FUTURE COOL SINGAPORE

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NSCC Webinar Series
3 September 2020

COOLING SINGAPORE

CREATE
Campus for Research Excellence And Technological Enterprise
(SEC) SINGAPORE-ETH CENTRE 新加坡-ETH研究中心
SMART
Singapore-MIT Alliance for Research and Technology
TUMCREATE
NUS National University of Singapore
Agency for Science, Technology and Research SINGAPORE

COOLING SINGAPORE

Future Urban Climate Design and Management

The COOLING SINGAPORE initiative is an integrated and holistic approach to address the URBAN HEAT CHALLENGE for Singapore and other cities around the world

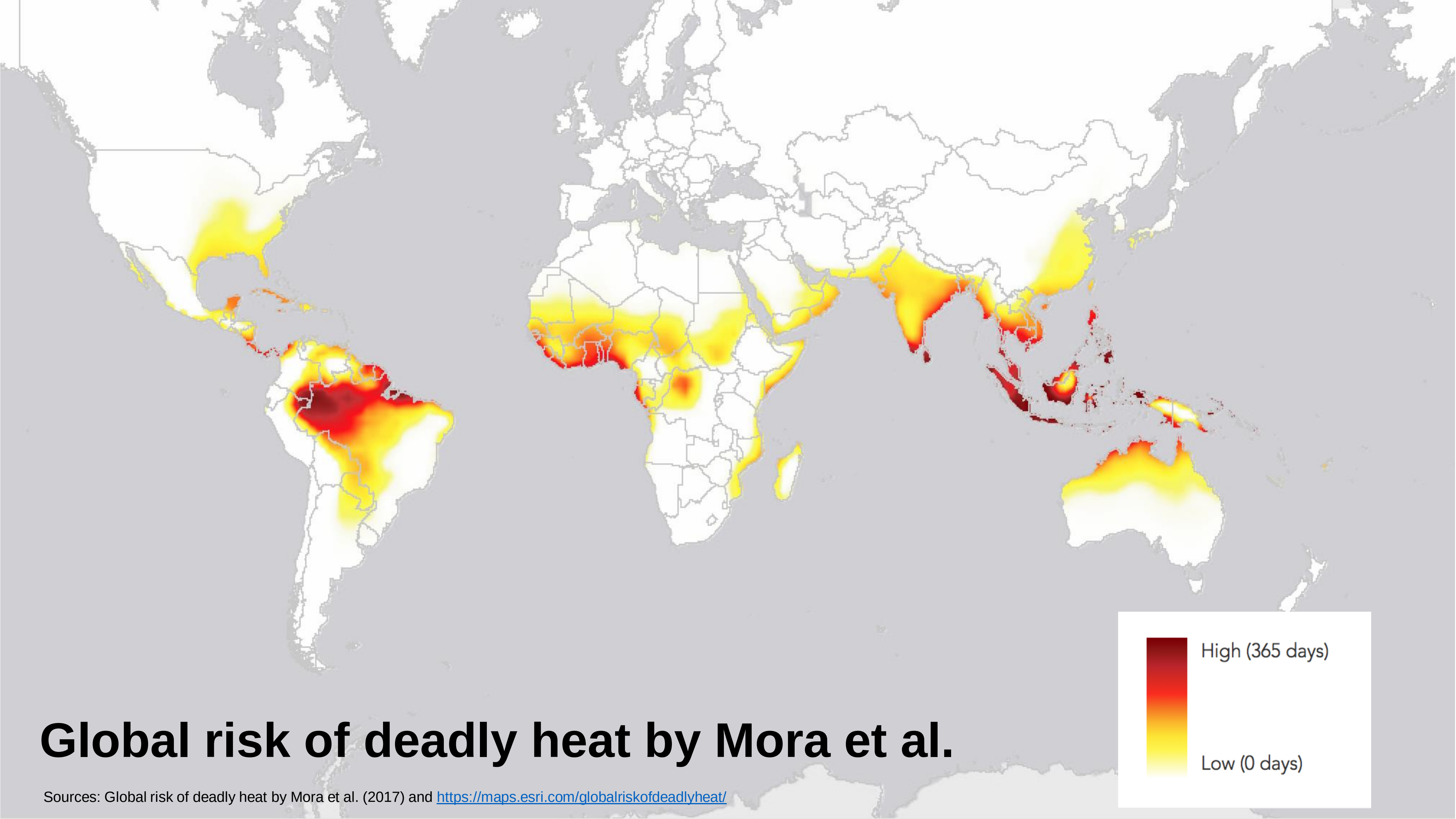
1

Thank you to the Team, Partners, UHI Workgroup and NRF

Supercomputing and Cooling Singapore

Supercomputing and Data Centres: UHI Cause and Solution?

2 The Existential Threat of Global Warming



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/

Health Reduced outdoor activities, reduced well-being, increase healthcare expenses.

Economy Reduced productivity, reduced attractiveness as a destination for investment, reduced liveability.

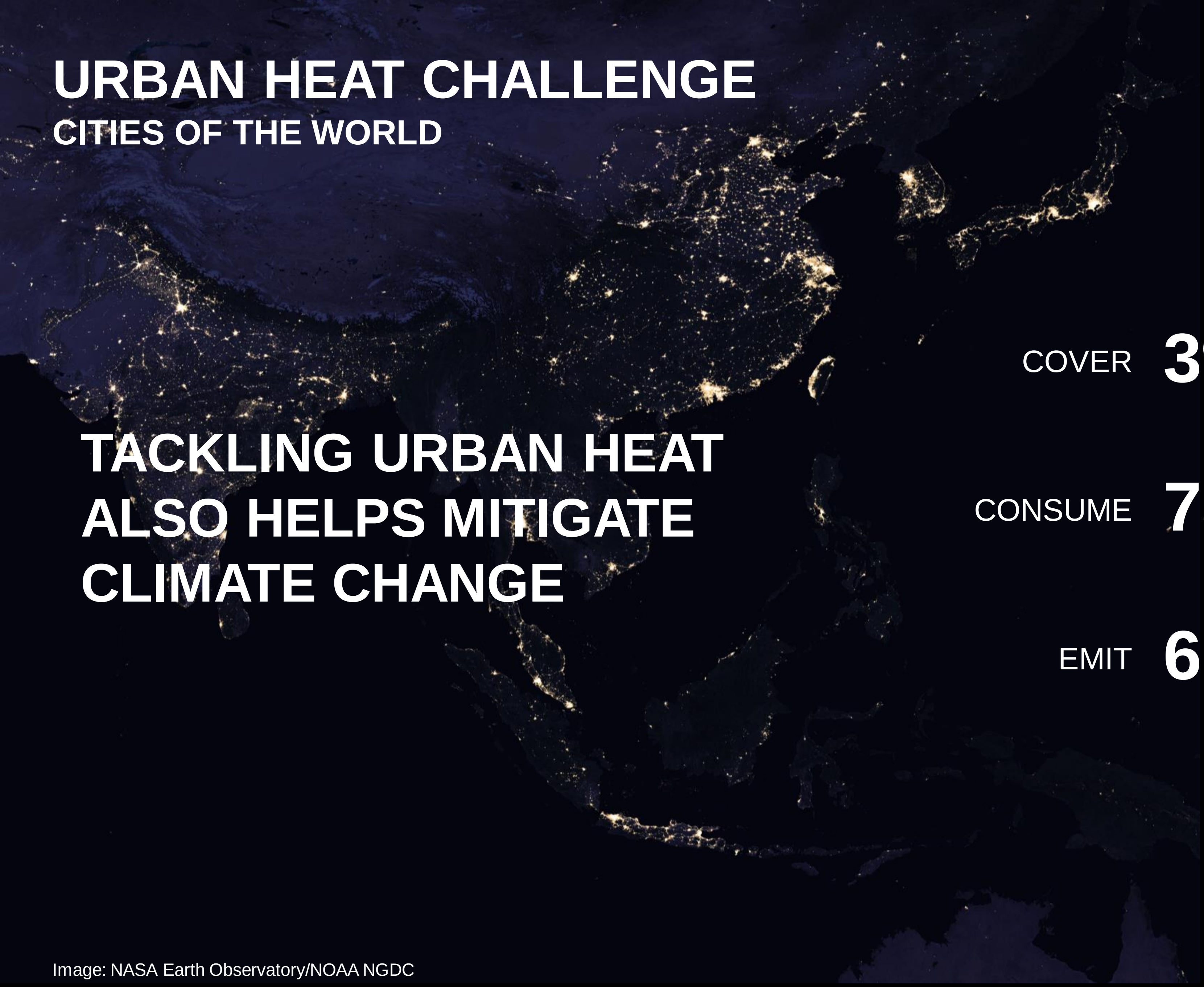
Disruption Increased occurrence of disruptive flash floods and falling trees, traffic disruption, etc.

Environment Loss of natural capital.

2 Why Cities Matter and the Urgency to Act

URBAN HEAT CHALLENGE

CITIES OF THE WORLD



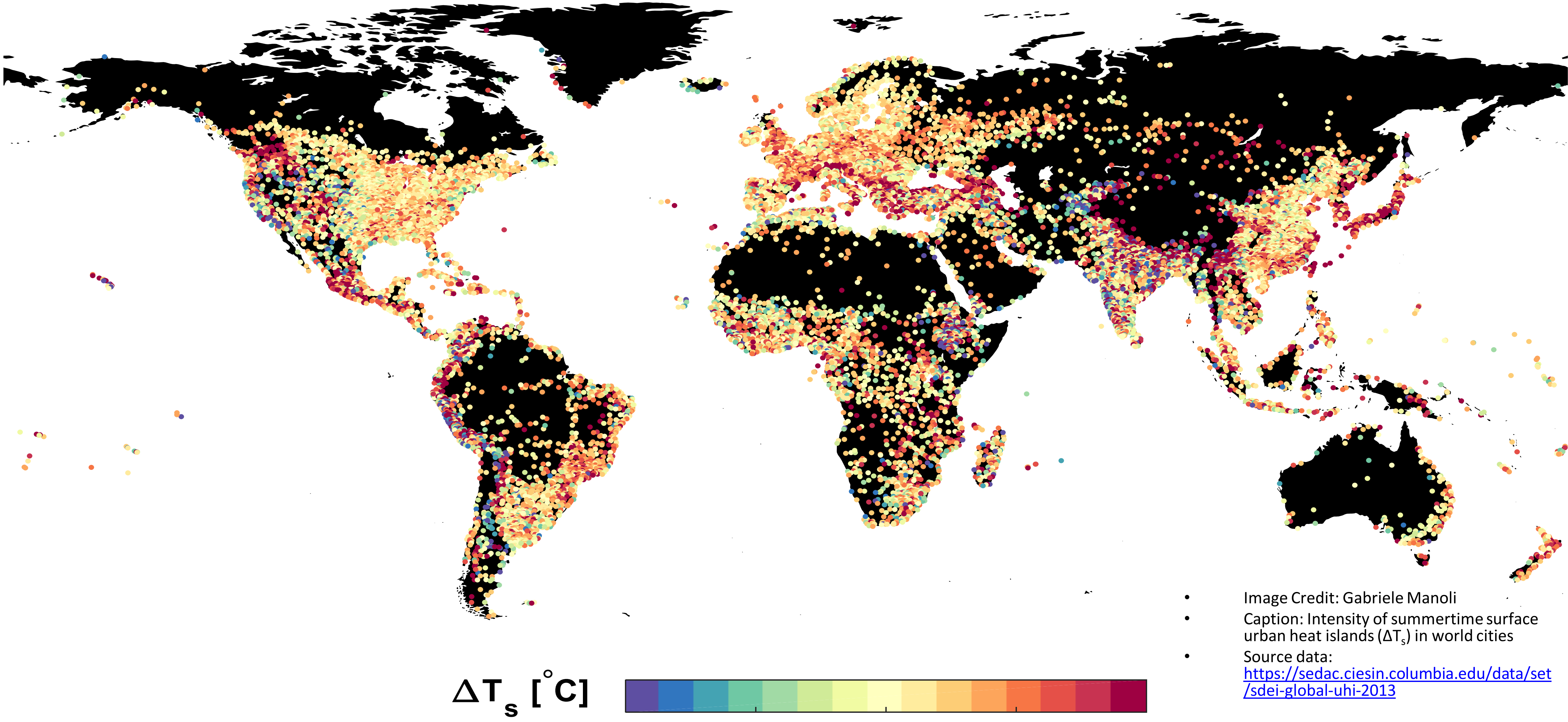
TACKLING URBAN HEAT ALSO HELPS MITIGATE CLIMATE CHANGE

COVER **3%** OF THE WORLD’S SURFACE

CONSUME **75%** OF GLOBAL PRIMARY ENERGY

EMIT **60%** OF THE WORLD’S TOTAL GREENHOUSE GASES

Image: NASA Earth Observatory/NOAA NGDC



- Image Credit: Gabriele Manoli
- Caption: Intensity of summertime surface urban heat islands (ΔT_s) in world cities
- Source data: https://sedac.ciesin.columbia.edu/data/set/sdei-global-uhi-2013

NEGATIVE CONSEQUENCES

EXAMPLE: IMPACT ON ECONOMY – PRE-CORONA

Accumulated economic impacts of global climate change (GCC) and urban heat island (UHI) separately and combined under different emission scenarios for the 1692 largest cities in the world (including Singapore).

	RCP8.5 (Business-as-usual)	RCP4.5 (Moderate mitigation)
GCC	$\$3.21 \times 10^{13}$ [38.9%]	$\$1.49 \times 10^{13}$ [26.9%]
UHI	$\$1.54 \times 10^{13}$ [18.6%] (0.48)	$\$1.54 \times 10^{13}$ [27.9%] (1.03)
Total	$\$8.26 \times 10^{13}$ (2.57)	$\$5.53 \times 10^{13}$ (3.71)

(1) (2)

Figures in brackets represent the present value of losses due to GCC/UHI as a percentage of the present value of the total losses. Figures in parenthesis represent the present value of the losses due to UHI/Total as a fraction of the present value of the losses produced by GCC alone. The symbol $ denotes US dollars. A 3% discount rate was used. Figures are rounded to three significant digits.

(1) Combined impact of UHI and GCC greater than the sum of both (i.e., UHI amplifies the effects of GCC).

(2) In some cases, the impact of UHI can be greater than that of GCC.

Economic losses in cities in terms of GDP could be:

- **2.6 times higher than they would be without UHI effects.**
- **As high as 10.9% due to the combined effect of GCC and UHI.**

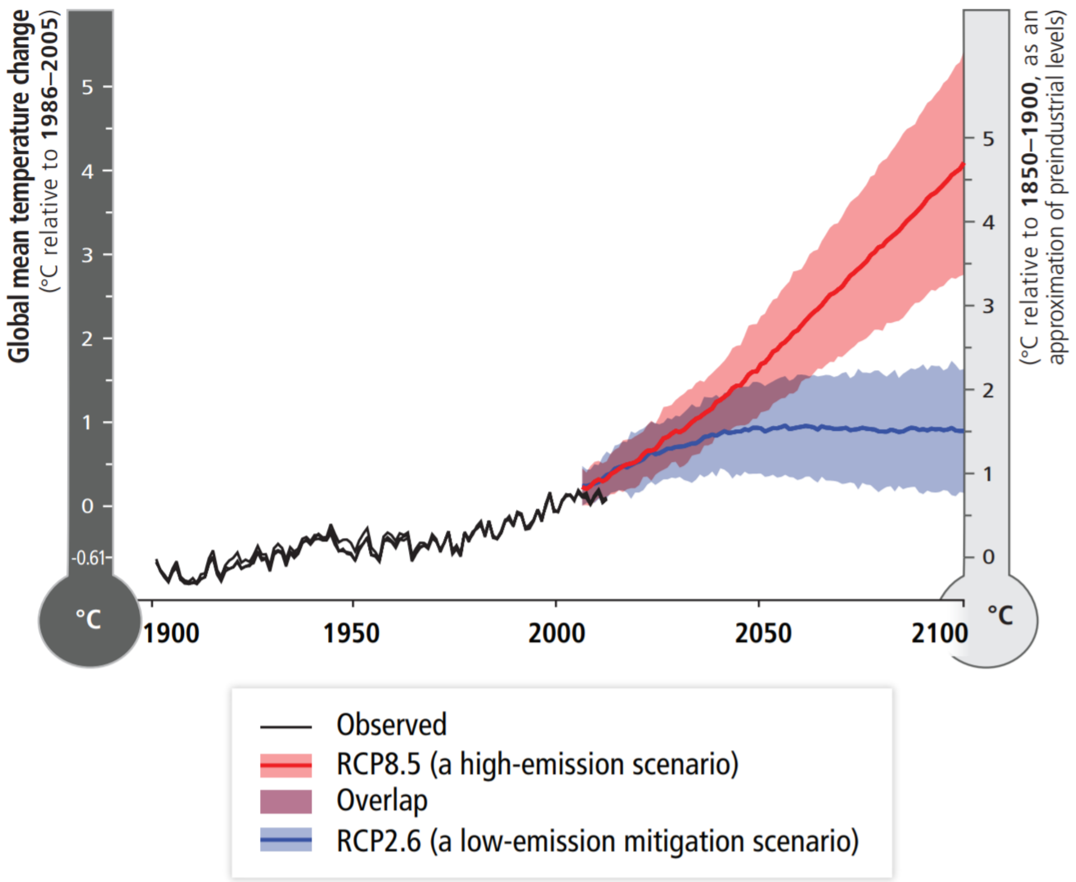
Source: adopted from Estrada, Francisco, WJ Wouter Botzen, and Richard SJ Tol. "A global economic assessment of city policies to reduce climate change impacts." Nature Climate Change (2017).

URBAN HEAT CHALLENGE

GLOBAL CLIMATE CHANGE (GCC)

Situation in Singapore:

23.9 – 32.3˚C	Daily mean temperature range (over reference period: 1981-2010)[1]
1.4 – 4.6˚C	Expected temperature increase due to climate change (by 2100)[2]
28.5 – 36.9˚C	Expected daily mean temperature range (by 2100 under RCP8.5 scenario **<u>if urban heat island does not change</u>**)



1: Minimum and maximum daily mean temperatures, measured by Changi Climate Station. Source: http://www.weather.gov.sg/climate-climate-of-singapore/
2: Second National Climate Change Study, 2015
Figure: IPPC WG2 AR5 (March 2014) Report: Summary for Policymakers

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.

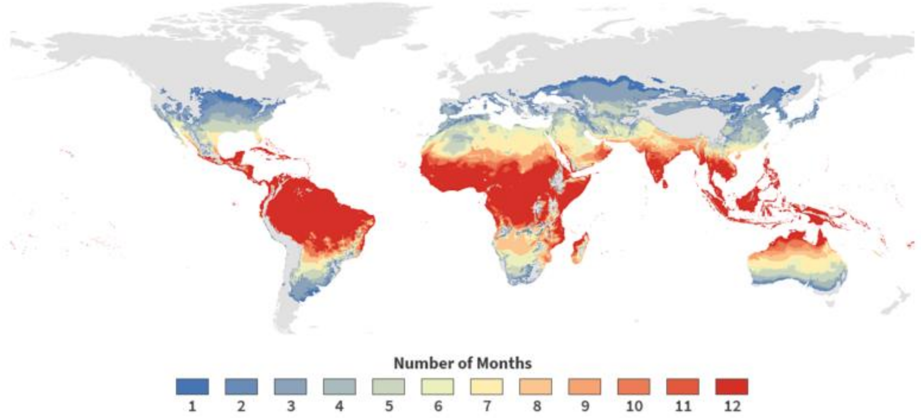
We know even less about how these individual effects may scale up and interact to impact Singapore's ecosystems as a whole.

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

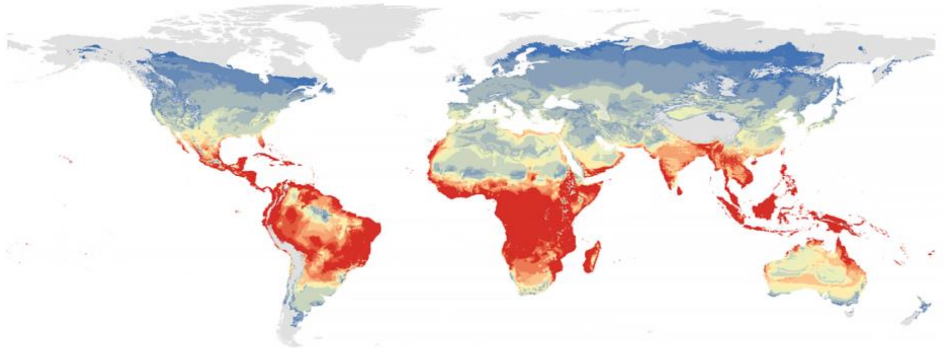
NEGATIVE CONSEQUENCES

EXAMPLE: IMPACT ON EMERGING DISEASES

Year 2019



Year 2080 – Business as usual



Worldwide distribution of the mosquito Aedes aegypti – which can spread **dengue fever, Zika virus, Chikungunya and yellow fever** – by duration of time in each region.

Higher temperatures and increased rainfall will cause an **increase in geographical range and seasonal duration of waterborne pathogens (bacteria, viruses) and disease-carrying vectors (mosquitoes, ticks)**.

Examples:

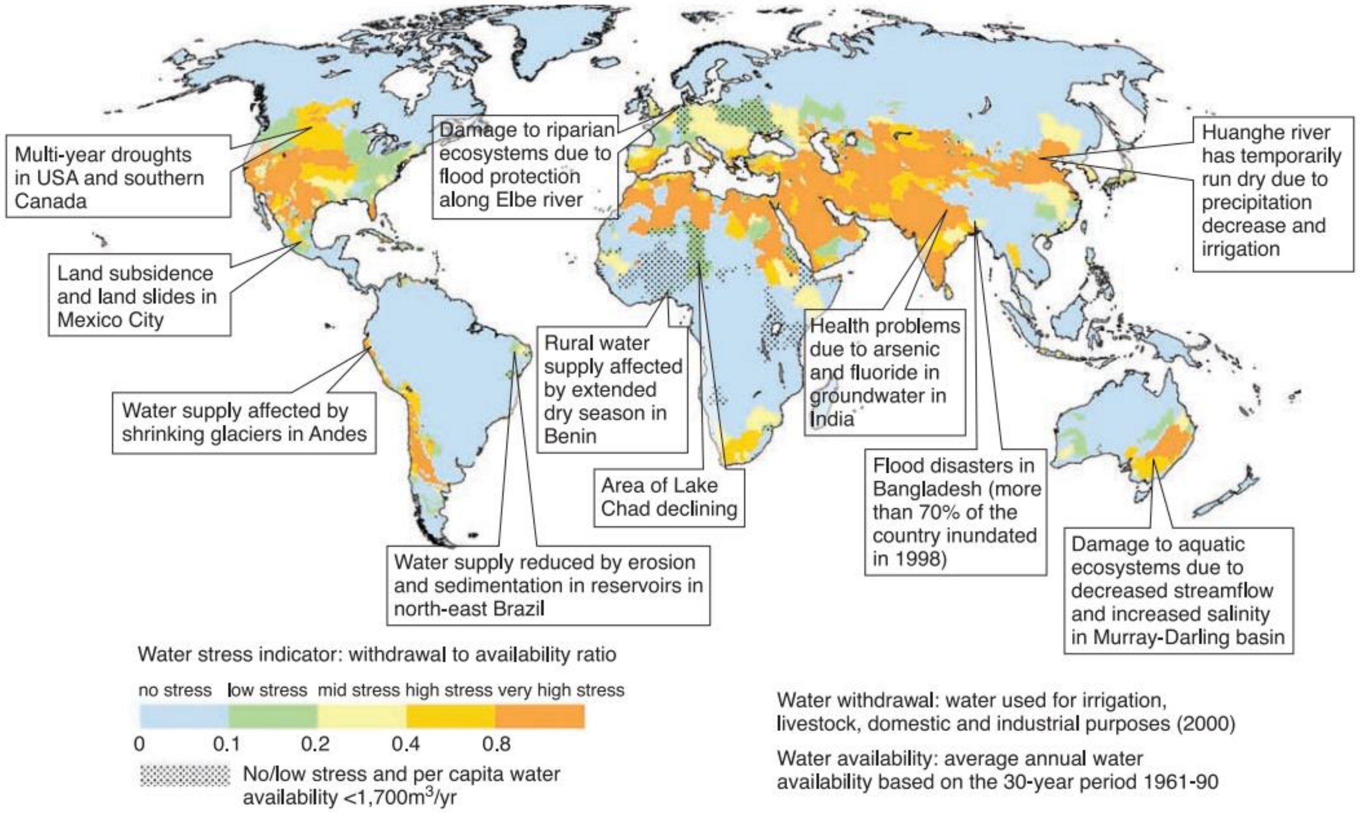
- Malaria: global temperature rise of 2 – 3ºC increases population at risk by several hundred million.
- *Vibrio* (flesh-eating bacteria): infection rates up in warmer coastal waters
- West Nile virus: 2018 outbreak in Europe

New unknown diseases: climate and ecological perturbations increase co-speciation and host-switching.

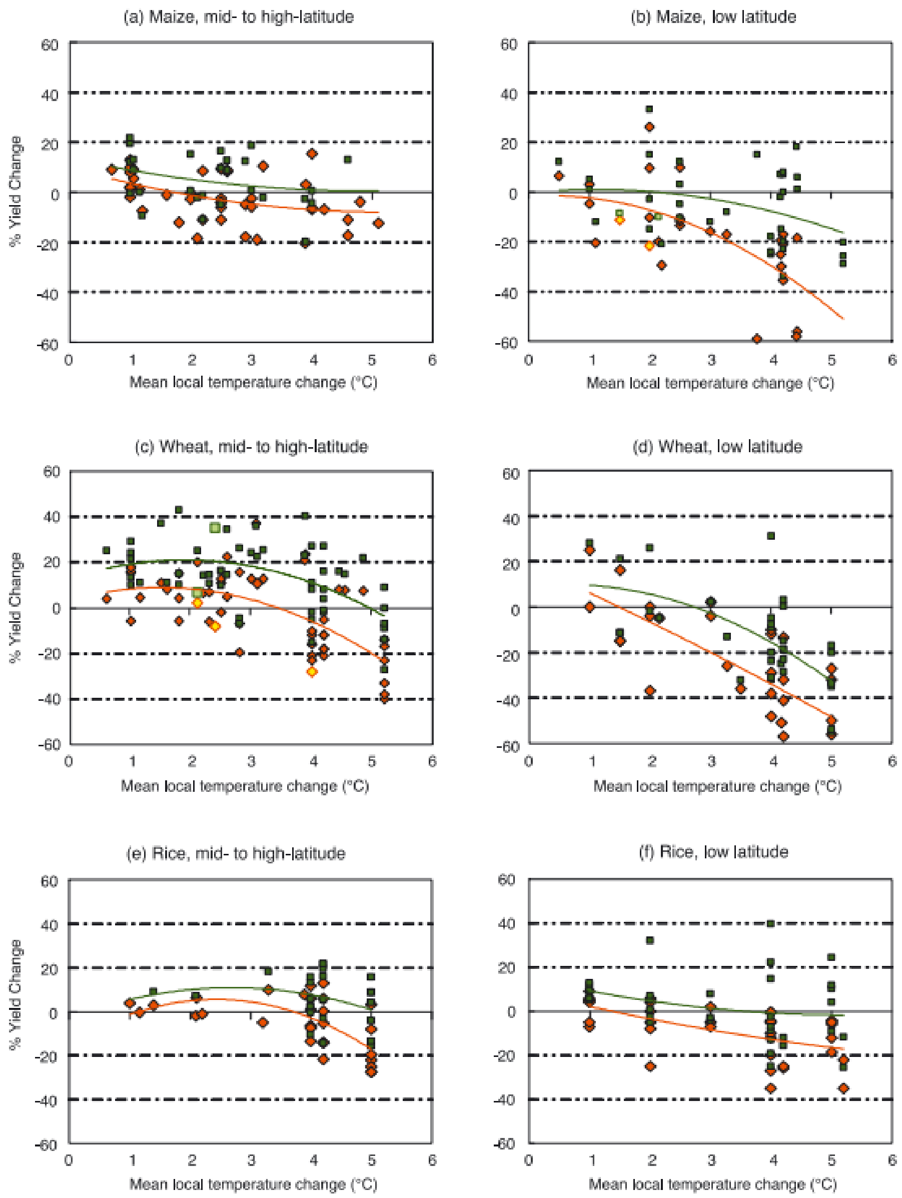
Source: Stanford Woods Institute for the Environment. https://news.stanford.edu/2019/03/15/effect-climate-change-disease/

NEGATIVE CONSEQUENCES

EXAMPLE: IMPACT ON ENERGY-WATER-FOOD NEXUS



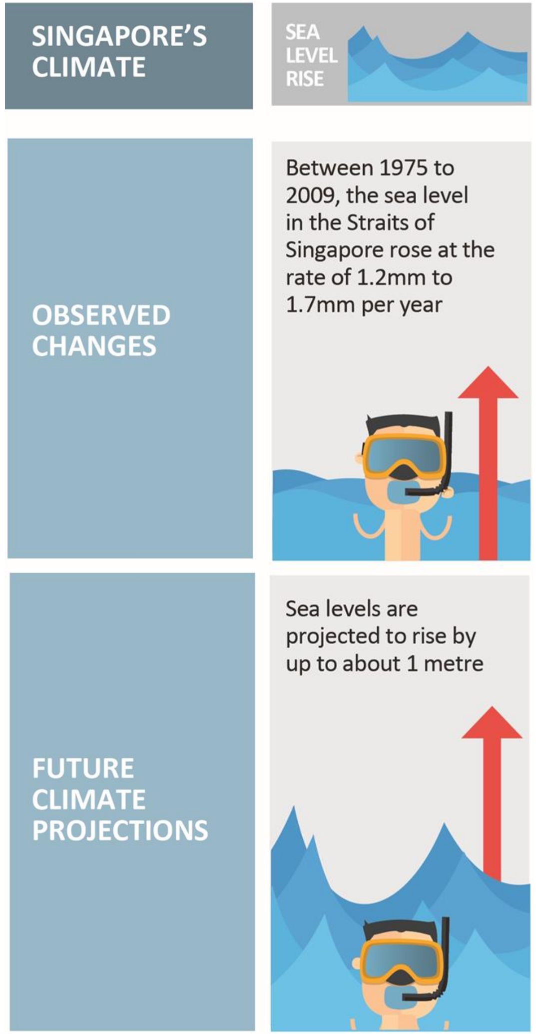
Water stress map and examples of vulnerabilities of freshwater resources and their management (IPCC 2007)



Projected changes in major crop yields at different levels of warming (IPCC, AR4, WG2, 2007)

NEGATIVE CONSEQUENCES

SPECIFICALLY FOR SINGAPORE

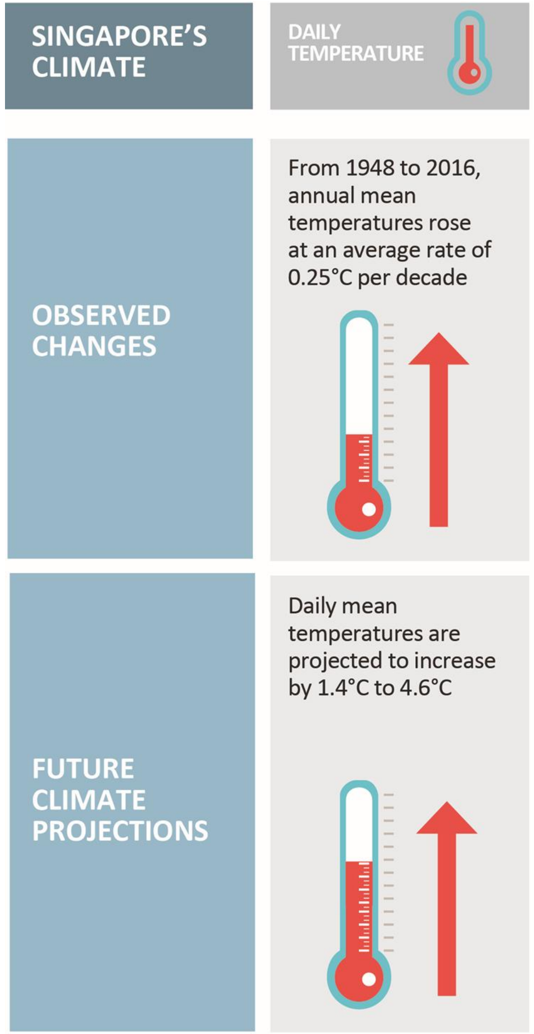


'Seawalls and rock slopes already protect over 70 % of Singapore's coastline.' *Strait Times, 28 May 2017*

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

NEGATIVE CONSEQUENCES
SPECIFICALLY FOR SINGAPORE



'2019 poised to be really hot year'

Strait Times, 22 March 2019

Daily mean temperature are projected to increase by 1.4 to 4.6 degree in 2100

Source: https://www.straitstimes.com/singapore/environment/2019-poised-to-be-really-hot-year, NCCS 2015, https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

NEGATIVE CONSEQUENCES
SPECIFICALLY FOR SINGAPORE

SINGAPORE'S CLIMATE	RAINFALL
OBSERVED CHANGES	From 1980 to 2016, annual total rainfall rose at an average rate of 101mm per decade
FUTURE CLIMATE PROJECTIONS	The contrast between the wet months (November to January) and dry months (February and June to September) is likely to be more pronounced. Intensity and frequency of heavy rainfall events is expected to increase as the world gets warmer Feb & Jun-Sep / Nov-Jan

'Half a month's rainfall in two hours'

Strait Times, 30 June 2018

Annual average rainfall increased by 600mm from 1980 to 2014

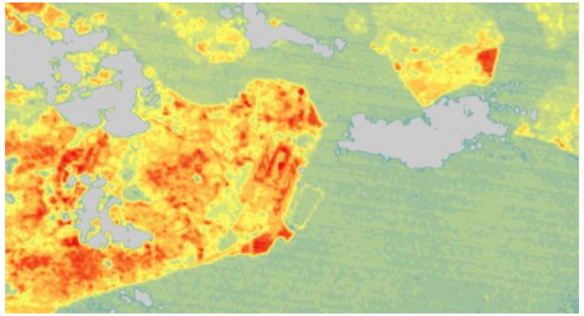
Source: https://www.straitstimes.com/singapore/environment/half-a-months-rainfall-in-two-hours, NCCS 2015, https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

SINGAPORE'S URBAN HEAT ISLAND

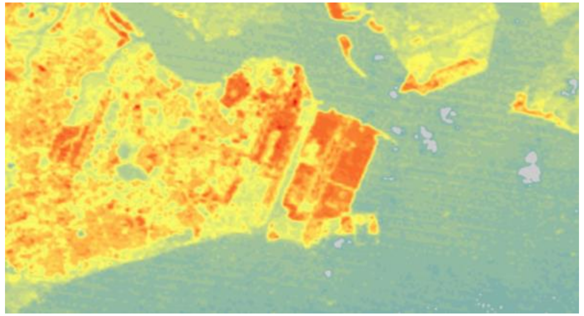
SINGAPORE’S LAND SURFACE TEMPERATURE

AIRPORT

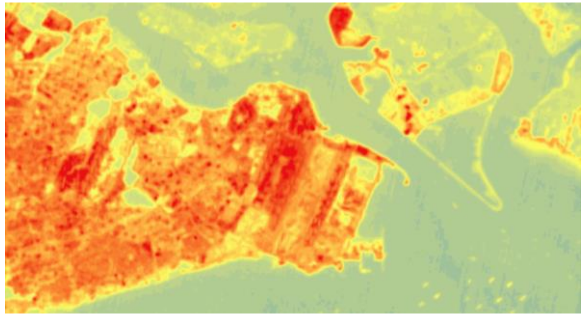
13 September 1989
10:42 am

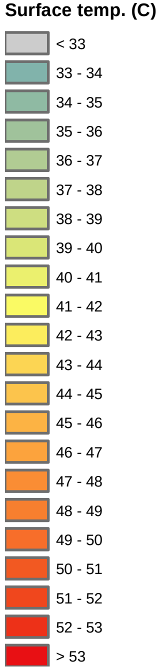


25 December 2003
10:55 am



8 May 2018
11.16 am



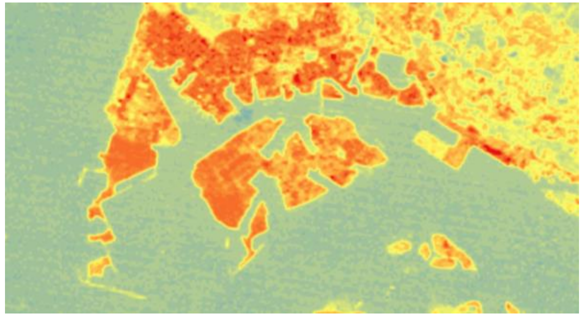


This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

JURONG

13 September 1989
10:42 am

25 December 2003
10:55 am



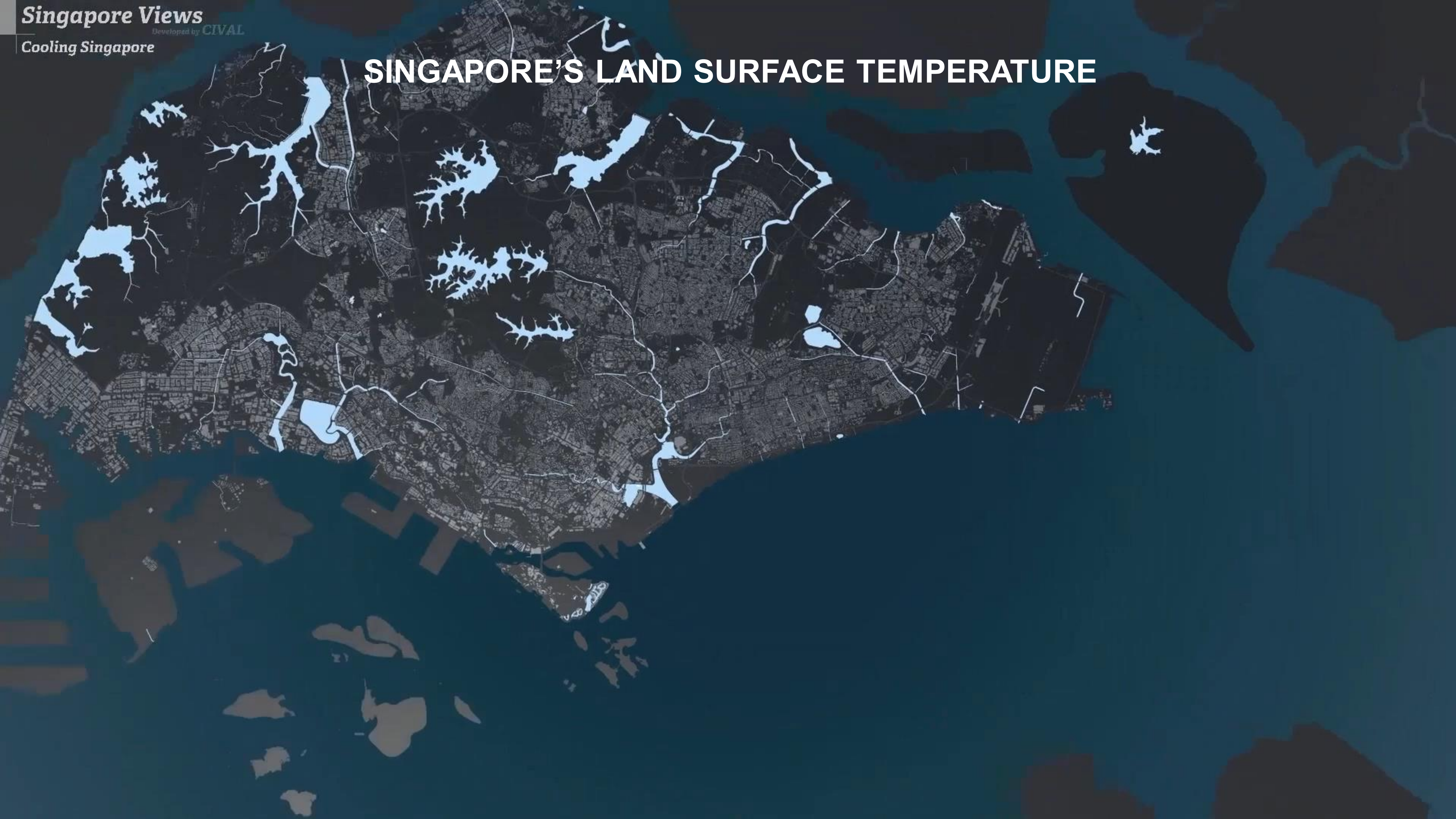
8 May 2018
11.16 am

Surface temp. (C)

< 33
33 - 34
34 - 35
35 - 36
36 - 37
37 - 38
38 - 39
39 - 40
40 - 41
41 - 42
42 - 43
43 - 44
44 - 45
45 - 46
46 - 47
47 - 48
48 - 49
49 - 50
50 - 51
51 - 52
52 - 53
> 53

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

SINGAPORE’S LAND SURFACE TEMPERATURE



Passive and Active ANTHROPOGENIC HEAT

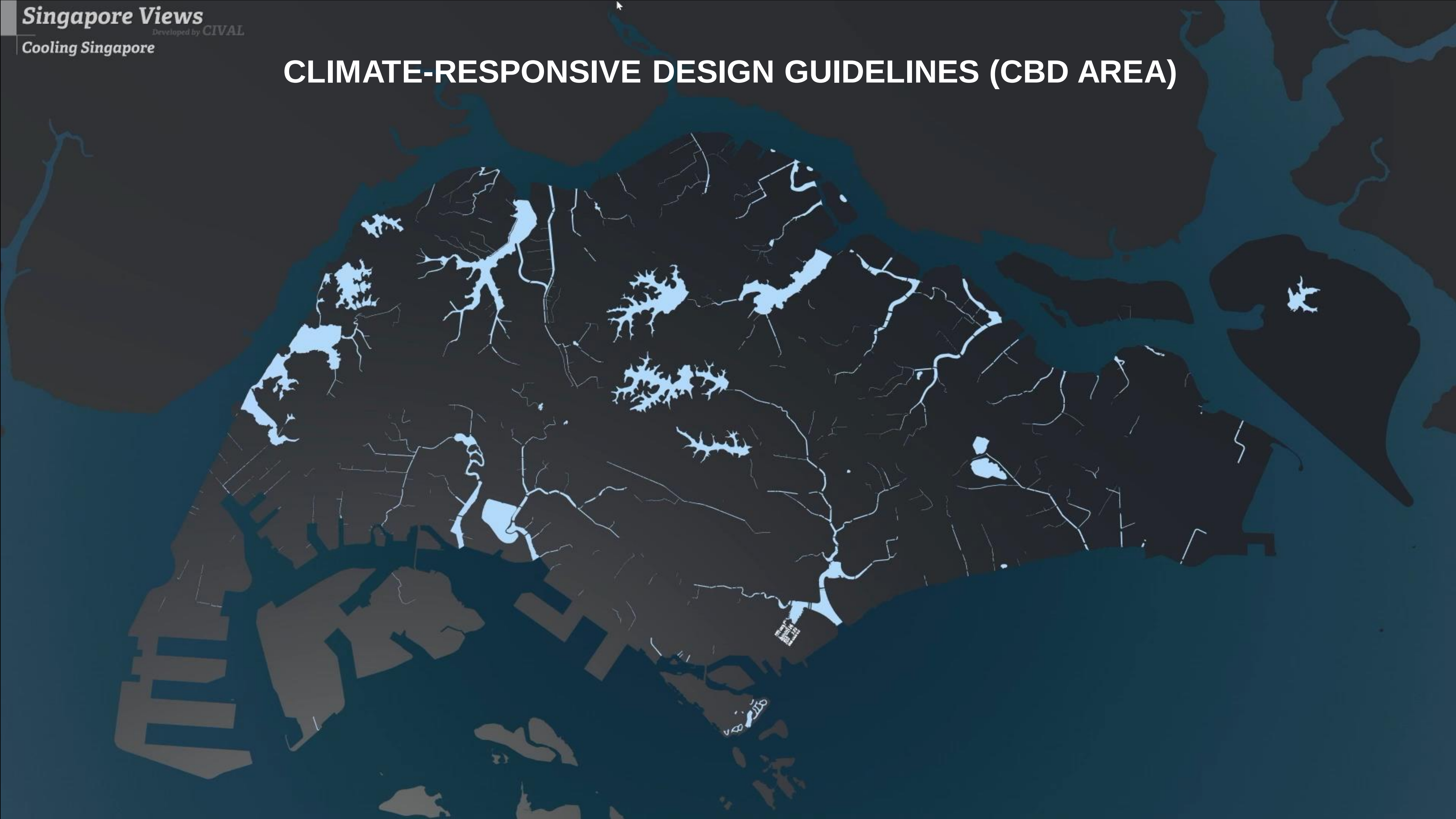
(Mostly Passive) ANTHROPOGENIC HEAT

CLIMATE RESPONSIVE DESIGN GUIDELINES

80+ MITIGATION STRATEGIES


URBAN GEOMETRY
Sky view factor
Aspect ratio
Mean building/tree height
Building form
Variation between building heights
Wider streets
Avoid obstruction
Open spaces along sea shore
Building porosity
Street axes orientation
Well ventilated sidewalks
Building arrangement
Open spaces at road junctions
Guide wind flows with urban elements
Passive cooling systems
Urban density by Local Climate Zones
Building Surface Fraction
Green Plot Ratio
Topography
URBAN GEOMETRY
VEGETATION
Green roofs
Vertical greeneries
Green walls/facades
Vegetation around buildings
Selective Planting
Green pavements
Infrastructure greenery
Macroscale urban greening
Local scale urban greening
Microscale urban greening
Green parking lots
Tree species
Urban farming
Transport corridors
VEGETATION
WATER BODIES
Cool sinks
Blue and green spaces
Wetlands
Water catchment areas
Ponds on roofs/ground floor
Evaporative cooling
Fountains
SHADING
Building orientation
Shading on buildings
Permanent shading devices
Moveable shading devices
Smart shading devices
Shaded pedestrian spaces
Shaded bicycle lanes
WATER BODIES
SHADING
ENERGY
Heat losses in buildings
Energy efficiency of air-conditioning systems
Energy efficiency of household appliances and office equipment
Energy efficiency of industries
Cooling load of buses
Indoor temperature setting
Sizing of the energy plants
Ventilation for heat release of air-conditioning units
Window-to-wall ratio
District Cooling
Renewable energy sources
Heat recovery systems
Mixed used neighbourhoods
Buffer zones
Hybrid ventilation in outdoor spaces
ENERGY
TRANSPORT
Vehicle population
Public transport
Centralised routing system
Active mobility
Electric private vehicles
Electric public transport
Autonomous mobility
Infrastructure of buses/bus stops
Types of road materials
Material and colour of cars
TRANSPORT
MATERIALS AND SURFACES
Cool pavements
Permeable surfaces
Photocatalytic cool pavements
Cool roofs
Cool façades
Photocatalytic cool building envelope
Retro-reflective materials
Phase Change Materials
Desiccant systems
Water cooling façade system
Thermochromic/selective materials
Dynamic and active roofs
Dynamic and active façades or building components
Building envelop performance
MATERIALS & SURFACES

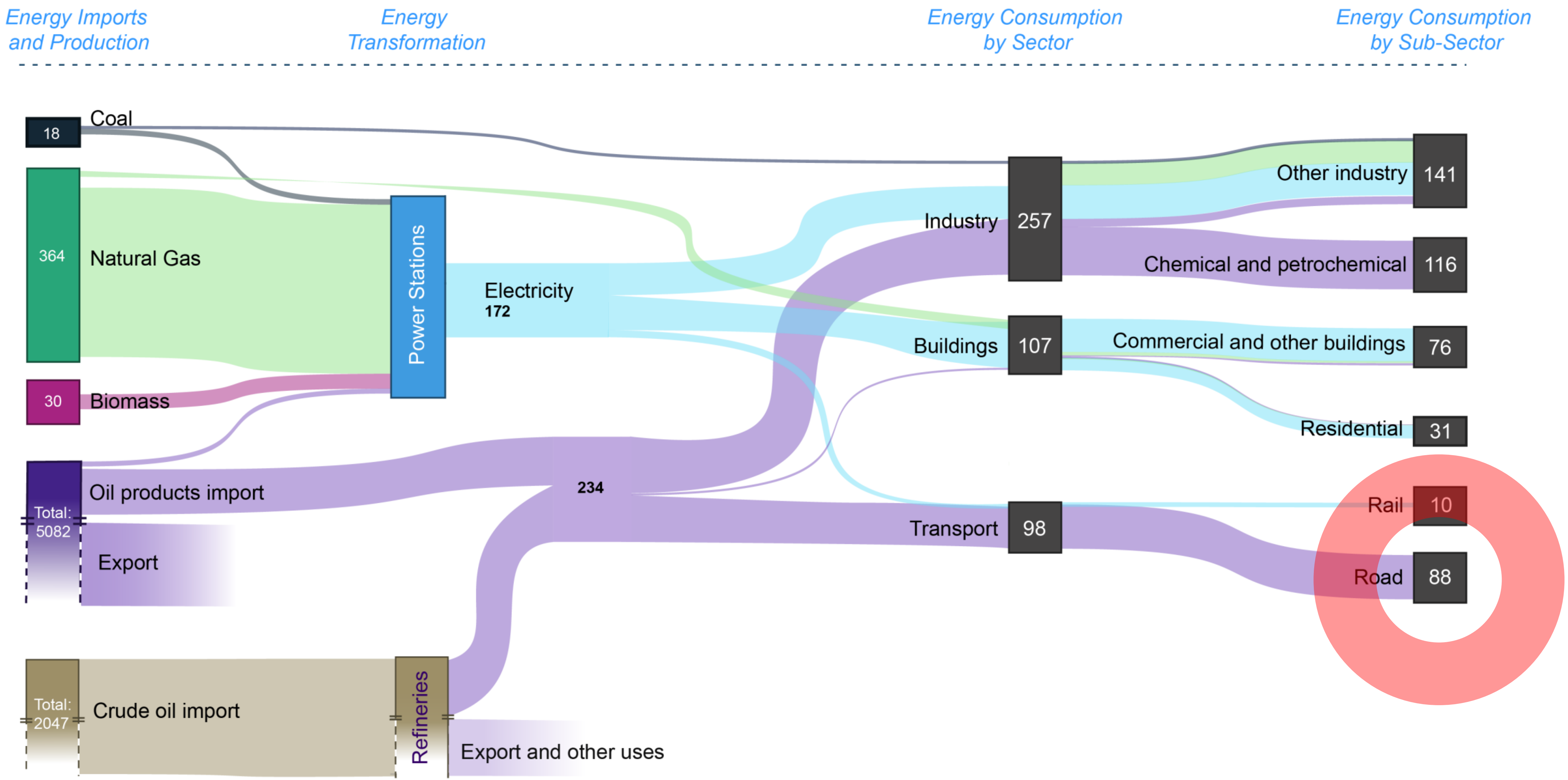
CLIMATE-RESPONSIVE DESIGN GUIDELINES (CBD AREA)



(Mostly Active) ANTHROPOGENIC HEAT

2016 Singapore Energy Flow Diagram

Domestic Use Petajoules PJ, based on IEA data



ENERGY

EXAMPLE: SINGAPORE ENERGY CONSUMPTION

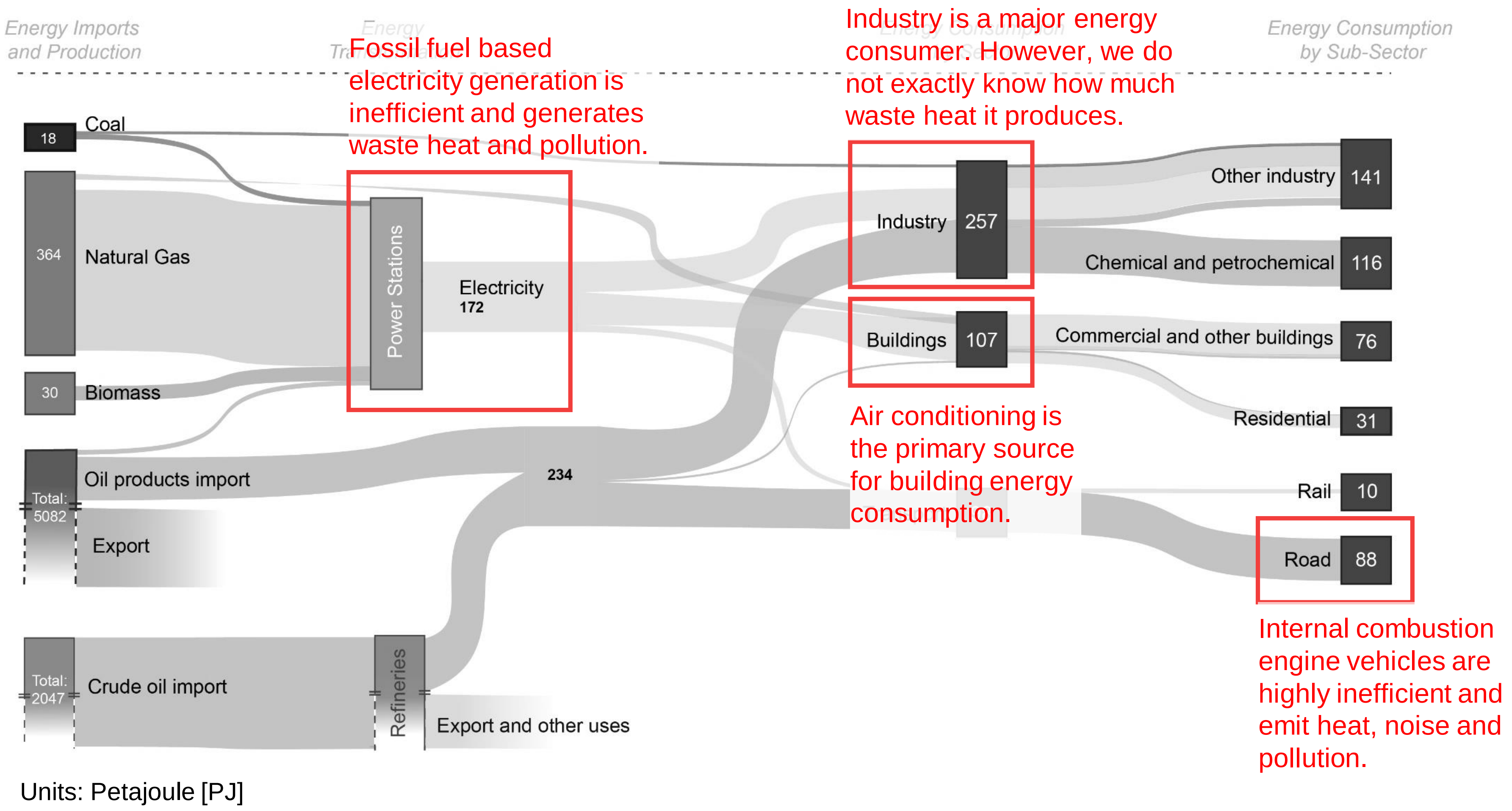
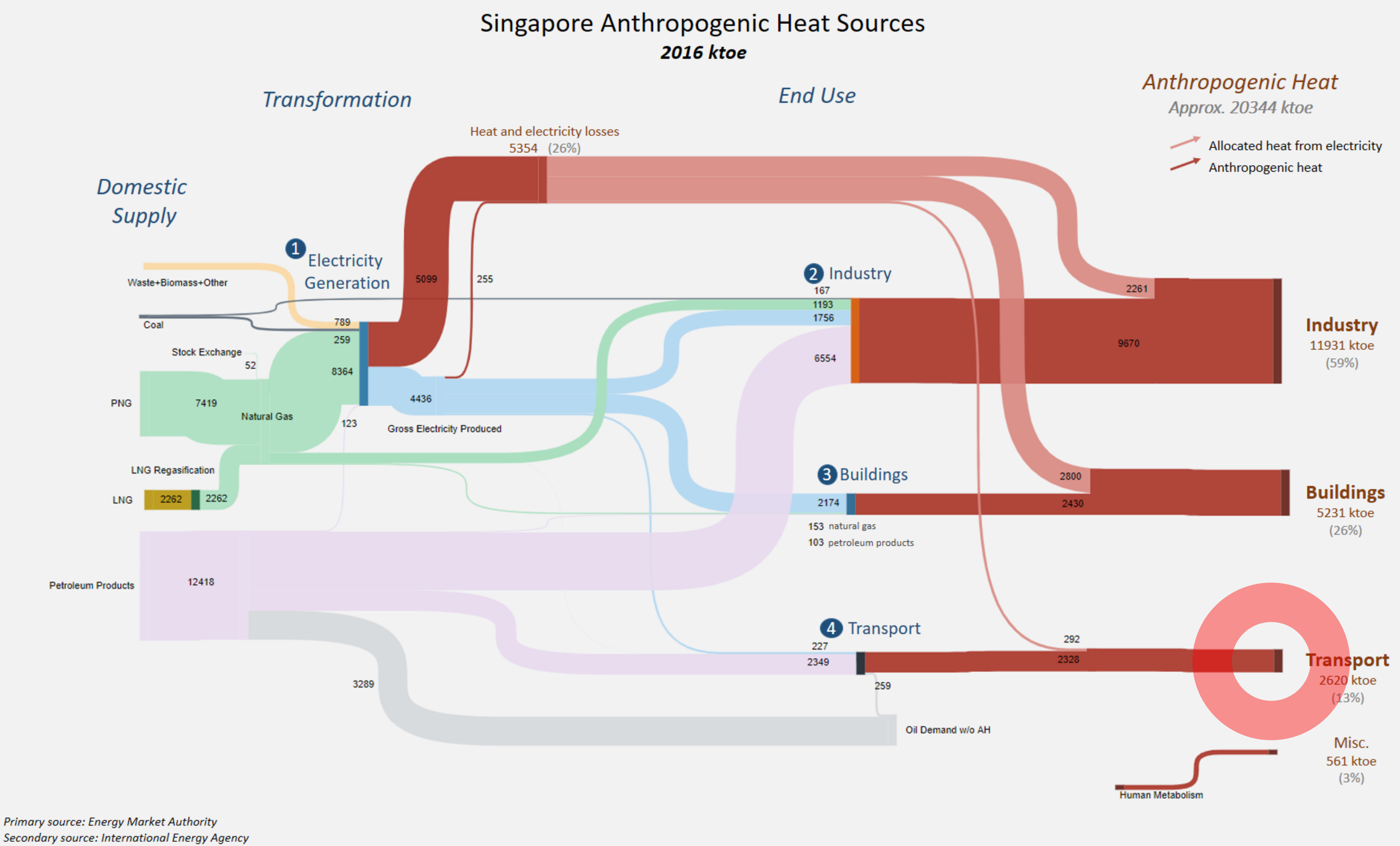


Figure: 2016 Singapore energy consumption; based on IEA data.


Singapore Anthropogenic Heat Sources
2016 ktoe
Domestic Supply
Transformation
End Use
Anthropogenic Heat
Approx. 20344 ktoe
Allocated heat from electricity
Anthropogenic heat
Heat and electricity losses
5354 (26%)
1 Electricity Generation
5099
255
Waste+Biomass+Other
Coal
789
259
Stock Exchange
52
8364
PNG
7419
Natural Gas
4436
123
Gross Electricity Produced
LNG Regasification
LNG
2262
2262
Petroleum Products
12418
3289
2 Industry
167
1193
1756
6554
2261
9670
Industry
11931 ktoe
(59%)
3 Buildings
2800
2174
2430
153 natural gas
103 petroleum products
Buildings
5231 ktoe
(26%)
4 Transport
227
2349
292
2328
259
Transport
2620 ktoe
(13%)
Oil Demand w/o AH
Misc.
561 ktoe
(3%)
Human Metabolism
Primary source: Energy Market Authority
Secondary source: International Energy Agency

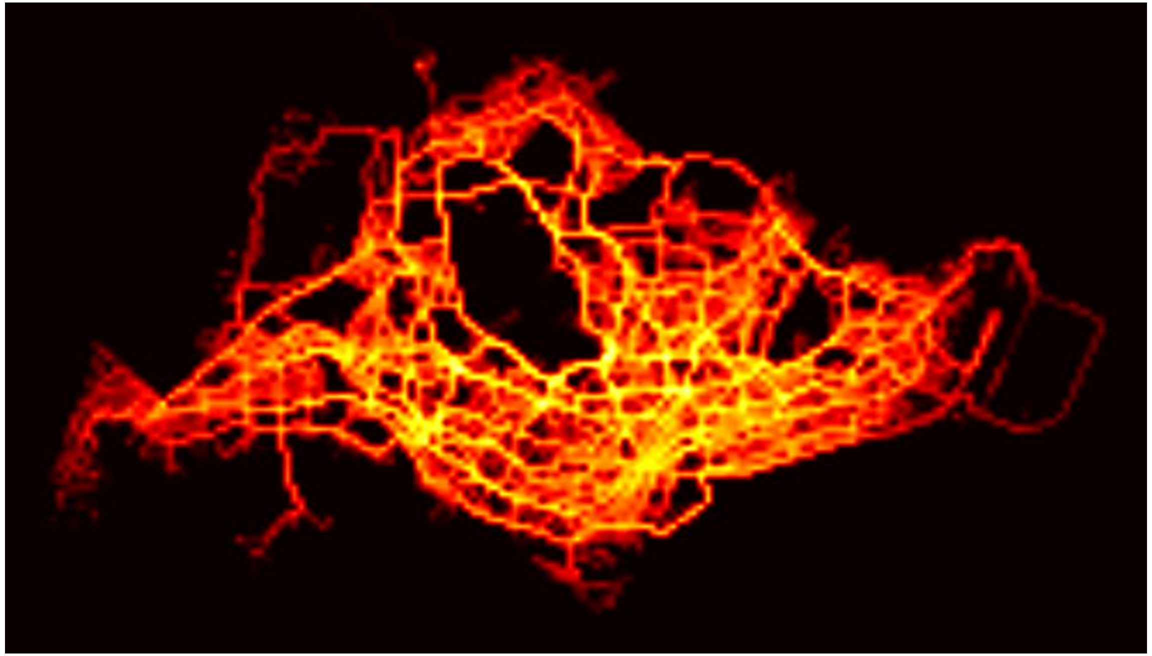
ANTHROPOGENIC HEAT OF TRANSPORT

RESULTS TO DATE

Produced a **spatial-temporal heat map** for:
- Base case scenario
- Full electrification scenario

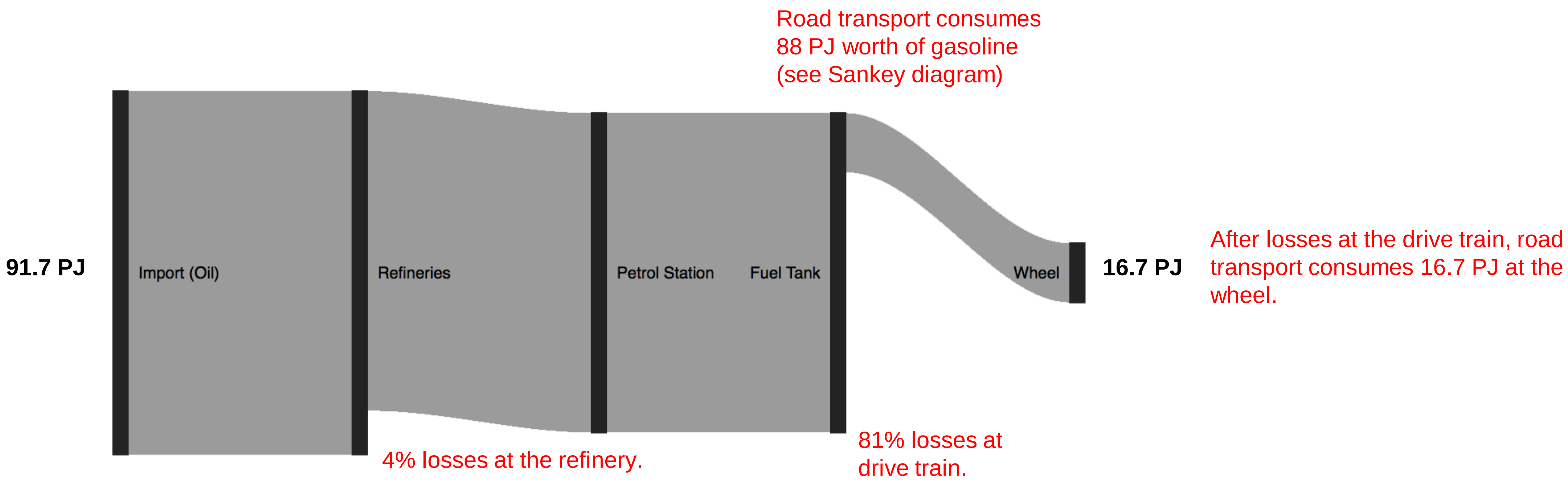
Produced a **temporal energy demand** for:
- Full electrification scenario

Spatial distribution of heat allows us to identify hotspots. The spatial map can also be done on a vehicle class level.



TRANSPORT

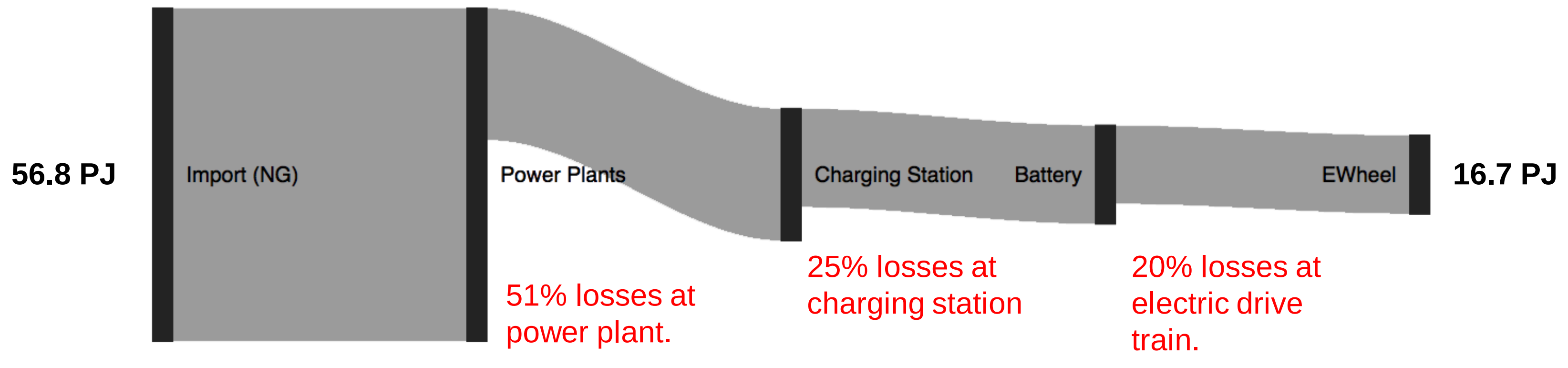
EXAMPLE: SWITCH TO ELECTRIC VEHICLES



Heat, noise and pollution is emitted where the cars are driving (i.e., across the entire island) due to the internal combustion engines.

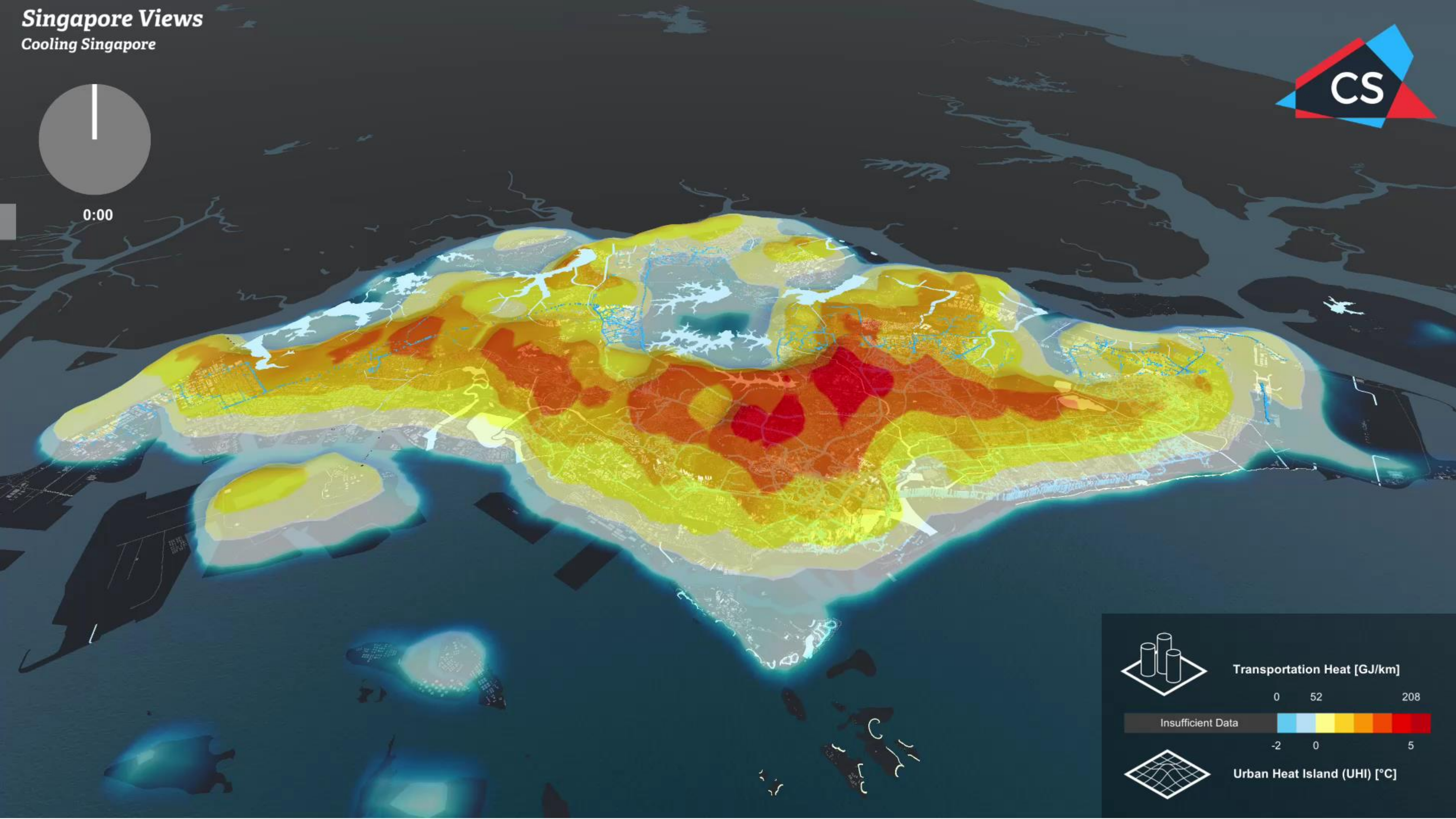
TRANSPORT

EXAMPLE: SWITCH TO ELECTRIC VEHICLES



Assumption: electric vehicles require the same amount of energy at the wheel as the internal combustion vehicles: 16.7 PJ (see previous slide).

Electric vehicles generally produce significantly less heat, noise and pollution. Emissions are mostly at the power plants and not across the entire city (as is the case with legacy vehicles).

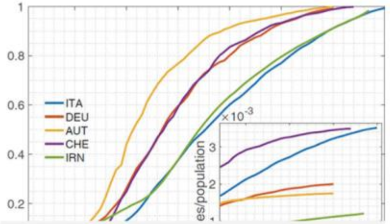

Singapore Views
Cooling Singapore
0:00
CS
Transportation Heat [GJ/km]
0
52
208
Insufficient Data
-2
0
5
Urban Heat Island (UHI) [°C]

HOW CAN SCIENCE, DESIGN AND INCLUSION HELP?

PRESS

INVESTIGADORES EXPLICAN EL CRECIMIENTO LINEAL DE LAS CURVAS DEL COVID-19 [SPANISH]

Cronica de Cantabria, Aug 25, 2020



NEWS Aug 24, 2020

WHY COVID-19 INFECTION CURVES BEHAVE SO UNEXPECTEDLY [EN, D]

PUBLICATION

S. Thurner, P. Klimek, R. Hanel

A NETWORK-BASED EXPLANATION OF WHY MOST COVID-19 INFECTION CURVES ARE LINEAR

PNAS Aug 24 (2020)

PUBLICATION

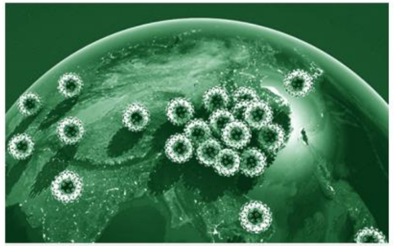
M. Kugler, S. Thurner

COMPLEX SYSTEMS AND THEIR ANALYSIS [D, EN]

in: H. Androsch, W. Knoll, A. Plimon (Eds.), Discussing Technology—Complexity, Vienna (2020) Holzhausen (German / English)

NEWS Aug 3, 2020

CRAZY IDEAS, BRILLIANT MINDS, GOOD TIMES!



NEWS Jul 29, 2020

CORONA | HOW FAR WE MOVE [JUNE & JULY]

Citizen Design Science

SINGAPOREANS' HEAT MITIGATION PREFERENCES

Inclusion

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)

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

Men are WTP 12.27% more than females

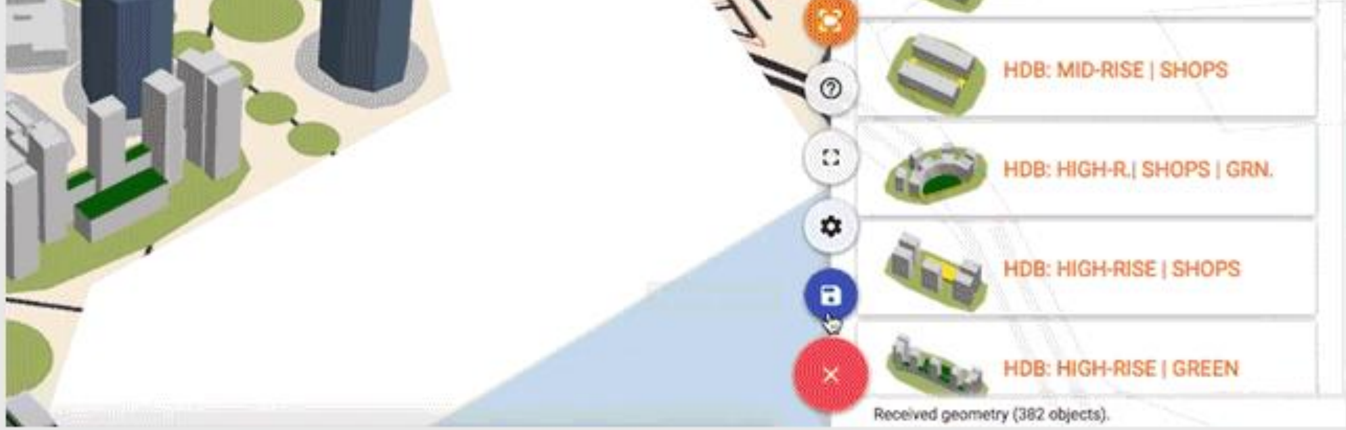
The higher the education, the higher the WTP. Postgraduate double as bachelor

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

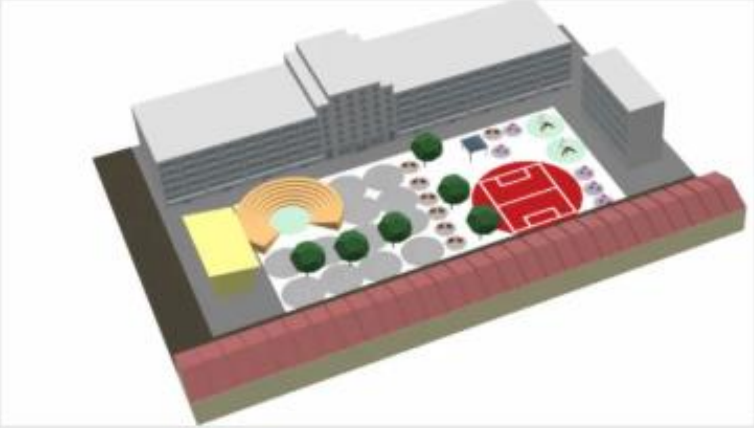

TANJONG PAGAR CONTAINER TERMINAL
HARBOUR FRONT
PULAU BRANI
SENTOSA
SHARE WITH US
IDEAS FOR
TANJONG
PAGAR!



What would you like to design?

Place HDB and condos of different height and shape in the future residential area

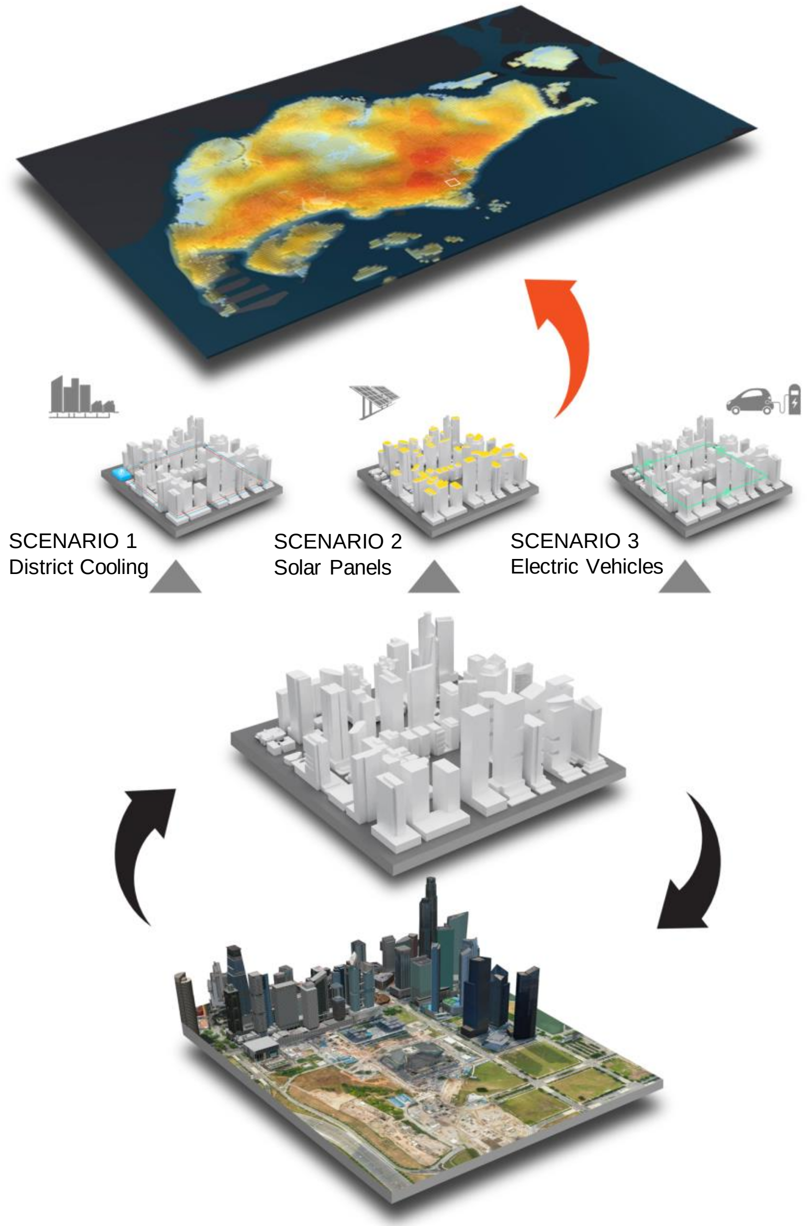
Place housing blocks, shops and parks to make your perfect neighbourhood



Place trees, benches and fountains to create your perfect public place

Digital Urban Climate Twin
Vision

DIGITAL URBAN CLIMATE TWIN
What-if Scenario Analysis



MICRO- & MESOSCLE SIMULATION

WHAT IF SCENARIO

DIGITAL TWIN

REAL WORLD

Image: Lea Rüfenacht (January 2020)

DIGITAL URBAN CLIMATE TWIN
Vision

Users Groups

Government Agencies

Urban Redevelopment Authority
Housing & Development Board
National Parks
jtc
Ministry of the Environment and Water Resources
BCA
NEA
Land Transport Authority

Academia

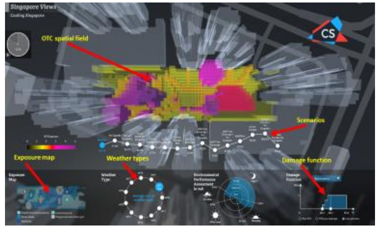
(SEC) SINGAPORE-ETH CENTRE
SMU Singapore Management University
Agency for Science, Technology and Research SINGAPORE
SMART Singapore-MIT Alliance for Research and Technology
NUS National University of Singapore
TUMCREATE

Industry

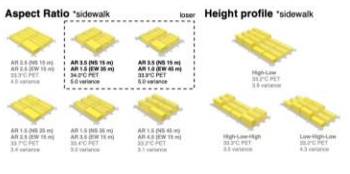
...

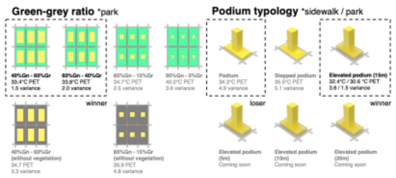
Applications

Decision Support System

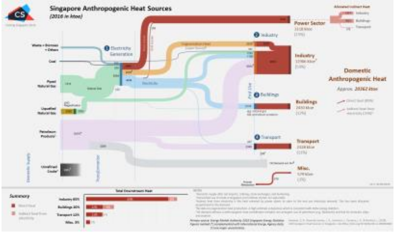


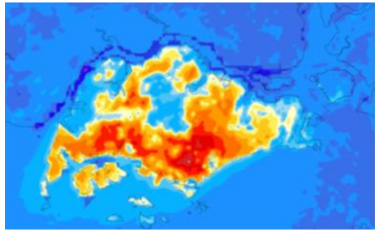
Strategy Specification and Evaluation





Report Generation and Data Visualisation

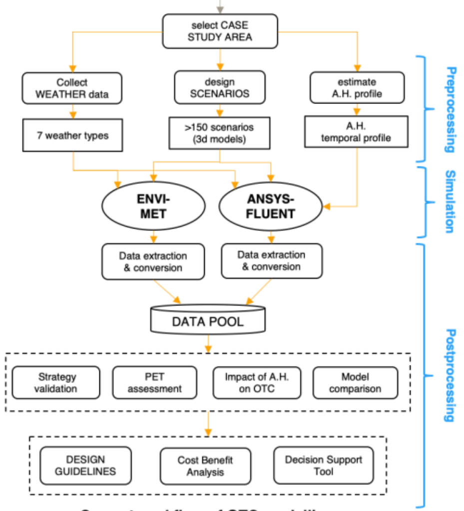




...

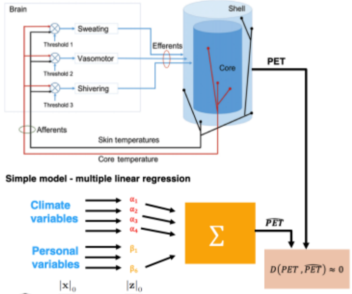
High-Performance Simulation and Computation

Complex Simulation Workflows



Current workflow of OTC modelling

Surrogate Models



$$\widehat{PET} = \sum_{i=1}^{|x|_0} \alpha_i x_i + \sum_{i=1}^{|z|_0} \beta_i z_i$$

...

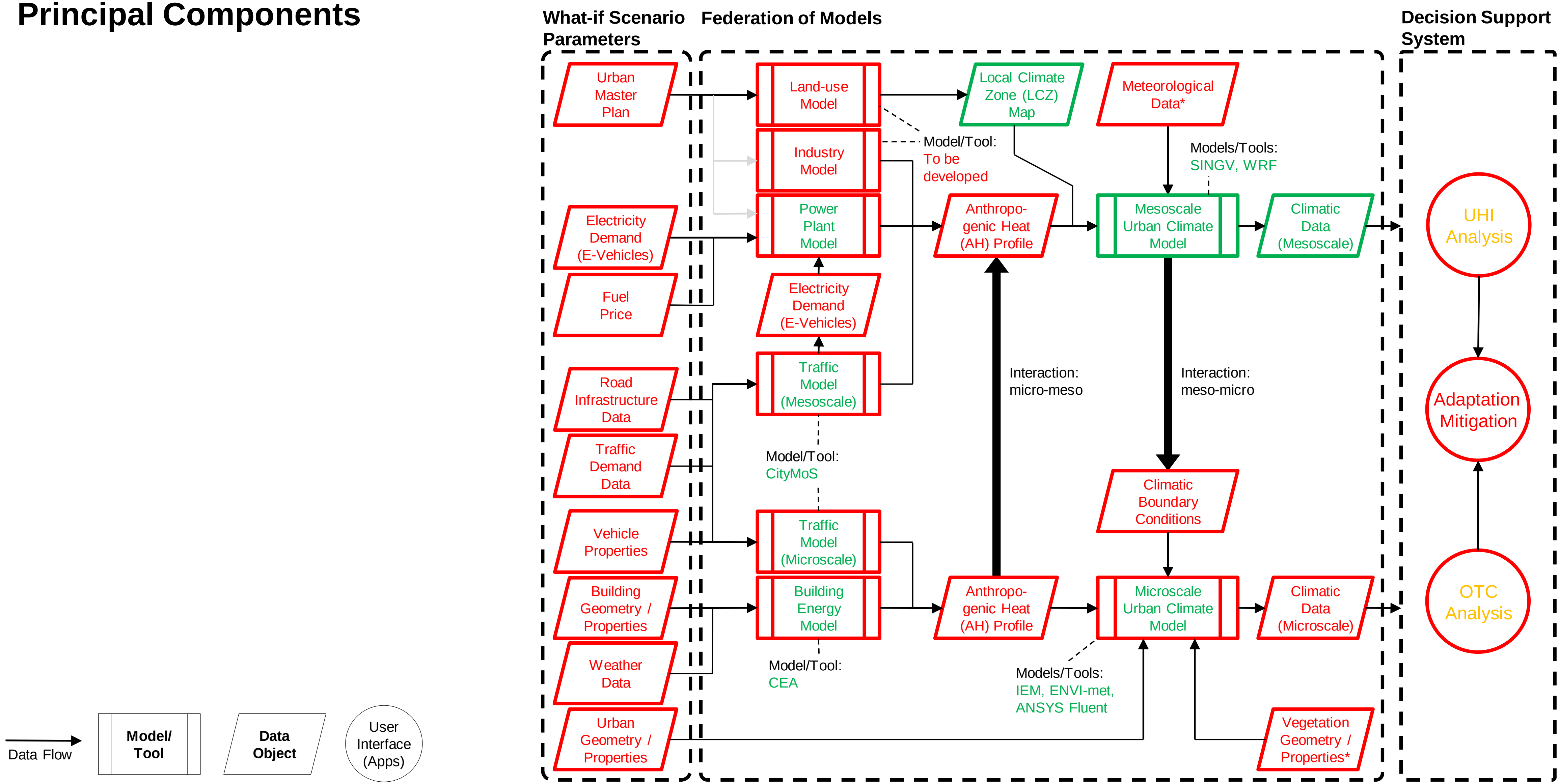
Variety of Modelling and Computation Tools

ENVI_MET
ANSYS FLUENT
CEA City Energy Analyst
MATLAB
AUTOCAD 2018
CityMoS
python
...

Images and logos: various members of CS and respective organisations.

Digital Urban Climate Twin Technical Design

DIGITAL URBAN CLIMATE TWIN
Principal Components



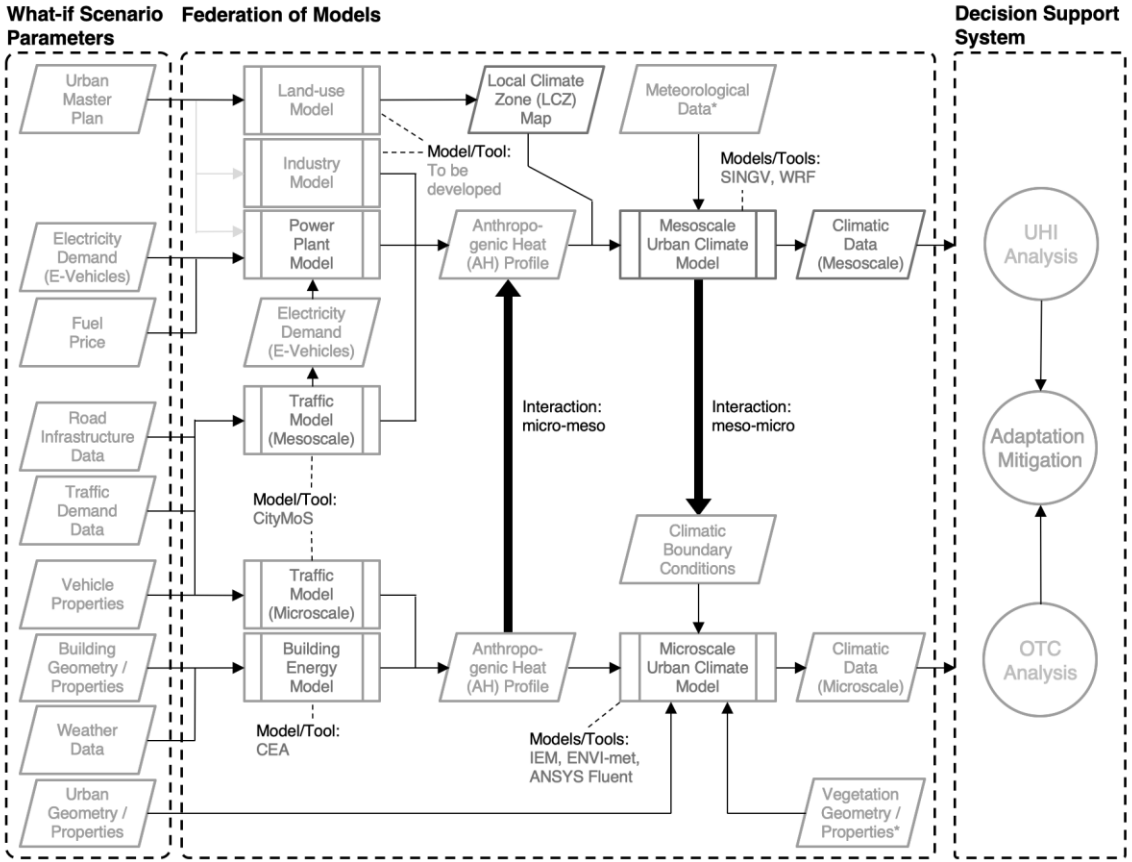
*) part of what-if scenario parameters but shown here for conciseness.

DIGITAL URBAN CLIMATE TWIN
Design Choices

<u>Federation of Models</u> vs. Monolithic Model
- Multiple specialised models
- Different technologies
- Multiple owners

<u>Loose Coupling</u> vs. Tight Coupling
- Tight coupling: needed if models affect each other
- DUCT mostly one-way flow of data
- Light coupling does not preclude tight coupling

<u>Distributed Deployment</u> vs. Centralised Deployment
- Centralised: single organisation operating all models
- Distributed: multiple organisations operate their models
- Distributed: more flexibility and granular control



*) part of what-if scenario parameters but shown here for conciseness.

SIMULATION-AS-A-SERVICE INFRASTRUCTURE
Prototype: Basics

Simulation-as-a-Service (SaaS)

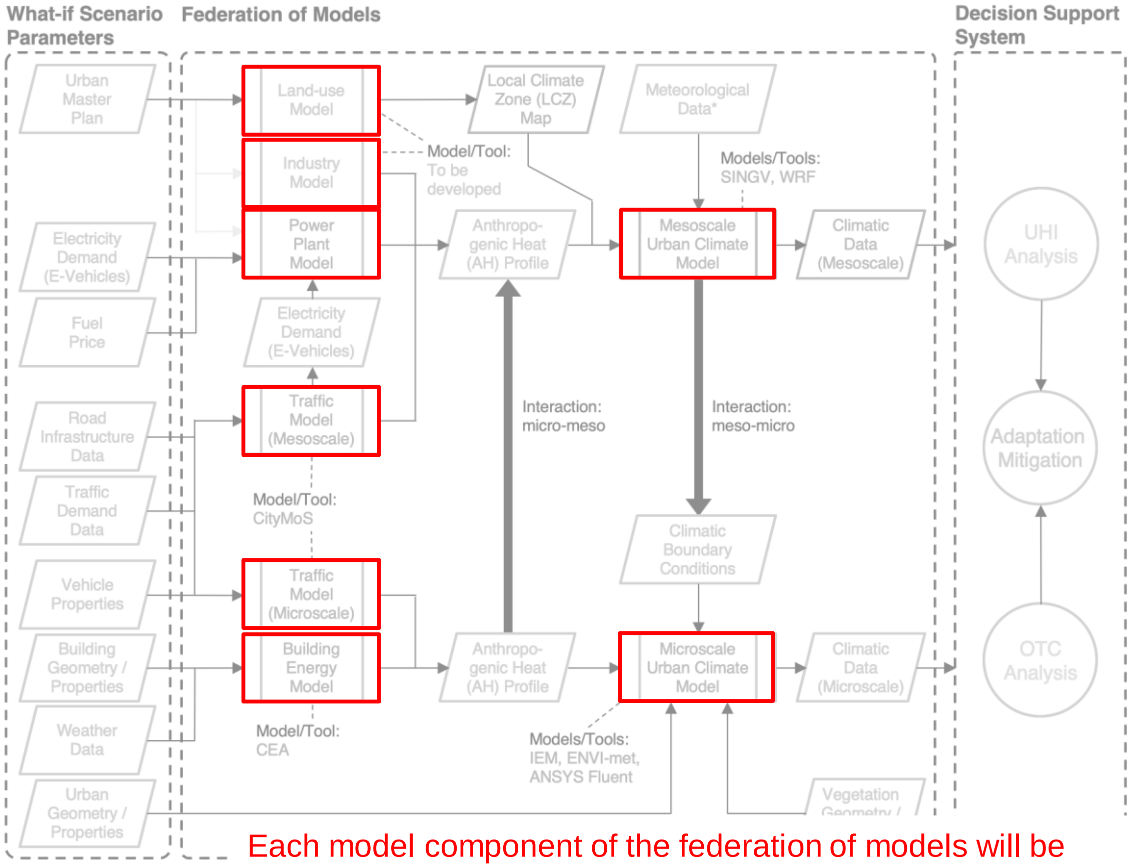
Think of executing simulations just like any other web service. Send a request, and get a response. Every model component should be realised as a service.

Choice of Technology: RESTful Web Service

REpresentational State Transfer (REST) is a software architectural style to be used for creating web services and to provide interoperability between computer systems on the internet.

Web services have been designed to facilitate interoperability and scalability of/between services and applications across the internet.

REST is widely used and there is a lot of support and up-to-date standard software available.



Each model component of the federation of models will be 'wrapped' with a RESTful service and provide a standard interface to facilitate interoperability with other components.

SIMULATION-AS-A-SERVICE INFRASTRUCTURE
Prototype: Design Principles

Specialisation vs. Generalisation

- Tailored to satisfy the requirements of a DUCT
- No intention to develop general-purpose middleware (similar to HLA for tight coupling)

Simplicity vs. Complexity

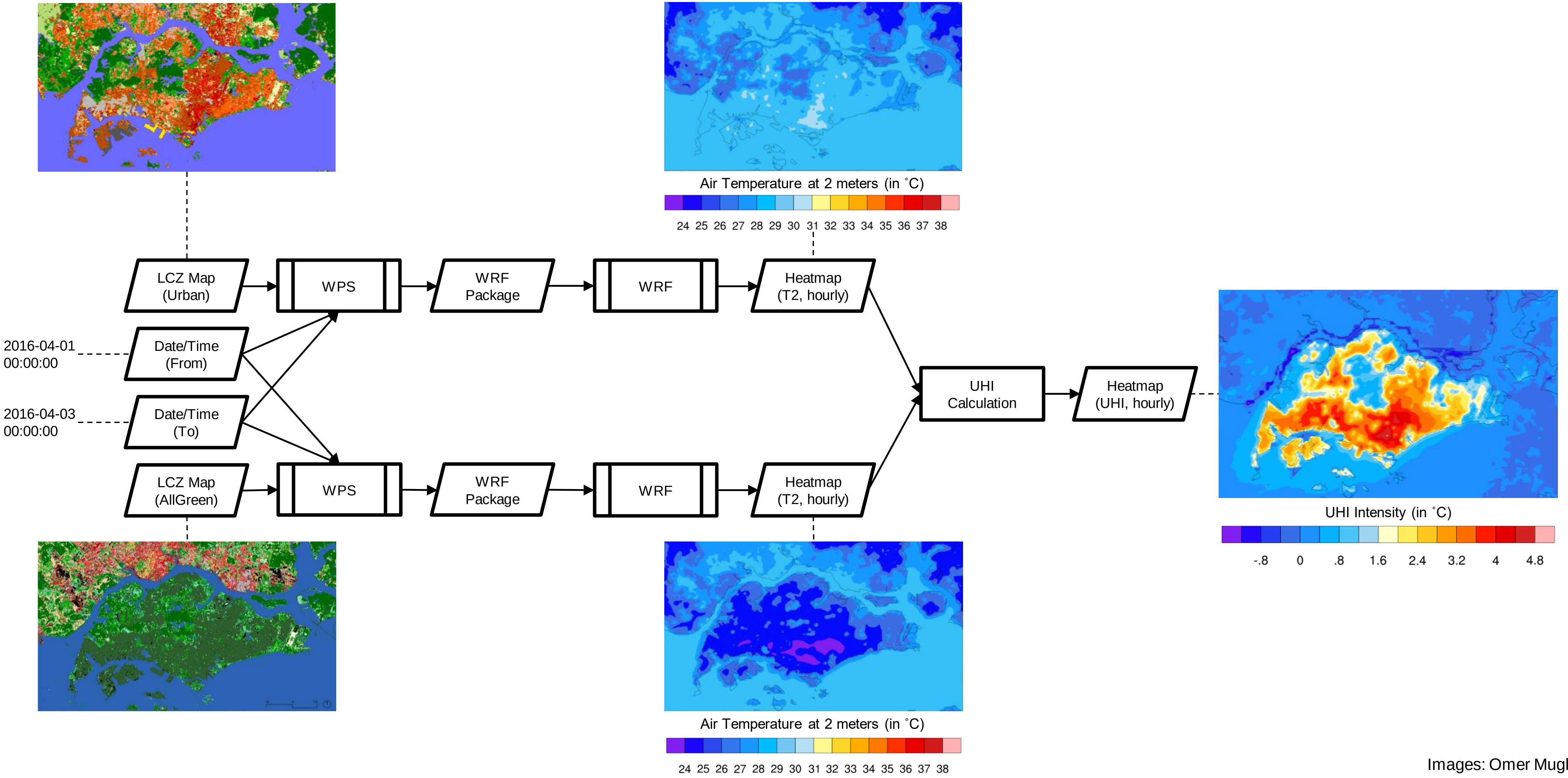
- Provide the features that are really needed
- Avoid unnecessary functionality

SaaS vs. M&SaaS (Modelling & Simulation-as-a-Service)

- DUCT: a few well-defined use cases and set of validated models
- No need for users to develop own models (not a good idea anyway)
- Domain experts can still add new models and workflows (modelling is just not supported as far as the user is concerned)

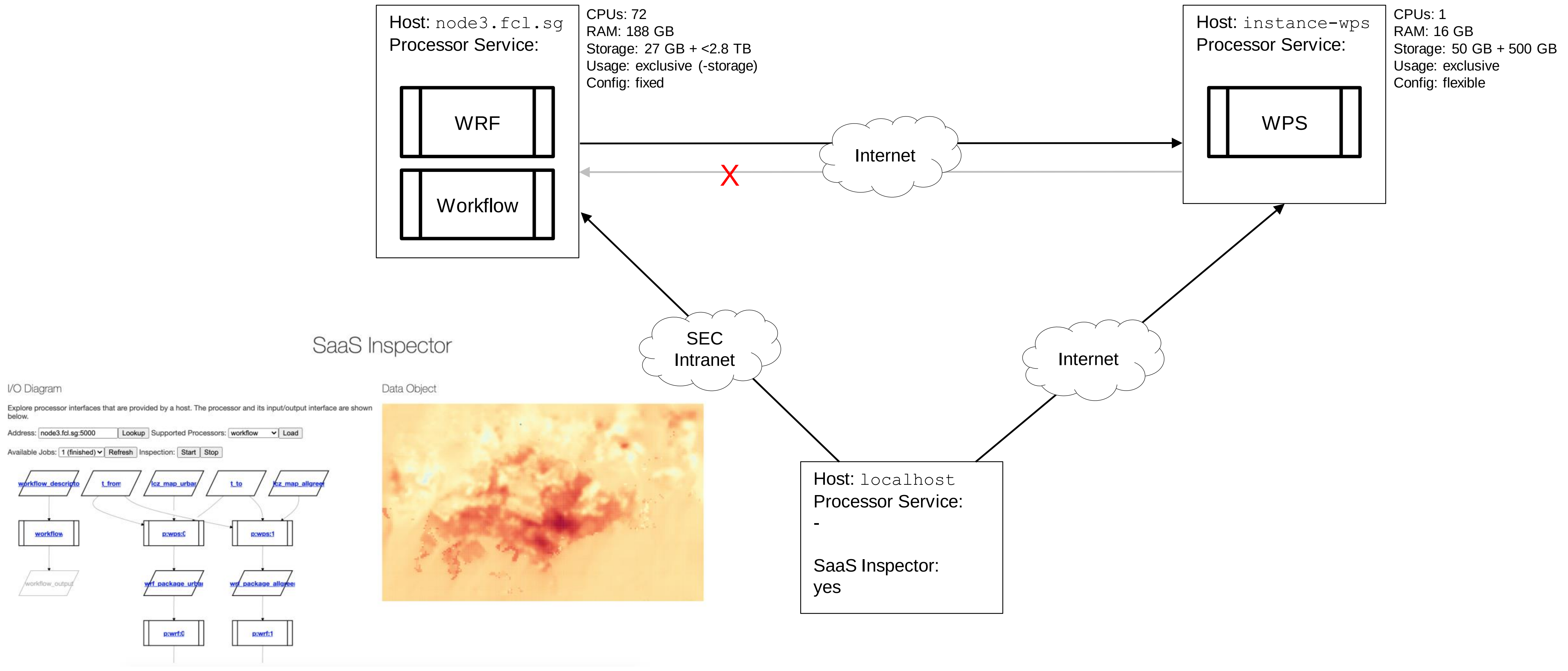
SaaSI POC Demonstrators

DEMONSTRATOR 1 – WORKFLOW AUTOMATION
Introduction



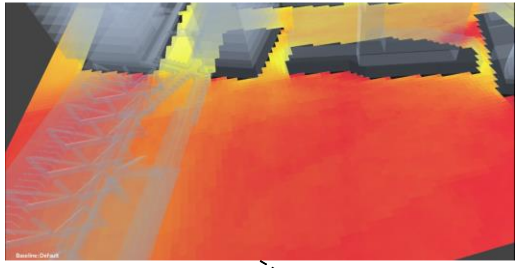
Images: Omer Mughal

DEMONSTRATOR 1 – WORKFLOW AUTOMATION
Deployment

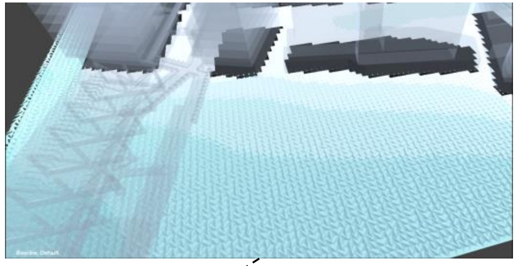


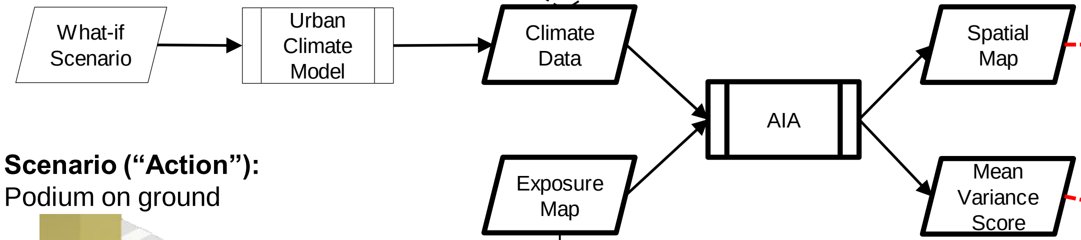
DEMONSTRATOR 2 – DSS INTEROPERABILITY
Introduction

Climate Variable: PET

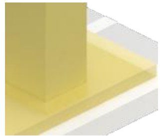


Climate Variable: Wind

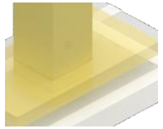




Scenario ("Action"):
Podium on ground



Podium elevated,



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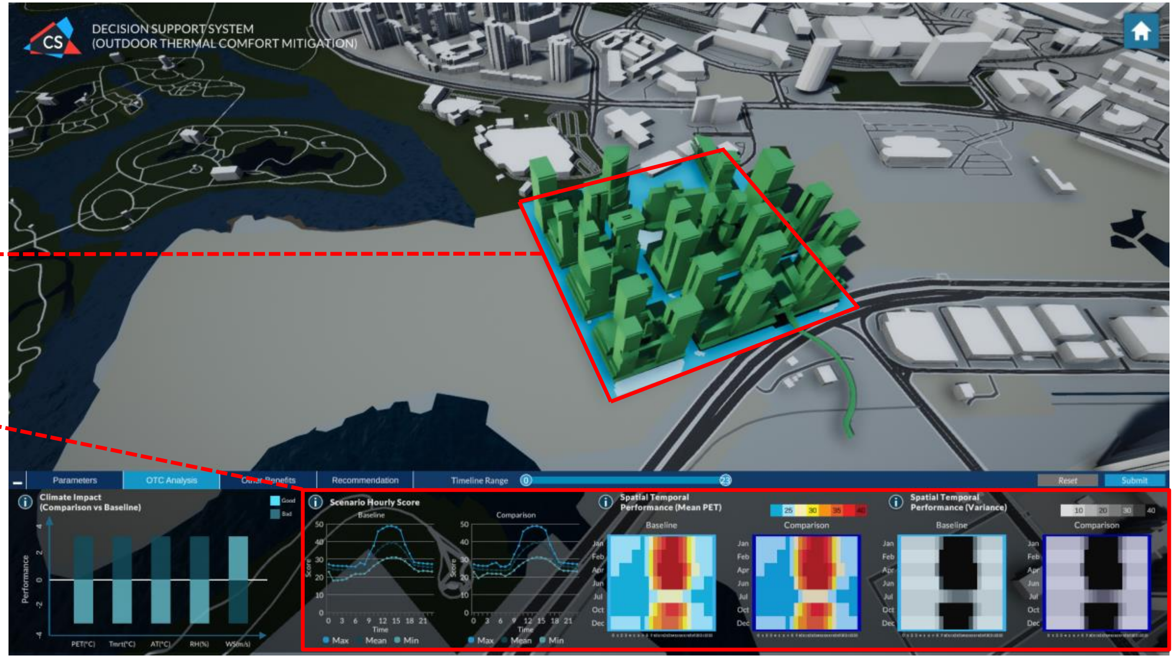
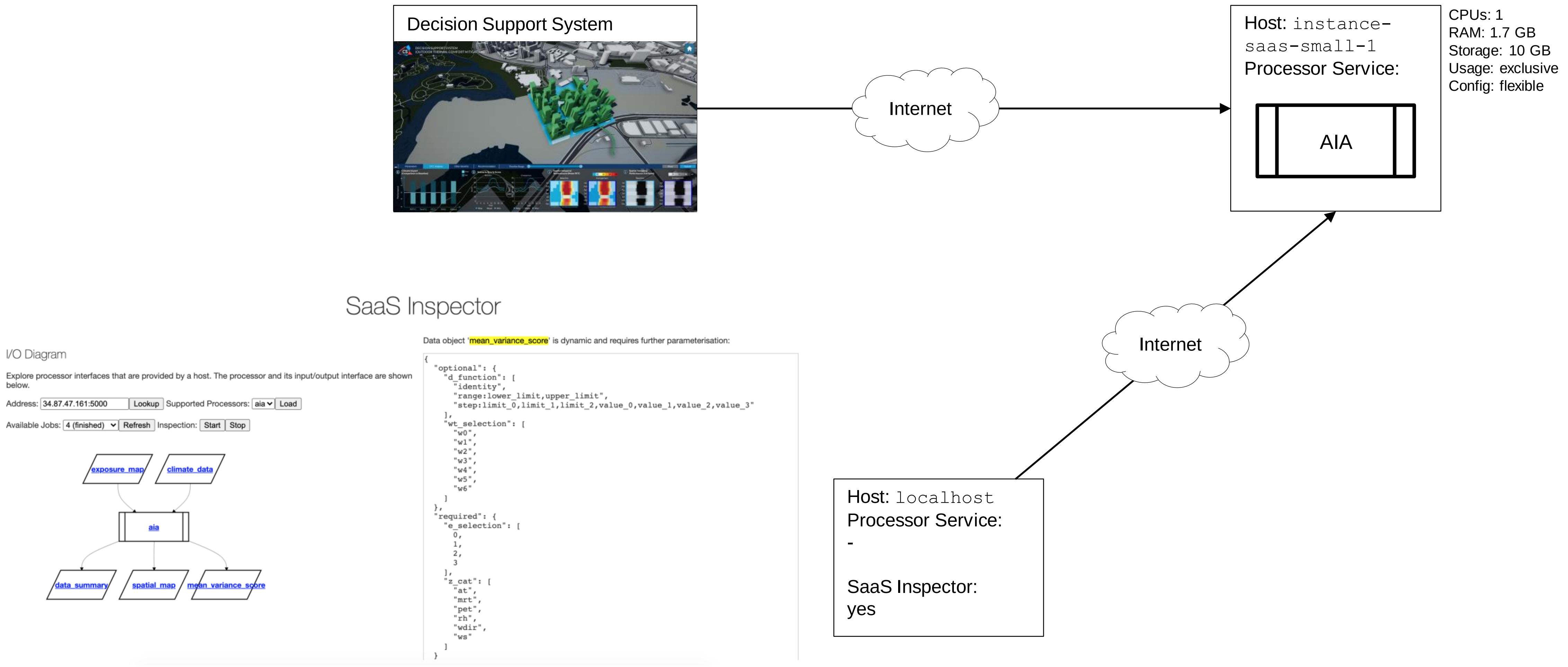
Decision Support System



Images: Ye Cong

DEMONSTRATOR 2 – DSS INTEROPERABILITY
Deployment



Digital Urban Climate Twin
CS 2.0 R&D

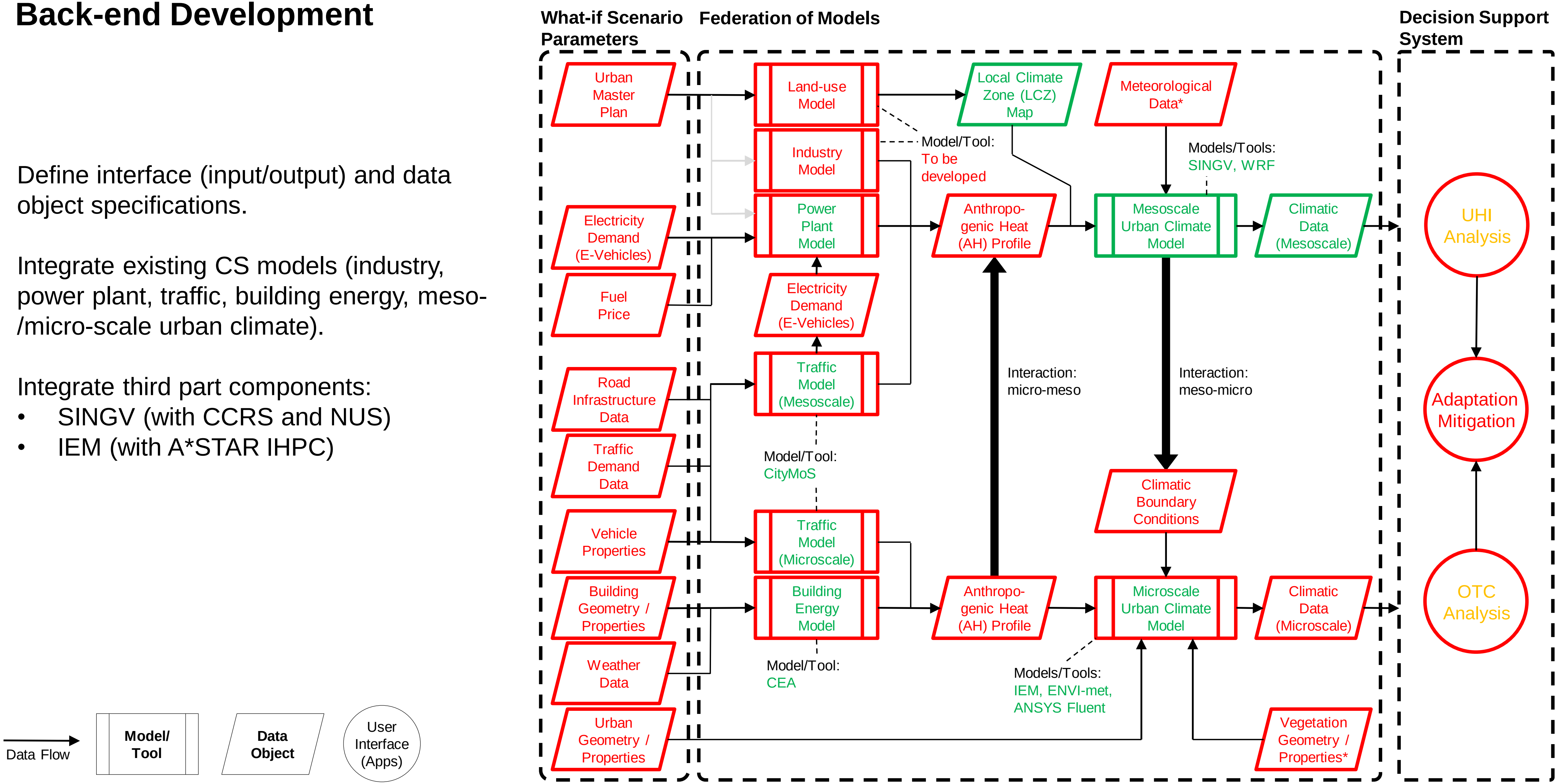
DIGITAL URBAN CLIMATE TWIN
Back-end Development

Define interface (input/output) and data object specifications.

Integrate existing CS models (industry, power plant, traffic, building energy, meso-/micro-scale urban climate).

Integrate third part components:

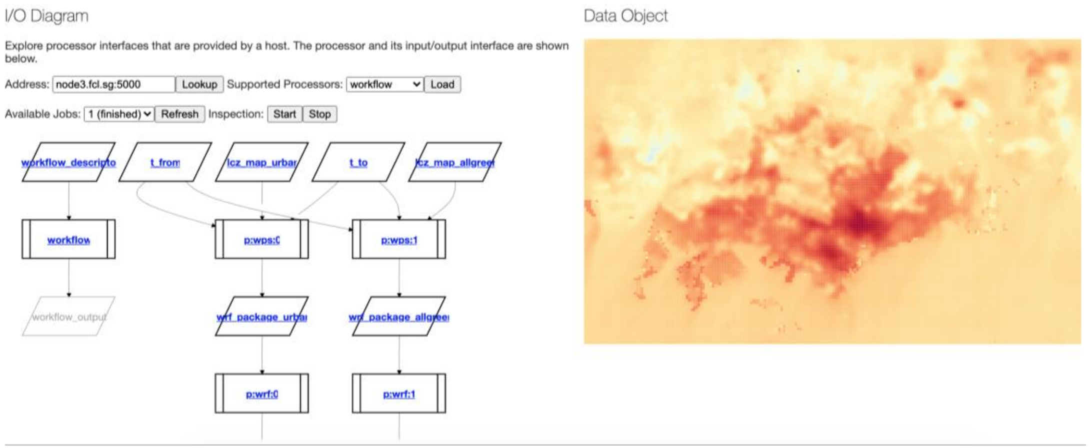
- SINGV (with CCRS and NUS)
- IEM (with A*STAR IHPC)



*) part of what-if scenario parameters but shown here for conciseness.

DIGITAL URBAN CLIMATE TWIN
Front-end Development

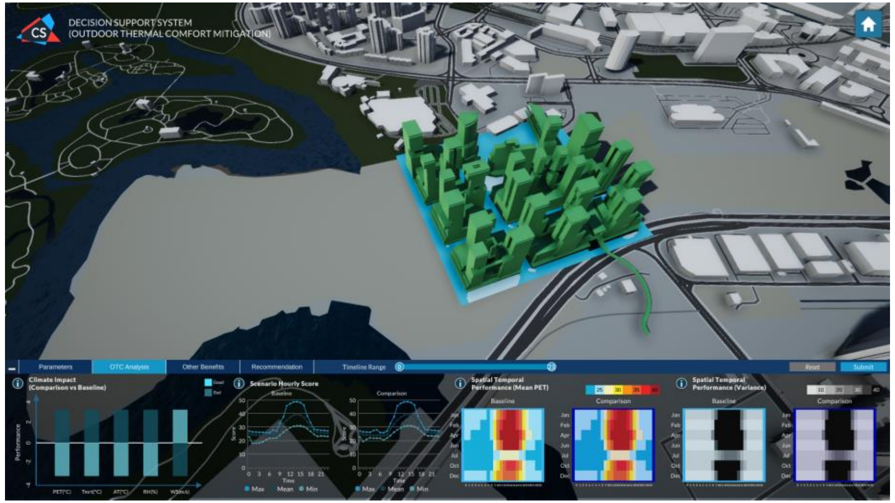
Inspector Tool



Needed for developing, debugging, and operating the DUCT with its many components.

Development will be driven by the needs of the <u>developers and technical users</u>.

Decision Support System



DSS is the front-end the end-users are supposed to use to interact with the DUCT: define scenarios, analyse scenarios (visually), export data (e.g., for further use in GIS software).

Development will be driven by the needs of the <u>end-users and researchers.</u>.

DIGITAL URBAN CLIMATE TWIN
Deployment

Back-end (SaaS Infrastructure + Model Components)

Depending on the needs of the individual components, they will be deployed in a corresponding environment.

High Performance Computing Environments

SG NSCC National Supercomputing Centre SINGAPORE

(+ others)

Cloud Computing Environments

Google Cloud

(+ others)

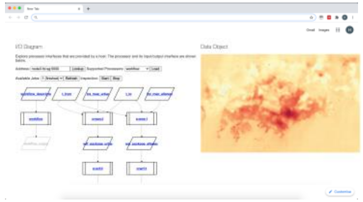
Front-end (DSS + SaaS Inspector)

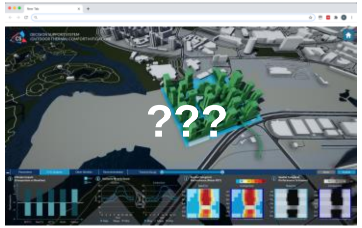
Combination of standalone and web-based applications. It will also depend on what is better for agencies to use.

Standalone

(+ more?)

Web-based





(+ more?)

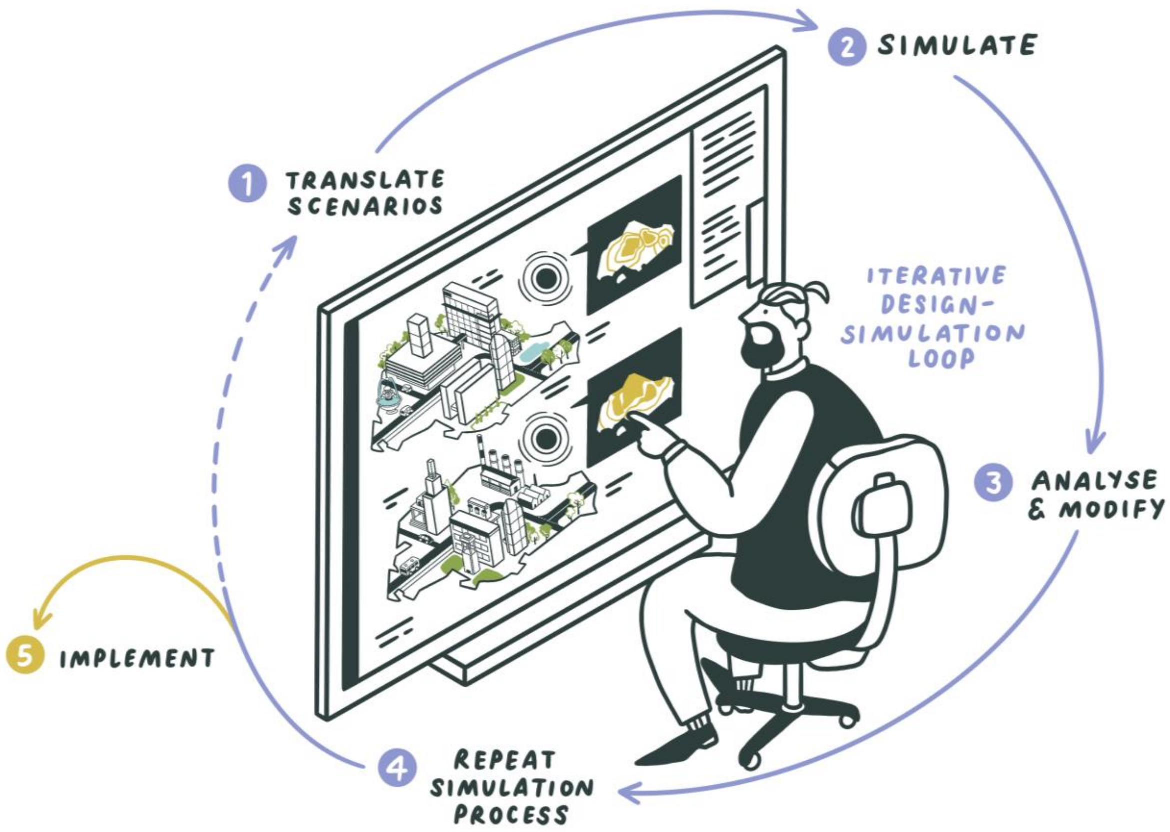
Digital Urban Climate Twin Opportunities for HPC

DIGITAL URBAN CLIMATE TWIN
Urban Climate Design and Management

“Urban climate design and management refers to ability to understand the climate science, to modify and maintain the urban climate (temperature, humidity and air-flow) on different urban scales (e.g., island-wide and building-scale), and to comprehend the social science of risks and mitigation to set targets and desired conditions accordingly.”

Provide planners and decision makers with a tool (== Digital Urban Climate Twin) that allows them to experiment with what-if scenarios in order to make better-informed decisions.

This will require a lot of computational power...

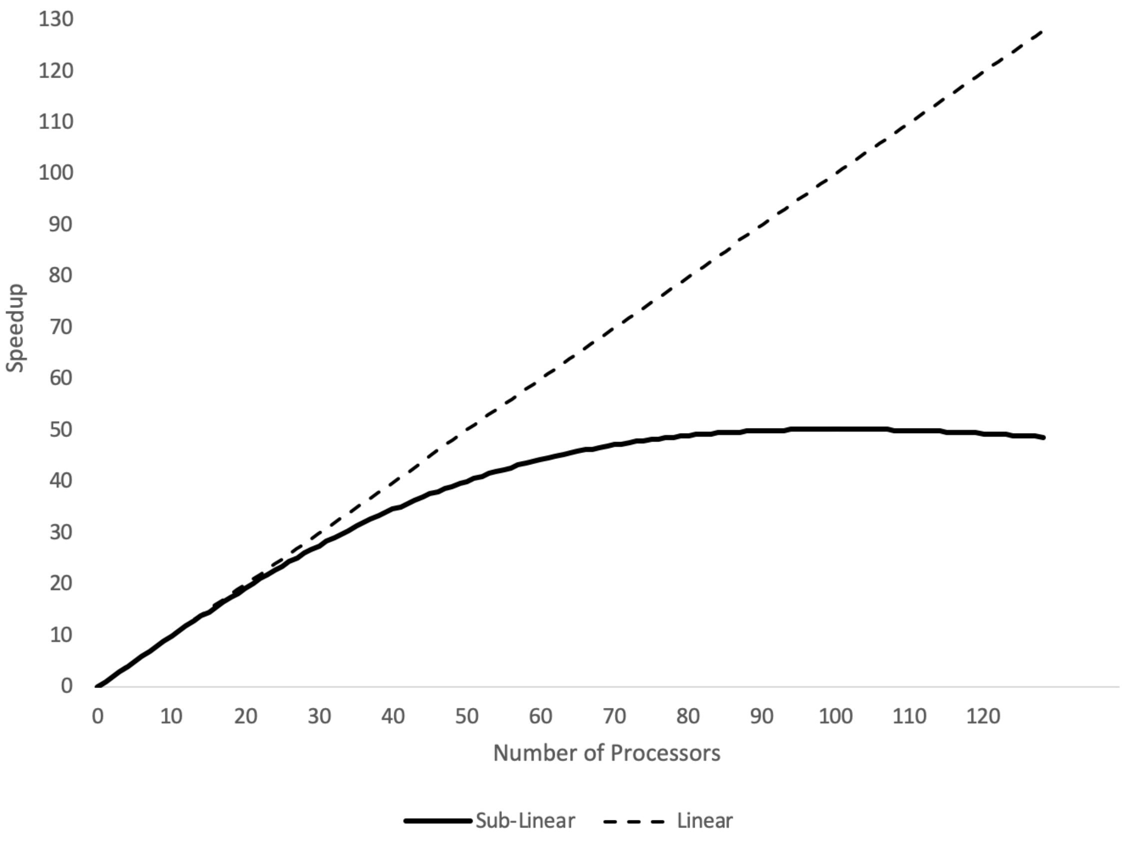


Source: H. Aydt (2020). Cooling Singapore – Towards Urban Climate Design and Management in Indicia 03, editors: S. Cairns and D. Tunas (forthcoming)

DIGITAL URBAN CLIMATE TWIN
Limits to Scalability

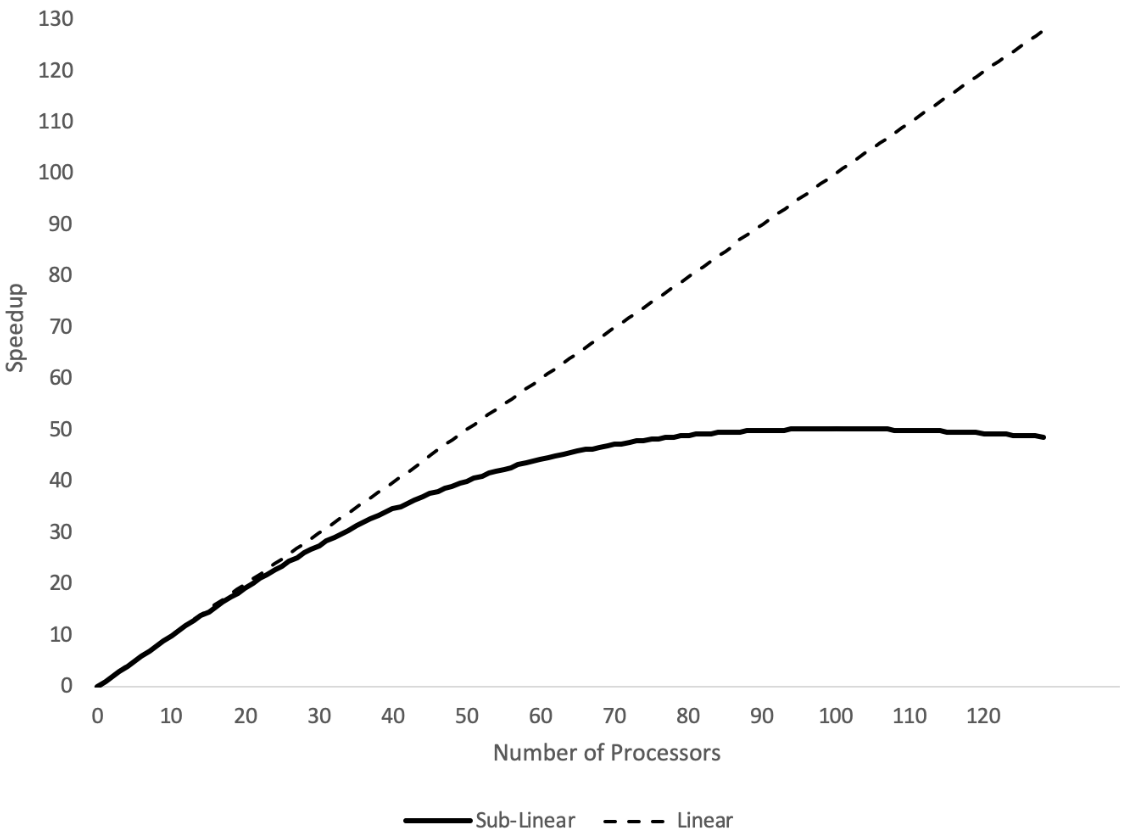
Need more speed? Assumption: if we double the computational resources (e.g., processors) then performance will also double (= **linear speedup**).

Unfortunately, that's not the case... Problem: communication between parallel processes cause overhead resulting in **sub-linear speedup** (see Amdahl's Law and Gunther's Universal Scalability Law).



DIGITAL URBAN CLIMATE TWIN
Limits to Scalability

You have 100 processors and 100 what-if scenarios. What to do?
a) Run 100 what-if scenarios with 1 processor each concurrently; or
b) Run 100 what-if scenarios with 100 processors each sequentially.



The Bad
The speed up we can achieve for a single simulation run is limited.

The Ugly
Marginal increase in performance, not only wastes a lot of computing resources but also energy!!

The Good
Different what-if scenarios are independent from each other and can run concurrently.

DIGITAL URBAN CLIMATE TWIN
Opportunities for HPC

HPC in Science
- Researchers use HPC for carrying out simulation experiments.
- Users work directly with the HPC.
- “One-off” experiments.

HPC for Urban Climate Design and Management
- HPC has to be seamlessly integrated into operational processes.
- Users shouldn’t be bothered with the technicalities of HPC.
- Recurring use and on-demand simulations experiments.

Cooling Singapore 2.0 has the **ambition to build an operational Digital Urban Climate Twin** (TRL6).

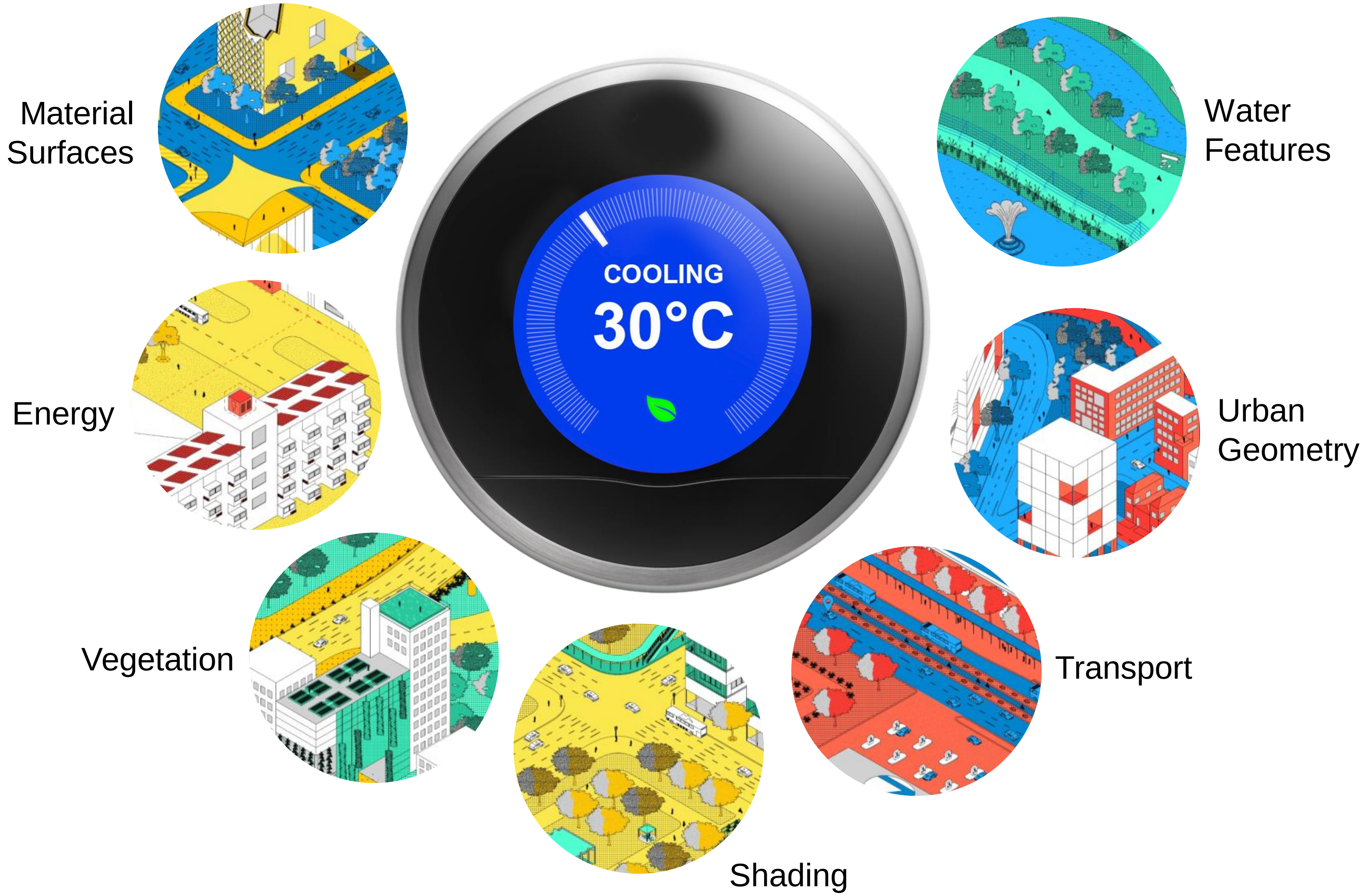
The goal is not to deliver a perfect solution (because we know that can’t be done) but a solution that planners and decision makers will find **useful** and **intuitive** to use.

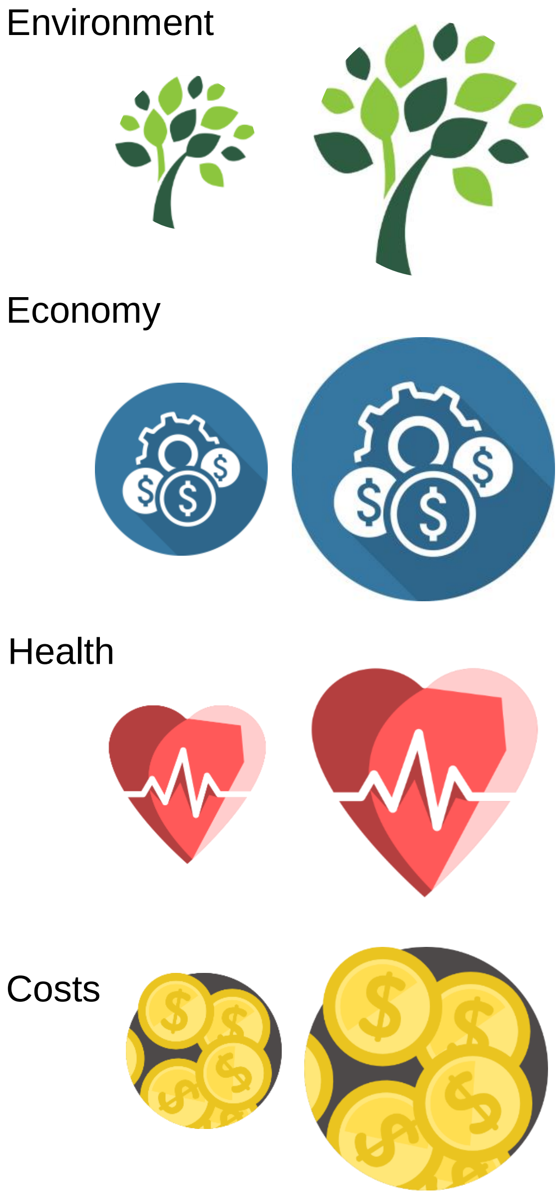
For this purpose, we are planning to work closely with NSCC (and others) to **ensure HPC resources can be seamlessly integrated**.

First step towards this goal is to discuss the **deployment of SaaS Infrastructure components in the HPC environment.**

COOLING SINGAPORE 2.0

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

AREAS TO FOCUS ON: URBAN SOCIAL SCIENCES

Winston CHOW

CASE SPECIFIC STUDY

VULNERABILITY MAP

Conrad PHILIPP

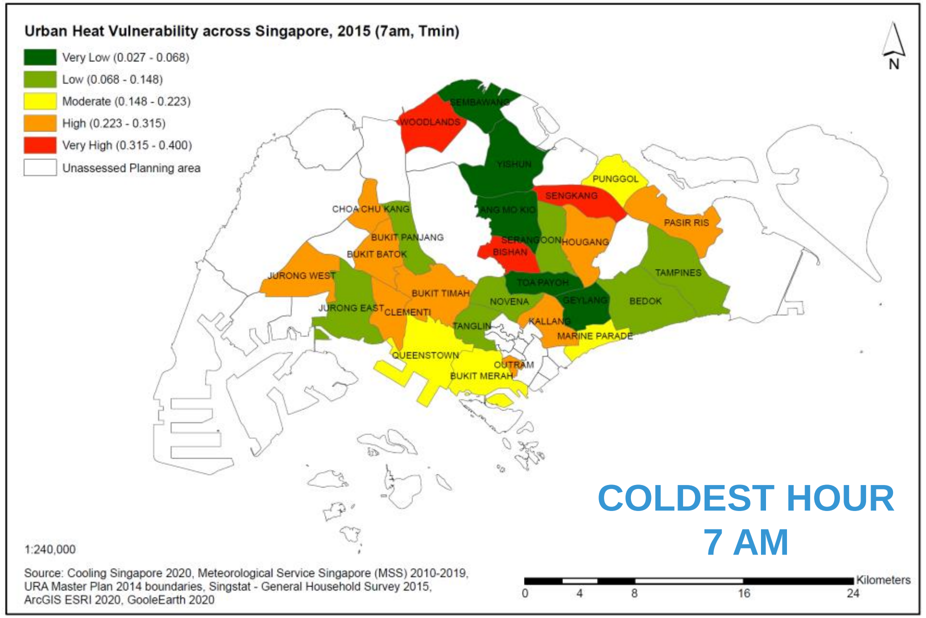
PRELIMINARY RESULTS

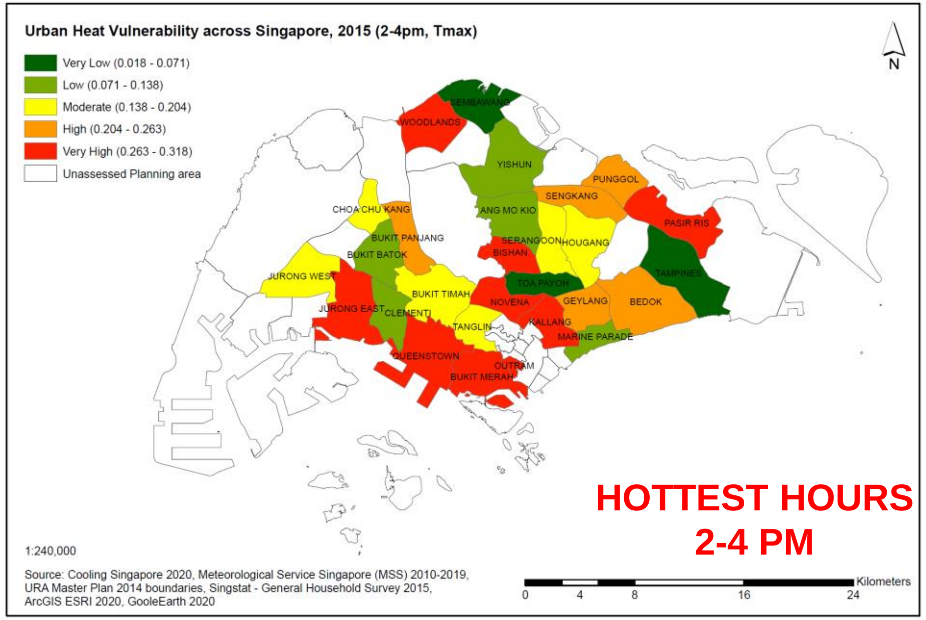
- **Urban Heat Vulnerability (UHV) map** for Tmin (7am) and Tmax (2-4pm)

URBAN HEAT VULNERABILITY (UHV) =
[((exposure to environmental hazard temperature) + (1 - NDVI)) / 2]
x [(sensitivity indicator) + (adaptive capacity indicator) / 10]

- UHV map separated into 5 classes: based on natural breaks (see Jenks-Caspall-Algorithmus)
    - Very low
    - Low
    - Moderate
    - High
    - Very high

- Spatial and temporal coverage
    - 28 of 55 planning areas assessed for Tmin and Tmax
    - 98.8% of the local population covered
    - 44% of the land area assessed
    - Year of investigation: 2015





WHAT OTHER CITIES AND COUNTRIES ARE DOING

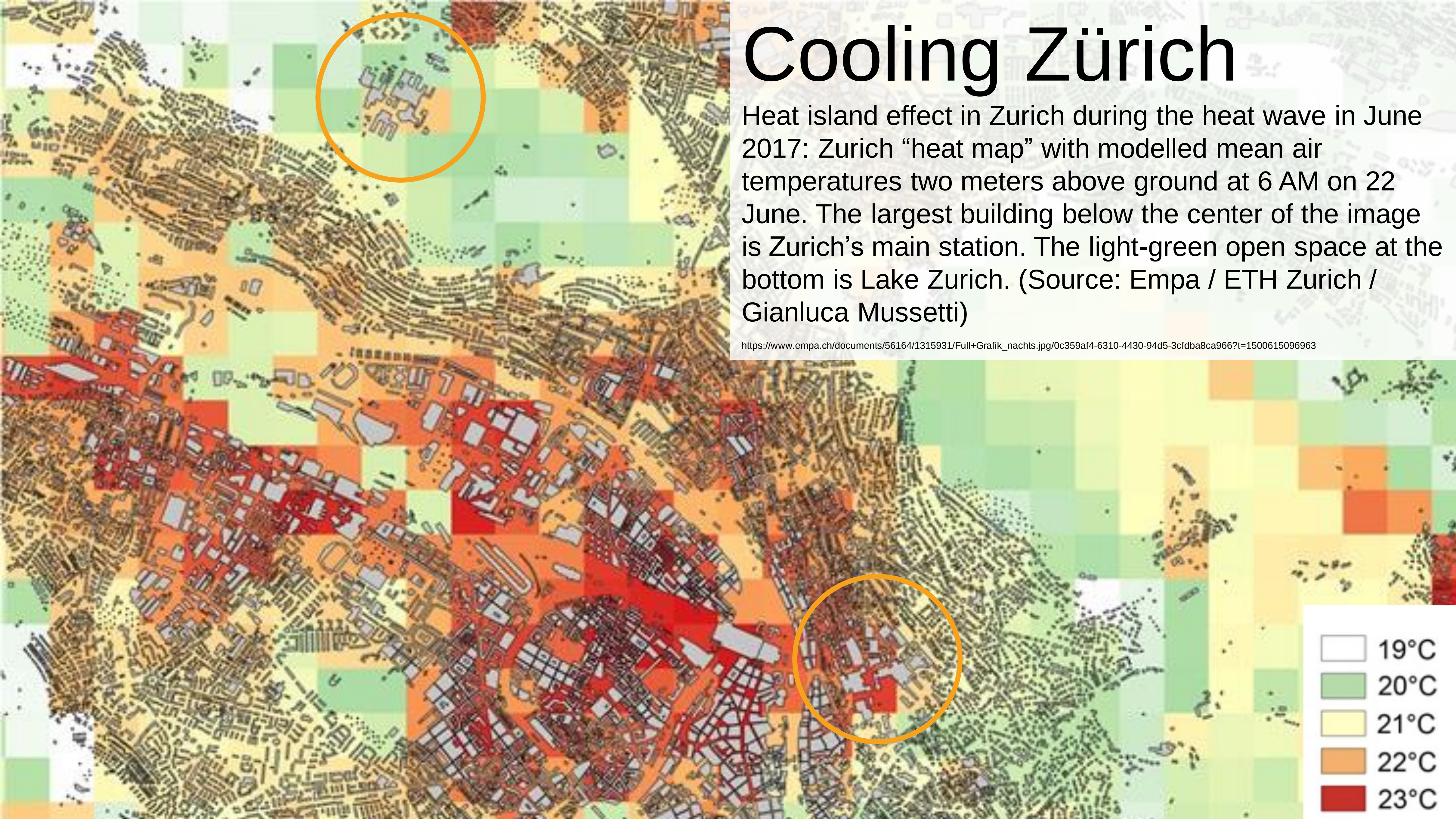
Heat records broken in **June 2019** at 27 locations in **SWITZERLAND**

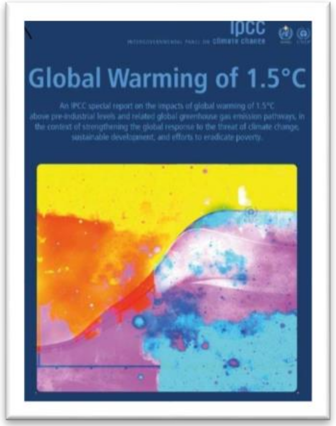
Source: https://lenews.ch/2019/06/26/heat-records-broken-at-nearly-30-locations-in-switzerland/

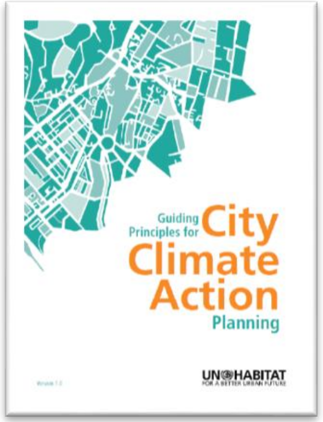
Cooling Zürich

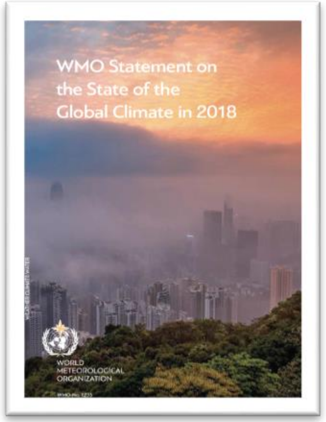
Heat island effect in Zurich during the heat wave in June 2017: Zurich “heat map” with modelled mean air temperatures two meters above ground at 6 AM on 22 June. The largest building below the center of the image is Zurich’s main station. The light-green open space at the bottom is Lake Zurich. (Source: Empa / ETH Zurich / Gianluca Mussetti)

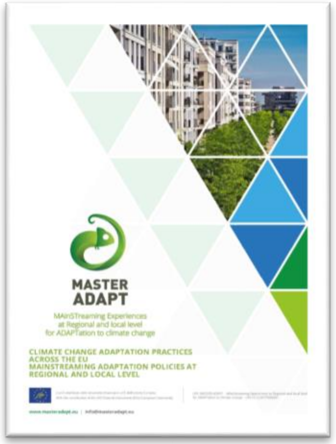
https://www.empa.ch/documents/56164/1315931/Full+Grafik_nachts.jpg/0c359af4-6310-4430-94d5-3cfdba8ca966?t=1500615096963

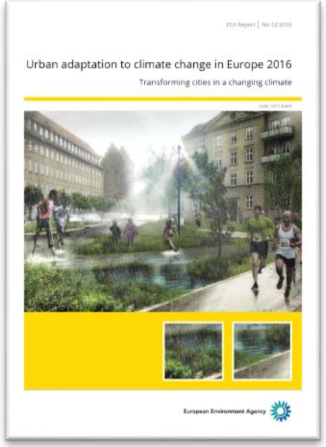


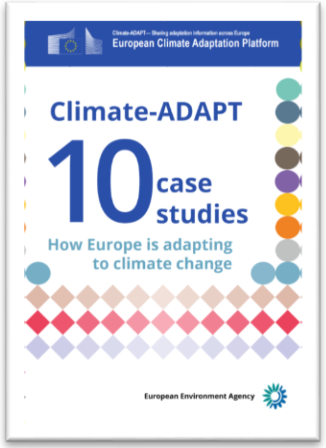


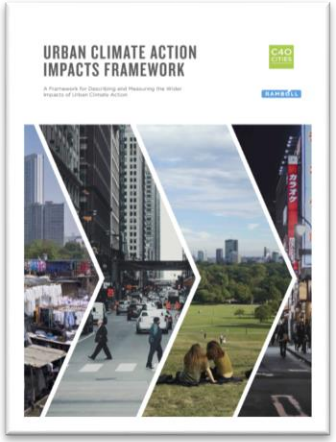


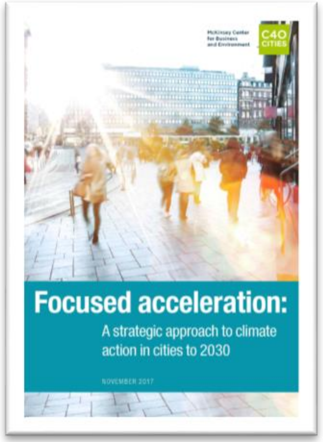












INTERNATIONAL PROGRAMMES
e.g. Intergovernmental Panel on Climate Change (IPCC), World Health Organization (WHO) UN-HABITAT orienting cities towards concrete, comprehensive climate action.

The **EUROPEAN UNION** has set itself targets for reducing its greenhouse gas emissions progressively up to 2050 to achieve the transformation towards a low-carbon economy as detailed in the 2050 long-term strategy.

The **C40 CITY NETWORK** provides comprehensive support to cities to develop ambitious and equitable climate action plans in line with the objectives of the Paris Agreement. **Status Singapore: Observer City**

Framework Programmes

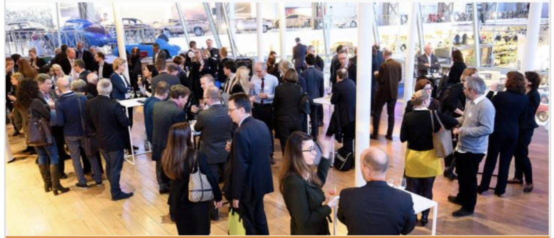
Science|Business journalists and experts in Brussels, together with our partners in the Science|Business Network, are closely following developments of the EU's research framework programmes, Horizon 2020 and Horizon Europe, which aim to boost innovation in Europe until 2020 and beyond.

Bookmark this page and register to our newsletter to follow developments closely – with Science|Business reports, events and news. For more information about how to get involved with the Science|Business Network and help to maximise the value of the Framework programmes, contact Maryline Fiaschi.

The Network

The unique forum convening public and private sector leaders for networking, intelligence and debates on research and innovation.

More info »



24 Aug 2020 | News

Paint the town green: Horizon Europe moonshot draws up 'fast and radical' plan for sustainable cities

Research, city governance and citizen engagement will play a crucial role in EU mission that aims to make 100 cities in Europe climate neutral by 2030

By Goda Naujokaitytė

One of Horizon Europe's five new research missions will strive to make 100 European cities climate-neutral by 2030, applying a cocktail of research, governance and citizen engagement to become sustainably green and offering role models for other metropolitan areas to follow.

This will provide a critical input for the EU in reaching its target of net-zero carbon dioxide emissions across the continent by 2050.

The exact details of the how the mission will be organised are still under discussion, but an EU official told Science|Business it will "necessarily have to go beyond Horizon Europe," in particular when it comes to the implementation of relevant technologies.

WHERE DO WE WANT TO BE IN 2050?

Design & Inclusion

Singapore most liveable City

High Outdoor Thermal Comfort
Clean Air
Clean Industry

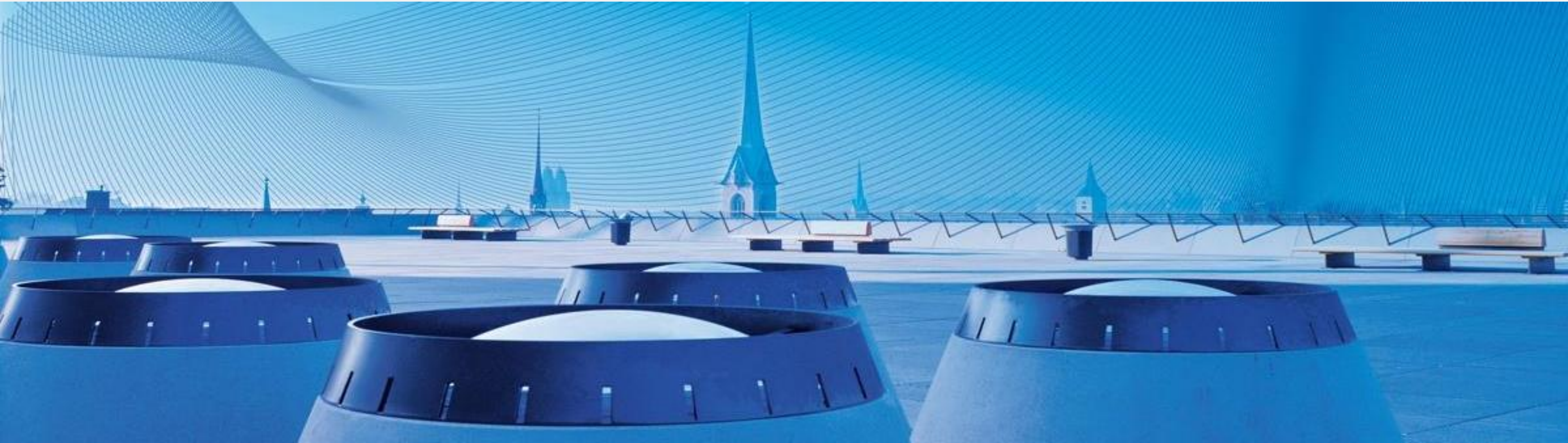
Jurong Lake District masterplan, with Kees Christiaanse, SEC-FCL Director

Image: Straits Times (2016). Singapore


Singapore most liveable City
Less Noise
Renewable Energy
Circular Economy
Image: Conrad Philipp

EVERY CITY HAS ITS OWN DNA

Prof. Gerhard Schmitt, ETH Zürich and Singapore ETH Centre SEC



WILLINGNESS TO PAY

Which mitigation strategy would you like see implemented first?

1	2	8
		
Green Streetscapes	Renewable Energy	Cool Bus Stations

If the government implements these mitigation strategies, how would you allocate the funding?

1	2	8
		
Renewable Energy	Green Streetscapes	Building Voids

1800 participants

WTP of 0.28% in mean of total annual income

Men are willing to pay 12.27% more than woman

Self-employed are willing to pay 50.4% more than employed

People exposed to information (e.g., UHI map) **are willing to pay 46% more**

The more children, the higher the WTP

The higher the income, the higher the WTP

Source: Cooling Singapore, Natalia Borzino (2018 / 2019)

Singapore can reduce its Urban Heat Island Effect

This will significantly increase Outdoor Thermal Comfort and air quality, reduce noise and CO_2 emissions, AND contribute to reducing climate change while improving urban health. Supercomputing will play a crucial role in the process.

Thank you!

Image: Conrad Philipp