



Introduction to Physics & Architecture

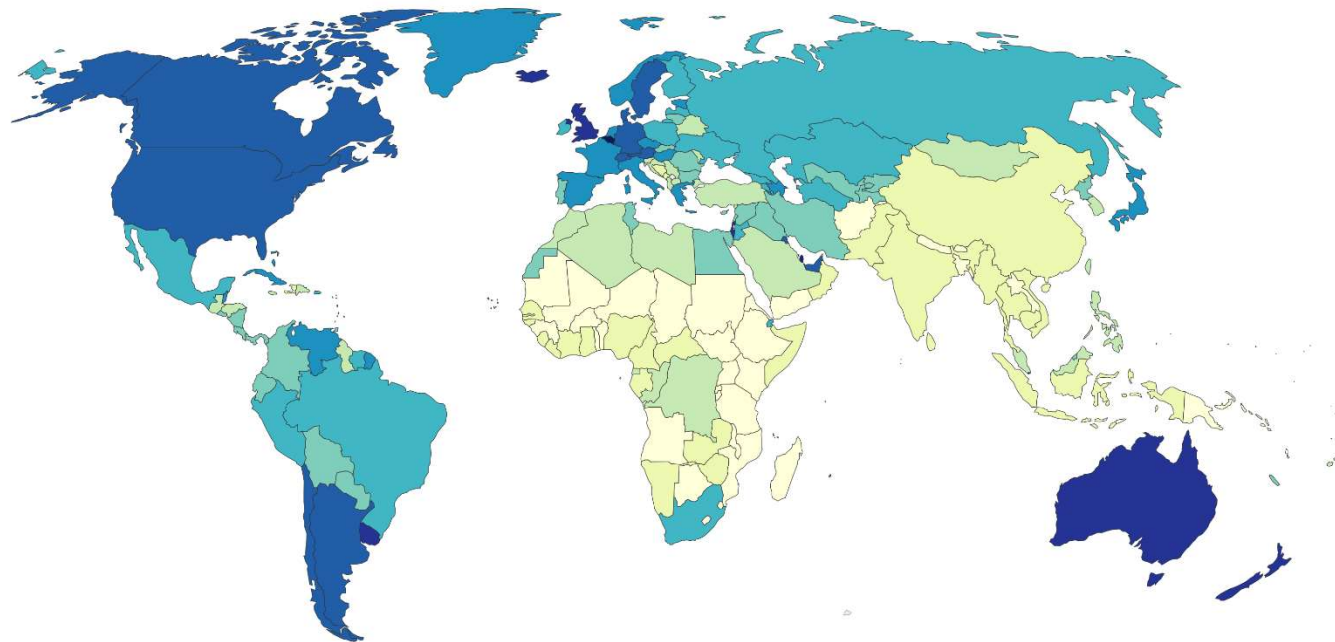
Magistère de Physique Fondamentale
Université Paris-Saclay
2019-2020

An increasing urban population

Share of the population living in urban areas, 1955

Share of the total population living in urban areas, with UN urbanization projections to 2050.

Our World
in Data



Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

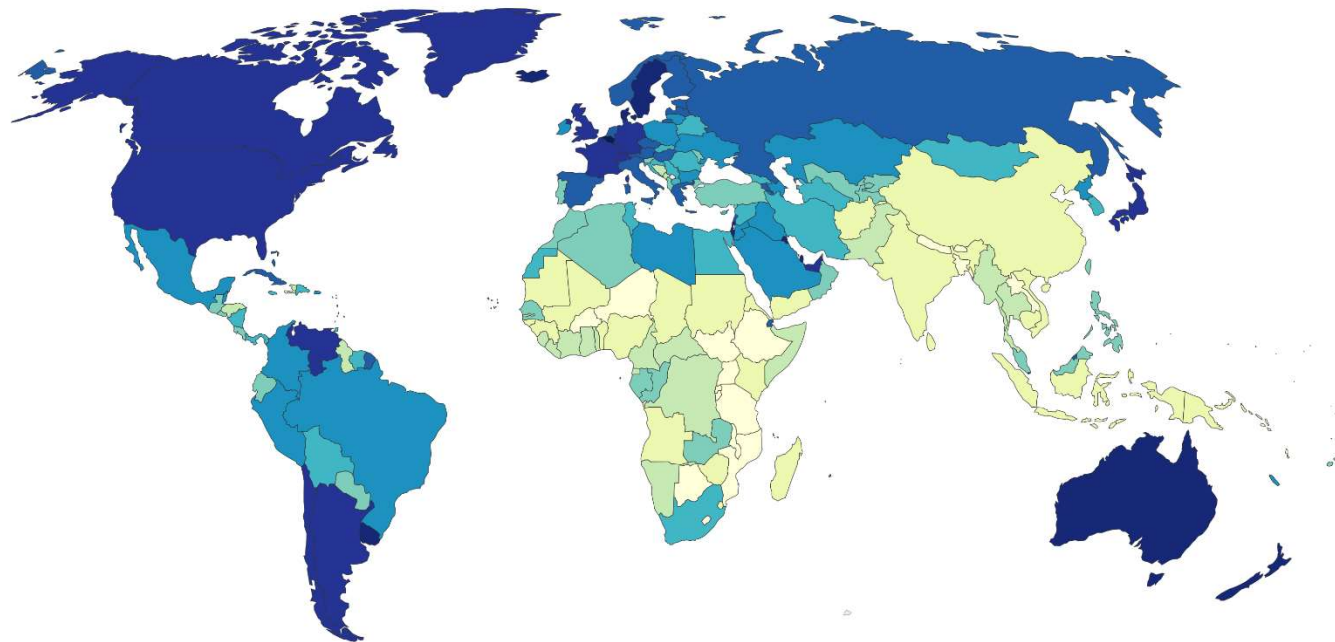
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An increasing urban population

Share of the population living in urban areas, 1971

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

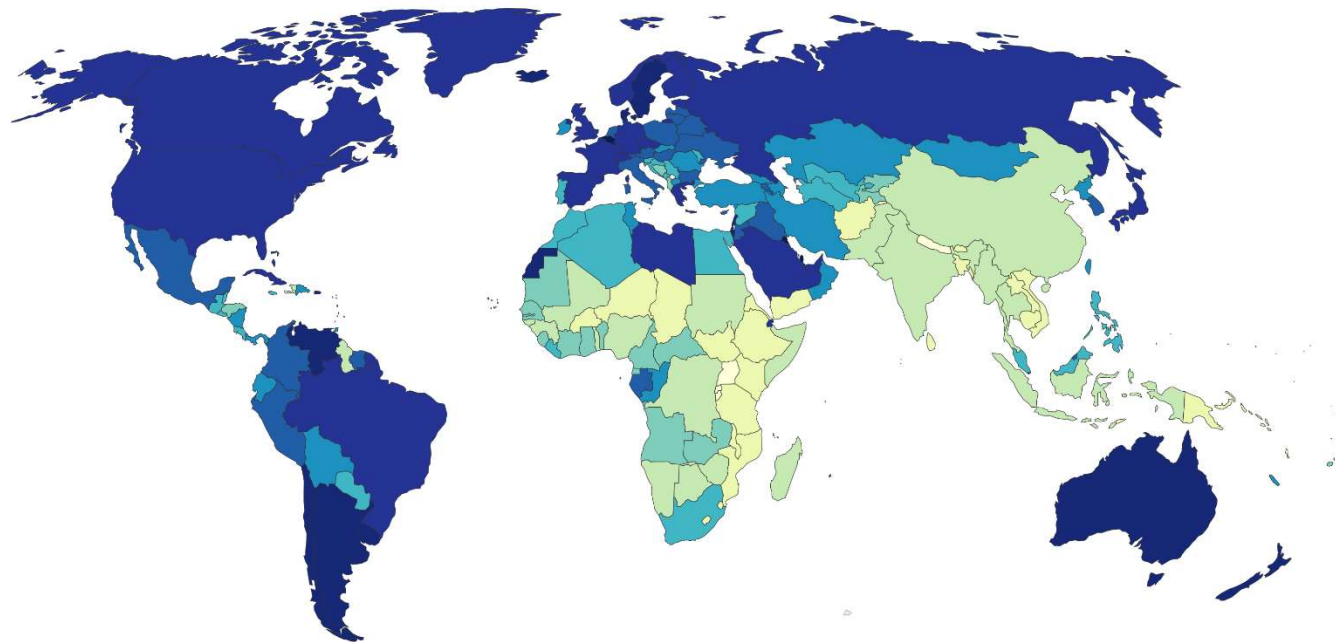
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An increasing urban population

Share of the population living in urban areas, 1986

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

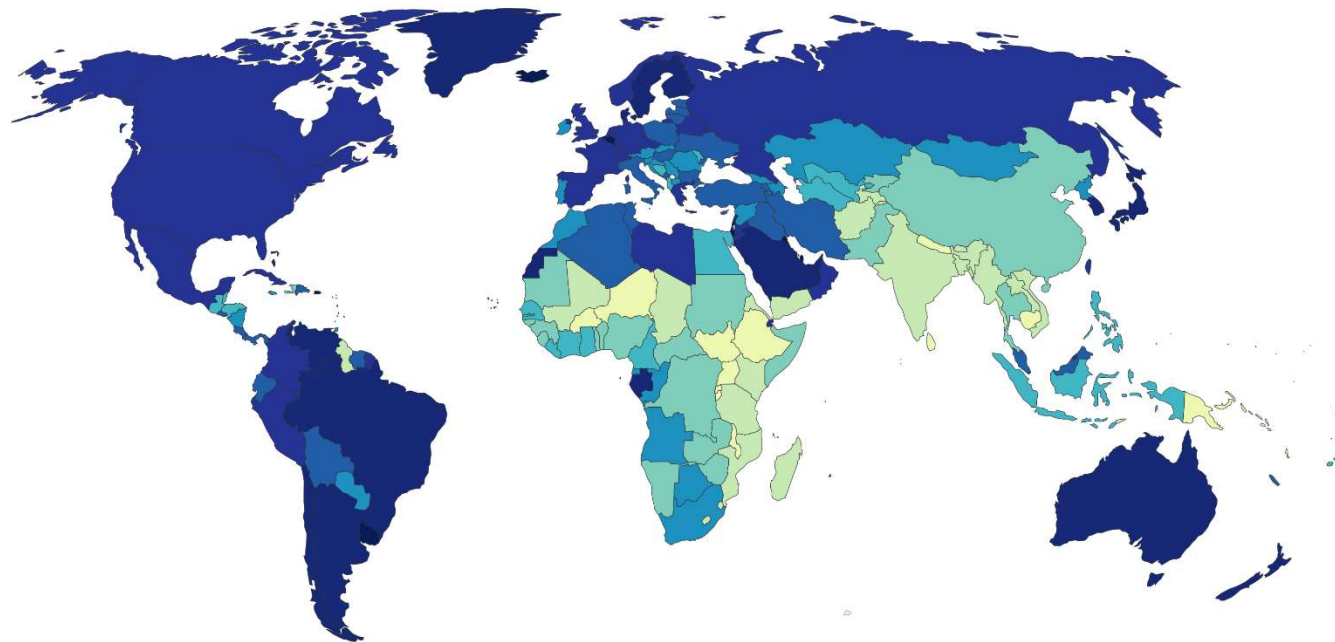
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An increasing urban population

Share of the population living in urban areas, 2002

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

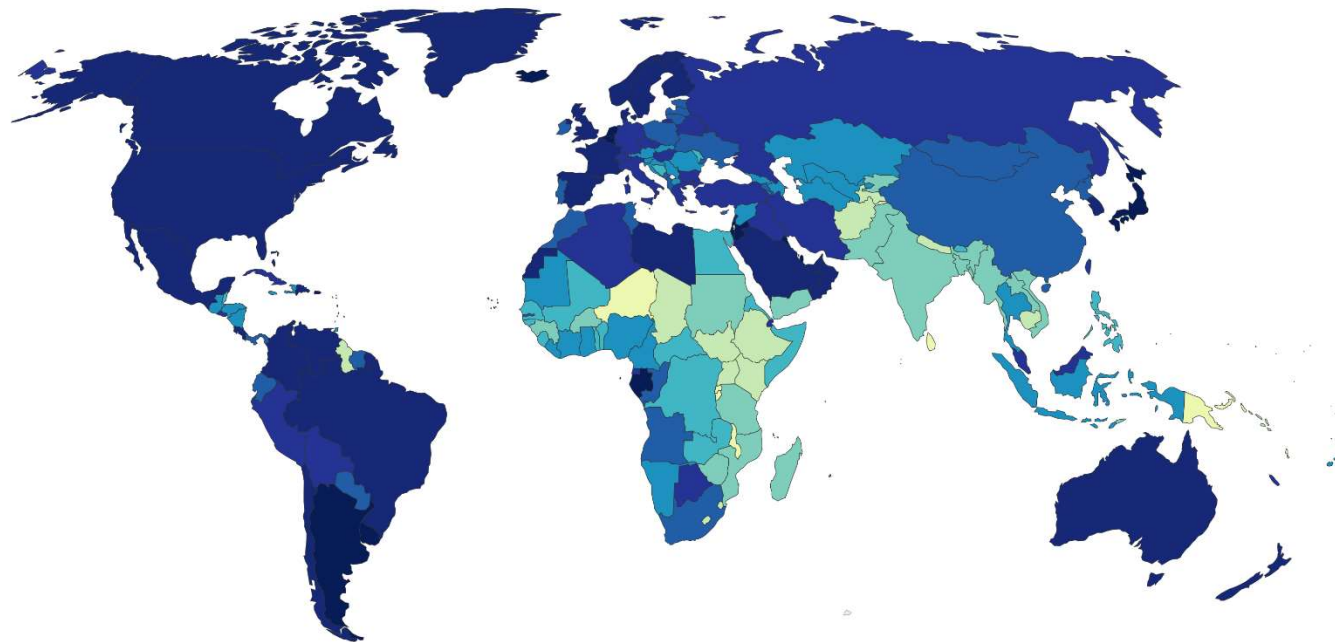
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An increasing urban population

Share of the population living in urban areas, 2020

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

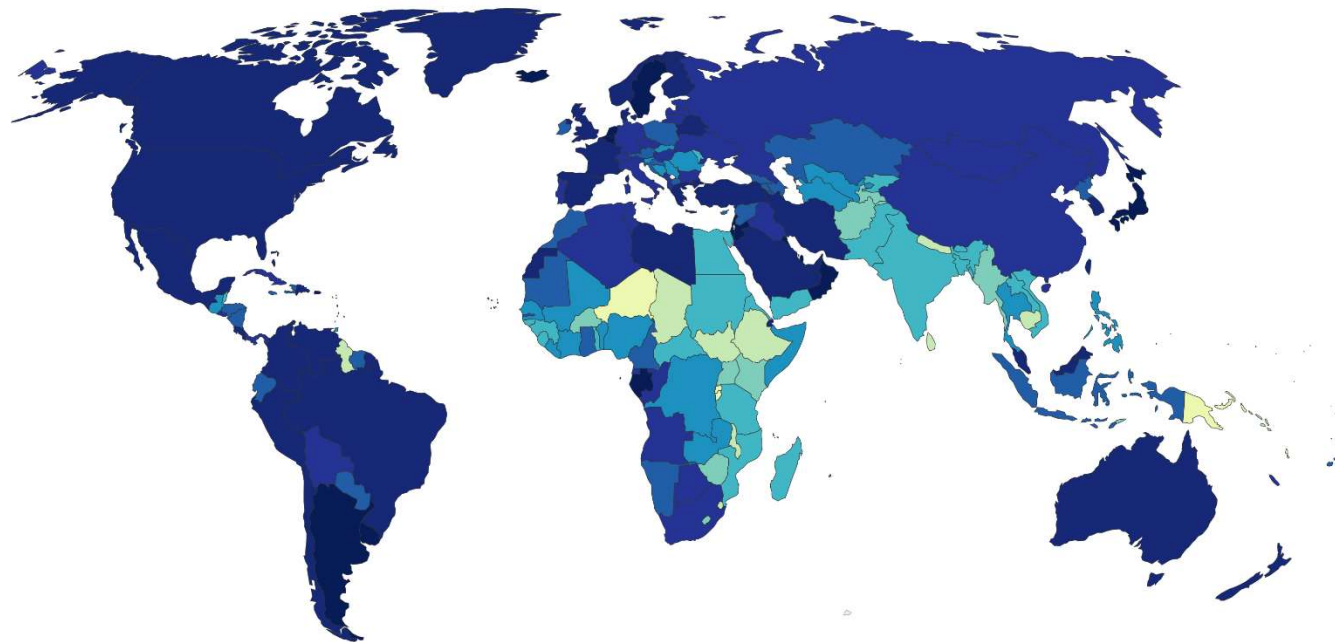
Note: Urban areas are defined based on national definitions which can vary by country.

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An increasing urban population

Share of the population living in urban areas, 2031

Share of the total population living in urban areas, with UN urbanization projections to 2050.



Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

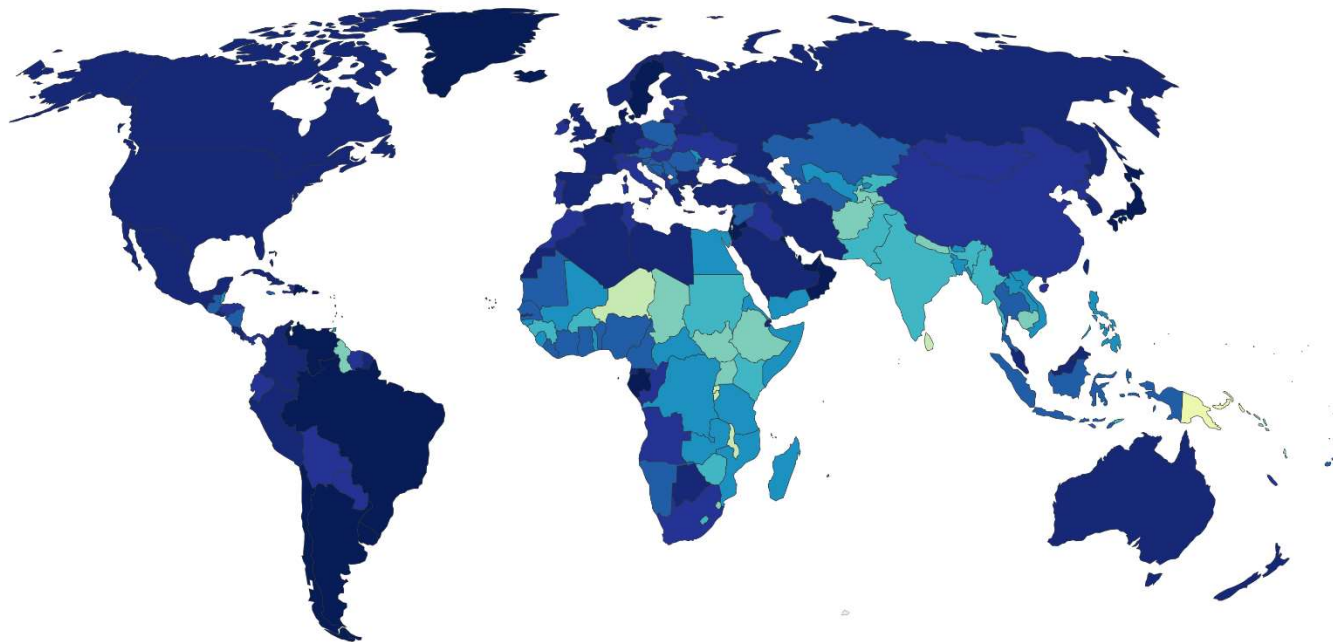
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An increasing urban population

Share of the population living in urban areas, 2042

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

Note: Urban areas are defined based on national definitions which can vary by country.

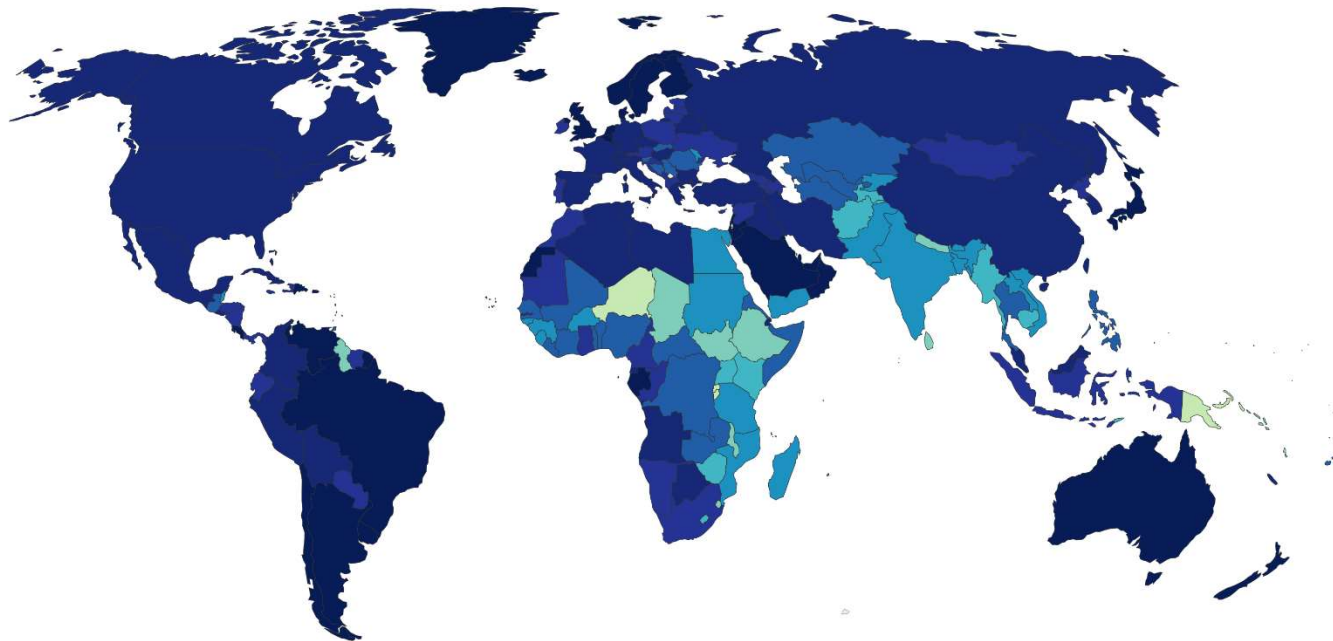
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An increasing urban population

Share of the population living in urban areas, 2050

Share of the total population living in urban areas, with UN urbanization projections to 2050.

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No data 0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)

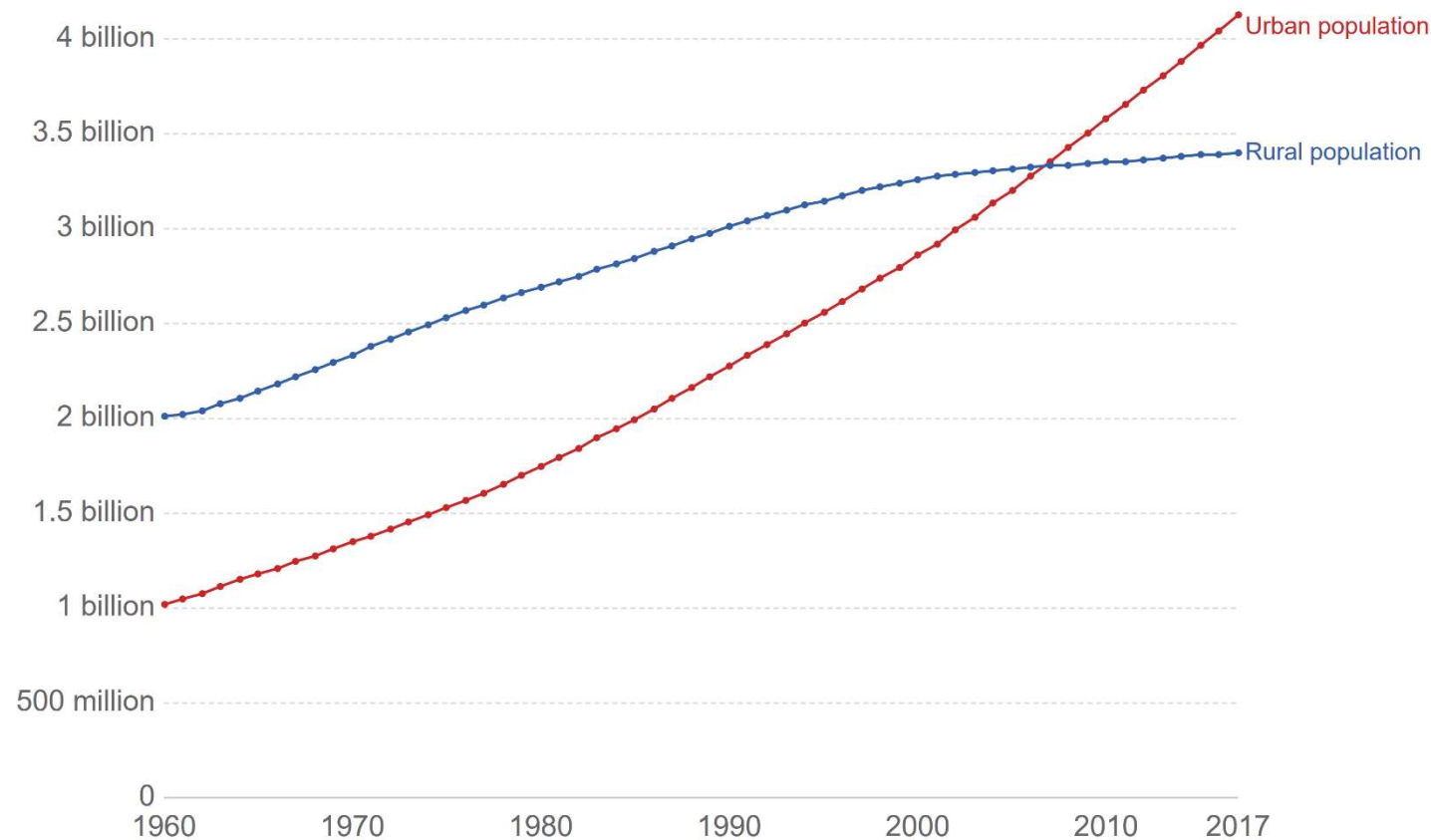
Note: Urban areas are defined based on national definitions which can vary by country.

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Urban population > rural population since 2007

Number of people living in urban and rural areas, World

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Source: UN World Urbanization Prospects (2018)

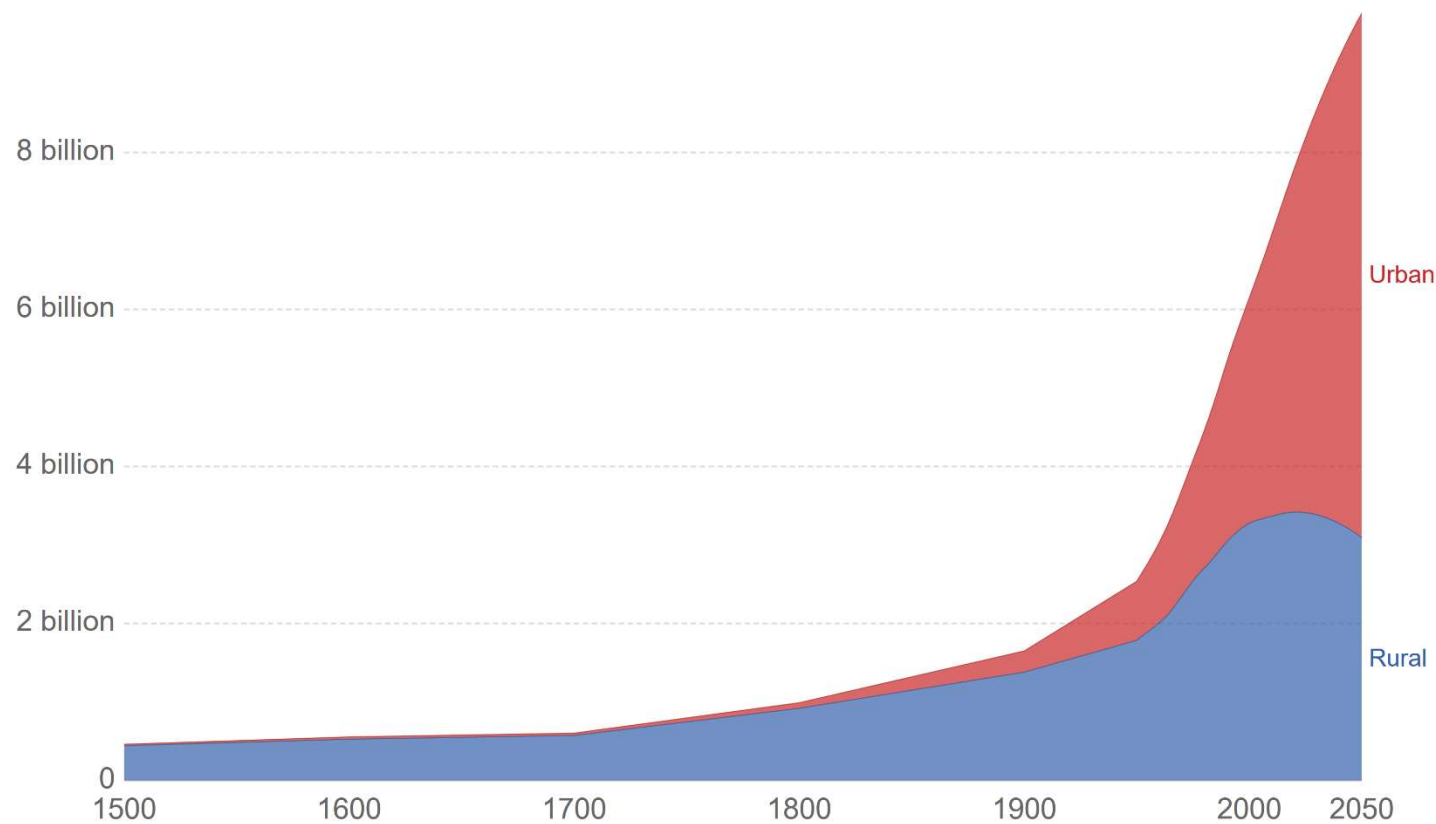
Note: Urban populations are defined based on the definition of urban areas by national statistical offices.
OurWorldInData.org/urbanization • CC BY

Explosion of cities

Urban and rural population projected to 2050, World

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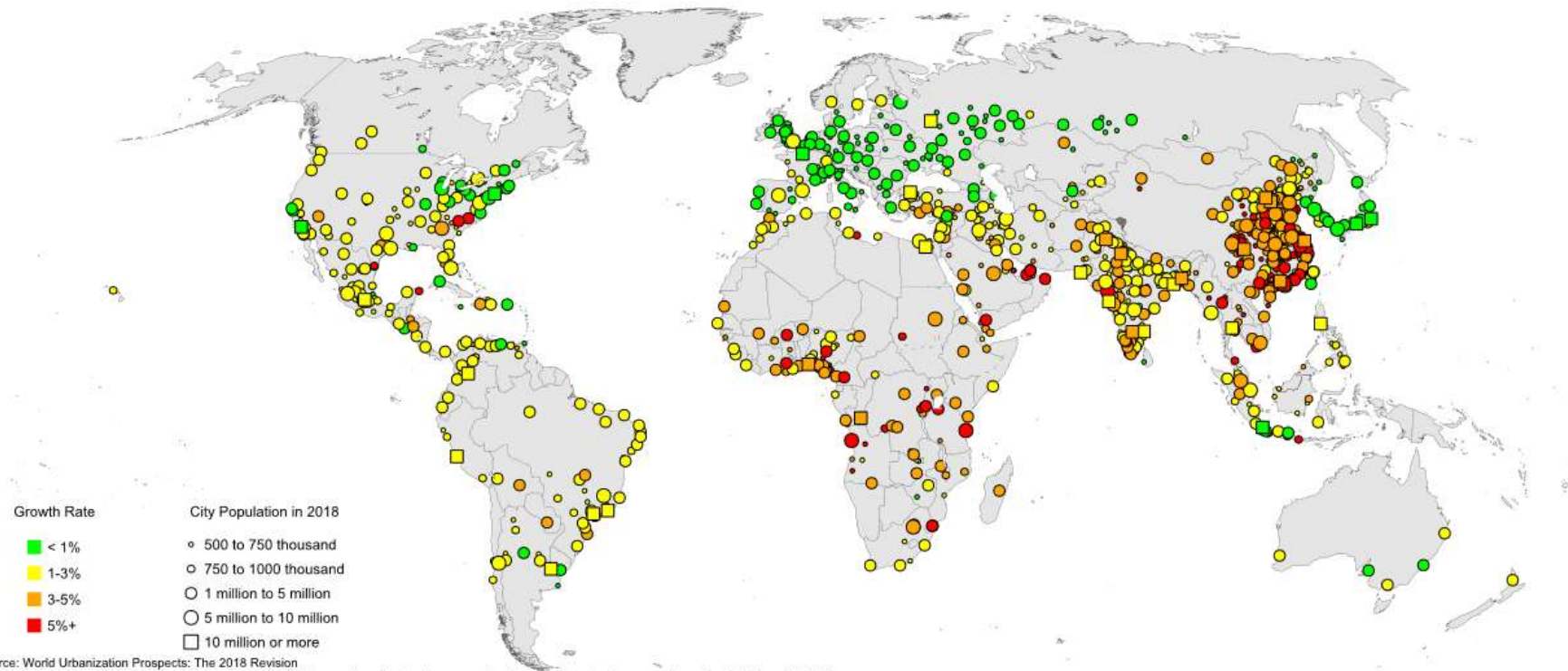
Total urban and rural population, given as estimates to 2016, and UN projections to 2050. Projections are based on the UN World Urbanization Prospects and its median fertility scenario.



Source: OWID based on UN World Urbanization Prospects 2018 and historical sources (see Sources)
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New cities mostly in developing countries

1990-2018



Data source: World Urbanization Prospects: The 2018 Revision
The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

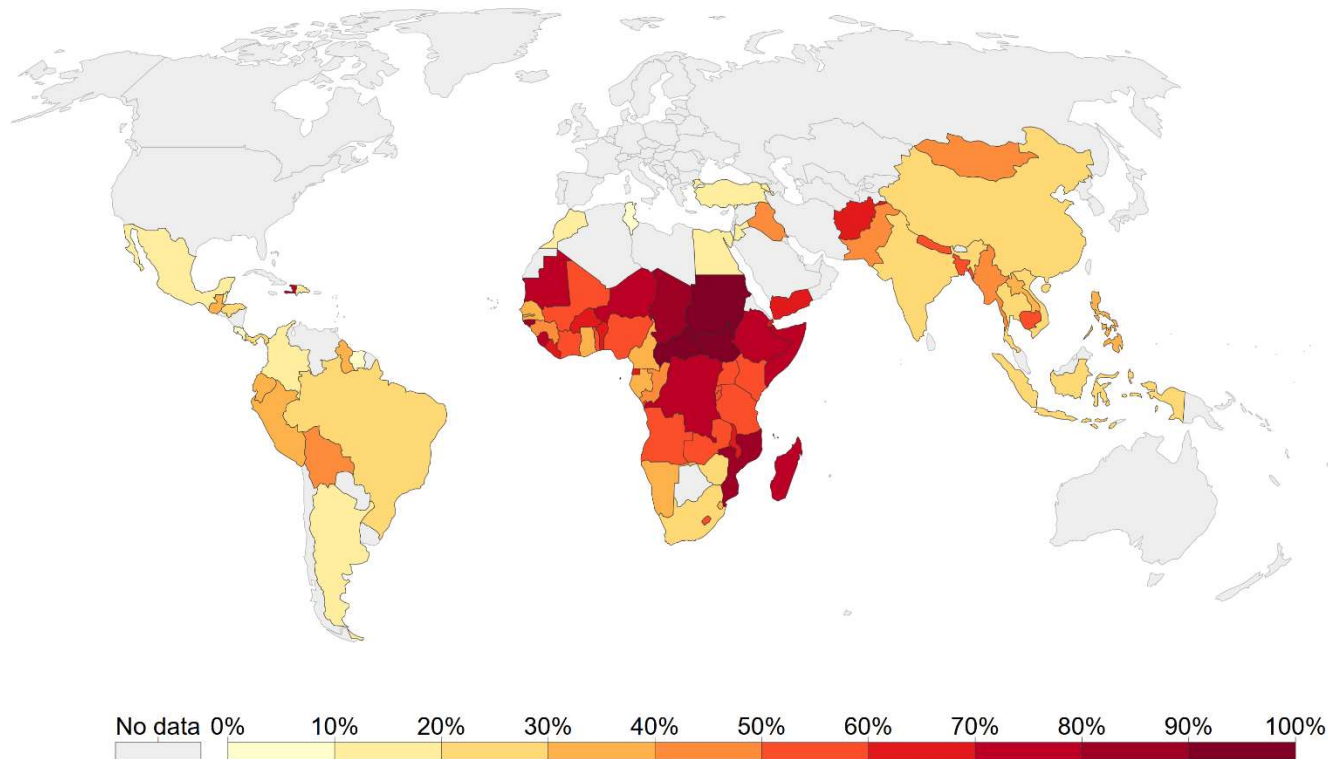
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Increasing development of slums

Share of urban population living in slums, 2014

A slum household is defined as a group of individuals living under the same roof lacking one or more of the following conditions: access to improved water, access to improved sanitation, sufficient living area, and durability of housing.

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Source: UN HABITAT
OurWorldInData.org/urbanization • CC BY

Cheaper habitat ?



Timber and earth – Shigeru Ban (for Sri Lanka post 2004 tsunami)

© Dominic Samsoni

Cheaper habitat ?

Johannesburg – LOT-EK

© Dave Southwood

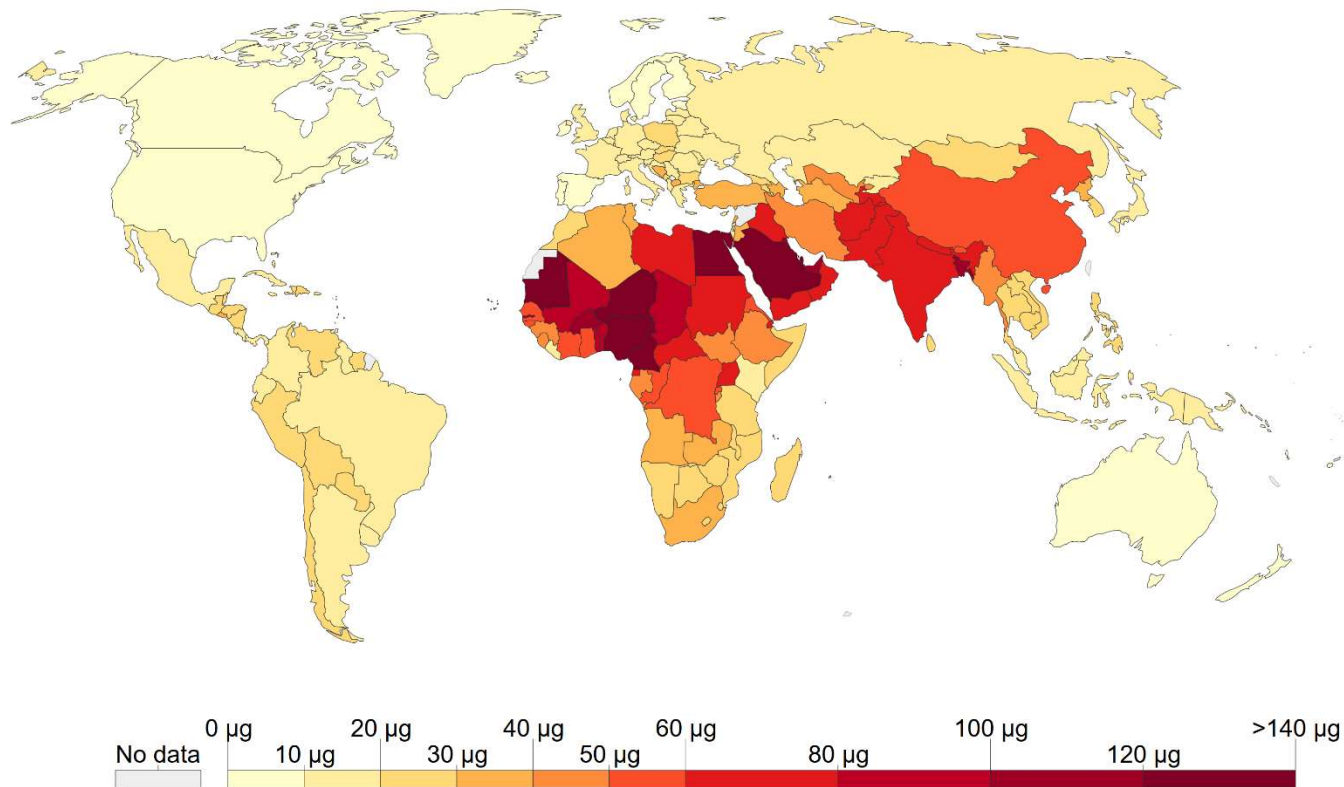


Increased air pollution

Particulate matter air pollution, 2016

Population-weighted average level of exposure to concentrations of suspended particles measuring less than 2.5 microns in diameter. Exposure is measured in micrograms per cubic metre ($\mu\text{g}/\text{m}^3$).

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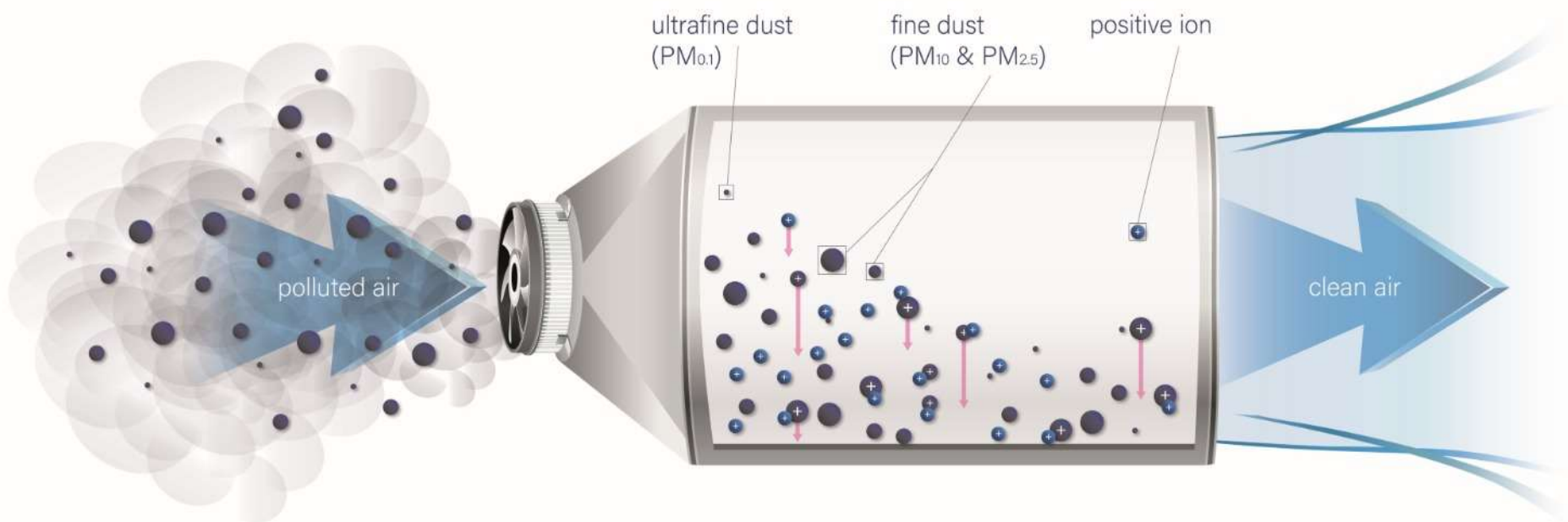
Source: World Bank
OurWorldInData.org/air-pollution/ • CC BY

Air filtering technologies ?



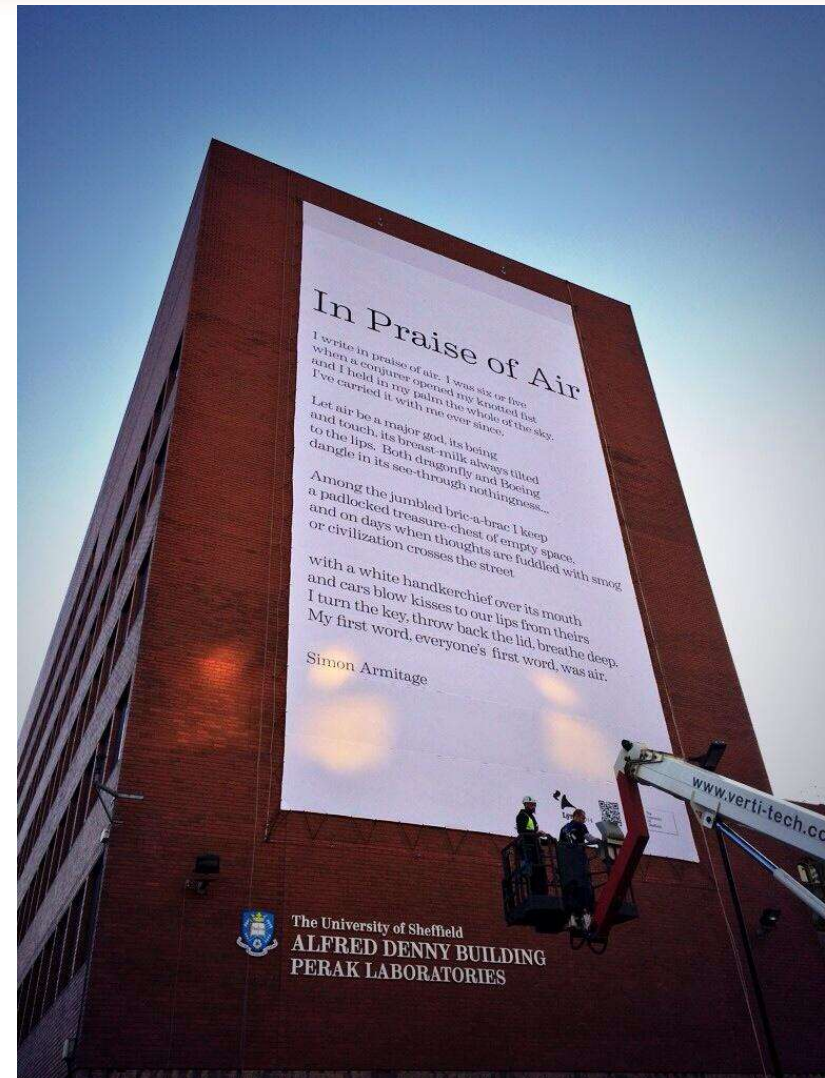
Smog Free Tower – Roosegaarde – ionization of PM
© Roosegaarde

Air filtering technologies ?



Ionization of PM
© ENS Cleanair

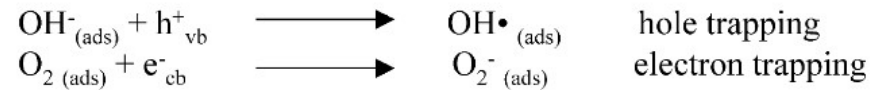
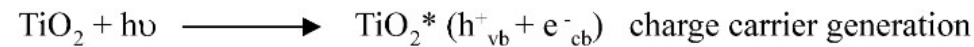
Air filtering technologies ?



In Praise of Air – University of Sheffield – TiO₂
© Eideard

Air filtering technologies ?

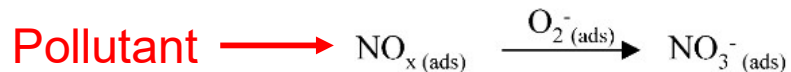
(1) Photocatalysis



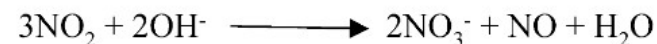
(2a) Oxidation using hydroxyl radicals: OH•



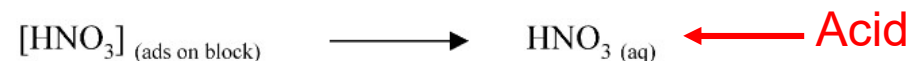
(2b) Oxidation using “active oxygen”: O₂⁻



(2c) Reaction with Ti-OH via disproportionation³



(3) Removal of [HNO₃] complex from surface of block by water



Air filtering technologies ?



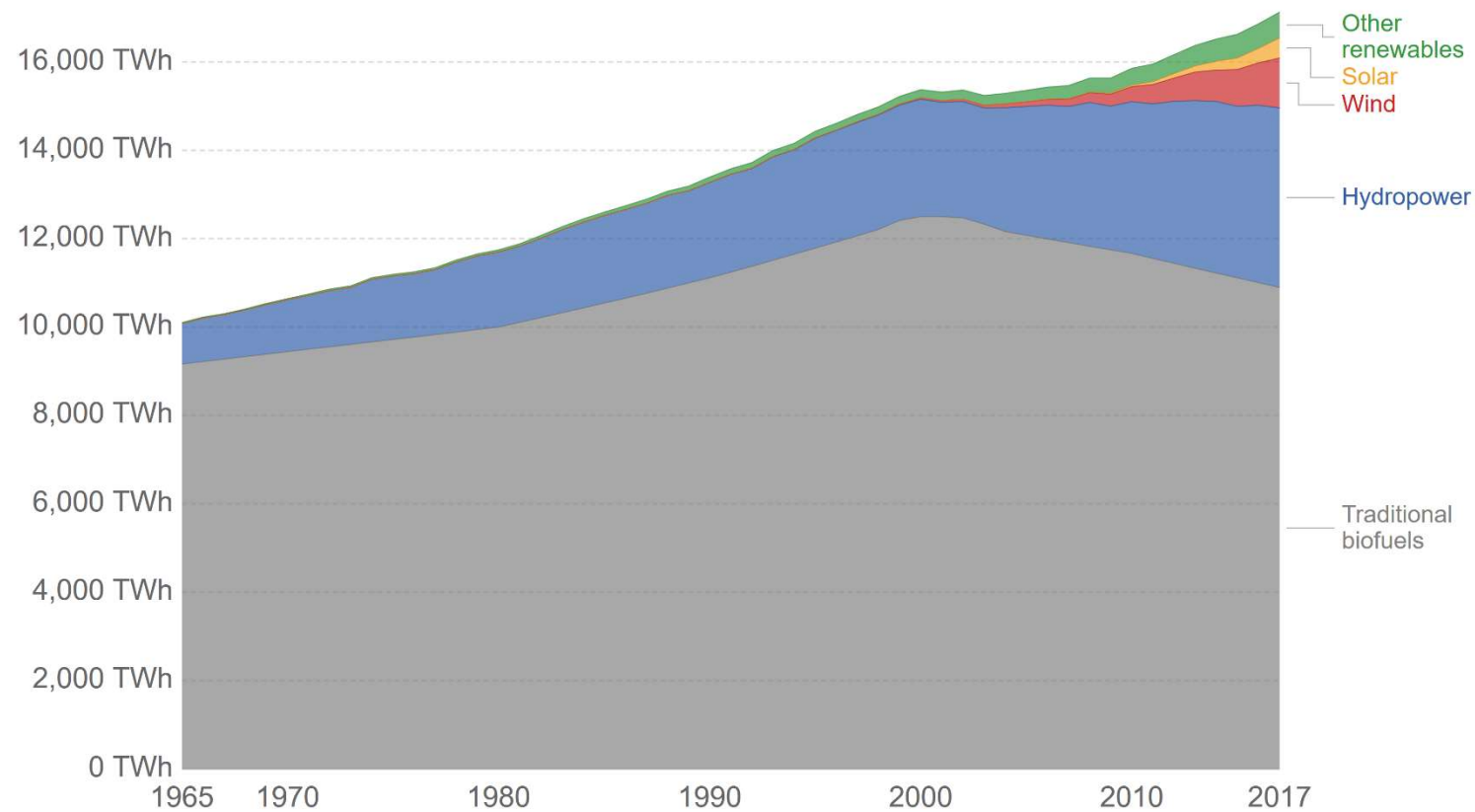
City-tree – Green City – moss
© Tony Kershaw

Energy consumption

Global renewable energy consumption, World

Renewable energy consumption measured in terawatt-hours (TWh) per year. Traditional biofuels refer to the consumption of fuelwood, forestry products, animal and agricultural wastes.

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Source: Vaclav Smil (2017) & BP Statistical Review of Global Energy (2019)
OurWorldInData.org/renewable-energy • CC BY

Cleaner energy sources ?



PV panels – Edmonton Convention Center
© Larry Wong

Cleaner energy sources ?



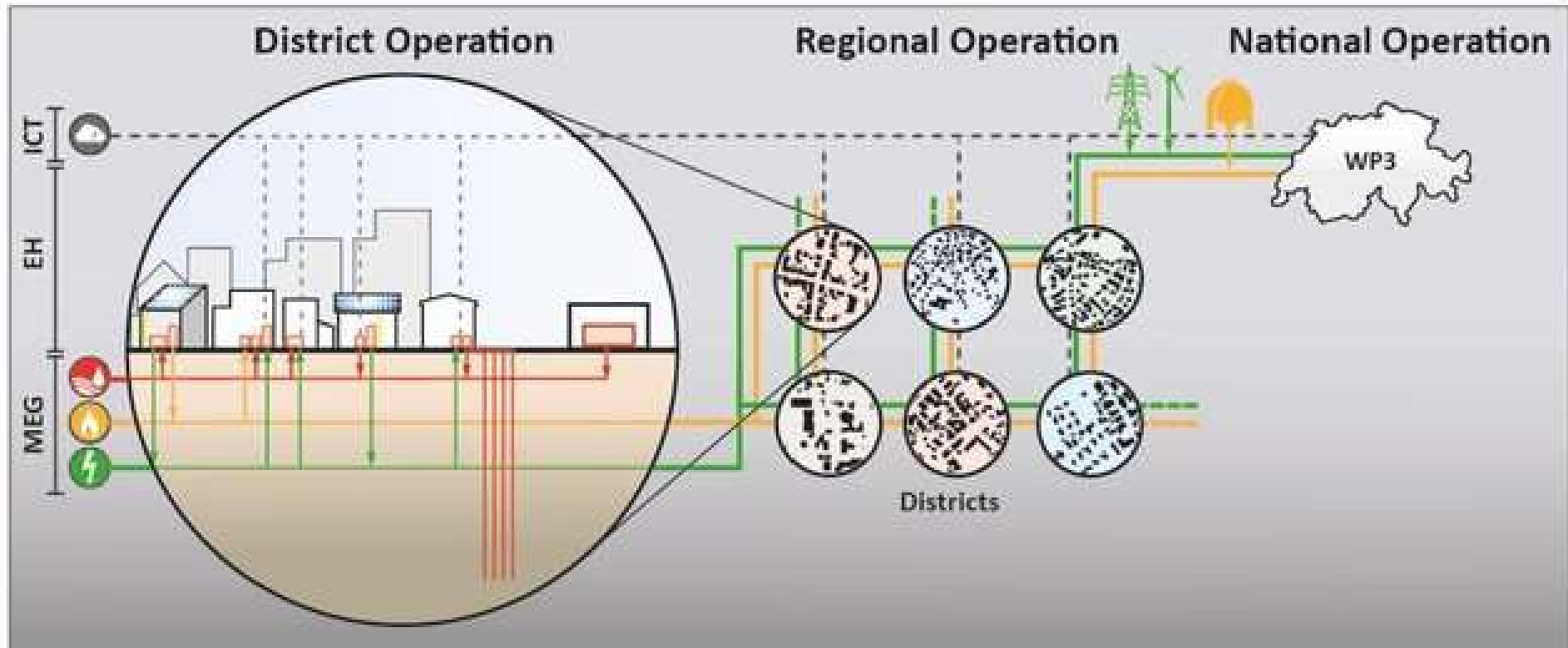
Wind Tree – COP 21
© NewWind

Cleaner energy sources ?



Hydropower
© Heliorec

Energy optimization ?

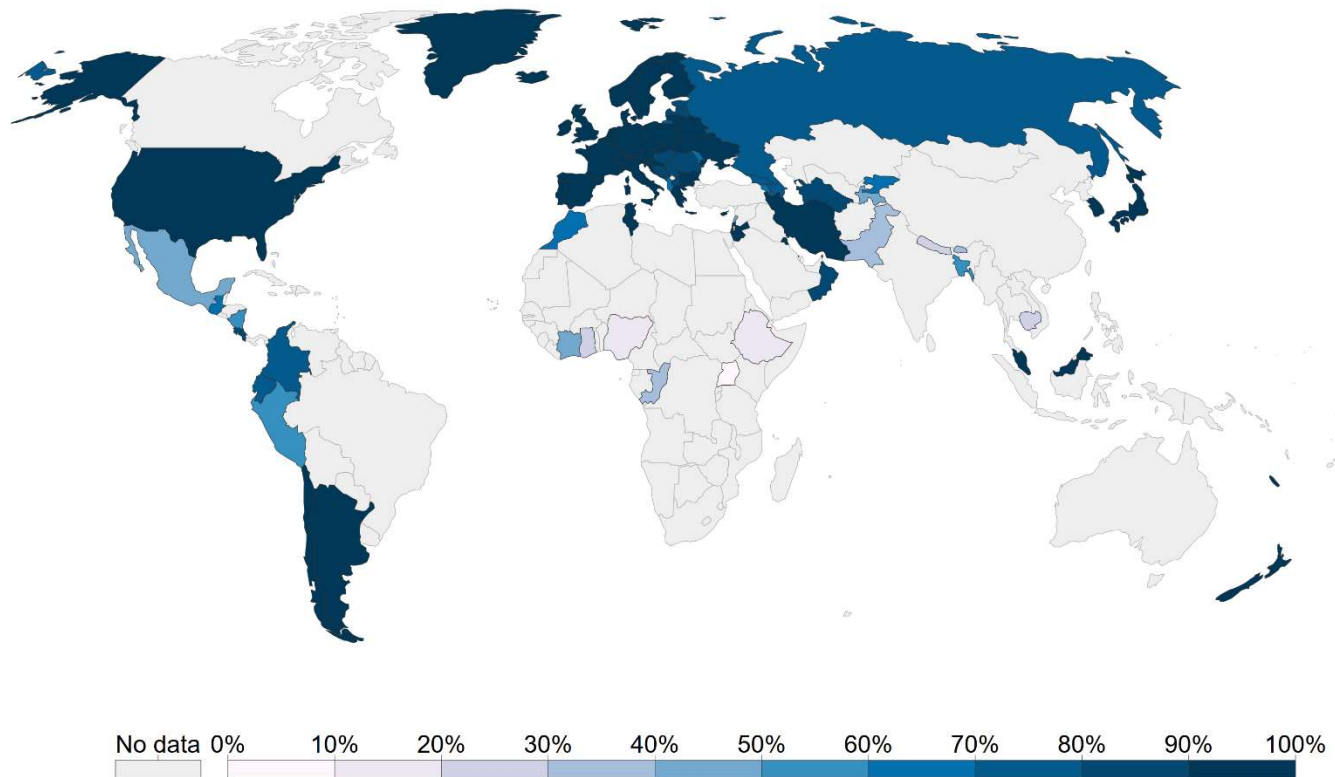


Multi-energy grids – Sulzer et al. 2018

Access to water

Share of the population using safely managed drinking water, 2015

A safely managed drinking water service is defined as one located on premises, available when needed and free from contamination.



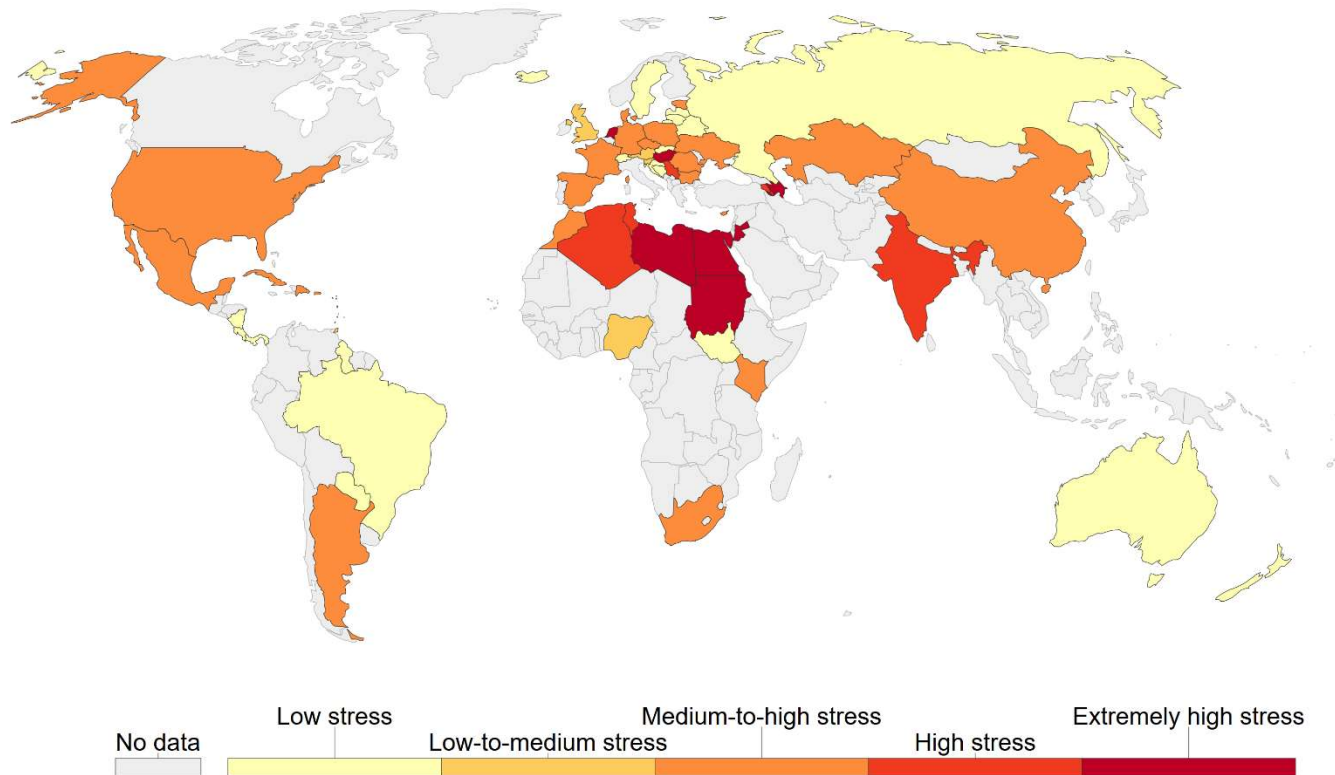
Source: WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP)
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Stress on freshwater resources

Freshwater withdrawals as a share of internal resources, 2014

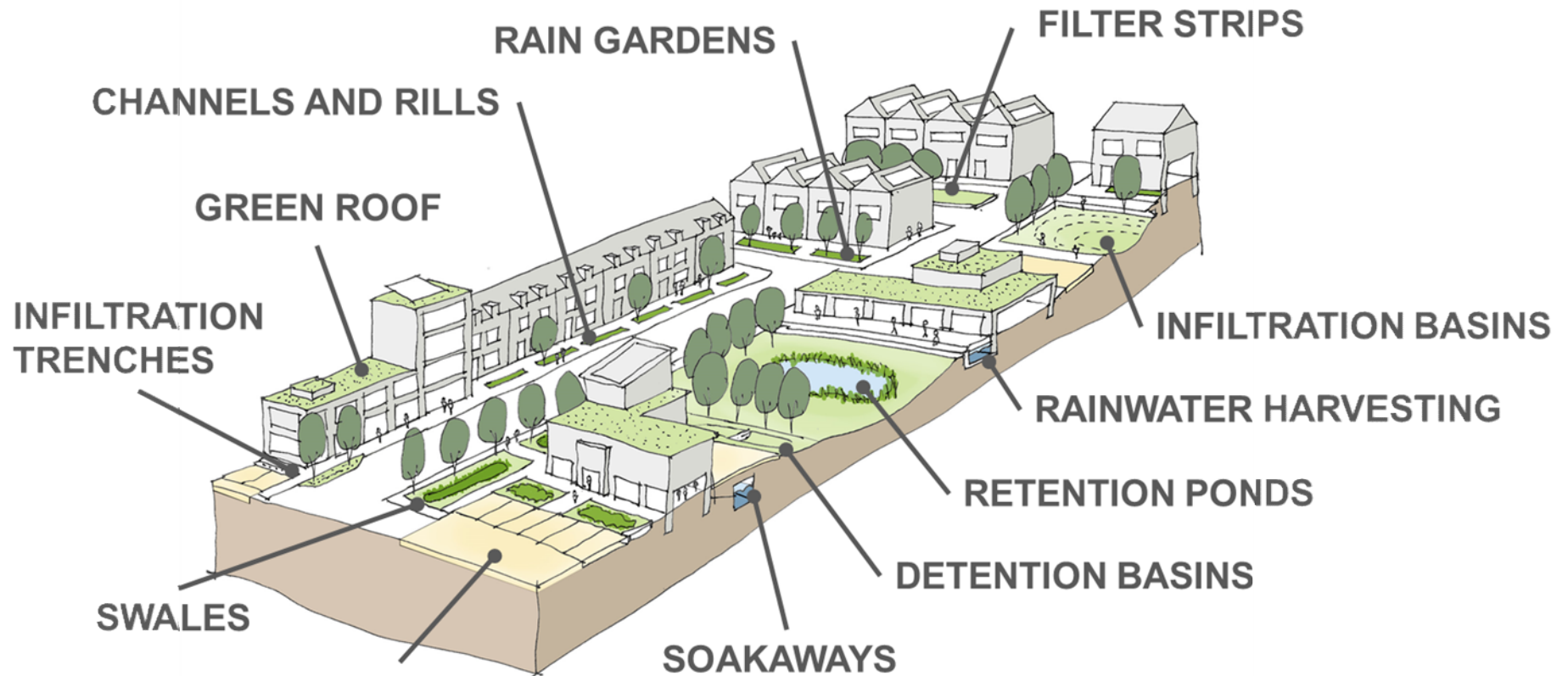
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Annual freshwater withdrawals refer to total water withdrawals from agriculture, industry and municipal/domestic uses. Withdrawals can exceed 100% of total renewable resources where extraction from nonrenewable aquifers or desalination plants is considerable.



Source: UN Food and Agriculture Organization (FAO)
OurWorldInData.org/water-access-resources-sanitation/ • CC BY

Water management

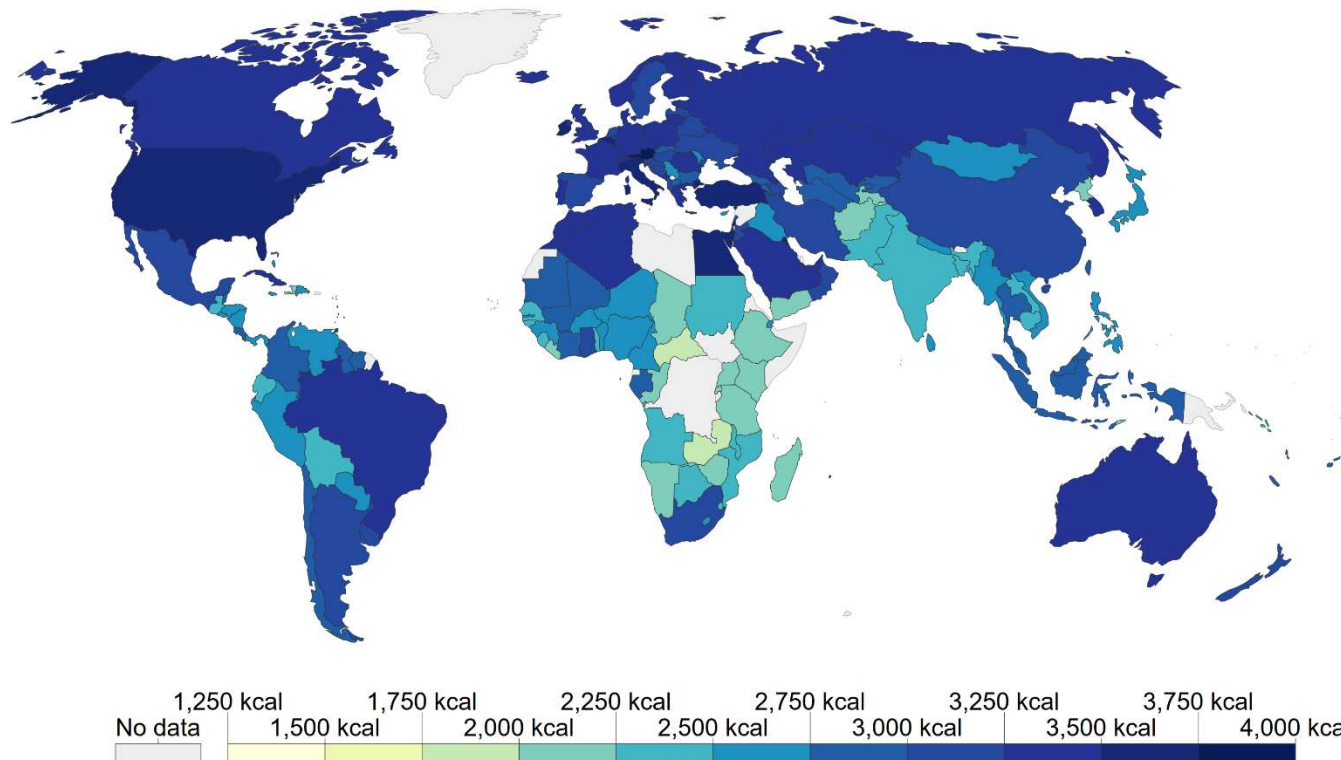


Source: European Natural Water Retention Measures Platform (NWRM)

Food supply

Daily per capita caloric supply, 2013

Average daily per capita caloric supply, measured in kilocalories per person per day. Note that this indicates the caloric availability delivered to households but does not necessarily indicate the number of calories actually consumed (food may be wasted at the consumer level).



Source: FAO (2017) & Various historical sources

Note: Historical data for the USSR is highly uncertain – it likely gives an overestimate of caloric supply

OurWorldInData.org/food-per-person/ • CC BY

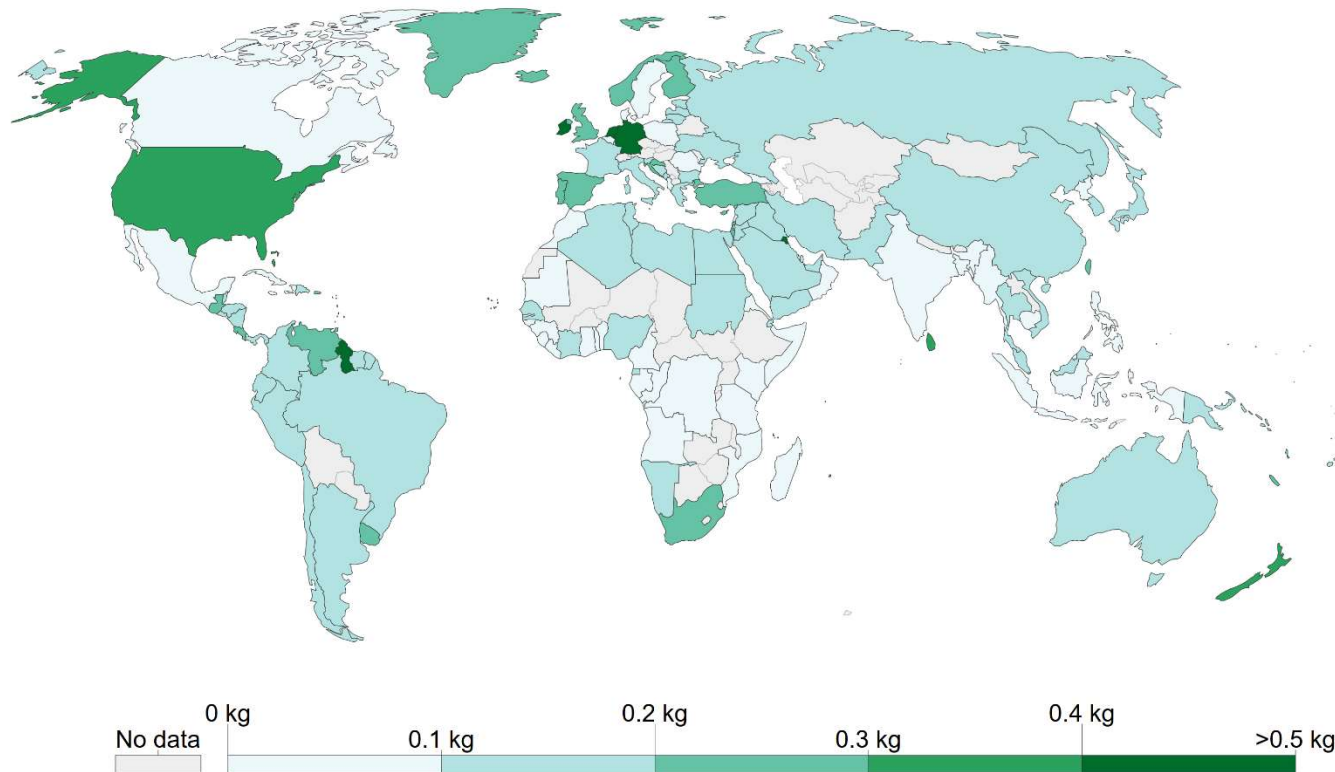
More efficient food supply ?



Brooklyn Grange
© Farmtopeople

Plastic waste generation per person, 2010

Daily plastic waste generation per person, measured in kilograms per person per day. This measures the overall per capita plastic waste generation rate prior to waste management, recycling or incineration. It does not therefore directly indicate the risk of pollution to waterways or marine environments.

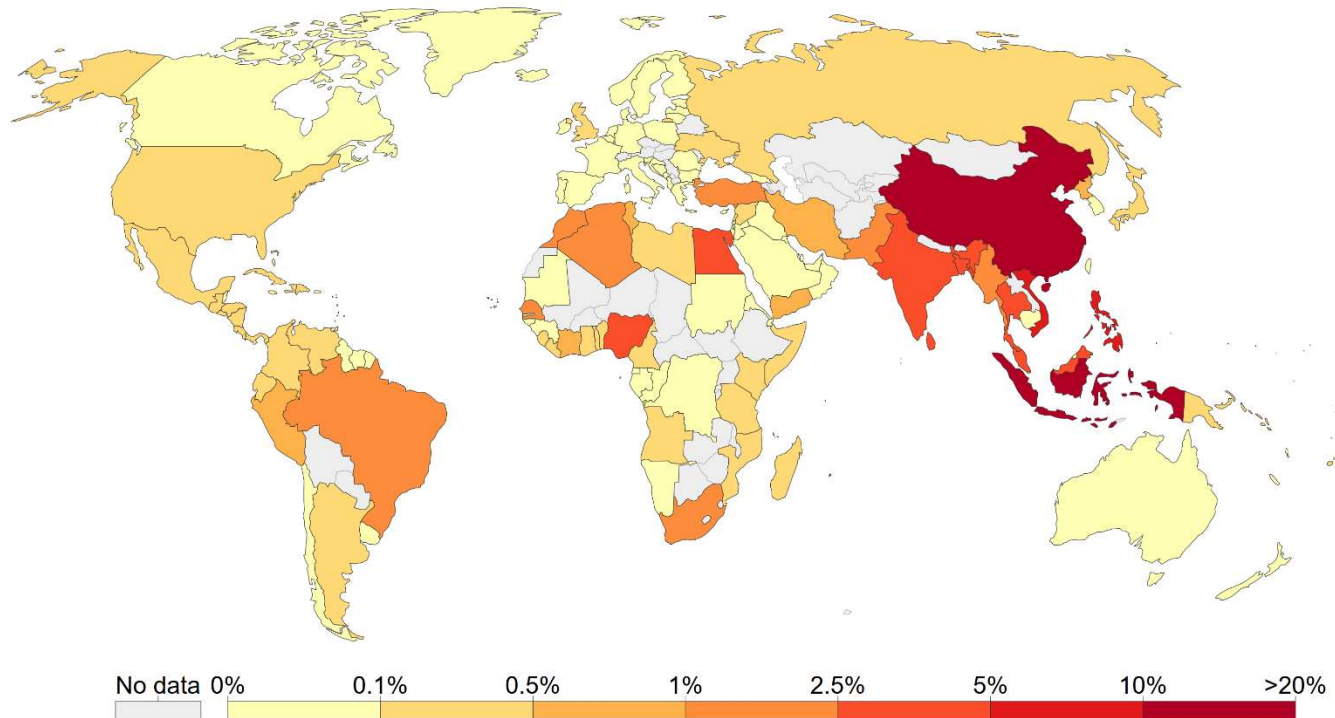


Source: Jambeck et al. (2015)
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Projected share of global mismanaged plastic waste in 2025



Projected share of global mismanaged waste produced in 2025. This is measured as the total mismanaged waste by populations within 50km of the coastline, and therefore defined as high risk of entering the oceans. Mismanaged plastic waste is defined as "plastic that is either littered or inadequately disposed. Inadequately disposed waste is not formally managed and includes disposal in dumps or open, uncontrolled landfills, where it is not fully contained. Mismanaged waste could eventually enter the ocean via inland waterways, wastewater outflows, and transport by wind or tides."

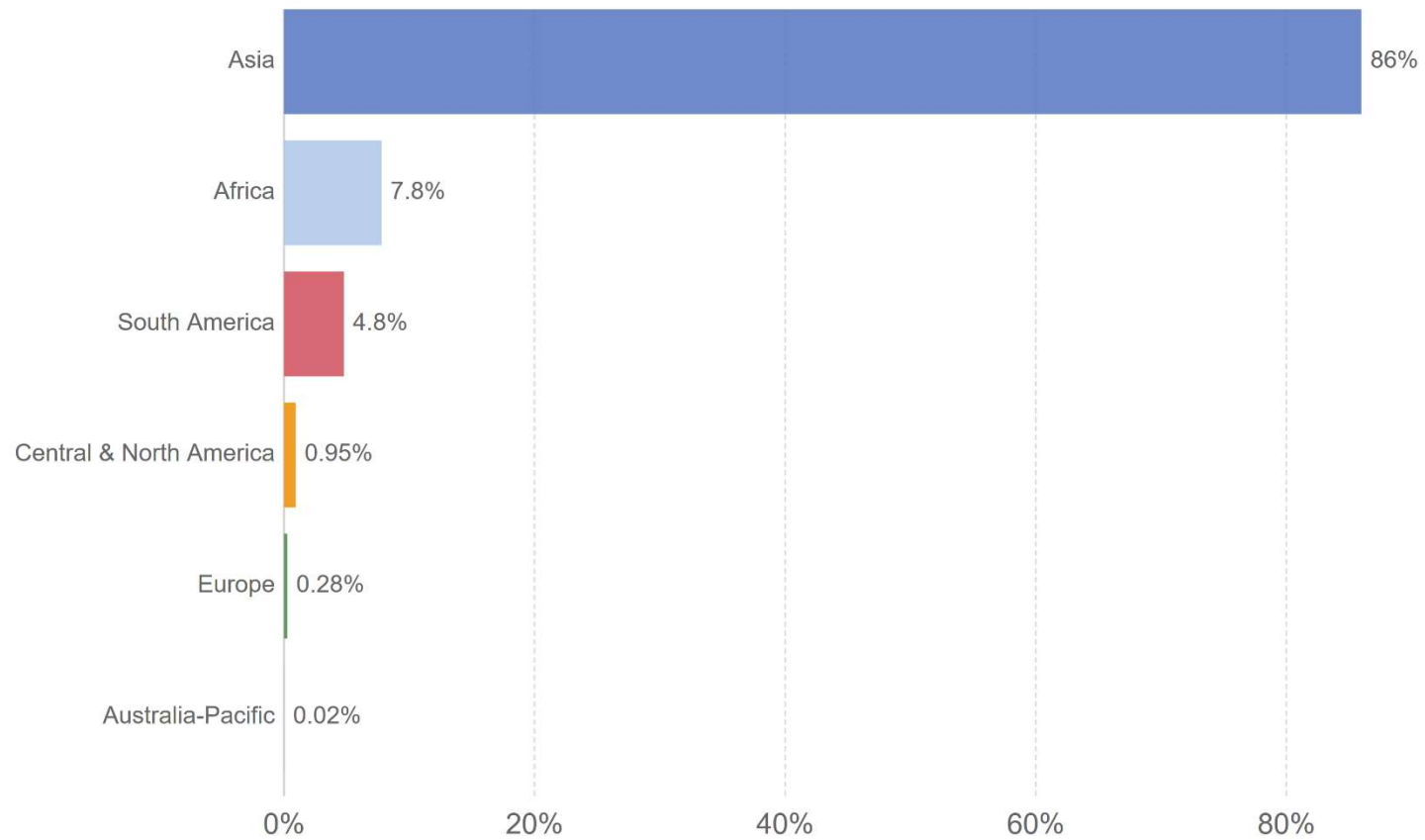


Source: Jambeck et al. (2015)
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Global river plastic input to the ocean by region, 2015

Share of annual global plastic inputs from rivers into the ocean, differentiated by region.

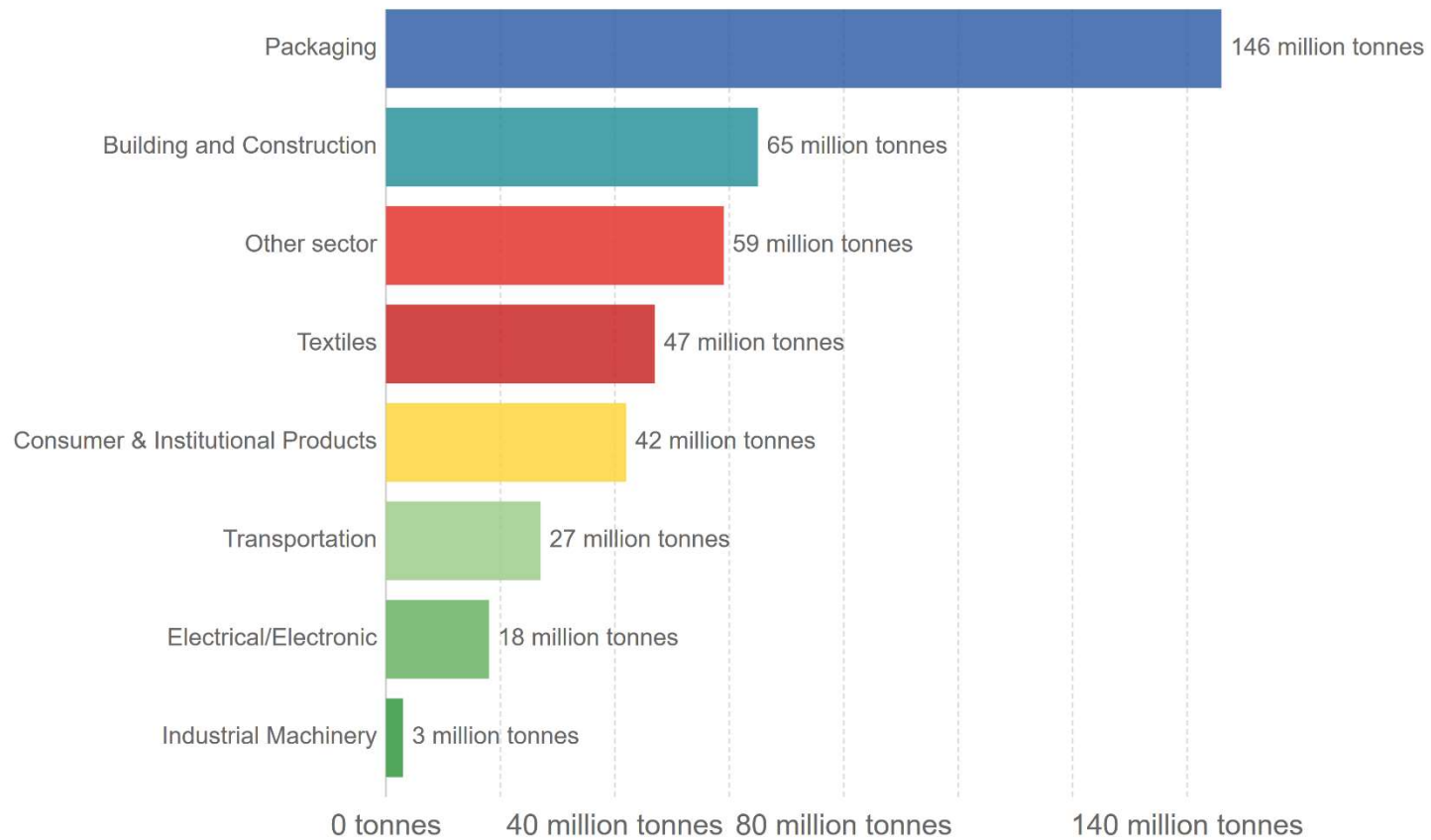
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Source: Lebreton et al. (2017)
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Primary plastic production by industrial sector, 2015

Primary global plastic production by industrial sector allocation, measured in tonnes per year.



Source: Geyer et al. (2017)
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Recyclable buildings ?

Straw insulation - Modcell



Recyclable buildings ?



The Living/ARUP – mushroom & corn stalks
© ARUP

Recyclable buildings ?

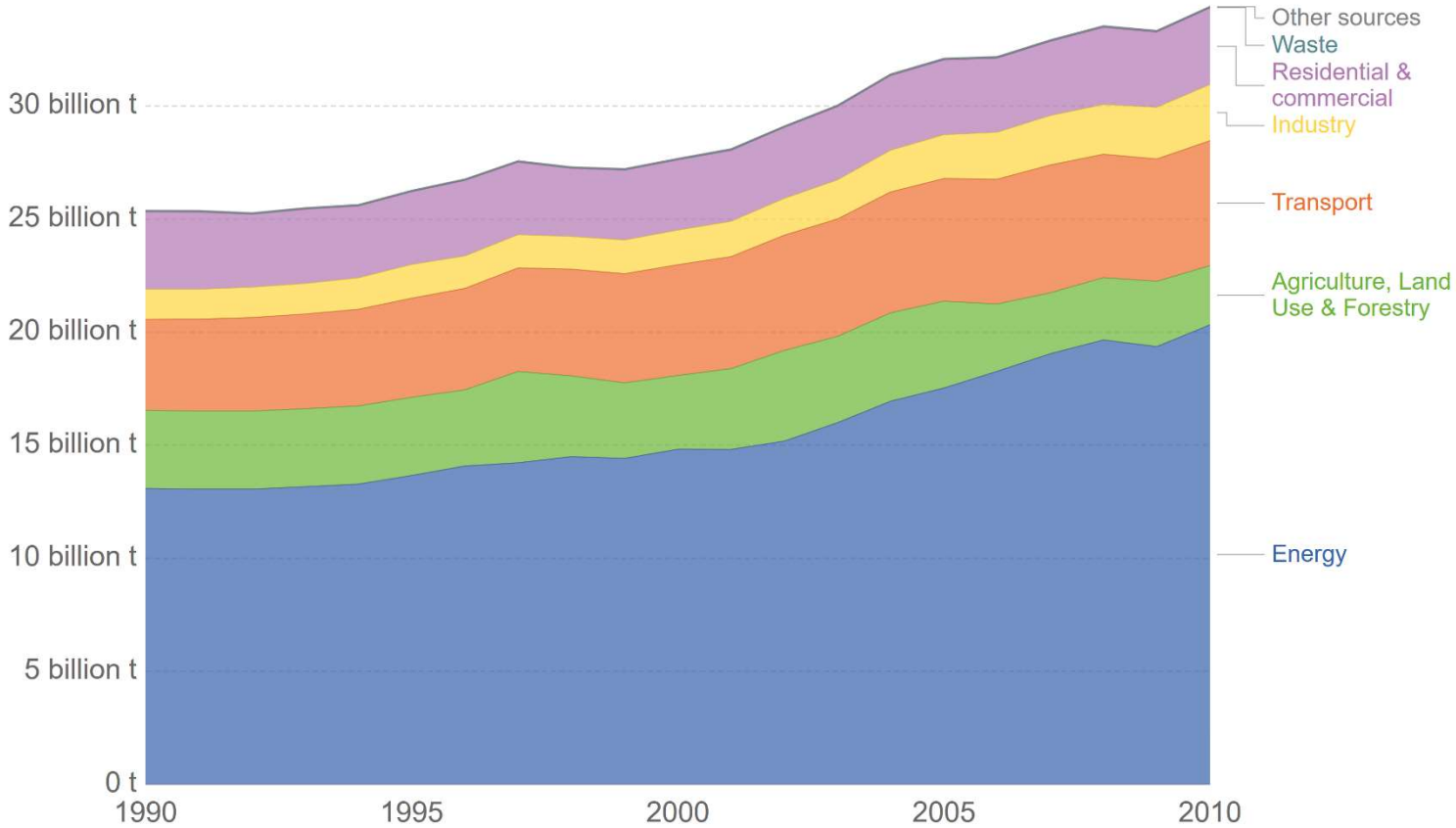
Cardboard & paper tubes –
Shigeru Ban (for Christchurch
post 2011 earthquake)



CO2 emissions

Carbon dioxide emissions by sector, World

Carbon dioxide (CO₂) emissions by sector, measured in tonnes per year.



Source: UN Food and Agricultural Organization (FAO)
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Different construction methods ?

Dry vs Wet
construction – Building
& Construction
Authority

	Concrete-Based Construction	Sustainable Construction (Steel and other Dry Construction)
Cost	Less costly	Increase overall construction cost by 2-3% compared to concrete-based construction.
Speed of construction	Slower in construction - need time for formwork, reinforcement work, concrete strengthening and removal of formwork	Faster in construction - projects are generally able to complete earlier using steel construction.
Manpower saving	Labour intensive	Less labour usage, savings of 20% to 30%.
Quality	Re-work and rectification more common as it is more dependant on the skill of workers	Better quality as components are factory-fabricated, standardised, therefore less dependant on the skill of workers.
Sustainability	Demolition waste from concrete buildings not reusable for building structures	Steel elements are highly recyclable material, with over 50% of steel currently being produced from scrap.
Aesthetics	Larger components sizes, shorter clear span (max. span approx. 12m)	Improved creativity as steel design can be more flexible, looks slimmer and can cater to longer span structures (max. span for steel trusses can stretch to more than 20m).
Weight	Heavier in dead weight	Steel has a higher strength-to-weight ratio, less requirement on foundation.

Outline of the course

Lecture #1 – Principles of bioclimatic construction

Lecture #2 – Thermal considerations

Lecture #3 – Energy in the building

Lecture #4 – Other fields where physicists could be of use to architects