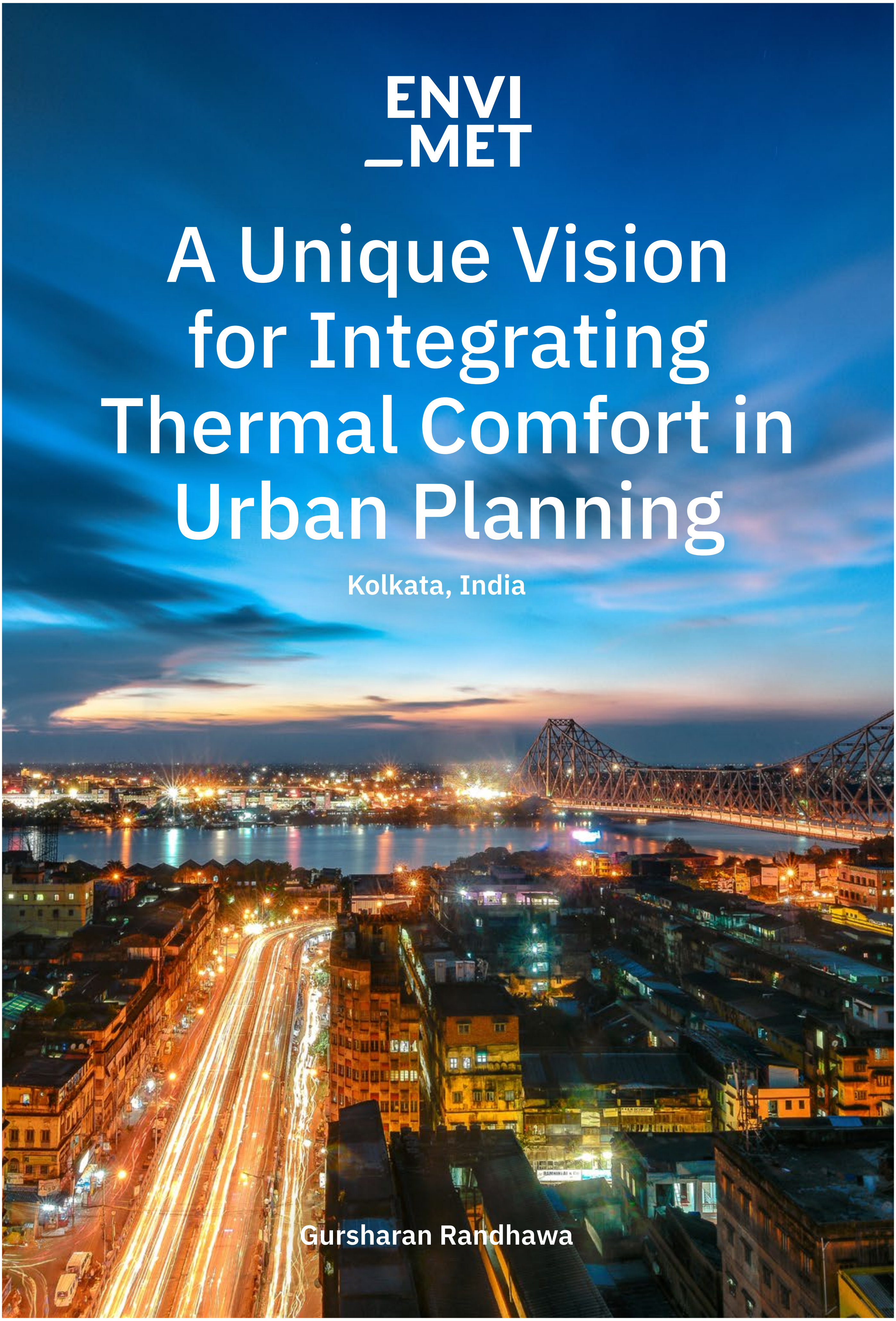


ENVI_MET

A Unique Vision for Integrating Thermal Comfort in Urban Planning

Kolkata, India

Gursharan Randhawa

Kolkata - the city of addas and conversations

Calcutta, now renamed "Kolkata," is the capital of the Indian state of West Bengal, located on the east bank of the Hooghly River. Kolkata has a total area of 185 square kilometers (71 square miles).

It is situated in the Ganges Delta, which is known for its fertile soil and dense population, making it India's third largest metropolitan area and the world's eighth largest urban agglomeration. Kolkata is in a tropical zone and has hot and humid weather all year. The annual temperature is 25.5 degrees Celsius on average (78 degrees Fahrenheit). The annual precipitation average is about 1,400 millimeters (55 inches). From March to June, the city experiences three distinct seasons: a hot and humid summer, a monsoon season from July to September, and a dry and cool winter from October to February. The city is flat, with low-lying hills surrounding it. The Hooghly River runs through the city's heart, dividing it into two distinct areas. The old city is located to the north and is filled with historic buildings, colonial architecture, and narrow winding streets. The new city, to the south, is filled with modern buildings and wide boulevards.

One of the most iconic aspects of the city is its addas, a meeting spot, usually at a roadside areas, gardens and parks, where people gather to catch up, discuss current events, and relax. These urban pockets form the backbone of this report as the investigation highlights these areas of human interaction in the city in two diverse urban fabric of the city - Salt Lake: a complete planned residential neighborhood with loose urban fabric formed during 2010; and Howrah: a mixed use dense urban settlement formed during 1800s when Kolkata was the capital of British India.

The study aims to study the interactions of the existing urban green pockets and parks in a typical neighborhood and rethink their proximity and response for a thermally comfortable eco-system.

Gursharan Randhawa
Architect | Environmental Consultant

Why Kolkata?

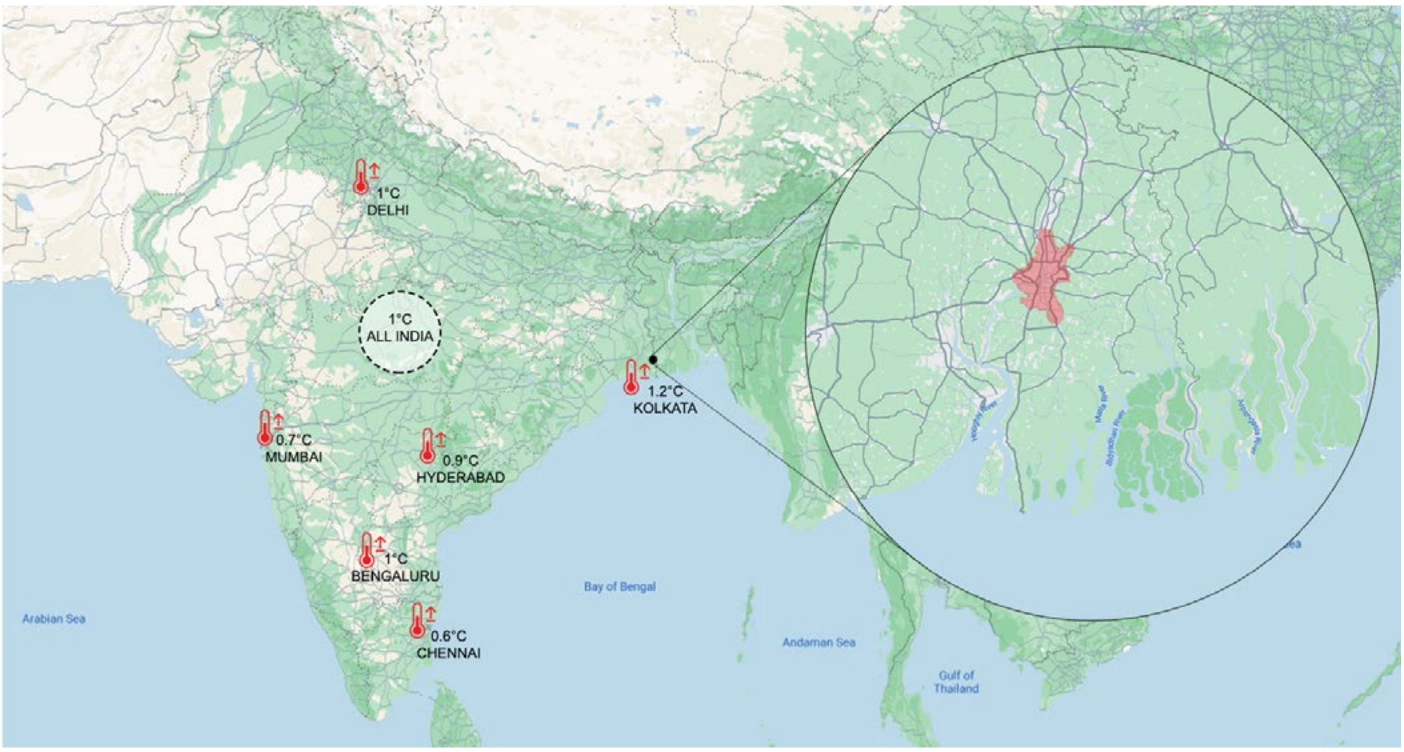
Kolkata is one of the most vulnerable cities in India to the impacts of climate change. The city's unique geographical location, population density and socio-economic situation – with large numbers of people living in poverty – makes it a risk hotspot.

The city is likely to face twin challenges of heat and humidity, and increased frequency of cyclones, reveals the 6th Assessment Report of the Working Group II of Intergovernmental Panel on Climate Change (IPCC).

The effects of climate change in Kolkata are becoming increasingly evident as the city experiences more extreme weather events, rising temperatures, and higher levels of air pollution. Due to its location in the Ganges Delta, Kolkata is particularly vulnerable to changes in sea level, and projections suggest that the city could see a sea level rise of up to 1.5 meters by the end of the century.

The heat waves that Kolkata experiences are also becoming more intense and frequent, with temperatures in the city reaching up to 45 degrees Celsius in the summer. This is leading to increased health risks as well as water, power, and food shortages.

The air quality in Kolkata is also declining due to increased emissions from vehicles, industry, and burning of biomass. This is causing a range of health impacts, including respiratory illnesses and cardiovascular diseases.



Study approach

To approach the research, first a basic review of both modern and traditional urban design literature is done.

Kolkata's history defines the urban context distinctly into three different periods:

- Old city Calcutta
- Colonial Era - Kolkata as British capital
- From Calcutta to Kolkata - rise as a megacity

Next a brief study of the urbanization pattern in Kolkata is done to comprehend the context.

For the study, two neighborhoods of Kolkata from old city and new planned municipality are selected and the green pockets and parks are studied for various parameters of thermal comfort.

Also, understanding the climatic conditions, all simulations are conducted for 21 May to observe the overall heat stress in summers which is of grave concern as stated by IPCC.

Approach

Climate Analysis

Analysis of city fabric and Site selection

Existing Microclimatic Simulations

Mitigation strategies

Improved Microclimatic simulations

Analysis - Impacts of Mitigation

Methodology

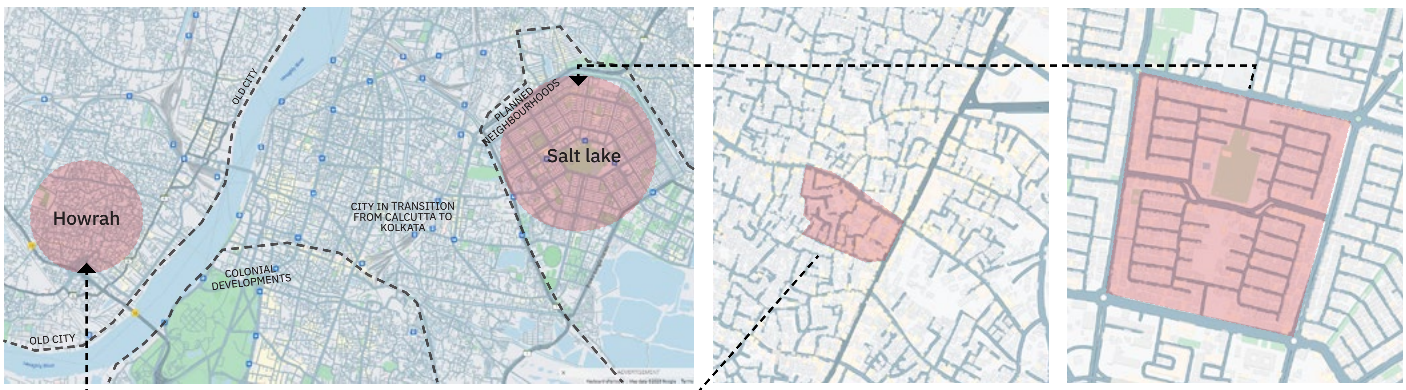
Analysis of weather data and understanding the periods of risk

Understanding the fabric of the city
Narrow down the area of study
Comprehension of the existing urban green pockets in the neighbourhoods

Simulation modelling on ENVI-met closely representing the selected neighbourhood

Microclimatic simulation during day and night; Analysis of air temperatures, wind conditions, solar radiations and thermal comfort parameters (PET) temps

Mitigation strategies followed by New microclimatic simulation models to validate



Shibpur, howrah neighbourhood
Old city
Dense settlement sparse vegetation

Bidhannagar, salt lake neighbourhood
Planned low to mid rise settlement
Community parks and green pockets present

Climatic Conditions

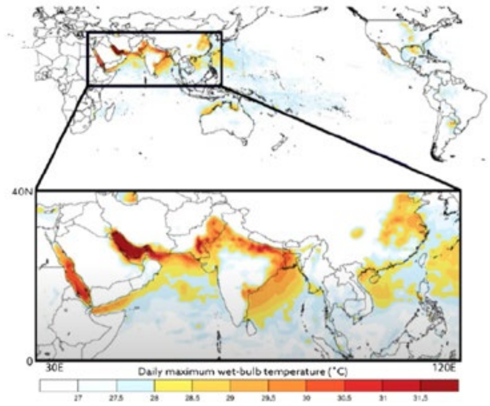
Kolkata’s climate is highly influenced by the sea, specifically the Bay of Bengal.

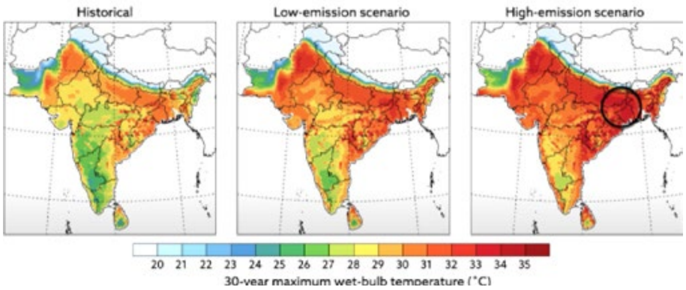
The annual mean temperature is approximately 27°C while the monthly mean temperatures range between 19°C to 30°C. The city is categorized by three distinct seasons: Summer, Monsoon and Winters. Summers are hot and humid with mean temperature of around 30°C while during dry spells, the hot summer mean temperatures easily touch 40°C in the months of April-May.

The Monsoons are heavily dominated by the South West winds bringing rain from the Bay of Bengal. The period easily stretches from mid-June to October with maximum rainfall captured in the month of July. Post monsoon brings heavy rain showers from the severe cyclonic storms in the Bay of Bengal.

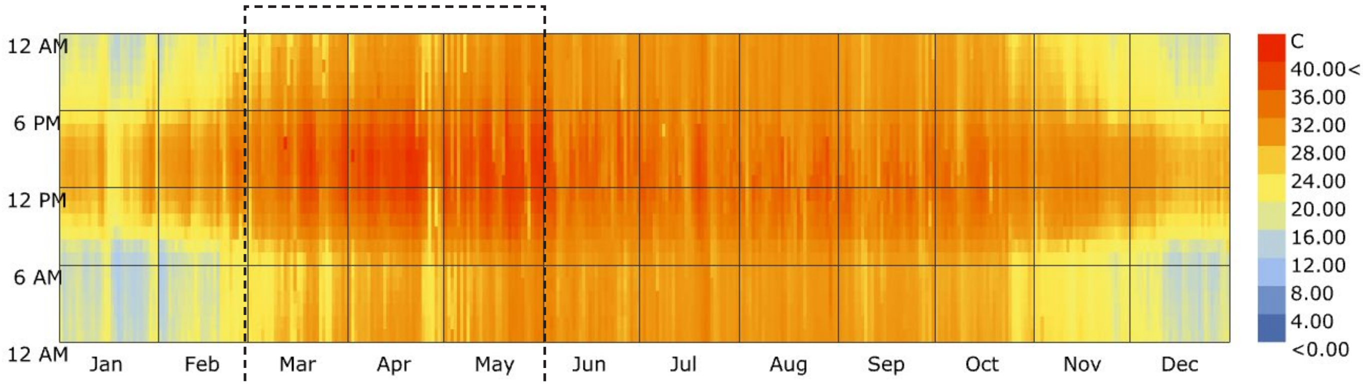
Studies of detection and attribution of recent climate change have found compelling evidence of human influence on regional heat waves, surface specific humidity, and temperature- and moisture-related heat stress.

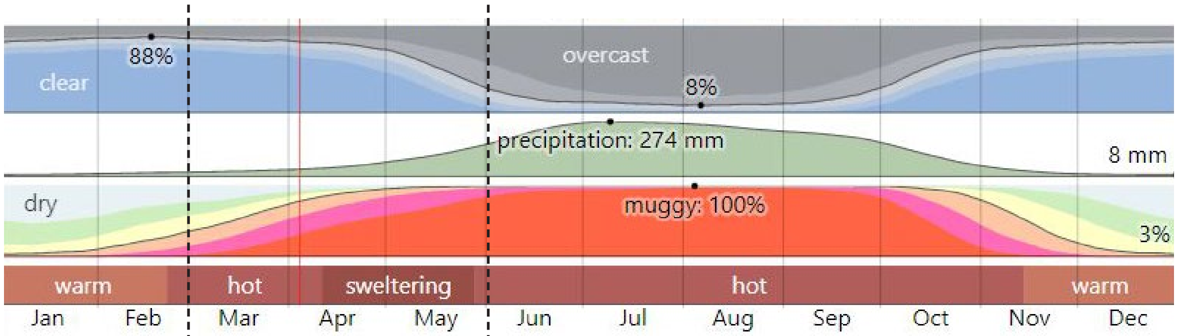
(Source: https://www.science.org/doi/10.1126/sciadv.1603322)





Source: Deadly Heat Waves Projected in the Densely-Populated Agricultural Regions of South Asia (https://www.youtube.com/watch?v=oSJLvs2lI5A&t=40s)





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Howrah - Existing Scenario

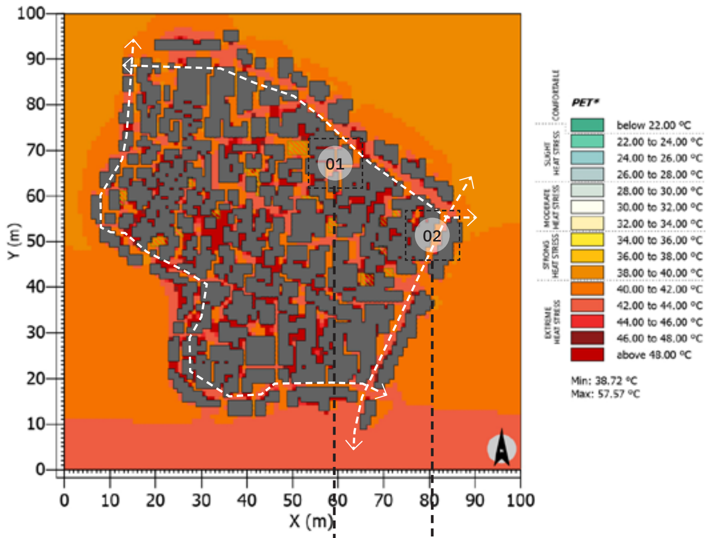
The PET graphs clearly indicate extreme heat stress with temperatures above 42°C in the afternoon hours in the gray areas between the built. Green pockets are sparse and scattered around the side. Below highlighted are two organic park pockets on the neighborhood with the following observations:

Pocket 01 (12m x 9m softscape)
Extreme heat stress with temperatures > 43°C observed during afternoon hours which drop by 2-3°C in the evening but still under strong heat stress making these open spaces unhabitable.

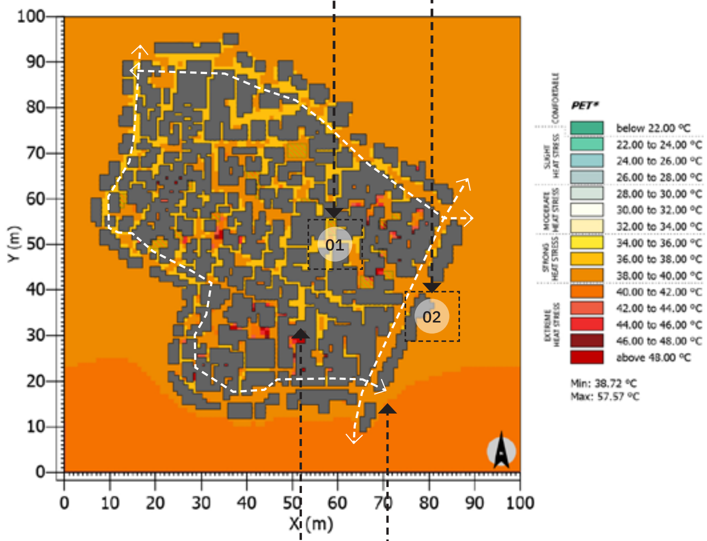
Pocket 02 (3m x 3m softscapes)
Higher PET temperatures observed compared to Pocket 1. Heat risk with temperature beyond 46°C with little to no stress relief in evening.

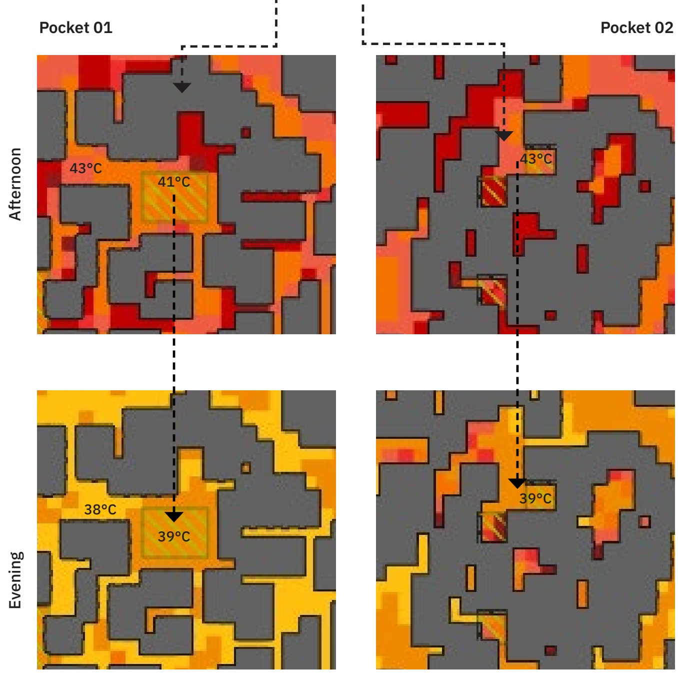
Observations (Neighborhood: approx 75m x75m)
High heat stress due to low/no wind movement resulting in heat being trapped during direct sun hours. Shrubs and small bushes with Low height trees providing little to no shade from direct Solar Radiation. More Gray areas (most of them being used as access roads to the houses) compared to greens in the neighborhood. Relative humidity levels are 1-2% lower in areas with built structures and low wind speed Corridors with more wind speed are 1-2% more humid compared to surrounding areas

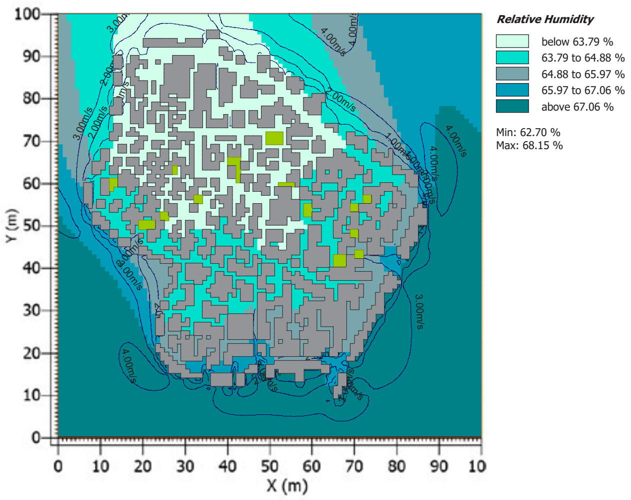
PET_Afternoon



PET_Evening







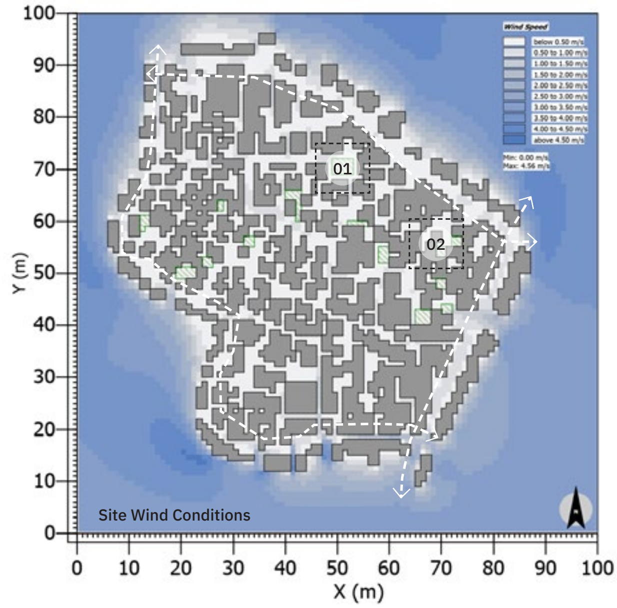
Howrah - Existing Scenario

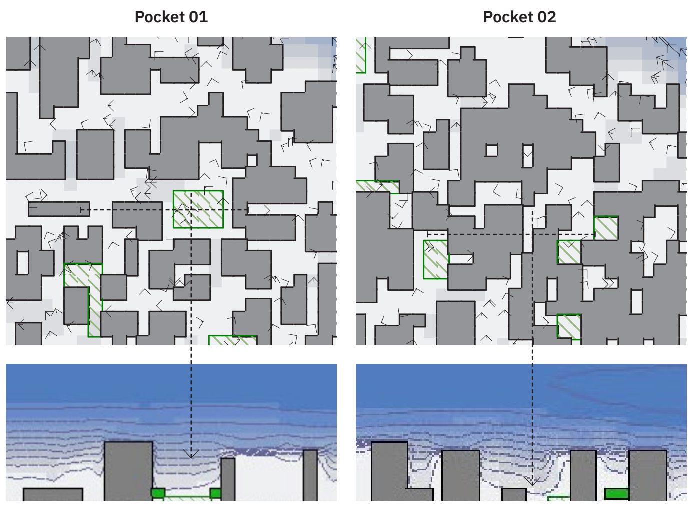
The site observes low wind speed level throughout the site (below 1.5 m/s) and no such high-pressure zones are observed. This answers for low PM2.5 levels in the core of the built environment but also results in moderate to poor air quality throughout the vehicular corridors

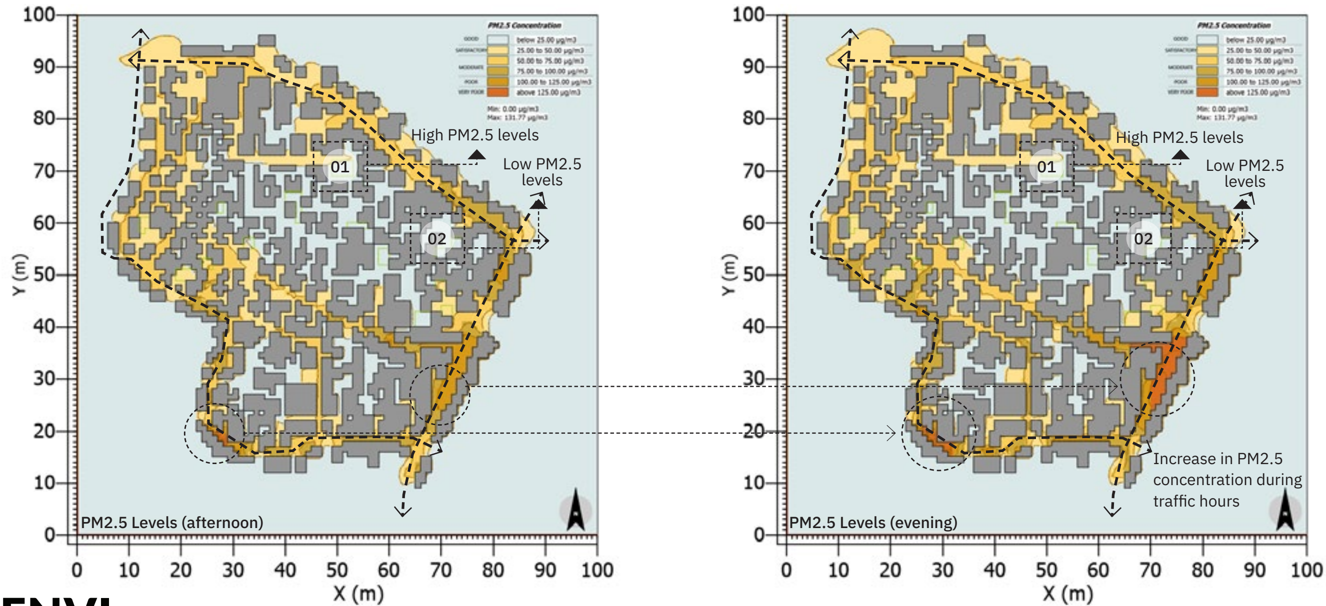
Pocket 01 (12m x 9 m softscape)
The closeup section highlights the movement of air into the built mass which accounts for 2° less PET temperatures compared to Pocket 02. Due to the proximity to the vehicular corridor the green pocket reflects moderate PM2.5 levels along the periphery.

Pocket 02 (3m x 3m softscapes)
Due to the low height structure in this pocket, we observe similar air movement as Pocket 01. This also concludes higher PET temperatures due to low h/w ratio of the canyon thus resulting in higher Solar Radiation.

Observations (Neighborhood: approx 75m x75m)
Pocket 01 with 12m open pocket and greater h/w ratio performed better compared to Pocket 2. Built geometry is also important to understand incident Solar radiations into the site which results in higher heat stress. PM2.5 concentration is higher during evening hours; mitigation strategies will be important to understand.







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Howrah - Interventions

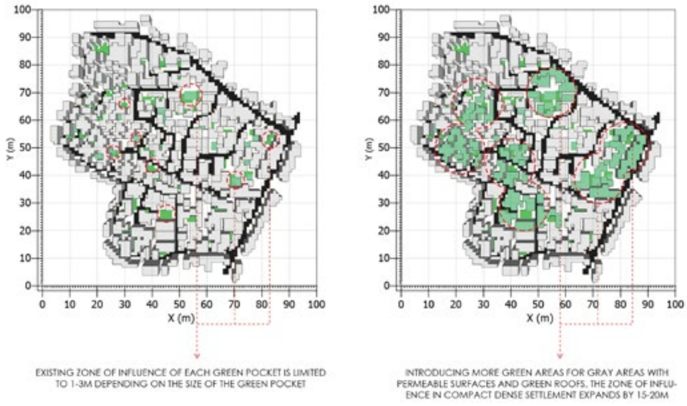
The narrow streets of Howrah's neighborhoods are considered as a combination of small (1-3m open spaces) to medium (9-12m) pockets in the built environment. These pockets are the intervention zones distributed organically on the site. Considering two pockets following was observed:

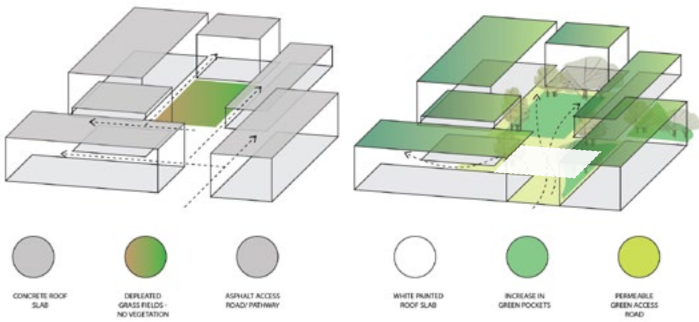
Pocket 01 - Interventions applied:
Asphalt roads → Permeable access road
Concrete roofs → White painted/ Simple Green roof system
Sparse tree cover → Increase in greens density
Shading system: No shade → Perforated shading system

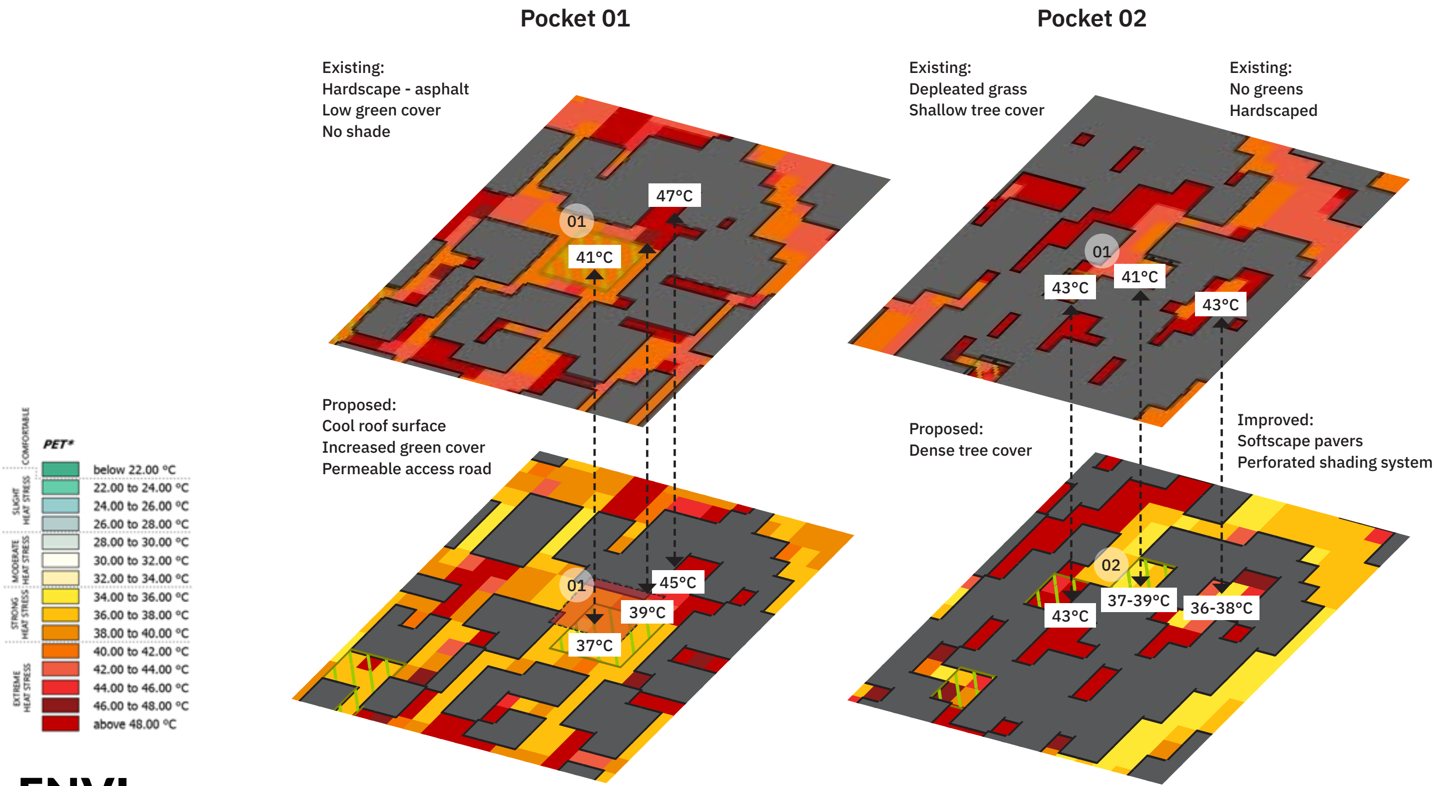
The above interventions applied to protect from direct Solar radiation in extreme conditions showed a reduction of 3-4°C PET although still under high heat stress. While for smaller pockets with open spaces less than 3m, introducing vegetation showed a decrease in PET temperatures by 2°C observed only under the shade of the tree while the directly exposed permeable surface showed a reduction of 1°C PET temperatures.

Pocket 02 - Interventions applied:
Sparse tree cover → Increase in greens density
Shading system → Perforated shading system in the courtyards

Introducing shade in courtyard showed a reduction in PET by 2-3°C from extreme to strong heat stress but the areas niched in the courtyard and spaces less than 3m in width remain under extreme heat stress. no difference in PET temperatures







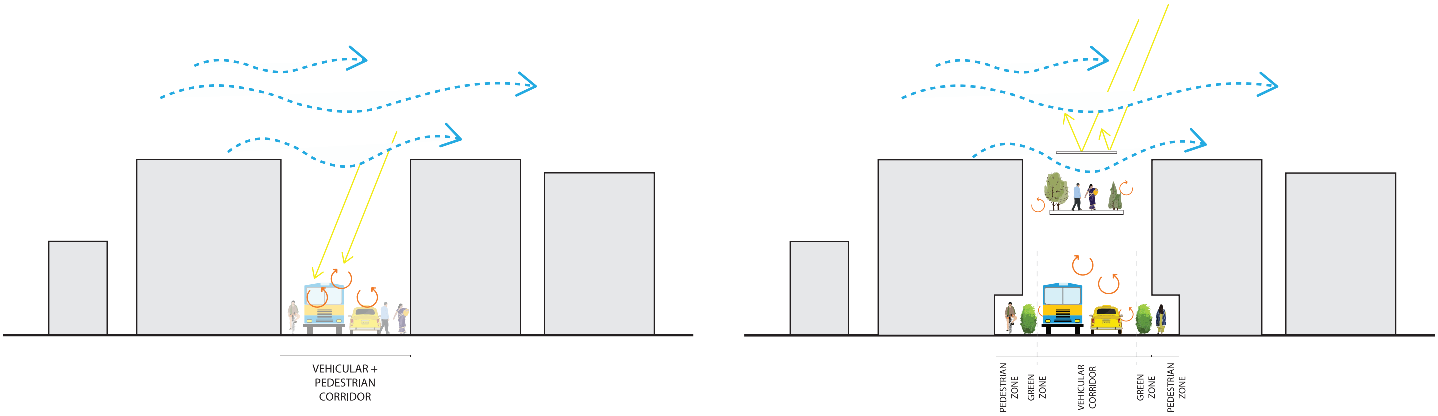
Howrah - Interventions

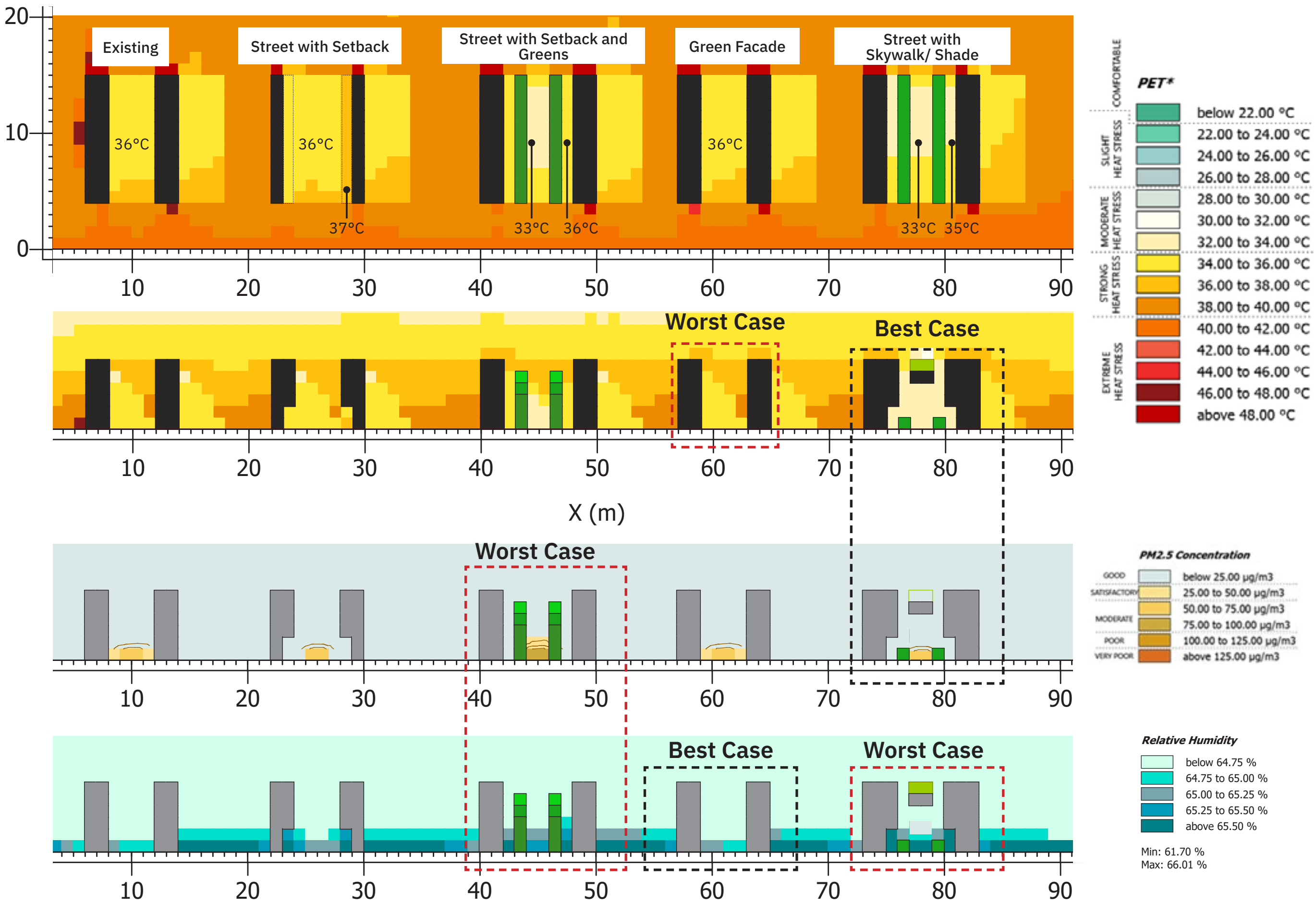
The narrow vehicular streets with varying widths between 6-8m showcase strong heat stress and 50-75μg/m3. The following study was conducted to understand the implication of narrow street changes on human thermal comfort and pollution mitigation. Four scenarios were studied along with existing site conditions to better compare the site mitigation strategies which could then be applied on the whole streets.

Scenario 1: Existing site conditions - 6m wide road with 18m high building on either side
Scenario 2: Introducing pedestrian setbacks
Scenario 3: Green hedges along with Pedestrian corridor
Scenario 4: Green facades
Scenario 5: Pedestrian corridor with shaded skywalk

Running the above scenarios for a hot summer afternoon, Scenario 5 showed the best PET drop of about 2-3°C, still under strong heat stress.
Introducing green facades showed no difference in thermal comfort levels while introducing tall hedges along the road dropped PER by 1-2°C but the pedestrian setback still showed no improvement in PET. Just introducing the walkway setback in the buildings in fact increased the thermal stress by 1-2°C.

The best cases for PET provide worst scenarios for humidity (rise of 0.5-1%) which could be reduced further with the help of aquasorbant facades - facade systems that absorb moisture from air or mechanical fans.





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Salt Lake - Existing Scenario

The planned neighborhood of Salt Lake displays Strong heat stress in the neighborhood with the central green spine 2-4° cooler compared to the gray areas in the block.

Pocket 01 (15m x 30 m school field)
Strong heat stress with PET between 34-36°C in afternoon drops down to 26-28°C displaying slight heat stress. The lower heat stress in the playing field is possibly due to the open wind from South allowing for greater air movement.

Pocket 02 (13m x 30m irr. green pocket between residences)
The dense park with trees displays 2-3°C cooler temperatures compared to the surroundings.

Pocket 03 (9m x 9m green pocket on the access road edge)
Proximity to the vehicular corridor and less trees in this green pocket PET temperatures are 2-4°C higher compared to Pocket 01 and 02.

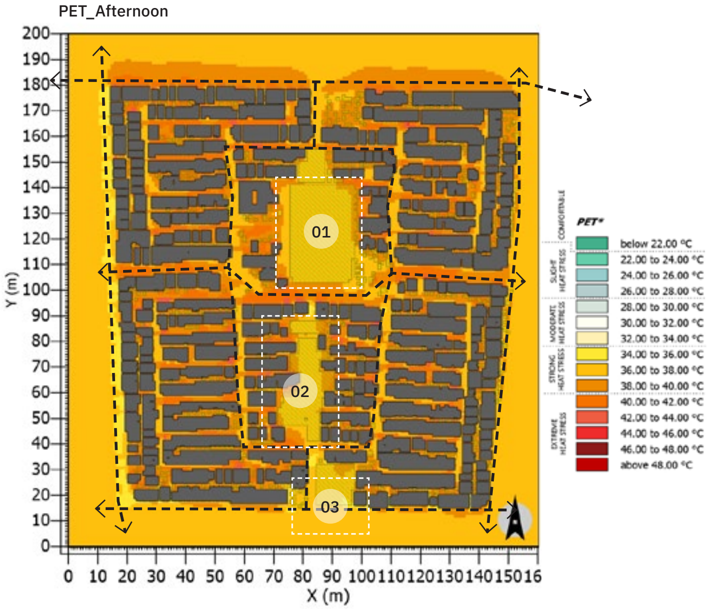
Observations: (Neighborhood size approx. 175m x 175m)

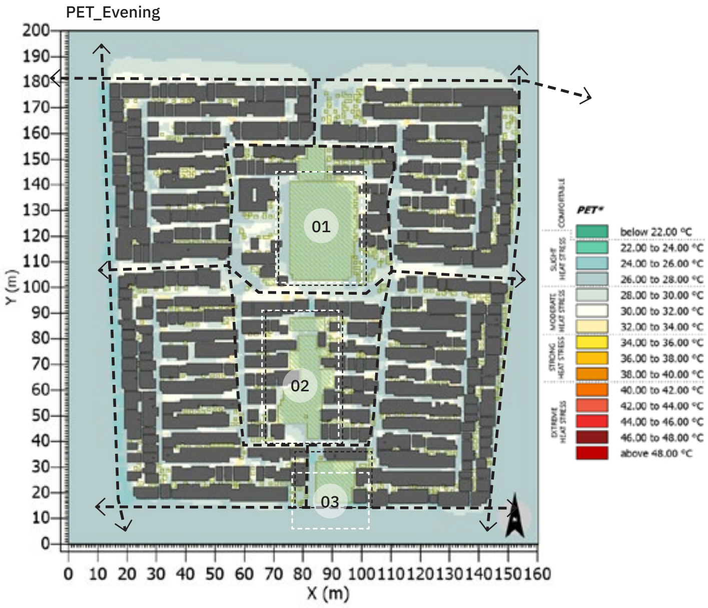
2-4°C less PET stress in the large green pockets compared to surrounding areas; Pocket 3 has comparatively higher heat stress due to the location in the neighborhood.

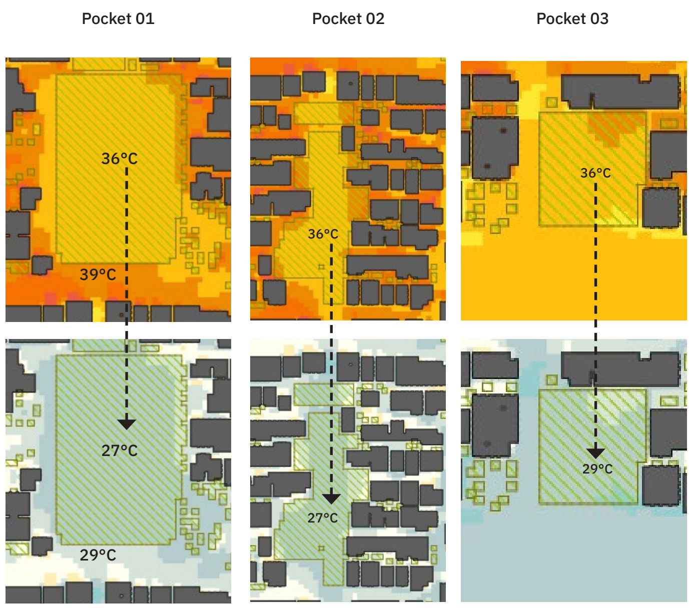
Shrubs and small bushes with Low height trees providing little to no shade from direct Solar Radiation for Pocket 03. More Gray areas (most of them being used as access roads to the houses) compared to greens in the neighborhood.

Streets showing strong heat stress due to the hardscaped surface with little to no vegetation.

The site observes strong heat stress in direct sun hours in afternoons but the PET reduces to slight heat stress in the evening hours.







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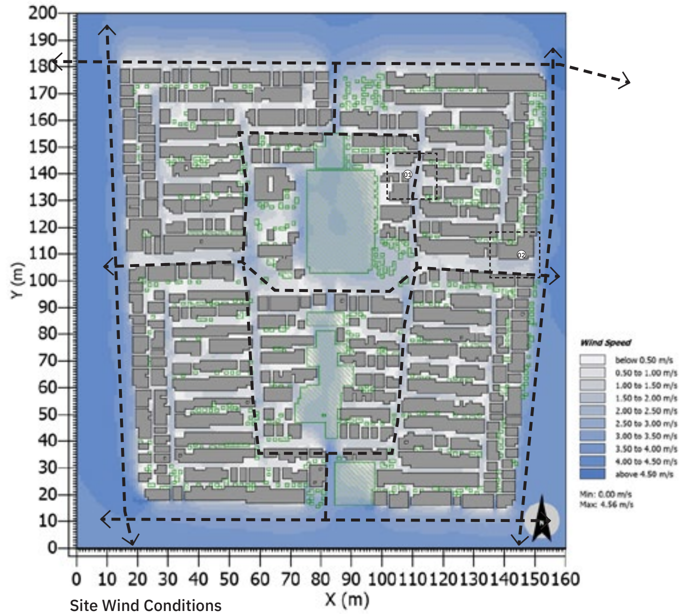
Salt Lake - Existing Scenario

The neighborhoods observe between 1-2.5m/s wind speed levels. The large park pockets allow for greater wind movement (above 2.5m/s) which explains for comparatively cooler PET levels although still under strong heat stress in direct sun hours.

Pocket 01 (12m x 9m softscape between the built labyrinth) Air movement into the site and presence of vegetation along the internal neighborhood's road allows PM2.5 concentration mainly along the vehicular corridor.

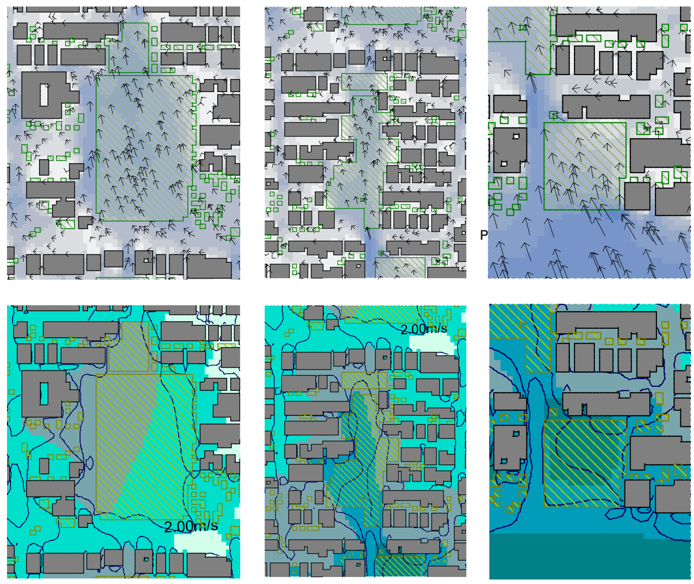
Pocket 02 (3m x 3m softscapes between built) Due to the park's location between residential building blocks and bottle neck from South, higher PM2.5 concentration is observed between 25-50µg/m3.

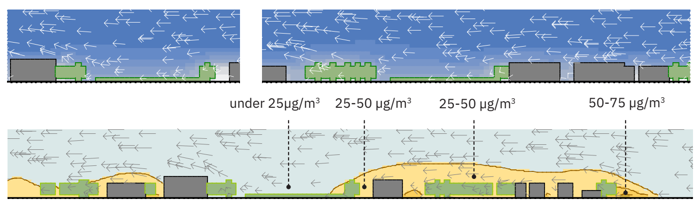
Observations
Pocket 03's proximity to Pollution source observed higher pollution concentration accelerated by wind's movement from South.

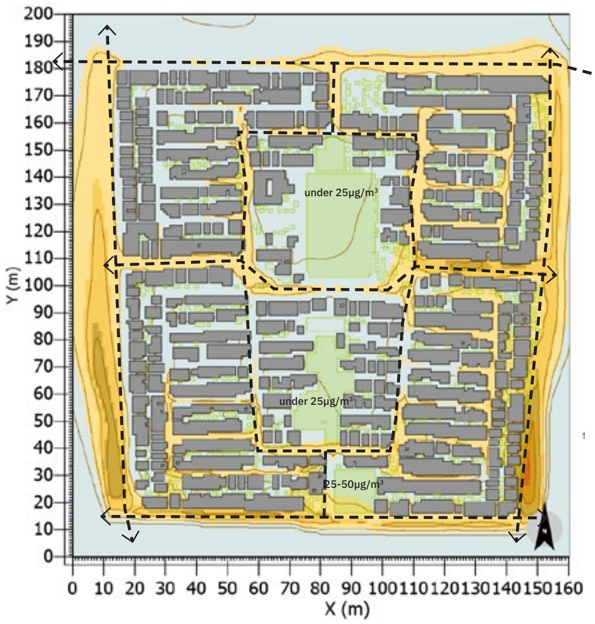


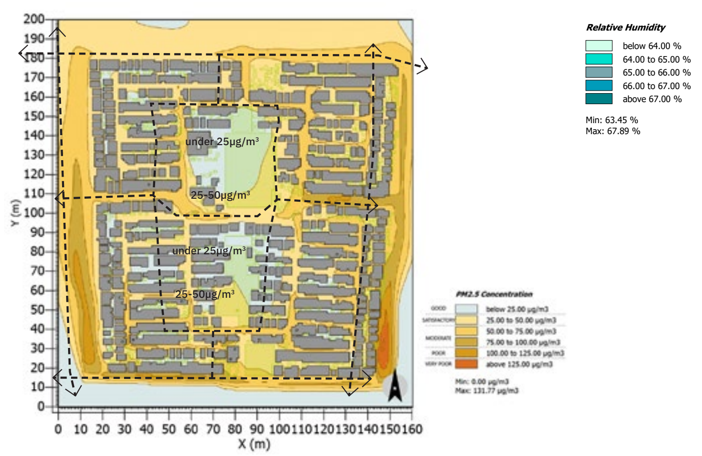
Site Wind Conditions

Pocket 01 Pocket 02 Pocket 03









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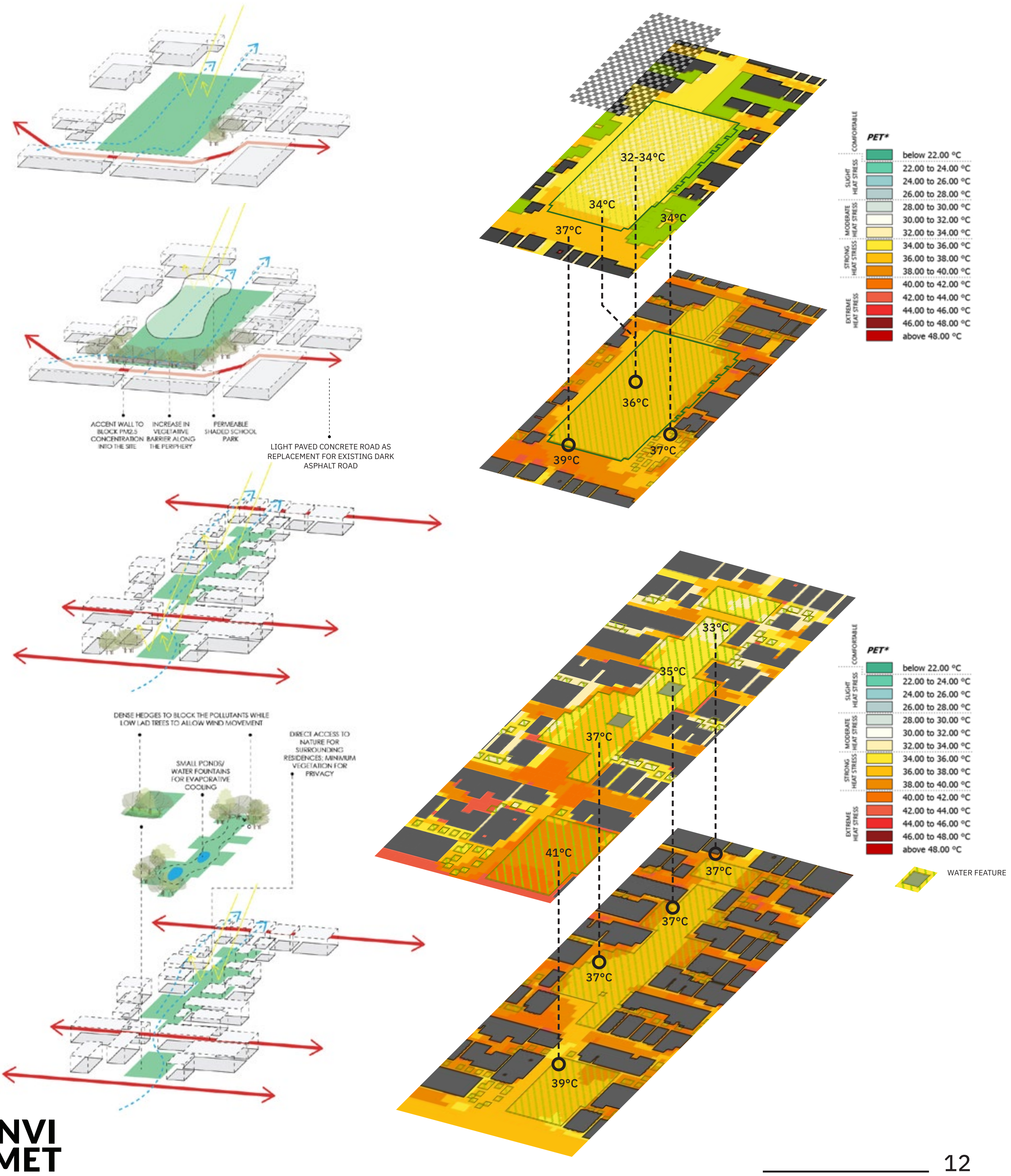
Salt Lake – Interventions

Pocket 1 is a play area so increase in vegetation was not feasible to reduce heat stress in summer afternoons in the center field, a chessboard shading strategy was introduced reflecting the direct harsh sun while still allowing for air to flow through. Vegetation along the periphery allowed for PM2.5 level filtrations but were considerably negligible for the site. This showed a reduction of 2-4°C PET from strong to moderate heat stress.

Pocket 2 nested in the residential blocks showed a decrease in PET by 1-2°C by planting trees along north south axis for the wind to flow through. While Pocket 03 showed a decrease in PET by 1-2° with dense hedges along the vehicular corridor in a zig zag pattern to filter the pollutants but still allow for wind movement.



Salt Lake – Interventions

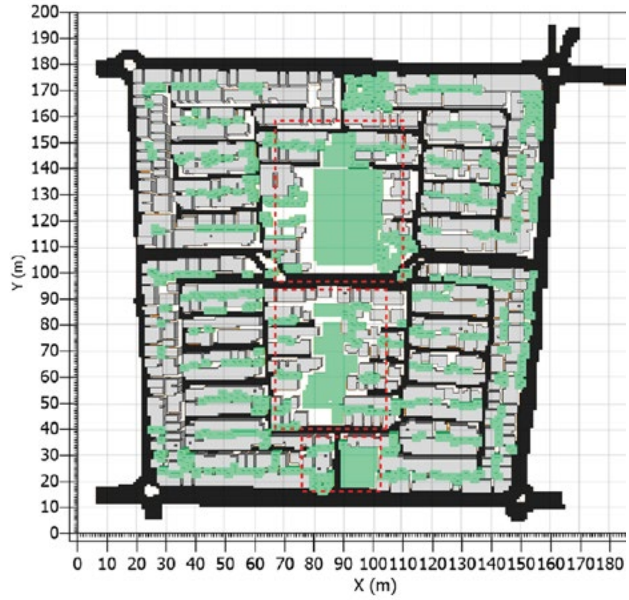
The existing green corridor in the Salt Lake neighborhoods covers the surrounding microclimate of 15m on either side of the parks and green pockets. For future planning projects another interesting finding could be dividing this central green pocket into 2 -3 different linear pockets with the longer side in the direction of wind flow. Two alternate hypothetical cases were studied:

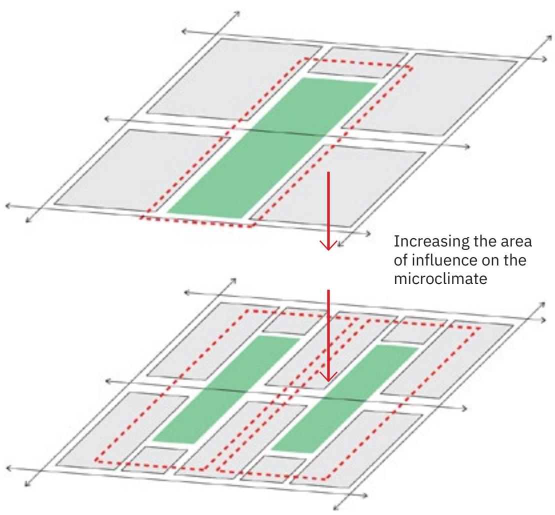
Case 1: Dividing the central park into 3 different parks to increase the area of influence of the greens on the built environment.

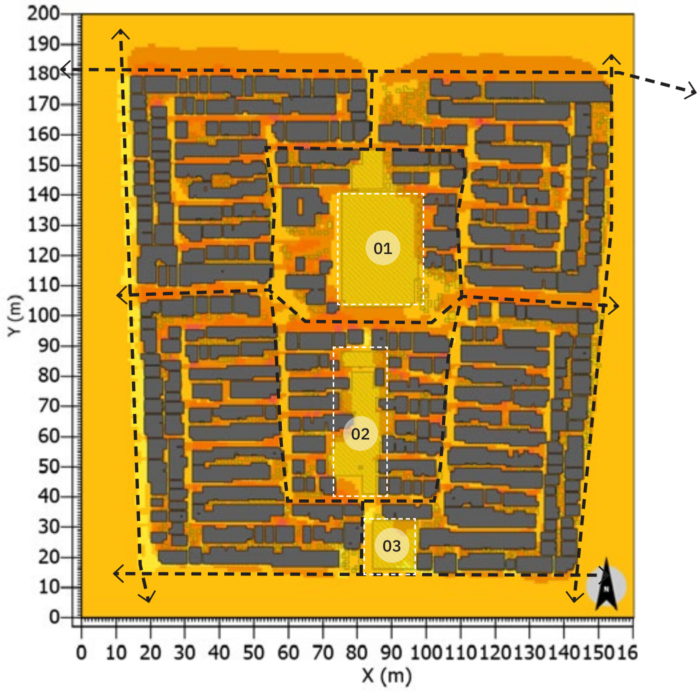
Case 2: Introducing wider neighborhoods parks instead of the smaller green pockets.

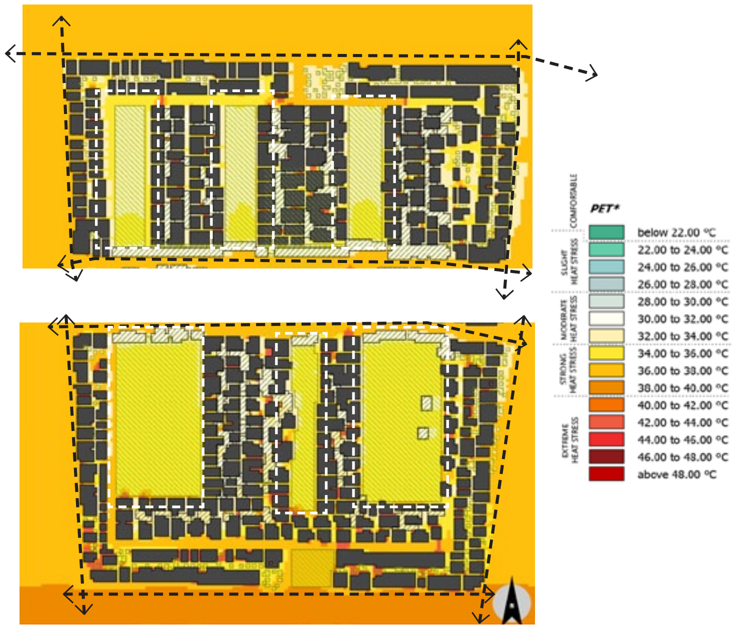
Case 1 tends to perform better thermally with heat stress reducing from strong to moderate with smaller linear parklets.

Case 2 performs better than the existing scenario but still reflects strong heat stress









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Kolkata - high temperatures throughout the year due to tropical climate

With its tropical climate, Kolkata experiences high temperatures throughout the year. During the summer season, the temperature can rise to 45°C, with the heat index reaching 50°C. This has led to heat-related health issues such as heat stroke, exhaustion, and dehydration, which has now reached the levels of life threatening if not managed properly.

The neighborhoods of Howrah and Salt Lake provided the necessary insight into the present conditions of Kolkata based on climate and existing living conditions along with the plausible mitigation strategies that could lower the heat stress.
Kolkata has experienced extreme temperature related heat stress and the high humidity levels only makes the stress worse. Breaking down the study as temperature and moisture related heat stress to clearly indicate the mitigation impact of nature-based solutions.

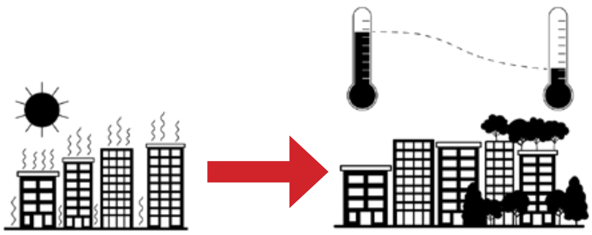
PET has been used as a base to indicate heat stress in this study and clearly indicates the planned neighborhoods of Salt Lake performing better than dense old town settlement of Howrah. Further, the impact of nature-based solutions helps lower down the heat stress from strong to moderate during direct sun hours in Salt Lake neighborhoods by 4-6 °C harnessing the open spaces and channeling the wind for greater impact. While in the compact dense neighborhoods of Howrah, creating green pockets in the urban open hardscaped spaces helped reduced the PET by 2-4°C but still in strong heat stress.
Another hypothetical situation created for Salt Lake neighborhoods with more evenly divided green parks and pockets to have a greater impact on the surrounding climate showed greater potential to reduce the temperatures up to 8°C in extreme heat conditions.

The old compact settlements are a hub for humidity and calls for mechanical means to generate air movement or techniques such as water absorbing facades to have a better impact on the microclimatic conditions. This could further bring down the moderate heat stress to mild or neutral temperature ranges.
The image on right captures the gist of the work undertaken for a more comfortable neighborhoods and re-thinking the green pockets and parks towards a more viable microclimate.

Extreme heat stress

Temperature related heat stress | **Moisture related heat stress**

Howrah	**Salt lake**
Dense Compact settlement	Planned open settlement
Less vegetation	Considerable vegetation
No parks	Neighbourhood and School parks
Asphalt roads and Dark pavers	Asphalt roads and Dark pavers
Low wind speeds in the core	Southern winds channeled into the core of the block through open park
Vehicular pollution	



Mitigation strategies

Howrah	Salt lake
Introducing Green Pockets	Green parks and pockets distributed evenly on the site
Perforated Shading	Perforated Shading
Cool Roofs (white painted)	Increase in green cover along the vehicular corridor
Permeable Ground surfaces	
2-4°C reduction in PET	**4-6°C reduction in PET**

Moisture related heat stress

Mechanically induced ventilation such as fans
Moisture abosrbing facades/ roofs to decrease water content in the air
To further bring down the pet thermal comfort levels to mid heat stress or neutral temperature range