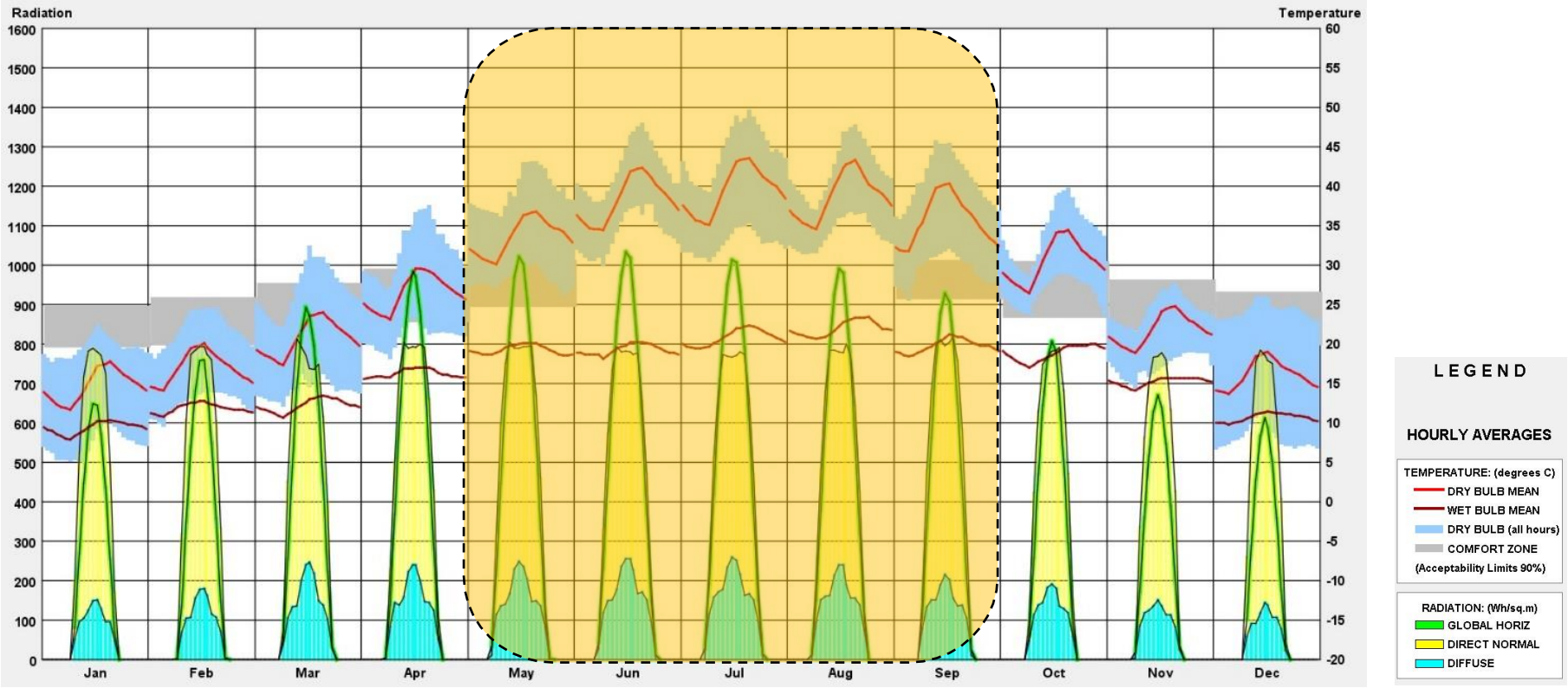
Introduction

Location : 29 N°, 47E°.

Kuwait is located on the North Eastern Edge of the Arabian Peninsula, at tip of the Persian Gulf. The general region has severely arid conditions. Kuwait City is located in the coastal zone, and the site is at a low altitude close to the mean Sea level.

The graph below plots the annual dry bulb & wet bulb temperature along with direct normal & diffuse radiation levels. The difference between the dry bulb & wet bulb levels are low throughout the year apart from the summer months, which indicates high ambient relative humidity present throughout the year. High amounts of direct radiation levels are observed throughout the year as the latitude is in the sub-tropical zone.

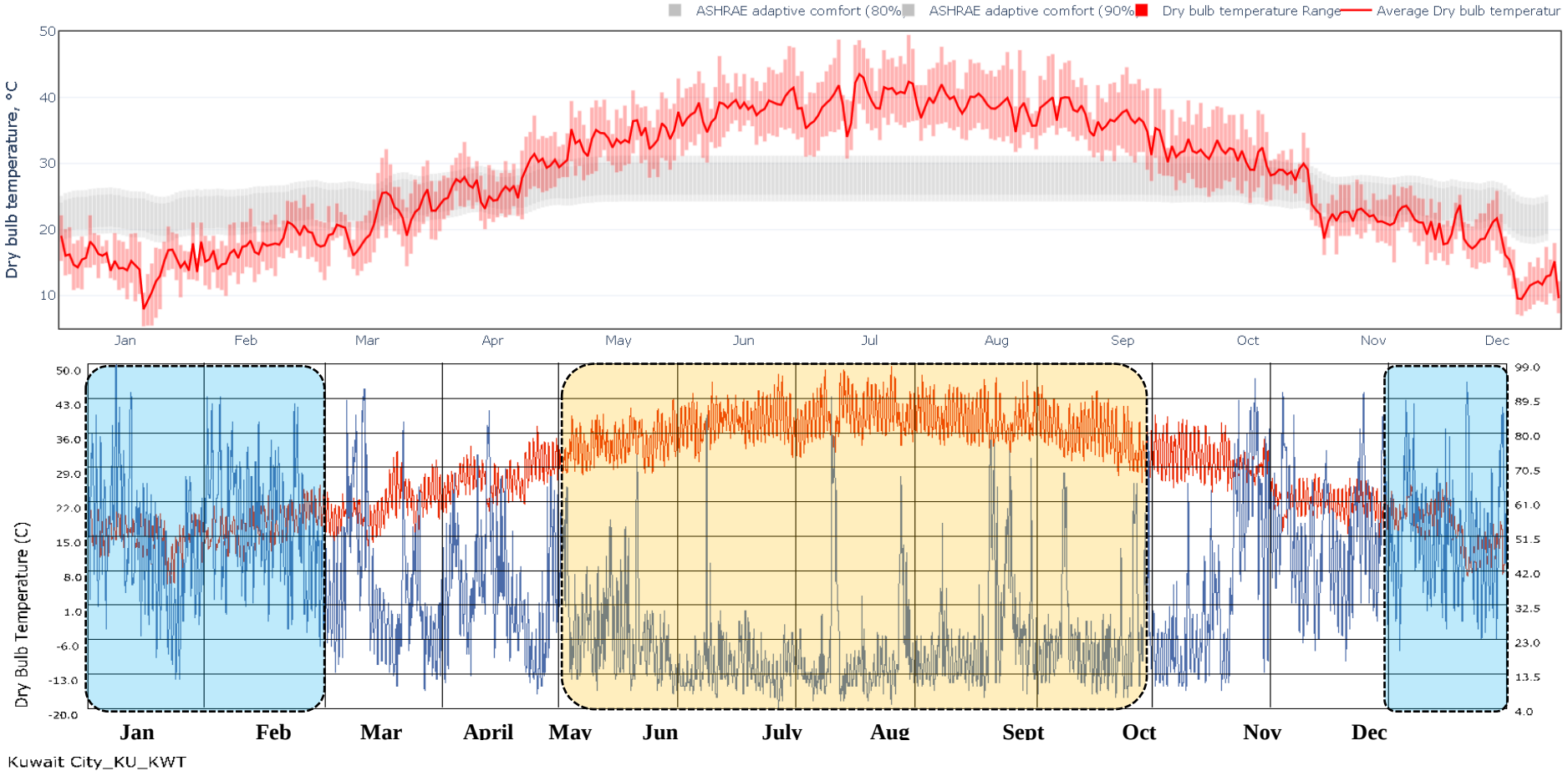
Figure 10 Annual Temperature & Radiation levels for Kuwait City



Temperature & Relative humidity Levels

There is a high temperature difference between summer & winter months. The summers are long and harsh in Kuwait extending from April to September. The temperatures are high and can reach upto 48°C whereas the relative humidity levels are 5% to 35%. The winter is short extending from December to February. The winters can be very cold with temperatures reaching below 10° C. The winter months have higher RH levels.

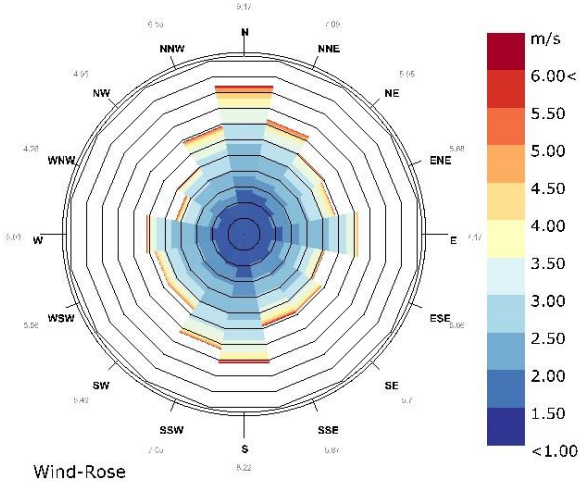
There is a high diurnal difference in RH levels noticed throughout the year. This is due to the night time sea-breeze over the landmass. This has been documented by several atmosphere scientific studies conducted in the region.



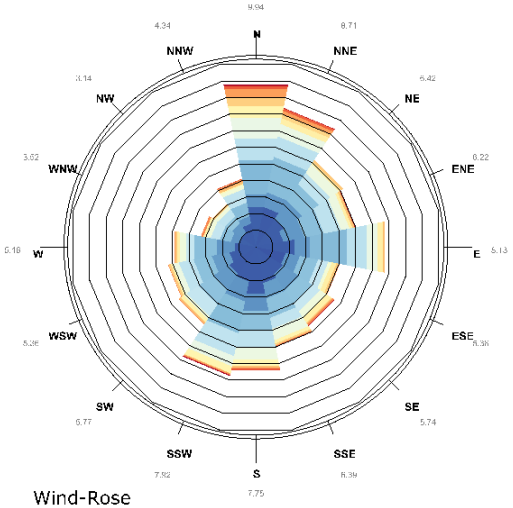
Wind Studies

The Primary wind direction is Kuwait is from the **North** & **North East** to **South** & **South West**. However , the short term wind directions are erratic and are largely dependent on pressure differentials and movement of Land & Sea breeze.
The percentage of calm hours are just 0.21%.

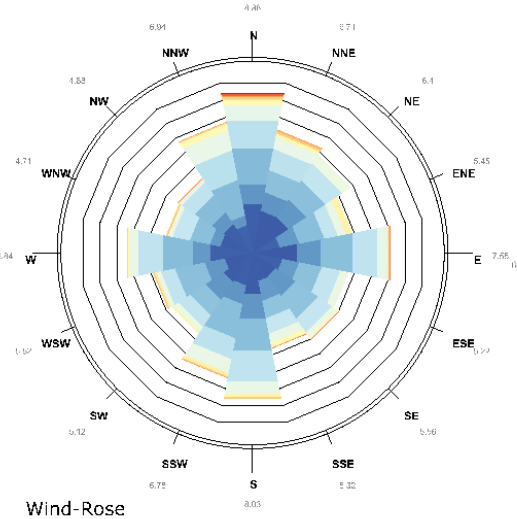
Naturally ventilated atriums/transition spaces can benefit from using active or passive wind catching devices to take advantage of sea-breeze during the night-time.



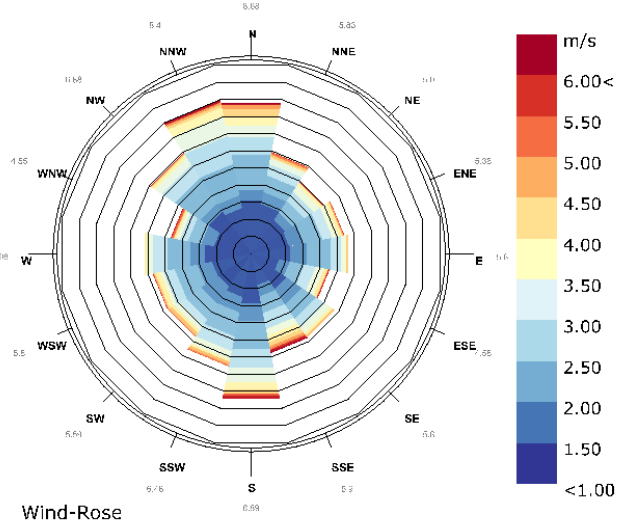
Wind-Rose
Kuwait City_KU_KWT
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.21% of the time = 18 hours.
Each closed polyline shows frequency of 0.9%. = 80 hours.



Wind-Rose
Kuwait City_KU_KWT
1 MAR 1:00 - 30 JUN 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.14% of the time = 4 hours.
Each closed polyline shows frequency of 1.0%. = 29



Wind-Rose
Kuwait City_KU_KWT
1 JUL 1:00 - 31 OCT 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.10% of the time = 3 hours.
Each closed polyline shows frequency of 0.9%. = 26



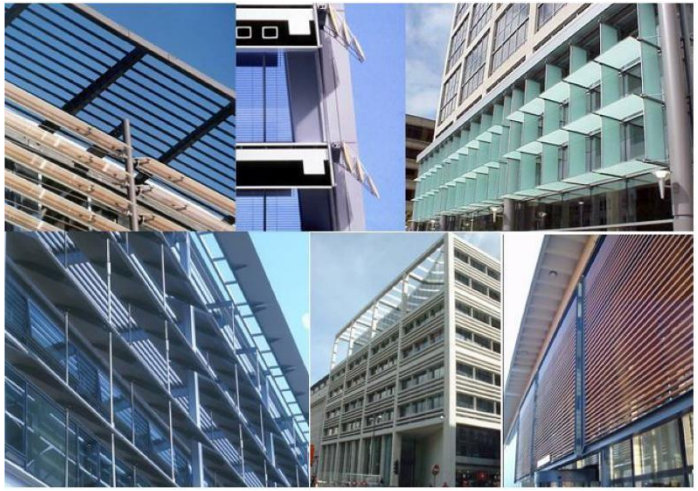
Wind-Rose
Kuwait City_KU_KWT
1 NOV 1:00 - 28 FEB 24:00
Hourly Data: Wind Speed (m/s)
Calm for 0.38% of the time = 11 hours.
Each closed polyline shows frequency of 0.9%. = 25 hours.

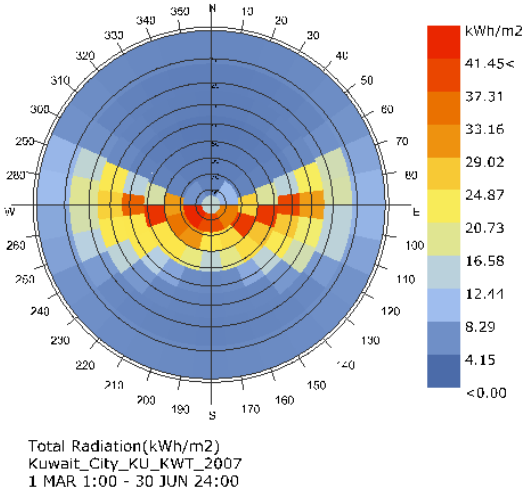
Radiation Dome Study

The radiation domes show that the direct normal radiation levels for summer & winter months. This radiation levels are determined by the latitude of the location & the solar geometry specifically calculated for Kuwait city.

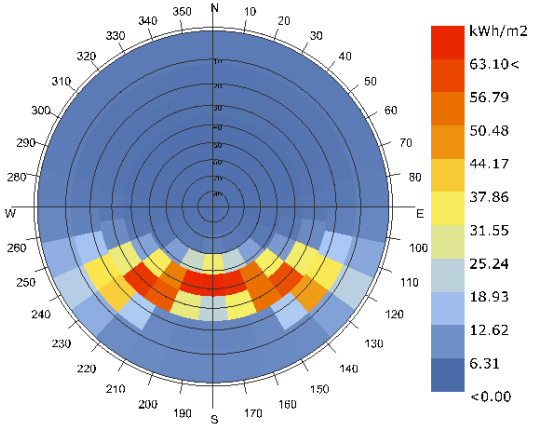
The radiation levels are equally high in both summer & winter months. The radiation primarily falls from the south during the winter as the sun is at a lower angle.

In the summer months shading is required predominantly on the East & West façade whereas in the winter months, shading is predominantly required on the South façade.

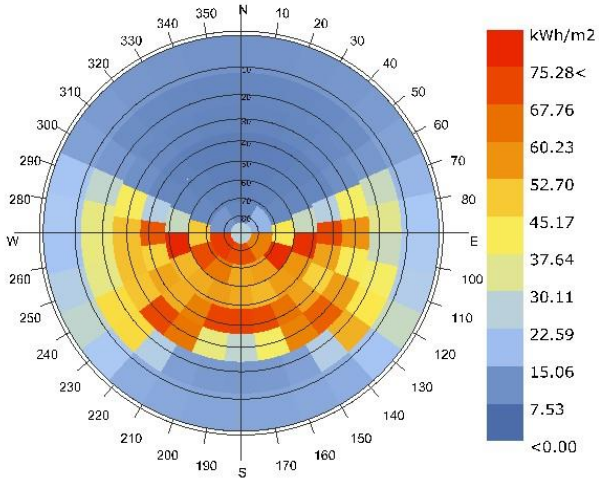




Summer



Winter



Annual

1.6.1.10. External Solar Heat Radiation Study

A comparative solar radiation analysis between the three concept alternative architectural models been undertaken to highlight & compare the impact of the solar gains, in the previous stage.

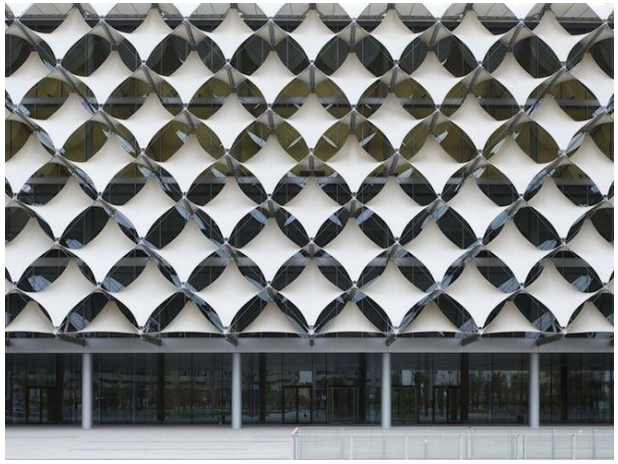
A detailed radiation study informed by the context massing & solar geometry is conducted to optimize shading and strategically design shading only on localized areas of the facades with high radiation levels.

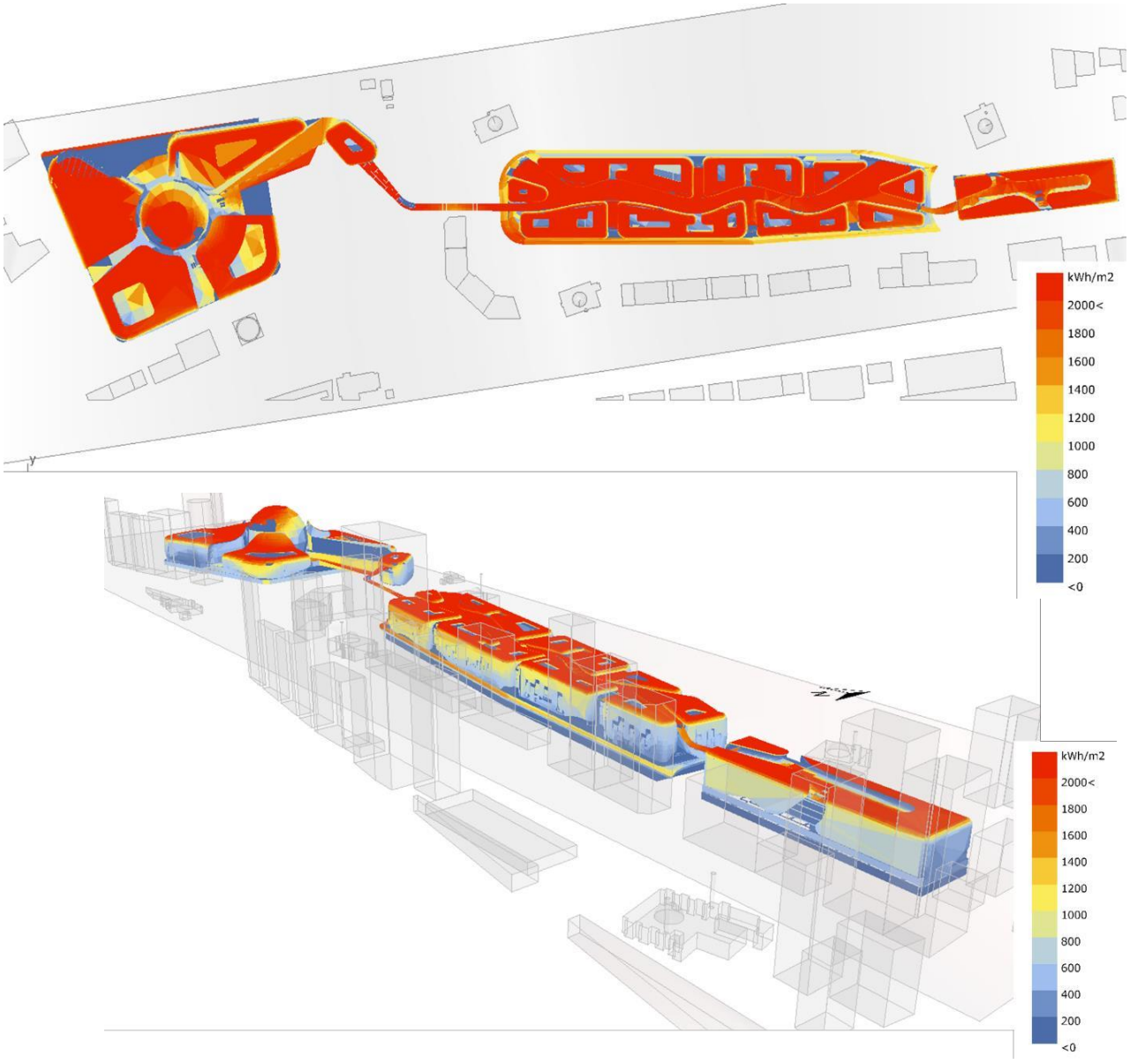
Alternative [1]

Total Annual Radiation on all surfaces: 133,005 MWhr/ Year

Surface Area -364,562 sqmt

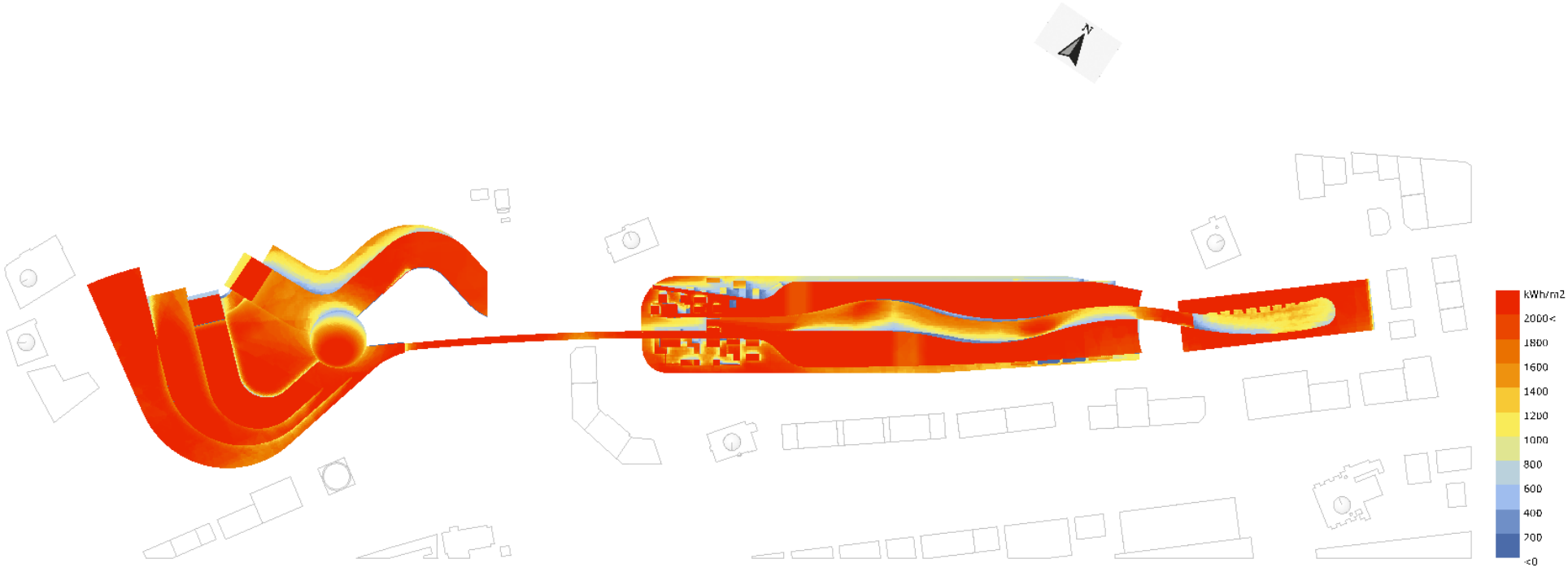
Average radiation per sqmt : 364 KW/m2

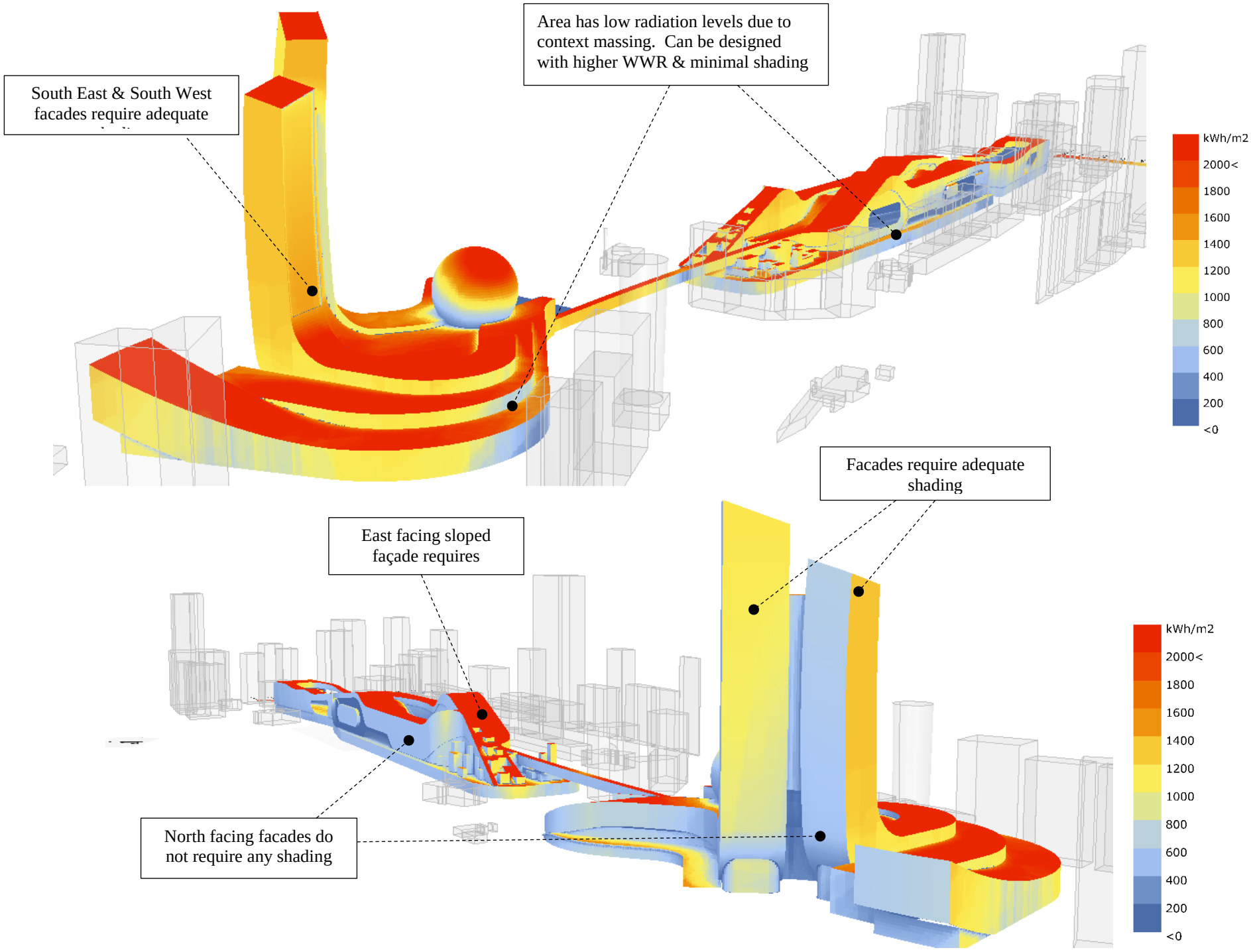




Alternative [2]

Total Annual Radiation on all surfaces: 151,893 MWhr/ Year
Surface Area -350,386 sqmt
Average Radiation per sqmt : 433 KW



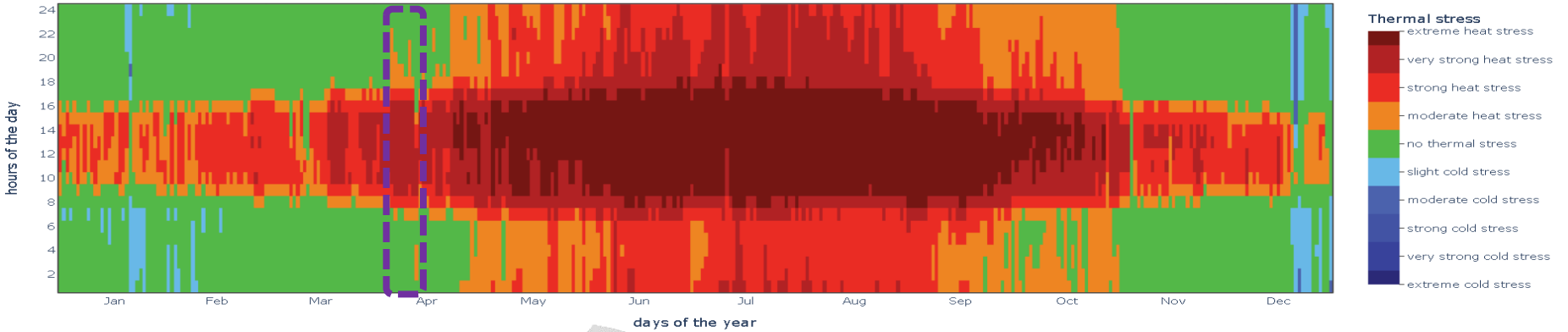

South East & South West facades require adequate
Area has low radiation levels due to context massing. Can be designed with higher WWR & minimal shading
kWh/m2
2000<
1800
1600
1400
1200
1000
800
600
400
200
<0
Facades require adequate shading
East facing sloped façade requires
North facing facades do not require any shading
kWh/m2
2000<
1800
1600
1400
1200
1000
800
600
400
200
<0

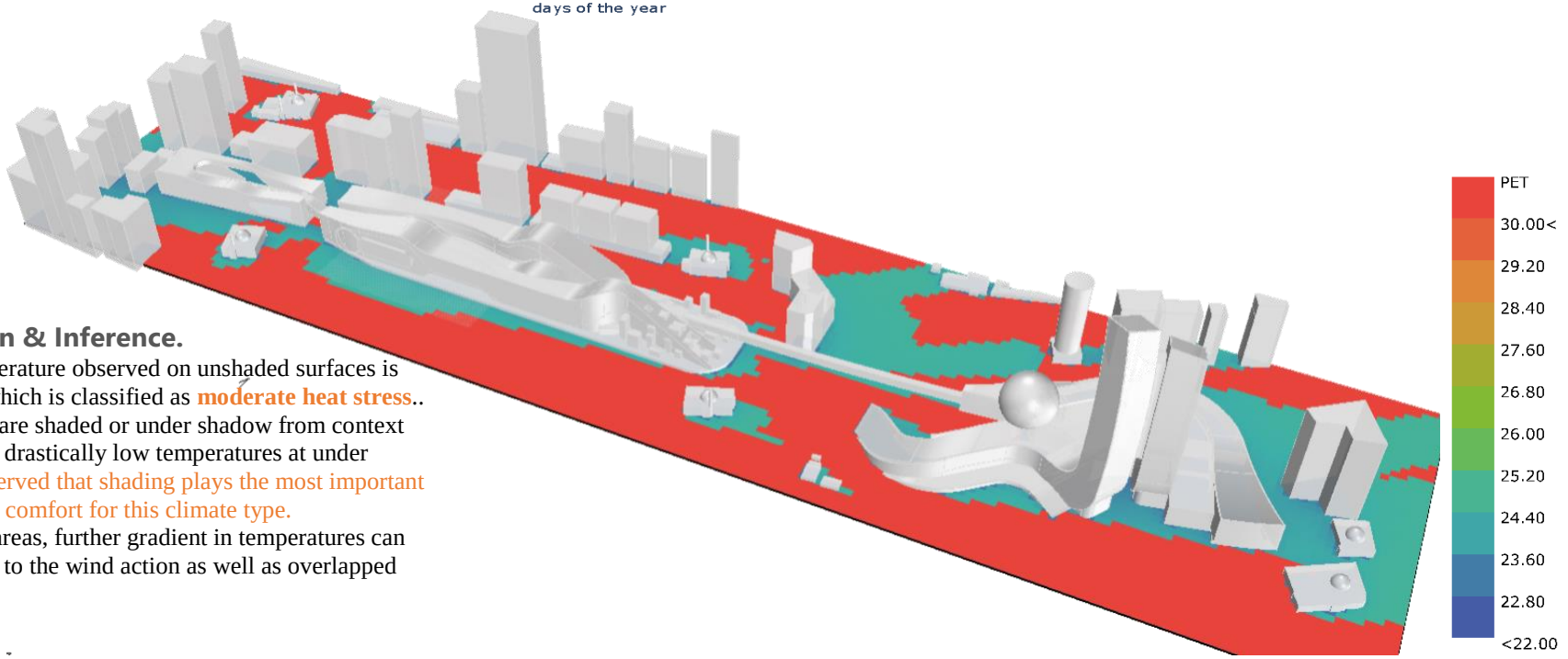
1.6.1.11. Outdoor Thermal comfort Study

A. Physiologically Equivalent Temperature

An preliminary comfort simulation was conducted based on the **Physiologically Equivalent Temperature (PET)** for the entire development including the surrounding urban context. PET takes into account both Meteorological & Non-Meteorological data. The below chart shows the annual thermal stress for Kuwait city. 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.

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





Observation & Inference.

The PET temperature observed on unshaded surfaces is above 30°C, which is classified as **moderate heat stress**.. The areas that are shaded or under shadow from context buildings have drastically low temperatures at under 25°C. It is observed that shading plays the most important role in thermal comfort for this climate type.

In the shaded areas, further gradient in temperatures can be noticed due to the wind action as well as overlapped shading.

A. Universal Thermal Comfort Index

A further study was conducted on specific areas on the podium & massing which will potentially be used for outdoor human activity such as outdoor events, roof top restaurants etc. The universal thermal comfort index was used for this study. 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.

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

Definitions

PET

PET is defined to be equivalent to the air temperature that is required to reproduce in a standardized indoor setting and for a standardized person the core and skin temperatures that are observed under the conditions being assessed (Verein Deutscher Ingenieure 1998; Höppe 1999). The standardized person is characterized by a work metabolism of 80 W of light activity, in addition to basic metabolism; and by 0.9 clo of heat resistance as a result of clothing.

The calculation of PET includes the following climate factors:

– Mean radiant temperature

– Air velocity (wind speed)

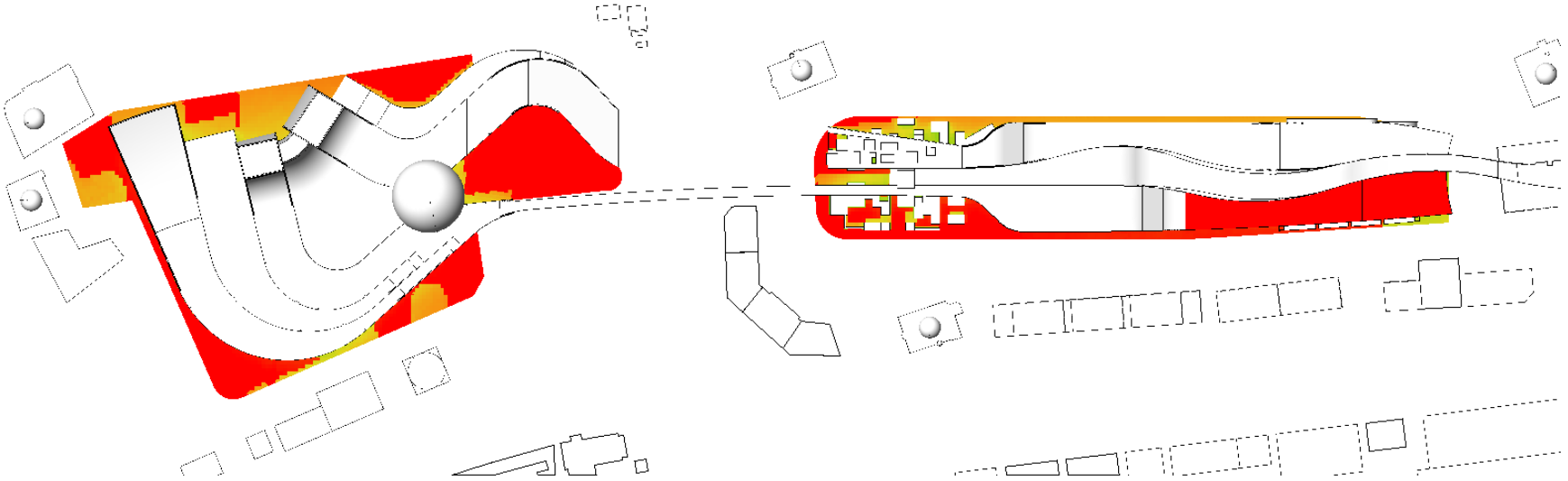
– Water vapor pressure or relative humidity

UTCI

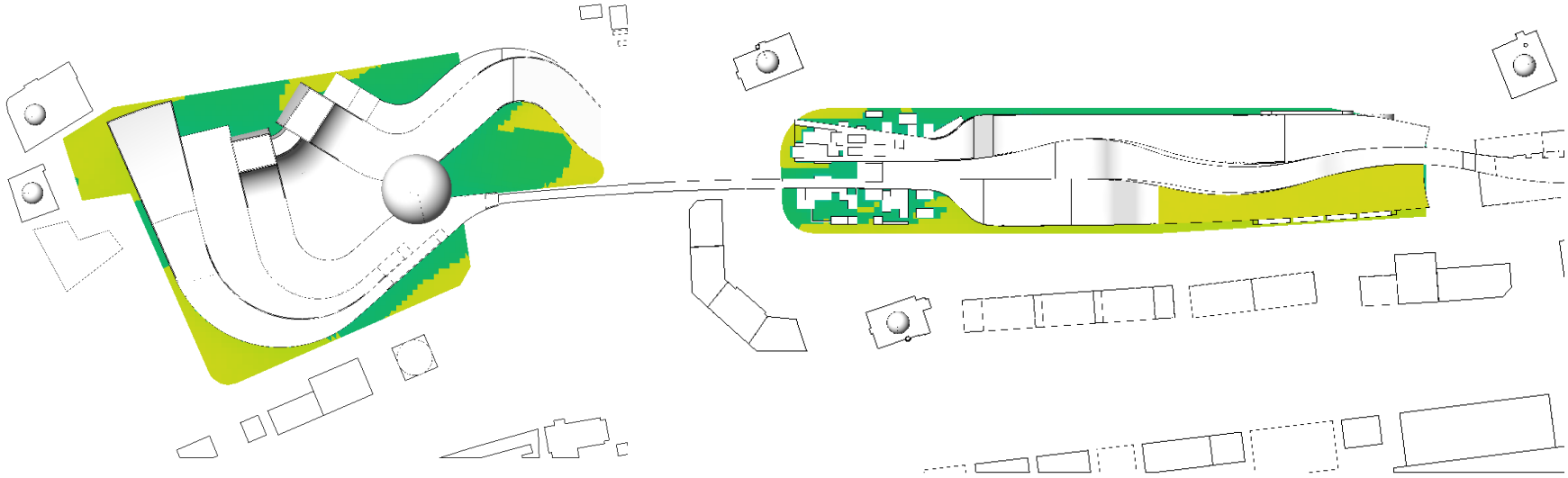
The UTCI originates from an approach that was proposed over 10 years ago by the International Society of Biometeorology (ISB) Commission. Fiala et al.'s advanced multi-node model of thermo-regulation provides the basis for the UTCI, which is defined as the capability of an organism to retain its body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

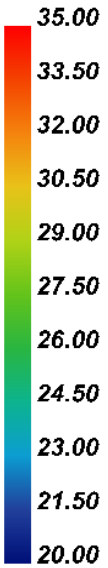
Universal thermal climate index (UTCI), introduced in 1994, considers dry temperature, relative humidity, solar radiation, and wind speed into account and is regarded as the reference environmental temperature causing strain (Baaghideh et al., 2016).

21st March at 12pm

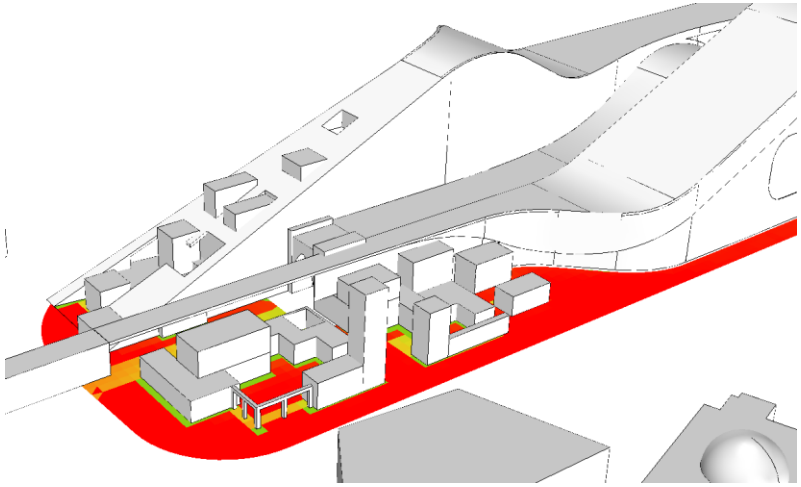


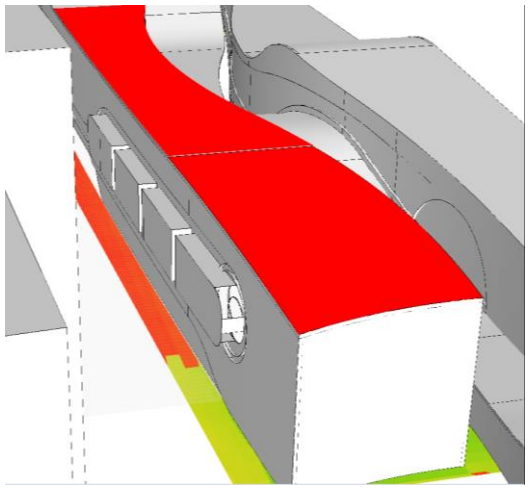
21st March at 4pm

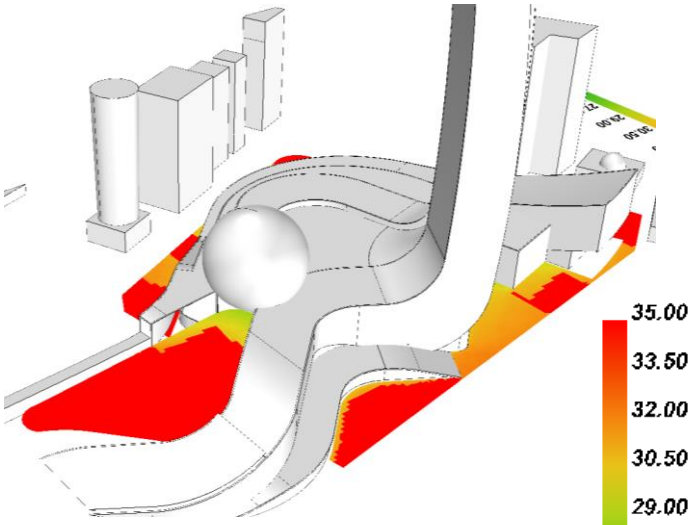




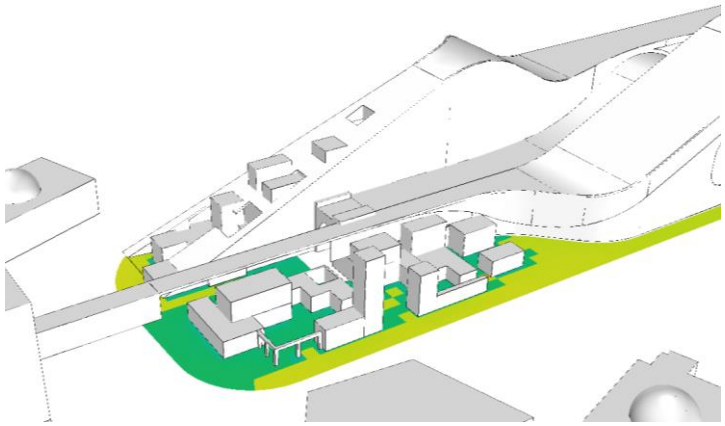
21st March at 12pm

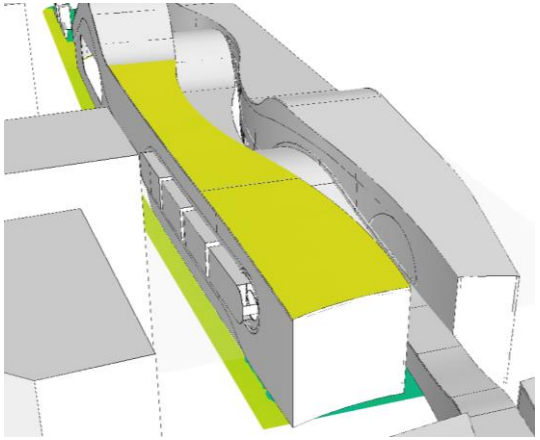


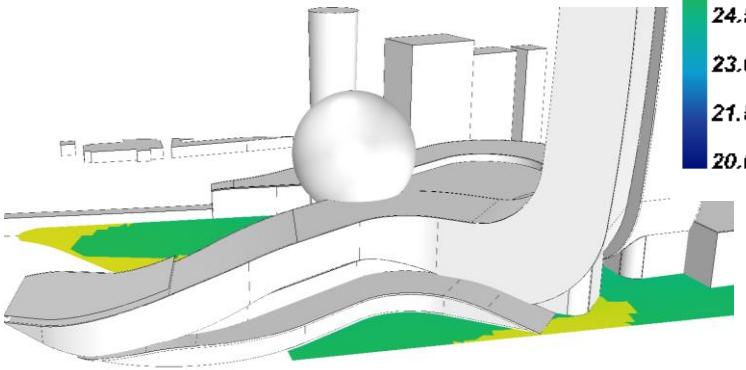




21st March at 4pm







Observation & Inference.

The UTCI results vary starkly for 12pm & 4pm, The unshaded surfaces at 12pm register a strong heat stress with temperatures going above 35°C. At 4pm the unshaded spaces suggest moderate heat stress. During noon , the shaded space temperatures can be reduced by adding shading. This is consistent with the PET results where shading placys the most important role in out door thermal comfort. For outdoor spaces intended to be used during the day , overhead shading is a crucial component in improving thermal comfort and making the space usable.