

# London's climate futures: Beyond the envelope

CIBSE Resilient Cities Group  
24 March, 2026.

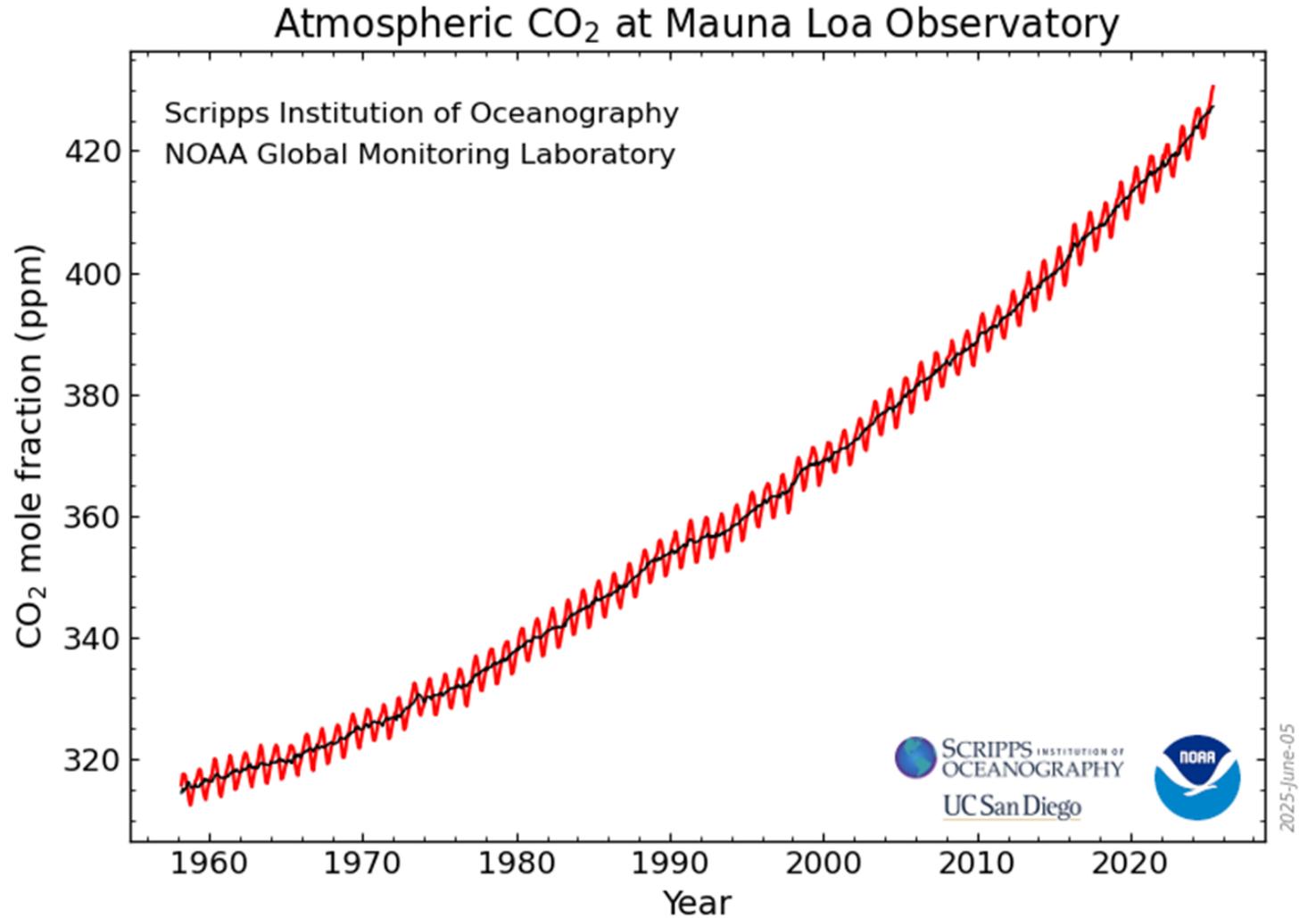
Gerald Mills UCD (Ireland)



Resilient Cities

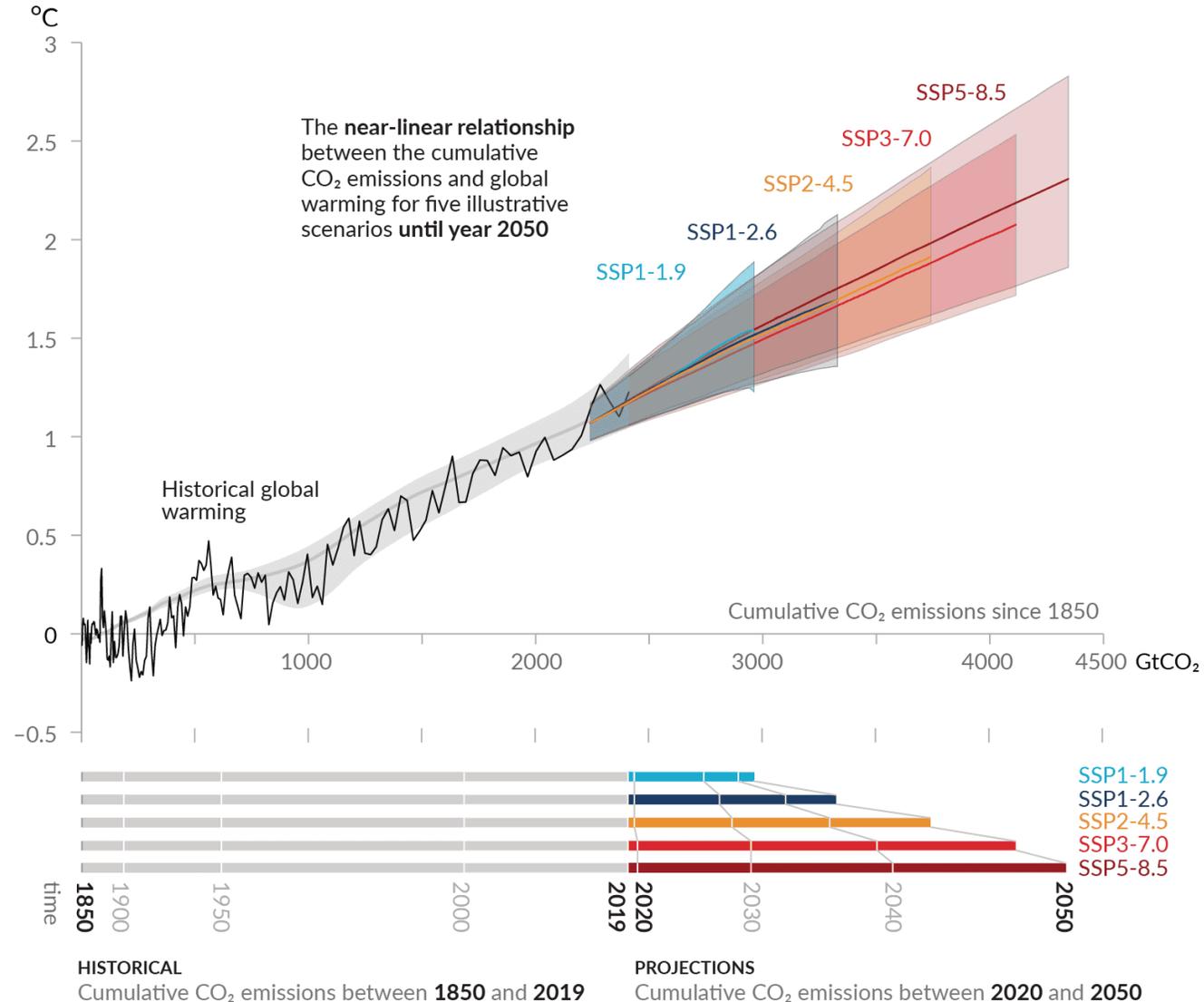
# Structure

1. Climate climate change
2. Urban climate effects
3. London & climate change
4. Discussion



# Every tonne of CO<sub>2</sub> emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO<sub>2</sub> emissions (GtCO<sub>2</sub>)

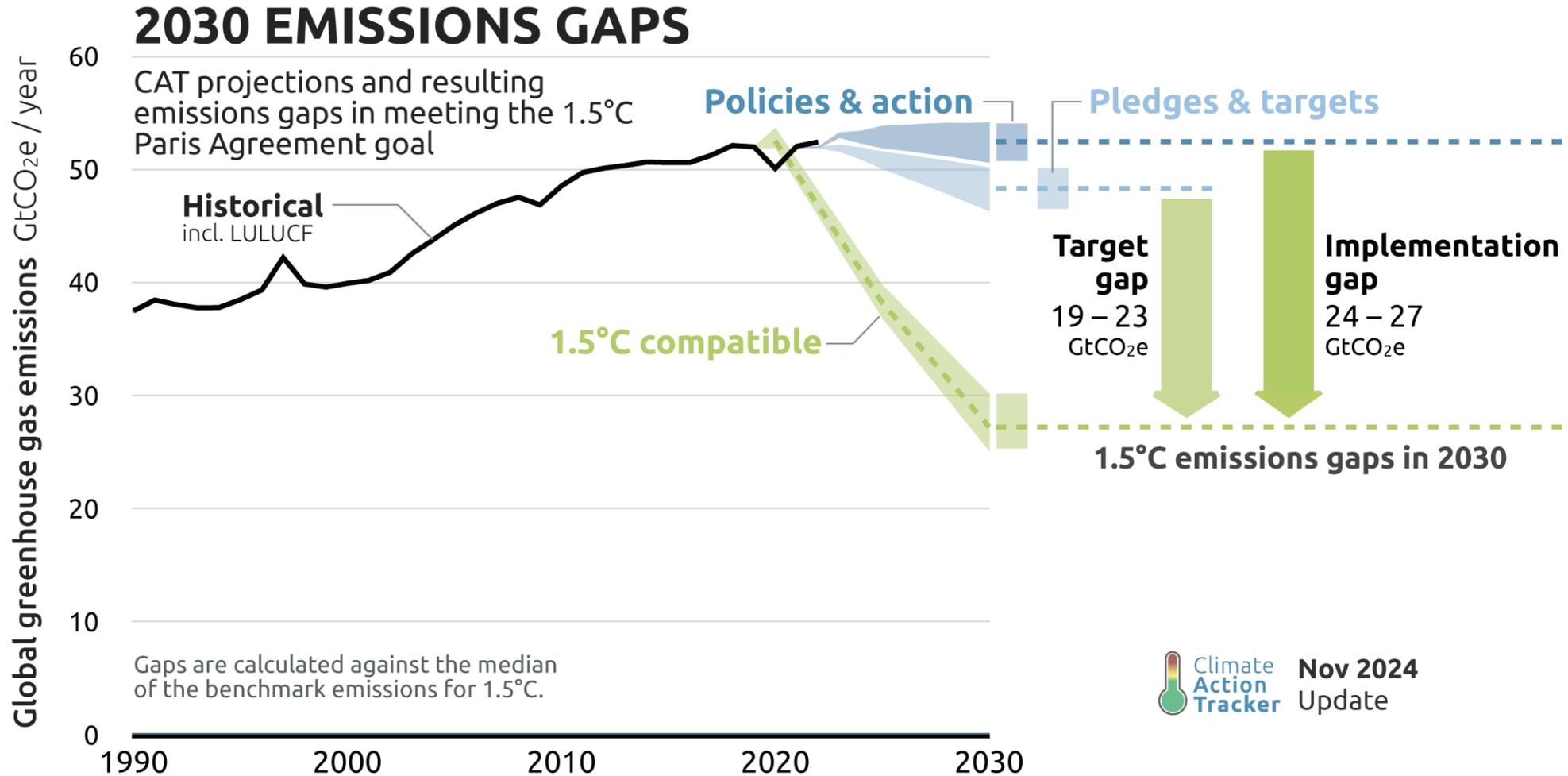


Accumulated (stored) CO<sub>2</sub>eq in the atmosphere and temperature change. A CO<sub>2</sub> molecule has a residence time in the atmosphere of >100 years.

Future temperature changes depends on the economic pathway (ssp) taken, which results in different outcomes (indicated by the radiative forcing)

Figure SPM.10 in IPCC, 2021

# The Paris Agreement and the 1.5°C limit

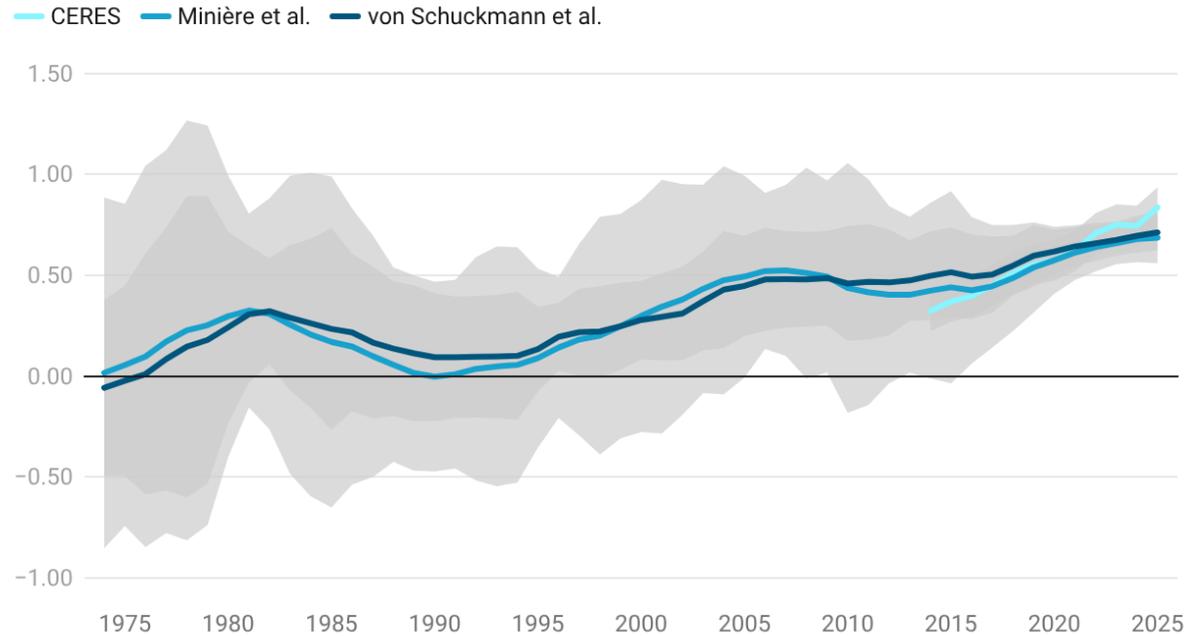


The agreement was to limit global warming to <2°C (compared to pre-industrial levels). This requires a radical reduction in GHG emissions.

# WMO State of the Global Climate 2025

## Earth's Energy Imbalance

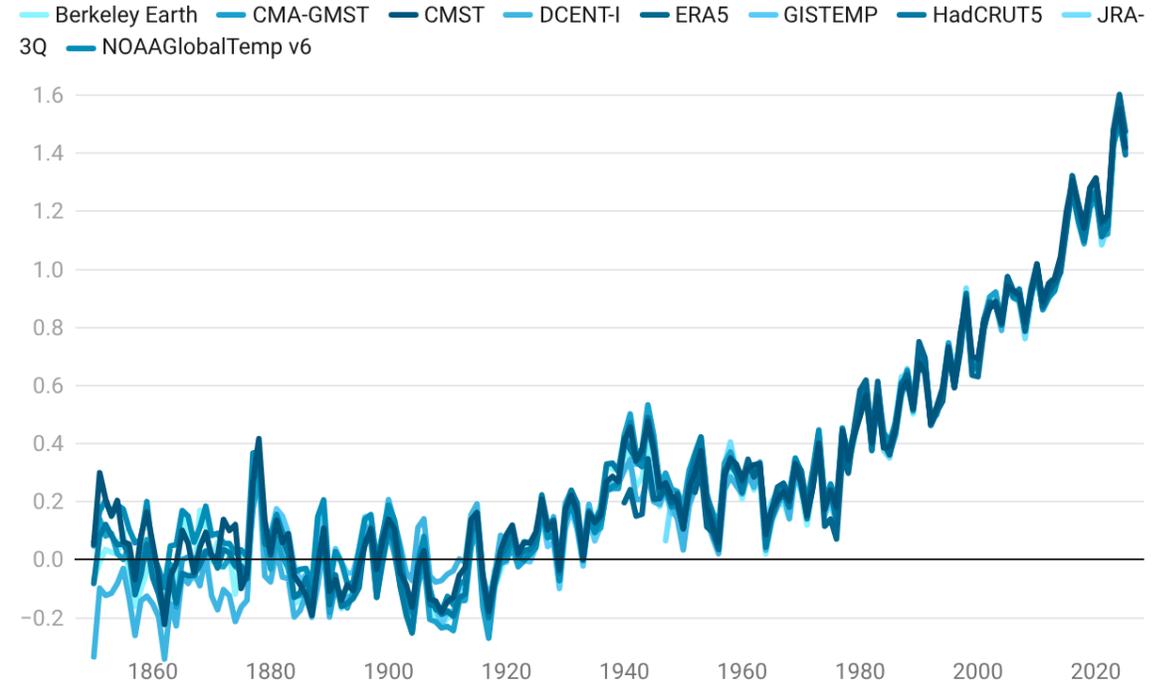
Measured in Watts per squared metre



Source: WMO • Created with Datawrapper

## Global mean temperature 1850-2025

Difference from 1850-1900 average in °C



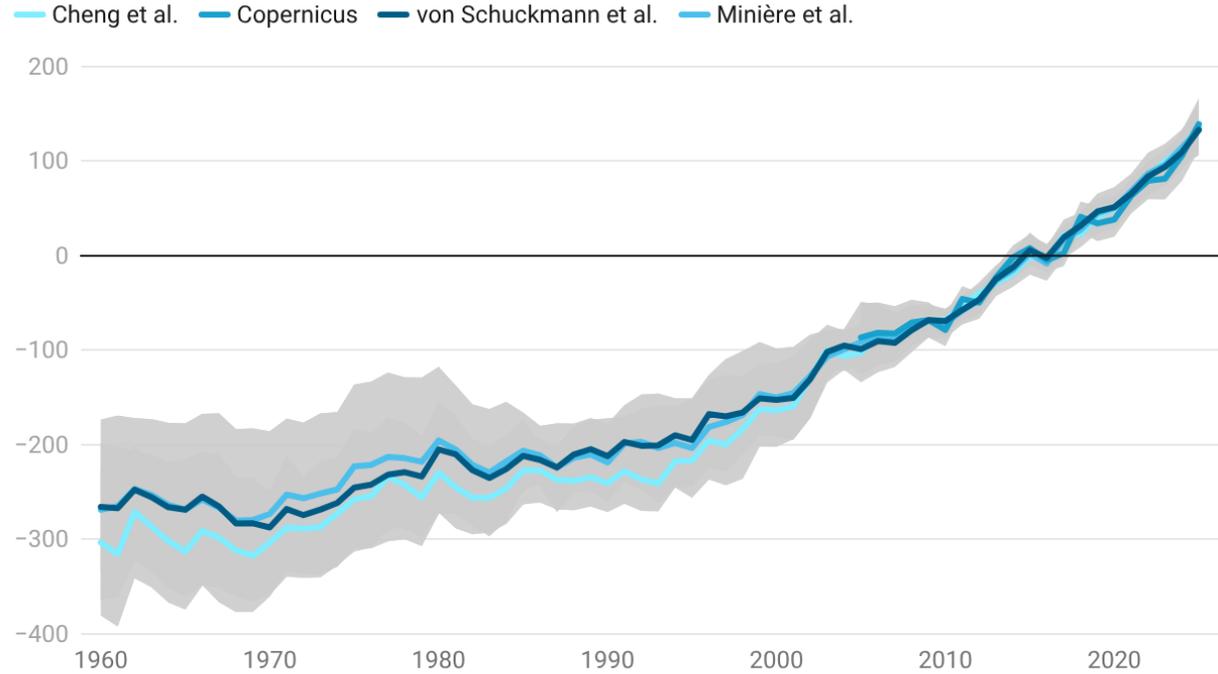
Source: WMO • Created with Datawrapper

The increased concentration of GHGs in the atmosphere is modifying the Earth's energy budget (increased heat storage), which results in global warming.

# WMO State of the Global Climate 2025

## Ocean heat content 0-2000m

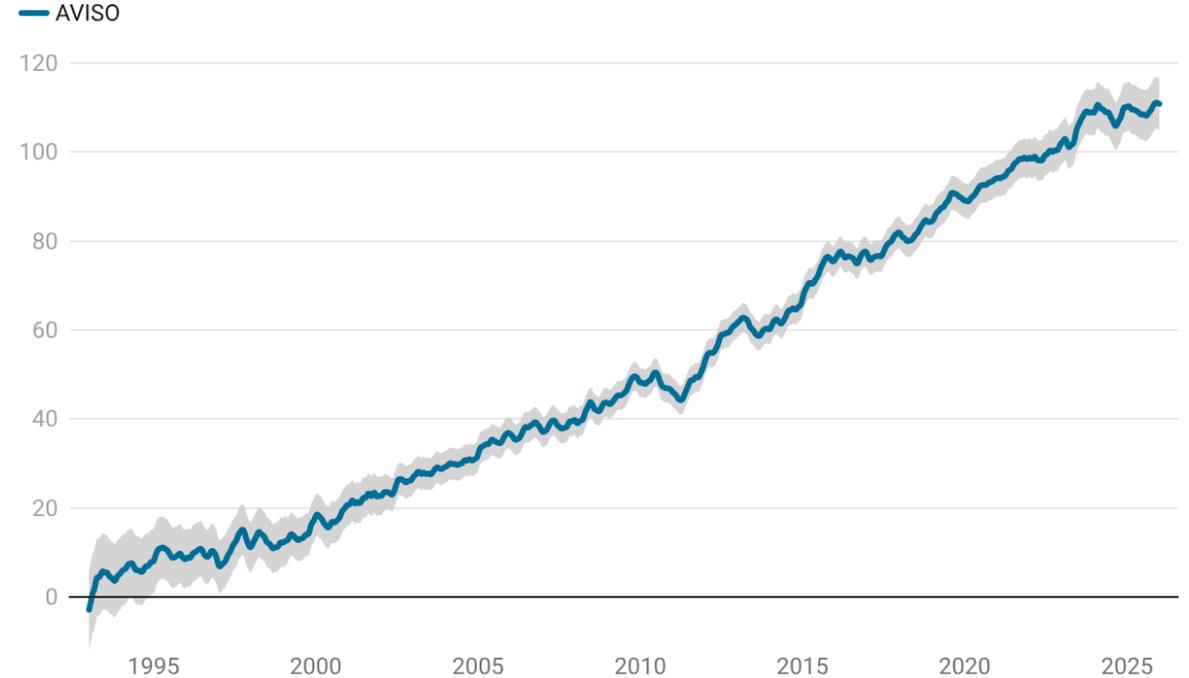
Difference from 2005-2025 average in zettajoules.



Source: WMO • Created with Datawrapper

## Global mean sea level change 1993-2025

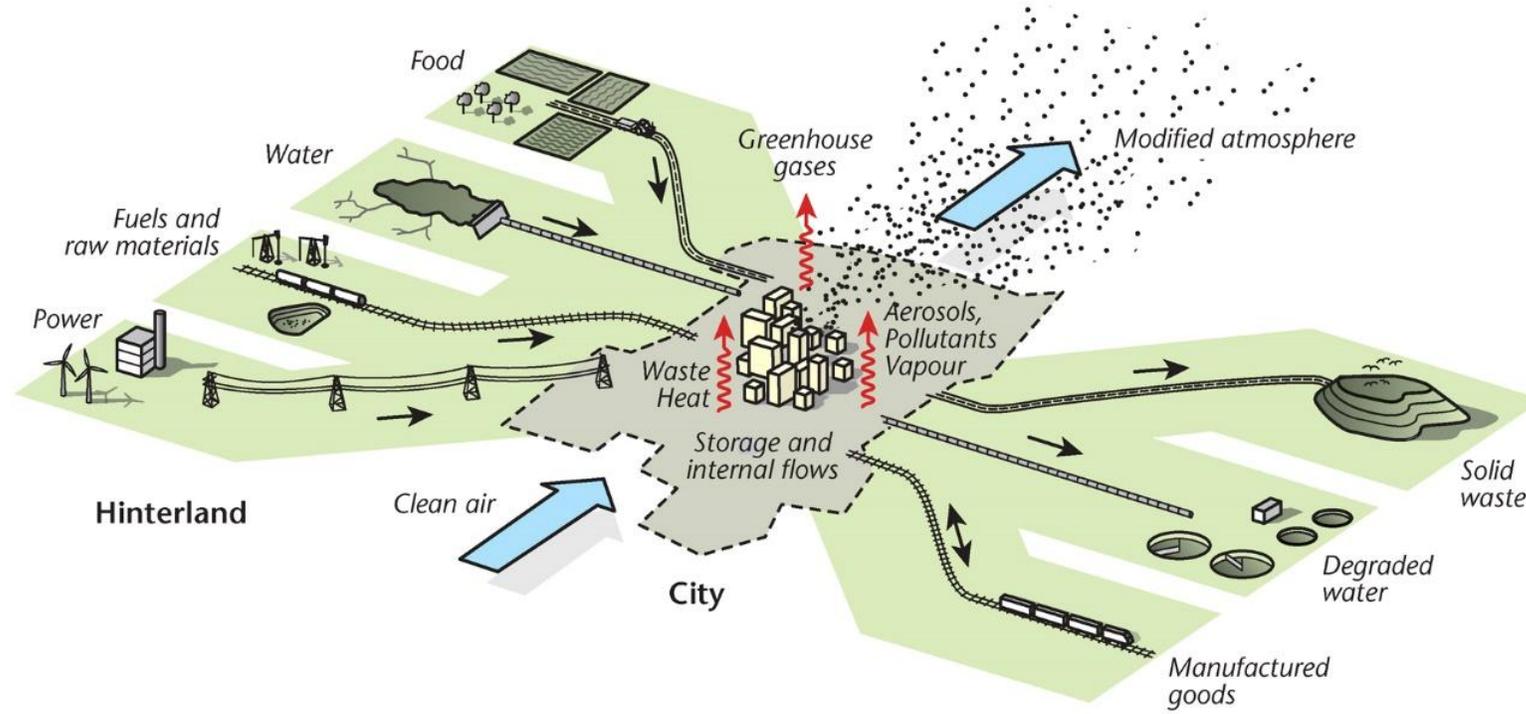
Change since 1993 in millimetres



Source: WMO • Created with Datawrapper

Much of stored heat is in the Oceans, which contributes to sea-level rise.

# Why cities?

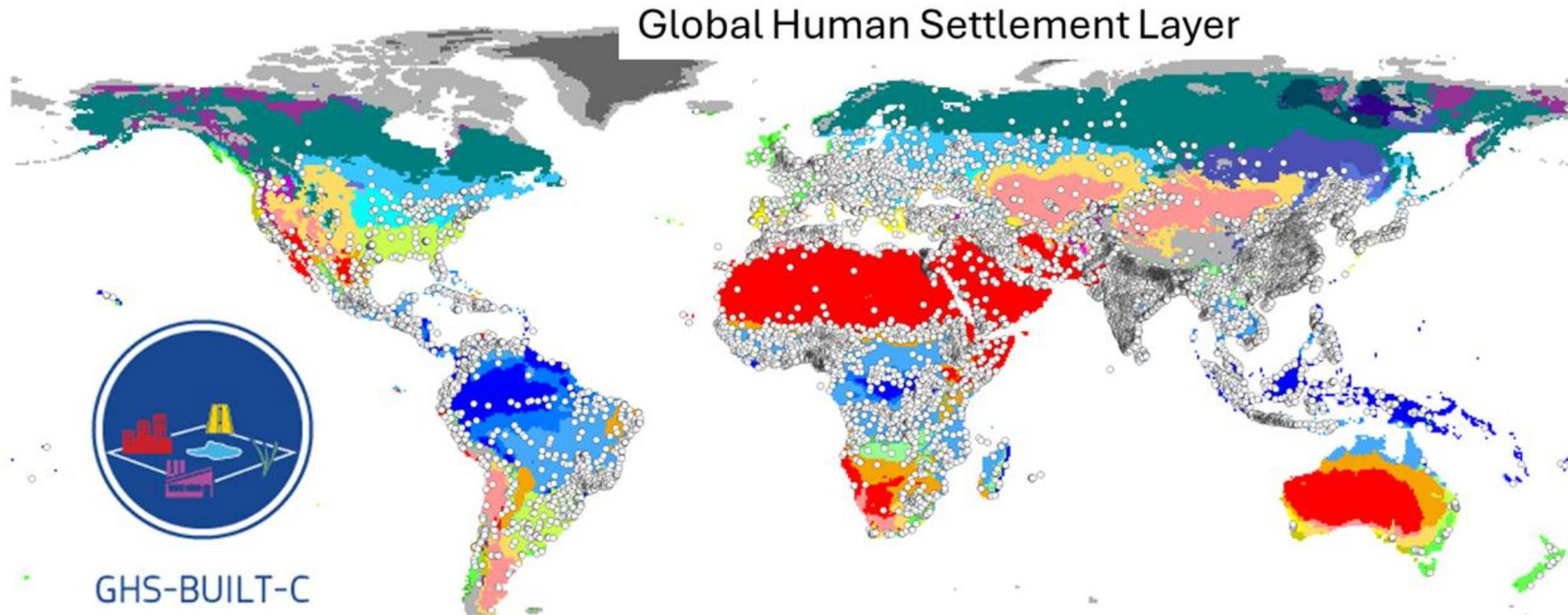


Cities are focussed areas of resource use and waste generation. Although urbanised areas occupy less than 3% of available land area, they are responsible for more than 70% of global CO<sub>2</sub> emissions.

Cities are especially exposed to the consequences of climate change owing to their geography, concentration of critical infrastructure and of built form.

Cities have management systems.

Cities are exposed to a range of natural hazards.



Most cities are located at low elevation along rivers (flooding)  
Many very large cities are situated along coastlines (flooding)  
Many very large cities are located in hot climates (heat stress)

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## COP30: cities prove what's possible when action meets implementation

STATEMENT November 20, 2025

**A new joint assessment from GCoM and C40 Cities reveals strong and accelerating growth in local climate implementation across CHAMP-endorsing countries.**

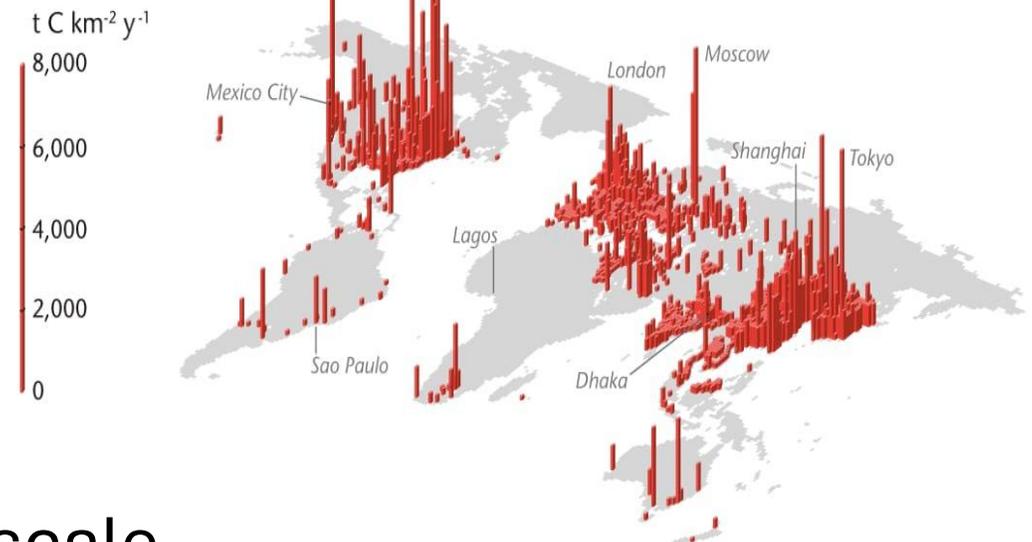
**Belém, Brazil (20 November 2025)** – As negotiations advance at COP30 to define the next era of climate ambition, a new joint assessment from the Global Covenant of Mayors for Climate and Energy (GCoM) and C40 Cities reveals a decisive global shift: cities are rapidly moving from pledges to real-world implementation, delivering climate results at a pace that already outstrip national progress.

Launched today at COP30, the findings demonstrate that local climate action is now an indispensable force for meeting the goals of the Paris Agreement and actively contributing to the UNFCCC's [Global Stocktake \(GST\)](#). The analysis provides strong evidence that empowering cities through multilevel governance is one of the most effective ways to close the ambition and implementation gap identified in the first Global Stocktake – particularly in countries endorsing the [Coalition for High Ambition Multilevel Partnerships \(CHAMP\)](#).

(a) Population density



(b) Carbon dioxide emissions

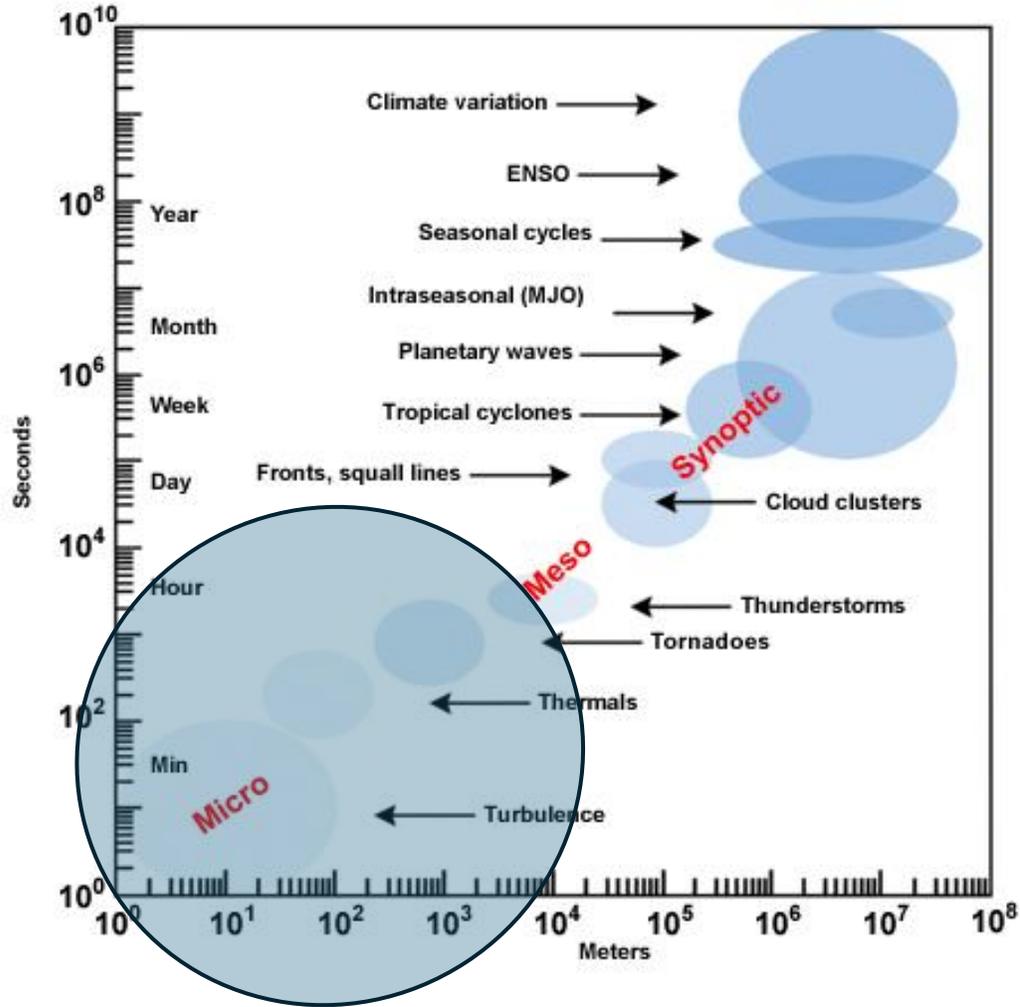


Exposure/Risk

Driver/Responsibility

Cities are political actors at the global scale

# Urban climate effects in context.



©The COMET Program

It is not possible to treat cities as isolated entities and many of the hazardous events (such as heatwaves) are much larger than the city. The city can adjust to this background climate.

Urban effects within a larger climate context that regulates the nature of the urban effect.

# Cities have climate effects that can enhance background hazards

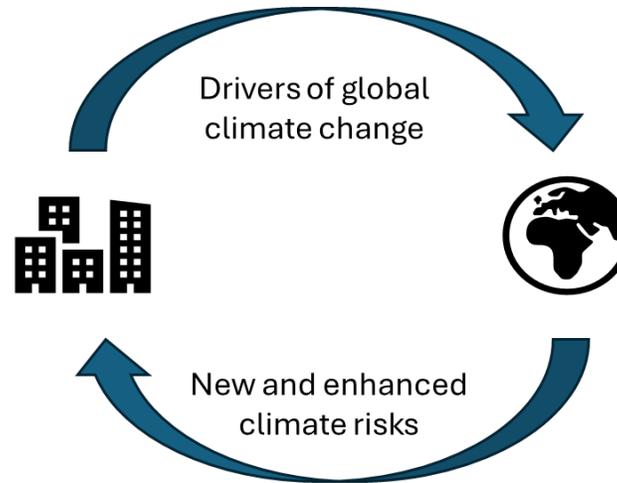
## Urban form & function

### Properties

- Built & Rough
- Paved & Impermeable
- Occupied & Emissions

### Urban effect/impacts

Air quality  
Urban heat island  
Runoff and flooding



## Background climate

### Climate

- Latitude
- Continentality
- Topography

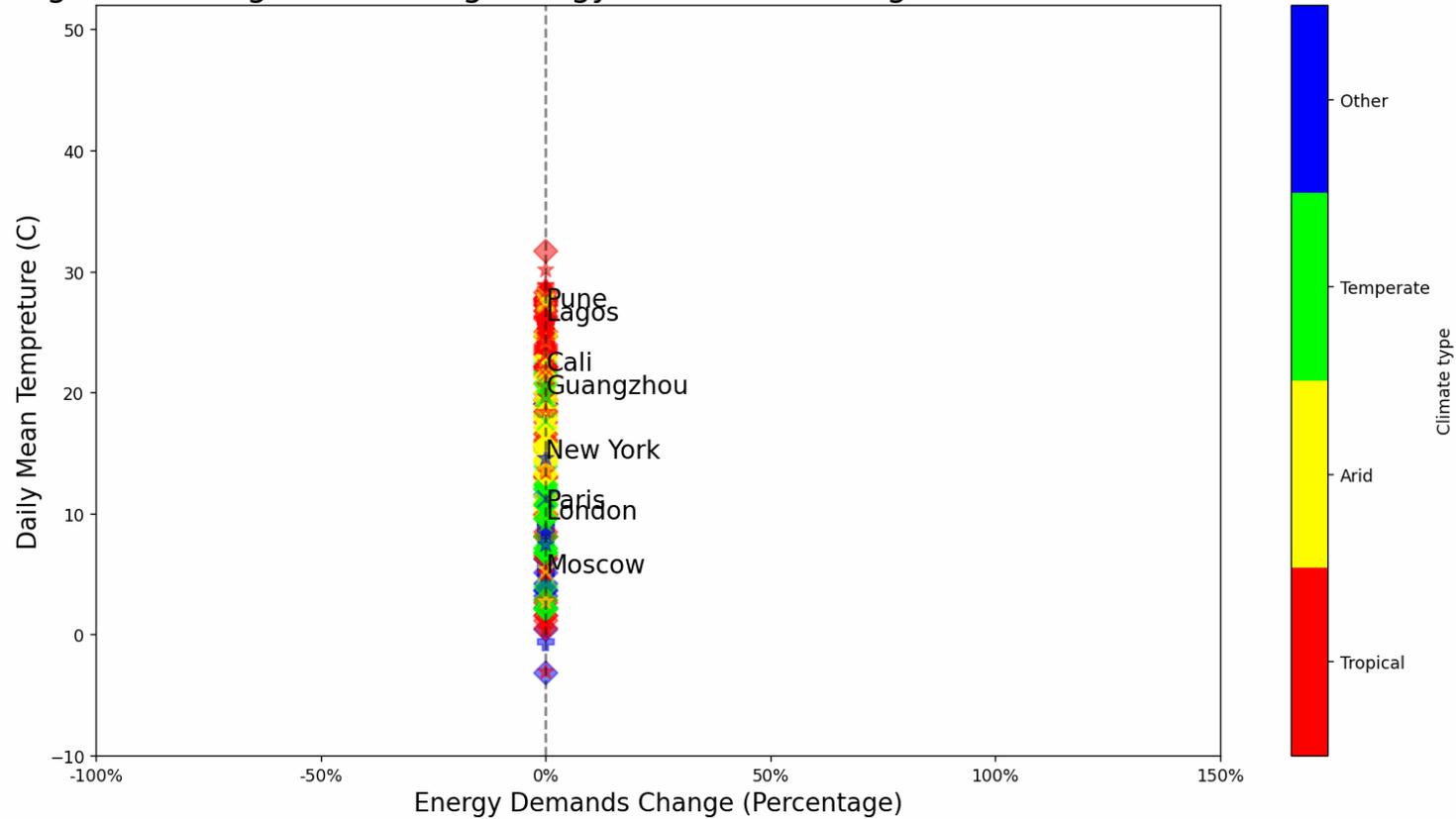
### Climate change

- Warmer/heat waves
- Heavy precipitation
- Cyclone activity
- High sea level

Urban climate effects are a product of aspects of urban form and functions – how cities are built and operated. These properties also contribute to climate change.

# Climate outcomes for cities in different climates

Change of Cooling and Heating Energy Demands in Large Cities from 2016 to 2100



## Change in Energy Usage for Cooling and Heating Demands

# One urban atmosphere

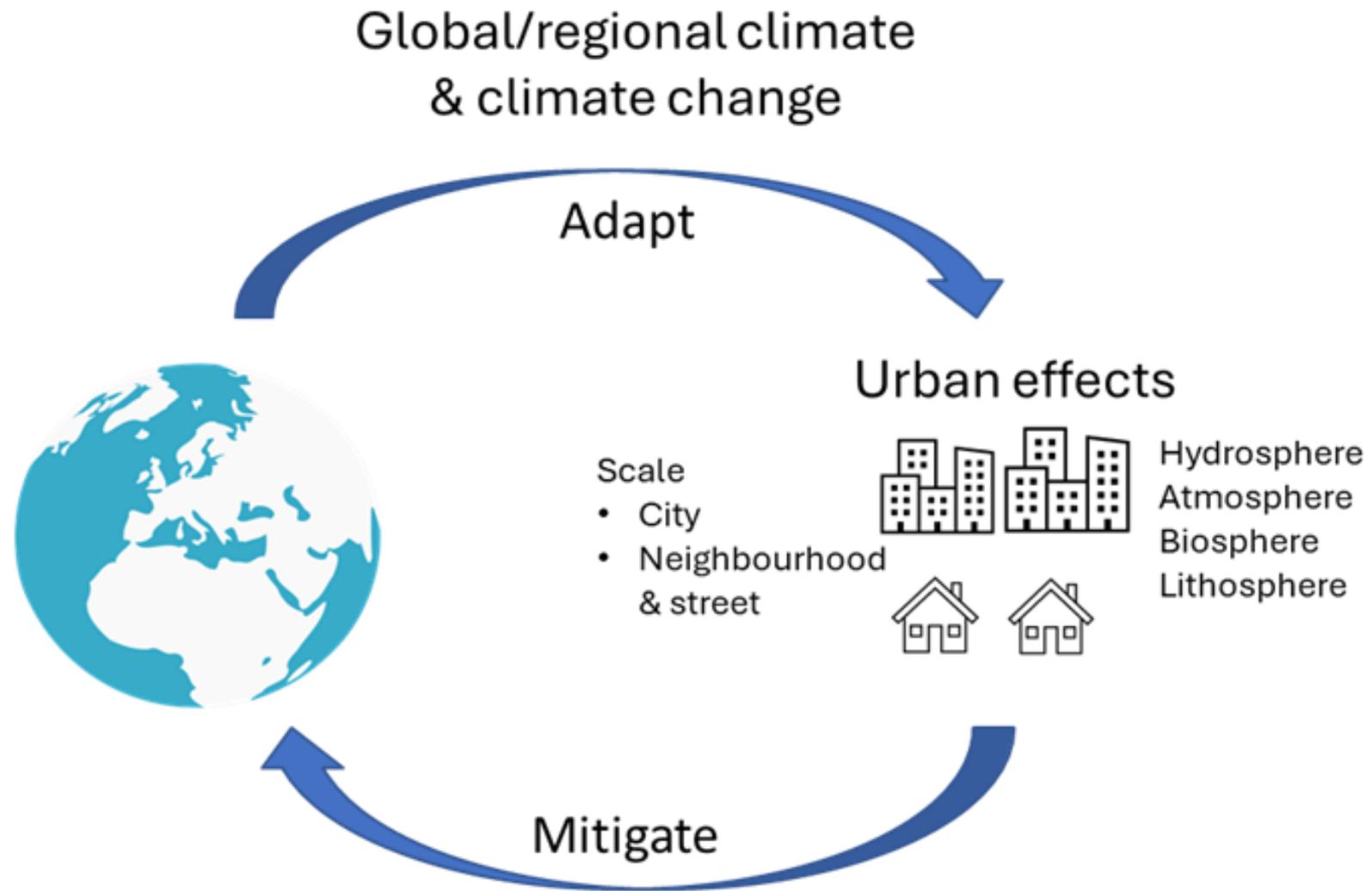
Architecture/design  
Building engineer  
Private/commercial  
Strong management  
Comfort

Meteorology/climatology  
Urban planning/design  
Urban commons  
Weak management  
Heat island/Air quality/Flooding

Exchanges across  
the envelope  
Strong/weak  
connections



Our understanding of the urban system and the proposed solutions are often based on a myopic view its parts and how they function. A key part of this is the integration of the study of the indoor and outdoor environments.



Understanding scale is critical to linking outcomes and actions at local (urban) scales to wider climate and climate change impacts.



### **Climate Resilient City**

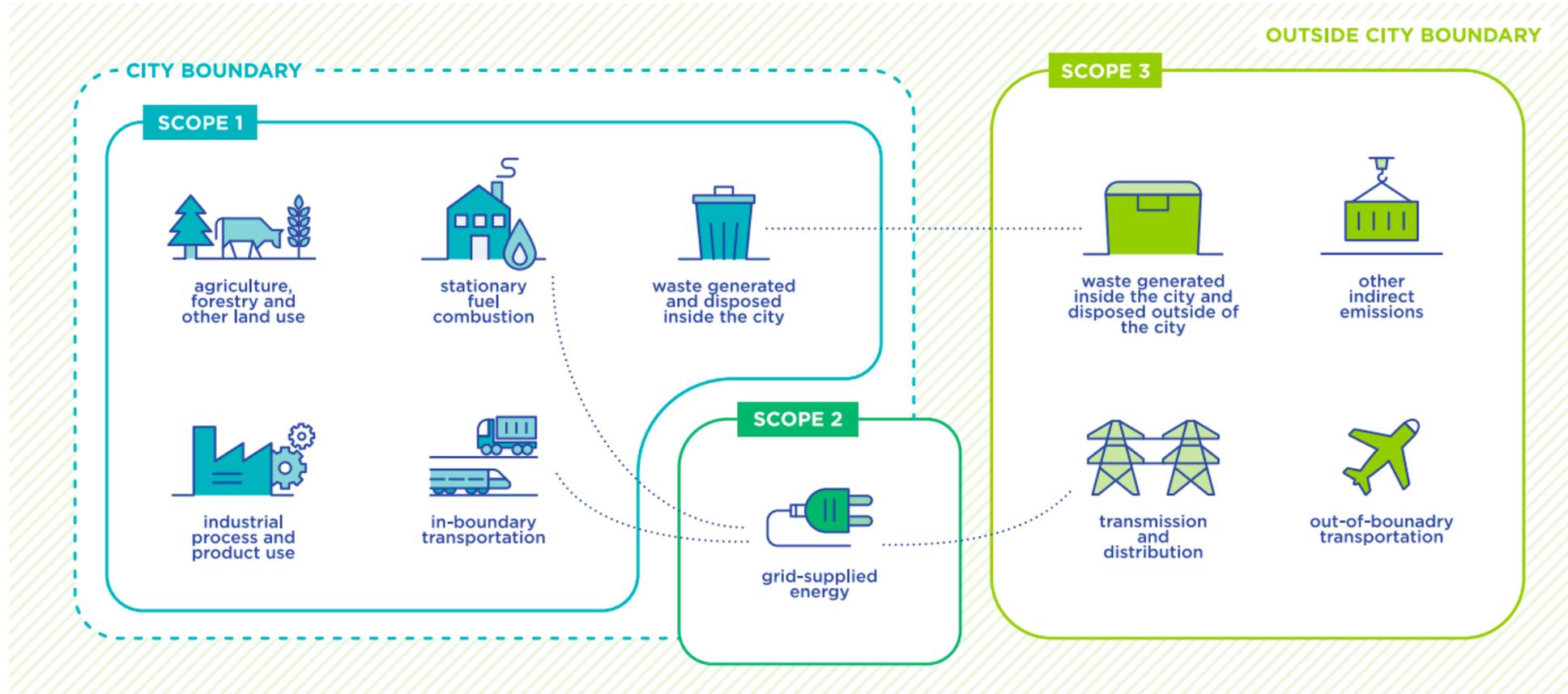
Climate change adaptation acknowledges that the global/regional climate is (will) changing and adjusts infrastructure and systems to account for enhanced risks. Adaptation can take the form of physical changes to the city to limit exposure and social-demographic changes to reduce vulnerability.



### **Zero Carbon Cities**

Climate change mitigation addresses the drivers, which include greenhouse gas emissions and land-cover change. Strategies seek to reduce fossil fuel use through infrastructure change (electrification and renewable energy) and managing energy demand (e.g. buildings and occupation, transport mode).

# Accounting for City emissions



Most systems account for Scope 1 and 2 emissions, which occur within city boundaries (1) or are due to the transfer of energy from outside the boundary (2). Scope 3 emissions includes the ‘embodied’ energy in the products consumed by the city (including building materials)

# Adaptation & Mitigation

## Mitigate

Urban hazards

- Pluvial flooding (permeable)
- Urban heat (shade and evaporation)

Global climate change

- Direct Carbon sequestration
- Indirect offset air conditioning demand

## Adapt

Global + urban hazards

- Increased green cover
- Heatwave refuge (requires population response)



Scale dependency

# An urban scientific infrastructure for climate change

## **Adapt**

Data on current risks: hazard, exposure & vulnerability.

Links to physical models (global-urban) to predict/project hazards.

Links to socio-economic models to estimate cost-benefits of options

## **Mitigate**

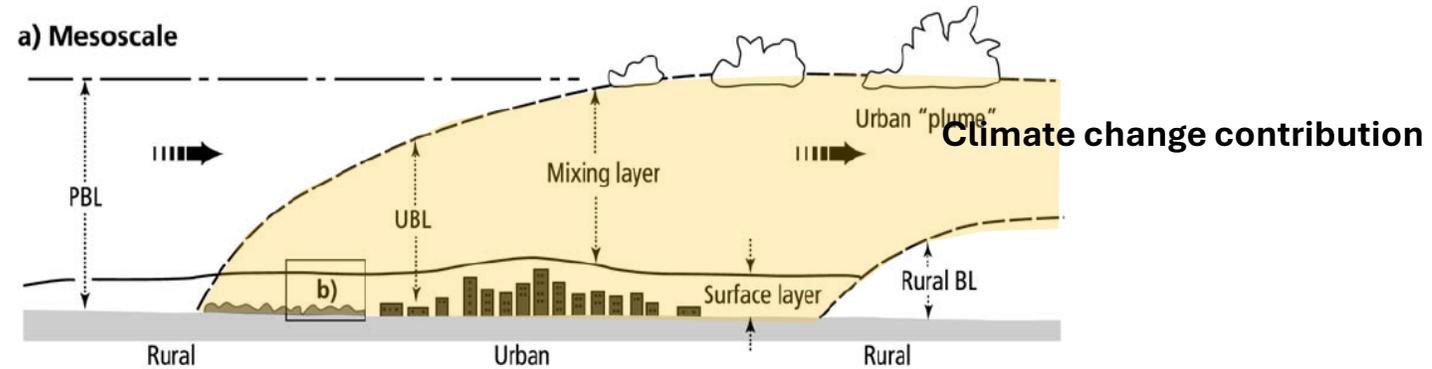
Data on greenhouse gas emissions (inventory) and observations on concentrations.

Consistent reporting mechanisms to measure progress.

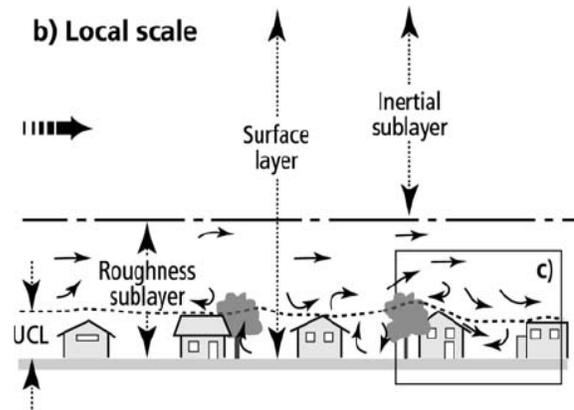
Links to socio-economic models to evaluate cost-benefits of options.

# Urban Climate Science

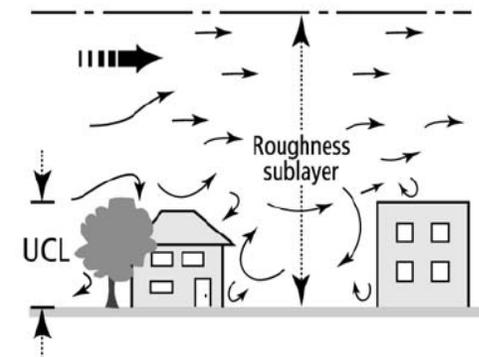
**City  
Planning**



**Neighbourhood  
Design**



c) Microscale



**Street/building  
Architecture  
Engineering**

Our understanding of urban climate effects is embedded in general boundary layer theory that identifies distinct vertical layers and urban scales. The urban effect at each scale differs.

# Urban effects



- Extreme microscale climate variation



- Enhanced heat stress

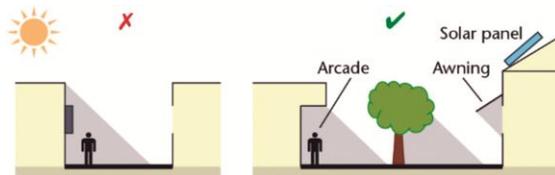
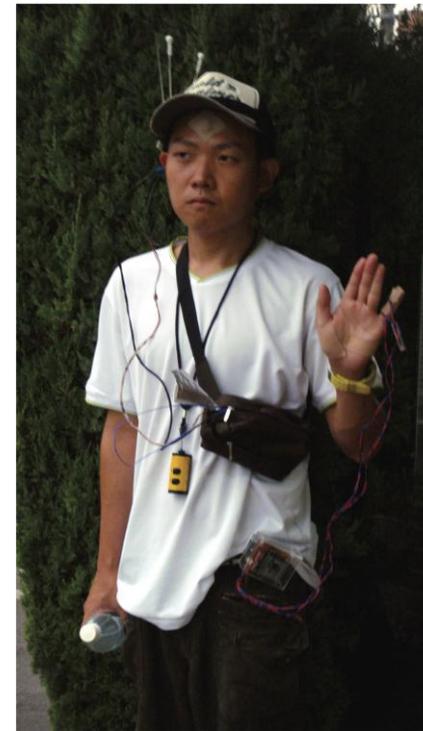
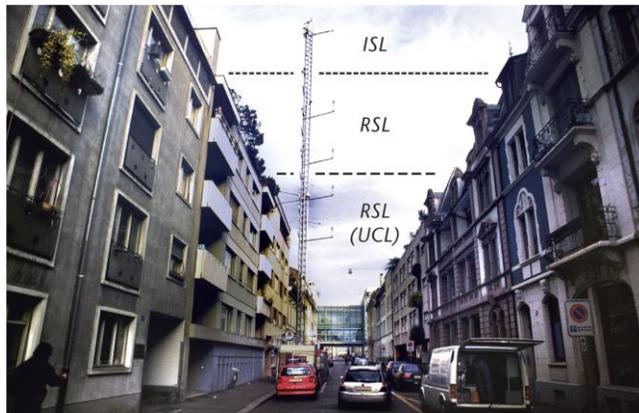
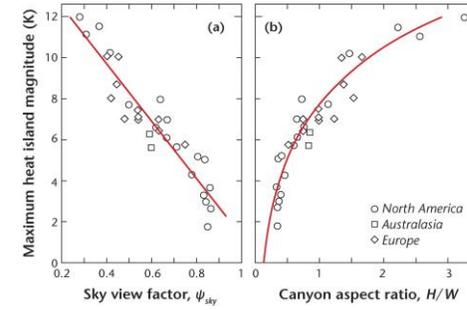


- Profoundly modified hydrology



- Poor air quality

# Development of an Urban Climate Science (1980-)



Observations of varying sophistication to detect urban microclimates

# Modern urban observations

There has been extraordinary developments in the acquisition of data.

- Satellite availability providing urban-scale data (<1km) at global scales.
- Crowd-sourced data providing detailed information on city climates.

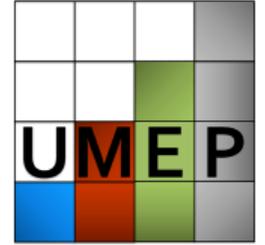
These data can fill in gaps in knowledge on urban climates outside of Europe/North America and provide much of the land-cover data that can be used in climate studies.

## BUT

- Over-reliance on temperature observations.
- We are still lacking in sophisticated observations over urban landscapes – much of our knowledge is based on few cities.
- We are only starting to explore the structure of the urban boundary layer.



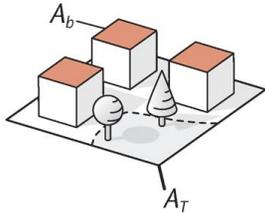
# Urban Climate Science: Modelling



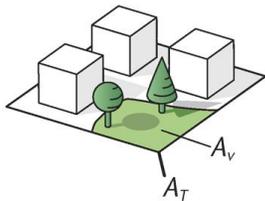
Atmospheric models have become more diverse and widely available. Apart from sophisticated models that have high knowledge and data requirements, there are other models that run within GIS (e.g. UMEP) and require limited capacity.

## Urban cover

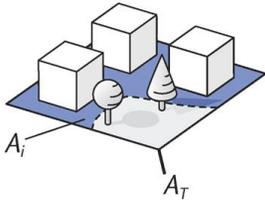
(a)  $\lambda_b = A_b/A_T$



(b)  $\lambda_v = A_v/A_T$

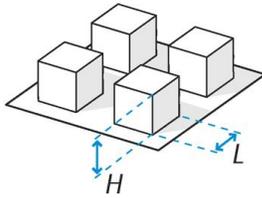


(c)  $\lambda_i = A_i/A_T$

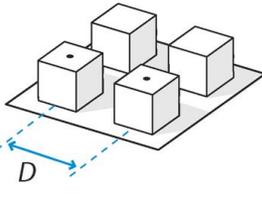


## Length scales

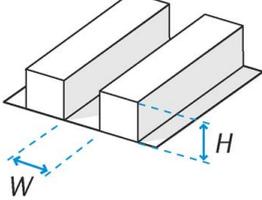
(d) Building dimensions



(e) Building spacing

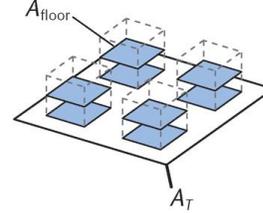


(f)  $\lambda_s = H/W$

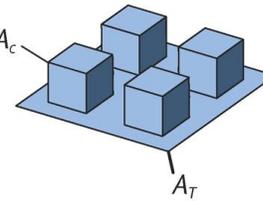


## Urban structure

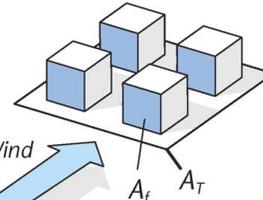
(g)  $\lambda_{floor} = A_{floor}/A_T$



(h)  $\lambda_c = A_c/A_T$



(i)  $\lambda_f = A_f/A_T$



## Models

Outdoor Thermal Comfort: ExtremeFinder

Outdoor Thermal Comfort: SOLWEIG

Solar Radiation: Daily Shadow Pattern

Solar Radiation: Solar Energy on Building Envelopes (SEBE)

Urban Energy Balance: GQF

Urban Energy Balance: LQF

Urban Energy Balance: Urban Energy Balance (SUEWS, simple)

Urban Energy Balance: Urban Energy Balance (SUEWS, advanced)

Urban Heat Island: TARGET

Urban Heat Island: Urban Weather Generator

Urban Wind Fields: URock

All models require numerical descriptions of the urban landscape.

# Knowledge transfer

## Local Climate Zones (LCZ)

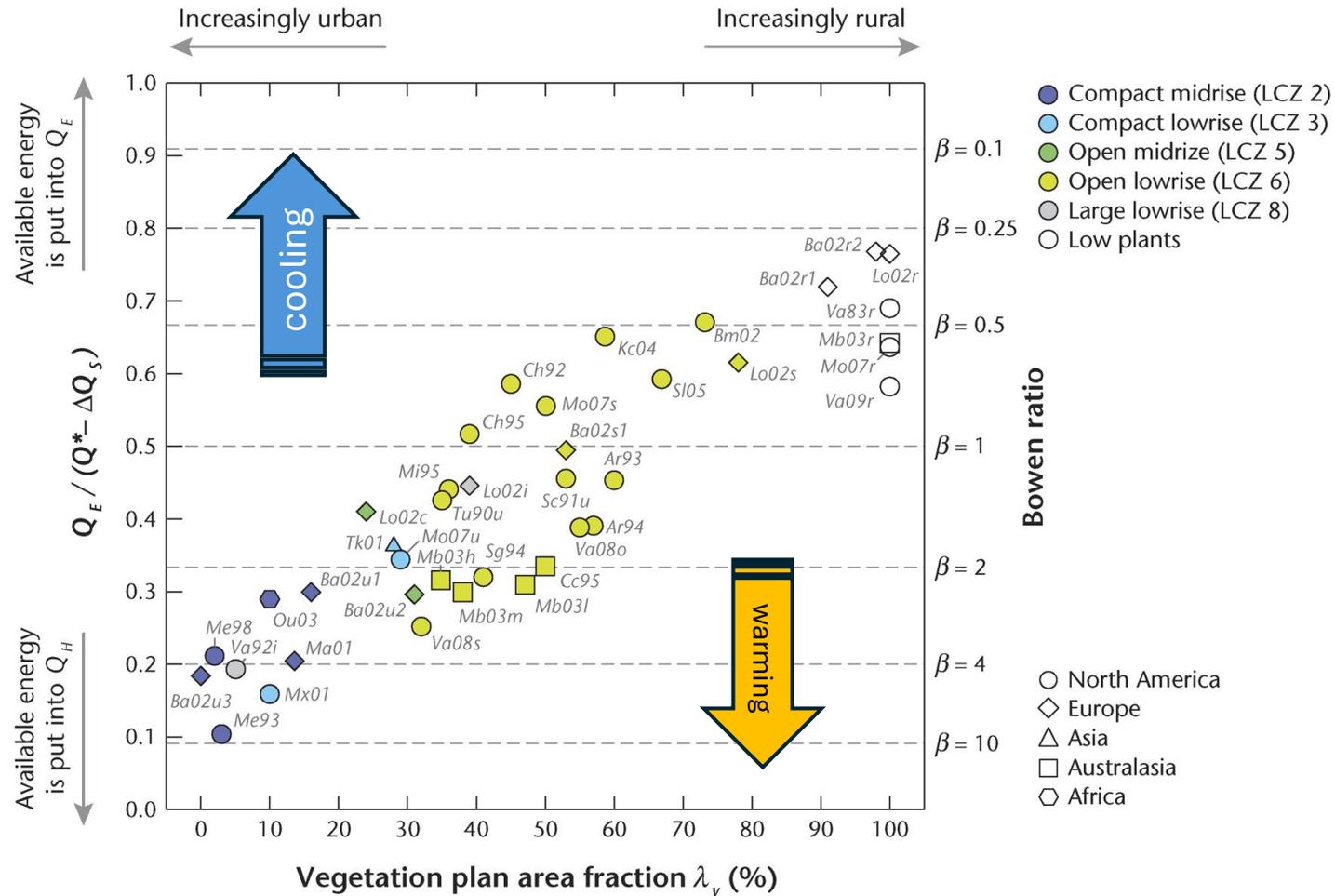


LCZ	$\lambda_B$	$\lambda_I$	$\lambda_T$	$H$	AHF
(1) Compact high-rise	40–60	40–60	> 80	> 25 <sup>a</sup>	50–300
(2) Compact mid-rise	40–70	30–50	> 70	10–25	< 75
(3) Compact low-rise	40–70	20–50	> 60	3–10	< 75
(4) Open high-rise	20–40	30–40	50–80	> 25 <sup>a</sup>	< 50
(5) Open mid-rise	20–40	30–50	50–90	10–25	< 25
(6) Open low-rise	20–40	20–50	40–90	3–10	< 25
(7) Lightweight low-rise	60–90	< 20	> 60	2–4	< 35
(8) Large low-rise	30–50	40–50	> 70	3–10	< 50
(9) Sparsely built	10–20	< 20	10–40	3–10	< 10
(10) Heavy industry	20–30	20–40	40–70	5–15	> 300 <sup>b</sup>

**Table 1A** selection of urban canopy parameter data associated with built LCZ types, sourced from [Stewart and Oke \(2012\)](#). Columns represent the urban canopy parameters included in the thematic benchmark: the percentage of built ( $\lambda_B$  (%), ratio of building plan area to total plan area), impervious ( $\lambda_I$  (%), ratio of impervious plan area to total plan area), and total impervious ( $\lambda_T$ ), the mean height of roughness elements  $H$  (m), and the mean annual anthropogenic heat flux AHF ( $W m^{-2}$ ).

The LCZ typology categorises neighbourhoods into distinct types. Each LCZ is associated with variables (parameters) that describe the typical land cover.

# Abstraction

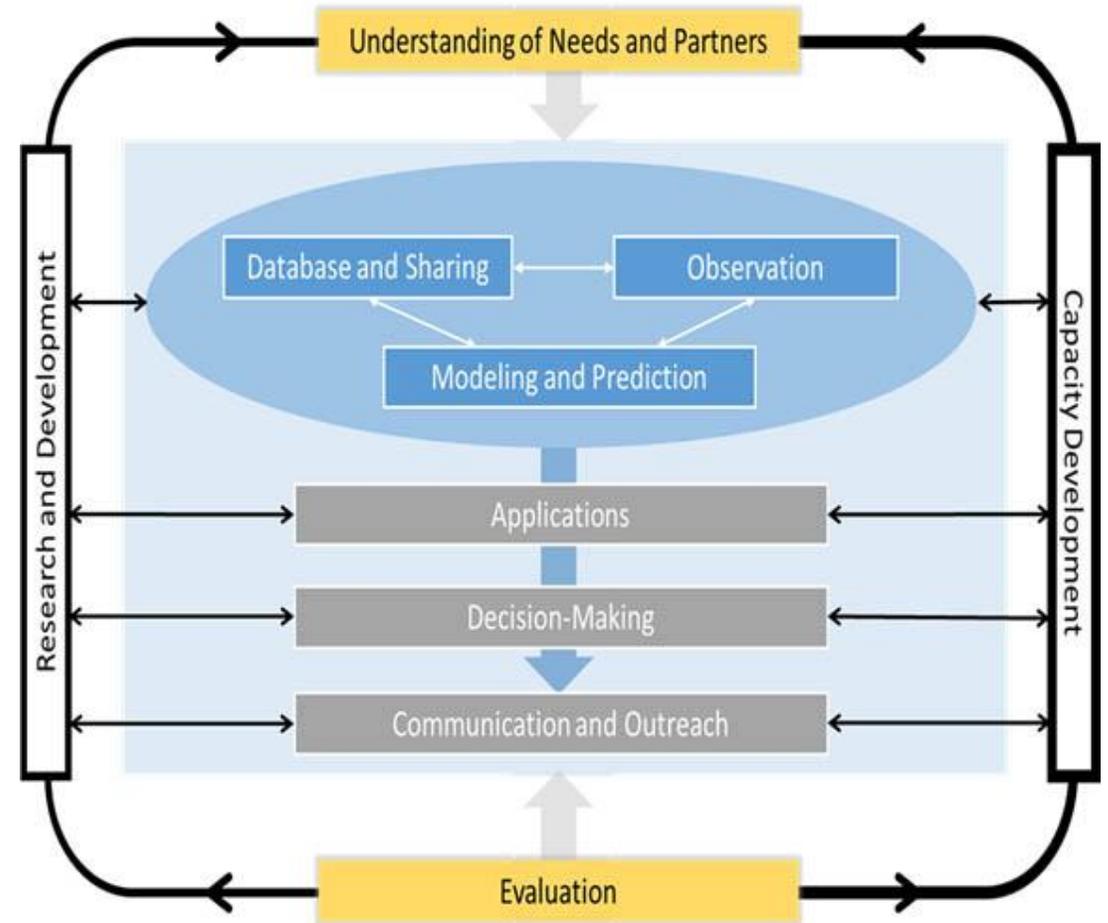


Increasing the vegetative fraction (reducing impervious surface cover) changes the exchanges at the urban surface and reduces UHI intensity.

# Applications: Integrated Urban Services

Some progress in development of IUS mostly in the context of weather (and warnings) rather than long-term planning issues. The WMO sees the creation of IUS by its members (mostly National Meteorological and Hydrological Services) as an important part of making cities more resilient.

Cities are seen as a focus for integrated services owing to their exposure to a range of hazards and vulnerability across sectors.



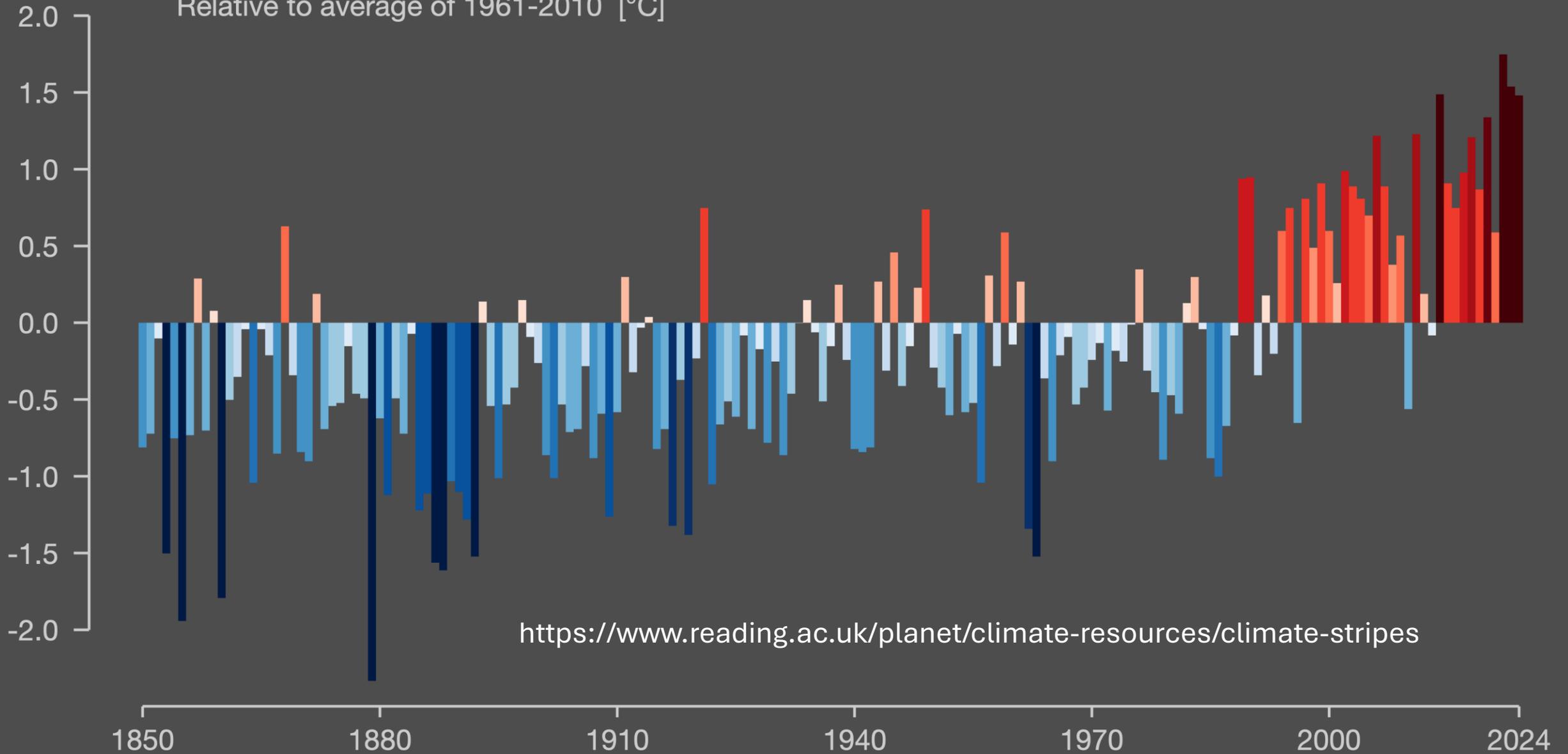
**In this context, urban effects are ‘amplifiers’ of wider weather/changes.**



**London**

# Temperature change in London

Relative to average of 1961-2010 [°C]

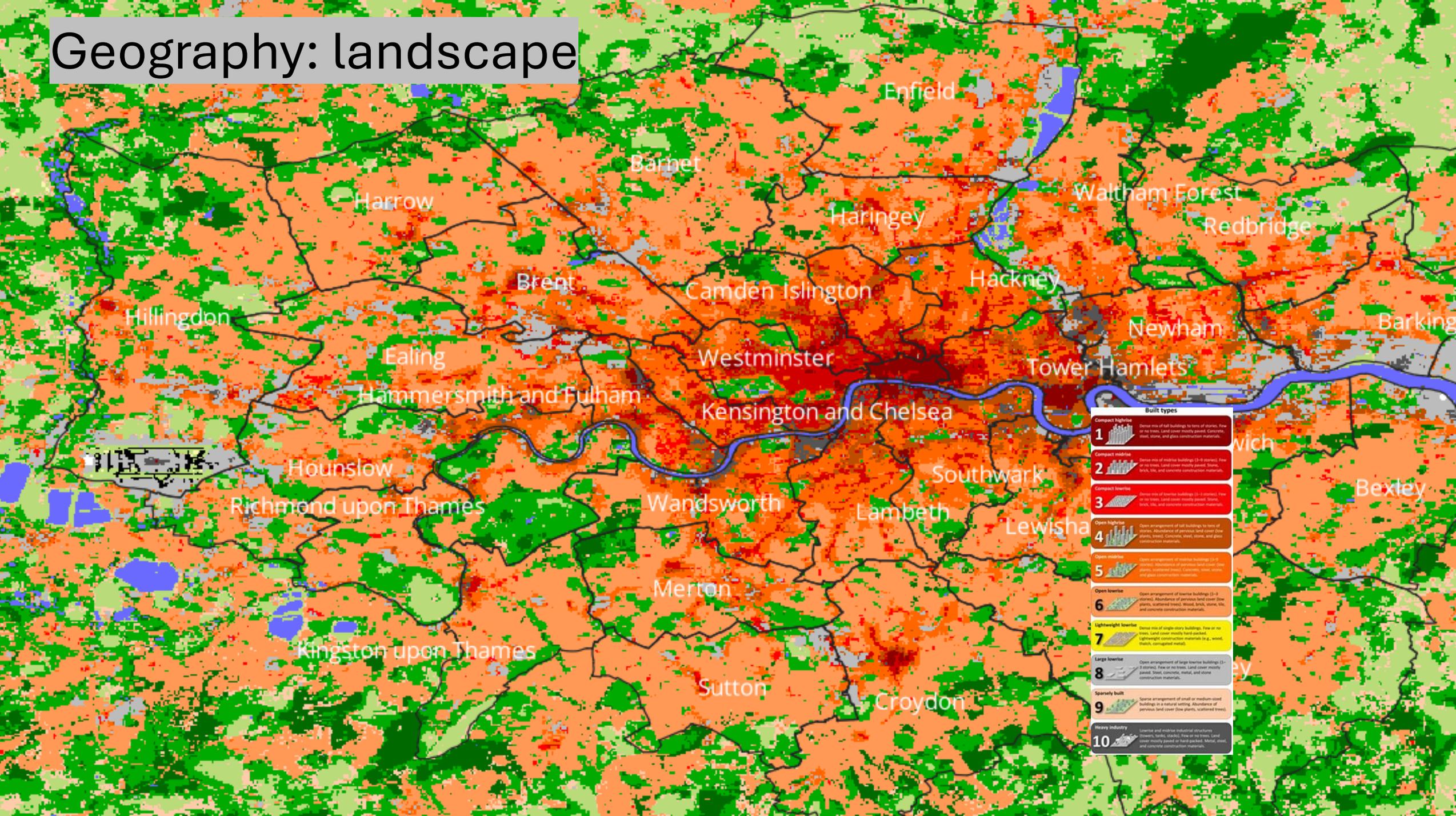


<https://www.reading.ac.uk/planet/climate-resources/climate-strips>

# Climate projections

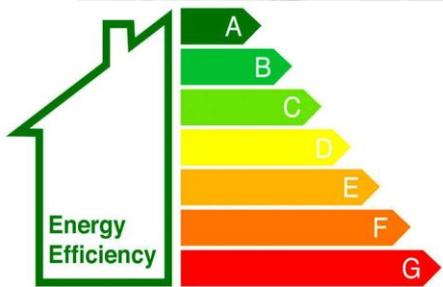
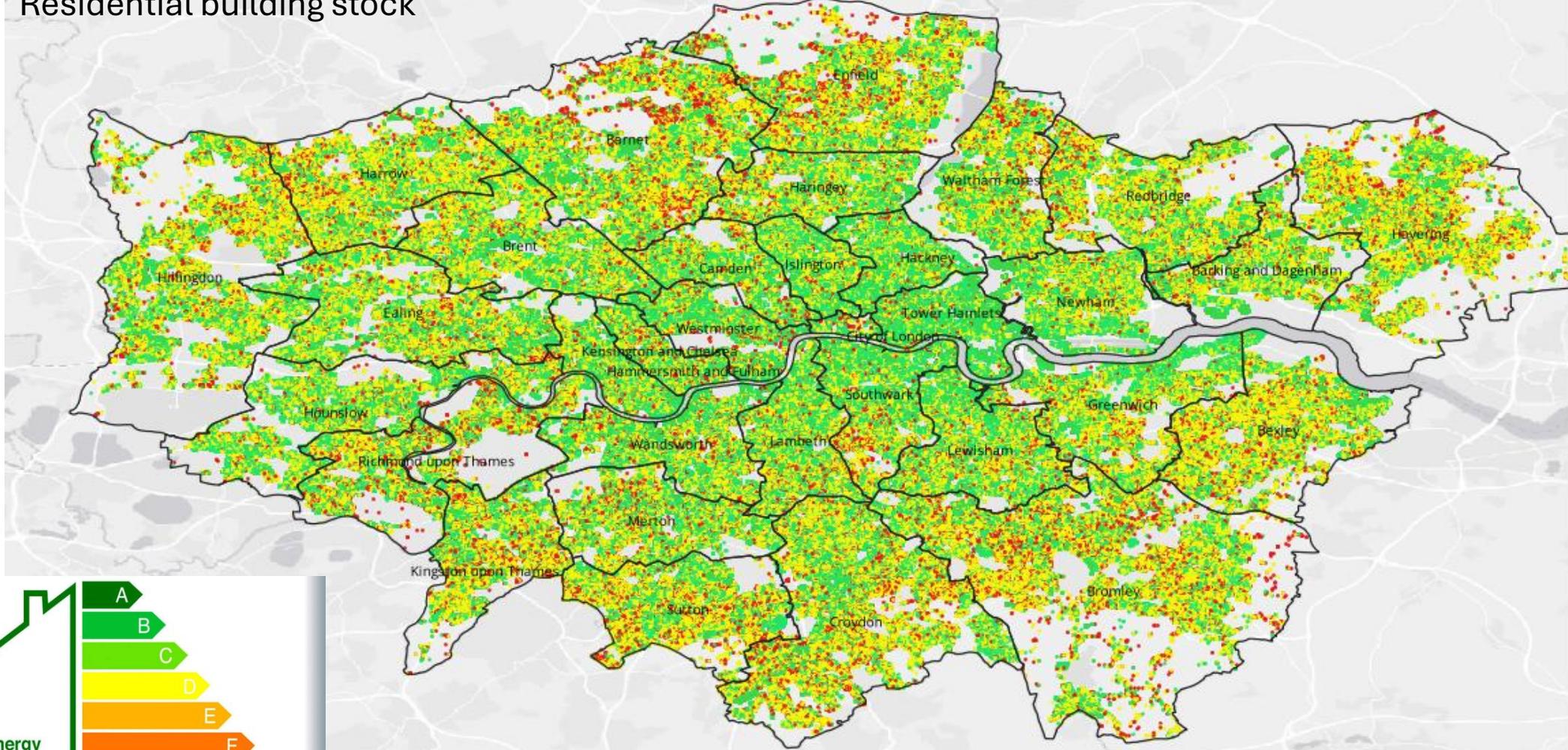
High emissions scenario projections for London.	Central estimate of change in 2020s	Central estimate of change in 2050s	Central estimate of change in 2080s
Summer mean temperature	+ 1.5°C very unlikely to be less than 0.5°C and is very unlikely to be more than 2.7°C;	+ 3.1°C very unlikely to be less than 1.4°C and is very unlikely to be more than 5.2°C;	+ 4.9°C very unlikely to be less than 2.6°C and is very unlikely to be more than 8.1°C;
Summer mean daily maximum temperature	+ 2°C very unlikely to be less than 0.5°C and is very unlikely to be more than 3.7°C	+ 4.3°C very unlikely to be less than 1.7°C and is very unlikely to be more than 7.4°C	+ 6.7°C very unlikely to be less than 3°C and is very unlikely to be more than 11.5°C
Winter mean precipitation	+ 7% very unlikely to be less than -3% and is very unlikely to be more than 18%	+ 16% very unlikely to be less than 2% and is very unlikely to be more than 35%	+ 26% very unlikely to be less than 6% and is very unlikely to be more than 58%
Summer mean precipitation	- 4% very unlikely to be less than -23% and is very unlikely to be more than 18%	- 19% very unlikely to be less than -43% and is very unlikely to be more than 9%	- 29% very unlikely to be less than -56% and is very unlikely to be more than 5%

# Geography: landscape



# Geography: landscape

Residential building stock



What is EPC Rating in UK and How to Improve EPC Rating

Energy Performance Certificates

# Adaptation: Climate change risks

London’s main climate challenges are flood risk, drought, heat risk and “interconnected risks”. There are four objectives for adaptation, and this report has particular relevance to the first of these.

- Understand and manage the risks and impacts of severe weather and future climate change in London on critical infrastructure, public services, buildings and people;
- Reduce risks and impacts of flooding in London on people and property and improve water quality in London’s rivers and waterways;
- Ensuring efficient, secure, resilient and affordable water supplies for Londoners; and
- London’s people, infrastructure and public services are better prepared for, and more resilient to, extreme heat events.

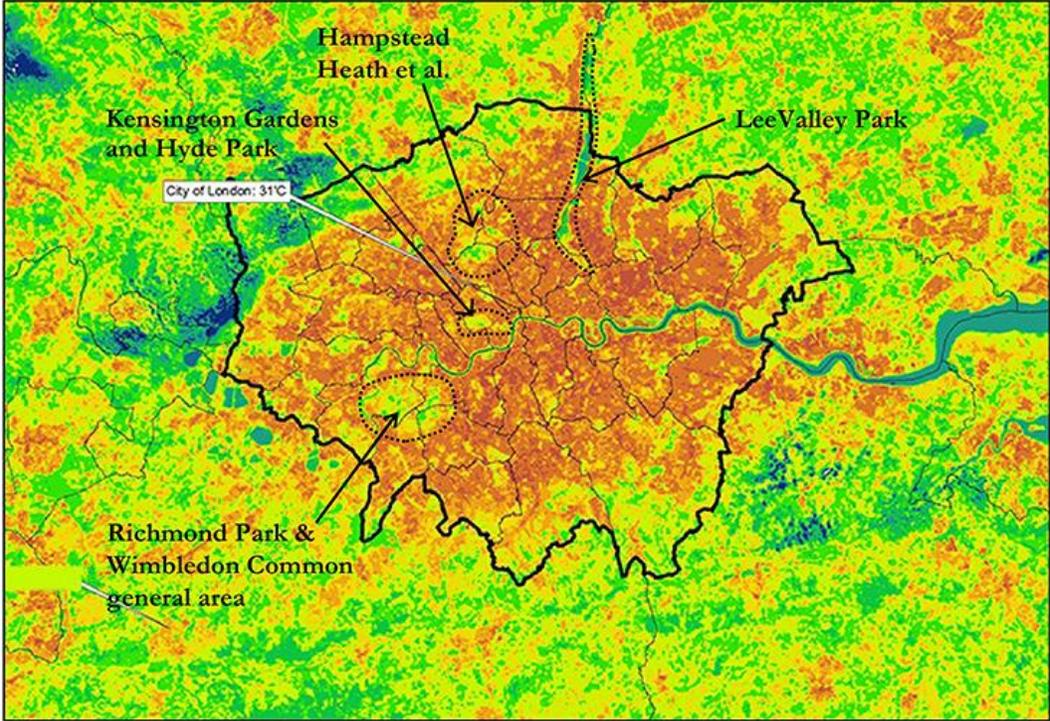
Hazard	Nature of impact	Nature of evidence reviewed
	Impact of fluvial and surface water flooding on residential and non-domestic buildings in terms of property damage.	Impacts quantified, some costs for London
	LOW    LOW    MED    MED    MED	
	Impact of flooding on building valuation and insurance premiums.	Impacts quantified, some costs for London
	LOW    LOW    MED    MED    MED	
	Impacts of subsidence and heave movement due to drought on building foundations and facades.	London impacts understood qualitatively
	MED    MED    HIGH    HIGH    HIGH	
	Impact of high temperatures on London’s buildings making them more expensive to run through cooling energy costs.	Impacts quantified, some costs for London
	MED    MED    MED    HIGH    HIGH	
	Impacts of high temperatures on London’s buildings making them more uncomfortable, reducing employee productivity, affecting health and wellbeing.	London impacts understood qualitatively
	MED    MED    MED    MED    HIGH	
<b>MULTI</b>	Damage to historic structures and sites from multiple climate-related hazards	Known at UK level but not London-specific
	LOW    UNKNOWN    UNKNOWN    UNKNOWN    UNKNOWN	

NOW    →    Scale of impact    →    FUTURE

Climate impacts on London’s built environment sector, across the 21<sup>st</sup> century

# London's urban thermal effect

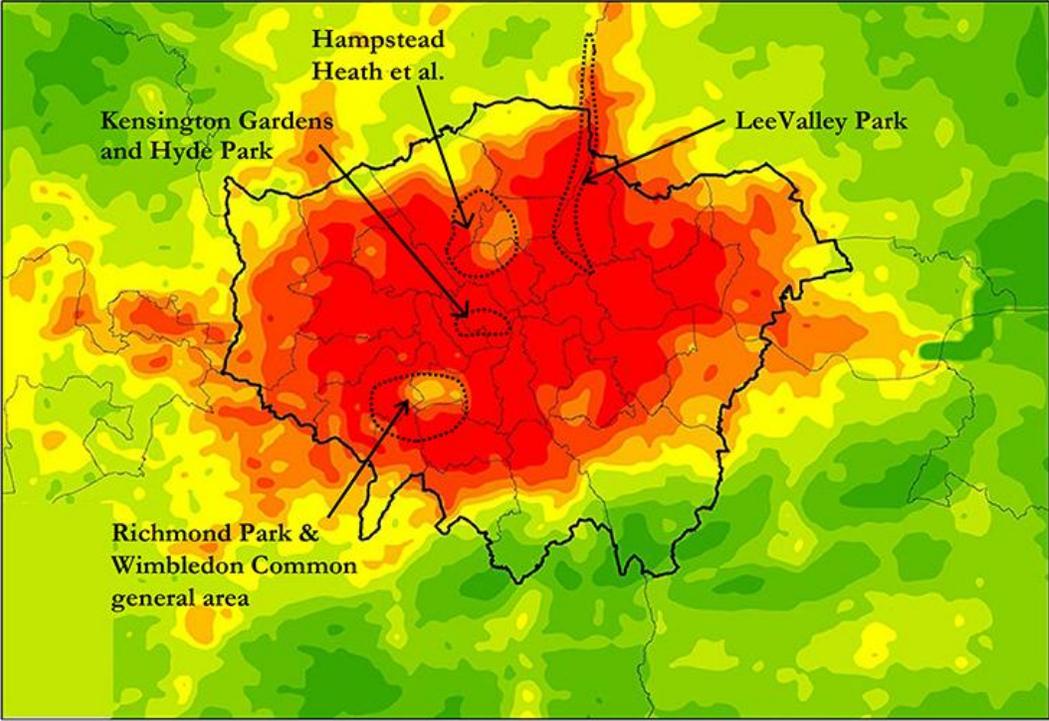
LandSat image of London



Land surface temperature (°C)

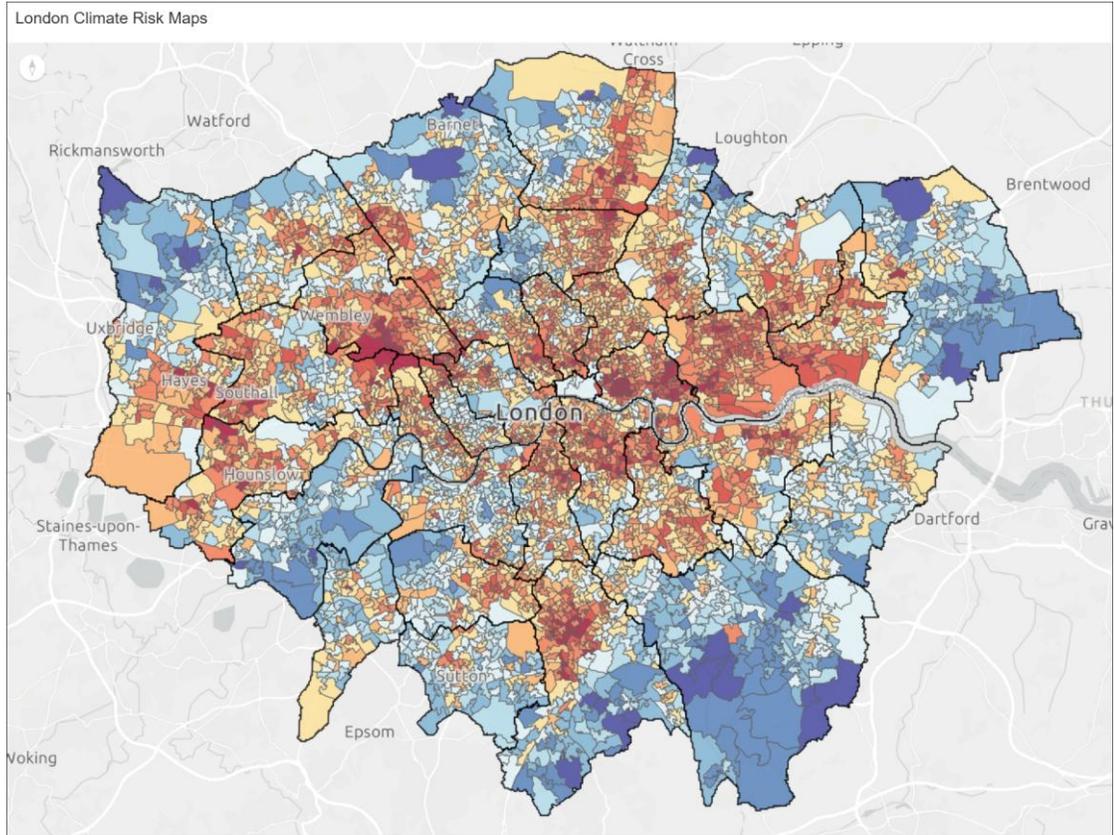


Average atmospheric UHI for London



Air temperature (°C)





Esri UK, Esri, TomTom, Garmin, FAO, METINASA, USGS



Heat risk



Esri UK, Esri, TomTom, Garmin, FAO, METINASA, USGS



Canopy cover

# Mitigation

## A Greenhouse Gas Inventory

Source	2010	2015	2020	2023	Percent of total
Domestic	15.26	12.77	10.93	8.74	31%
Industrial & Commercial	19.50	15.24	9.89	9.40	33%
Transport	9.06	9.99	7.32	8.72	31%
tCO <sub>2</sub> per capita_all	5.69	4.68	3.40	3.20	
Net CO <sub>2</sub>	45.72	40.34	30.03	28.53	

**In 2022, London's emissions were 28.40 million tonnes (MtCO<sub>2</sub>e).**

Over the longer term, emissions are 37 per cent lower than 1990 levels and 44 per cent below the peak of emissions in 2000. Despite a 30 per cent increase in population since 1990 and significant economic growth over that period, London's per capita emissions have reduced by 52 per cent, from 6.7 tCO<sub>2</sub>e in 1990 to 3.2 tCO<sub>2</sub>e in 2022. Compared to the rest of the UK, London has the lowest per capita emissions of any region

# Transport emissions

Transport CO2/sq.km

LonBorCO2

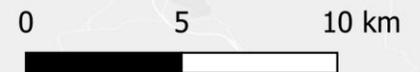
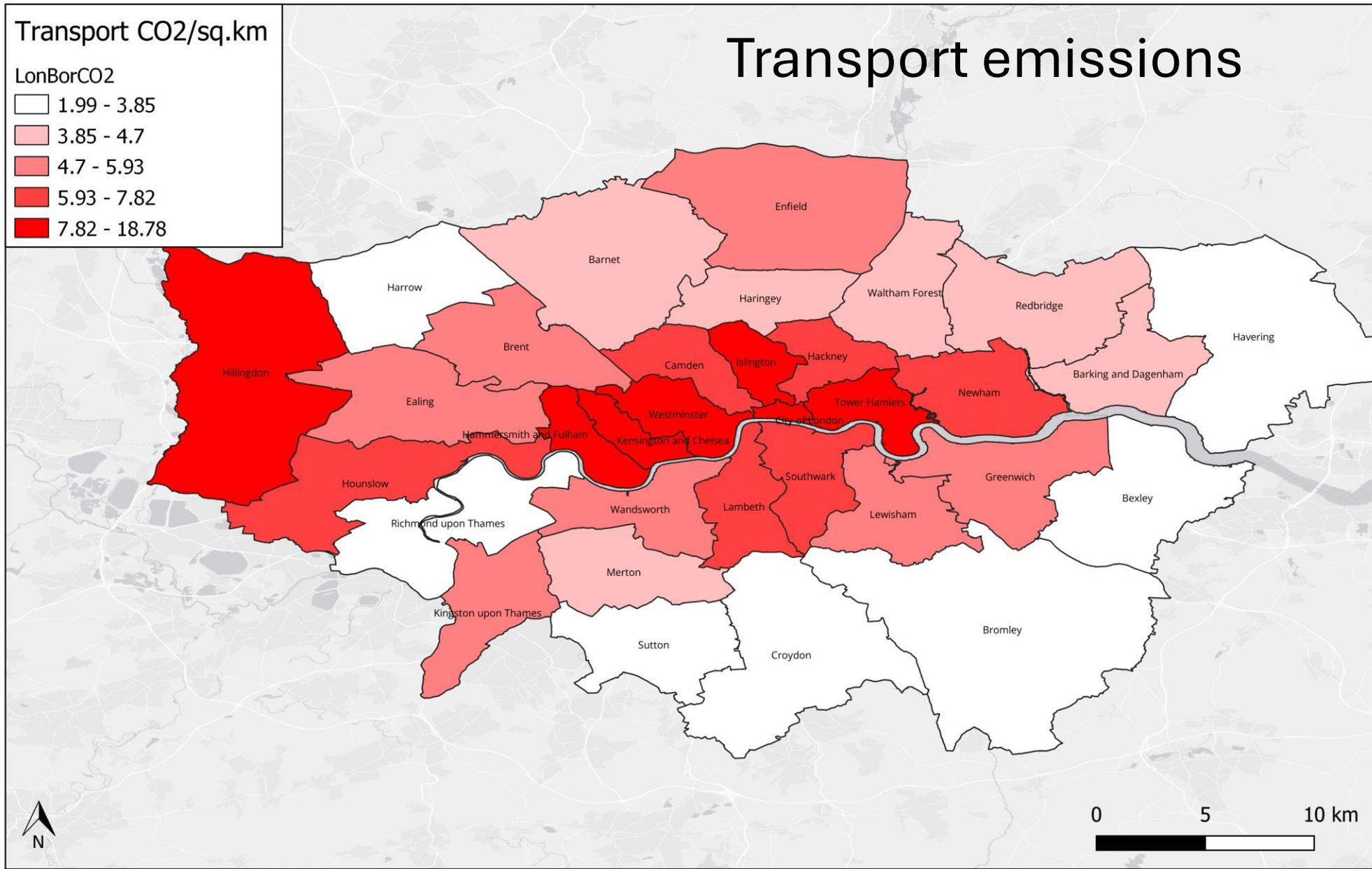
1.99 - 3.85

3.85 - 4.7

4.7 - 5.93

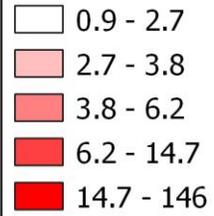
5.93 - 7.82

7.82 - 18.78

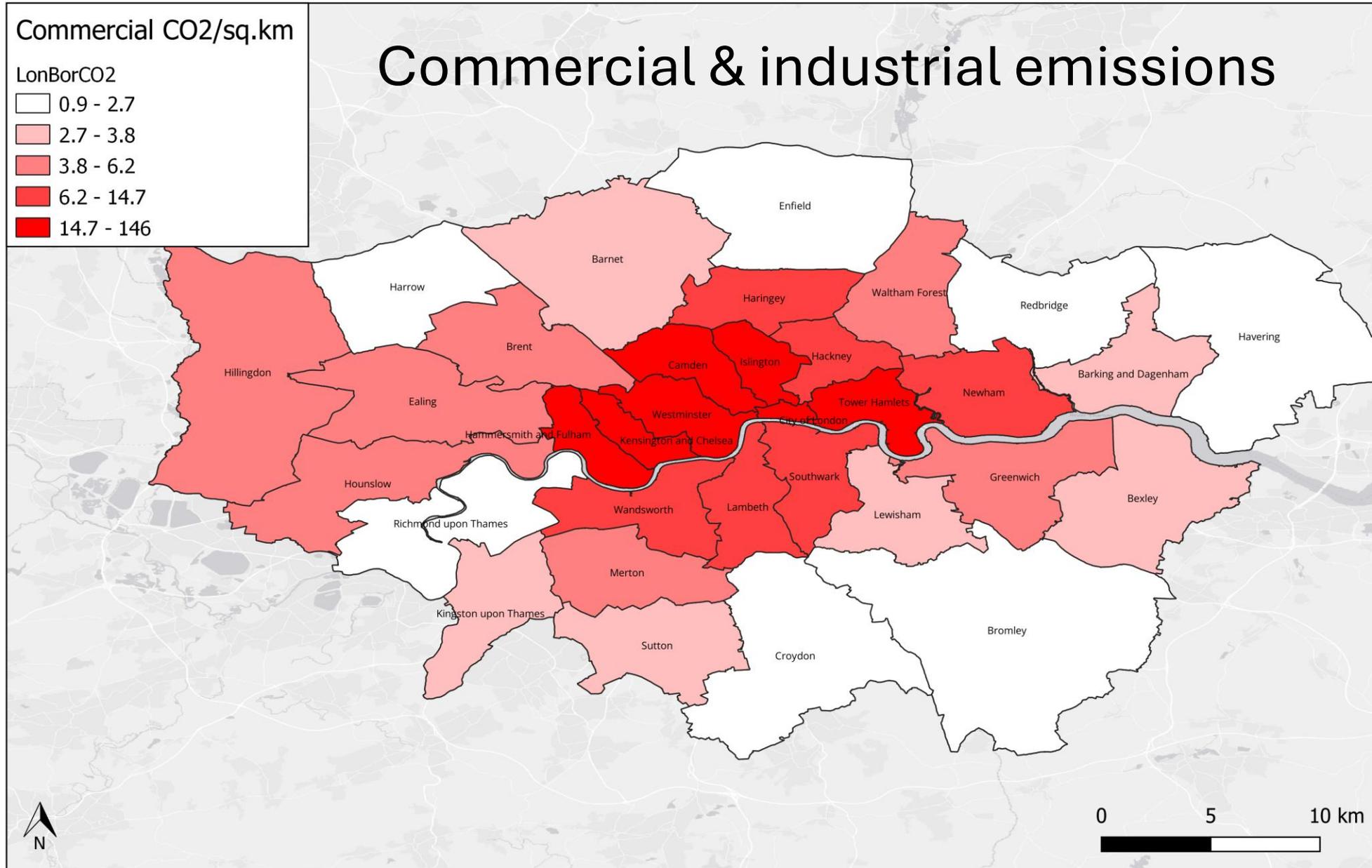


## Commercial CO<sub>2</sub>/sq.km

LonBorCO<sub>2</sub>



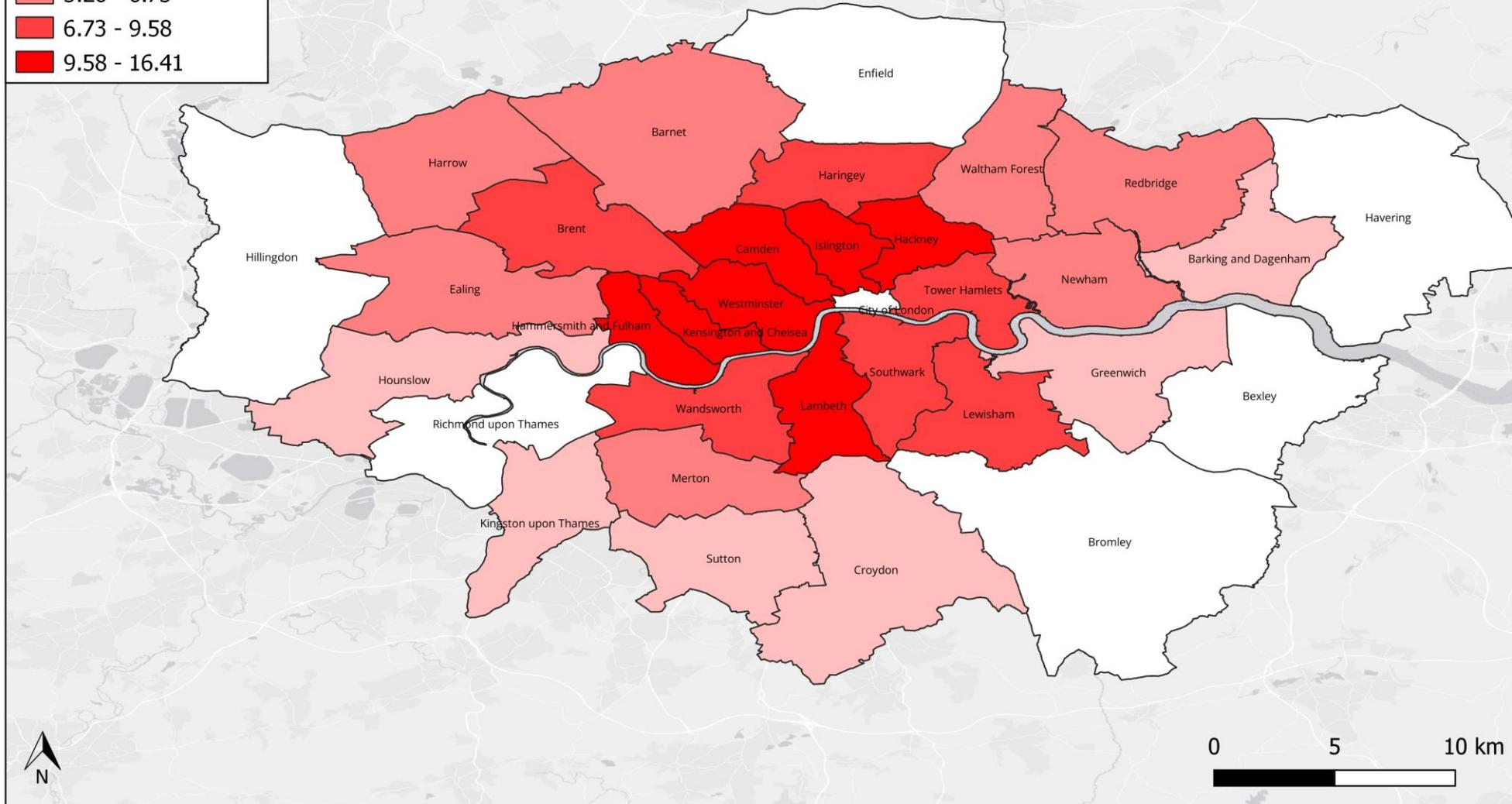
# Commercial & industrial emissions

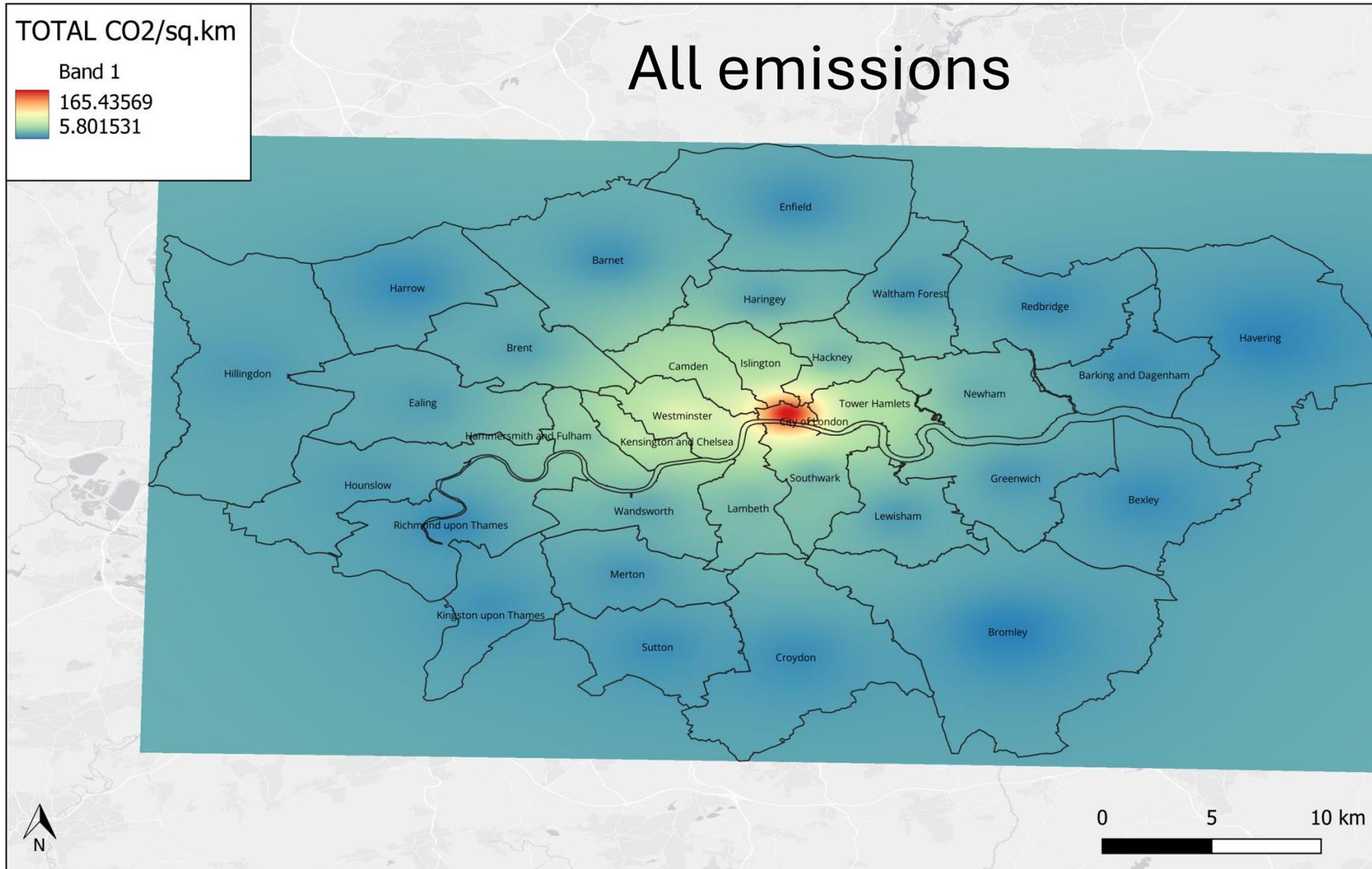


## Domestic CO2/km



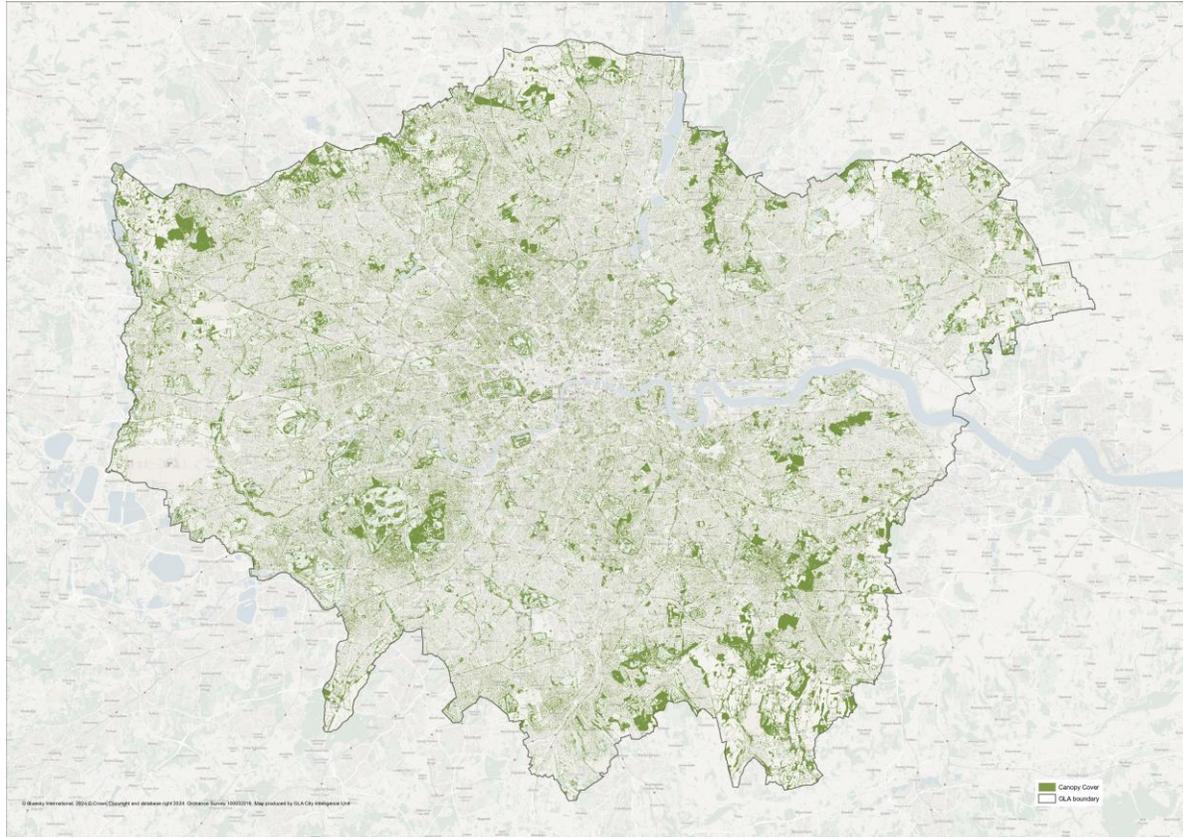
# Domestic emissions





This shows the total emission of CO<sub>2</sub> (per sq. km) across London presented as a heat map; the contribution of each borough is treated as a value at the borough centroid.

# Planting trees to offset emissions.



Total Carbon Stored: Approximately 2.4 million tonnes of carbon are stored in London's trees.

Annual Carbon Sequestration: London's trees remove (sequester) about 77,000 tonnes of carbon from the air every year.

Top Carbon Absorbers: The London Plane and Oak are among the best species for carbon storage in the UK due to their large size and long lifespans.

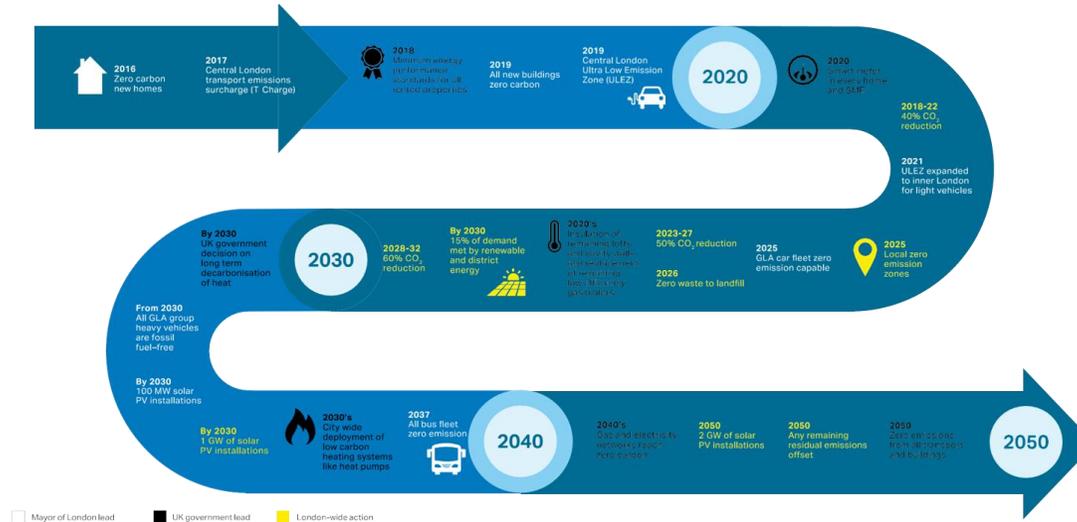
i-Tree Tools

## Tree Canopy Cover 2024

In 2023, London's emissions were 28.61 million tonnes (MtCO<sub>2</sub>e), so the trees can sequester just 0.27% of the annual emissions.

# Mitigation policy

The Mayor of London has set a target for London to be net zero carbon by 2030.



## London Net Zero 2030: An Updated Pathway

Achieving this will require many things, including:

- nearly 40 per cent reduction in the total heat demand of our buildings. This requires over 2 million homes and a quarter of a million non-domestic buildings to become properly insulated
- 2.2 million heat pumps in use in London by 2030
- 460,000 buildings connected to district heating networks by 2030
- a 27 per cent reduction in car vehicle kilometres travelled by 2030
- fossil fuel car and van sales ended by 2030, and enforced in line with Government's existing commitments.

**Table 1-1 Scenario definition in terms of deployment of technologies in London by 2050**

	Baseline	Decentralised	High electrification	Decarbonised gas	Patchwork
<b>Electricity Grid</b>	Low 155 gCO <sub>2</sub> /kWh by 2050	High Falls to 28 gCO <sub>2</sub> /kWh by 2050			
<b>Energy Efficiency</b>	High energy efficiency retrofit standards 81% of buildings EPC C or better, 50% appliance energy reduction, 80% lighting energy reduction by 2050				
<b>Solar thermal</b>	Arup central scenario 4% buildings, 0.26 TWh/year				
<b>Heat Pumps</b>	Low <5% buildings	Medium 32% buildings	High 75% buildings	Low <5% buildings	High 75% buildings
<b>Heat networks</b>	Low 6% buildings	High 27% buildings	Low 6% buildings	Medium 18% buildings	Medium 18% buildings
<b>Green gas &amp; Hydrogen</b>	Low 1.3 TWh green gas	Medium 7 TWh green gas	Low 1.3 TWh green gas, then gas grid decommissioned	High 100% H <sub>2</sub> gas grid conversion	Medium 7 TWh green gas + 7% H <sub>2</sub> blending + H <sub>2</sub> backbone
<b>Solar PV</b>	Low 2% buildings	High 10% buildings	High 10% buildings	Medium 4% buildings	Medium 4% buildings
<b>Transport</b>	Low TfL Baseline scenario	High - 100% ZEV's by 2050 TfL MTS Scenario with high BEVs			
			TfL MTS Scenario with high BEVs	TfL MTS Scenario with high H <sub>2</sub> FCEVs	TfL MTS Scenario with selective H <sub>2</sub> FCEVs

Scenarios represents a different pathway to meeting London’s decarbonisation goals:

- Decentralised scenario promotes decentralised energy production and distribution.
- High electrification scenario promotes electrification of heat and transport using an increasingly decarbonised electricity grid.
- Decarbonised gas scenario promotes the conversion of London’s gas grid to 100% hydrogen by 2045.
- Patchwork scenario aims to represent a pragmatic, mixed pathway, encompassing aspects of all the above scenarios to meet carbon targets.

# Conclusion

Cities have a background climate effect that has been accounted for in its engineering and building. These responses have relied on plentiful fossil-fuel based energy supplies.

The emission of GHG over hundreds of years is changing the background climate that cities experience. **Cities have to adapt.**

Limiting GHG emissions (globally) can limit the magnitude of global climate change. **Cities must mitigate.**

Across city scales, adaptation and mitigation actions need to be systemic and consistent. The solutions are not simply technical and require innovative designs.

From a climate science point of view, we need new models that can better simulate the city system – its components and links – to develop coherent policies.



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Thank you



The Donore neighbourhood in Dublin, which represents some of the poor housing stock in Dublin and less affluent residents.