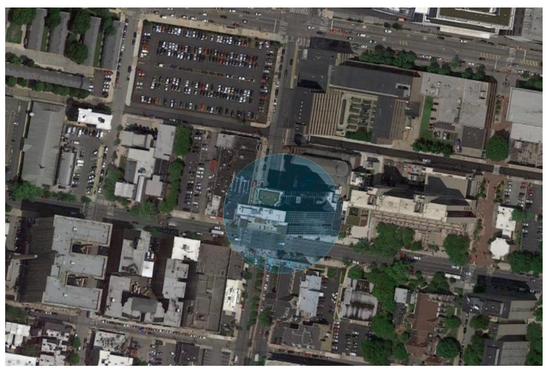
MAKE THE APARTMENT GREAT AGAIN!

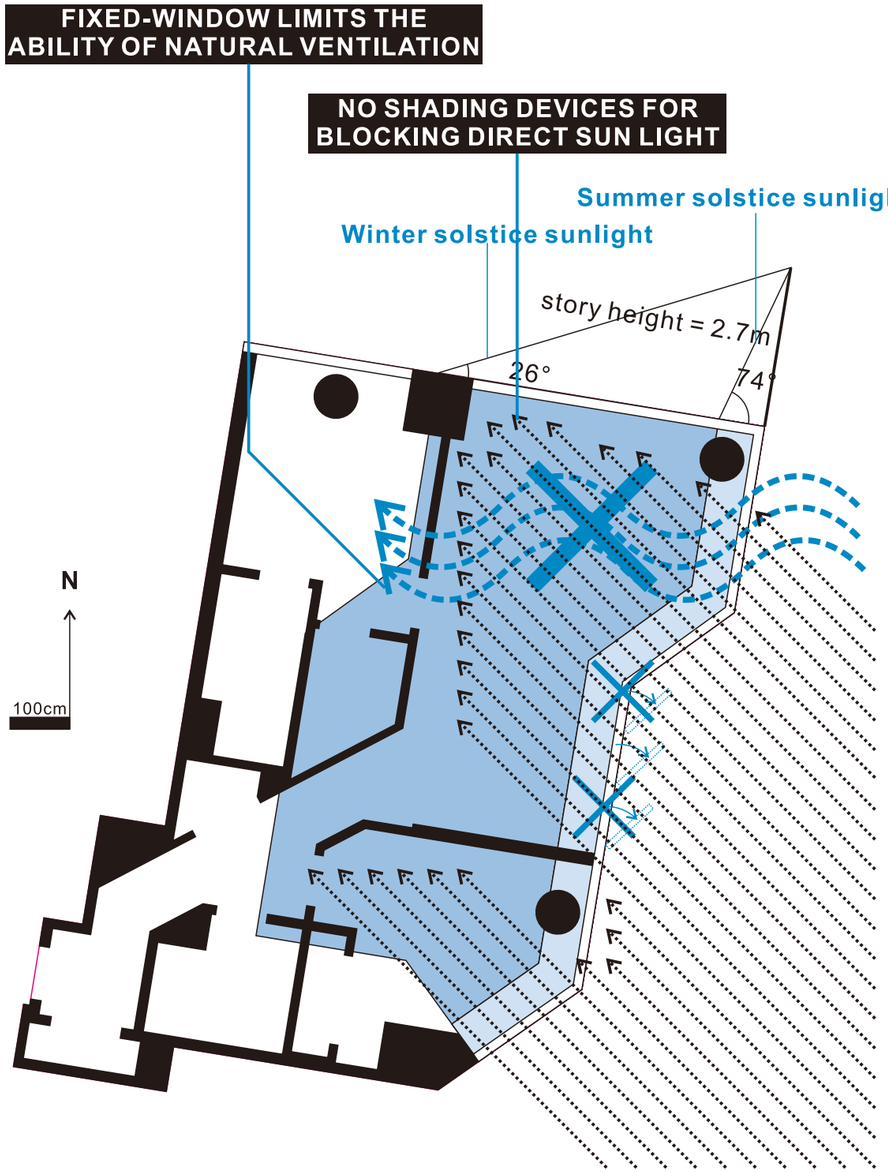
Building Performance Simulation Final Project

Weston Huang

ABOUT THE SITE

Location: Philadelphia (39°57′N 75°10′W)
Tower total height: 80m, 26 floors
Location height of the dream room: 42m, 14th floor
Using type: Residential
Structural type: RC
Room area: 93.74 square meter
Description: The room is located in a high-rise condominium. Since being above surrounding buildings, the room enjoys the unblocked view of Philadelphia and the sun. However, the facades are curtain window and can not be opened. So, natural ventilation is impossible now.

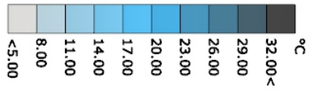




CLIMATE AROUND THE SITE

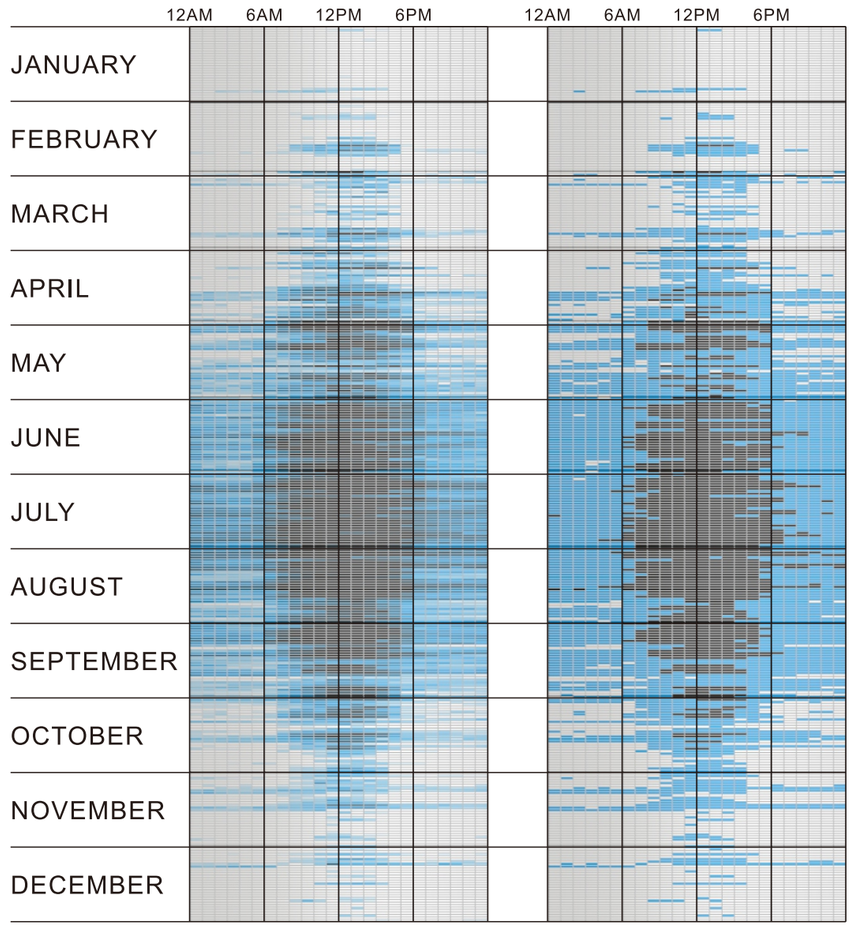
Temperature: Universal Thermal Climate Index in Philadelphia

Universal Thermal Climate Index



Time of Comfort or Not

COLD	COMFORT	HOT
31.6%	37.3%	12.5%

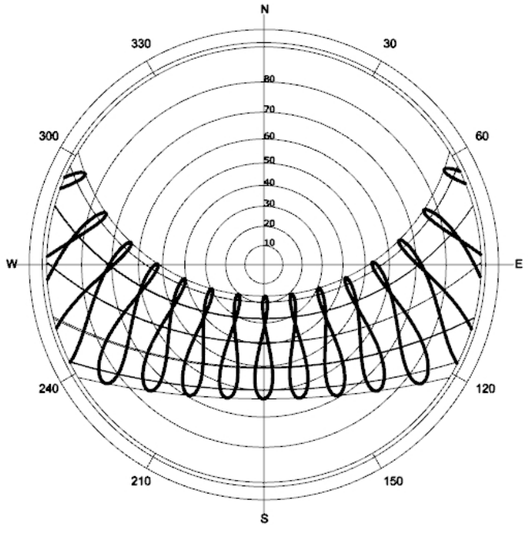


BASE-CASE ASSESSMENT: IT IS TOO BRIGHT HERE.

VISUAL COMFORT

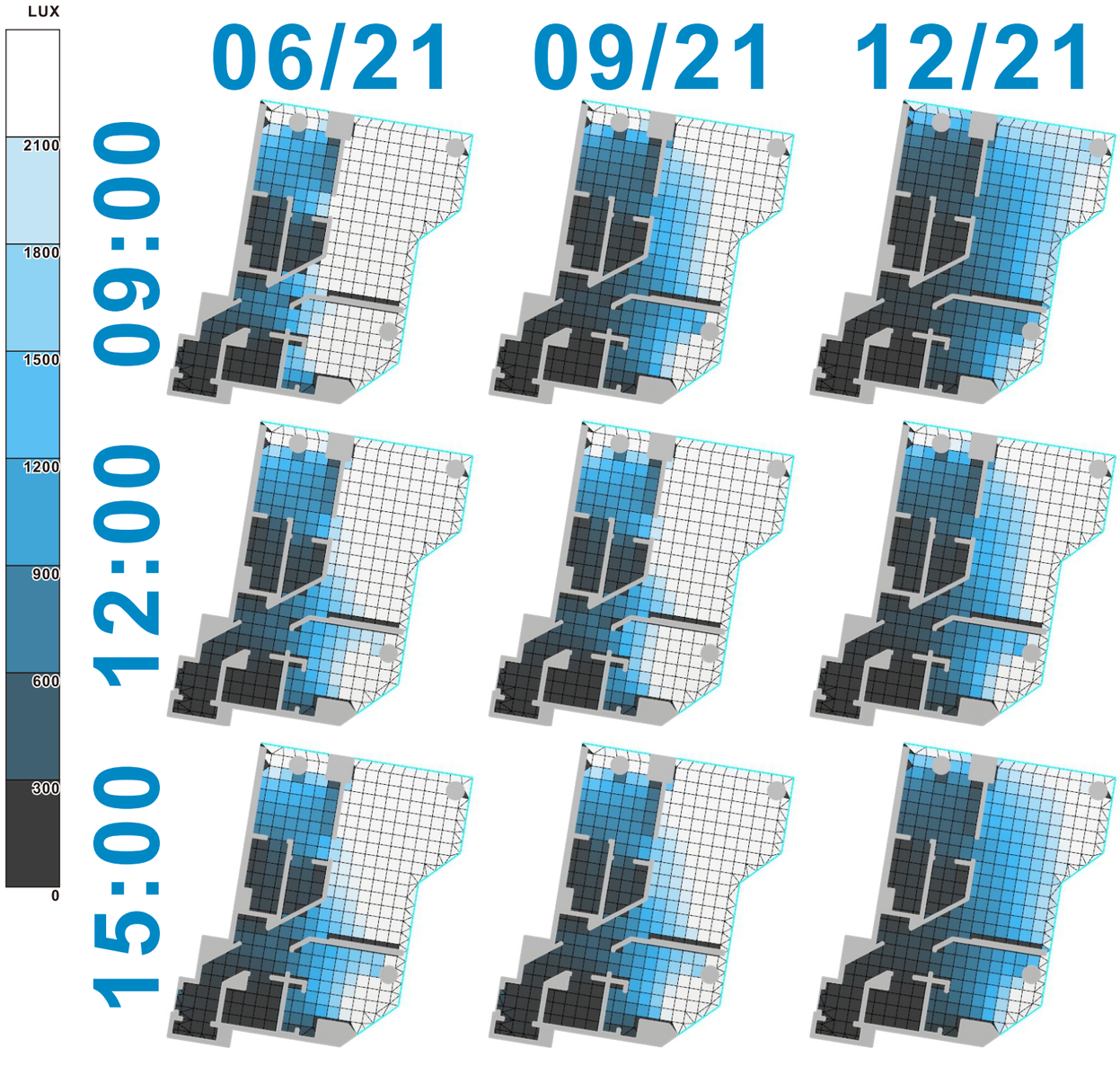
The illuminance analysis reveals the uncomfortable reality in the apartment. Due to facing the East without shading devices, the sunlight can get into it directly. Only in winter morning, the resident can get rid of the overly bright sunlight, which usually leads to glare.
When the sunlight can arrive the apartment directly, it implies that the apartment has the high possibility of being over-heated, which is uncomfortable. For example, the white area in the illuminance analysis is the place gaining too much sunlight and radiation. And in reality, the resident always complaints about the heat stress and the glare issue when he stays at that place. Hence, preventing the direct sunlight will be the first problem needing to deal with.

Sun Path of Philadelphia



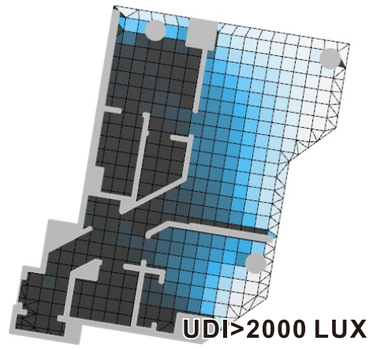
ILLUMINANCE ANALYSIS

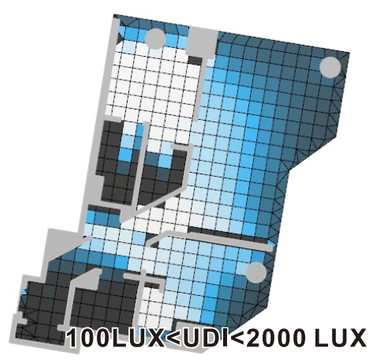
TOO BRIGHT IN THE APARTMENT, UNUSEFUL DAYLIGHT

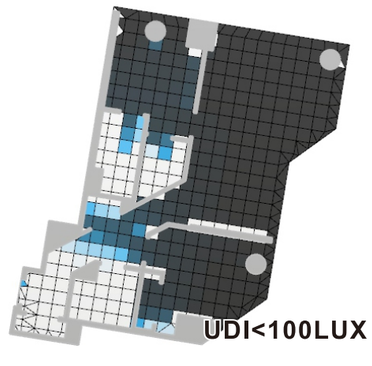


Percentage of Illuminance in A Year Hourly

0%	10%	20%	30%	40%
50%	60%	70%	80%	90%







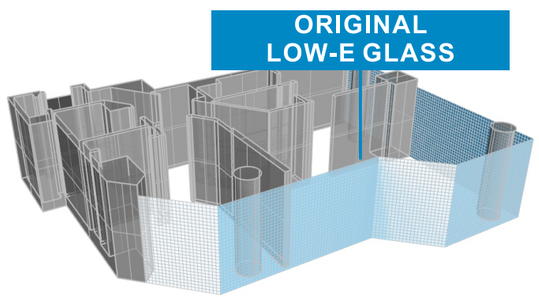
BASE-CASE ASSESSMENT: IT IS TOO HOT/COLD HERE.

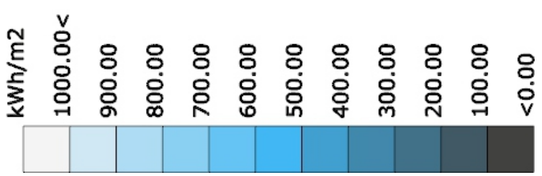
THERMAL COMFORT

Originally, people feel either hot or cold in the apartment. The hot feeling is contributed by the insulating effect of Low-E glass, which it used on the window. However, the performance of the glass is not perfect enough to prevent the heat leak out in the chilly winter, which leads to the cold result indoor.

But with the multi-layers window design, surprisingly, the cold percentage is cut half. Moreover, by opening the originally fixed window, people will hardly feel hot inside the apartment! It seems that the window design is the most influential part for thermal comfort improvement. More details about the window design improvement will be showed in page six.

Yearly Radiation Gain





ADAPTIVE COMFORT ANALYSIS WITH DIFFERENT STRATEGIES

COLD & HOT HERE!

Original Design Without Any Improvement

COLD 20.9% | COMFORT 14.0% | HOT 65.1%

STILL HOT HERE!

Insulation: Multi-layers Glass

COLD 10.0% | COMFORT 16.2% | HOT 73.8%

STILL COLD HERE!

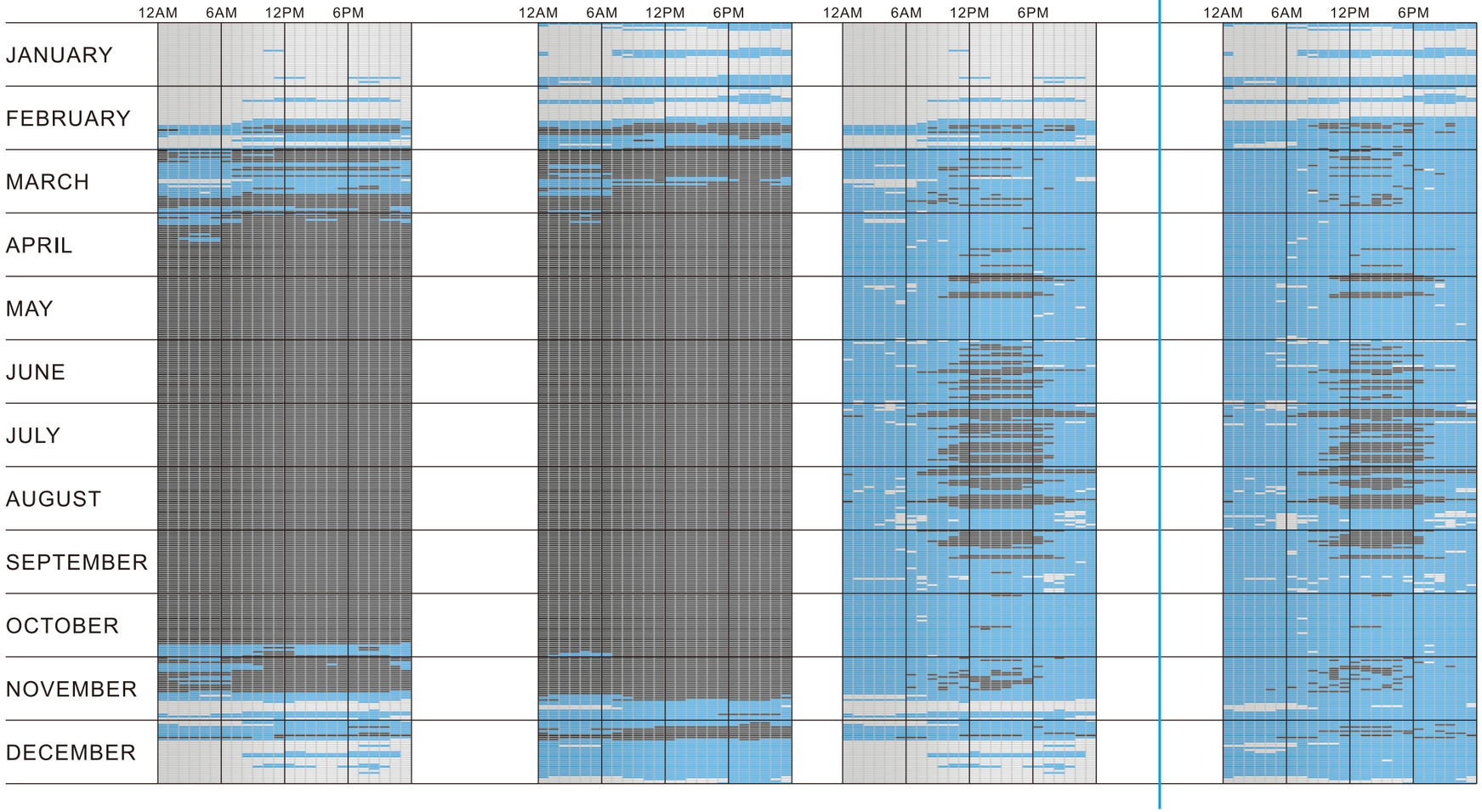
Natural Ventilation: 90% Openable Windows

COLD 23.0% | COMFORT 67.0% | HOT 10.0%

COMFORTABLE!

Natural Ventilation + Insulation

COLD 12.5% | COMFORT 78.4% | HOT 9.1%



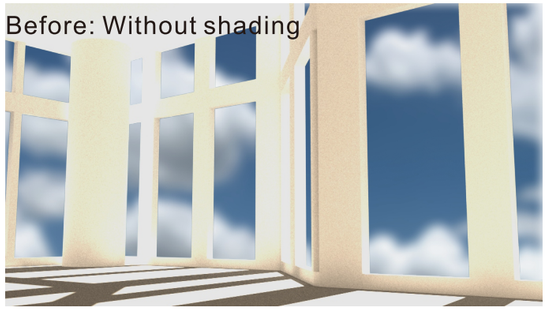
STRATEGIES OF IMPROVEMENT: VISUAL COMFORT.

MODIFIED RESULT

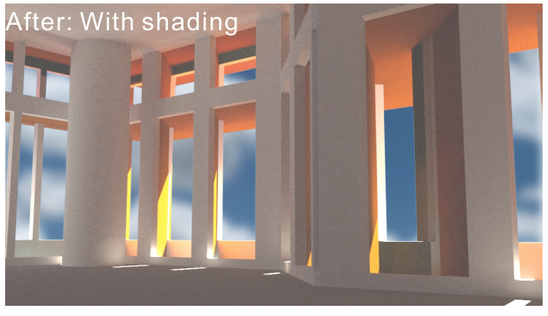
With the shading design, the indoor illuminance will be improved distinctly. Nearly everyday in the apartment has the useful daylighting, which has the illuminance within the range from 100 to 2000 Lux. Besides, the resident will get rid of the possibility of glare, with the DGP range from 0.24 to 0.30.
Even though the shading device will block some view in certain angle, the resident still can enjoy the magnificent view as usual. Meanwhile, the harmful sun light will be blocked, which help maintaining the visual comfort and the over-heating from the sun radiation.

The Render on June/21st 09:00

Before: Without shading

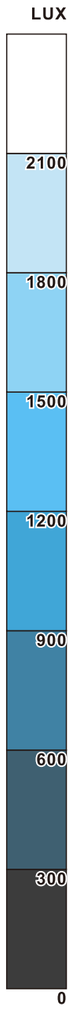


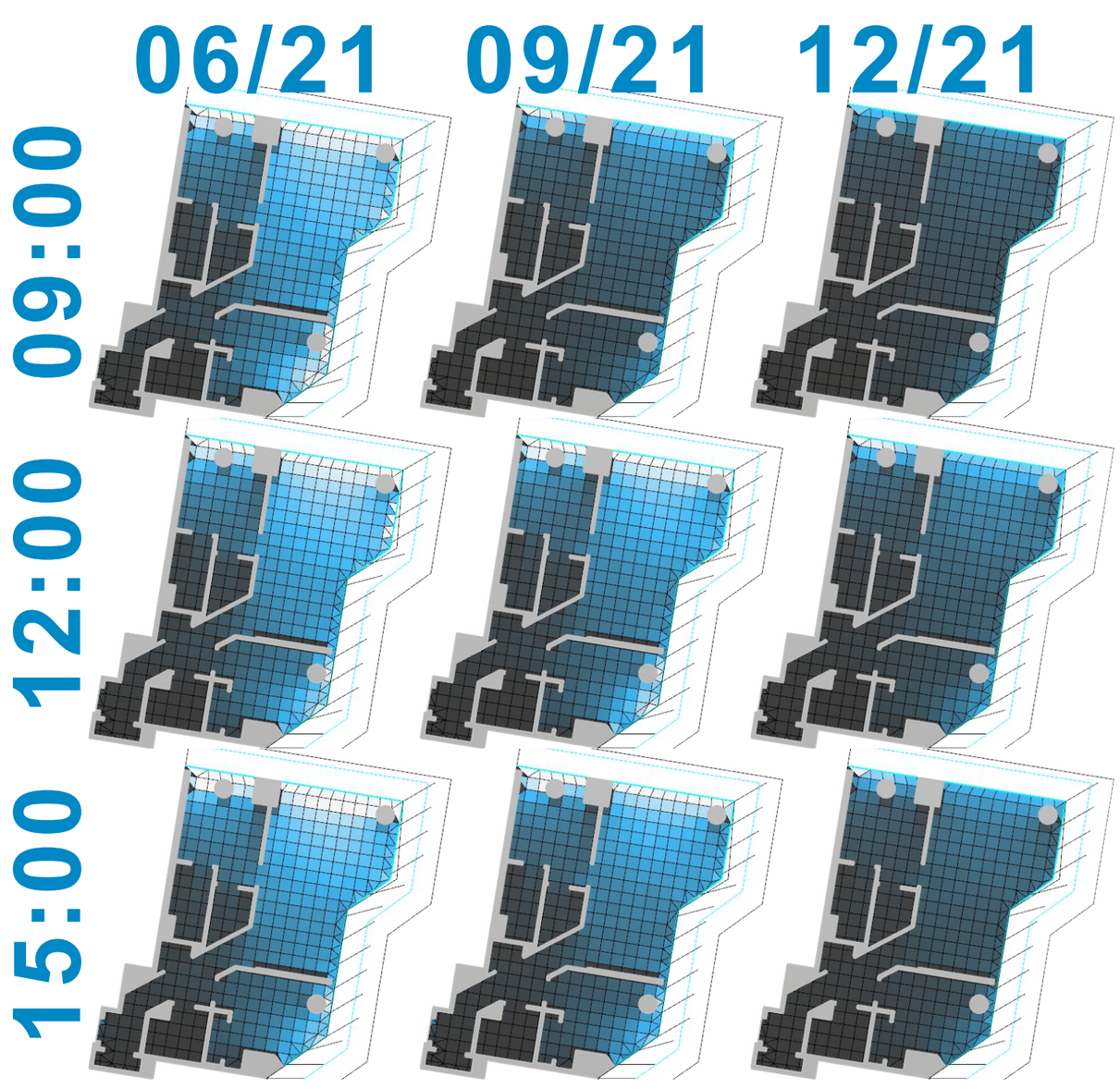
After: With shading



ILLUMINANCE RESULT

USEFUL & COMFORTABLE DAYLIGHTING EFFECT





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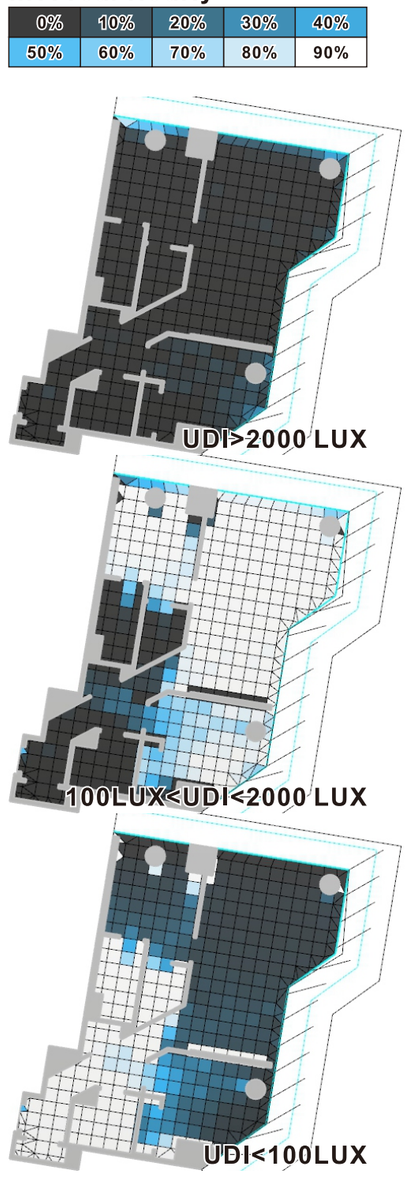

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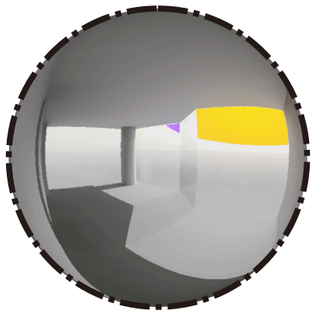
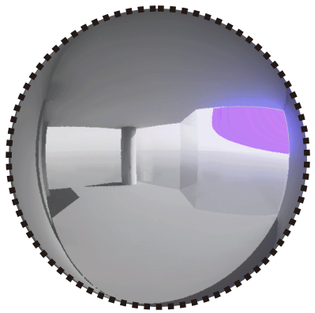
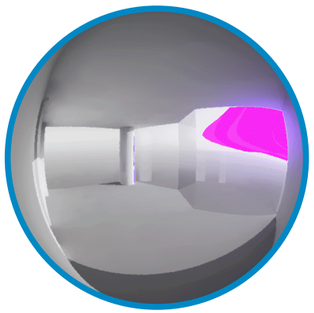
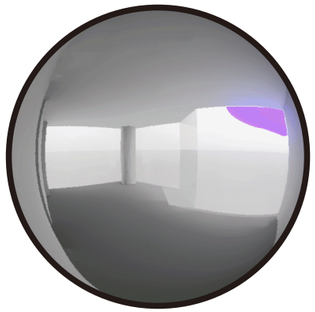
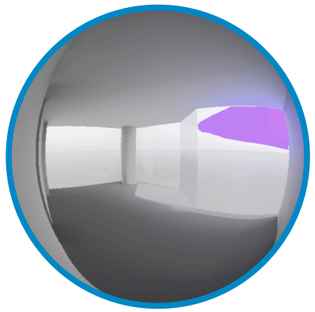
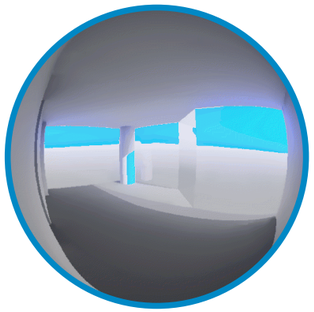
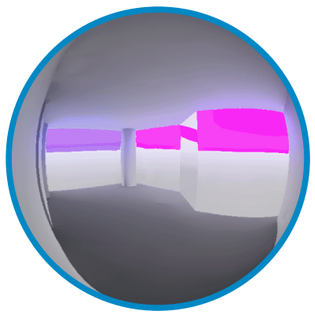
STRATEGIES OF IMPROVEMENT: VISUAL COMFORT.

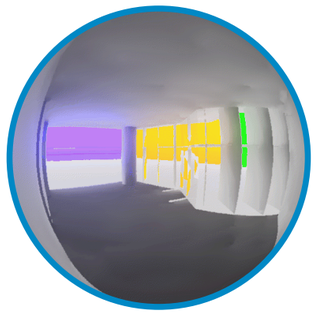
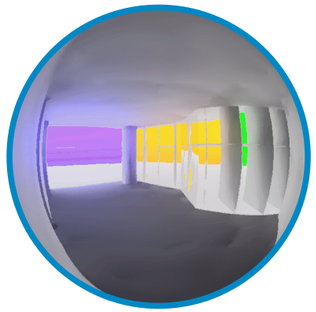
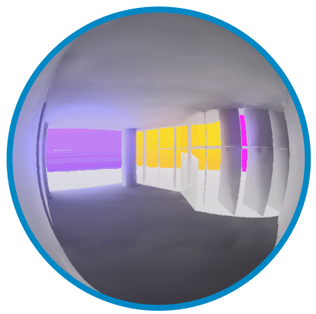
ORIGINAL GLARE RESULT

Imperceptible Glare | Disturbing Glare
Perceptible Glare | Intolerable Glare

MODIFIED GLARE RESULT

NO GLARE!

	06/21	09/21	12/21
09:00	 DGP = 0.450121	 DGP = 0.430394	 DGP = 0.284593
12:00	 DGP = 0.359113	 DGP = 0.345157	 DGP = 0.320667
15:00	 DGP = 0.333719	 DGP = 0.309539	 DGP = 0.257320

	06/21	09/21	12/21
09:00	 DGP = 0.304742	 DGP = 0.282844	 DGP = 0.241491
12:00	 DGP = 0.303628	 DGP = 0.291683	 DGP = 0.263487
15:00	 DGP = 0.288848	 DGP = 0.268148	 DGP = 0.241713

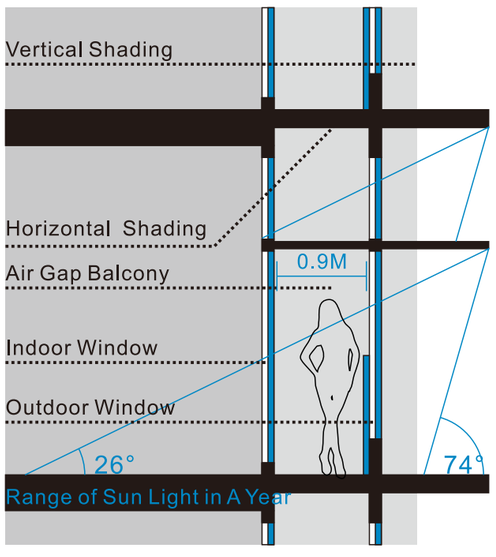
STRATEGIES OF IMPROVEMENT: THERMAL COMFORT.

MODIFIED RESULT

After improving the shading, the ability of opening the window, glazing insulation and double window skins, the percentage of indoor comfort drastically increases from 14 to almost 81.

In hotter day, when the shading devices prevent the radiation heat up the apartment, the openable window creates an ability of natural ventilation that makes the heat inside out. In colder day, the well-performance of insulation prevent the heat escape out from the apartment. In order to achieve that performance, Low-E glass with double layers is applied. Besides, by adding another window skins and air gap room, witch has 0.9 meter, outside the original window facade, the ability of retaining heat inside the apartment is upgraded.

Section of The Improvement (Scale: 1/50)



ADAPTIVE COMFORT ANALYSIS WITH DIFFERENT STRATEGIES

Original Setting

UNCOMFORTABLE TIME: 86.0%!

Outside Environment in Philadelphia

COLD 31.6% | COMFORT 37.3% | HOT 12.5%

Original Design Without Any Improvement

COLD 20.9% | COMFORT 14.0% | HOT 65.1%

Improved Setting

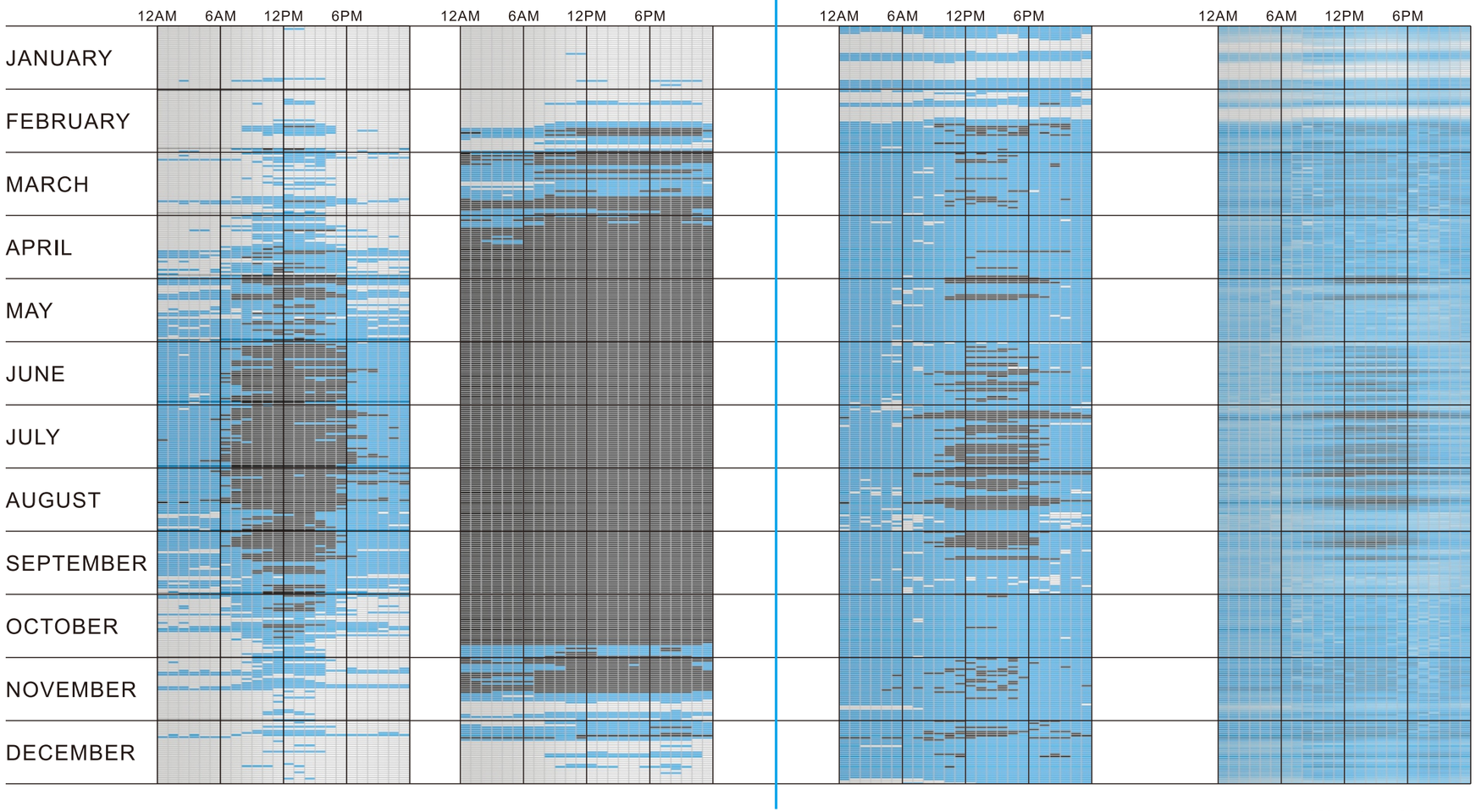
COMFORTABLE TIME: 80.6%!

Improvement With All Strategies

COLD 9.7% | COMFORT 80.6% | HOT 9.7%

Degrees from Target Temperature

<-6.00 | -4.00 | -2.00 | 0.00 | 2.00 | 4.00 | 6.00 | 8.00< | C



DISCUSSION: WHY DON'T YOU OPEN YOUR WINDOW?

ABOUT RESULT

When taking a look at the general result, the effect of natural ventilation created by opening windows is the most influential variable for improving the indoor comfort. Although the construction of the glass also plays an important role, it can only prevent the cold stress. When the main problem of the apartment is hot stress, the great-performance of insulation can barely help.

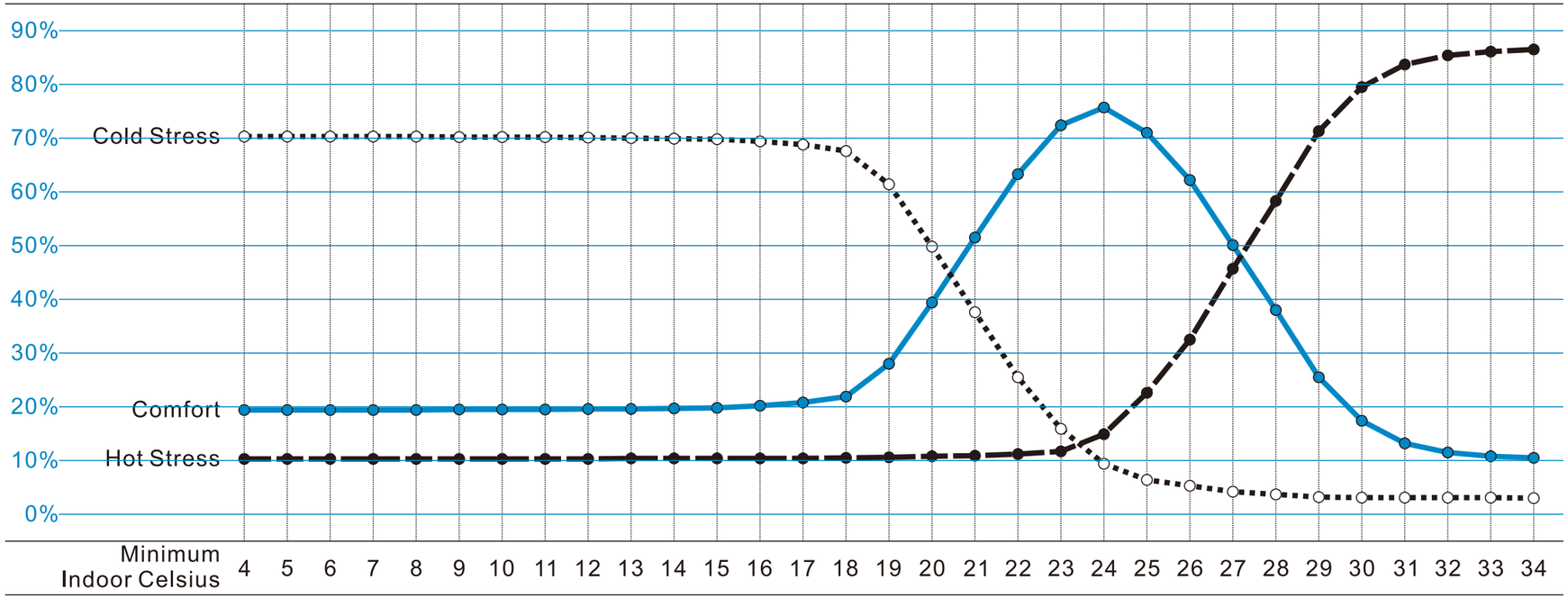
Surprisingly, the setting of the minimum indoor temperature for opening a window dominates the percentage of comfort hours. In this case, 24 Celsius is the optimized value that contributes to the highest percentage. However, this might be questionable. Do people always feel comfortable with the indoor temperature higher than 24 Celsius? It is believed that the air quality such as the concentration of pollutants or Carbon Dioxide may contaminate the feeling of comfort. But in the Energy Plus simulation, which is applied in this project, those factors are not included.

Nevertheless, regardless the air quality, opening window for natural ventilation do help improving the indoor comfort.

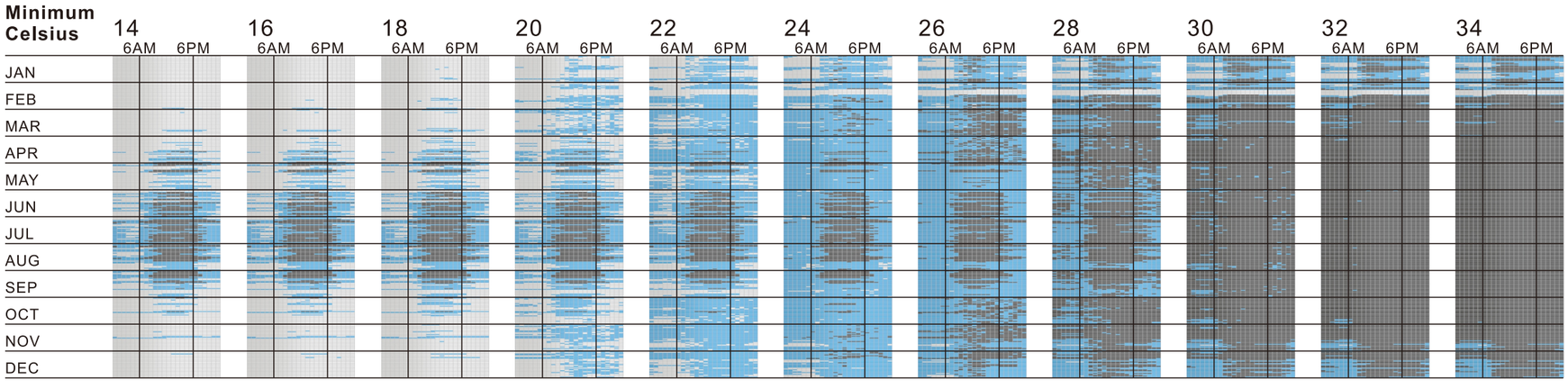
Detail of Low-E Glass Material in The Improved Design

Thickness	0.01	meter
Solar Transmittance	55	percent
Visible Transmittance	49	percent
Solar Reflectance	5	percent
Visible Reflectance	5	percent
Front Emissivity	20	percent
Back Emissivity	20	percent

ADAPTIVE COMFORT ANALYSIS WITH DIFFERENT SETTING



* Compare with the original design with some invariable factors: one window layer, Low-E glass, no shading device. The variable factor is the minimum indoor temperature of opening a window for natural ventilation.



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