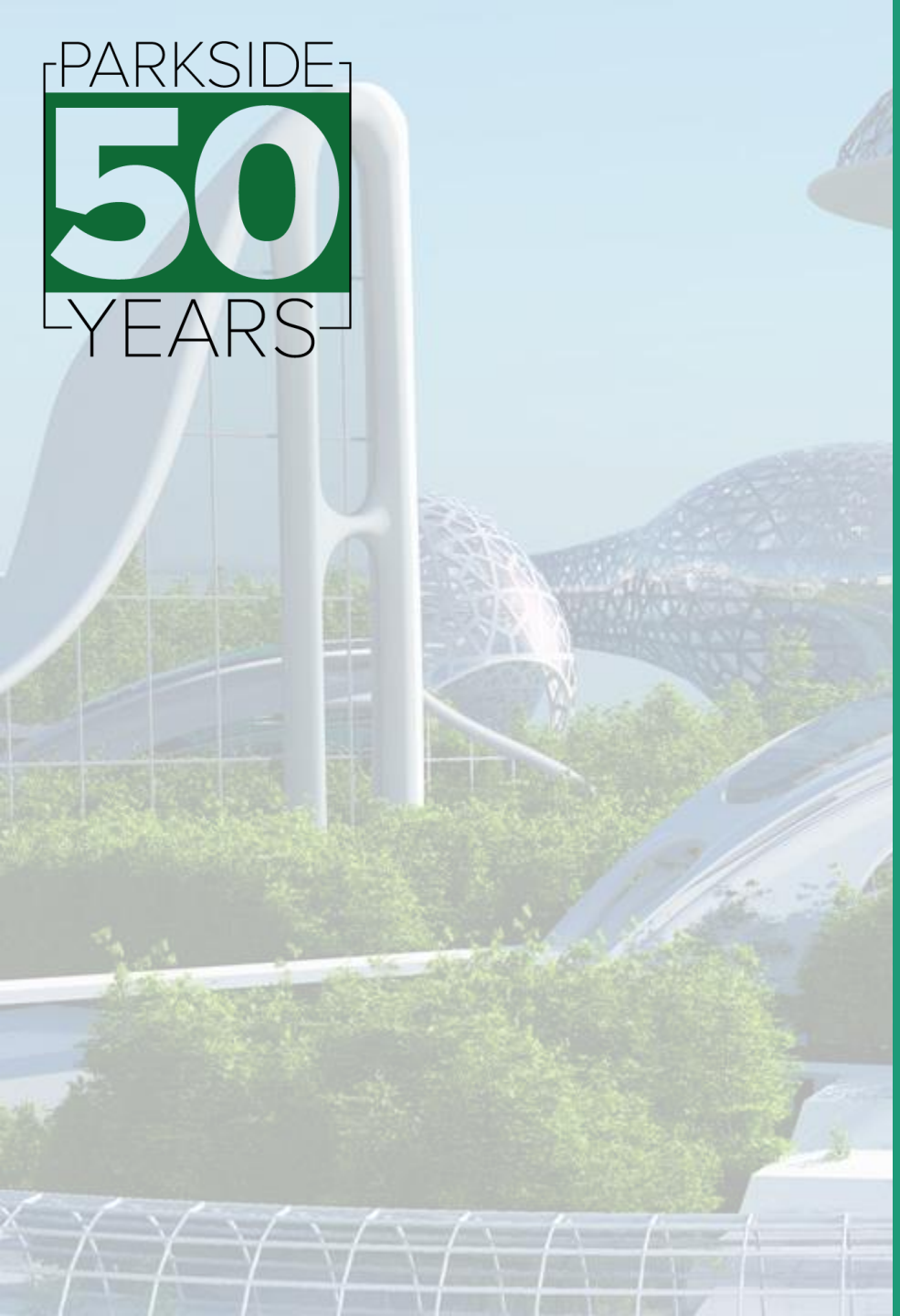

It’s not easy being green: Environmental challenges and smart cities

3 October 2018

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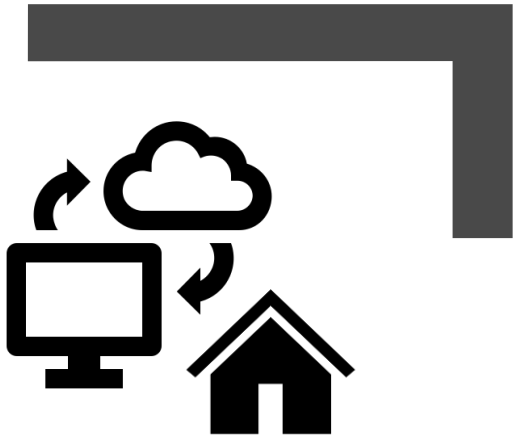
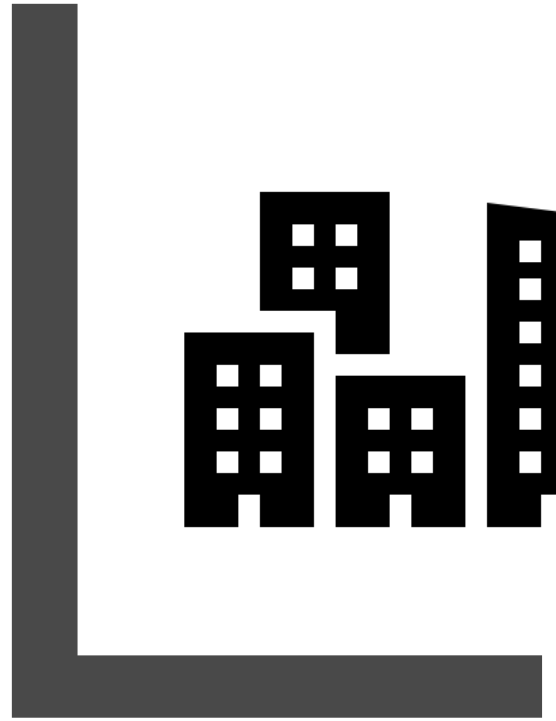


Environmental Challenges and Smart Cities

- Sustainability & Sustainable Development
- Carbon Footprints and Greenhouse Gases
- Urban Development
- Smart Cities & the Environment



Sustainability

The ability to meet humanity's current needs without compromising the ability of future generations to meet their needs

Sustainable Development

Economic growth that meets the needs of the present without compromising the ability of future generations to meet their needs

- Must meet the needs of the poor
- Can only occur within the limits of the environment

How can we measure sustainability?

Footprints of ecologic impacts: how much of a natural resource is used (or pollutant produced) in the production of goods, services, and transportation of a person or groups of people

- Carbon: CO_2 emissions
- Water: Amount of water
- **Ecological:** The amount of land, fresh water, and ocean

Competing Interests in Sustainability

Ecological Footprint

The amount of land, fresh water, and ocean required on a continuous basis to supply a person with food, wood, energy, water, housing, clothing, transportation, and waste disposal.

Biocapacity

"The capacity of ecosystems to regenerate what people demand from those surfaces."

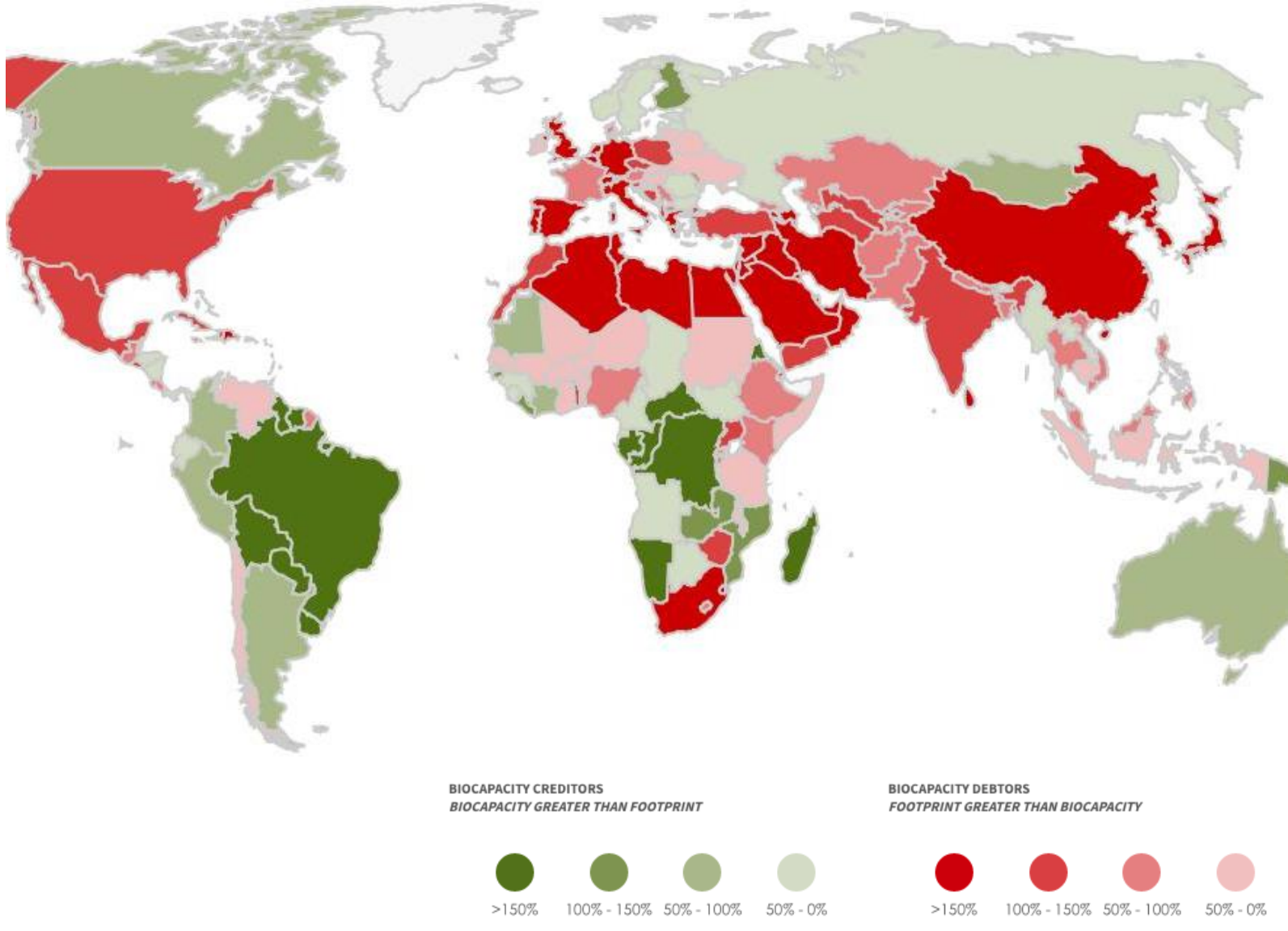
-www.footprintnetwork.org

The productivity of lands' ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land)

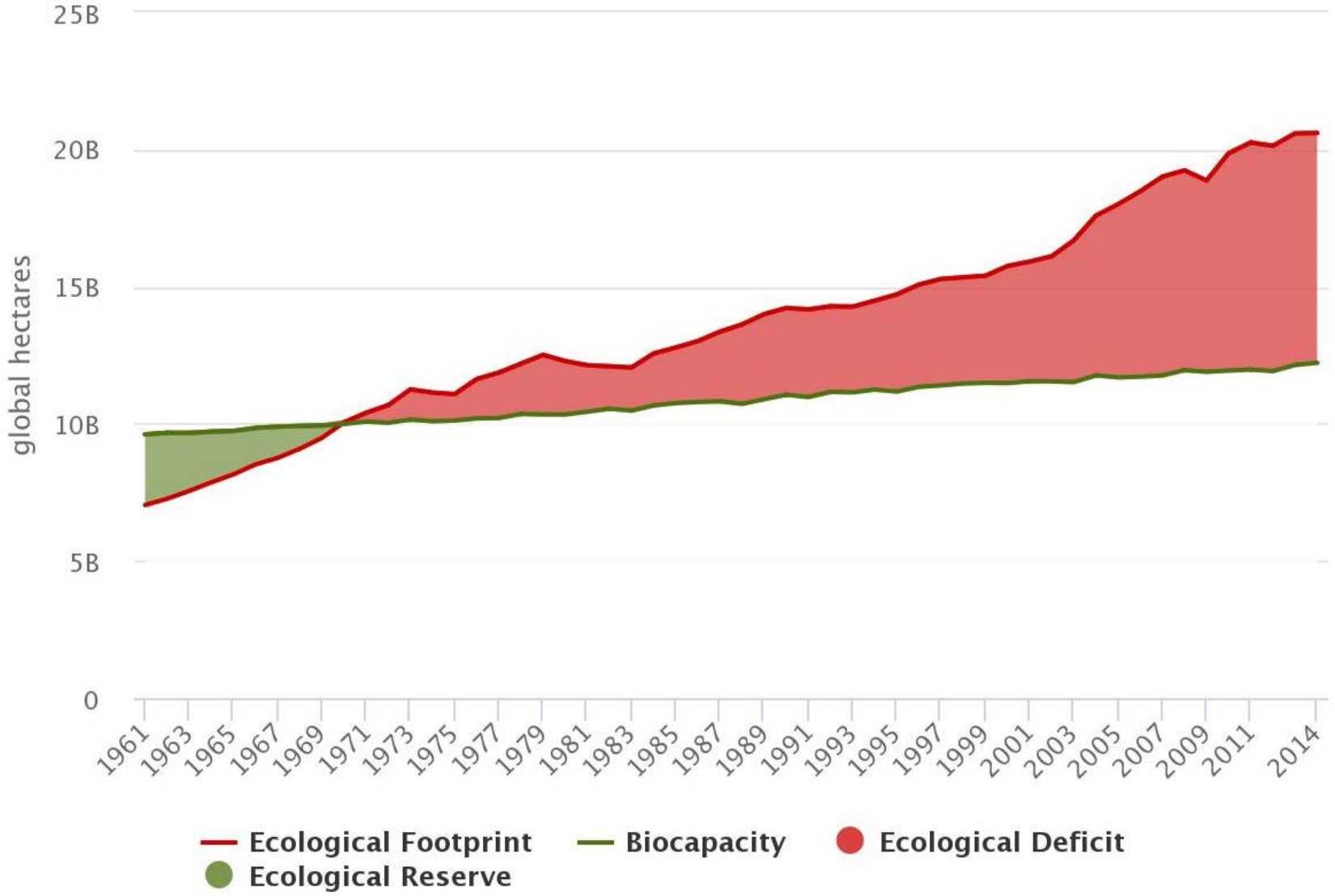
Why is sustainable development important?

The world cannot sustain everyone at the levels of consumption of the US, Europe, and Japan.

Economic disparity and access to natural resources is a big problem.



Global Ecological Footprint

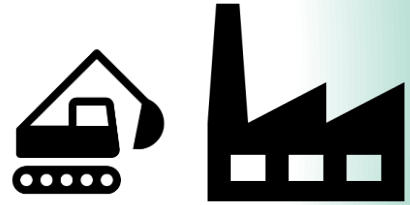


Global Footprint Network, 2018 National Footprint Accounts

Carbon Footprints & Carbon Dioxide

Carbon footprint: CO_2 produced in the production of goods, services, and transportation of a person or groups of people

Manufacturing, energy production (non-renewable and non-nuclear), and transportation are common sources of CO_2.



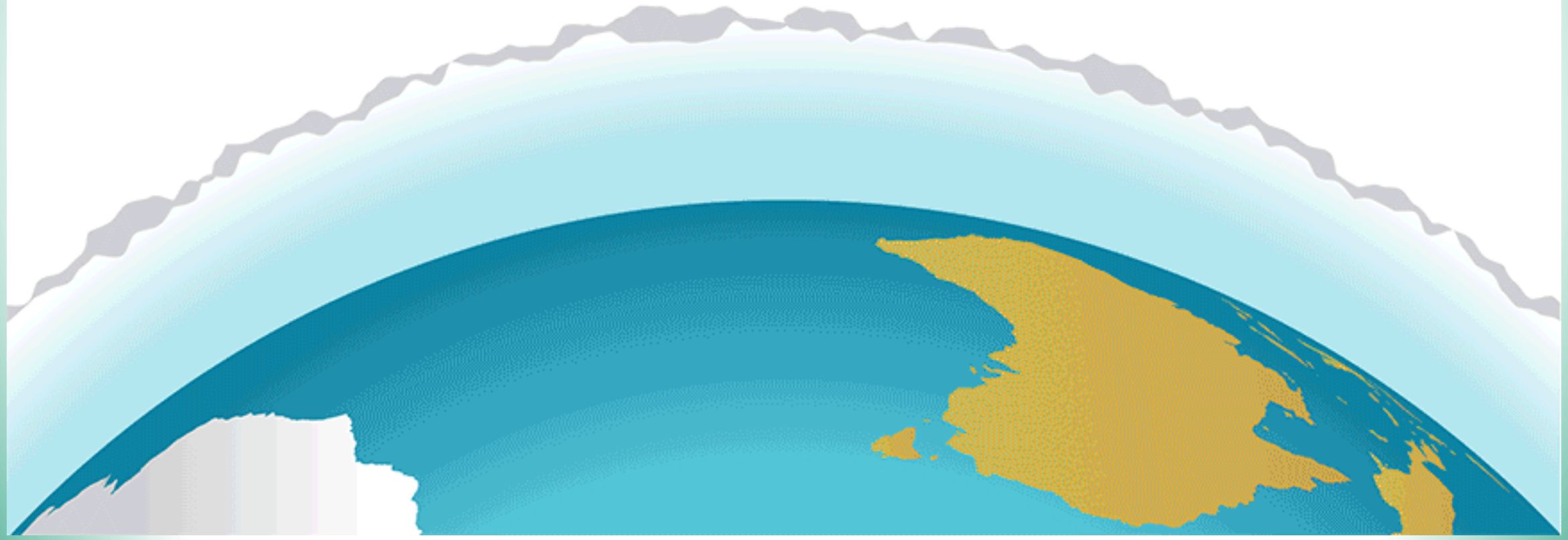
CO_2 is commonly produced in combustion processes (i.e., when things are burned).

It can also be emitted from cement production, respiration (breathing), and certain geologic processes.



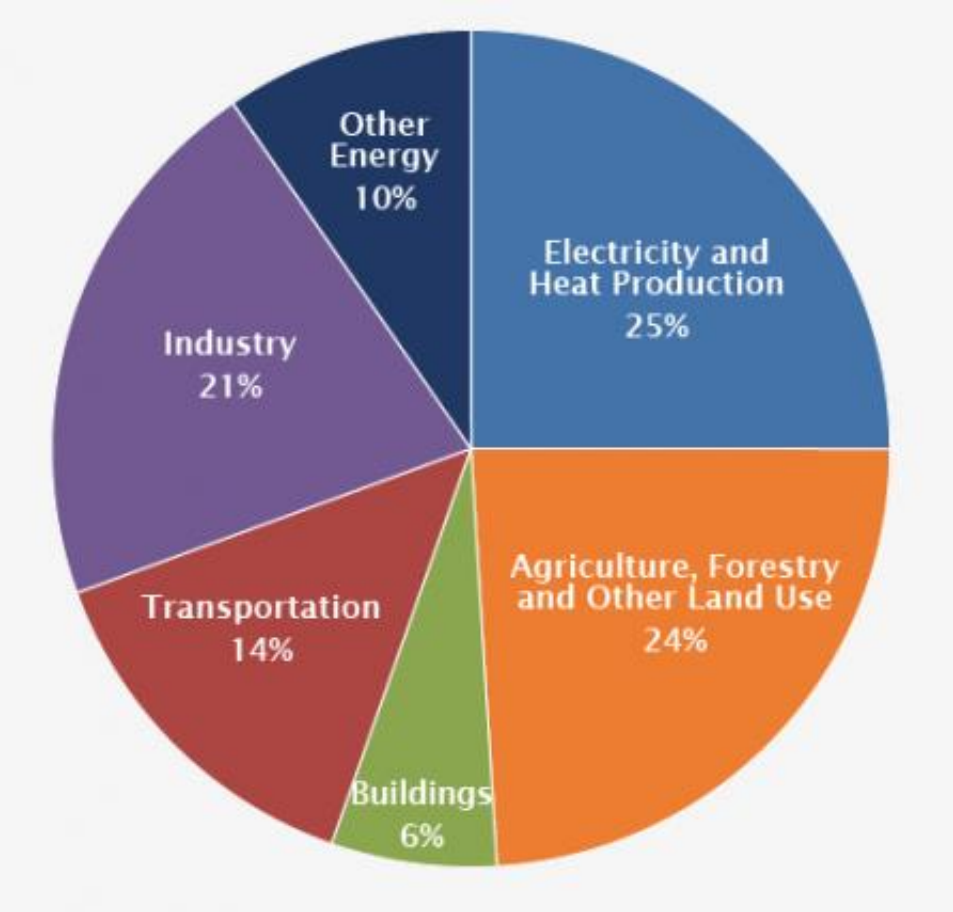



Greenhouse Effect



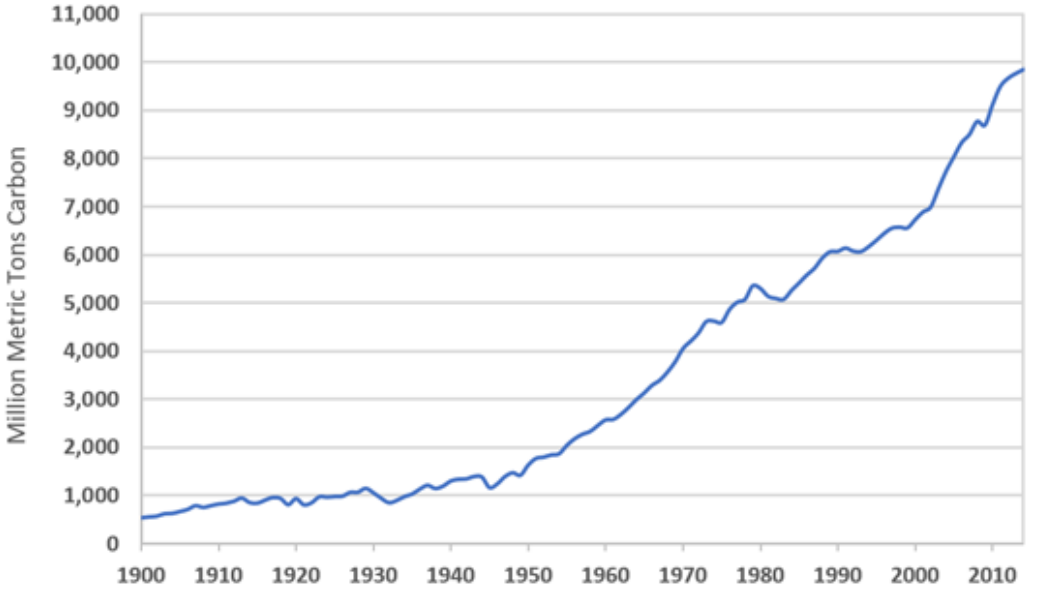
Australian Government Department of the Environment and Energy

Global Greenhouse Gas Emissions



2014 IPCC

Global Atmospheric Carbon Dioxide Emissions



Boden, T.A., Marland, G., and Andres, R.J. (2017). Global, Regional, and National Fossil-Fuel CO2Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

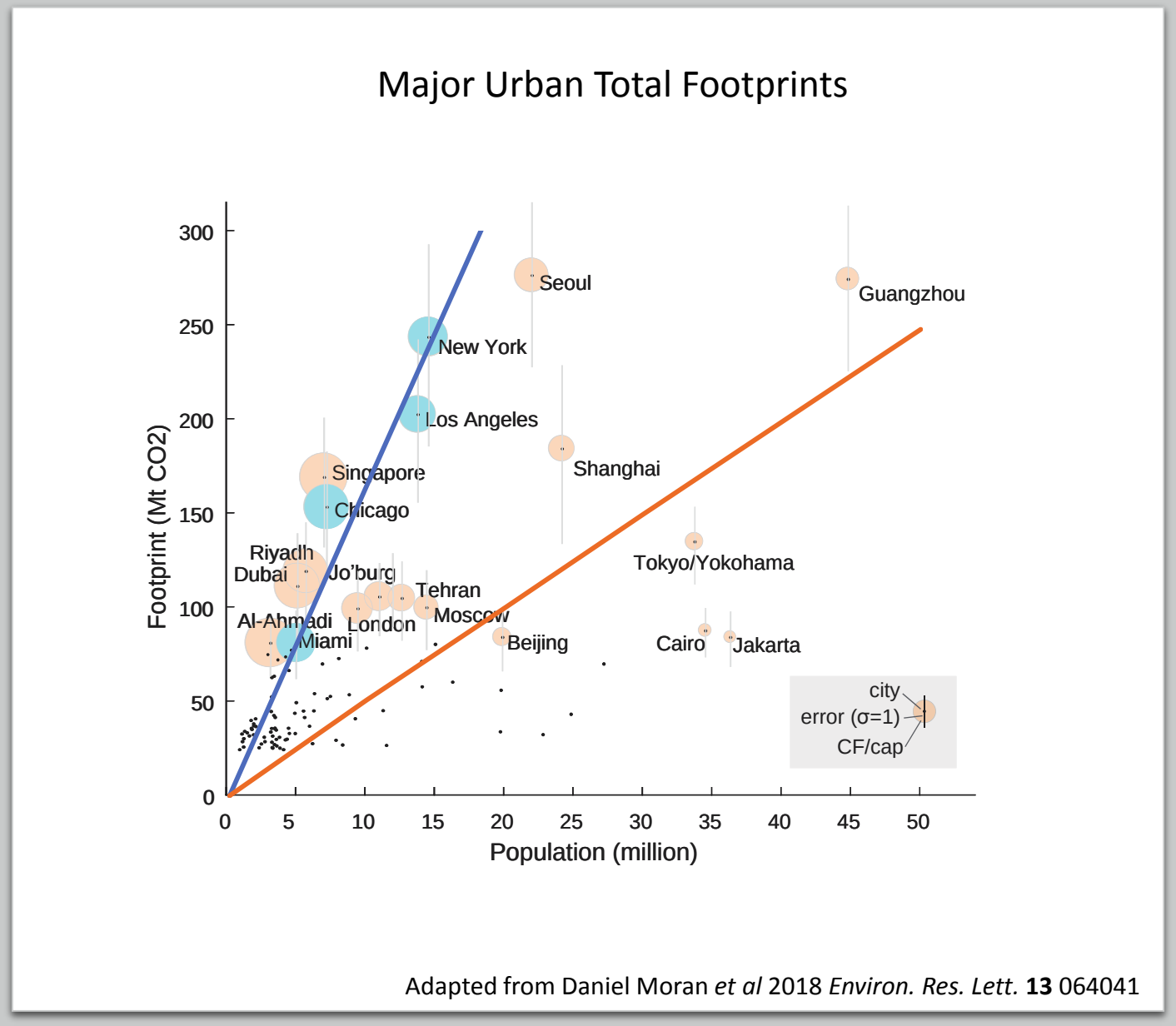
Carbon Footprints: Urban

As a region, urban areas have large carbon footprints due to the large populations, manufacturing, and energy needs/production.

Blue line: US per capita carbon footprint (16.5 metric tons)

Red line: Global per capita carbon footprint (4.97 metric tons)

2014 World Bank Data



Adapted from Daniel Moran *et al* 2018 *Environ. Res. Lett.* **13** 064041

Carbon Footprints: Urban versus Rural

Lower Carbon Outputs for Urban

- Mass transportation and better infrastructure for walking/biking.
- Central hub for transportation of goods and products.
- Denser housing can be more energy efficient (apartment versus single-family house).

Higher Carbon Outputs for Rural

- Higher socio-economic status of urbanites leads to more energy consumption overall.
- Housing might not be built as efficiently (older, cheaper, etc.)
- Farther away from food sources and other products (longer transport)

Evidence: Urban versus Rural

A 2009 study of 11 cities showed that

- Londoners had 1/2 the greenhouse gas (GHG) emissions of UK average.
- New Yorkers had <1/3 the GHG emission of US average.
- Most cities had lower per capita emissions than the country average.

A 2011 study of global cities shows high variability

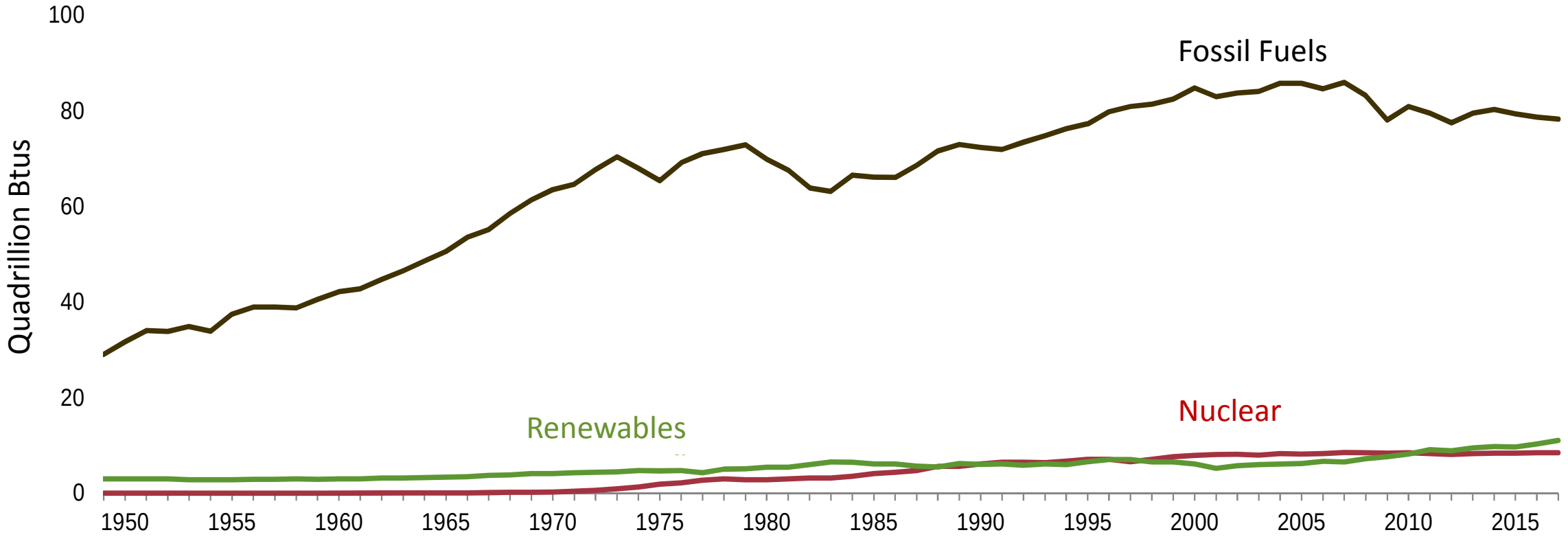
- Denver has substantially higher per capita GHG emissions than NY.
- Suburbs tend to have substantially higher per capita GHG emissions than urban and rural areas.
- Cities in poorer countries can have significantly high per capita GHG emissions.

tldr; Urban areas tend to have small per capita but large overall carbon footprints.

Are Smart Cities the environmental solution?

- Energy usage and grid
  - Global renewable versus non-renewable use
  - Energy use
  - Carbon neutrality
  - Smart technology and efficiency
- Sustainable development
  - Other ecological challenges
  - Environmental equity and justice

Current Global Energy Production Sources

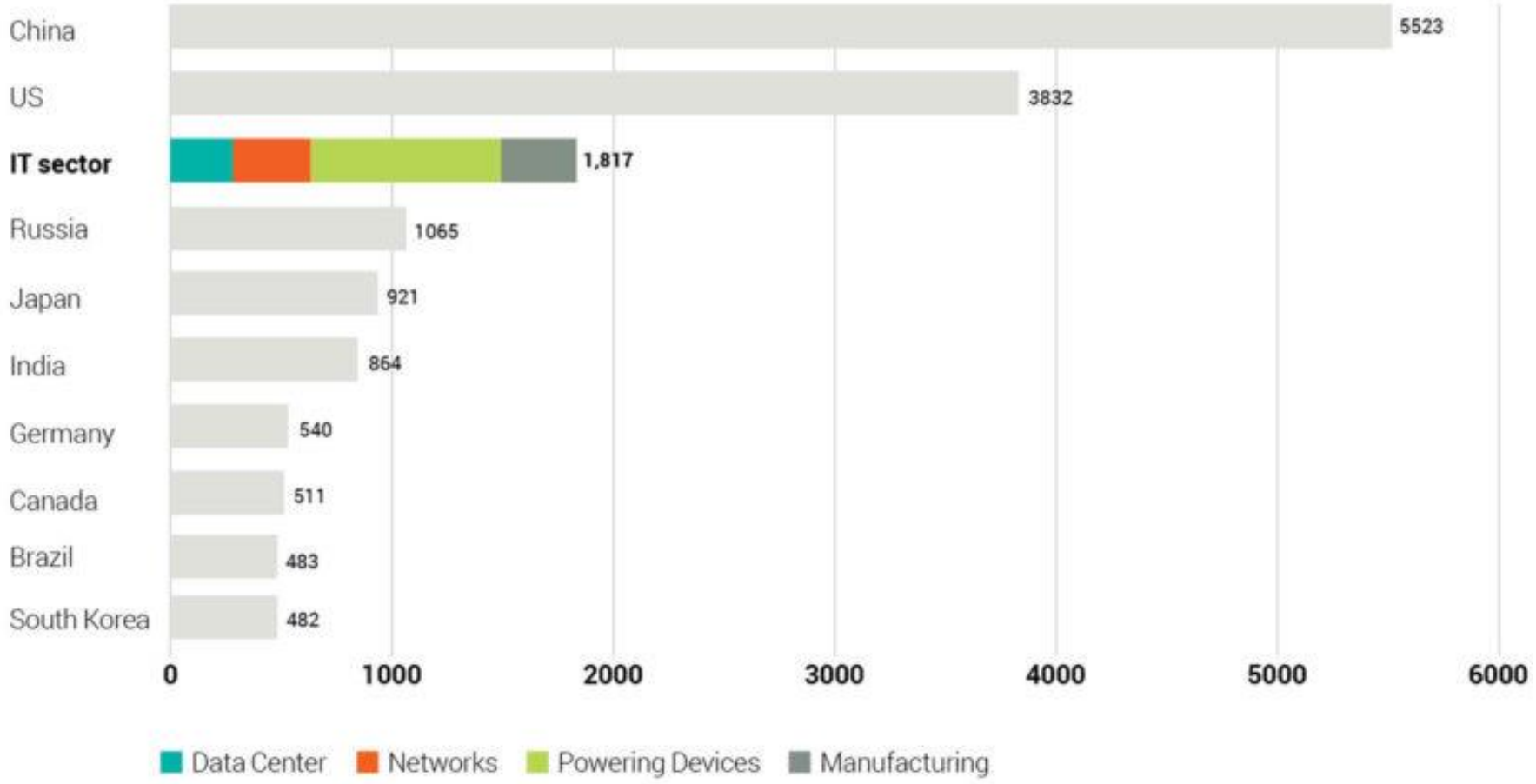


US EIA

Smart City Energy Use

- Construction and remodeling
- Transportation and shipping
- Climate control
- Industrial Usage
- Data centers and technological services
- …

Data Center Energy Consumption



(billion kilowatt-hours) 2012 Greenpeace

Smart Technologies & Energy Savings

Residential end use	% total energy consumption	% energy saved with smart technology*	Estimated savings as % of total energy use
Space heating	25.8%	29.3%[a]	7.6%
Space cooling	10.8%	33.7%[b]	3.7%
Water heating	13.2%	15.0%	2.0%
Dishwashers	1.4%	7.0%	0.1%
Refrigerators and freezers	6.1%	3.0%	0.2%

Residential end use	% total energy consumption	% energy saved with smart technology*	Estimated savings as % of total energy use
Clothes washers and dryers	3.7%	5.5%	0.2%
TVs, computers, and related equipment	5.6%	37.5%	2.1%
Lighting	6.4%	17.0%	1.1%
Total	73.0%		17.0%

Integrating smart technology into a city's infrastructure could significantly lead to lower electrical usage for basic needs.

In turn, this could contribute to lower emissions.

American Council for an Energy-Efficient Economy

Developing a carbon neutral grid

- Carbon neutrality can be obtained by a combination of non-emitting technologies, conventional sources, and additional carbon sinks.
- Ideally, renewable and localized sources are used.

- Can this work?
  - Masdar City, Abu Dhabi was originally planned to be carbon neutral with its own grid but has since been connected to the conventional grid.
  - However, renewable technology (solar and wind, in particular) are becoming more efficient and cheaper overall.
  - Nuclear is another non-emitting option.

Environmental Equity & Justice

- Are certain groups being disposed or displaced?
  - Farmers opposed Dholera, India because of land loss. (The Guardian)
- Can everyone have access to smart city functions and technology?
- Can everyone use and participate in smart city functions?

US household internet subscriptions

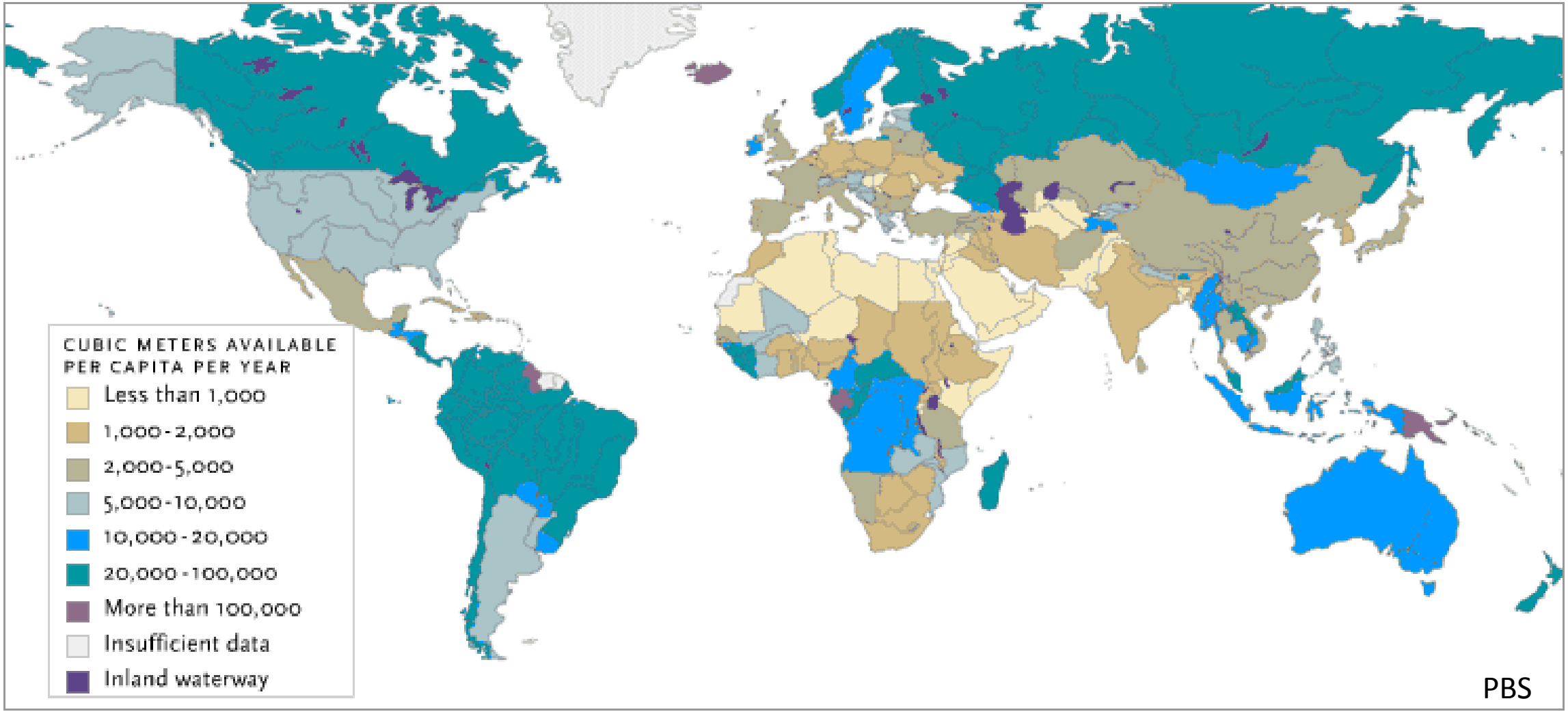
Adapted from ACEEE and 2017 Census

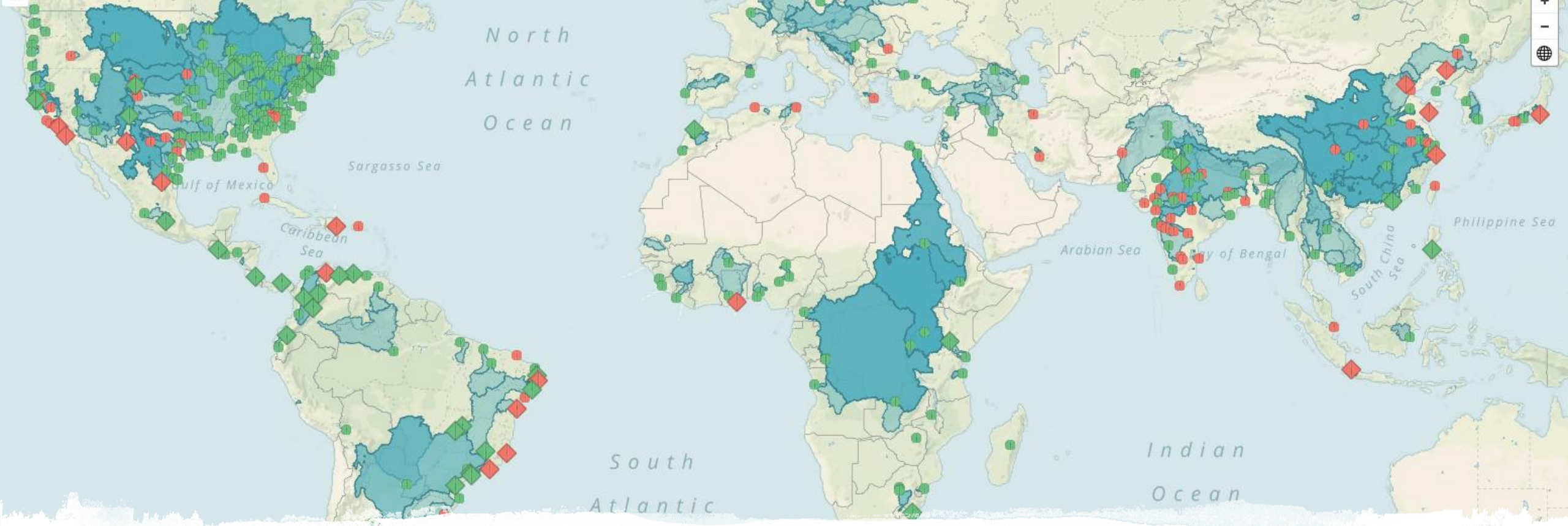
Other Smart City Ecological Challenges

- Air and water pollution due to leaks or problems in industrial and residential systems
  - Smart technology has the capability to better monitor for spills or leaks and divert away from problem areas. Who might be exposed to problems?
- Waste disposal (sewage, municipal trash, etc.)
  - Not all materials can be recycled. What happens to this waste?
  - Waste disposal needs space. Where does it go and who is in proximity?
- Hazardous waste
  - Many forms of advanced electronics contains metals and other materials that are highly toxic and need special disposal or recycling. Who takes care of this? Where does it go?
  - If nuclear is part of an energy solution, nuclear waste needs to be dealt with. Where would a plant go? Who would be impacted? Disaster response?

Global Water

- Less then 3% of the world's water is fresh.
- Global freshwater is not uniformly distributed.





Global Water Stresses

All dots show modern, major cites. Blue areas show major watershed that currently are used by urban areas. Red areas are regions where the surface water withdrawn for use is a significant portion of the available water.

Nature Conservancy

Smart Cities & Water Resources

- Historically, many cities have been built up around freshwater sources and waterways.
- If new smart cities are built in regions with little freshwater resources, it needs to come from somewhere.

How would this work?

- Masdar had a pilot project on desalination (removing salt from salt water), which is very energy intensive.
- Pilot was successful in desalinating using renewables.

Smart Cities & Environmental Challenges

- As technology currently stands, smart cities should have lower carbon footprints:
  - Smart technology is more efficient.
  - Dense cities typically have lower carbon footprints.
- However, smart cities might not be particularly more efficient:
  - New construction produces emissions from energy usage, manufacturing, and cement production.
  - Data center energy usage might not be completely accounted for.
- To actually fulfill the mandate of sustainable design and be truly carbon-neutral, smart cities will need to incorporate:
  - Carbon neutral consumer and data center electrical production grids
  - Addressing access and equity issues w/r/t technologies.