Cities and climate change

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1. Why focus on cities?
   - Cities concentrate populations, wealth, activities, and emissions
   - Cities as actors of the environmental transition
   - Diversity of urban forms

2. What is the optimal urban form?
   - Mitigation
   - Adaptation
   - Which urban form to reconcile these goals?

3. A few concluding thoughts
   - Ambitious climate policies can come with high levels of well-being
   - A large mitigation potential might come from demand solutions
   - We have more and more tools to monitor urban issues
   - Still, we lack data and studies on developping countries' cities

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55% of the global population (4.3 billion people) live in cities in 2018 (United Nations, 2019)

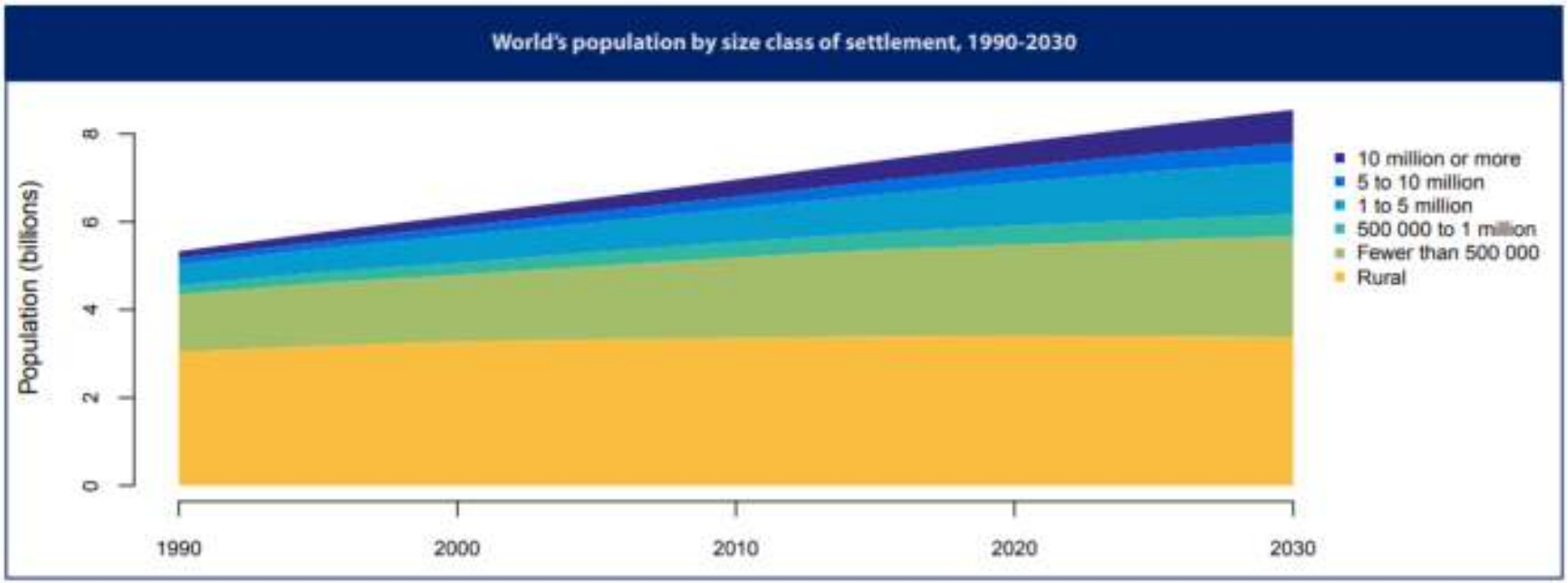

Figure: United Nations, 2018

The share of global urban population should reach 68% in 2050 (United Nations, 2019)

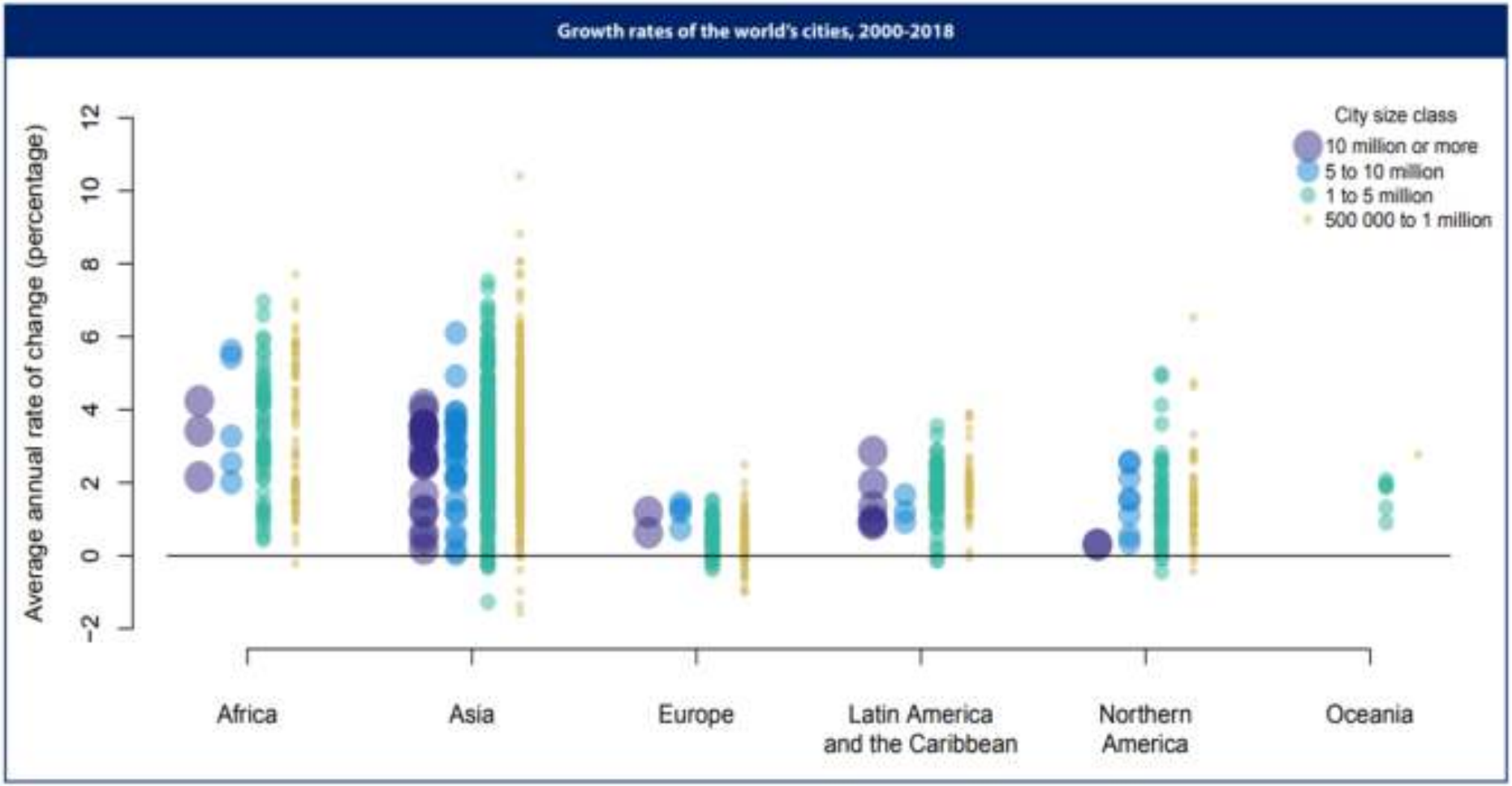

Figure: United Nations, 2018

Cities concentrate wealth and economic activities

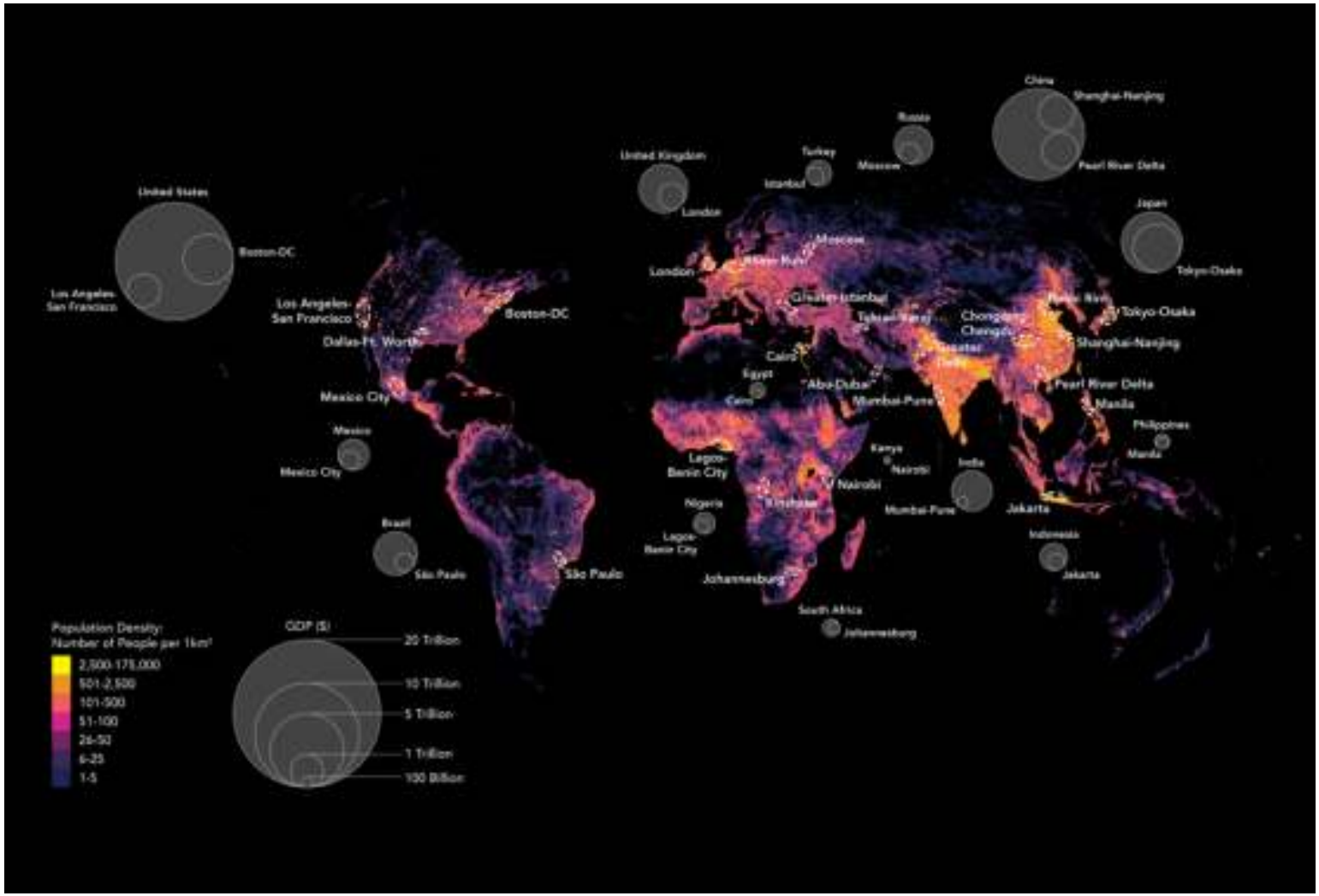

Figure: Parag Khanna, 2016

Urban emissions account for 67-72% of global emissions in 2020 (IPCC AR6 WGIII)

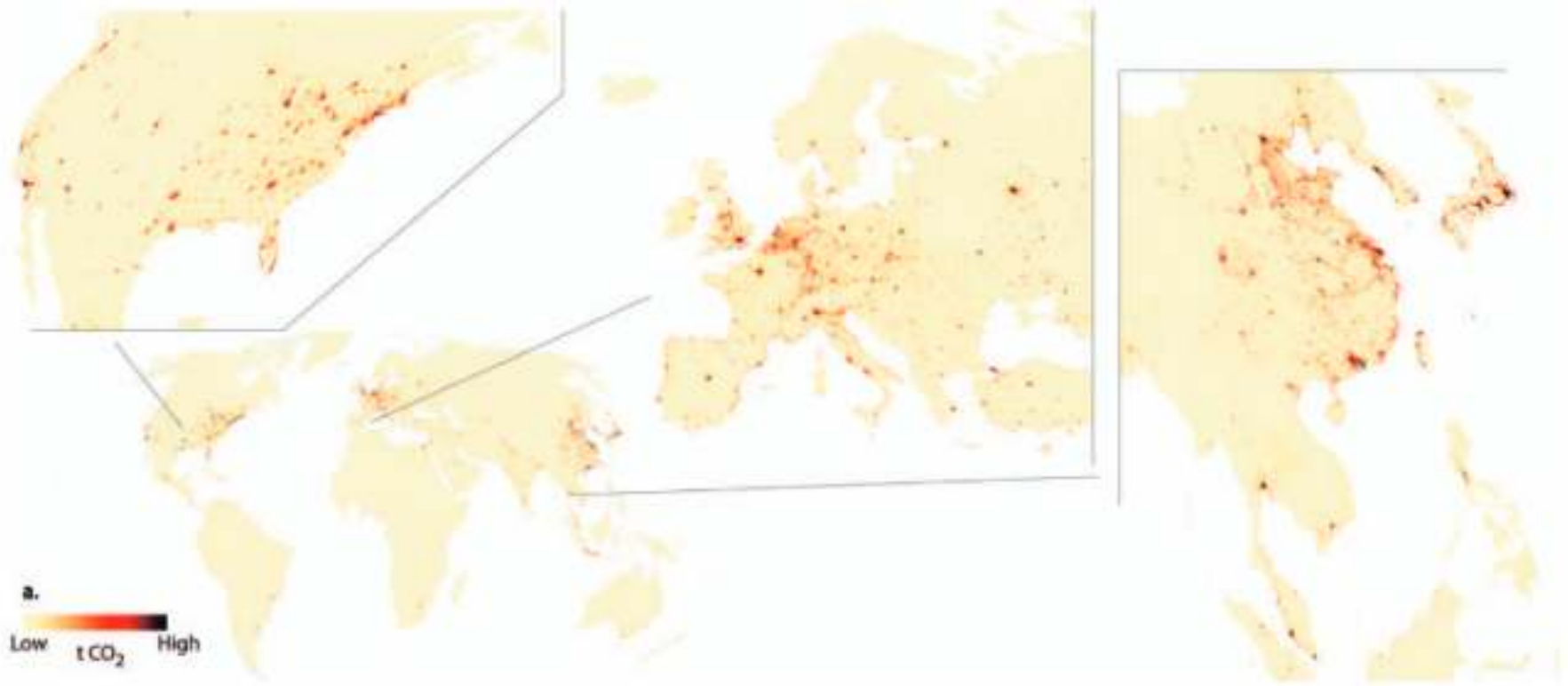

Figure: The highest emitting 100 urban areas account for 18% of the global carbon footprint (Moran et al., 2018)

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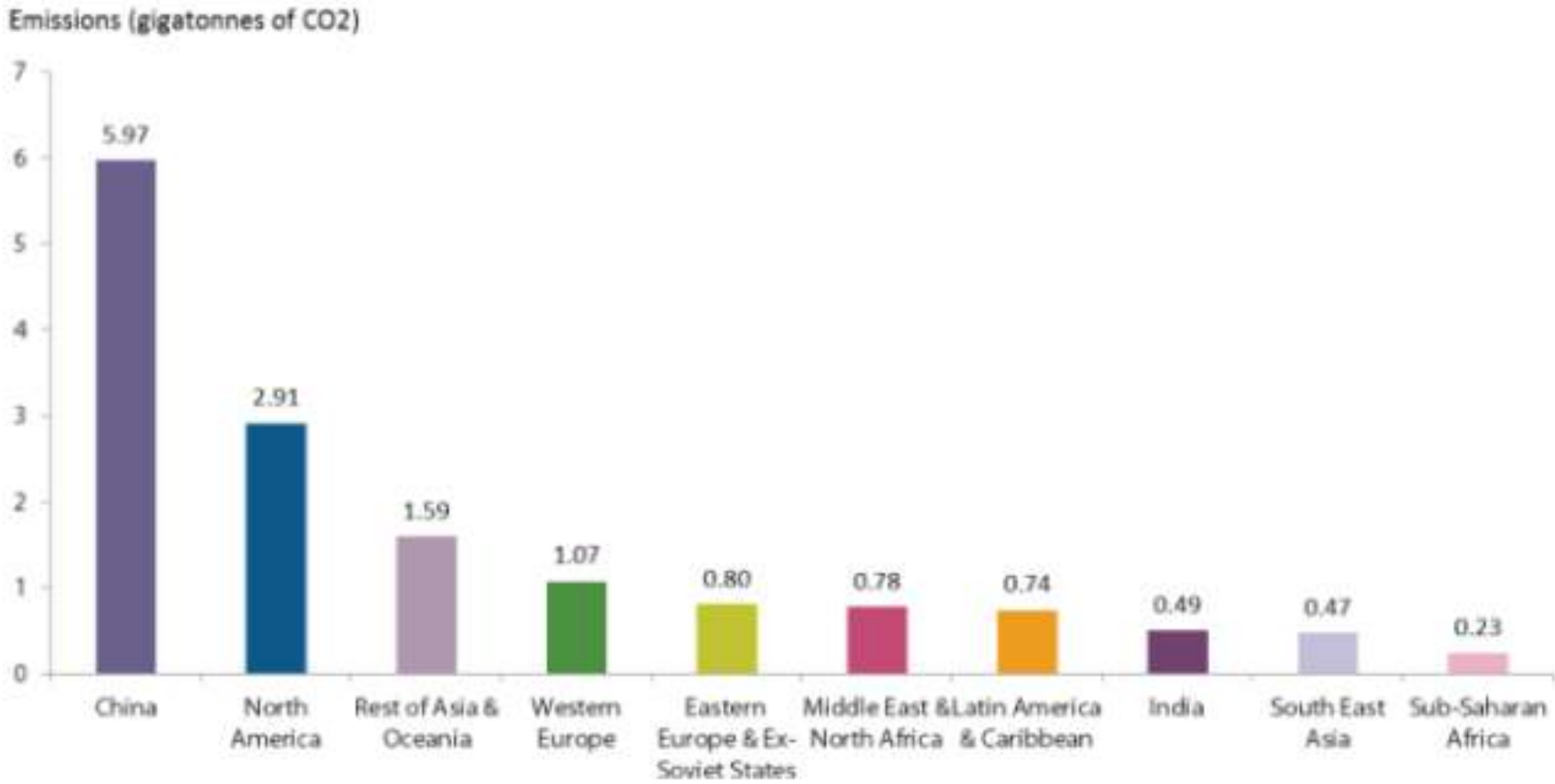
Total carbon emissions of cities above 0.5 million in 2012



Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

What about emissions per capita?

- Urban populations are generally richer, and consume more than rural populations.
- But urban density allows to mitigate transportation and buildings emissions (public transports, denser and more isolated buildings,...).

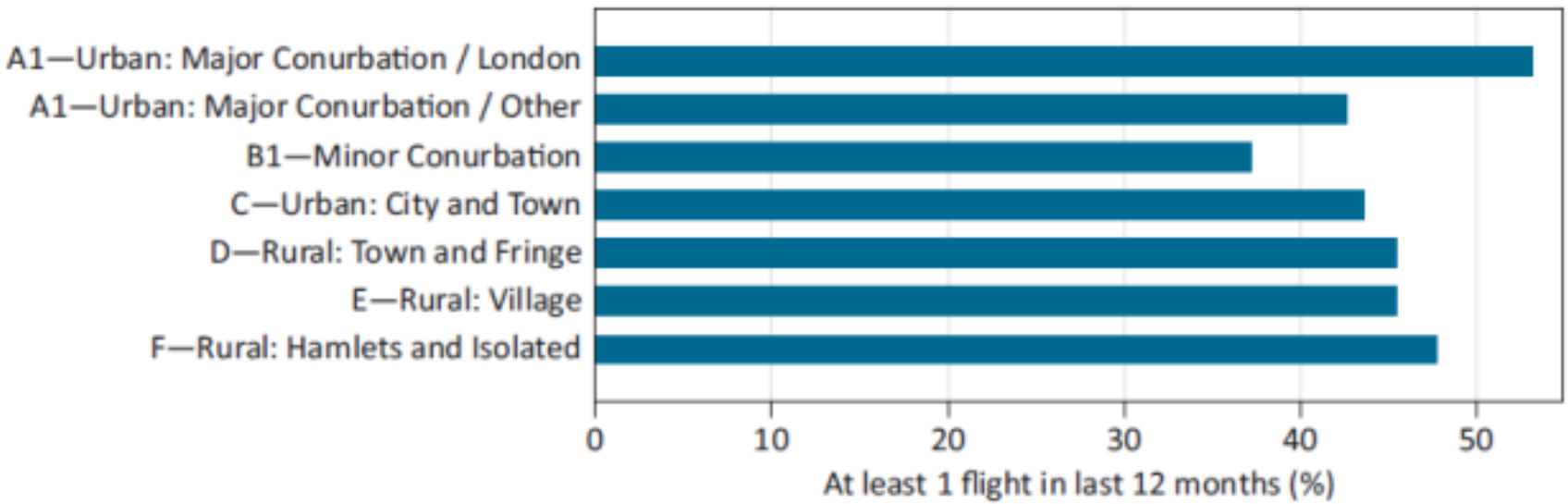


Figure: Participation in private air travel in the UK (Mattioli et al., 2021)

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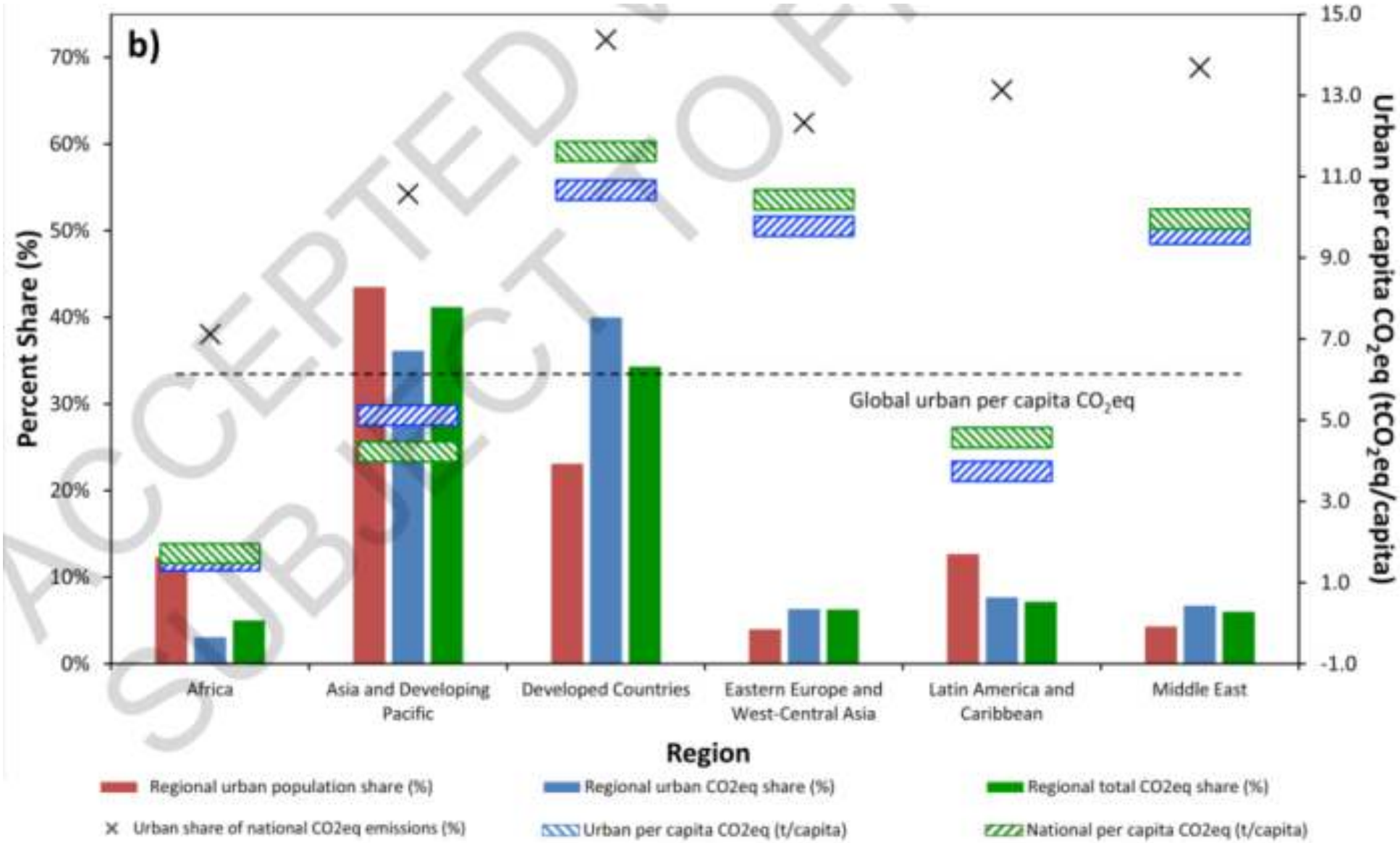
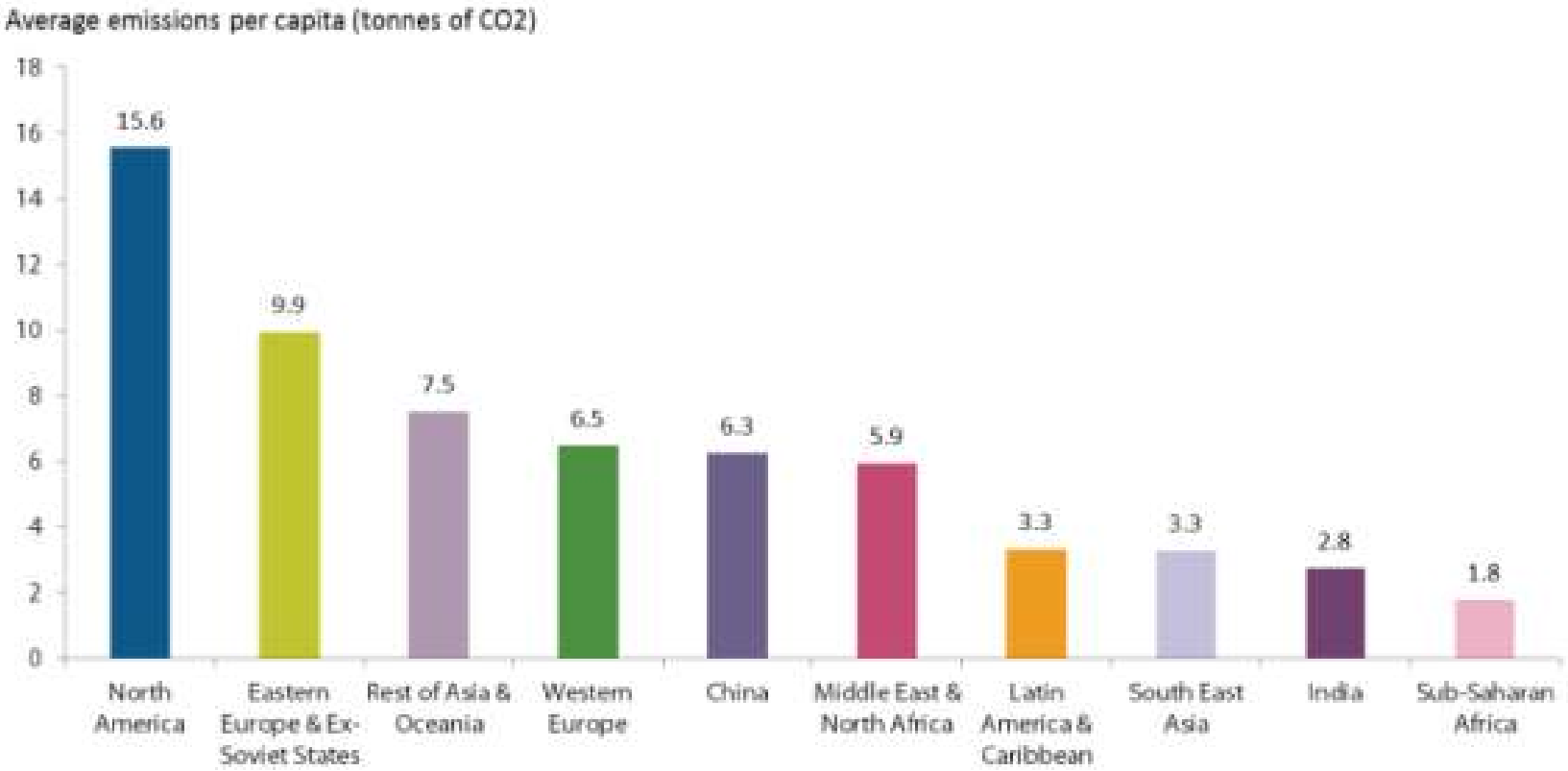
Emissions per capita (IPCC AR6 WG3)



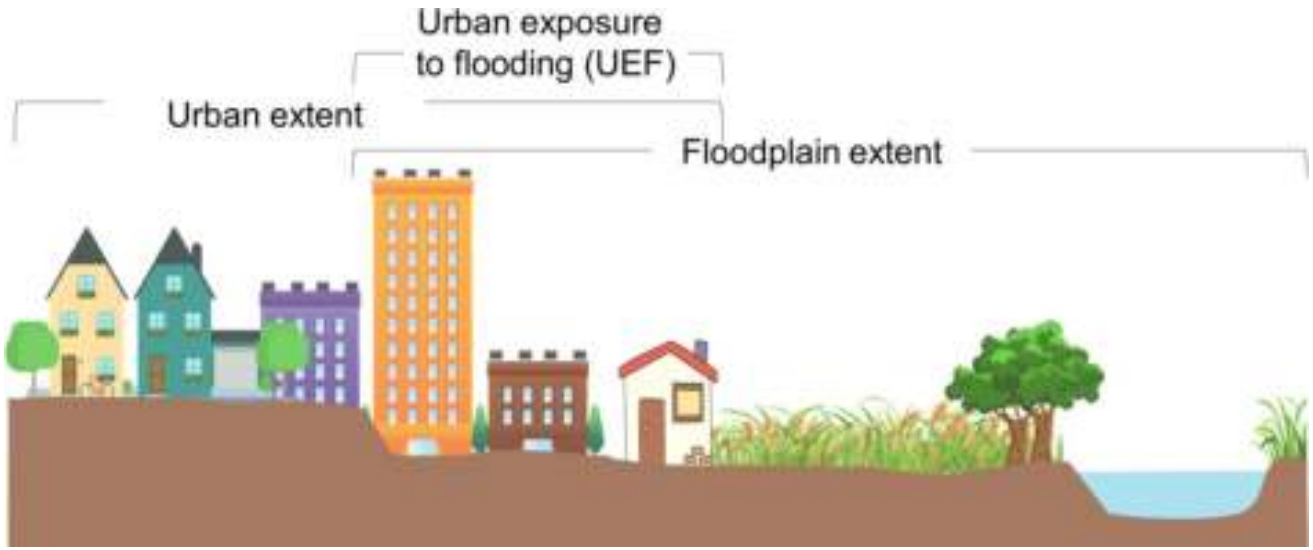
Average carbon emissions per capita of cities above 0.5 million by region in 2012



Source: LSE Cities 2014 (based on LSE Cities analysis using data from Oxford Economics)

Exposure to extreme events

- The concentration of populations in cities makes them vulnerable to extreme events (floods, urban heat islands, etc.).
- Güneralp et al (2015): even without accounting for climate change, flood-prone urban areas will increase by a factor of 2.7 between 2000 and 2030, urban areas exposed to drought risk will increase by a factor of two, and urban areas exposed to both risks will increase by a factor of 2.5.



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City networks (Transnational municipal networks)

Main ideas behind TMNs:

- Shared commitments to climate and sustainability goals, that add up to NDCs.
- Collaborative approach: local experimentation and knowledge sharing.
- Examples of TMNs: C40, ICLEI, 100 Resilient Cities, Global Covenant of Mayors,...

C40

- Mainly megacities (at least 10 million inhabitants).
- Performance-based requirements: member must have a climate action plan consistent with the 1.5°C goal of the Paris Agreement.
- Work areas: sustainable mobility, energy, food, water, and waste management,...
- Emphasis on health issues and equity.

Figure: Villes du C40

ICLEI

- 2500 cities, towns or regions representing together 25% of the global urban population.
- 5 development pathways:
  - Low emission development pathway;
  - Nature-based development pathway;
  - Circular development pathway;
  - Resilient development pathway;
  - Equitable and people-centered development pathway.

ICLEI

Figure: Members of ICLEI

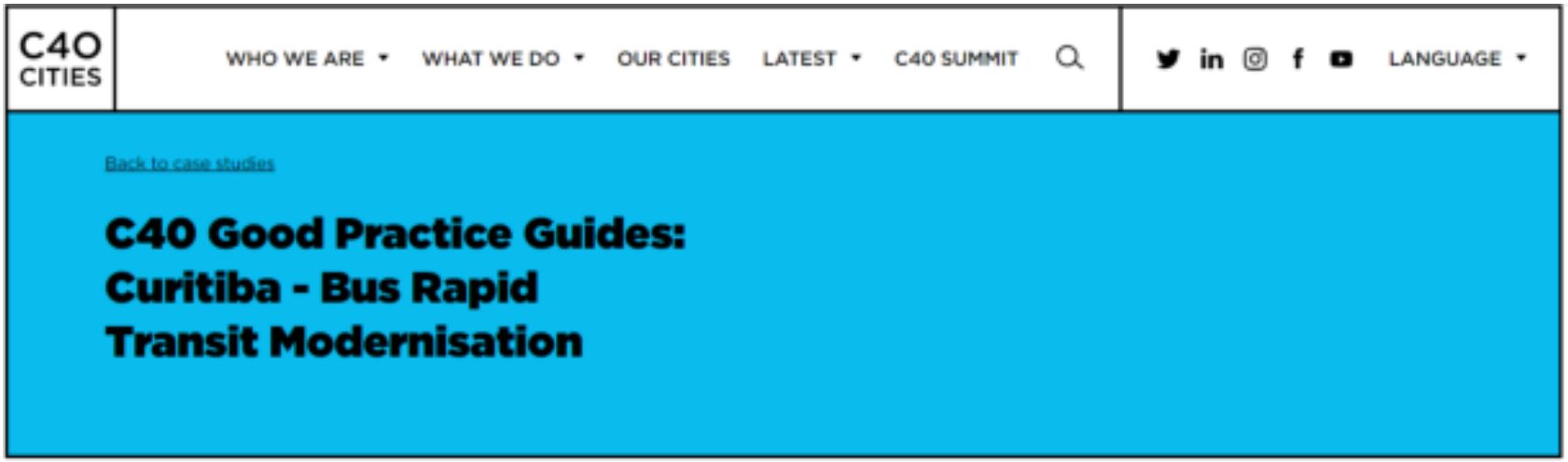
100 Resilient Cities

- Pioneered by the Rockefeller foundation.
- Goal: help more cities build resilience to the physical, social, and economic challenges.
- 4 main pathways:
  - Helping cities in establishing a new position in city government, a Chief Resilience Officer;
  - Expert support for the development of a robust Resilience Strategy;
  - Access to solutions, service providers, and partners from the private, public and NGO sectors who can help them develop and implement their Resilience Strategies;
  - Membership of a global network of member cities who can learn from and help each other.

100 Resilient Cities

Figure: Members of the Resilient Cities network

Experimentation / knowledge sharing



CURITIBA February 2016

Summary

Curitiba was the first city to develop Bus Rapid Transit in 1974 and today the city continues to be a transit innovator, having recently launched a program to implement hybrid and electric buses. Curitiba's BRT system was developed as an integral part of an overall Masterplan (1966),[xxxii] its main objectives included radial expansion of the city along five corridors, integrating land use and transport, and creating a dedicated planning institute IPPUC.[xxxiii] The Masterplan is revised every 10 years, and the latest revision includes a comprehensive urban sustainable development plan for the next 50 years.

In the 1990s, after creating the BRT system thanks to a partnership between the municipality and bus operators (which made the first BRT lanes cost 50 times less than subway[xxxiv]), Curitiba tackled the integration of all bus lines into the Rede Integrada de Transporte, with a hierarchy of bus service types and common terminals, allowing

Emissions mitigation goals

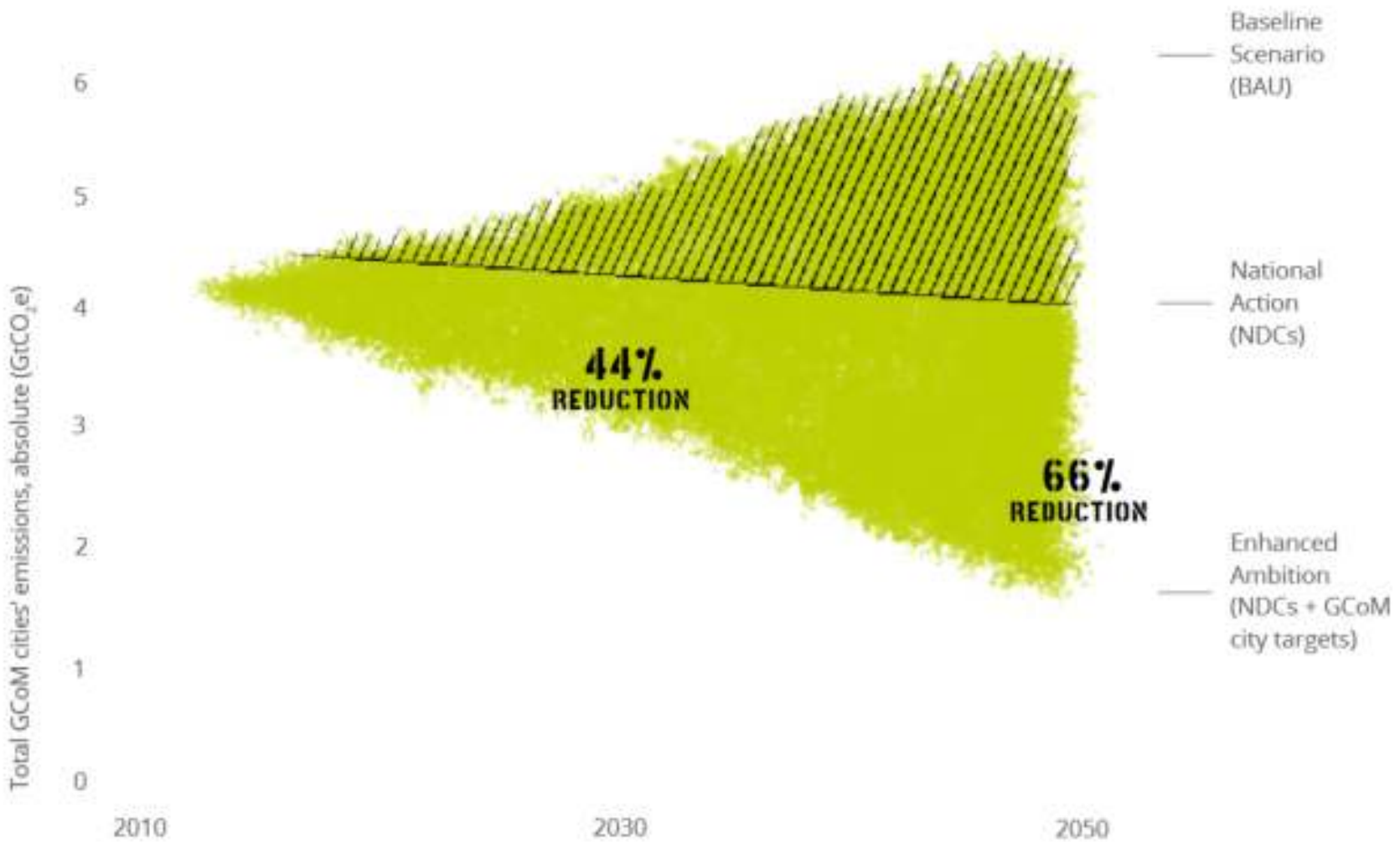


Figure: GCoM, 2019

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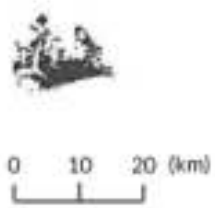
Diversity of urban forms

ATLANTA'S BUILT-UP AREA

POPULATION:	5.25 MILLION
URBAN AREA: TRANSPORT	4,280 KM²
CARBON EMISSIONS: TONNES CO_2 PER PERSON (PUBLIC + PRIVATE TRANSPORT)	7.5

BARCELONA'S BUILT-UP AREA



POPULATION:	5.33 MILLION
URBAN AREA: TRANSPORT	162 KM²
CARBON EMISSIONS: TONNES CO_2 PER PERSON (PUBLIC + PRIVATE TRANSPORT)	0.7

Source: Bertraud and Richardson, 2004.[10]

Population densities - 3D representations

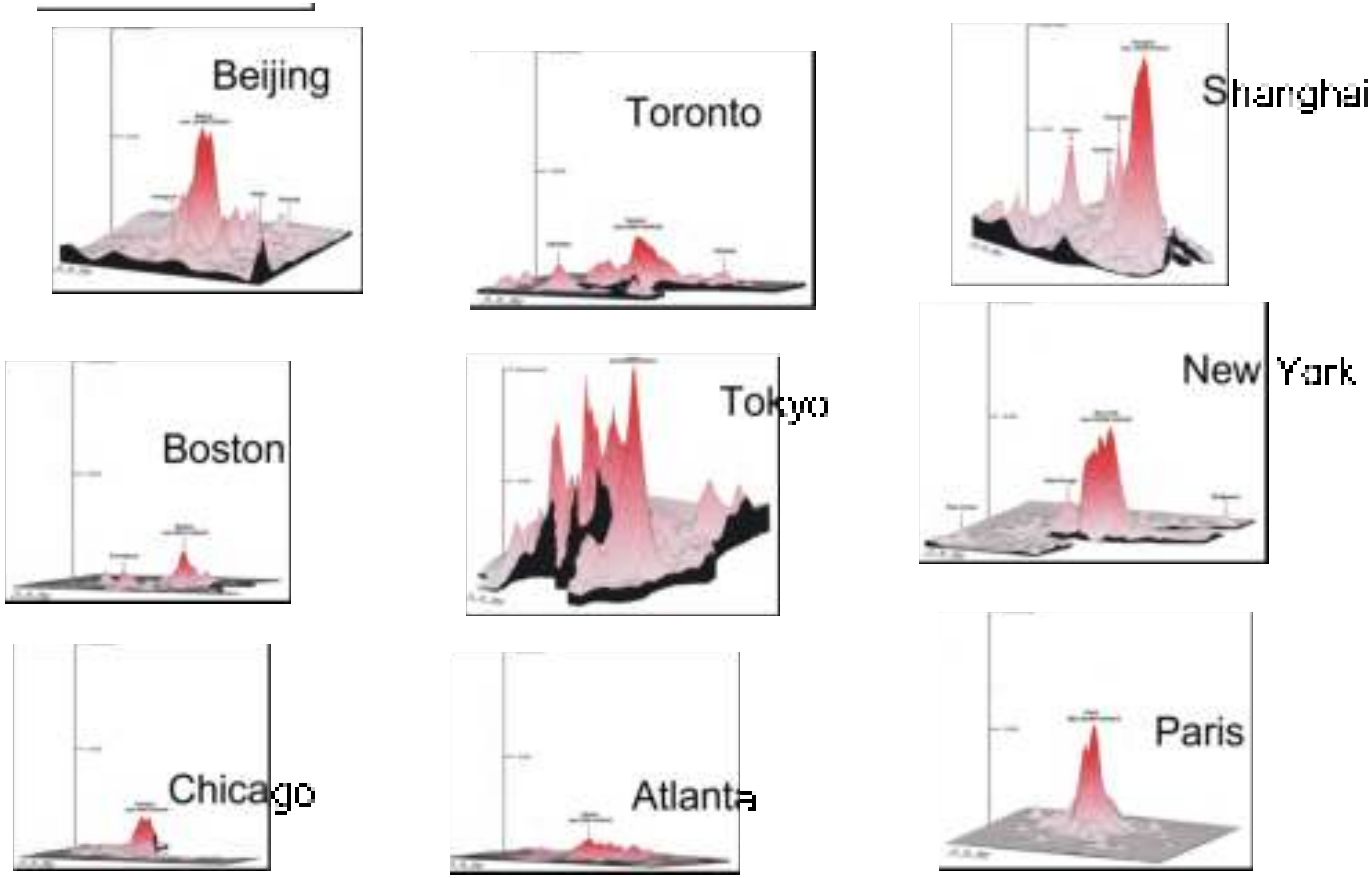


Figure: Hoornweg et al., 2011

Diversity of 3D urban forms

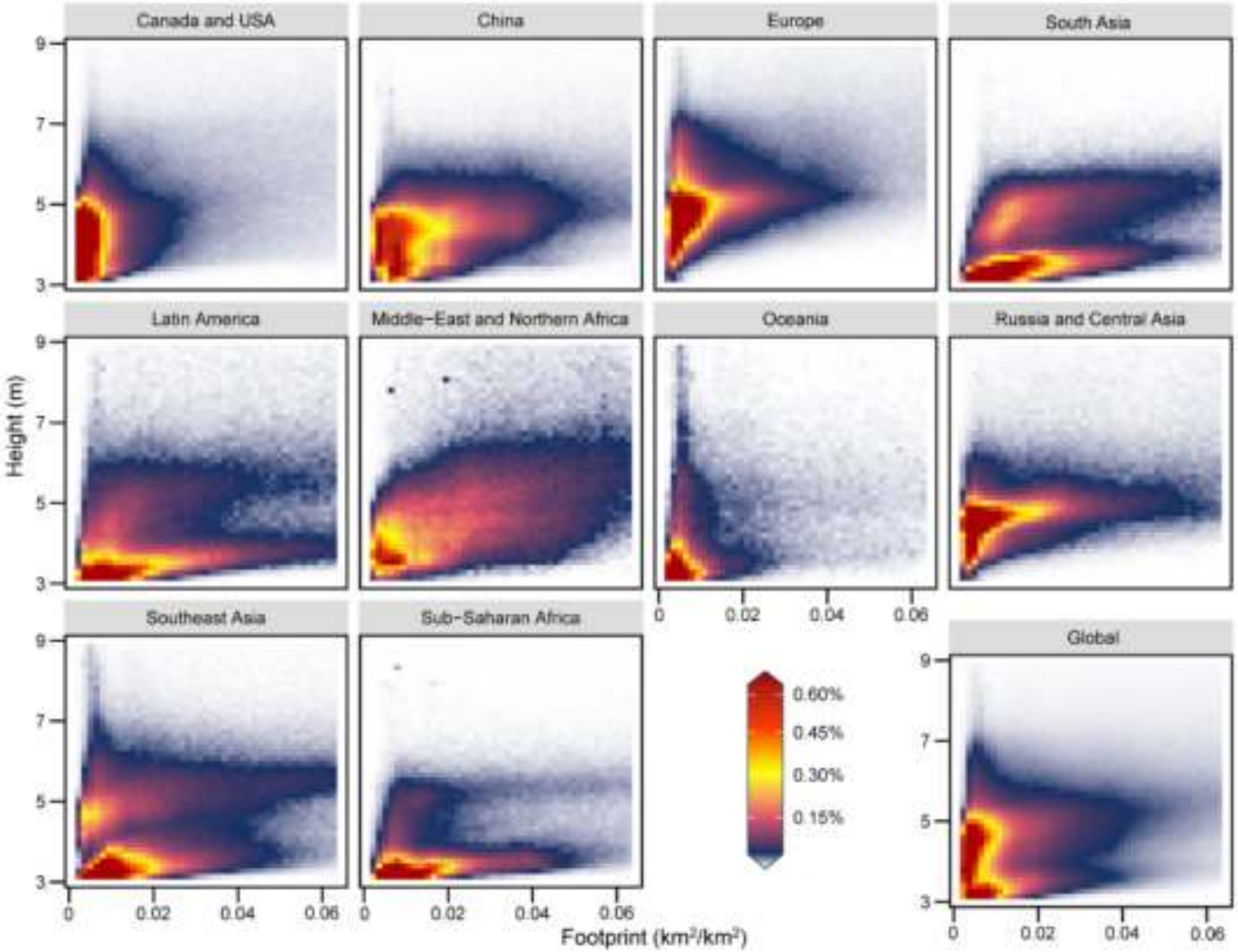


Figure: Li et al., 2022

Diversity of development patterns

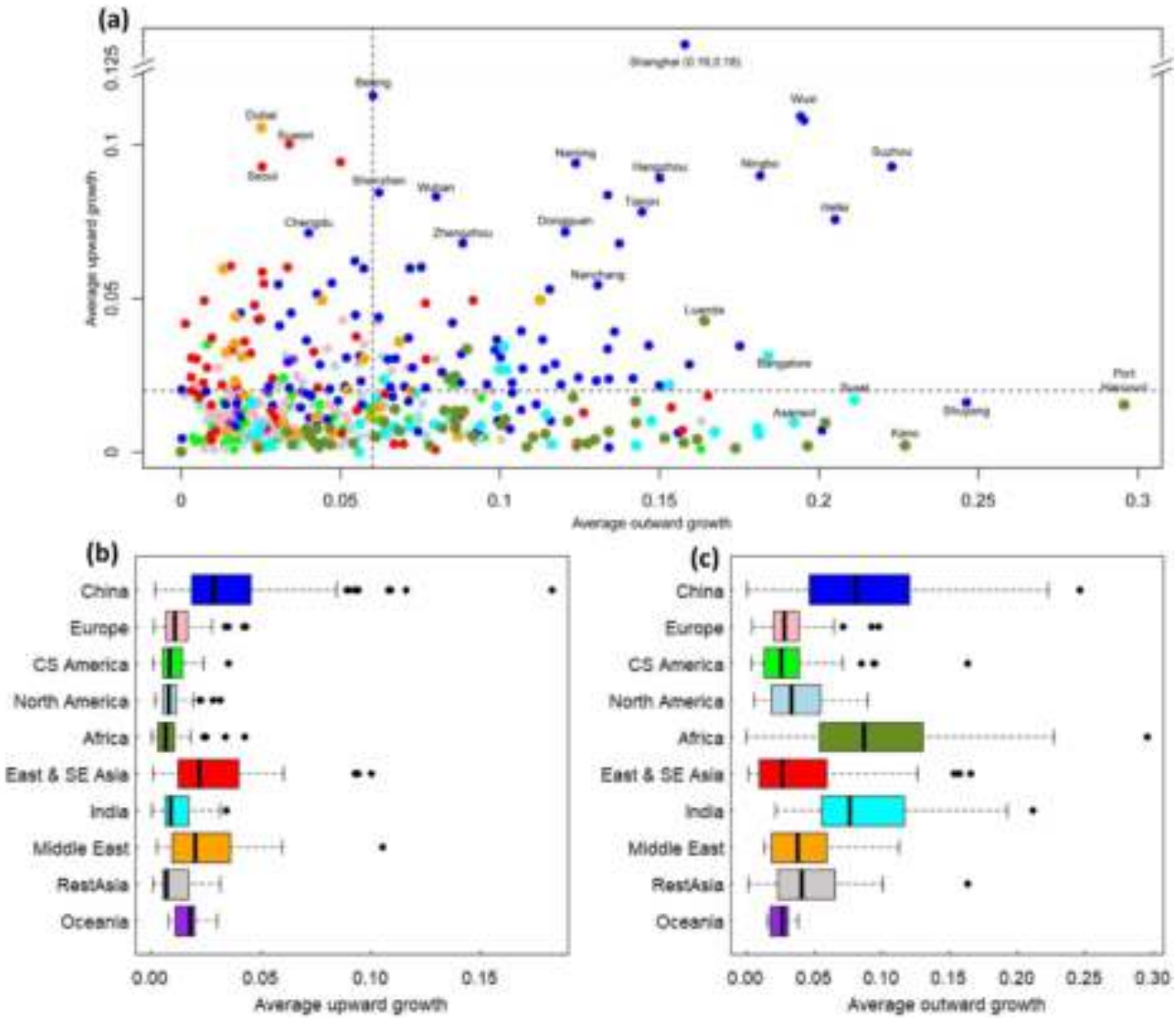


Figure: Mattha et al., 2022

... and thus diversity of strategies

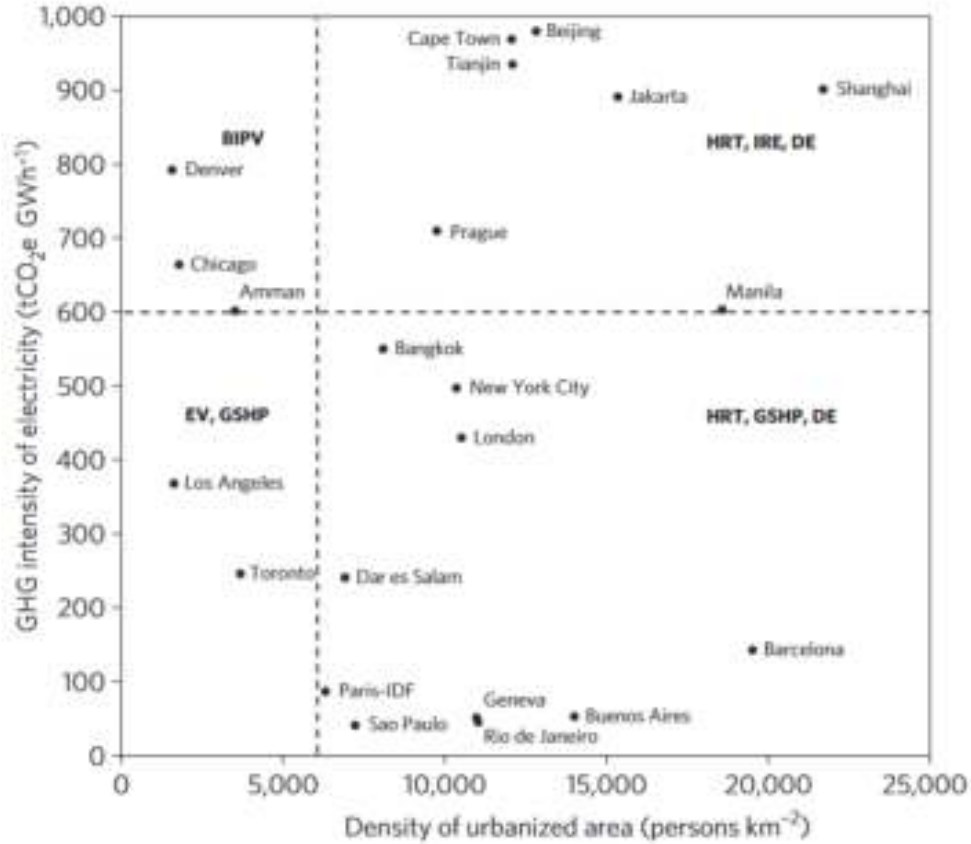


Figure 4 | Examples of low-carbon infrastructure strategies tailored to different cities. Prioritization according to urban population density and the average GHG intensity of existing electricity supply. EV, electric vehicle; GSHP, ground-source heat pumps; BIPV, building integrated photovoltaics; HRT, heavy rapid transit; IRE, import renewable energy; DE, district energy.

Figure: Kennedy, Ibrahim and Hoornweg, 2014

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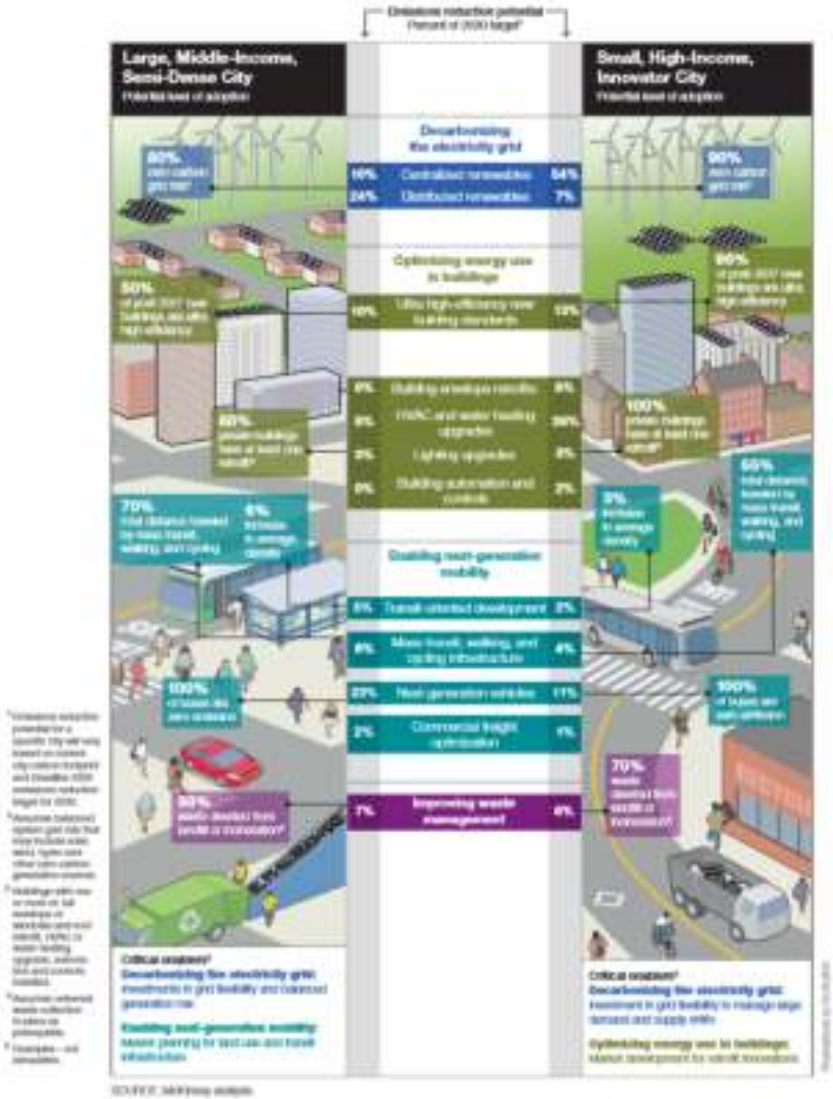

Figure: McKinsey, C40, 2017

... even within cities

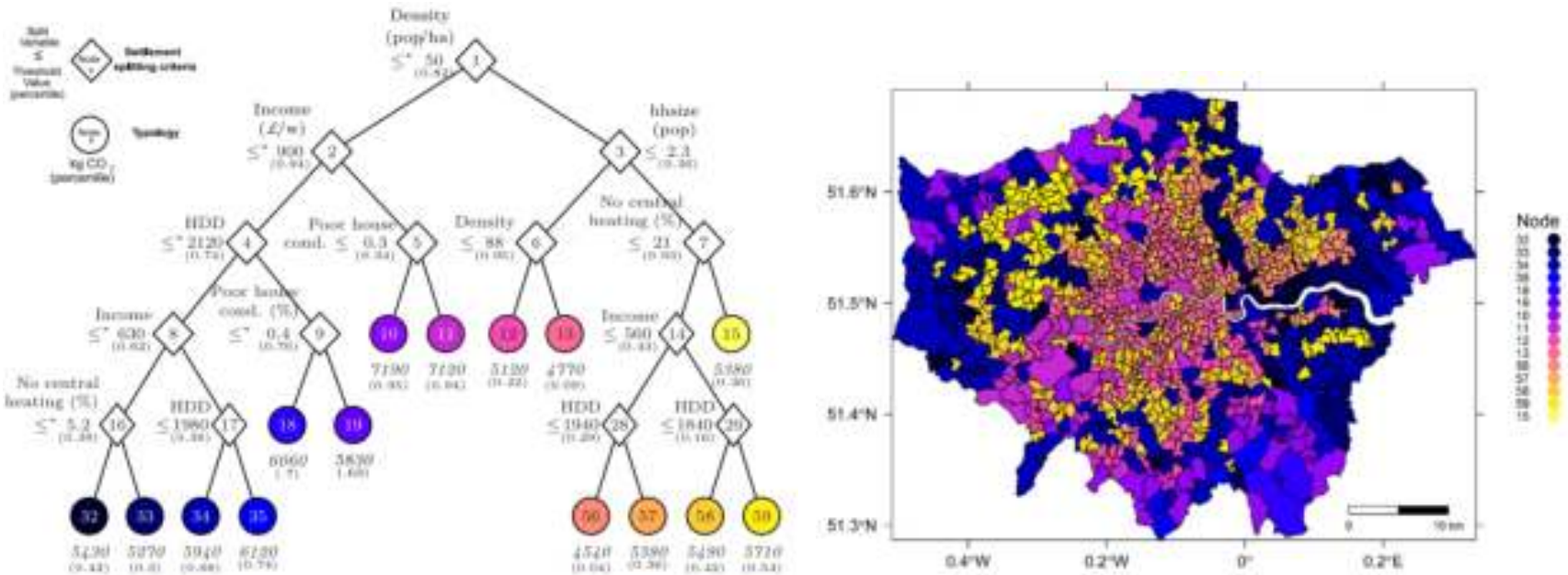

Figure: G. Baiocchi et al. (2015)

Conclusion of this part

- High population densities in cities as an opportunity for climate change mitigation.
- Exposure to extreme events makes the implementation of urban adaptation policies necessary.
- The urban scale is a good scale to efficiently implement policies.
- We need to design tailored climate policies for each local context.

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Urban mitigation potential by sector

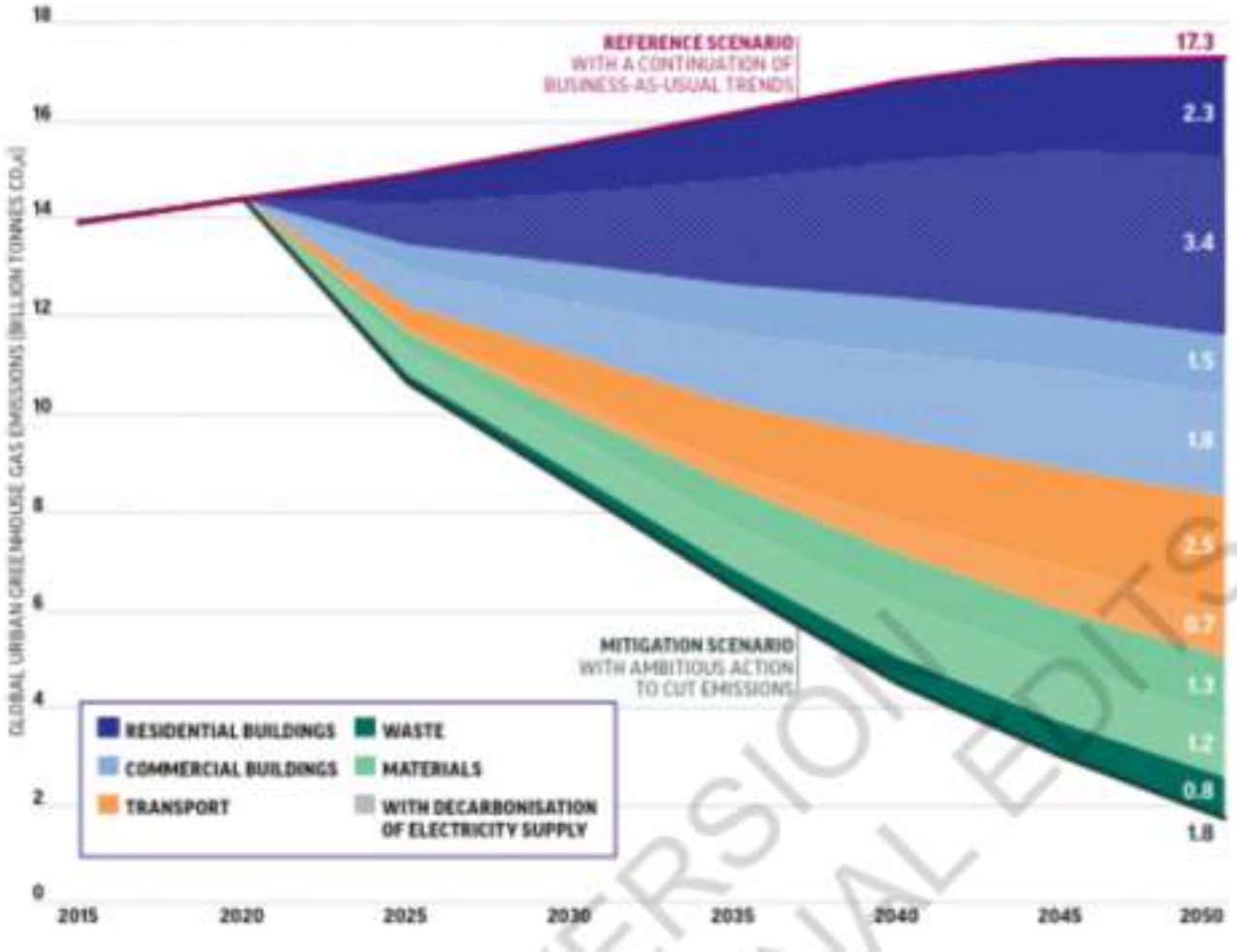


Figure: Coalition for Urban Transition, 2019

Transport

- **Urban transport:**
  - 3 GtCO2-eq per year, corresponding to 8% of global emissions (Creutzig et al., 2016).
  - Transport is one of the fastest-growing sector in terms of emissions (Minx et al., 2021).

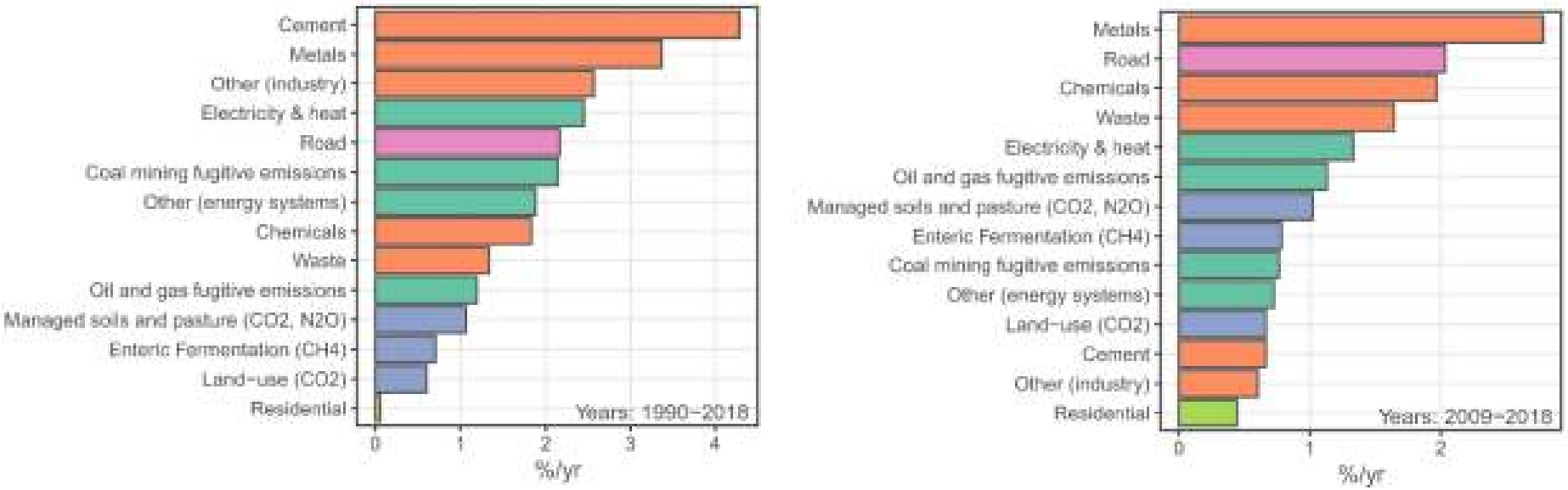


Figure: Minx et al. (2015)

Increasing Motorization

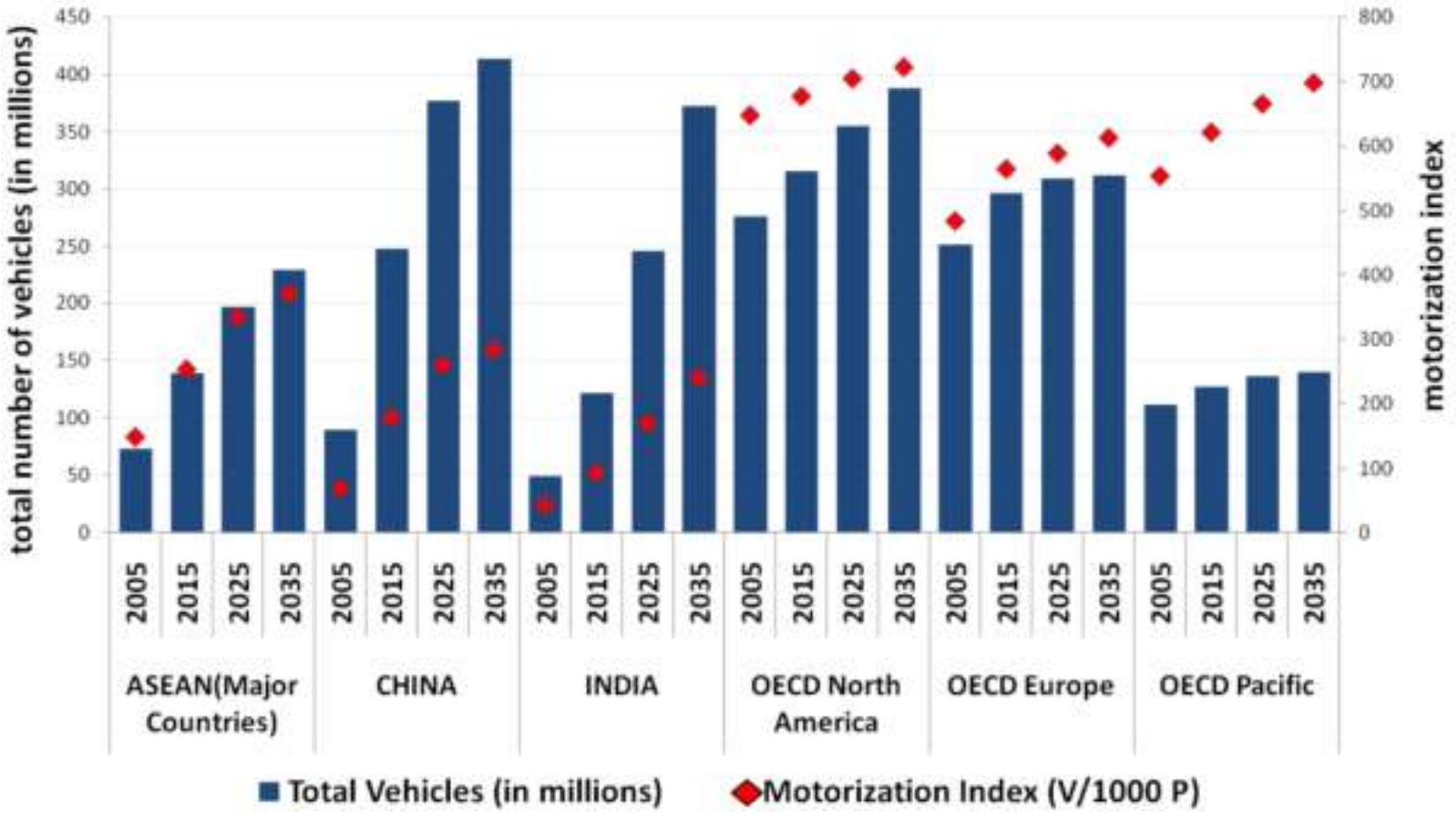
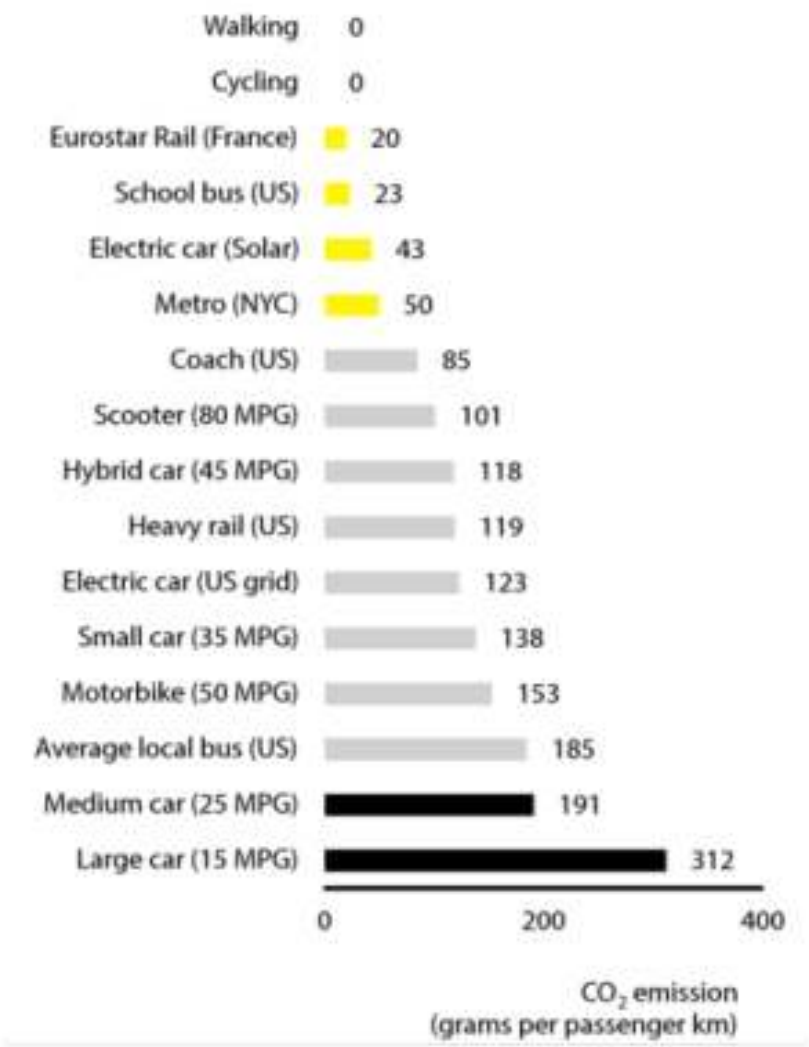


Figure: Source: ADB/IEA, 2009

Emissions per passenger-km by urban transport mode



Source: LSE Cities 2014 based on STF 2014

Transport cobenefits in Bangkok

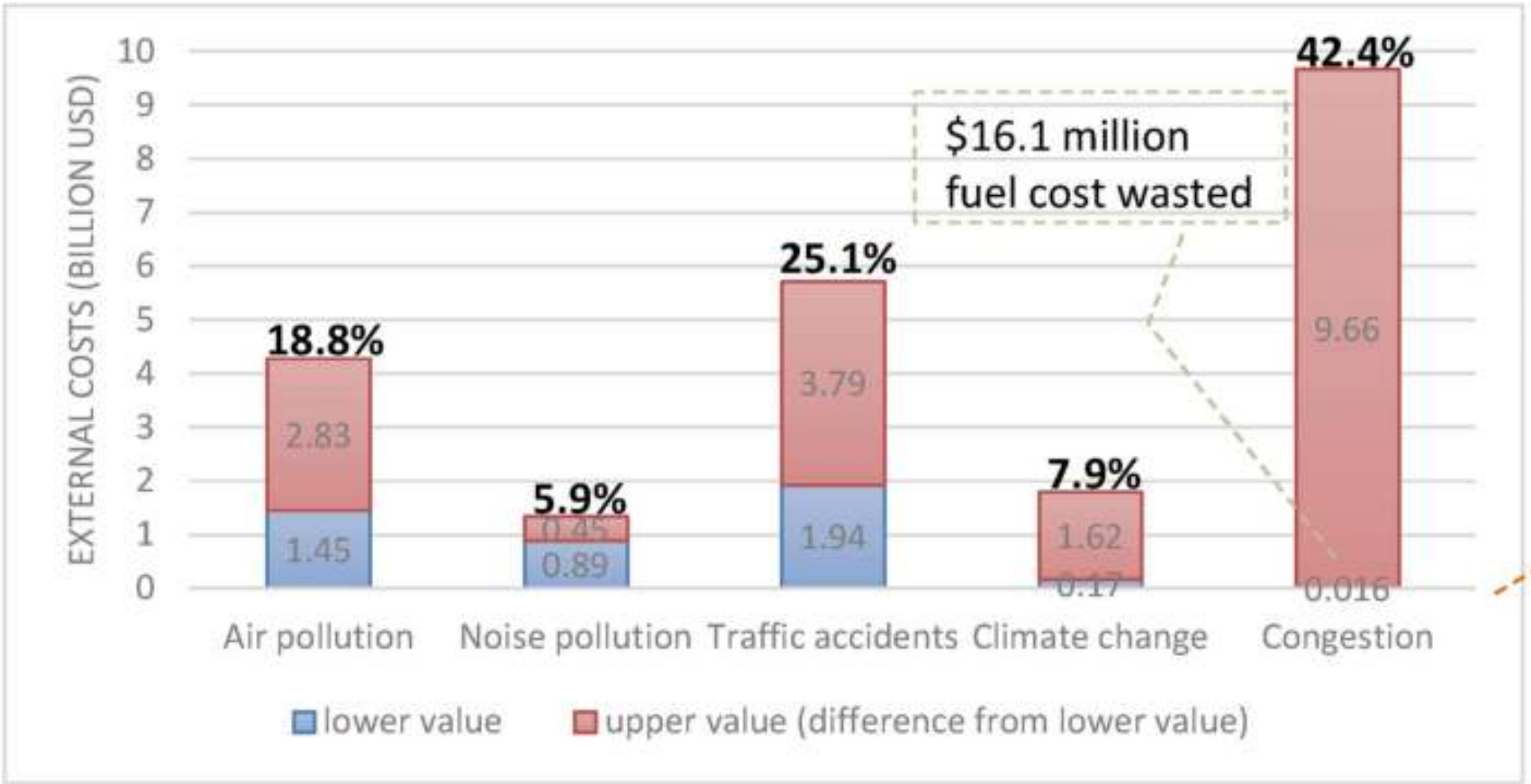
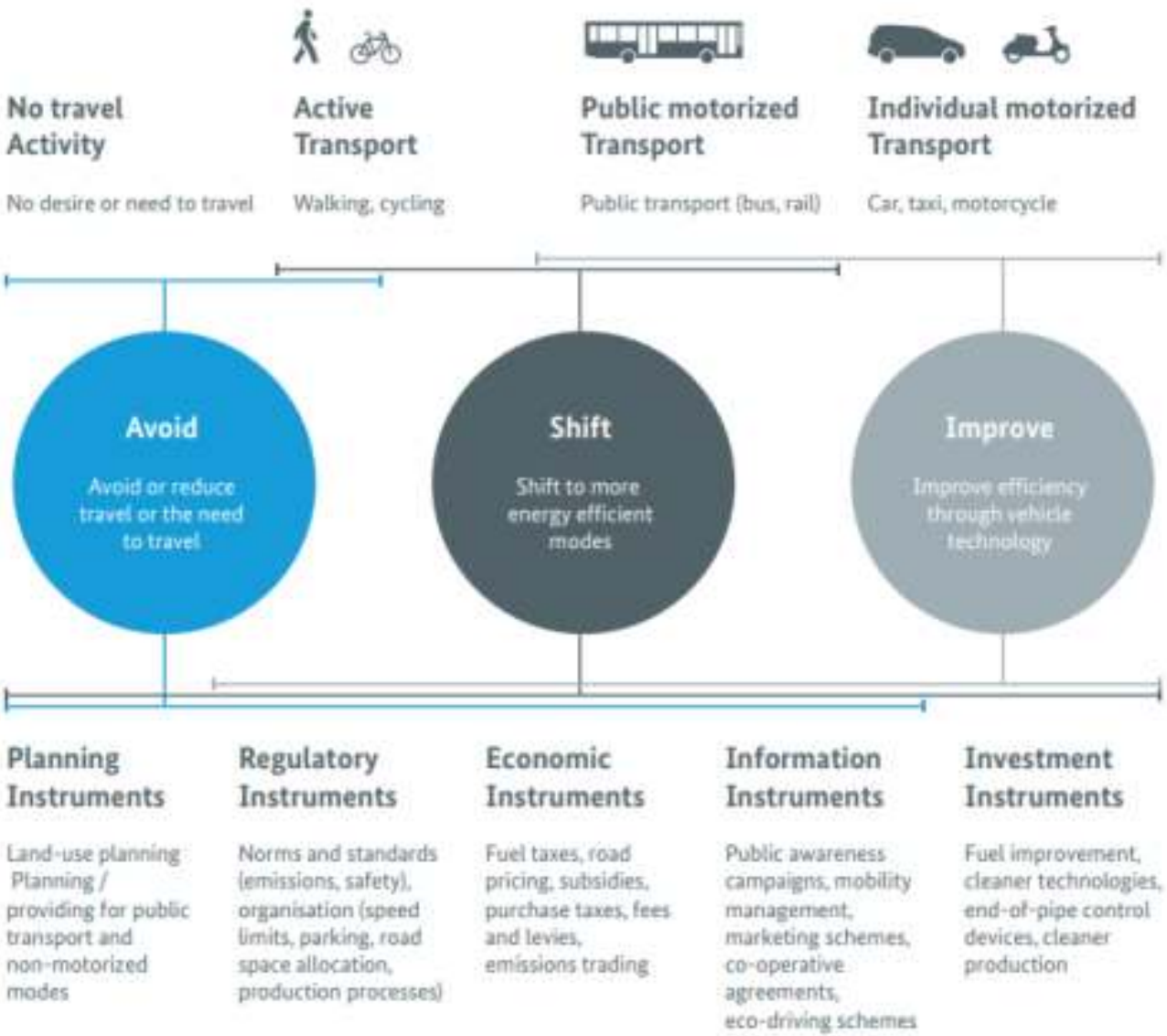


Figure: Ayaragarnchanakul and Creutzig, 2022. Total: 7 - 10.8% of Bangkok's GRP (15 - 22.9 milliards par an).

Urban transport mitigation policies



Global adoption of sustainable transport systems

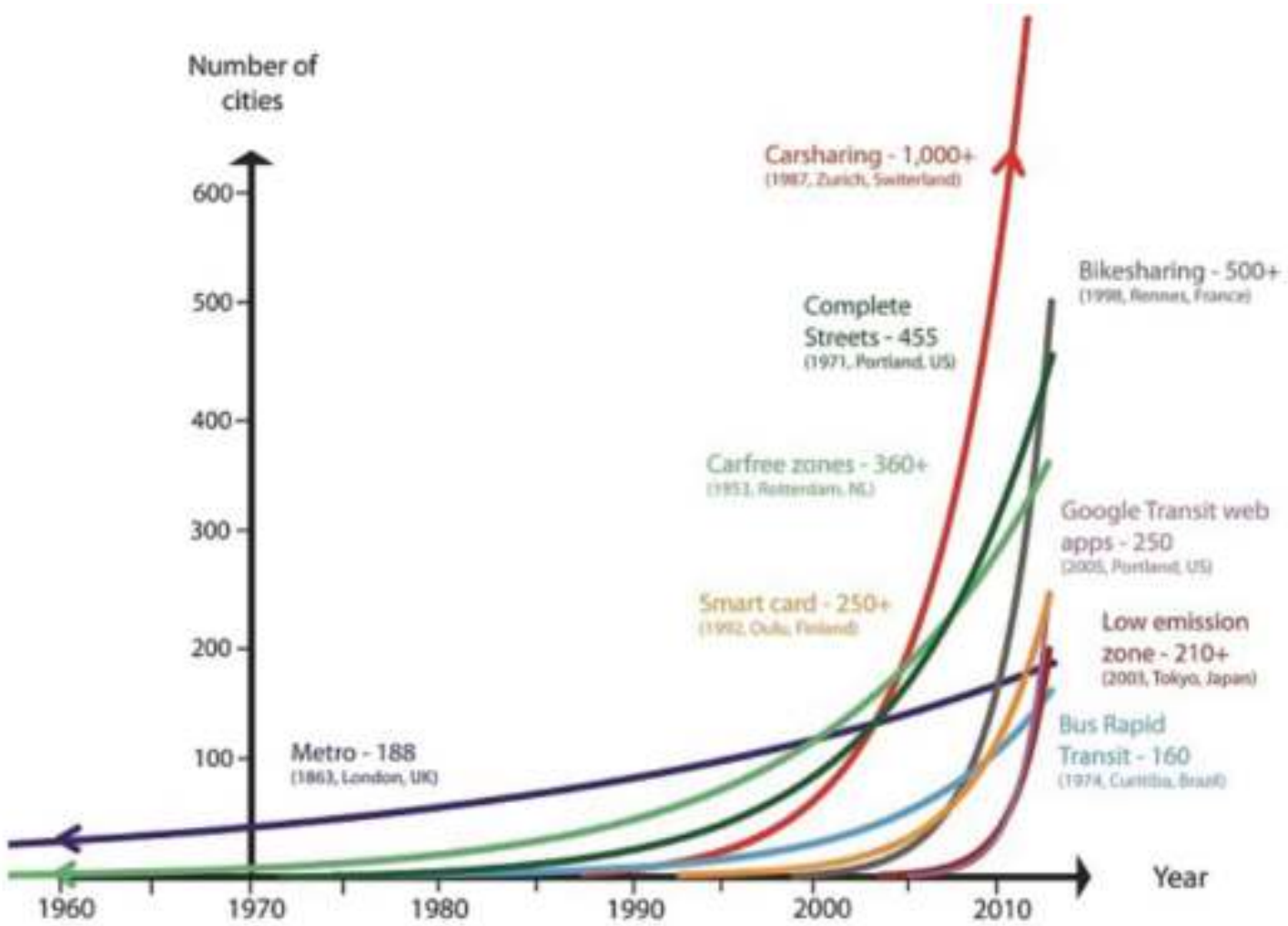
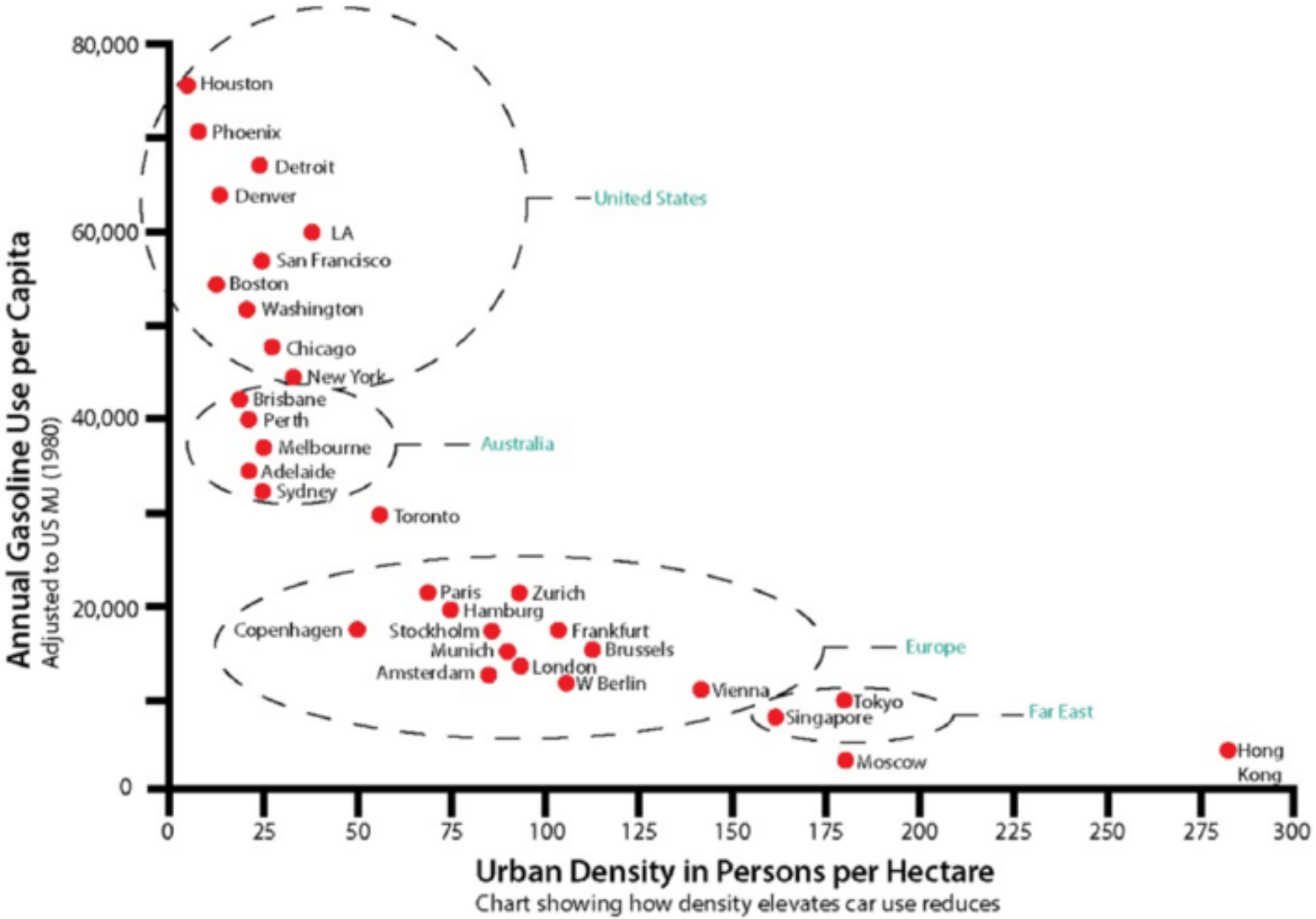


Figure: Source: Hidalgo and Zheng, 2013

Newman et Kenworthy, 1989



Buildings

- GHG emissions from buildings:
  - **21%** of global GHG emissions in 2019, splitted between:
    - **57% of indirect emissions** from offsite generation of electricity and heat.
    - **24% of direct emissions** produced onsite.
    - **18% of embodied emissions** from the use of cement and steel.

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- Buildings' emissions growth is due to:
  - **Population** growth.
  - **Floor Area per Capita** growth.
  - The energy inefficiency of **new buildins** (developping countries) and of **retrofittings** (developped countries).
  - The growing use of domestic **equipments**, including in particular AC.
  - Fossil fuels dependency, and **slow decarbonation** of the energy supply.

Energy use and urban forms

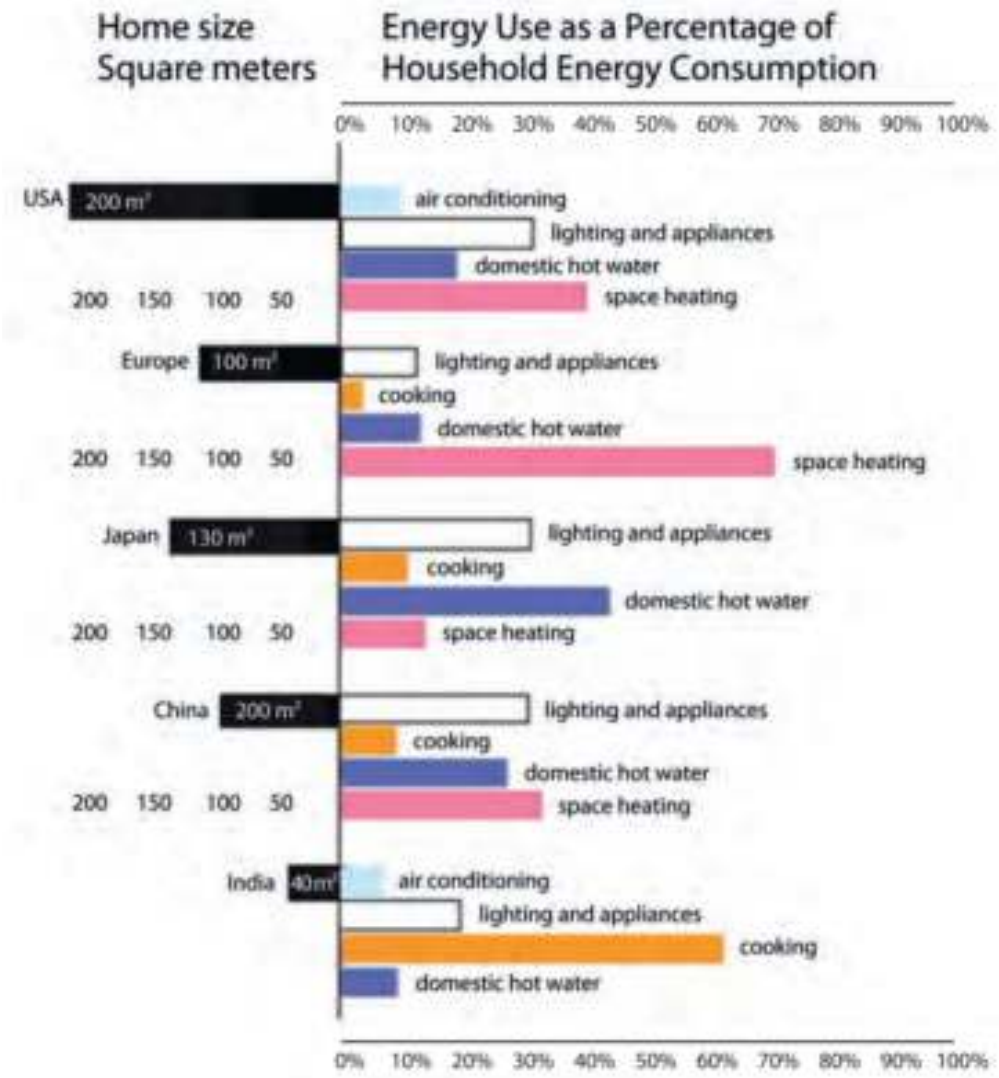


Figure: Source: WBCSD, 2009

Energy use and urban forms

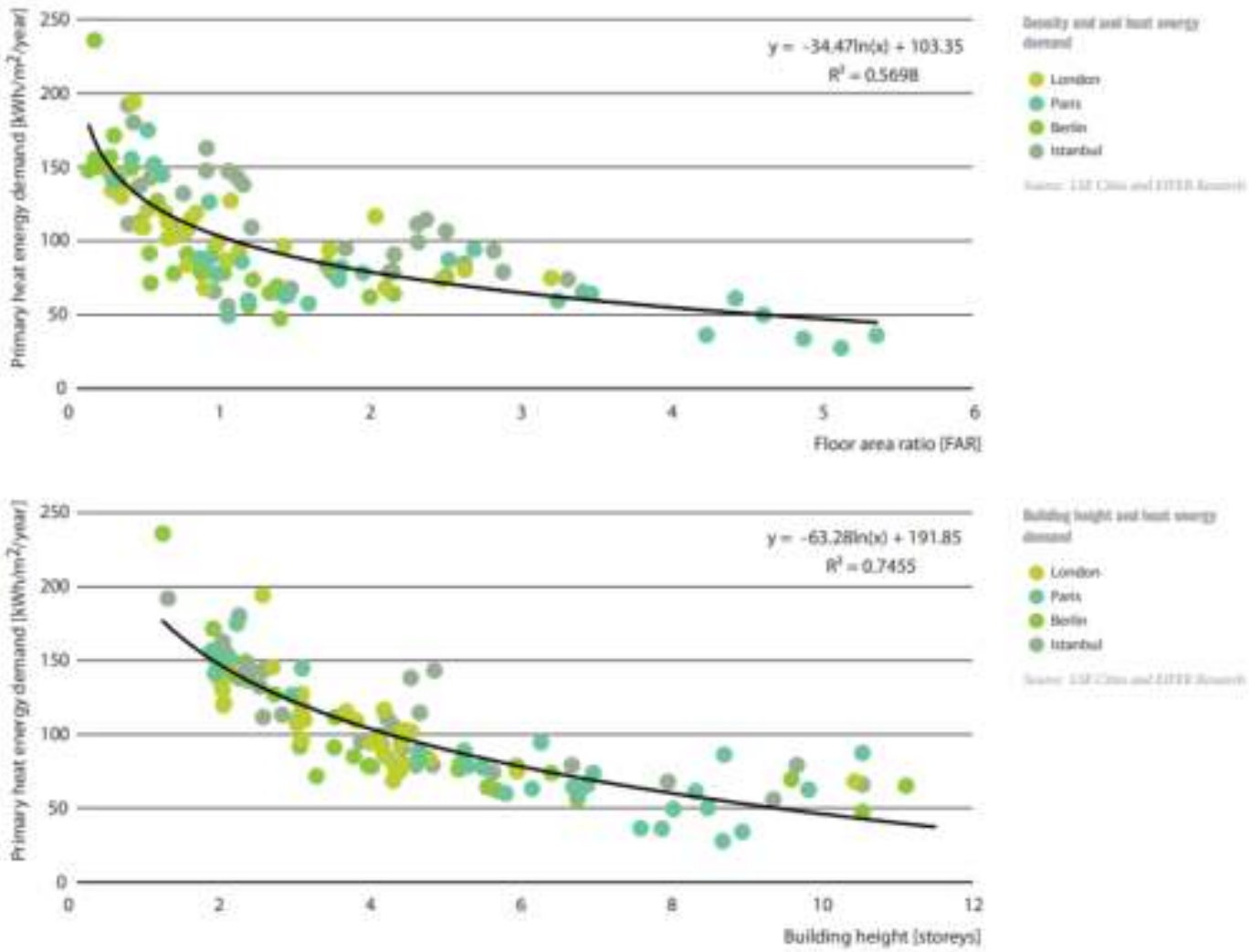
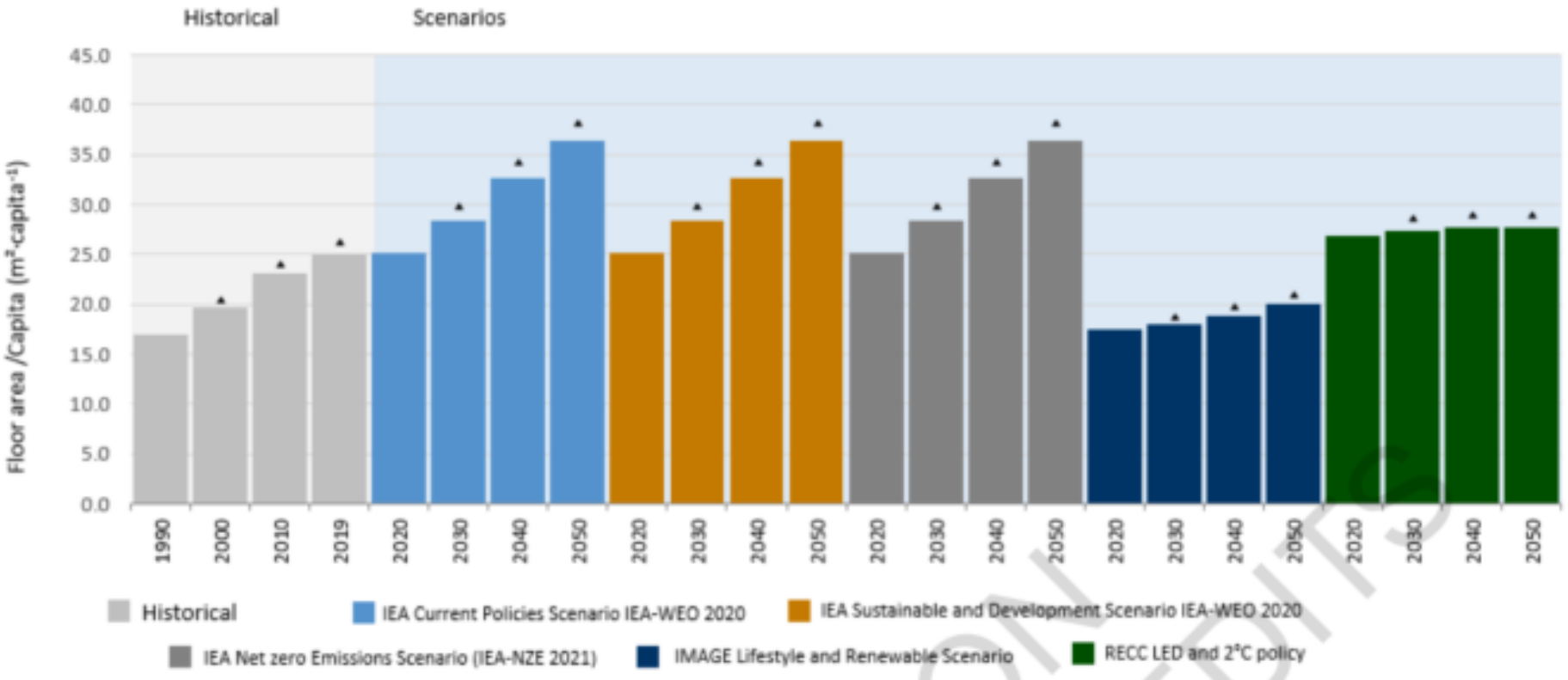


Figure: Source: LSE Cities and EIFER Research, 2014

Efficiency gains are approximately offset by a growth in the per-capita area



Reporterre

Faire un don au

Reportage – Monde

Contre l'étalement urbain, l'Allemagne commence à interdire les pavillons neufs

Low consumption practices

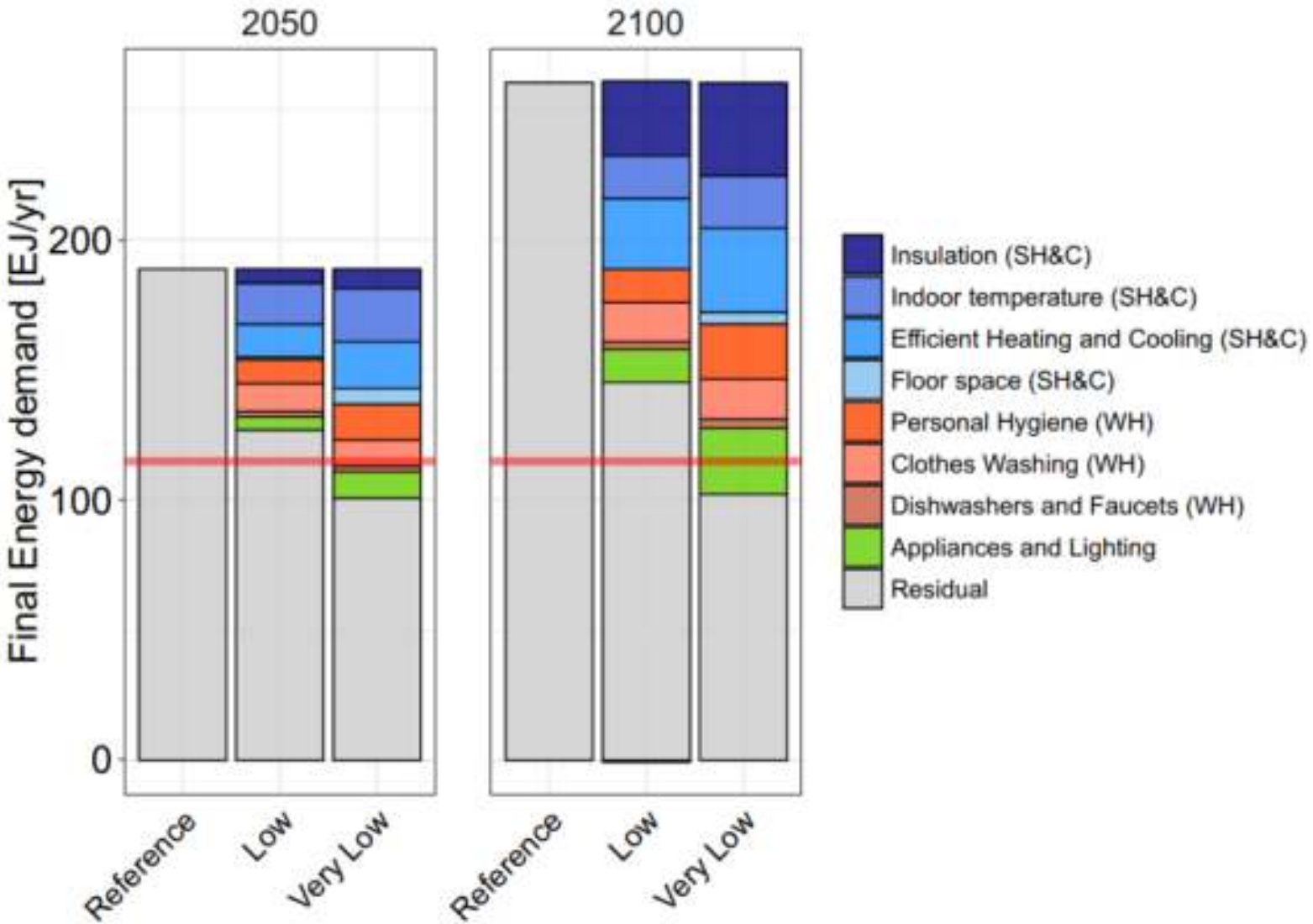


Figure: Levesque, Pietzcker and Luderer, 2019.

Building sector mitigation potential

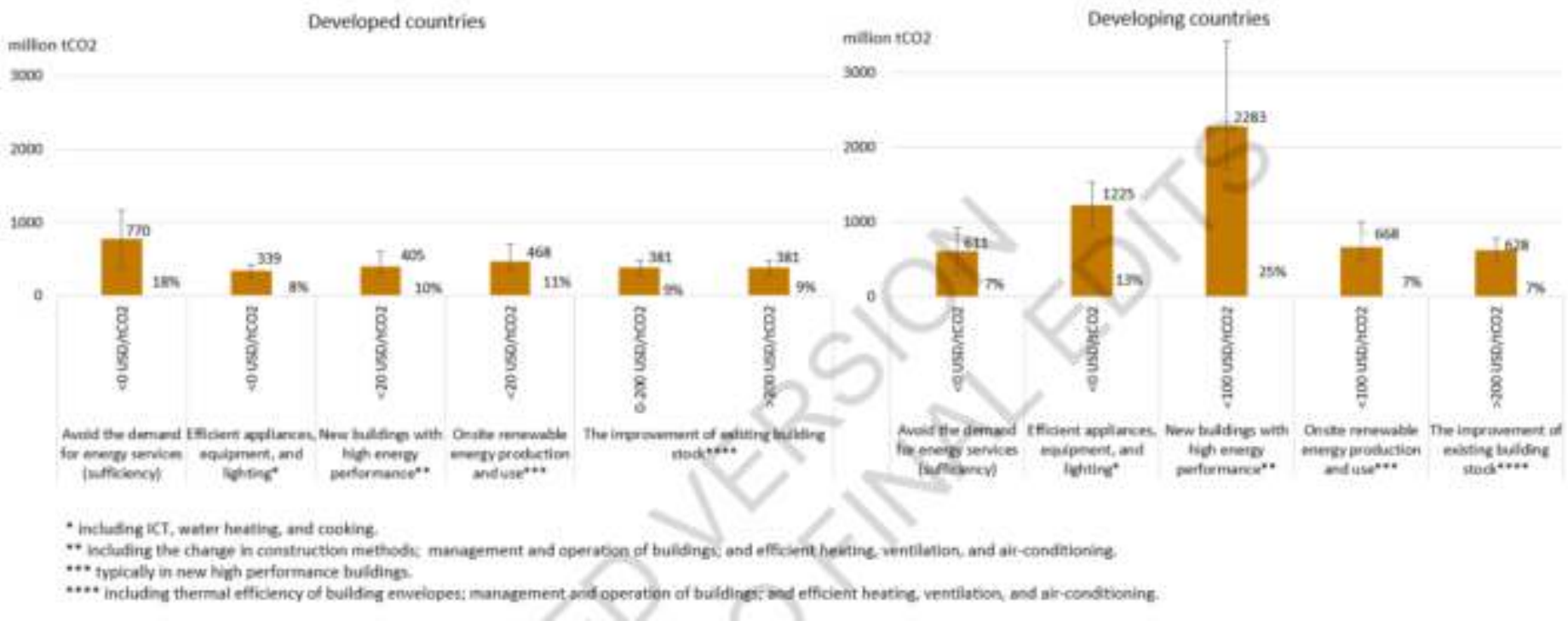


Figure: IPCC AR6 WG3

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Floods

Floods impacts are worsening:

- Increased frequency and intensity of extreme precipitation events due to climate change.
- Urban sprawl in flood-prone area.
- Soil impermeabilization that worsens the consequences of flooding.
  - Case-study on 4 European cities: Soil impermeabilization increases by 1% = floodings increase by more than 10% (Kaspersen et al., 2017).

Urban sprawl and flood risks

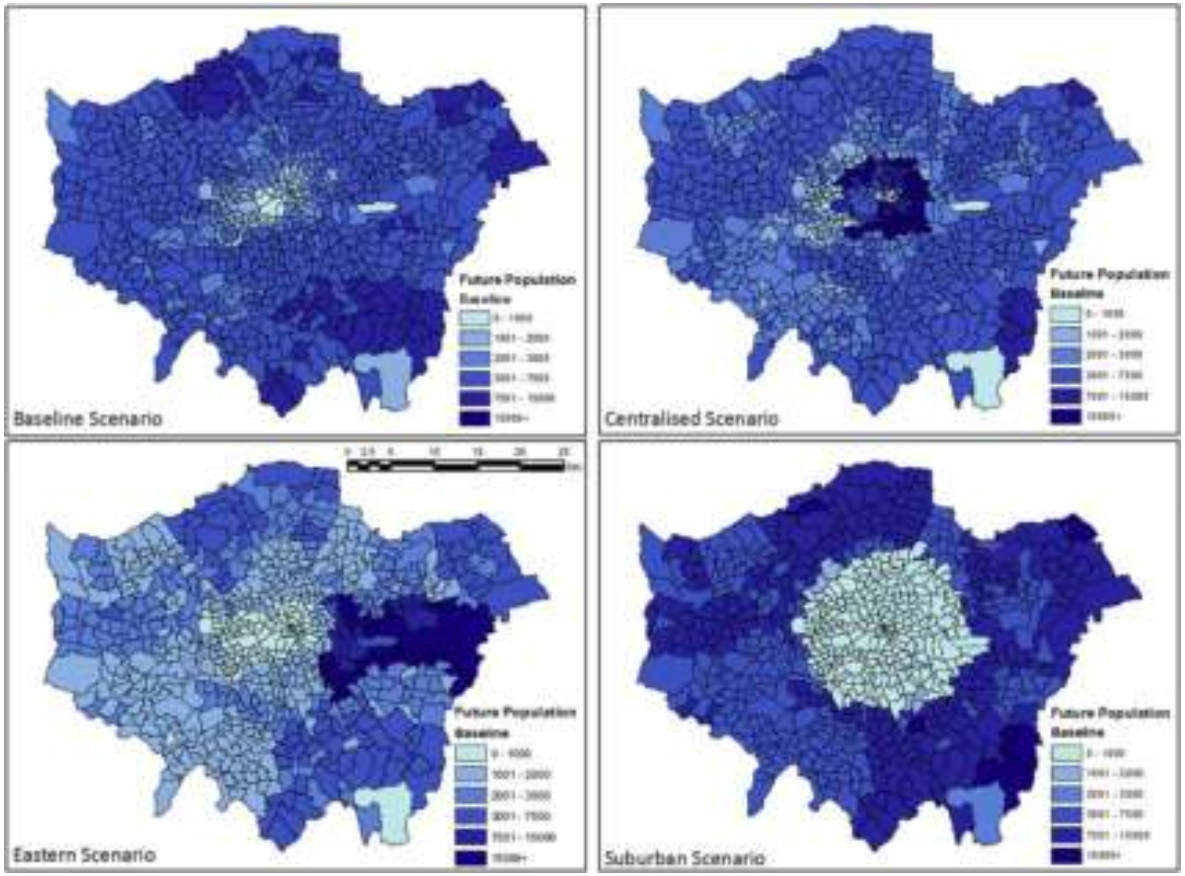


Figure: Ford et al., 2019

Urban sprawl and flood risks

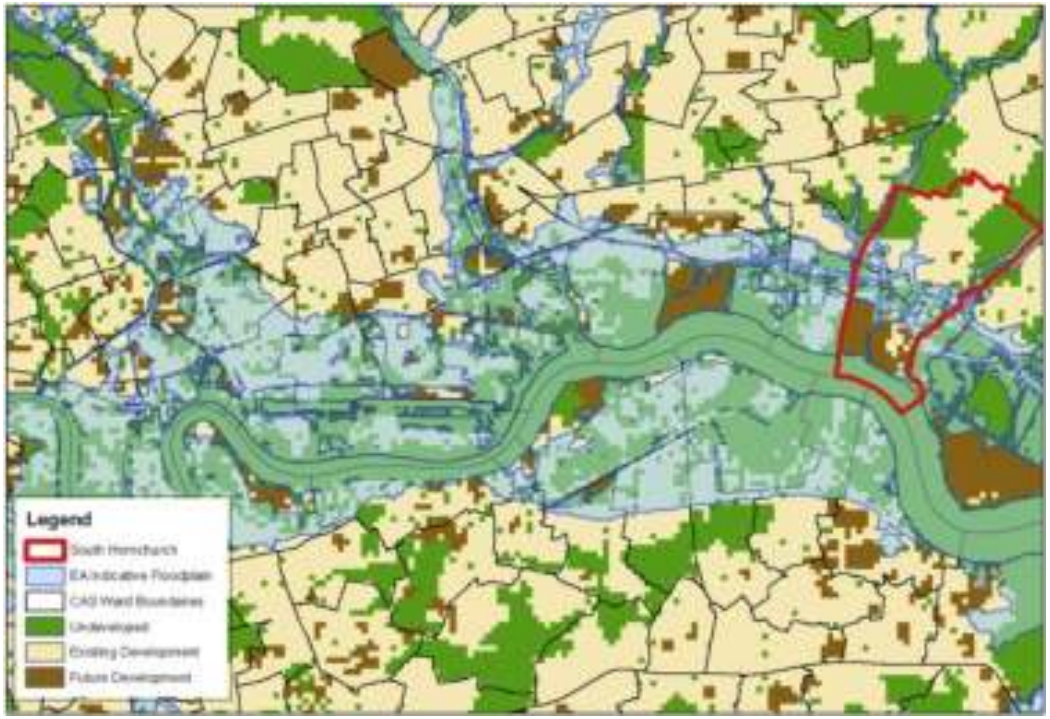


Figure: Ford et al., 2019

Urban sprawl and flood risks

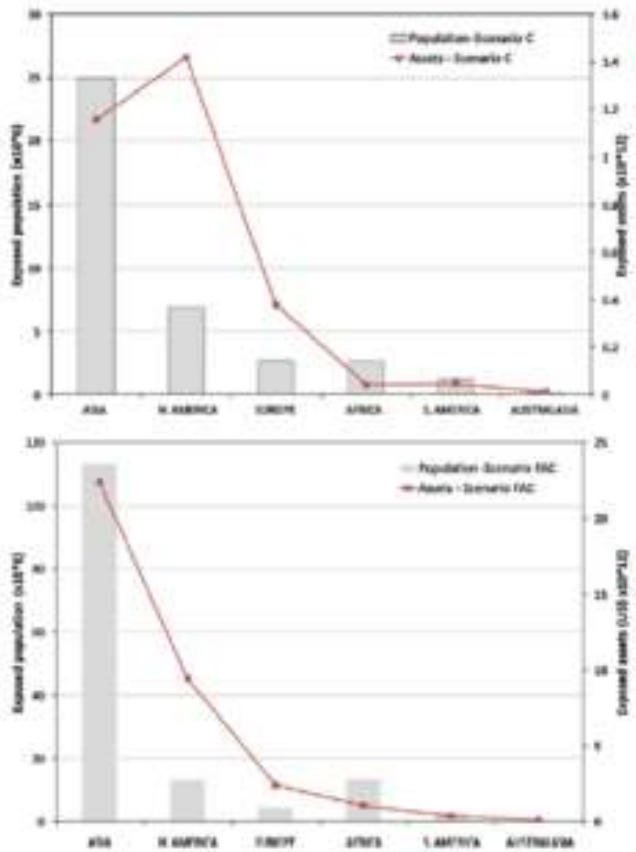
Scenario	Area of development in flood plain	Population density in new development (mean)	Expected annual damages from flooding
Current	8419 ha	93.25 people/ha	£29 million
Baseline	10,131 ha	114.50 people/ha	£76 million
Eastern	10,964 ha	106.30 people/ha	£118 million
Centralised	9986 ha	123.10 people/ha	£72 million
Suburban	9937 ha	115.30 people/ha	£62 million

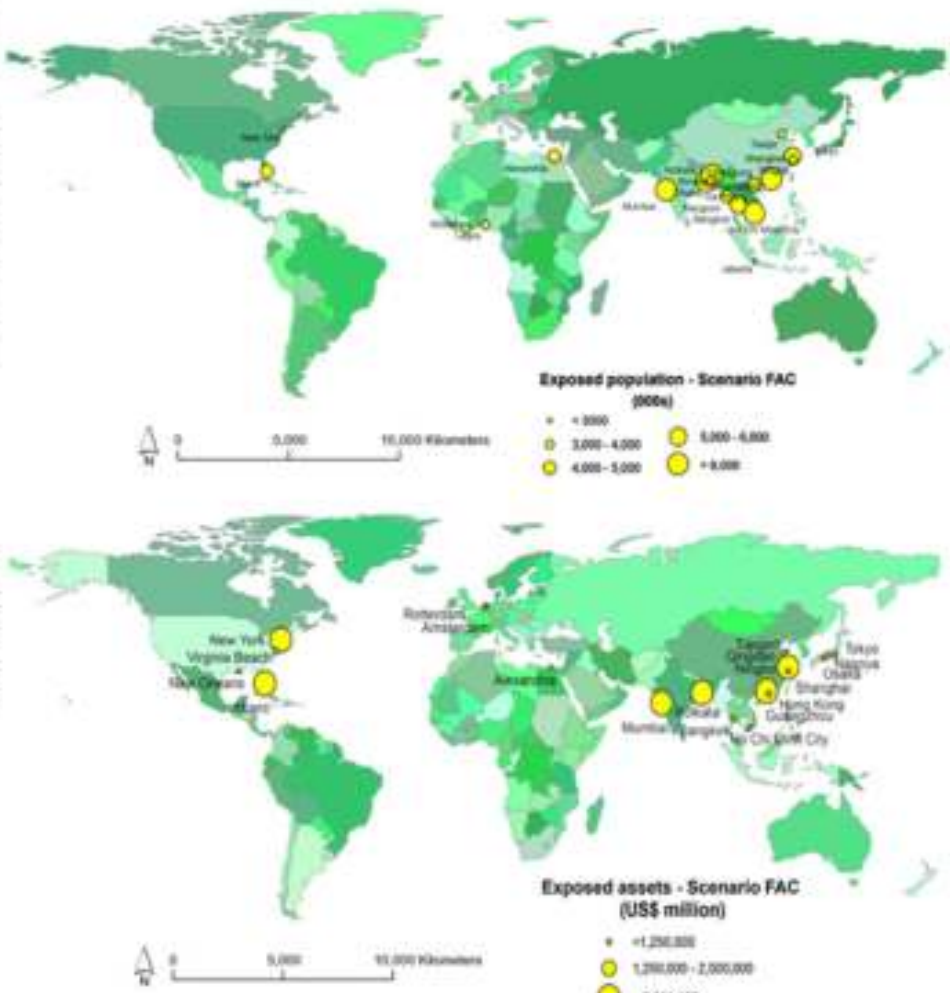
Figure: Ford et al., 2019

Informal settlements and flood risks

Figure: Floods in Cape Town. Source: Claus Rabe

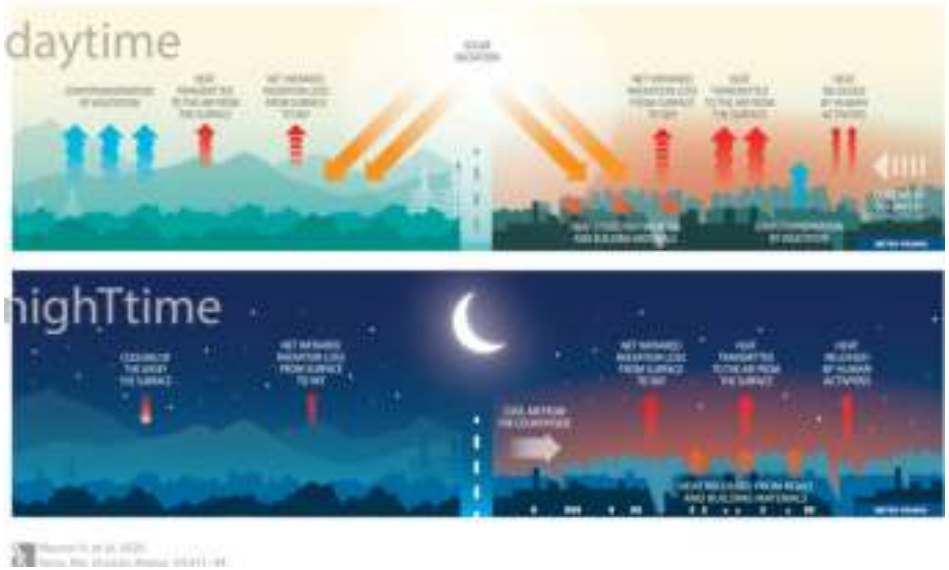
Sea-level rise and storm surge in port cities of more than 1 million inhabitants (Hallegatte et al. 2011)





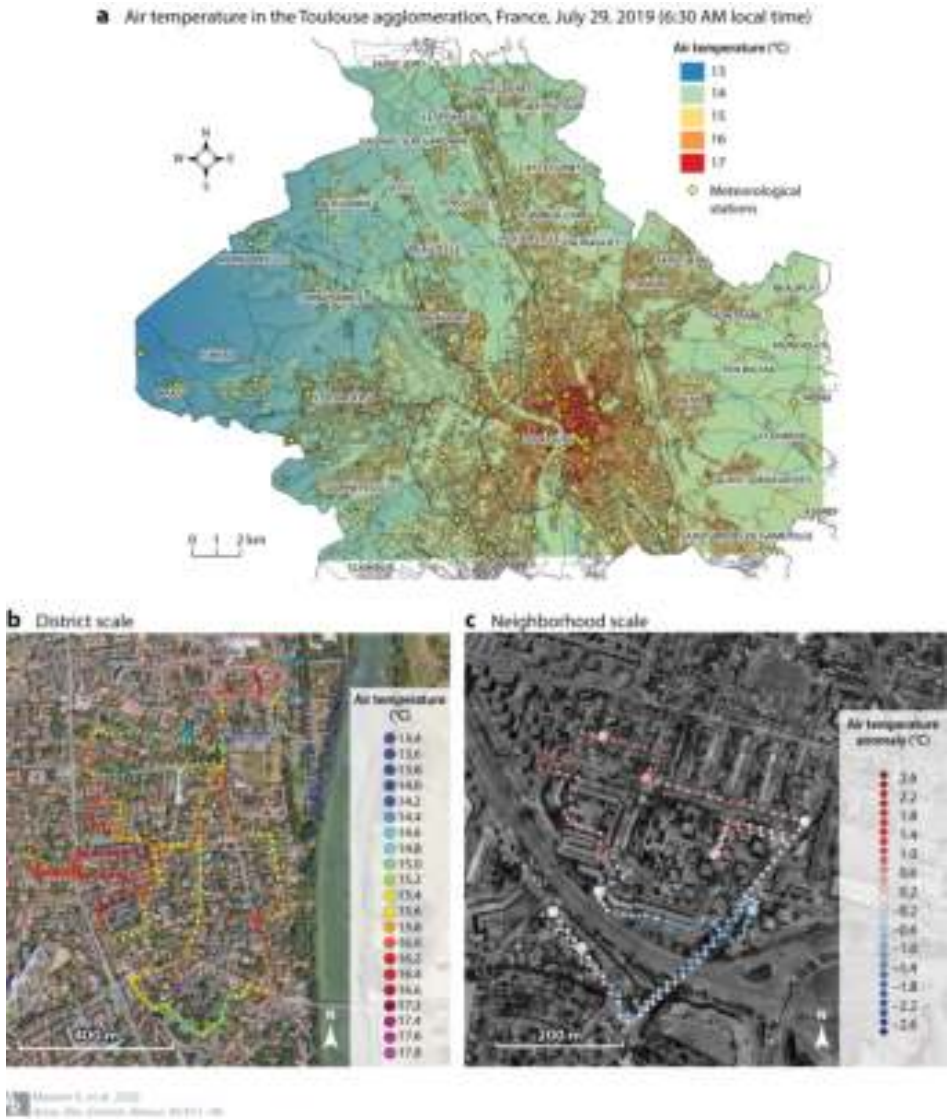
Urban heat islands

- During the day, a large part of the sun radiation heats the urban materials.
- This stored heat is released at night, limiting the nighttime cooling of the air in cities.
- Also influenced by the heat released by human activities and the air flow from the countryside.



Urban form and UHI

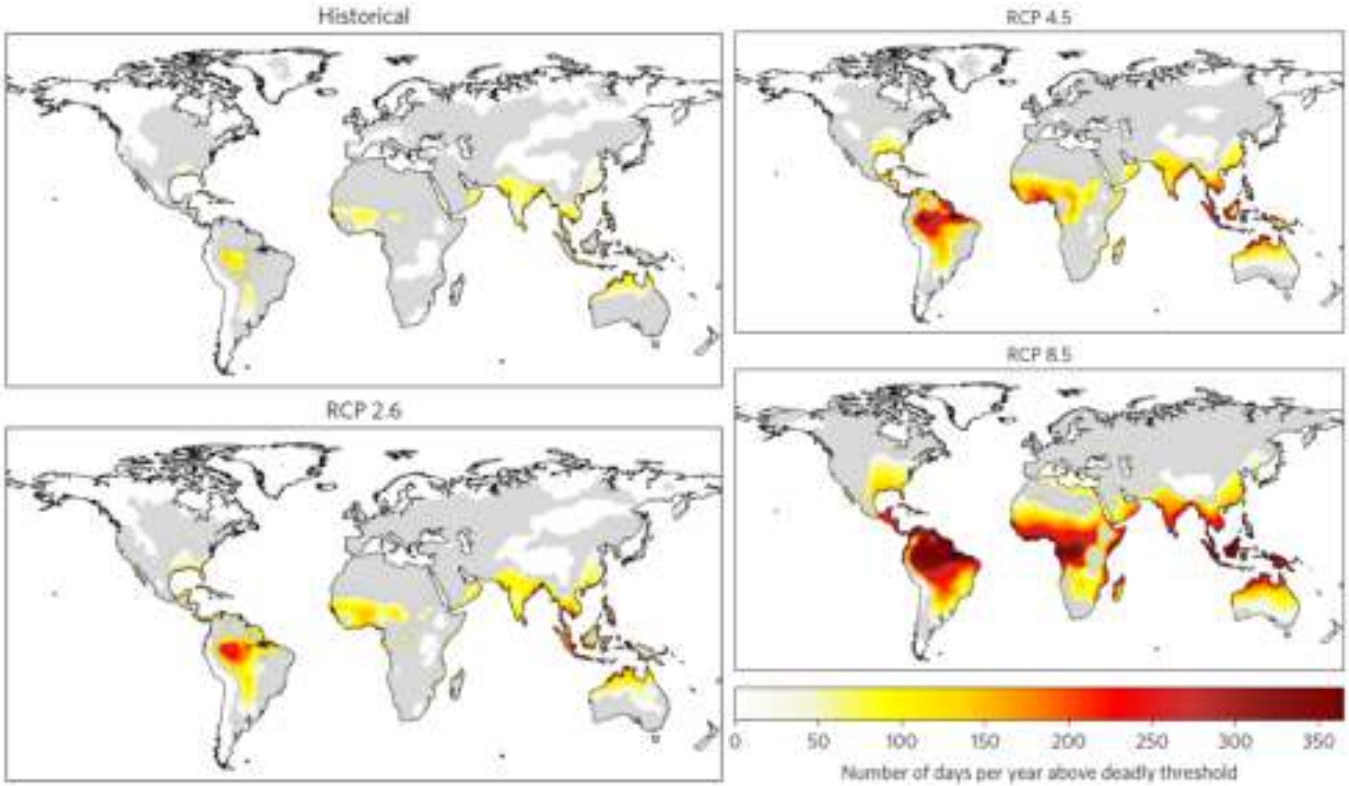
- **Local scale:** buildings influence the wind flow and cast shadows, and often release heat to the atmosphere.
- **Neighborhood scale:** urban climate sensitive to urban forms, land cover, land use, and the presence of vegetation.



Urban heat islands

- UHI exposure will increase because of:
  - Climate change ;
  - Population growth in cities already subject to extreme heat events (Africa, India, Middle East).
- Depending on the scenario, between half and two-thirds of the world's population could be exposed to extreme heat events in 2100 (Mora et al., 2017).
- Unequal exposure: the poorest, children, the elderly, and ethnic minorities are likely to be more exposed.

Mora et al., 2017



Droughts, fires, air pollution

- **Water resources**:
  - 1/3 of the world's cities will exhaust their water resources before 2050 (Flörke et al, 2018).
  - 350 million additional urban dwellers will be exposed to droughts under a 1.5°C-warming or 410.7 million under a 2°C-warming (Liu et al., 2018).

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- **Wildfires**:
  - Warmer and drier climates that favor forest fires (e.g. in Australia, the United States, Russia) that can impact cities in these regions.

Nature-based solutions

Benefits from green spaces:

- Temperature regulation.
- Air quality regulation.
- Rainwater regulation.
- Protection against coastal and river flooding.
- Food production and water management.

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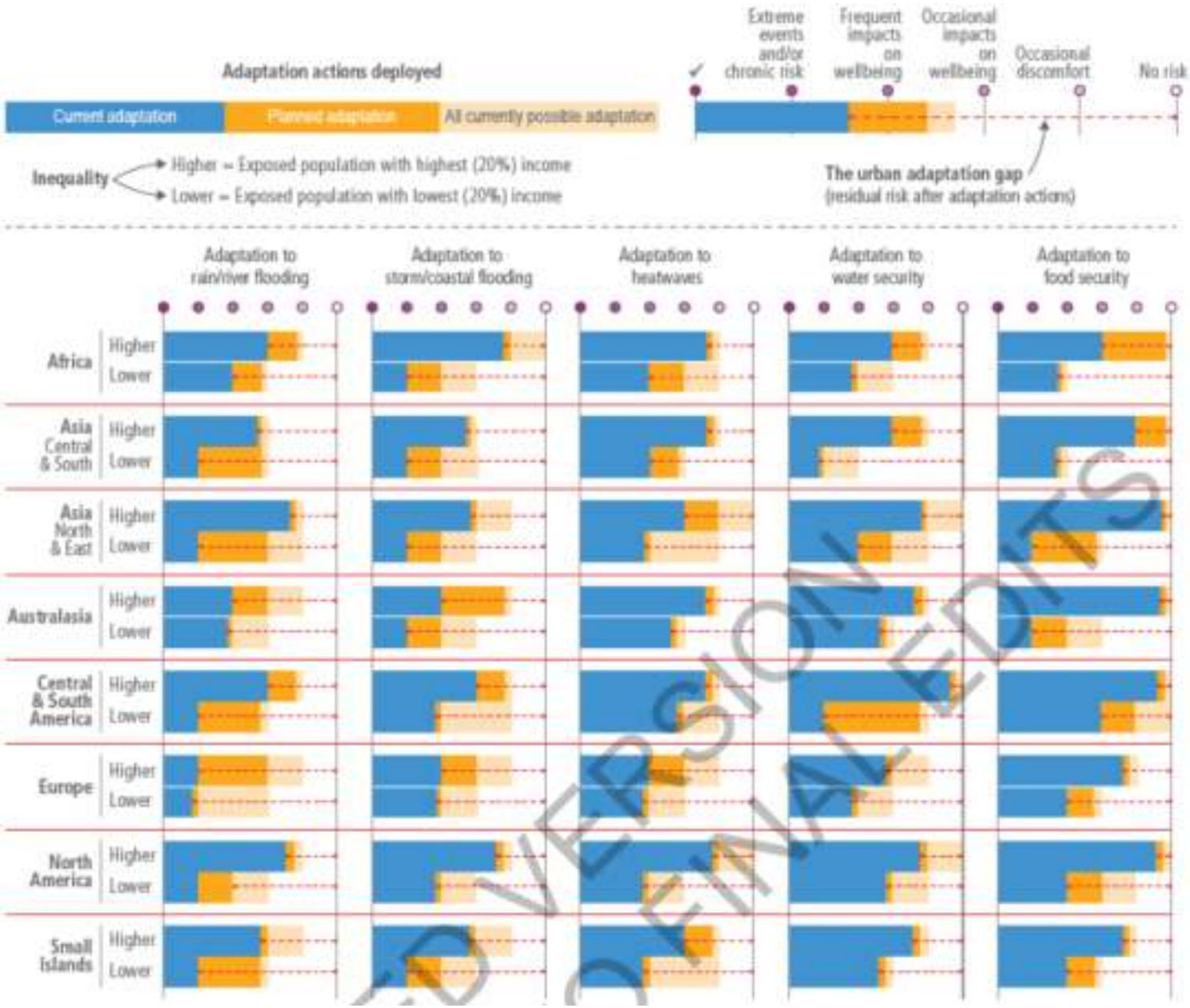
Wider sustainability cobenefits from green spaces:

- Impacts on obesity
- Impacts on mental health
- Impacts on social connections
- Equity issues:
  - Related to green spaces distribution
  - Green gentrification

Equity and adaptation (IPCC AR6 WG2)



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Which urban form to reconcile these goals?

- **Compact cities:**
  - Transport:
    - Reduce distances (Avoid)
    - Develop public transport (Shift)
    - Promote active mobilities (Shift)
  - Buildings:
    - Decrease area per capita
    - Increase heights
  - Floods:
    - Decrease urbanization in flood-prone areas
    - Decrease soil impermeabilisation
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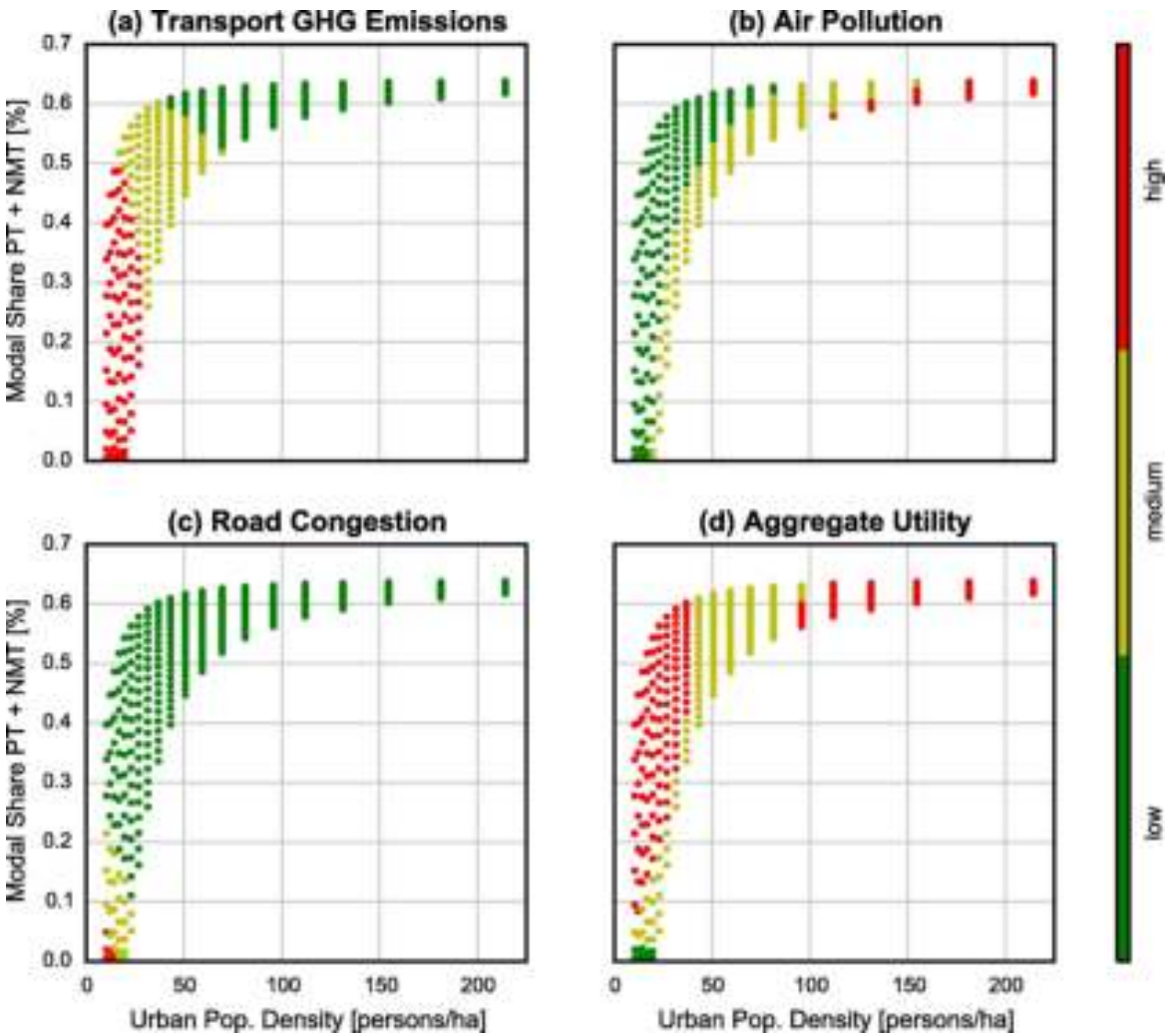
  - Biodiversity
- **Sprawled cities:**
  - Urban green spaces: Cooling effect, recreation, flood regulation,...
  - Better air quality, less exposure to noise,...
  - Urban heat island effect less intense.

A sustainability window of urban form? (Lohrey and Creutzig, 2016)



Sustainability window:

- Residential population density between 50 and 150 persons/ha
- Modal share of environmental modes above at least 50%

Different visions: compact cities

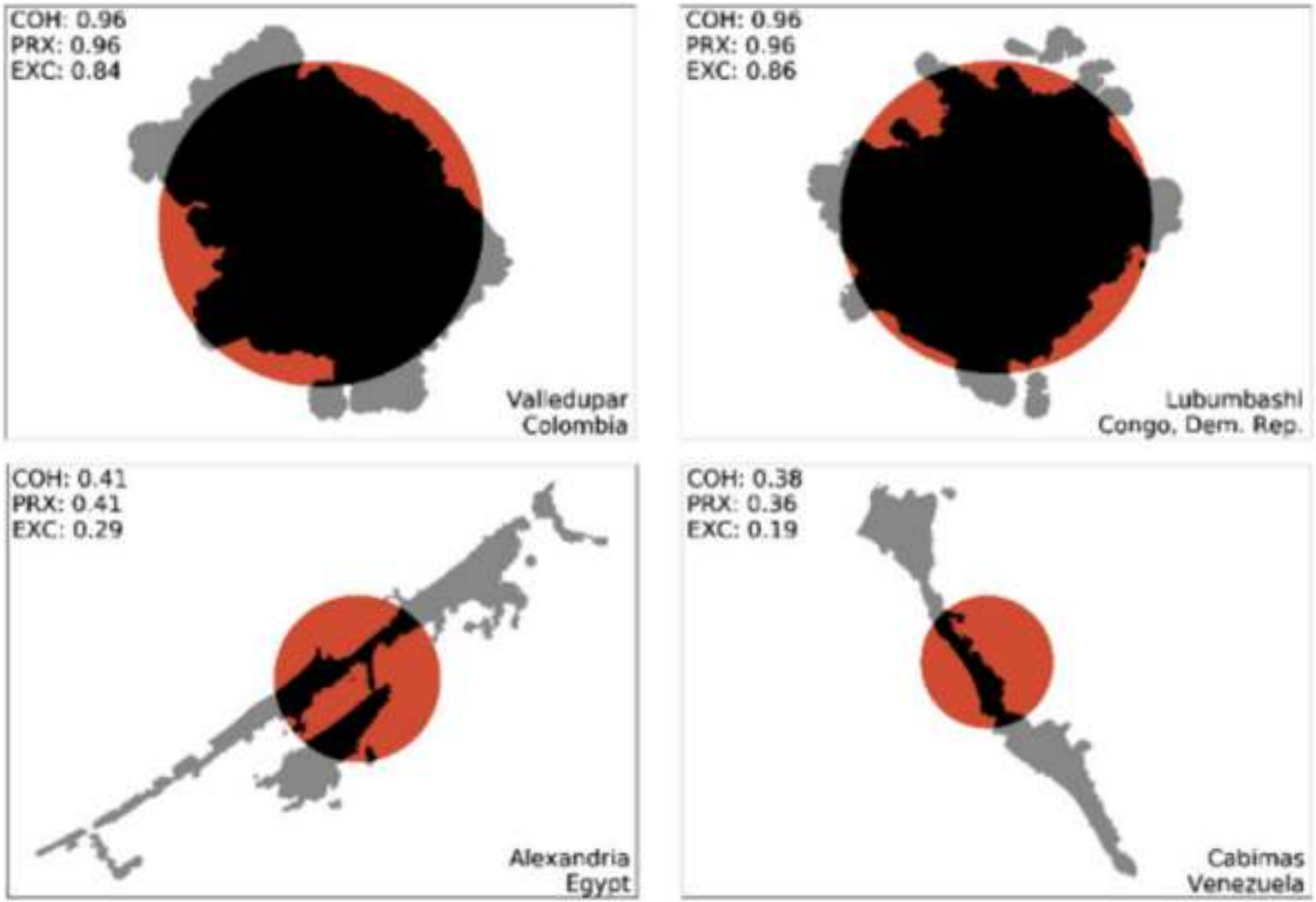


Figure: Angel et al. (2020)

Different visions: IPCC AR6 WG3

- IPCC AR6 WG3:
  - Beyond density: Connectivity, accessibility, land-use mix.
  - "Compact and walkable" urban forms.

Emphasizing accessibility

Importance of ensuring access to:

- Social infrastructures:
  - Leisure
  - Education
  - Health and social services
  - Sport and recreation facilities
  - Childcare
- Food
- Public transport
- Public open space

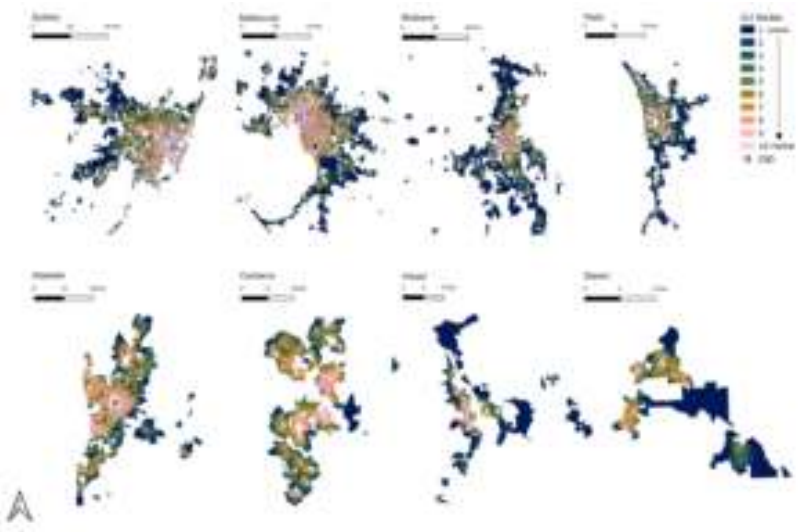


Figure: Source: Giles-Corti et al. (2022)

Jobs locations

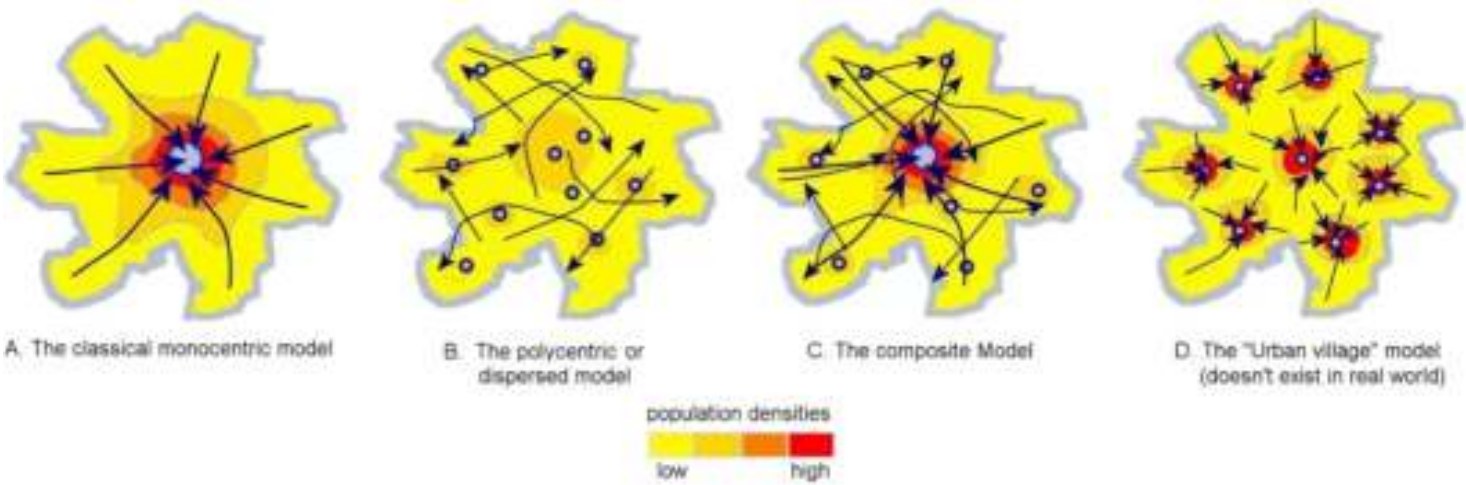
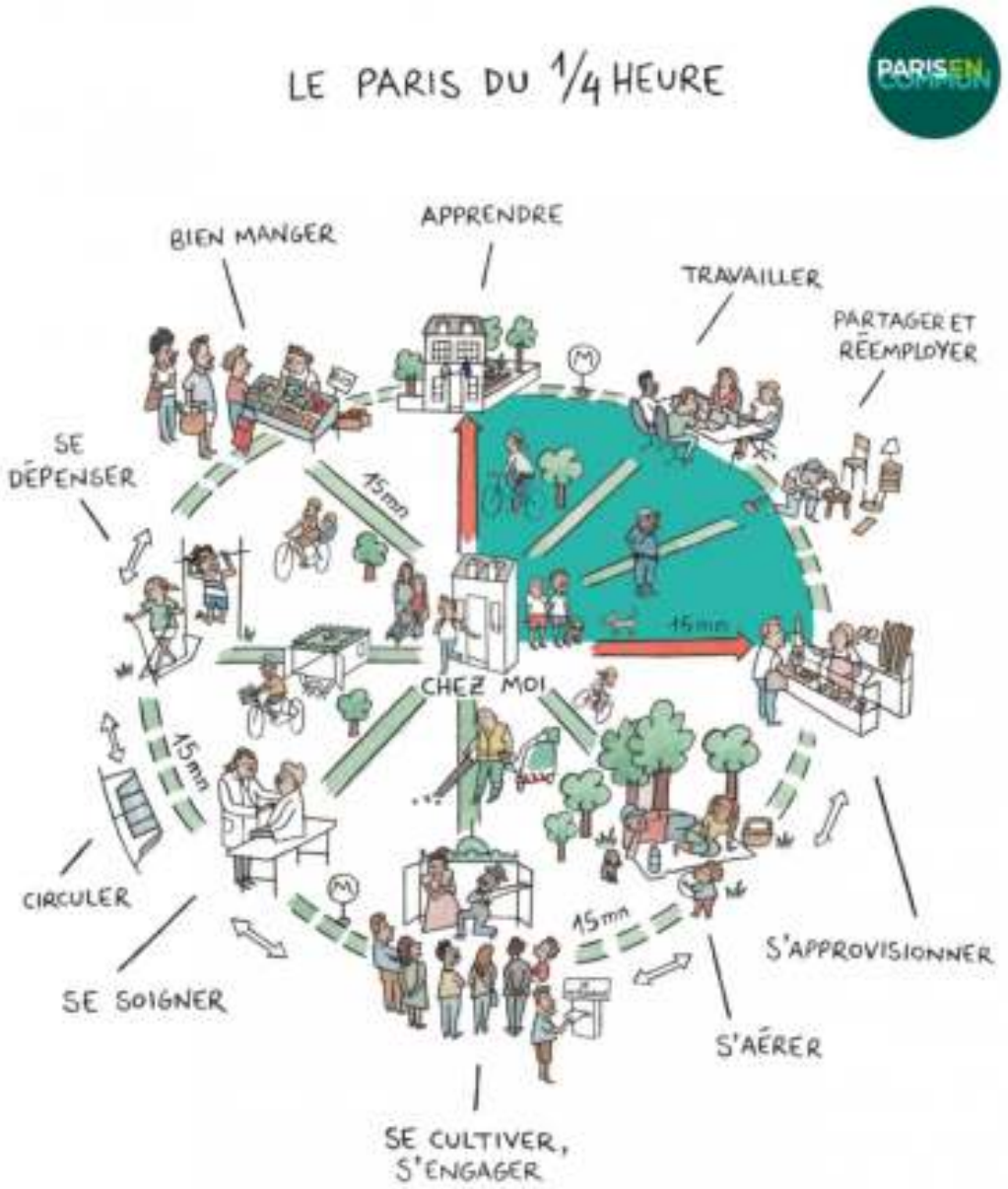


Figure: Source: Alain Bertaud.

15-minute city ?



Star-shaped city

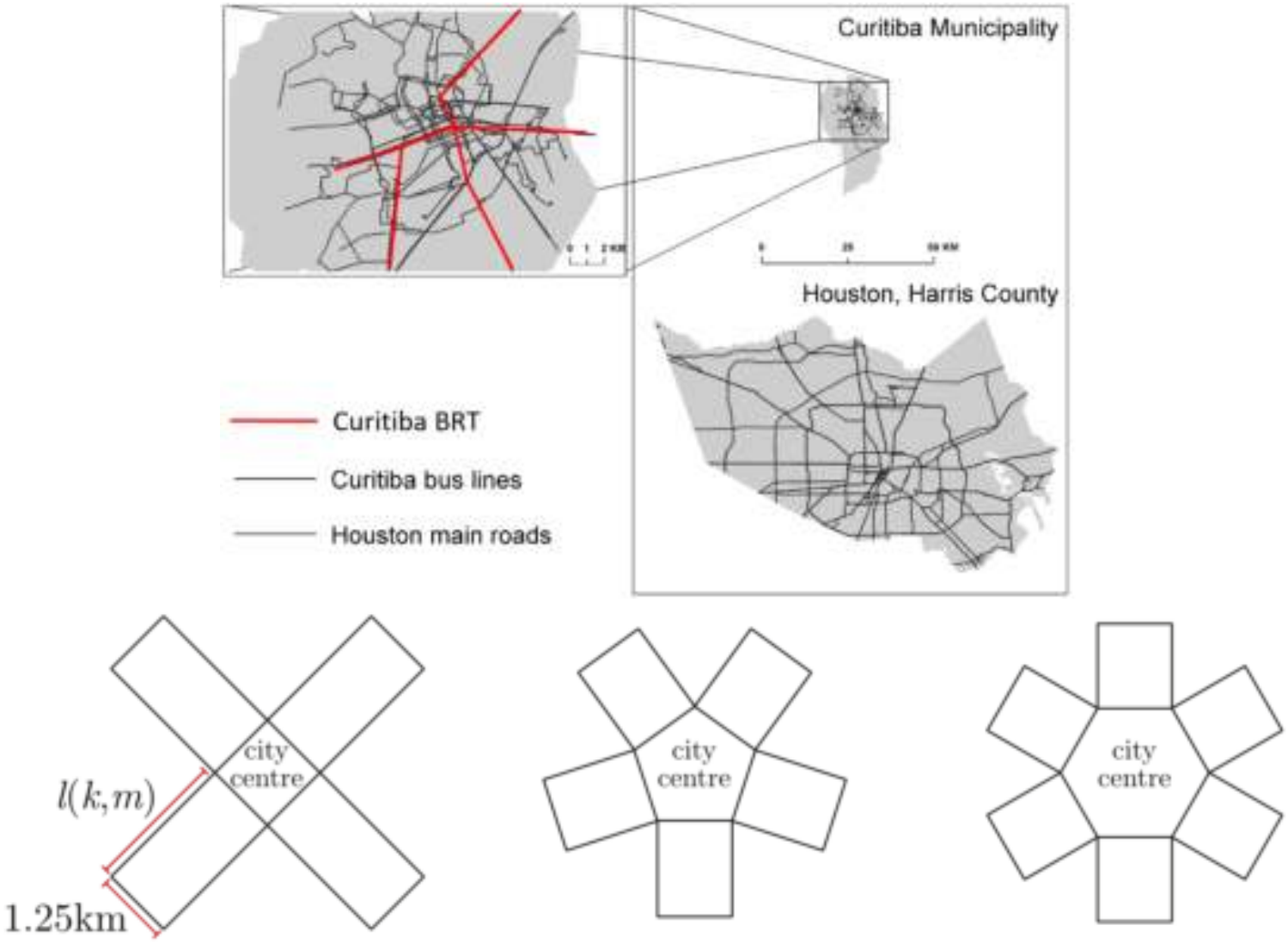


Figure: Pierer and Creutzig (2019)

Current trends (Güneralp et al., 2020)

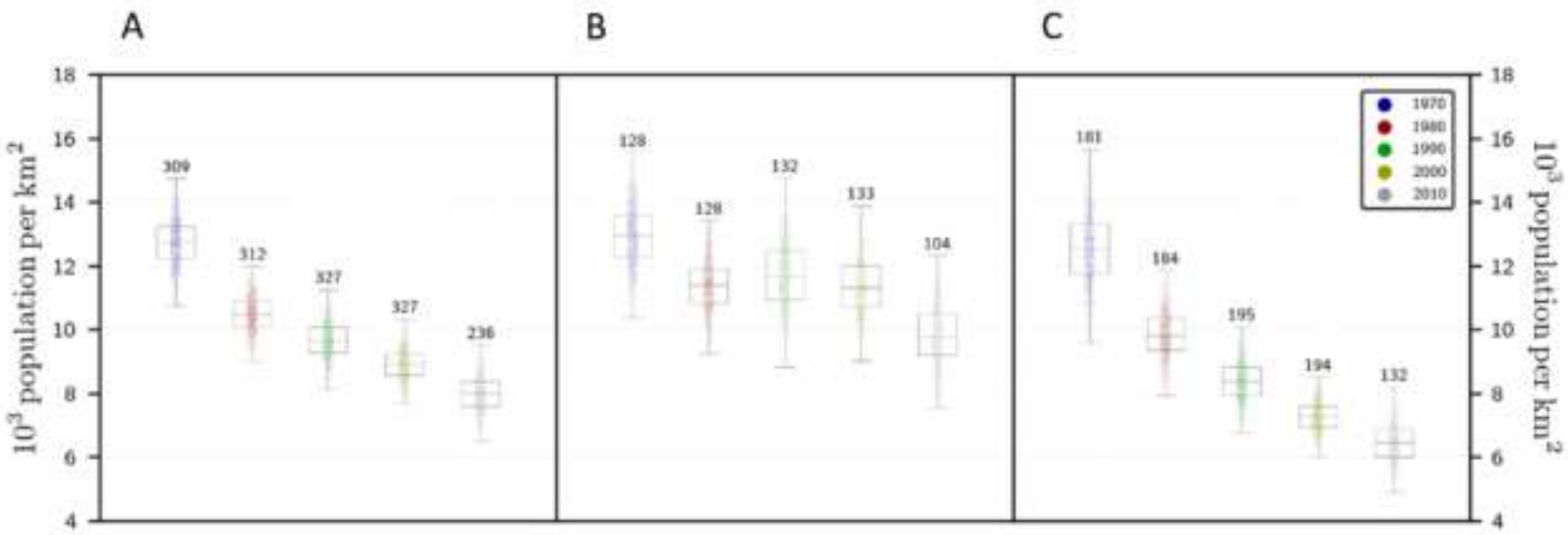
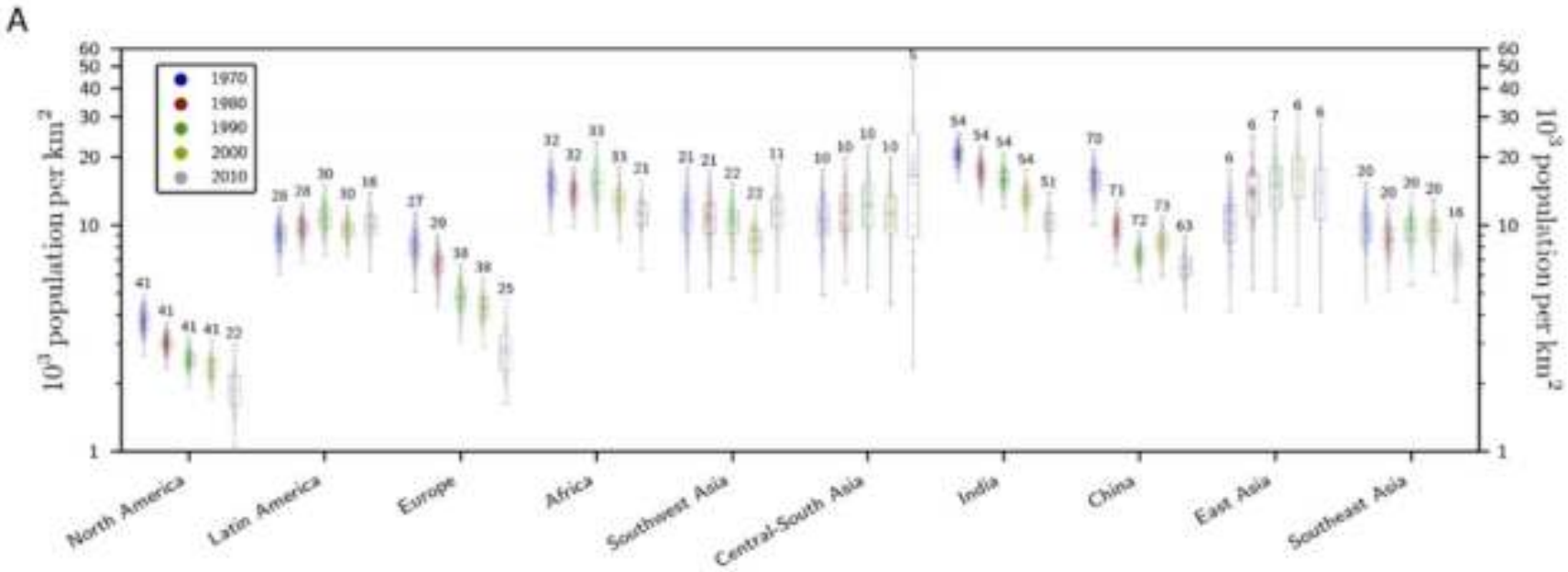


Figure: Global aggregated decadal trends in urban population density. A: Population $>$ 300 000, B: Population $>$ 2 million, C: Population $>$ 300 000 and $<$ 2 million.

Current trends (Güneralp et al., 2020)



Current trends

In practice, controlling urban sprawl is very difficult:

- It is a multidimensionnal phenomenon, hard to define and measure.
- The public and scientific debate focuses on big cities and developed countries.
- Social acceptability of anti-sprawl measures.

Conclusion of part 2

- We need to deeply rethink the way we build cities:
  - Need for ambitious actions, implemented as fast as possible to avoid carbon lock-in
  - Need for an integrated approach accounting for transportation, housing, land-use, green spaces, adaptation, and equity issues.
    - Urban plans involving a wide diversity of actors, working at different scales.
    - Policy packages.
  - There is no magic bullet.

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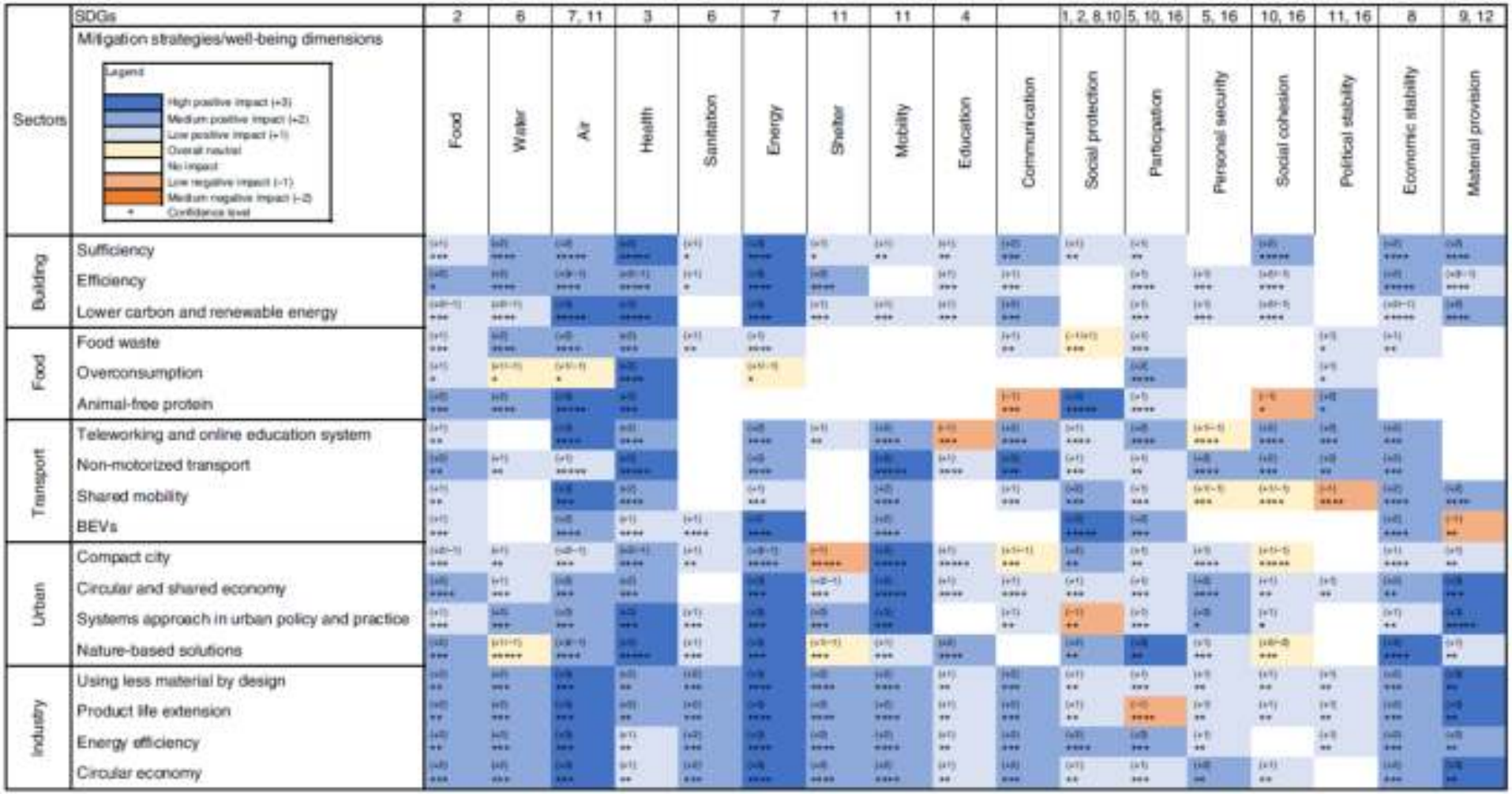
Creutzig et al. (2021)



IPCC AR6 WG3

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Demand-side solutions

- Examples of *demand-side* solutions for urban emissions mitigation:
  - **Urban planning** for denser cities: mitigation potential of 23-26% in 2050 (Creutzig et al., 2015, 2016).
  - **Modal shift** towards walking, cycling, public transport.
  - **Telecommuting**.
  - ***Shared mobility***: sharing an asset (bike, car) and use of technologies (apps,..) to put in touch supply and users.
  - **Shared appartments**.
  - **More flexibility** in the building sector: help the relocation of old people, avoid vacant land,...

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Increasing data availability

Data sources:

- From transnational municipal networks (GHG emissions, energy use,...)
- From satellite imagery (land-use data, population density, night-time lights,...)
- From collaborative approaches (transport data, amenities,...)
- From webscrapping, machine learning,...

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A few examples:

- http://openghgmap.net/
- https://viewer.esa-worldcover.org/worldcover/

Potential for large-scale urban growth modeling

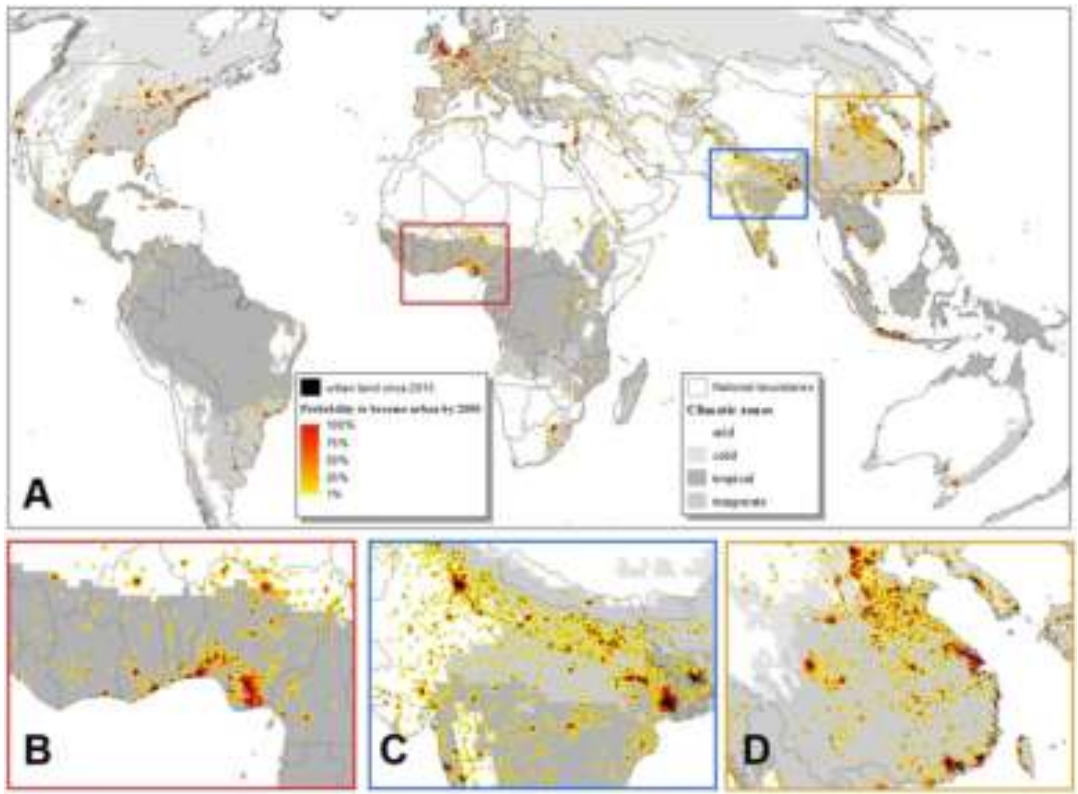

Figure: Global forecasts of probabilities of urban expoansion through 2050, under the SSP5 scenario. Source: Huang et al. (2019)

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Challenges specific to cities in developing countries

- **Fast urbanization.**
  - Per capita emissions 7 times lower in developing country cities than in developed country cities.
  - But growing rapidly: between 2000 and 2015, +22.6% in Africa, +71.7% in Asia / Pacific, +40.4% in Latin America,...
  - Transportation: increasing urbanization rates.

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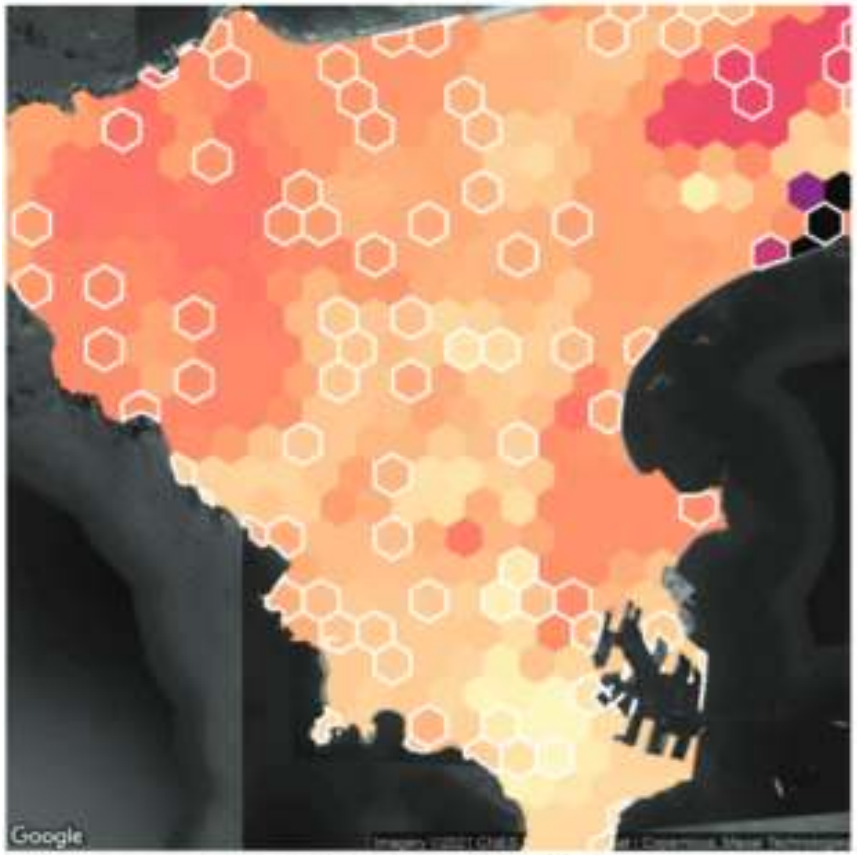
- Potential **co-benefits** of actions against global warming (strengthening political institutions).
- 23.5% of the world's urban population lives in **informal housing**:
  - Populations more exposed to climatic risks.
  - Upgrading informal housing could be an opportunity to reduce emissions.

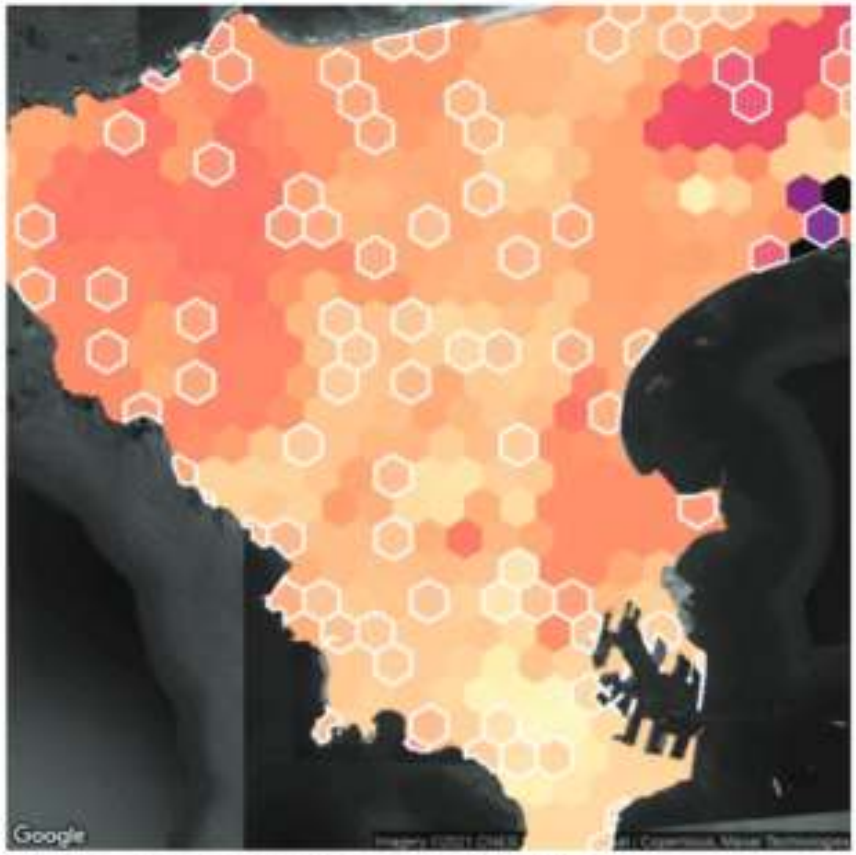
Knowledge gaps

- Literature on the emissions reduction potential of the informal sector too limited.
- There is little data on income, employment, inequality, etc. in the cities of developing countries, which does not allow for in-depth studies or modeling.

Knowledge gaps



(a) Observed employment density



(b) Predicted employment density

Figure: Dakar. Barzin et al. (2021)