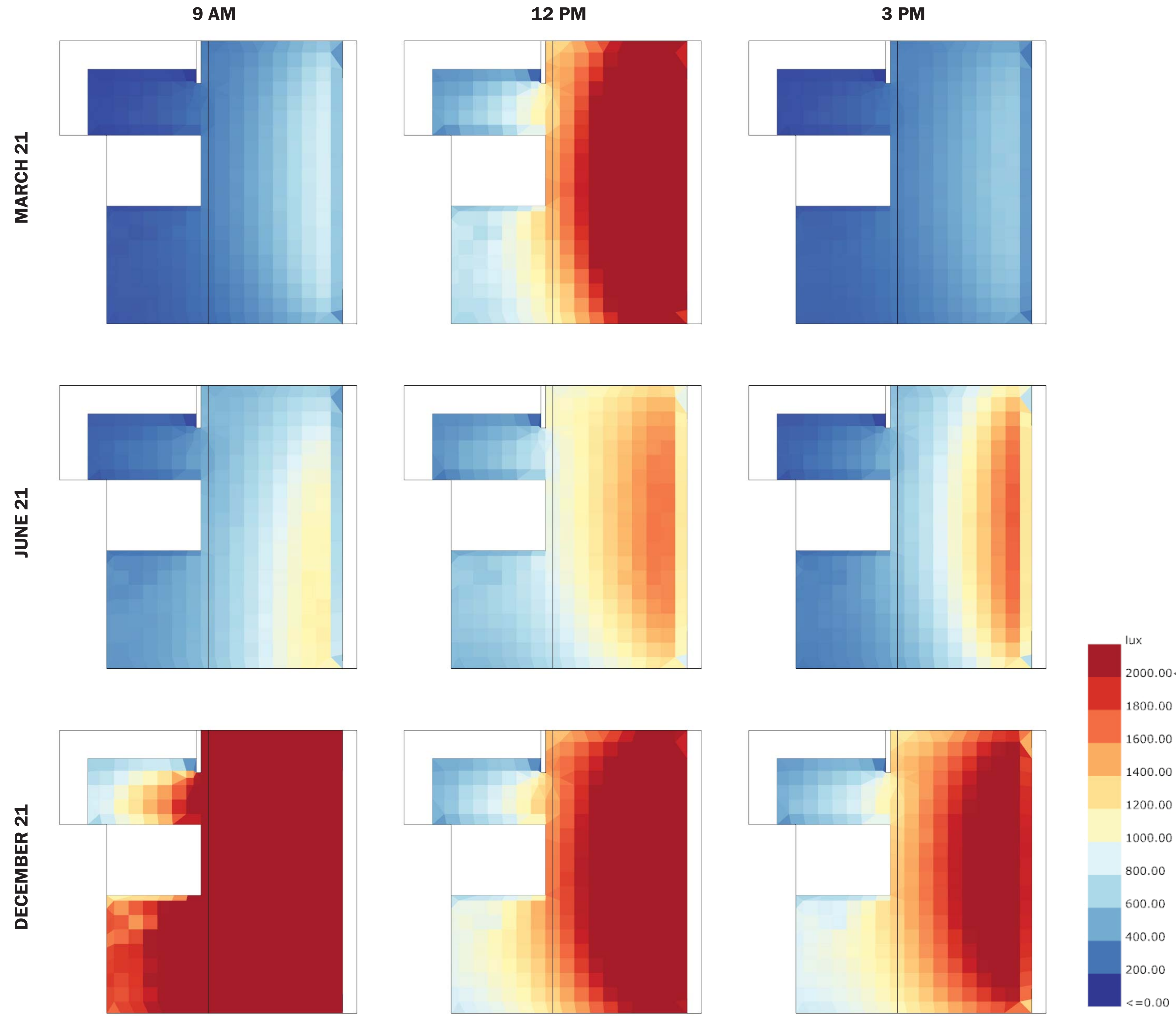
Furthermore, it is critical to know the parameters used to run the daylight simulation, as different inputs can result in a slightly different simulation result. For these simulations, the following parameters were used.

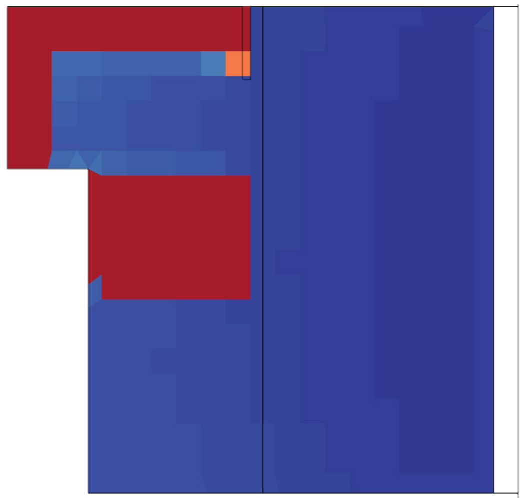
Ambient Bounces 3
Ambient Accuracy 0.2
Ambient Divisions 512
Ambient Resolution 64



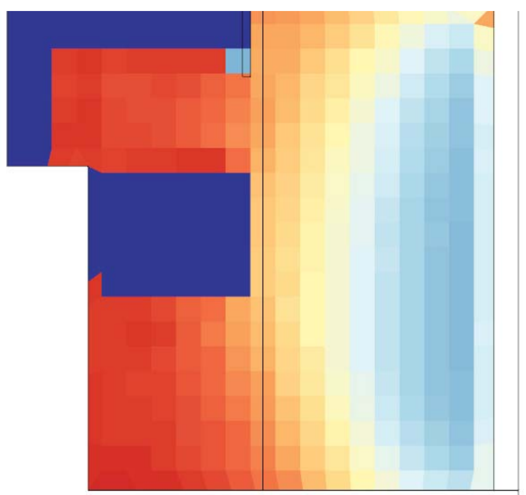
SUN PATH with location of sun for each simulation

POINT-IN-TIME ILLUMINANCE

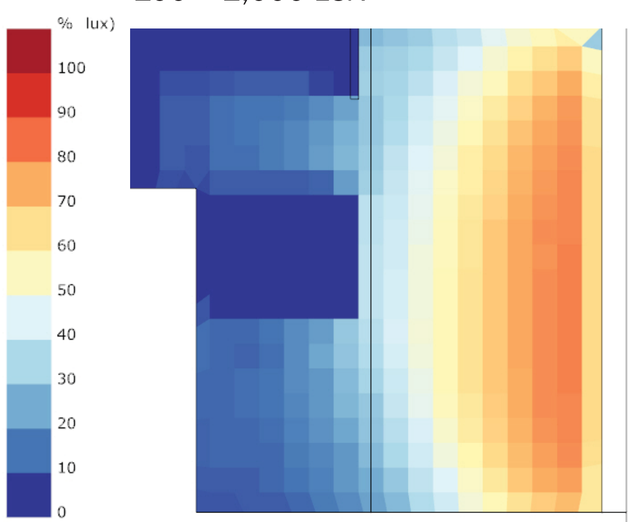




USEFUL DAYLIGHT ILLUMINANCE
< 100 LUX



USEFUL DAYLIGHT ILLUMINANCE
> 100 < 2,000 LUX



USEFUL DAYLIGHT ILLUMINANCE
> 2,000 LUX

Daylight Autonomy (DA)
Useful Daylight Illumination (UDI)
A measure of the percentage of occupied hours a point in a space receives a required illuminance threshold. This metric does not establish a range of lighting levels, only tells you how often one illuminance value is met. Thus, it is not a good measure of overlit spaces. To account for overlit spaces a variation of DA, Useful Daylight Illuminance, which establishes three thresholds: how often the illuminance on a point is below 100 lux, between 100 and 2,000 and over 2,000. UDI considers values above 2,000 lux to be in the glare or thermal discomfort.

RADIANCE PARAMETERS

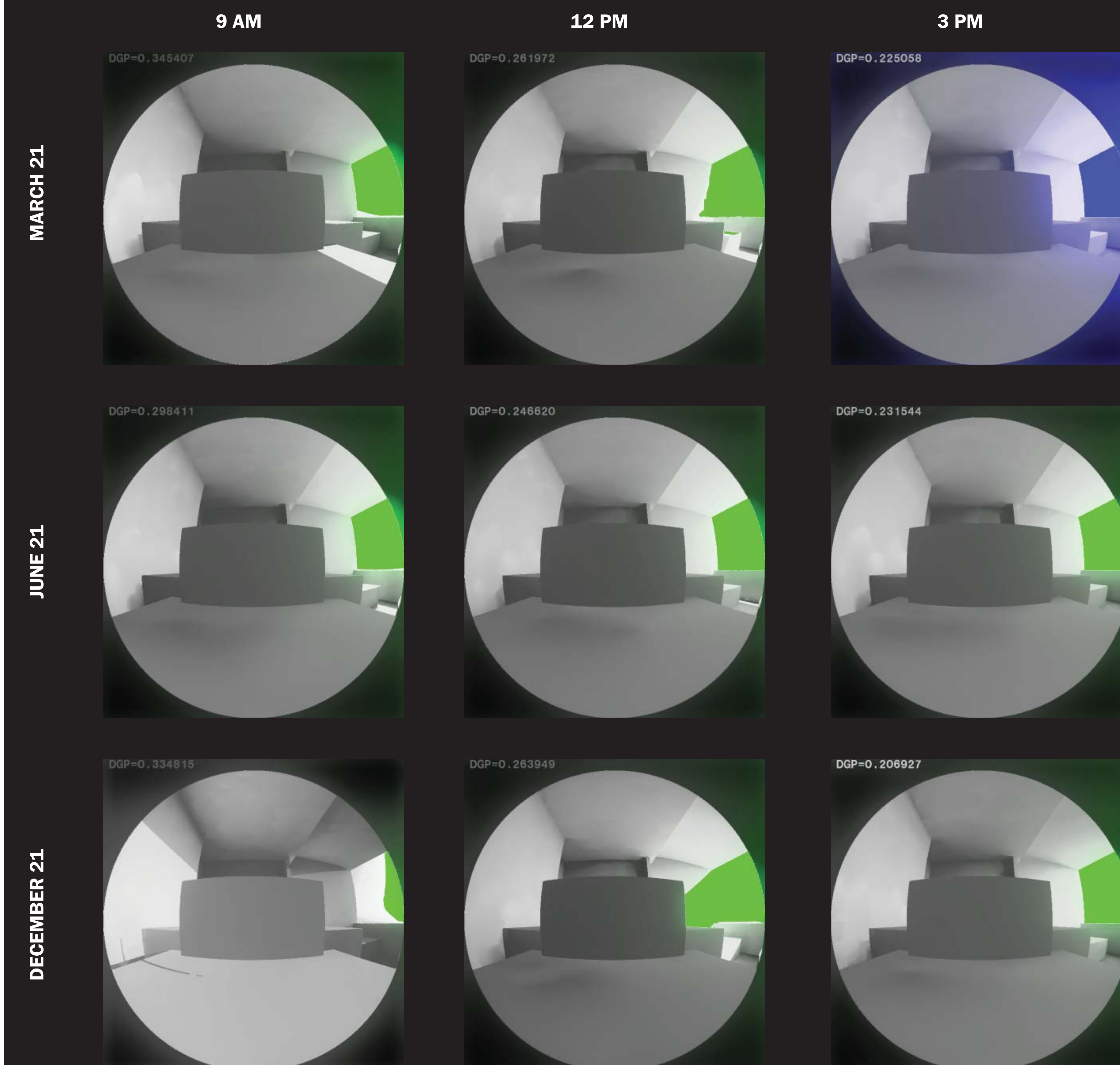
Ambient Bounces	2
Ambient Accuracy	0.2
Ambient Divisions	512
Ambient Resolution	16

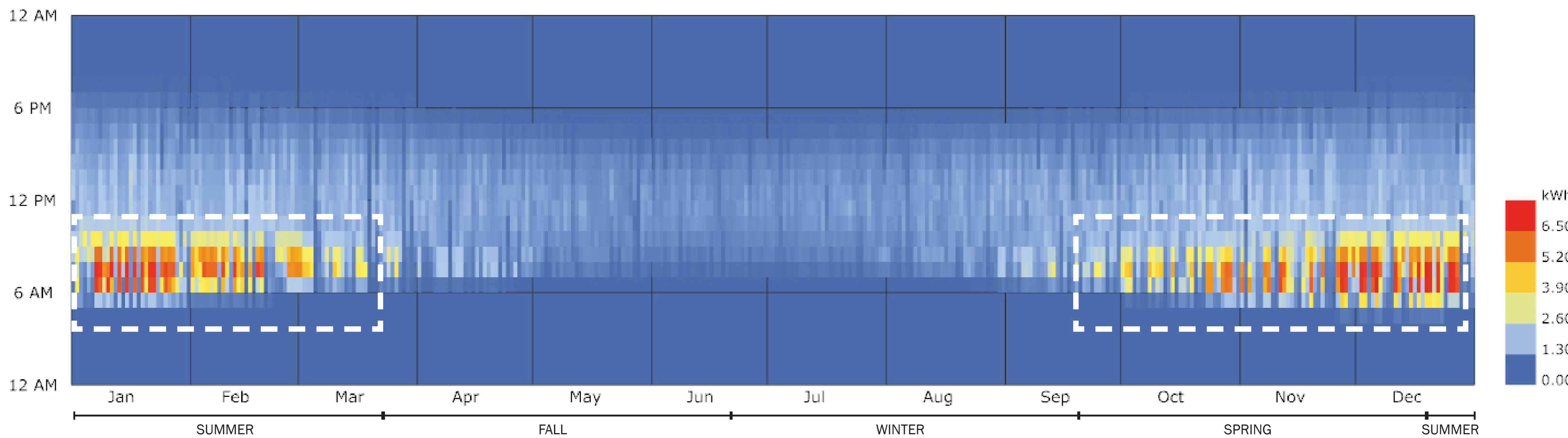
Daylight Glare Probability (DGP) Ratio
The probablilty of glare is determined on a point-by-point basis. Since there are hundreds of points possible, its important to test glare at points where it will interfere with activities. The glare analysis here is simulated for the computer desk where an occupant would be stationary and more susceptible to glare.

DGP < 0.35	Imperceptible
0.4 > DGP ≥ 0.35	Perceptible
0.45 > DGP ≥ 0.4	Disturbing
DGP ≥ 0.45	Intolerable

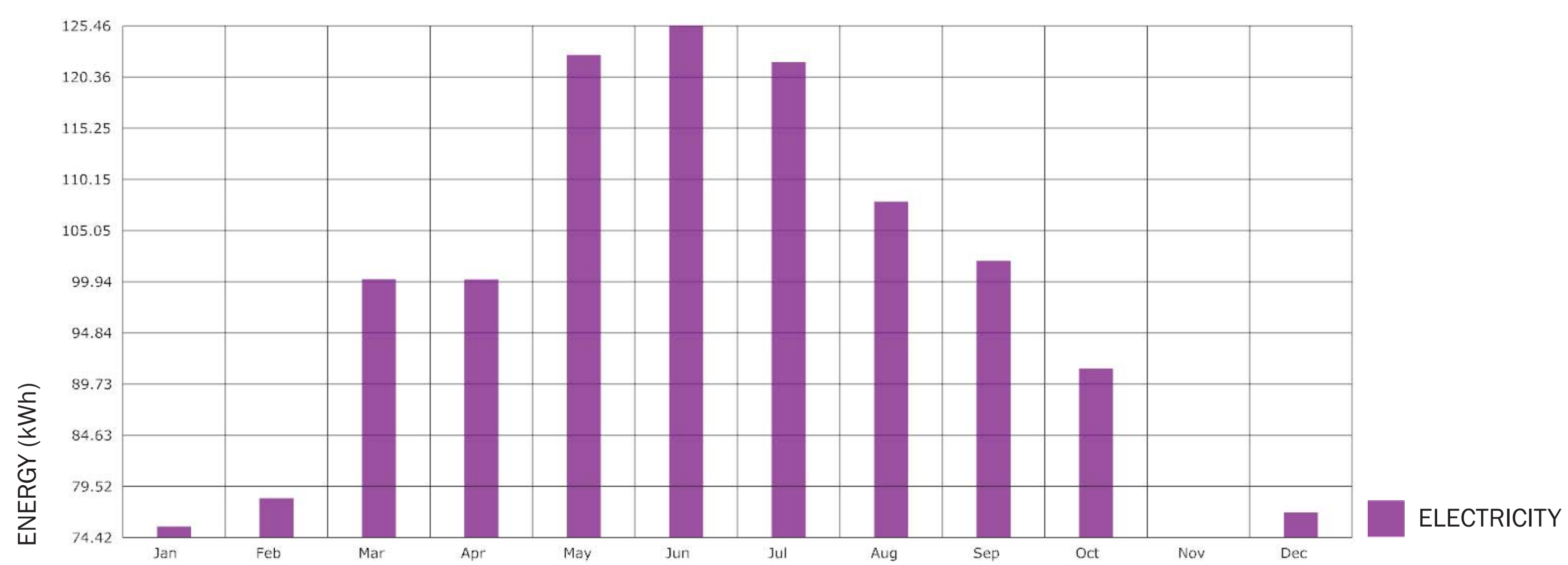
Based on the Point-in-Time analysis for the baseline case, all simulations fall in the imperceptible range. So glare does not seem to be an issue for the baseline case.

GLARE ANALYSIS

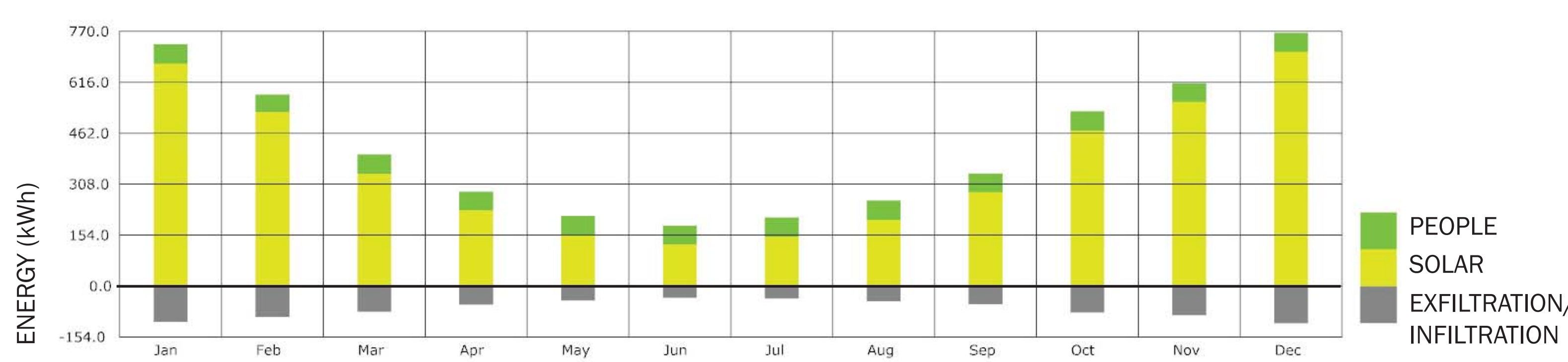




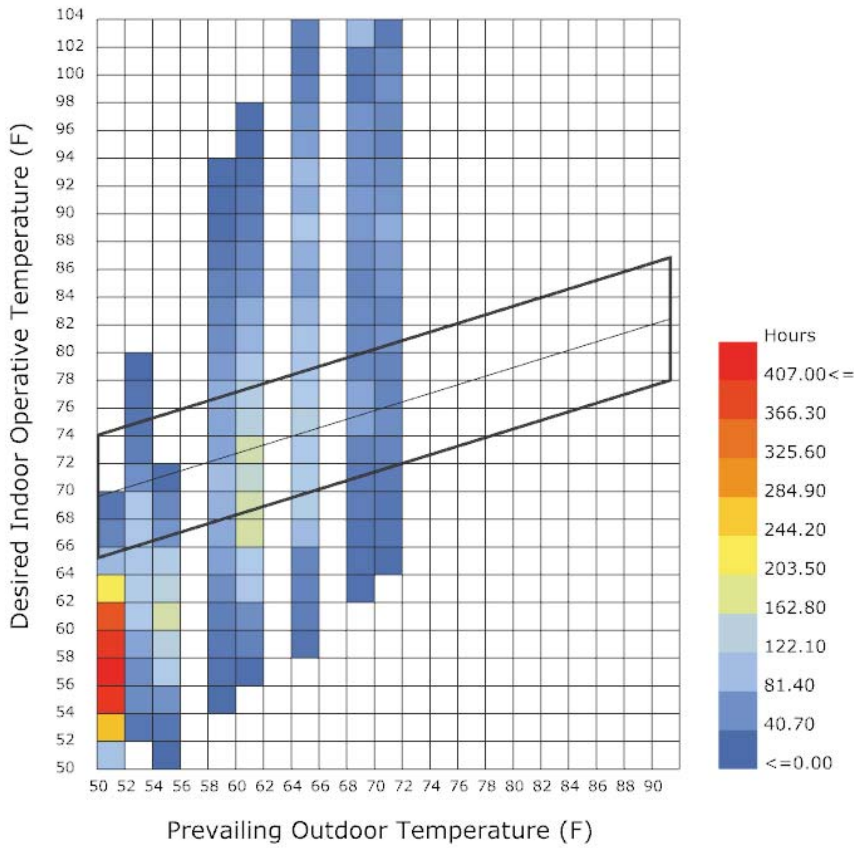
SOLAR GAIN ANNUAL CONDITIONS

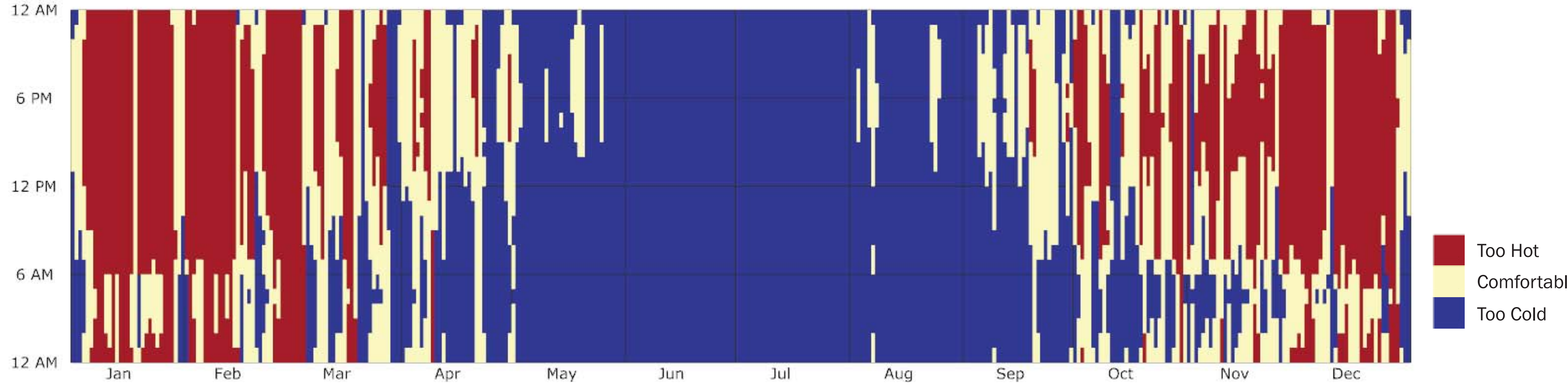


ARTIFICIAL LIGHT ENERGY USE



ENERGY LOSSES OR GAINS





ADAPTIVE COMFORT RANGE

23.7% COMFORTABLE

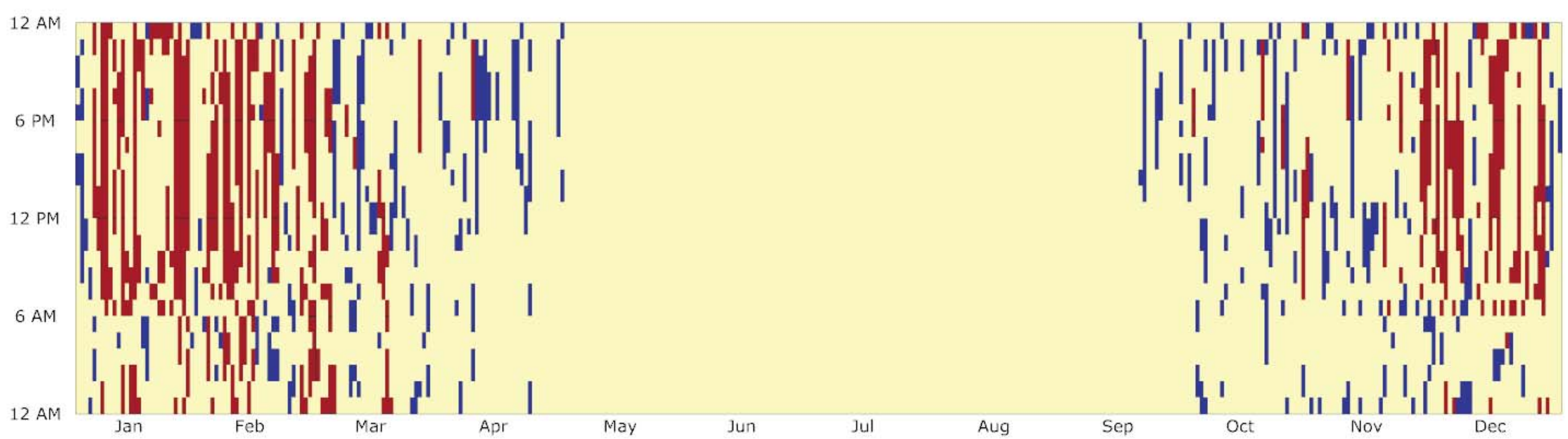
27.2% HOT

49% COLD

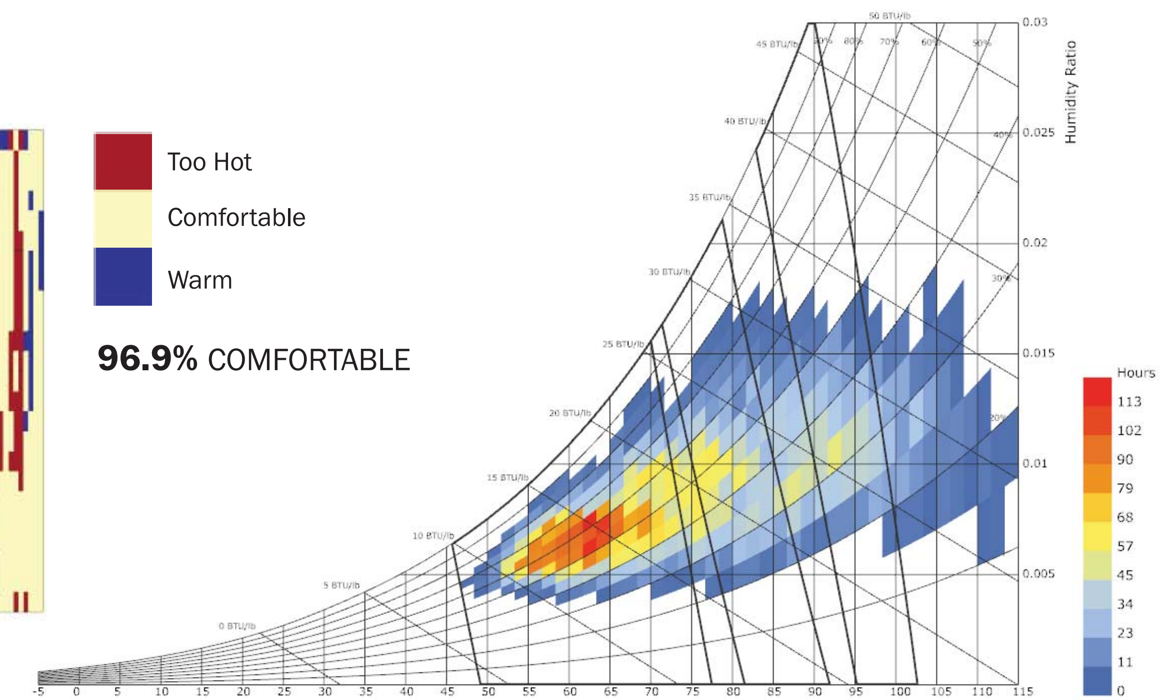
PMV PARAMETERS

Metabolic Rate	Clothing Values
0.8 Sleeping	0.5 Summer Typical
1.0 Sitting	0.75 Fall Typical
1.2 Walking About	1.0 Winter Typical
1.7 Household Tasks	

There are two prevalent comfort models in use currently, the Predicted Mean Vote (PMV) model and the Adaptive Comfort model. Both use two different means by which to measure comfort, both clearly resulting in varying levels of comfort. The PMV model takes into account human activity and clothing levels, which when aggregated on a phychrometric chart, results in a comfort level of almost 100%. But a higher level of comfort is possible while using the Adaptive Comfort model. So this report will focus on achieving a higher level of thermal comfort. Based on the Adaptive Comfort Range chart, almost 49% of the year is identified as being too cold, while approximately 27% is too cold.



96.9% COMFORTABLE

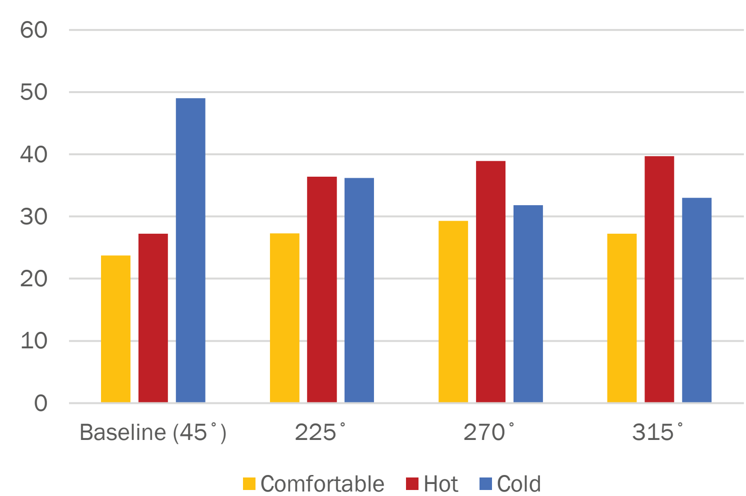


PMV COMFORT RANGE

DESIGN CONSIDERATION

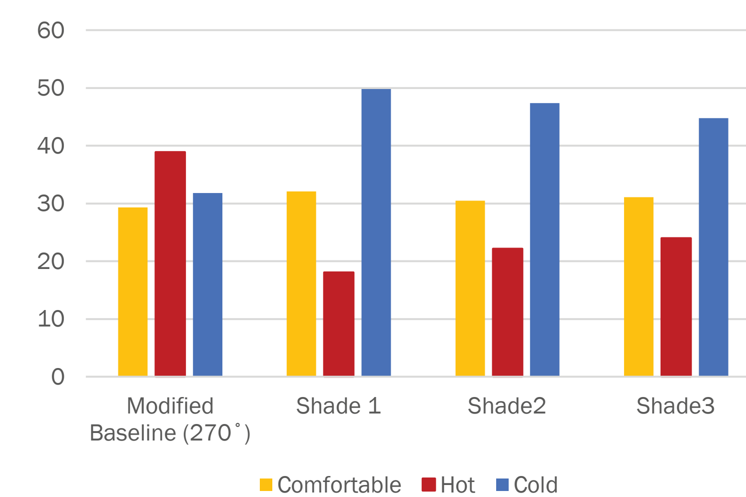
When considering passive design strategies, there are two main environmental elements that a designer should focus on, sun and wind. The design options explored in the following pages focus mainly on sunlight, followed by ventilation to increase comfort when possible. The first step involved finding the right orientation to maximize solar gain for heating in the colder periods. Then providing shade for when the solar shading will be a liabiity instead of an asset. Ventilation for comfort was the the second element to be tested. While changing construction elements was the last.

OPTIMAL ORIENTATION & SOLAR GAIN



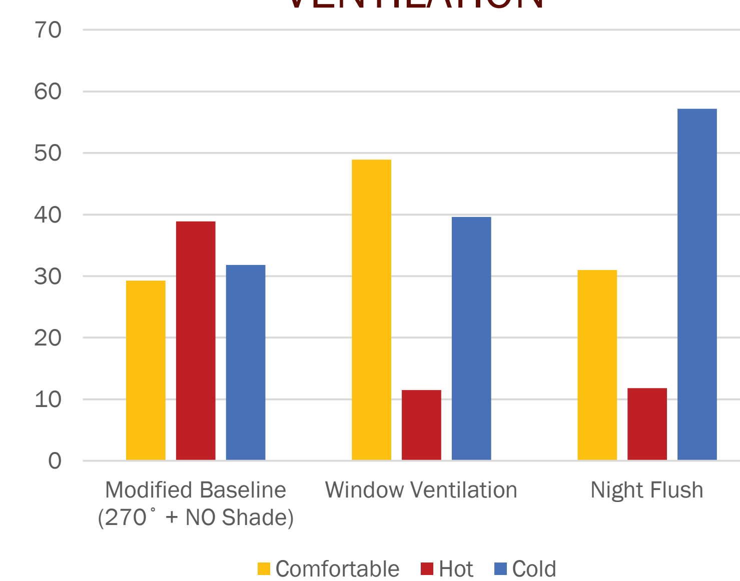
The base case had the building in a southwestern orientation, which at Melbourne's latitude means the sun was behind the buidling for most of the day. We know from climate data and from the baseline solar gain study that there is a significant time period from March to September where the building benefits from solar gain. So the three orientations tested are facing North to maximize solar gain in the room.

SHADE



By making the decision to orient the main glazed facade to the North, we run the risk of overheating in the summer. So shading will be required to block some of the summer sun. But in providing shading, the number of cold hours can increase, so let's see how ventilation helps or hurts the design before settling on a shading design.

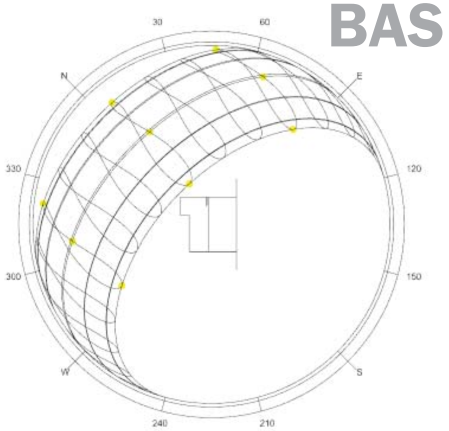
VENTILATION



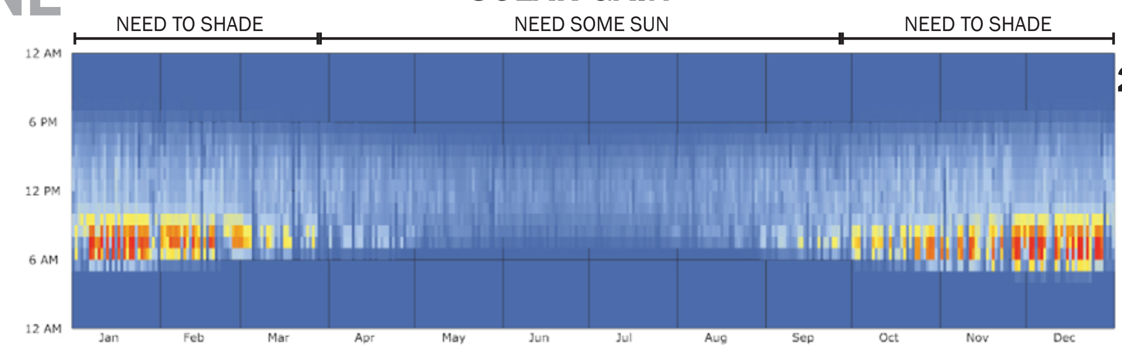
Wentilation is introduced, mainly to try and bring the hot hours down to the comfortable hours when outdoor temperatures are within a comfortable range. Since Melbourne has cooler nights, it seemed like night flushing would be a good strategy, however, the simulations showed it performing slightly worse then using windows for ventilation. Base on ventilation simulations, it is also clear that ventilation can help with the hot hours significantly and keep cold hours hours constant when there is no shade provided.

BASELINE

45°

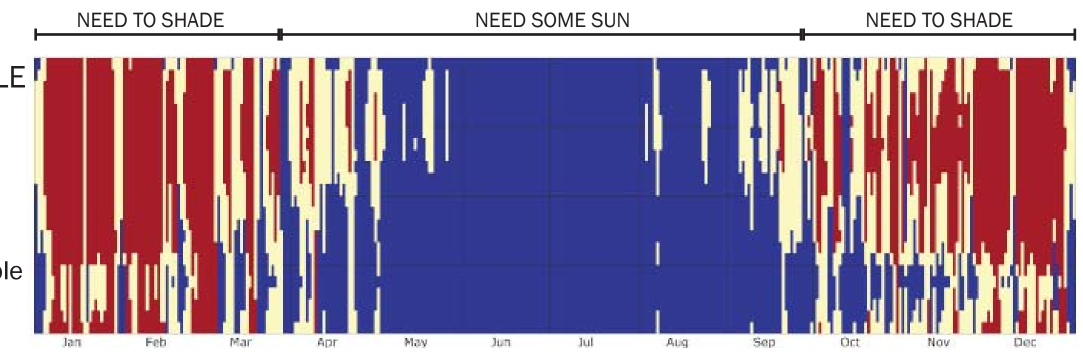


SOLAR GAIN



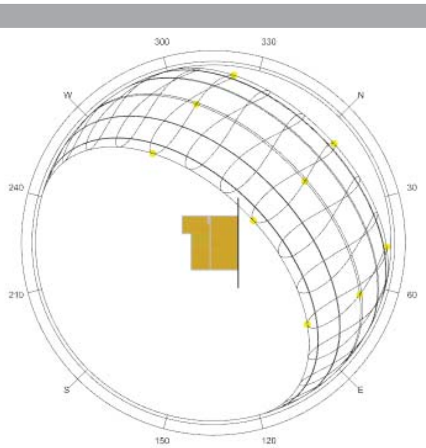
23.7% COMFORTABLE
27.2% HOT
49% COLD

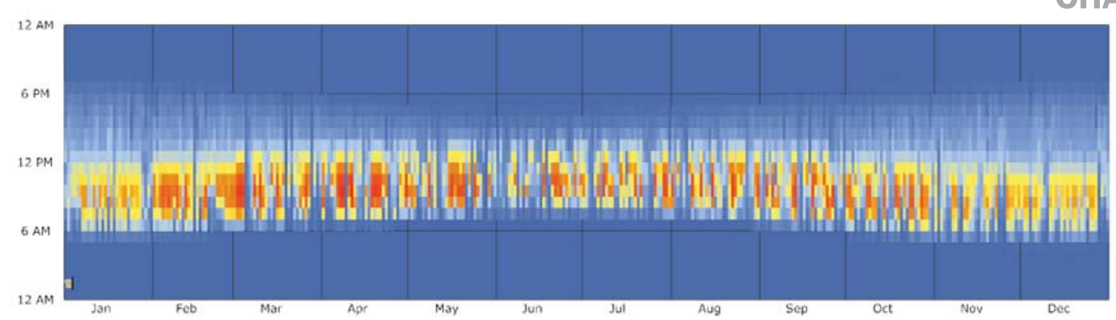
ADAPTIVE COMFORT



The baseline orientation, does not benefit from the sun in the winter months, resulting in colder temperatures in the building. So test orienting glazed facade to the south.

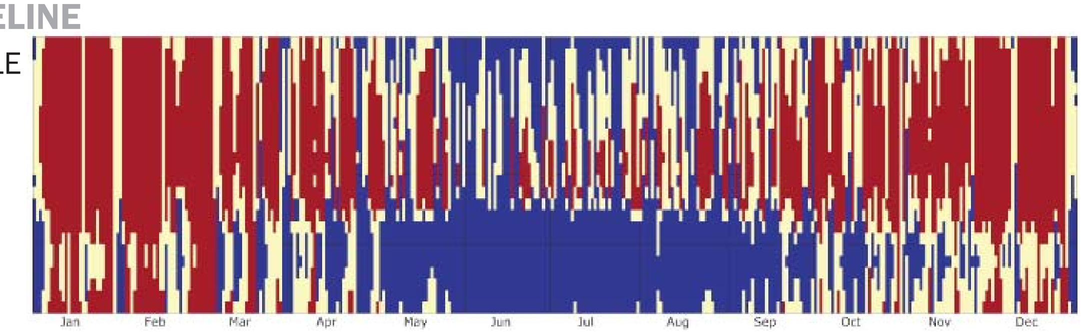
225°



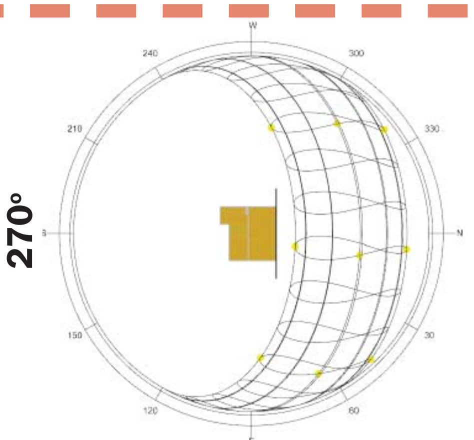


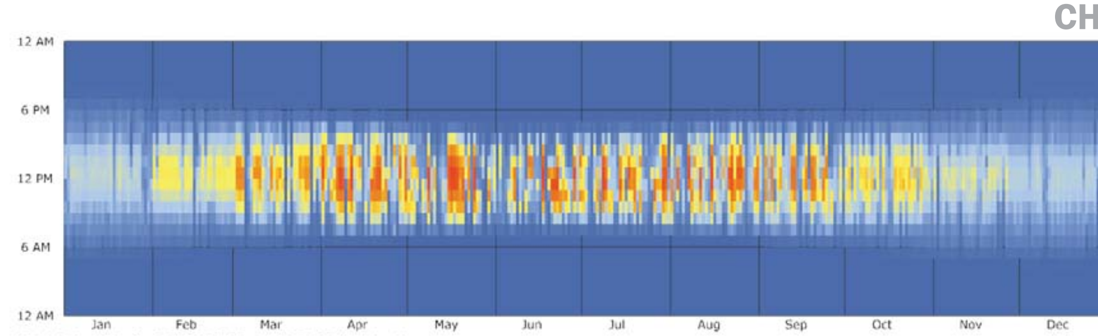
CHANGE FROM BASELINE

+15% COMFORTABLE
+34% HOT
-26% COLD



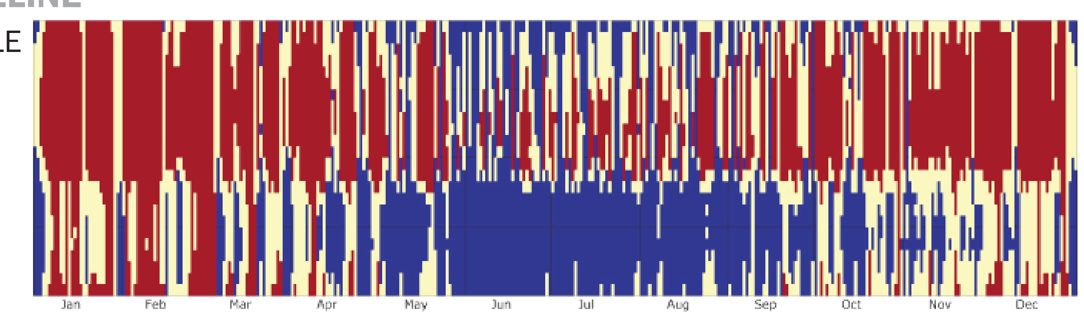
270°



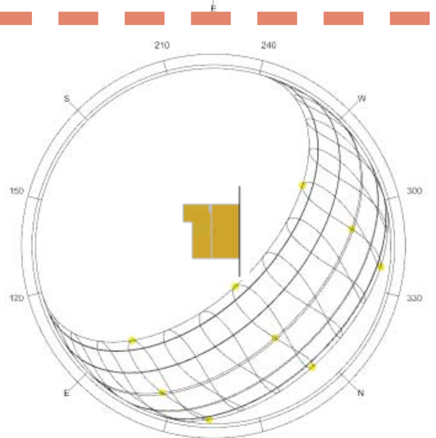


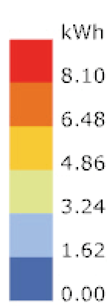
CHANGE FROM BASELINE

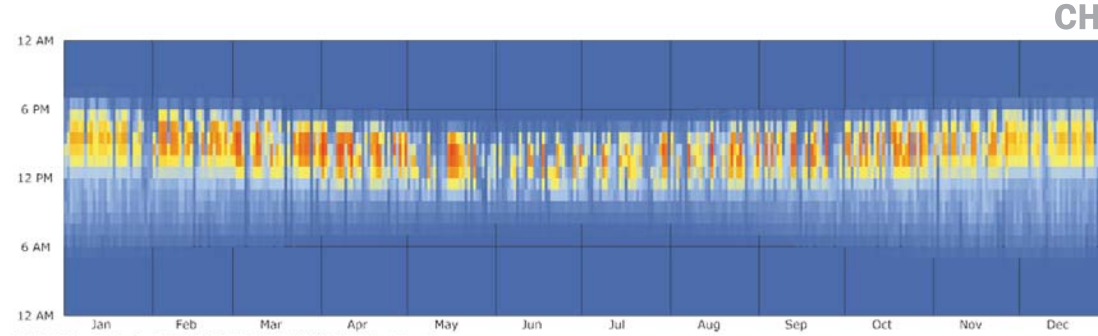
+24% COMFORTABLE
+43% HOT
-35% COLD



315°

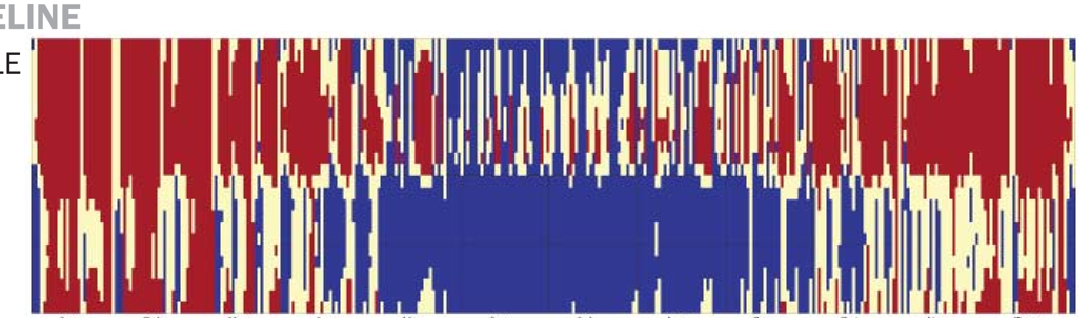






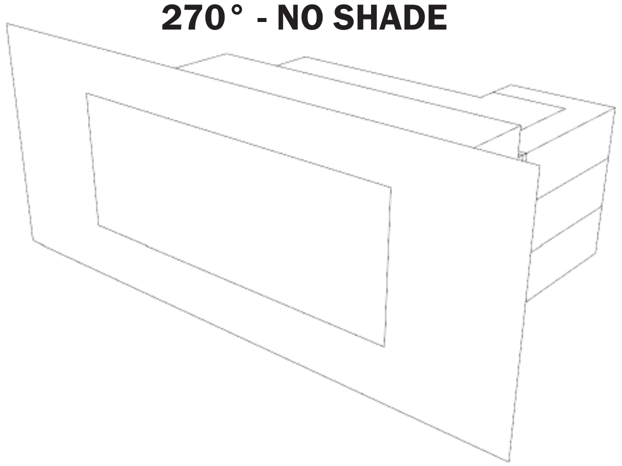
CHANGE FROM BASELINE

+15% COMFORTABLE
+46% HOT
-33% COLD

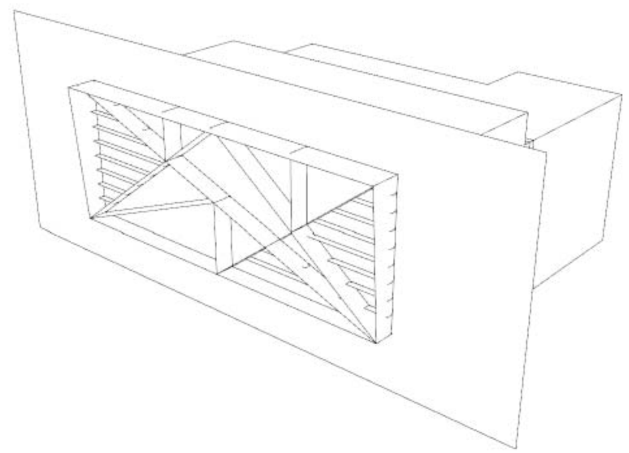


All 3 orientations increase the comfortable hours by reducing the cold hours, but there is an increase in the number of hot hours. Let's choose 270° & look into some shading.

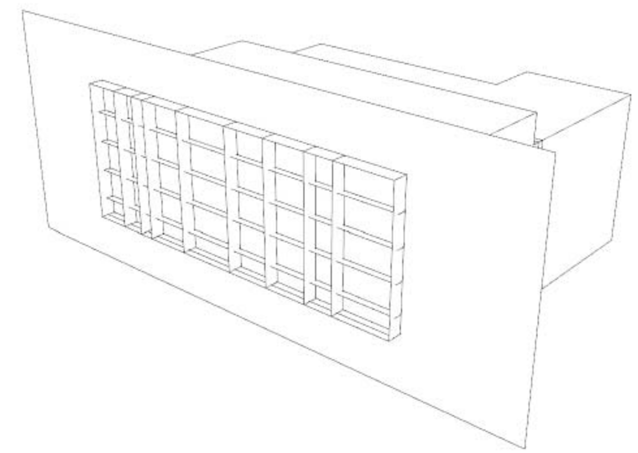
MODIFIED BASELINE
270° - NO SHADE



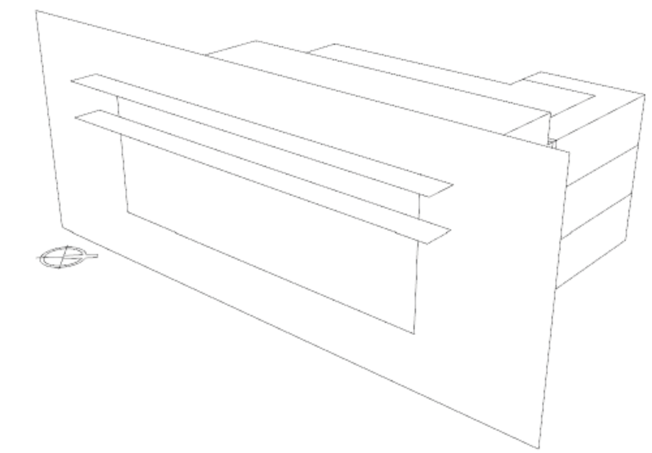
SHADE 1



SHADE 2



SHADE 3



	Modified Baseline (270˚) %	Effects of Shade 1 Comfort %	Effects of Shade 1 Change Δ	Effects of Shade2 Comfort %	Effects of Shade2 Change Δ	Effects of Shade3 Comfort %	Effects of Shade3 Change Δ
Comfortable	29.3	32.1	10%	30.5	4%	31.1	6%
Hot	38.9	18.1	-53%	22.2	-43%	24	-38%
Cold	31.8	49.8	57%	47.4	49%	44.8	41%

"adding shading makes it much colder compared to the optimal rotation"

VENTILATION CONDITIONAL STATEMENT

Since ventilation is only effective with certain outdoor conditions, the simulations used to assess the effectivness of two ventilation strategies used different conditional statements for weather conditions that would result in effective ventilation, as follows:

Window Ventilation	Night Flush
75°F (Min Indoor)	68°F (Min Indoor)
82°F (Max Outdoor)	75°F (Max Outdoor)

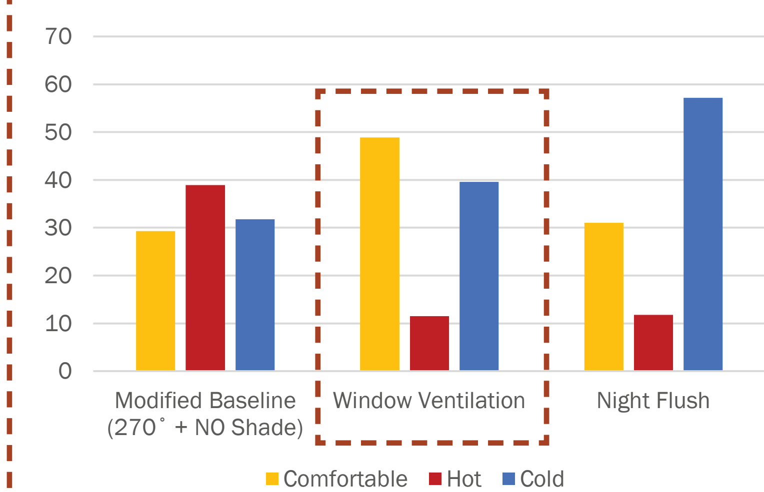
	Modified Baseline (270˚+ No Shade)	Window Ventilation Comfort %	Window Ventilation Change Δ	Night Flush Comfort %	Night Flush Change Δ
Comfortable	29.3	48.9	67%	31	6%
Hot	38.9	11.5	-70%	11.8	-70%
Cold	31.8	39.6	25%	57.2	80%

	Modified Baseline (270˚ + Shade 1)	Window Ventilation Comfort %	Window Ventilation Change Δ	Night Flush Comfort %	Night Flush Change Δ
Comfortable	32.1	40.3	26%	22.7	-29%
Hot	18.1	6.1	-66%	6.7	-63%
Cold	49.8	53.6	8%	70.6	42%

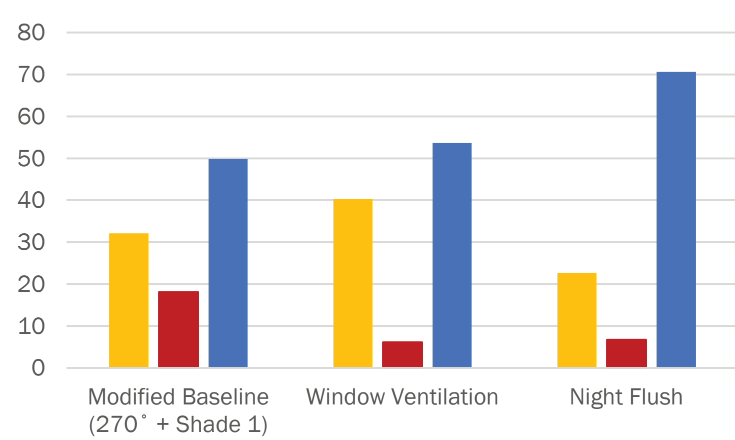
	Modified Baseline (270˚ + Shade 2)	Window Ventilation Comfort %	Window Ventilation Change Δ	Night Flush Comfort %	Night Flush Change Δ
Comfortable	30.5	41.3	35%	24.6	-19%
Hot	22.2	6.8	-69%	7.6	-66%
Cold	47.4	51.8	9%	67.8	43%

	Modified Baseline (270˚ + Shade 3)	Window Ventilation Comfort %	Window Ventilation Change Δ	Night Flush Comfort %	Night Flush Change Δ
Comfortable	31.1	43.2	35%	26.5	-15%
Hot	24.1	7.3	-60%	7.8	-68%
Cold	44.8	49.5	-1%	65.7	47%

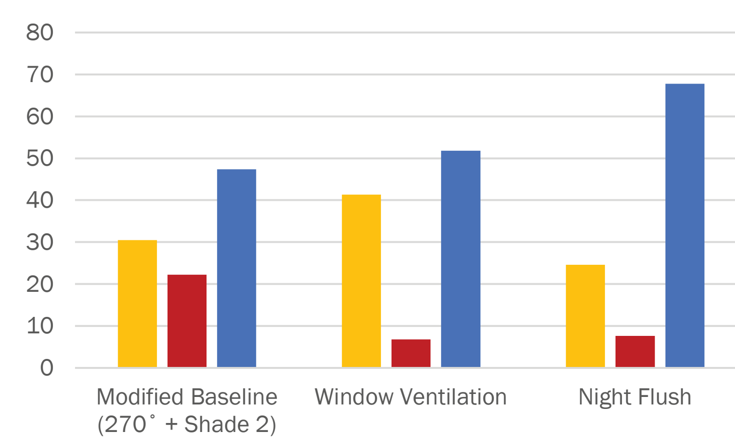
MODIFIED BASELINE w VENTILATION



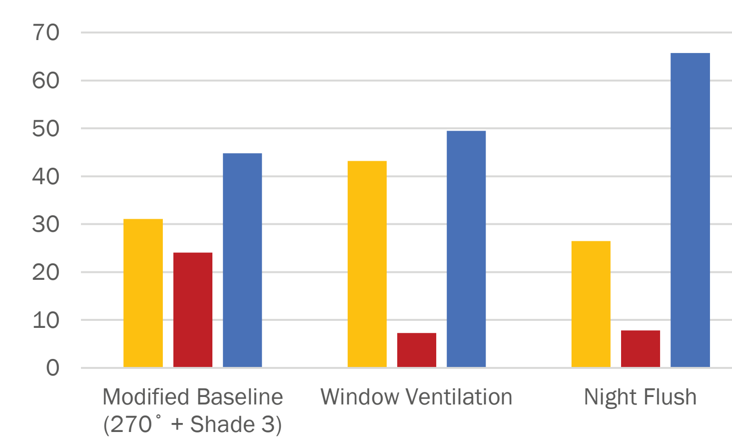
SHADE 1 w VENTILATION



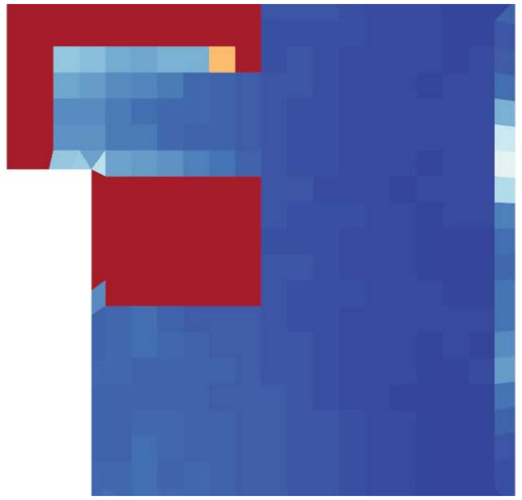
SHADE 2 w VENTILATION



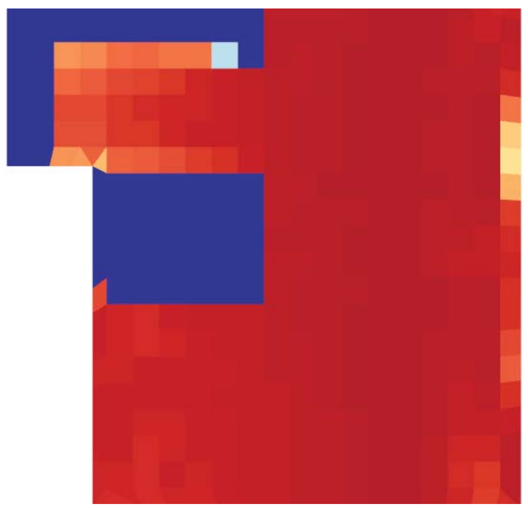
SHADE 3 w VENTILATION



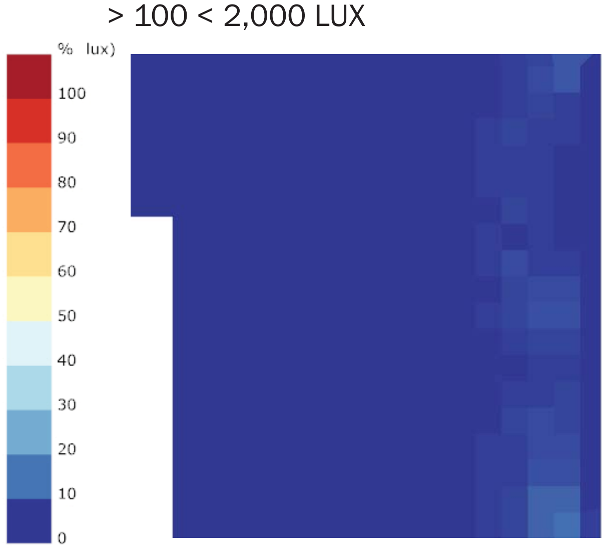
"adding ventilation makes it colder, but helps tremendously with the heat"



USEFUL DAYLIGHT ILLUMINANCE
< 100 LUX



USEFUL DAYLIGHT ILLUMINANCE
> 100 < 2,000 LUX



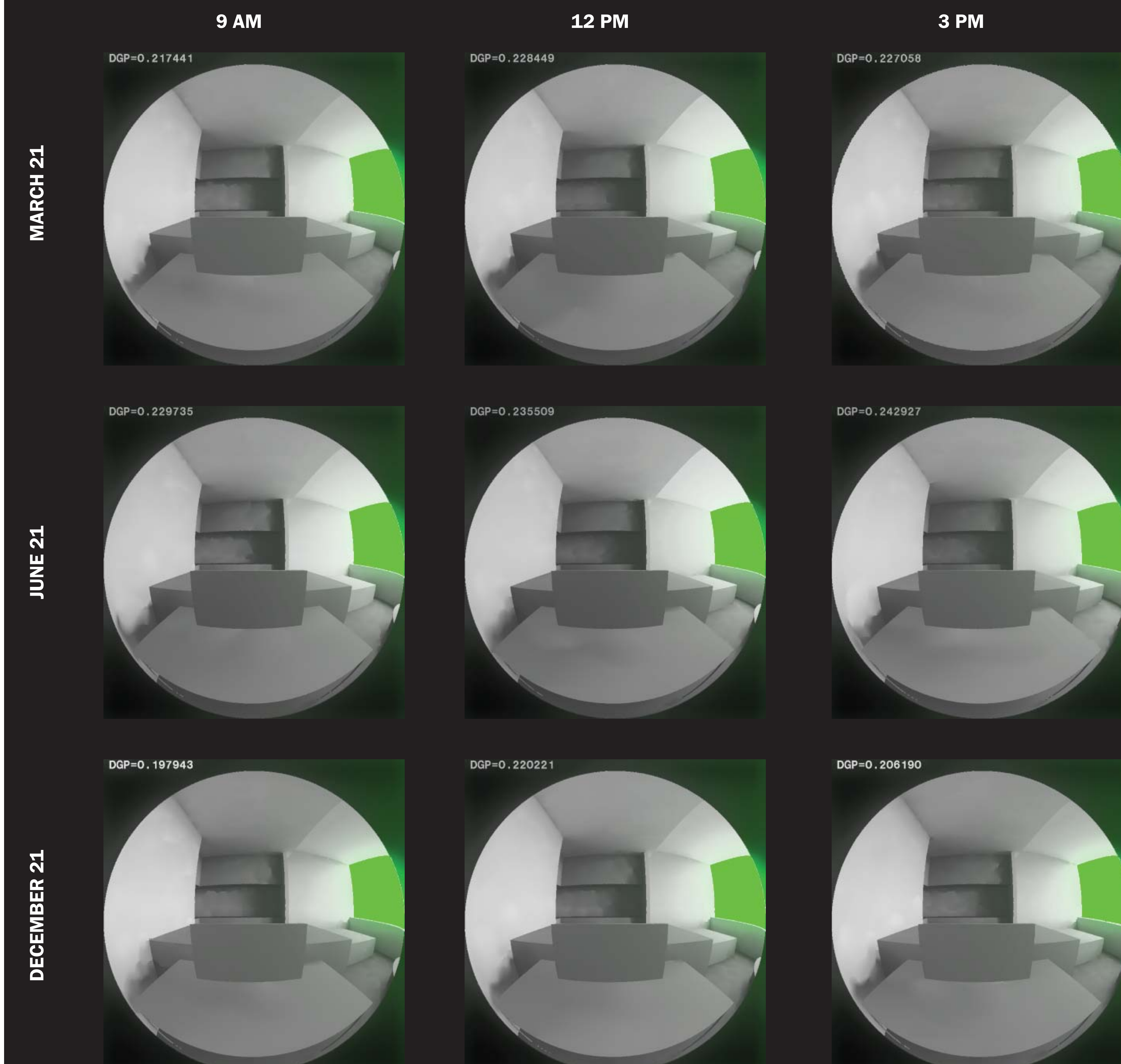
USEFUL DAYLIGHT ILLUMINANCE
> 2,000 LUX

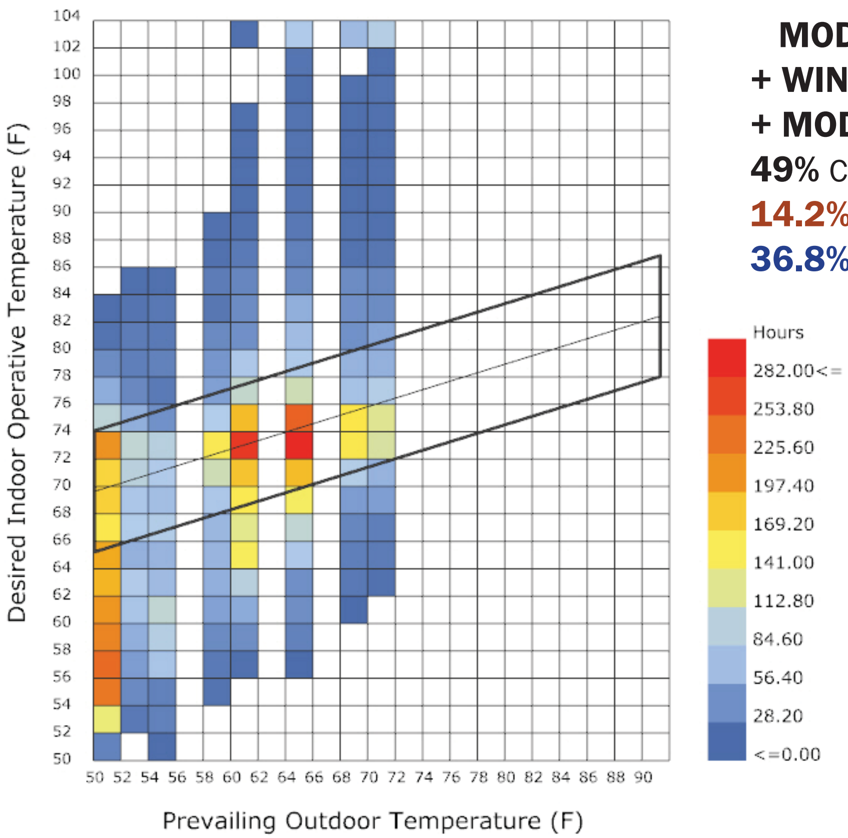
RADIANCE PARAMETERS

Ambient Bounces	2
Ambient Accuracy	0.2
Ambient Divisions	512
Ambient Resolution	16

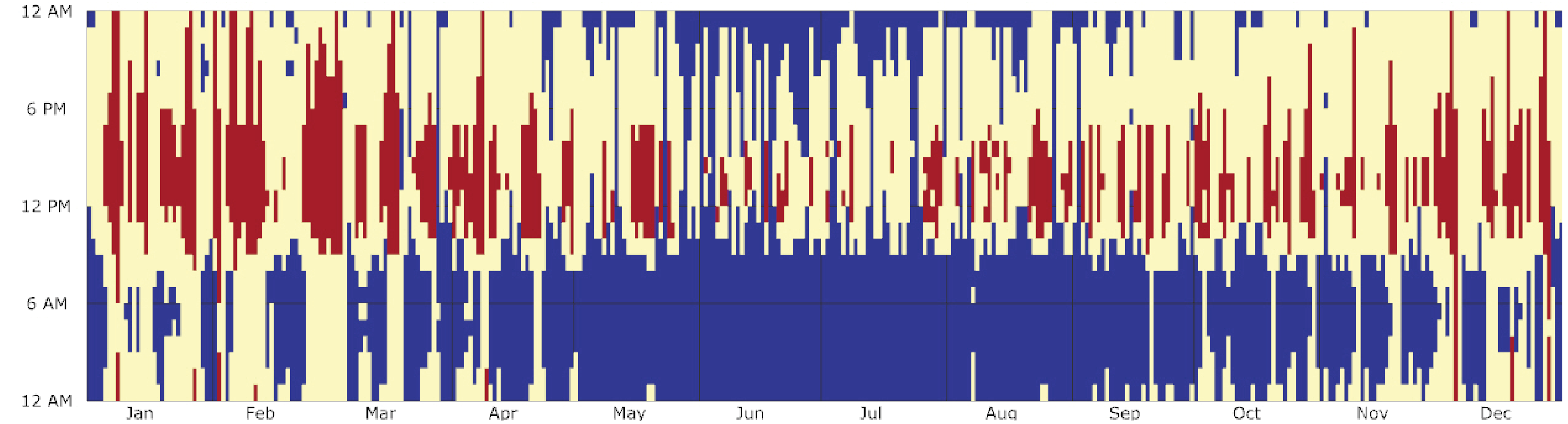
DGP < 0.35	Imperceptible
0.4 > DGP ≥ 0.35	Perceptible
0.45 > DGP ≥ 0.4	Disturbing
DGP ≥ 0.45	Intolerable

GLARE ANALYSIS





MODIFIED BASELINE
+ WINDOW VENTILATION
+ MODIFIED CONSTRUCTION
49% COMFORTABLE
14.2% HOT
36.8% COLD



ADAPTIVE COMFORT

After running several different scenarios, orientations and shading devices, indoor temperatures in the residential building are only able to be maintained at temperatures close to outdoor comfort hours simulated using the Universal Climate Temperature Index (UTCI).

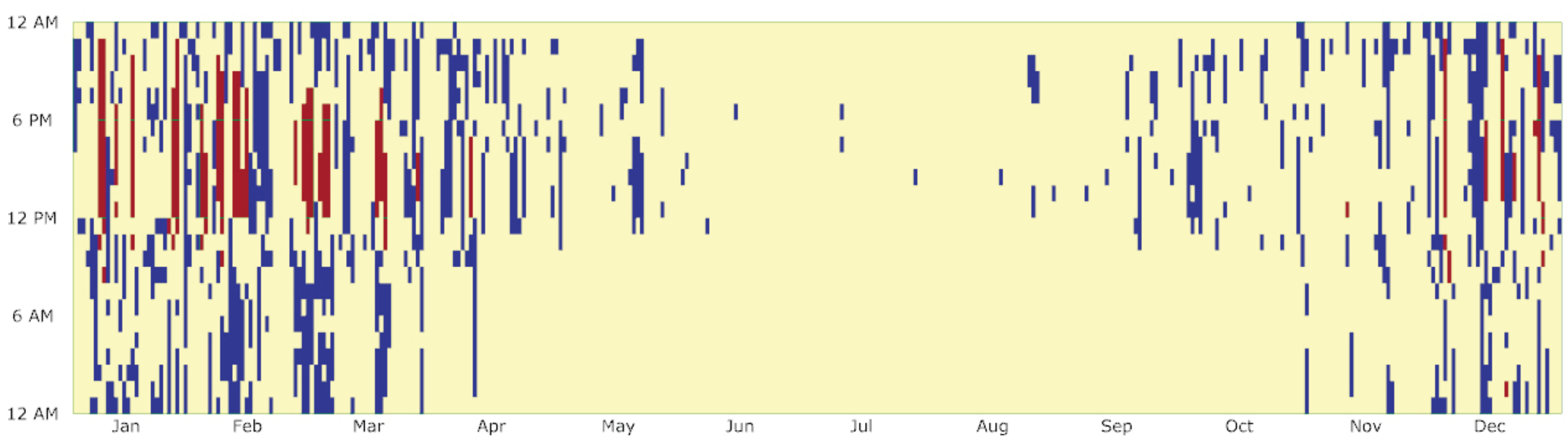
Some iterations considered for improvement but not shown here for clarity included testing multiple construction types. Decreasing and increasing ventilation temperature conditional statements for minimum and maximum interior and exterior temperature values.

Where I think there could be some benefit to the nighttime and early morning cold periods is improvement with the air tightness rate of the building. This is an area that I am not familiar with simulating, but from prior experience, this can help in cold climates.

Nonetheless, when the final iterative design is compared to the PMV comfort range calculator, the results show comfort above 100%. Which requires some additional investigation but does point to the fact that a higher degree is possible.

"...finally adjusting the building construction resulted in an increase of hot hours"

WALL CONSTRUCTION	ROOF CONSTRUCTION	FLOOR CONSTRUCTION
ASHRAE 90.1-2010	ASHRAE 189.1	ASHRAE 189.1
MASS ALT RES	METAL ROOF	ATTIC FLOOR



PMV COMFORT

MODIFIED BASELINE
+ WINDOW VENTILATION
+ MODIFIED CONSTRUCTION
109% COMFORTABLE