NEOM PROFESSIONAL VILLAGE A & B

- *Climate Analysis*
- *Outdoor thermal comfort*

8.1.6 MICRO-CLIMATE ANALYSIS

Project Data

Al Wajh, Saudi Arabia (WMO: 404000) is chosen for the climatological region due to its proximity to the site

Location.

Location: 27.47° N, 35.60° E (Al Wajh, KSA)

Climate Summary

In Al Wajh, the summers are long, hot, oppressive, arid, and clear and the winters are short, comfortable, dry, windy, and mostly clear. Average annual temperature ranges between 13-35º. The Red Sea in Al Wajh is warm enough for swimming all year round, although it goes down to 23 °C (73 °F) in February and March, while it gets very warm in summer.

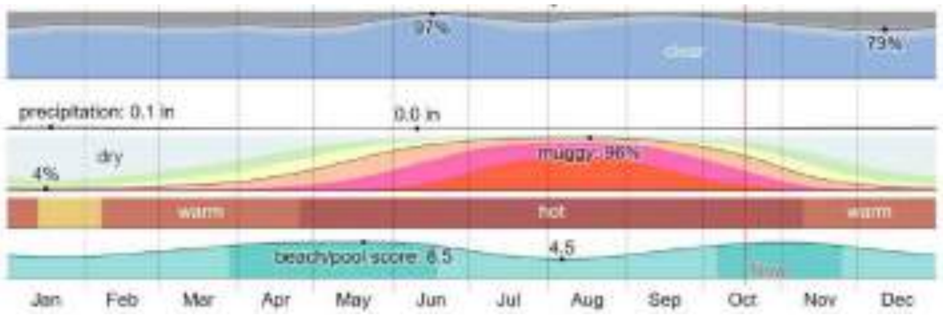


Figure 8.1.5. Annual Precipitation

Temperature

The hot season lasts for 4.3 months, from May 31 to October 8, with an average daily high temperature above 32°C.
The hottest day of the year is August 3, with an average high of 35°C and low of 25°C.. The cool season lasts for 2.8 months, from December 16 to March 8, with an average daily high temperature below 26°C. The coldest day of the year is January 21, with an average low of 13°C and high of 24°C.

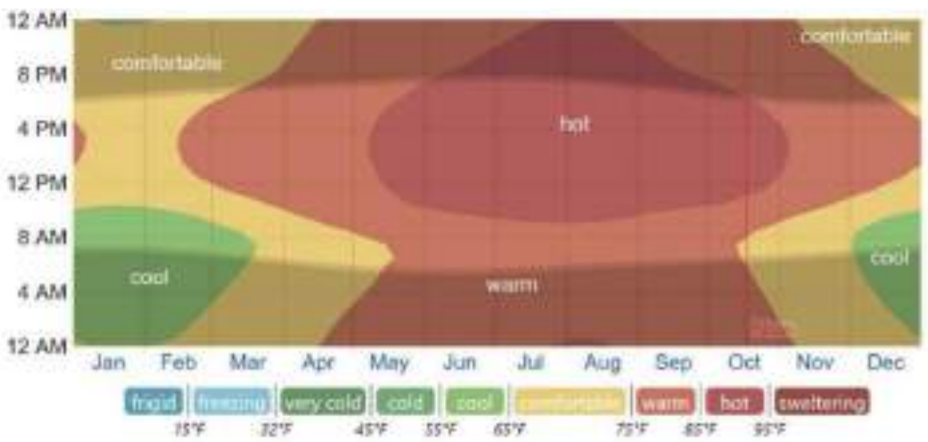


Figure 8.1.6. Annual Temperature

The average hourly temperature, color coded into bands. The shaded overlays indicate night and civil twilight. In terms of the cooling and heating design conditions for the critical spaces shall be based on Extreme Annual Design. Conditions with return period of 20 years to comply with the tier requirements of the Uptime Institute. Non-critical spaces shall utilize the annual design condition of 0.4% for cooling and enthalpy, and 99.6% for heating and humidification. The summary of design conditions is summarized in the table below:

DESIGN CONDITIONS	COOLING °CDB / °CWB	ENTHALPY °CDB / °CWB	HEATING °CDB / °CWB	HUMIDIFICATION °CDB / °CWB
AL WAJH, SAUDI ARABIA (WMO: 404000) Standard atmospheric pressure = 101.080 kPa				
Critical services (N20 criteria)	46.0 / 33.0		6.6 / 1.5	
Non-critical services (0.4% / 99.6%)	35.9 / 24.5	33.2 / 30.3	12.2 / -	18.7 / 9.3

Table 8.1.2. Annual Temperature

The average hourly wind speed in Al Wajh experiences mild seasonal variation over the course of the year. The windier part of the year lasts for 3.8 months, from December 20 to April 13, with average wind speeds of more than 9.5 miles per hour. The windiest day of the year is March 11, with an average hourly wind speed of 10.3 miles per hour. The calmer time of year lasts for 8.2 months, from April 13 to December 20. The calmest day of the year is October 23, with an average hourly wind speed of 8.6 miles per hour. The predominant average hourly wind direction in Al Wajh varies throughout the year. The wind is most often from the west for 5.5 months, from March 23 to September 9, with a peak percentage of 62% on July 22. The wind is most often from the north for 6.5 months, from September 9 to March 23, with a peak percentage of 41% on January 1.

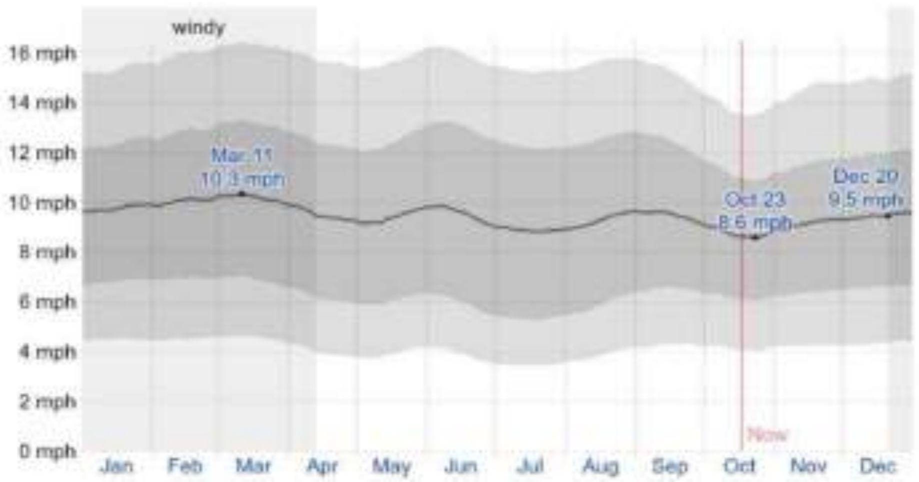


Figure 8.1.7. Average Wind Speed

Humidity

Al Wajh experiences extreme seasonal variation in the perceived humidity. The muggier period of the year lasts for 6.8 months, from April 17 to November 11, during which time the comfort level is muggy, oppressive, or miserable at least 27% of the time. The muggiest day of the year is August 17, with muggy conditions 96% of the time. The least muggy day of the year is January 16, with muggy conditions 4% of the time.

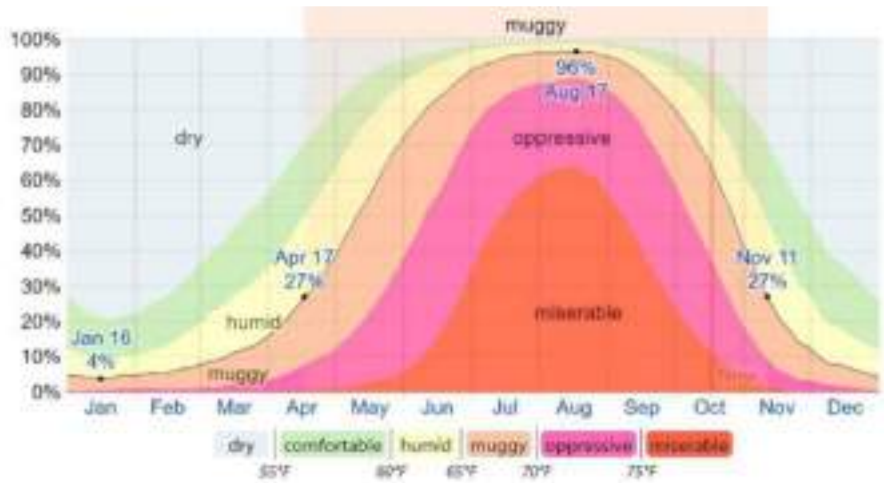


Figure 8.1.8. Annual Humidity & Comfort Levels Chart

Sun & Solar Radiation

The length of the day in Al Wajh varies over the course of the year. In 2020, the shortest day is December 21, with 10 hours, 30 minutes of daylight; the longest day is June 21, with 13 hours, 47 minutes of daylight.

Moreover,

the predominant Solar radiation will be from East, East-South & West Directions.

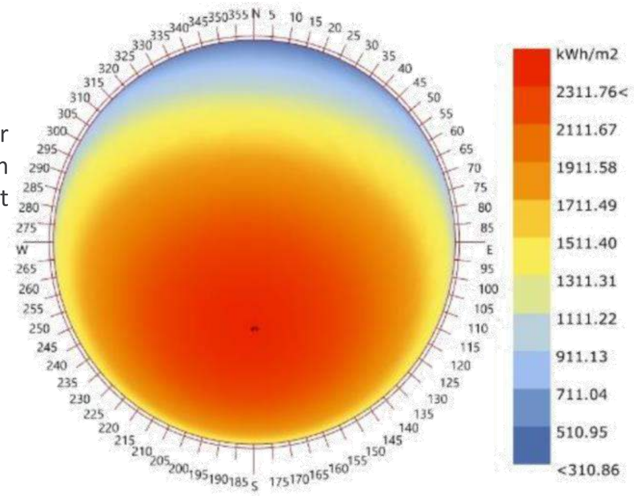
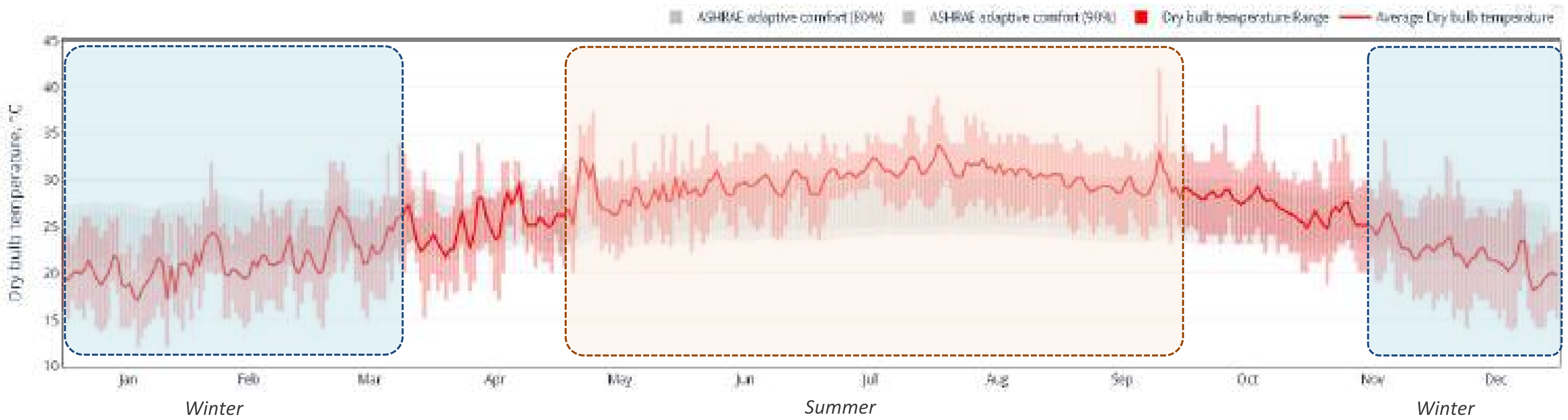


Figure 8.1.9. Solar Radiation Dome

Radiation Calla Dome (kWh/m2)
Wajh_AP_TB_SAU_2008
1 JAN 1:00 - 31 DEC 24:00

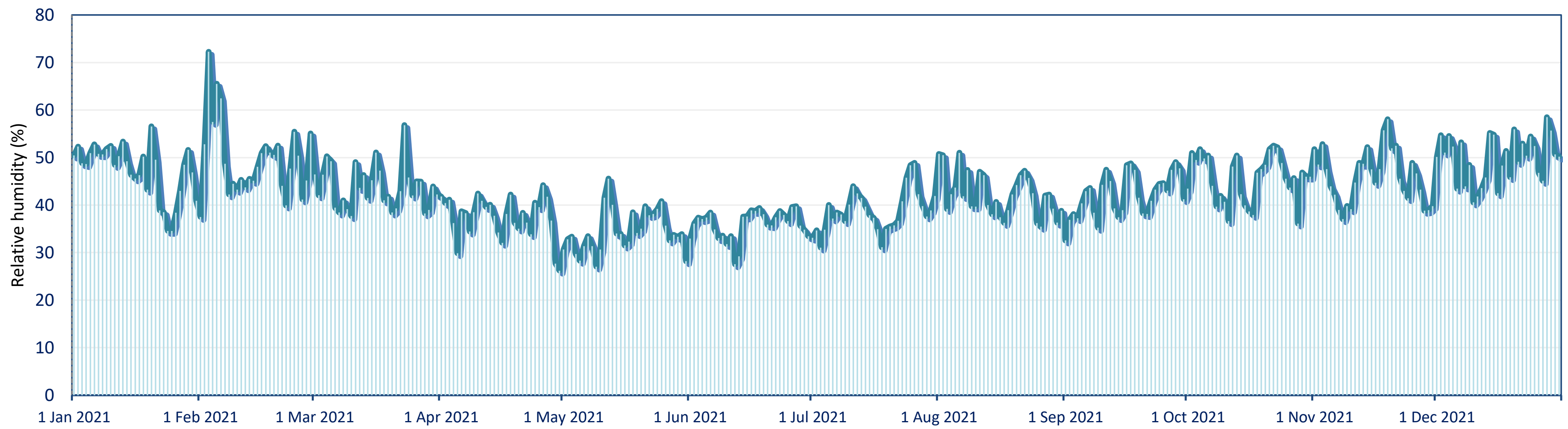
ANNUAL DRY BULB TEMPERATURE

The climate file for Al Wajh is used for the climate analysis as it is the closest location which has the coastal climate typology. The maximum temperature during summer reaches close to 40°C whereas the lowest is 24°C. The summer is long, dry and lasts from Mid-April to Mid –September. The winter is short & mild with temperatures ranging between mid November & mid March. The Coastal micro-climatic factors have an effect in making the climate milder. The Graph below shows Ashrae Adaptive comfort limits . The ambient temperature stays within the 90% acceptability limit for 64% time of the year.

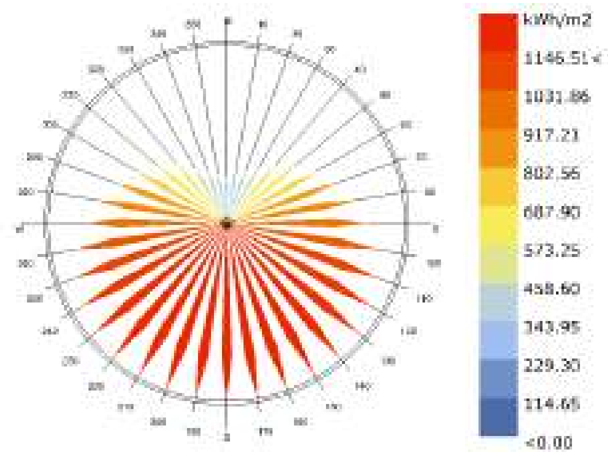


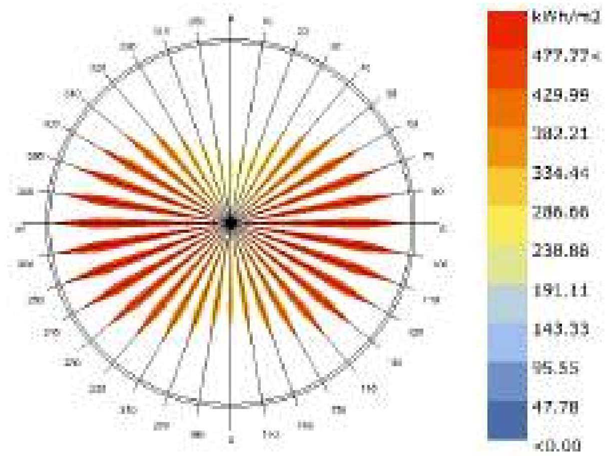
RELATIVE HUMIDITY

Due to the coastal influence on the arid climate , the Relative Humidity is remains between 30% to 50% relative humidity throughout most of the year. The annual data relative humidity at 2m is derived from MERRA-1 satellite through the Power Access Data viewer for the year 2021. The weather remains moderately humid through out the year.

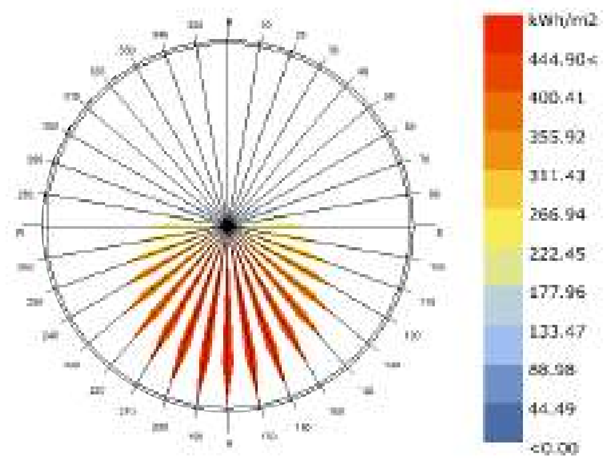


Radiation rose



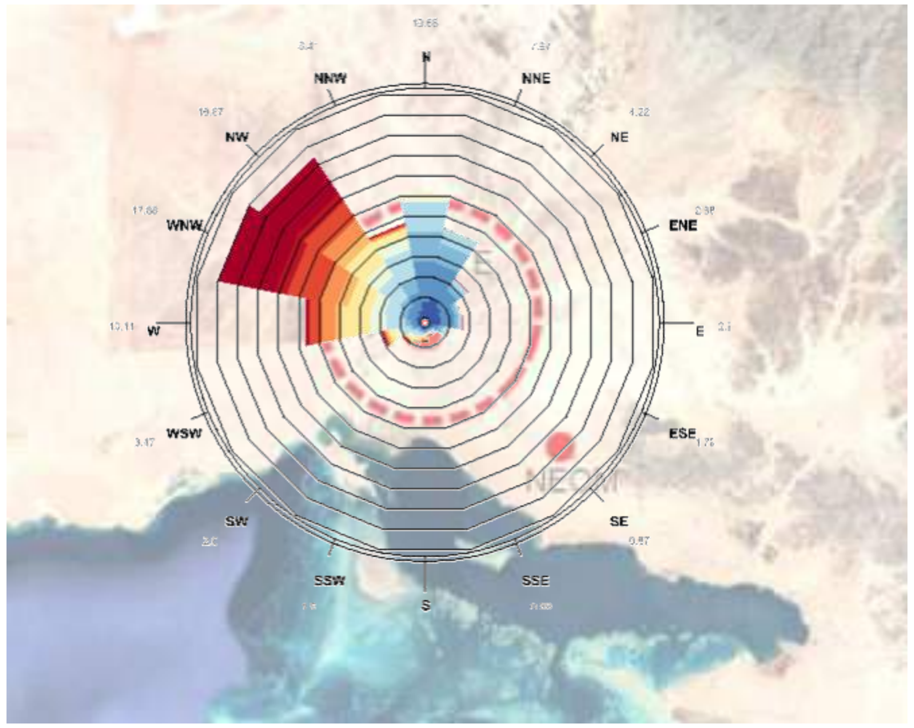


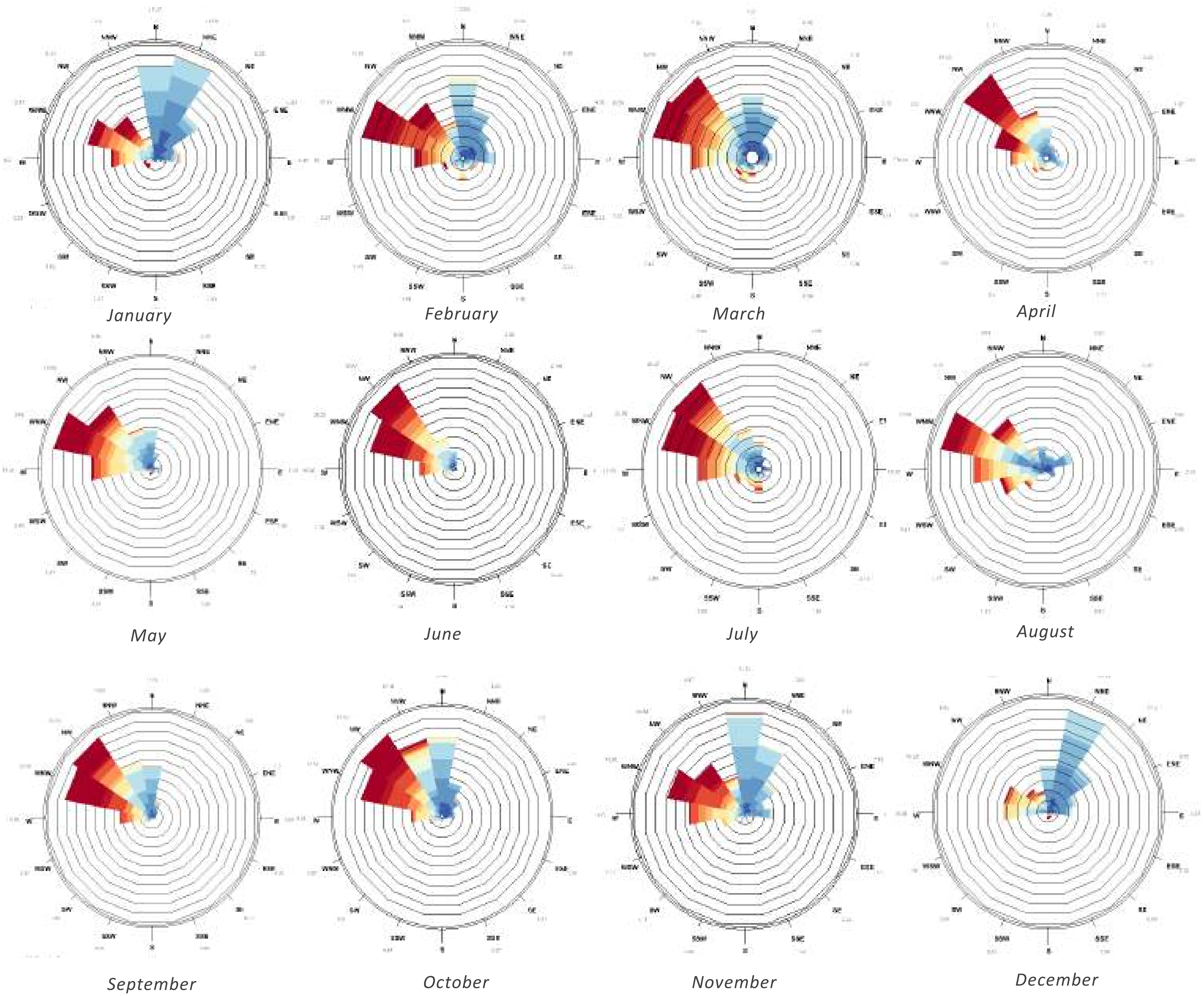
Maximum direct radiation received from April to September (Summer) is from the East & West Directions



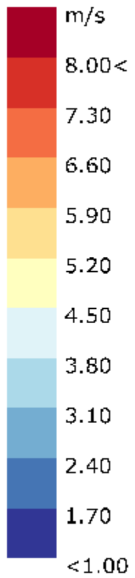
Maximum direct radiation received from November to March is from the South . This is due to the latitudinal location of Neom.

PREVAILING WIND DIRECTION Wind Rose Analysis



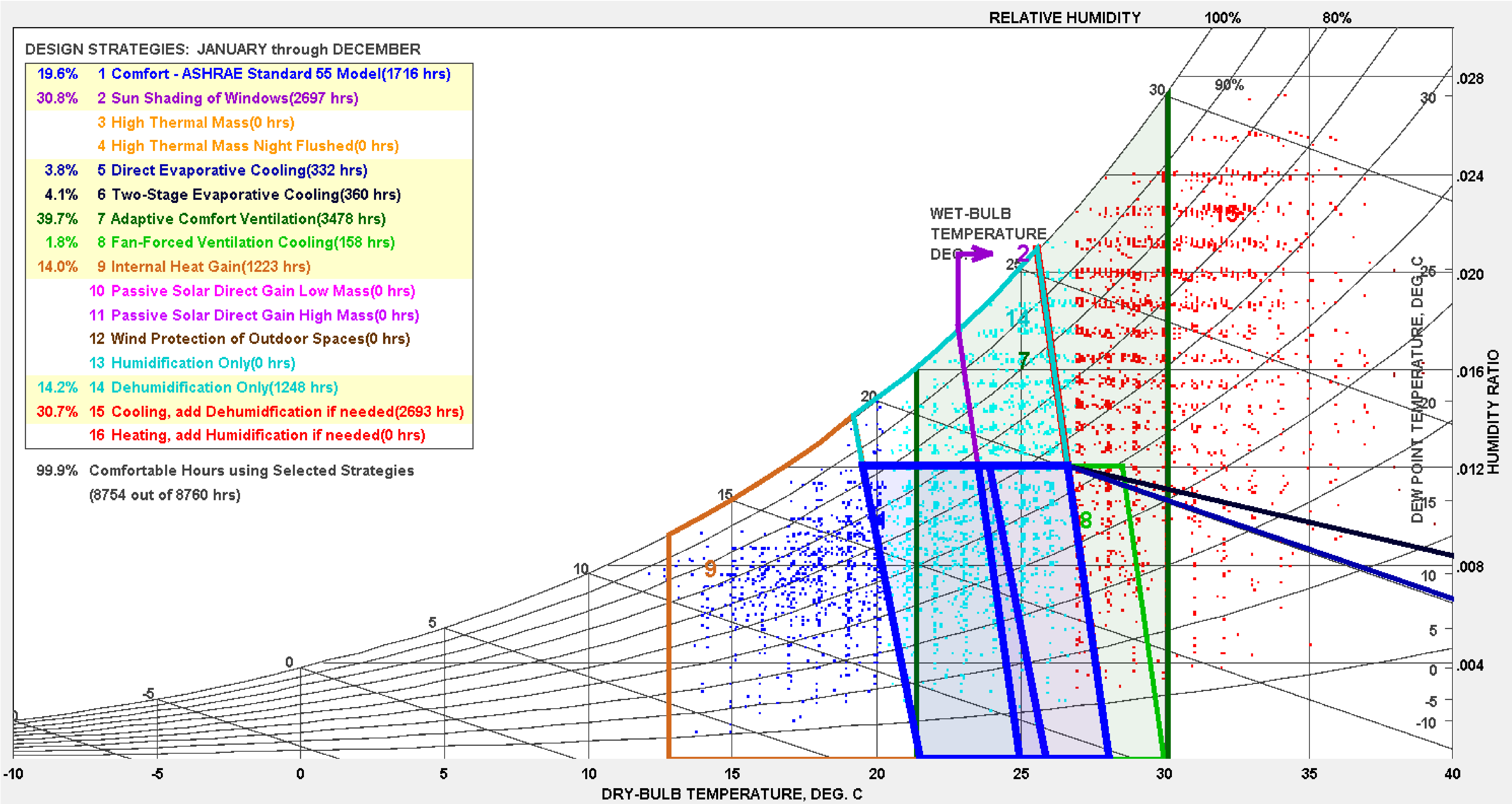


The prevailing Wind direction is from the West & North West. From November to February, wind from the north & north east are observed at low wind speeds.
The seasonal cool breezes can be used for natural ventilation . Fenestration on the north façade of the facilities buildings can be made operable to channel Winter breezes instead of relying on active cooling systems.



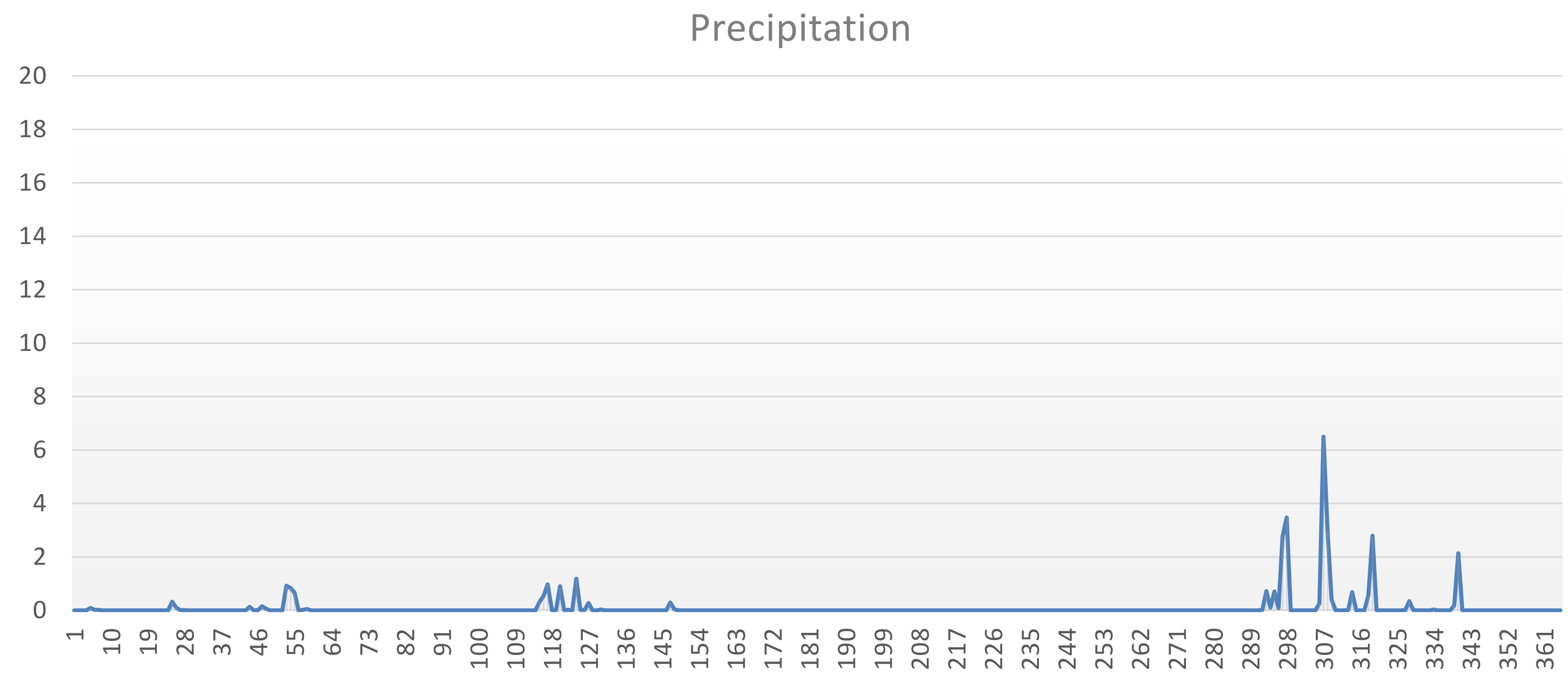
PASSIVE COMFORT STRATEGIES – PSYCHOMETRIC CHART

The below psychometric chart plots the comfort conditions based on the climatic factors. As per the chart **19.6%** of the time is comfortable as per ASHRAE 55 adaptive comfort model.
Addition of Sun shading to fenestration systems can account for up to **30%** comfort condition during the year.
Secondly, addition of ventilation through mechanical or natural or mixed mode means can improve comfort by up to **39.7%**. This is due to the presence of humidity in the air which improves comfort when wind evaporates moisture from skin surface.
The difficult to achieve comfort conditions during peak summer when dry bulb temperature is the highest can be achieved through active cooling systems & dehumidification.
Hence , up to 70% of the annual hours can achieve comfortable indoor conditions through just passive means. The recommendation for façade design will be detailed out in the upcoming stages.



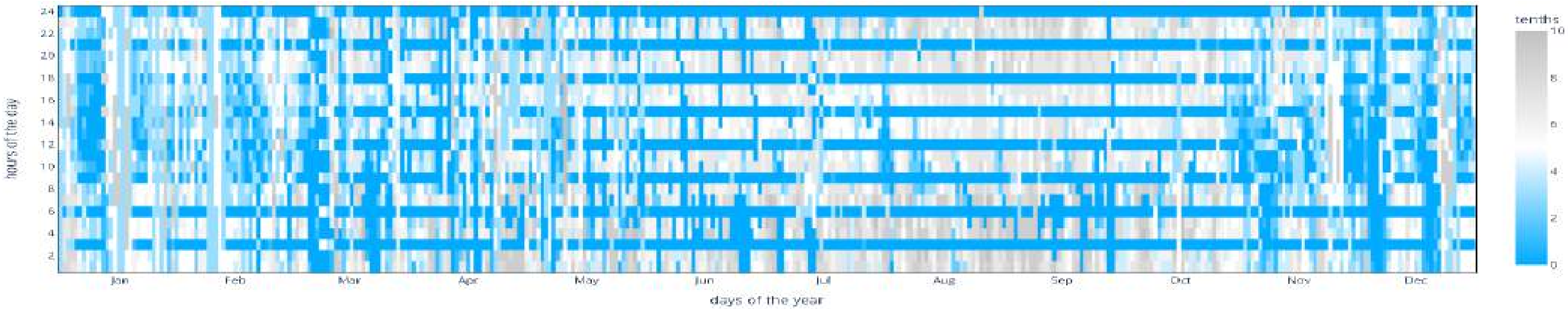
ANNUAL PRECIPITATION

The below graph plots the annual precipitation data derived from MERRA-1 satellite through the Power Access data viewer for the year 2021. Even though the relative Humidity in the air is moderately high, the precipitation levels are abysmal in the arid climate. The total annual precipitation is less than 35mm. **Hence, water efficient plant species & irrigation systems must be chosen to reduce water consumption.**



CLOUD COVER

The graph of annual cloud cover shows low to medium cloud cover. This is uniformly distributed through out the year. Consequently clear skies through out the year indicate high levels of direct normal radiation. **These conditions are also extremely beneficial for improved efficiency & output of Solar Photovoltaic panels for water heating & electricity generation.**



OUTDOOR THERMAL COMFORT STUDY

Universal Thermal Comfort Index

A UTCI study was conducted on specific areas on the typical housing cluster typologies in the two masterplans – Site E & Site F. UTCI study was used as it is a universally accepted thermal comfort index with a wider temperature range. In simple terms, the "feels like" temperature reported by weathermen is the UTCI It takes into account variables such as outside air temperature, relative humidity, wind speed, mean radiant temperature, metabolic rate of activity, and clothing value. The thermal perception & temperature ranges for both indices are depicted in the table below. The study was conducted for the spring equinox on 21st March at 12pm & 4 pm to understand the variation in outdoor comfort during different times of the day. An additional set of simulations is carried out for summer solstice (21st June 12pm) with & without the effects of shading.

Table 1Comparing thermal perception in bioclimatic indices

Thermal perception	Indices				
	UTCI	WBGT	SET	PMV	PET
Very cold[1] (Extreme cold stress[1,2])	< -40			-3	<4
(very strong cold stress[2])	-40 to -27				
Cold[1] (Strong cold stress[1,2])	-27 to -13			-2.5	4-8
Cool[1,3] (Moderate cold stress[1,2]/ Moderate Hazard[3])	-13 to 0		<17	-1.5	8-13
Slightly cool[1] (Slight cold stress[1,2])	0 to +9			-0.5	13-18
Comfortable[1,3] (No thermal stress[1,2]/ No Danger[3,4])	+9 to +26	<18	17-30	0	18-23
Slightly warm[1] (Slight heat stress[1])				0.5	23-29
Warm[1,3,4] (Moderate heat stress[1,2]/ Caution[3,4])	+26 to +32	18-23	30-34	1.5	29-35
Hot[1,3,4] (Strong heat stress[1,2]/ Extreme caution[3,4])	+32 to +38	23-28	34-37	2.5	35-41
(very strong heat stress[2])	+38 to +46				
Very hot[1,3,4] (Extreme heat stress[1,2]/ Danger[3,4])	> +46	28-30	>37	3	>41
Sweltering[4] (extreme danger[4])		≥30			

[1] PET and PMV [2]UTCI [3]SET [4]WBGT

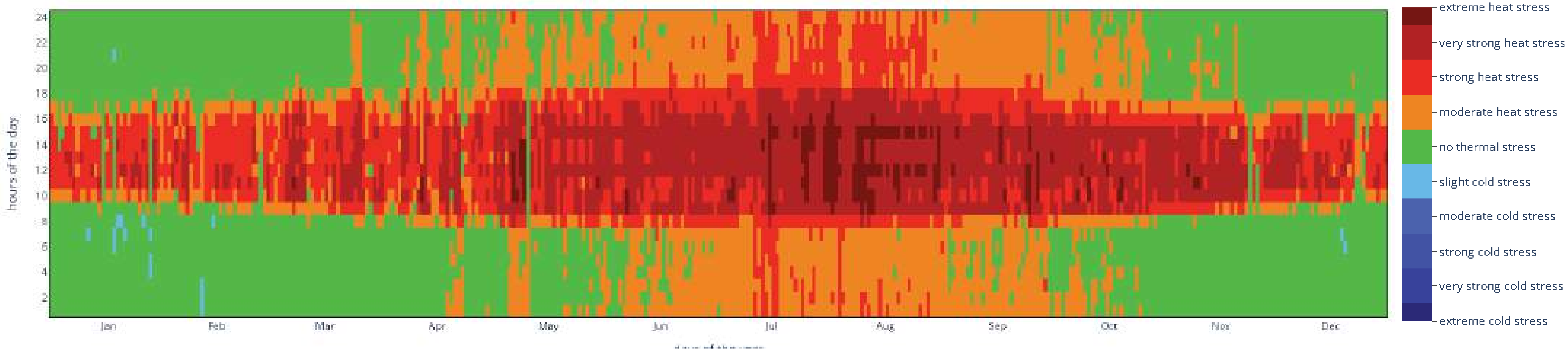
UTCI – Definition

The UTCI originates from an approach that was proposed over 10 years ago by the International Society of Biometeorology (ISB) Commission. Fiala et al.'s advanced multi-node model of thermo-regulation provides the basis for the UTCI, which is defined as the capability of an organism to retain its body temperature within a particular limit even if the surrounding temperature is totally different (Fiala et al., 2012).

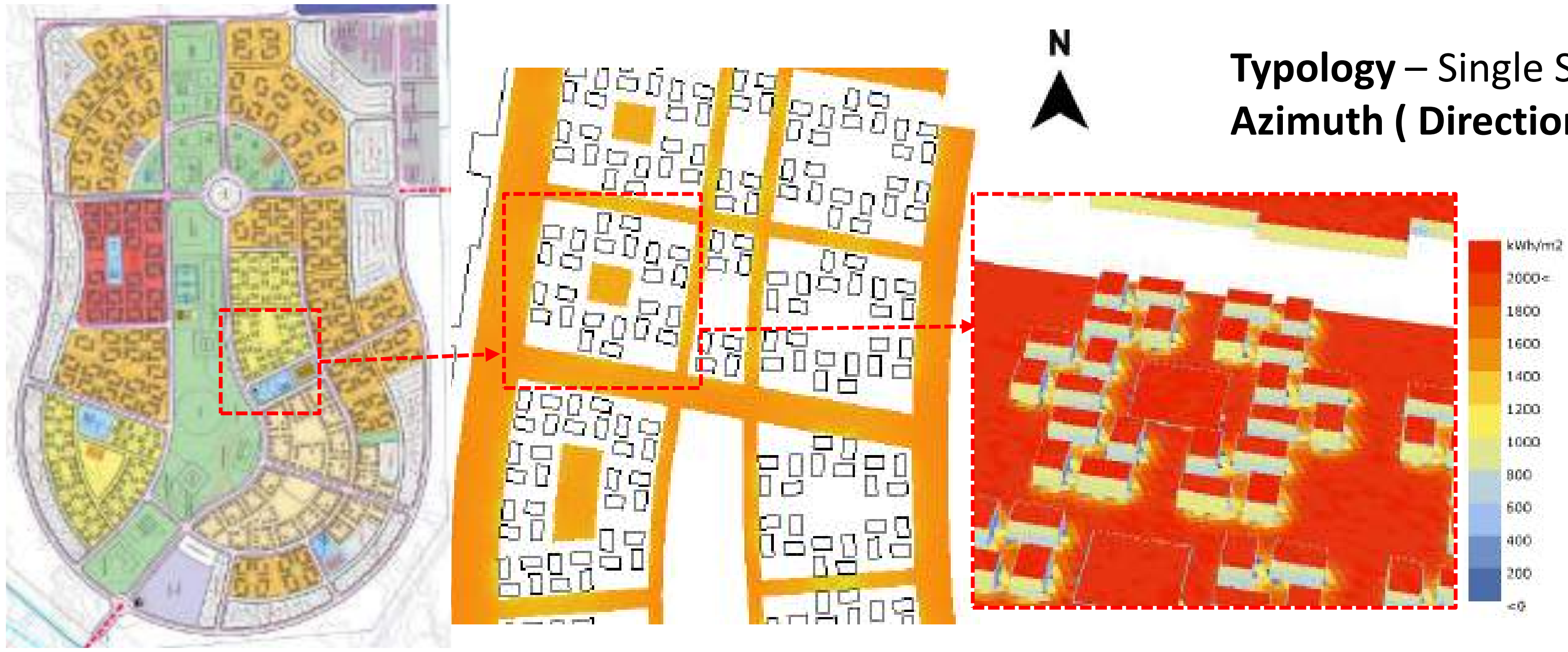
Universal thermal climate index (UTCI), introduced in 1994, considers dry temperature, relative humidity, solar radiation, and wind speed into account and is regarded as the reference environmental temperature causing strain (Baaghideh et al., 2016).

The below chart shows the annual thermal stress for Al Wajh. The period before the start & after the end of summer are the shoulder periods where there is maximum potential for improving comfort conditions to extend comfortable period. The Climate files used is for Al Wajh EPW File taken for from Climate.One Building.

Therefore, the study was conducted for the spring equinox on **21st June at 12pm.**



8.1.7 PASSIVE DESIGN ANALYSIS: Universal Thermal Comfort Index[UTCI]



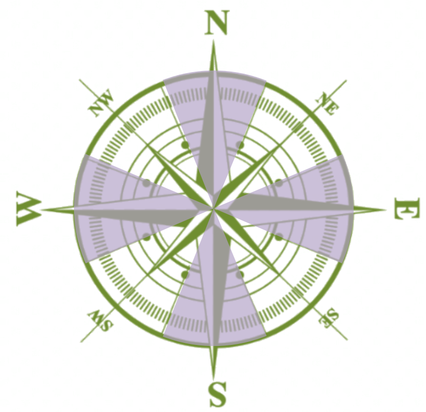
Typology – Single Storey cluster
Azimuth (Direction from north) - ± 15°

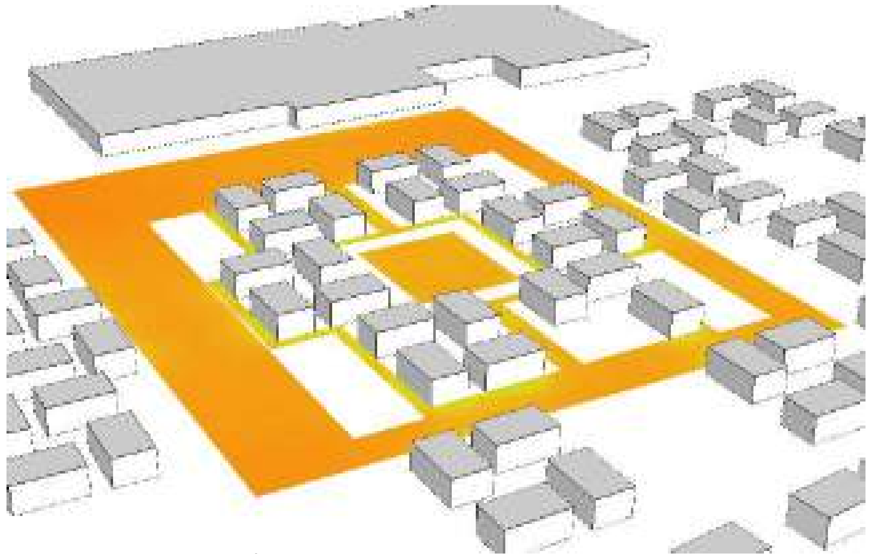
NEOM Village

An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).

Observation
As per radiation study , maximum radiation from the south is received only during winter at a very low angle. No direct radiation is observed on the north facades. Only diffuse radiation is observed. Hence, no interventions may be added on the north façade.

Azimuth

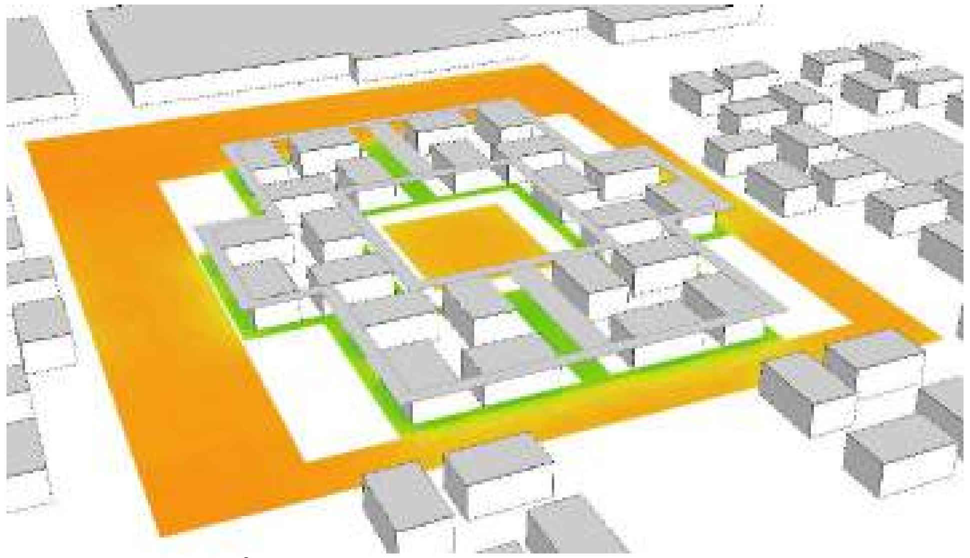




Average UTCI - 39.68°

Baseline

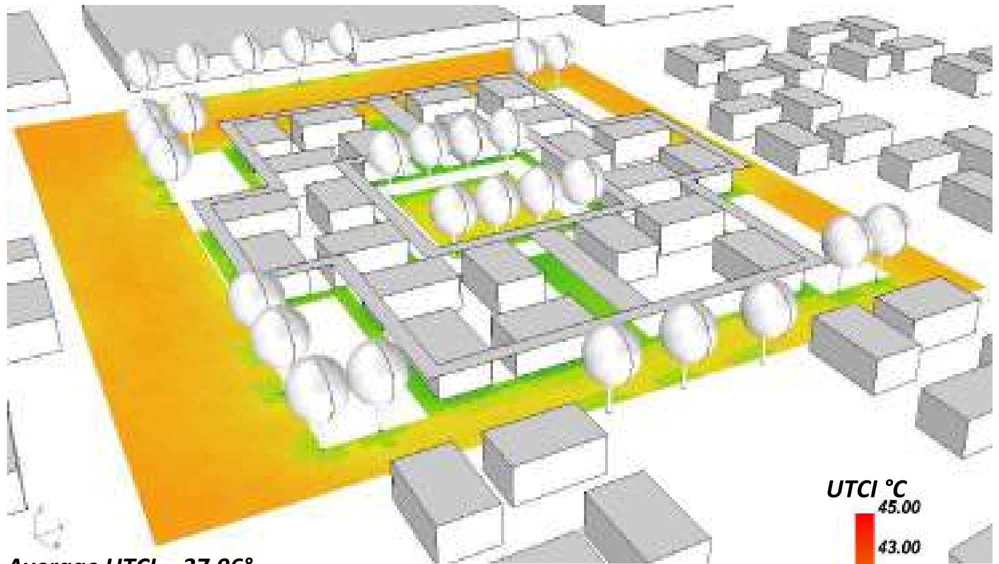
- Low density & low height of single storey masses reduces self-shading potential of housing clusters.
- Higher density of housing clusters is recommended with smaller clusters to improve self shading potential.
- **Walkways whether shaded or unshaded are advised to be designed as close as possible to the building masses to take advantage of shade from building.**



Average UTCI - 38.85°

Level 1 interventions

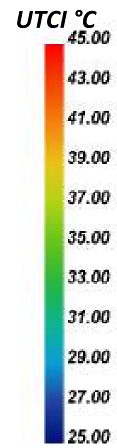
- A covered walkway is proposed that ties the clusters. The walkway is proposed on the outer edges as well as along the inner courtyard.
- Outer shaded walkway improves thermal comfort & walkability of pedestrian paths along the access roads.
- In addition, shaded walkways provide protection from solar radiation to the housing clusters and aids in creating a communal transition space within the cluster



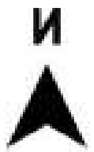
Average UTCI - 37.96°

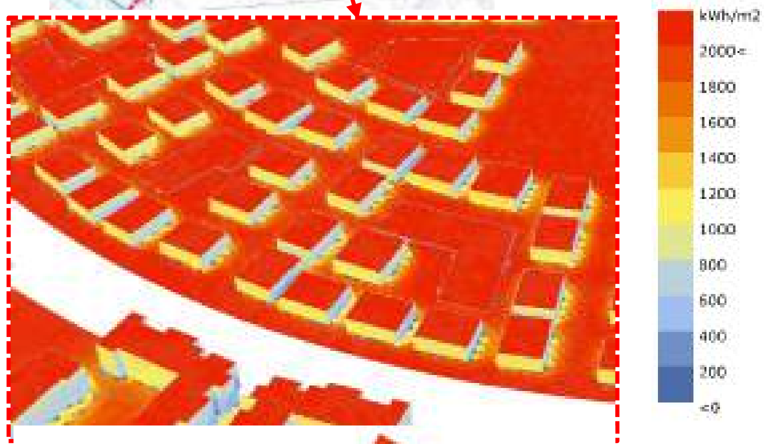
Level 2 interventions

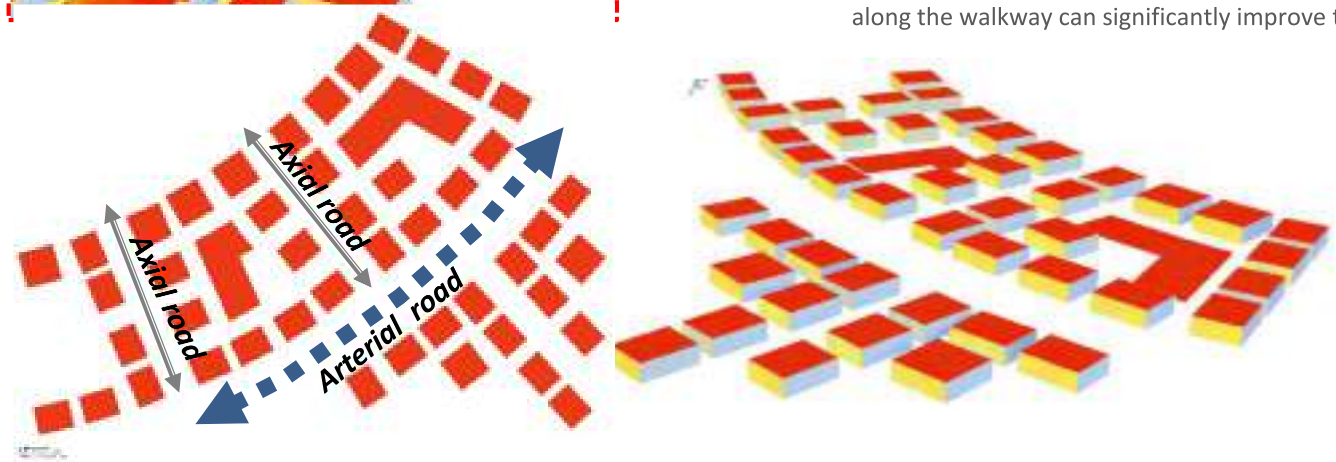
- Addition of trees strategically along the walkway and inner courtyard provides maximum coverage of shade for walkable surfaces throughout the day.
- Trees along the outer edge of the cluster must be added in **East & West** directions predominantly where there is no covered walkway.



An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).







Typology – Single Storey cluster
Azimuth (Direction from north) - ± 45°

Observation

As per the irradiation study , a walkway along the 20m wide arterial road receives high amounts of radiation and is exposed on the south , east & west directions which receive maximum radiation. The narrow 9m wide axial roads are fairly well shaded by context geometry.

Baseline

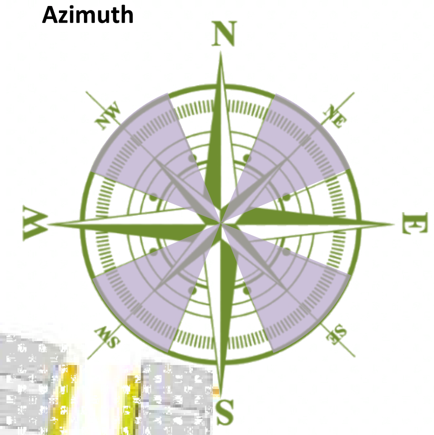
- Low density & low height of single storey masses reduces self-shading potential of housing clusters.
- Walkways along the Axial roads do not require any shading as they are amply shaded by the context massing.

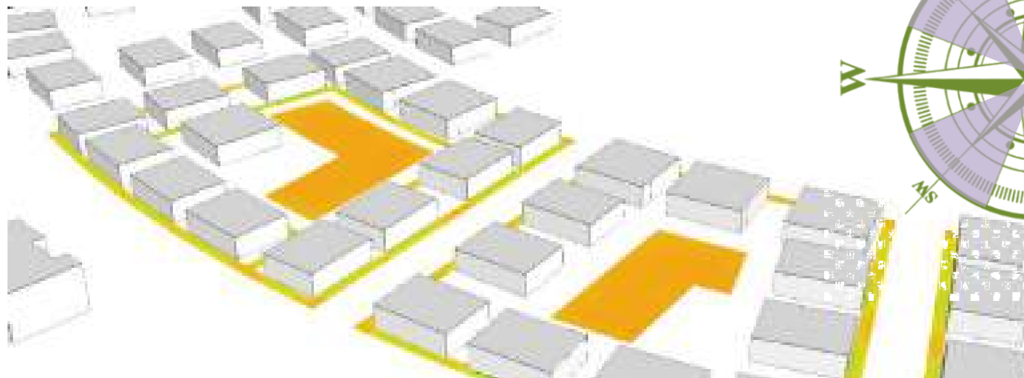
Level 1 interventions

- Walkways along Arterial road that runs through the cluster in the north south direction requires shaded walkways on both sides of the road as it.
- Outer shaded walkway improves thermal comfort & walkability of pedestrian paths along the access roads.
- In addition, inner shaded walkways provide protection from solar radiation to the housing clusters and aids in creating a communal transition space within the cluster

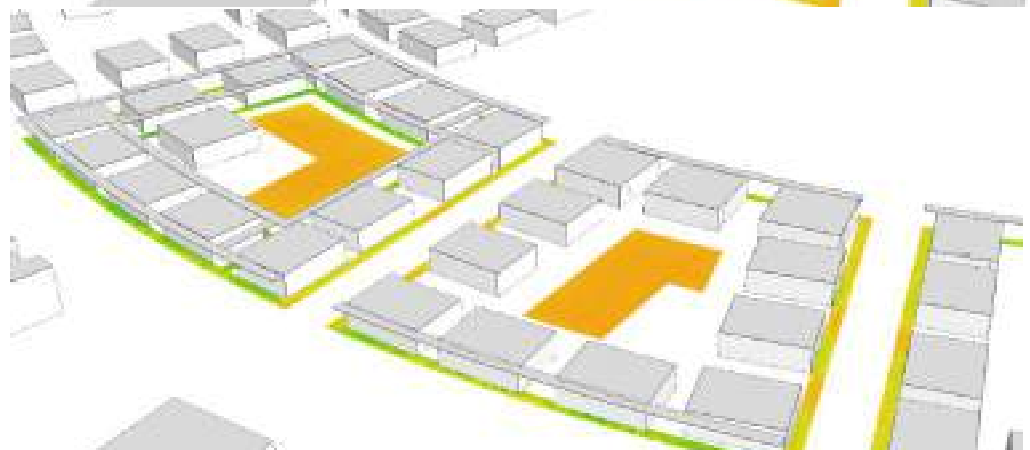
Level 2 interventions

- Addition of trees strategically on the south & west edges of the open courtyard protects the courtyard from low angle sun during the afternoon.
- Trees maybe added along the axial roads to cover gaps in context massing . However no additional shading is required.
- The current study does not take into account the wind speeds to assess comfort. However, means to improve natural ventilation along the walkway can significantly improve thermal comfort.

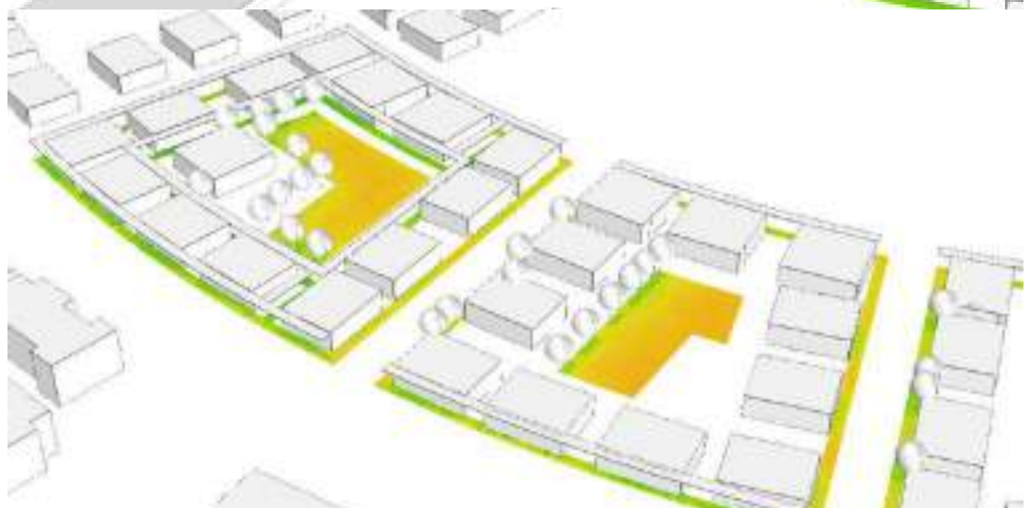




Average UTCI - 38.63°



Average UTCI - 37.67°



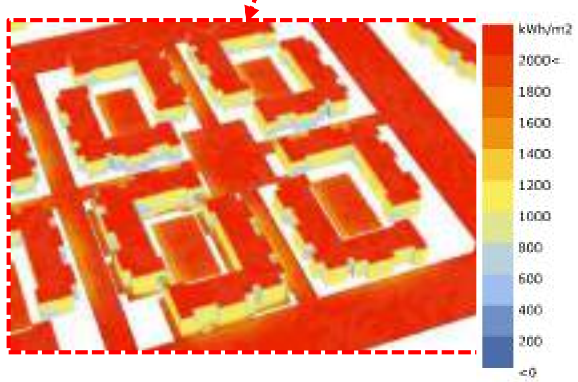
Average UTCI - 36.72°

8.1.7 PASSIVE DESIGN ANALYSIS: Universal Thermal Comfor

Typology – Ground +1 Storeys

Azimuth (Direction from north) - ± 45°

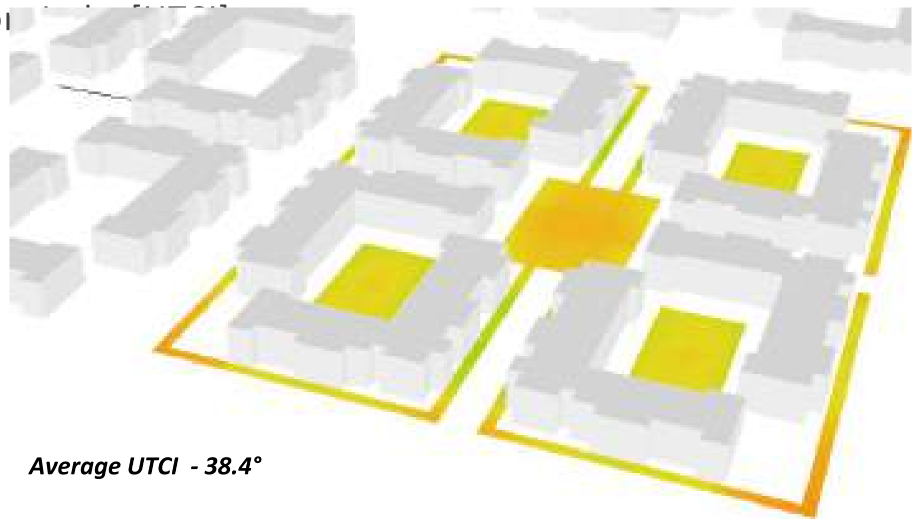
An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).



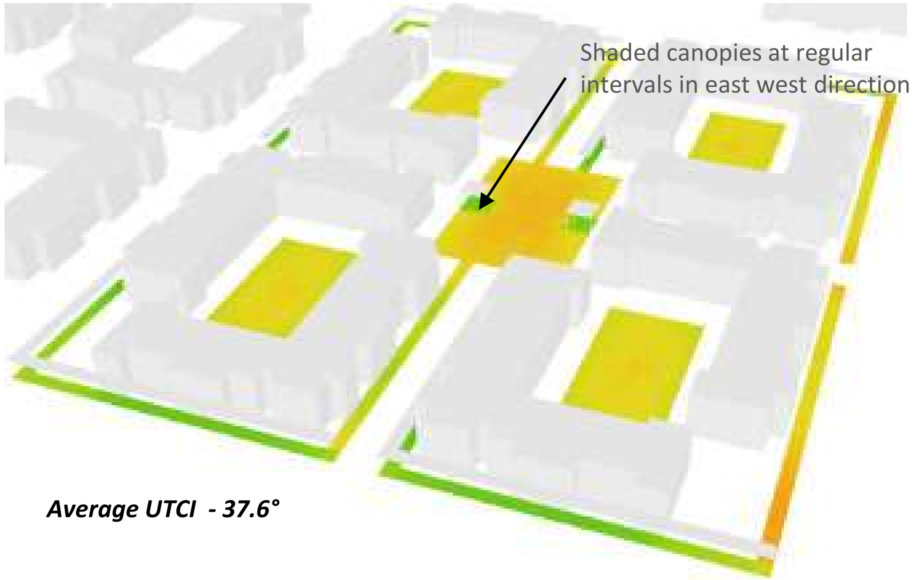
Observation

The Ground +1 Storey Blocks are a set of 2 L shaped blocks with the longer sides in the north and south facing directions. The north side registers very little radiation.

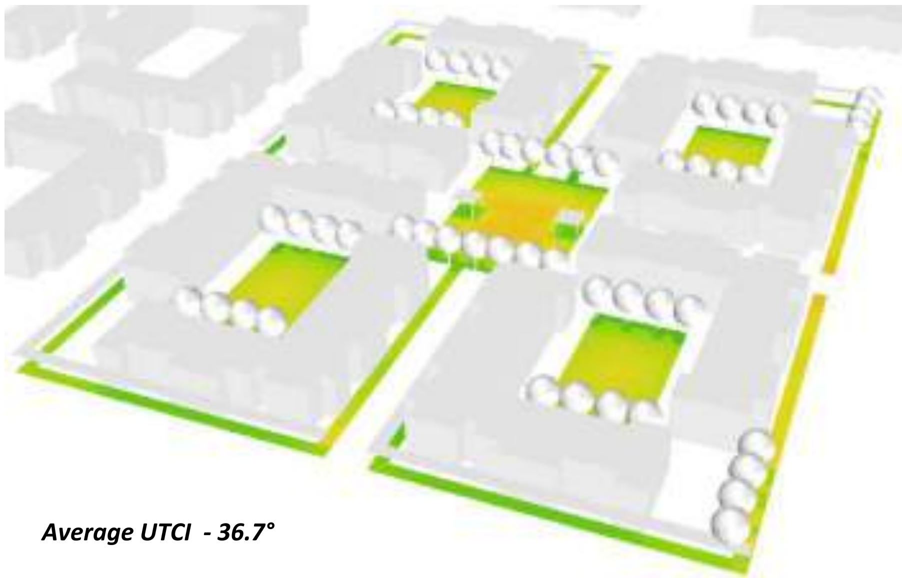
The central park between 4 clusters has longer directions facing east & west which registers high amounts of radiation



Average UTCI - 38.4°

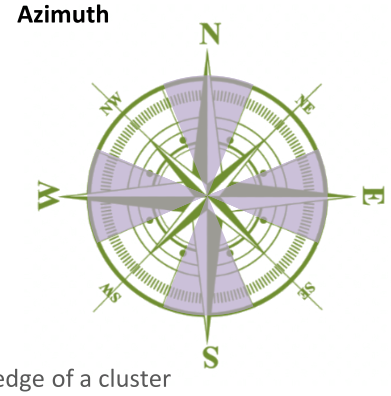


Average UTCI - 37.6°



Average UTCI - 36.7°

Azimuth

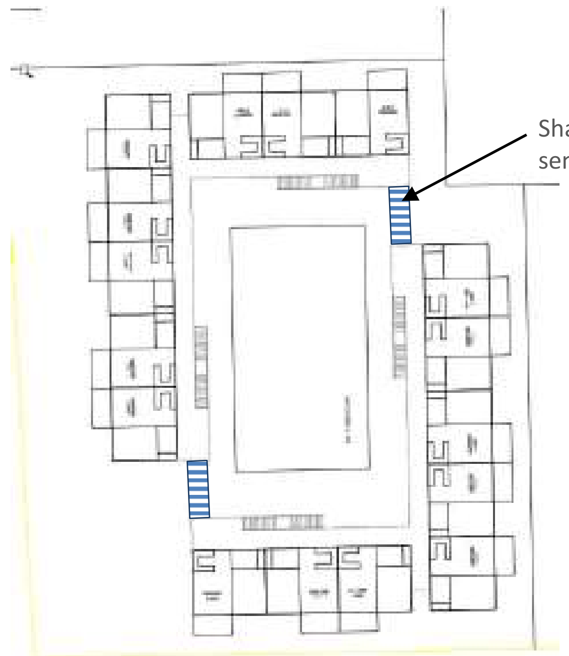


Baseline

- Two storey Massing provides protection to adjacent walkways from solar radiation on the North & South.
- Walkways along the East & West are exposed to high solar radiation.

Level 1 interventions

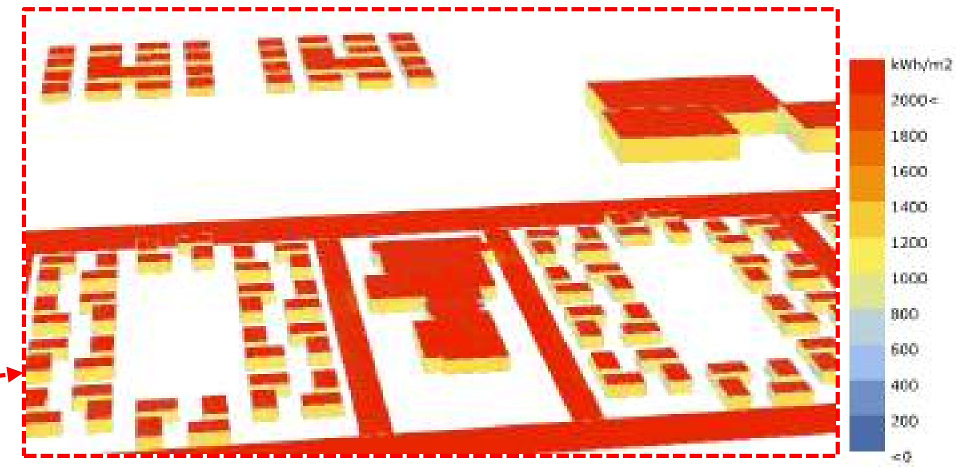
- Shaded walkways are required only on the outer edge of a cluster of 4 blocks.
- No shading is required on the north side of the cluster.
- However walkway on the north side of the cluster must be planned close to the building massing to take advantage of the context shading
- The semi open corridor in the two L-shaped blocks are proposed to be connected using shaded walkways for ease of walkability.



Level 2 interventions

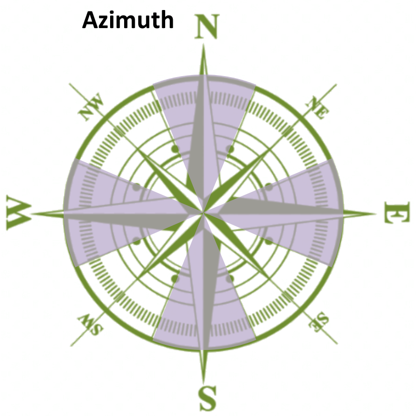
- The longer sides of the parks face north & south. Ample shading is required in the east & west direction.
- Shaded canopies are suggested at every 30m in shared parks. Individual block parks are well shaded from context geometry & can be enhanced using trees on east & west edges
- Further improvement in Outdoor thermal comfort can be achieved by overhead tensile shades across the park if required.

Typology – Single Storey cluster
Azimuth (Direction from north) - ± 15°

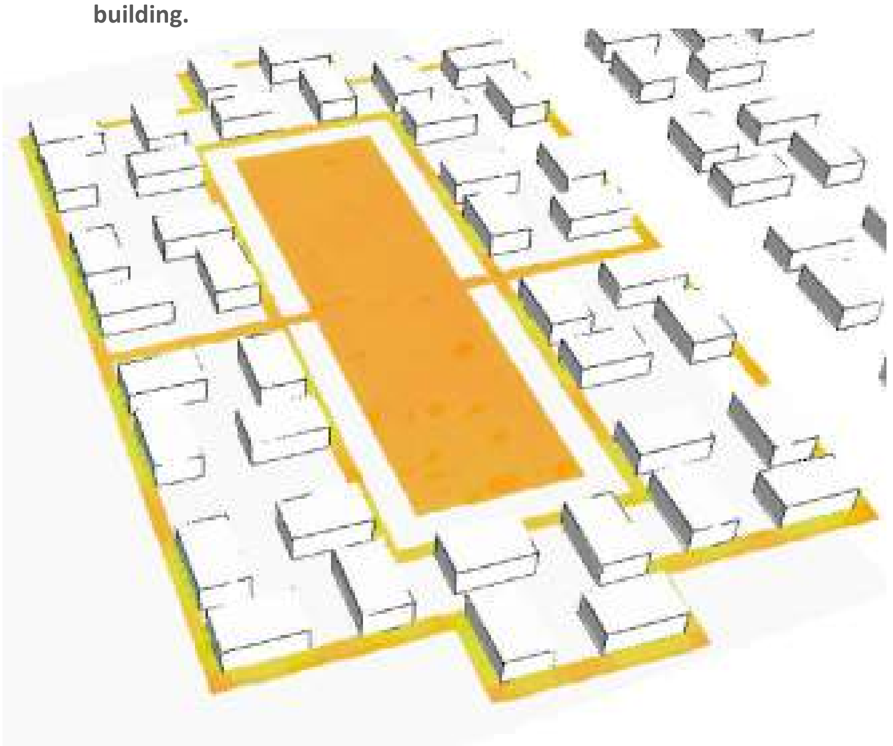


An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).

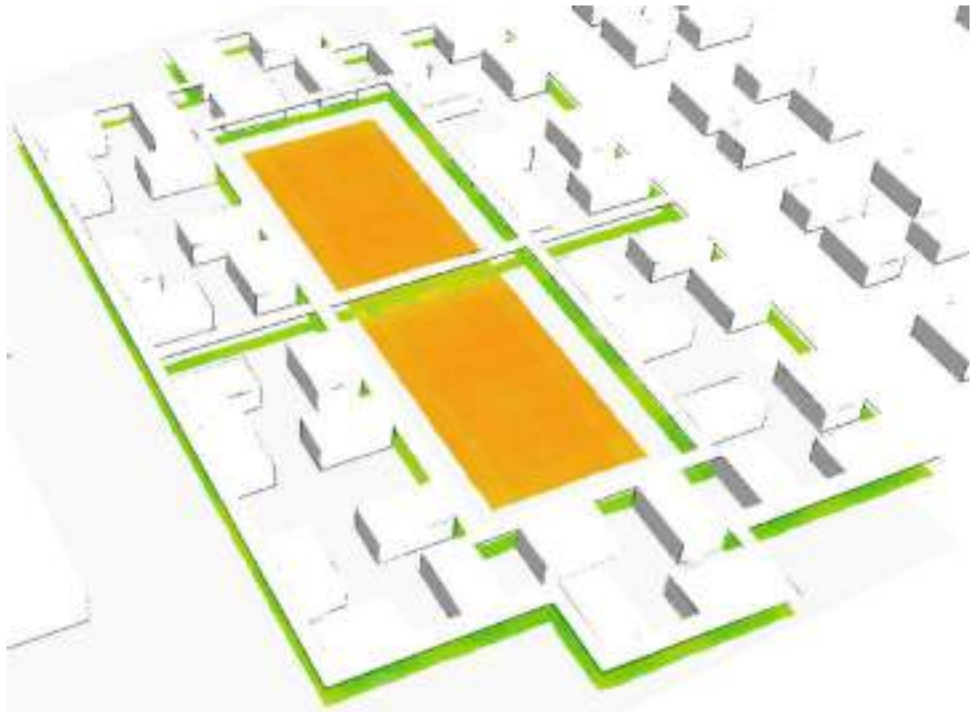
Observation
Low density & low height of single storey masses reduces self-shading potential of housing clusters.
The longer sides of the park & building massing facing east – west causes high amounts of radiation.



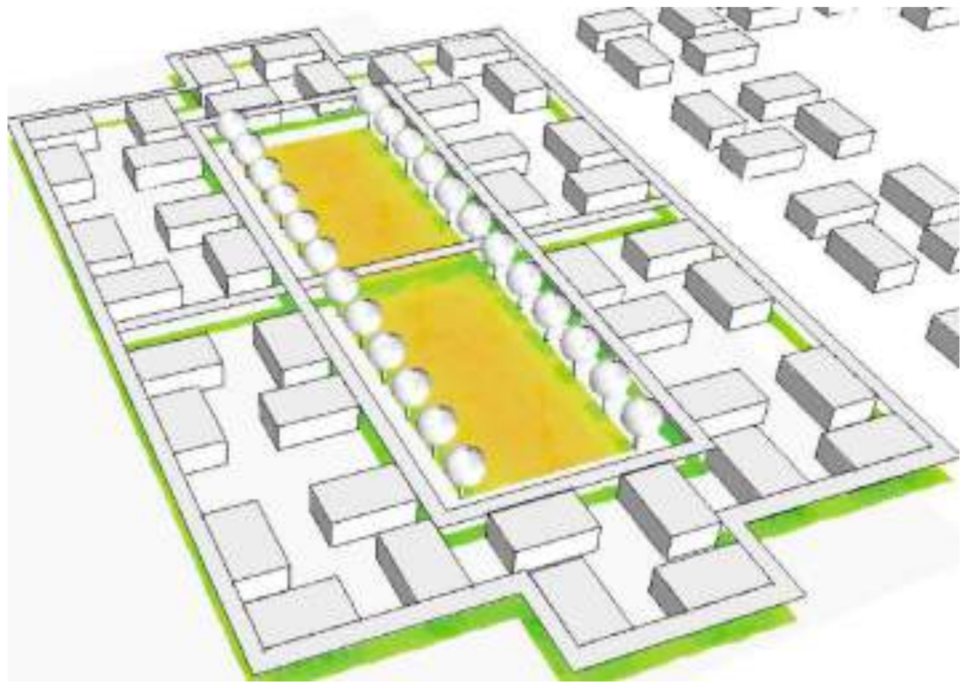
Baseline
- Ideal Orientation of Building massing is with the longer sides facing north & south. This reduces exposure throughout the summer during the day. South orientation can be easily shaded.
- Higher density of housing clusters is recommended with smaller clusters to improve self shading potential.
- **Walkways whether shaded or unshaded are advised to be designed as close as possible to the building masses to take advantage of shade from building.**



Level 1 interventions
- A covered walkway is proposed that ties the clusters. The walkway is proposed on the outer edges as well as along the inner courtyard.
- Outer shaded walkway improves thermal comfort & walkability of pedestrian paths along the access roads.
- In addition, shaded walkways provide protection from solar radiation to the housing clusters and aids in creating a communal transition space within the cluster



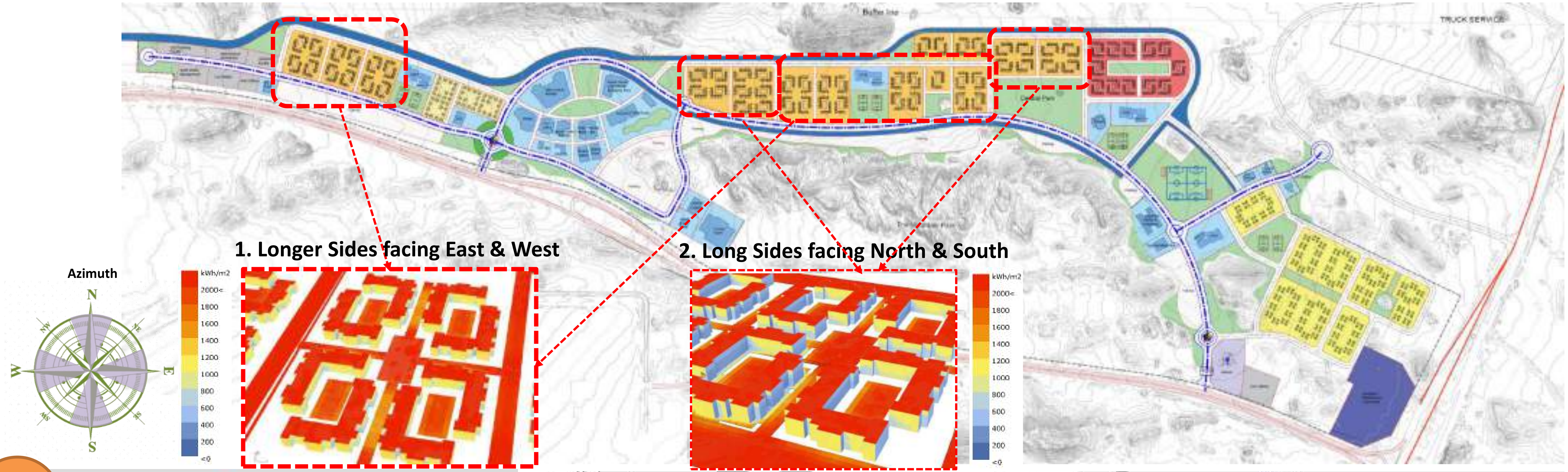
Level 2 interventions
- Addition of trees strategically along the walkway and inner courtyard provides maximum coverage of shade for walkable surfaces throughout the day.
- Trees along the outer edge of the cluster must be added in **East & West** directions predominantly where there is no covered walkway.

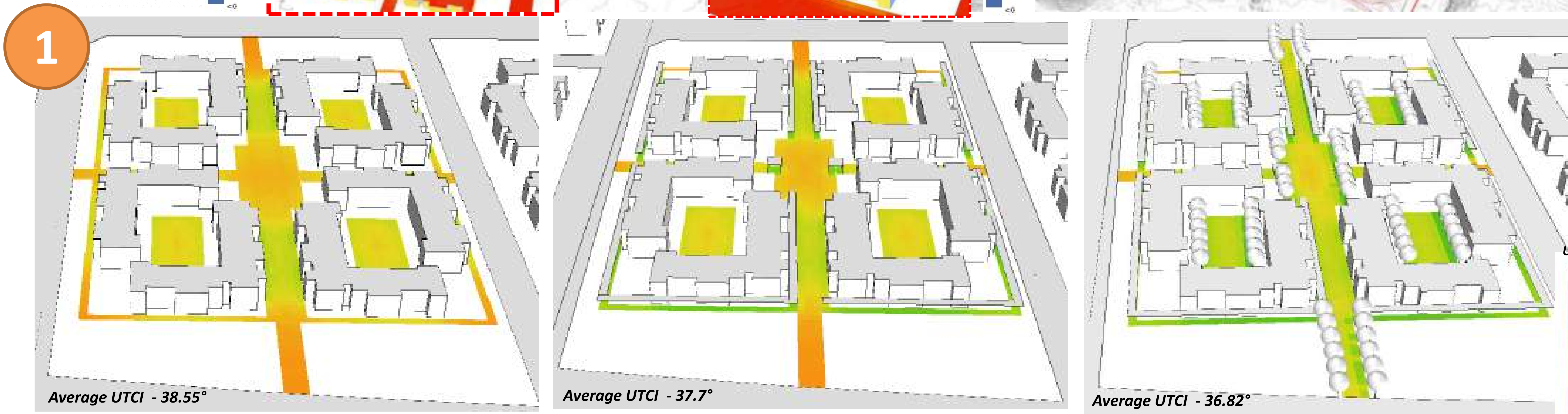


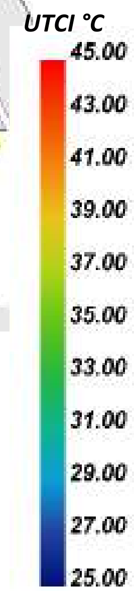
NEOM

Typology – Ground +1 Storeys

Azimuth (Direction from north) - ± 15°







Baseline

- Two storey Massing provides protection to adjacent walkways from solar radiation on the North & South.
- Walkways along the East & West are exposed to high solar radiation
- High solar radiation noticed on the larger open spaces such as central park space & exposed roads.

Level 1 interventions

- Shaded walkways are required only on the outer edge of a cluster of 4 blocks.
- No shading is required on the north side of the cluster.
- However walkway on the north side of the cluster must be planned close to the building massing to take advantage of the context shading
- The semi open corridor in the two L-shaped blocks are proposed to be connected using shaded walkways for ease of walkability.

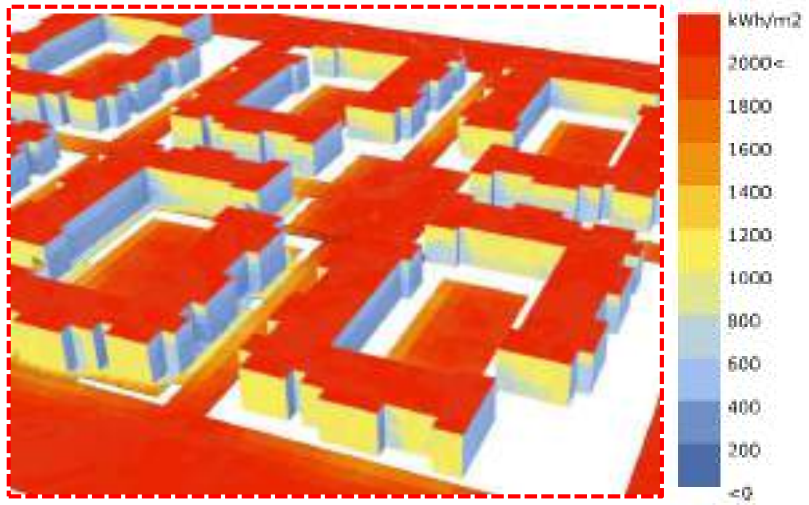
Level 2 interventions

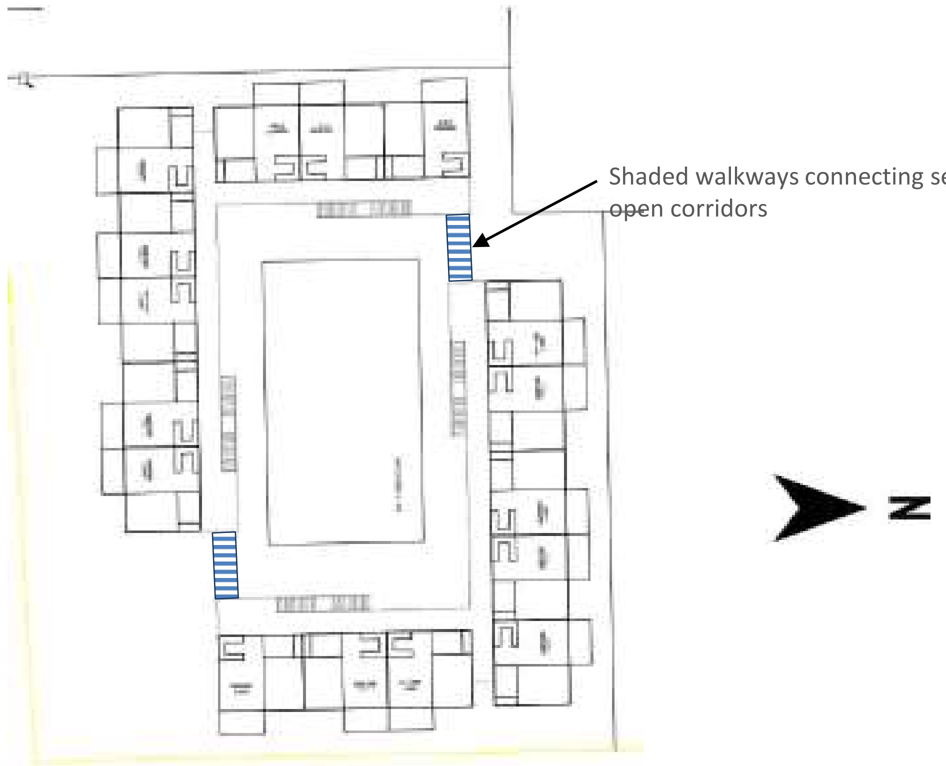
- The longer sides of the parks face **East & West**. Ample shading is required in the east & west direction.
- Shaded canopies are suggested at every 30m in shared parks. Individual block parks are well shaded from context geometry & can be enhanced using trees on east & west edges
- Further improvement in Outdoor thermal comfort can be achieved by overhead tensile shades across the park if required.

An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).

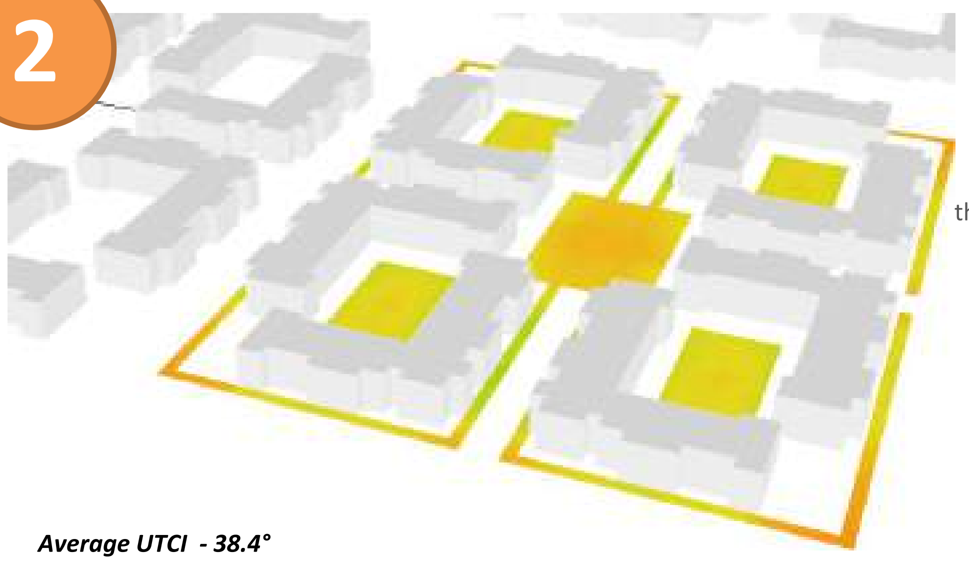
Observation
The Ground +1 Storey Blocks are a set of 2 L shaped blocks with the longer sides in the north and south facing directions. The north side registers very little radiation.
The central park between 4 clusters has longer directions facing east & west which registers high amounts of radiation

2. Long Sides facing North & South





2



Average UTCI - 38.4°

Baseline
- Two storey Massing provides protection to adjacent walkways from solar radiation on the North & South.
- Walkways along the East & West are exposed to high solar radiation.

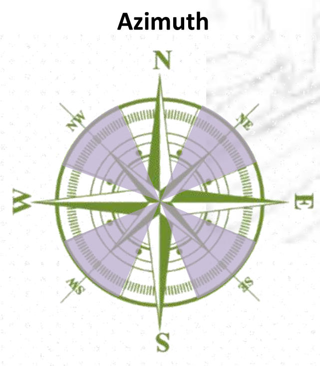
Average UTCI - 37.6°

Level 1 interventions
- Shaded walkways are required only on the outer edge of a cluster of 4 blocks.
- No shading is required on the north side of the cluster.
- However walkway on the north side of the cluster must be planned close to the building massing to take advantage of the context shading
- The semi open corridor in the two L-shaped blocks are proposed to be connected using shaded walkways for ease of walkability.

Average UTCI - 36.7°

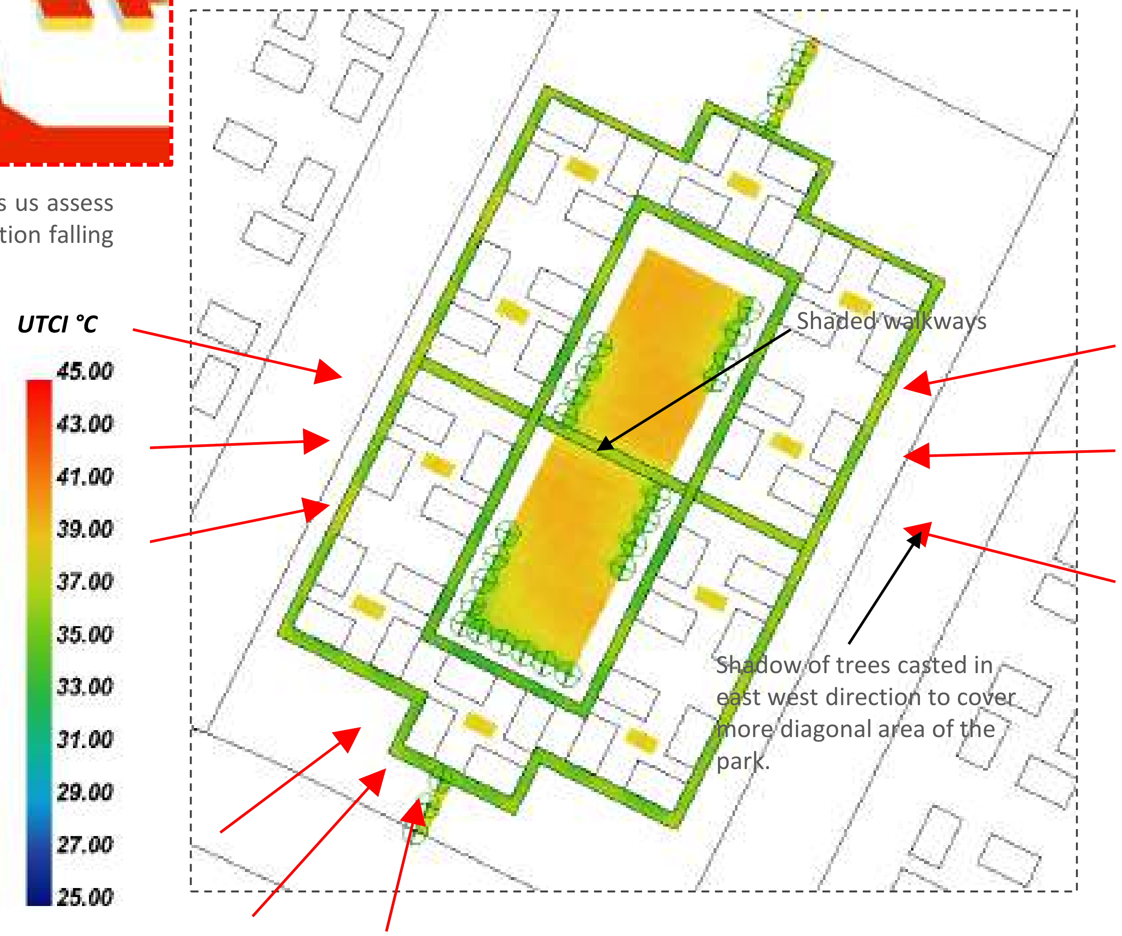
Level 2 interventions
- The longer sides of the parks face north & south. Ample shading is required in the east & west direction.
- Shaded canopies are suggested at every 30m in shared parks. Individual block parks are well shaded from context geometry & can be enhanced using trees on east & west edges
- Further improvement in Outdoor thermal comfort can be achieved by overhead tensile shades across the park if required.

Typology – Ground +1 Storeys
Azimuth (Direction from north) - ± 15°



An irradiation study was conducted as a precursor to the UTCI study. This helps us assess the critical directions wrt. orientation. The irradiation study measures the radiation falling on each façade in (KWh/m2).

Observation
The individual Ground story units receive high radiation & are exposed in all directions. The longer sides of the park face South East & North West & face large amounts of radiation. A cohesive strategy to improve thermal comfort and shelter from solar heatgains is outlined in the next slide.

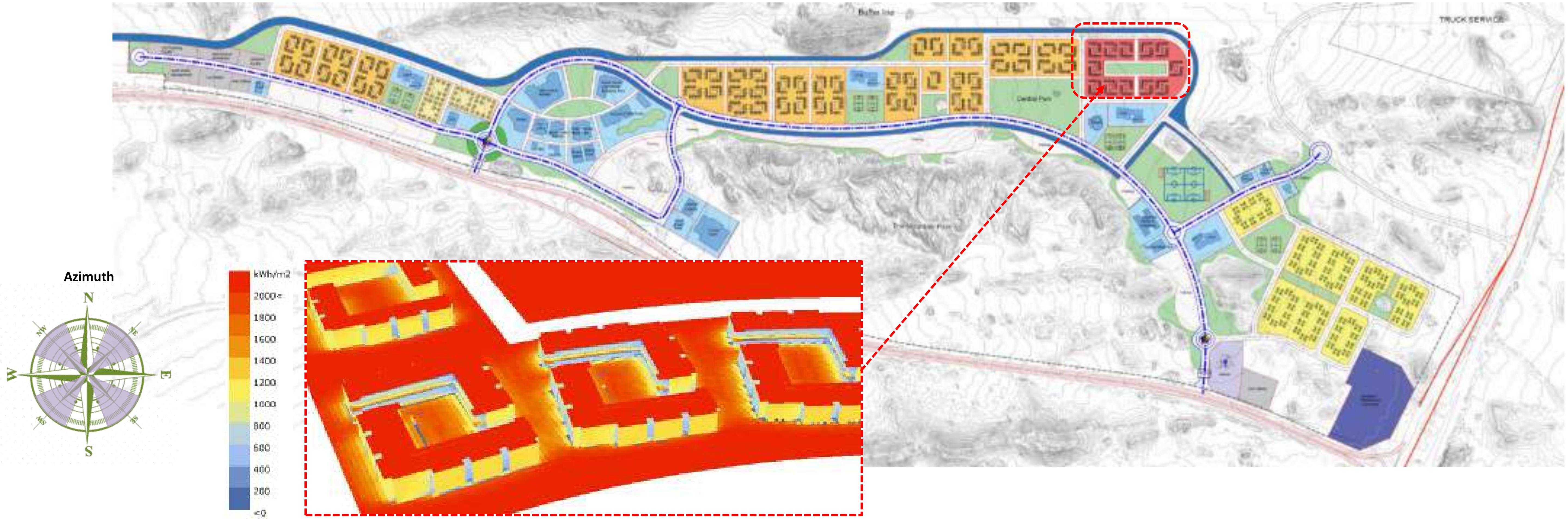


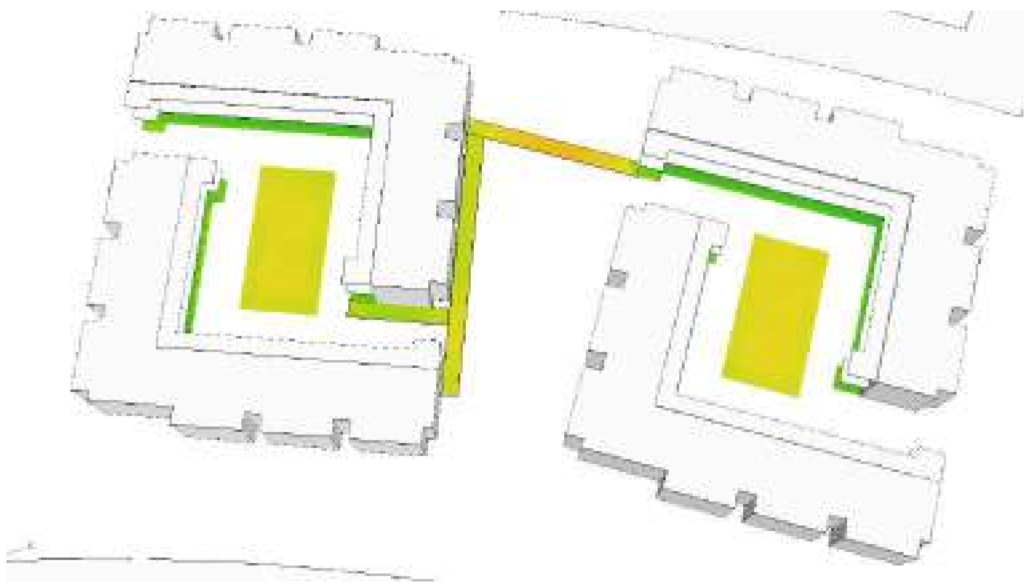
Recommendations
Smaller clusters are recommended such as the one above are recommended as the open park spaces are better shaded due to the compact nature of cluster

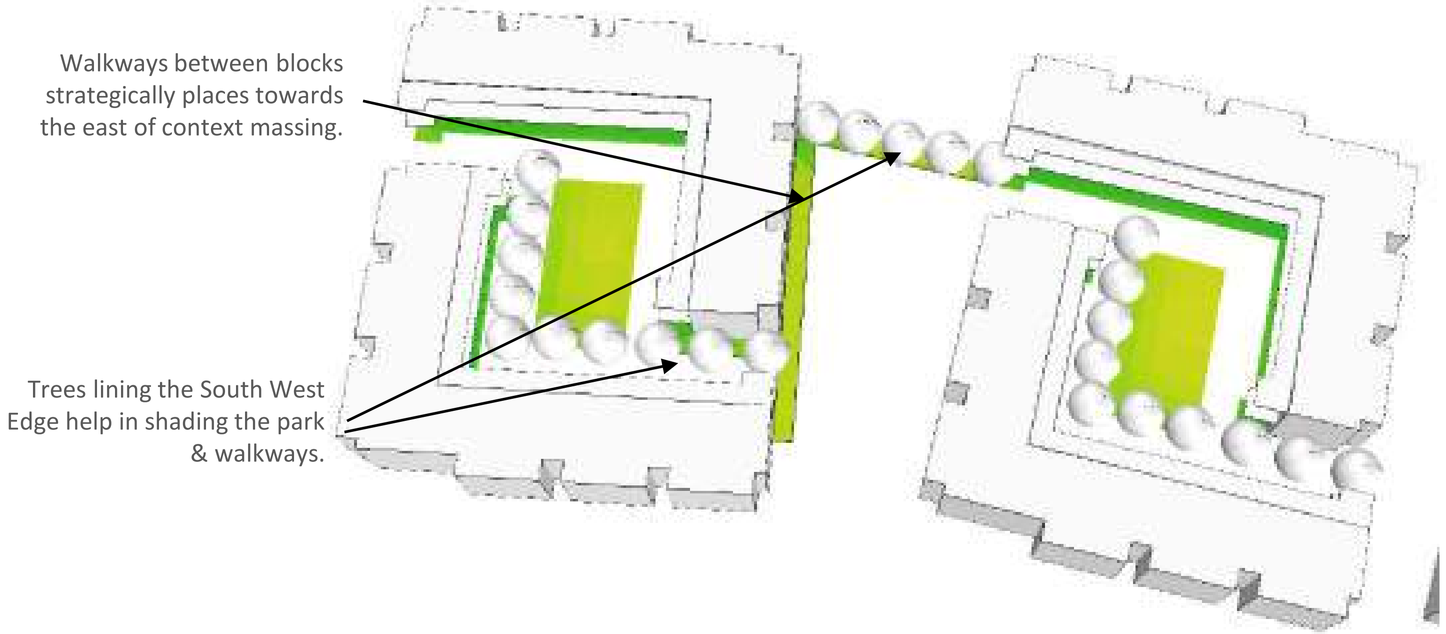
The long park is broken down into two parts in the larger cluster through the use of shaded walkway .

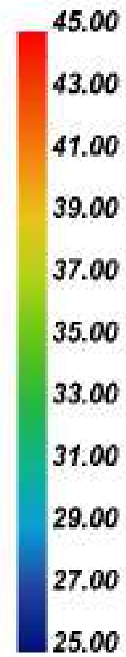
Extra trees are added on the South west & North East corners of each part of the park strategically to cast shadows towards the east & west.

Typology – Ground +1 Storeys
Azimuth (Direction from north) - ± 45°









Baseline
- Semi –open corridors in each block are well shaded and effective.
- The central court is compact and the density of the Ground +1 block helps shade the central open space to. an extend.

Level 1 interventions
- Walkway between masses must connect the existing semi-open corridors
- Walkways between masses must be strategically designed to the East of context massing to take advantage of the shade during the hot afternoons
- Trees are proposed on the South West side as well as unshaded walkways to provide comfortable walkways.

External Thermal Comfort Solutions [Shading]