Thermal and Visual Comfort Maximization of an Unconditioned Space

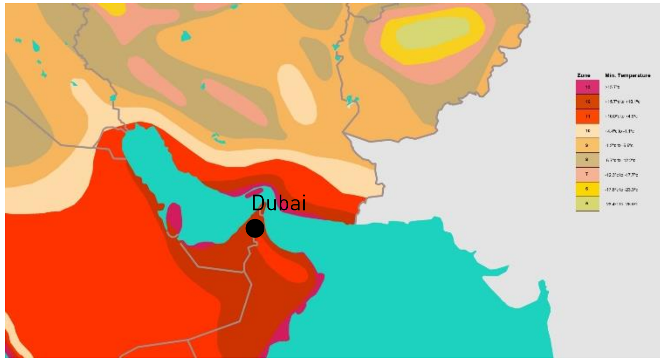
ARCH-753 - Building Performance Simulation

Yuntian Wan

Climate Report I

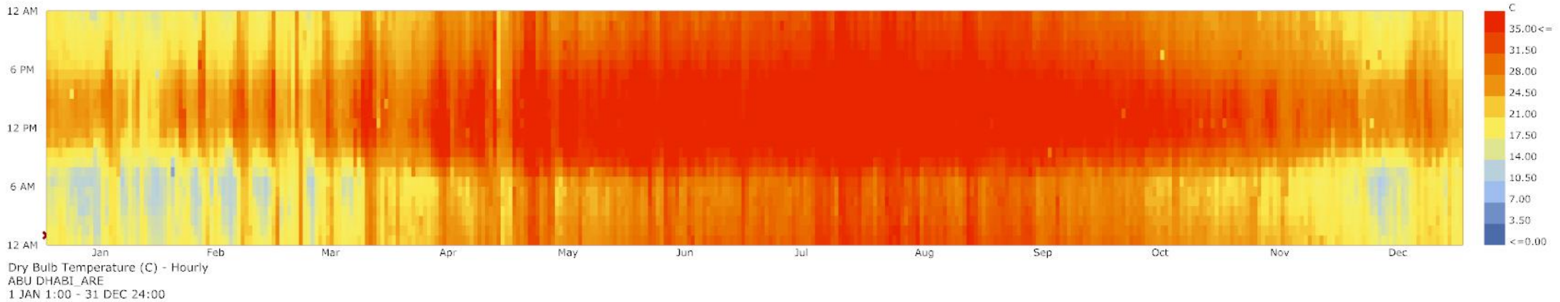
Site Map

Climate Zone

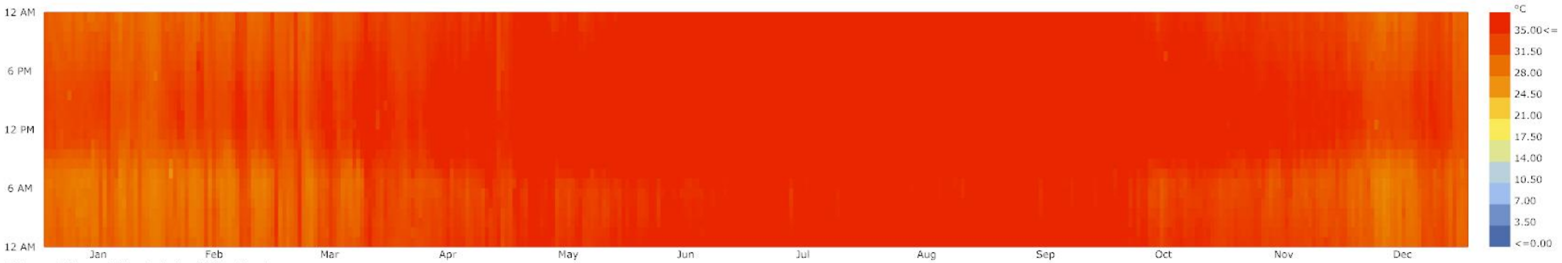


Hot and humid

Dry Bulb Temperature



Universal Thermal Climate Index

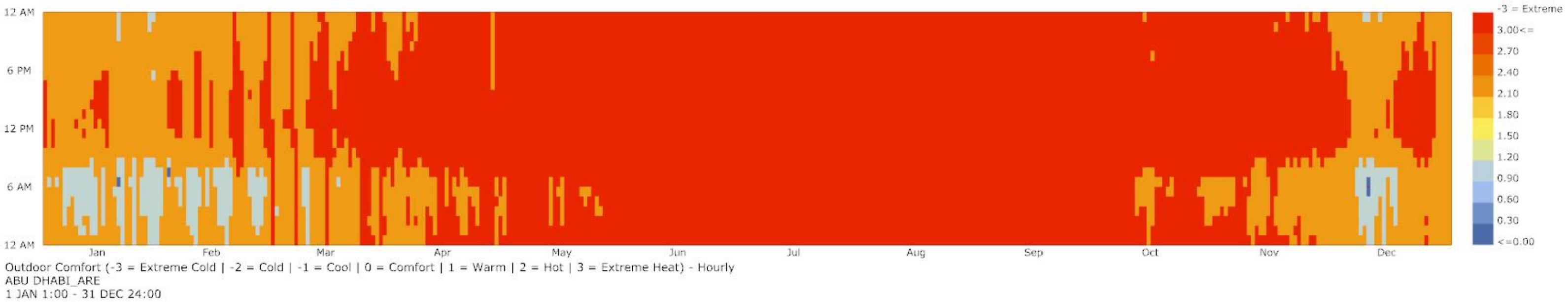


Universal Thermal Climate Index (°C) - Hourly
ABU DHABI_ARE
1 JAN 1:00 - 31 DEC 24:00

In Universal Thermal Climate Index analysis, people's feeling about temperature is higher than the dry bulb temperature.

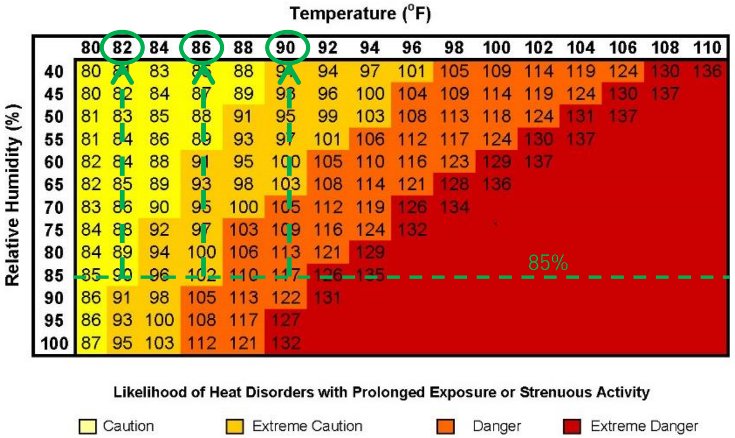
4.6%
Comfort time

Condition of Person (outdoor)



Climate Report II

Heat Index



Temperature (°F)

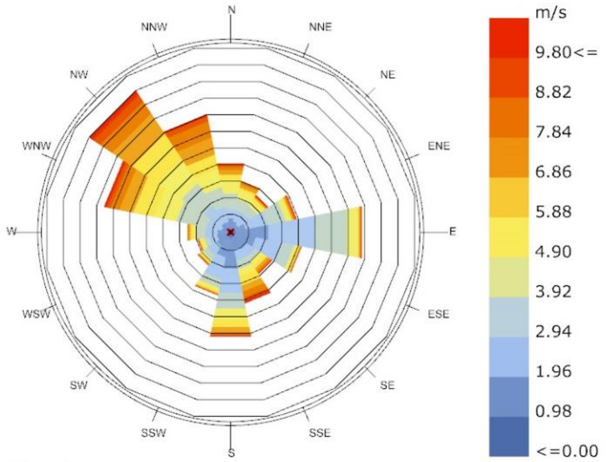
Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

85%

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

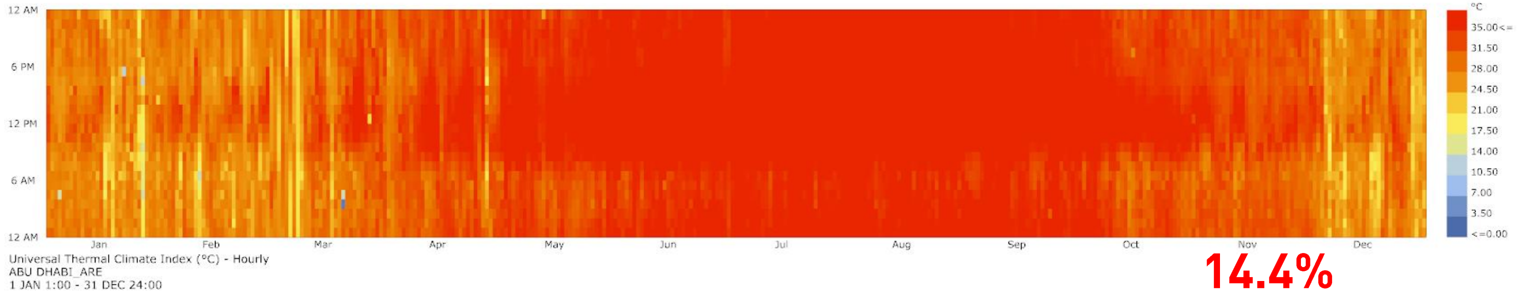
Wind Direction



Wind-Rose
ABU DHABI_ARE
1 JAN 1:00 - 31 DEC 24:00

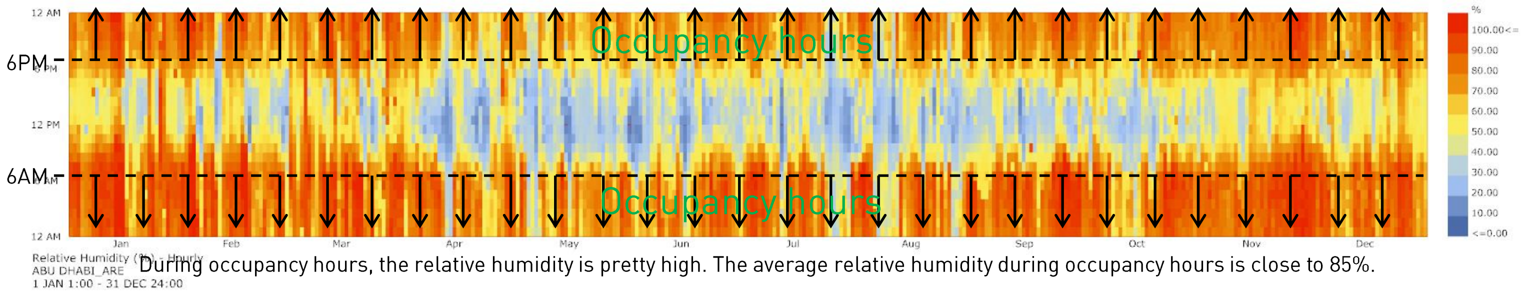
Dominant Direction: NW

Universal Thermal Climate Index (with wind)



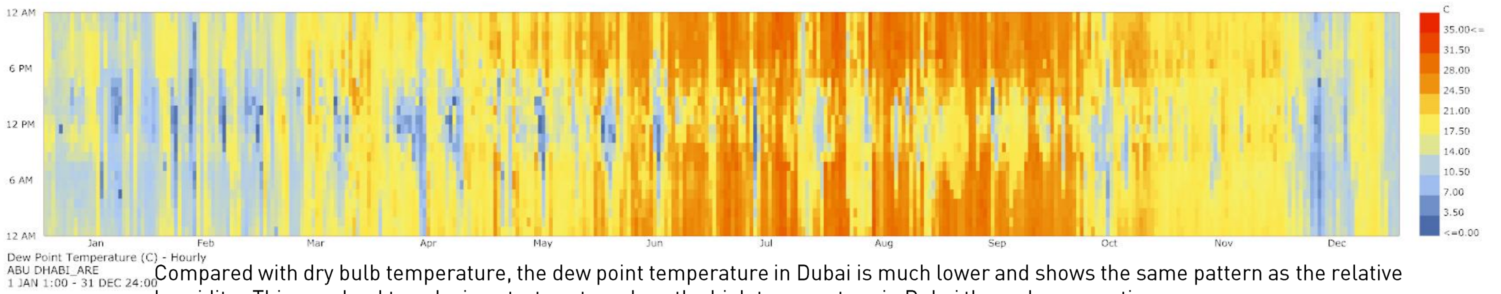
14.4%
Comfort time

Humidity During Occupancy Hours



During occupancy hours, the relative humidity is pretty high. The average relative humidity during occupancy hours is close to 85%.

Dew Point Temperature

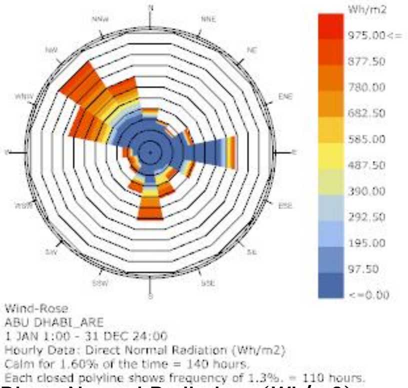


Compared with dry bulb temperature, the dew point temperature in Dubai is much lower and shows the same pattern as the relative humidity. This may lead to a design strategy to reduce the high temperature in Dubai through evaporation.

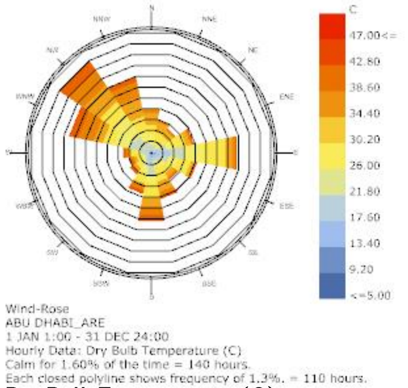
Climate Report III

Dubai has a hot desert climate. Summers in Dubai are extremely hot, windy, and humid, with an average high around 41 °C (106 °F) and overnight lows around 30 °C (86 °F) in the hottest month, August. Most days are sunny throughout the year. Winters are warm with an average high of 24 °C (75 °F) and overnight lows of 14 °C (57 °F) in January, the coldest month. Precipitation, however, has been increasing in the last few decades, with accumulated rain reaching 94.3 mm (3.71 in) per year. Dubai summers are also known for the moderate to high humidity level, which can make it uncomfortable for many. The highest recorded temperature in Dubai is 49 °C (120 °F), reached in July 2002.

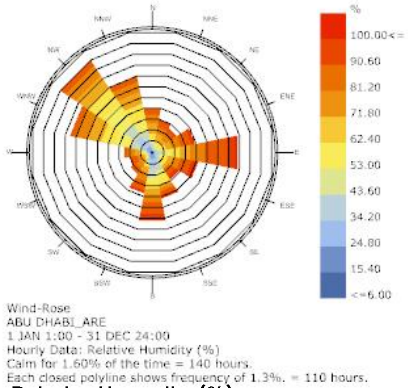
Wind rose analysis



Direct Normal Rediation （Wh/m2）

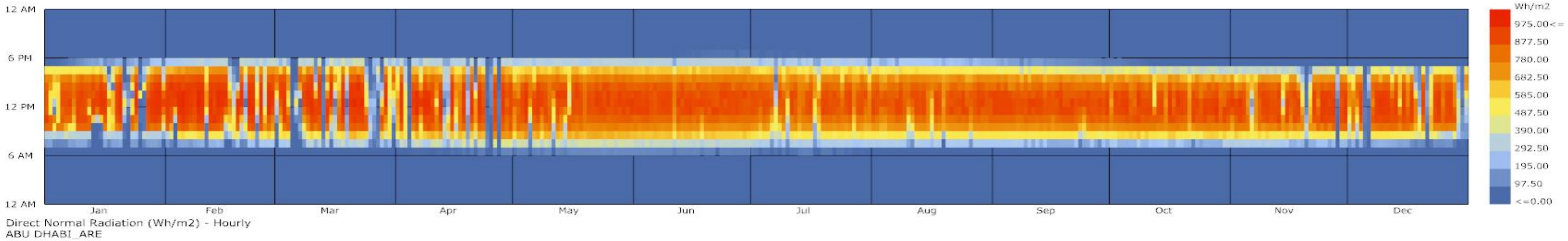


Dry Bulb Temperature （C）

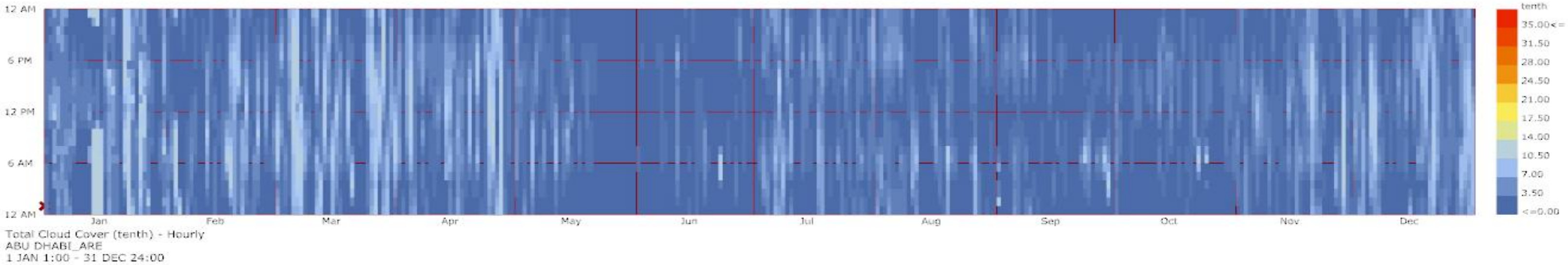


Relative Humudity (%)

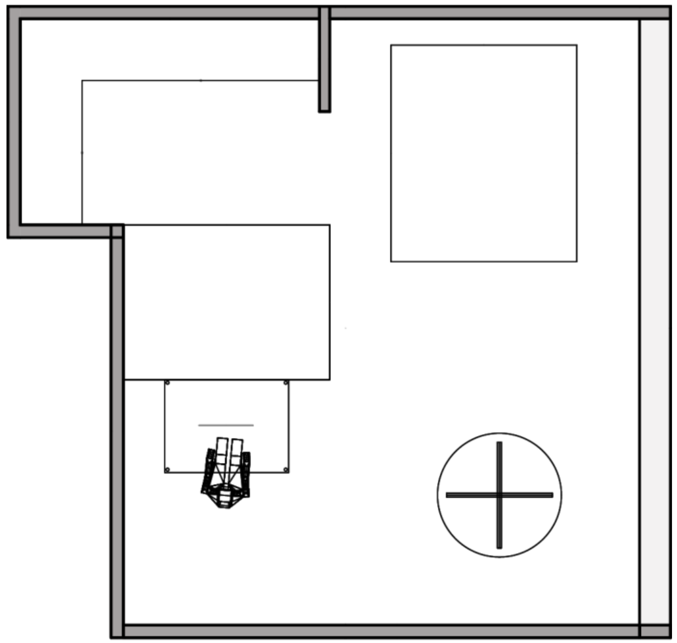
Solar Radiation



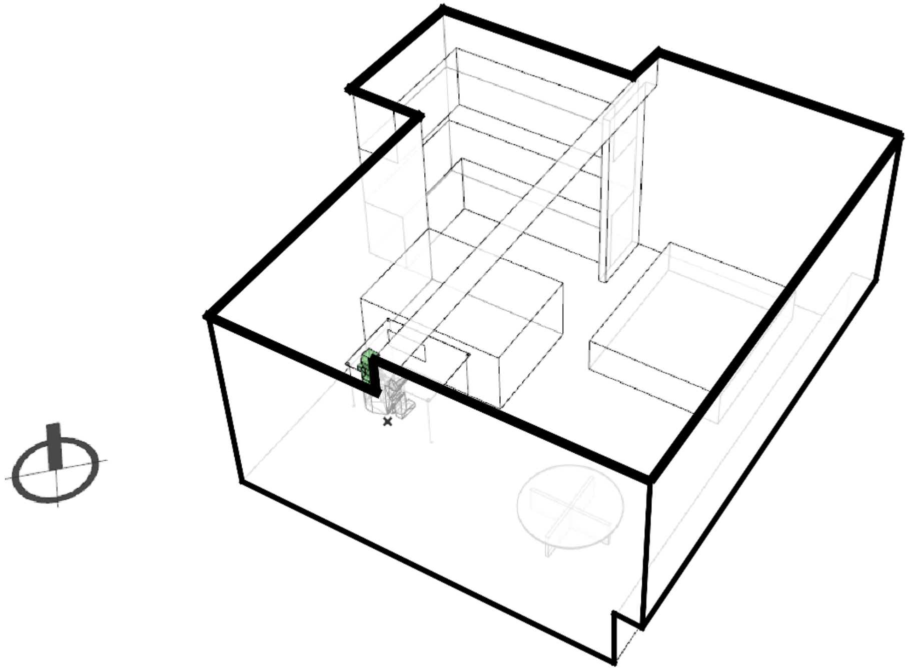
Skycover



Baseline · Background Information



Plan



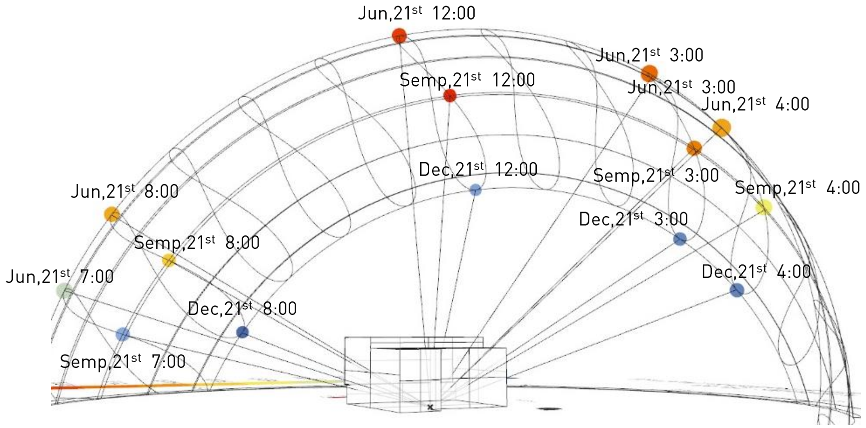
Perspective

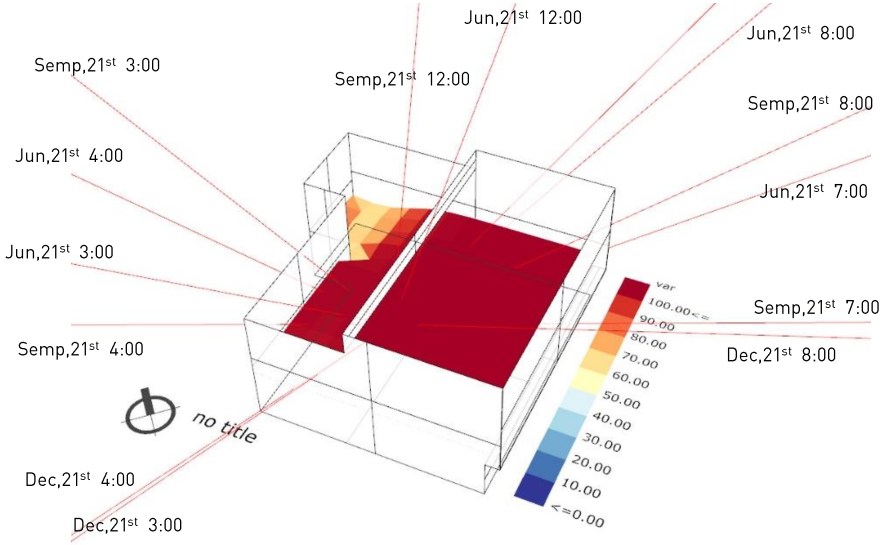
Description:

Use a typical simple bedroom for analysis. In order to get the best daylight and achieve the maximam thermal comfort according to occupancy and user's activities, the first strategy is to avoid excessive sunlight around the bed but if there is some excessive sunlight is near the study desk or dinner table, it is acceptable.

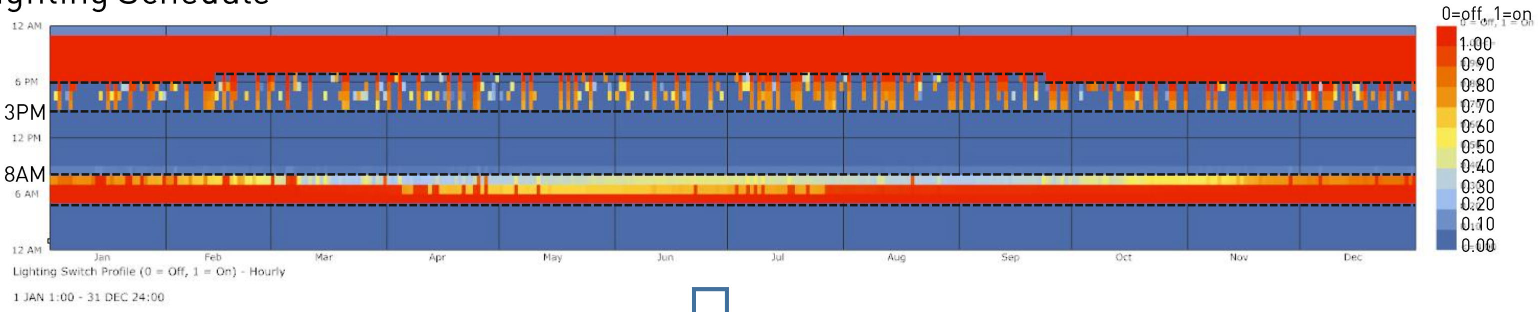
Baseline I · Daylighting

Sunpath

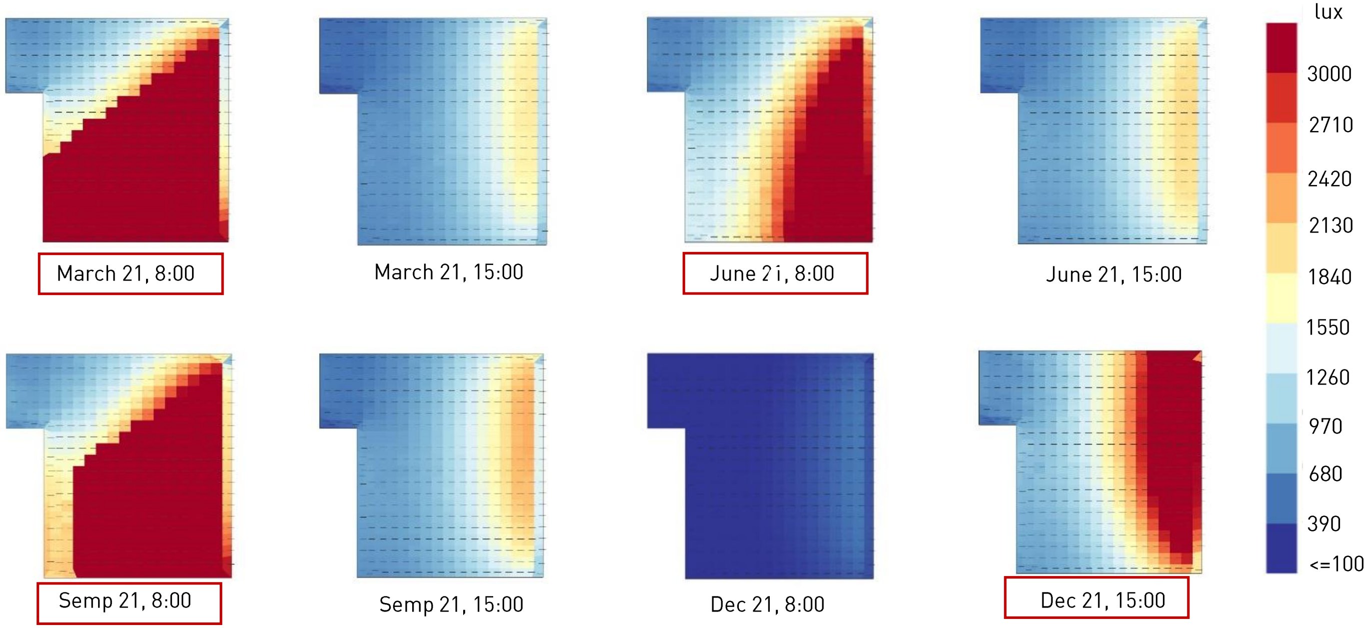




Lighting Schedule



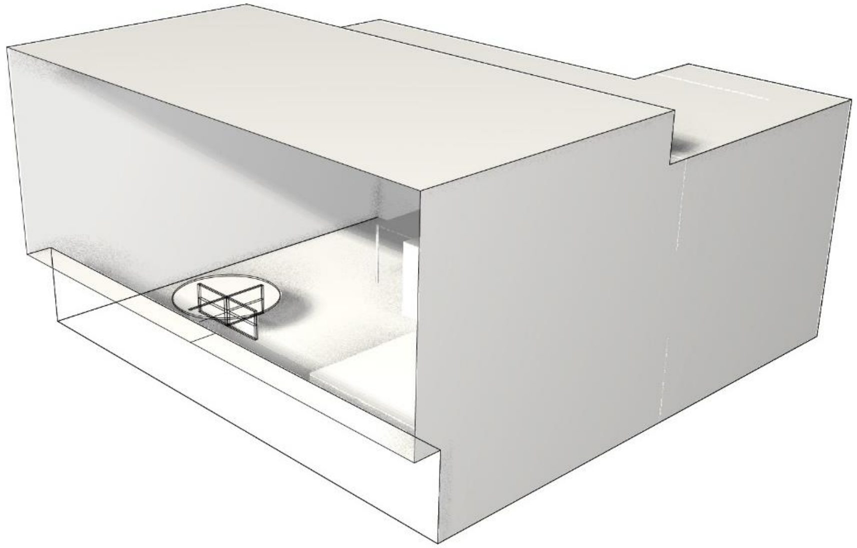
Daylighting Simulation



According to the lighting schedule, the occupancy hours is from 3pm to 8 am and sleep time is from 12am to 5 am, when there is no need for artificial light. In winter, there is not enough light in the morning. In spring and fall, the daylight is too strong in the morning. There need to be strategies to shade the excess sunlight in the morning of spring and fall.

Baseline I · Daylighting II

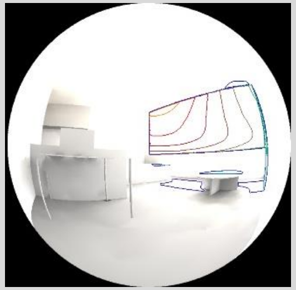
Model



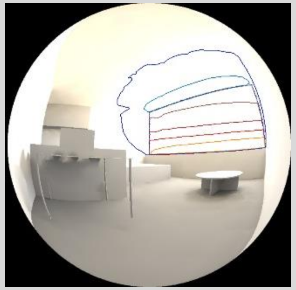
Description

According to the analysis and rendering pictures, we can fin that in most time of the year in Dubai, the daylight inside the room is enough and especially places near the windows get exccesive sunlight, which causes dazzle and influence users' sleep and daily life. On the other hand, in order to save energy, we recommend to use more daylight than artificial light. Then there raise two questions: avoid too much sunlight and use daylight as much as possible. Using normal shading, like louvers can reduce the sunlight to some extend but also may cause not enough daylight deep inside. We need to distinguish the excesive light and enough light. Then we trace back to find where could be most possibly put shading.

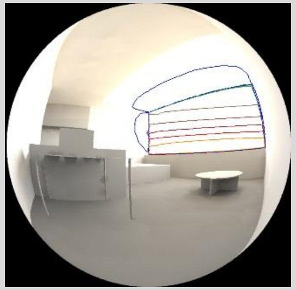
Daylight Fisheye Rendering



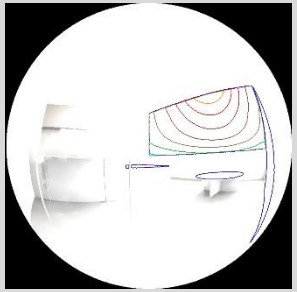
June 21, 9:00



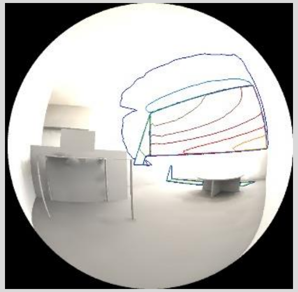
June 21, 12:00



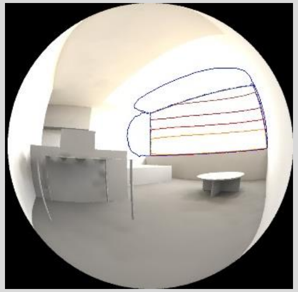
June 21, 3:00



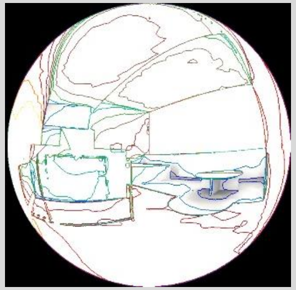
Sep 21, 9:00



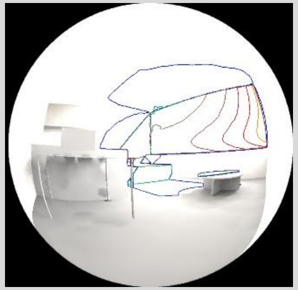
Sep 21, 12:00



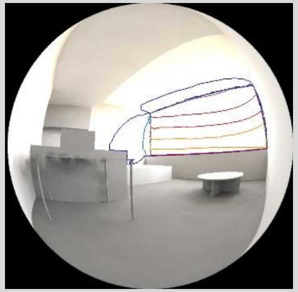
Sep 21, 3:00



Dec 21, 9:00



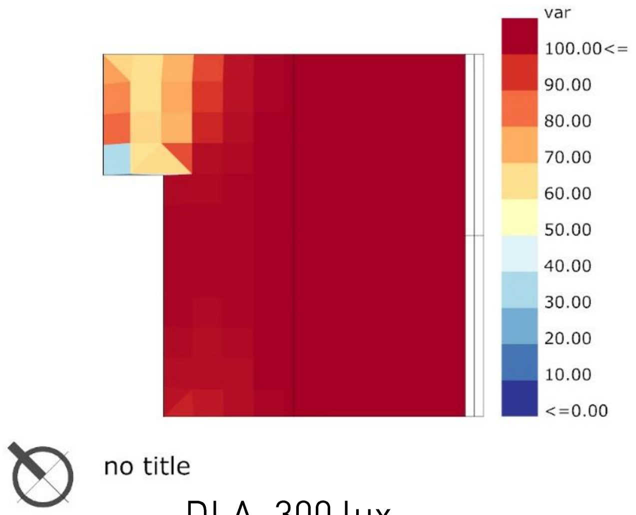
Dec 21, 12:00



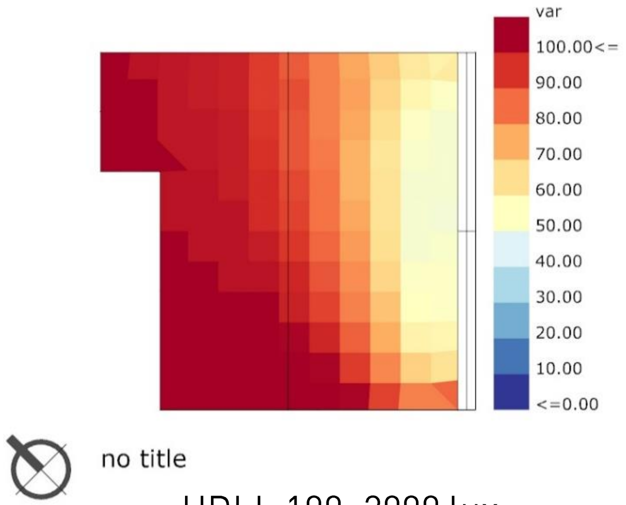
Dec 21, 3:00

Baseline I · Annual Daylighting Analysis

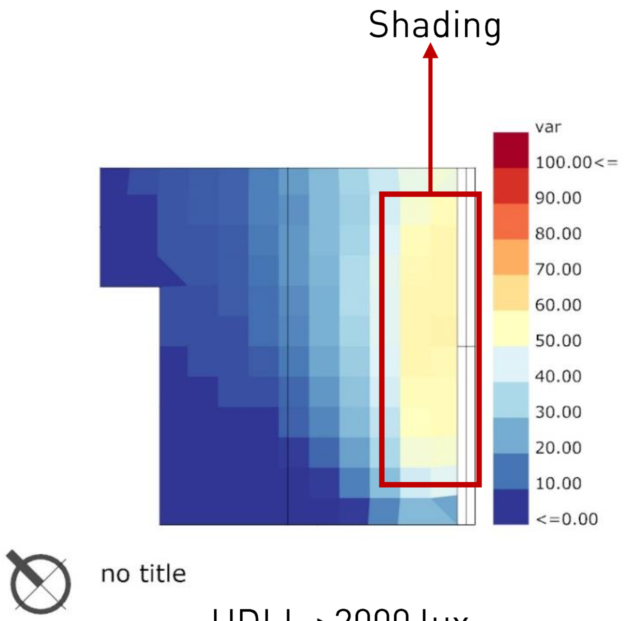
sDA = 97.06



DLA_300 lux

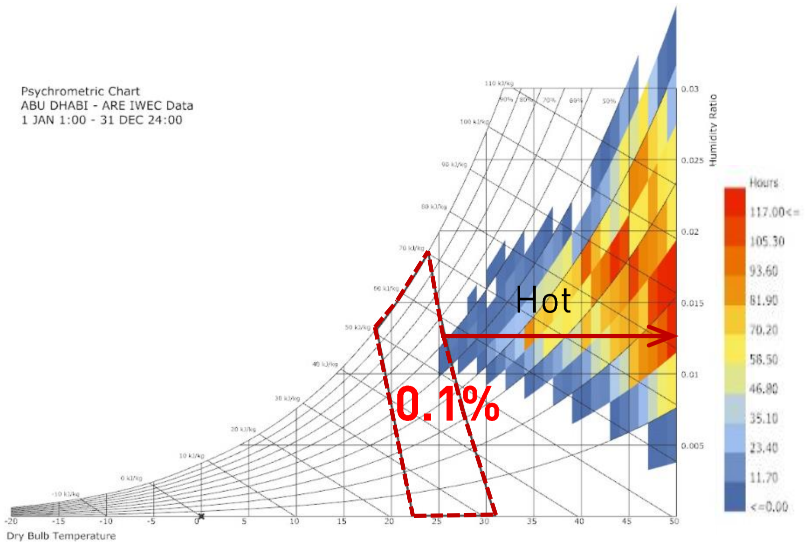


UDLI_100~2000 lux



UDLI_>2000 lux

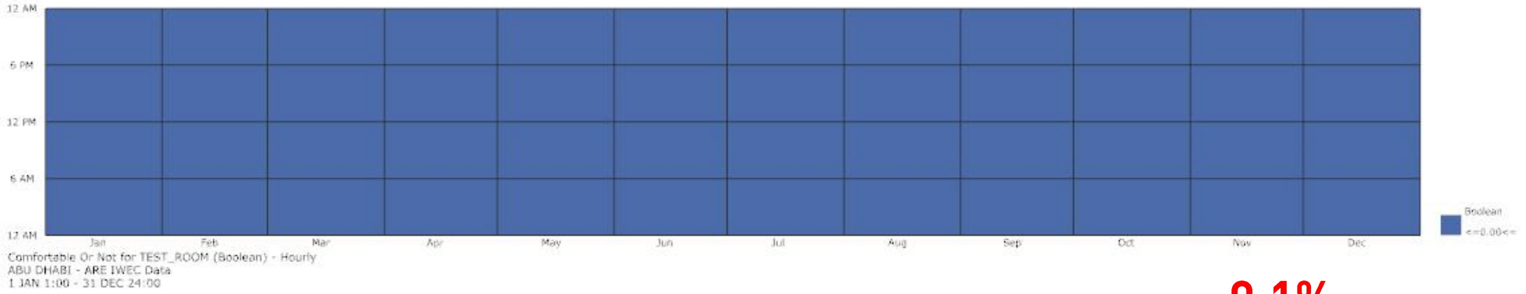
Baseline II · Comfort Analysis



Psychrometric Chart

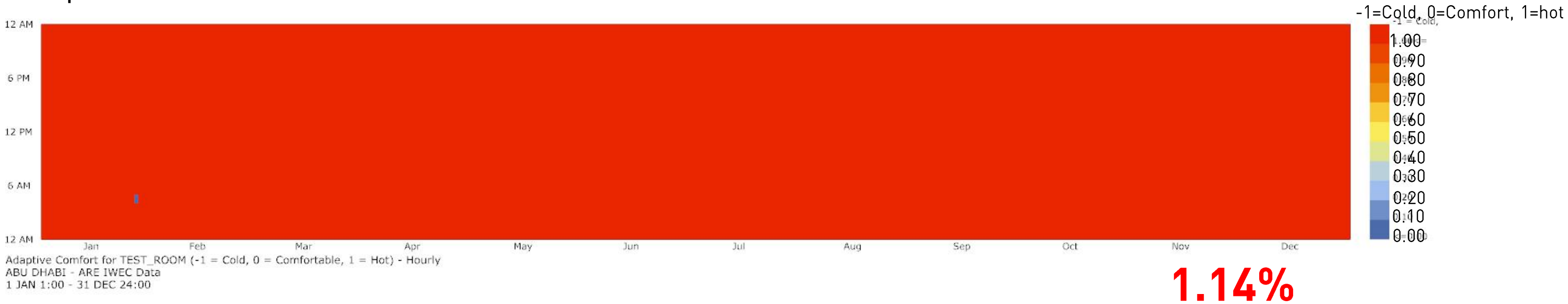
Not comfort at all, and it is extremely hot, especially inside the room.

PMV Comfort



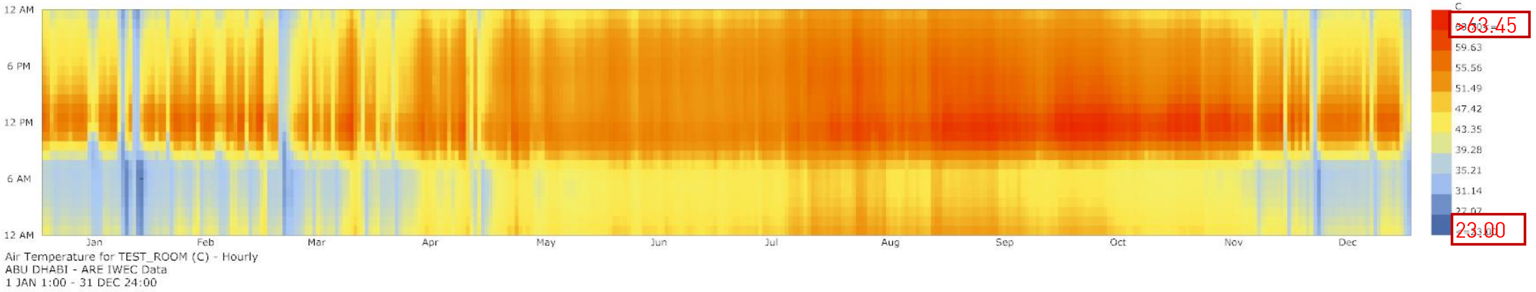
0.1%
Comfort time

Adaptive Comfort



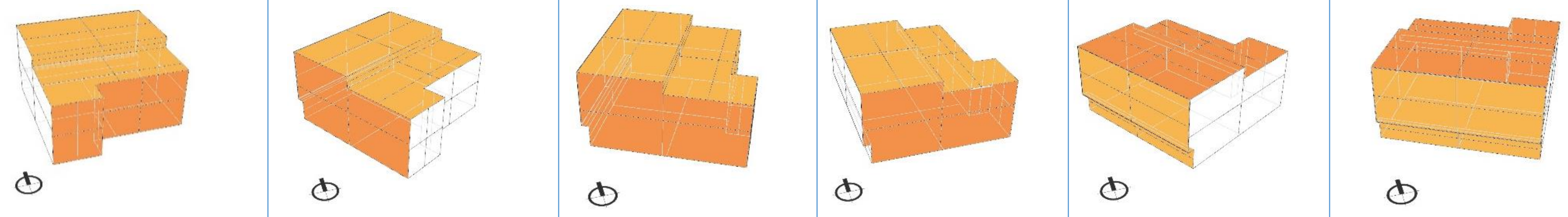
1.14%
Comfort time

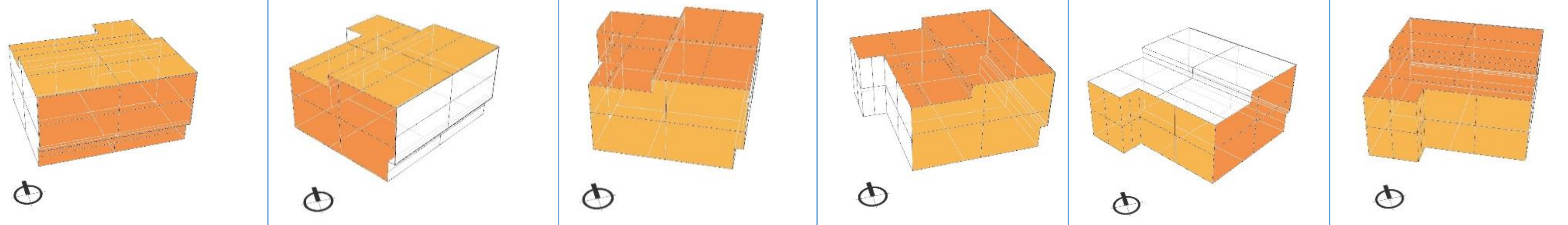
Indoor Air Temperature



Proposal I · Optimal Orientation

North Angle		0°	30°	60°	90°	120°	150°
PMV	Percentage Comfort time	0.034	0.0	0.0	0.0	0.0	0.0
Adaptive	Comfort	0.19	0.10	0.01	0.0	0.0	0.0
	Hot	99.81	99.90	99.99	100.0	100.0	100.0
	Cold	0.0	0.0	0.0	0.0	0.0	0.0

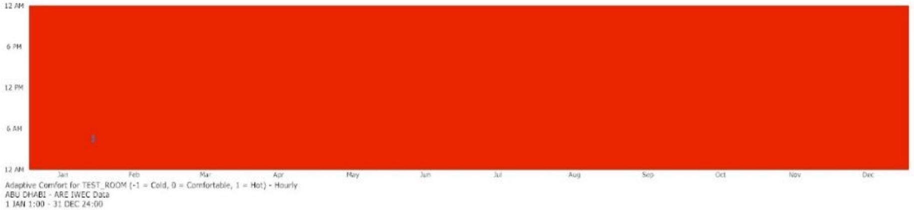




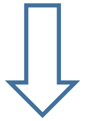
North Angle		180°	210°	240°	270°	300°	330°
PMV	Percentage Comfort time	0.0	0.16	0.57	0.50	0.50	0.21
Adaptive	Comfort	0.12	0.59	2.04	1.85	1.87	0.63
	Hot	99.89	99.41	97.95	98.15	98.13	99.37
	Cold	0.0	0.0	0.0	0.0	0.0	0.0

Strategy· Adding Natural Ventilation

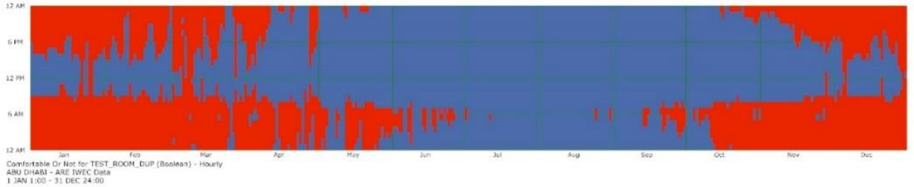
Adaptive Comfort

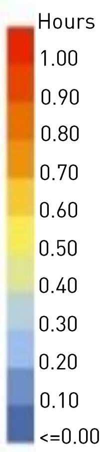


1.14%
Comfort time



Adaptive Comfort

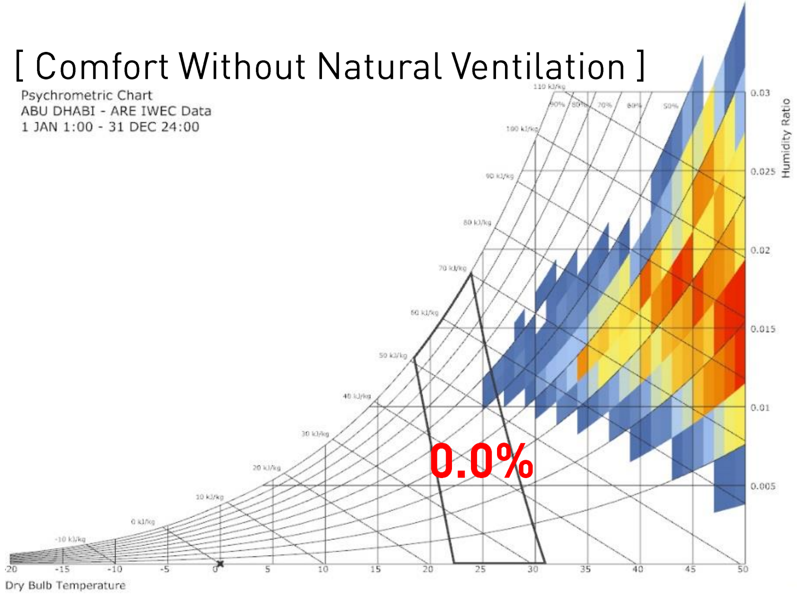




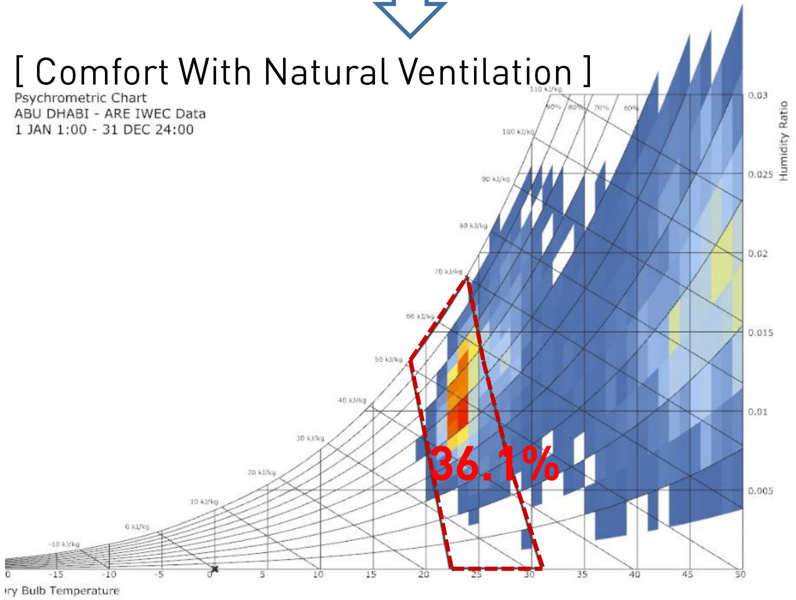
36.1%
Comfort time

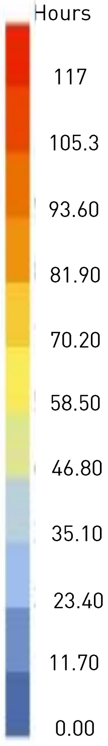
It is quite humid in Dubai, especially during the night, so people there feels hotter than the temperature should be. In winter, even though the temperature in summer is lower but people still don't feel comfortable because of the high humidity. For inner environment, because of lower wind speed and continuous solar heat gain, people inside feel even more uncomfortable. Therefore, adding the natural ventilation can be a good way to reduce the inner temperature and makes people feel more comfortable.

[Comfort Without Natural Ventilation]



[Comfort With Natural Ventilation]



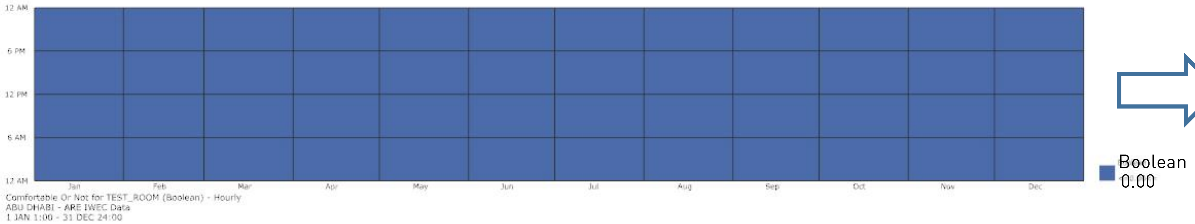


Strategy· Adding Natural Ventilation

[Comfort Without Natural Ventilation]

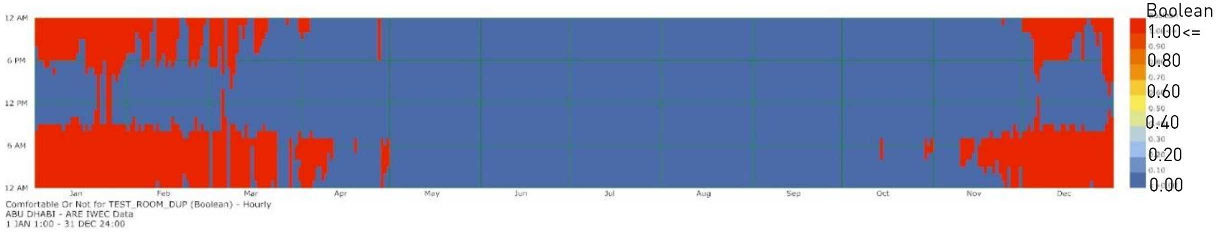
[Comfort With Natural Ventilation]

PMV Comfort



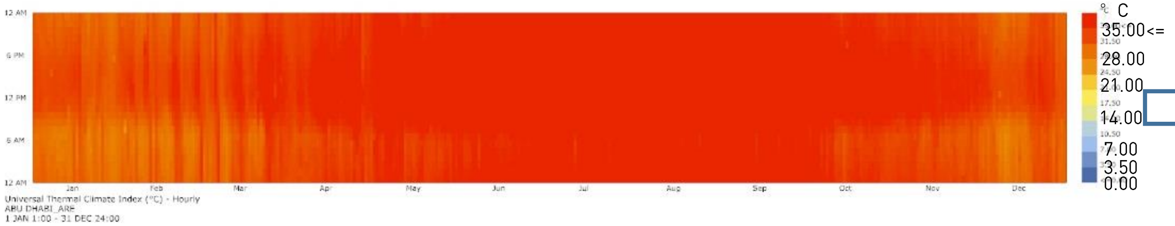
0.1%
Comfort time

PMV Comfort



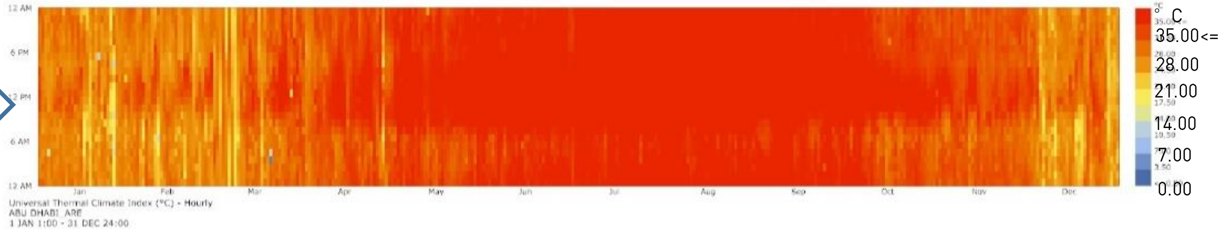
20.0%
Comfort time

Universal Thermal Climate Index



4.6%
Comfort time

Universal Thermal Climate Index (with wind)



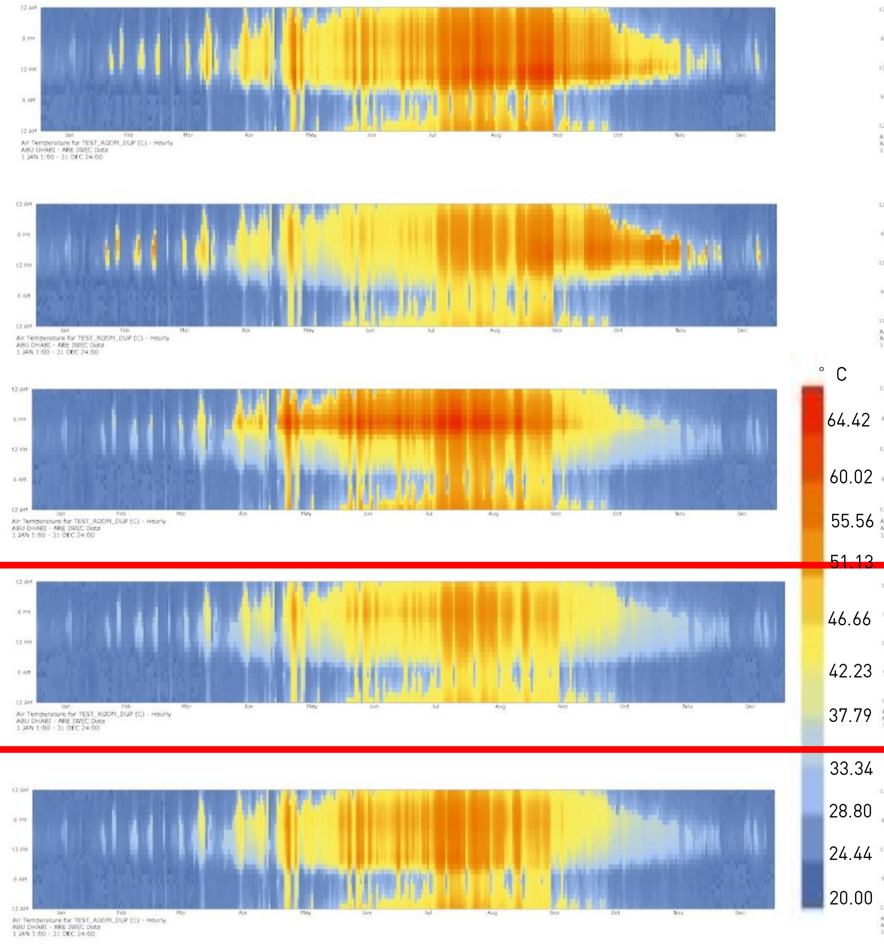
14.4%
Comfort time

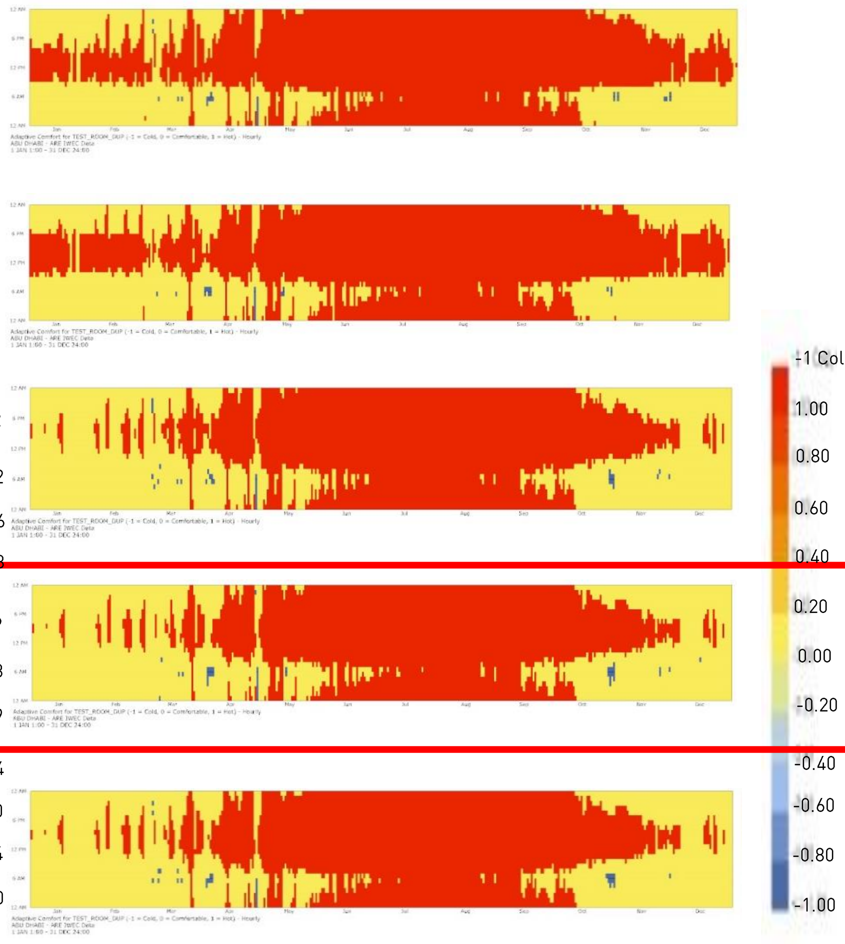
According to the PMV and Adaptive comfort analysis, adding natural ventilation will significantly increase the percentage of comfort time. Just as the same idea analyzed before, dew bulb temperature is lower because when water veporates it takes away heat too. It is quite humid in Dubai. Therefore, adding natural ventilation will provide more opportunities for water veporation and take away the inner heat.

Natural ventilation provide the best way in hot and humid places to cool down and make people feel cooler. Therefore, in order to get max comfort, we need to analyze the dominant wind direction first to let most frequent wind through the room. So I run the energy simulation of different to find out which orientation throughout the year makes users more comfortable than others.

Strategy· Optimal Combination of Natural Ventilation + Orientation

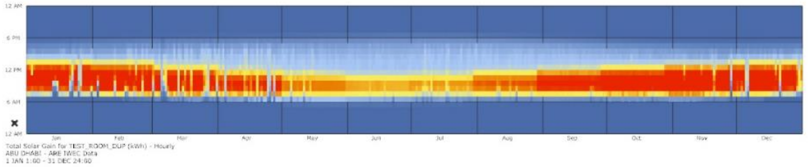
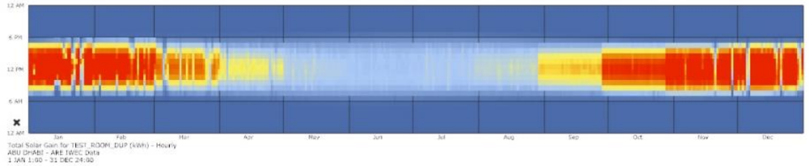
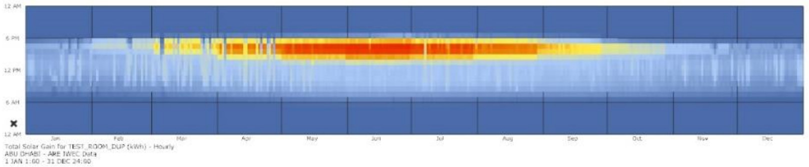
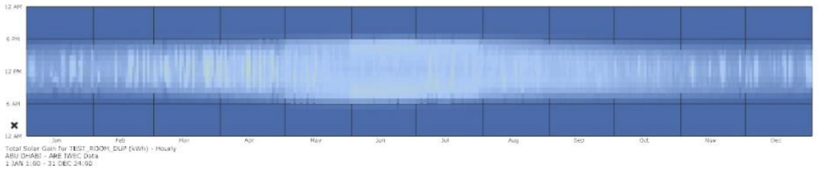
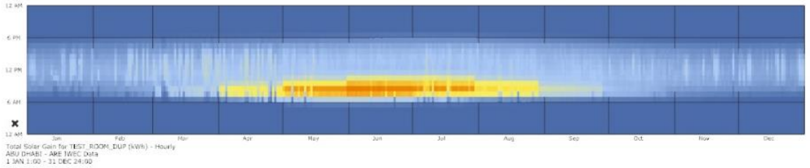
Orientation | Indoor Air Temperature | Adaptive Comfort | Percent of Comfort Time

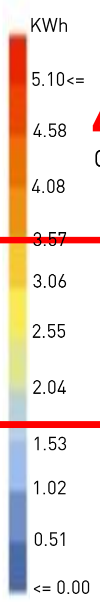




Orientation	Percent of Comfort Time
45°	**36.1%** Comfort time
90°	**38.84%** Comfort time
225°	**44.8%** Comfort time
270°	**46.8%** Comfort time
300°	**45.9%** Comfort time

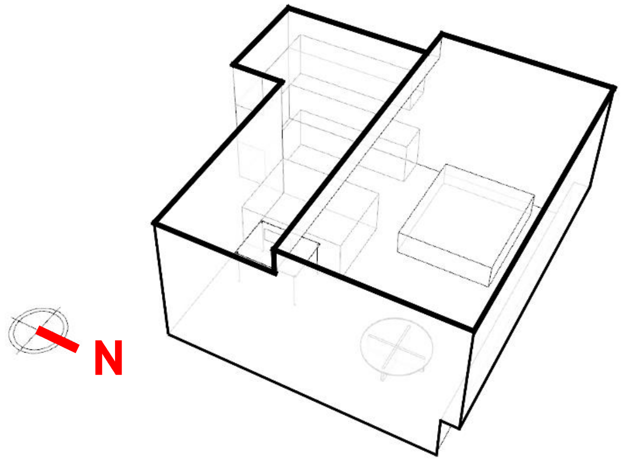
Strategy· Optimal Combination of Natural Ventilation + Orientation

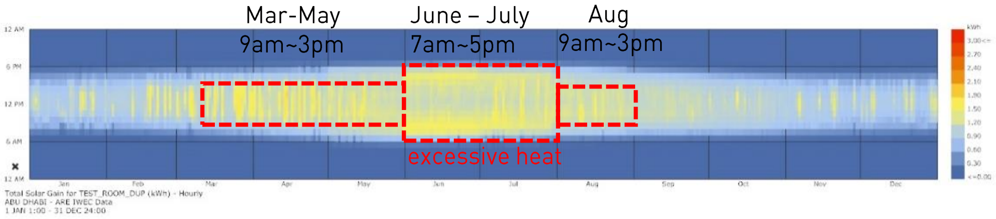
Orientation	Solar Heat Gain	Percent of Comfort Time
45°		**36.1%** Comfort time
90°		**38.84%** Comfort time
225°		**44.8%** Comfort time
270°		**46.8%** Comfort time
300°		**45.9%** Comfort time



Description

In Dubai, because it is close to the equator, solar radiation is usually the major reason that cause the excessive indoor heat. And this heat will lead to extreme high indoor temperature and cause uncomfortable. After we analyze the orientation and natural ventilation, and find the best angle that can best reduce direct sunlight getting in through window and also be beneficial to natural ventilation, there is still sometime in summer, the indoor temperature is pretty high. I try to find out the exact time of the day when the temperature is too high and use it for next-step shading design.

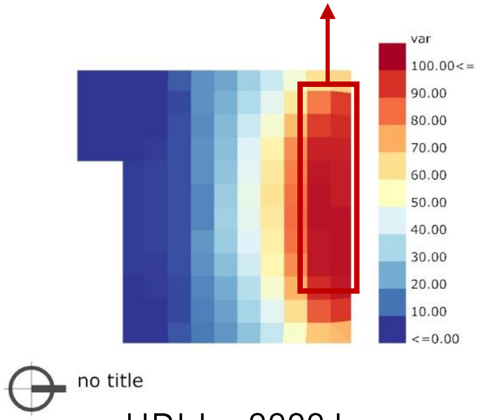




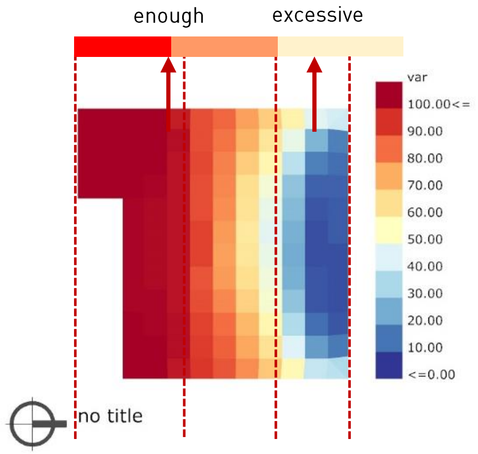
Strategy II · Shading Design

Baseline

Shading

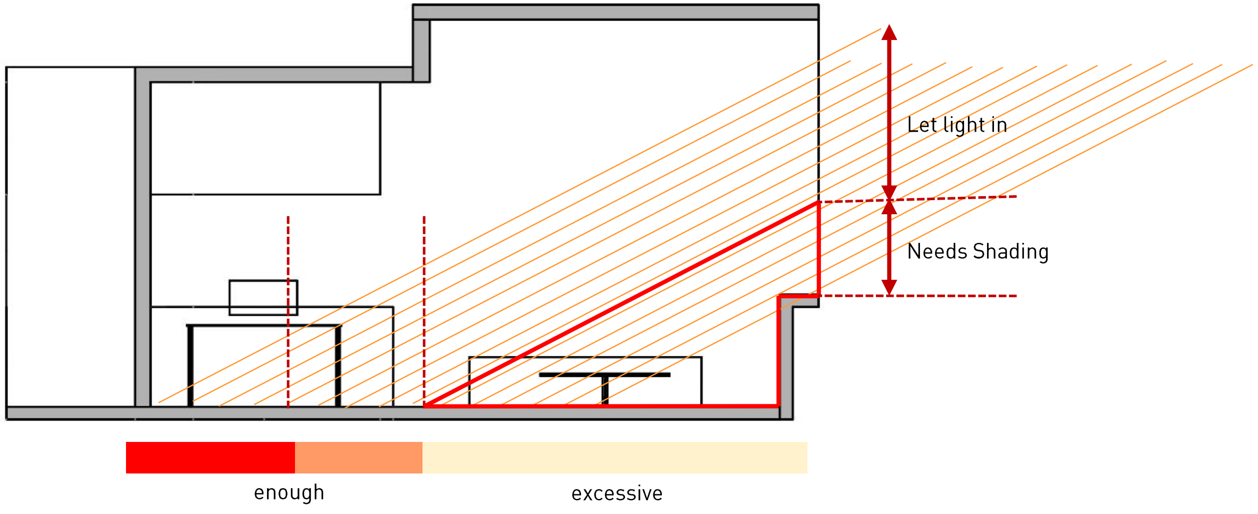


UDLI_>2000 lux



UDLI_100~2000 lux

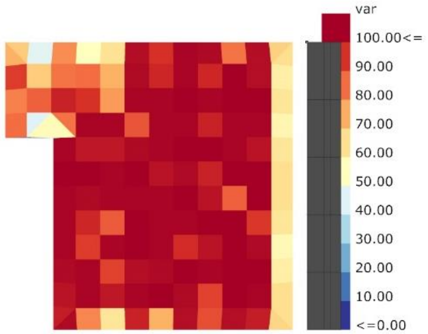
Concept Shading



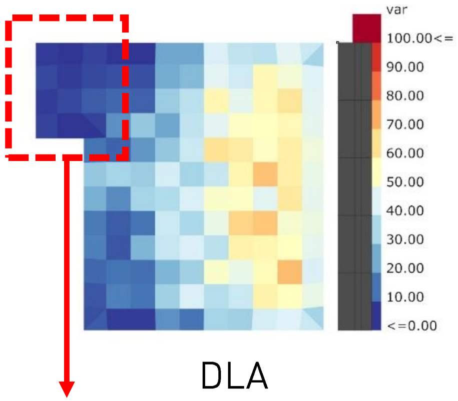
Possible Strategies

1. Reduce the glare ratio in shade needing area. Use glass curtain wall on “Let light in” area.
2. If using louvers, increase the density of louvers in the shading needing area and reduce the density of louvers in “Let light in” area.
3. Increase the depth of the louvers in the shade needing area and reduce the depth of the louvers in “Let light in” area.

Strategy II · Shading Design I



UDLI_100-2000

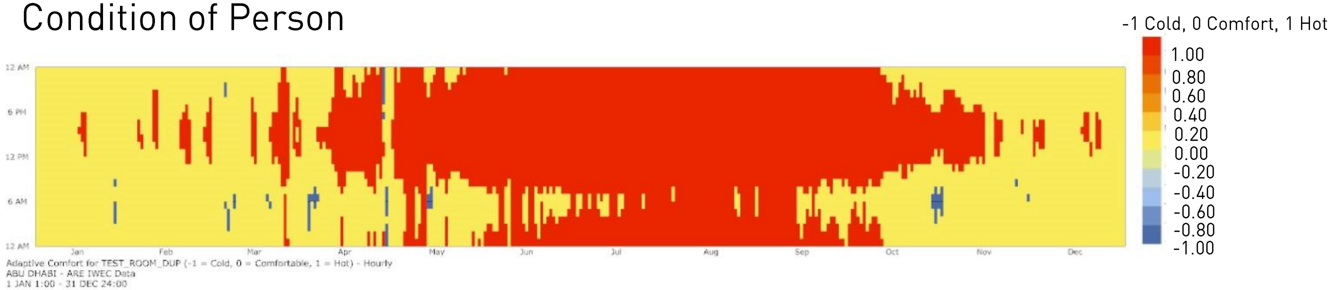


DLA

Not Enough

16.18%
SDA

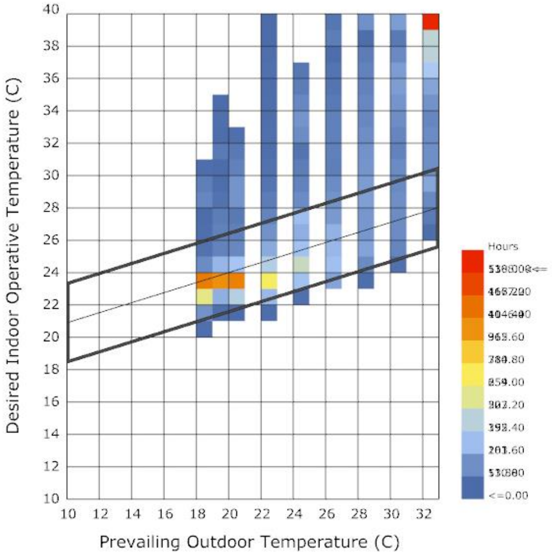
Condition of Person



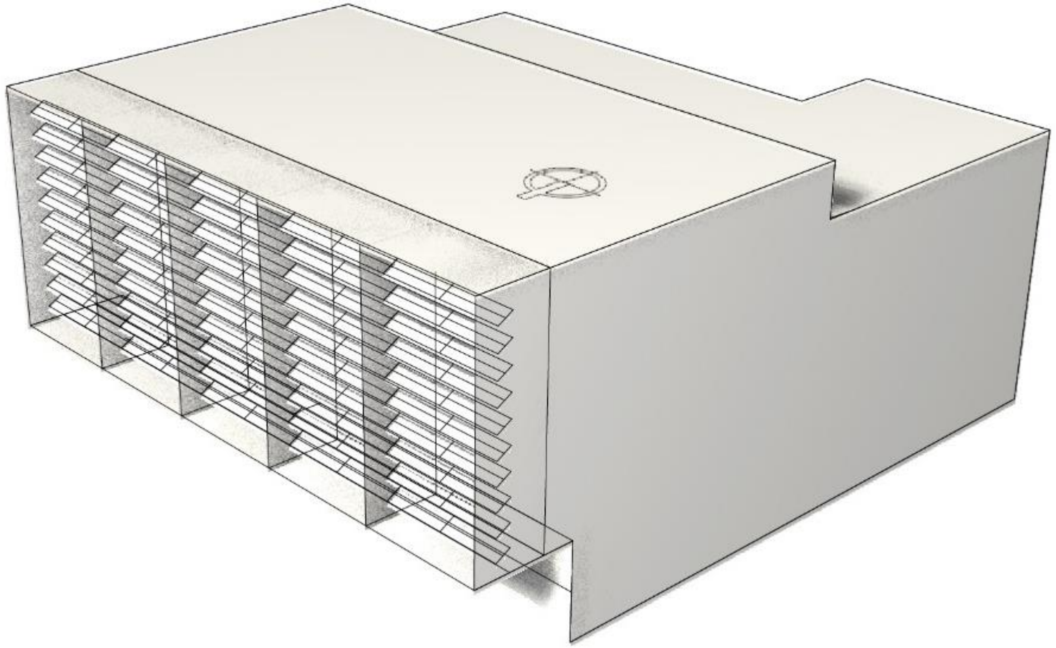
50.9%
Comfort time

Possible Strategies

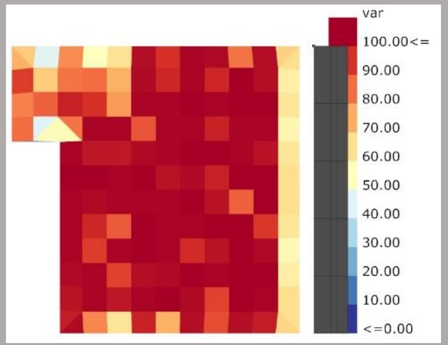
1. Because the radiation is pretty strong in Dubai and it usually casue excessive heat, to shade as much sunlight as possible is usually what we can think first. However, if we put too much shading(louvers, for example), the daylight deep inside the room will not be enough.



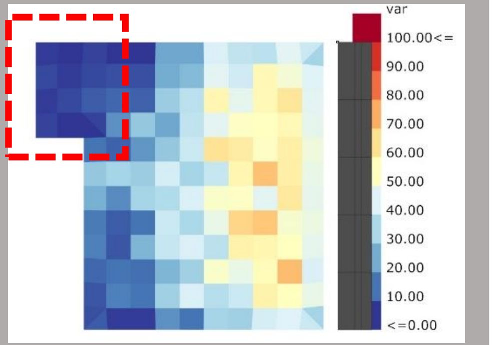
Adaptive Comfort Chart



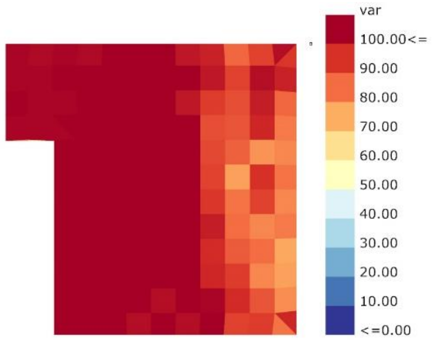
Strategy II · Shading Design II



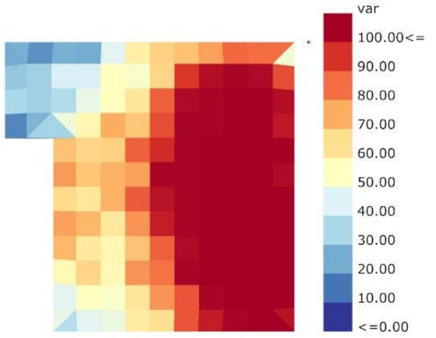
UDLI_100-2000



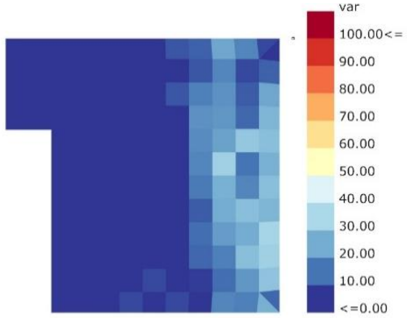
DLA



UDLI_100-2000



DLA

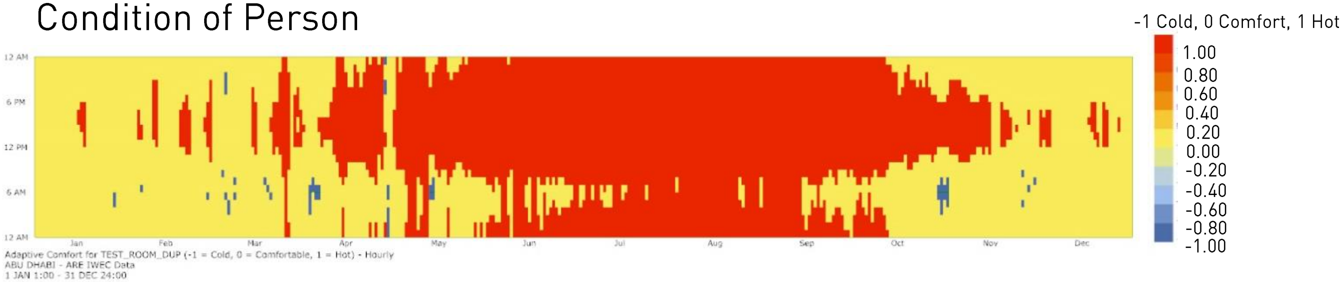


UDLI_>2000

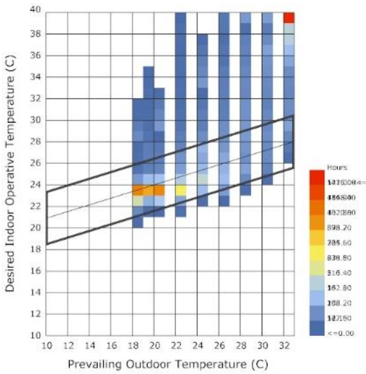
16.18%
SDA

78.68%
SDA

Condition of Person



50.7%
Comfort time

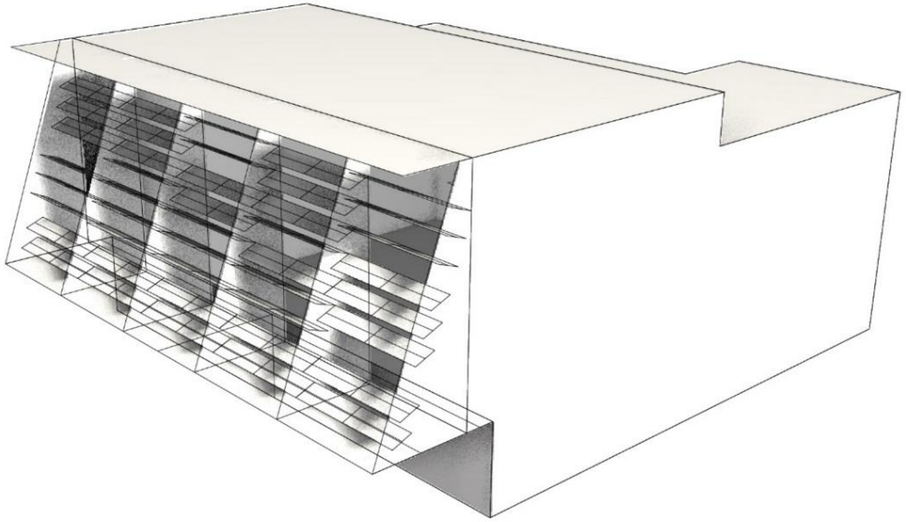


Adaptive Chart
ABU DHABI_ARE
1 JAN 1:00 - 31 DEC 24:00

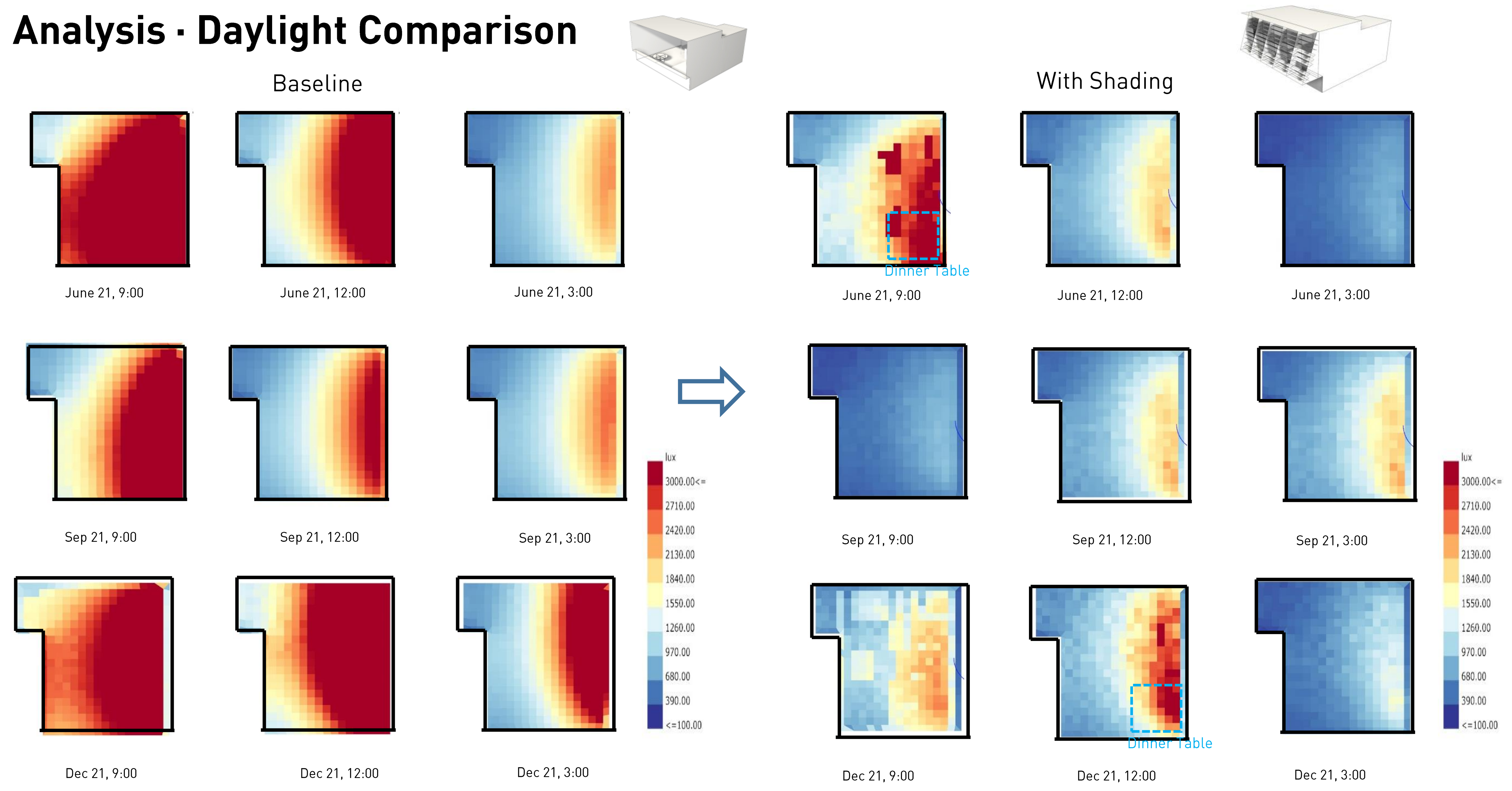
Adaptive Comfort

Possible Strategies

2. After analyzing the first shading case, which daylight deep inside is not enough, I found out making the shading have different depth vertically will work better for daylight and the percentage of the comfort time stays the same with the previous case. Therefore, when considering best daylight and comfort, this shading system is much better than previous one.



Analysis · Daylight Comparison



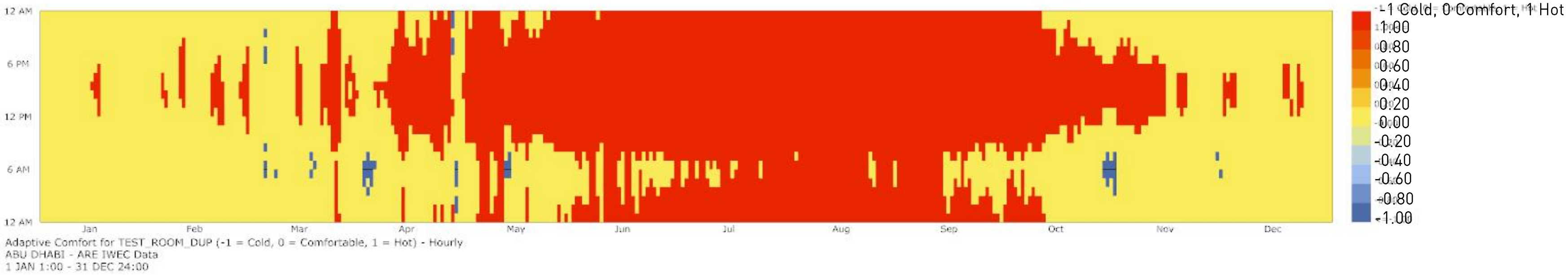
Proposal IV · Changing Materials

Material

Baseline: Ashrae 2009 EXTWALL ALT-RES 4

Proposal: Ashrae 2010 EXTWALL 7-8

Adaptive Comfort

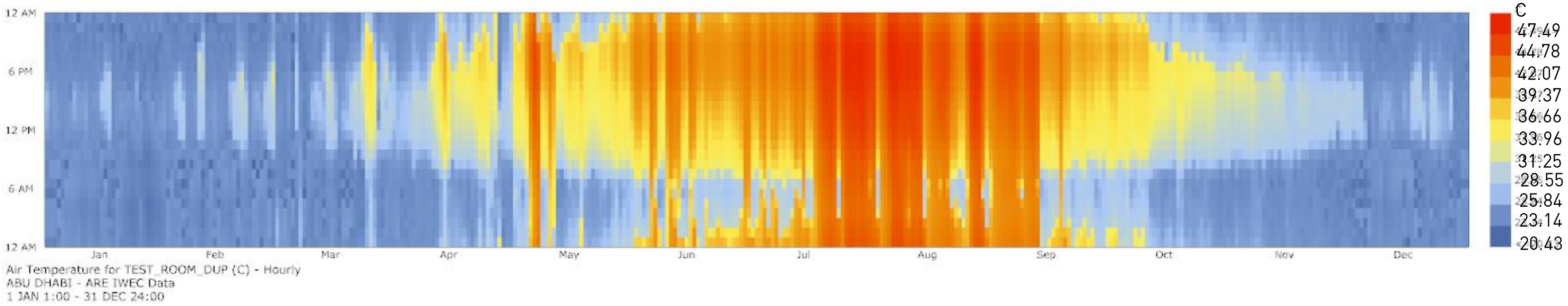


Comfort

50.7%
Comfort time

51.4%
Comfort time

Indoor Air Temperature



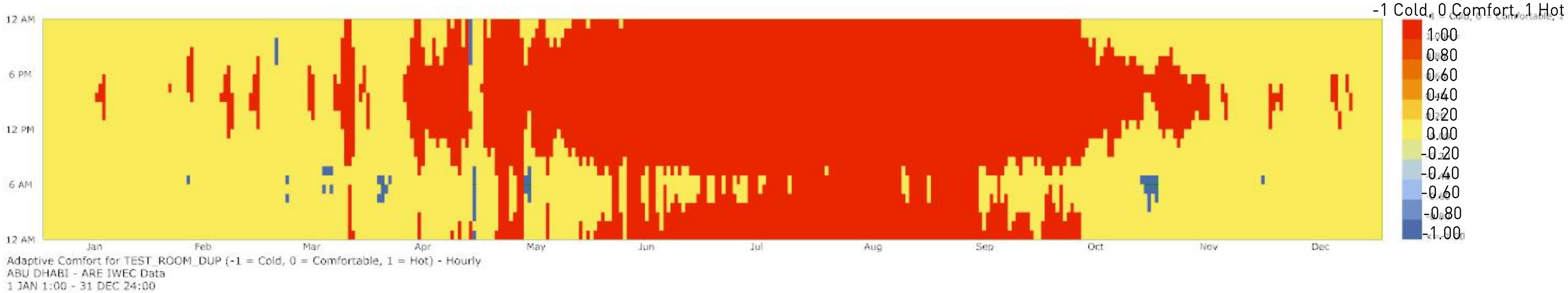
Proposal IV · Changing Materials

Material

Baseline: Base window

Proposal: Ashrae 2010 EXTWINDOW 7-8

Adaptive Comfort



Comfort

51.4%
Comfort time

53.4%
Comfort time

Indoor Air Temperature