DREAM ROOM DESIGN PROJECT

Samantha Aguilar
ARCH 753: Building Performance Simulation
Fall 2016
Penn Design
University of Pennsylvania

PHILADELPHIA, PENNSYLVANIA
LATITUDE 39.87 | LONGITUDE -75.23

CLIMATE ANALYSIS: To maximize the comfort of the Dream Room, we must look at the climate within which the apartment is located. The climate context informs us of the conditions needed for cooling, heating and designing a proper daylight modification. The apartment is located in Philadelphia, Pennsylvania. There are prescriptive requirements for residential buildings in Pennsylvania to guarantee a minimum comfort level that I've included on this page.
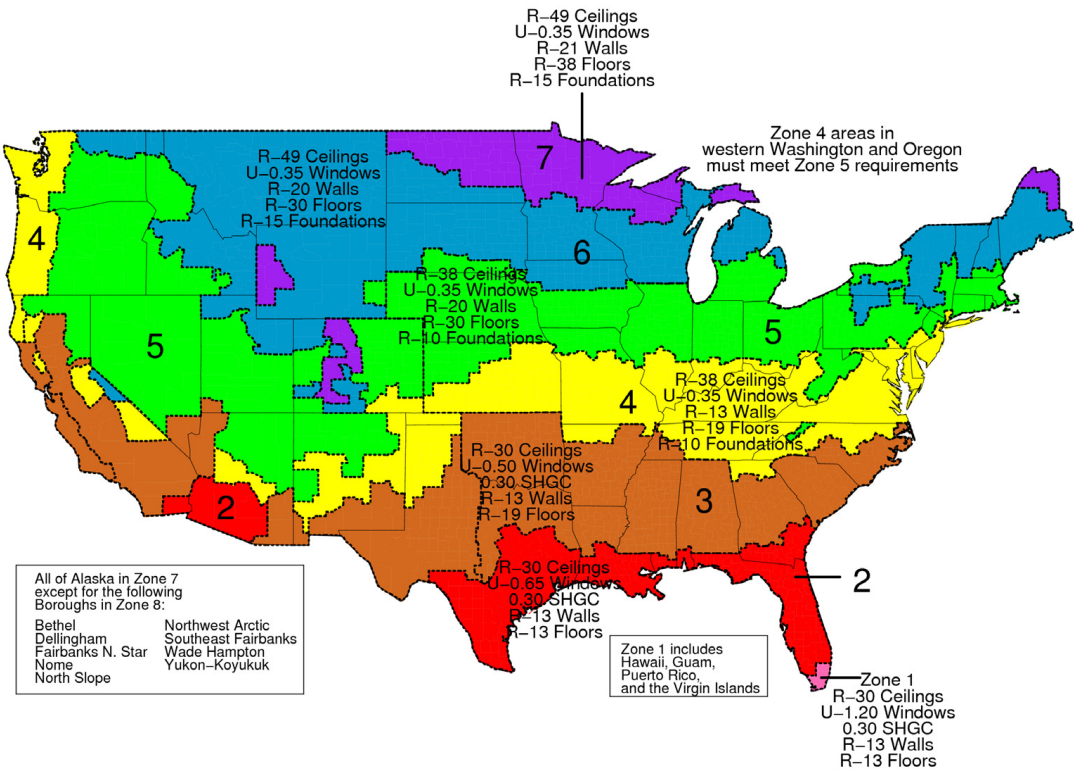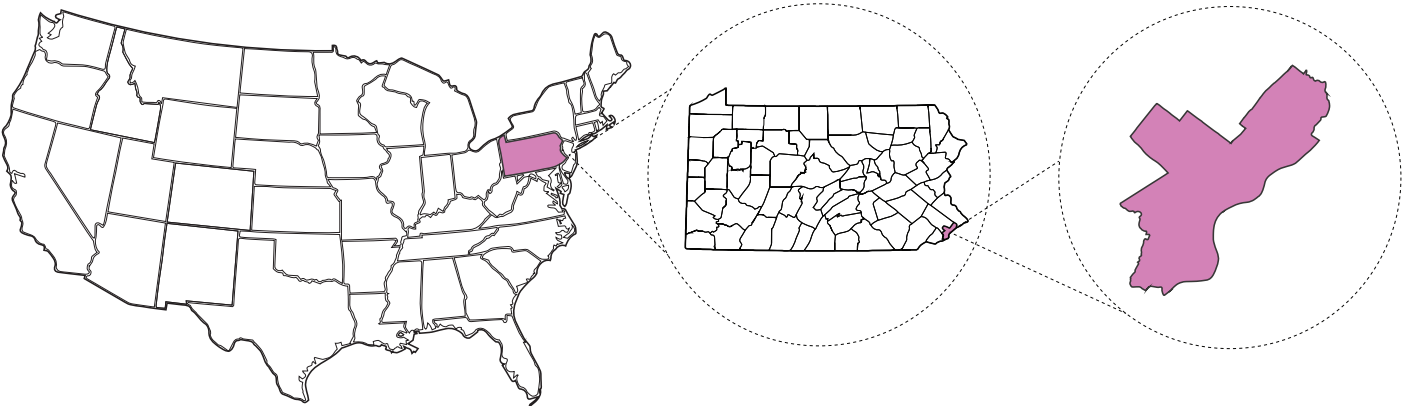

**Figure PA201.1
Pennsylvania Climate Zones**

Figure 1. **Prescriptive Envelope requirements**

Table PA301
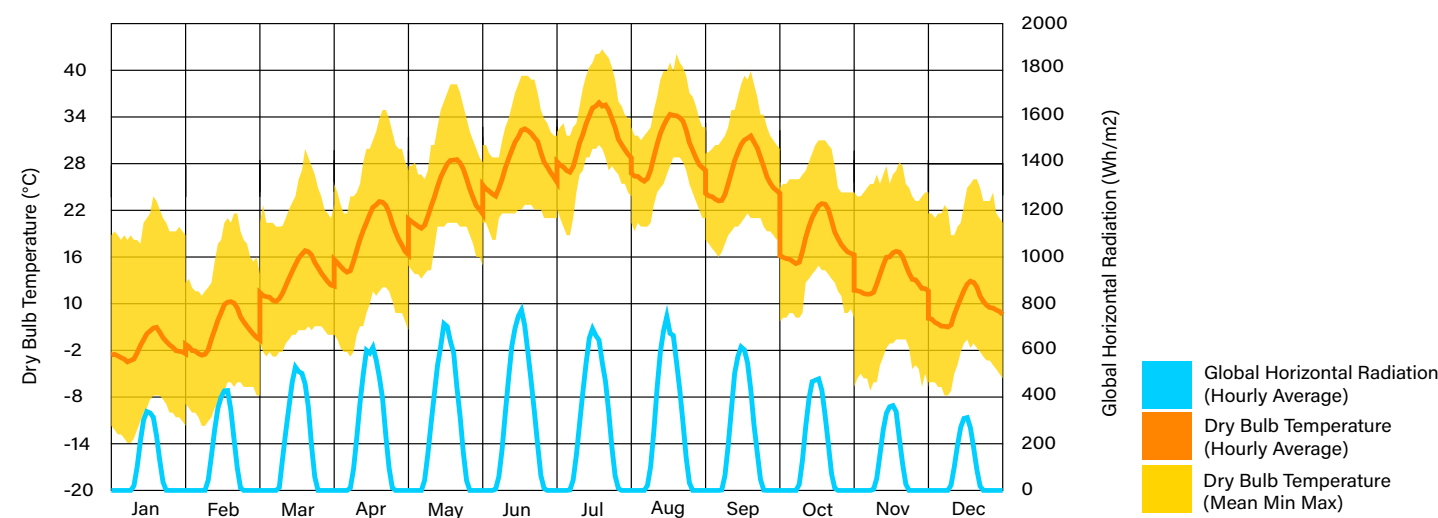Insulation and Fenestration Requirements by Component [a]

Climate Zone	Fenestration U-factor	Skylights[b] U-factor	Ceiling R-value	Wood frame wall R-value	Mass Wall R-value[h]	Floor R-value	Basement[c] wall R-value	Slab[d] R-value and depth	Crawlspace[c] wall R-value
South	0.35	0.60	38	13	5/10	19	10/13	10, 2 ft	10/13
Central	0.35	0.60	38	20[e] or 13 + 5[g]	13/17	30[f]	10/13	10, 2 ft	10/13
North	0.35	0.60	49	20[e] or 13 + 5[g]	15/19	30[f]	15/19	10, 4 ft	10/13

ZONE 4 MINIMUM REQUIREMENTS: Philadelphia, Pennsylvania is located in Zone 4 of the US Department of Energy's categorization of minimum requirements for residential buildings.
Source: "Impacts of the 2009 IECC for Residential Buildings at State Level." *US Department of Energy*. September 2009. Web. https://www.energycodes.gov/sites/default/files/documents/Residential_Pennsylvania_0.pdf

SOUTH ZONE MINIMUM REQUIREMENTS: Philadelphia is located in the South Climate Zone of the Pennsylvania State categorization of minimum requirements for residential buildings.
Source: "Pennsylvania's Alternative Residential Energy Provisions" *Pennsylvania Housing Research/ Resource Center*. 2009. Web. https://www.energycodes.gov/sites/default/files/documents/PA_residential_alternative_2009.pdf
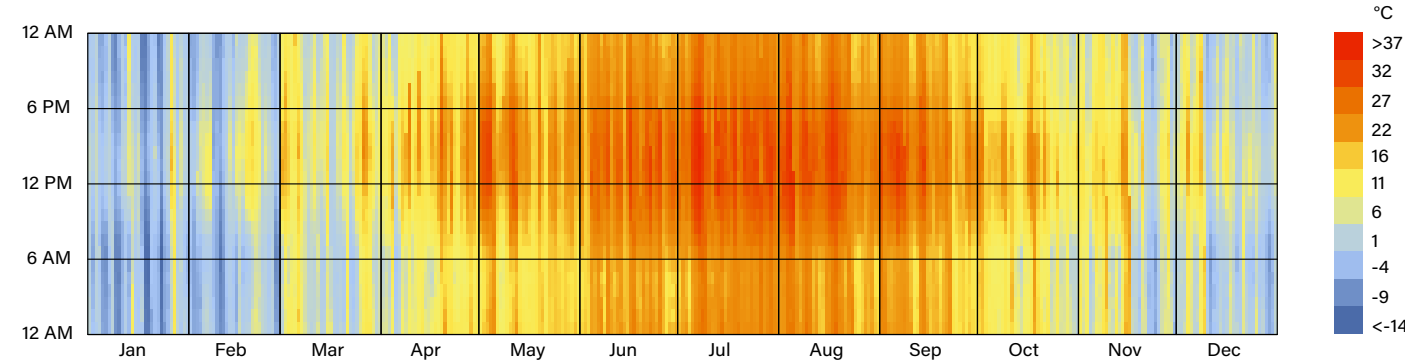
CLIMATE ANALYSIS

UNIVERSAL THERMAL COMFORT INDEX (UTCI): UTCI is a measure of the multiple factors that make up the thermal environment (dry-bulb temperature, relative humidity, wind speed & direction, solar radiation, etc.) relative to the human body to determine conditions with which we can determine comfort. We start our assessment by looking at the external climate within which the Dream Room is located.
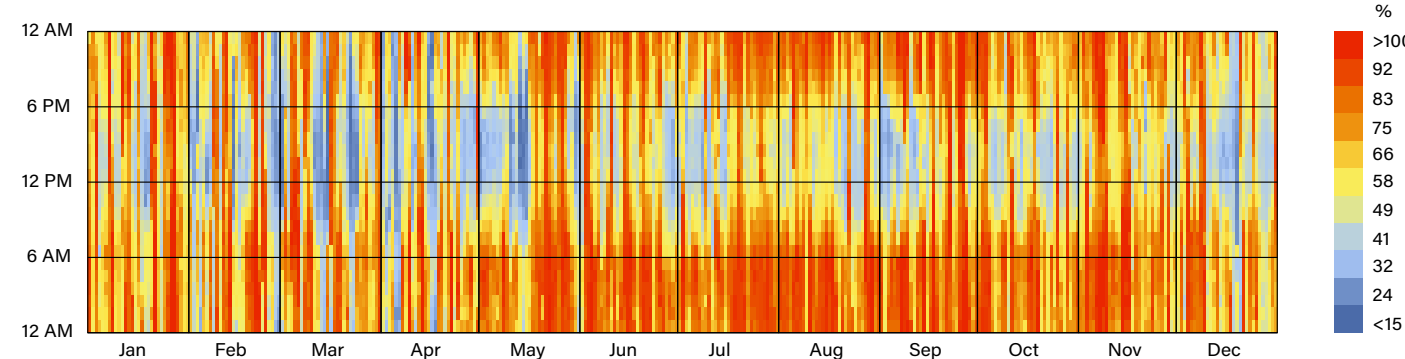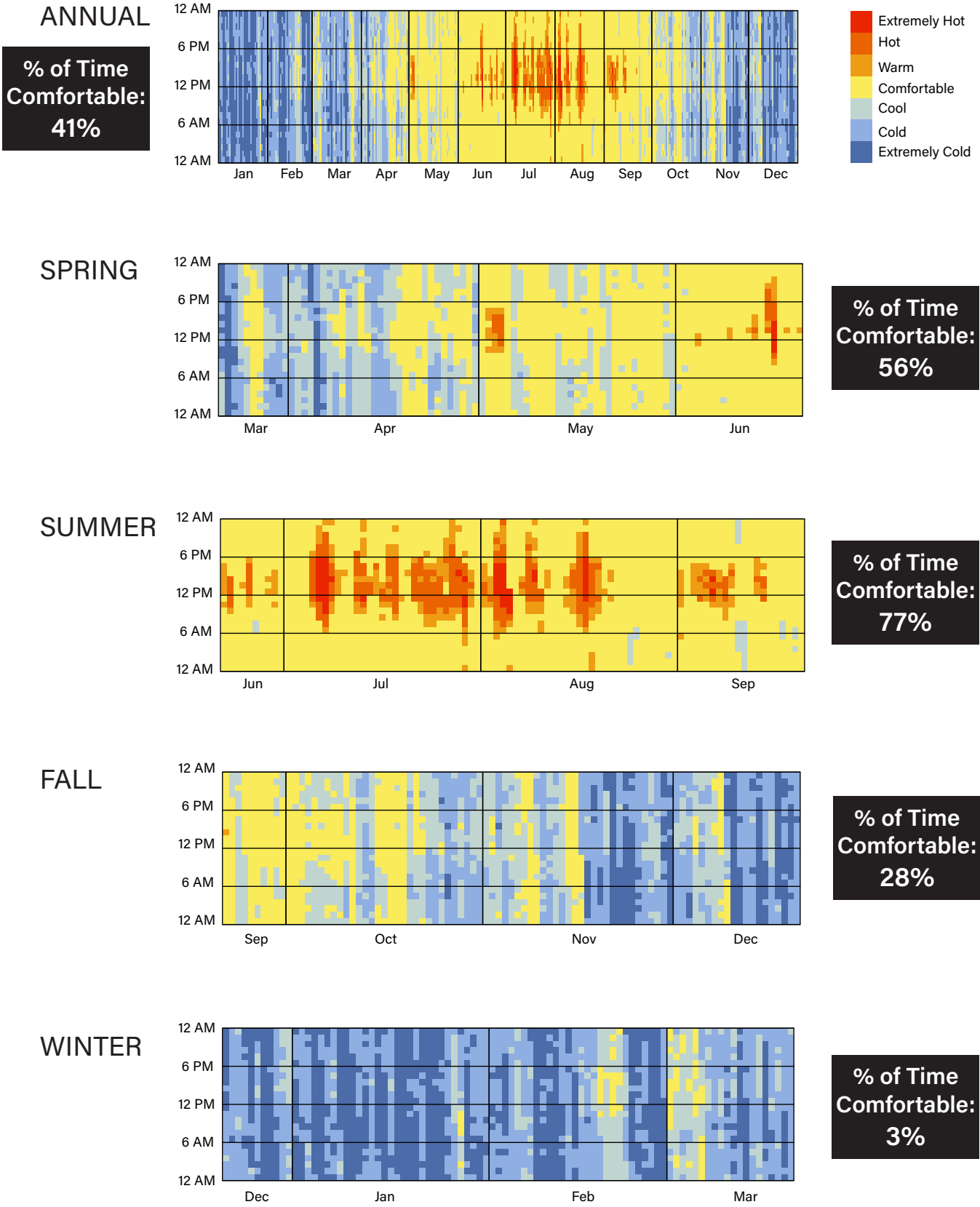
MONTHLY MEAN MIN-MAX TEMPERATURE

Global Horizontal Radiation (Hourly Average)

Dry Bulb Temperature (Hourly Average)

Dry Bulb Temperature (Mean Min Max)

DRY-BULB TEMPERATURE

°C
>37
32
27
22
16
11
6
1
-4
-9
<-14

RELATIVE HUMIDITY

%
>100
92
83
75
66
58
49
41
32
24
<15

UTCI RELATIVE TO COMFORT ANNUAL & BY SEASON

ANNUAL

% of Time Comfortable: 41%

Extremely Hot
Hot
Warm
Comfortable
Cool
Cold
Extremely Cold

SPRING

% of Time Comfortable: 56%

SUMMER

% of Time Comfortable: 77%

FALL

% of Time Comfortable: 28%

WINTER

% of Time Comfortable: 3%

SOLAR RADIATION   Amount of sun received in Philadelphia by season by intensity and direction.

SPRING   SUMMER   FALL   WINTER

kWh/m2
>247
222
197
173
148
123
99
74
49
25
0
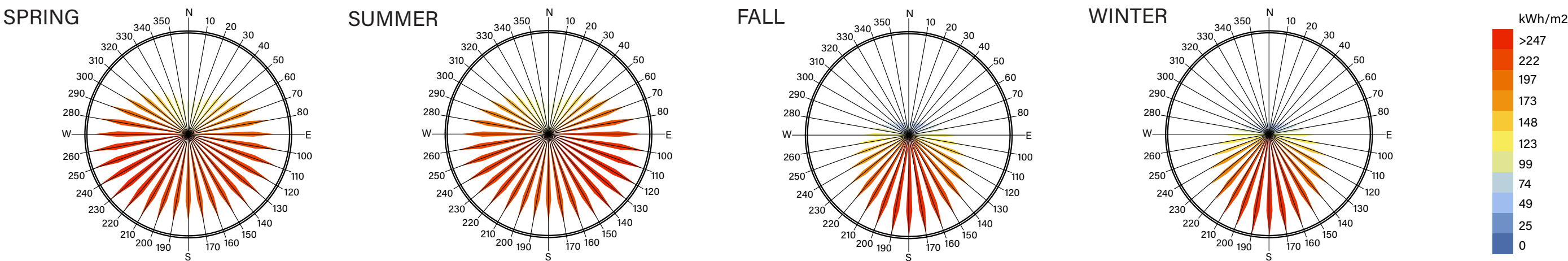
WIND SPEED & DIRECTION   Wind speed and direction in Philadelphia by meters per second.

SPRING   SUMMER   FALL   WINTER

m/s
18
16
14
13
11
9
7
5
4
2
0
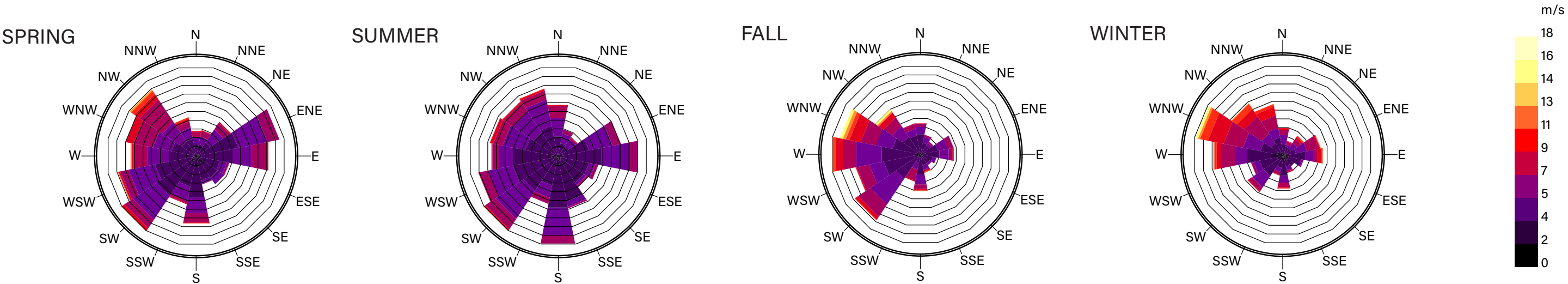
SKY COVER   Percentage of annual cloud cover in Philadelphia by hour.

%
100
90
80
70
60
50
40
30
20
10
0
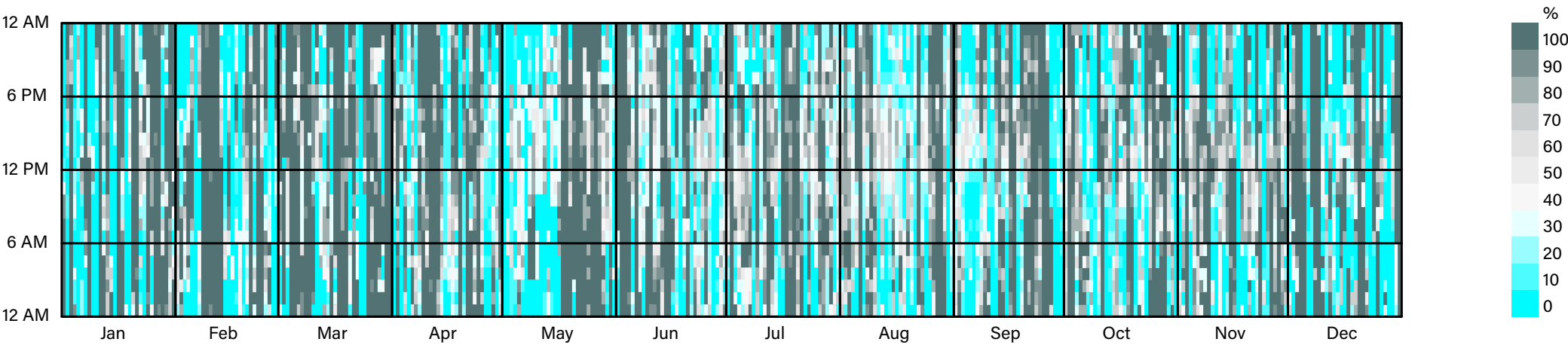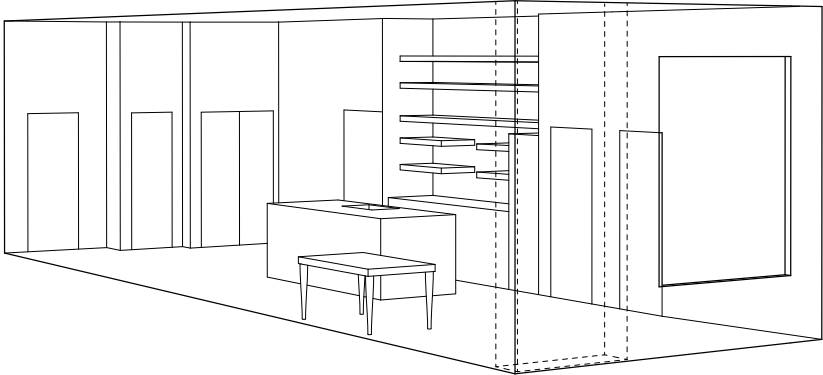
Dream Room Analysis: The blue highlighted region in the plan below (left) shows the area of the apartment most used, especially for studying, and for which conditions could be improved for increased comfort and productivity. The main problems with the space are shown in the diagrams below. For each problem I offer a potential solution to be tested in the following building performance simulations. The end result is to create a room with maximum comfort conditions; a "dream room."


PROBLEM: Daylight from the living room window (south-facing) does not reach the back of the apartment. The back of the apartment requires the need for electric lighting even during the day.

PROBLEM: The HVAC system located on the south-west corner of the apartment blocks the light coming in from the window. This limits light to the rest of the apartment as well as making the corner too dark for reading.

PROBLEM: Natural cross-ventilation does not occur between the windows on the south facade. Instead, air flow occurs between the windows and the hallway of the apartment building, which is not conditioned well.
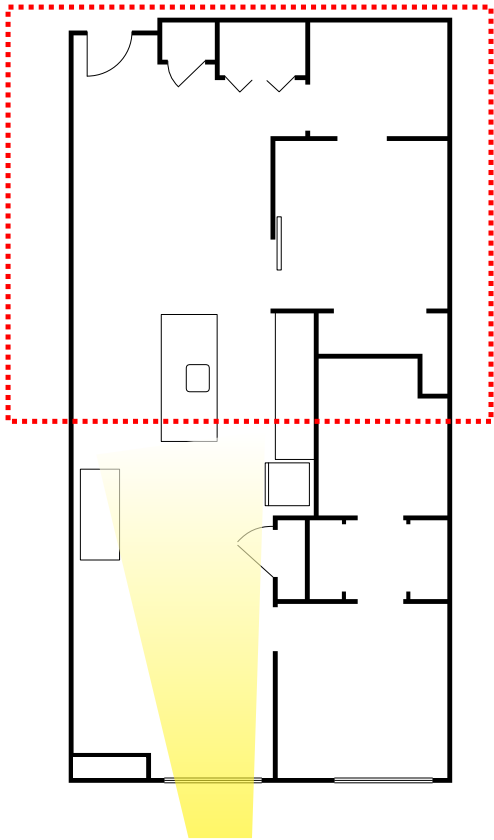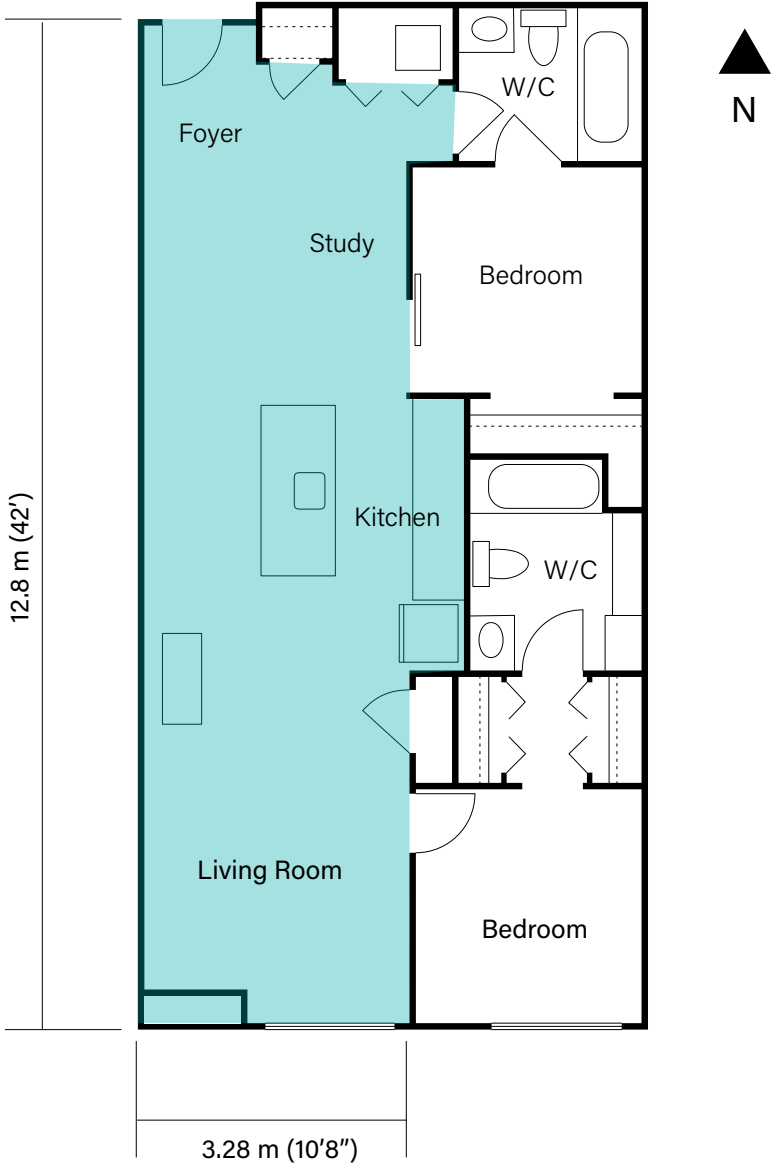
POTENTIAL SOLUTION: Add a light shelf to take advantage of the reflectivity of the ceiling to potentially draw light further into the apartment.
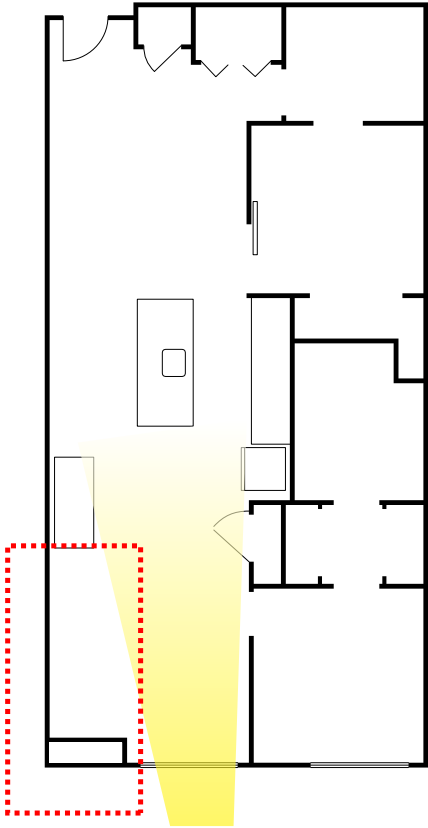
POTENTIAL SOLUTION: Add a louver to the right side of the window to try to reflect light into the corner
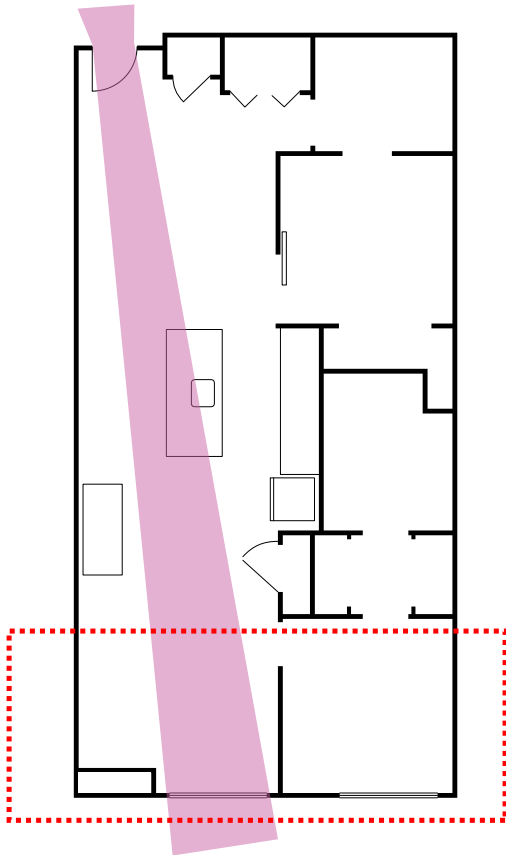
POTENTIAL SOLUTION: Increase air flow within the apartment by sealing the space underneath the door, this will block air from the hallway into the apartment. Decreasing infiltration may help the HVAC system ventilate the space better.
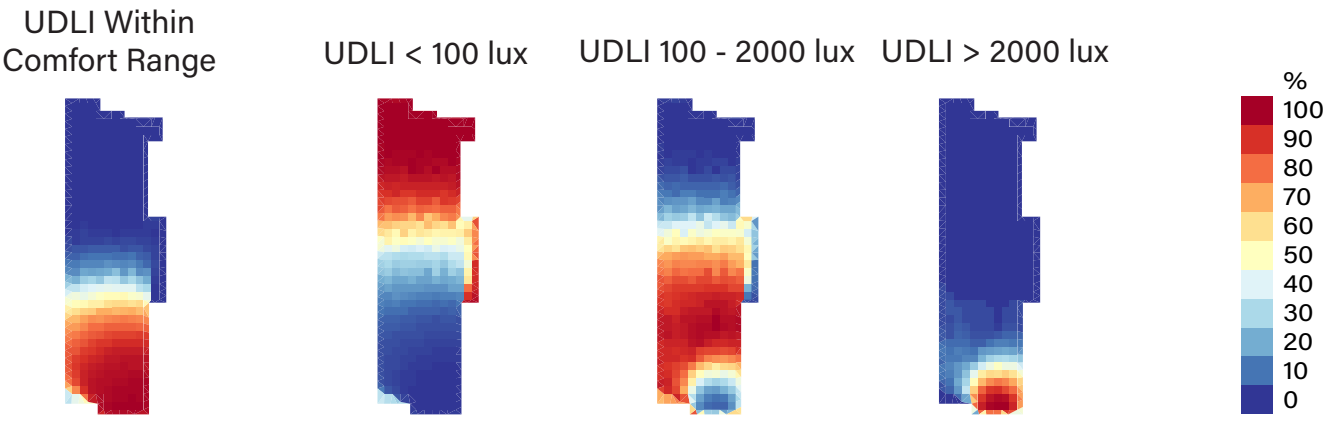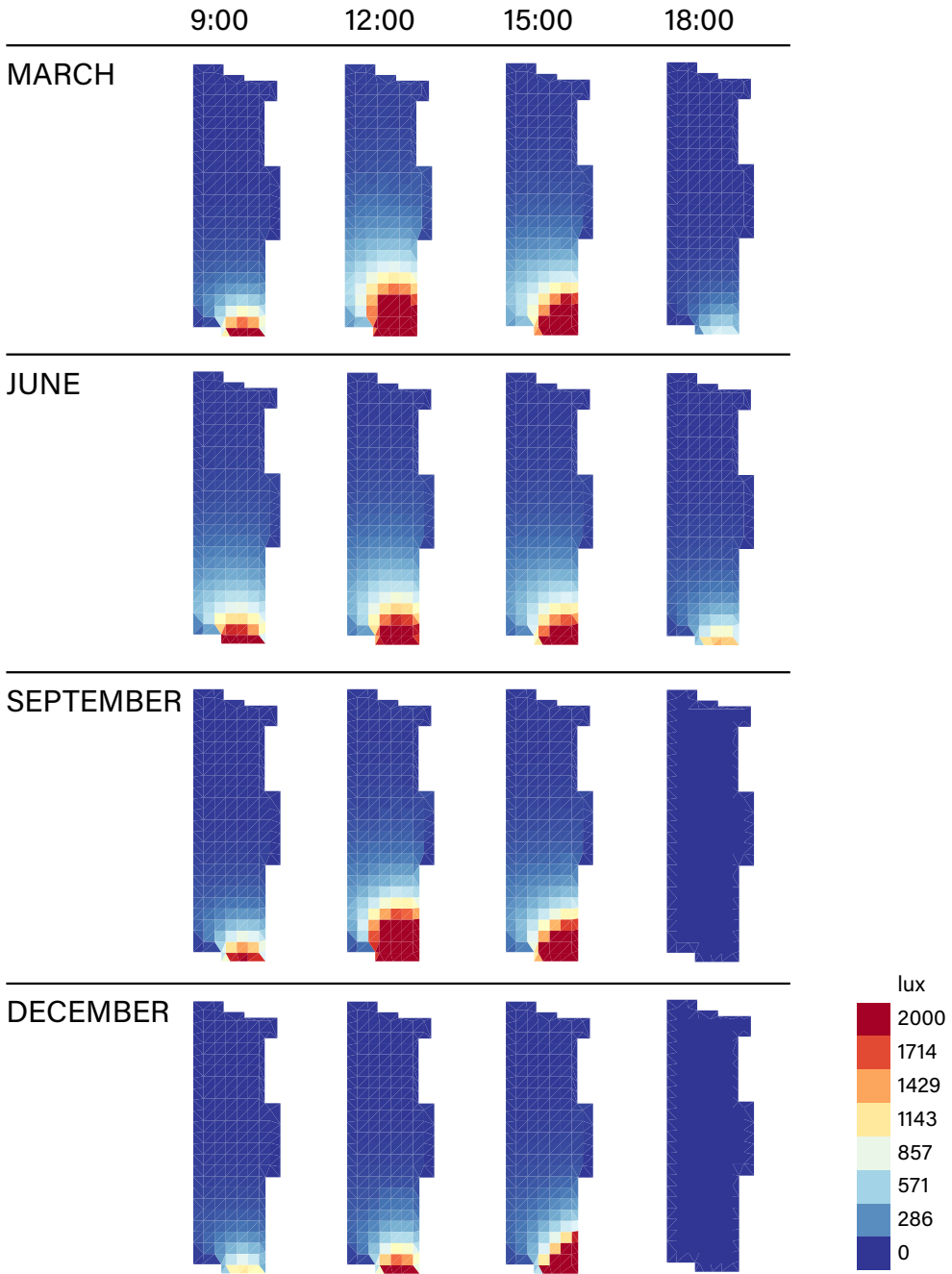
DAYLIGHT ANALYSIS - BASELINE

AVAILABLE DAYLIGHT BY POINT: The diagram below shows the extent of daylight received year-round at 3 points within the apartment; closest to the window, the middle of the apartment, and the innermost area.


POINT A

POINT B

POINT C
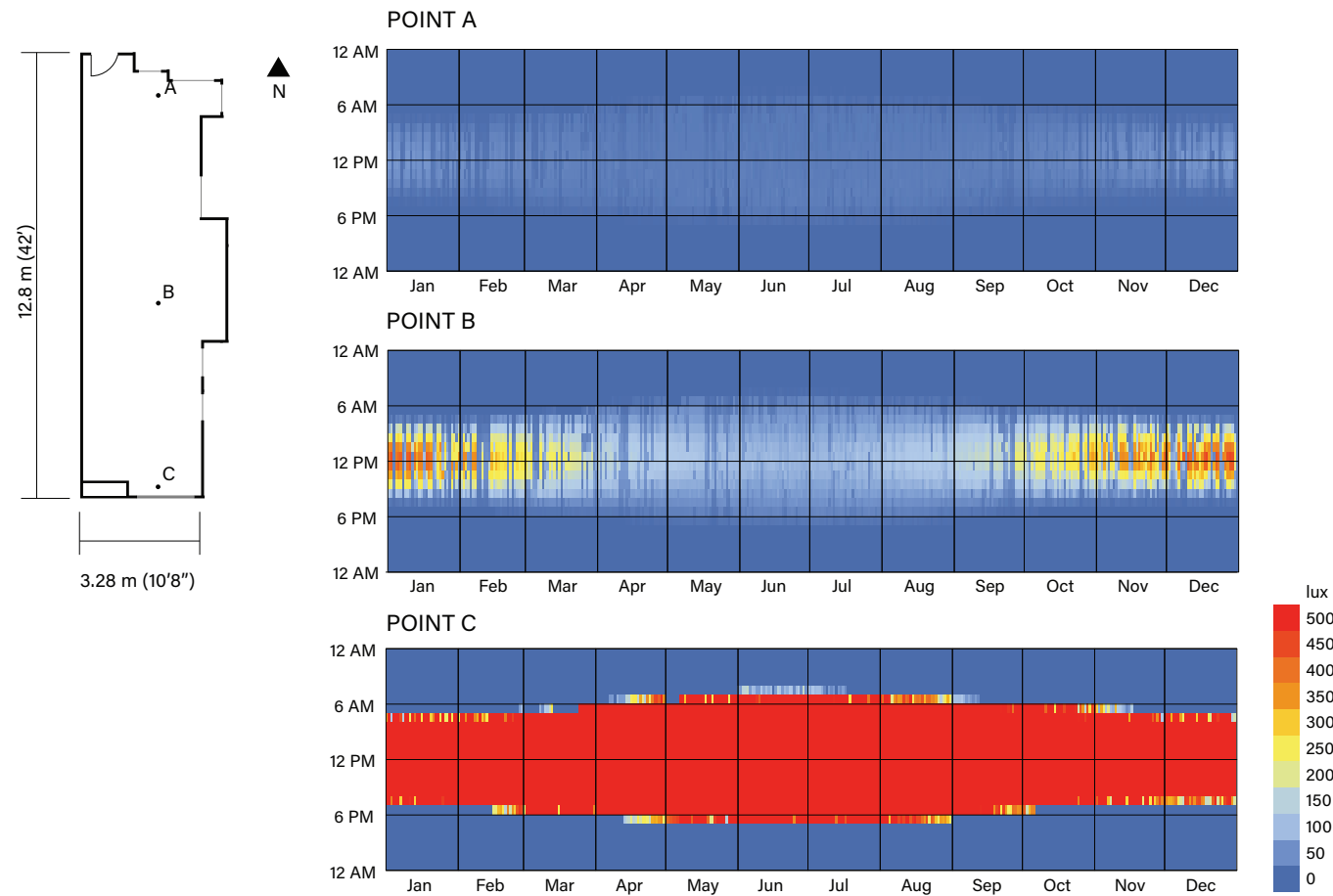
PERCENTAGE OF ANNUAL DAYLIGHT: The diagrams below show the percentage of Useful Daylight Illuminance (UDLI) by region within the apartment at the stated values. Best UDLI values between 300 and 2000 lux; below or above that is too little and too much light; i.e., considered uncomfortable.

UDLI Within Comfort Range

UDLI < 100 lux

UDLI 100 - 2000 lux

UDLI > 2000 lux

SEASONAL DAYLIGHT ANALYSIS: The diagram below shows the amount of light within the range of 0 to 2000 lux that the apartment receives at various locations. Regardless of the season, we can see the uneven daylight is consistent year-round; the back of the apartment receives too little useful light year-round.

SUN POSITION & ANNUAL COMFORT
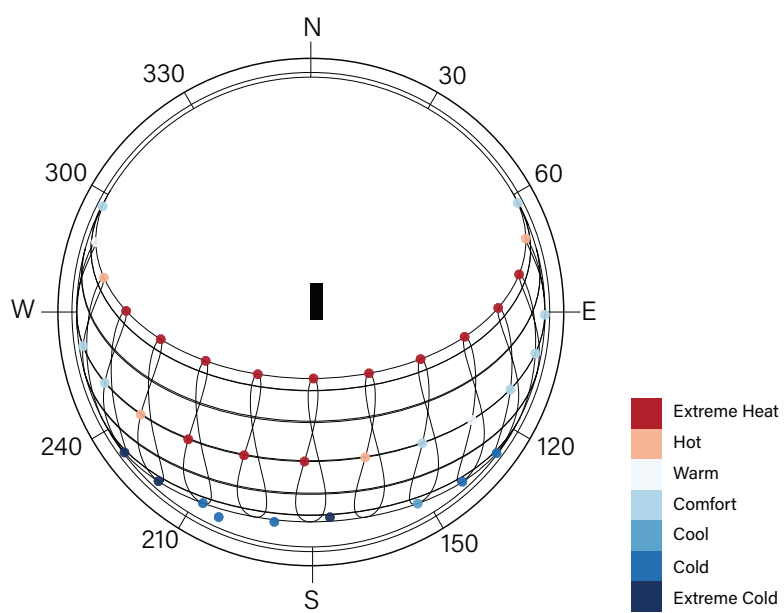
SUN POSITION & ANNUAL COMFORT: The diagram to the left shows the sun's position in the sky and its relationship to comfort.
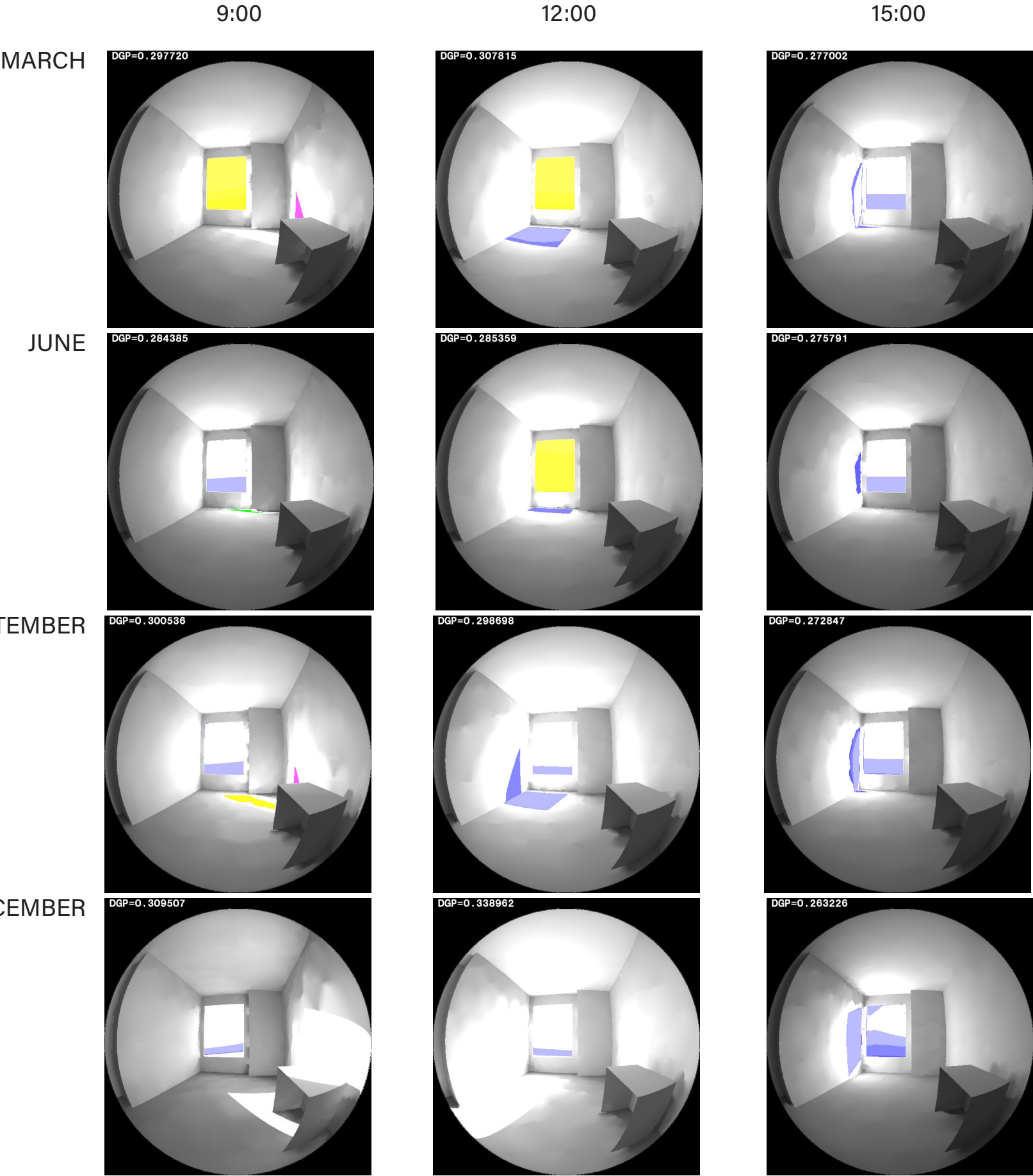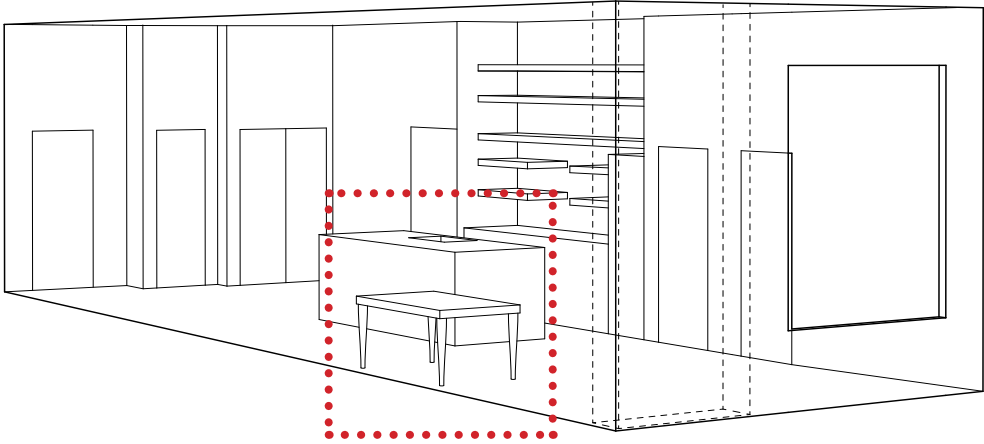

9:00   12:00   15:00   18:00

MARCH

JUNE

SEPTEMBER

DECEMBER

GLARE ANALYSIS - BASELINE

DAYLIGHT GLARE ANALYSIS: The glare analysis shows us the amount of light available in the room and if that light is in a comfortable range. The parameters for what is comfortable are listed as follows, as Daylight Glare Probability (DGP):

Imperceptible Glare: DGP < 0.35
Perceptible Glare: 0.40 > DGP > 0.35
Disturbing Glare: 0.45 > DGP > 0.40
Intolerable Glare: DGP > 0.45

Looking at the highlighed region in red below, where the desk is located, the range of glare is 0.26 to 0.34. The results fall below the range for Perceptible Glare; however, at the upper level of Imperceptible Glare and close enought to Perceptible Glare to try to bring these numbers down with aid from a light shelf.

	9:00	12:00	15:00
MARCH	DGP=0.297720	DGP=0.307815	DGP=0.277002
JUNE	DGP=0.284385	DGP=0.285359	DGP=0.275791
SEPTEMBER	DGP=0.300536	DGP=0.298698	DGP=0.272847
DECEMBER	DGP=0.309507	DGP=0.338962	DGP=0.263226

MATERIALS & CONSTRUCTION

INSULATION: Our perception of comfort is a factor or air temperature, humidity, among other factors. Designing for these factors determines the materials we use. The information below is taken from assumed insulation values for lack of knowing the construction materials of the apartment.

BASE MODEL CONSTRUCTION DETAILS

Exterior Wall R-Value 5.5
Exterior Window R-Value 1.0 & SHGC 0.7
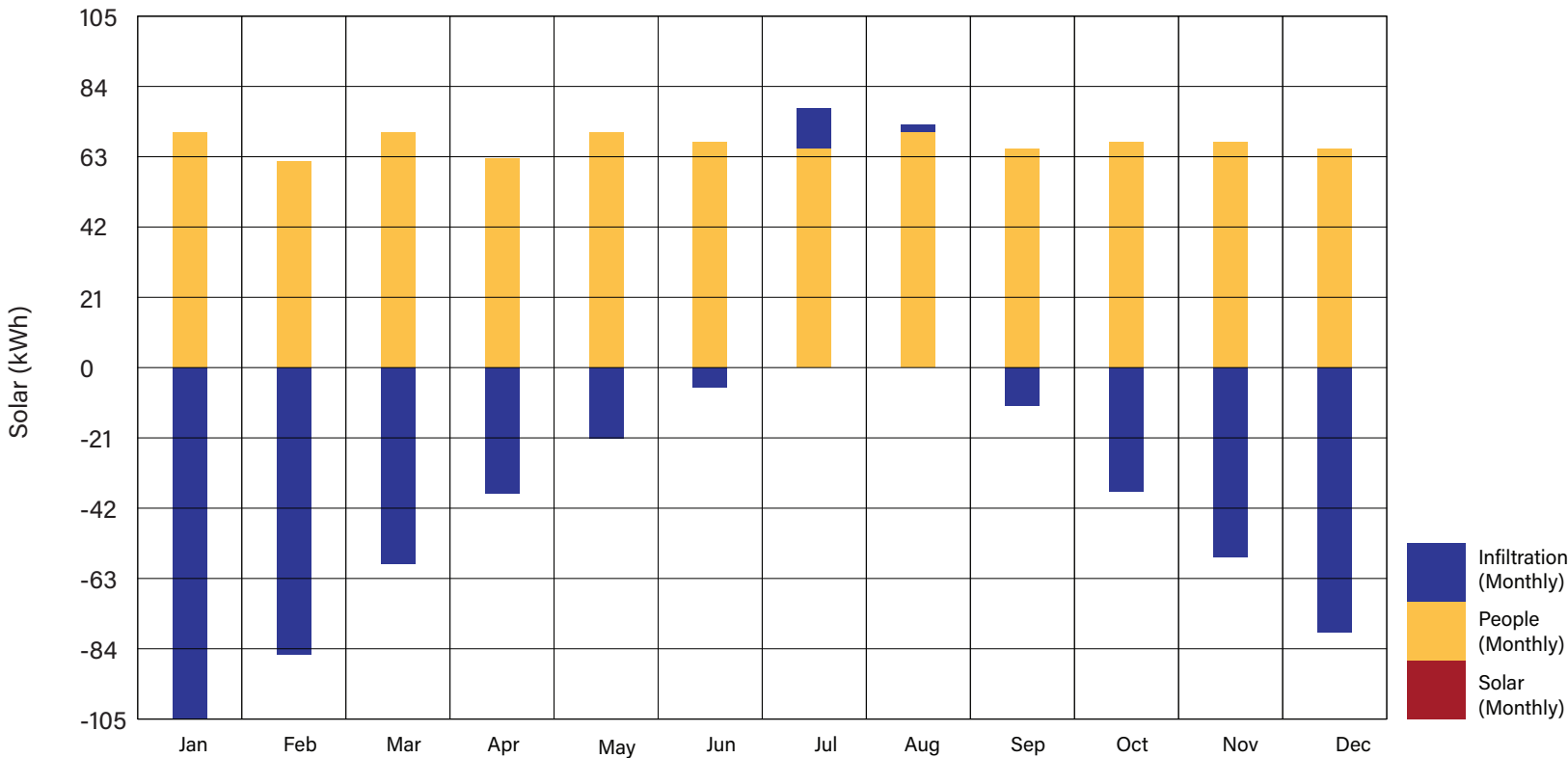Exterior Roof -Value 9.2
Air Change Rate 2.0

Looking at the results, the challenge here is to design materials that insulate well considering cold is the biggest hindrance to comfort.

> **% of Time Comfortable: 53%**
> **Hot: 2.66%**
> **Cold: 44.11%**

ENERGY LOSSES OR GAINS

PSYCHROMETRIC CHART
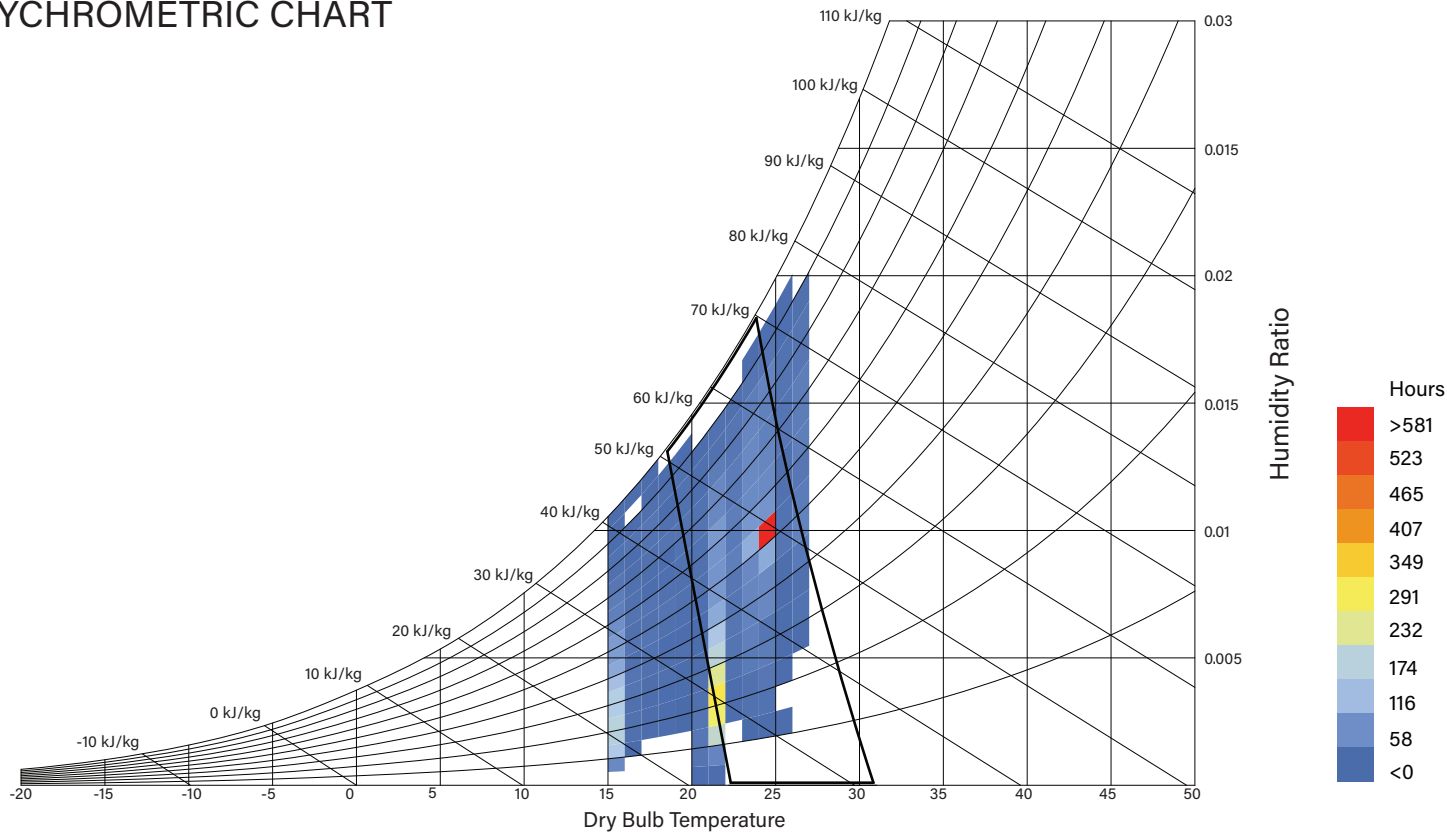
ADAPTIVE COMFORT
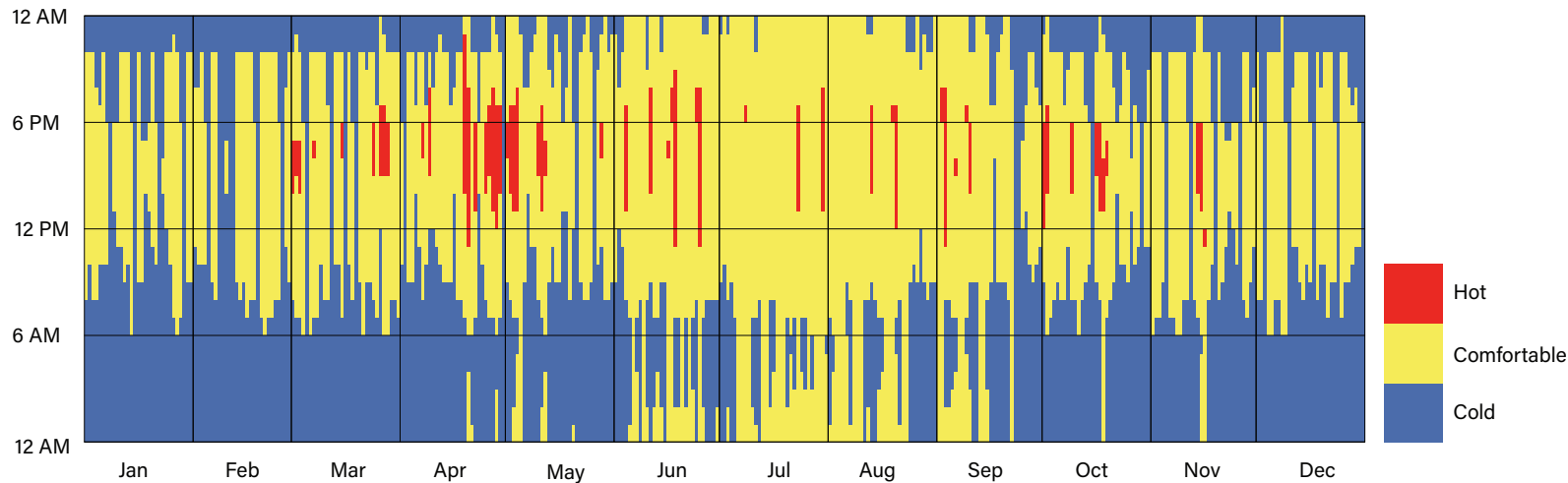
DAYLIGHT ANALYSIS - LIGHT SHELF

LIGHT SHELF DESIGN: I propose that by adding a light shelf, the light could possibly reach the interior of the room and provide useful daylight. I have included two designs and will test them against the base model.

The first design adds a light shelf 0.25 m from the top of the window. I've included two depths for the light shelf, the first is 0.5 m wide, split half-way; half inside and half outside. The second is 1 m wide, split the same.

The diagram shows that each have achieved more light deeper into the apartment, but not necessarily all the way into the back of the apartment.
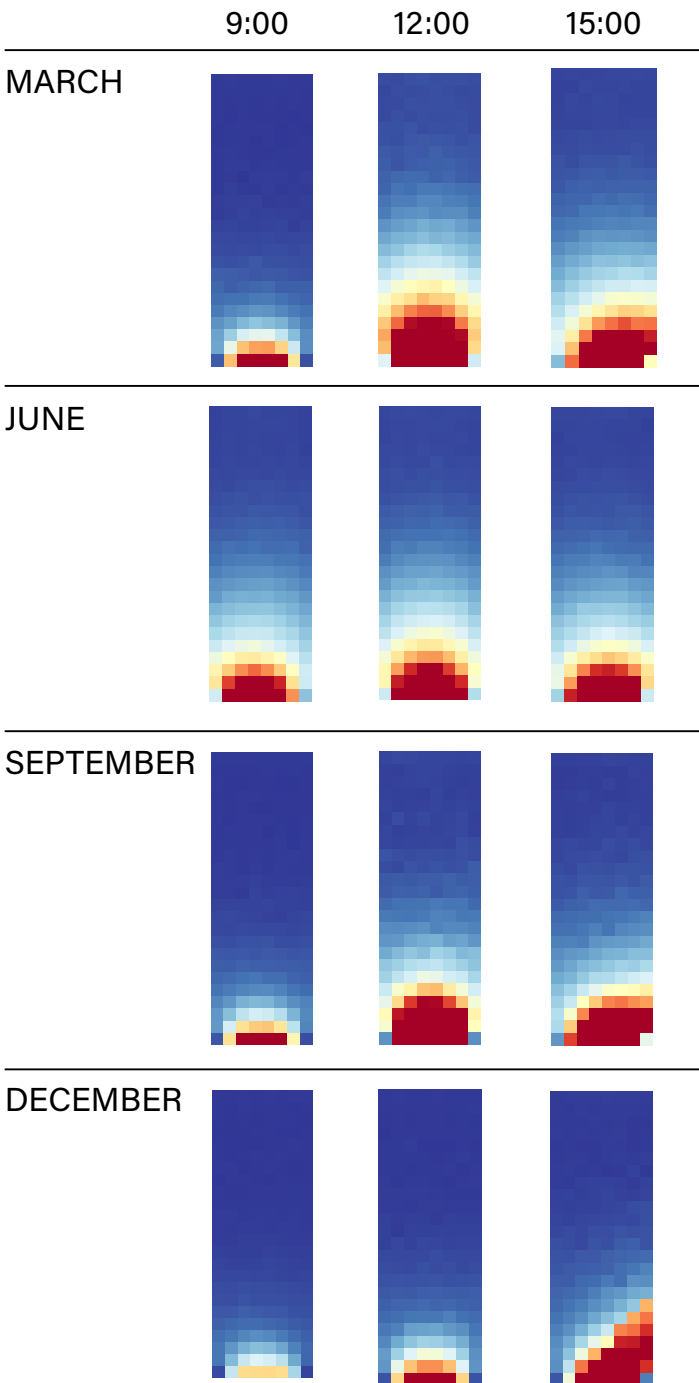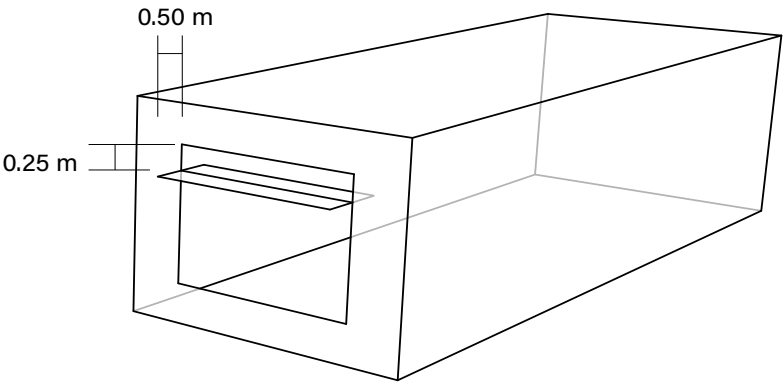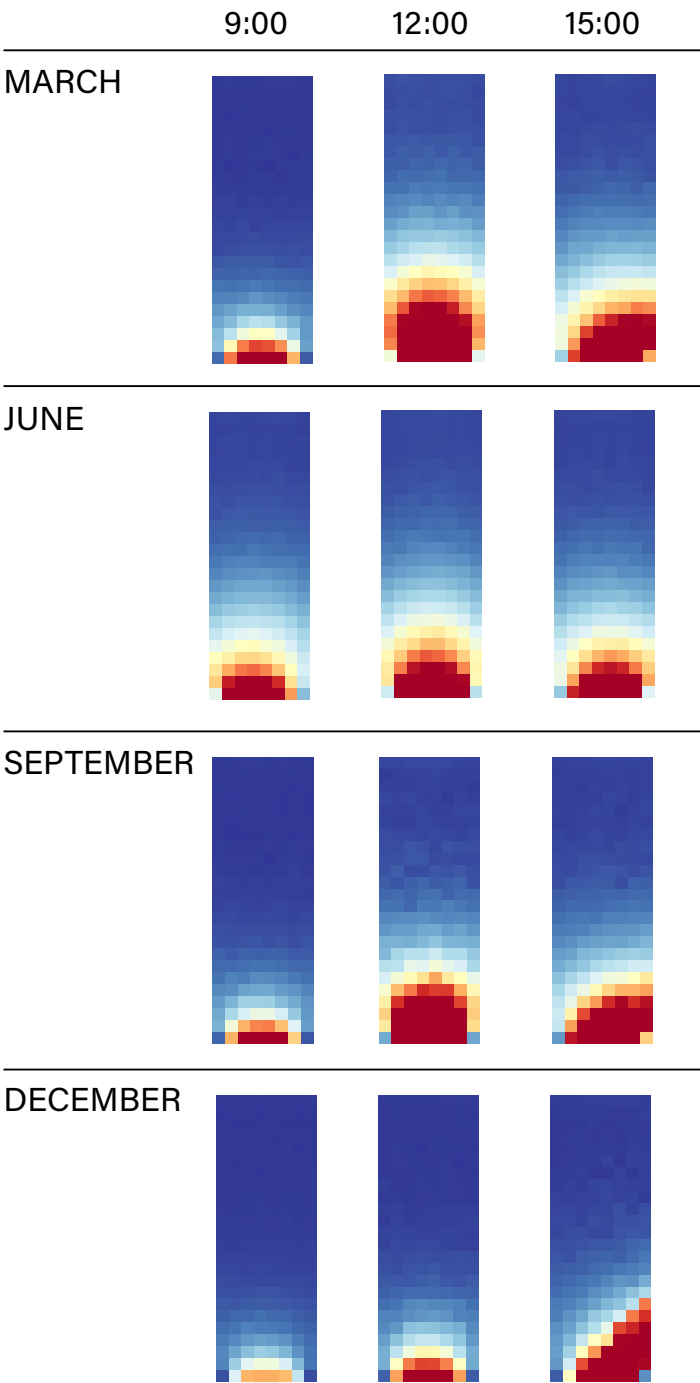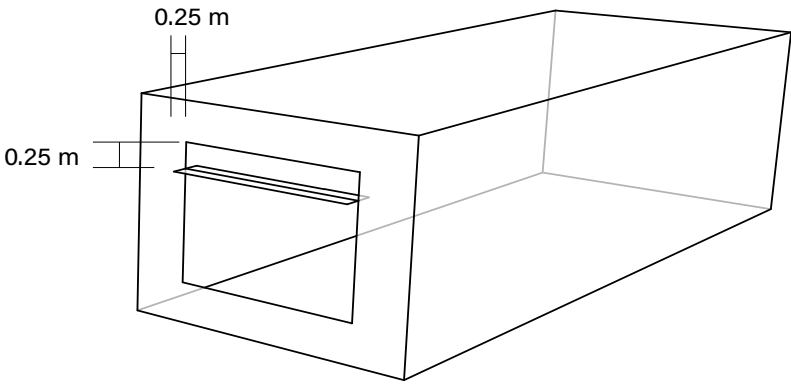
DAYLIGHT ANALYSIS - LIGHT SHELF

LIGHT SHELF DESIGN: The second set of light shelves try to achieve the goal of increasing light to the back of the apartment.

The second design adds a light shelf 0.5 m from the top of the window. I've included two depths for the light shelf, the first is 0.5 m wide, split half-way; half inside and half outside. The second is 1 m wide, split the same.

The diagram shows that each have achieved more light deeper into the apartment, further than the light shelves that are 0.5 m wide. Although it doesn't reach the back of the apartment, the amount of light in the middle of the apartment has increased.
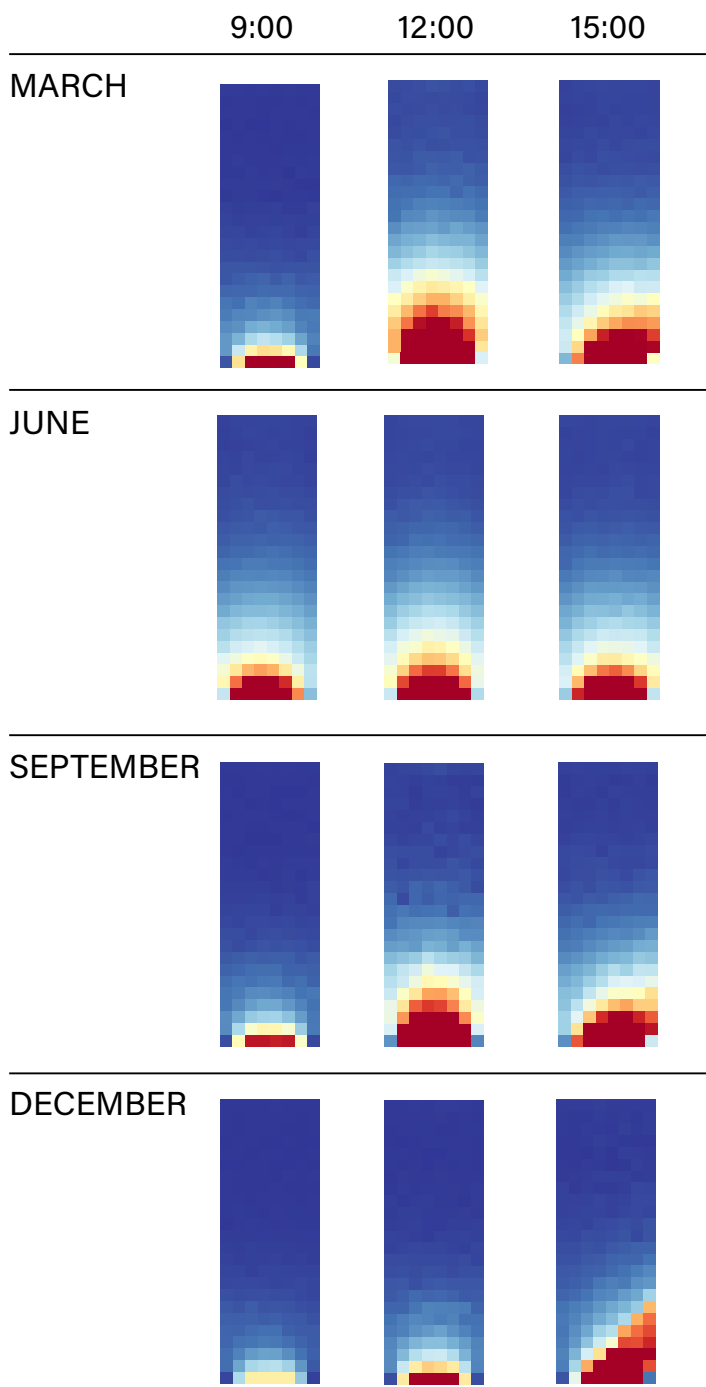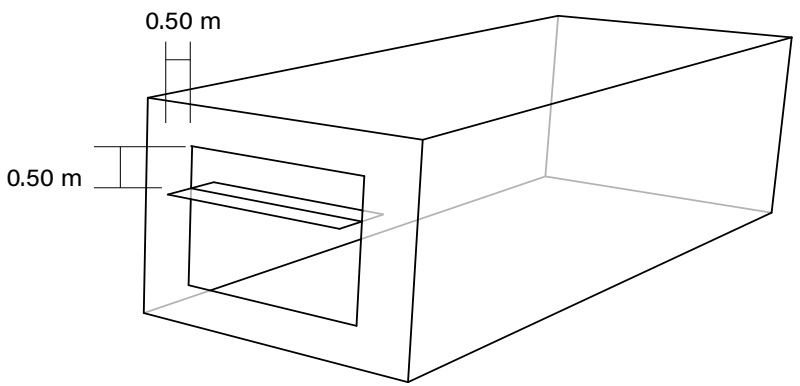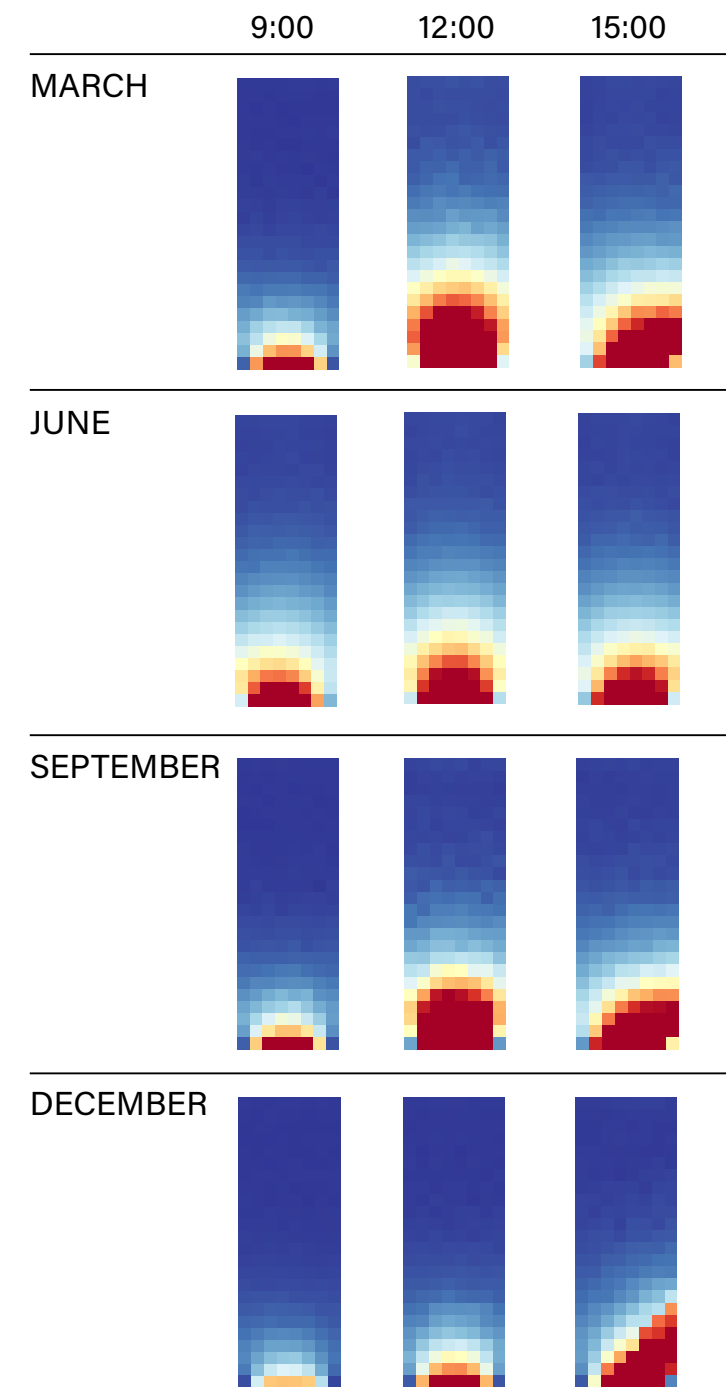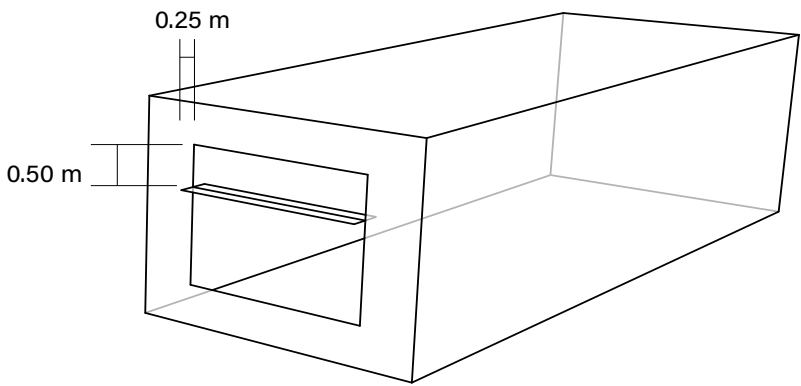
GLARE ANALYSIS - LIGHT SHELF

DAYLIGHT GLARE ANALYSIS FOR LIGHT SHELF: The first light shelf design is 0.25m down from the top of the window and is 1m wide. The following analysis looks to test the effect of the light shelf on glare.

Imperceptible Glare: DGP < 0.35
Perceptible Glare: 0.40 > DGP > 0.35
Disturbing Glare: 0.45 > DGP > 0.40
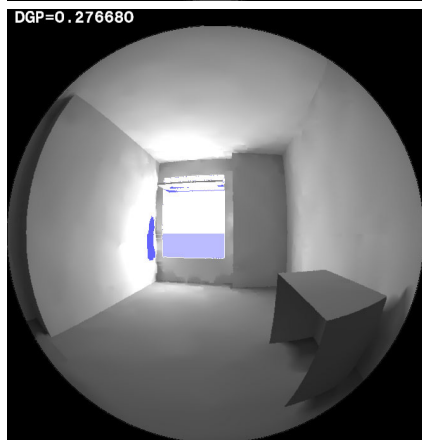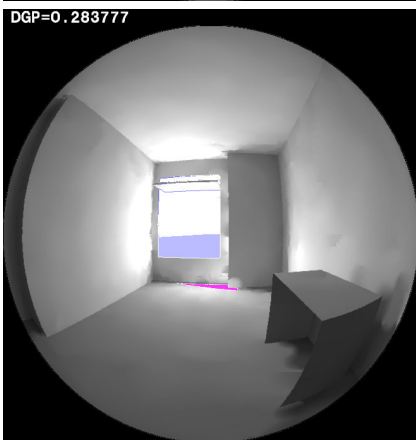Intolerable Glare: DGP > 0.45

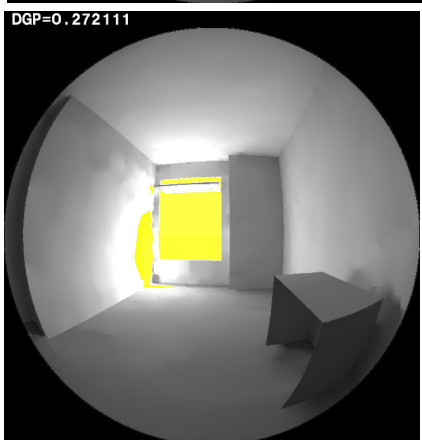The range of glare for this design is between 0.26 and 0.32, a similar range as without the light shelf in the base model; .26 and 0.34.
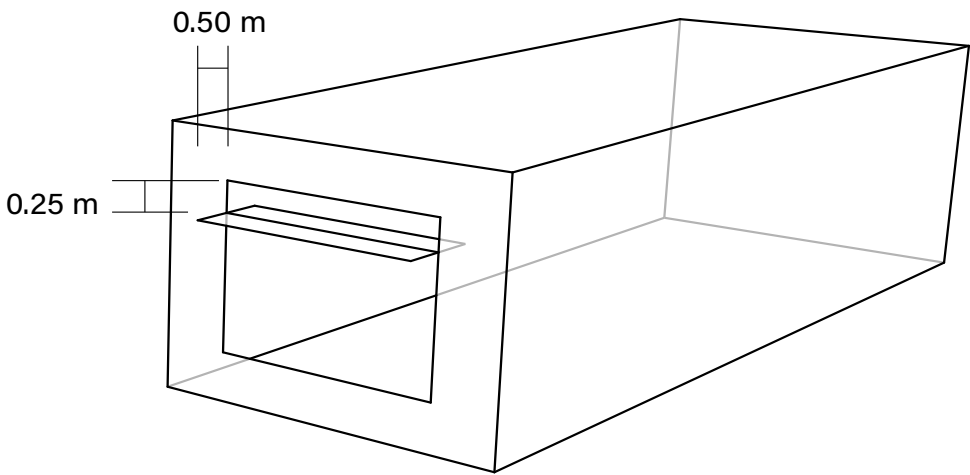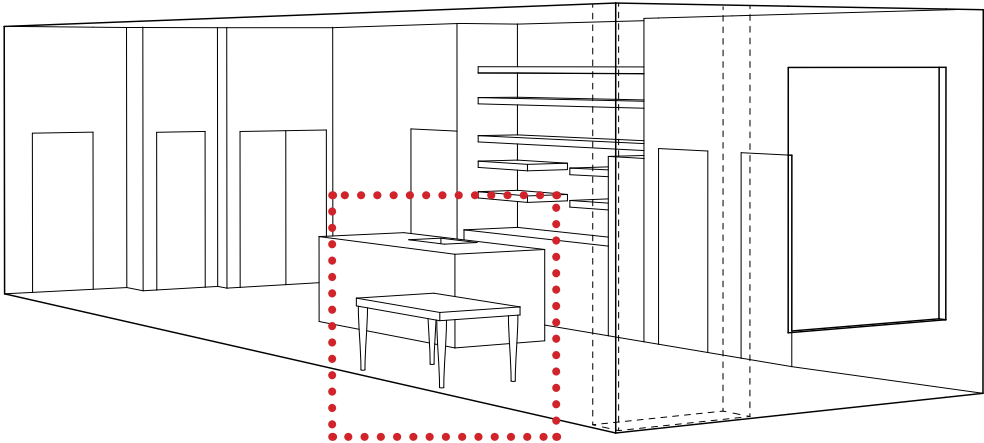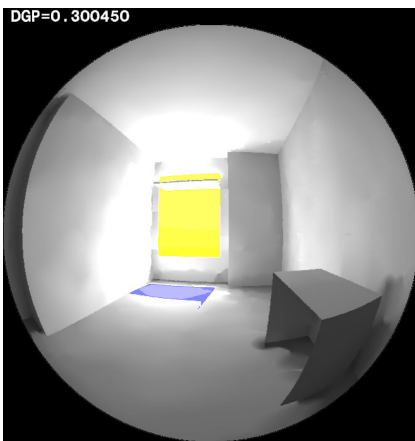
0.50 m

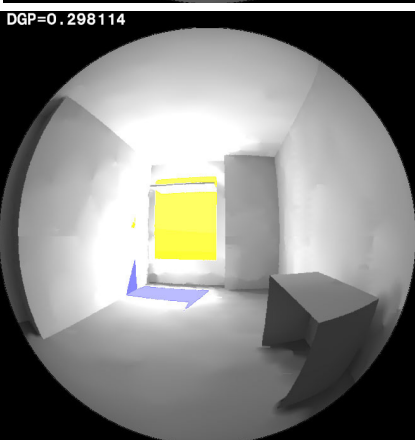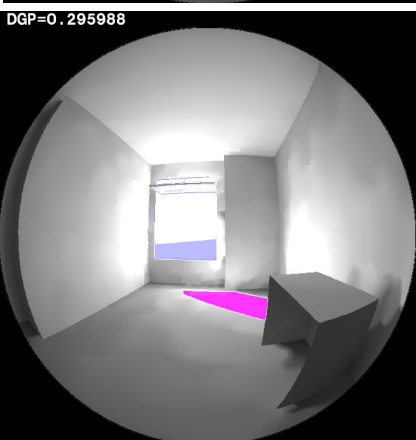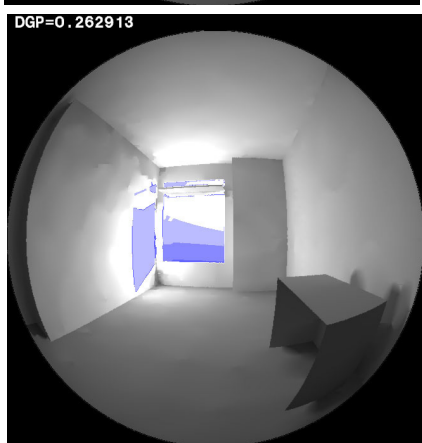0.25 m

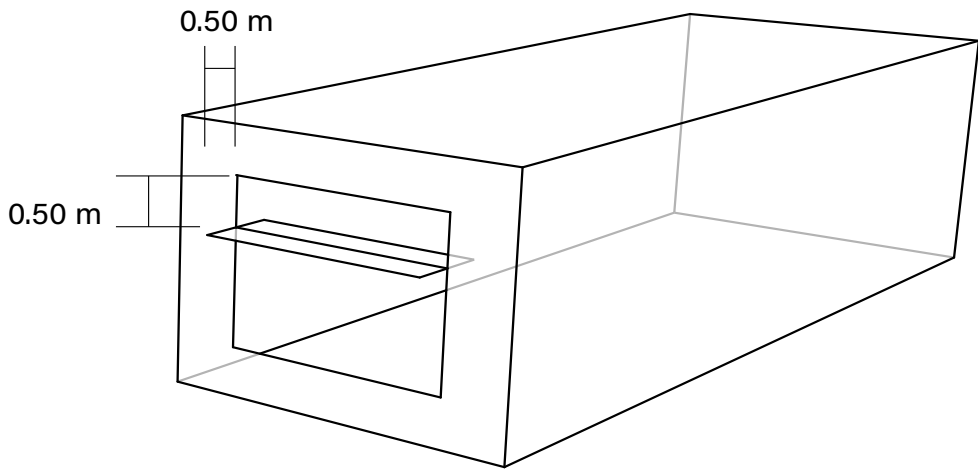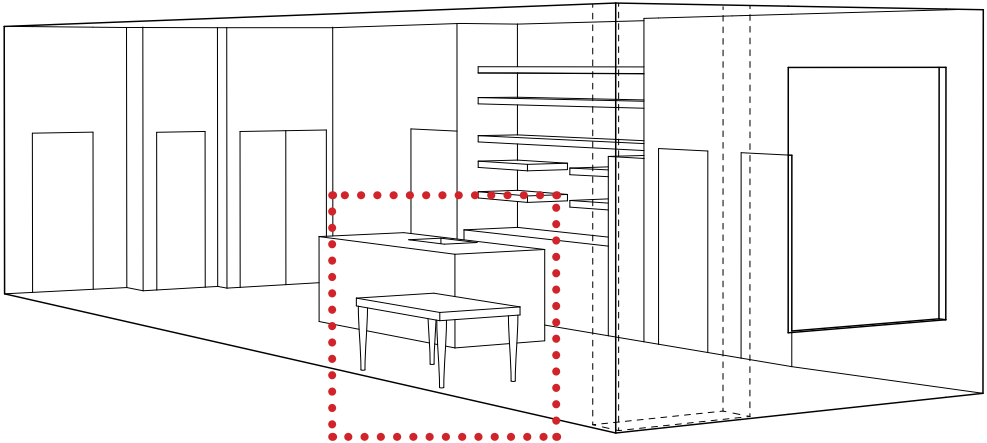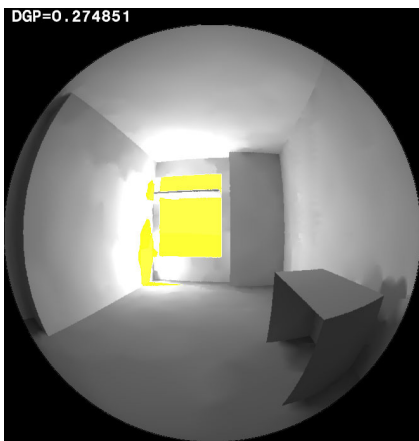|	9:00	12:00	15:00
MARCH	DGP=0.294193	DGP=0.300450	DGP=0.275450
JUNE	DGP=0.283777	DGP=0.283375	DGP=0.276680
SEPTEMBER	DGP=0.295988	DGP=0.298114	DGP=0.272111
DECEMBER	DGP=0.304685	DGP=0.324923	DGP=0.262913
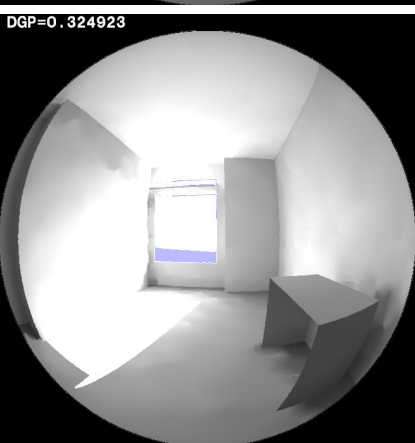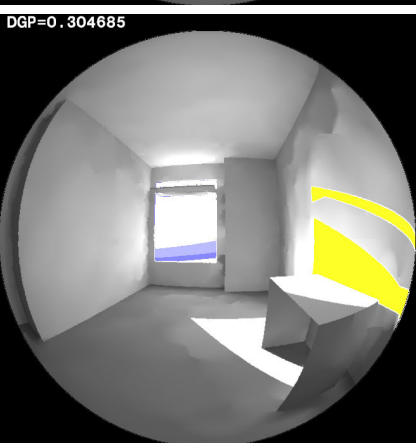
GLARE ANALYSIS - LIGHT SHELF

DAYLIGHT GLARE ANALYSIS FOR LIGHT SHELF: The second light shelf design is 0.5m down from the top of the window and is 1m wide. The following analysis looks to test the effect of the light shelf on glare.

Imperceptible Glare: DGP < 0.35
Perceptible Glare: 0.40 > DGP > 0.35
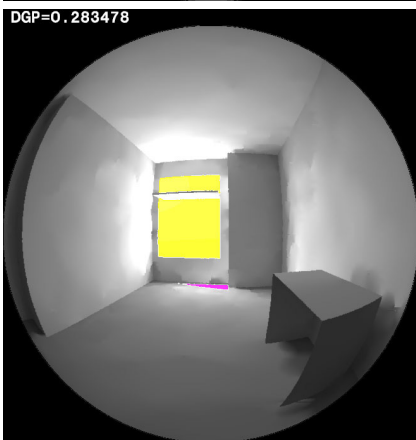Disturbing Glare: 0.45 > DGP > 0.40
Intolerable Glare: DGP > 0.45

The range of glare for this design is between 0.26 and 0.33, a similar range as without the light shelf in the base model; .26 and 0.34.
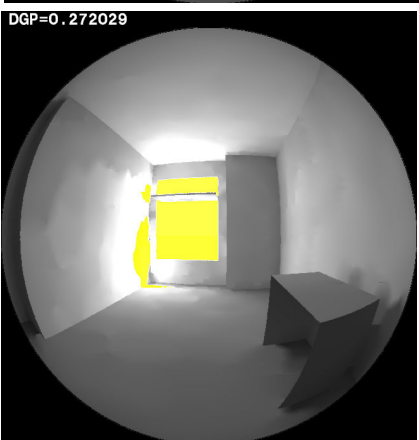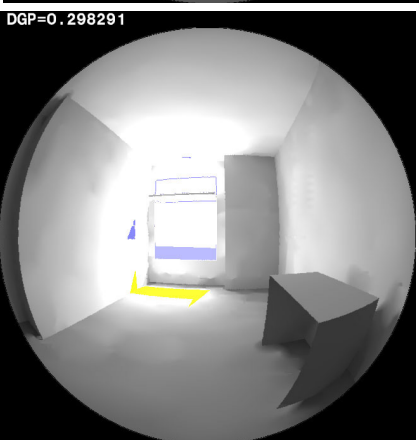
0.50 m
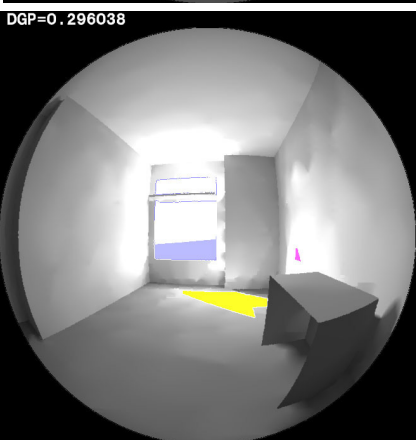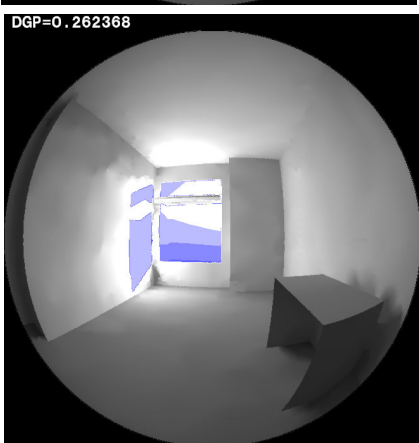
0.50 m

	9:00	12:00	15:00
MARCH	DGP=0.294198	DGP=0.298291	DGP=0.274851
JUNE	DGP=0.283478	DGP=0.282840	DGP=0.277463
SEPTEMBER	DGP=0.296038	DGP=0.298291	DGP=0.272029
DECEMBER	DGP=0.304091	DGP=0.326337	DGP=0.262368
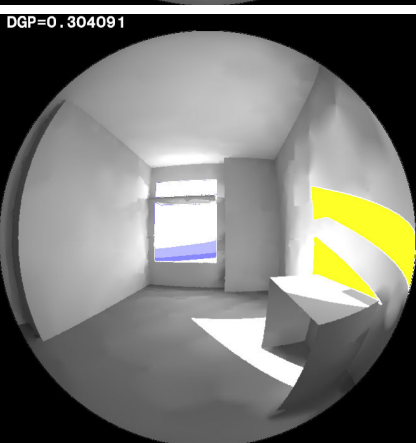
MATERIALS & CONSTRUCTION

INSULATION: To increase comfort we can increase the insulation of the construction and use materials that have better insulating values. The new materials are listed below:
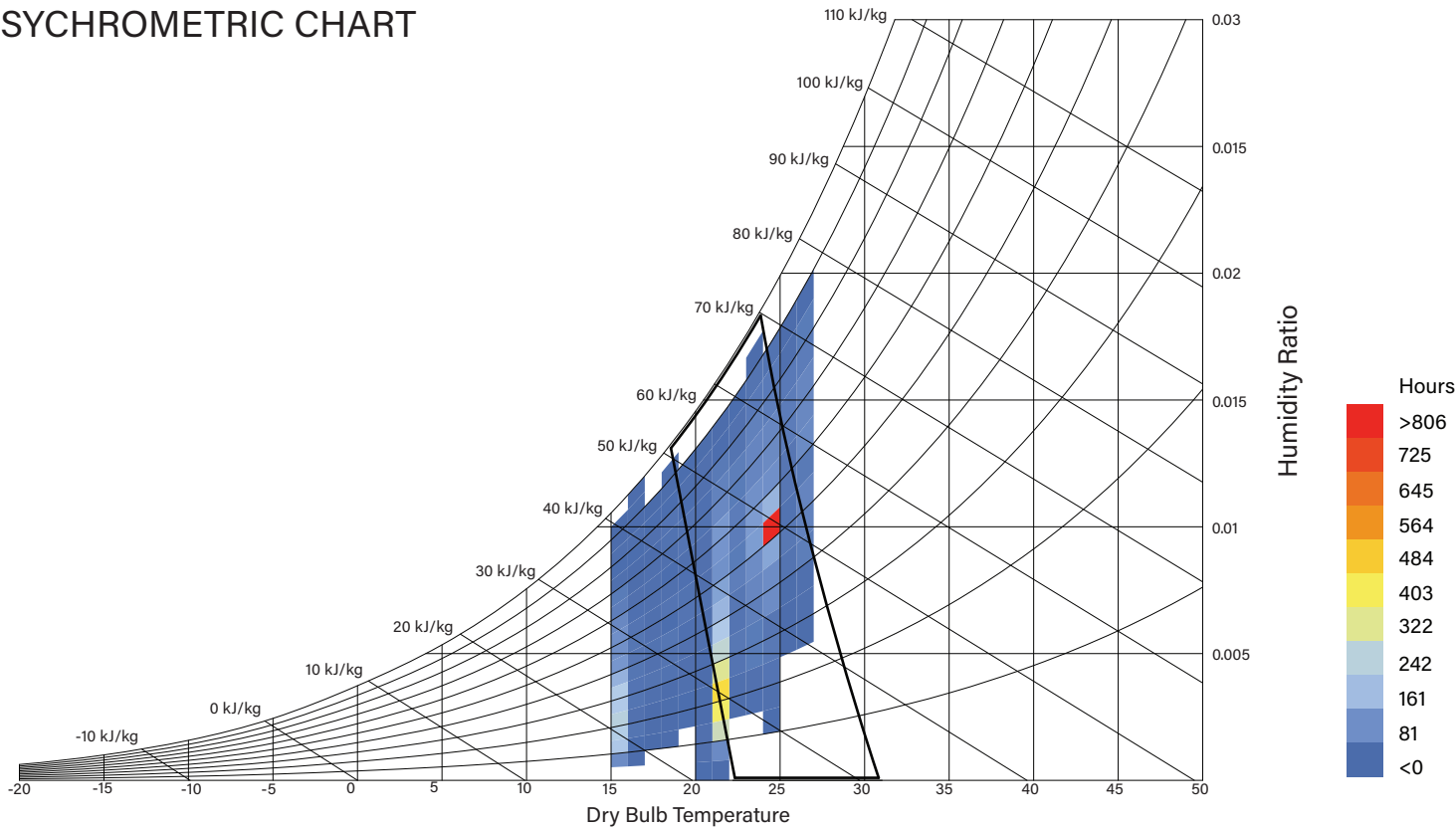
BASE MODEL CONSTRUCTION DETAILS

Exterior Wall R-Value 14.8
Exterior Window R-Value 1.9 & SHGC 0.39
Exterior Roof -Value 14.8
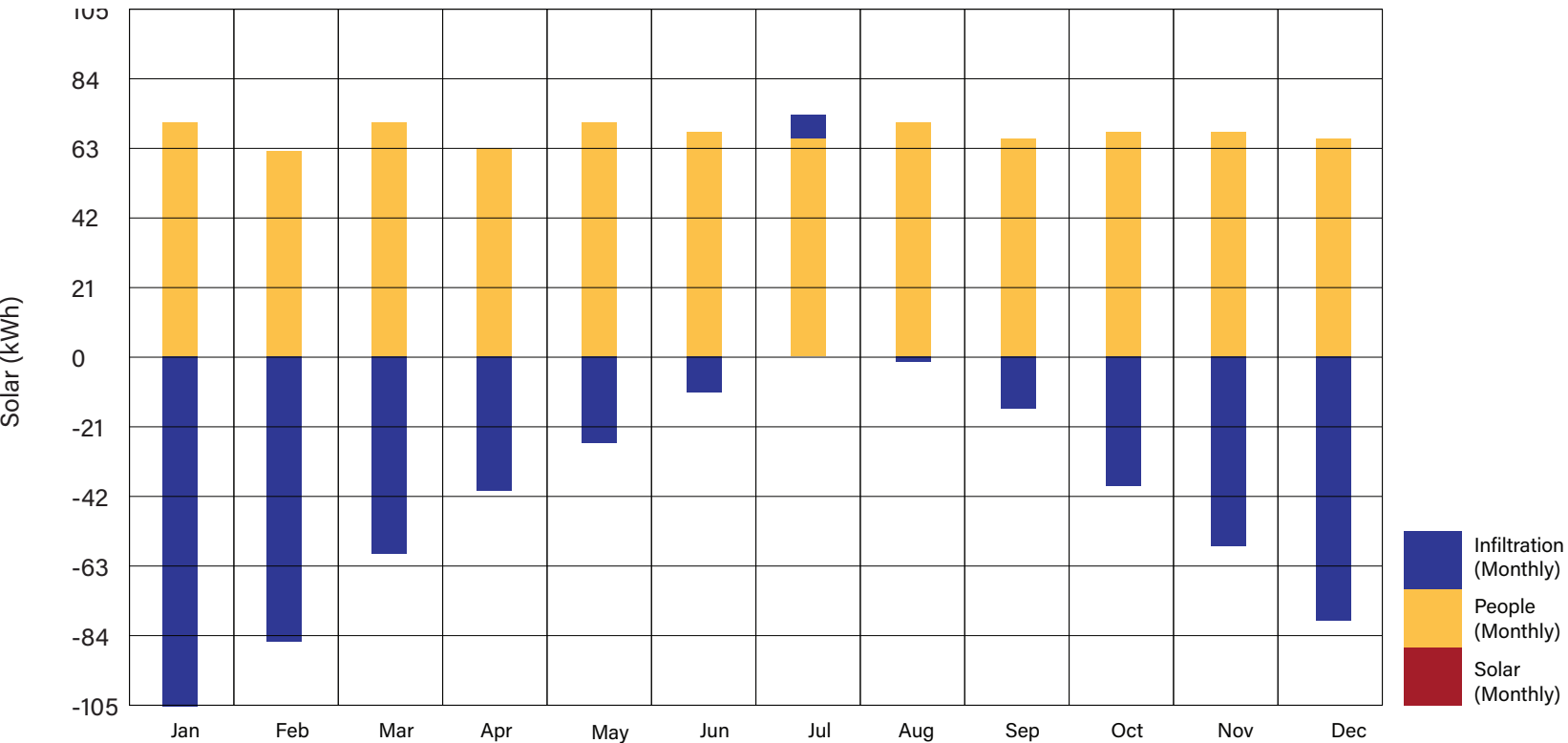Air Change Rate 2.0

Looking at the results, we can identify that the we've improved upon comfort but not 100% comfortable.

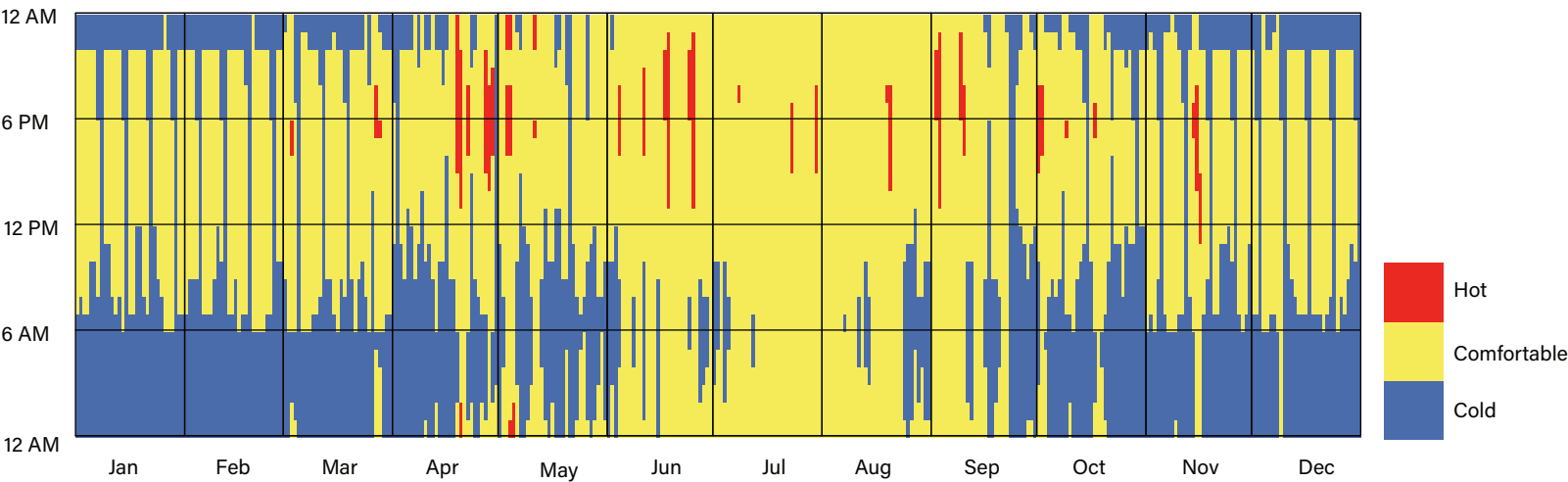**% of Time Comfortable: 64%**
Hot: 1.91%
Cold: 34.59%

PSYCHROMETRIC CHART

ENERGY LOSSES OR GAINS

ADAPTIVE COMFORT

MATERIALS & CONSTRUCTION

INSULATION: To increase comfort we can increase the insulation even further of the construction and use materials that have better insulating values. The new materials are listed below:
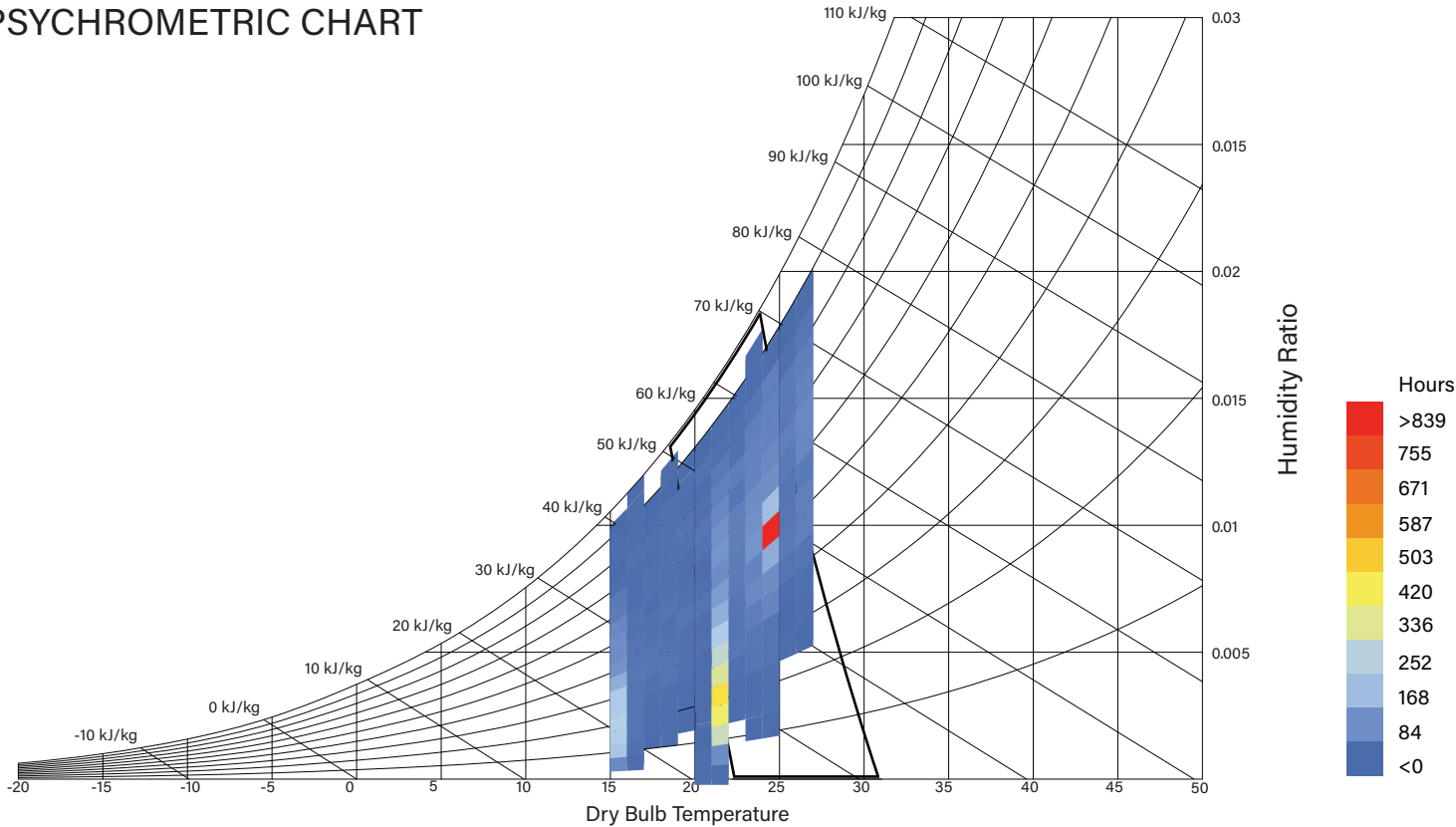
BASE MODEL CONSTRUCTION DETAILS

Exterior Wall R-Value 34.4
Exterior Window R-Value 1.9 & SHGC 0.39
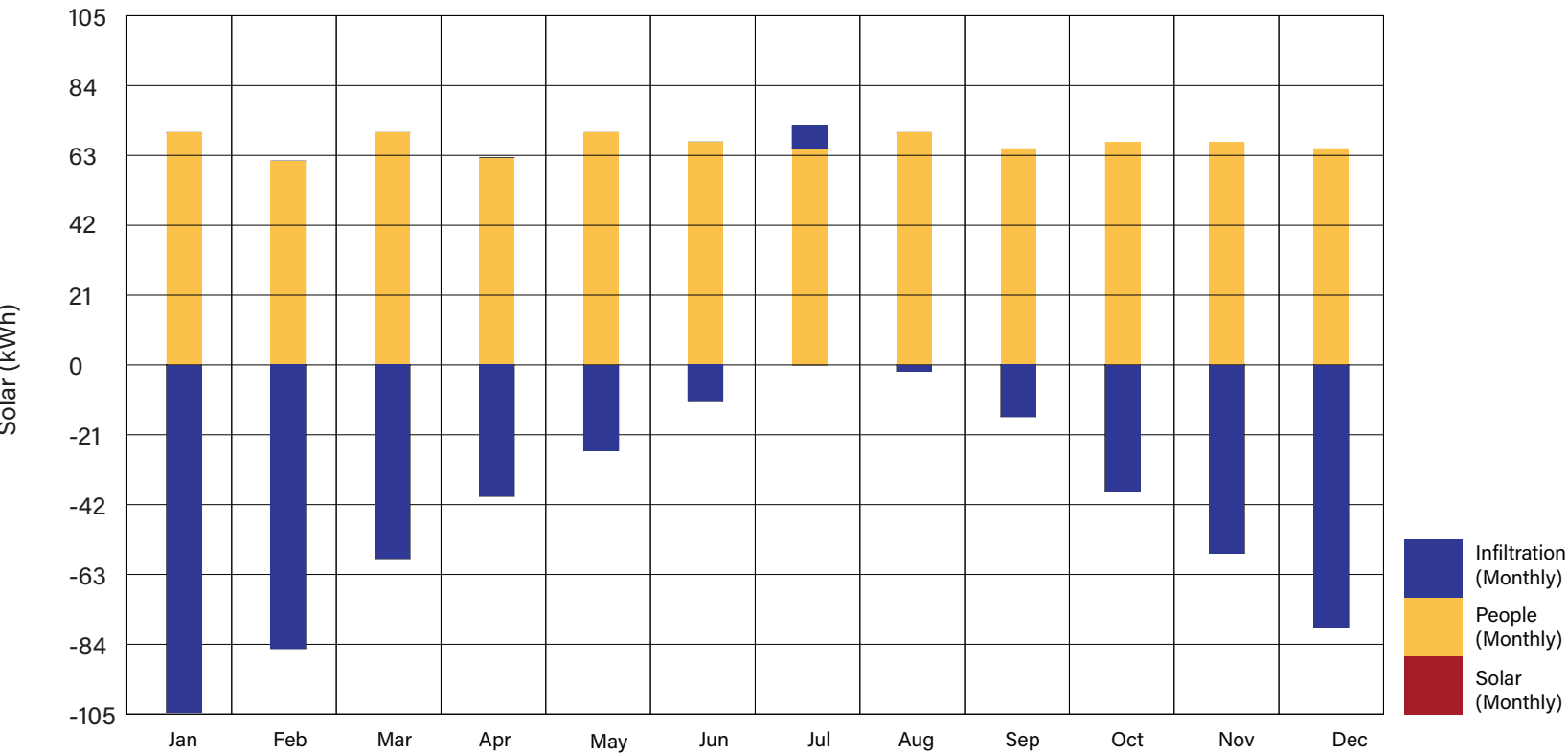Exterior Roof -Value 34.4
Air Change Rate 2.0

Looking at the results of this second design, we can identify that the we've improved upon comfort but not 100% comfortable. Even with these numbers it may be that not enough sun can be used to heat the apartment in its current design.

% of Time Comfortable: 67%
Hot: 0.58%
Cold: 32.16%
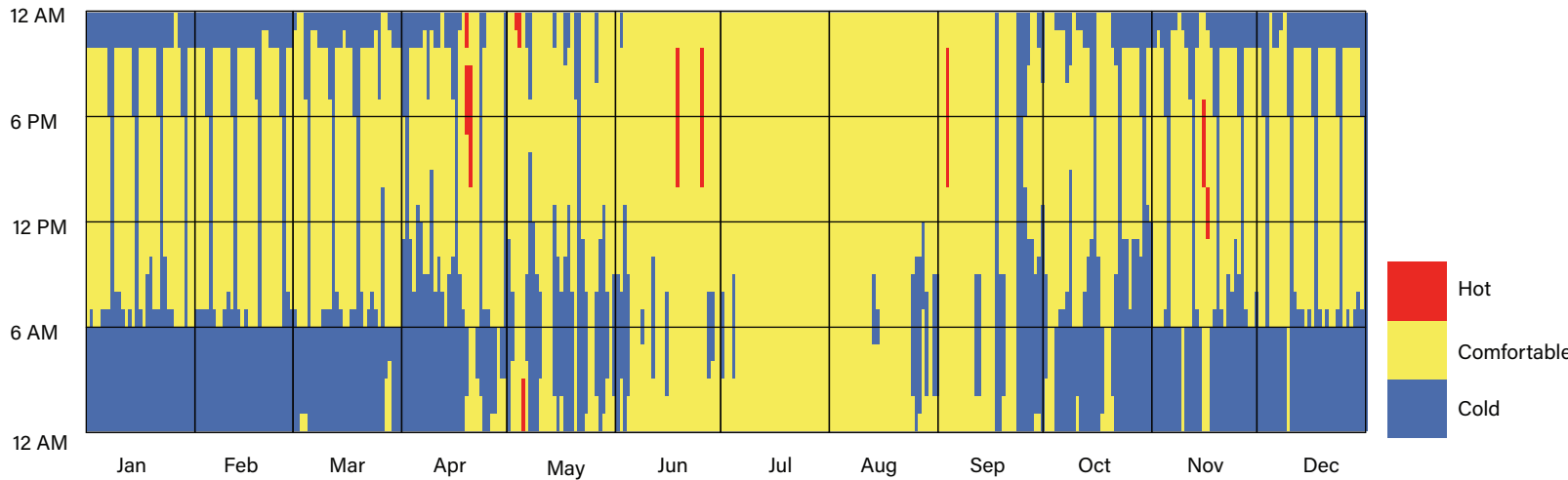
PSYCHROMETRIC CHART

ENERGY LOSSES OR GAINS

Legend:
- Infiltration (Monthly)
- People (Monthly)
- Solar (Monthly)

ADAPTIVE COMFORT

Hours legend:
>839, 755, 671, 587, 503, 420, 336, 252, 168, 84, <0

- Hot
- Comfortable
- Cold

MATERIALS & CONSTRUCTION

Change the materials to increase insulation values:

Exterior Wall R-Value 34.4
Exterior Window R-Value 1.9 & SHGC 0.39
Exterior Roof -Value 34.4
Air Change Rate 2.0

Given that this will only give us a % of time comfortable at 67% - the next step is to look at mechanical systems that can fit the heating and cooling load most efficiently.

LIGHT SHELF

Design a light shelf that is 1 m wide and place it 0.5 m from the top of the window. This will increase light further into the apartment.