THERMAL AND VISUAL COMFORT MAXIMIZATION OF AN UNCONDITIONED SPACE

Miami, FL

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Fall 2015 | ARCH 753 Building Performance Simulation

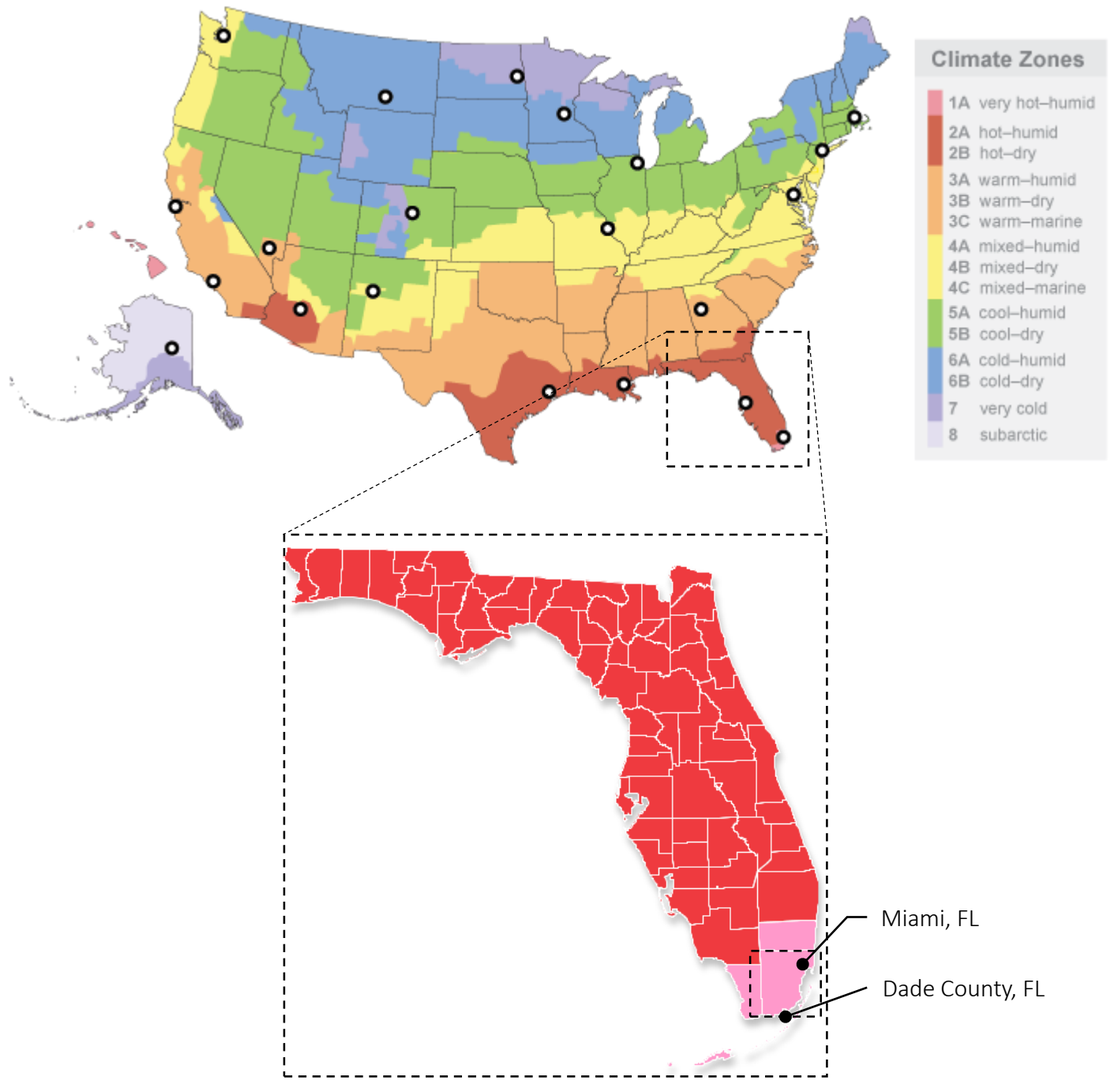
PennDesign | University of Pennsylvania

CLIMATE ZONES

WEATHER DATA: USA_FL_Miami.Intl.AP.722020_TMY3
LATITUDE: 25.82
LONGITUDE: 80.30
CDD: 978 Degree days
HDD: 137 Degree days

CLIMATE ZONE: 1A
CHARACTERISTIC: Very hot-humid

From the climate classification, temperature and relative humidity should be aware throughout entire design process, and main target would be regulating (reducing) both temperature and relative humidity.



Residential Prescriptive Requirements for Zone 1 (2009 IECC)

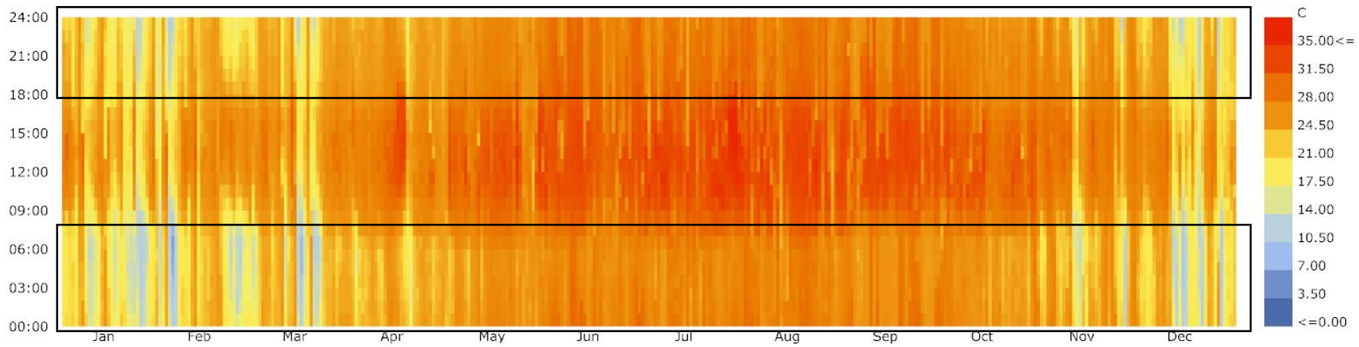
Ceiling R-value	**30**
Wood Frame Wall R-value	**13**
Mass Wall R-value [i]	**3/4**
Floor R-value	**13**
Basement Wall R-value [c]	**0**
Slab R-value [d], Depth	**0**
Crawlspace Wall R-value [c]	**0**
Fenestration U-Factor [b]	**1.2**
Skylight U-Factor [b]	**0.75**
Glazed fenestration SHGC [b, e]	**0.30**

https://energycode.pnl.gov/EnergyCodeReqs/?state=Florida

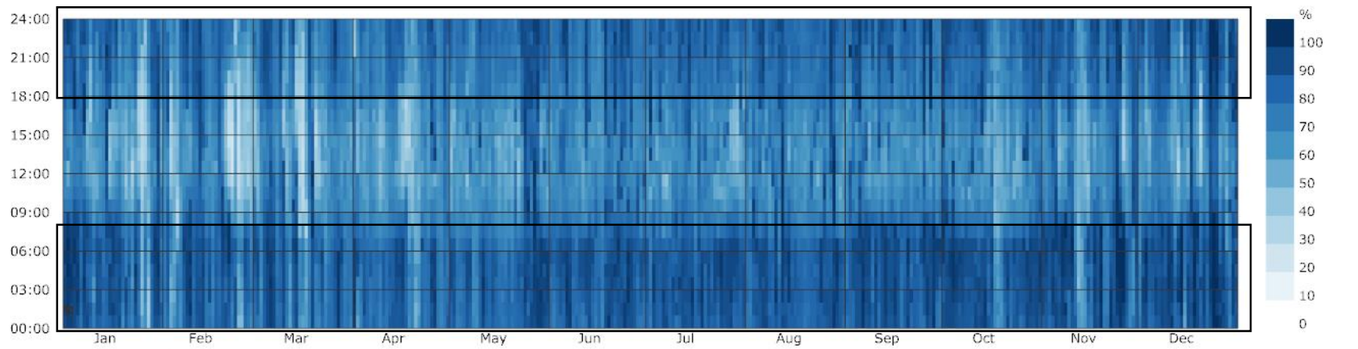
EXTERIOR FACTORS

By looking at TMY3 data, temperature in Miami is mainly between 17 to 30 °C trough out the year, and relative humidity is really high, reaches up to 80% - 100% at nighttime. However, relative humidity during daytime decreases to about 50%, which helps cooling temperature down by using evaporative strategy.

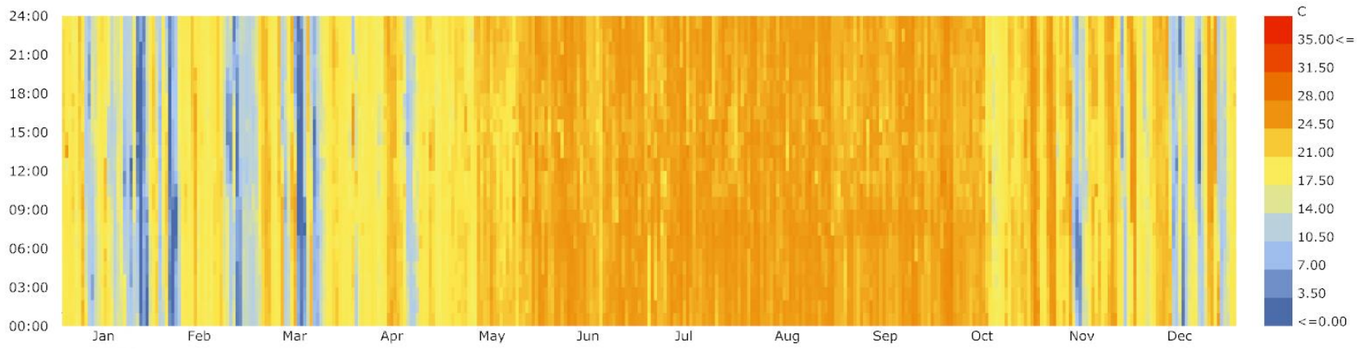
The building type of this project is residential apartment, and the occupied hour is mainly from 6pm to 8am, in which the outside temperature is not as high as daytime, but relative humidity might cause a problem which increases “feeling temperature”.



DRY BULB TEMPERATURE °C



RELATIVE HUMIDITY %



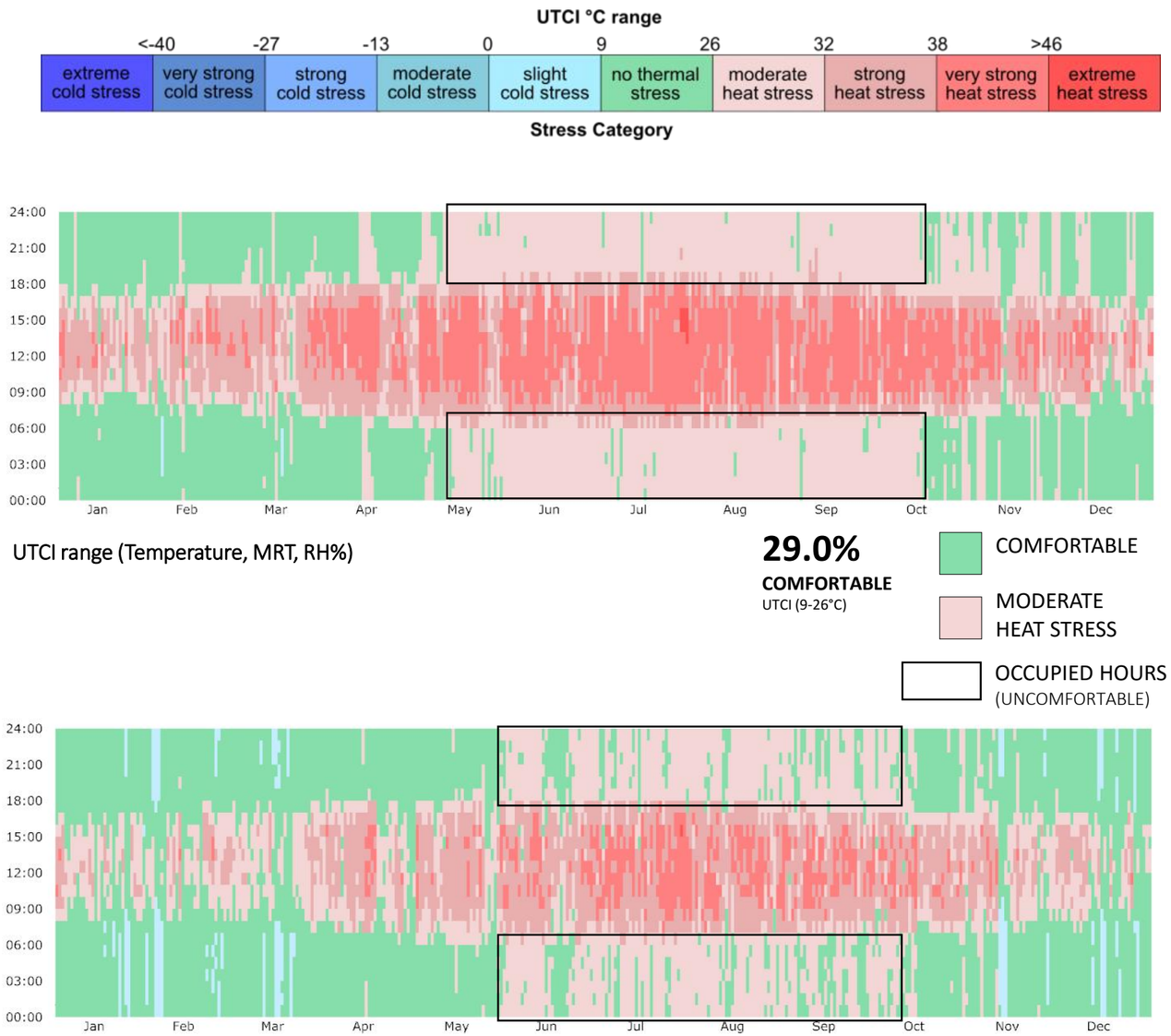
DEW POINT TEMPERATURE **°C**

Occupied Hours
6PM – 8AM

UTCI

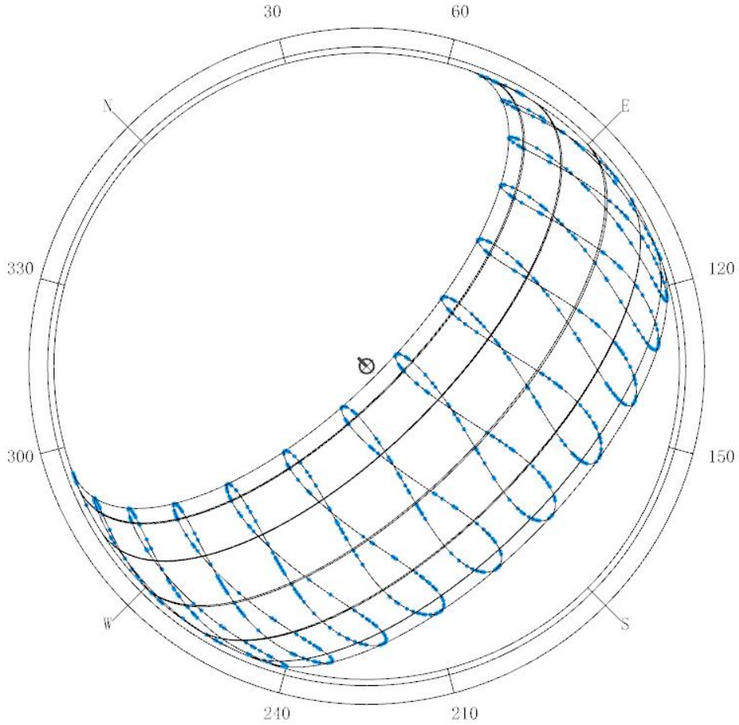
“UTCI, is Universial Thermal Climate Index, meaning the temperature of what the weather "feels like" and it takes into account radiant temperature (usually including solar radiation), relative humidity, wind speed and uses them in a human energy balance model to give a temperature value that is indicative of the heat stress or cold stress felt by the human body.”

From the UTCI mapping on the left, the main issue is during daytime, it is in strong heat stress range, and from May to October at nighttime, it is about in moderate heat stress range(right - top). However, the annual comfort (UTCI 9-26°C) percentage increases from 29% to 45.3% when considering local wind condition (right - bottom). Therefore, passive ventilation may help interior increase more comfort percentage.

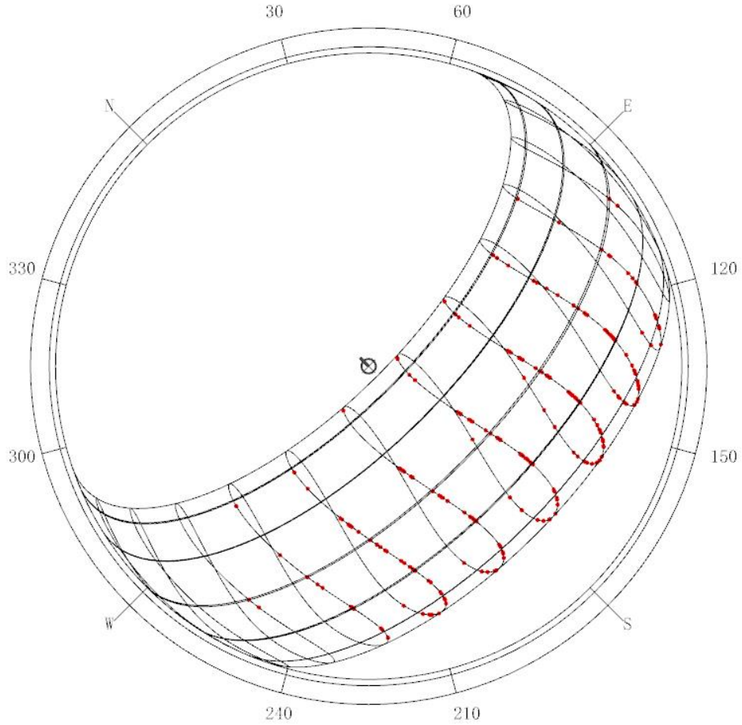


SUN PATH

SKY COVER & Direct Solar Radiation



Sun Positions (Sky Cover = 10)

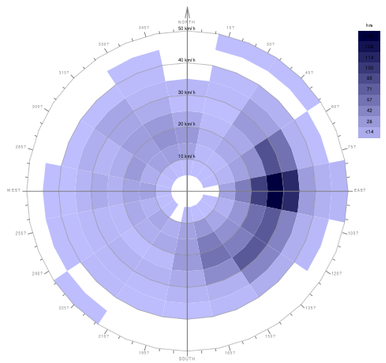


Sun Positions (Direct Solar Radiation > 800 Wh/m2)

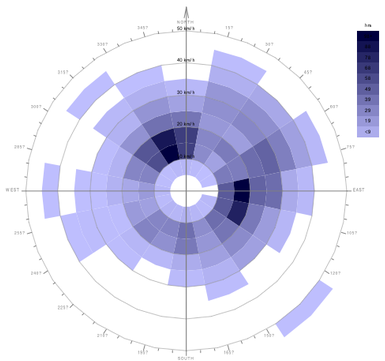
Two sun path shown above mapped with filtered sky cover (=10) and direct solar radiation (>800 Wh/m2), illustrates both Summer and Winter have more cloudy days than Spring and Fall, but winter have more solar radiation than any other seasons.

OTHER INFORMATION

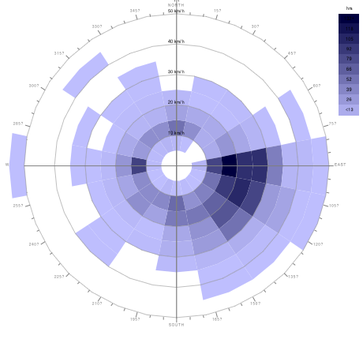
Wind Frequency & Psychrometric Chart & Precipitation



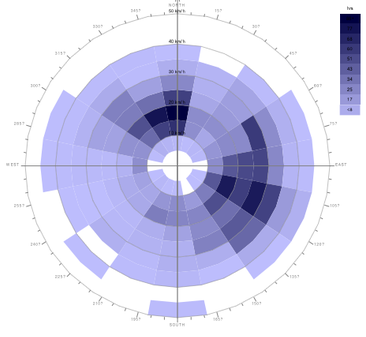
SPRING WIND FREQUENCY



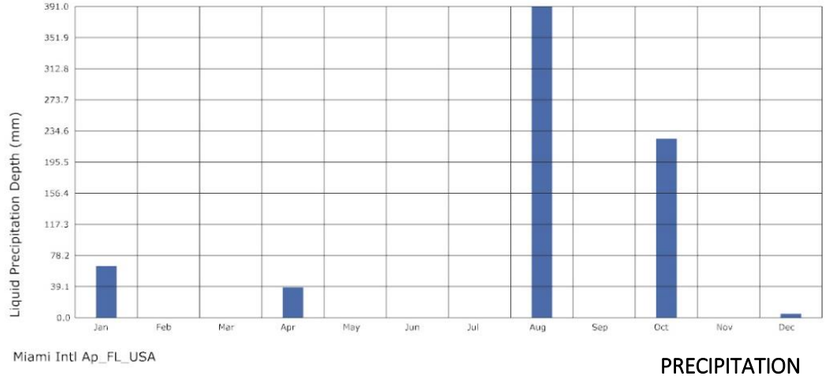
FALL WIND FREQUENCY



SUMMER WIND FREQUENCY

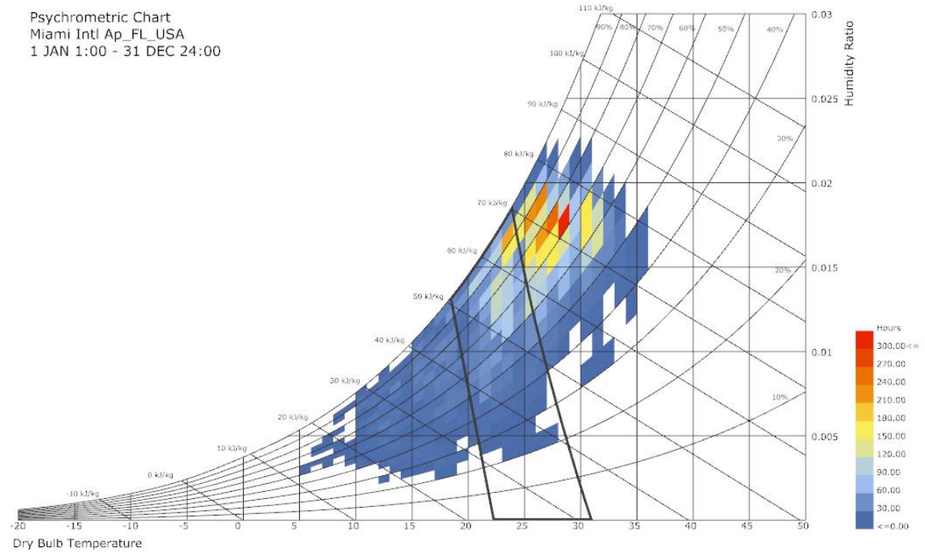


WINTER WIND FREQUENCY

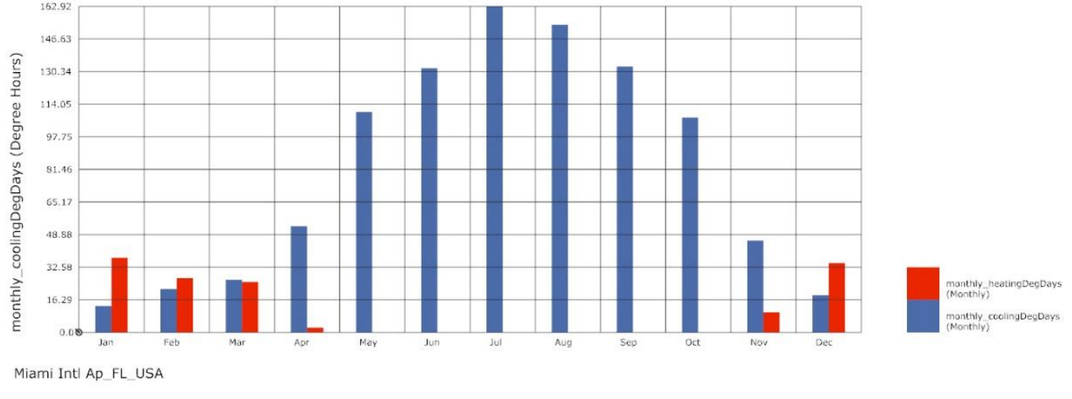


PRECIPITATION

Psychrometric Chart
Miami Intl Ap_FL_USA
1 JAN 1:00 - 31 DEC 24:00

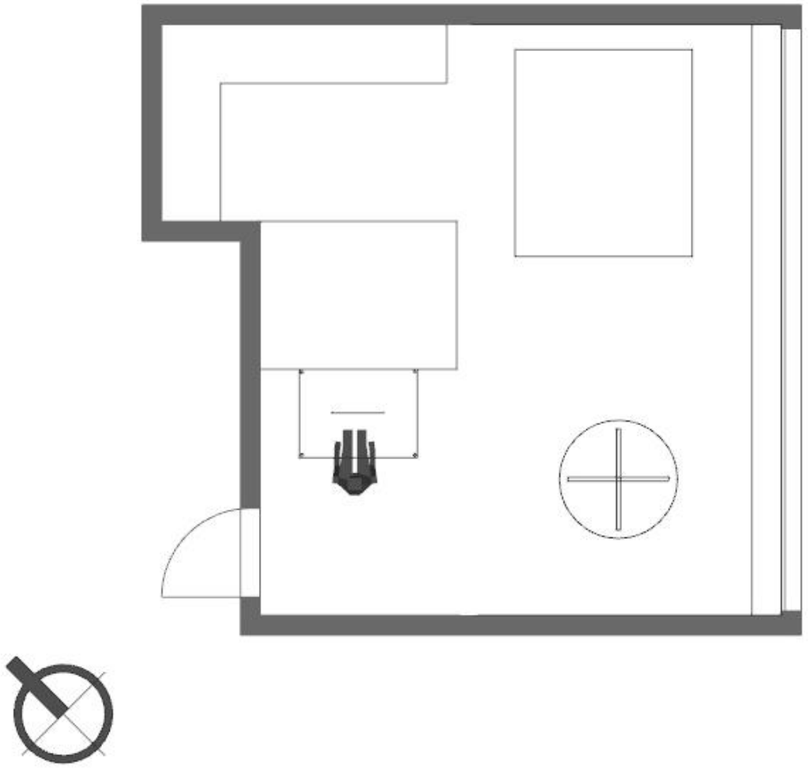


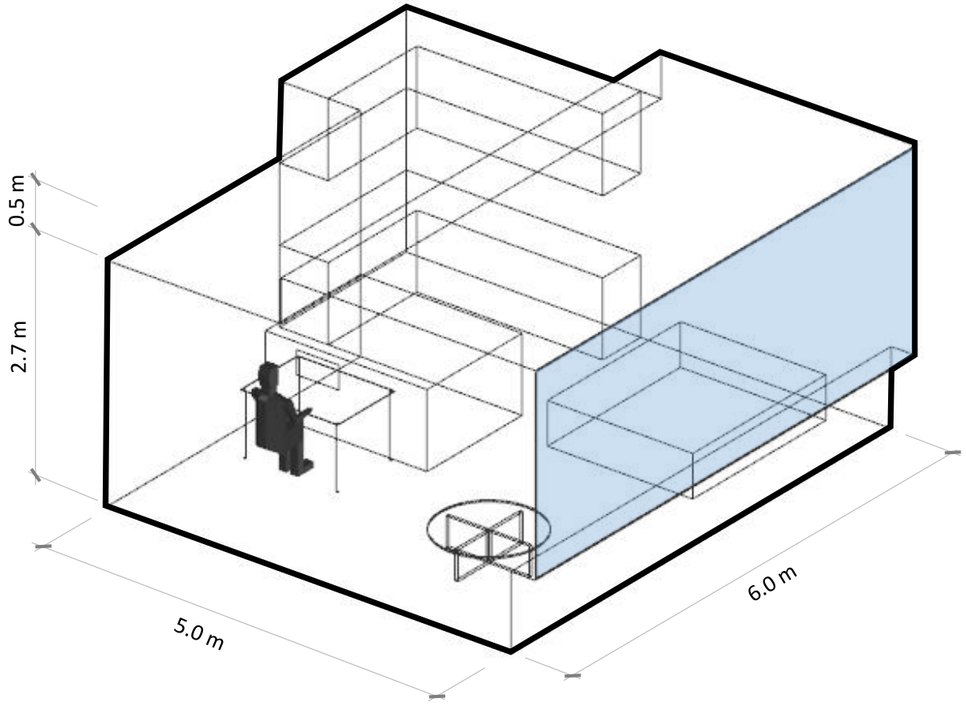
PSYCHROMETRIC CHART



DEGREE DAYS

TEST ROOM



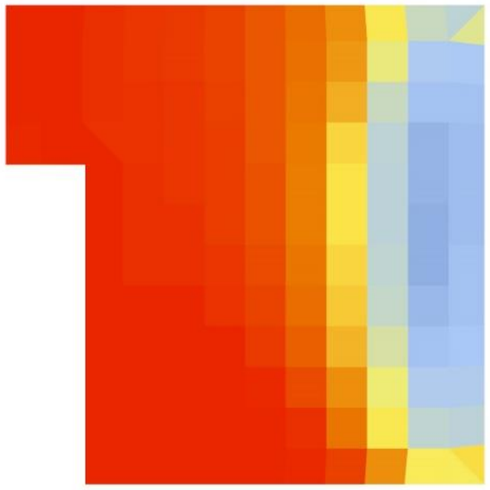


Area:	32 m2
Glazing area:	13.5 m2
Orientation	45 degree
Program:	Midrise Apartment
Occupied Hour:	6 PM – 8AM

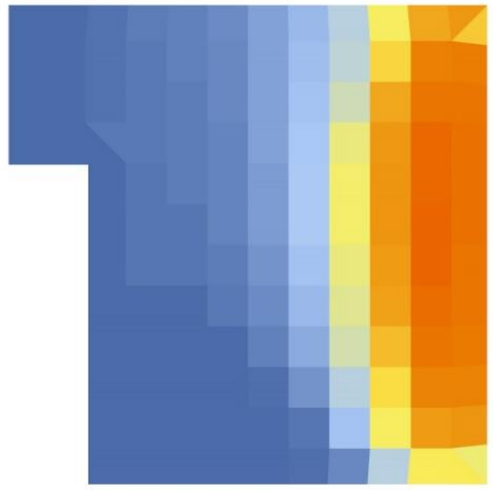
BASELINE-DAYLIGHTING

ANNUAL DAYLIGHT ANALYSIS

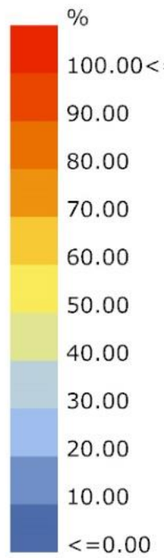
DAYLIGHT AUTONOMY (DLA)
300 LUX



Useful Daylight (UDLI)
100-2000 LUX



Useful Daylight (UDLI)
>2000 LUX



sDA:98.53%

Two sun path shown above mapped with filtered sky cover (=10) and direct solar radiation (>800 Wh/m2), illustrates both Summer and Winter have more cloudy days than Spring and Fall, but winter have more solar radiation than any other seasons.

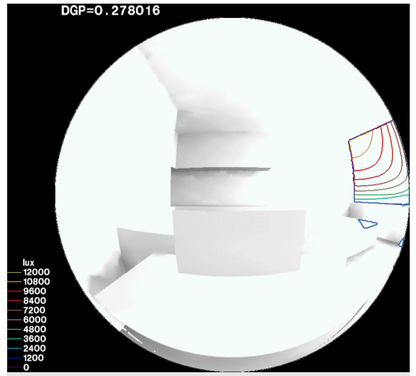
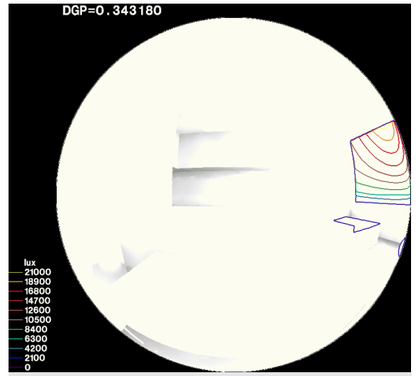
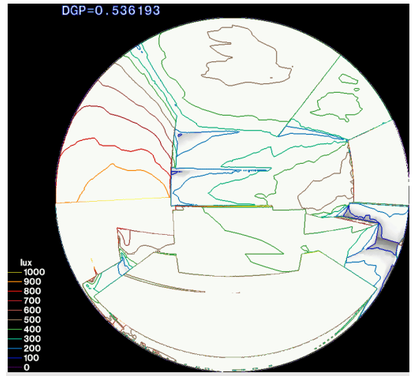
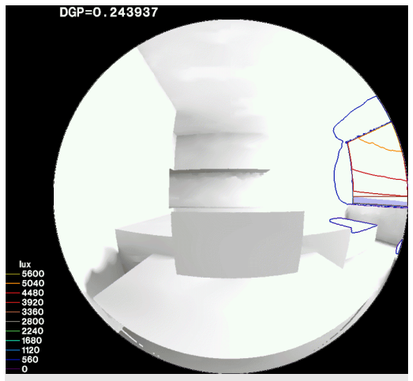
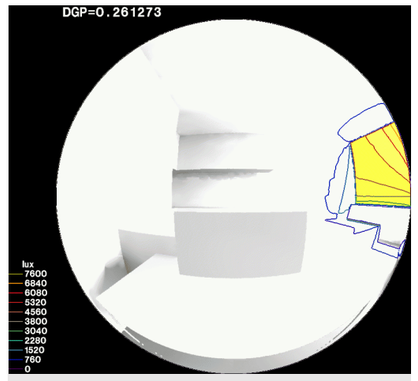
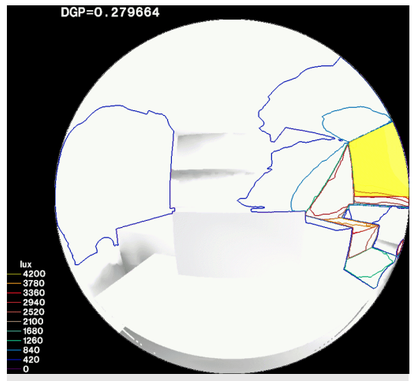
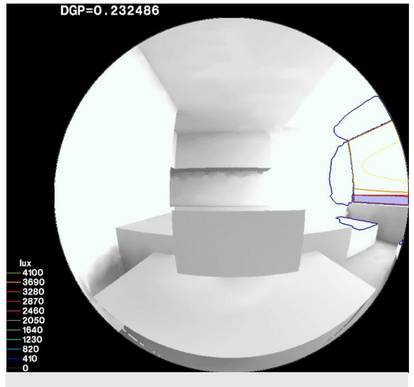
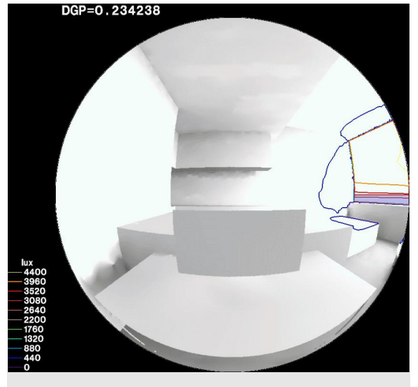
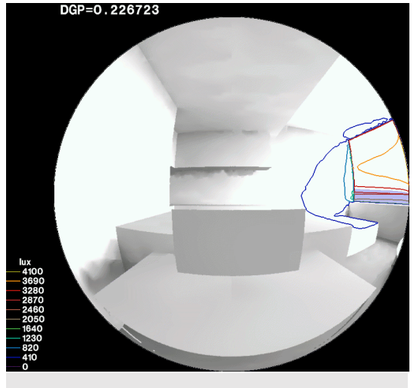
GLARE ANALYSIS

Daylight Glare Probability

Glare analysis is tested at 9 points of time on the position, where user uses computer and glare might be an issue on screen.

The results show only at 9 am, December 21st has a problem with glare, the other 8 points of time have imperceptible glare. Shading device can be used to improve this situation.

Imperceptible: **<35%**
Perceptible: **35-40%**
Disturbing: **40-45%**
Intolerable: **>45%**

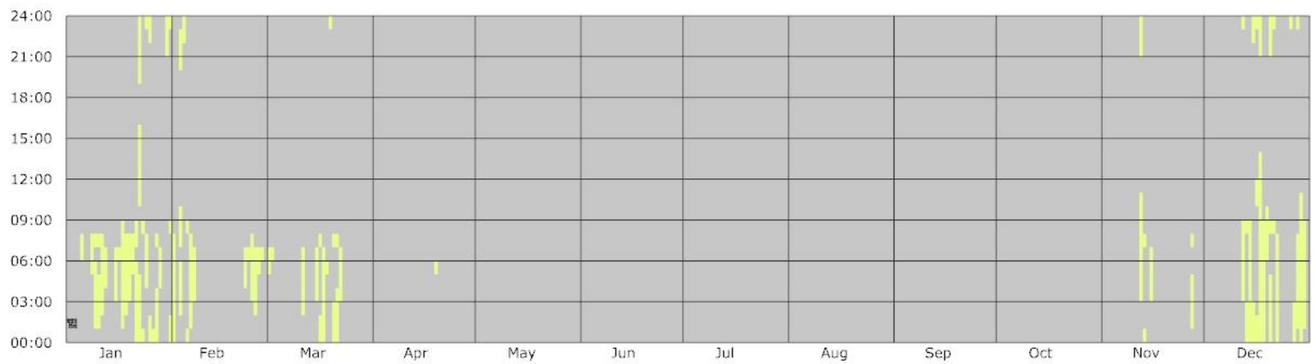
	JUNE	SEPTEMBER	DECEMBER
9 AM	 DGP: 27.8%	 DGP: 34.3%	 DGP: 53.6%
12 PM	 DGP: 24.4%	 DGP: 26.1%	 DGP: 28.0%
15 PM	 DGP: 23.2%	 DGP: 23.4%	 DGP: 22.7%

INDOOR COMFORT

PMV vs. Adaptive Comfort

Indoor comfort analysis for baseline shows only about 3.69% PMV comfort and 8.47% adaptive comfort of entire year hours. Comparing to outdoor UTCI comfort, there is 30 – 40 % reduction in both PMV and adaptive comfort of indoor environment.

By looking at comfort condition chart, the major reason caused uncomfortable is hot issue, but it need more details about indoor temperature to be checked to tell how hot inside is.

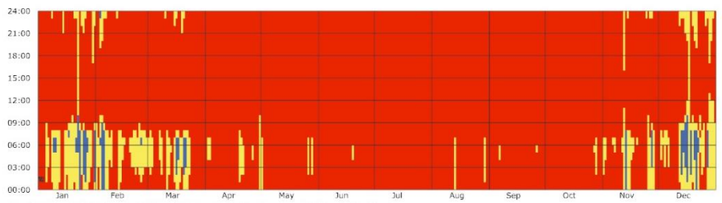


PMV COMFORT OR NOT

3.69%
COMFORTABLE

COMFORTABLE

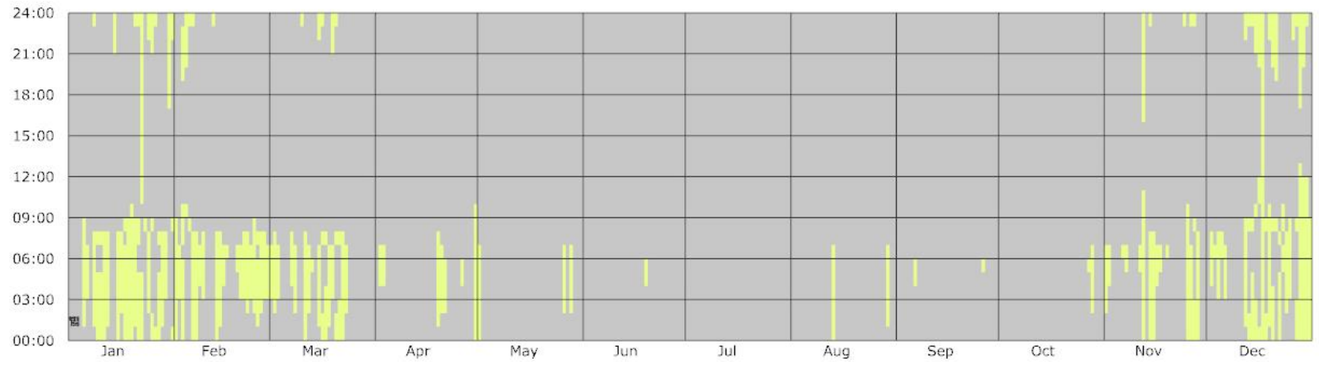
NOT COMFORTABLE



ADAPTIVE COMFORT CONDITION

HOT

COLD



ADAPTIVE COMFORT OR NOT

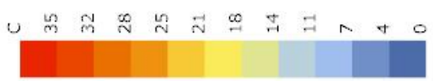
8.47%
COMFORTABLE

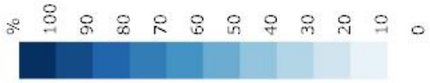
COMFORTABLE

NOT COMFORTABLE

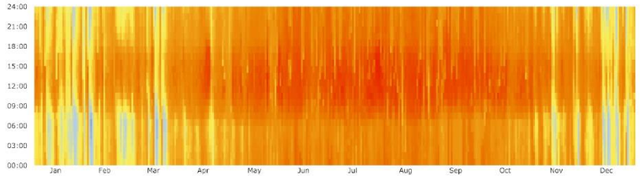
INDOOR FACTORS

Temperature & Relative Humidity

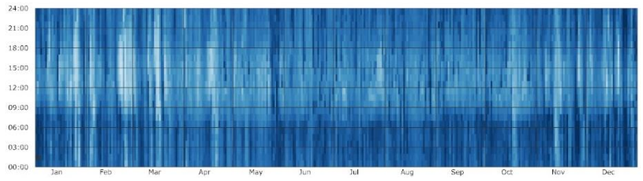




OUTDOOR

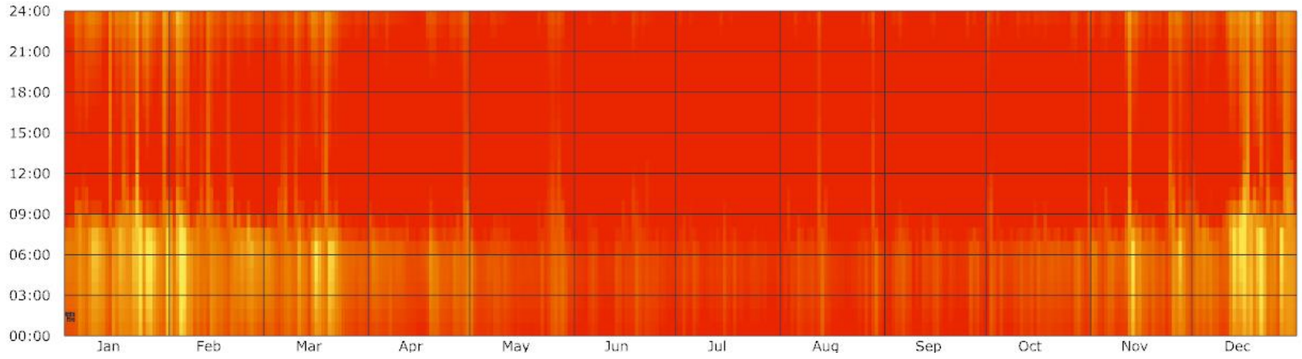


TEMPERATURE °C

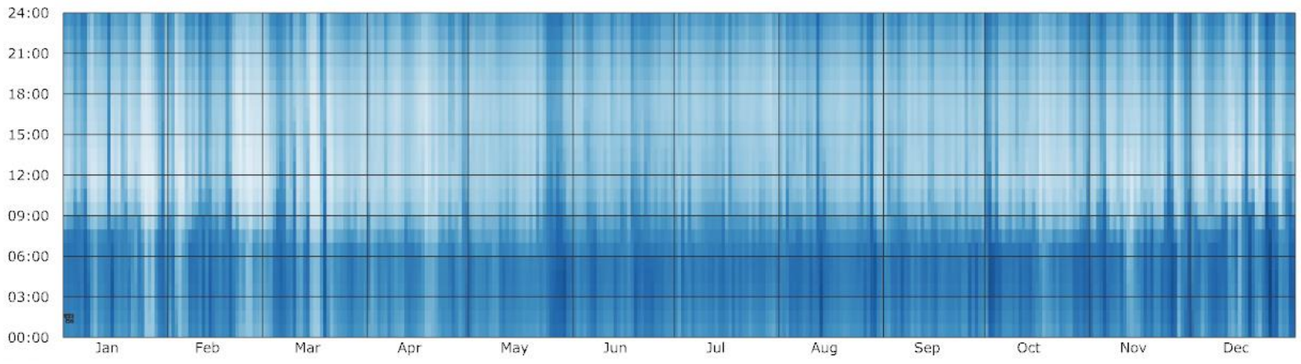


RELATIVE HUMIDITY %

INDOOR



INDOOR TEMPERATURE °C

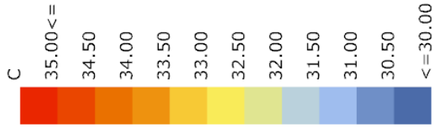


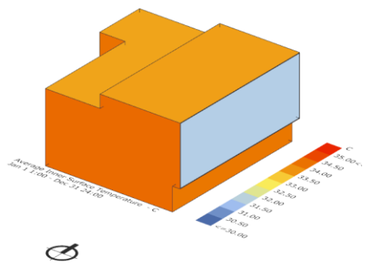
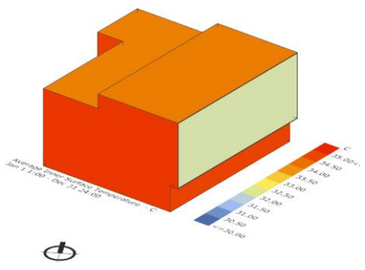
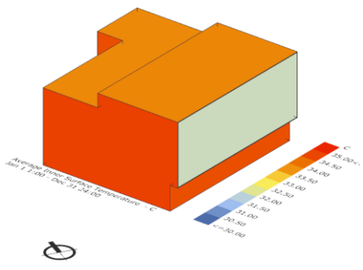
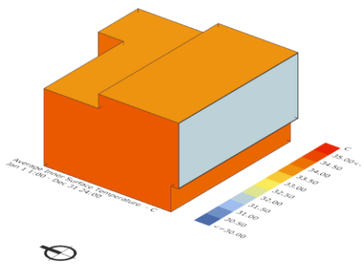
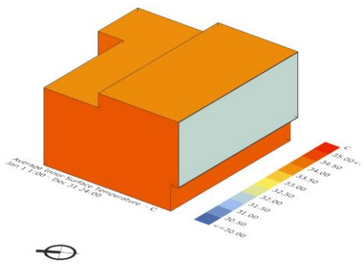
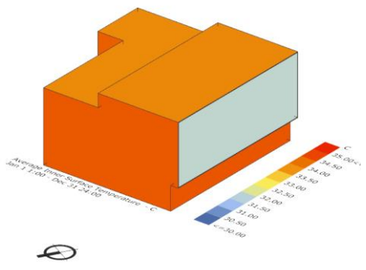
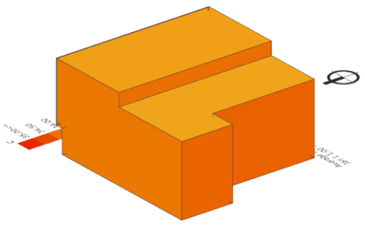
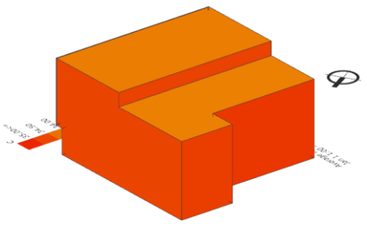
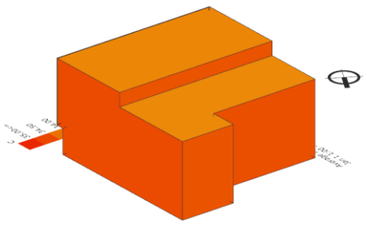
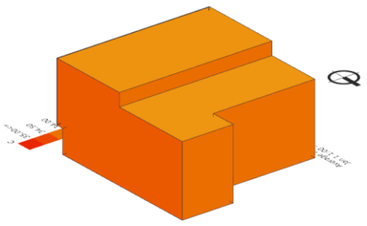
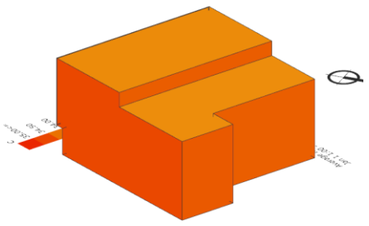
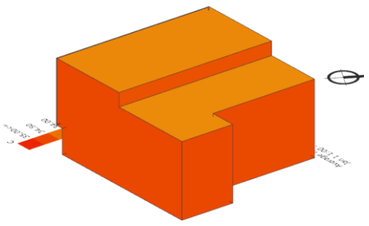
RELATIVE HUMIDITY %

Indoor temperature has a significant increases while comparing with outdoor temperature, which is due to the insolated room traps heat inside. Relative humidity decreases generally about 20% throughout year. In this case, adding operable windows to introduce natural wind might help decrease indoor temperature. Meanwhile, shading device is needed for windows, and decrease glazing area is also needed to prevent unwanted solar heat gain, which is the main heat source in this case.

ORIENTATION

Indoor Surface Temperature
Solar Heat Gain
Comfort

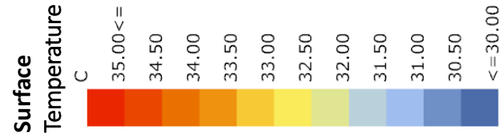


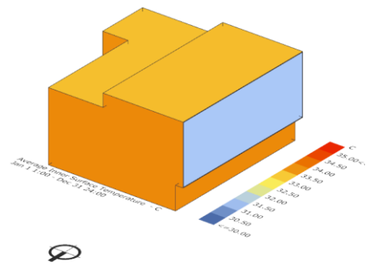
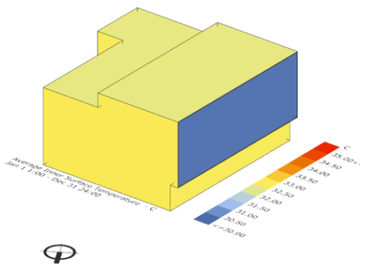
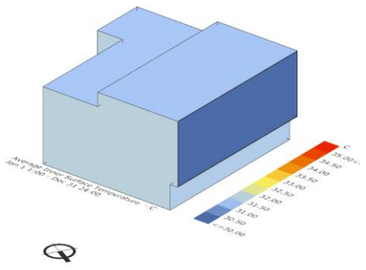
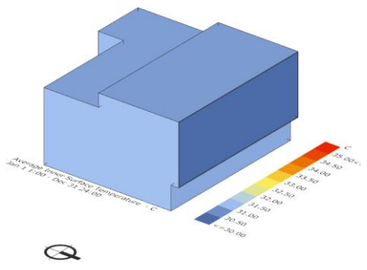
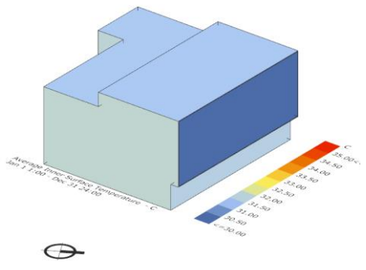
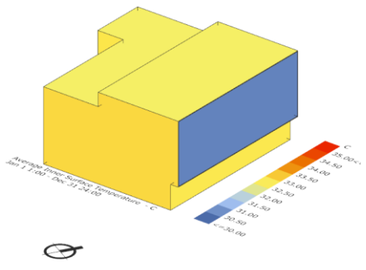
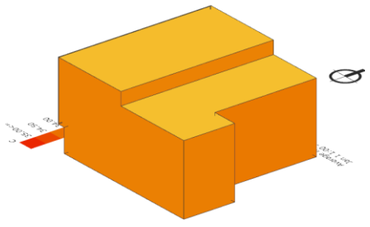
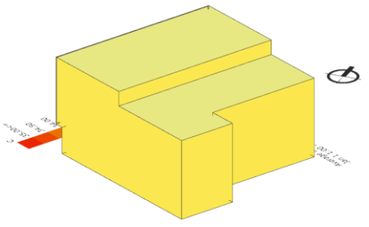
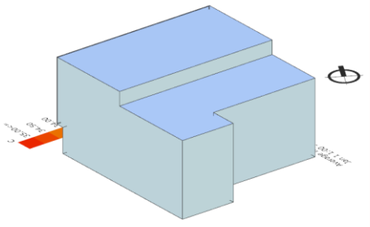
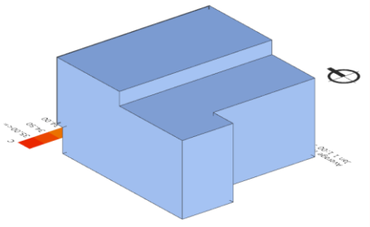
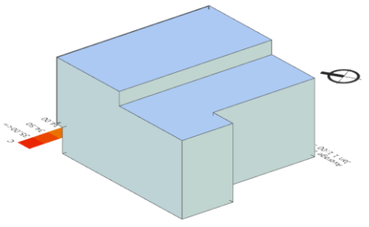
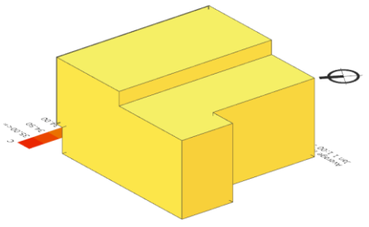
0°	30°	60°	90°	120°	150°
					
					
SHG: 7922 kWh	SHG: 8750 kWh	SHG: 8514 kWh	SHG: 8177 kWh	SHG: 8368 kWh	SHG: 8441 kWh
Adaptive: 10.67%	Adaptive: 9.00%	Adaptive: 8.16%	Adaptive: 8.21%	Adaptive: 9.10%	Adaptive: 10.01%

12 energy simulations have been executed with different orientations to test if orientation was going to help to decrease indoor temperature, and total solar heat gain, adaptive comfort were tested as well.

ORIENTATION

Indoor Surface Temperature
Solar Heat Gain
Adaptive Comfort

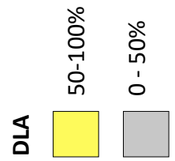


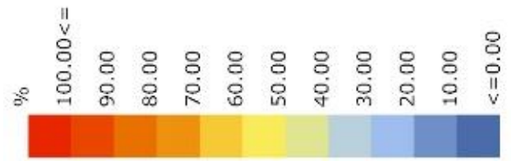
180°	210°	240°	270°	300°	330°
					
					
SHG: 7922 kWh	SHG: 8750 kWh	SHG: 4405 kWh	SHG: 3750 kWh	SHG: 4562 kWh	SHG: 6249 kWh
Adaptive: 10.67%	Adaptive: 14.34%	Adaptive: 16.83%	Adaptive: 17.51%	Adaptive: 16.82%	Adaptive: 13.88%

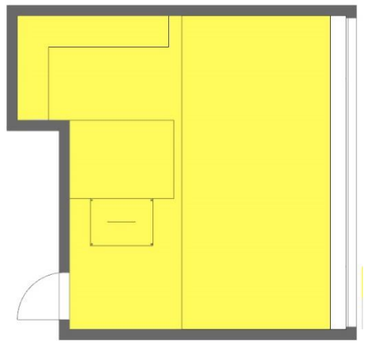
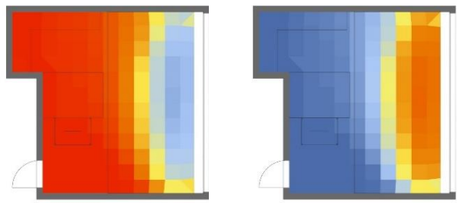
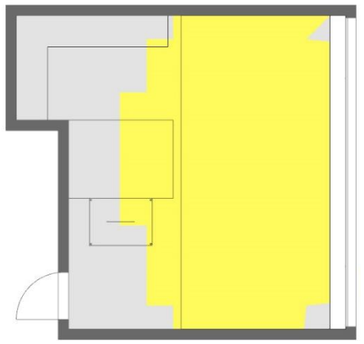
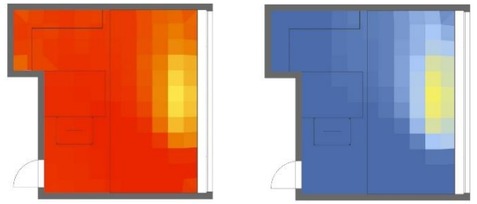
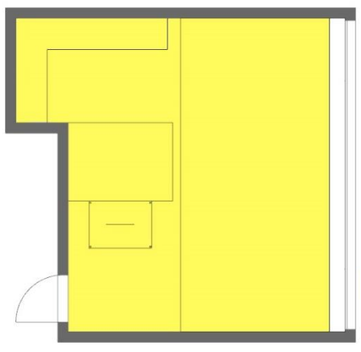
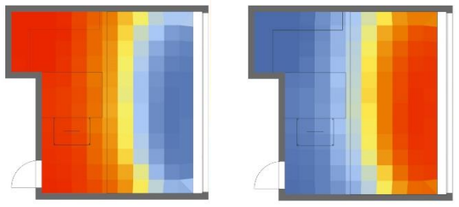
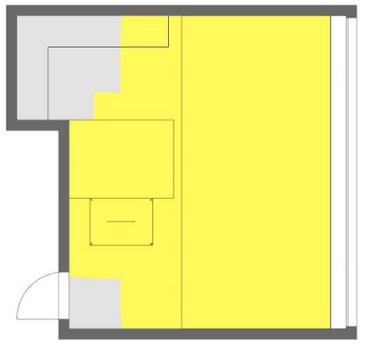
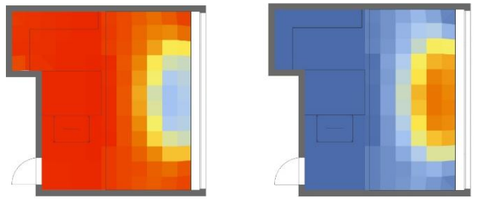
While window facing north (270°), building has the lowest solar heat gain (3749 Wh/m2) and highest adaptive comfort (17.51%). It is about 100% increase compared to baseline (8.47%). However, daylighting level is needed to be checked to verify if indoor space getting enough daylight.

ORIENTATION
GLAZING RATIO

Daylight Autonomy (DLA)
Useful Daylight (UDLI)



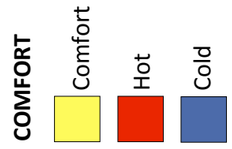


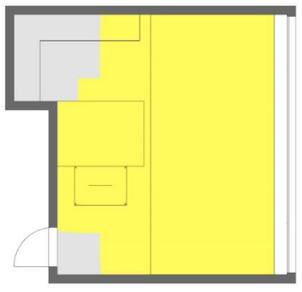
	DLA - 100% Glazing	UDLI - 100% Glazing	DLA - 60% Glazing	UDLI - 60% Glazing
45°				
	sDA 300Lux, 50% **98.53%**	**UDLI** 100-2000 Lux **UDLI** >2000 Lux	**sDA** 300Lux, 50% **63.24%**	**UDLI** 100-2000 Lux **UDLI** >2000 Lux
270°				
	sDA 300Lux, 50% **98.53%**	**UDLI** 100-2000 Lux **UDLI** >2000 Lux	**sDA** 300Lux, 50% **81.62%**	**UDLI** 100-2000 Lux **UDLI** >2000 Lux

Two sets of daylighting simulation (45°& 270° orientation) were executed. 270° was the best result from orientation study, and 45° was the baseline for comparison. The results show the room is still getting enough daylight when its window facing north. 60% glazing options were tested with the original 100% glazing ratio, and the result shows north facing window with 60% glazing ratio has enough daylighting.

ORIENTATION
GLAZING RATIO

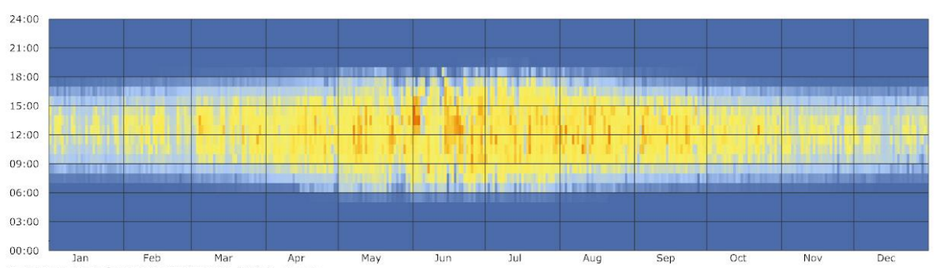
Solar Heat Gain
Comfort Condition





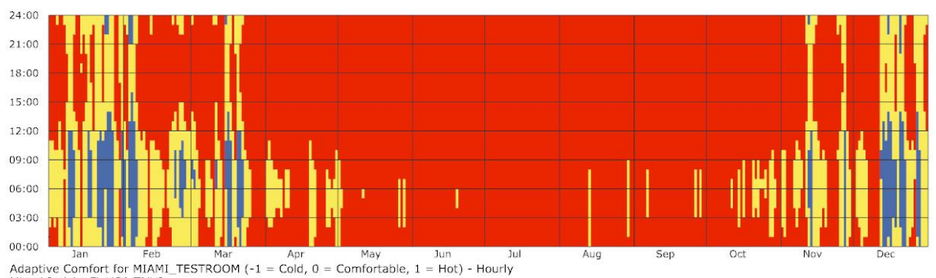
annual analysis
sDA:81.62

100% Glazing



Total Solar Gain for MIAMI_TESTROOM (kWh) - Hourly
Miami Intl Ap FL USA TMY3
1 JAN 1:00 - 31 DEC 24:00

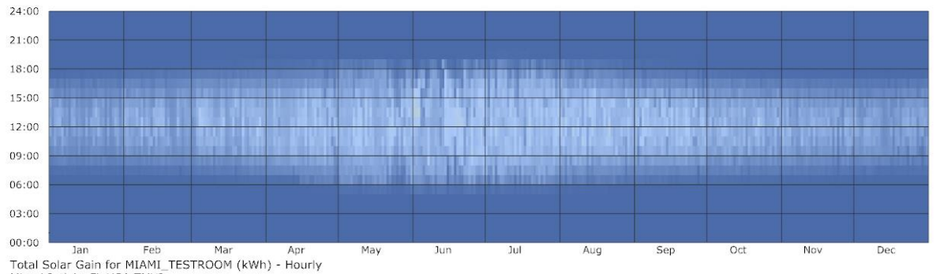
SHG: 3750 kWh



Adaptive Comfort for MIAMI_TESTROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Miami Intl Ap FL USA TMY3
1 JAN 1:00 - 31 DEC 24:00

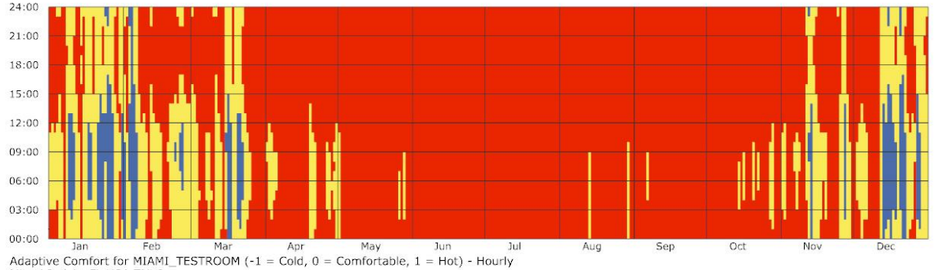
Adaptive: 17.51%

60% Glazing



Total Solar Gain for MIAMI_TESTROOM (kWh) - Hourly
Miami Intl Ap FL USA TMY3
1 JAN 1:00 - 31 DEC 24:00

SHG: 1383 kWh

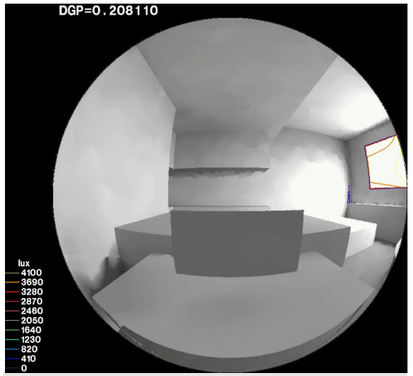
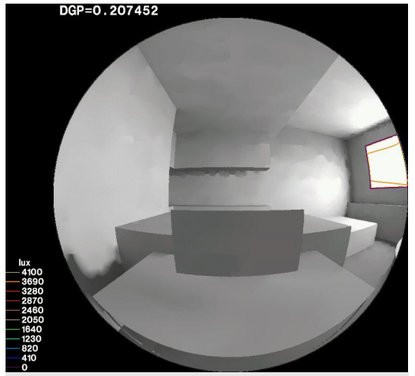
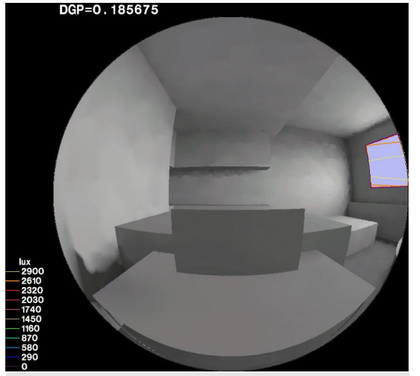
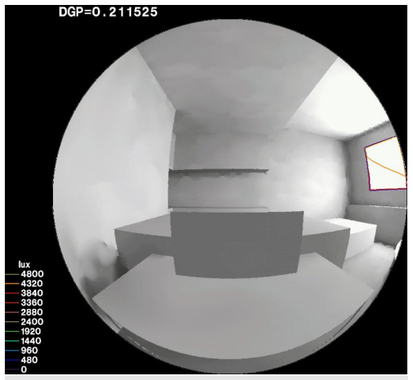
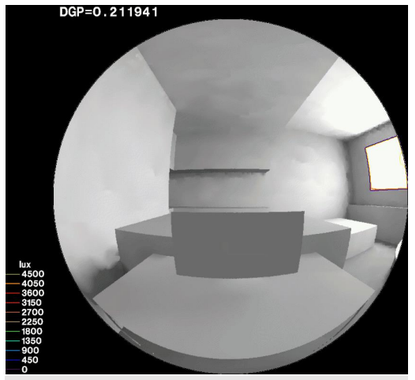
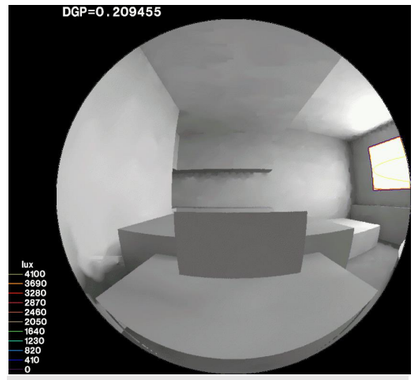


Adaptive Comfort for MIAMI_TESTROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Miami Intl Ap FL USA TMY3
1 JAN 1:00 - 31 DEC 24:00

Adaptive: 18.97%

GLARE ANALYSIS

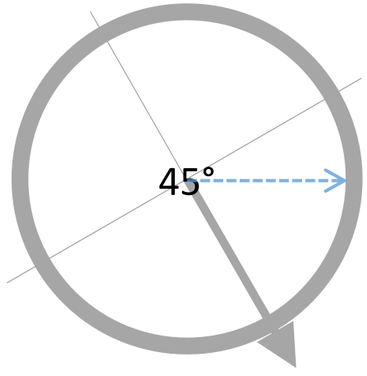
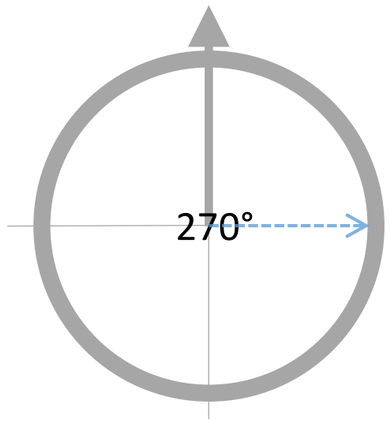
Daylight Glare Probability

	JUNE	SEPTEMBER	DECEMBER
9 AM	 DGP: 20.8%	 DGP: 20.8% (was 34.3%)	 DGP:18.6% (was: 53.6%)
12 PM	 DGP: 21.2%	 DGP: 21.2%	 DGP: 21.0%
15 PM	 DGP: 21.8%	 DGP: 21.3%	 DGP: 20.6%

After changing building's orientation, daylight glare probability has been reduced from 53.6% to 18.6% at December 9am, and DGI at the other 8 points of time have more or less reduction

Imperceptible: **<35%**
Perceptible: **35-40%**
Disturbing: **40-45%**
Intolerable: **>45%**

FIRST RUN SUMMARY

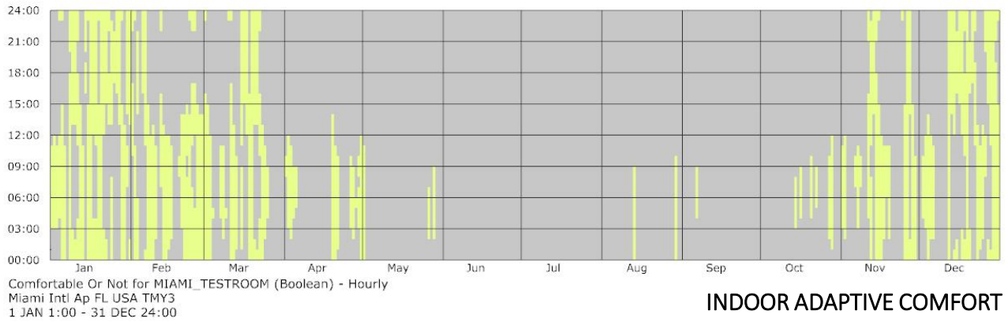
	STRATEGIES		RESULTS	
	Orientation	Glazing Ratio	Daylighting	Adaptive Comfort
Original		100%	sDA 98.53% 300, 50%	8.47% COMFORTABLE OF 8760 HOURS
First Run		60%	sDA 81.62% 300, 50%	18.97% COMFORTABLE OF 8760 HOURS

NEXT STRATEGIES

VENTILATION	MATERIALS
Use natural ventilation	Increase insulating material's resistance
Decrease indoor temperature	Heat Buffer

TARGETING

Natural Ventilation



INDOOR ADAPTIVE COMFORT

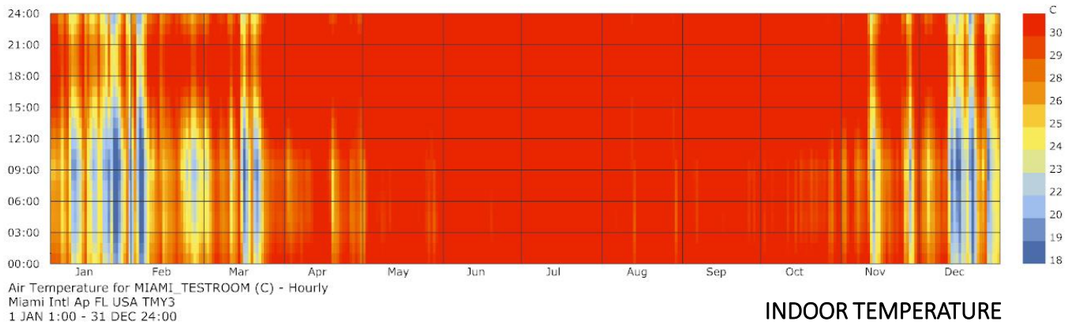
COMFORT

Comfortable

Not Comfortable

18.97%
COMFORTABLE OF 8760 HOURS

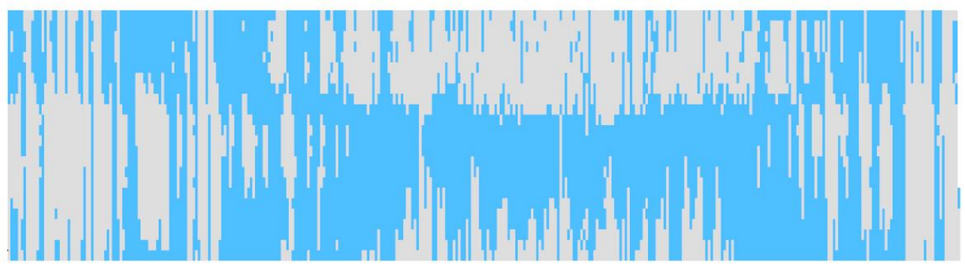
20.16%
COMFORTABLE OF OCCUPIED HOURS



INDOOR TEMPERATURE

30.63 °C
AVERAGE TEMP OF 8760 HOURS

30.44 °C
AVERAGE TEMP OF OCCUPIED HOURS



TEMPERATURE (22 -28 °C) FOR VENTILATION

NO

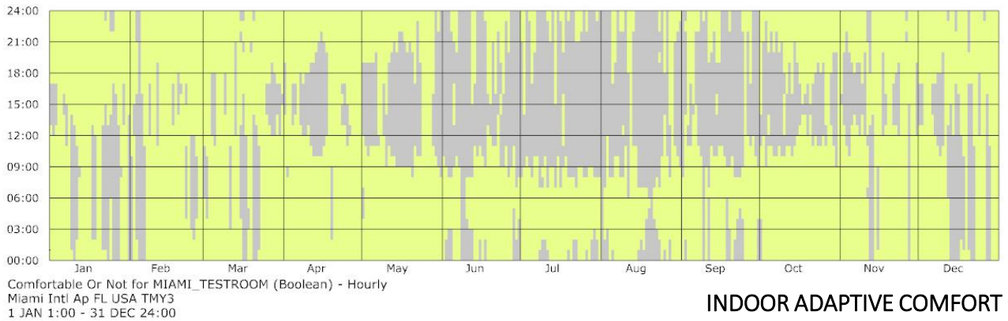
YES

OUTDOOR TEMPERATURE

The result from last simulation has 18.97% comfort, and 20.16% comfort of occupied hours, which is due to majority time indoor space is over heated. By checking outdoor temperature diagram flited by comfort temperature for natural ventilation, which is marked in blue, using natural ventilation could be able to reduce indoor temperature where marked in red.

TARGETING

Natural Ventilation



INDOOR ADAPTIVE COMFORT

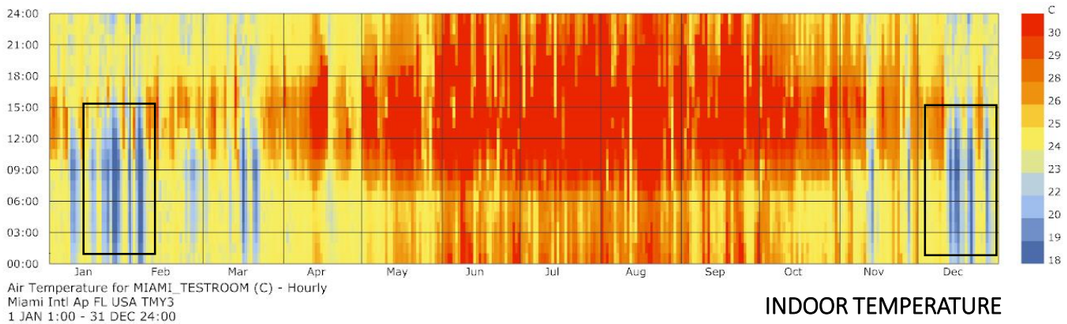
COMFORT

Comfortable

Not Comfortable

64.75%
COMFORTABLE OF 8760 HOURS

76.47%
COMFORTABLE OF OCCUPIED HOURS



INDOOR TEMPERATURE

26.49 °C
AVERAGE TEMP OF 8760 HOURS

25.52 °C
AVERAGE TEMP OF OCCUPIED HOURS

NATURAL VENTILATION THRESHOLD

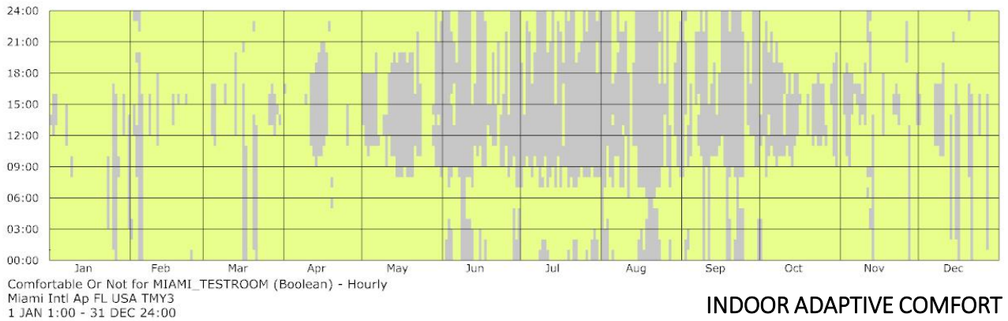
Minimum Indoor Temperature: 24C
Maximum Outdoor Temperature: 28C

Natural ventilation works very well in this case, because originally in exterior environment, there are sufficient wind resource could be used for interior ventilation.

But there are a few points of time during winter time need a little bit more heat to provide comfort, therefore, thermal mass could help to solve this problem by acting as a buffer.

TARGETING

CONSTRUCTION MATERIAL



INDOOR ADAPTIVE COMFORT

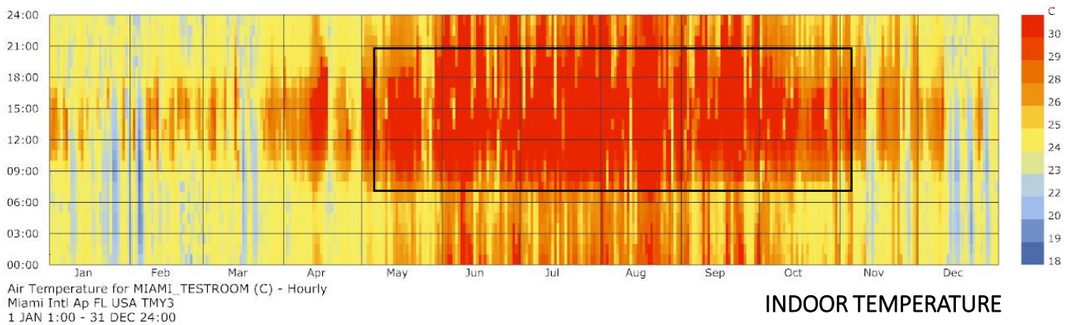
COMFORT

Comfortable

Not Comfortable

70.63%
COMFORTABLE OF 8760 HOURS

81.88%
COMFORTABLE OF OCCUPIED HOURS



INDOOR TEMPERATURE

26.46 °C
AVERAGE TEMP OF 8760 HOURS

25.59 °C
AVERAGE TEMP OF OCCUPIED HOURS

CONSTRUCTION LIST

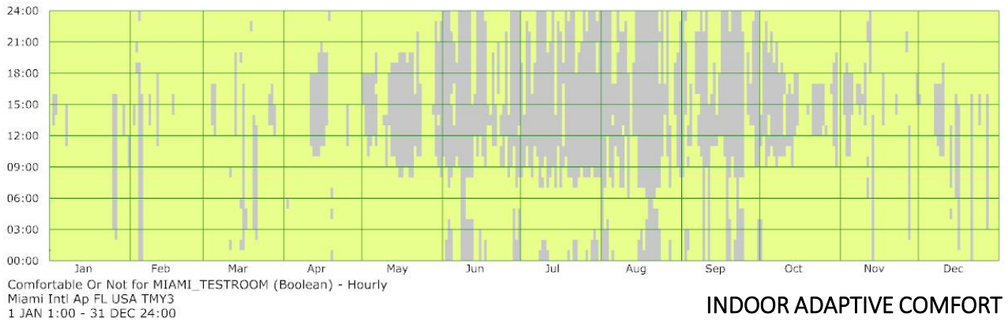
R27.8 Metal Roof
R22.8 Concrete Wall

There is about 6% increase in annual comfort by changing construction's material, and average temperatures were stabilized around 26°C.

Comfort of occupied hour has reached to 82%, which is already sufficient for a space. The last step is replacing current glazing material to Low-E double glazing with 0.6 solar heat gain coefficient to reduce total solar heat gain further.

TARGETING

CONSTRUCTION MATERIAL



INDOOR ADAPTIVE COMFORT

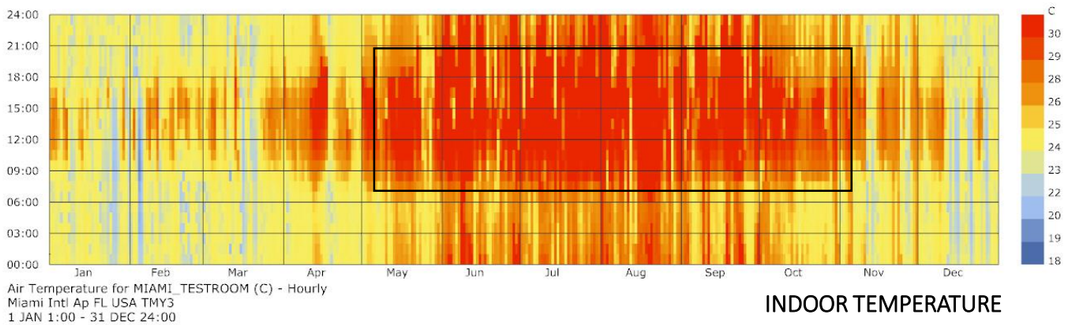
COMFORT

Comfortable

Not Comfortable

72.87%
COMFORTABLE OF 8760 HOURS

83.11%
COMFORTABLE OF OCCUPIED HOURS



INDOOR TEMPERATURE

26.39 °C
AVERAGE TEMP OF 8760 HOURS

25.61 °C
AVERAGE TEMP OF OCCUPIED HOURS

CONSTRUCTION LIST

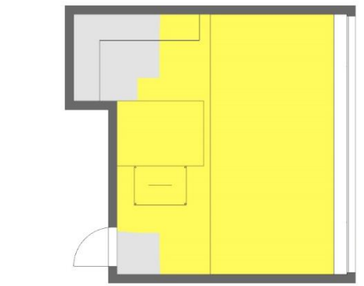
R27.8 Metal Roof
R22.8 Concrete Wall

GLAZING MATERIAL

Low-E double glazing SC=0.6
VT:0.73
SHGC:0.6
U:0.37

The improvement of changing higher performance glazing is very minimum, which is due to building's orientation, which has limited direct solar radiation access to interior.

SUMMARY



	STRATEGIES		RESULTS	
	Orientation	Glazing Ratio	Daylighting	Adaptive Comfort
Original	45°	100%	sDA 98.53% 300, 50%	8.47% COMFORTABLE OF 8760 HOURS
First Run	270°	60%	sDA 81.62% 300, 50%	18.97% COMFORTABLE OF 8760 HOURS

STRATEGIES	
VENTILATION	MATERIALS
64.75% COMFORTABLE OF 8760 HOURS	72.87% COMFORTABLE OF 8760 HOURS
76.47% COMFORTABLE OF OCCUPIED HOURS	83.11% COMFORTABLE OF OCCUPIED HOURS