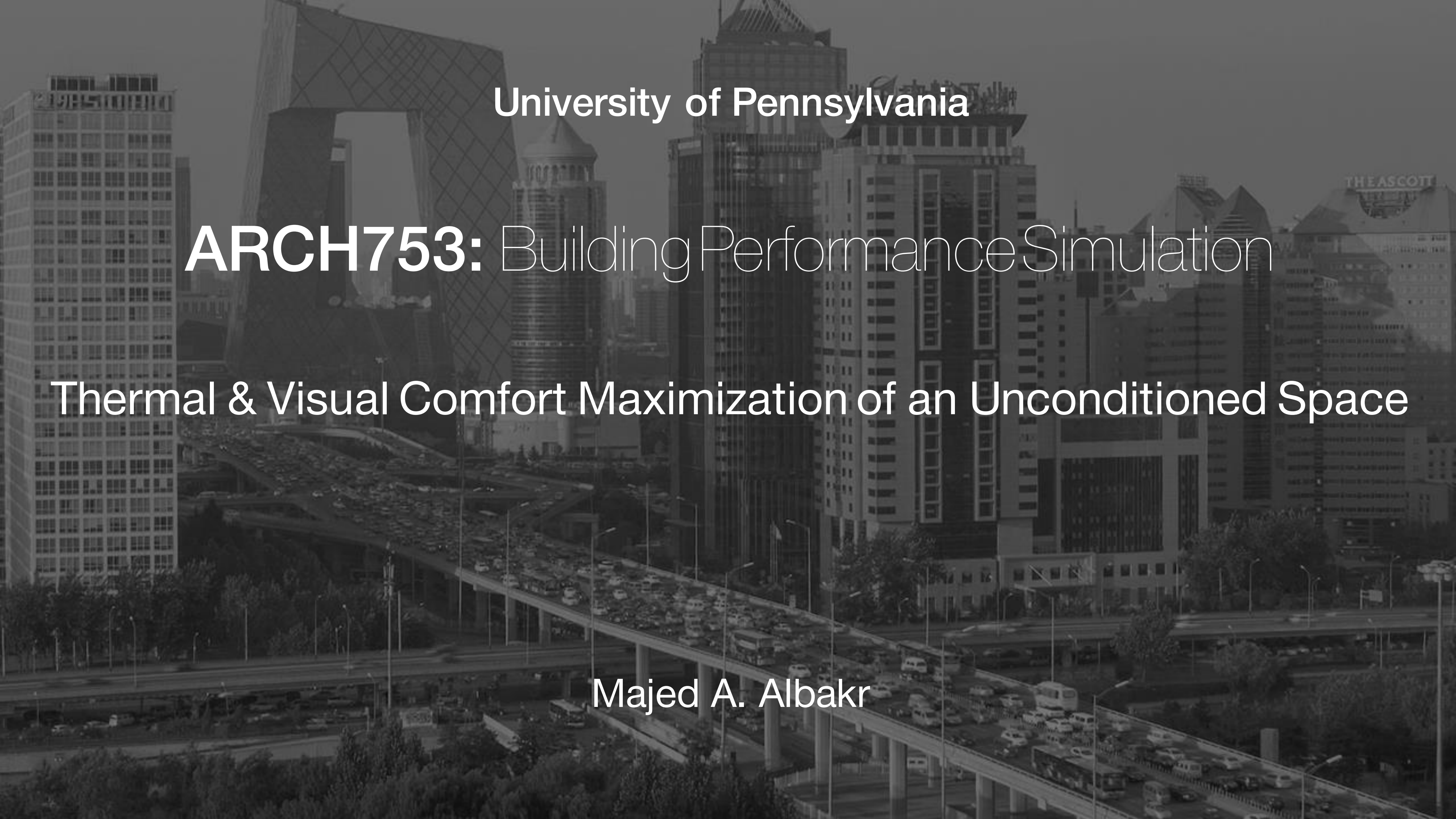


University of Pennsylvania

ARCH753: Building Performance Simulation

Thermal & Visual Comfort Maximization of an Unconditioned Space

Majed A. Albakr

The project studies a small house in regards to its performance ad current comfort for its occupants. The aim is to provide the maximum hours of comfort in a passive manner while using less materials in the redesign process. A comfortable, well day lit indoor space, optimal passive performing space is what is hoped to achieve.

The project relies on data generated from Grasshopper’s LadyBug and HoneyBee, along with the support of Climate Consultant data and other online sources.

PROJECT LOCATION:
39.9167° N, 116.3833° E

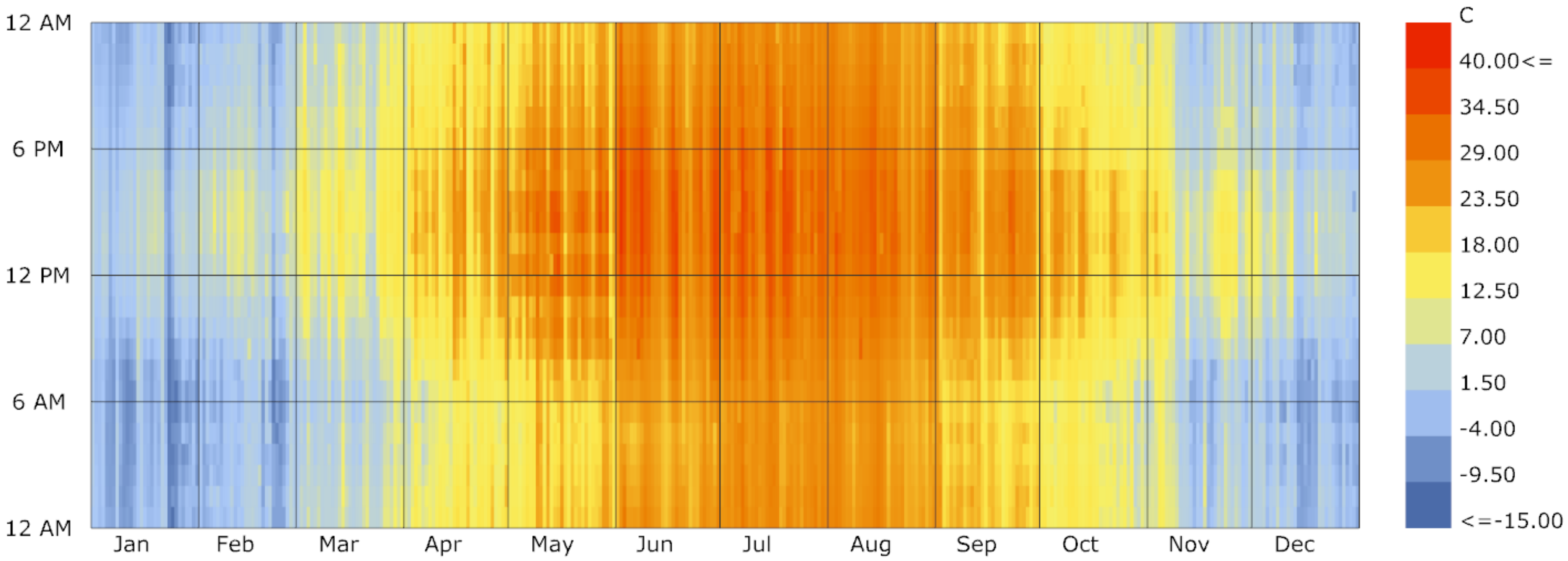
Beijing, China

Contents:

Climate Analysis:

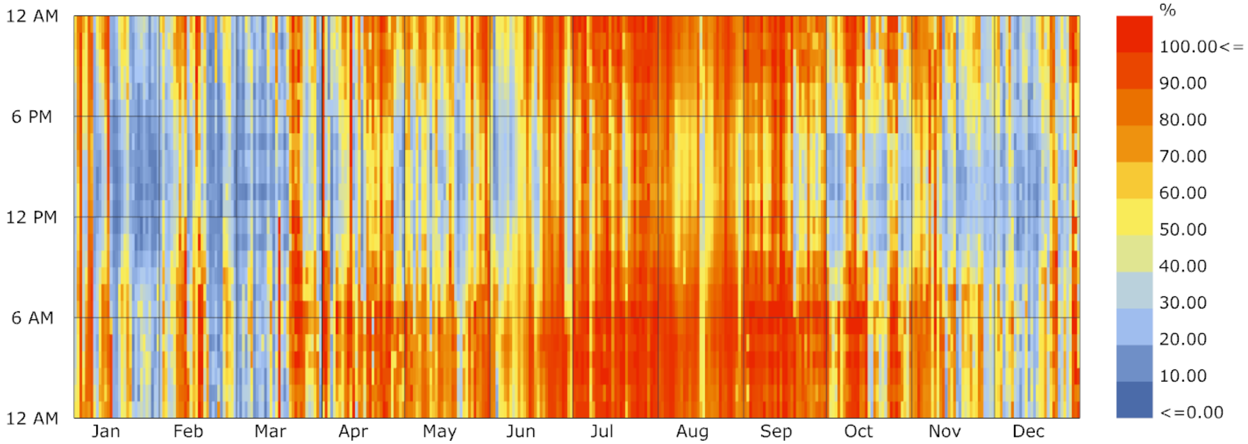
By analyzing the patterns of weather, the appropriate deign methods could be reached

The highs reach somewhere in the mid 35C

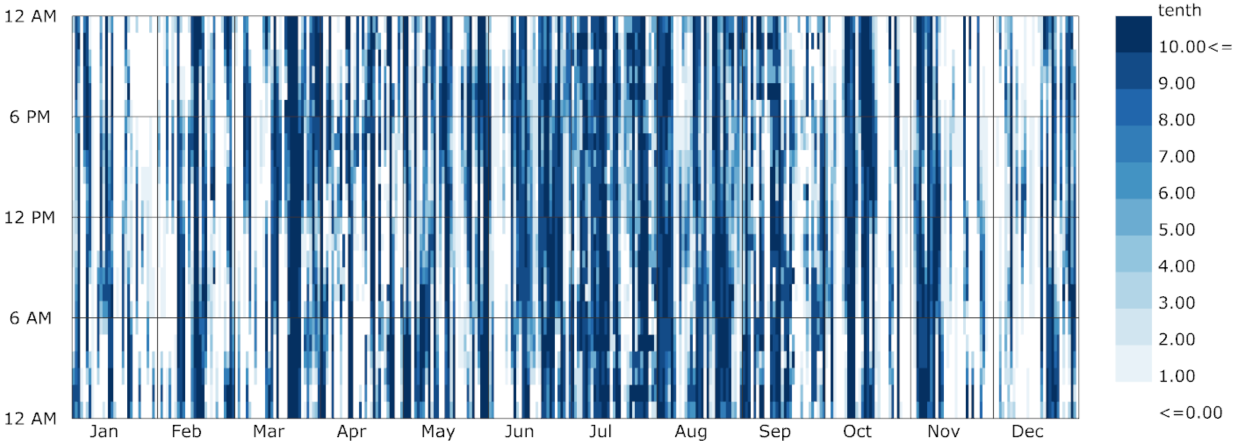


Dry Bulb Temperature (C) - Hourly
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00

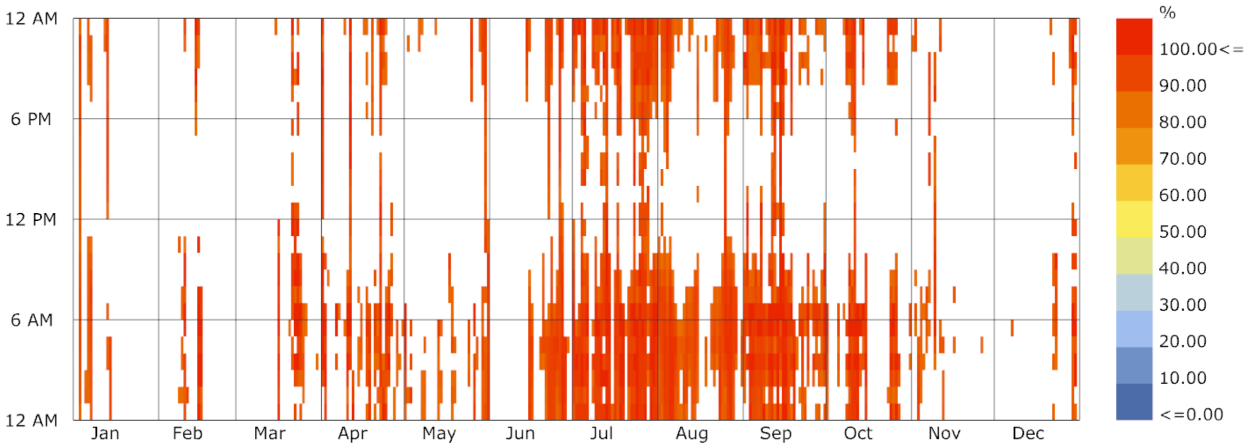
Relative Humidity + Cloud Coverage:



Relative Humidity (%) - Hourly
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00

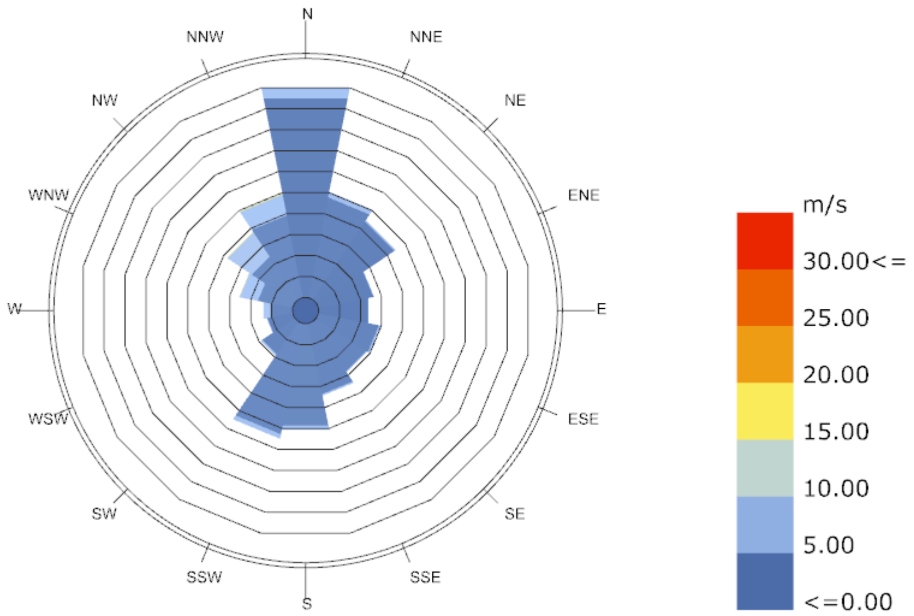


Total Cloud Cover (tenth) - Hourly
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00



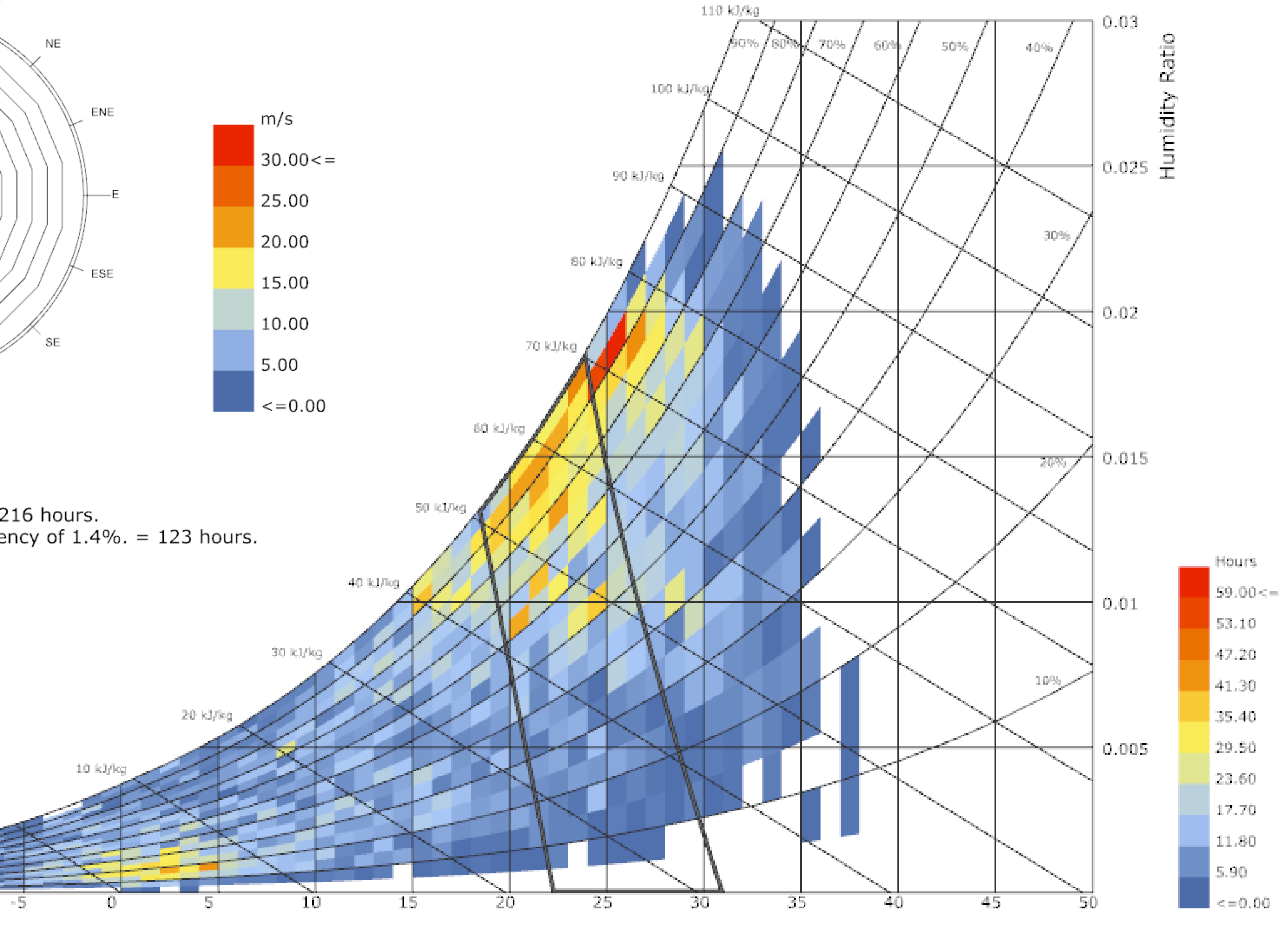
Relative Humidity (%) - Hourly
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00

RH>80%

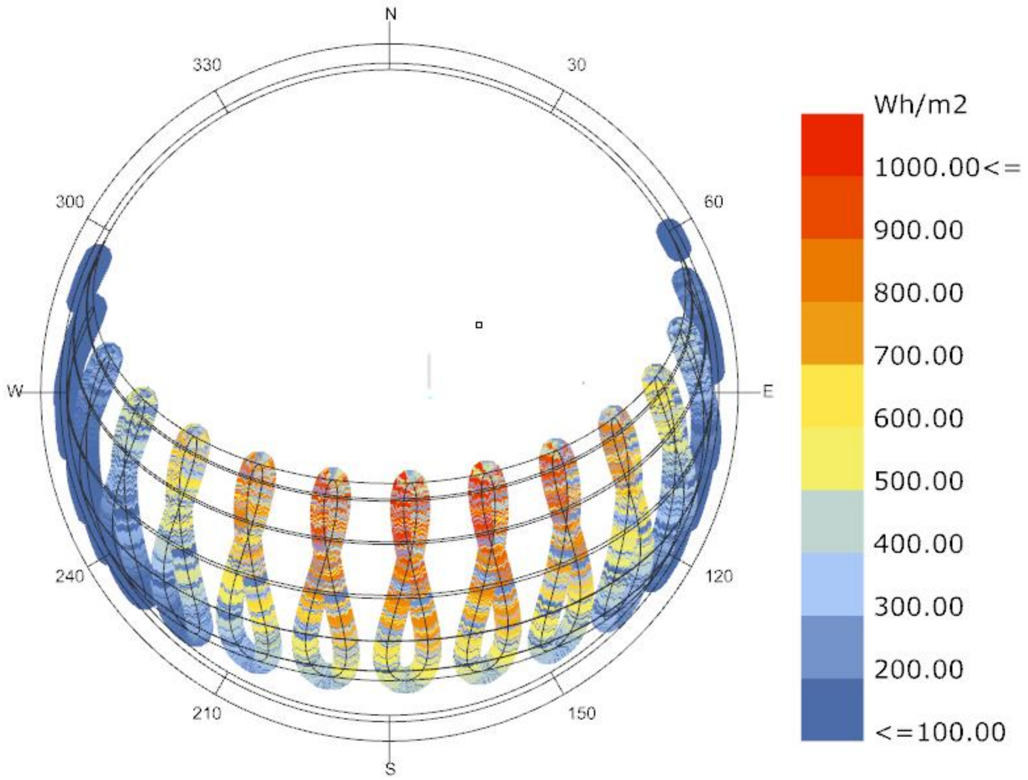


Wind-Rose
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 13.88% of the time = 1216 hours.
Each closed polyline shows frequency of 1.4%. = 123 hours.

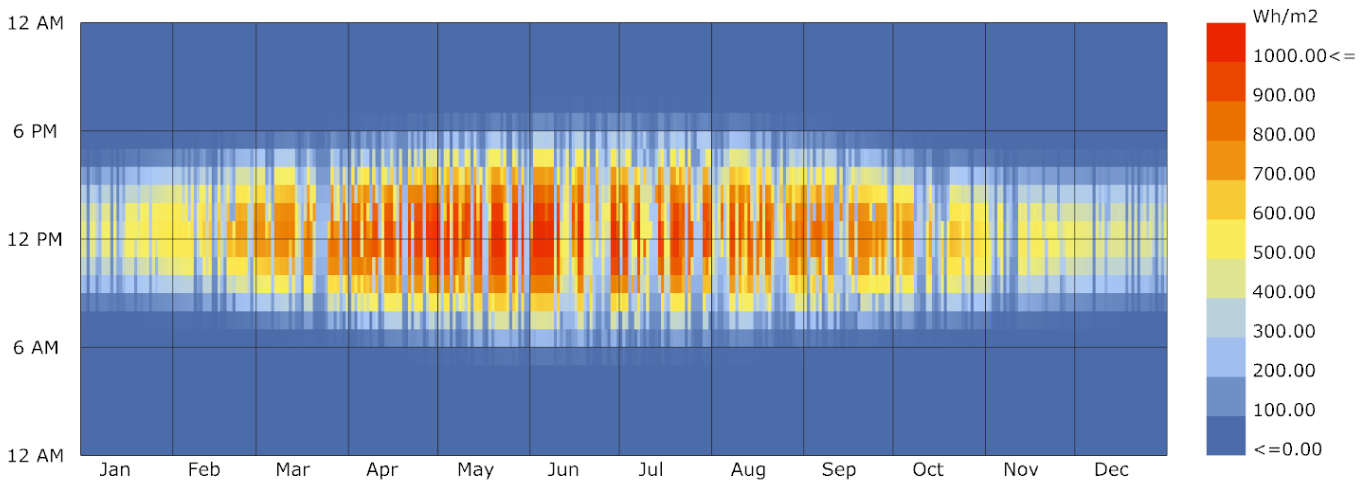
Psychrometric Chart
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00



Radiation Analysis:



Sun-Path Diagram - Latitude: 39.8
Hourly Data: Global Horizontal Radiation (Wh/m2)
BEIJING_CHN



Global Horizontal Radiation (Wh/m2) - Hourly
BEIJING_CHN
1 JAN 1:00 - 31 DEC 24:00

Base Case Analysis:

In order to determine what needs to be maintained or improved, a thorough analysis will indicate those parameters.
The Building's façade is facing south east

The areas of focus are:

- **Daylight Autonomy (DLA):** The percent of time in which a point in space receives daylight above illuminance threshold.
- **Spatial Daylight Autonomy (sDA):** Percent of area that receive an excess of 300lux.
- **Useful Daylight Illuminance (UDLI):** Percentage of time a given test point receives a determined range of lux (<100, 100-2000, >2000).
- **Glare Analysis:** Percentage of glare for a given field of view.
- **Comfort Hours:** The number of hours occupants are comfortable in a space. (Utilizing Adaptive comfort and Parametric Mean Vote-PMV)
- **Comfort Percentage:** The percent of hours occupants are comfortable in a space. (Utilizing Adaptive comfort and Parametric Mean Vote-PMV)

Base Case:

In order to determine what needs to be maintained or improved, a thorough analysis will indicate those parameters. The Building's façade is facing south east.

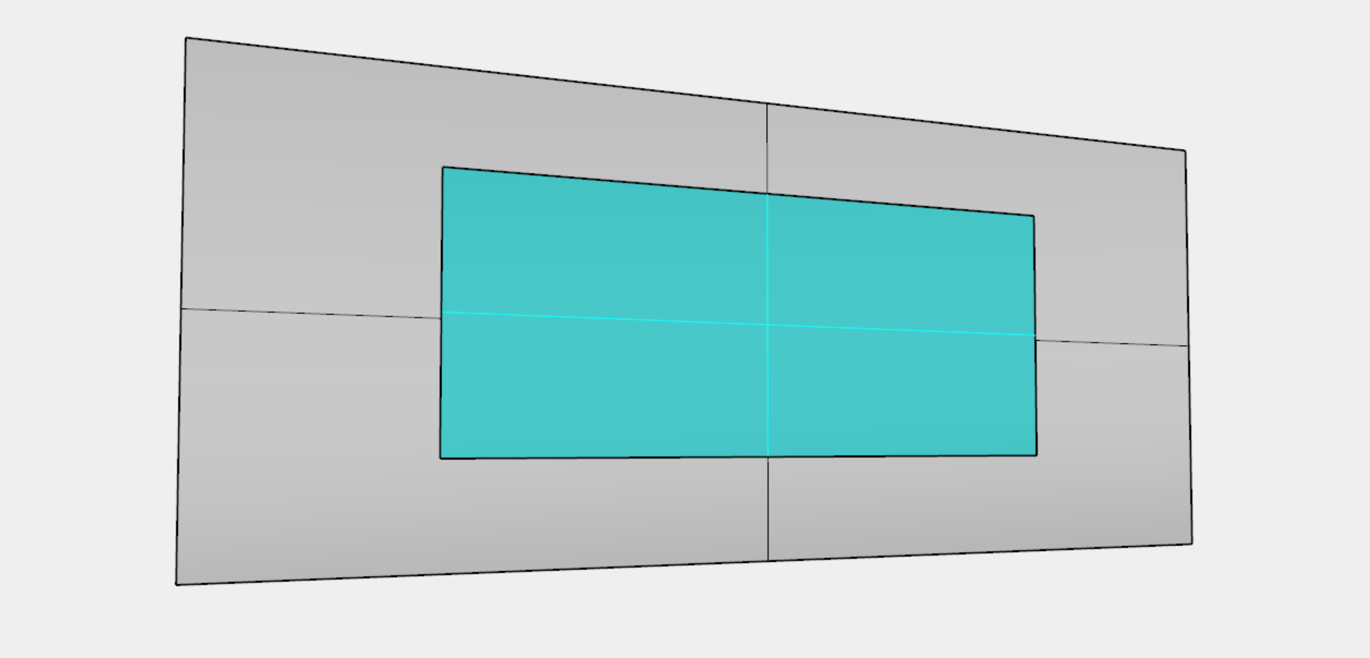
The Aim:

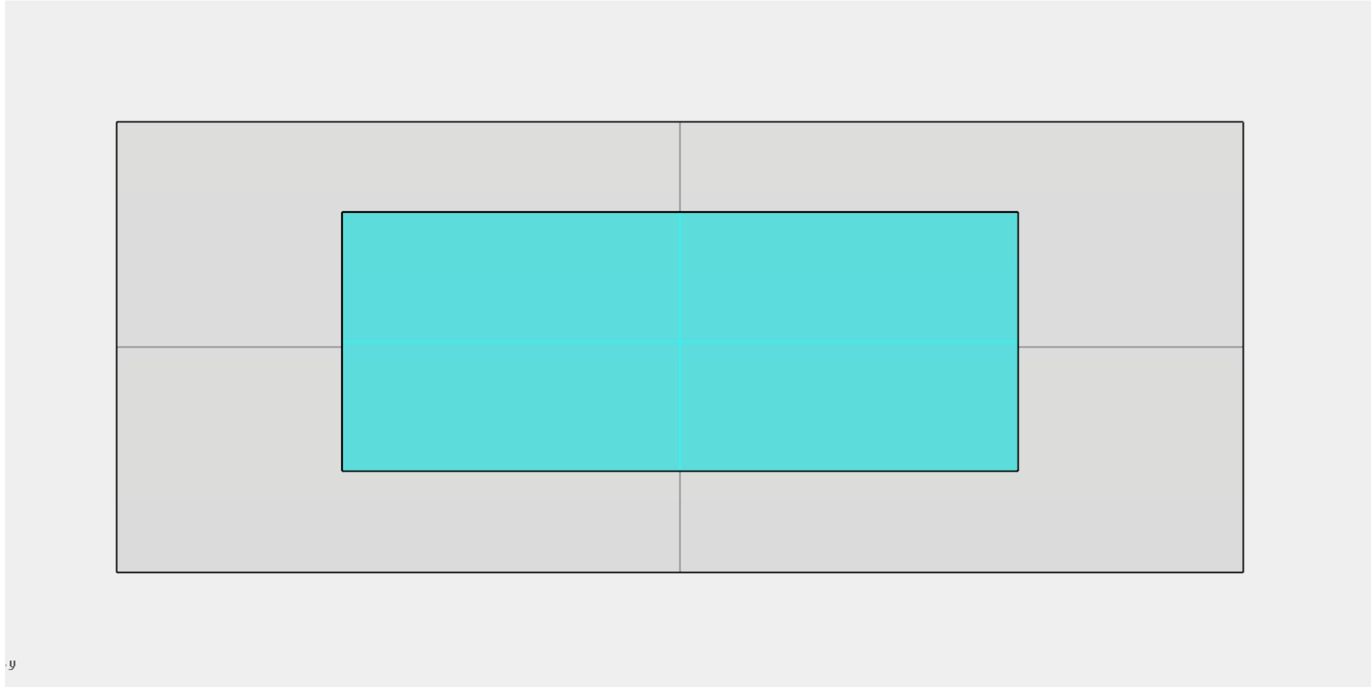
sDA>55%

UDLI =100-2000lux

Glare<35%

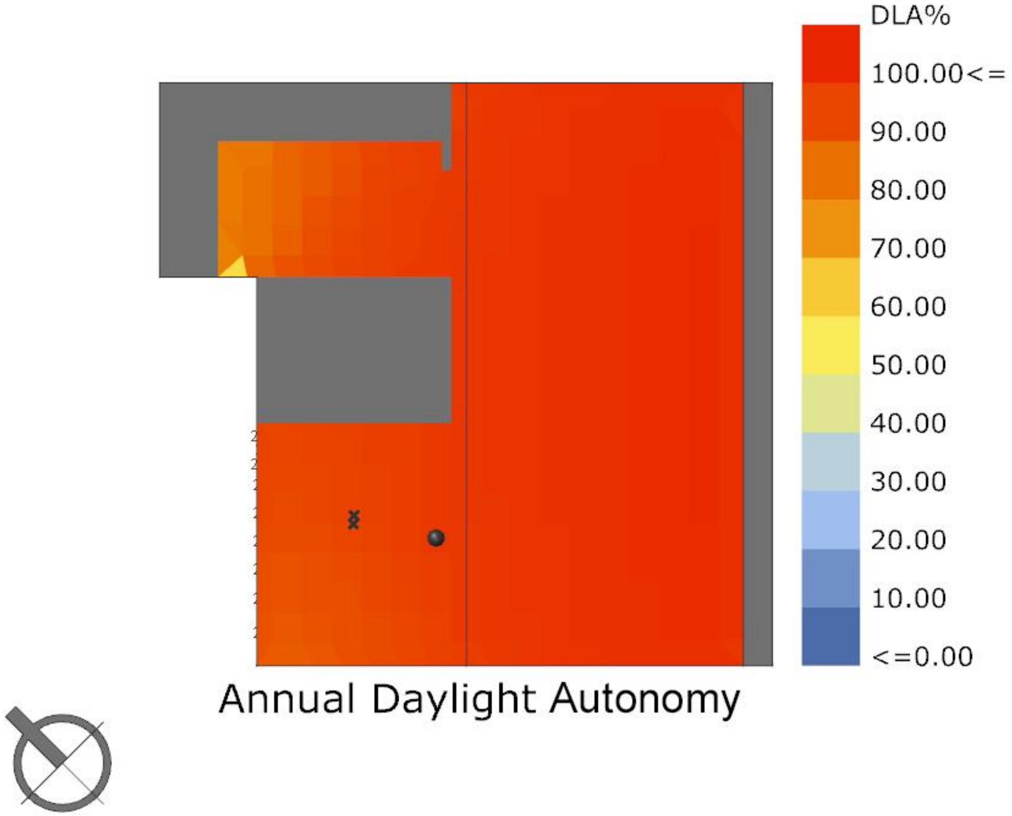
Comfort=100%





Daylight Autonomy (DLA):

While facing south east as a base case, DLA reaches 100% on more than half the test points.

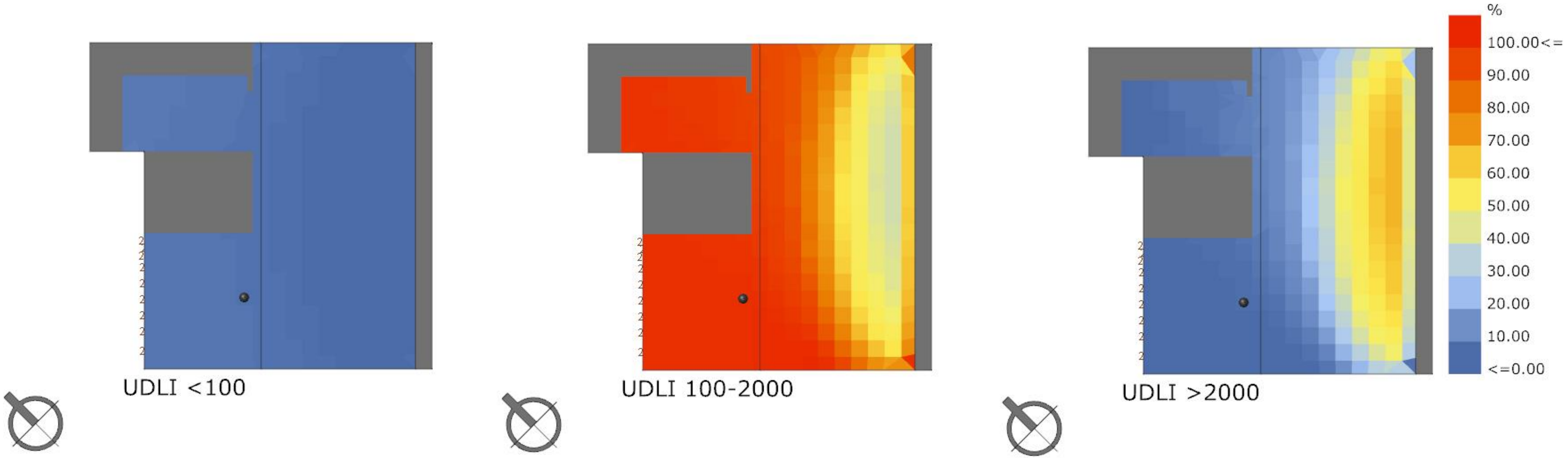


Spatial Daylight Autonomy (sDA):

sDA=**99.42**

The base case is achieving a much higher percentage than the LEED minimum, which is 55% for 50% of the space.

Useful Daylight Illuminance (UDLI):



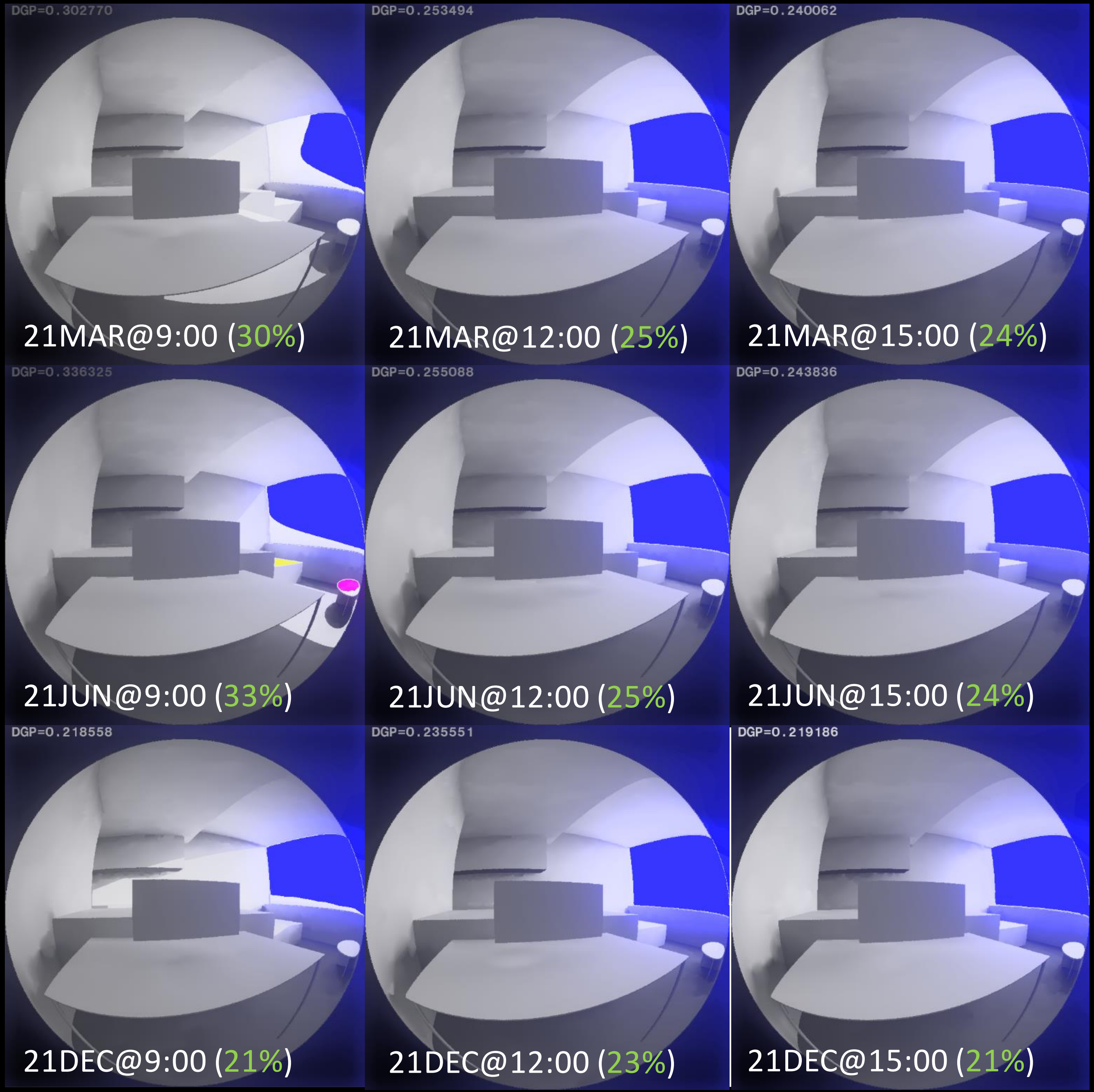
UDLI in the base case illustrates almost all test point don't receive an annual lux reading under 100 (10% max in a few test points). Many test points around the window receive above 2000. the latter should be eliminated during the re-design process.

Glare Analysis:

DGP: Daylight glare probability:

Imperceptible Glare [0.35 > DGP]
Perceptible Glare [0.4 > DGP >= 0.35]
Disturbing Glare [0.45 > DGP >= 0.4]
Intolerable Glare [DGP >= 0.45]

The base case achieved 100% Imperceptible Glare percentage at 9 points of time. That is a property that should be maintained during the design process.



Orientation Study:

By running the base model in different orientations, we are able to determine the optimal direction.

The compression between the active and passive situation helps in giving a perspective of how much the mechanical means along with orientation differ from the lack of a system.

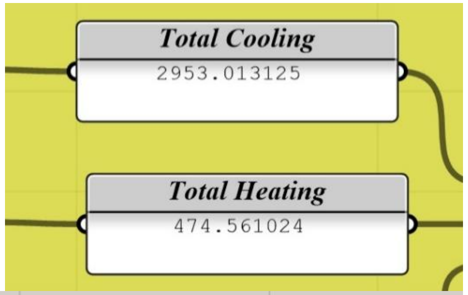
		Mechanical system conditioning		Passive and ventilation	
Angle	Orientation	Comfort Hours	Comfort %	Comfort Hours	Comfort %
45 °	SE	1707	19%	700	8%
0 °	E	1601	18%	433	5%
90 °	S	1907	21%	438	5%
180 °	W	1534	18%	558	6%
270 °	N	1321	15%	577	6%

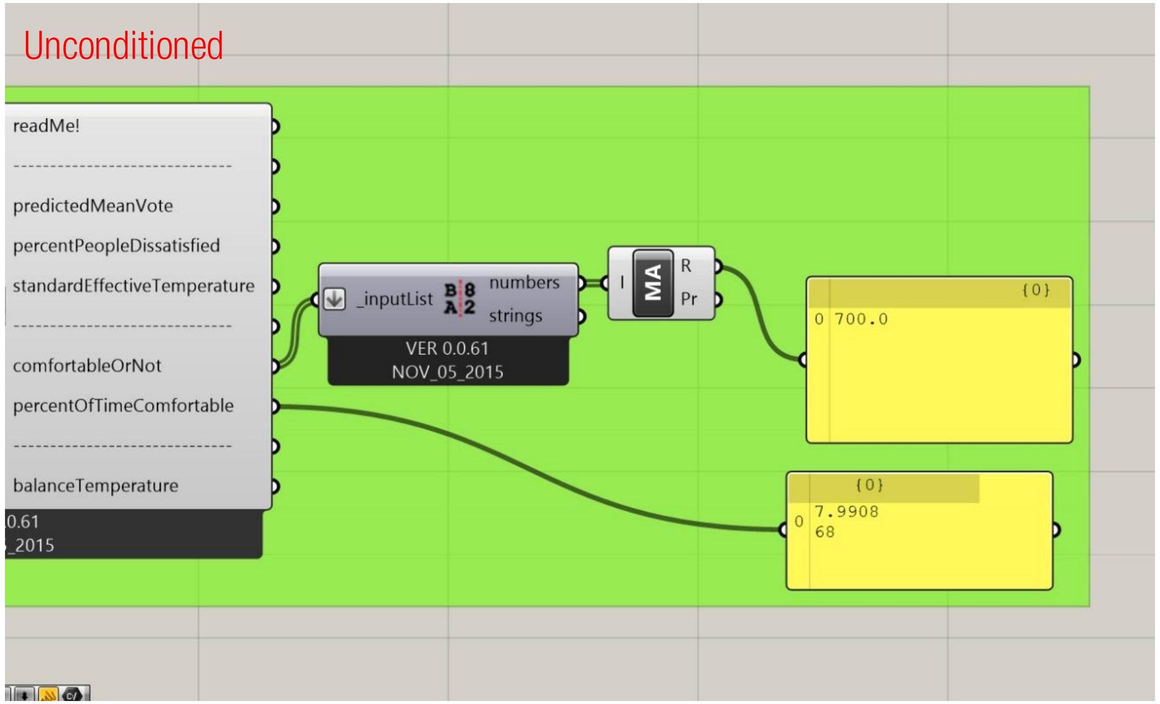
Although the base case orientation has the higher percentage, It is the south orientation that will be considered, mostly to maximize solar heat gain during winter. Which is in accordance with climatic recommendations.

PASSIVE vs. ACTIVE

Indication of how big a role mechanical systems significantly improve comfort. Although cooling and heating will not be taken into confederation for the base case or the final design, the numbers indicate the critical issues that should be addressed. Such as, the need for more heat, cooling, etc.

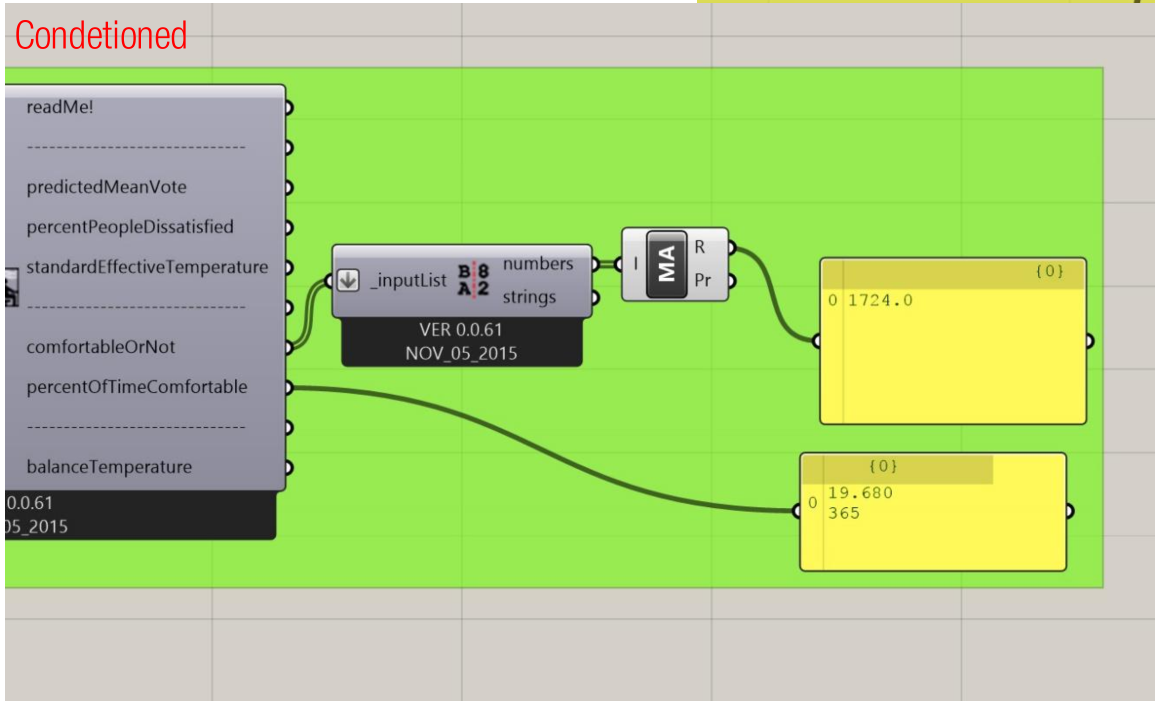
The unconditioned approach is going to be taken for a more realistic result.





Hours of Comfort: **700**

Percentage of comfort: 8%



Hours of Comfort: 1724

Percentage of comfort: 19%

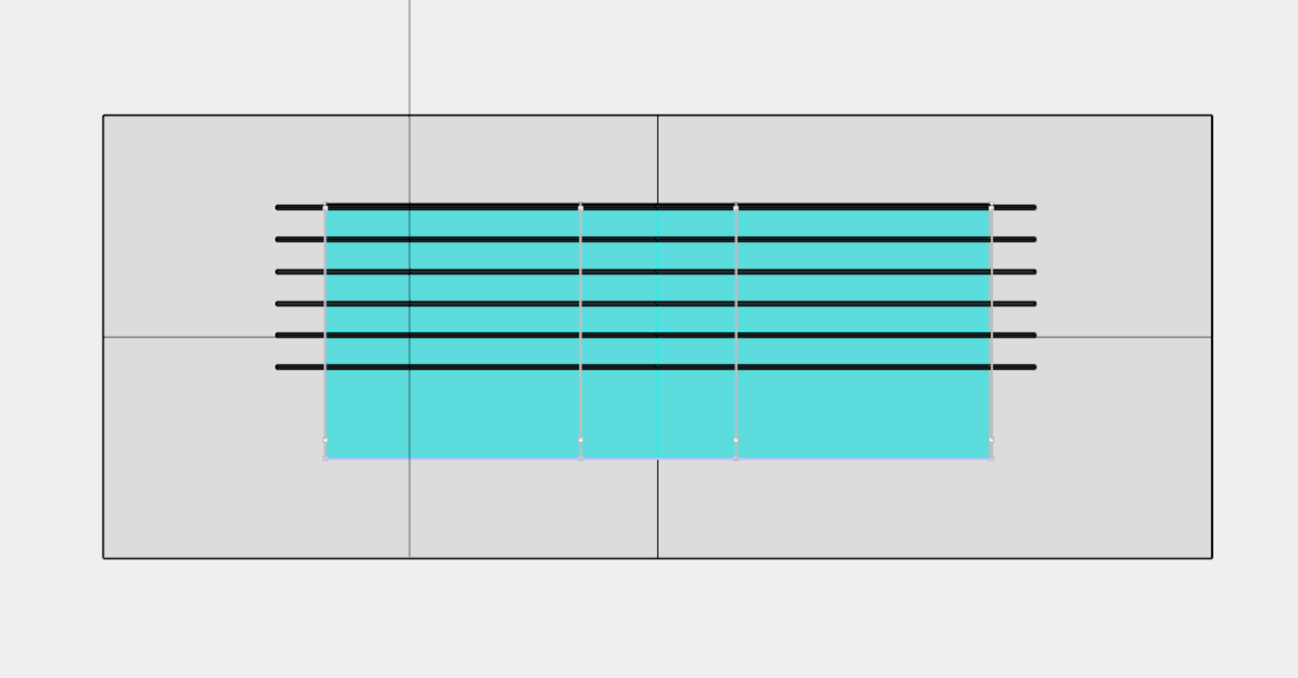
Shading Design (1st run):

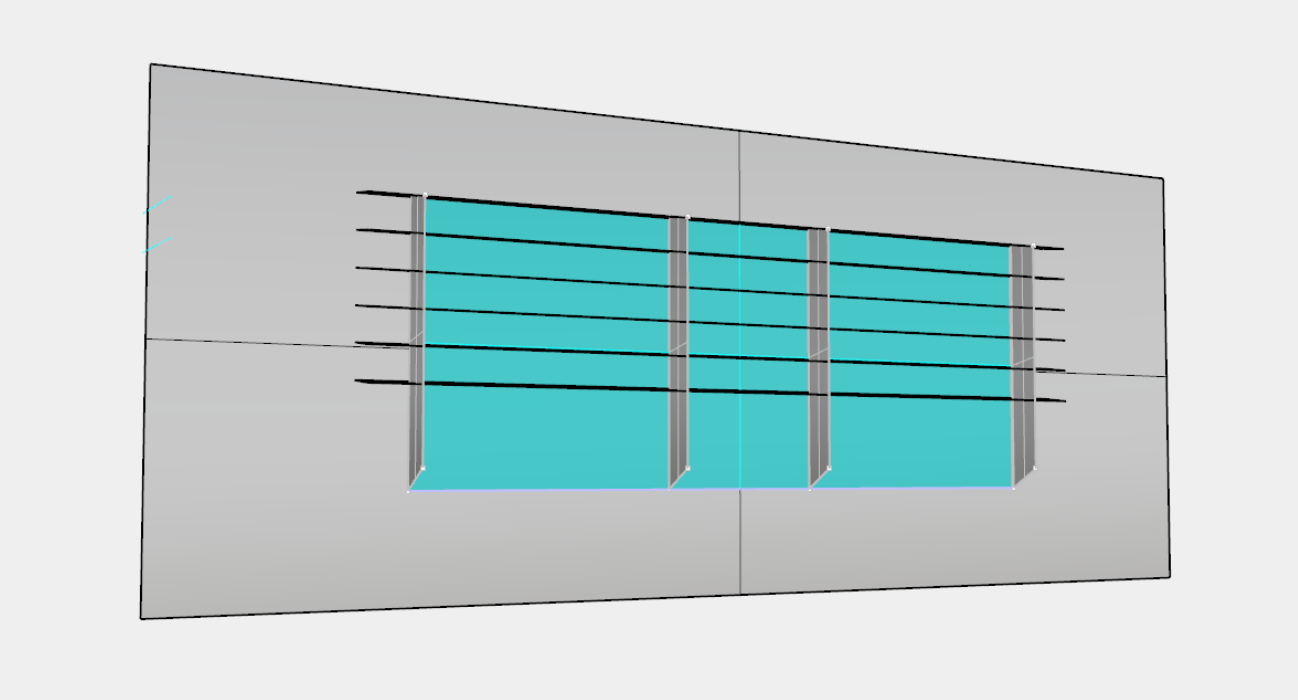
The design aims to achieve a higher occupant thermal comfort while maintain a well day lit space. The balance between the two is crucial.

While the glazing is facing south, The thin horizontal strips block the sun while allowing for infiltration during winter for heating.

The approach:

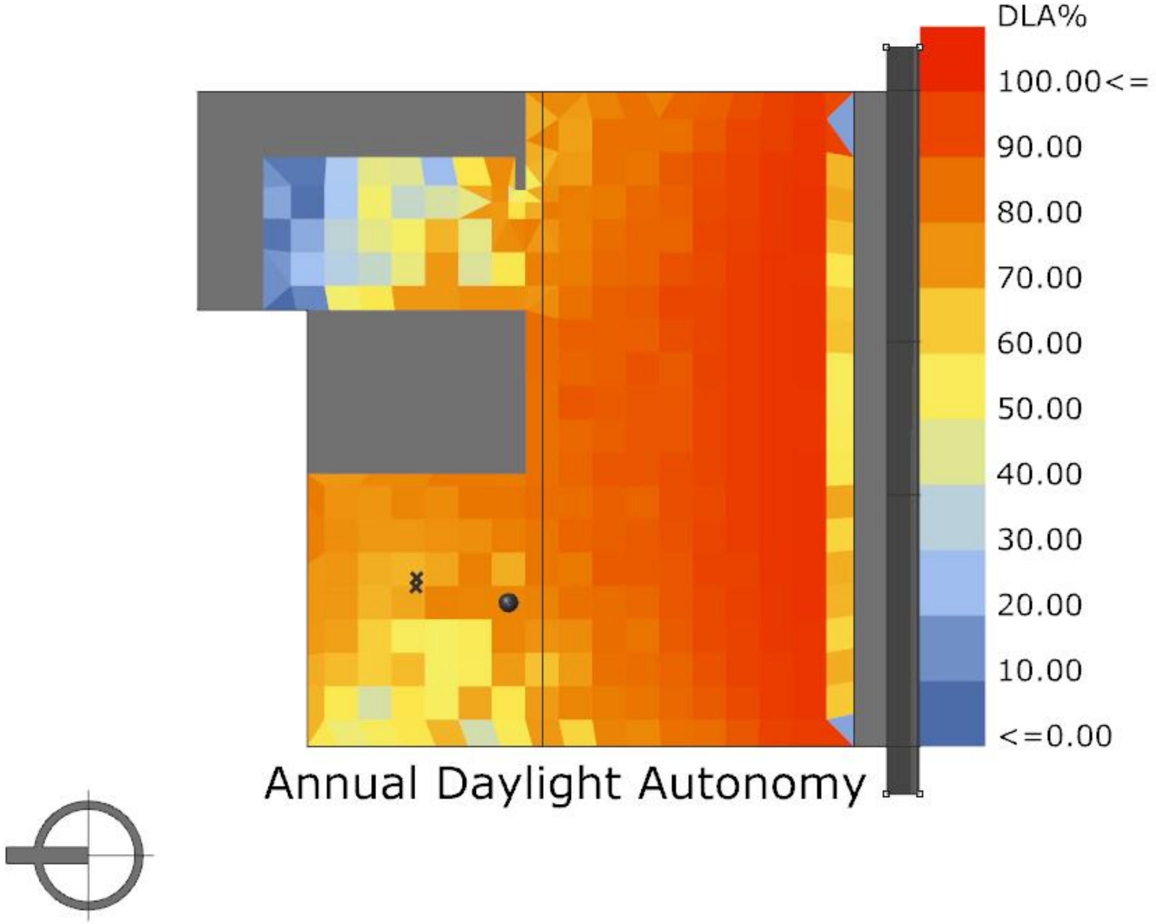
- Mechanical systems are **eliminated**.
- Use of **natural ventilation**.
- Façade oriented **south**.
- Addition of **shading elements**.
- **Adiabatic** surfaces maintained.





Daylight Autonomy (DLA):

While the redesigned space faces south, DLA reaches is significantly decreased the further back into the space. Which reaches low levels in some areas.

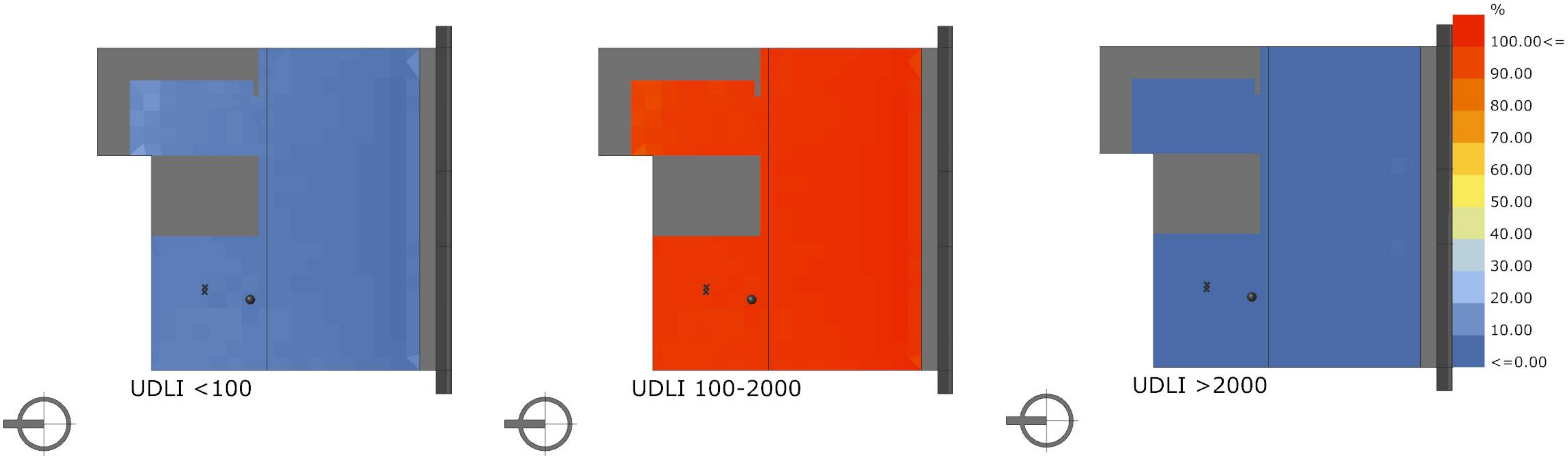


Spatial Daylight Autonomy (sDA):

sDA=86.49%

The re-design is maintaining the sDA percentage, which is 55% for 50% of the space.

Useful Daylight Illuminance (UDLI):



UDLI simulations illustrate That lux are within comfort range (100-2000). Unlike the base case, almost all test point don’t receive an annual lux reading under 100 (10% max in a few test points) and almost no points above 2000 lux (10% max in a few test points).

Glare Analysis (Re-design):

DGP: Daylight glare probability:

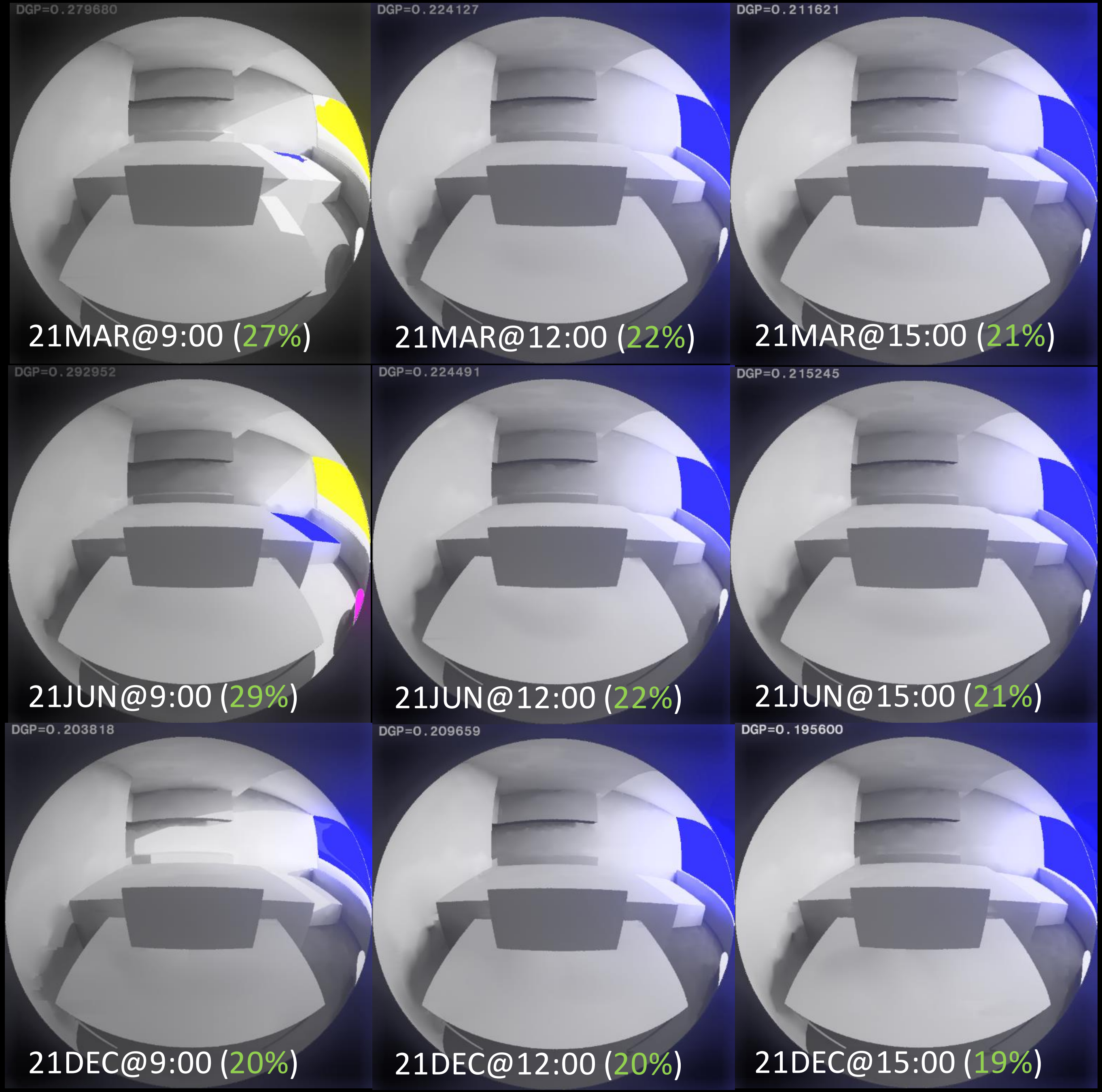
Imperceptible Glare [0.35 > DGP]

Perceptible Glare [0.4 > DGP >= 0.35]

Disturbing Glare [0.45 > DGP >= 0.4]

Intolerable Glare [DGP >= 0.45]

The re-design improved the already achieved 100% Imperceptible Glare percentage. That is a property was maintained and improved after the re-desing process.



Indoor Comfort:

By:

Using PMV comfort matrix

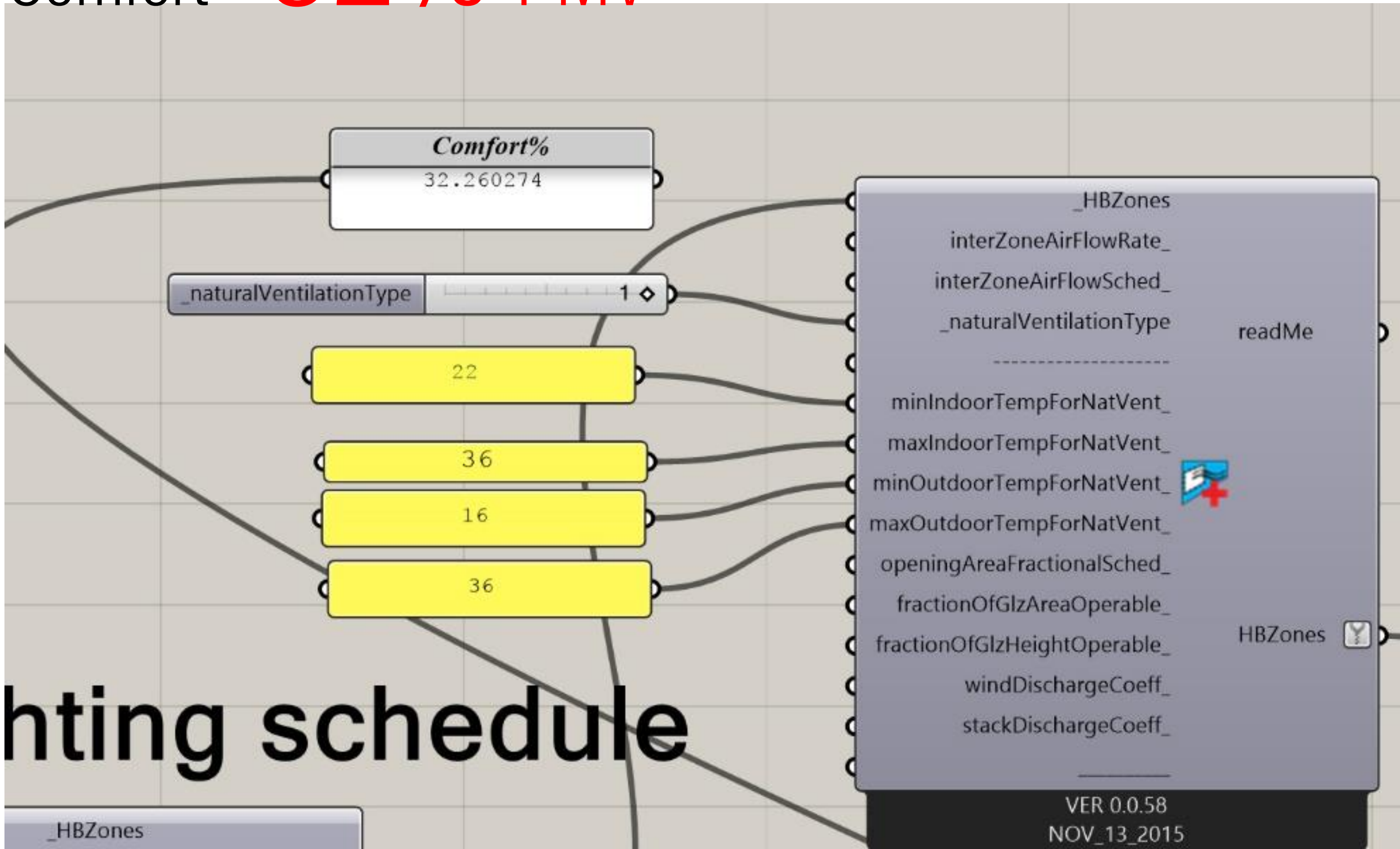
Adiabatic surfaces

Natural ventilation

The shading design failed to achieve a significant indoor comfort percentage.

Not implementing materials might have also contributed to not achieving a higher comfort percentage.

Comfort= 32% PMV



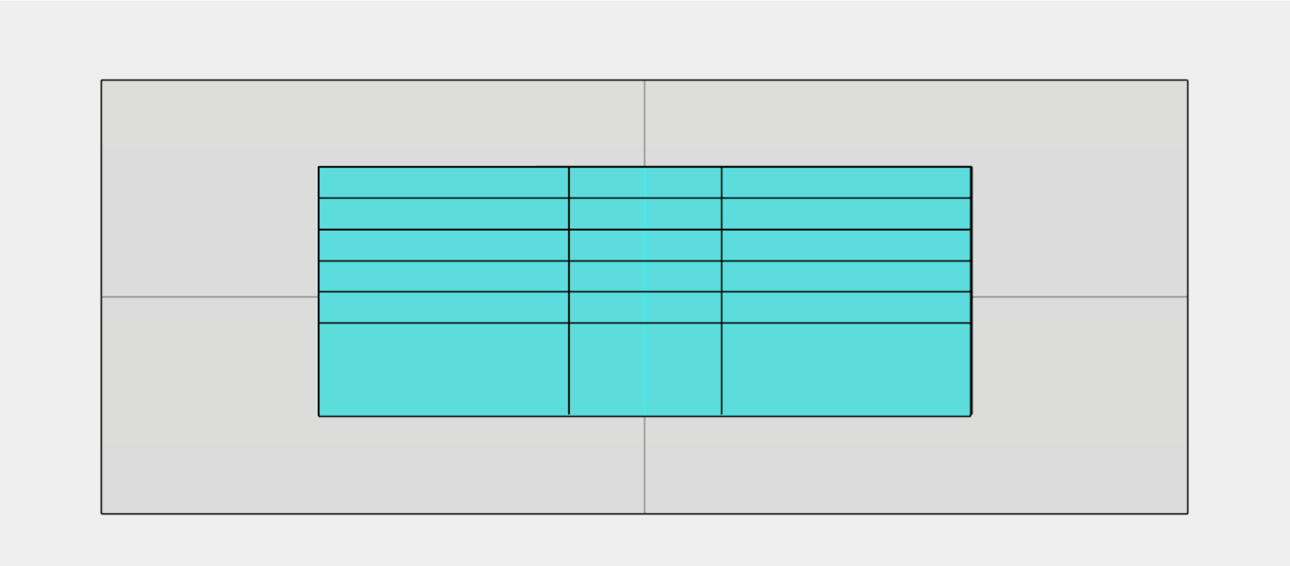
Shading Design (2nd run):

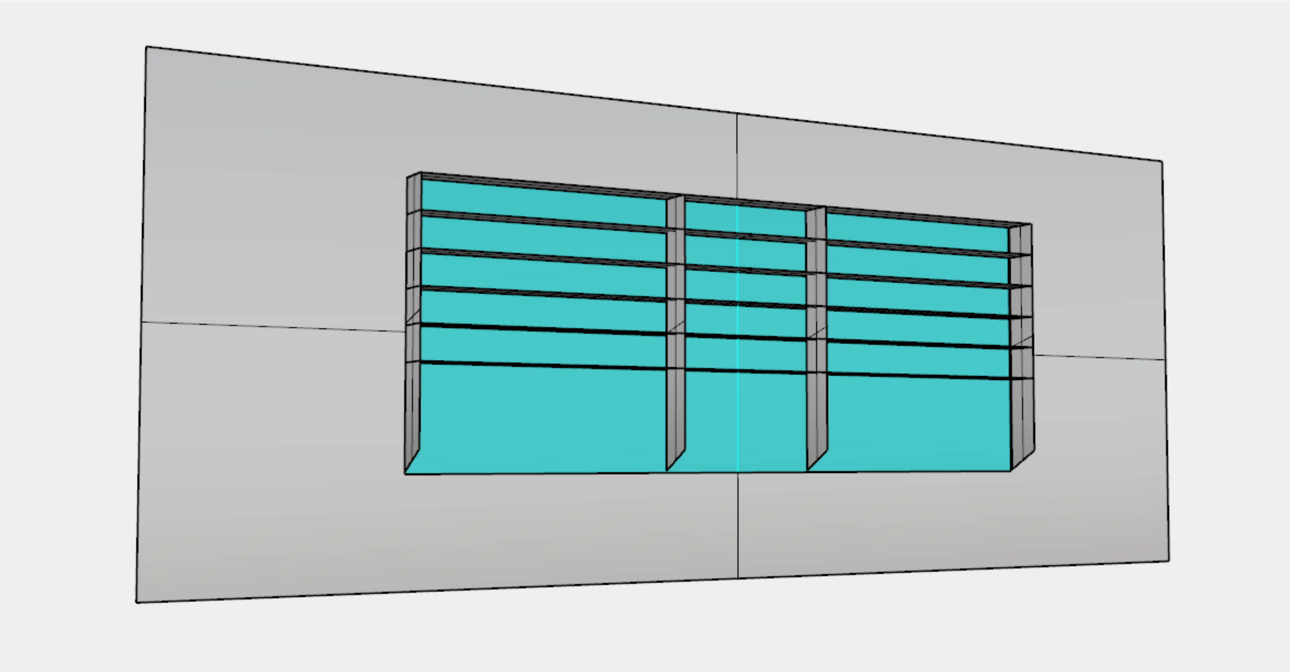
As the previous case, the design aims to achieve a higher occupant thermal comfort while maintain a well day lit space. The balance between the two is crucial.

A minor adjustment to the shading elements has been made. The façade still faces south, The thin horizontal strips block the sun while allowing for infiltration during winter for heating.

The approach:

- Mechanical systems are **eliminated**.
- Use of **natural ventilation**.
- Façade oriented **south**.
- Addition of **shading elements**.
- **No adiabatic** surfaces.
- **RAD glass material** used.

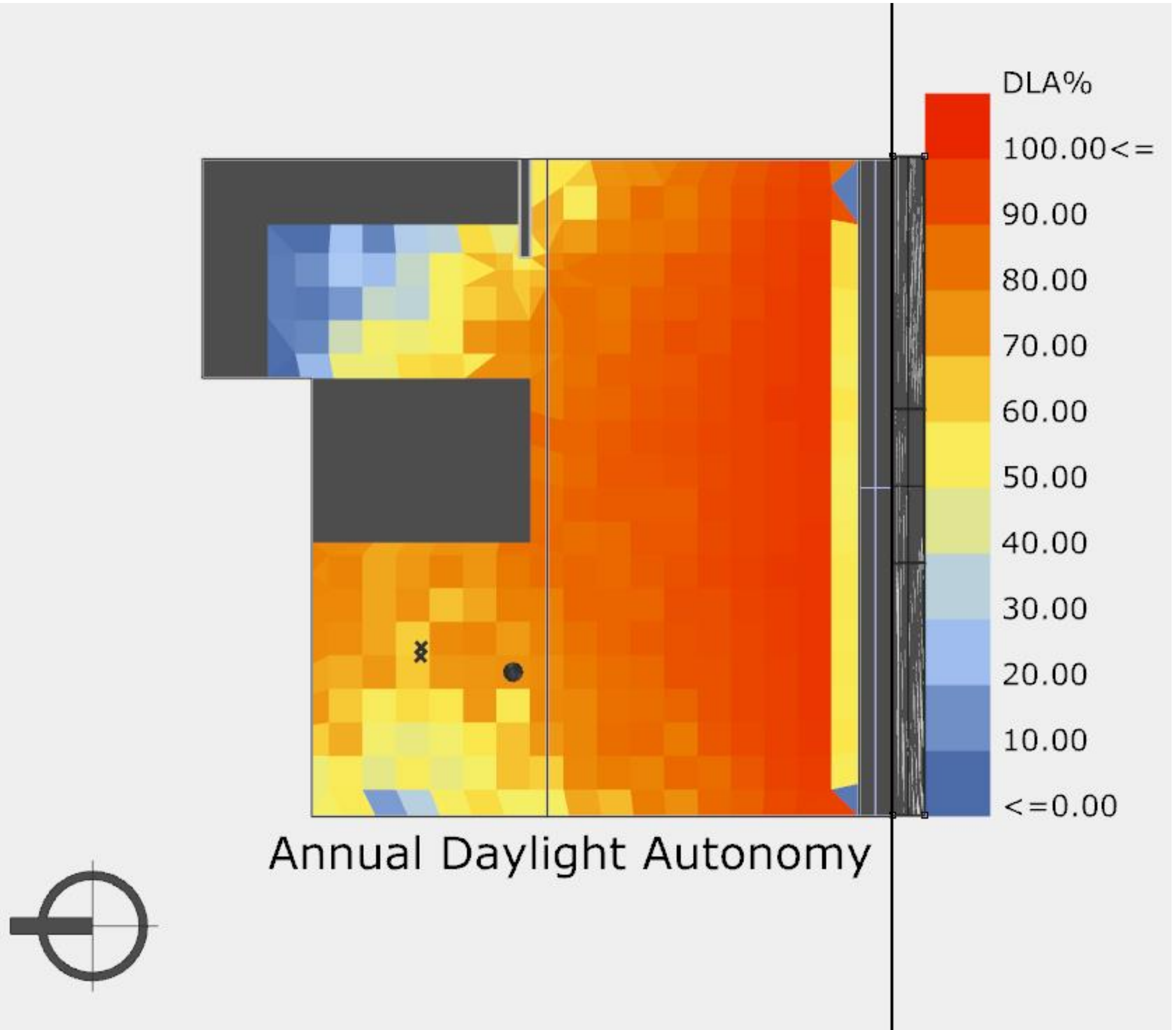




The RE-DESIGN

Daylight Autonomy (DLA):

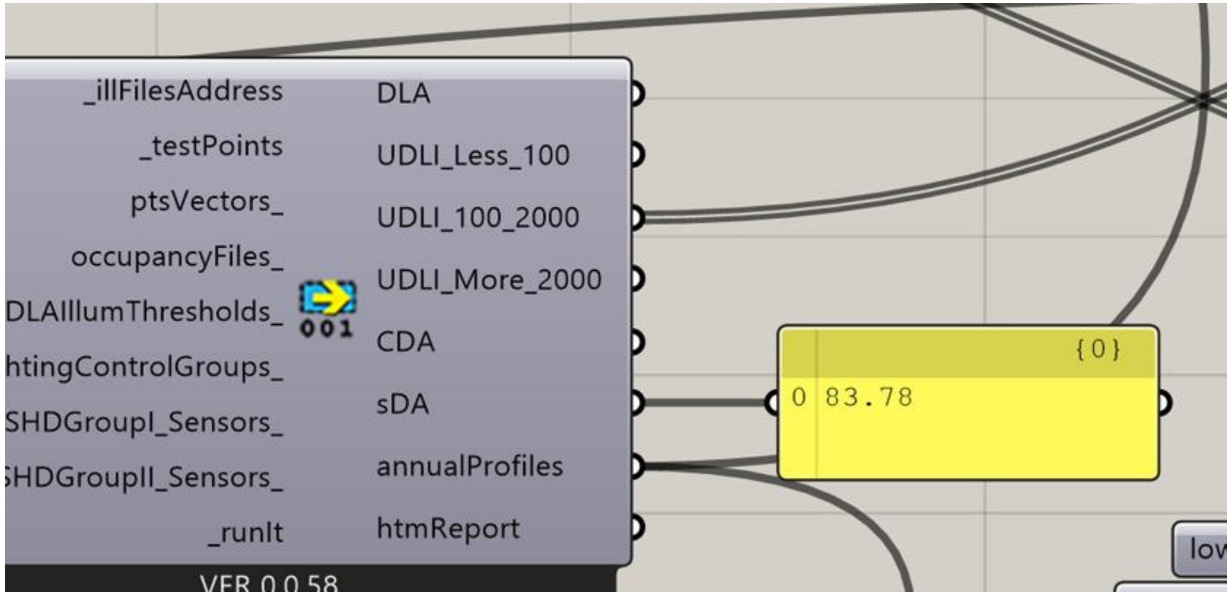
While the redesigned space faces south, DLA reaches is significantly decreased the further back into the space. Which reaches low levels in some areas.



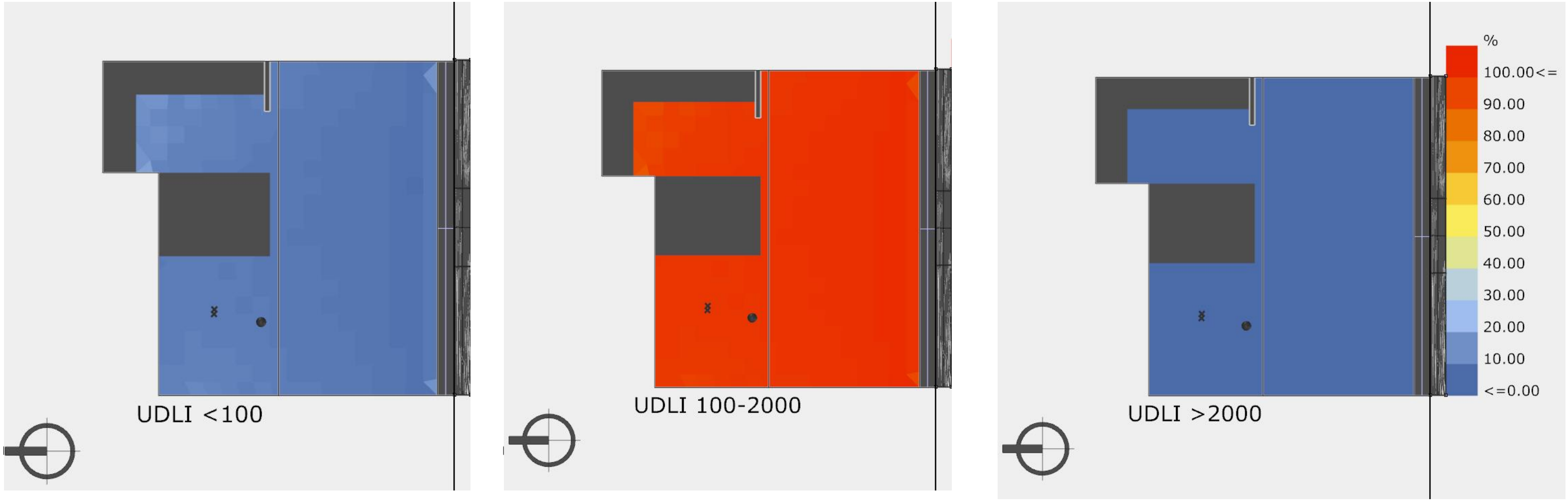
Spatial Daylight Autonomy (sDA):

sDA=83.78%

The re-design is maintaining the sDA percentage, which is 55% for 50% of the space.



Useful Daylight Illuminance (UDLI):



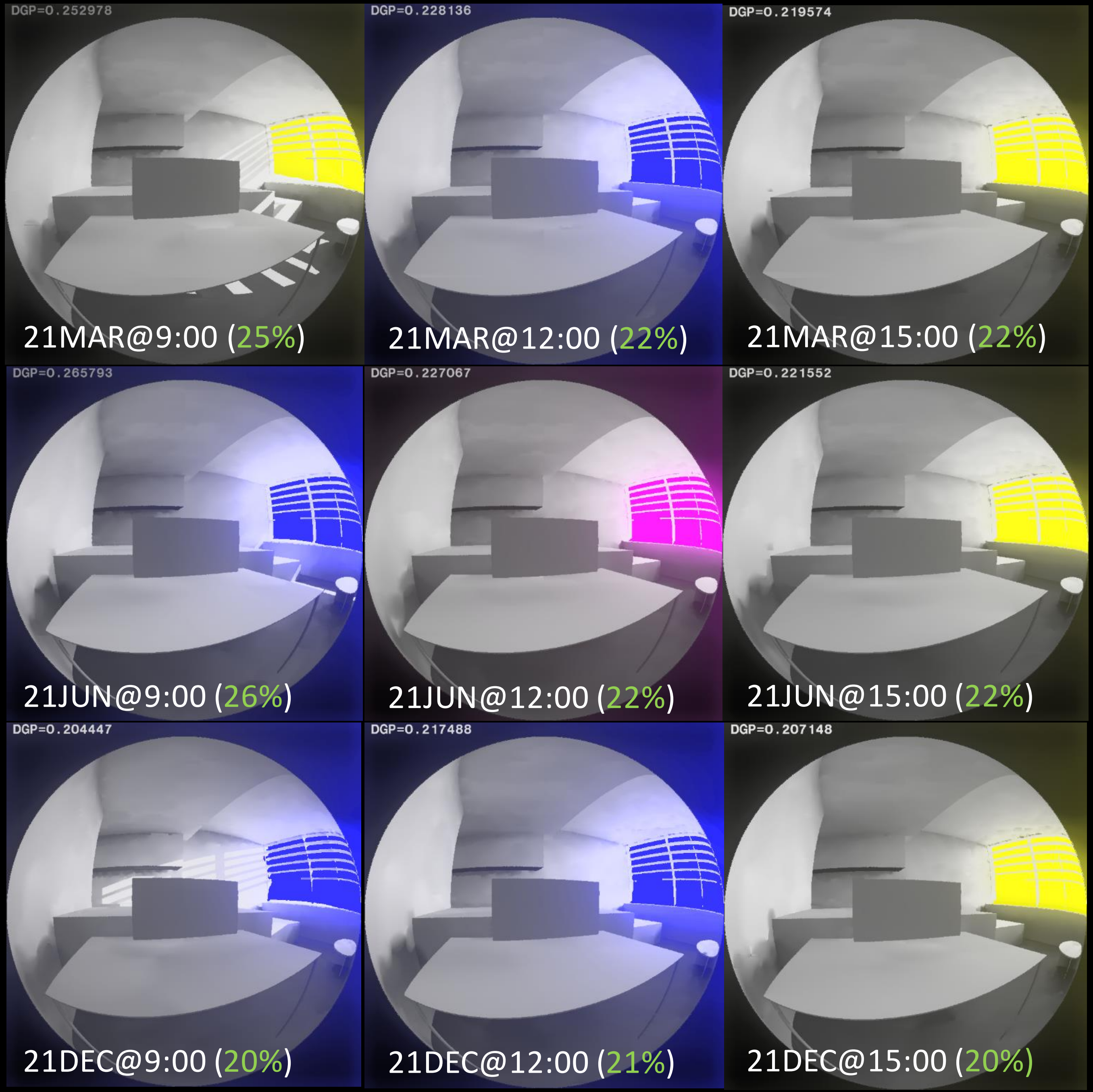
UDLI simulations illustrate That lux are within comfort range (100-2000). Unlike the base case, almost all test point don't receive an annual lux rreadin under 100 (10% max in a few test points) and almost no points above 2000 lux (10% max in a few test points).

Glare Analysis (Re-design):

DGP: Daylight glare probability:

Imperceptible Glare [0.35 > DGP]
Perceptible Glare [0.4 > DGP >= 0.35]
Disturbing Glare [0.45 > DGP >= 0.4]
Intolerable Glare [DGP >= 0.45]

The re-design improved the already achieved 100% Imperceptible Glare percentage. That is a property was maintained and improved after the re-desing process.



Indoor Comfort:

By:

Using PMV + Adaptive comfort matrix

Non-Adiabatic surfaces

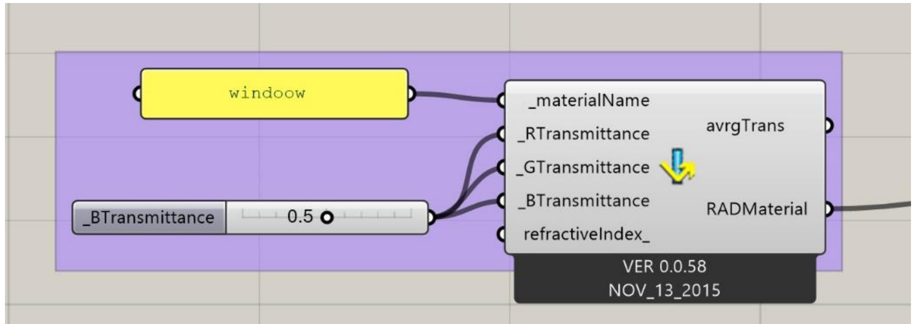
Natural ventilation

RAD glass material

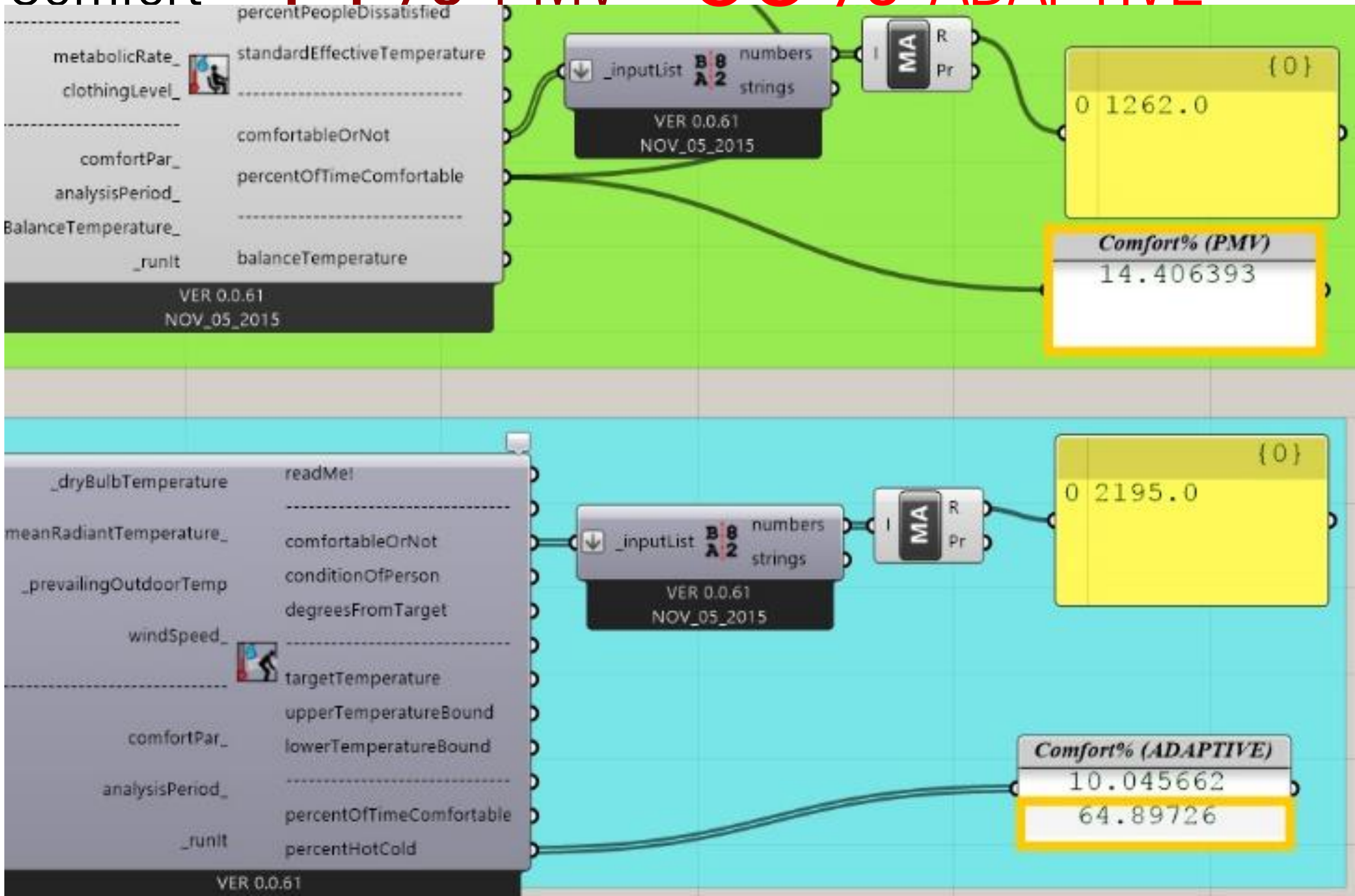
The re- design failed to achieve a significant indoor comfort percentage.

PMV comfort was significantly reduced due to using non-adiabatic surfaces (allowing heat transfer). It is most likely that it would be increased should there be materials implemented for other surfaces other than the glass.

The adaptive comfort is still isn't close to 100%. Most likely to the reason mentioned above.



Comfort= 14% PMV 65% ADAPTIVE



Conclusion:

The re-design aimed to achieve a high percent of comfort by utilizing passive means for ventilation and shading for thermal and visual comfort. The daylighting studies in the re-design process were successful at achieving desired comfort (DLA, sDA, UDLI, and Glare Analysis). As for the passive the thermal comfort, that is when the some areas of the study became problematic. The challenge was to re-design not only by shutting of mechanical systems and providing natural ventilation, but also turn surfaces to non-adiabatic (which significantly affects comfort result). Which is most likely why the percentages (PMV and Adaptive) were so far from the desired 100%.

The perfect balance between shading design, passive means, and material properties was not achieved to provide a high indoor thermal comfort level in the building. For daylighting however, that was not the case. Although the intention was for both to go hand in hand.