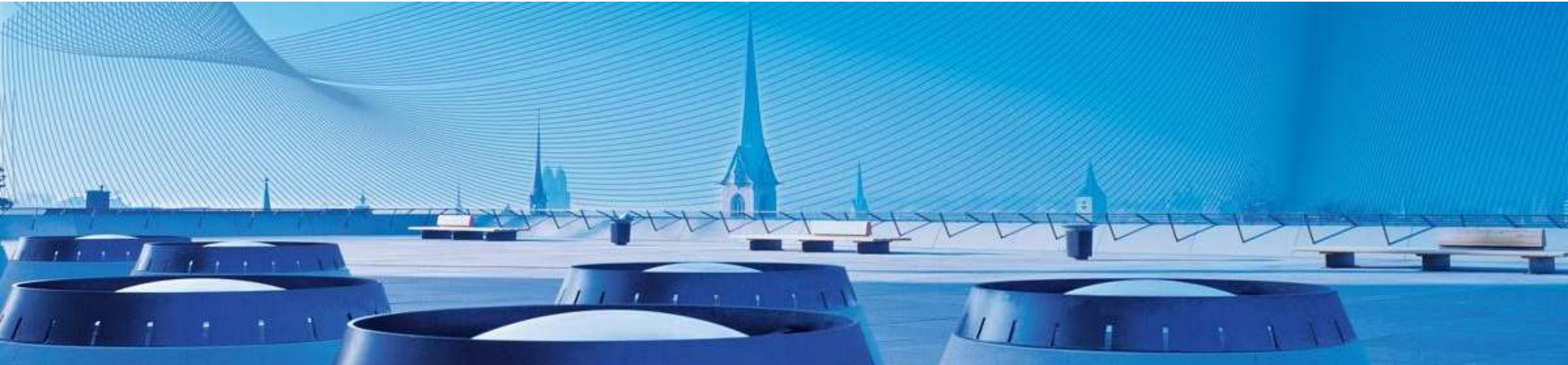
Klimamodell Singapur

Prof. em. Dr. Gerhard Schmitt, ETH Zürich



Existentieller Test für alle Städte: Klimawandel und Urbane Wärmeinseln

URBAN HEAT CHALLENGE

CITIES OF THE WORLD

TACKLING URBAN HEAT 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

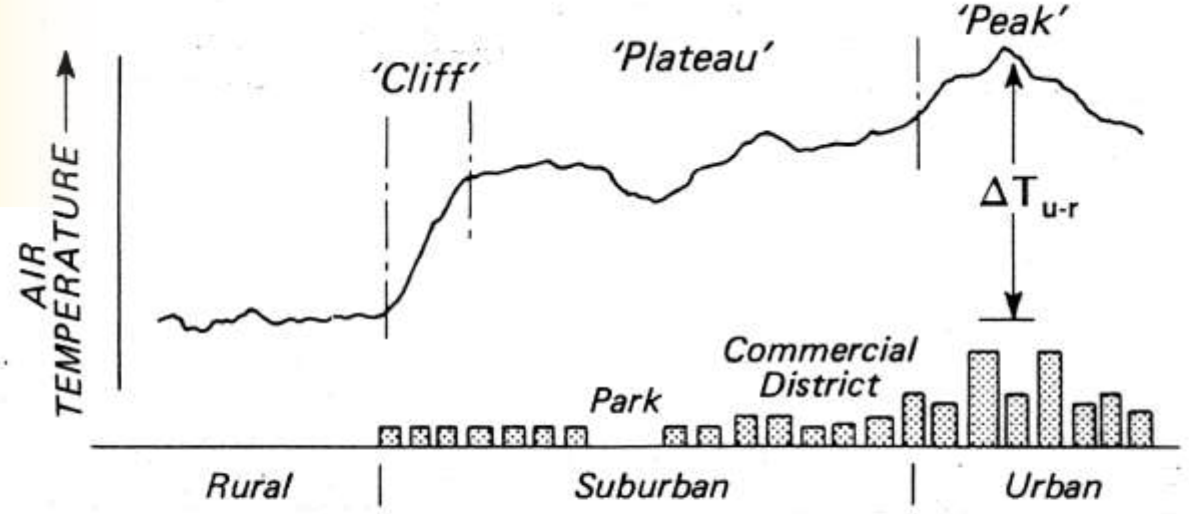
Städte - Smart Cities - Hitze

Städte sind gleichzeitig Verursacher des Klimawandels, aber oft viel stärker Opfer der lokalen Hitze (Urbane Wärmeinseln).

Hitze in der Stadt

- Urbane Wärmeinseln gab es immer
- Sie entstehen durch «passive» und «aktive» anthropogene, durch Menschen verursachte Einträge

Temperature profile of UHI's

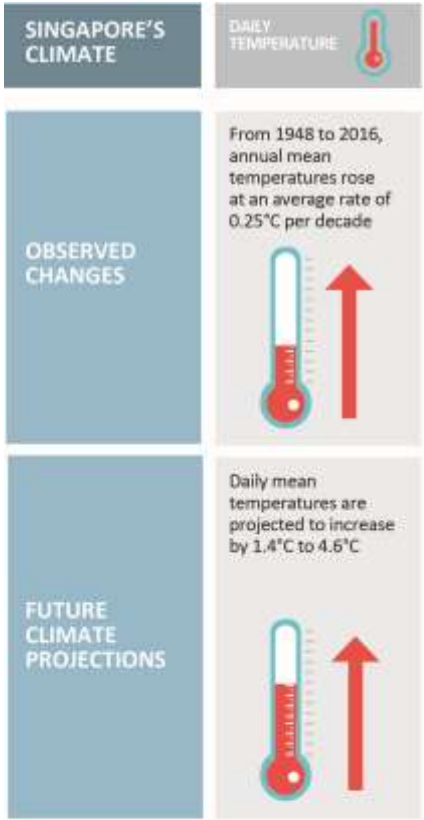


T. R. Oke, "City size and the urban heat island," *Atmospheric Environment (1967),* vol. 7, pp. 769-779, 1973.
T. R. Oke, "The energetic basis of the urban heat island," *Quarterly Journal of the Royal Meteorological Society,* vol. 108, pp. 1-24, 1982.

Chettinad, Tamil Nadu, Indien: Villen der Kaufleute, GS 2019

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

Urban Climate SPECIFICALLY FOR SINGAPORE

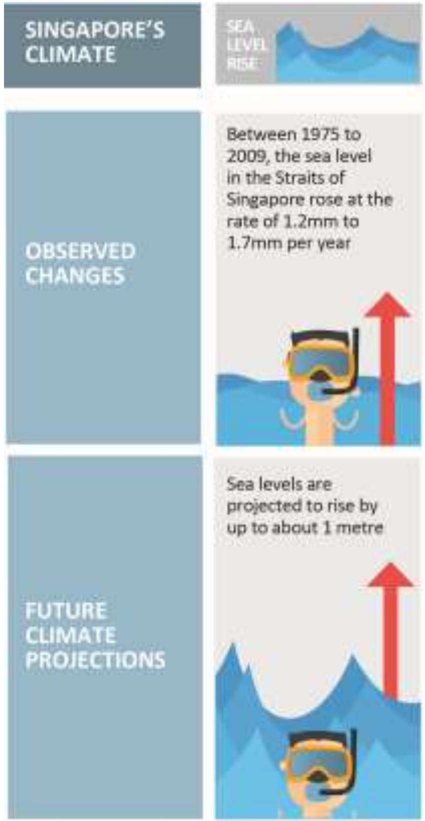
'Half a month's rainfall in two hours'
Strait Times, 30 June 2018

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

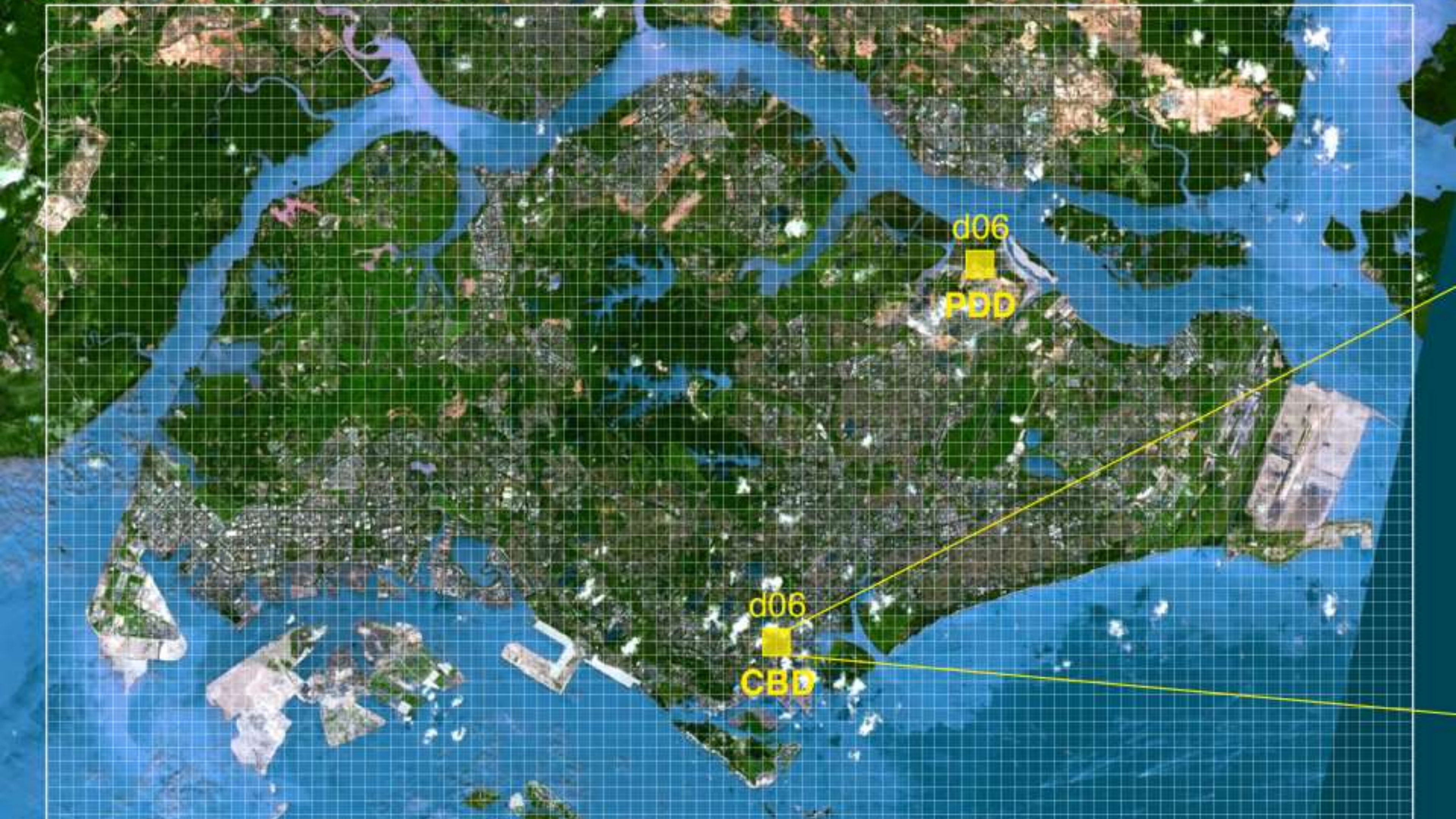
Source: https://www.straitstimes.com/singapore/as-sea-levels-rise-singapore-prepares-to-stem-the-tide, NCCS 2015, https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/impact-of-climate-change-on-singapore

Städte – Ansprechpartner

- Schweiz: Bürger:innen kontrollieren mehr als die Hälfte der Emissionen (→ Ansprechpartner: verantwortungsbewusste Bürger:innen)
- Singapur: Industrie und Handel verursachen mehr als 2/3 der Emissionen (→ Ansprech-partner Industrie und Regierung)

Startpunkt

- Erzählungen älterer Menschen
- Anpassung – Adaption – an das heisse und feuchte Klima Singapurs



d06
PDD
d06
CBD

Botanischer Garten, Singapur: Villa des Direktors GS 2017


Image: Conrad Philipp



Daten

- Historische lokale Klimadaten
- Aniruddh Shrivastava I.I.T Bombay, Praktikant am Singapore-ETH Centre 2013
- NUS, NTU, MIT, SMU

"COOLER CALMER SINGAPORE"- Final Documentation of Internship work (15TH May to 15th July, 2013)

Contents (ctrl+click to directly reach the topic)

Thank you very much Professor Schmitt (really can't thank you enough!) and Dr. Mattiaz Berger (hope you are honoured with your post doctorate soon!) for the opportunity and the constant guidance!

It was a huge learning experience, and hopefully, my work has contributed something to "cooler calmer Singapore"

Regards-

Aniruddh

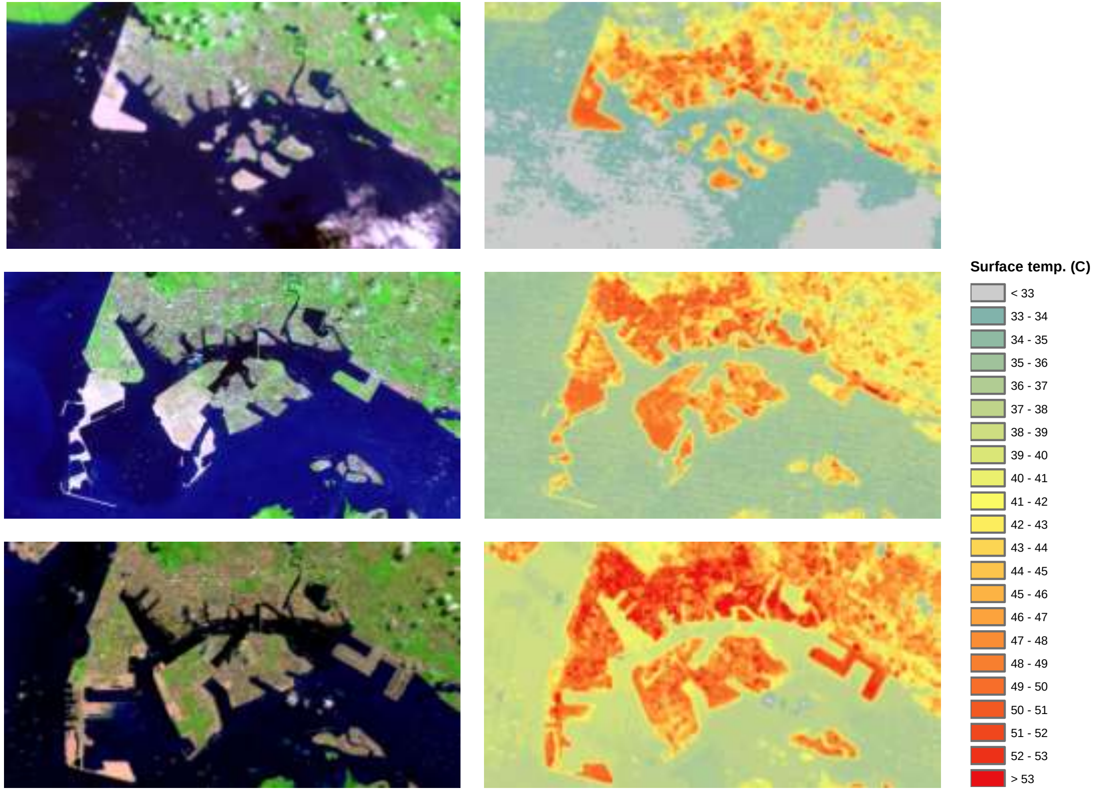
SINGAPORE’S LAND SURFACE TEMPERATURE

JURONG

13 September 1989
10:42 am

25 December 2003
10:55 am

8 May 2018
11.16 am



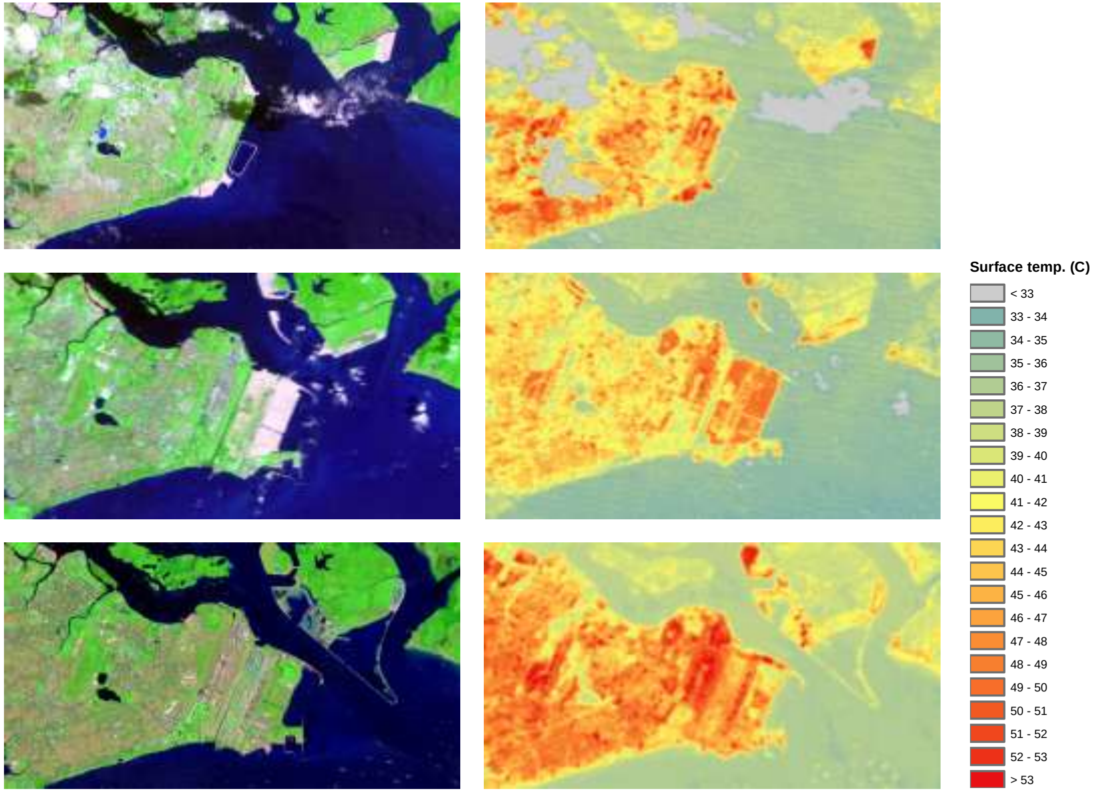
This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

AIRPORT

13 September 1989
10:42 am

25 December 2003
10:55 am

8 May 2018
11.16 am

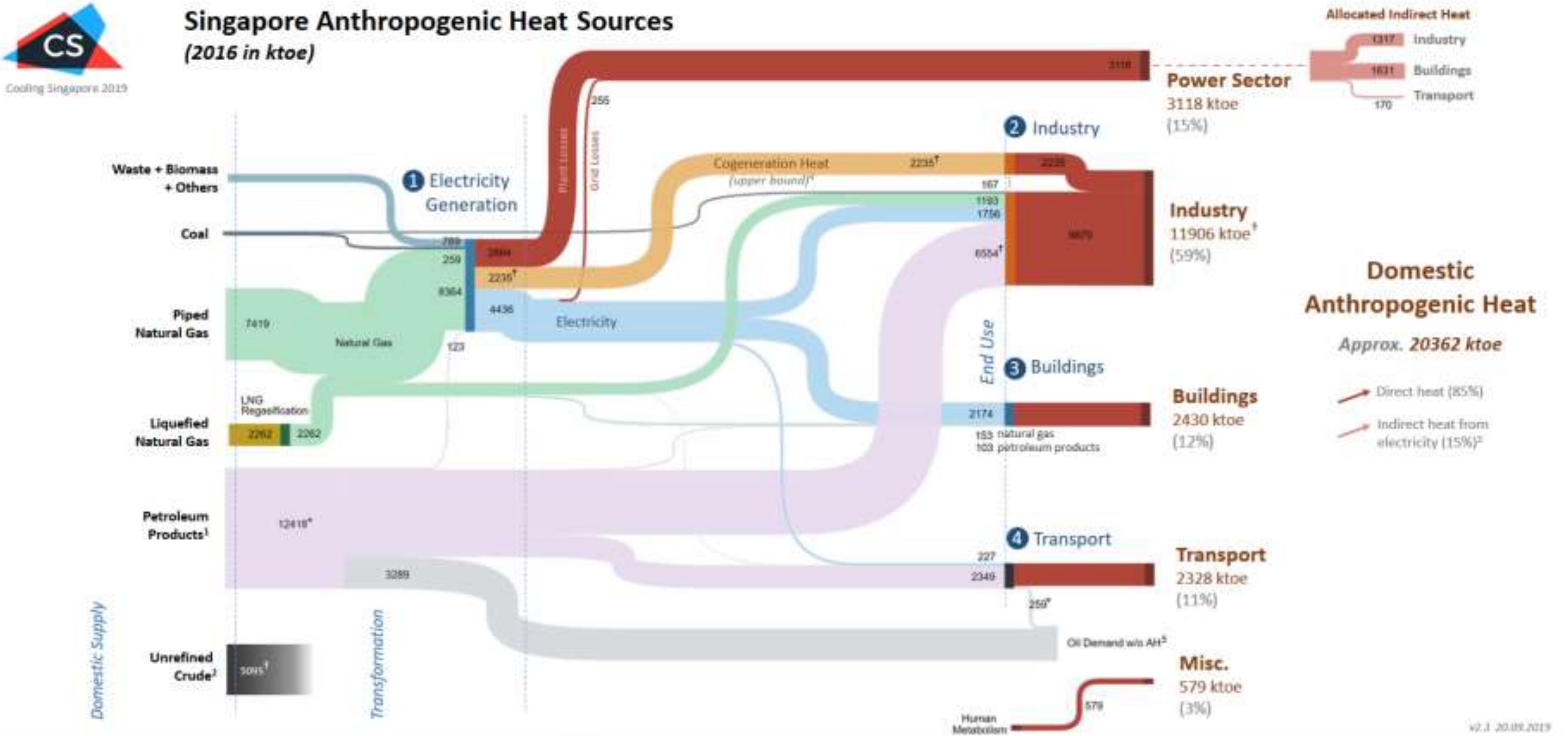


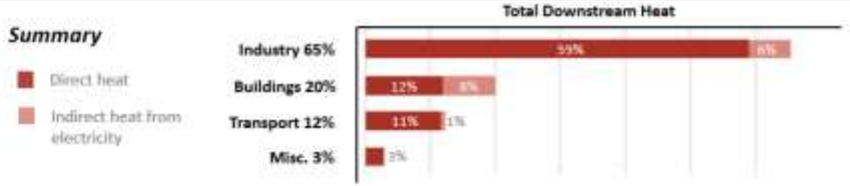
This is work in progress. The surface temperature map can be used as an initial indicator to understand the impact of the building mass.

Singapore Anthropogenic Heat Sources

(2016 in ktoe)

Cooling Singapore 2019





NOTES

[1]Domestic supply after net imports, refining, stock exchanges, and bunkering.

[2]Unresolved use of crude in Singapore (not refined, stored, nor exported).

[3]Indirect heat from electricity is the heat released by power plants to cater to the end use electricity demand. This has been allocated proportional to the demand.

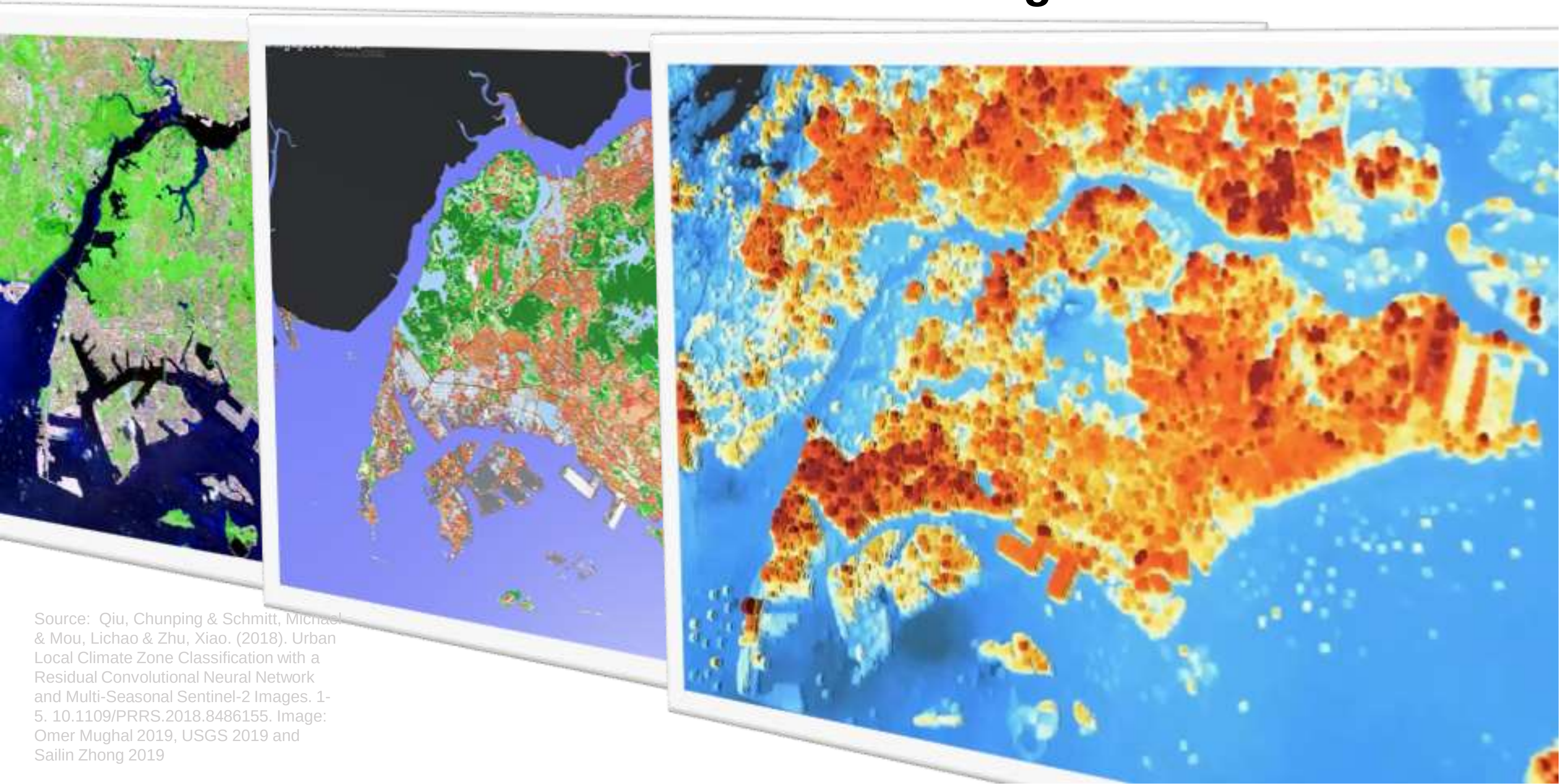
[4]No data on cogeneration heat production. A high estimate is depicted, which is consistent with EMA energy statistics.

[5]Oil demand without a anthropogenic heat contribution includes non-energetic use of petroleum (e.g. feedstock) and fuel for domestic ships and aviation.

Primary source: Energy Market Authority 2018 Singapore Energy Statistics
Figures marked (*) complemented with International Energy Agency data;
(†) are major uncertainties.

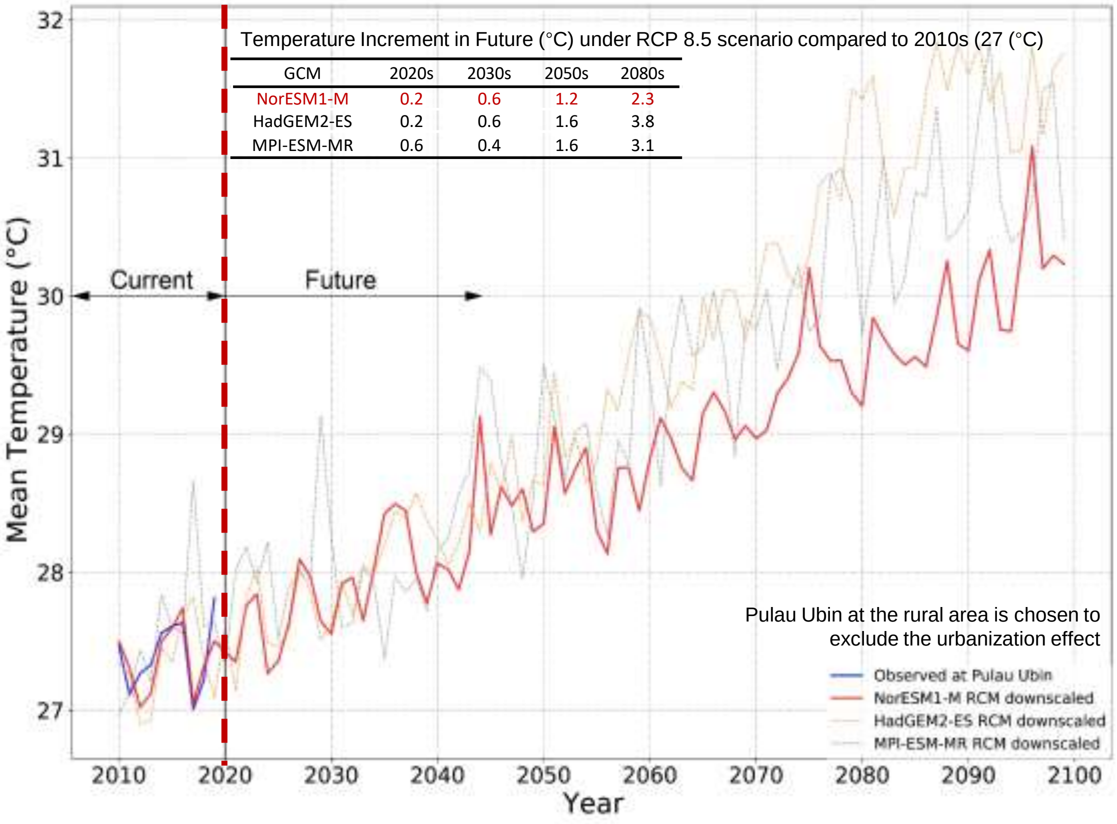
Kayanan, D. R., Resende Santos, L. G., Ivanchev, J., Fonseca, J. A., & Norford, L. (2019). Anthropogenic Heat Sources in Singapore. doi:10.3929/ethz-b-000383683

Maschinelles Lernen und Künstliche Intelligenz



Source: Qiu, Chunping & Schmitt, Michael & Mou, Lichao & Zhu, Xiao. (2018). Urban Local Climate Zone Classification with a Residual Convolutional Neural Network and Multi-Seasonal Sentinel-2 Images. 1-5. 10.1109/PRRS.2018.8486155. Image: Omer Mughal 2019, USGS 2019 and Sailin Zhong 2019

Global/Regional Climate Change Effect on Temperature in Singapore Courtesy Prof. Yuan Chao, NUS

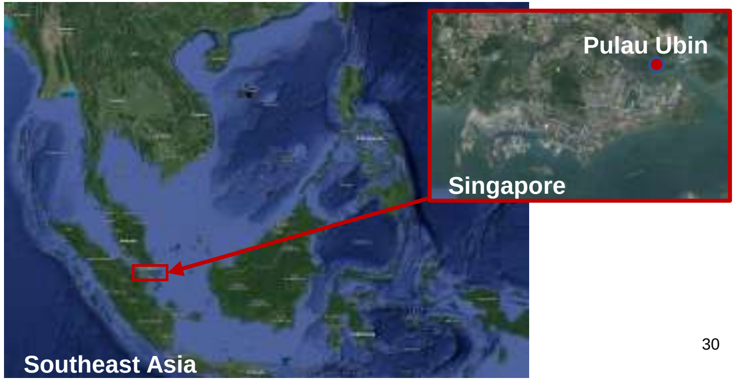


Temperature Increment in Future (°C) under RCP 8.5 scenario compared to 2010s (27 (°C)

GCM	2020s	2030s	2050s	2080s
NorESM1-M	0.2	0.6	1.2	2.3
HadGEM2-ES	0.2	0.6	1.6	3.8
MPI-ESM-MR	0.6	0.4	1.6	3.1

Research methods and data applied in the projection:

Global Climate Model (GCM)	I. MPI-ESM-MR II. HadGEM2-ES III. NorESM1-M
Regional Climate model (RCM)	using RegCM4.7 downscaling (CORDEX-SEA) (Resolution 25 * 25 km)
Downscale Method	Quantile mapping (QM) bias-correction
Observe data	weather station (Pulau Ubin — reference station)
Scenario	Representative Concentration Pathway (RCP) 8.5
Calibrated Period	2010-2019
Projection Period	2020-2099

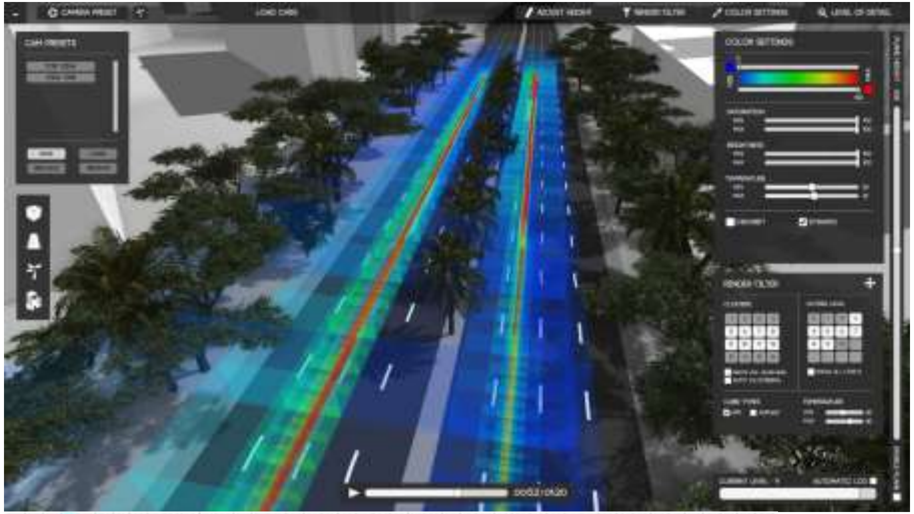


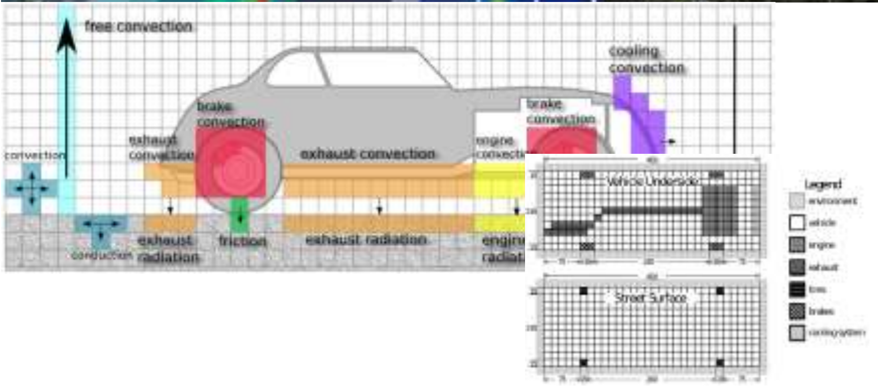
Klimamodelle Singapur

- Mikro-, Meso- und regionale Klimamodelle
- Aktive und passive anthropogene Einträge

CCS PILOT STUDY

In FCL1, we worked together with TUM CREATE on a pilot study. The focus of this study was modeling and simulation of heat emissions by traffic. The CCS Impact Project will continue this work.





Site 1 – AYE: Located at AYE between Clementi Ave 6 and Clementi Ave 2 flyover

Site 2 – CBD: Located at Finlayson Green which is next to Equity Plaza

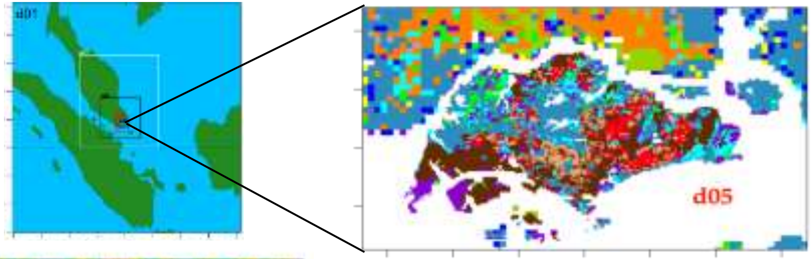
TUM CREATE – EVA TAXI

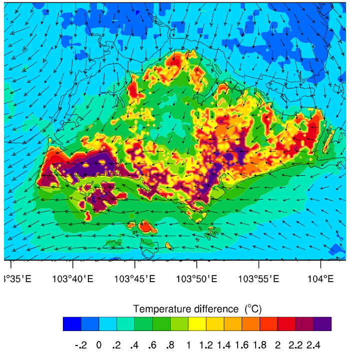
TUMCREATE

EVA – Singapore's First Electric Taxi

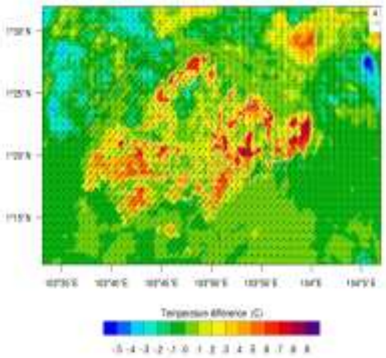
- Completely purpose-built for taxi-usage in Singapore
- Design to Full Vehicle in 4 years
- Super-fast charging capability (200km with 15 min charge)
- Sophisticated cooling system optimized for Tropical Weather

SMART – UHI IN SINGAPORE





04:00 LT



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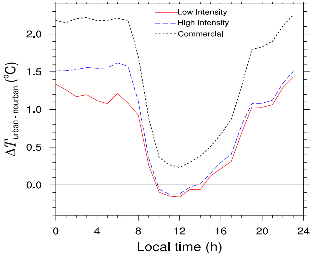
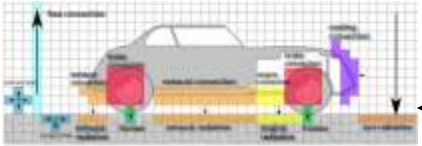


CCS IMPACT PROJECT

Part 1: Computational Model

Part 2: Design Loop Tool

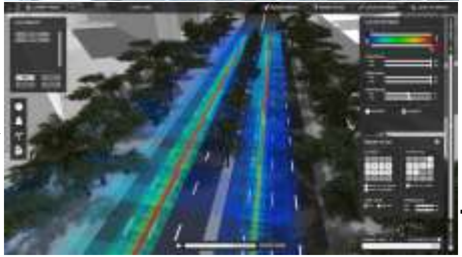
Part 3: Towards Policy Making



(2) Simulation: use generated 3D model of city (or parts of it) as input for the computational model.

(1) City Specification: use City Engine to generate a city according to design what-if scenarios.

(3) Visualisation/Interaction: use 3D game engine (e.g., Unreal) for visualisation, and interactive exploration of space.



(4) Analysis: analyse the results, revise design what-if scenarios, and guide policy makers by providing them the necessary facts and figures.

NVIDIA PHYSX

Idea: use 3D large-scale particle simulation instead CA model.

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

Klimamodelle Singapur

- «Federation of Models»
- «Digital Urban Climate Twin (DUCT)»

DIGITAL URBAN CLIMATE TWIN
What-if Scenario Analysis

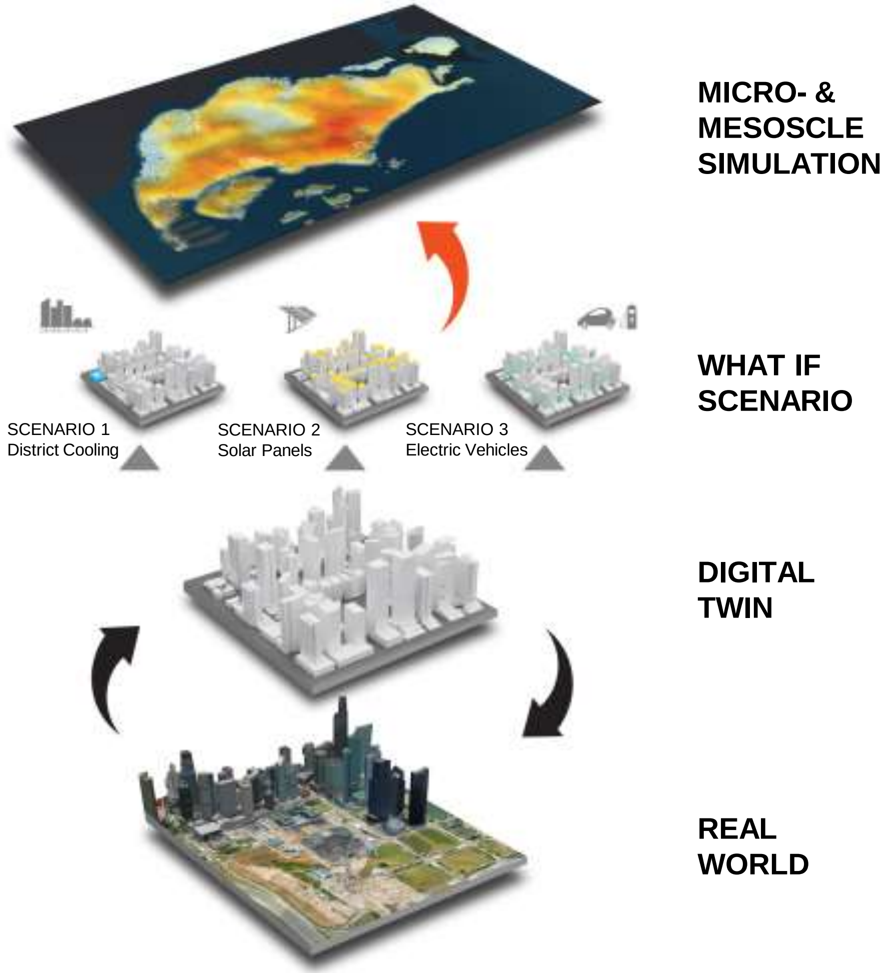


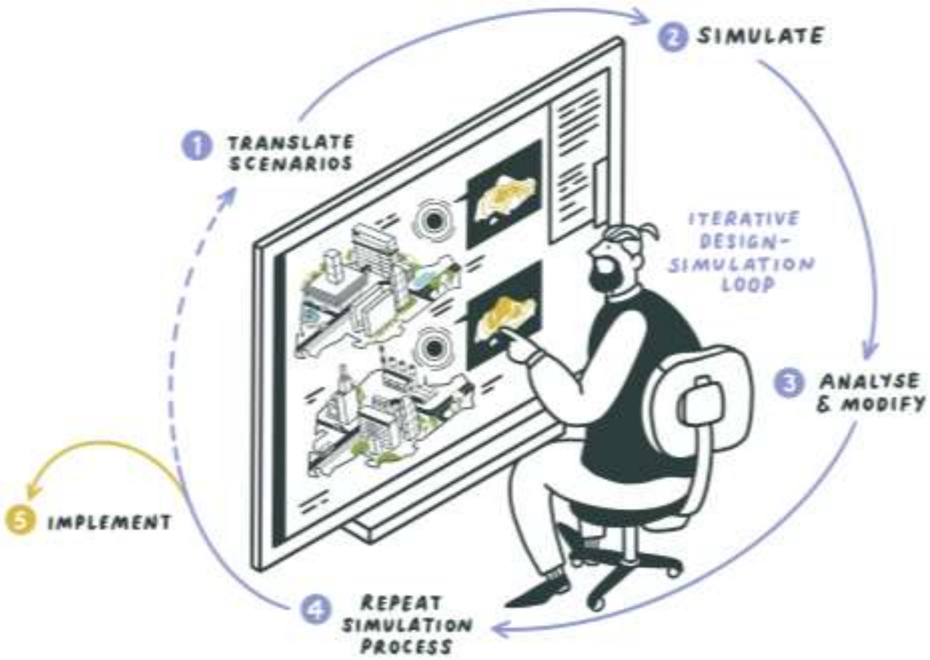
Image: Lea Rüfenacht (January 2020)

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...

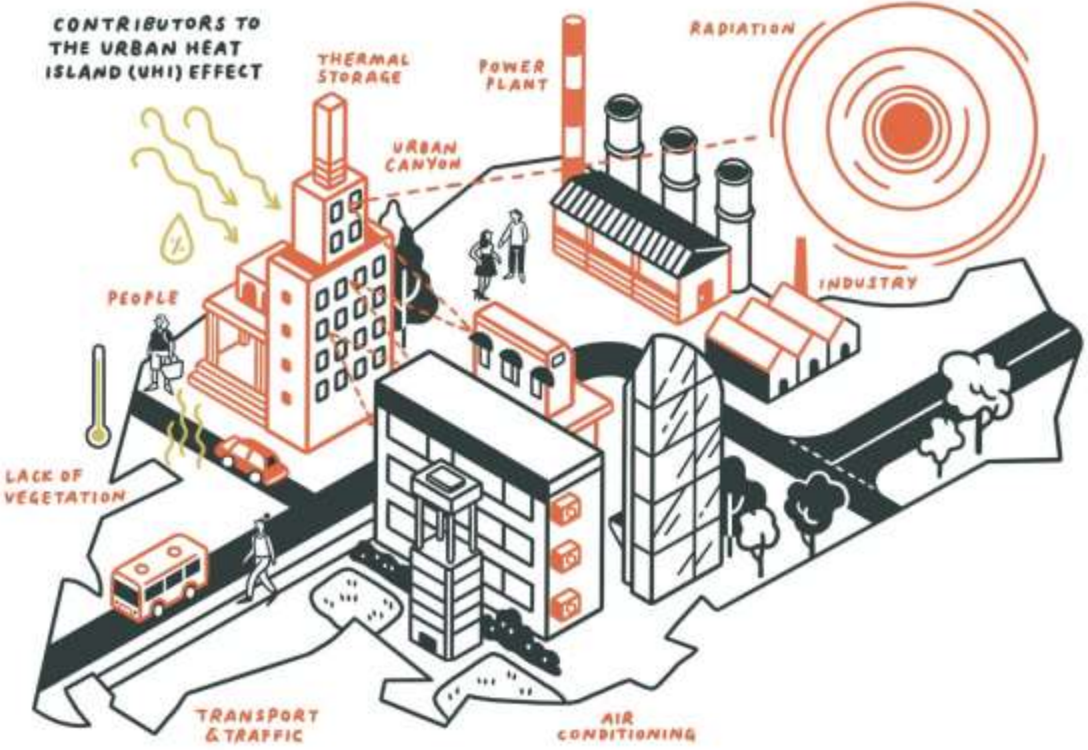


Source: H. Aydt (2020). Cooling Singapore – Towards Urban Climate Design and Management in Indicia 03, editors: S. Cairns and D. Tunas (forthcoming)

What is a Digital Urban Climate Twin?

A Digital Urban Climate Twin (DUCT) is a digital urban twin specialised for urban climate.

Cooling Singapore is building a DUCT for Singapore.



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

COOLING SINGAPORE

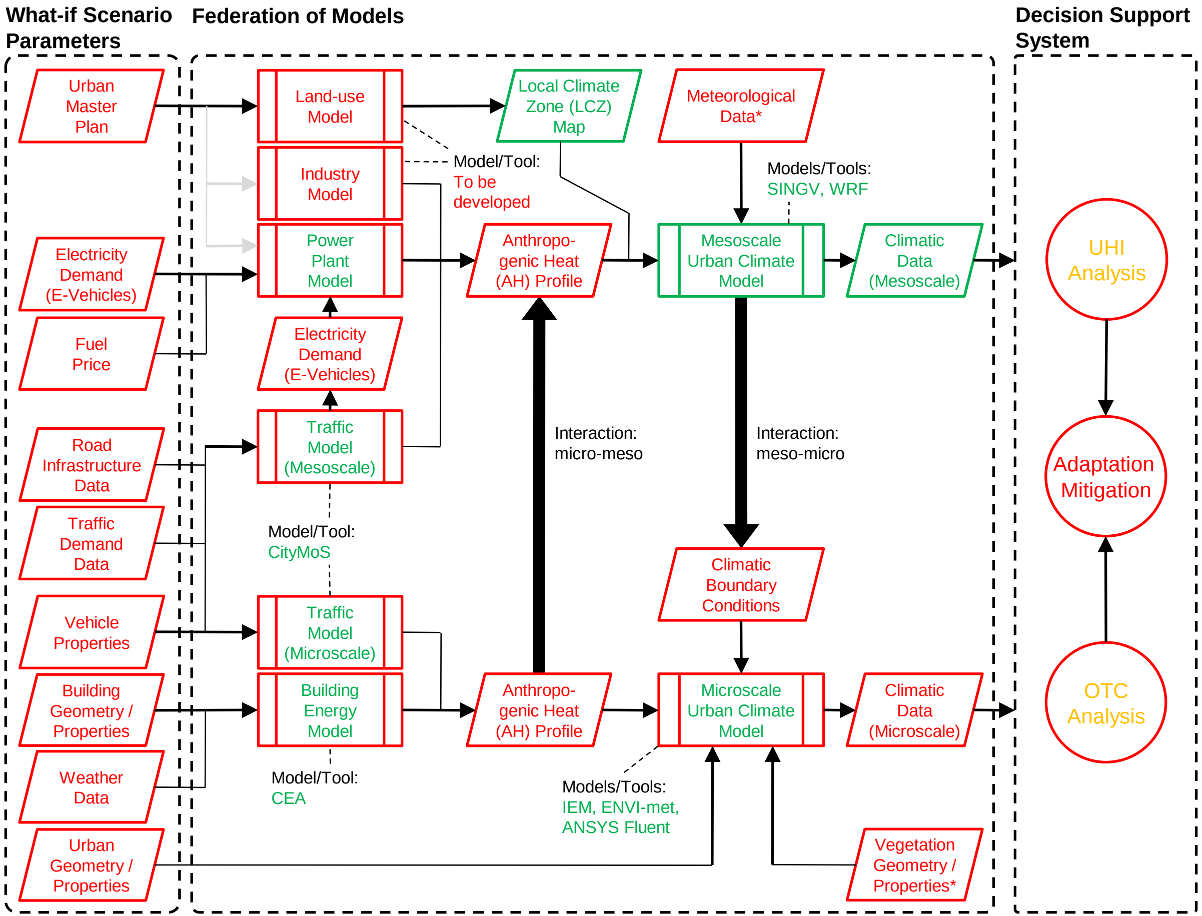
https://www.thegpsc.org/sites/gpsc/files/cooling_singapore_-_digital_urban_climate_twin.pdf

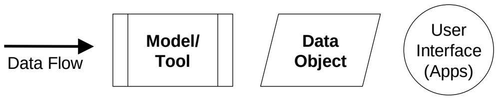
DIGITAL URBAN CLIMATE TWIN
Back-end Development

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)

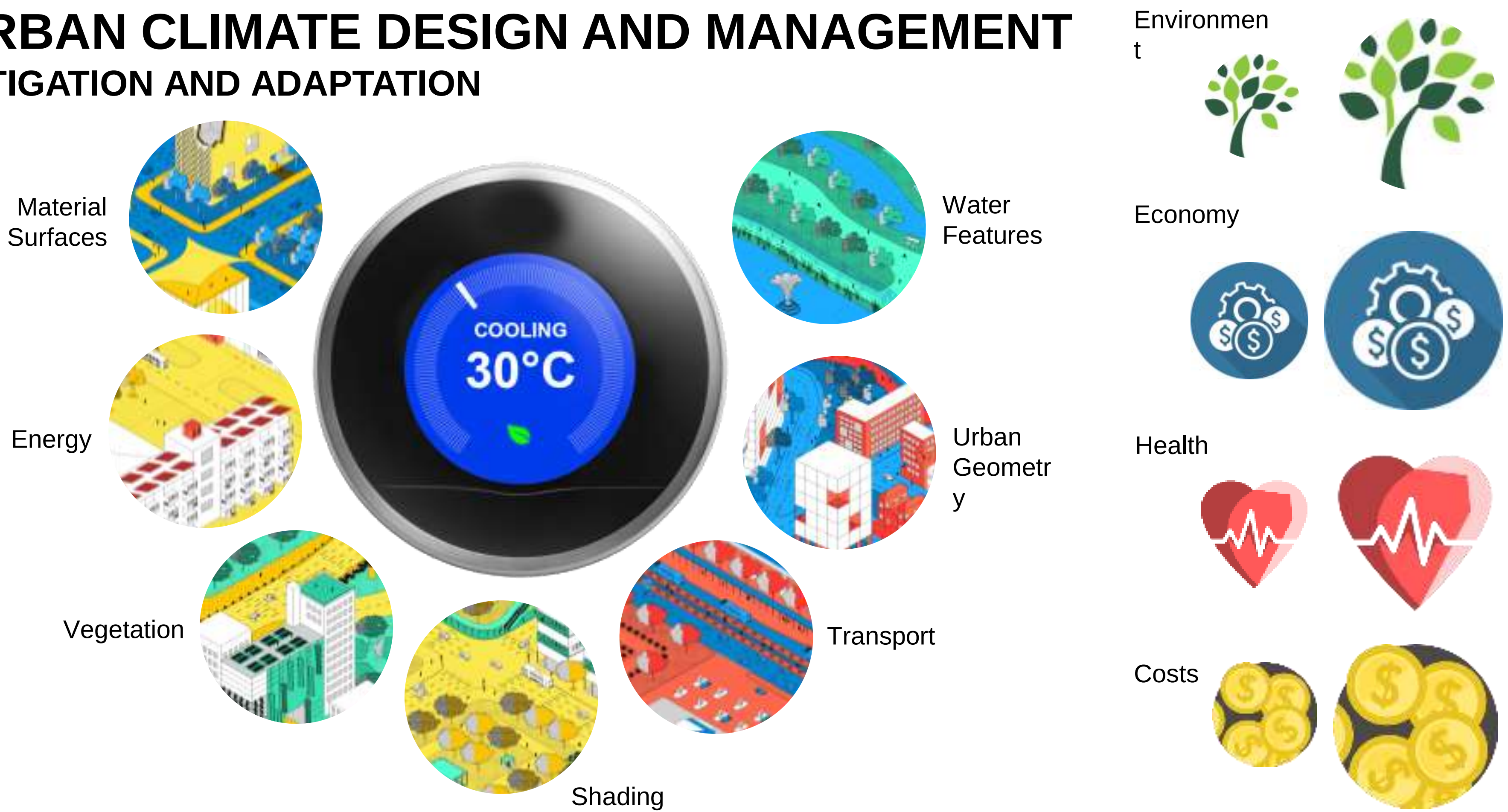




*) part of what-if scenario parameters but shown here for conciseness.

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

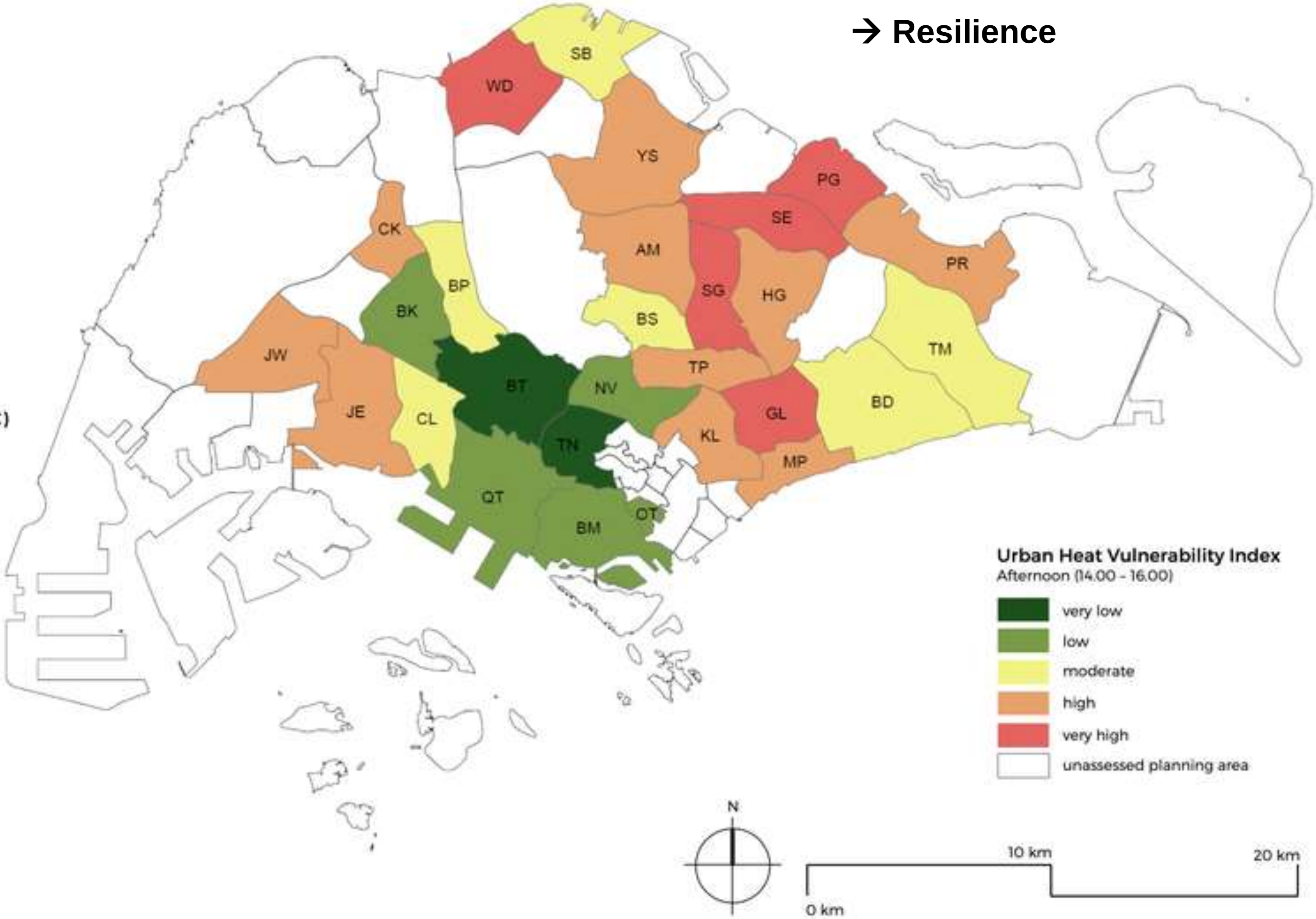
→ Resilience

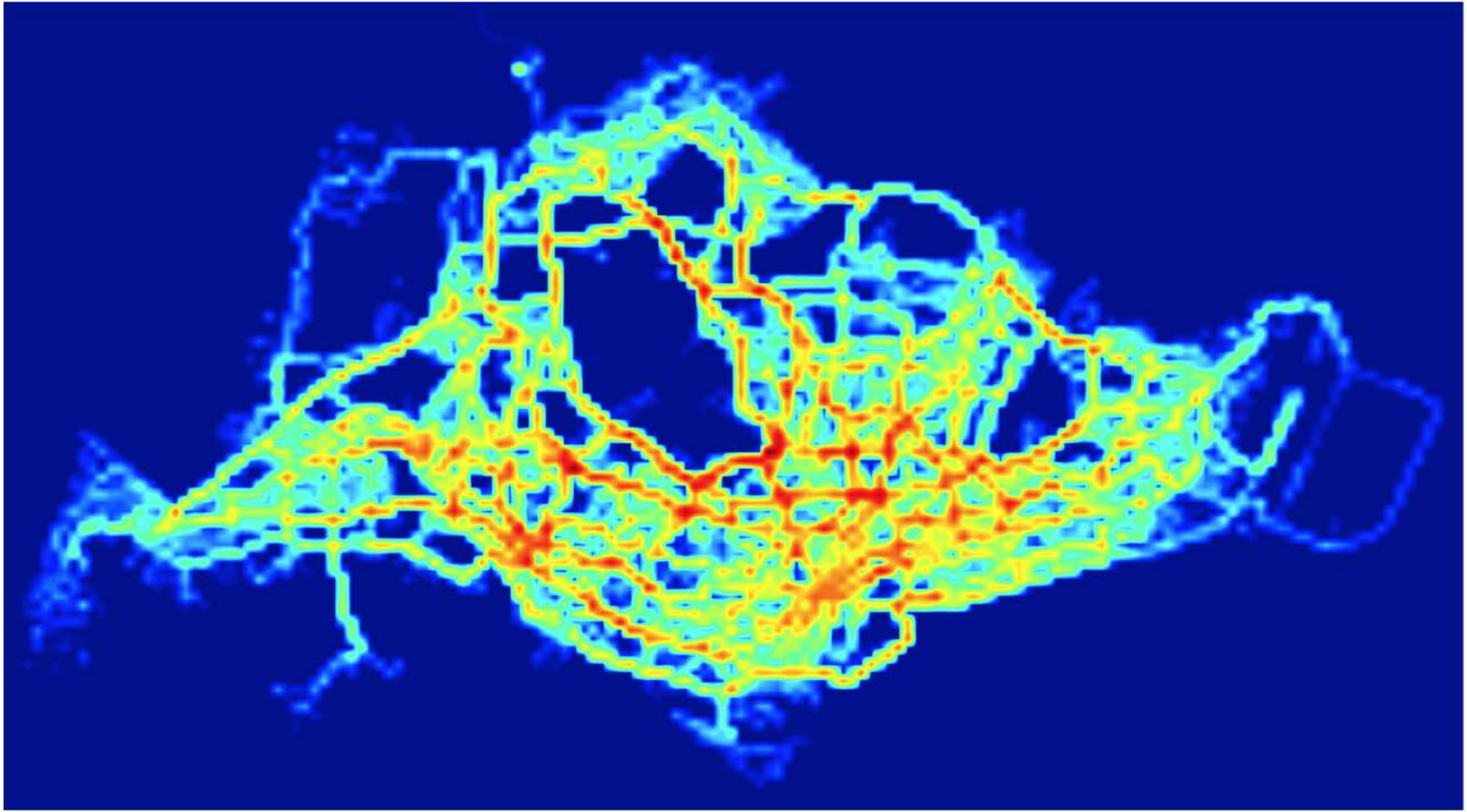
Air Temperature (°C)
Afternoon (14.00 - 16.00)

Dew Point Temperature (°C)
Afternoon (14.00 - 16.00)

Physical exposure indicators
Afternoon (14.00 - 16.00)

Sensitivity and adaptive capacity indicators

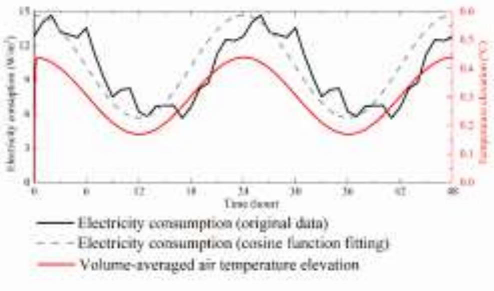


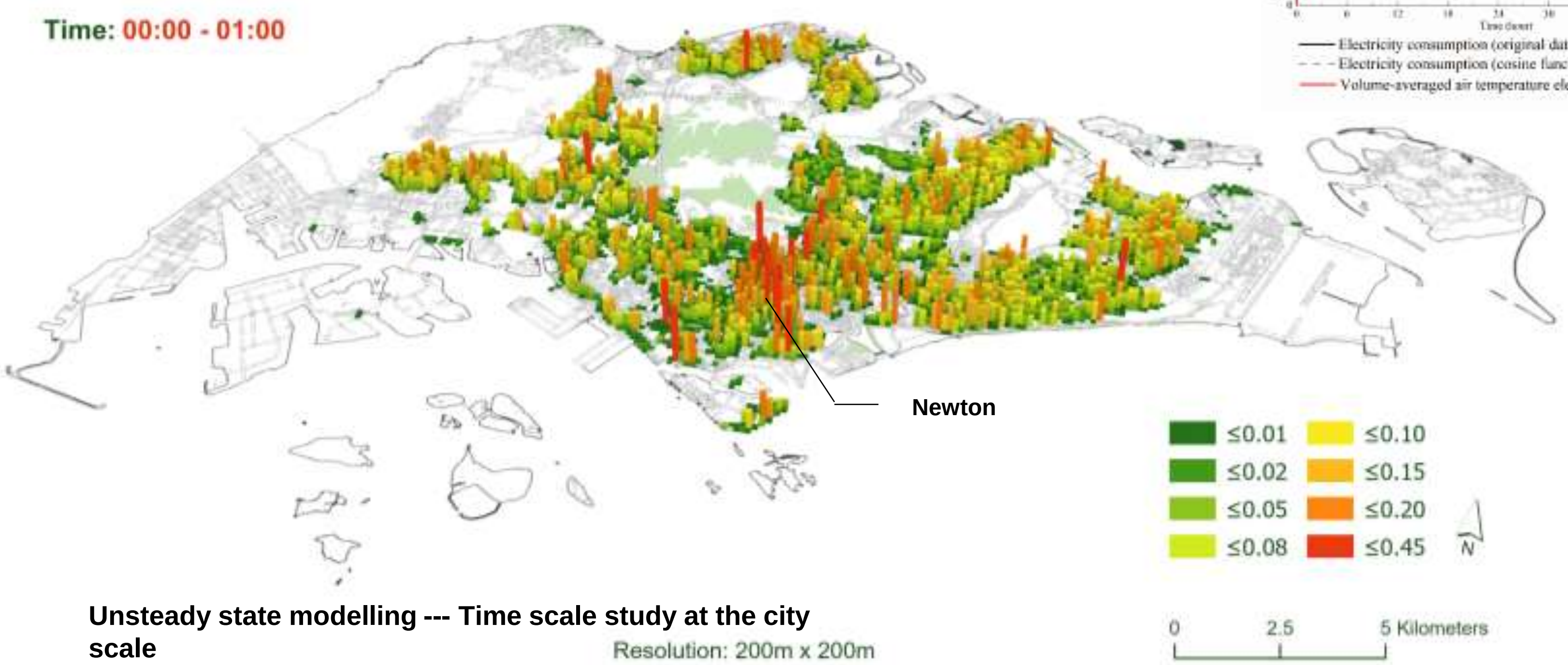


Anthropogenic Heat Dispersion at Urban Areas **Courtesy Prof. Yuan Chao, NUS**

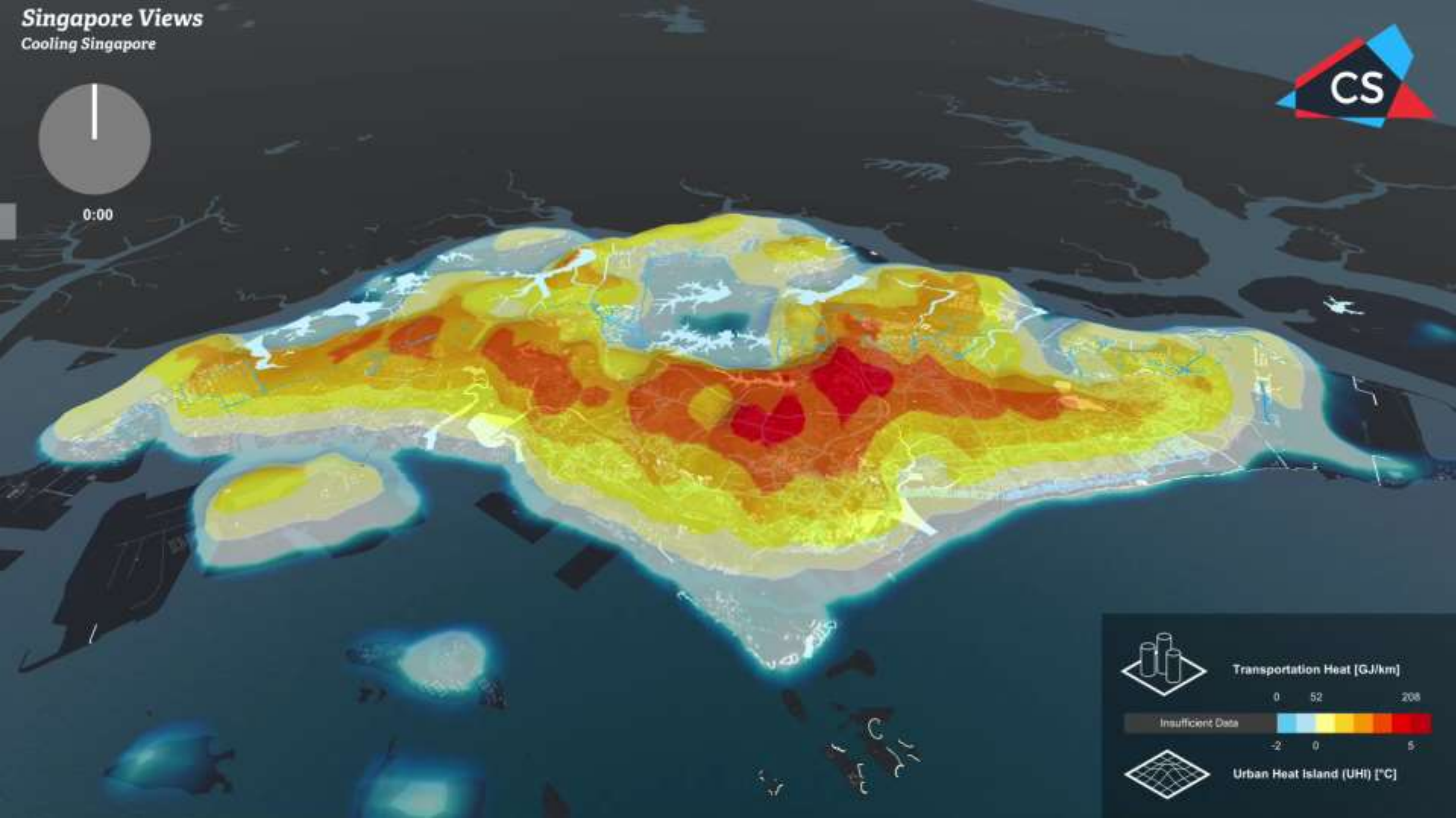
Map of Air Temperature Increment by Anthropogenic Heat Emission from Residential Buildings (°C)

Results at **Newton** as the example





Unsteady state modelling --- Time scale study at the city scale


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

COOLING SINGAPORE

Gerhard Schmitt & Heiko Aydt

Image: Lina Meisen Photography

“COOLING SINGAPORE” des Singapore-ETH Centre

CREATE | (SEC) SINGAPORE-ETH CENTRE 新加坡－ETH研究中心 | SMART | TUMCREATE | NUS National University of Singapore

Cooling Singapore

Cooling Singapore is a multi-disciplinary research project dedicated to developing solutions to address the urban heat challenge in Singapore.

Fahrul Azmi, Unsplash

(SEC) SINGAPORE-ETH CENTRE

Cooling Singapore

- About
- Partners
- Research
- Publications
- Journal & conference papers

Team

Lead Principal Investigator

- Dr Kristina OREHOUNIG

Principal Investigators

- ↗ Prof. Winston CHOW
- ↗ Prof. Markus KRAFT
- ↗ Prof. Matthias ROTH

Zusammenfassung

- Das Kühlen von Städten ist eine politische, planerische, finanzielle, technische und wissenschaftliche Herausforderung

Zusammenfassung

- Das Kühlen von Städten ist eine politische, planerische, finanzielle, technische und wissenschaftliche Herausforderung

Stadtklima und Gesundheit

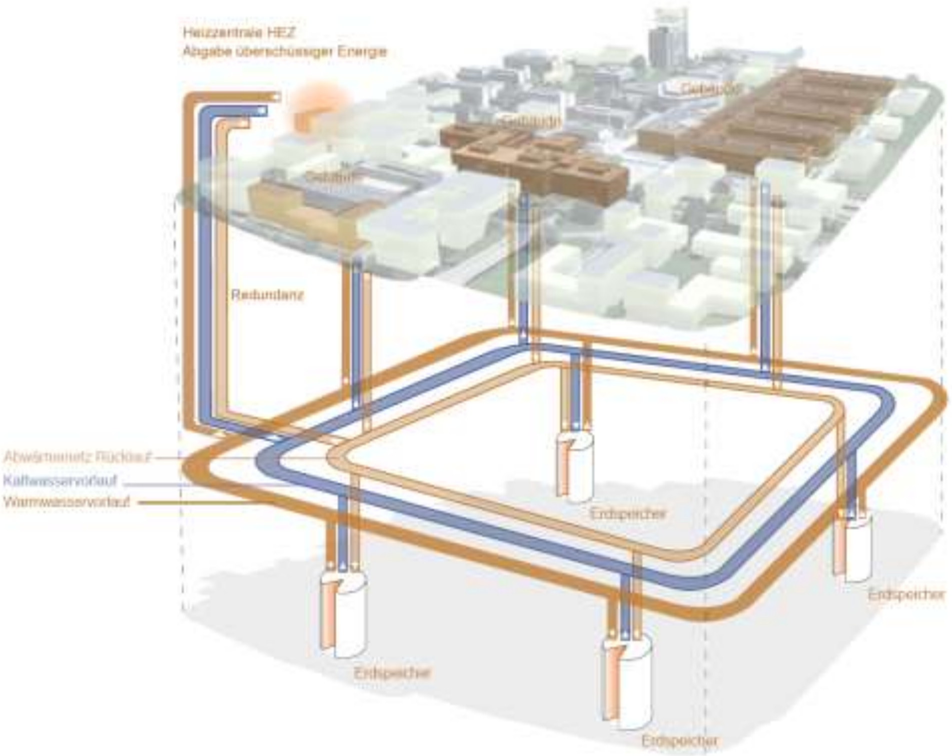
Beste Wirkung durch Sektorenkopplung: Entkarbonisierung, integrierte Mobilität als Service, lokale Energie-Gemeinschaften, intelligente Heiz/Kühlsysteme, urbane Lebensmittelproduktion

Stadtklima und Gesundheit

Weniger Abgase, weniger Lärm, weniger Hitze, bessere Elektrizitätsnetz-Nutzung, weniger Transportverkehr, bessere Gesundheit der Bevölkerung


Vielen Dank!

Master Plan Science City



Verbraucher

Verteil-Netz

Gewinnung/Speicherung

Project in operation 2019

Future Urban Systems:

Liveable
Generative
Responsive