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 1

11:00-11:30 Introduction

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

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

11:30-12:10 Session 1 Modelling Linking Outdoor and Indoor

Michael Bruse, Uni Mainz, Chief Development Officer ENVI-MET

Victoria López-Cabeza, University of Sevilla

Naga Manapragada, TECHNION, Israel Institute of Technology

12:10-12:40 Coffee Break

Agenda: Day 1

12:40-13:50 Session 2 Microclimate, Form and Surfaces

Carmen Galán-Marín, University of Sevilla

Miguel Núñez Peiró, ETSAM-Polytechnic University of Madrid

Agnese Salvati, Polytechnic University of Catalunya

Massimo Palme, Universidad Técnica Federico Santa María, Chile

Francesco de Luca, Tallin University of Technology

Angelos Chronis, INFRARED

13:50-14:40 Session 3 Climate Change and Modelling Overview

Giandomenico Vurro, Salvatore Carlucci, The Cyprus Institute

Nestoras Antoniou, Univrsity of Cyprus

Vahid Nik, Kavan Javanroodi, Lund University

Alberto Martilli, Centre for Energy, Environmental and Technological Research, CIEMAT

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
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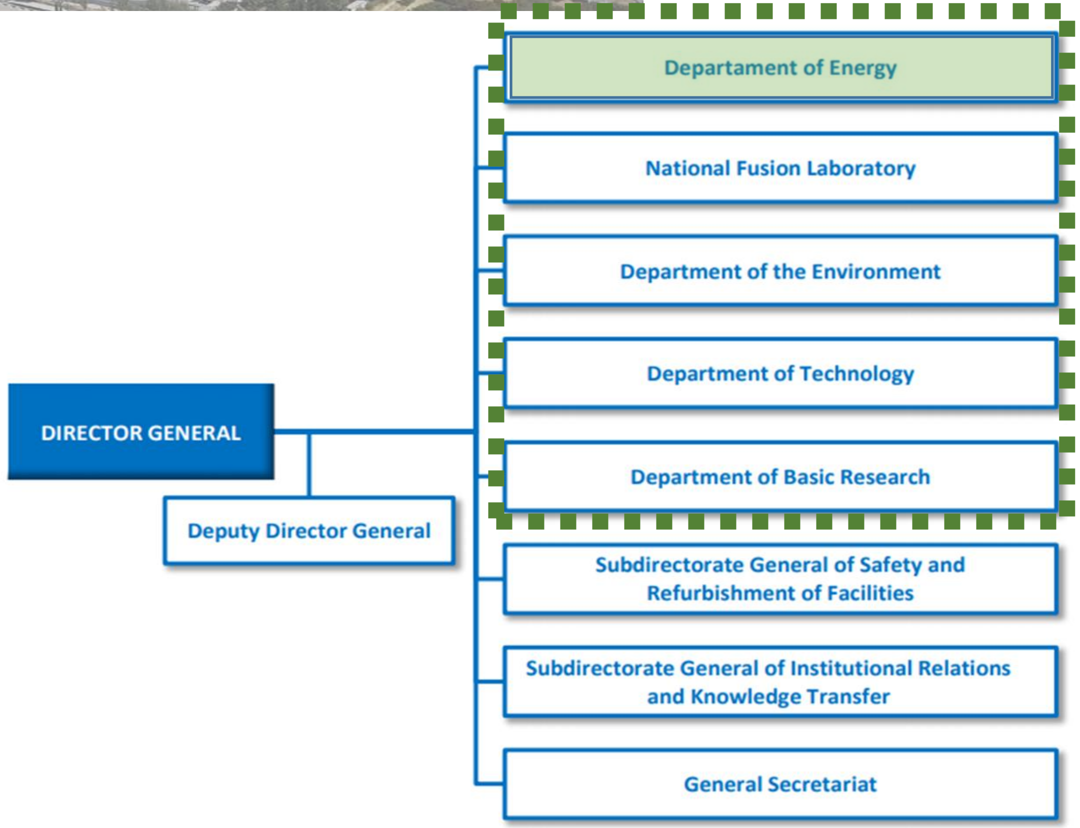
AGENCIA ESTATAL DE INVESTIGACIÓN

Ministry of Science and Innovation

CIEMAT

Center for Energy, Environmental and Technological Research



CIEMAT

Energy Efficiency Activities

Characterization of climatology and environment

Reduction of the energy demand. Passive Systems

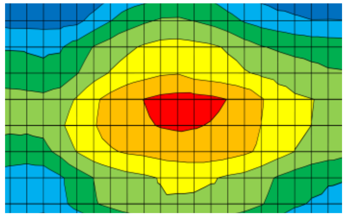
Envelope characterization

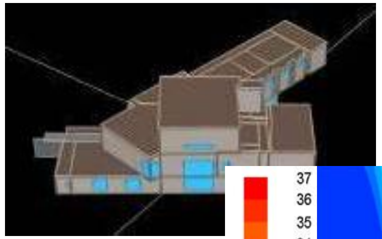
Modeling, dynamic simulation, experimental evaluation and monitoring

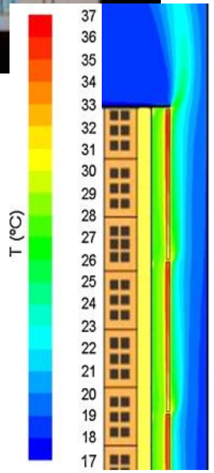
Efficient and integral energy management

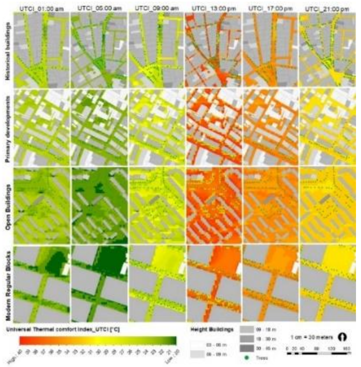
Integration of renewable energy

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

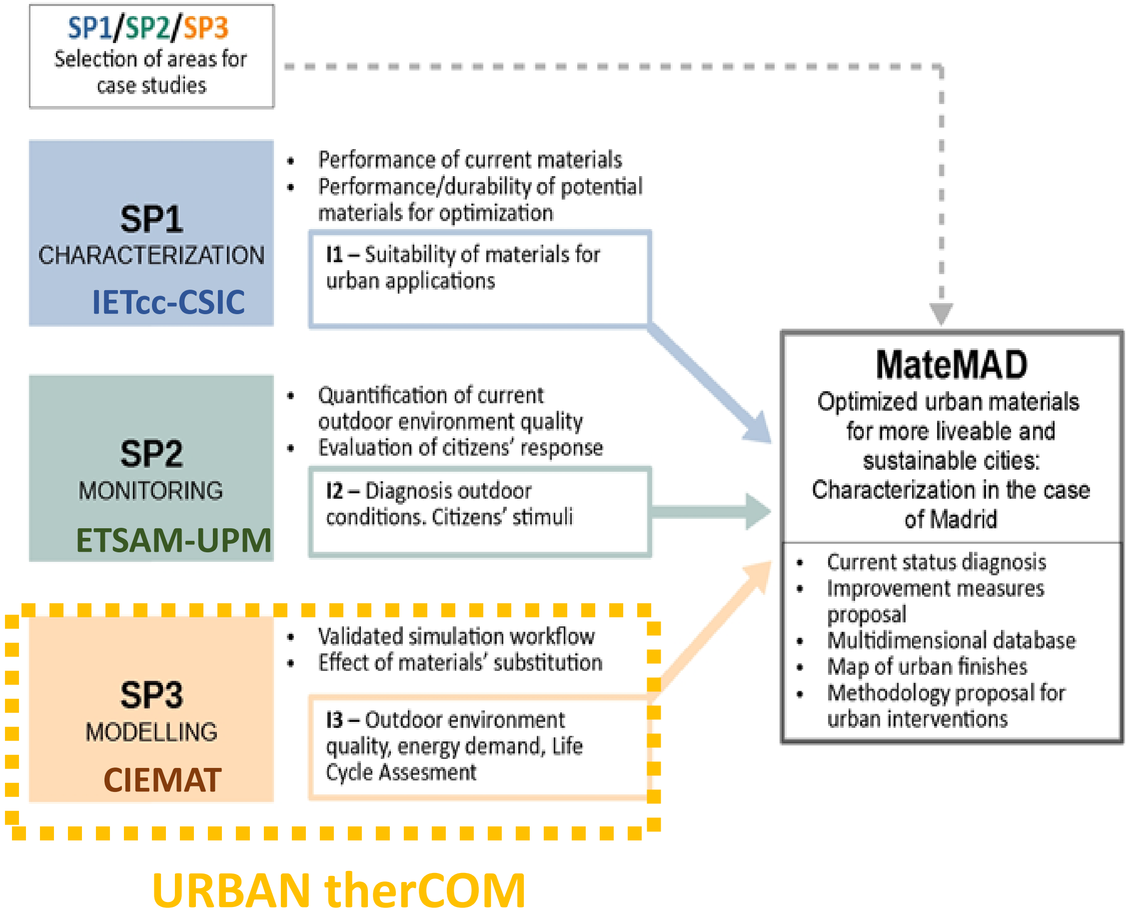
mateMAD Concept

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

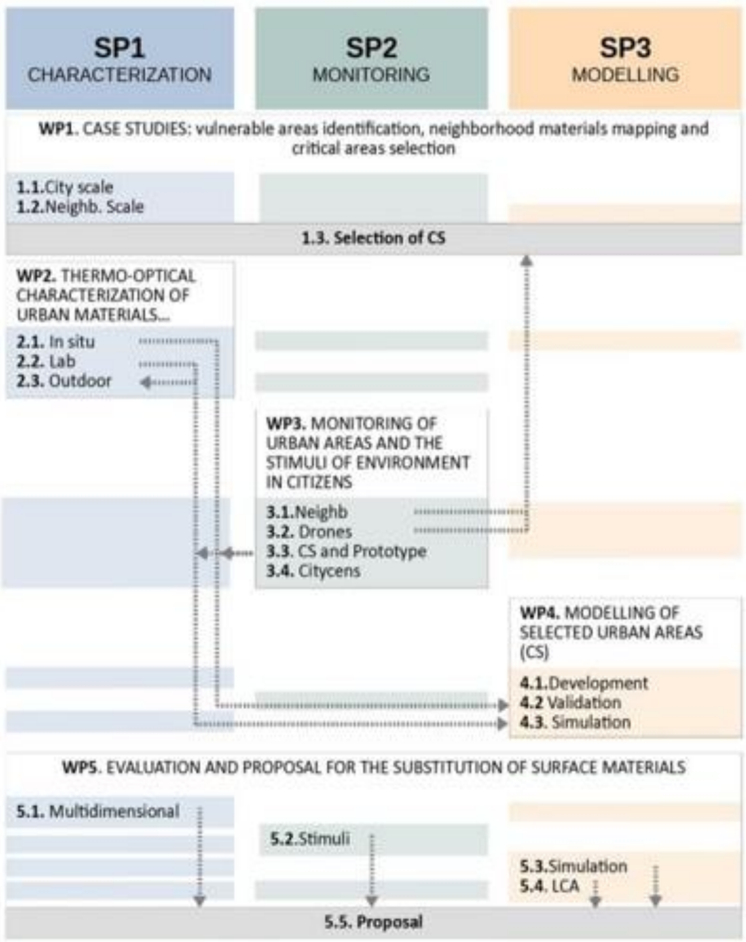
The second details thermo-optical (**TO**) characterization of a wide range of surface urban materials: in-situ, laboratory

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

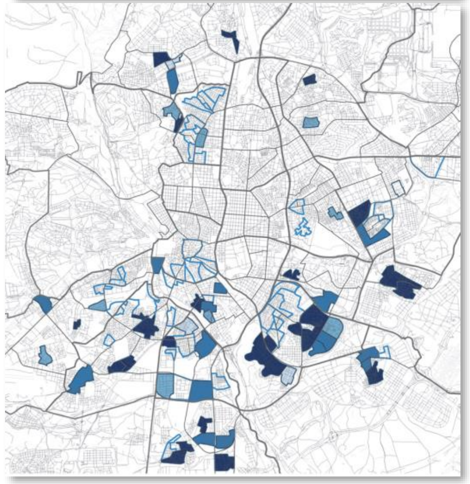


SELECTION OF NEIGHBORHOODS

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

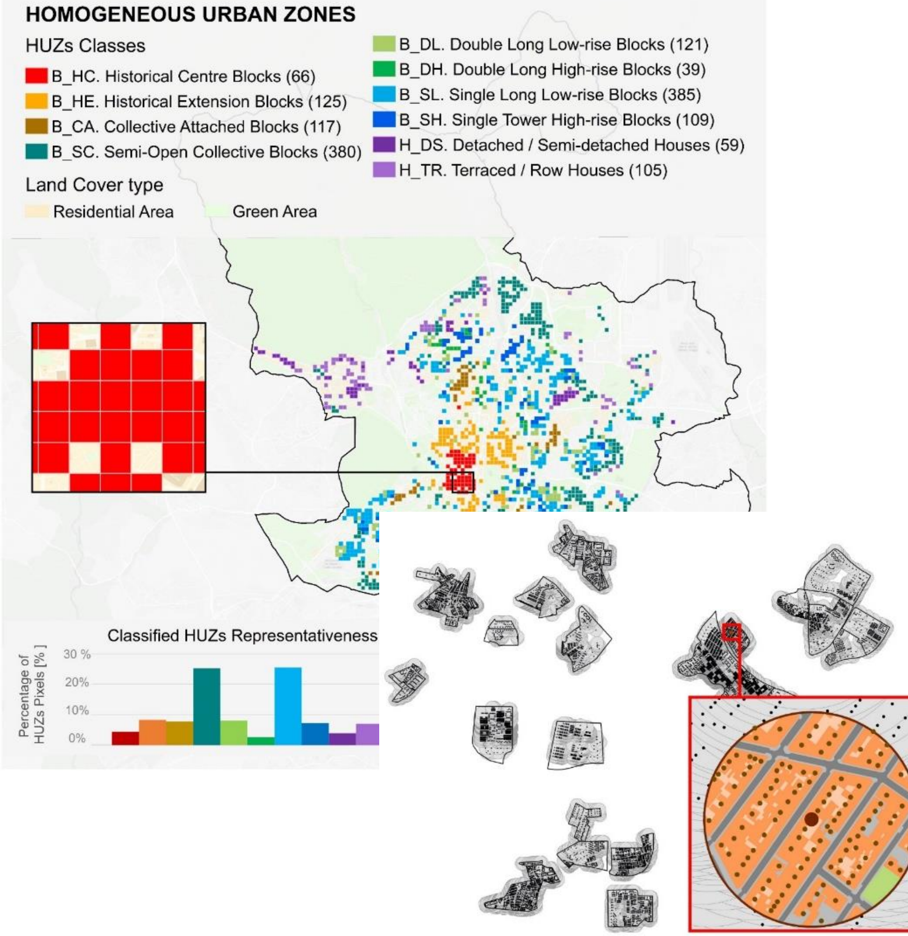
Severity of urban vulnerability

Energy poverty index



UHI intensity day+night

From: IETcc-CSIC. Paper presented to PLEA2022



From: Helena López Moreno (UiE3, CIEMAT)

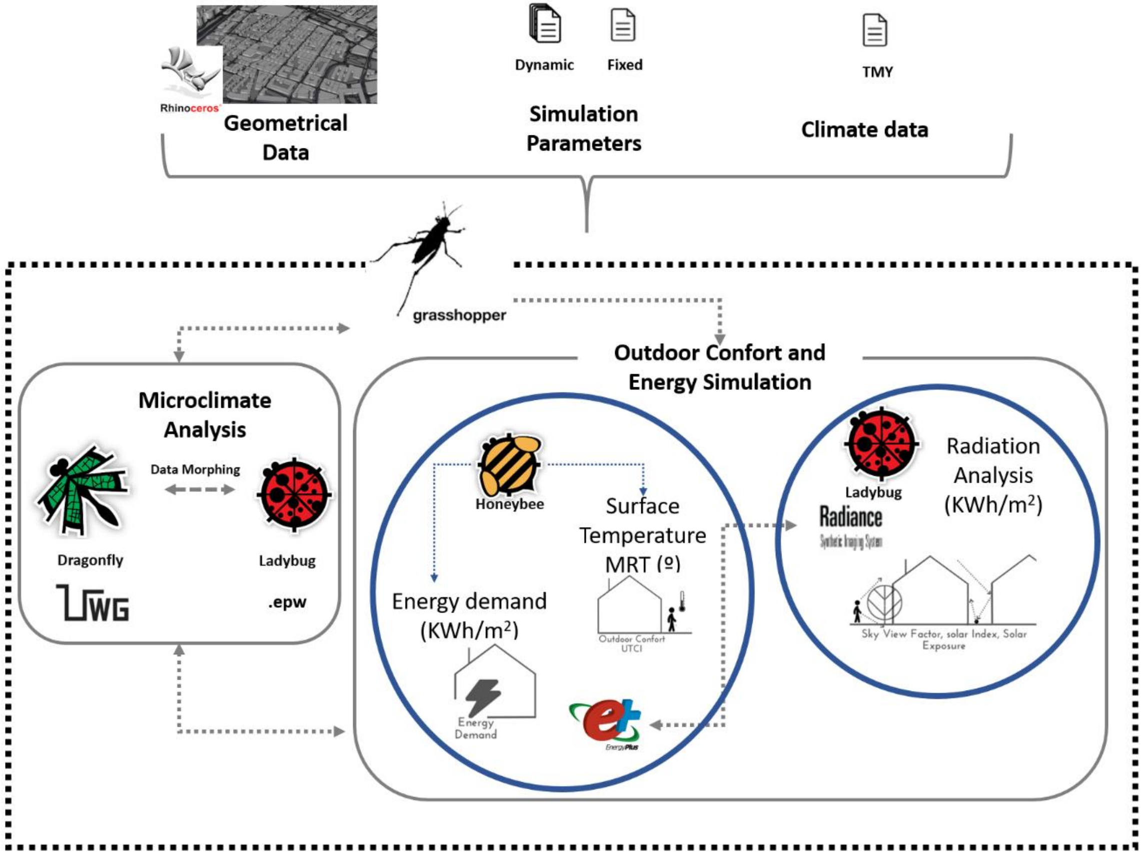
HUZ (Homogeneous Urban Zones) METHODOLOGY

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

mateMAD

MODELLING OF SELECTED URBAN AREAS

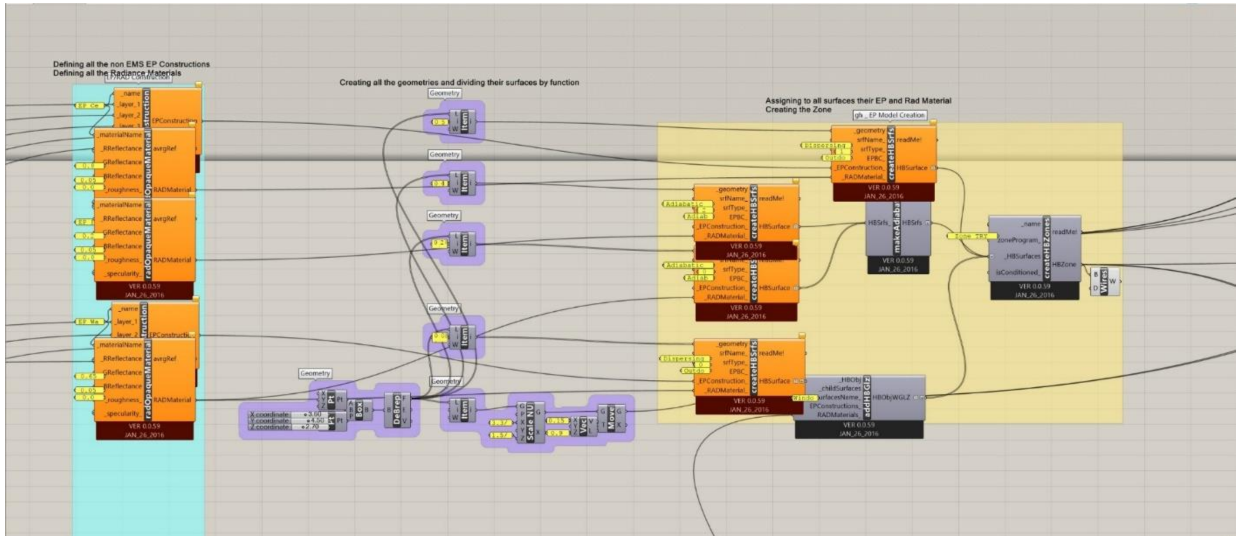
An **ad-hoc developed BPS tool** which enables to appropriately simulate the simulation of indoor and outdoor thermal field through an integrated approach, Grasshopper (GH) **based digital workflow** by means of add-ons Droagonfly, **HoneyBee** and **LadyBug**.



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

THANK YOU

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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

IPCC 6th Assessment Report

*Efforts to halt **catastrophic climate change** are being held back by **"inertia"** in the built environment sector*

*Engineers, Architects and urban planners should really look at **rethinking the way they work**…*

*…they need to develop a new vocabulary **and more climate change specific solutions***

Scales to “rethink” Envelopes of Climate Change.

Key Words

Regional Climate Change

Microclimate

Building Form

Facade design

Energy Flows

Indoor

Microclimatic Cities

Facade Interfaces

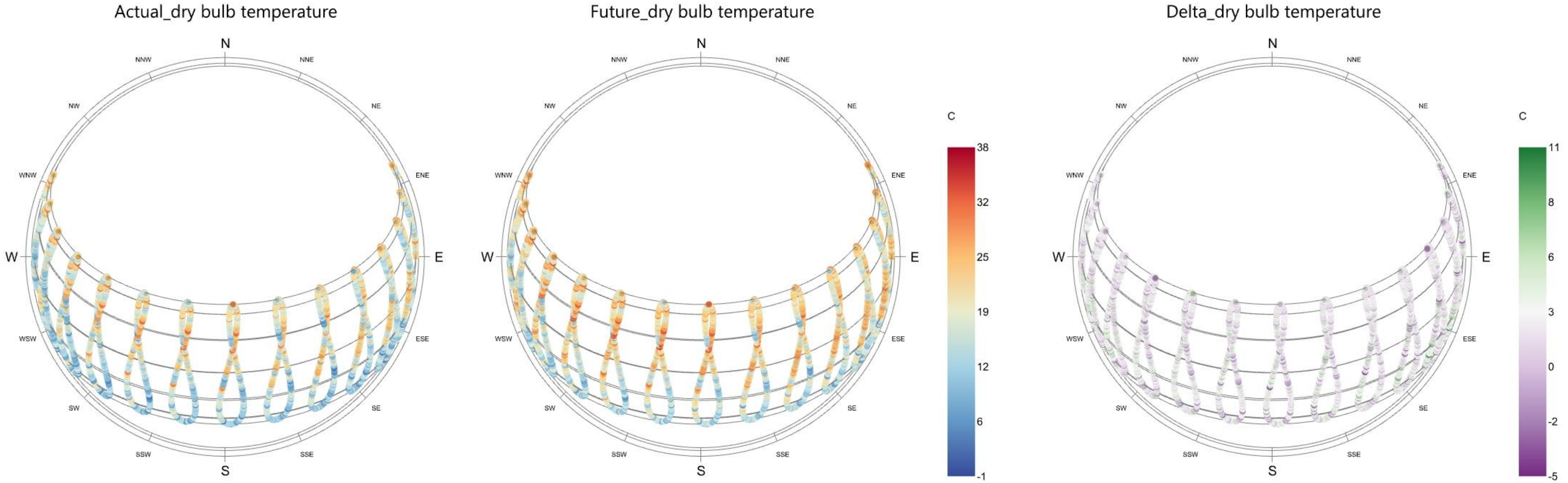
Indoor Microclimate

Ecological Living Layers

Computing

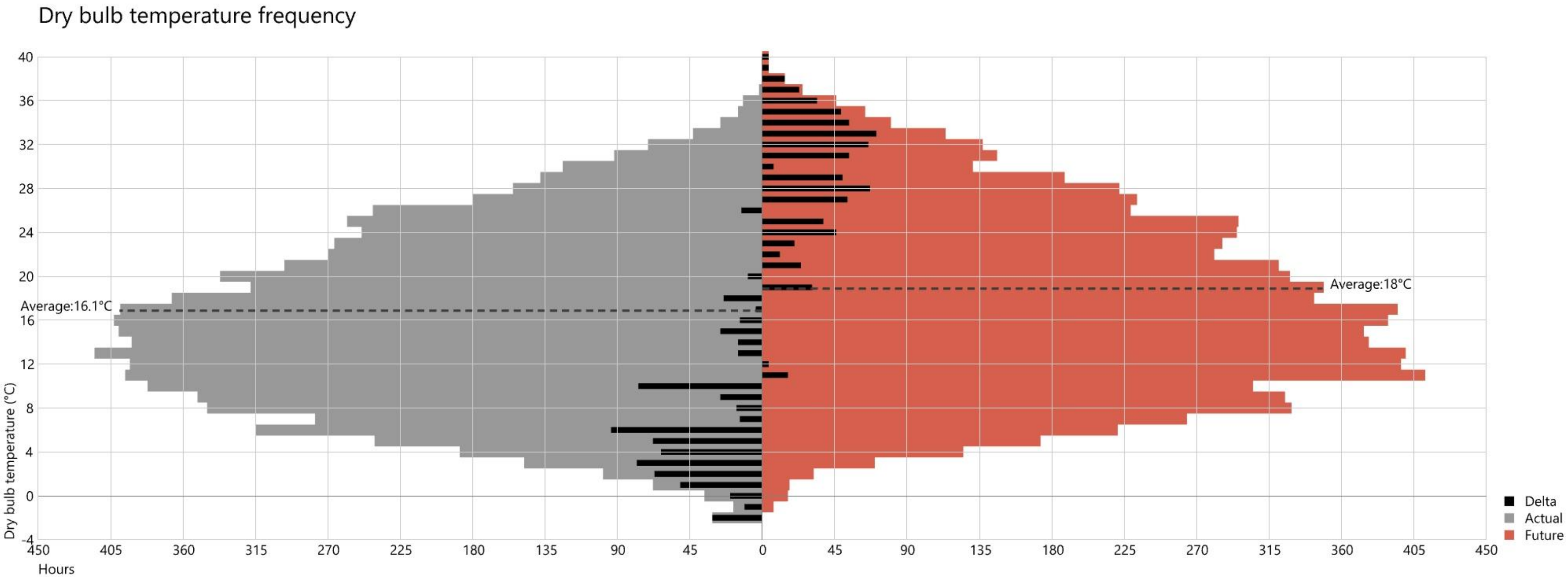
Climate Change

CBE tool climate panel (with Turrini and prof. Schiavon)

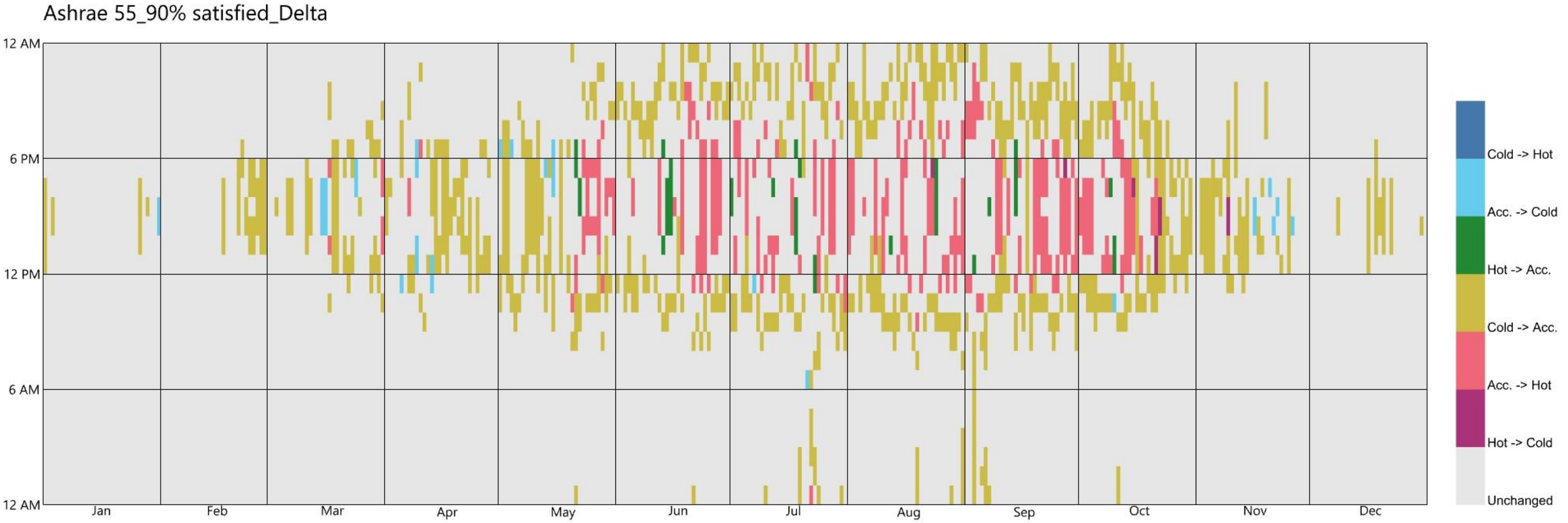


Climate Change

CBE tool climate panel (with Turrini and prof. Schiavon)



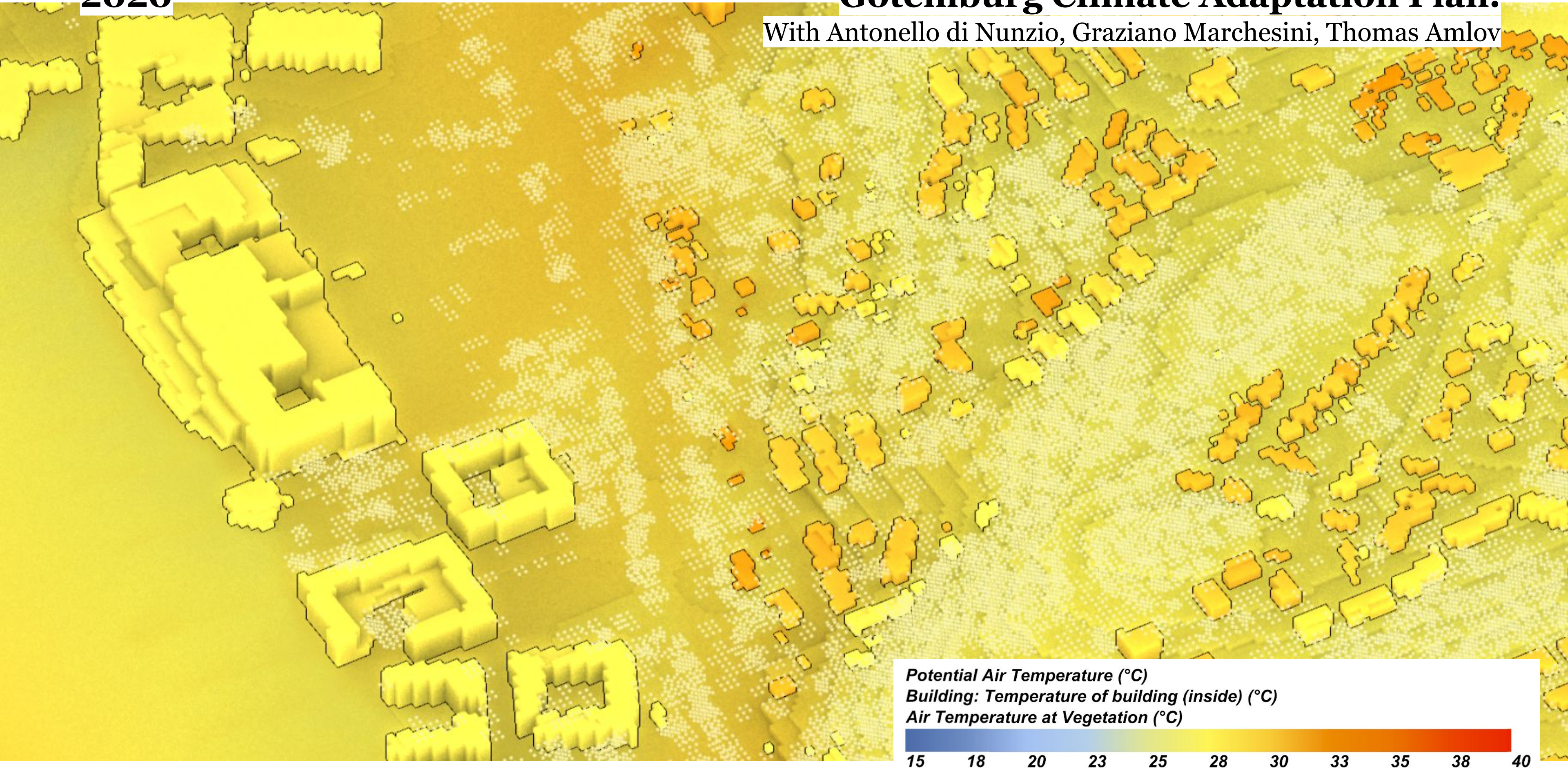
Climate Change
CBE tool climate panel (with Turrini and prof. Schiavon)



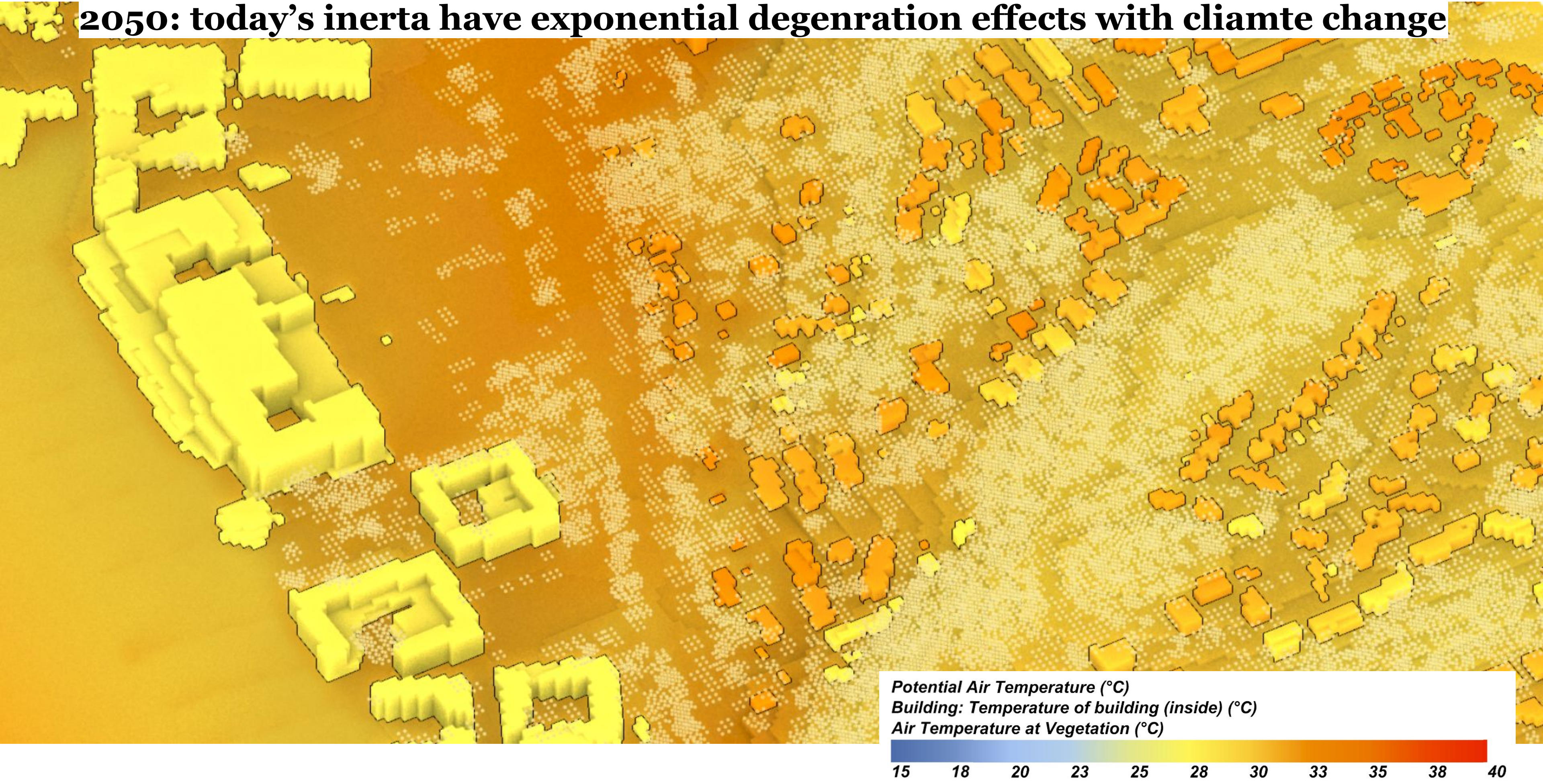
2020

Gotemburg Climate Adaptation Plan.

With Antonello di Nunzio, Graziano Marchesini, Thomas Amlov

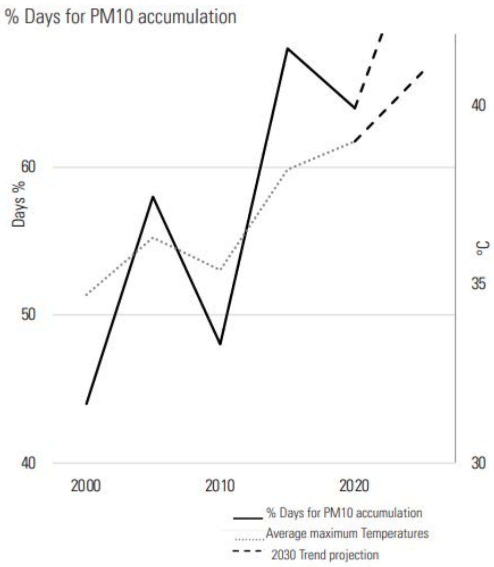


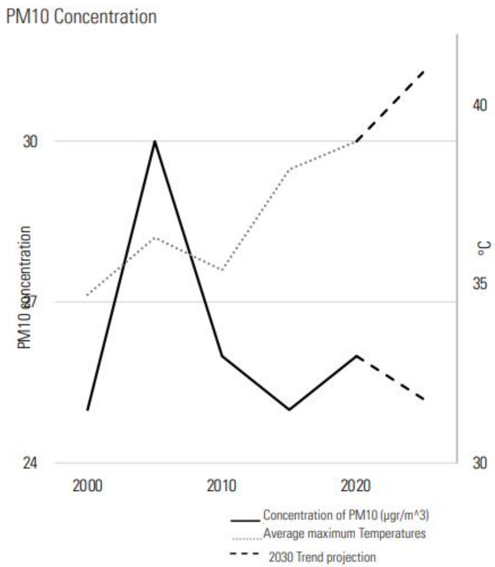
2050: today's inerta have exponential degenration effects with cliamte change

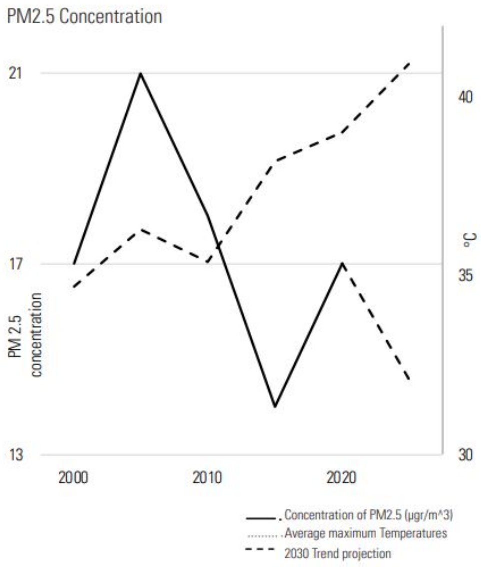


Air Pollution

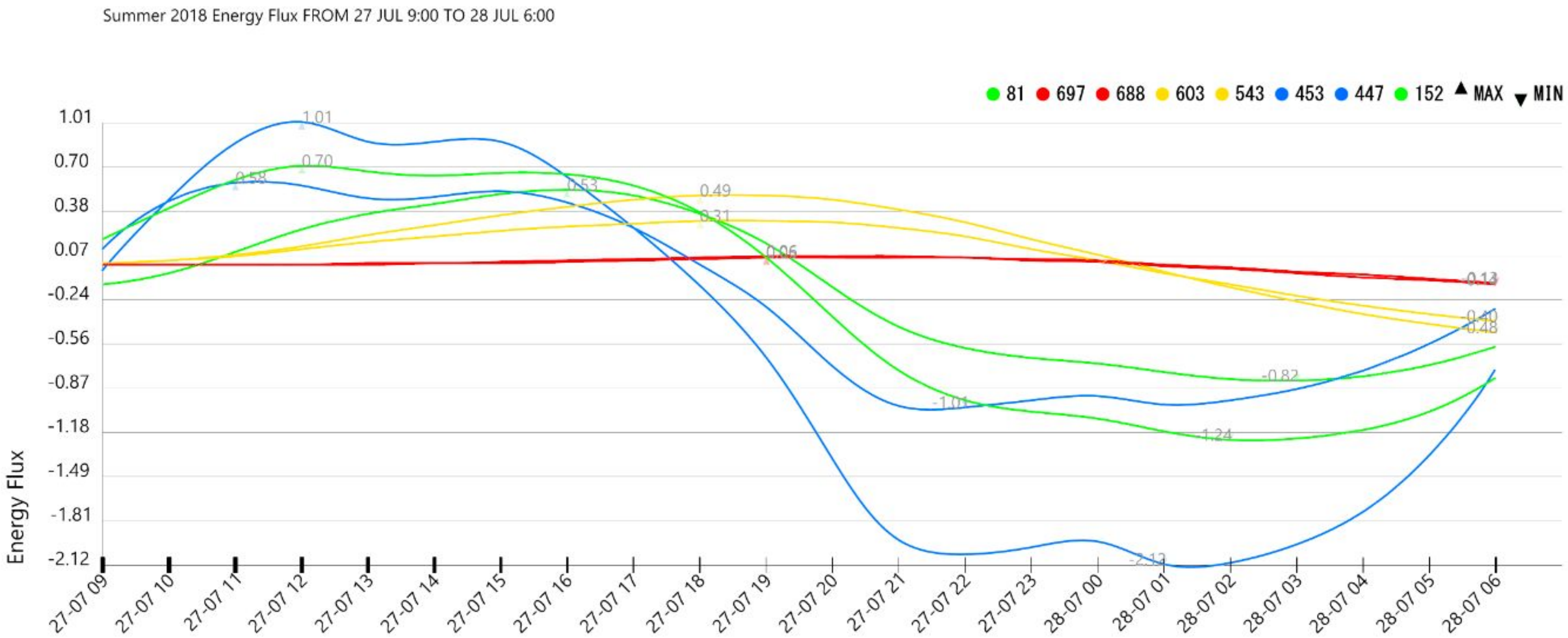
Parametric Modelling







Indoor buildings temperature



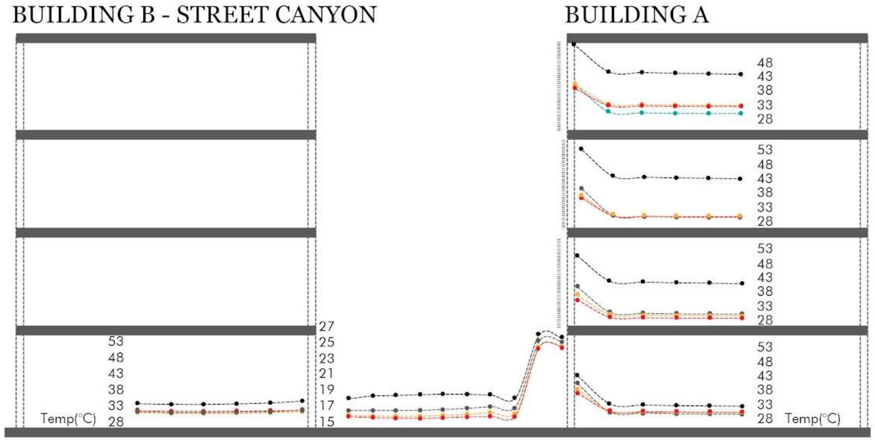
Milan Expo
with B22

Lavazza
with Manens

Park Hotel
with SOM

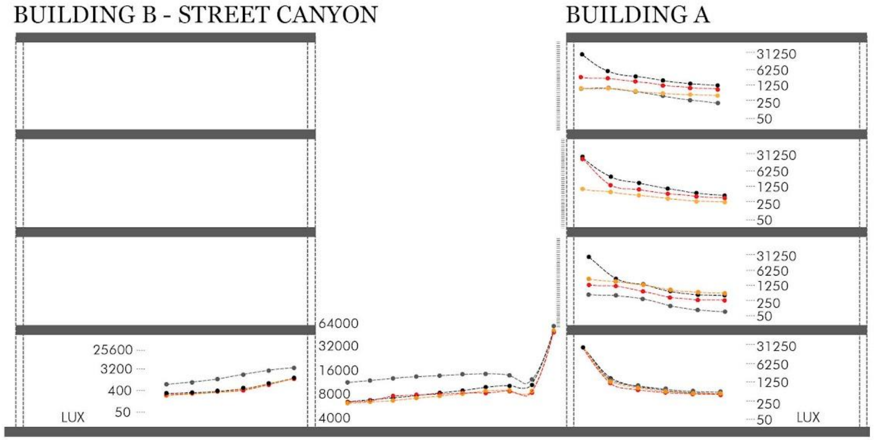
Facade as an Outdoor and Indoor Climate Giver

Copenhagen (with Angel Perez)



RESULTS - THERMAL COMFORT 15:00-16:00 4TH AUGUST

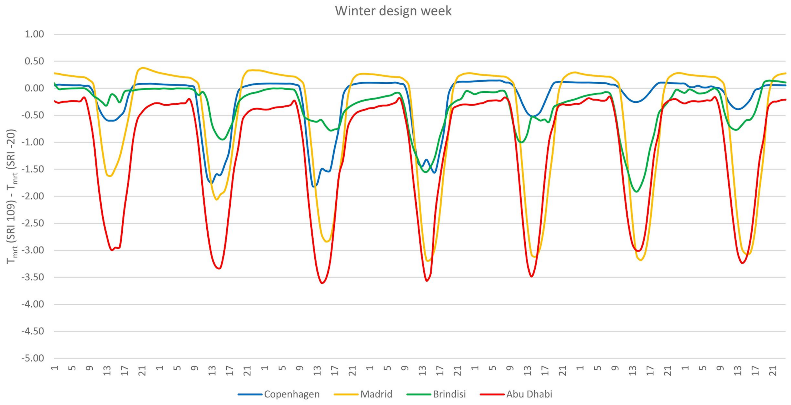
- no shading
- steady state
- dynamic venetian blind
- adaptive facade
- the applied adaptive facade

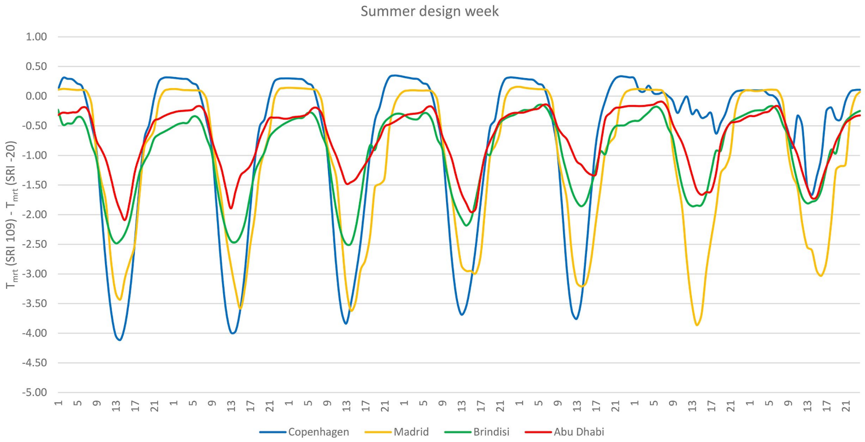


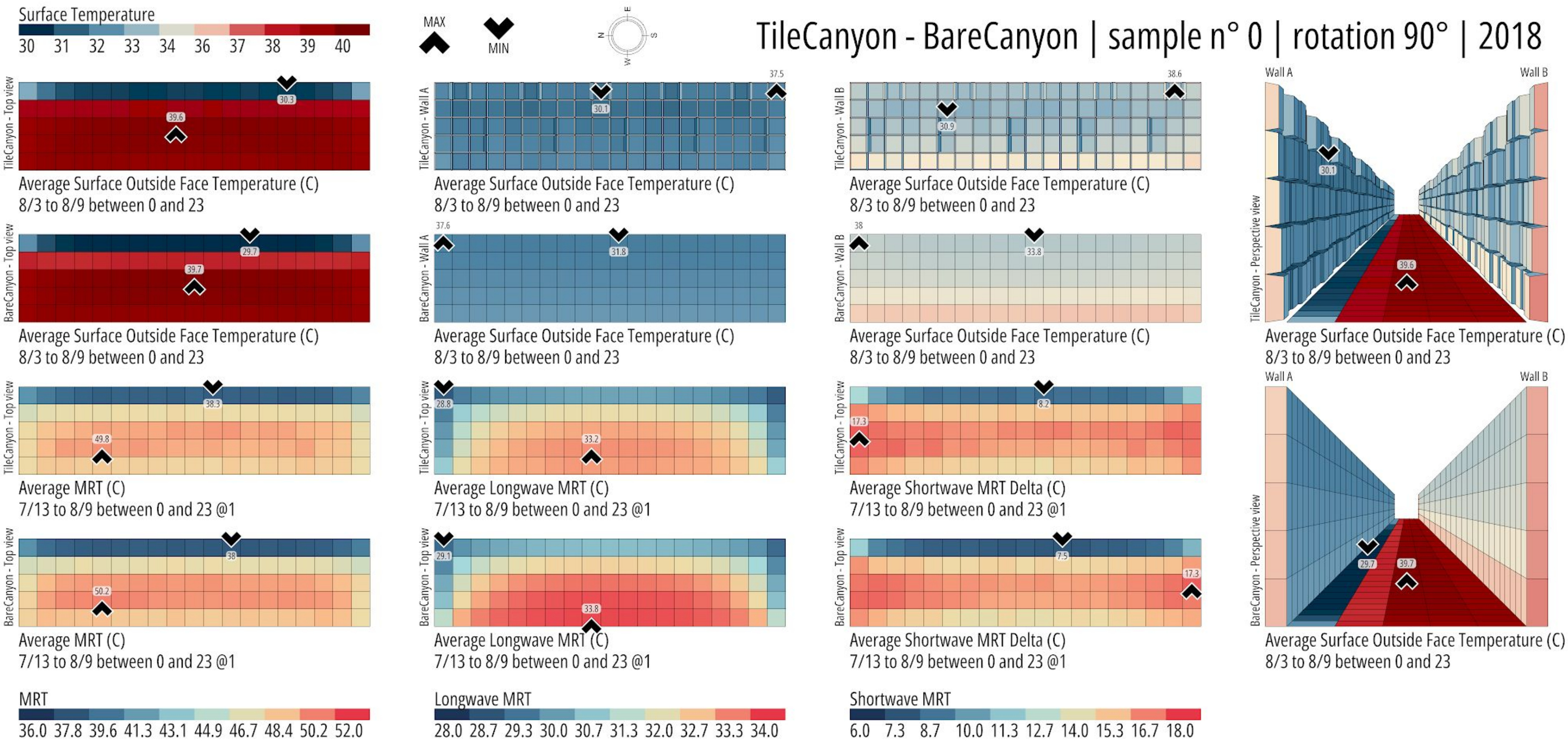
RESULTS - DAYLIGHT URBAN CANION 15:00 4TH

- no shading
- steady state
- dynamic venetian blind
- adaptive facade
- the applied adaptive facade

Facade as an Outdoor and Indoor Climate Giver. Systematic Studies
Thermal Emittance (0.1 - 0.9) Solar Reflectance (0.1 - 0.9)
with F. Fiorito






TileCanyon - BareCanyon | sample n° 0 | rotation 90° | 2018
Surface Temperature
30 31 32 33 34 36 37 38 39 40
MAX
MIN
TileCanyon - Top view
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
TileCanyon - Wall A
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
TileCanyon - Wall B
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
Wall A
Wall B
TileCanyon - Perspective view
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
BareCanyon - Top view
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
BareCanyon - Wall A
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
BareCanyon - Wall B
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
TileCanyon - Top view
Average MRT (C)
7/13 to 8/9 between 0 and 23 @1
TileCanyon - Top view
Average Longwave MRT (C)
7/13 to 8/9 between 0 and 23 @1
TileCanyon - Top view
Average Shortwave MRT Delta (C)
7/13 to 8/9 between 0 and 23 @1
Wall A
Wall B
BareCanyon - Perspective view
Average Surface Outside Face Temperature (C)
8/3 to 8/9 between 0 and 23
BareCanyon - Top view
Average MRT (C)
7/13 to 8/9 between 0 and 23 @1
BareCanyon - Top view
Average Longwave MRT (C)
7/13 to 8/9 between 0 and 23 @1
BareCanyon - Top view
Average Shortwave MRT Delta (C)
7/13 to 8/9 between 0 and 23 @1
MRT
36.0 37.8 39.6 41.3 43.1 44.9 46.7 48.4 50.2 52.0
Longwave MRT
28.0 28.7 29.3 30.0 30.7 31.3 32.0 32.7 33.3 34.0
Shortwave MRT
6.0 7.3 8.7 10.0 11.3 12.7 14.0 15.3 16.7 18.0

Alaska: Carbon Positive Sustainable Protein Production

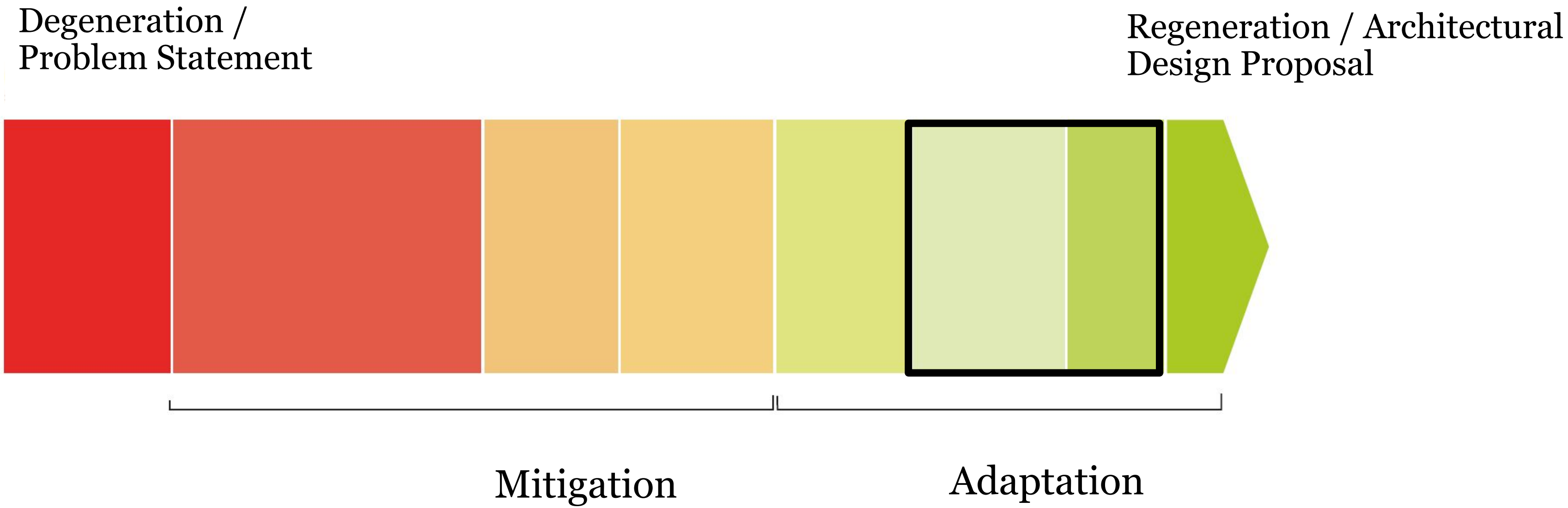
with AEE Royal Danish Academy and David Garcia

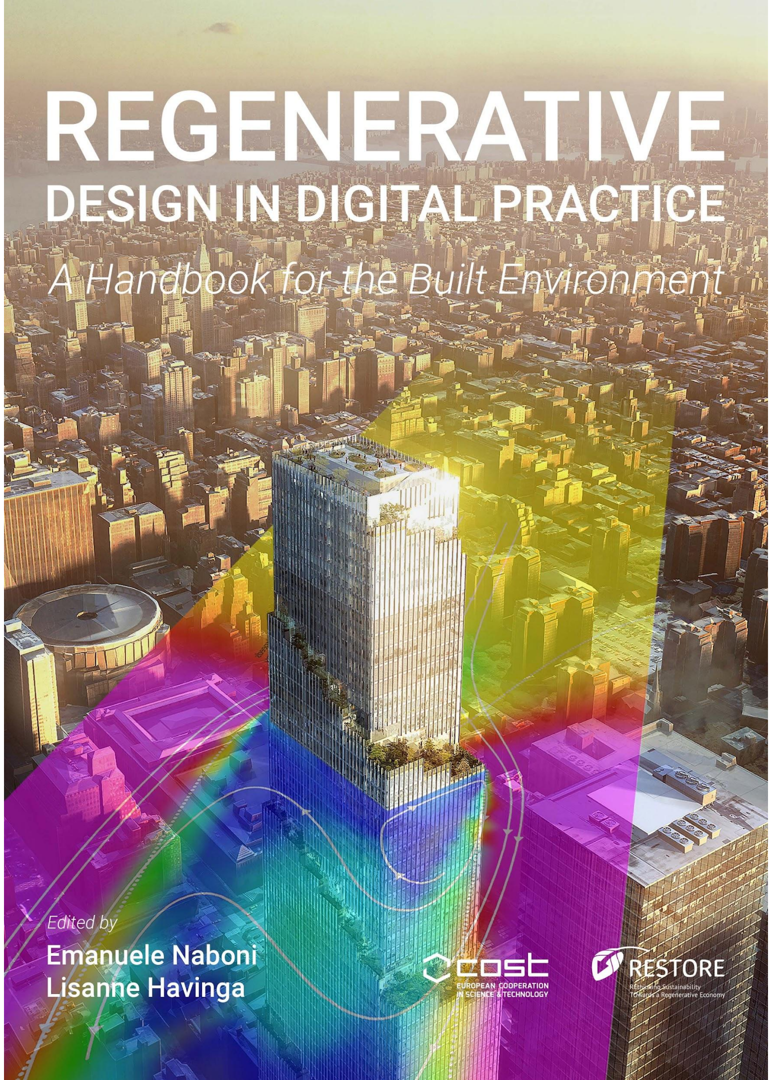
Living Layers

with AEE Royal Danish Academy and David Garcia

VS

What is the correct formulation of a climate change strategy?





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go to Emanuele Naboni

Let’s be in touch!

instagram:
emanuele_naboni_climate

or email:
emanuele.naboni@gmail.com

Session 1:

Modelling Linking Outdoor and Indoor

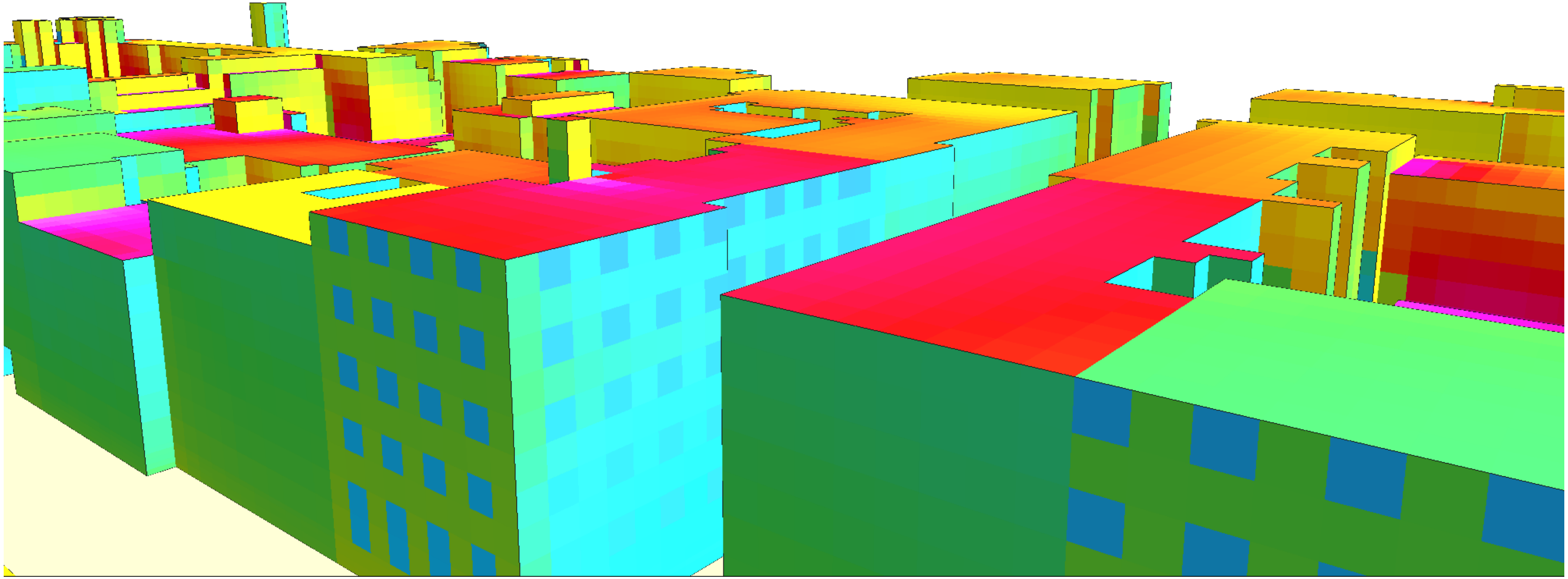
ENVI_MET

Inside the Outside

26.04.2023

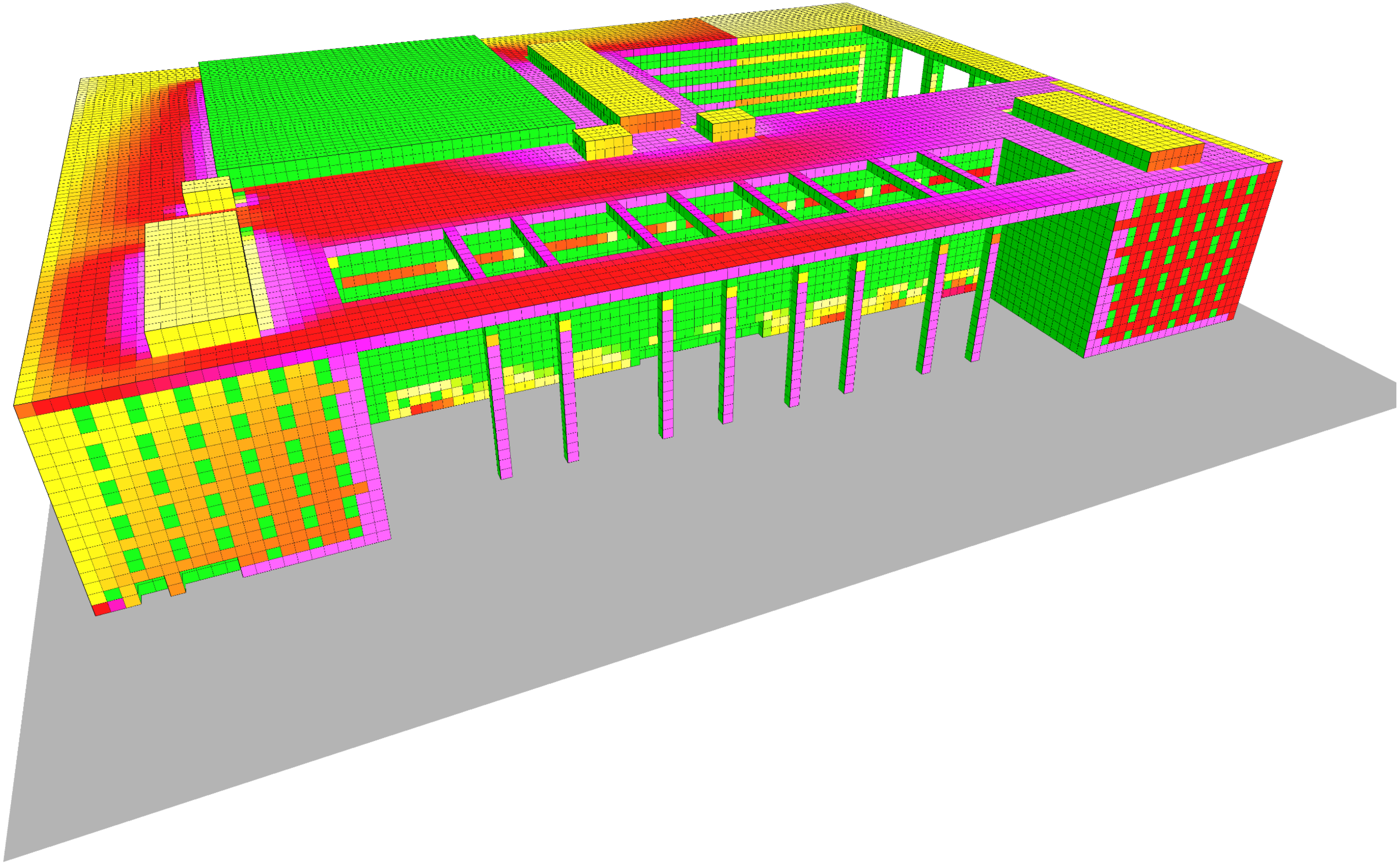
Decoding Urban Nature

Outside influencing Inside



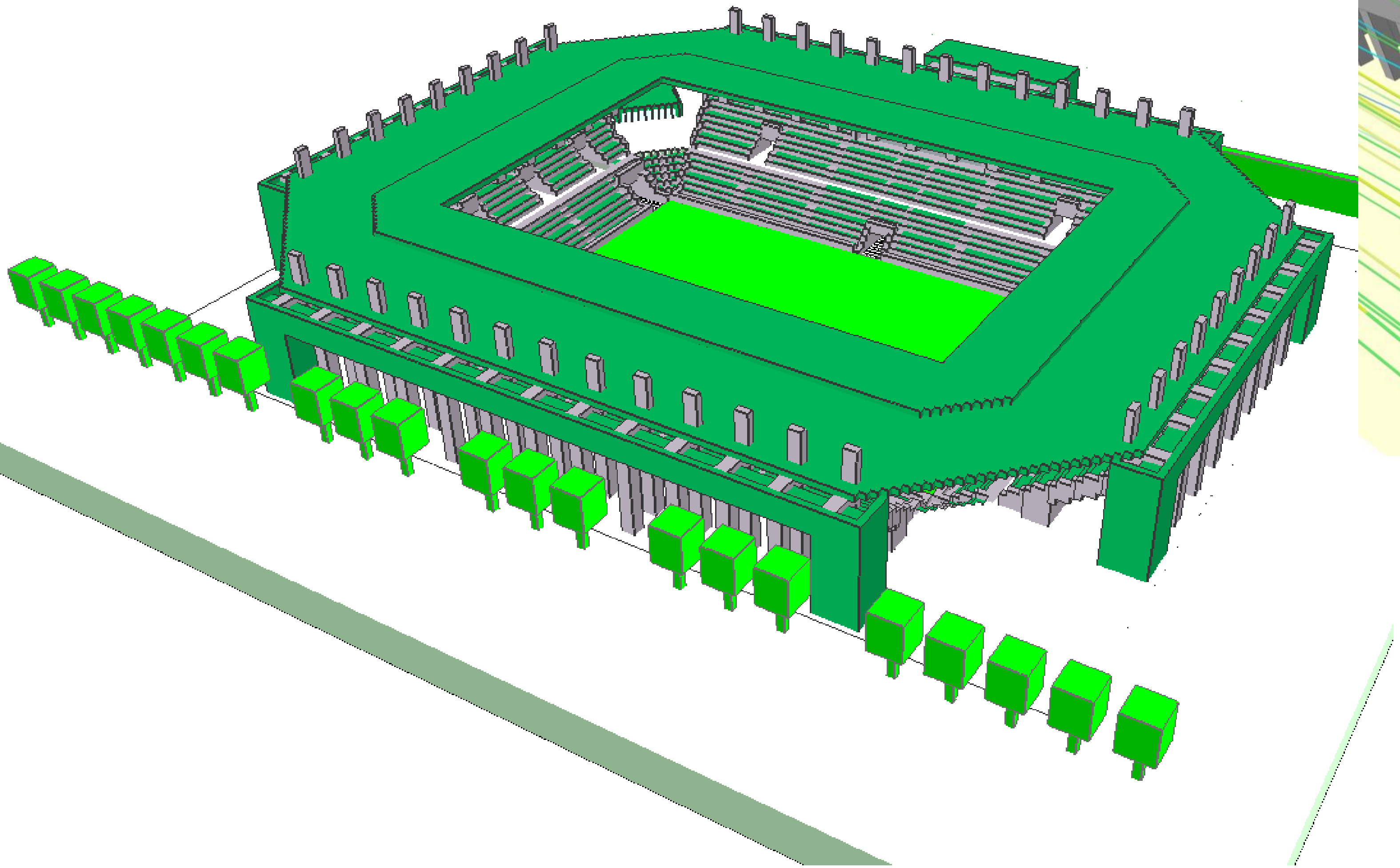
ENVI_MET

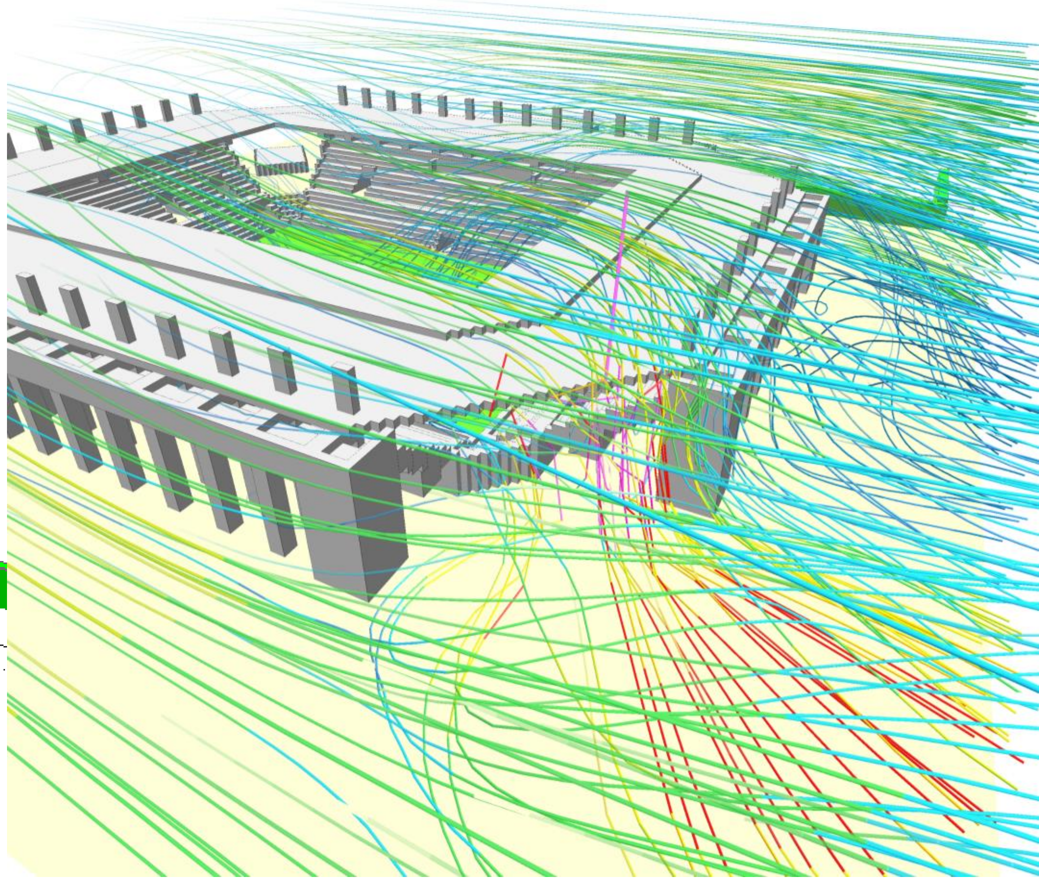
Outside influencing Inside



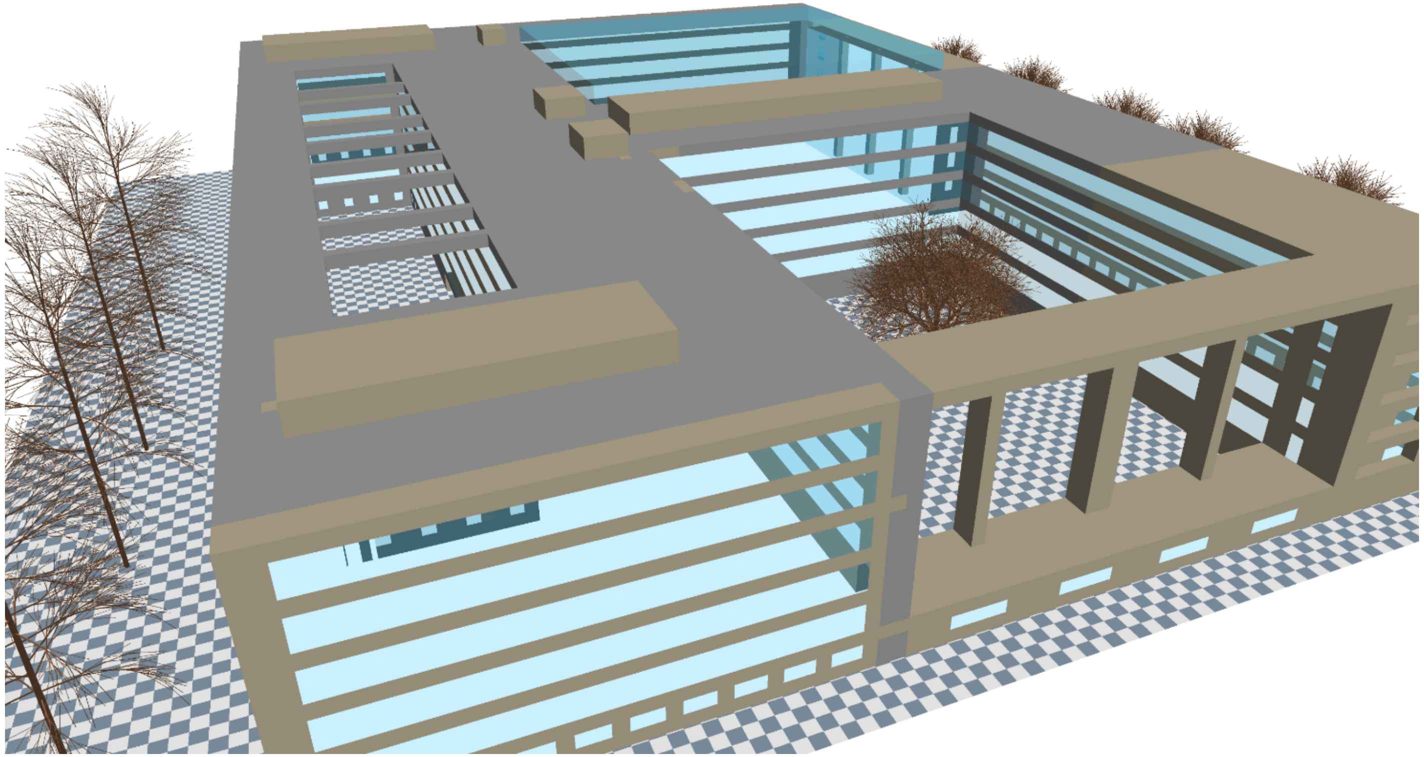
ENVI_MET

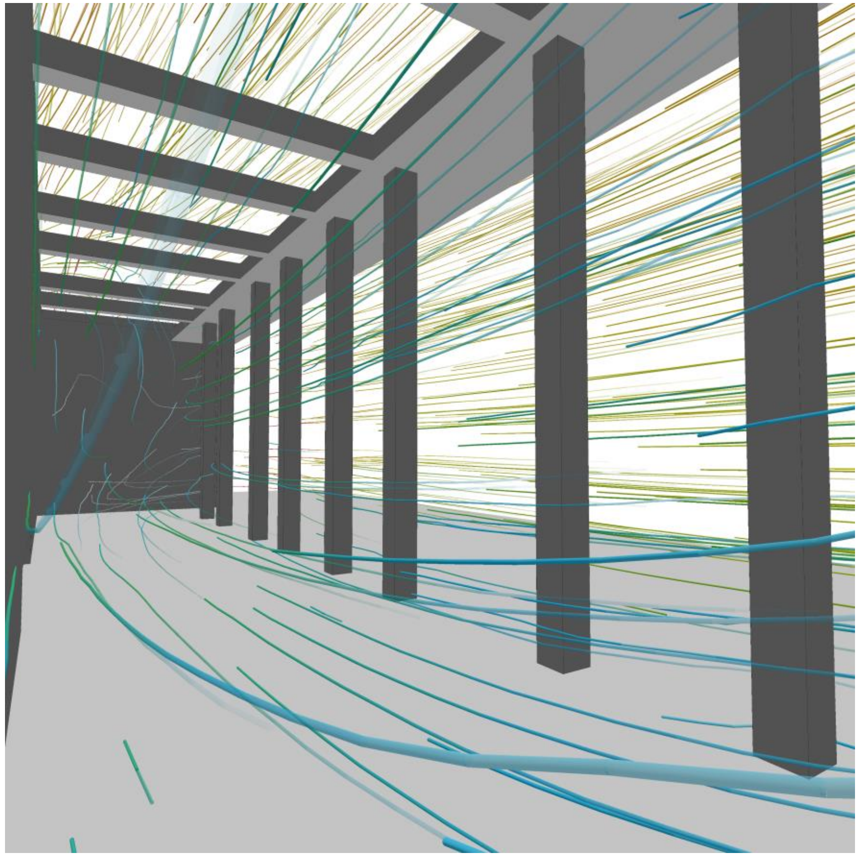
Ambiguous Spaces





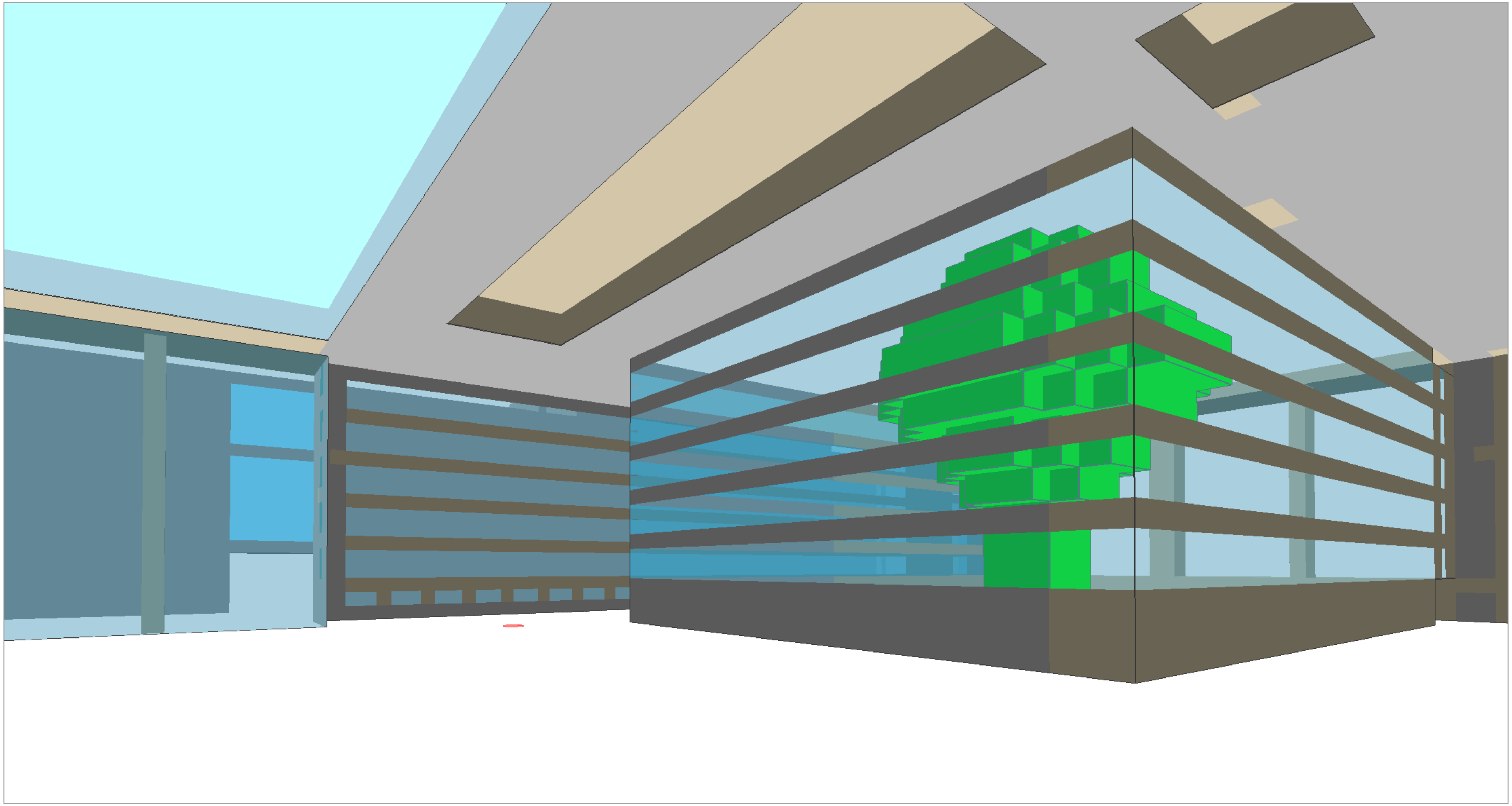
Ambiguous Spaces



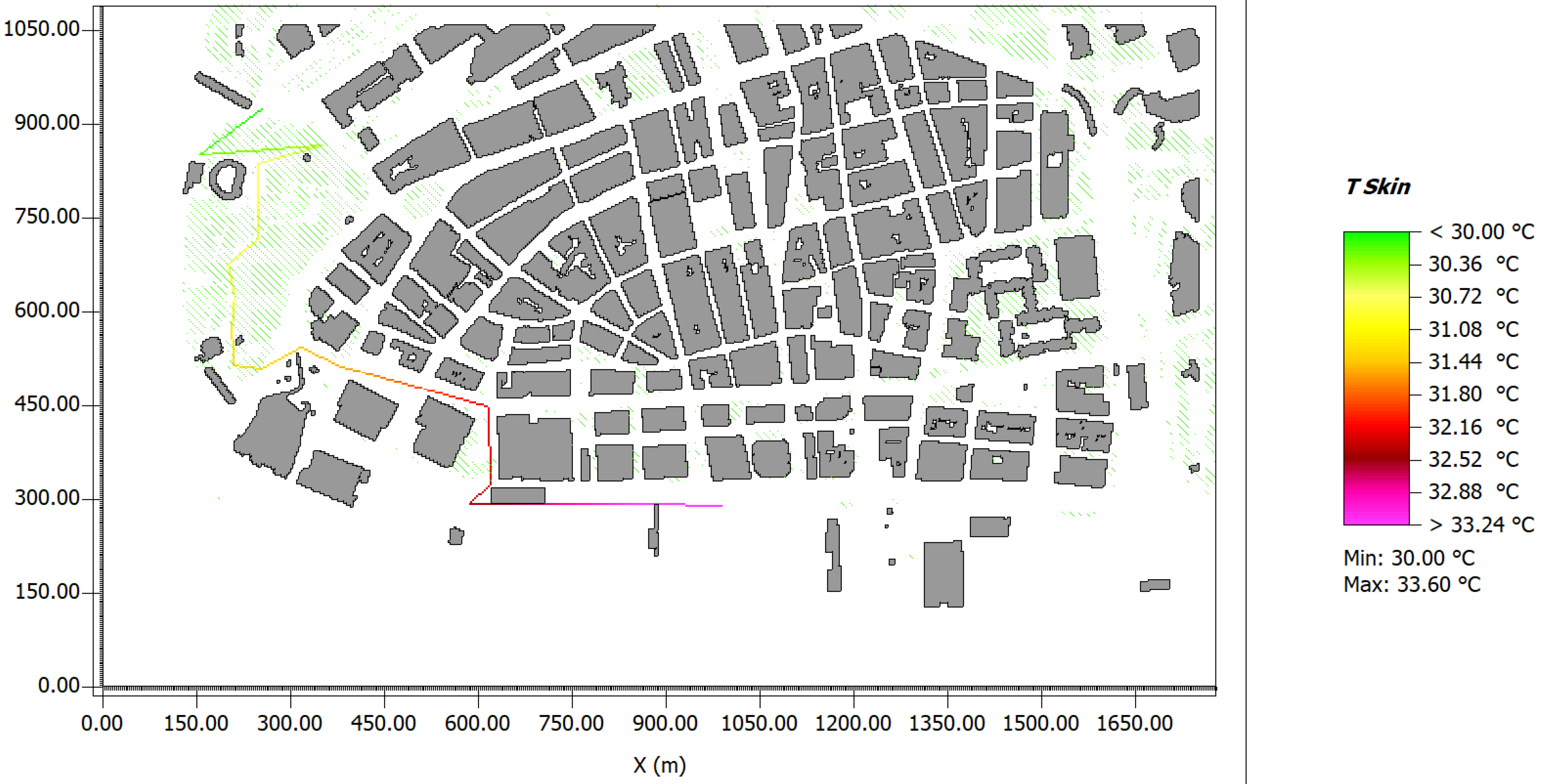


ENVI_MET

From Inside to Outside: Views



From Inside to Outside: Walks



Connecting micro-microclimates and energy performance

Victoria Patricia Lopez-Cabeza, PhD. *Universidad de Sevilla*

UNIVERSIDAD DE SEVILLA

sath tep206

Sostenibilidad en Arquitectura, Tecnología y Patrimonio
Materialidad y Sistemas Constructivos

PRESENTATION

Dr. Victoria Patricia Lopez-Cabeza

PhD in Architecture. Universidad de Sevilla
MDes Energy and Enviroment. Harvard University
Architect. Universidad de Sevilla

sath tep206

Sostenibilidad en Arquitectura, Tecnología y Patrimonio
Materialidad y Sistemas Constructivos

MORE-PATIO

From: **15-01-2018**
To: **31-12-2019**

GOBIERNO DE ESPAÑA | MINISTERIO DE CIENCIA E INNOVACIÓN

Eco efficient Design of Courtyards in Buildings through Reduced Order Modeling.

ROAD / BETTER

From: **01-01-2019**
To: **30-09-2022**

GOBIERNO DE ESPAÑA | MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

ROM **O**ptimization for **A**rchitecture and **D**esign
BEnchmarking **T**hermal behavior in **T**ransitional spaces as **E**nergy efficiency **R**esource.

AURA STRATEGY

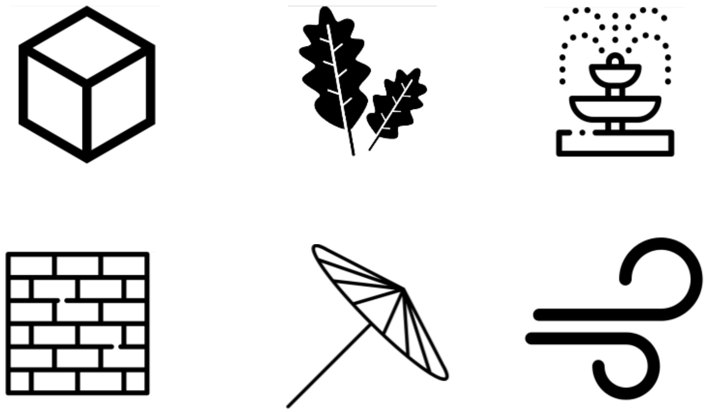
From: **19-09-2021**
To: **9-12-2022**

Junta de Andalucía

Direct applications of "Aura Strategy" from Solar Decathlon US Team on the restoration of Andalusian obsolete neighborhoods.

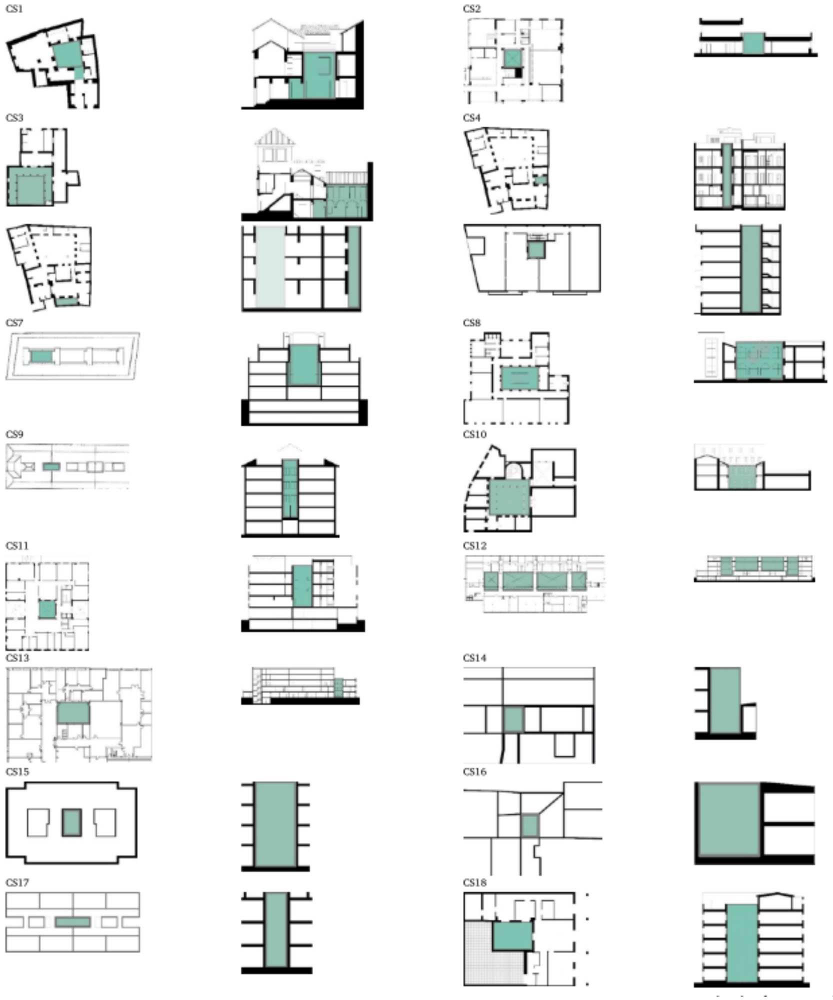
INTRODUCTION

- Courtyards can be key elements in passive conditioning of buildings in hot climates.
- Monitoring results show a significant reduction of the outdoor temperature in courtyards.
- The effect of the microclimate of courtyards is not usually considered in building design.



Factors that impact the performance of the courtyard

COURTYARD PERFORMANCE



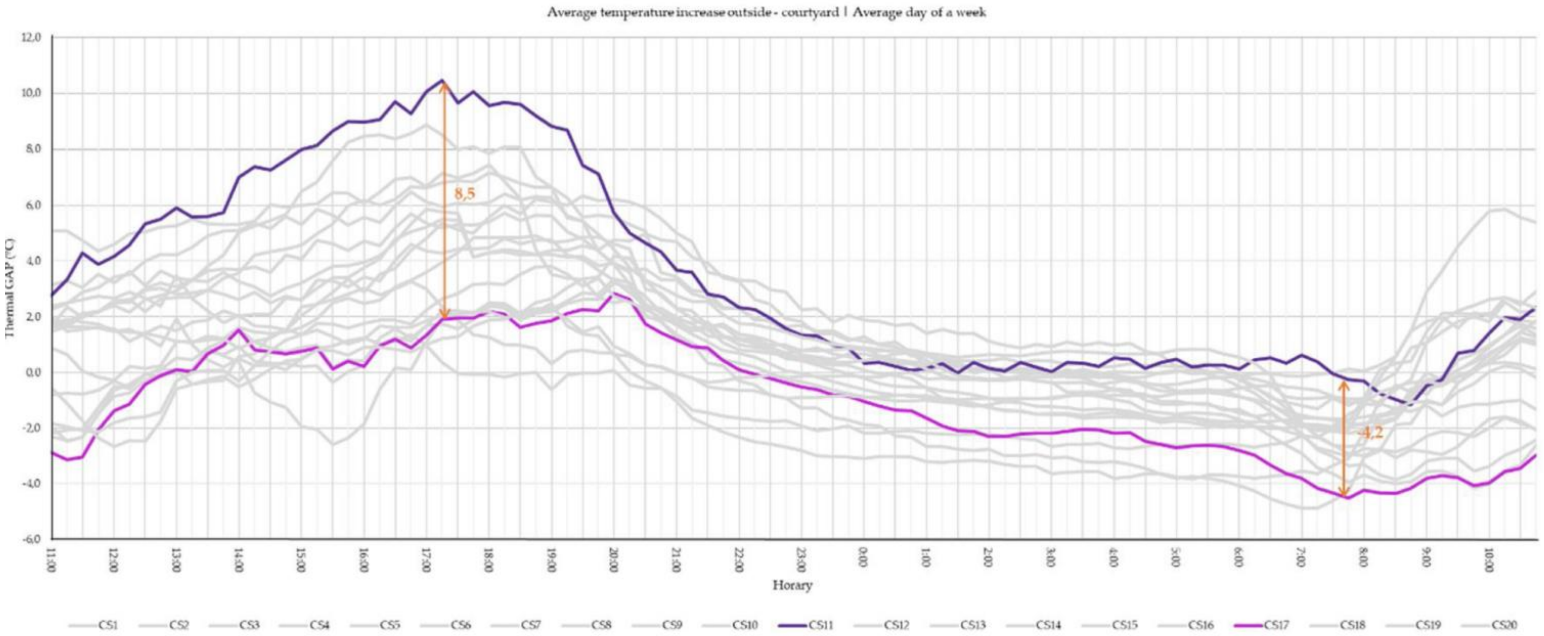


Fig. 4. TG representation contrasting all the courtyards temperatures versus the outdoor ones.

C. Rivera-Gómez, E. Diz-Mellado, C. Galán-Marín, V. López-Cabeza, **Tempering potential-based evaluation of the courtyard microclimate as a combined function of aspect ratio and outdoor temperature, Sustainable Cities and Society.** 51 (2019) 101740. https://doi.org/10.1016/j.scs.2019.101740.

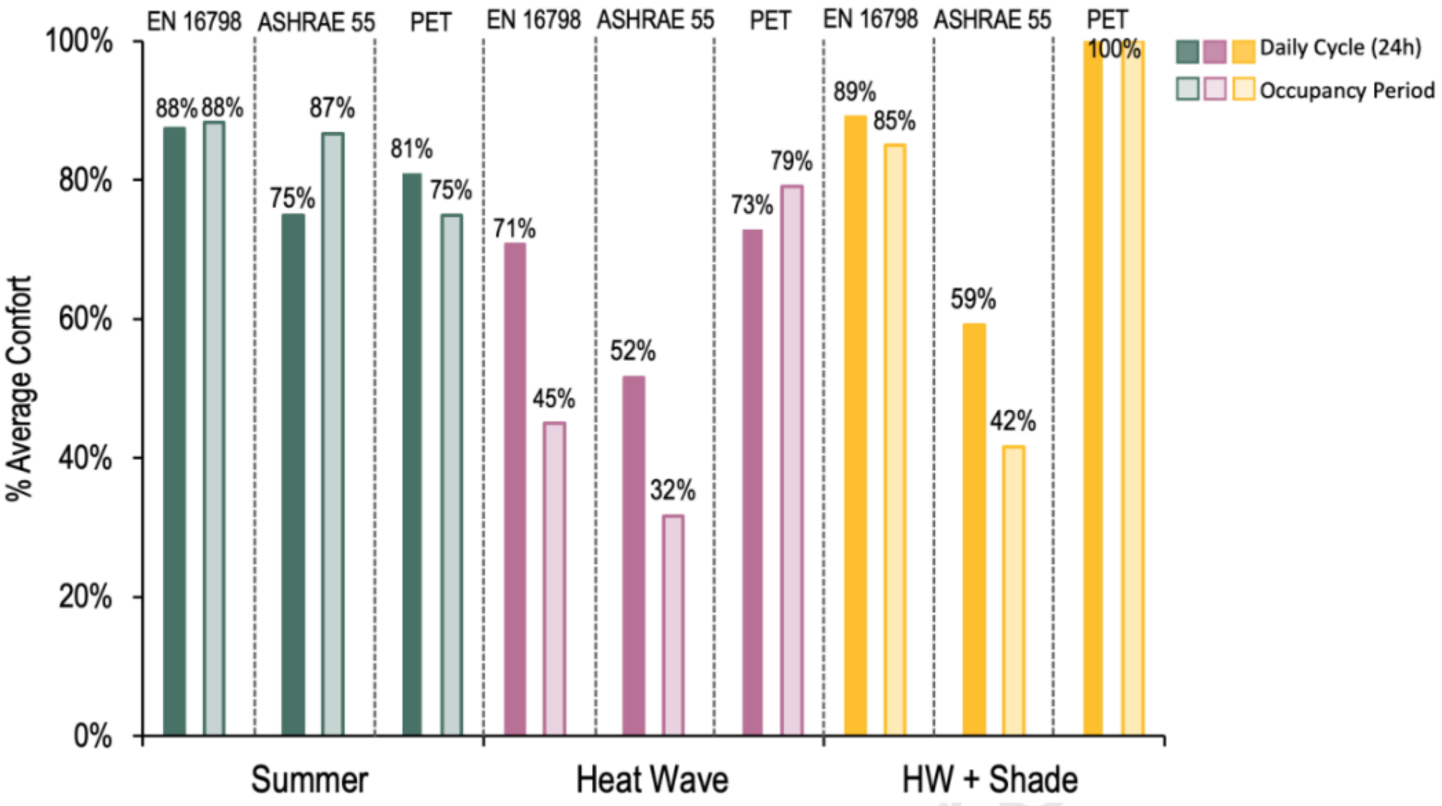
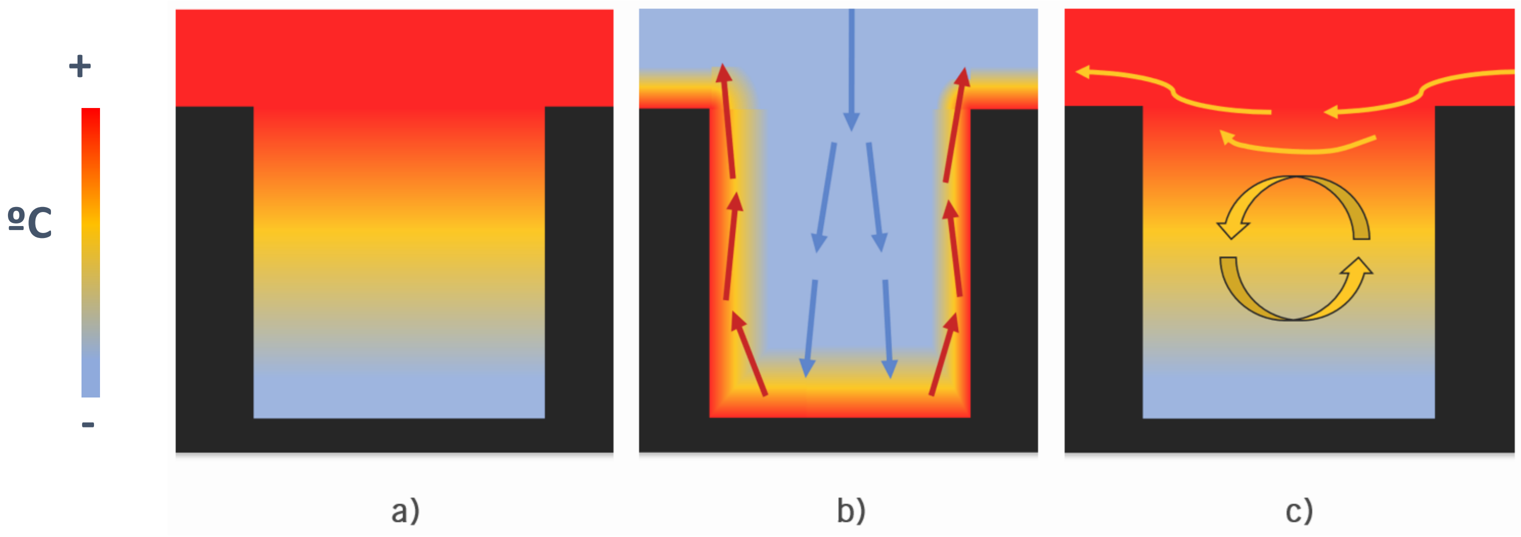


Figure 16. Percentage of comfort hours EN 16798 vs ASHRAE 55.

E. Diz-Mellado, M. Nikolopoulou, V.P. López-Cabeza, C. Rivera-Gómez, C. Galán-Marín, **Cross-evaluation of thermal comfort in semi-outdoor spaces according to geometry in Southern Spain, Urban Climate**. 49 (2023) 101491. https://doi.org/10.1016/J.UCLIM.2023.101491.

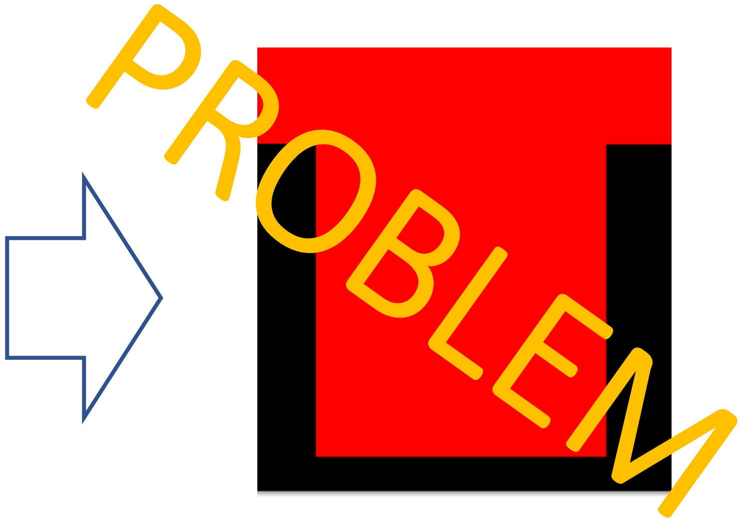
Thermal Delta (TD)

$T_{outdoor} - T_{courtyard} = TD\ (°C)$

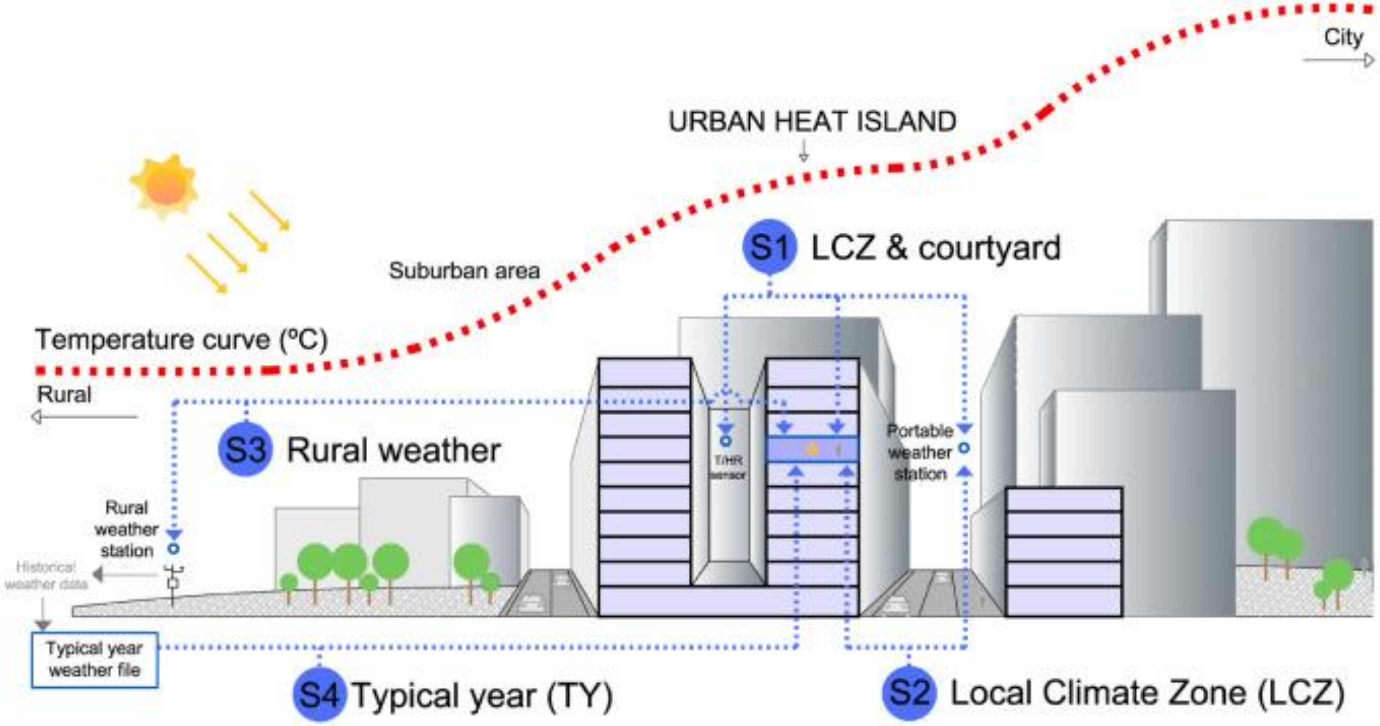


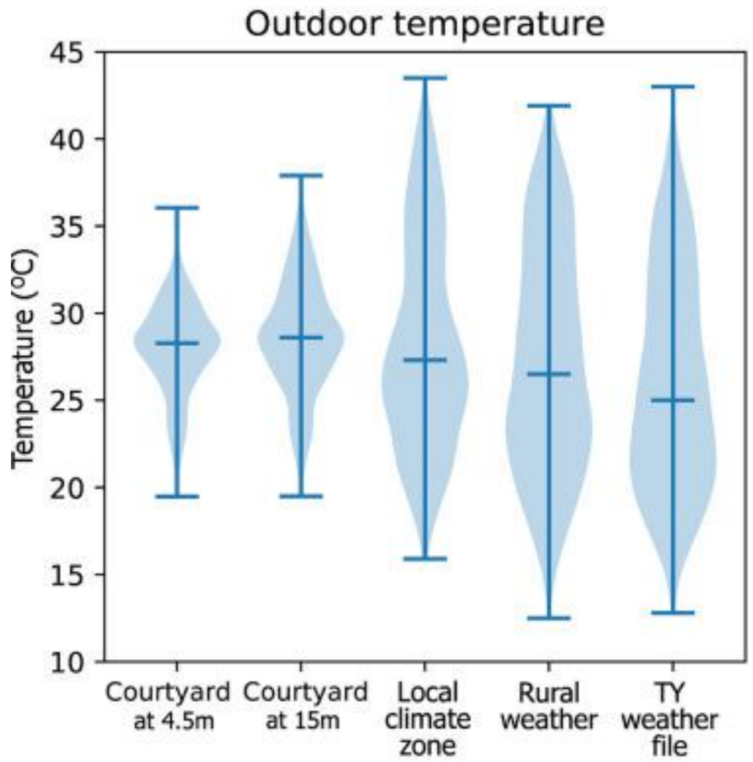
Thermodynamic effects in courtyards. CFD simulation. a) Stratification. b) Convection. c) Flow patterns from the effect of wind. Adapted from *Rojas, Galán-Marín and Fernández-Nieto, 2012.*

ENERGY SIMULATION TOOLS:
NO THERMAL DELTA

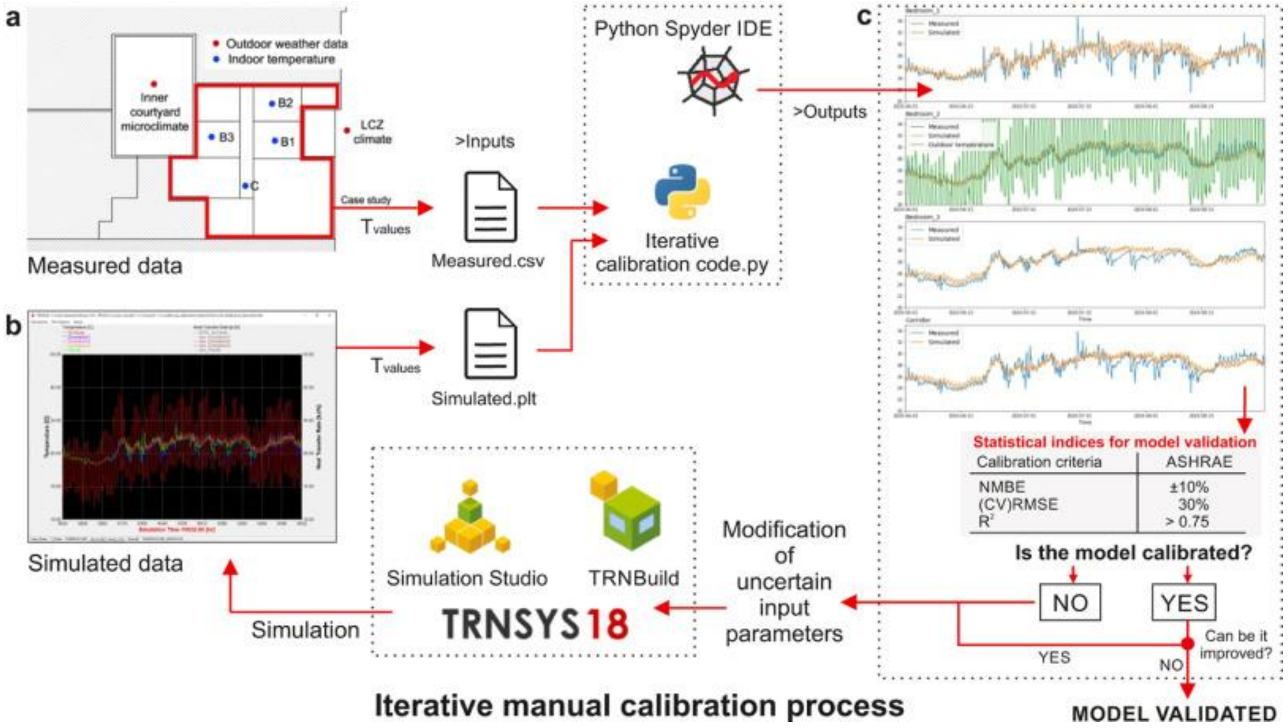


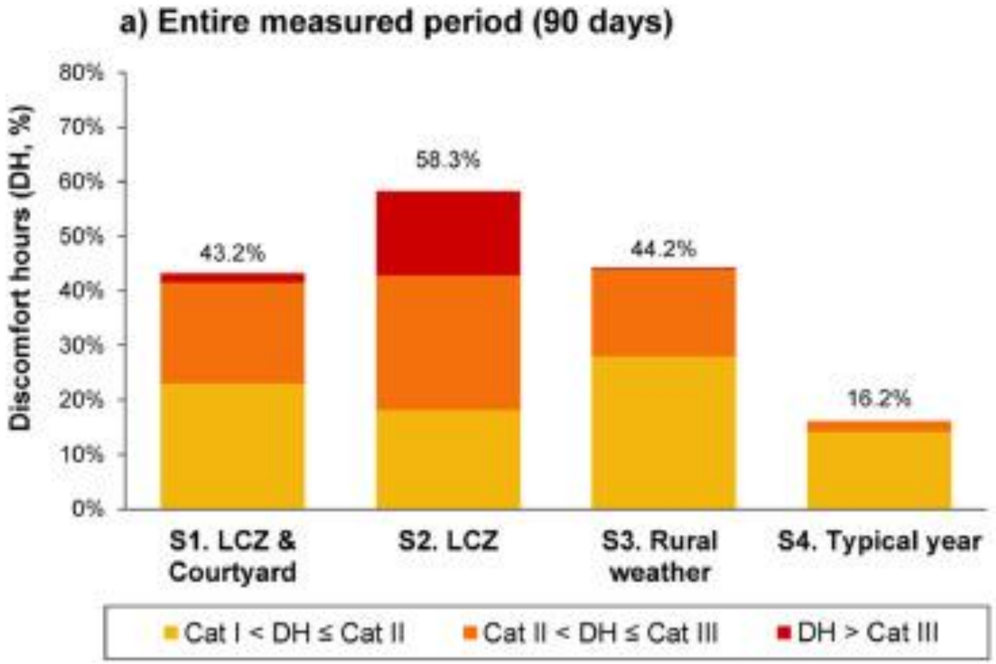
What is considered by most energy simulation tools.





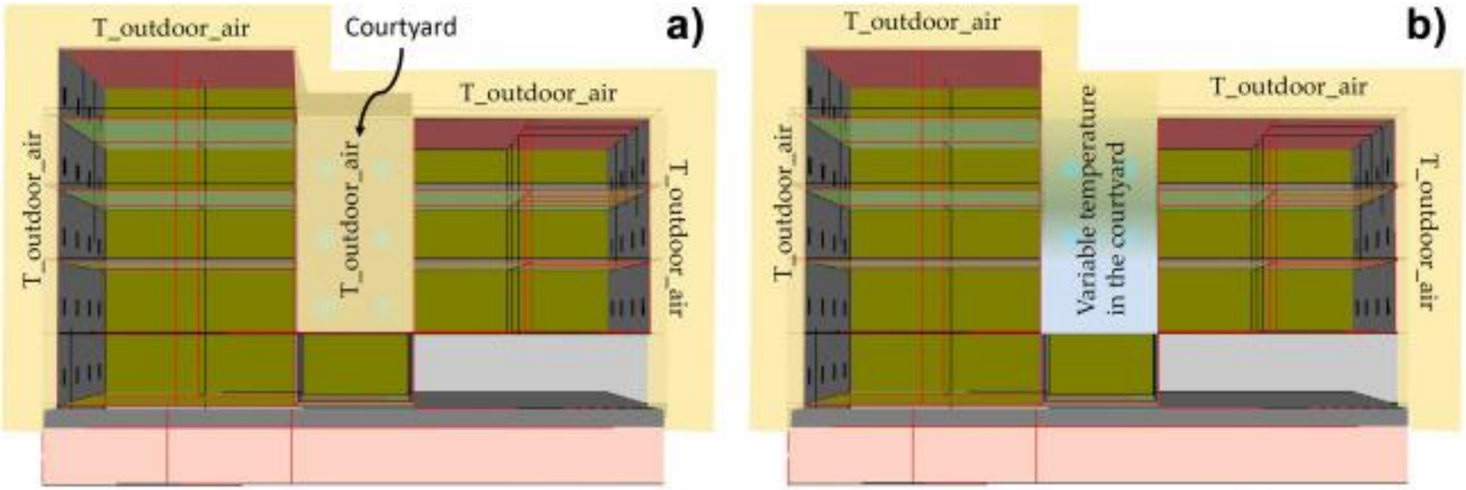
J. Lizana, V.P. Lopez-Cabeza, R. Renaldi, E. Diz-mellado, C. Rivera-Gomez, C. Galan-Marin, **Integrating courtyard microclimate in building performance simulation to mitigate extreme urban heat impacts**, Sustainable Cities and Society. (2021) 103590. https://doi.org/10.1016/j.scs.2021.103590.





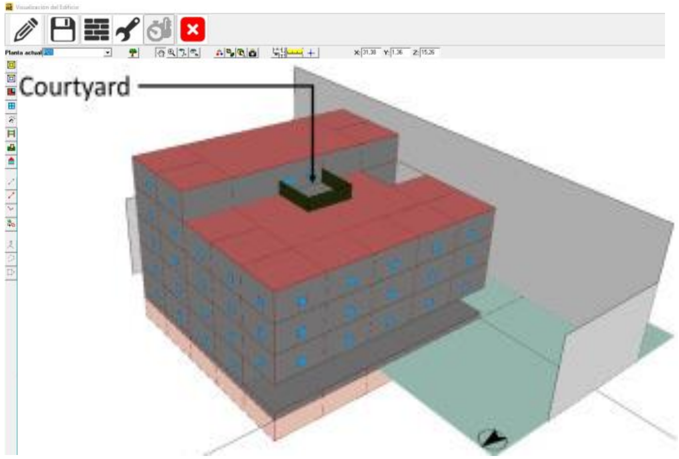
J. Lizana, V.P. Lopez-Cabeza, R. Renaldi, E. Diz-mellado, C. Rivera-Gomez, C. Galan-Marin, **Integrating courtyard microclimate in building performance simulation to mitigate extreme urban heat impacts**, **Sustainable Cities and Society**. (2021) 103590. https://doi.org/10.1016/j.scs.2021.103590.

PREVIOUS STUDIES



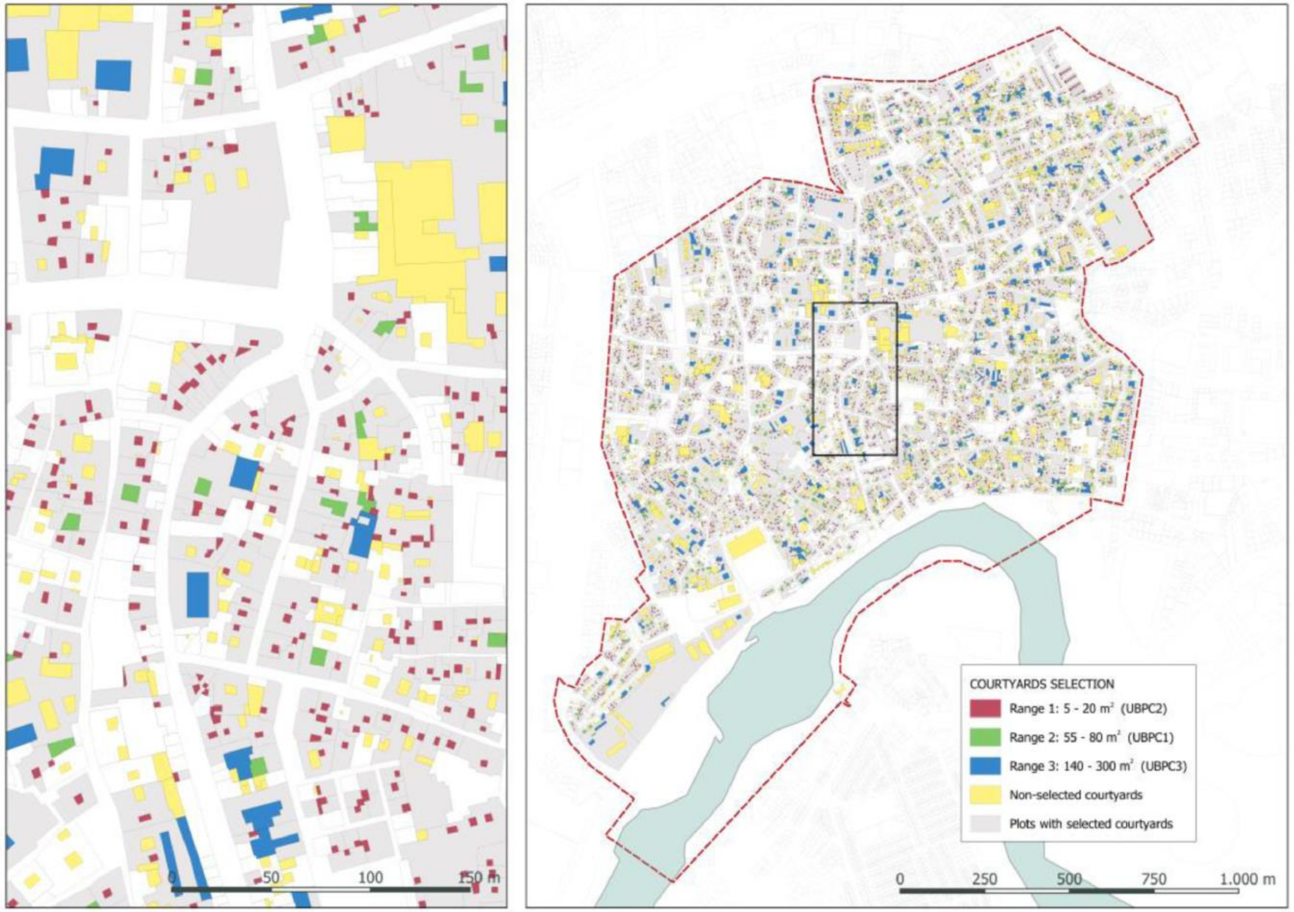
CTE HE
Herramienta Unificada
LIDER - CALENER

Space	Case study (kWh/m^2)	Reference case (kWh/m^2)	Absolute difference (kWh/m^2)	Percentage difference
Third floor 1	23.67	25.74	2.07	9%
Fourth floor 1	18.38	20.17	1.79	10%
Fifth floor 1	27.62	29.27	1.65	6%
Third floor 2	15.47	15.96	0.49	3%
Fourth floor 2	16.09	16.65	0.56	4%
Fifth floor 2	17.20	17.75	0.55	3%

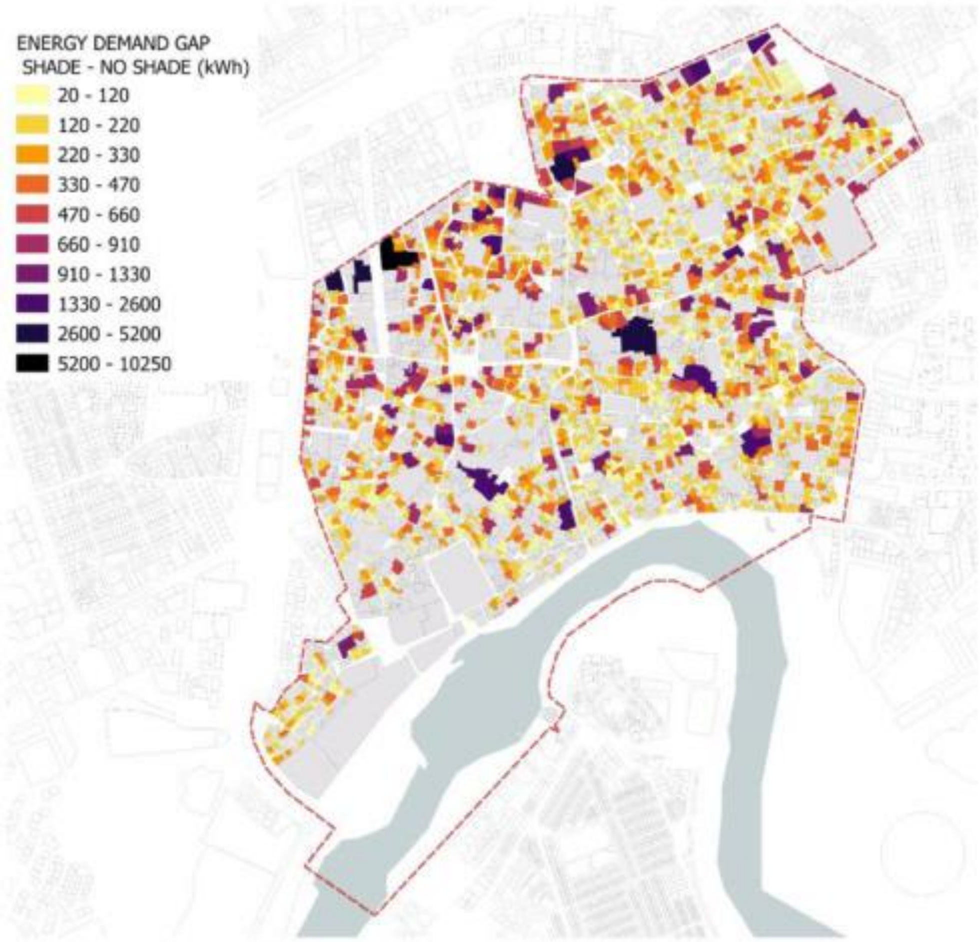


F.J. Sánchez de la Flor, Á. Ruiz-Pardo, E. Diz-Mellado, C. Rivera-Gómez, C. Galán-Marín, **Assessing the impact of courtyards in cooling energy demand in buildings**, **Journal of Cleaner Production**. 320 (2021) 128742. https://doi.org/10.1016/j.jclepro.2021.128742.

ENERGY-SAVINGS POTENTIAL OF COURTYARDS

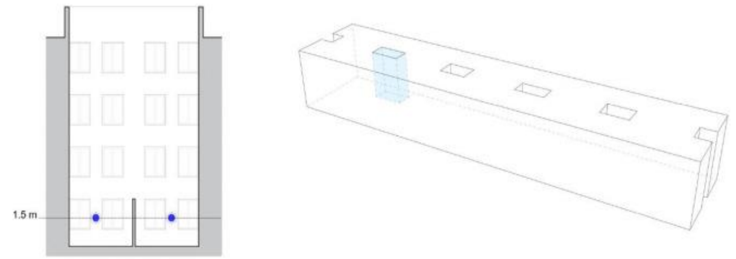


GIS model of courtyard dimensions in the city center of Cordoba.

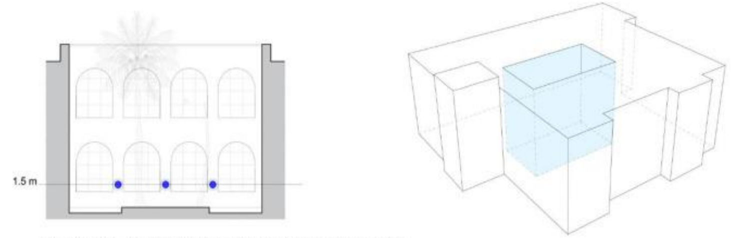


GIS model of energy demand difference between courtyards with shade and unshaded.

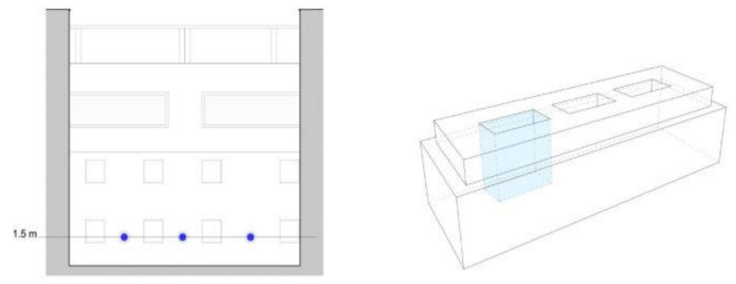
E. Diz-Mellado, V.P. López-Cabeza, J. Roa-Fernández, C. Rivera-Gómez, C. Galán-Marín, Energy-saving and thermal comfort potential of vernacular urban block porosity shading, Sustainable Cities and Society. 89 (2023) 104325. https://doi.org/10.1016/j.scs.2022.104325.



a) Case 1. Residential. South-west façade and perspective.

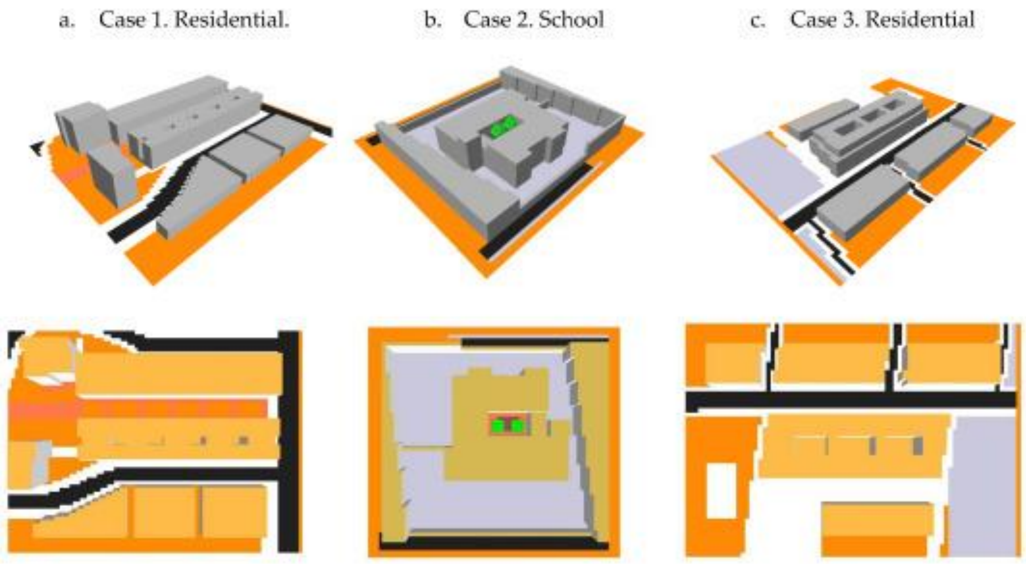


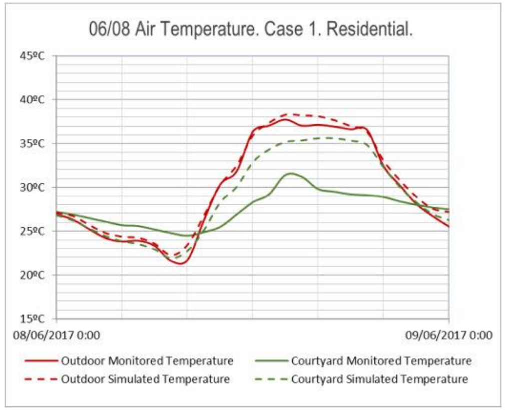
b) Case 2. School. South-east façade and perspective.

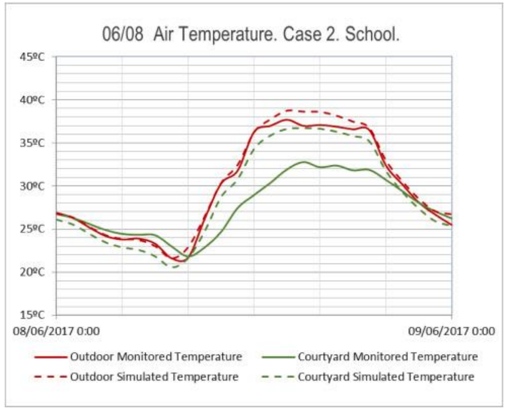


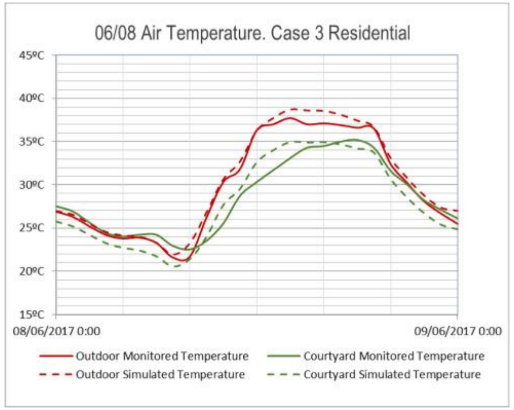
c) Case 3. Residential. South façade and perspective.

		R^2	RMSE (°C)
Case 1	Outdoor	0.99	0.77
	Courtyard	0.84	3.35
Case 2	Outdoor	0.99	0.73
	Courtyard	0.88	2.92
Case 3	Outdoor	0.99	0.82
	Courtyard	0.93	1.52



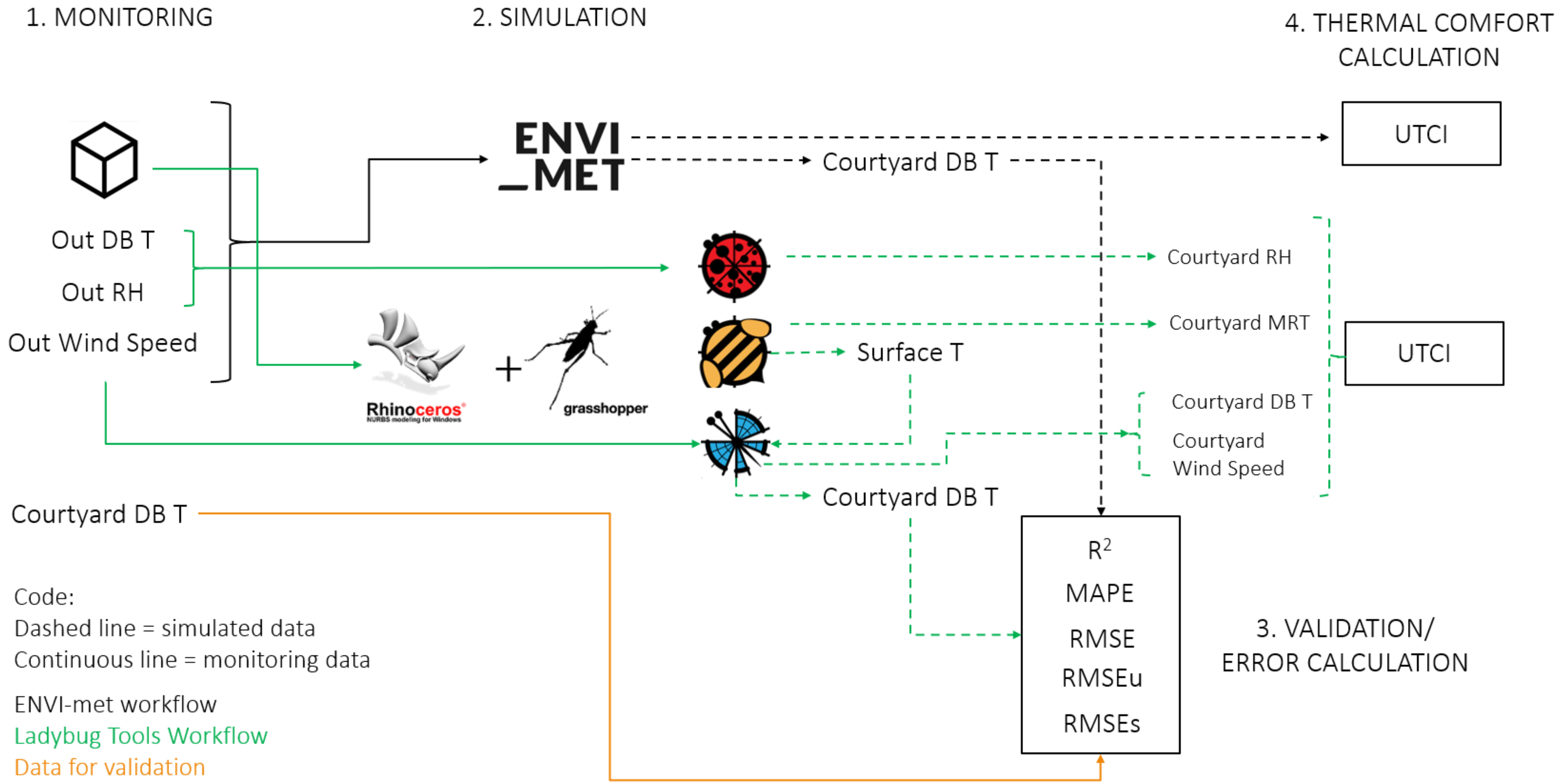






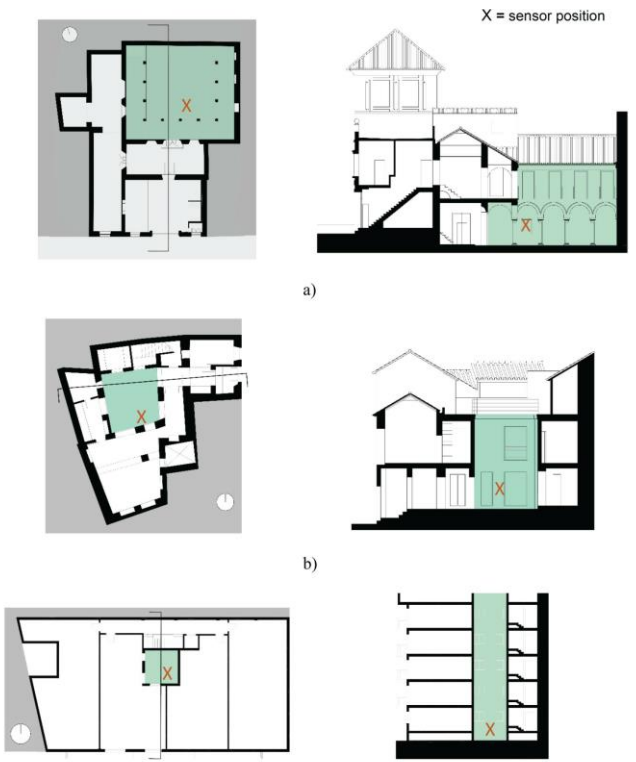
V.P. López-Cabeza, C. Galán-Marín, C. Rivera-Gómez, J. Roa-Fernández, **Courtyard microclimate ENVI-met outputs deviation from the experimental data**, Building and Environment. 144 (2018) 129–141. https://doi.org/10.1016/j.buildenv.2018.08.013.

HYBRID WORKFLOWS



V.P. López-Cabeza, E. Diz-Mellado, C. Rivera-Gómez, C. Galán-Marín, H.W. Samuelson, **Thermal comfort modelling and empirical validation of predicted air temperature in hot-summer Mediterranean courtyards, Journal of Building Performance Simulation**. 15 (2022) 39–61. https://doi.org/10.1080/19401493.2021.2001571.

HYBRID WORKFLOWS



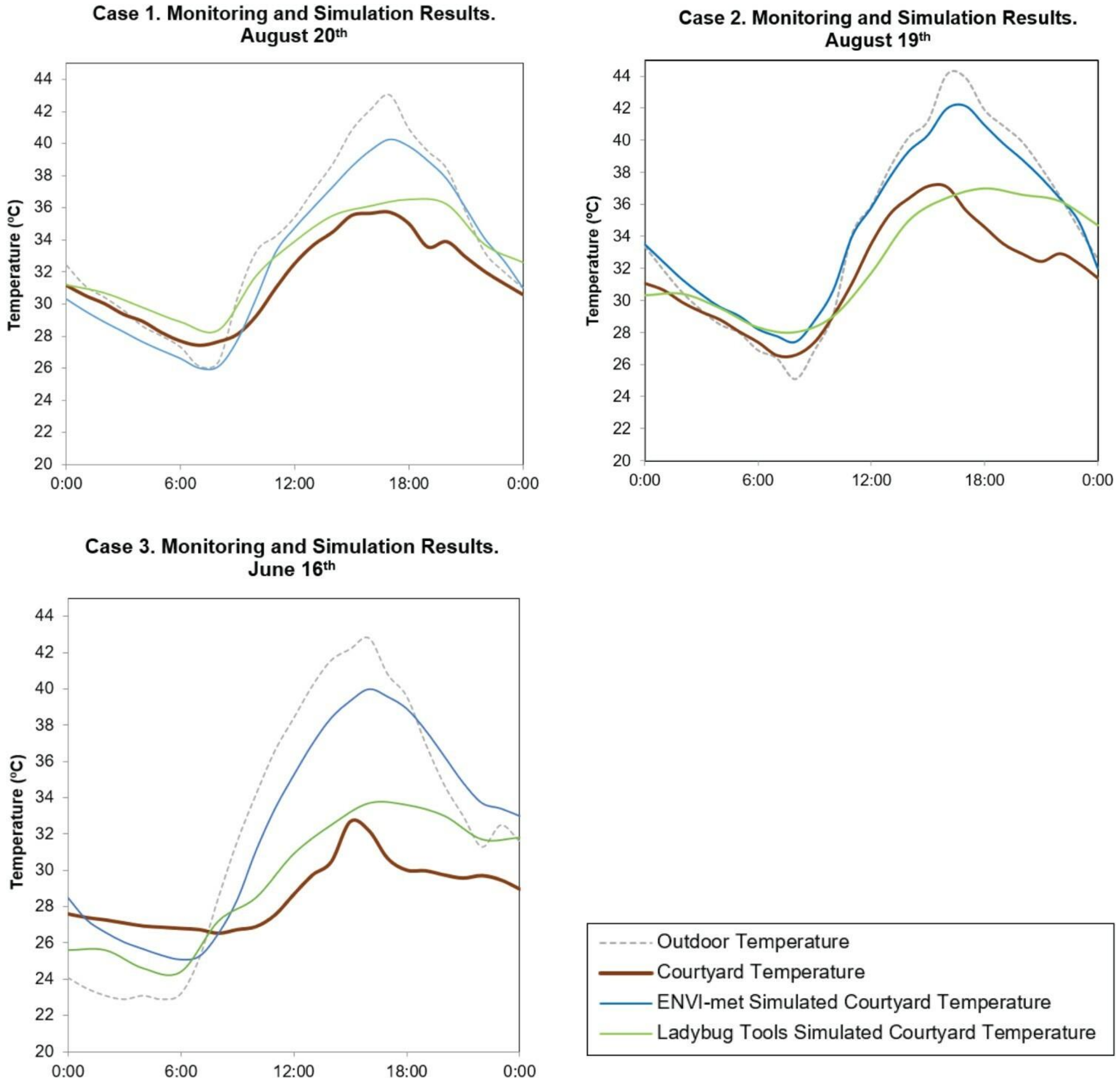
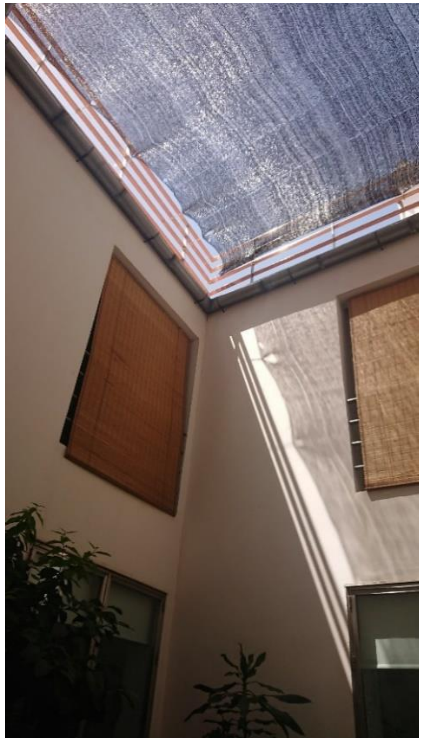


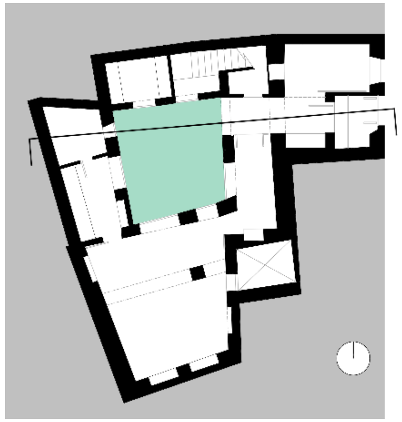
Table 6. Quantitative evaluation of the simulation's performance for the courtyard temperature output.

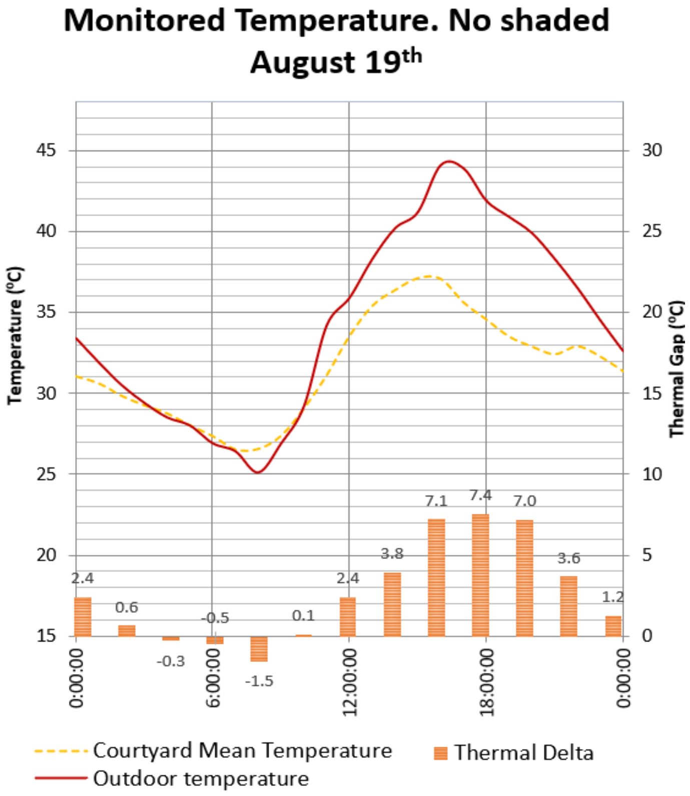
		AR	R^2	MAPE (%)	RMSE (°C)	RMSEu (°C)	RMSEs (°C)
ENVI-met simulation	Case 1	0.9	0.96	6.85	2.61	3.96	1.42
	Case 2	1.5	0.92	8.74	3.46	5.54	2.20
	Case 3	4.6	0.84	14.38	5.22	6.76	1.66
Ladybug Tools simulation	Case 1	0.9	0.94	3.81	1.37	2.41	1.12
	Case 2	1.5	0.73	5.07	2.00	2.41	0.96
	Case 3	4.6	0.78	7.55	2.29	3.09	1.03

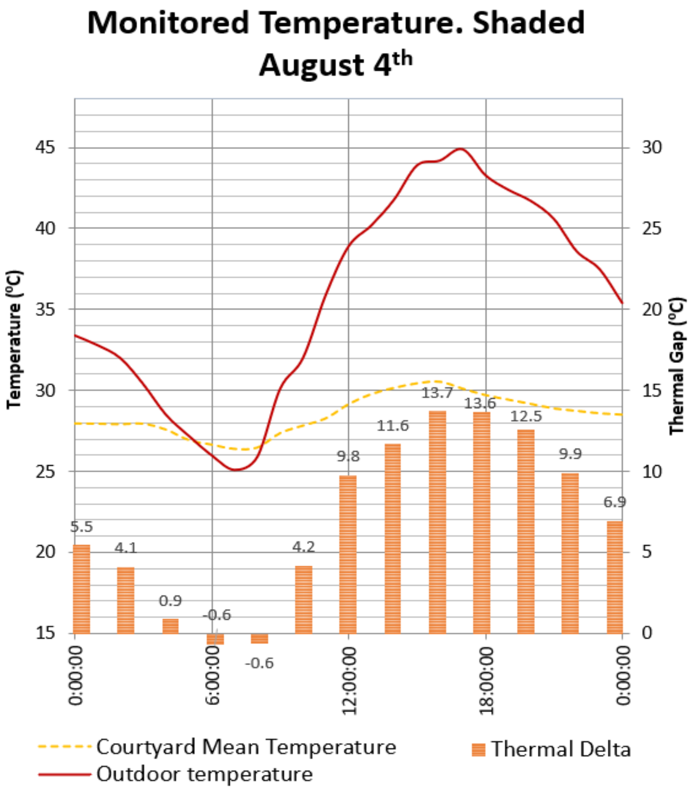
Legend: Best result of each parameter between the two simulations
Worst result of each parameter between the two simulations

V.P. López-Cabeza, E. Diz-Mellado, C. Rivera-Gómez, C. Galán-Marín, H.W. Samuelson, **Thermal comfort modelling and empirical validation of predicted air temperature in hot-summer Mediterranean courtyards**, **Journal of Building Performance Simulation**. 15 (2022) 39–61. https://doi.org/10.1080/19401493.2021.2001571.





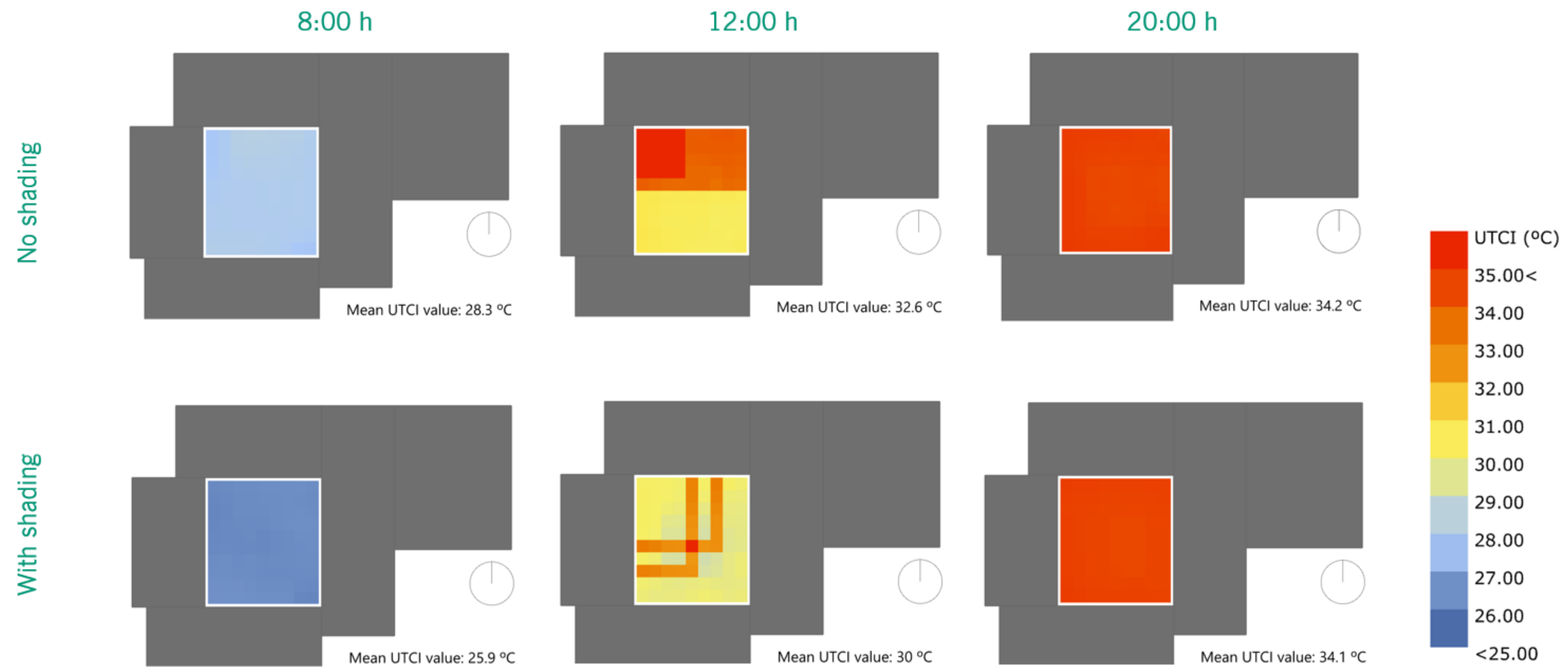




Monitored Outdoor and Courtyard Dry Bulb Temperature on the selected days.

V.P. López-Cabeza, E. Diz-Mellado, C.A. Rivera-Gómez, C. Galán-Marín, **Shade and Thermal Comfort in Courtyards: Experimental Versus Simulation Results, Buildings**. 12 (2022) 1961. https://doi.org/10.3390/BUILDINGS12111961.

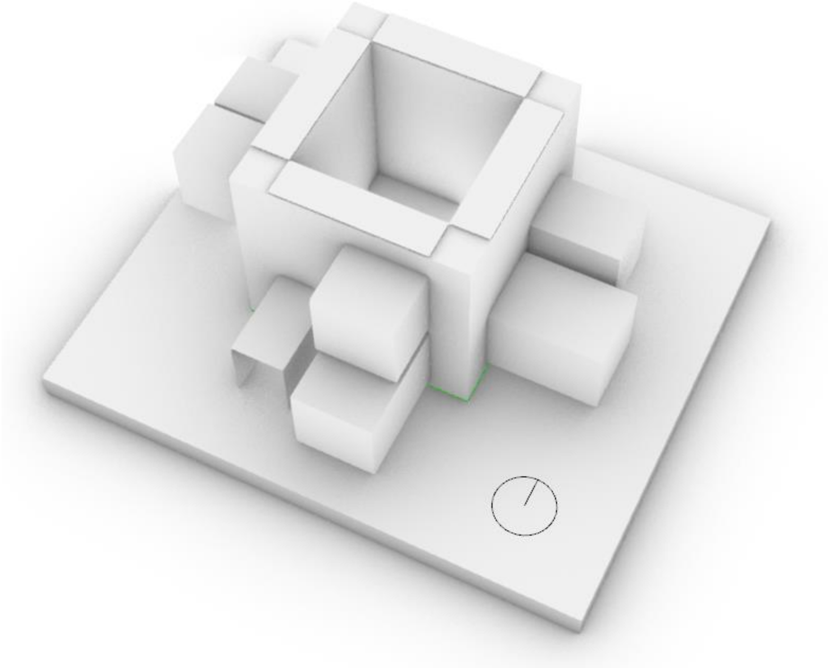
SHADING DEVICE



UTCI values at 1.5 m height in the courtyard at different hours from the Ladybug Simulation Workflow.

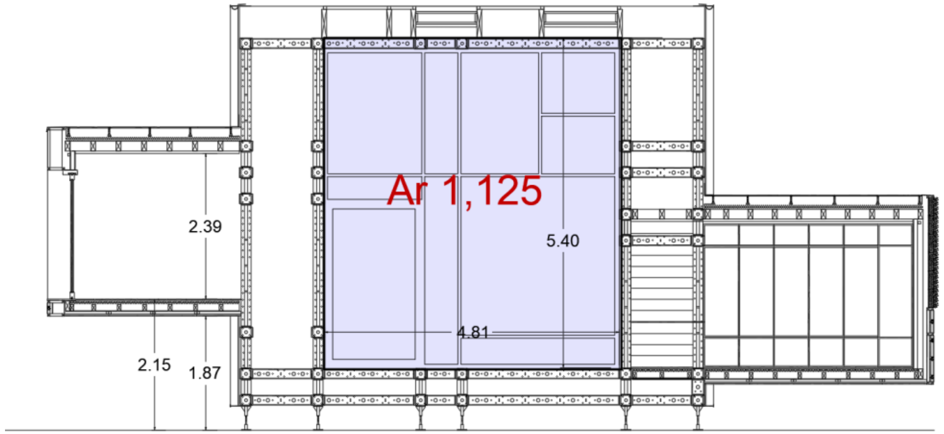
V.P. López-Cabeza, E. Diz-Mellado, C.A. Rivera-Gómez, C. Galán-Marín, **Shade and Thermal Comfort in Courtyards: Experimental Versus Simulation Results, Buildings**. 12 (2022) 1961. https://doi.org/10.3390/BUILDINGS12111961.

THERMAL INERTIA AND VENTILATION



Simulation model in Rhinoceros for the Case Study.

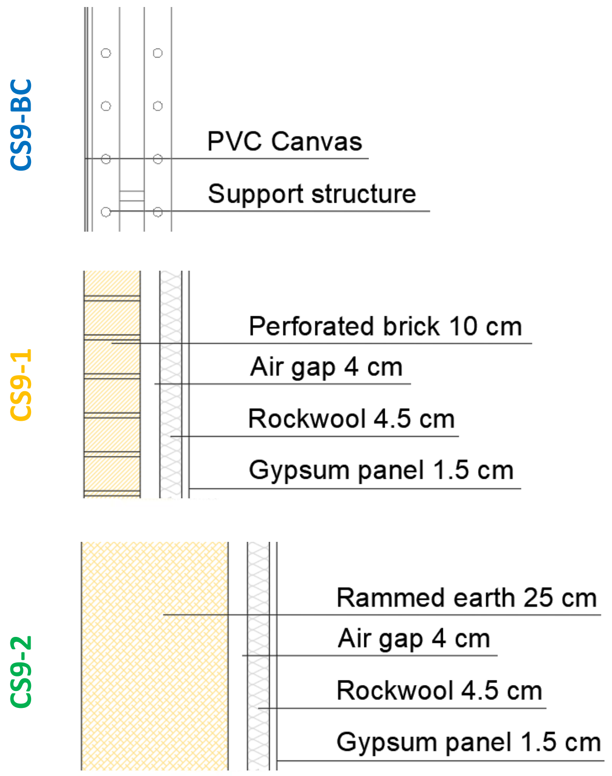
On site view of the Case Study.



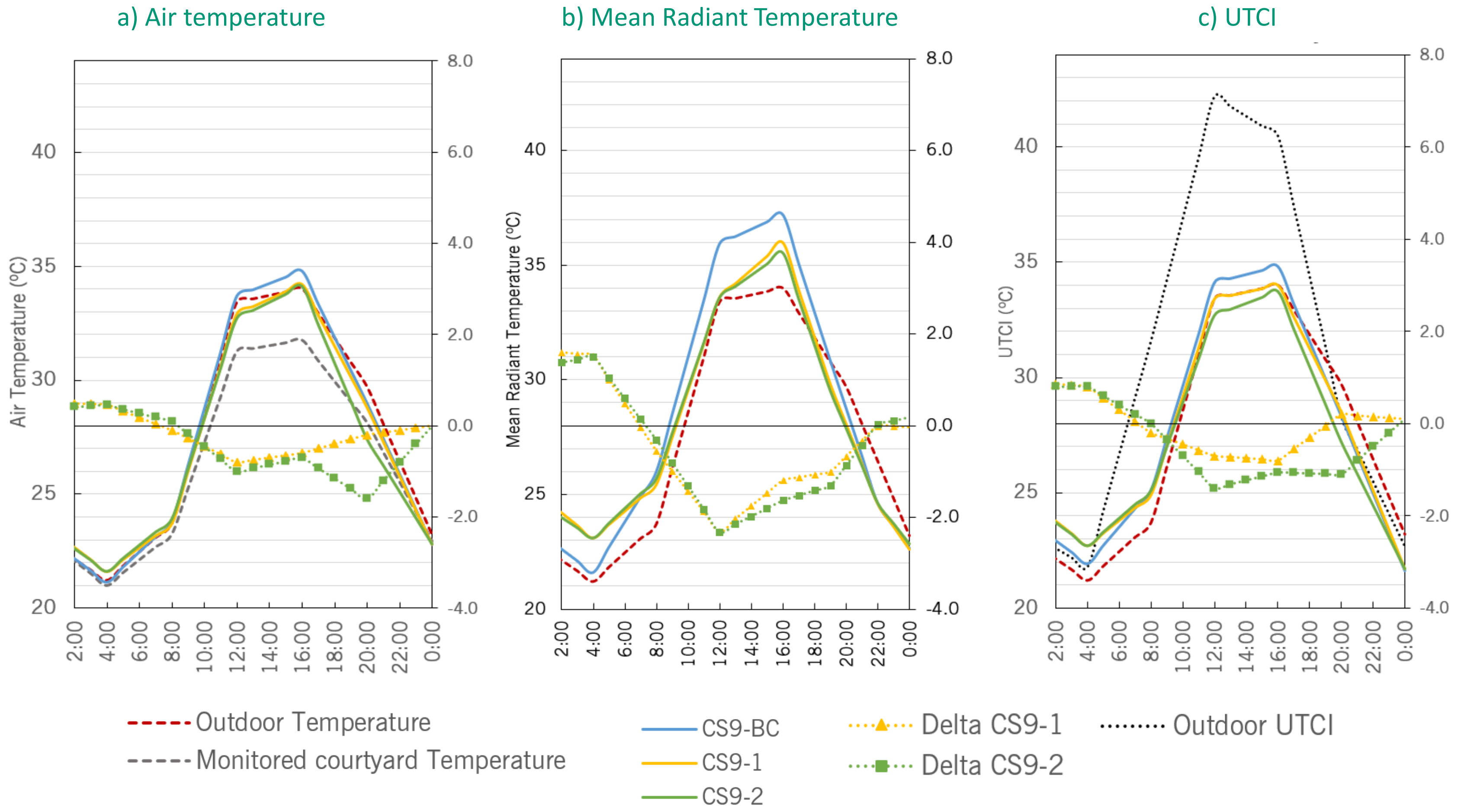
Cross section through the courtyard.

V.P. López-Cabeza, C. Rivera-Gómez, J. Roa-Fernández, M. Hernandez-Valencia, R. Herrera-Limones, **Effect of thermal inertia and natural ventilation on user comfort in courtyards under warm summer conditions,** Building and Environment. 228 (2023) 109812. https://doi.org/10.1016/j.buildenv.2022.109812.

THERMAL INERTIA AND VENTILATION



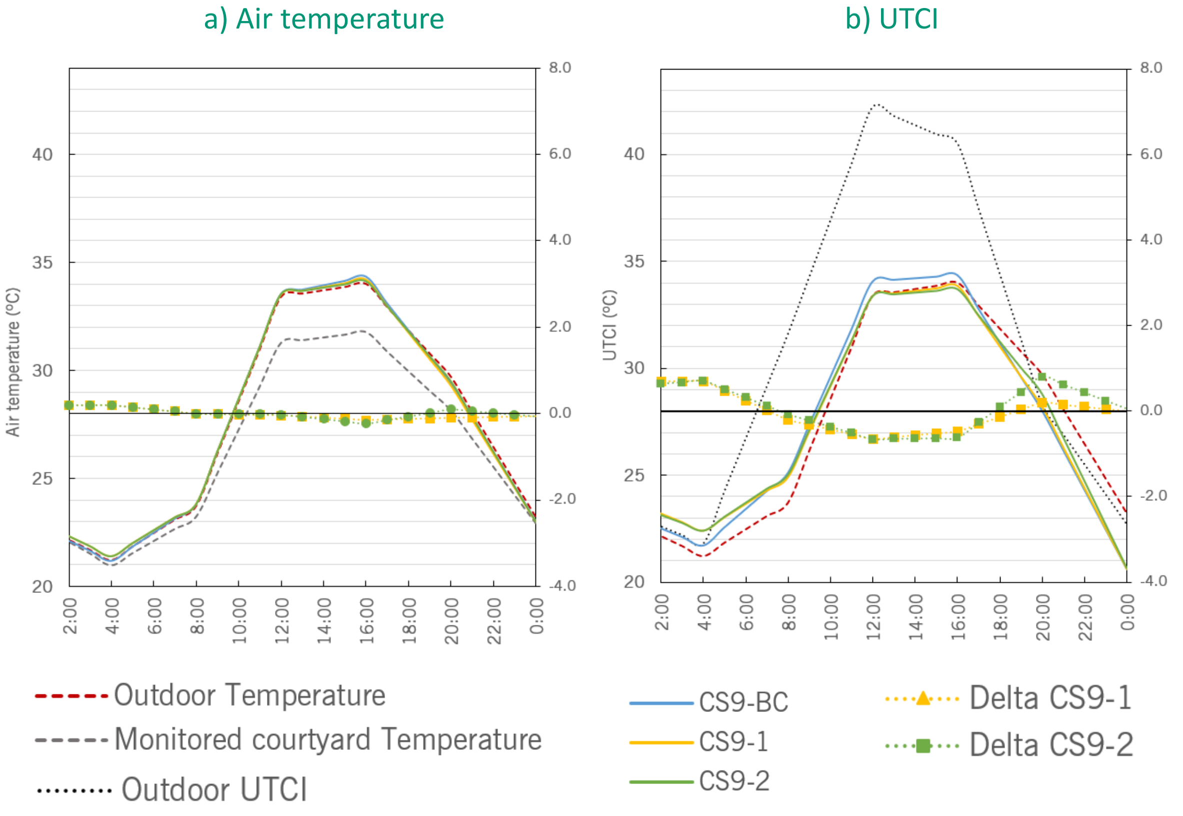
Detail sections of the three types of courtyard wall analyzed.



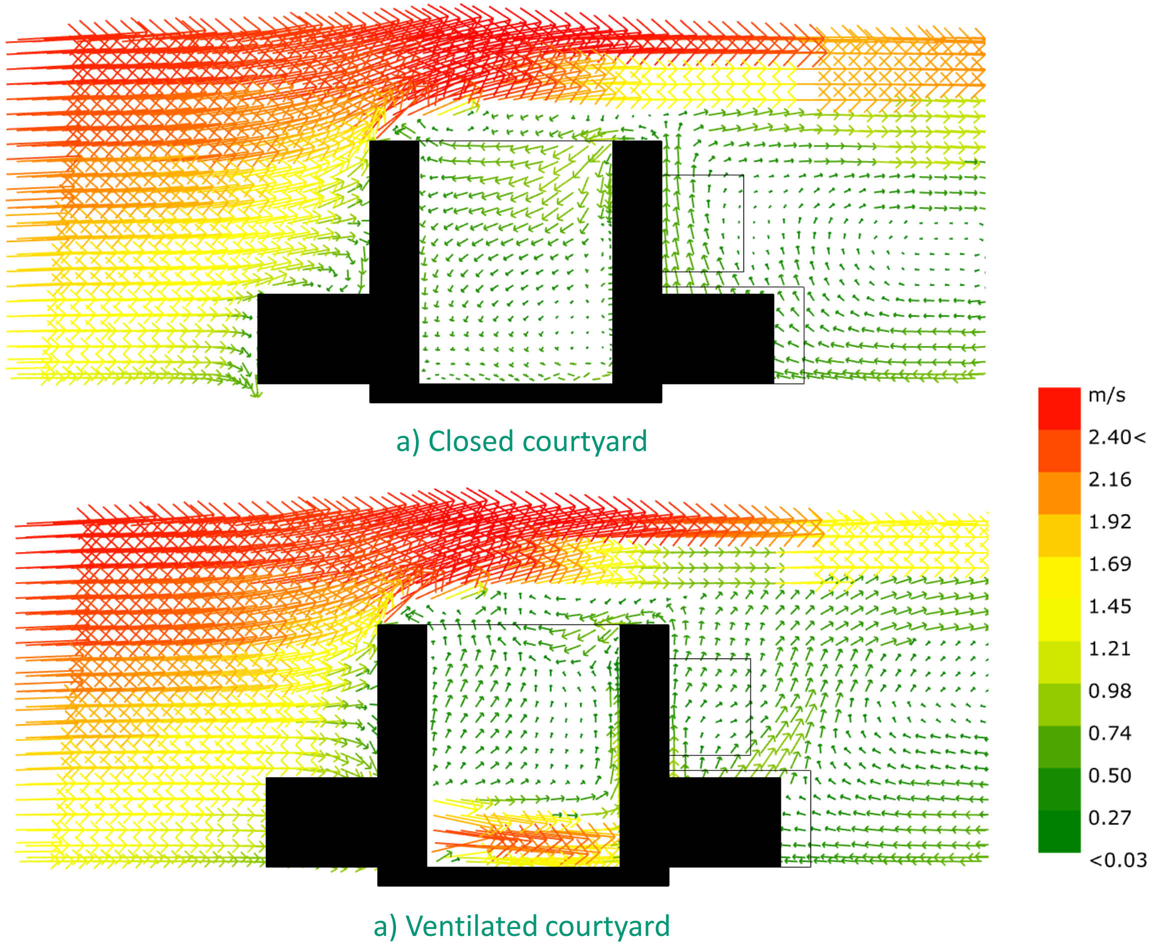
Closed courtyard simulation results at 1.5 m above the ground.

V.P. López-Cabeza, C. Rivera-Gómez, J. Roa-Fernández, M. Hernandez-Valencia, R. Herrera-Limones, **Effect of thermal inertia and natural ventilation on user comfort in courtyards under warm summer conditions, Building and Environment**. 228 (2023) 109812. https://doi.org/10.1016/j.buildenv.2022.109812.

THERMAL INERTIA AND VENTILATION



Open courtyard simulation results at 1.5 m above the ground.



Wind flow pattern in a cross-section of the courtyard in the wind direction at 16.00 hours.

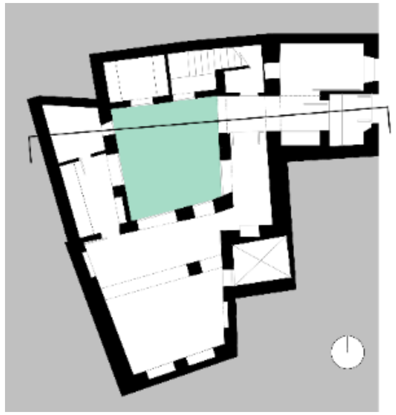
V.P. López-Cabeza, C. Rivera-Gómez, J. Roa-Fernández, M. Hernandez-Valencia, R. Herrera-Limones, **Effect of thermal inertia and natural ventilation on user comfort in courtyards under warm summer conditions, Building and Environment**. 228 (2023) 109812. https://doi.org/10.1016/j.buildenv.2022.109812.

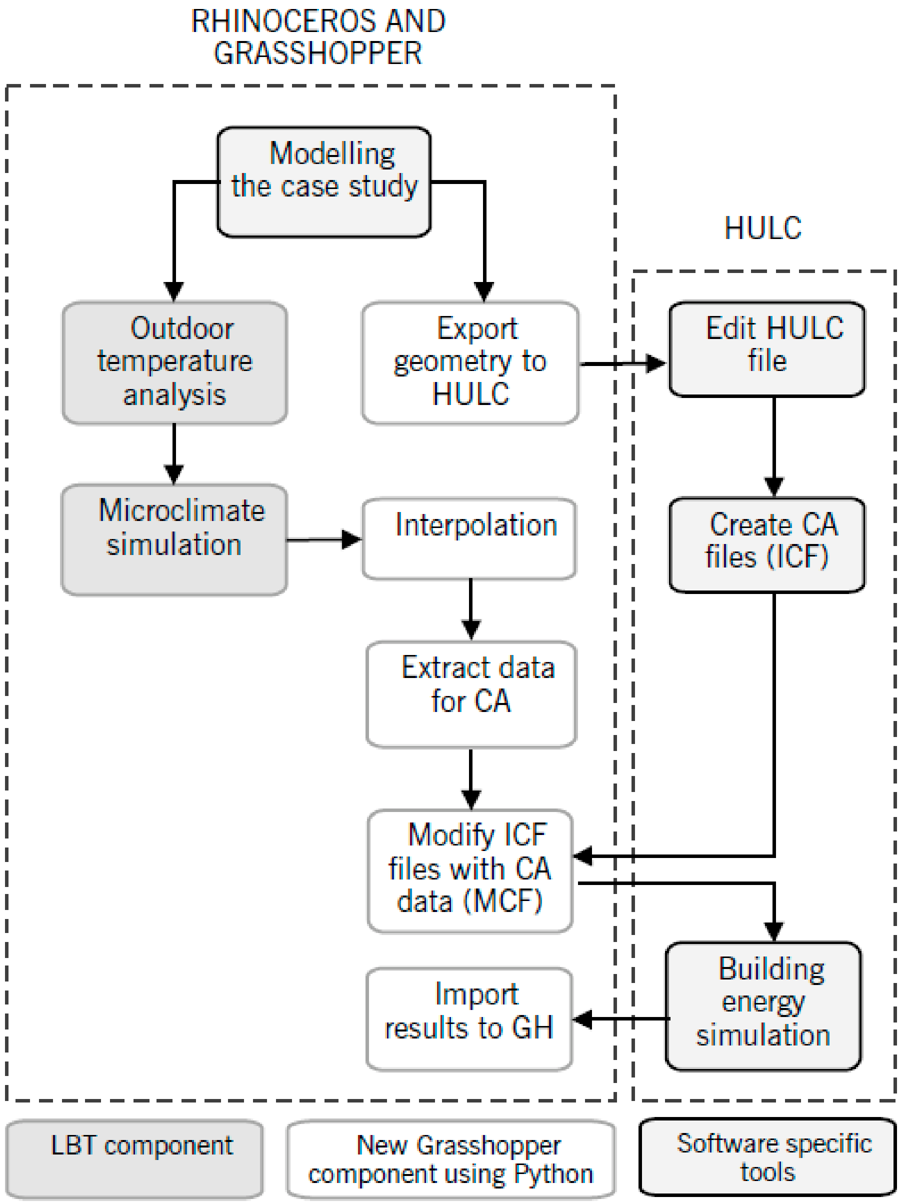
COUPLING COURTYARD SIMULATION WORKFLOW WITH ENERGY CERTIFICATION TOOL

HULC: Spanish energy certification tool provided by government

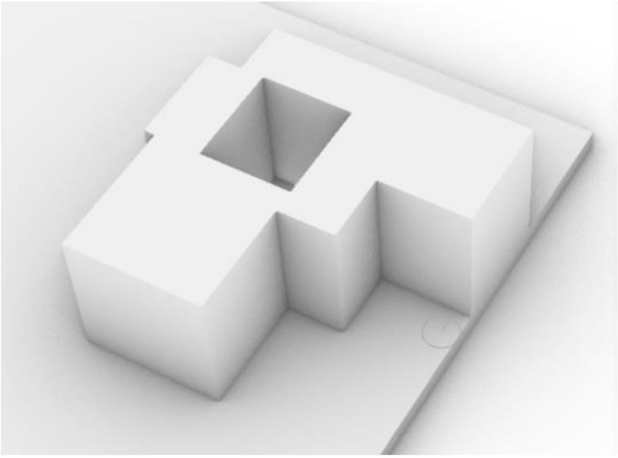
- BES → Based on DOE2
- Additional Capacities (CA)

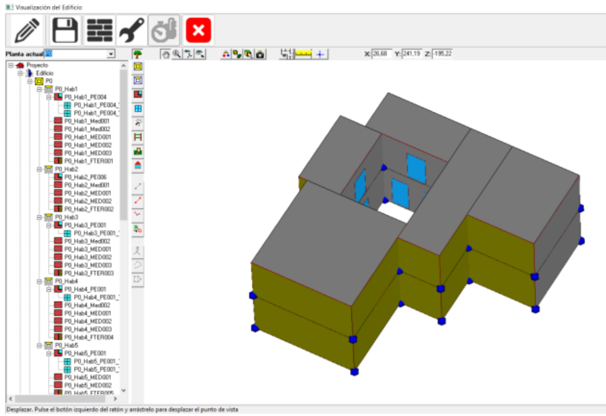
Objective: Link HULC with courtyard simulation workflow

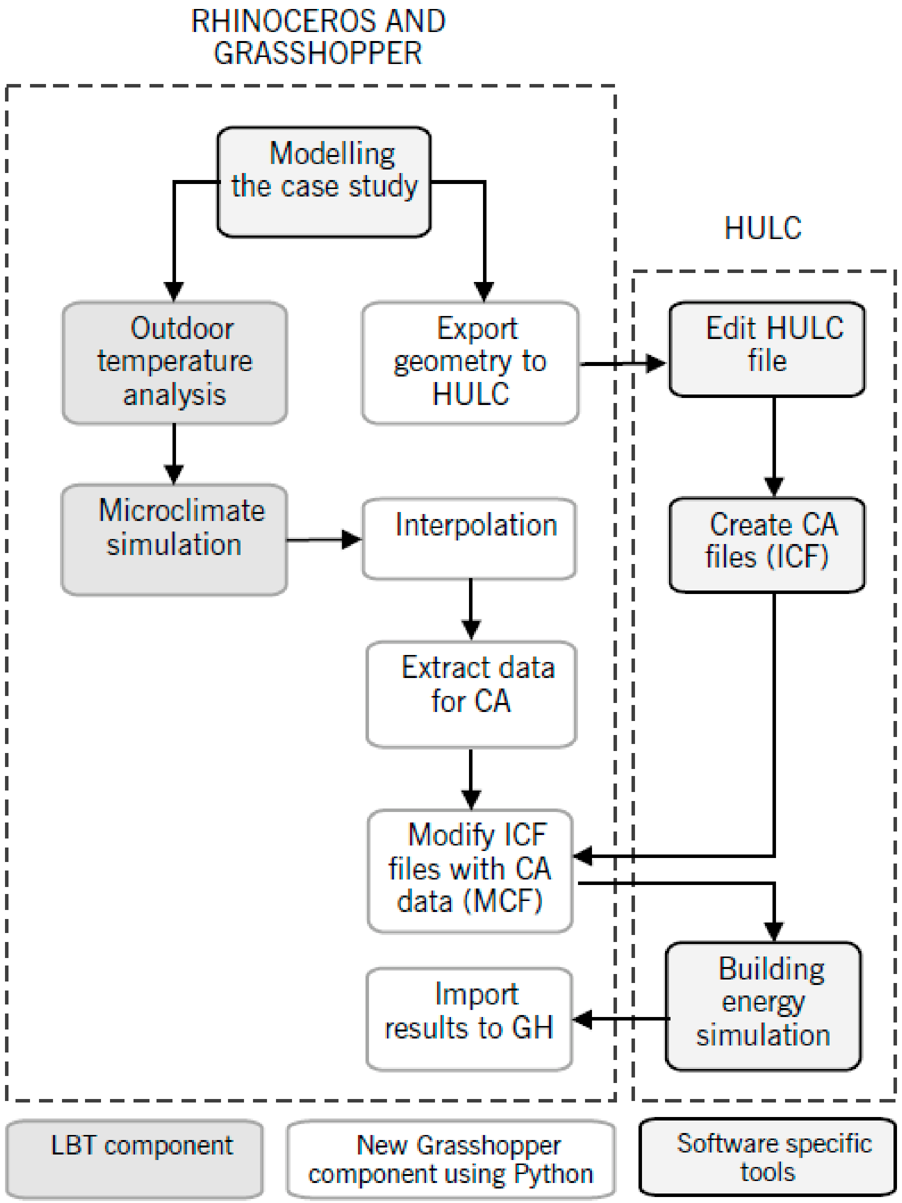




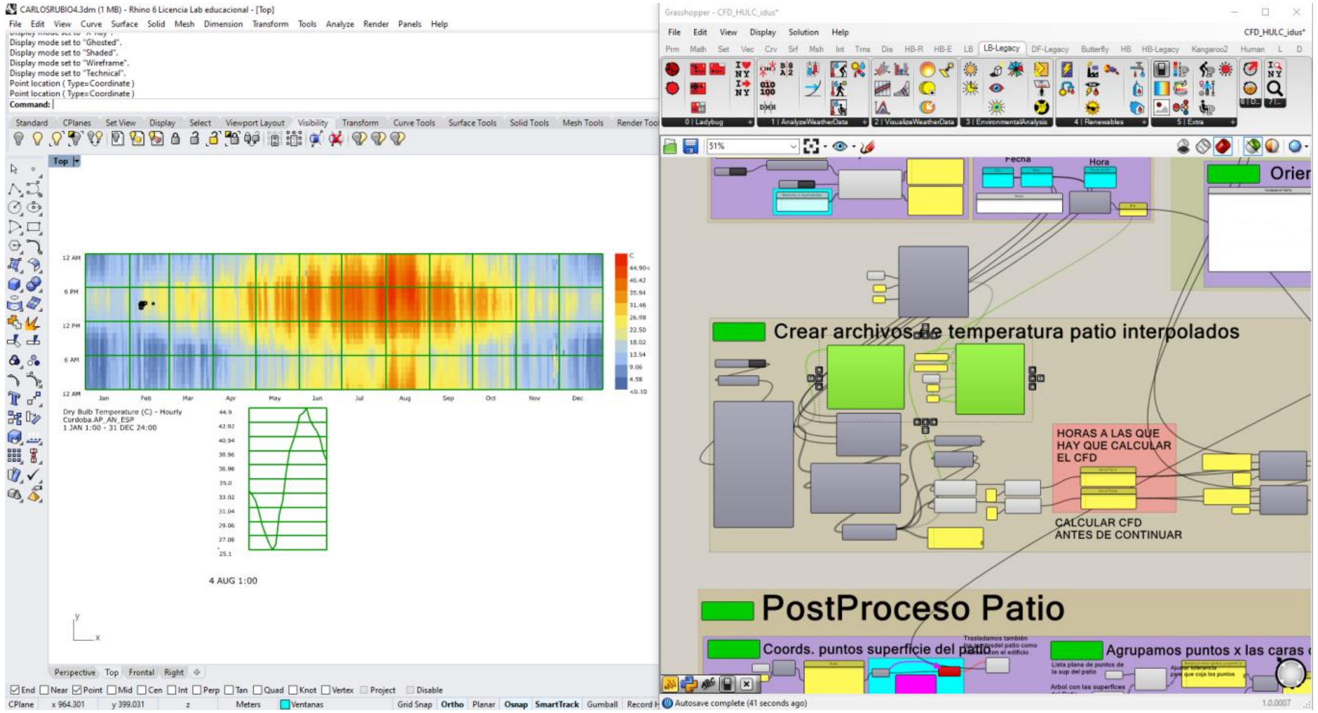
COUPLING COURTYARD SIMULATION WORKFLOW WITH ENERGY CERTIFICATION TOOL

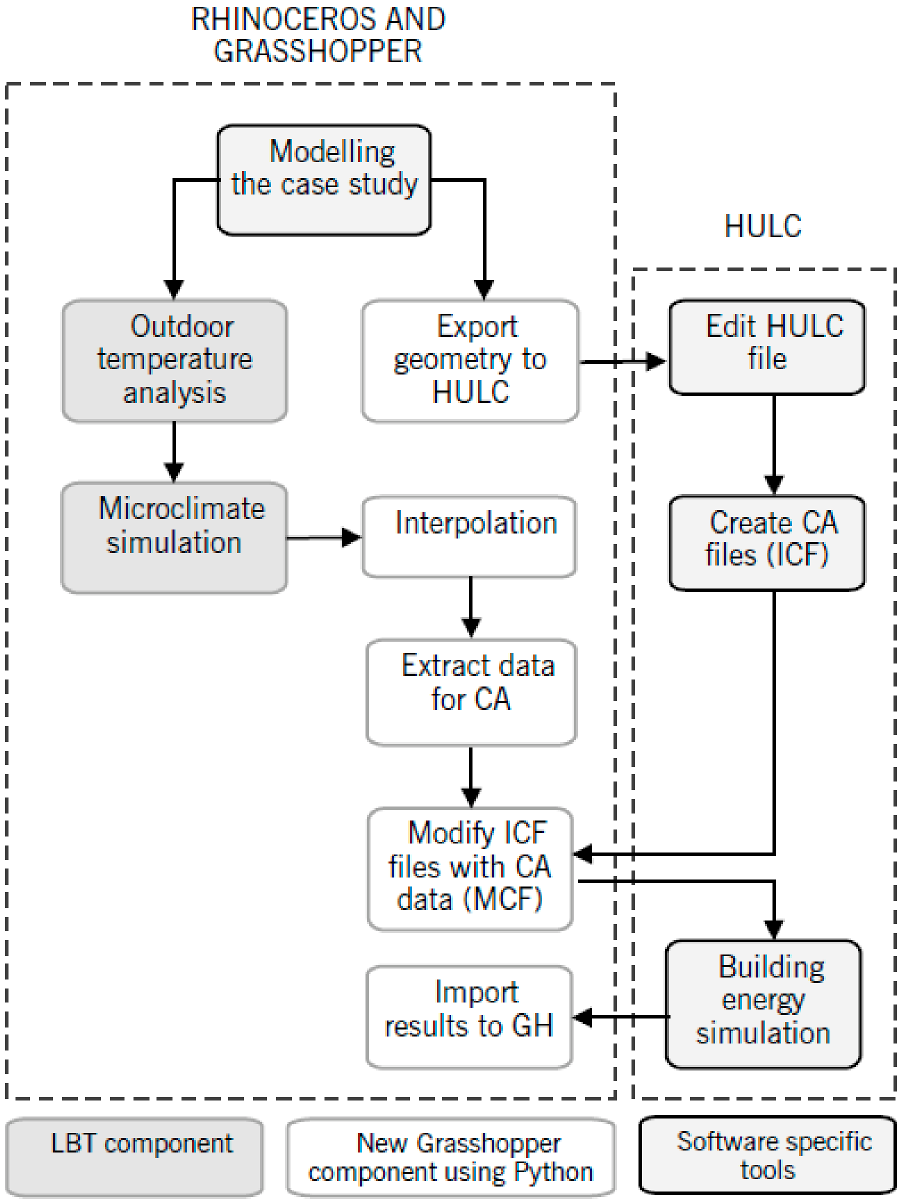




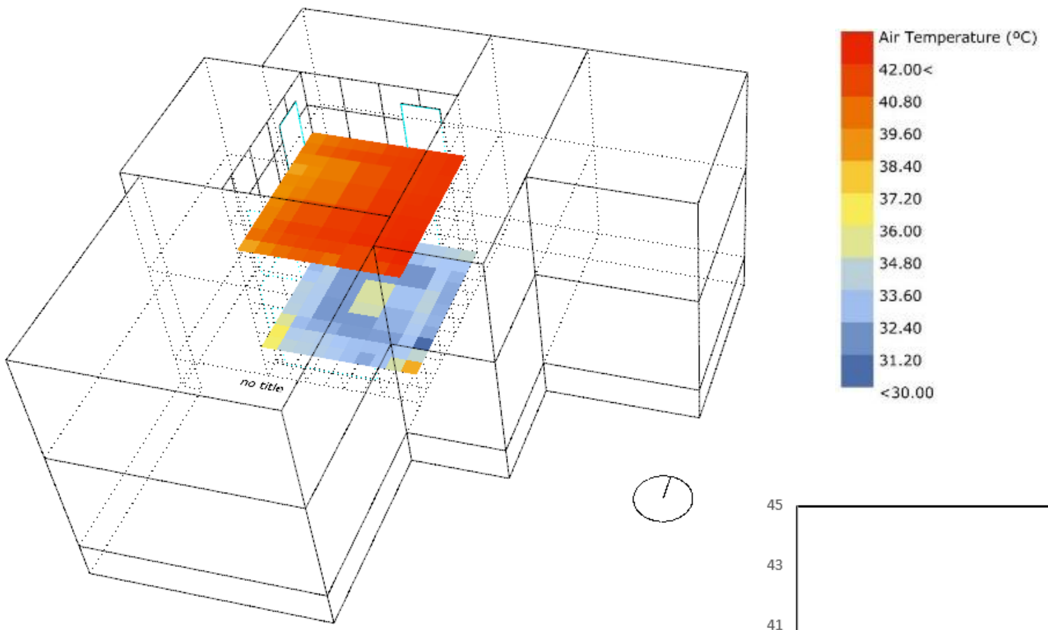


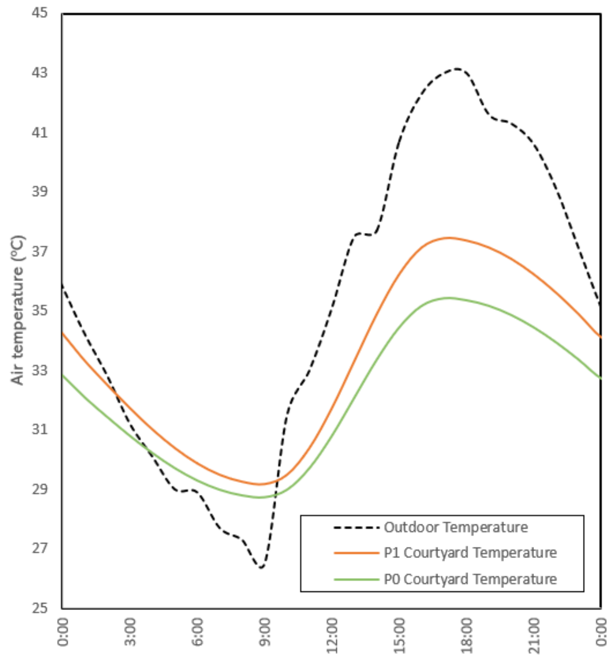
COUPLING COURTYARD SIMULATION WORKFLOW WITH ENERGY CERTIFICATION TOOL

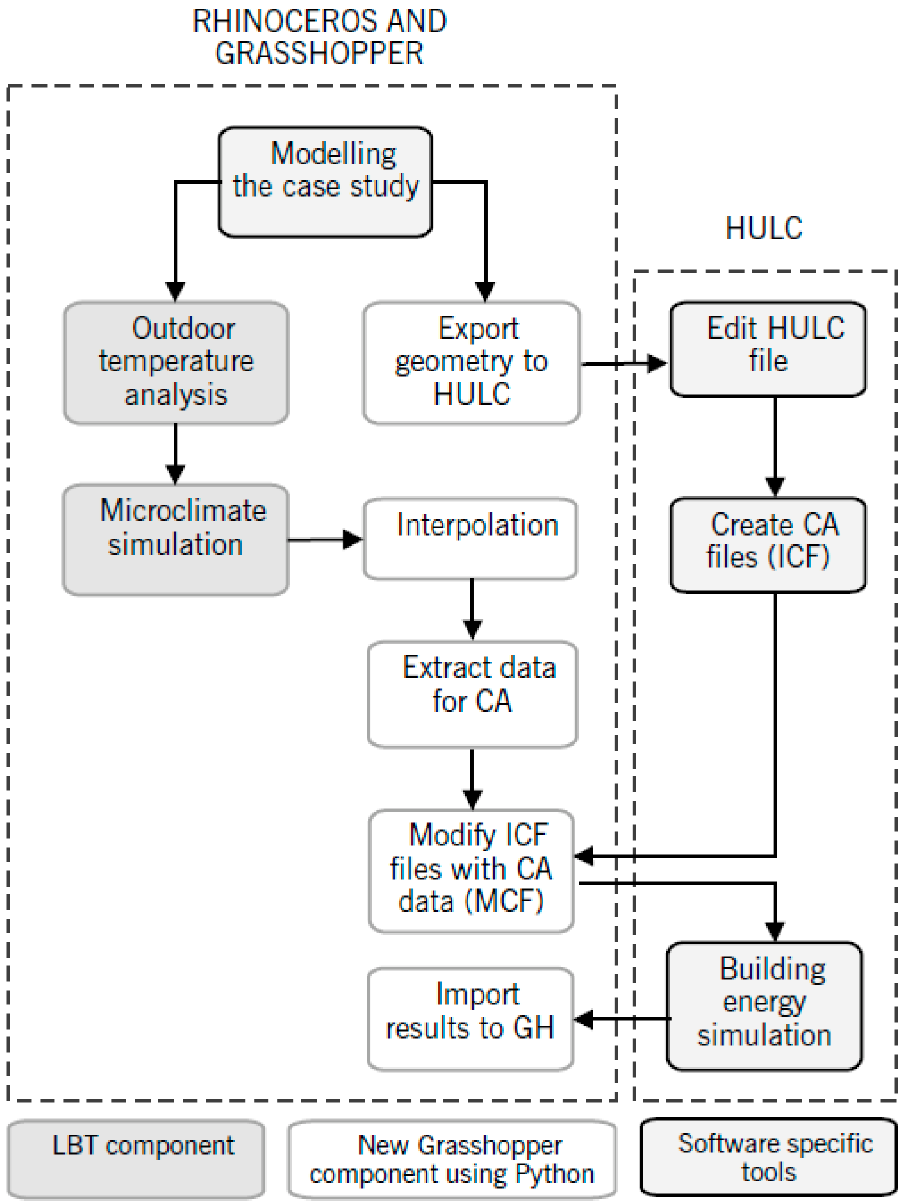




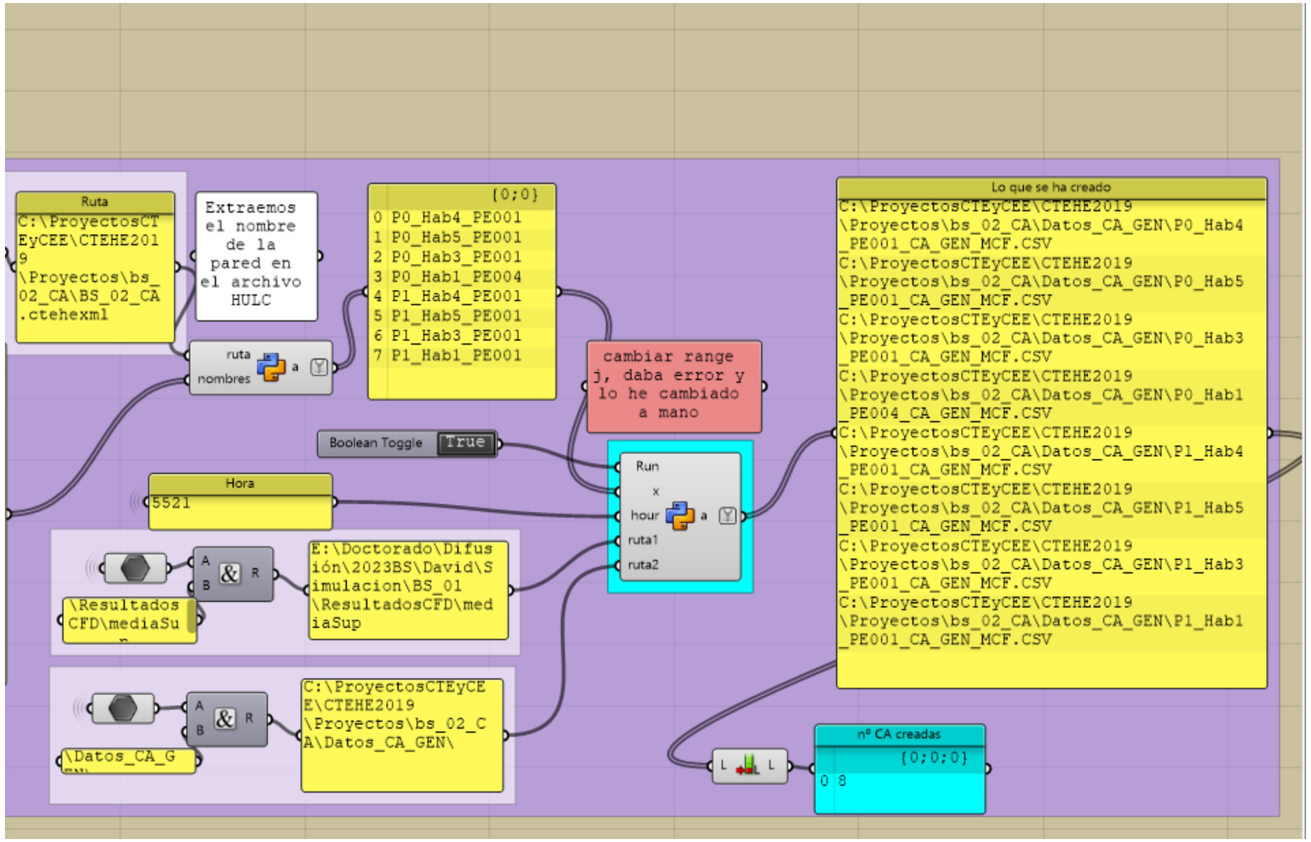
COUPLING COURTYARD SIMULATION WORKFLOW WITH ENERGY CERTIFICATION TOOL

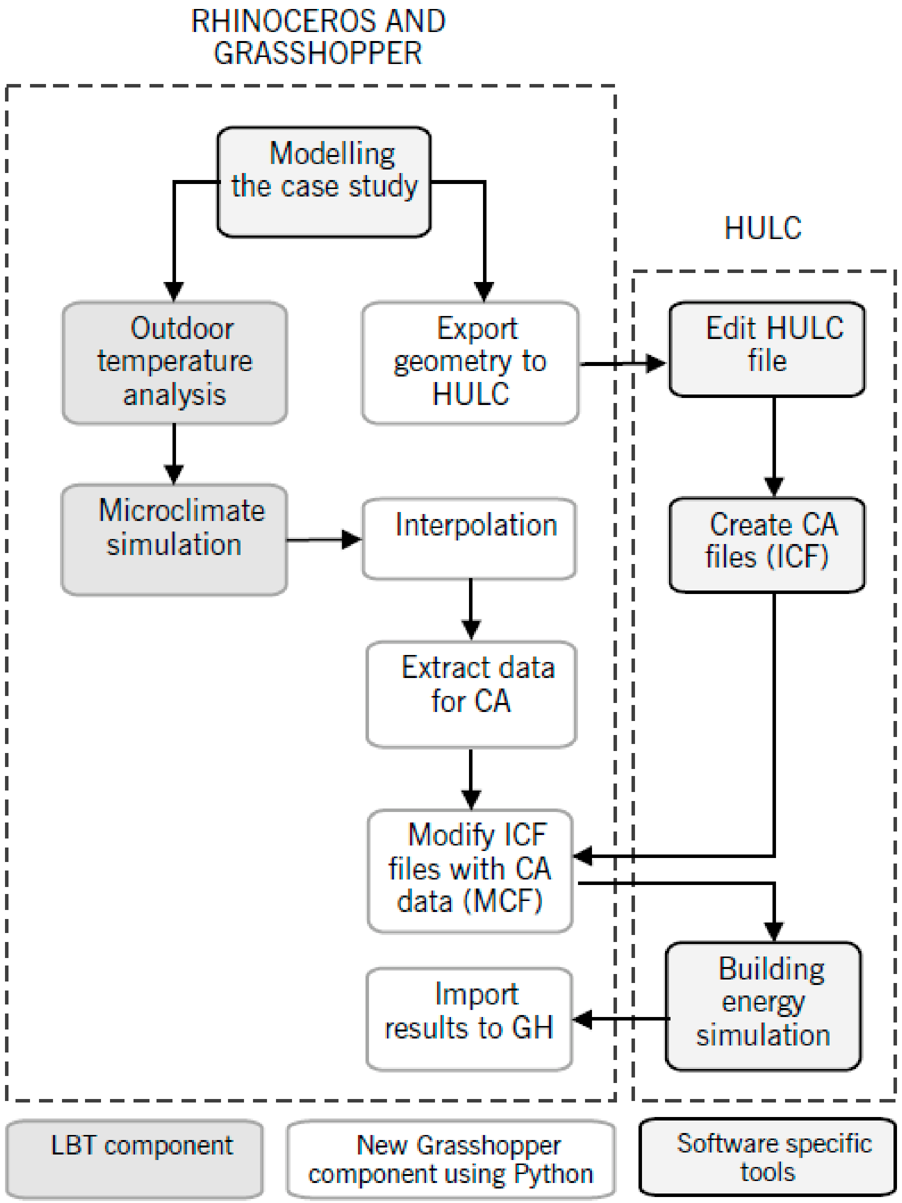






COUPLING COURTYARD SIMULATION WORKFLOW WITH ENERGY CERTIFICATION TOOL





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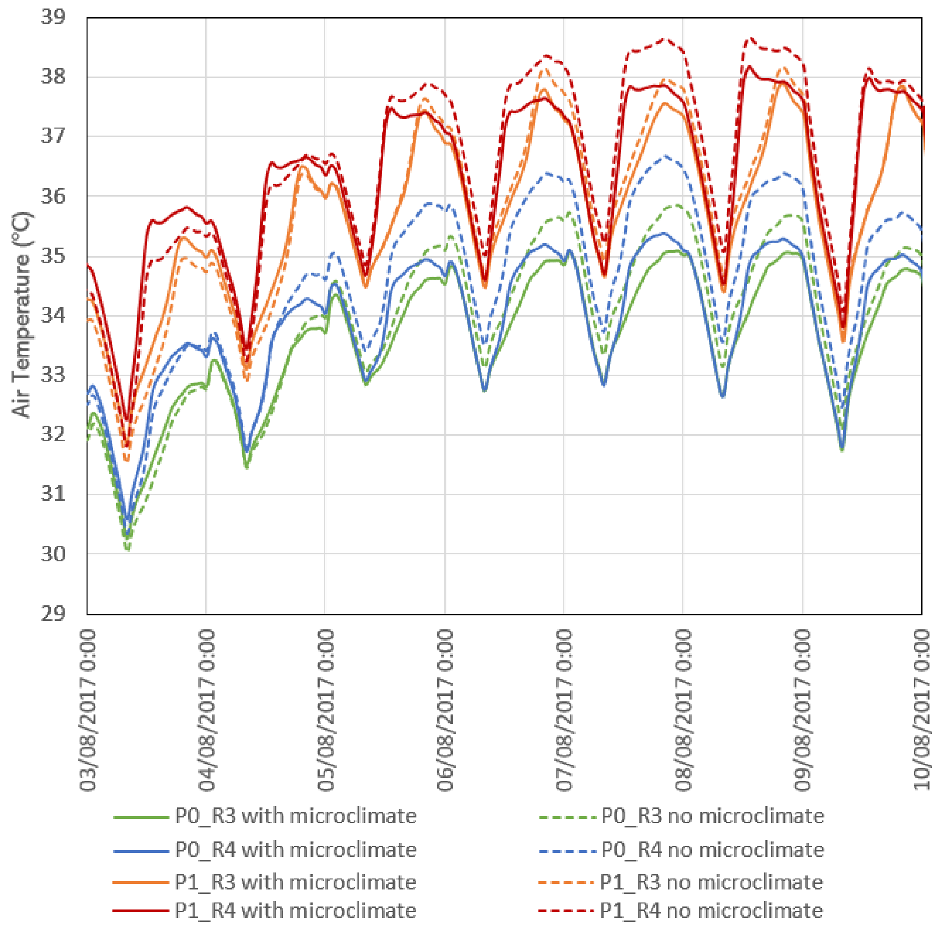
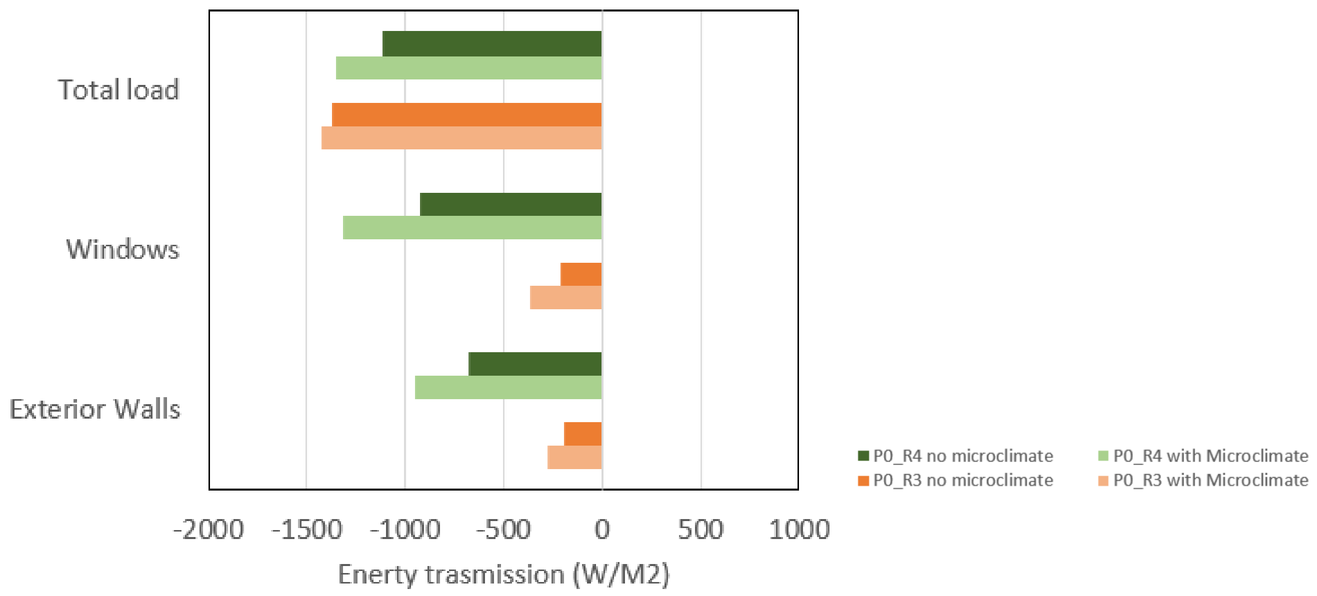
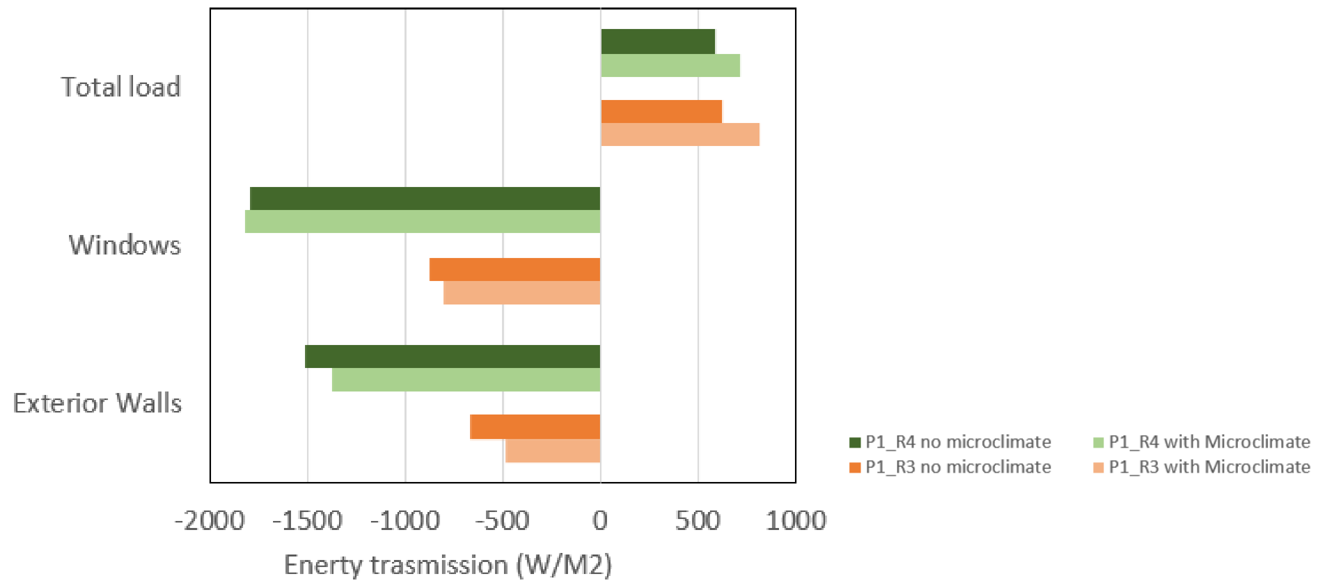


Room	Exterior Walls	Windows	Total load
P0_R3	30%	43%	4%
P0_R4	29%	30%	18%
P1_R3	38%	9%	24%
P1_R4	10%	1%	18%





CONCLUSIONS

- **Microclimates** generated in the outdoor spaces of buildings **influence the energy demand** and **thermal comfort** of users.

- The simulation of the microclimate of these spaces is not possible using the traditional energy simulation tools for buildings.

- Hybrid workflows connecting different kind of simulations are a suitable approach.

- It is still essential to enable better accessibility to the professional sector to promote a better climate change adaptation of the built environment

- The connection of a CFD-BES hybrid simulation workflow and an existing BES tool required for regulations compliance is proposed and tested.

- The effect of the microclimate in a courtyard is quantified.

THANK YOU!

Dr. Victoria Patricia López-Cabeza

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UNIVERSIDAD DE SEVILLA

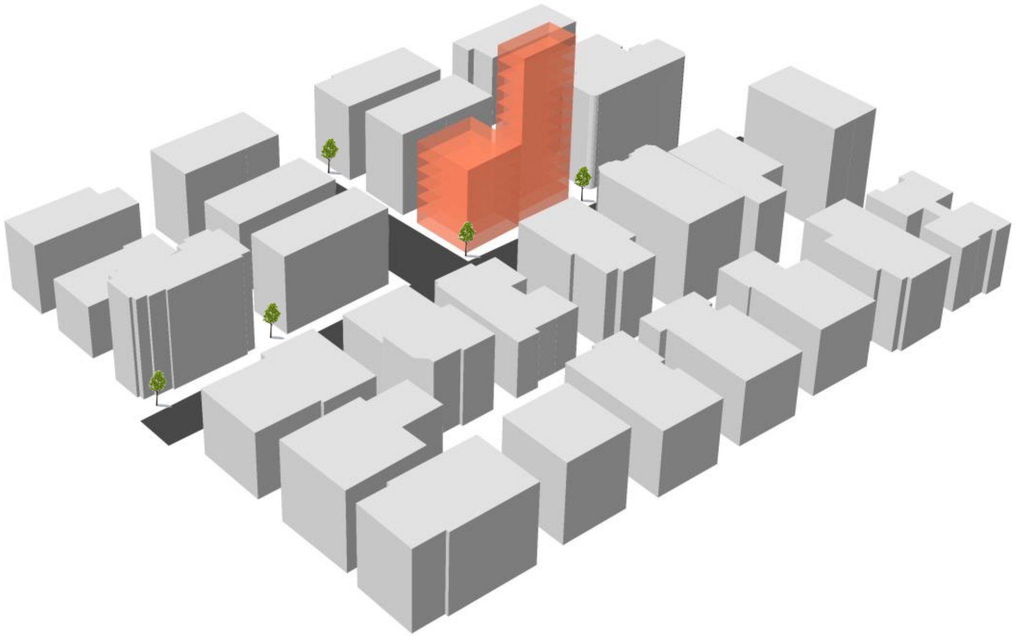
sath tep206

Sostenibilidad en Arquitectura, Tecnología y Patrimonio
Materialidad y Sistemas Constructivos

Urban microclimate
integrated
Building energy modeling

neither "Simple" nor "Complex"...

EPDL | TECHNION Israel Institute of Technology

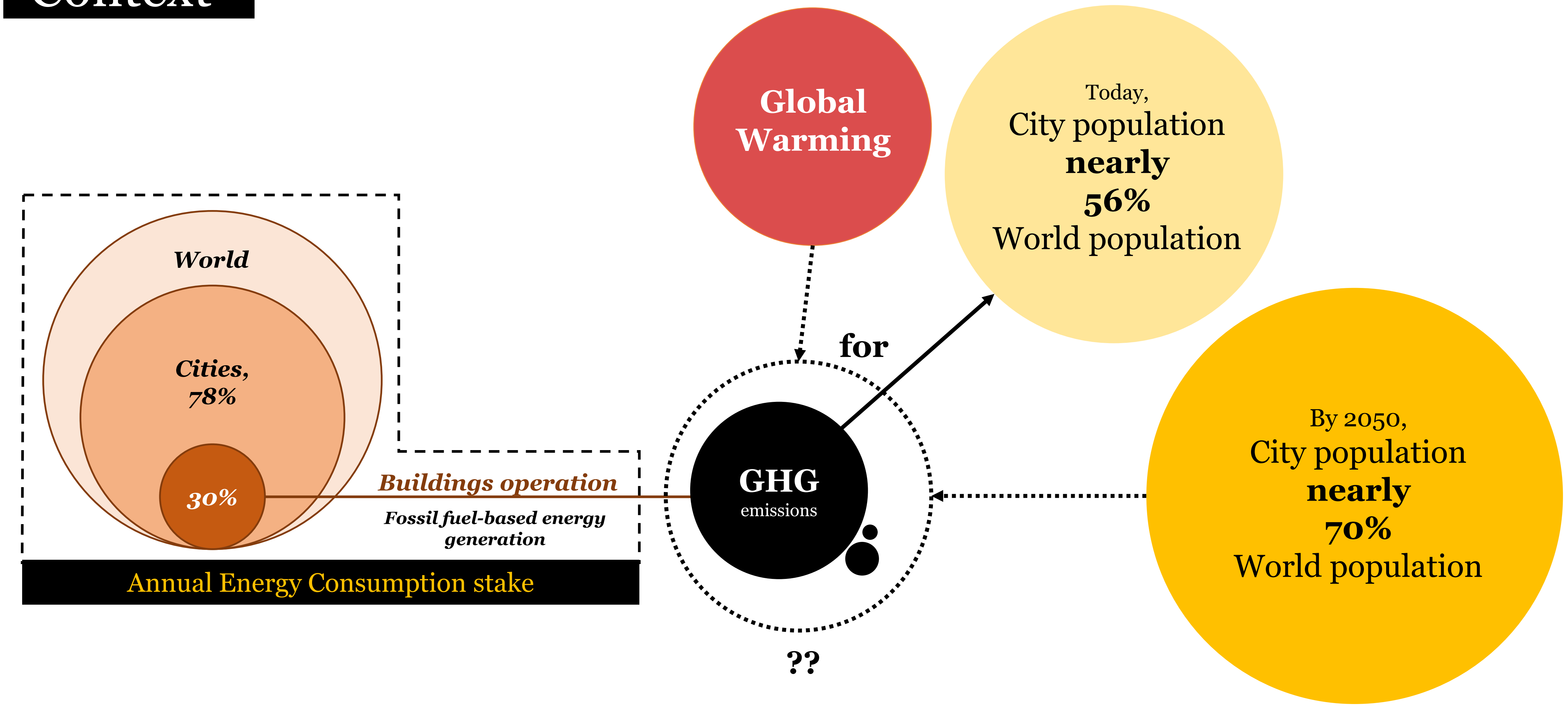


Agenda

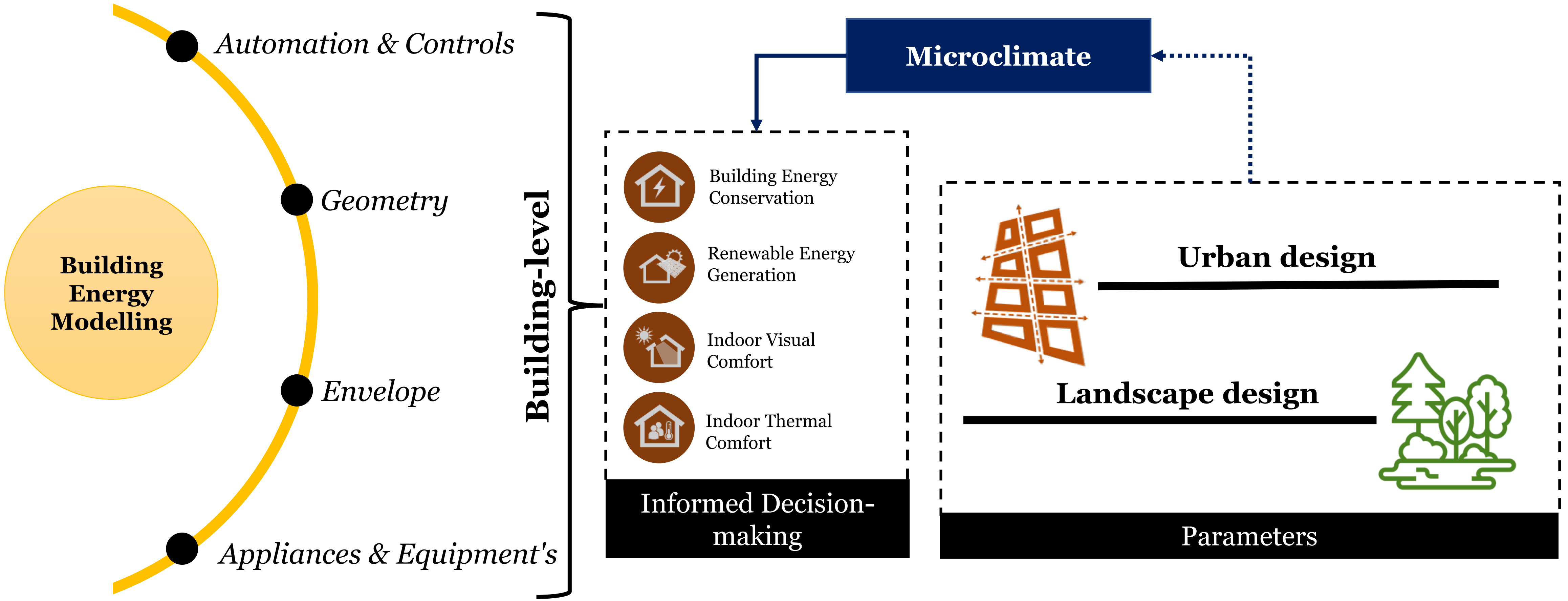
To understand -

1. Why is integrated simulation required?
2. What are the methods available for integration? (In-brief)
3. How are integration approaches neither simple nor complex?

Context


World
Cities,
78%
30%
Buildings operation
Fossil fuel-based energy generation
Annual Energy Consumption stake
Global Warming
for
GHG
emissions
??
Today,
City population
nearly
56%
World population
By 2050,
City population
nearly
70%
World population

BEM - benefits & limitations

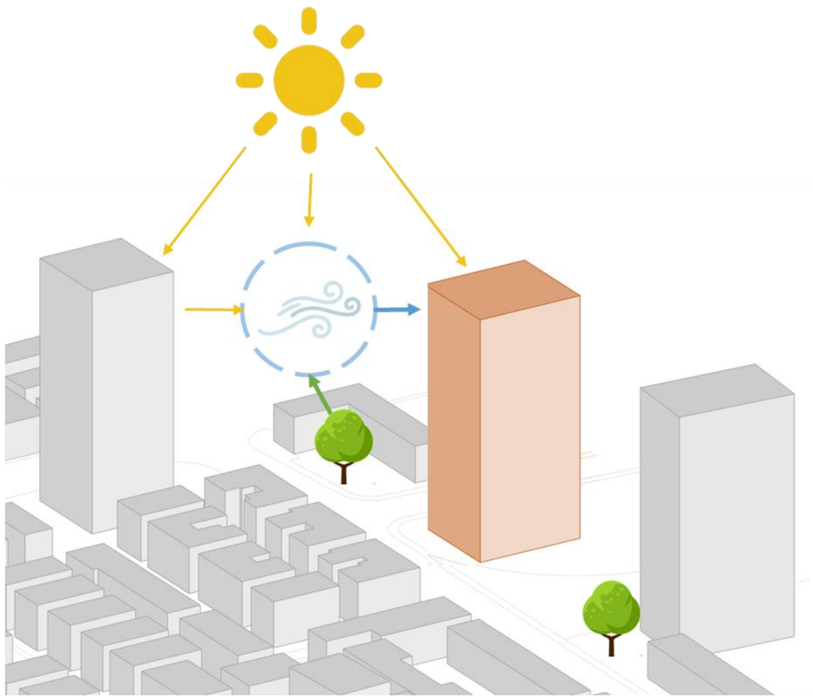


Urban microclimate impact

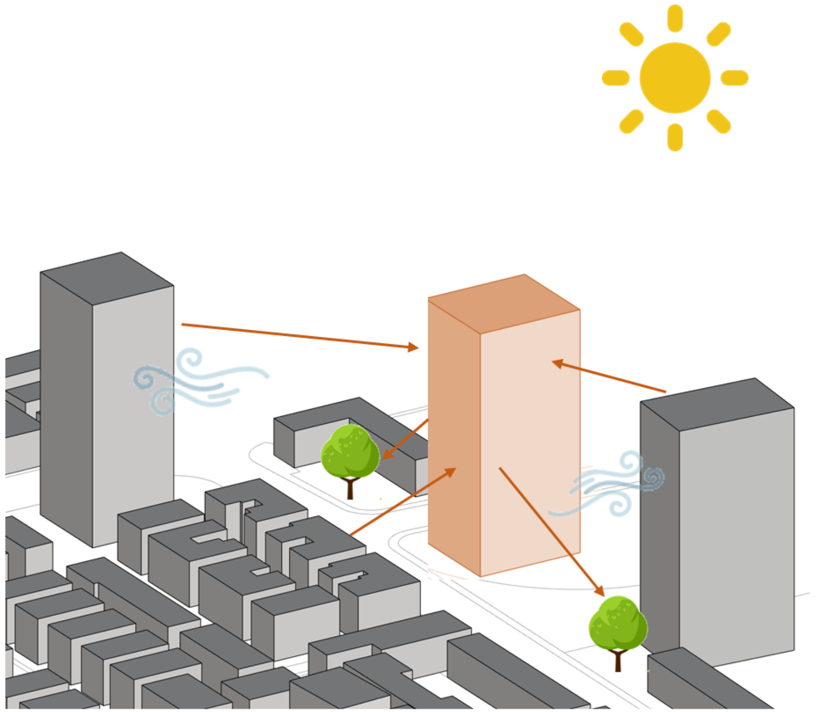
"Previous studies have shown that **15% - 89% of energy for heating is neglected** if the urban context and climate are not considered, **131% - 200% for space cooling**, and several degrees for indoor air temperature for non-air-conditioned spaces in summer."

- ***Lauzet N. et al.***, *How building energy models consider the local climate in an urban context – A review. Renewable and Sustainable Energy Reviews 2019;116*

Classification of approaches

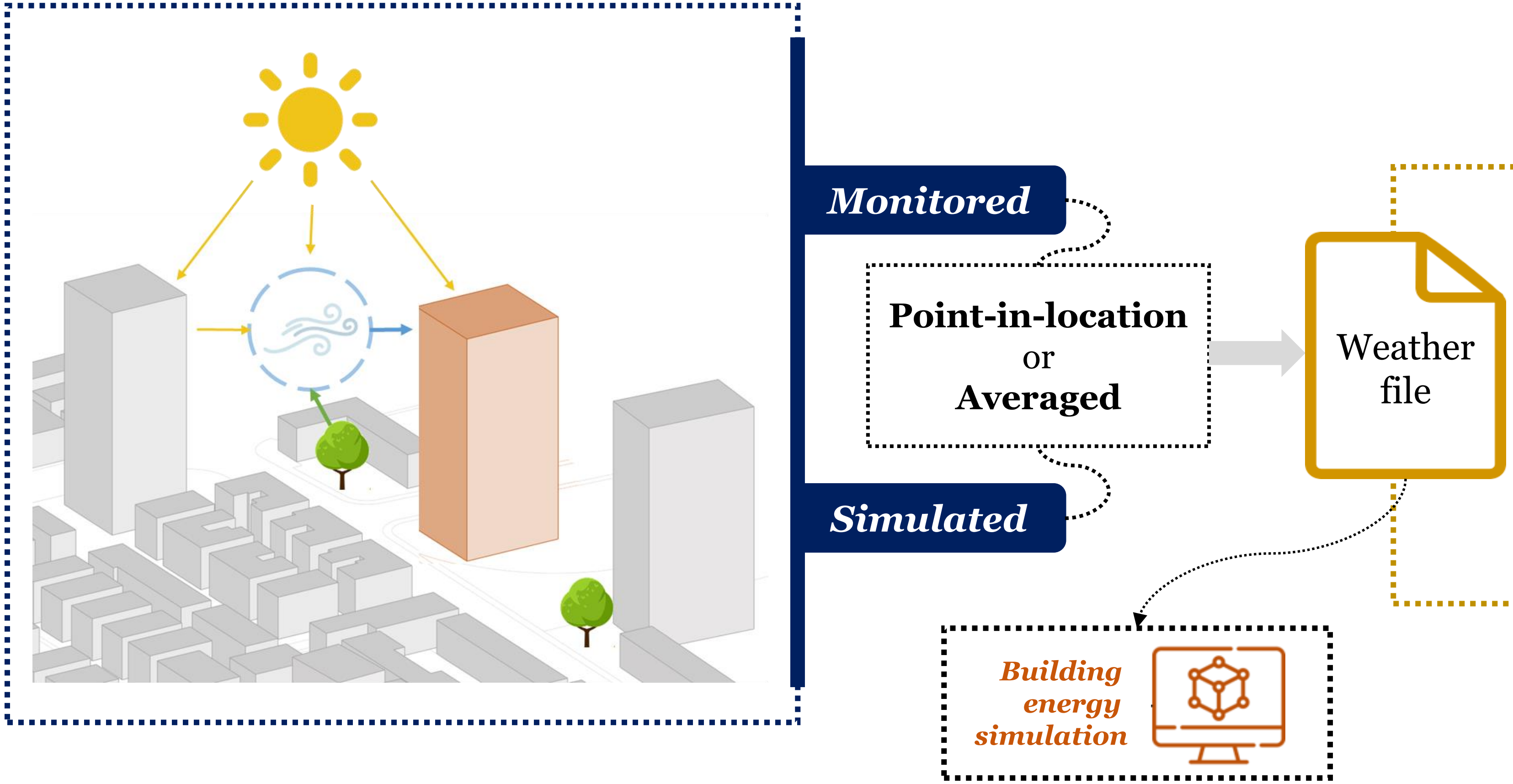


Representative data



Surface-specific data

Representative data

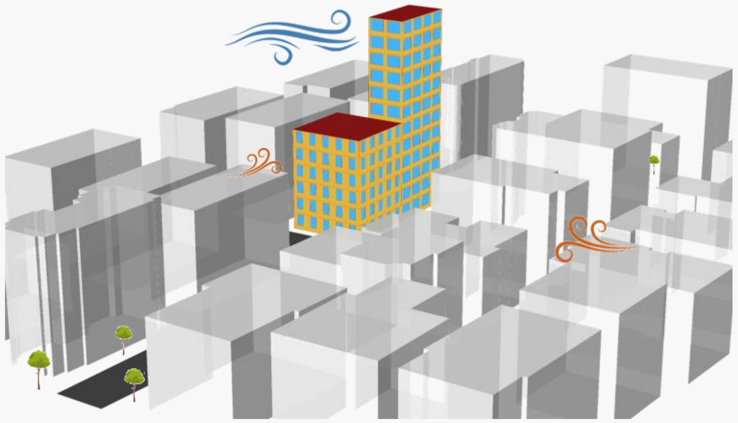


- Which point(s) data represent the microclimate?
- Can the representative data in the weather file help BEM tools account for varying heat flux around the building?

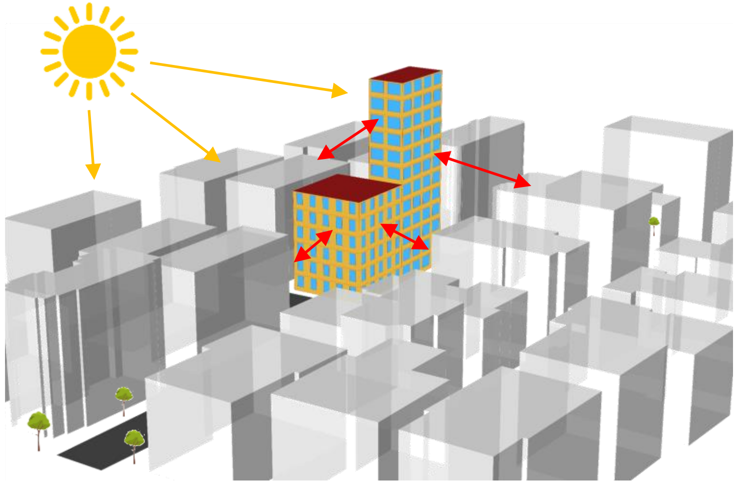
Heat transfer in urban context

Discharge

1. Wind speed ***changes with height*** [1]
2. Wind speed and *direction* ***varies with building form and urban context*** [2]



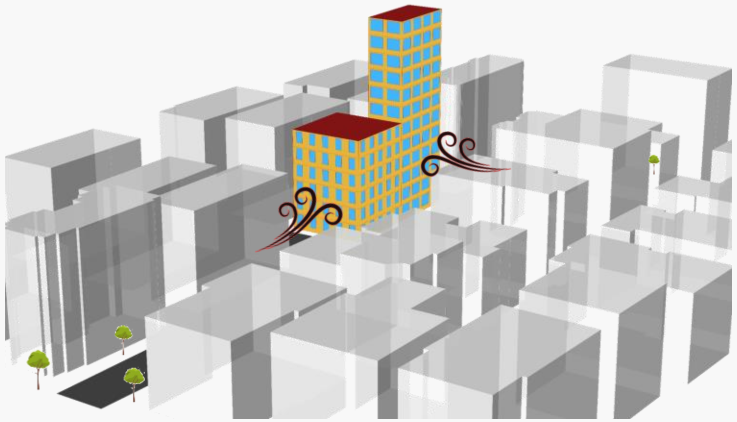
Radiation



1. Contextual ***shade and shadows are not uniform***
2. Surrounding hot or cold surfaces ***can induce or absorb heat flux*** *in building surface* [3,4]

Convection

1. Convective heat transfer is a function of ***wind speed, air temperature & temperature of the building surface*** [5]



[1] Gui C, Yan D, Hong T, Xiao C, Guo S, Tao Y. Vertical meteorological patterns and their impact on the energy demand of tall buildings. Energy Build 2021;232:110624
[2] Brozovsky J, Radivojevic J, Simonsen A. Assessing the impact of urban microclimate on building energy demand by coupling CFD and building performance simulation. Journal of Building Engineering 2022;55:104681.
[3] Colucci C, Mauri L, Grignaffini S, Romagna M, Cedola L, Kanna R. Influence of the façades convective heat transfer coefficients on the thermal energy demand for an urban street canyon building. Energy Procedia 2017;126:10–7
[4] Hadavi M, Pasdarshahri H. Investigating effects of urban configuration and density on urban climate and building systems energy consumption. Journal of Building Engineering 2021;44:102710
[5] Liu J, Heidarinejad M, Nikkho SK, Mattise NW, Srebric J. Quantifying impacts of urban microclimate on a building energy consumption-a case study. Sustainability (Switzerland) 2019;11

Default & custom BEM

Local outdoor air temperature

Variation in outdoor air temperature is calculated using the U.S. Standard Atmosphere (1976). According to this model, the relationship between air temperature and altitude in a given layer of the atmosphere is:

$$T_z = T_b + L\left(H_z - H_b\right) \quad (3.70)$$

where
T_z = air temperature at altitude z
T_b = air temperature at the base of the layer, i.e., ground level for the troposphere
L = air temperature gradient, equal to –0.0065 K/m in the troposphere
H_b = offset equal to zero for the troposphere
H_z = geopotential altitude.
The variable H_z is defined by:

External Longwave radiation

The ground surface temperature is assumed to be the same as the air temperature. The final forms of the radiative heat transfer coefficients are shown here.

$$h_{r,gnd} = \frac{\varepsilon\sigma F_{gnd}(T_{surf}^4 - T_{air}^4)}{T_{surf} - T_{air}} \quad (3.66)$$

$$h_{r,sky} = \frac{\varepsilon\sigma F_{sky}\beta(T_{surf}^4 - T_{sky}^4)}{T_{surf} - T_{sky}} \quad (3.67)$$

$$h_{r,air} = \frac{\varepsilon\sigma F_{sky}\left(1-\beta\right)\left(T_{surf}^4 - T_{air}^4\right)}{T_{surf} - T_{air}} \quad (3.68)$$

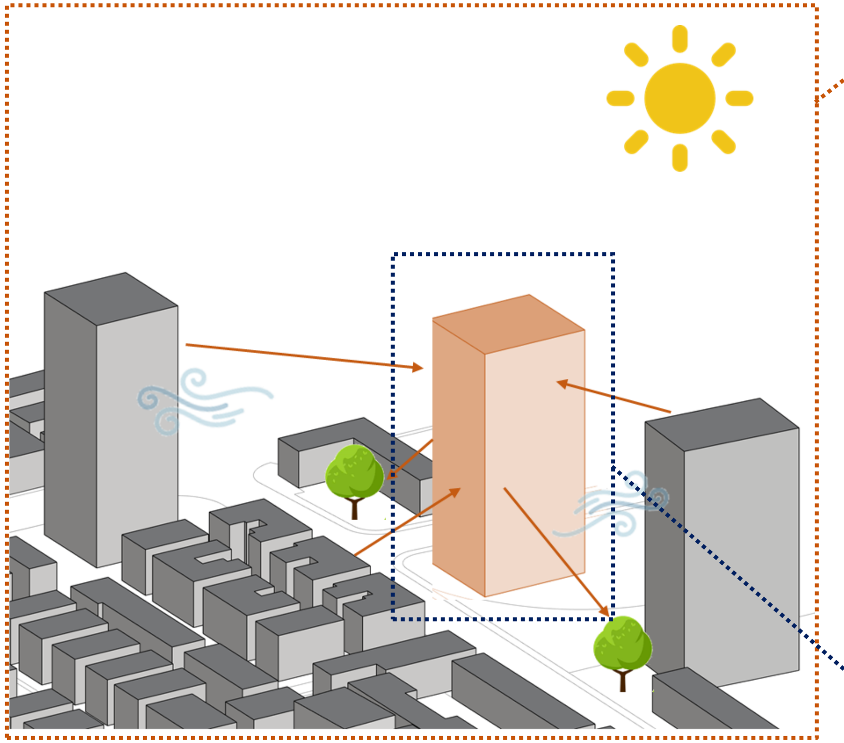
Local outdoor wind speed

In Chapter 16 of the Handbook of Fundamentals (ASHRAE 2005), the wind speed measured at a meteorological station is extrapolated to other altitudes with the equation:

$$V_z = V_{met}\left(\frac{\delta_{met}}{z_{met}}\right)^{\alpha_{met}}\left(\frac{z}{\delta}\right)^{\alpha} \quad (3.73)$$

**EnergyPlus Engineering Reference (2022), U. S. Department of Energy, DOE

Surface-specific data



Urban climate model

↓

Climate variables

↓

Coefficients

↓

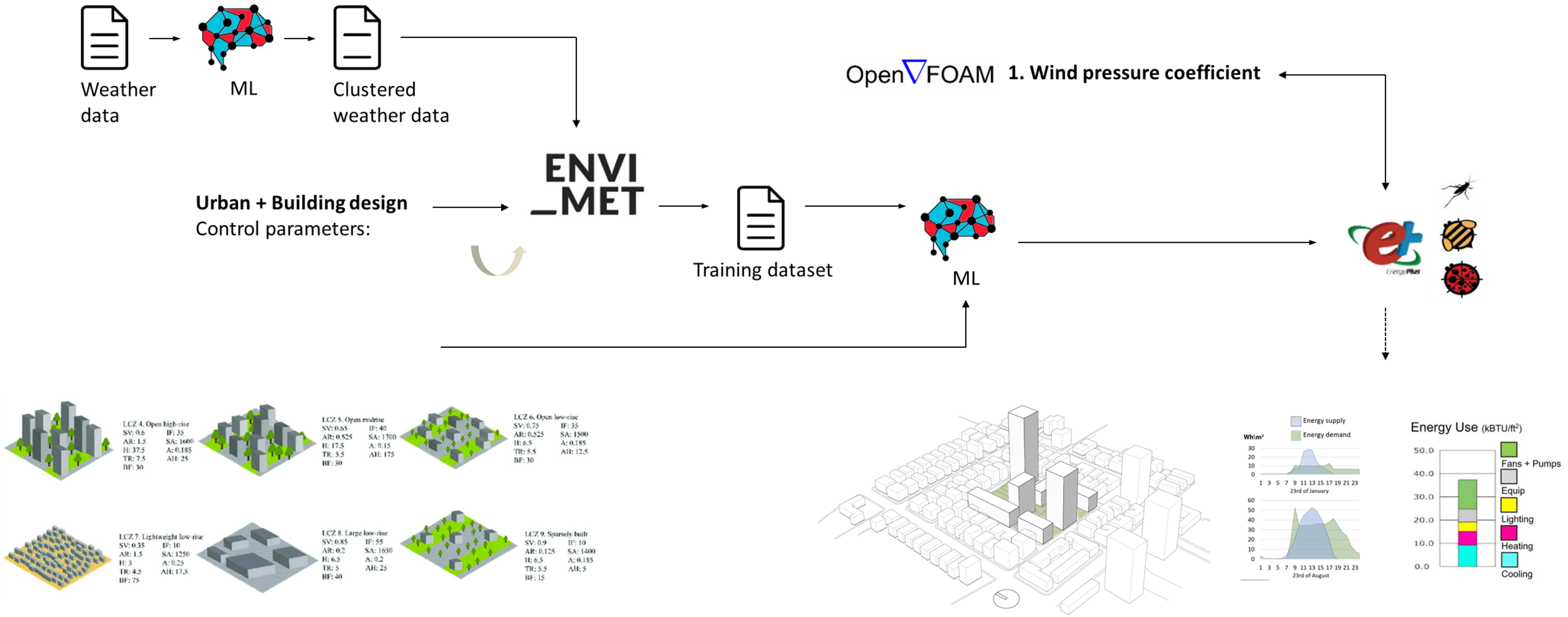
Building energy model

Simple or complex?

- **No current approach** accounted for **all heat transfer modes.**
- There are only **one-way coupling approaches** devised.
- The **physical process adopted** by **UCMs to assess heat flux from buildings** is **not equal** to the estimate by the **BEM**.
- **CFD-based UCMs** are **computationally expensive.**
- **Co-simulation** requires **programming skill**

Coupling | Chaining

We at EPFL



Microclimate metamodels training >> for microclimate integrated energy evaluation

Thank you

Proyecto PID2020 – 114873RA – C33 financiado por:

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

Programa Estatal de I+D+i Orientado a los Retos de la Sociedad 2020

URBAN THERCOM

BUILD UP

Discussion

Coffee break

We will return at 12.40

Session 2:

Microclimate, Form and Surfaces

Urban Microclimate: Ongoing projects

Carmen Galán-Marín. Professor at E.T.S. Arquitectura. Universidad de Sevilla. cgalan@us.es

Sostenibilidad en Arquitectura, Tecnología y Patrimonio
Materialidad y Sistemas Constructivos

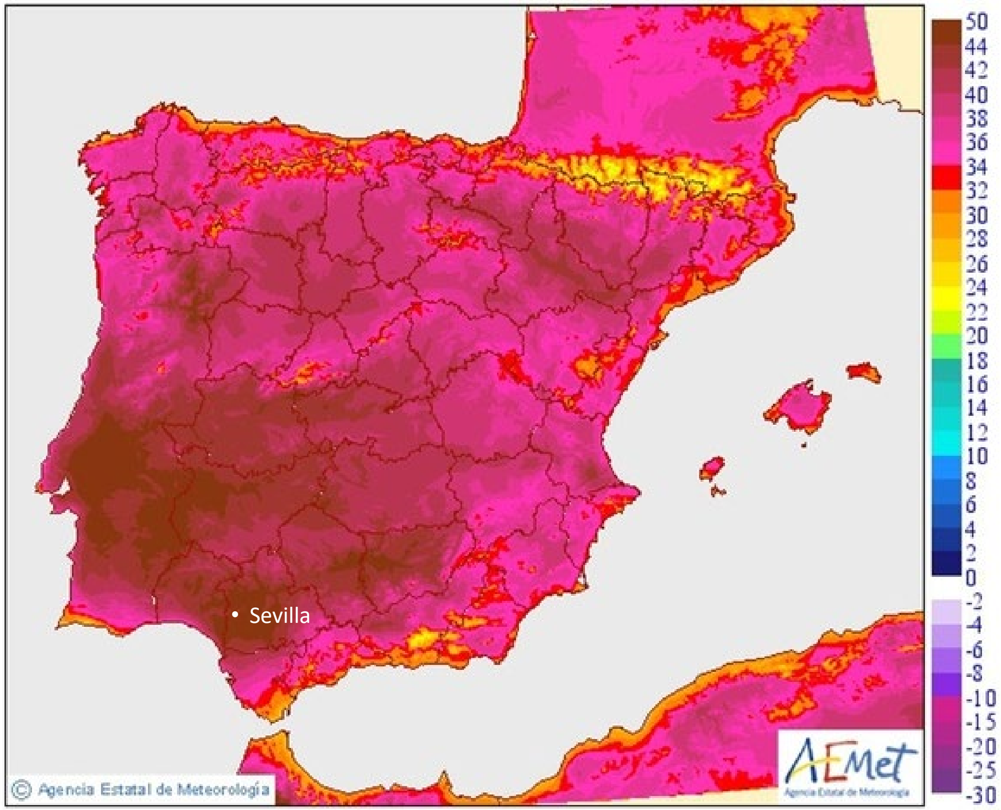
PRESENTATION

TEP206

SATH Sustainabilty in Architecture: Technology and Heritage

sath tep206

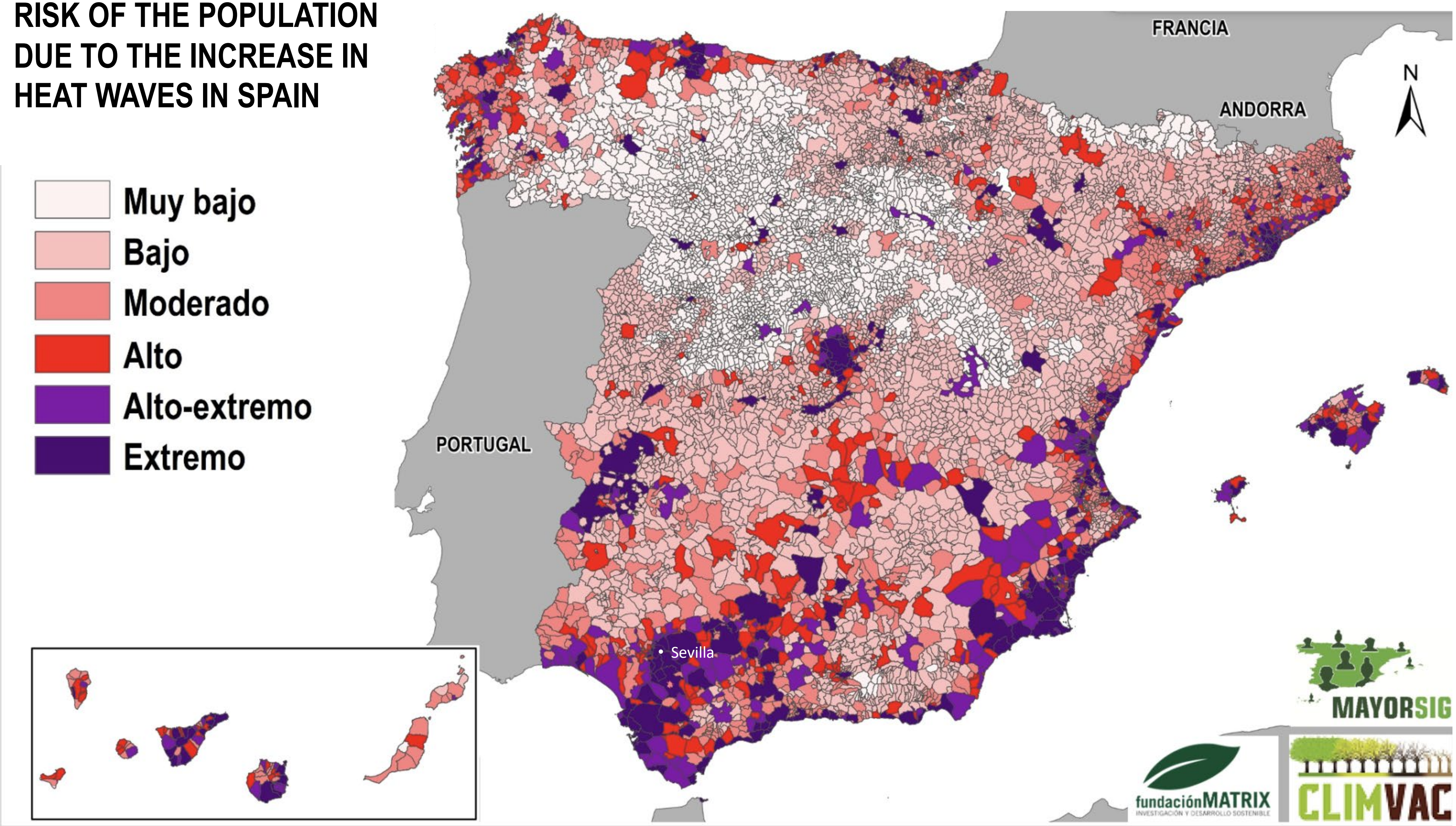
Sostenibilidad en Arquitectura, Tecnología y Patrimonio
Materialidad y Sistemas Constructivos



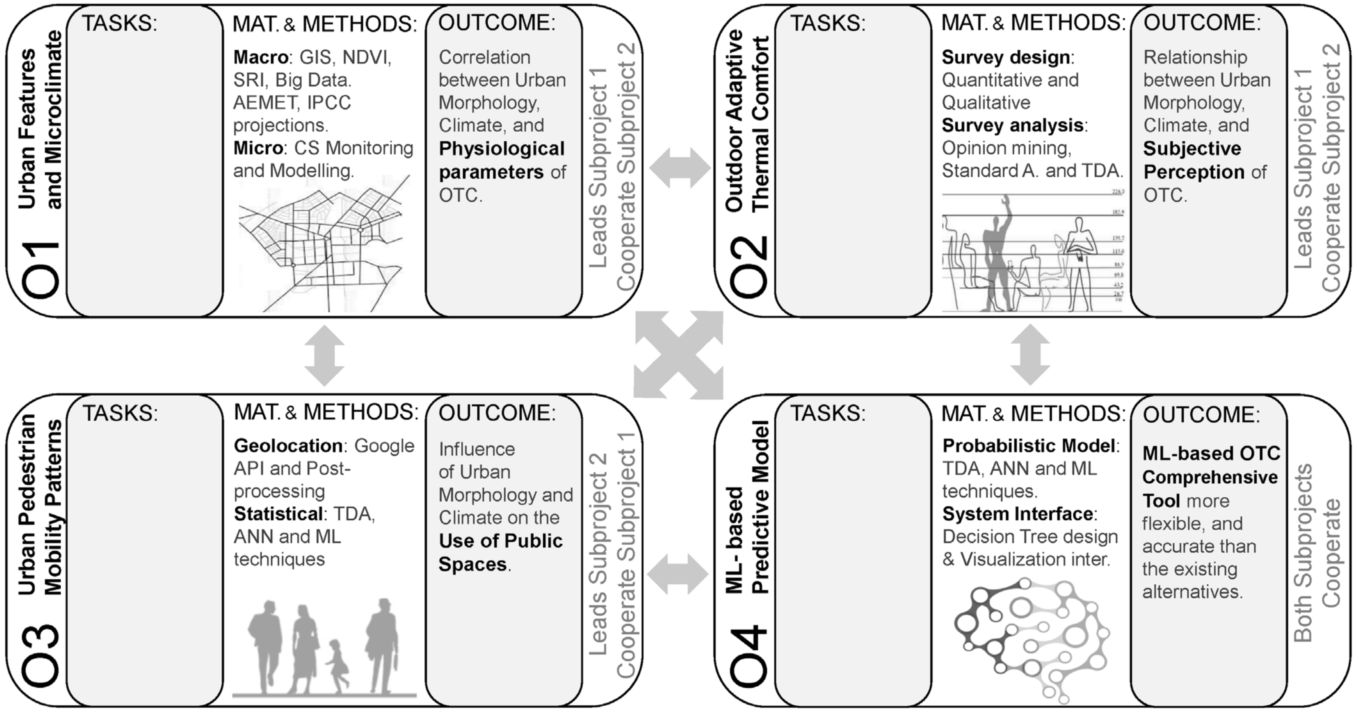
Carmen Galan Marin • José Antonio López Martínez • Mercedes Ponce Ortiz de Insagurbe • Jorge Roa Fernandez • Carlos Alberto Rivera Gomez • Juan Manuel Rojas Fernández • José María Rincón Calderón • Angela Barrios Padura • Antonio serrano Jiménez • Begoña Blandón González • Marta Molina Huelva • Carmen Diaz Lopez • Victoria Patricia López Cabeza • Eduardo M. Diz Mellado • Javier de Sola Caraballo • José Antonio Rodríguez Gallego

http://grupo.us.es/tep206/

RISK OF THE POPULATION DUE TO THE INCREASE IN HEAT WAVES IN SPAIN



https://fundacionmatrix.es/riesgo-de-la-poblacion-por-aumento-de-las-olas-de-calor-en-espana/



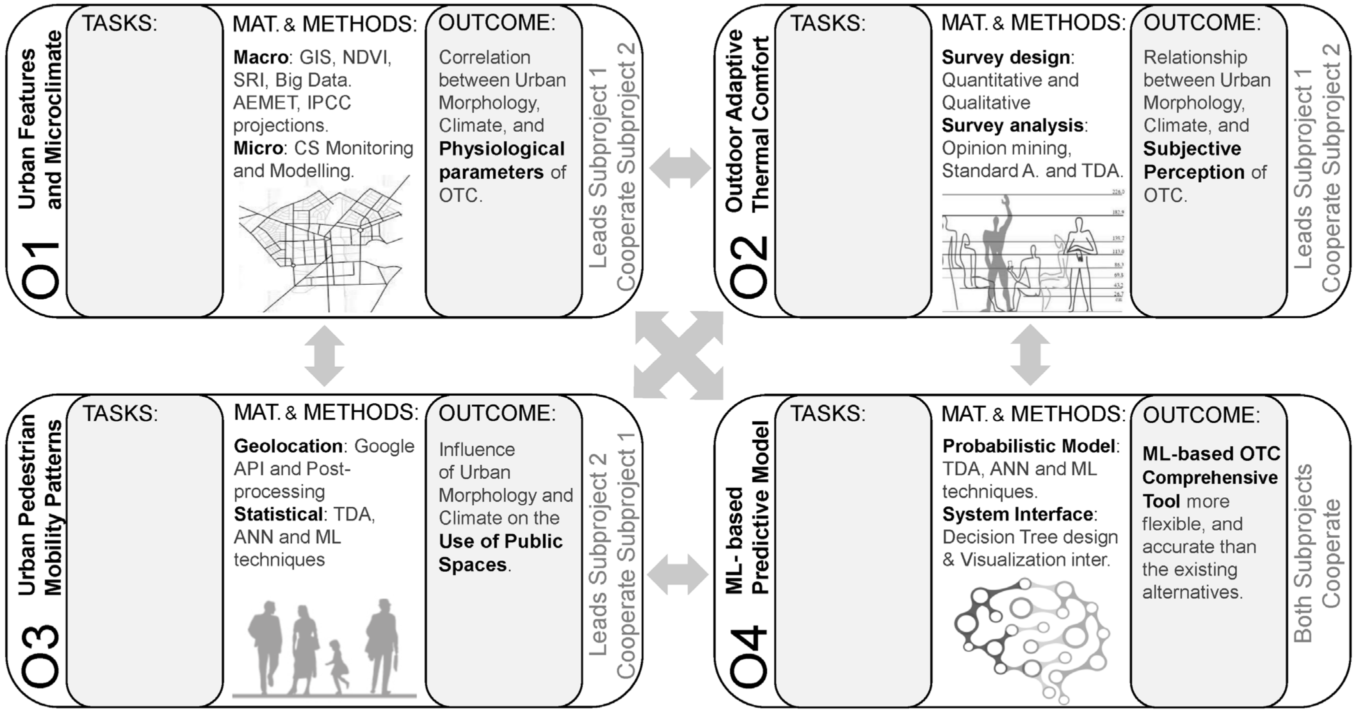
REACTS

TED2021-129347B-C21

2022 - 2024

Benchmarking urban morphology by Reviewing Adaptive Comfort and Thermal Stress

Proyect TED2021-129347B-C21 financed by MCIN/ AEI /10.13039/501100011033/ and by European Union NextGeneration EU / PRTR Plan de Recuperación, Transformación y Resiliencia de España



REACTS

TED2021-129347B-C21

2022 - 2024

-

UTHECA (COORDINATED PROJECT)

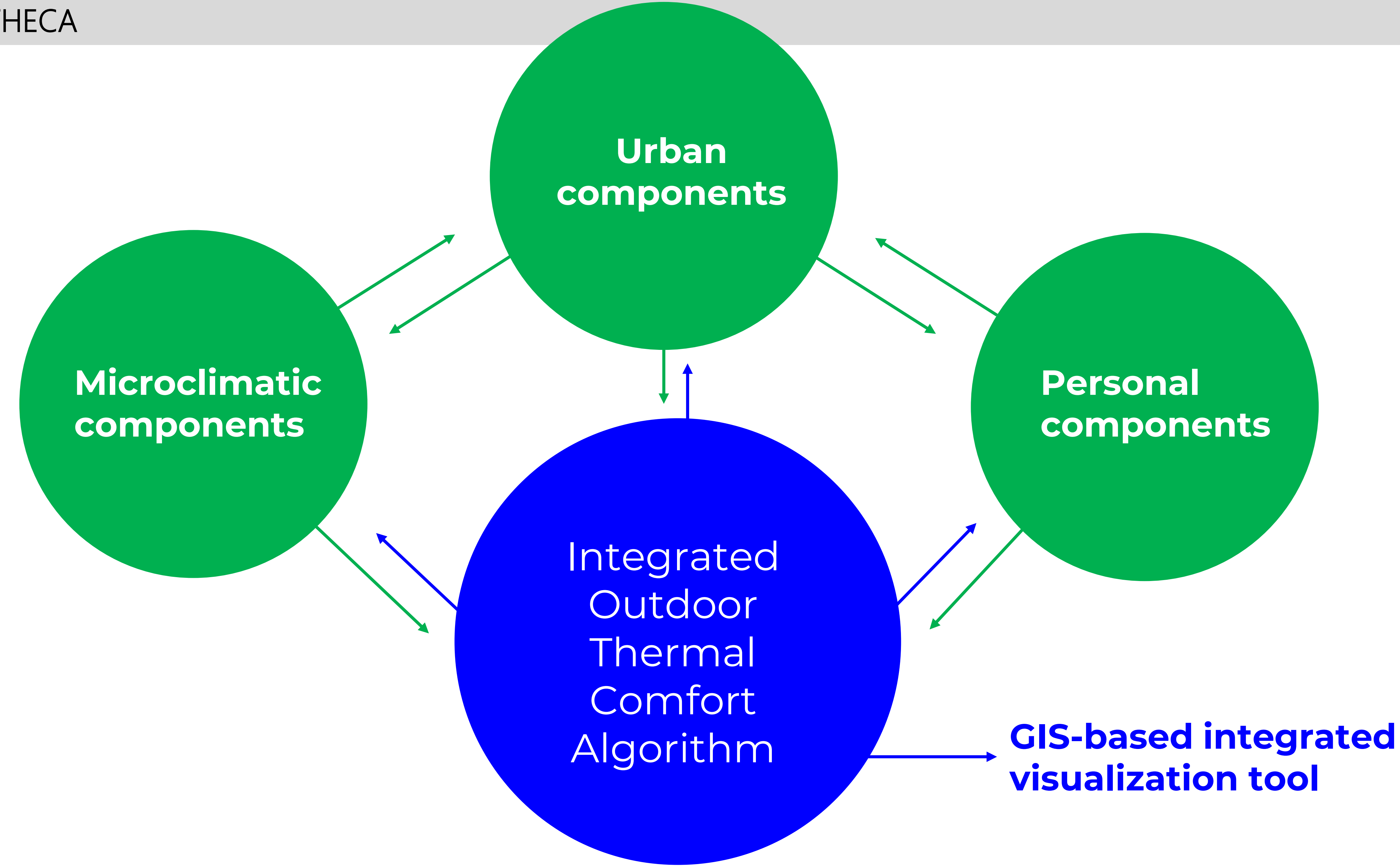
Machine Learning-based forecasting model for integrated assessment of thermal resilience using **U**rban **The**rmal **C**omfort **A**lgorithms.

Proyect TED2021-129347B-C21/22 financed by MCIN/ AEI /10.13039/501100011033/ and by European Union NextGeneration EU / PRTR Plan de Recuperación, Transformación y Resiliencia de España

Currently there is no integrated and harmonized outdoor thermal comfort index

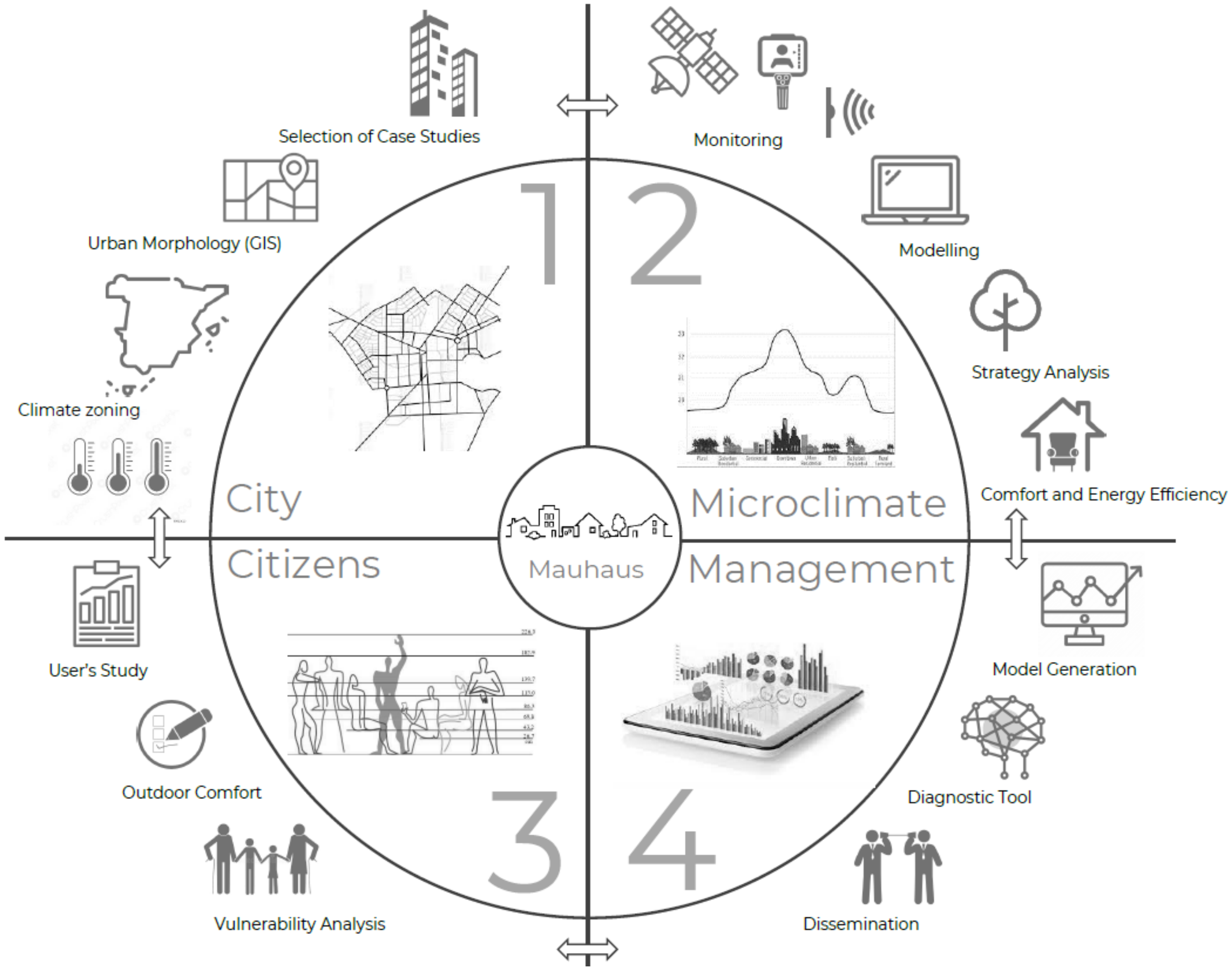
Drawbacks:

1. The most frequent indices (UTCI and PET) do not consider the subjective perception of comfort.
2. UTCI and PET do not adequately describe the subjective perception of thermal comfort.
3. As a complex system, there is no global tool for assessing thermal comfort.
4. It is not possible to optimize thermal resilience conditions due to undefined or inaccurate ranges of thermal comfort.
5. It is not possible to discriminate the thermal comfort range for the population segments more sensitive to thermal stress.
6. Cross-analyses cannot be performed to determine specific comfort conditions according to the attributes of one, or more, population segments.
7. Urban interventions to improve climate resilience follow partial, incomplete and / or wrong guidelines


Urban components
Microclimatic components
Personal components
Integrated Outdoor Thermal Comfort Algorithm
GIS-based integrated visualization tool

Motivation of the Project

This project aims to improve urban thermal resilience in a Climate Change context by developing **ML-based models** to accurately predict the subjective perception of comfort and its interactions with the climatic and built environments in order to generate **better intervention strategies oriented to adaptation and improvement of outdoor public spaces**. In addition, the inclusion of Subproject 2 will allow the use of topological data analysis for the attribute data input and management, enabling optimization of model evaluation algorithms.



MINISTERIO DE CIENCIA E INNOVACIÓN
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AGENCIA ESTATAL DE INVESTIGACIÓN

MAUHAUS

PID2021-124539OB-I00.

2022 - 2025

Multiscale Assessment of Urban Heat-Island Applied to Urban Suburbs (MAUHAUS)

Proyect PID2021-124539OB-I00 financed by MCIN/ AEI /10.13039/501100011033/ and by FEDER A way of making Europe

Aim of the Project

To contribute to the climate adaptation challenges of our cities from a multi-scale, comprehensive and innovative approach, promoting urban public policies that are capable of identifying risk areas and incorporating proposals that guarantee their resilience to the effects of climate change, contrasting their technical and social viability.

Proposal

- Holistic, hybrid and multiscale perspective that contemplates the dimension of the problem from a quantitative approach (different urban scales and their microclimatic patterns) and qualitative ones (climate vulnerability, thermal comfort, social habits, functionality and habitability).

- Identify public spaces with a high viability of climate adequacy within cities, spaces of opportunity or potential Urban Cool Islands, which can serve as climatic and social laboratories have to incorporate new evaluation mechanisms that facilitate the identification of strategies.

- Systematize the instrumental nature of the results of the study that must materialize in tools to help decision-making in the field of public administration.

Objetives

1. CITY

- Value the importance of urban porosity through its analysis and climate contextualization in order to determine a priority zoning and obtain case studies (through GIS and study of seasonal climatic severity for outdoor urban spaces)

2. MICROCLIMATE

- Evaluate UHI of the selected cities by determining the possibilities of mitigation of excess urban heat at local scale (micro and meso scales) considering the characteristics of the macro scale (remote sensing systems, aerial thermography, conventional, intra-urban and in situ meteorological stations or field work will be used; to validate simulation results).

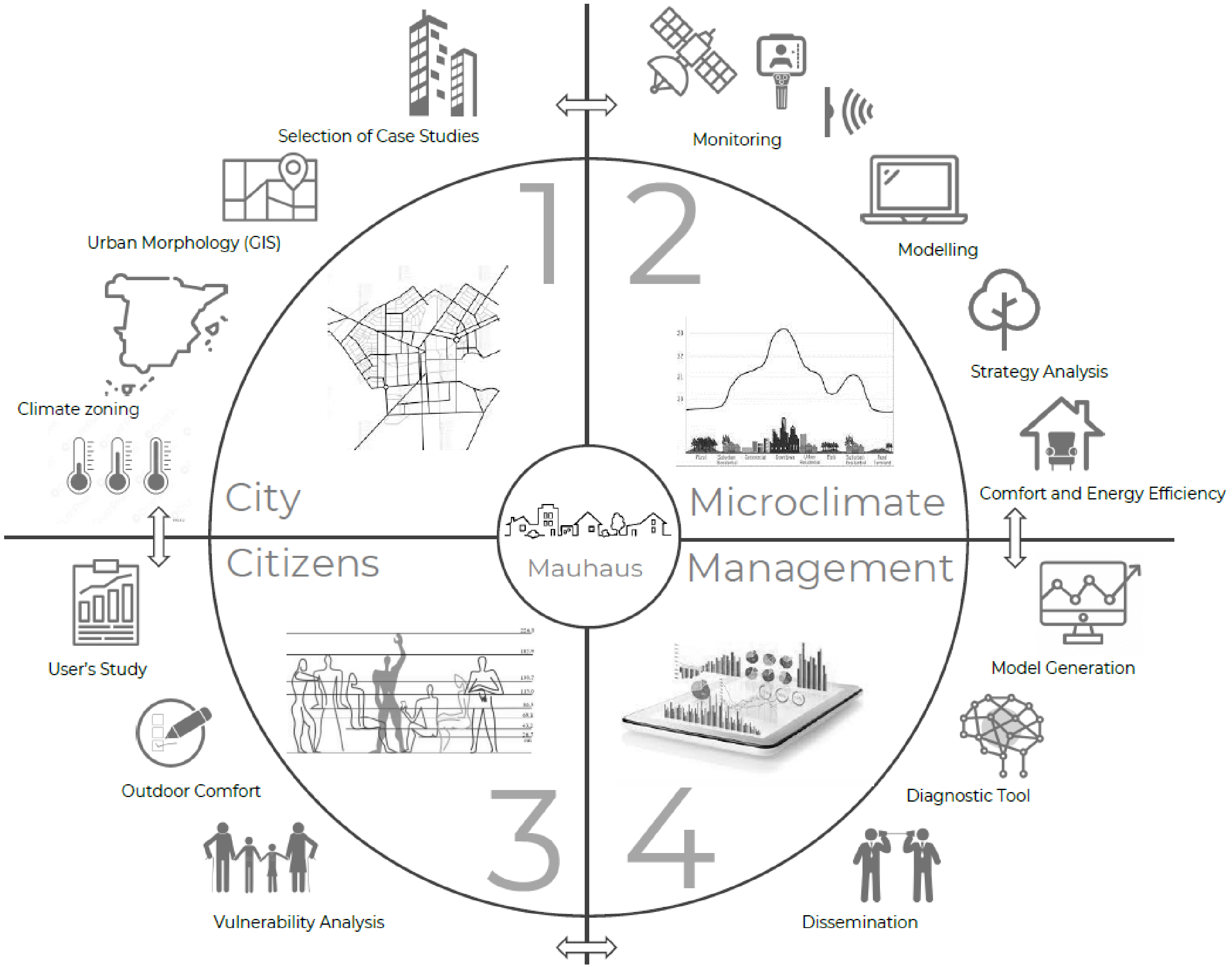
3. CITIZENS

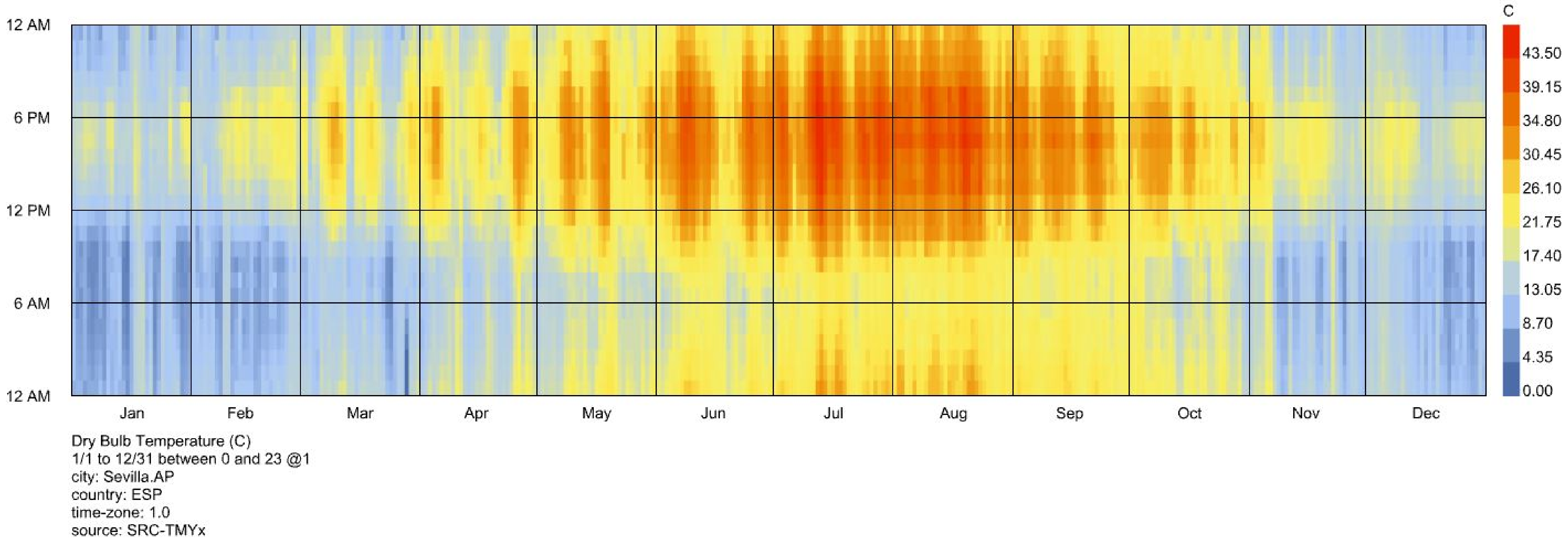
- Identify the impact of the climate of public space on the citizens, defining the concept of climate vulnerability (social, functional and thermal comfort studies: census data, urban information and questionnaires on the perception of thermal comfort).

4. MANAGEMENT

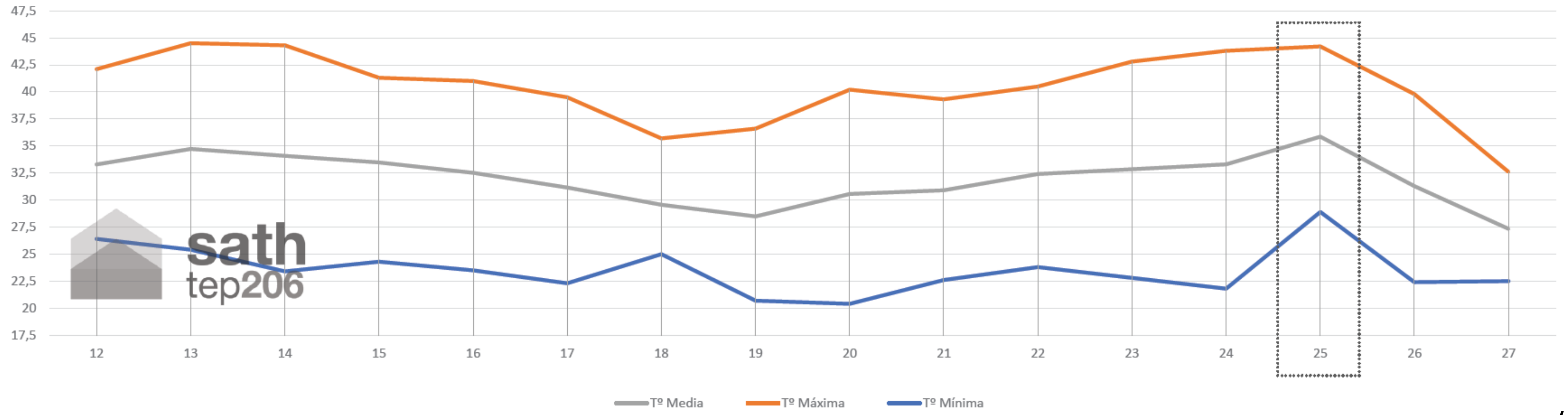
- Develop decision-support tools that facilitate the choice of effective and viable action proposals at the urban scale that mitigate the risk of overheating. Guides will be generated for the identification of priority areas, optimization of existing infrastructures, hierarchization of areas to intervene and selection of specific strategies. Tools based totally or partially on machine learning are mainly proposed.

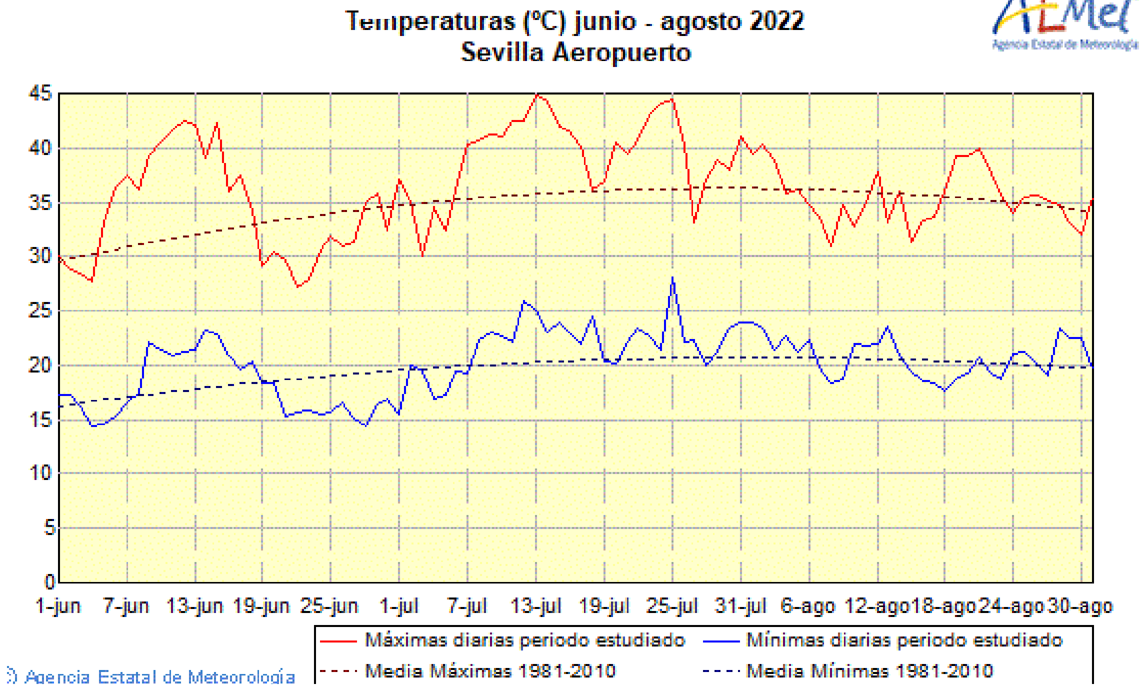
Metodology


Selection of Case Studies
Monitoring
Urban Morphology (GIS)
Modelling
Strategy Analysis
Climate zoning
Comfort and Energy Efficiency
1
2
City
Microclimate
Mauhaus
Citizens
Management
User's Study
Model Generation
Outdoor Comfort
Diagnostic Tool
3
4
Vulnerability Analysis
Dissemination



Dry bulb temperature of the city of Seville during one year. Extracted from Ladybug Tools.



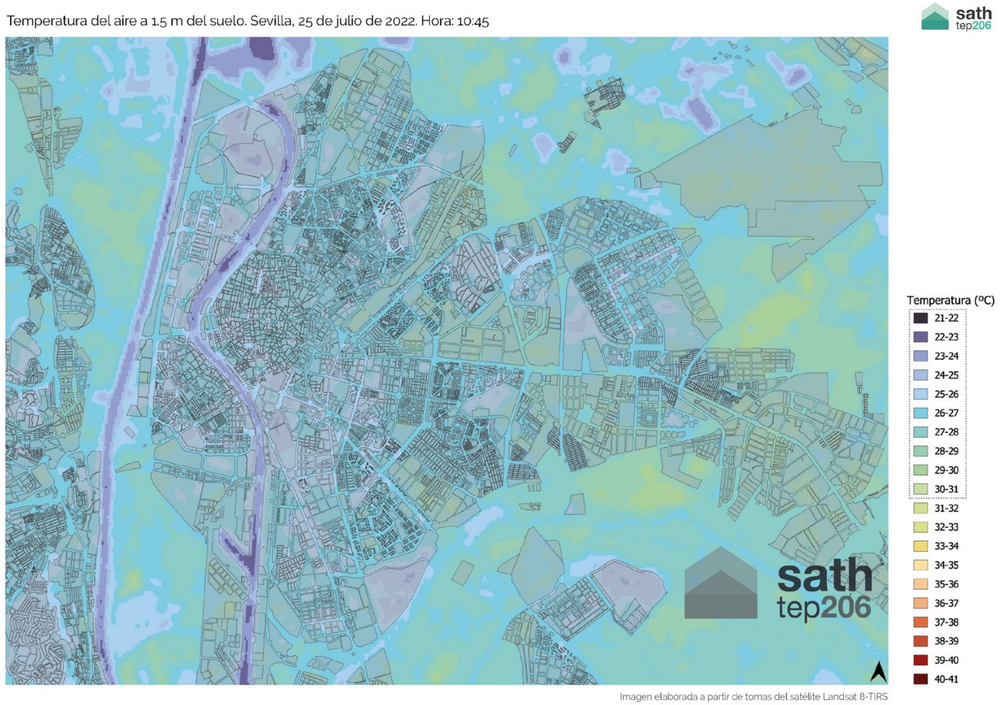


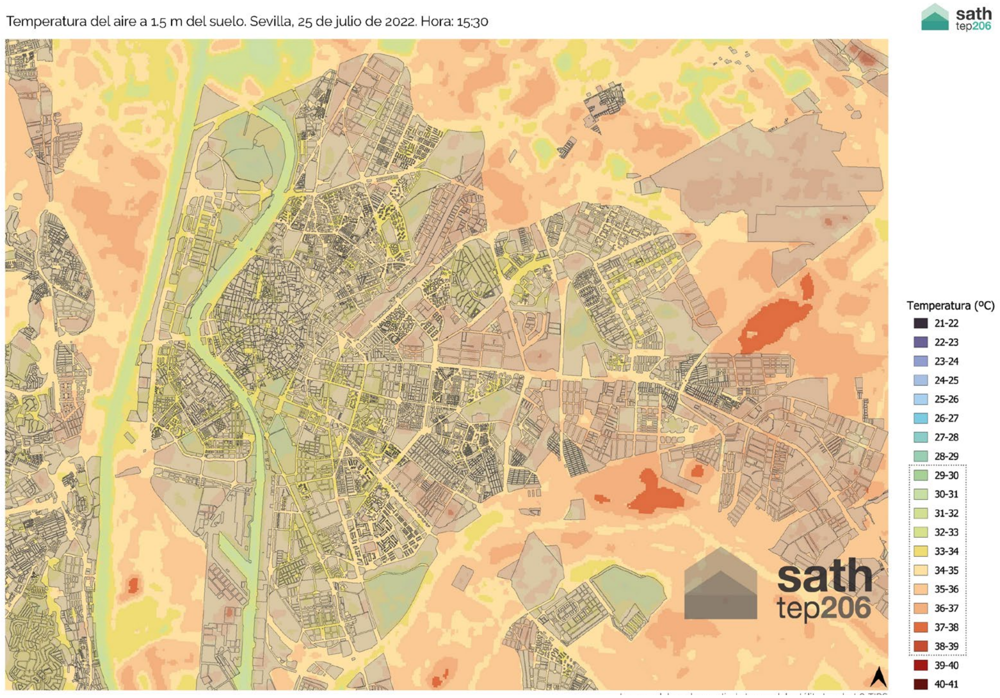
Summer 07/2022
Heat wave

MAUHAUS

Identification

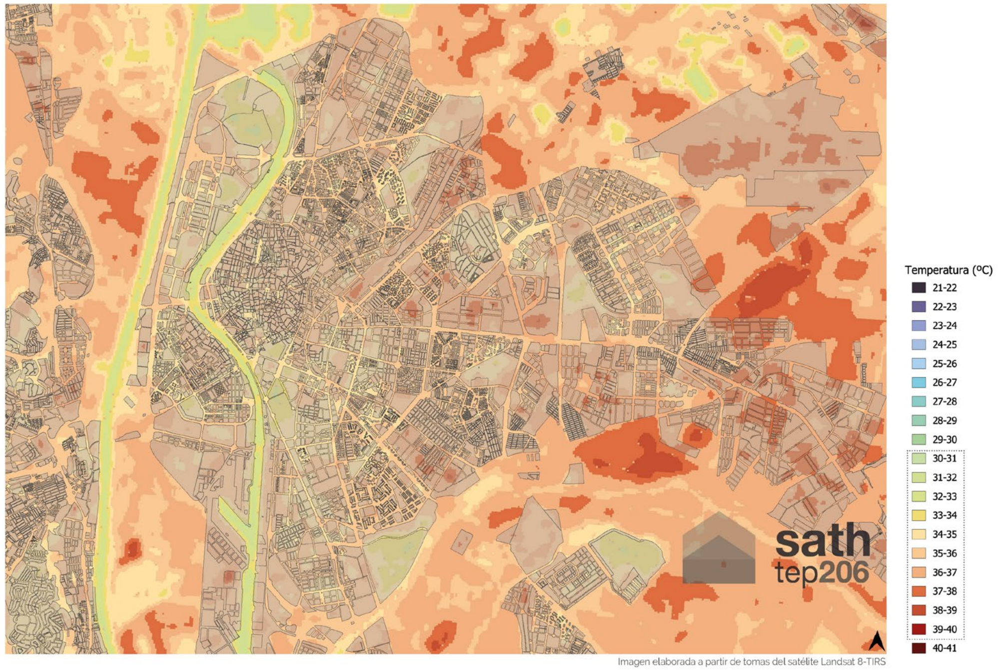
(satellite images) of locations in the urban context with higher levels of urban overheating potential risk (UOPR)

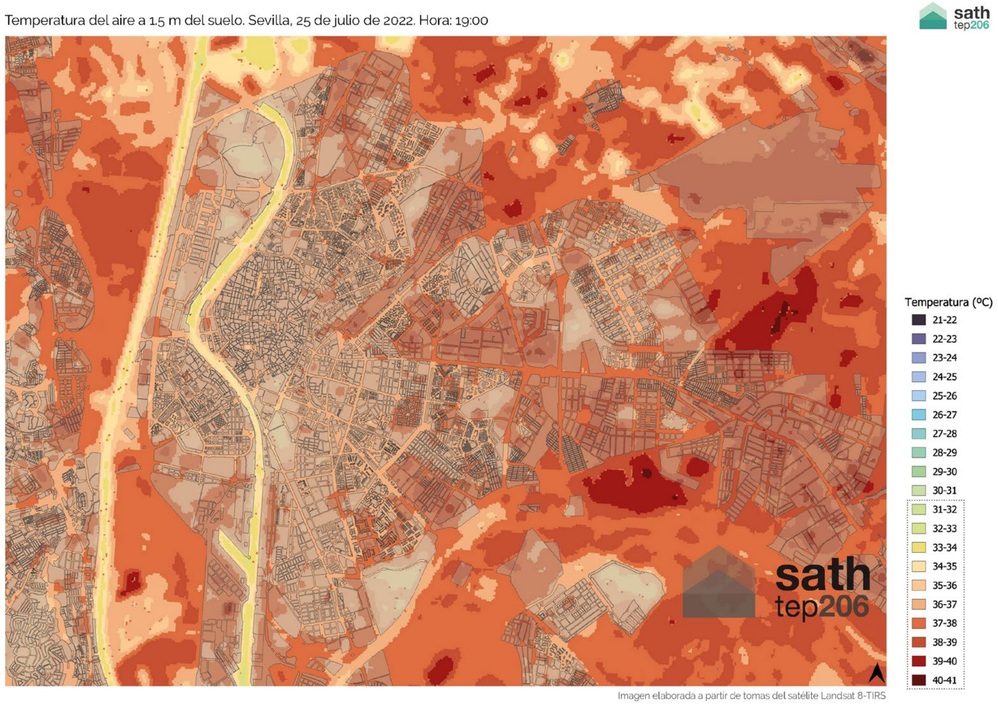




CÁTEDRA CONFORT CLIMÁTICA URBANO | SVQ URBANLAB

Grupo TEP-206 SATH





CÁTEDRA CONFORT CLIMÁTICA URBANO | SVQ URBANLAB

Grupo TEP-206 SATH

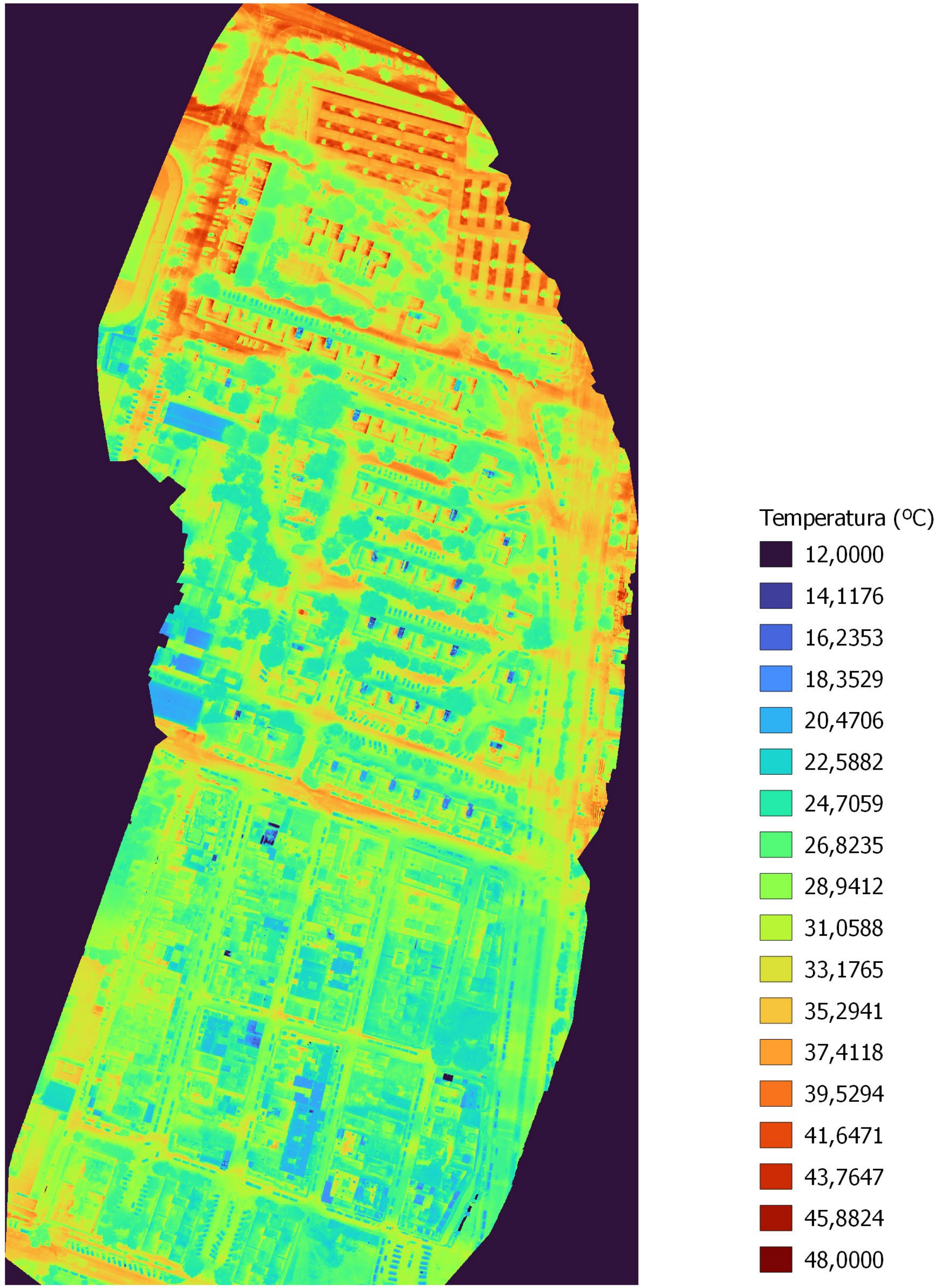
CÁTEDRA CONFORT CLIMÁTICA URBANO | SVQ URBANLAB

Grupo TEP-206 SATH

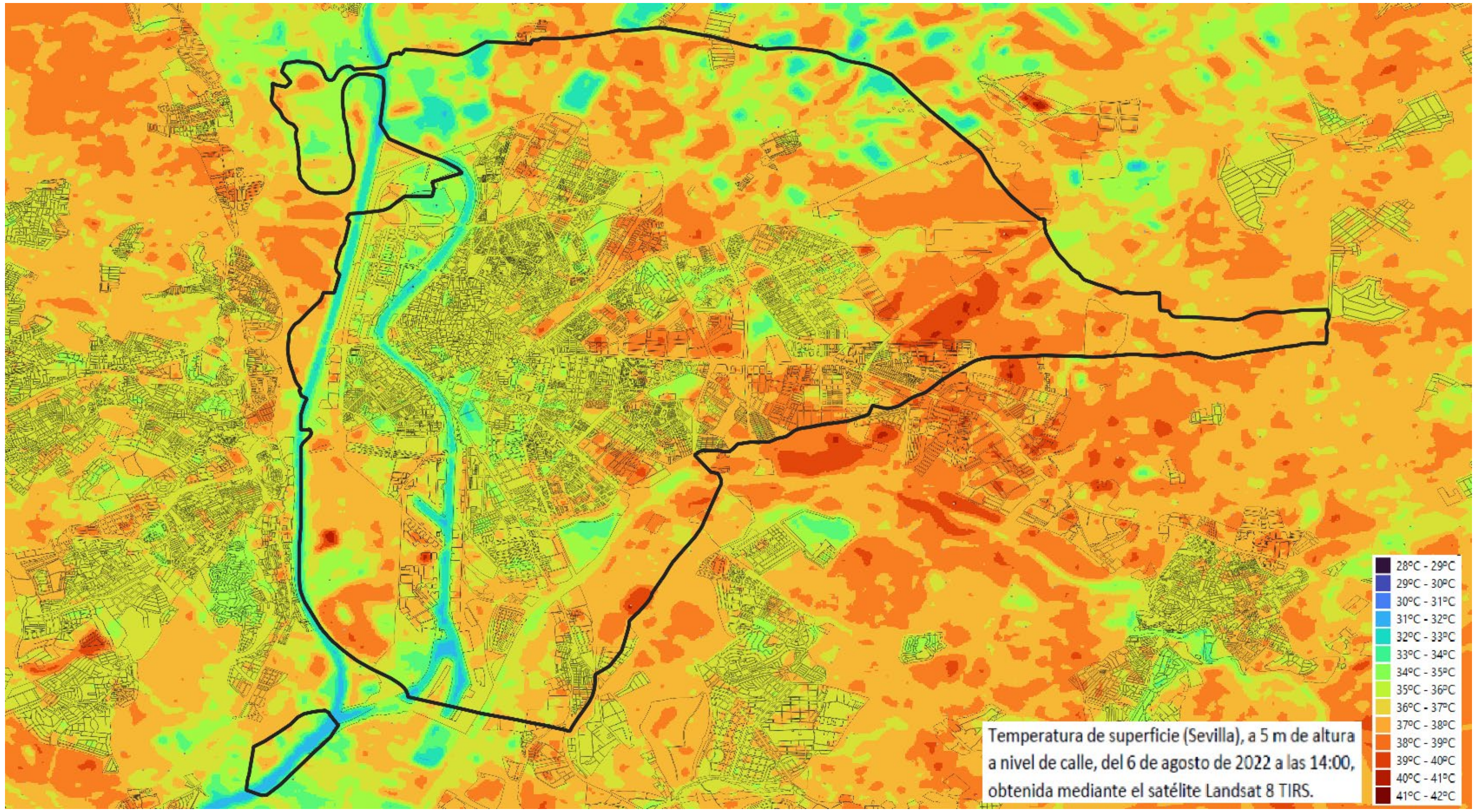
MAUHAUS

Aerial Thermography

Global characterization of the UOPR corresponding to the groups of dwellings selected as study models.



Junta de Andalucía | Consejería de Fomento, Articulación del Territorio y Vivienda



URBATERM

US.22-07

2022-2024

Climate Resilience and Perception of Comfort: Potential Overheating Risk Urban Zoning in Andalusian cities.

Consejería de Fomento, Articulación del Territorio y Vivienda.
Junta de Andalucía.

Aim of the Project

The project aims to analyze the thermal profile of Andalusian cities determining both risk areas and the possibilities of mitigating excess urban heat at the local level.

It is also intended to identify the urban characteristics that determine the impact of public space on the perception of thermal stress of the citizen, considering parameters of adaptive comfort and climate vulnerability through functional studies.

It is also proposed to value the importance of urban morphology through its analysis and climatic contextualization in order to determine a climatic categorization and zoning.

URBATHERM

Identify areas of thermal risk due to the persistence of excessive temperatures and locate public spaces with a high viability of climatic adequacy within cities, spaces of opportunity or potential *Urban Cool Islands*.

Cátedra Confort Climático
SVQ URBANLAB.
Ayuntamiento de Sevilla / US


Thank you!
sath
tep206

Creating a set of urban weather files from a monitoring campaign

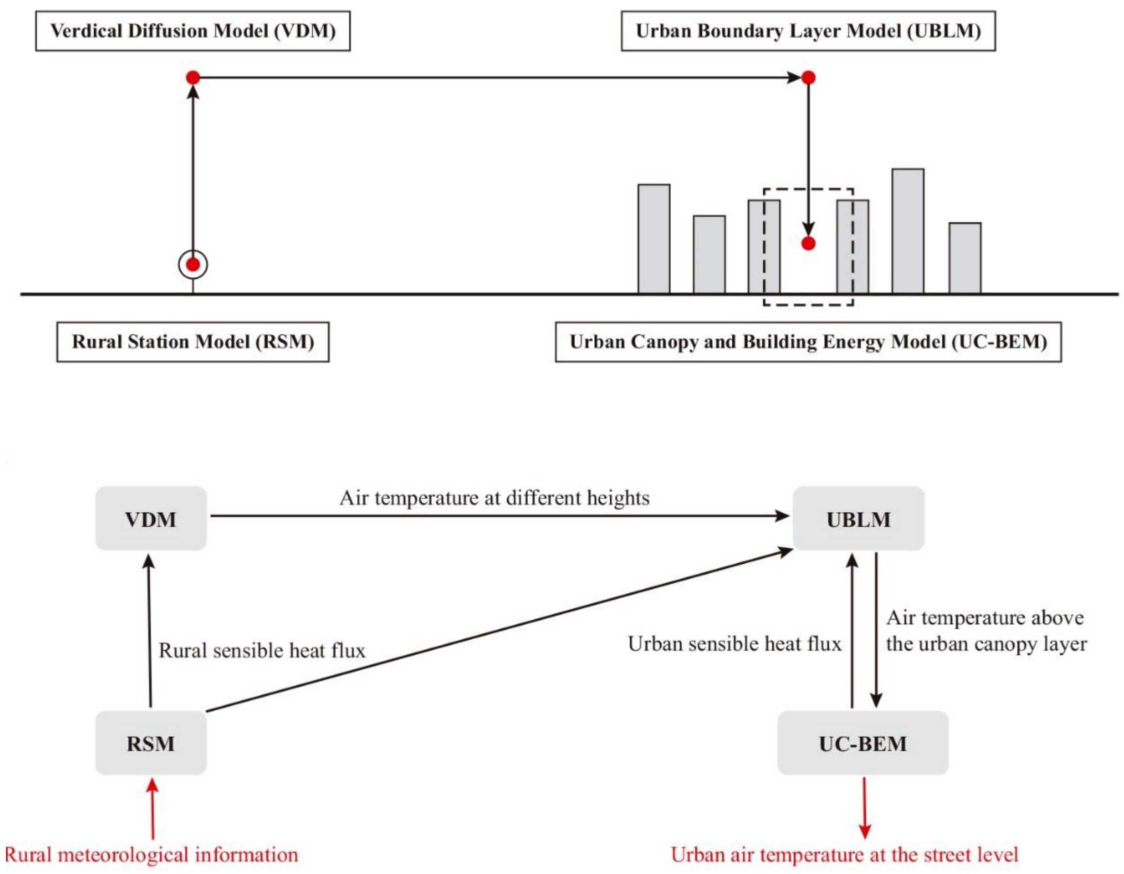
Recent experience and future prospects

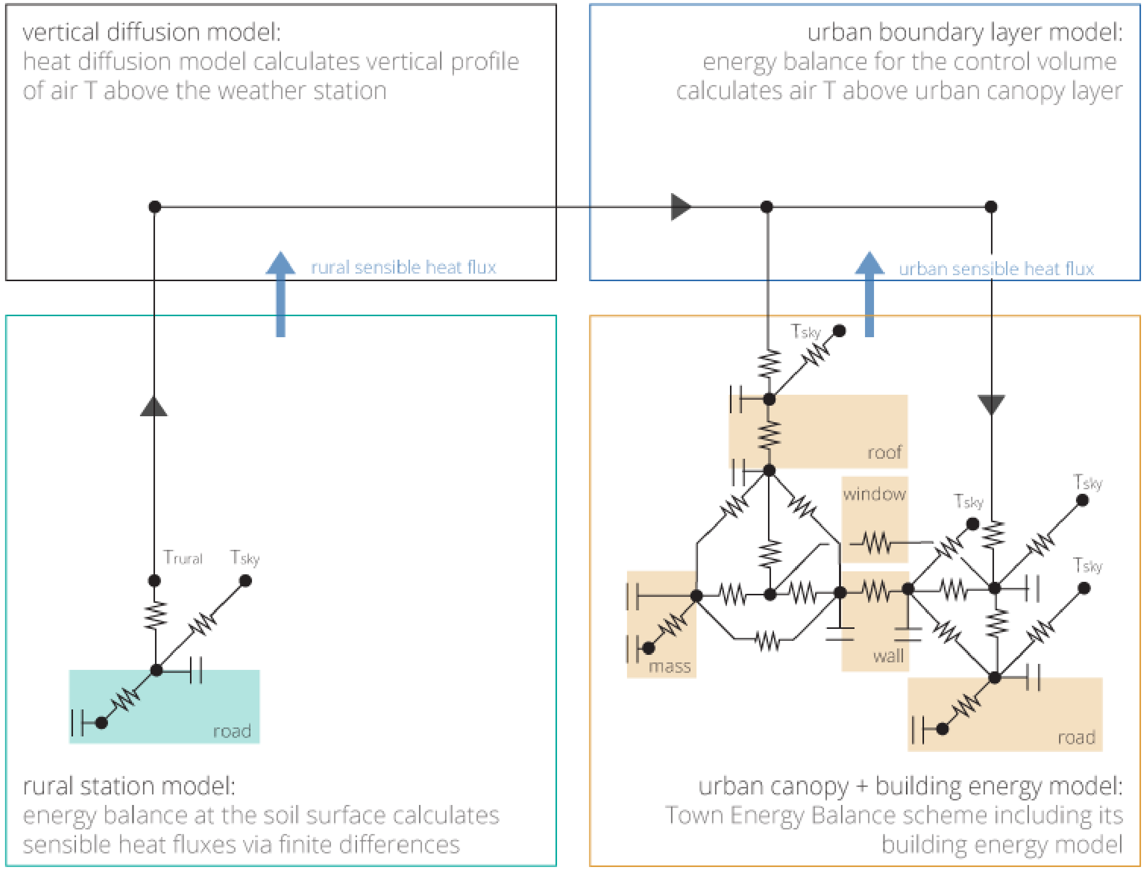
Miguel Núñez Peiró
Postdoctoral Research Fellow
Universidad Politécnica de Madrid (UPM)
miguel.nunez@upm.es

Webinar **Micro-Climate Change and Envelopes**

April, 27-28th 2023

The example of the *Urban Weather Generator* (Bueno et al. 2013)





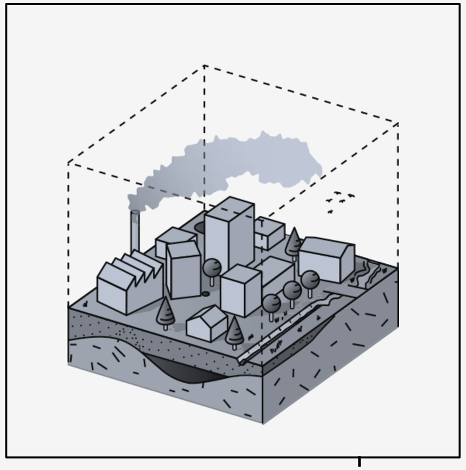
Source: Mao & Nordford (2021); urbanmicroclimate.scripts.mit.edu

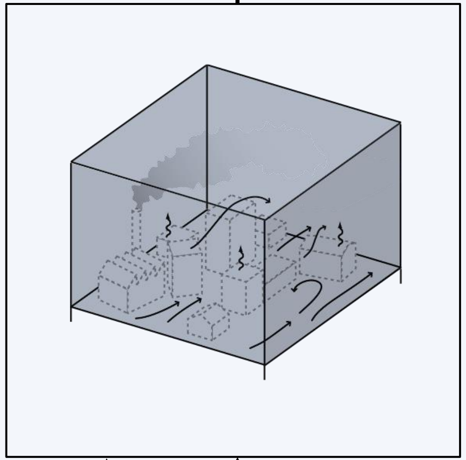
Alternative approach to weather files morphing

PHYSICAL SYSTEM

NUMERICAL MORPHING

Output morphed meteorological data



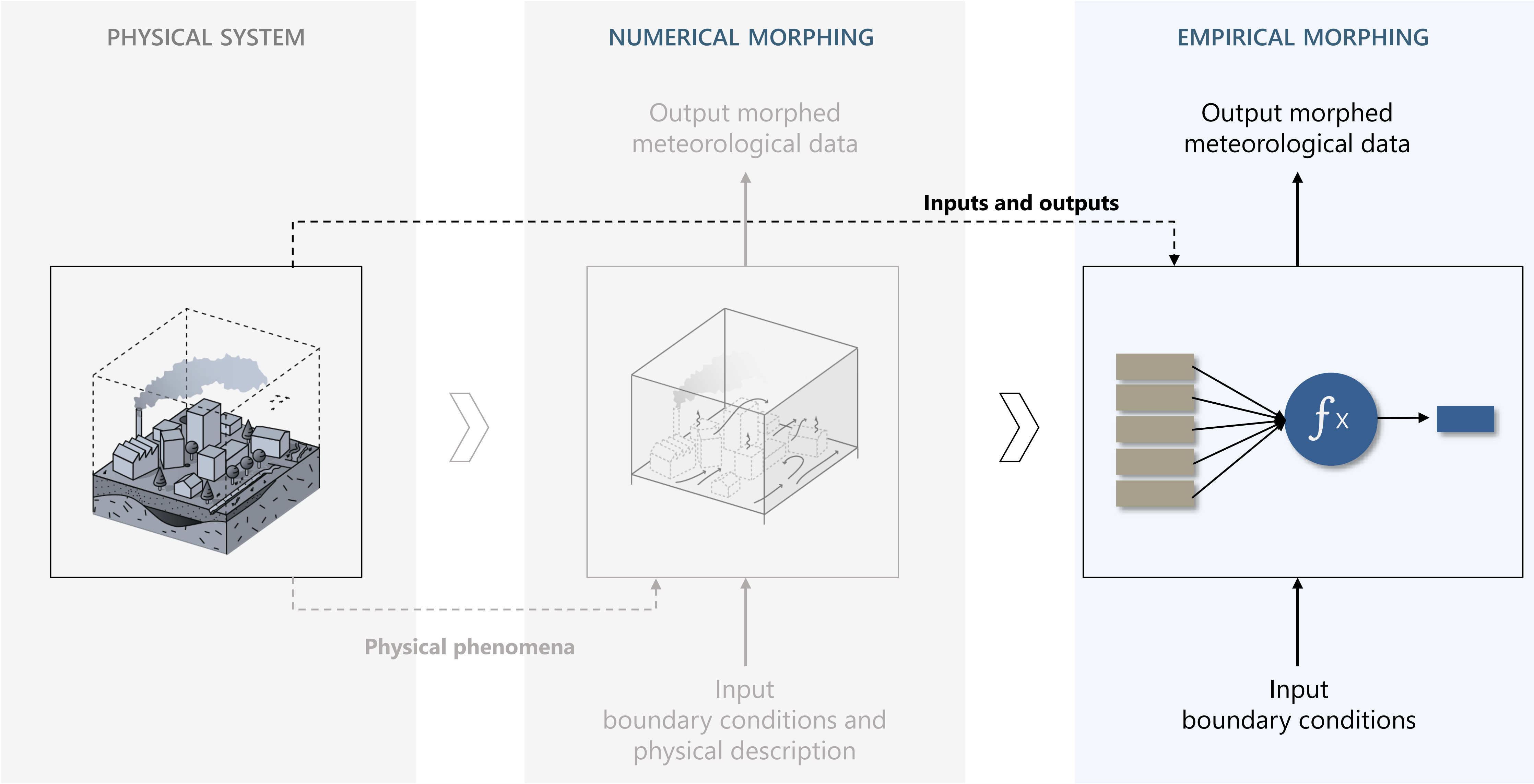


Physical phenomena

Input
boundary conditions and
physical description

Credits illustrations: Oke et al. (2017)

Alternative approach to weather files morphing



Credits illustrations: Oke et al. (2017)

Why empirical morphing

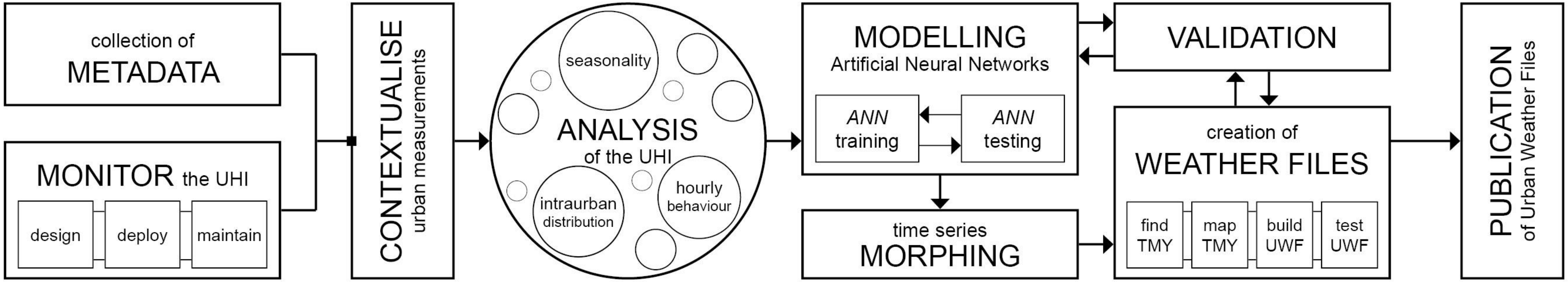
1. **More and better access to data.** Information coming from satellites and land-based networks.

2. **Improved data contextualisation**. Metadata, urban climate classification schemes and source area definitions

3. **Improved Quality Assessment and Quality Control** procedures. WMO, specific procedures for CWS,…

4. **More and better modelling tools**. Artificial Intelligence

Designed workflow



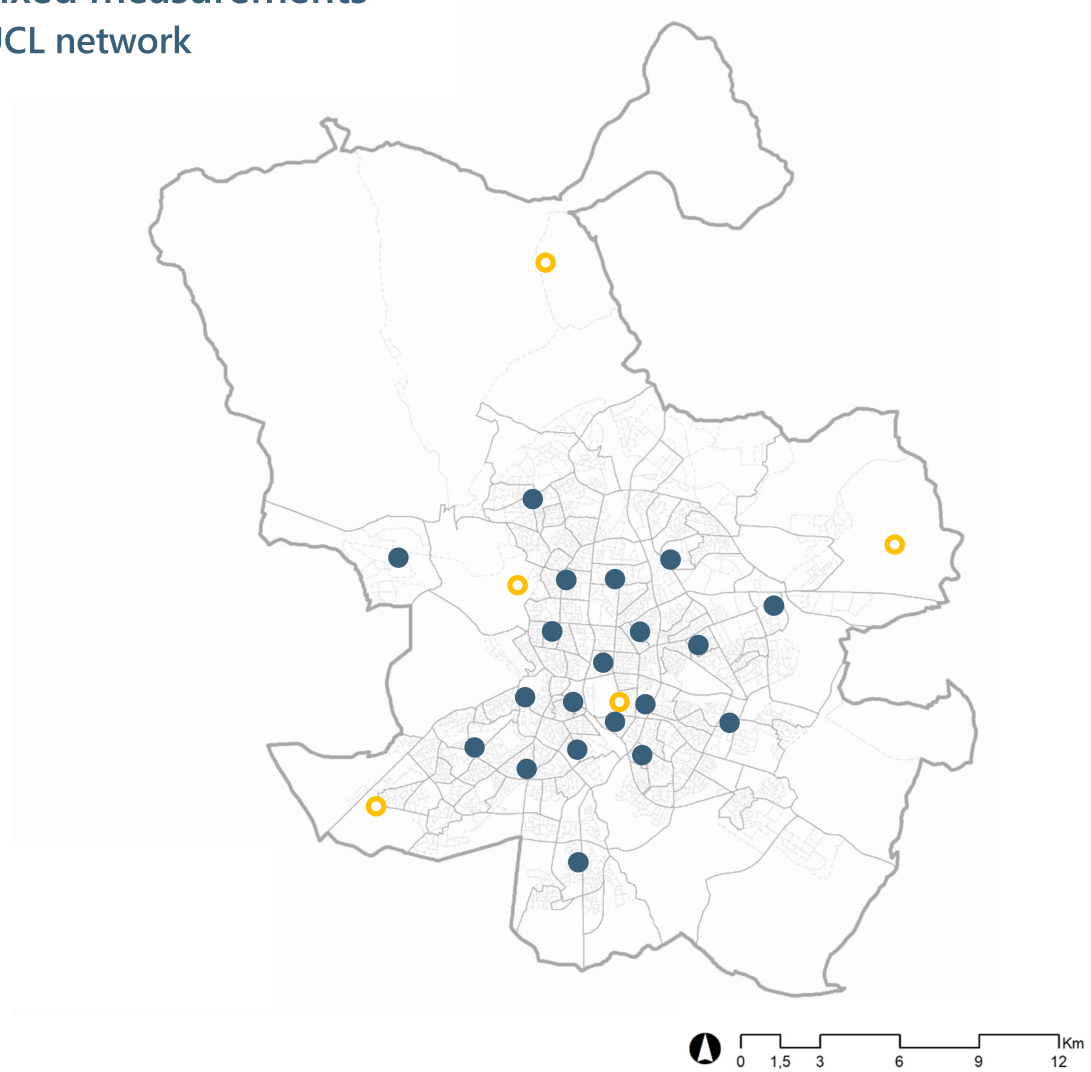
Monitoring campaigns

Mobile measurements

UCL traverses

Fixed measurements

UCL network

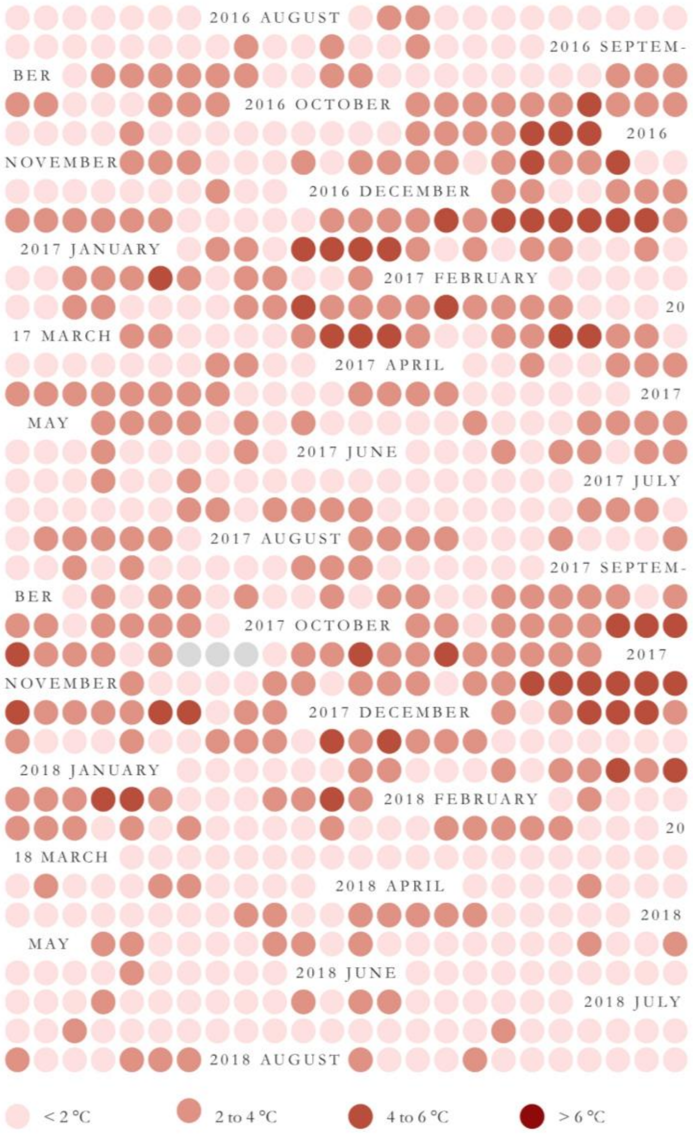


Source: Núñez-Peiró et al. (2017; 2021a)

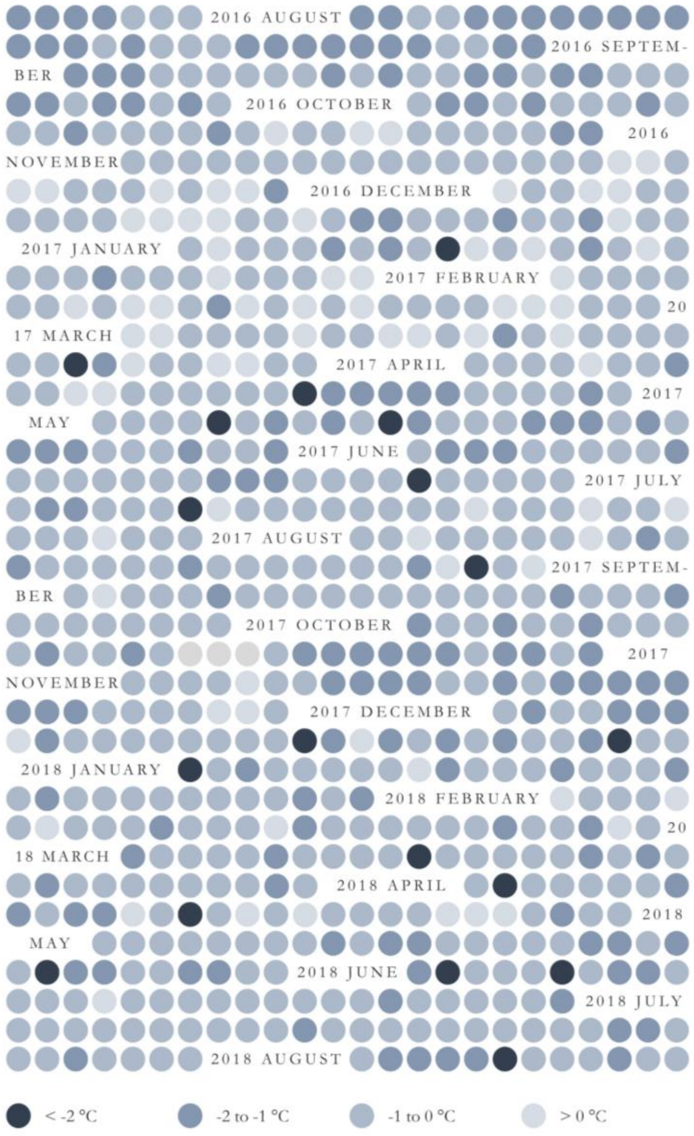
Annual evolution of urban heat: 01 – Embajadores

Source: Núñez-Peiró et al. (2022)

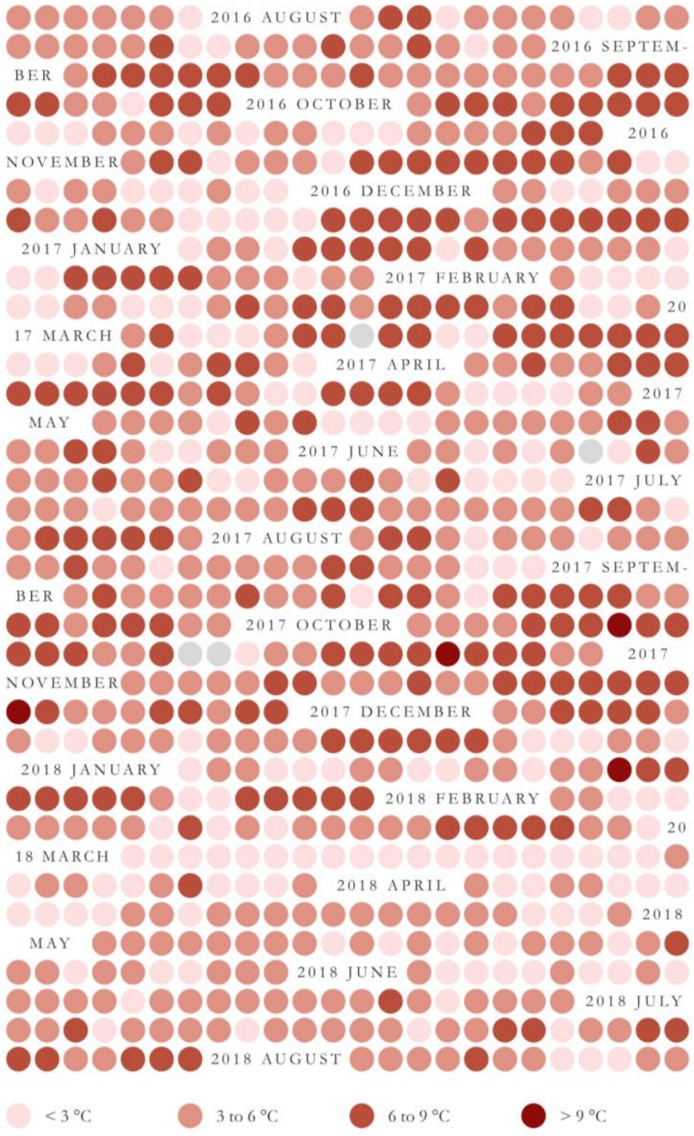
Average daily intensity



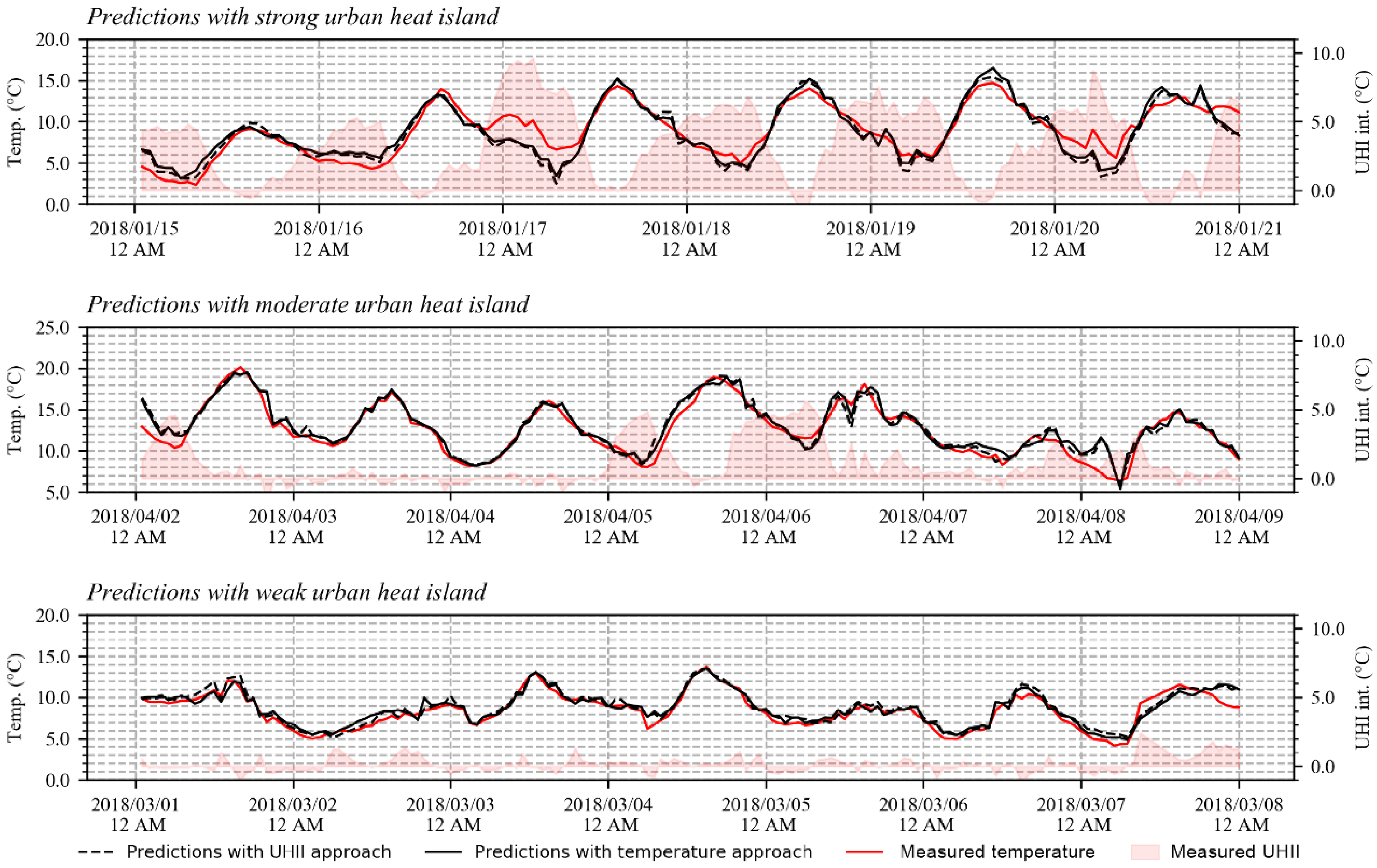
Minimum daily intensity



Maximum daily intensity

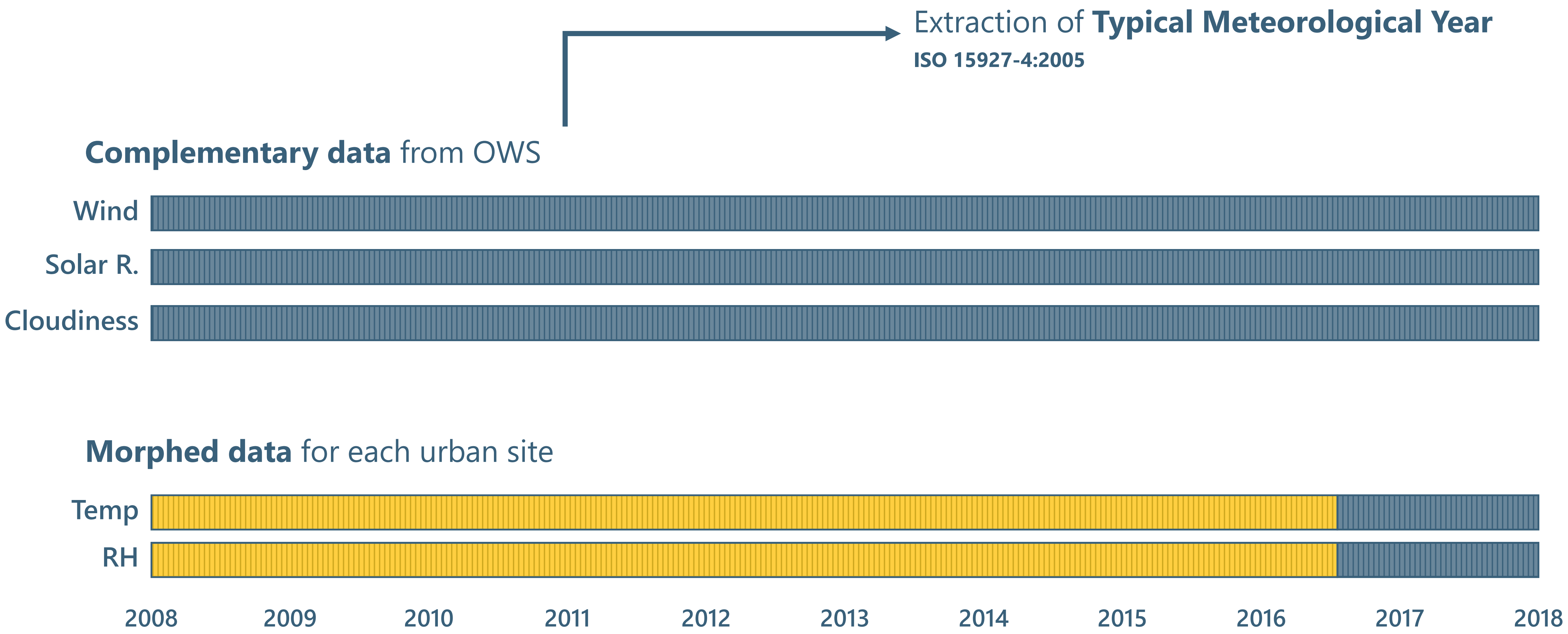


Data morphing: Context of standard data availability (12 months)

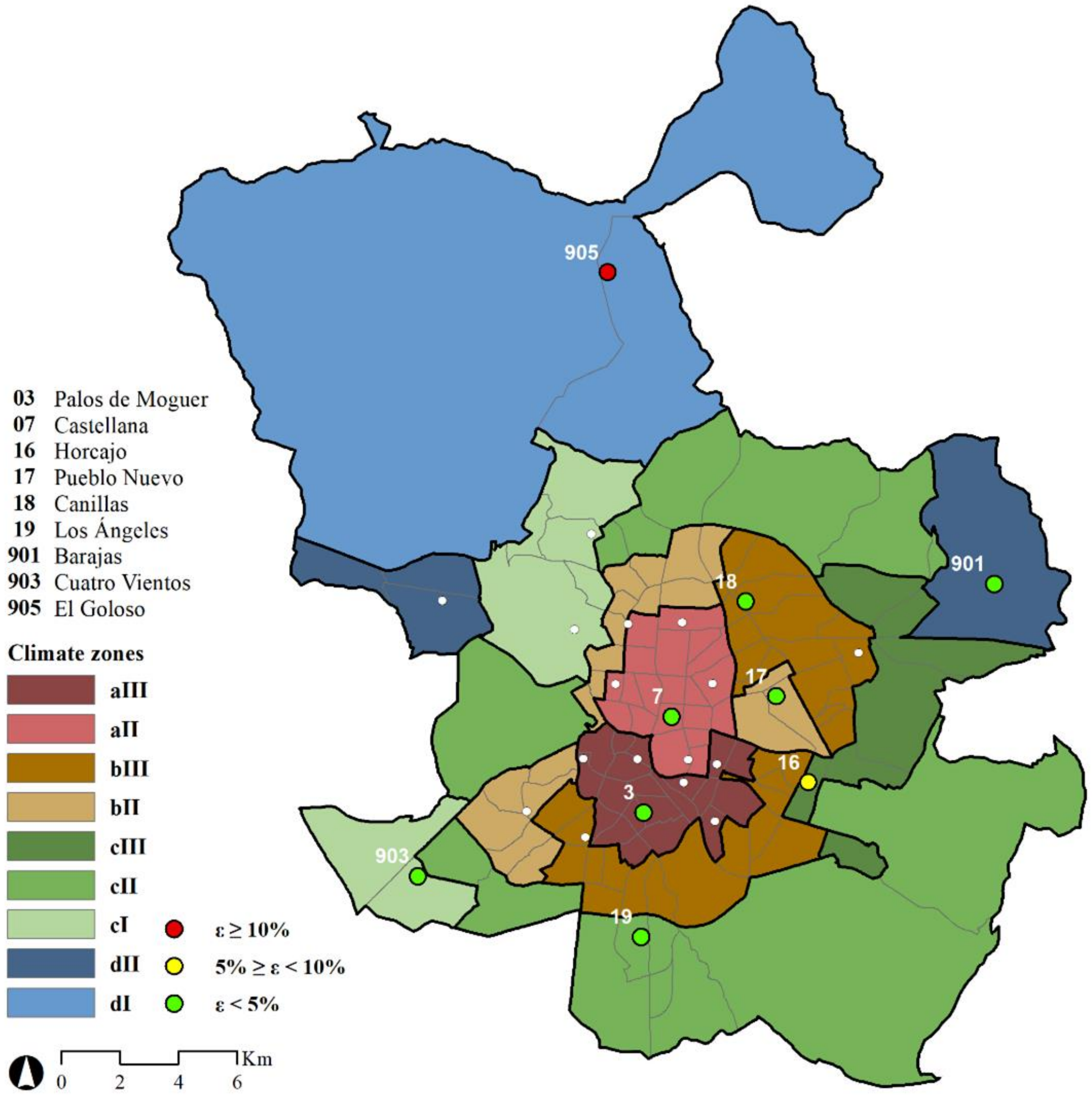


Source: Núñez-Peiró et al. (2021b)

Aproximación: Datos disponibles



Case study: city of Madrid, Spain



Increased winter severity →

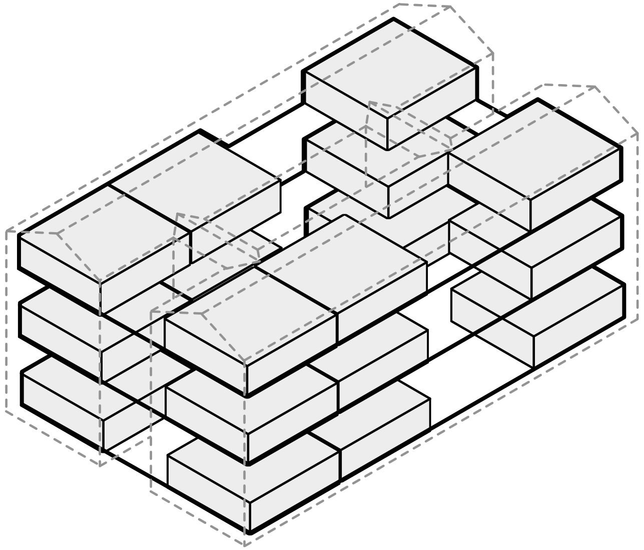
Increased summer severity ↑

aIII ID03 2008 · 2017 2021	bIII ID18 2008 · 2017 2021	cIII ID16 2008 · 2017 2021	
aII ID07 2008 · 2017 2021	bII ID17 2008 · 2017 2021	cII ID19 2008 · 2017 2021	dII ID901 2008 · 2017 2021
		cI ID903 2008 · 2017 2021	~~dI ID905 2008 · 2017 2021~~

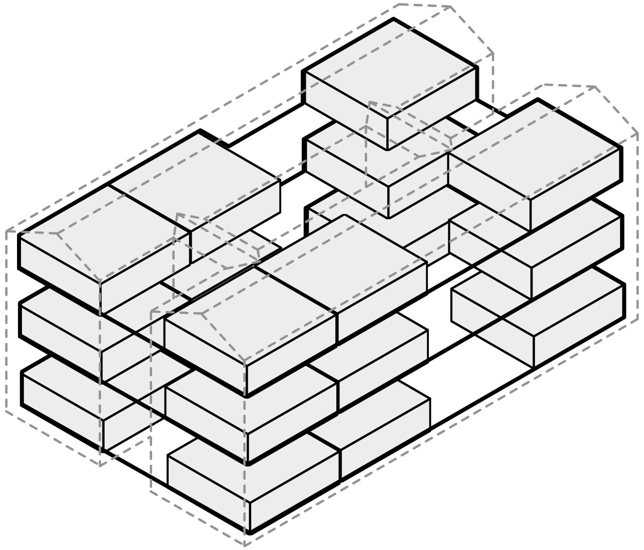
Source: Núñez-Peiró et al. (2022)

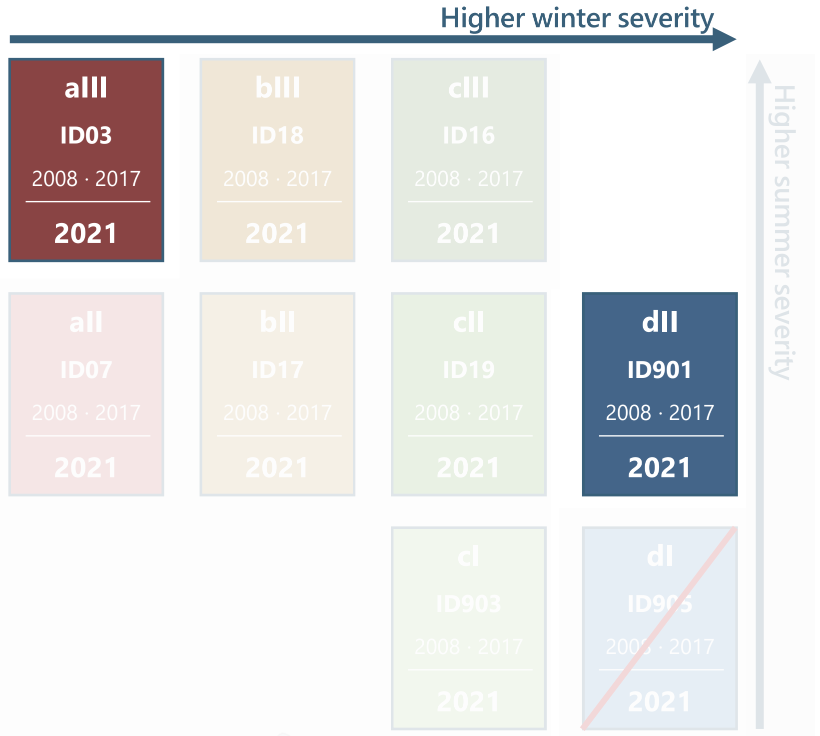
Heating energy demand

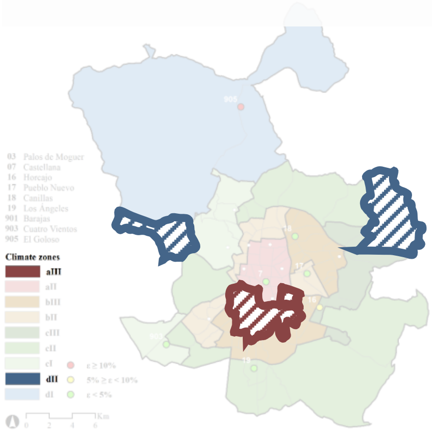
Zone aIII



Zone dII



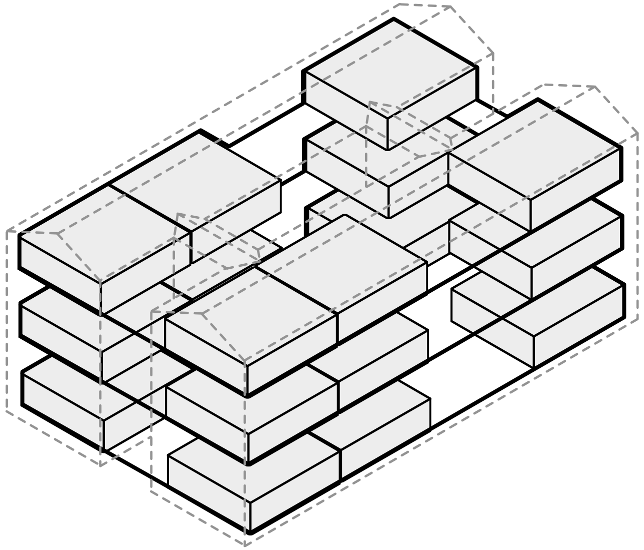




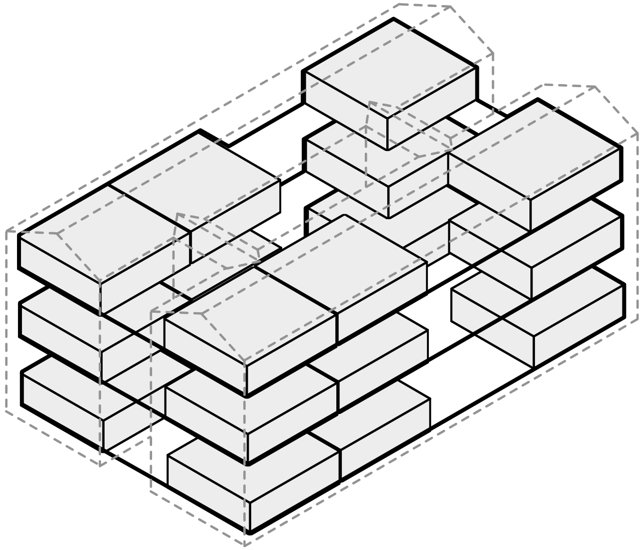
Source: Núñez-Peiró et al. (2022)

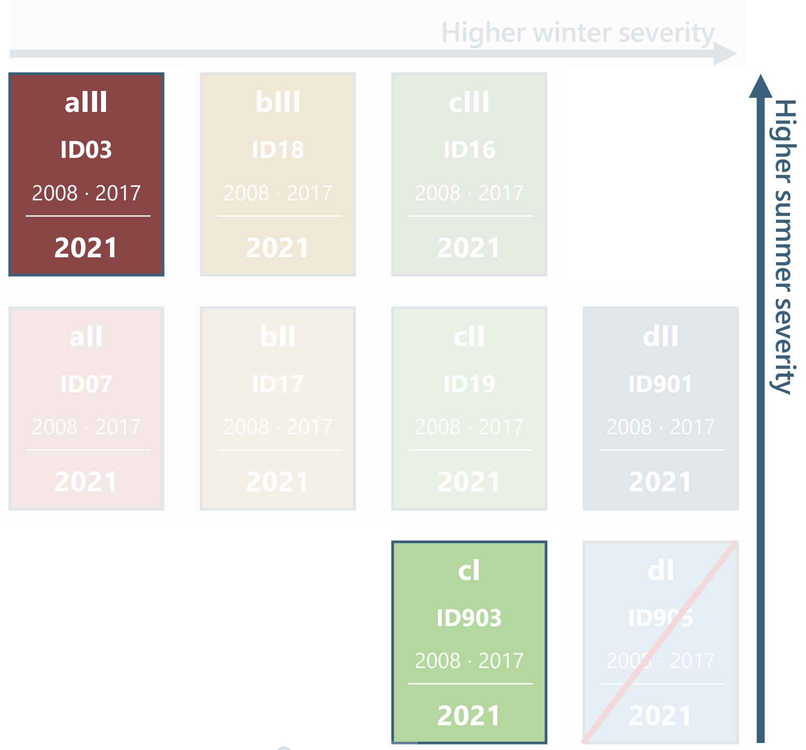
Cooling energy demand

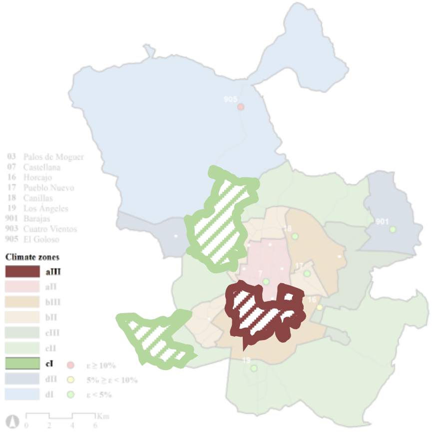
Zone aIII



Zone cI





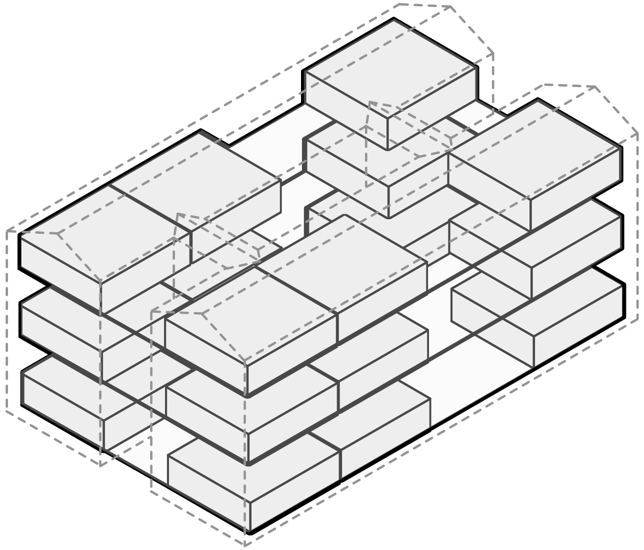


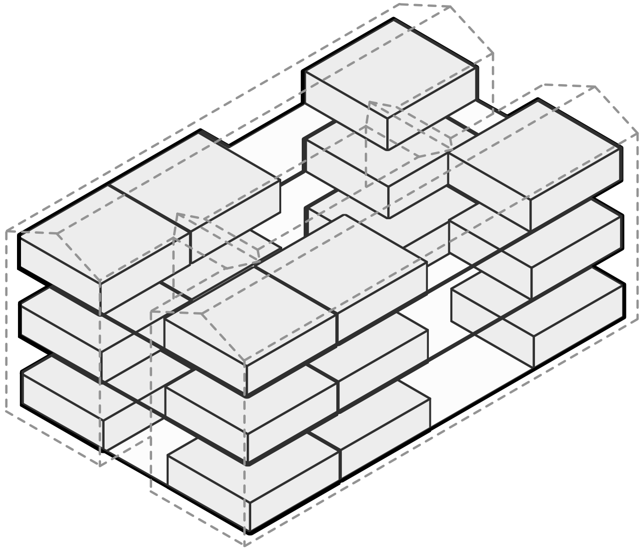
Source: Núñez-Peiró et al. (2022)

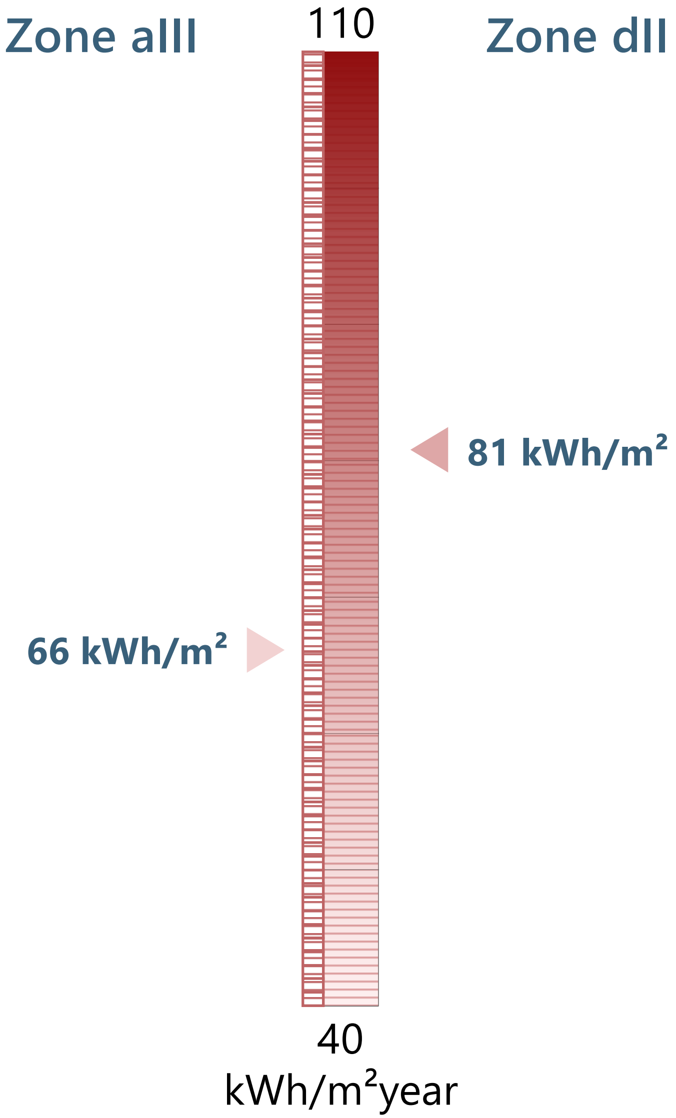
Heating energy demand per building

Zone aIII

Zone dII



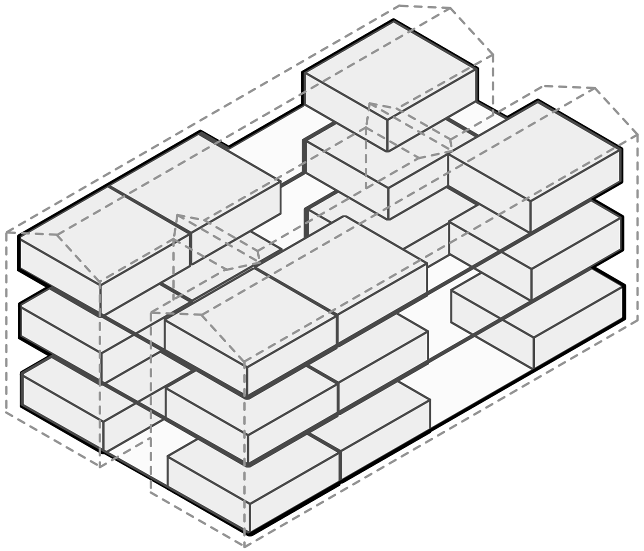




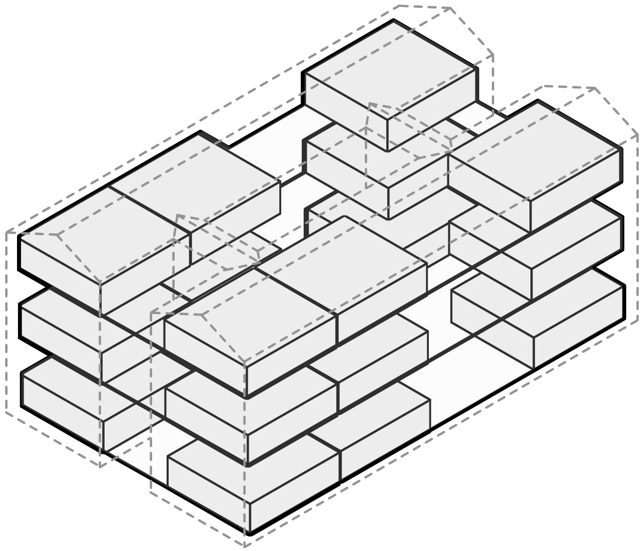
Source: Núñez-Peiró et al. (2022)

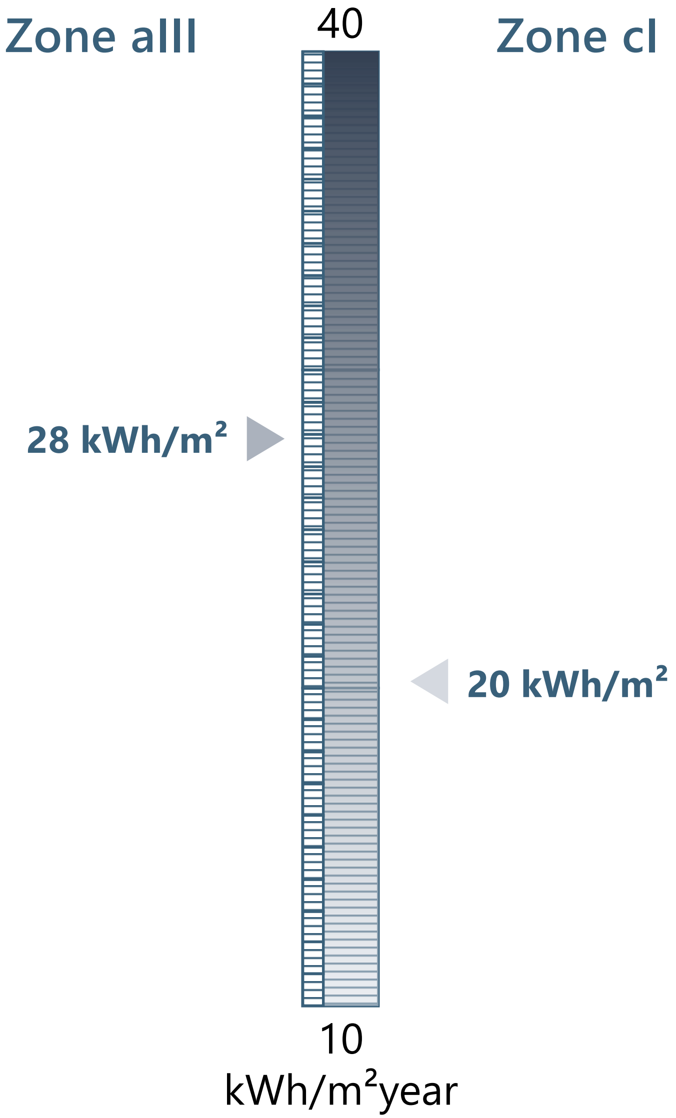
Cooling energy demand per building

Zone aIII



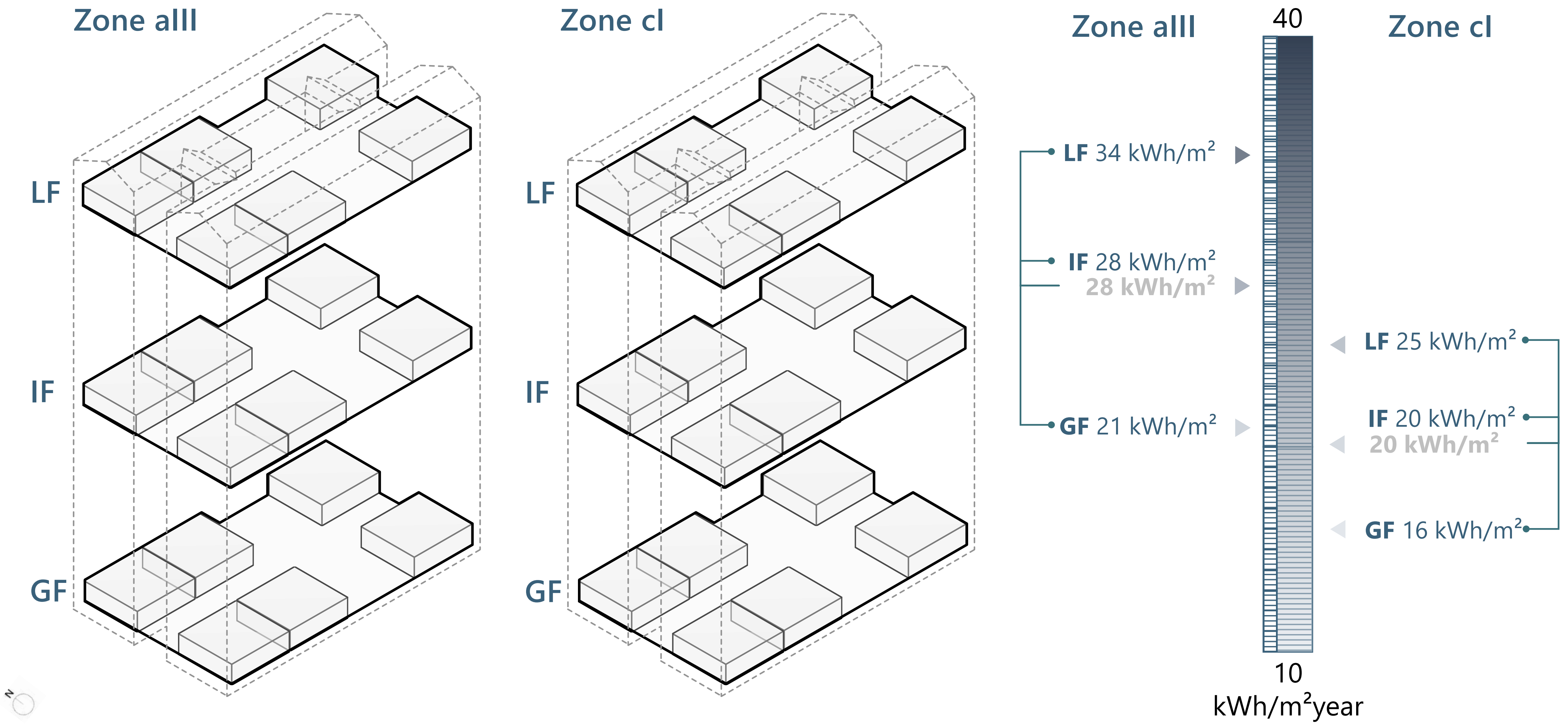
Zone cI





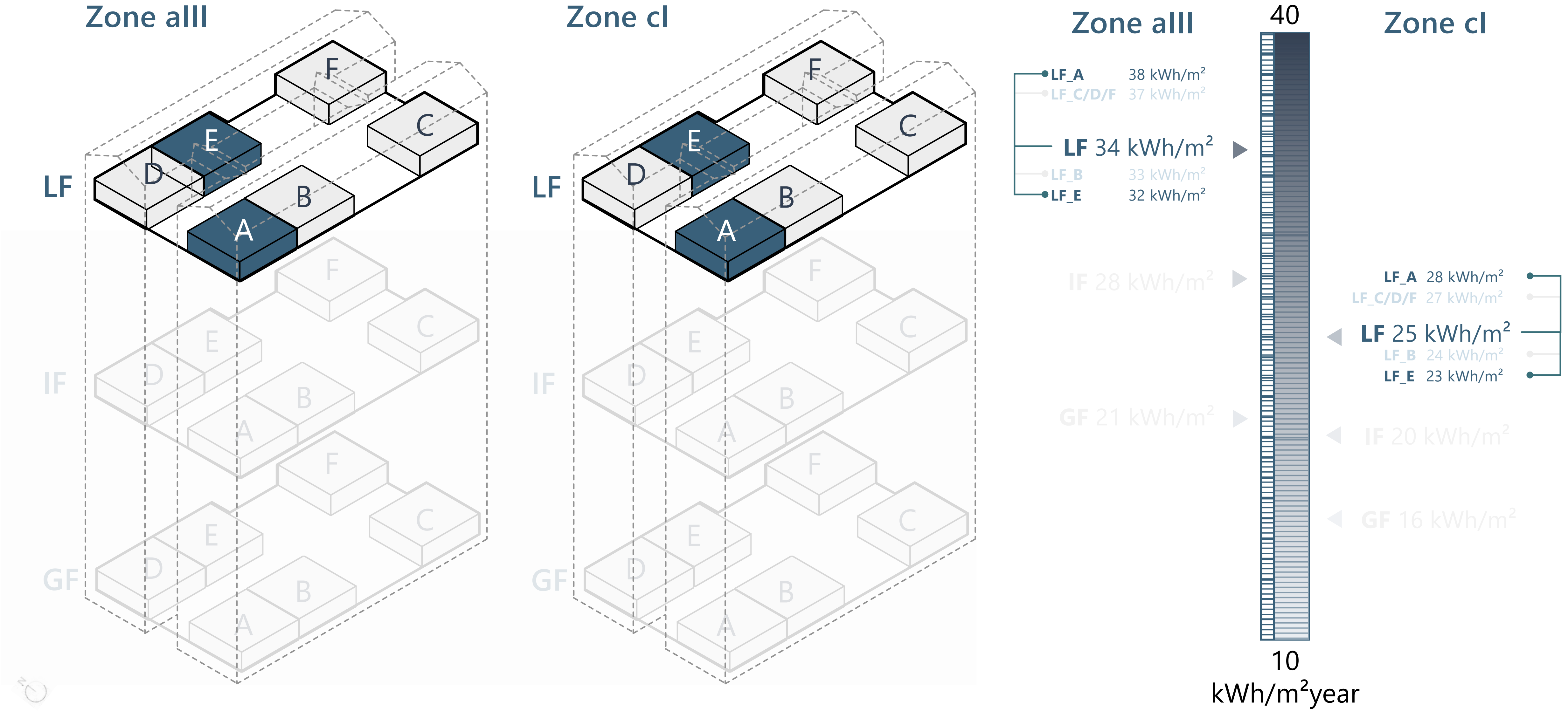
Source: Núñez-Peiró et al. (2022)

Cooling energy demand per floor



Source: Núñez-Peiró et al. (2022)

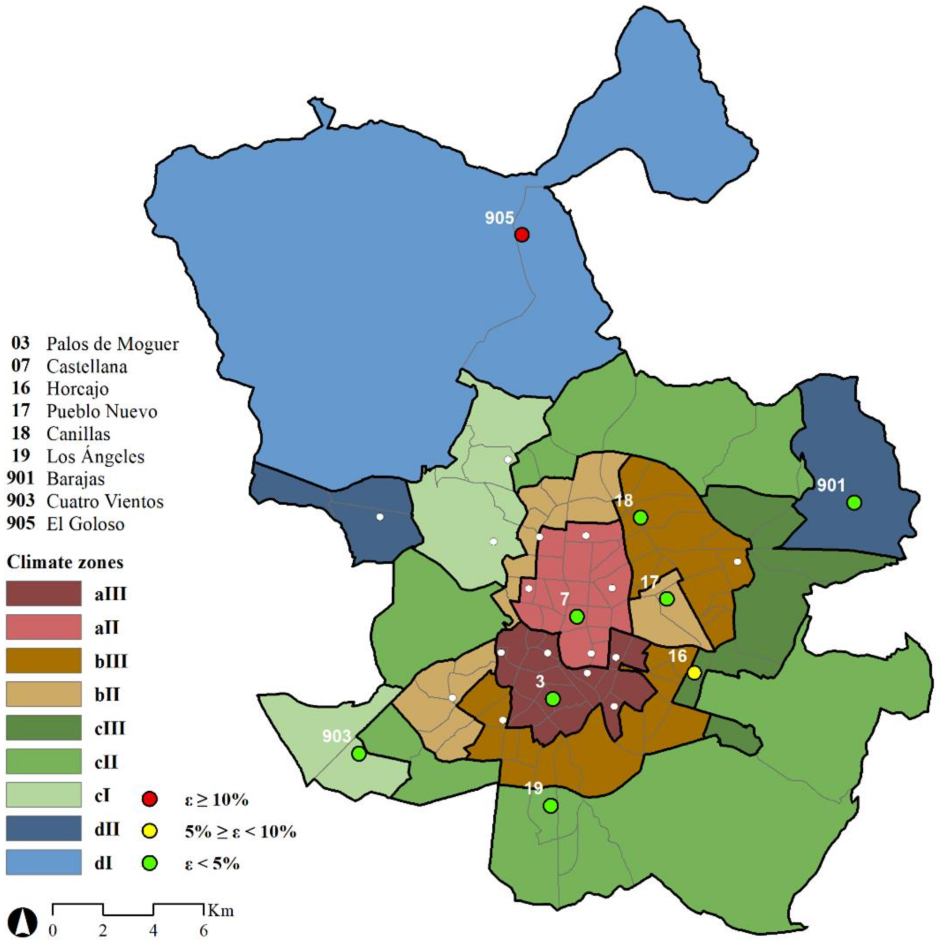
Cooling energy demand per housing unit

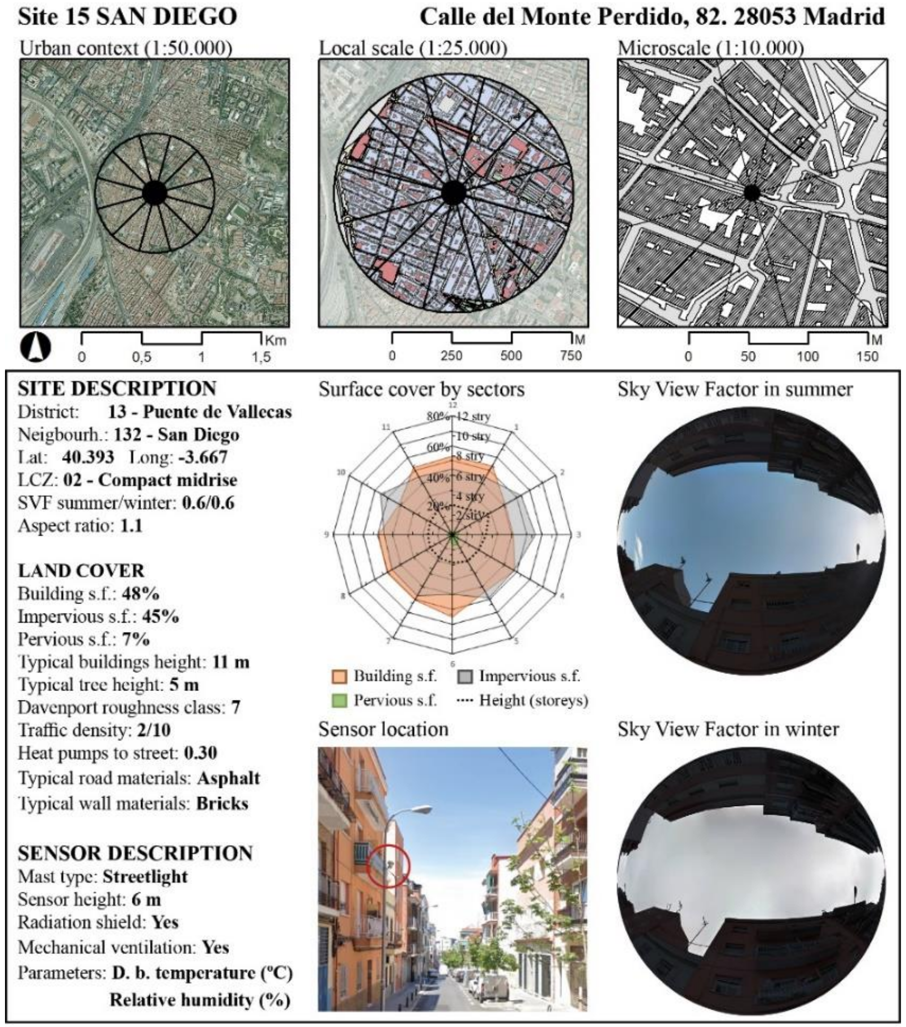


Source: Núñez-Peiró et al. (2022)

Future prospects and next steps

1. Limited representativity of the morphed weather files. **Approach the microclimatic scale.**





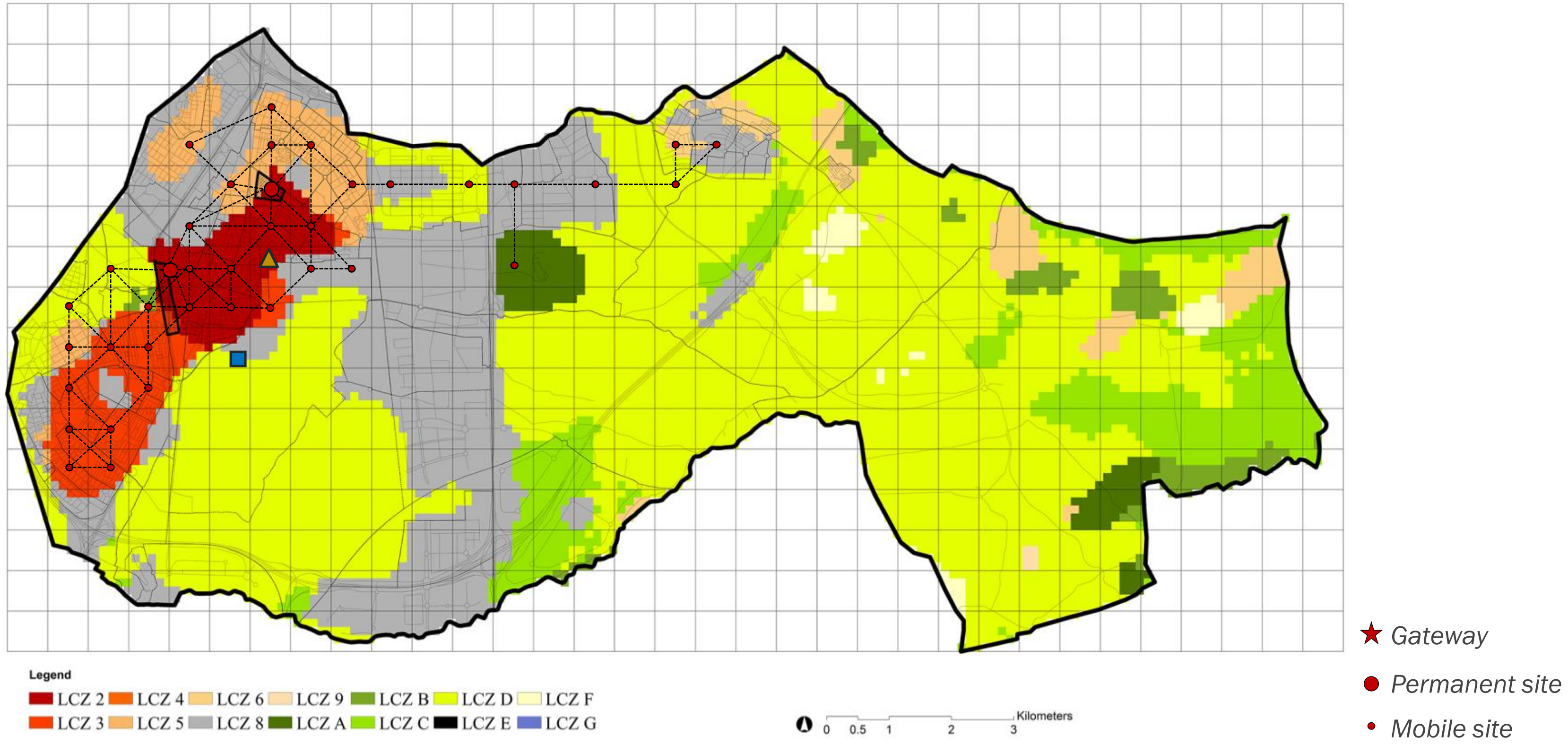
Source: Núñez-Peiró et al. (2021a; 2022)

Future prospects and next steps

EPIU Getafe
Hogares saludables

This project is co-financed by the European Regional Development Fund through the Urban Innovative Actions Initiative

1. Limited representativity of the morphed weather files. **Approach the microclimatic scale. EPIU Project** (2019 – 2023)



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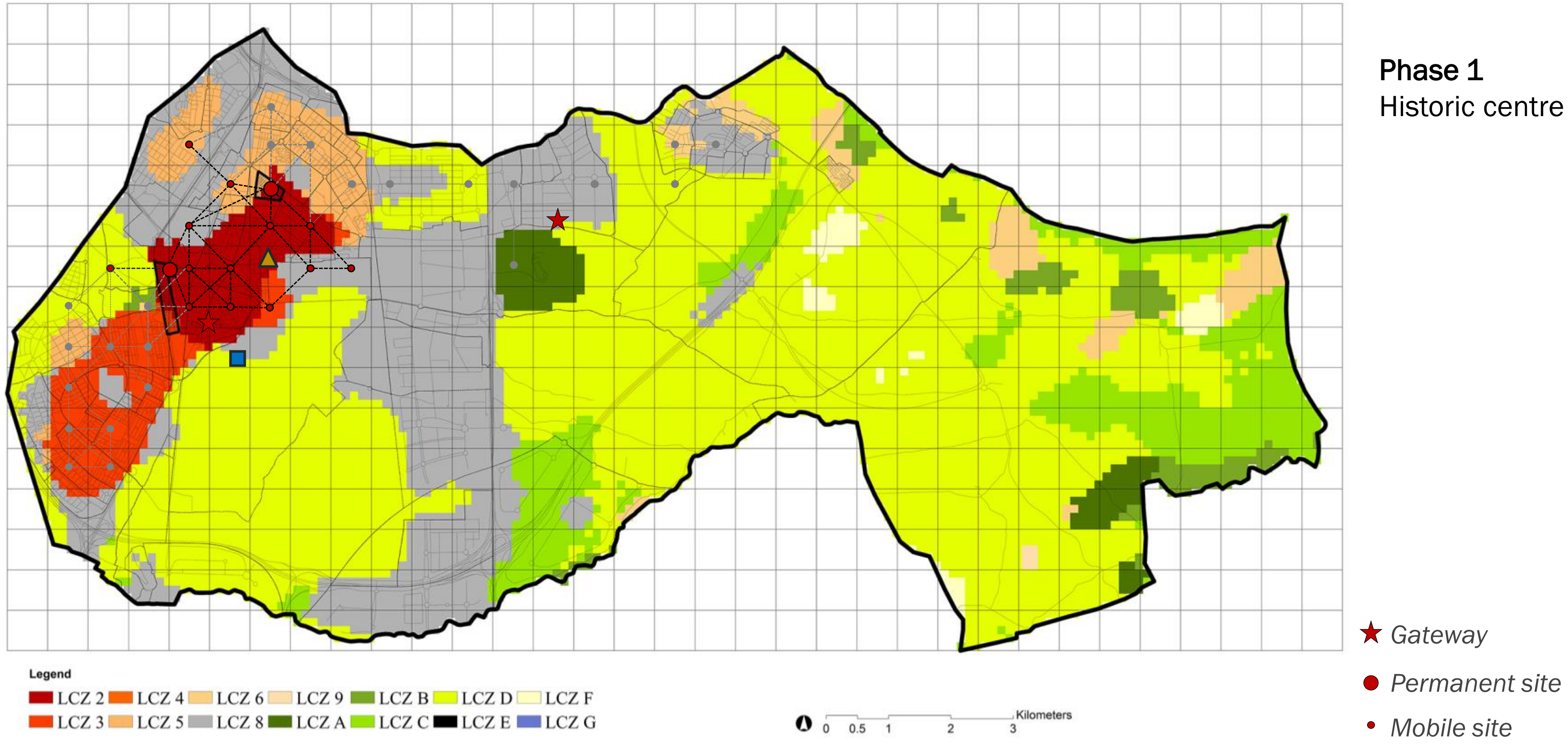

Future prospects and next steps

EPIU Getafe
Hogares saludables
URBAN POVERTY
This project is co-financed by the European Regional Development Fund through the Urban Innovative Actions Initiative
UIA URBAN INNOVATIVE ACTIONS
EUROPEAN UNION

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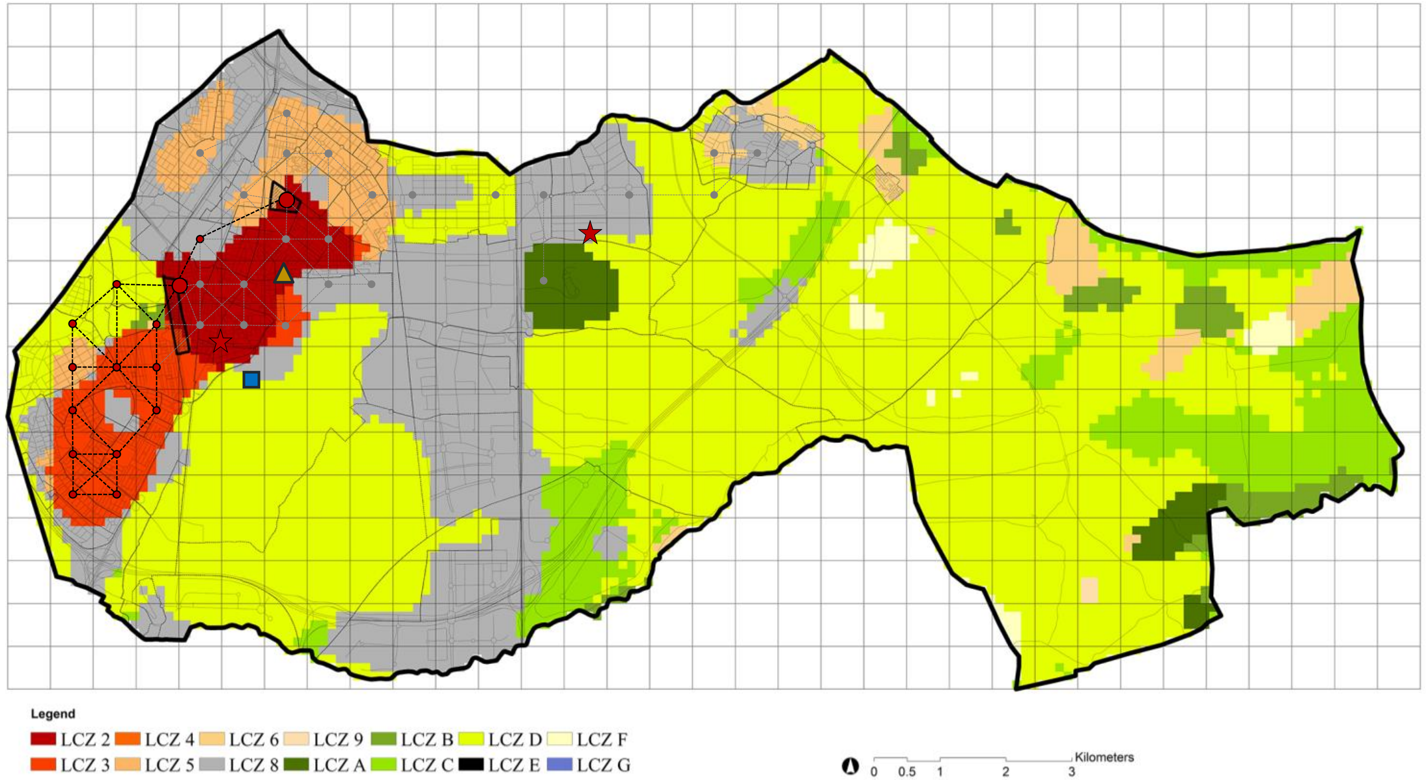

Phase 2
Southwest developments

★ *Gateway*
● *Permanent site*
• *Mobile site*

Future prospects and next steps

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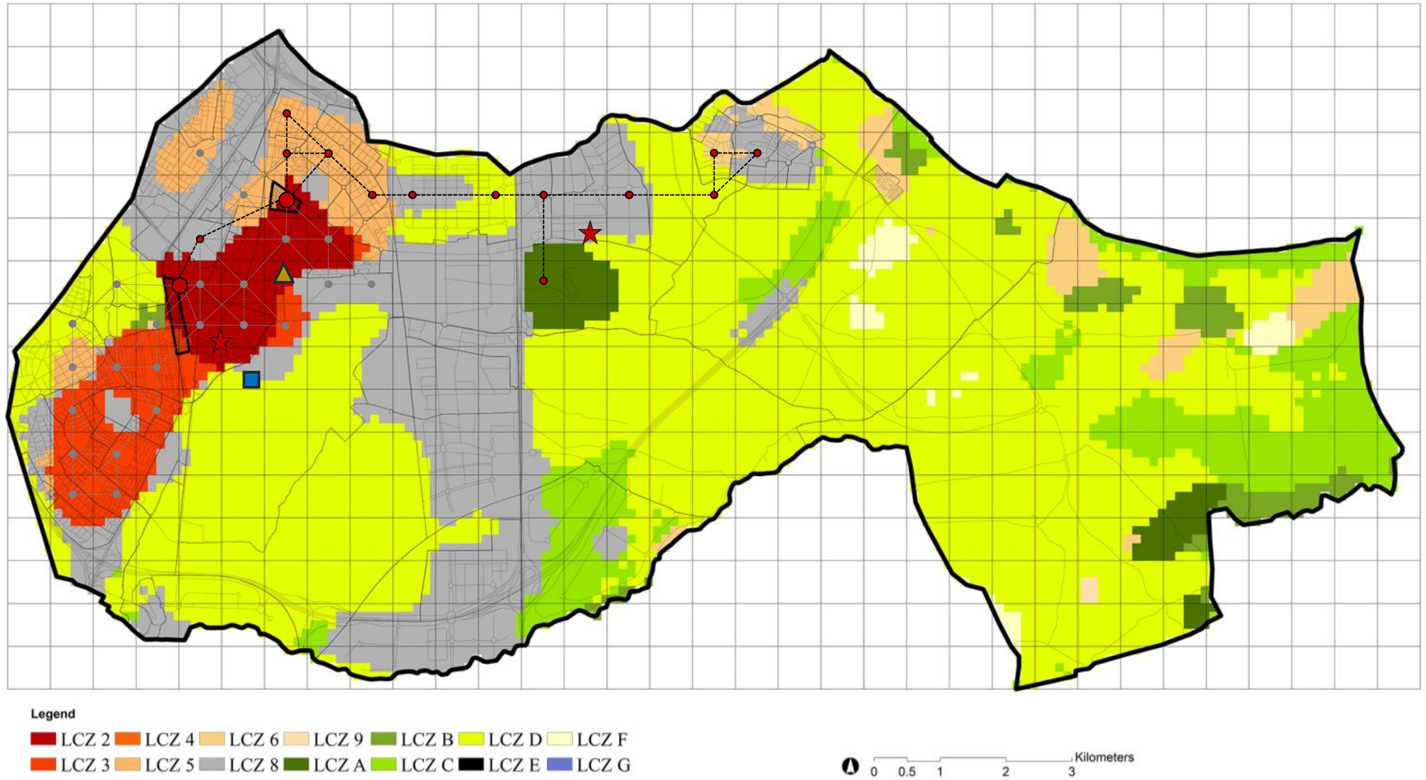


Phase 3
Northeast developments

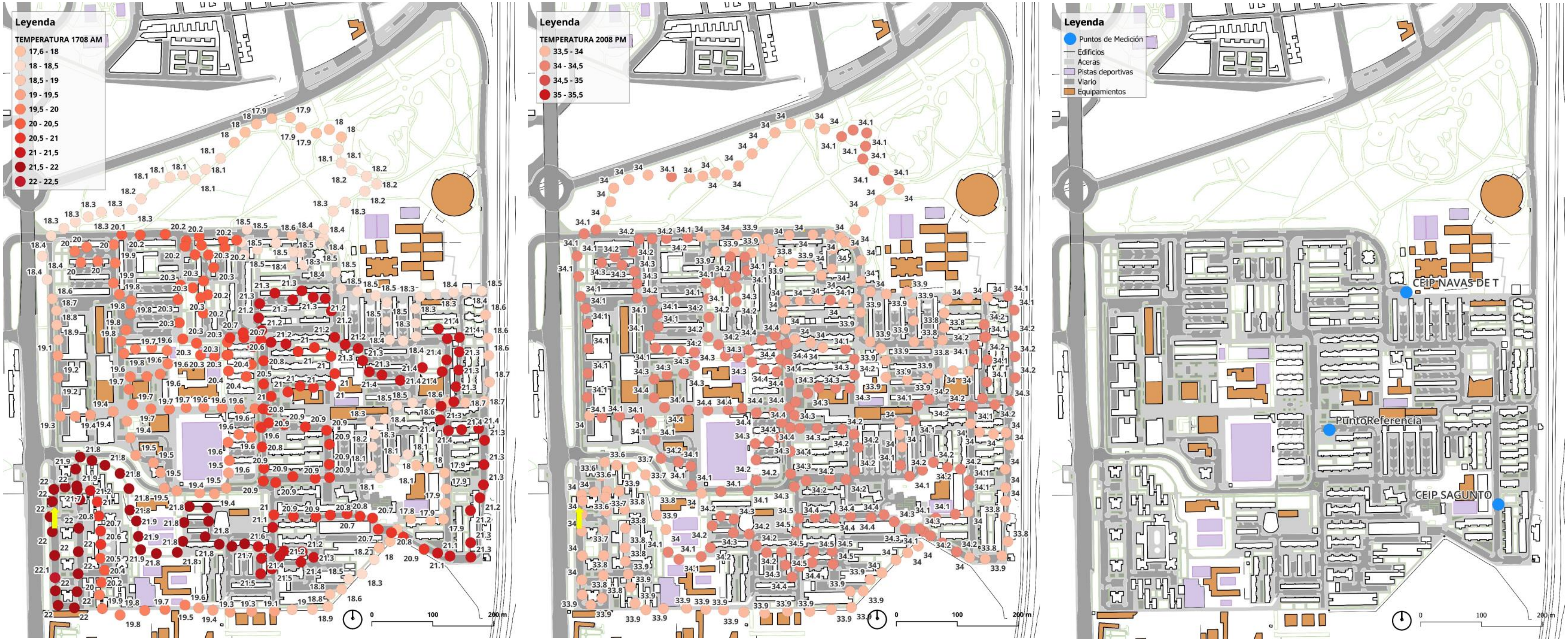
★ *Gateway*

● *Permanent site*

• *Mobile site*

Future prospects and next steps

1. Limited representativity of the morphed weather files. **Approach the microclimatic scale. MATEMAD Project** (2021-2024)



Future prospects and next steps

BUILDSPACE

Funded by the European Union

2. Limited replicability of the morphed weather files. **Standardisation and scalability. BUILDSPACE Project** (2023-2026)

BUILDSPACE APPLICATIONS

CONSTRUCTION, RENOVATION & MONITORING (**Building level**)

- **SE1**: Digital Twin Generation
- **SE2**: Digital Twin Enrichment

DT Exposure to city layer

ANALYSIS, FORECAST & RESILIENCE (**City level**)

- **SE3**: Built Environment Climate Scenarios
- **SE4**: Urban Heat Analysis and Resilience
- **SE5**: Urban Flood Analysis and Resilience

BUILDSPACE CORE PLATFORM

- USER MANAGEMENT
- DATA DISCOVERY
- DATA FEDERATION LAYER
- CORE AND EXTERNAL SERVICES LAYER
- External data repositories, IoT data, etc.

Future prospects and next steps

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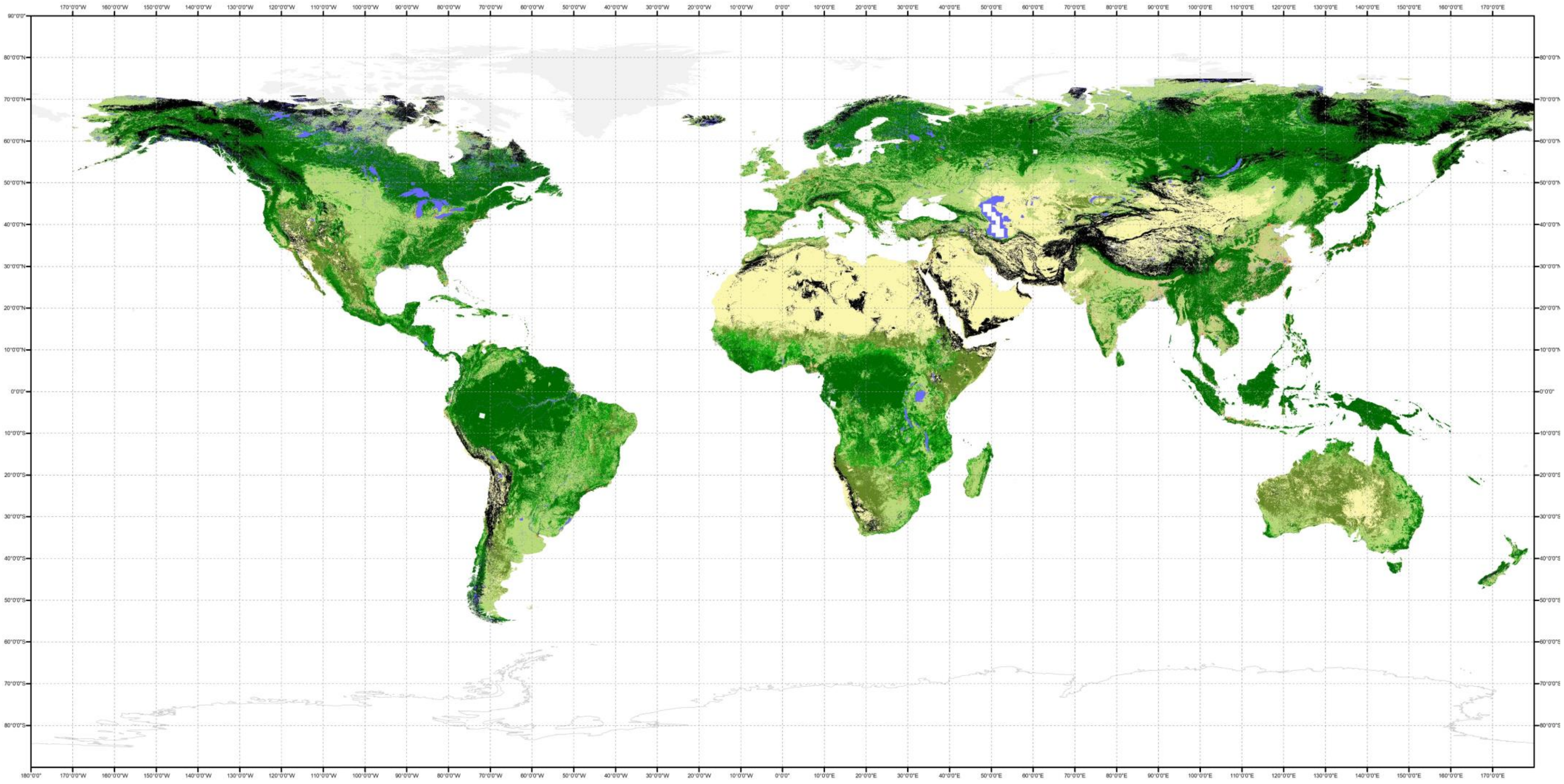


Source: Demuzere et al. (2022)

Thank you!

Creating a set of urban weather files from a monitoring campaign

Recent experience and future prospects

Miguel Núñez Peiró

Postdoctoral Research Fellow

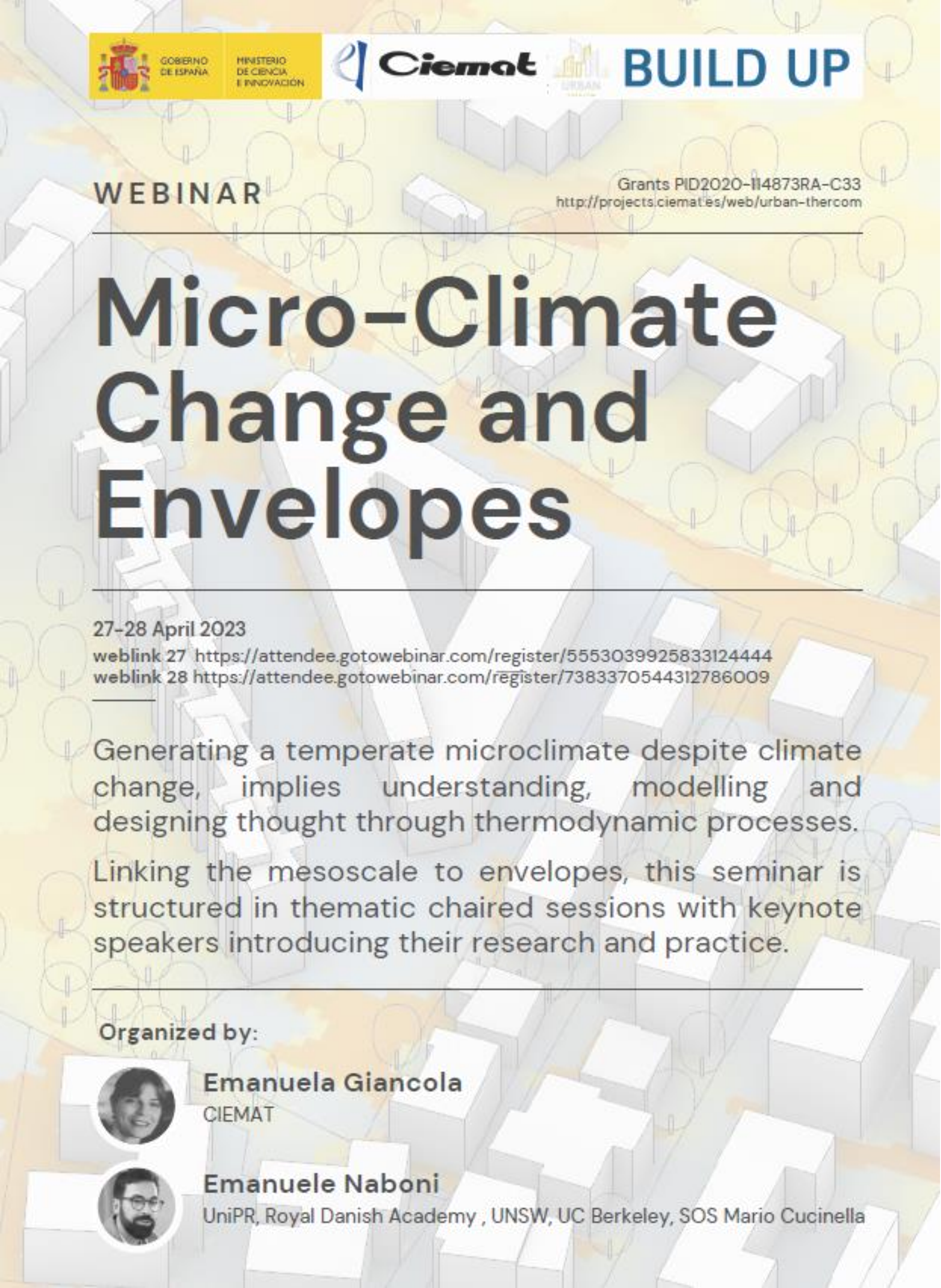
Universidad Politécnica de Madrid (UPM)

miguel.nunez@upm.es

Webinar **Micro-Climate Change and Envelopes**

April, 27-28th 2023

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
cfp CIEMAT física de partículas
POLITÉCNICA
UNIVERSIDAD POLITÉCNICA DE MADRID



Microclimate, Form and Surfaces

Impact of reflective materials on outdoor and indoor microclimates

PhD Agnese Salvati

AiEM arquitectura, energia i medi ambient

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

2021 – Current **Lecturer**
Department of Architectural Technology
Research group AiEM Architecture & Energy
Barcelona School of Architecture ETSAB
Polytechnic University of Catalonia UPC

2018 - 2021 **Research fellow**
Resource Efficient Future Cities, Institute of Energy Futures
Brunel University London, London, UK

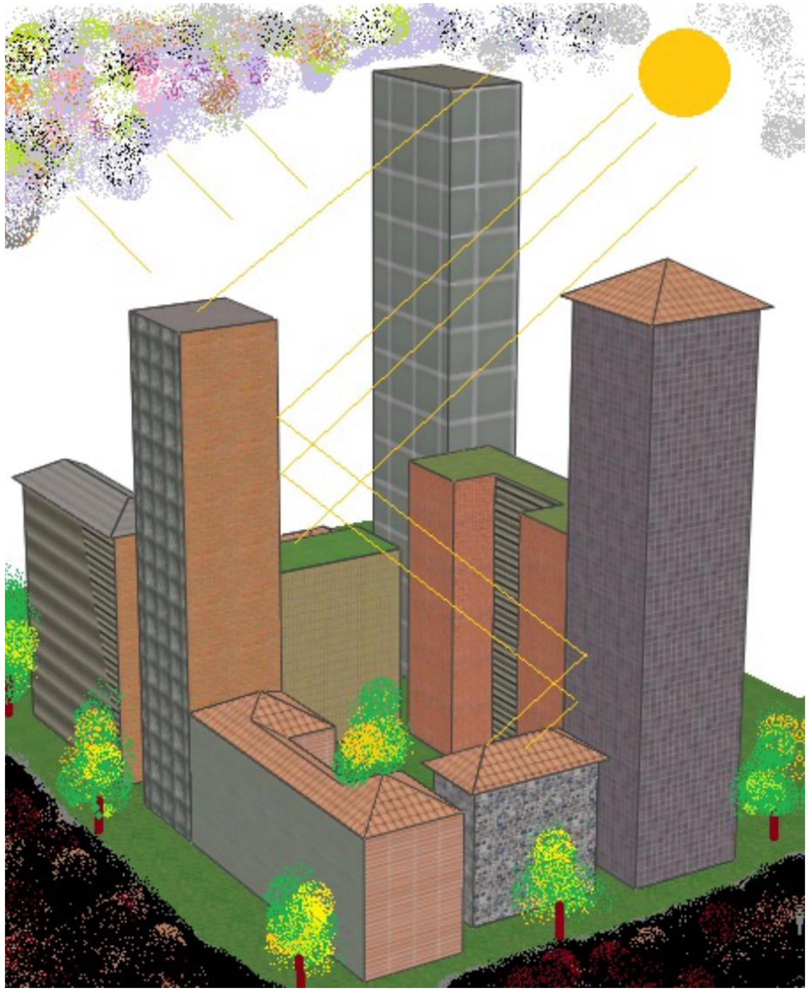
2017 – 2018 **Research Fellow**
Low Carbon Building group
School of Architecture
Oxford Brookes University, Oxford, UK

2017 **Postdoctoral researcher**
School of Architecture
Universidad Católica del Norte, Antofagasta, Chile

2016 **Double PhD title**
Sapienza University of Rome PhD programme in Engineering-based Architecture and Urban
Polytechnic University of Catalonia PhD programme in Architecture, Energy and Environment

PhD Thesis
The compact city in Mediterranean climate: heat island, urban morphology and sustainability

https://futur.upc.edu/19013190



EPSRC
Engineering and Physical Sciences Research Council

Urban albedo computation in high latitude locations: An experimental approach

Aim of the project:

To investigate the impact of **urban geometry** and **materials** on urban albedo and its impact on:

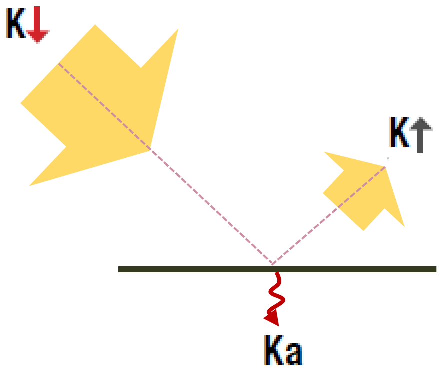
- **outdoor thermal comfort**
- **building overheating risk**

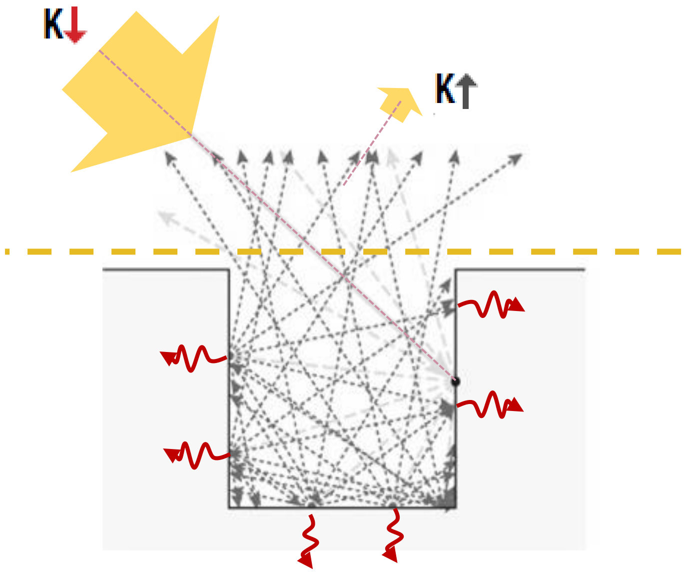
https://research.kent.ac.uk/urbanalbedo/

Prof. Marialena Nikolopoulou (PI)
Dr Giridharan Renganathan (CoI)
Dr Richard Watkins (CoI)
Dr Alkis Kotopouleas (PDRA)
Kent School of Architecture | Centre for Architecture & Sustainable Environment (CASE)

Prof. Maria Kolokotroni (CoI)
Dr Agnese Salvati (PDRA)
Brunel University London

Prof. Bala Vaidhyanathan (CoI)
Dr Aashu Anshuman (PDRA)
Loughborough University

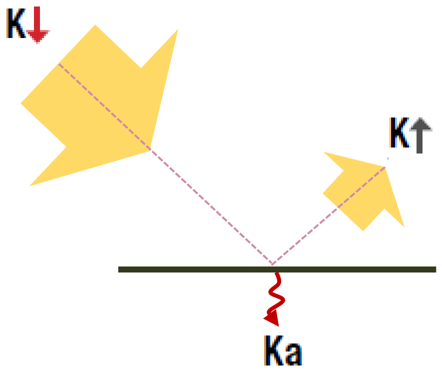




Urban albedo the ratio of the outgoing to the incoming shortwave radiation at the upper edge of the urban canopy layer (roof level).

Depends on:

- SURFACES **> solar reflectance** of materials
- FORM > **Urban geometry**



Urban albedo the ratio of the outgoing to the incoming shortwave radiation at the upper edge of the urban canopy layer (roof level).

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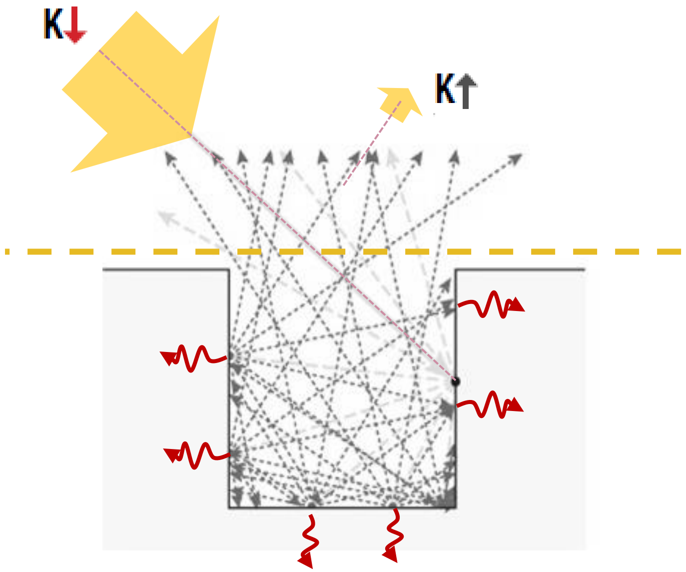
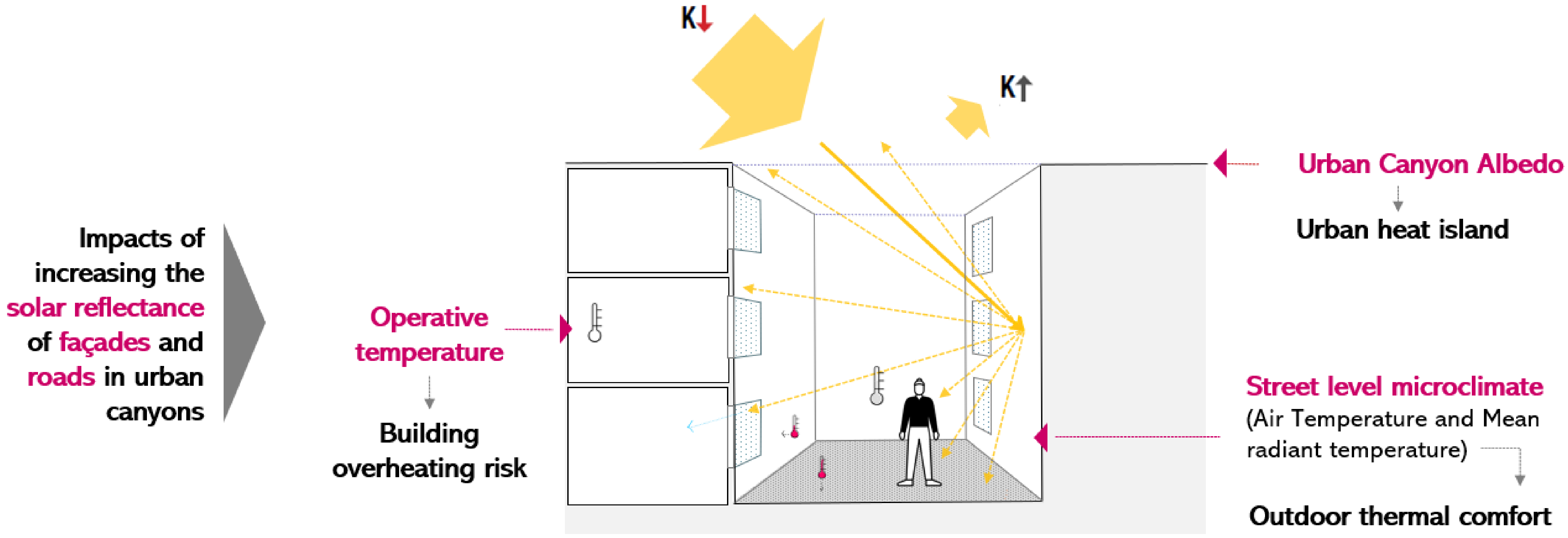


Low urban albedo value is responsible for:

- intensifying the **urban heat island**
- Negative impact on **outdoor thermal comfort**
- Increasing **overheating risk** of urban buildings


Impacts of increasing the solar reflectance of façades and roads in urban canyons
K↓
K↑
Urban Canyon Albedo
Urban heat island
Operative temperature
Building overheating risk
Street level microclimate
(Air Temperature and Mean radiant temperature)
Outdoor thermal comfort

Methods

A residential area in London is used as case study

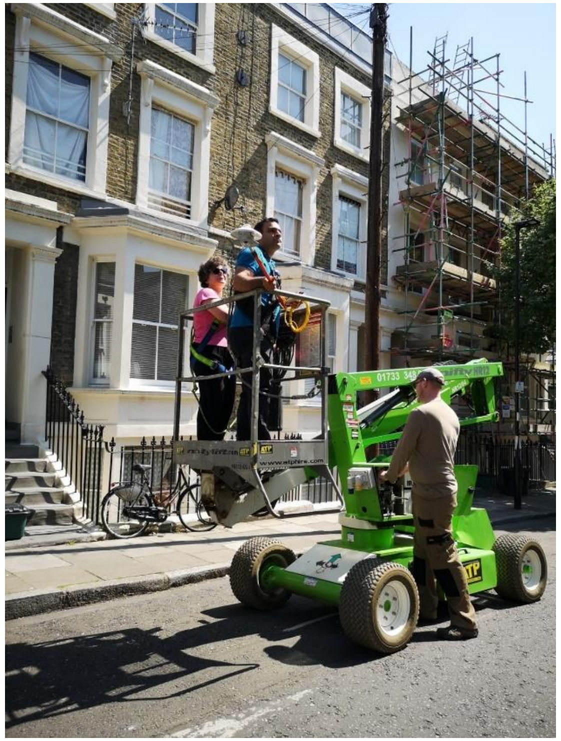
In situ measurements

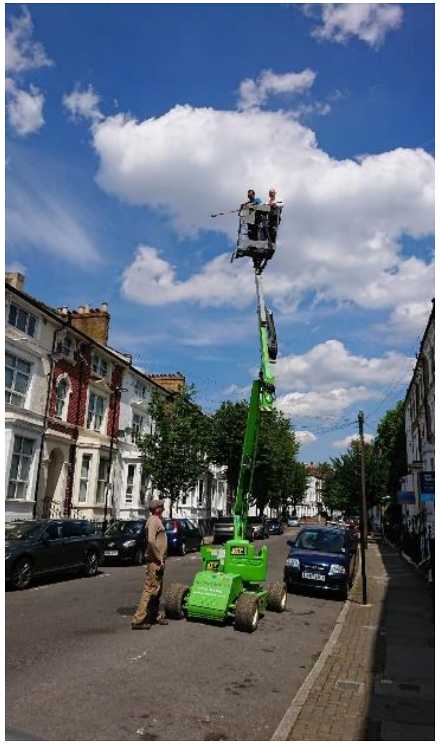
Physical model monitoring

Microclimate and building performance simulations

In situ measurements

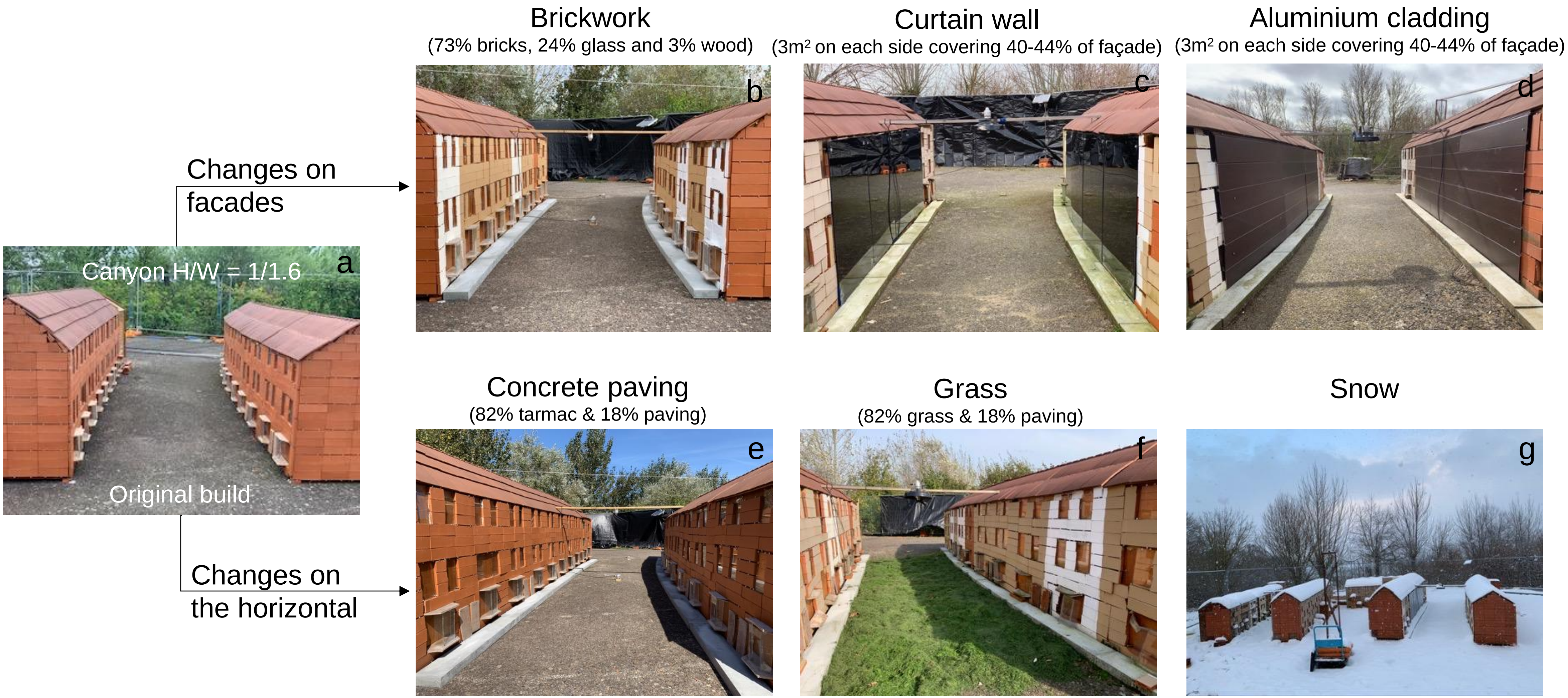
Incoming and reflected radiation at different heights





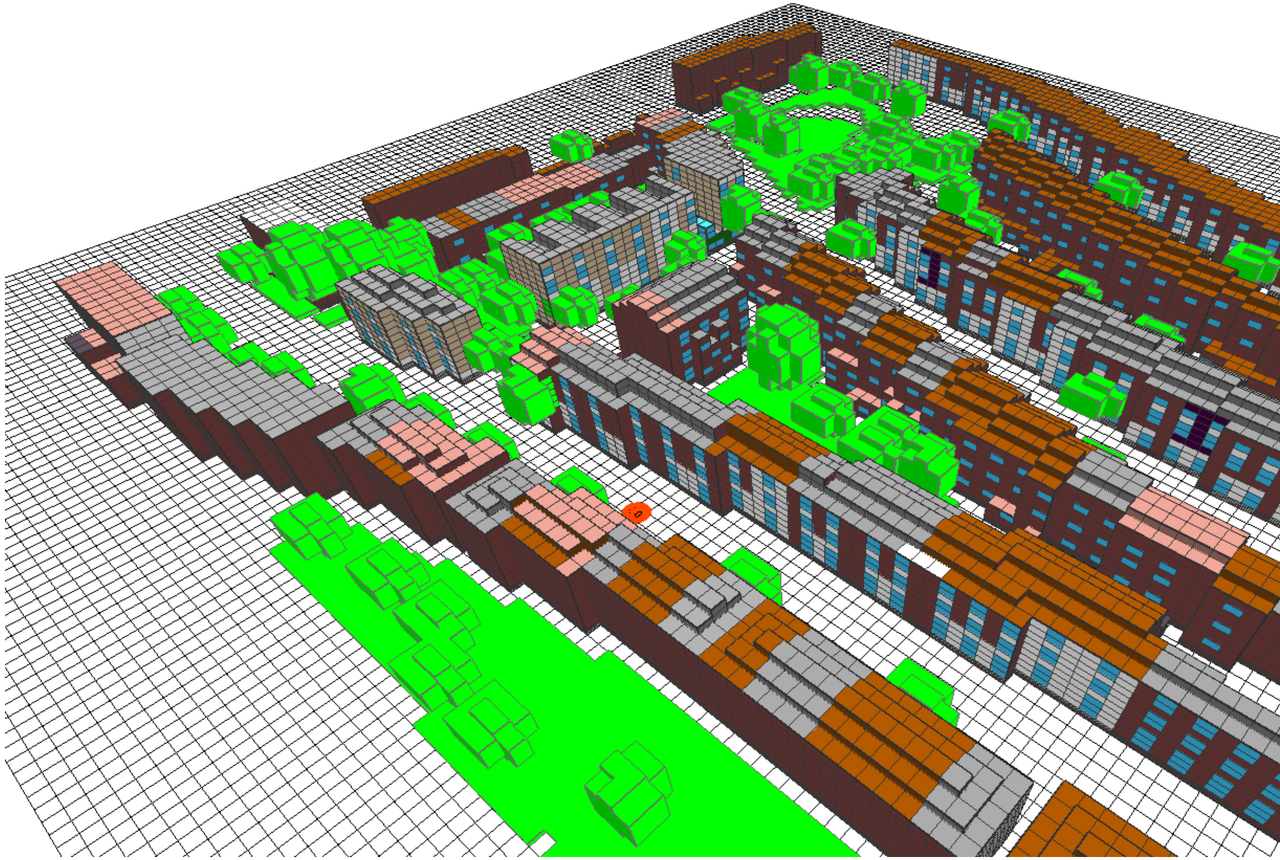
Physical model monitoring

Incoming and reflected radiation at different heights



Microclimate simulations (ENVImet)

Material & reflectivity coefficients		K_rd		S_Rd		L_Rd	
Façade (divided by orientation)		**ESE**	**WNW**	**SSW**	**NNE**	**SSE**	**NNW**
Red Bricks	r= 0.32	9%	40%		69%	8%	4%
Yellow bricks	r= 0.43	25%		33%		31%	33%
painted brick	r= 0.2	9%					
Dark paints	r= 0.08			3%	1%		
White painted bricks	r= 0.56	38%	35%	40%	17%	33%	42%
Clear glass	r= 0.05	19%	25%	24%	13%	28%	22%
Roads							
Tarmac	r= 0.19	100%		100%		100%	

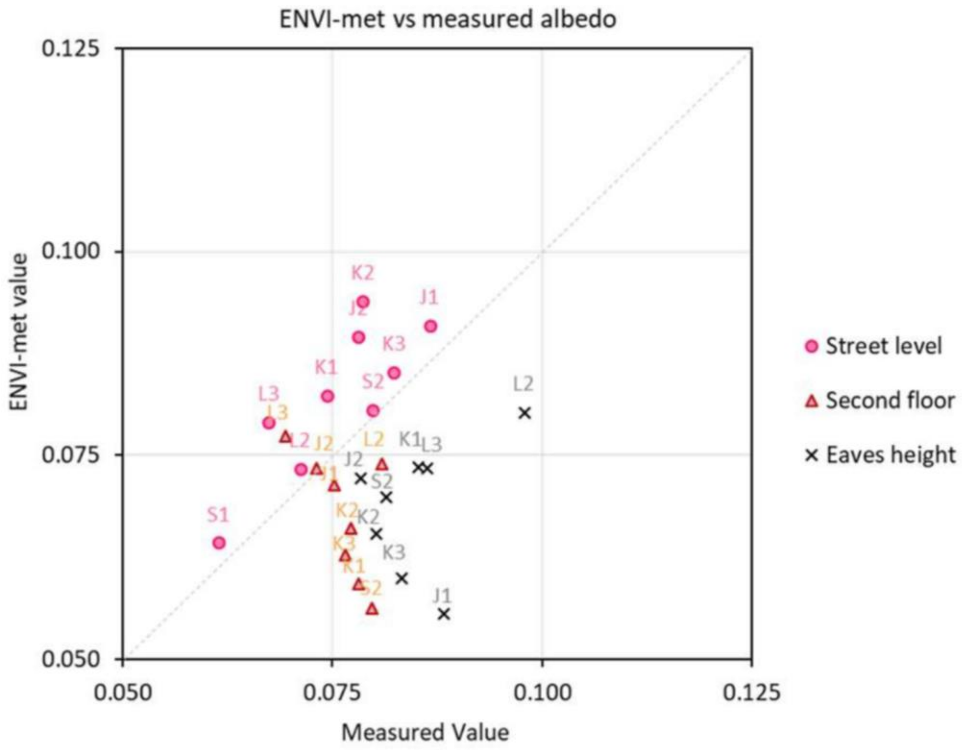


Microclimate simulations (ENVImet)

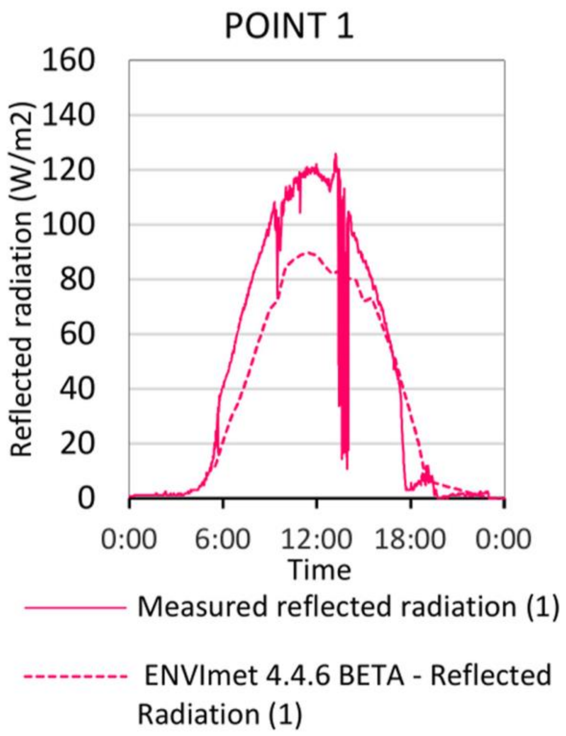
ENVImet performance

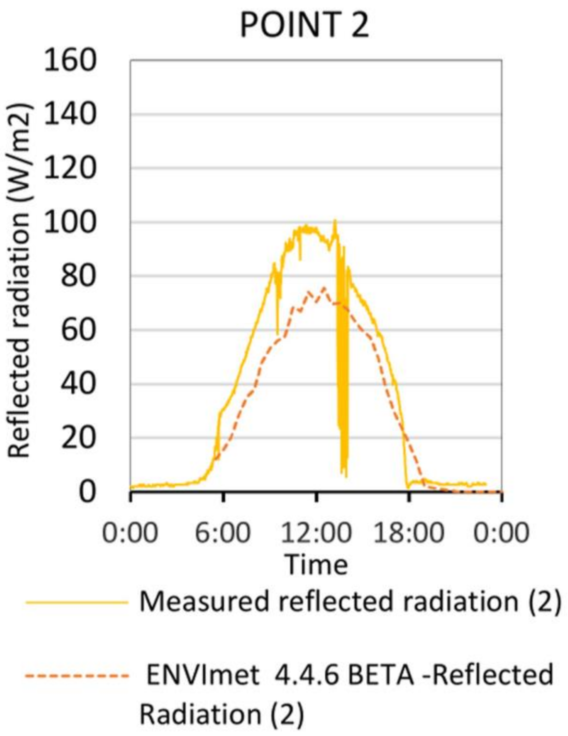
- Overestimates reflected radiation at the Street level
- Underestimates reflected radiation at the roof level

Vs **site measurements**



Vs **Scale Model measurements**





Microclimate simulations (ENVImet)

BC : Baseline model

Roads:

SR = 0.19 (Tarmac and concrete paving)

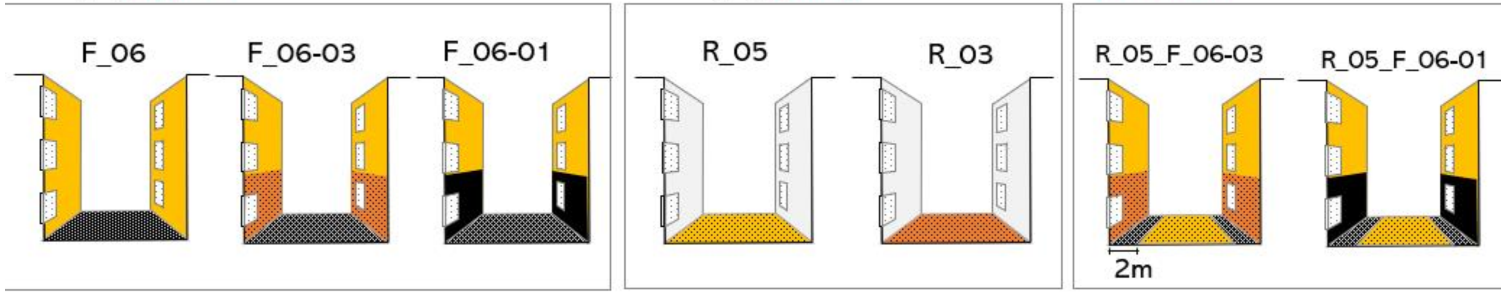
Façades:

SR = 0.05 (Glass) ~ 22% of the façade area

SR = 0.32 – 0.43 (bricks) ~ 50% + 0.56 (light-colour paint) ~ 45% + 0.08 - 0.2 (dark colour paint) ~ 5%

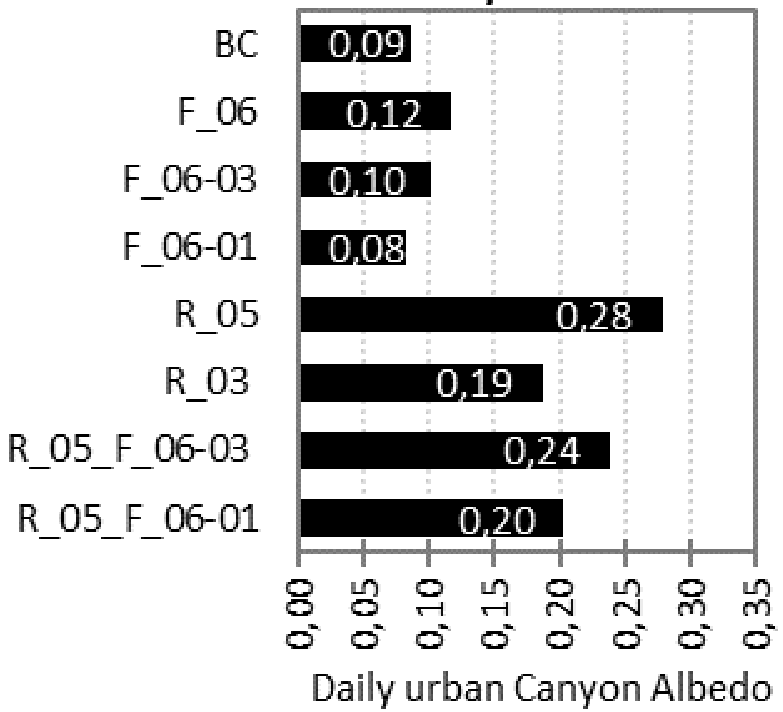
Reflective scenarios

Changing façades' reflectance | Changing paving reflectance | Combined scenario

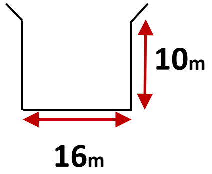


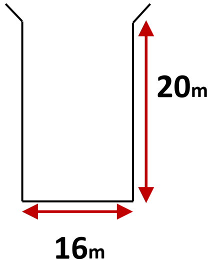
Colour legend:

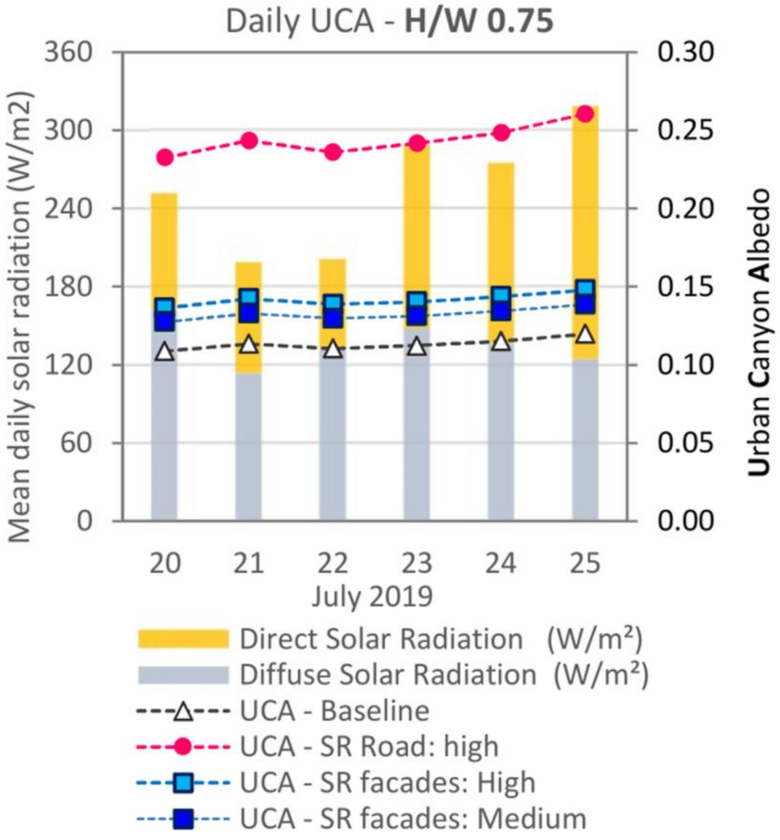
SR = 0.05 | SR = 0.1 | SR = 0.19 | SR = 0.3 | SR = 0.5 | SR = 0.6 | SR = as in baseline model

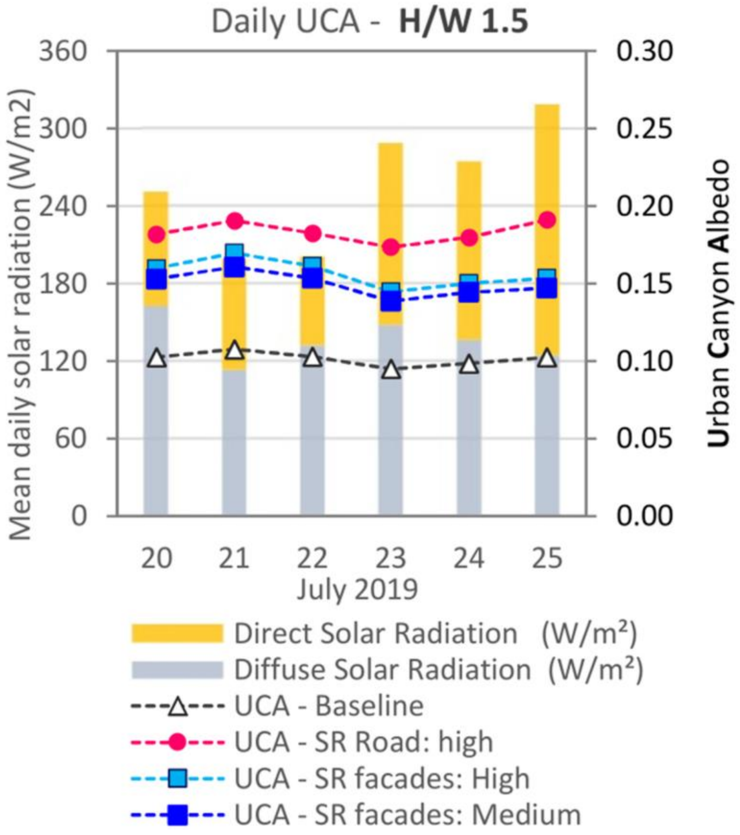


Microclimate simulations (ENVImet)

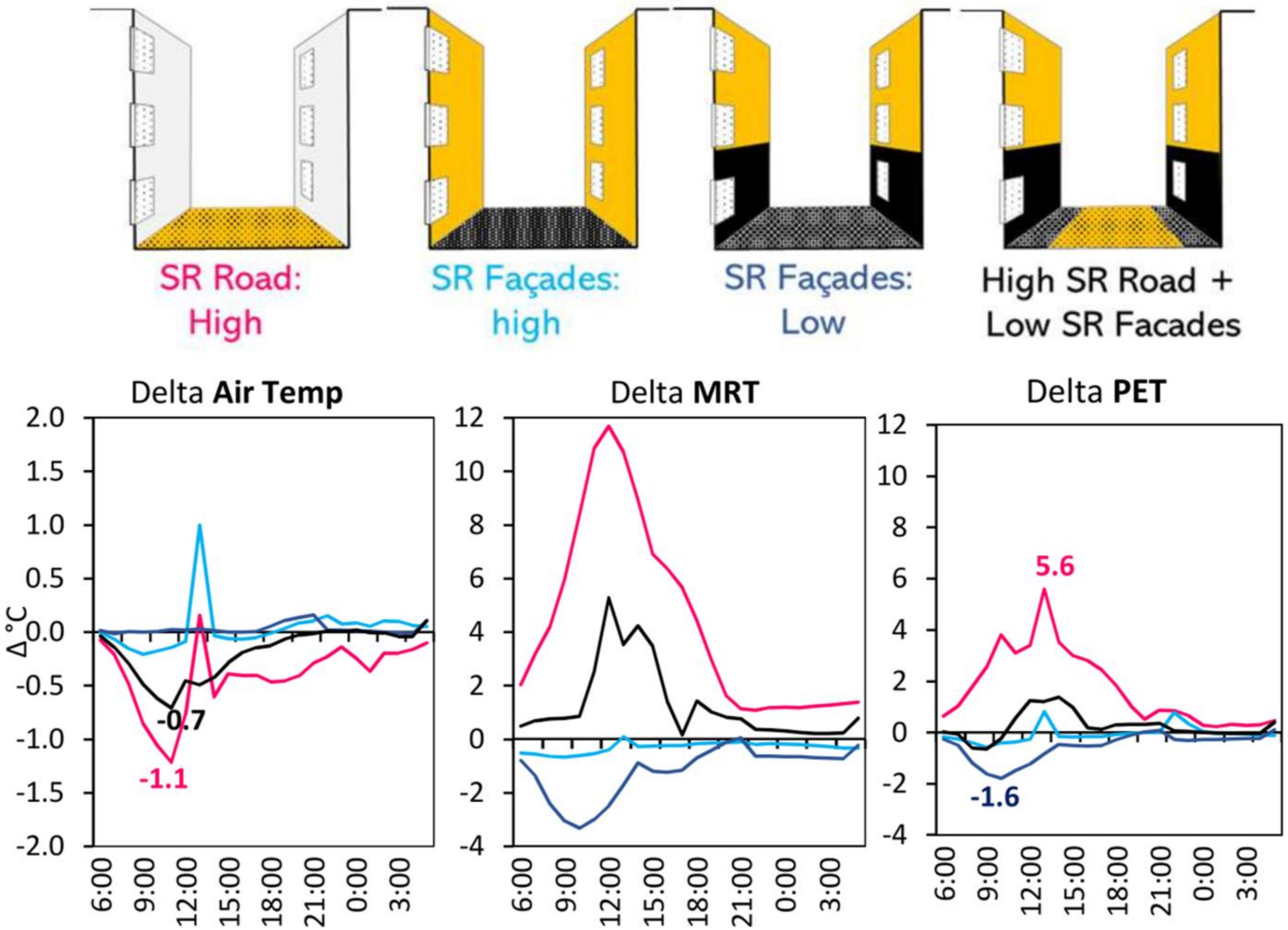








Microclimate simulations (ENVImet)



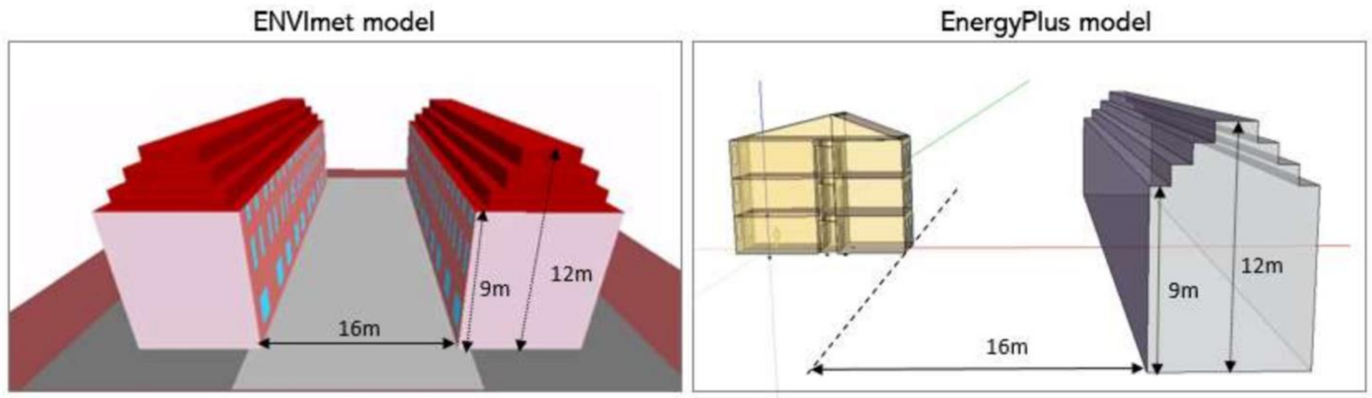
High reflectance roads increase urban albedo and reduce air temperature in wide canyons

BUT

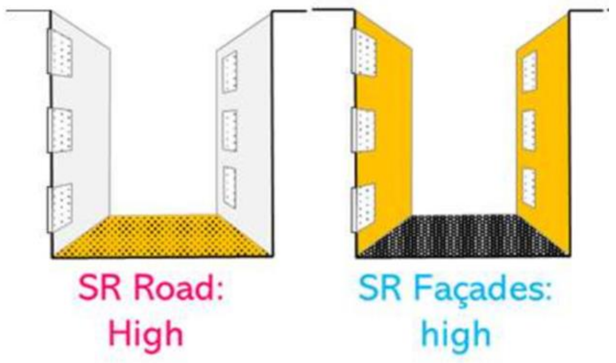
Also increase the mean radiant temperature, with negative impact on outdoor thermal comfort

Higher road reflectivity and lower façades reflectivity in the bottom part would be the **best strategy** for residential areas in London

Building overheating risk (EnergyPlus)



ENVImet outputs are used to run EnergyPlus simulations to assess the **impact of reflective scenarios on building indoor thermal conditions**



> **Cool walls** have a **slight positive effect**

> **High reflectance on roads** has a **negative impact on indoor operative temperatures**, entailing some risk of increasing the building cooling loads and heat stress.

Main Publications

Salvati A, Kolokotroni M, Kotopouleas A, Watkins R, Renganathan G and Nikolopoulou M (2022) ‘Impact of reflective materials on urban canyon albedo, outdoor and indoor microclimates’ Building and Environment 207 (available at https://doi.org/10.1016/j.buildenv.2021.108459)

Kotopouleas A, Renganathan G, Nikolopoulou M, Watkins R and Yeninarcilar M (2021) ‘Experimental investigation of the impact of urban fabric on canyon albedo using a 1:10 scaled physical model’ Solar Energy 230 449–461 (available at https://doi.org/10.1016/j. solener.2021.09.074)

Nikolopoulou, Marialena and Kotopouleas, Alkis and Renganathan, G. and Watkins, Richard and Yeninarcilar, Muhammed and Kolokotroni, M. and Salvati, Agnese and Vaidhyanathan, Bala and Anshuman, Aashu (2022) Research Insight 06: Urban albedo: developing a canyon albedo calculator. Technical report. CIBSE

Thank you!

Dr Agnese Salvati

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08028 Barcelona

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ETSAB Escola Tècnica Superior d'Arquitectura de Barcelona

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Local UHI mitigation through green roofs in mediterranean environments

Massimo Palme
Universidad Técnica Federico Santa María

UHI mitigation: which strategy for which context?

UHI intensity depends on many factors: urban fabrics, geo-morphological conditions, macroclimatic emplacement

Similarly, mitigation strategies can be very different in effectiveness across contexts, and could include at least:

- Green infrastructure at street level
- Nature based solutions (blue, green) incorporated in buildings’ envelopes
- Cool materials for pavements, roofs, sometime façades
- Urban ventilation
- Geothermal cooling
- Urban blue spaces
- Interventions in urban fabrics

UHI mitigation: which strategy at which scale of intervention?

UHI is a city phenomenon, tipically more intense in the center and quite depending on city size.

However, recent studies put in evidence that local spots (hot and cold) are always present and may be the key concept to be considered in developing mitigation strategies.

At different scales of analysis and intervention, different methodologies should be use

This presentation:

Green roofs as preferred mitigation strategy

Mediterranean environments: Barcelona and Valparaíso

Two scale of analysis: from the whole city to exposed sectors

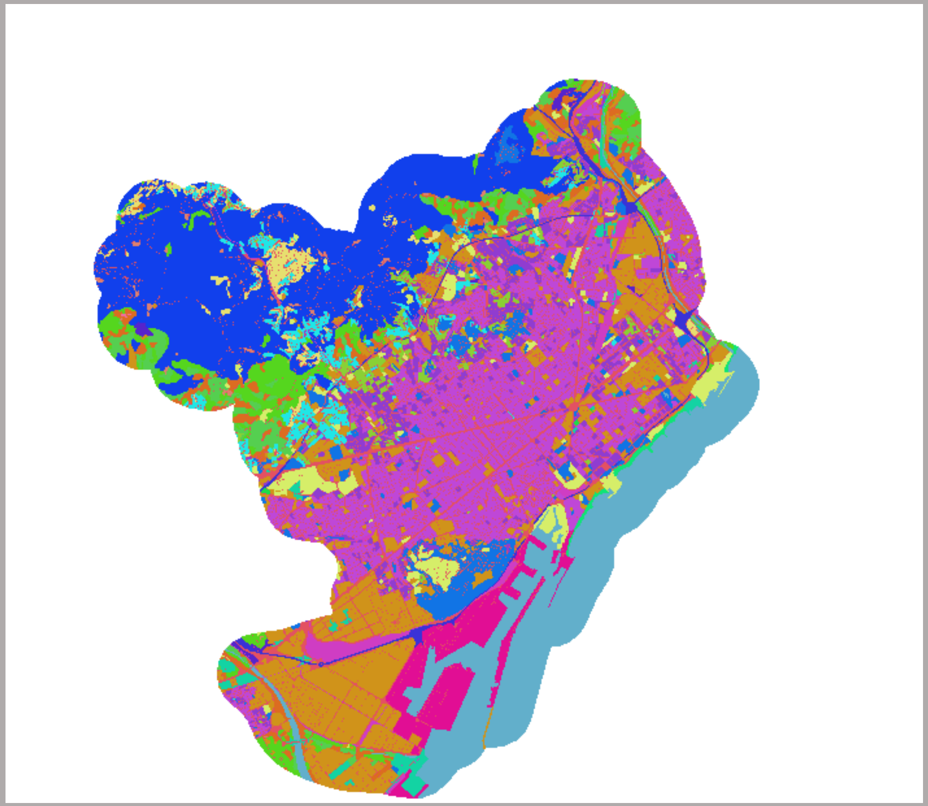
Two very different tools: INVEST (case 1: Barcelona) and ENVIMET (case 2: Valparaíso)

Mediterranean climates

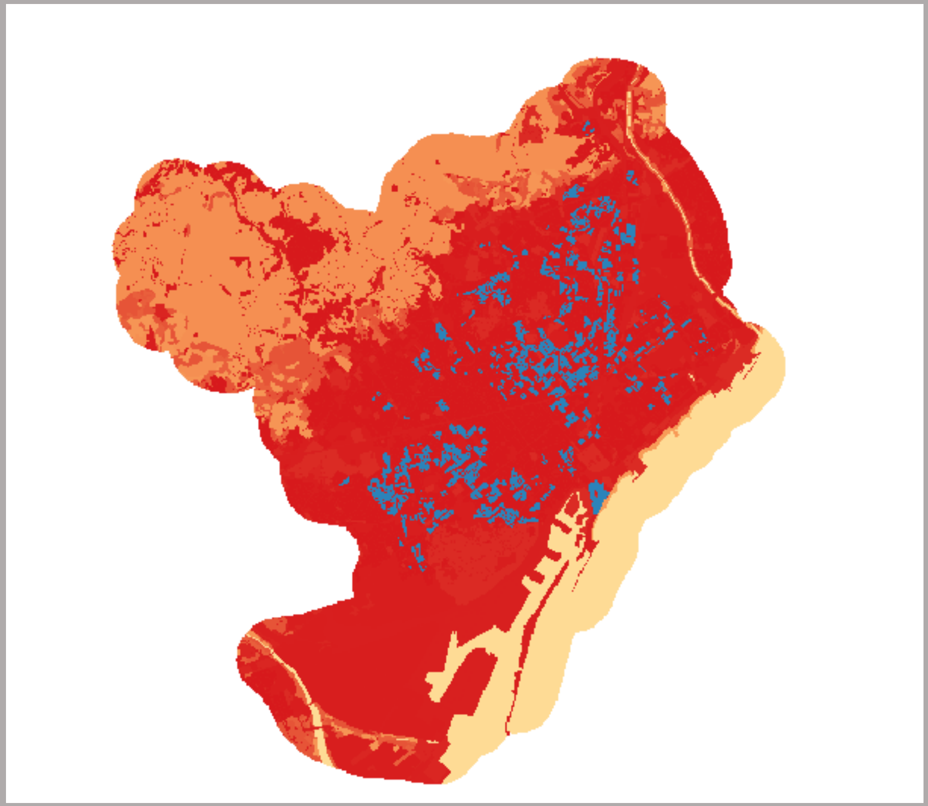
Following Köppen-Geiger classification, Mediterranean climates are part of the temperated climates and locates between latitude 30 and 45 in both hemispheres. This include the Pacific coast of the American continent, the Medierraenan Sea basin, and some small parts of South Africa and Australia.

Urban form is quite different across Mediterranean cities. In general, North America, Australia and South Africa present a more disperse urban structure, while in Europe and South America a low or medium urban density is priviledged.

Case 1. Barcelona, Spain



Land Use according to Urban Atlas definitions

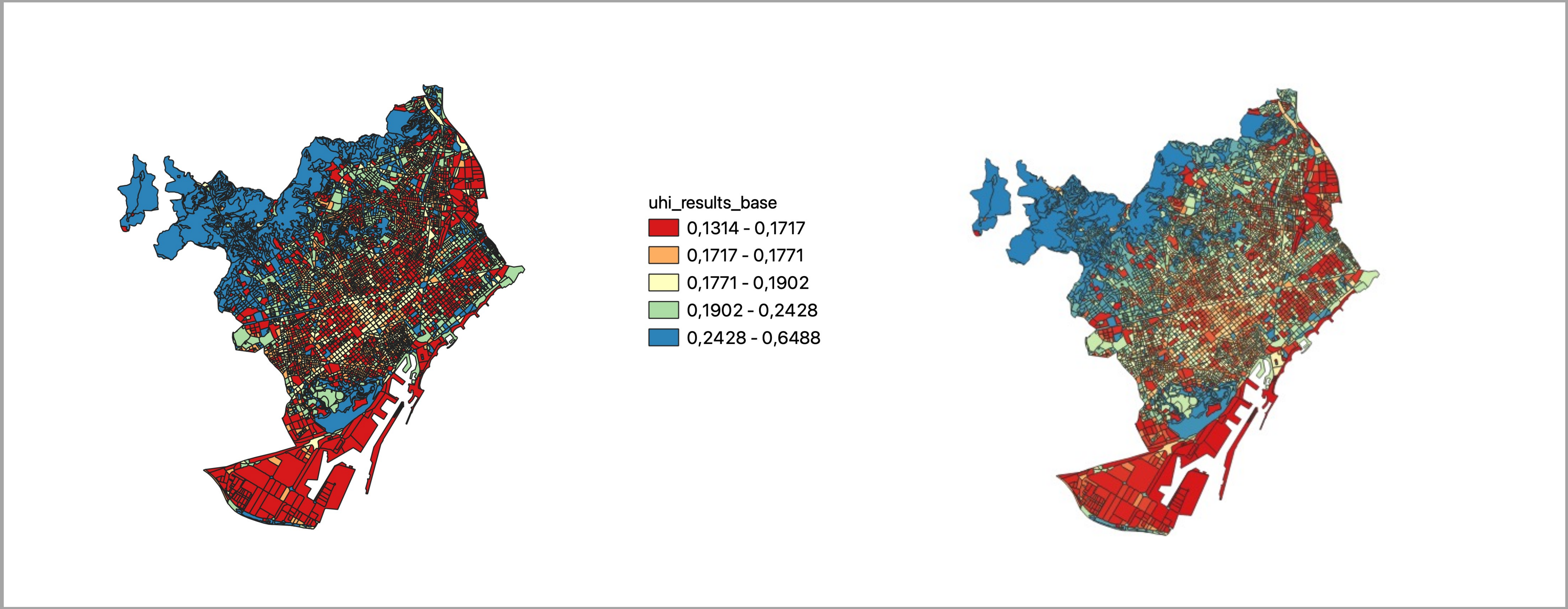


Residential blocks with density more tan 0.05 p/m2

Strategy to mitigate UHI: green roofs

- Only high-density blocks have been considered
- 15% of roofs’ surface was occupied with green
- Albedo, evapotranspiration and run-off retention properties were changed

UHI reduction coefficient



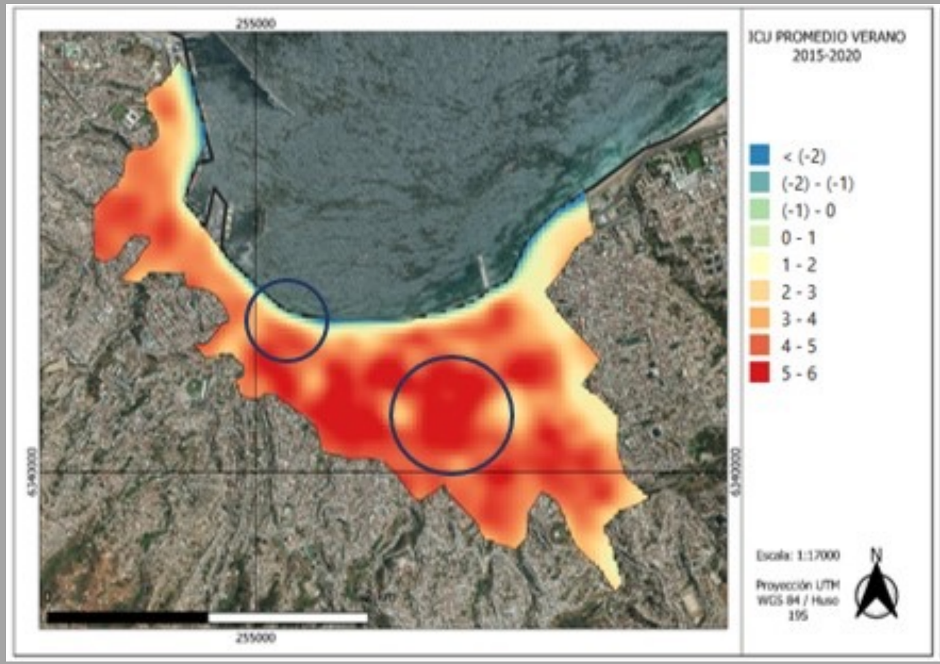
Results:

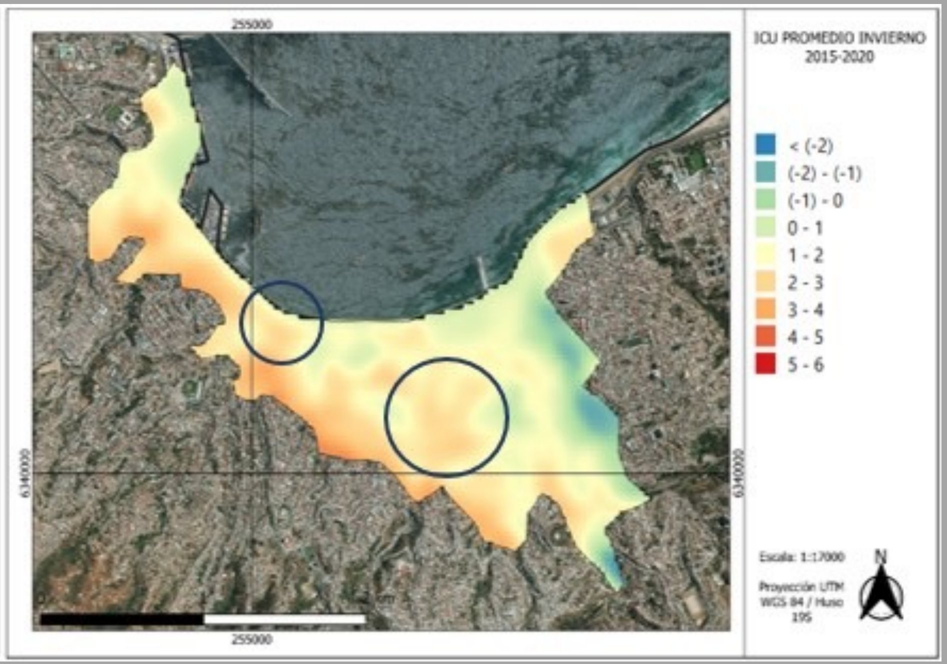
- Local effect: cooling capacity increases of 13% in blocks with green roof intervention
- Almost no global effect: average UHI intensity for the whole city remains the same
- If mitigation strategy relates to exposition, cooling capacity increased in the target points (where UHI intensity and the number of citizens exposed were high)
- Multy-risk mitigation strategy: runoff is also reduced in a 30% for target blocks

Limitations:

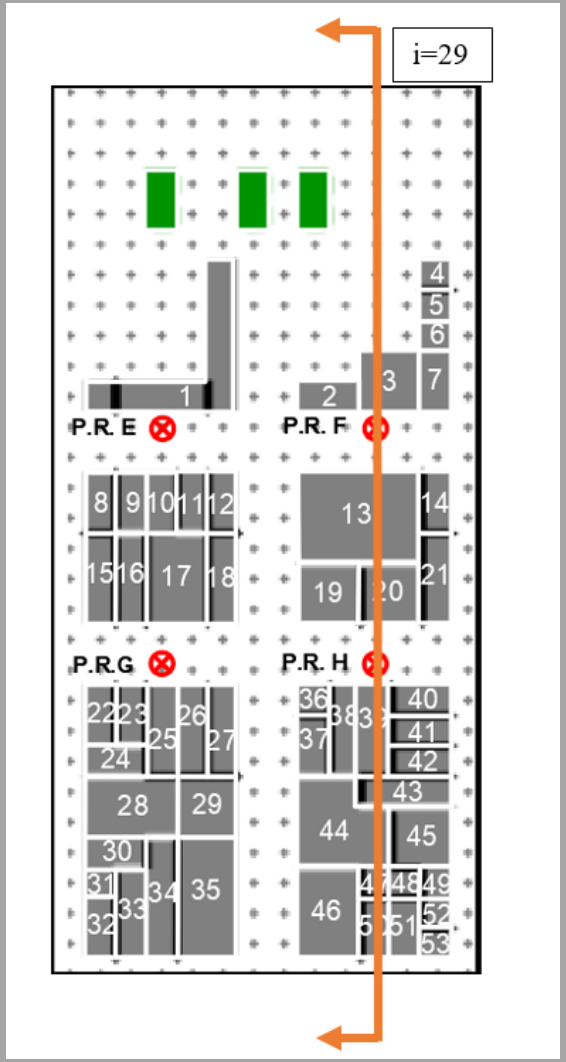
- INVEST is a tool that simplify the calculation of cooling capacity by using albedo and evatranspiration of vegetal surfaces as main parameters
- No ventilation effect is considered, nor accurate radiation exchange is accounted
- No 3D assessment of urban temperature is done

Case 2. Valparaíso, Chile





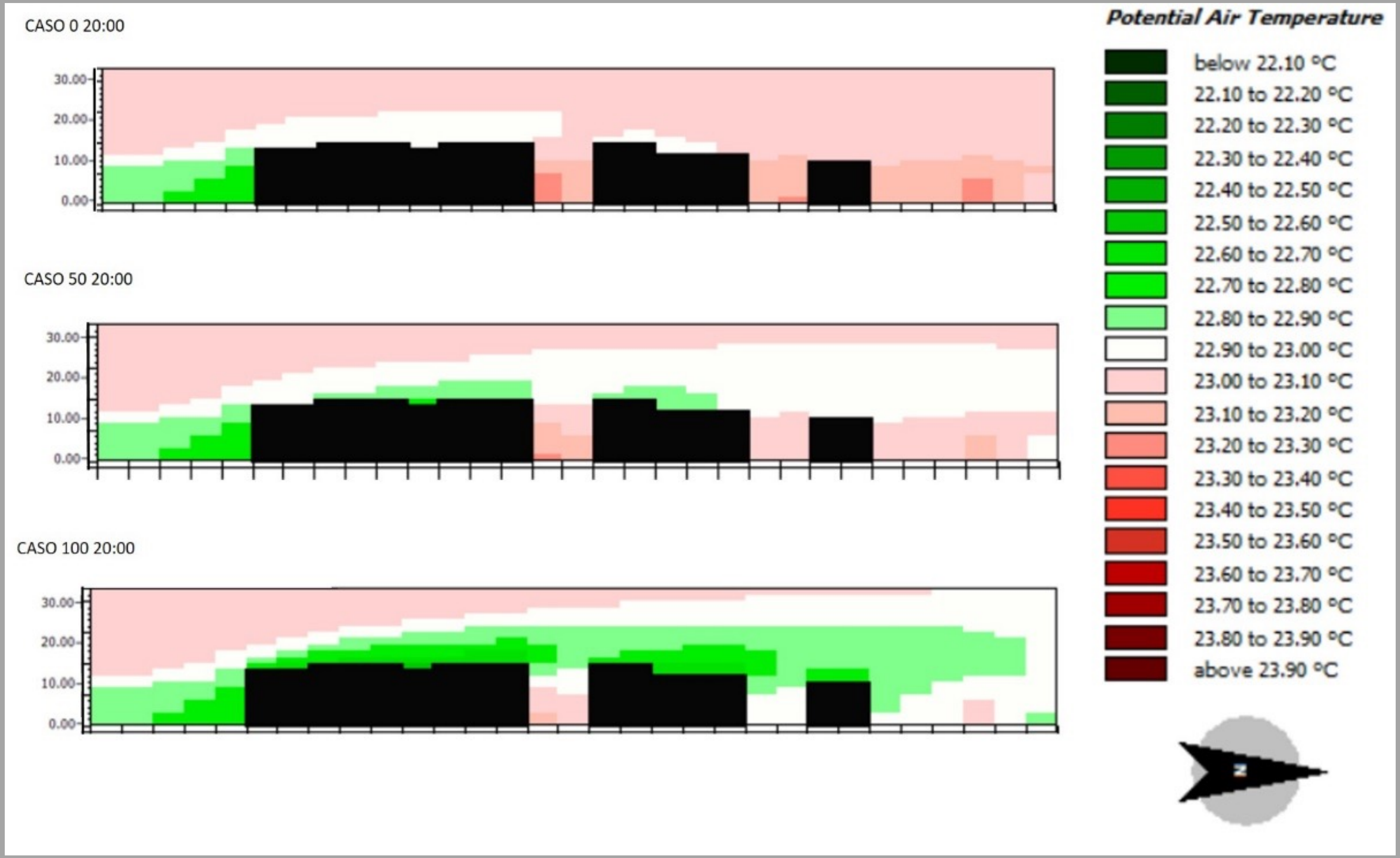
Sector "El Almendral": 3D Envimet model



Strategy to mitigate UHI: green roofs

- All roofs in the sectors have been considered
- 0-50-100% of roofs’ surface was occupied with green
- Albedo and evapotranspiration properties have been modeled in Envi-met
- A set of simulations was conducted for summer and winter solstice at different hours

Results summer solstice 20 h



Advantages and limitations:

- Envi-met is a complete tool to simulate urban climate, however it is time-consuming and the computational power the is needed to run the simulations is high
- Air temperature vertical profile is obtained, allowing more informed decisions on the specific benefit generated by each green roof intervention
- Air circulation and precise long-wave radiation exchanges are considered

Conclusions:

- Green roofs are important to reduce local UHI intensity in Mediterranean climates
- Benefits should be accounted at different scales, using different tools for different pouposes
- INVEST is very usefull to communicate the general improvement that can be obtained by a diffuse intervention in buildings
- Envi-met is needed to specifically test the influence of green roofs in a city sector, and should be used to design the interventions

References:

- Palme, M., Carrasco, C. (2022). Urban heat island in Latin American cities: a review of trends, impacts, and mitigation strategies. In “Global Urban Heat Island Mitigation”. Publisher: Elzevier
- Carrasco, C., Palme, M., Valenzuela, J. (2022). Impacto y mitigación de las cubiertas vegetales en el clima urbano e isla de calor de la ciudad de Valparaíso, Chile. Congreso Internacional Ciudad y Territorio Virtual, Bogotá, 31/8-5/9 2022
- Valenzuela, J. (2022). Influencia de la implementación de cubiertas verdes en la ciudad de Valparaíso. Tesis de grado en Ingeniería en Construcción, Universidad de Valparaíso

BUILD UP
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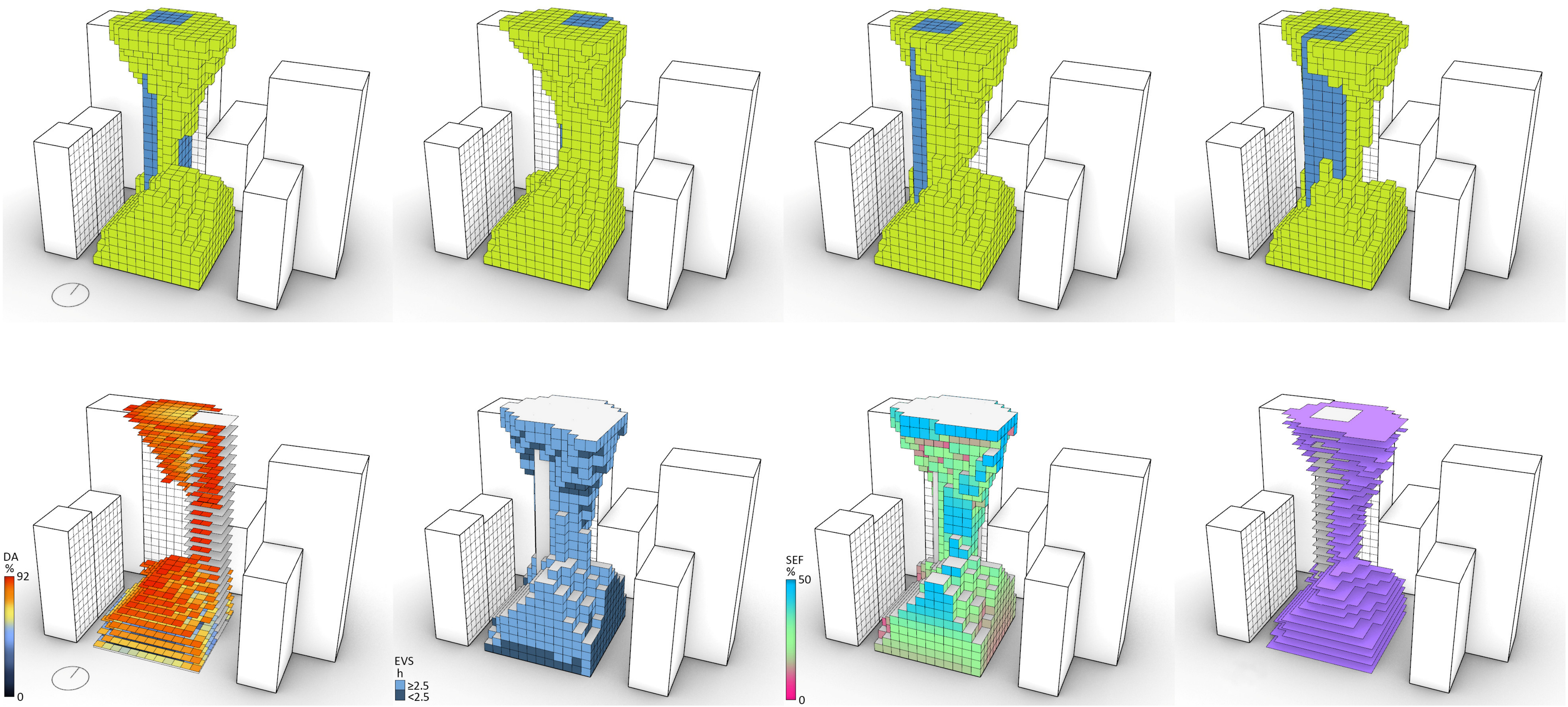
27-28.04.2023

Micro-Climate Change and Envelopes

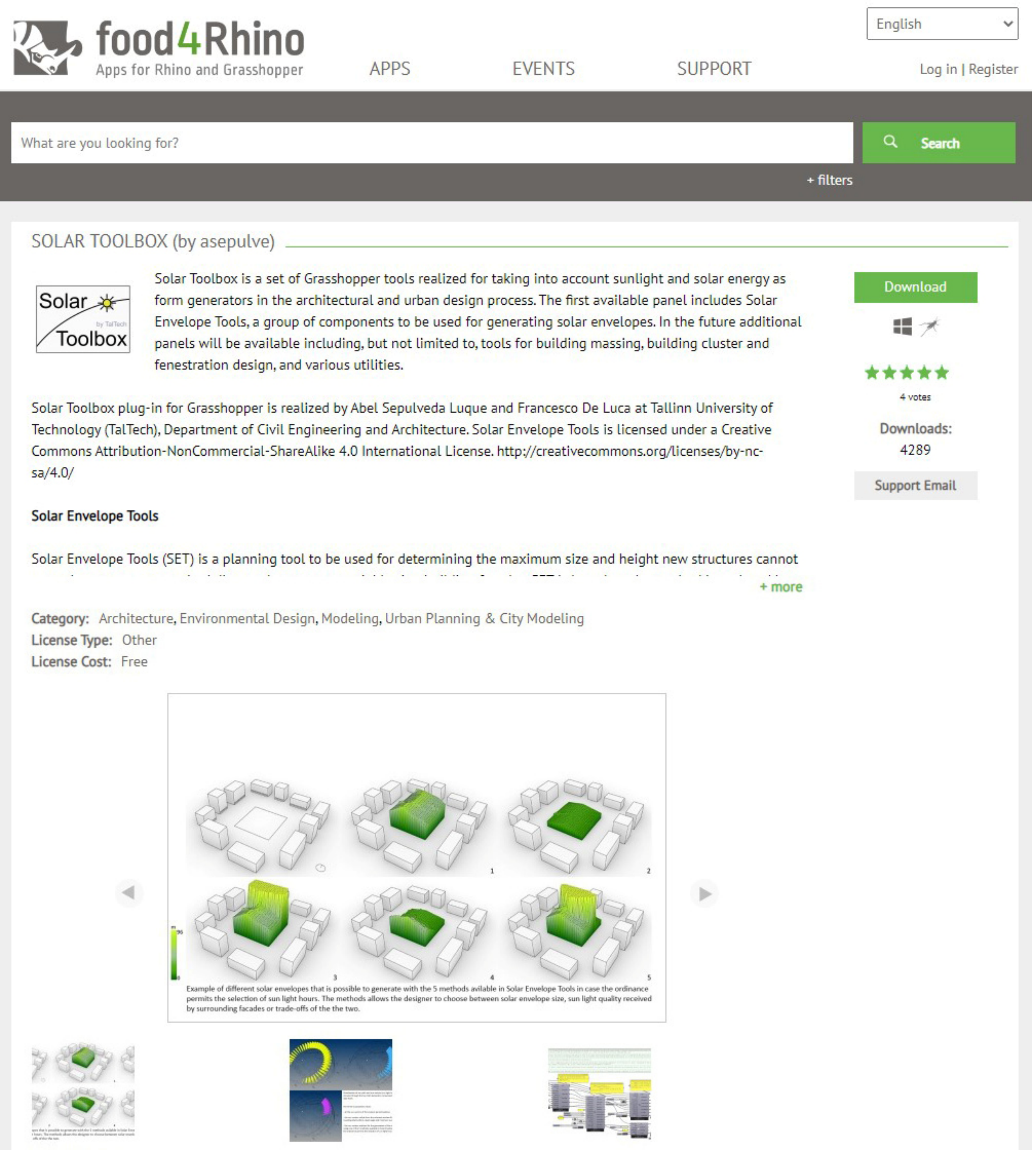
Urban Shaderade
Building Form Generation Method for Reducing Energy Use in the Built Environment

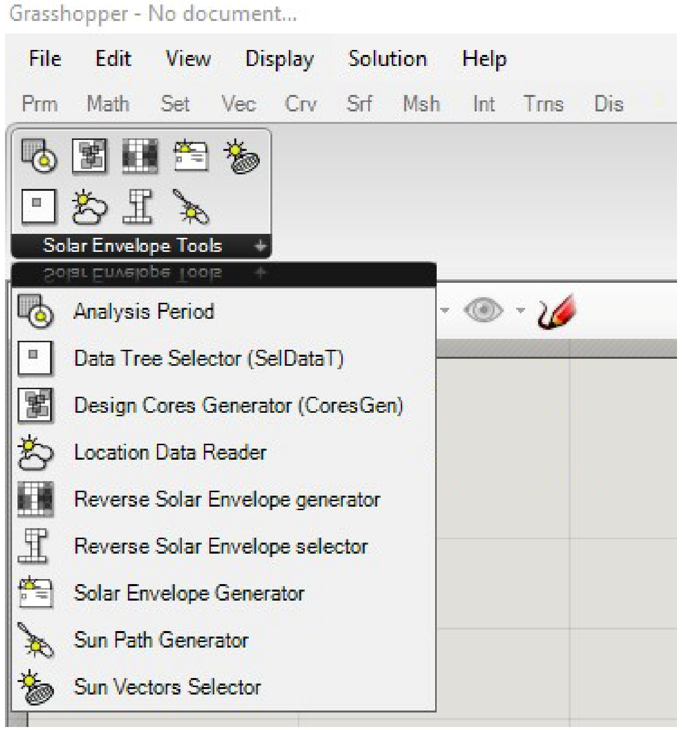
Francesco De Luca
Tallinn University of Technology

Background



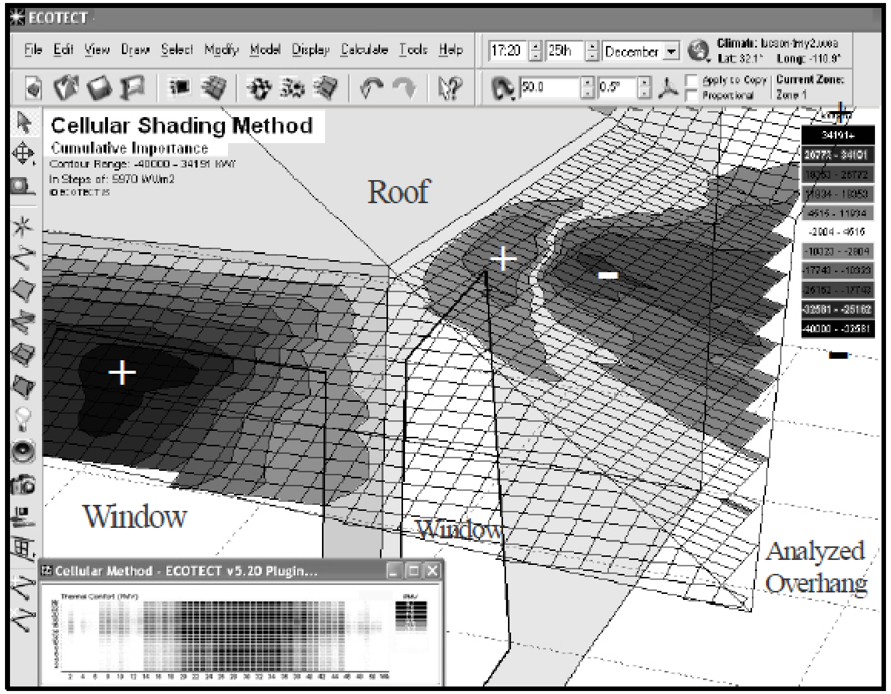
De Luca, F., Dogan, T. and Sepúlveda, A., Reverse Solar Envelope Method. A New Building Form-finding Method That Can Take Regulatory Frameworks into Account. Aut. Const., 123 (2021) 103518.



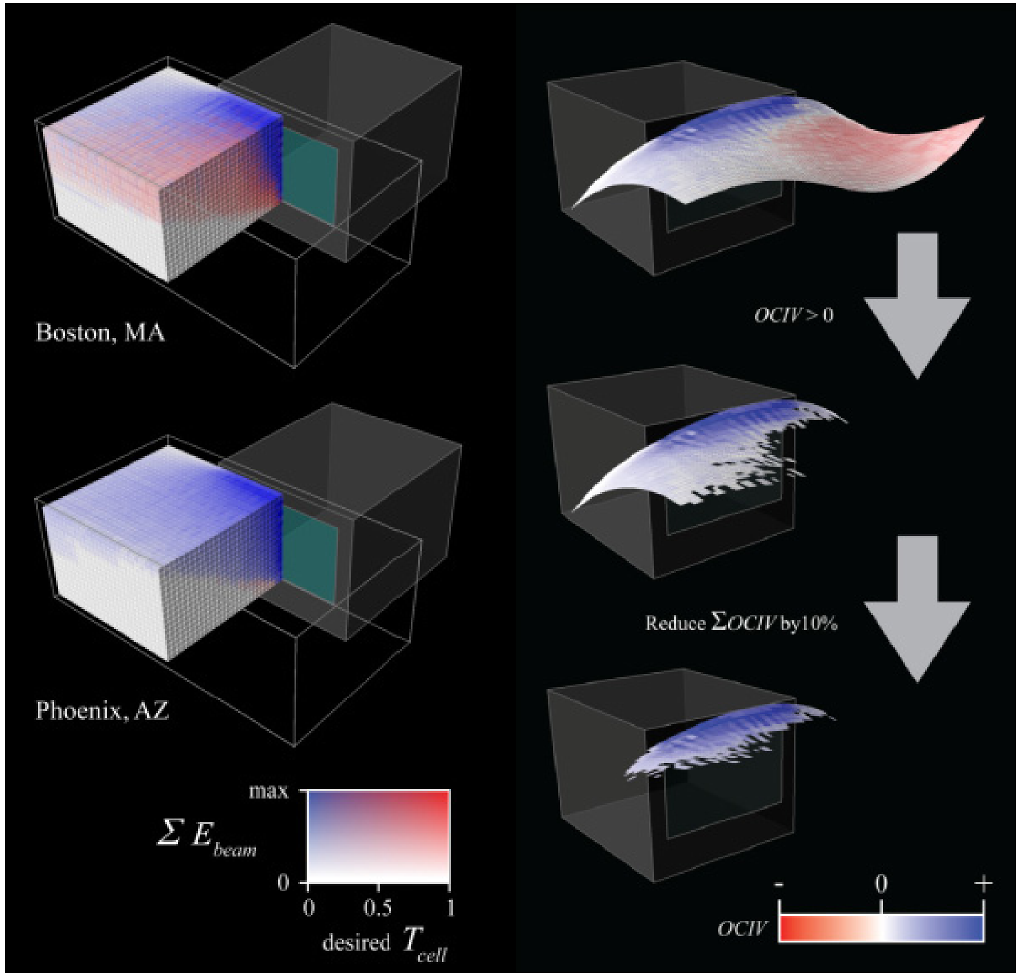


Abel Sepúlveda, Francesco De Luca - Solar Envelope Tools https://www.food4rhino.com/en/app/solar-toolbox

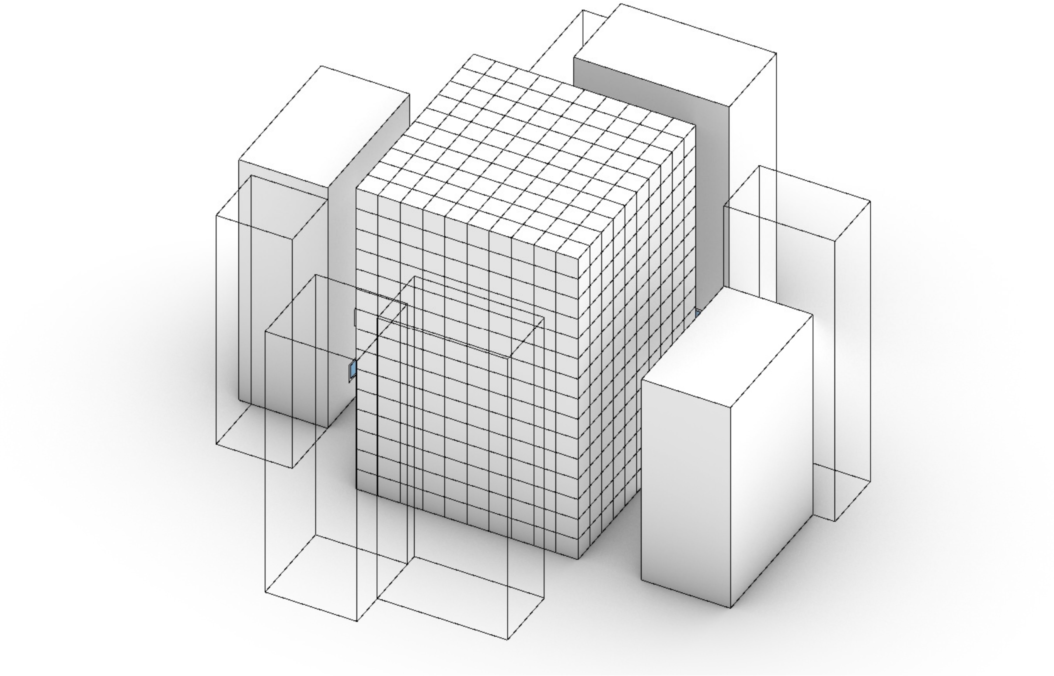
Urban shaderade



Kaftan, E., Marsh, A.: Integrating the cellular method for shading design with a thermal simulation. In: Proceedings of 1st International Conference on Passive and Low Energy Cooling for the Built Environment (Palenc 2005), pp. 965-970. Santorini, Greece (2005).



Sargent, J.A., Niemasz, J., Reinhart, C.F.: Shaderade: Combining Rhinoceros and EnergyPlus for the Design of Static Exterior Shading Devices. In: Proceedings of Building Simulation 2011, pp. 310-317. IBPSA, Sydney (2011).

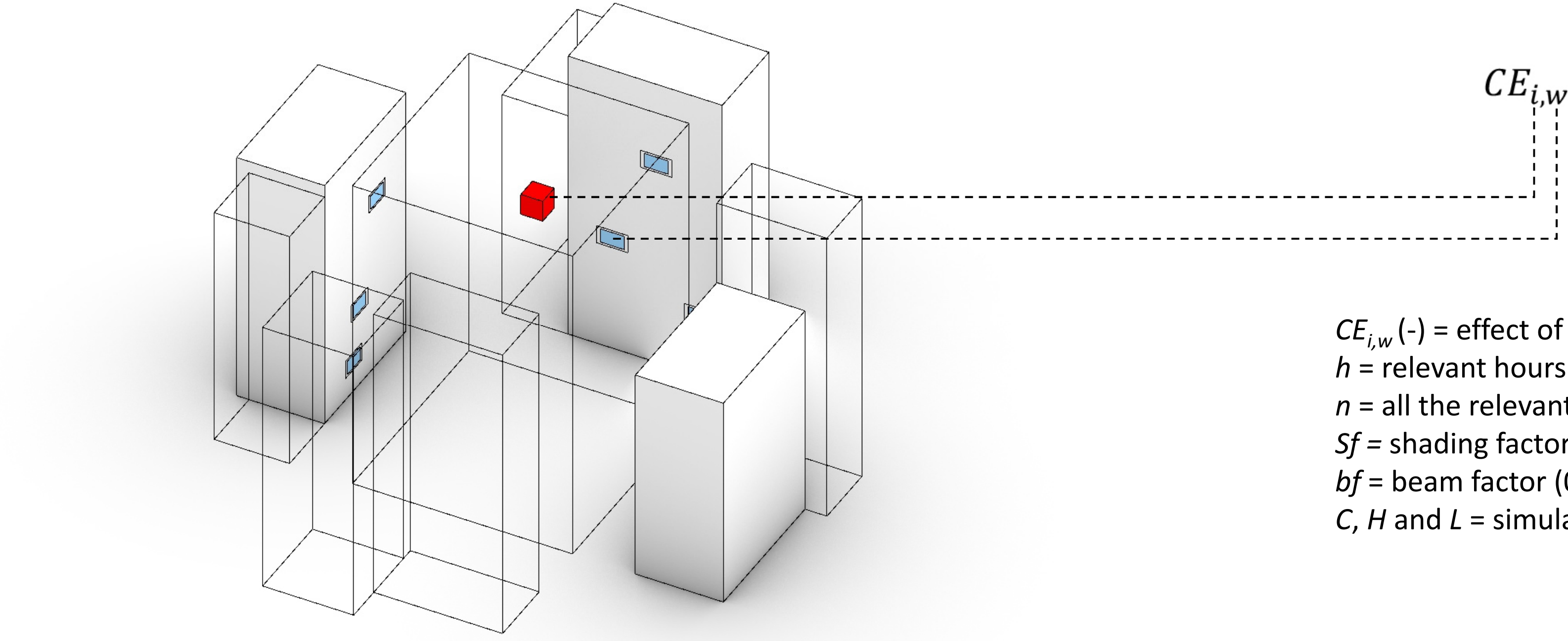


Assumption

A cell blocking beam solar radiation during hour *h* would:

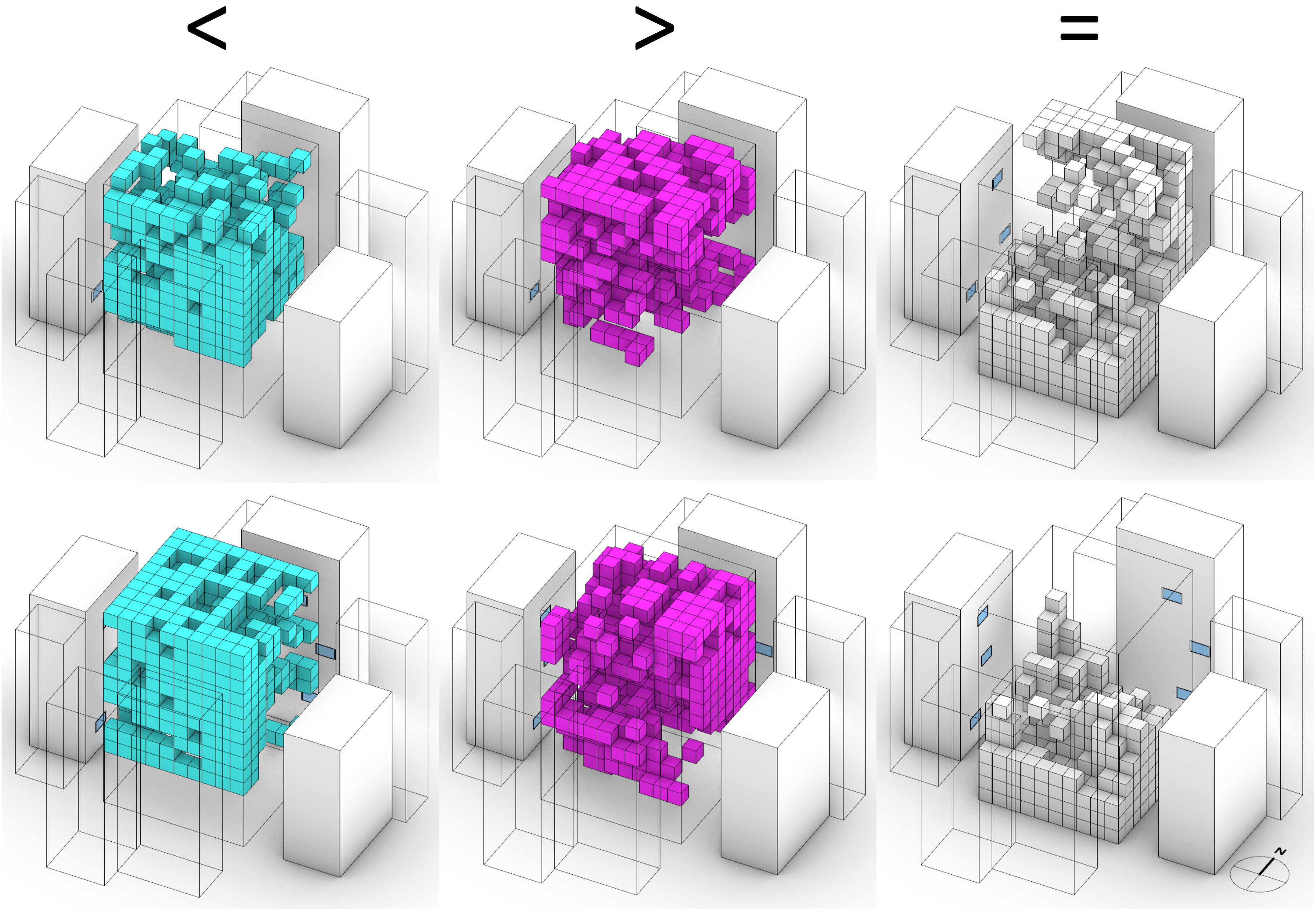
- shade the window reducing cooling energy use (if present).
- prevent solar gains increasing heating energy use (if present).
- increase electric lighting use (if present).

A cell absence would have the opposite effect.



$$CE_{i,w} = \sum_{h=1}^{n} (sf \ x \ bf) \ x \ (C - H - L)$$

$CE_{i,w}$ (-) = effect of cell *i* on window *w*
h = relevant hours used for energy and solar beam simulations for each *w*
n = all the relevant hours
Sf = shading factor (0-1)
bf = beam factor (0-1)
C, *H* and *L* = simulated cooling, heating and electric lighting energy use



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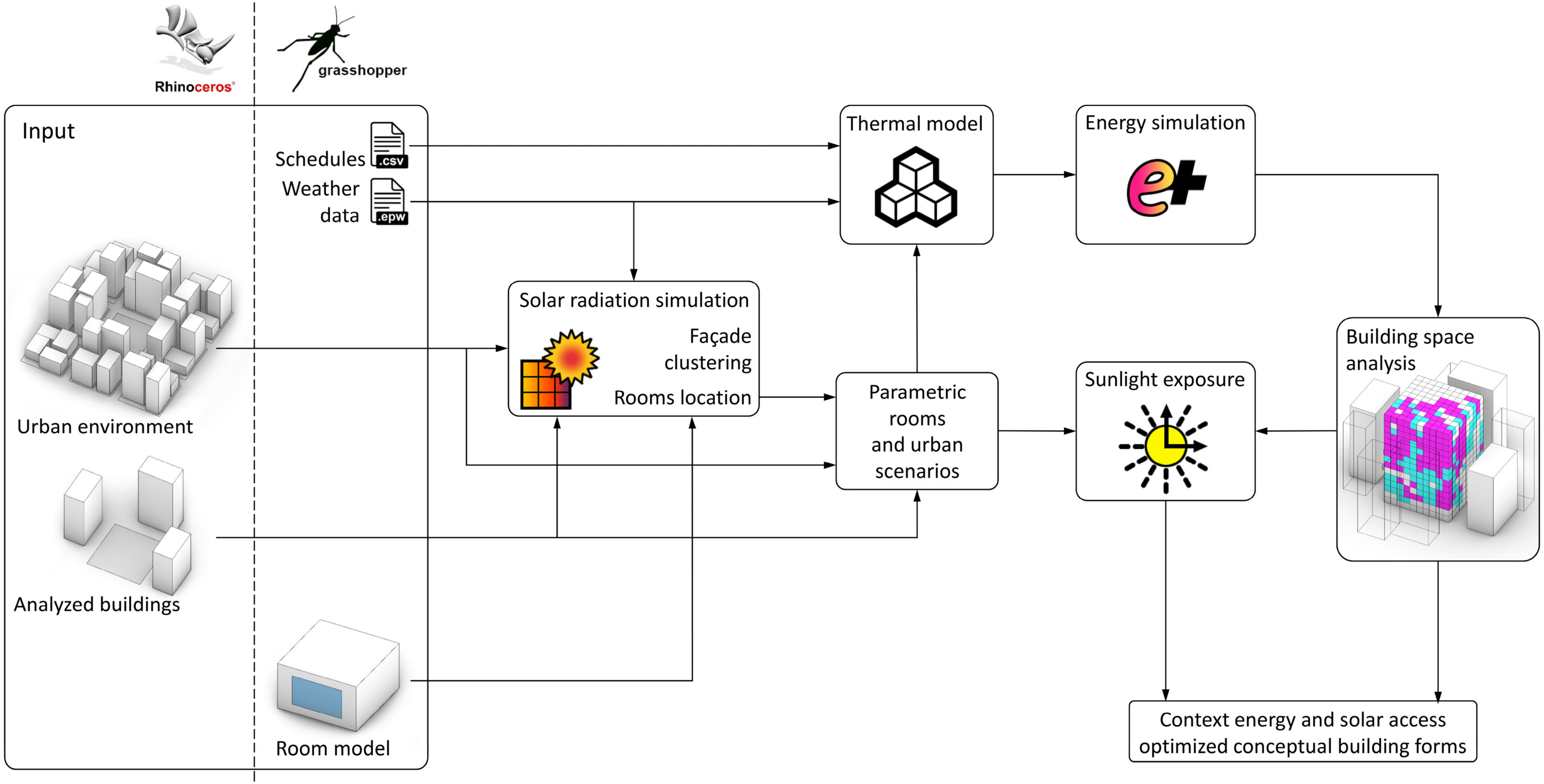

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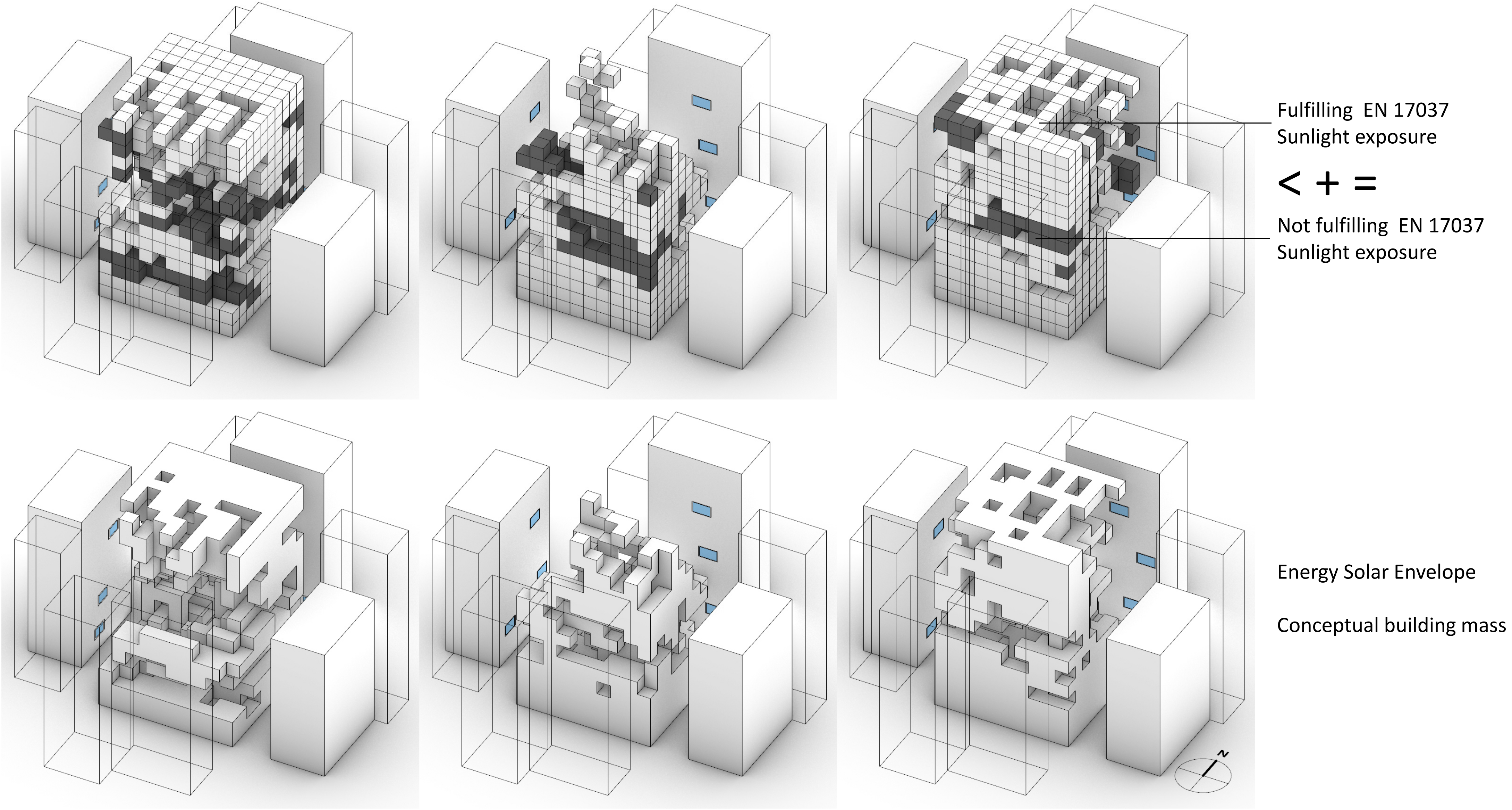
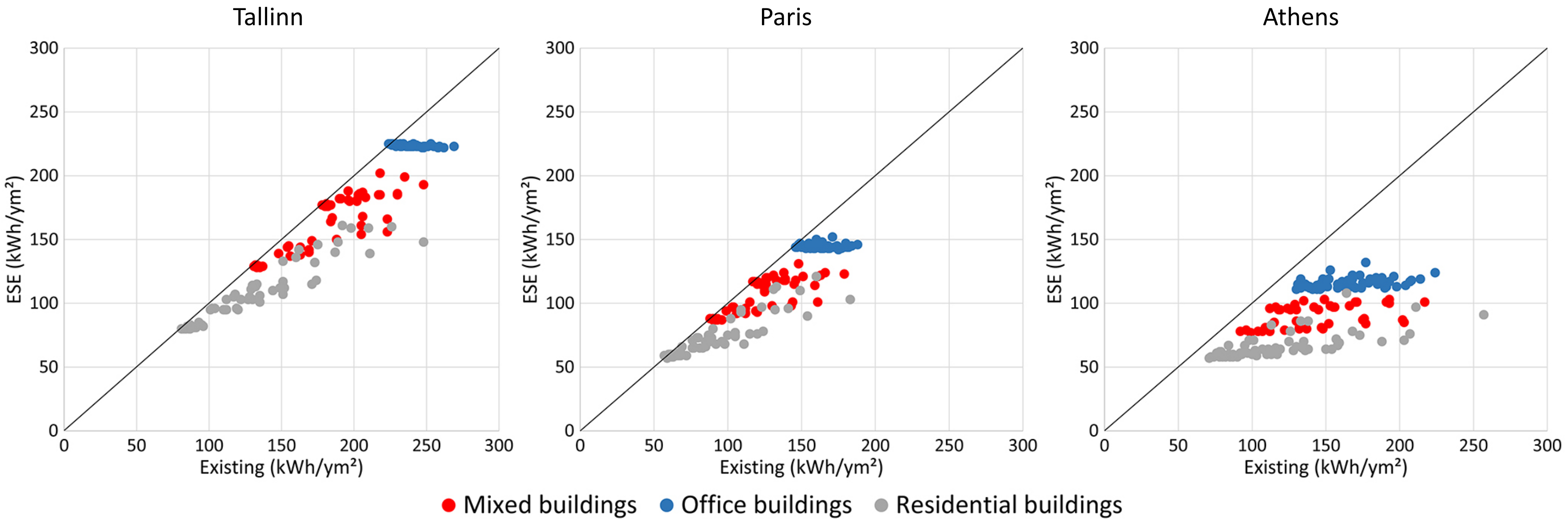


De Luca, F. and Sepúlveda, A. 2023, Urban Shaderade. Building Space Analysis Method for Energy and Sunlight Consideration in Urban Environments. CAAD Futures 2023.



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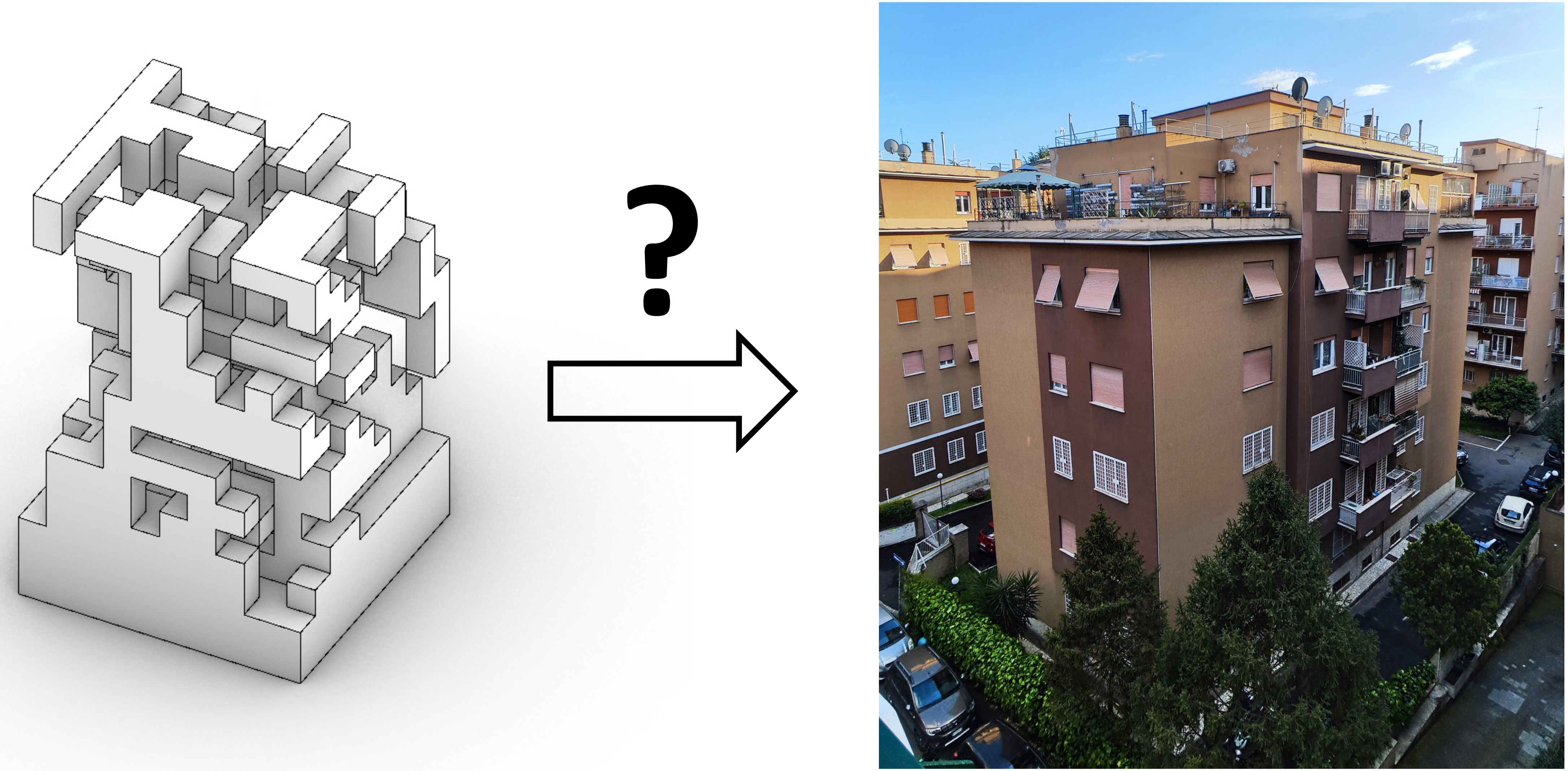

Future work

Improve usability and constructability of the conceptual building mass

- Larger cells
- Trade-offs between existing premises energy use reduction and new building massing uniformity

Performance analysis of the generated building mass

Outdoor environment

Thank you for the attention!

francesco.deluca@taltech.ee

Discussion

Session 3

Climate Change and Modelling Overview

Cooling the City: Mitigation of Heat Extremes through Adaptation Strategies for Cities in a Semi-arid Climate

Giandomenico Vurro – Ph.D. Candidate

Prof. Salvatore Carlucci – **EEWRC**
Assoc. Prof. Panos Hadjinicolaou – **CARE-C**

27 April 2023

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

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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

Generating a temperate microclimate despite climate change implies understanding, modelling and designing through thermodynamic processes.

Linking the mesoscale to envelopes, this seminar is structured in thematic chaired sessions with keynote speakers introducing their research and practice.

Organized by:

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

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

Micro-Climate Change and Envelopes

27 APRIL

Introduction 11:00-11:30

Aránzazu Galán, BUILD UP
Emanuela Giancola, CIEMAT
Emanuele Naboni, UniPR, RDA, UC, UNSW

Modelling Linking Outdoor and Indoor 11:30-12:10

Michael Bruse, UniMainz, ENVI-MET
Victoria López-Cabeza, USE
Naga Manapragada, TECHNION

Microclimate, Form and Surfaces 12:40-13:50

Carmen Galán-Marín, USE
Miguel Núñez Peiró, ETSAM-UPM
Agnese Salvati, UPC
Massimo Palme, USM, Chile
Francesco De Luca, TalTech
Angelos Chronis, INFRARED

Climate Change and Modelling Overview 13:50-14:40

Giandomenico Vurro, Salvatore Carlucci, CYI
Nestoras Antoniou, UCY
Vahid Nik, **Kavan Javanroodi**, Lund Univ.
Alberto Martilli, CIEMAT

28 APRIL

Energy and Climate Change 10:00-10:50

Andras Reith, ABUD
Umberto Berardi, TMU, PoliBa
Gabriele Lobaccaro, Mattia Manni, NTNU
Giovanni Betti, HENN

Envelopes in Light of Climate Change 10:50-11:50

Jesus Lizana, Oxford University
Miren Juaristi, EURAC
Ioannis Kousis, UniPG
Alessandro Cannavale, PoliBa
Fabio Favoino, V. Serra, S. Fantucci, PoliTo

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

Roberta Cocci Grifoni, UniCAM
Katia Perini, UniGE
M. Beatrice Andreucci, La Sapienza

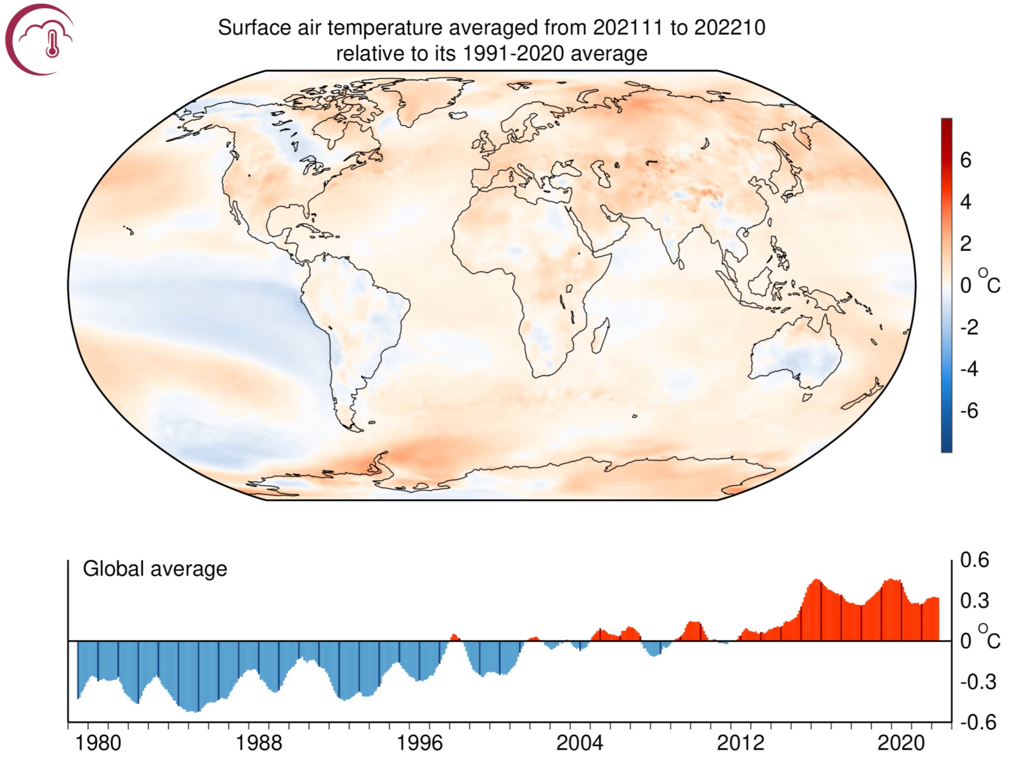
Linking Scales, Tools and Design 13:00-13:20

Emanuele Naboni, UniPR, RDA, UC, UNSW

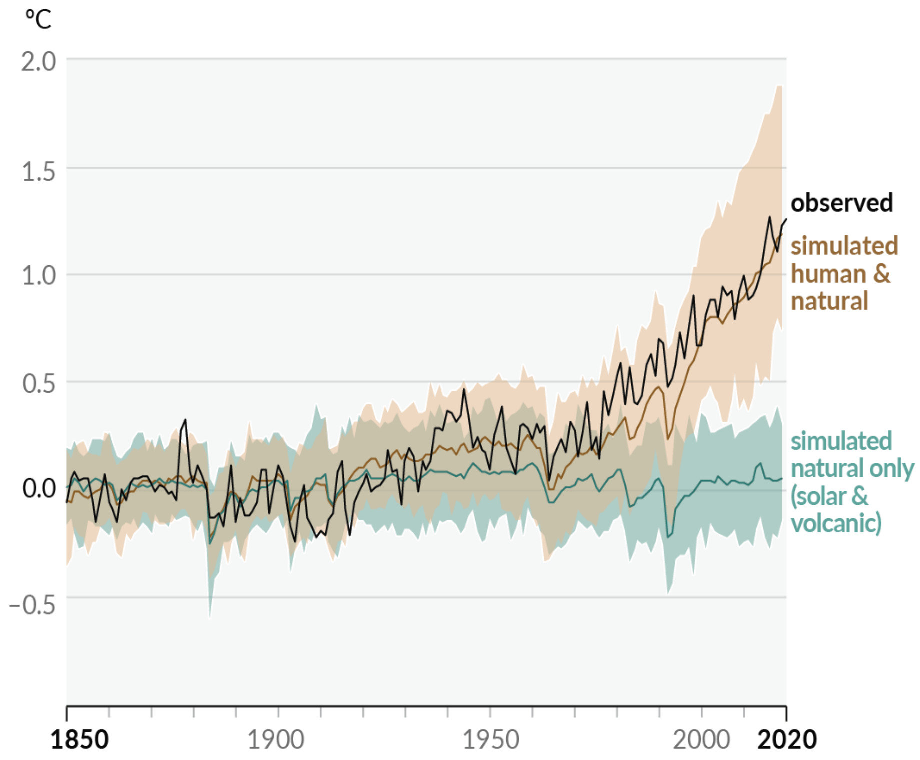
Discussions 13:20-14:00

Moderated by **Emanuele Naboni** & **Emanuela Giancola**

Global warming – Global climate change

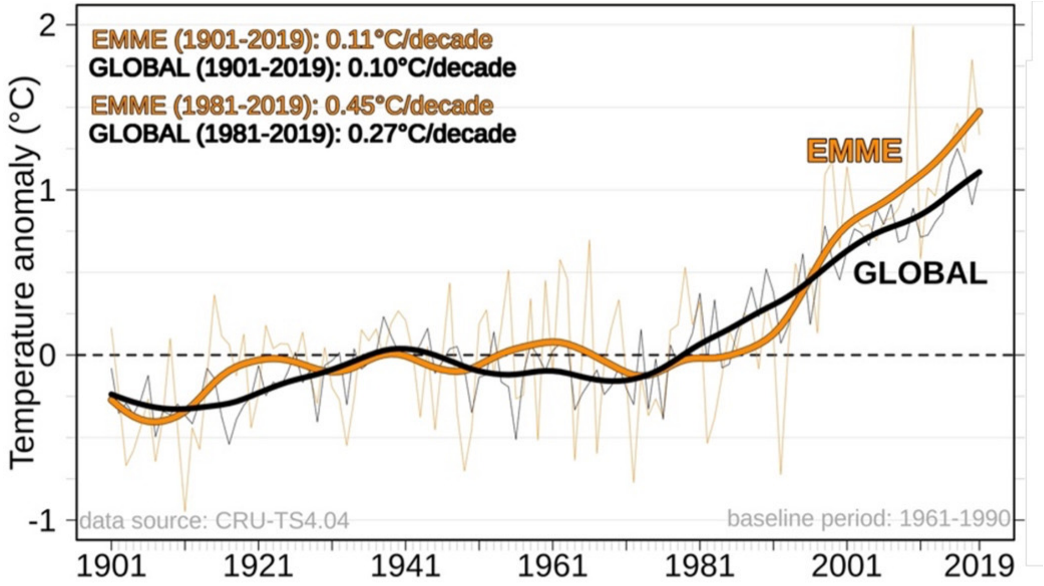


Copernicus Climate Change Service



Adapted from IPPC, (AR6) 2021

Regional climate change – EMME region

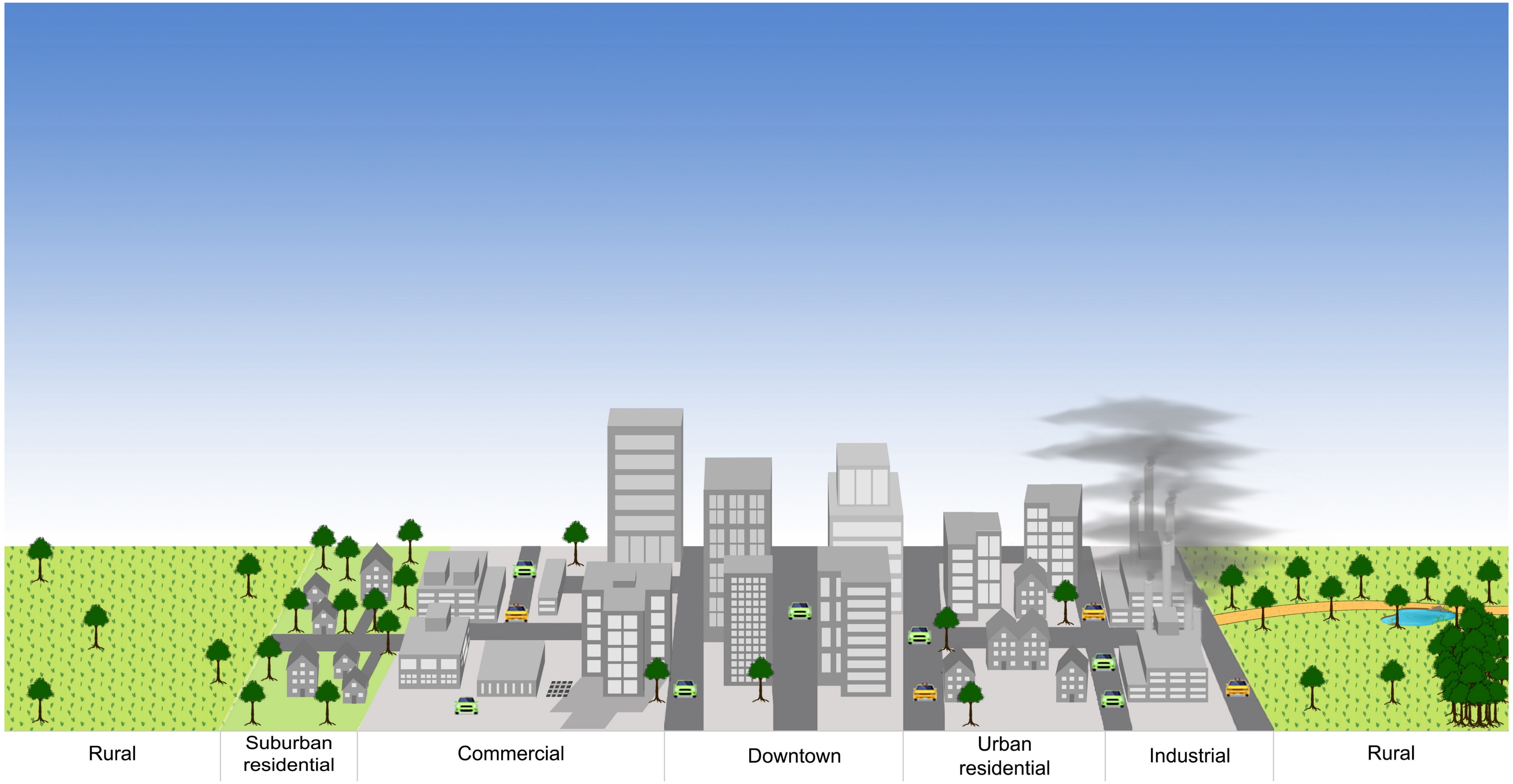


EMME is a **climate change hotspot**

- Particular geographic location at **crossroads** of **different climates**
- Diverse meteorological characteristics
- **Sensitivity** to change in **large-scale climatic dynamics**
- Robust urbanization and population growth

Zittis et al., 2022

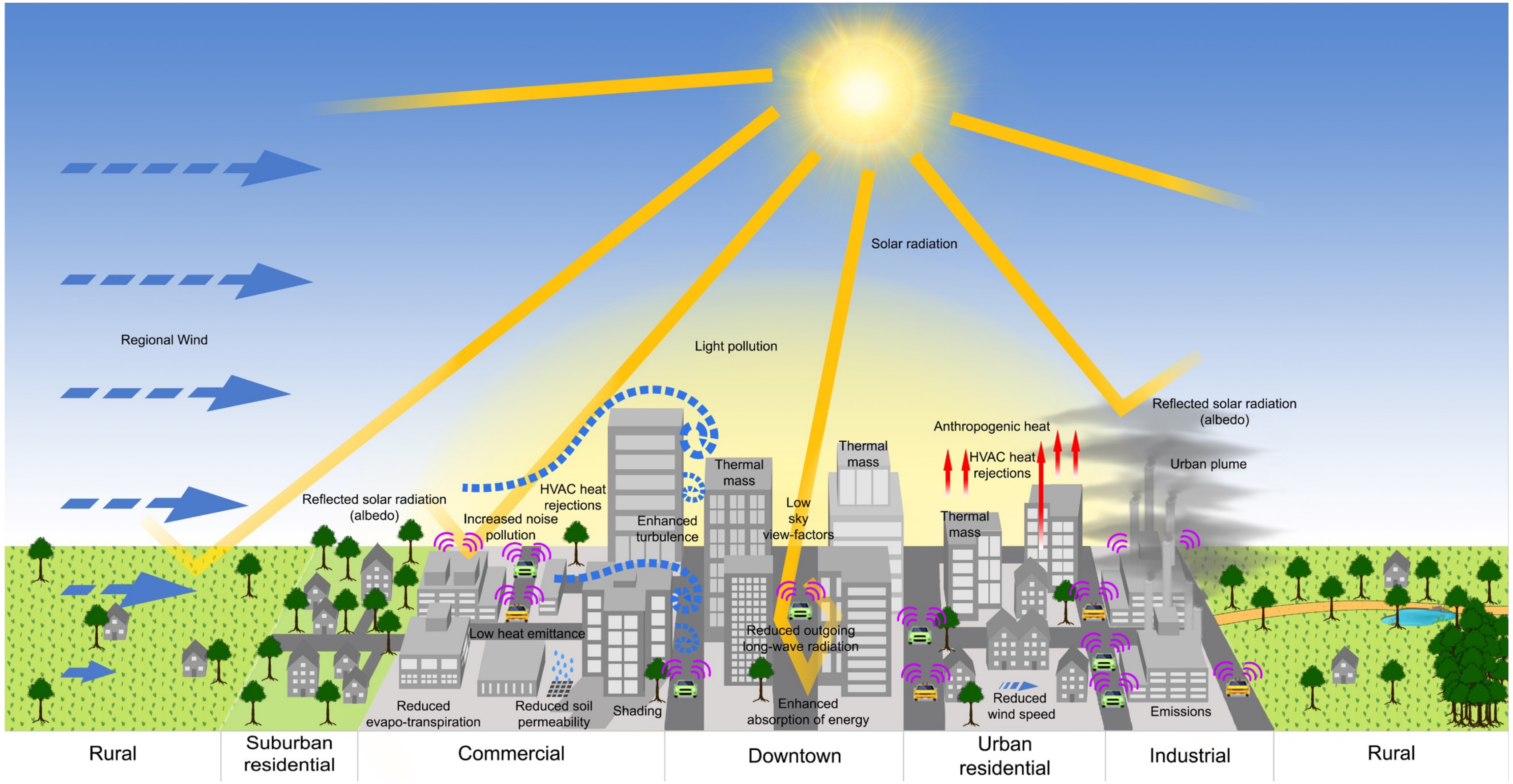
Climate change and Built environment



- Human-made environment for activities
- Includes buildings and infrastructures
- Different scales range from buildings to neighborhoods to cities
- Primary receptors (cities in particular) and drivers of climate change

Adapted from Vurro & Carlucci, 2022

Climate change and Built environment



- Human-made environment for activities
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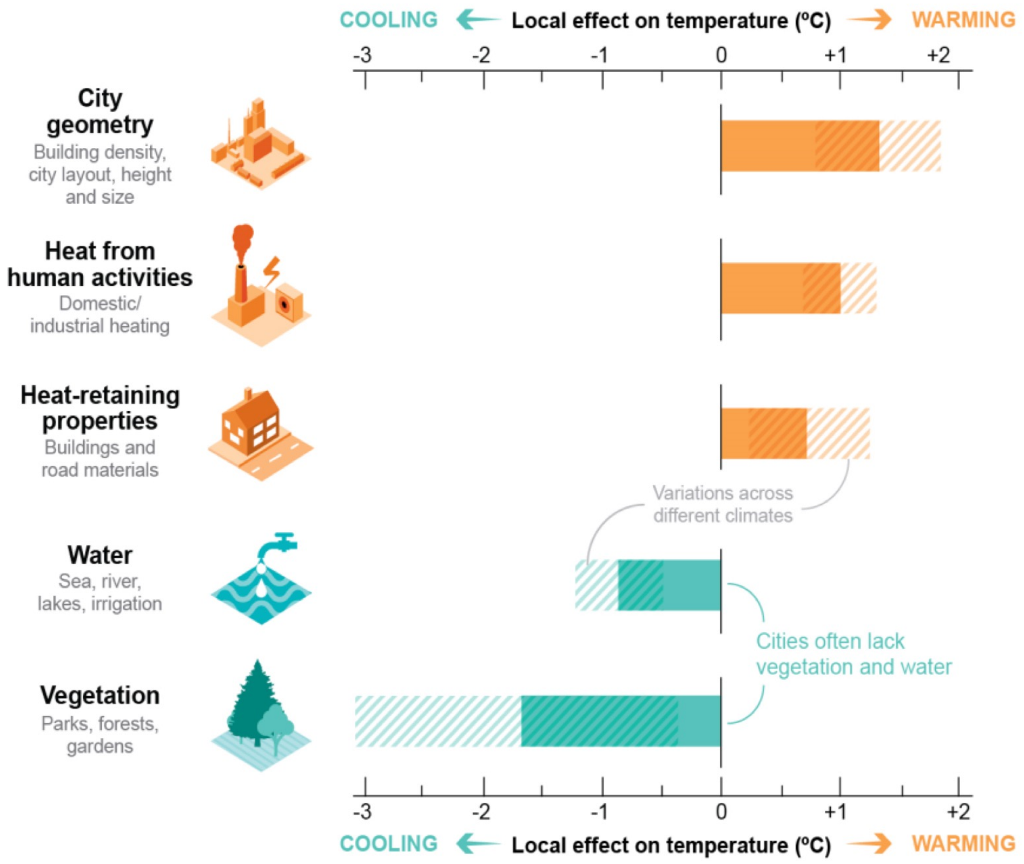
Adapted from Vurro & Carlucci, 2022

Climate change and Built environment



Cities are usually warmer than their surrounding area because of the **presence of factors** that **trap and release heat** and the **lack of natural cooling influences**.

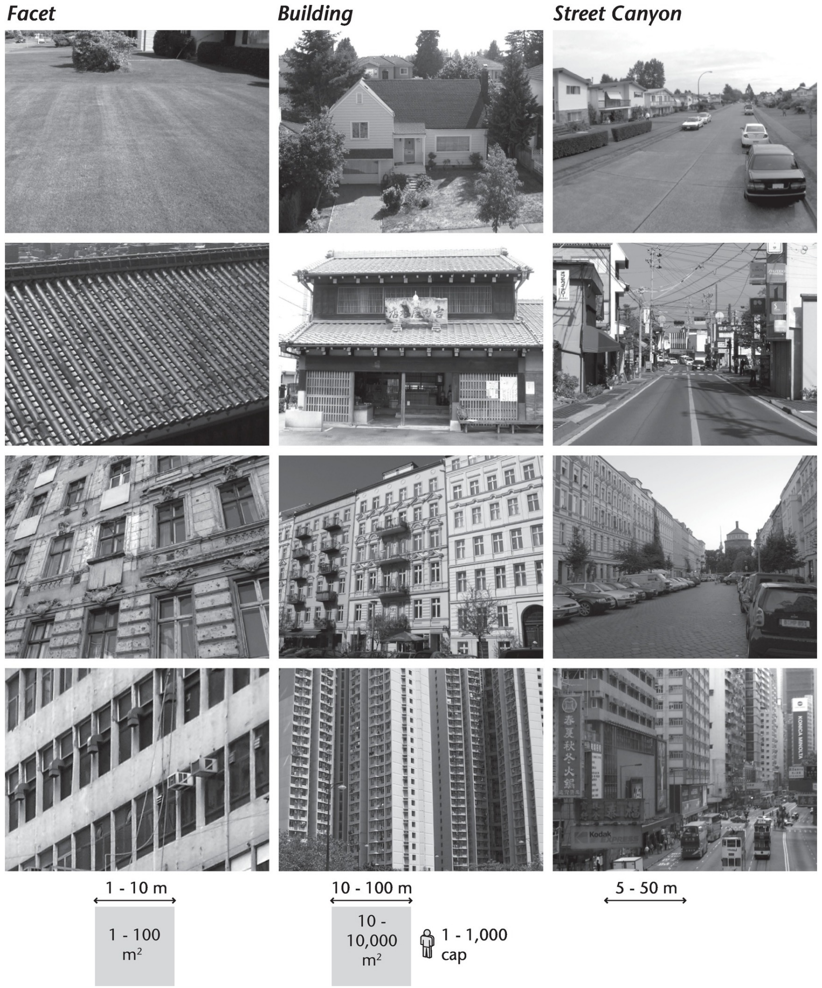
Three factors mainly contribute to the amplified warming of urban areas:

- Urban geometry
- Human activities
- Materials used in the city

The urban heat island effect is further amplified in cities lacking vegetation and water bodies.

Adapted from *IPPC, (AR6) 2021*

Climate change and Built environment

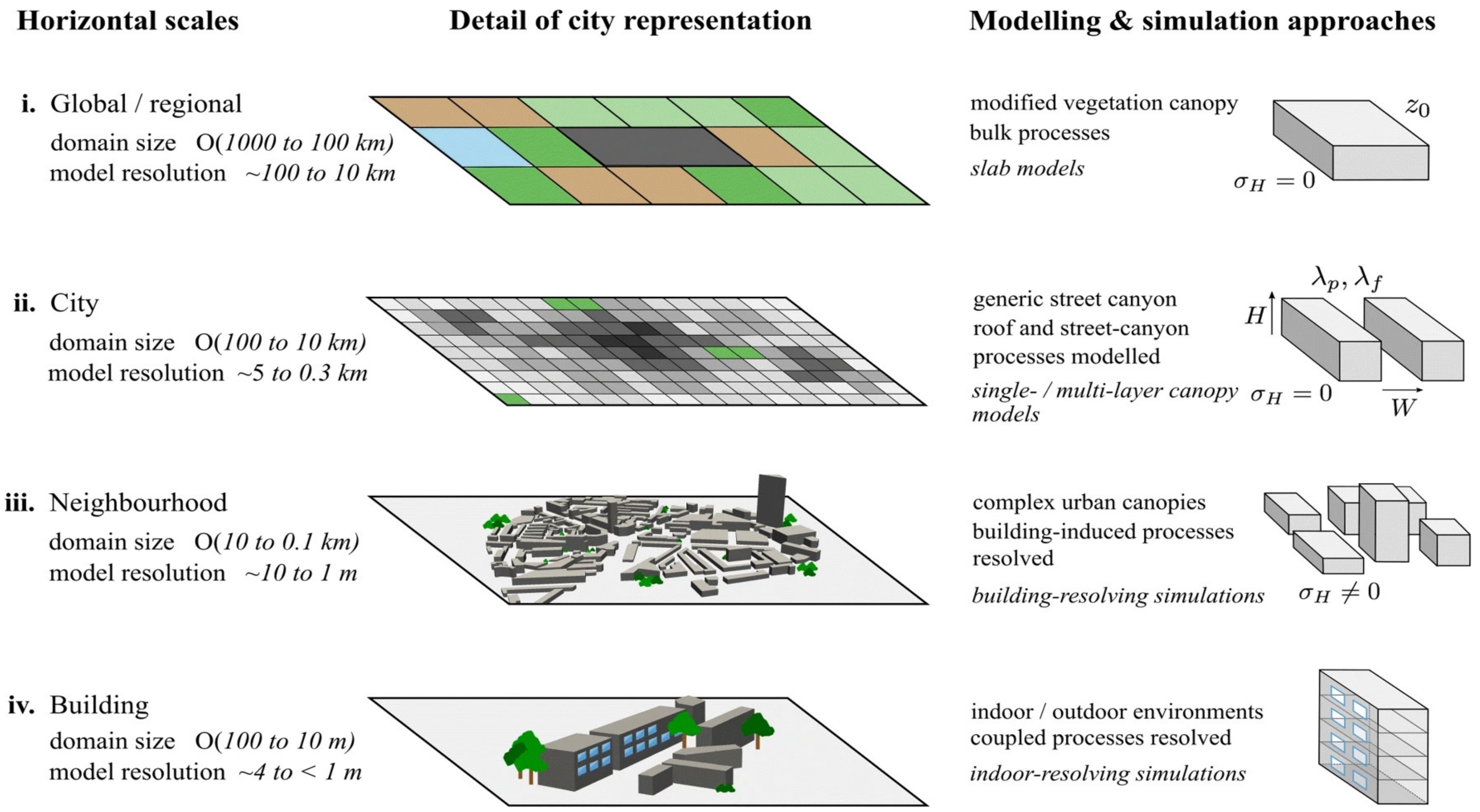


Urban units	Built features	Green and water features	Urban climate phenomena	Typical horizontal length scales	Climate scale[(1)]
Facet	Roof, wall, road	Leaf, lawn, pond	Shadows, storage heat flux, dew and frost patterns	10 × 10 m	Micro
Element	Residential building, high-rise, warehouse	Tree	Wake, stack plume	10 × 10 m	Micro
Canyon	Street, canyon	Line of street trees or gardens, river, canal	Cross-street shading, canyon vortex, pedestrian bioclimate, courtyard climate	30 × 200 m	Micro
Block	City block (bounded by canyons with interior courtyards), factory	Park, wood, storage pond	Climate of park, factory cumulus	0.5 × 0.5 km	Local
Neighbourhood or **Local Climate Zone**	City centre, residential (quarter), industrial zone	Greenbelt, forest, lake, swamp	Local neighbourhood climates, local breezes, air pollution district	2 × 2 km	Local
City	Built-up area	Complete urban forest	Urban heat island, smog dome, patterns of urban effects on humidity, wind	25 × 25 km	Meso
Urban region	City plus surrounding countryside		Urban 'plume', cloud and precipitation anomalies	100 × 100 km	Meso

Adapted from Oke et al., 2017

Modeling scales and approaches

Urban growth affects the **atmospheric processes** developing consequently **distinct urban climates**.
Urban climates **range** over **different time** and **horizontal space scales**.



Hertwig et al., 2020

Knowledge gaps & Research questions

Models at different scales provide a not detailed description of the built environment.

- **Lack of studies that adopt advanced UCMs in the EMME.**
- **Identifying a tool that considers all the city's fluxes is challenging.**
- **Cities parameterization in UCMs considers very generally urban features.**

Knowledge gaps & Research questions

Models at different scales provide a not detailed description of the built environment. → **RQ.1 How can we better model the urban environment considering current and future climates?**

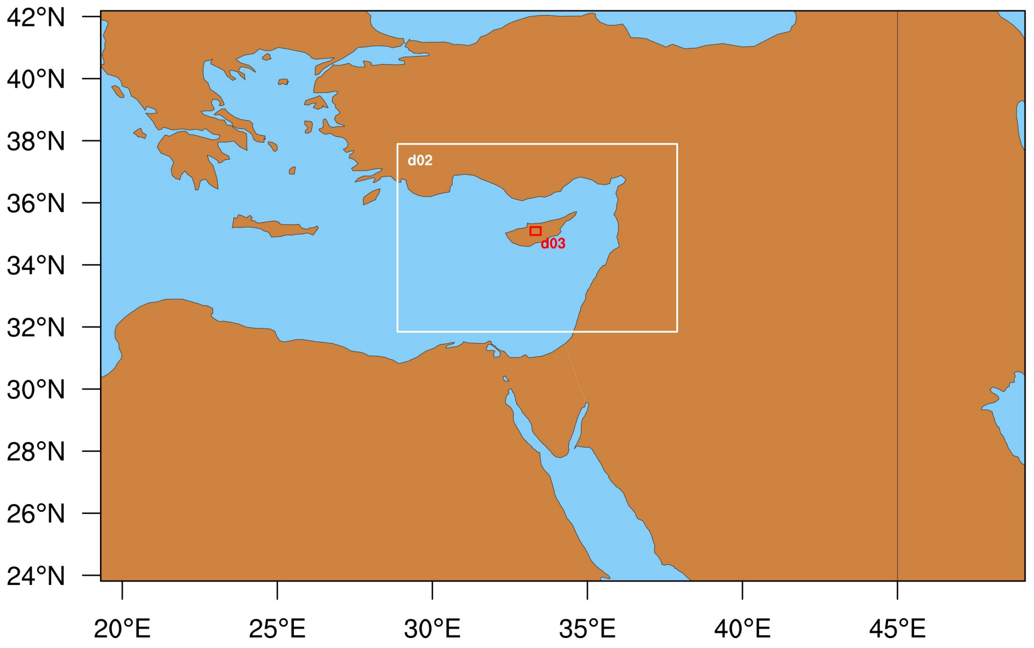
- **Lack of studies that adopt advanced UCMs in the EMME.** → **RQ.1.1 Which are the most reliable modeling schemes for urban mesoscale simulations?**
- **Identifying a tool that considers all the city's fluxes is challenging.** → **RQ.1.2 Which are the most suitable and reliable tools for urban microclimate simulations?**
- **Cities parameterization in UCMs considers very generally urban features.** → **RQ.1.3 Can a detailed description of the built environment be used to tailor urban mesoscale simulations?**

Methodology

Weather Research and Forecasting (WRF) model

Nested simulations:

- **d01**: Eastern Mediterranean and Middle East (EMME) region - 12km horizontal resolution
- **d02**: Levant region - 4km horizontal resolution
- **d03**: Greater Nicosia - 1km horizontal resolution



Simulation period: 27.07.2021 - 05.08.2021

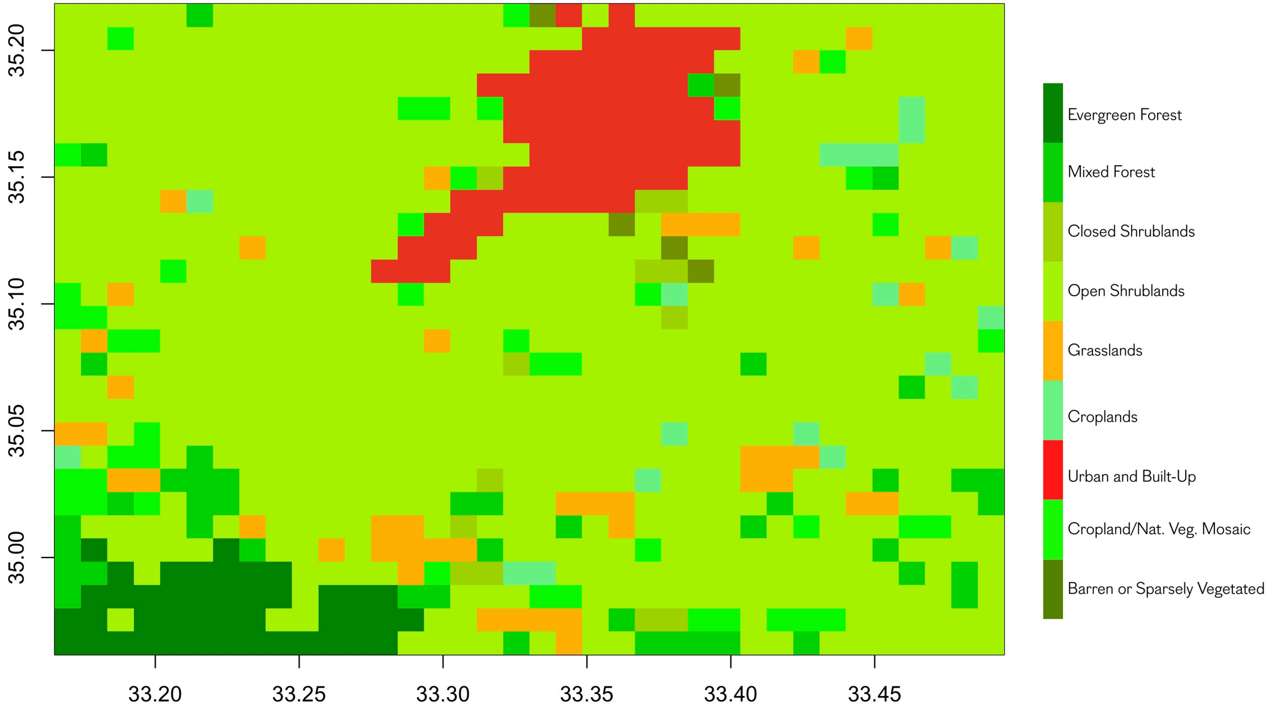
Land surface scheme: NoahMP (dynamical vegetation option = ON)

Urban parameterization schemes:
Bulk - BEP - BEP/BEM

Convection permitting option = ON

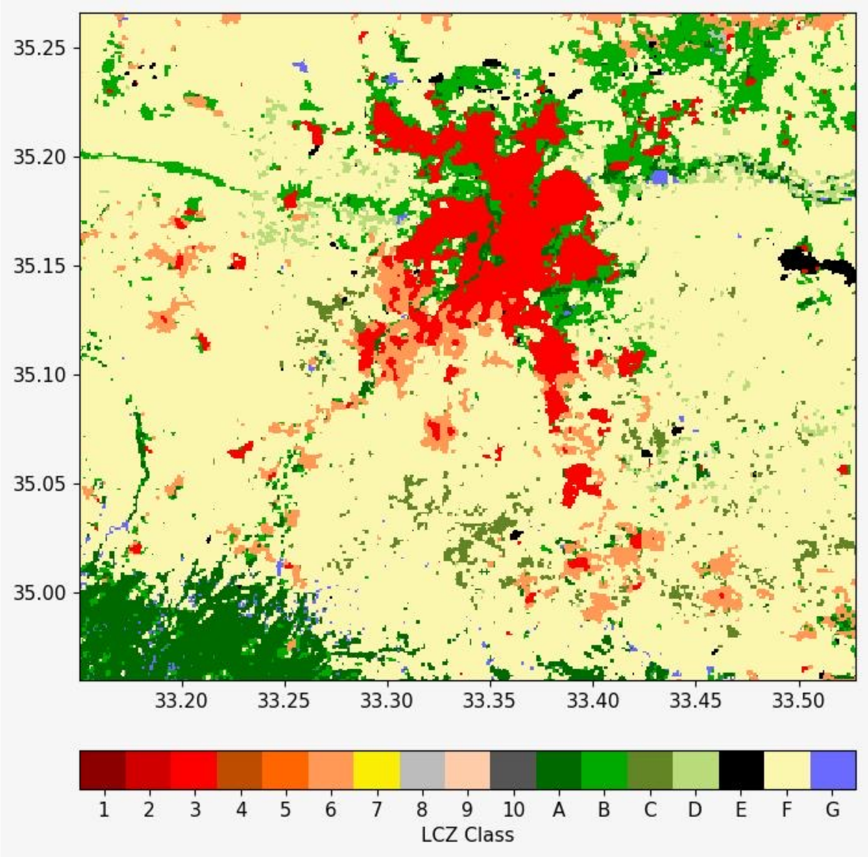
Variables investigated: T2, T2MAX and T2MIN

Preliminary results

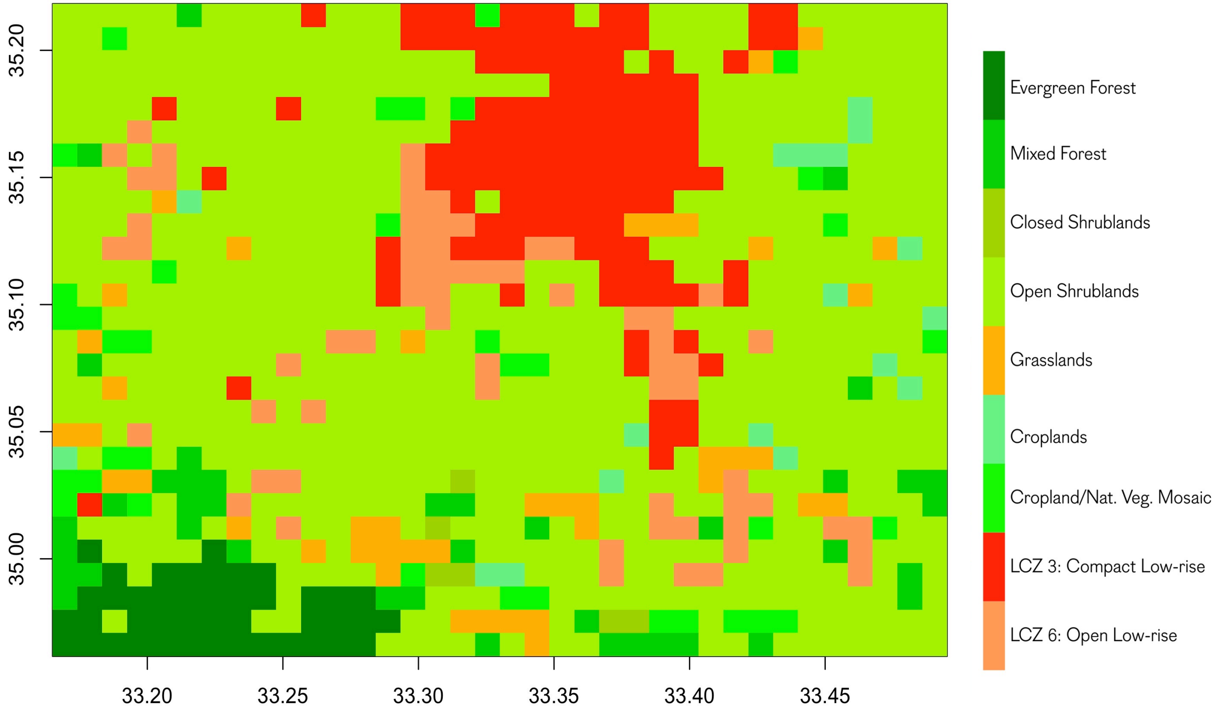


Land use index for MODIS_MODIFIED_IGBP_NOAH

Preliminary results

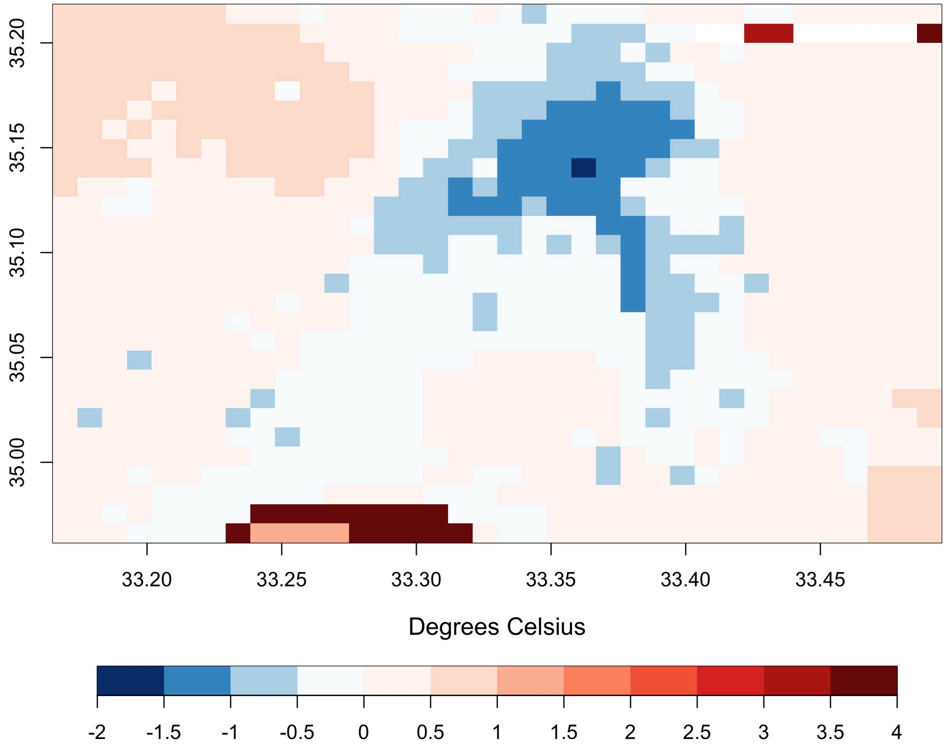


LCZ Classification*([Koutroumanou Kontosi, K. 2022]())*

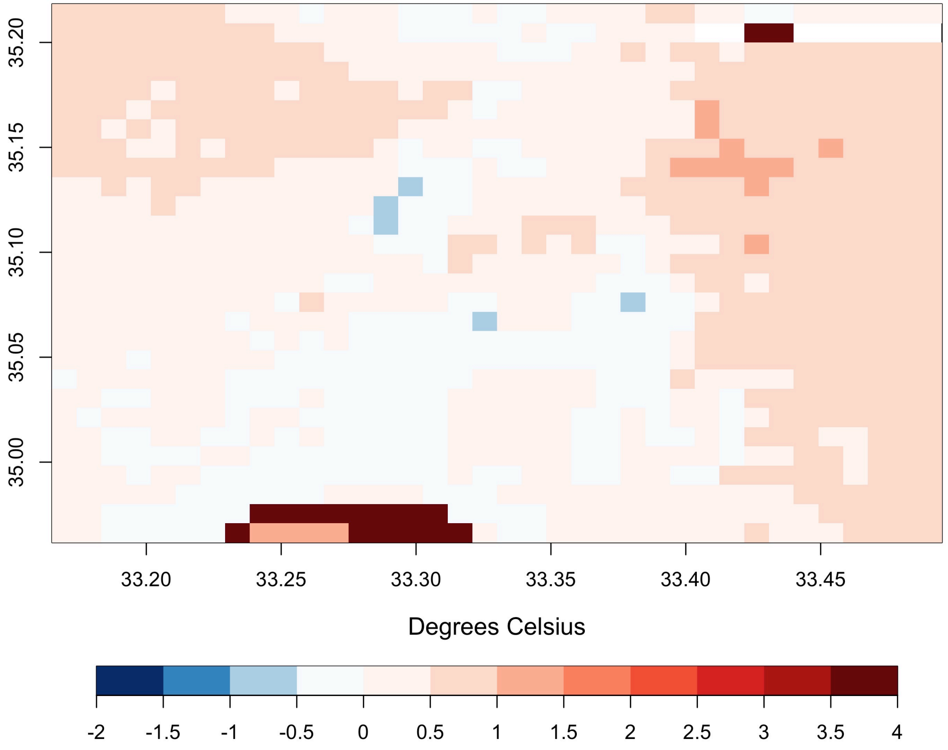


Land use index for MODIS_MODIFIED_IGBP_ NOAH implemented with LCZ classification

Preliminary results



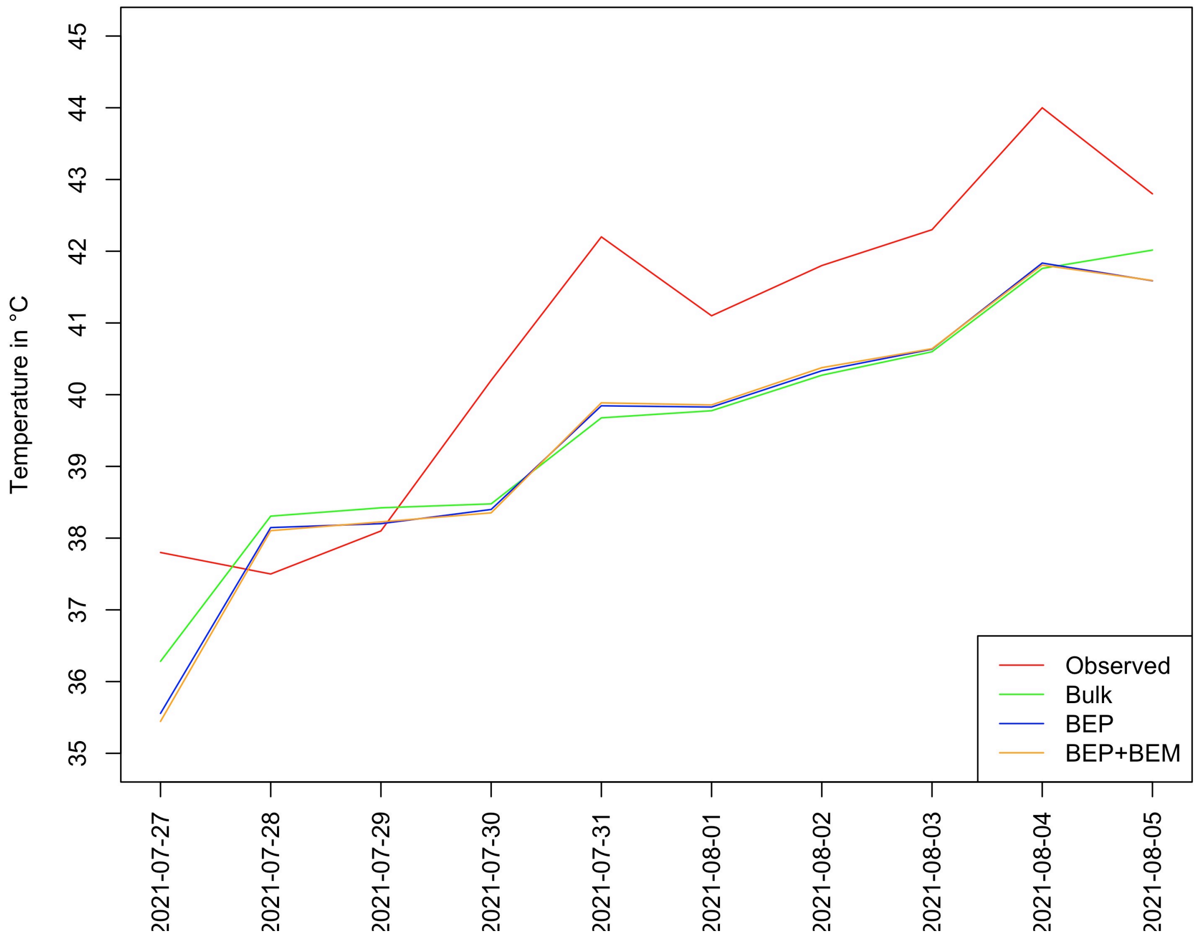
Simulated mean air temperature differences between **BEP** and **Bulk** for simulation period 27.07.2021 – 05.08.2021



Simulated mean air temperature differences between **BEP/BEM** and **Bulk** for simulation period 27.07.2021 – 05.08.2021

Preliminary results

- Comparison of observed and simulated temperature extremes during daytime
- Model output of a grid box nearest observing city center station
- Daily average time series
- All the schemes follow the same variation
- Overall, Bulk, BEP, and BEP/BEM underestimate the temperature



Conclusions

- The **schemes** adopted **follow** the **variation** of the **observed temperatures**.
- **BEP** shows a counter-intuitive behavior with cooler temperatures over the city compared to **Bulk**. Therefore this aspect needs to be investigated in more detail.
- Overall, **BEP/BEM** is slightly hotter than the other models due to the share of heat generated by a/c systems.
- **LCZs** provide too **general built environment features** precisely **to be used** as **widely** as possible. But **real built environment data** are **required to represent specific areas**' **behavior** better.
- Therefore **collaboration** between the community of **atmospheric modelers** and **urban/buildings modelers** can **help overcome** fundamental **gaps** related to the **lack of data** that **affect** a thorough **representation** of the **effect of climate change in the cities**.

Thank you for your attention!

EMME-CARE
EASTERN MEDITERRANEAN MIDDLE EAST – CLIMATE & ATMOSPHERE RESEARCH CENTRE

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Climate and Atmosphere Research Center (CARE-C)

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Tel.:+357 94043952
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Web-site: **www.cyi.ac.cy**

Micro-climate changes and envelopes
27th April 2023

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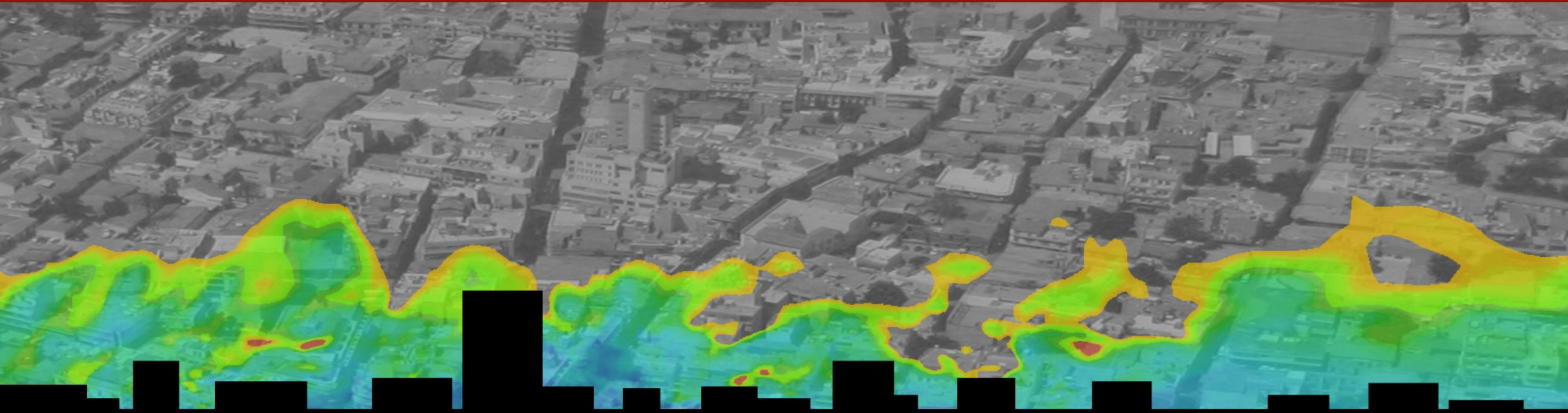
University of Cyprus

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Numerical simulations of climate change impact on urban microclimate, and pedestrian thermal comfort



Nestoras Antoniou

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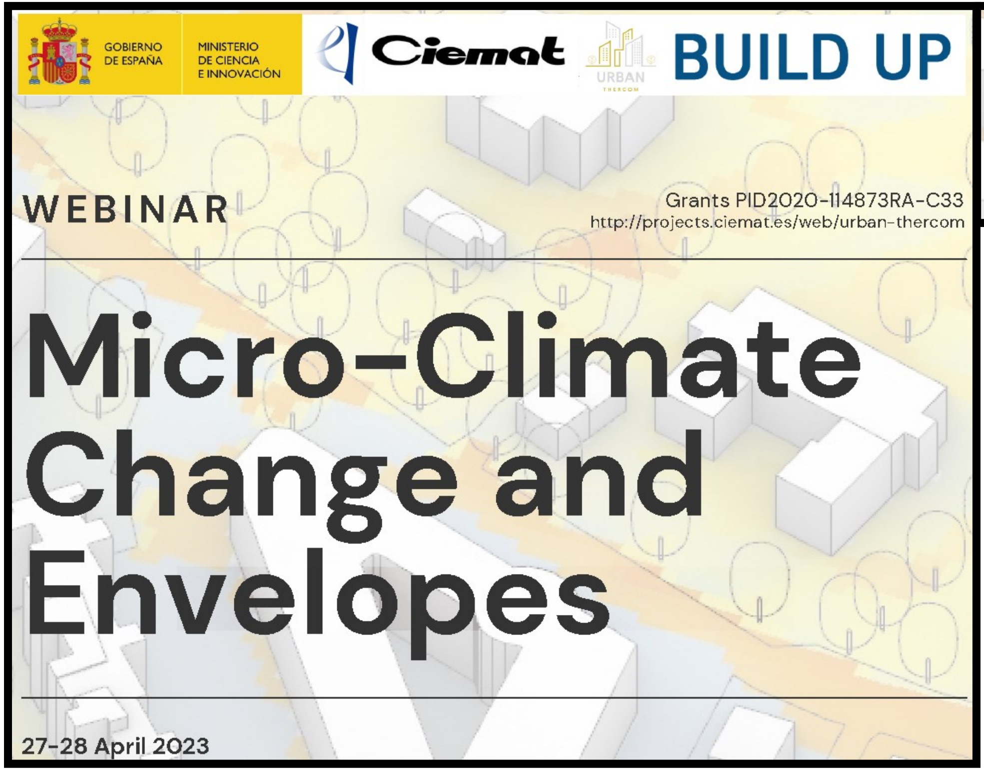

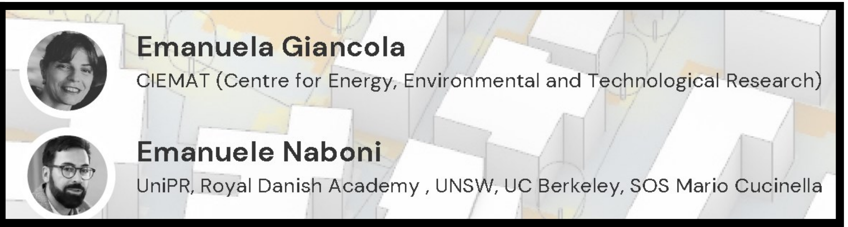

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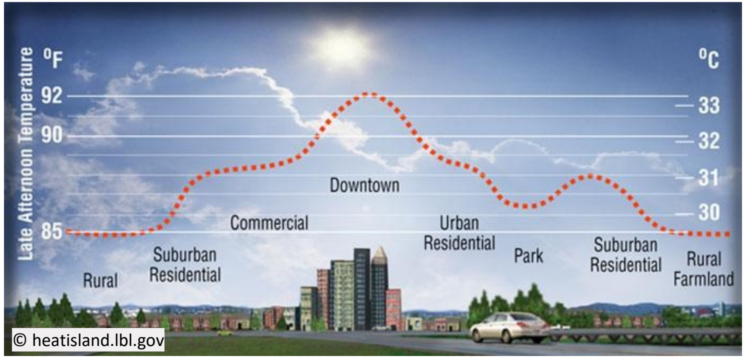
Urban microclimate and climate change



- Urban population is expected to increase
- Higher air temperatures in urban areas compared with surrounding areas
- Increased frequency and intensity of heat waves
- Urban population exposed to poor air quality levels
- Human morbidity and mortality increase due to climatic reasons

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Urban microclimate and climate change


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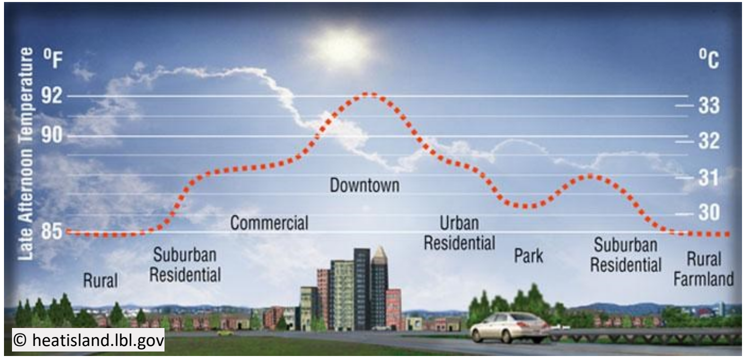

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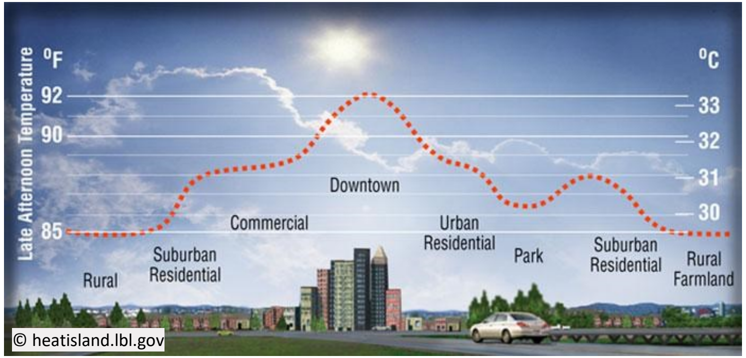
- Adaptation strategies need to be evaluated and implemented to reduce heat stress in the outdoor built environment

Urban microclimate and climate change



- Adaptation strategies need to be evaluated and implemented to reduce heat stress in the outdoor built environment
- It is essential to understand the full complexity of urban microclimate

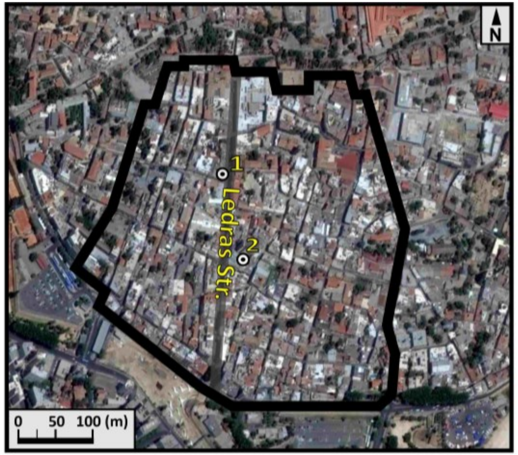
Research objective

- Combine numerical and experimental techniques to investigate the impact of climate change on urban microclimate in a real compact heterogeneous urban area

Research objective

- Combine numerical and experimental techniques to investigate the impact of climate change on urban microclimate in a real compact heterogeneous urban area

Case study area

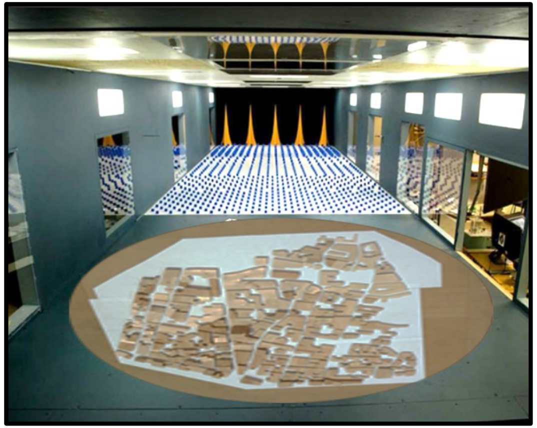


- Cyprus, Nicosia old city center
- Compact heterogeneous area of 0.247 km^2

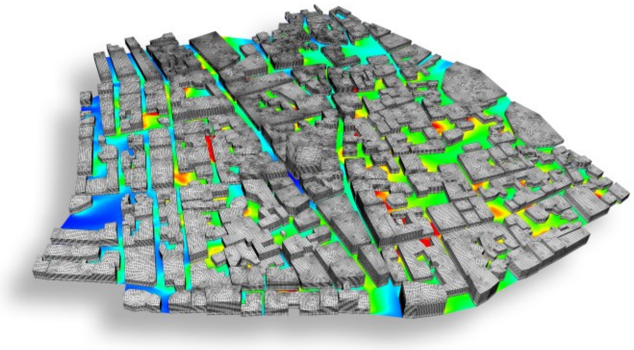
Methodology

- The methodology includes using full-scale field measurements, reduced-scale wind-tunnel measurements, and CFD simulations

Full-scale field measurements



Reduced-scale wind-tunnel experiments



Computational Fluid Dynamics (CFD)

Multi-scale field measurements

Research objective:

- Obtain and analyze multi-scale field measurements

Novelty:

- High resolution dataset for validation of CFD simulations

1. Multi-scale field measurements

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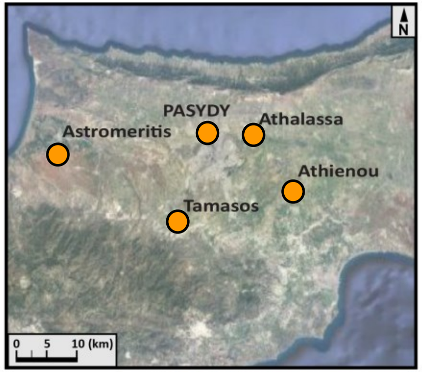
regional-scale
(>100 or 200 km)

Radiosoundings



city-scale
(> 10 or 20 km)

Meteorological stations

neighb.-scale
(> 1 or 2 km)

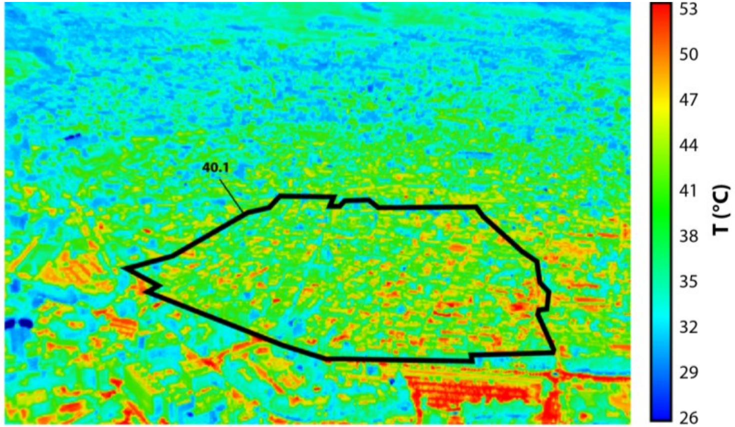
Aerial thermography
Mobile met. stations

street-scale
(> 100 or 200 m)

Ground based thermography
Thermocouples

Main findings:

- Multi-scale field measurements given insights into the complex urban microclimate



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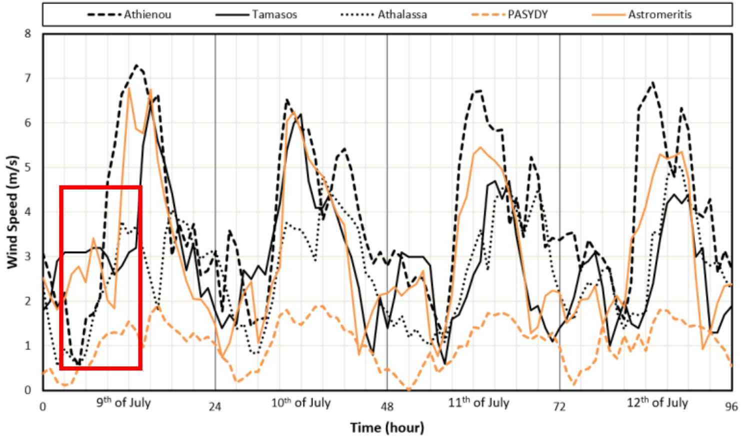
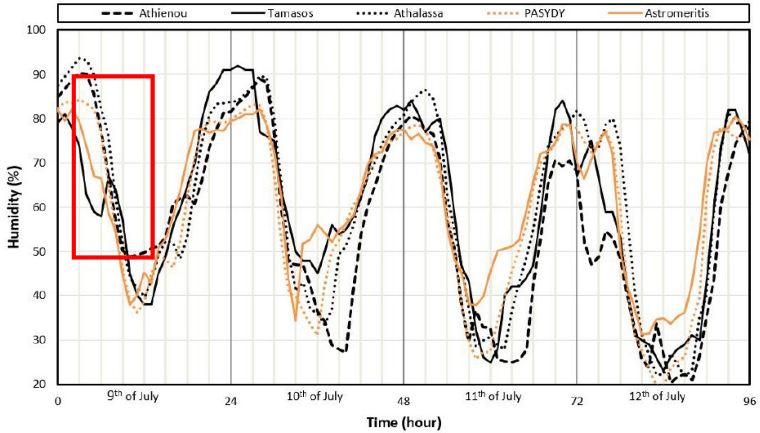
Main findings:

- Multi-scale field measurements given insights into the complex urban microclimate
- Microclimatic phenomena like katabatic winds and sea breeze strongly affect the intensity of the UHI





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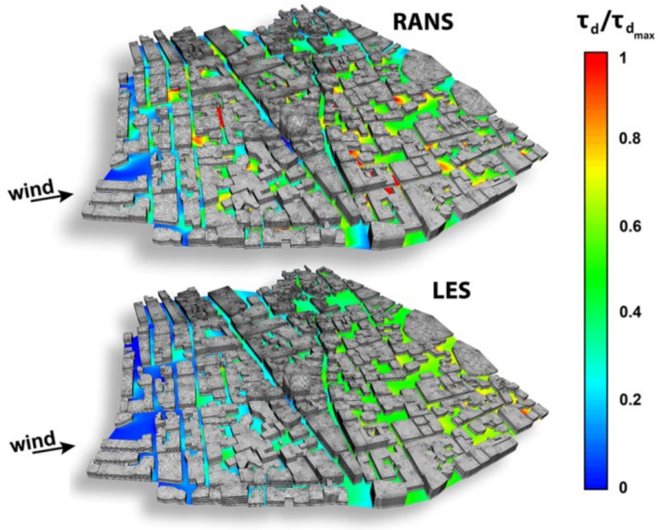
CFD and wind-tunnel analysis for outdoor urban ventilation

2



Research objective:

- Develop and validate a CFD model for predicting outdoor ventilation

Novelty:

- Detailed evaluation of RANS and LES for predicting outdoor ventilation in real urban area
- Introducing a new ventilation indicator for outdoor ventilation (air delay)

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Building and Environment 126 (2017) 355–372

Contents lists available at ScienceDirect

Building and Environment

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

CFD and wind-tunnel analysis of outdoor ventilation in a real compact heterogeneous urban area: Evaluation using "air delay"

Nestoras Antoniou[a,b,*], Hamid Montazeri[b,c], Hans Wigo[d], Marina K.-A. Neophytou[a], Bert Blocken[b,c], Mats Sandberg[d]

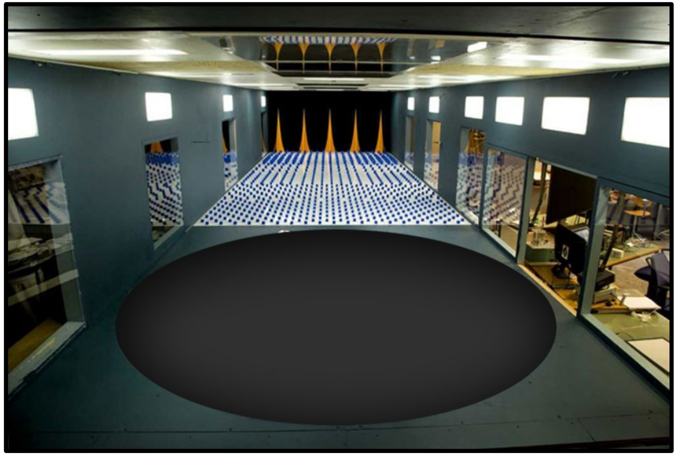
Research objective:

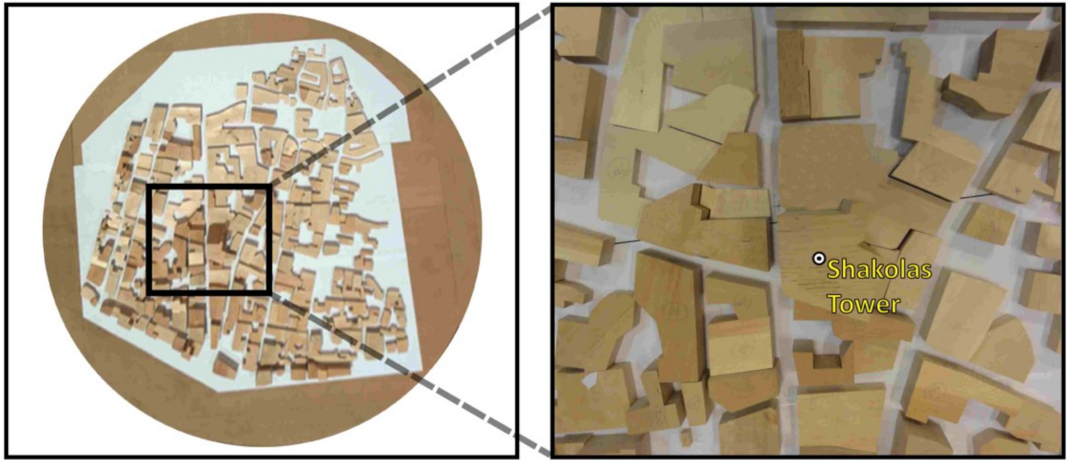
- Develop and validate a CFD model for predicting outdoor ventilation

Novelty:

- Detailed evaluation of RANS and LES for predicting outdoor ventilation in real urban area
- Introducing a new ventilation indicator for outdoor ventilation (air delay)

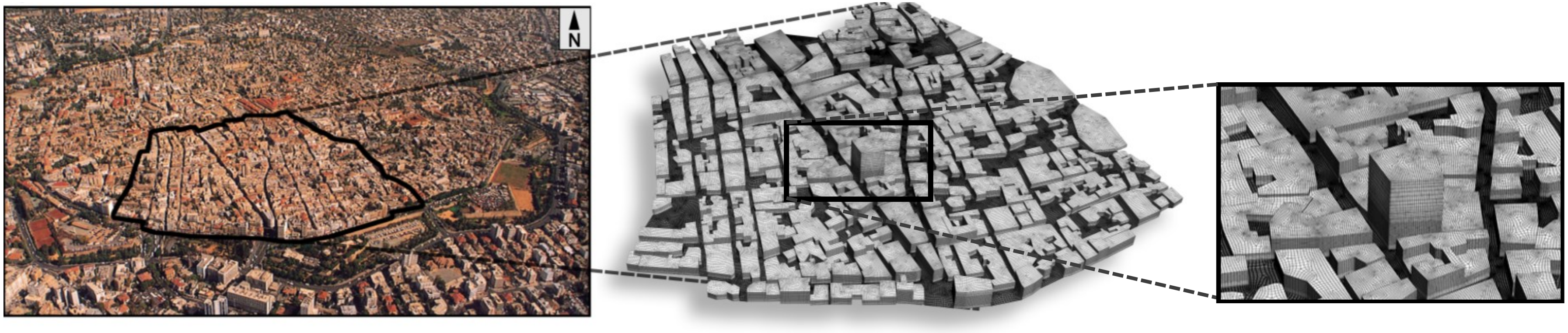
Wind-tunnel measurements





- Atmospheric boundary layer wind tunnel
- Test section: 3 m x 1.5 m
- Measurements at 1261 points along 38 vertical lines
- Wind velocity and turbulence intensity

CFD simulations

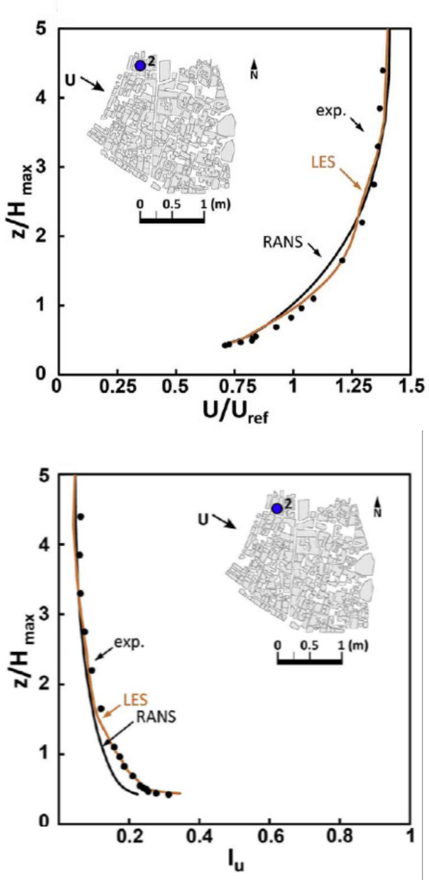


- Dimensions based on best practice guidelines[1,2]
- Geometry based on the reduced-scale model
- 13.4 million hexahedral cells

[1] Franke et al. (2007) [2] Tominaga et al. (2008)

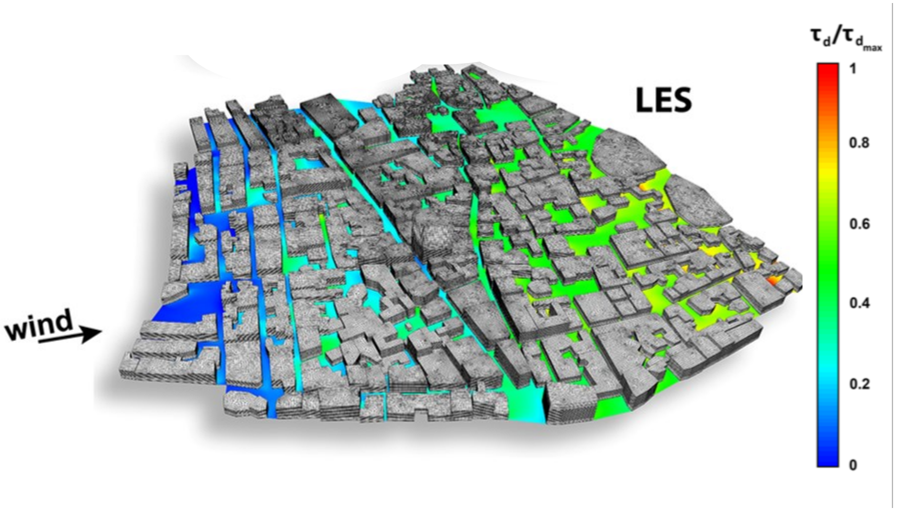
Main findings:

- RANS is less accurate than LES in predicting urban ventilation



Main findings:

- RANS is less accurate than LES in predicting urban ventilation
- Areas with higher building height variability are better ventilated



CFD simulation of urban microclimate

3

Research objective:

- Develop and validate a CFD model for predicting urban microclimate

Novelty:

- Detailed evaluation of URANS for predicting urban microclimate in real urban area
- Validation with high-resolution field measurements

Science of the Total Environment 695 (2019) 133743

Contents lists available at ScienceDirect

Science of the Total Environment

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

CFD simulation of urban microclimate: Validation using high-resolution field measurements

Nestoras Antoniou [a,b,*], Hamid Montazeri [b,c], Marina Neophytou [a], Bert Blocken [b,c]

Research objective:

- Develop and validate a CFD model for predicting urban microclimate

Novelty:

- Detailed evaluation of URANS for predicting urban microclimate in real urban area
- Validation with high-resolution field measurements

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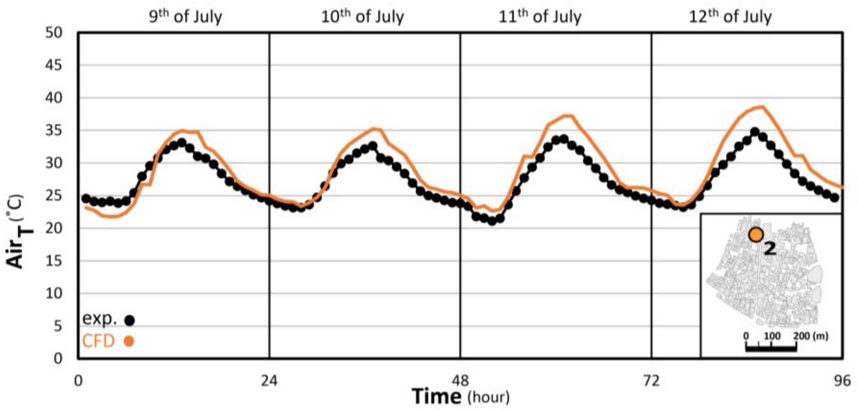
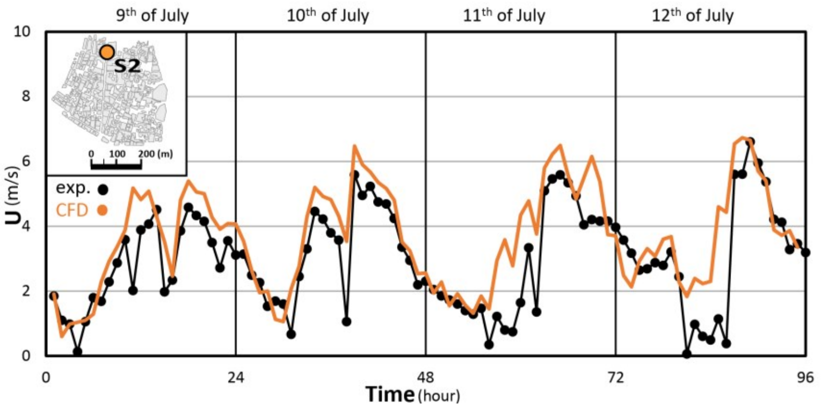
University of Cyprus
TU/e

Main findings:

- URANS can accurately predict air and surface temperatures in real complex urban environments





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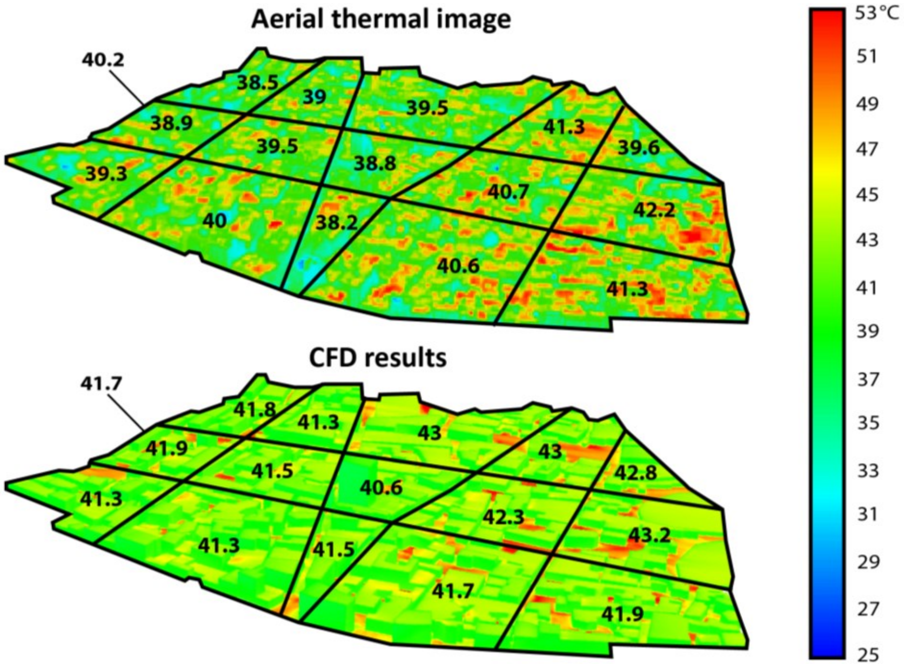
Main findings:

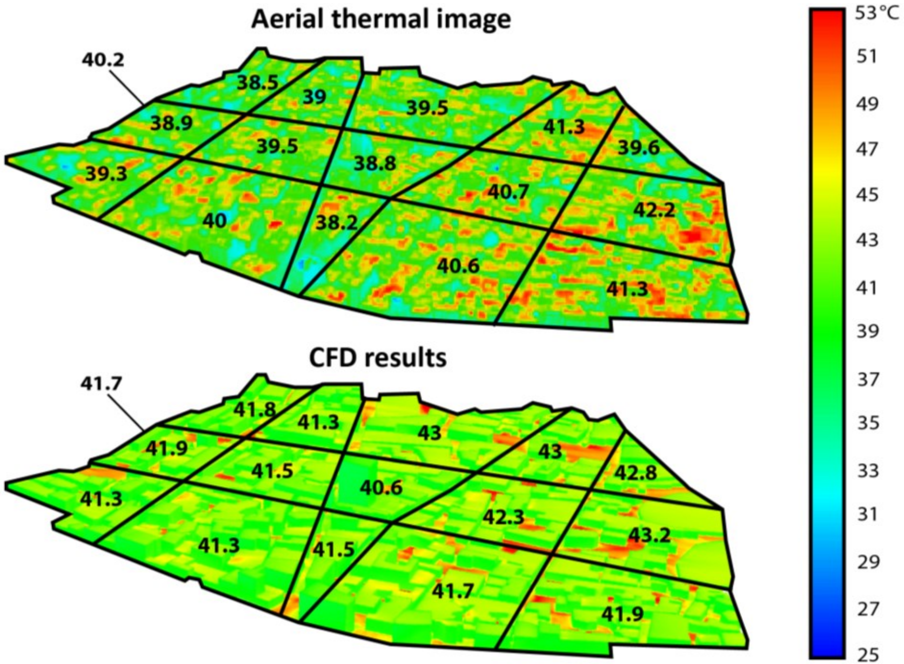
- URANS can accurately predict air and surface temperatures in real complex urban environments



Πανεπιστήμιο Κύπρου University of Cyprus TU/e

Main findings:

- URANS can accurately predict air and surface temperatures in real complex urban environments
- Possible reasons for deviations between CFD and measurements: Geometrical and materials simplifications on CFD model



Climate change impact on urban microclimate

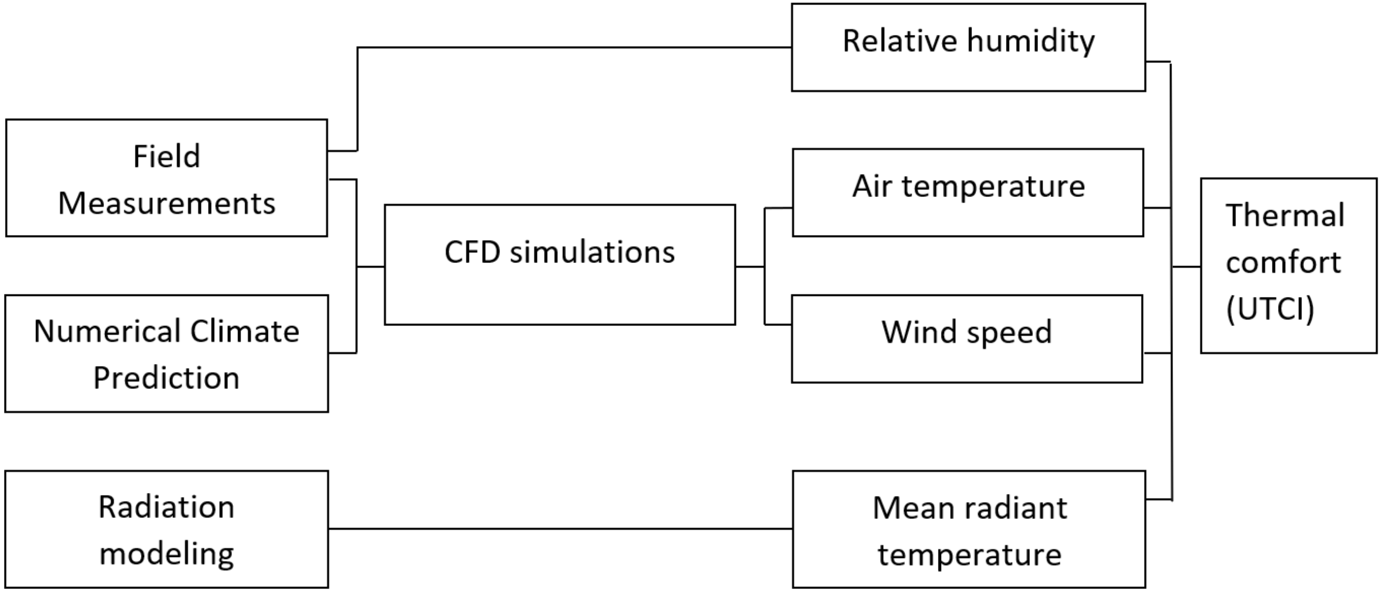
Research objective:

- Investigate the impact of climate change on urban microclimate

Novelty:

- Coupling of CFD simulations and numerical climate prediction models

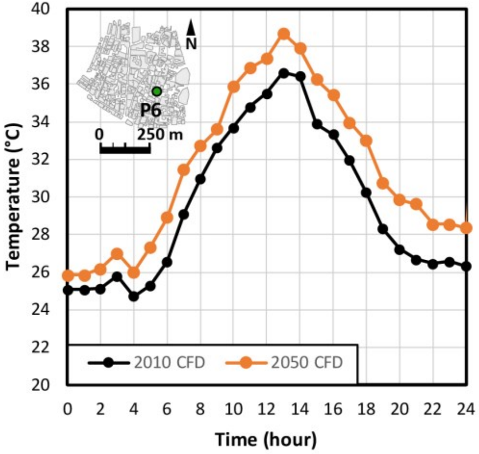
Methodology:

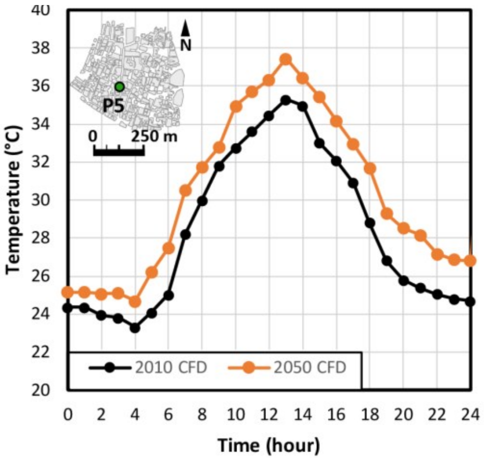


Παvεπιστήμιο Κύπρου University of Cyprus TU/e

Main findings:

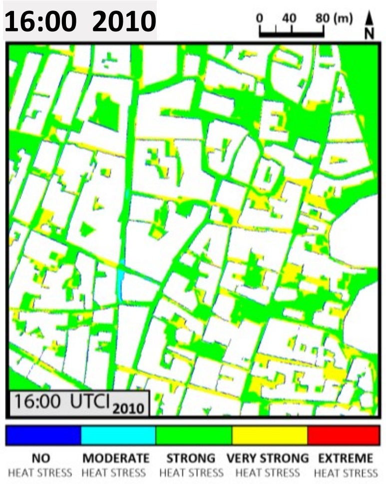
- Temperature increase could lead to more than 3 times higher heat-related mortality

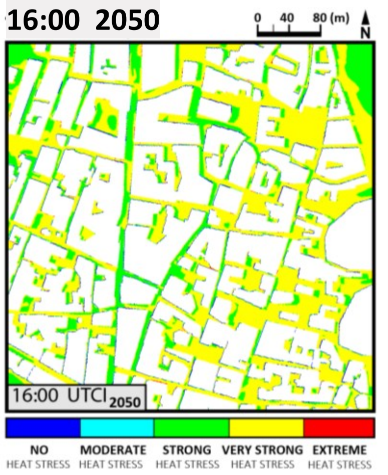




Main findings:

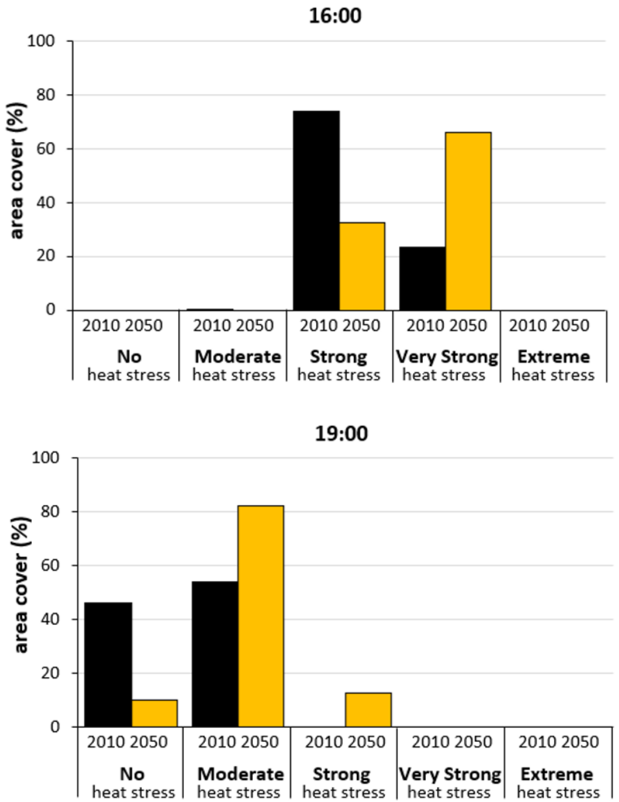
- Temperature increase could lead to more than 3 times higher heat-related mortality
- UTCI is expected to increase especially in the afternoon hours





Main findings:

- Temperature increase could lead to more than 3 times higher heat-related mortality
- UTCI is expected to increase especially in the afternoon hours
- The time period that "very strong heat stress" conditions will prevail is expected to double, leading to higher health risks



Micro-climate changes and envelopes
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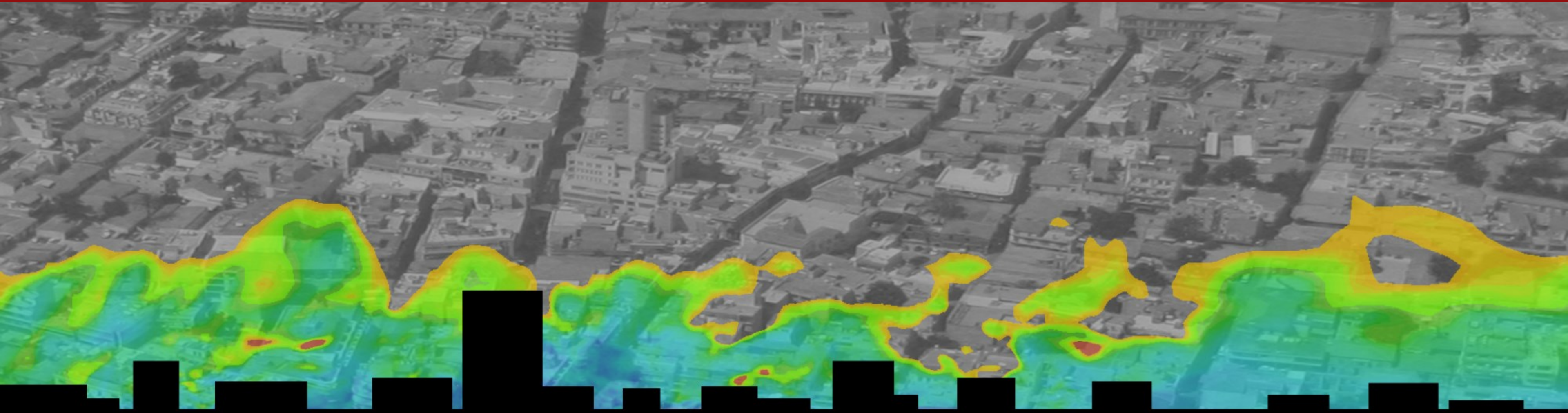
Numerical simulations of climate change impact on urban microclimate, and pedestrian thermal comfort



Nestoras Antoniou

Bridging Climate Change Modelling and Engineering Design for Sustainable and Resilient Adaptation Solutions

Vahid M. Nik

Kavan Javanroodi

Lund University

Climate Resilience

Climate extremes and shocks

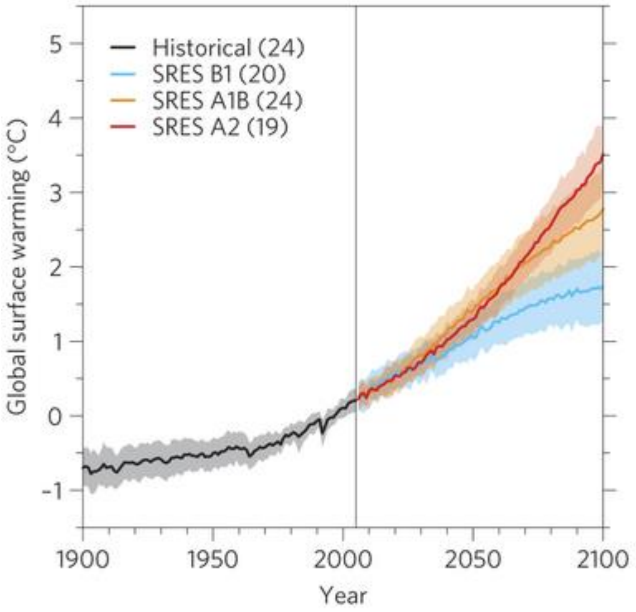
How to prevent or slow down climate change?

How to face climate change?
How to decrease future risks?

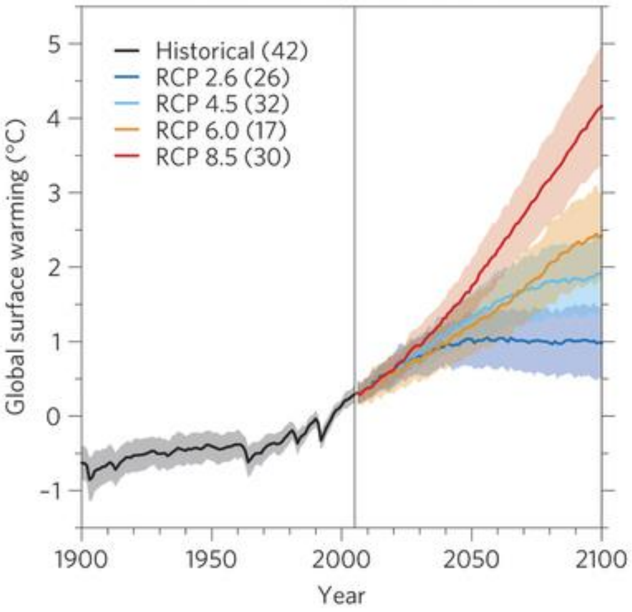
Climate Change Mitigation

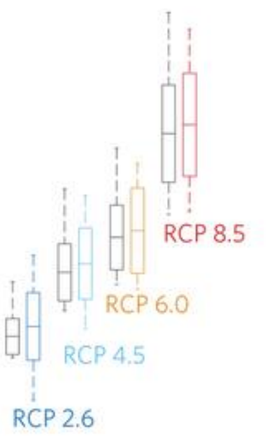
Climate Change Adaptation

Impact Assessment of Climate Change



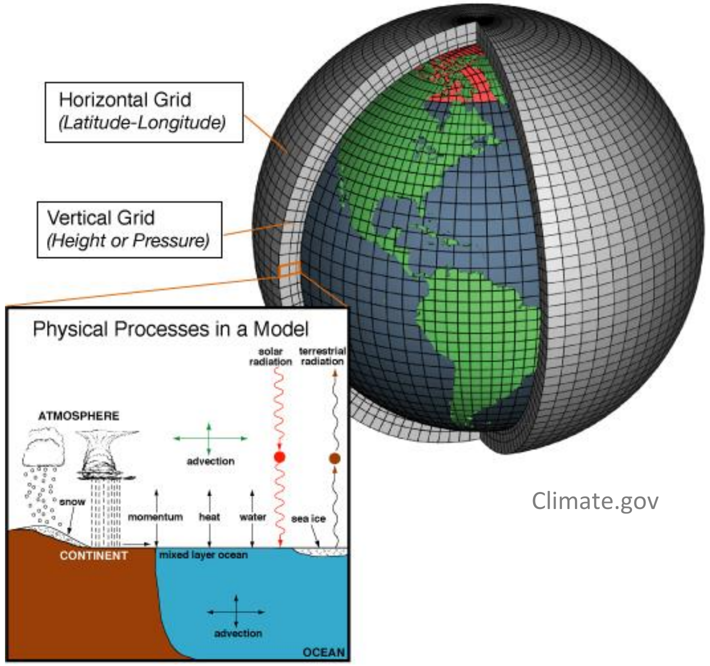
Emissions Scenarios





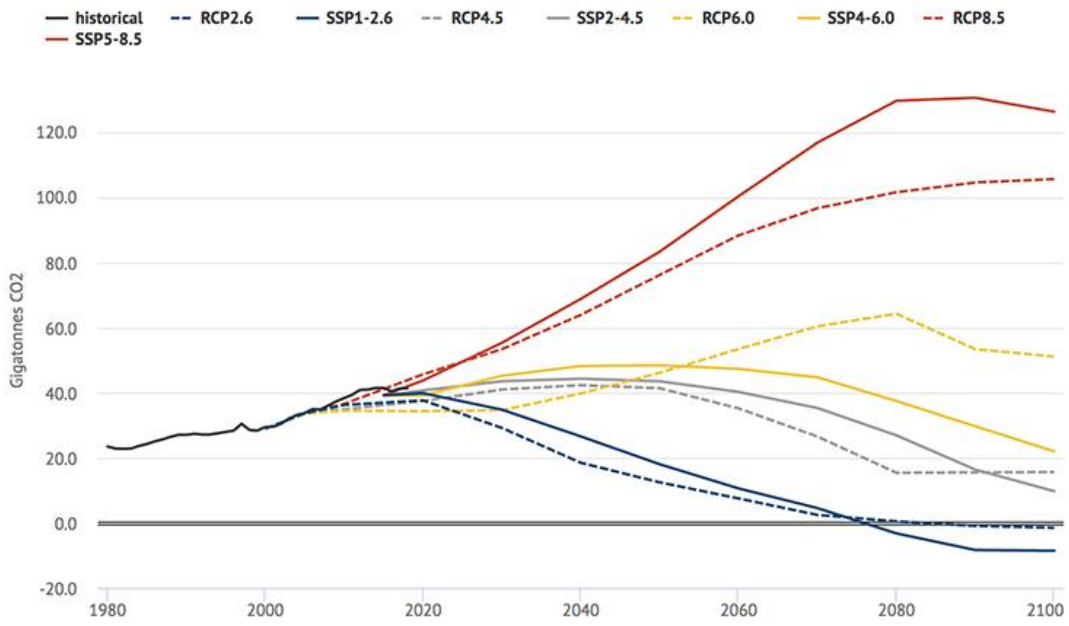
Representative Concentration Pathways (RCPs)

R. Knutti and J. Sedláček, 'Robustness and uncertainties in the new CMIP5 climate model projections', Nat. Clim. Change, vol. 3, no. 4, pp. 369–373, 2013.



Climate.gov

CO2 emissions in comparable CMIP5 and CMIP6 scenarios



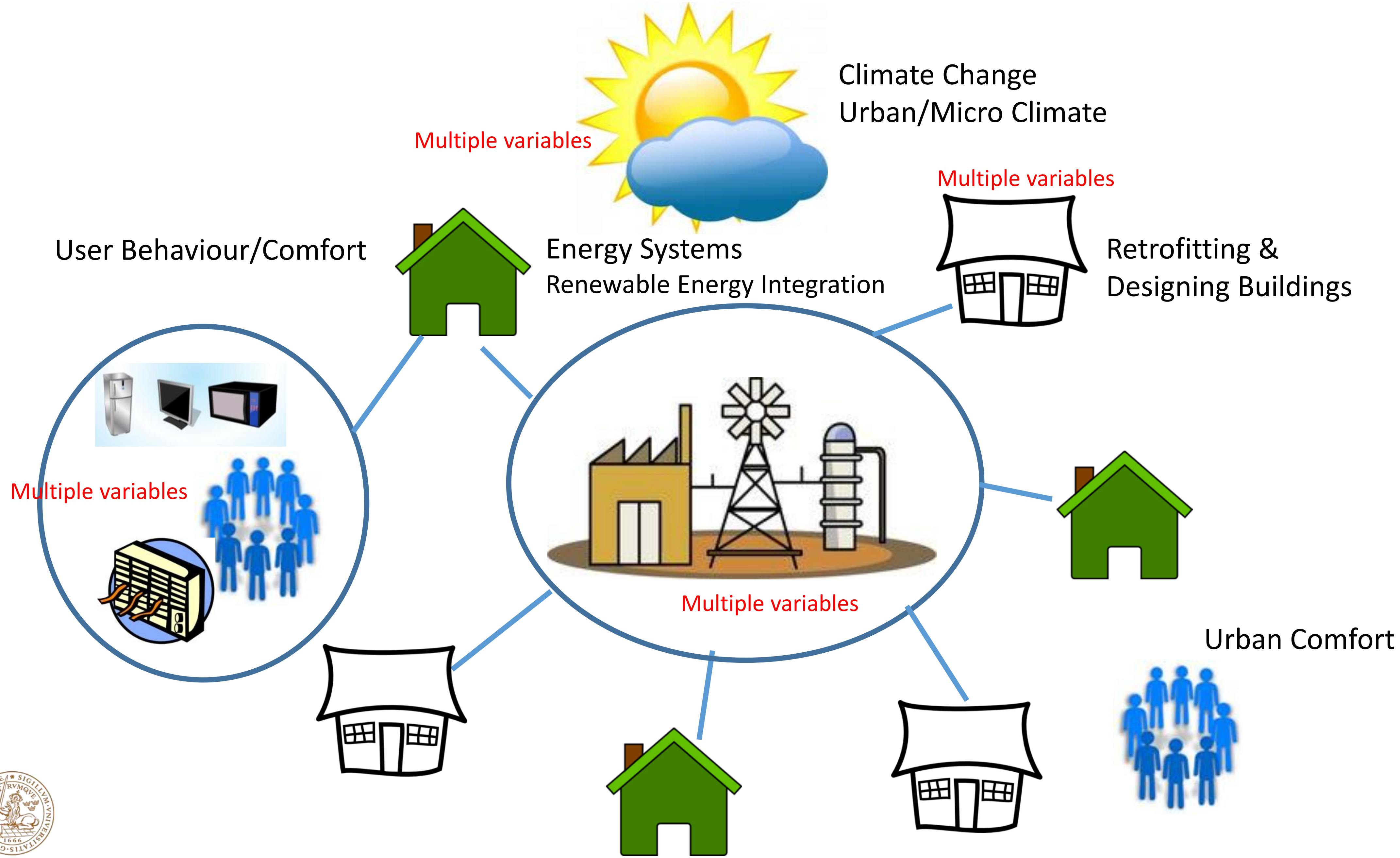
www.carbonbrief.org

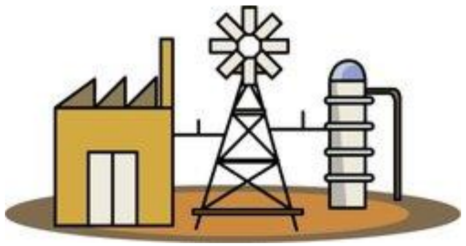
LUND UNIVERSITY

There exist several models and plausible scenarios for future climate and none of them is more valid than the other.

www.ethlife.ethz.ch

Nik, V.M., Perera, A.T.D., Chen, D., "Towards climate resilient urban energy systems: A review", National Science Review. doi.org/10.1093/nsr/nwaa134.


Climate Change
Urban/Micro Climate
Multiple variables
Multiple variables
User Behaviour/Comfort
Energy Systems
Renewable Energy Integration
Retrofitting &
Designing Buildings
Multiple variables
Multiple variables
Urban Comfort



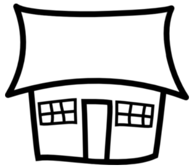
Climate Modelling

Engineering Design/Assessment

Climate Change Mitigation

Climate Change Adaptation

Challenges



Climate uncertainties
Large data sets
Spatial and temporal resolutions
…

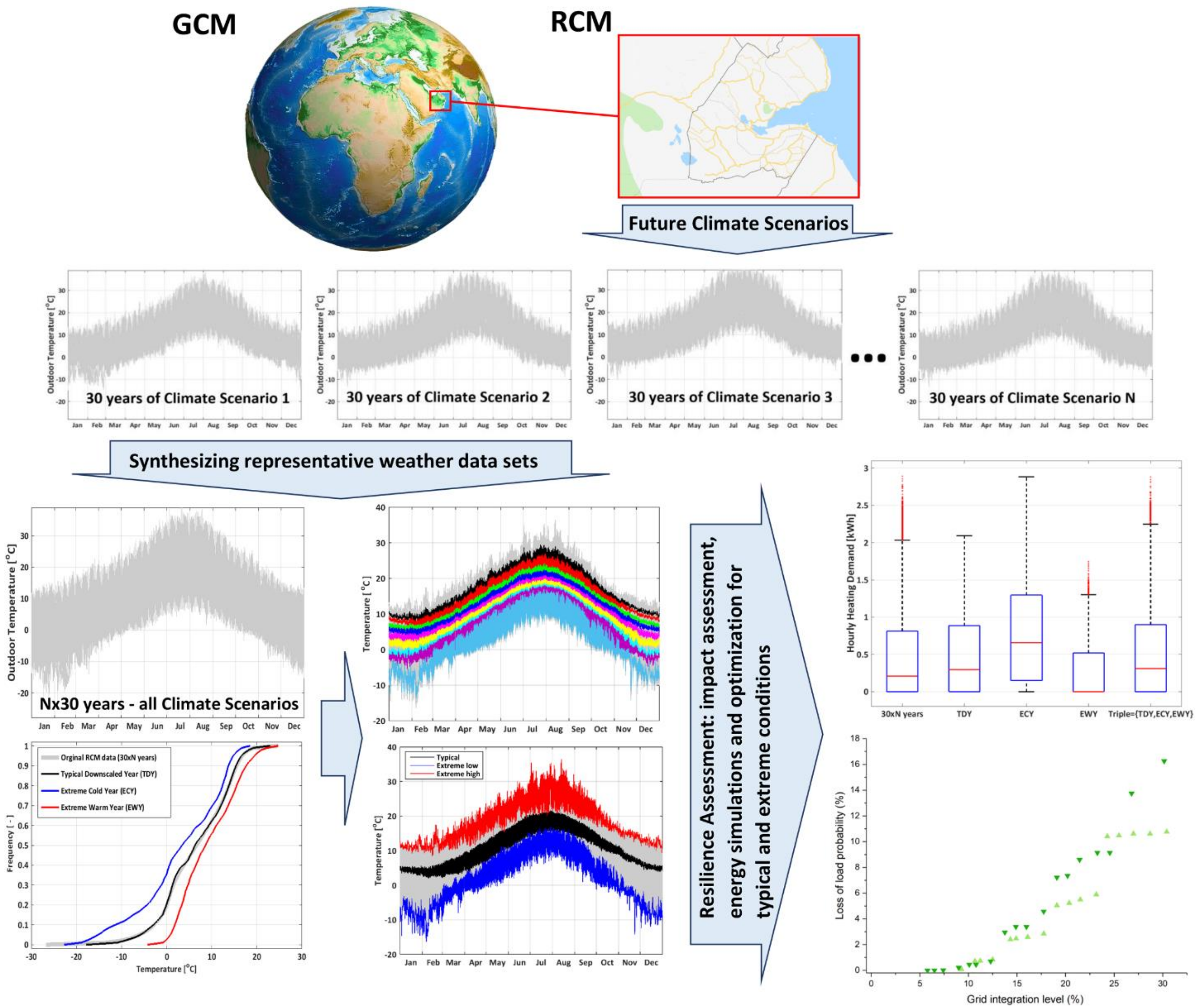
NEED

Suitable climate data sets
Suitable methods for assessment and analysis

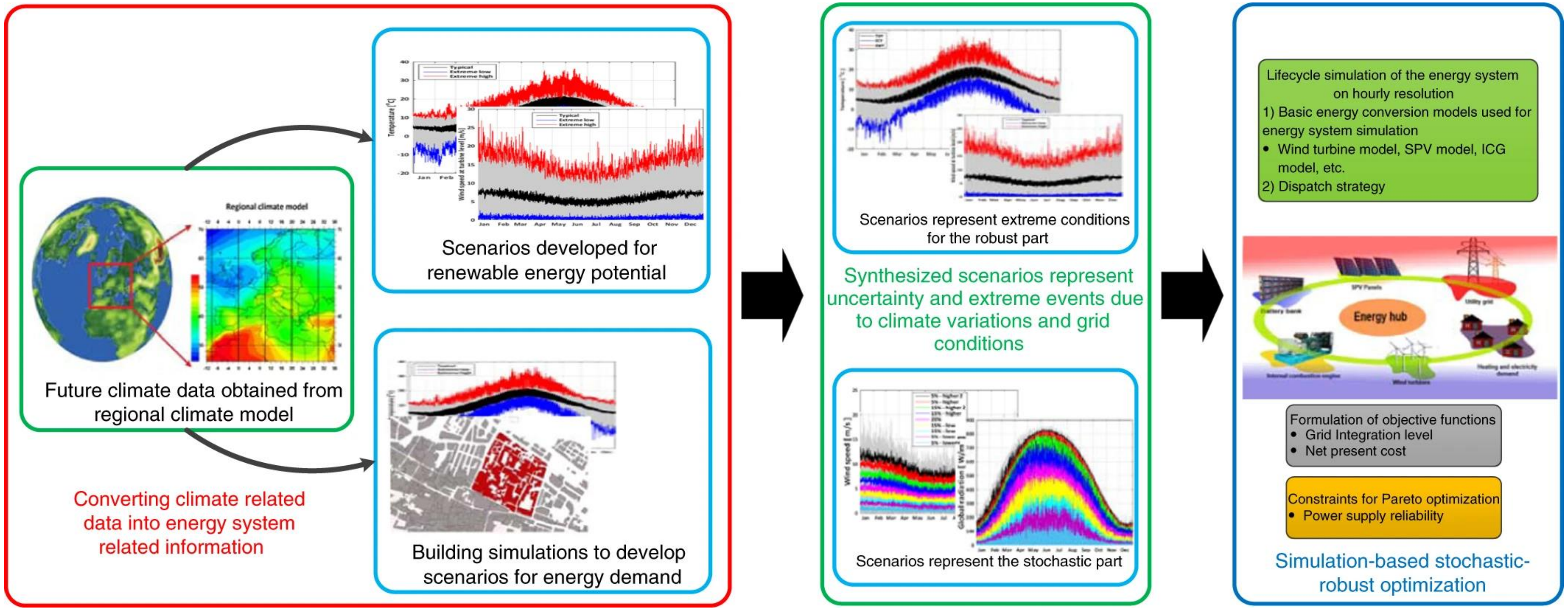
We have developed novel methods/approaches:

- **Representative Future Weather Data** [1, 2]
- **Impact Assessment** [1-8]
- **Energy System Design and Control** [6-8]
- **Urban/Micro-Climate Simulation** [5, 8]
- **Statistical and Uncertainty Analyses** [3]

1. Nik, VM, "Making energy simulation easier for future climate - Synthesizing typical and extreme weather data sets out of regional climate models (RCMs)", Applied Energy, vol. 177, pp. 204–226, Sep. 2016.
2. Nik, VM, "Application of typical and extreme weather data sets in the hygrothermal simulation of building components for future climate – A case study for a wooden frame wall", Energy and Buildings, vol. 154, pp. 30–45, Nov. 2017.
3. Nik VM. Hygrothermal Simulations of Buildings Concerning Uncertainties of the Future Climate. PhD thesis. Chalmers University of Technology, 2012.
4. Perera ATD, Nik VM, Wickramasinghe PU, Scartezzini J-L. Redefining energy system flexibility for distributed energy system design. Appl Energy 2019;253:113572.
5. Javanroodi K, Nik VM, Giometto MG, Scartezzini J-L. Combining computational fluid dynamics and neural networks to characterize microclimate extremes: Learning the complex interactions between meso-climate and urban morphology. Sci Total Environ 2022;829:154223.
6. Nik VM, Moazami A. Using collective intelligence to enhance demand flexibility and climate resilience in urban areas. Appl Energy 2021;281:116106.
7. Perera, A.T.D., Nik, V.M., Chen, D., Scartezzini, J.-L., Hong, T., "Quantifying the impacts of climate change and extreme climate events on energy systems", Nature Energy 2020;5:150–9.
8. Perera ATD, Javanroodi K, Mauree D, Nik VM, Florio P, Hong T, et al. Challenges resulting from urban density and climate change for the EU energy transition. Nat Energy 2023:1–16.

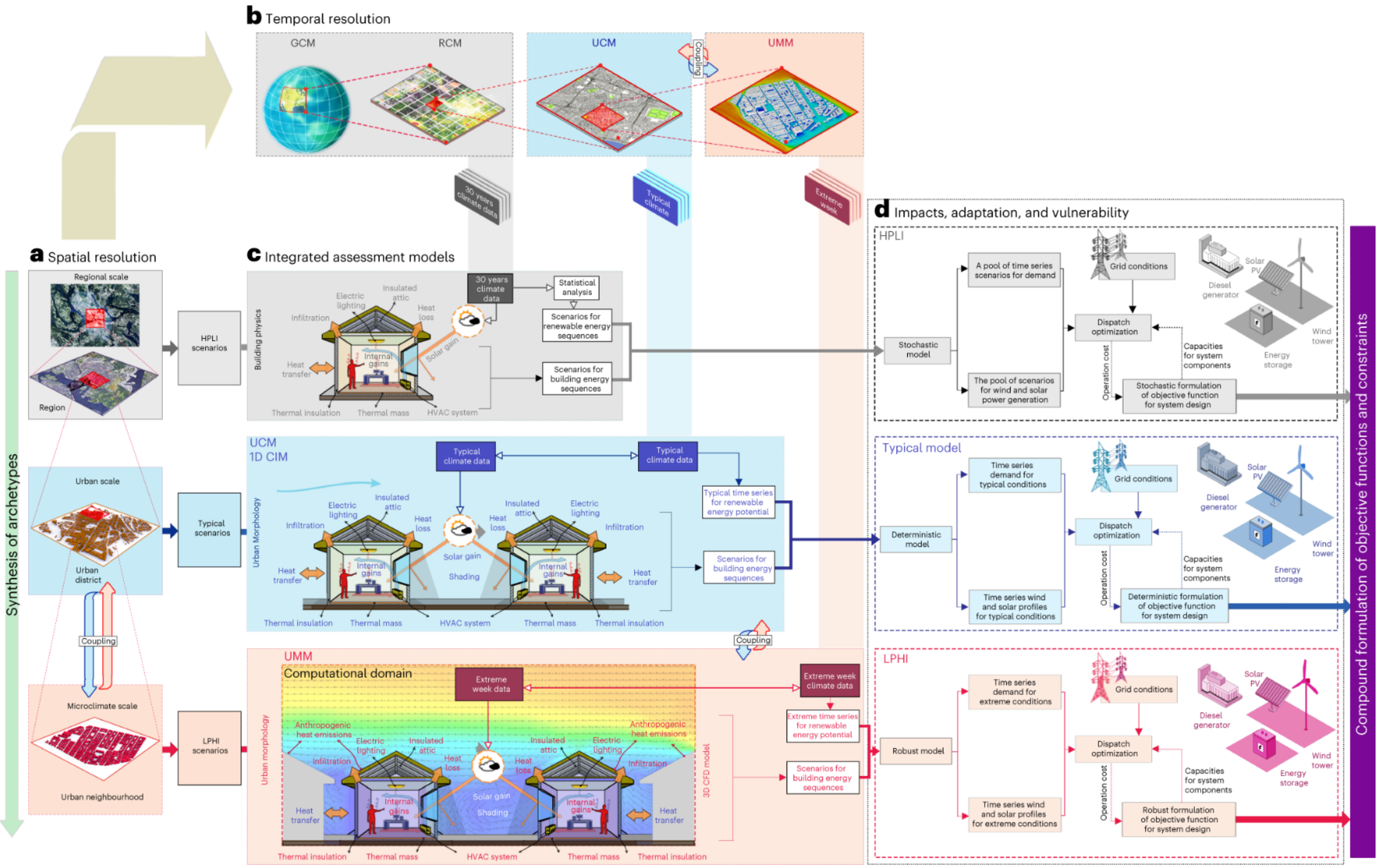


The interlinks between the climate model and the energy system model are not straightforward.
We developed a workflow to synthesize a pool of scenarios to link the climate model with the energy system model.



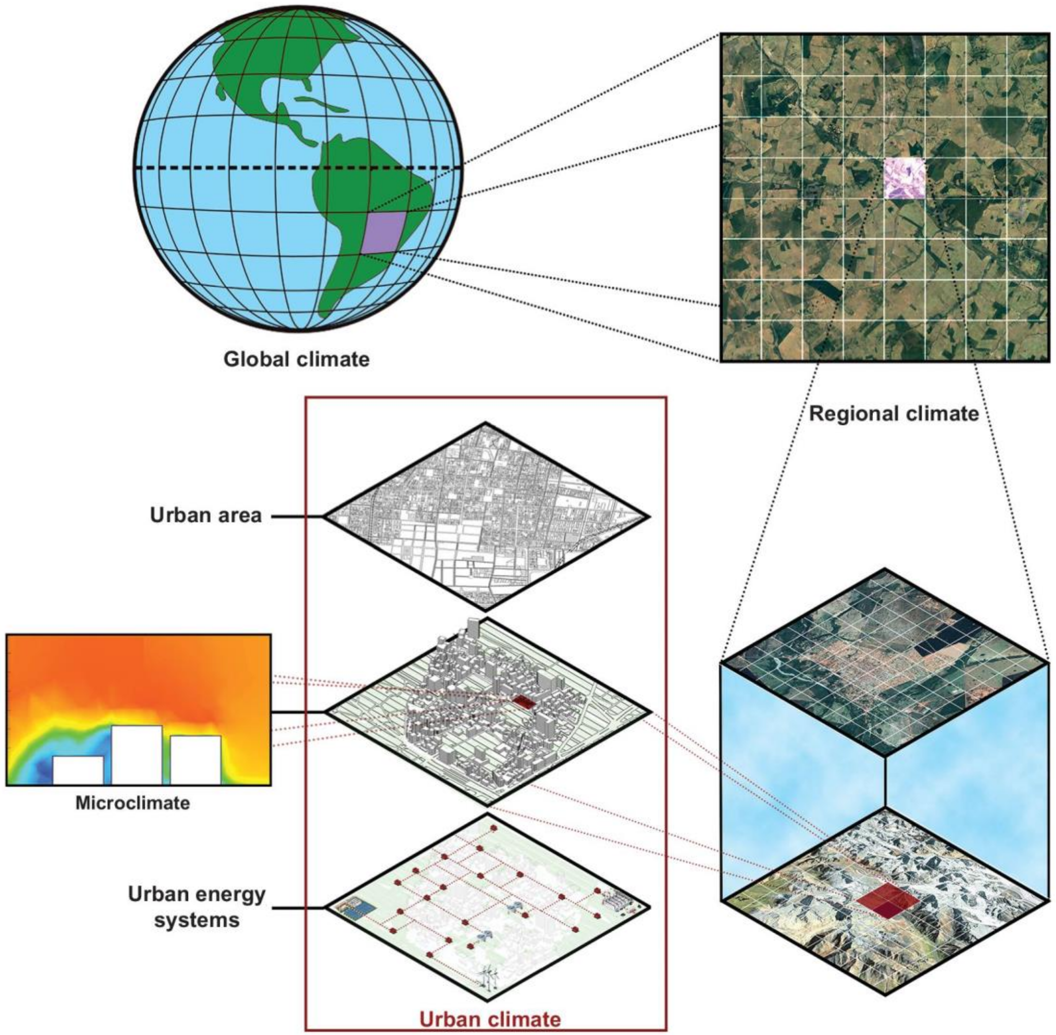
Perera, A.T.D., Nik, V.M., Chen, D., Scartezzini, J.-L., Hong, T., “Quantifying the impacts of climate change and extreme climate events on energy systems”, *Nature Energy* 2020;5:150–9. doi.org/10.1038/s41560-020-0558-0.

We further developed the workflow to interlink energy models and climate models at the urban/micro-climate level.



Perera ATD, Javanroodi K, Mauree D, Nik VM, Florio P, Hong T, et al. Challenges resulting from urban density and climate change for the EU energy transition. Nat Energy 2023:1–16. https://doi.org/10.1038/s41560-023-01232-9

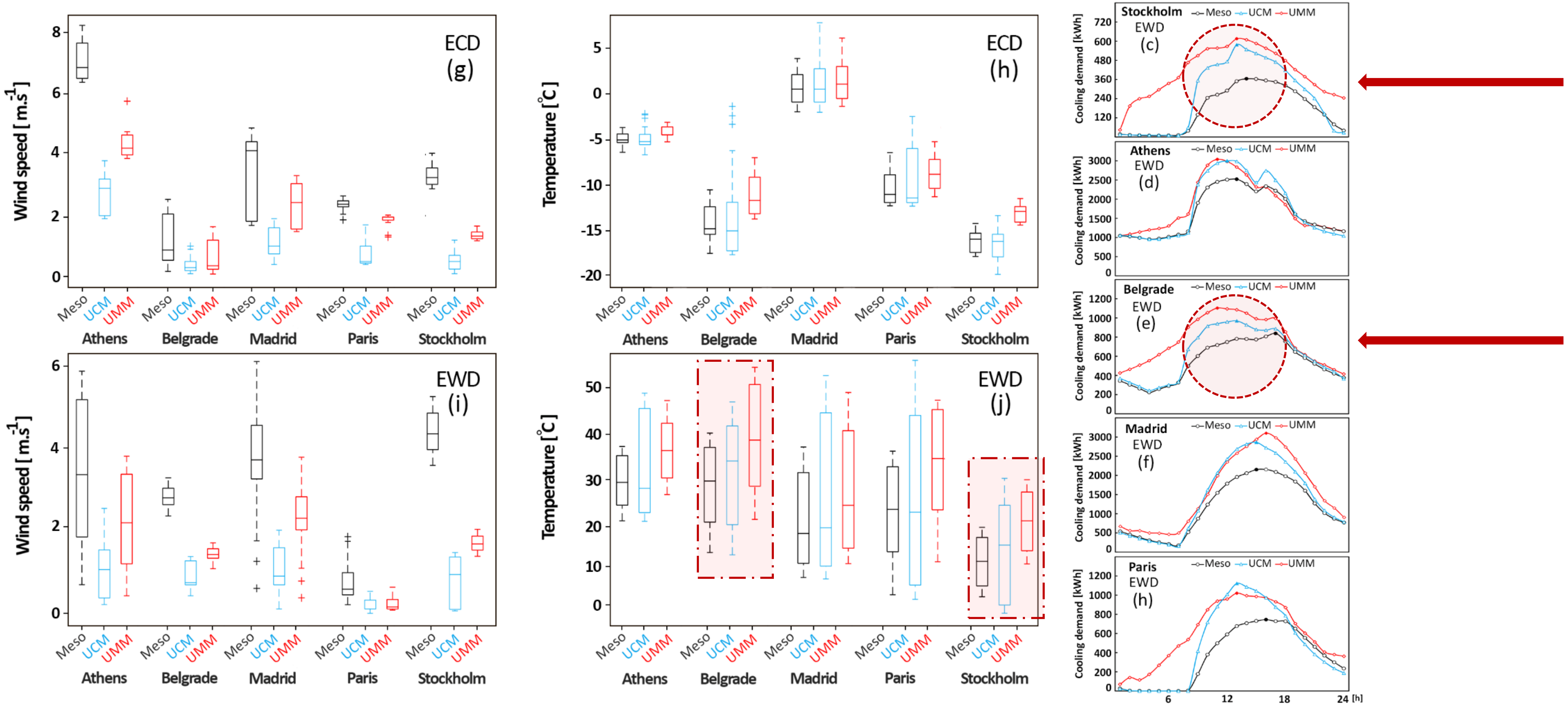
We link urban/micro-climate models with mesoscale climate models for building and urban energy system analysis.



Javanroodi, K., Nik, V.M., "Interactions between extreme climate and urban morphology: Investigating the evolution of extreme wind speeds from mesoscale to microscale", Urban Climate, 2020; 31:100544. doi:10.1016/j.uclim.2019.100544.

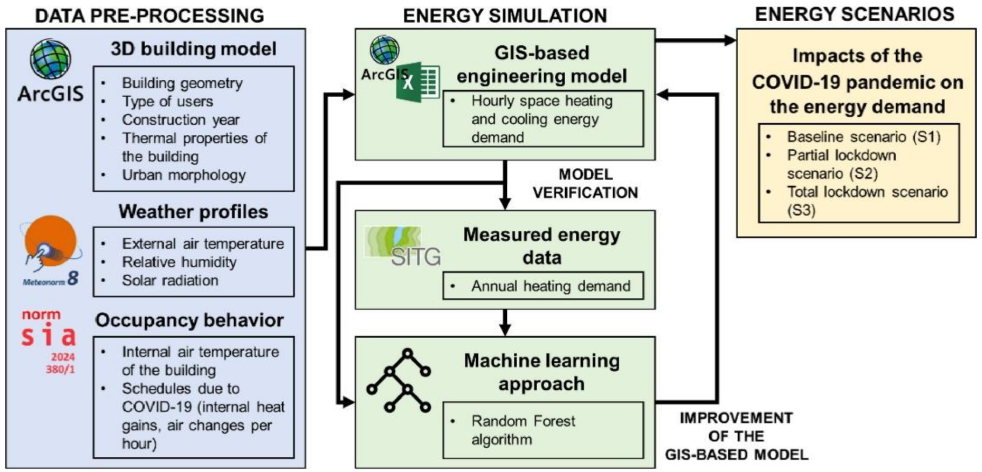
Nik, V.M., Perera, A.T.D., Chen, D., "Towards climate resilient urban energy systems: A review", National Science Review. doi.org/10.1093/nsr/nwaa134.

How do urban climate (UCM), microclimate (UMM) and Mesoscale climate data (Meso) affect climate variable fluctuations and energy demand profiles?

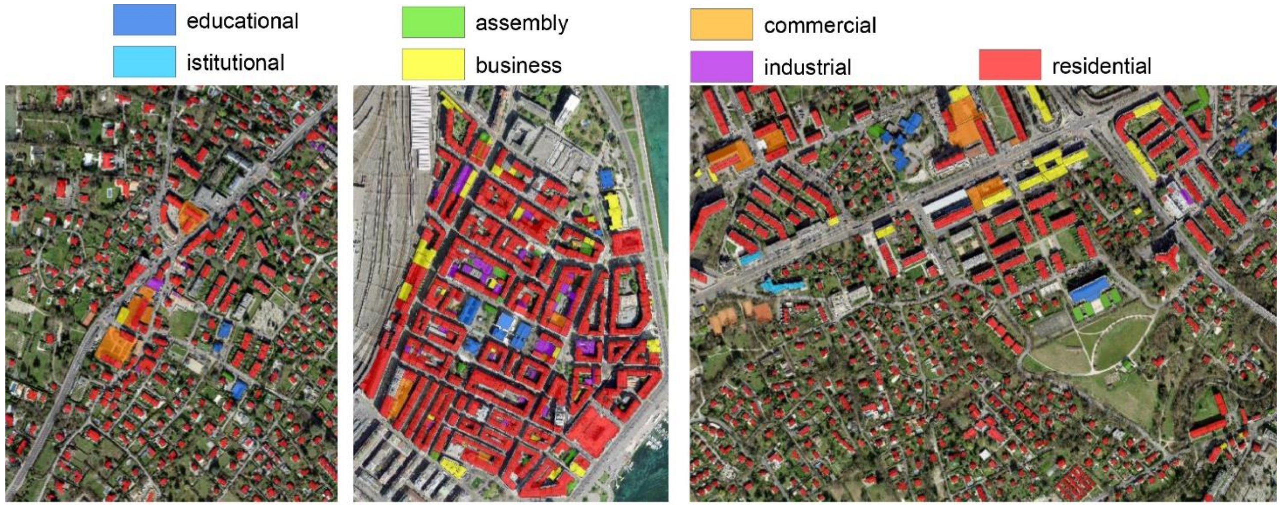


Perera ATD, Javanroodi K, Mauree D, Nik VM, Florio P, Hong T, et al. Challenges resulting from urban density and climate change for the EU energy transition. Nat Energy 2023:1–16. https://doi.org/10.1038/s41560-023-01232-9

Linking Urban Morphology to climate variations at the microscale using historical data. The impacts on cooling, heating demands as well as indoor temperature.



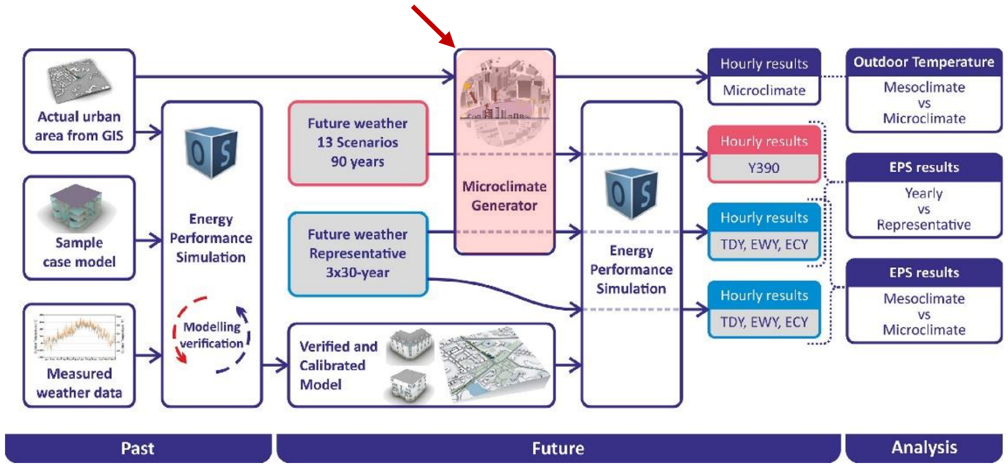
Neighborhood		BH (m)	H/H_{avg} (m/m)	BCR (m^2/m^2)	BD (m^3/m^2)	H/W (m^2/m^2)	SVF (-)
1		10.79	1.32	0.16	1.61	0.25	0.82
	SD	*2.14*	*0.13*	*0.07*	*1.03*	*0.15*	*0.02*
2		23.69	1.28	0.38	8.15	0.81	0.74
	SD	*5.29*	*0.29*	*0.17*	*3.47*	*0.29*	*0.18*
3		15.60	1.51	0.15	2.02	0.30	0.81
	SD	*6.95*	*0.46*	*0.08*	*1.50*	*0.27*	*0.01*

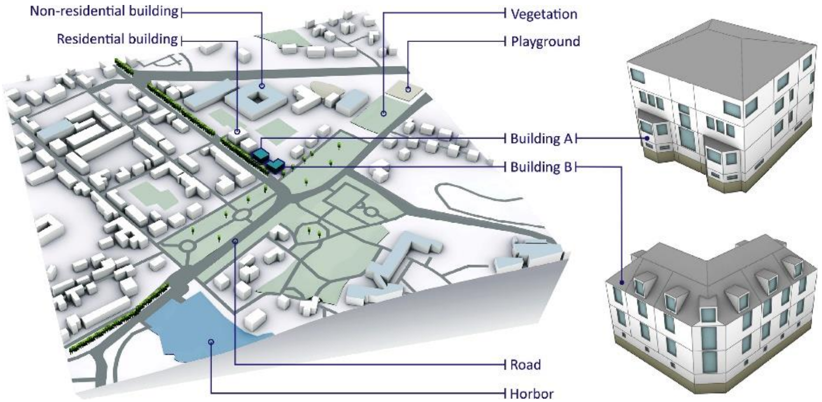


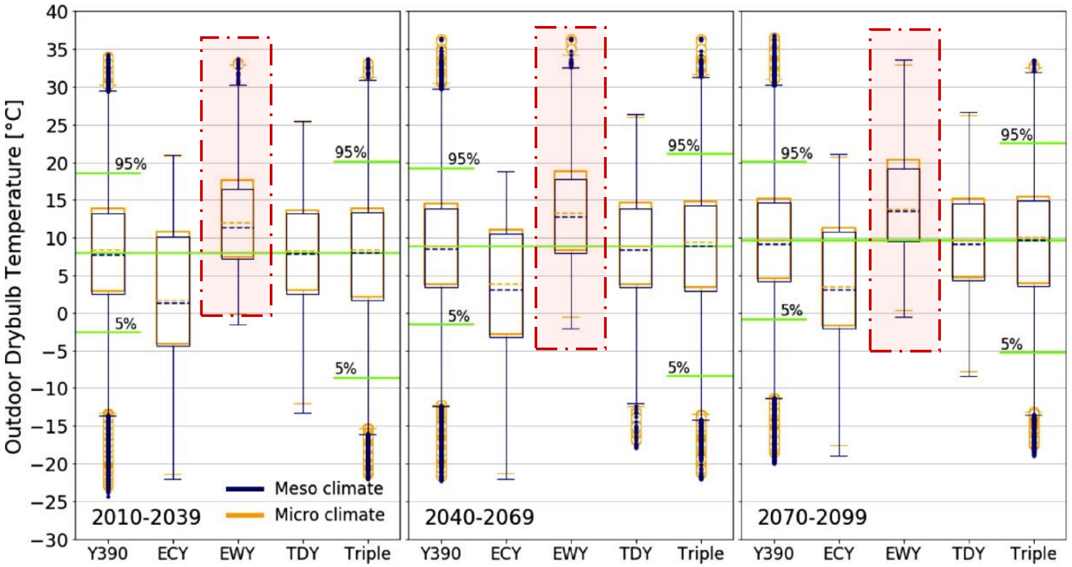
(a) (b) (c)

Todeschi V, Javanroodi K, Castello R, Mohajeri N, Mutani G, Scartezzini J-L. Impact of the COVID-19 pandemic on the energy performance of residential neighborhoods and their occupancy behavior. Sustain Cities Soc 2022:82. https://doi.org/10.1016/j.scs.2022.103896
.

Microclimate data is crucial during extreme climate events (e.g. heatwaves, cold snaps)

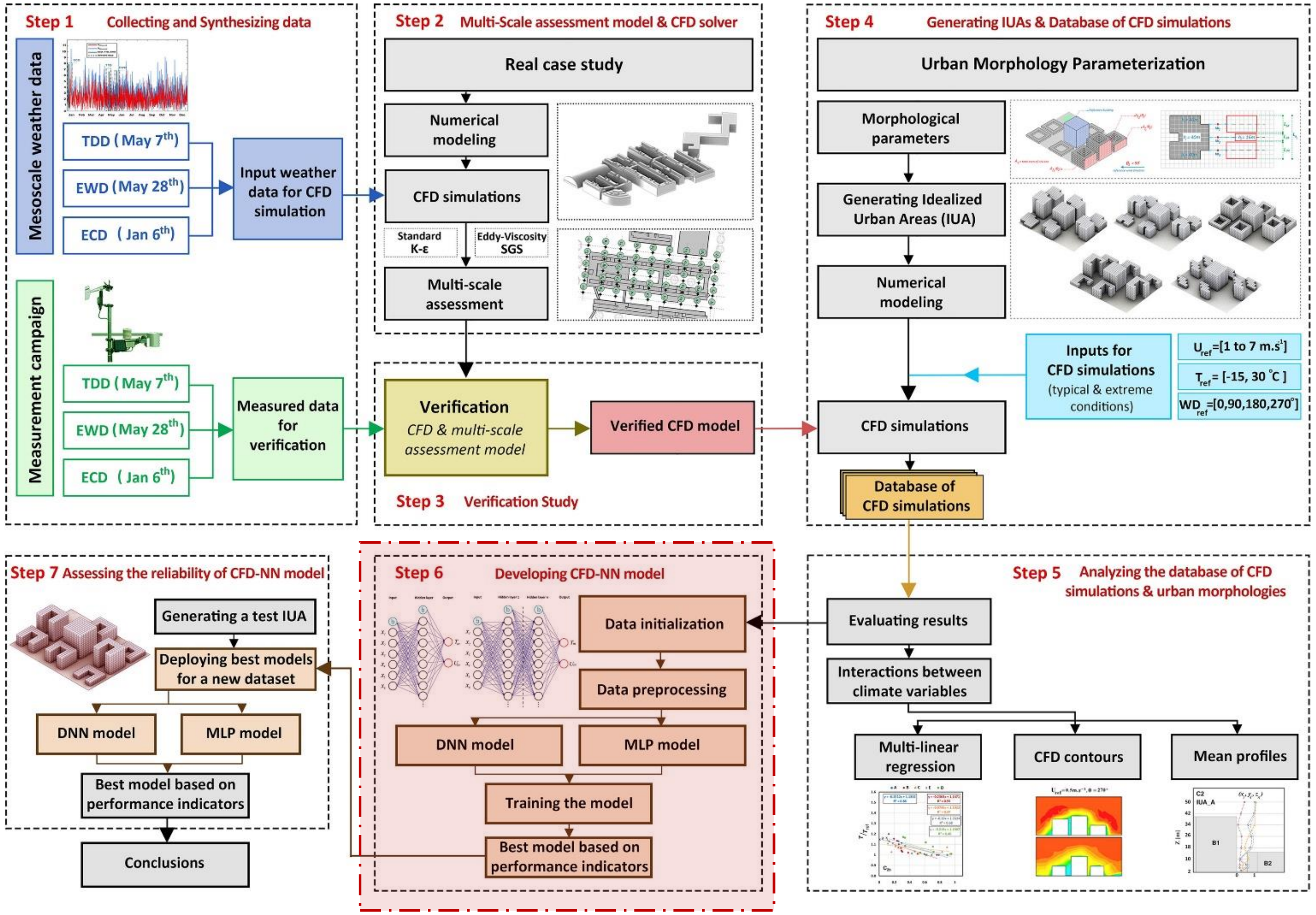




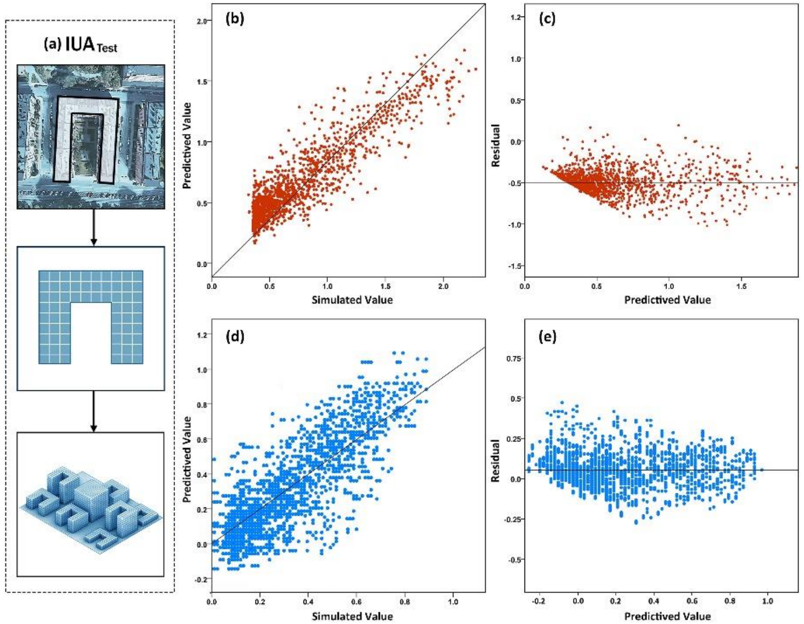


Hosseini, M, Javanroodi, K, Nik, V.M, High-resolution impact assessment of climate change on building energy performance considering extreme weather events and microclimate – Investigating variations in indoor thermal comfort and degree-days, Sustain. Cities Soc, 2021: 78, https://doi.org/10.1016/j.scs.2021.103634

We introduced CFD-NN to provide Extreme Microclimate for unseen urban morphologies



Performance of CFD-NN for unseen Urban Morphology



Javanroodi K, Nik VM, Giometto MG, Scartezzini J-L. Combining computational fluid dynamics and neural networks to characterize microclimate extremes: Learning the complex interactions between meso-climate and urban morphology. Sci Total Environ 2022: 829. https://doi.org/10.1016/j.scitotenv.2022.154223

Thank you!

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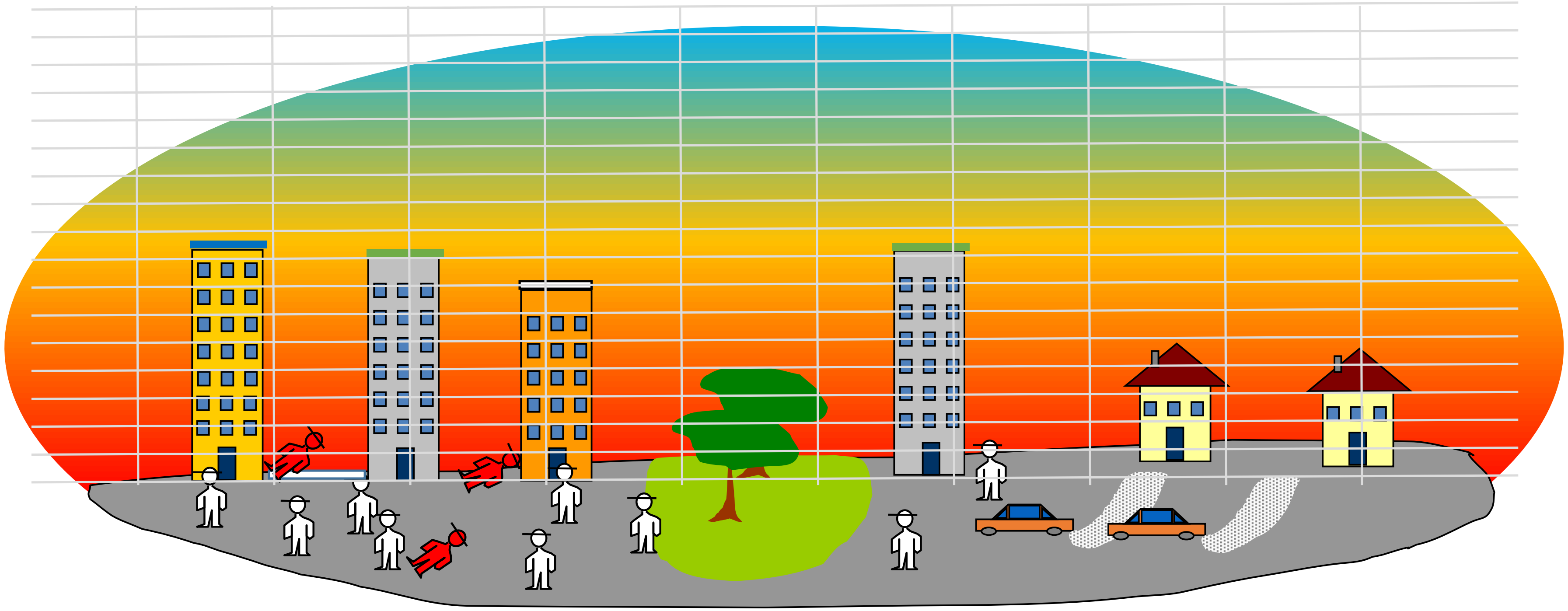
Mesoscale modelling of urban overheating

Alberto Martilli
CIEMAT
Spain



GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Research questions that motivate my work:

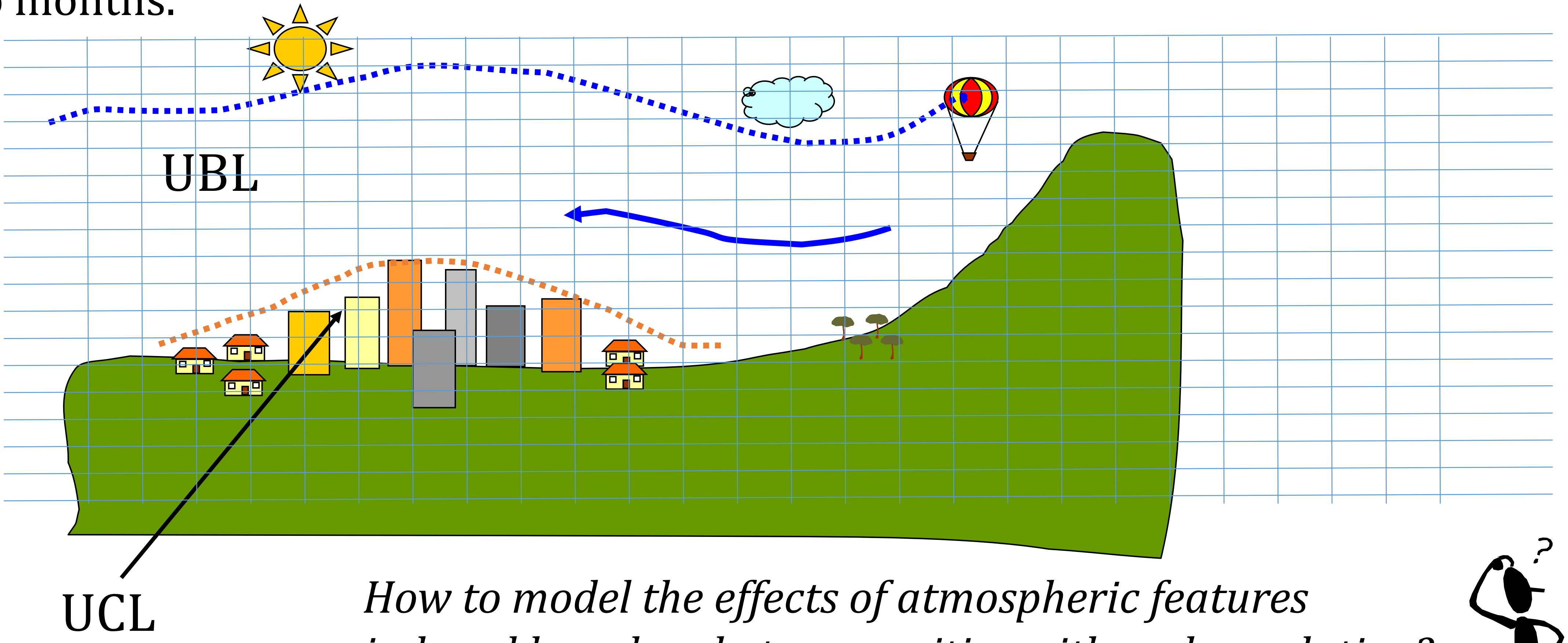
How to simulate the two-way, ***city scale*** interactions between cities, citizens and the urban atmosphere?

How to quantify the ***city scale*** impact of mitigation/adaptation measures, based on the modification of the city characteristics, on thermal confort and building energy consumption? How these measures affect air quality?

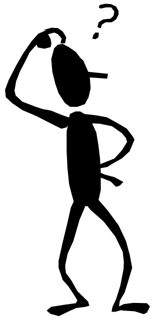
The tool

Mesoscale models

Spatial resolution of the order of 1km, domain size of 100 km, simulations from several days to months.

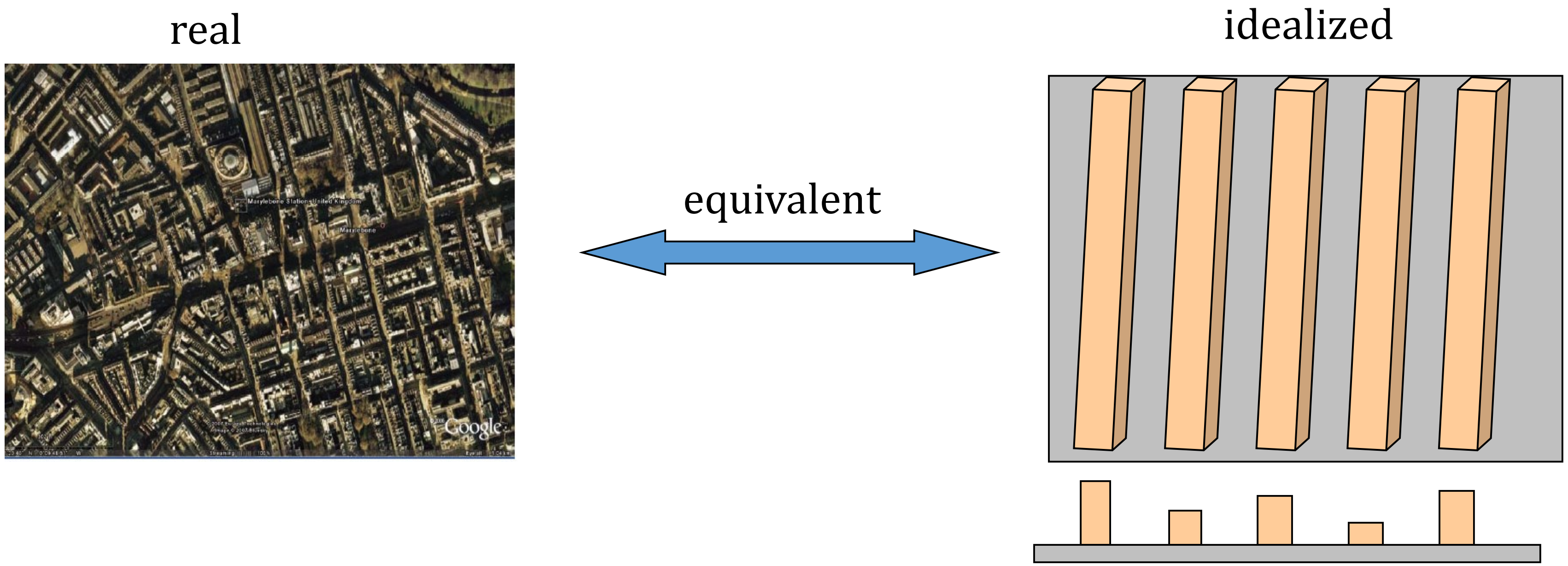


How to model the effects of atmospheric features induced by urban hetereogenities with such resolution?



A parameterization is needed.

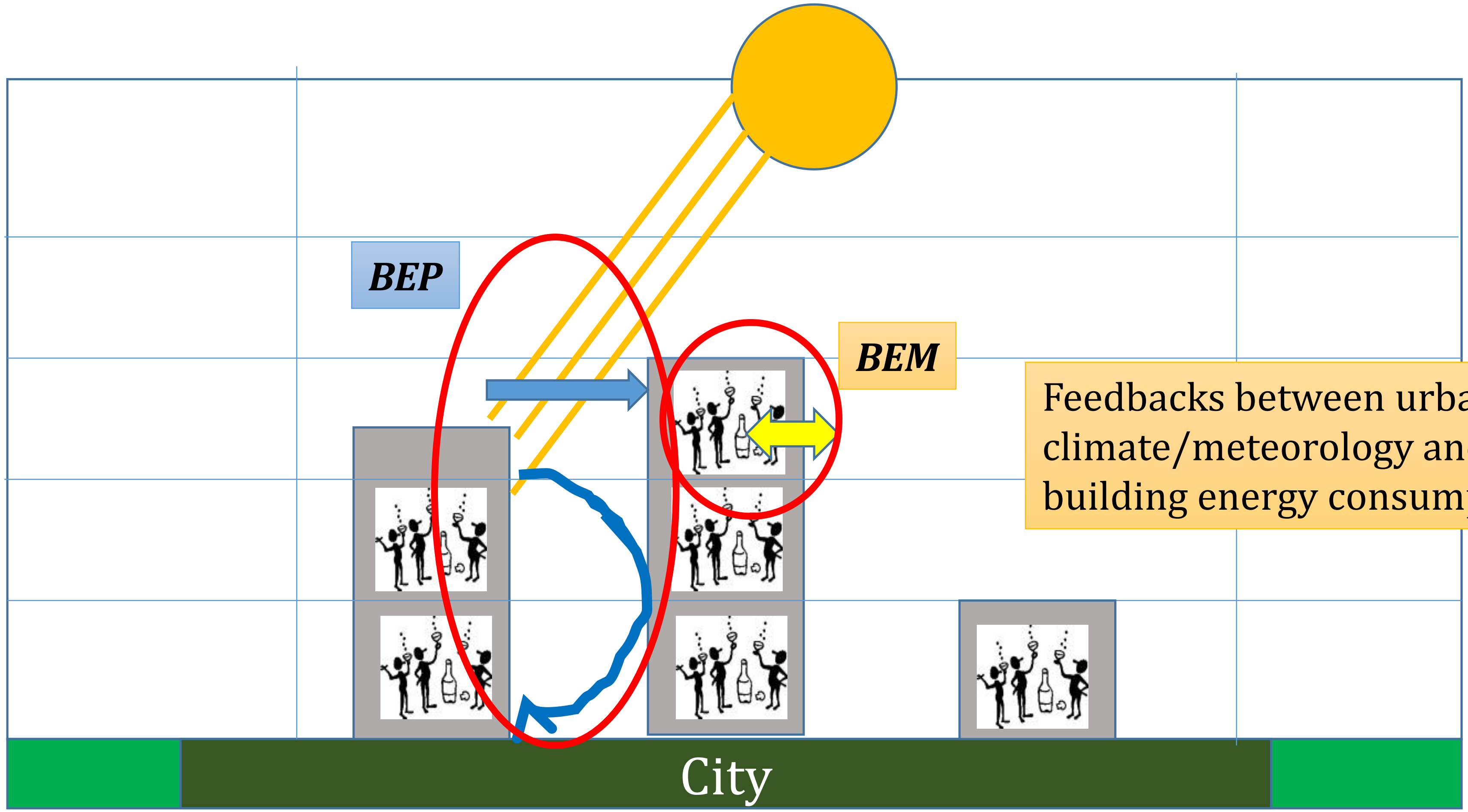
Philosophy of the parametrizations:



Advantage: every building behaves in the same way and also every street behaves in the same way. By computing the fluxes for one building and for one street, the fluxes for the whole grid cell can be easily estimated.

BEP-BEM

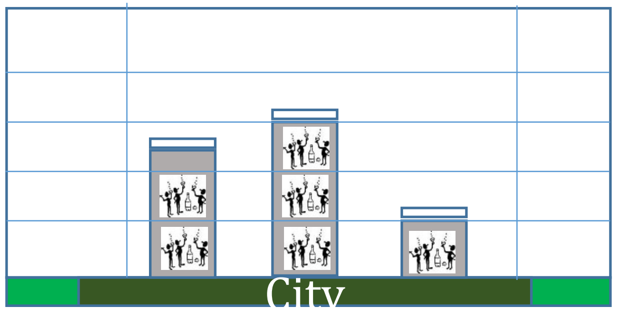
BEP (Building Effect Parameterization, Martilli et al. 2002) is the *multilayer urban canopy paramterization* coupled to a *Building Energy Model* (BEM, Salamanca et al. 2010), embedded in ***WRF.***



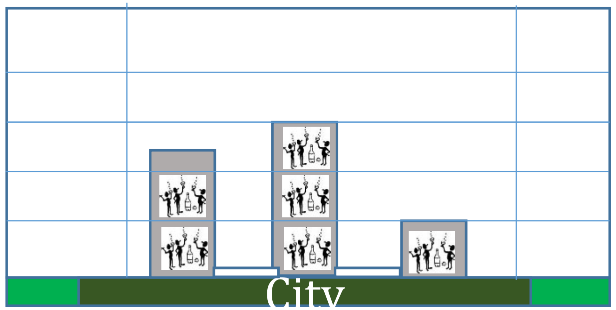
Feedbacks between urban climate/meteorology and building energy consumption

Currently with the model we can represent different measurs like

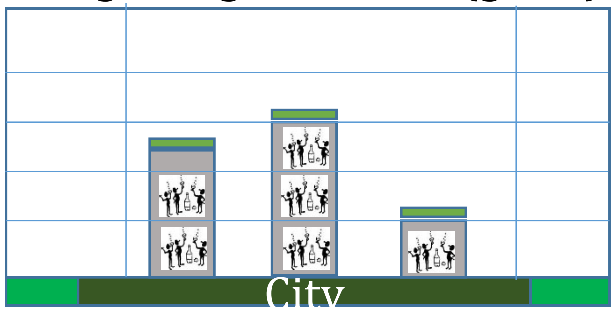
Cool roofs



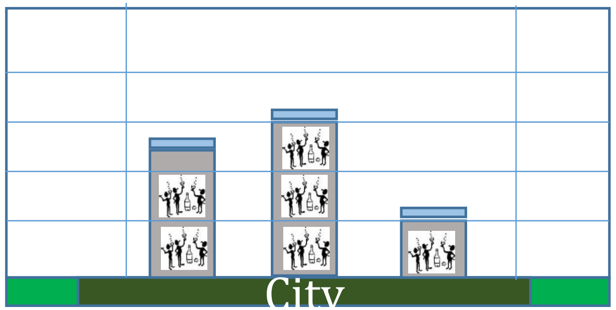
Cool pavements



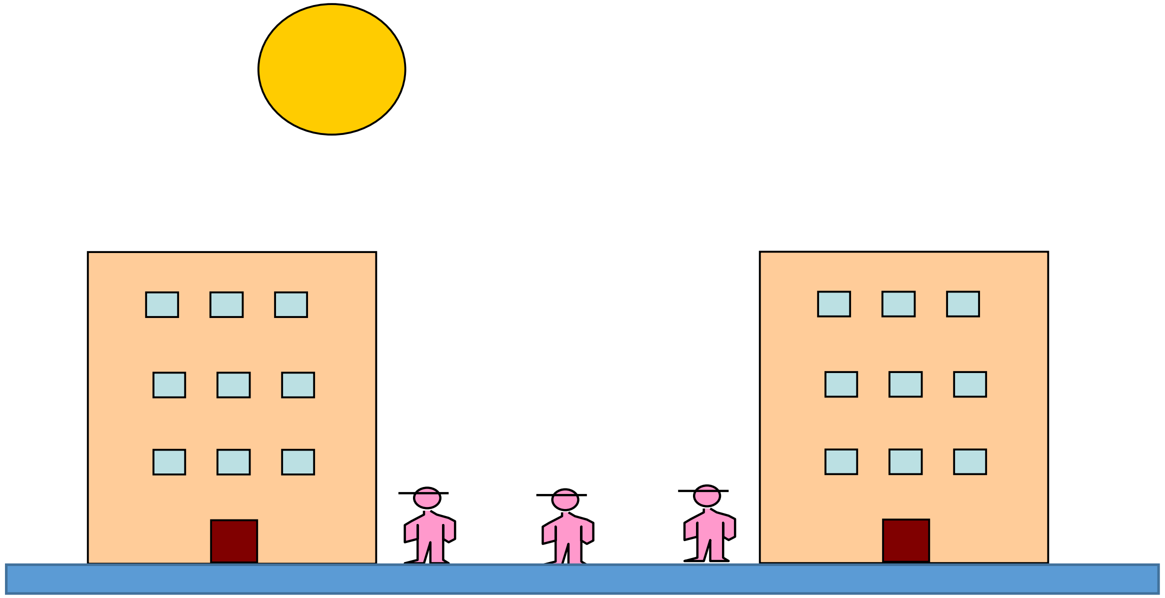
Irrigated green roofs (grass)



Roof top solar panels



And estimate thermal comfort parameters like UTCI

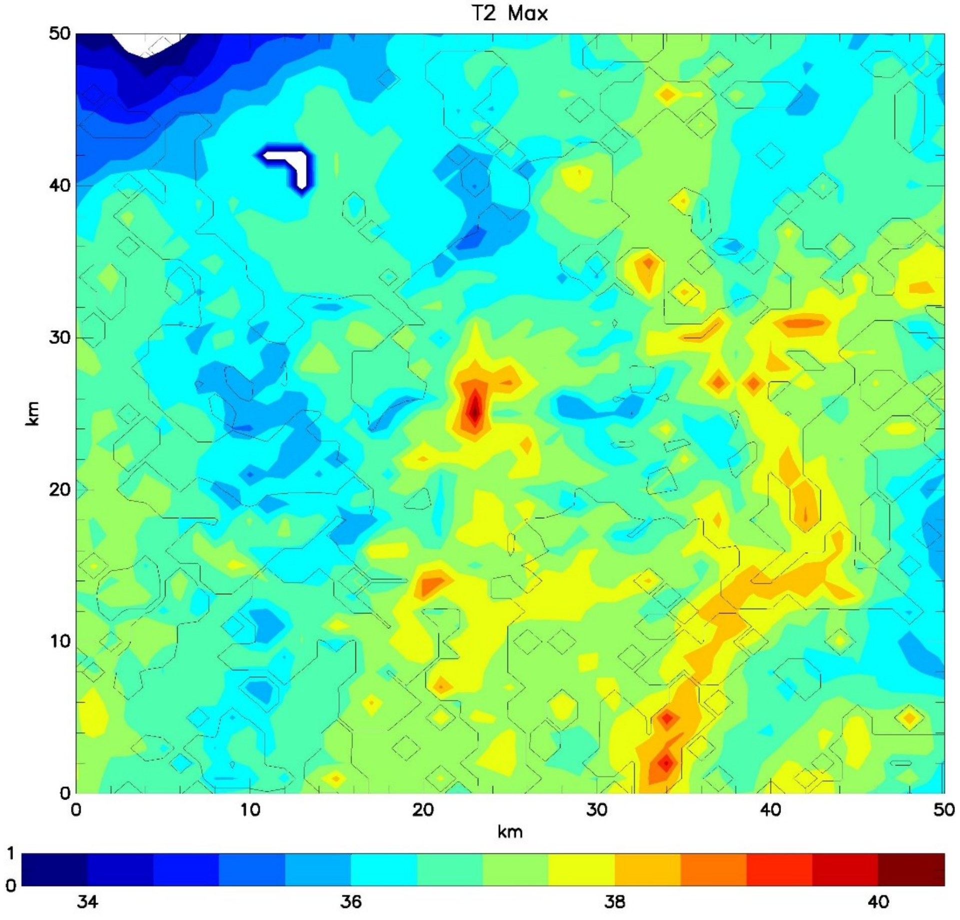


What can we do with the mesoscale model with the urban canopy parameterization?

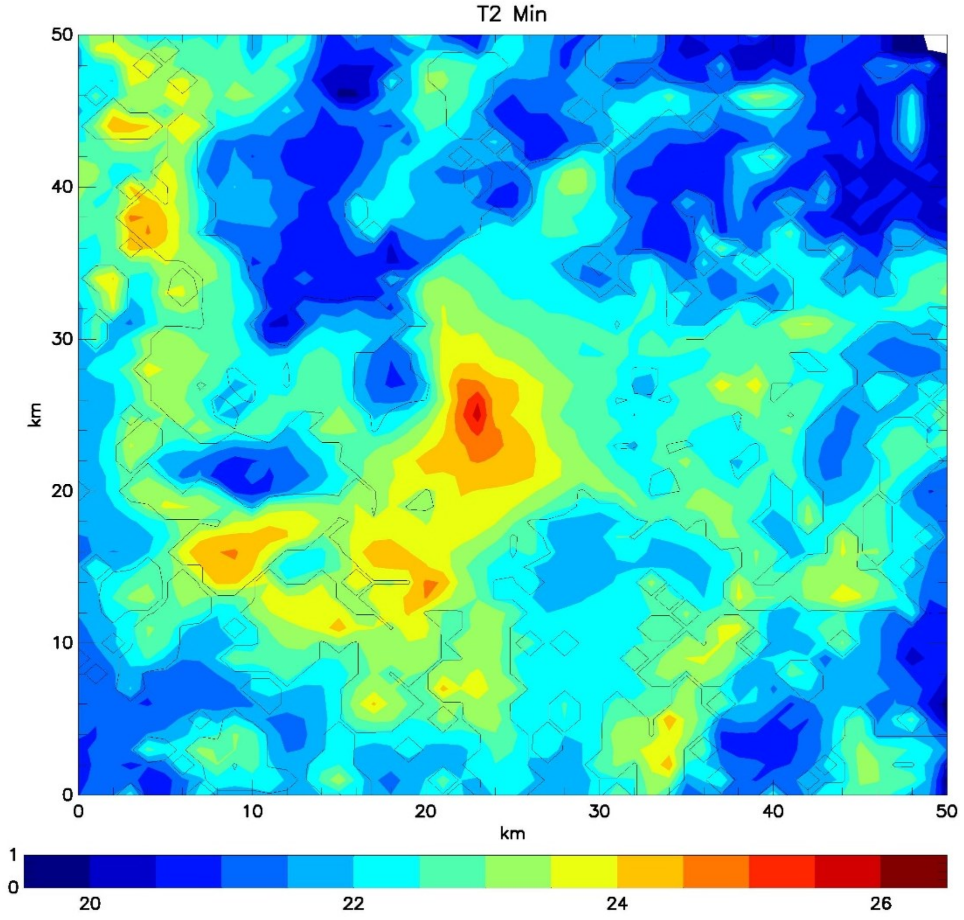
Maps of meteorological variables

Madrid during a heat wave

2m maximum air temperatures (Celsius)



2m minimum air temperatures (Celsius)



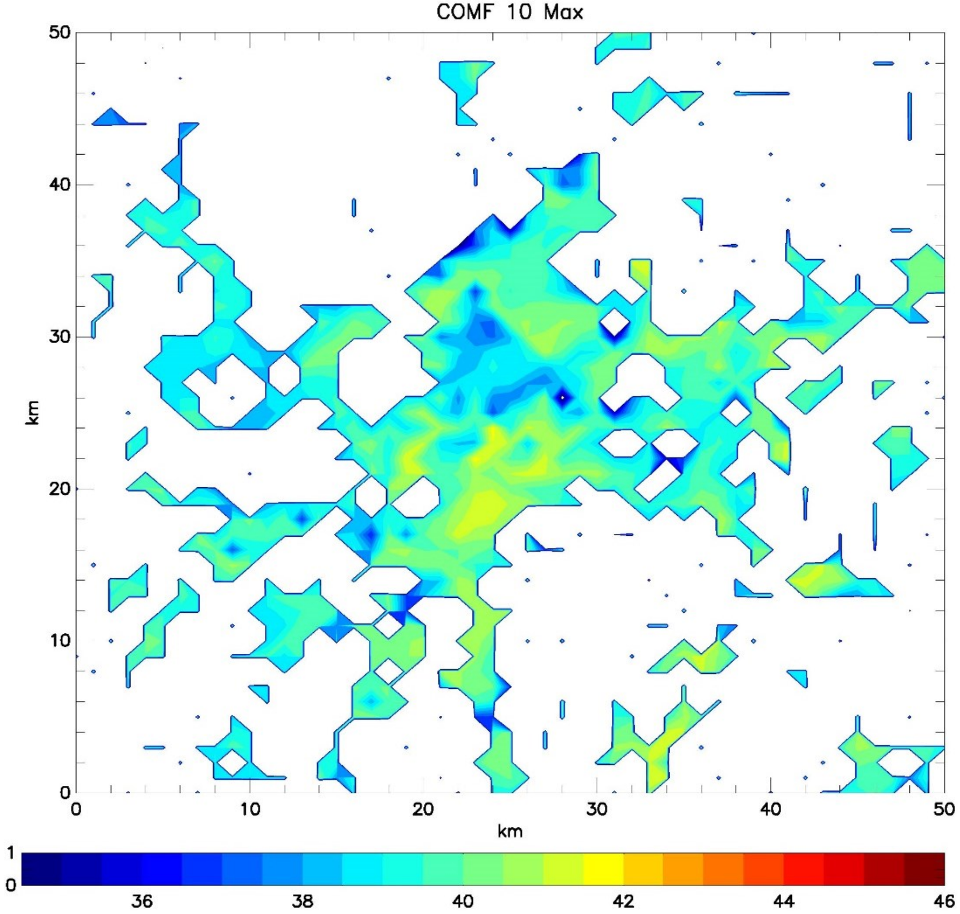
What can we do with the mesoscale model with the urban canopy parameterization?

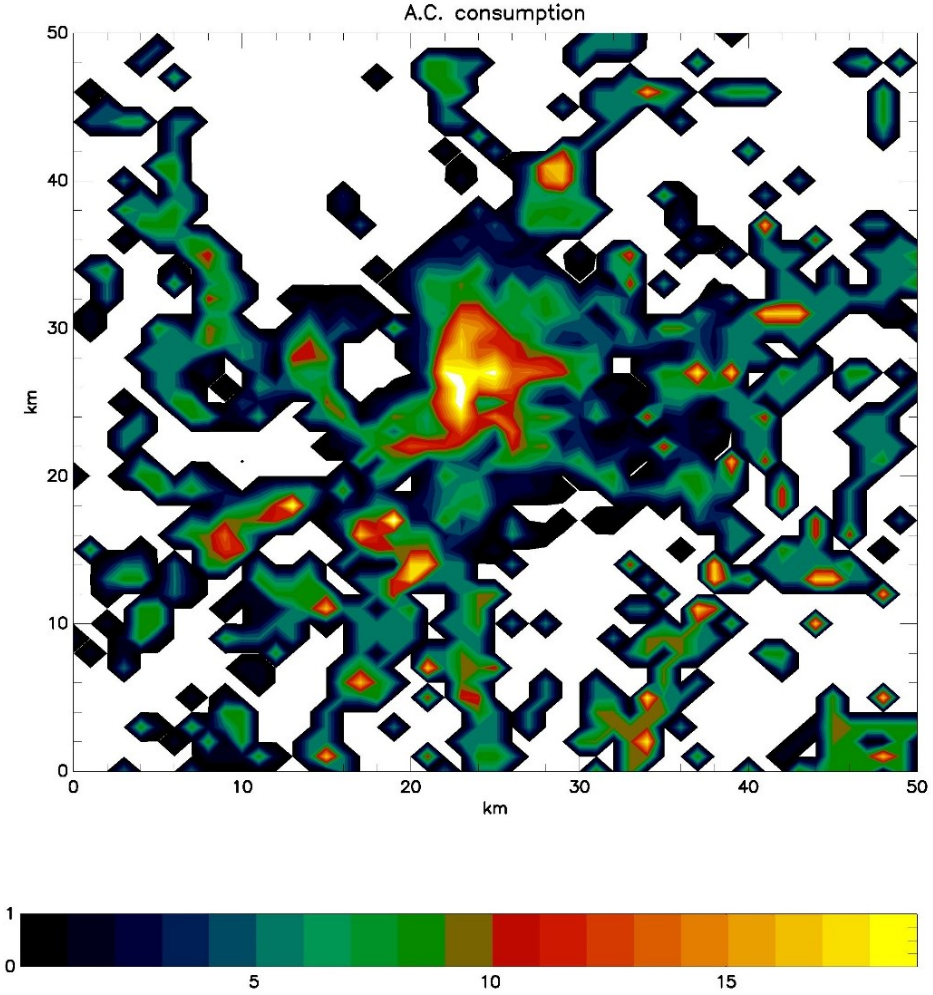
Madrid during a heat wave

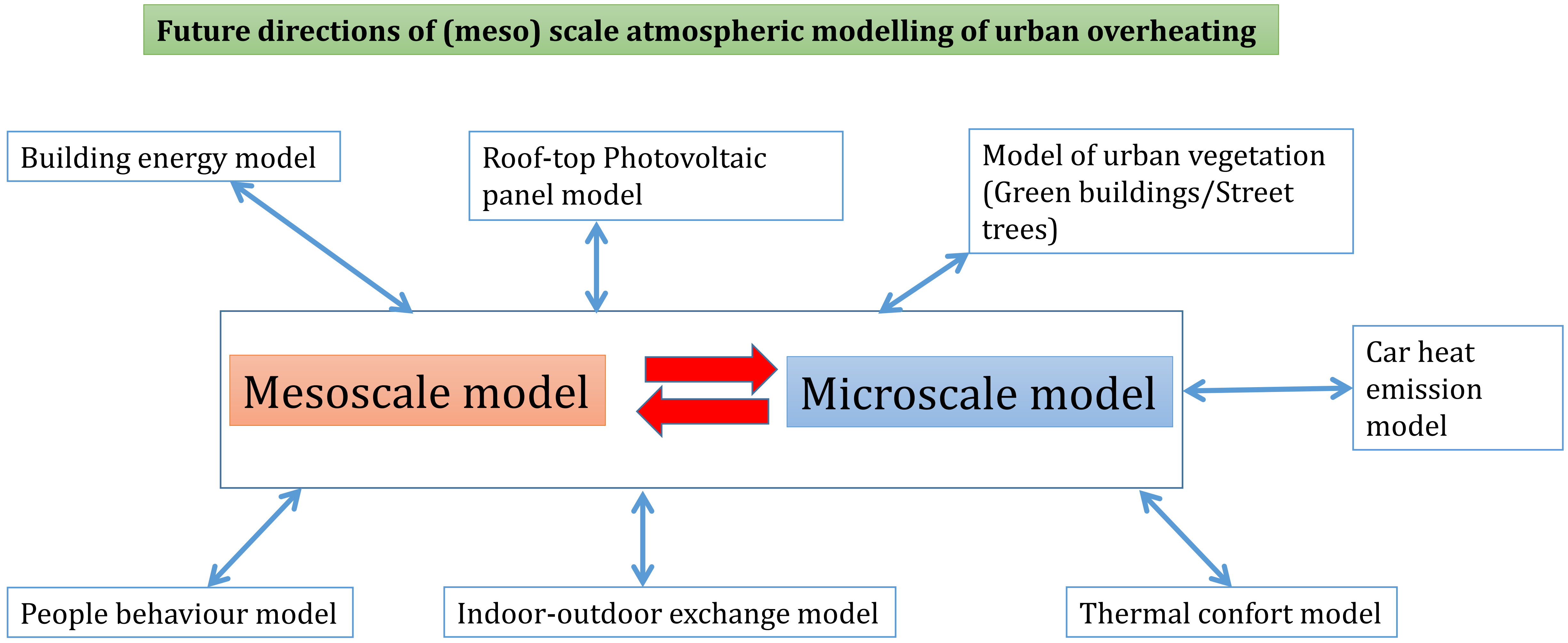
Maps of heat stress

Maps of A.C. energy consumption

Max UTCI






Future directions of (meso) scale atmospheric modelling of urban overheating
Building energy model
Roof-top Photovoltaic panel model
Model of urban vegetation (Green buildings/Street trees)
Mesoscale model
Microscale model
Car heat emission model
People behaviour model
Indoor-outdoor exchange model
Thermal confort model

Thank you

Discussion

Thank you!

See you again tomorrow at 10.00 CET