CLIMATIC FORM FINDING

TORONTO

20.203 / Architectural Energy Systems
Architecture & Sustainable Design
Spring 2020

Audrey Chan | Chen Ran | Chin Kee Ting | Rachel Lau | Benjamin Chong

CONTENT

1.0 CLIMATE ANALYSIS

1.1 TORONTO

Greater Toronto Area

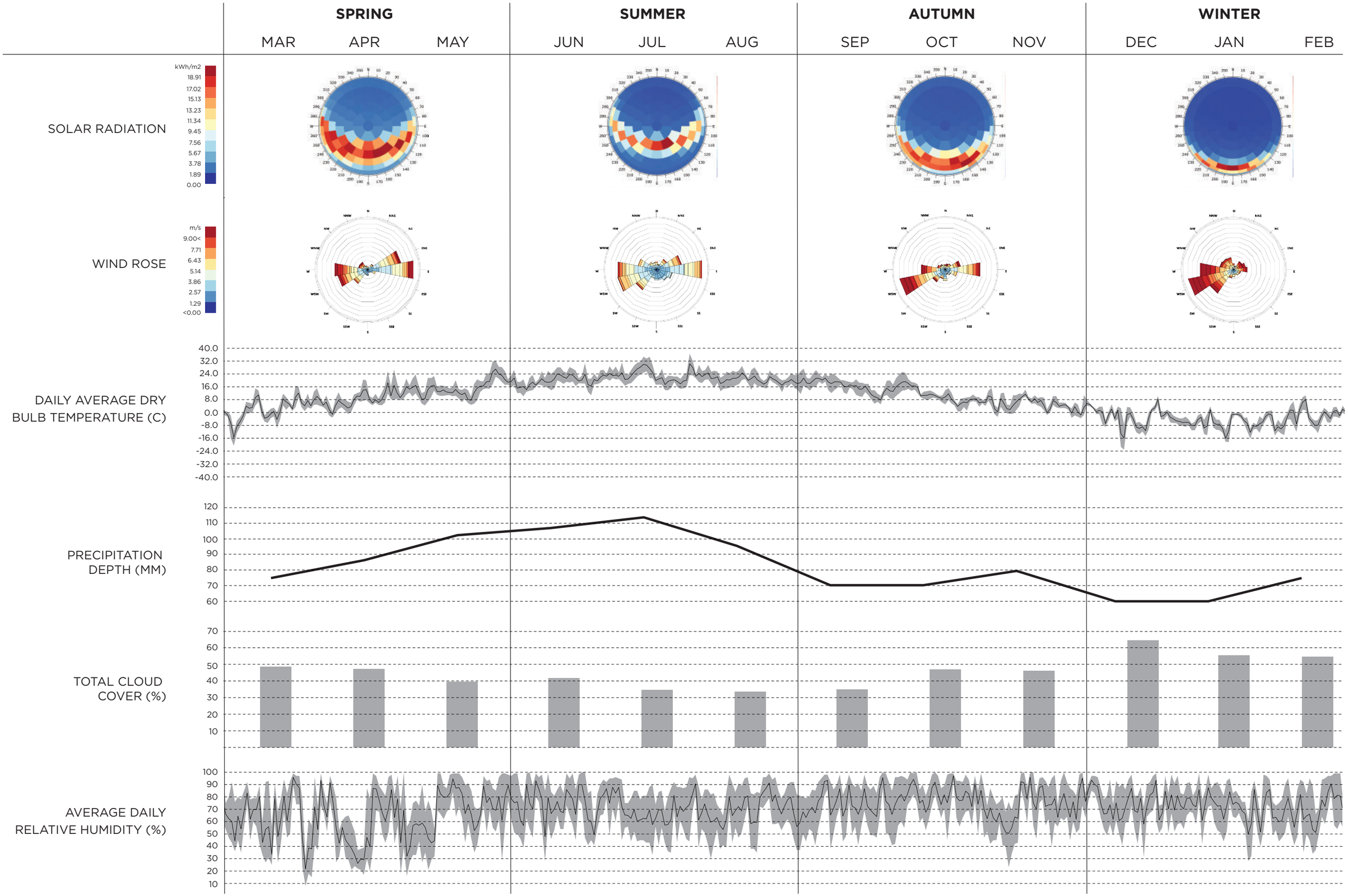
Toronto, Ontario, Canada
Latitude: 43.653° N
Longitude: 79.383° W
Elevation: 76m
City Population: 2.93 million (2017)
City Area: 630 km²

Köppen Classification: Dfa

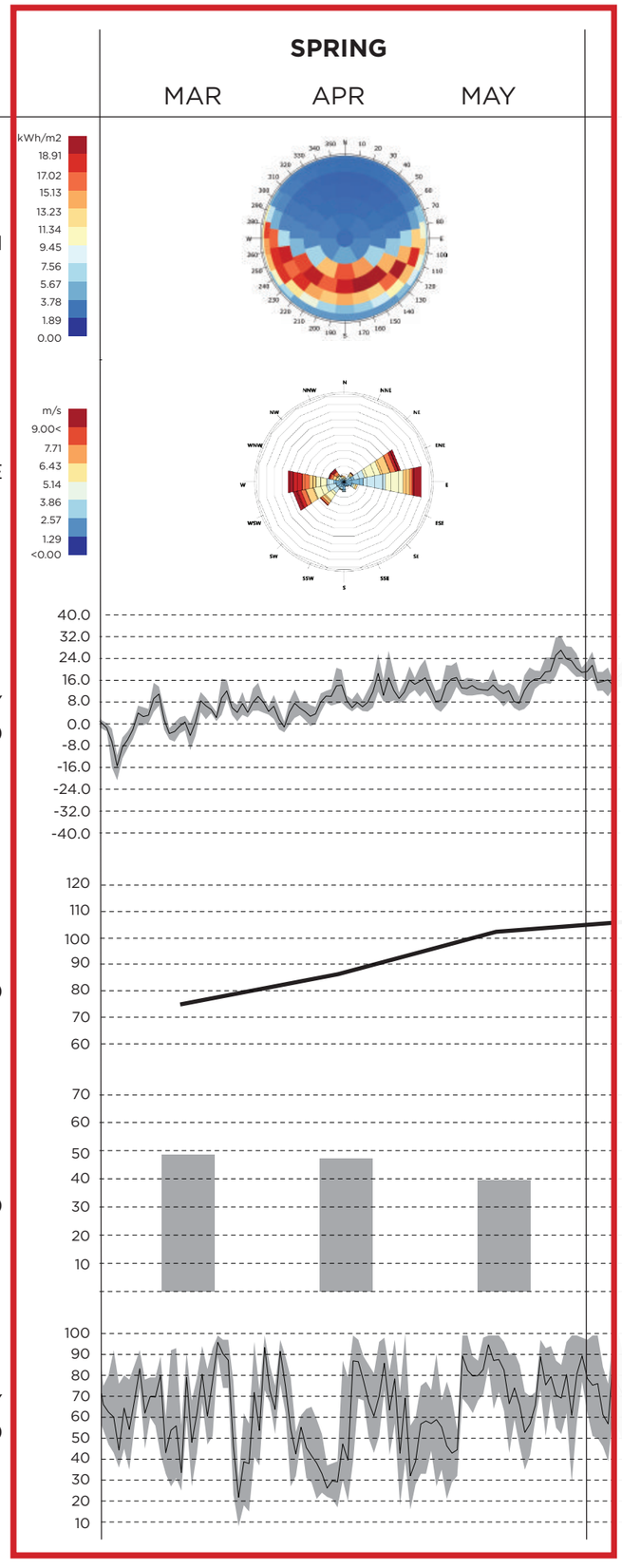
Proposed Site

Lake Ontario

1.2 ANNUAL CLIMATE



1.3 SPRING ANALYSIS

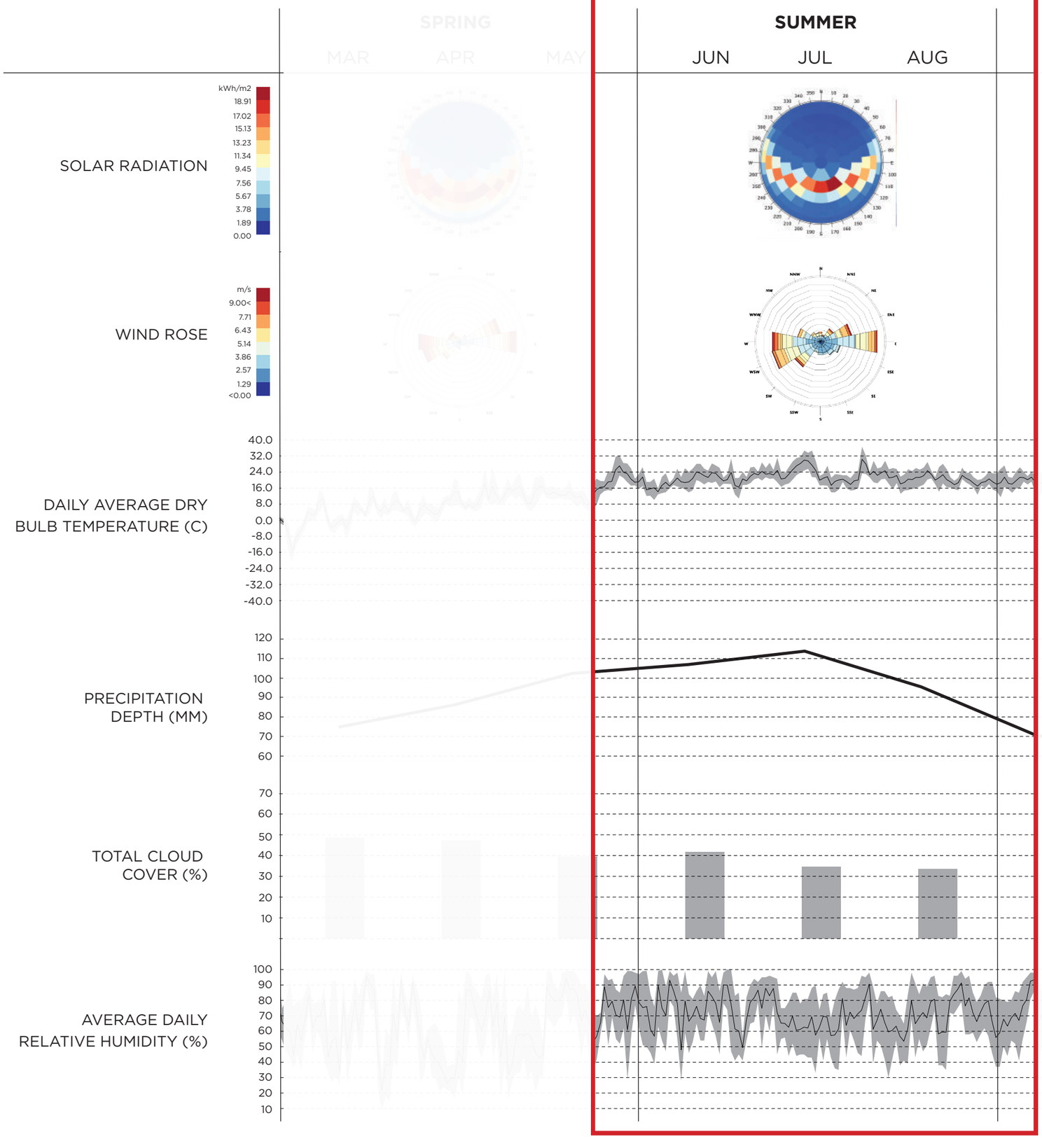


ANALYSIS

Temperatures in the beginning of spring is low with days reaching -20°C. Across the season however, temperatures start rising and could reach 32°C by end spring. This could be a result of the decreasing cloud covers as well. High solar radiation during the season could help improve the comfort levels in the beginning of the season. Wind speeds are especially high in the beginning of the season with speeds greater than 10 m/s coming in from both the east and west. Precipitation level is generally increasing as well.

To maximise comfort levels, active and passive solar and heating methods should be used. Large south facing facade openings are useful to capture sunlight during the colder days, but require overhangs to limit direct sunlight as the sun's angle gets higher and days get warmer. East and west openings should be able to regulate high winds speeds, which is needed as temperature increase.

1.3 SUMMER ANALYSIS



ANALYSIS

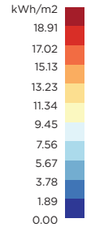
Summer is the hottest season in Toronto with temperatures reaching as high as 36°C. These high temperatures and increased solar radiation could be a result of the low cloud covers of around 30%, which combined with high humidity would be quite uncomfortable. Higher precipitation levels and wind speeds averaging 6.5 m/s could act as a passive cooling method and improve comfort levels.

To achieve the comfort zones as seen in the psychrometric chart, improving natural ventilation, such as larger opening in the East and West facades, would help. Overhangs and shelter can also shade users from direct sunlight, and green roofs can be used to regulate building temperatures.

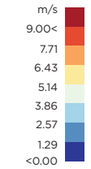
1.3 AUTUMN ANALYSIS

SPRING MAR APR MAY | SUMMER JUN JUL AUG | AUTUMN SEP OCT NOV | WINTER DEC JAN FEB

SOLAR RADIATION



WIND ROSE

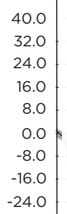


ANALYSIS

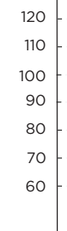
Temperature decreases through autumn with mean temperatures of around 20°C (°C) at the begining of the season, eventually dropping to temperatures as low as 0°C towards the end. Solar radiation seems to have increased compared to summer, but at a lower angle from the south. Wind speeds are still predominantly in the East-West direction. November also sees prolonged wind speeds greater than 10 m/s. Precipitation level is relatively constant at 70 mm each month, while cloud cover is increasing. The strong winds, coupled with precipitation and low temperatures could make individuals feel colder than it actually is.

To improve comfort, active and passive solar heating methods should be used. Openings facing east and west should be minimized, reducing wind chill, while south facing openings should take advantage of the sun's low angle to direct sunlight into the building.

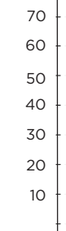
DAILY AVERAGE DRY BULB TEMPERATURE (C)



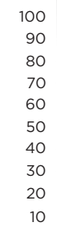
PRECIPITATION DEPTH (MM)

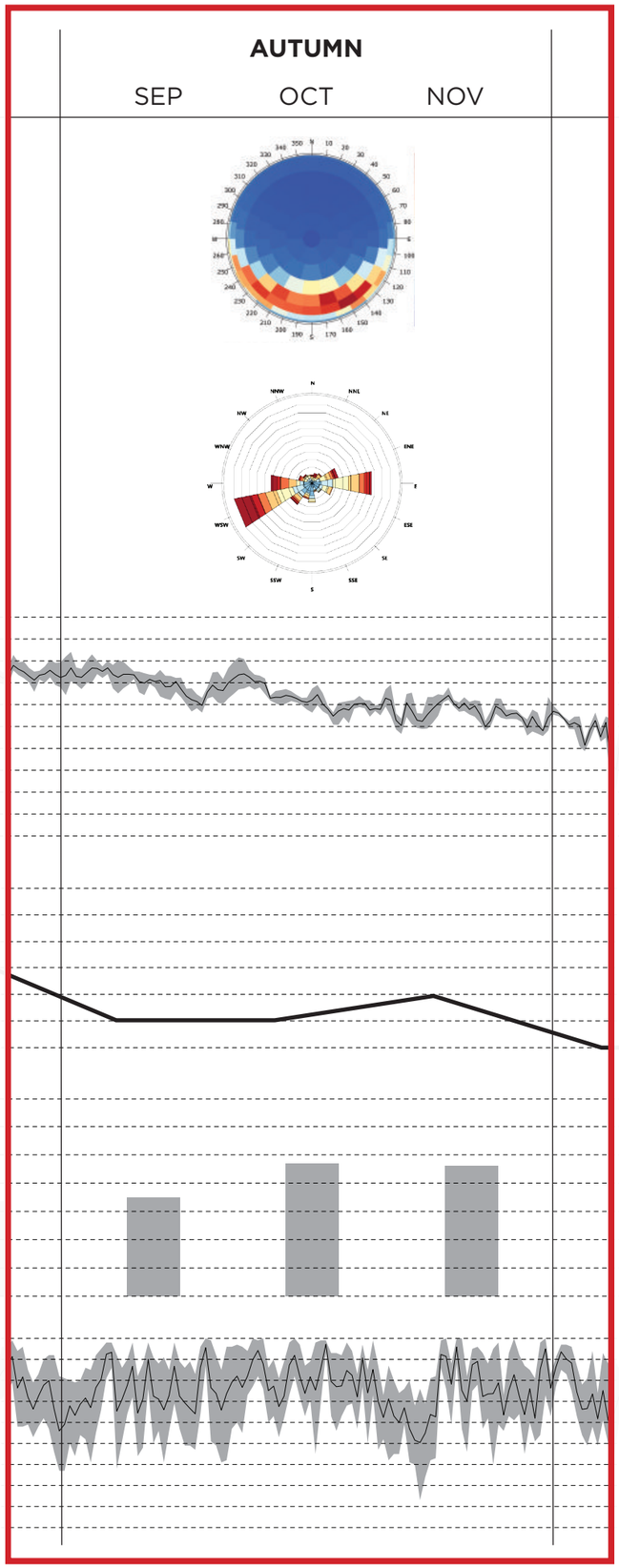


TOTAL CLOUD COVER (%)

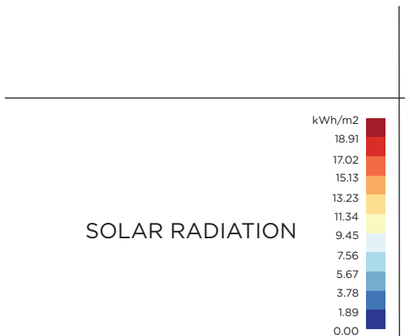


AVERAGE DAILY RELATIVE HUMIDITY (%)





1.3 WINTER ANALYSIS



SOLAR RADIATION

WIND ROSE

DAILY AVERAGE DRY BULB TEMPERATURE (C)

PRECIPITATION DEPTH (MM)

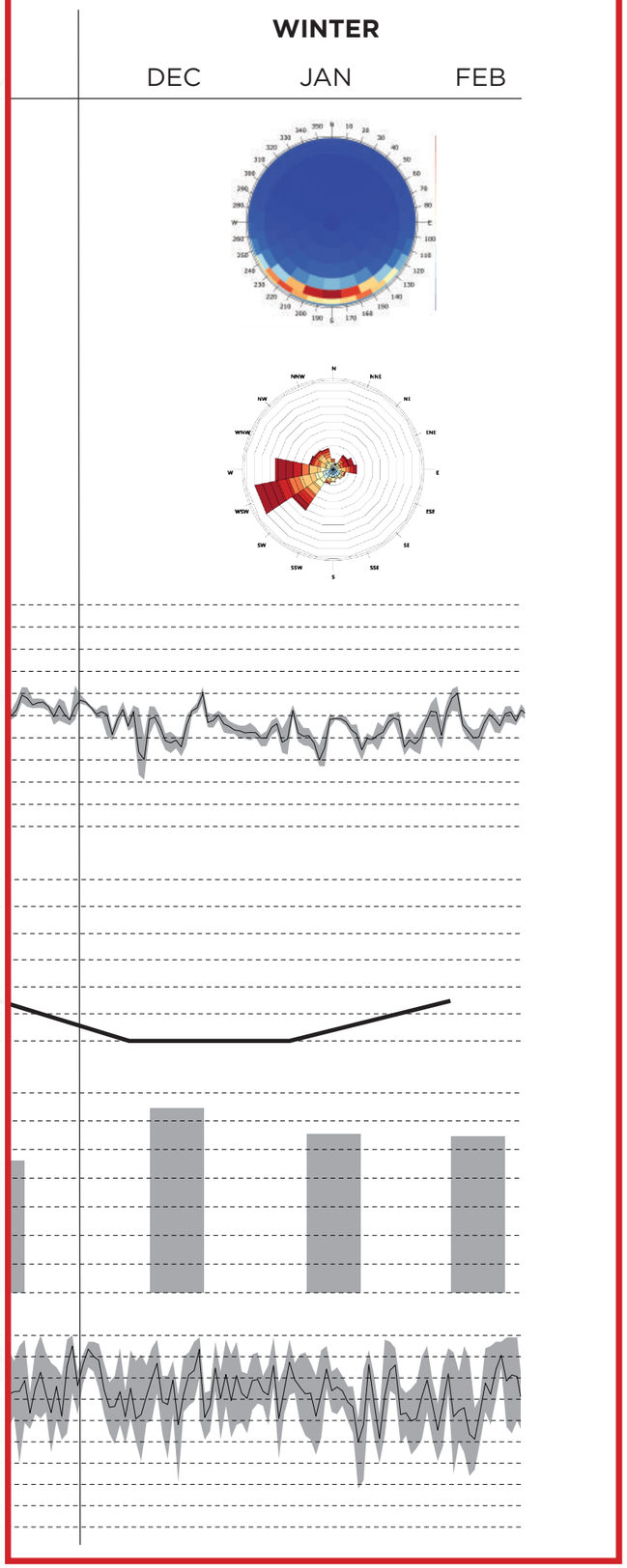
TOTAL CLOUD COVER (%)

AVERAGE DAILY RELATIVE HUMIDITY (%)

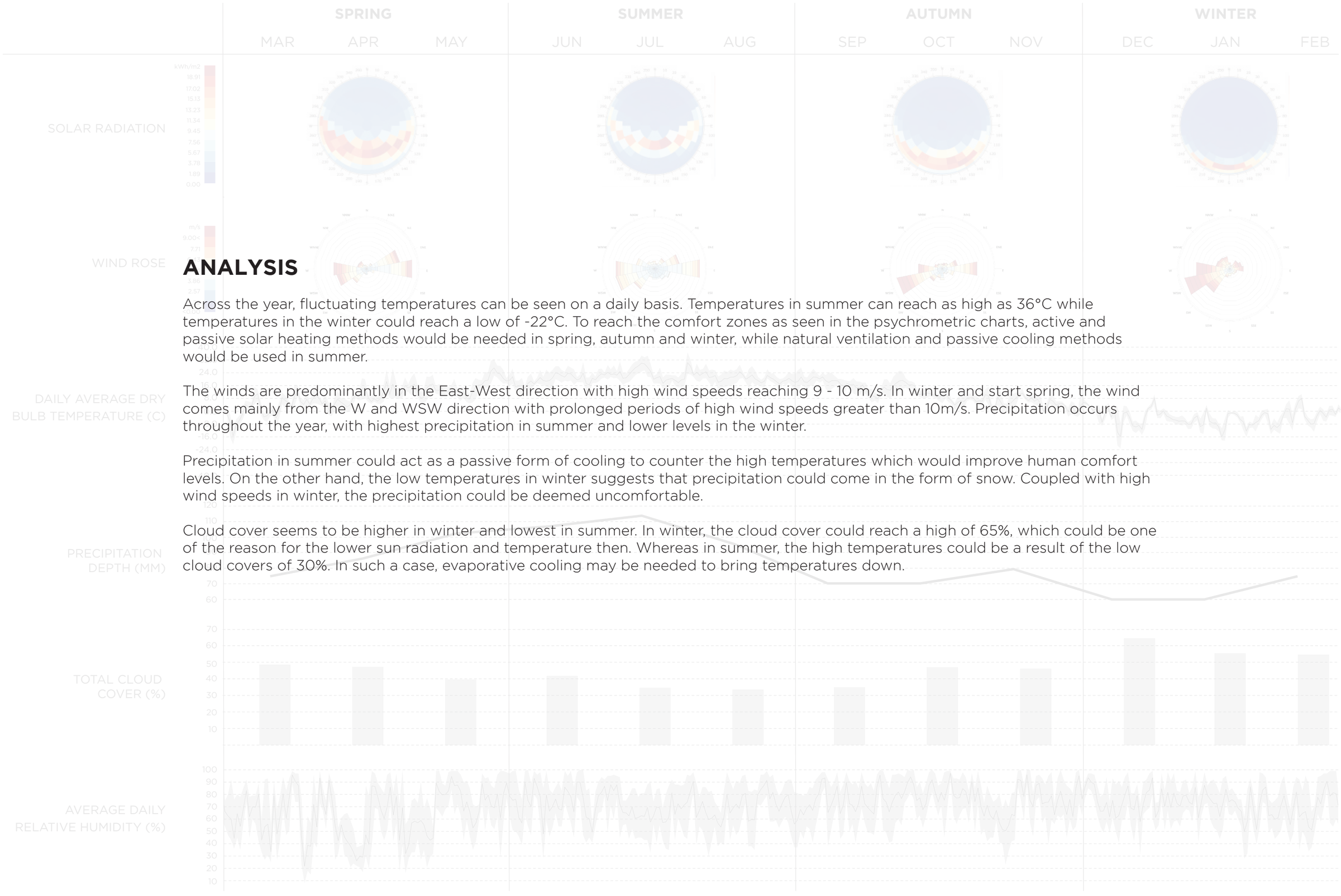
ANALYSIS

Winter is the coldest season in Toronto with temperatures reaching as low as -22°C (°C). These low temperatures and limited solar radiation could be compounded by the high cloud covers reaching 65%, resulting in extreme cold. The low temperatures in winter suggests that precipitation could come in the form of snow. Coupled with high and prolonged wind speeds of greater than 10 m/s, winter would be perceived to be much colder than the dry bulb temperature suggests.

To reach the comfort zones as seen in the psychrometric charts, active and passive solar heating methods should be used. Large south facing openings are necessary to capture as much of the limited daylight as possible, and west facing openings should be minimized. Buildings with high thermal mass would also be well suited to regulate internal temperatures and keep heat in.



1.4 ANNUAL ANALYSIS



ANALYSIS

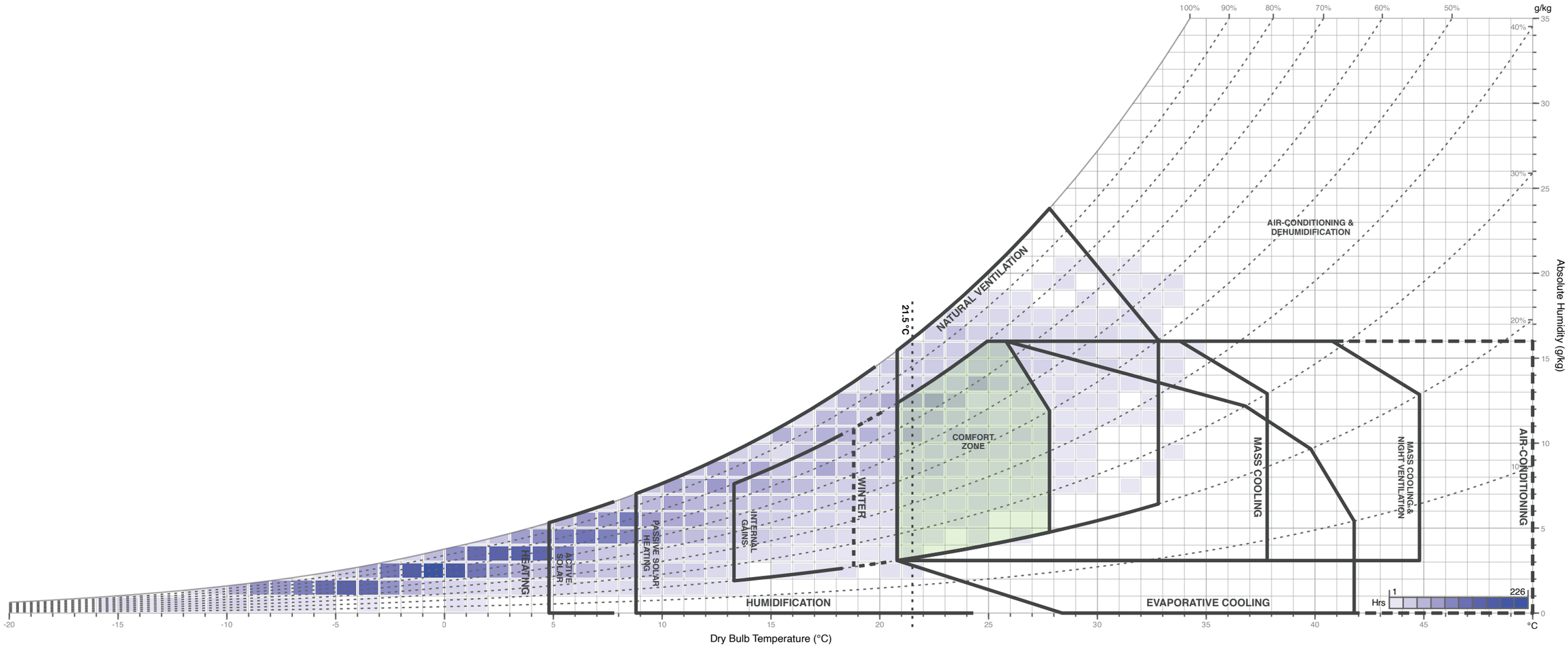
Across the year, fluctuating temperatures can be seen on a daily basis. Temperatures in summer can reach as high as 36°C while temperatures in the winter could reach a low of -22°C. To reach the comfort zones as seen in the psychrometric charts, active and passive solar heating methods would be needed in spring, autumn and winter, while natural ventilation and passive cooling methods would be used in summer.

The winds are predominantly in the East-West direction with high wind speeds reaching 9 - 10 m/s. In winter and start spring, the wind comes mainly from the W and WSW direction with prolonged periods of high wind speeds greater than 10m/s. Precipitation occurs throughout the year, with highest precipitation in summer and lower levels in the winter.

Precipitation in summer could act as a passive form of cooling to counter the high temperatures which would improve human comfort levels. On the other hand, the low temperatures in winter suggests that precipitation could come in the form of snow. Coupled with high wind speeds in winter, the precipitation could be deemed uncomfortable.

Cloud cover seems to be higher in winter and lowest in summer. In winter, the cloud cover could reach a high of 65%, which could be one of the reason for the lower sun radiation and temperature then. Whereas in summer, the high temperatures could be a result of the low cloud covers of 30%. In such a case, evaporative cooling may be needed to bring temperatures down.

1.4 ANNUAL PSYCHROMETRIC CHART



ACTIVE SOLAR HEATING

Due to the harsh weather conditions in Toronto, winters get very cold requiring methods like insulation for buildings

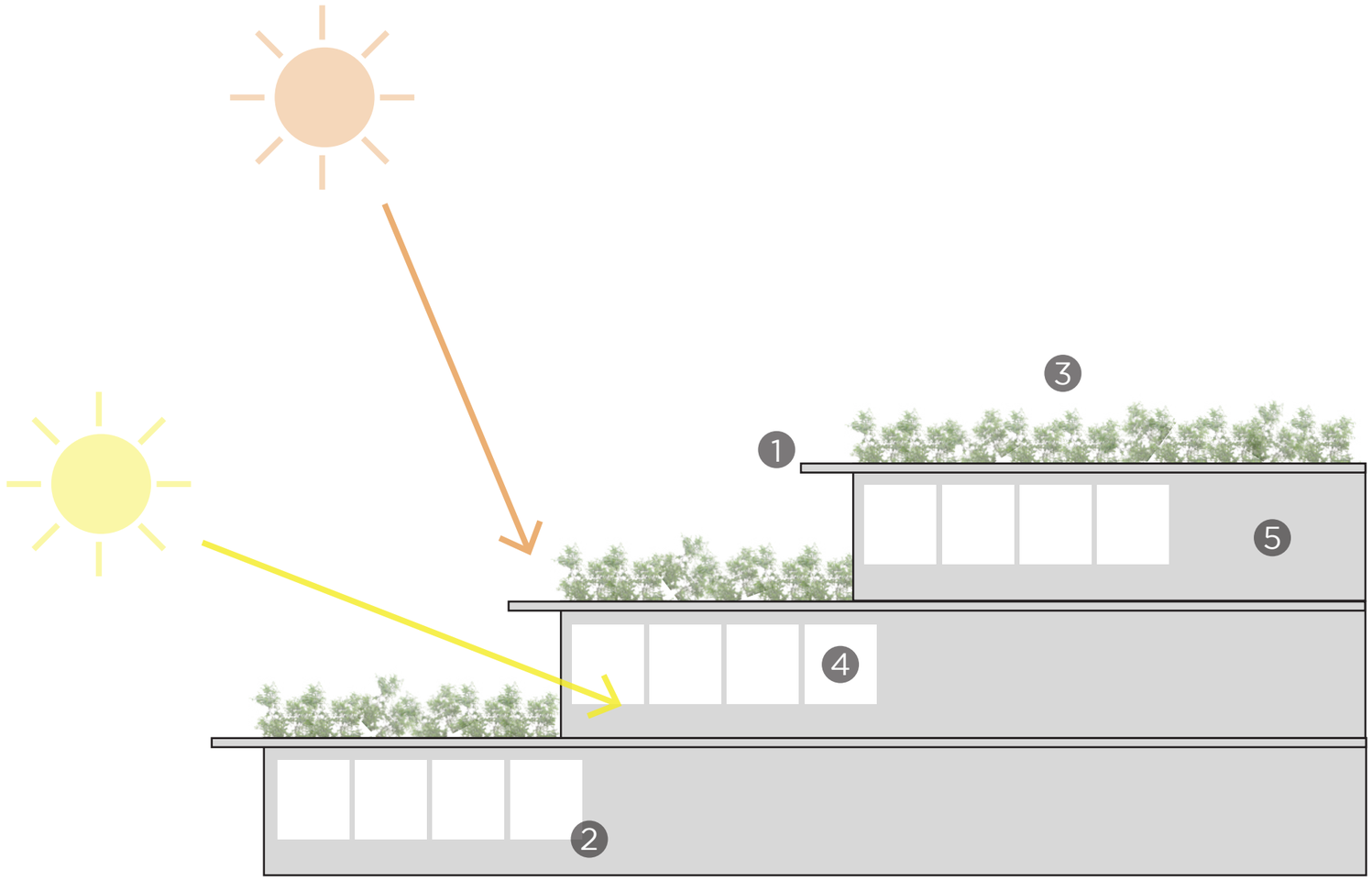
PASSIVE SOLAR HEATING

To allow for passive solar heating during the winter months, buildings require large windows to allow more solar radiation and natural sunlight into the space

NATURAL VENTILATION

In order for natural ventilation to occur during the summer, buildings can adopt methods to allow for cross ventilation through their buildings

1.5 CLIMATE STRATEGIES



1 Facade Design

• Large south-facing openings to allow more winter sunlight

• Horizontal overhangs to shade spaces from direct summer sunlight

2 Programmatic Layout

• Living areas should be placed on the south side of the building, where there is most the most sunlight

3 Green Roofs

• To regulate building temperatures throughout the year

• Lower temperatures in summer by reflecting sunlight and through evaporative cooling

• Keep heat in during winter with its thermal mass

4 Natural Ventilation

• Openings oriented east-west to allow for natural ventilation into the building in the summer

• Close openings during winter, when wind is undesirable

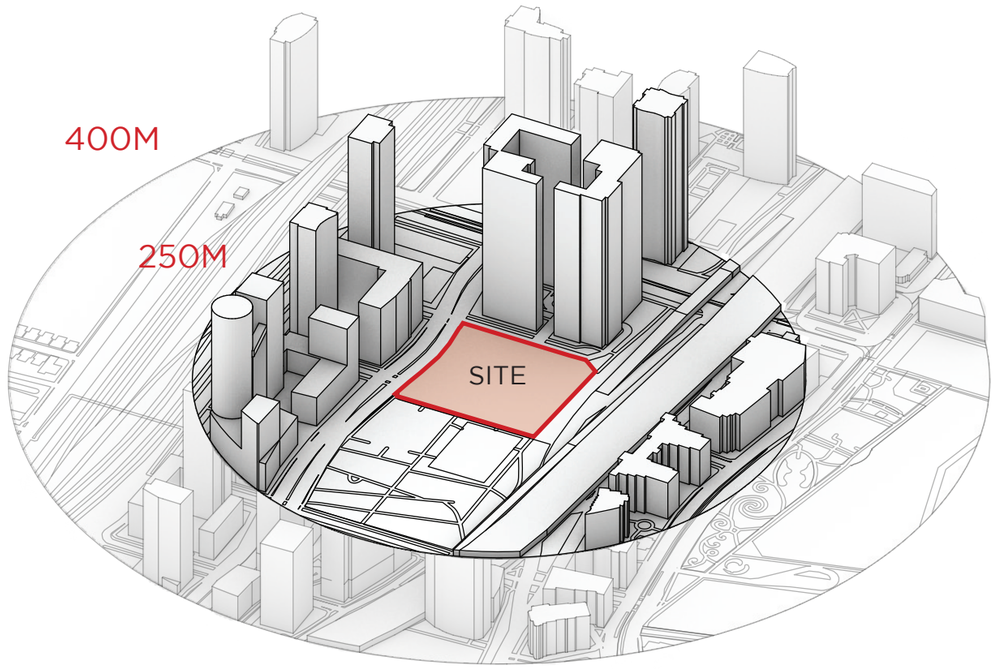
5 Structural Elements

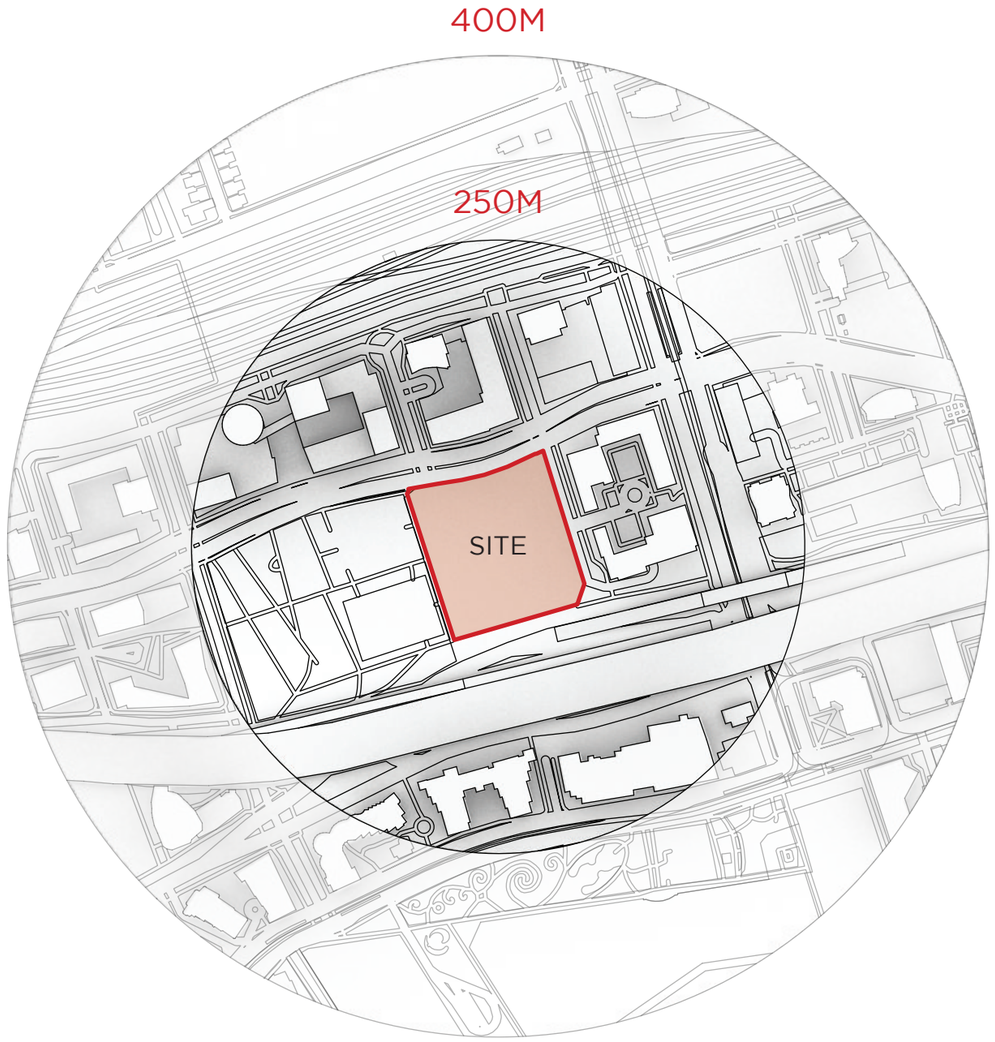
• Well insulated walls with large thermal mass can keep heat in during winter and out in the summer

2.0 SITE ANALYSIS

Site Info
Area: 14,012.79 m^2
Elevation: 80m
Latitude: 43.639° N
Longitude: 79.395° W

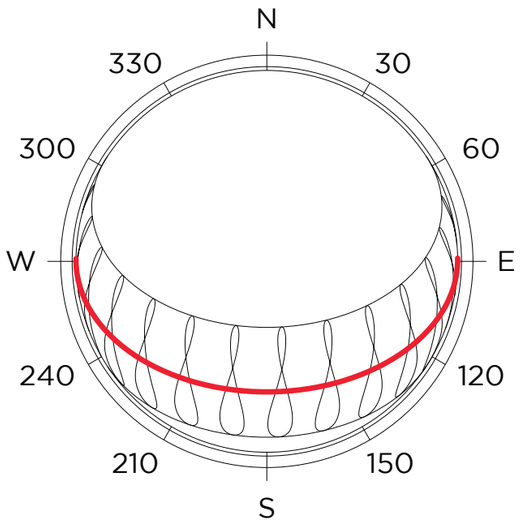
2.2 SITE MODEL



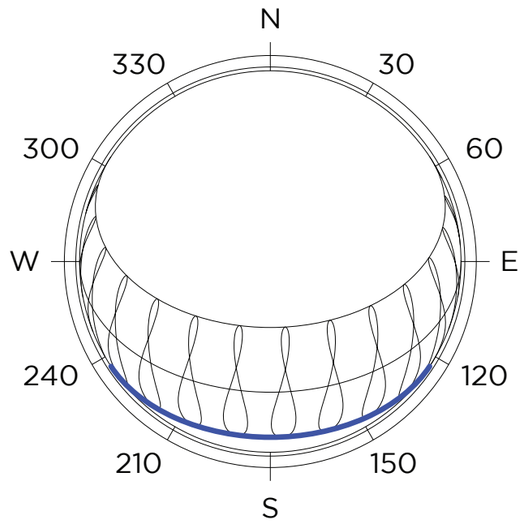


2.3 SUN PATH

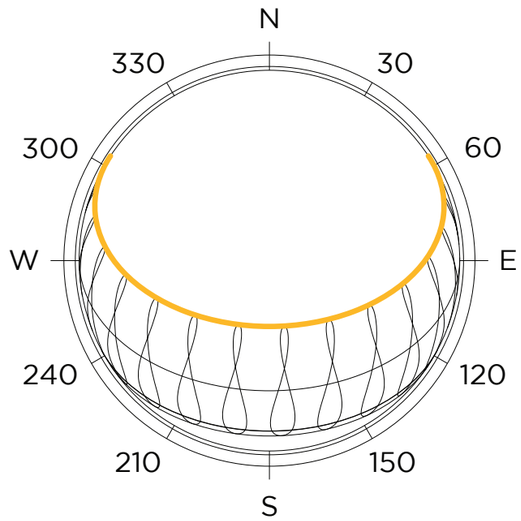
SPRING / AUTUMN EQUINOX



WINTER SOLSTICE



SUMMER SOLSTICE

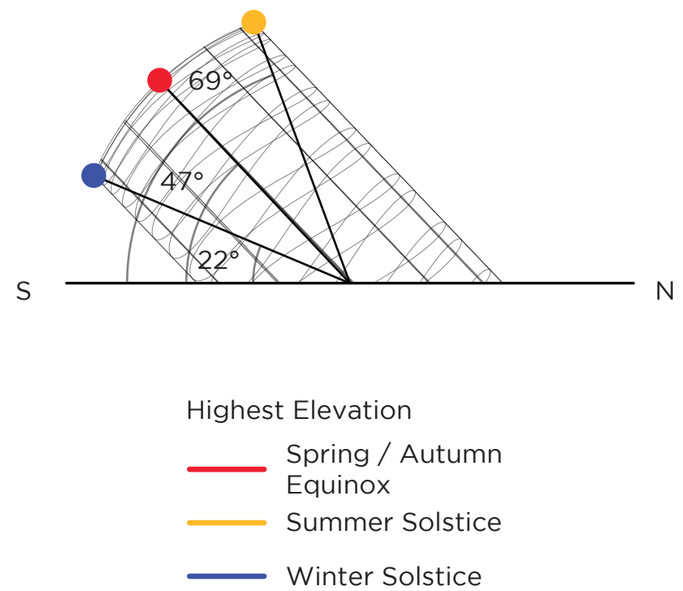


ANALYSIS

- The Sun predominantly shines from the South
- The angle of elevation ranges from 69° in the summer solstice to a mere 22° in the winter solstice

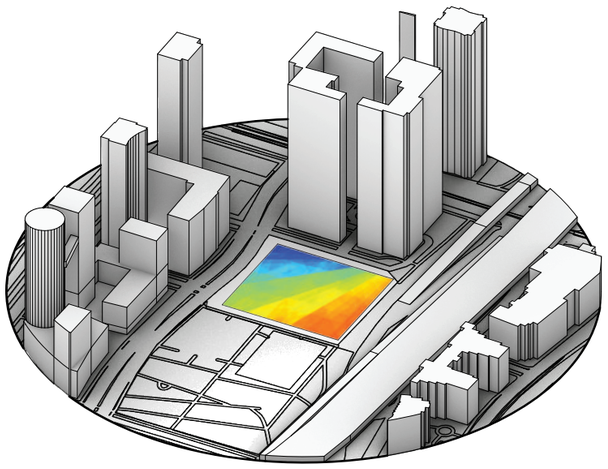
STRATEGIES

- Building openings and cantilevers should be designed to allow sun into the building only when the sun altitude falls below 47° (angle of elevation of the sun at the equinox)

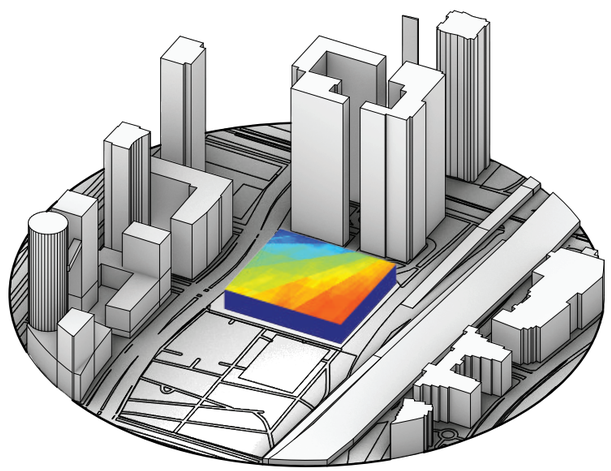


2.4 ANNUAL SOLAR RADIATION

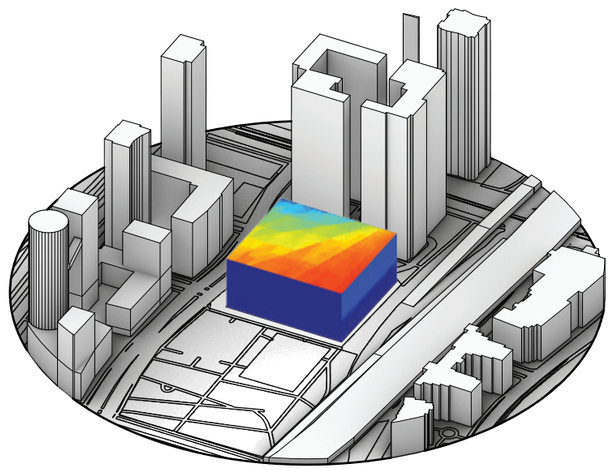
0m



+20m

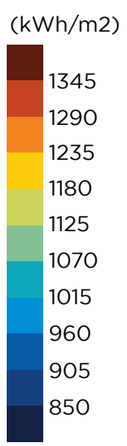


+50m



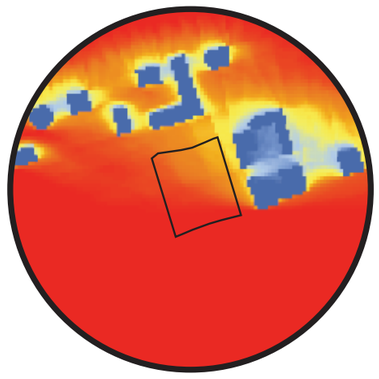
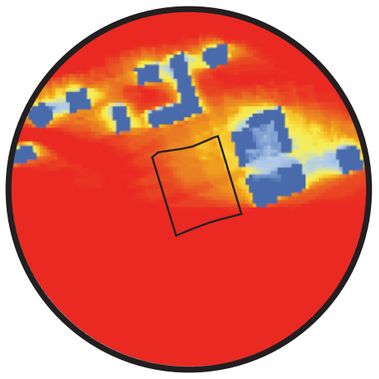
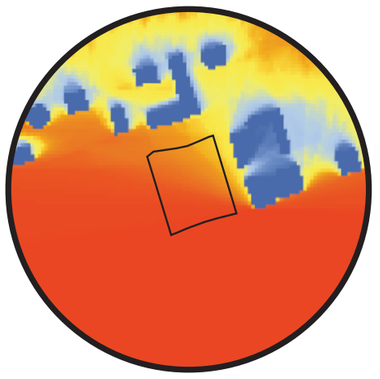
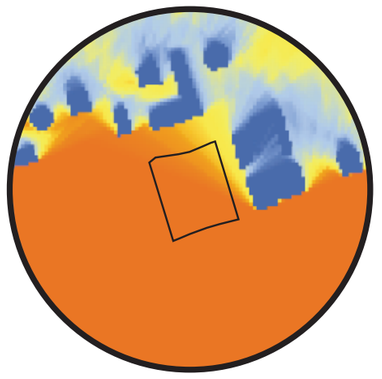
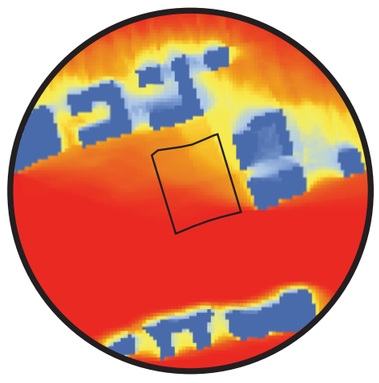
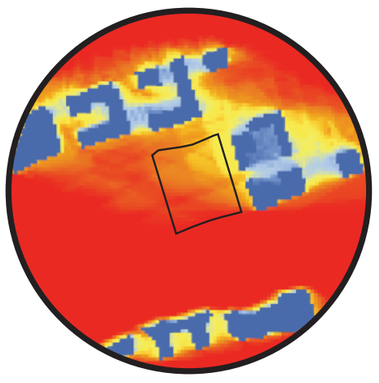
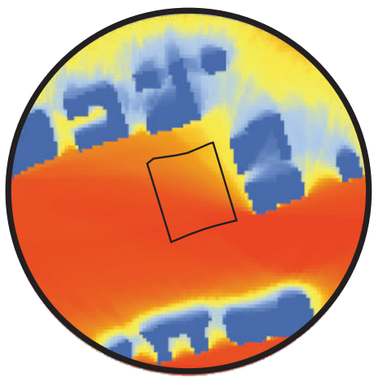
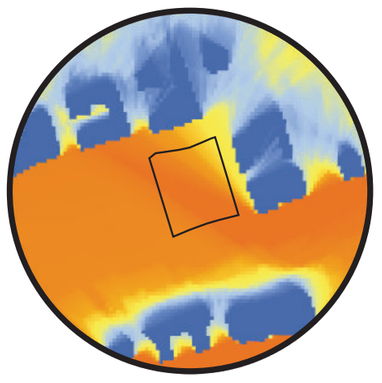
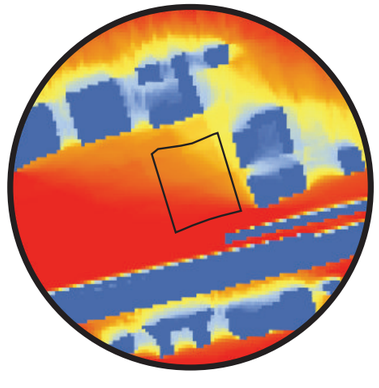
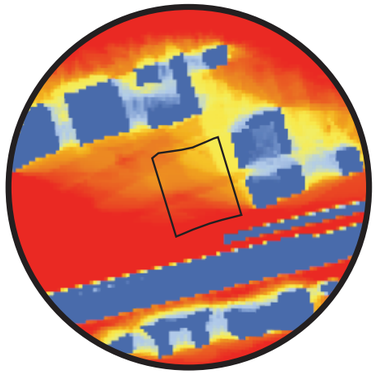
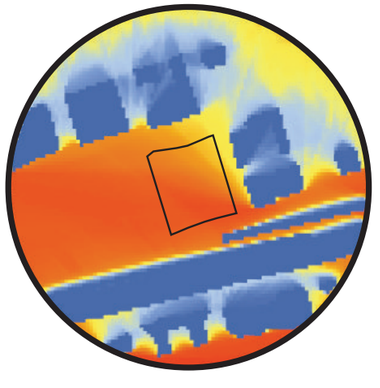
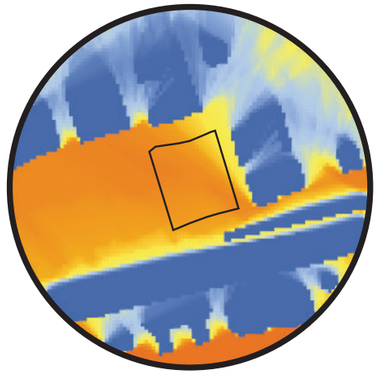
ANALYSIS

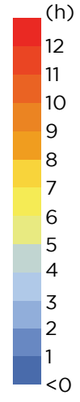
- Radiation on the roof has a large variance due to shading by surrounding buildings, while on the walls it is mostly constant
- Radiation on the roof exceeds radiation on the walls by 65% at its maximum, and 40% on average.



2.5 SUNLIGHT HOURS

ANNUAL AVERAGE SUNLIGHT HOURS = 12 HRS/DAY

	SPRING	SUMMER	AUTUMN	WINTER
+50m				
+20m				
0m				
	AVERAGE SUNLIGHT HOURS 13 HRS	AVERAGE SUNLIGHT HOURS 14 HRS	AVERAGE SUNLIGHT HOURS 11 HRS	AVERAGE SUNLIGHT HOURS 9 HRS



N

2.6 SHADOW HOURS

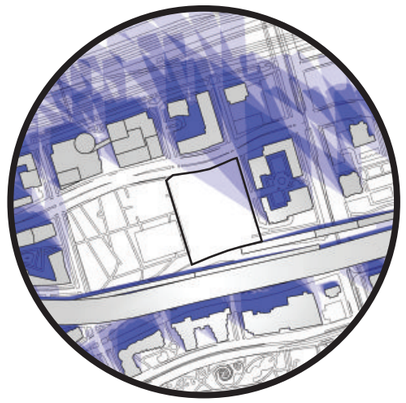
SPRING

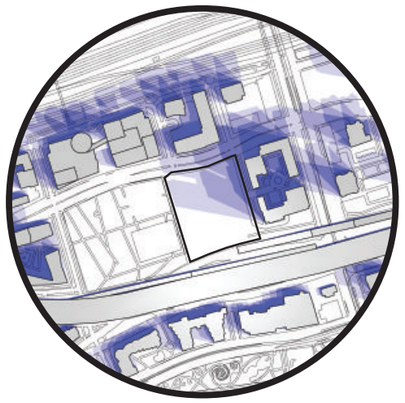
SUMMER

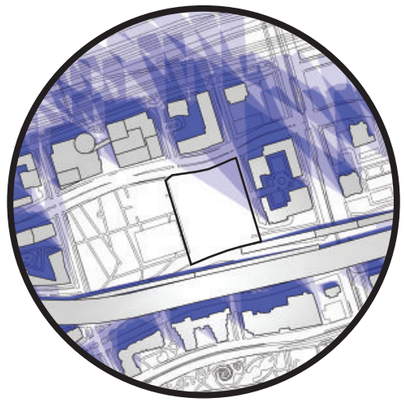
AUTUMN

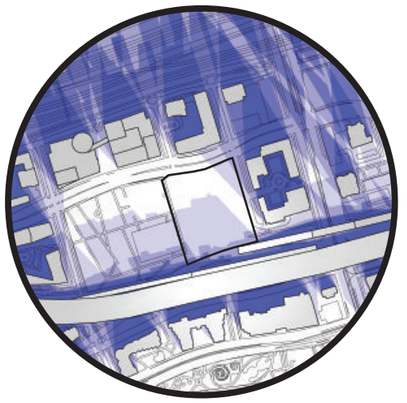
WINTER

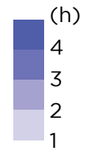
AM



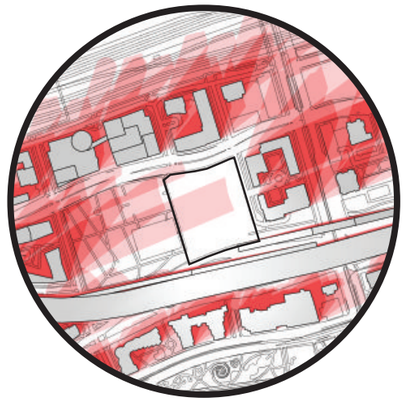


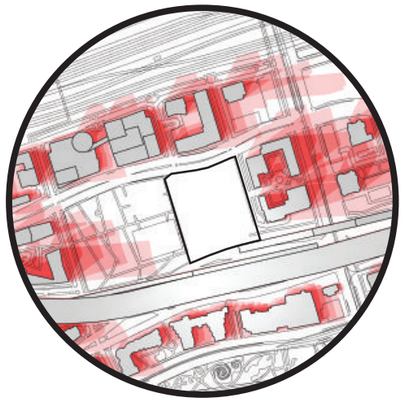


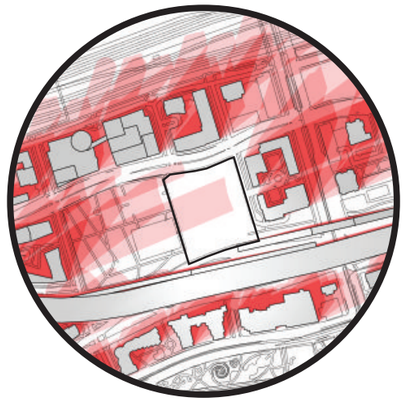


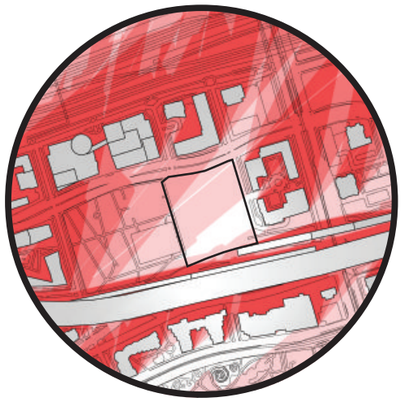


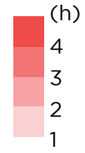
PM











AVERAGE SHADOW HOURS
2 HRS

AVERAGE SHADOW HOURS
1 HRS

AVERAGE SHADOW HOURS
2 HRS

AVERAGE SHADOW HOURS
2 HRS

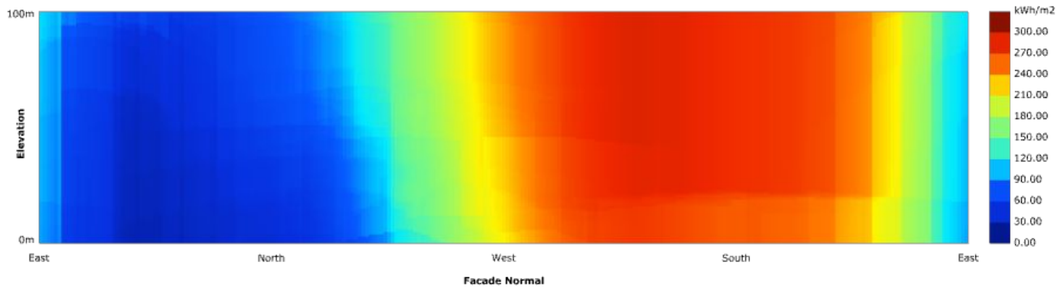
ANALYSIS

- The site receives the longest sunlight hours (>13 hrs) in summer and the shortest sunlight hours (~8 hrs) in winter
- As a result, the site also has the longest shadow hours in winter both in the morning and in the afternoon.

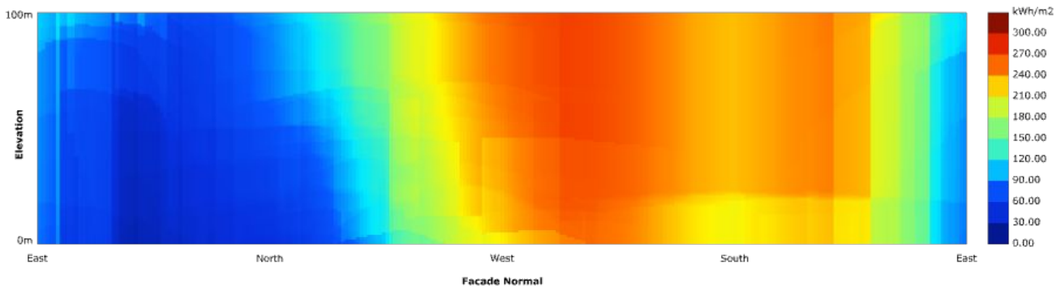
STRATEGIES

- Due to shading, the northeast corner of the site receives less sunlight in the mornings. This corner must be treated with additional active heating strategies, or programmed for purposes that people only spend short periods of times at.

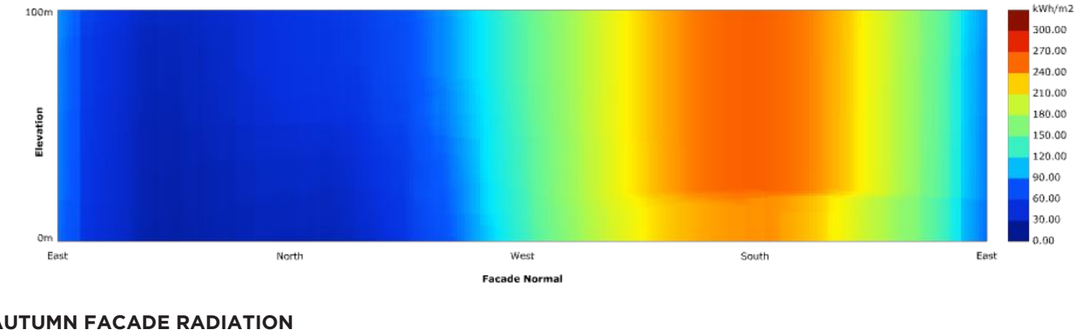
2.7 FACADE RADIATION ANALYSIS



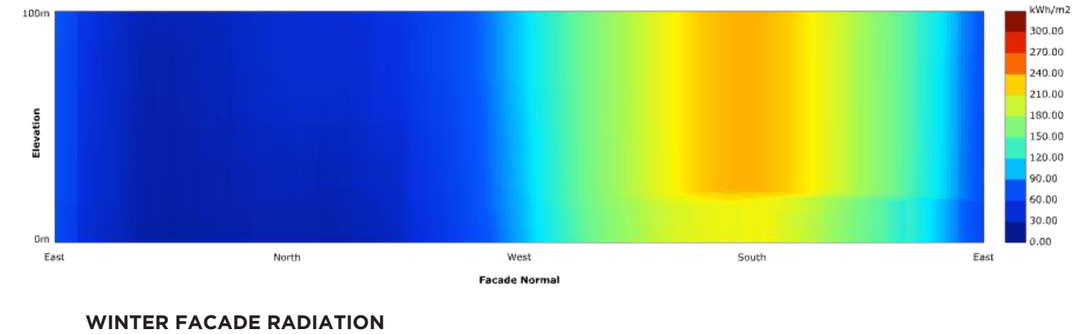
SPRING FACADE RADIATION



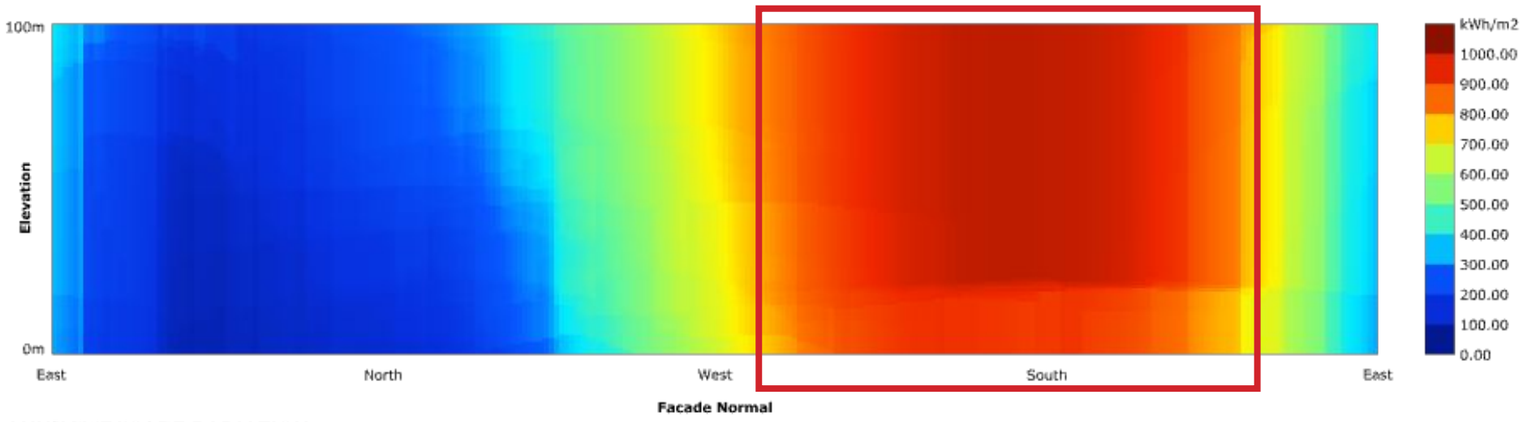
SUMMER FACADE RADIATION



AUTUMN FACADE RADIATION



WINTER FACADE RADIATION



ANNUAL FACADE RADIATION

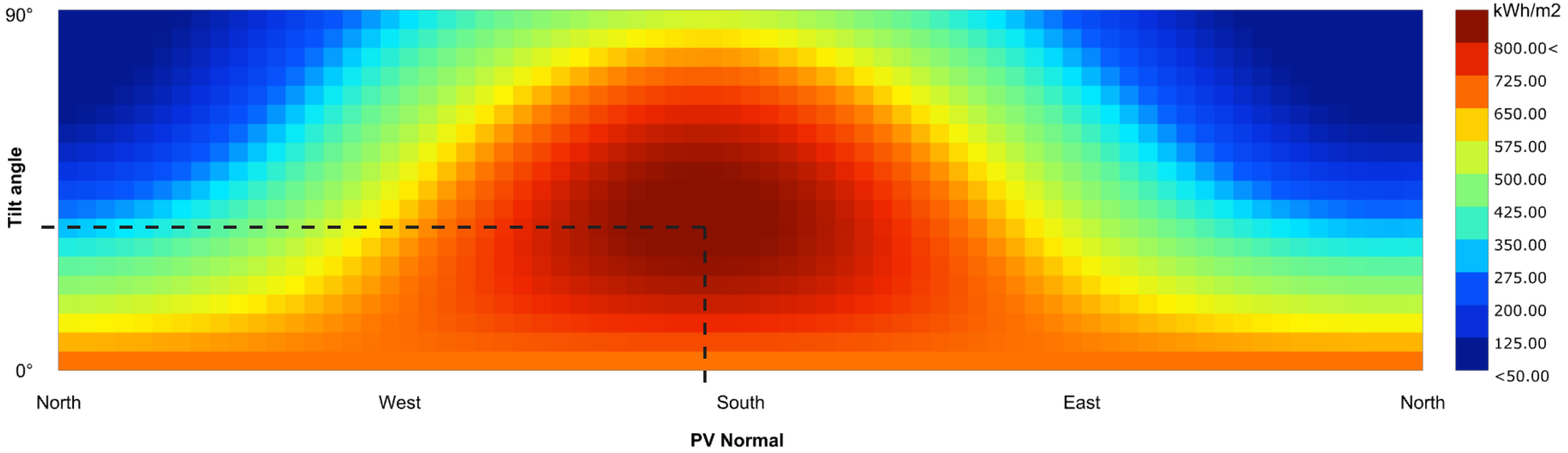
ANALYSIS

- Greatest radiation towards the south facade, least along the north facade
- Higher elevations see more radiation, especially towards the west and south

STRATEGIES

- South facade requires more shading, especially at higher elevations, in the form of horizontal fins or overhangs

2.8 PV OPTIMISATION



ANNUAL SOLAR RADIATION

ANALYSIS

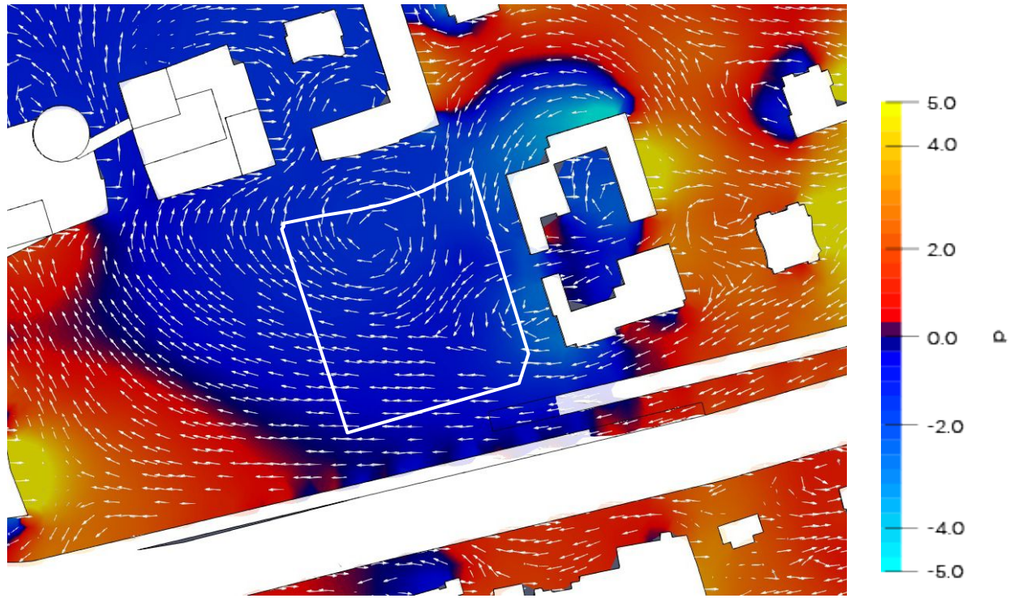
- Highest radiation is generally towards SSW, at around a 35° inclination, receiving more than 800 kWh/m^2 over the year
- Spring and summer receive almost 300 kWh/m^2, in the SSW direction at a 30° inclination, which could be due to the tall buildings east of the site
- The optimal angle increases in autumn to 45° and winter to about 70°, but receives very little sunlight, averaging 225 kWh/m^2 and 150 kWh/m^2 respectively, and the optimal direction changes to face south

STRATEGIES

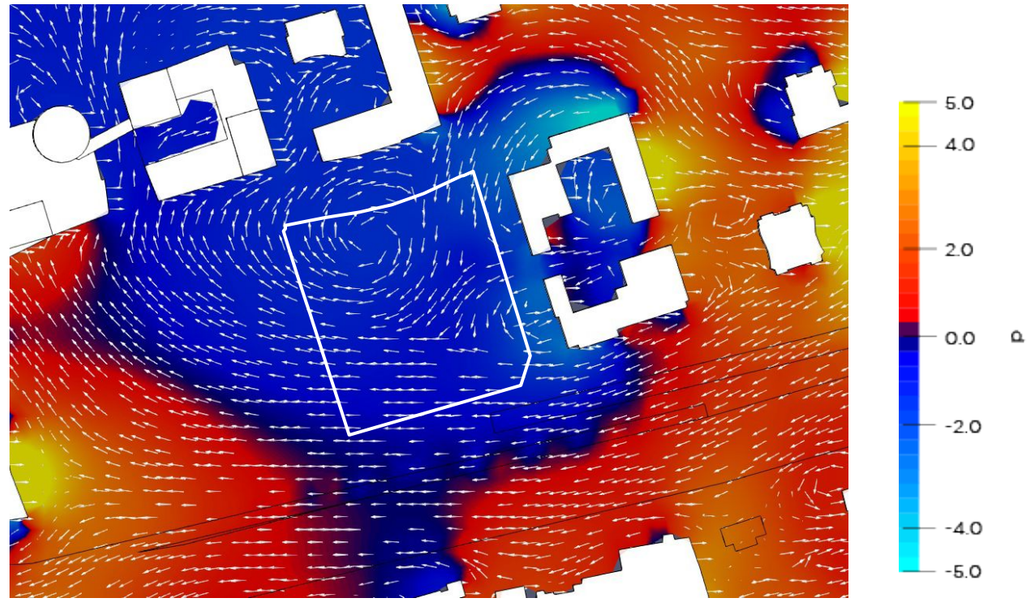
- If PV panels are required, they should be arranged to face SSW at a 35° inclination, to receive the most solar radiation possible, especially during spring and summer
- Given the 35° angle, PV panels should also be arranged to not shade other panels from direct sunlight

2.9 WIND ANALYSIS

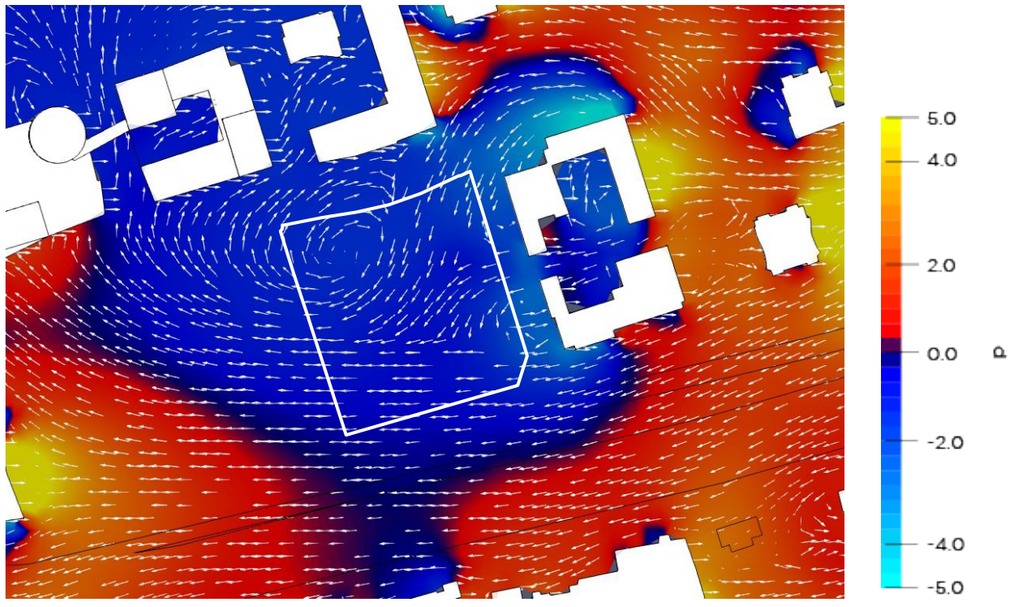
EAST (SUMMER)



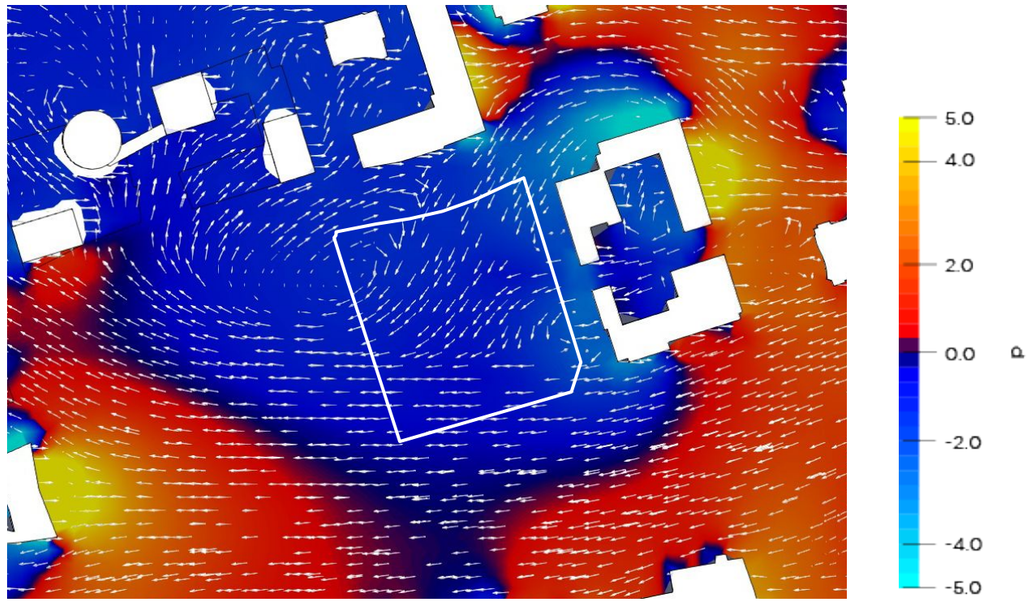
1M



10M



20M

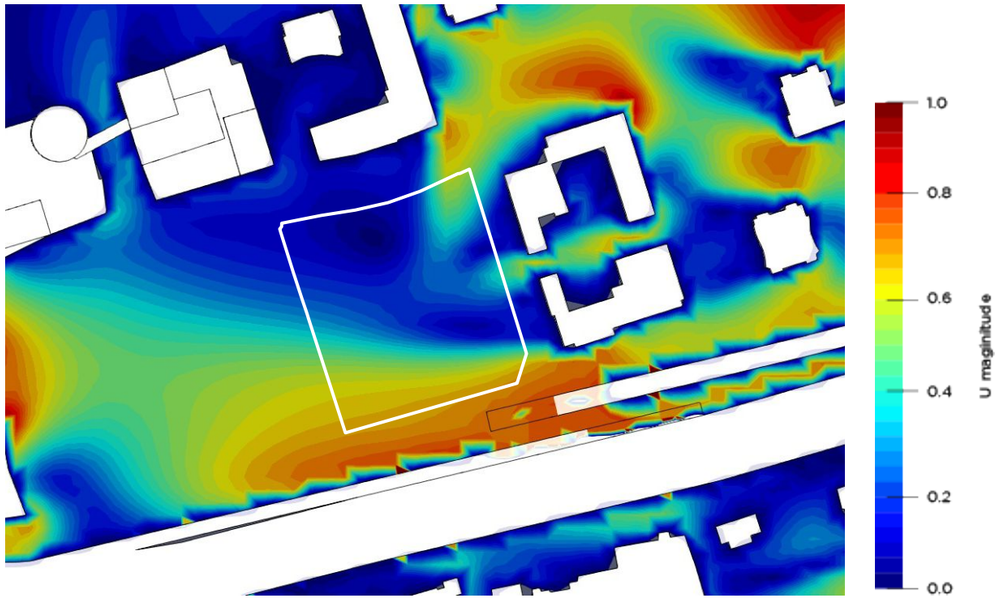


30M

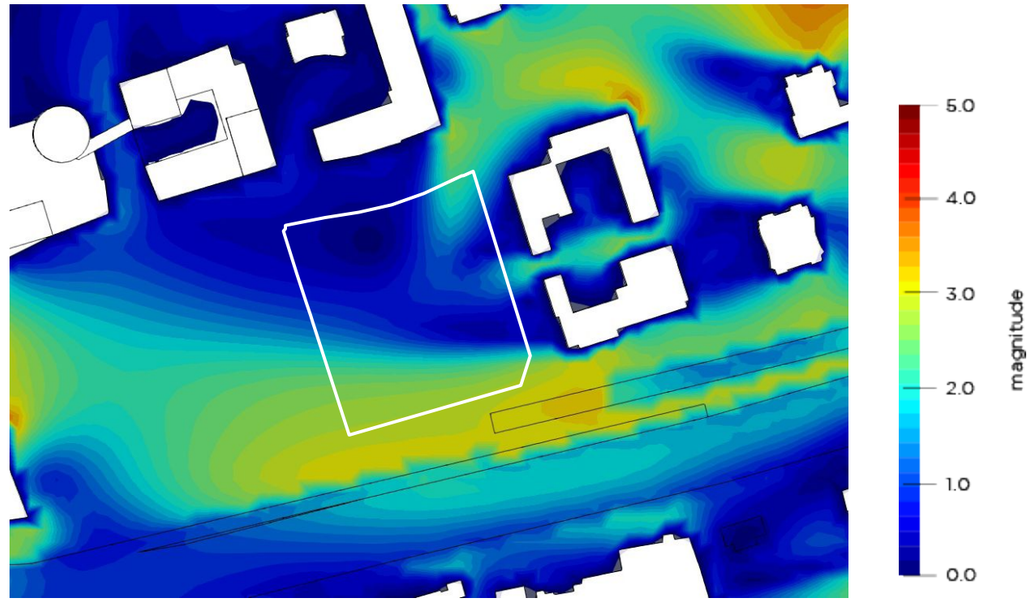
N

2.9 WIND ANALYSIS

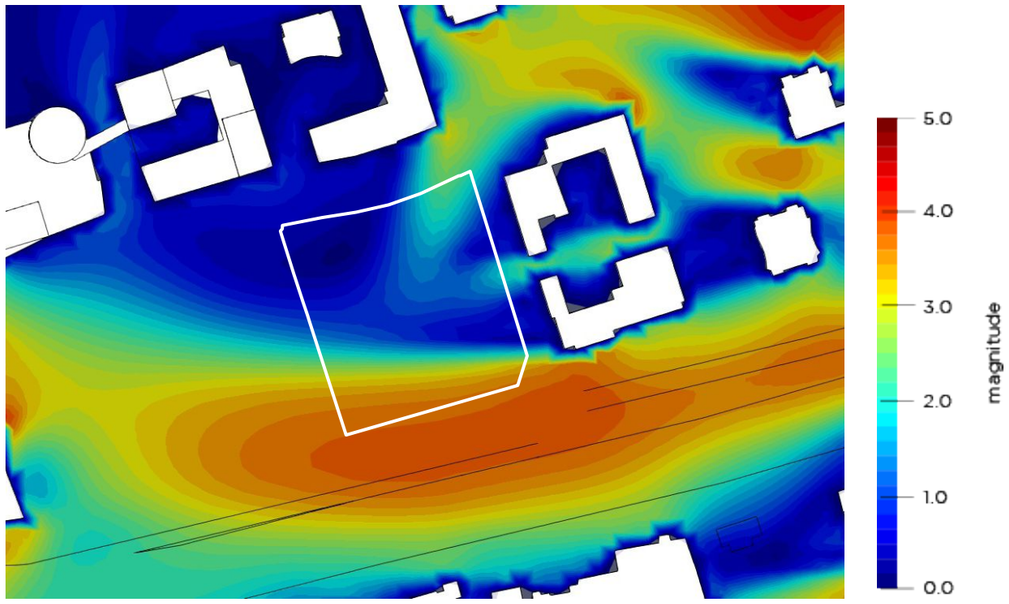
EAST (SUMMER)



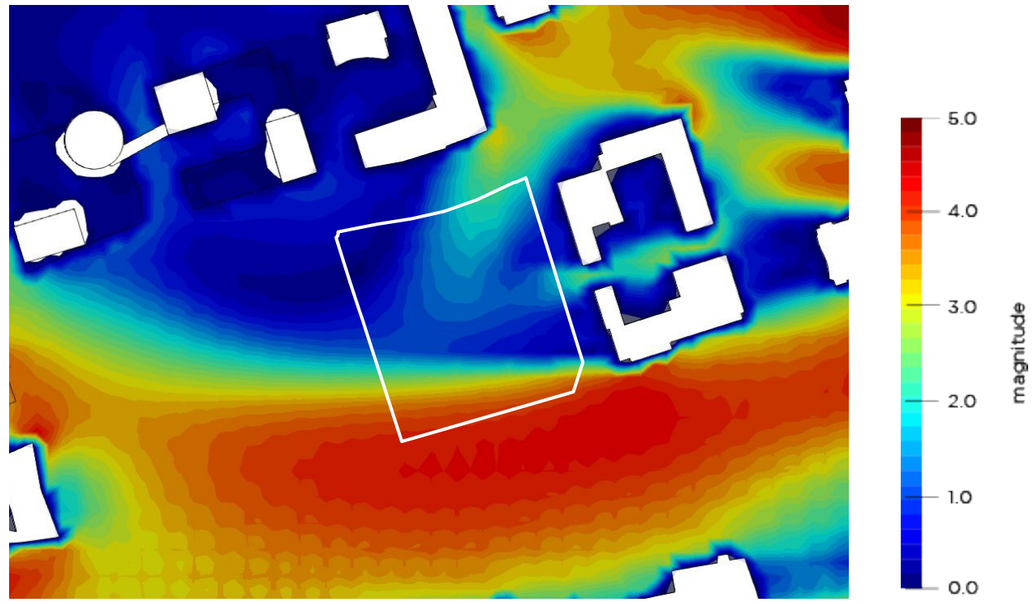
1M



10M



20M

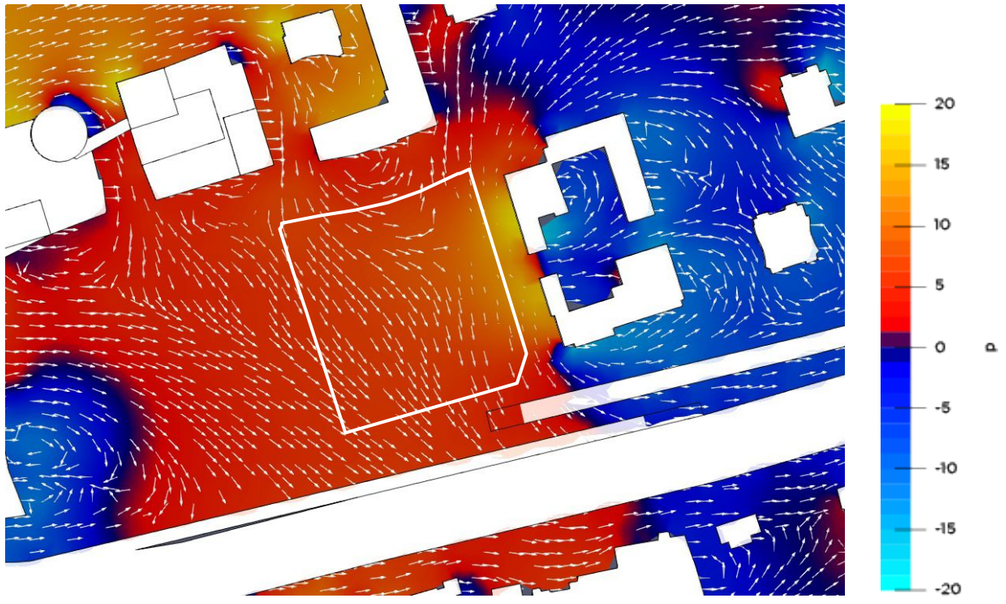


30M

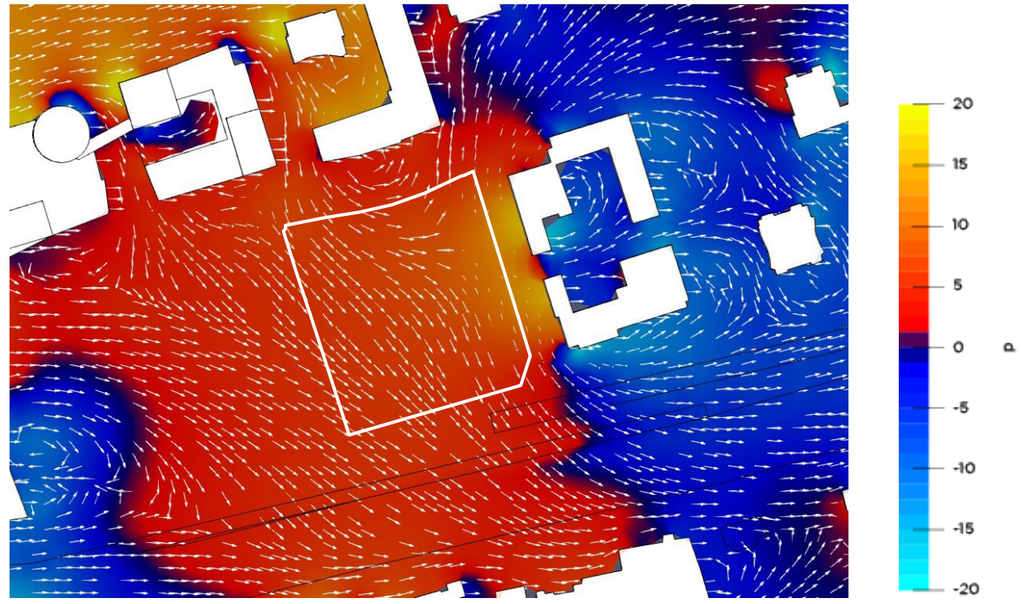
N

2.9 WIND ANALYSIS

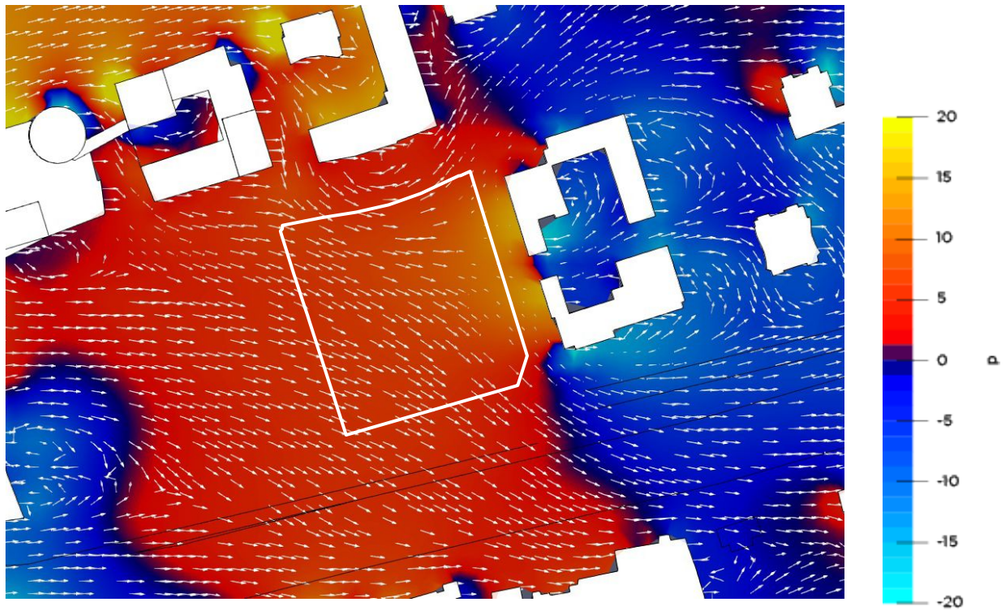
WEST (WINTER)



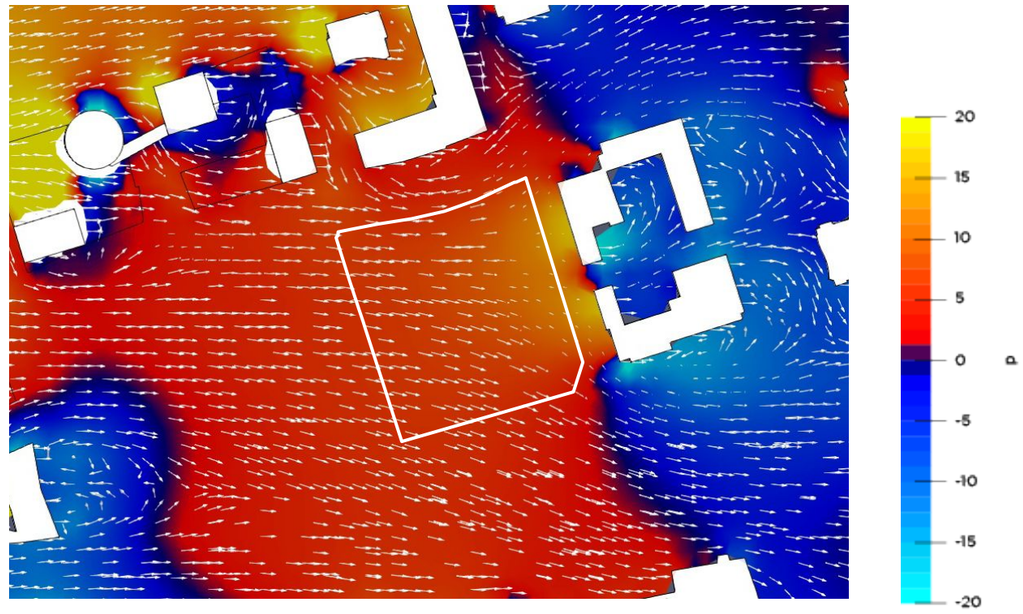
1M



10M



20M

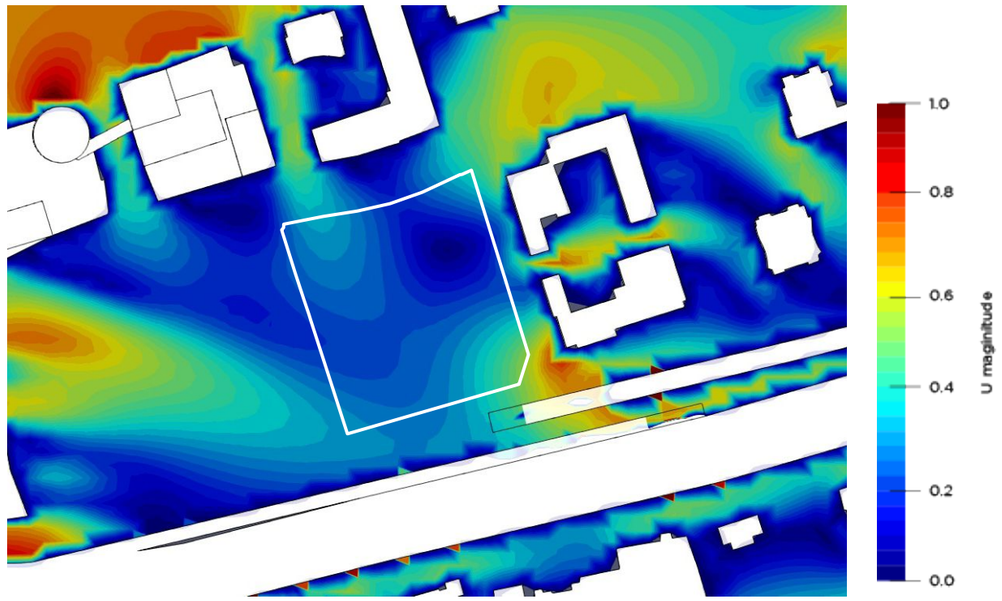


30M

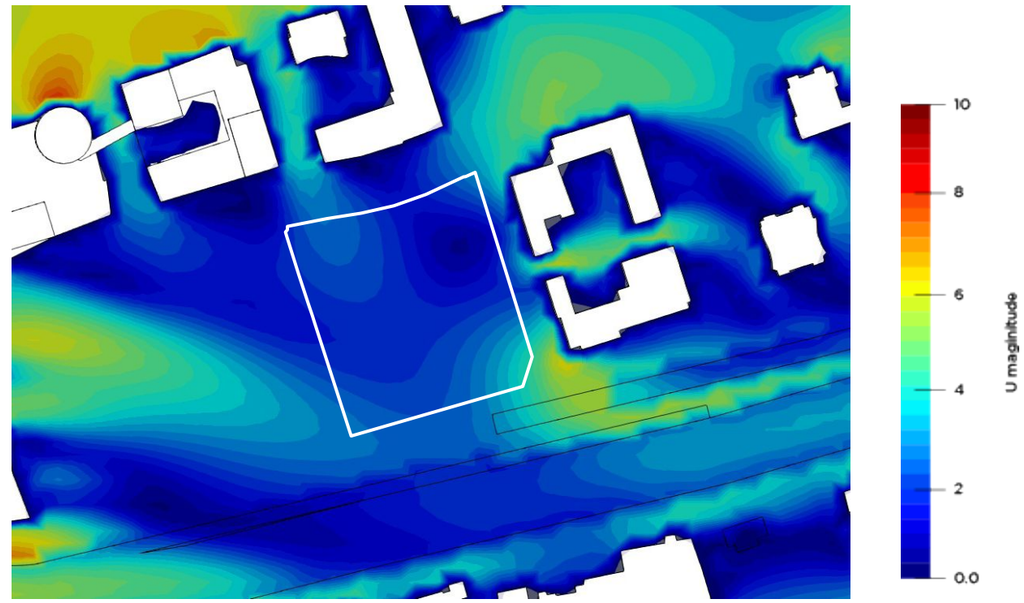
N

2.9 WIND ANALYSIS

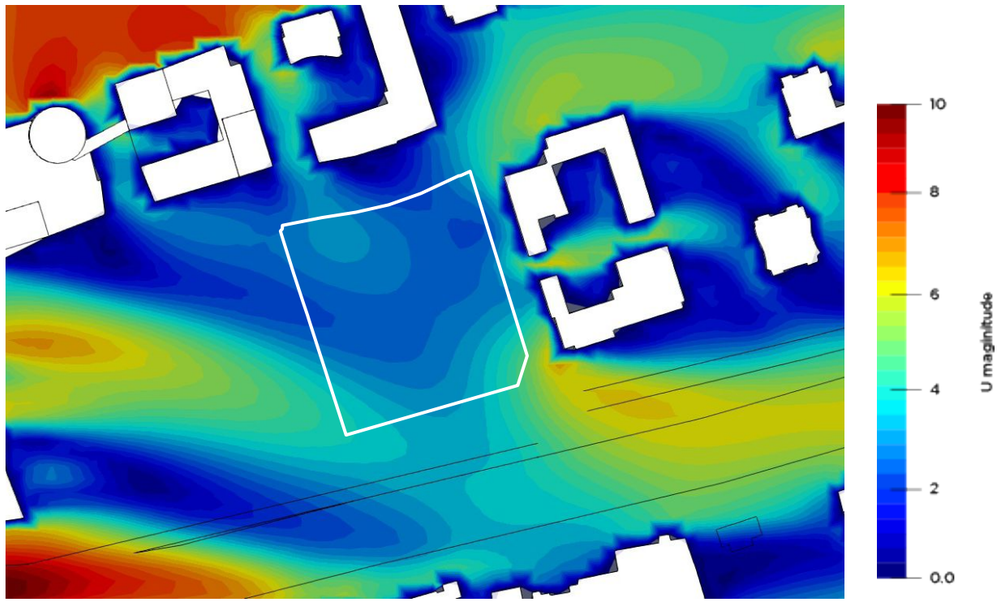
WEST (WINTER)



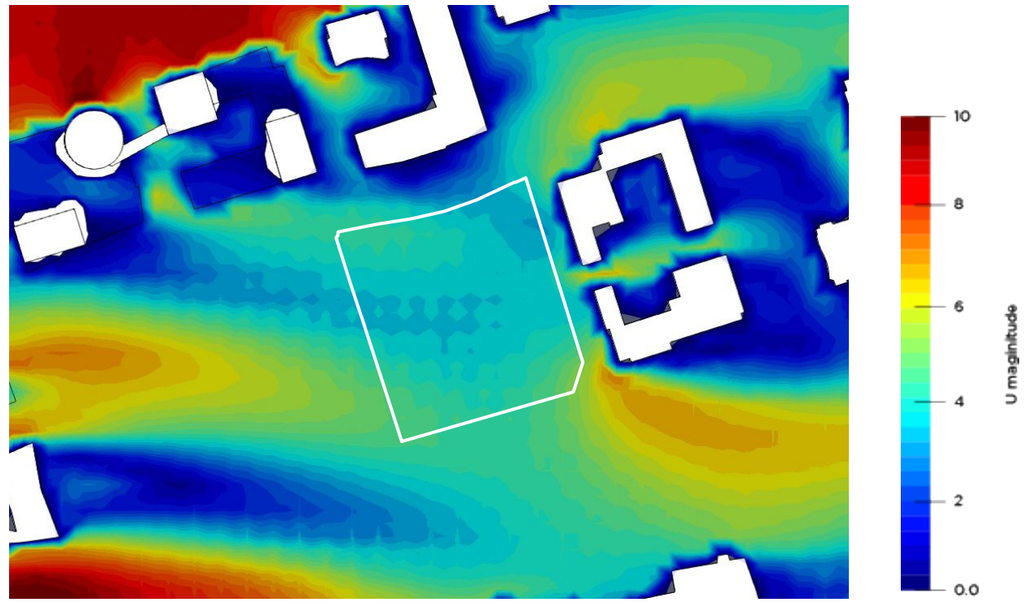
1M



10M



20M



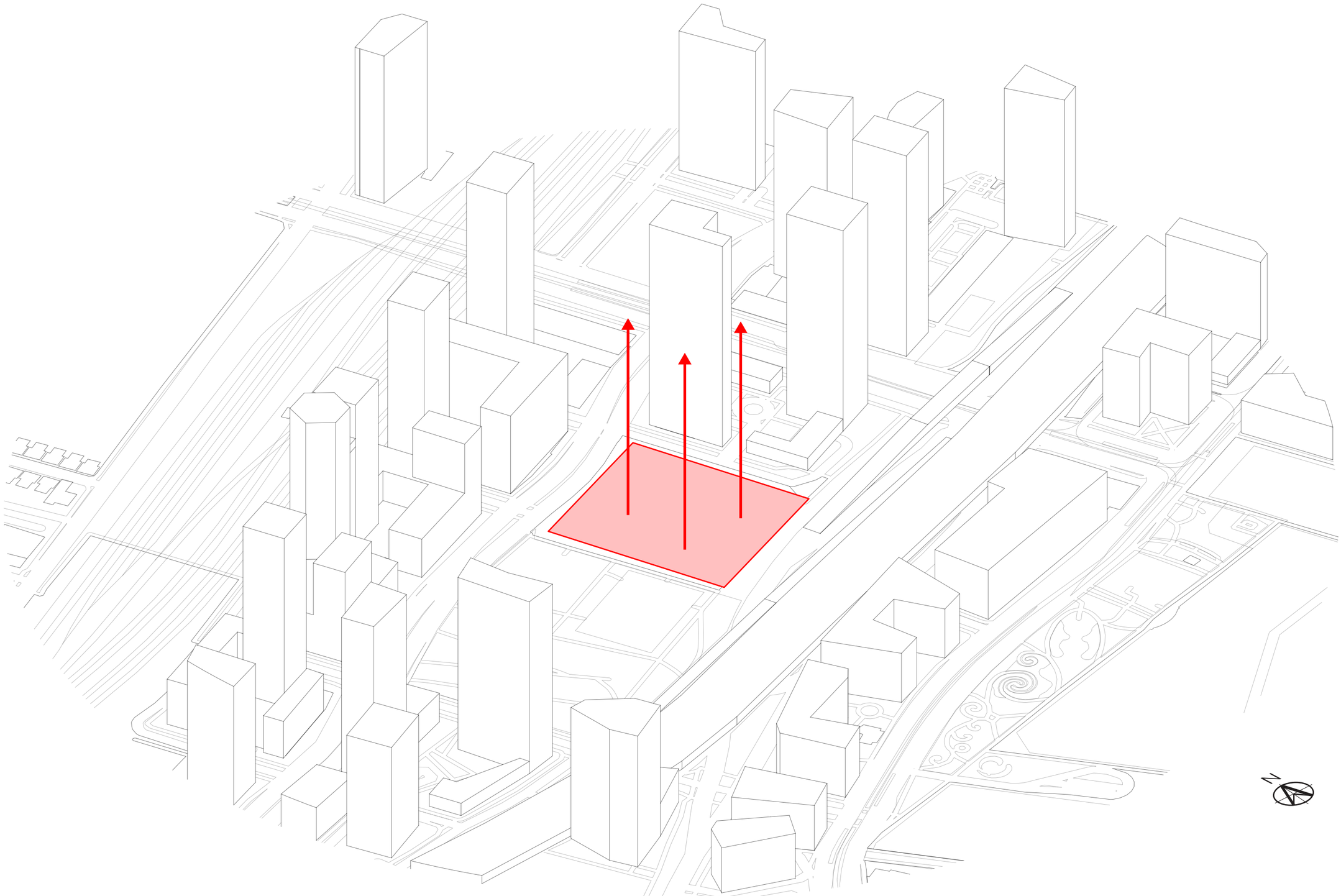
30M

N

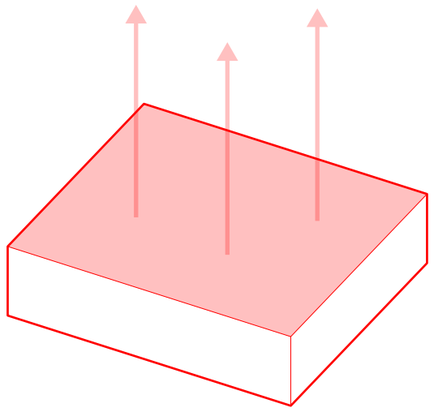
3.0 MASSING

3.1 MASSING A

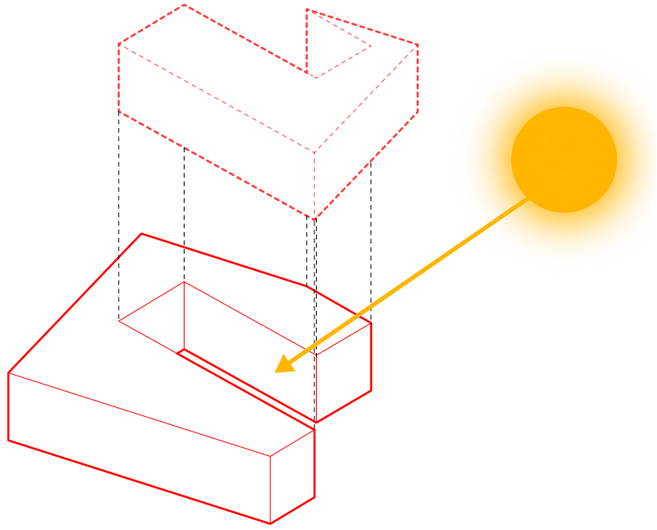
3.1.1 MASSING STRATEGY



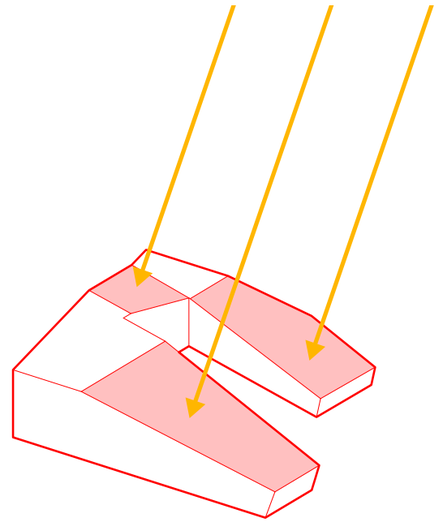
SITE BOUNDARY



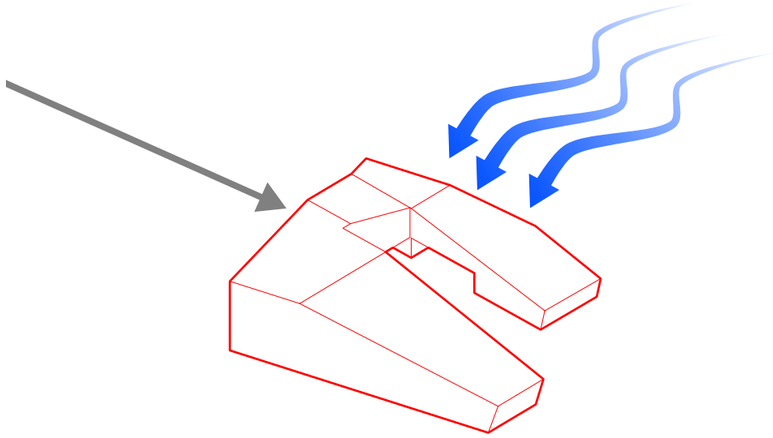
1. Extrusion of the site boundary



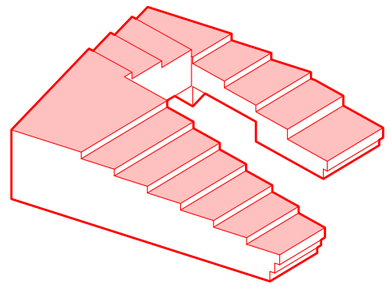
2. Angled cut out of massing to increase surface area for sun for passive heating to access all units and to increase natural daylight into all spaces.



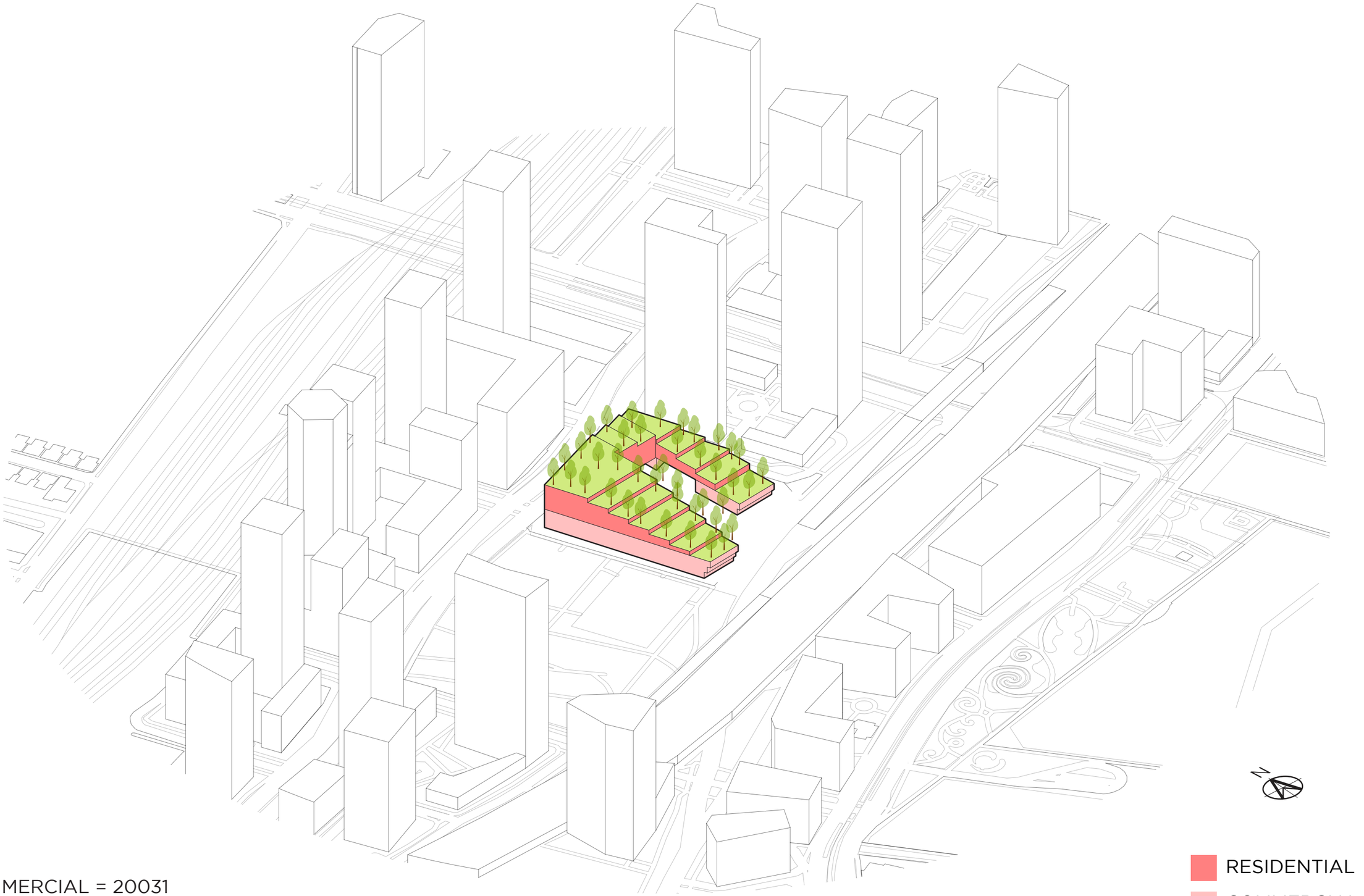
3. Diagonal cut along top of building to optimise angle for sun to penetrate in order for passive heating on the roofs of the building and natural sunlight into the spaces.



4. Carve holes for entrance and an increase in wind flow on the ground floor for natural ventilation



5. Terracing to optimise internal spaces and create external courtyards

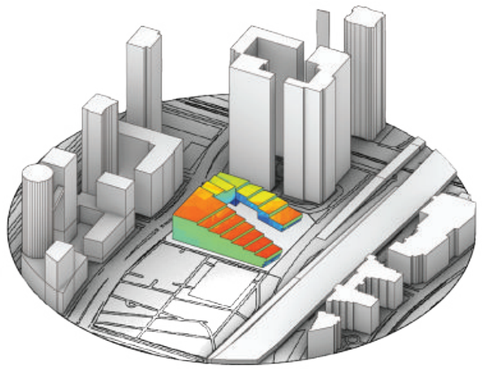


GFA
COMMERCIAL = 20031
RESIDENTIAL = 26566
TOTAL = 46597
PLOT RATIO = 3.24

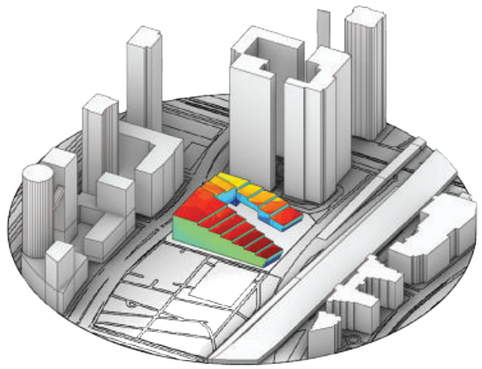
RESIDENTIAL
COMMERCIAL
GREEN SPACE

3.1.2 ANNUAL SOLAR RADIATION

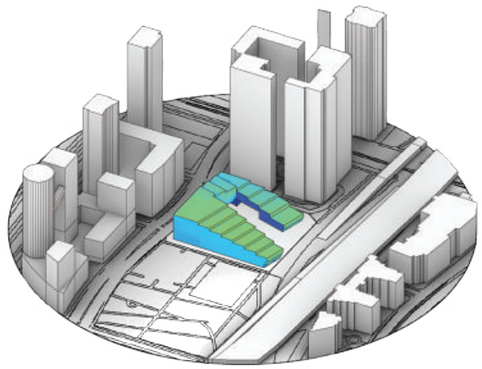
Spring



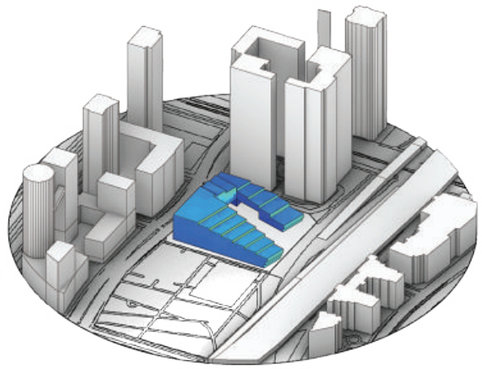
Summer

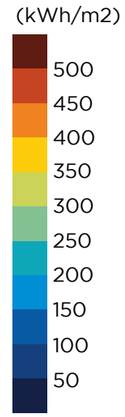


Autumn



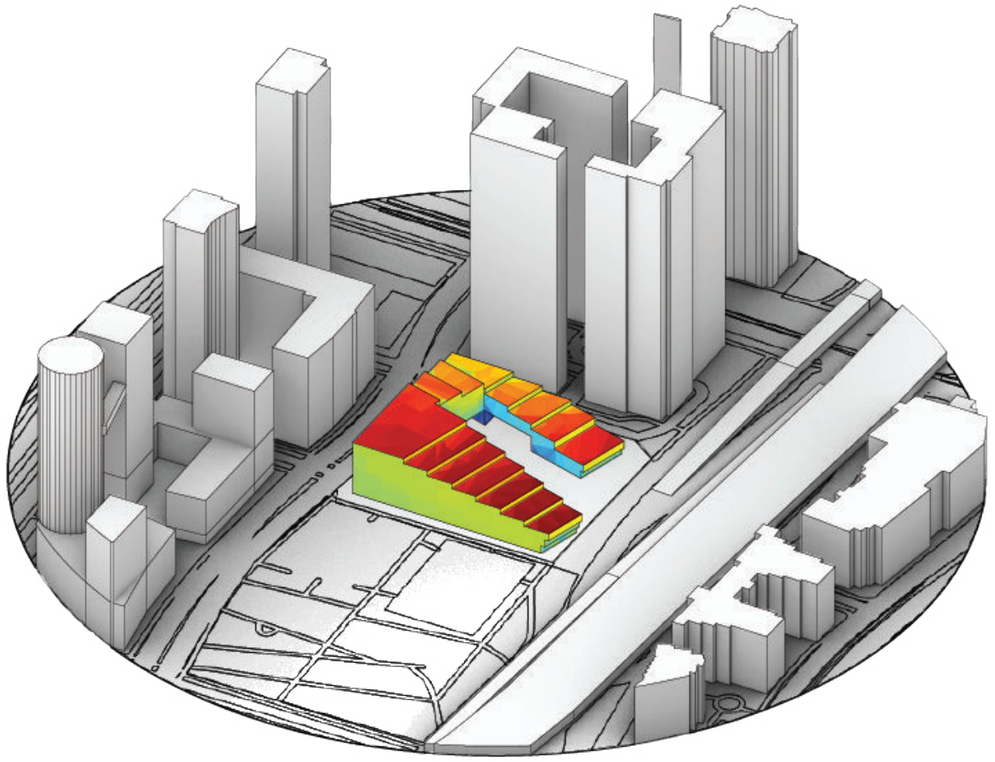
Winter

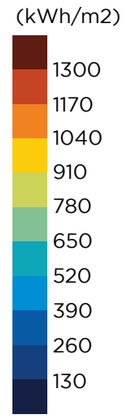




ANALYSIS

- By terracing the roof and increasing the surface area on both the South side and the roof, the total radiation on the massing has been increased.





Annual

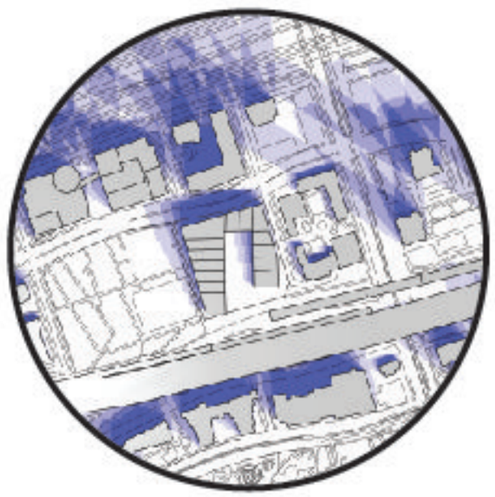
3.1.2 SHADOW HOURS ON BUILDING

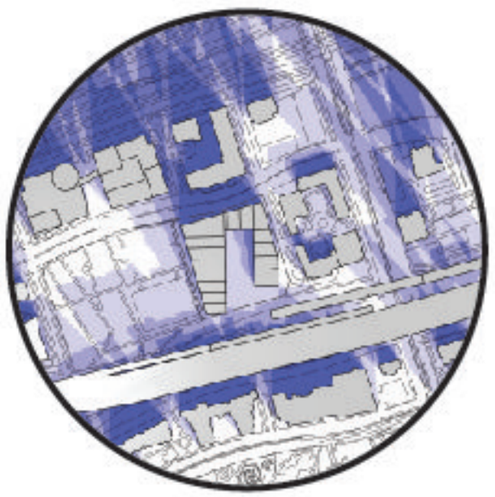
SPRING / AUTUMN EQUINOX

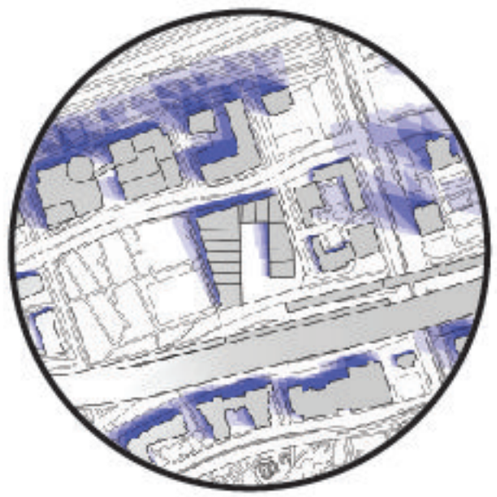
WINTER SOLSTICE

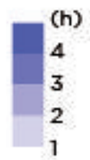
SUMMER SOLSTICE

AM

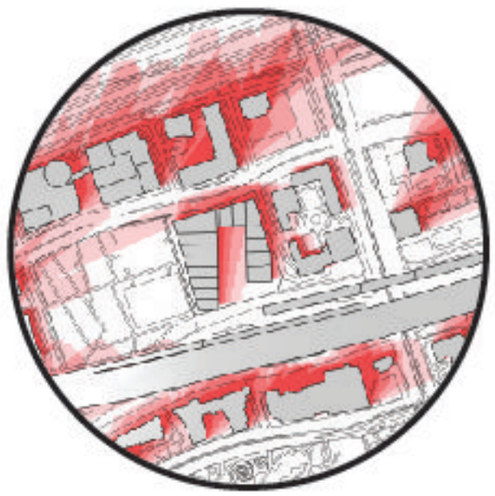


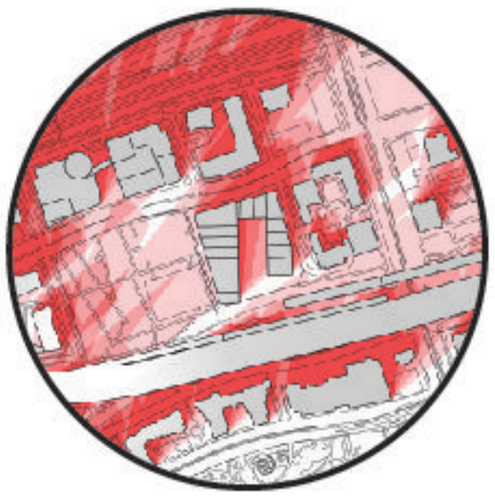


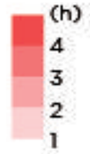




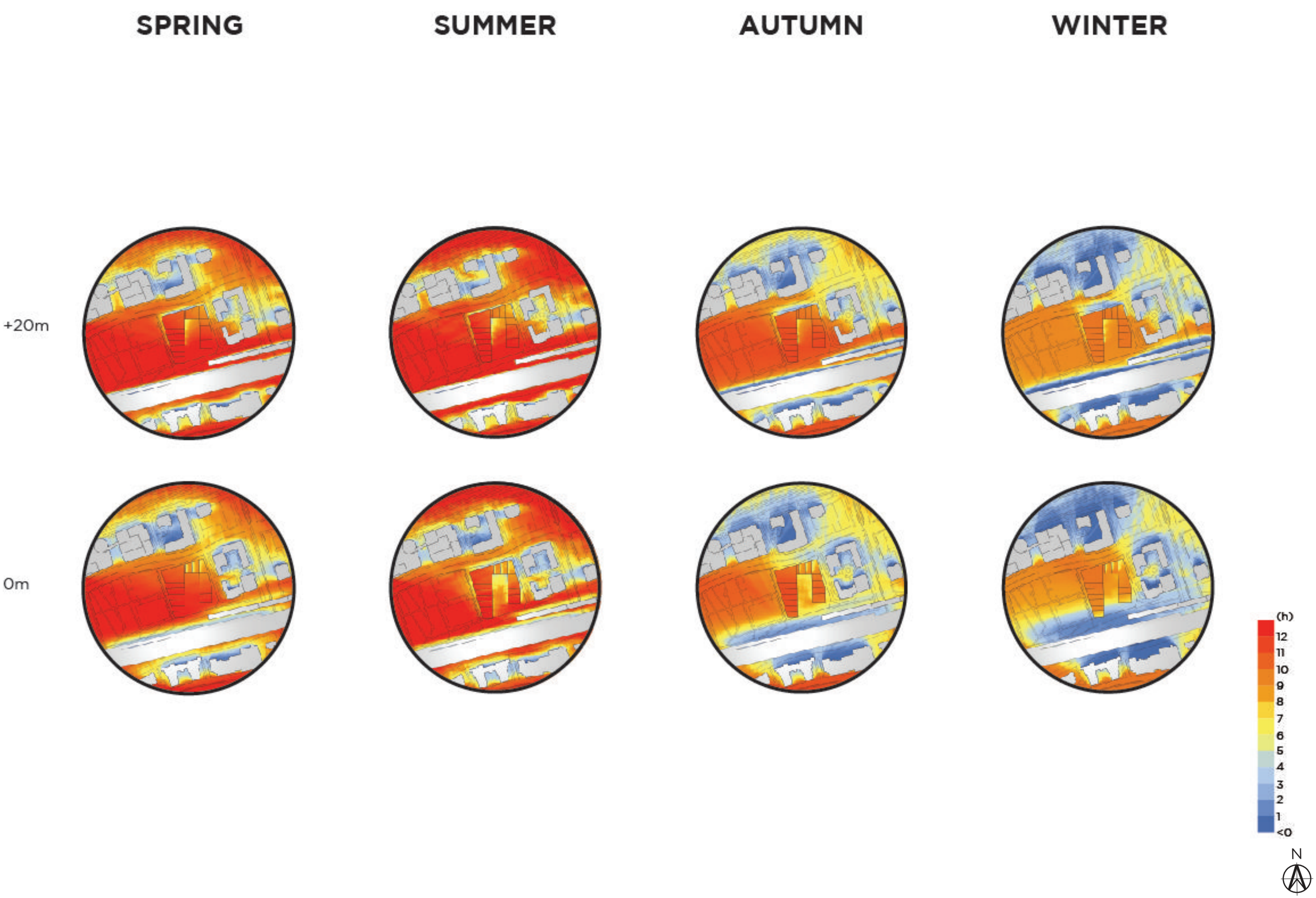
PM







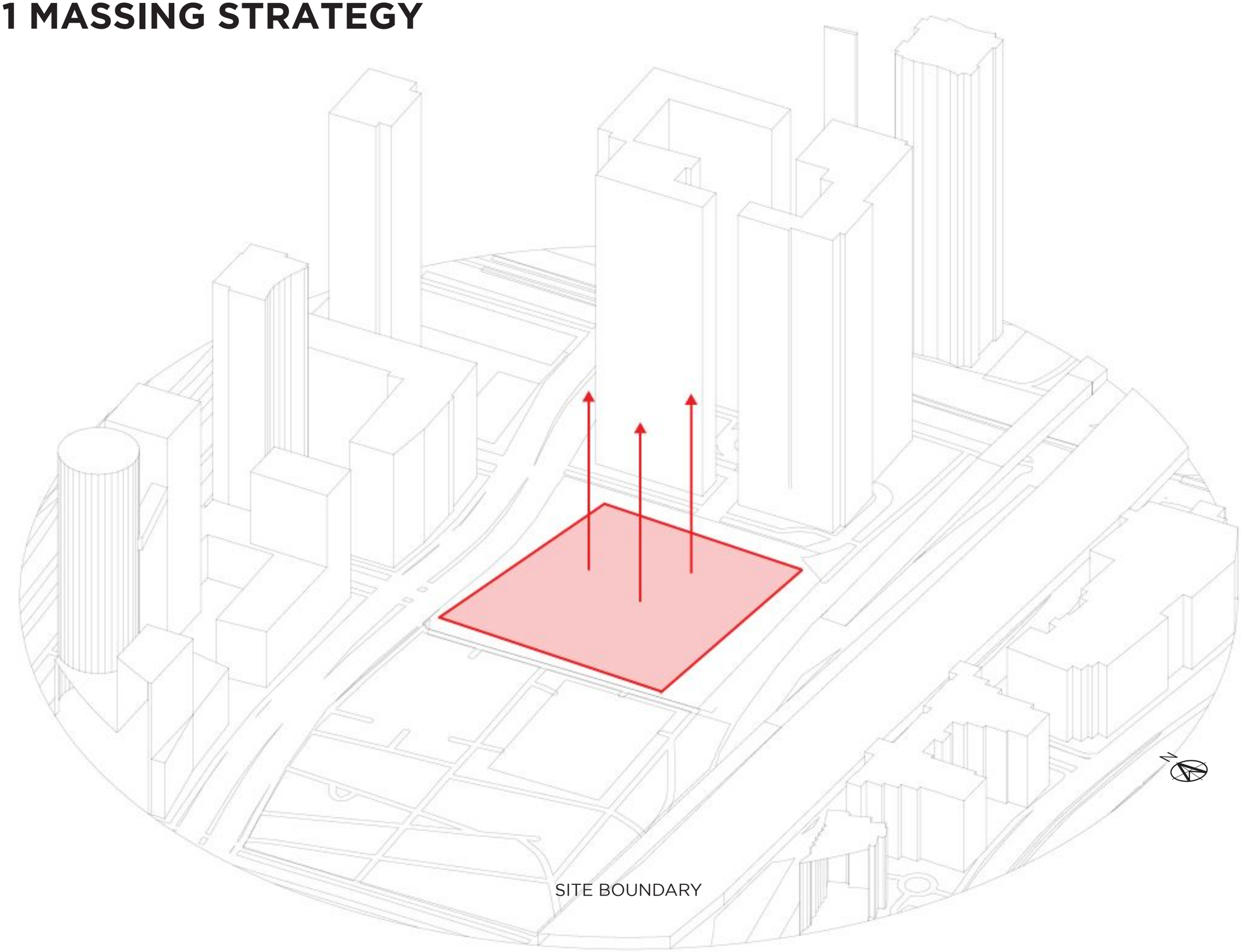
3.1.2 SUNLIGHT HOURS ON BUILDING



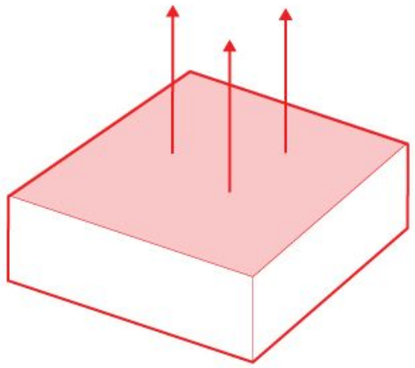
3.0 MASSING

3.2 MASSING B

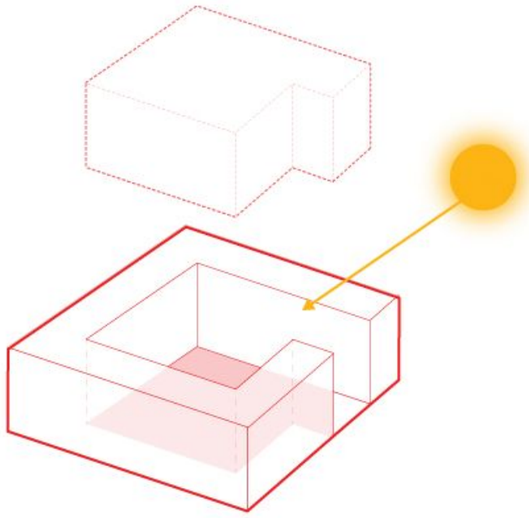
3.2.1 MASSING STRATEGY



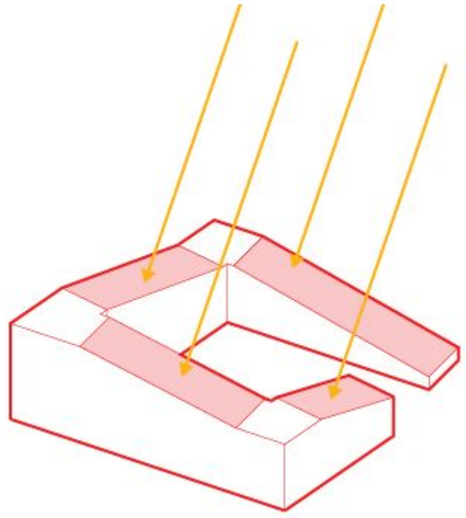
SITE BOUNDARY



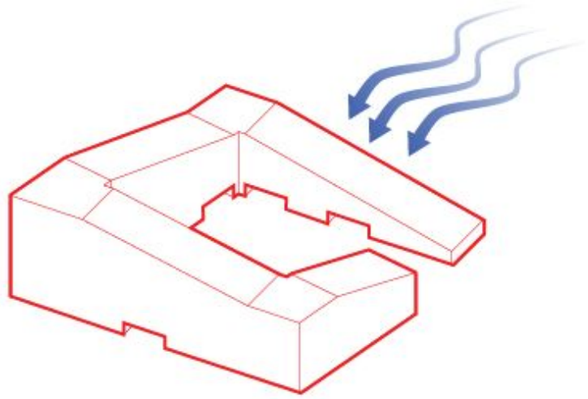
1. Extrusion of the site boundary



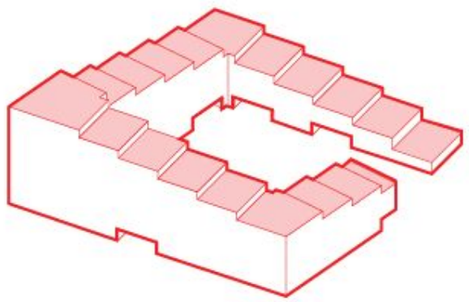
2. Cut to increase surface area for sun and to create a central courtyard for activities on the ground floor. This also increases the number of units receiving natural sunlight and passive heating



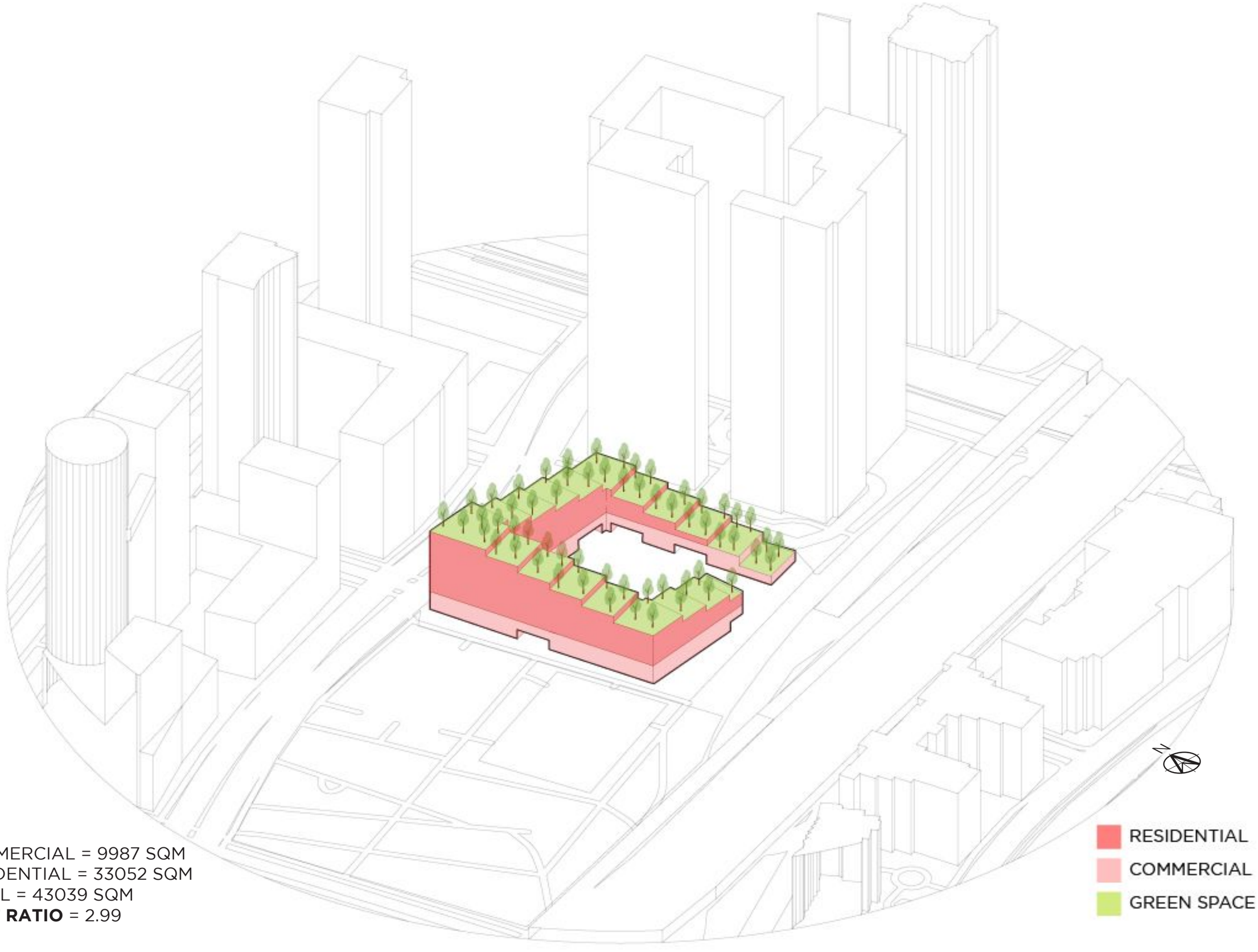
3. Diagonal cut on the top of the building to optimise the angle for sun by creating a slanting roofscape. This allows for passive heating on the roofs of the building and for natural sunlight to enter



4. Carve holes on the ground floor of the building for entrances and an increase in wind flor during summer time, improving natural ventilation in the space

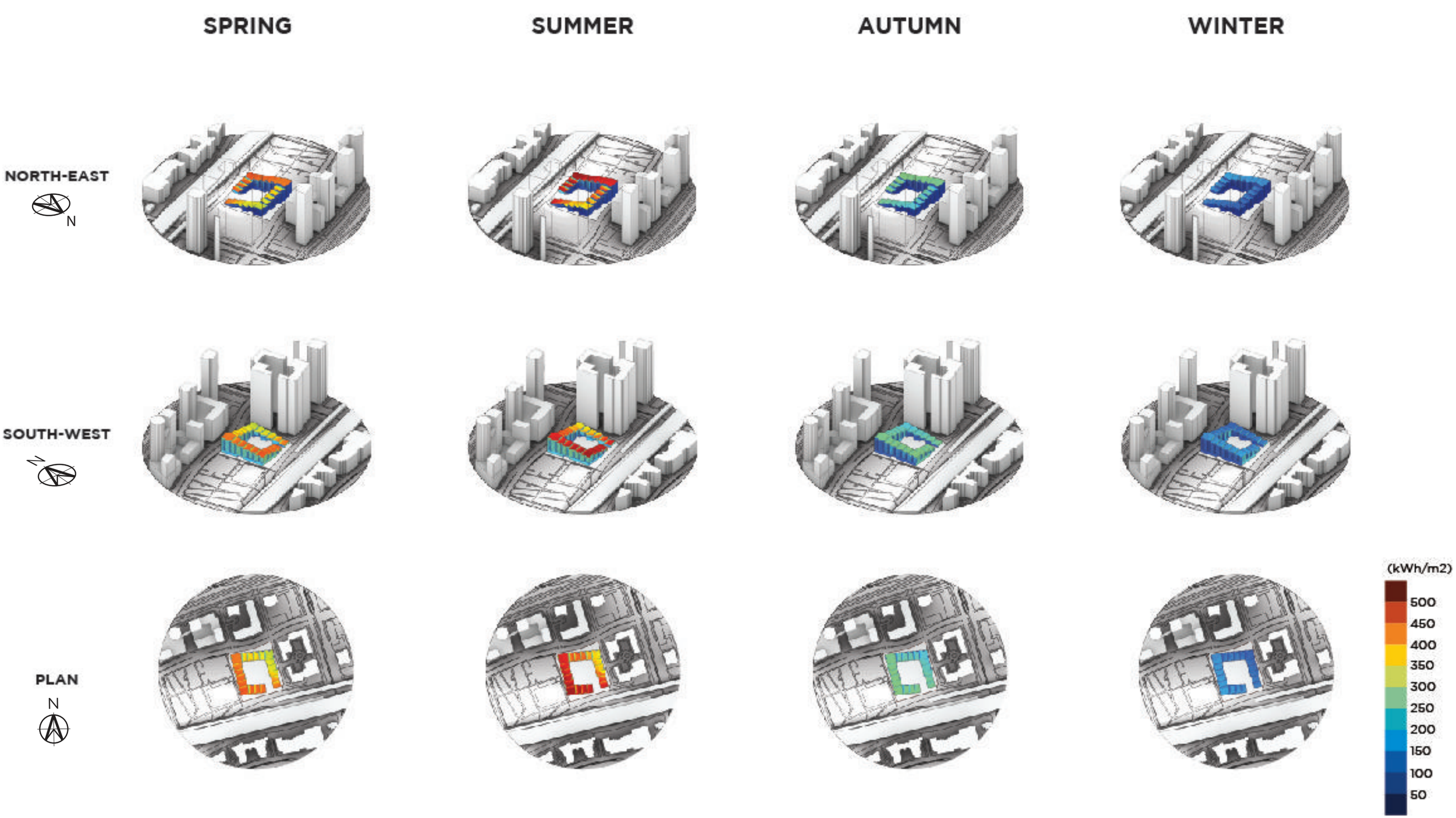


5. Terracing to optimise internal spaces and create external courtyards. This method allows for more units to receive more sunlight for passive heating measures.

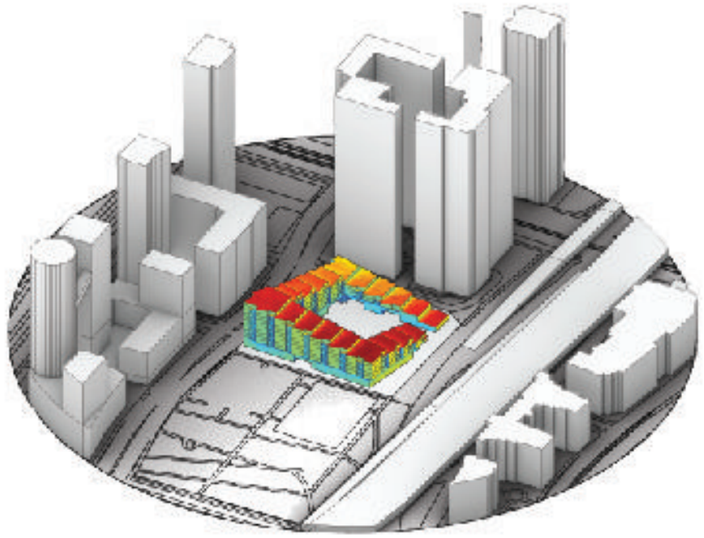


GFA
COMMERCIAL = 9987 SQM
RESIDENTIAL = 33052 SQM
TOTAL = 43039 SQM
PLOT RATIO = 2.99

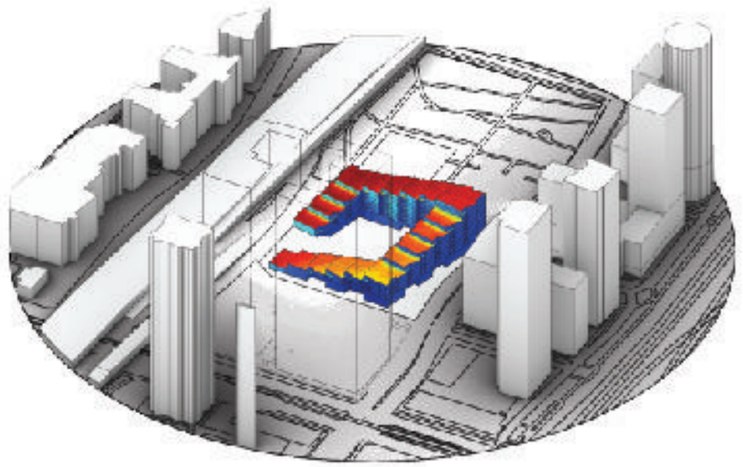
3.2.2 ANNUAL SOLAR RADIATION



3.2.2 ANNUAL SOLAR RADIATION



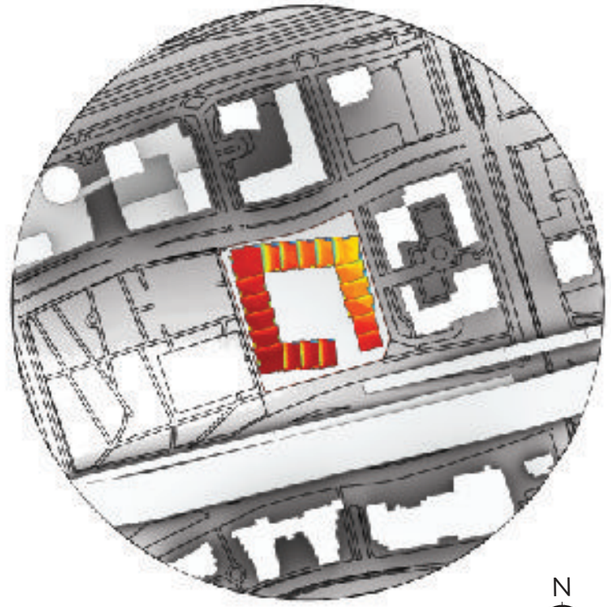
NORTH-EAST



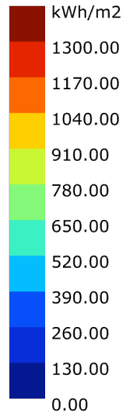
SOUTH-WEST

ANALYSIS

- As seen in the seasonal solar radiation, in summer, the solar radiation on the roof of the building is the highest.
- By terracing the roof, the total radiation on the massing has been increased.



PLAN



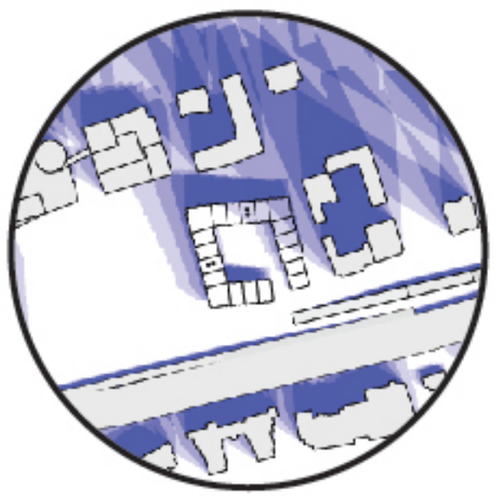
3.2.2 SHADOW HOURS ON BUILDING

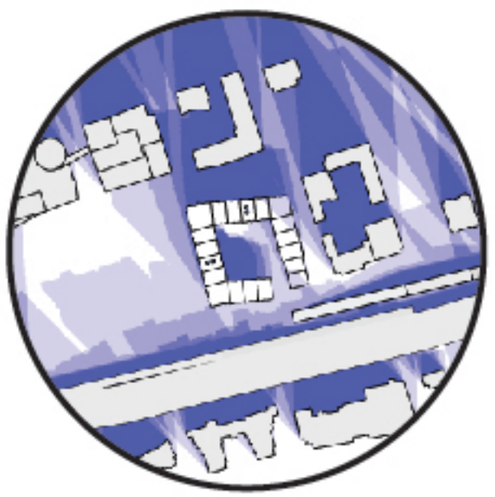
SPRING / AUTUMN EQUINOX

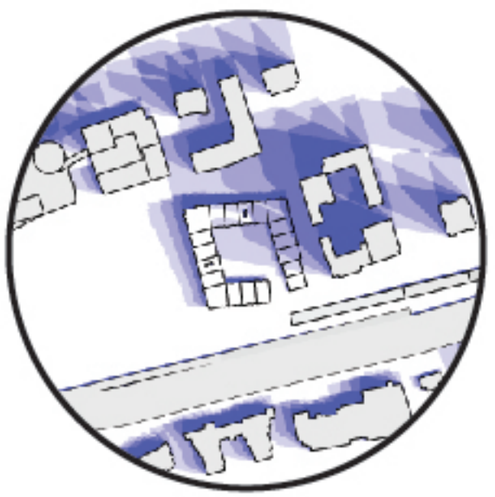
WINTER SOLSTICE

SUMMER SOLSTICE

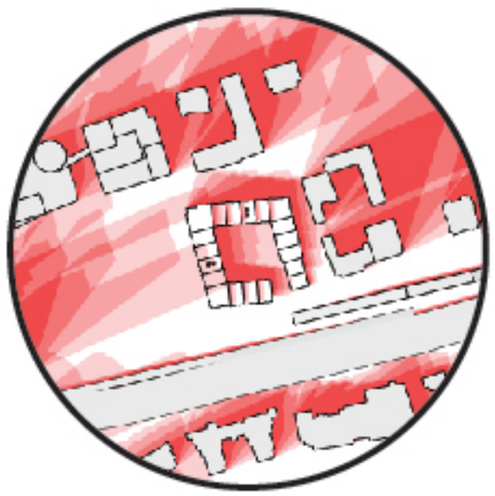
AM

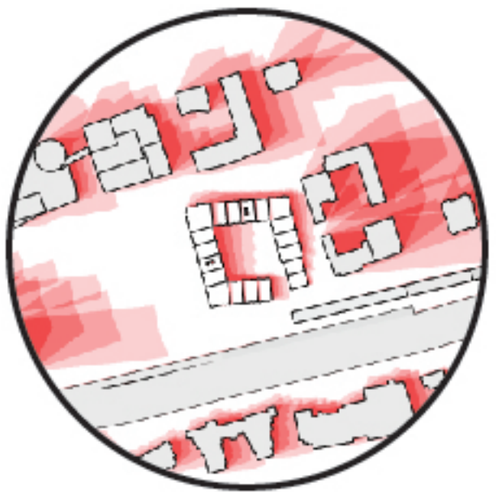


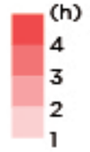




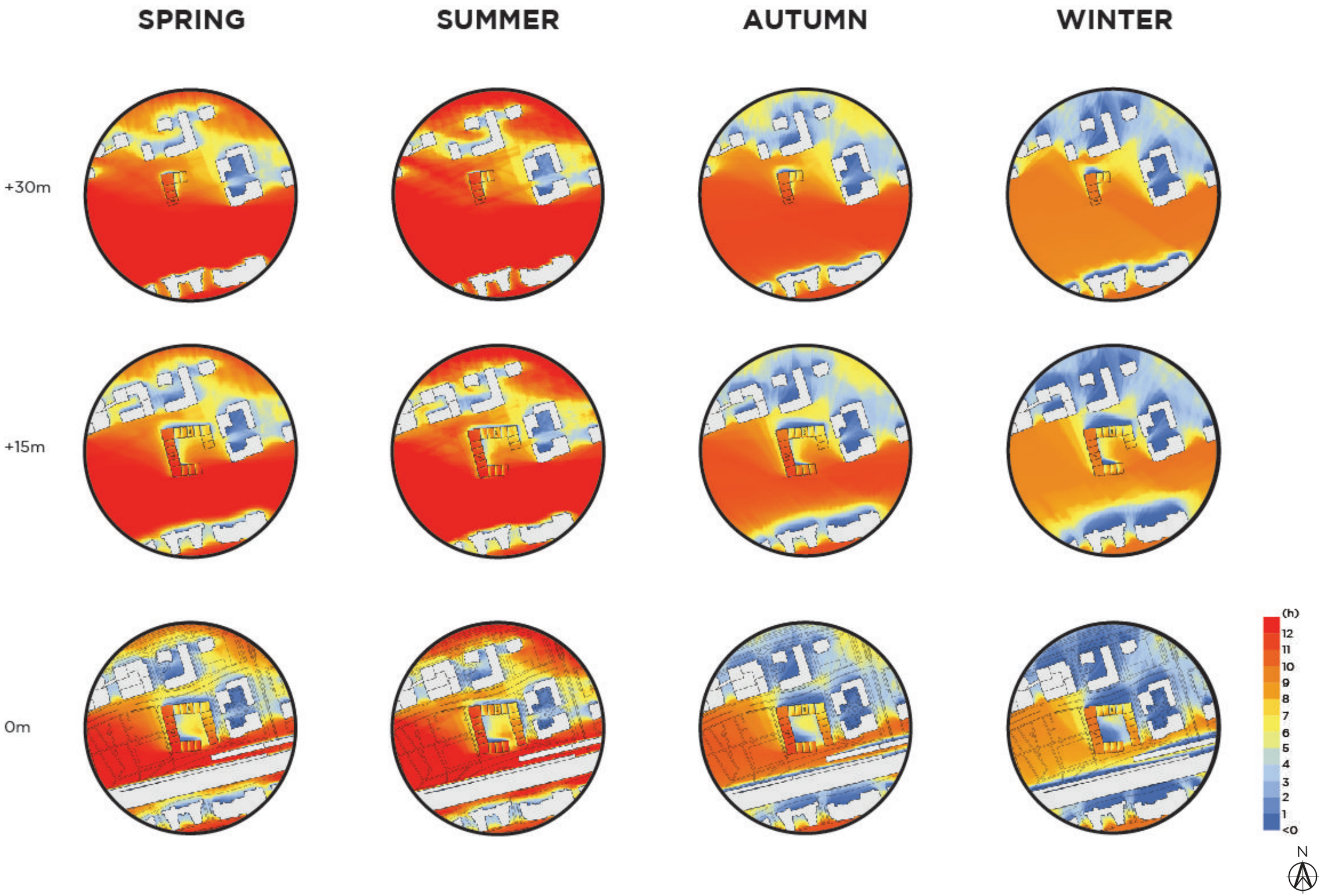
PM







3.2.2 SUNLIGHT HOURS ON BUILDING



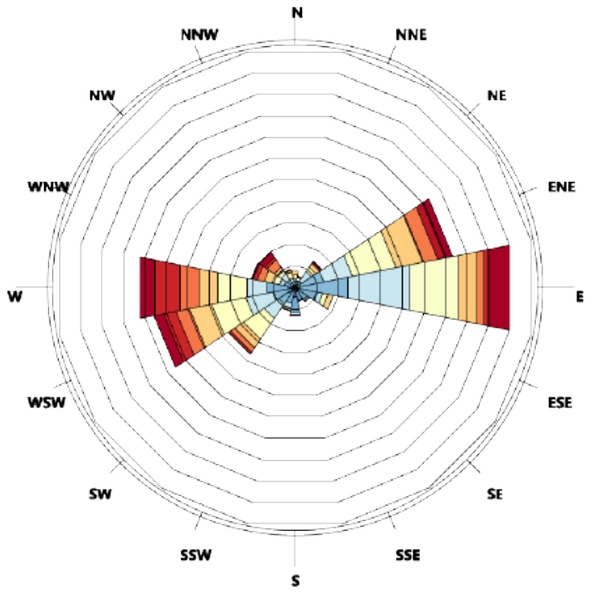
3.3 OVERALL ANALYSIS

From the simulations above for each massing, both massings show similar results for the amount of solar radiation on the roofs, with the west side having higher solar radiation as it is taller than the other sides. For massing B, we can see that the shadow hours around the building seem to be longer than that of massing A during both the morning and the afternoon, allowing the central courtyard spaces to receive long shadow hours during the summer time. Similarly, massing A receives more sunlight hours in most areas as compared to massing B. These factors could be due to the fact that the building in massing B as it is taller than massing A, causing the difference in shadow hours and sunlight hours on the building and the site.

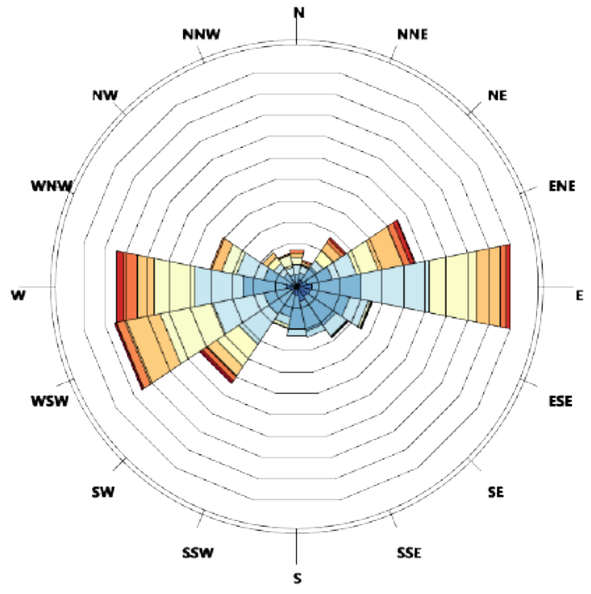
We chose to work with massing B as it gives us more favourable results, where in the summer, we can see that the central courtyard space has lesser sunlight hours, allowing the space to be more comfortable in the summer. In addition, Massing B has more spaces with longer sunlight hours in the winter despite its height, which allows for more passive heating during the winter time.

4.0 WIND ANALYSIS

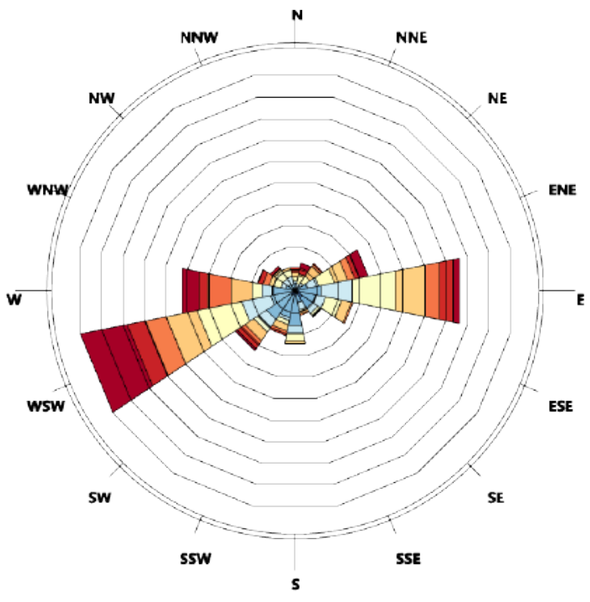
4.1 WIND ROSES



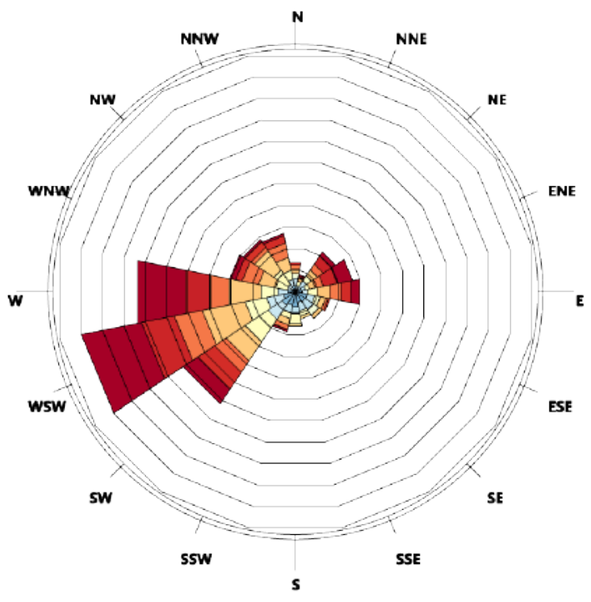
SPRING



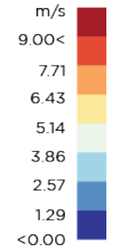
SUMMER



AUTUMN

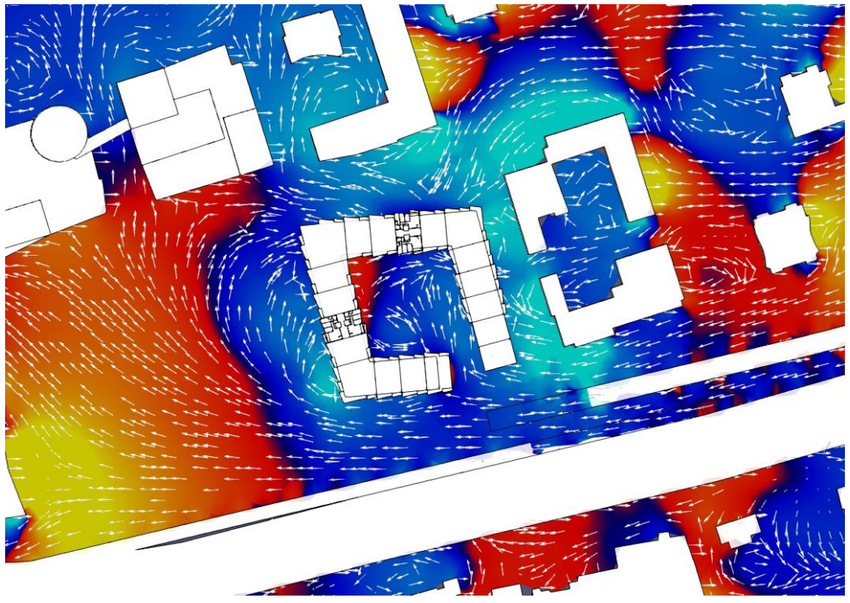


WINTER

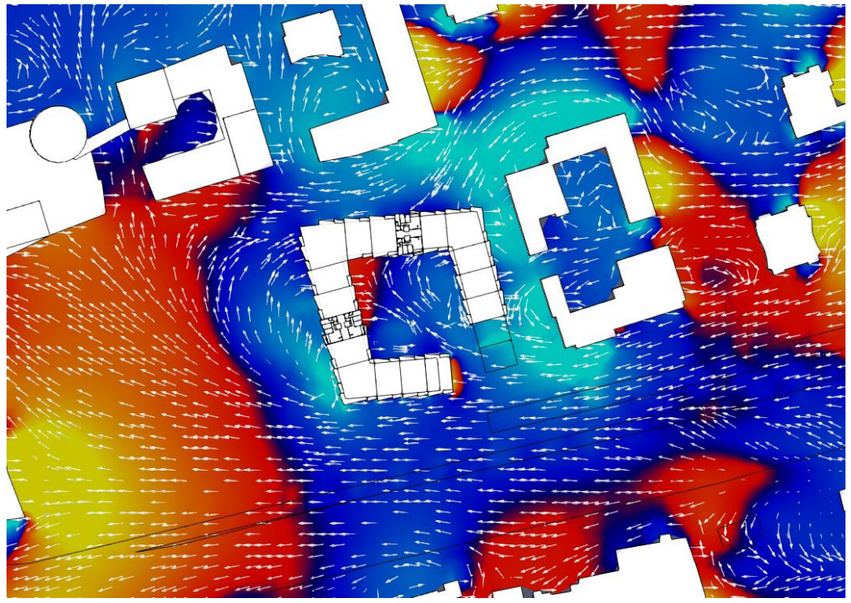


4.2.1 EAST WIND (SUMMER)

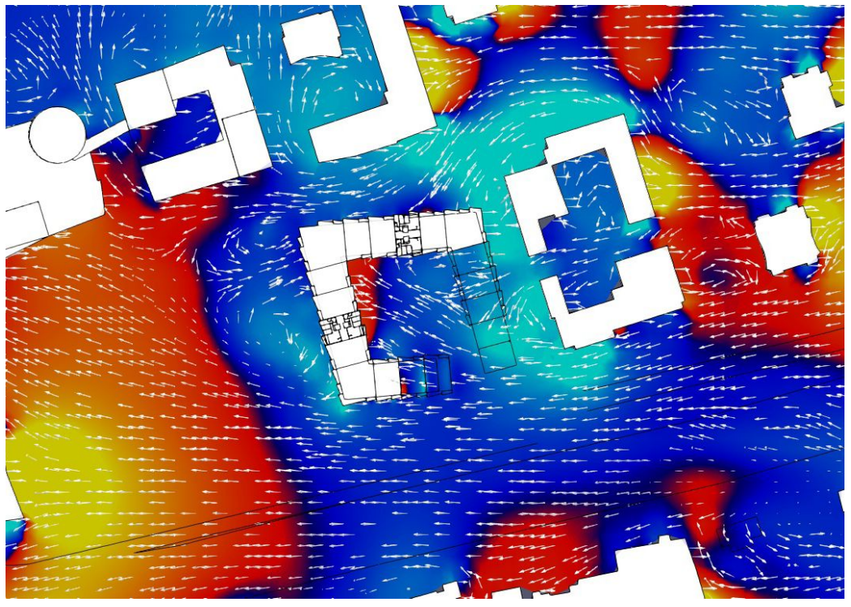
PRESSURE



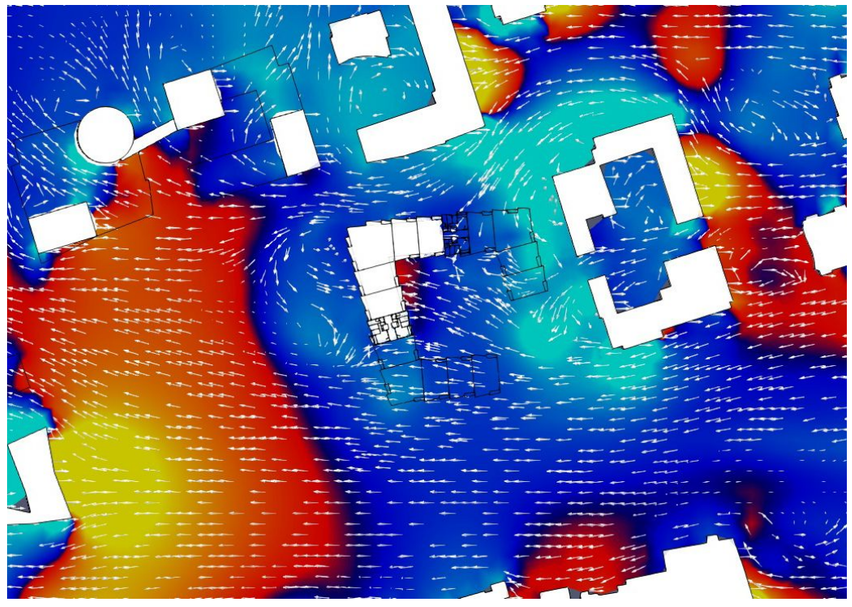
1M



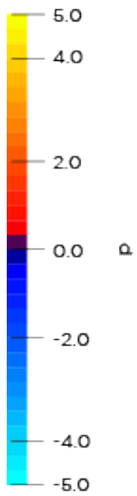
10M



20M

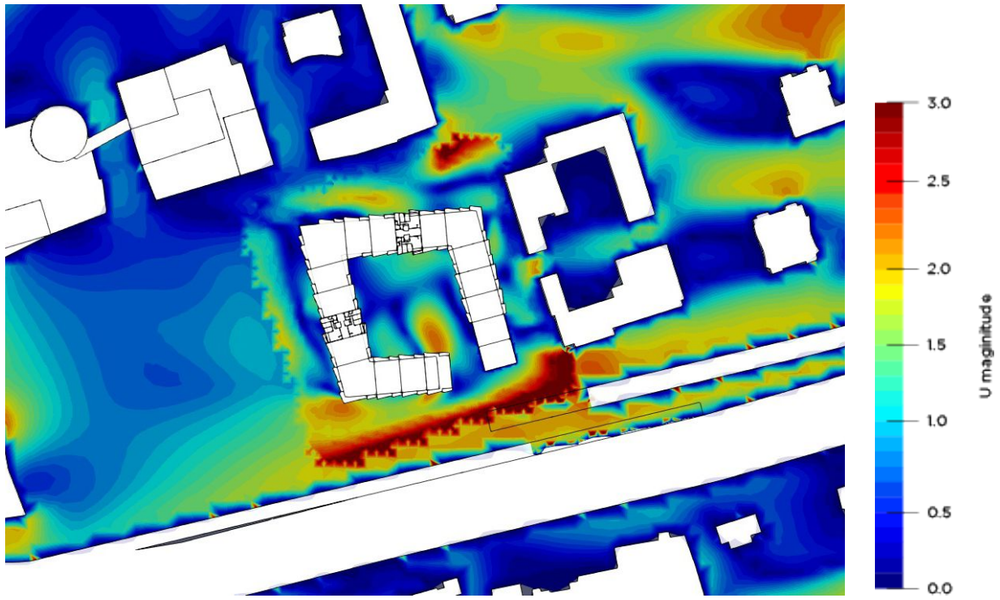


30M

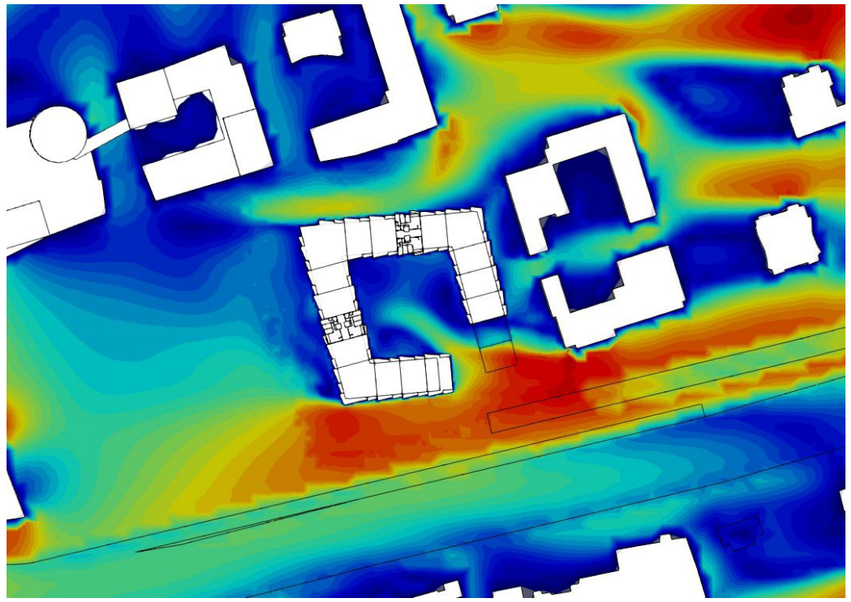


4.2.1 EAST WIND (SUMMER)

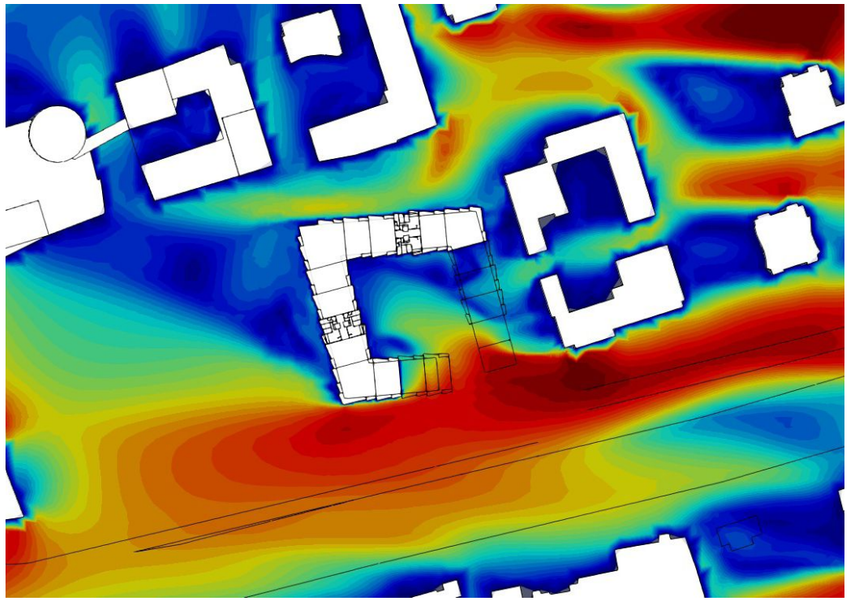
VELOCITY



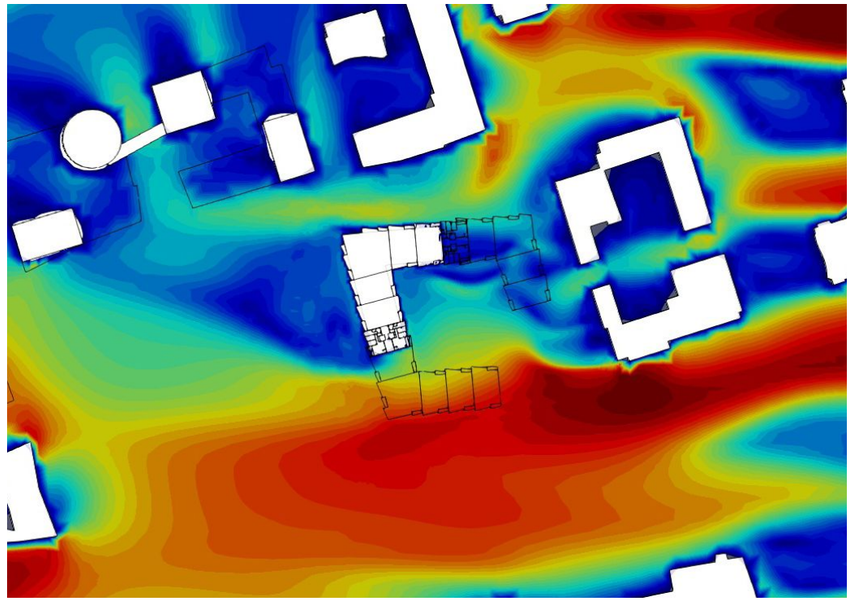
1M



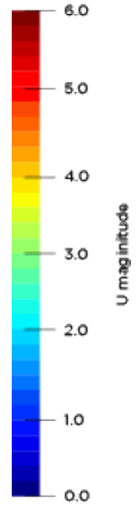
10M



20M

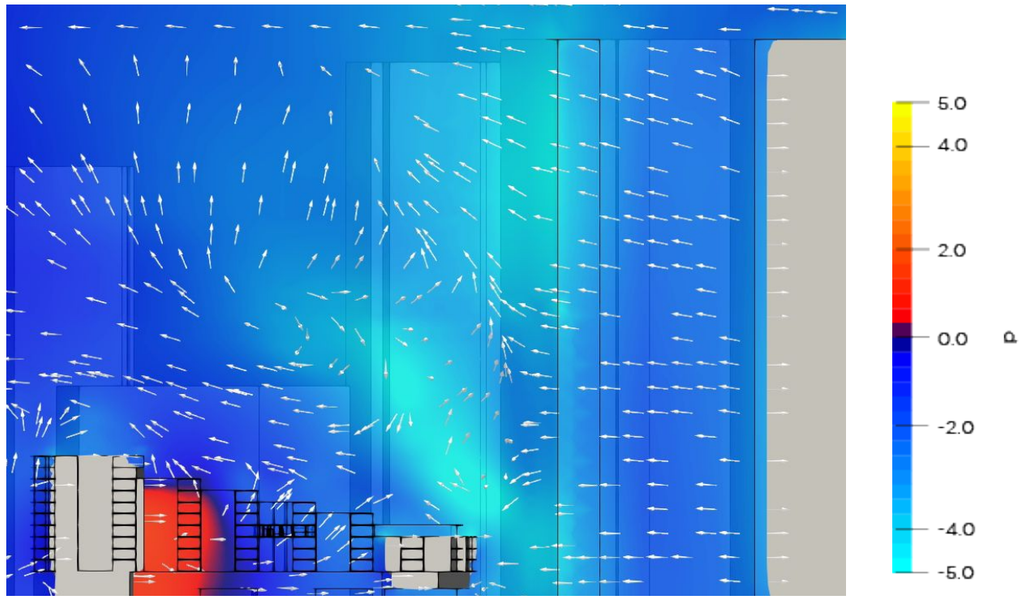


30M

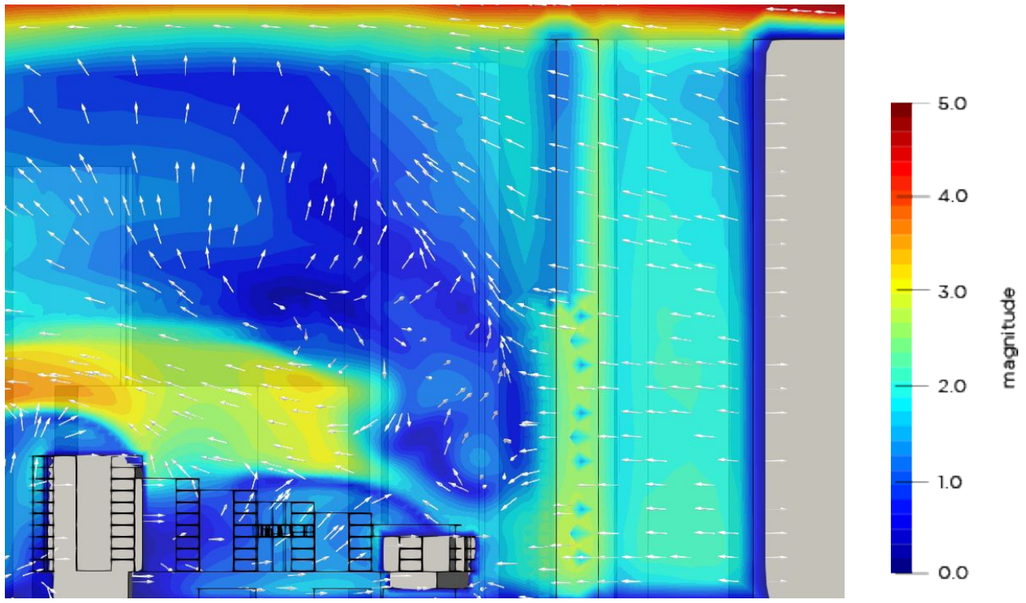


4.2.1 EAST WIND (SUMMER)

SECTIONS



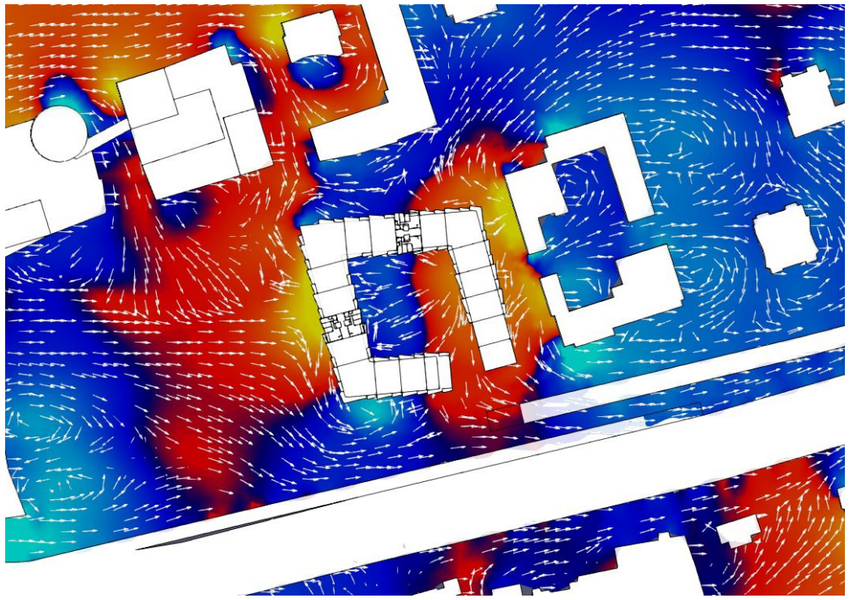
PRESSURE



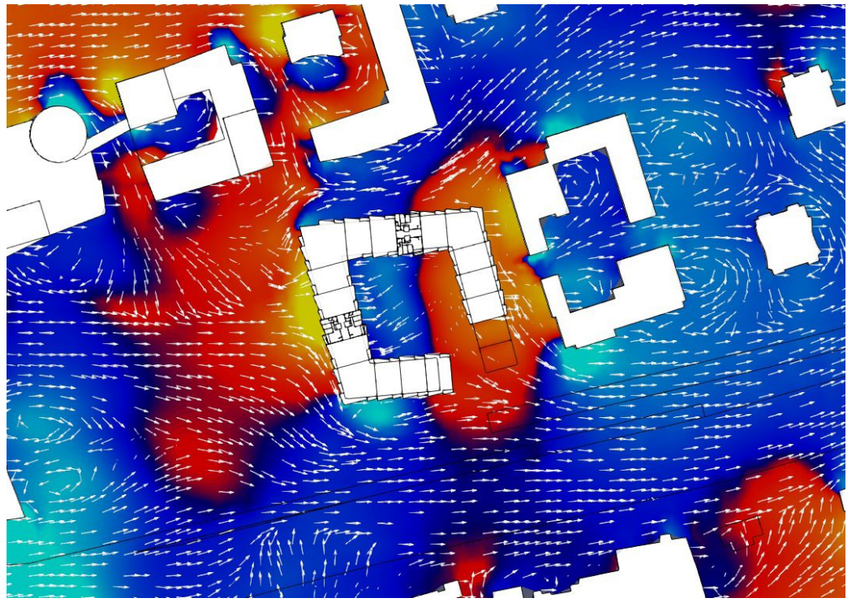
VELOCITY

4.2.2 WEST WIND (WINTER)

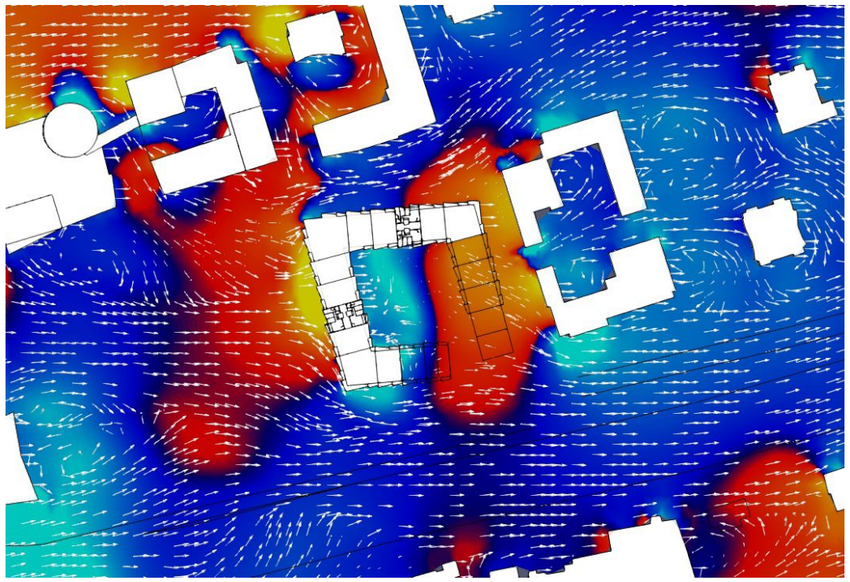
PRESSURE



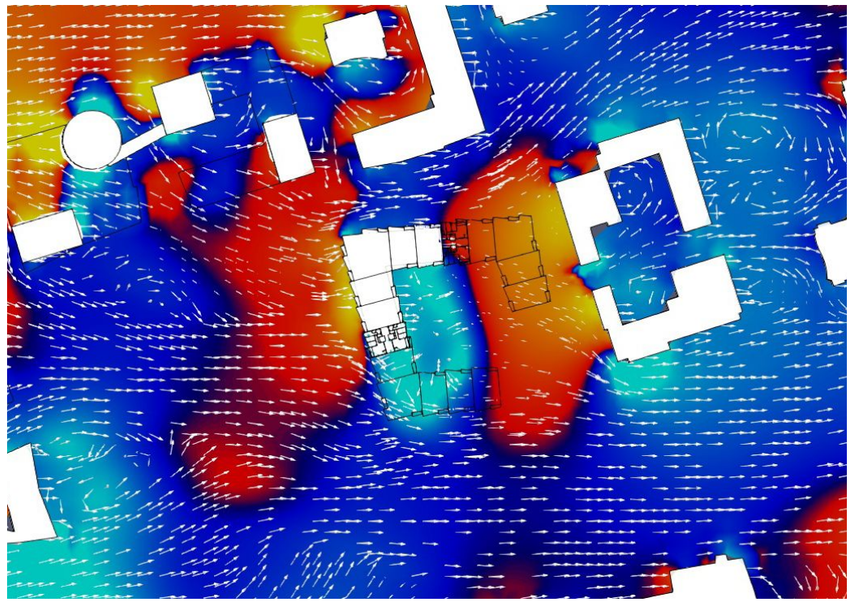
1M



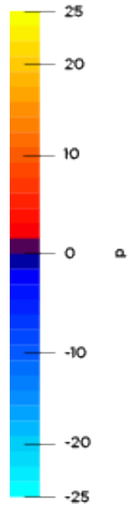
10M



20M

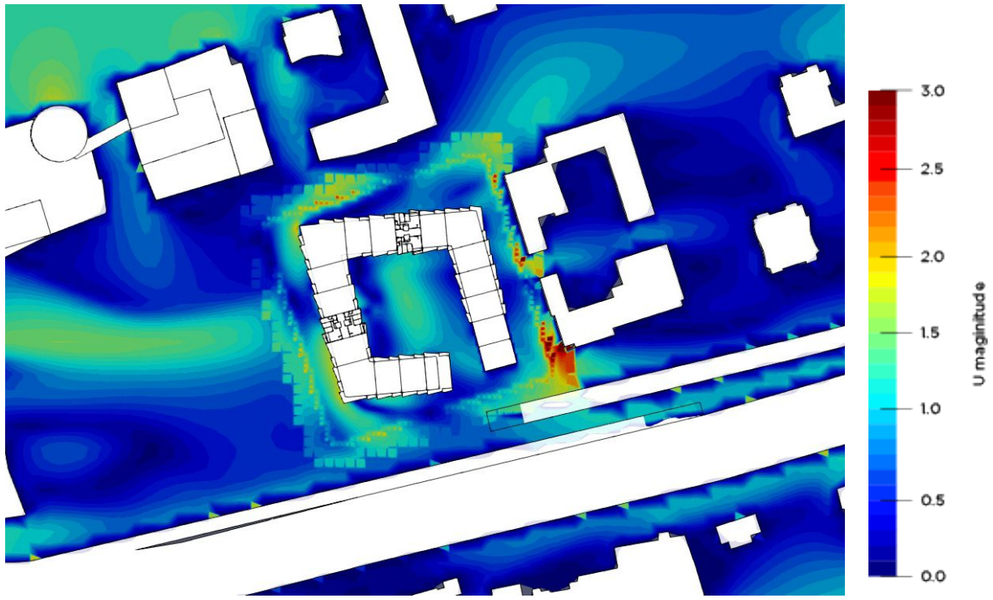


30M

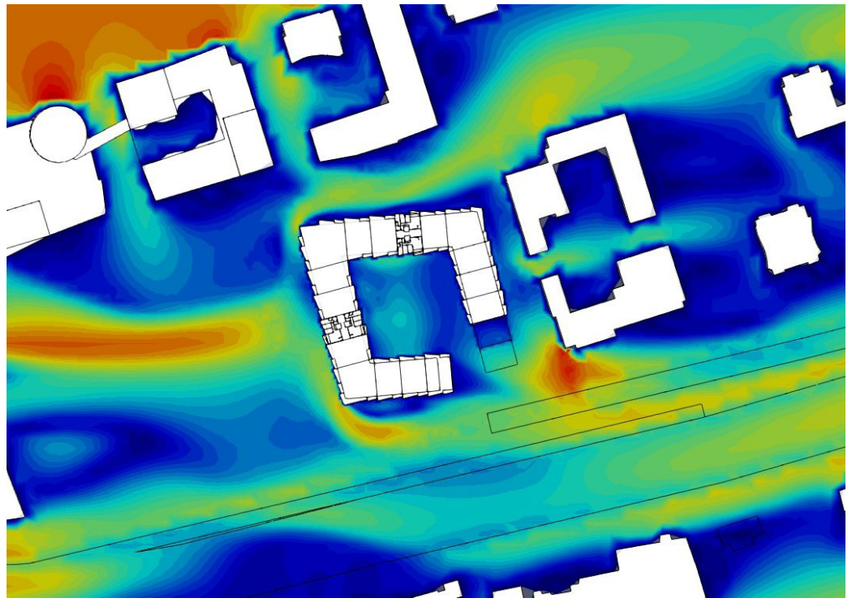


4.2.2 WEST WIND (WINTER)

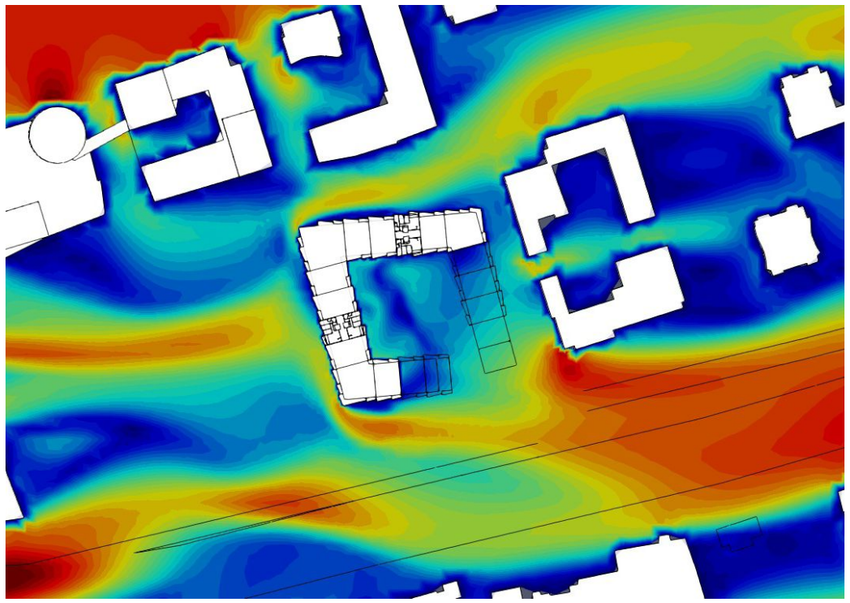
VELOCITY



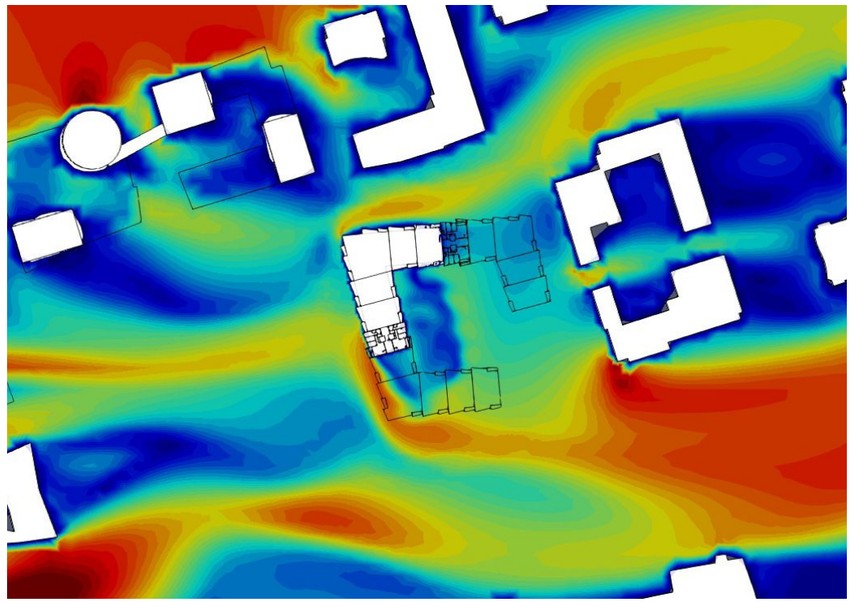
1M



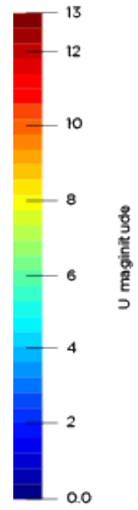
10M



20M

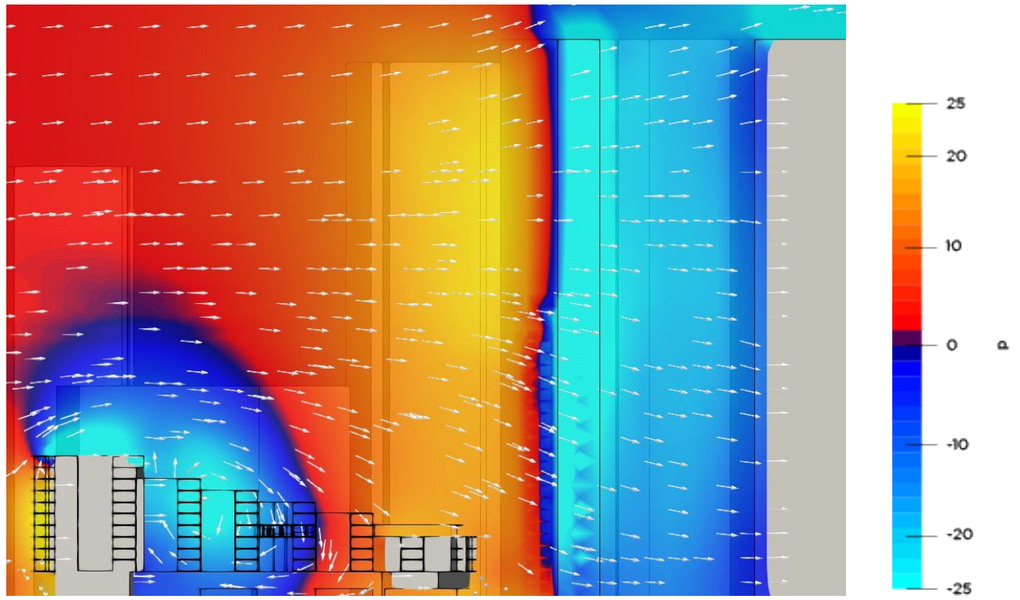


30M

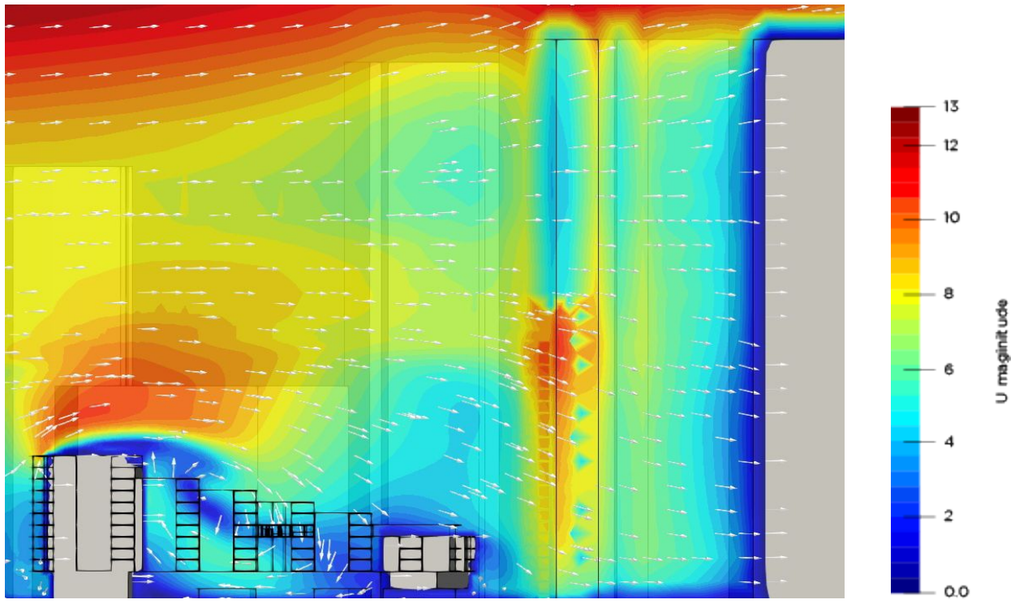


4.2.2 WEST WIND (WINTER)

SECTIONS



PRESSURE



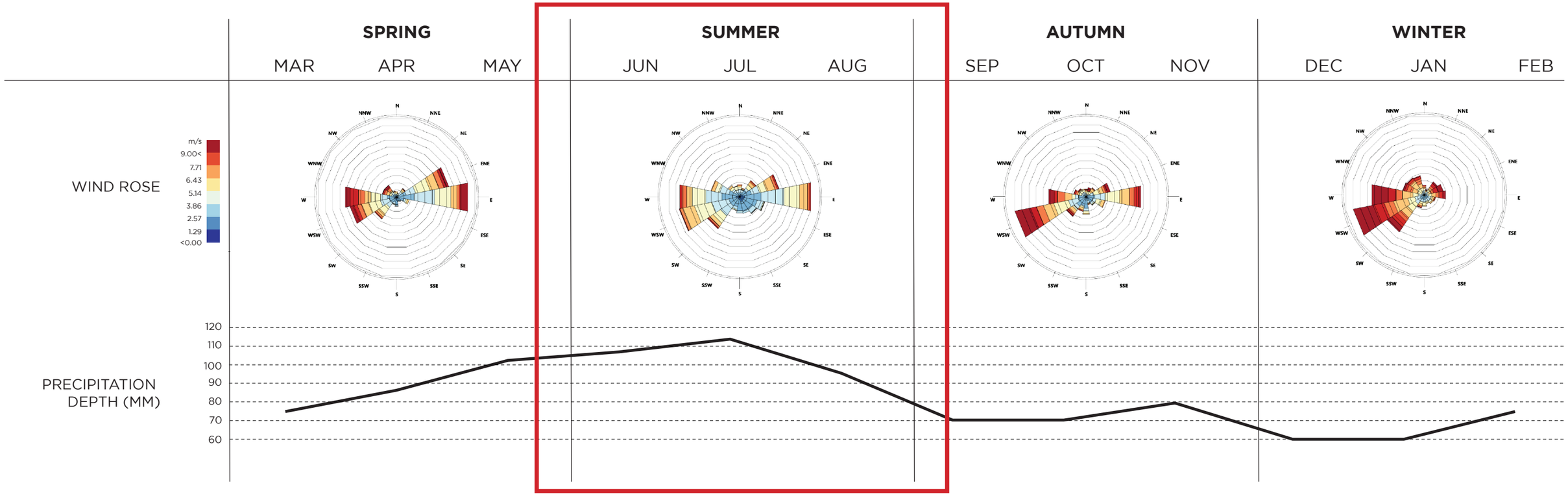
VELOCITY

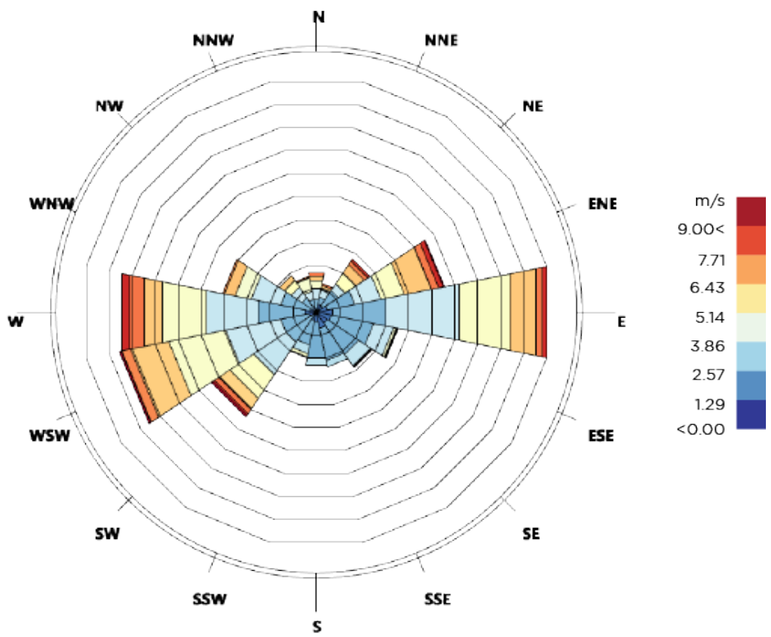
4.3 OVERALL ANALYSIS

From the wind simulations, we can gather that in the summer, where the winds are coming in from the east, it can be seen that massing B experiences low pressure and low velocity winds in the central courtyard space of the building. However, in the winter, where the winds are coming in from the west, we can see high pressures along the east side and low pressures along the west side with low wind speeds. As during the winter time, we want to to reduce the winds in the central courtyard, hence having low pressure winds within that area the central courtyard can help provide more comfortable spaces.

5.0 WIND DRIVEN RAIN

5.1 WIND SPEED PROFILE

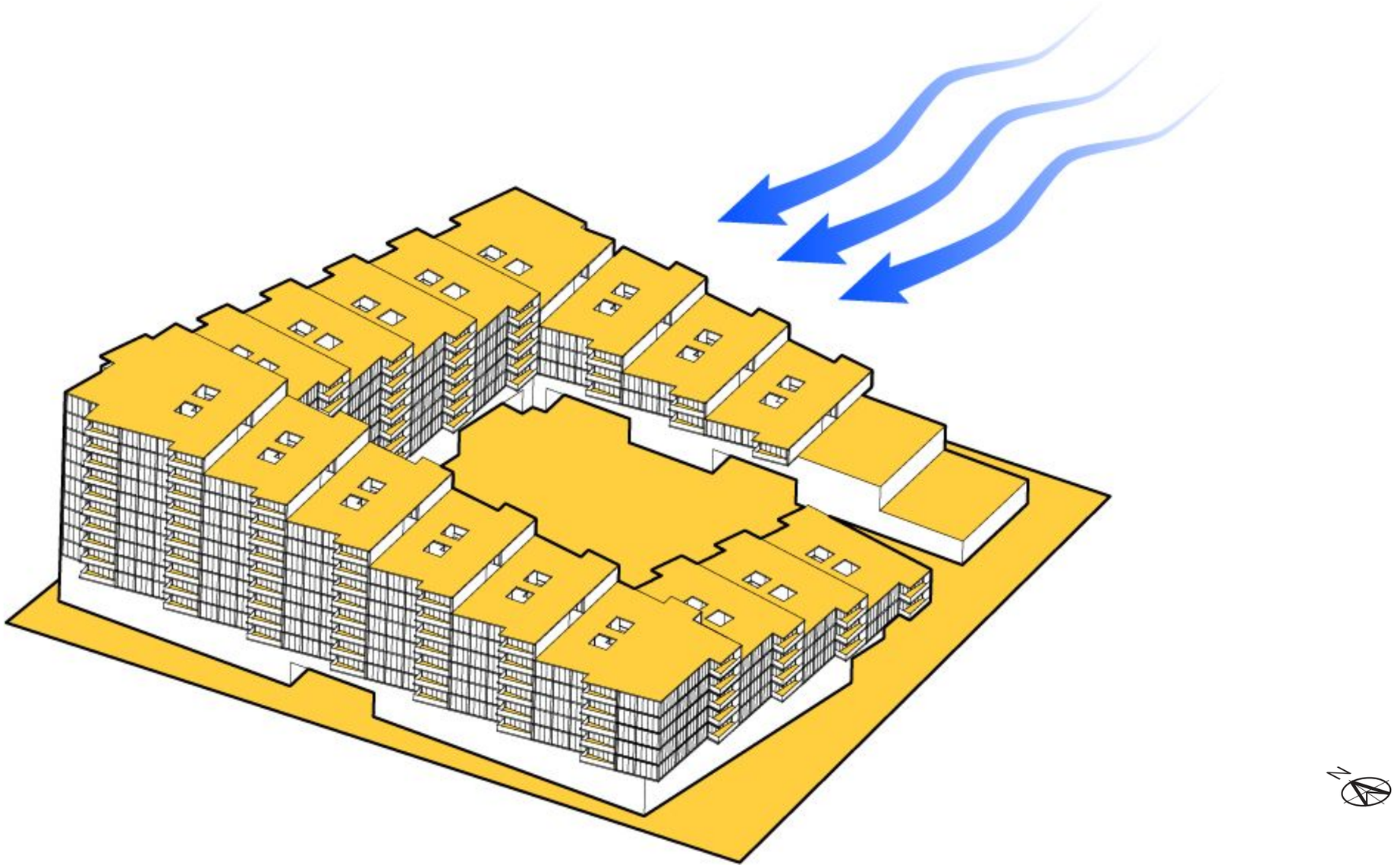




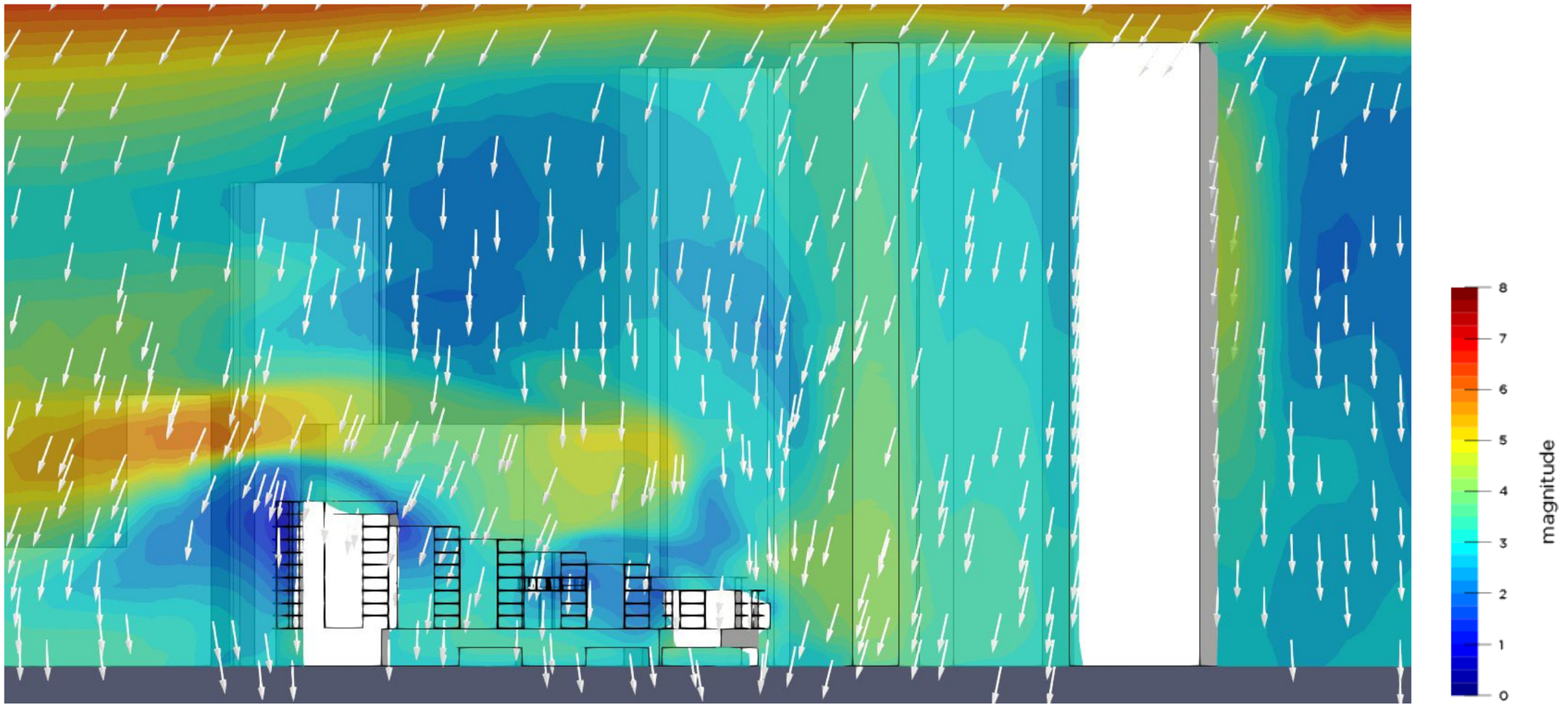
HIGHEST PRECIPITATION DEPTH: 115 mm (JULY)
HIGHEST WIND SPEED: 10 m/s
CHOSEN WIND DIRECTION: EAST

Since precipitation is the highest in summer, analysis for Wind Driven Rain is done with the summer wind rose. Due to prolonged east winds as well as most of our openings being east facing, the chosen wind direction for analysis is east, with a wind speed of 10m/s.

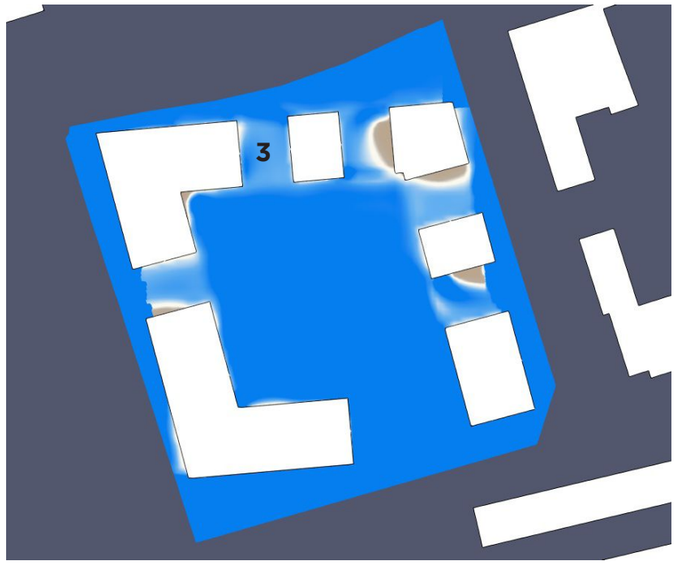
5.2.1 NATURALLY VENTILATED AREAS



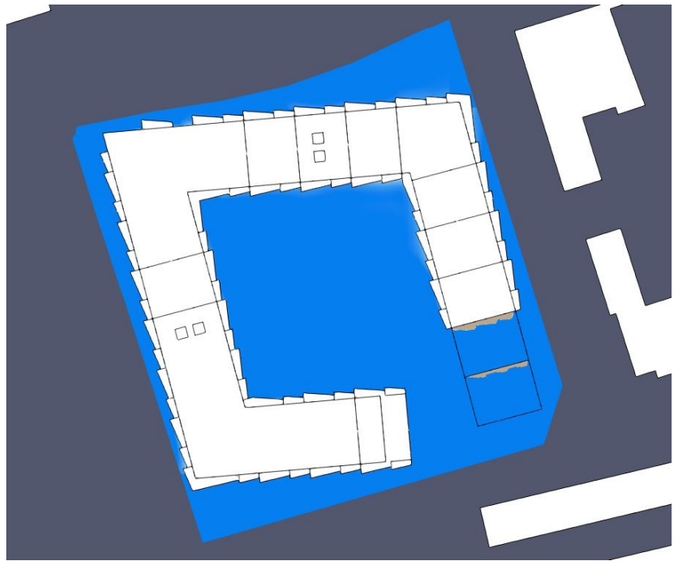
5.2.2 SECTIONAL WIND SPEED: 0.5mm DROPLETS



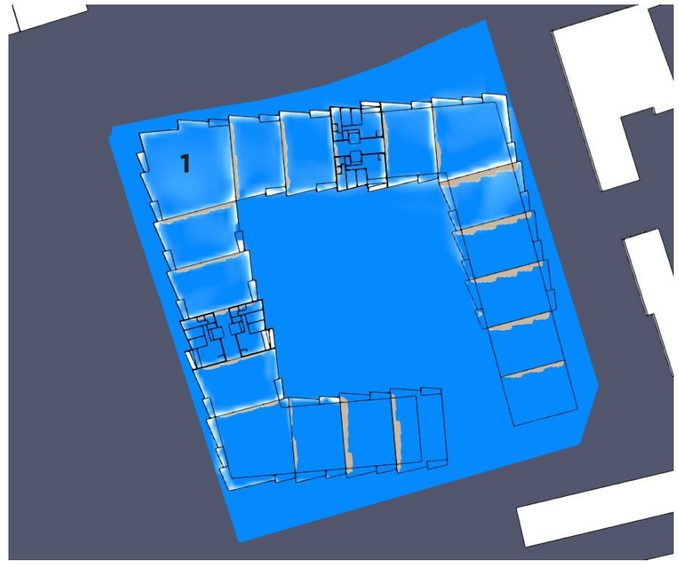
5.2.2 WDR SIMULATION: 0.5mm DROPLETS



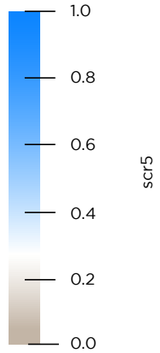
0m

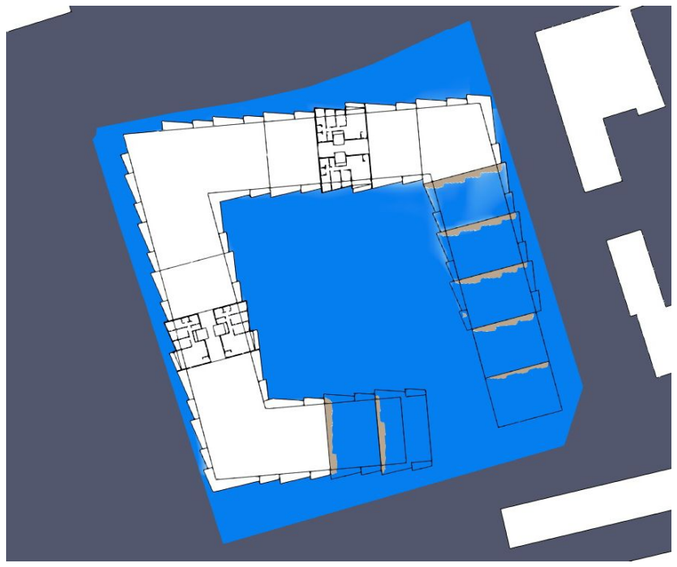


10m

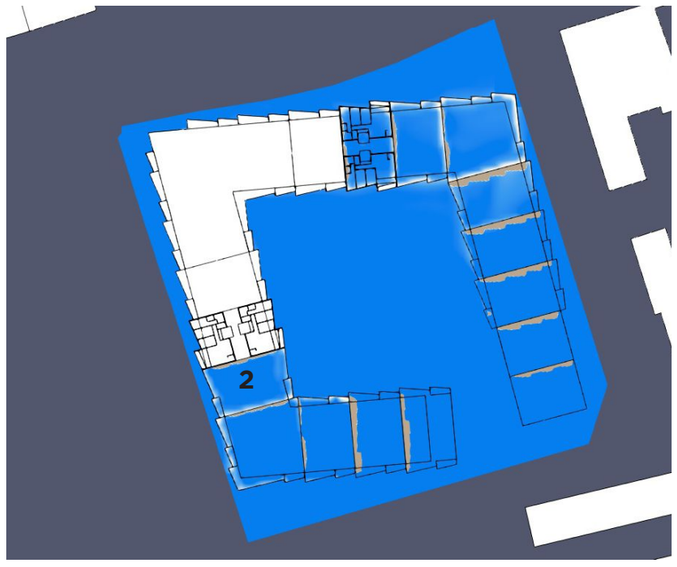


ROOF VIEW





20m



30m

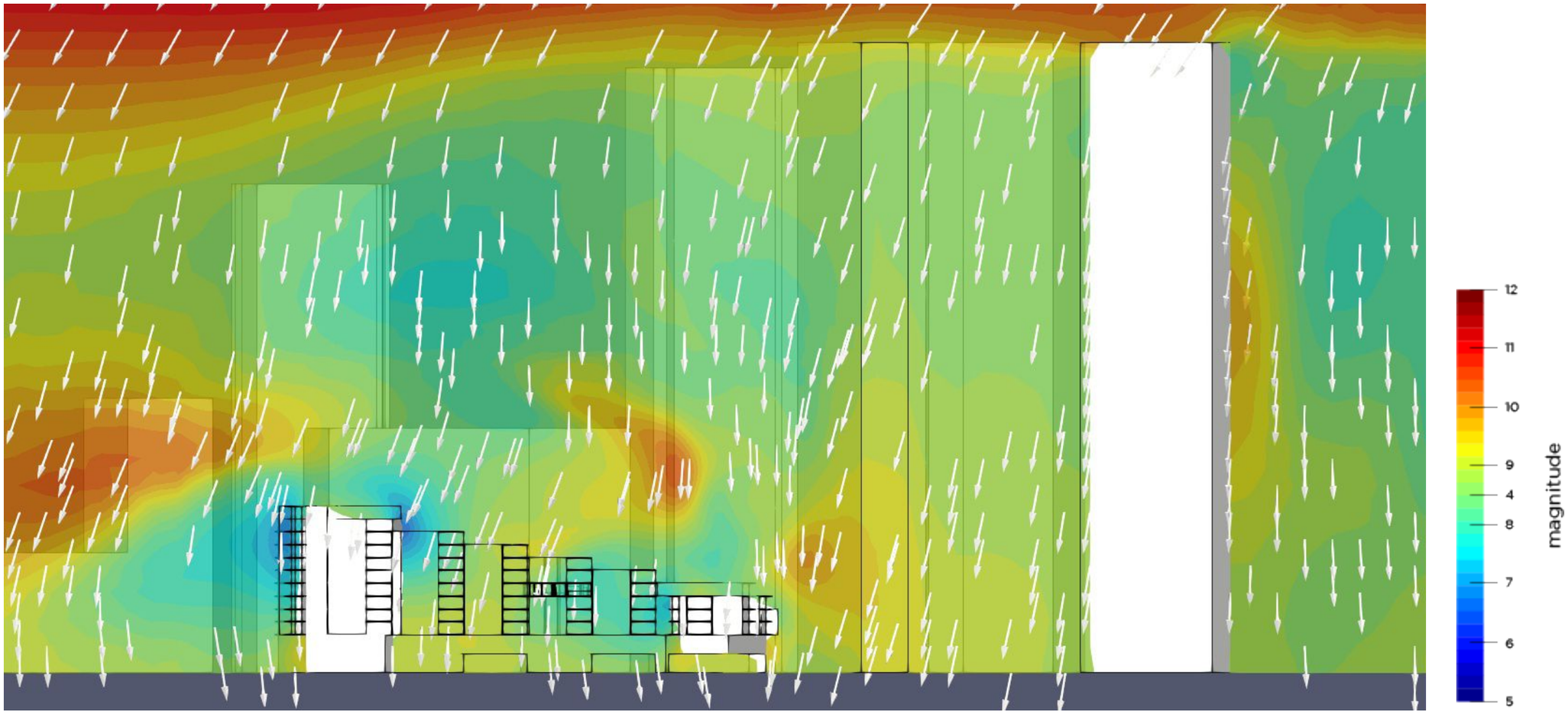
ANALYSIS

1. Terraces are completely exposed to rain
2. Entrances from the living areas to the terraces are sheltered and thus dry
3. The ground floor openings are greatly affected by rain as most of the entrances are wet. However, the NE, E and W edges of the entrances are slightly sheltered hence showing dry spots in that area

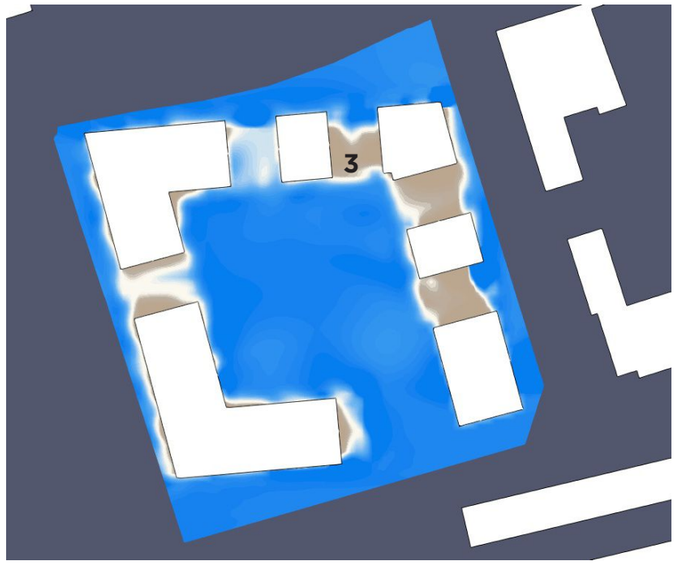
STRATEGIES

Non-porous parapets are used to reduce rain being blown onto the exposed balconies. An additional overhang above the balconies also aids in reducing the rain ingress area.

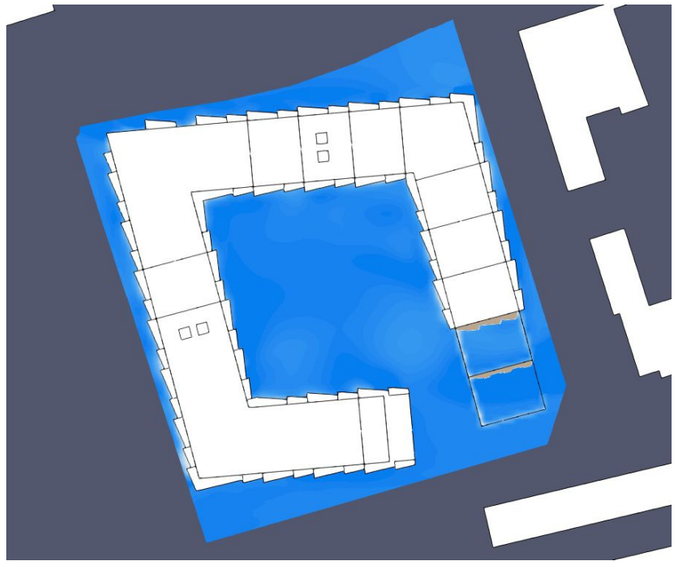
5.2.3 SECTIONAL WIND SPEED: 5.0mm DROPLETS



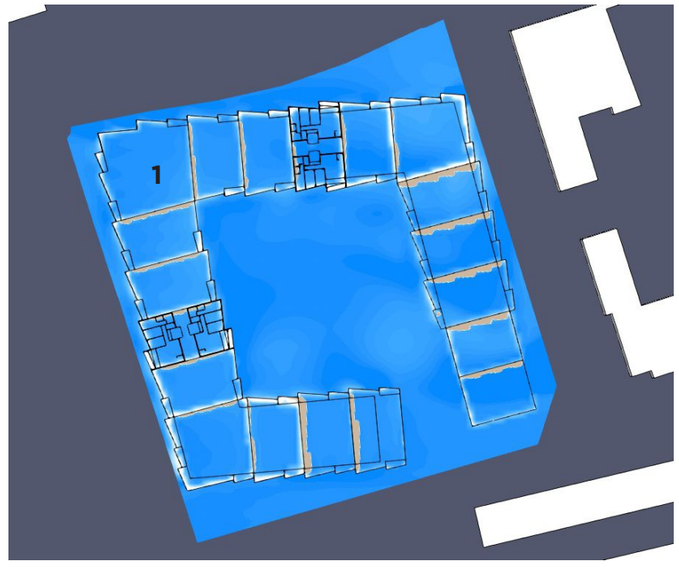
5.2.3 WDR SIMULATION: 5.0mm DROPLETS



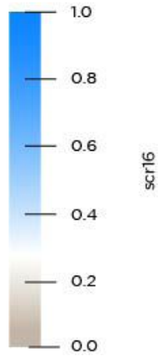
0m

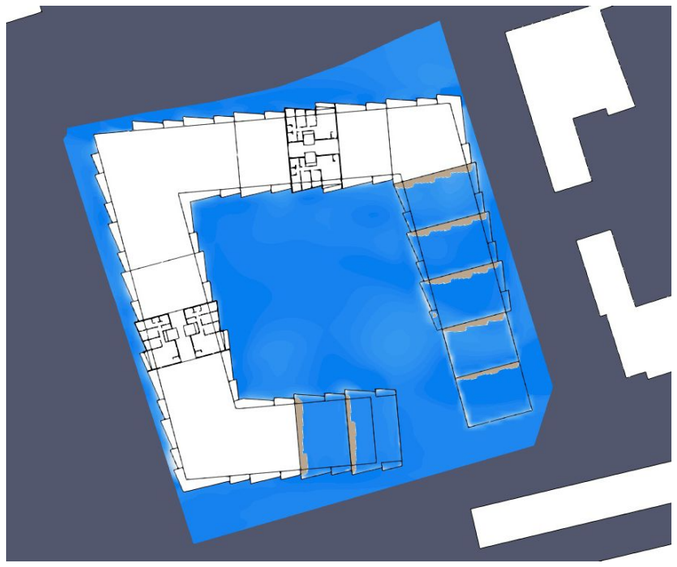


10m

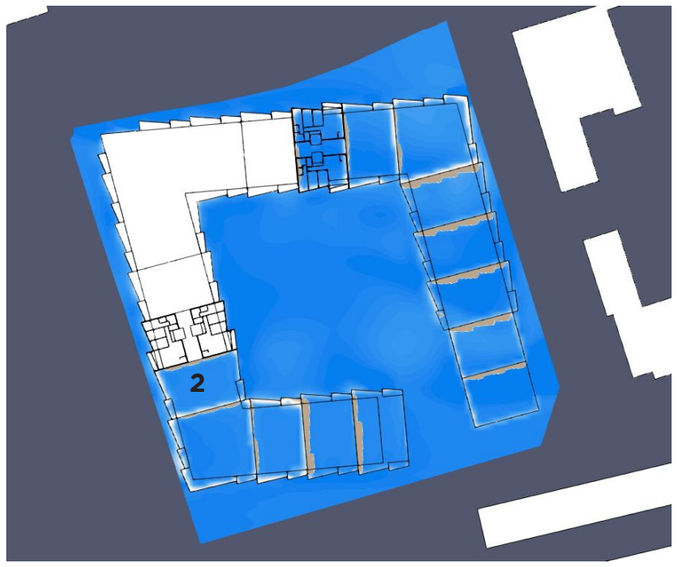


ROOF VIEW





20m



30m

ANALYSIS

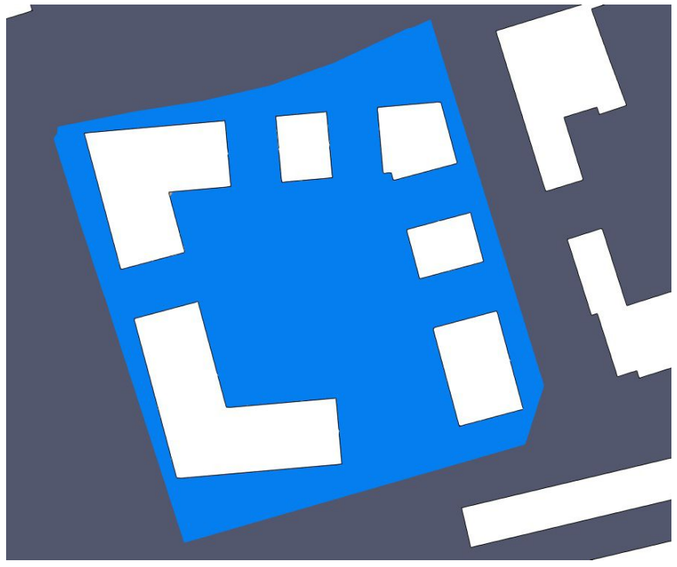
1. Terraces are completely exposed to rain
2. Entrances from the living areas to the terraces are sheltered and thus dry
3. The ground floor opening are less affected in this case due to the difference in droplet size. NE, E and W edges and openings are less affected by the rain and thus shows a largely dry area. However, the North facing opening is still greatly affect, thus showing it fully wet.

STRATEGIES

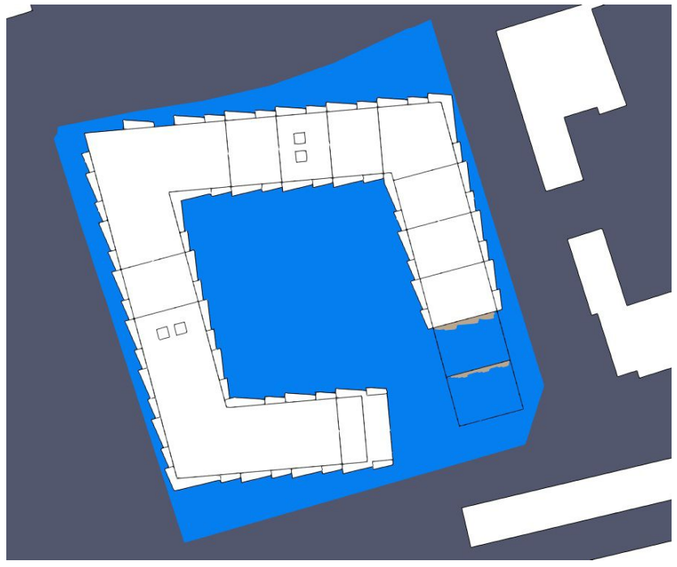
Openings are reduced in size and more spread out along the ground floor.

Non-porous parapets are used to reduce rain being blown onto the exposed balconies. An additional overhang above the balconies also aids in reducing the rain ingress area.

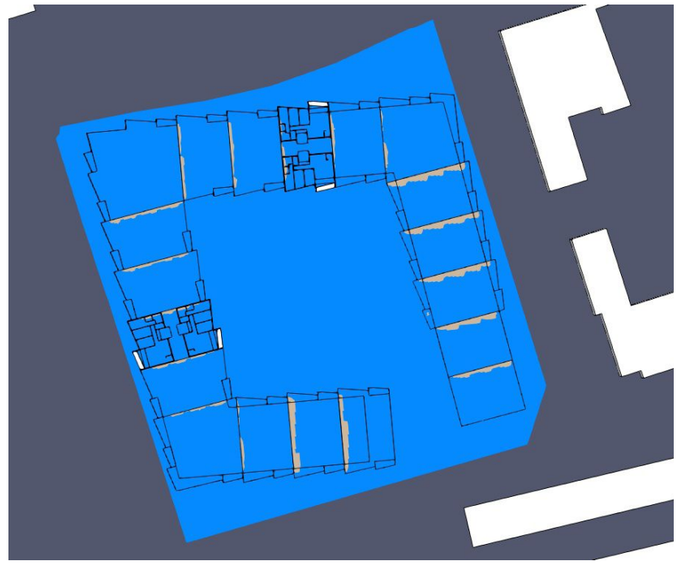
5.2.4 WDR SIMULATION: GLOBAL CATCHMENT RATIO



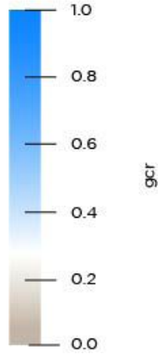
0m

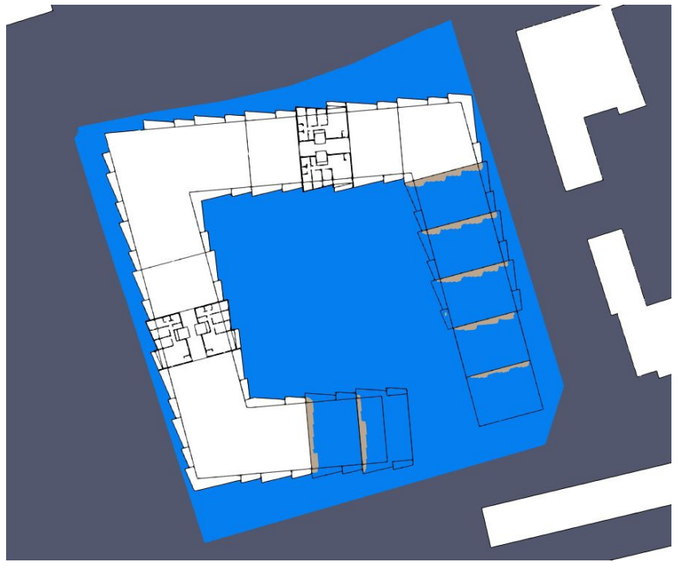


10m

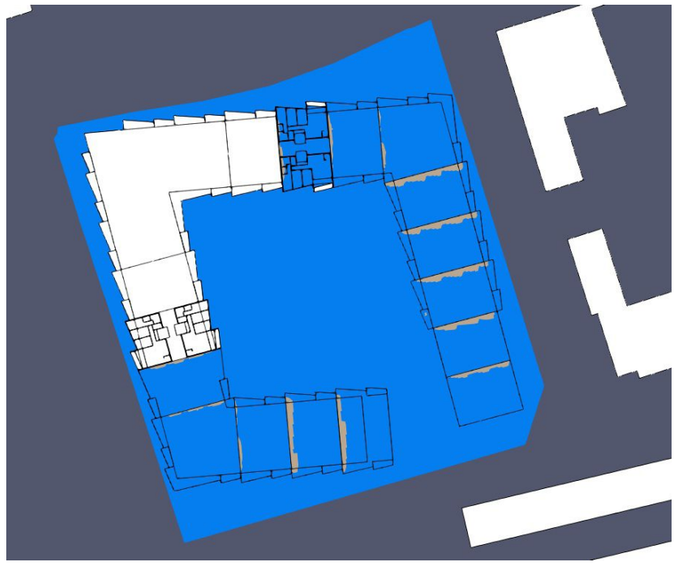


ROOF VIEW





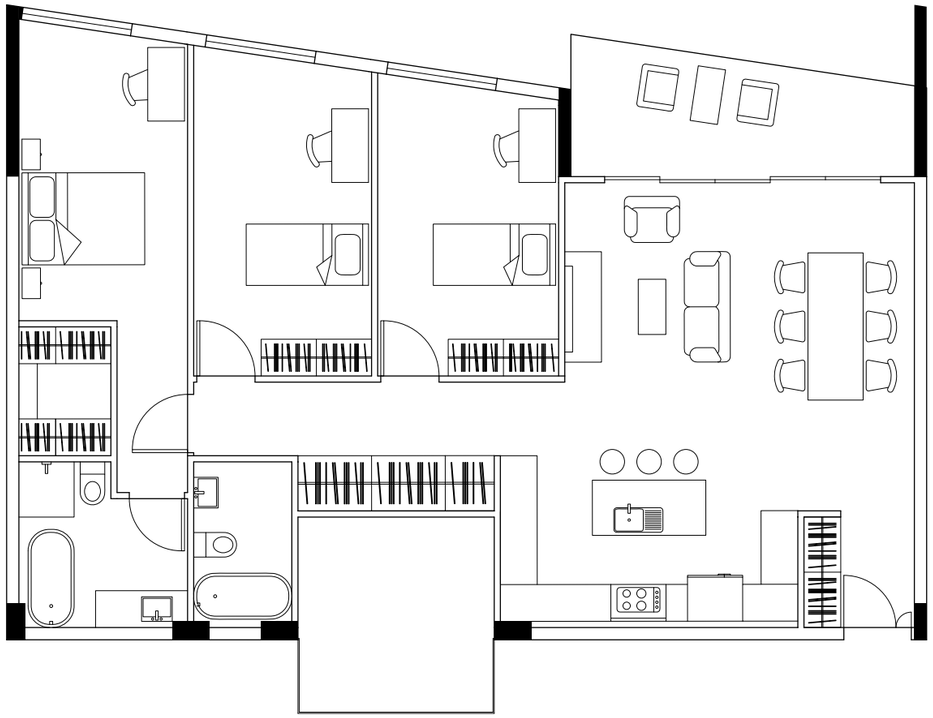
20m



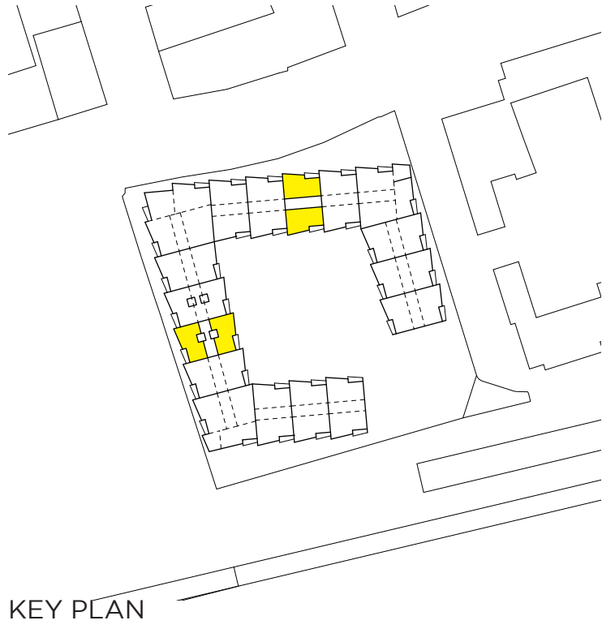
30m

6.0 UNIT AND FACADE DESIGN

6.1 UNIT FLOOR PLAN



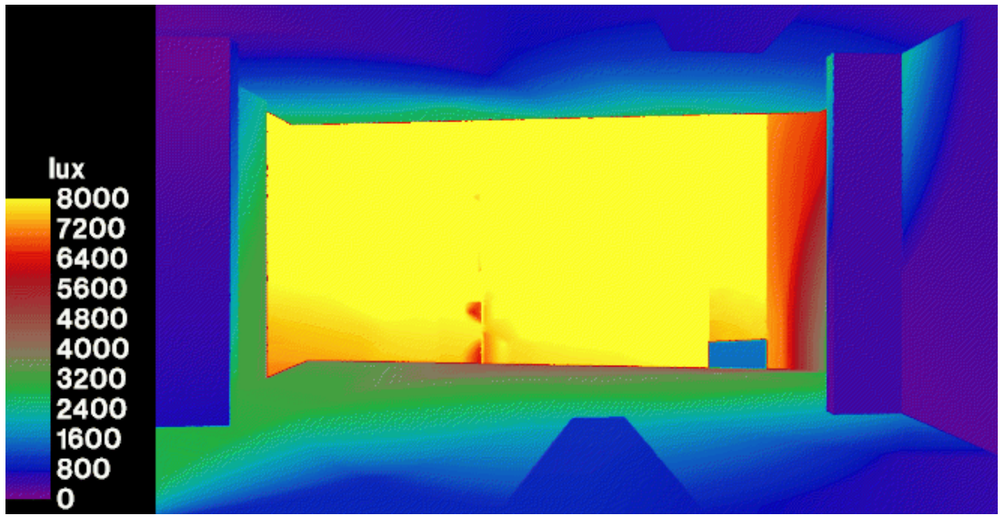
LEVEL 6 UNIT PLAN
(E-W facing units)
SCALE 1:100



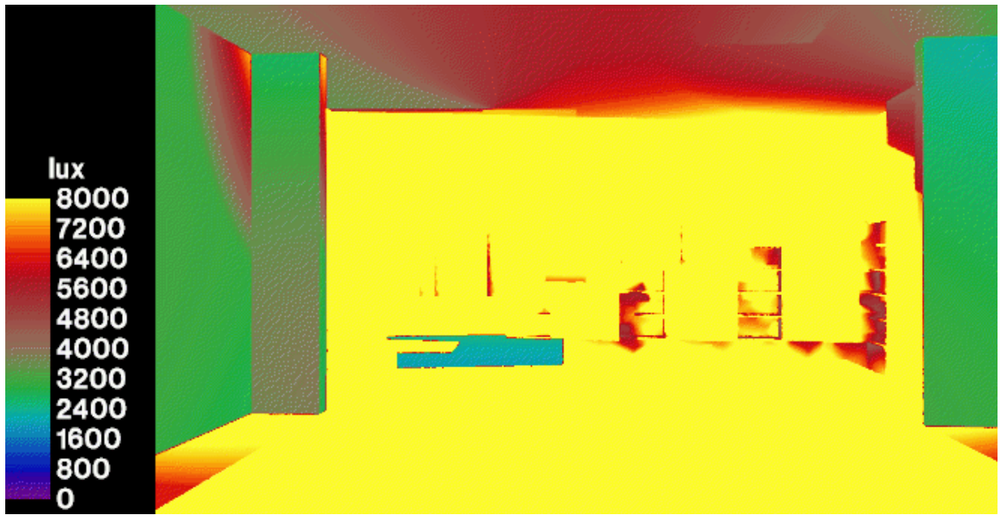
KEY PLAN
SCALE 1:250

6.2 BASE MODEL ANALYSIS

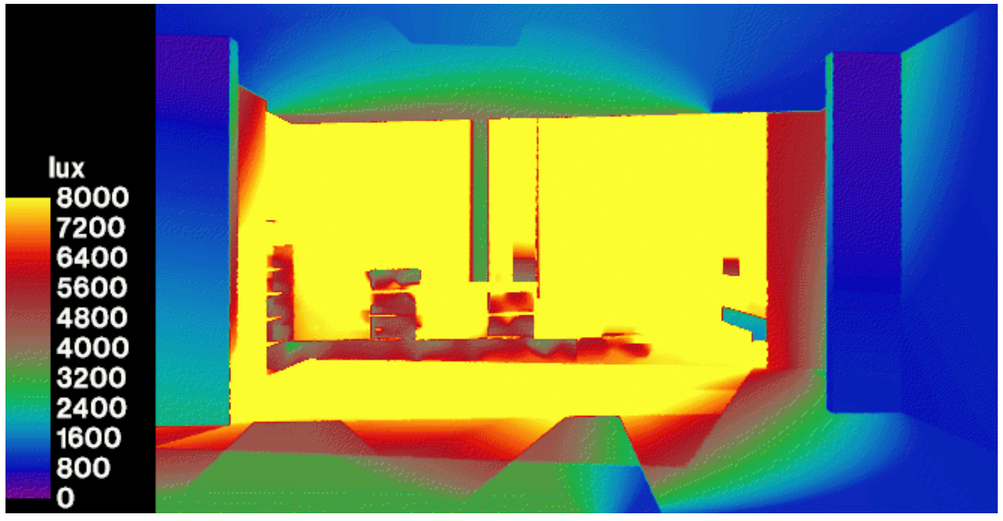
POINT-BASED LUMINANCE



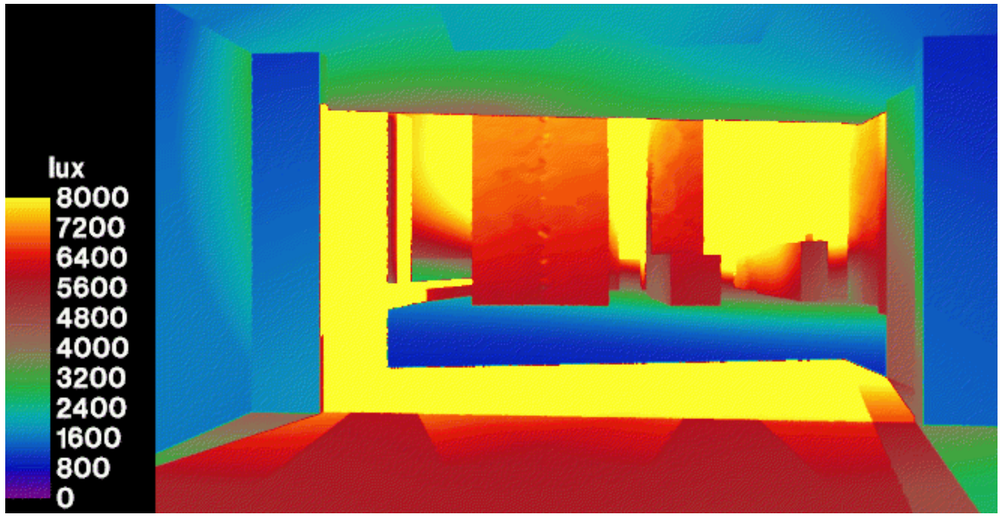
NORTH FACING



SOUTH FACING



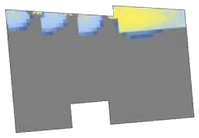
EAST FACING

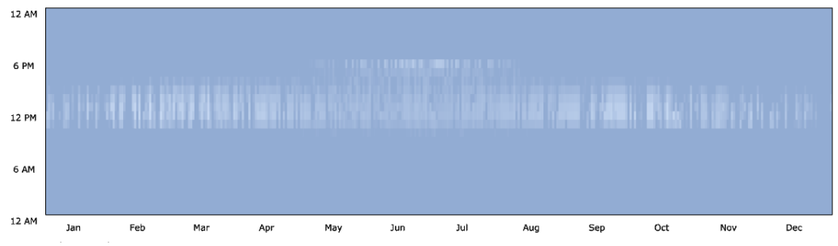


WEST FACING

6.2 BASE MODEL ANALYSIS

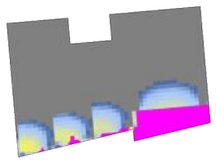
ANNUAL ILLUMINANCE

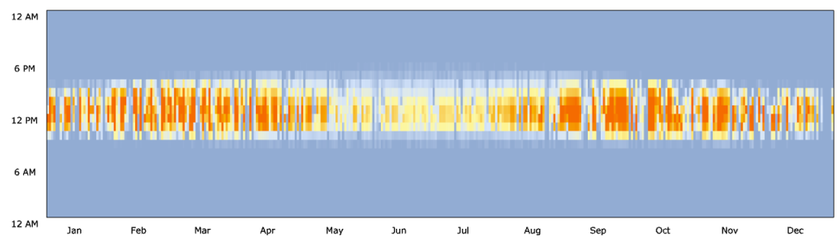




NORTH FACING

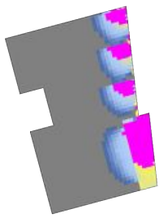
$UD_{200lx,50\%}$ = 32.57%
$UDI_{3000lx,10\%}$ = 10.12%
$DA_{200lx,50\%}$ = 22.45%

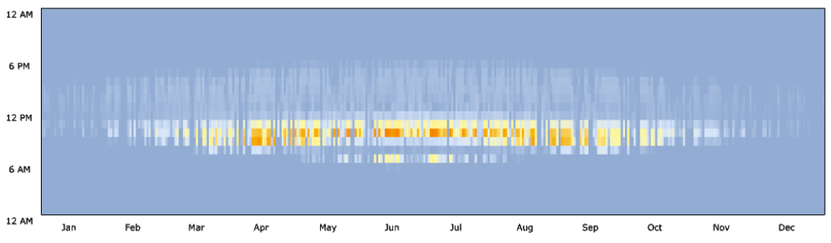




SOUTH FACING

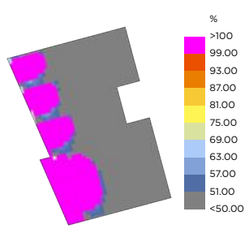
$UD_{200lx,50\%}$ = 34.65%
$UDI_{3000lx,10\%}$ = 28.33%
$DA_{200lx,50\%}$ = 6.32%

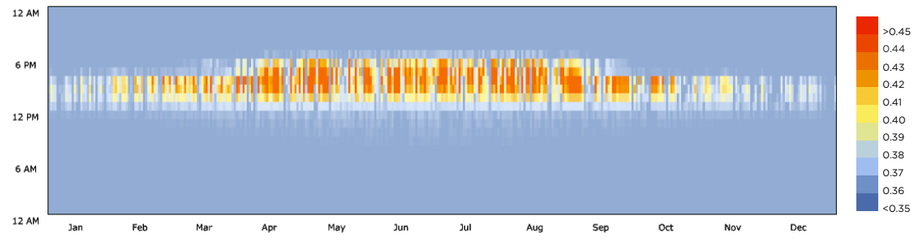




EAST FACING

$UD_{200lx,50\%}$ = 19.86%
$UDI_{3000lx,10\%}$ = 0%
$DA_{200lx,50\%}$ = 19.86%



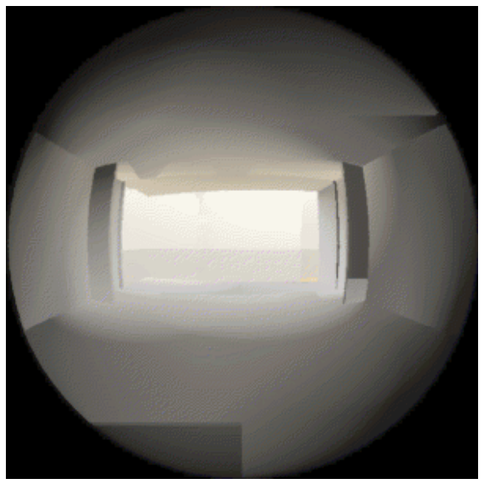


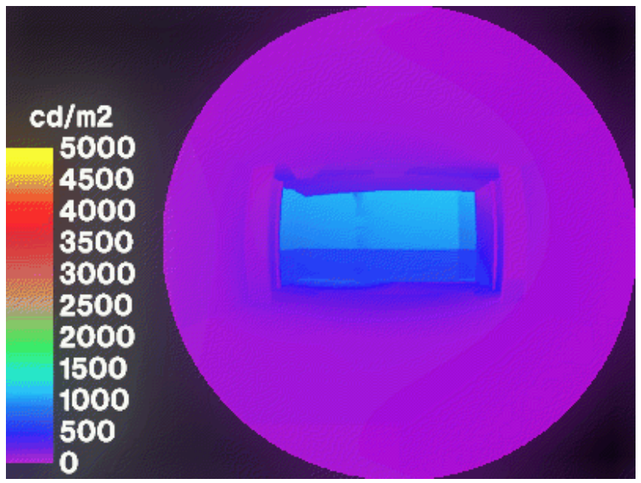
WEST FACING

$UD_{200lx,50\%}$ = 29.55%
$UDI_{3000lx,10\%}$ = 11.60%
$DA_{200lx,50\%}$ = 17.95%

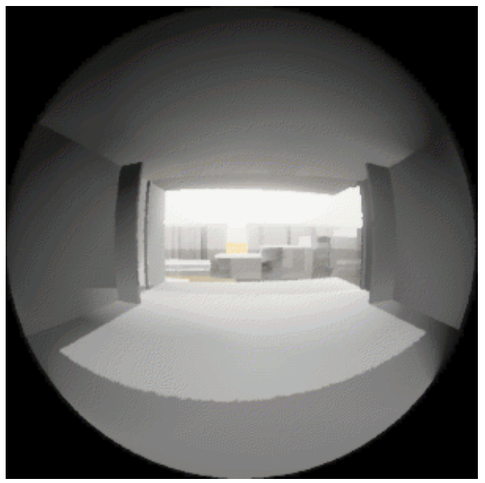
6.2 BASE MODEL ANALYSIS

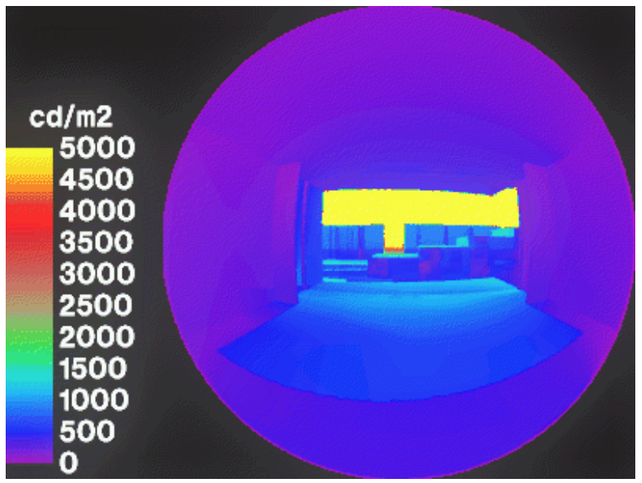
POINT-BASED GLARE (LIVING ROOM)



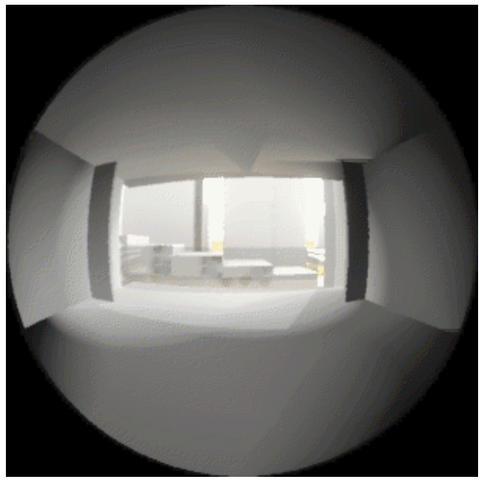


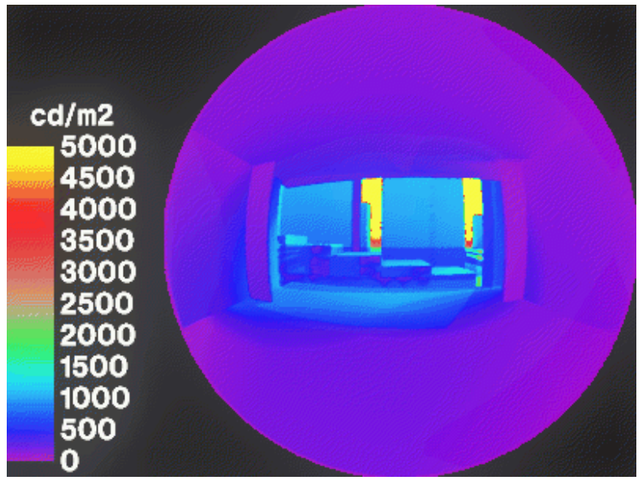
NORTH FACING (JUN 12PM)
DGP = 0.232



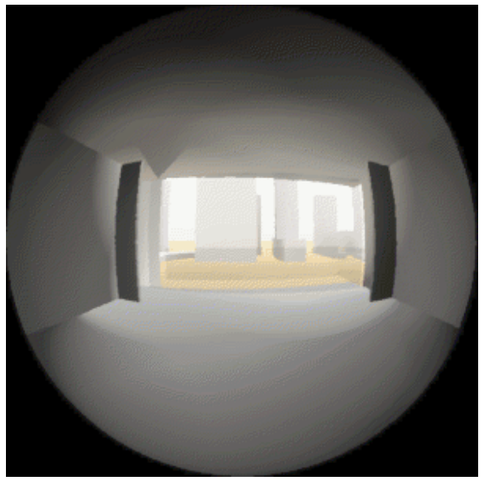


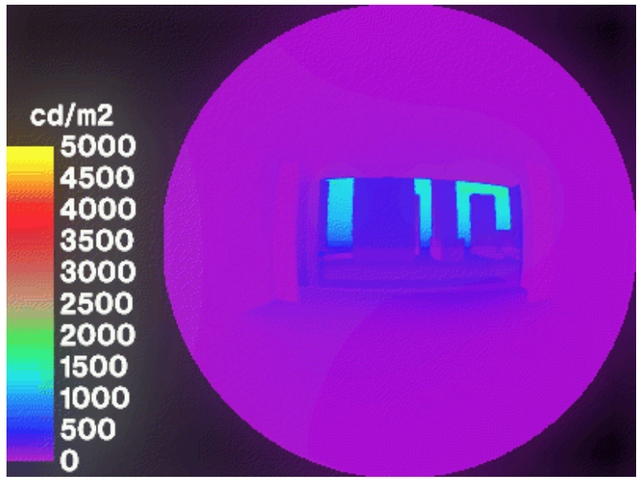
SOUTH FACING (JAN 12PM)
DGP = 0.382





EAST FACING (MAY 9AM)
DGP = 0.269

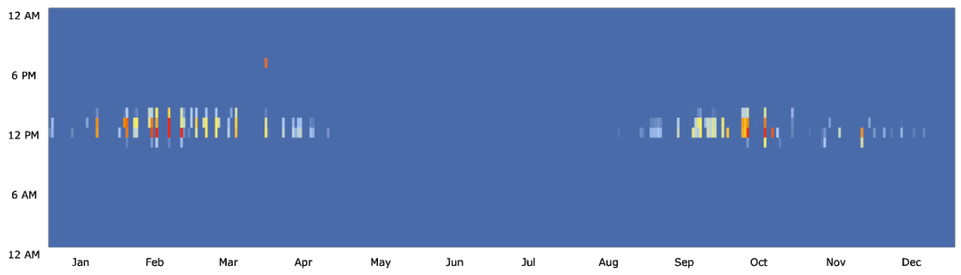




WEST FACING (AUG 6PM)
DGP = 0.199

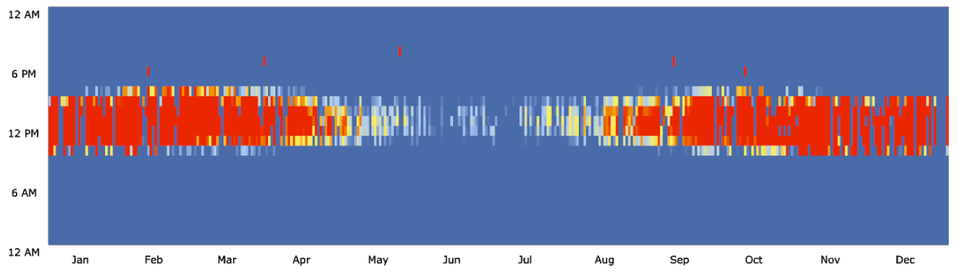
6.2 BASE MODEL ANALYSIS

ANNUAL DAYLIGHT GLARE POTENTIAL (DGP)



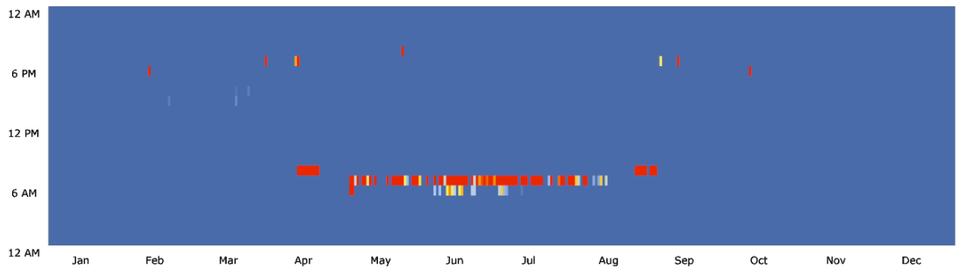
NORTH FACING

$UD_{200lx,50\%}$ = 32.57%
$UDI_{3000lx,10\%}$ = 10.12%
$DA_{200lx,50\%}$ = 22.45%



SOUTH FACING

$UD_{200lx,50\%}$ = 34.65%
$UDI_{3000lx,10\%}$ = 28.33%
$DA_{200lx,50\%}$ = 6.32%



EAST FACING

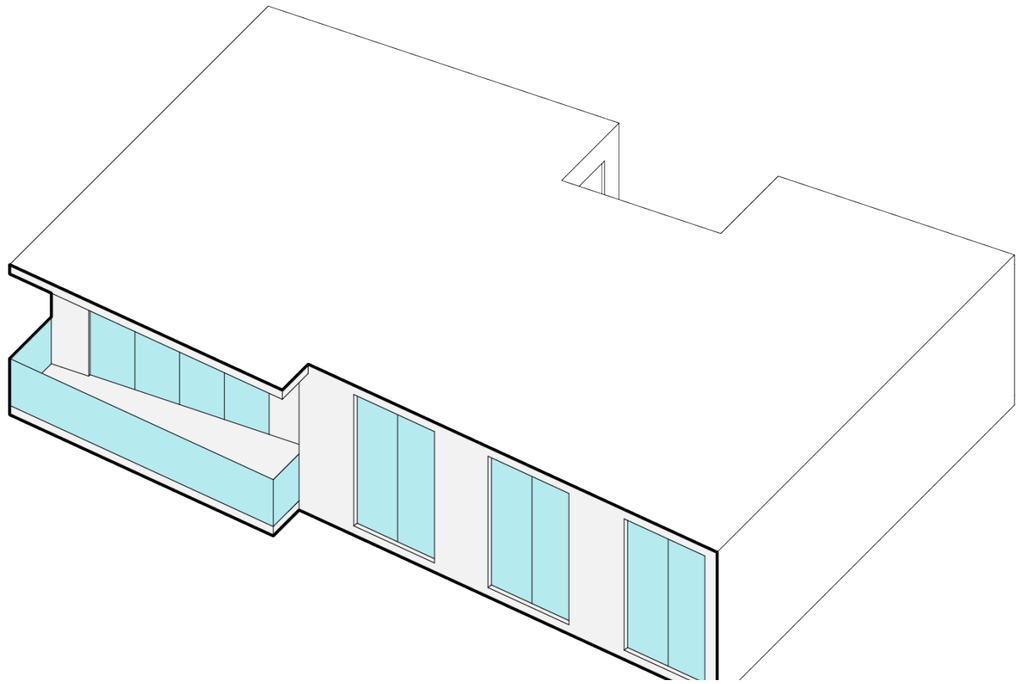
$UD_{200lx,50\%}$ = 19.86%
$UDI_{3000lx,10\%}$ = 0%
$DA_{200lx,50\%}$ = 19.86%

WEST FACING

$UD_{200lx,50\%}$ = 29.55%
$UDI_{3000lx,10\%}$ = 11.60%
$DA_{200lx,50\%}$ = 17.95%

6.2 BASE MODEL ANALYSIS

EVALUATION



ILLUMINANCE

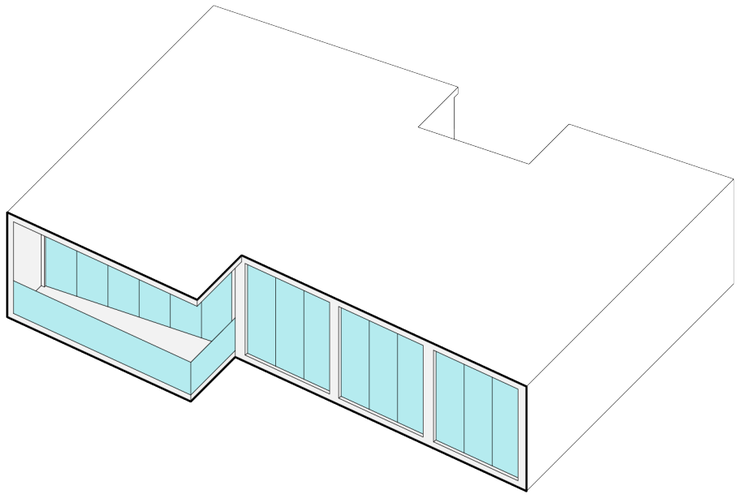
From the simulations done for annual illuminance, the units oriented west and south are generally more illuminated throughout. The unit orient west faces greater illumination in the summer from April to September, where as the unit oriented south receives greater illumination from August to April. However, the overlit areas, $UDI_{3000LX,10\%}$ for both these units are relatively large at 28.33% and 11.60% respectively, leaving the useful daylit area, $DA_{200LX,50\%}$ for the west unit at 6.32% and the south at 17.95%. In comparison, the east and north units have a lower $UD_{200LX,50\%}$ and $UDI_{3000LX,10\%}$,but are still able to maintain higher $DA_{200LX,50\%}$ at 22.45% in the east and 19.86% in the north.

GLARE

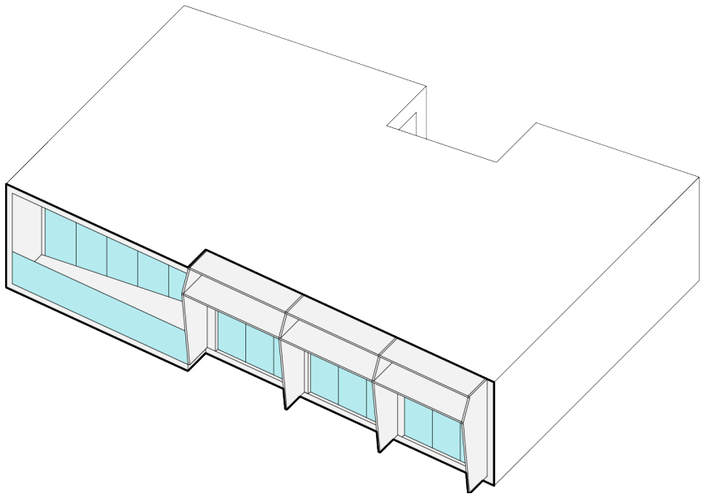
From the graph received from the annual DGP simulation, we are able to obtain the approximate time period for the worst glare situation for each unit orientation. The point-based glare simulation done in reciprocal to these time periods than gives us a relatively low illuminance from 0 to 1000 cd/m2. The west facing unit has the lowest DGP of 0.199, while the South facing unit has the most intense glare with a DGP of 0.382. The east and north facing units have a DGP of 0.269 and 0.232 respectively. This is in contrast to the annual DGP graph which indicates that the west should receive high gare as well together with the south facing unit.

While the DGP value obtained from the point-based glare simulation does not seem to correlate with the graph obtained from that of the annual DGP, this could be due to the fact that the DGP obtained is point-based at a specific time, and may not be representative of the glare received at the west facing unit at that time period. However, the same time was used for analysis for all the proposed facade design for the west facing units, and thus our aims of lowering the glare in that unit will not be affected by this anomaly and will still be effective in analysing the facade design strategies to be used.

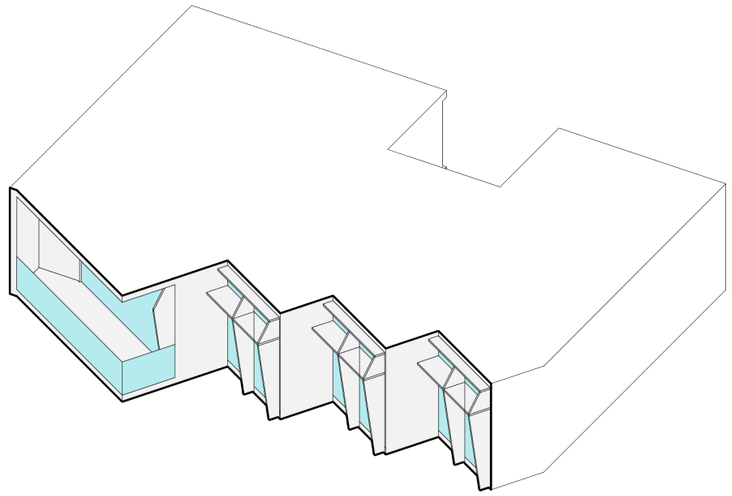
6.3 FACADE DESIGN STRATEGIES



DESIGN A
Increase WWR ratio by having more glass to allow more light in



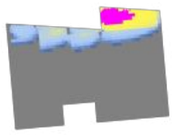
DESIGN B
Vertical fins and overhangs are designed in addition to design A

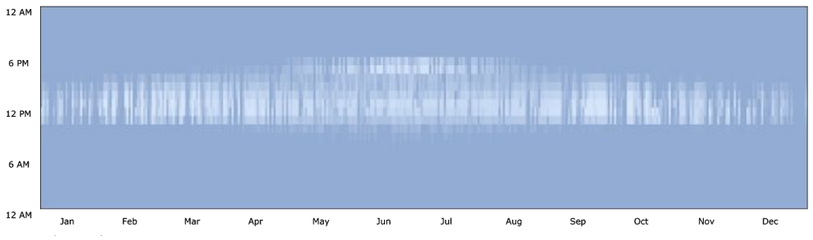


DESIGN C
More angled glass with same placement of fins and overhang as design B

6.3.1 DESIGN A

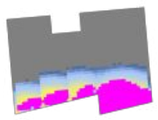
ANNUAL ILLUMINANCE

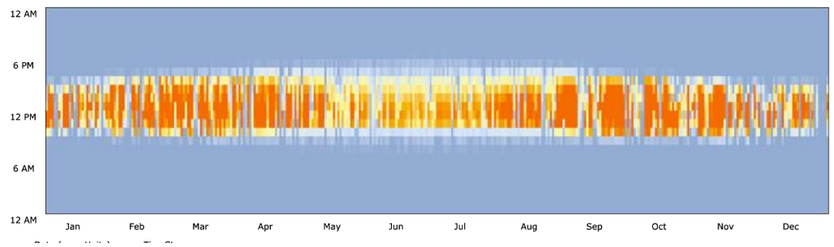




NORTH FACING

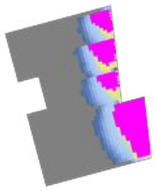
$UD_{200lx,50\%}$ = 27.14%
$UDI_{3000lx,10\%}$ = 3.2%
$DA_{200lx,50\%}$ = 23.94%

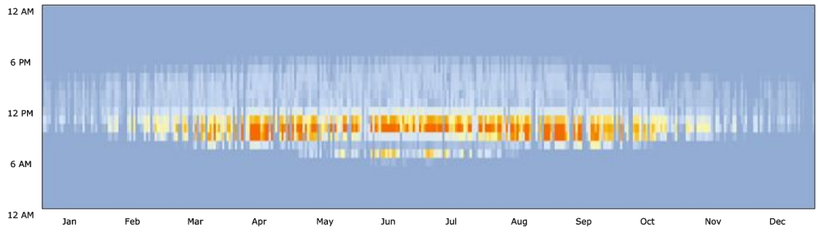




SOUTH FACING

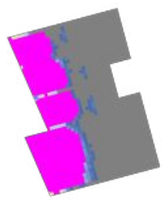
$UD_{200lx,50\%}$ = 41.75%
$UDI_{3000lx,10\%}$ = 19.07%
$DA_{200lx,50\%}$ = 22.68%

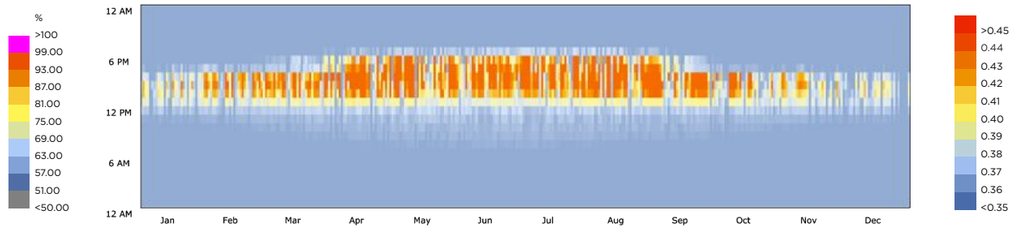




SOUTH FACING

$UD_{200lx,50\%}$ = 41.4%
$UDI_{3000lx,10\%}$ = 18.00%
$DA_{200lx,50\%}$ = 23.41%



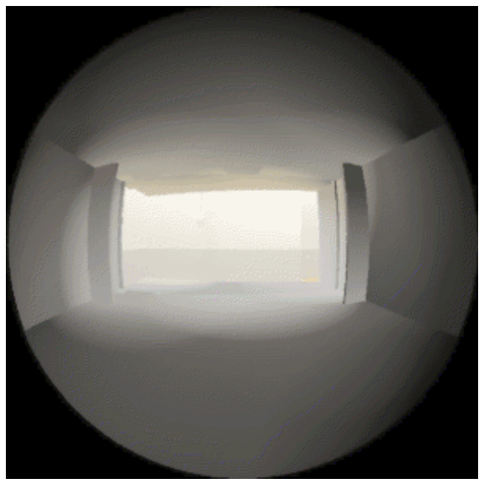


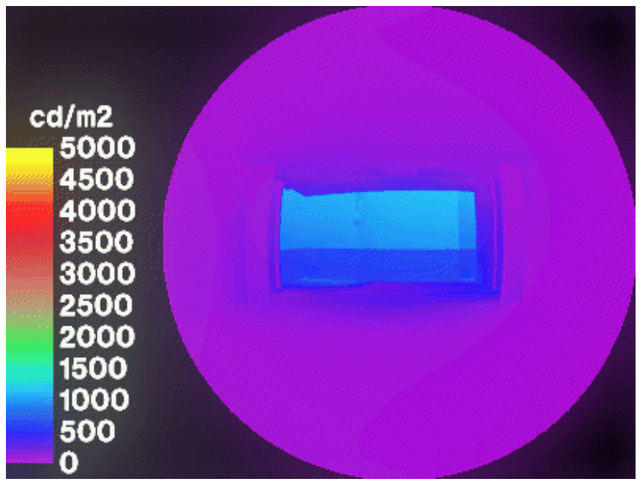
WEST FACING

$UD_{200lx,50\%}$ = 46.36%
$UDI_{3000lx,10\%}$ = 36.23%
$DA_{200lx,50\%}$ = 10.13%

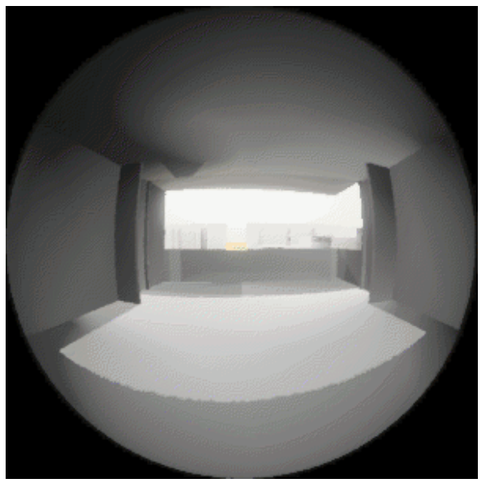
6.3.1 DESIGN A

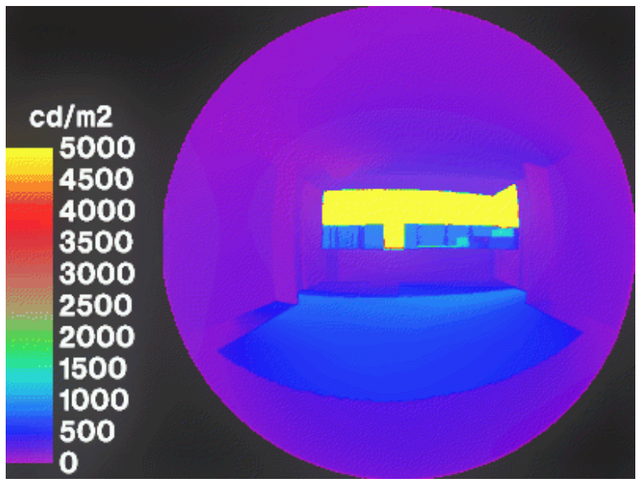
POINT-BASED GLARE (LIVING ROOM)



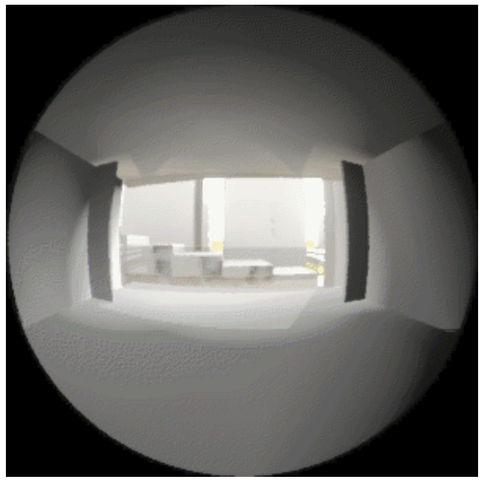


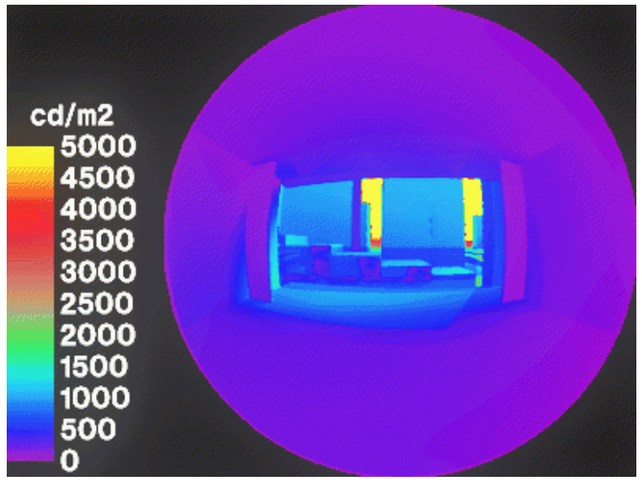
NORTH FACING (JUN 12PM)
DGP = 0.232



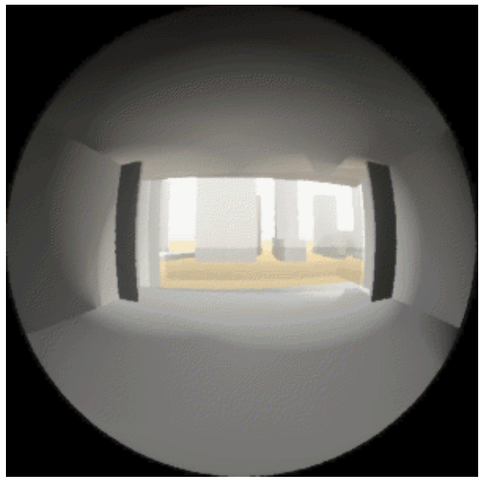


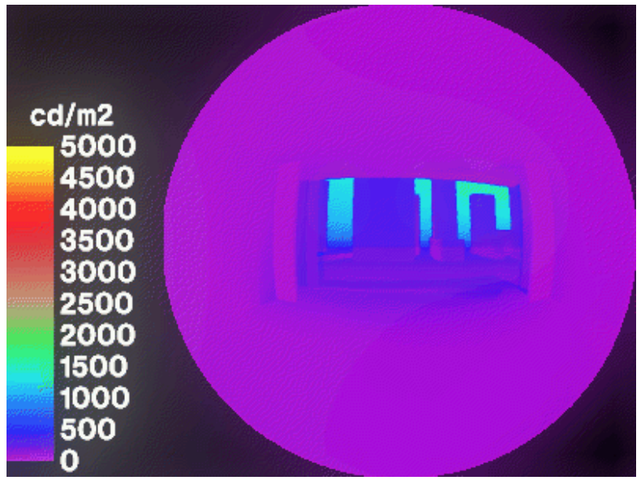
SOUTH FACING (JAN 12PM)
DGP = 0.381





EAST FACING (MAY 9AM)
DGP = 0.270

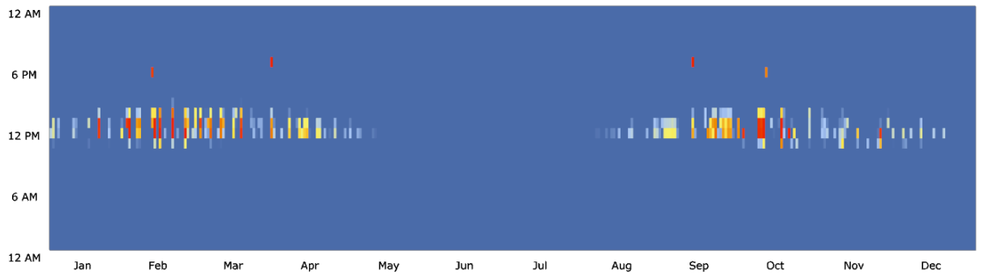




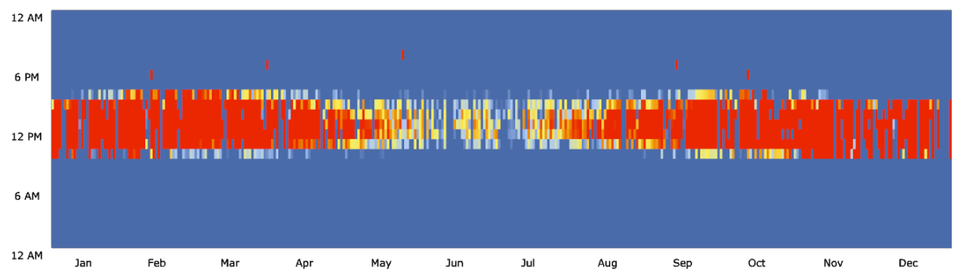
WEST FACING (AUG 6PM)
DGP = 0.201

6.3.1 DESIGN A

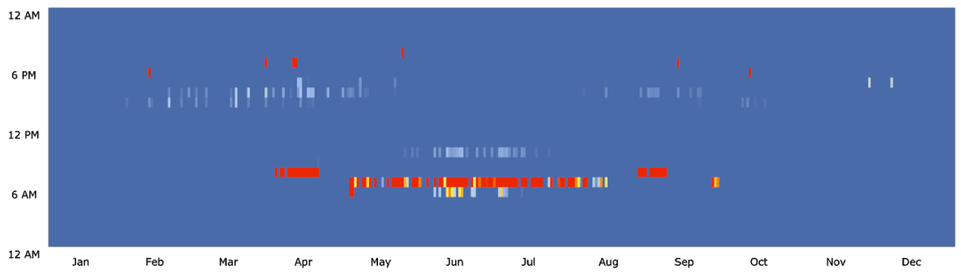
ANNUAL DAYLIGHT GLARE POTENTIAL (DGP)



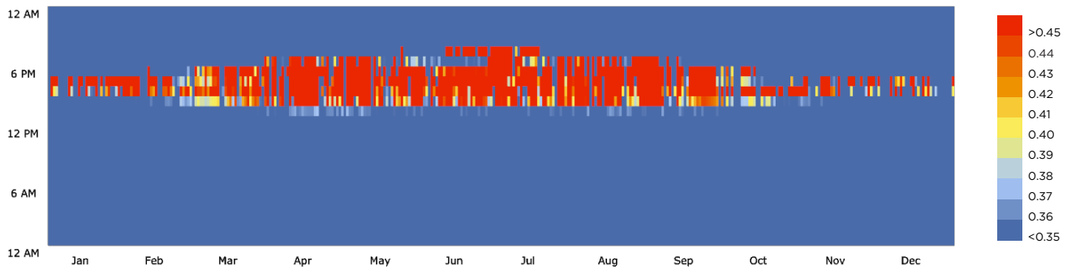
NORTH FACING



SOUTH FACING



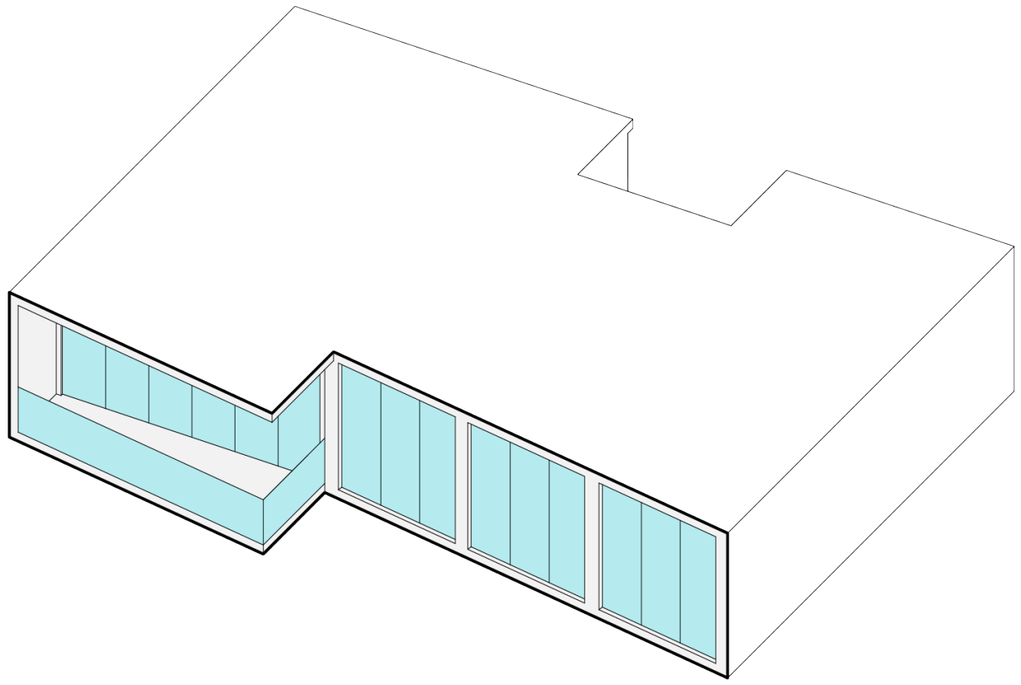
EAST FACING



WEST FACING

6.3.1 DESIGN A

EVALUATION



ILLUMINANCE

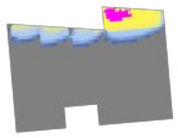
To increase the useful daylit area within the unit, design A opts to have larger windows to increase the illuminance of the unit. However, with larger windows, the overlit areas also increase together with the total daylit area, resulting in the overall useful daylit area to be lower than that of the baseline unit for all unit orientations.

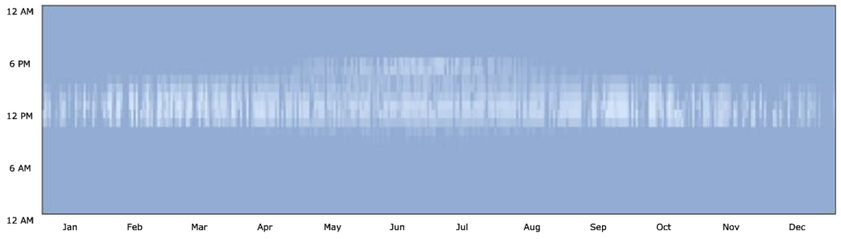
GLARE

With design A, the glare does not change much. The DGP values obtained in comparison to the baseline model only deviate by 0.001, and this is constant throughout the orientations. Thus, it is safe to say that design A does not result in a change to the glare in the unit.

6.3.2 DESIGN B

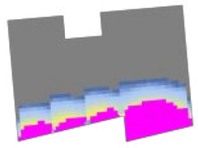
ANNUAL ILLUMINANCE

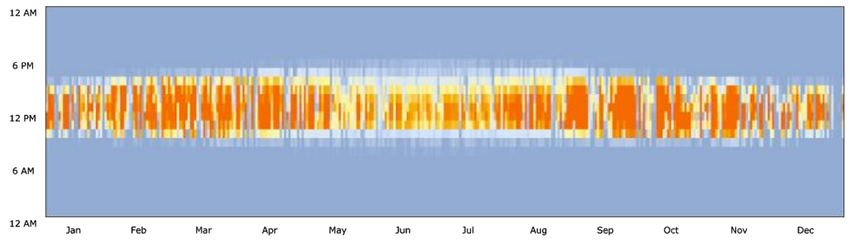




NORTH FACING

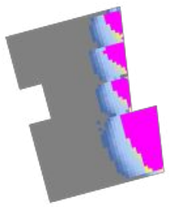
$UD_{200lx,50\%}$ = 23.41%
$UDI_{3000lx,10\%}$ = 1.75%
$DA_{200lx,50\%}$ = 21.66%

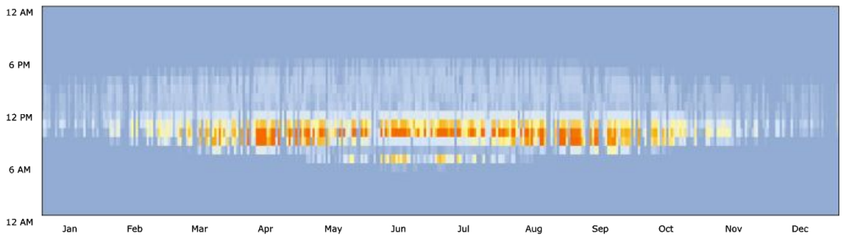




SOUTH FACING

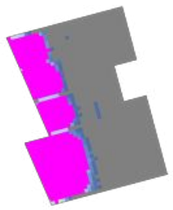
$UD_{200lx,50\%}$ = 37.92%
$UDI_{3000lx,10\%}$ = 17.82%
$DA_{200lx,50\%}$ = 20.10%

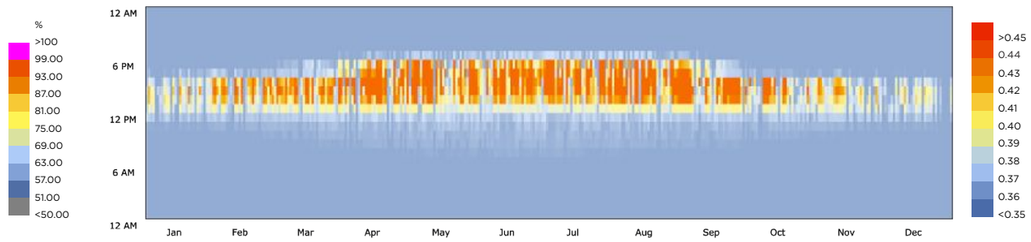




EAST FACING

$UD_{200lx,50\%}$ = 37.51%
$UDI_{3000lx,10\%}$ = 17.24%
$DA_{200lx,50\%}$ = 20.27%



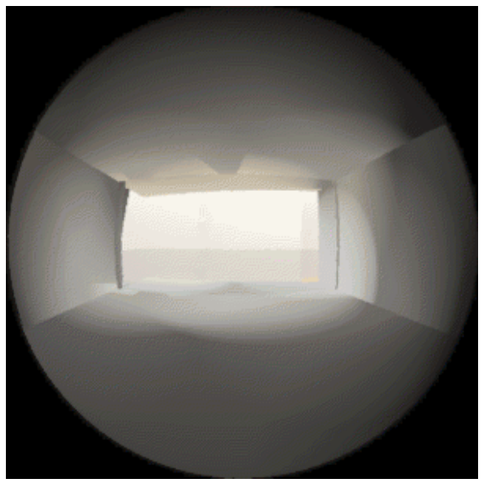


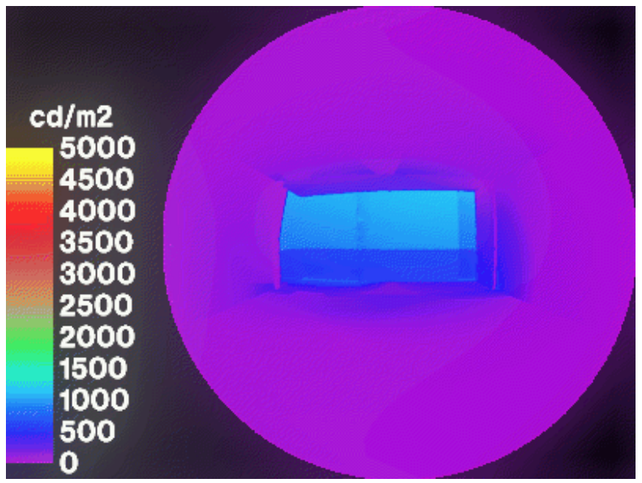
WEST FACING

$UD_{200lx,50\%}$ = 41.35%
$UDI_{3000lx,10\%}$ = 33.20%
$DA_{200lx,50\%}$ = 8.15%

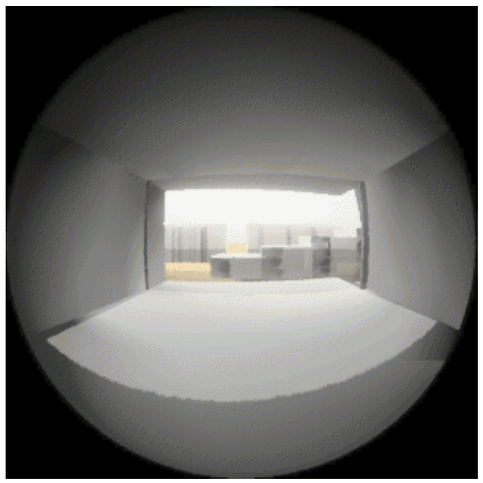
6.3.2 DESIGN B

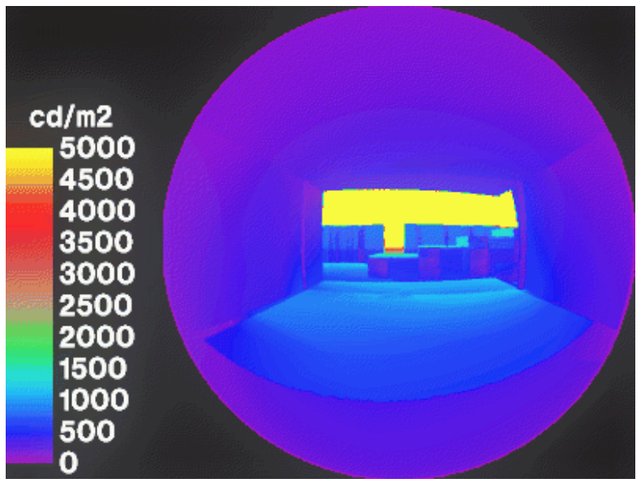
POINT-BASED GLARE (LIVING ROOM)



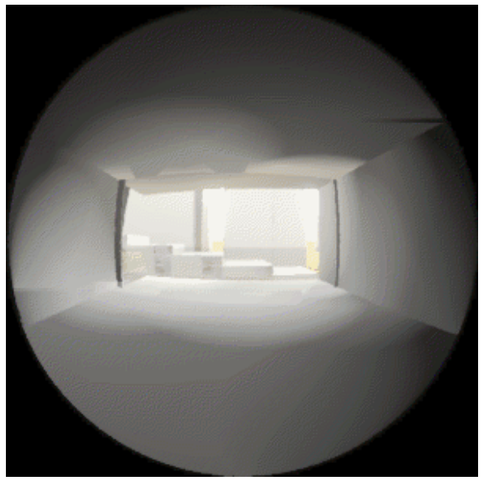


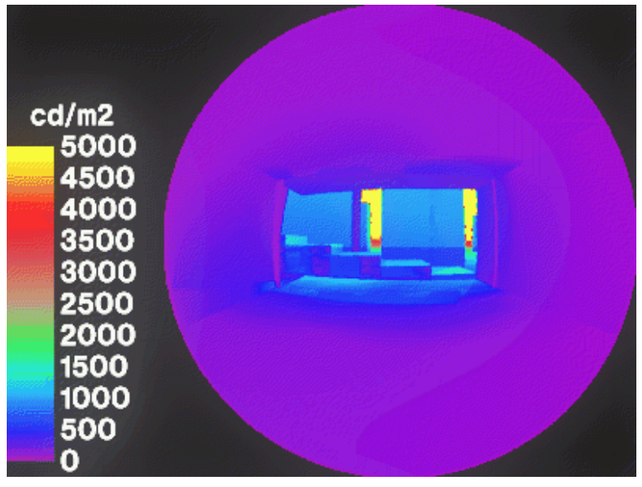
NORTH FACING (JUN 12PM)
DGP = 0.232



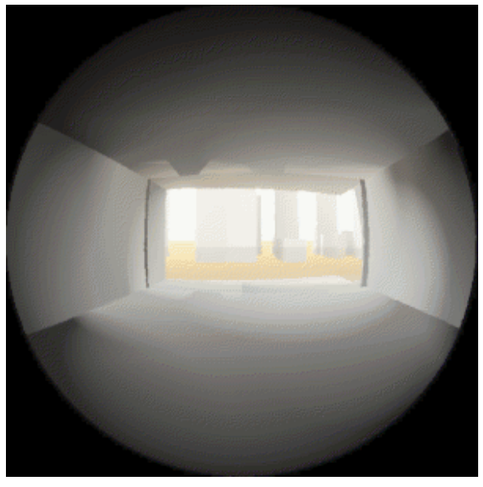


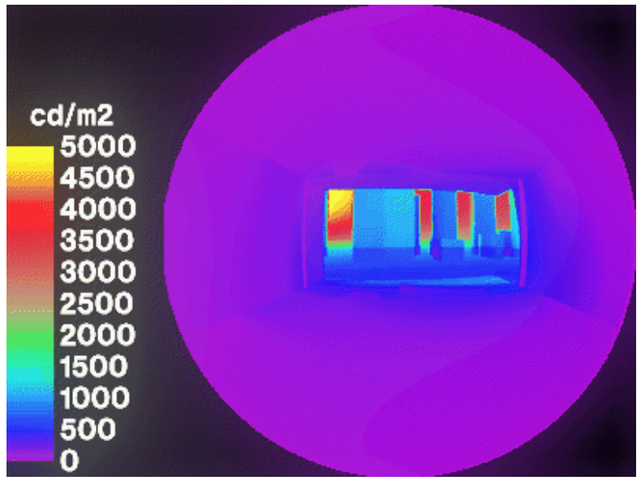
SOUTH FACING (JAN 12PM)
DGP = 0.383





EAST FACING (MAY 9AM)
DGP = 0.247

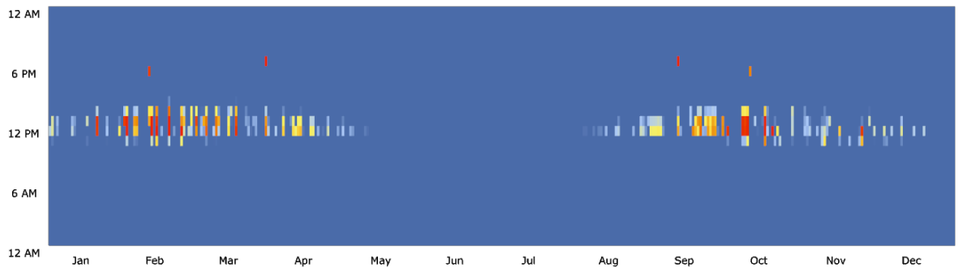




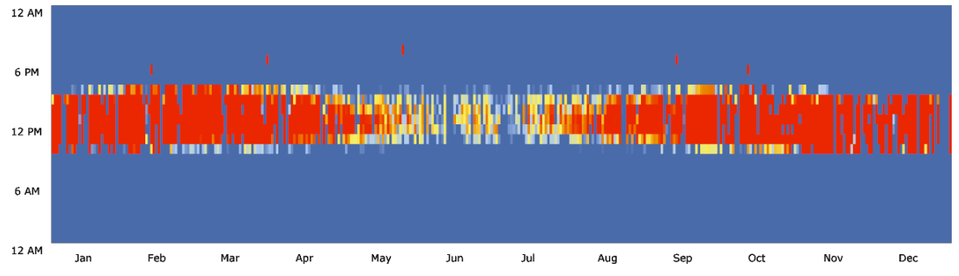
WEST FACING (AUG 6PM)
DGP = 0.248

6.3.2 DESIGN B

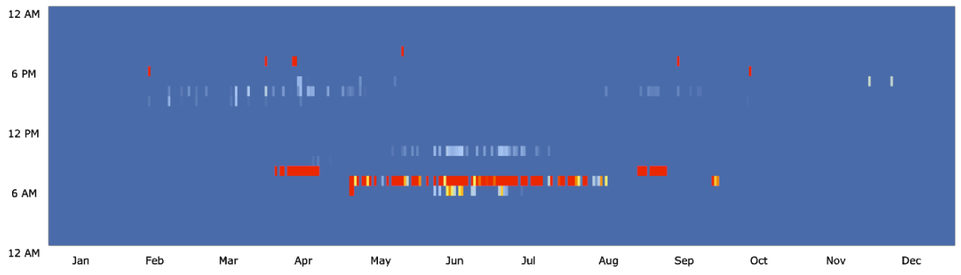
ANNUAL DAYLIGHT GLARE POTENTIAL (DGP)



NORTH FACING



SOUTH FACING

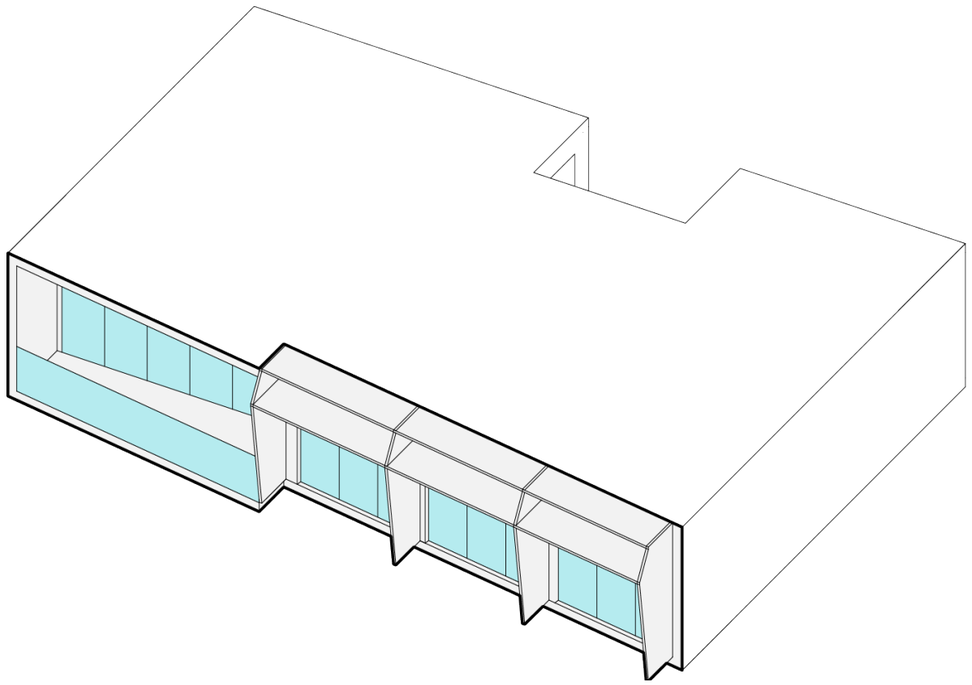


EAST FACING

WEST FACING

6.3.2 DESIGN B

EVALUATION



ILLUMINANCE

Similar to the baseline model, the units oriented west and south are generally more illuminated. Alongside the enlargement of all windows and addition of fins in this Design B, the illumination across all units has increased. This increase includes both the overlit area and useful daylit area, for all units except for the east-facing one. In the east-facing unit, the number of overlit hours has been increased overly significantly to 37.51% such that the useful daylit area has suffered a drop from 22.45% to 20.27%.

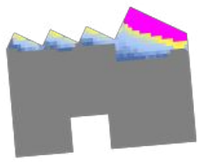
GLARE

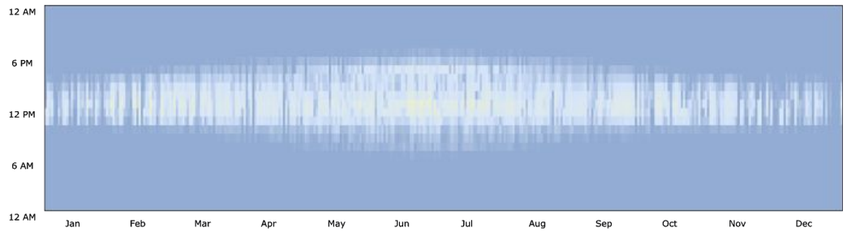
In comparison to the baseline model's point-based glare simulation, the DGP for the west-facing units increased (from 0.1999 to 0.248), indicating worse glare in those units. However, in the east-facing unit, glare reduced slightly (from 0.269 to 0.247), while the north and south-facing units are generally unaffected. When compared to Design A, a similar trend where the east-facing unit improves and west-facing unit worsens signifi cantly is also present.

In the annual daylight glare potential results, glare in the east-facing unit has increased drastically to be highly undesireable. There is a slight worsening of glare in the west-facing unit as well, while the other units remain unaffacted.

6.3.3 DESIGN C

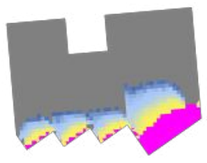
ANNUAL ILLUMINANCE

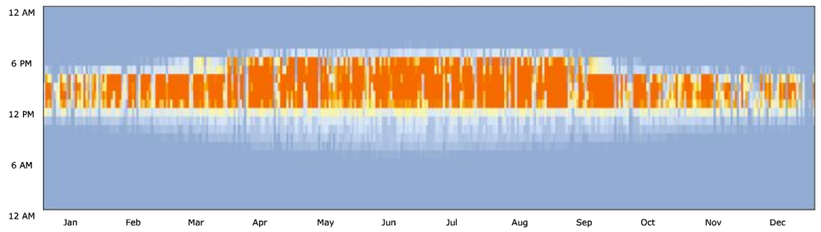




NORTH FACING

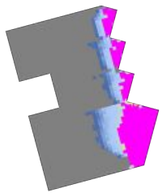
$UD_{200lx,50\%}$ = 24.81%
$UDI_{3000lx,10\%}$ = 8.65%
$DA_{200lx,50\%}$ = 15.53%

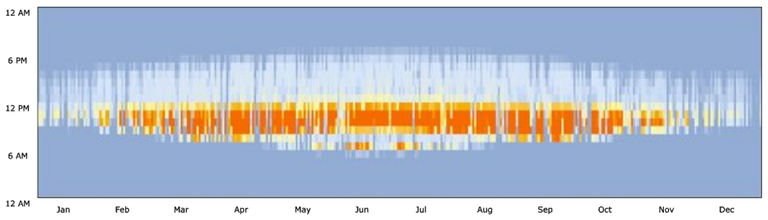




SOUTH FACING

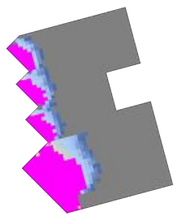
$UD_{200lx,50\%}$ = 33.78%
$UDI_{3000lx,10\%}$ = 13.07%
$DA_{200lx,50\%}$ = 20.71%

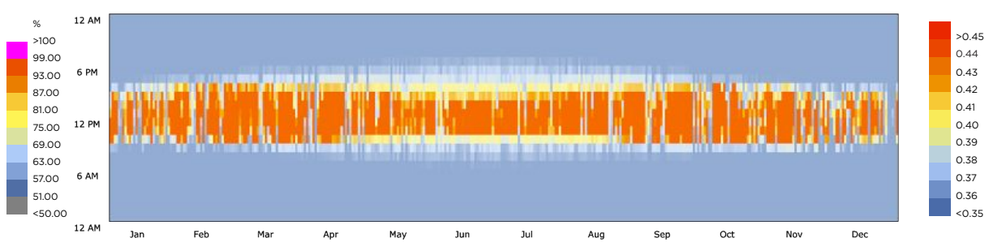




EAST FACING

$UD_{200lx,50\%}$ = 35.23%
$UDI_{3000lx,10\%}$ = 33.20%
$DA_{200lx,50\%}$ = 8.15%



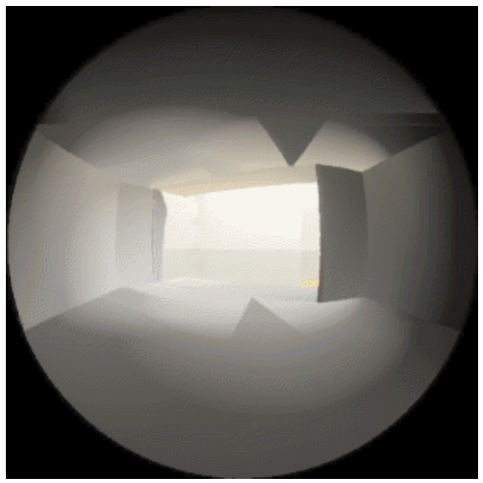


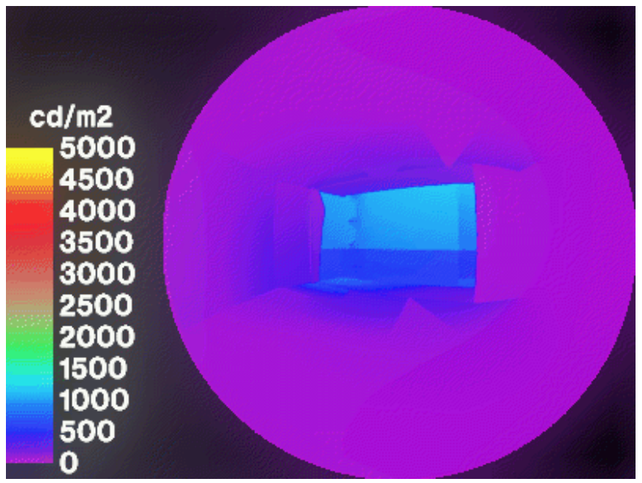
WEST FACING

$UD_{200lx,50\%}$ = 41.35%
$UDI_{3000lx,10\%}$ = 33.20%
$DA_{200lx,50\%}$ = 8.15%

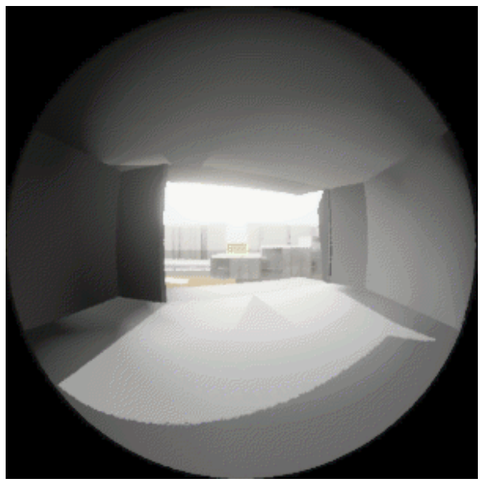
6.3.3 DESIGN C

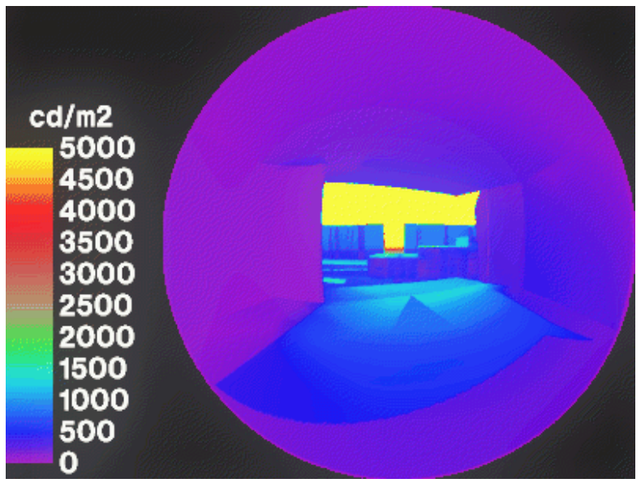
POINT-BASED GLARE (LIVING ROOM)



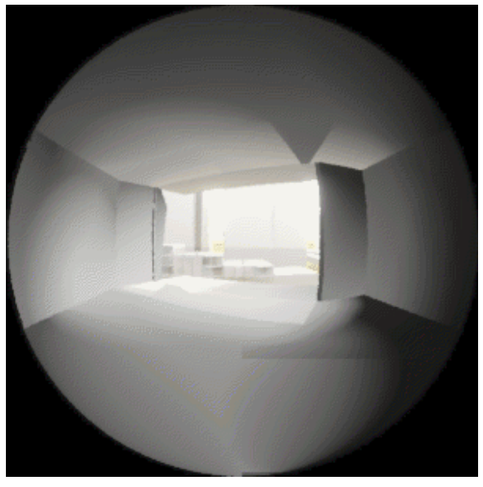


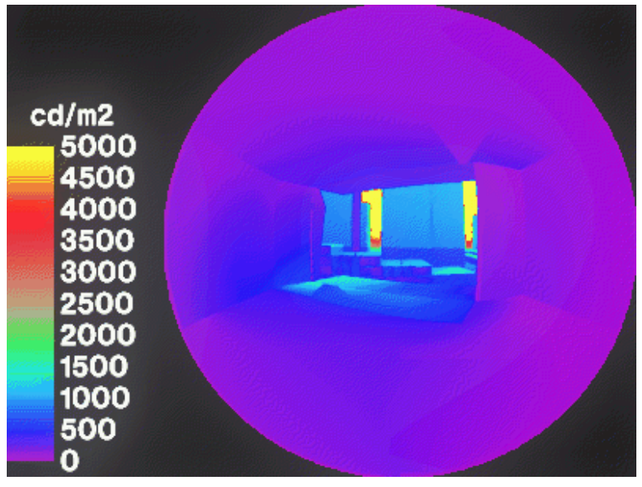
NORTH FACING (JUN 12PM)
DGP = 0.232



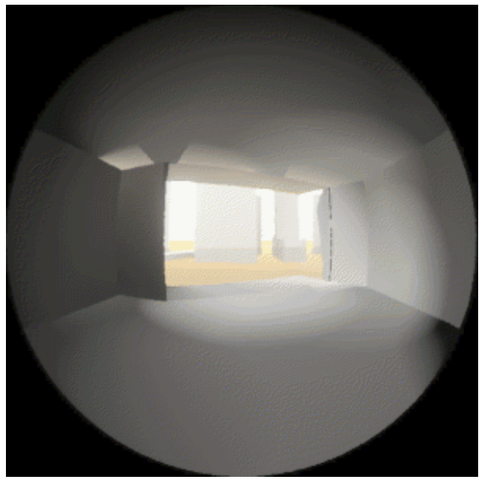


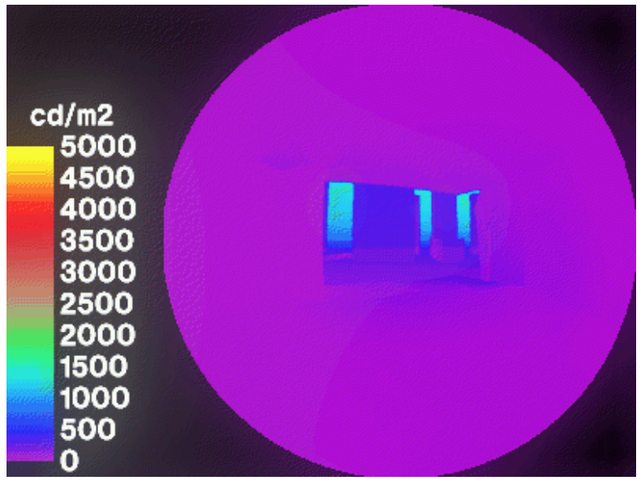
SOUTH FACING (JAN 12PM)
DGP = 0.367





EAST FACING (MAY 9AM)
DGP = 0.253

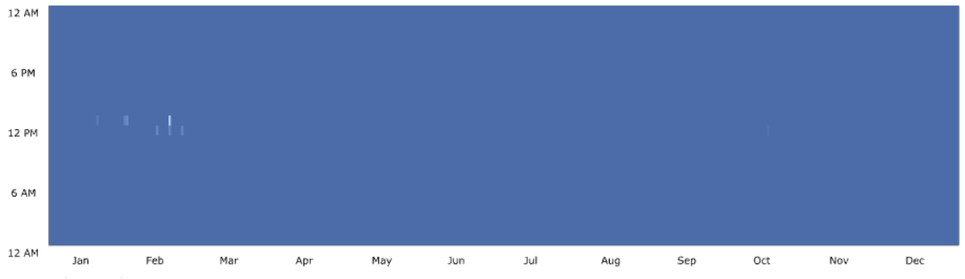




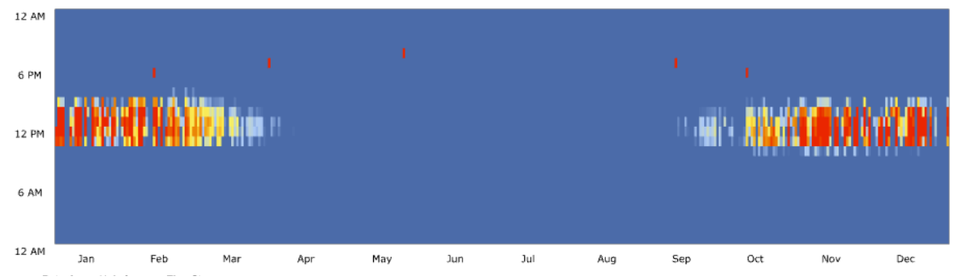
WEST FACING (AUG 6PM)
DGP = 0.142

6.3.3 DESIGN C

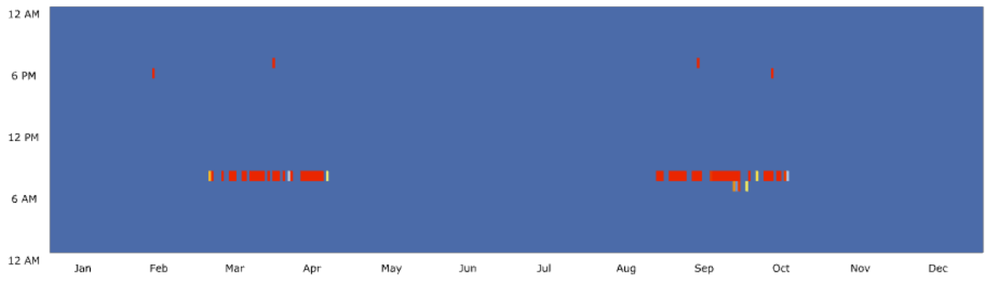
ANNUAL DAYLIGHT GLARE POTENTIAL (DGP)



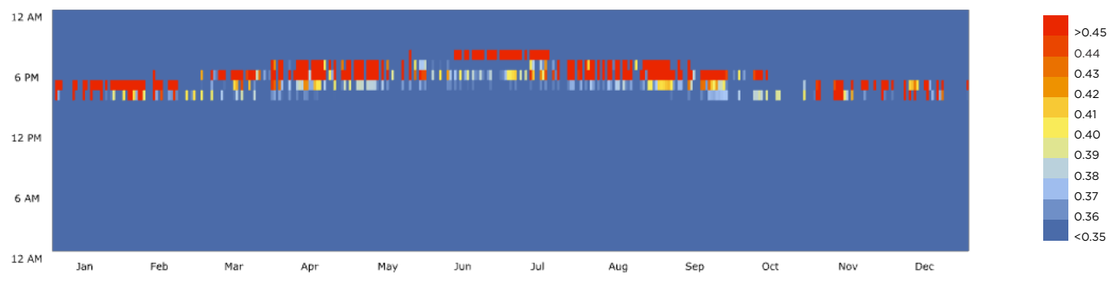
NORTH FACING



SOUTH FACING



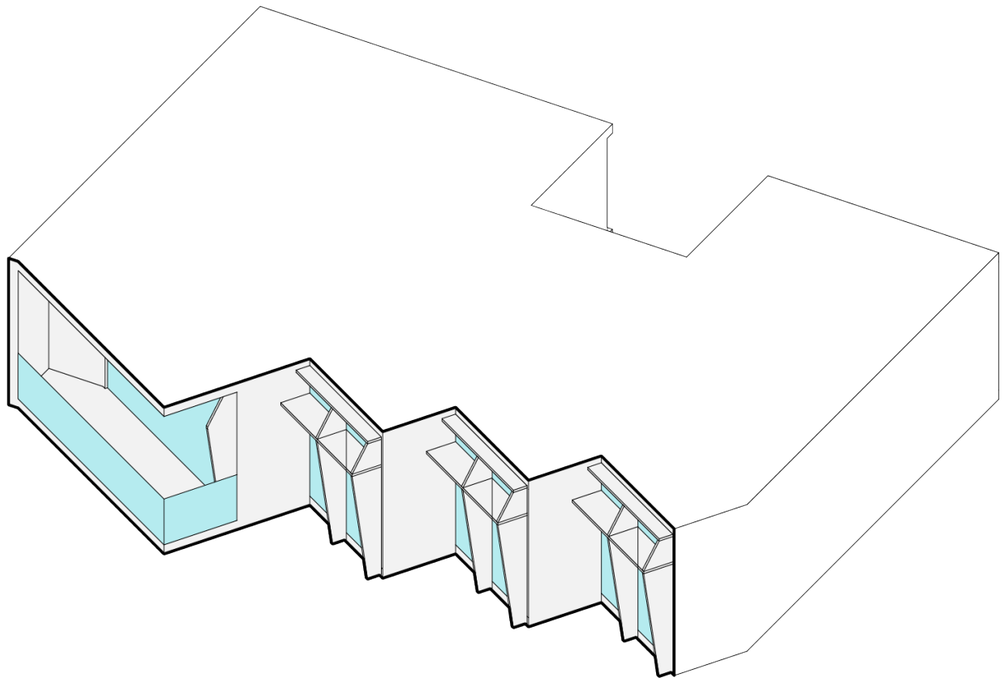
EAST FACING



WEST FACING

6.3.3 DESIGN C

EVALUATION



ILLUMINANCE

To increase illuminance in the rooms, the windows are angled slightly and fins are added. According to the analysis of Design C, the annual illuminance for the south, west and east facing units increased resulting in the useful daylit areas for these faces to also increase from the baseline model. However, for the north-facing unit, even though its illuminance has shown an increase from the baseline model, it is still low as compared to its other faces. As the overall illuminance in the rooms have increased, it proves that it is an effective facade strategy.

GLARE

According to the analysis of design C, the glare has decreased in comparison to the baseline model. As we can tell from the annual glare probability graph, the north and south facing units face close to no glare, hence being an effective facade strategy for reducing glare. In addition, even though there is still glare on the east and west facing units, the annual alre probability is still reduced throughout the year, hence showing an improvement from the baseline to design C. This glare is also mainly found on the balcony, and has little impact on the indoor living areas, and is thus no too much of a concern.

6.4 TABLE OF VALUES

		BASELINE	FACADE 1	FACADE 2	FACADE 3
NORTH	UD (%)	19.86	27.14	23.41	24.81
	UDI (%)	0	3.2	1.75	8.65
	DA (%)	19.86	23.94	21.66	15.53
SOUTH	UD (%)	29.55	41.75	37.92	33.78
	UDI (%)	11.60	19.07	17.82	13.07
	DA (%)	17.95	22.68	20.10	20.71
EAST	UD (%)	32.57	41.41	37.51	35.23
	UDI (%)	10.12	18.00	17.24	19.77
	DA (%)	22.45	23.41	20.27	15.46
WEST	UD (%)	34.65	46.36	41.35	34.95
	UDI (%)	28.33	36.23	33.20	22.17
	DA (%)	6.32	10.13	8.15	12.78

ANNUAL ILLUMINANCE

	BASELINE	FACADE 1	FACADE 2	FACADE 3
NORTH	0.232	0.232	0.232	0.232
SOUTH	0.382	0.381	0.383	0.367
EAST	0.269	0.270	0.247	0.253
WEST	0.199	0.201	0.248	0.142

DGP VALUES

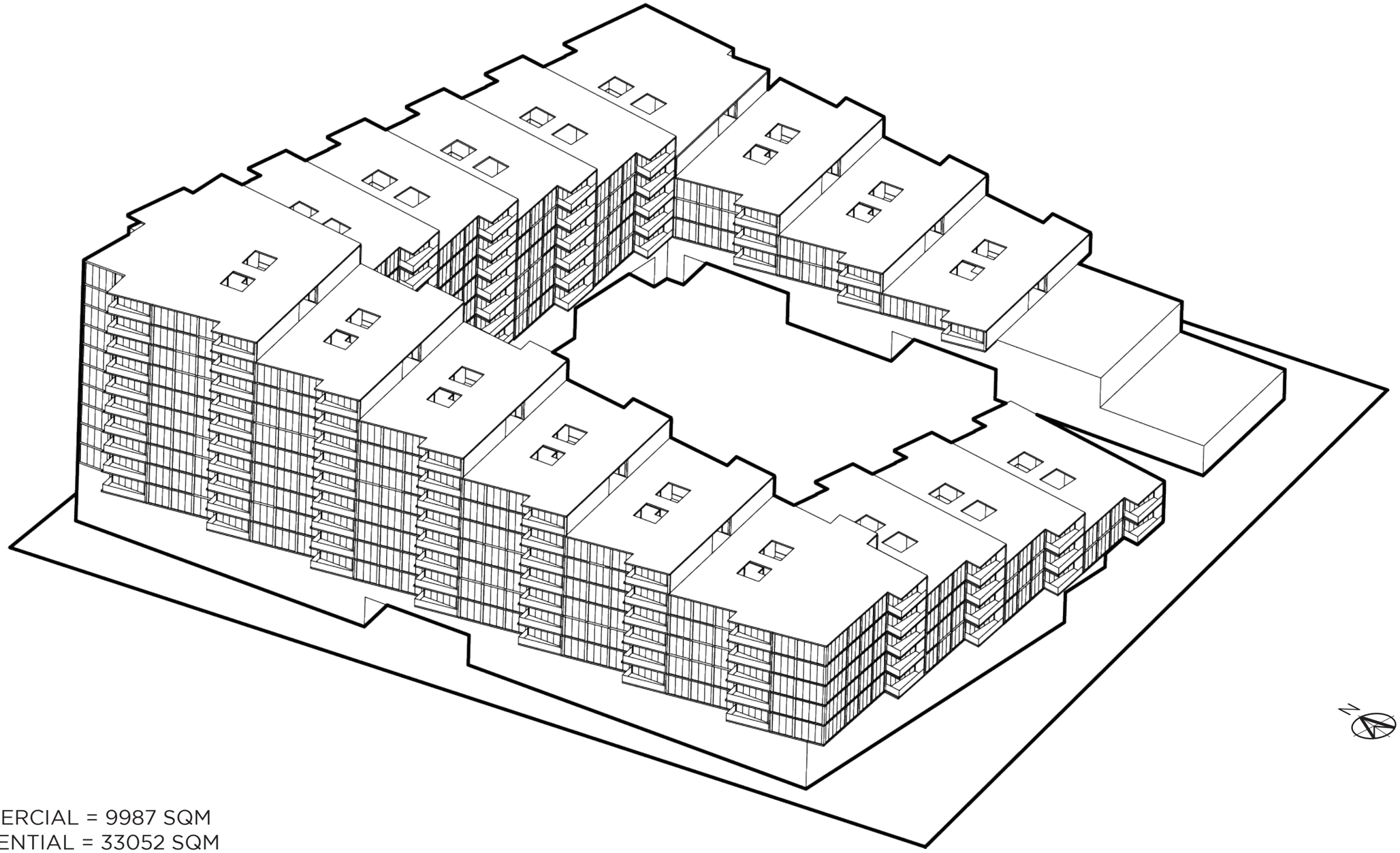
6.5 OVERALL ANALYSIS

The design has units oriented in 4 different directions, and all the different directions to give different results. Facade A was chosen in the final design as it allowed for the greatest daylight autonomy, $DA_{200lx,50\%}$ at 23.94% (north), 22.68% (south), 23.31% (east) and 10.13% (west), as compared to the other Facade designs and the baseline model. Despite Facade A having a more glare towards the south and the west facing units as compared to Facade C, due to the slight DGP fluctuations between the different facade designs and the higher daylight autonomy, Facade A is chosen. The point-based glare for the baseline and all facade options remained constant, around or below 0.35, which is imperceptible glare, and thus had little consideration for facade choice. In addition, glare can easily be resolved by the use of curtains or anti-glare glass for the windows.

7.0 CONCLUSION

7.1 FINAL DESIGN

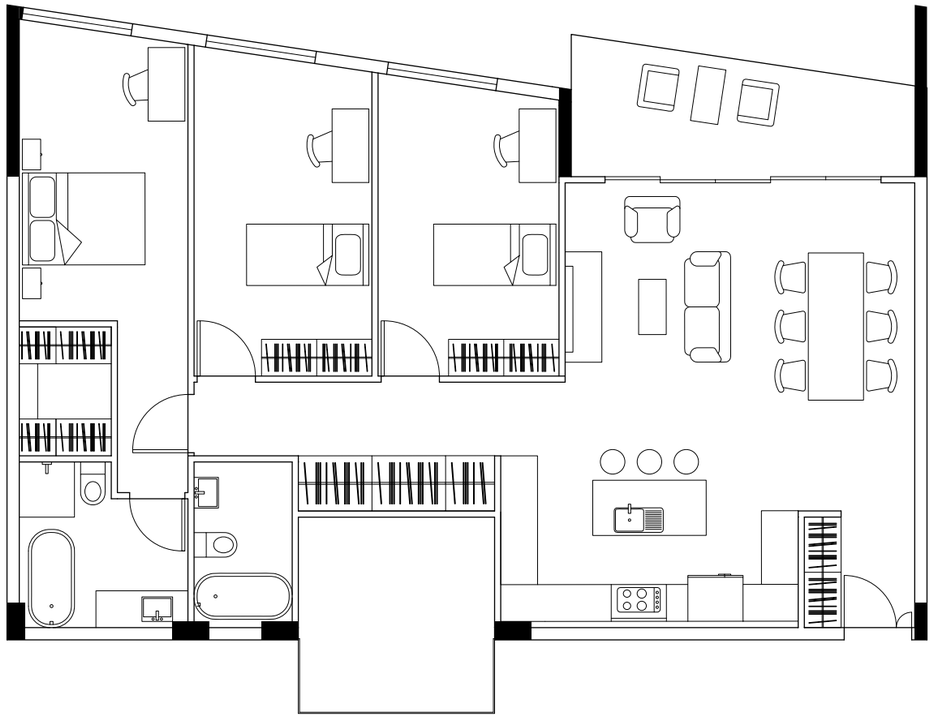
AXONOMETRIC MODEL



GFA
COMMERCIAL = 9987 SQM
RESIDENTIAL = 33052 SQM
TOTAL = 43039 SQM
PLOT RATIO = 2.99

7.1 FINAL DESIGN

UNIT FLOOR PLAN



SCALE 1:100

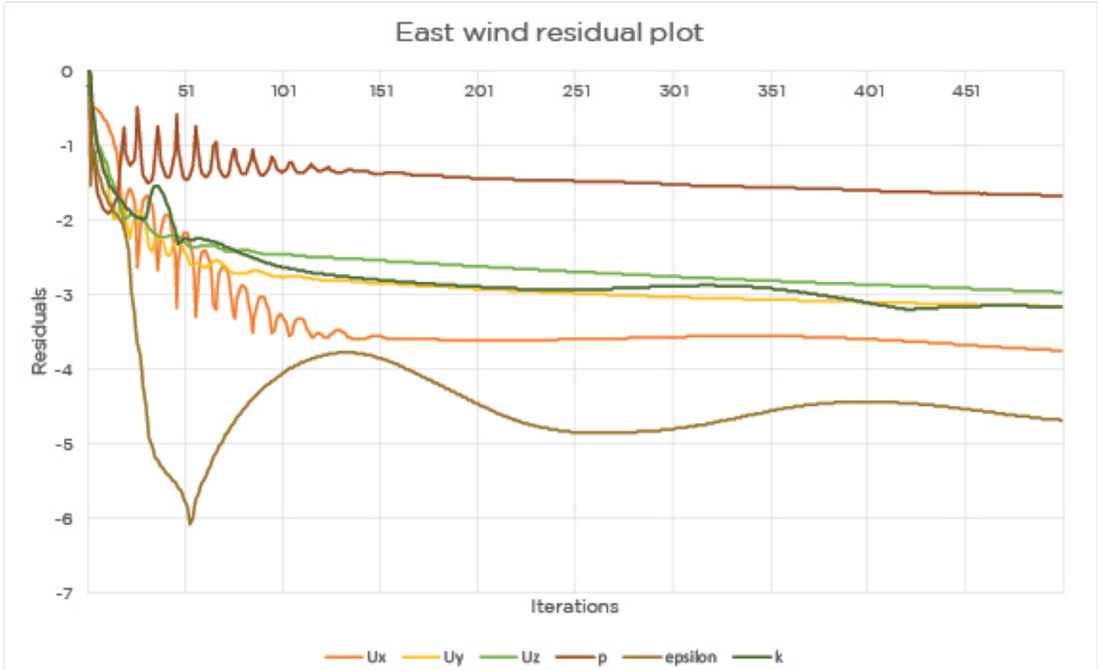
7.2 FINAL ANALYSIS

In conclusion, we decided to choose **Massing B** and **Facade A** for our final design. With the considerations of all factors such as sun, wind and rain for the massing, are able to conclude that massing B is a better fit due to its ability to weather these conditions more favourably than massing A. In addition, Facade A provides us with better results for both illuminance and glare. Hence, the best facade for a country like Toronto is one with larger and more extensive windows. The use of fins in this case would not be as favourable.

8.0 APPENDIX

8.1 RESIDUAL PLOTS

WIND ANALYSIS (MASSING B)



8.1 RESIDUAL PLOTS

WIND DRIVEN RAIN (MASSING B)