

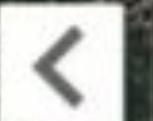
# *Role of data and AI for Climate Change Mitigation and Adaptation in Cities*

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Environment  
University of North Carolina at Chapel Hill  
July 2024



Sea-level rise under Rising Global Temperature  
Climate Central

20 km  
20 mi



# Poll Question

- Which area do you think AI can best help cities when it comes to climate change?
  - a) identifying emission hotspots and areas for reducing them;
  - b) characterizing risks and vulnerabilities within urban areas;
  - c) comparing best practices for managing climate change;
  - d) improve planning for transportation, waste-related emissions;

# Overview

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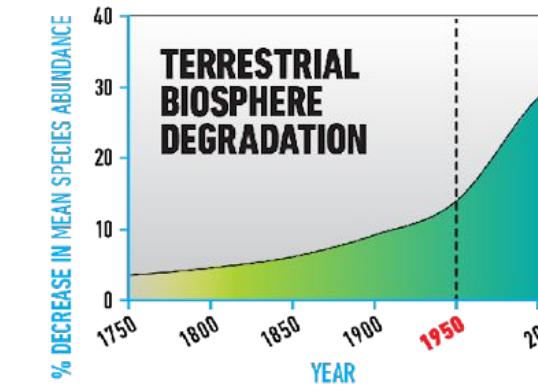
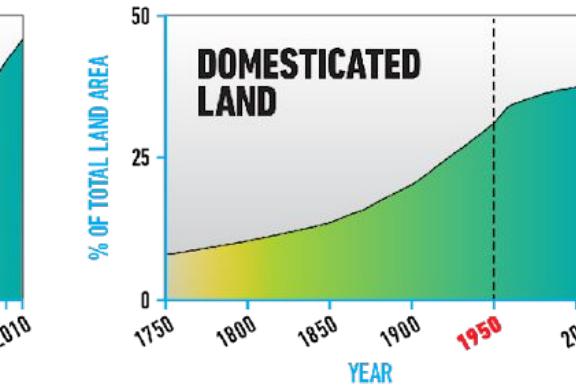
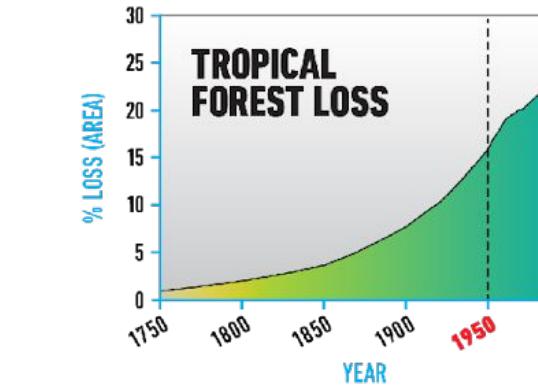
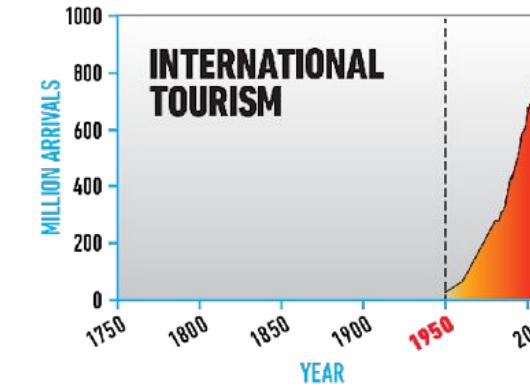
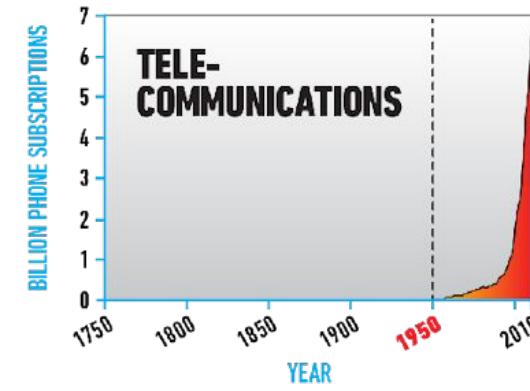
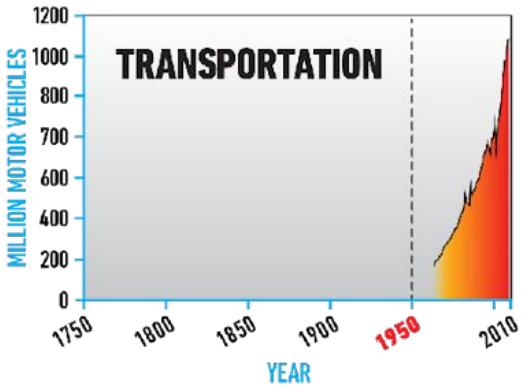
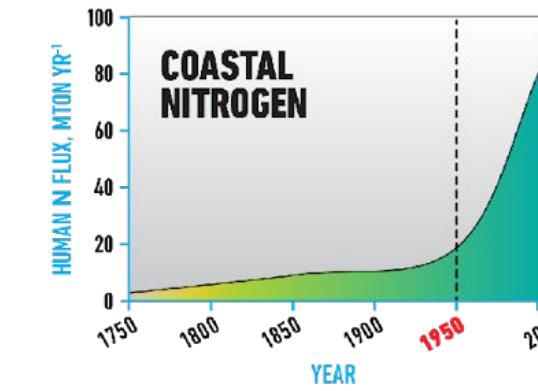
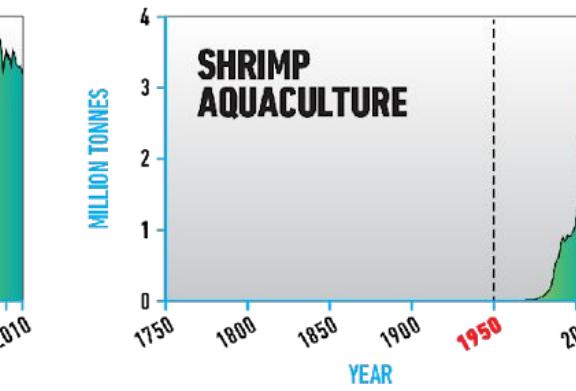
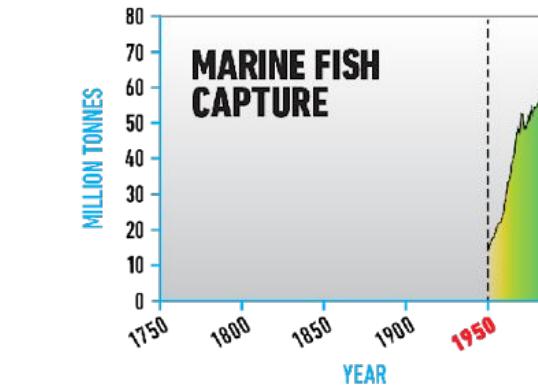
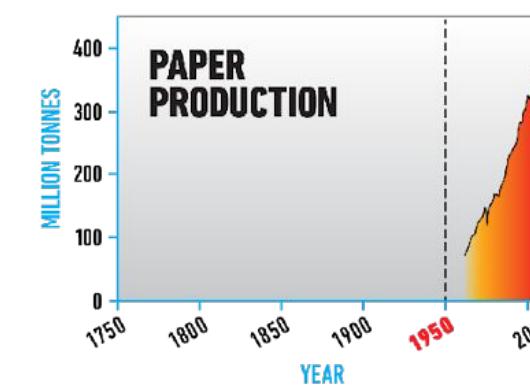
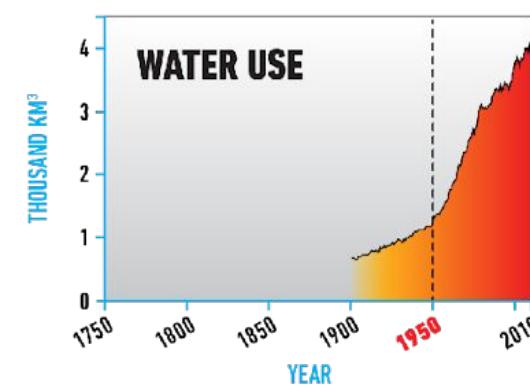
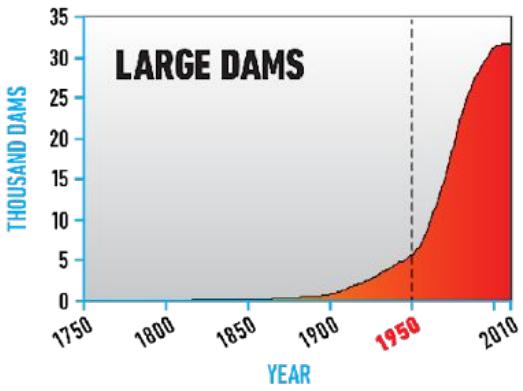
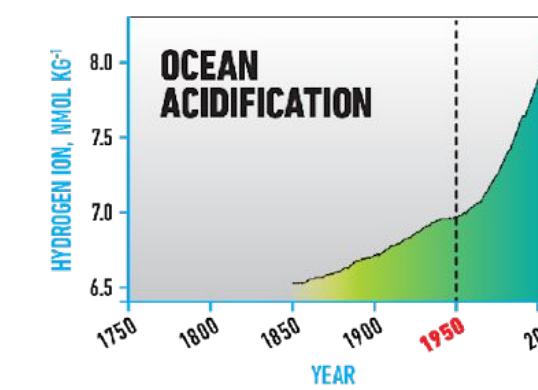
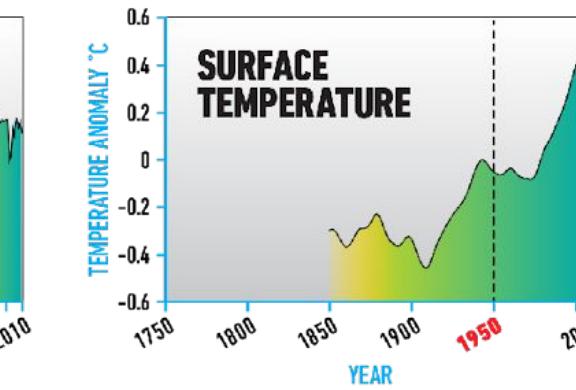
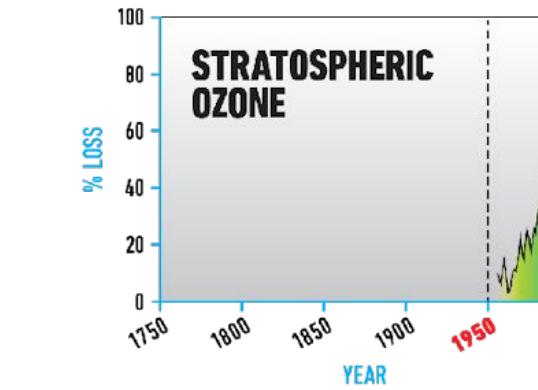
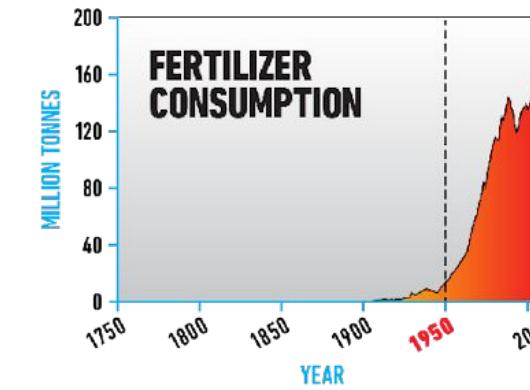
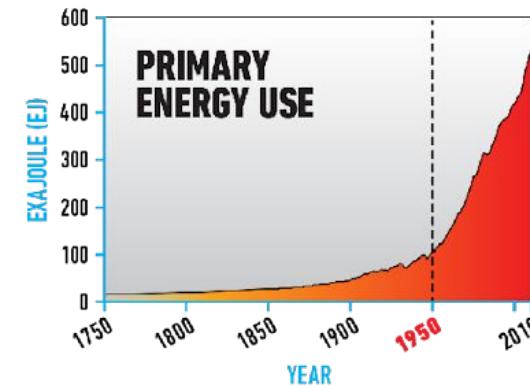
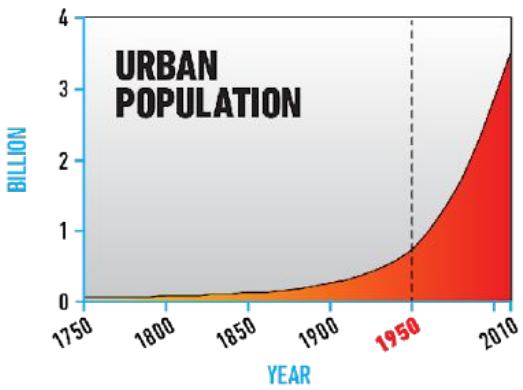
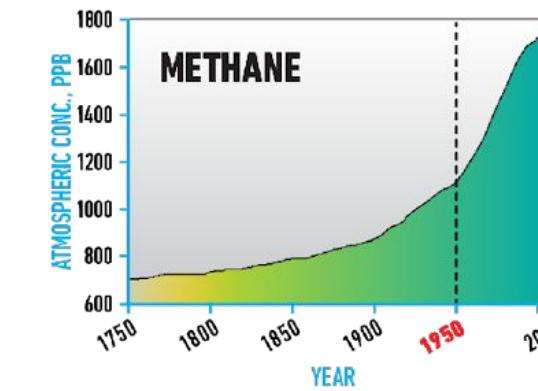
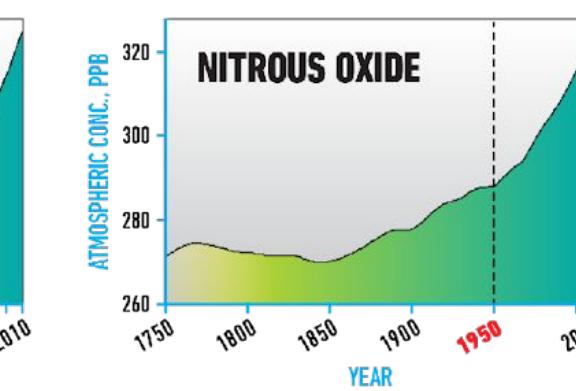
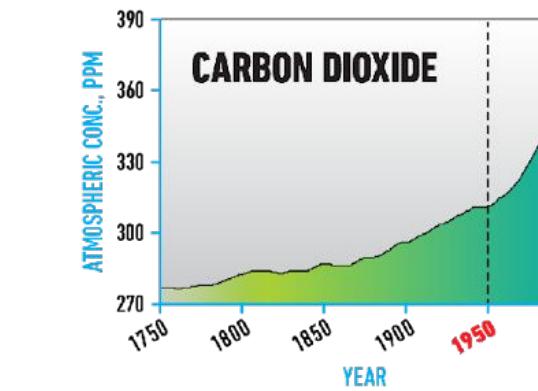
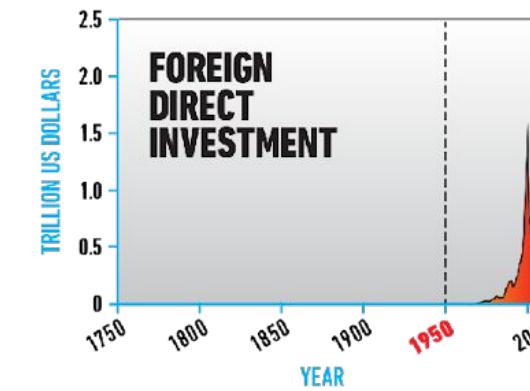
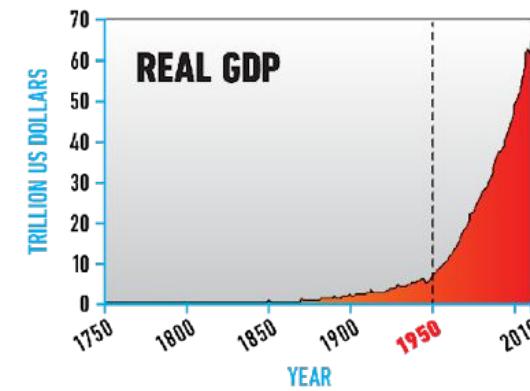
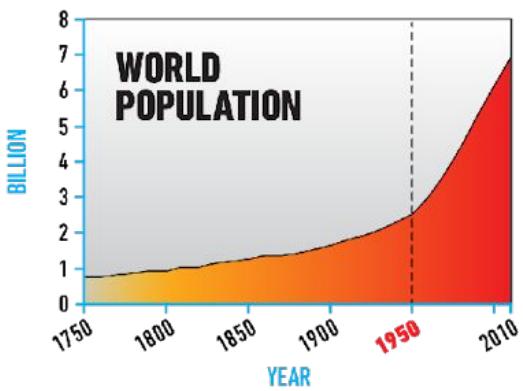
- 1. Introduction – Cities and the climate crisis
  - 2. The data challenge within cities
  - 3. Opportunities for AI in mitigation
  - 4. Opportunities for AI in adaptation
  - 5. Challenges
-



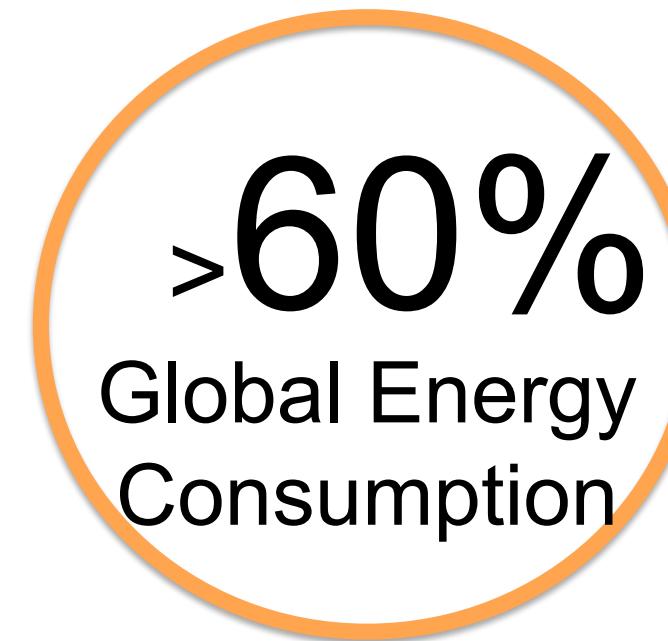
# 1. Cities and the Climate Crisis.

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# The Great Acceleration



# Cities occupy less than 2% of global land area ...



Source: UN  
Habitat.org

# Cities contribute to global climate change

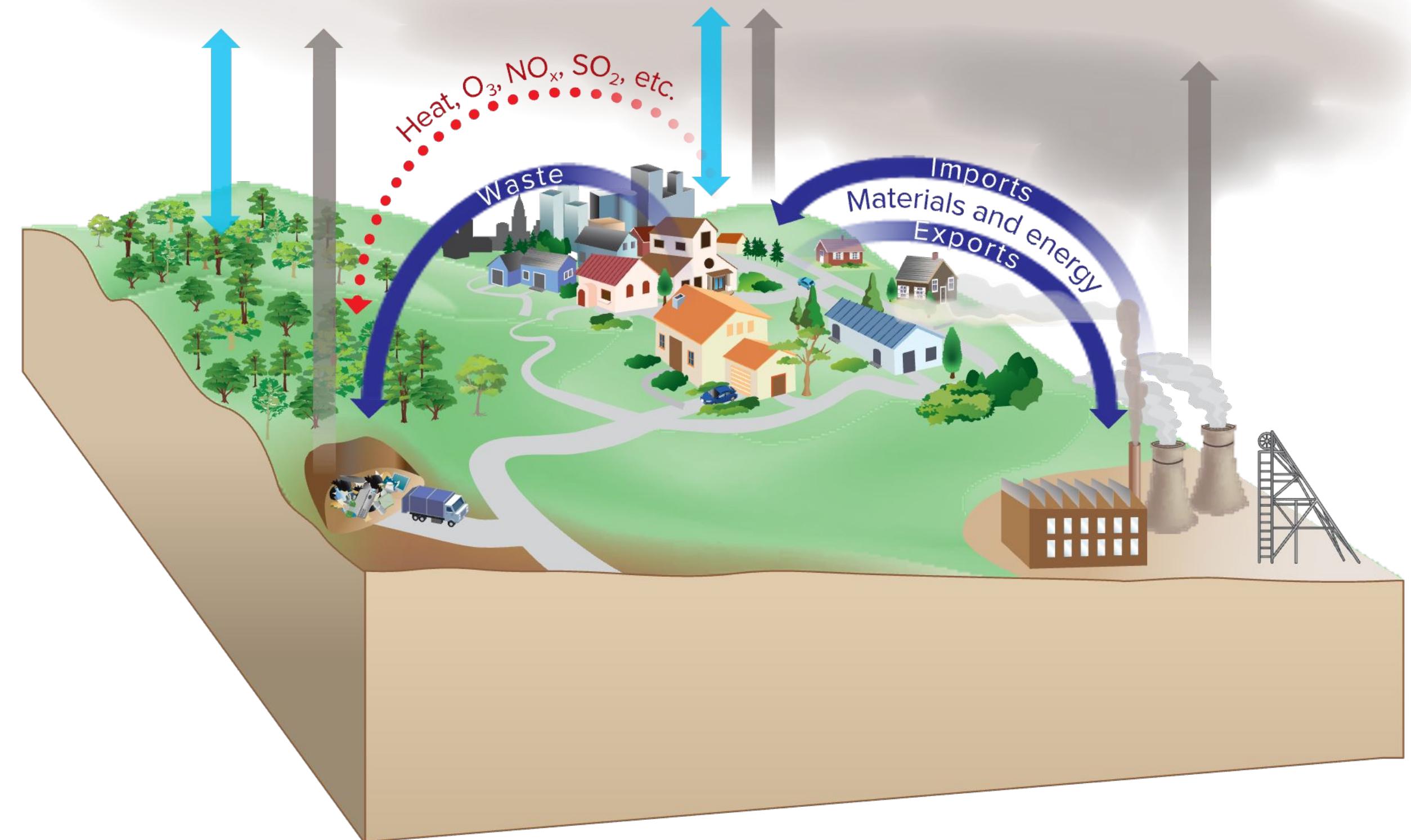
## Carbon fluxes:

↑ Driven by anthropogenic activities

↔ Driven by natural processes

← Lateral connection with urban footprint

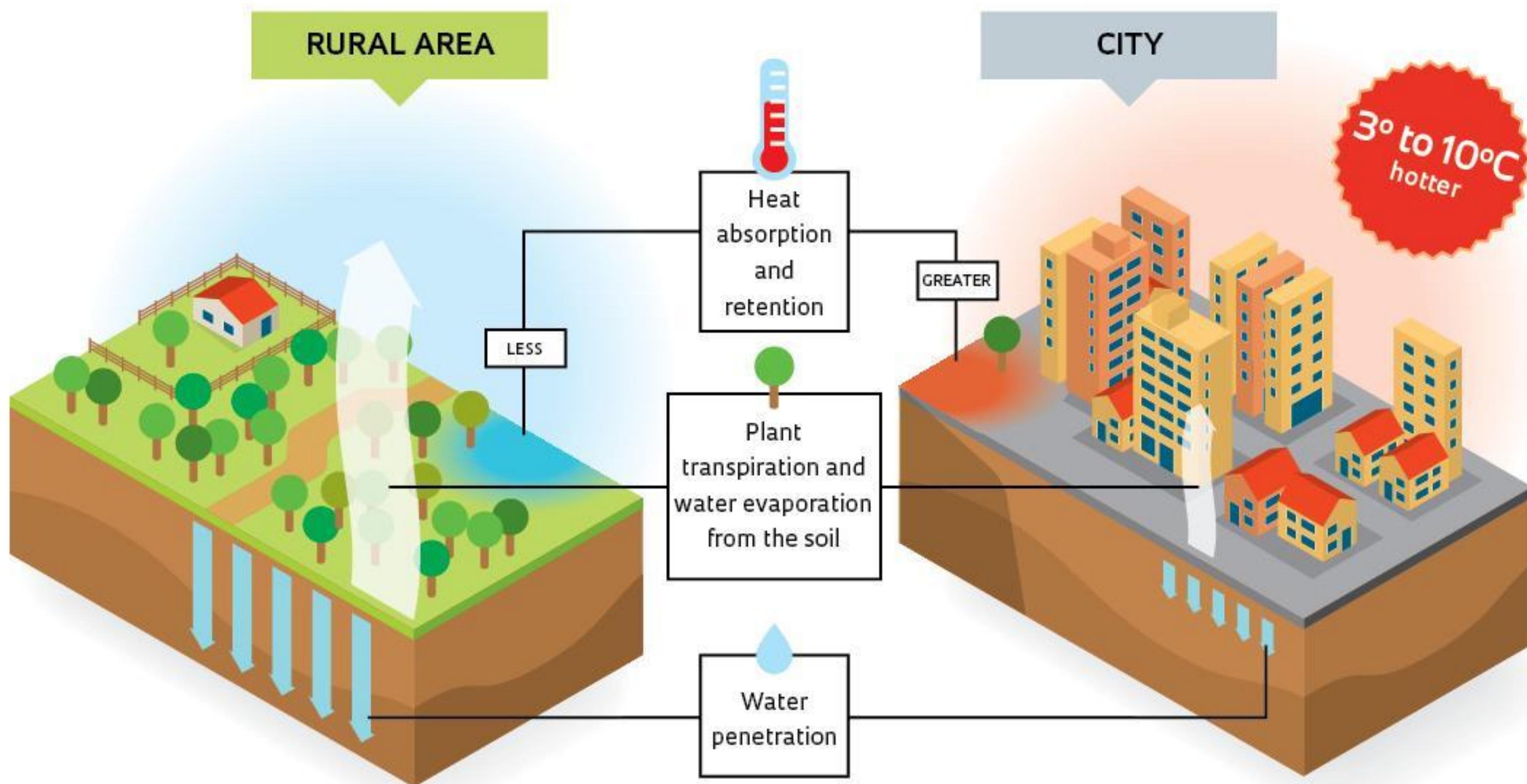
↔ Indirect effects



Carbon flows associated with human settlements

# Cities contribute to global climate change

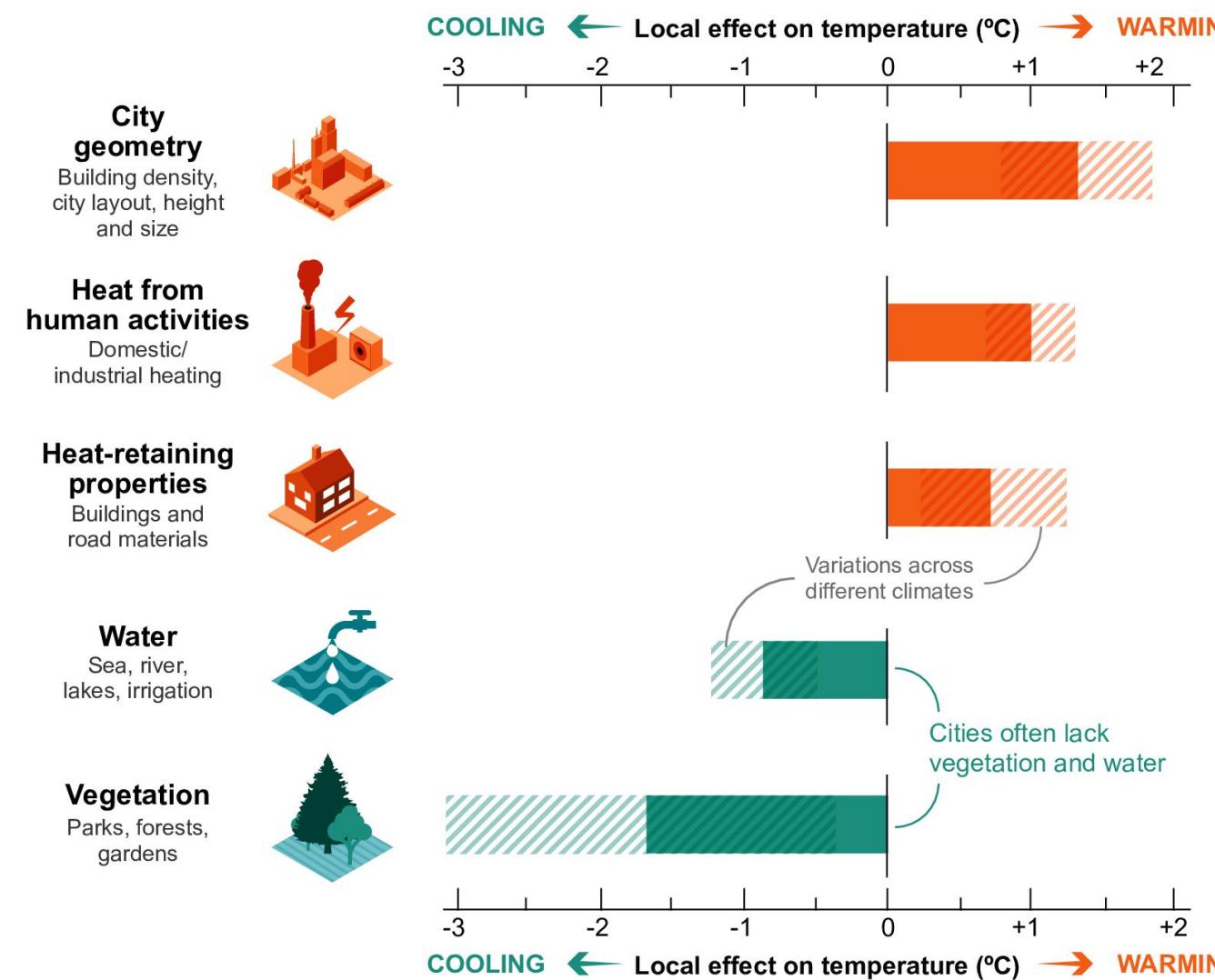
GRAPHIC: ALEXA



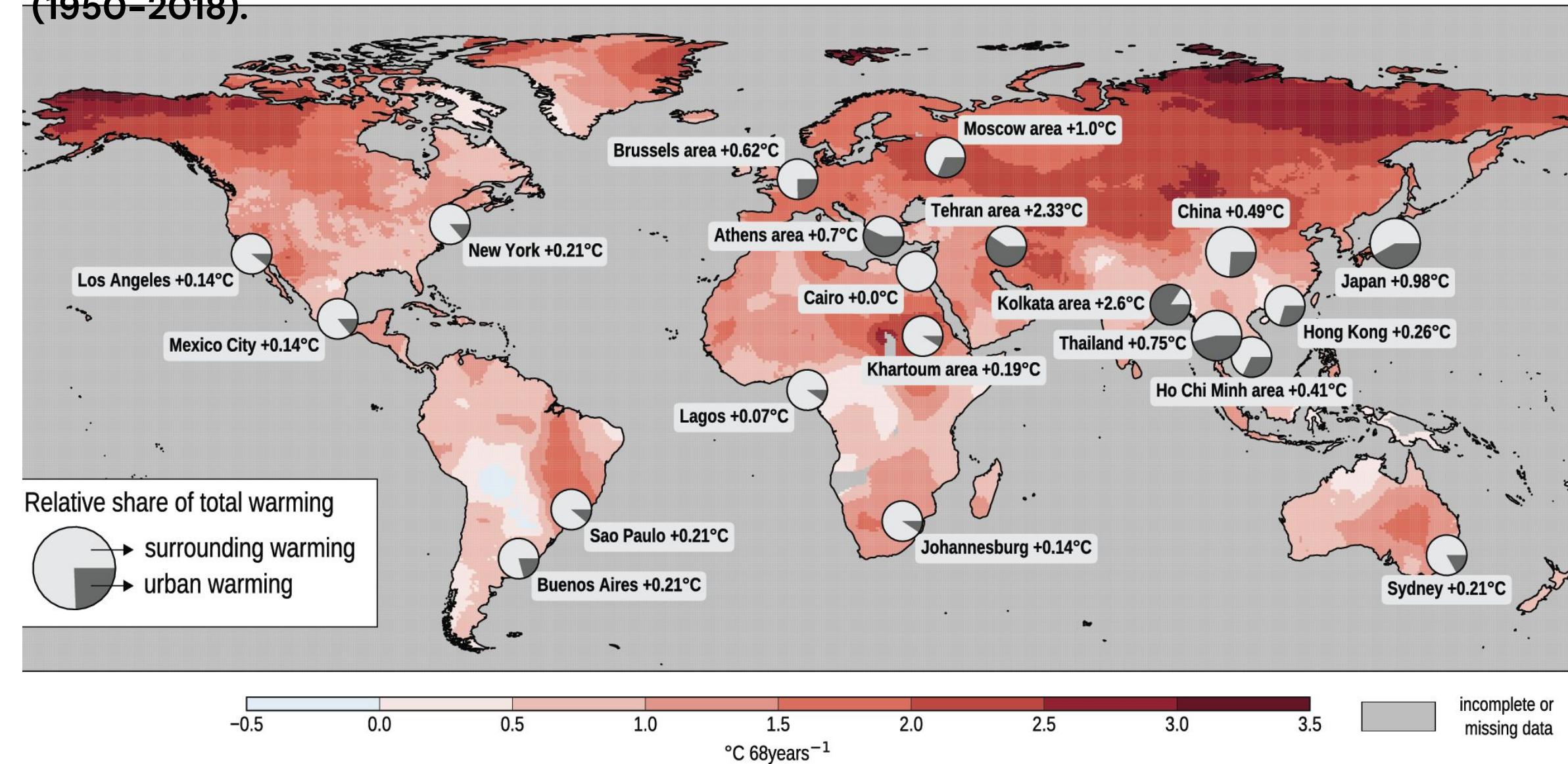
# Cities contribute to global climate change

## FAQ 10.2: Why are cities the hotspots of global warming?

Cities are usually warmer than their surrounding areas due to factors that trap and release heat and a lack of [natural cooling influences](#), such as water and vegetation.

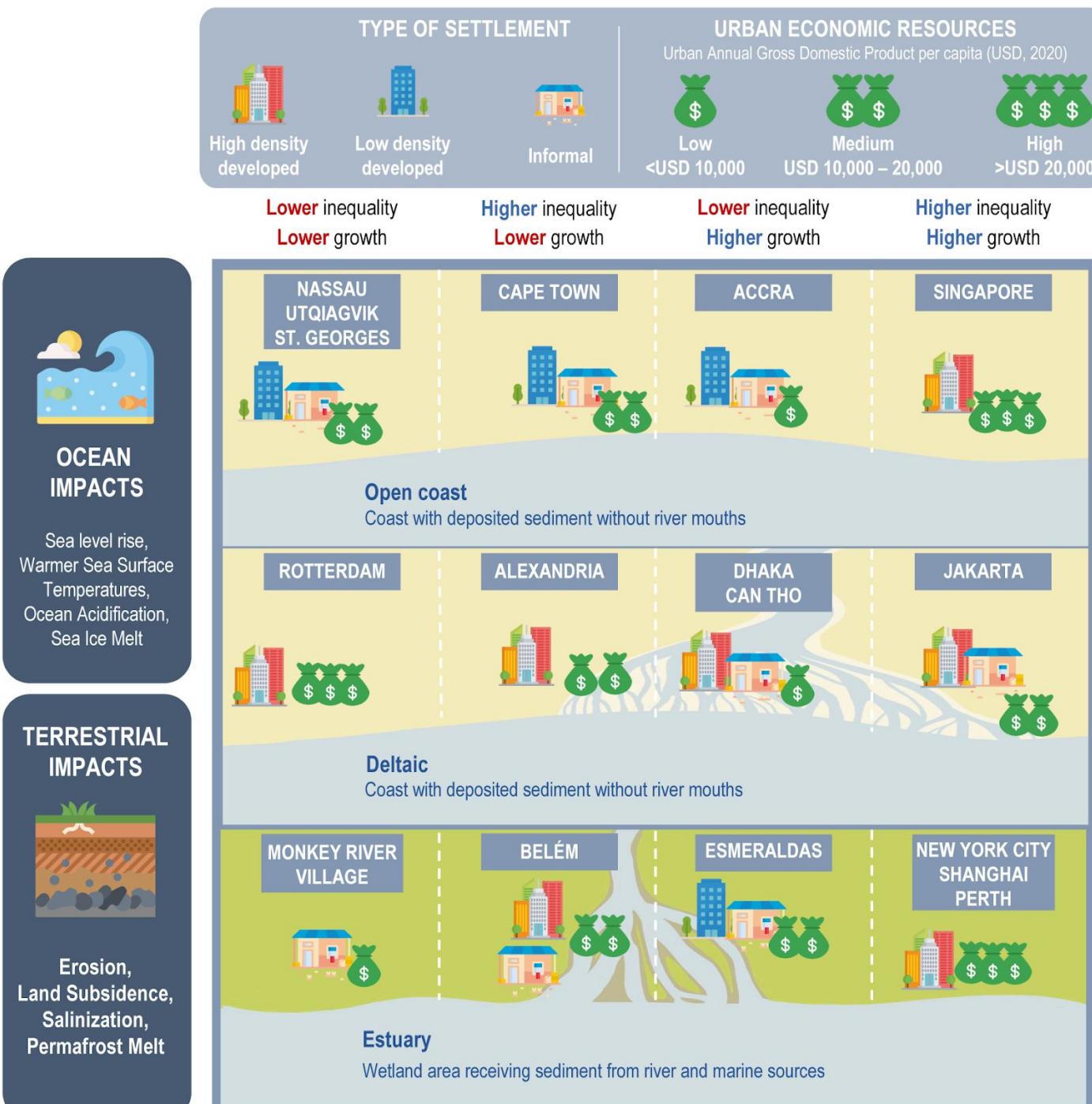


## Trend in global surface air temperature (1950–2018).

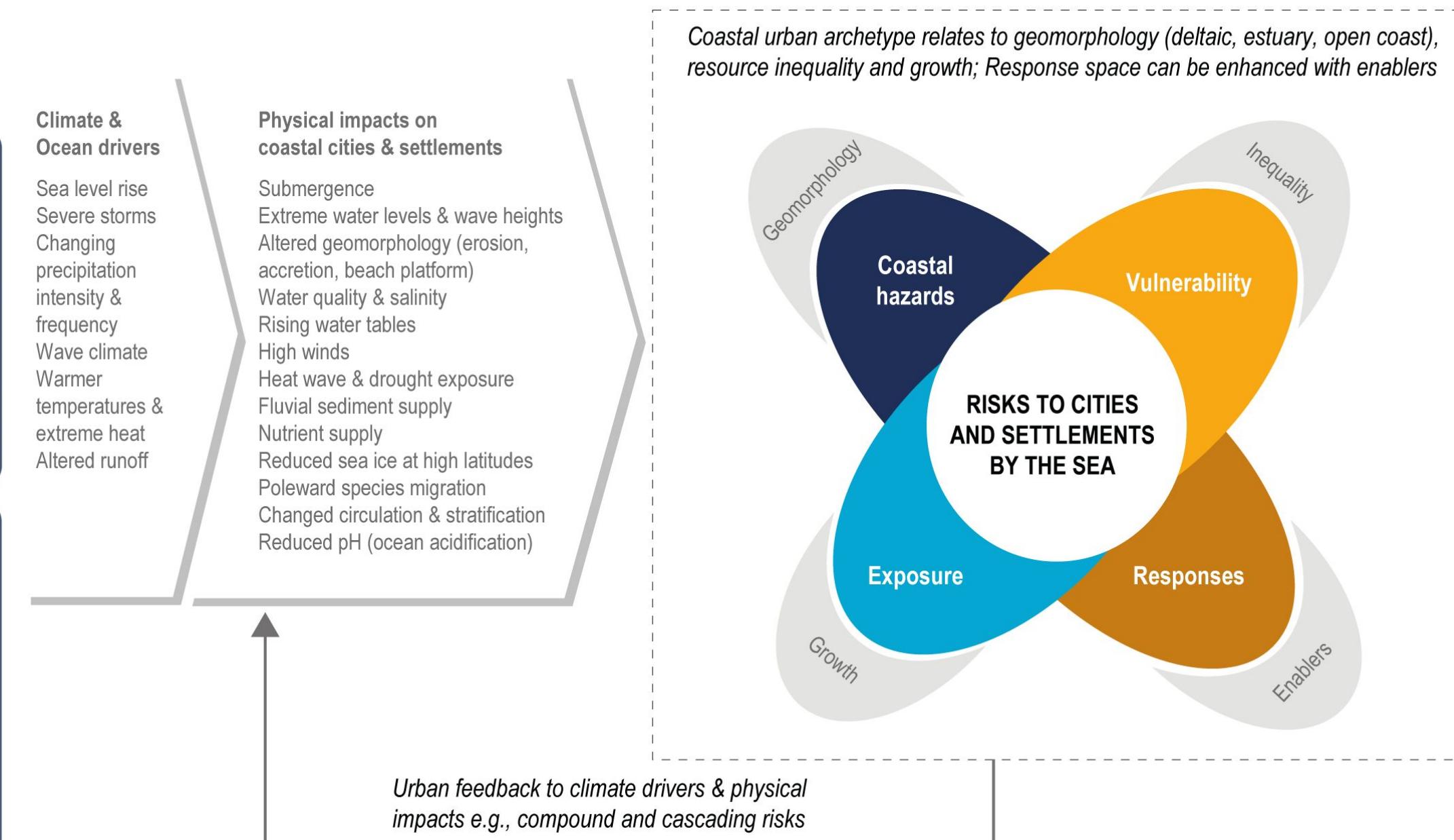


# Cities are also impacted by climate change

Archetypal C&S affected by ocean, terrestrial, geological, atmospheric and hydrological hazards driven by climate change



Schematic of how climate- and ocean-drivers (from WGI Chapter 12.4.10.2) and consequential physical impacts on coastal C&S influence risks assessed in (CCP2.2; Figure based on Simpson et al. (2021) and Section 1.3.1.2).



# What can cities do?

Mitigate =  
Reduce carbon footprint



Adapt = Reduce vulnerability;  
increase resilience

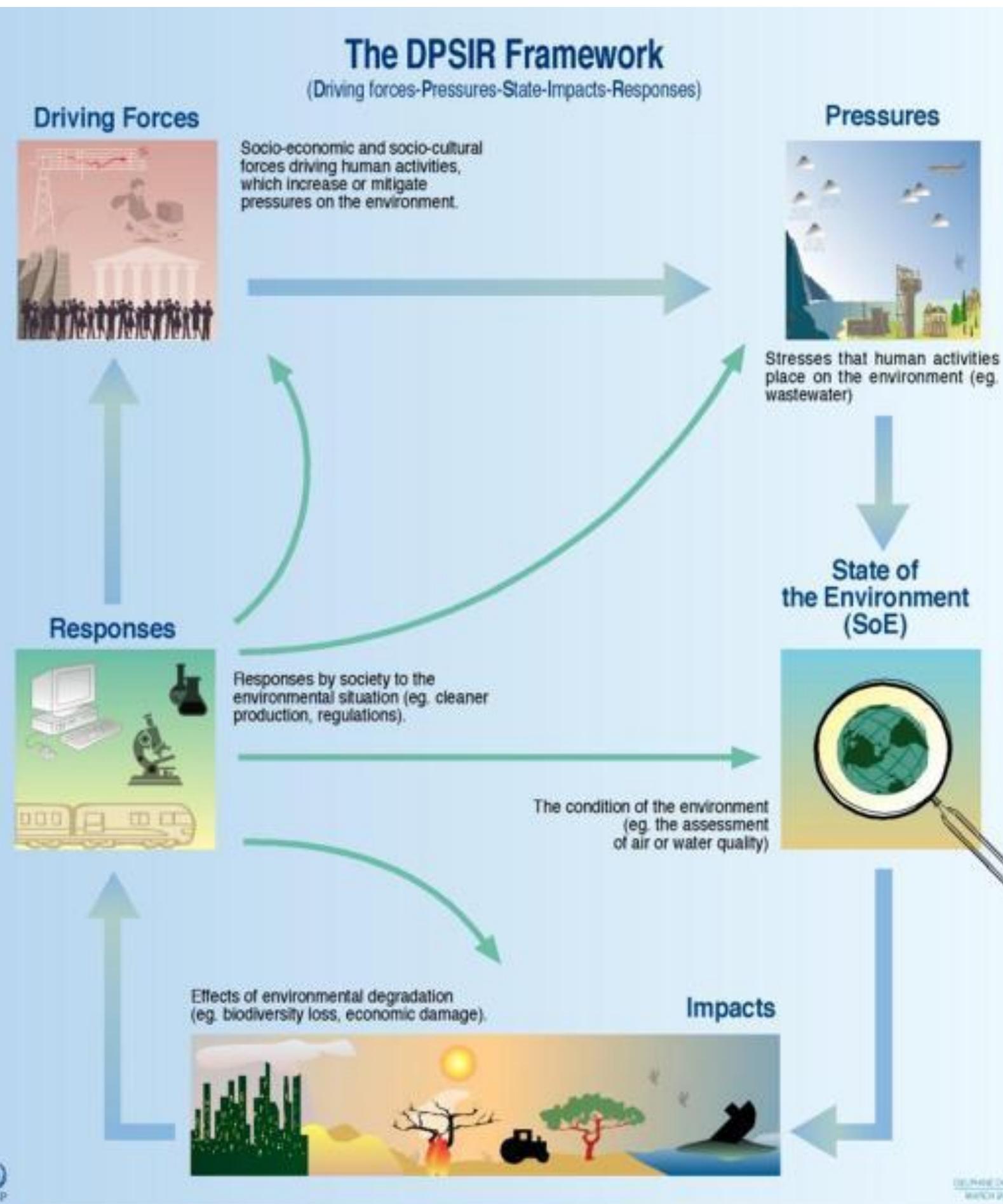




## 2. The Data challenge.

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# Data challenge



- **Driving Forces**
  - Mitigation: greenhouse gas emissions
  - Adaptation: inequality, poverty data
- **Pressures**
  - Mitigation & Adaptation: spatial data on land-use, deforestation
- **State**
  - Mitigation: remaining carbon budget.
  - Adaptation: regional differences in impacts of extreme events
- **Impacts**
  - Mitigation: benefits of mitigation
  - Adaptation: biodiversity loss
- **Responses**
  - Mitigation & Adaptation: efficacy of policy and management responses.

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This chapter should be cited as:

Seto K.C., S. Dhakal, A. Bliglo, H. Blanco, G.C. Delgado, D. Dewar, L. Huang, A. Inaba, A. Kansa, S. Lwasa, J.E. McMahon, D.B. Müller, I. Murakami, H. Nagendra, and A. Ramaswami, 2014: Human Settlements, Infrastructure and Spatial Planning. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Klemm, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

## 12.1 Introduction

Urbanization is a global phenomenon settlements. The shift from primary evident through the transformation and the built environment. In each unprecedented for its speed and trend of the 21st century. With cities are being absorbed by, or coalescing and agglomerations. This rapid transformation is reshaping the world, and in many places it is

Today, more than half of the global urban population lives in agglomerations with populations of one million or more, and this figure is expected to rise to only 13% in 1900 (UN DESA, 2012). In developing countries, where two-thirds of the world's population live, the global urban population is expected to grow from 2.3 billion in 2010 to 5.6 billion by 2050, corresponding to 64% to 69% of the world's population (Cleary et al., 2007; IIASA, 2009; UN DESA, 2012, 2013). The rate of growth of the urban population is increasing by approx-

Future trends in the levels, patterns, and region-  
ization will be significantly different from those of

the urban population growth will take place in small- to [12.9] urban areas. Nearly all of the future population growth will be by urban areas in developing countries (IIASA, 2009; UN DESA, 2011). In many developing countries, infrastructure and urban growth will be greatest, but technical capacities are limited, and governance, financial, and economic institutional capacities are weak (Bräutigam and Knack, 2004; Rodrik et al., 2004). The kinds of towns, cities, and urban agglomerations that ultimately emerge over the coming decades will have a critical impact on energy use and carbon emissions.

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) did not have a chapter on human settlements or urban areas. Urban areas were addressed through the lens of individual sector chapters. Since the publication of AR4, there has been a growing recognition of the significant contribution of urban areas to GHG emissions, their potential role in mitigating them, and a multi-fold increase in the corresponding scientific literature. This chapter provides an assessment of this literature and the key mitigation options that are available at the local level. The majority of this literature has focused on urban areas and China.<sup>12</sup>

Assessment highlights a number of key knowledge gaps. First, there is lack of consistent and comparable emissions data at local levels, making it particularly challenging to assess the urban share of global GHG emissions as well as develop urbanization typologies and their emissions pathways. Second, there is little scientific understanding of the magnitude of the emissions reduction from altering urban form, and the emissions savings from integrated infrastructure and use planning. Third, there is a lack of consistency and thus comparability on local emissions accounting methods, making cross-comparisons of emissions or climate action plans difficult. Fourth, there are few evaluations of urban climate action plans and their effectiveness. Fifth, there is lack of scientific understanding of how cities prioritize mitigation strategies, local actions, investments, and policies that are locally relevant. Sixth, there are large uncertainties about future urbanization trajectories, although urban form and infrastructure will play large roles in determining emissions pathways.

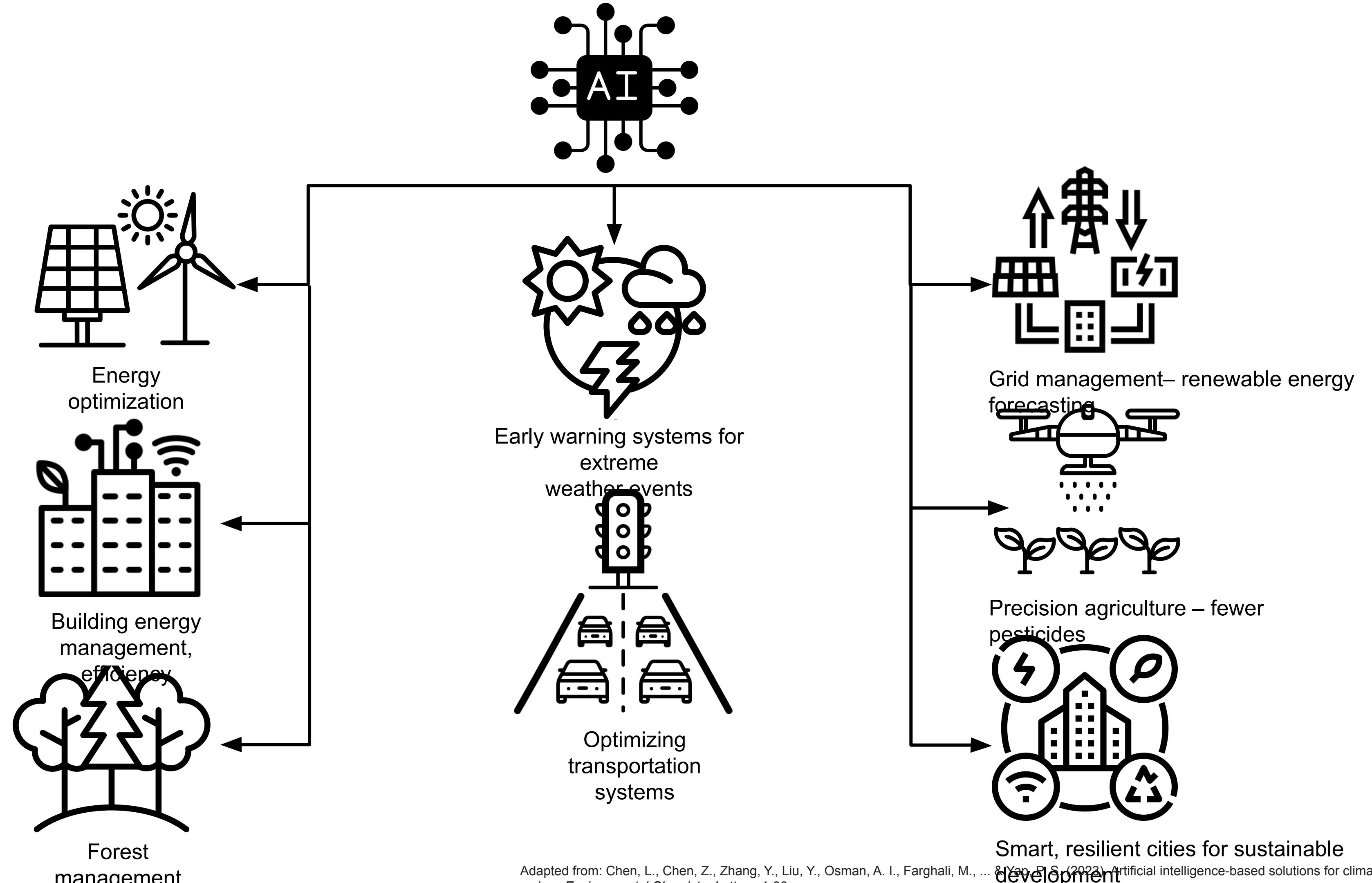
of mitigation in urban areas (12.9). In addition, major gaps in knowledge with respect to mitigation of climate change in urban areas (12.9).

# More than 13,000 cities pledge climate action ...



# But fewer than 10% publish emission inventories





# Poll Question

- Which area do you think cities have the least data to make climate-related decisions?
  - a) finance – how much climate-related actions cost to implement and what the benefits are;
  - b) risks – what climate-related risks are the most urgent and where;
  - c) nature & biodiversity – what nature-based solutions are available & how is nature being affected by climate;
  - d) policy – how effective policies to mitigate & adapt to climate are performing;

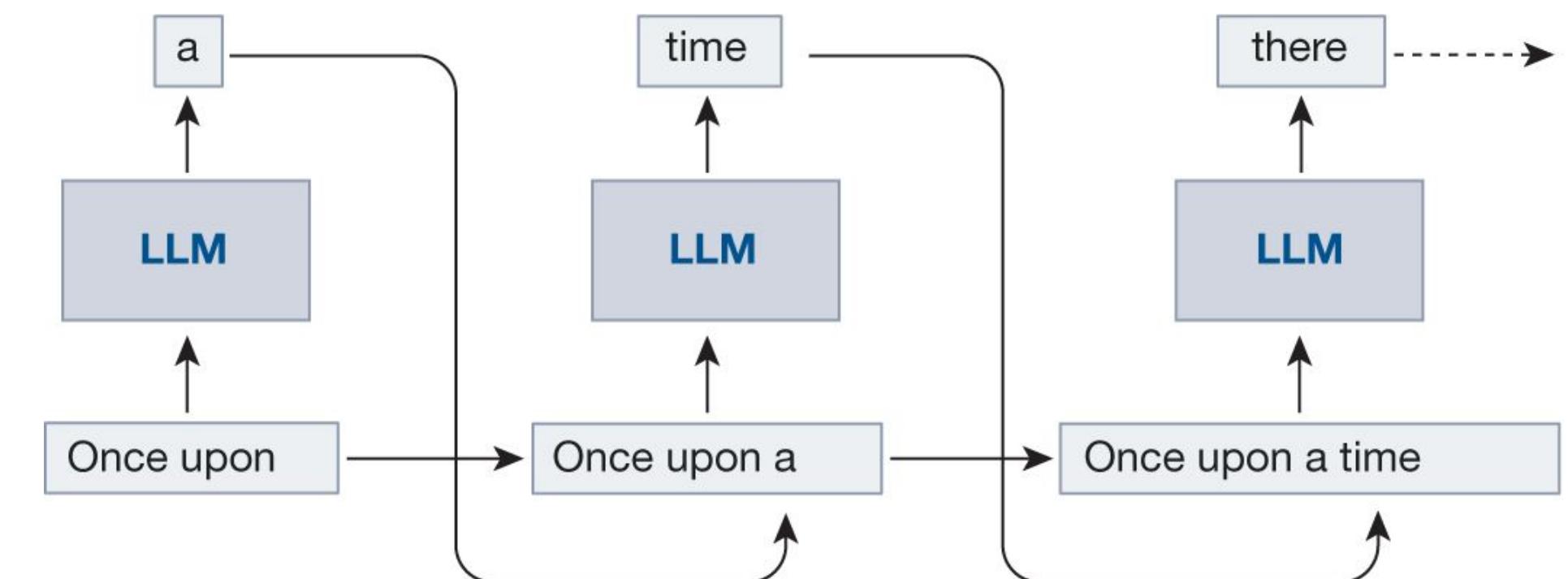


### 3. AI opportunity for mitigation

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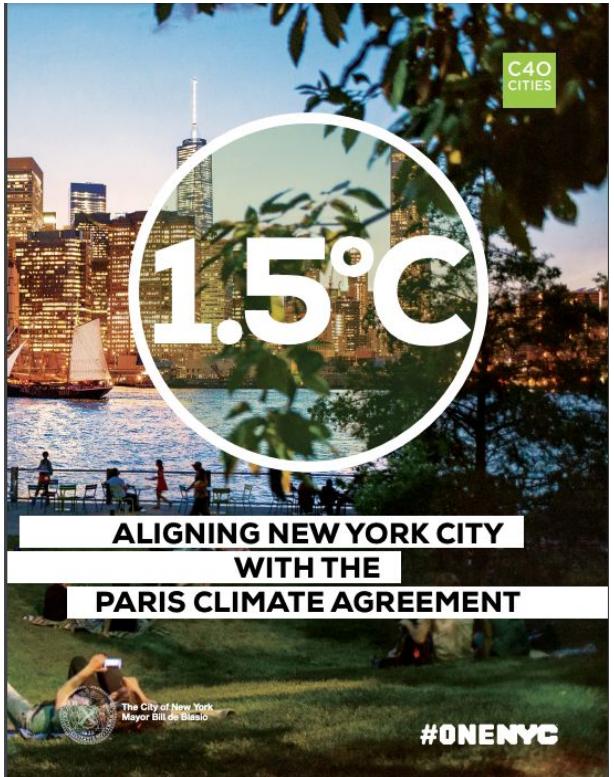
# Text as Data presents enormous opportunity to understand climate action within cities.

- “Language is the medium for politics.”
- Large volume of texts now available, but cumbersome to manually read/code
- Computers can help to parse language + employ machine learning to “learn” or recognize patterns, sentiment, etc.

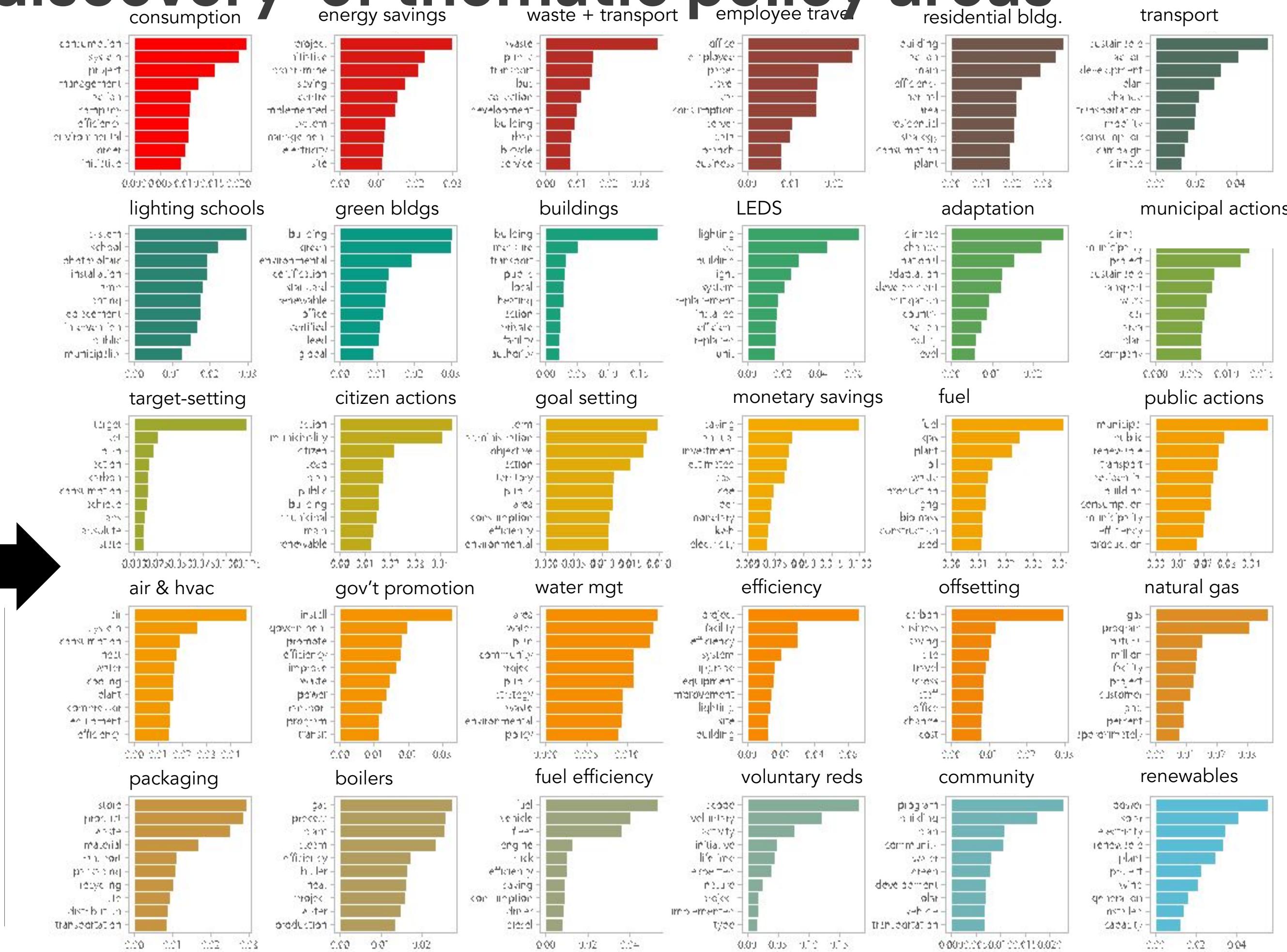


Source: Shanahan, M., McDonell, K., & Reynolds, L. (2023). Role play with large language models. Nature, 623(7987), 493-498.

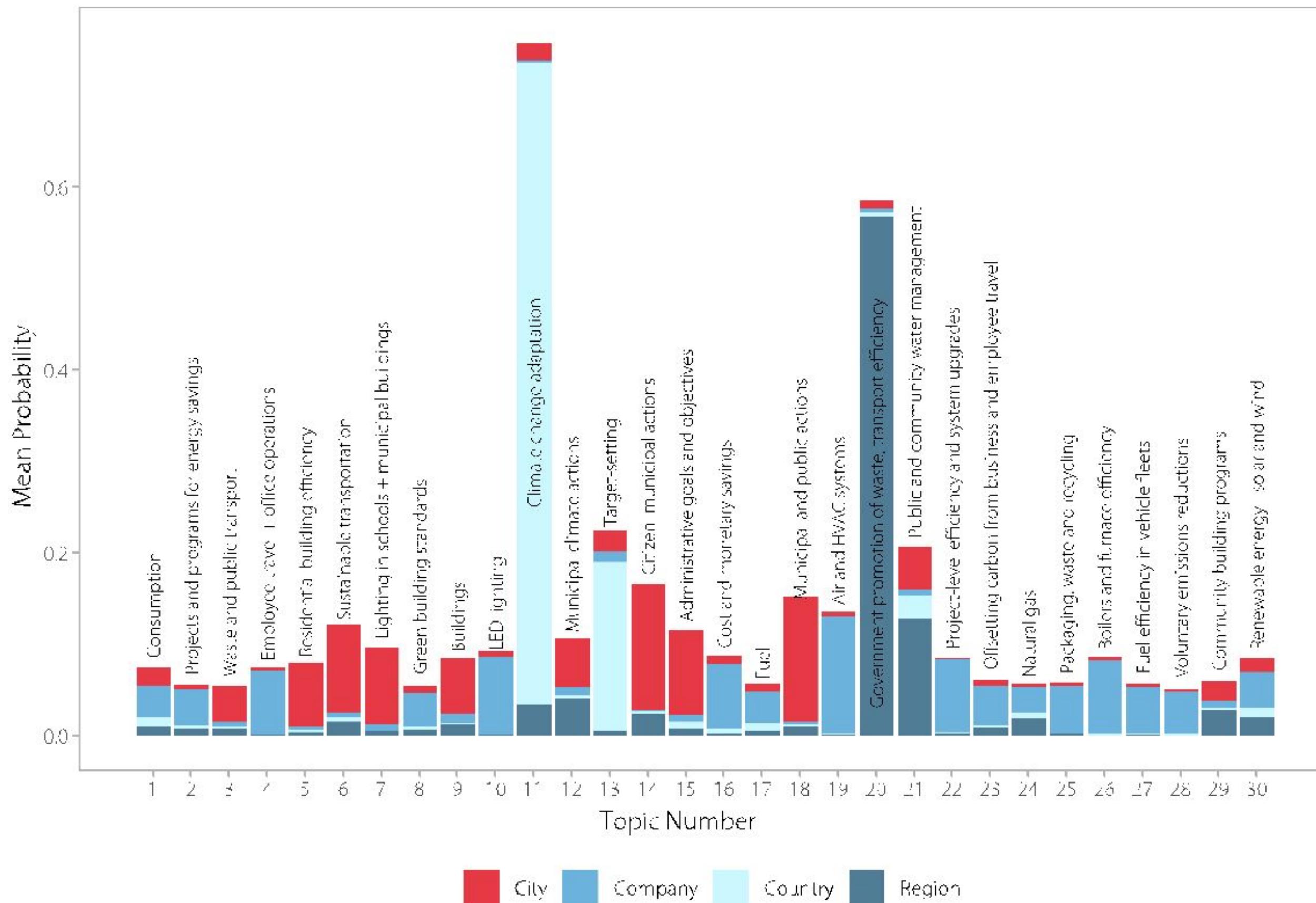
# Topic modeling – ‘discovery’ of thematic policy areas



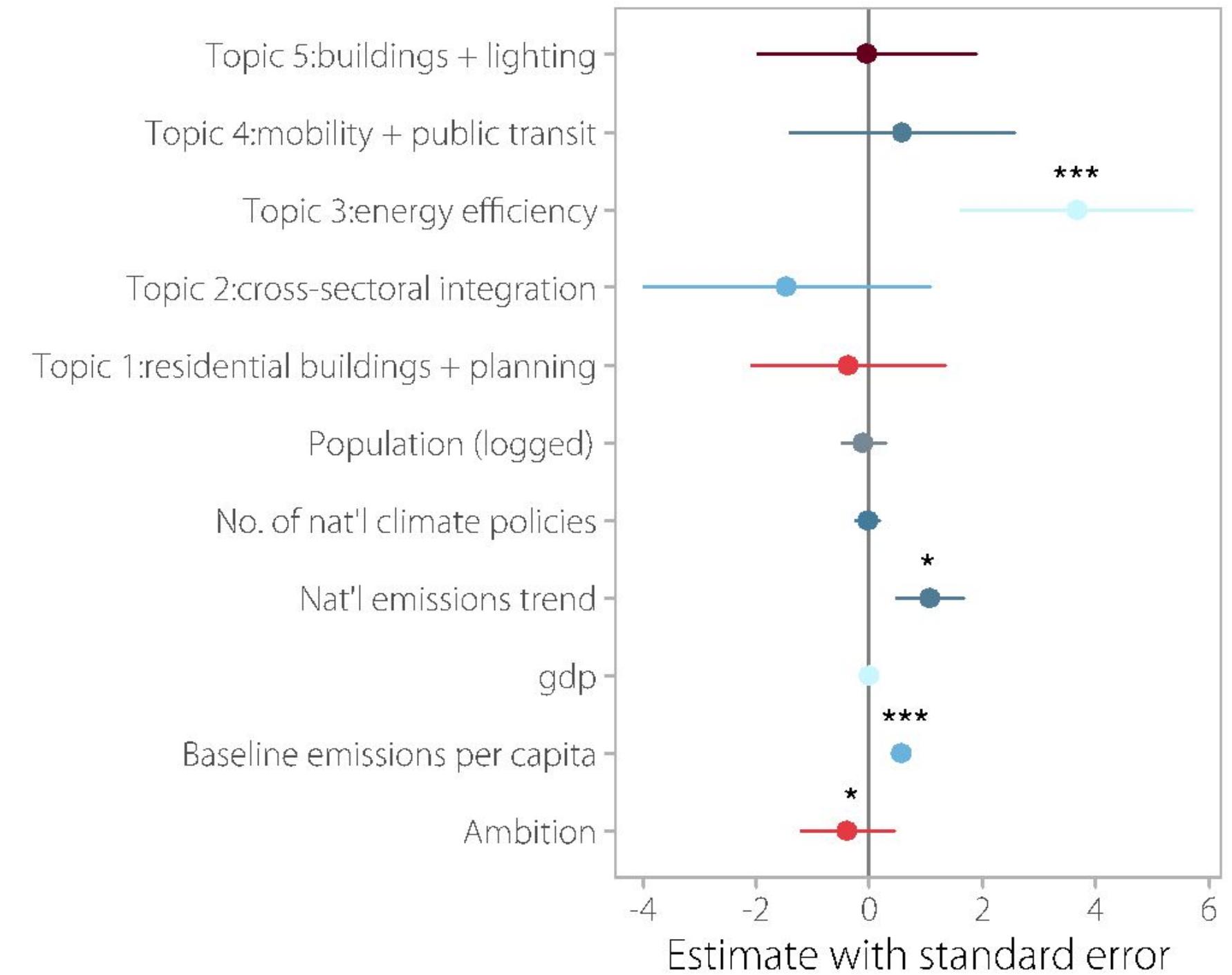
ABERDEEN CITY COUNCIL	
COMMITTEE	URGENT BUSINESS COMMITTEE
DATE	6 May 2020
EXEMPT	No
CONFIDENTIAL	No
REPORT TITLE	Net Zero Vision and Infrastructure Plan
REPORT NUMBER	PLA/20/088
DIRECTOR	Commissioning
REPORT AUTHOR	RICHARD SWEETNAM
TERMS OF REFERENCE	UBC 1
<b>1. PURPOSE OF REPORT</b>	
The purpose of the report is to update Committee on the work done on the development of a Net Zero Vision for Aberdeen and associated infrastructure investment needed to support the achievement of the vision.	
<b>2. RECOMMENDATION(S)</b>	
That the Committee:	
(i) Approves the Net Zero Vision for Aberdeen;	
(ii) Agree the governance framework to drive and lead the vision for the city and instructs the Chief Executive to report back to the June 2020 Urgent Business Committee on the proposed governance model, its composition and the terms of reference (including monitoring of delivery to target emissions);	
(iii) Approves the Strategic Infrastructure Plan – Energy Transition and the outcome;	
(iv) Instructs the Chief Officer City Growth and Strategic Place Planning to update the evidence base and baseline data in order to provide a monitoring and evaluation framework against which progress can be measured;	
(v) Instructs the Chief Officer City Growth and Strategic Place Planning to engage external partners to develop business cases for priority projects; and	
(vi) Instructs the Chief Officer – City Growth, in consultation with the Chief Officer – Finance to develop a supporting cohesive finance and investment plan to support delivery of the city's energy transition, including those projects with national and transformational significance.	



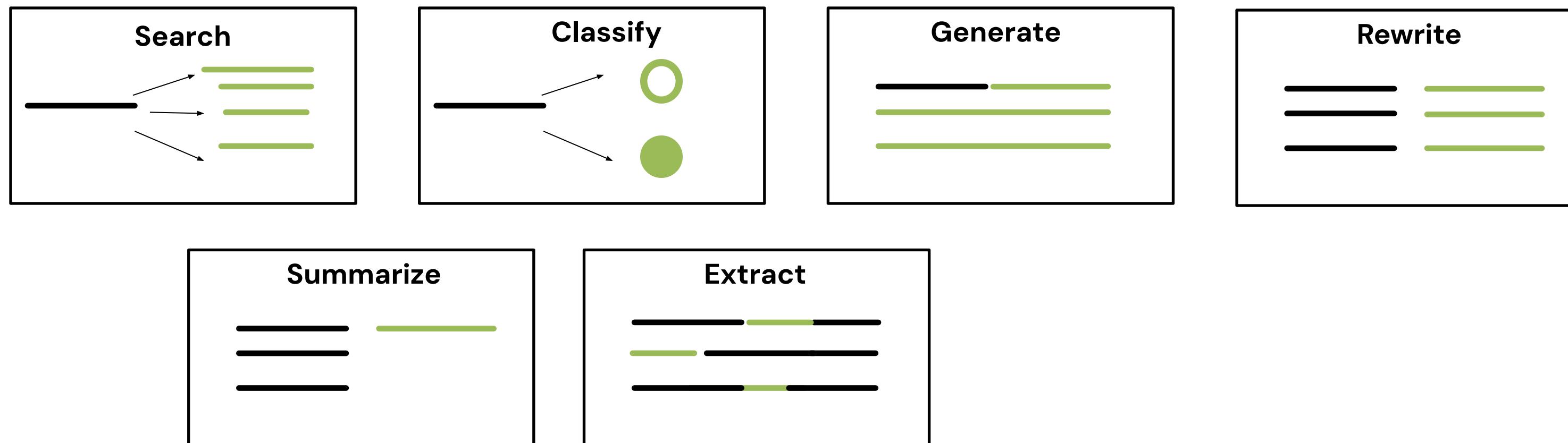
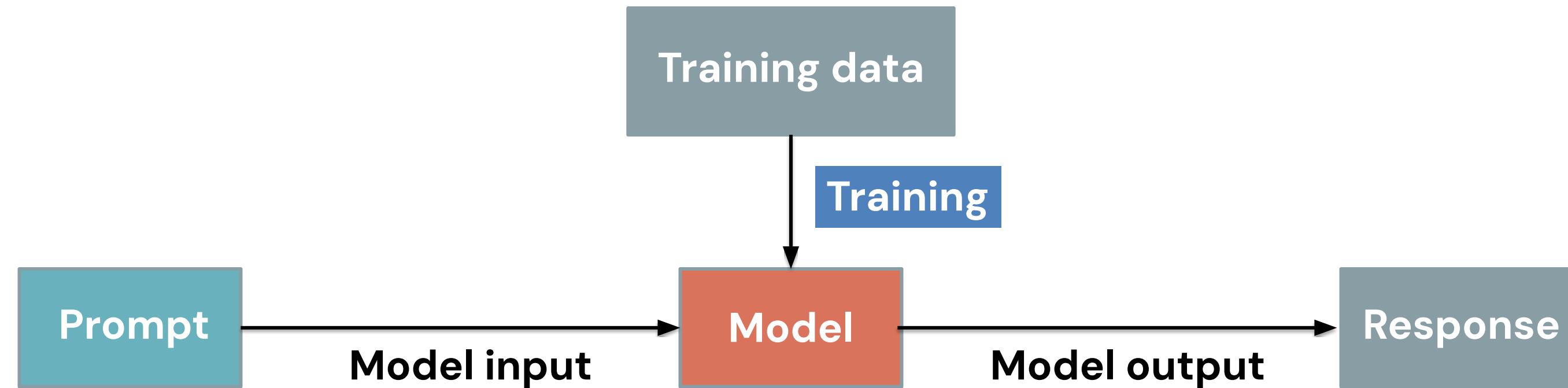
# Topic modeling – ‘discovery’ of thematic policy areas



# Energy efficiency plans positively associated with reductions



# Large Language Models (LLMs) + GenAI = opportunity



Bottom figure adapted from : <https://attri.ai/blog/introduction-to-large->

# Climate-specific LLMs emerging to guide policy



## ChatNetZero

A dedicated LLM-based application to ground Generative AI to climate change expertise

### LLM ChatBot for Q&A

- Active hallucination checking algorithm
- Fine-tuned LLM process made for net-zero context
- Verified references included for each statement

### Net Zero dashboard

- Automatically display net zero data from the Net Zero Tracker
- Access data for over 4000 non-state actors + countries

The screenshot shows the ChatNetZero website. At the top, there's a navigation bar with links for HOME, CHAT, FAQ, ABOUT, CONTACT, and a red button labeled "Net Zero Tracker". The main header features the "CHAT NET ZERO" logo and the tagline "Helping to demystify net zero.". Below this, there's a search bar with the placeholder "Ask me a question e.g. Does Walmart's net zero target cover all of its emissions?". To the right of the search bar is a small icon of a paper airplane. The page then displays three sections with icons and text: 1) A cloud icon with CO<sub>2</sub> and O<sub>2</sub> molecules, asking if the net-zero target covers all emissions. 2) A factory icon with smoke, asking if relying on fossil fuels means it's not credible. 3) A cloud icon with the text "SCOPE 3", asking if companies should cover scope 3 emissions in their net zero targets. At the bottom, a footer note states: "ChatNetZero is engineered to merge expert-level Net Zero domain knowledge with the capabilities of Large Language Models (LLMs), all while overcoming the limitations that have made LLMs less trusted within the climate change community."

# Example: fact-checking credibility

**Question:** “If an entity relies on fossil fuels, is it still pledging net zero credibly?”

Answer: “No” from a credible source

## ChatNetZero

If an entity relies on fossil fuels and does not have a specific plan to phase down and out fossil fuel extraction and use, **it is not pledging net zero credibly.**

The recommendations state that non-state actors cannot claim to be net zero while continuing to build or invest in new fossil fuel supply.

Achieving credible net zero requires the phasing down and out of fossil fuel extraction and use, with any residual emissions being removed by carbon dioxide removal.

Therefore, an entity that relies on fossil fuels without a clear plan to transition away from them is not credibly pledging net zero.

Source:  
[https://www.un.org/sites/un2.un.org/files/high-level\\_expert\\_group\\_n7b.pdf](https://www.un.org/sites/un2.un.org/files/high-level_expert_group_n7b.pdf)  
page: 7

Answer: “Yes”

## GPT-4

An entity (such as a company, government, or institution) that currently relies on fossil fuels **isn't necessarily failing to make a credible net-zero pledge.** The credibility of a net-zero commitment depends on several factors, including:

Timeframe: How quickly is the entity planning to achieve net-zero emissions? Some industries may take longer to transition away from fossil fuels due to technological or financial limitations.

Transition Plan: Does the entity have a detailed, transparent plan for how it will transition away from fossil fuels? A credible plan would outline specific measures such as adopting renewable energy, improving energy efficiency, and making operational changes.

Scope: Does the net-zero commitment cover all scopes of emissions, including Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased electricity), and Scope 3 (other indirect emissions from the supply chain, employee travel, etc.)?

Accountability: Is there a third-party verification system in place to validate the entity's emissions reductions and offset strategies?

Interim Targets: Does the entity have short- and medium-term targets that align with its long-term net-zero commitment? Meeting these interim milestones can provide evidence of the entity's commitment.

Investment in New Technologies: Is the entity investing in new technologies that will allow it to transition away from fossil fuels more effectively?

Public Reporting: Does the entity regularly report on its progress towards achieving its net-zero commitment?

Integrity of Offsets: If the entity plans to use carbon offsets to achieve net-zero, are these offsets credible, verifiable, and contributing to additional carbon reductions?

Governance: Is climate action integrated into the entity's governance structures, with clear responsibilities and incentives for achieving net-zero?

Stakeholder Engagement: Is the entity engaging with stakeholders, including communities, employees, and investors, in its transition to net-zero?

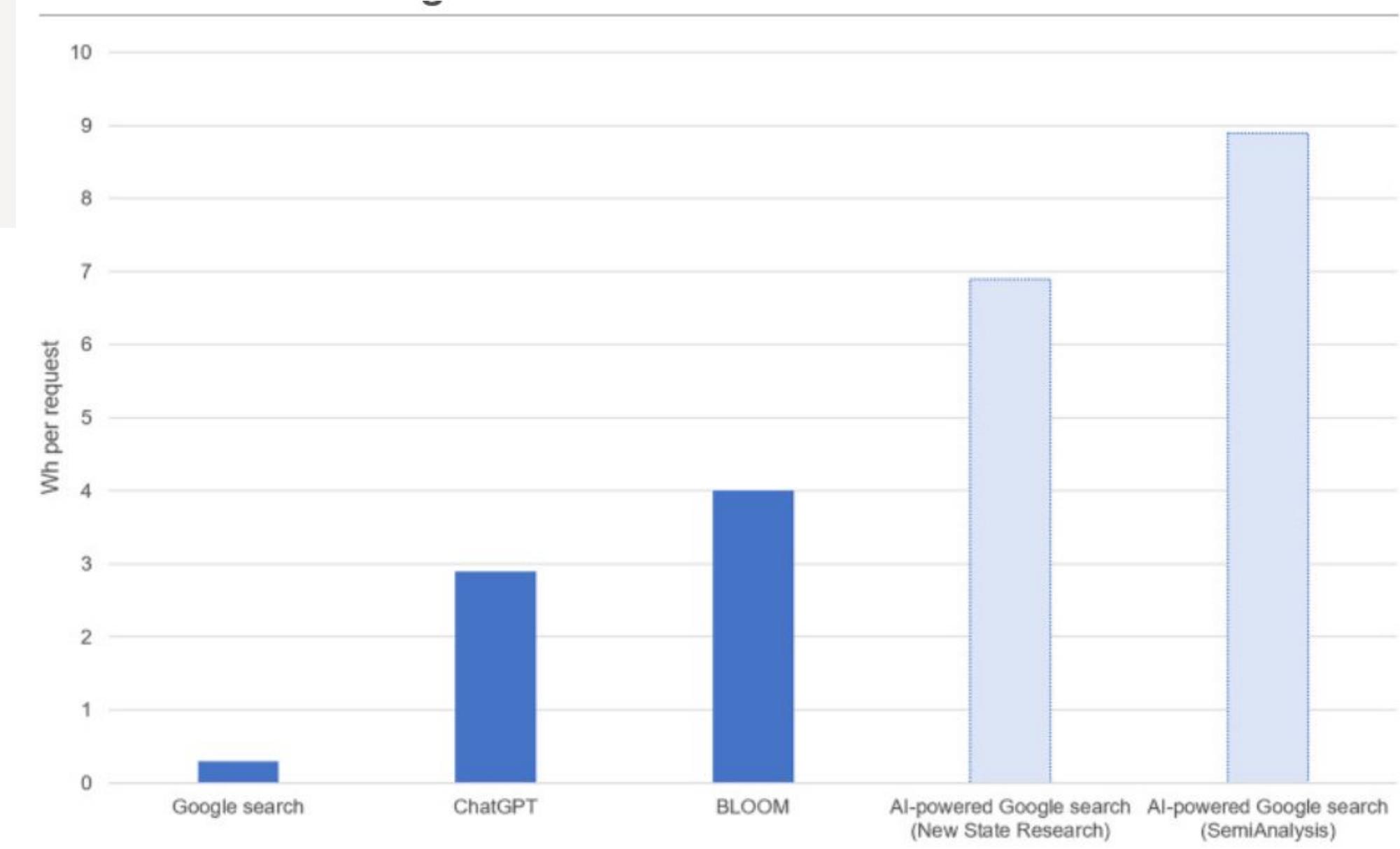
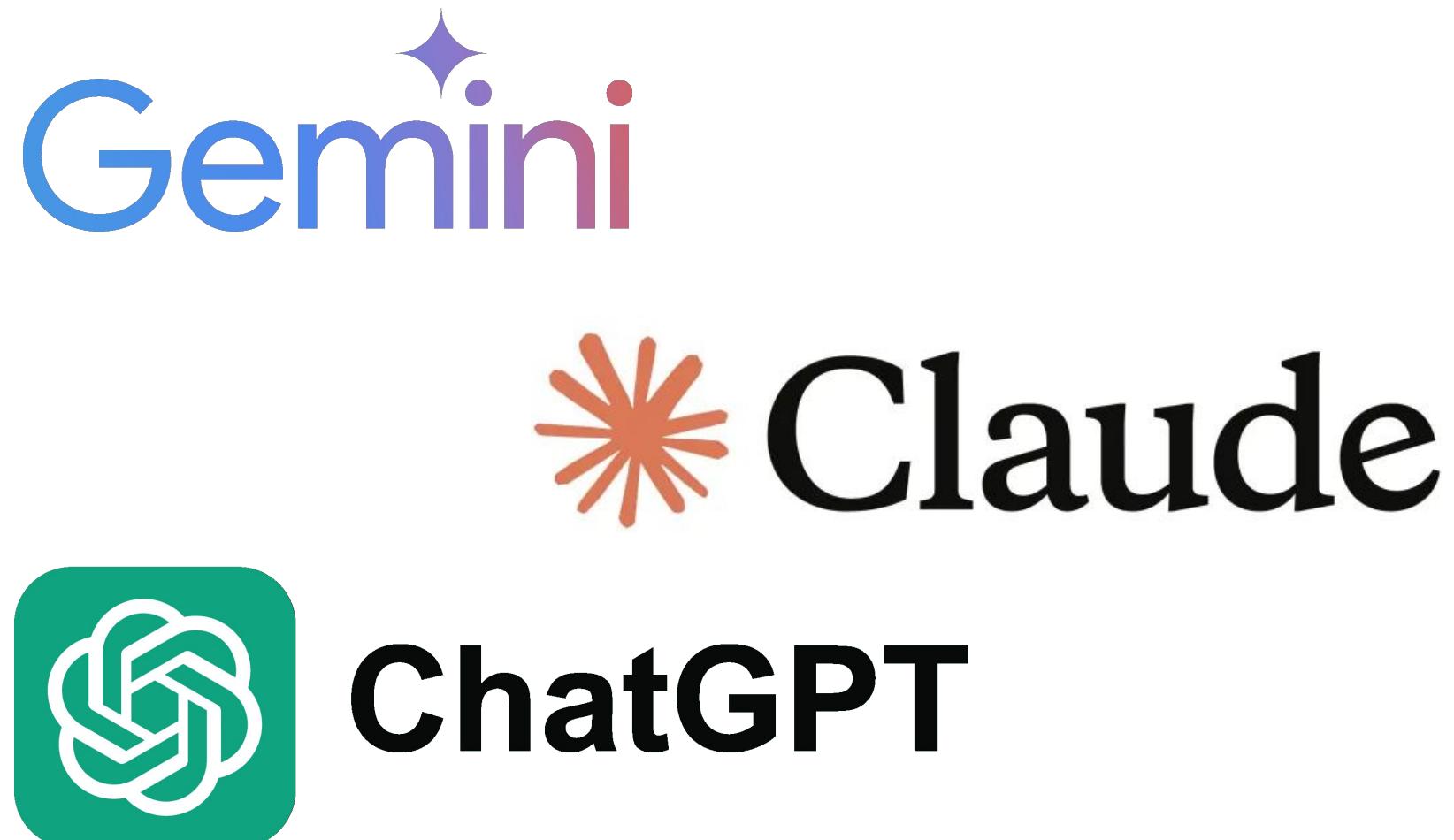
If an entity currently relies on fossil fuels but has a credible plan addressing the above points, its net-zero pledge could be considered credible. However, continued reliance on fossil fuels without a clear and accountable transition plan would likely cast doubt on the credibility of a net-zero commitment.

Answer: “No”

## ChatClimate

**Relying on fossil fuels does raise questions about the credibility of an entity's pledge to achieve net zero emissions.** The transition away from fossil fuels is necessary to meet the goals of the Paris Agreement, and studies have shown that it is technically feasible and relatively low in cost to replace fossil fuels with renewables (McCollum et al. 2018). However, the transition is constrained by existing fossil fuel-based infrastructure and stranded investments (IPCC\_AR6\_WGIII\_Chapter17, p. 45). Fossil fuel-dependent countries are particularly vulnerable to the impacts of climate change and may face challenges in transitioning their economies away from fossil fuels (Peszko et al. 2020). Additionally, the extraction of fossil fuel resources may not be compatible with limiting global warming to 2 degrees Celsius or below, and developing countries reliant on fossil fuel extraction will need to find alternative sources of income (McGlade and Ekins 2015; IPCC\_AR6\_WGIII\_Chapter17, p. 19). Overall, relying on fossil fuels can undermine the credibility of a net zero pledge due to the need for a transition away from fossil fuels and the associated challenges and risks (IPCC\_AR6\_WGIII\_Chapter17, p. 45). (In-house knowledge)

# Large Language Models (LLMs) + GenAI = opportunity but also a risk to increase energy consumption



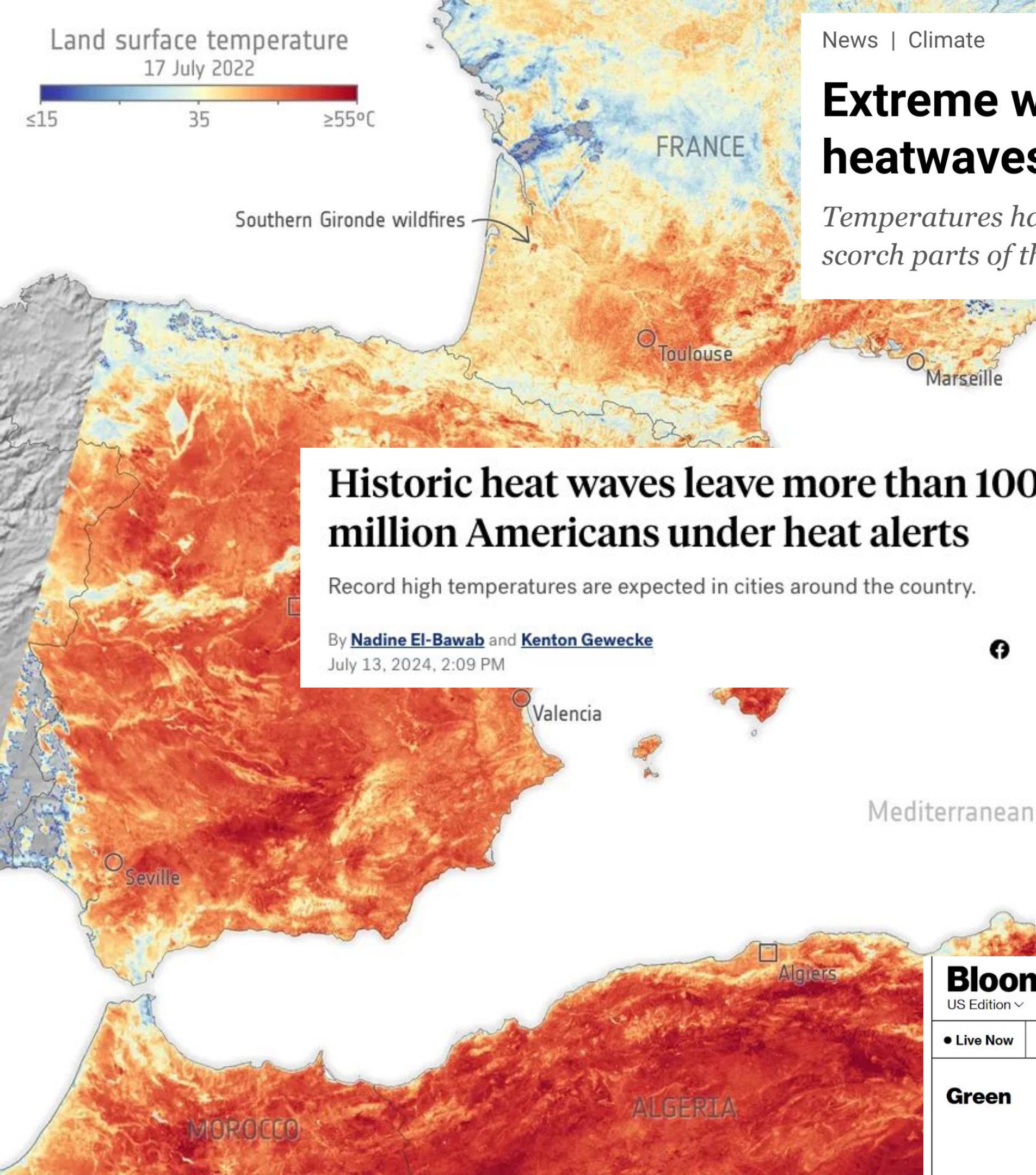
**Figure 1** Estimated energy consumption per request for various AI-powered systems compared to a standard Google search

Source: de Vries, A. (2023). The growing energy footprint of artificial intelligence. *Joule*, 7(10), 2191-2194.



## 4. AI opportunity for adaptation

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News | Climate

# Extreme weather grips the globe as heatwaves and wildfires rage

Temperatures have reached new highs as heatwaves and wildfires scorch parts of the northern hemisphere.

AUGUST 23, 2023

Editors' notes

## Climate change could bring year-round heat waves: UN researcher

by Nina LARSON



NORTH CAROLINA PUBLIC RADIO 91.5

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WEATHER

### China battles its worst heat wave on record

August 20, 2022 · 8:03 AM ET  
Heard on Weekend Edition Saturday



EMILY FENG

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Seattle Area Had Six Deaths Blamed on Last Week's Heat Wave



# Taylor Swift postpones Rio de Janeiro concert after death of fan

2 days ago



Brazil is experiencing an unprecedented heatwave, triggering health alerts.

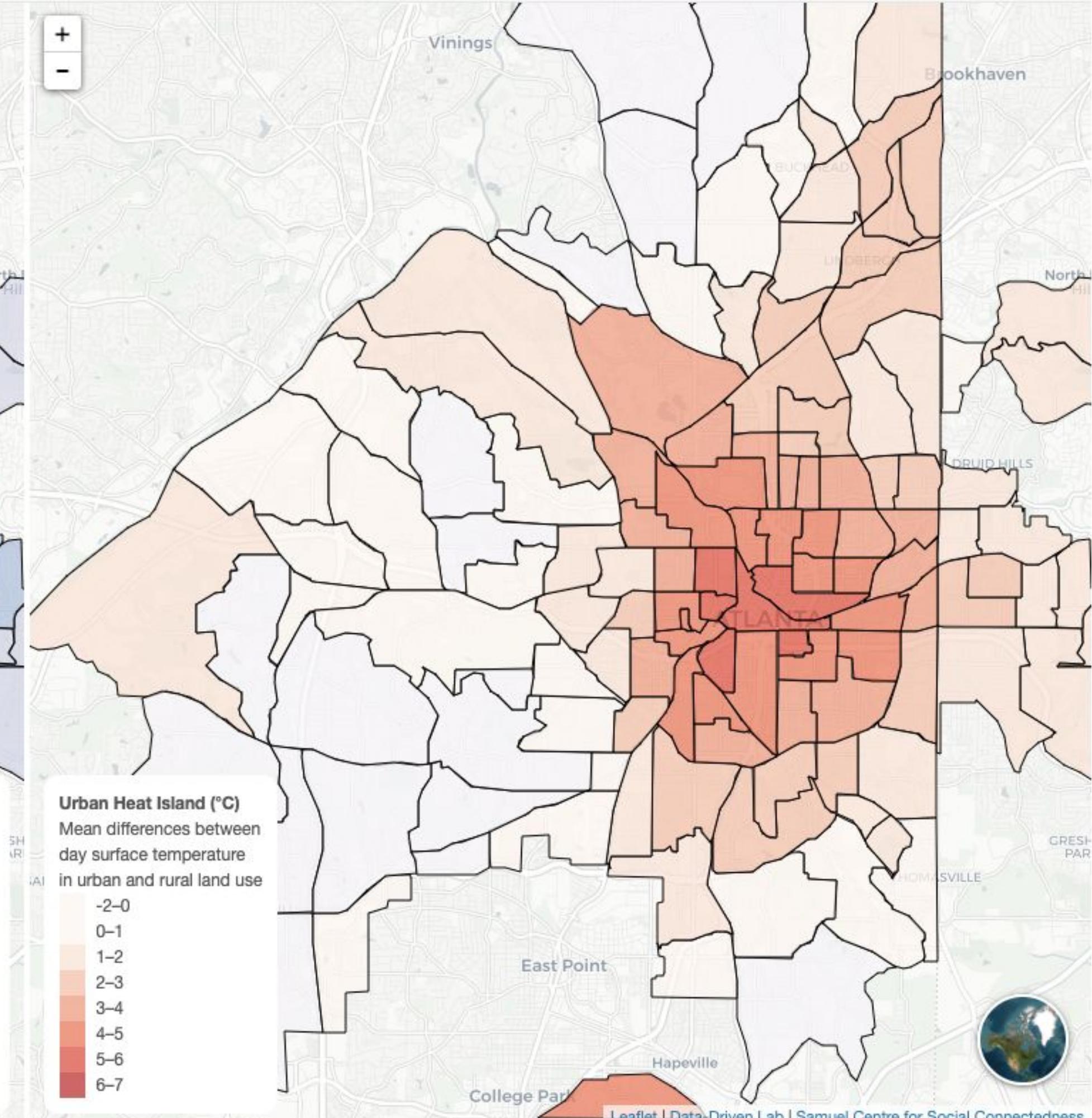
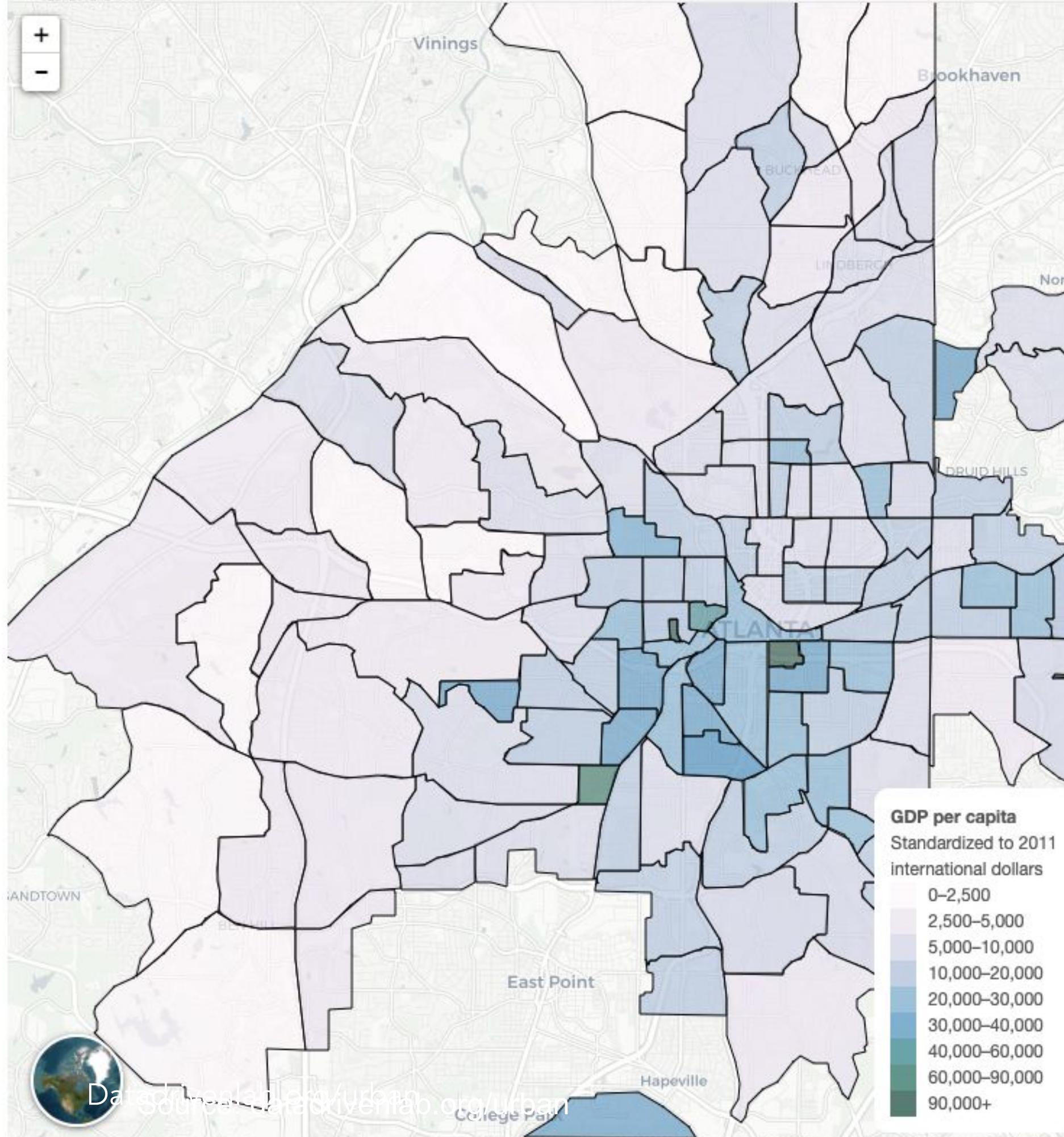
Authorities warned of the danger to life as it recorded a heat index, which combines temperature with humidity, of 59.3C (138.7F) on Friday followed by 59.7C (139.5) on Saturday.



Source: Johnny Miller / Unequal Scenes; <https://uneq>



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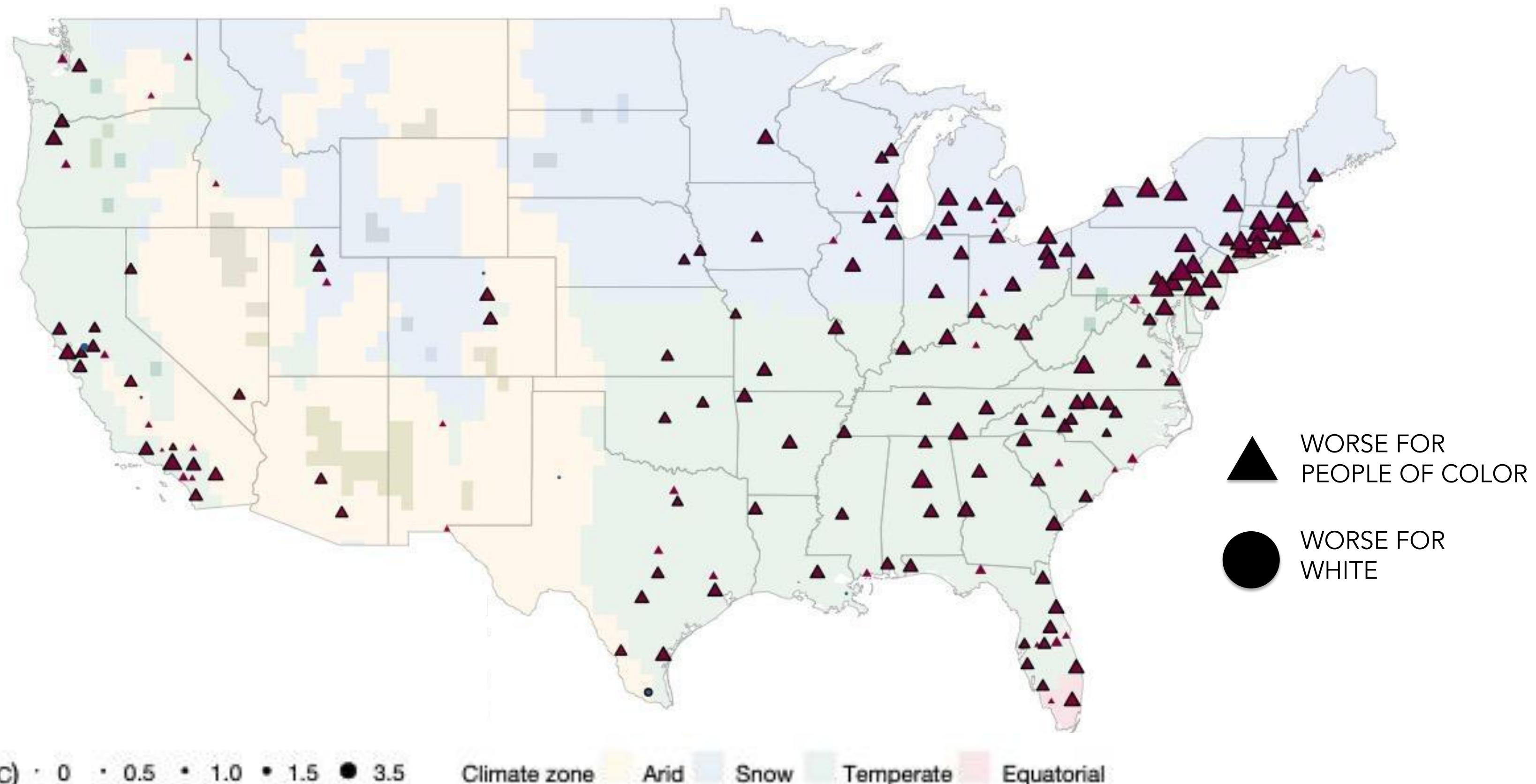


Data Source: [www.uberlab.org/](http://www.uberlab.org/)

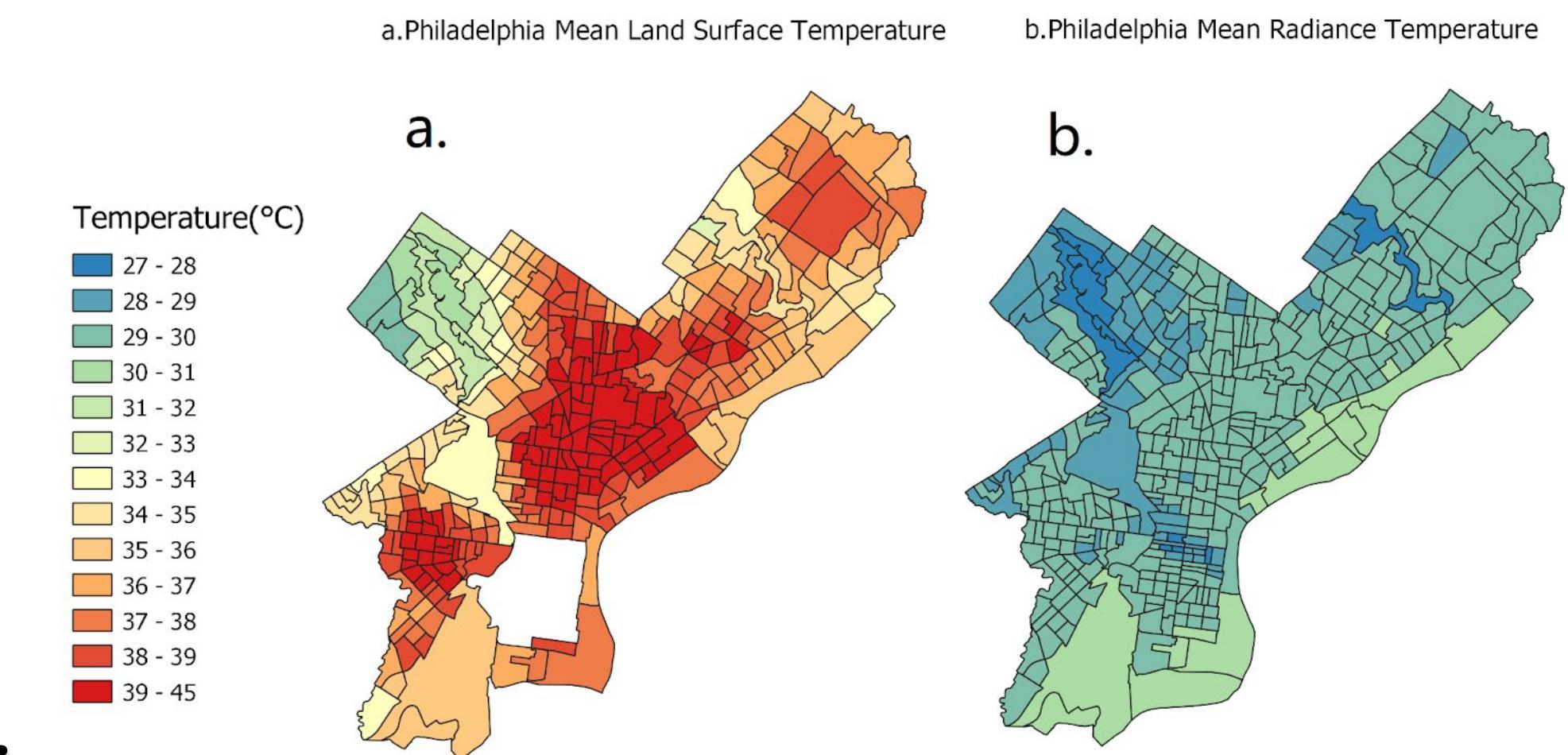
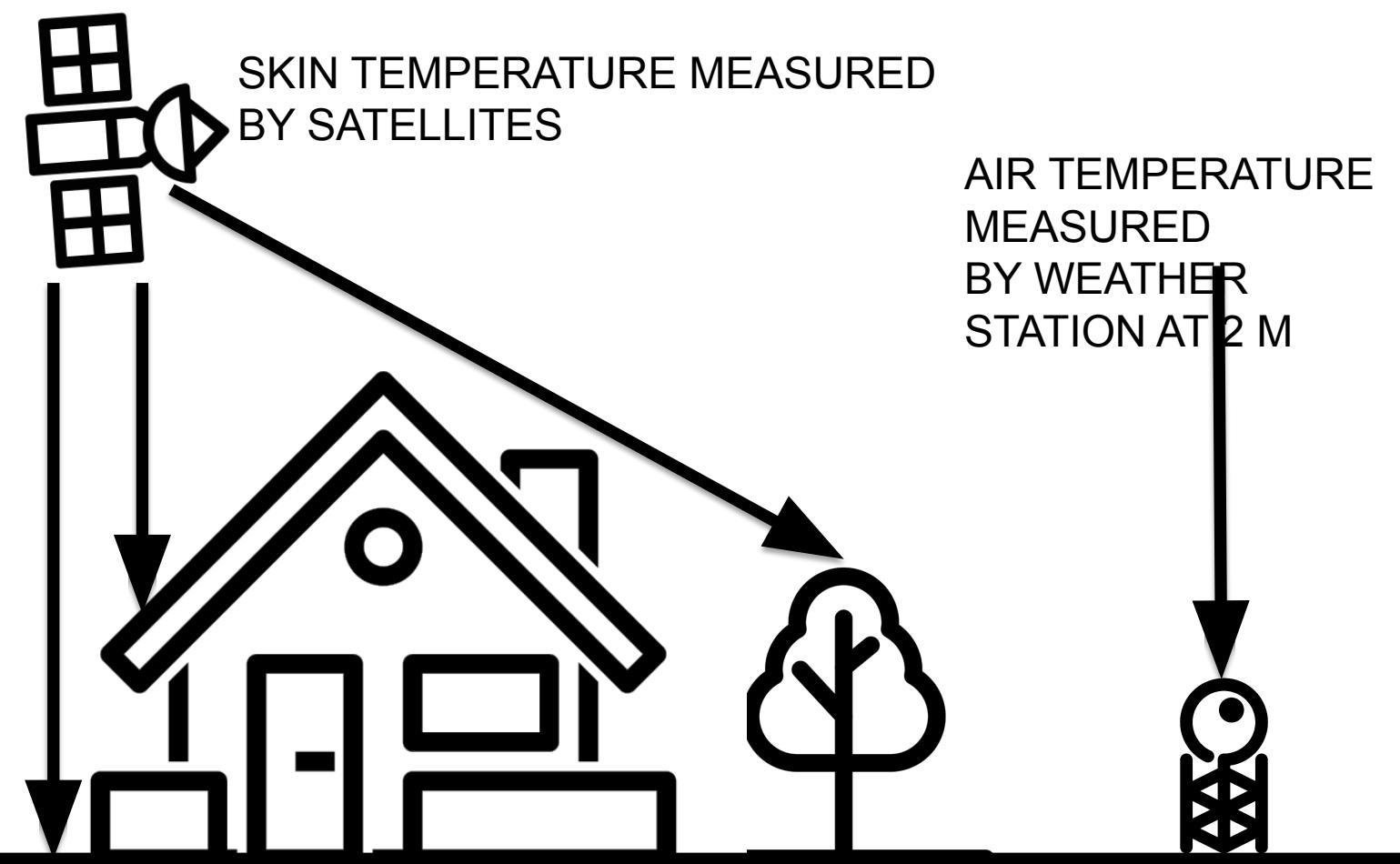
College Park



# 97% MAJOR US CITIES – EXPOSE MINORITY POPULATIONS TO HIGHER URBAN HEAT ISLAND INTENSITY

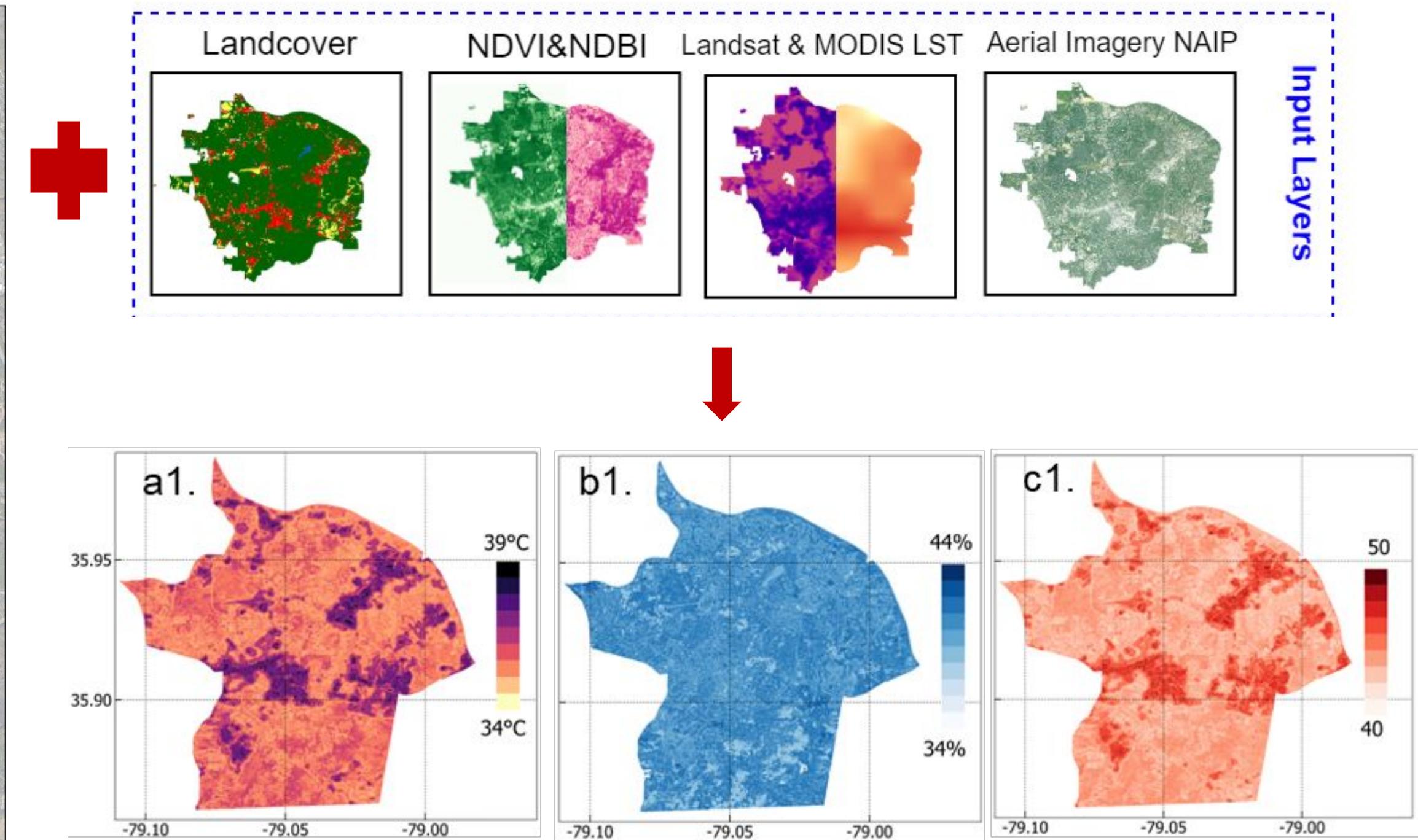
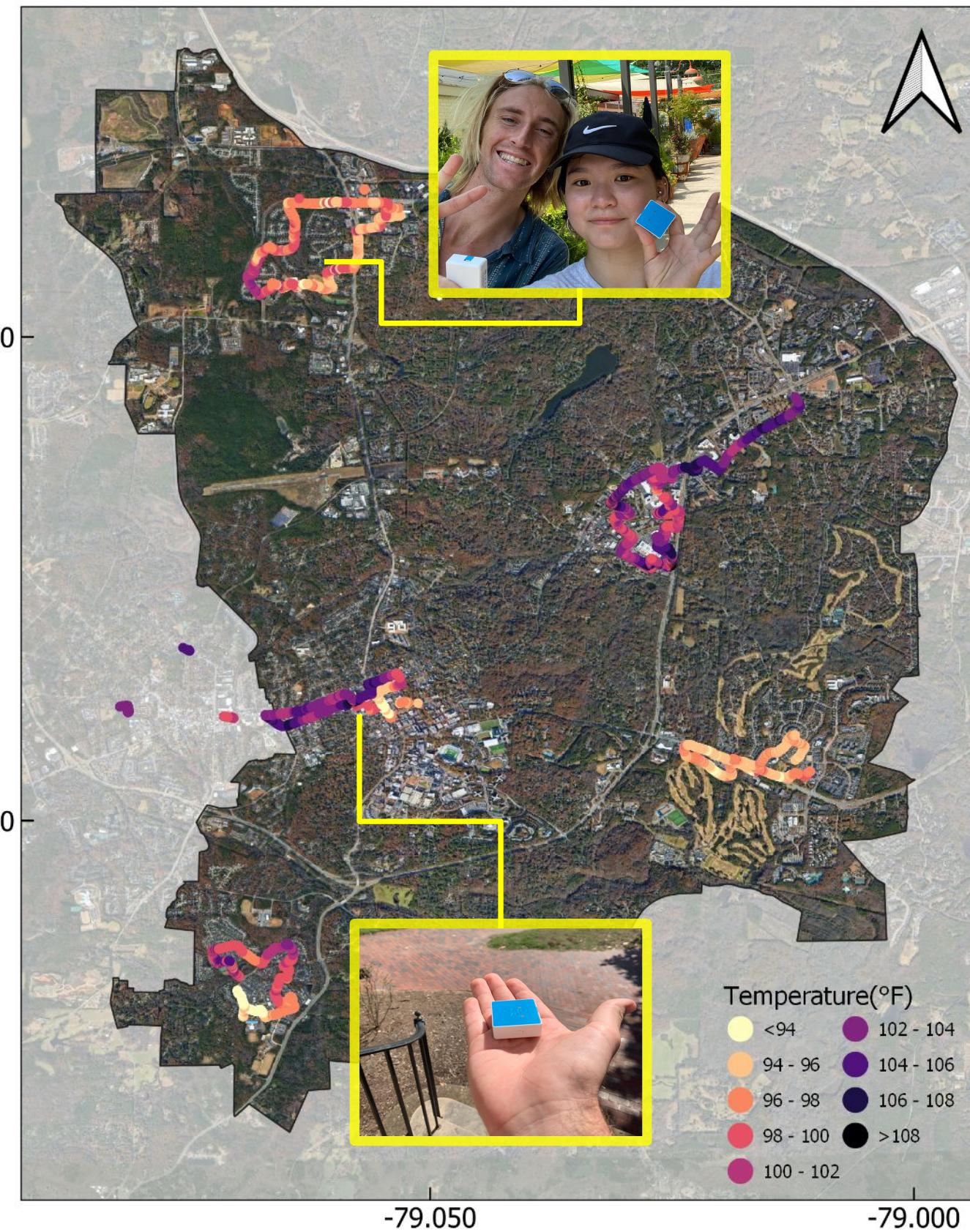


# Satellite-derived land surface data tends to overestimate disparities



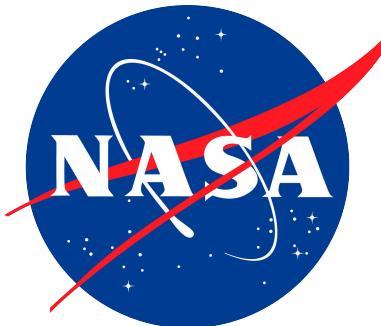
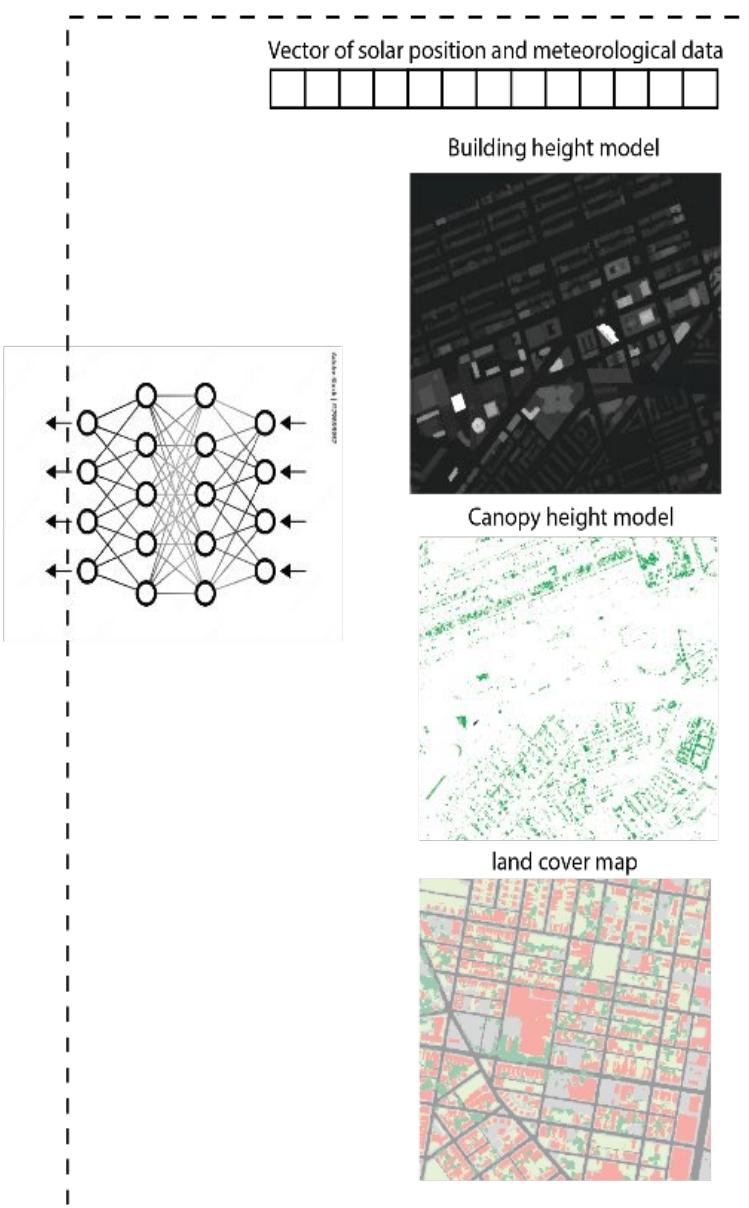
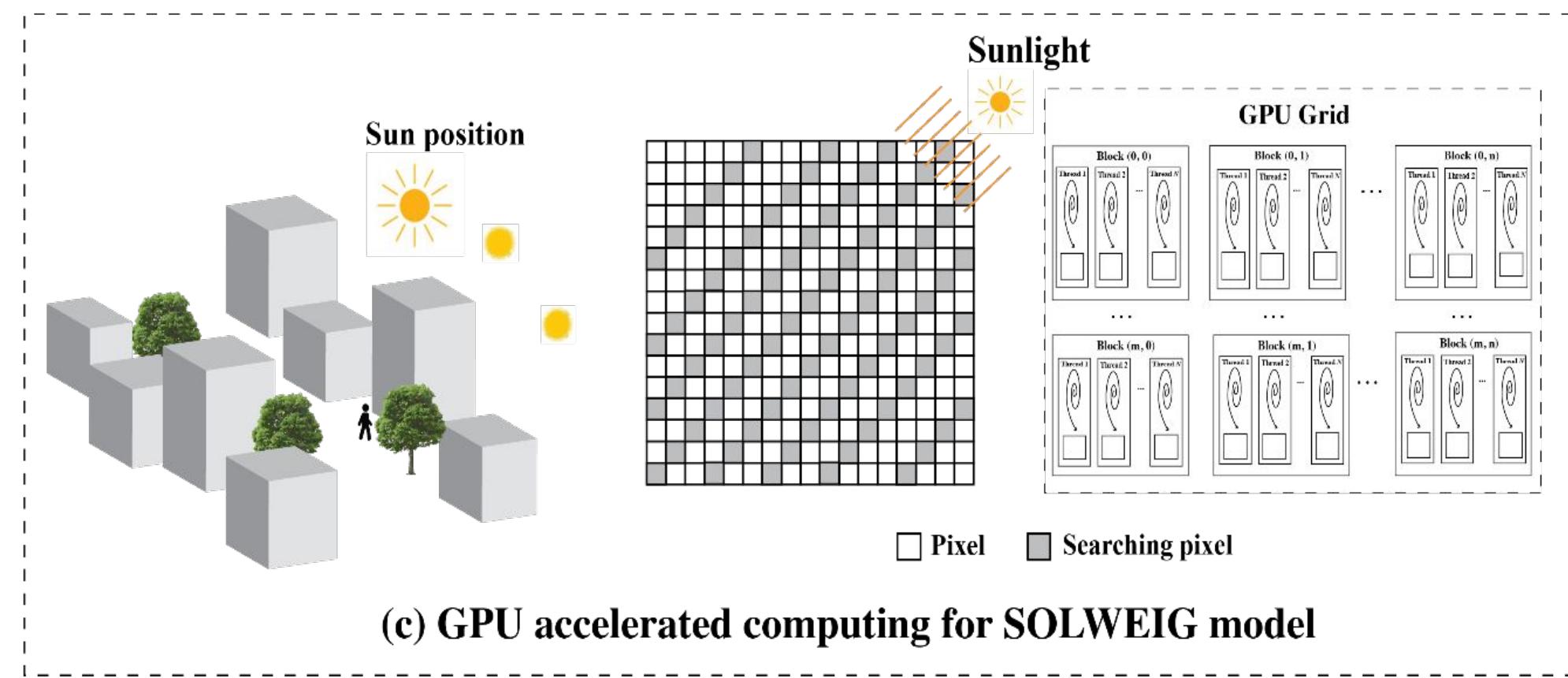
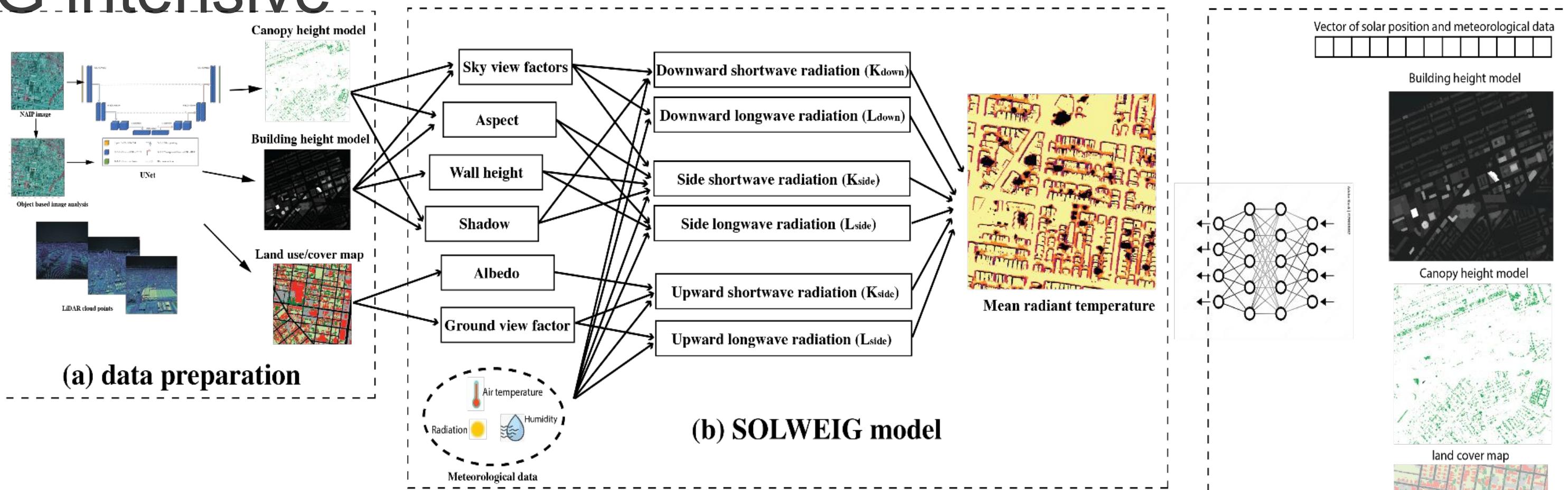
# Citizen heat mapping in the Research Triangle, NC

Chapel Hill 2-3 pm Traverse Map



Source: Wang, X., Hsu, A., and Chakraborty, T. (2023). Citizen and machine learning-aided high-resolution mapping of urban heat exposure and stress. Environ. Res.: Infrastruct. Sustain. <https://doi.org/10.1088/2634-4505/acef57>

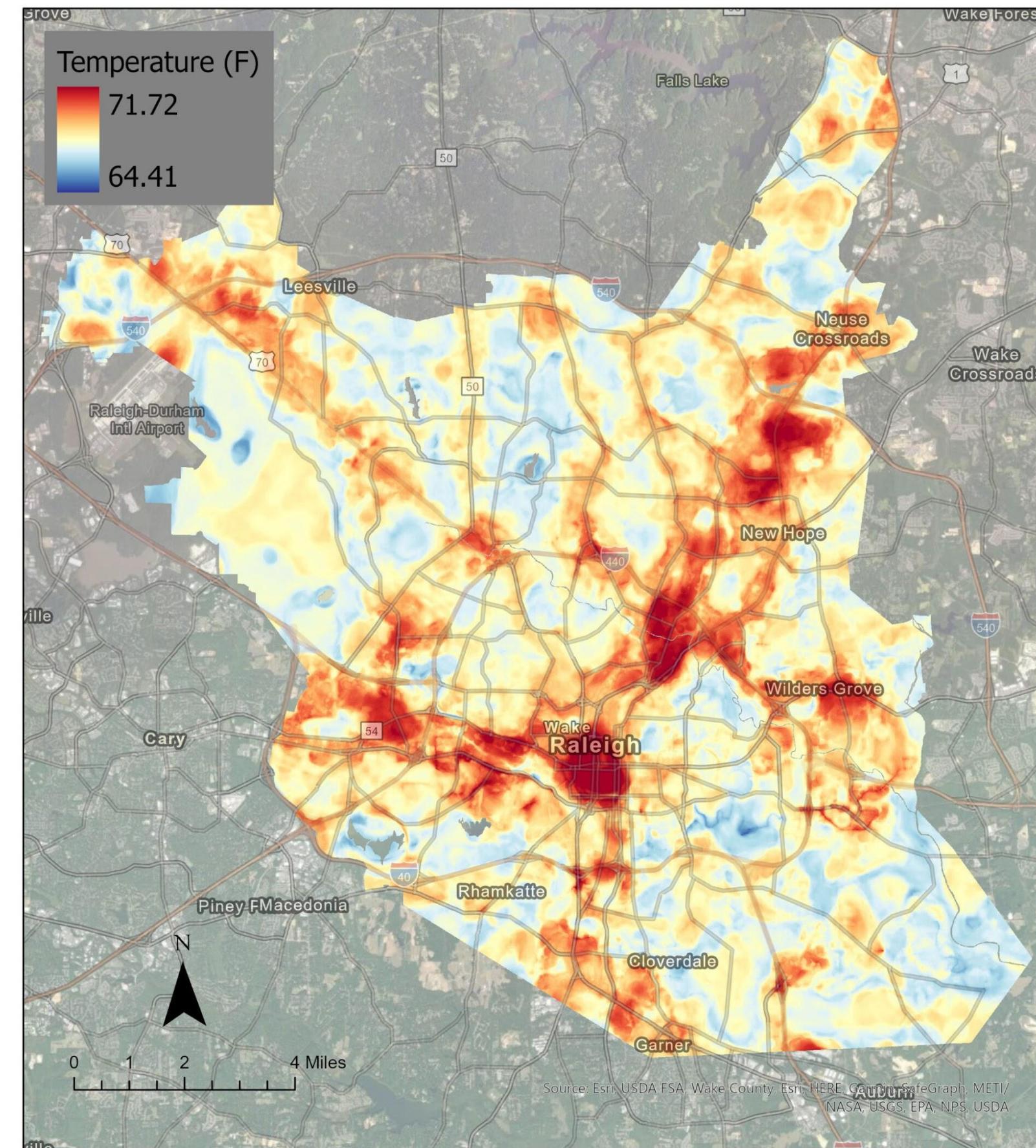
# Using ML to simulate urban microclimate modeling that is energy + GHG intensive





Source:  
<https://raleighnc.gov/climate-action-and-sustainability/mitigating-extreme-heat>

## Raleigh Morning Temperature (6-7am) July 23, 2021



Urban Heat Island Mapping  
[climate.ncsu.edu/research/uhi](http://climate.ncsu.edu/research/uhi)

to the sky, beautifully ~~rolling~~<sup>smoothly</sup> orn'd clouds. Vaguely appearing like windows in  flight. The sun still out and is beginning to set. The

## 5. Challenges

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# Challenges

- Data quality
  - Validation
  - Representativeness/biases
- Capacity
  - analytical capacity
- ‘Black box’
- Communication is key
- Hallucination
  - Disinformation, misinformation



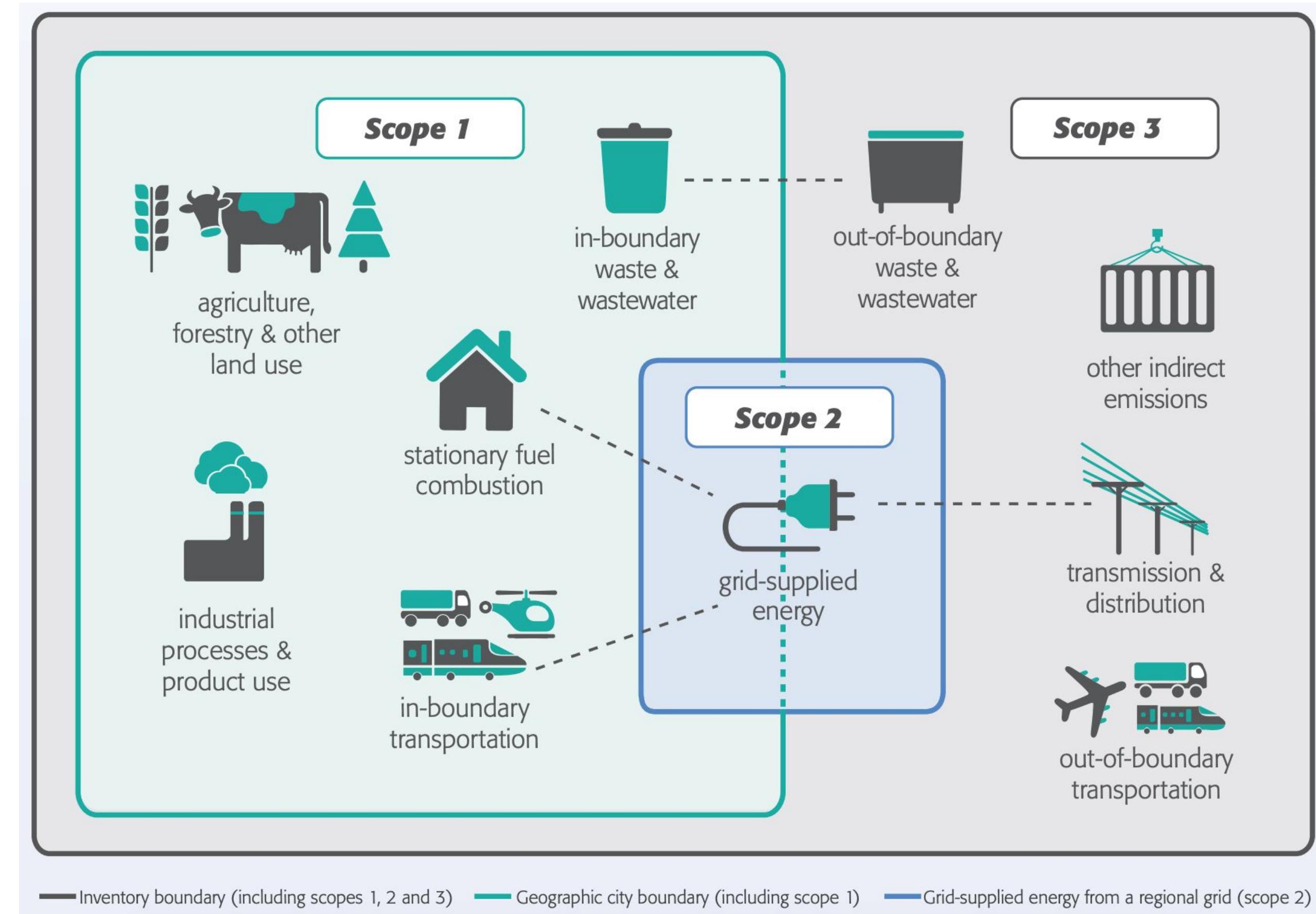
# THANK YOU

// angel.hsu@unc.edu

//datadrivenlab.org

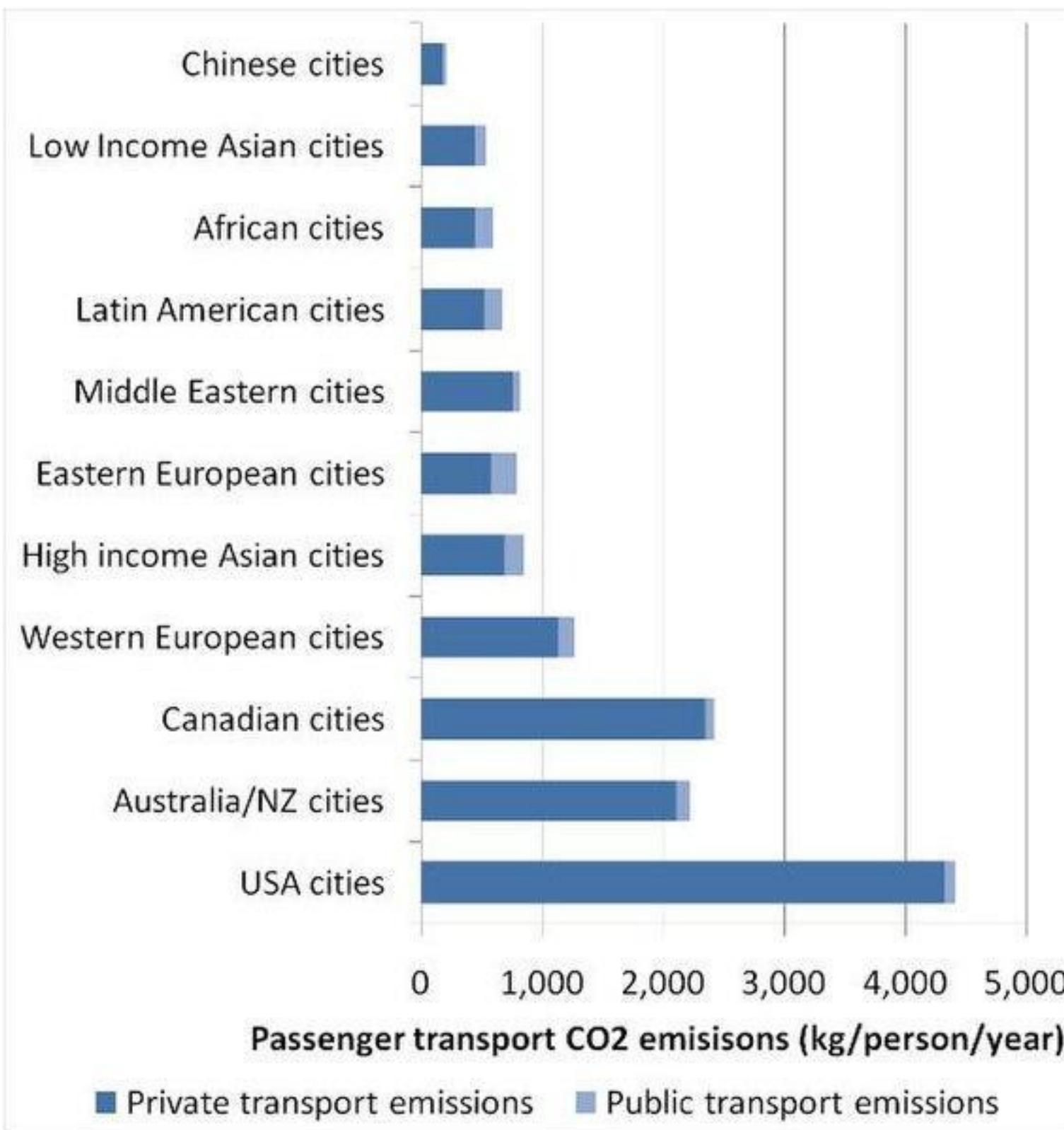
@datadrivenlab

# Most urban emissions come from: 1) transport; 2) buildings; 3) waste



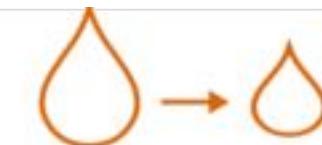
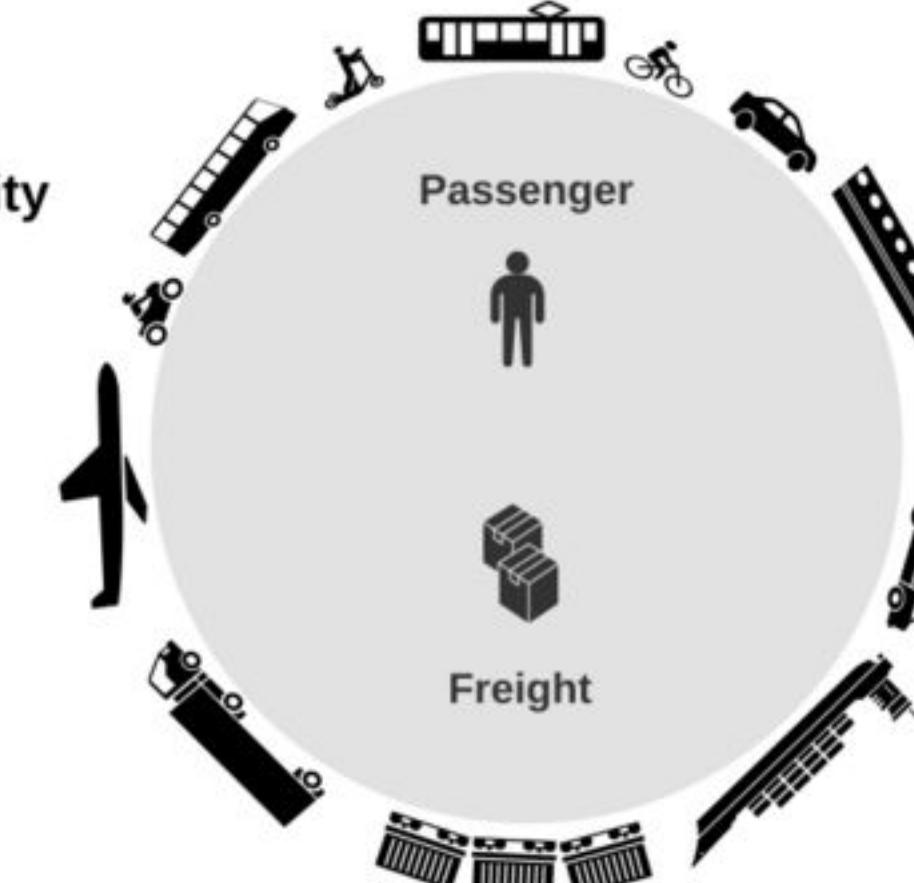
Source:

# Nearly 1/3 of global emissions come from transport



## Reducing transportation activity

*Analyzing data  
Remote sensing  
Forecasting  
Freight consolidation  
Alternatives to transport*



## Vehicle efficiency

*Designing for efficiency  
Detecting loading inefficiency  
3-D printing  
Autonomous vehicles*



## Alternative fuels

*Research and development*



## Electric vehicles

*Charging patterns  
Charge scheduling  
Congestion management  
Vehicle-to-grid algorithms  
Battery energy management  
Battery R&D*