CENTRE for LiveableCities SINGAPORE

LECTURE SERIES

BUILDING & COOLING SINGAPORE IN AN ERA OF CLIMATE CHANGE

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COOLING SINGAPORE

Building & Cooling Singapore in an Era of Climate Change

8 August 2019

Gerhard Schmitt
Director, Singapore-ETH Centre

EXISTENTIAL THREAT OF WARMING

80 million jobs by 2030: UN

01 Jul 2019 06:58PM
(Updated: 01 Jul 2019 07:06PM)

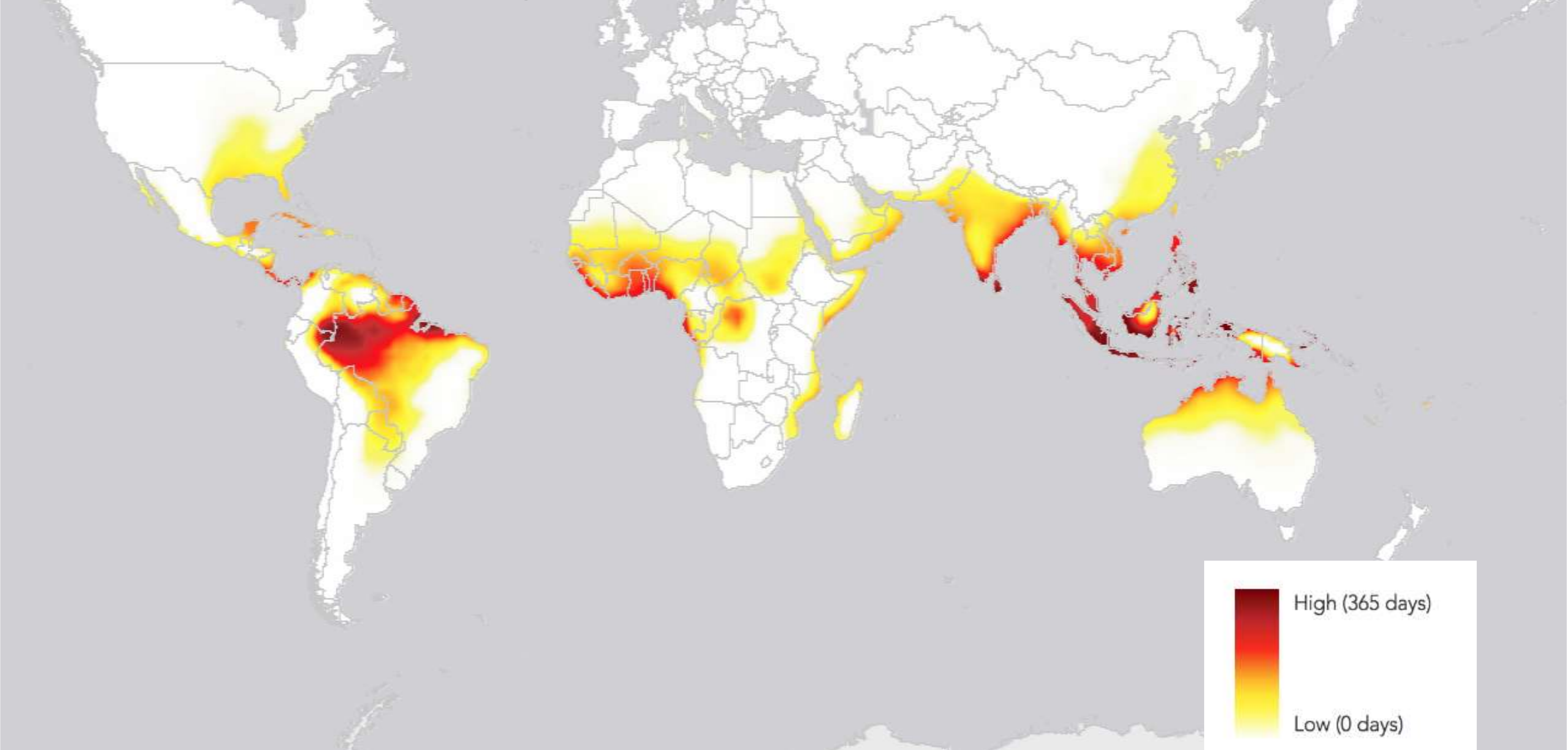
Bookmark

Tens of thousands of young climate activists rallied across Europe demanding urgent action against global warming. (File photo: AFP/Jonathan Nackstrand)

GENEVA: As climate change worsens, growing heat stress on workers in agriculture and other sectors will cause a productivity loss equal to 80 million full-time jobs over the next decade, the UN warned Monday (Jul 1).

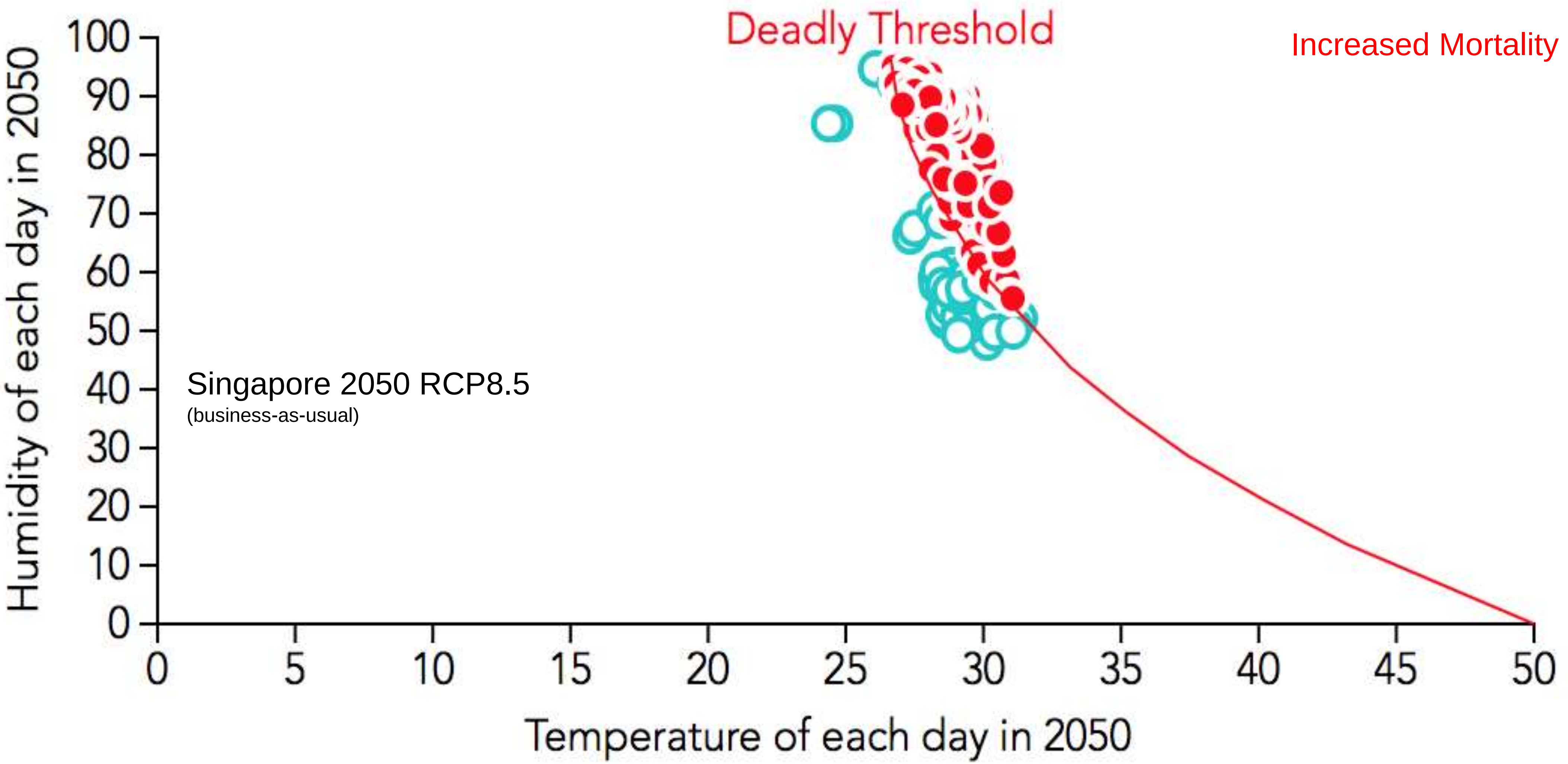
A report from the International Labour Organization (ILO) estimated that in 2030, 2.2 per cent of total working hours worldwide will be lost because of higher temperatures.

Global risk of deadly heat by Mora et al.



Sources: Global risk of deadly heat by Mora et al. (2017) and https://maps.esri.com/globalriskofdeadlyheat/

Estimated number of deadly heat days in 2050 under the RCP8.5 (business as usual) climate change scenario.



Sources: Global risk of deadly heat by Mora et al. (2017) and https://maps.esri.com/globalriskofdeadlyheat/

NEGATIVE CONSEQUENCES

EXAMPLE: IMPACT ON ECOSYSTEM

Higher temperatures may damage or kill some animals and plants. Examples include: faster maturation of pests such as mosquitoes, increased tree stress and risk of failure, disruption to marine organisms.

Ecosystems are interconnected complex systems. **Changes in one species may have unpredictable consequences across the system.**

We know little about the species-specific impacts of elevated temperatures on animals and plants in Singapore.

We know even less about how these individual effects may scale up and interact to impact Singapore's ecosystems as a whole.

Photo: https://commons.wikimedia.org/wiki/File:Aedes_aegypti.jpg

NEGATIVE CONSEQUENCES

SPECIFICALLY FOR SINGAPORE

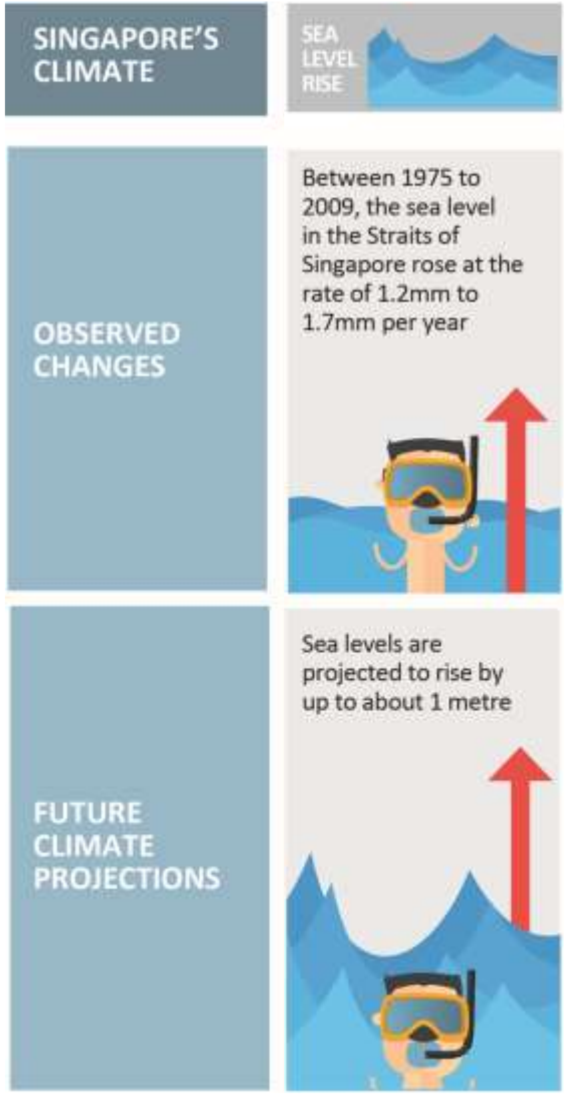
'Half a month's rainfall in two hours'

Strait Times, 30 June 2018

Annual average rainfall increased by 600mm from 1980 to 2014

Source: https://www.straitstimes.com/singapore/environment/half-a-months-rainfall-in-two-hours, NCCS 2015, https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

NEGATIVE CONSEQUENCES
SPECIFICALLY FOR SINGAPORE



'Seawalls and rock slopes already protect over 70 % of Singapore's coastline.' *Strait Times, 28 May 2017*

Sea level 1.2-1.7mm increase each year from 1975 to 2009

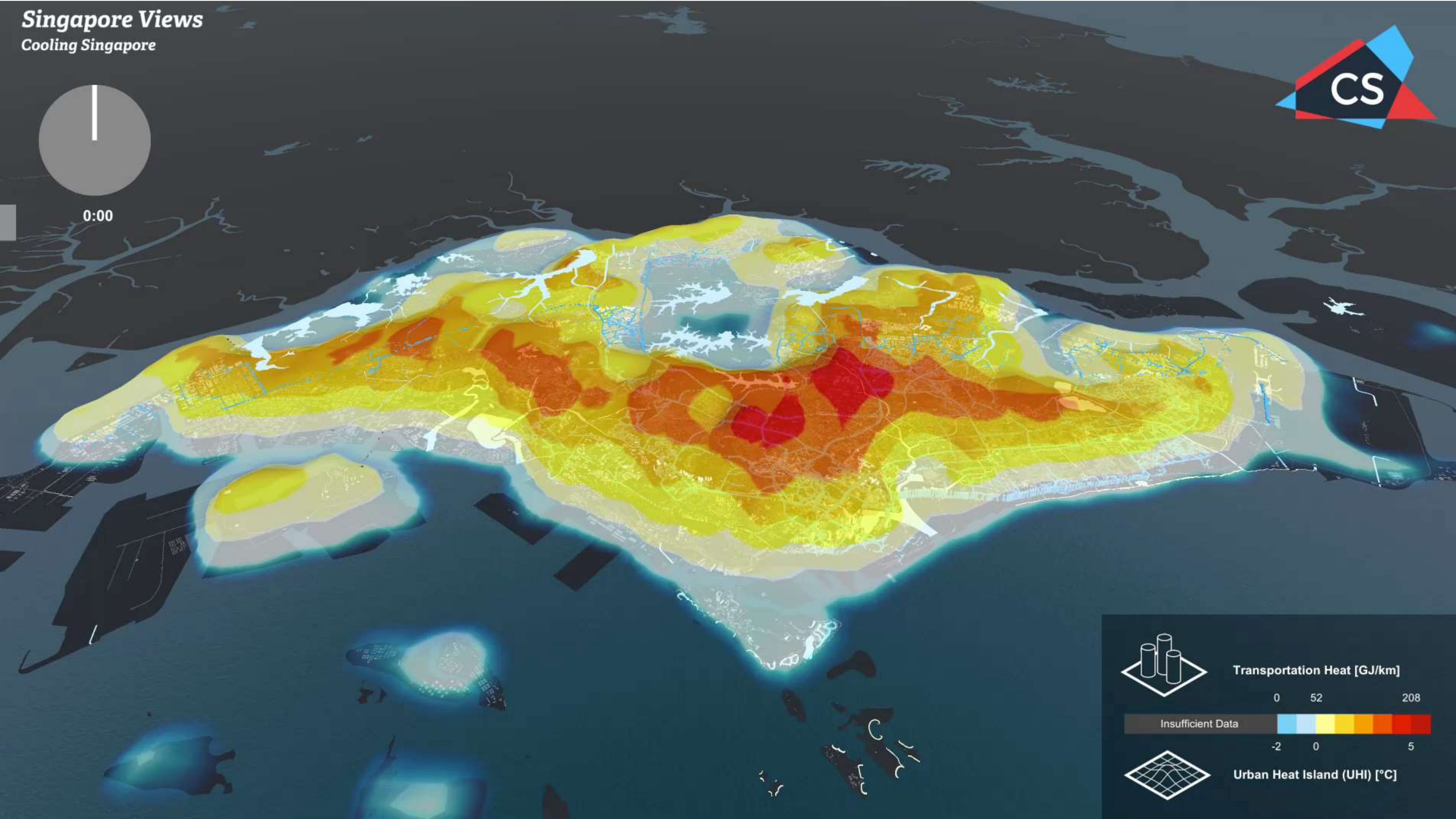
Source: https://www.straitstimes.com/singapore/as-sea-levels-rise-singapore-prepares-to-stem-the-tide, NCCS 2015, https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

SINGAPORE’S URBAN HEAT ISLAND

URBAN HEAT ISLAND (UHI)

Defined as the air temperature difference between rural and urban areas

UHI magnitude is measured by comparing the simulation results of the current urbanised condition (‘current-scenario’) with results of a plausible rural condition where all urban areas are replaced with vegetation (‘all-green scenario’)

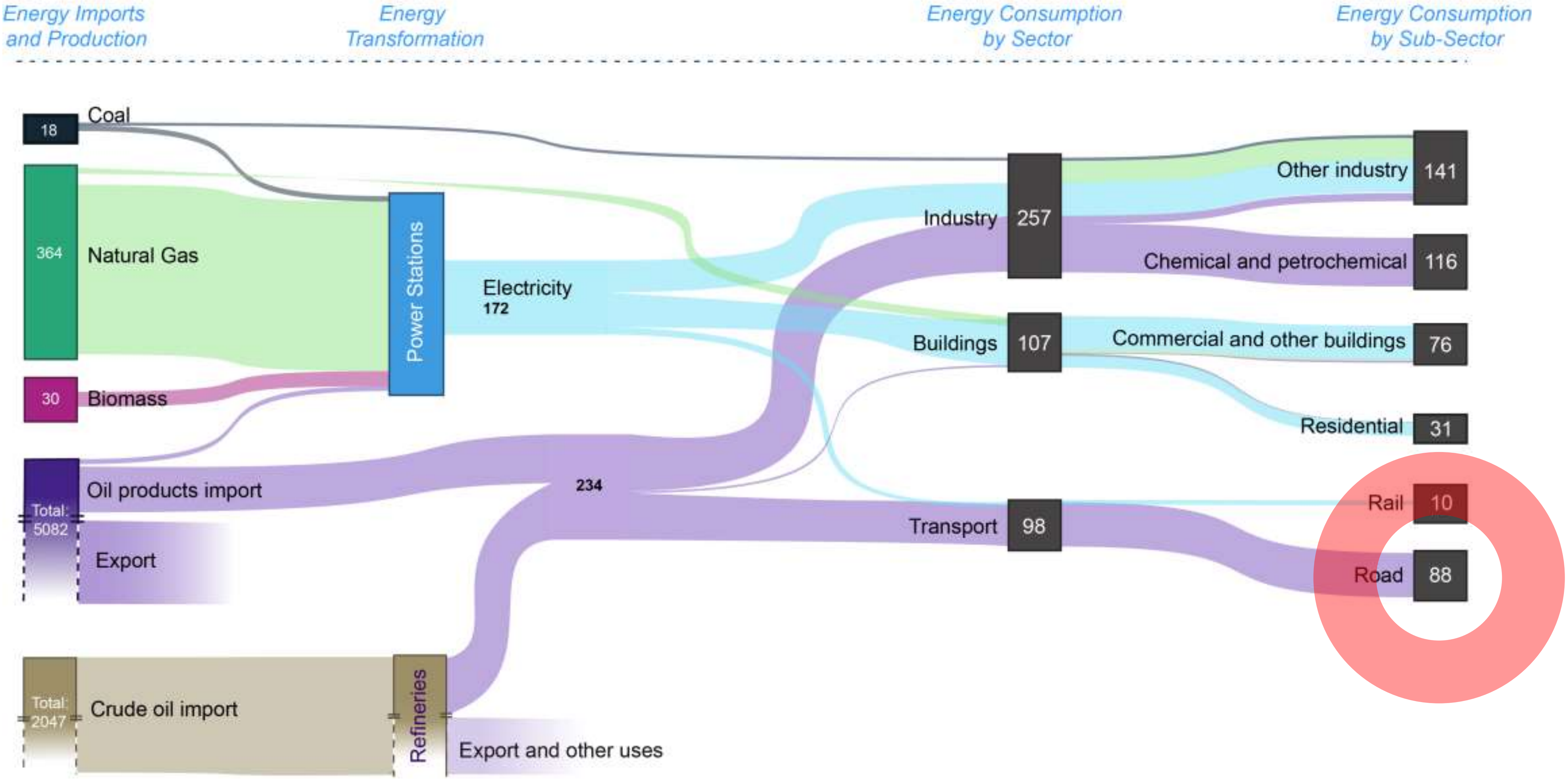

Singapore Views
Cooling Singapore
0:00
CS
Transportation Heat [GJ/km]
0
52
208
Insufficient Data
-2
0
5
Urban Heat Island (UHI) [°C]

IMPACT OF ANTHROPOGENIC HEAT

IMPACT OF ANTHROPOGENIC HEAT (VEHICLES)

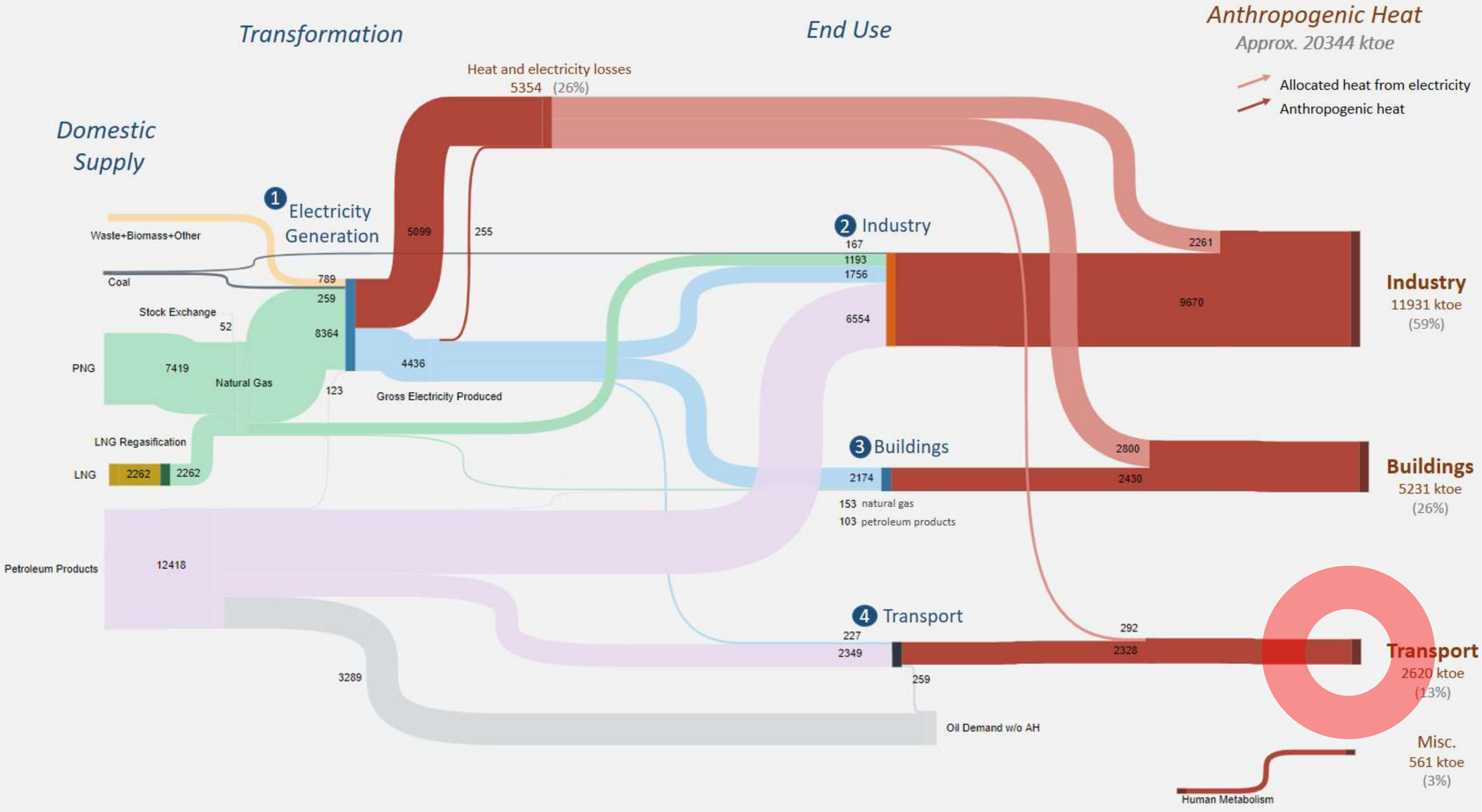
2016 Singapore Energy Flow Diagram

Domestic Use Petajoules PJ, based on IEA data



Singapore Anthropogenic Heat Sources

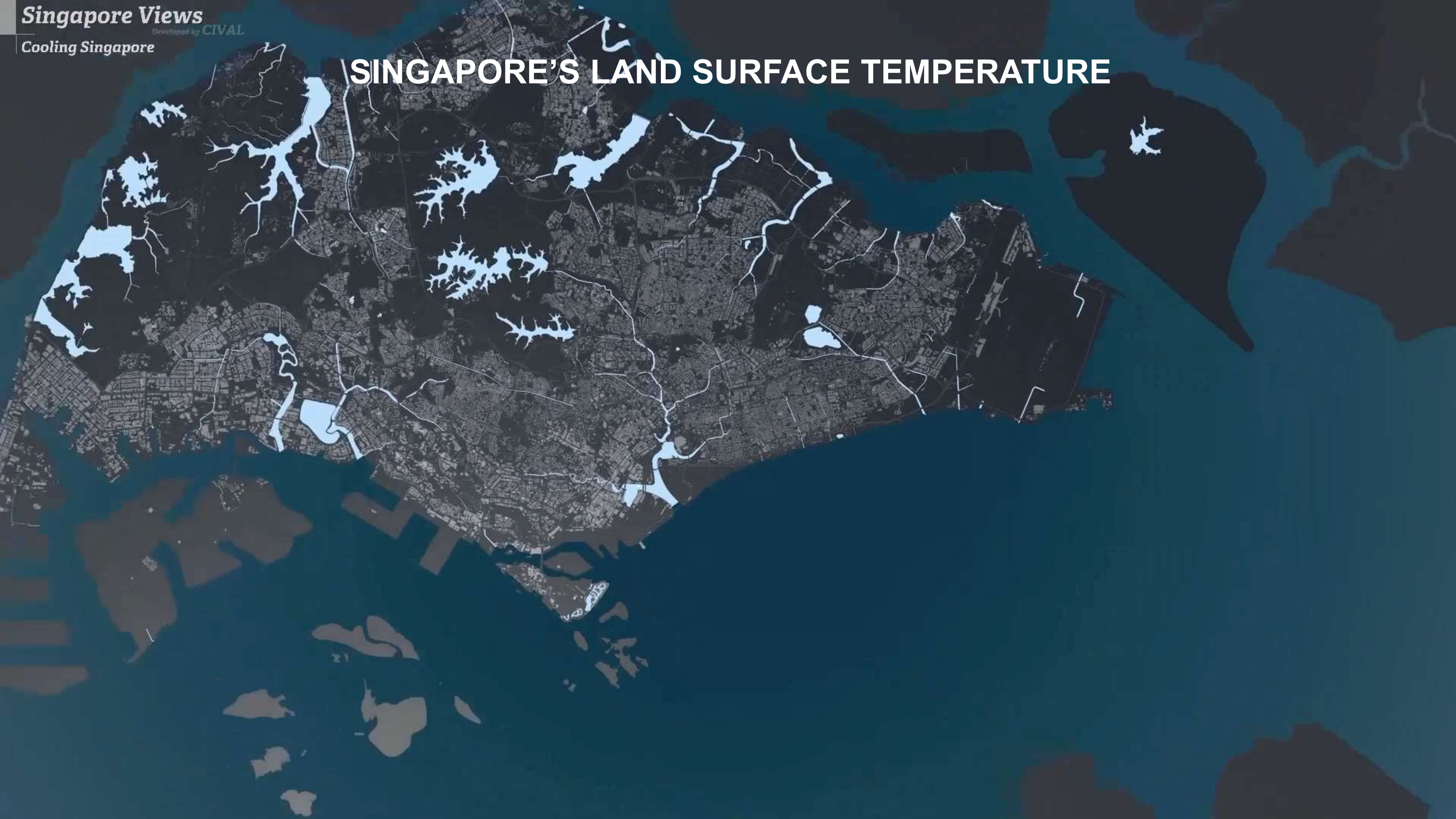
2016 ktoe



Primary source: Energy Market Authority
Secondary source: International Energy Agency

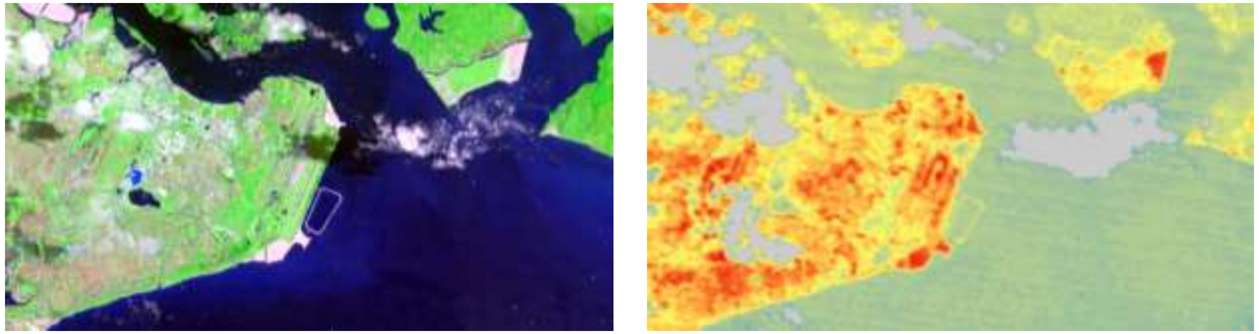
SINGAPORE’S LAND SURFACE TEMPERATURE

SINGAPORE’S LAND SURFACE TEMPERATURE

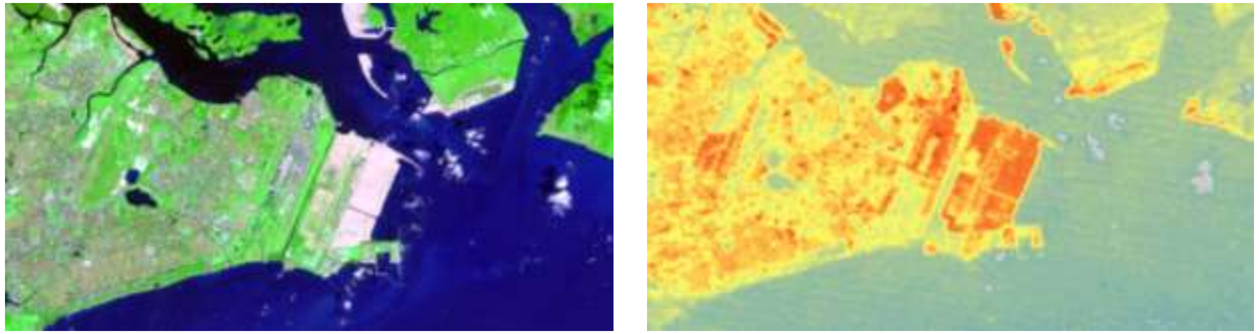


AIRPORT

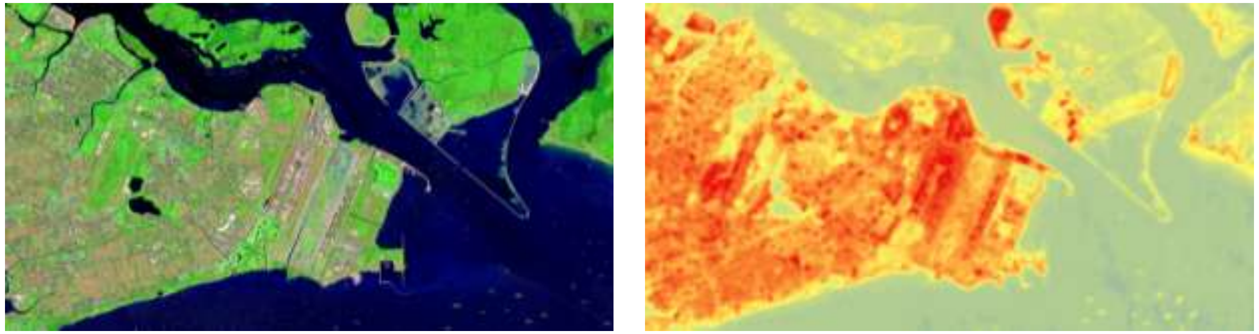
13 September 1989
10:42 am

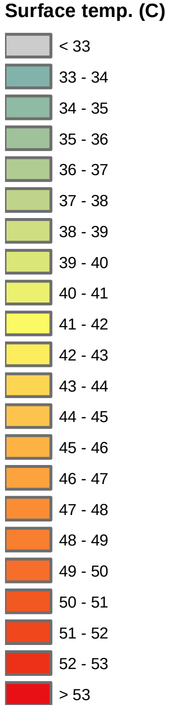


25 December 2003
10:55 am



8 May 2018
11.16 am



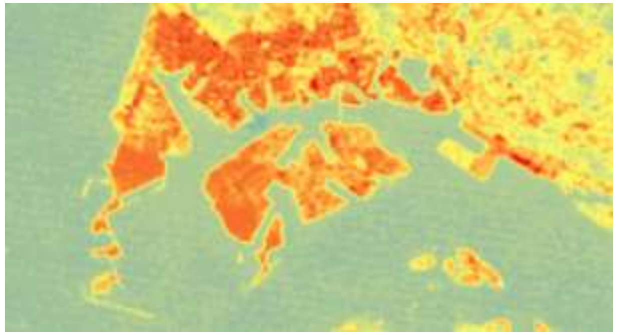


This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

JURONG

13 September 1989
10:42 am

25 December 2003
10:55 am



8 May 2018
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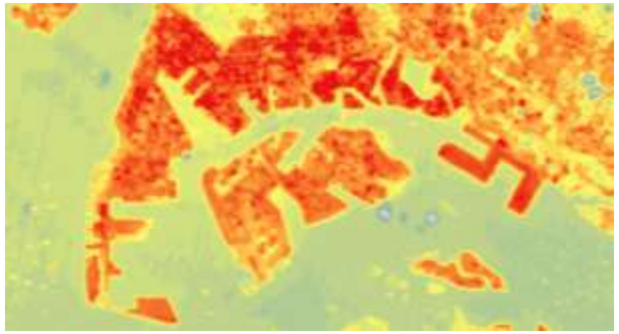
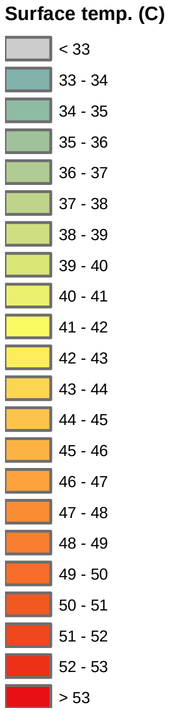




This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

WHERE DO WE WANT TO BE IN 2050?

Singapore most liveable city

High Outdoor Thermal Comfort
Clean Air
Clean Industry

Jurong Lake District masterplan, with Kees Christiaanse, SEC-FCL Director

Image: Straits Times (2016). Singapore

Singapore most liveable City

Less Noise
Renewable Energy
Circular Economy

Image: Conrad Philipp

HOW CAN SCIENCE HELP?

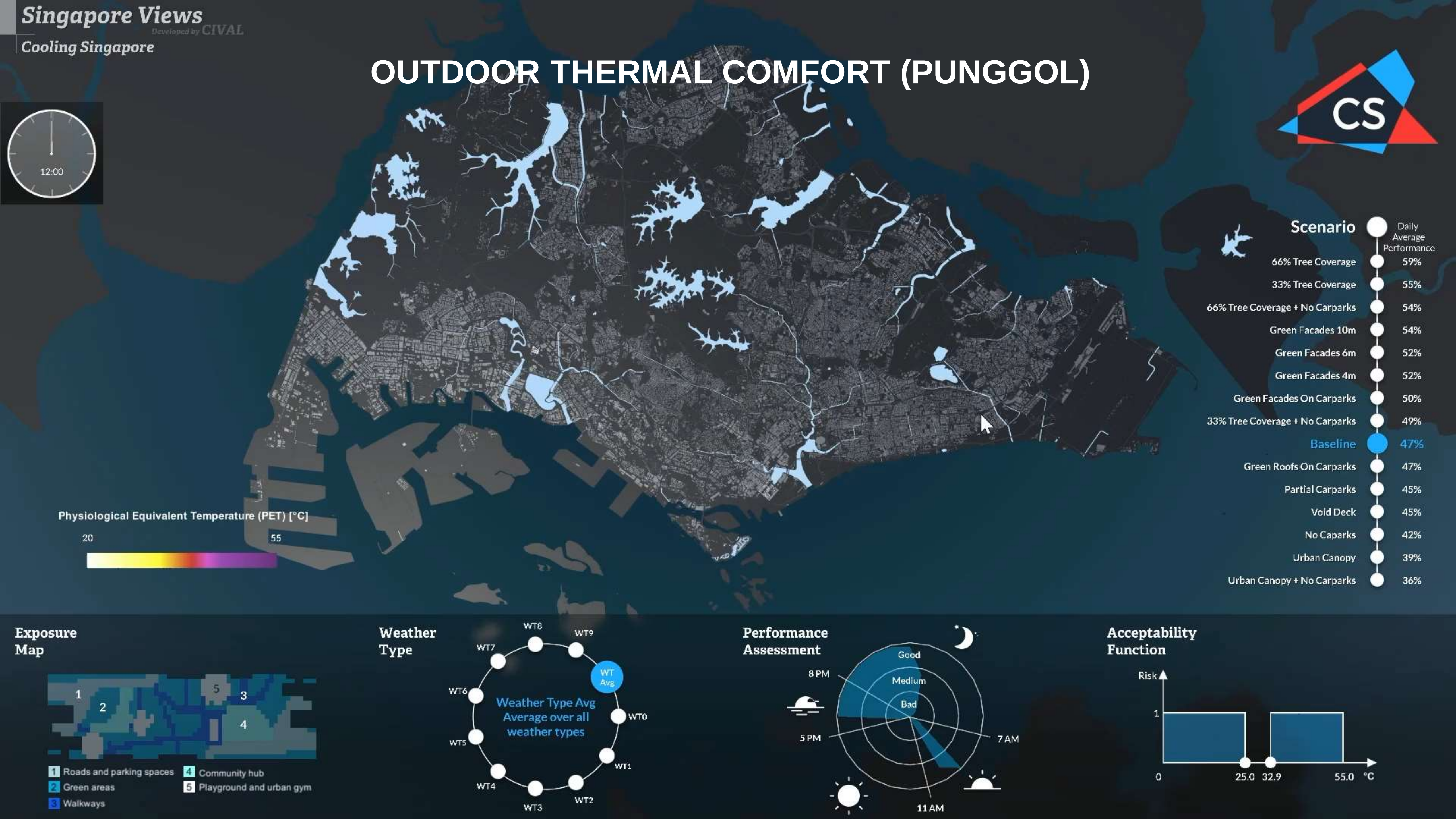
OUTDOOR THERMAL COMFORT

OUTDOOR THERMAL COMFORT

Helps us to understand the complex relationship between climate, urban spaces and the users of these spaces

Goal: to better understand the short- and long-term impacts of different strategies and to help make better decisions on where to invest in implementing specific strategies

OUTDOOR THERMAL COMFORT (PUNGGOL)



PEOPLE'S HEAT MITIGATION PREFERENCES

What **mitigation** strategy would you like to see implemented in **your neighbourhood?**

Case Studies

(Example Outcome Phase 1)

SOCIAL CAMPAIGNS

Willingness To Pay (WTP)

Population Survey Campaign
(1,882 participants)

Men are WTP 12.27% more than females

The more children, the higher the WTP. Three times higher between 2 and 1 child

The higher the education, the higher the WTP. Postgraduate double as bachelor

People who saw the UHI map are 46% more willing to pay

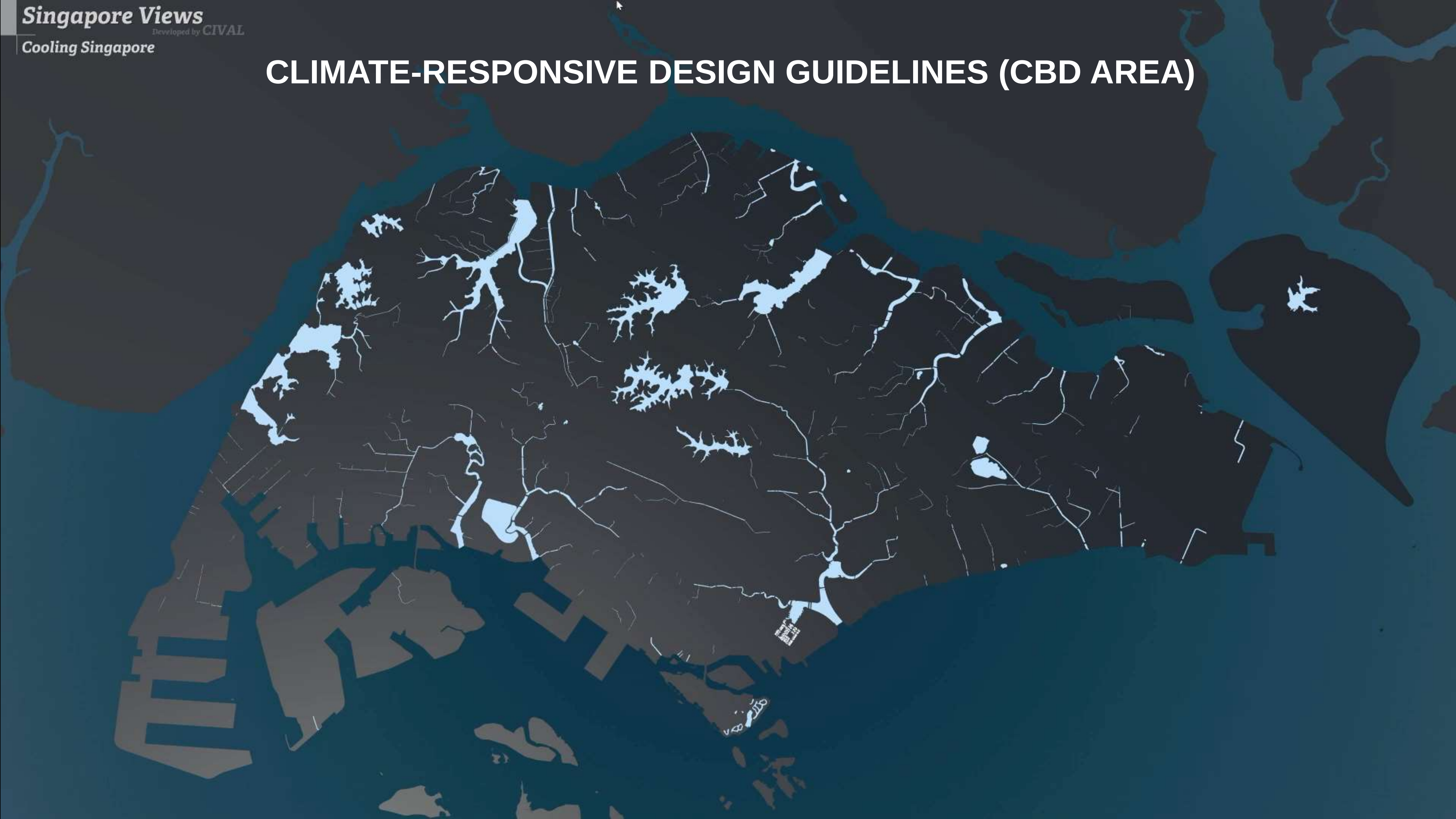
The higher the age, the lower the WTP. Highest: 20-29 yrs

Self-employed are WTP 50.4% more than employed

CLIMATE RESPONSIVE DESIGN GUIDELINES


80+ MITIGATION STRATEGIES
VEGETATION
URBAN GEOMETRY
SHADING
MATERIALS & SURFACES
WATER BODIES & FEATURES
TRANSPORT
ENERGY

CLIMATE-RESPONSIVE DESIGN GUIDELINES (CBD AREA)



COOLING SINGAPORE 2.0

DIGITAL URBAN CLIMATE TWIN (DUCT)

DIGITAL URBAN CLIMATE TWIN (DUCT)

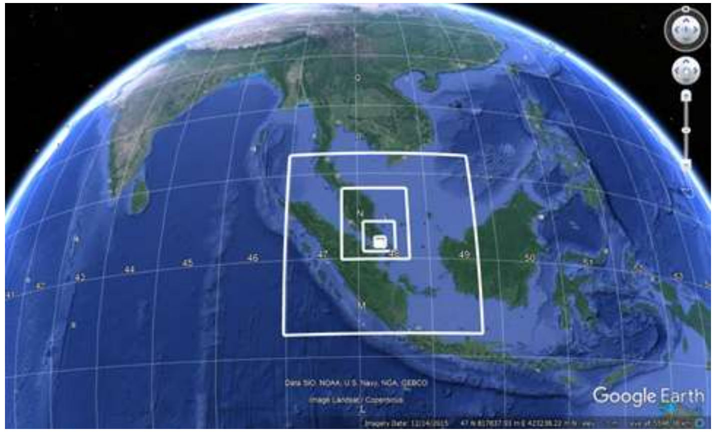
The DUCT is a modular platform of inter-operable models and tools and not a monolithic mother-of-all-models. Output of one model may serve as input (e.g., boundary conditions) for another.

Examples of DUCT model components:

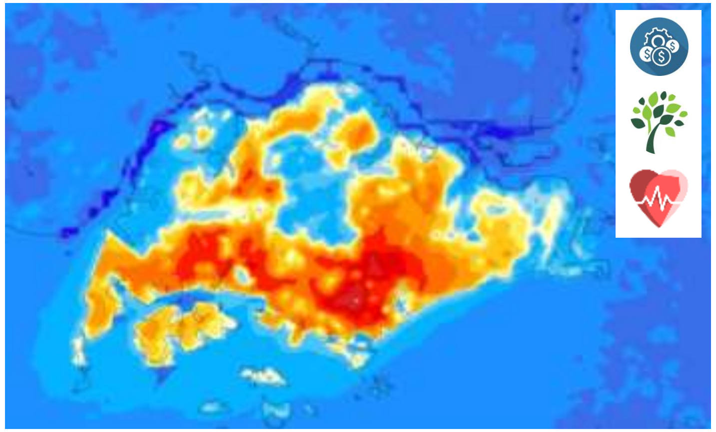
Multiscale climatic models:
- Macroscale: regional climate (SINGV)
- Mesoscale: island-wide climate (WRF)
- Microscale: neighbourhood climate (ENVI-met)

Risk and impact models:
- Economy
- Environment
- Health.

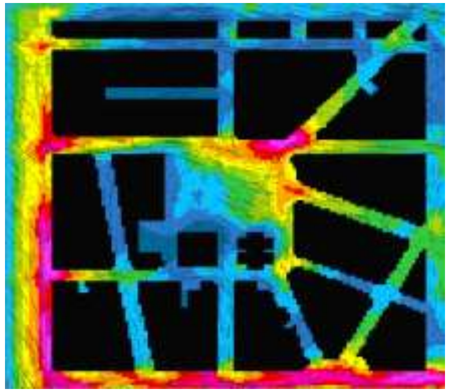
...



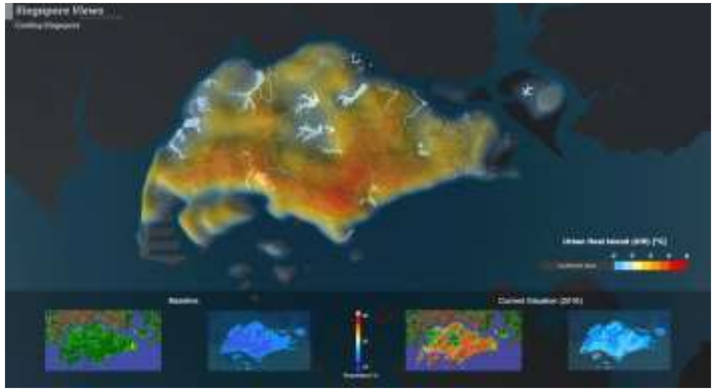
Downscaling: from regional to local climate.



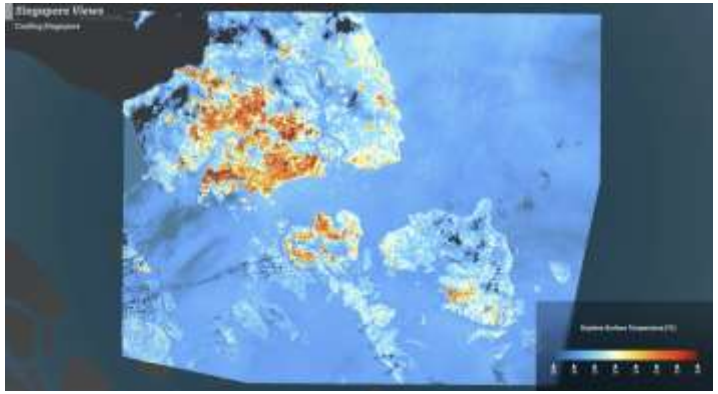
Impact on economy, environment and health.



Neighbourhood scale thermal comfort models.



Island-wide urban climate models.

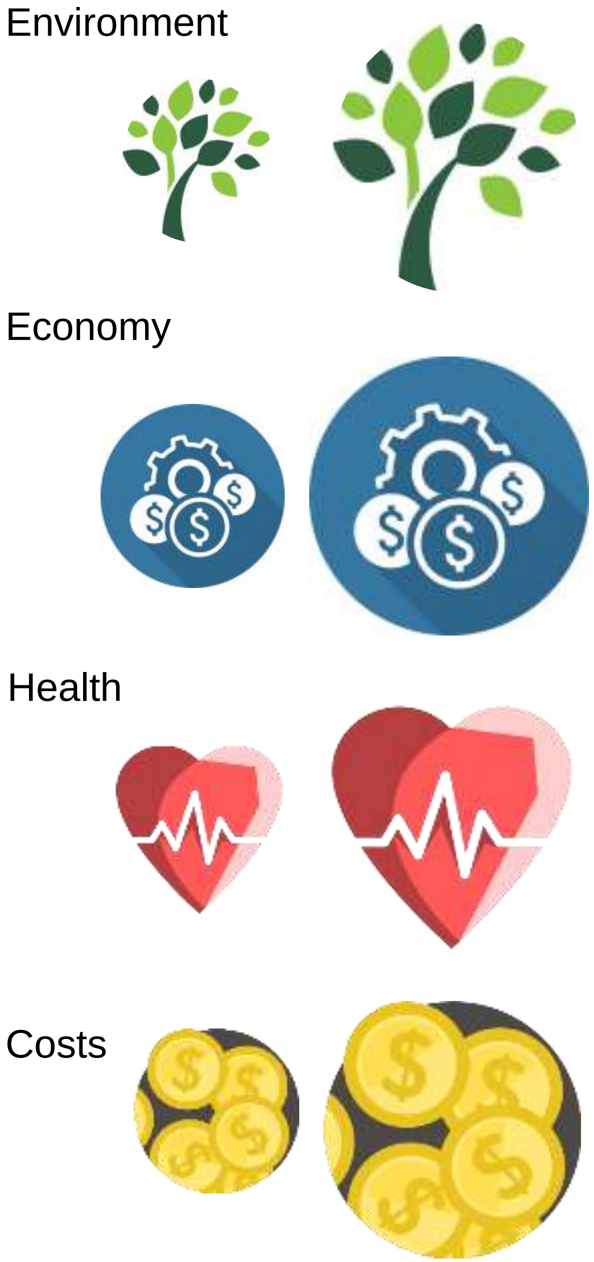


Remote sensing: surface UHI.

Images for illustration purposes only.

URBAN CLIMATE DESIGN AND MANAGEMENT

MITIGATION AND ADAPTATION



The temperature of 34 degree is based on MSS data where 30.0˚C is indicated as the highest monthly mean temperature[1] plus additional up to 4.6 degree (°C) temperature increase through to climate change[2]

1: Highest Monthly Mean Temperature (°C) / 1929-1941 and since 1948, average over all MSS Climate Station http://www.weather.gov.sg/climate-historical-extremes-temperature/

2: https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

URBAN CLIMATE DESIGN AND MANAGEMENT SYSTEM (UCMS)

URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

HOW IT WORKS STEP BY STEP

What will happen to the urban climate if we implement the master plan?

URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

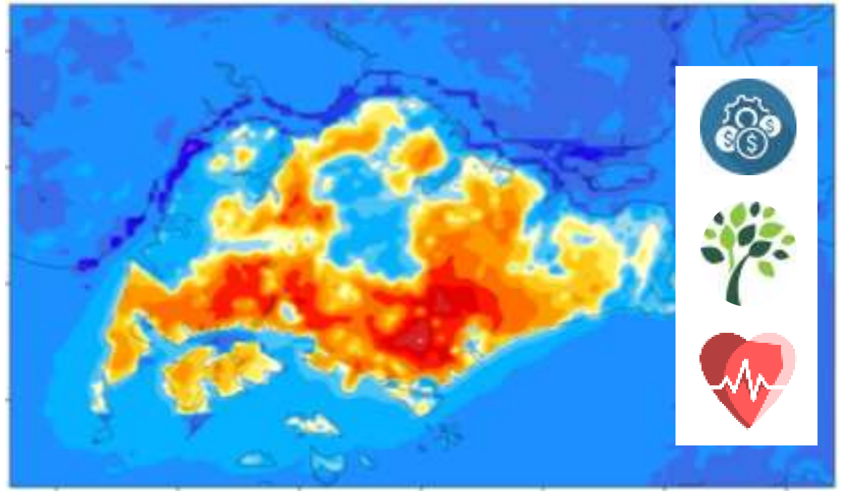
HOW IT WORKS STEP BY STEP

STEP 1 – SCENARIO TRANSLATION
Translate a planning scenario (e.g., master plan - top left) into a model (bottom right).

URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

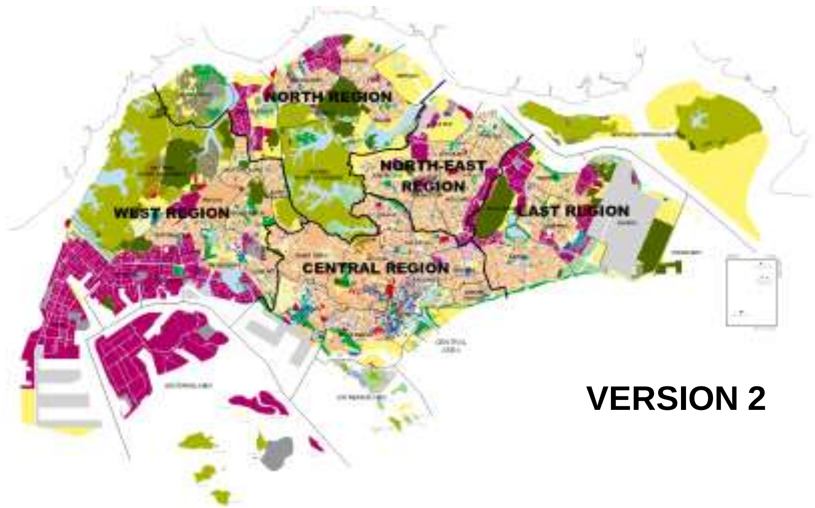
HOW IT WORKS STEP BY STEP

STEP 2 – SCENARIO EVALUATION
Simulate the planning scenario using the model (bottom right) and evaluate the resulting urban climate conditions, e.g., urban heat island (bottom left). Furthermore, evaluate the resulting impact on economy, environment, and health of the population.

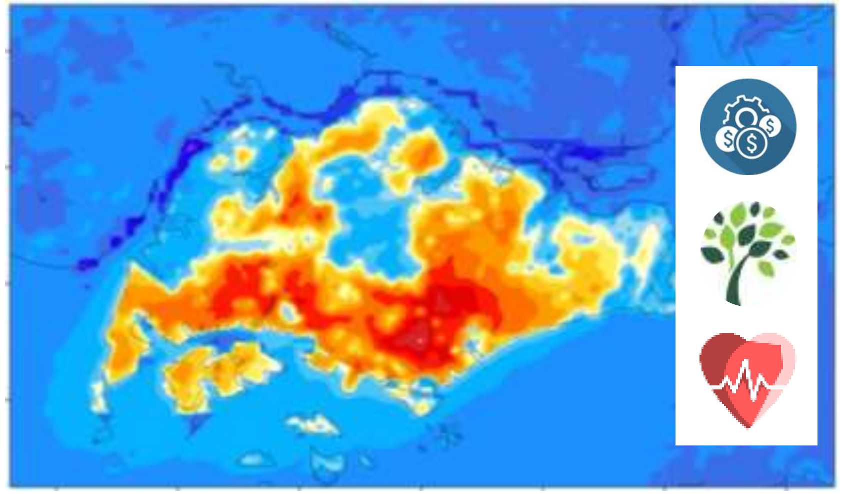


URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

HOW IT WORKS STEP BY STEP



VERSION 2

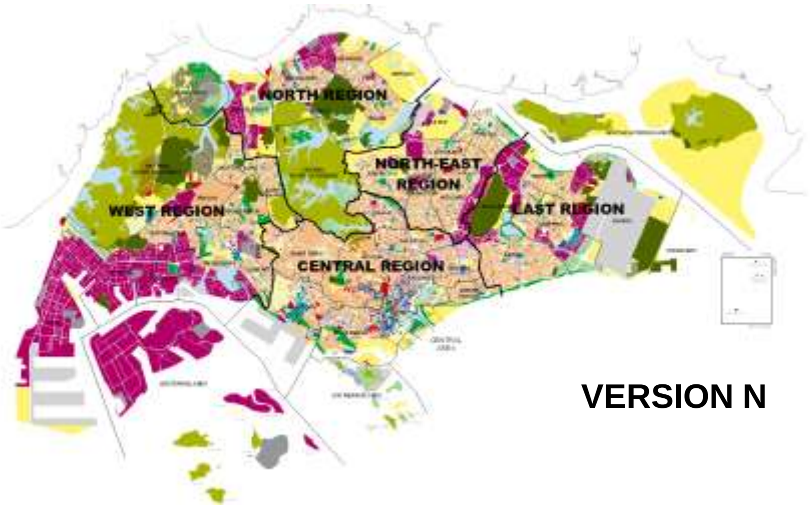


STEP 3 – SCENARIO MODIFICATION

Using the insights gained from the simulation (bottom left), modify the original planning scenario (top left) with the aim to improve urban climate results.

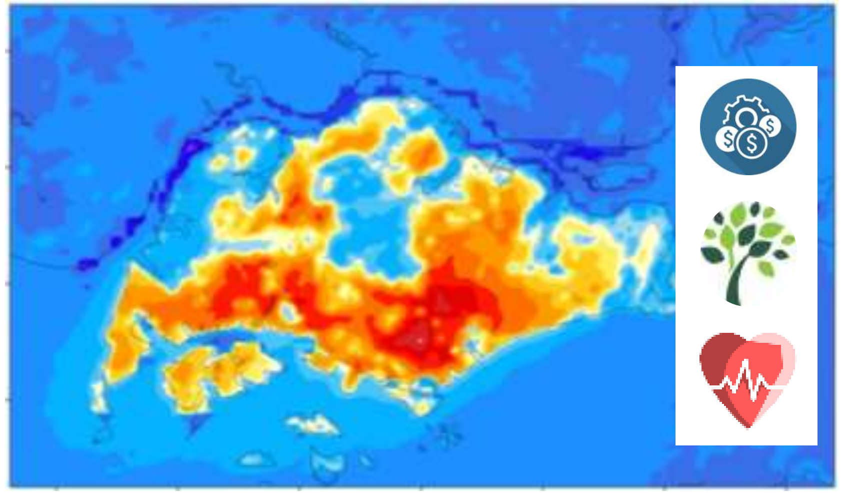
URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

HOW IT WORKS STEP BY STEP



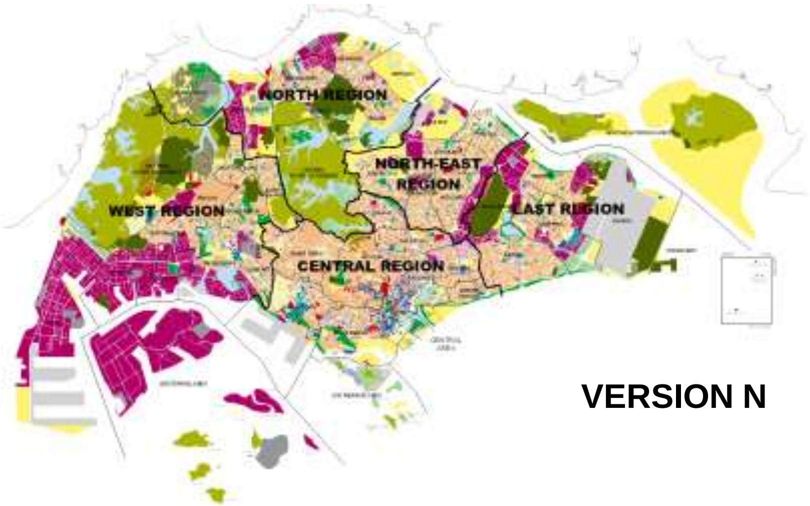
VERSION N

STEP 4 – PLANNING/SIMULATION LOOP
Repeat Steps 1 to 3 until desired outcomes and targets have been achieved.



URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)

HOW IT WORKS STEP BY STEP



VERSION N

STEP 5 – DECISION MAKING AND IMPLEMENTATION

Once the desired outcomes have been achieved in the simulation, a planning scenario can be considered for implementation.

URBAN CLIMATE MANAGEMENT SYSTEM (UCMS)
OVERVIEW

UCMS concept: integration of modelling and simulation into the planning and decision-making process.

UCMS concepts is based on:

- Urban Climate Scenario Planning Group (UC-SPG)
- Urban Climate Modelling and Simulation Group (UC-MSG)

CS 2.0 aim at developing a prototypical UCMS.

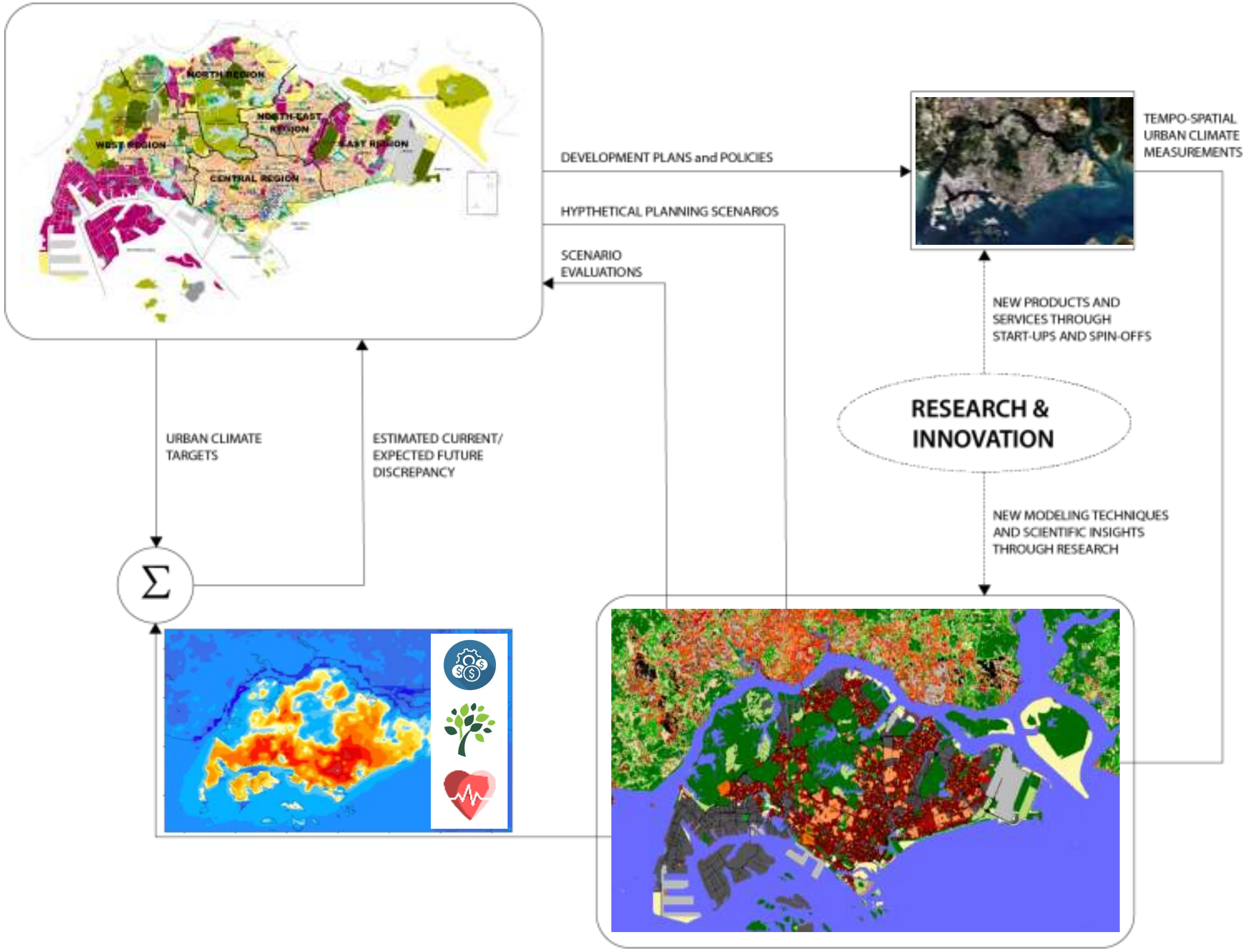


Image: Conrad Philipp

Cooling Singapore (CS)
www.cs.sec.ethz.ch
coolingsingapore.sg