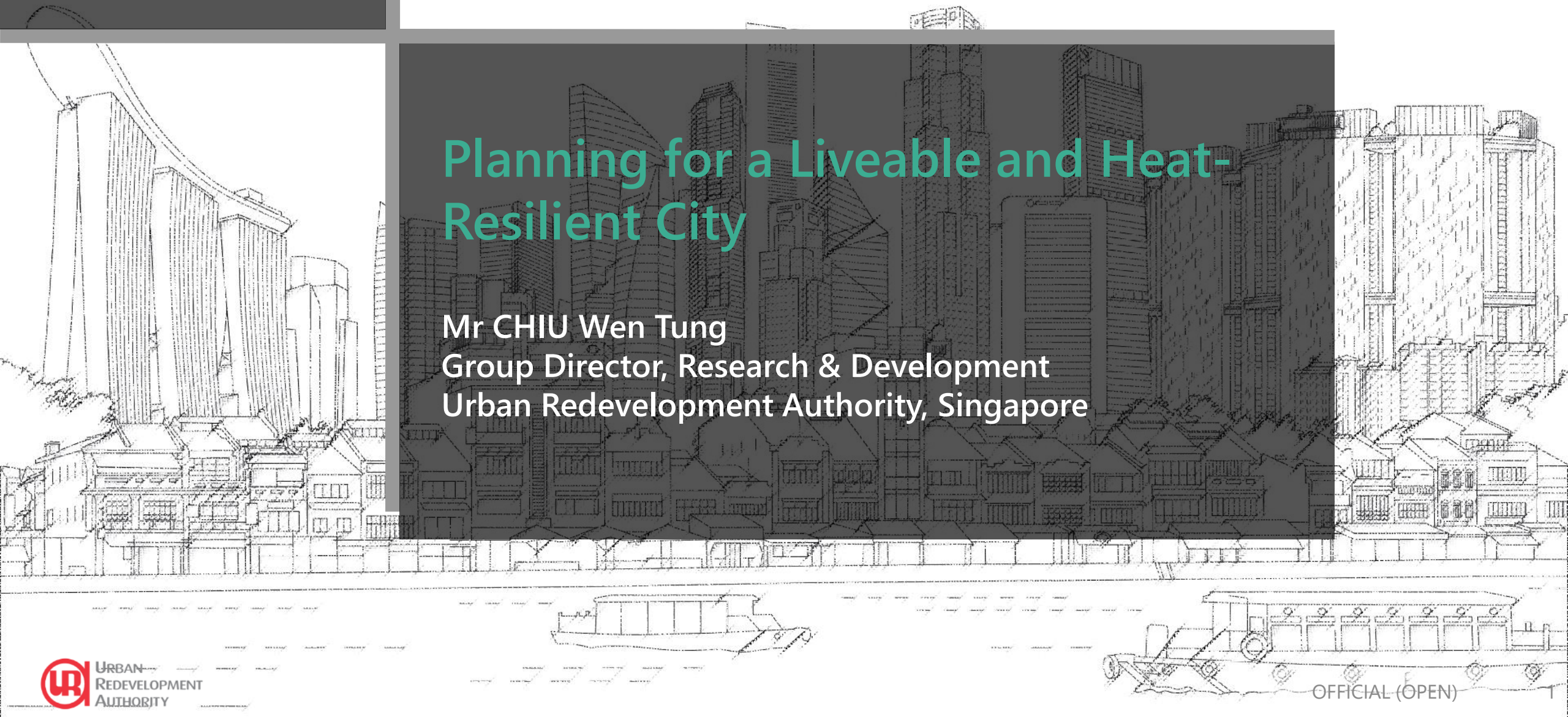
World Bank: Technical Deep Dive on Urban Heat
24 April 2023

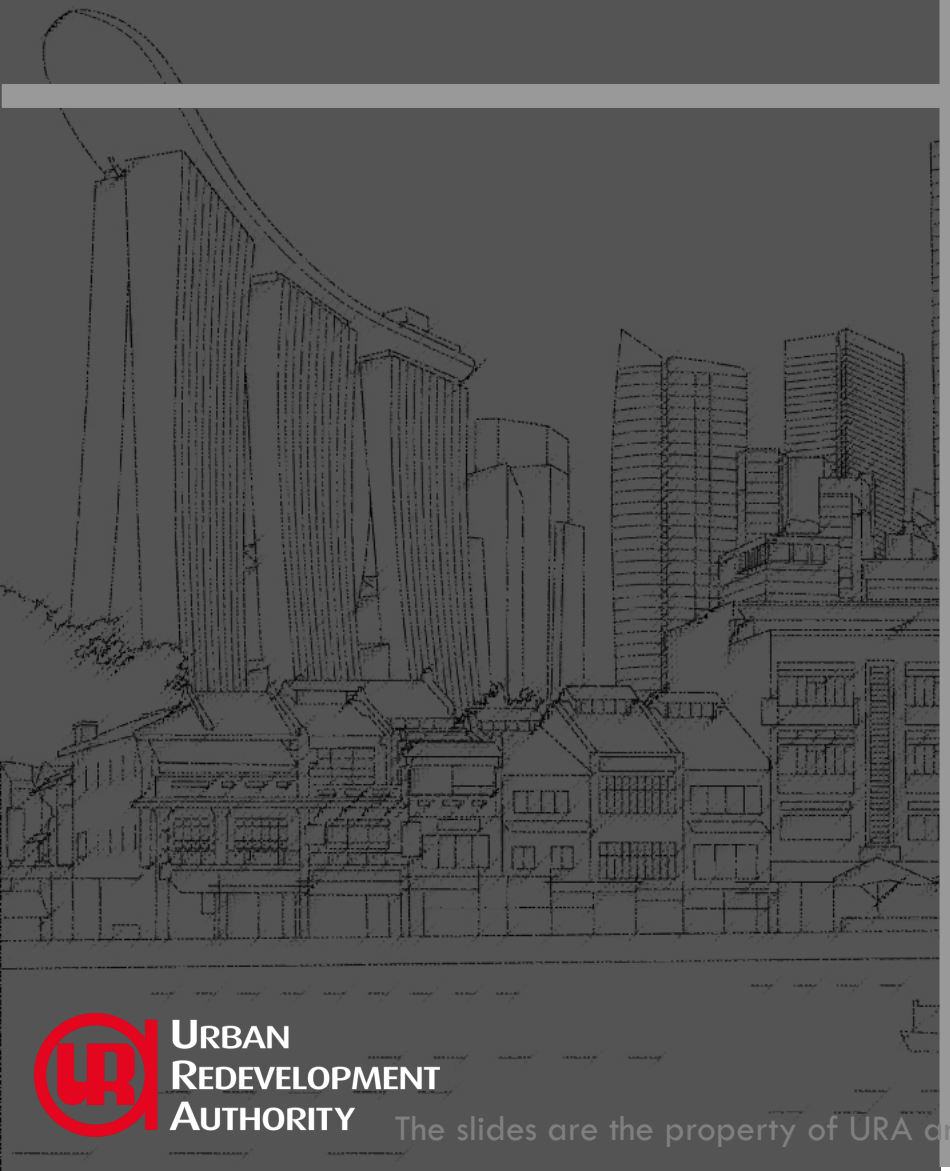
Planning for a Liveable and Heat-Resilient City

Mr CHIU Wen Tung
Group Director, Research & Development
Urban Redevelopment Authority, Singapore



URBAN REDEVELOPMENT AUTHORITY

OUTLINE



- Urban Heat in Singapore
- Mitigating against Urban Heat in Singapore
- Leveraging Technology and Innovation in our Policy and Planning
- Moving Forward

URBAN REDEVELOPMENT AUTHORITY

ABOUT US

- Singapore's land use planning and conservation authority
- Our mission is to make Singapore a great city to live, work and play

OUR CORE FUNCTIONS

URBAN REDEVELOPMENT AUTHORITY

To make Singapore a Great City to Live, Work & Play

PLANNING
- Land Use Planning
- Urban Design
- Development Control
- Design and Planning Lab
- Infrastructure Planning
- Conservation of Built Heritage

FACILITATING
- Government Land Sales
- Property Research

PROMOTION
- Place Management of Key Areas - *e.g. Marina Bay*
- Promotion of Architectural, Urban Design and Planning Excellence

URBAN HEAT IN SINGAPORE

Projected impact of global climate change trends on Singapore's daily temperatures

Daily Temperature

Observed Changes	From 1948 to 2016, annual mean temperatures rose at an average rate of 0.25°C per decade
Future Climate Projections	Daily mean temperatures are projected to increase by **1.4°C to 4.6°C** by the end of the century

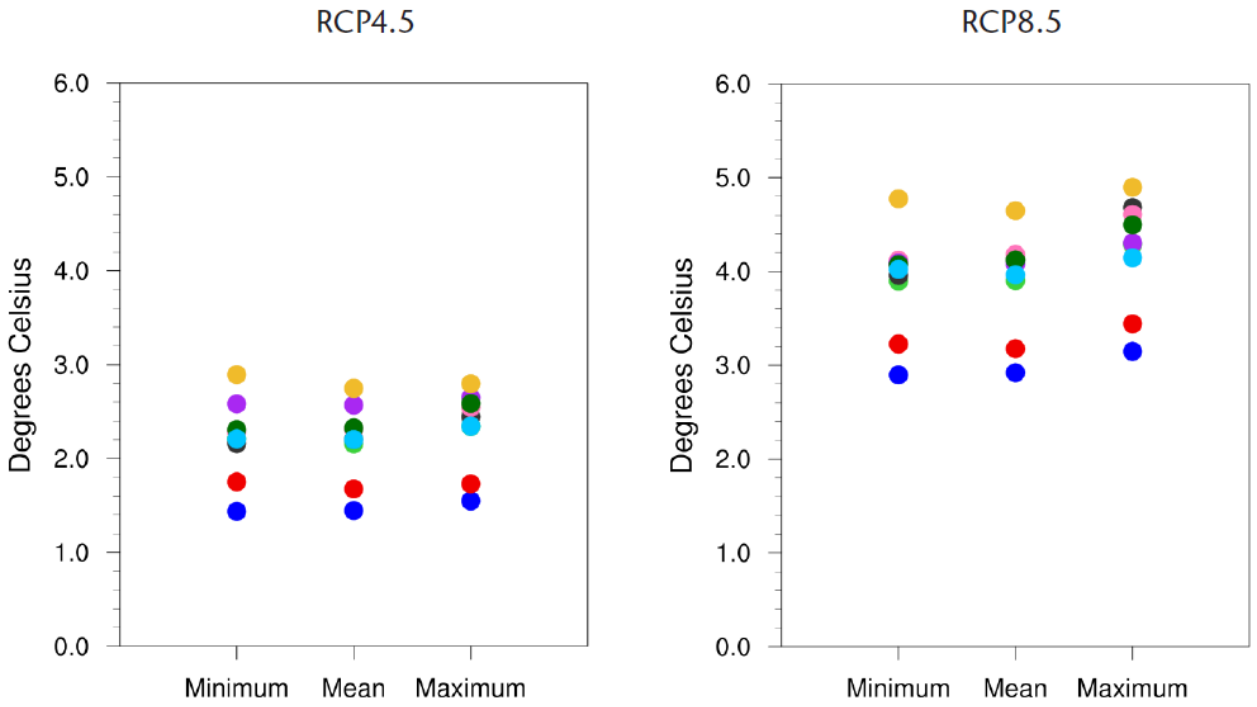
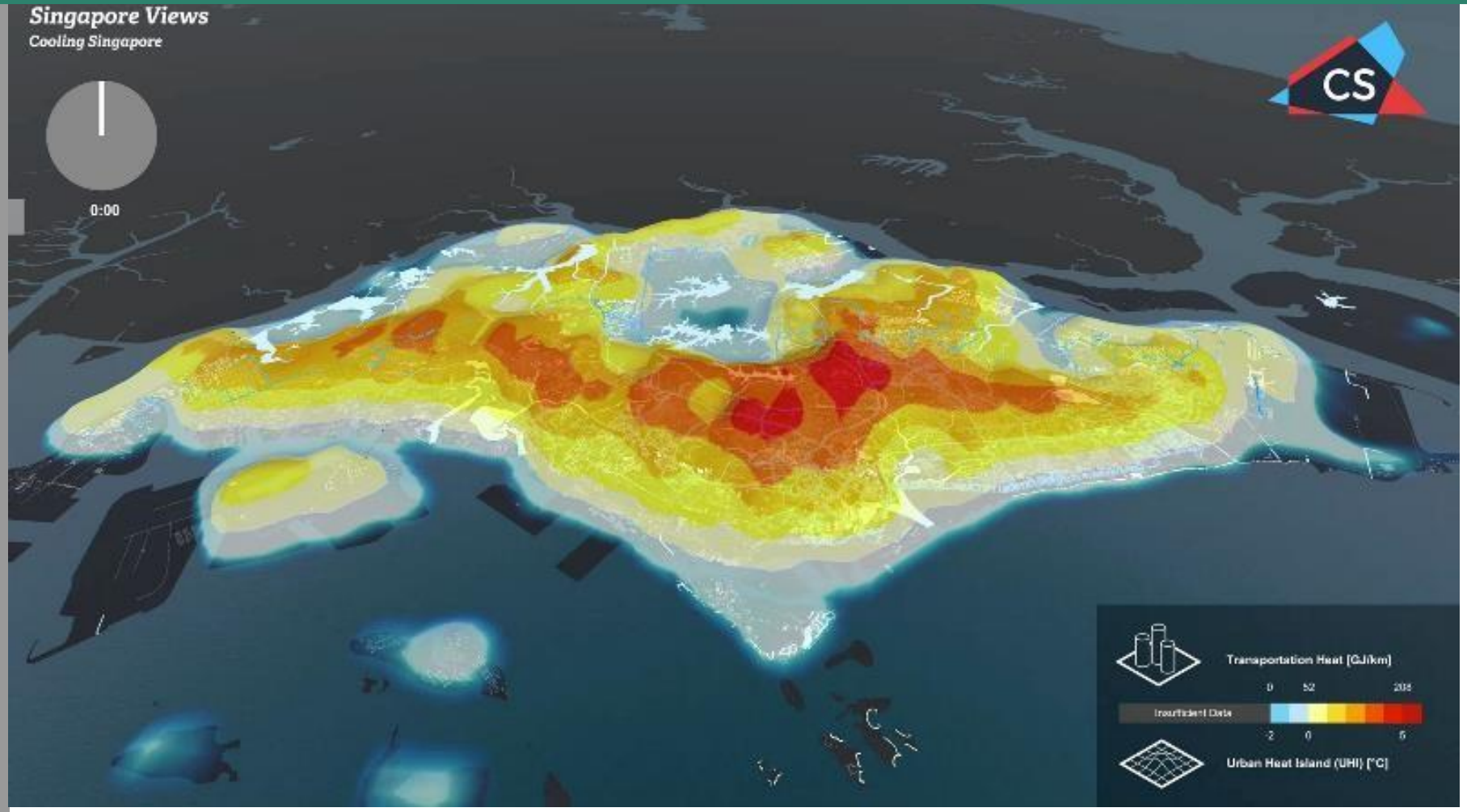


Figure 4.3: Change in average daily minimum, mean and maximum temperature for end-century (2070-2099) with respect to baseline period 1980-2009 for the RCP4.5 (left) and RCP8.5 (right).

Source: CCRS, 2015

Impact of the Urban Heat Island Effect



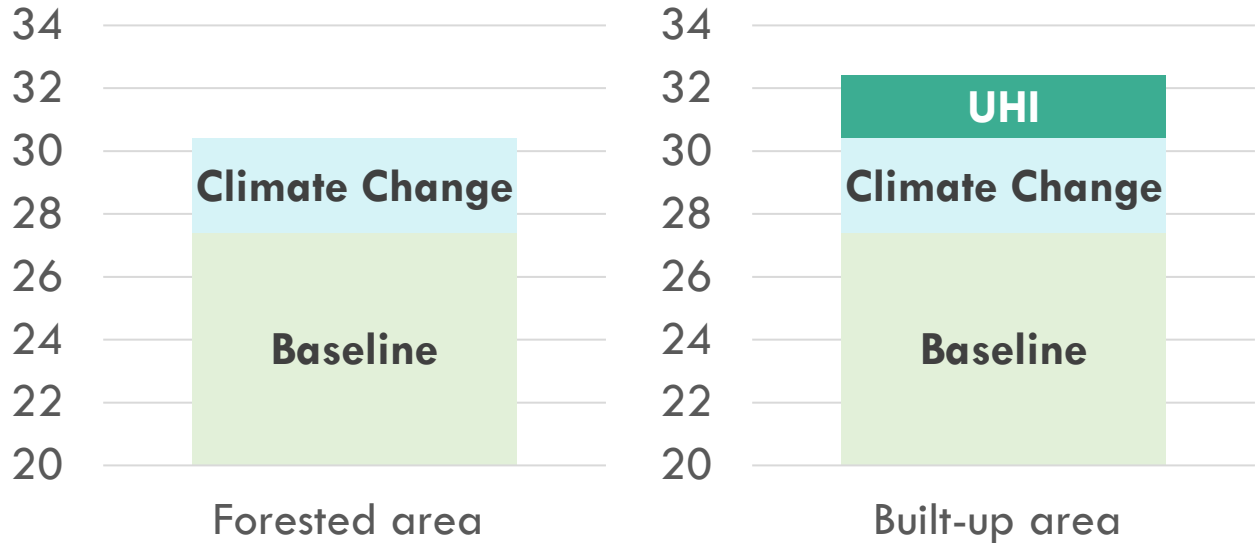
UHI Effect

Compared to forested areas, urban areas are around **0-2°C hotter in the day, and 2-4°C at night.**

Source: Cooling Singapore 1.5

Climate change will lead to rising temperatures.

But urban areas will be even hotter.



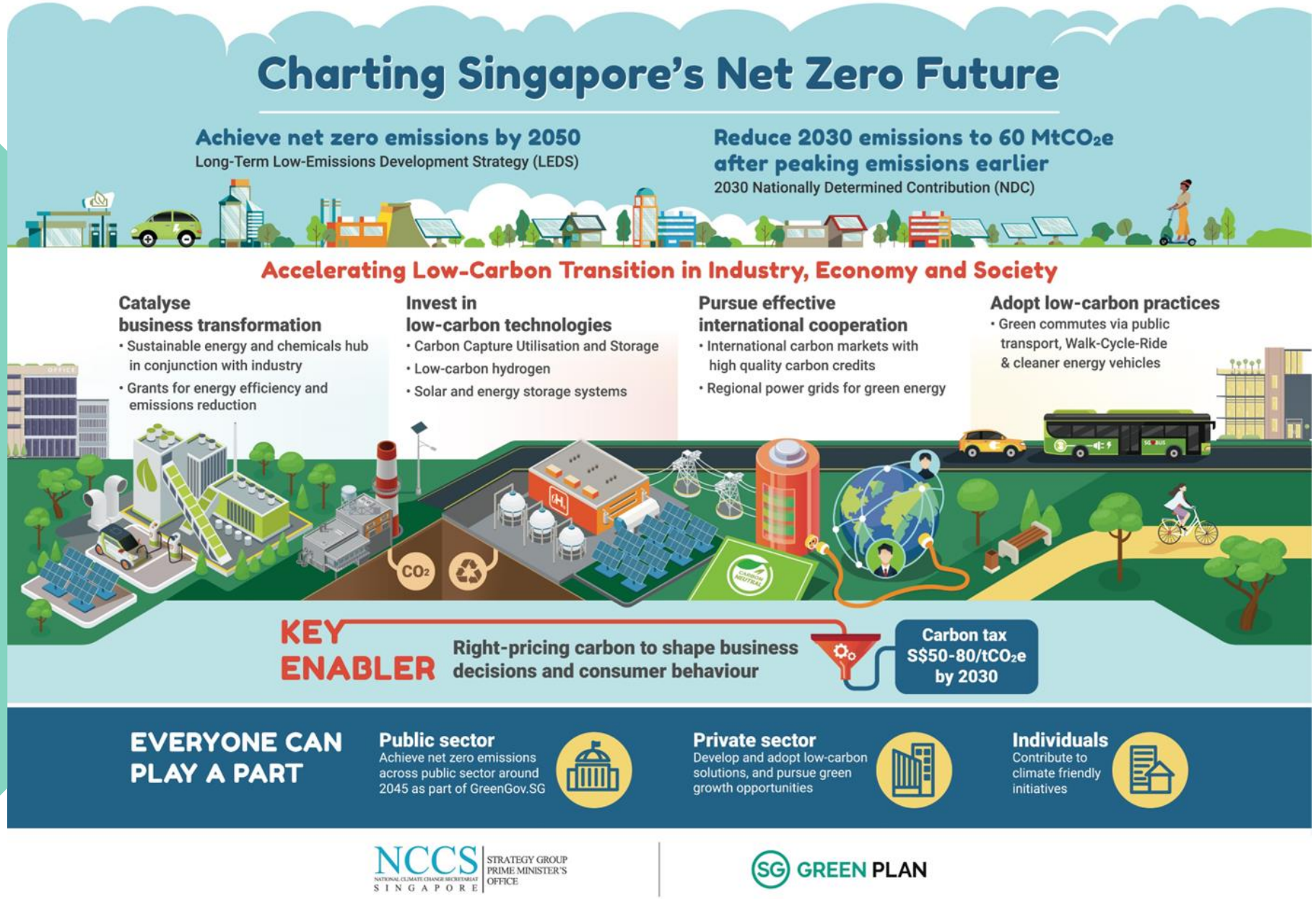
To mitigate temperature rises due to climate change, we need longer-term reductions in carbon emissions and international collaboration.

But urban heat island effects, due to heat absorption by urban infrastructure, and heat production by vehicles and appliances, can be mitigated by local interventions.

Source: CCRS, 2015; Cooling Singapore 1.5

MITIGATING AGAINST URBAN HEAT

Charting Singapore's Low-carbon & Heat-resilient Future



Source: NCCS, 2022

City in Nature

Green Government

Sustainable Living

Energy Reset

Green Economy

Resilient Future

- Safeguarding our Coastlines against Rising Sea Levels
- Safeguarding Food Security
- **Keeping Singapore Cool**

Overview of nationwide measures to mitigate Urban Heat

Mitigating Urban Heat

Facilitating wind corridors and ensuring shade

- Urban Planning
- Building Design
- Urban Greenery

Reducing heat absorption

- Cool Materials

Reducing heat emissions

- Electric Vehicles
- District Cooling
- Energy Efficiency Schemes

Supported by

- Measurement
- Modelling
- Research

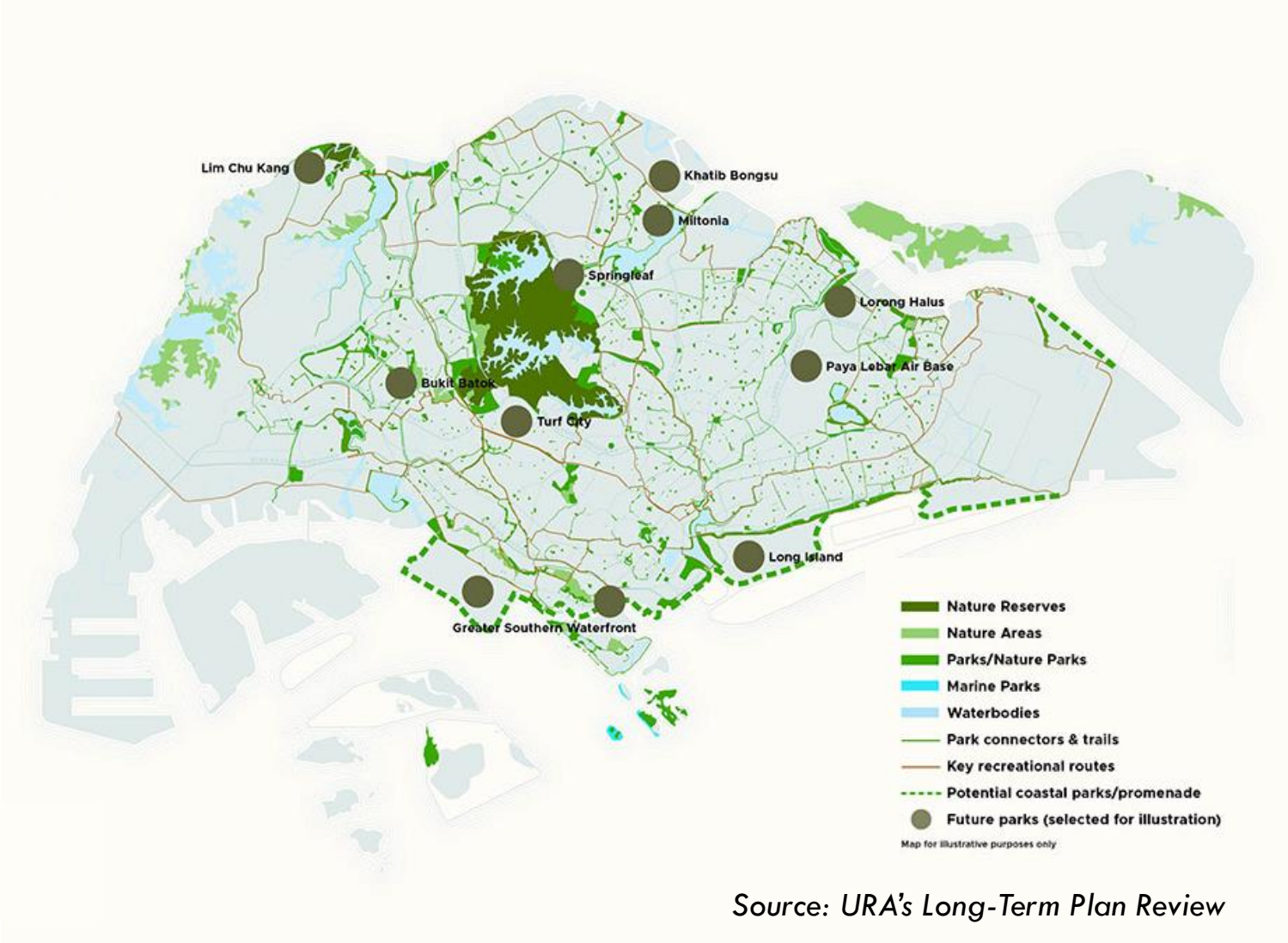
Urban Greenery

Park Provision

- Urban parks not only provide better thermal environment within them, but can also **cool nearby urban areas**

- As part of our goals for Singapore Green Plan 2030 and to achieve our City in Nature vision:
  - By **2030,** 100% of homes will be within a **10-min walk** to a park
  - In **10-15 years, 1000 ha** more land will be set aside for green spaces like parks and park connectors island-wide

- Implementation of urban parks are considered in relation to where temperature hotspots are to alleviate the UHI effect



Source: URA's Long-Term Plan Review

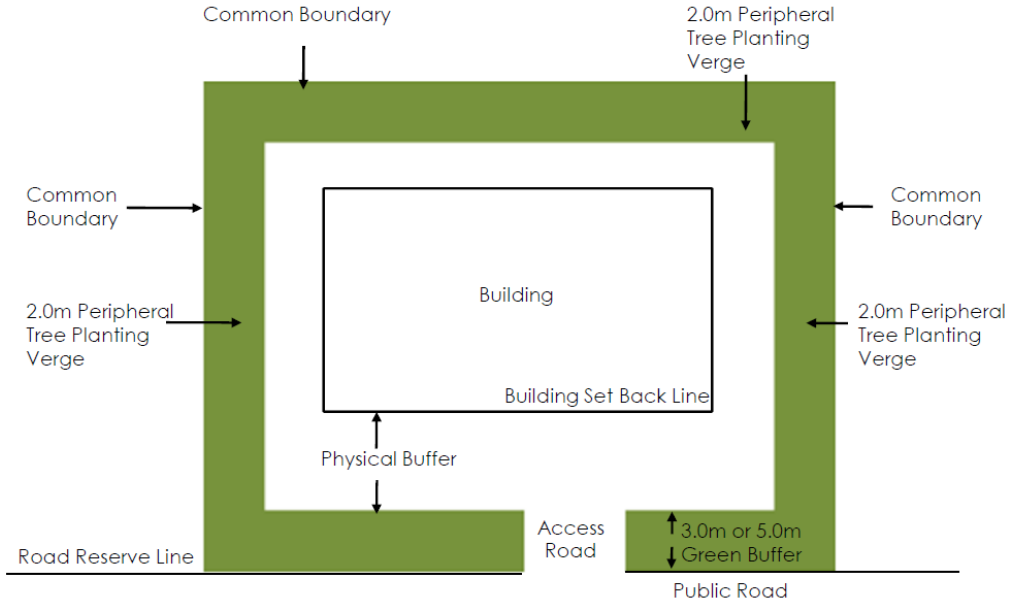
Street Trees

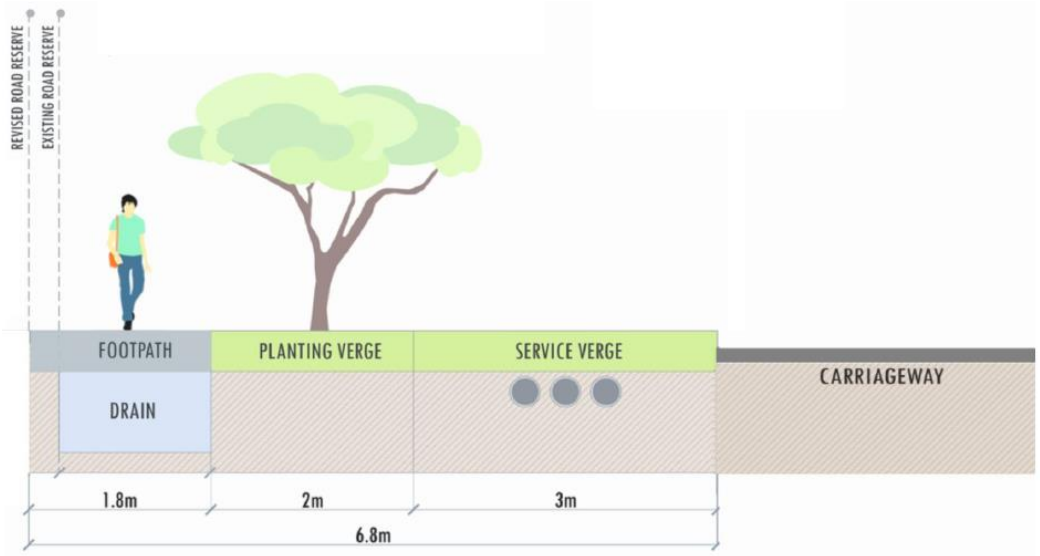
- Trees around buildings can provide **shade** to pedestrians, building and ground surfaces. This is particularly important in improving thermal comfort during daytime (Shashua-Bar et al., 2012)

- The cooling effect **vary** depending on the **vegetation coverage, size and distribution.** Gillner et al. (2015) estimated that tree-shadowed streets could **reduce the air temperature by between 0.9 – 2.6°C.**

- **Under our Singapore Green Plan 2030,** we also plan to **plant one million more trees** as part of our OneMillion Trees movement and to achieve our City in Nature vision

Planting verges within developments and along streets





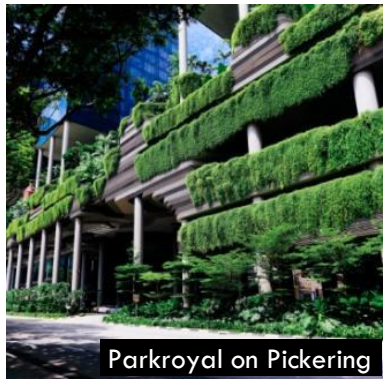
Vertical Greenery

- Vertical greenery **reduces the temperature of building facades,** especially where intense sun radiation occurs.
  - Temperature inside the building can **remain more stable** and thus there is reduction in the building **energy consumption** for cooling
  - Similarly, there is a reduction of the nearby air temperature providing benefits for pedestrians' **thermal comfort**

- Studies in Singapore have shown that **thicker greenery** is key to getting positive results when shading a building and that reductions between **10 – 31%** energy cooling load can be achieved due to the effect of vertical greeneries (Wong et al., 2009)

- Vertical energy can also **lower the mean radiant temperature** of its surroundings for up to 1 m away from the wall (Tan et al., 2014).

- Skyrise greenery has been mandated and/or encouraged in buildings via URA's Landscaping for Urban Spaces and High-Rises (LUSH) scheme since 2009. As of March 2022, LUSH has played a key role in the introduction of more than 300ha of greenery within new developments.


Parkroyal on Pickering


Lee Kong Chian Natural History Museum


Tree House


The Sandcrawler


Oasia Hotel Downtown


Khoo Teck Puat Hospital


Sky Terrace@Dawson


Westgate


Solaris

Green Roofs

- Green roofs reduce urban heat accumulation by **lowering the temperature of roof surfaces,** mitigating UHI and reducing building energy consumption.

- Solar PV panels co-located on green roofs can produce more energy due to a cooler environment.

- Research shows that:
  - Surface temperature of an individual green roof can be reduced by **15 – 45°C** compared to conventional roofs
  - Nearby air temperature can be reduced by **2 – 5°C.**
  - If extensive use of green roof is undertaken in an urban area, air temperature at pedestrian level could be reduced by **0.5 – 1.7°C** (Peng and Jim, 2013).

Rooftop solar panels above greenery at Alice@Mediapolis (left); green roof at Funan Mall (right)

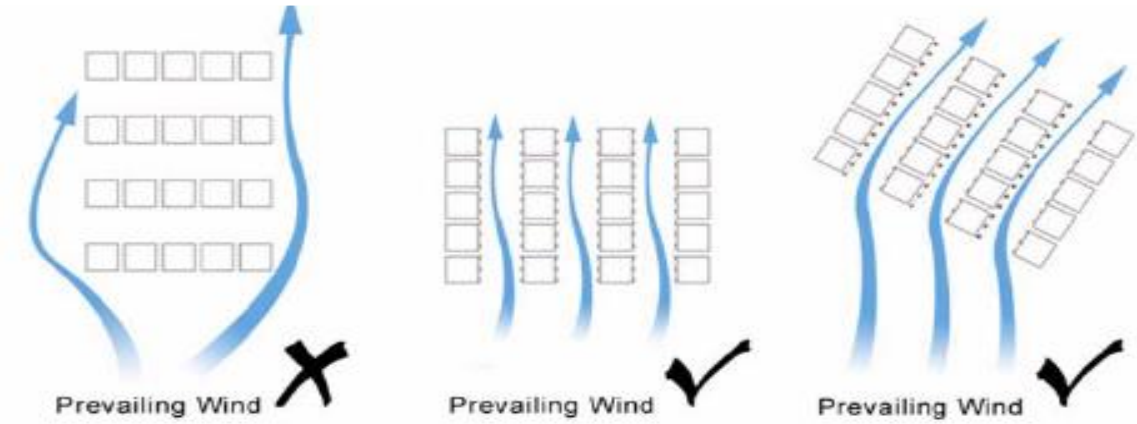
Urban Planning & Design

Street & Building Alignment

Streets and buildings should be aligned with the prevailing wind direction.

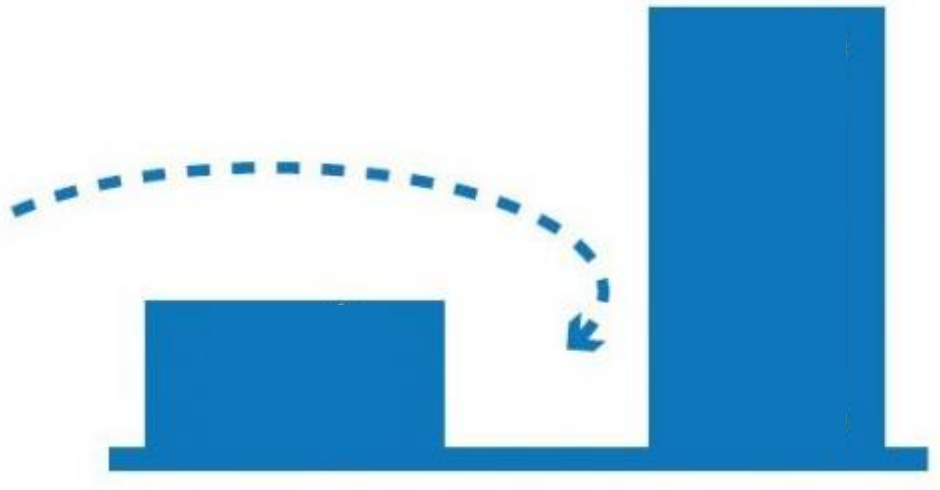
It is important to explore the urban breezeway patterns to optimise the arrangement of both the street and corridor networks.

The longer frontage of building plots should also be aligned in parallel to the wind direction.



Varying Building Heights

We can also improve wind capture by varying building heights.



Site Coverage & Building Spacing

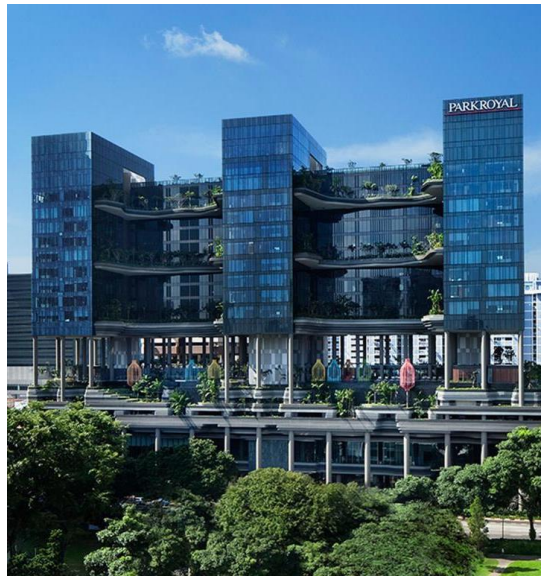
Lowering the site coverage will provide more open space around the buildings and decrease the air temperature by avoiding heat accumulation during the day and heat release during the night.

It will also facilitate greater natural ventilation of pedestrian spaces.

Building Form & Permeability

Void decks at the ground floor and sky terraces can increase the building permeability.

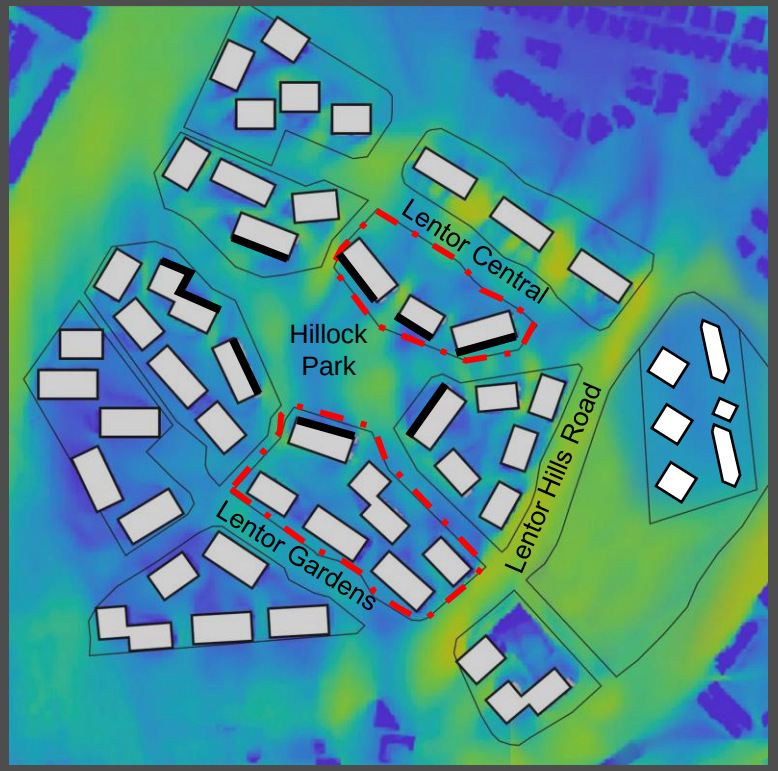
It encourages the air flow through and around the buildings, and channelling airflow to rear blocks.



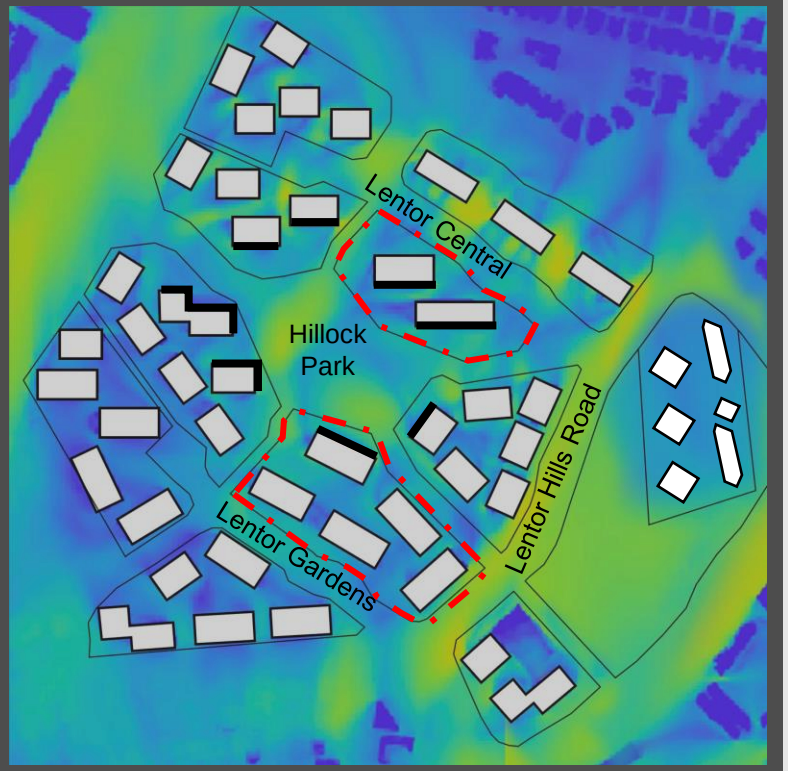
Microscale Modelling Simulations for Urban Design

Case Study: Wind Flow Studies in Lentor Hills Estate

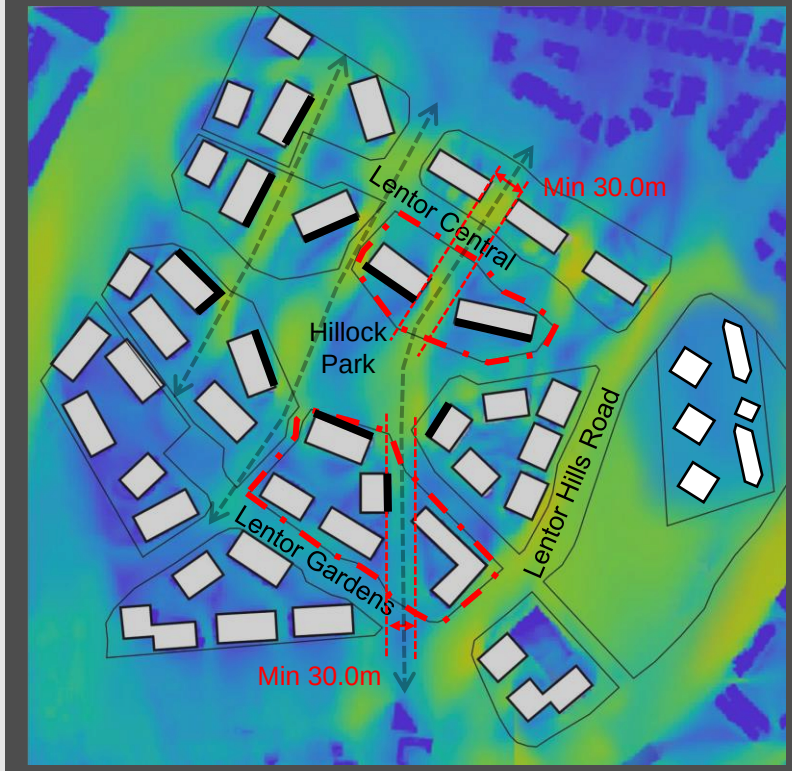
Baseline: No safeguarding of porosity



Op 1: No safeguarding of wind corridors



Op 2: With safeguarding of wind corridors



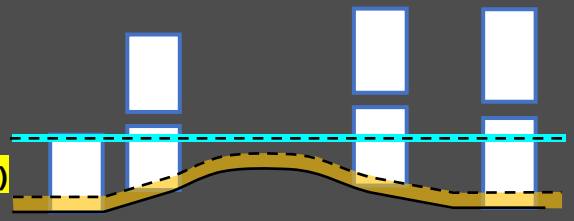
Site boundary

Wind corridors

Cut planes for analysis

Mid-height (20m cut plane)
Ventilation of Blocks

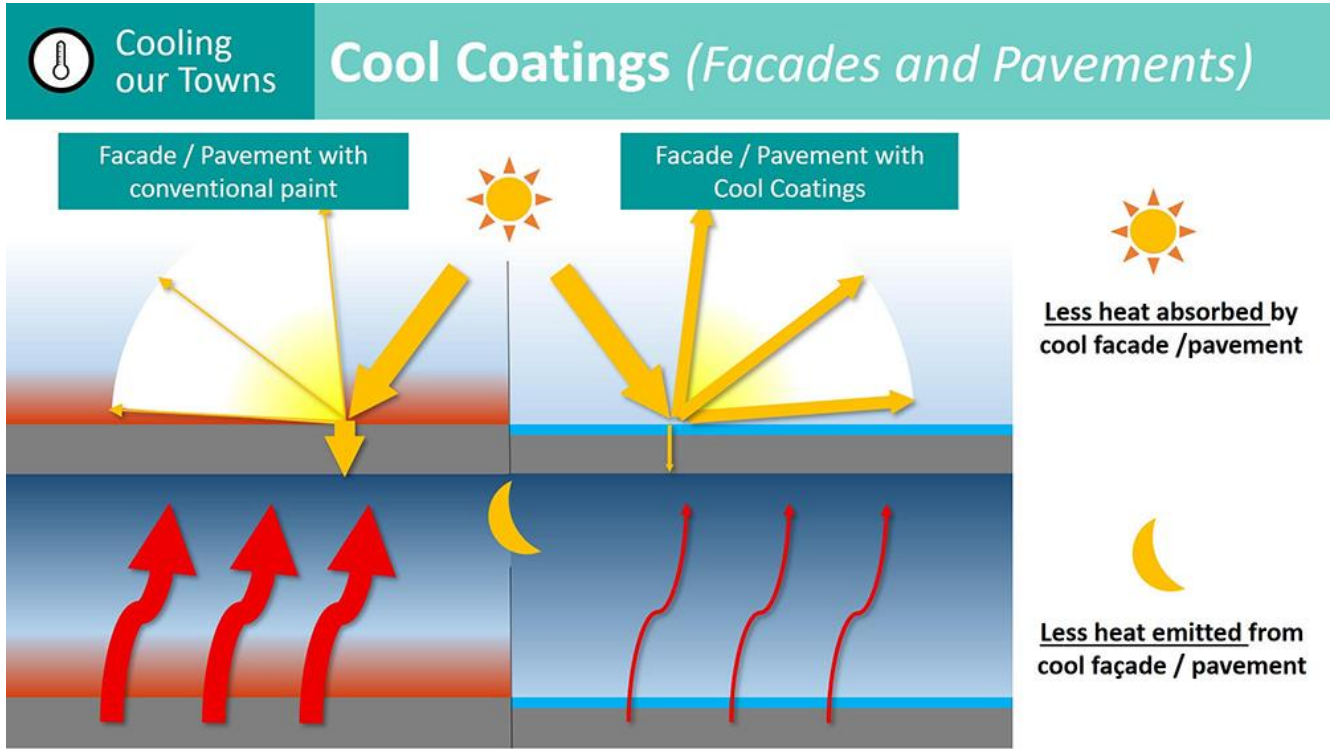
Street Level (12 m cut plane)
Public and shared spaces



- **Mid-height plane (20m cut plane) was found to follow similar wind patterns but at higher intensity**

Cool Paints

Cool Paints



- Cool coatings/films/paints are one of the mitigation strategies currently adopted to help lower ambient temperatures around buildings
- In the day, it helps to absorb less heat, while at night, it emits less heat into the surroundings (as compared to conventional paints)
- Currently, we understand that such cool paints come with a cost premium
  - Compared to conventional paint, cool paint is approximately ~25-30% more expensive
- Cool films work similarly to cool paints, although compared to cool paints, they are:
  - Made up of different materials
  - Work better on transparent surfaces such as glass
  - Considerably more expensive

Why Cool Paints?

Several research studies have shown efficacy of cool paints in reducing outdoor air temperature

Applying cool coating on **all urban surfaces** can reduce the **outdoor** air temp 2m above a surface by **up to 2.0°C (midday)**[1]

Cool roofs are **significantly better (1.5°C)** than walls **(0.25°C)** and roads **(0.1°C)**, which are already shielded by buildings.

Another study indicated that cool surfaces can reduce **outdoor** air temp by **1.4°C** at around **2pm**[2]**.**

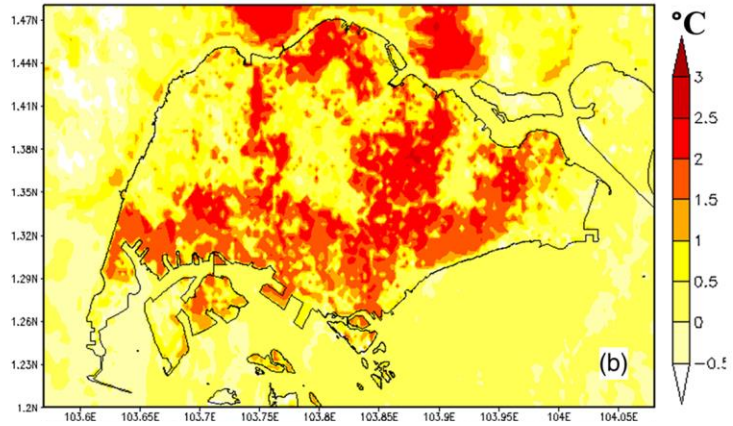


Figure:
***heat map** of difference in air temperature **at 2 metres above surface** between baseline and cool materials scenario **at 1300hrs** for 2 to 7 July 2016*

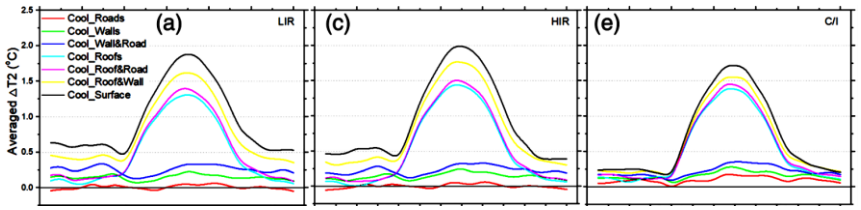
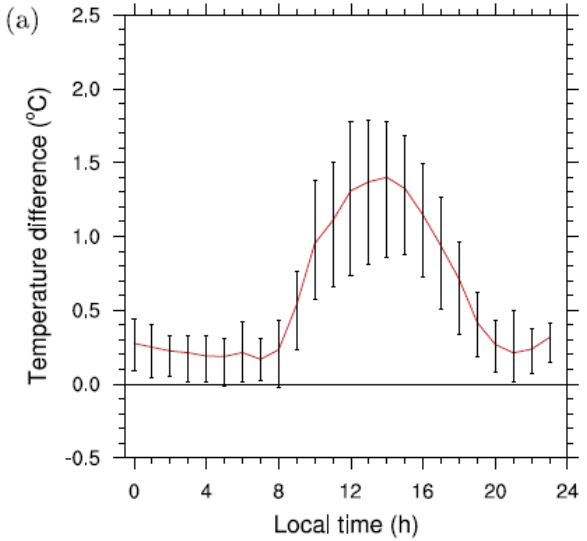


Figure:
*Difference in air temperature **at 2 metres above surface** between baseline and cool materials scenario for low-intensity residential areas (a), high-intensity residential areas (c), and commercial / industrial areas (e) **at 1300hrs***

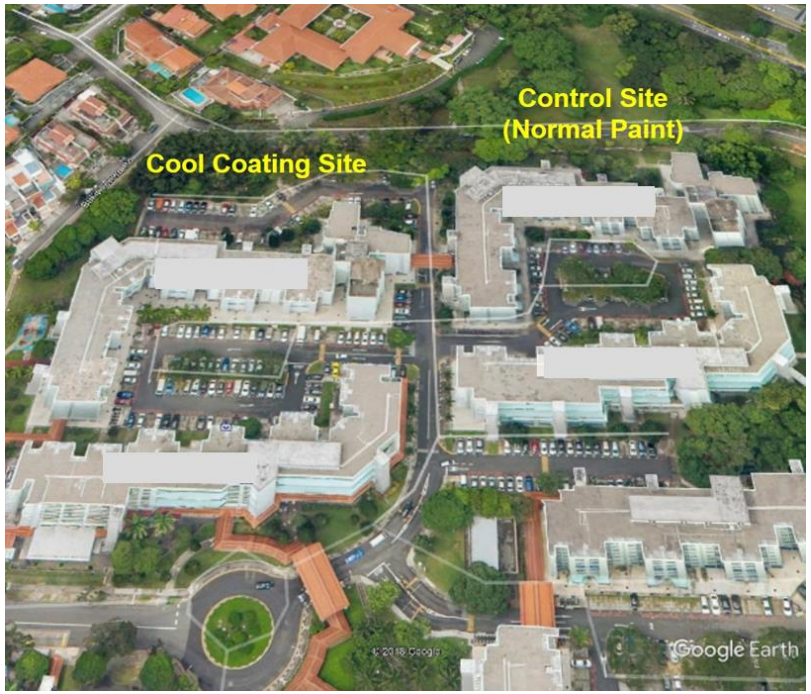


Source: [1]Zhou et al. (2020); [2]Li & Norford (2016)

As a WOG effort, we have begun several cool paints trials within the public sector to test its efficacy

Cool Paints in HDB Residential Estates

Preliminary findings have shown that cool paint could reduce the ambient temperature around the buildings coated with cool paint up to 2°C in the day and night.



Trial at eight blocks in Bukit Purmei

Large-scale pilot project at 130 blocks in Tampines

Source: HDB

Cool paints adoption within the Private Sector

In addition to public sector cool paints trials, the following developments are among the examples of private sector adoption:

Residential	**Condominiums such as:** **Parc Mondrian, Costa Del Sol, Bellewaters, Asana**
Commercial	**Northpoint, Mapletree**

Costa Del Sol (Source: AsiaOne)

Bellewaters (Source: EdgeProp)

Northpoint (Source: Mothership)

UHI Standards within the Built Environment

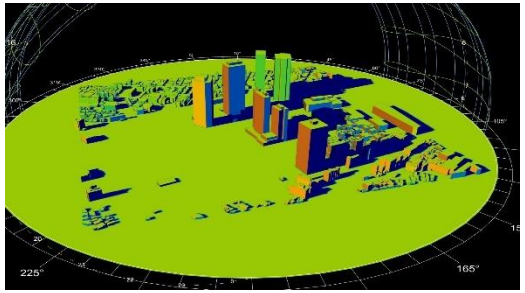
Under BCA's Green Mark Assessment Criteria

Developers are encouraged to adopt mitigation measures such as:

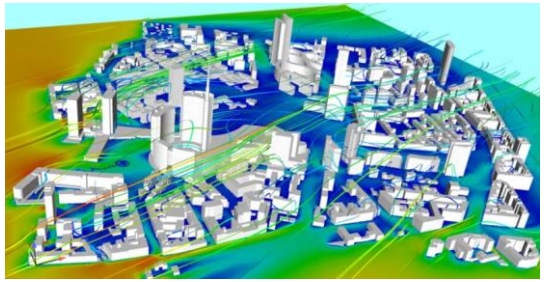
- Green and blue spaces for landscaping and roof
- Roofing materials or coatings or cool paints with high Solar Reflectance Index (SRI) > 40
- Unshaded hardscape areas with SRI > 39, inclusive of unshaded carparks, internal roads, and pedestrian walkways
- Use of permeable paving strategies such as gravel or open paving systems

Developers are encouraged to conduct environmental modelling of the site to demonstrate that outdoor thermal comfort (OTC) is maintained or improved, and UHI effect is minimised and reduced.

Solar irradiance



Wind Flow



Source: BCA

LEVERAGING TECHNOLOGY AND INNOVATION

Developing a Digital Urban Climate Twin

Land Use Model |
Master Plan, Local Climate Zones

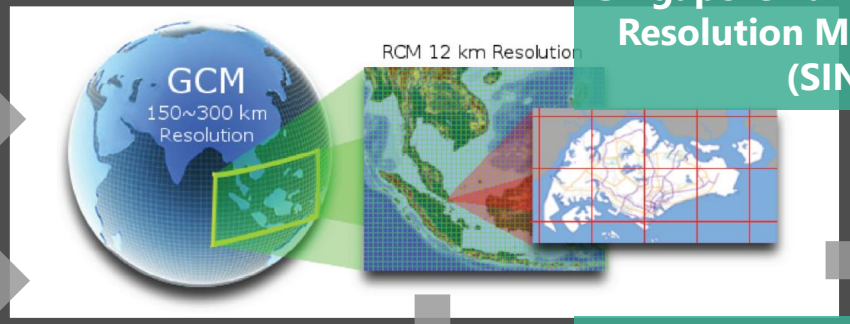
Industry Model |
Industrial processes

Power Plant Model |
Electricity demand, Fuel prices

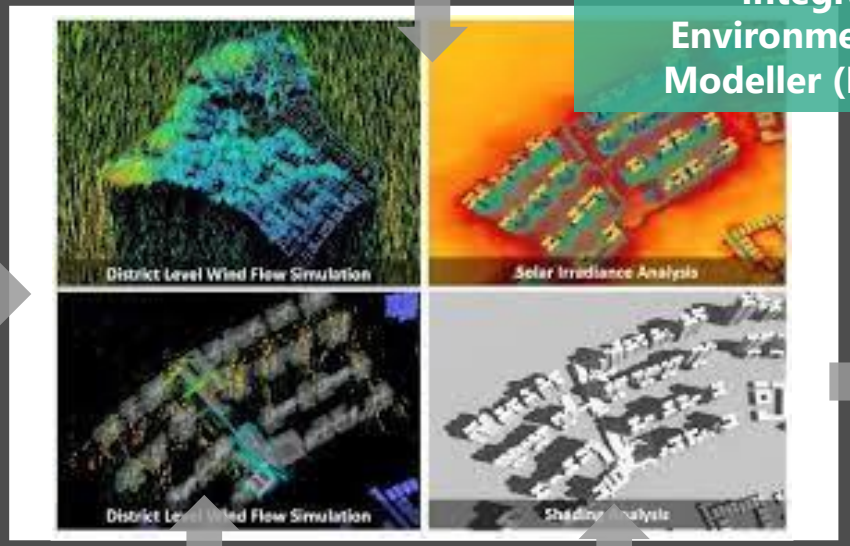
Traffic Model |
Road infrastructure, traffic demand, vehicle properties

Building Energy |
Building geometry/properties, weather data

Anthropogenic heat profile



Singapore Variable Resolution Model (SINGV)



Integrated Environmental Modeller (IEM)

Urban Heat Island (UHI) Analysis

Outdoor Thermal Comfort (OTC) Analysis

Urban geometry/ properties

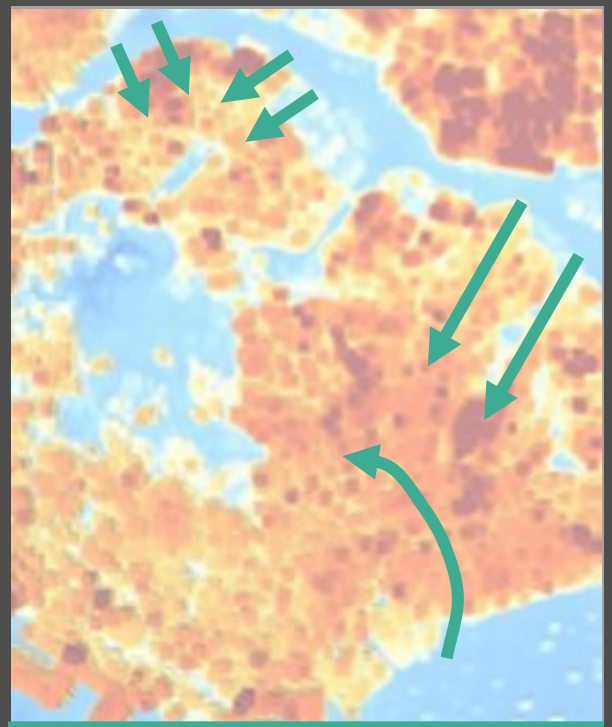
Vegetation geometry/ properties

*Source: Cooling Singapore 2.0; CCRS, 2015; HDB, A*STAR*

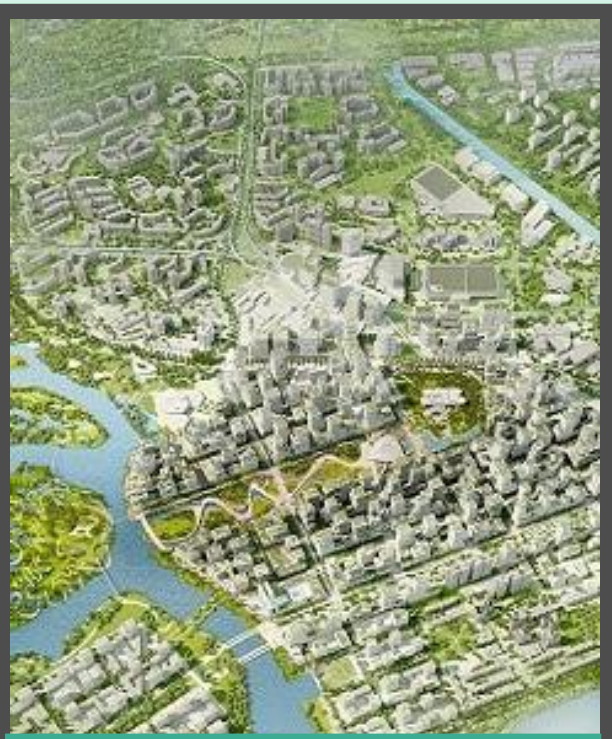
Leveraging the Digital Urban Climate Twin in Policy & Planning

WHAT-IF SCENARIOS

Introducing new parks and open spaces in temperature hotspots



Planning for wind corridors, and bringing coastal winds inland



Optimising the energy efficiency of buildings

Planning for urban density and urban geometry to minimise the UHI effect

Source: NParks; Cooling Singapore, 2019; URA; Mike Enerio, Unsplash

MOVING FORWARD

- Heat will continue to be a pressing issue for our island-city state
- To work towards implementing more cooling strategies and further strengthening our understanding of the heat problem in Singapore
- To collaborate with research partners and private sector to address knowledge gaps, innovate new solutions and build capabilities

URBAN REDEVELOPMENT AUTHORITY

Receive our monthly updates: www.ura.gov.sg/subscribe