Resilient cooling to mitigate climate change impact in cities

a H2020 Marie Curie Project

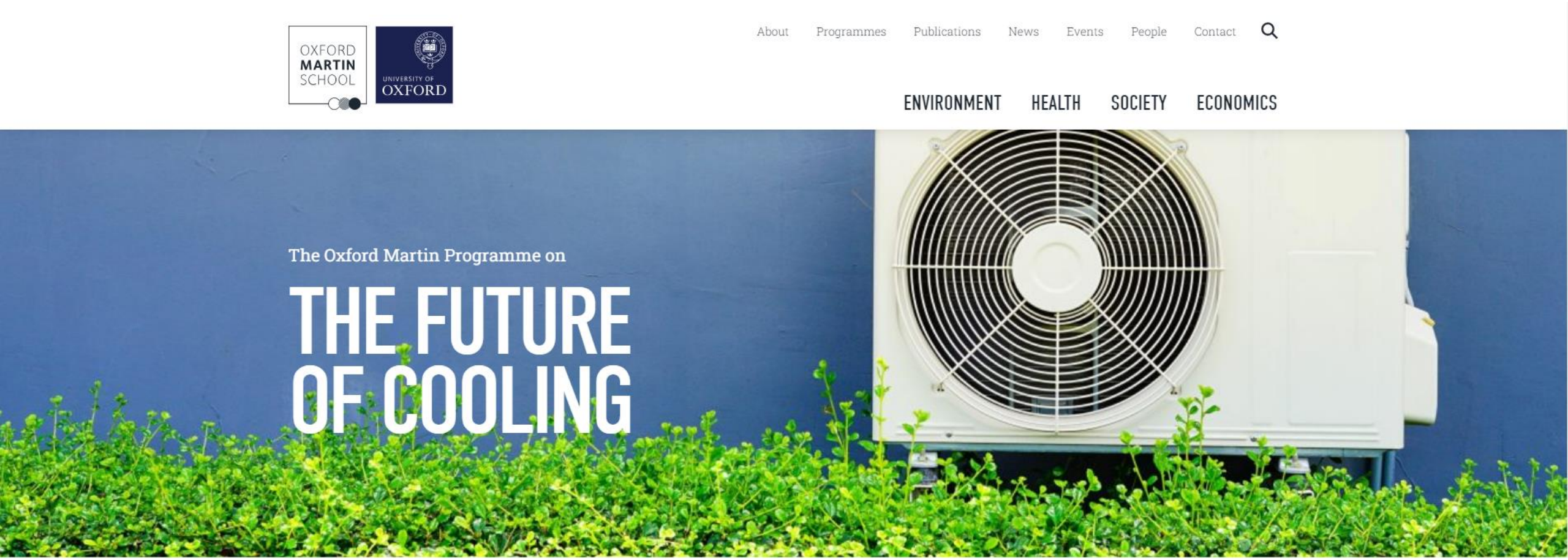
Dr Jesus Lizana
Architect, Postdoctoral researcher, Marie Curie Fellow
EPG group, Department of Engineering Science
Future of Cooling Programme of the Oxford Martin School

University of Oxford
jesus.lizana@eng.ox.ac.uk

@lizanafj
@OxfordCooling

Member of the Editorial Board of Sustainable Cities and Society

The Oxford Martin Programme on The Future of Cooling



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

Oxford Future of Cooling Programme
@OxfordCooling

Seville, Spain

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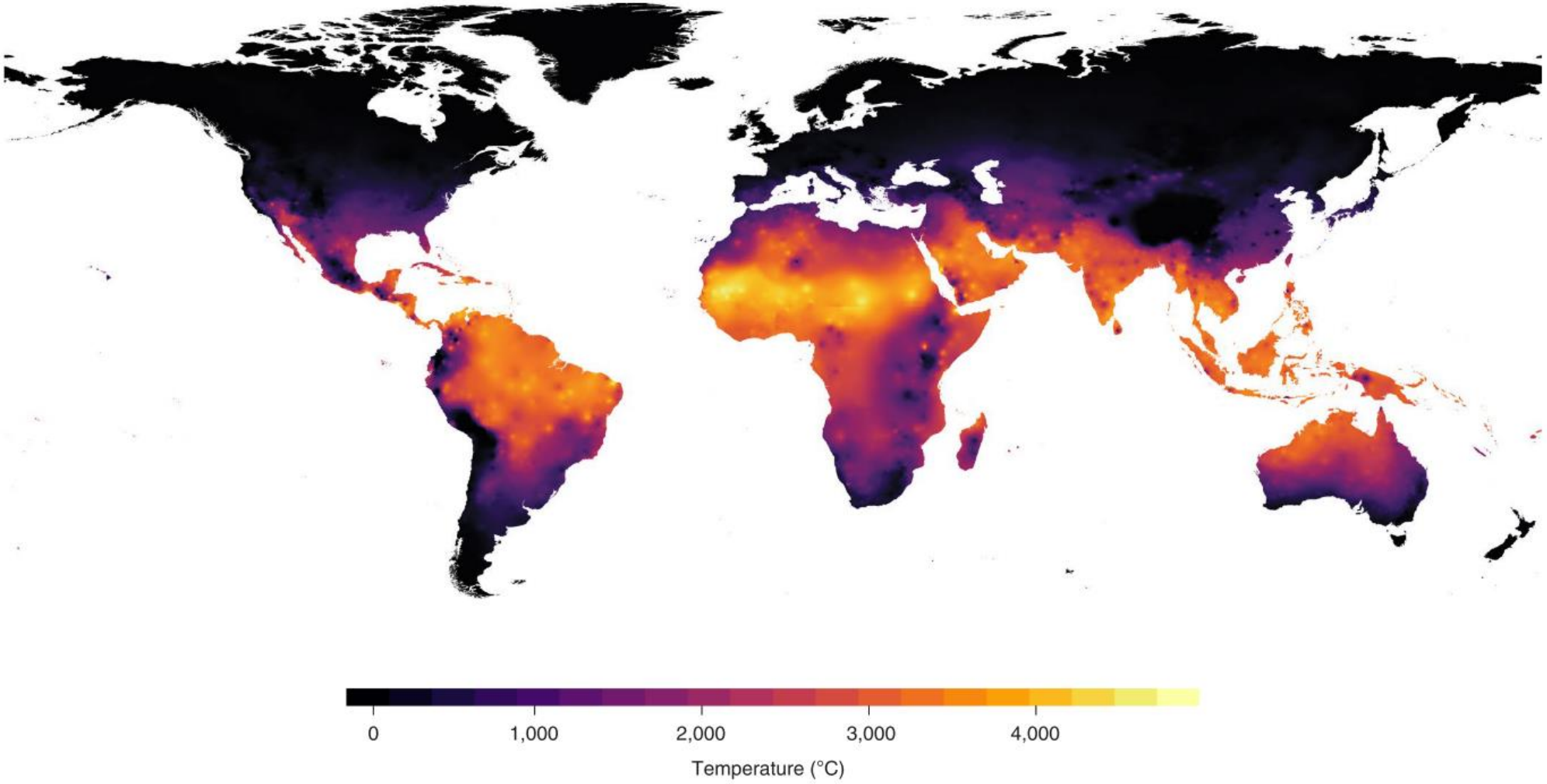
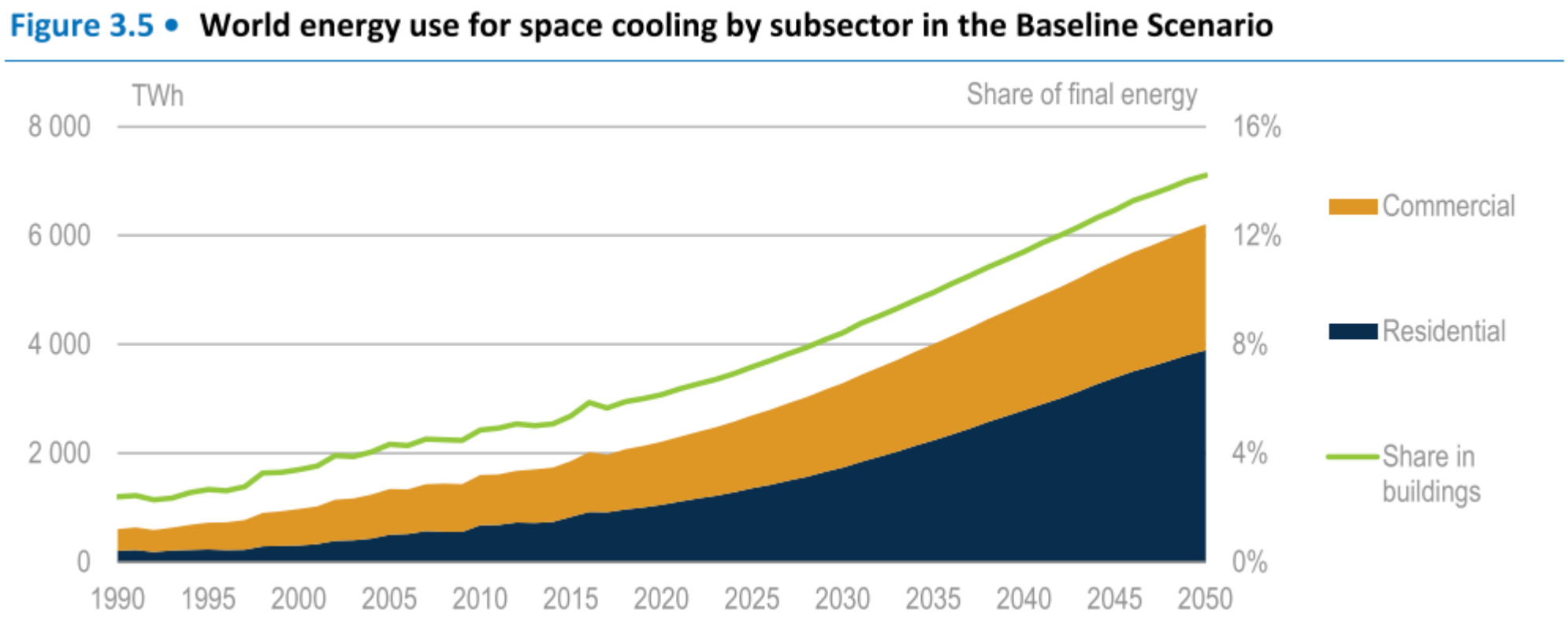
Challenge



Average annual cooling degree days (CDDs) for the period 2009–2018

Biardeau, L. T., Davis, L. W., Gertler, P., & Wolfram, C. (2020). Heat exposure and global air conditioning. Nature Sustainability, 3(1), 25–28. https://doi.org/10.1038/s41893-019-0441-9

Challenge



Energy needs for space cooling will grow more than triple by 2050

IEA. (2018). The Future of Cooling. Opportunities for energy-efficient air conditioning. IEA Publications. https://www.iea.org/reports/the-future-of-cooling

WHAT IS THE HEAT RESILIENCE OF CITIES?

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The ability of buildings and their systems to continue functioning as intended in the face of heat stress imposed by climate change

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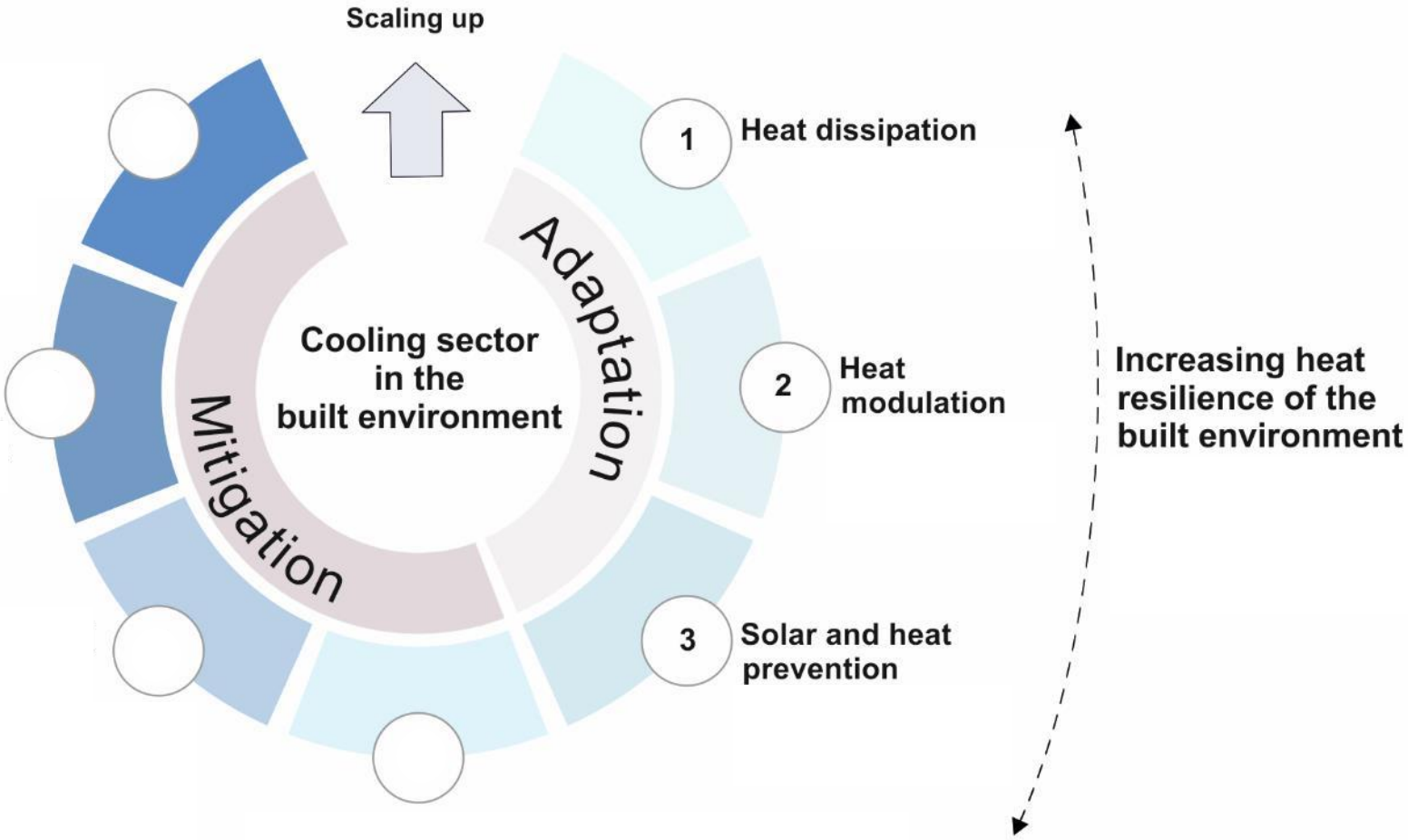
Mitigation ⟶ **Mitigation + ADAPTATION**

The zero-carbon **and RESILIENT COOLING** pathway

THE ZERO-CARBON AND RESILIENT COOLING PATHWAY



1 – Heat dissipation

Resilient cooling

Heat dissipation | Heat modulation | Solar and heat prevention

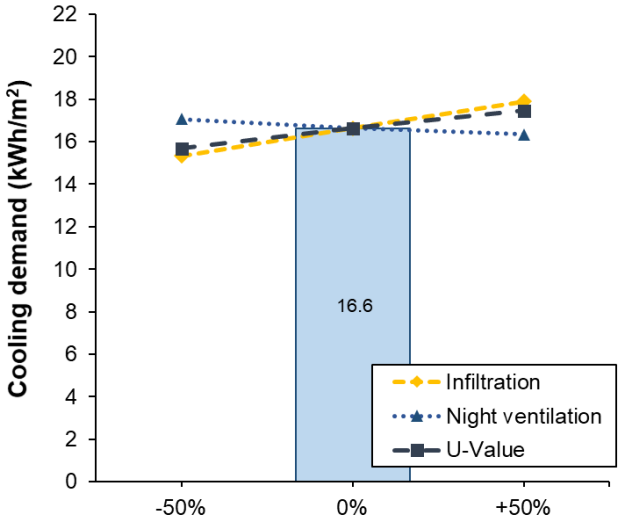
Lizana et al. (2021) Integrating courtyard microclimate in building performance to mitigate extreme urban heat impacts. sustainable city and society, 103590. https://doi.org/10.1016/j.scs.2021.103590

1 – Heat dissipation

Resilient cooling

Heat dissipation | Heat modulation | Solar and heat prevention

Thermal cooling demand (kWh/m² y)



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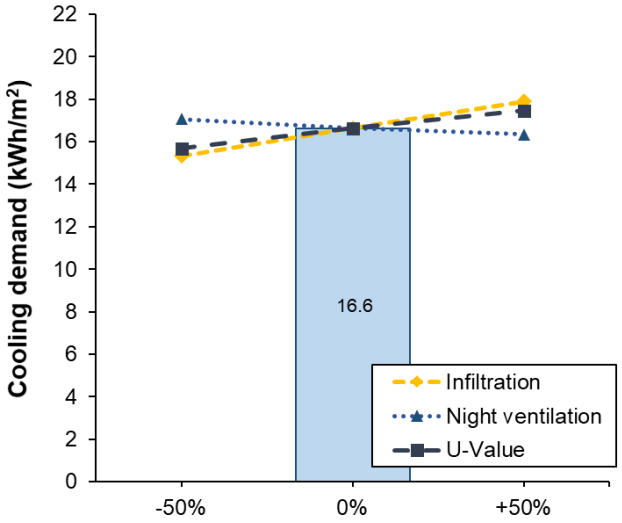
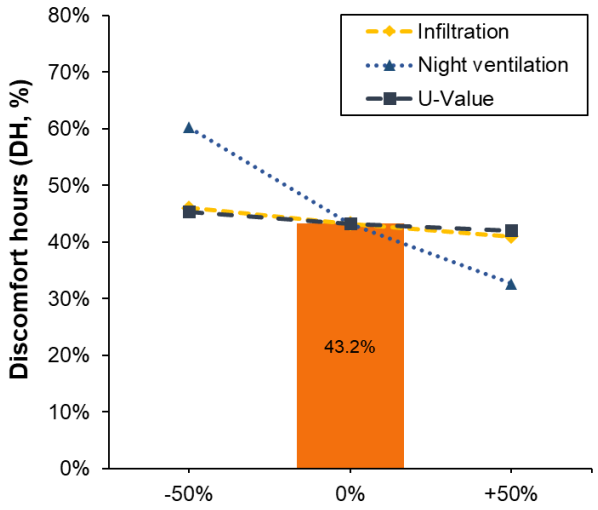


Discomfort hours (% of hours)



Insulation and infiltration can increase overheating by 5% if ventilation is not appropriately addressed.

Lizana et al. (2021) Integrating courtyard microclimate in building performance to mitigate extreme urban heat impacts. sustainable city and society, 103590. https://doi.org/10.1016/j.scs.2021.103590

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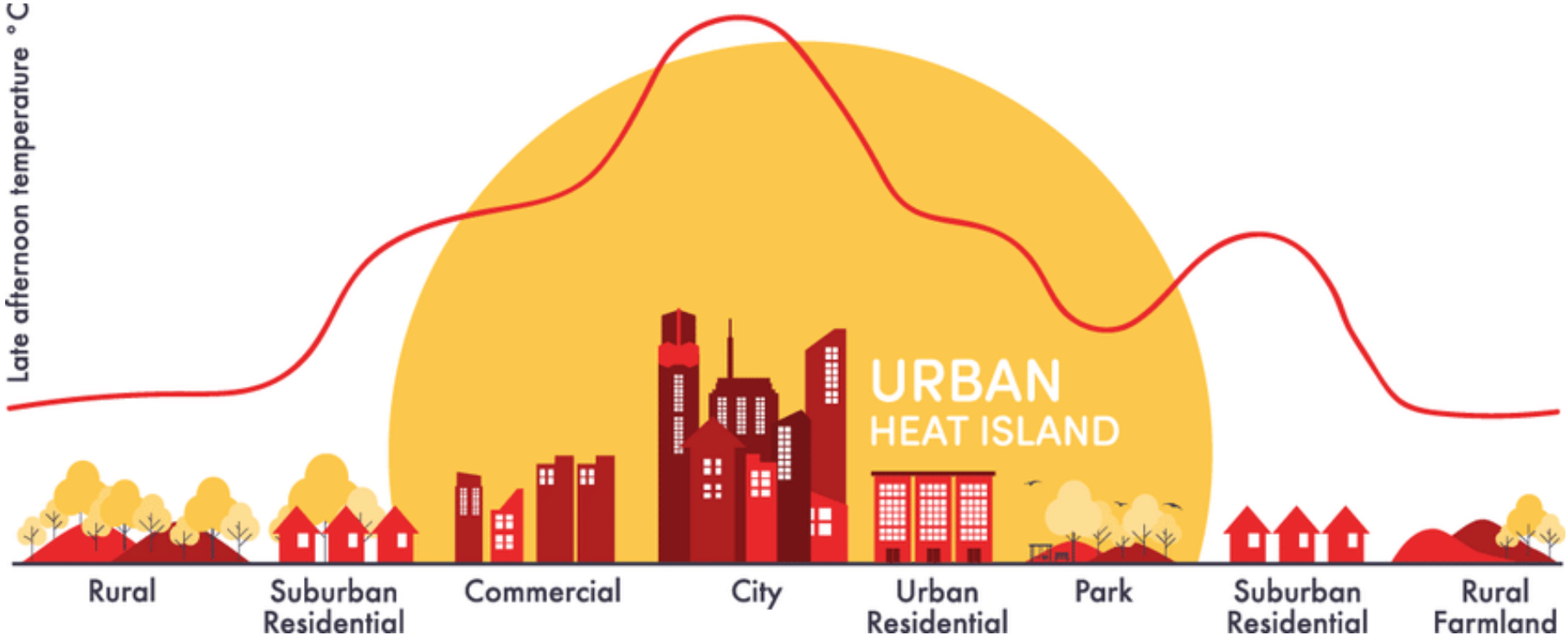

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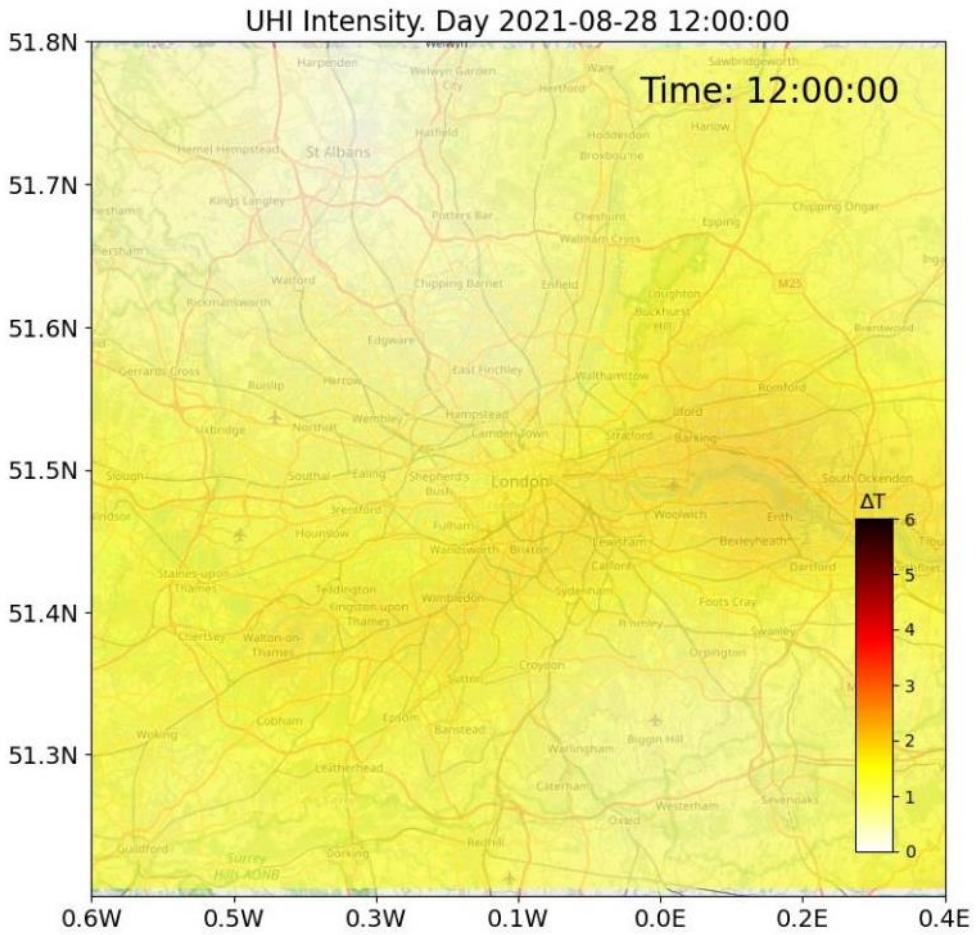

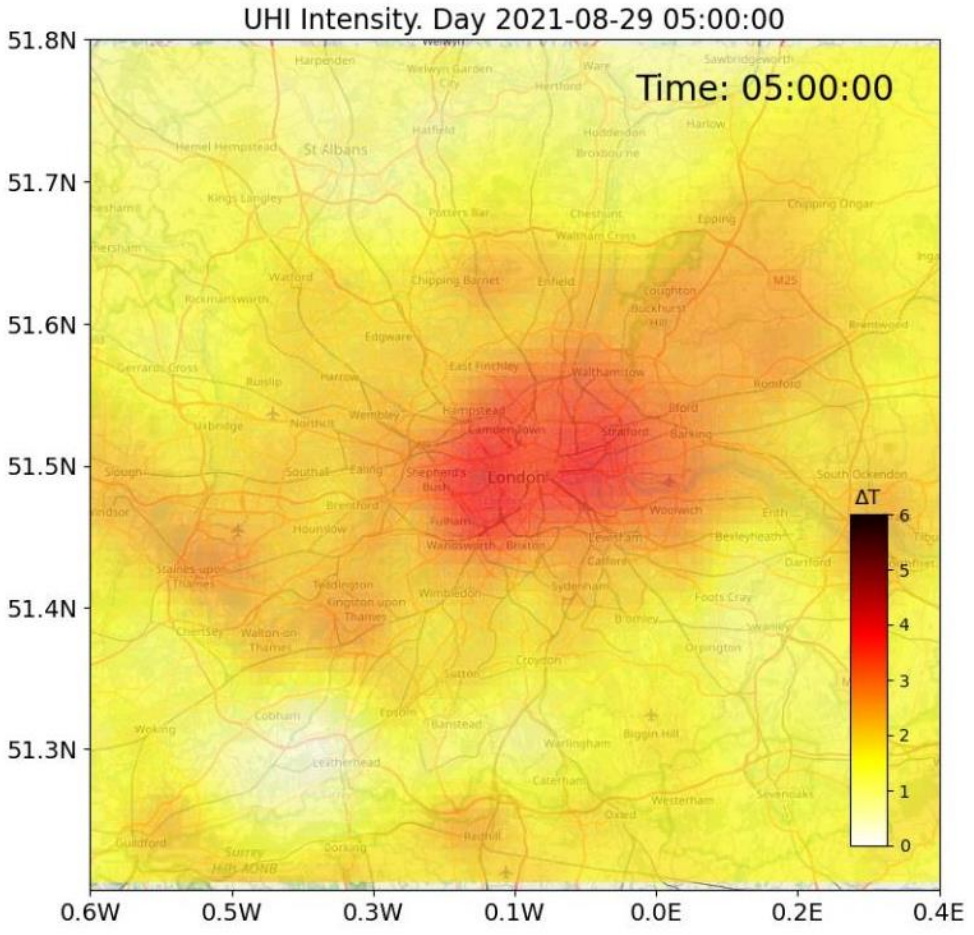

LONDON, UK

Lizana et al. (2022) – Citizens weather stations data for urban climate studies (pending)

1 – Heat dissipation

Resilient cooling

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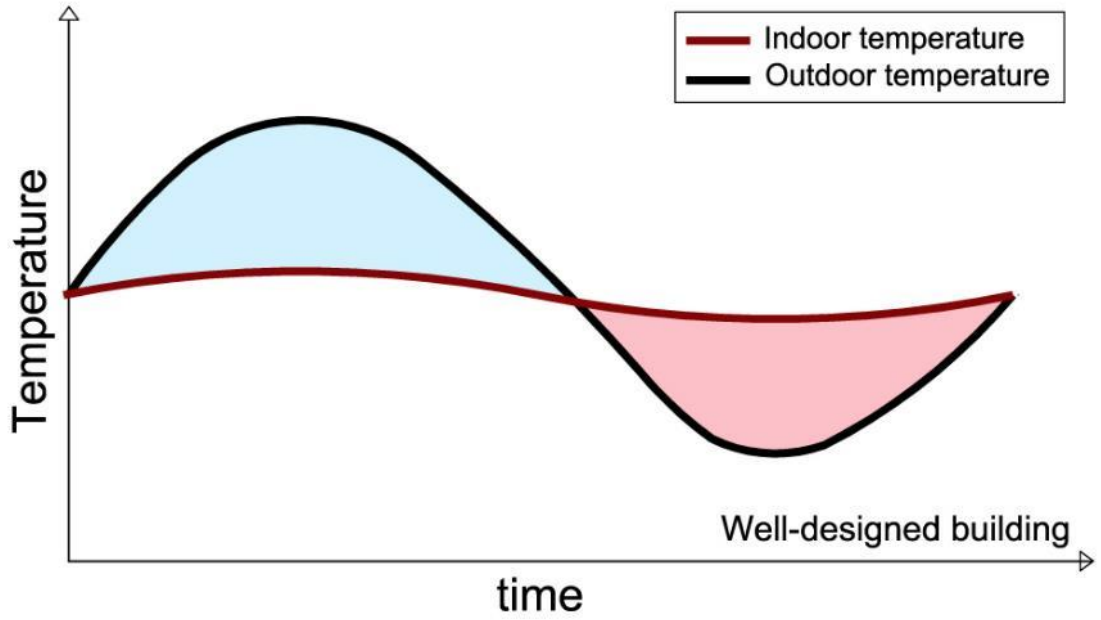
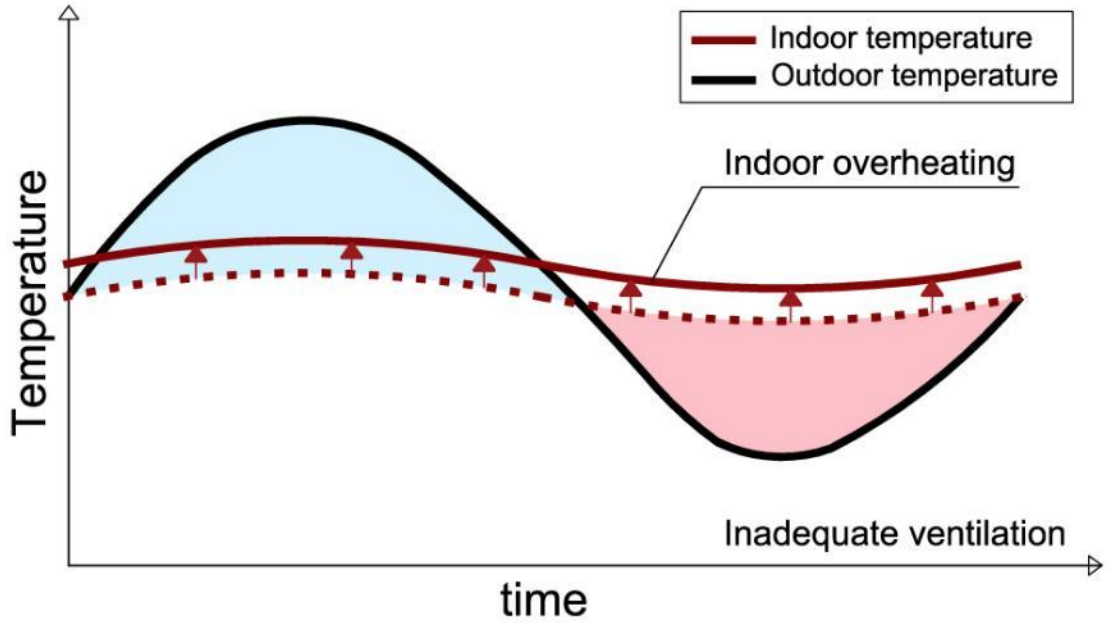


Comparison between indoor and outdoor temperature

1 – Heat dissipation

Resilient cooling

Heat dissipation | Heat modulation | Solar and heat prevention



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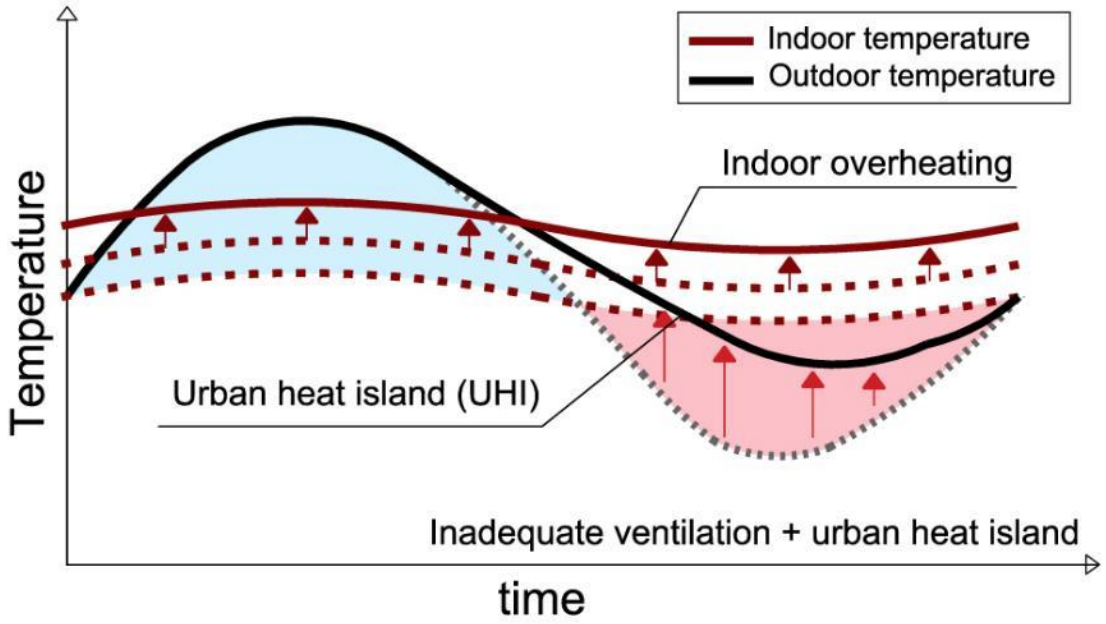

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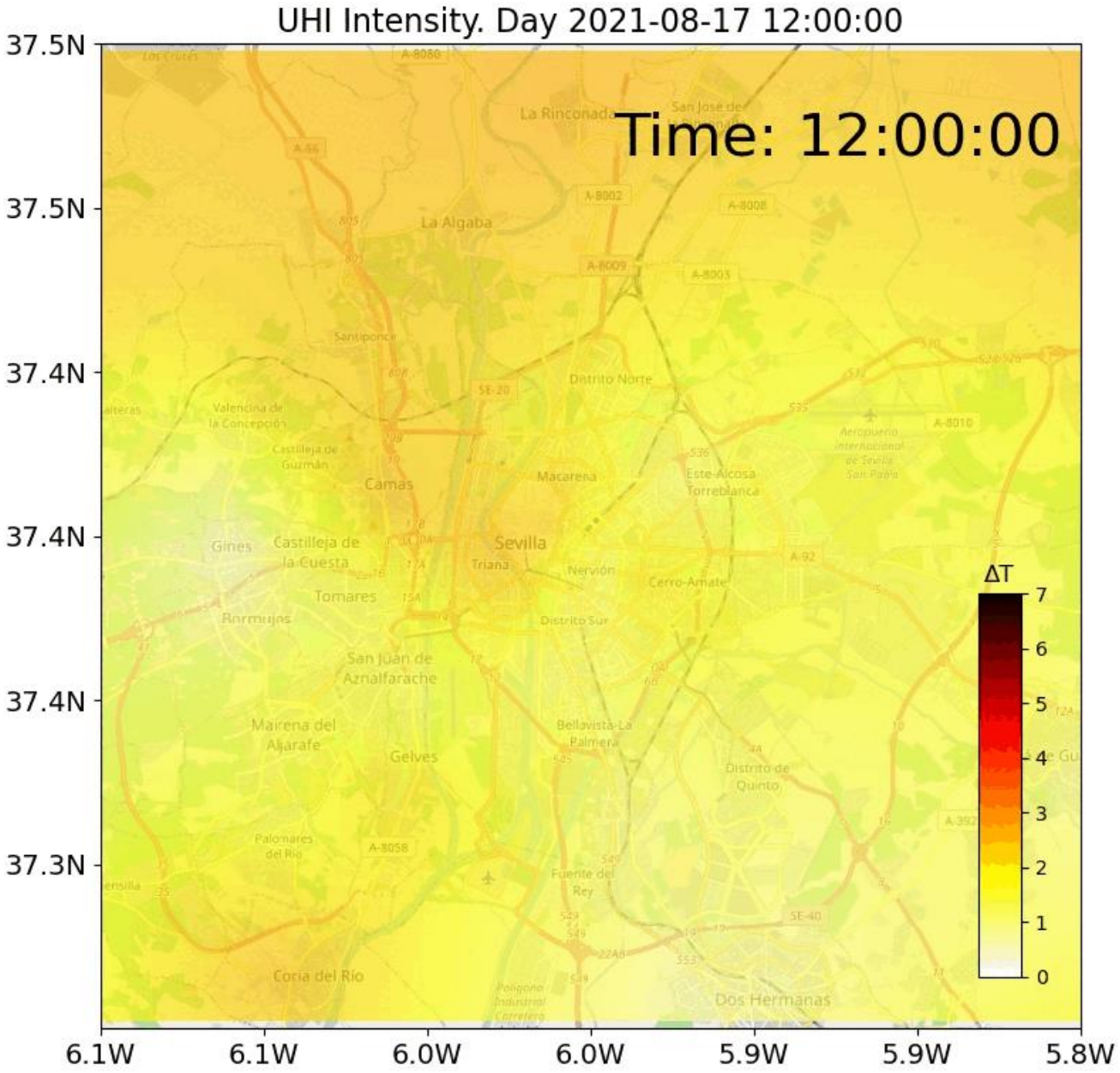


SEVILLE, Spain

Lizana et al. (2022) – Citizens weather stations data for urban climate studies (pending)

HOW TO INCREASE THE HEAT RESILIENCE OF BUILDINGS?

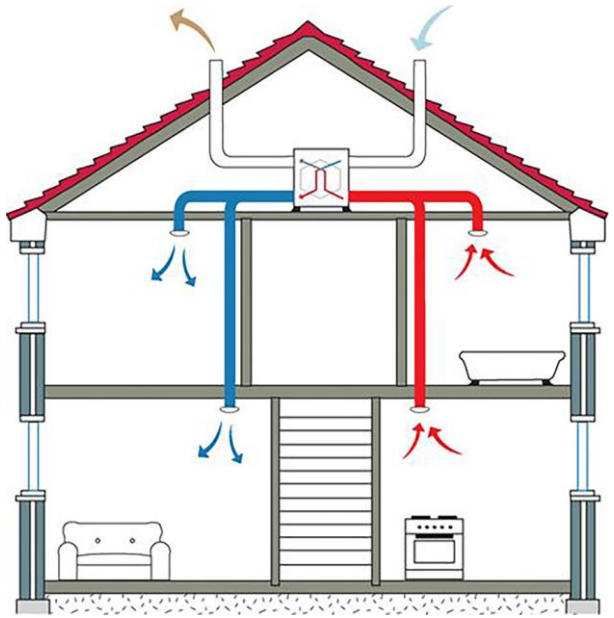
HOW TO INCREASE THE HEAT RESILIENCE OF BUILDINGS?

$$Q_{ven_i} = \boldsymbol{ACH_i} \cdot V \cdot \rho \cdot c_p \left(\mathbf{T_{out_i}} - T_{ind_i} \right)$$

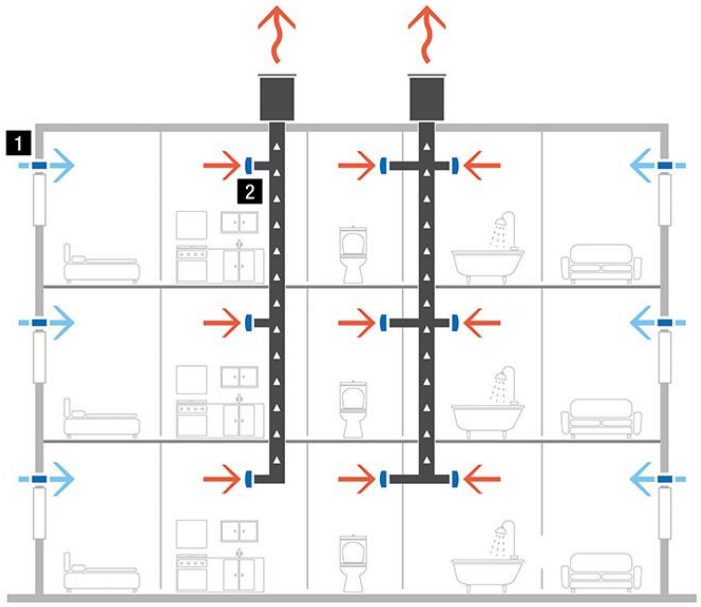
Air changes

Urban temperature

Current mechanical or hybrid ventilation systems – limited to minimum ventilation required



Mechanical ventilation with heat recovery system

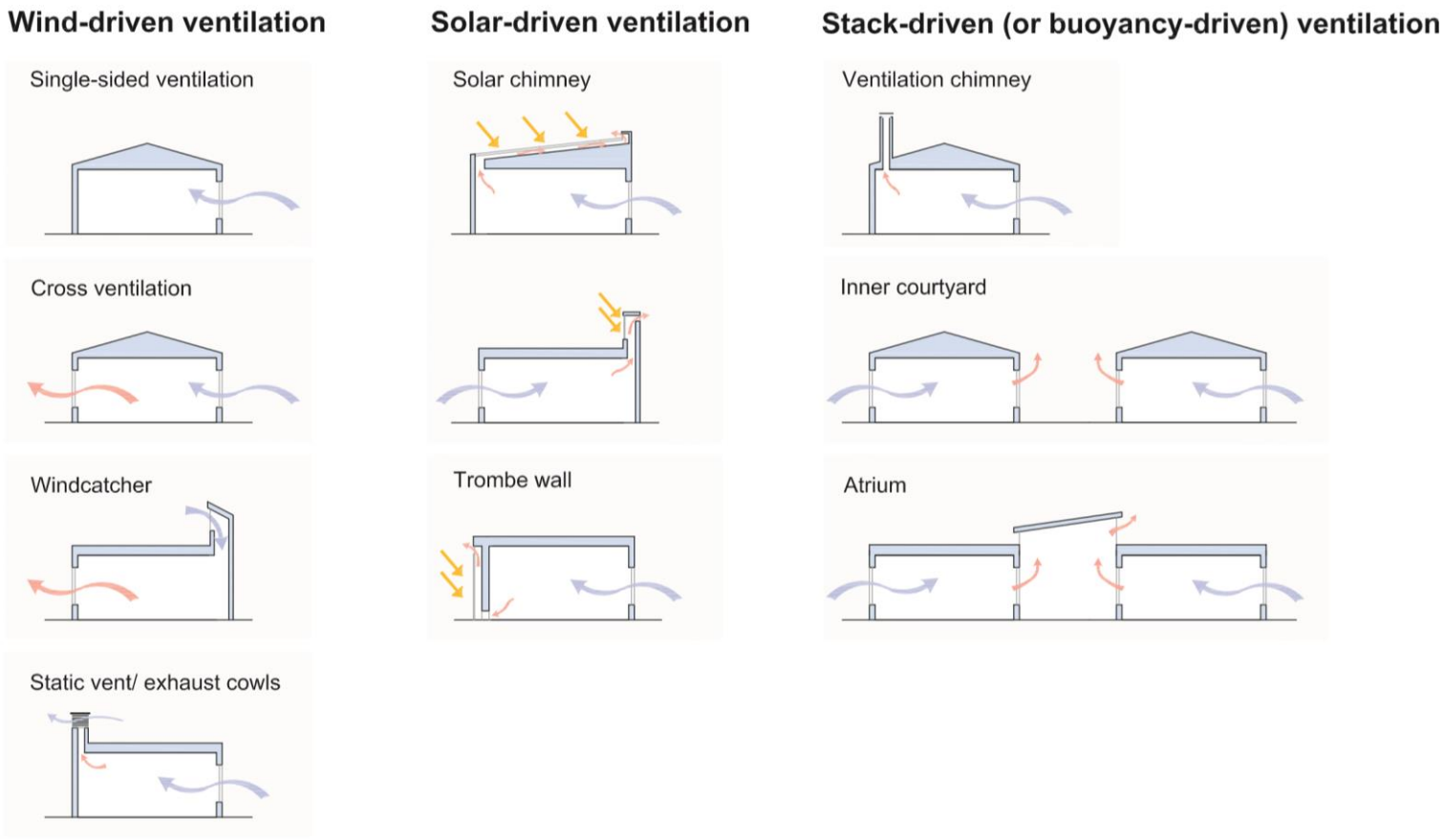


Hybrid ventilation

https://www.bpcventilation.com/blog/do-heat-recovery-systems-work/
https://www.aereco.com/ventilation/ventilation-systems/hybrid-ventilation/

Actions in building design:

Natural ventilation alternatives to achieve higher air changes (ACH) for heat dissipation



Khan, N., Su, Y., & Riffat, S. B. (2008). A review on wind driven ventilation techniques. Energy and Buildings, 40(8), 1586–1604. https://doi.org/10.1016/j.enbuild.2008.02.015
Neila-González, F. J. (2004). *Arquitectura bioclimática en un entorno sostenible*. MUNILLALERIA.
Dirección General de Arquitectura y Vivienda (Ed.). (1997). Arquitectura y Clima en Andalucía. Manual de diseño. Junta de Andalucía. Consejeria de Obras Públicas y Transportes.
https://www.bbc.com/future/article/20210810-the-ancient-persian-way-to-keep-cool

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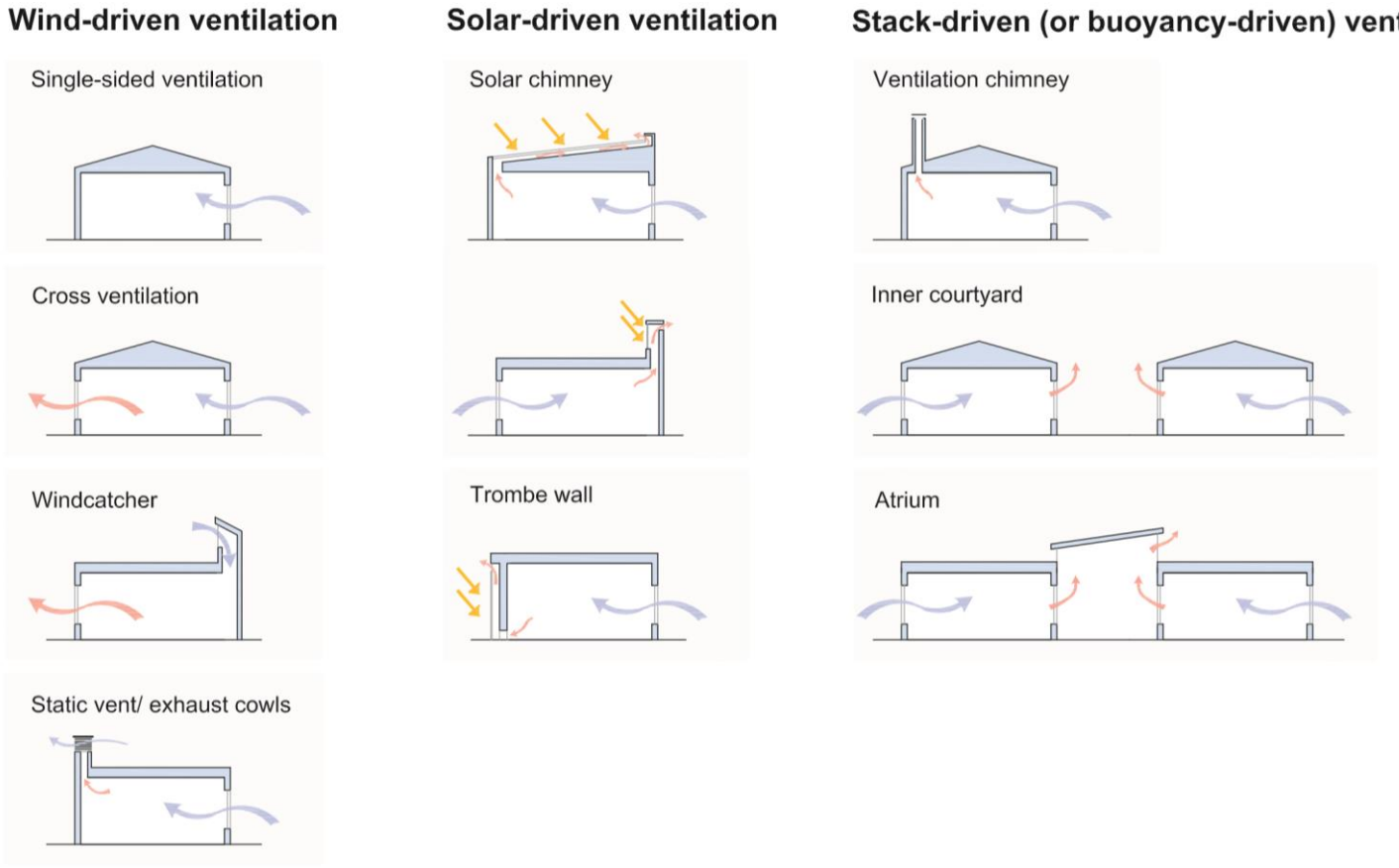

The wind catchers of Iran
The ancient Persian way to keep cool

Khan, N., Su, Y., & Riffat, S. B. (2008). A review on wind driven ventilation techniques. Energy and Buildings, 40(8), 1586–1604. https://doi.org/10.1016/j.enbuild.2008.02.015
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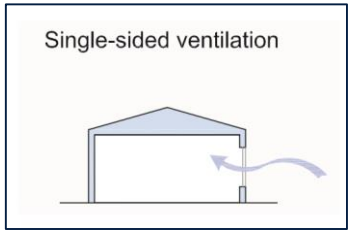
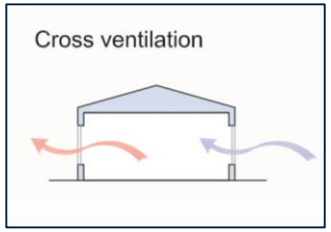
https://www.bbc.com/future/article/20210810-the-ancient-persian-way-to-keep-cool

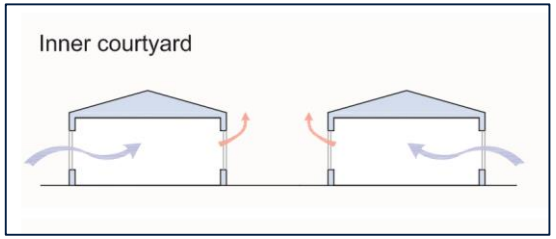
Home 1



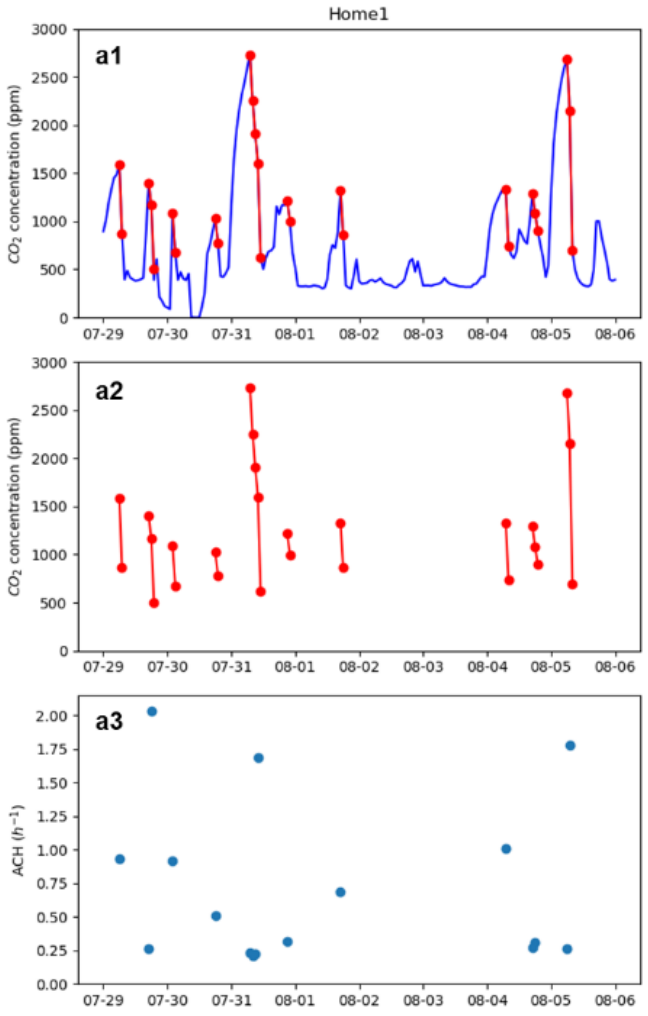
Home 2



Home 3

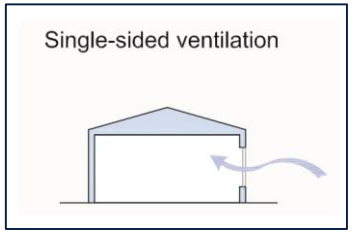


García, E., Lizana, J (2022) Monitoring and analytics to support passive building retrofit (pending)

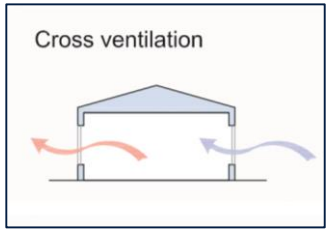


CO_2-based decay method to measure natural ventilation rate

Home 1



Home 2



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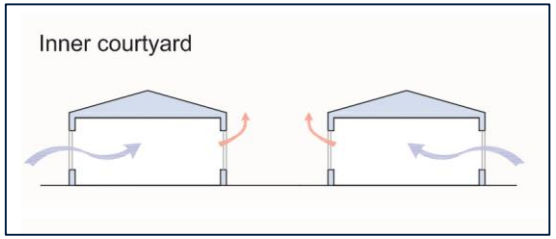
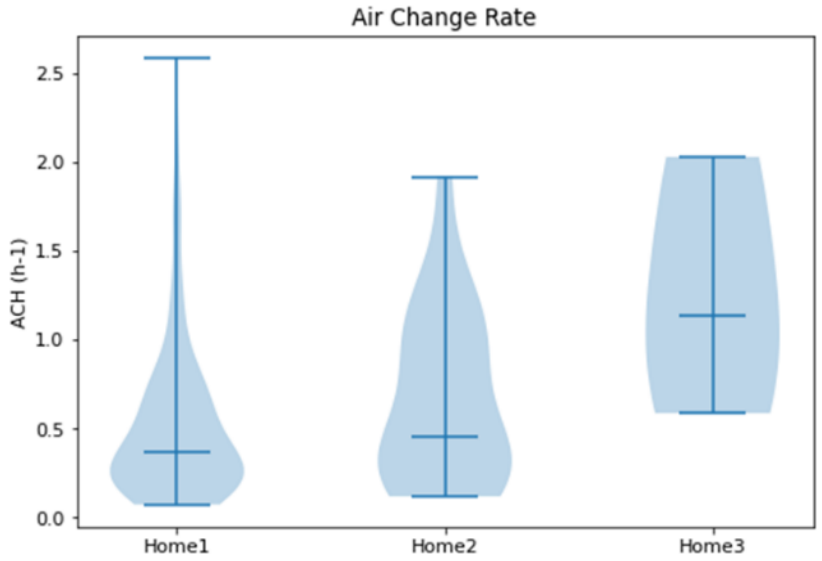




Adequate building design can increase heat dissipation by more than double

García, E., Lizana, J (2022) Monitoring and analytics to support passive building retrofit (pending)

Actions in urban design:

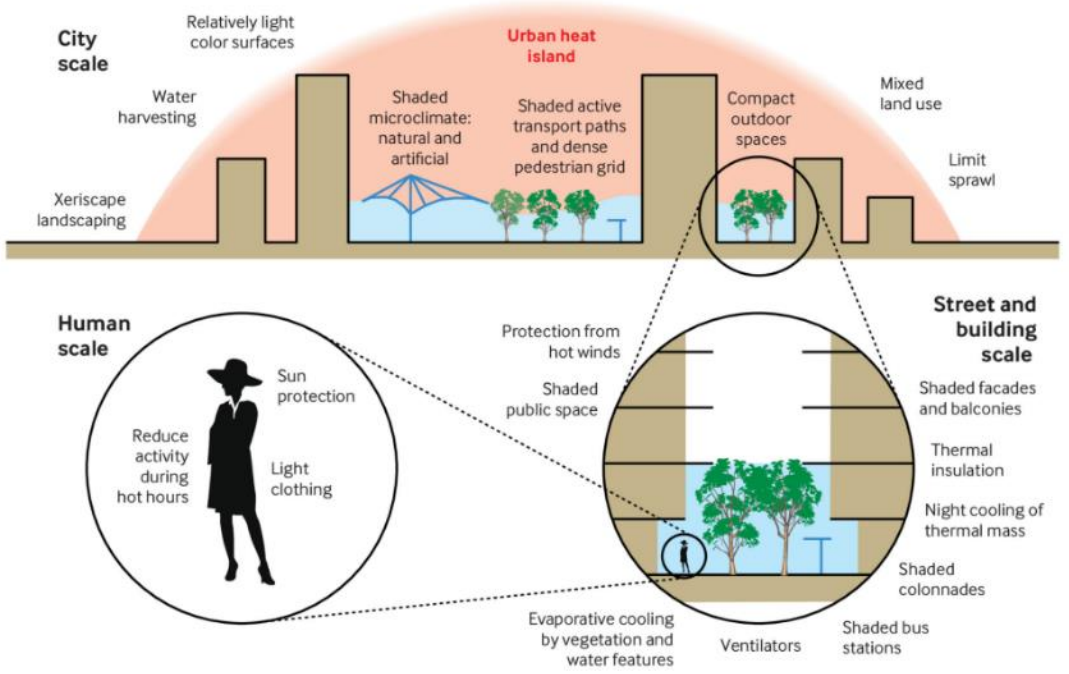
Urban planning less car-centric

Land surface:
-Shades
-Evaporative cooling
-Solar reflection

→ Nature based solutions or Artificial solutions

Waste heat
-Transport sector
-Building sector

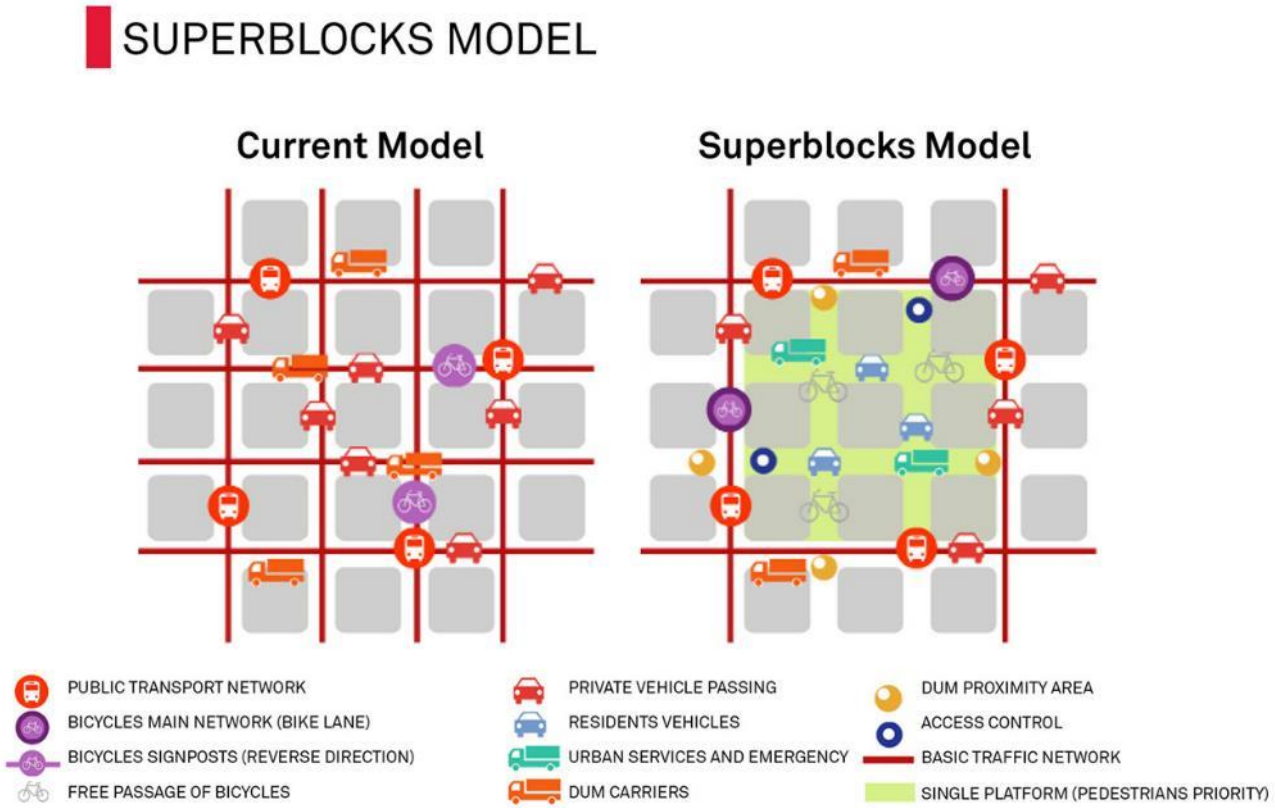
→ Alternatives to heat rejection



City, street, and building, and human scale means for designing a healthy city in hot and dry climate.

Negev, M., Khreis, H., Rogers, B. C., Shaheen, M., & Erell, E. (2020). City design for health and resilience in hot and dry climates. The BMJ, 371(November), 1–7. https://doi.org/10.1136/bmj.m3000

Example - the case of Superblocks (Barcelona, Spain)



https://barcelonarchitecturewalks.com/superblocks/
https://www.domestika.org/en/projects/187575-supermanzana-en-barcelona

2 – Heat modulation

Resilient cooling

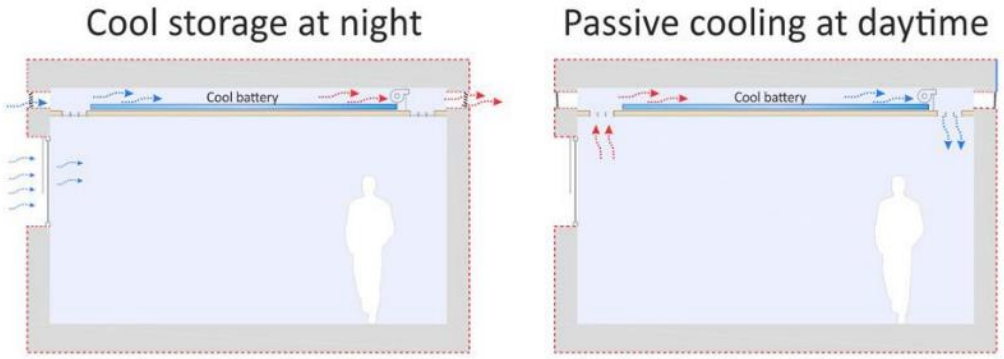
Heat dissipation | **Heat modulation** | Solar and heat prevention

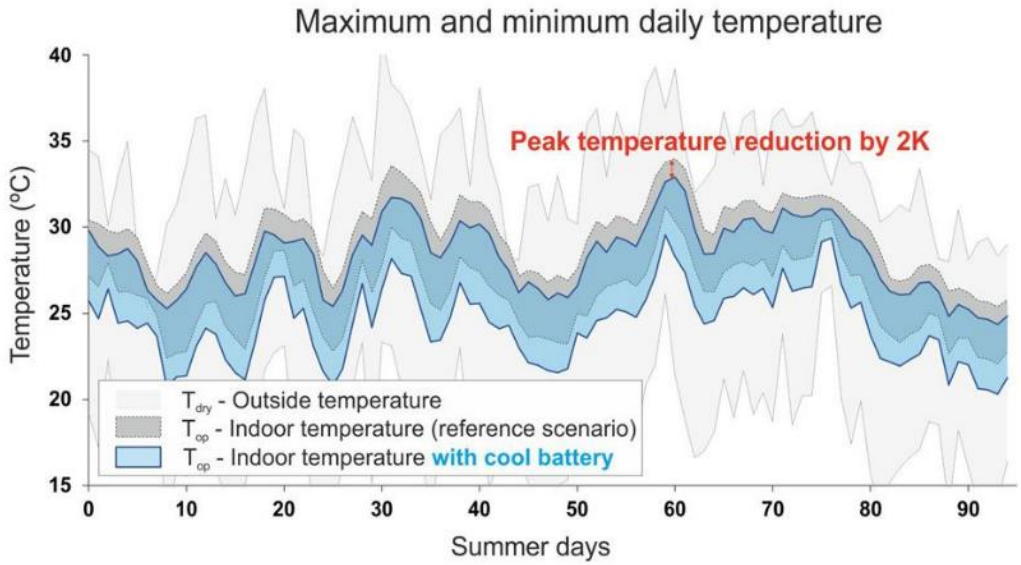
Building thermal mass

2 – Heat modulation

Resilient cooling

Heat dissipation | **Heat modulation** | Solar and heat prevention





Heat modulation can reduce discomfort hours by up to 65%.

It is highly dependent on:

- thermal energy storage capacity;
- minimum temperature at night;
- and convective heat transfer rate.

Lizana, J., et al., 2019. Passive cooling through phase change materials in buildings. A critical study of implementation alternatives. Applied Energy 254, 1–17. https://doi.org/10.1016/j.apenergy.2019.113658

3 – Solar and heat protection

Resilient cooling

Heat dissipation | Heat modulation | **Solar and heat prevention**

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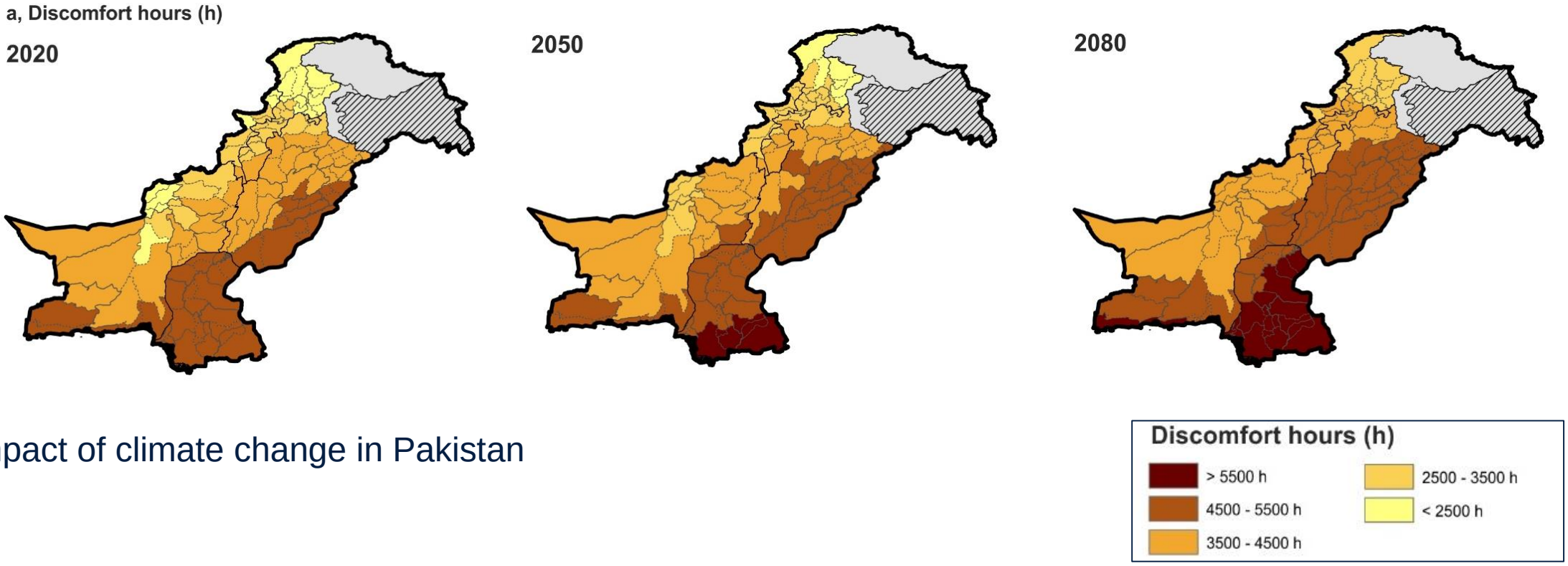
Resilient cooling

Heat dissipation | Heat modulation | **Solar and heat prevention**



Impact of climate change in Pakistan

Sajid and Lizana (2022) – Resilient cooling for extremely hot countries (pending)

3 – Solar and heat protection

Resilient cooling

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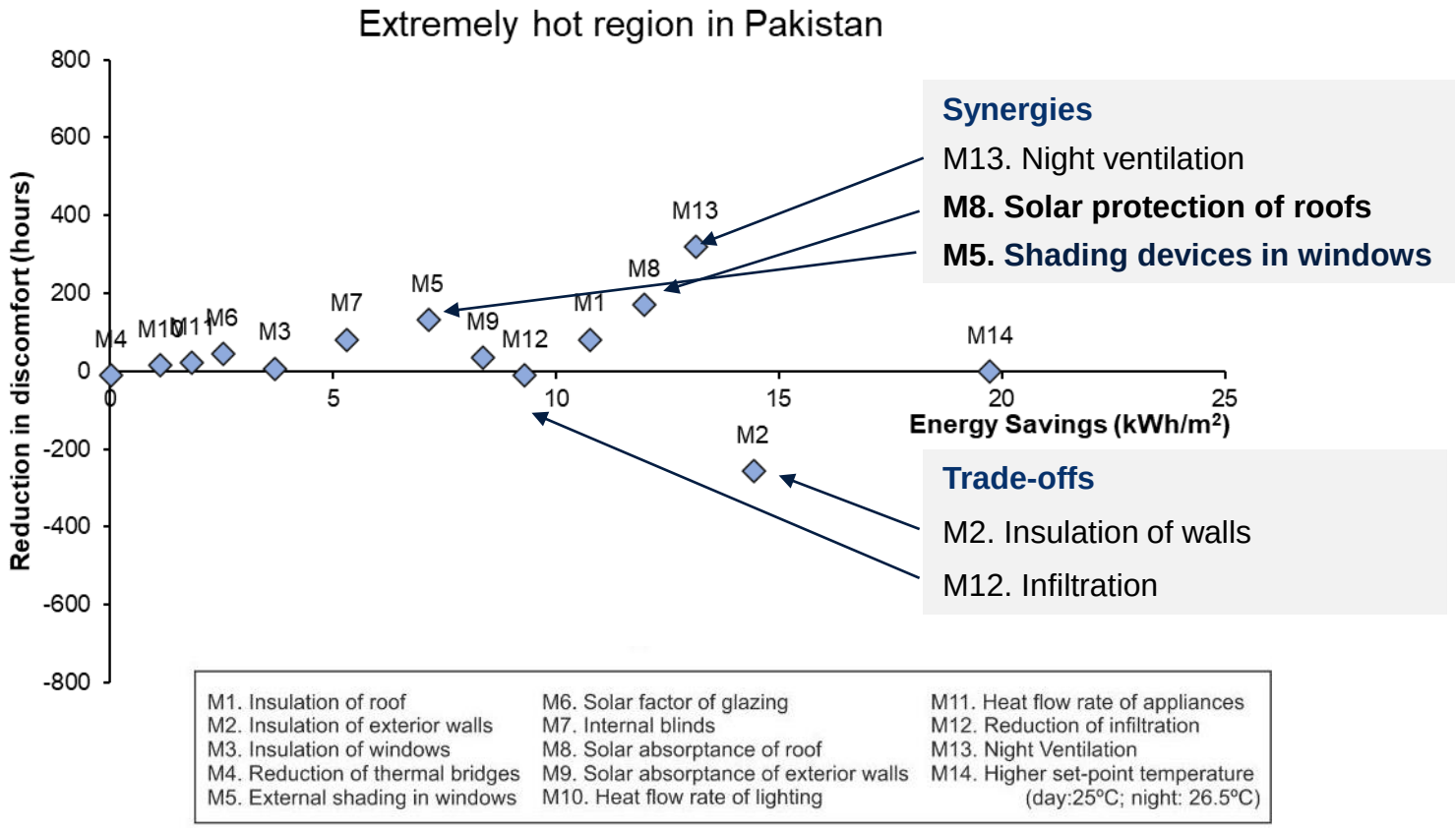


Effect of resilient cooling techniques on energy savings and reduction of discomfort hours

Solar protection on roofs and shading devices in windows can mitigate discomfort hours by 4-7% (and energy by 8-15%).

Sajid and Lizana (2022) – Resilient cooling for extremely hot countries (pending)

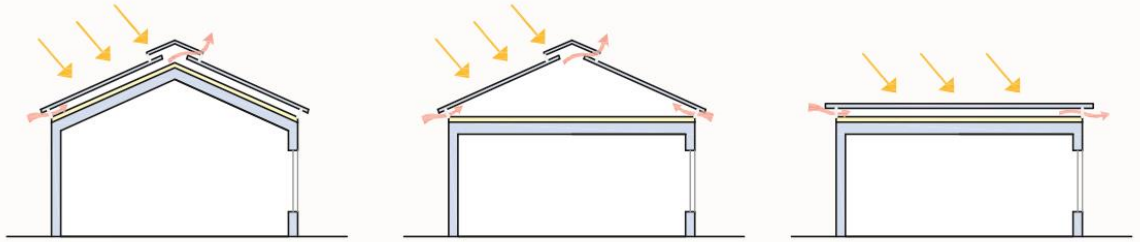
3 – Solar and heat protection

Resilient cooling

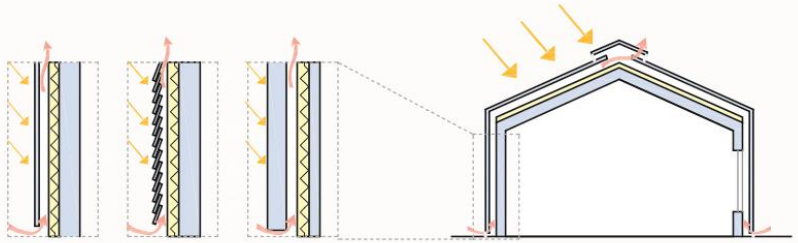
Heat dissipation | Heat modulation | **Solar and heat prevention**

Opaque surfaces

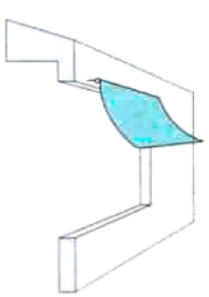
Ventilated and reflective roofs



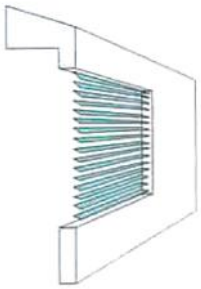
Ventilated and reflective walls



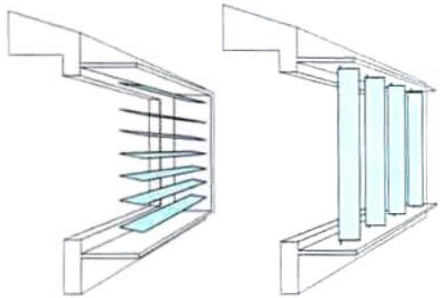
Openings



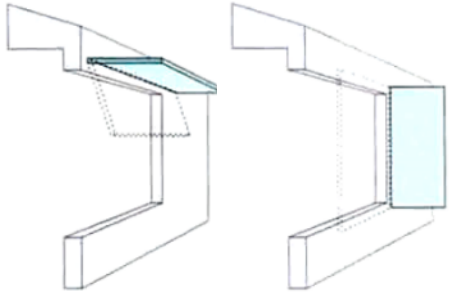
Awning



External blinds
External roller shutters

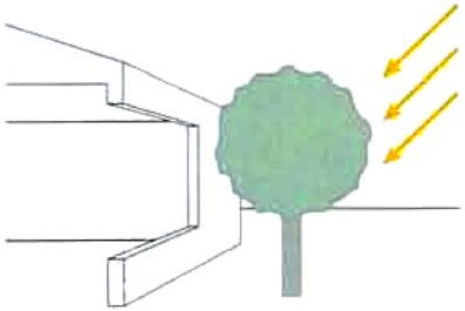


Vertical louvers or fins
Horizonal louvers or fins



Horizontal overhand
Vertical overhang

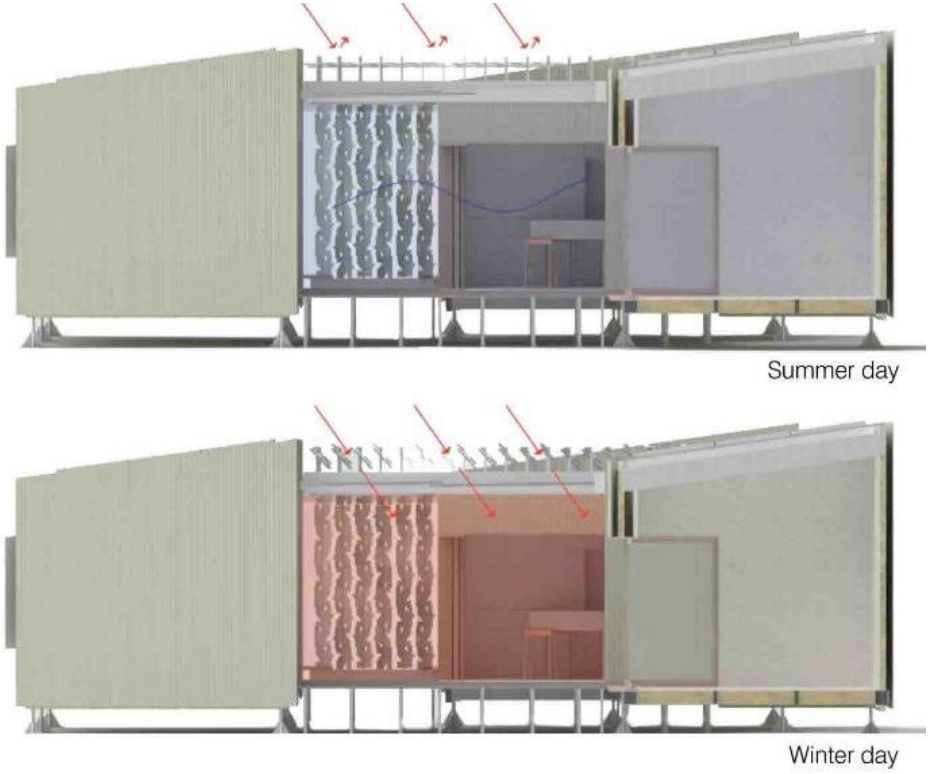
Shrubs and tree shade

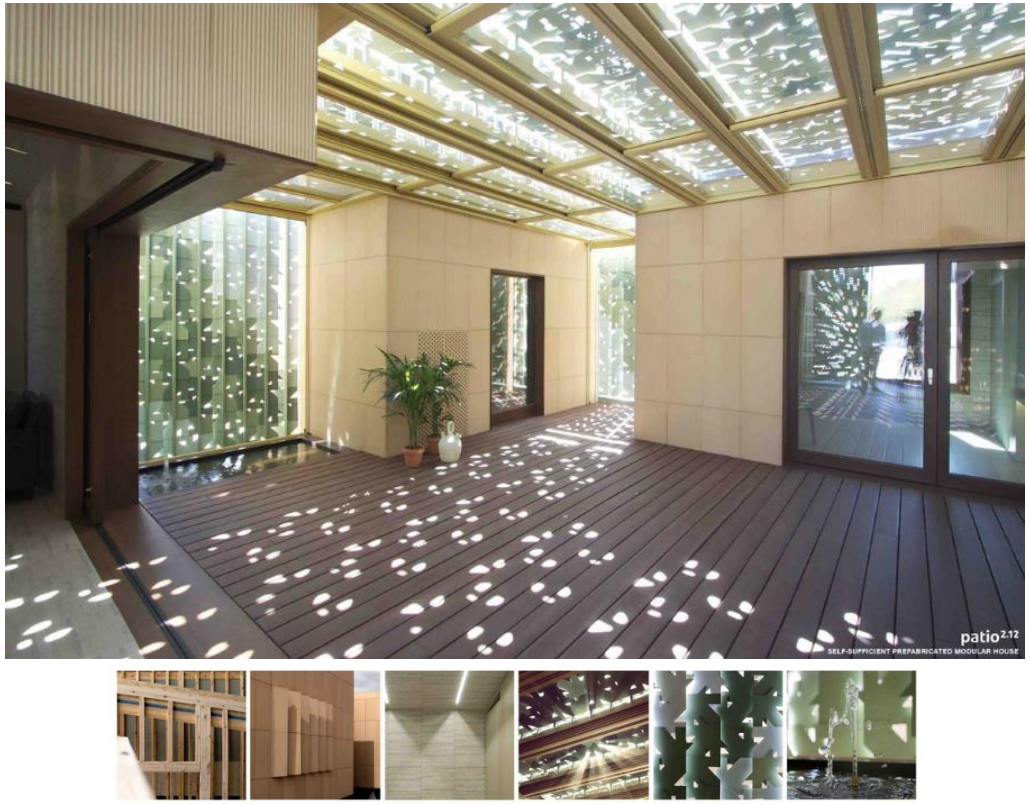


External obstacles

Route of the white villages in Spain

Climate responsive house - Patio 2.12
Solar Decathlon Competition 2012

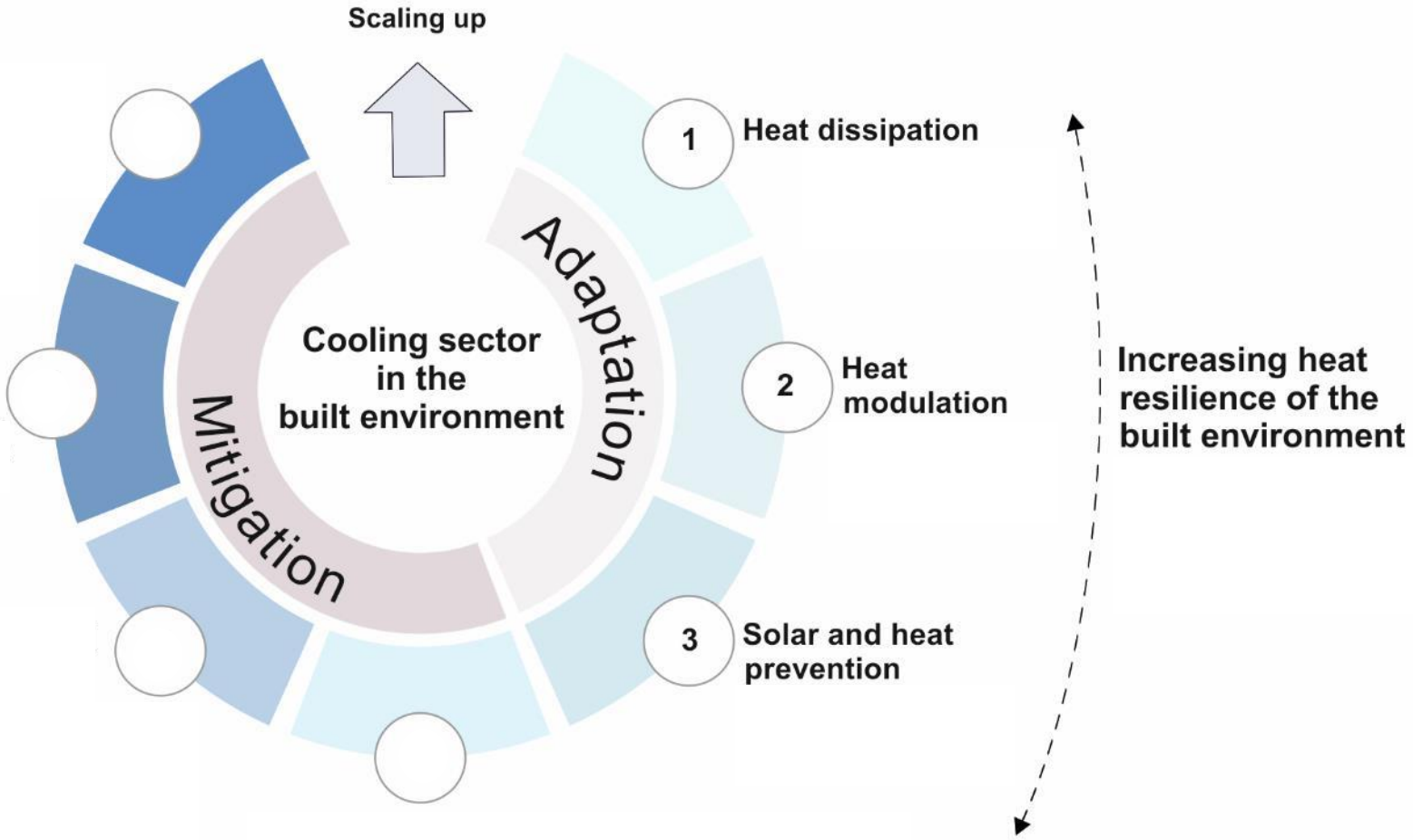




Building design considering heating and cooling as a whole

Patio 2.12. Self-sufficent and prefabricated modular house for Solar Decathlon Competition 2012. Andalucia Team (Spain)

THE ZERO-CARBON AND RESILIENT COOLING PATHWAY



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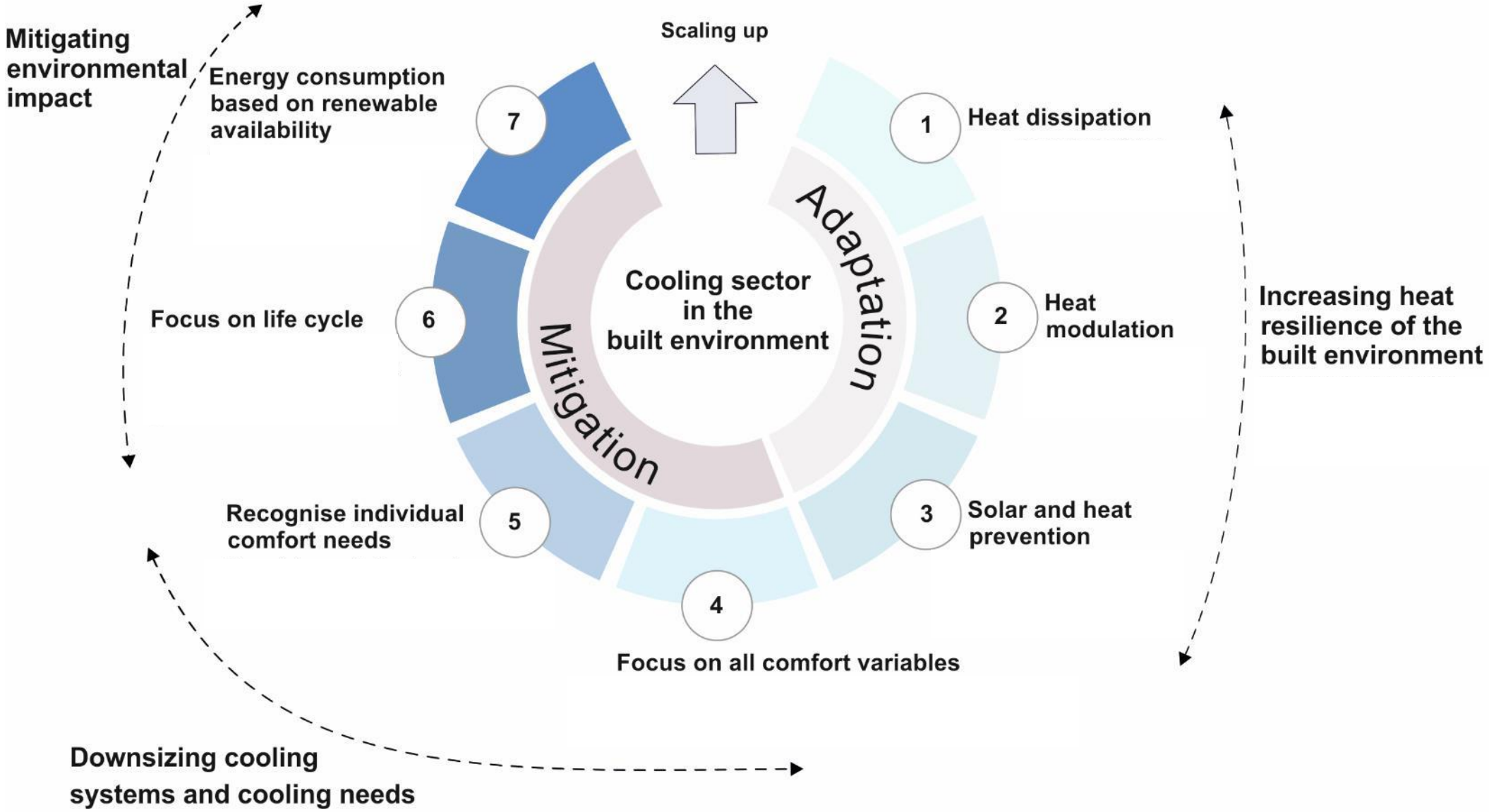

ResCool

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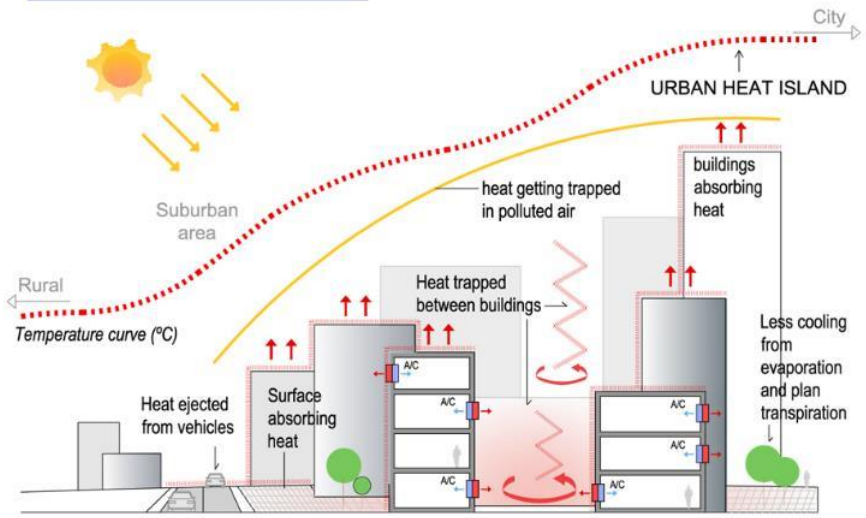

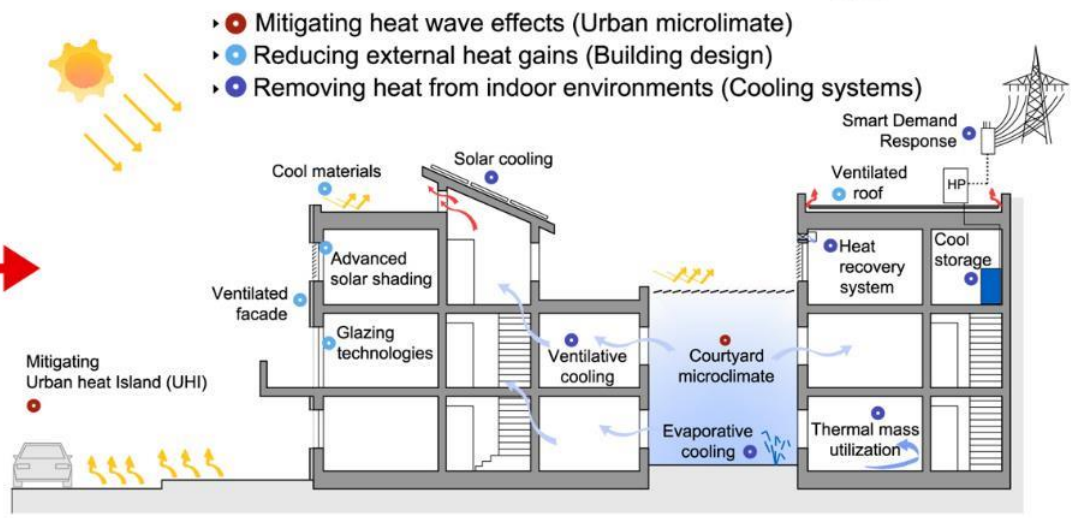

Climate risk assessment → **Climate risk mitigation**

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

European Commission | HORIZON 2020

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

Oxford Future of Cooling Programme
@OxfordCooling

THE ZERO-CARBON AND RESILIENT COOLING PATHWAY