# Welcome to BUILD UP

The European Portal for Energy Efficiency in Buildings

## WEBINAR

BUILD UP The European Portal For Energy Efficiency In Buildings

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
URBAN THERCOM
BUILD UP

WEBINAR

Grants PID2020-114873RA-C33
http://projects.ciemat.es/web/urban-thercom

# Micro-Climate Change and Envelopes

27-28 April 2023

**weblink 27** https://attendee.gotowebinar.com/register/5553039925833124444
**weblink 28** https://attendee.gotowebinar.com/register/7383370544312786009

# Agenda: Day 2

**10:00-10:50 Session 4 Energy and Climate Change**

András Reith, ABUD

Umberto Berardi, Toronto Metropolitan University; Polytechnic University of Bari

Gabriele Lobaccaro, Mattia Manni, Norwegian University of Science and Technology

Giovanni Betti, HENN

**10:50-11:50 Session 5 Envelopes in Light of Climate Change**

Jesus Lizana, University of Oxford

Miren Juaristi, Eurac

Ioannis Kousis, University of Perugia

Alessandro Cannavale, Polytechnic University of Bari

Fabio Favoino, Valentina Serra, Stefano Fantucci, Polytechnic University of Torino

**11:50-12:20 Coffee Break**

# Agenda: Day 2

**12:20-13:00 Session 6 Nature Based Envelopes for Climate Change**

Roberta Cocci Grifoni, University of Camerino

Katia Perini, University of Genova

Maria Beatrice Andreucci, University La Sapienza Rome

**13:00-13:20 Session 7 Linking Scale, Tool and Design**

Emanuele Naboni, UniPR, Royal Danish Academy, UNSW, UC Berkeley, SOS Mario Cucinella

**13:20-14:00 Conclusion and Discussion**

Emanuela Giancola, Centre for Energy, Environmental and Technological Research, CIEMAT

Emanuele Naboni, UniPR, Royal Danish Academy, UNSW, UC Berkeley, SOS Mario Cucinella

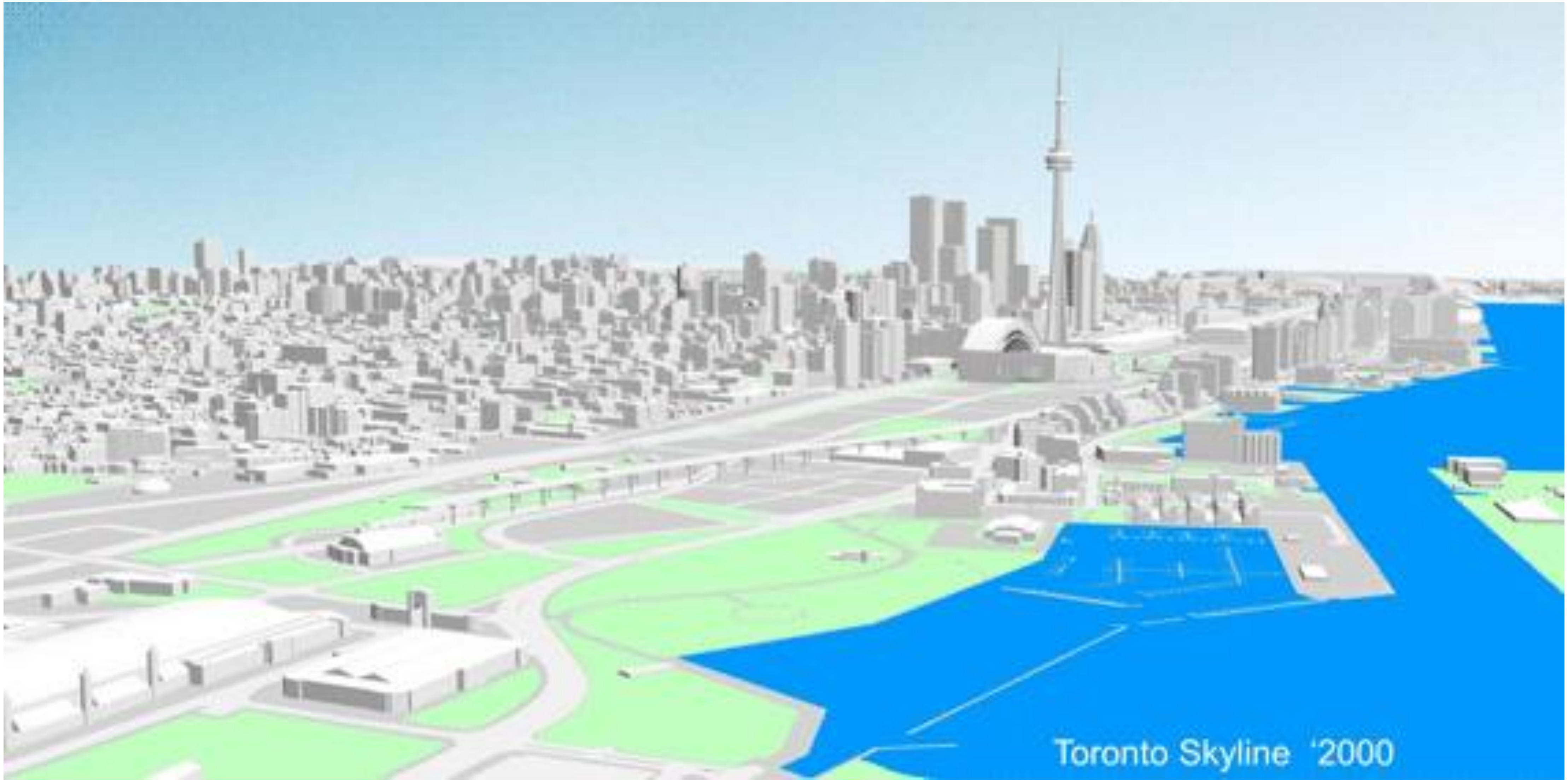
# Data driven statistical UBEM for the resilience to Climate Changes: Toronto2030 platform

**Dr. Umberto Berardi**
Canada Research Chair in Building Science

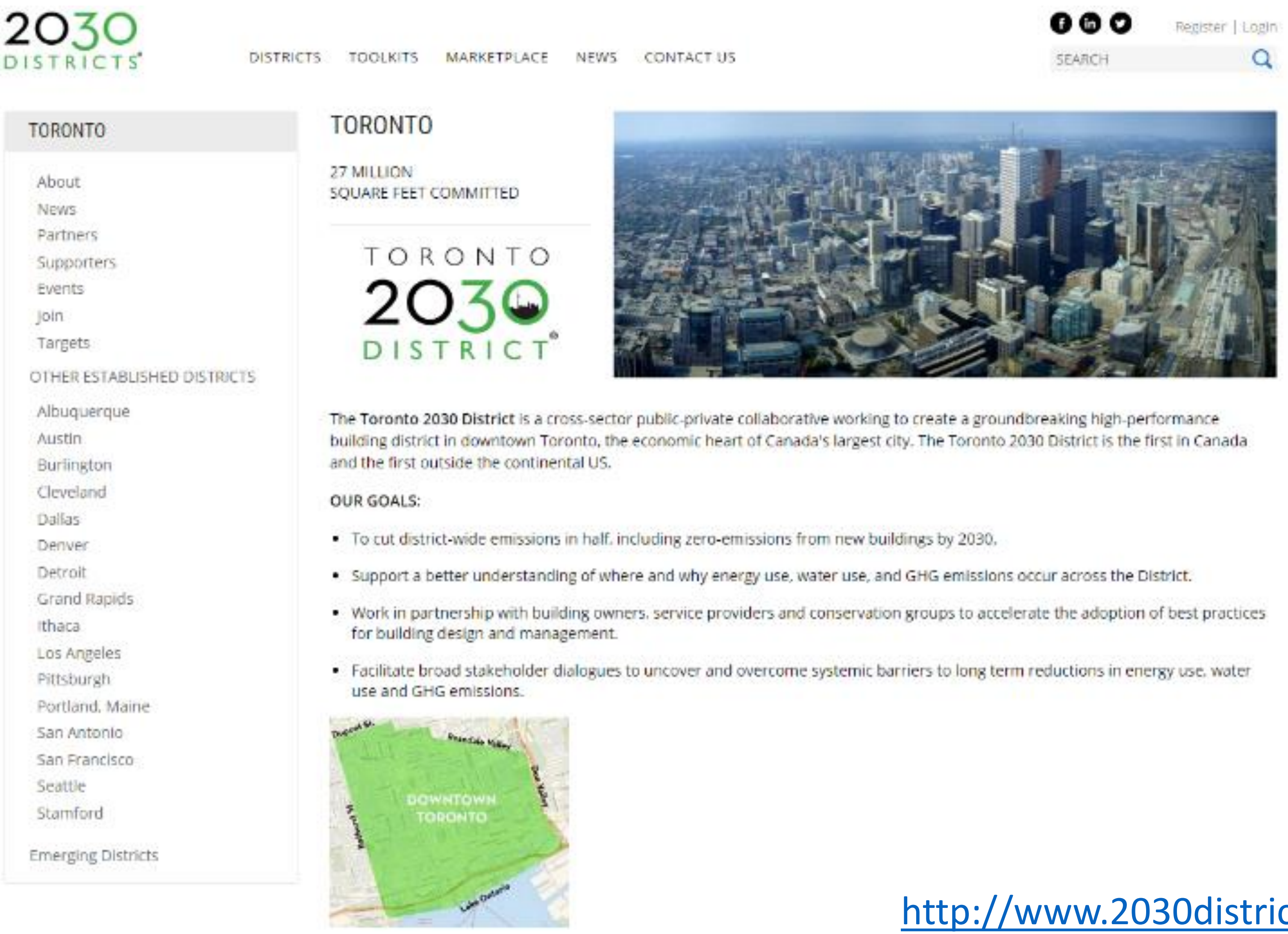
The Climate Reality Project

Toronto Metropolitan University

# BeTOP: Zero Building-Urban Energy Group

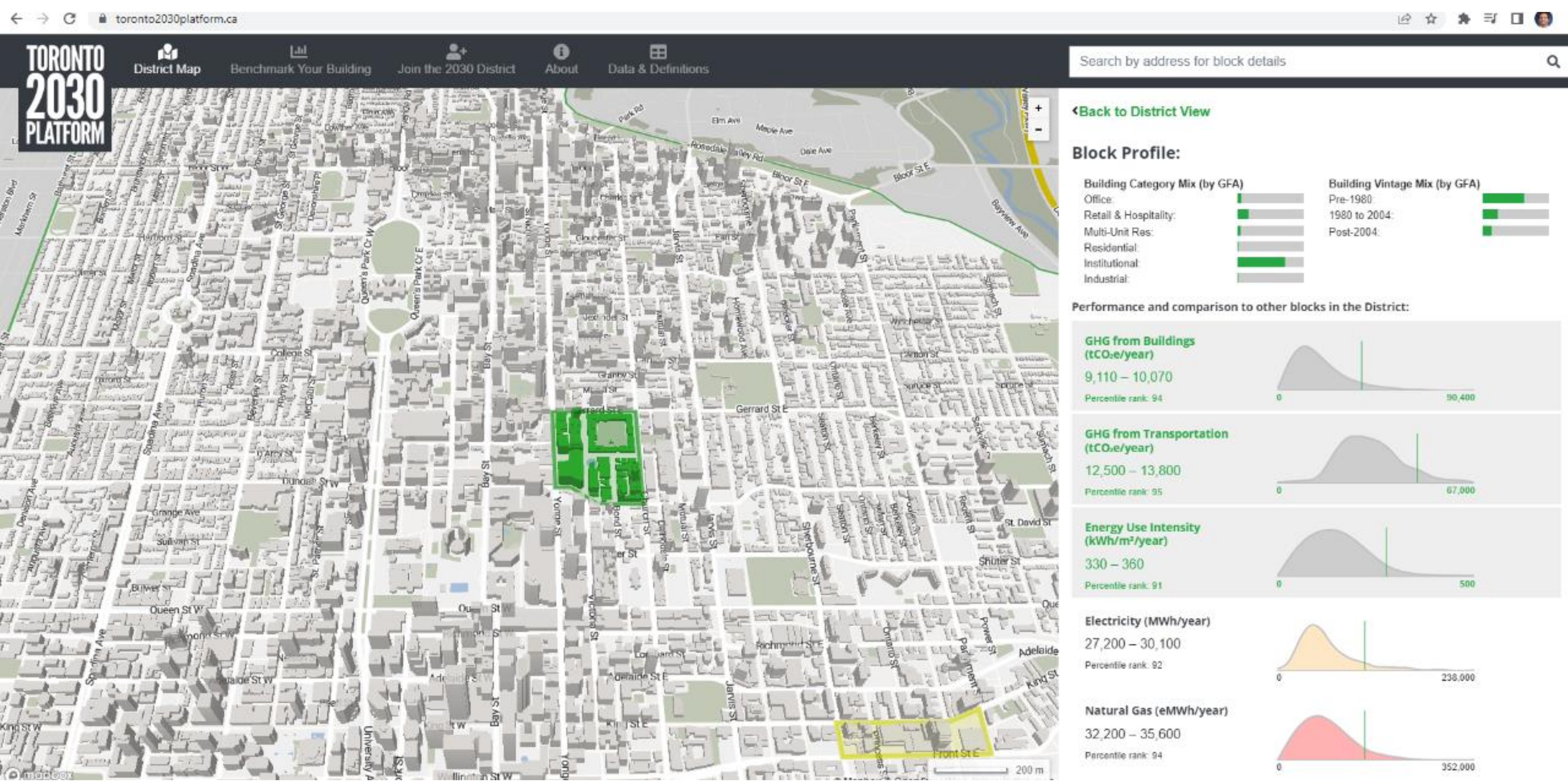


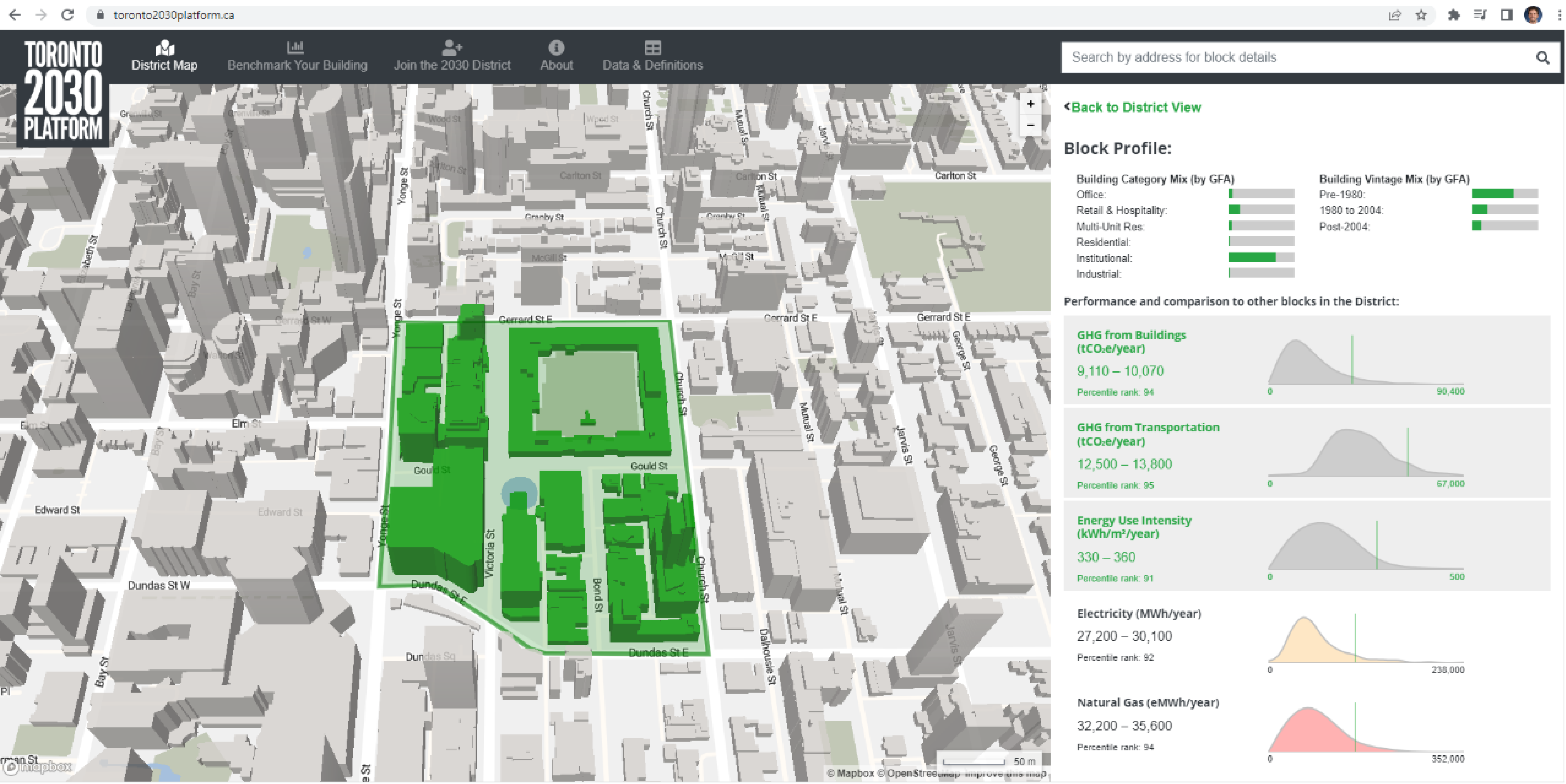
# Toronto 2030




TORONTO 2030 DISTRICT®

http://www.2030districts.org/toronto


toronto2030platform.ca
TORONTO 2030 PLATFORM
District Map
Benchmark Your Building
Join the 2030 District
About
Data & Definitions
Search by address for block details
‹Back to District View
Block Profile:
Building Category Mix (by GFA)
Office:
Retail & Hospitality:
Multi-Unit Res:
Residential:
Institutional:
Industrial:
Building Vintage Mix (by GFA)
Pre-1980:
1980 to 2004:
Post-2004:
Performance and comparison to other blocks in the District:
GHG from Buildings (tCO₂e/year)
9,110 – 10,070
Percentile rank: 94
0
90,400
GHG from Transportation (tCO₂e/year)
12,500 – 13,800
Percentile rank: 95
0
67,000
Energy Use Intensity (kWh/m²/year)
330 – 360
Percentile rank: 91
0
500
Electricity (MWh/year)
27,200 – 30,100
Percentile rank: 92
0
238,000
Natural Gas (eMWh/year)
32,200 – 35,600
Percentile rank: 94
0
352,000
Gerrard St E
Bloor St E
Dundas St W
Queen St W
Yonge St
Bay St
Jarvis St
Front St E
200 m


toronto2030platform.ca
TORONTO 2030 PLATFORM
District Map
Benchmark Your Building
Join the 2030 District
About
Data & Definitions
Search by address for block details
Back to District View
Block Profile:
Building Category Mix (by GFA)
Office:
Retail & Hospitality:
Multi-Unit Res:
Residential:
Institutional:
Industrial:
Building Vintage Mix (by GFA)
Pre-1980:
1980 to 2004:
Post-2004:
Performance and comparison to other blocks in the District:
GHG from Buildings (tCO₂e/year)
9,110 – 10,070
Percentile rank: 94
GHG from Transportation (tCO₂e/year)
12,500 – 13,800
Percentile rank: 95
Energy Use Intensity (kWh/m²/year)
330 – 360
Percentile rank: 91
Electricity (MWh/year)
27,200 – 30,100
Percentile rank: 92
Natural Gas (eMWh/year)
32,200 – 35,600
Percentile rank: 94
Gerrard St E
Dundas St E
Dundas St W
Yonge St
Church St
Victoria St
Bond St
Gould St
Elm St
Edward St
Carlton St
Jarvis St
George St
Mutual St
Dalhousie St
© Mapbox © OpenStreetMap

# Challenges

UBEM results have to be reported back to the user in spatial and/or temporal form or otherwise.

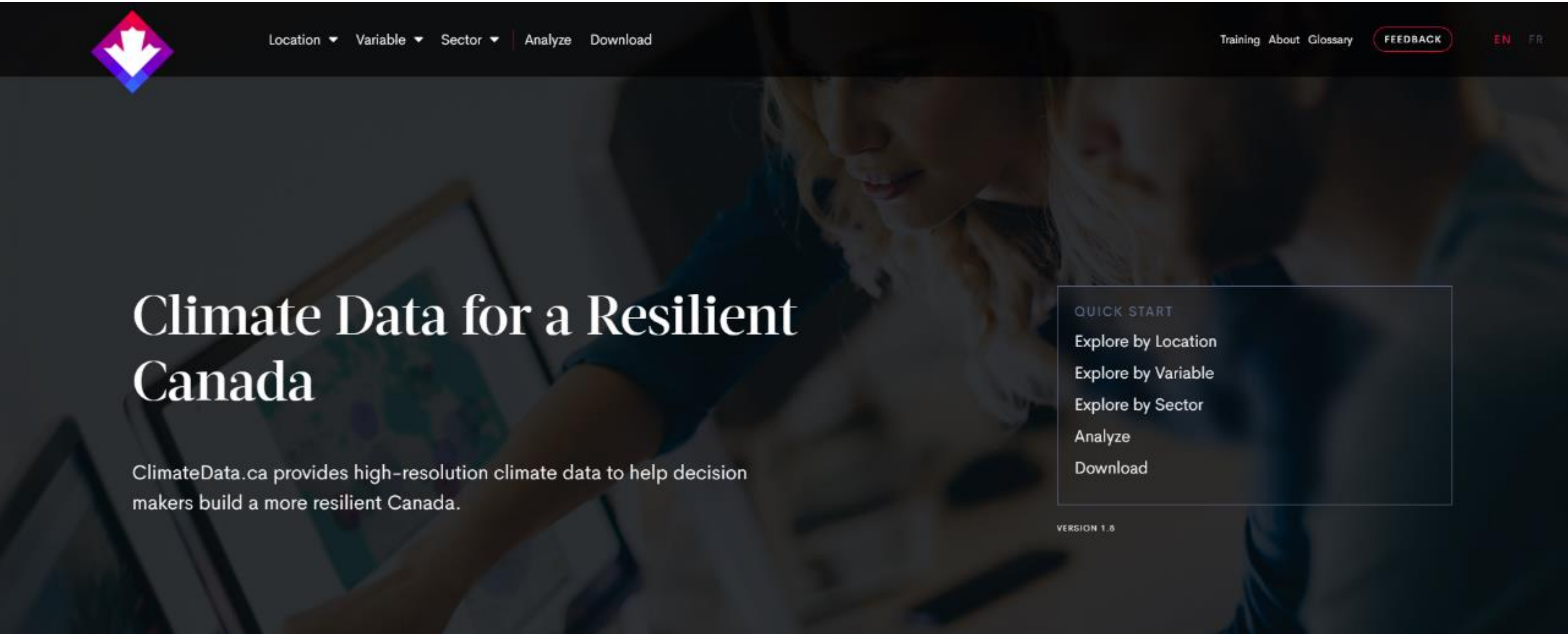
The challenge of communicating massive amounts of energy data to stakeholders as actionable information falls under the exponentially growing field of **big data visualization**..

Privacy concerns oftentimes preclude utilities or public agencies to release data and in doing so to calibrate model

Building occupants should be treated as individual agents rather than identical robots. Stochastic user behavior models are needed.

Stronger intellectual engagement between planners, policymakers, utility representatives and the building modeling community is necessary.

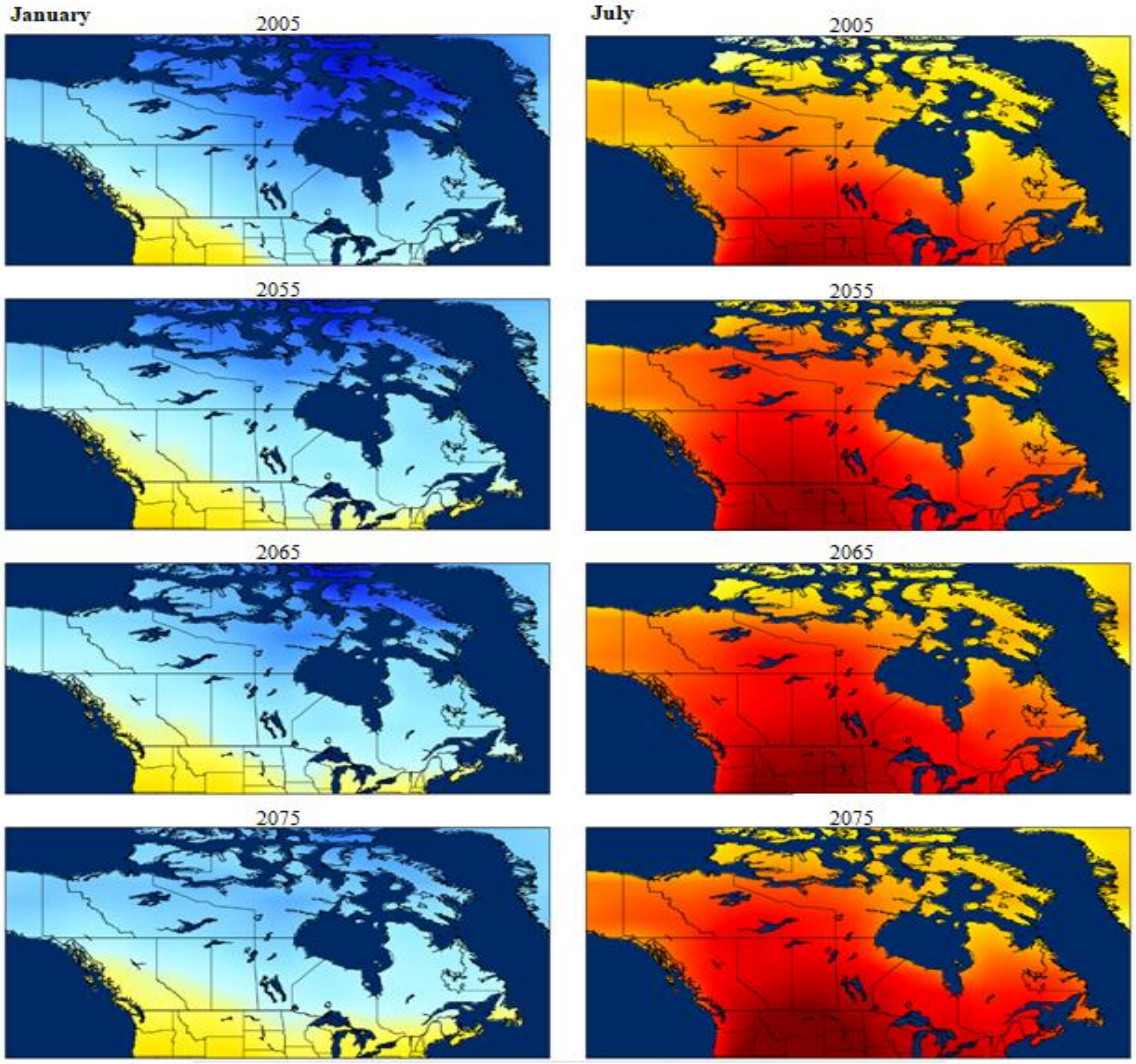
# Climate change impact on buildings and climate

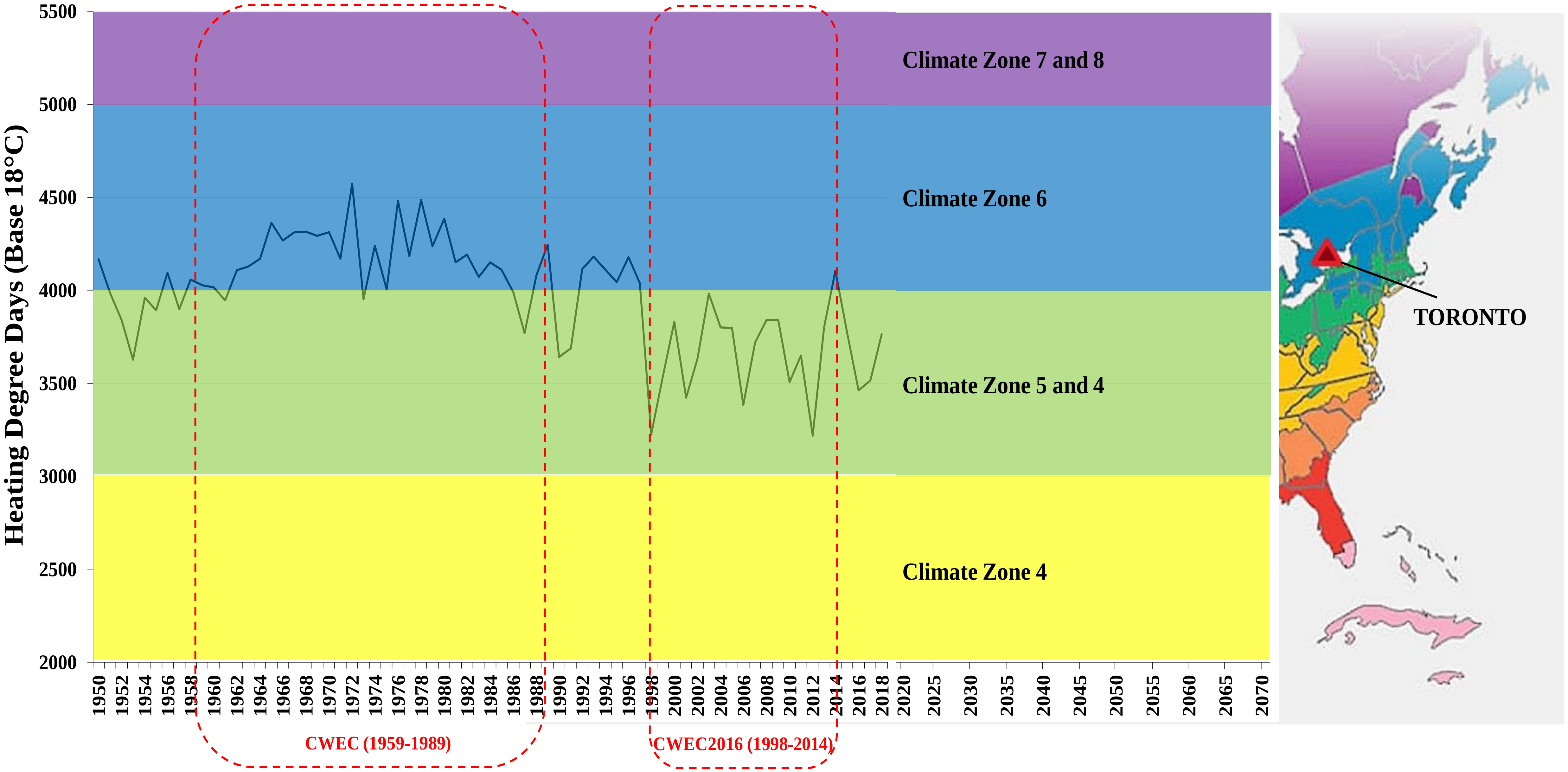


# Canada

IPCC - RCP 8.5:

Temperatures in Canada under CanESM2 (Global Climate Model [GCM]) projections for 2055, 2065, and 2075 compared to 2005 temperatures

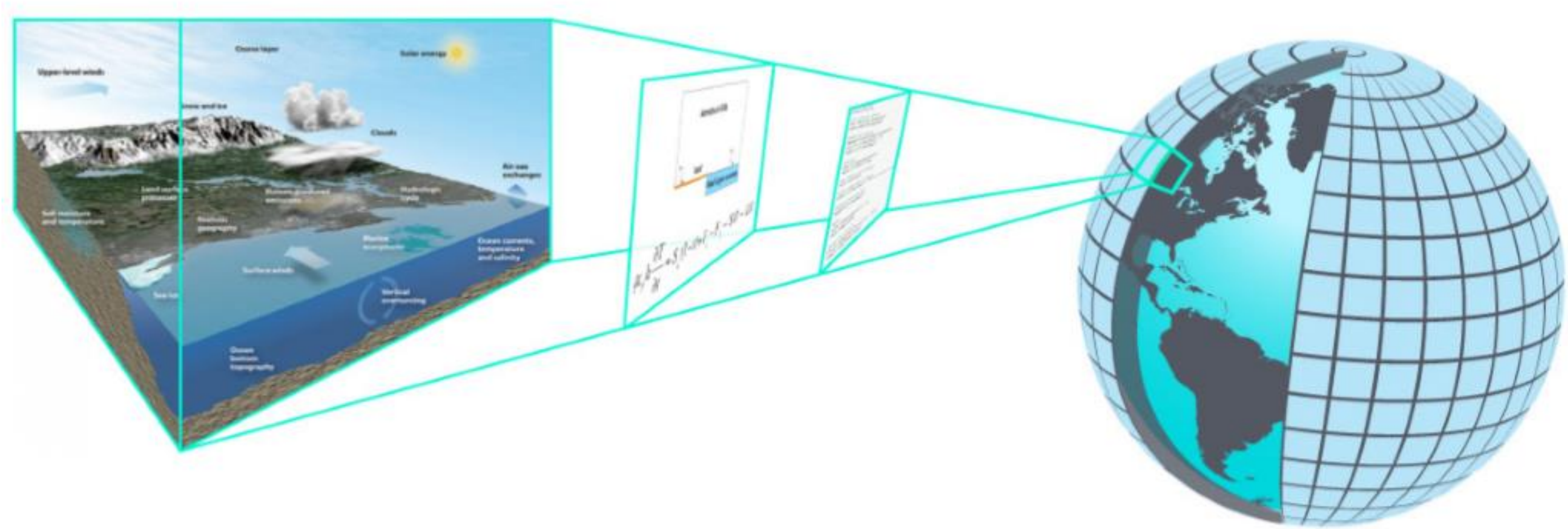


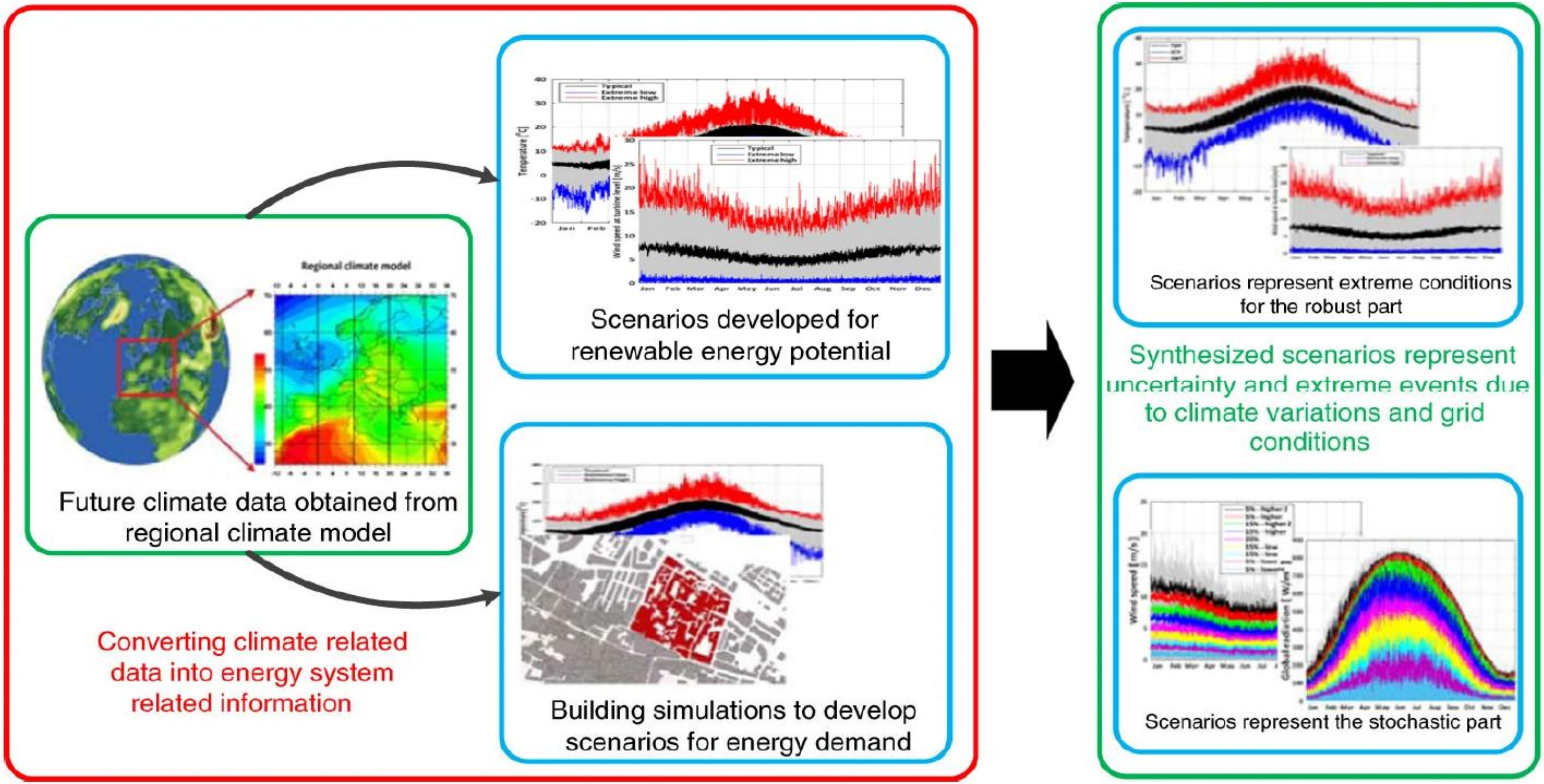
Heating Degree Days (Base 18°C)
5500
5000
4500
4000
3500
3000
2500
2000
Climate Zone 7 and 8
Climate Zone 6
Climate Zone 5 and 4
Climate Zone 4
TORONTO
CWEC (1959-1989)
CWEC2016 (1998-2014)
1950 1952 1954 1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070

# Creating Future Weather Files – WRF

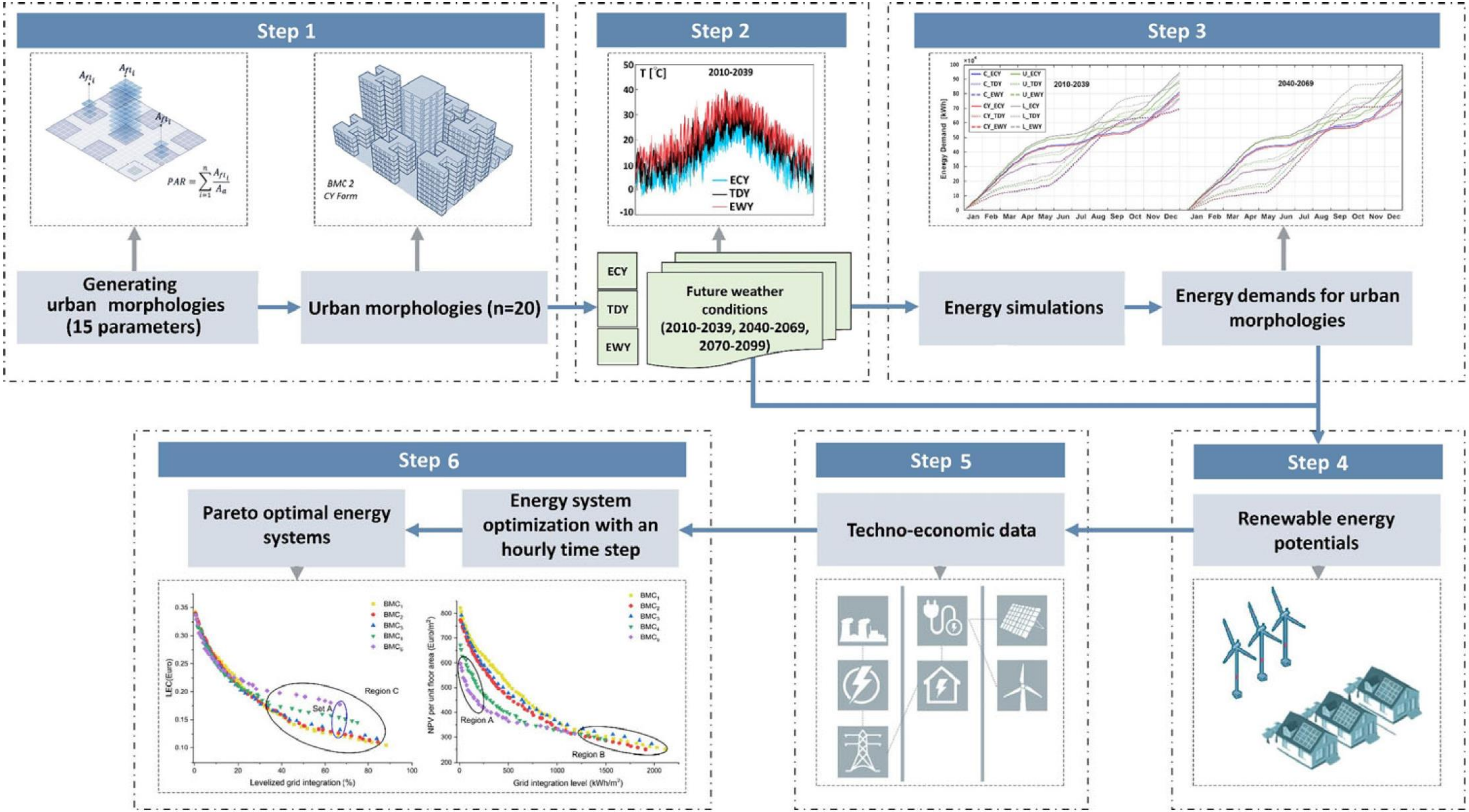
- Complex computer models are used to reconstruct atmosphere, ocean, and land interactions
- Mathematical equations describing physical processes are solved on three-dimensional grid



The interlinks between climate models and energy models are not straightforward. We need to develop a workflow to synthesize a pool of scenarios and link climate models with energy system models.



# Interconnected infrastructures in urban areas – Urban climate and extreme weather events



# Study 1

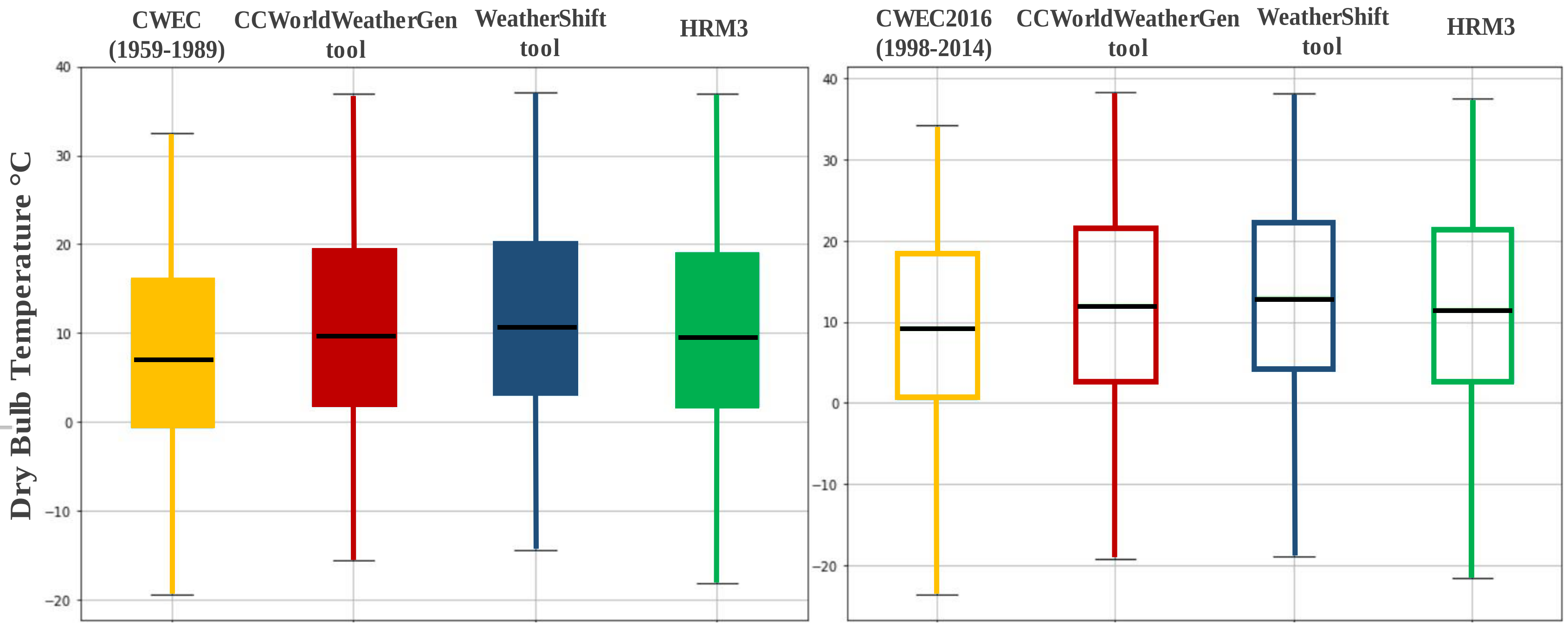
## IMPACTS OF CLIMATE CHANGE ON BUILDING HEATING AND COOLING ENERGY DEMAND IN TORONTO

Investigate the effects of climate changes on the heating and cooling energy demand of buildings in the most populated urban region in Canada, i.e. the City of Toronto using various climate models.

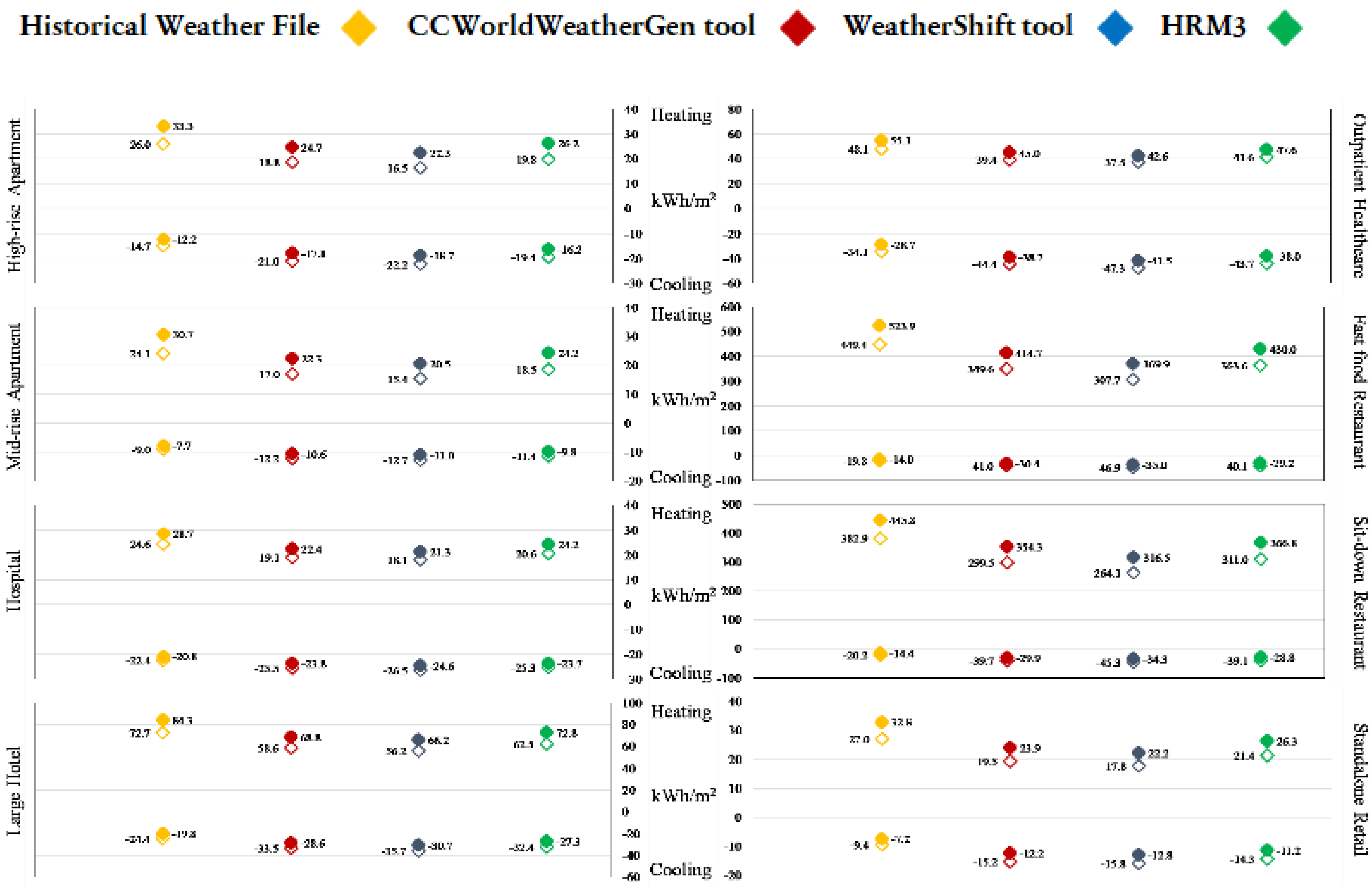
# Future weather files for Toronto

➢ The future weather files forecast a mean temperature increase of 3.7–4.5 C for Toronto. This increase is 2.0 C greater than the IPCC forecast of global mean surface temperature

| Weather Files | HDD |
|---|---|
| CWEC (1959-1989) | 4,179 |
| *CCWorldWeatherGen tool* | 3,427 |
| *WeatherShift tool* | 3,157 |
| *HRM3* | 3,509 |
| CWEC2016 (1998-2014) | 3,695 |
| *CCWorldWeatherGen tool* | 3,033 |
| *WeatherShift tool* | 2,769 |
| *HRM3* | 3,122 |



# Results: Building Energy Simulation




Heating and Cooling Energy Use Intensity (EUI)

# Study 2

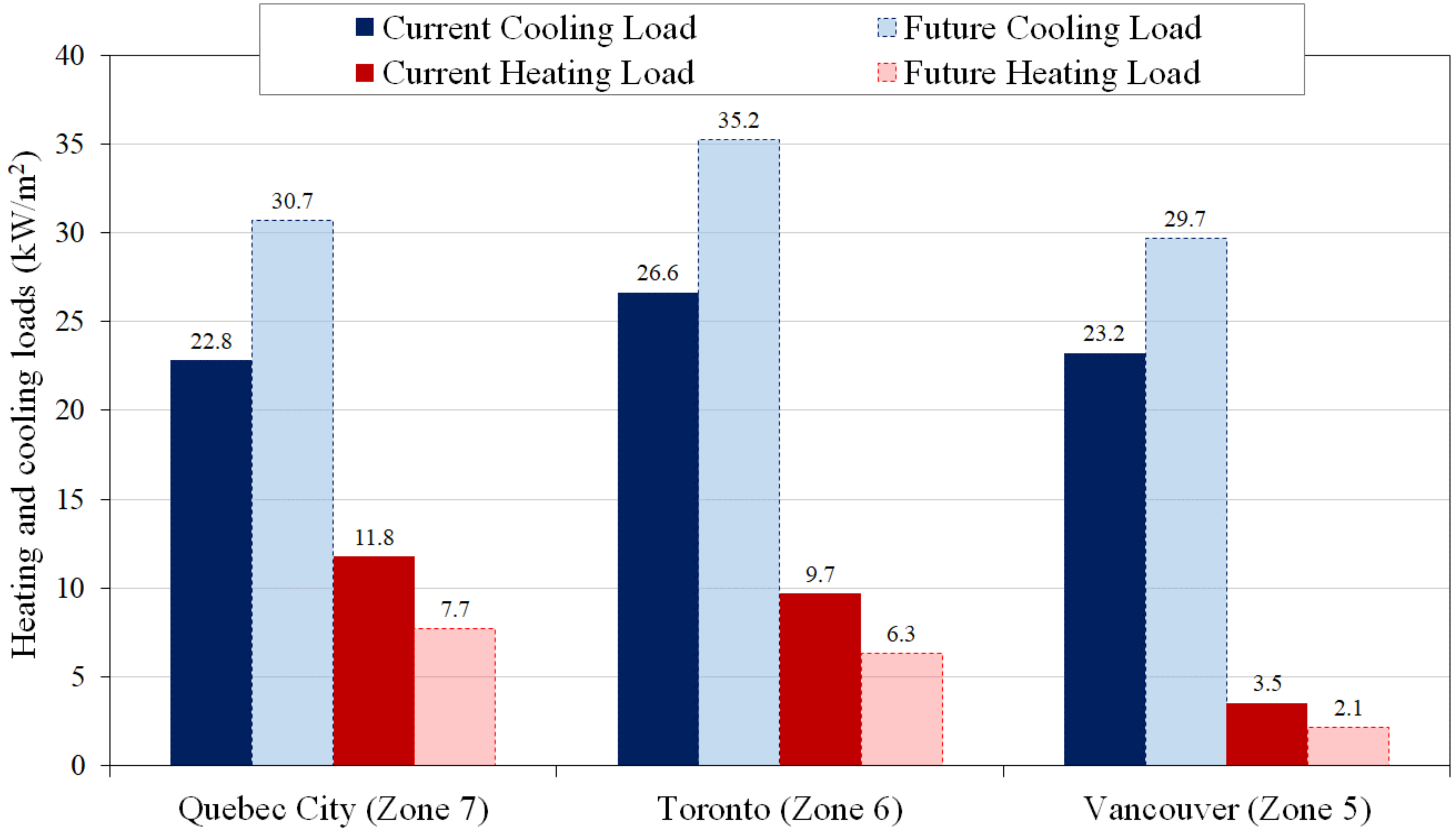
## INFLUENCE OF SETPOINT TEMPERATURE ON THE ENERGY DEMAND

Quantify the energy demand for various thermal comfort target of a office building in three climate zones across Canada: Vancouver (cool-humid), Toronto (cold-humid), and Quebec City (very cold).

# Results: cooling and heating loads

There is an increasing trend in cooling load across all cities for the future.

The projected increase in cooling load varies between cities, corresponding to the magnitude of temperature increases in summer.

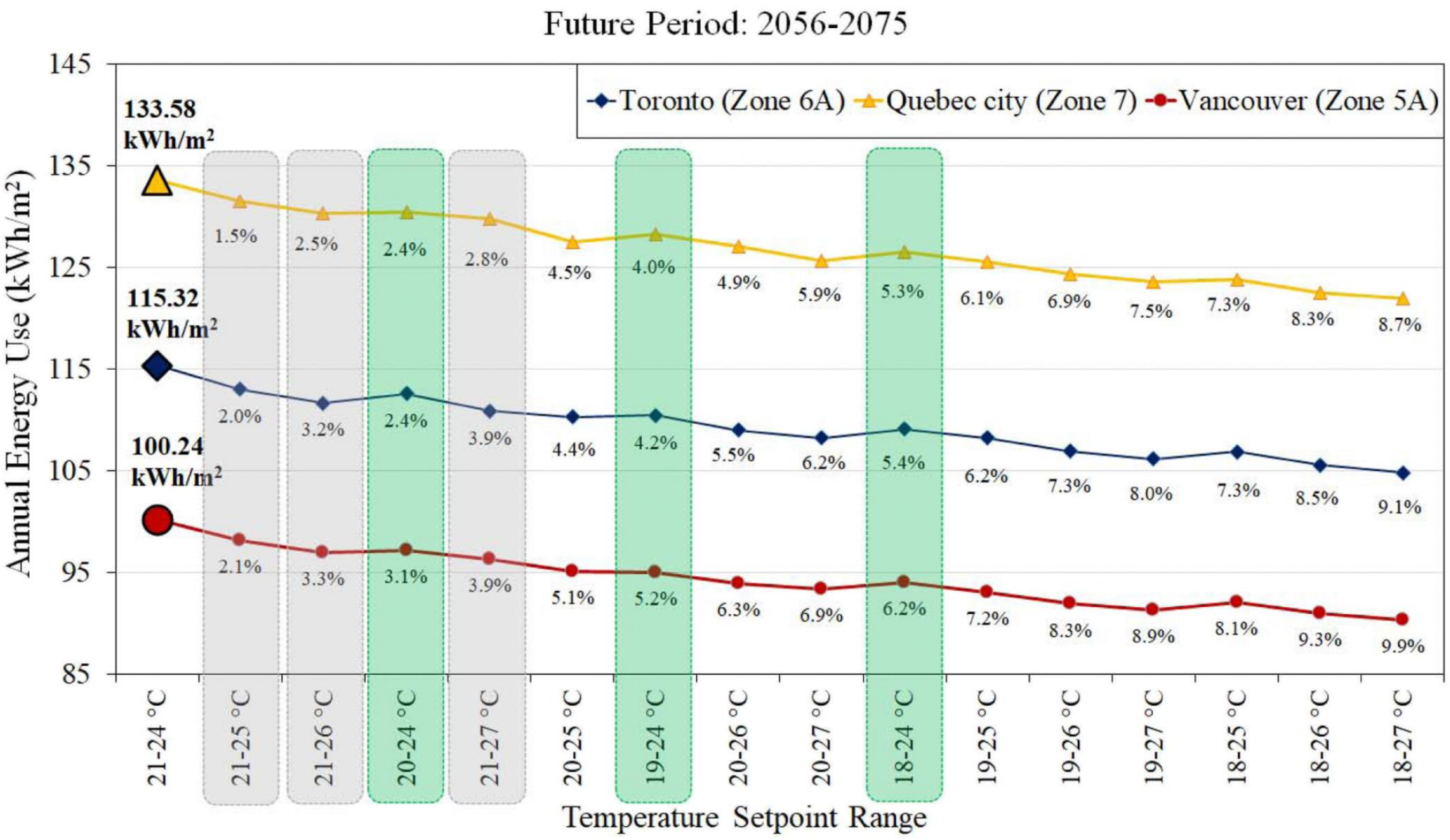


# Results: cooling and heating loads

**Quebec City:** Decreasing heating setpoint by 1°C reduced energy use by an average of 3.8%, while increasing cooling setpoint by 1°C resulted in an average saving of 2.4%.

**Toronto:** 1°C reduction in heating setpoint lowered energy use by an average of 2.0% and a rise of 1°C in cooling setpoint saved an average of 0.9%.

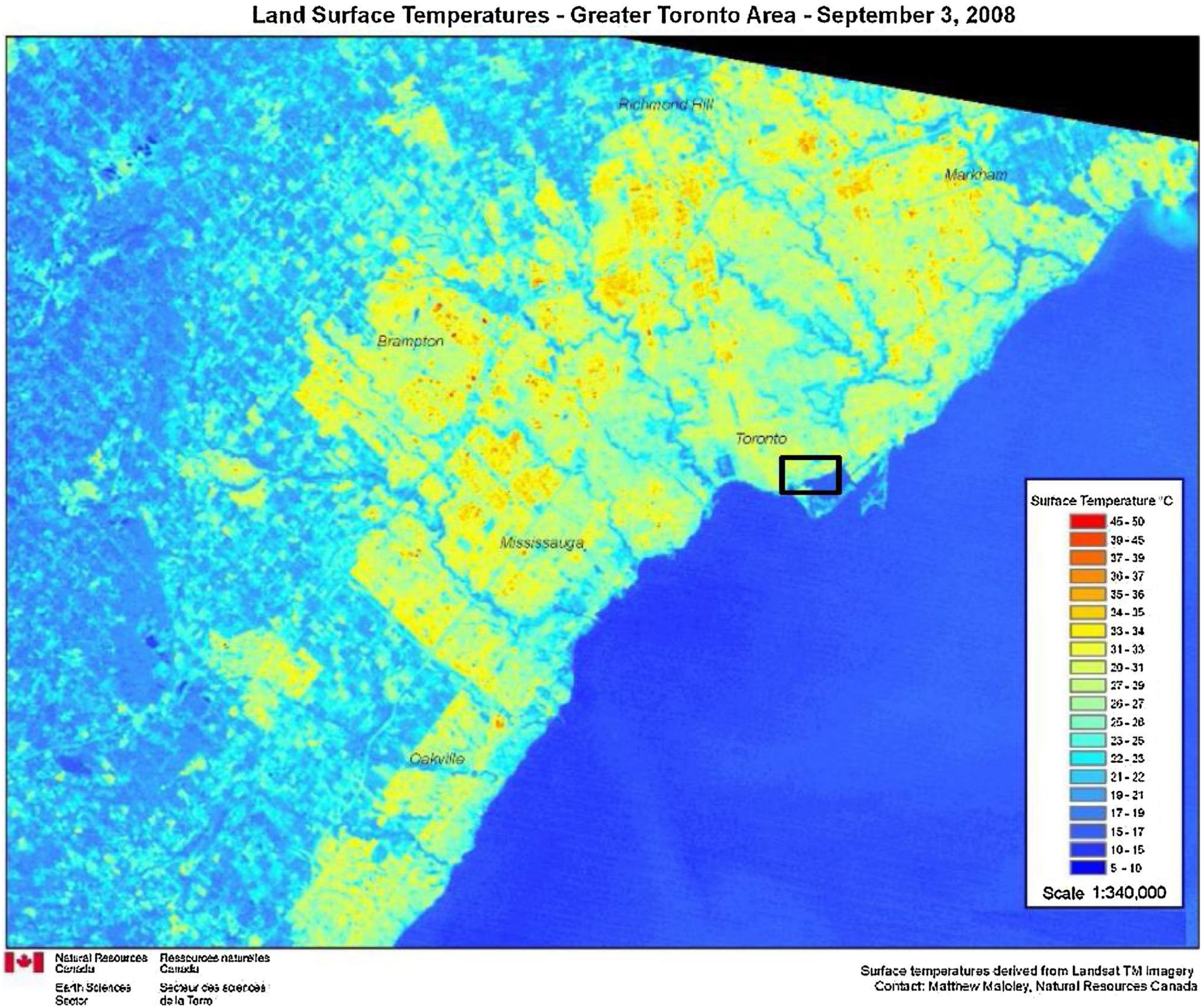
**Vancouver:** Decreasing heating and increasing cooling setpoints resulted in an average saving of 2.3% and 0.8% for every 1°C.



# Study 3

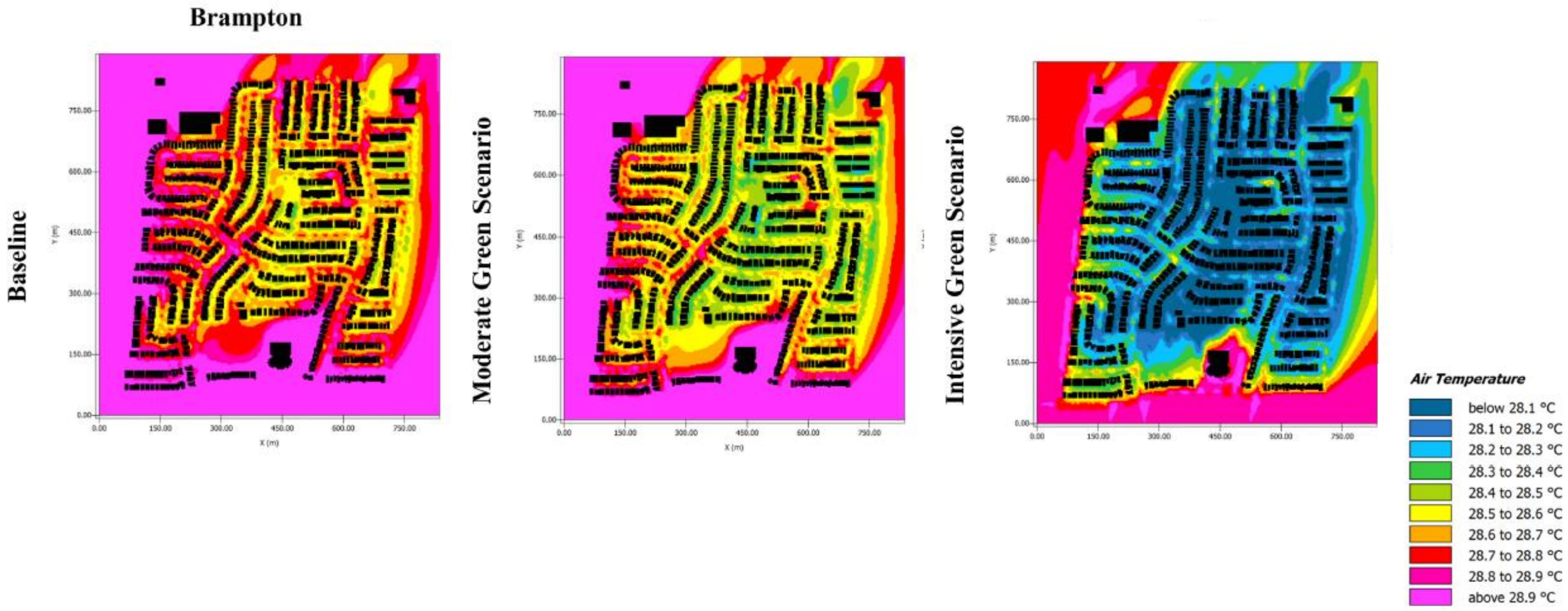
## URBAN HEAT ISLAND (UHI) and (MICRO-)CLIMATE

# UHI



Land Surface Temperatures - Greater Toronto Area - September 3, 2008
Richmond Hill
Markham
Brampton
Toronto
Mississauga
Oakville
Surface Temperature °C
45 - 50
39 - 45
37 - 39
36 - 37
35 - 36
34 - 35
33 - 34
31 - 33
29 - 31
27 - 29
26 - 27
25 - 26
23 - 25
22 - 23
21 - 22
19 - 21
17 - 19
15 - 17
10 - 15
5 - 10
Scale 1:340,000
Natural Resources Canada
Earth Sciences Sector
Surface temperatures derived from Landsat TM imagery
Contact: Matthew Maloley, Natural Resources Canada

# Mesoscale (WRF) and microscale (Envi-met) modeling



# Next steps

1. Real-time evaluation for balancing energy networks
2. Synergies (and energy exchanges) between different subsystems
3. Integration of technical aspects with user behaviors
4. Integration of historical data but also of externality and uncertainties
5. Availability of large computer clusters for launching massive parallel simulations
6. ..finally, ability to visualize, share and manage future energy consumption

# Data driven statistical UBEM for the resilience to Climate Changes: Toronto2030 platform

**Dr. Umberto Berardi**
Canada Research Chair in Building Science

The Climate Reality Project

Toronto Metropolitan University

# HELIOS

## Enhancing exploitation of solar energy at high latitudes through the digitalization of the built environment

Mattia Manni
Postdoc Fellow
mattia.manni@ntnu.no

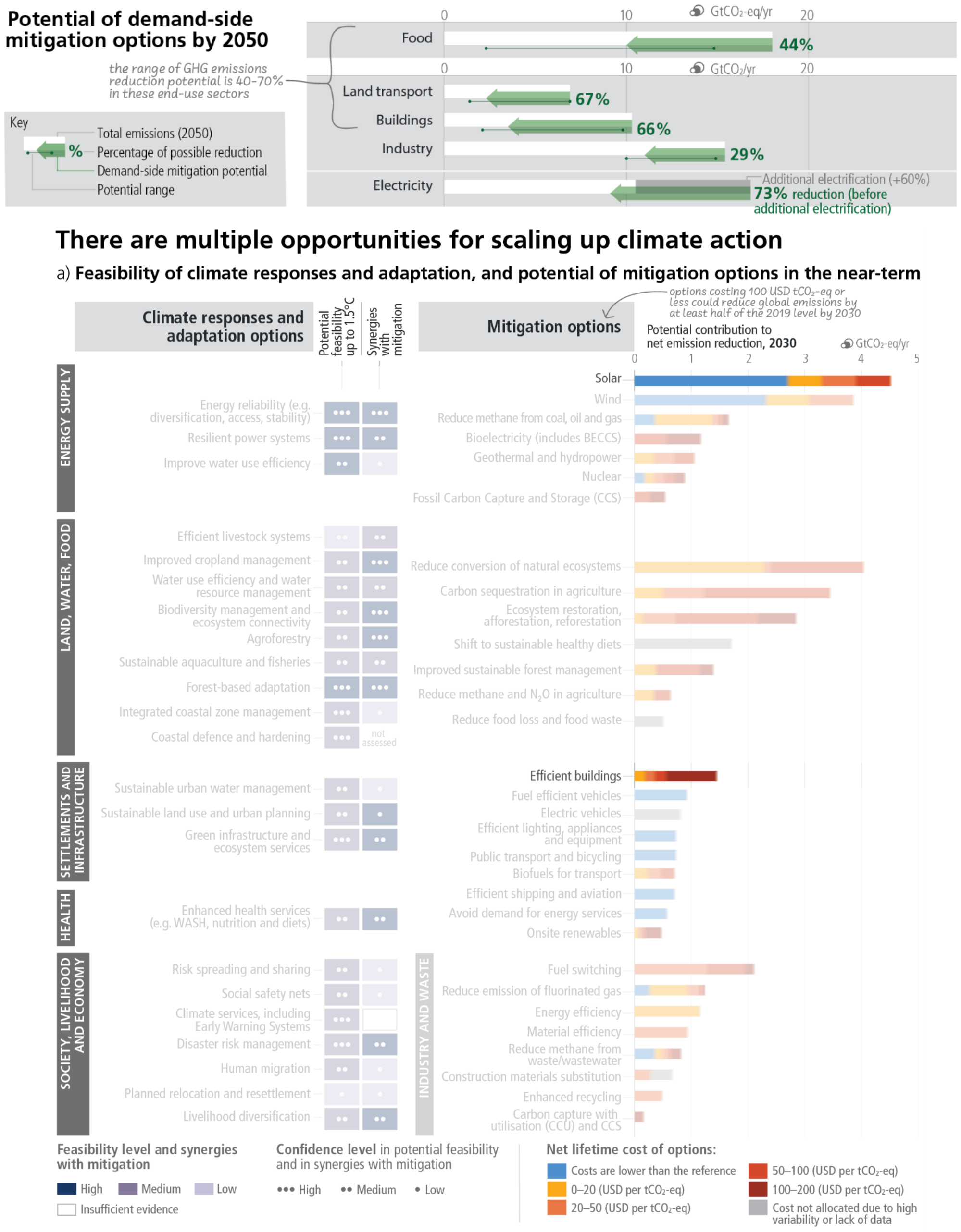
NTNU
Fakultet for ingeniørvitenskap
Institutt for bygg- og miljøteknikk

# Digitalization for solar energy exploitation at high latitudes

**By 2050**, the GHG emissions from the **building sector** are expected to be reduced by **66%**

Optimal and full exploitation of building **solar potential** can positively impact on **solar energy supply** and building's **energy efficiency**

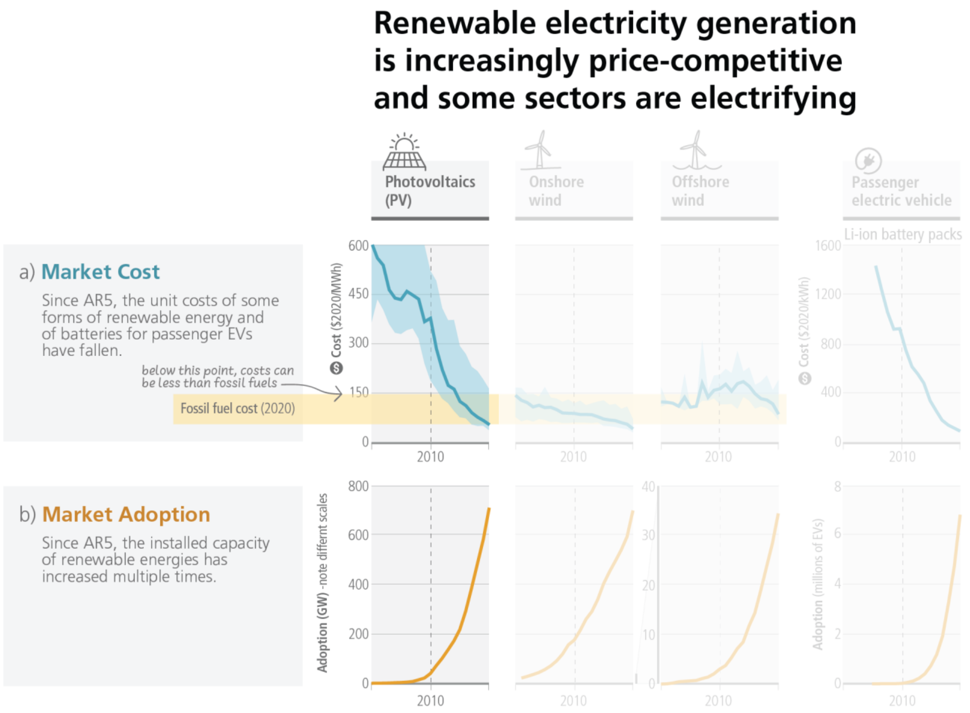
**Land use** and **habitat loss** represent **risks** associated to the uncontrolled and unplanned exploitation of solar energy




From *Synthesis report of the IPCC Sixth Assessment Report (AR6)*, March 2023

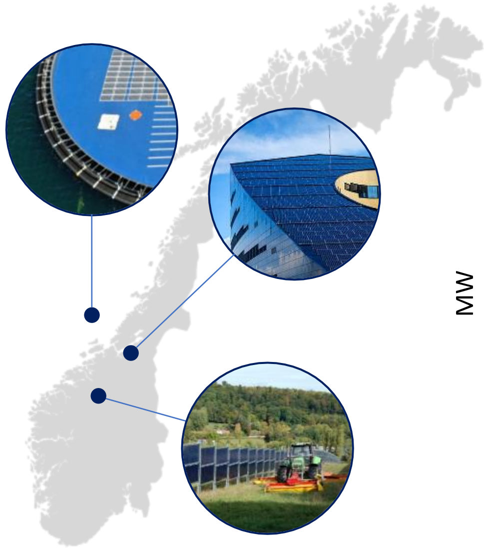
The **unit costs** of solar technologies have fallen consistently since 2010

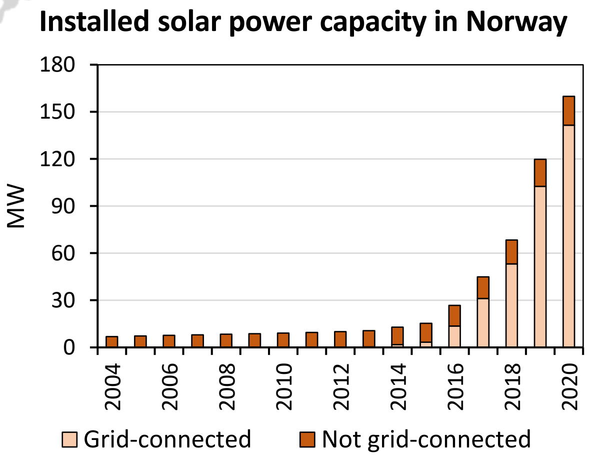
**Near-commercial availability** of low and zero emissions options in buildings, transport and industry




## In **Norway**:

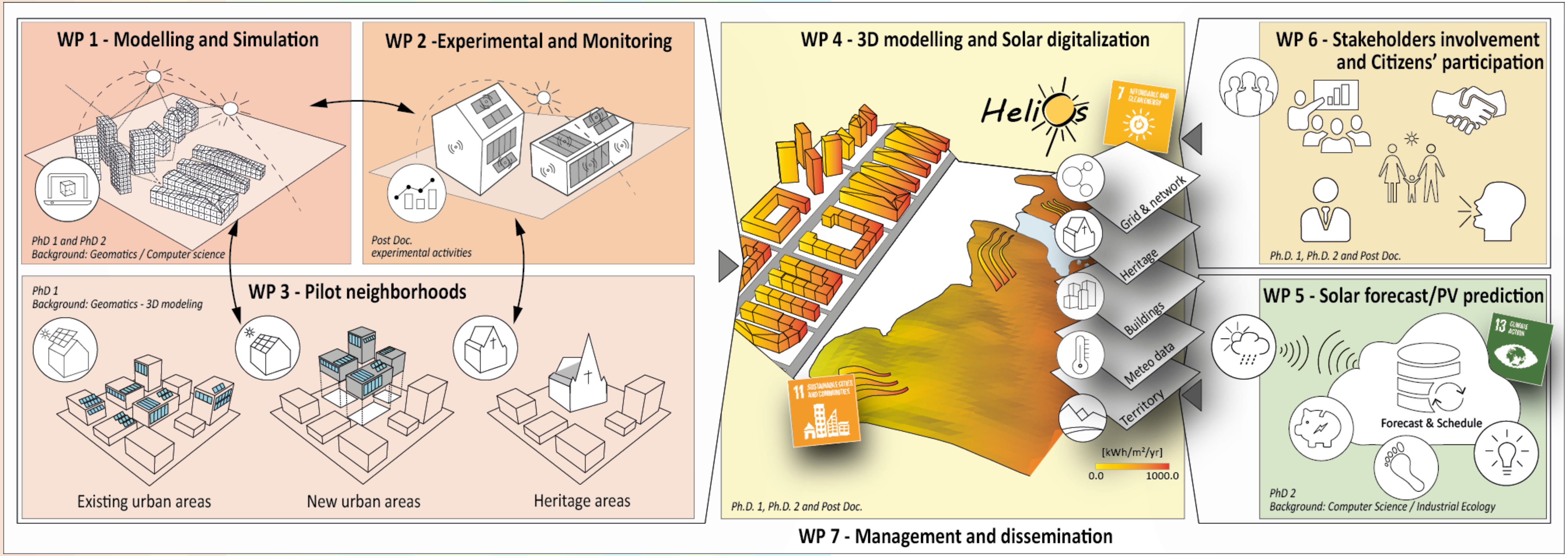
- Installed capacity for solar power in Norway has increased tenfold during the last five years
- **New opportunities** for solar energy (i.e., building-integrated photovoltaic, agrivoltaic, floating solar systems)
- Needs for **tools** and **platforms** such as the Solar Cadaster to support designers and urban planner






From *Synthesis report of the IPCC Sixth Assessment Report (AR6)*, March 2023

# Digitalization for solar energy exploitation at high latitudes




Project owner: *NTNU / IV / IBM*
Project manager: *Ass. Prof. Gabriele Lobaccaro*
NTNU Partners: *IDI, IndEcol, MTP, IMA*
National partners: *SINTEF Community, Trondheim Kommune*

International partners:
*HEPIA - Geneva School of Eng., Arch. and Landscape – Univ. of Applied Sciences and Arts Western Switzerland;*
*USMB/INES - University Savoie Mont Blanc / National Institute of Solar Energy (France);*
*UCB Lyon 1/CETHIL - Claude Bernard University / Centre d'énergétique et de thermique de Lyon (France).*

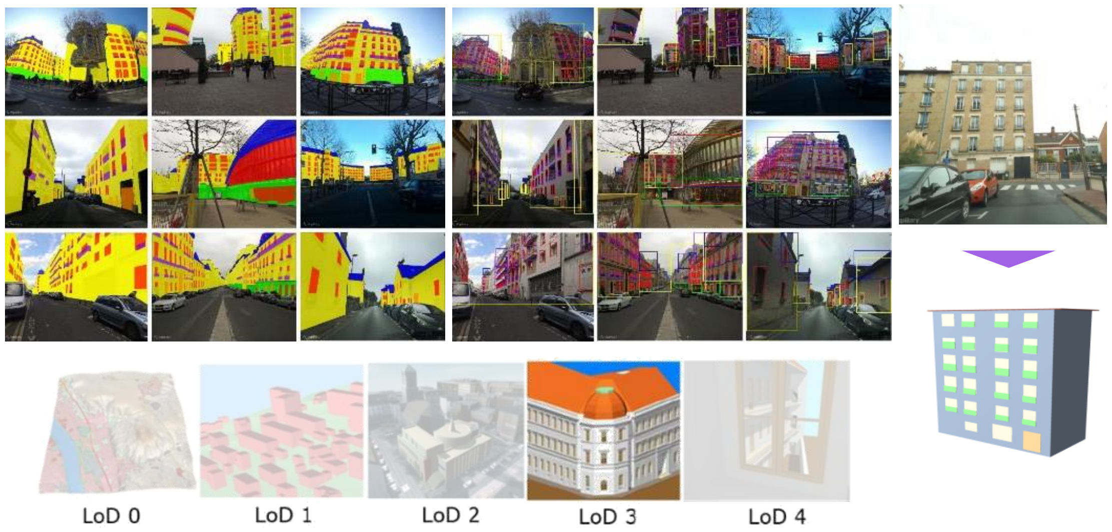
Digitalization for solar energy exploitation at high latitudes

## PILLAR ONE Solar data sources

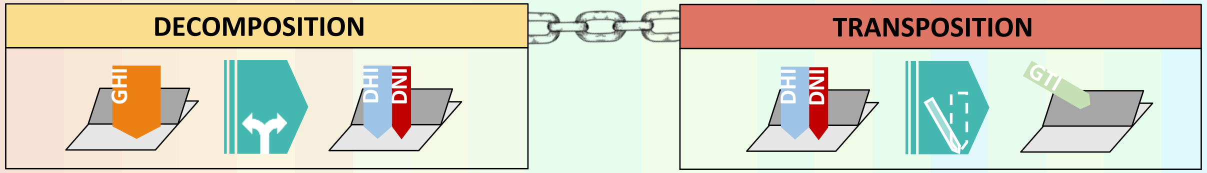
Numerical reanalysis and satellite observations

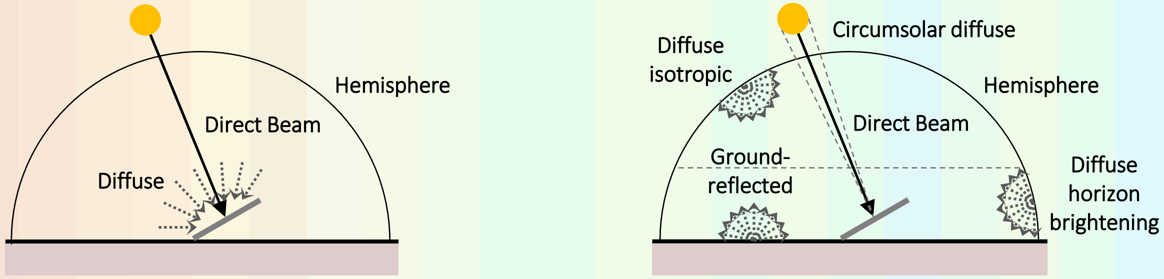

Ground monitoring network at high latitudes

## PILLAR TWO Semi-automated geometry detection

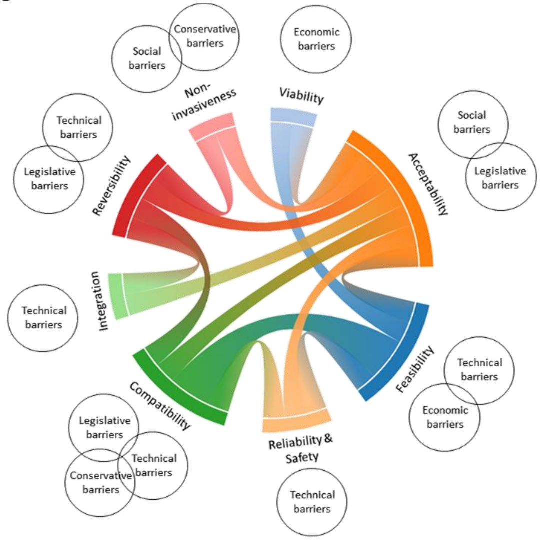



## PILLAR THREE Solar irradiance model chain




## PILLAR FOUR Citizens engagement

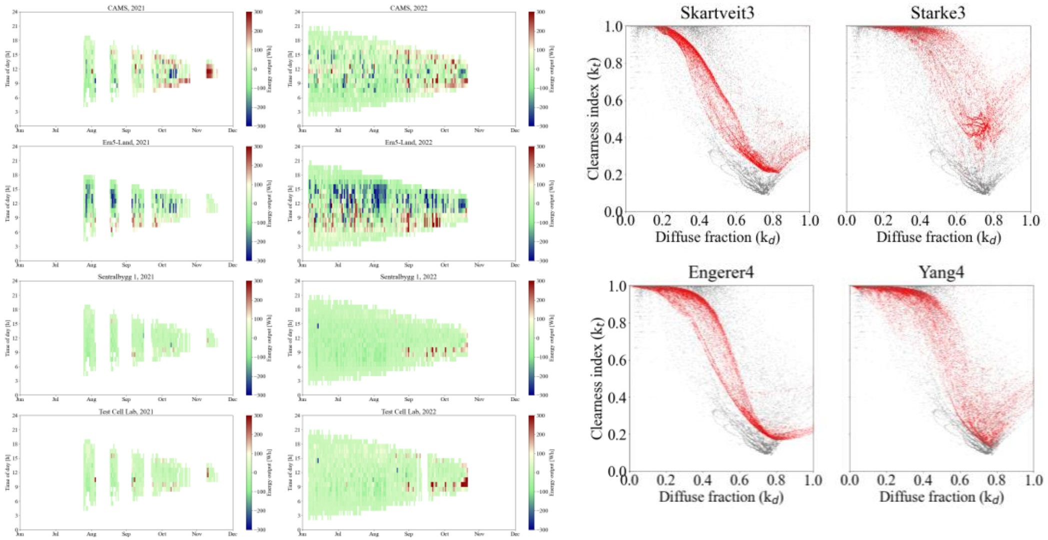




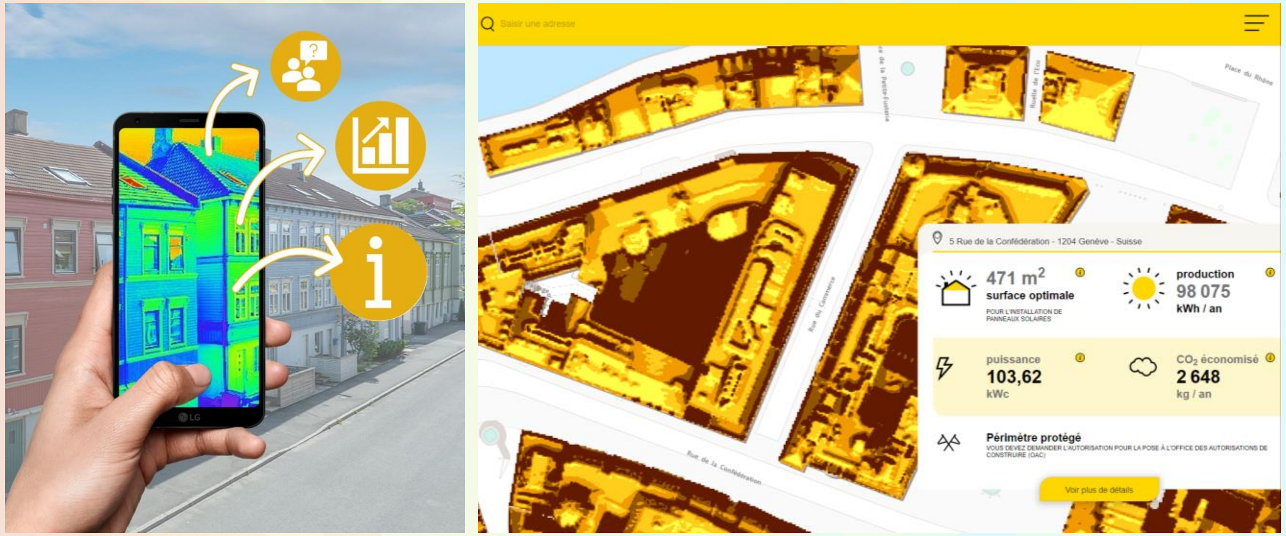

Mattia Manni, PhD
NTNU

## APPLICATION ONE Advanced photovoltaic simulations

## APPLICATION TWO Solar Neighborhood planning




## APPLICATION THREE Key Performance Indicators




## APPLICATION FOUR Arctic decomposition model

# Take home message

- **Solar energy potential** can contribute to achieve GHG reduction target
- There are many **opportunities** for solar energy at high latitudes
- There will be a **tool** to support you in designing solar strategies

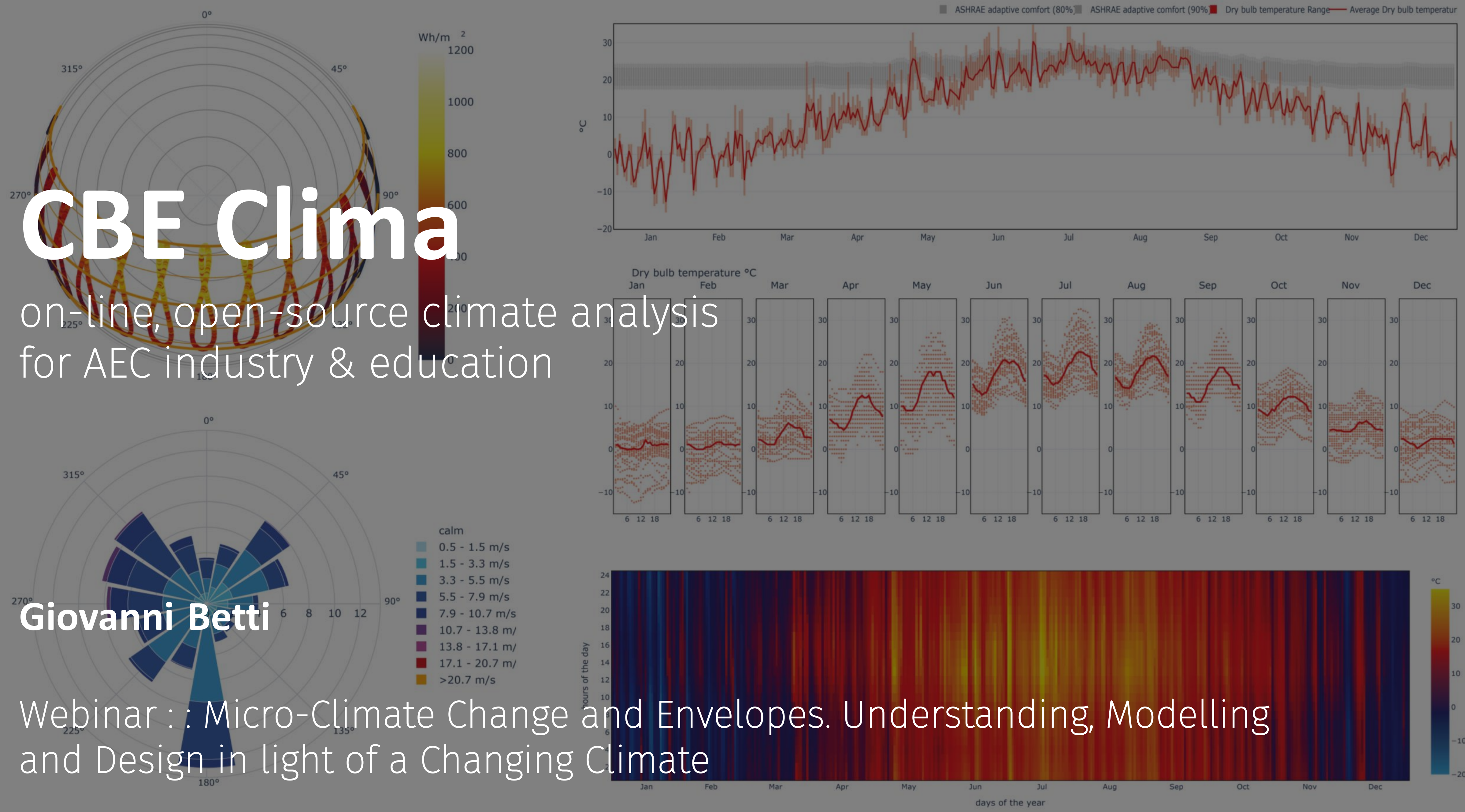
# THANKS

Do not hesitate to contact me!

e-mail: mattia.manni@ntnu.no

NTNU
Fakultet for ingeniørvitenskap
Institutt for bygg- og miljøteknikk

Helios




# CBE Clima

on-line, open-source climate analysis
for AEC industry & education

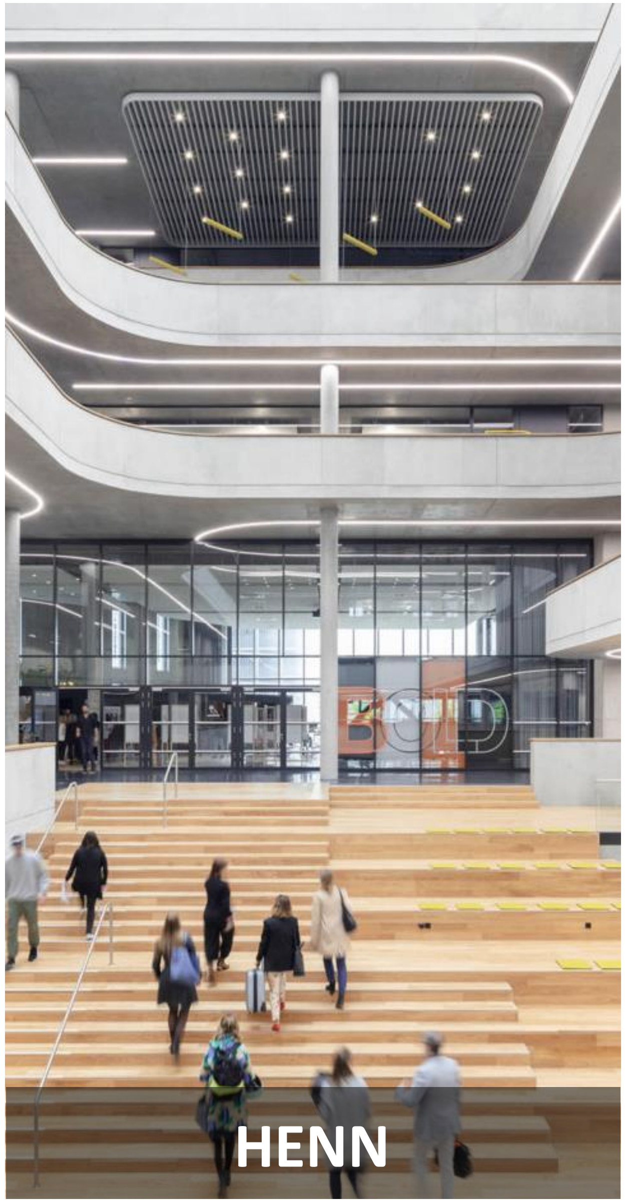
**Giovanni Betti**

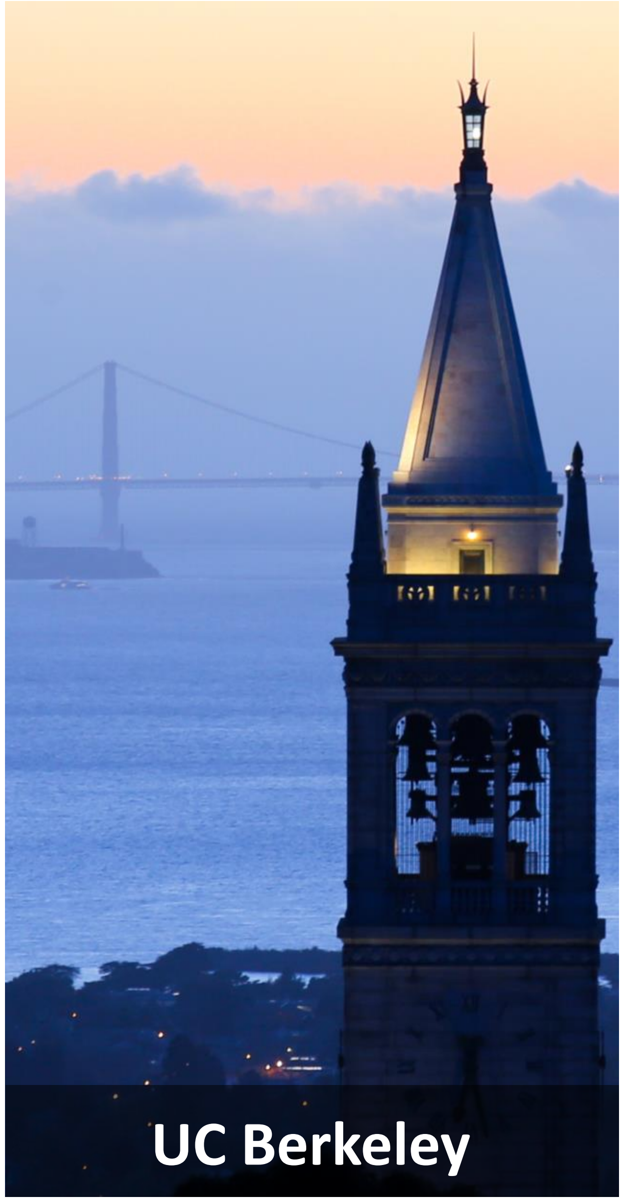
Webinar : : Micro-Climate Change and Envelopes. Understanding, Modelling and Design in light of a Changing Climate

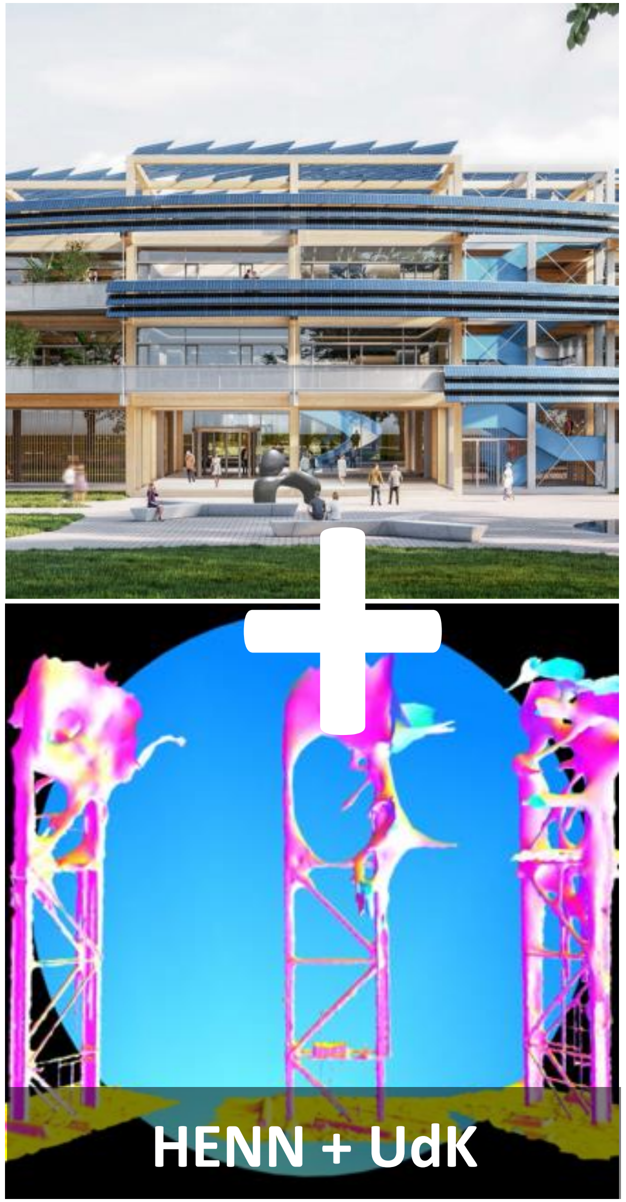
# Giovanni Betti

Architect OAR
M.Arch. (Hons), M.Sc
Head of Sustainability @ HENN
Guest Professor for Digital & Experimental Design @ UdK


Foster+ Partners


HENN

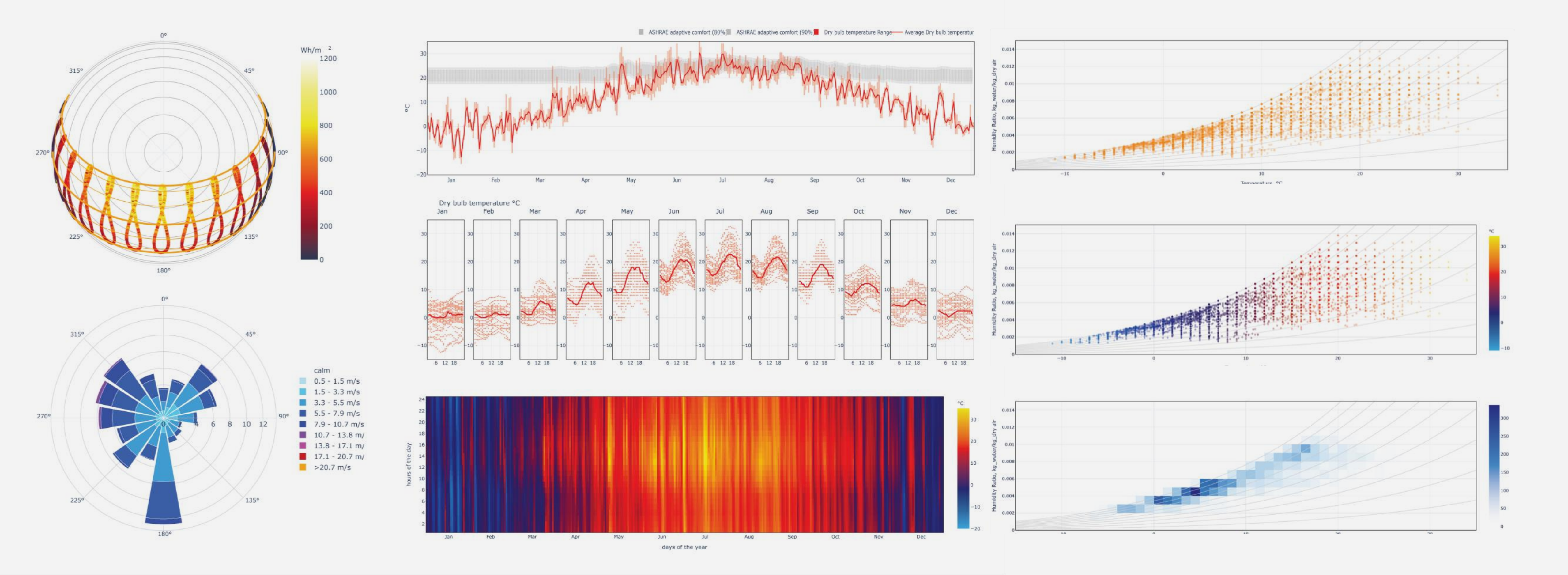

UC Berkeley


HENN + UdK

# CBE Clima

## on-line, open source climate analysis

## for the AEC Industry



# Climate Responsive Architecture
nothing new under
the scorching sun

Yazd Province, ایزد، خیابان مسجد جامع، Iran

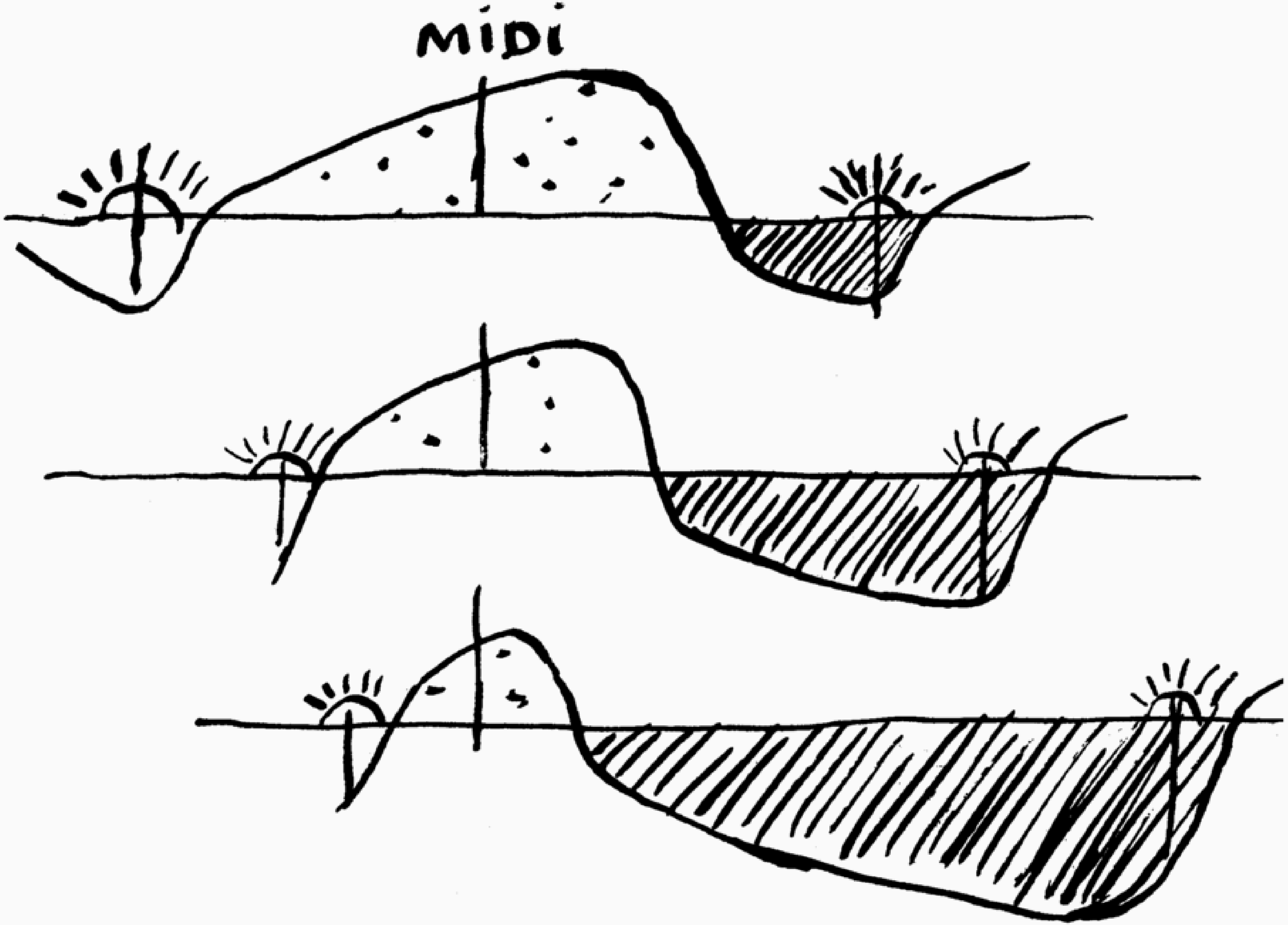
Giovanni Betti

# Climate Responsive Architecture
nothing new under
the pouring rain

Wae Rebo village, Satar Lenda, Manggarai Regency, East Nusa Tenggara, Indonesia

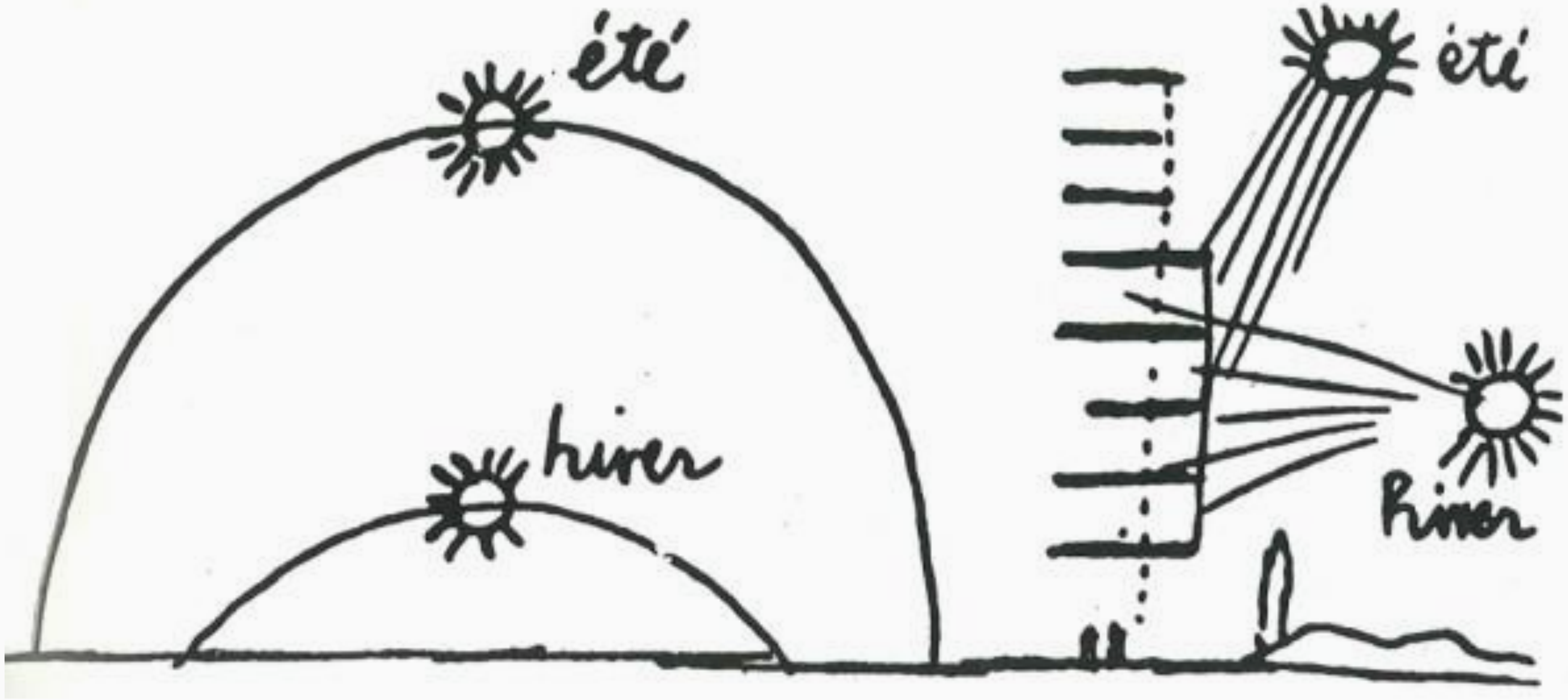
**Climate Responsive Architecture**
nothing new in the neighborhood

# Climate Analysis:
A modern invention



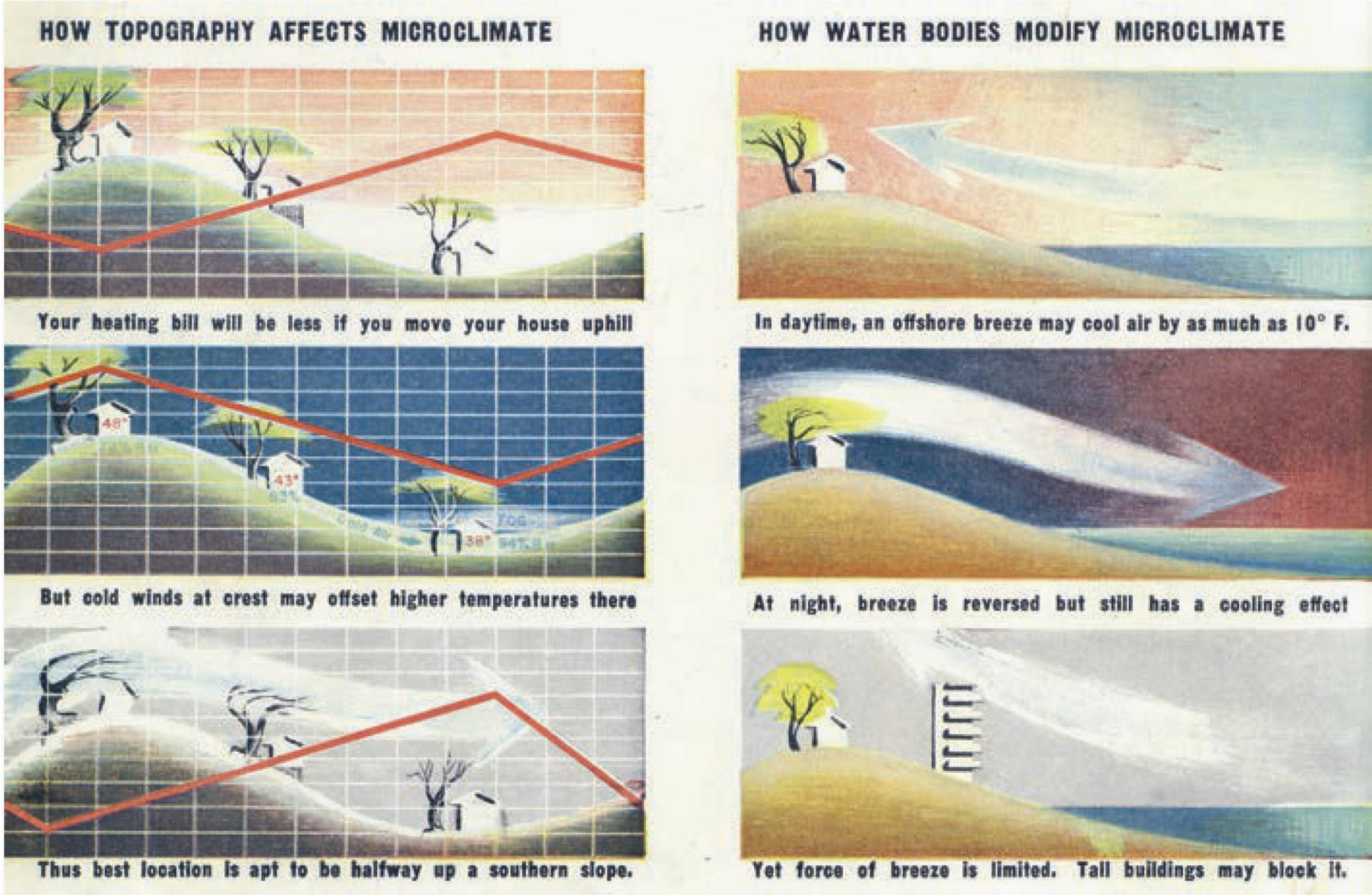

Le Corbusier,
Day-Night Sun Path Diagram

# Climate Analysis:
A modern invention



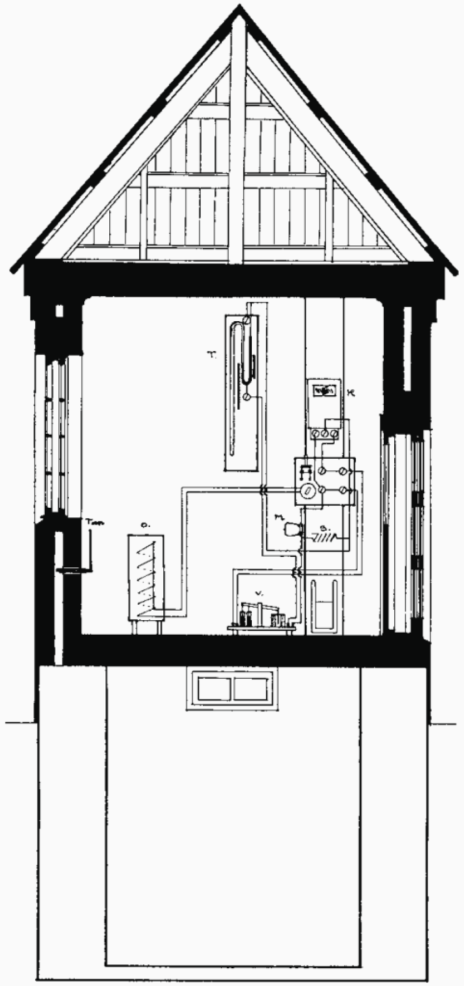

Le Corbusier,
Day-Night Sun Path Diagram

# Climate Analysis:
A modern invention




Illustrations of microclimatic factors from Helmut Landsberg, "Microclimatology," in Architectural Forum, March 1947.

# Climate Analysis:
A modern invention



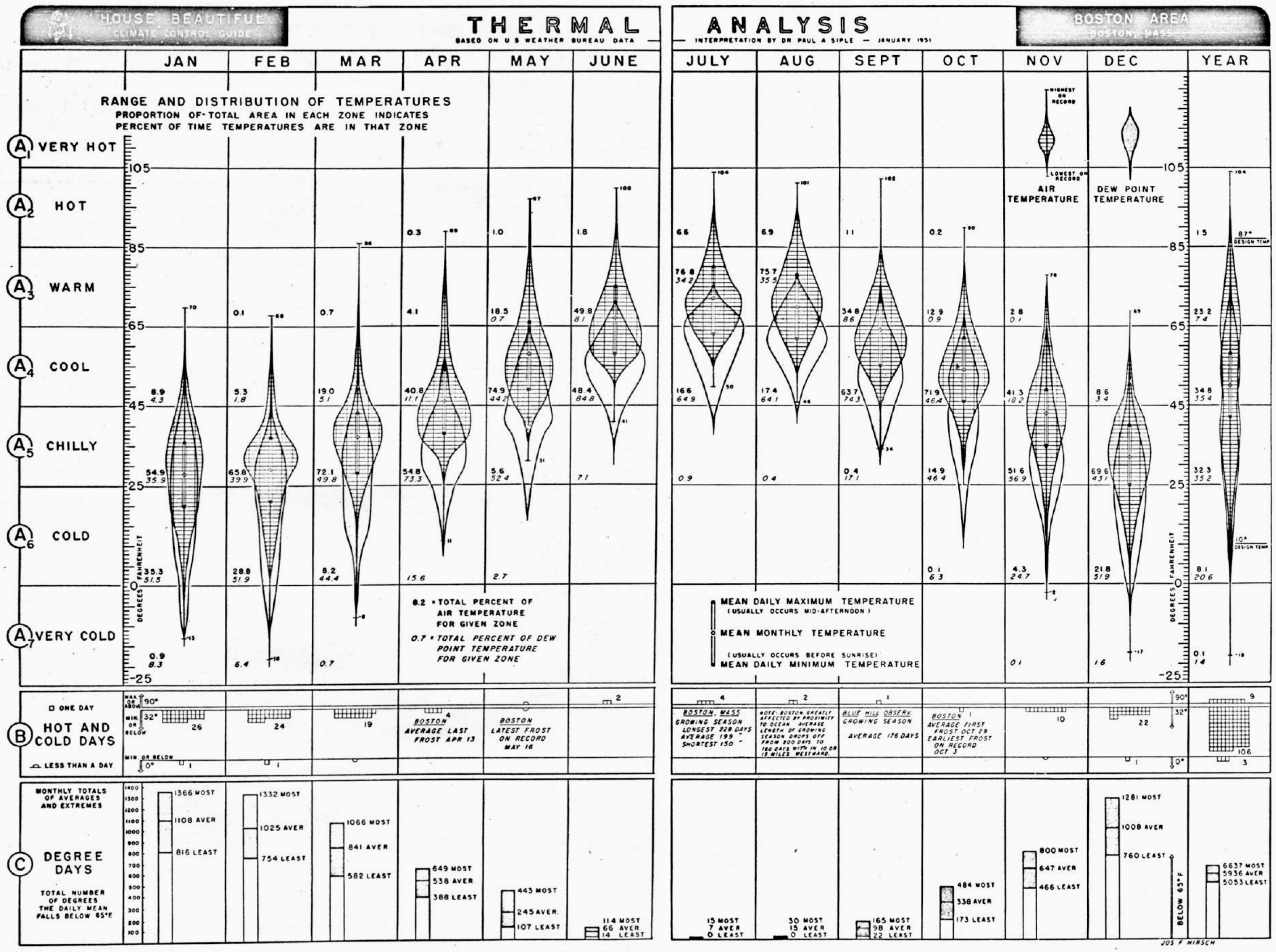
*Mounting af the Instruments.*

K = kilowatt-hour-indicator. M = resistance-lamp.
O = electrical stove. T = thermo-regulator.
S = shunt. V = current-switch.
Tm = Thermometer.

Fig. 30.

Andreas Fredrik Bugge,
"Warm and Cheap" test huts,
Trondheim, Norway, 1930-1960

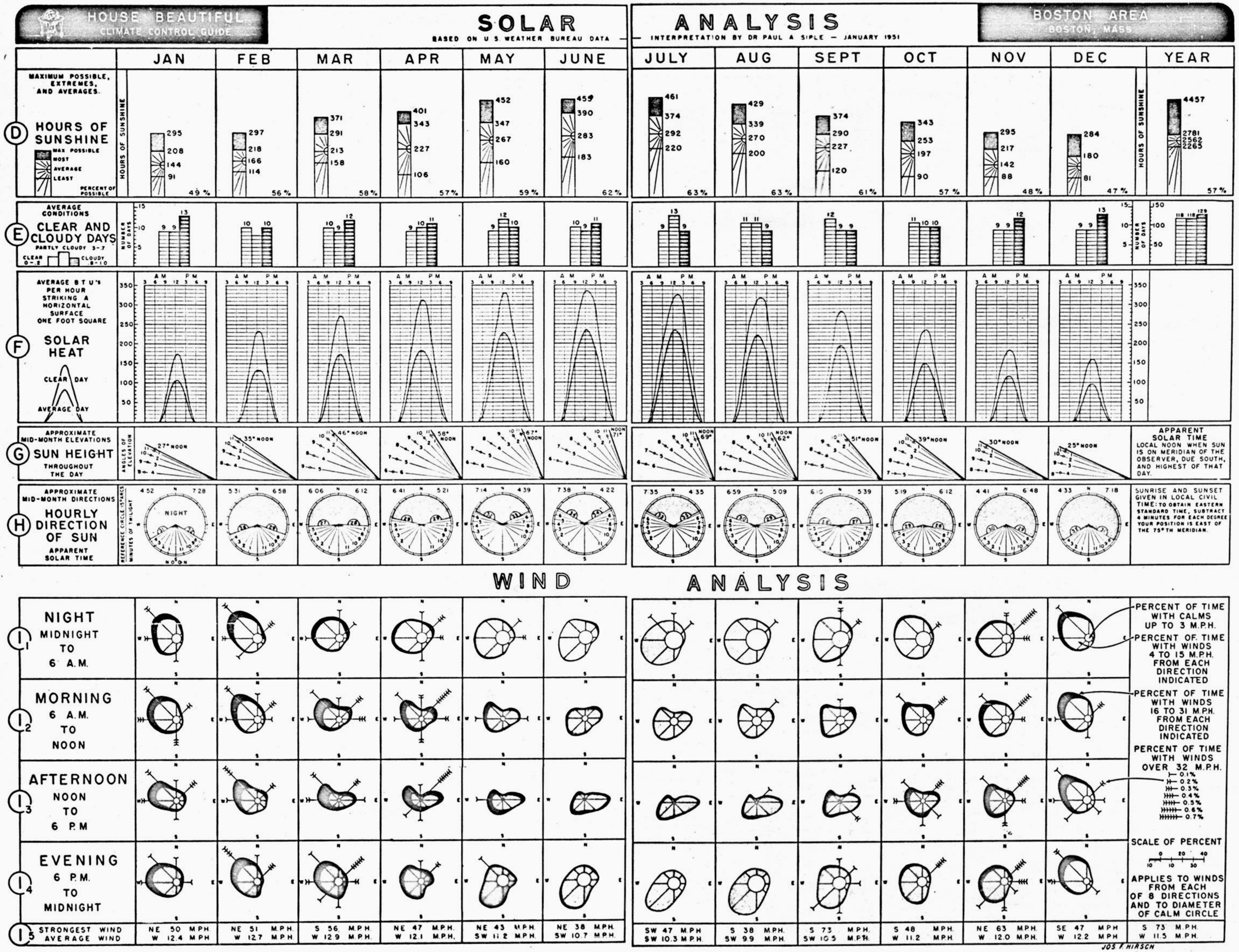
# Climate Analysis:
## A modern invention




Thermal Analysis of the Boston Area, from the AIA's Regional Climate Analyses and Design Data, March 1951 Bulletin.

Giovanni Betti

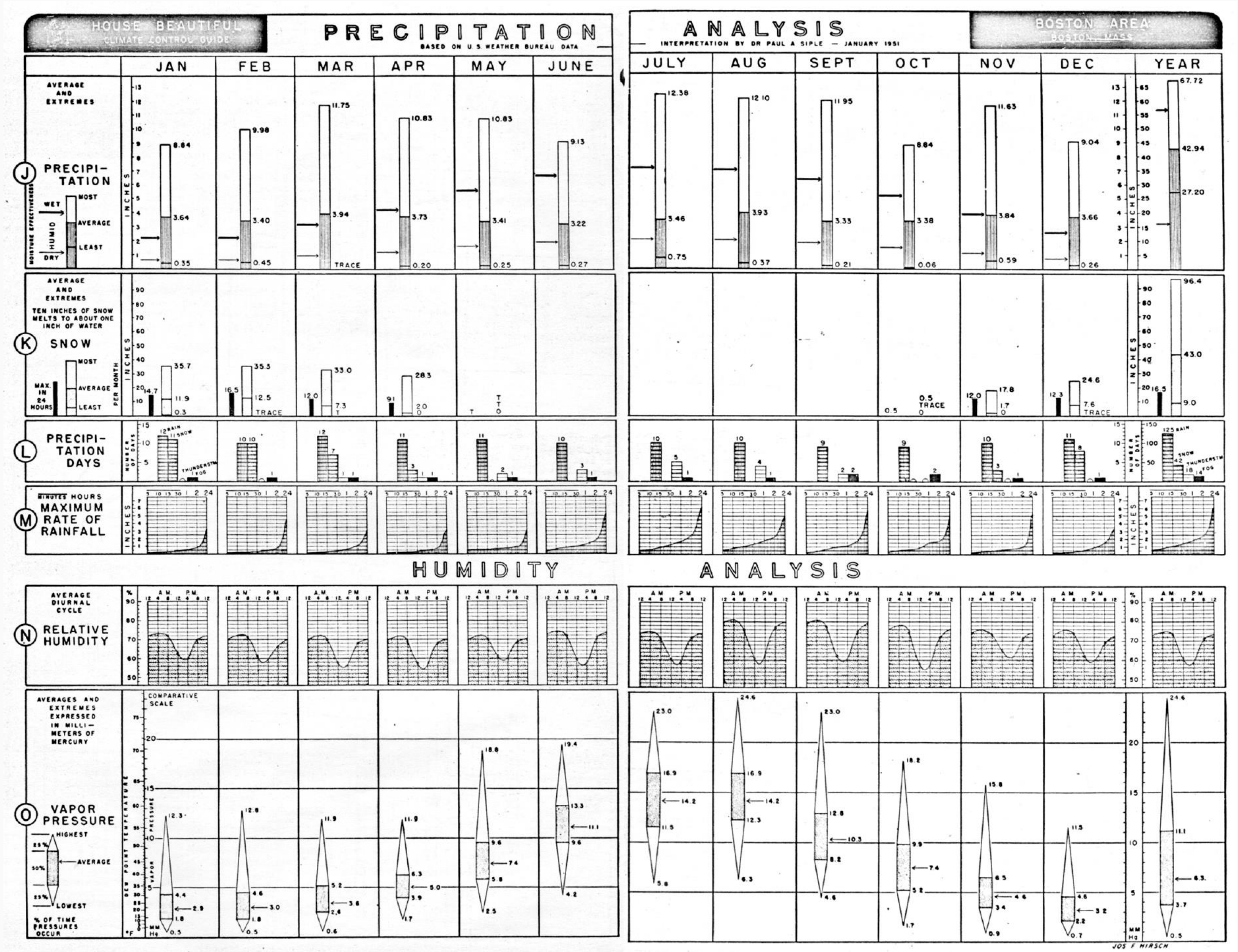
# Climate Analysis:
## A modern invention




Solar and Wind Analysis of the Boston Area, from the AIA's Regional Climate Analyses and Design Data, March 1951 Bulletin.

Giovanni Betti

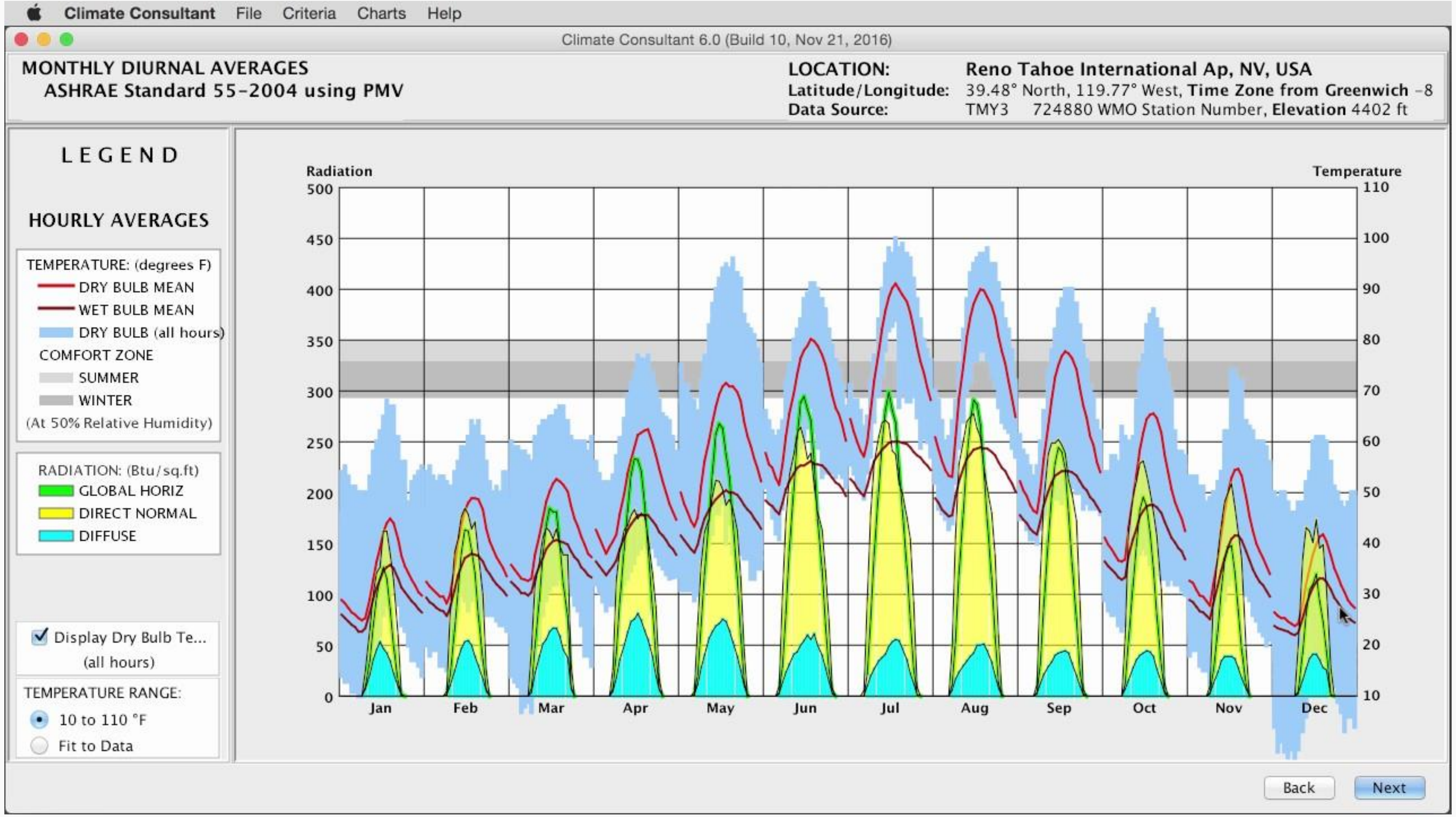
# Climate Analysis:
## A modern invention




Precipitation and Humidity Analysis of the Boston Area,
from the AIA's Regional Climate Analyses and Design Data,
March 1951 Bulletin.

Giovanni Betti

Climate analysis is a
niche and
time consuming task



# Goals for a climate analysis tool

**Easy to access**

**Easy to use**

**Easy to understand**

**Flexibile**

# What is under the hood?

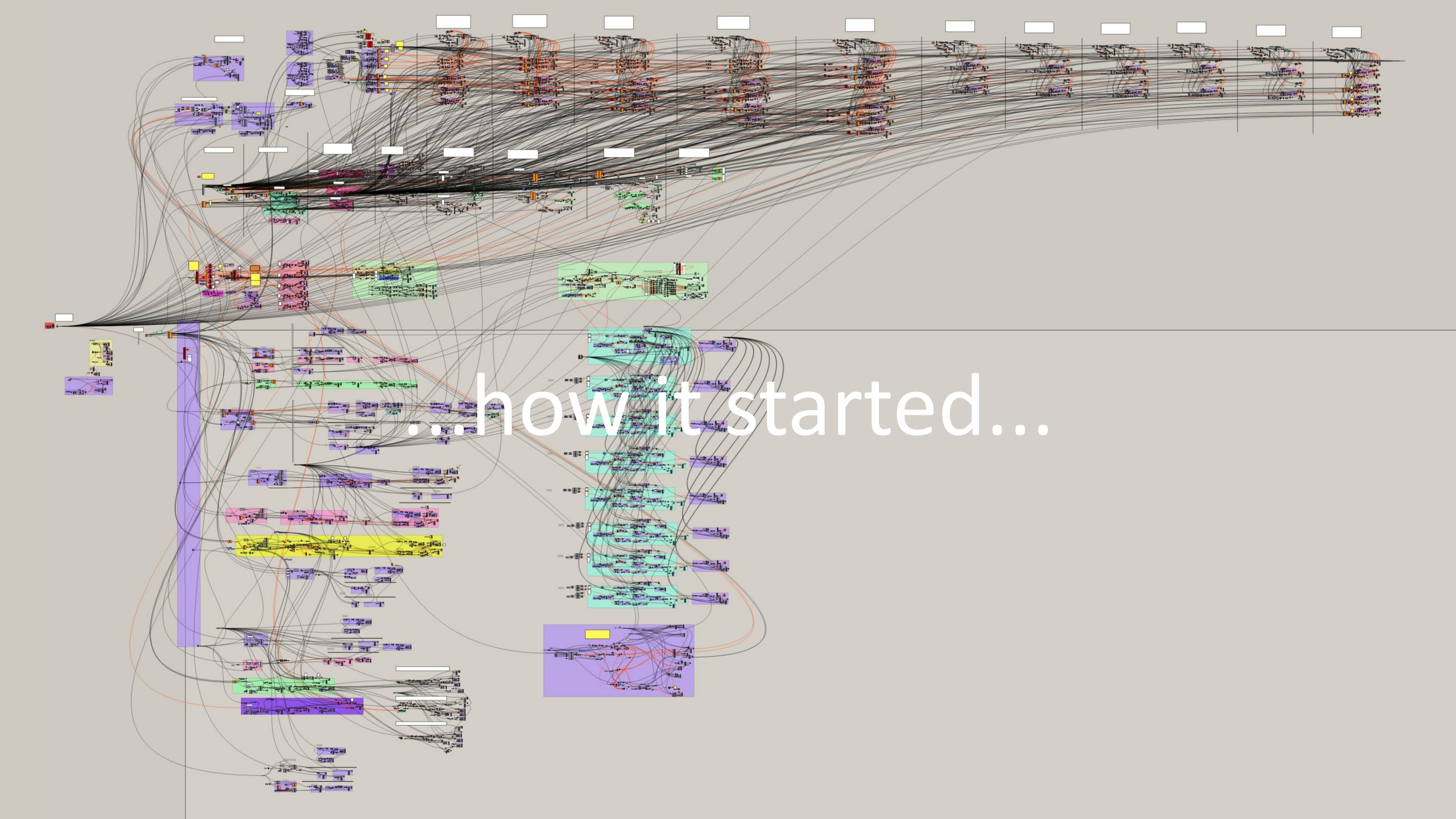
**Language** ▶ **Data processing** ▶ **Psychrometrics + Solar geometry** ▶ **Graphs** ▶ **App**

*

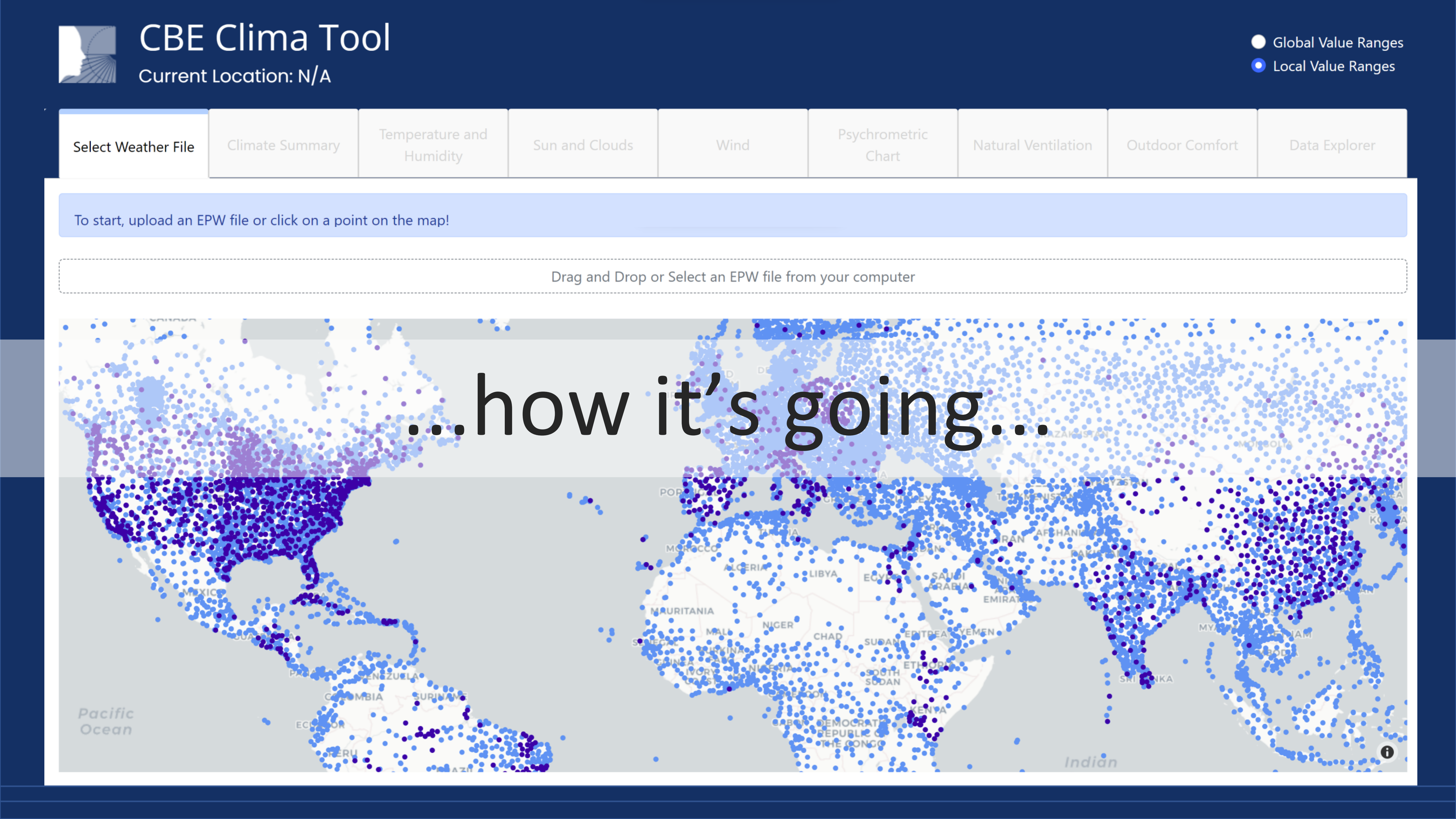
* Tartarini, F., Schiavon, S., 2020. pythermalcomfort: A Python package for thermal comfort research. SoftwareX 12, 100578. https://doi.org/10.1016/j.softx.2020.100578

All code uder
**MIT licence**

All graphics under
**CC 4.0**


...how it started...

# ...how it started...

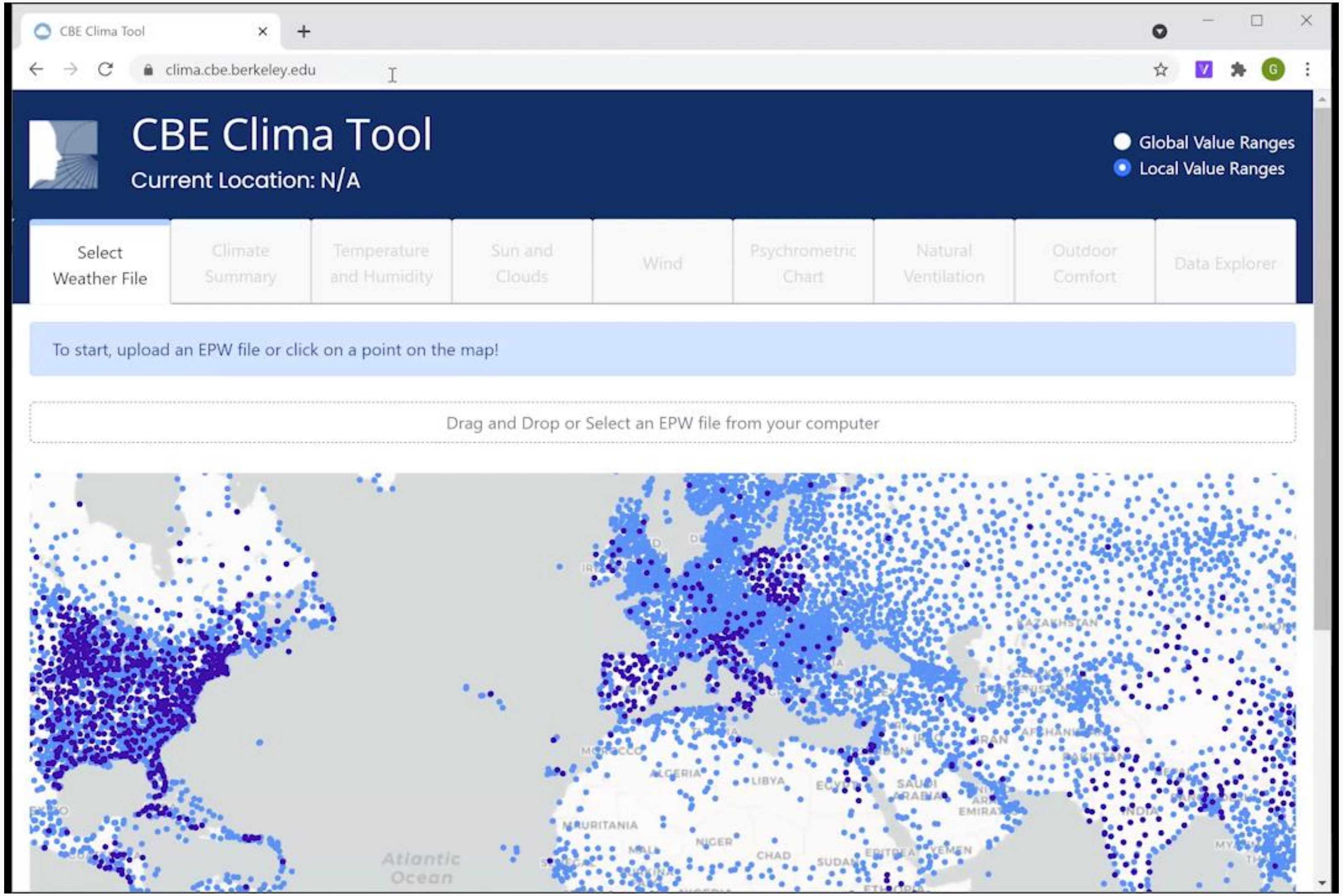



…how it's going…

Intuitive navigation through
interactive map

Access to
~30,000 weather files
worldwide

High quality data from:
Energy Plus
OneBuilding.org
Upload your own



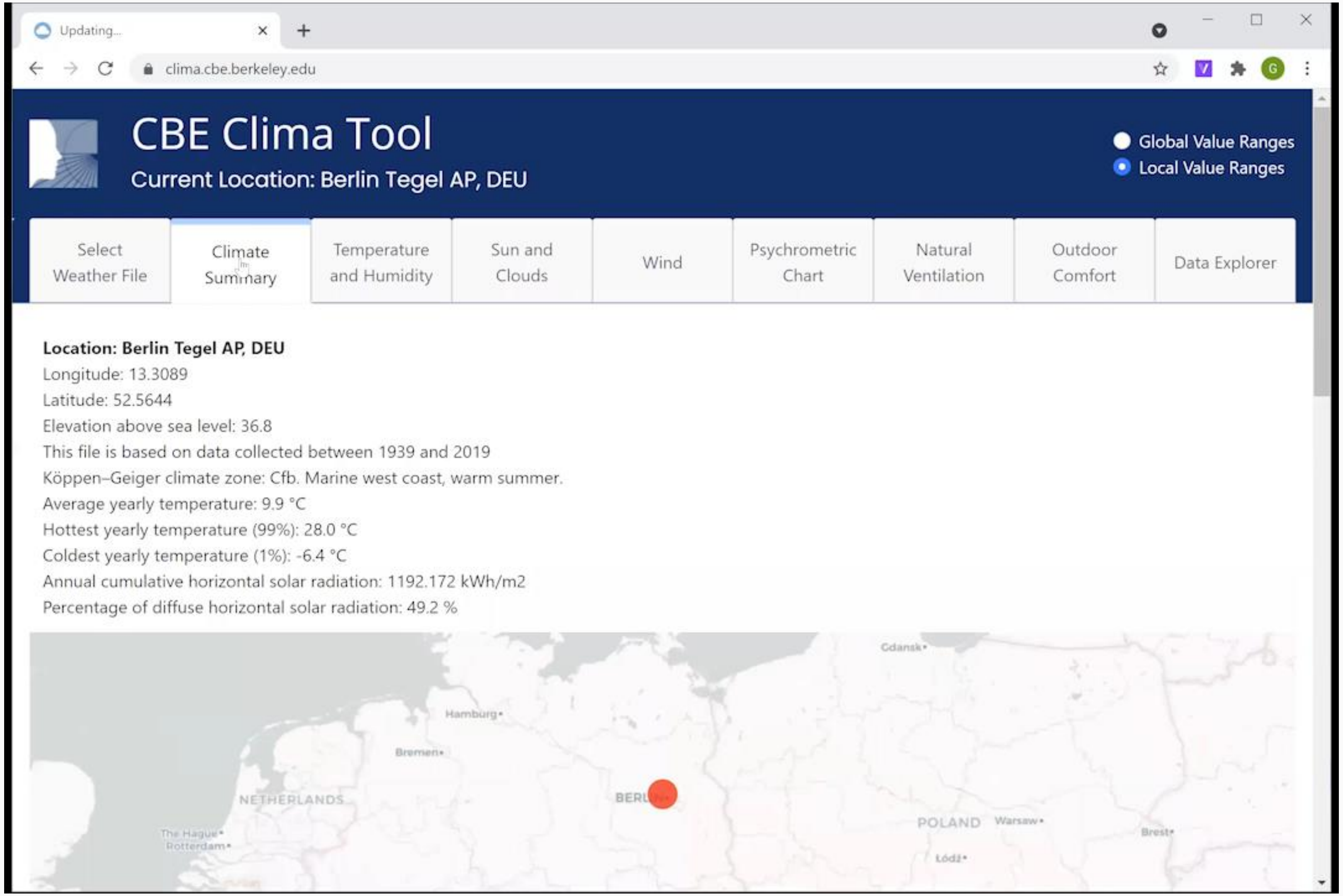
## Climate Summary

Weather Location Check

Summary statistics

(customizable) Heating/Cooling degree Days

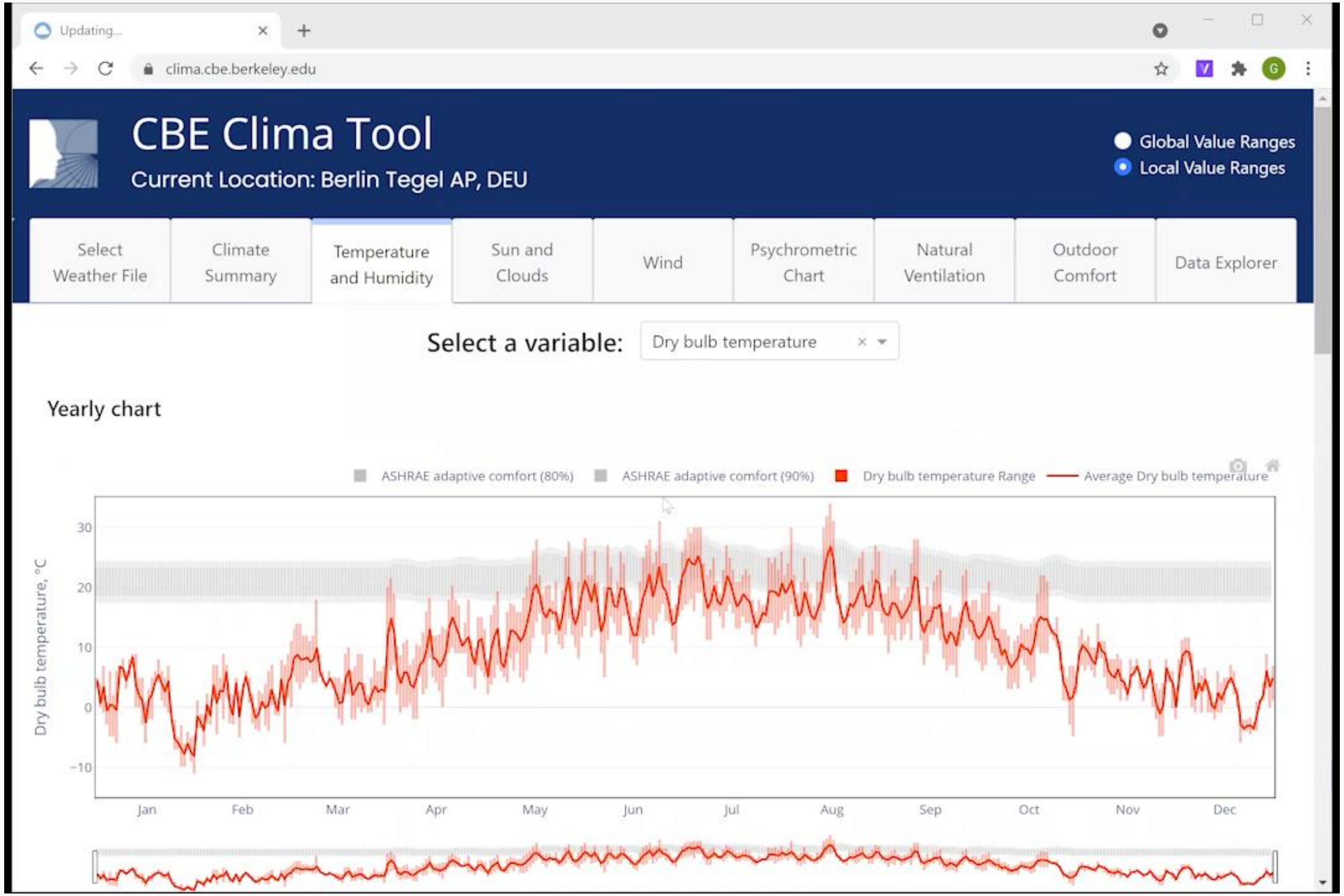
Climate Profiles



# Temperature and Humidity

Annual profile
Monthly profile
Hourly profile

Interactive, data-rich mouse-over interactions
Zoomable, interactive graphs



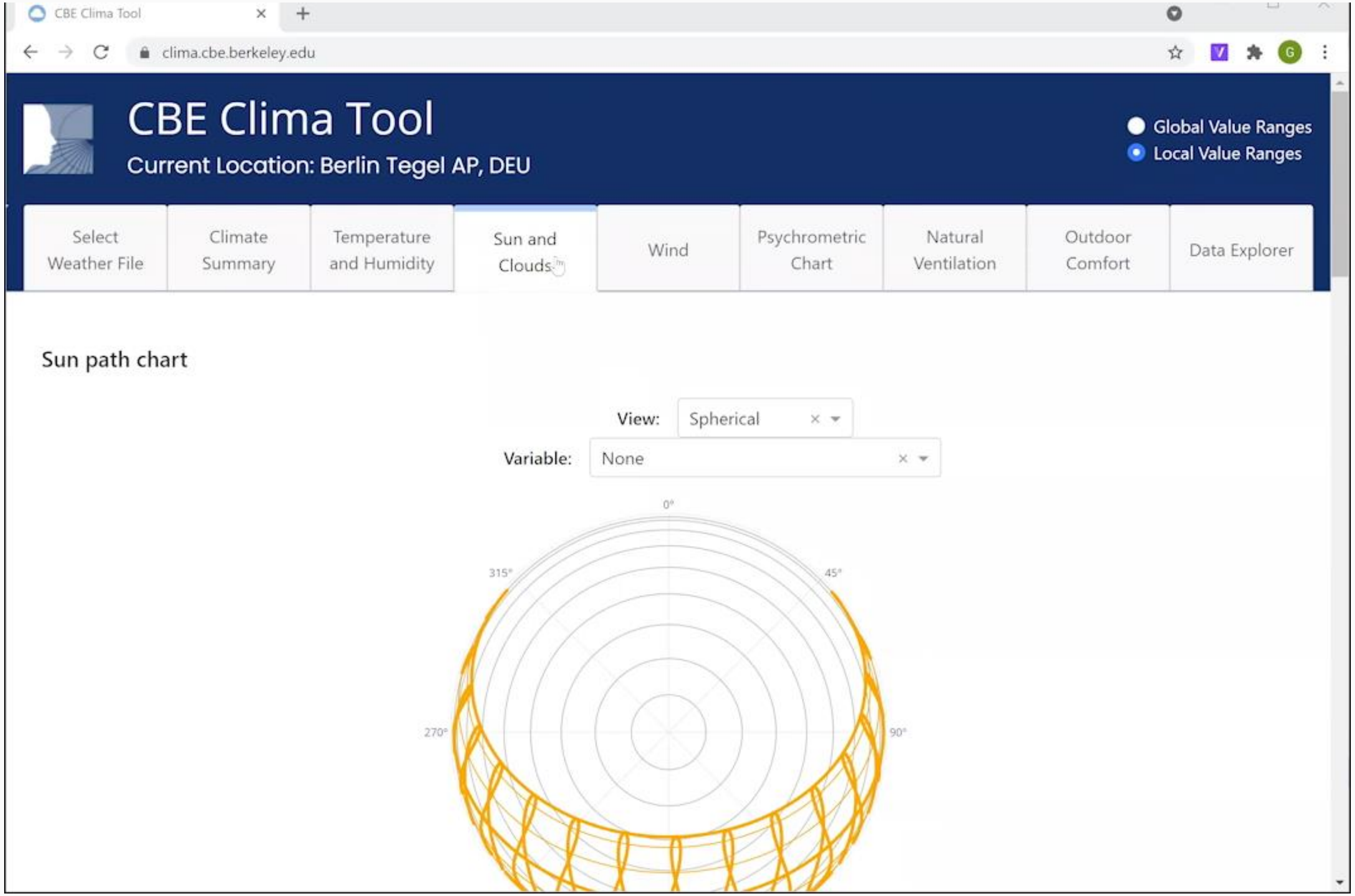
# Sun and Clouds

Selection of sun path projection
Spherical
Cartesian

Overlay data on sunpath

Global vs diffuse horizontal radiation

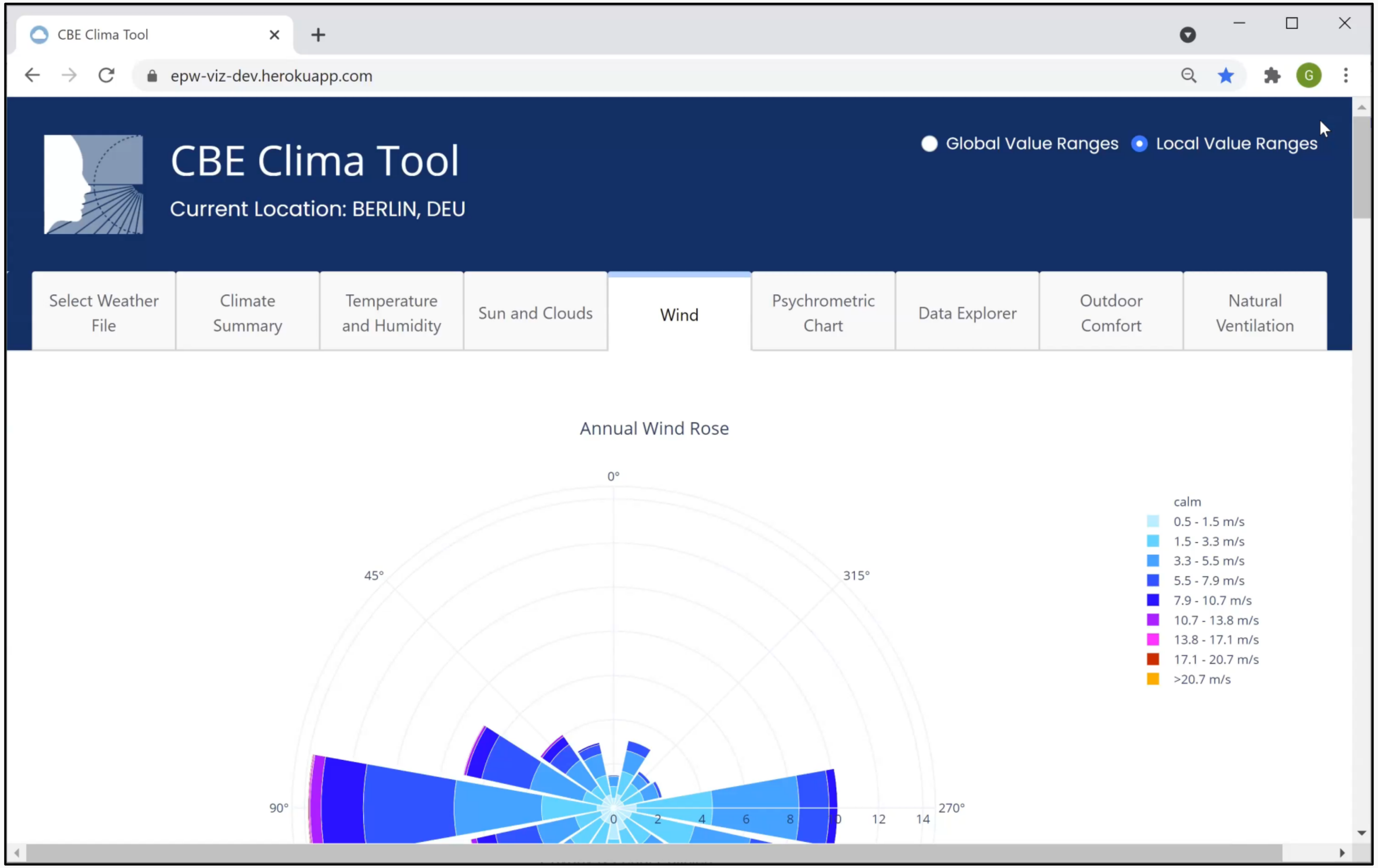
Cloud cover
Plot custom variables



# Wind

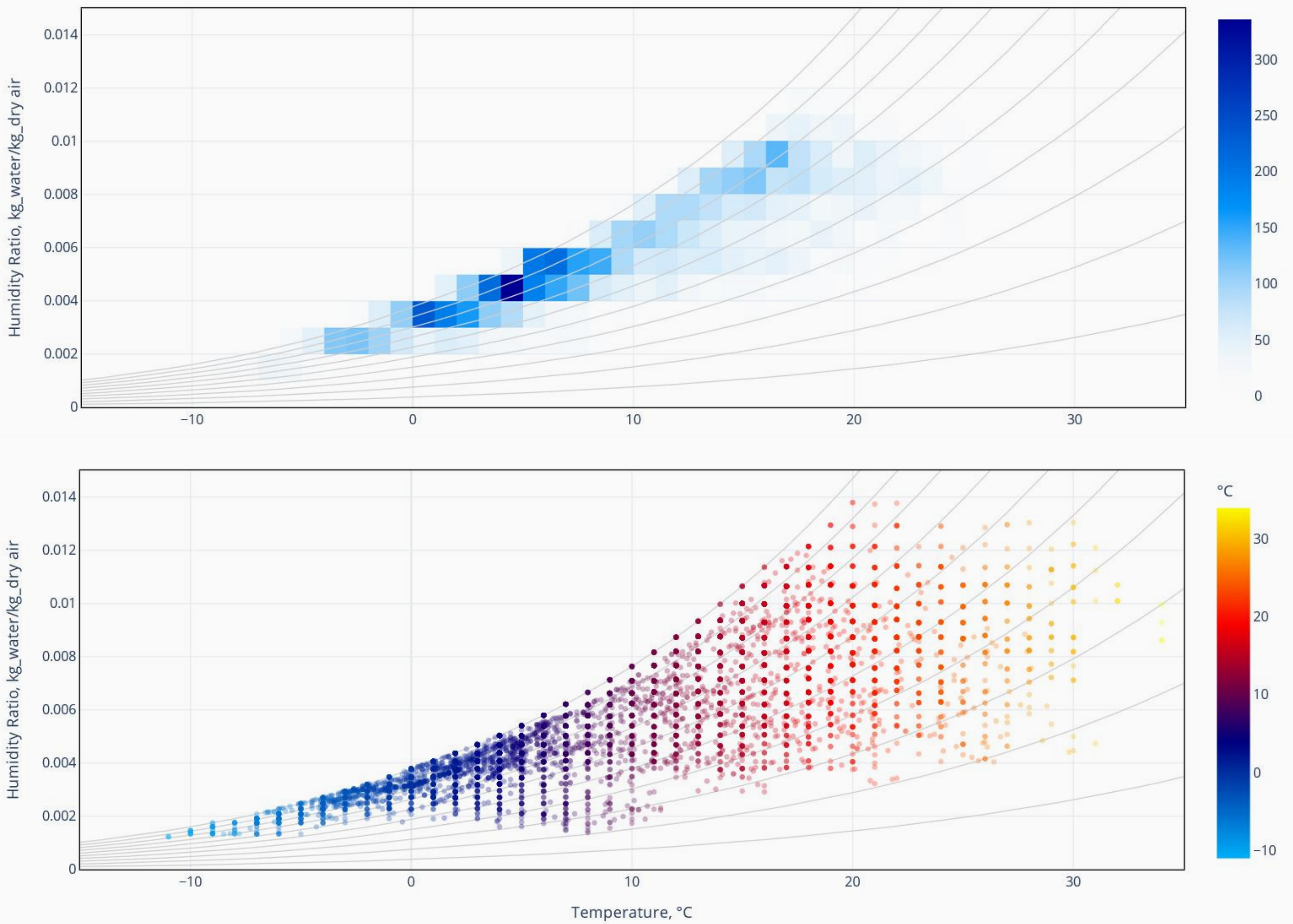
Wind roses:
- Yearly
- Seasonal
- Daily
- Custom

Hourly profiles:
Wind speed
Wind direction



# ...and more!

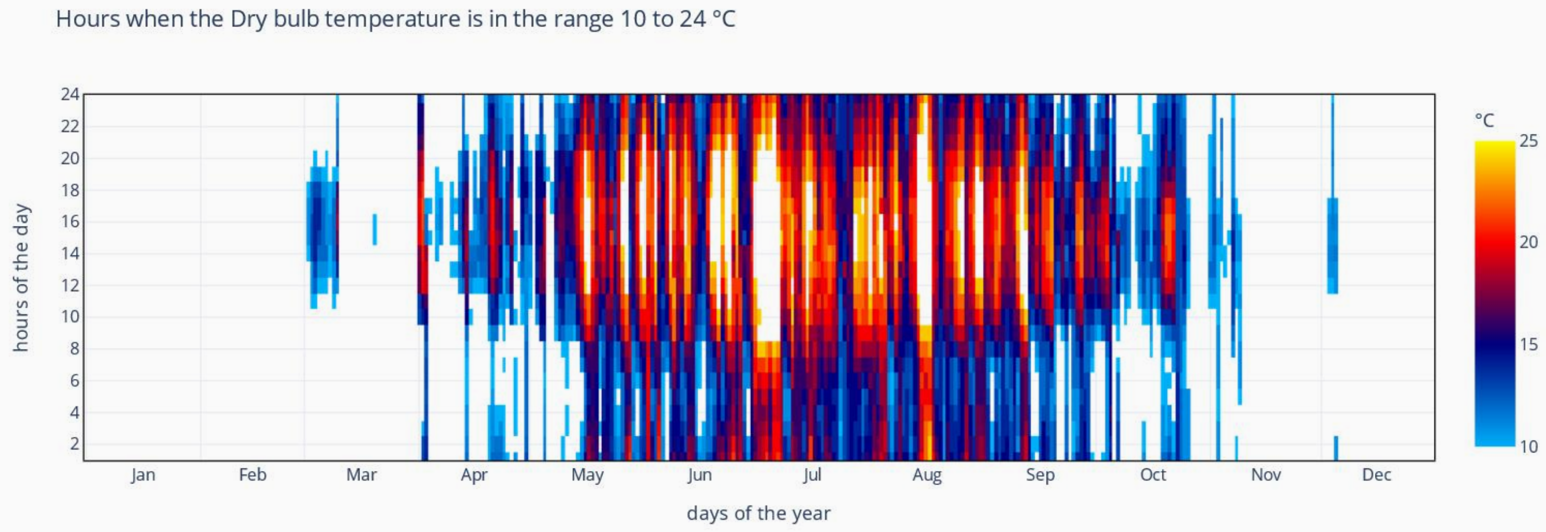
## Customizable psycrometric charts

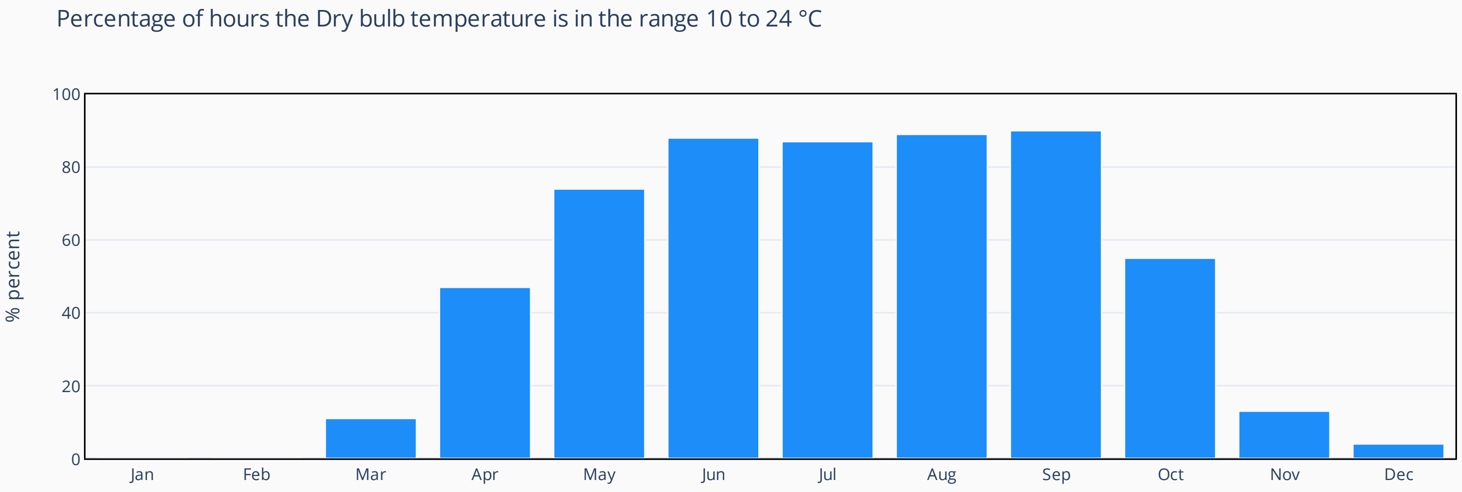


# ...and more!

Customizable psycrometric charts

Natural Ventilation Potential



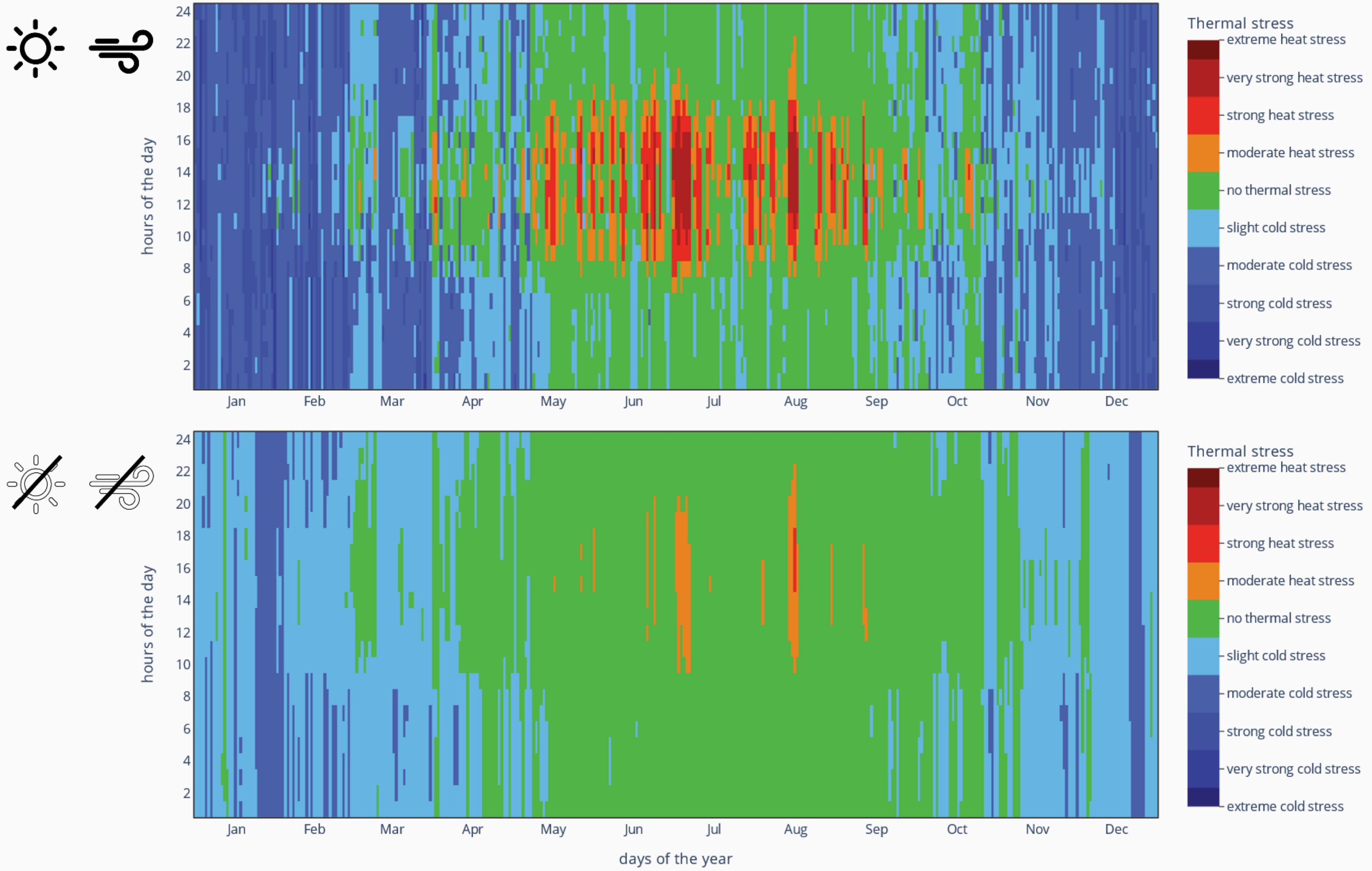



...and more!

Customizable psycrometric charts

Natural Ventilation Potential

Outdoor “felt” temperature (UTCI)



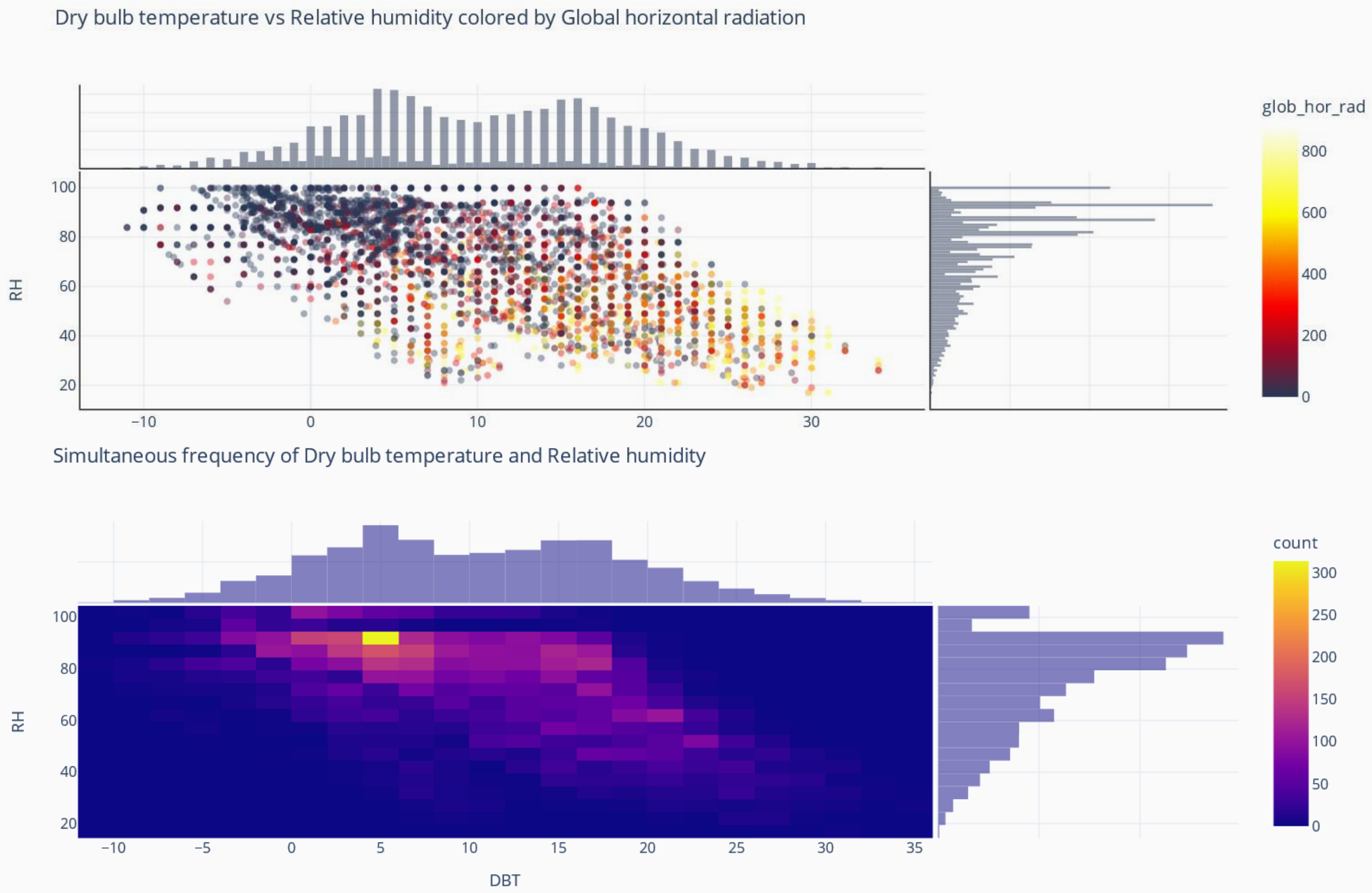
# ...and more!

Customizable psycrometric charts

Natural Ventilation Potential

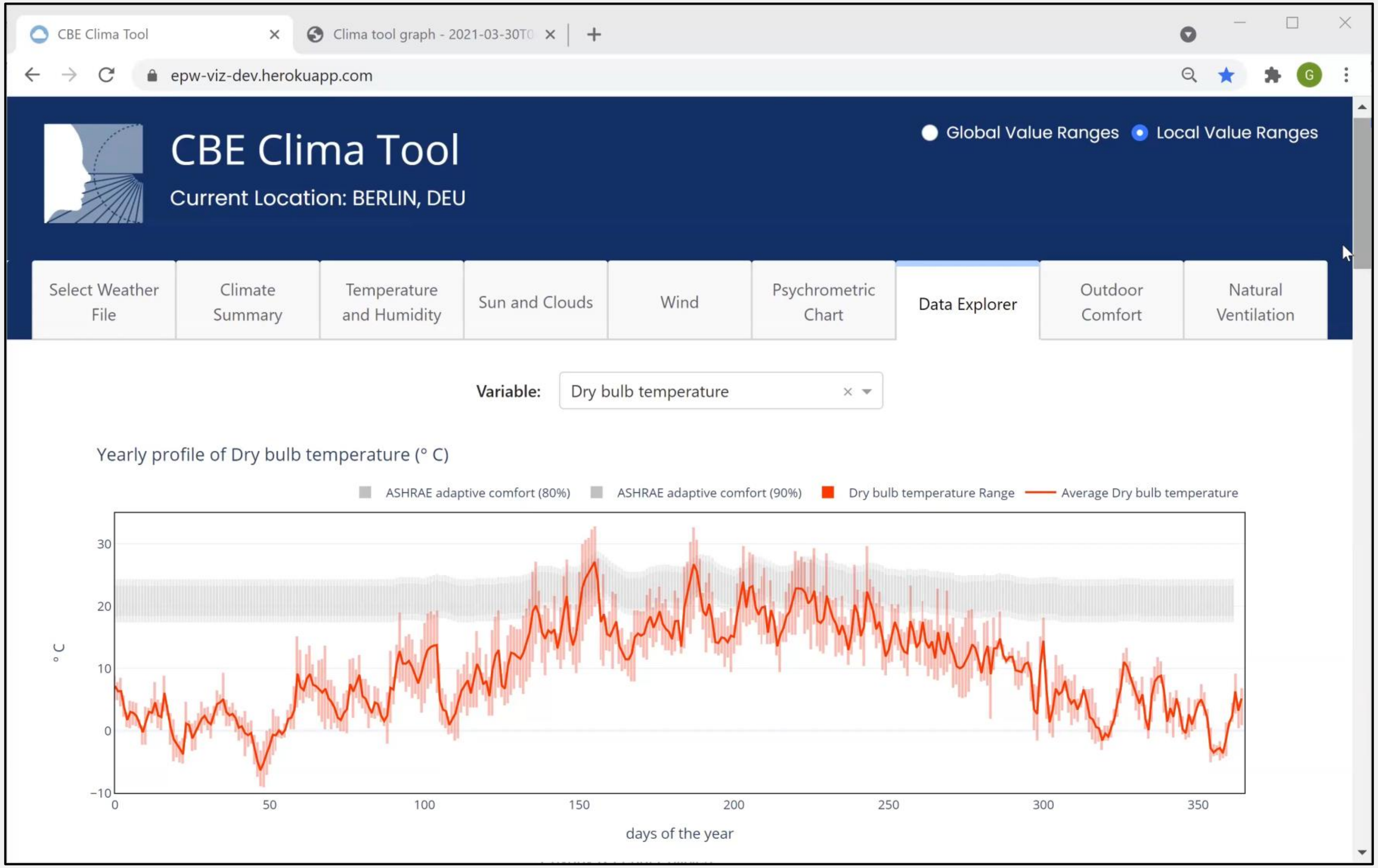
Outdoor “felt” temperature (UTCI)
´

Custom multivariable plots



# Vector graphics

All graphs are downloadable in their current state as vector graphics (*.svg)

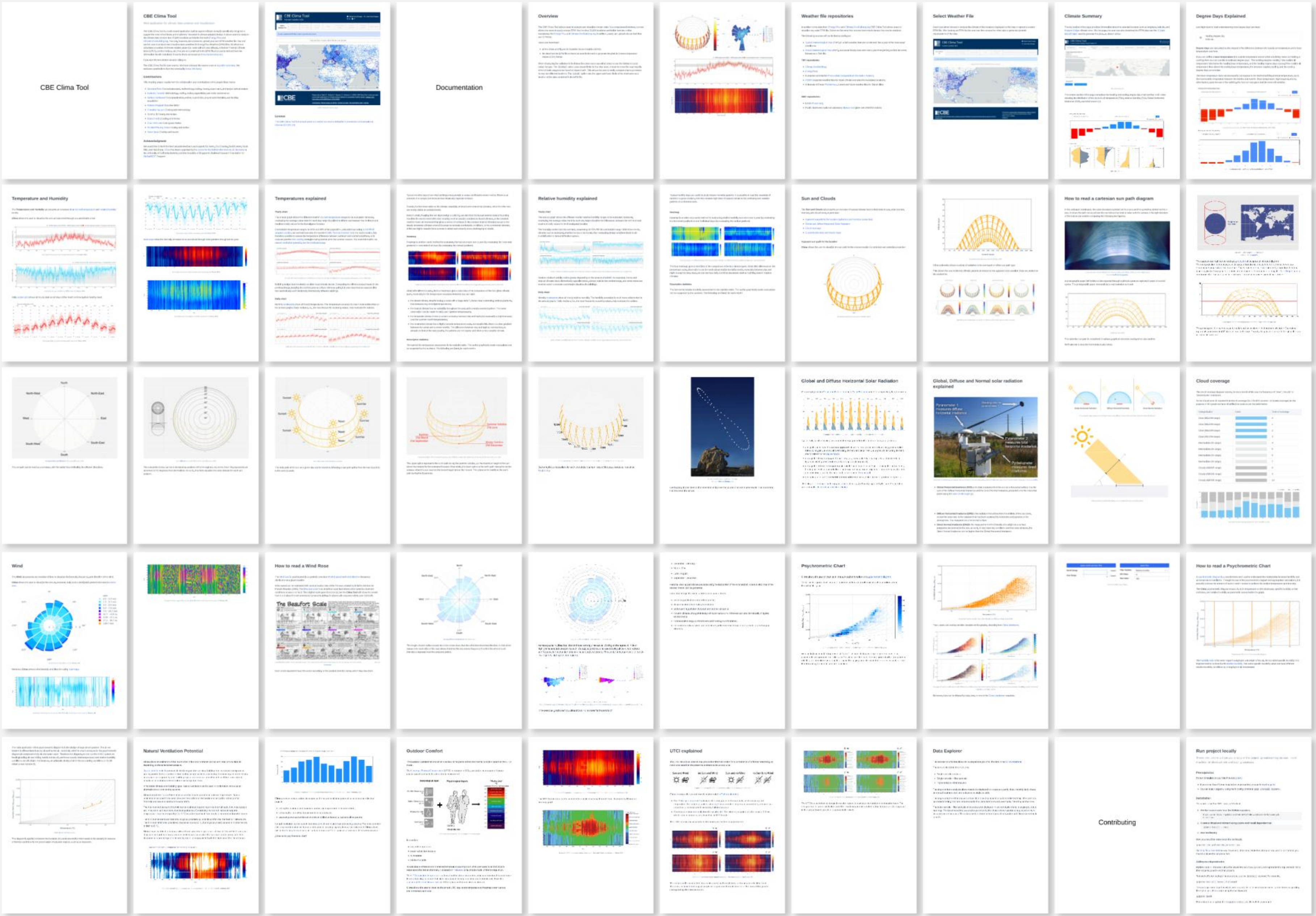


CBE Clima

# Documentation

Over 50 pages of graphics and text explaining each graph and climate analysis

cbe-berkeley.gitbook.io/clima/




Giovanni Betti

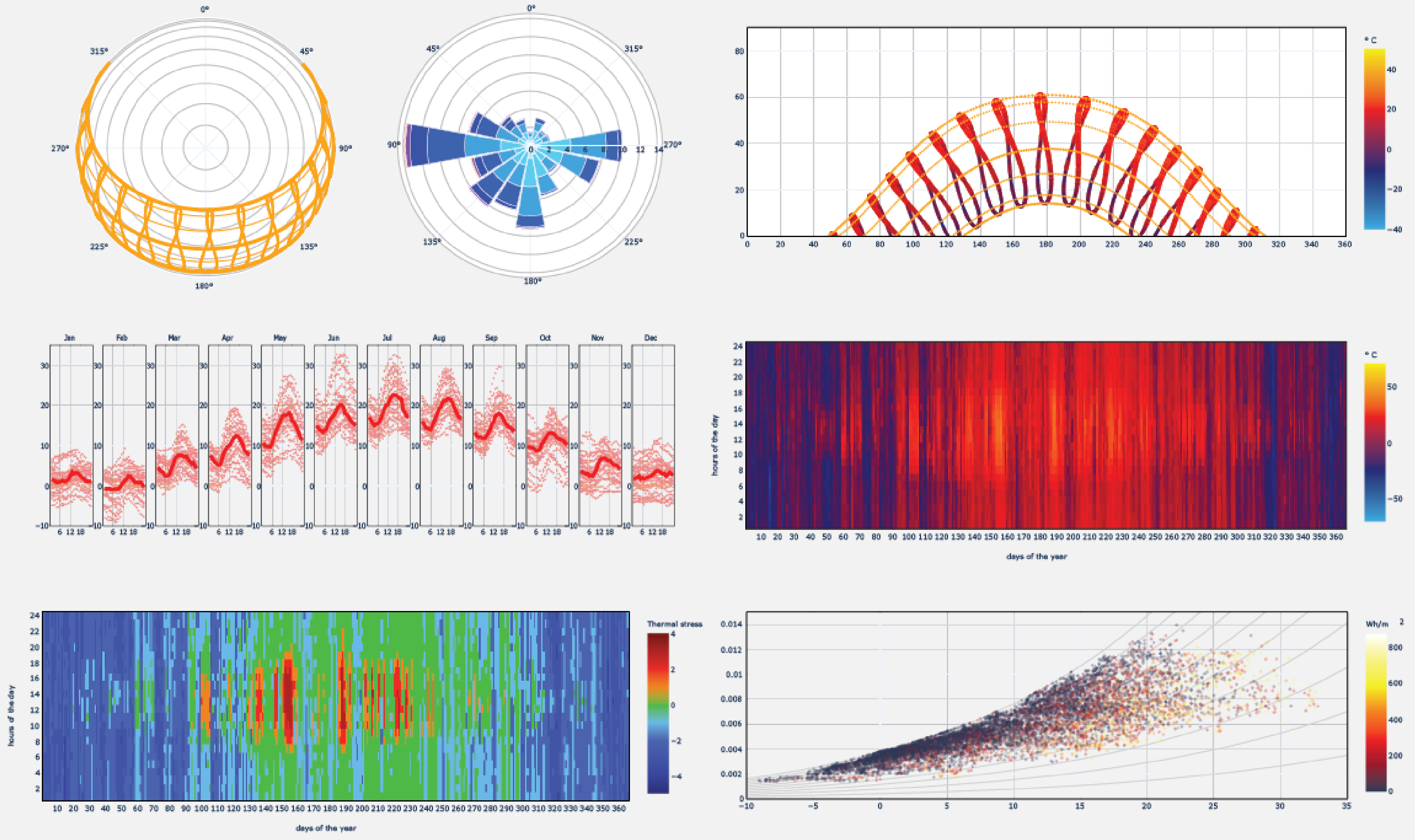
# Next steps

Gather User Feedback!

Various UI improvements

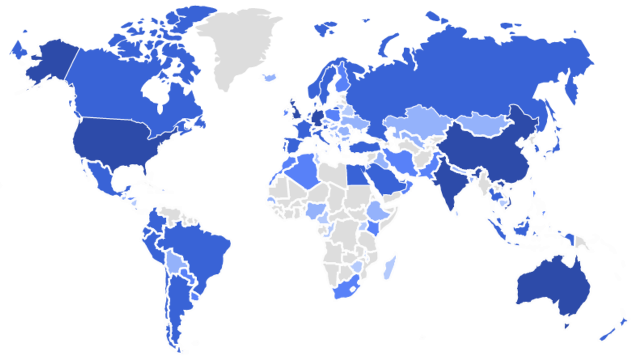
Hunting bugs

Future Weather Files



# Beta Version launched 20th August 2021

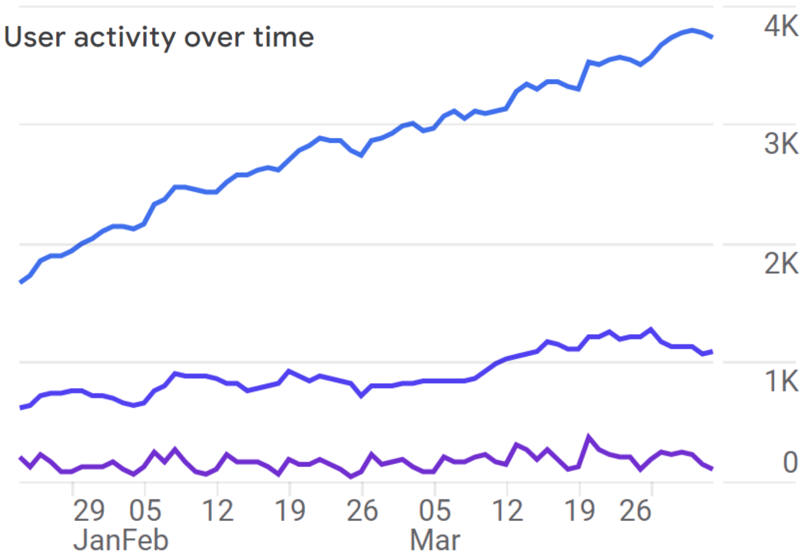
clima.cbe.berkeley.edu



| COUNTRY ID | USERS | |
|---|---|---|
| United States | 1.7K | ↑ 86.1% |
| China | 862 | ↑ 13.7% |
| India | 469 | ↓ 20.9% |
| United Kingdom | 451 | ↓ 18.3% |
| Australia | 698 | ↑ 619.6% |
| Germany | 393 | ↑ 30.1% |
| Italy | 330 | ↑ 9.3% |

Last 90 days

User activity over time




30 DAYS
3.7K

7 DAYS
1.1K

1 DAY
109

GRIMSHAW MASS. H&dM BIG HENN H SOM ARUP BURO HAPPOLD CALLISONRTKL A DESIGN CONSULTANCY OF ARCADIS KIERANTIMBERLAKE atelier ten ELEMENTA

# Want to contribute?

code:
**GitHub**

github.com/CenterForTheBuiltEnvironment/clima

documentation:
**GitBook**

cbe-berkeley.gitbook.io/clima

anything else:
**Contact us**

g.betti@udk-berlin.de

Team

Funding

CENTER FOR THE BUILT ENVIRONMENT

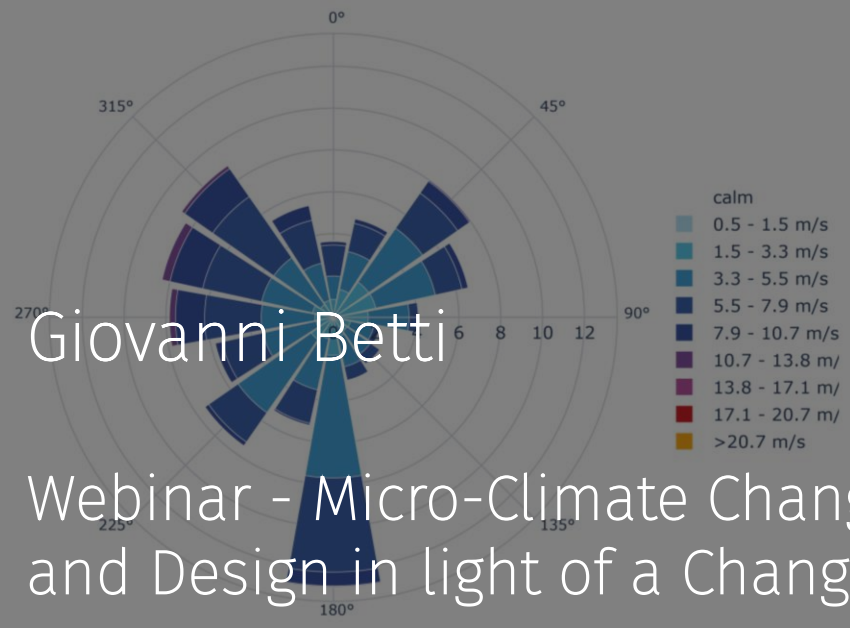
Giovanni Betti
Center for the Built Environment, University of California Berkeley, USA

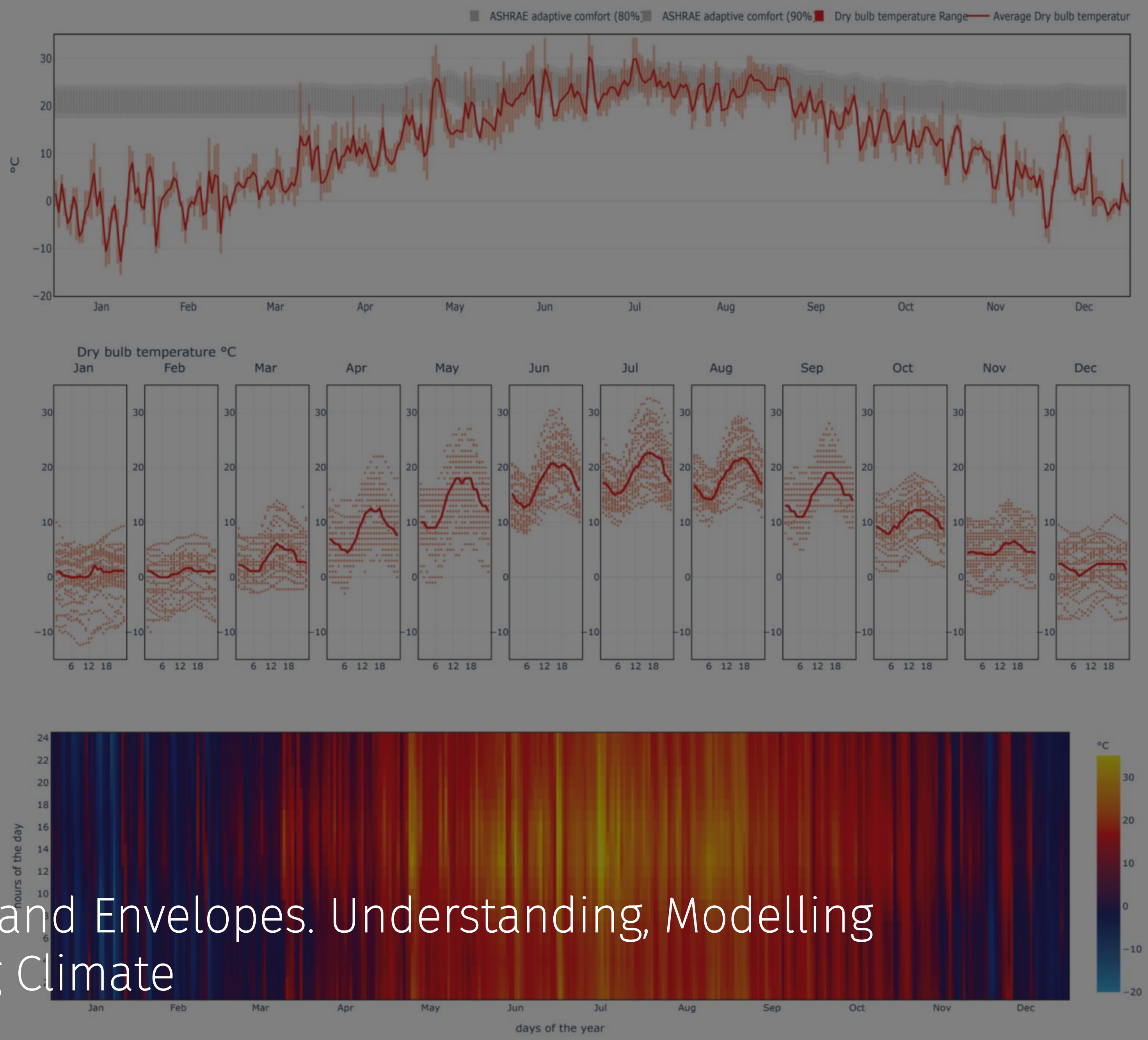
Federico Tartarini
Berkeley Education Alliance for Research in Singapore, Singapore

Christine Nguyen
College of Letters and Sciences, University of California Berkeley, USA

Stefano Schiavon
Center for the Built Environment, University of California Berkeley, USA

# Thank you


Giovanni Betti

Webinar - Micro-Climate Change and Envelopes. Understanding, Modelling and Design in light of a Changing Climate


# The role of citizen data towards climate resilient cities

Future of Cooling Programme of the Oxford Martin School
University of Oxford

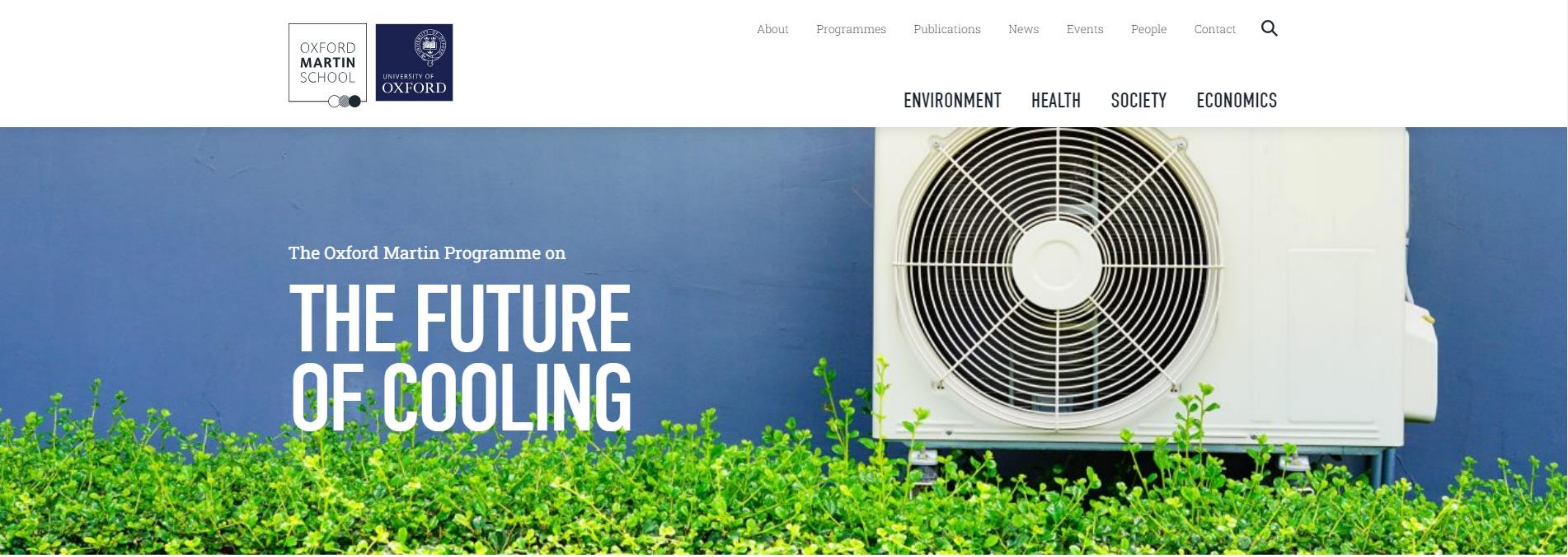
Dr Jesus Lizana
Architect, Marie-Curie Research Fellow
Department of Engineering Science
University of Oxford

jesus.lizana@eng.ox.ac.uk

@lizanafj

Department of Engineering Science · University of Oxford · ResCool · European Commission

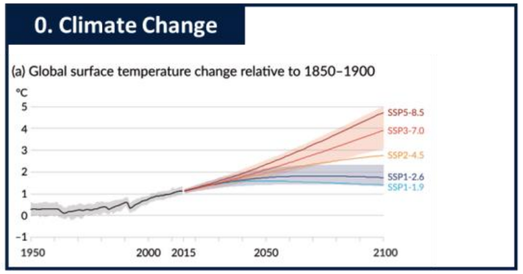
# The Oxford Martin Programme on The Future of Cooling

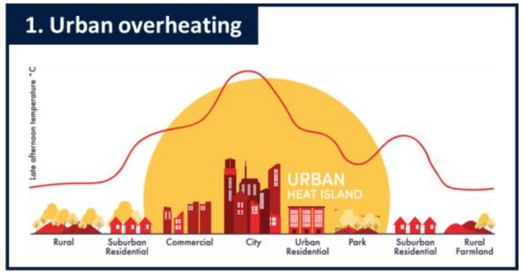


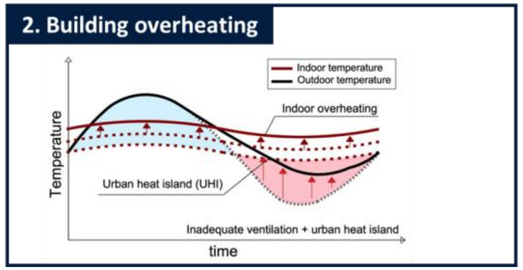

**Oxford Future of Cooling Programme**
**@OxfordCooling**

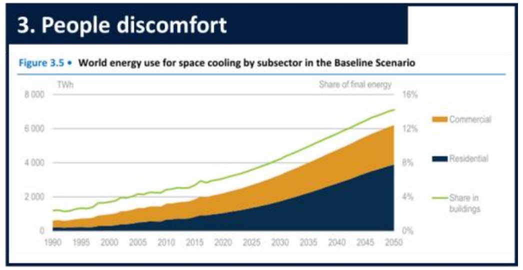
# WHAT CAN WE DO TO MITIGATE THE IMPACT OF HEAT?

## ACTION SCALES




Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

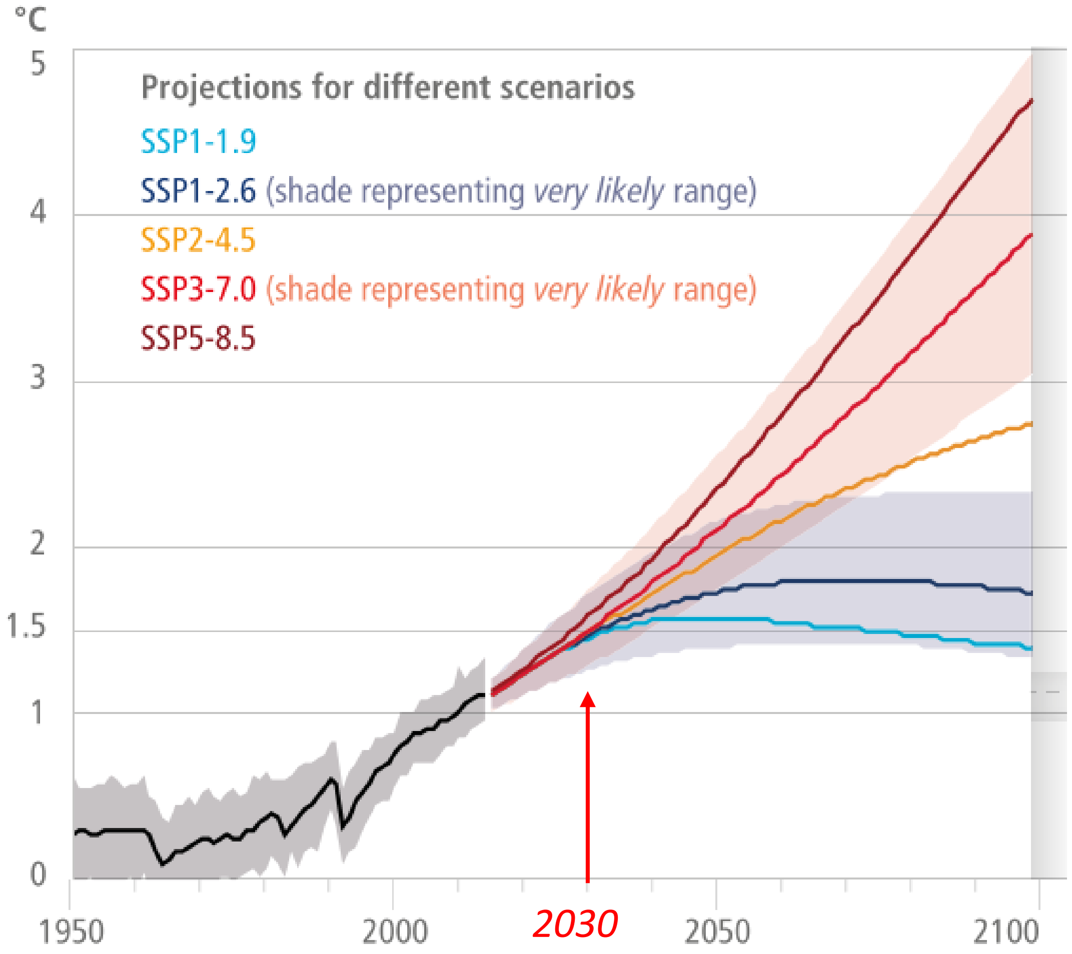
# Challenge

Increase in global surface temperature above pre-industrial levels

-1.09°C by 2011-2020

-Keeping temperature increase below 1.5ºC is out of reach

-1.5ºC is expected by 2030




IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009325844.001

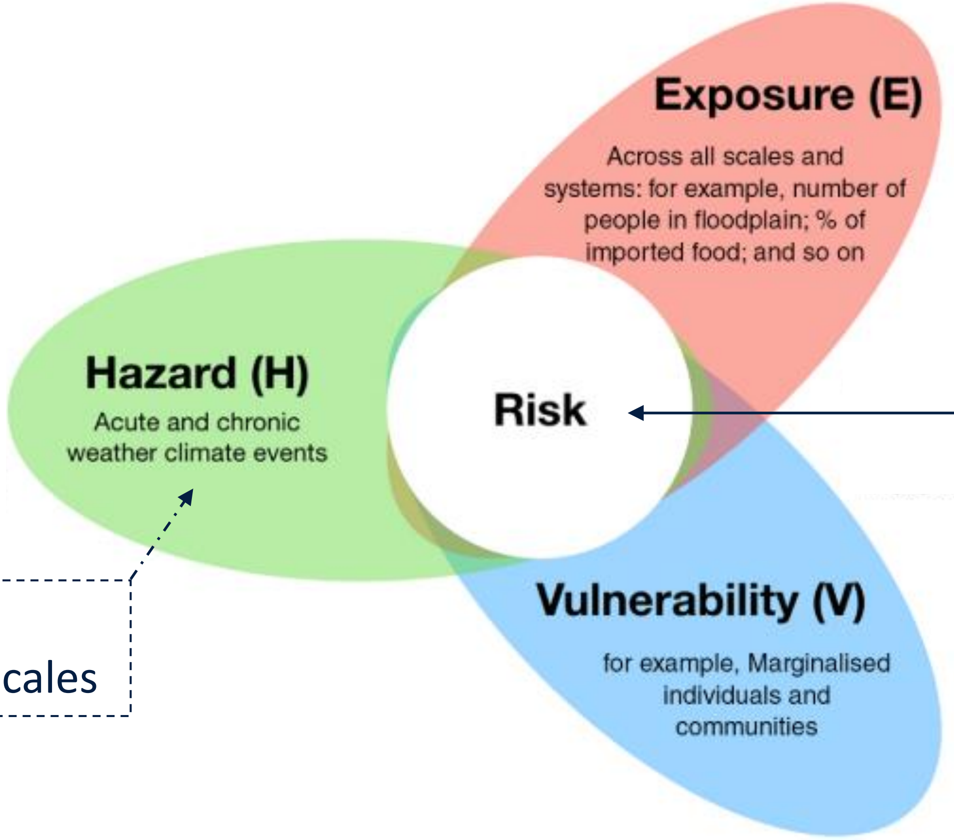
Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

# Challenge

Looking at from 1.5°C to 2°C global warming

Which cities and regions are under the highest climate risk?

**Mitigation policies**




**Resilience and adaptation policies**

**Accurate climate information**
At the macro, meso, local and micro scales

Viner, D. et al. (2020) 'Understanding the dynamic nature of risk in climate change assessments—A new starting point for discussion', Atmospheric Science Letters, 21(4), pp. 1–8.

# Citizen science for accurate climate information

## *Citizen-driven distributed computing*

**Global climate modelling**
Scale: global (macro and meso)
Spatio-temporal resolution: 6h at 60km$^2$
Platform: Climateprediction.net(CPDN)

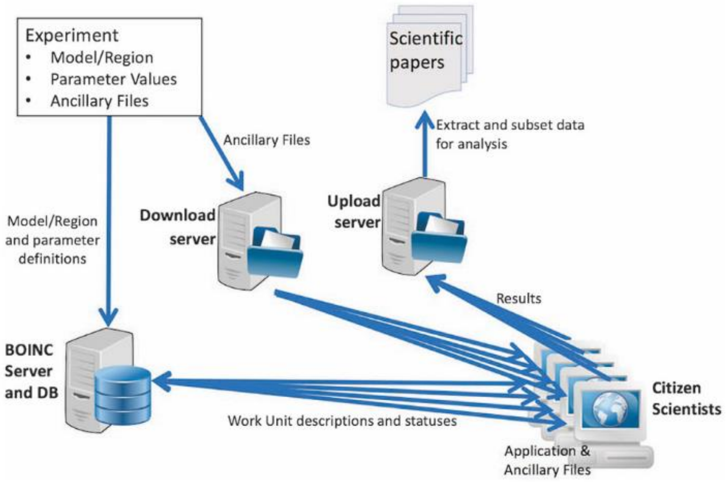



Fig. 1. Workflow of publically volunteered computers for climate modelling

## *Citizen weather data*

**Local climate information**
Scale: city (local and micro)
Spatio-temporal resolution: 1h at 1km$^2$
Platform: Netatmo, Wunderground

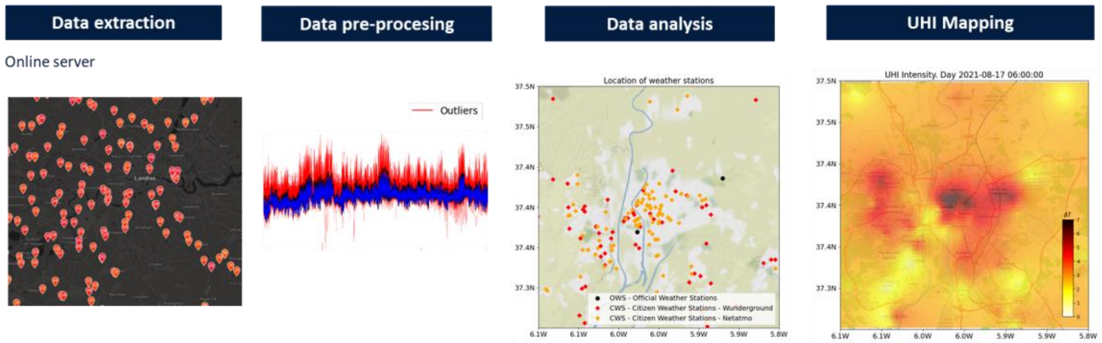


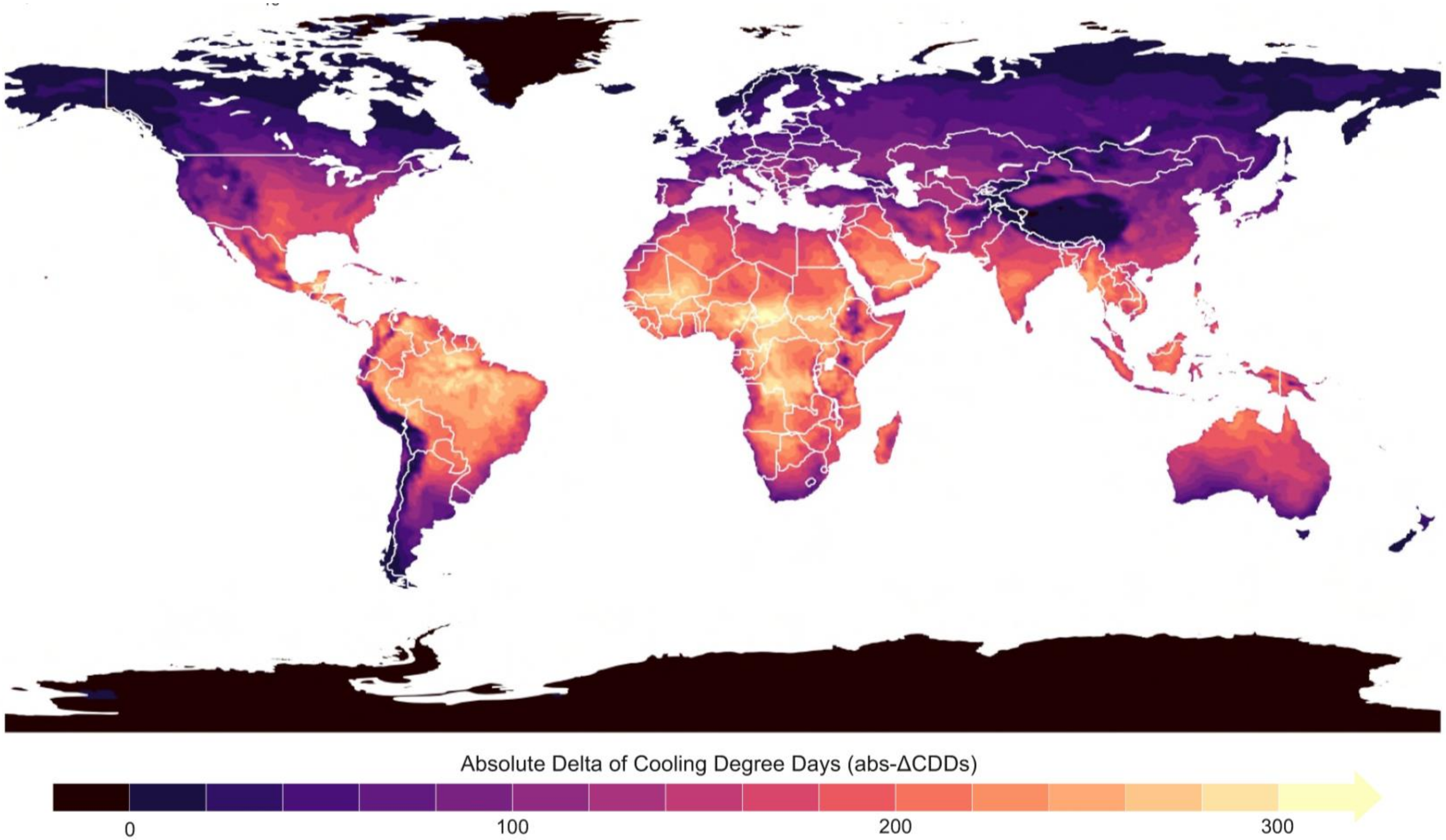

Fig. 2. Workflow of citizen weather data for high-resolution urban climate mapping

Schaller, N. et al. (2018) ‘Data descriptor: Ensemble of european regional climate simulations for the winter of 2013 and 2014 from HadAM3P-RM3P’, Scientific Data, 5, pp. 1–9.

Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

# Citizen-driven distributed computing

## *Increase in Cooling Degree Days from 1.5°C to 2°C*




*Largest spatiotemporal resolution of 1.5°C and 2.0°C climate change scenarios*
*Identification of regions more affected using Cooling Degree Days*

-African countries have the highest increase in cooling requirements.

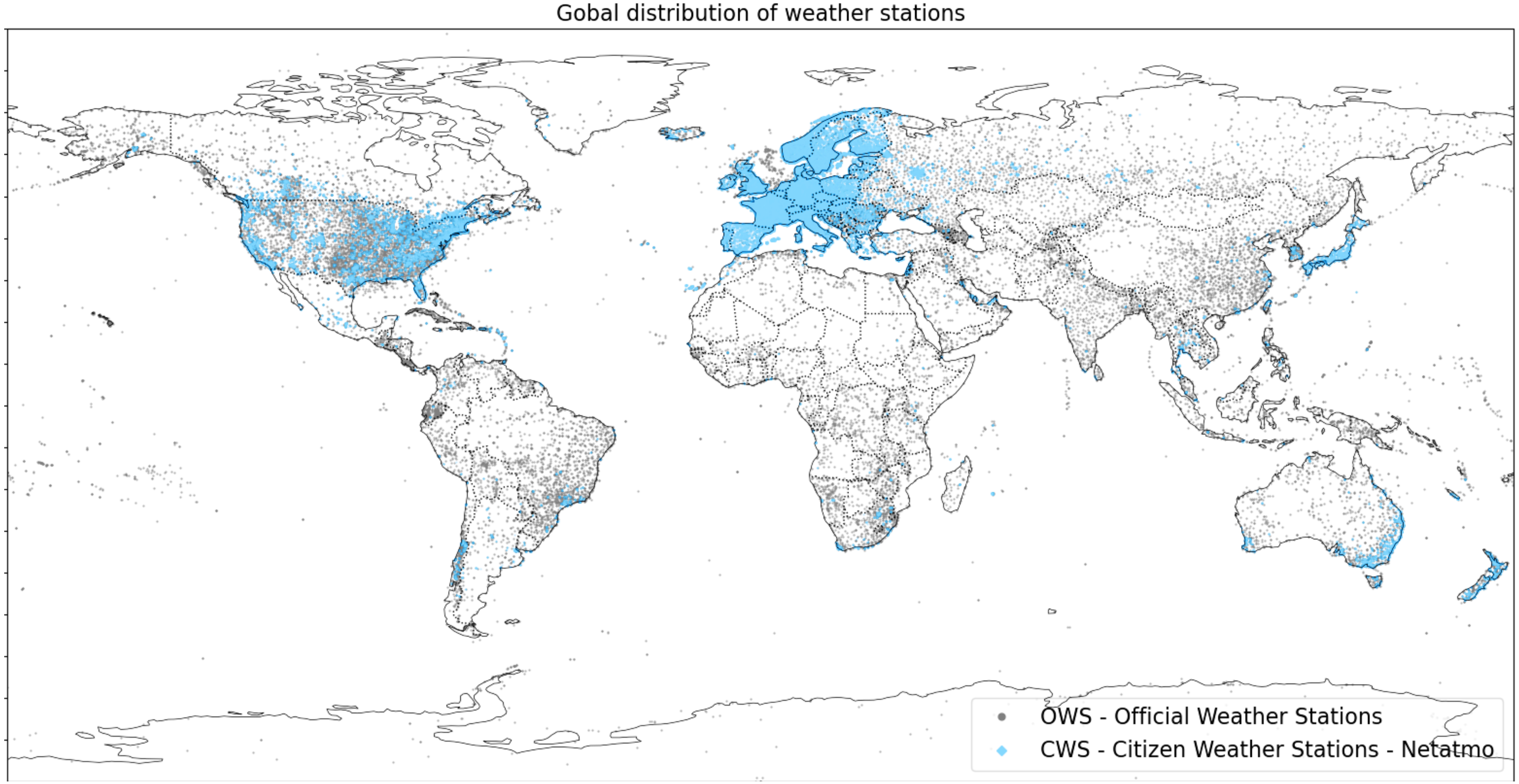
-In Europe, Mediterranean countries will suffer the highest increase in cooling needs.

Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

# Citizen weather data

***550,000 citizen weather stations are found globally***

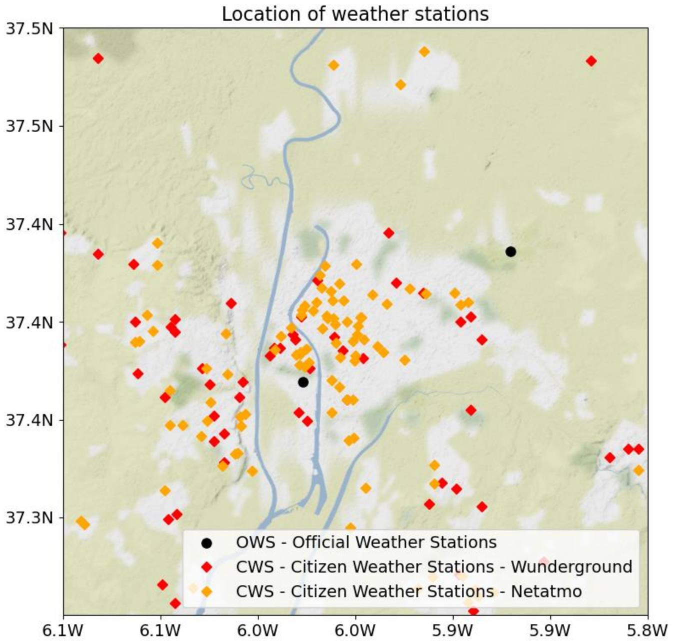
***Higher citizen weather data density in Europe***

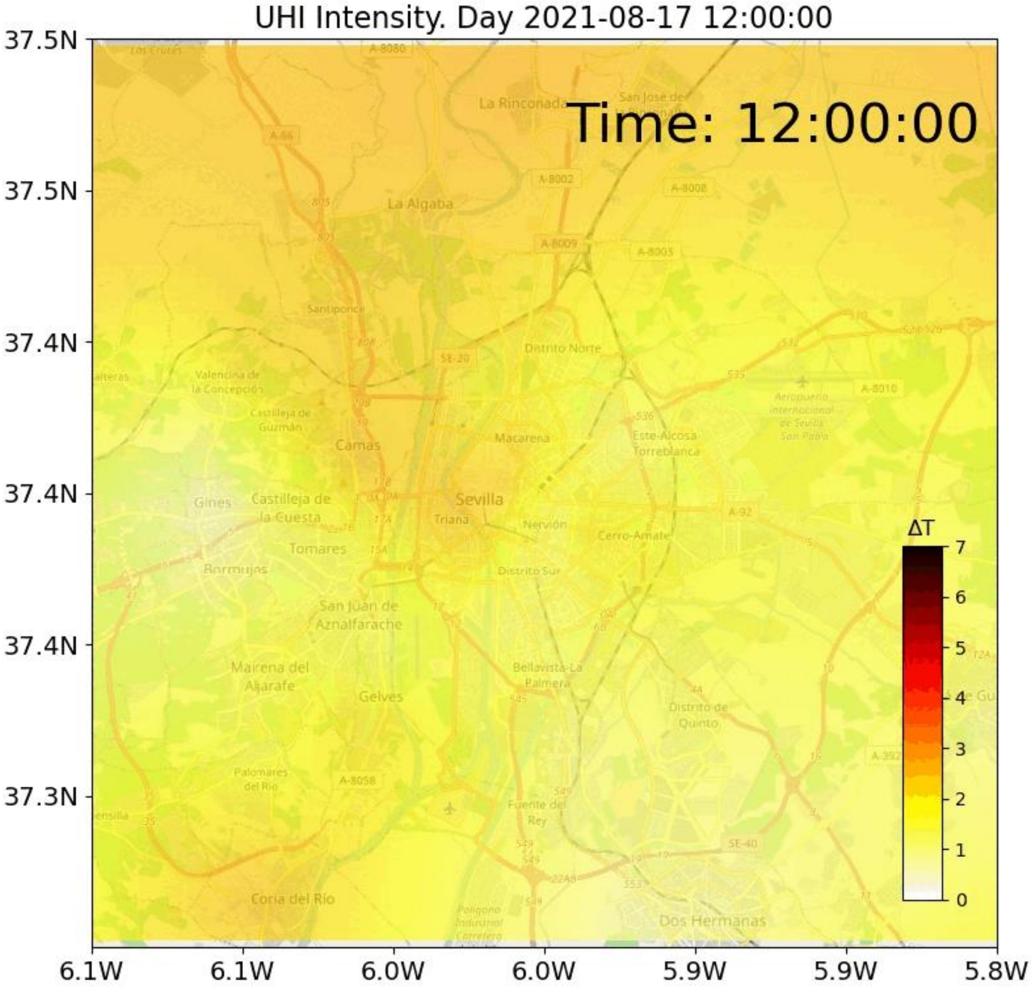




Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

# *Citizen weather data*

## *Atmospheric urban heat island mapping*




-Identification of urban areas with an additional temperature increase by 6°C

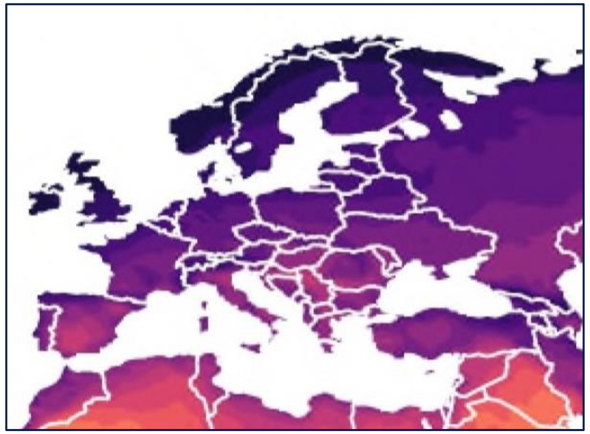
Dr Jesus Lizana – jesus.lizana@eng.ox.ac.uk

# *The role of citizen data*

- Citizen science can play an important role in supporting the generation of accurate climate information:
- to evidence the regions with higher climate-related impact;
- and to prioritise the climate adaptation policies in the built environment;
- towards climate-resilient cities

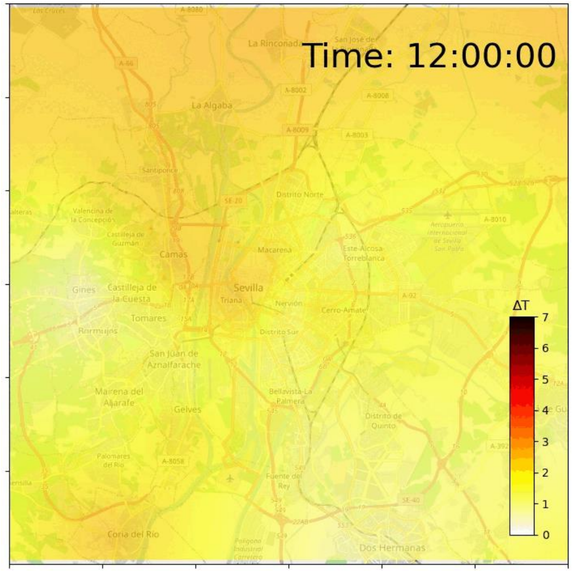
Macro and meso scales

*Citizen-driven computing*



Local and micro scales

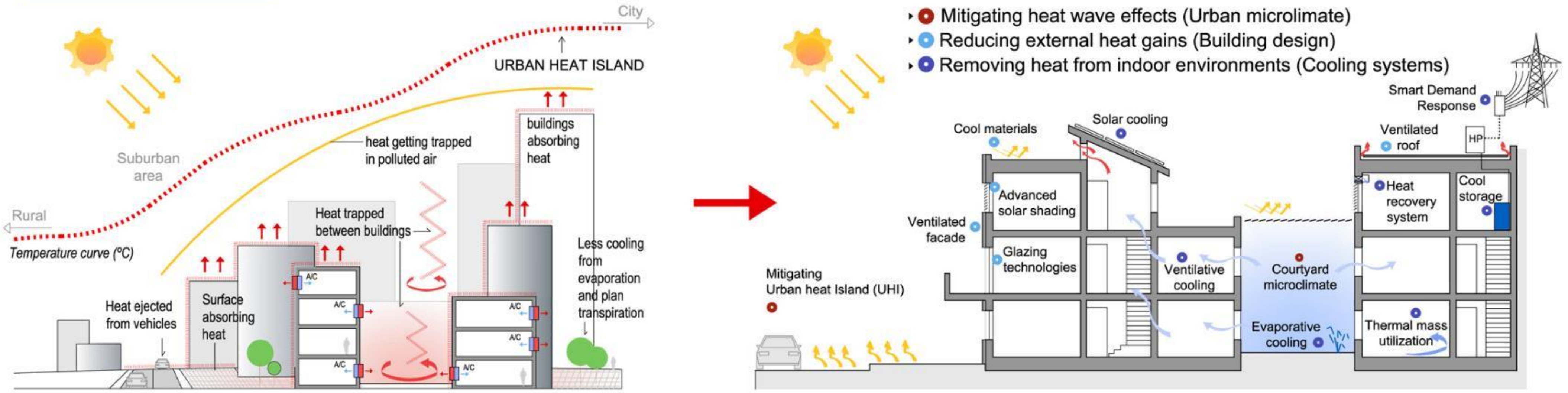
*Citizen weather data*



ResCool

a H2020 Marie Curie Project

FUTURE OF COOLING · OXFORD MARTIN SCHOOL · UNIVERSITY OF OXFORD




## Climate risk assessment → Climate risk mitigation

**ResCool** - *Resilient cooling towards climate change adaptation of cities and buildings*

European Commission · HORIZON 2020

**Jesus Lizana**
**@lizanafj**
**jesus.lizana@eng.ox.ac.uk**

**Oxford Future of Cooling Programme**
**@OxfordCooling**

# Envelopes in Light of Climate Change

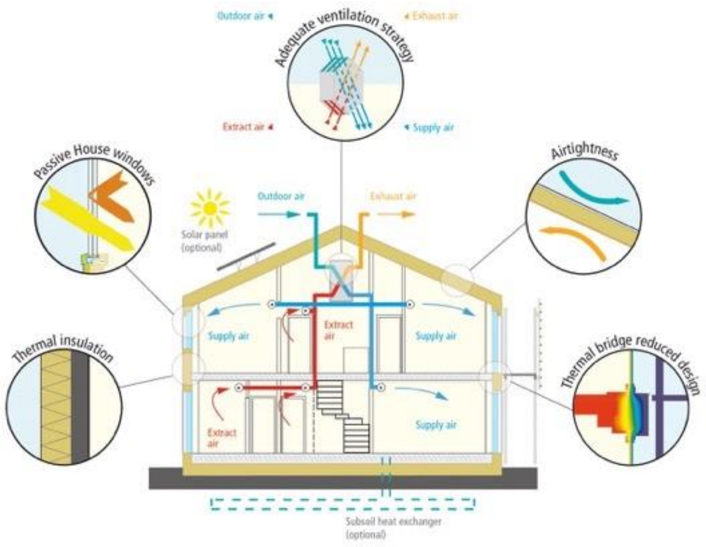
## Adaptive Opaque Facades

### Shifting from highly-insulated envelopes to thermal modulators

Miren Juaristi
Postdoctoral Researcher
Energy Efficient Buildings group - Eurac Research

28.04.2023

# How do we build energy efficient building envelopes?



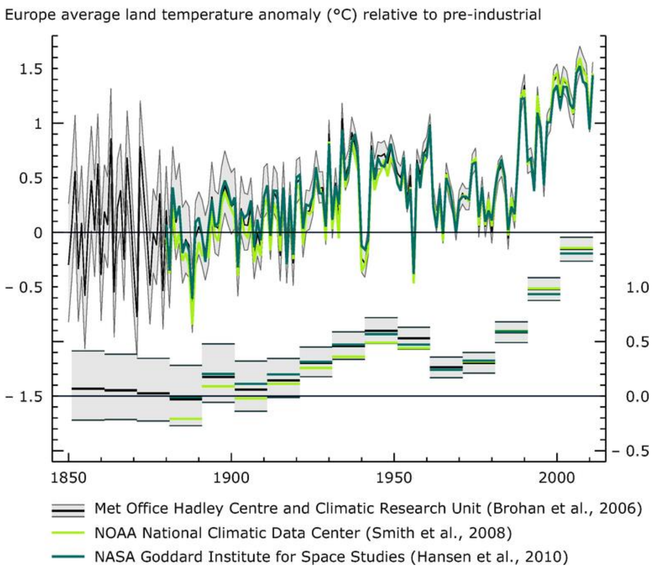

Excluding approach

High insulation level


Air-tightness

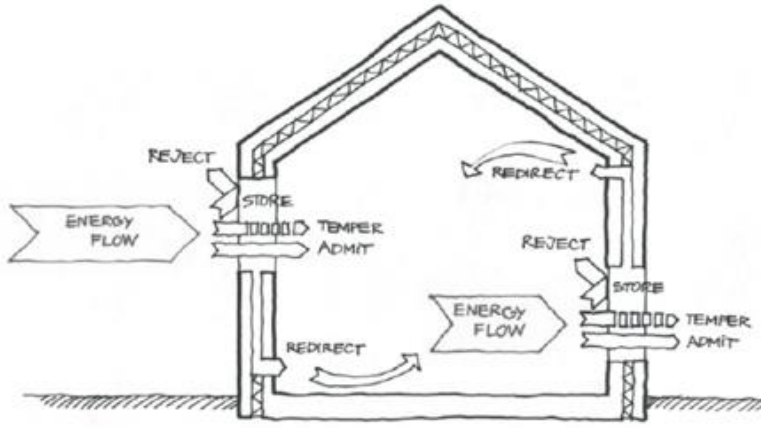
# The problem of building for average situations

Internal heat gains
may not be constant



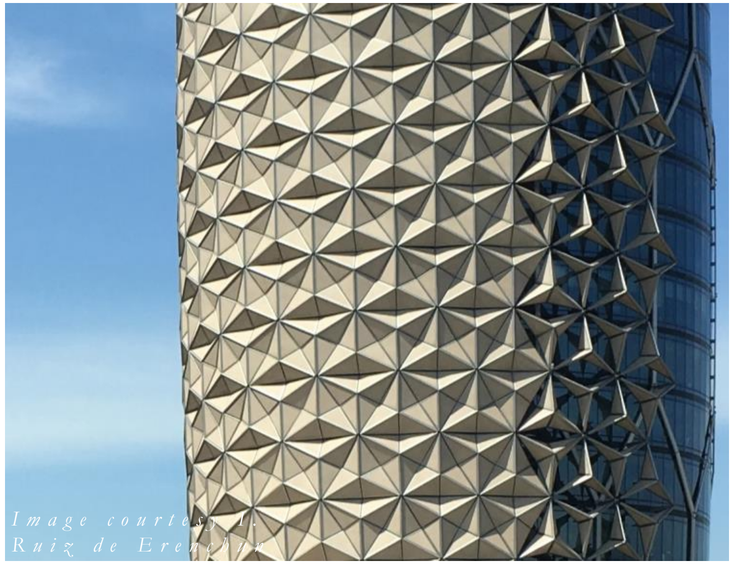

Climate change: average conditions are changing, and thus energy demand could evolve

# Selective approach or Adaptive Facade concept




*http://: IEA EBC Annex 44*
*adapted by Fernández Solla*

Selective approach

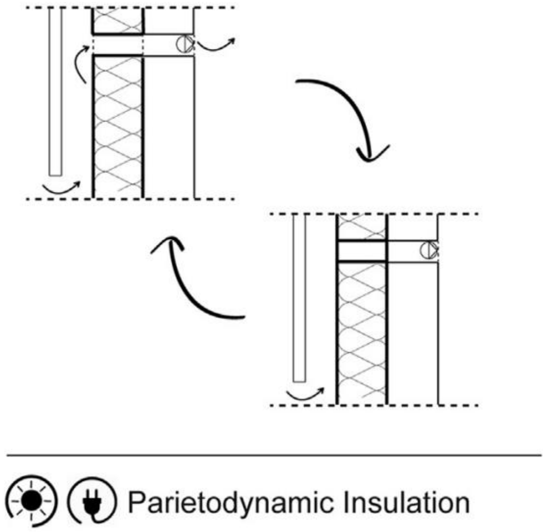


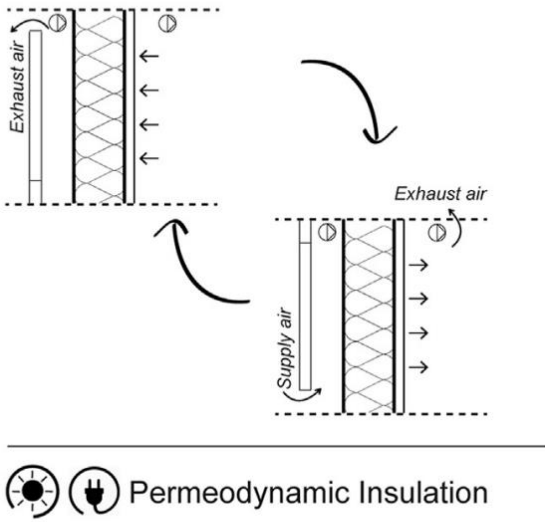

There are already buildings with transparent Adaptive Facades

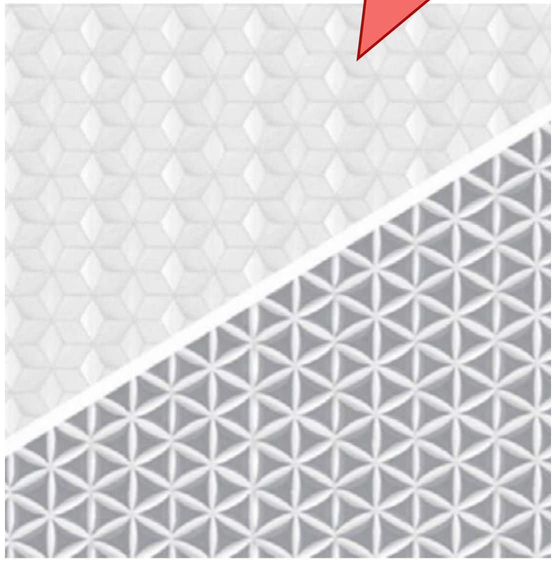
Adaptive opaque façades have not yet been successful in the market uptake

# Adaptive Opaque Facades

They could also be useful in reducing the urban heat island effect.



Parietodynamic walls

Permeodynamic walls

Dynamic Insulations

Kinetic claddings

Source: Juaristi, M.; Gómez-Acebo, T.; Monge-Barrio, A. Qualitative analysis of promising materials and technologies for the design and evaluation of Climate Adaptive Opaque Façades. Build. Environ. 2018, 144, 482–501, doi:10.1016/j.buildenv.2018.08.028.

Image by author. Prototype at Larson Building System Laboratory at the University of Colorado, Boulder. Concept patented by Krarti and tested in a laboratory to characterise its dynamic thermal behaviour

Source: Juaristi M, Loonen R, Isaia F, et al. (2020) Dynamic climate analysis for early design stages: A new methodological approach to detect preferable adaptive opaque facxade responses.Sustainable Cities and Society 60: 102232

# Adaptive Opaque Facades

## Which solution is best for... ?

| Heat control solution type | Noise insulation | Air pollution insulation | Durability | Cooling demand reduction | Heating demand reduction |
|---|---|---|---|---|---|
| NATURAL VENTILATION | ★ | ★ | ★★★ | ★★ | ★ |
| PARIETODYNAMIC | ★ | ★★★ | ★★ | ★★ | ★★ |
| PERMEODYNAMIC | ★★★ | ★★★ | ★ | ★★ | ★★ |
| GAS-FILLED PANELS | ★★ | No air exchange | ★★ | ★★★ | ★★★ |
| CLOSED-LOOP DYNAMIC INSULATION | ★★ | No air exchange | ★★ | ★★★ | ★★★ |
| MOVABLE MULTI-LAYER PANELS | ★ | No air exchange | ★★ | ★★★ | ★★★ |
| MOBILE COATINGS | No noise insulation | No air exchange | ★★ | ★ | ★★★ |

*Build up, infographics made by EURAC*

# Adaptive Opaque Facades need to be further tested

## ZERAF – A Disruptive Facade Concept for Zero-Carbon Buildings

## Objectives

The aim of the **EIC-EU funded project** is to scientifically prove that ZERAF concept **can control all heat transfer mechanisms in opaque building facades to a significant level**. Prototypes will be manufactured for the first time and their thermal behaviour will be characterized in a dedicated laboratory. To prove that used materials, fabrication processes and assembly methods do not jeopardize the carbon footprint reduction, most relevant sustainability parameters will be quantified through a building life cycle method.

- First prototyping of adaptive opaque facade systems
- Prototypes testing to identify dynamic thermal properties
- Calculating the impact of reducing energy demand throughout the life cycle
- Planning exploitation strategies for a future market uptake

ZERAF European Innovation Council Funded by the European Union
This project has received funding from the European Union's Horizon Europe research and innovation programme under GA n. 101098490

# Thank you!

Miren Juaristi Gutierrez
miren.juaristigutierrez@eurac.edu

Adaptive opaque facades

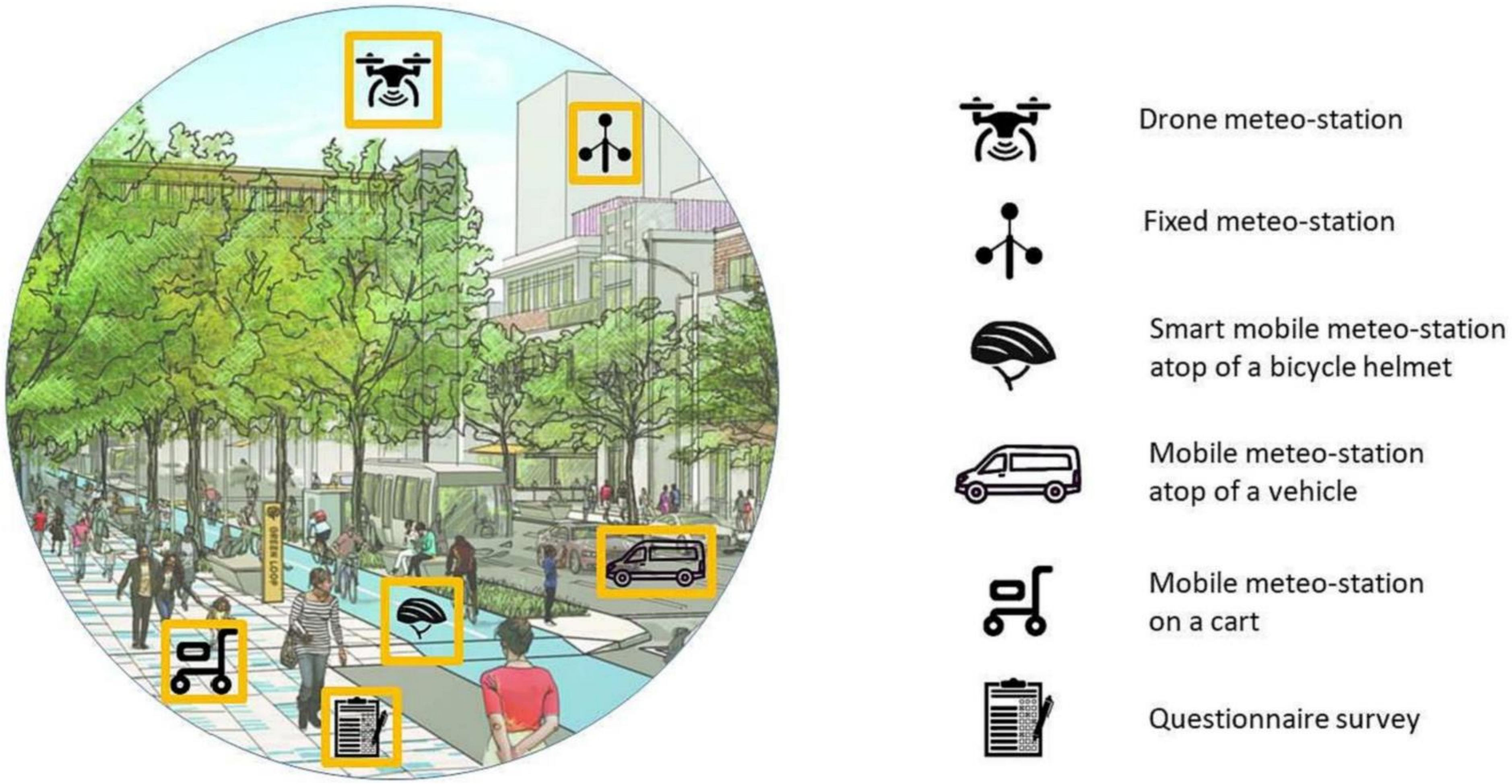
www.zeraf-technology.eu

# BUILDING RESILIENT CITIES:

# How Materials and Urban Monitoring are Driving Climate Action in Urban Environments

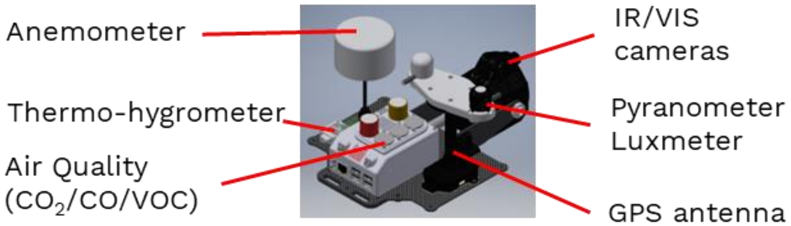
**Ioannis Kousis**

# URBAN MONITORINGING



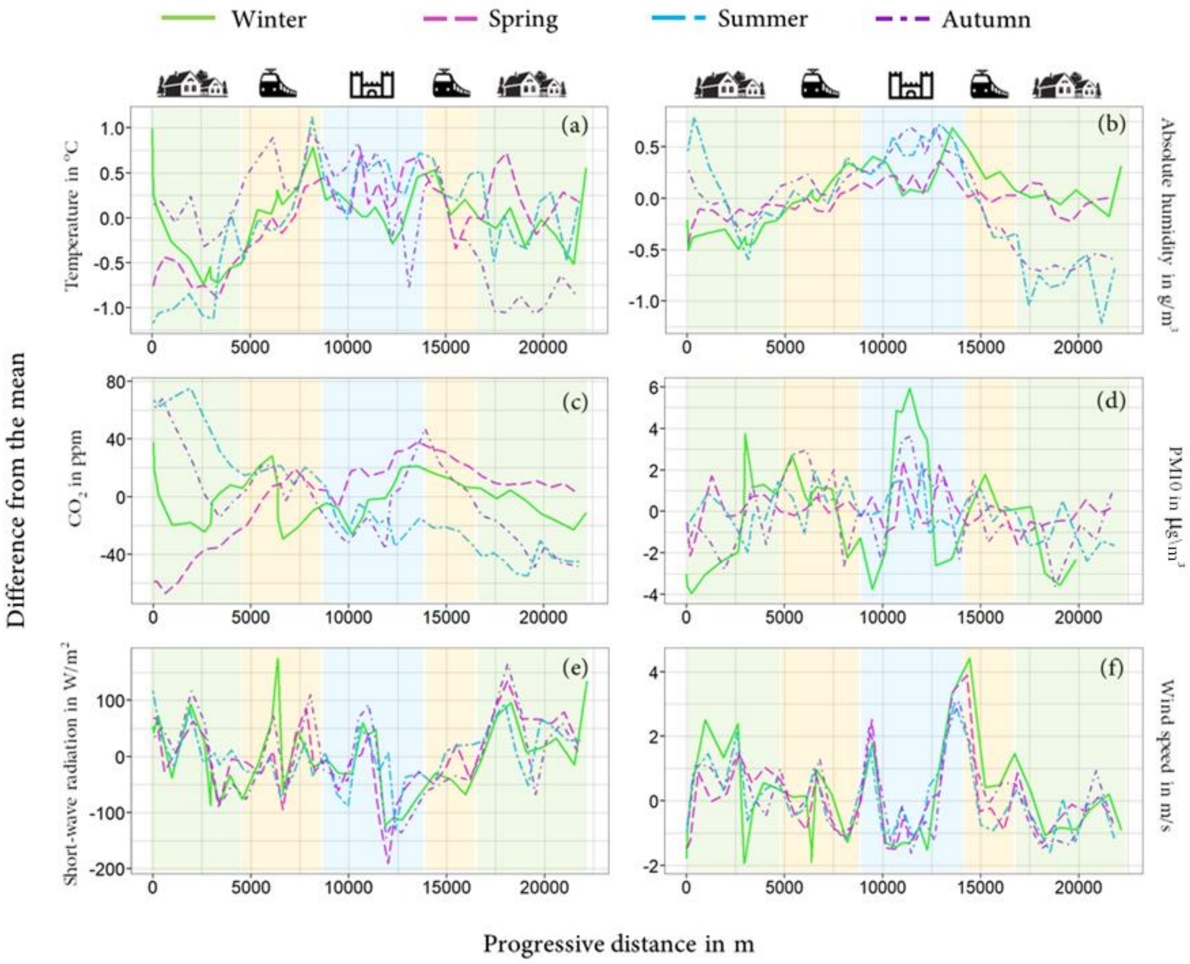

Kousis, I., & Pisello, A. L. (2023). Evaluating the performance of cool pavements for urban heat island mitigation under realistic conditions: A systematic review and meta-analysis. Urban Climate, 49, 101470.

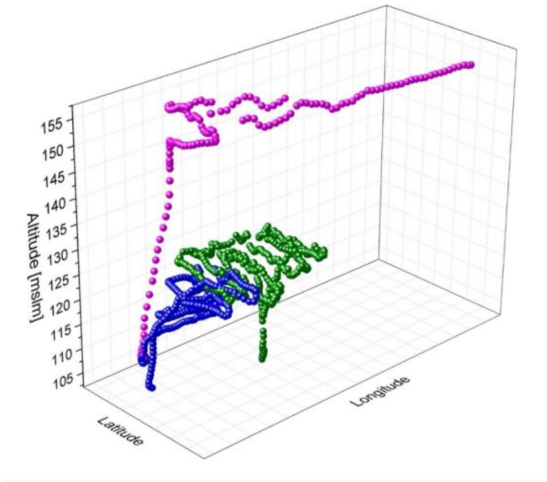
# URBAN MONITORINGING

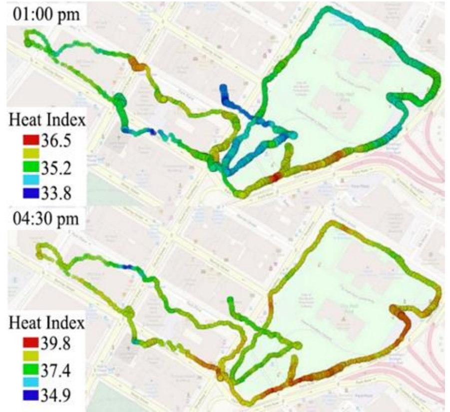


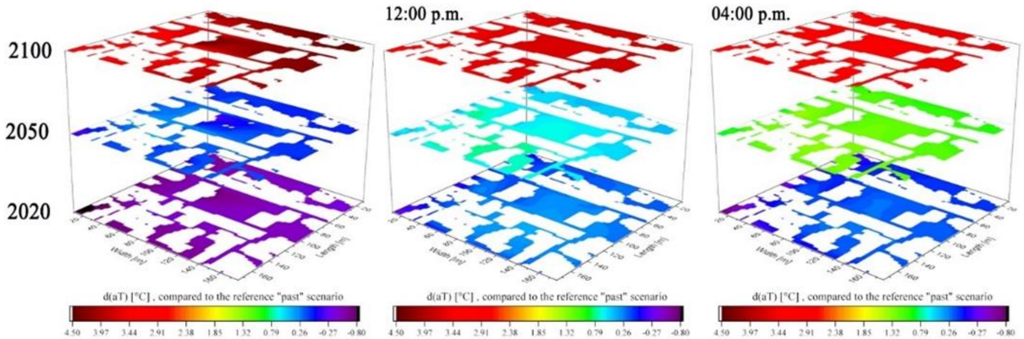

Kousis, I., Manni, M., & Pisello, A. L. (2022). Environmental mobile monitoring of urban microclimates: A review. Renewable and Sustainable Energy Reviews, 169, 112847.

# URBAN MONITORINGING



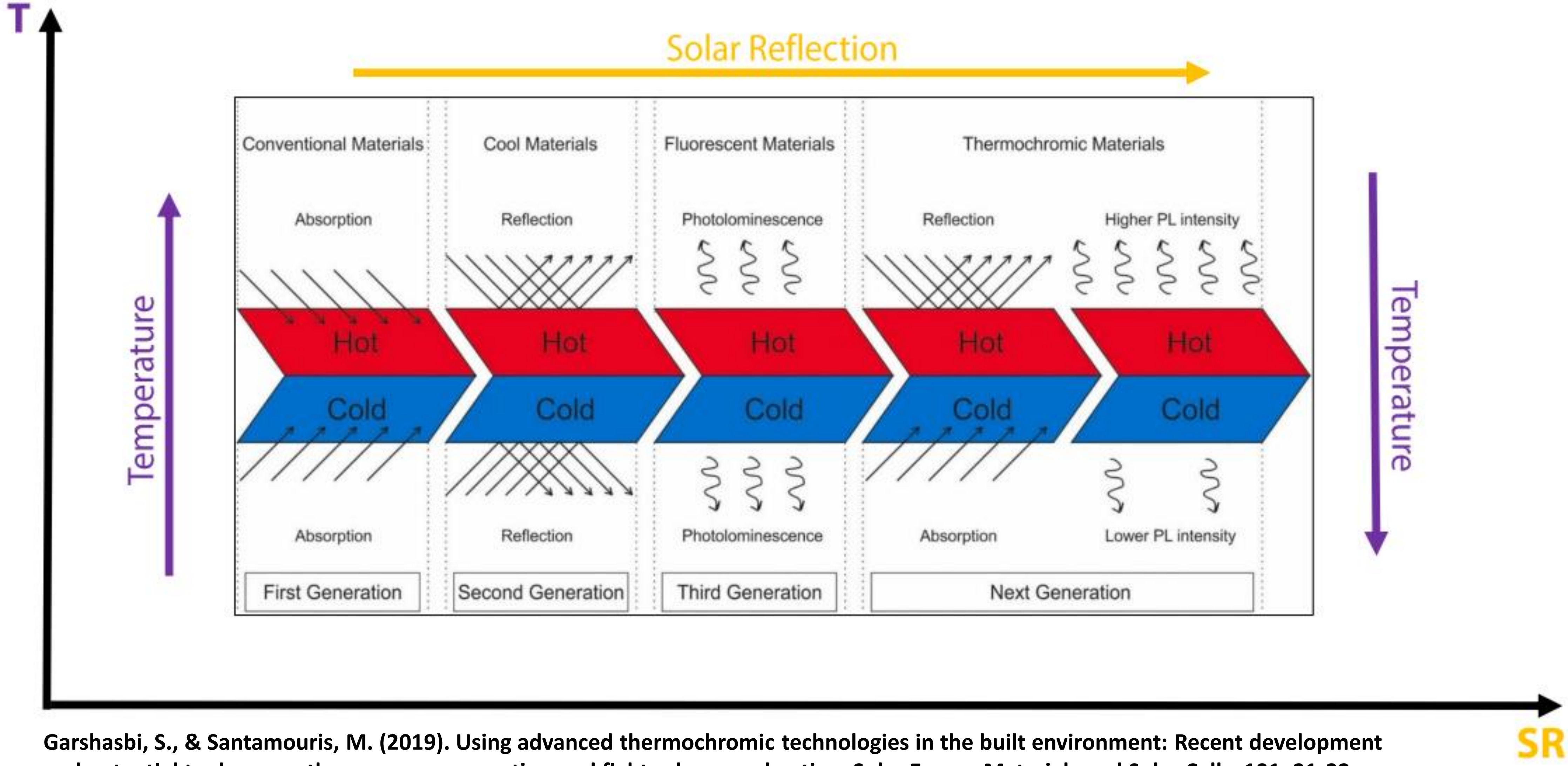



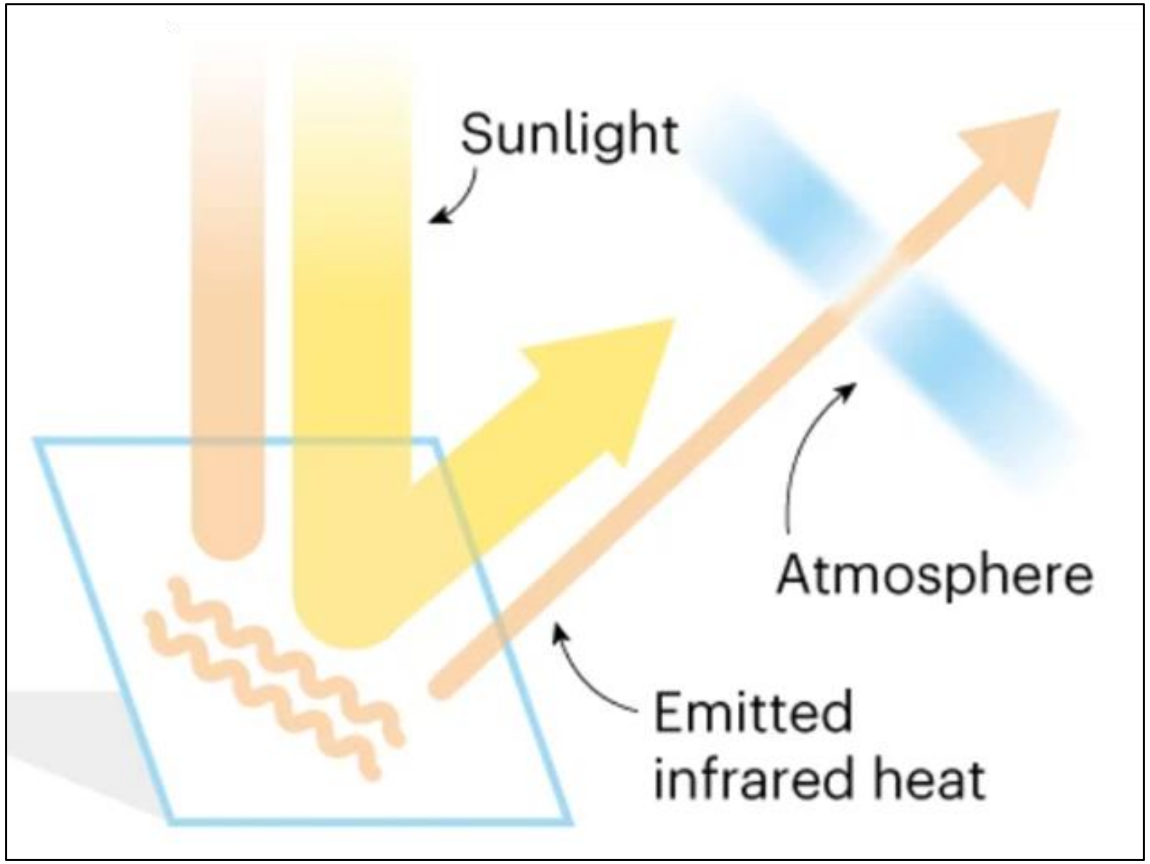

Kousis, I., Pigliautile, I., & Pisello, A. L. (2021). Intra-urban microclimate investigation in urban heat island through a novel mobile monitoring system. Scientific Reports

# URBAN MATERIALS

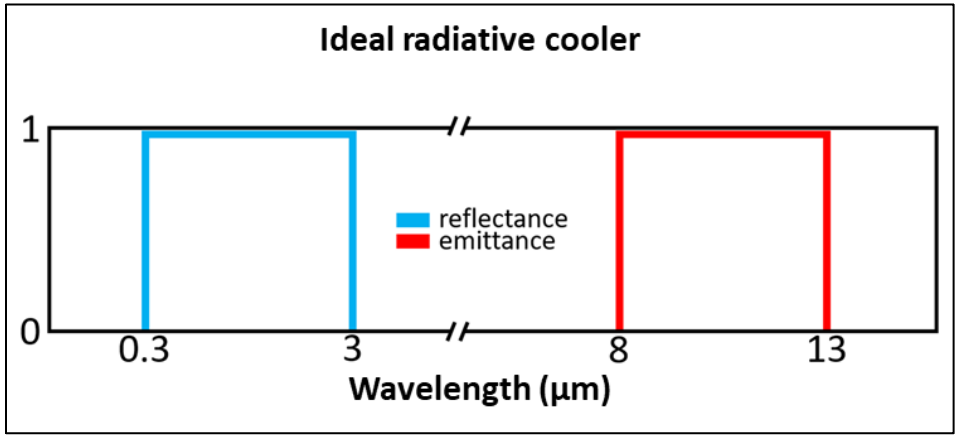



Garshasbi, S., & Santamouris, M. (2019). Using advanced thermochromic technologies in the built environment: Recent development and potential to decrease the energy consumption and fight urban overheating. Solar Energy Materials and Solar Cells, 191, 21-32.

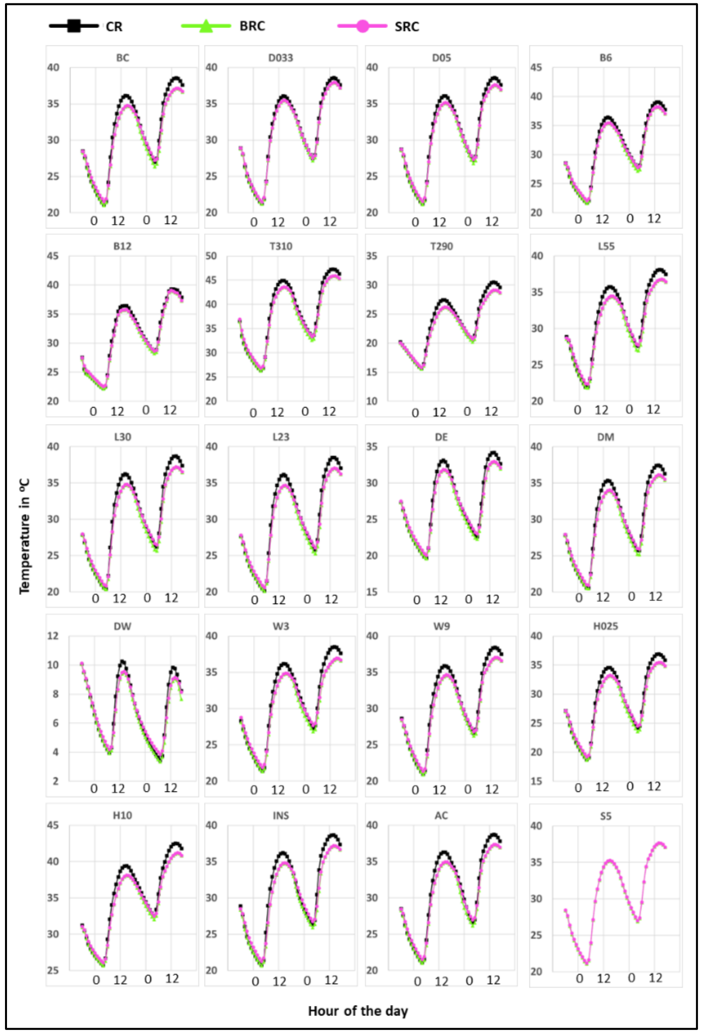
# URBAN MATERIALS: Radiative Cooling

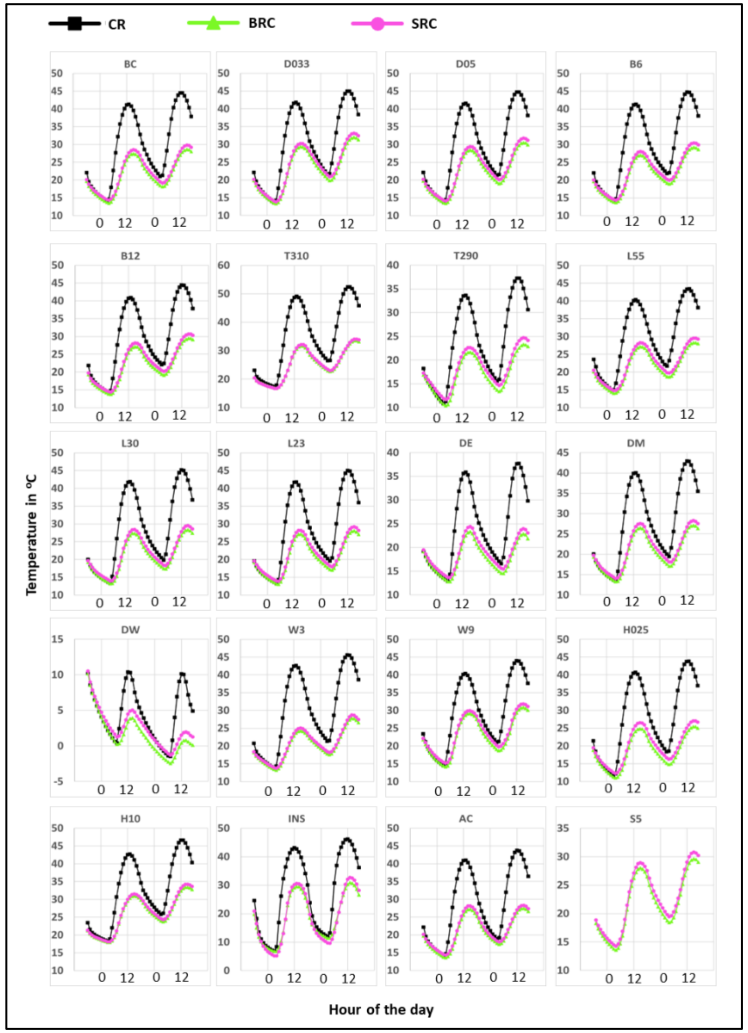


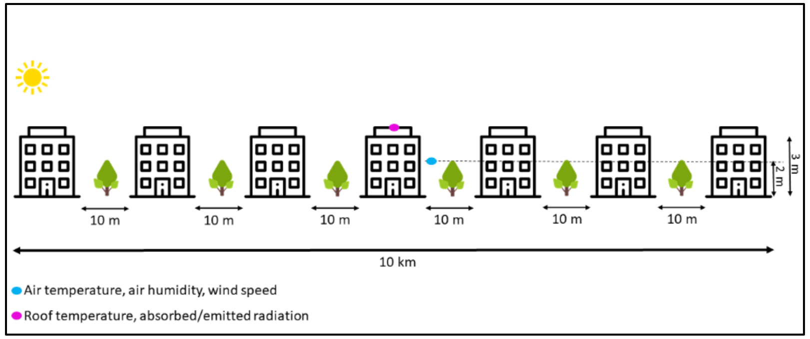

- **Reflect** incoming Sunlight
- **Emit** through the atmospheric window



# URBAN MATERIALS: Radiative Cooling




Surface temperature reduction

Air temperature reduction

European Research Council
Established by the European Commission

Kousis, I., Martilli, A. and Pisello, A.L., 2023. Modelling radiative coolers for the built environment in the urban context. Under review

# KEY MESSAGES

Detailed intra-urban evaluation of urban environment

Human-centered approaches

Understand the microclimate boundaries and patters

Be smart: use smart materials

Radiative Cooling: substantial cooling effect with a variety of applications

# THANK YOU


## Ioannis Kousis

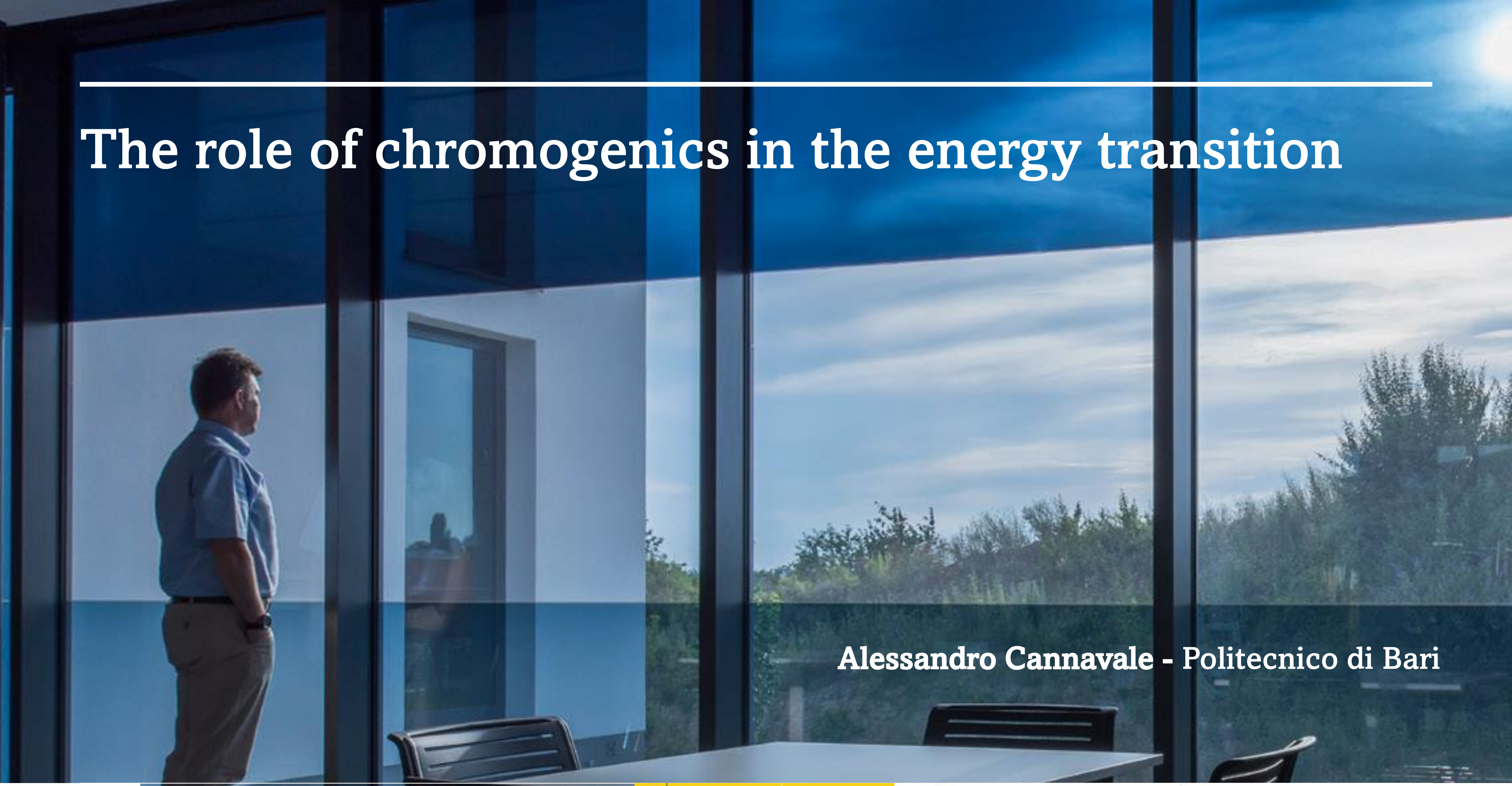
ioannis.kousis@unipg.it

https://orcid.org/0000-0002-4433-1878

linkedin.com/in/ioannis-kousis-bb3481158/

twitter.com/IKousis

# The role of chromogenics in the energy transition



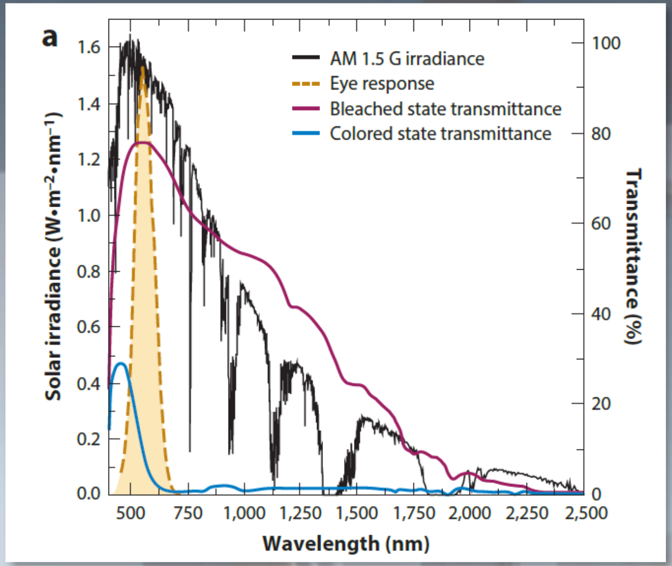
**Alessandro Cannavale** - Politecnico di Bari

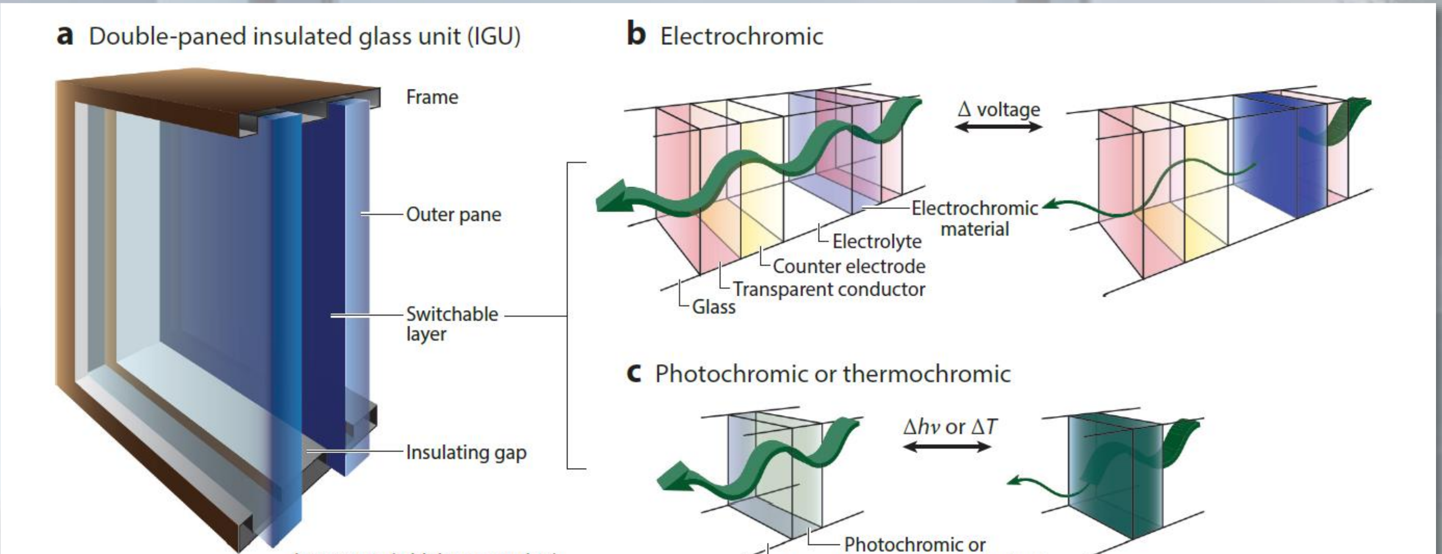
# The role of chromogenics in the energy transition

New regulations require higher standards for indoor illuminance and effective shading strategies.

Indoor Visual comfort and energy saving are interconnected, in the roadmap towards the energy transition.

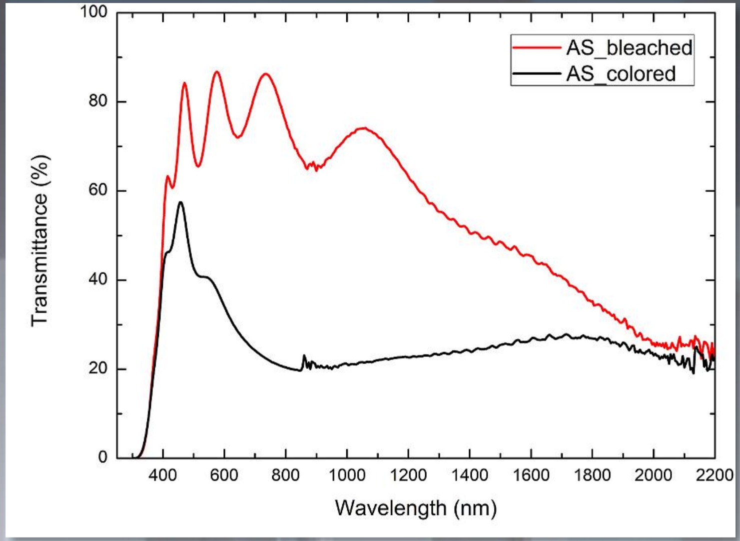
Chromogenic technologies could play an important role in responding with innovative solutions to these multiple needs.

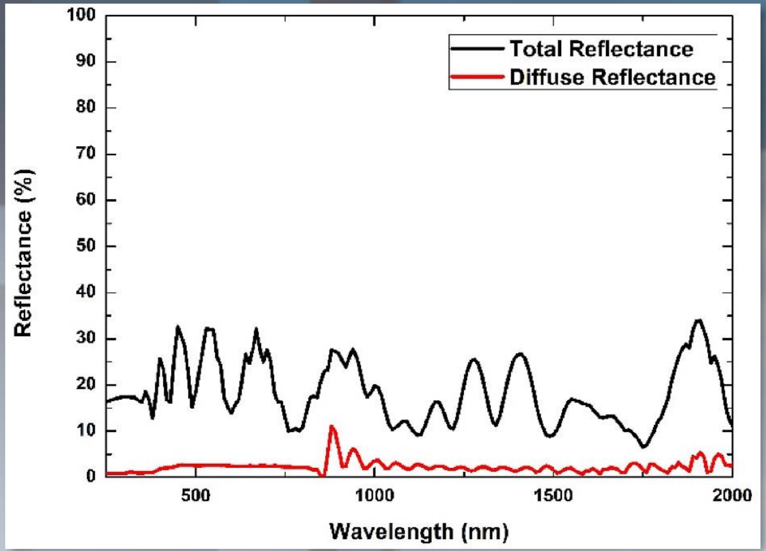


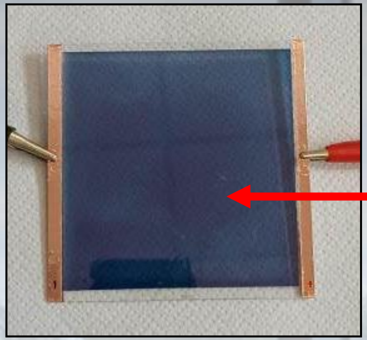

Wang et al.,2015

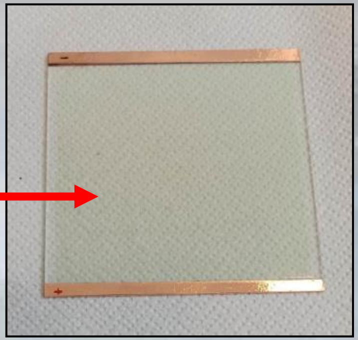
# Low-cost electrochromic devices







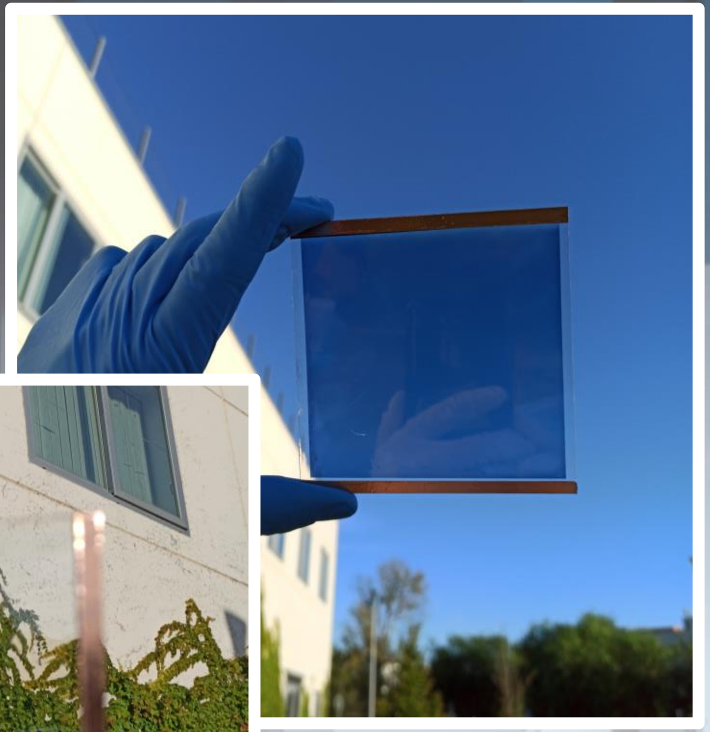


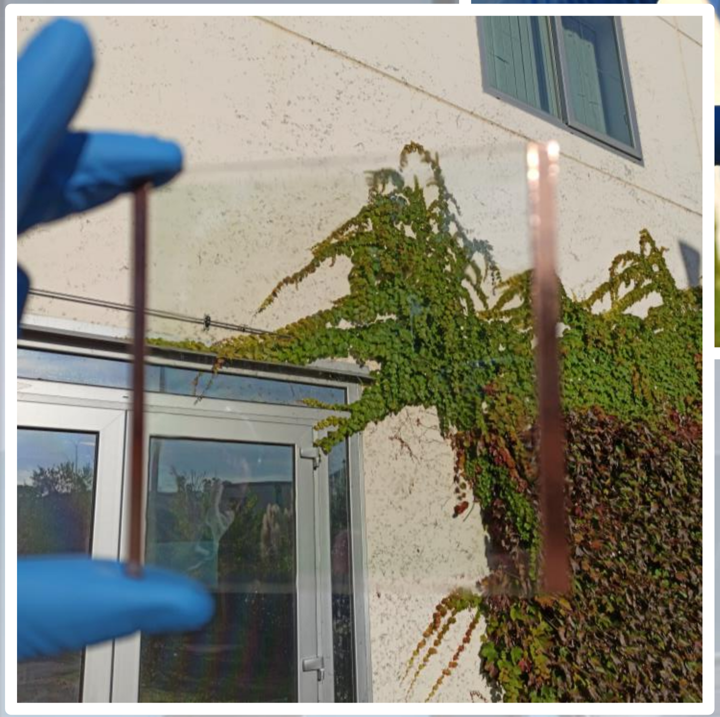
*A. Cannavale et al.* *Solar Energy Materials and Solar Cells 241 (2022) 111760*

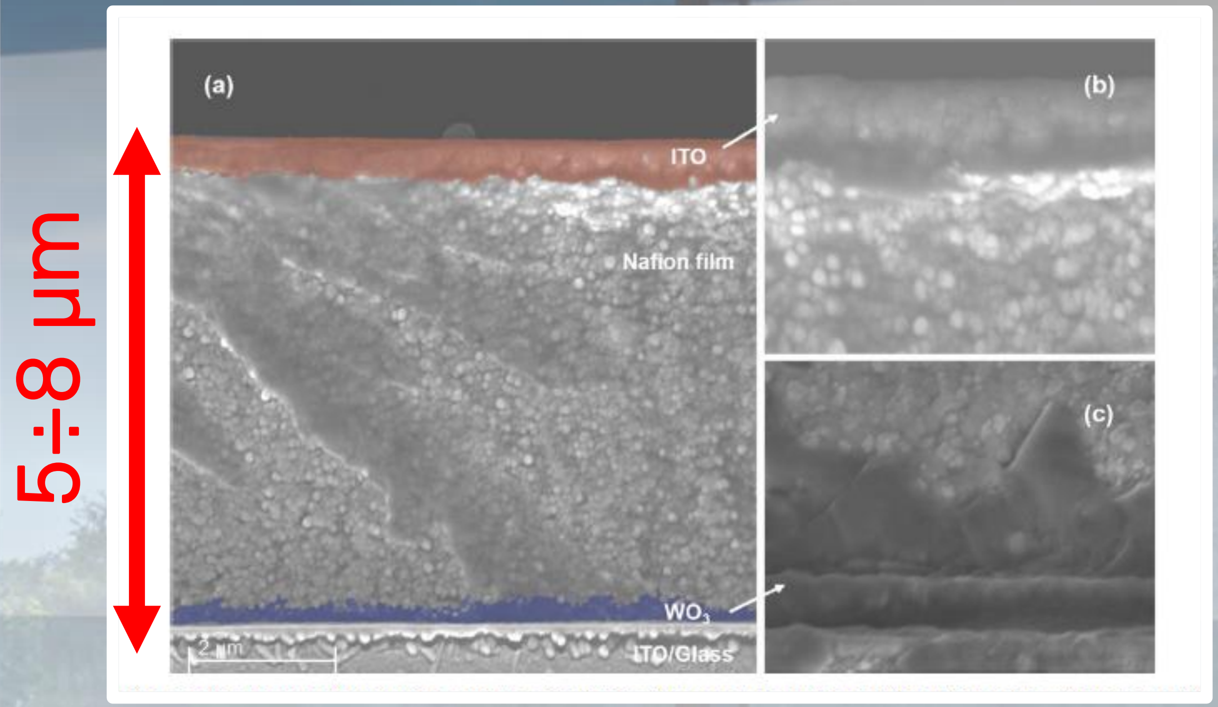
**Table 2**
Thermal and optical properties of Device AS in bleached and colored conditions ($\varepsilon_f$ and $\varepsilon_b$ represent the emissivity of front and back surface of glazing, respectively).

| Device state | $T_{vis}$ | $T_{sol}$ | $R_{fvis}$ | $R_{bvis}$ | $R_{fsol}$ | $R_{bsol}$ | $\varepsilon_f$ | $\varepsilon_b$ | SHGC |
|---|---|---|---|---|---|---|---|---|---|
| AS bleached | 0.77 | 0.67 | 0.08 | 0.18 | 0.08 | 0.16 | 0.84 | 0.52 | 0.73 |
| AS colored | 0.26 | 0.25 | 0.08 | 0.18 | 0.08 | 0.16 | 0.84 | 0.52 | 0.39 |

# Low-cost electrochromic devices

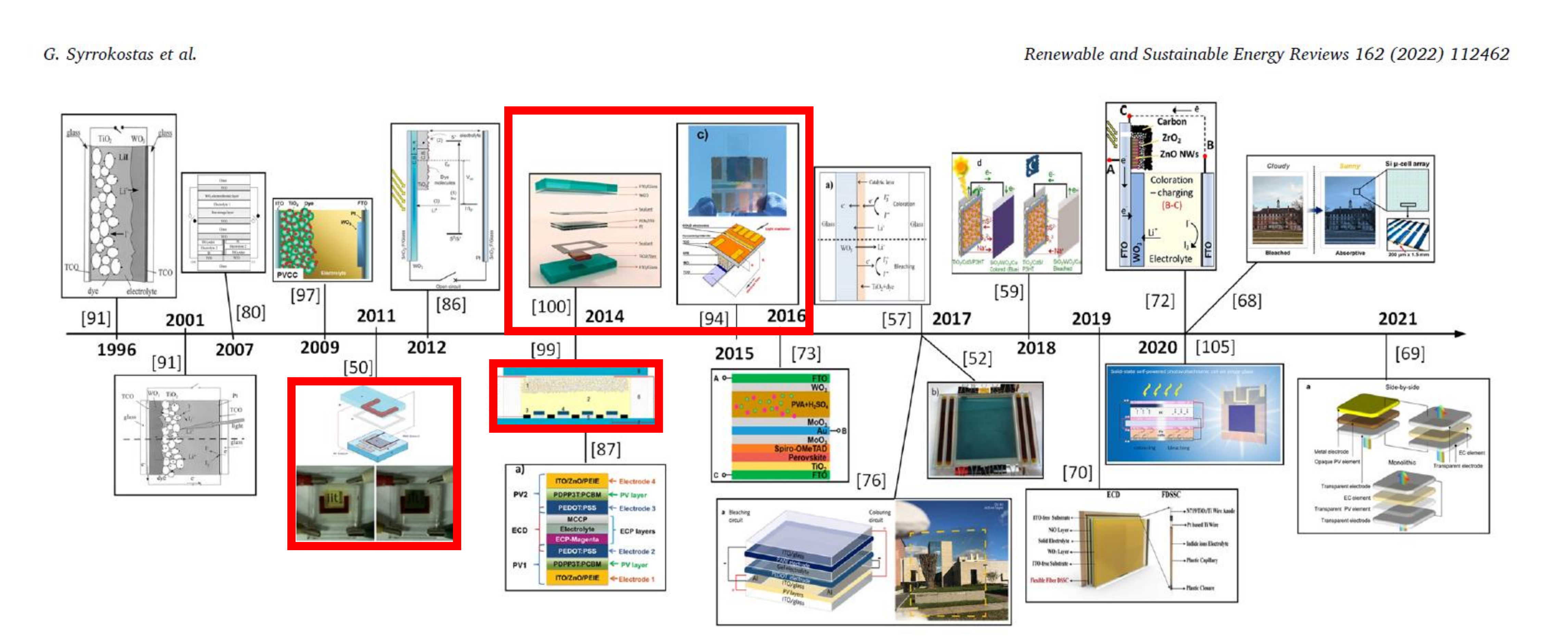







CNRNANOTEC
INSTITUTE OF NANOTECHNOLOGY

# Photoelectrochromic/Photovoltachromic Devices

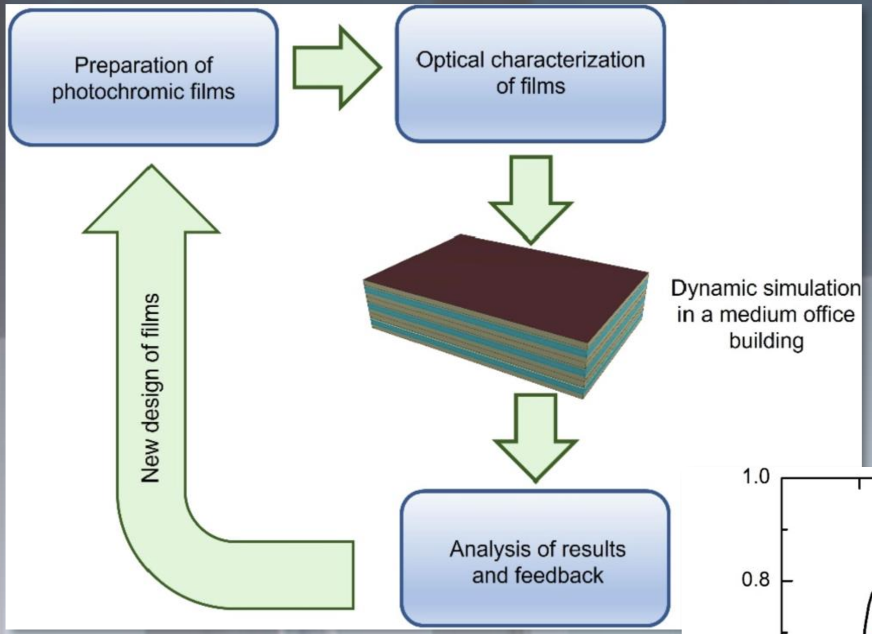


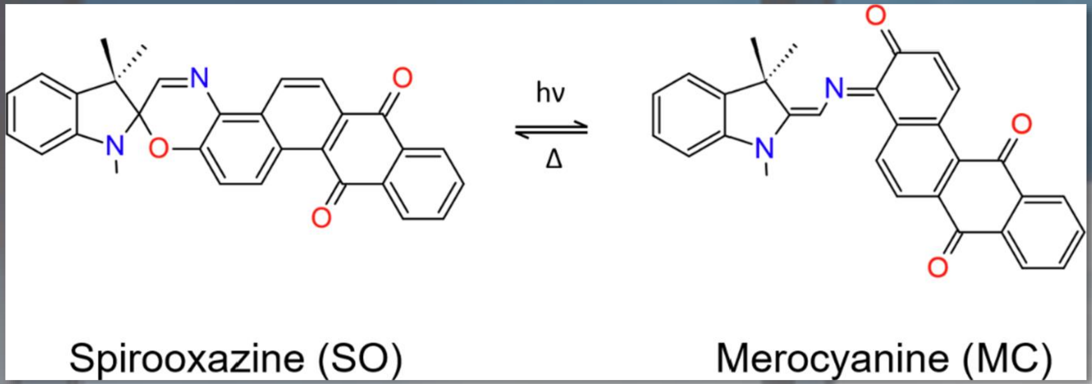

Smart shading but also PV conversion

UNIVERSITY OF OXFORD

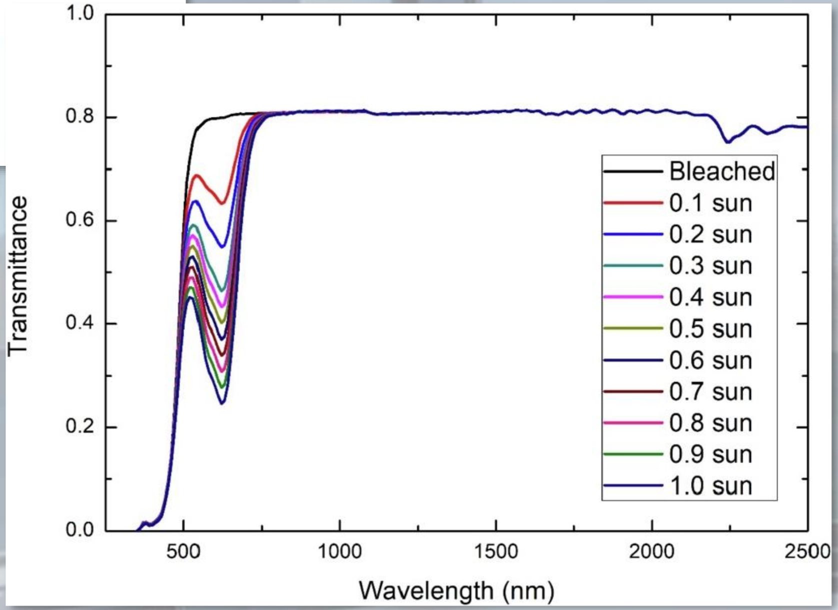
CNRNANOTEC INSTITUTE OF NANOTECHNOLOGY

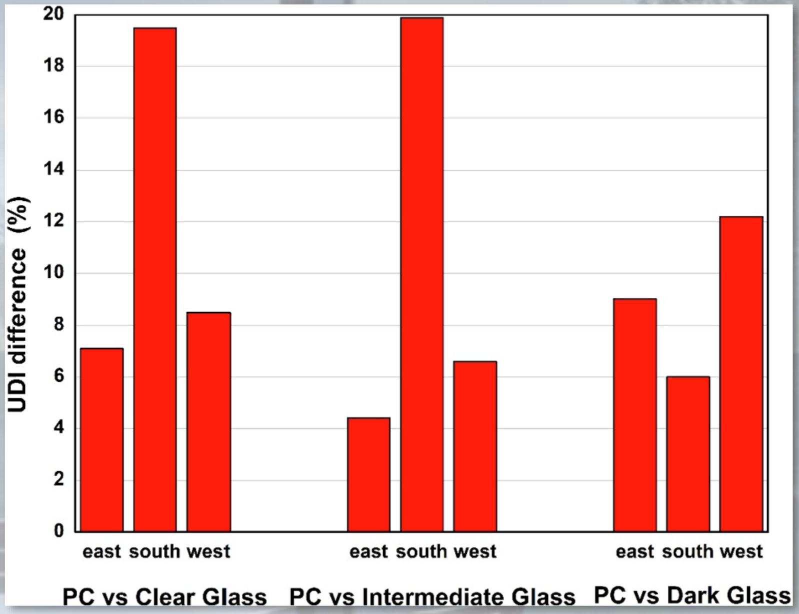
# Passive technologies: the role of photochromics.



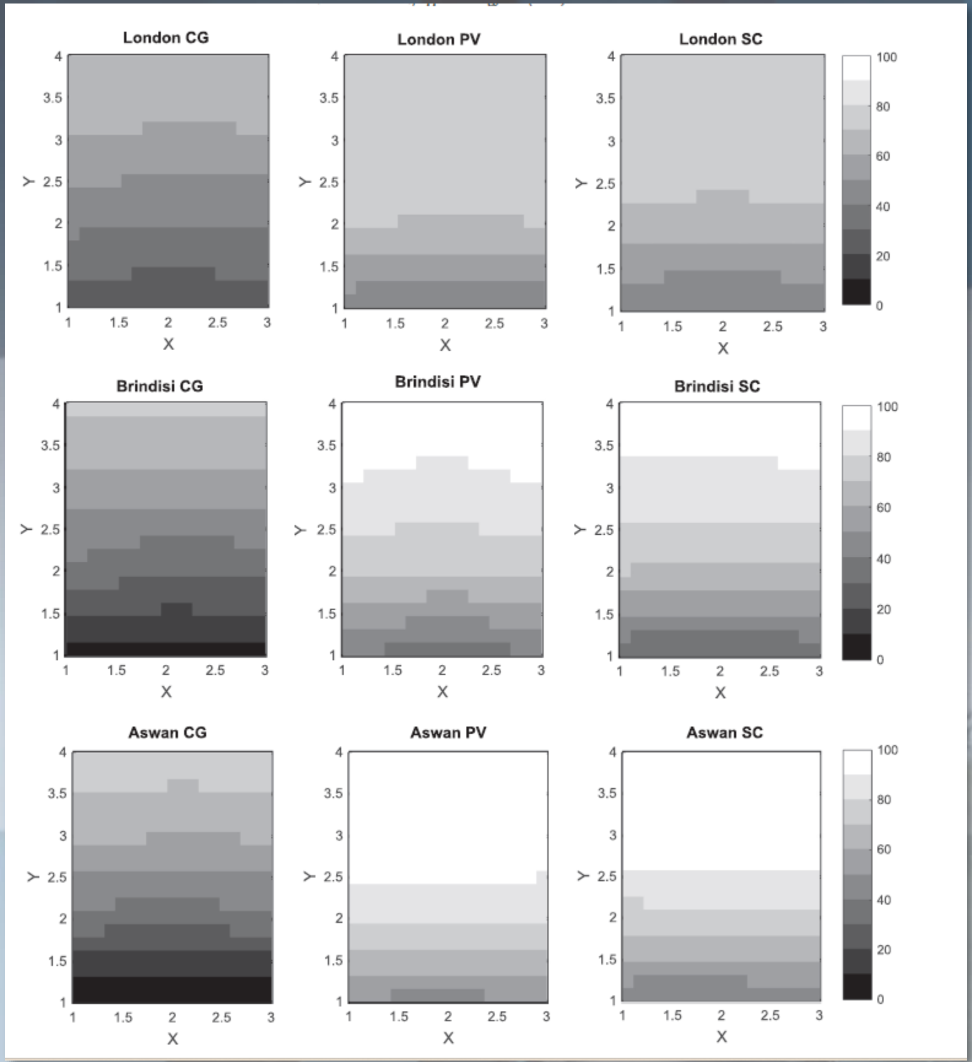

UNIVERSITÀ DEGLI STUDI DI PERUGIA

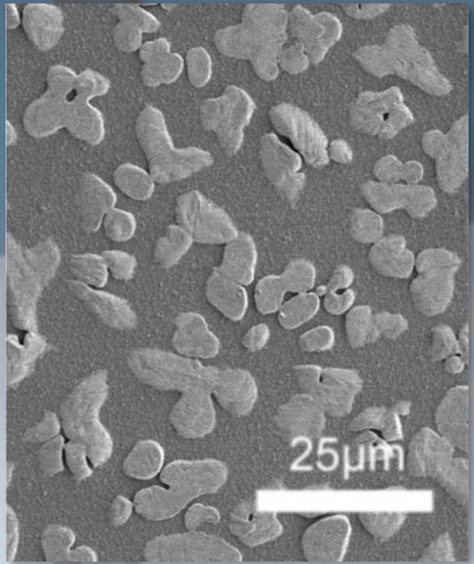



Cannavale et al., Solar Energy
Volume 242, August 2022, Pages 424-434

# Highly transparent PVs: is it really an oximoron?



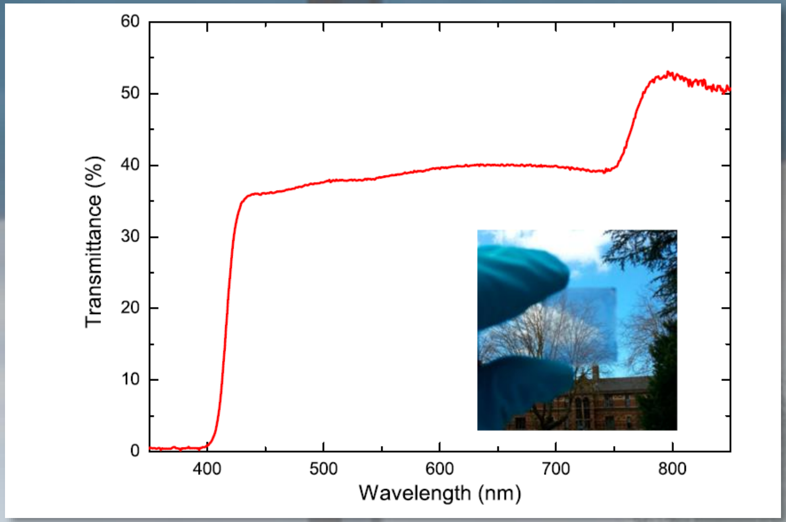




**Table 6**
Use of electric lighting for offices having strip windows with a WWR = 32%. Load is meant as the annual electric lighting energy load in the test room; Yield is the Annual Electric energy yield (including temperature effect).

| Location | Type of glazing | LOAD [kWh/yr] | YIELD [kWh/yr] | Yield/Load [%] |
|---|---|---|---|---|
| Brindisi | CG | 78 | – | – |
| | SC | 108 | – | – |
| | PV | 118 | 129.0 | 109.3 |
| London | CG | 136 | – | – |
| | SC | 198 | – | – |
| | PV | 200 | 82.40 | 41.2 |
| Aswan | CG | 52 | – | – |
| | CG | 68 | – | – |
| | PV | 68 | 143.40 | 210.9 |

Cannavale et al., Applied Energy 194 (2017) 94–107

UNIVERSITY OF OXFORD

# Thank you very much for your kind attention!

Politecnico di Bari

alessandro.cannavale@poliba.it

# Technology Energy in Building Environment research group

## High performance building envelopes & Special environments

**Fabio Favoino**
Associate Professor
fabio.favoino@polito.it

TECHNOLOGY
ENERGY
BUILDING
ENVIRONMENT

TEBE

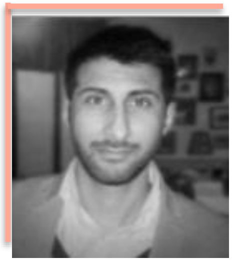
approx. 50 people strong ( 40% permanent staff )

## Permanent Staff


Marco Perino
Full Professor


Valentina Serra
Full Professor


Fabio Favoino
Associate Professor


Stefano Fantucci
Assistant Professor

...

## Researchers and PhD students


Luigi Giovannini
Post Doc


Elena Badino
PhD student


Elisa Fenoglio
PhD student


Giovanni Gennaro
PhD student
POLITO - EURAC


Manuela Baracani
PhD student


Giorgia Autretto
PhD student


Lorenzo Rapone
PhD student


Milad Heiranipour
PhD Student
POLITO - EURAC


Yangkong Zhou
PhD Student
POLITO – Un. NICE

- Smart Building Cities and communities
- Building Energy Performance
- **Building Envelope**
- HVAC and RES
- **Lighting and Daylight**
- Applied Acoustics
- **Indoor and Outdoor Environmental Quality**
- Cultural Heritage
- **Special Enclosures**

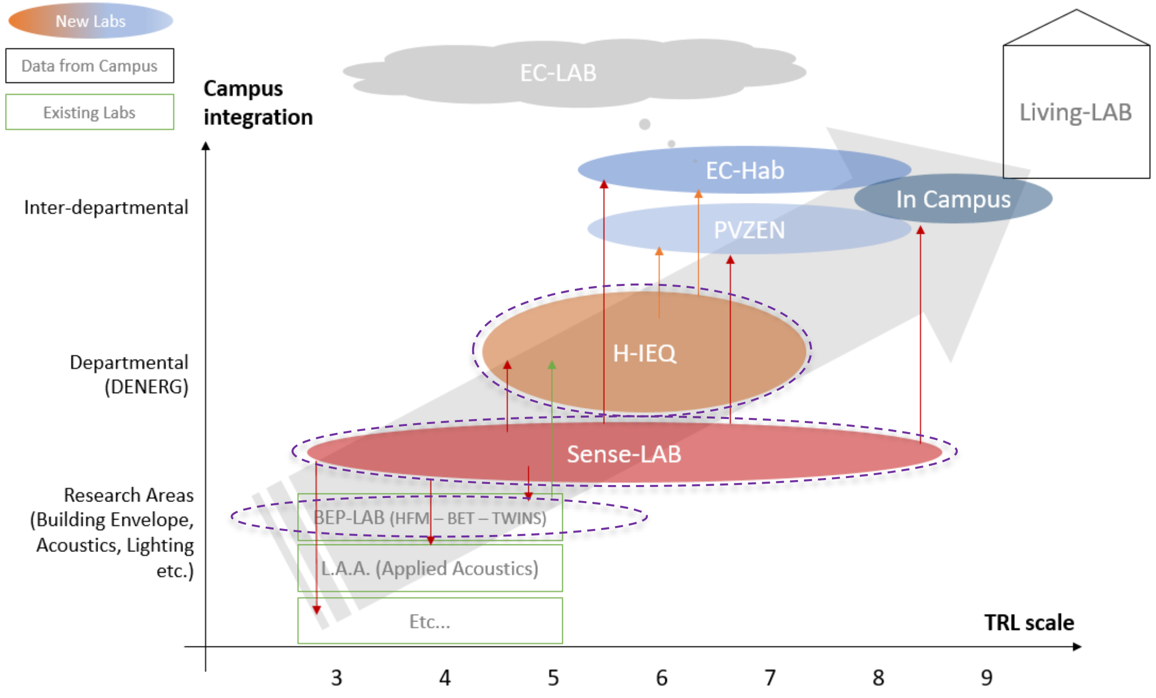
# Main research areas

1. **Development, Characterisation and Intergration of innovative building envelope technologies:**
   a) Responsive and adaptive opaque facades (Double skin Façades, smart glazings)
   b) Responsive and adaptive opaque facades (i.e. PCM, active insulation etc.)
   c) Vegetated envelopes (green roof, living wall)
   d) Superinsulation (VIP, Aerogel…)
   e) Integration of building envelope with HVAC systems and RES
2. **Measuring / Simulating impact of innovative building envelope technologies on IEQ and personalised comfort** (thermal and daylight comfort in perimeter zone, personal comfort devices)
3. **Advanced control of building envelope techonlogies integrated with HVAC components** (embedded controllers and IoT, from rule to model based and model free controls, digital twins)
4. **Low Carbon Building Envelopes for heat resilient buildings**
5. **Special enclosures (envelope for museum showcases, transportation etc.)**

Smart Building Cities and communities
Building Energy Performance
Building Envelope
HVAC and RES
Lighting and Daylight
Applied Acoustics
Indoor and Outdoor Environmental Quality
Cultural Heritage
Special Enclosures

TEBE
TECHNOLOGY ENERGY BUILDING ENVIRONMENT
1859

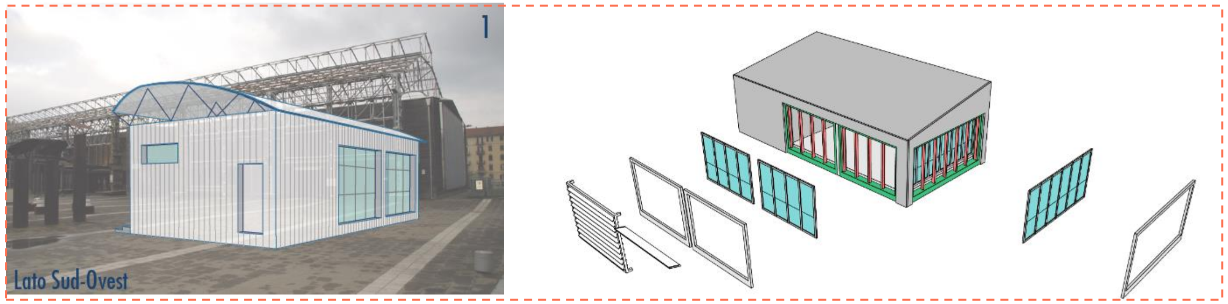
# TEBE Lab platform
# Building Envelope Related Labs




Building Envelope related

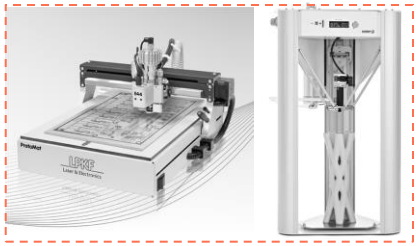
Currently being built

## H-IEQ Living-Lab




## **Sense-LAB** Advanced sensors and IoT Lab

## 3D prototyping LAB

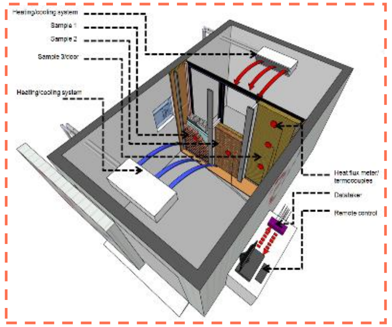


## **HTC-LAB** Material Hygro-Thermal Characterisation

## TWINS

## BEBI

## BET cell



## TRIS

# TWINS Test facility - 2023

New HVAC fully controllable remotely (T air indoor, ACH)
DAQ on HVAC system

BEBI test cell
1 single module
~1400 x ~1500 mm

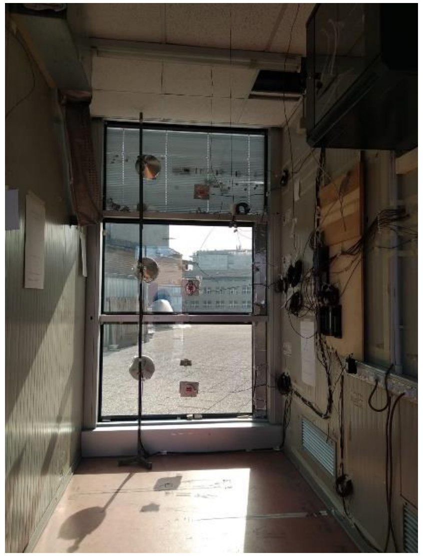
2 small modules
~60 x ~1500 mm

4 small modules
~60 x ~80 mm
(actually)


TWINS test cells
1 single module
1430 x 2850 x 59mm

3 small modules
1430 x 805 x 59mm
1430x ~830 x 59mm
1430 x ~830 x 59mm

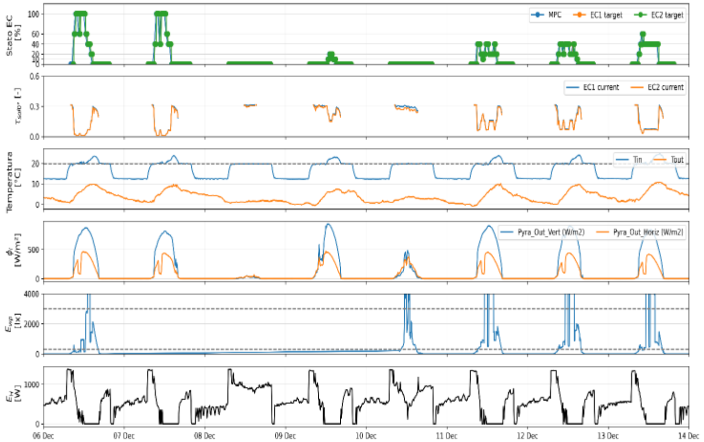
(currently)



Data Acquisition, Monitoring and Control system of Building Envelope and indoor environment:

- NI dataloggers
- Datatakers
- Rspy
- Data storage on FTP
- Automatic Data integration & post-processing
- Data Visualisation
- Real Time Simulation and Control

**+ DigiTWINS**
(real time visualization, control on HVAC and facades and what-if scenarios)



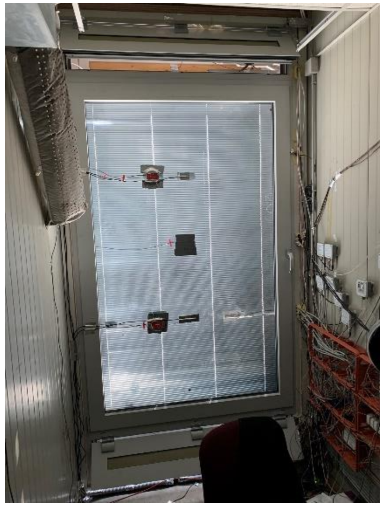
1859

# Research activity by means of virtual – physical testing

2005 — 2010 — 2020

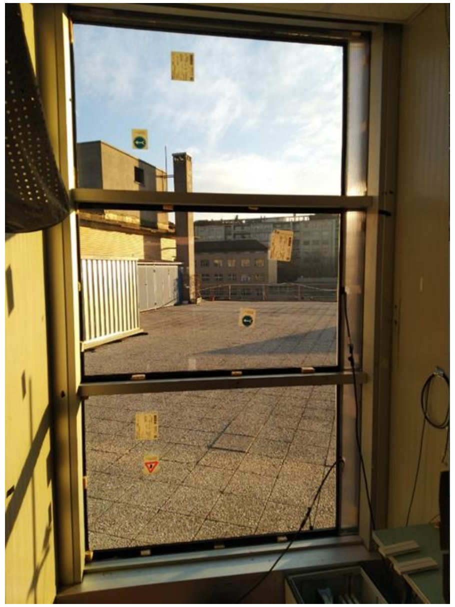
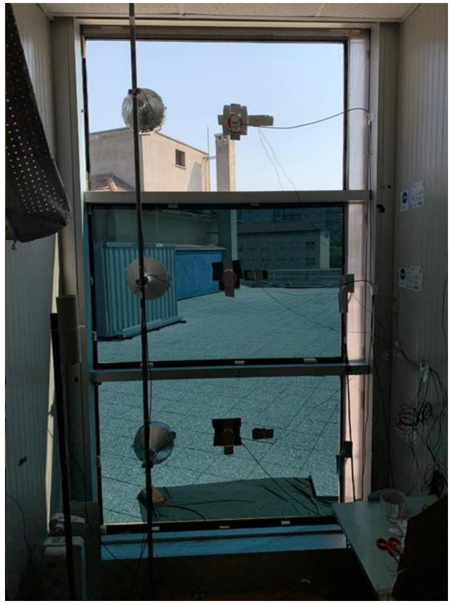




2010 — 2020



# Building Envelope as heat and mass transfer regulator of indoor environment

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

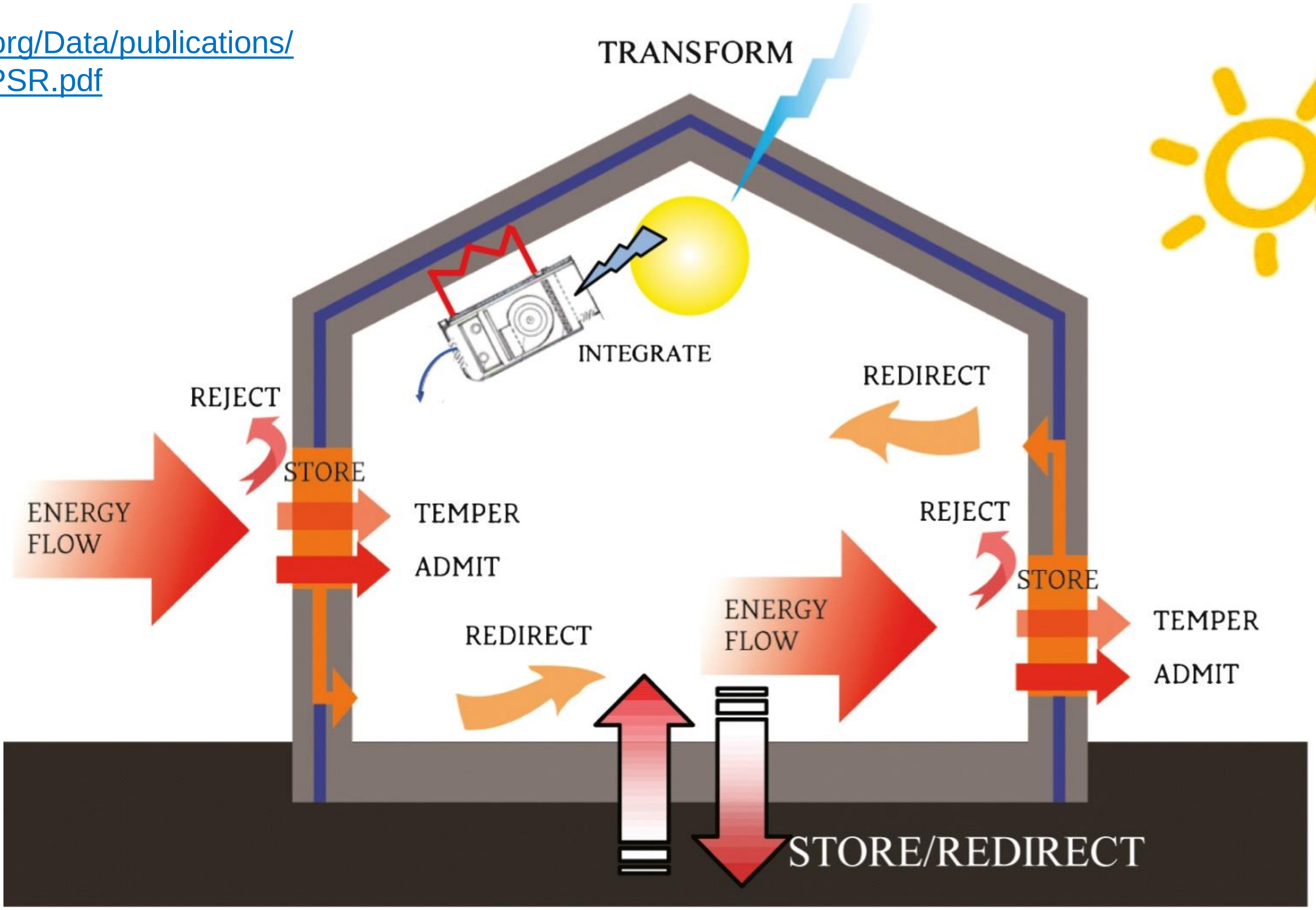
**ECBCS Annex 44**

**Integrating Environmentally Responsive Elements in Buildings**

http://www.ecbcs.org/Data/publications/EBC_Annex_44_PSR.pdf

COST TU1403
fn/Adaptive facades network

http://tu1403.eu/

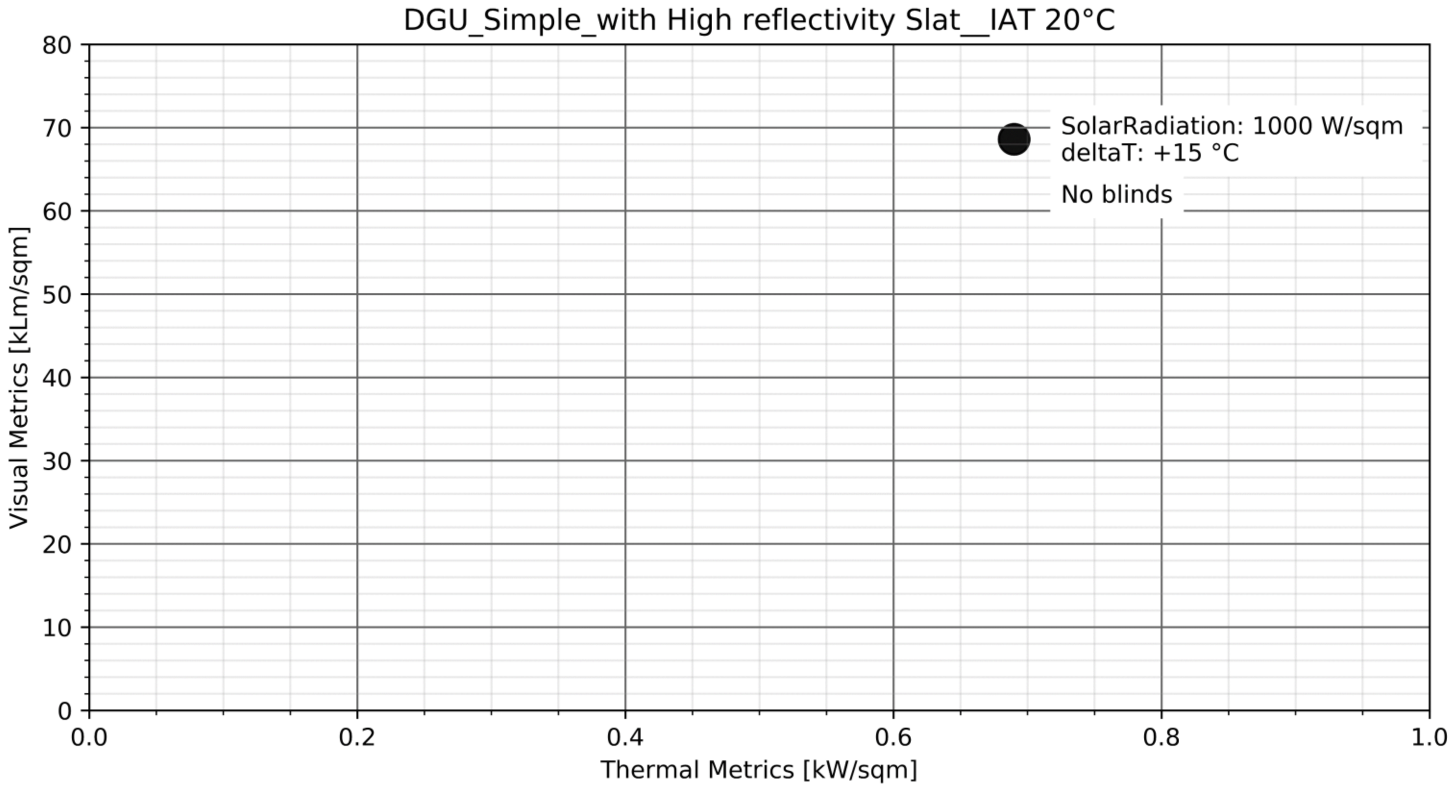


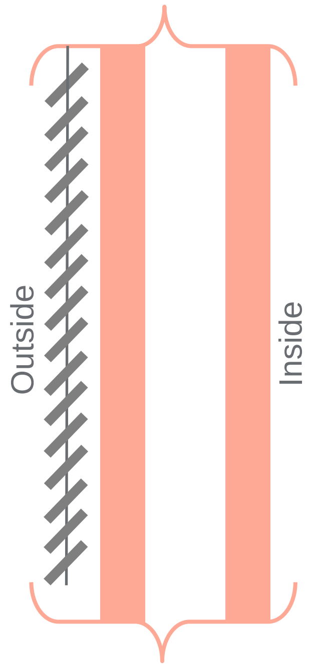

Conceptual scheme of dynamic, responsive, multifunctional and integrated facades (adapted from Van der Aa et al., 2011).

TEBE
TECHNOLOGY ENERGY BUILDING ENVIRONMENT

POLITECNICO DI TORINO 1859 1906

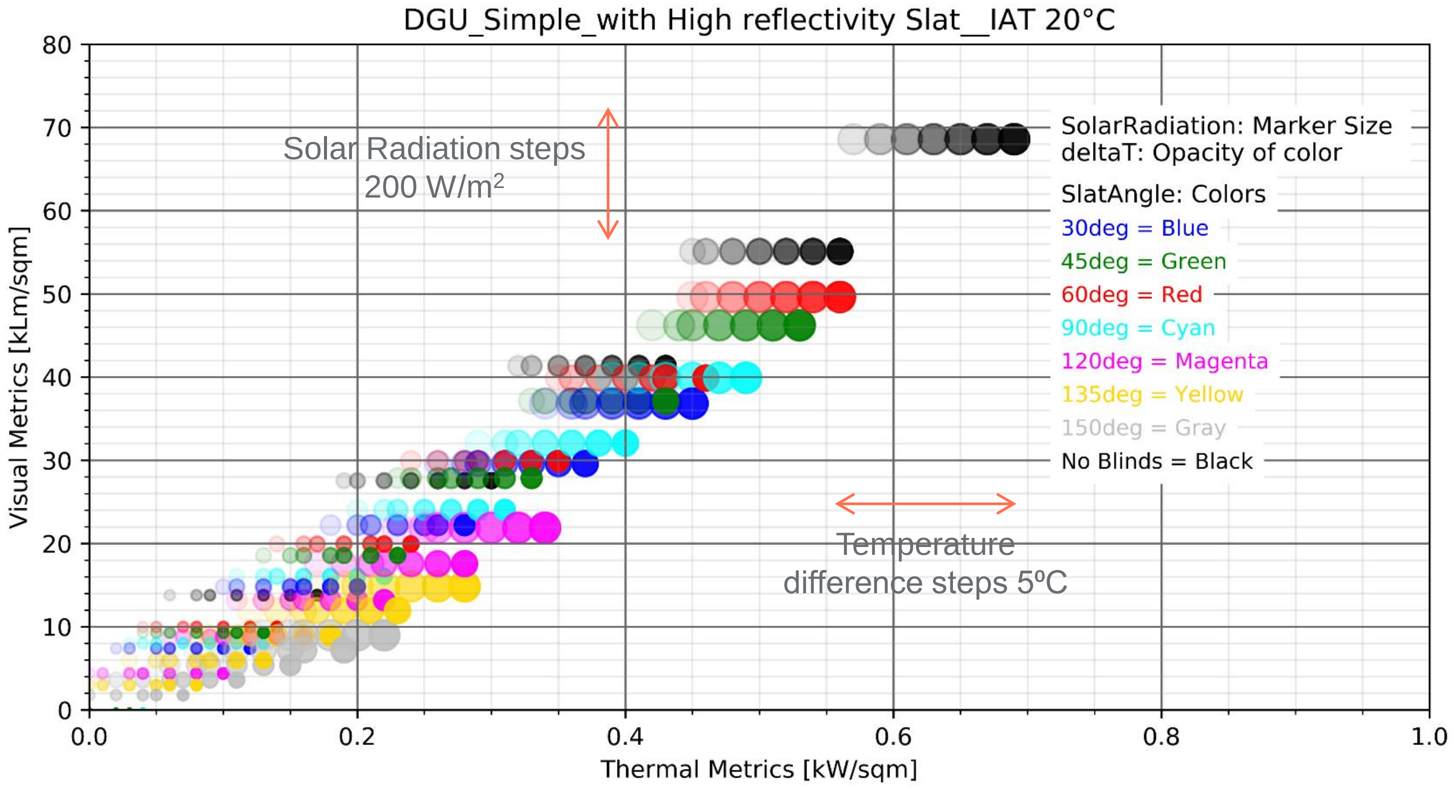
# Performance of IGU with integrated blinds

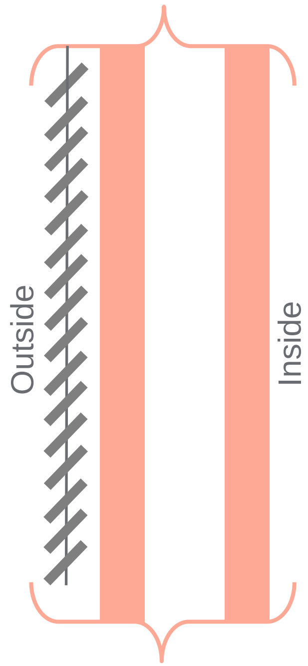



**Simple Double glazing**
U-value = **2.526 W/m2-K**,
G-value = **0.770**, VLT = **0.8**

# Performance of IGU with integrated blinds




**Simple Double glazing**

U-value = **2.526 W/m2-K**,
G-value = **0.770**, VLT = **0.8**

# Performance and control strategies for highly flexible Double Skin Facade

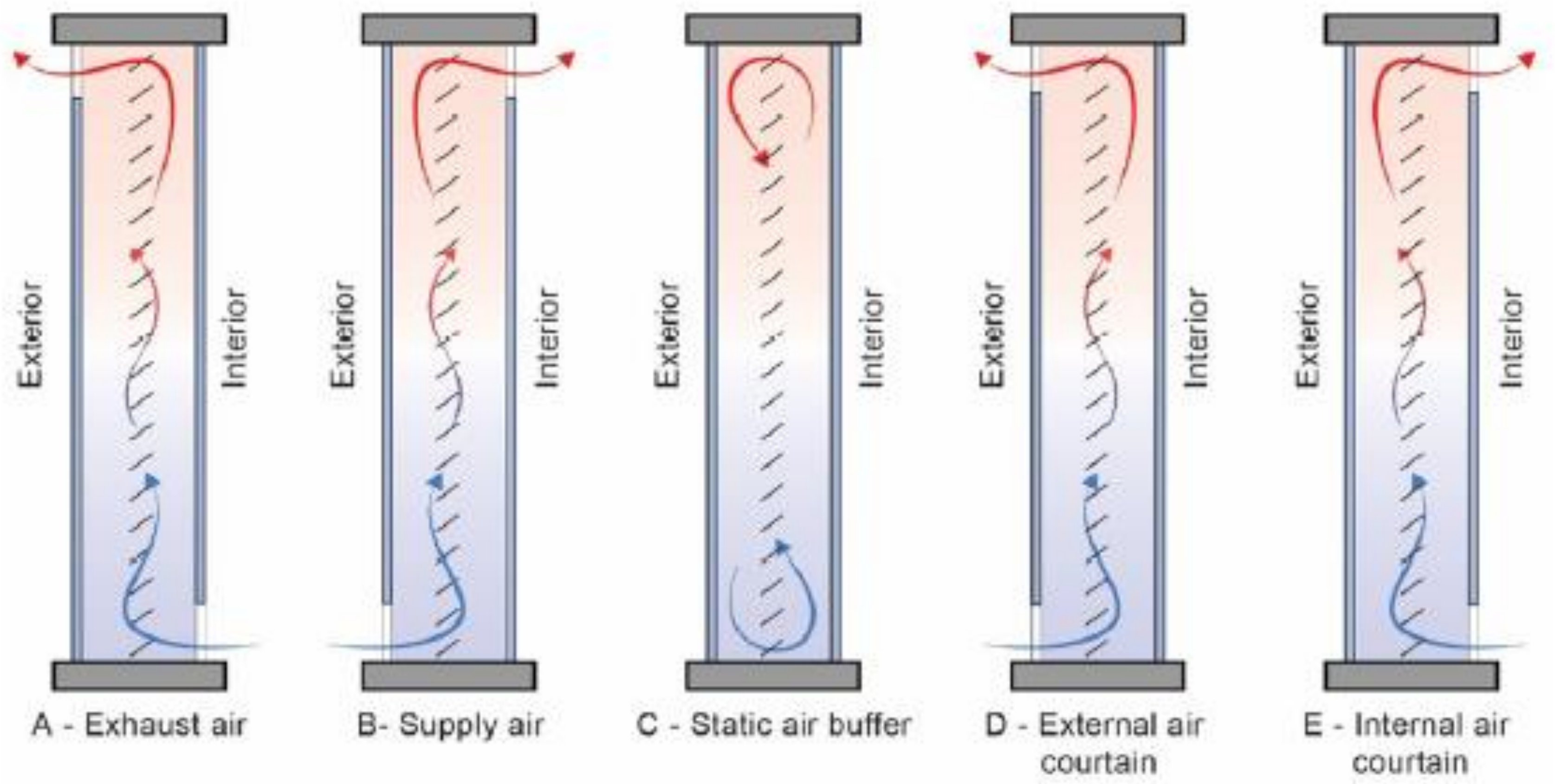
*REINVENT - REsponsive, INtegrated , VENTilated - windows*

NTNU
Norwegian University of Science and Technology

WICONA By Hydro

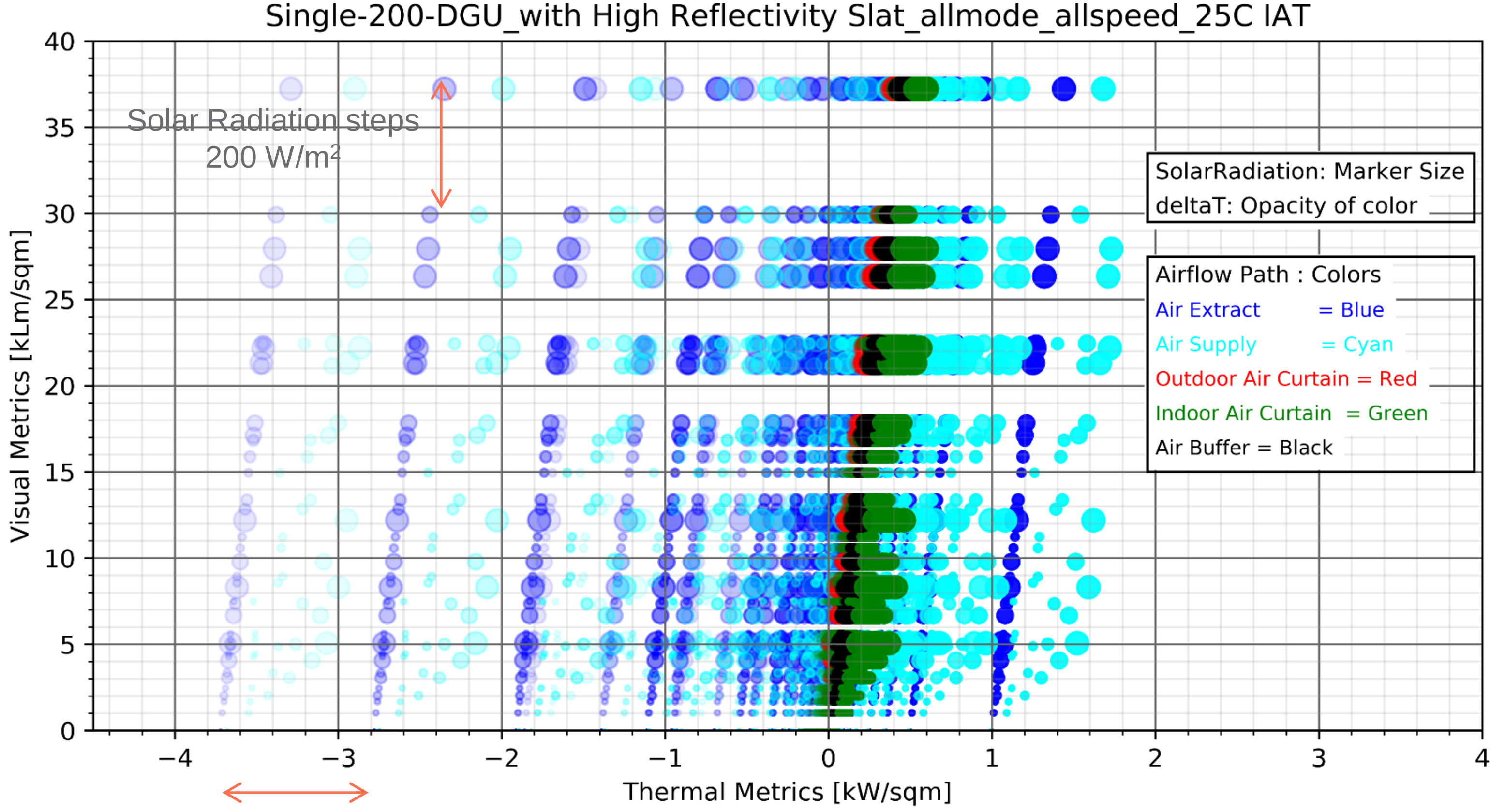
Politecnico di Torino

Aalto University



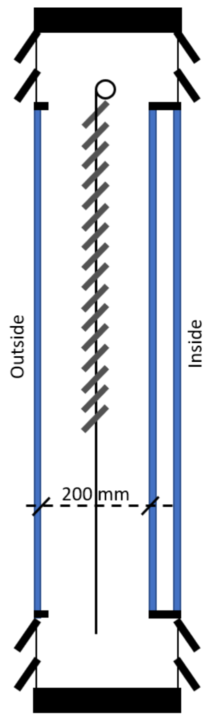

TEBE
TECHNOLOGY ENERGY BUILDING ENVIRONMENT

# Performance and control strategies for highly flexible Double Skin Facade



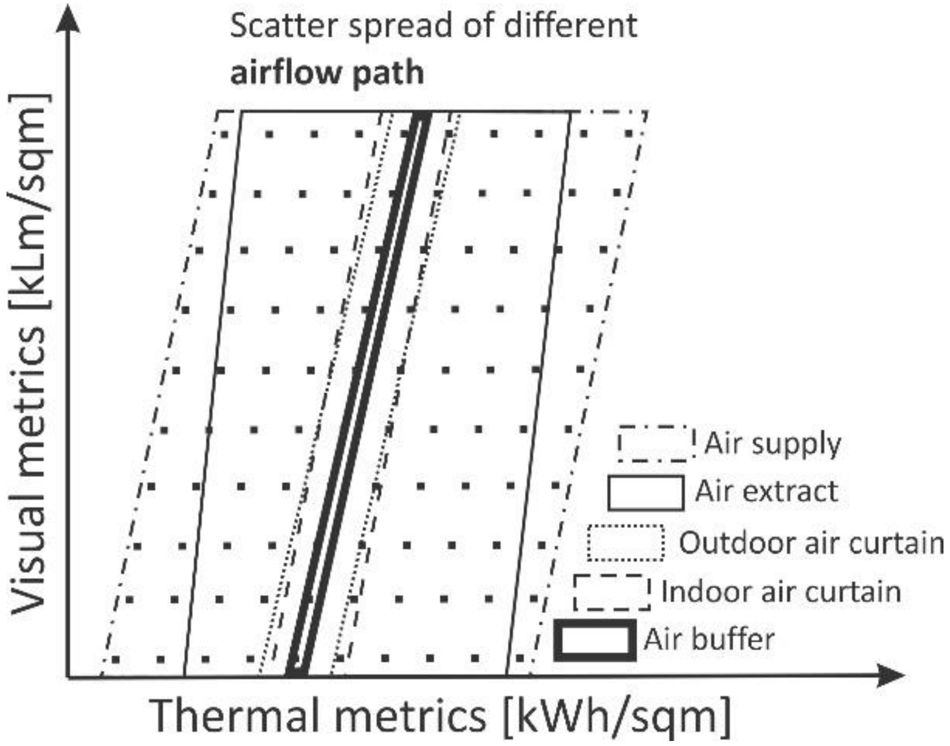

Temperature difference steps 5ºC

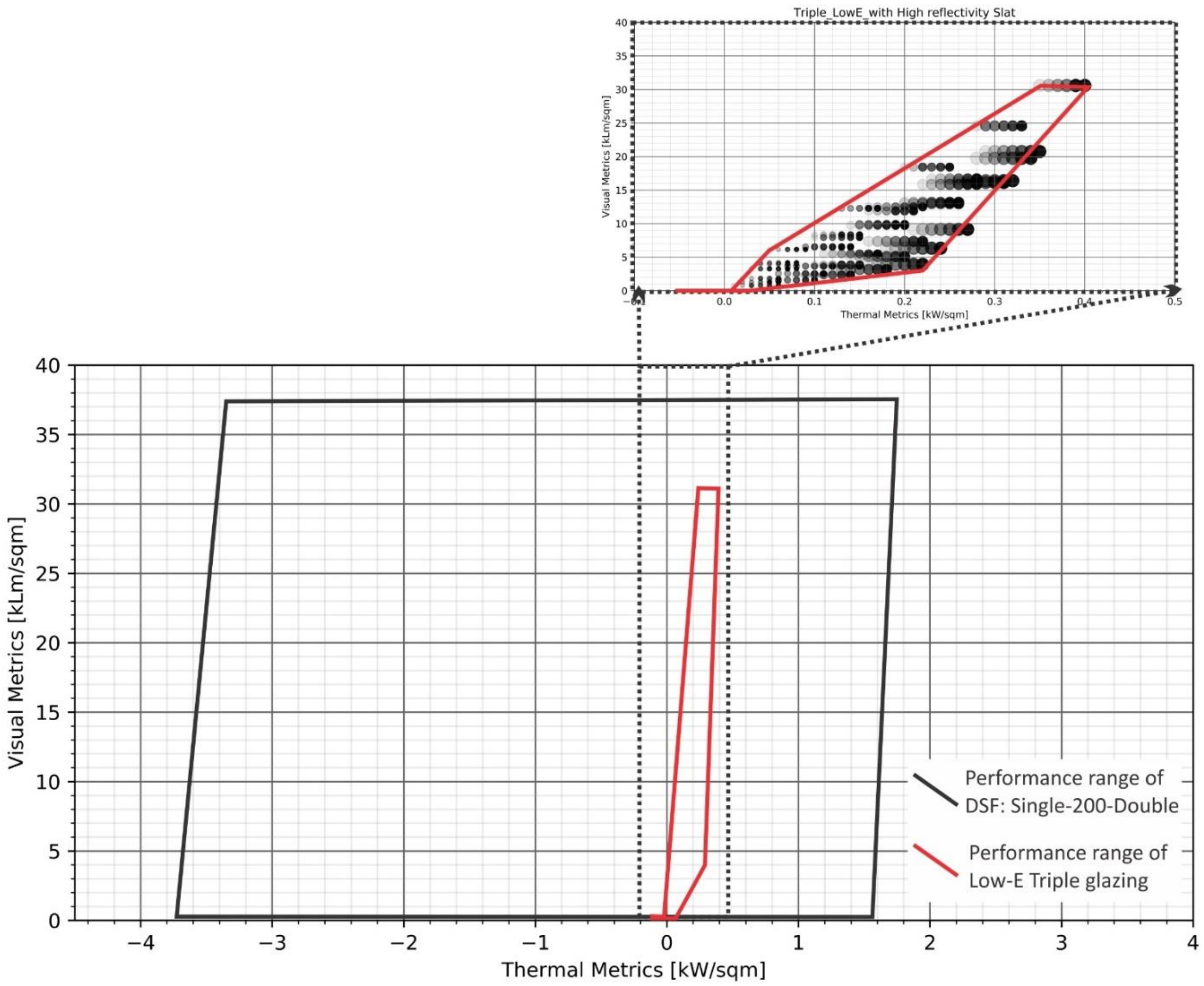
Air Velocity steps 0.1 m/s

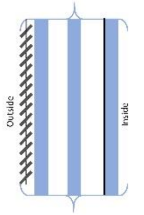


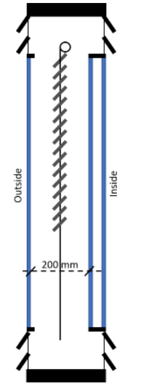

Single glazing – 200 mm– Double glazing

# Performance and control strategies for highly flexible Double Skin Facade




Single glazing – 200 mm– Double glazing

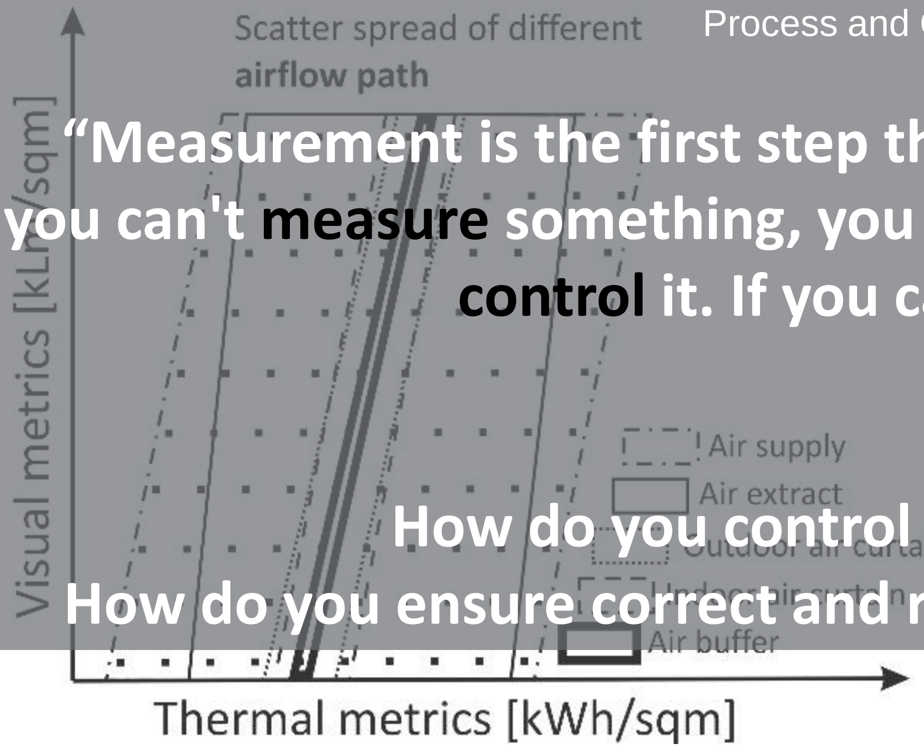
# Performance and control strategies for highly flexible Double Skin Facade

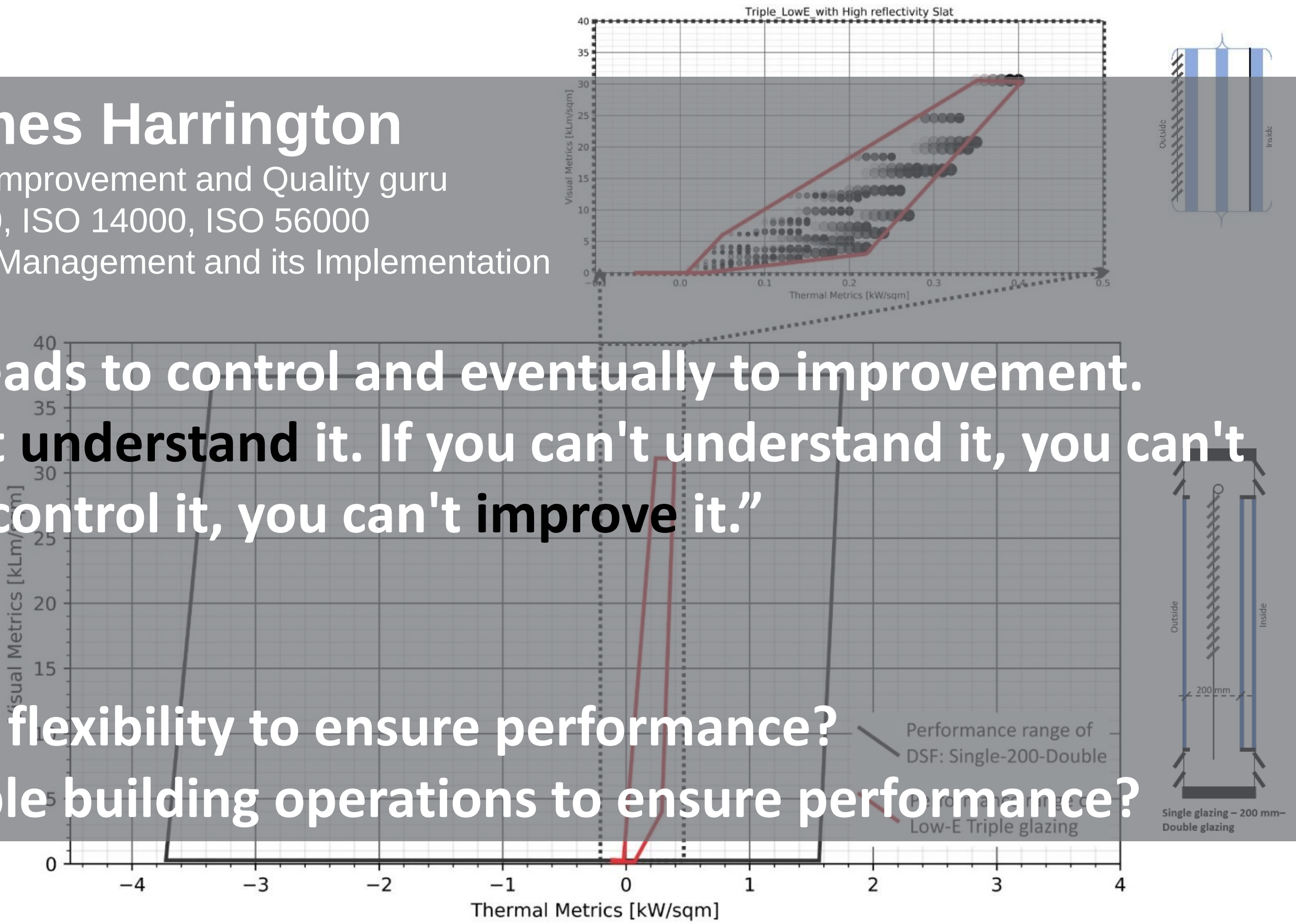
## H. James Harrington

Performance Improvement and Quality guru
ISO 9000, ISO 14000, ISO 56000
Process and Quality Management and its Implementation

**“Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it.”**

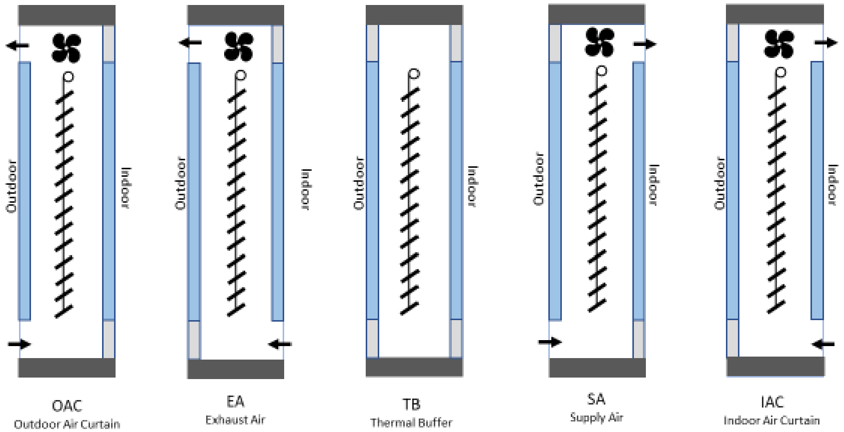
**How do you control such flexibility to ensure performance?**
**How do you ensure correct and reliable building operations to ensure performance?**

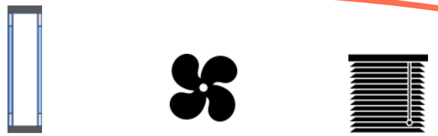


# Tool chain for design and testing advanced control strategies for dynamic facades

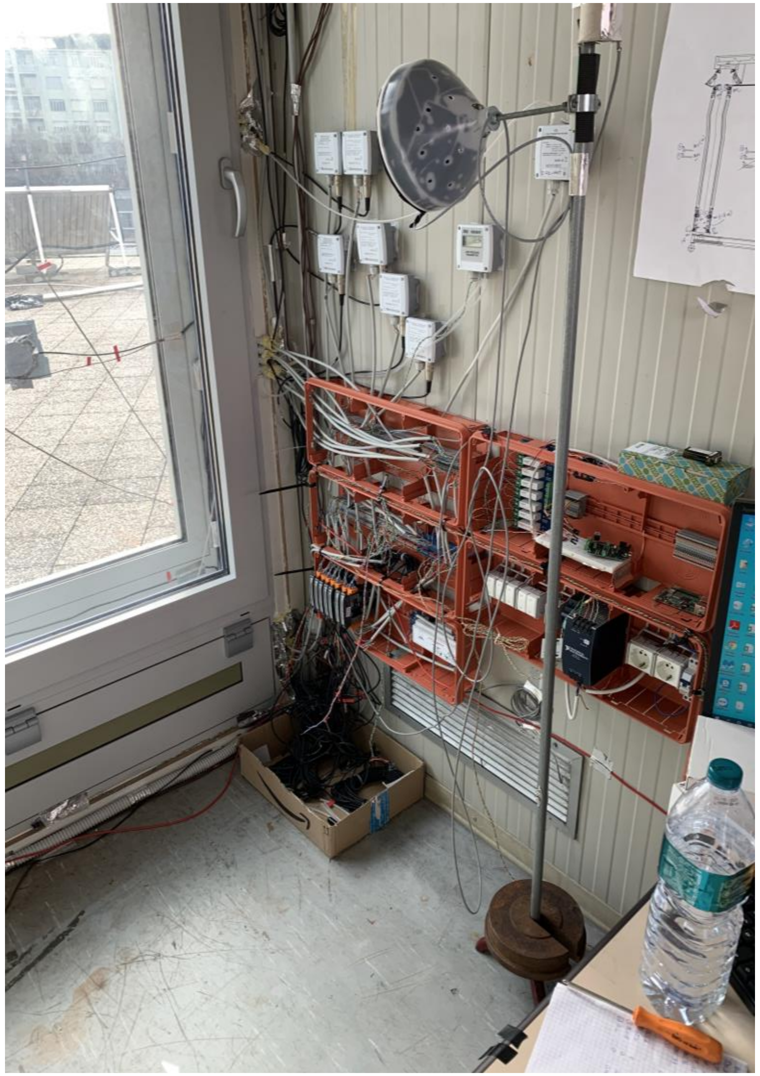
PhD of Giovanni Gennaro



More than 70 DSF configurations!

# Tool chain for design and testing advanced control strategies for dynamic facades



Modelling flexible DSF (naturally and mechanically ventilated) BES tools

Enhancing BES tools performance through co-simulation with improved ISO standard DSF model, validated with experimental data of 1.5 y exp. campaign)

Design and in field implementation of advanced control strategies for highly complex façade

Proof of concept / demonstration at experimental level

Evaluate impact at building level by virtual experiments

TECHNOLOGY ENERGY BUILDING ENVIRONMENT

1859

# Tool chain for design and testing advanced control strategies for dynamic facades

ELSEVIER
Building and Environment
Volume 212, 15 March 2022, 108803

## Tracer gas techniques for airflow characterization in double skin facades

Aleksandar Jankovic [a], Giovanni Gennaro [b], Ga
Fabio Favoino [b]

ELSEVIER
Building and Environment
Volume 199, 15 July 2021, 107906

## Modelling double skin façades (DSFs) in whole-building energy simulation tools: Validation and inter-software comparison of a mechanically ventilated single-story DSF

Elena Catto Lucchino [a], Adrienn Gelesz [b c], Kristian Skeie [a], Giovanni Gennaro [d e], András Reith [b f], Valentina Serra [d], Francesco Goia [a]

ELSEVIER
Building and Environment
Volume 231, 1 March 2023, 110002

## Modelling double skin façades (DSFs) in whole-building energy simulation tools: Validation and inter-software comparison of naturally ventilated

Giovanni Gennaro [a b]

ELSEVIER
Building and Environment
Volume 226, December 2022, 109704

## Modelling and validation of a single-storey flexible double-skin façade system with a building energy simulation tool

Elena Catto Lucchino [a], Giovanni Gennaro [b c], Fabio Favoino [b], Francesco Goia [a]

TECHNOLOGY ENERGY BUILDING ENVIRONMENT
TEBE
1859

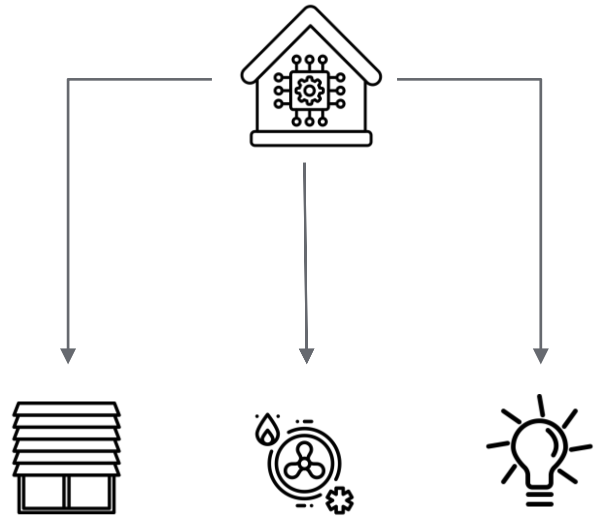
# Tool chain for design and testing advanced control strategies for dynamic facades

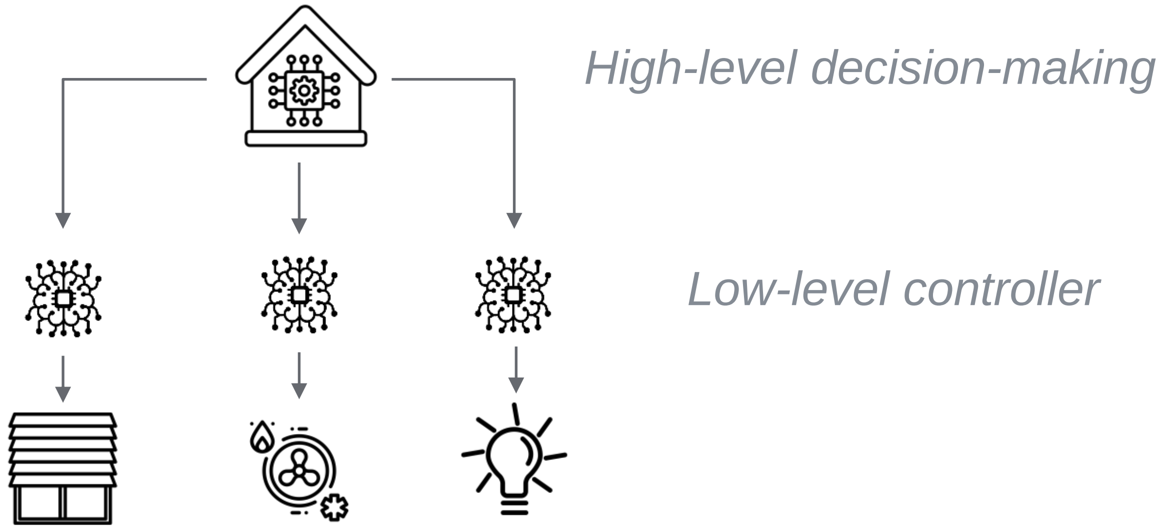
## Traditional BMS

- Centralized architectures;
- Simple control strategies (e.g. RBC, schedule)

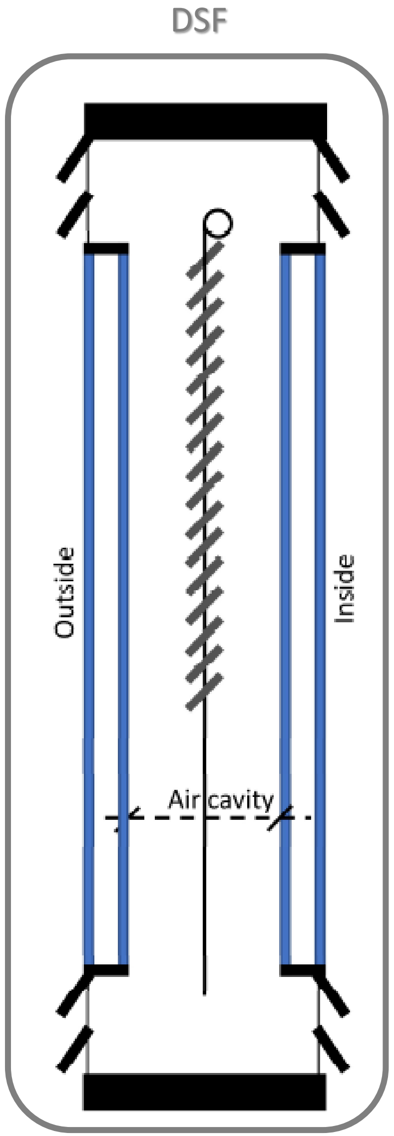
## Novel BMS

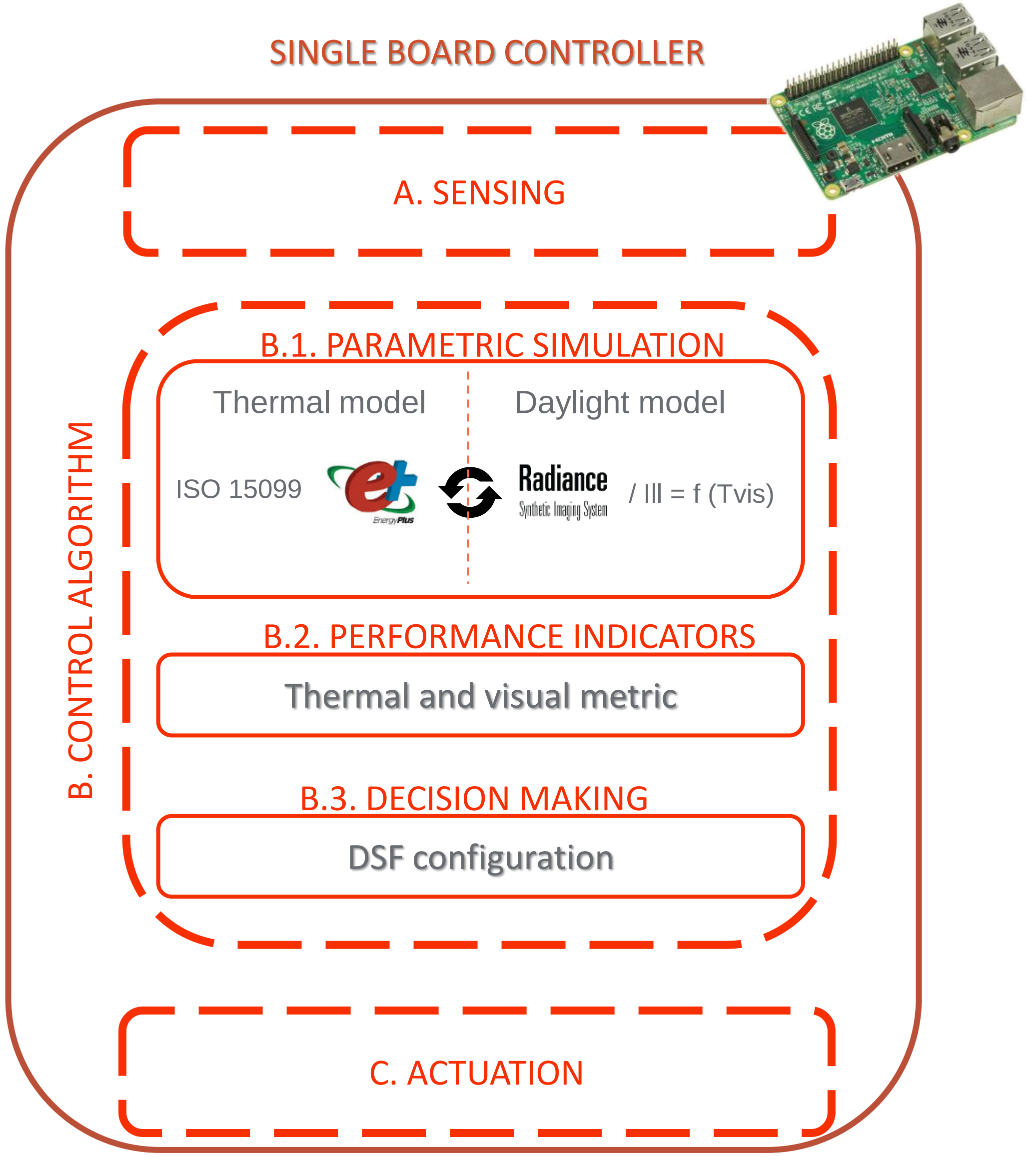
- De-centralized architecture;
- Dedicated low-level controllers;
- Advanced control strategies (e.g. MBC)



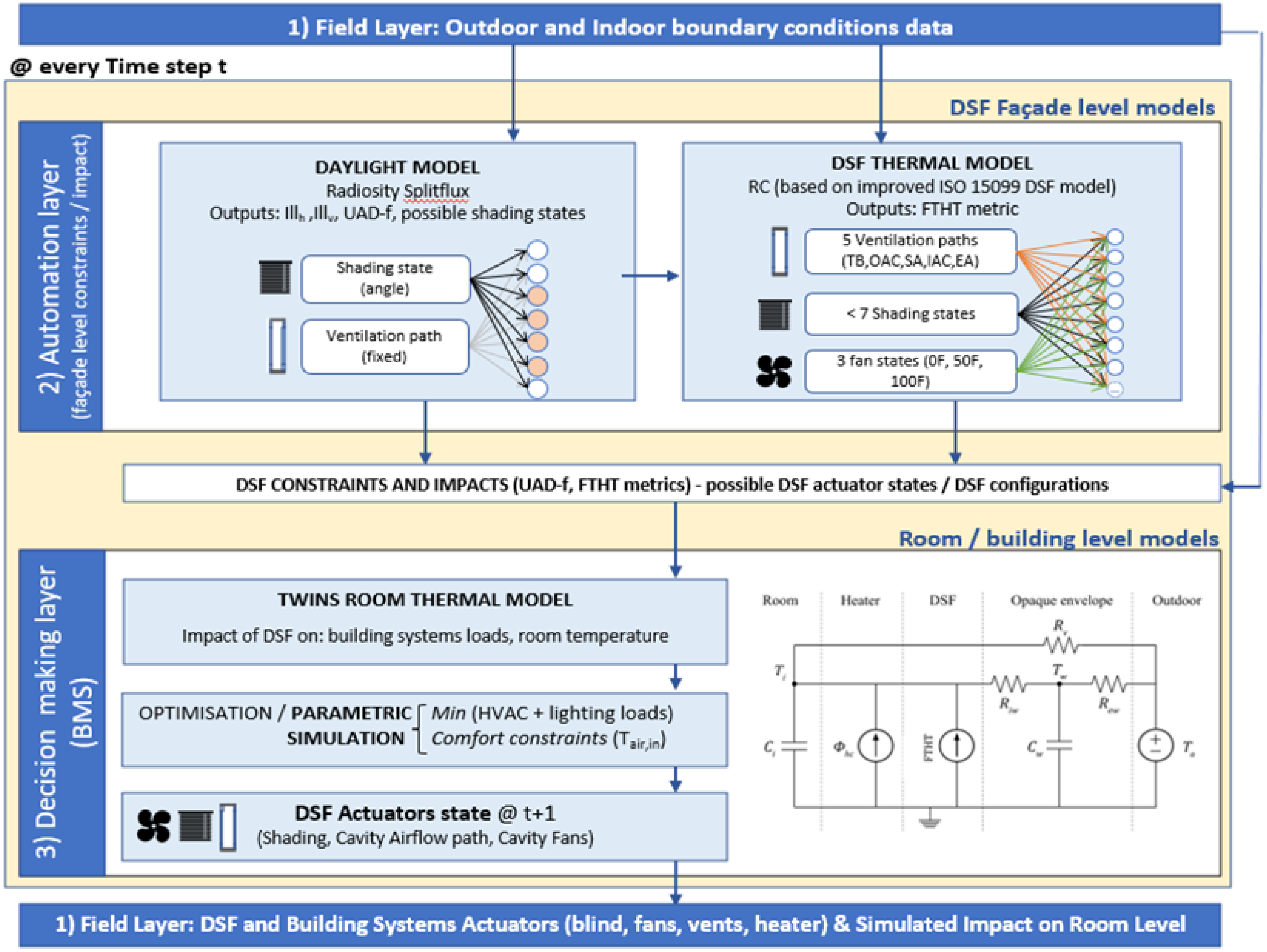


# Tool chain for design and testing advanced control strategies for dynamic facades

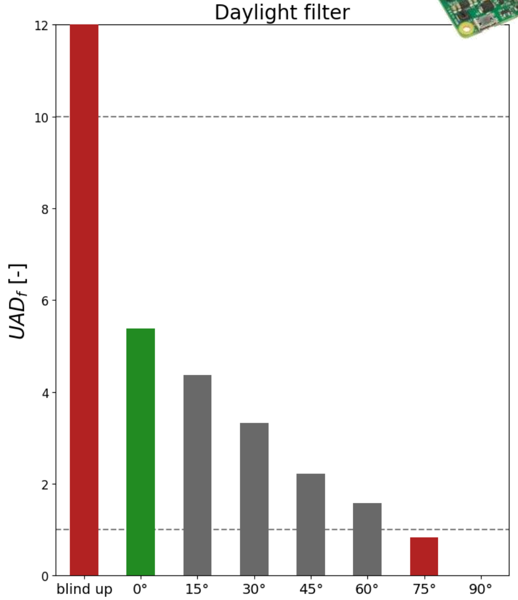


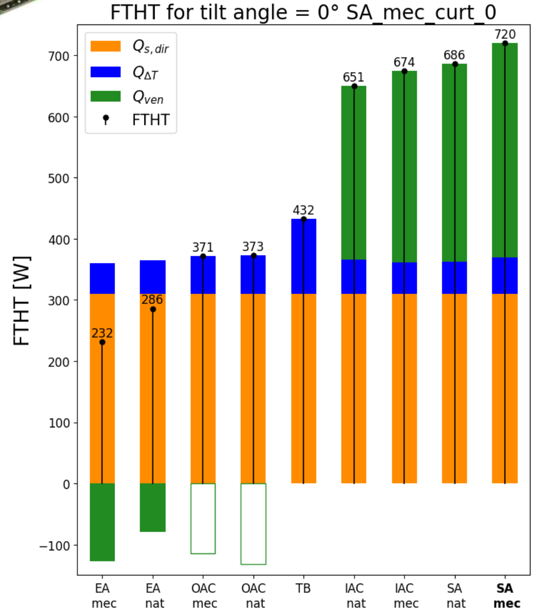



# Tool chain for design and testing advanced control strategies for dynamic facades



# Tool chain for design and testing advanced control strategies for dynamic facades



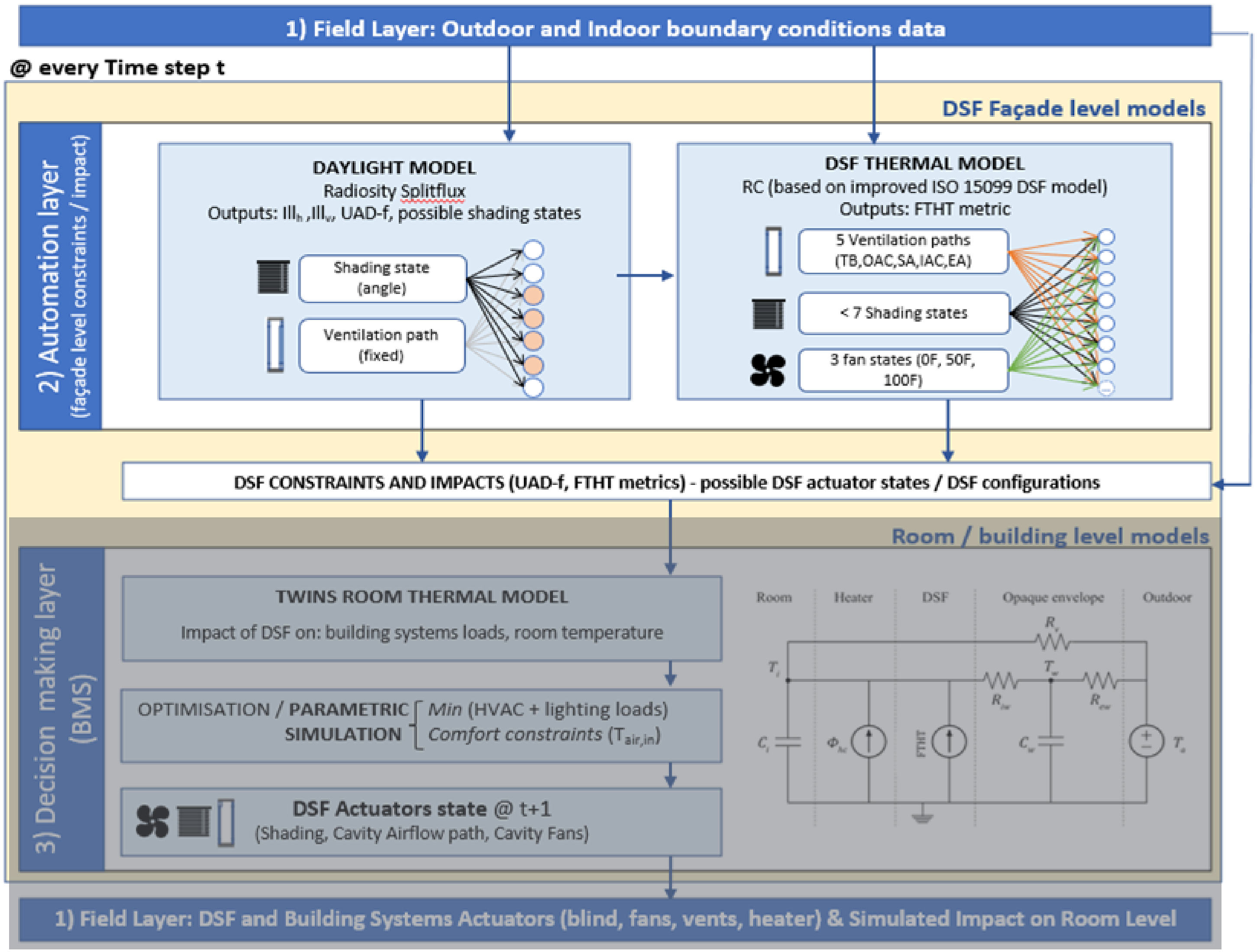




$$UAD_f = \frac{Ill_{h,i}}{Ill_{h,autonomous}} \quad [-]$$

$$FTHT = Q_{\Delta T} + Q_{s,dir} + Q_v \quad [W]$$

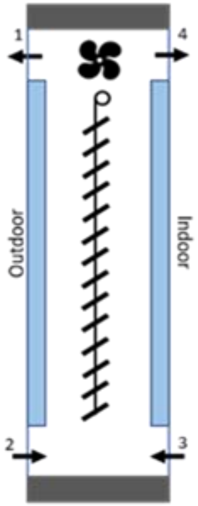
*From Daylight Model*

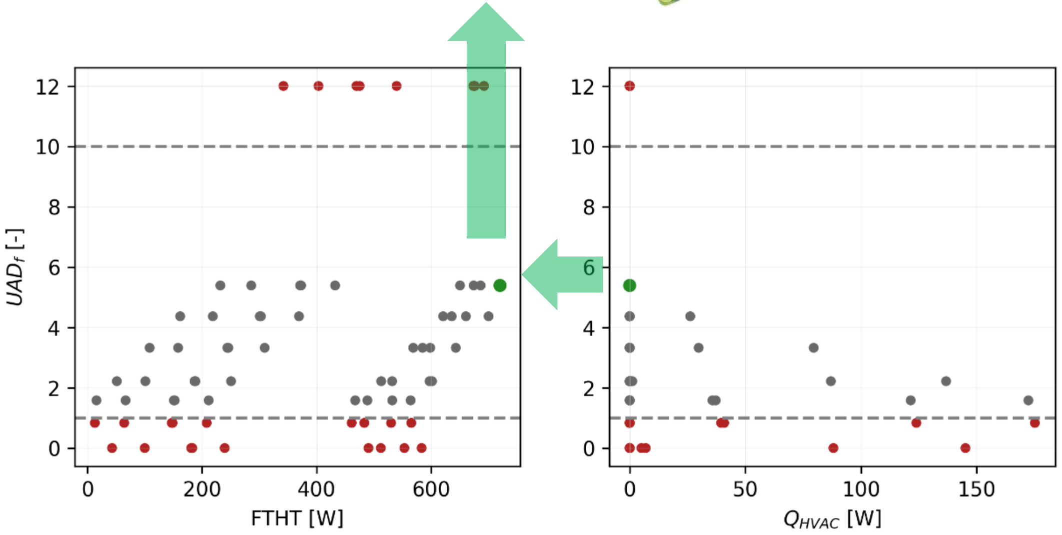
*From Validated improved ISO 15099 DSF model*

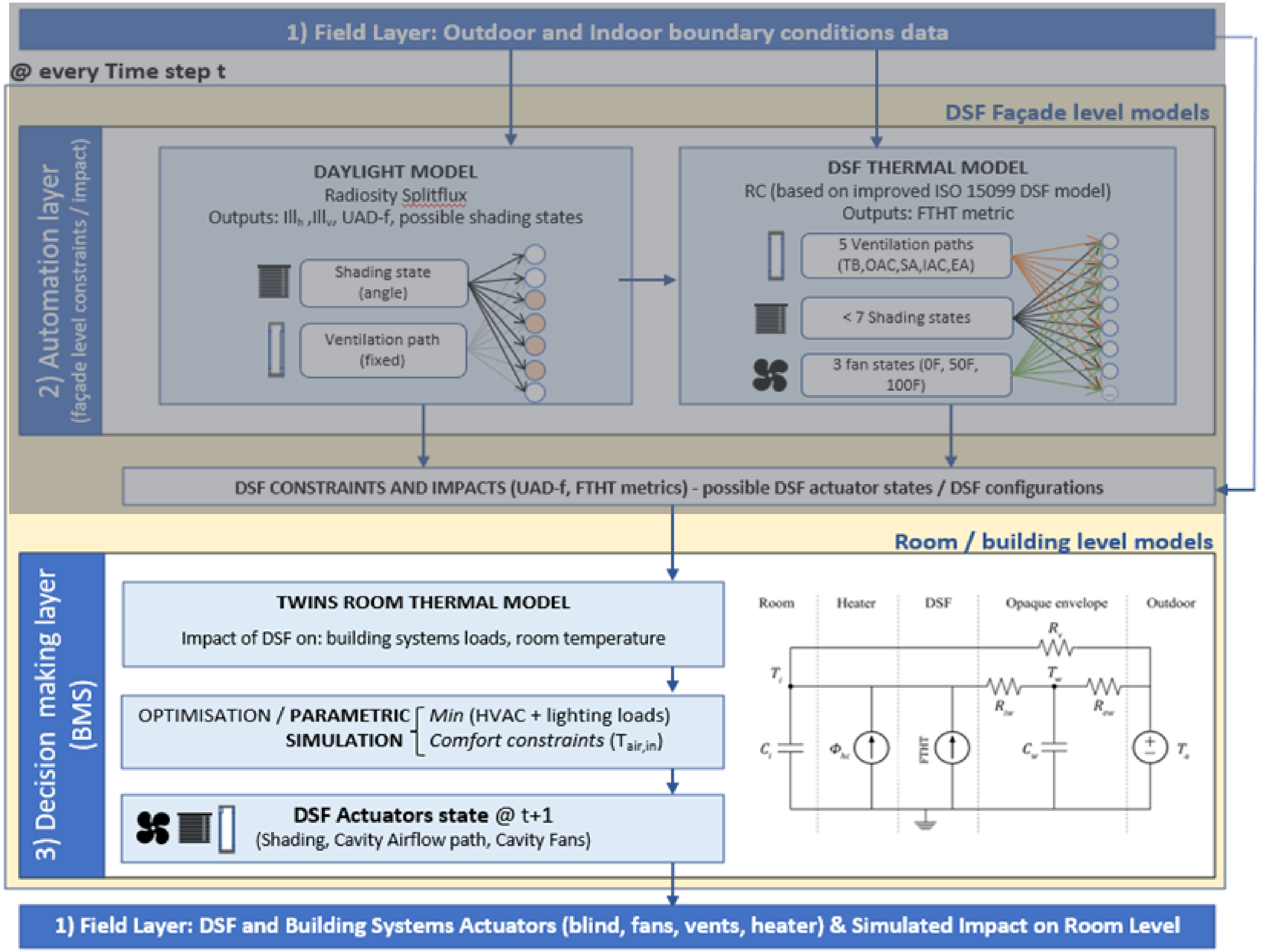



TEBE
TECHNOLOGY ENERGY BUILDING ENVIRONMENT
1859

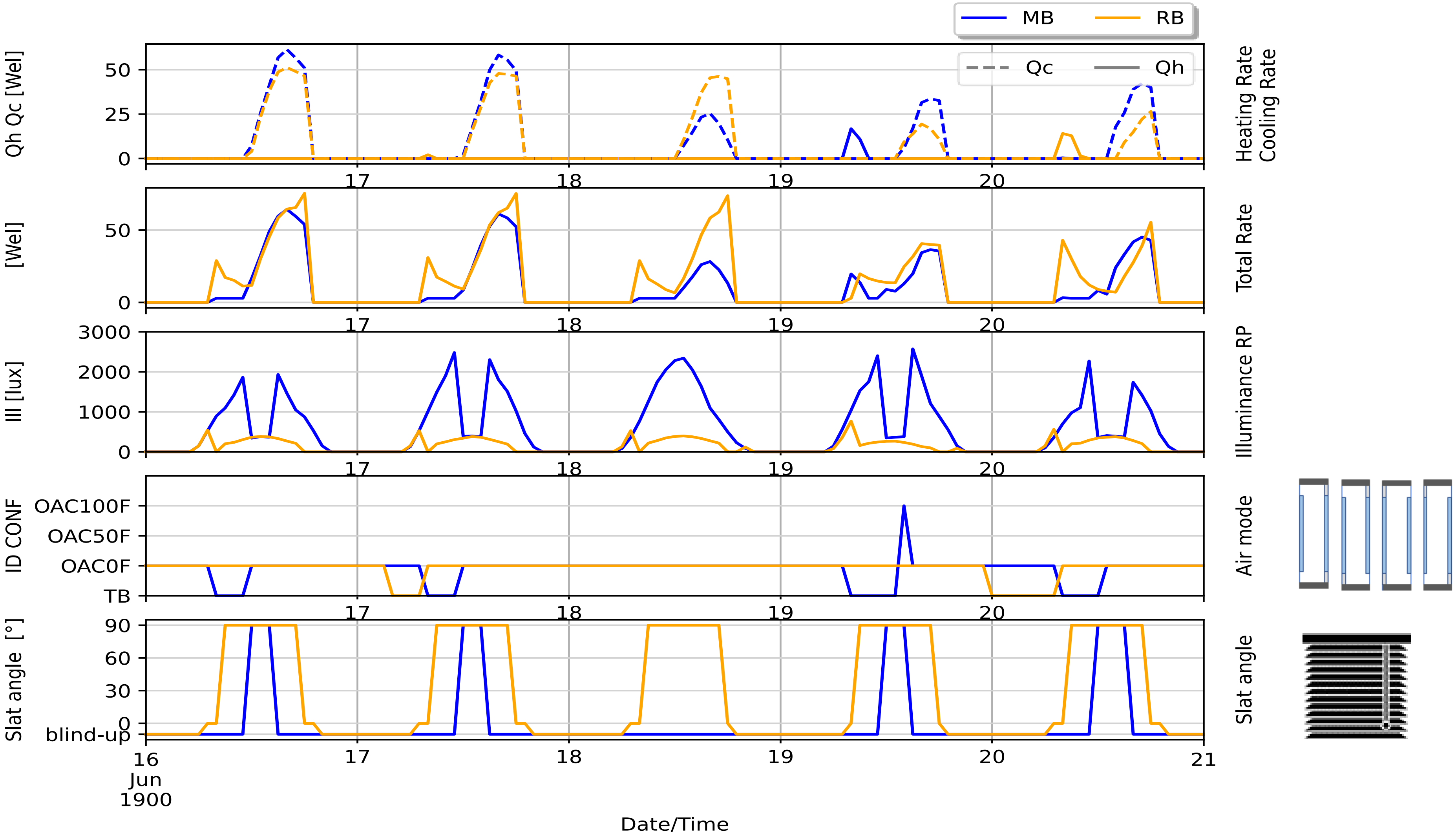
# Tool chain for design and testing advanced control strategies for dynamic facades



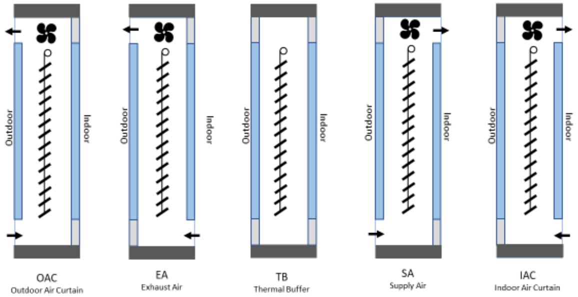



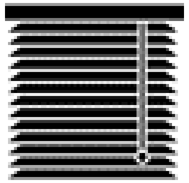



# Tool chain for design and testing advanced control strategies for dynamic facades



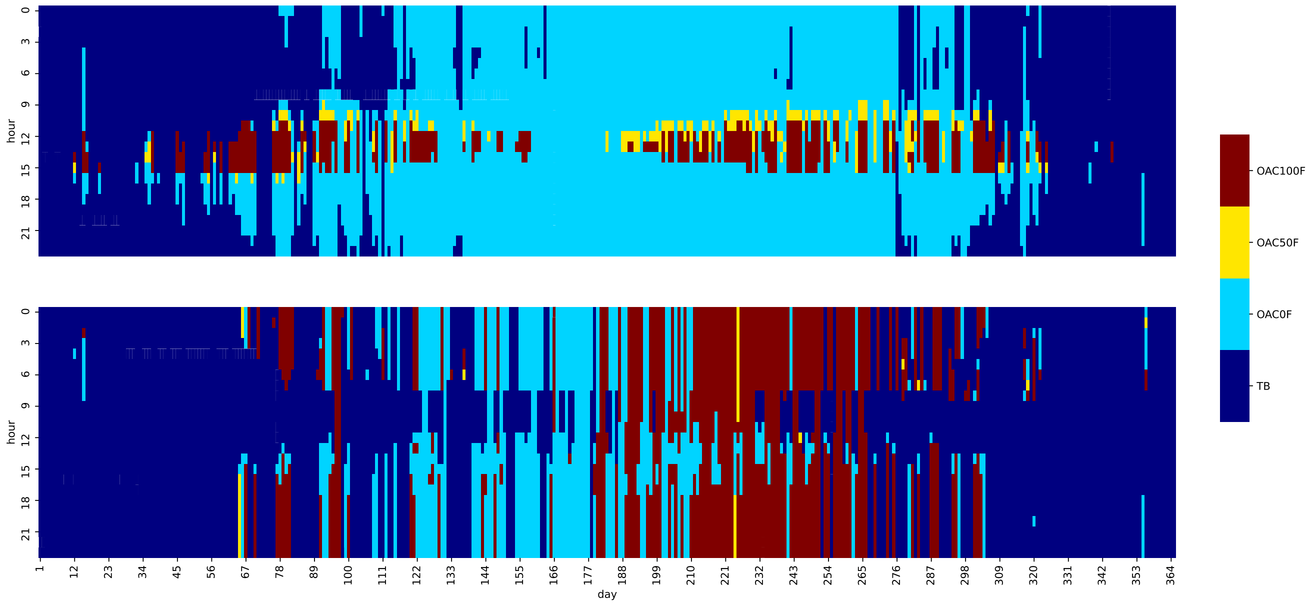
# Tool chain for design and testing advanced control strategies for dynamic facades

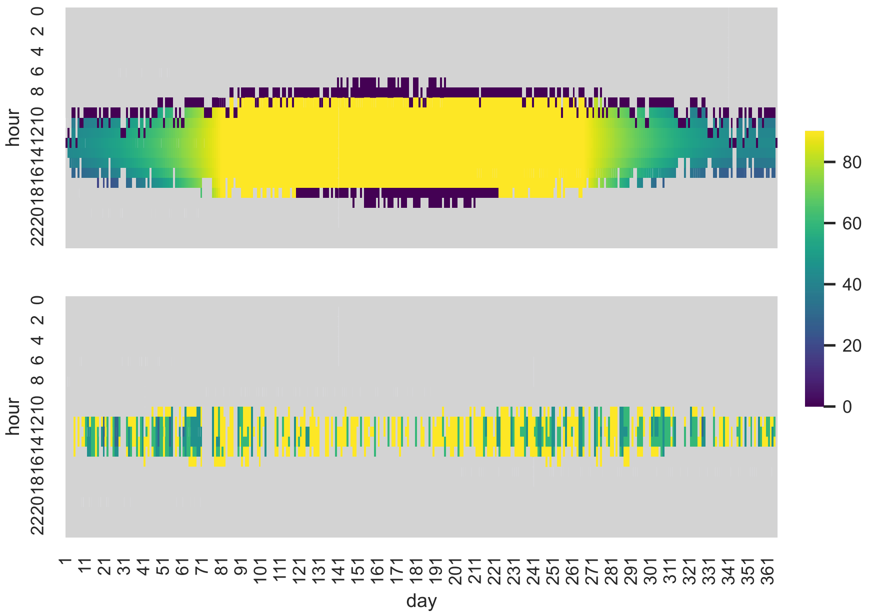


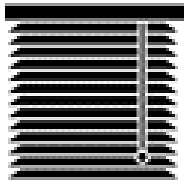
Rule Based

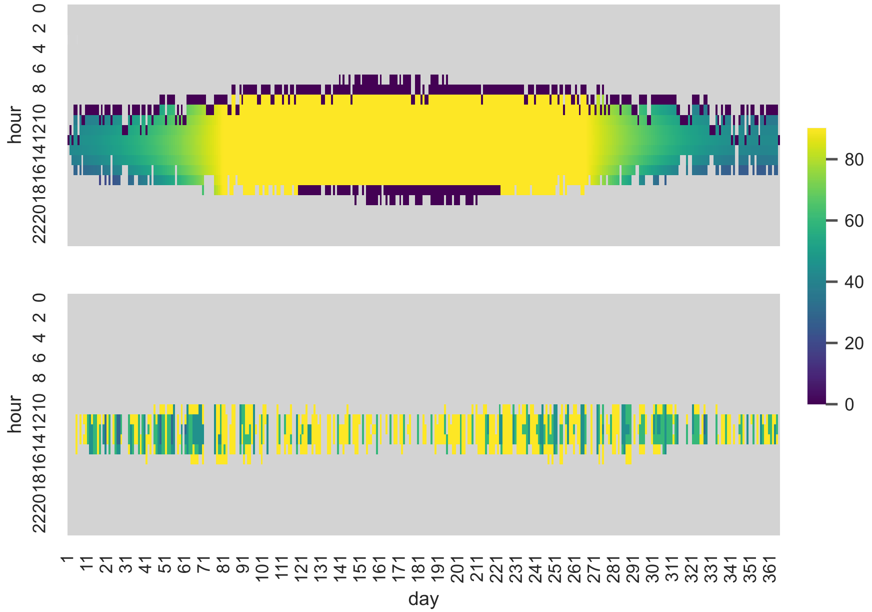
Model Based

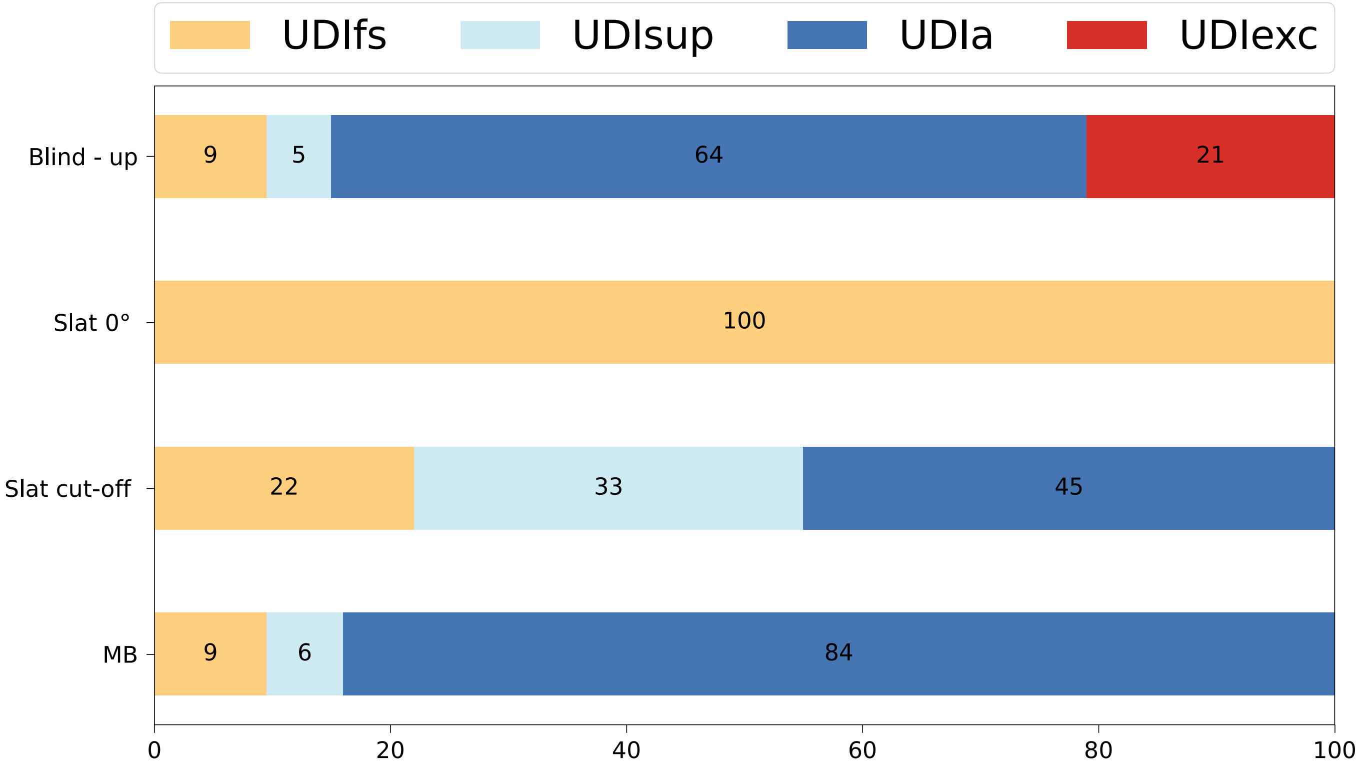


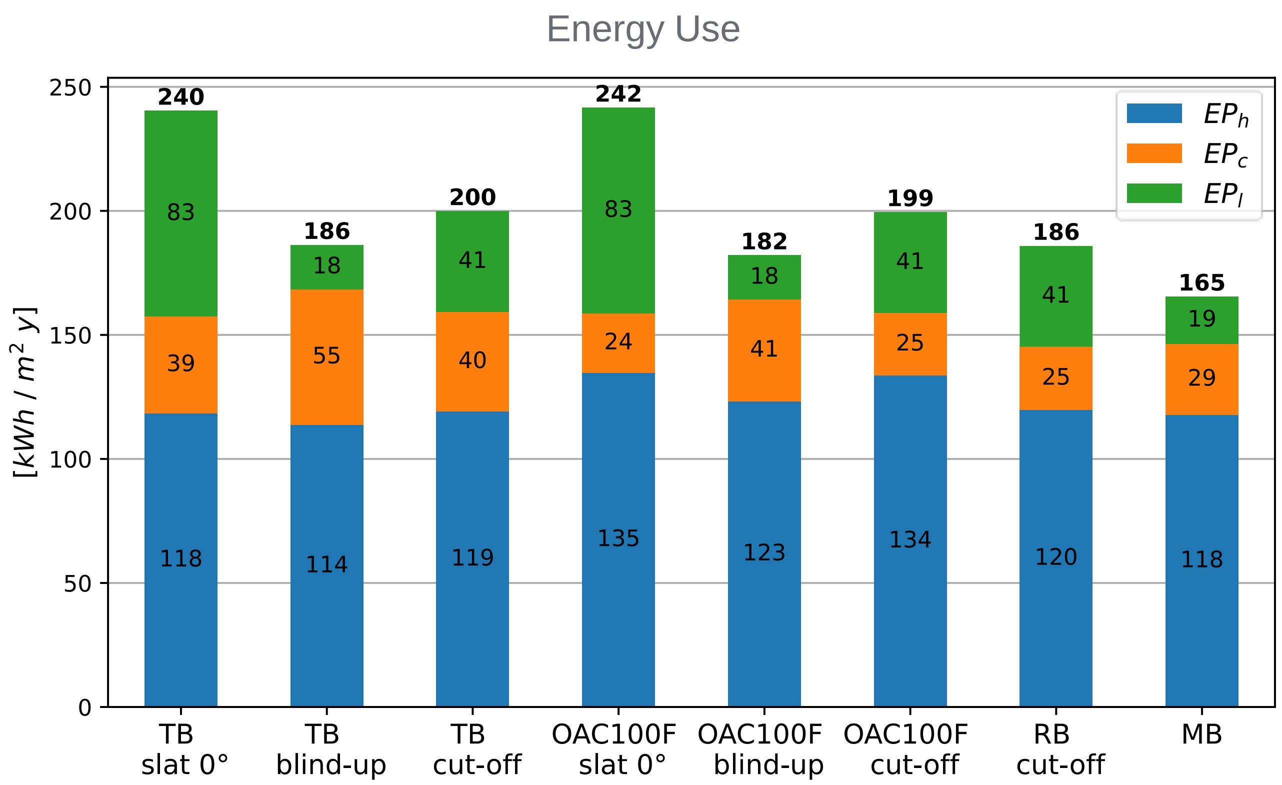
# Tool chain for design and testing advanced control strategies for dynamic facades





# Tool chain for design and testing advanced control strategies for dynamic facades



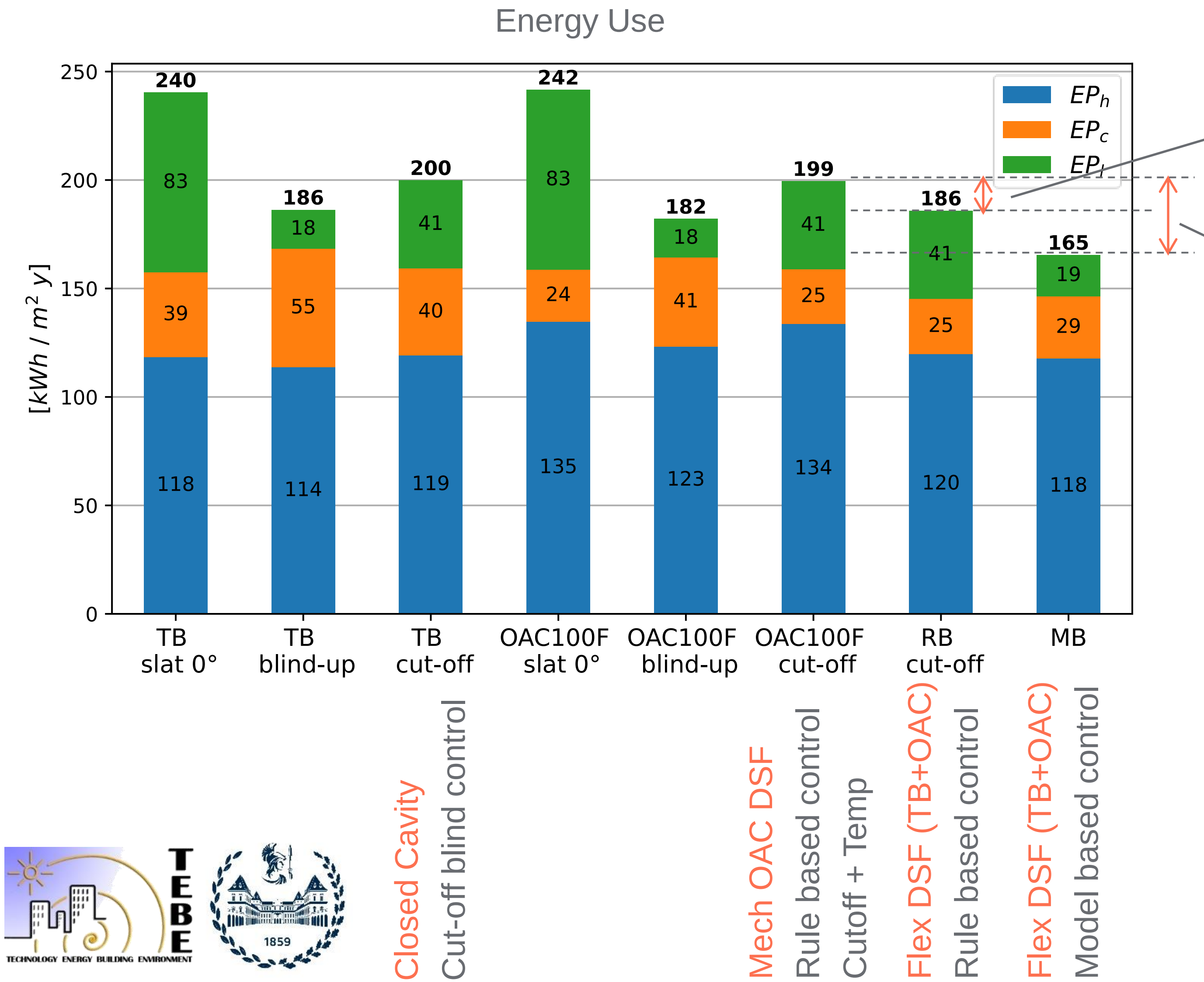

Closed Cavity
Cut-off blind control

Mech OAC DSF
Rule based control
Cutoff + Temp

Flex DSF (TB+OAC)
Rule based control

Flex DSF (TB+OAC)
Model based control

# Tool chain for design and testing advanced control strategies for dynamic facades




**Flexible DSF + Rule based (industry standard)**

3.12 €/m2 (of 5 m perimeter zone) saving
For 10.000 m$^2$ of façade, there are 52’000 € saving (1.3 M€ for 25 years)

**Flexible DSF + Model based (no additional hardware costs)**

7.58 €/m2 (of 5 m perimeter zone) saving
For 10.000 m$^2$ of façade, there are 126’367 € saving (3.2 M€ for 25 years)

(10000 m$^2$ bespoke unitized systems, 100k €)

Cost of performance mock ups 50-100k €
Cost of controllers 10 €/m2 of façade – 100k € total (now accounted in BMS)
Similar cost of maintenance for DSF
Not accounting for now long-term costs and maintenance of façade level controllers (now accounting in the BMS)
Cost of BEC (excluding performance mock-ups) depending on m$^2$, overall size of building and complexity

**Potential ROI of 3-4 years compared to Rule Based control**

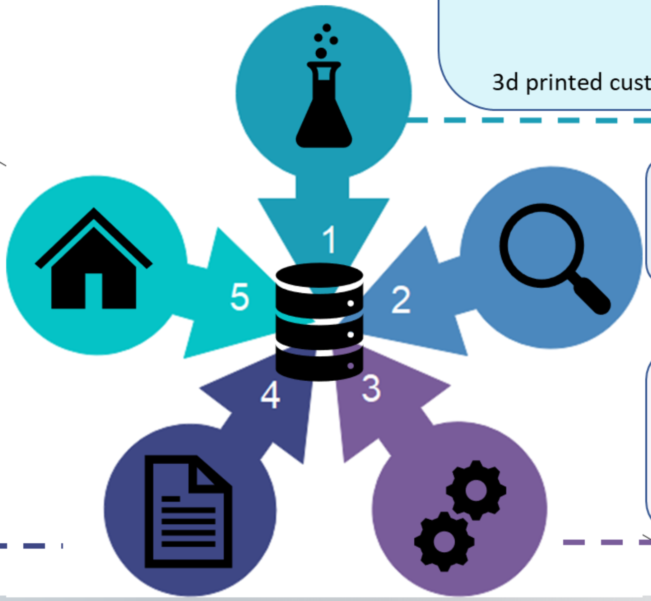
TECHNOLOGY ENERGY BUILDING ENVIRONMENT
TEBE
1859

# iclimabuilt (H2020) – OITB

Functional and advanced insulating and energy harvesting/storage materials across climate adaptive building envelopes

<u>**Objective:**</u> Support the **translation of research results into innovations** and help **small high-tech firms to scale up** and cope with the continuous rising of technological complexity **by providing a Single-Entry-Point** for necessary infrastructures and tools to test, validate and upscale new technological solutions

**iclimabuilt ecosystem services**




### Pilot Lines

- PCMs
- BIPVs
- TEGs
- Aerogels
- Omniphobic Coatings
- Advanced cement-based materials
- Insulation components from wastes
- Multifunctional Composite Sandwiches
- 3d printed customizable passive components for wellbeing

### Advanced characterization

Material/component characterisation metrics and testing

### Multi-scale simulations and virtual performance analysis

Materials-components-whole building simulation

### Standards, testing protocols and regulation

Structural, mechanical, functional properties, Safety, hazard, toxicity and environmental impact assessment, current regulations in national building codes

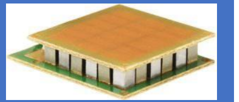
### Technology validation in 'living laboratories' & sustainability

materials performance verification under different climates for highly promising applications in energy and resource efficient buildings iCLIMABUILT

## Pilot Lines

- PCMs

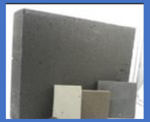
- TEGs



- Multifunctional Composite Sandwiches
- SAE materials

- Customizable 3d- printed components for well-being

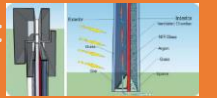
- Advanced cement-based materials
- Insulation components from wastes
- Aerogels



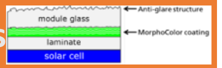
- Omniphobic coatings

## Test Cases

- Smart ventilated heat harvesting window



- BIPV & BIST collectors

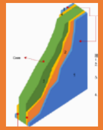



- TEG modules

- TRC/CLCi composite panels

- Eco-sustainable insulating components (+ waste material)

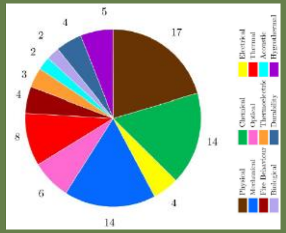
- MCS solutions



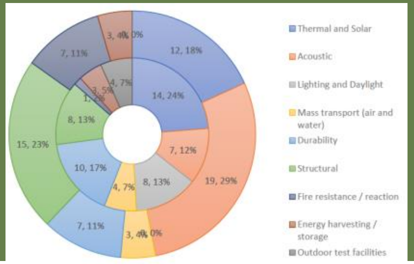
- 3D printed customizable components

## Upscaling support

- **Multiscale simulation:** from nano-material to building component to whole Building performance
- **Exp. Characterisation:** Material characterisation (137)



Building component performance testing (120, 4 OTF)




## Demos

Amposta, Spain

Manresa, Spain

Torino, Italy

Dresden, Germany

Trondheim, Norway

## Open Call

- Validation to technological solutions from outside consortium
- Call dedicated to SMEs and research center
- Supporting Upscaling from TRL4 to TRL6-7
- 70%-30% funding (on eligible costs)
- End of August opening

**MTaaS Platform**

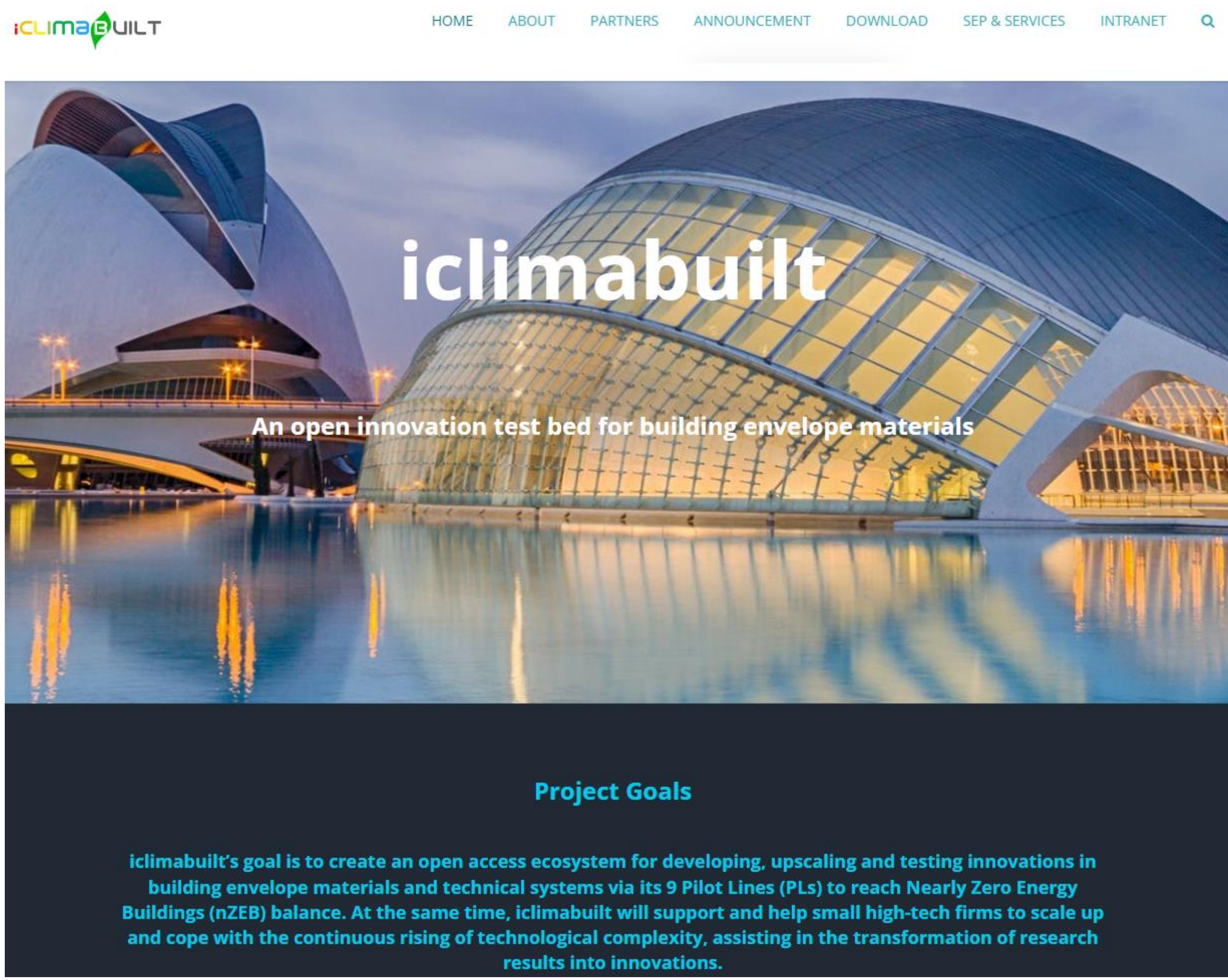
TEBE

Customer-oriented configuration capability to translate user needs to adaptive workflows

# Thank you!

Fabio Favoino
Associate Professor
fabio.favoino@polito.it

https://iclimabuilt.eu/#



# Green envelopes as a microclimatic boundary condition

School of Architecture and Design
University of Camerino
Roberta Cocci Grifoni

# Agenda in 8 minutes

- Nature as design material
- Green envelopes/boundary conditions
- Parametric optimization
- Microforestation as environmental acupuncture

# Green Mind Theory

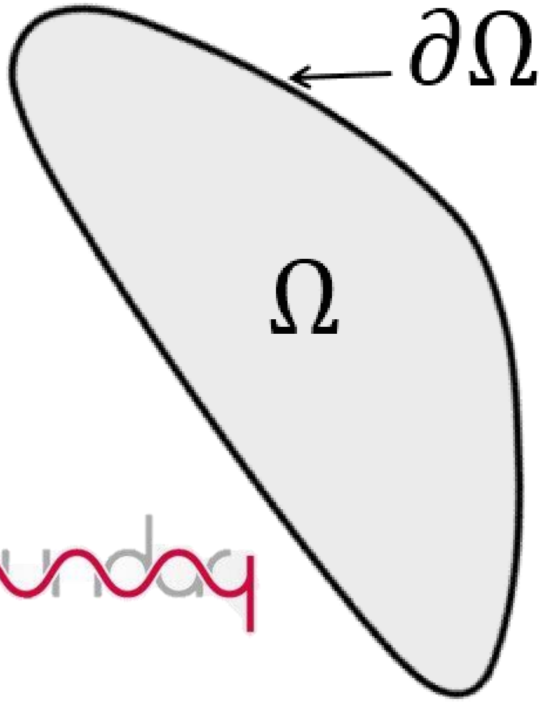
Artist: Paola Tassetti

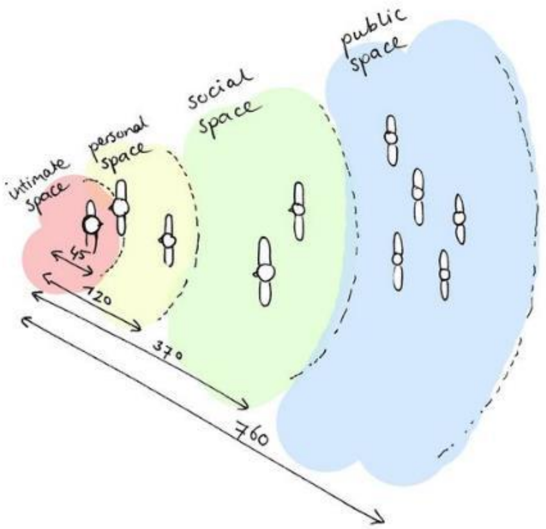
# Boundary Conditions

Resolution domain and boundary

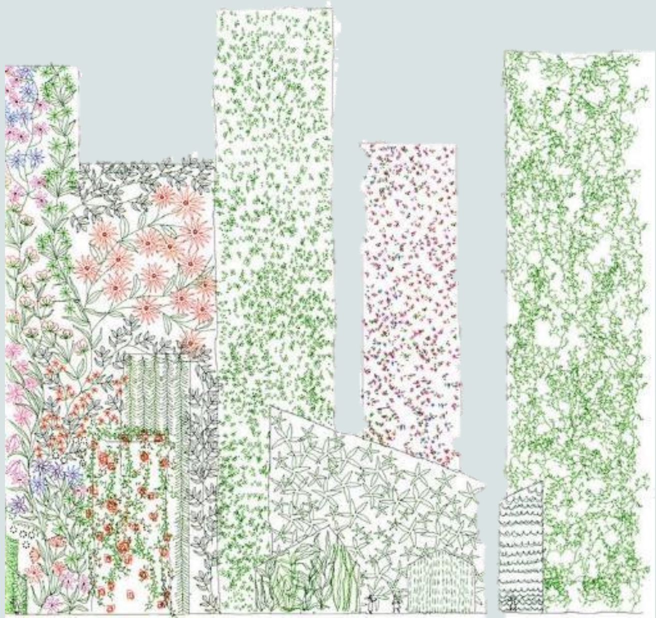
Boundary conditions are constraints necessary for the solution of a boundary value problem.

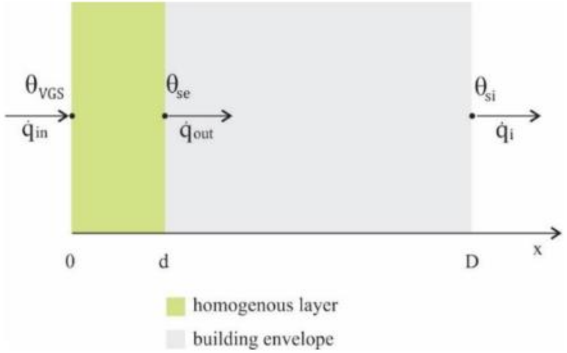
A boundary value problem is a differential equation (or system of differential equations) to be solved in a domain on whose boundary a set of conditions is known.

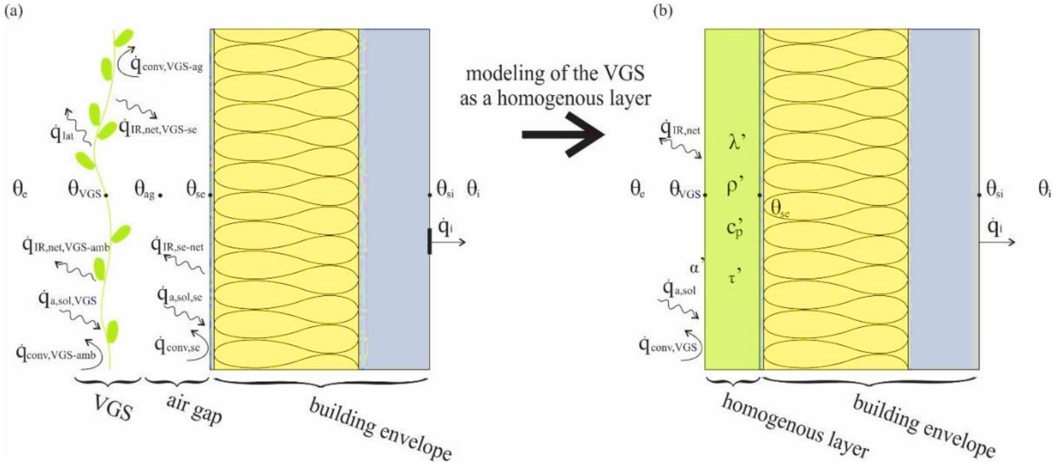


# Vertical Green System as homogenous layer (Boundary conditions)






Šuklje, Tomaž & Hamdy, Mohamed & Arkar, Ciril & Hensen, Jan & Medved, Saso. (2018). An inverse modeling approach for the thermal response modeling of greenfaçades. Applied Energy. 235. 1447-1456. 10.1016/j.apenergy.2018.11.066.

# Optimization

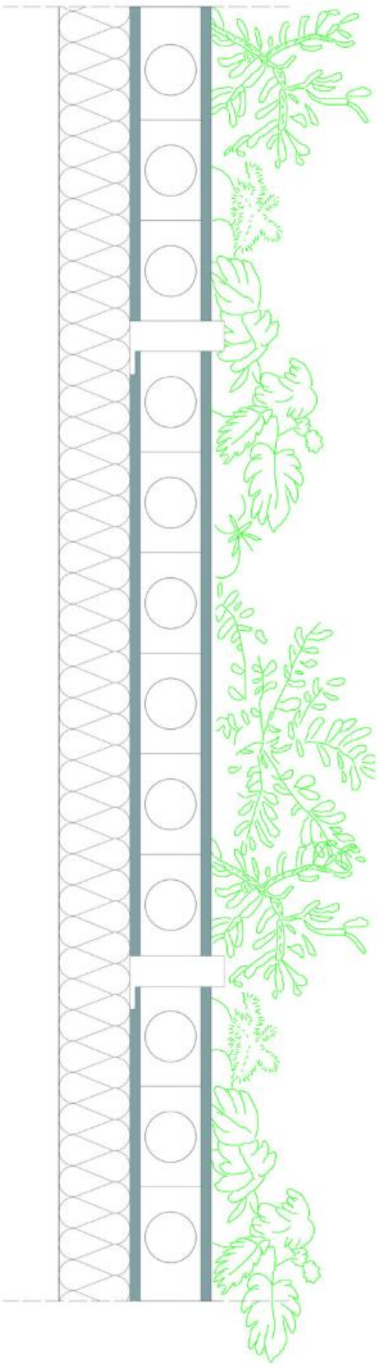


Fig. 4. Section of the green wall.

Contents lists available at ScienceDirect

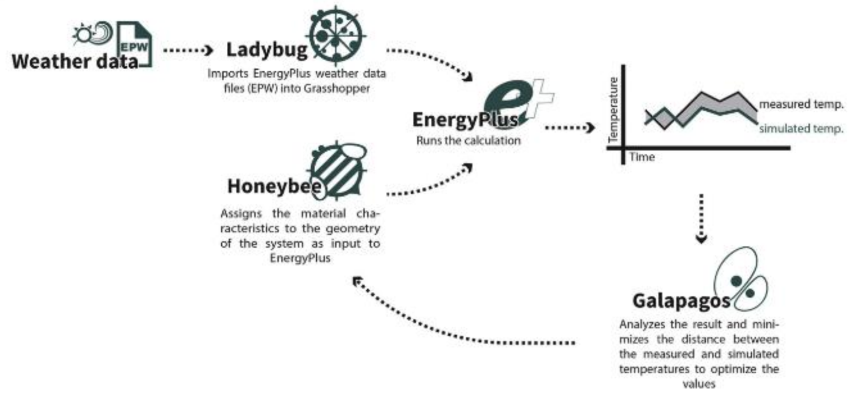
Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

## An experimental method to quantitatively analyse the effect of thermal insulation thickness on the summer performance of a vertical green wall

F. Olivieri[a,*], R. Cocci Grifoni[b], D. Redondas[c], J.A. Sánchez-Reséndiz[d], S. Tascini[b]

Universidad Politécnica de Madrid, E.T.S. Arquitectura, Department of Construction and Technology in Architecture, Avda. Juan de Herrera 4, 28040 Madrid, Spain
School of Architecture and Design, University of Camerino, Via Della Rimembranza, 63100 Ascoli Piceno, Italy
Universidad Politécnica de Madrid, E.T.S. Edificación, Department of Applied Mathematics, Avda. Juan de Herrera 6, 28040 Madrid, Spain
Universidad Politécnica de Madrid, Innovation and Technology for Development Centre, Avda. Complutense, 28040 Madrid, Spain



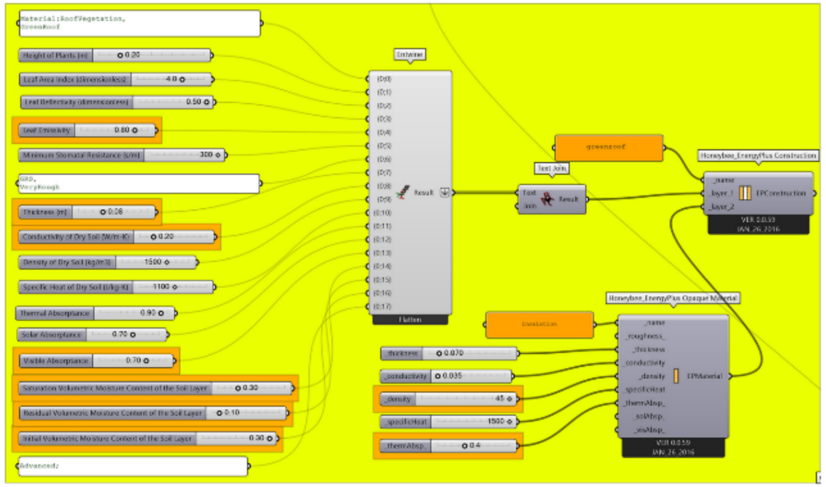
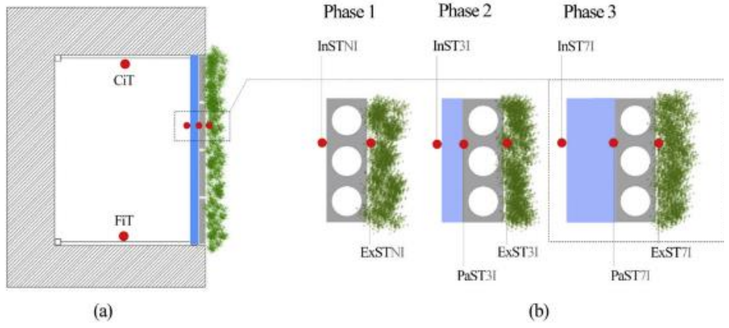
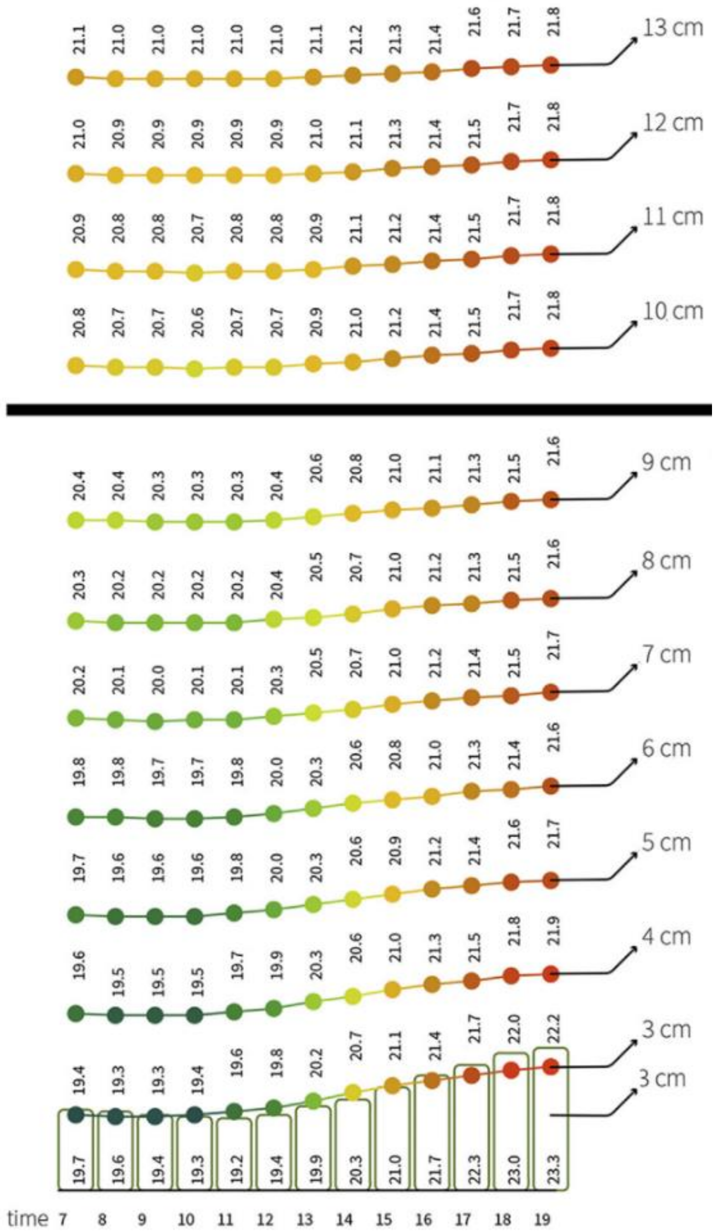



Fig. 10. Parameters of the GreenRoof module.

# Results



CiT
FiT
(a)
Phase 1
Phase 2
Phase 3
InSTNI
InST3I
InST7I
ExSTNI
ExST3I
ExST7I
PaST3I
PaST7I
(b)

13 cm
21.1 21.0 21.0 21.0 21.0 21.0 21.1 21.2 21.3 21.4 21.6 21.7 21.8
12 cm
21.0 20.9 20.9 20.9 20.9 20.9 21.0 21.1 21.3 21.4 21.5 21.7 21.8
11 cm
20.9 20.8 20.8 20.7 20.8 20.8 20.9 21.1 21.2 21.4 21.5 21.7 21.8
10 cm
20.8 20.7 20.7 20.6 20.7 20.7 20.9 21.0 21.2 21.4 21.5 21.7 21.8
9 cm
20.4 20.4 20.3 20.3 20.3 20.4 20.6 20.8 21.0 21.1 21.3 21.5 21.6
8 cm
20.3 20.2 20.2 20.2 20.2 20.4 20.5 20.7 21.0 21.2 21.3 21.5 21.6
7 cm
20.2 20.1 20.0 20.1 20.1 20.3 20.5 20.7 21.0 21.2 21.4 21.5 21.7
6 cm
19.8 19.8 19.7 19.7 19.8 20.0 20.3 20.6 20.8 21.0 21.3 21.4 21.6
5 cm
19.7 19.6 19.6 19.6 19.8 20.0 20.3 20.6 20.9 21.2 21.4 21.6 21.7
4 cm
19.6 19.5 19.5 19.5 19.7 19.9 20.3 20.6 21.0 21.3 21.5 21.8 21.9
3 cm
19.4 19.3 19.3 19.4 19.6 19.8 20.2 20.7 21.1 21.4 21.7 22.0 22.2
3 cm
19.7 19.6 19.4 19.3 19.2 19.4 19.9 20.3 21.0 21.7 22.3 23.0 23.3
time 7 8 9 10 11 12 13 14 15 16 17 18 19

# Optimization

sustainability

MDPI

Article

## A Parametric Optimization Approach to Mitigating the Urban Heat Island Effect: A Case Study in Ancona, Italy

**Roberta Cocci Grifoni *, Rosalba D'Onofrio, Massimo Sargolini and Mariano Pierantozzi**

School of Architecture and Design "E. Vittoria", University of Camerino, Camerino 62032, Italy; rosalba.donofrio@unicam.it (R.D.); massimo.sargolini@unicam.it (M.S.); mariano.pierantozzi@unicam.it (M.P.)

* Correspondence: roberta.coccigrifoni@unicam.it; Tel.: +39-073-740-4259

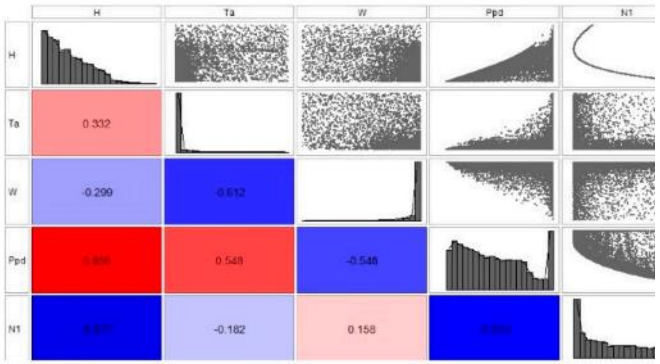



**Figure 9.** Matrix representation of the relation among optimization variables for parameter $N_1$.

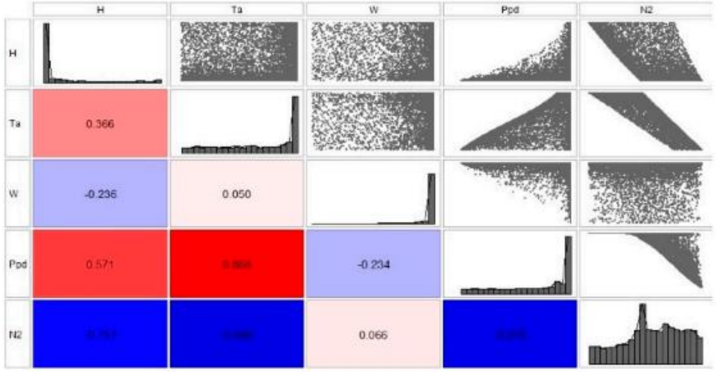



**Figure 10.** Matrix representation of the relation among optimization variables for parameter $N_2$.

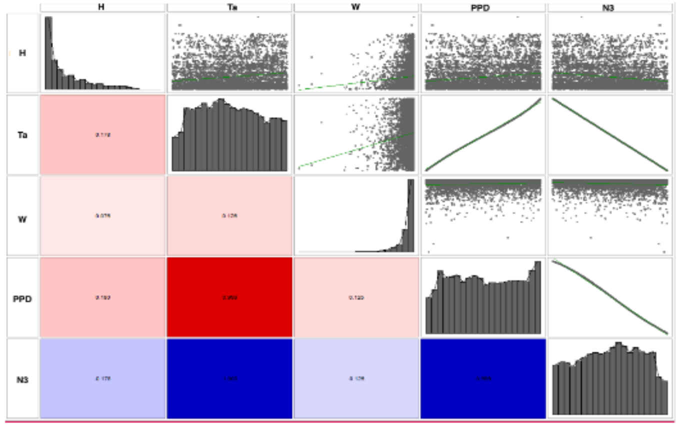



**Figure 11.** Matrix representation of the relation among optimization variables for parameter $N_3$.

**Table 2.** Possible mitigation measures to control the urban heat island [2].

| Scale | Intervention | Control |
|---|---|---|
| Building | Roughness | Airflow, ventilation |
| | Trees, overhangs, narrow spaces | Provide shade and shelter |
| | Impervious surface fraction | Energy partitioning between sensible (heating) and latent, evaporative (cooling) exchanges |
| | Porous pavement | Increase surface wetness, evaporative cooling, reduce runoff |
| | Vegetated roofs | Cool rooftop through shading and evaporative cooling and provide additional insulation to improve building energy performance |
| | High albedo, light surfaces | Influences surface heat absorption and ensures high reflection of radiation |
| | Sky view factor | Influences solar access and radiative cooling |
| | Thermal admittance | Modulates heating and cooling cycles of materials |
| | Thick walls, roof insulation | Modulates heat storage |
| Neighborhood | Morphology, building and pavement materials, amount of vegetation and transport | Influence airflow, ventilation, energy use, anthropogenic heat emissions, pollution, and water use via city form and function |

# Green Optimization

*2.1. Parameters*

The UHI effect, the difference in temperature between urban and rural areas, is directly related to the urban morphology. Oke [29] related this temperature difference to the height-to-width ratio ($H/w$) of the urban streets, which defines the sky view factor (SVF) and urban compacity:

$$\Delta t_{(u-r)} = 7.45 + 3.97 \ln(\frac{H}{w}) \tag{3}$$

According to Salat ans Morterol [30], the non-dimensional parameter compacity, $N_1$ (Equation (4); [31]), is an interesting descriptor of urban morphology. It describes the amount of exposed building envelope ($A_{ext}$) per unit volume ($V$):

$$N_1 = \sum_{buildings} \frac{A_{ext}}{V_b^{2/3}} \tag{4}$$

and determines the thermal losses of buildings in an urban environment. To focus on the form rather than the size, the ratio $A/V^{2/3}$ is considered; the lower the ratio, the higher the compacity.

Other factors that influence the thermal state of the city include the solar radiation, $H_s$, the temperature difference between the average indoor ($T_i$) and outdoor temperatures, and the energy coefficient $K$, which is the ratio of the total energy needs of the building to the average external air temperature. Two external temperatures were considered: $T_a$ is the ambient temperature and $T_c$ is the sky temperature.

The collective behavior of these parameters was studied by considering three dimensionless numbers that are closely related to the urban morphology and the local climate conditions [33,34]:

$$\begin{aligned} N_1 &= A_{ext}/V_b^{2/3} \\ N_2 &= A_{ext}^{0.5} K\,(T_i - T_a)/H_s = A_{me}^{0.5} K \Delta T / H_s \\ N_3 &= A_{ext}^{0.5} K\,(T_a - T_c)/H_s = A_{me}^{0.5} K \Delta T' / H_s \end{aligned} \tag{5}$$

$N_1$ is the compacity of the building as described above (Equation (4)). On the building scale, $N_2$ is related to energy consumption and describes the ratio of the building's energy loss to the solar energy gain. $N_3$ is another energy consumption parameter, but it expresses energy loss on a larger, citywide scale, between the built area and the sky; $N_2$ and $N_3$ differ in the temperature difference used. $N_1$, $N_2$, and $N_3$ represent thermodynamic energy system indicators for urban energy planning. Each of these aggregate parameters encompasses many variables in the built environment and can be used to define the built area, the extent of green space, and service areas. They also allow the quality of an urban area to be evaluated by referring to the analysis made on the current conditions [34].

Figure 3. The case study (City of Ancona, in central Italy).

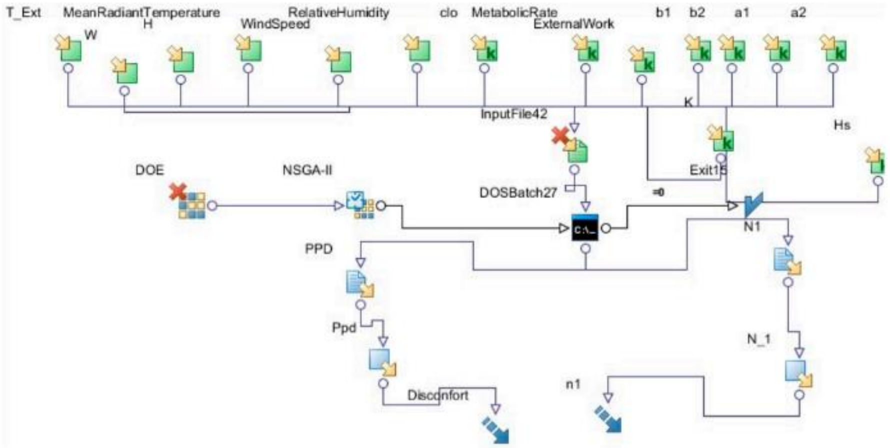



**Figure 1.** The modeFRONTIER workflow.

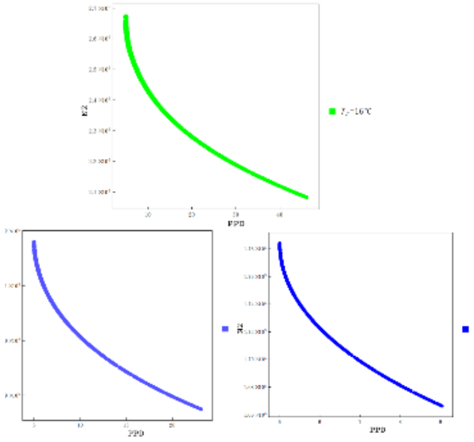


Figure 7. $N_2$ vs. PPD for different temperatures. No Pareto frontier is formed for higher temperatures.

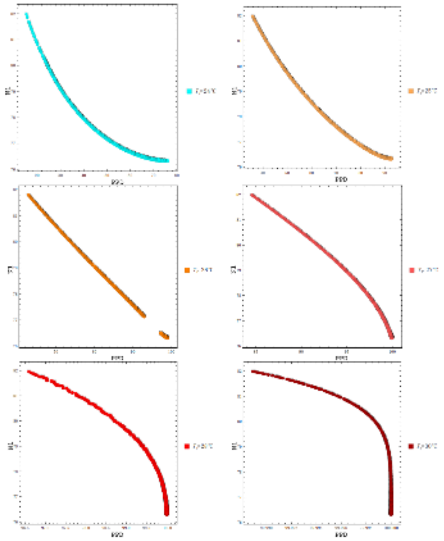


Figure 5. $N_1$ vs. PPD for different temperatures.

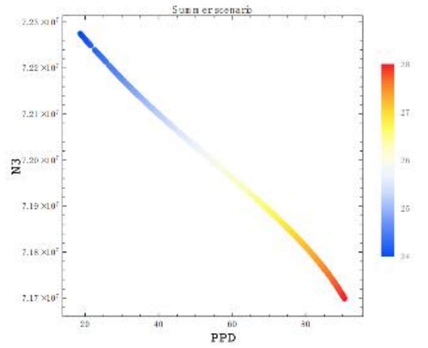



**Figure 8.** Pareto frontier of solution clusters for the summer scenario. The $N_3$ parameter is on the $y$-axis and PPD is on the $x$-axis.

## 4. Conclusions

In recent years, a lot of research and applications have looked at the energy efficiency of buildings. Many models have developed knowledge regarding insulation, thermal inertia, and renewable energy production. In contrast, themes related to phenomena on the larger urban scale have not been sufficiently investigated, and a well-accepted theory that can be used by planners still has not been formulated. One aspect that remains unresolve
general trend to increase building density and t
microclimate and the quality of life in the city. Th
and energy efficiency, but there are numerous par
specifically, and reciprocal relationships that ne
emissions and improve energy efficiency. Wideni
would encourage adoption of a global vision th
buildings, the effectiveness of new technologies
manner. This, then, becomes the way to orient th

The main objective of this research was
relationships between different attributes of the
The results of this type of multi-objective optin
building scenarios leading to the selection of th
policies for change indicated as objectives for ea

Analysis of the case study (Ancona) allowed
and their effectiveness in mitigating the UHI eff
effective support for the parametric analysis of

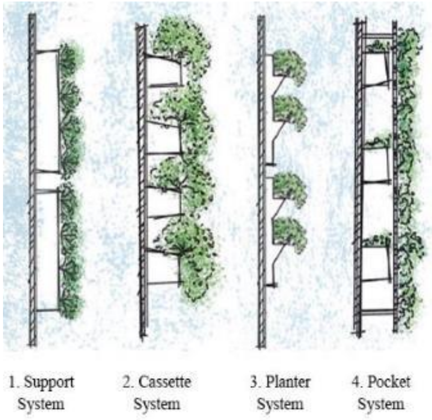
indicators with meteorological parameters. Thermodynamic indicators ($N_1$, $N_2$, and $N_3$) useful for the energy planning of urban areas, and for defining scenarios of integrated low-environmental-impact energy strategies and actions in an urban area were considered. The results show that compacity ($N_1$) and thermodynamic indicator $N_2$ can be useful parameters when designing comfortable cities. Their optimization implies different planning/building layouts to improve thermal comfort, such as wide streets and medium-height buildings in places where the wind speed is low. Parameter $N_3$, on the other hand, shows that, within the limits of the model, it is even more difficult to find optimal solutions when dealing with the city as a whole. The temperatures examined are not at all extreme for summers in Ancona but represent typical real values in the representative summer scenario. This analysis shows that the external temperature can be considered the "dominant" variable in planning. On the building scale ($N_1$), increasing the external temperature leads to an inversion of the Pareto frontier and therefore for temperatures greater than 33 °C (in the case study presented here) there are no possible solutions. Analogously for $N_2$, there are no solutions for temperatures higher than 30 °C, and there is complete discomfort (100% PPD) even at 28 °C.

External temperatures are increasing due to climate change, and Italy in particular is seeing a higher increase in temperature compared to the European average. The analysis thus highlights the importance of reducing the outdoor temperature with physical elements such as green areas, green canopies, highly retroreflective materials, and urban shading. This initial result, applied to a typical Mediterranean city (Ancona), shows how important it is to mitigate the increase in temperature from a planning point of view. This research highlights a series of possible solutions that would allow energy consumption to be limited while improving the thermal comfort for users.

However, this is only the first step in this new technique and further development efforts are already being considered. In particular, an in-depth analysis should also be carried out for the winter

# Microforestation

Microforest

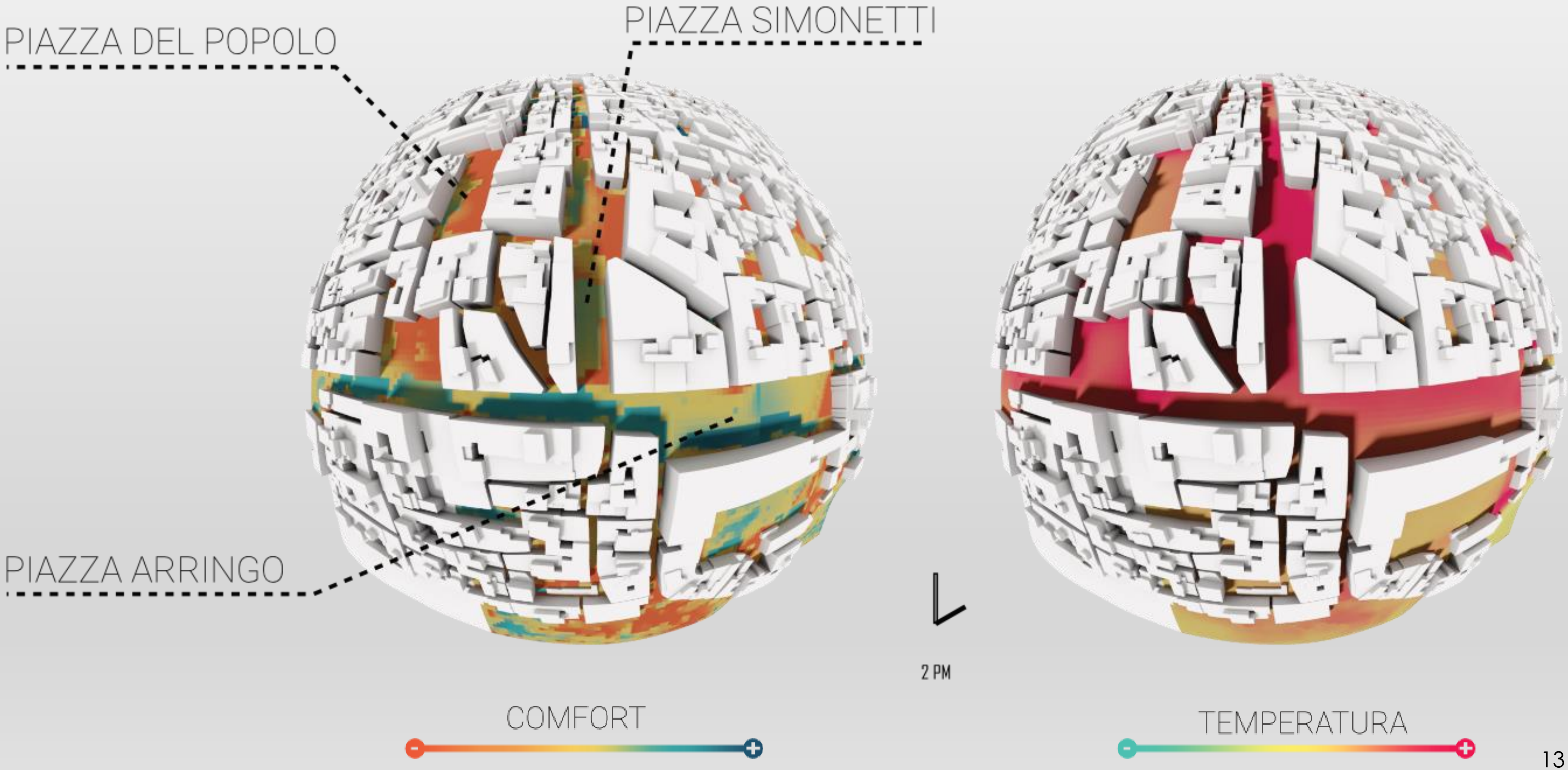



Vertical Green Systems

Orizontal Green Systems

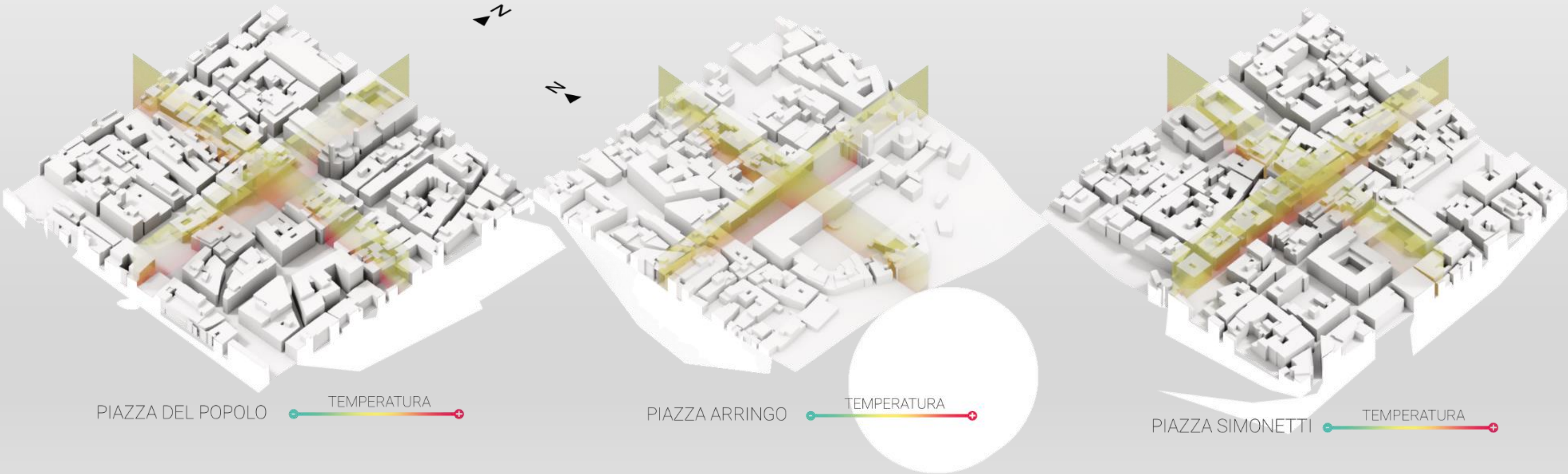
Green agopuntucture

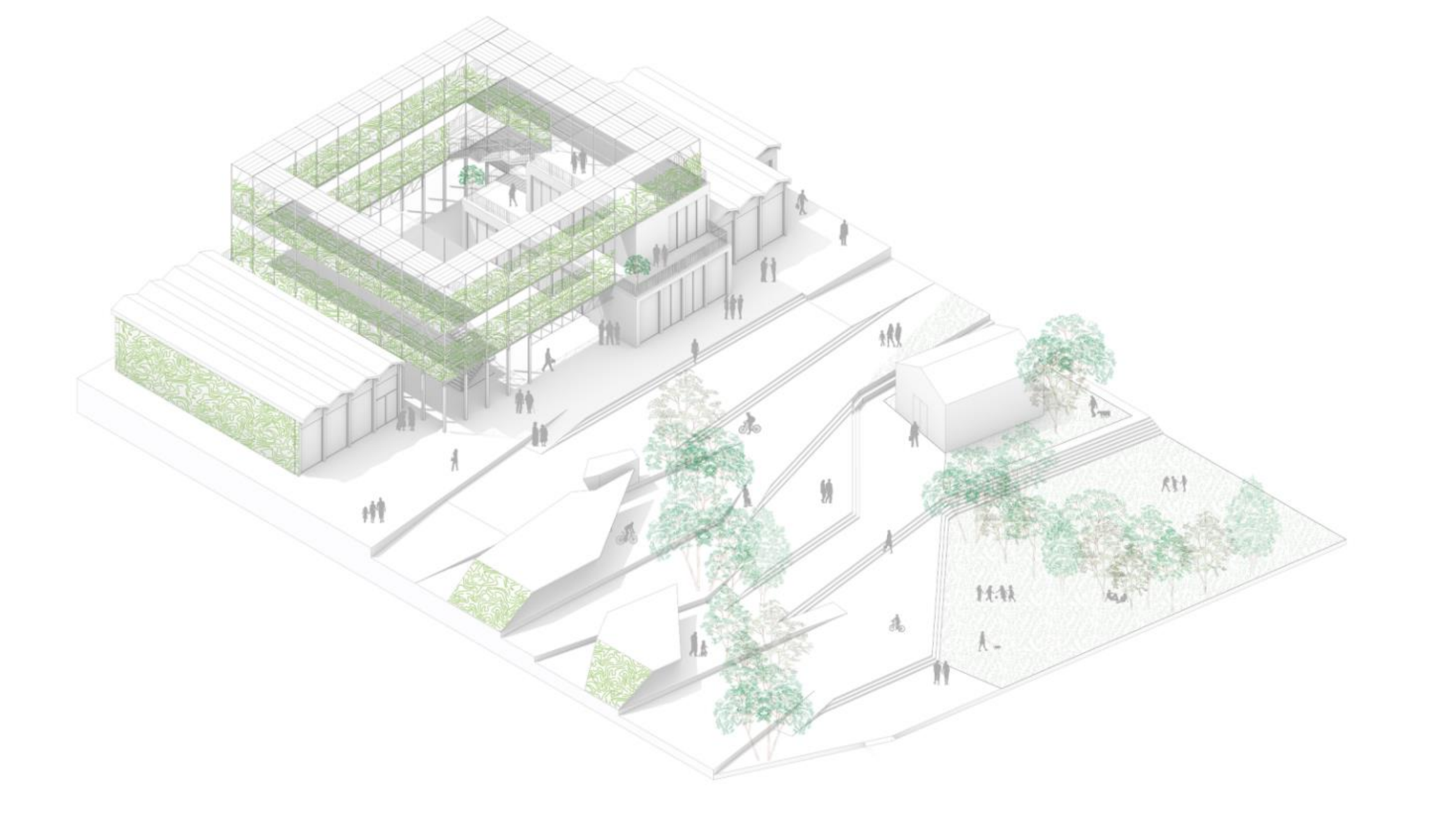
# Microclimatic Analysis



# TENS Analysis

2 PM





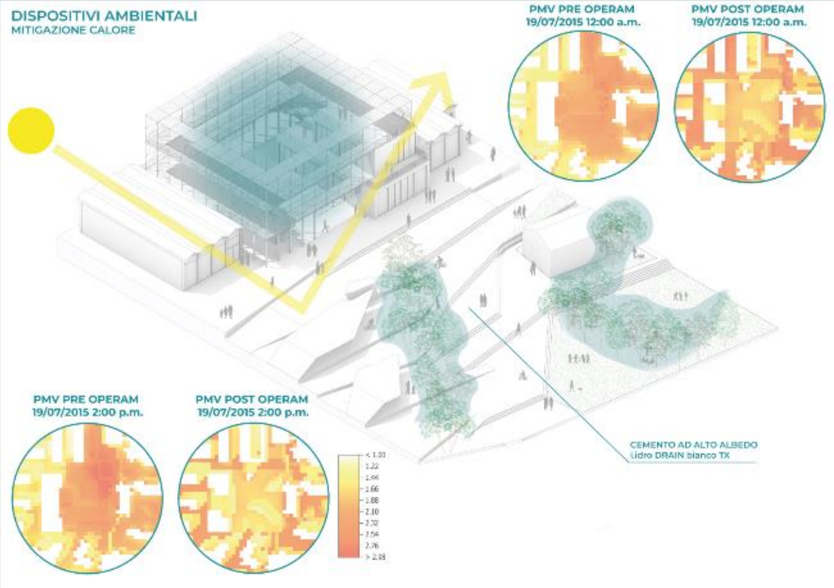
# City_Leaf

Ascoli Piceno

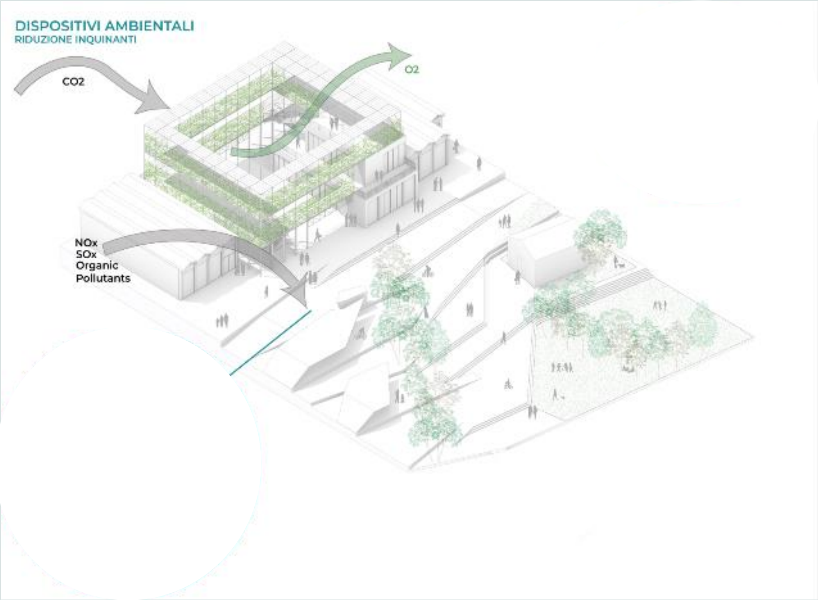
# City_Leaf

## Ascoli Piceno

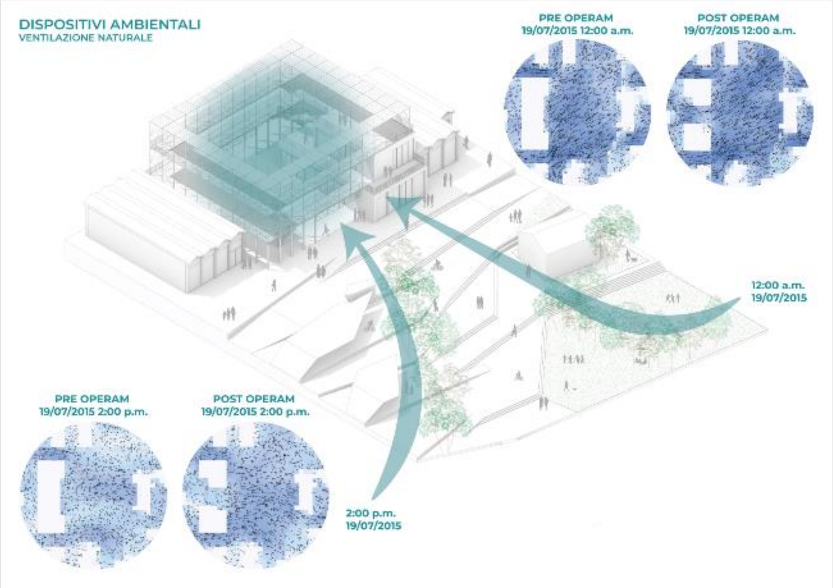
### COMFORT OUTDOOR




### AIR QUALITY

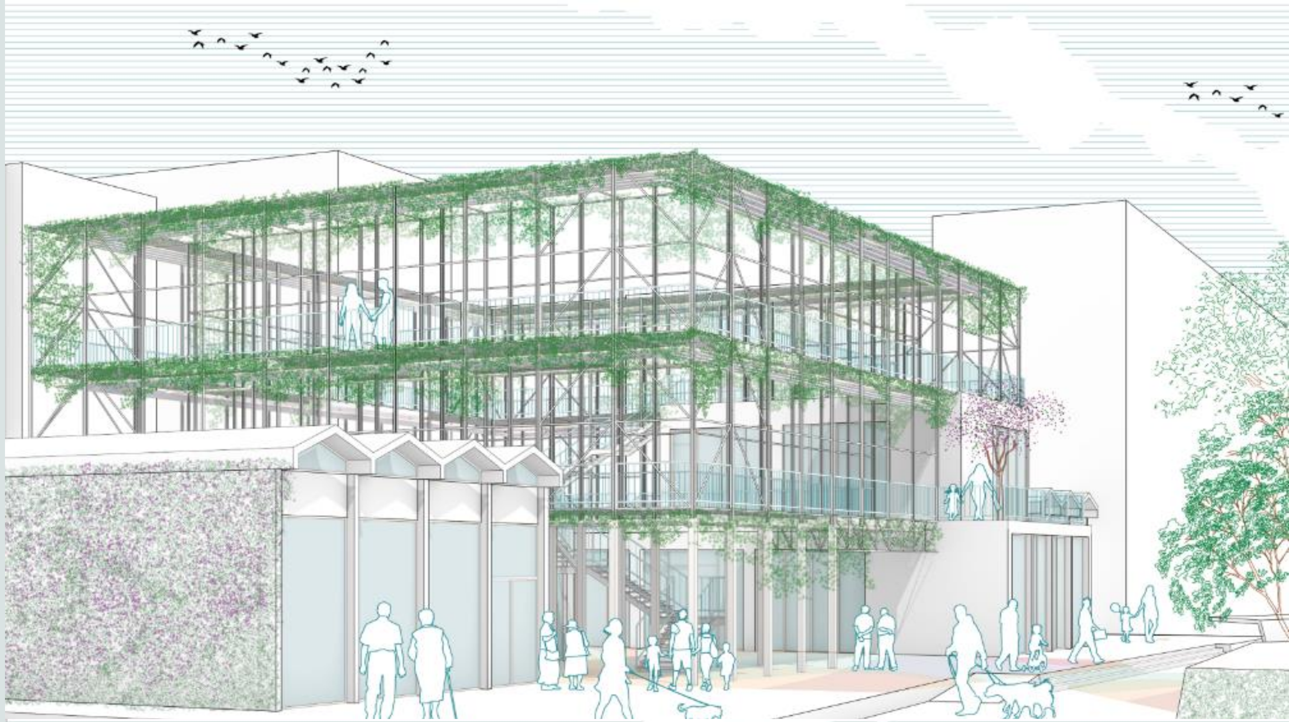



### NATURAL VENTILATION



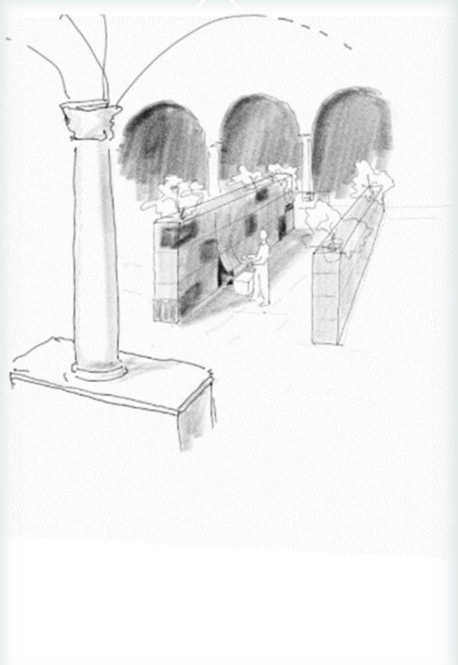
# City_Leaf

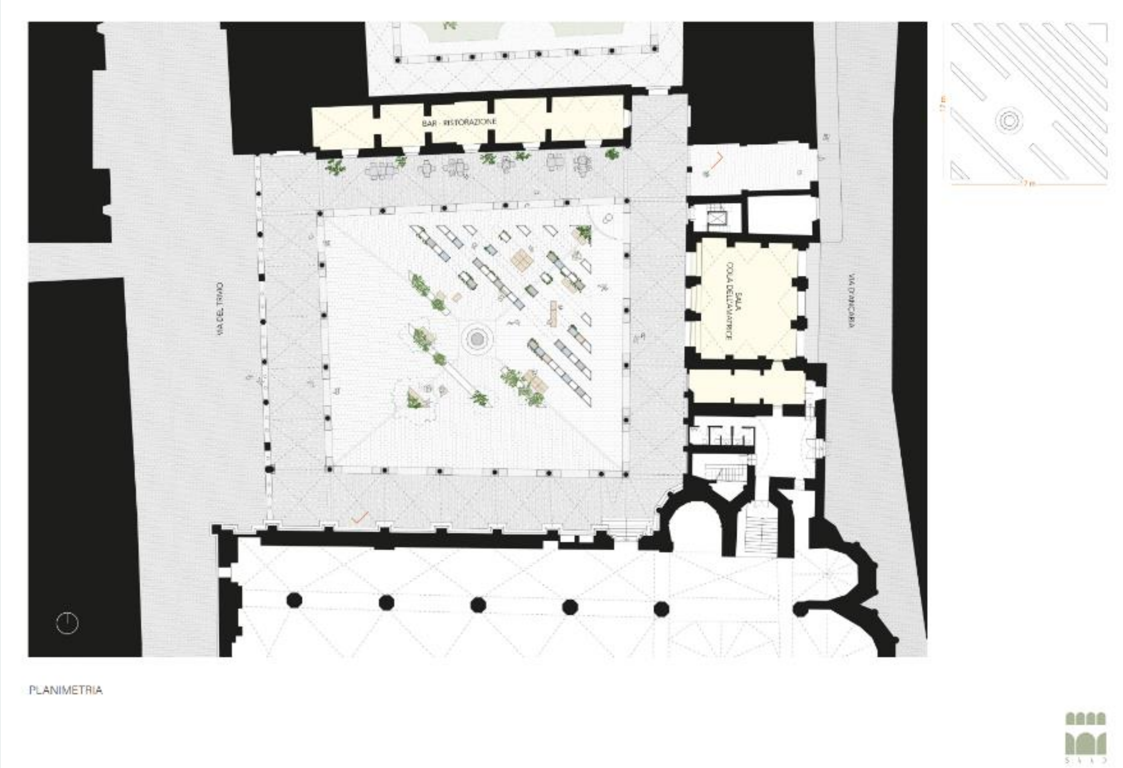
## Ascoli Piceno



# Green Transparency

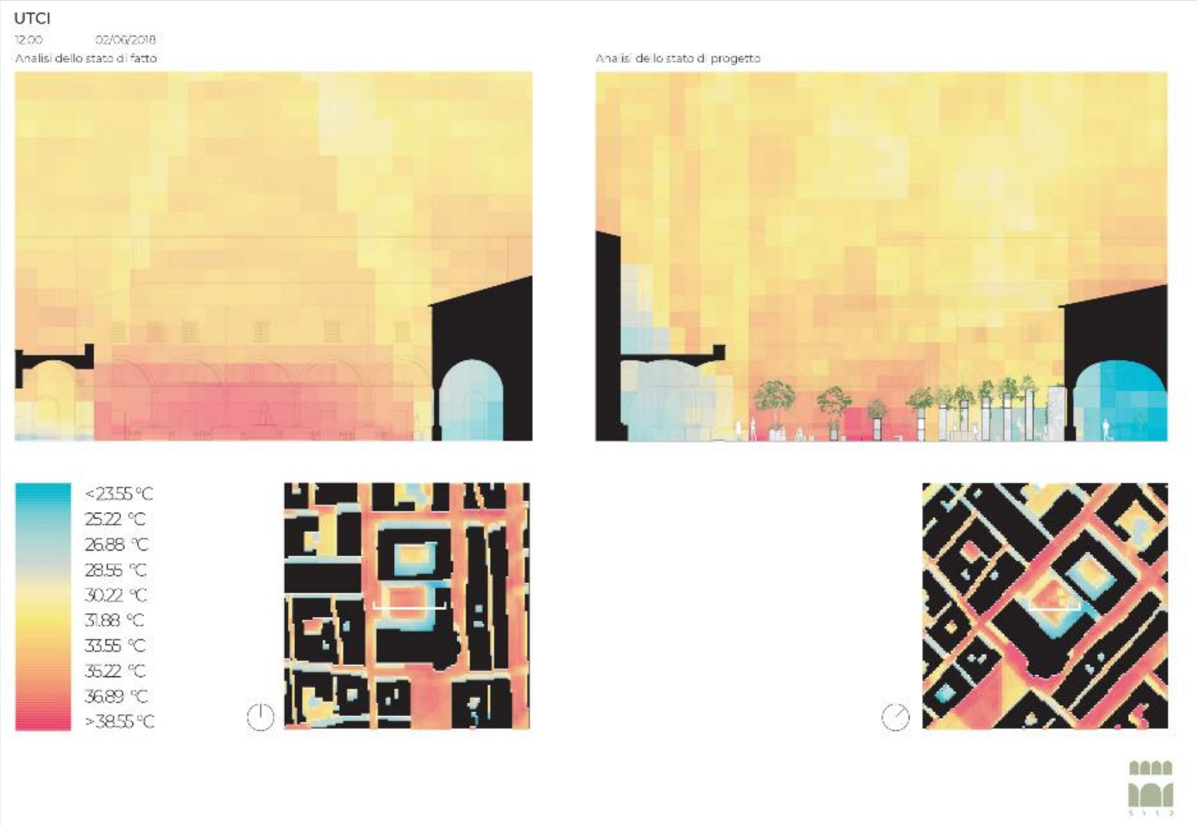
Ascoli Piceno

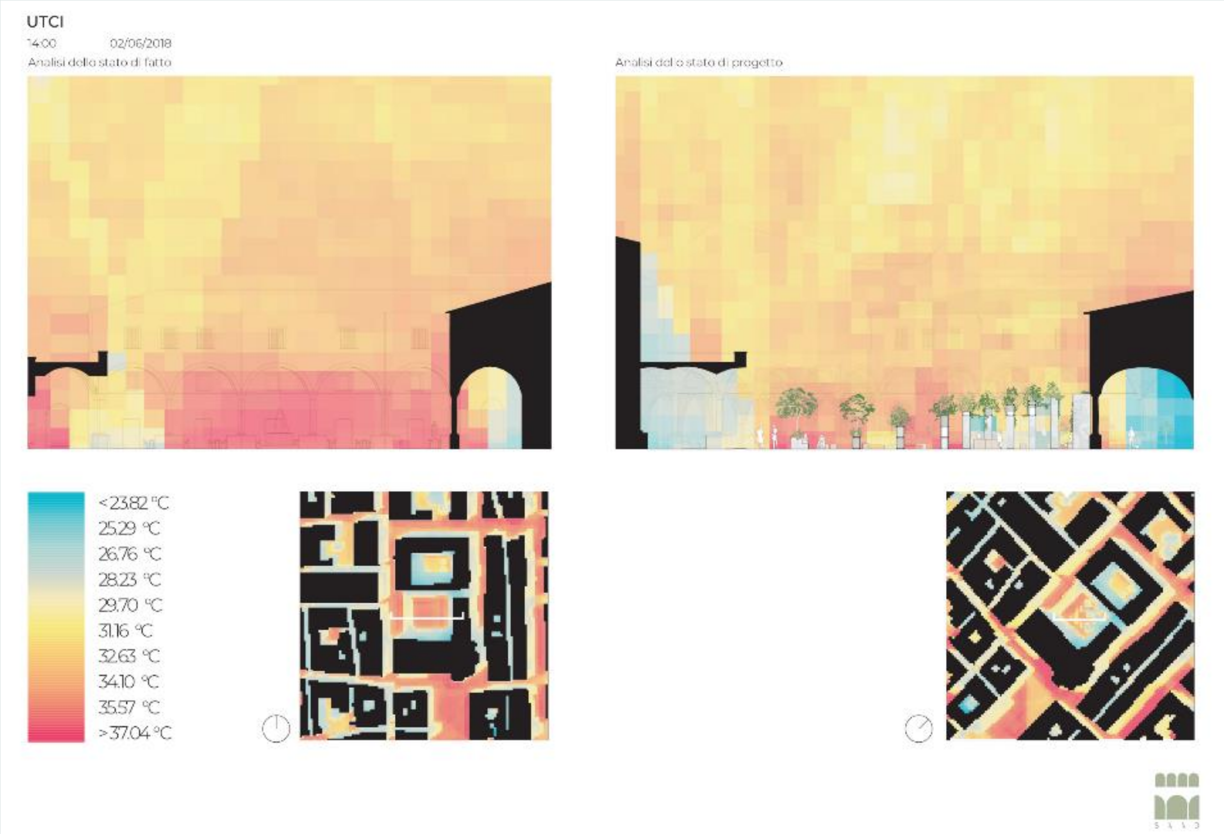




# Green Transparency

## Ascoli Piceno



UTCI
12:00 02/06/2018
Analisi dello stato di fatto
Analisi dello stato di progetto
<23.55 °C
25.22 °C
26.88 °C
28.55 °C
30.22 °C
31.88 °C
33.55 °C
35.22 °C
36.89 °C
>38.55 °C


UTCI
14:00 02/06/2018
Analisi dello stato di fatto
Analisi dello stato di progetto
<23.82 °C
25.29 °C
26.76 °C
28.23 °C
29.70 °C
31.16 °C
32.63 °C
34.10 °C
35.57 °C
>37.04 °C

# Present and future work

## Eu Research&Innovation

LIFE+ A GreeNet
ADRIATIC CLIMATE URBAN NETWORK

CliCHE
Climate Change, Cities, Communities and Equity in Health
Ka220 HED–Progetto n. 2021-1-IT02-KA220-HED-000032223

life imagine

EDUSCAPE

## Regional Research&Innovation



## Pnrr Research&Innovation

VITALITY

Mims
Ministero delle infrastrutture
e della mobilità sostenibili

PINQUA
#INASCOLI

# Thank you

Roberta Cocci Grifoni

Roberta.coccigrifoni@unicam.it

ECOLOPES

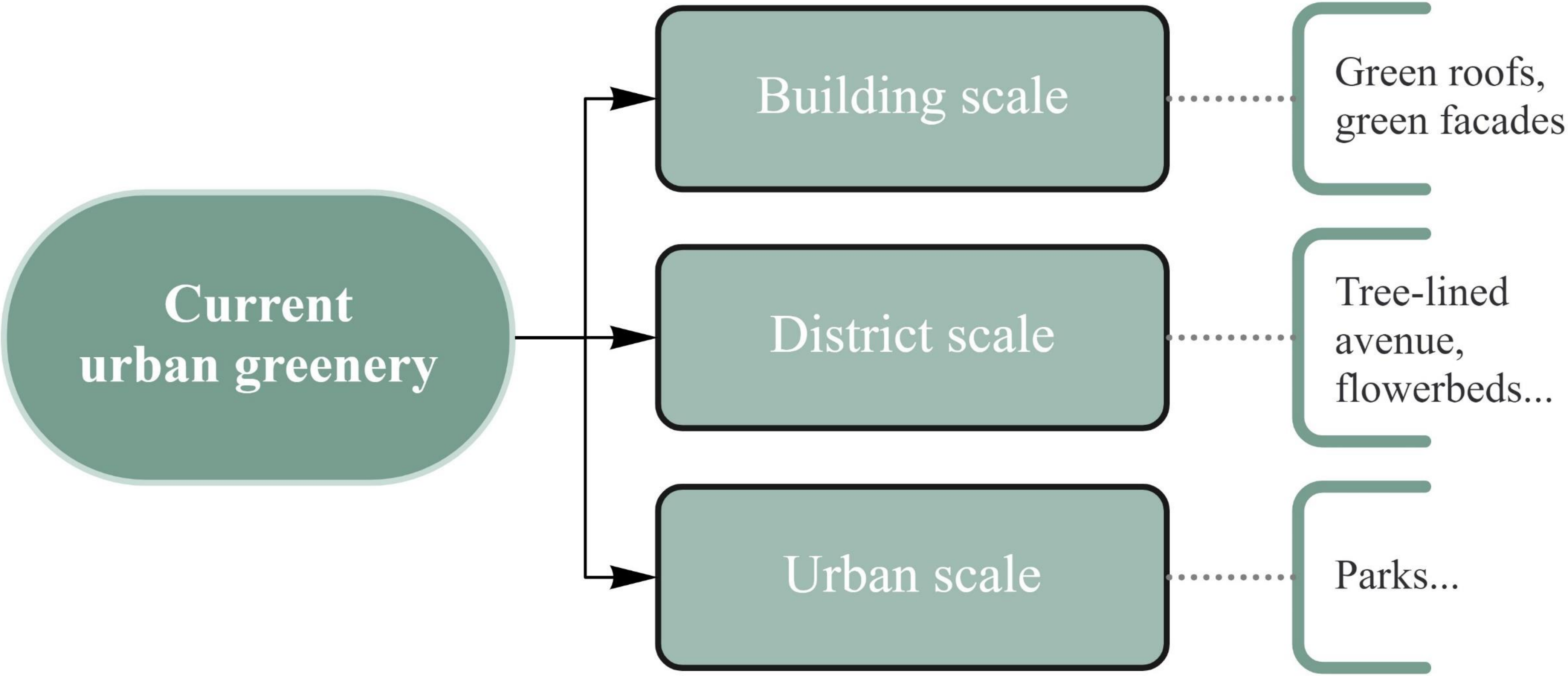
ECOlogical building enveLOPES

Microclimatic Change and Envelopes – 28th April 2023

**ECOLOPES: multi-species building envelopes**

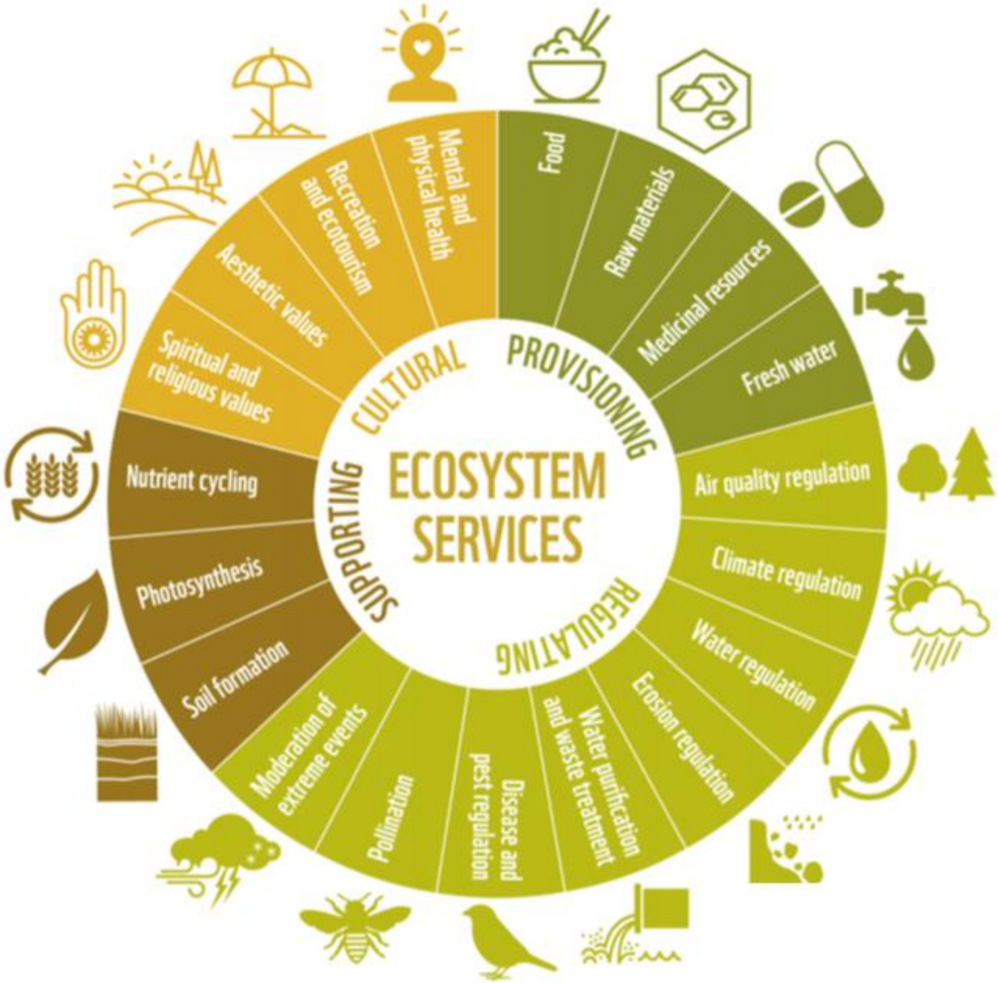
Katia Perini – Università degli Studi di Genova - DAD

# Background



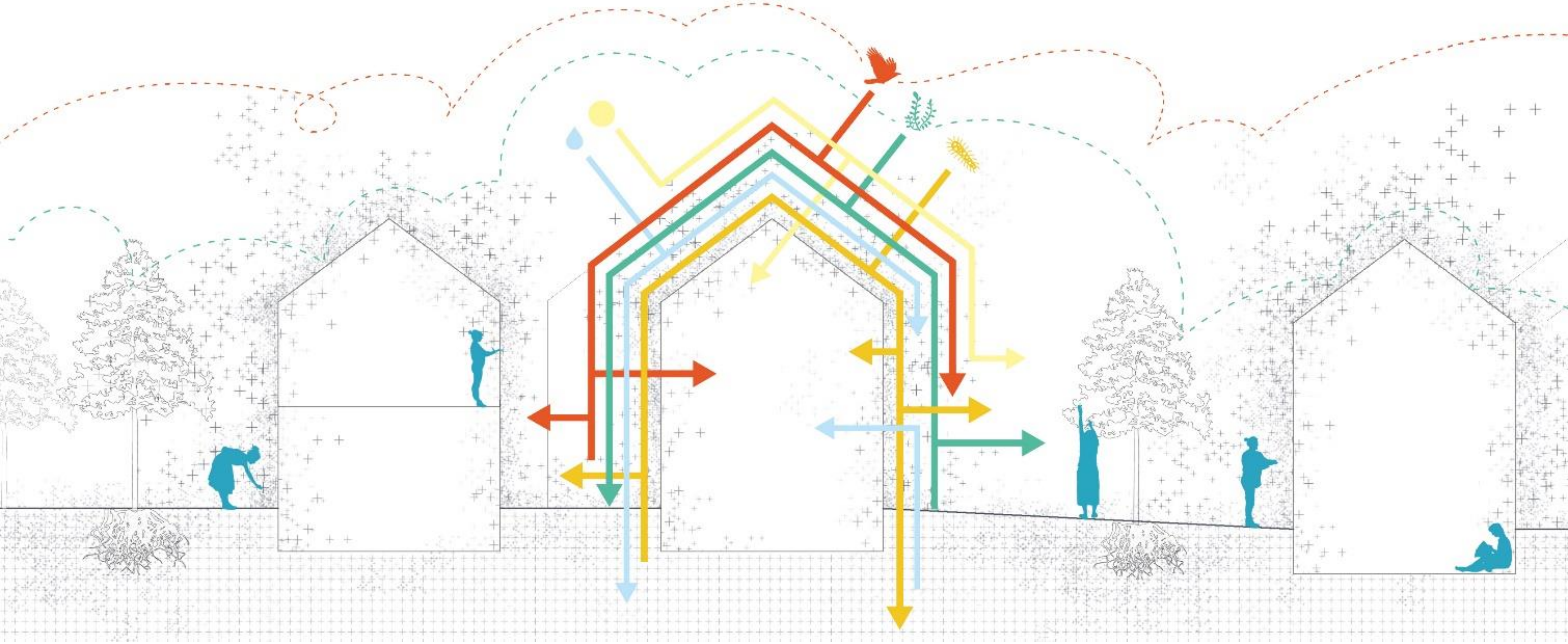

Maria Canepa, Francesca Mosca, Shany Barath, Alexandre Changenet, Thomas E. Hauck, Ferdinand Ludwig, Marta Pianta, Enrica Roccotiello, Surayyn Uthaya Selvan, Verena Vogler, Katia Perini, 2022. ECOLOPES BEYOND GREENING. A multi-species approach for urban design. Accepted in Agathon

# Background



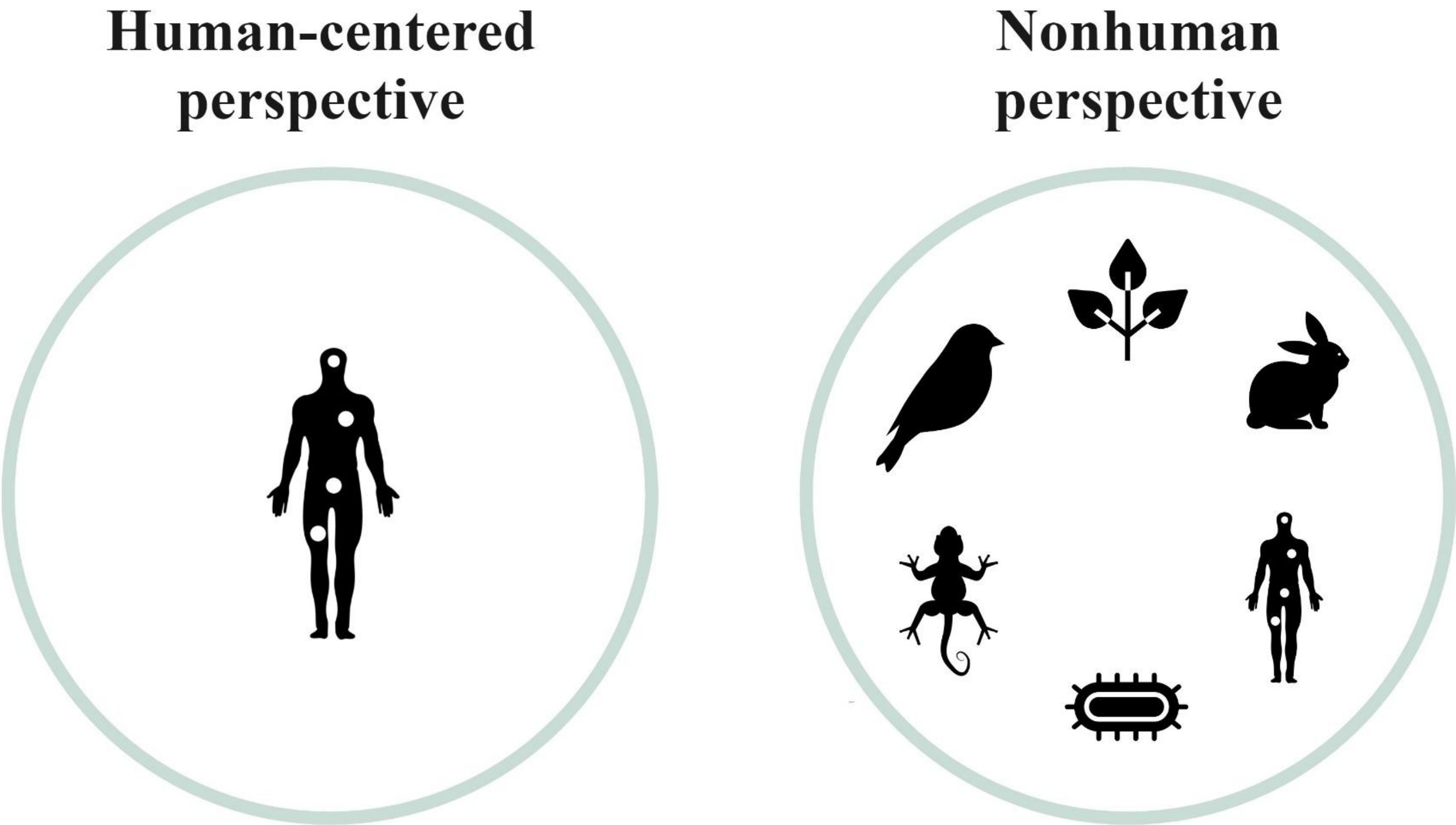

Range of ecosystem services provided by nature to humans
(WWF Living Planet Report, 2016)

## Aim of ECOLOPES



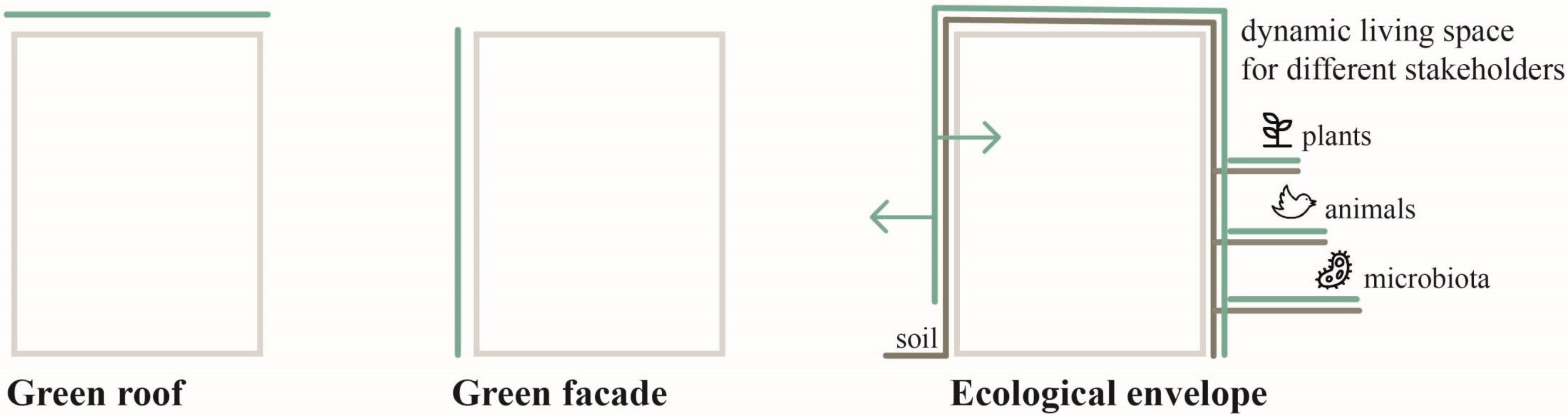
We propose a data-driven design recommendation system to assist architects and planners in the design of *ecolopes*, a multi-species living space for four types of inhabitants: humans, plants, animals, and microbiota

# Aim of ECOLOPES




Maria Canepa, Francesca Mosca, Shany Barath, Alexandre Changenet, Thomas E. Hauck, Ferdinand Ludwig, Marta Pianta, Enrica Roccotiello, Surayyn Uthaya Selvan, Verena Vogler, Katia Perini, 2022. ECOLOPES BEYOND GREENING. A multi-species approach for urban design. Accepted in Agathon

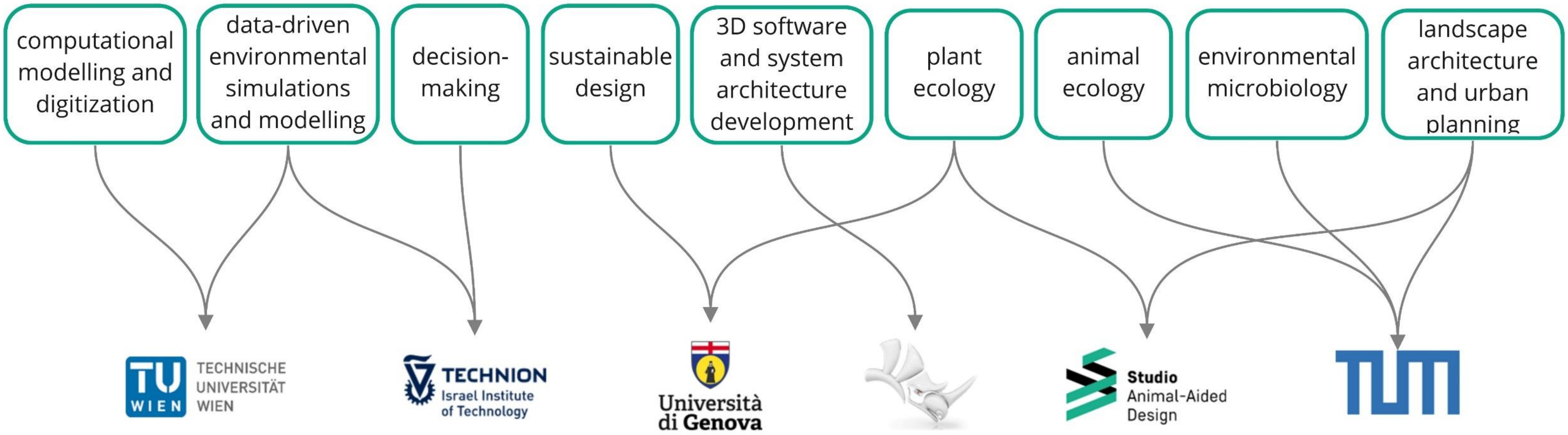
# Aim of ECOLOPES




Maria Canepa, Francesca Mosca, Shany Barath, Alexandre Changenet, Thomas E. Hauck, Ferdinand Ludwig, Marta Pianta, Enrica Roccotiello, Surayyn Uthaya Selvan, Verena Vogler, Katia Perini, 2022. ECOLOPES BEYOND GREENING. A multi-species approach for urban design. Accepted in Agathon

## Consortium and expertise

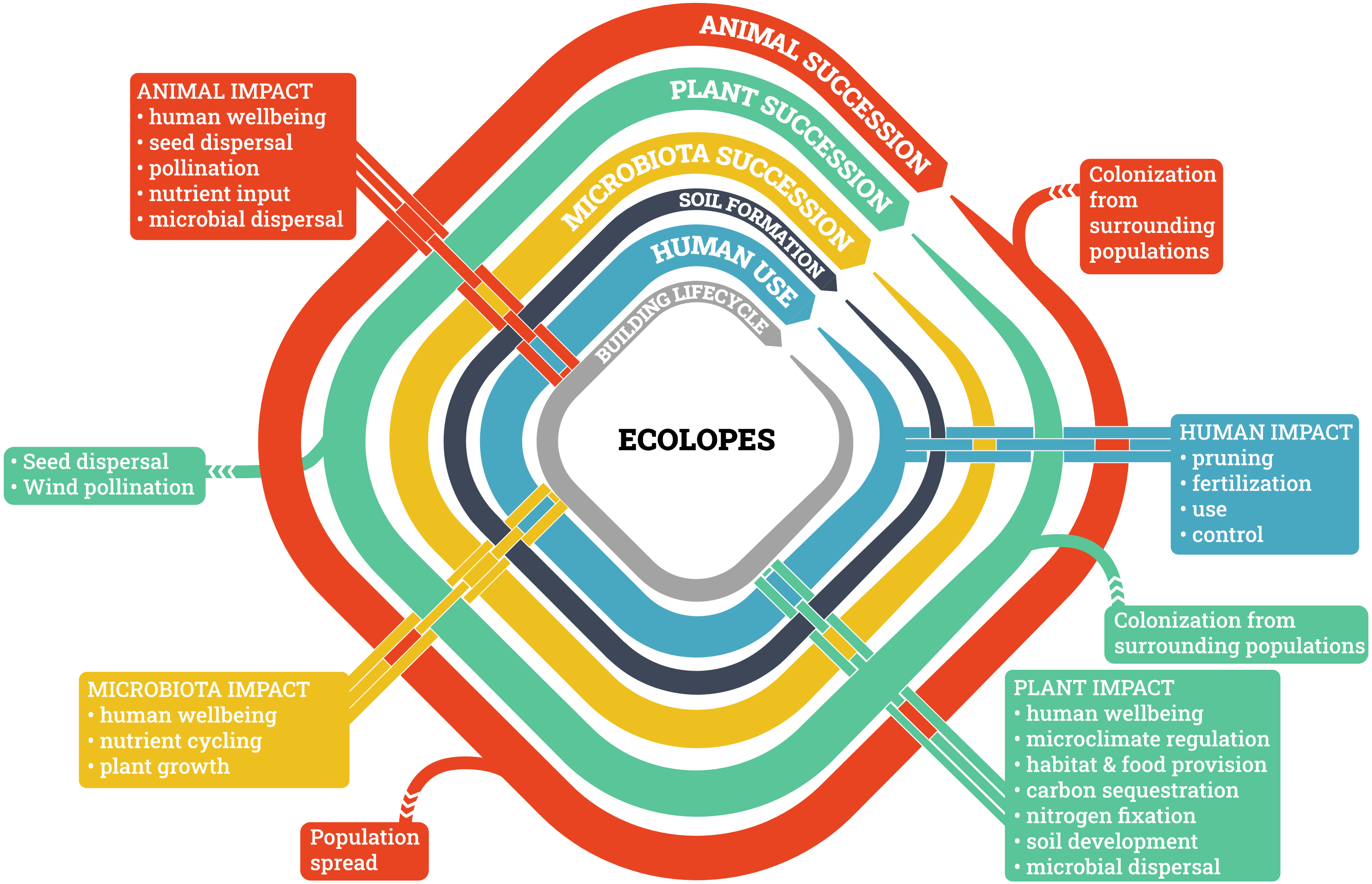
PE: interactions between biotic and abiotic components;
LS: identification and modelling of the interactions;
SH: requirements of a building envelope and perception of novel designs.






Katia Perini, UNIGE

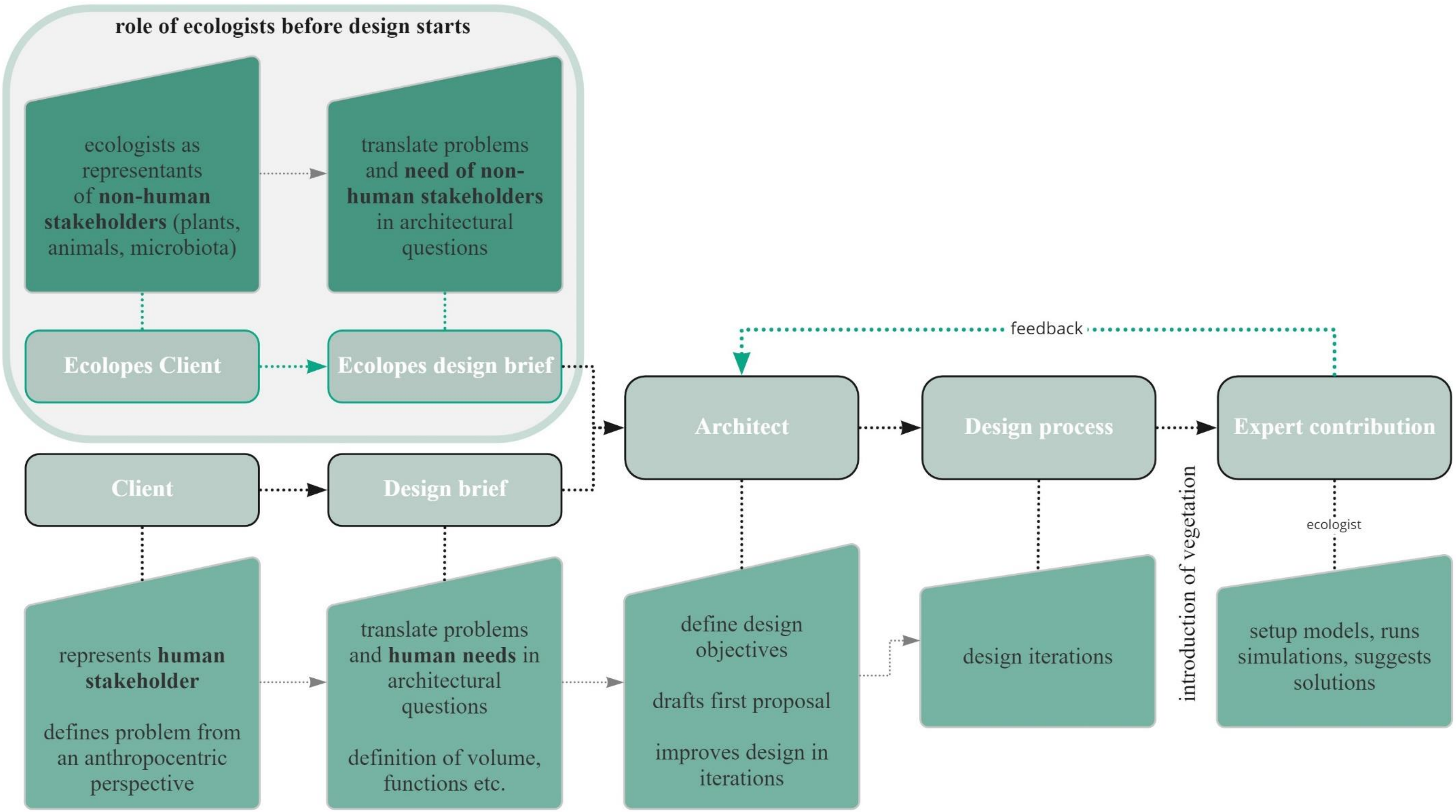
# ECOLOPES dimensions





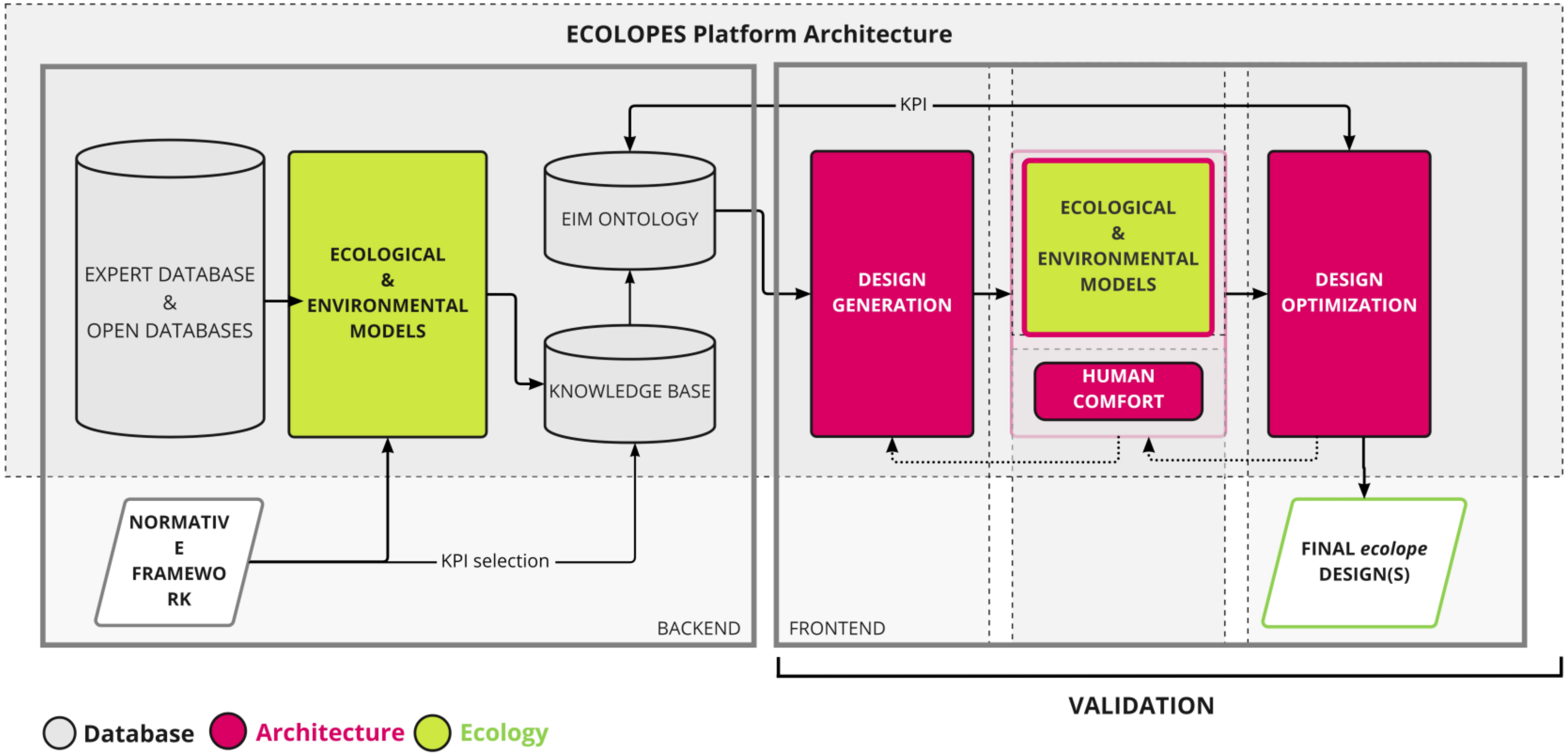

Katia Perini, UNIGE

# ECOLOPES design workflow



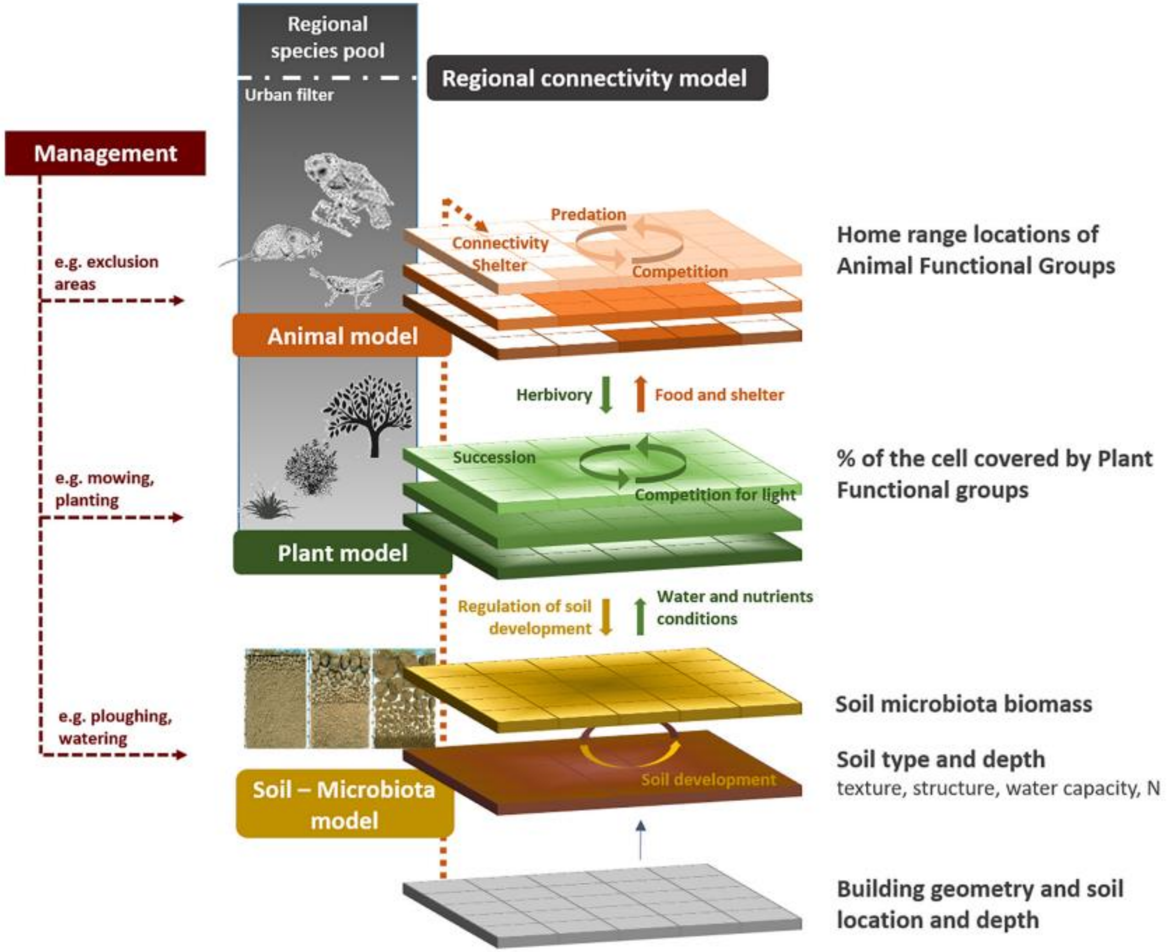

Maria Canepa, Francesca Mosca, Shany Barath, Alexandre Changenet, Thomas E. Hauck, Ferdinand Ludwig, Marta Pianta, Enrica Roccotiello, Surayyn Uthaya Selvan, Verena Vogler, Katia Perini, 2022. ECOLOPES BEYOND GREENING. A multi-species approach for urban design. Accepted in Agathon

# ECOLOPES computational framework




Weisser et al., 2023. Creating ecologically sound buildings by integrating ecology, architecture and computational design. People Nat. 5, 4–20. https://doi.org/10.1002/pan3.10411

# Integration of environmental and ecological models

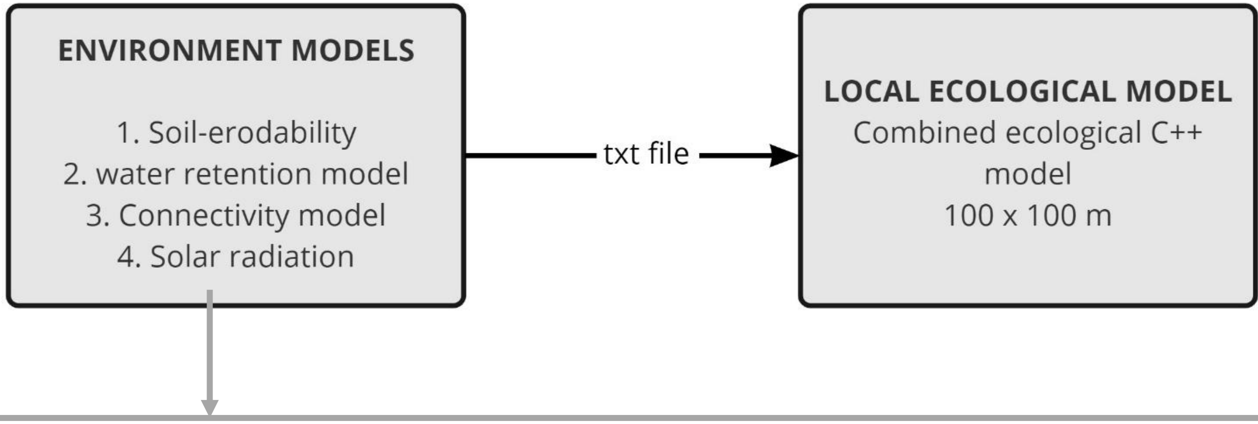


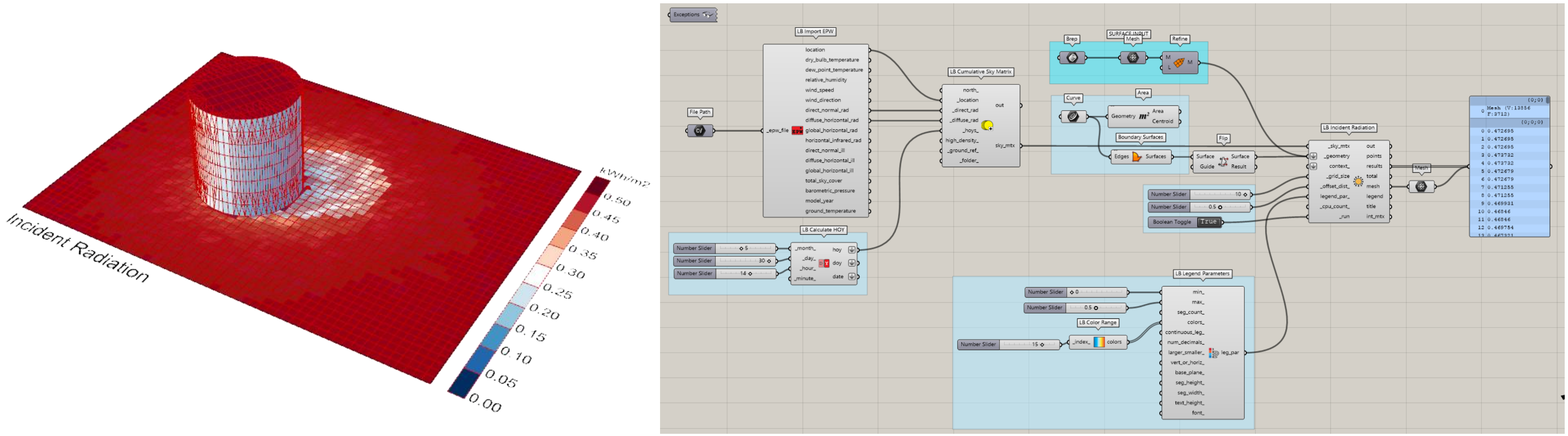

ECOLOPES ecosystem model includes a number of models and elements

Weisser et al., 2023. Creating ecologically sound buildings by integrating ecology, architecture and computational design. People Nat. 5, 4–20. https://doi.org/10.1002/pan3.10411

# Integration of environmental and ecological models

Environmental model outputs are
Used as input for local ecological
Models, in order to start combining
Building form and orientation with
Ecological performances:




Francesca Mosca, 2022: Solar radiation model setup with Ladybug (GH, Rhino 3D) – outputs from the model are input for the Plant FG model (shading effects of the building on plants).

## Work-in-progress: Evaluation of ECOLOPES design outcomes multifunctionality

x n

**MUNICH**

x n

**GENOA**

x n

**VIENNA**

x n

**TEL AVIV**

Analysis of trade-offs and synergies among the inhabitants

Overall validation of ECOLOPE with a cost-benefit approach

Identification of indicators of success for real-world realizations of buildings designed using our algorithms

Thank you!

European Commission

Horizon 2020
European Union funding
for Research & Innovation

ECOLOPES - ECOlogical building enveLOPES: a game-changing design approach for regenerative urban ecosystems

H2020 FET OPEN - 2021-2015

# *Closing the Water Cycle at the Building Scale: The Contribution of Multifunctional Envelopes*

Maria Beatrice Andreucci
Department of Planning, Design, Technology of Architecture, Sapienza University of Rome

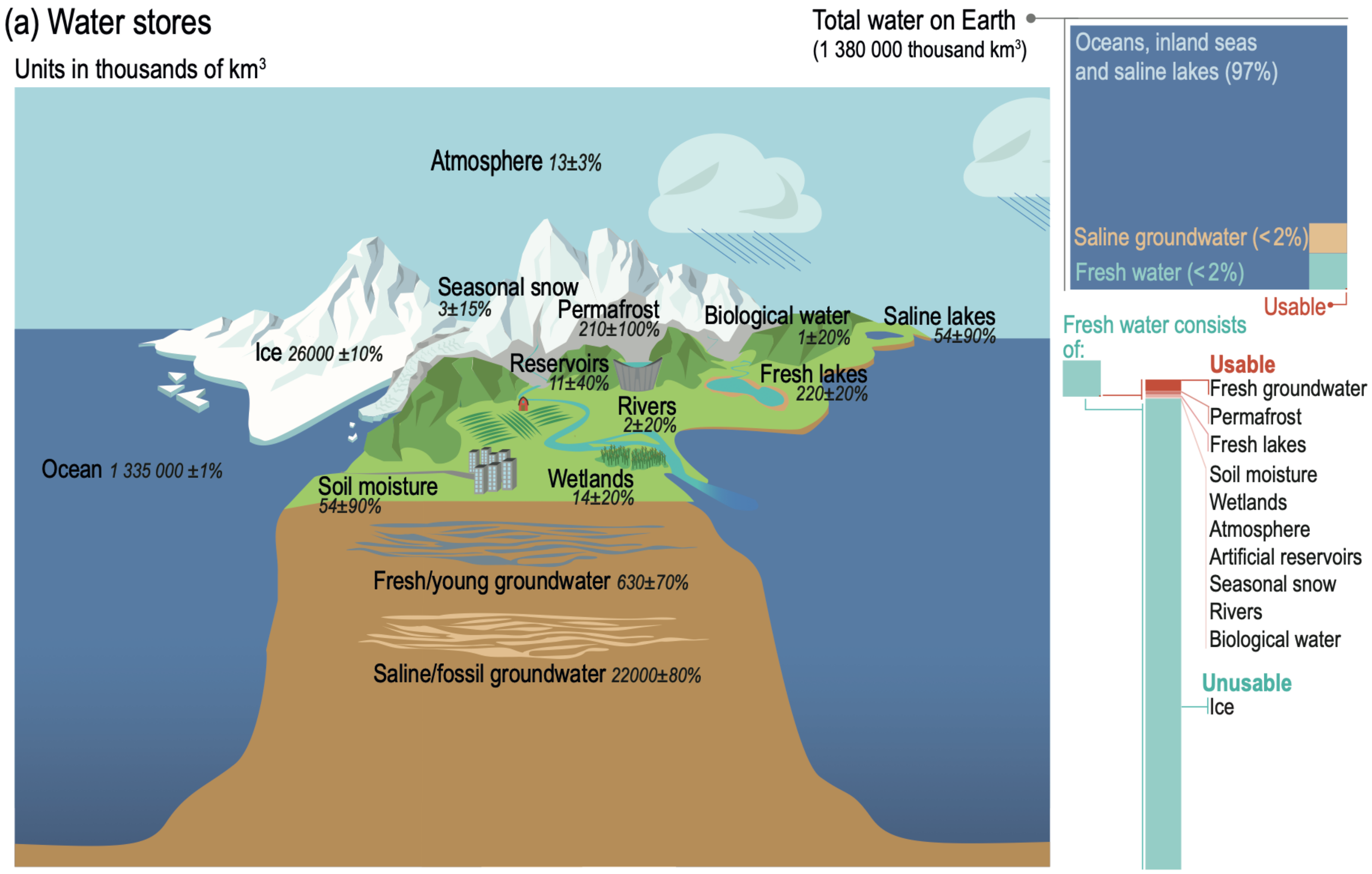
On-line Webinar
Micro-Climate Change and Envelopes
28.04.2023

Ramboll

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN Ciemat URBAN BUILD UP

# Global Water and Climate Change

- Human pressure on freshwater resources is increasing, as is human exposure to weather-related extremes (droughts, storms, floods) caused by climate change.




IPCC 2021

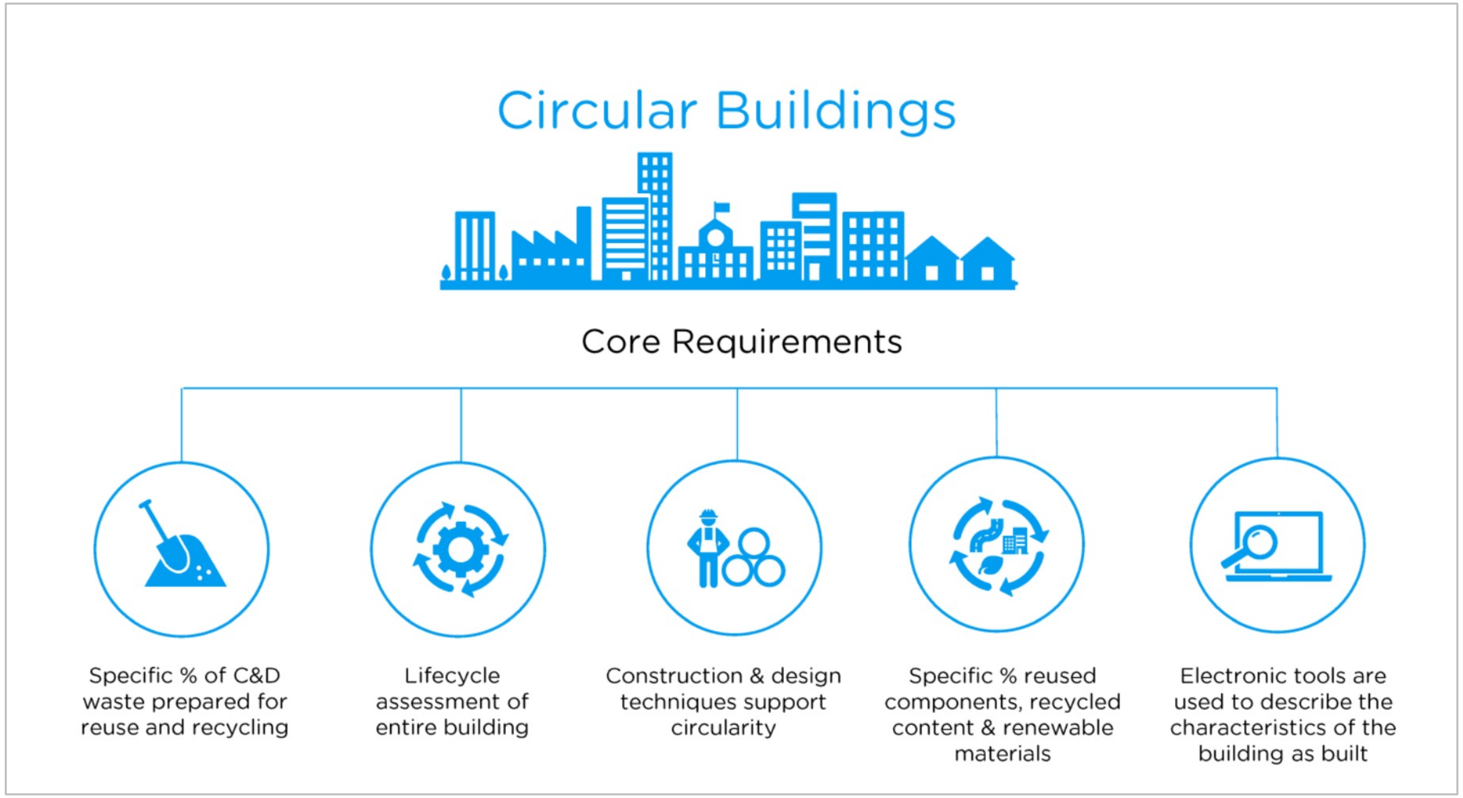
# Water issues at urban and building scale

- The restoration and maintenance of the water cycle, as well as the treatment, recovery and reuse, are among the greatest challenges of the urban built environment.

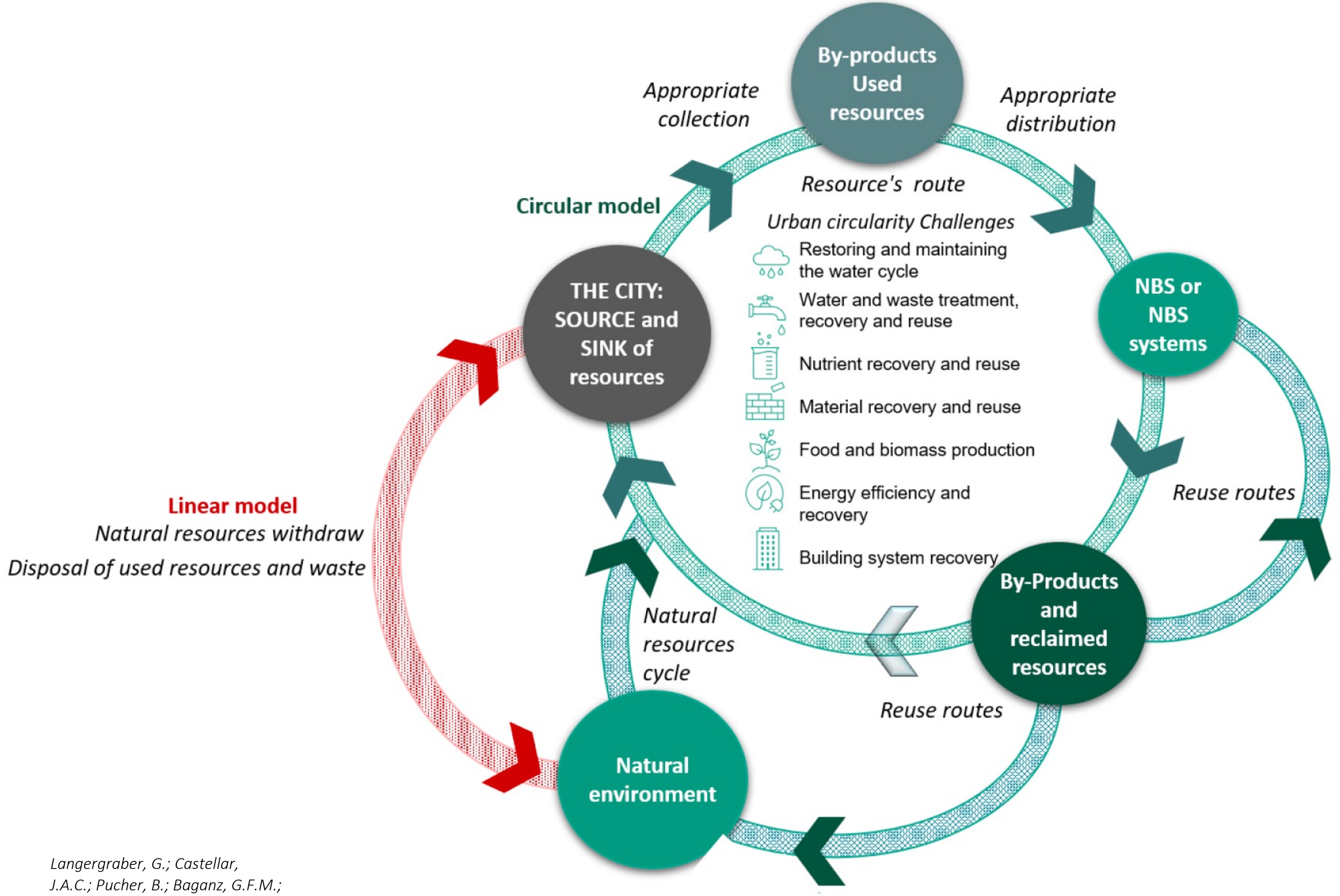
The Claude "Bud" Lewis Carlsbad Desalination Plant on the California coast provides 190 million liters of fresh water a day to San Diego. POSEIDON WATER

# Circular Buildings

- The building value chain has been experiencing in the last few years increased emphasis on the transition to a circular economy.




Ramboll




*Langergraber, G.; Castellar, J.A.C.; Pucher, B.; Baganz, G.F.M.; Milosevic, D.; Andreucci, M.-B. et al., 2021*

# NbS to address urban circularity challenges

- With the introduction of the *circular economy* and *circular city* concepts and the definition of urban circularity challenges, NBSs are emerging as effective strategies to foster sustainable urban development and resource reuse strategies.

# *Nature-Based Solutions for Greywater Treatment at the Building Scale*

# The Contribution of Green Multifunctional Envelopes: Simulation Case study

Vesterbro district, Copenaghen, Denmark. Ph Daves Rossell

Pombaline buildings, Lisbon,  Portugal. Ph Kyle Magnuson

Kadıköy district, Istambul, Turkey. Ph Andra Moclinda-Bucuţa

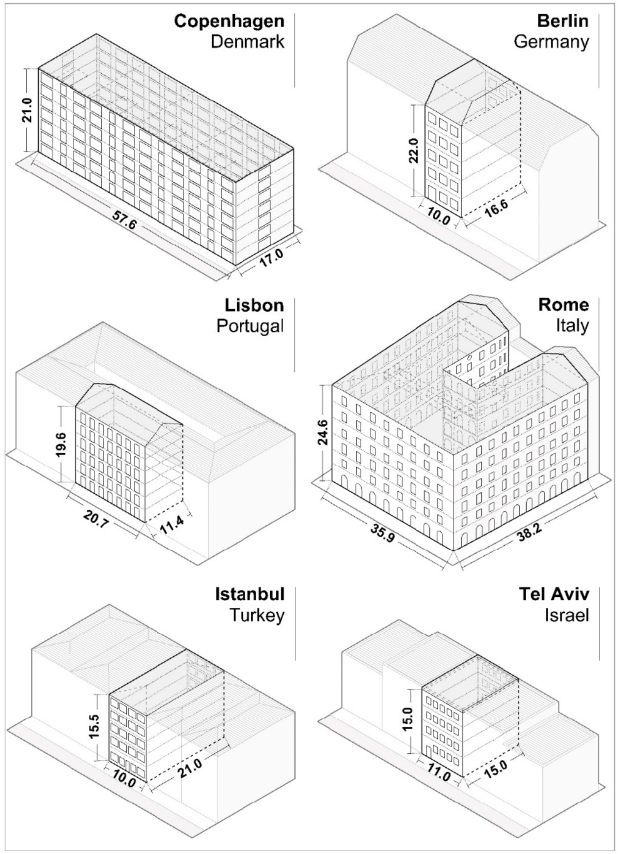
Esquilino district, Rome, Italy. Ph Antonio Bevilacqua

Typical Wilhelmine Ring residential building, Berlin, Germany. CC BY-SA 3.0

Florentin district, Tel Aviv, Israel CC BY-SA 3.0.

Pearlmutter, D. et al. Closing Water Cycles in the Built Environment through Nature-Based Solutions: The Contribution of Vertical Greening Systems and Green Roofs. *Water* 2021, 13, 2165.

# The Contribution of Green Multifunctional Envelopes: Simulation Case study




Selection of buildings representing typical architecture in neighbourhoods that are severely affected by UHIs in individual cities. The drawings are isometric. Illustration: Alessandro Stracqualursi.

photography by Garry Belinsky

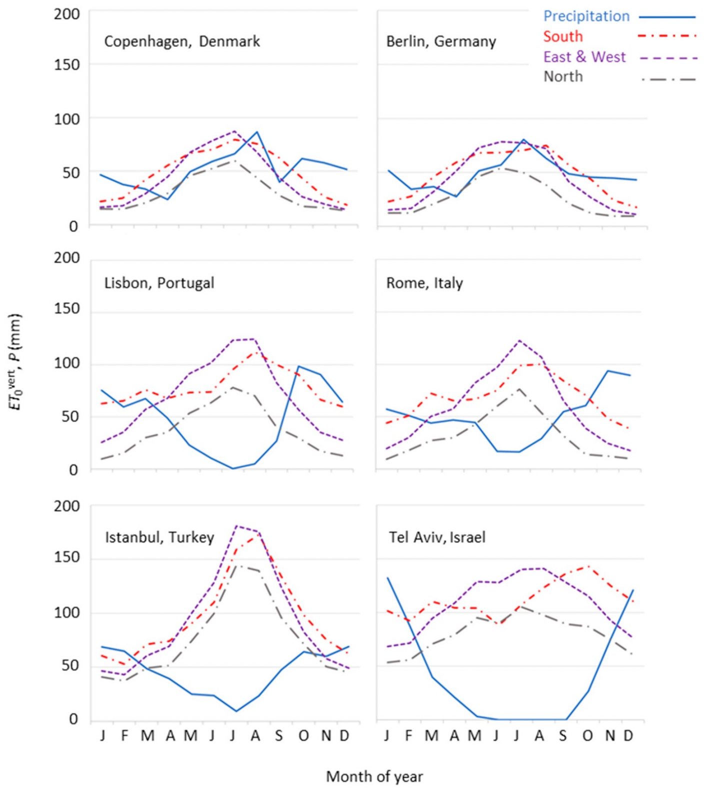
**Table 1.** Parameters describing the climatic, architectural, and hydrological characteristics of the case studies. The presented data included precipitation (P), temperature (T), evapotranspiration (ET), greywater (GW) production per inhabitant, occupancy (O) and run-off (RO) generation.

| City | Climate [2] | | | | | Typical Building | | | | | Water Availability | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class [1] | *P* | *T* | *P-ET* Oct-Mar | Apr-Sep | Ground | Facade | Window | v/h | *O* | *GW* Capita | *GW* Facade | *RO* Facade |
| | | mm/a | °C | mm | | m² | | | (-) | inh/m² | L/inh d | L/m² d | |
| Copenhagen | Dfb | 614 | 9.4 | 151 | −206 | 980 | 3206 | 1408 | 3.27 | 0.044 | 51 | 0.69 | 0.37 |
| Berlin | Dfb | 585 | 10.3 | 118 | −238 | 166 | 440 | 132 | 2.65 | 0.065 | 63 | 1.54 | 0.43 |
| Rome | Csa | 605 | 17.8 | 135 | −644 | 1302 | 3996 | 813 | 3.07 | 0.029 | 90 | 0.85 | 0.41 |
| Lisbon | Csa | 571 | 17.4 | 126 | −791 | 237 | 407 | 142 | 1.72 | 0.021 | 81 | 0.99 | 0.71 |
| Istanbul | Csa | 546 | 16.0 | −18 | −840 | 231 | 310 | 132 | 1.34 | 0.170 | 58 | 7.35 | 0.82 |
| Tel-Aviv | Csa | 506 | 21.5 | −171 | −1090 | 165 | 330 | 66 | 2.00 | 0.040 | 58 | 1.16 | 0.57 |

[1] acc. to Köppen-Geiger, [2] acc. to Meteonorm 8, Meteotest Bern, Switzerland 2000–2019.


Pearlmutter, D. et al. Closing Water Cycles in the Built Environment through Nature-Based Solutions: The Contribution of Vertical Greening Systems and Green Roofs. *Water* 2021, 13, 2165.

# The Contribution of Green Multifunctional Envelopes: Simulation Case study




Long-time average standard evapotranspiration for vertical greening systems for the different cities together with precipitation (Meteonorm, 2021; years 2005-2019).

**$e_{RO}$**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Berlin | 1.2 | 2.2 | 3.6 | 7.7 | 4.7 | 4.4 | 2.9 | 3.5 | 3.0 | 2.1 | 1.3 | 1.2 |
| Copenhagen | 1.8 | 2.3 | 4.5 | 10.3 | 5.7 | 5.0 | 5.2 | 3.1 | 5.3 | 2.0 | 1.6 | 1.4 |
| Istanbul | 1.3 | 1.3 | 2.4 | 3.2 | 6.9 | 8.8 | 39.2 | 11.9 | 4.1 | 2.2 | 1.8 | 1.4 |
| Rome | 1.7 | 2.6 | 5.1 | 4.8 | 6.2 | 23.7 | 25.4 | 11.8 | 4.3 | 2.6 | 1.1 | 0.9 |
| Lisbon | 0.9 | 1.4 | 1.8 | 2.8 | 8.3 | 18.0 | nd | 51.1 | 6.3 | 1.3 | 0.9 | 1.1 |
| Tel Aviv | 1.3 | 2.0 | 5.9 | 11.9 | 121.3 | nd | nd | nd | nd | 10.8 | 3.0 | 1.6 |

**$e_{GW}$**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Istanbul | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.6 | 0.8 | 0.7 | 0.6 | 0.4 | 0.3 | 0.2 |
| Berlin | 0.4 | 0.4 | 0.7 | 1.1 | 1.4 | 1.6 | 1.5 | 1.4 | 0.9 | 0.6 | 0.3 | 0.3 |
| Copenhagen | 0.8 | 1.0 | 1.5 | 2.2 | 3.0 | 3.4 | 3.8 | 3.1 | 2.2 | 1.4 | 1.0 | 0.7 |
| Lisbon | 1.0 | 1.4 | 1.9 | 2.1 | 2.6 | 3.0 | 3.6 | 3.6 | 2.6 | 2.0 | 1.3 | 1.1 |
| Rome | 0.9 | 1.4 | 2.0 | 2.2 | 2.7 | 3.4 | 4.2 | 3.6 | 2.5 | 1.6 | 1.1 | 0.8 |
| Tel Aviv | 2.1 | 2.3 | 2.7 | 3.0 | 3.3 | 3.2 | 3.6 | 3.6 | 3.6 | 3.3 | 2.8 | 2.3 |

Monthly values of eRO and eGW, with e being the efficiency number describing how much of the accruing respective water can be evapotranspirated by VGS, calculated here as the ratio of monthly sums of ET0vert and the respective water resource (**left**: available rainwater runoff from the roof RO; **right**, greywater accruing in the building GW) for the different cities (applying long-term average for meteorological parameters 2005-2019; Meteonorm 8, Meteotest Bern, Switzerland.

| City | Water Management Potential | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (a) Solely RO Irrigation | | (b) Optimized RO Irrigation | | | (c) Full RO + GW Irrigation | | |
| | Facade Greened | Evaporated RO | Facade Greened | Evaporated RO | Evaporated GW | Facade Greened | Evaporated RO | Evaporated GW |
| | % | | % | | | % | | |
| Copenhagen | 10 | 35 | 26 | 79 | 11 | 46 | 92 | 41 |
| Berlin | 13 | 39 | 64 | 95 | 29 | 87 | 100 | 47 |
| Rome | 4 | 17 | 24 | 64 | 21 | 28 | 67 | 27 |
| Lisbon | - | - | 28 | 44 | 28 | 28 | 44 | 28 |
| Istanbul | 3 | 9 | 100 | 100 | 30 | 136 | 100 | 45 |
| Tel-Aviv | - | - | 28 | 60 | 53 | 28 | 60 | 53 |

Water management potential for 3 different irrigation regimes: a) solely RO; b) RO prioritised but dry months outbalanced with GW; c) Ro irrigation prioritised but all months added with GW.

Pearlmutter, D. et al. Closing Water Cycles in the Built Environment through Nature-Based Solutions: The Contribution of Vertical Greening Systems and Green Roofs. *Water* 2021, 13, 2165.


EPA/Sunling China Out

# Closing the Water Cycle at the Building Scale: Challenges & Opportunities

- Structural Issues
- Ecosystem (Dis)Services
- Future-Proof NBS
- Policy Framework

# *Acknowledgments*

This research work was carried out within the **COST Action CA17133 Circular City** "Implementing nature-based solutions for creating a resourceful circular city", https://circular-city.eu, duration 22 October 2018–21 April 2023.

COST Actions are funded within EU Horizon Programmes.

The authors are grateful for the support.


Circular City
circular-city.eu

# Envelope , Microclimate, Energy

Emanuele Naboni, PhD, Associate Professor

- UNIPR, Architecture
- Institute of Architectural Technology, The Royal Danish Academy
- UNSW
- UC Berkeley
- SOS School of Sustainability of MCA, Milan

# Present Positions

Environmental Sustainability Module - **SOS School of Sustainability** - with Mario Cucinella
Since 2021

Associate Professor of Sustainable Design. Institute of Architectural Technology
**The Royal Danish Academy**. Since 2010 (half time since 2022)

Associate Professor of Climate Change and Regenerative Architecture. **UNIPR**
Since 2021

Adjunct Professor, **University of New South Wales**
March 2023 to October

Visiting Professor, Architectural and science researcher at **CBE UC Berkeley**, College Of Environmental Design
Since 2023

# Past Position

Visiting Professor, **Norwegian University of Science and Technology**, Department of Civil and Environmental Engineering. Faculty of Engineering
2022

Invited Professor at **ETH**. Future Cities Lab Singapore
2019

Researcher at **EPFL**
2016, 2017

Invited Professor at **Architectural Association**
2013

Visiting Professor at **The University of Nottingham**
2015

Adjunkt at **UC Berkeley**, CED, College Of Environmental Design
2012

Post Doc Rsearcher at **LBNL**
2006 - 10 + 2011

Sustainable Design Tools Development Consultant for **Autodesk**
2010 – 2012

Sustainable Design Specialist at **SOM** (Skidmore Owings and Merrill, Llp)
2006 – 2010

Sustainable Design Specialist **William McDonough** and Loisos + Ubbelohde
2005

Phd Building Science, **Politecnico di Milano + University of California**
Awarded 2005

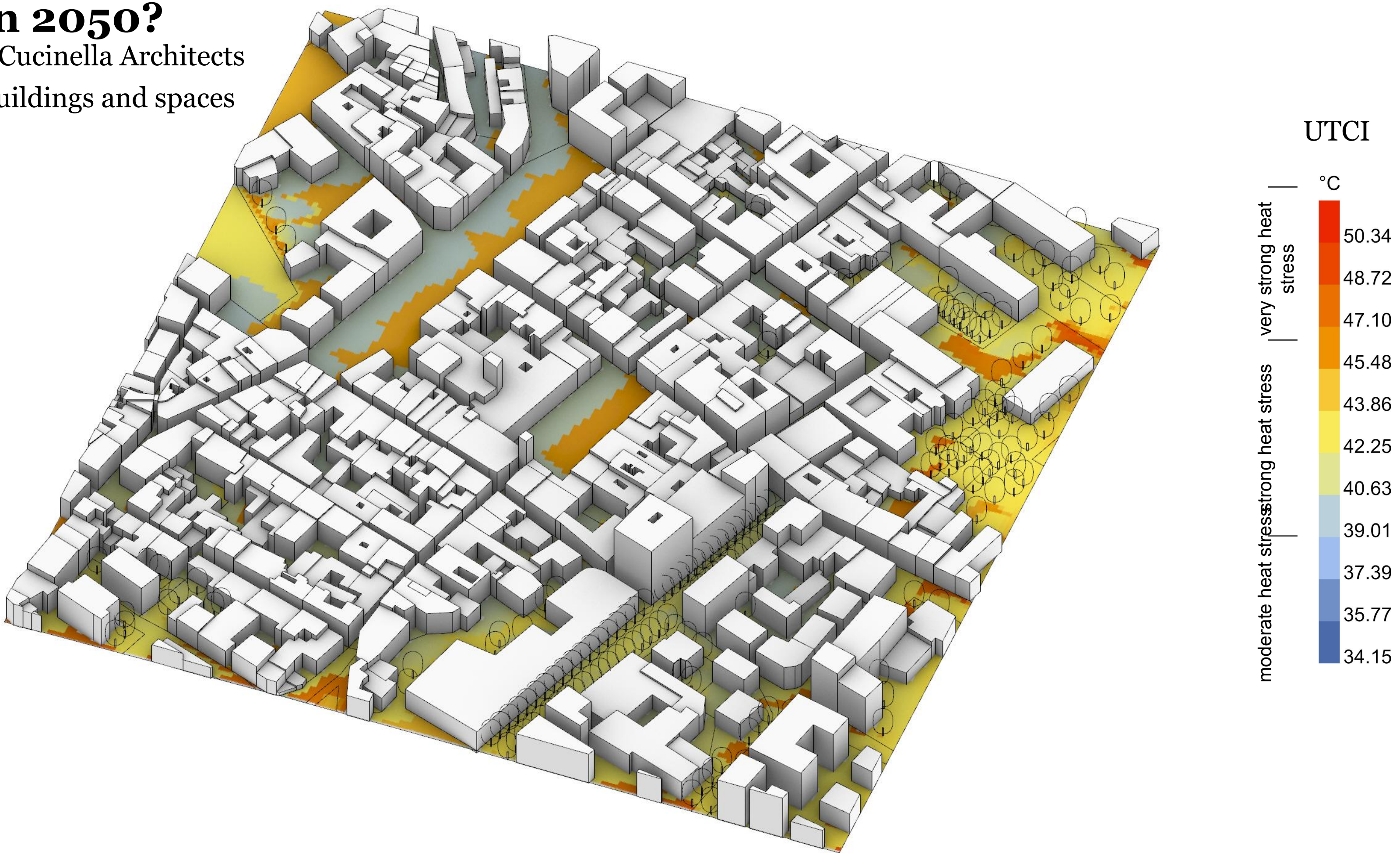
## 2023 active projects

# MESOSCALE - MICROCLIMATIC MODELLING FOR PLANNERS

*Bologna Province with Mario Cucinella Architects*
*(Naboni, Turrini, Gherri)*

# What in 2050?

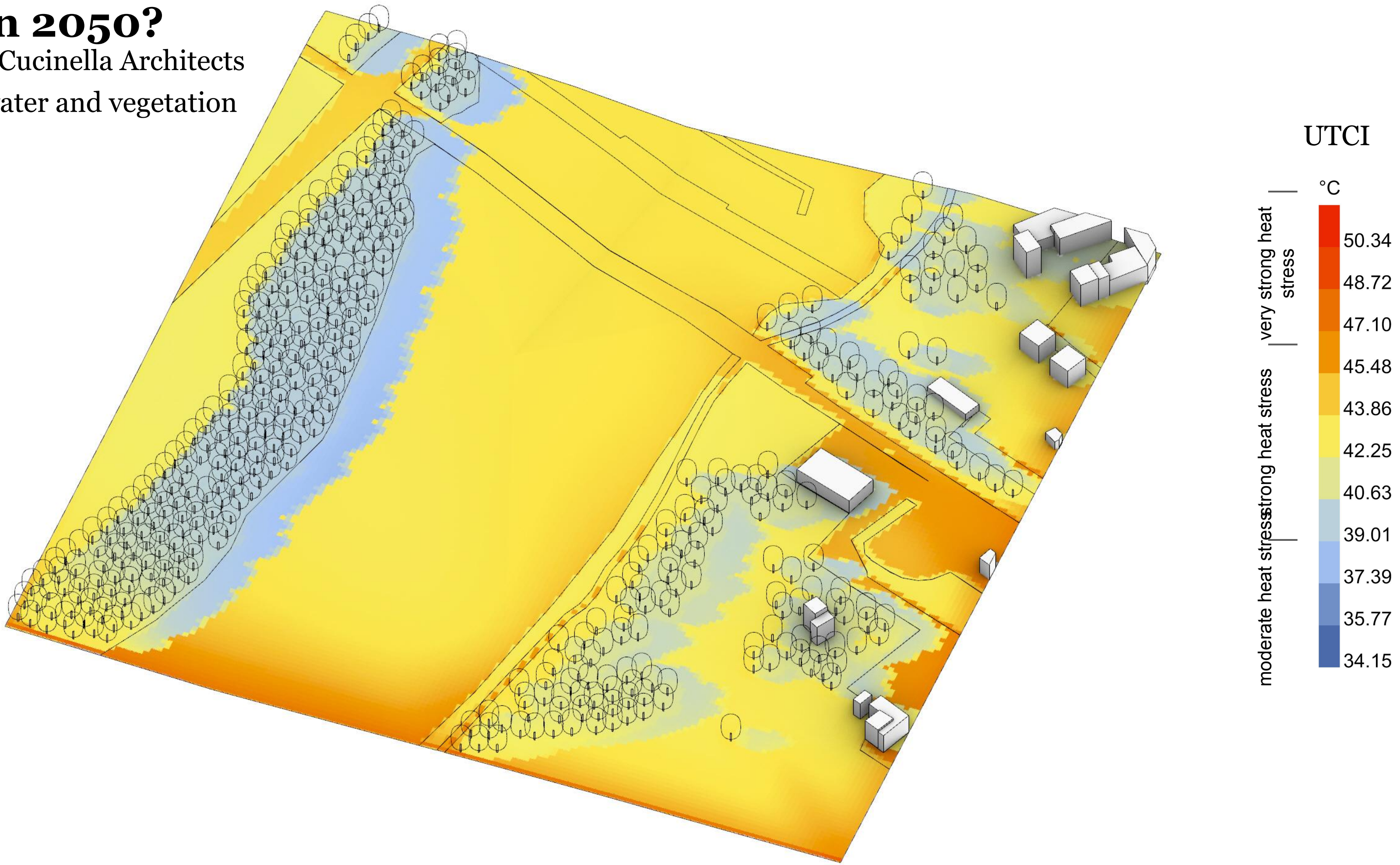
With Mario Cucinella Architects
modelling buildings and spaces

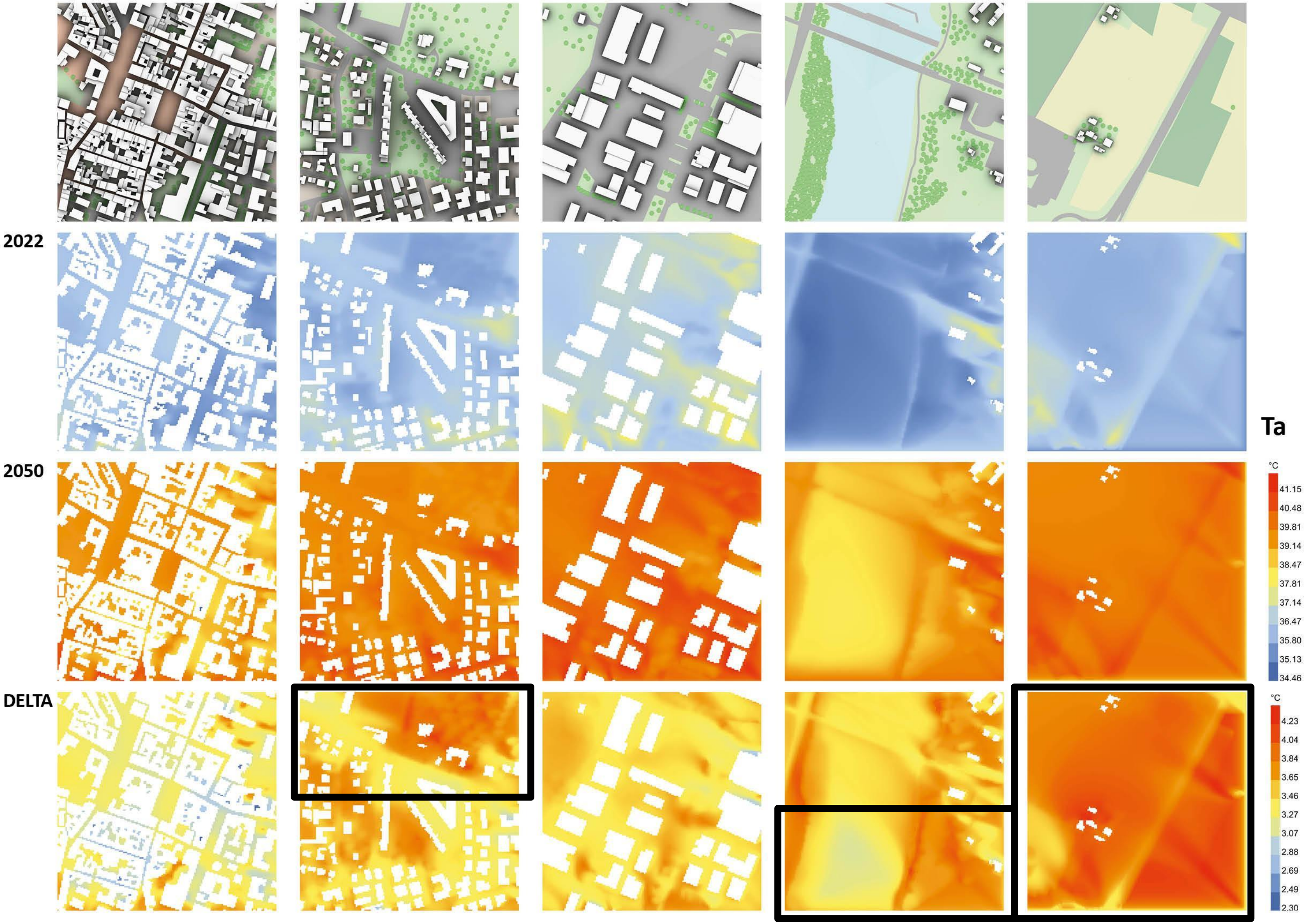


# What in 2050?

With Mario Cucinella Architects

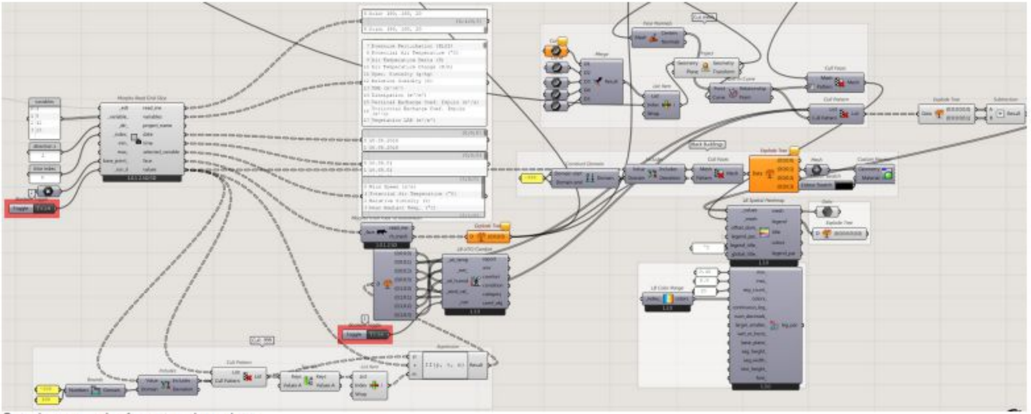
modelling water and vegetation



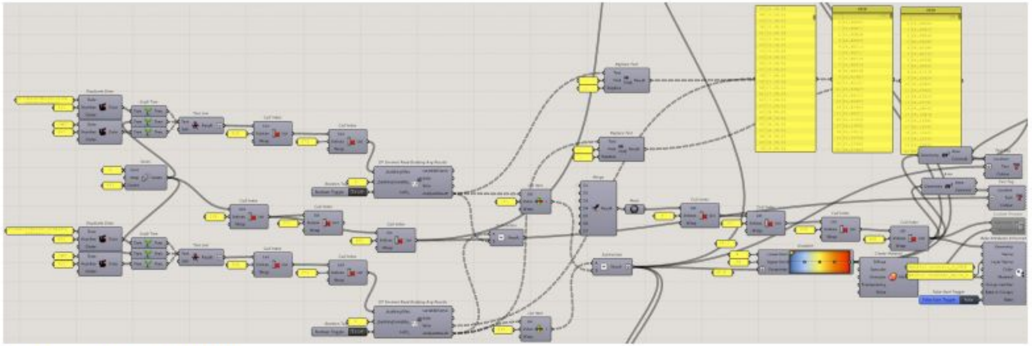

2022
2050
DELTA
Ta
°C
41.15
40.48
39.81
39.14
38.47
37.81
37.14
36.47
35.80
35.13
34.46
°C
4.23
4.04
3.84
3.65
3.46
3.27
3.07
2.88
2.69
2.49
2.30

# Parametric Modelling to join - domains

Climate Change and Eco-data. With Environmental Agencies



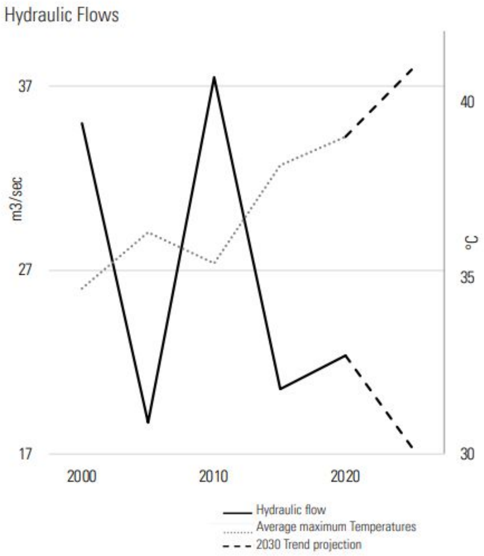
Grasshopper script for atmosphere data

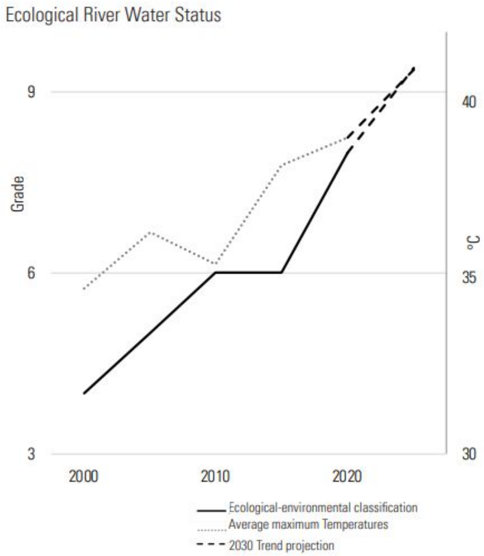


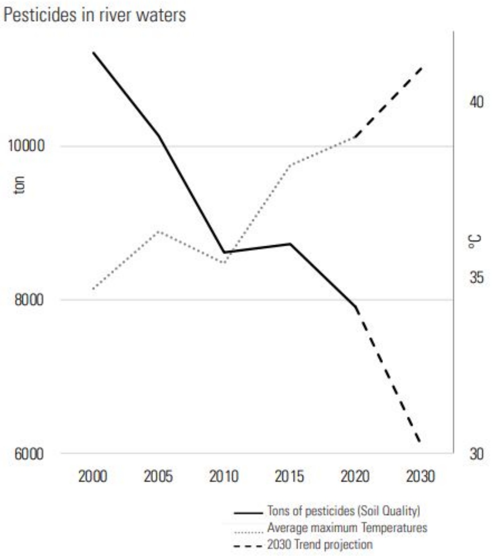
Grasshopper script for buildings data

# Water

## Parametric Modelling

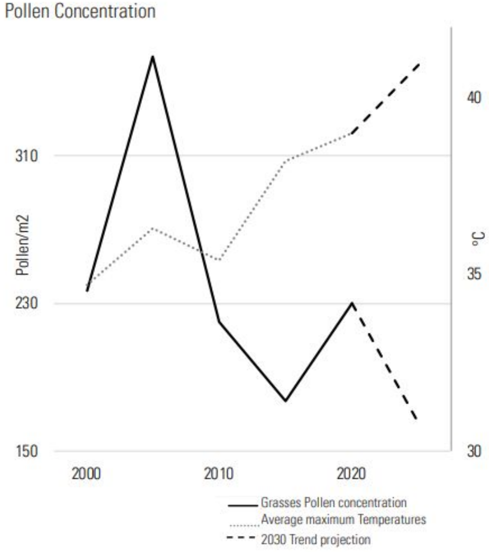


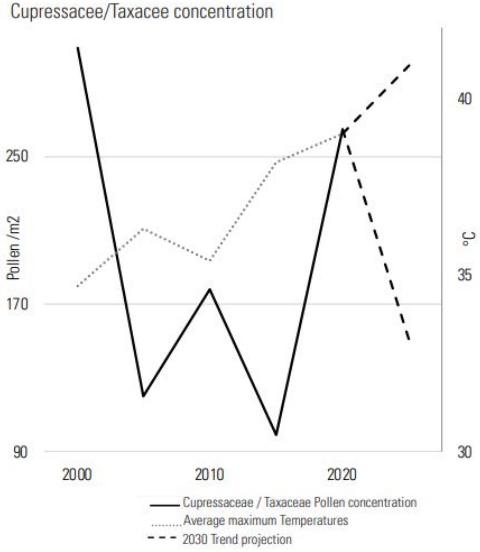



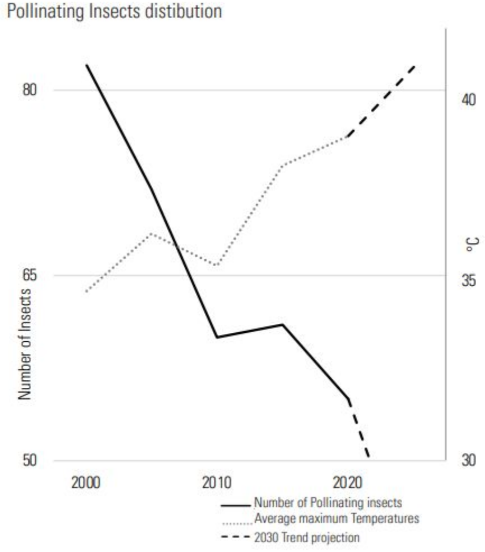



# Ecosystem Health - Pollination

Parametric Modelling

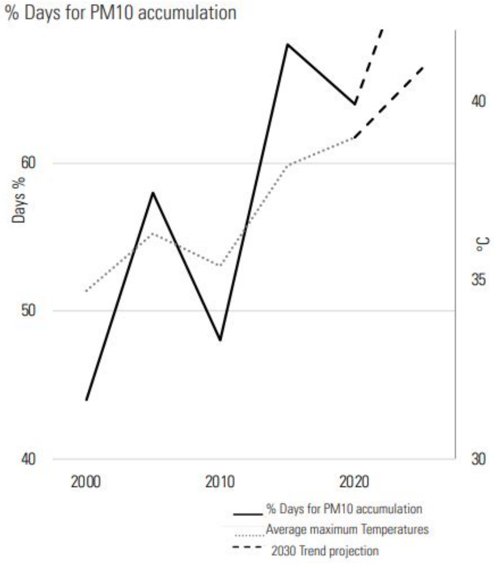


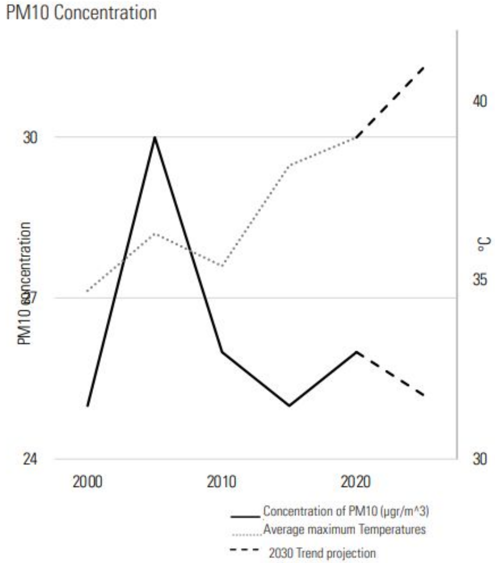



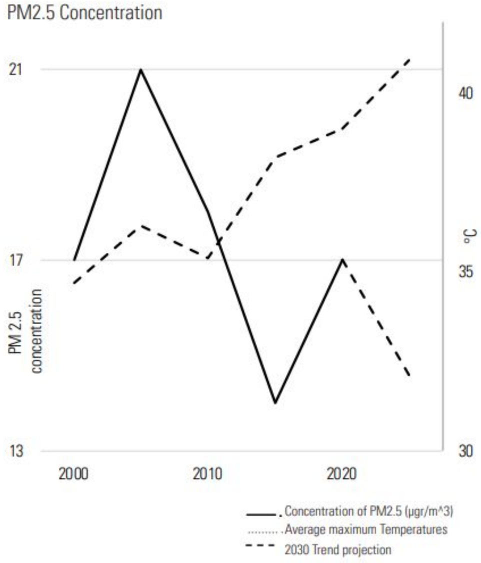



# Air Pollution

Parametric Modelling

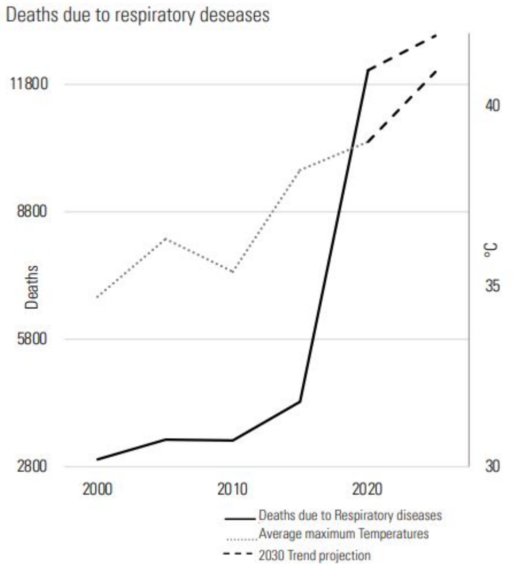


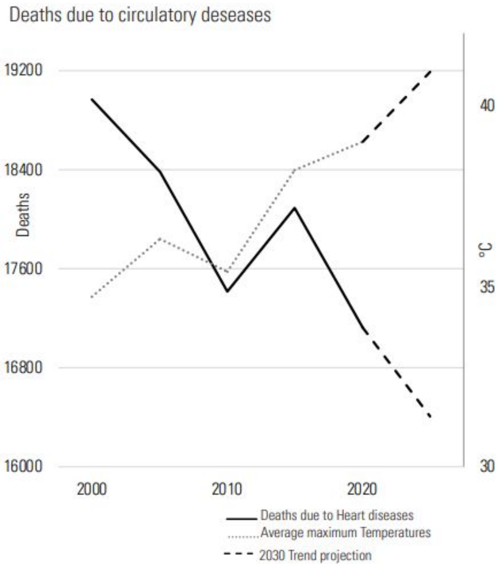



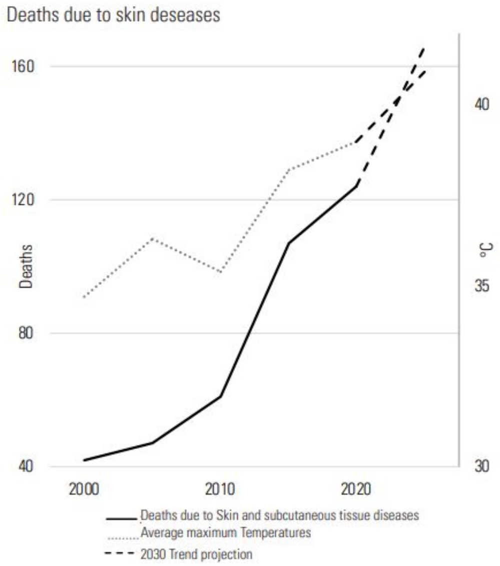



# Human Health

Parametric Modelling



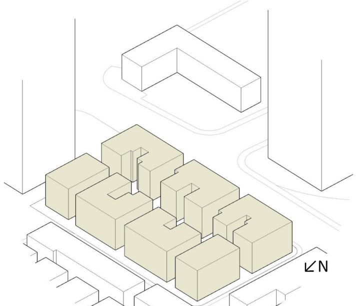
# URBAN BLOCK

Craft the block for different cities

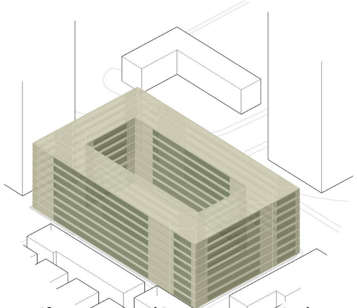
Malaga, Tallinn, **Tel Aviv**

# City of Tel Aviv

## with Johnatan Nathanian and Francesco De Luca




**Existing condition**
FAR 2.5, Residential

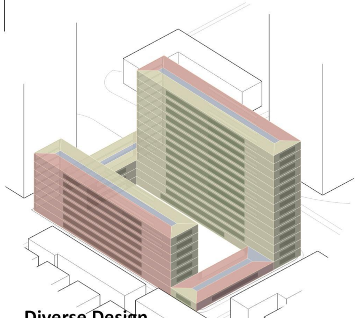


**Uniform Design (Common practice)**
FAR 5, Residential

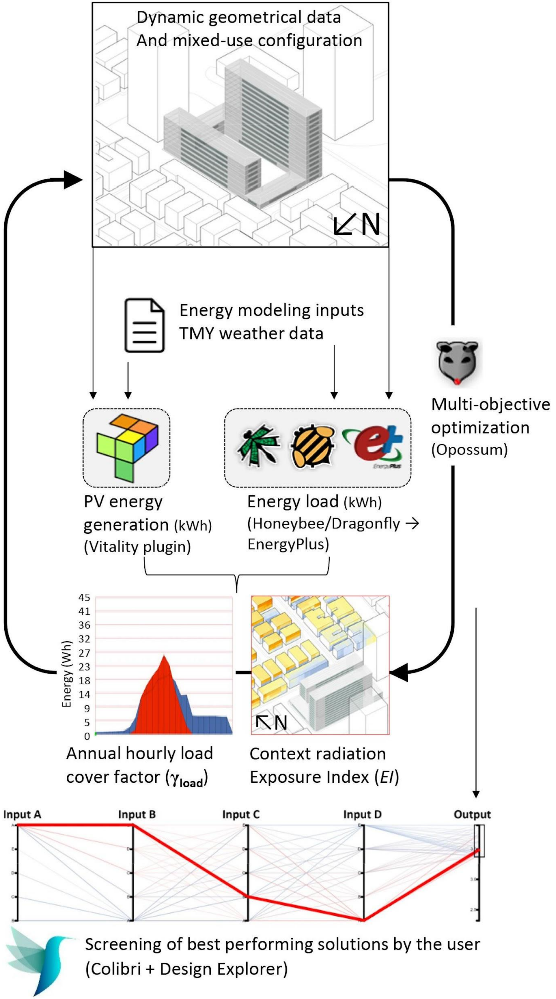
**Design-based variables for the diversity optimization study:**

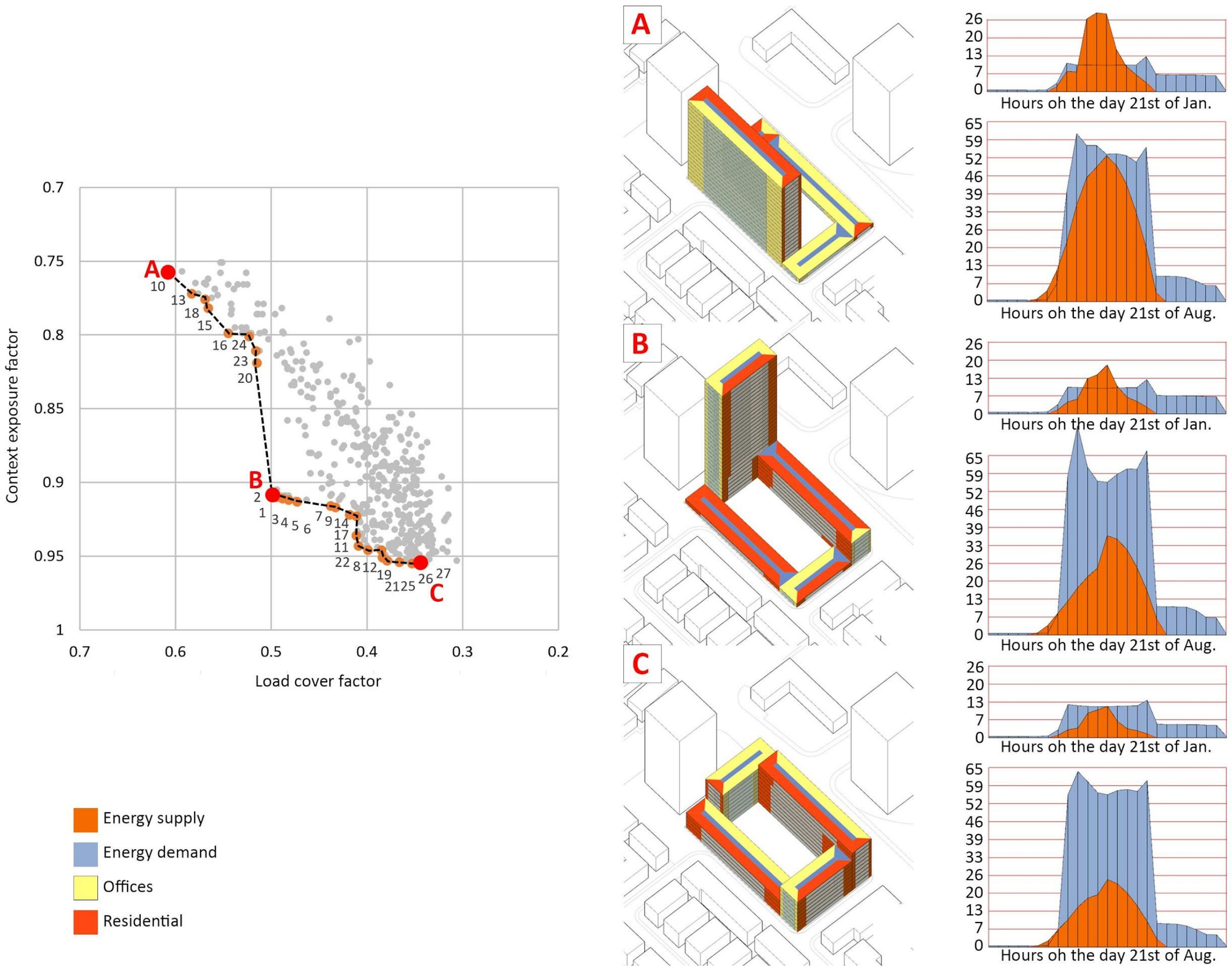
**(1) Building mass height**
Range: 4 to 100 m
Spatial boundary: for each building wing

**(2) Building use**
Range: Resifential or Office use
Spatial boundary: for each perimeter zone cluster

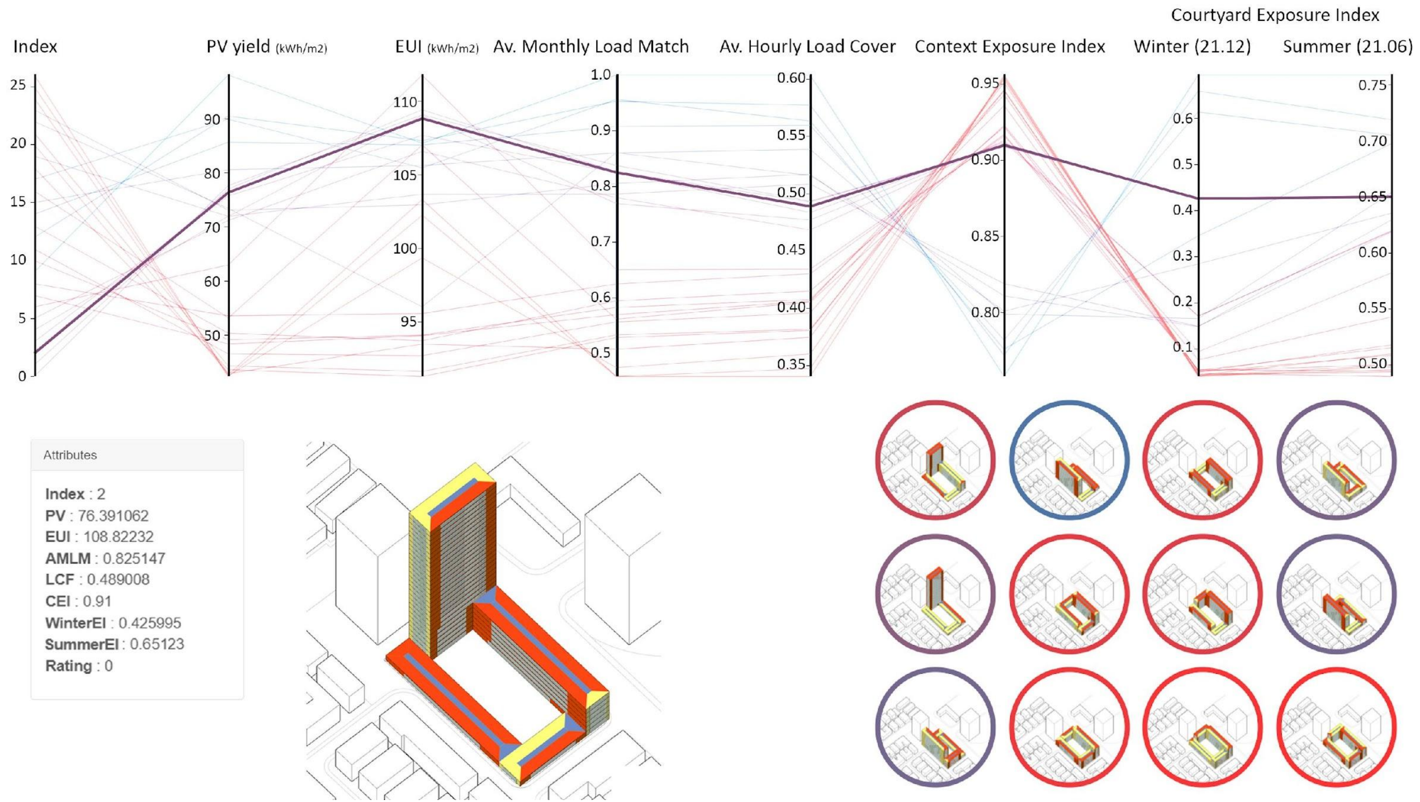


**Diverse Design**
FAR 5, Residential + Offices (in red)





Context exposure factor
Load cover factor
0.7
0.75
0.8
0.85
0.9
0.95
1
0.7 0.6 0.5 0.4 0.3 0.2
A
B
C
10 13 18 15 16 24 23 20
2 1 3 4 5 6 7 9 14 17 11 22 8 12 19 21 25 26 27
Energy supply
Energy demand
Offices
Residential
A
B
C
Hours oh the day 21st of Jan.
Hours oh the day 21st of Aug.
Hours oh the day 21st of Jan.
Hours oh the day 21st of Aug.
Hours oh the day 21st of Jan.
Hours oh the day 21st of Aug.
0 7 13 20 26
0 7 13 20 26 33 39 46 52 59 65

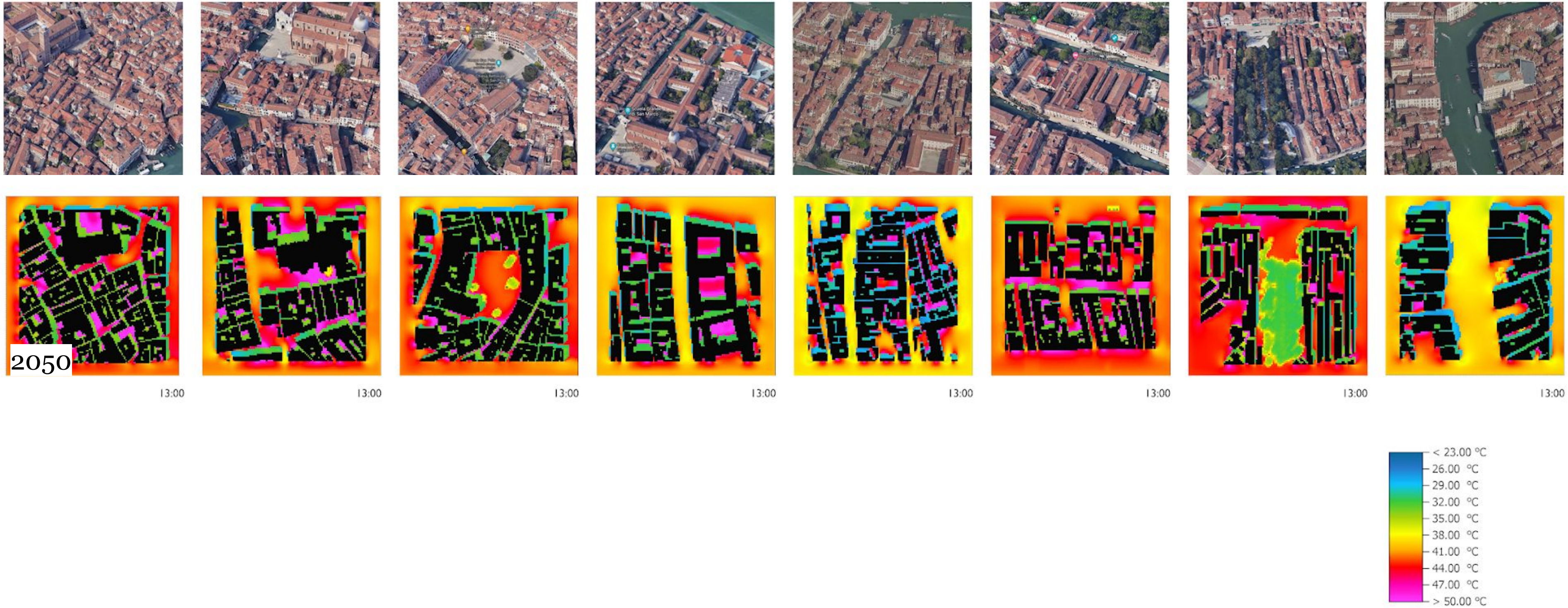

Courtyard Exposure Index
Index
PV yield (kWh/m2)
EUI (kWh/m2)
Av. Monthly Load Match
Av. Hourly Load Cover
Context Exposure Index
Winter (21.12)
Summer (21.06)
25
20
15
10
5
0
90
80
70
60
50
110
105
100
95
1.0
0.9
0.8
0.7
0.6
0.5
0.60
0.55
0.50
0.45
0.40
0.35
0.95
0.90
0.85
0.80
0.6
0.5
0.4
0.3
0.2
0.1
0.75
0.70
0.65
0.60
0.55
0.50
Attributes
Index : 2
PV : 76.391062
EUI : 108.82232
AMLM : 0.825147
LCF : 0.489008
CEI : 0.91
WinterEI : 0.425995
SummerEI : 0.65123
Rating : 0

# 4) THE HISTORICAL CITY

Understanding of Human Health and Energy flows

(With Gherri, Daniela Maiullari)

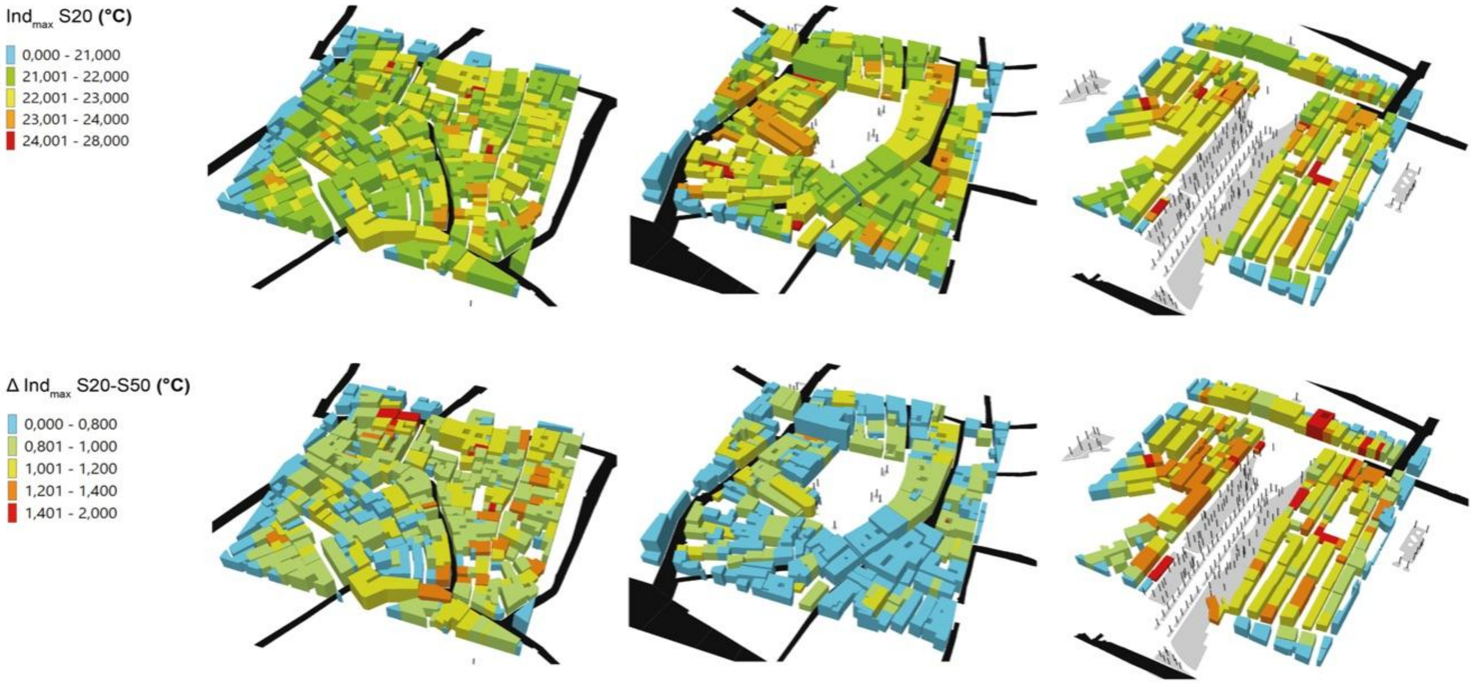
# **Venice Microclimatic Studies 2020 + 2050** (with TU Delft)
Hotter Summer Day at 13:00 (PET Studies)



# Climate Resilience

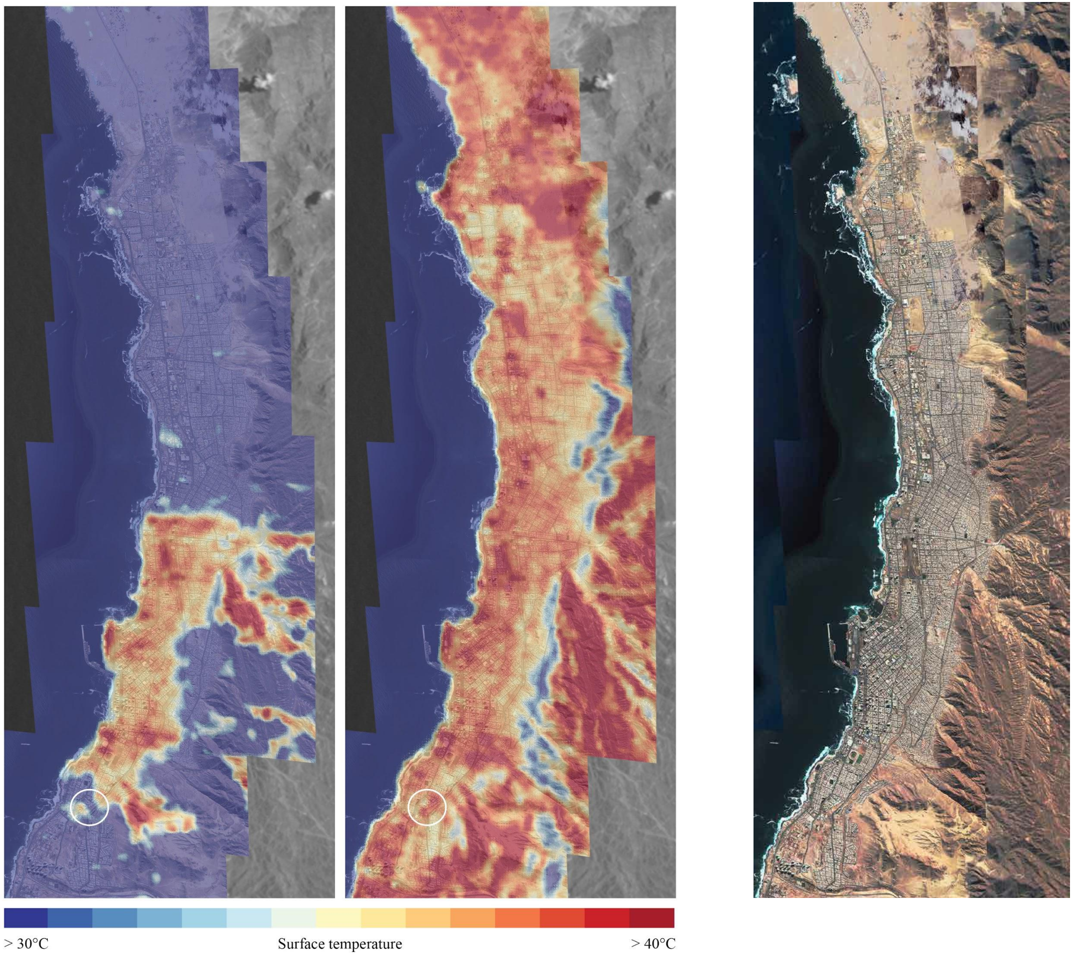
average outdoor temperatures in 2050 (avg. 6°C)

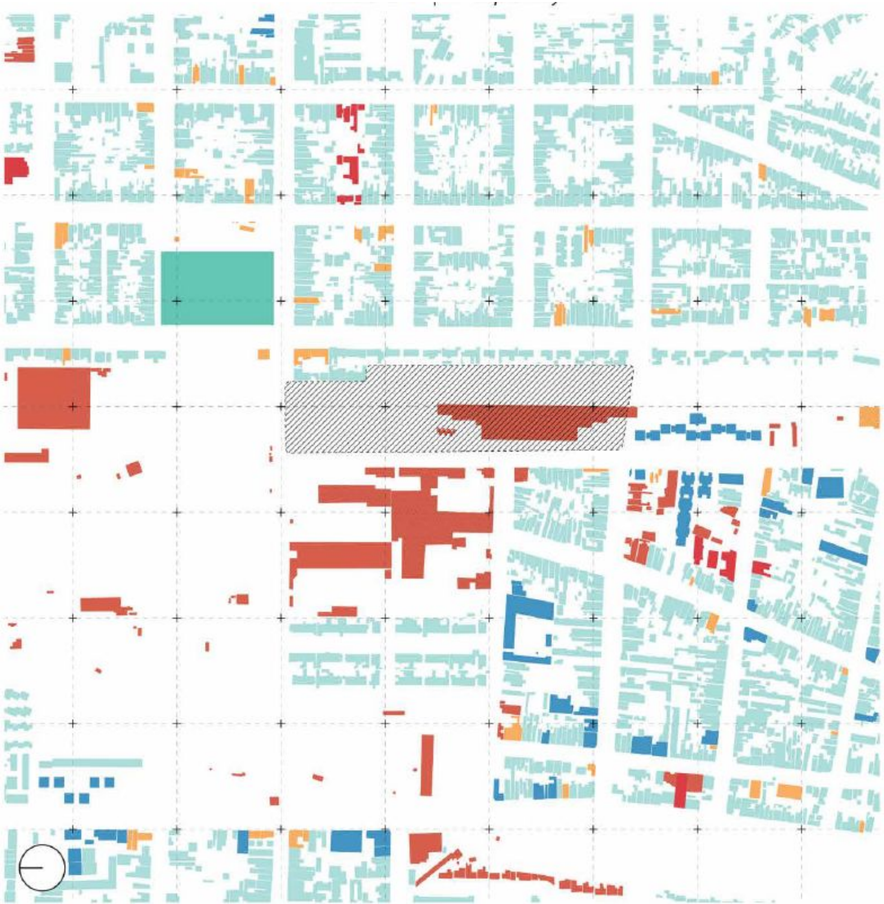
the higher the urban fabric compactness, the lower the frequency of high indoor temperatures

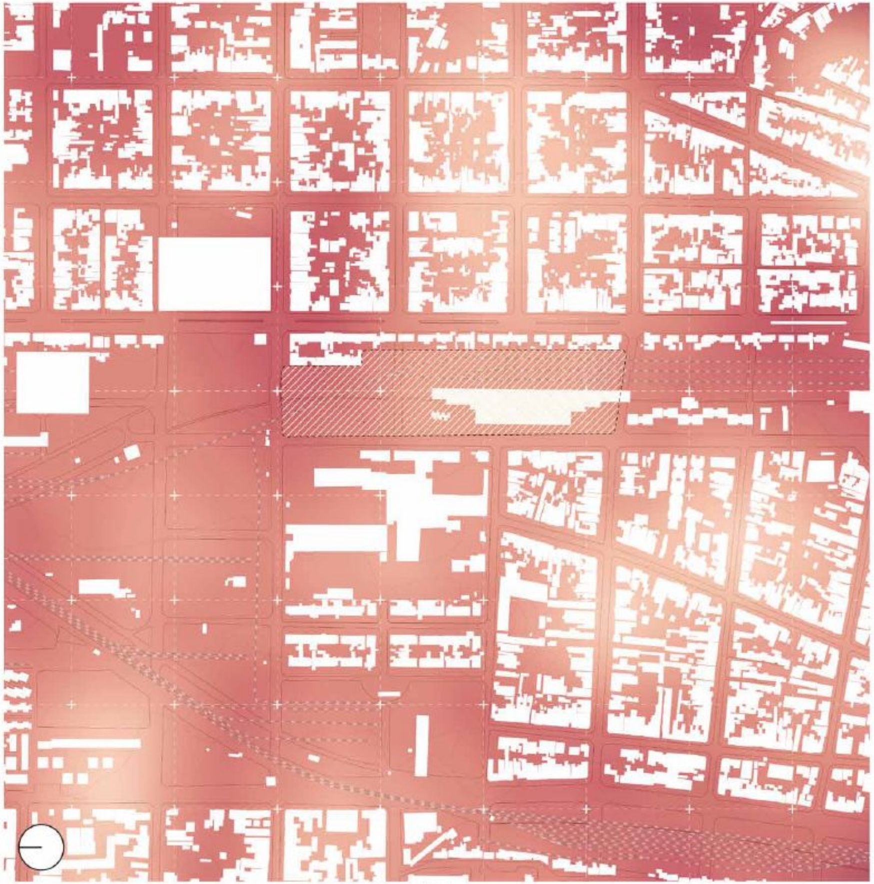


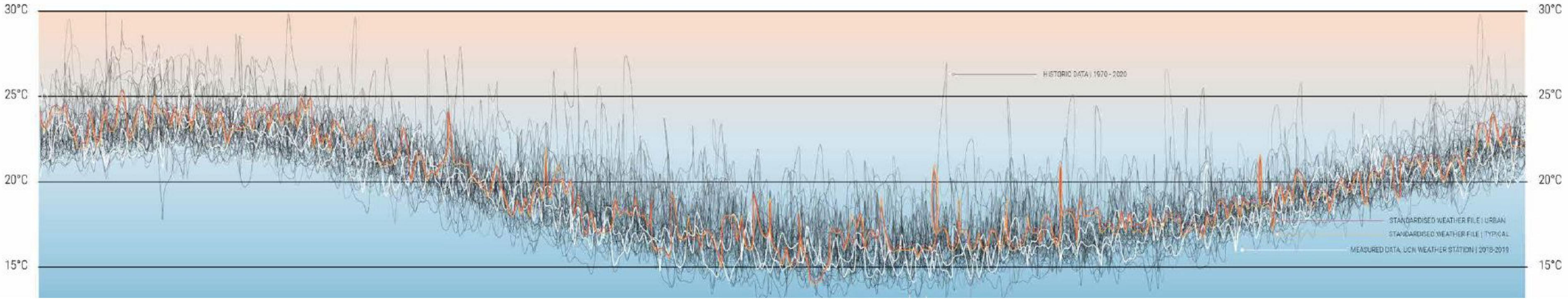
# Aftamagosta (Atacama Desert Chile)

with Aimee Desert and David Garcia AEE

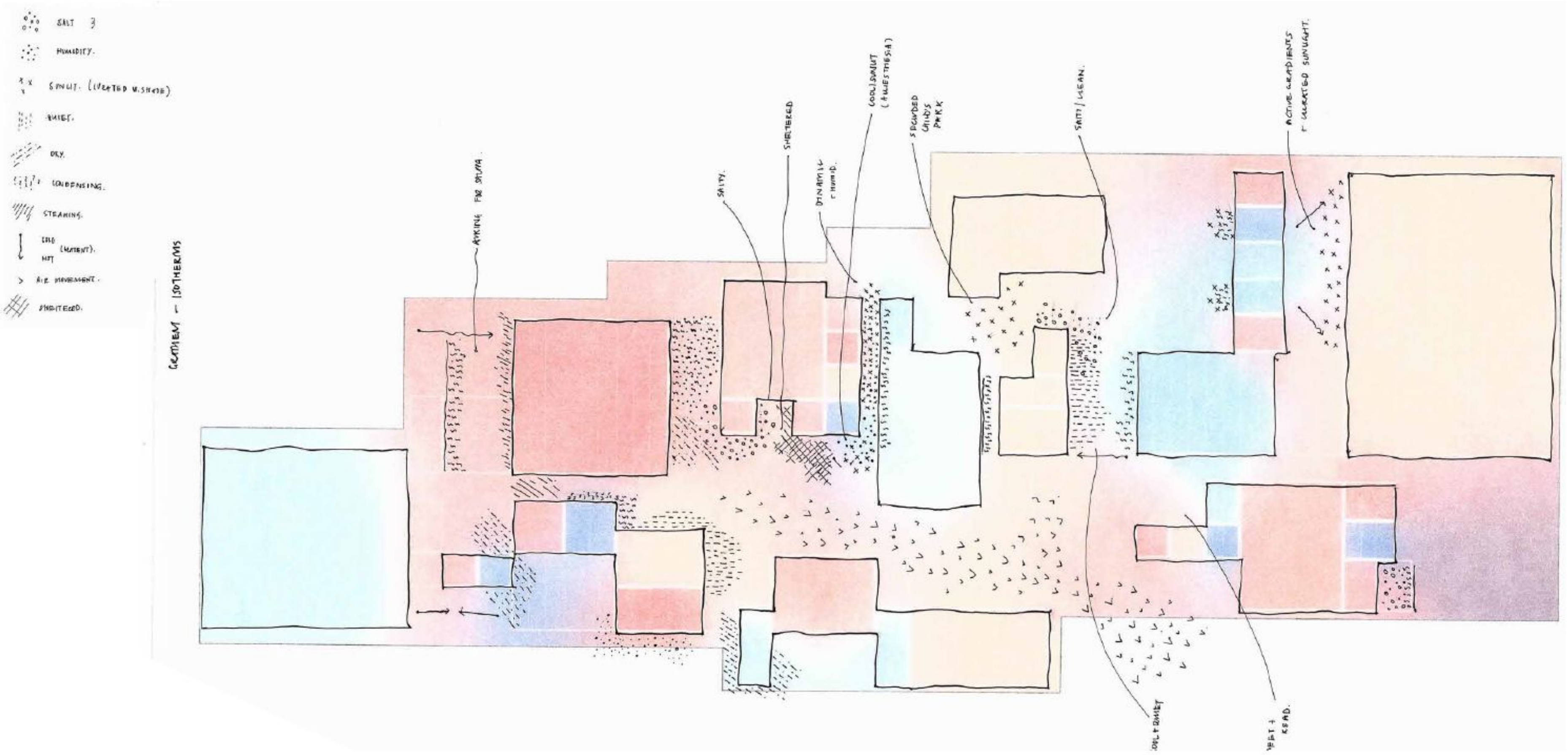

> 30°C
Surface temperature
> 40°C



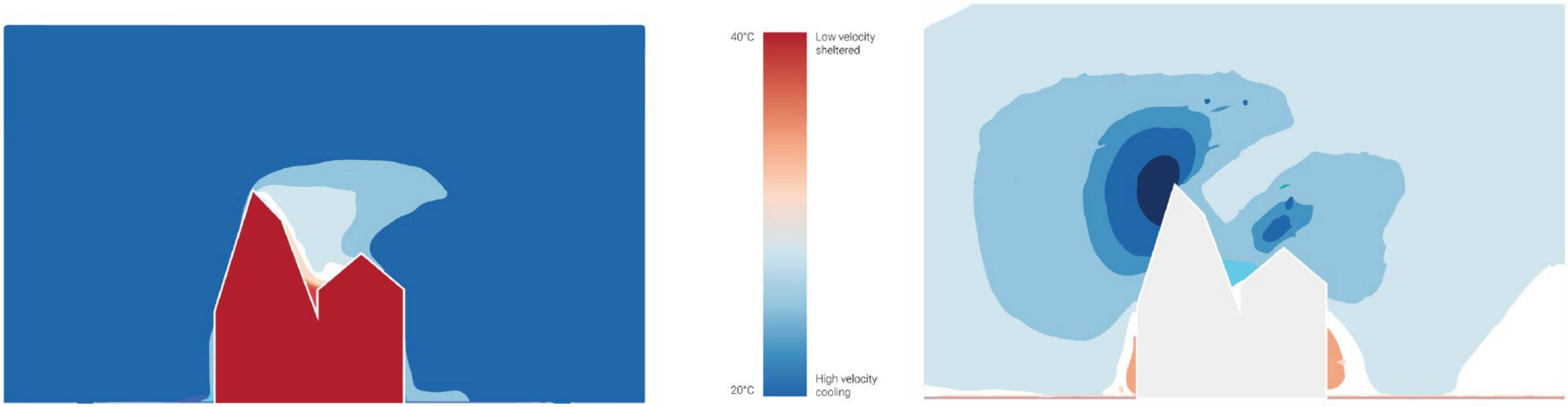



30°C
25°C
20°C
15°C
HISTORIC DATA | 1970 - 2020
STANDARDISED WEATHER FILE | URBAN
STANDARDISED WEATHER FILE | TYPICAL
MEASURED DATA, UCN WEATHER STATION | 2018-2019
30°C
25°C
20°C
15°C

# Use climate change as a resource



# Adaptation of Functions by CFD studies

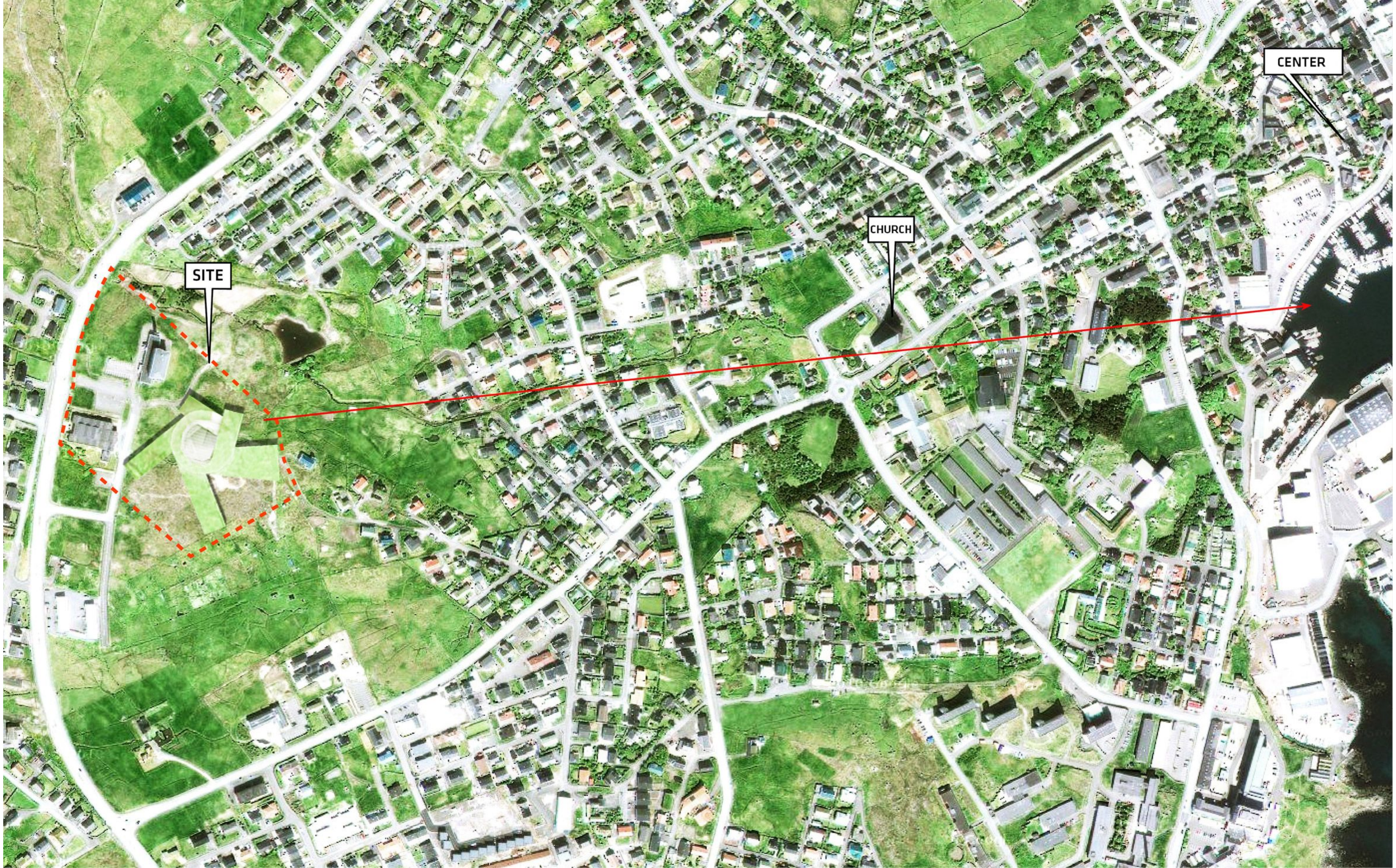

40°C
Low velocity
sheltered
20°C
High velocity
cooling

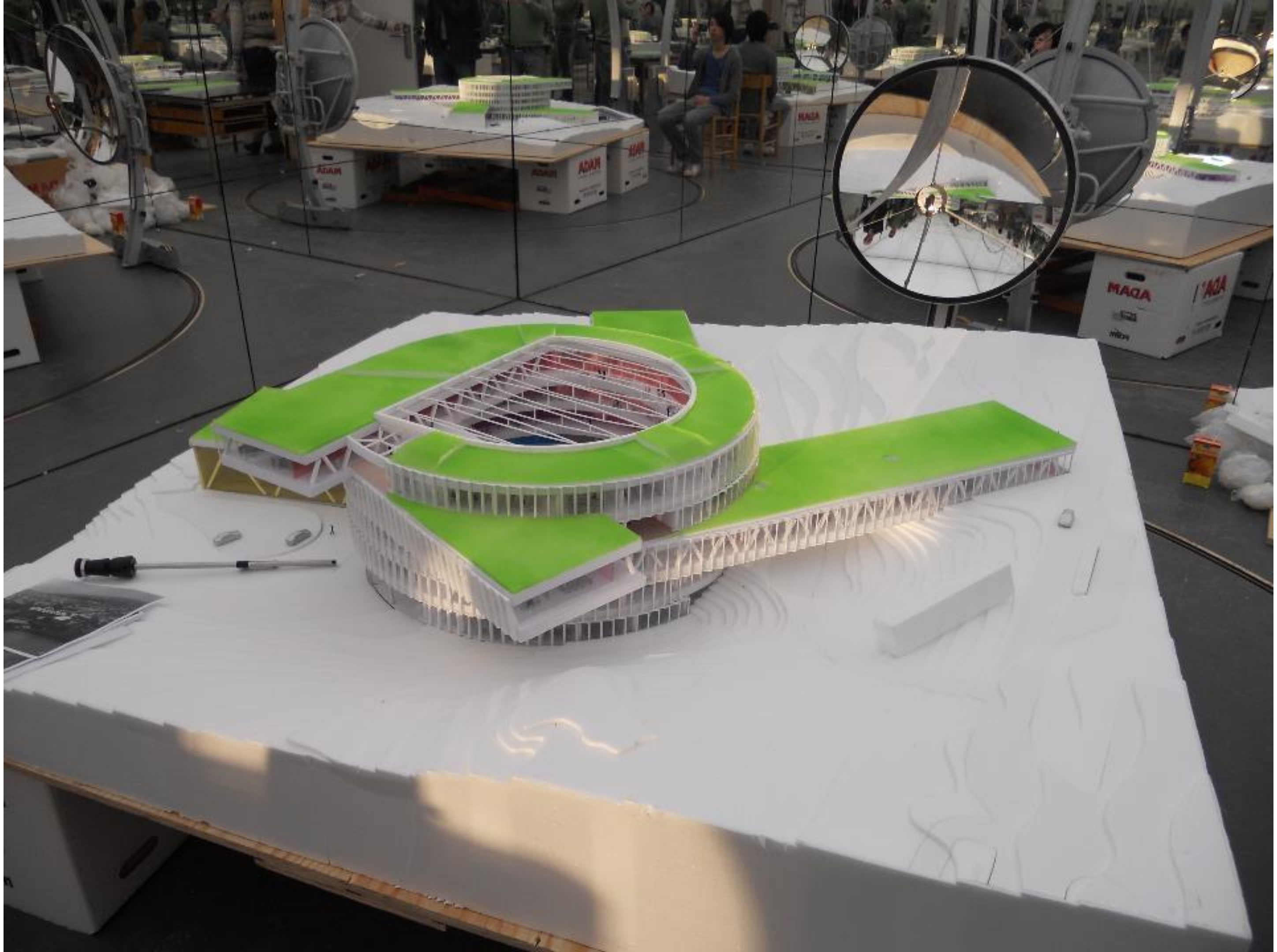
# BUILDING FORM

AIRFLOW + THERMODYNAMIC SHAPING

# Playing with new climatic extremes

Consultancy for BIG – FarOer Educational Center

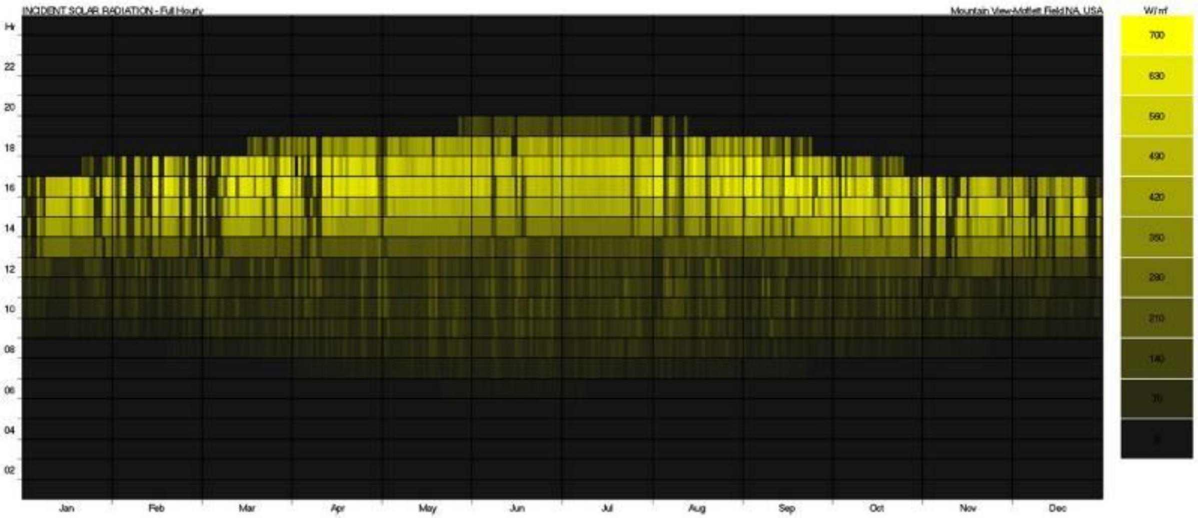

CENTER
CHURCH
SITE



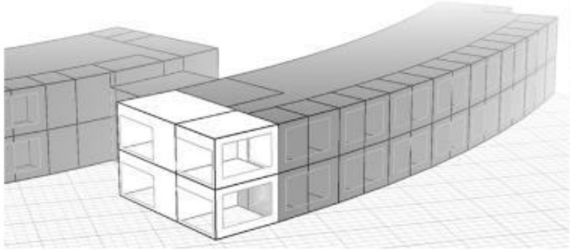
# FACADE DESIGN

AIRFLOW + THERMODYNAMIC SHAPING

**RELATE TO SUN**
**Nasa Sustainability Base / William McDonough / Ubbelhode**



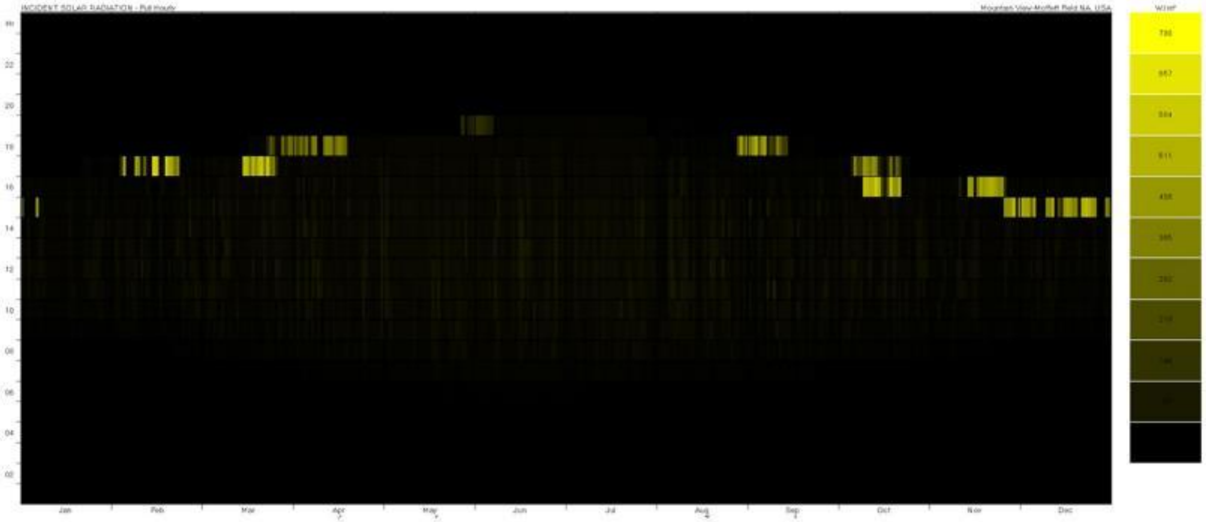

# Current Design Without Shading



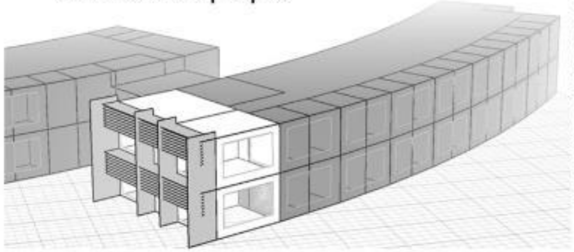
TOTAL MONTHLY SOLAR EXPOSURE
Mountain View-Moffett Field NA, USA
Object: 429 (16.874 m2) (Azi: -112.31 °, Alt: 0.00 °)

| MONTH | AVAIL. Wh/m2 | AVG SHADE | | INCIDENT Wh/m2 | INCIDENT TOT.Wh | ABSORBED Wh/m2 | ABSORBED TOT.Wh | TRANSMITTED Wh/m2 | TRANSMITTED TOT.Wh |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 137070 | 41% | 0 | 48891 | 824978 | 4796 | 80932 | 8453 | 142637 |
| Feb | 125195 | 43% | 0 | 46041 | 776877 | 4517 | 76213 | 7960 | 134321 |
| Mar | 212103 | 48% | 0 | 70984 | 1197766 | 6964 | 117503 | 12273 | 207091 |
| Apr | 246989 | 50% | 0 | 79968 | 1349357 | 7845 | 132375 | 13826 | 233301 |
| May | 289422 | 51% | 0 | 90241 | 1522693 | 8853 | 149379 | 15602 | 263271 |
| Jun | 284453 | 50% | 0 | 85213 | 1437856 | 8360 | 141057 | 14733 | 248602 |
| Jul | 297707 | 48% | 0 | 91348 | 1541372 | 8961 | 151212 | 15794 | 266500 |
| Aug | 237291 | 48% | 0 | 83753 | 1413216 | 8216 | 138639 | 14481 | 244342 |
| Sep | 234425 | 50% | 0 | 79954 | 1349121 | 7844 | 132351 | 13824 | 233260 |
| Oct | 190316 | 43% | 0 | 67755 | 1143269 | 6647 | 112157 | 11715 | 197669 |
| Nov | 144145 | 43% | 0 | 50646 | 854593 | 4969 | 83837 | 8757 | 147757 |
| Dec | 118445 | 38% | 0 | 40815 | 688702 | 4004 | 67563 | 7057 | 119075 |
| TOTALS | 2517561 | | 0 | 835608 | 14099801 | 81975 | 1383218 | 144475 | 2437827 |

credits : Susan Ubbelhode




# Current Design
## Horiz Louvers (half height of bay)
## lower 30 in opaque



TOTAL MONTHLY SOLAR EXPOSURE
Mountain View-Moffett Field NA, USA
Object: 429 (16.874 m2) (Azi: -112.31 °, Alt: 0.00 °)

| MONTH | AVAIL. Wh/m2 | AVG SHADE | | INCIDENT Wh/m2 | INCIDENT TOT.Wh | ABSORBED Wh/m2 | ABSORBED TOT.Wh | TRANSMITTED Wh/m2 | TRANSMITTED TOT.Wh |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 137070 | 98% | 0 | 5749 | 74904 | 564 | 7348 | 994 | 12951 |
| Feb | 125195 | 92% | 0 | 10474 | 136461 | 1028 | 13387 | 1811 | 23594 |
| Mar | 212103 | 93% | 0 | 14753 | 192212 | 1447 | 18856 | 2551 | 33233 |
| Apr | 246989 | 95% | 0 | 14034 | 182838 | 1377 | 17937 | 2426 | 31612 |
| May | 289422 | 99% | 0 | 11159 | 145386 | 1095 | 14263 | 1929 | 25137 |
| Jun | 284453 | 98% | 0 | 12023 | 156647 | 1180 | 15367 | 2079 | 27084 |
| Jul | 297707 | 100% | 0 | 11109 | 144730 | 1090 | 14196 | 1921 | 25023 |
| Aug | 237291 | 99% | 0 | 11459 | 149295 | 1124 | 14646 | 1981 | 25813 |
| Sep | 234425 | 97% | 0 | 10622 | 138393 | 1042 | 13577 | 1837 | 23928 |
| Oct | 190316 | 90% | 0 | 16255 | 211782 | 1595 | 20776 | 2811 | 36617 |
| Nov | 144145 | 91% | 0 | 12388 | 161393 | 1215 | 15833 | 2142 | 27905 |
| Dec | 118445 | 88% | 0 | 12318 | 160487 | 1208 | 15744 | 2130 | 27748 |
| TOTALS | 2517561 | | 0 | 142344 | 1854528 | 13964 | 181933 | 24611 | 320644 |

# Beyond uniform Thermal Comfort

with Rich Kramer, University of Maastricht

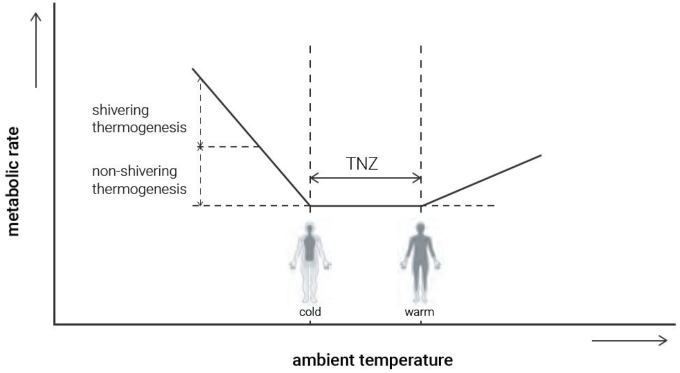
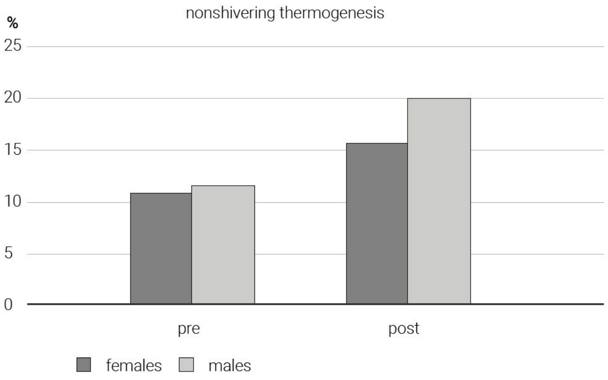


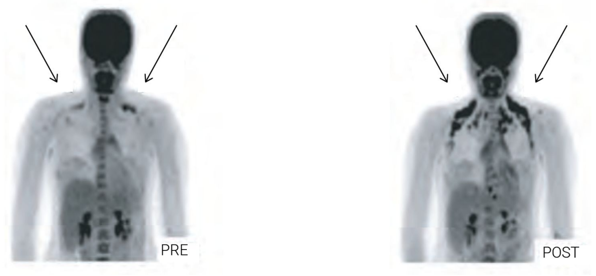

**Figure 12**

The physiological thermo-neutral zone (TNZ, adapted from [18]) (non-shivering thermogenesis, NST; shivering thermogenesis).

**Figure 13**

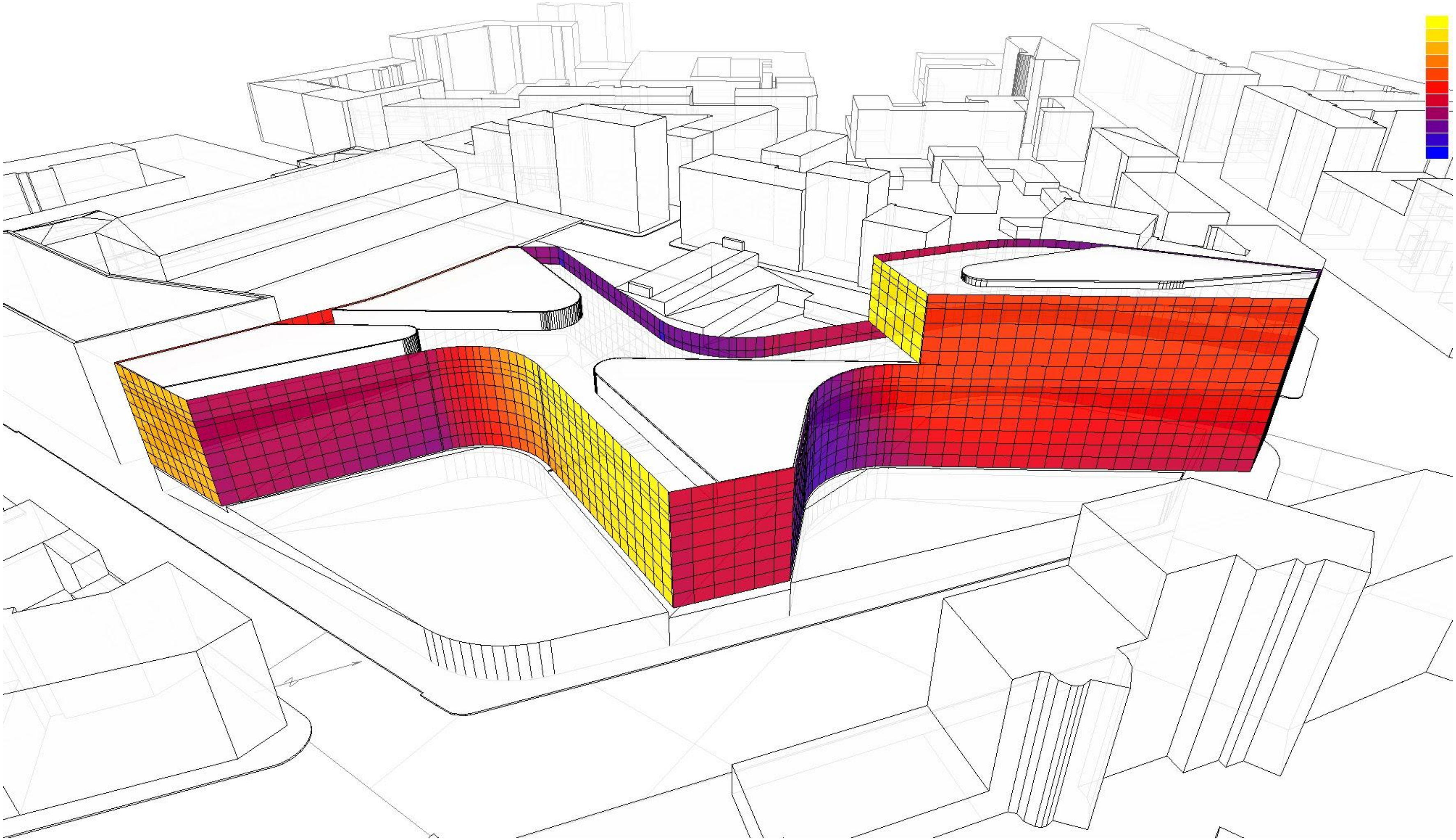
Cold acclimation increases non-shivering thermogenesis and brown fat activity (arrows) before (PRE) and after (POST) cold acclimation [19].

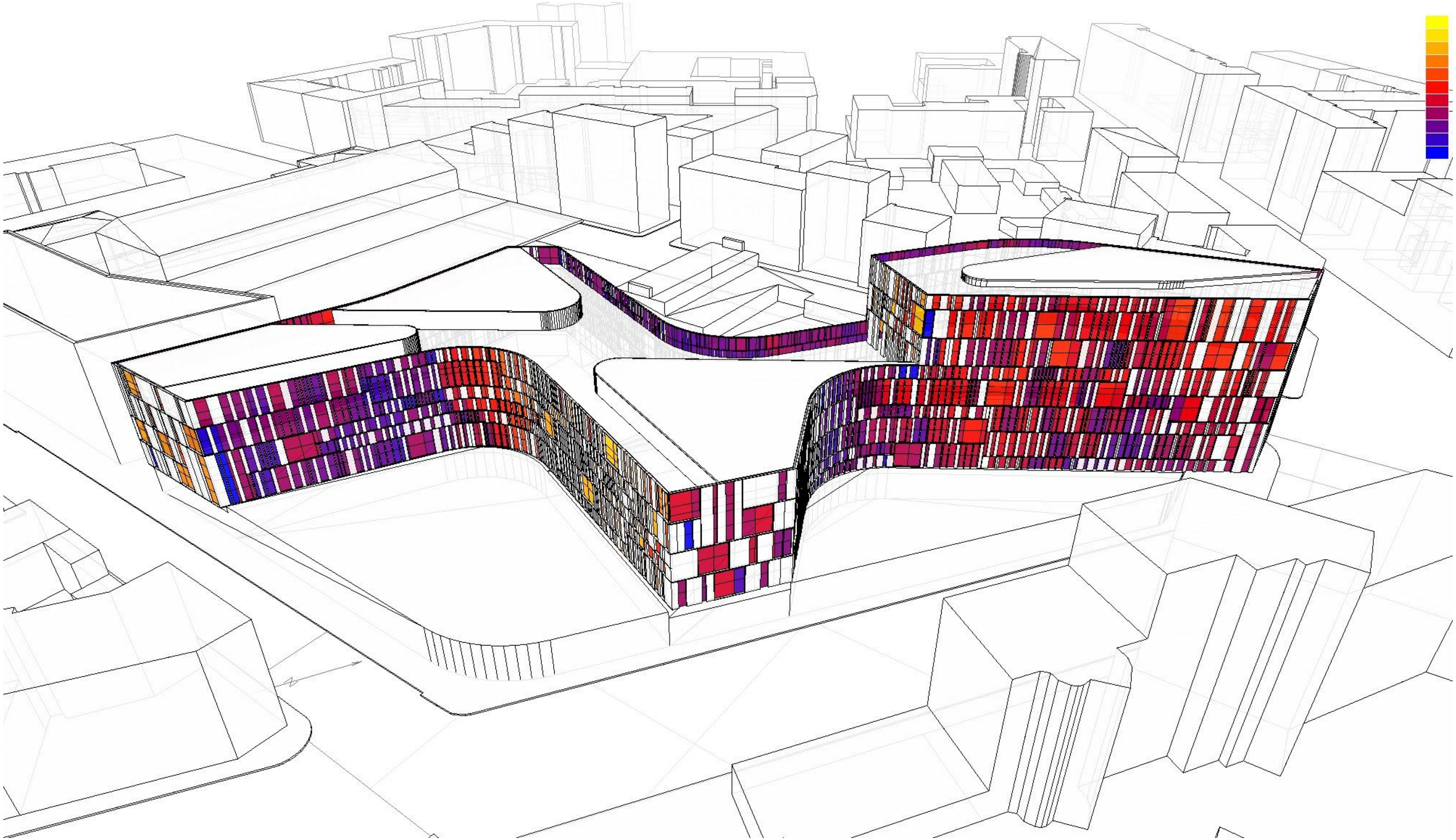


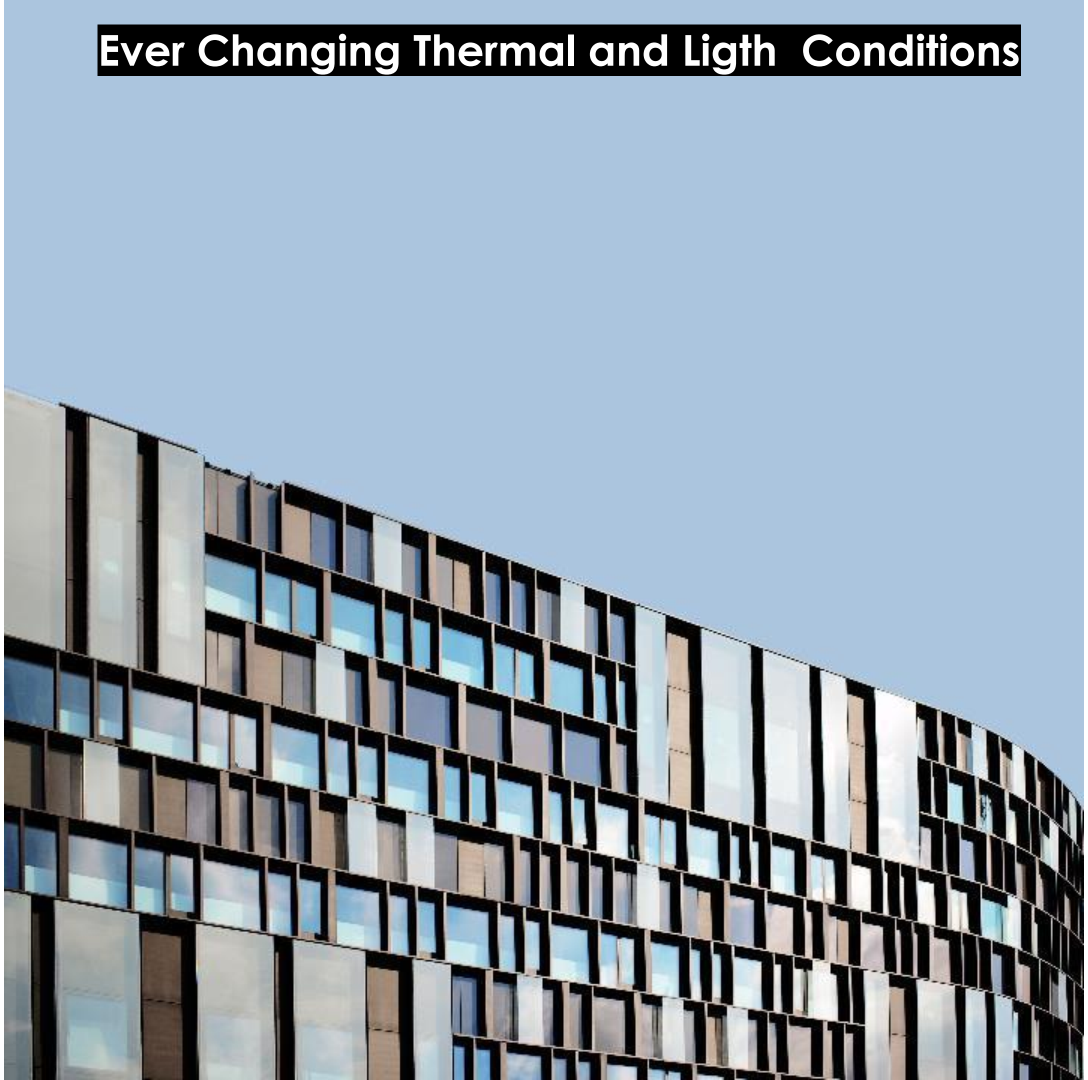
## Climatic variations

Lavazza, with Cino Zucchi



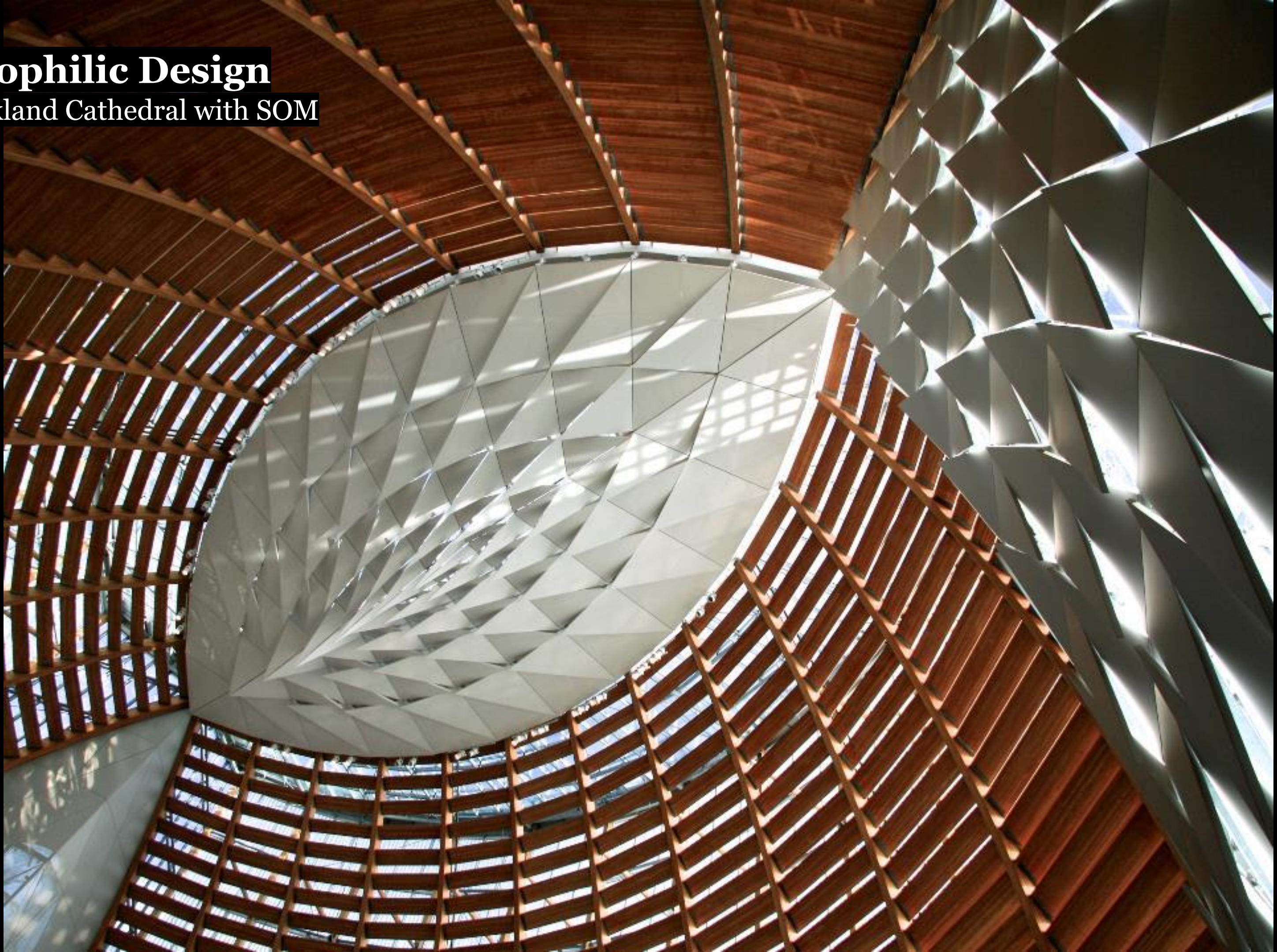


# Ever Changing Thermal and Ligth  Conditions

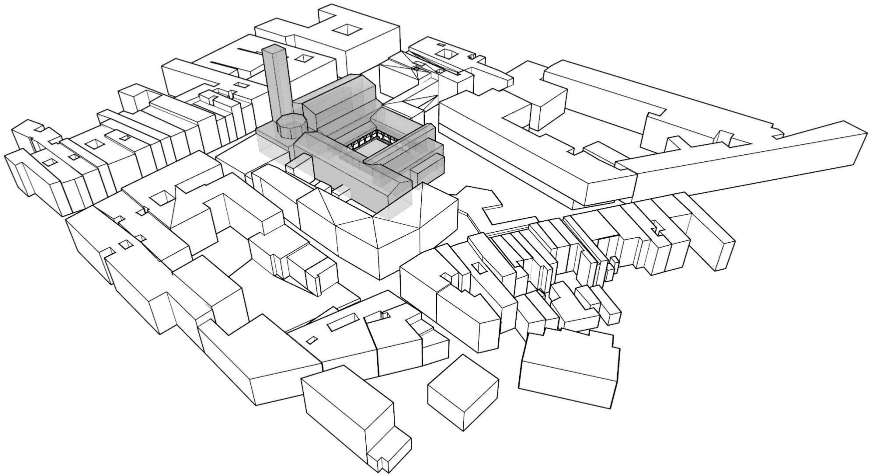


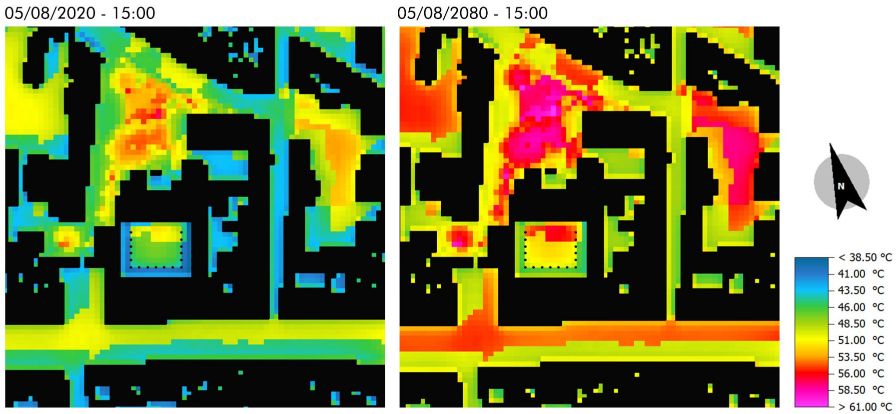
**Biophilic Design**

Oakland Cathedral with SOM

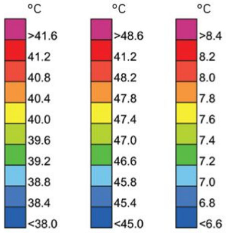


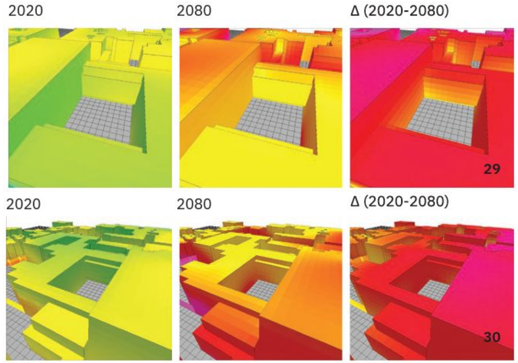
# Use climate change as a resource





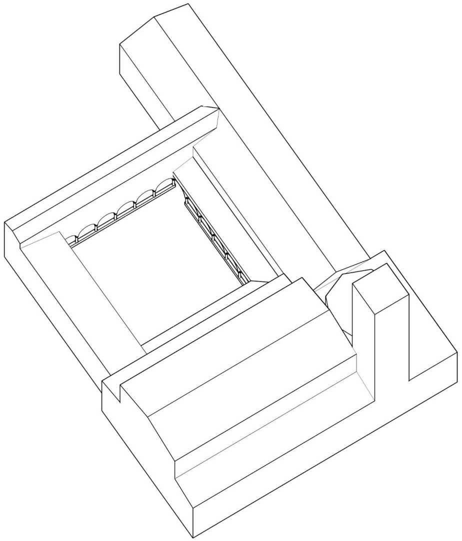

Air temperature in front of facades inside the cloister for 2020, 2080 and as a difference.



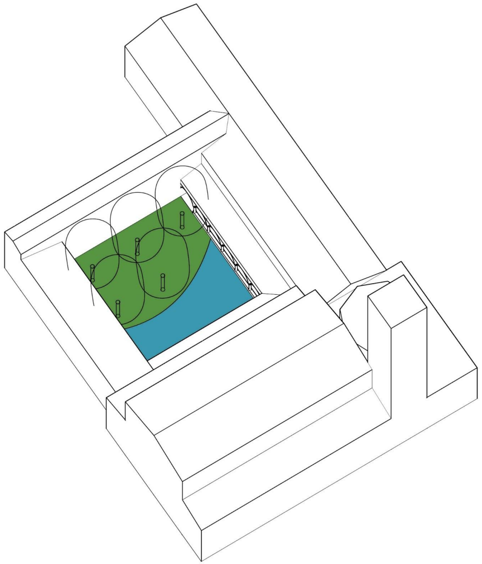



# What is best to acclimatize courtyards to Climate Change?

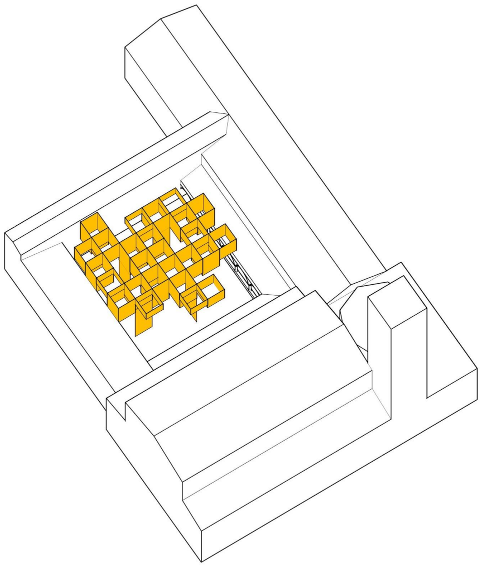
*Cross Ventilation*
*Ventilation)*



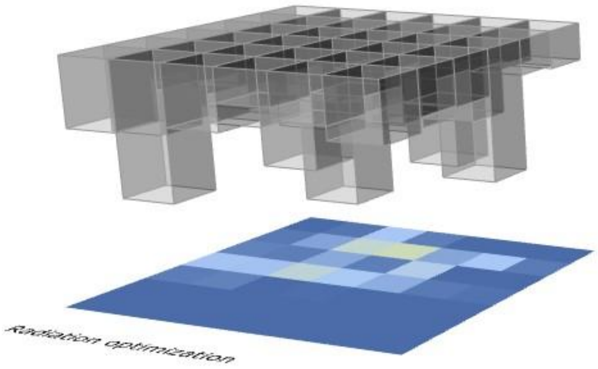
*Vegetation + Water optimiziation*

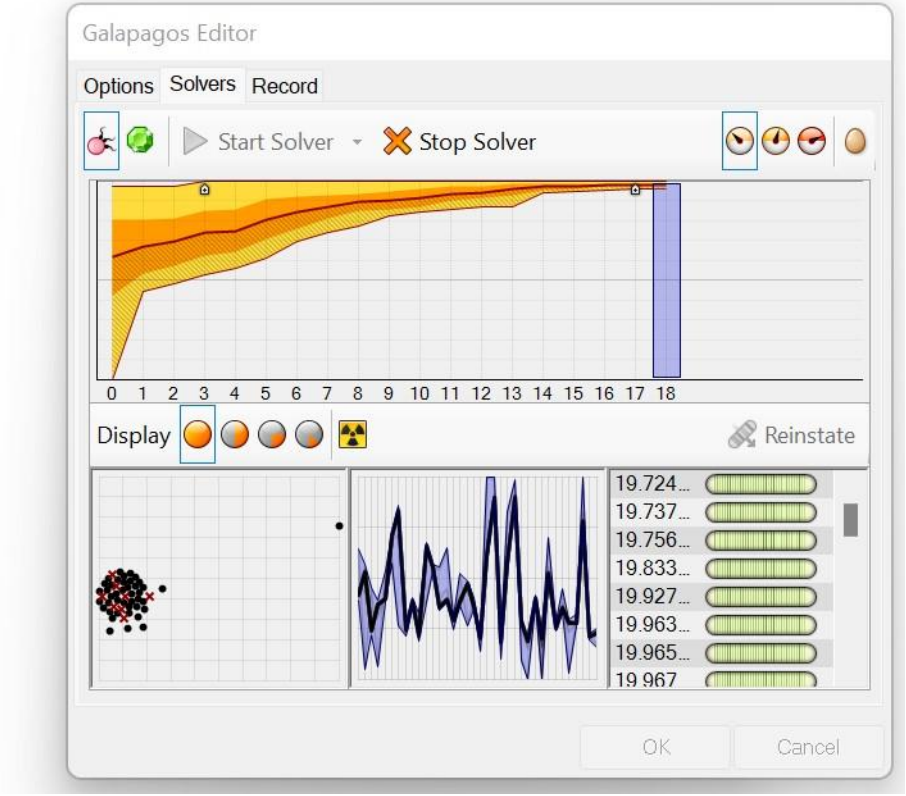


*Shading (Unobstructed)*

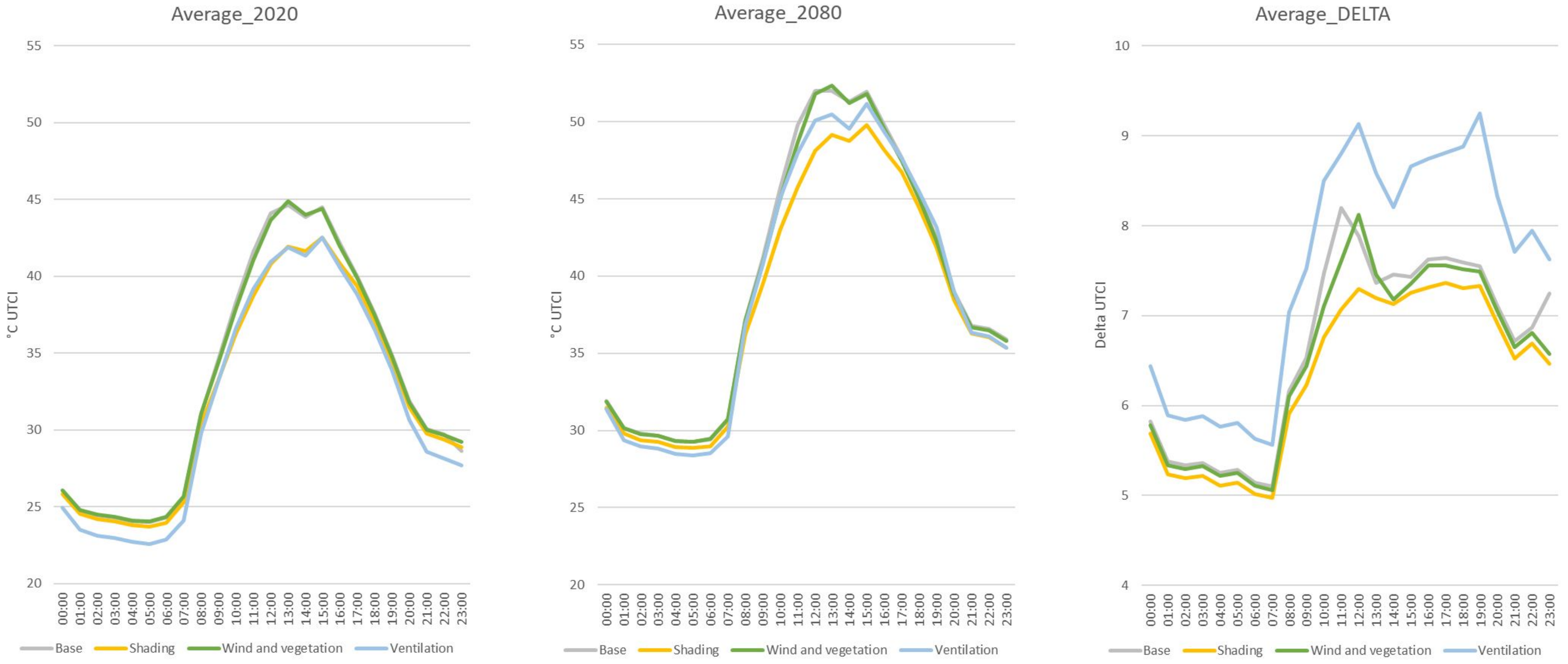


# Optimization with UTCI of both shading systems and Green - Blue



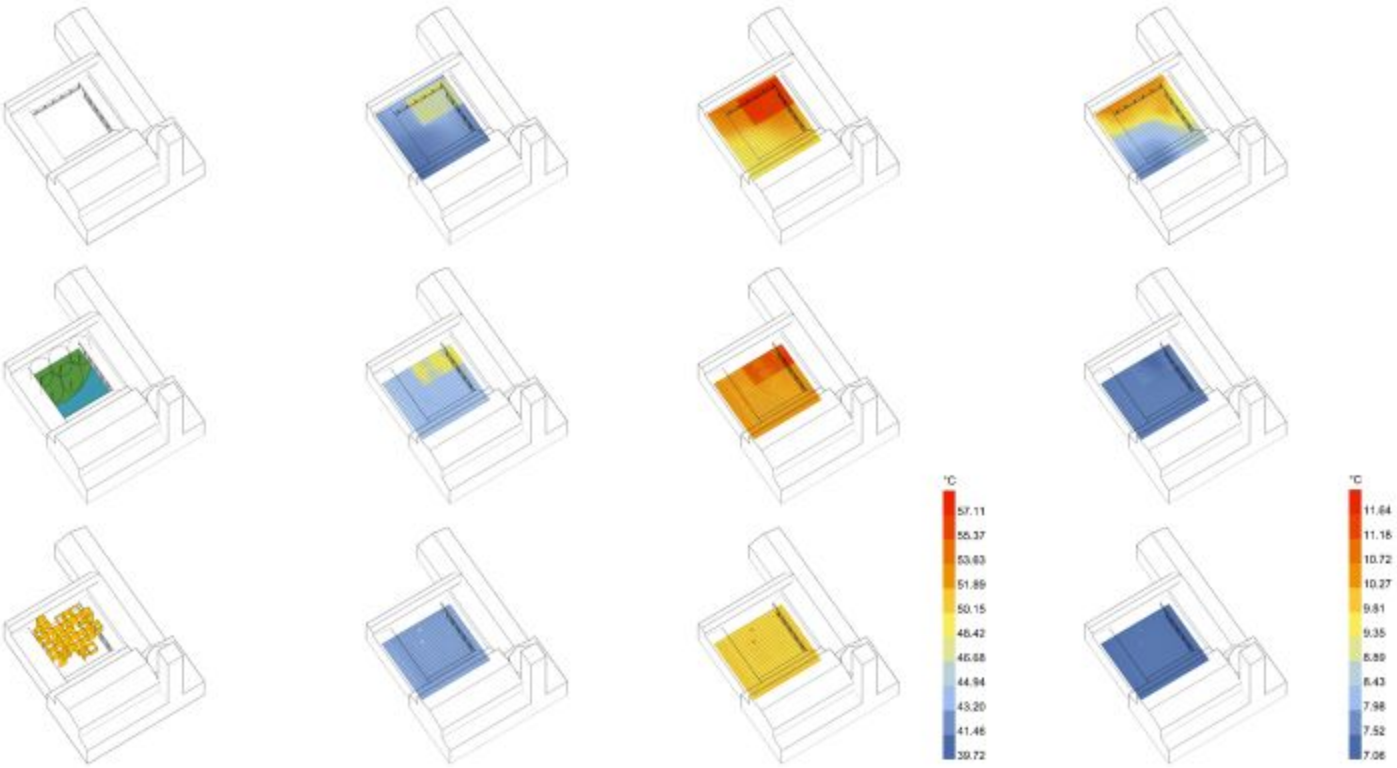



# UTCI 24 hours - summer

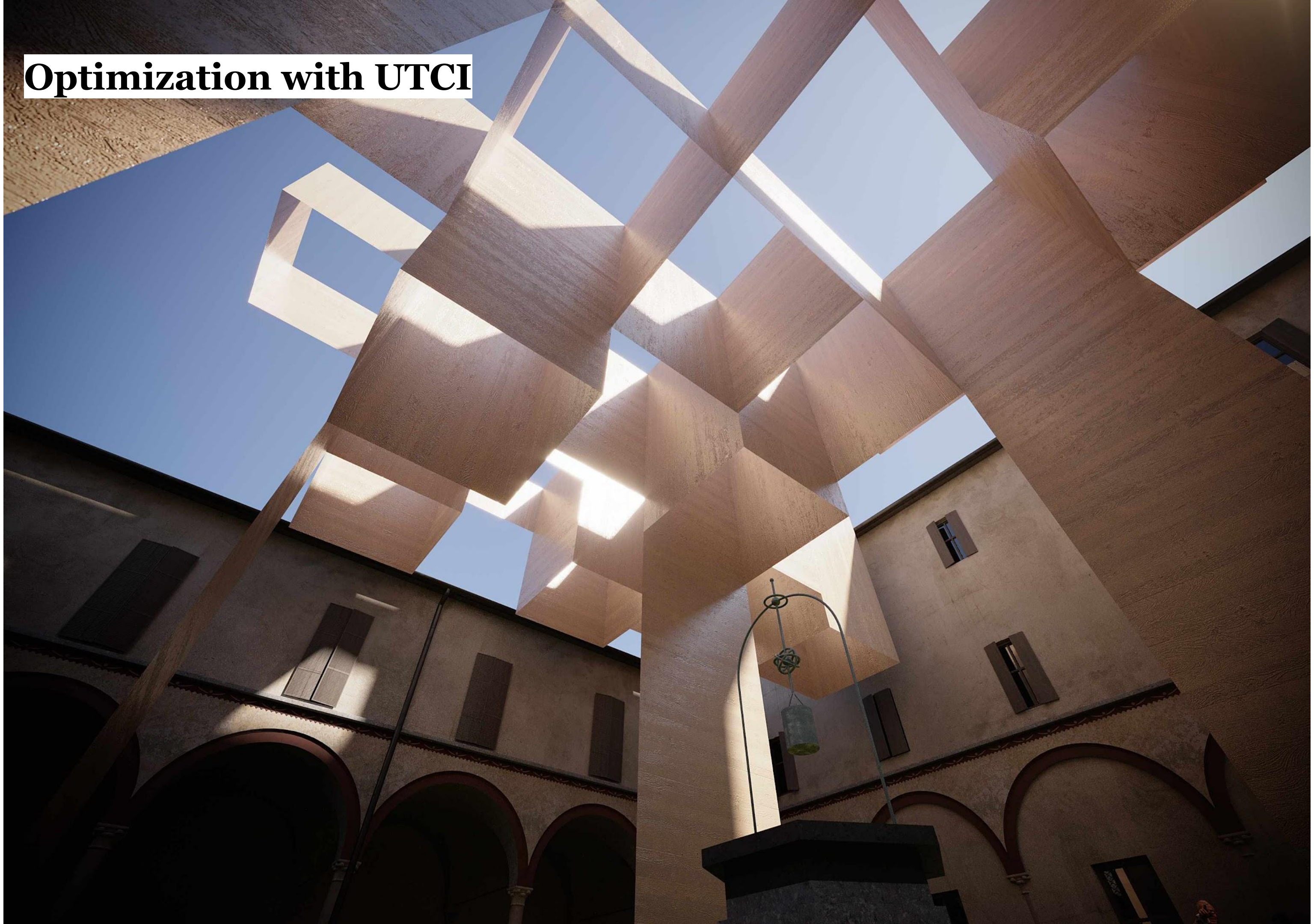


# UTCI at 15 summer

*UTCI 2022* *UTCI 2050* *DELTA*

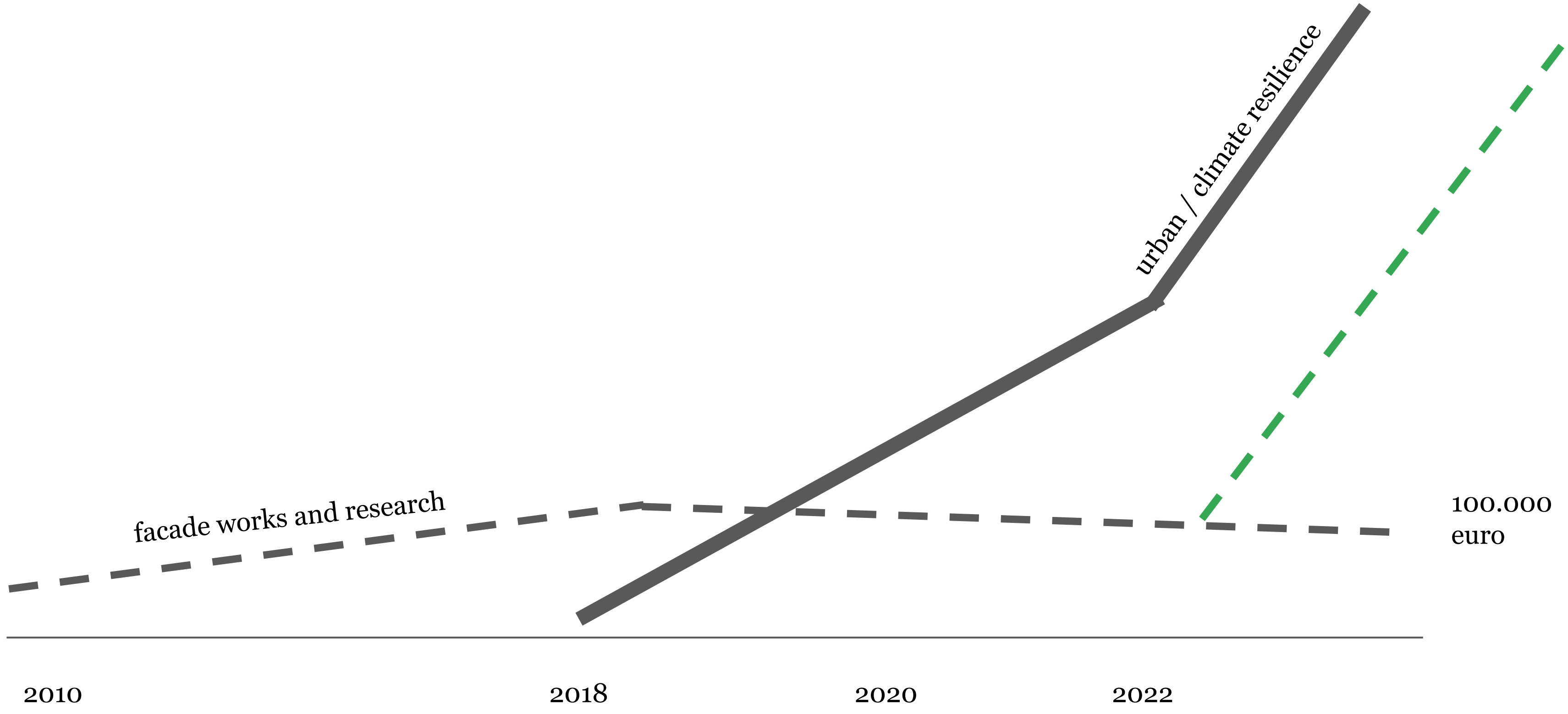


# Optimization with UTCI



# Design Direction

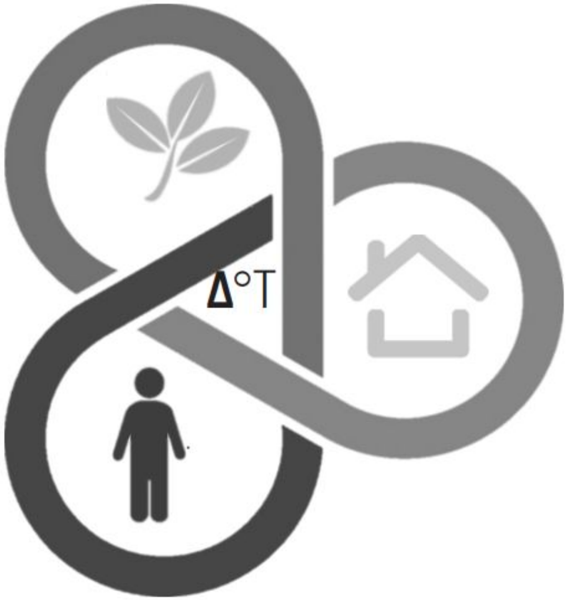
Fundings and Projections



# Leveraging Climate Change for achieving Co-benefits

Core Values of my Urban Design and Facade Design Research

Increase biodiversity
Urban Agriculture
Restorative Green, Blue Spaces
Water Flow




Create Microclimate for Operations
Energy Positive Solutions
Maximize Existing Spaces Activation

Increase Outdoor Thermal Comfort
Increase Air Quality
Achieve biophilia

# Scheme of Collaborations

District Energy Specialist

Digital Twin Specialist

Smart City Specialist

*Microclimatic Cities*

Climatologist

Ecosystem Engineering /
Environmental Agencies

Agriculture

Mobility

Indoor Comfort

Indoor Air Quality

Psycophisiologist

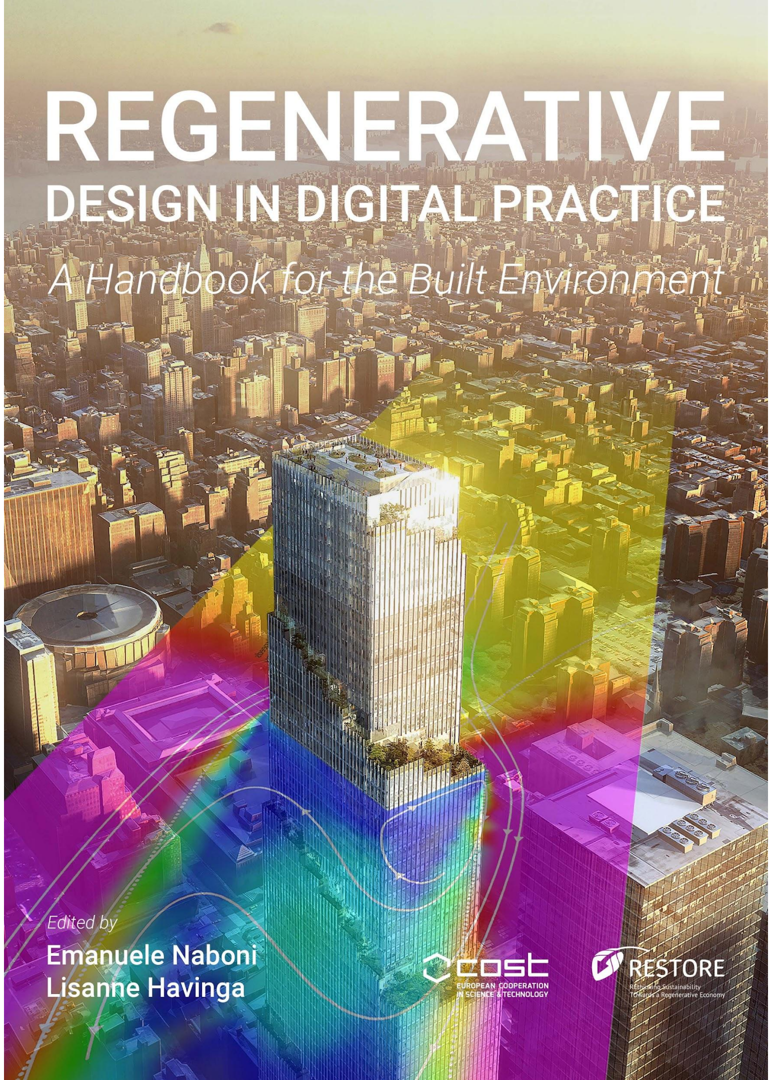
Indoor HVAC Specialist

*Facade Interfaces*

Sensoring Expert

Entomologist

Medical Doctor




**download the open access book:**
go to *ResearchGate*
go to Emanuele Naboni

**Let’s be in touch!**

instagram:
emanuele_naboni_climate

or email:
*emanuele.naboni@gmail.com*

# A comprehensive strategy for modelling urban material for thermally liviable cities. URBAN therCOM Project

**Emanuela Giancola**

**CIEMAT**

Center for Energy, Environmental and Technological Research

URBAN THERCOM

Grants PID2020-114873RA-C33 funded by

GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN | AGENCIA ESTATAL DE INVESTIGACIÓN

Ministry of Science and Innovation

# CIEMAT

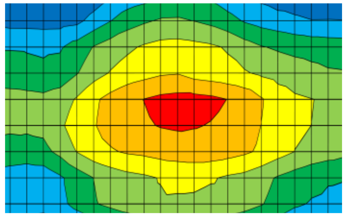
Center for Energy, Environmental and Technological Research

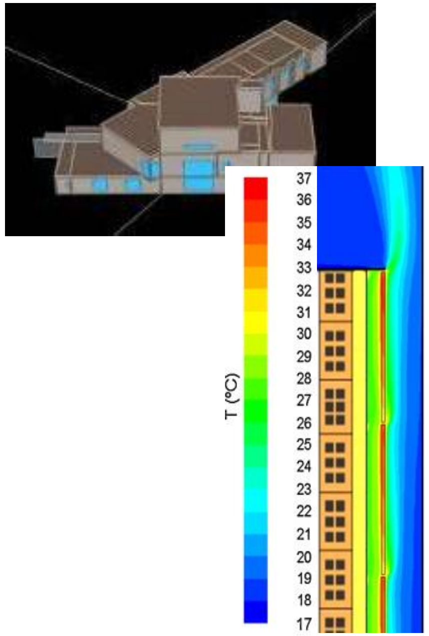
- DIRECTOR GENERAL
  - Deputy Director General
  - Departament of Energy
  - National Fusion Laboratory
  - Department of the Environment
  - Department of Technology
  - Department of Basic Research
  - Subdirectorate General of Safety and Refurbishment of Facilities
  - Subdirectorate General of Institutional Relations and Knowledge Transfer
  - General Secretariat

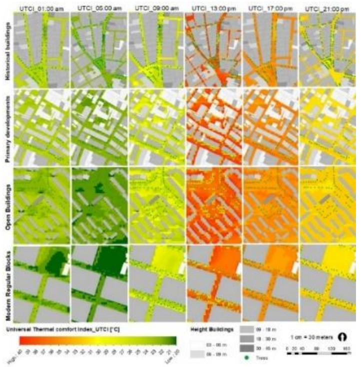
# CIEMAT

## Energy Efficiency Activities

- Characterization of climatology and environment
- Reduction of the energy demand. Passive Systems
- Envelope characterization
- Modeling, dynamic simulation, experimental evaluation and monitoring
- Efficient and integral energy management
- Integration of renewable energy
- Distributed generation based on renewable energies





## mateMAD Concept

**Spanish research coordinated project** based on the hypothesis that optimized materials, like chromogenic smart materials for urban surfaces can provide efficient solutions to the Urban heat Island (UHI) effect.

Multidisciplinary approach for the systematic analysis of representative case studies of **vulnerable areas of the city of Madrid**. The goal is to generate:

- knowledge about the **impact of urban materials** on the habitability and sustainability of cities
- a reliable proposal to **improve the quality of the outdoor environment**, the energy demand and the well-being of the inhabitants through the substitution of outdoor surface materials

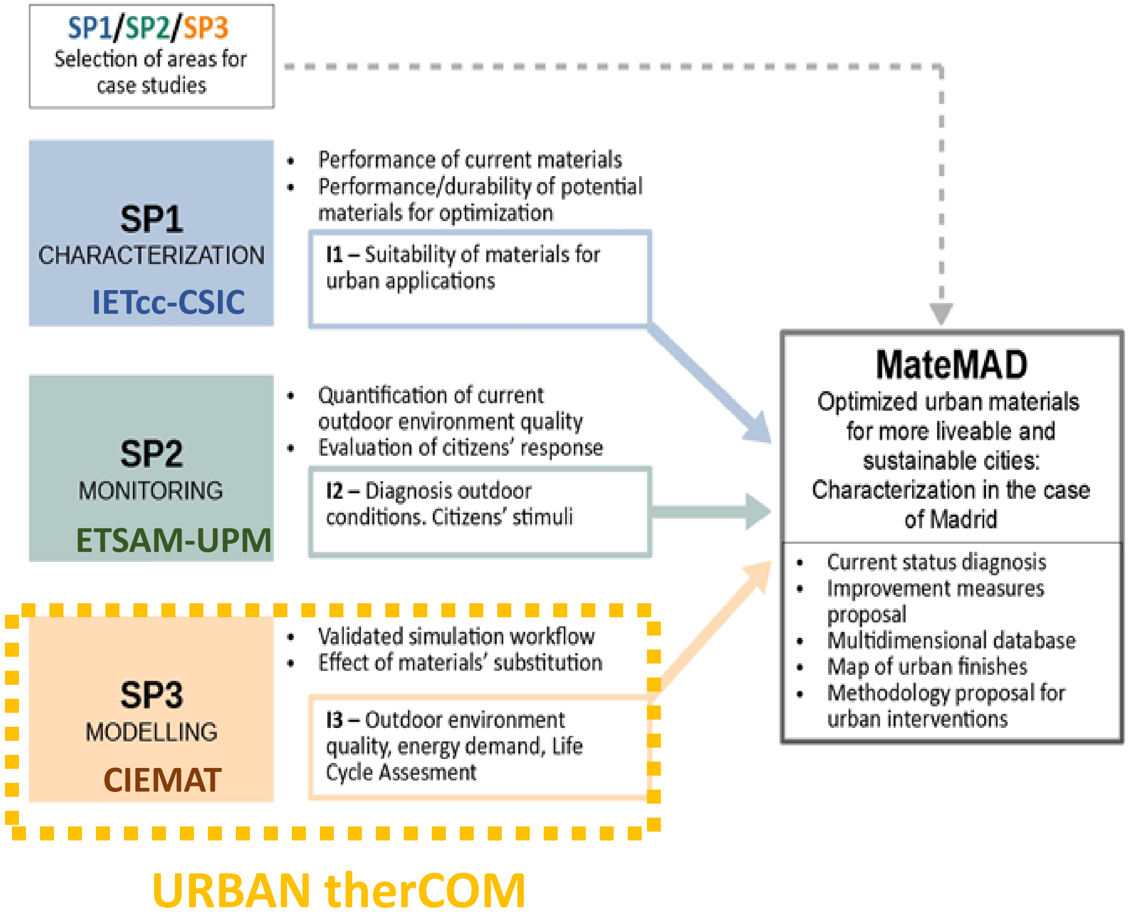
## mateMAD Concept

Activities performed under three subprojects:

- Subproject 1 (**SP1**). **Characterization of urban materials.**

- Subproject 2 (**SP2**). **Monitoring of environmental parameters.**

- Subproject 3 (**SP3**), named **URBAN therCOM**. **Modelling outdoor thermal comfort and energy demand in urban areas**.



# MEASURE, CALIBRATION AND SIMULATION STRATEGY

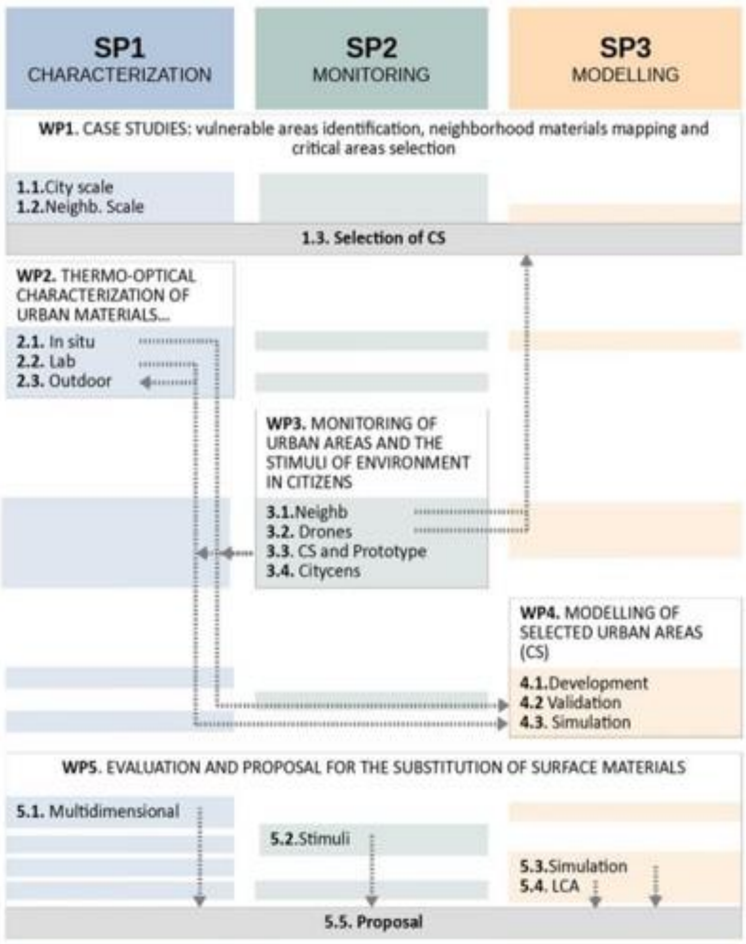
The first step assess the  of **vulnerability** within the city, on those aspects related to Climate Change, discomfort

The second details thermo-optical (**TO**) characterization of a wide range of surface urban materials: in-situ, laboratory

The third step **monitors** at four levels: neighbourhood, case study areas, outdoor tests, and citizens

The fourth provides a **modelling strategy** to evaluate mutual relations amongst relevant urban factors building energy performance and outdoor thermal comfort

The final step **prepares a complete and justified proposal for the substitution of surface materials** in the case studies based on the results obtained from previous steps. And assess the environmental impact of the materials along their life cycle **LCA**

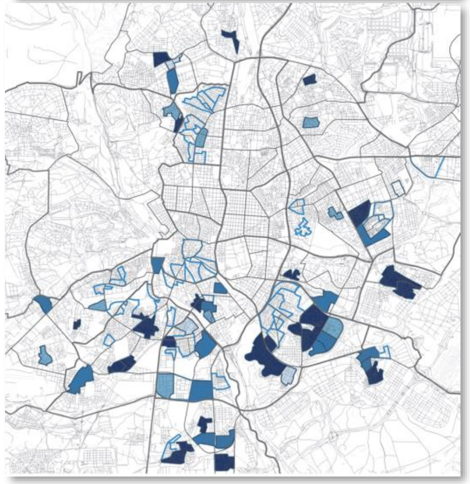


# SELECTION OF NEIGHBORHOODS

27 vulnerable neighborhoods affected simultaneously by problems of energy poverty and high intensity of the urban heat island

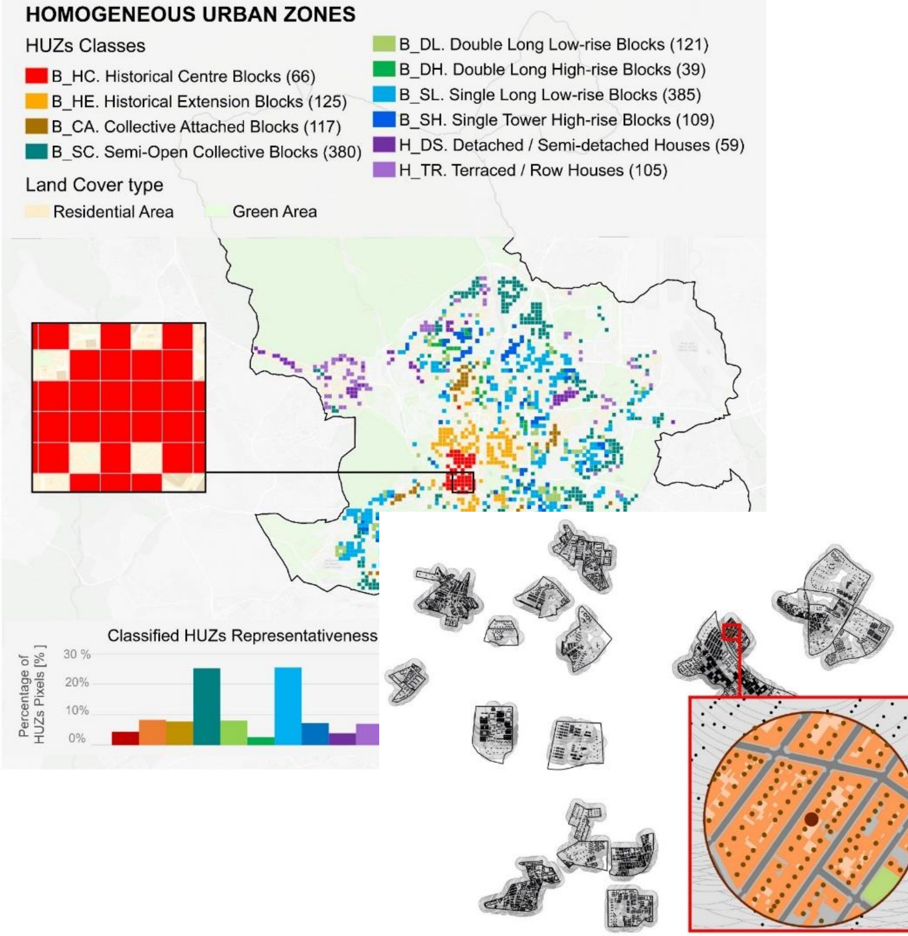
Severity of urban vulnerability

Energy poverty index



UHI intensity day+night

From: IETcc-CSIC. Paper presented to PLEA2022




From: Helena López Moreno (UiE3, CIEMAT)

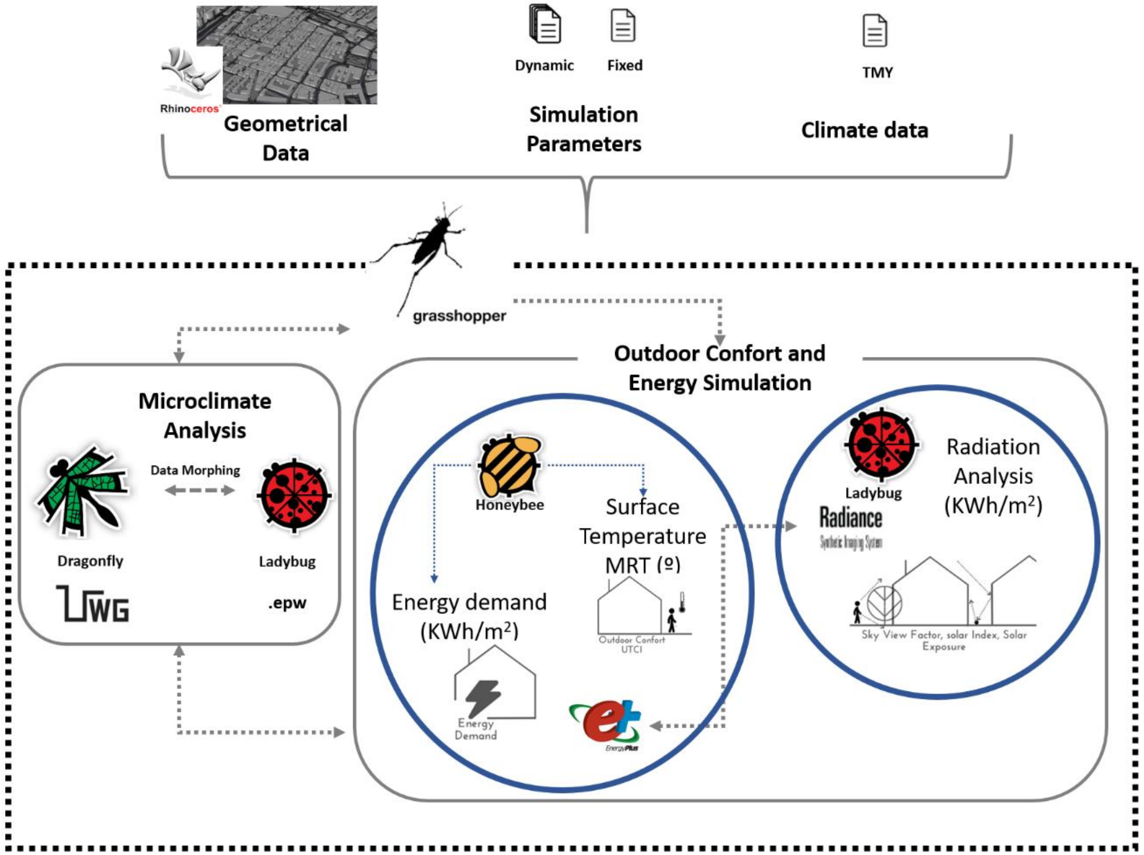
## HUZ (Homogeneous Urban Zones) METHODOLOGY

- **Objective:** facilitate the energy analysis of residential buildings.

mateMAD

# MODELLING OF SELECTED URBAN AREAS

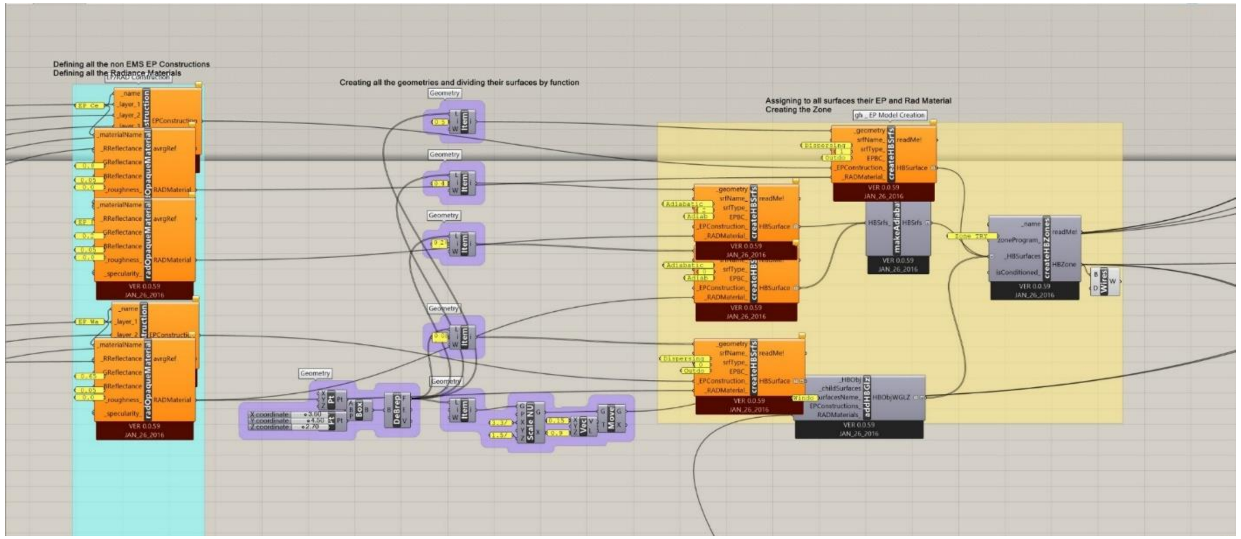
An **ad-hoc developed BPS tool** which enables to appropriately simulate the simulation of indoor and outdoor thermal field through an integrated approach, Grasshopper (GH) **based digital workflow** by means of add-ons Droagonfly, **HoneyBee** and **LadyBug**.




URBAN THERCOM

# MODELLING OF SELECTED URBAN AREAS

The timestep-by-timestep simulation approach allows the variation of the thermo-optical properties of the TC material within the simulation runtime itself, which in turn implies precisely considering the thermal inertia of the building and its effects on the energy demands for heating and cooling




URBAN THERCOM

## Conclusions & Future Work

The preliminary results are used to test the simulation strategy of TC materials and are presented in the **perspective of extending the developed BPS** to be applied to the evaluation of this problem generally and to be more seamlessly integrated into the design process.

Future work and further investigation is needed **to test and validate the strategy and the general digital workflow with real cases studies of Madrid** through the information that will be acquired throughout the duration of the mateMad project.

URBAN THERCOM

# A comprehensive strategy for modelling urban material for thermally liviable cities. URBAN therCOM Project

**Emanuela Giancola**

**emanuela.giancola@ciemat.es**

**THANK YOU**

URBAN
THERCOM

Grants PID2020-114873RA-C33
funded by

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
AGENCIA ESTATAL DE INVESTIGACIÓN