Syllabus_Environmental Economics [HS31072]

Introduction; Economy-environment Interaction

The Material Balance Principle, Entropy Law; Market failure, Property Rights, Open Access Resources, Collective Action; Long Term Views of Economic Activities and the Environment Limits to Growth, Optimistic View/Sustainability;

Capital Theory and Discount Rates; Environmental Issues in India: Sources and Types of Pollution (Air, Water, Solid Waste, Noise, Land Degradation);

Causes and Effects of Environmental Degradation, Urban and Rural Environmental Problems; Energy-Environment Interaction; Economics of Pollution Control and Pollution Policy Targets and Instruments: The Efficient Level of Pollution;

Incentive-Based Strategies: Taxes and Subsidies; Command and Control Strategies: Ambient Environmental Quality Standard, Emission Standard, Technology Standard; Environment-Development Trade-off: Relation between Development and Environment Stress;

Environmental Kuznets Curve, Concept of Sustainable Development; Indicators of Sustainability; Various Approaches for Environmental Accounting

Suggested Readings

1. Perman et al. Natural Resource and Environmental Economics. Pearson, 4th Edition, 2011.
2. Barbier, E.B. Natural Resources and Economic Development. Second Edition, Cambridge University Press, Second Edition, 2019.
3. Kolbert, E. The Sixth Extinction: An Unnatural History. 2014
4. Hanley, N., and Barbier, E.B. Pricing Nature: Cost-Benefit Analysis and Environmental Policy, Edward Elgar, 2010.
5. Hanley, N., Shorgren, J.F., and White, B. Environmental Economics in Theory and Practice. Second Edition, Palgrave, 2007.
6. Ristinen, R. and J. Kraushaar, Energy and the Environment, John Wiley and Sons, 1998.
7. Seeley, Karl. Macroeconomics in Ecological Context. Springer, 2007.
8. Tietenberg, T. Environmental and Natural Resource Economics, seventh edition, Addison Wesley, 2006
9. Tomain, J.P. Ending Dirty Energy Policy: Prelude to Climate Change. Cambridge University Press, 2011.
10. Hubacek, K., & Guan, D. (2011). The net effect of green lifestyles. Nature Climate Change, 1(5), 250-251.
11. Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. The Journal of Energy and Development, 401-403.
12. York, R. (2012). Do alternative energy sources displace fossil fuels?. Nature Climate Change, 2(6), 441-443.

MAN, ECONOMY AND NATURE: WHY STUDY ENVIRONMENTAL ECONOMICS?

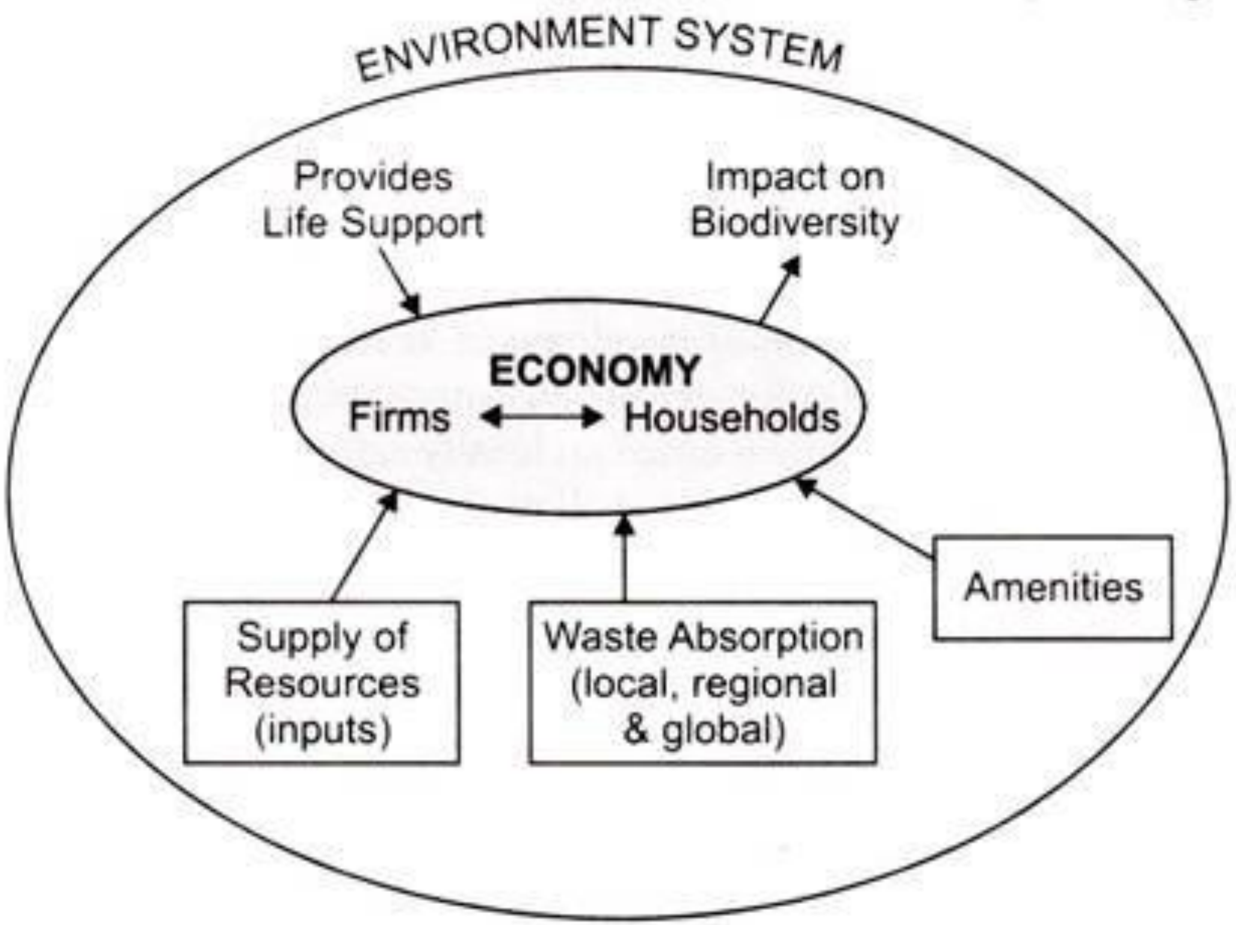


Fig. 56.1. *Economy–environment linkages or relations*

https://adamasuniversity.ac.in/man-economy-and-nature-why-study-environmental-economics/

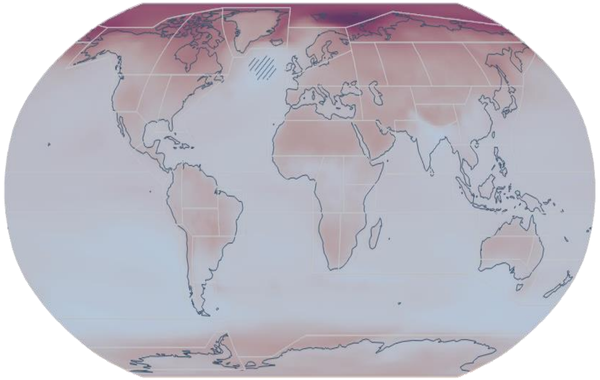
Why Environmental Economics?

- Across the globe, nine out of every ten people are breathing unclear air.
- Ultimately, around **7 million people die every year from diseases and infections related to air pollution** – more than five times the number of people who die in road traffic collisions. Air pollution causes.
- **43%** of deaths from chronic obstructive pulmonary disease. 
- **24%** of deaths from heart disease.
- **25%** of deaths from stroke.
- **29%** of deaths from lung cancer. 
- Exposure to air pollution has also been linked to increased vulnerability to COVID-19. 

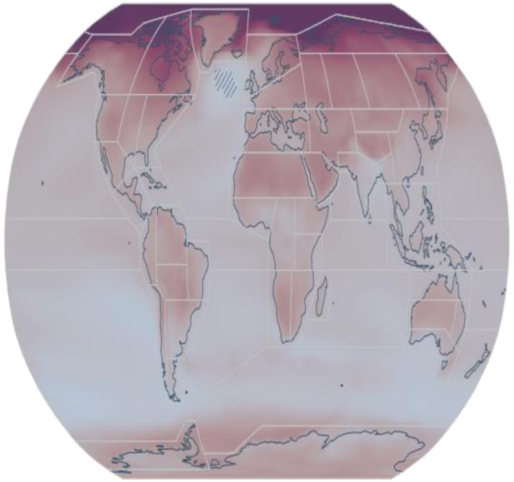
https://www.unep.org/interactive/all-you-need-to-know-air-pollution/

Possible Future Climate Changes

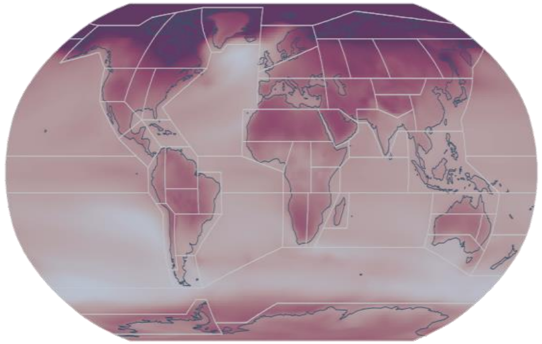
- ❖ Rising concentrations of greenhouse gases lead to climate change.
- ❖ Climate change manifests in the trend of rising global temperatures and more extreme weather events.



Warming 1.5°C



Warming 2°C



Warming 3°C

Warming 4°C

[Source: https://interactive-atlas.ipcc.ch/](https://interactive-atlas.ipcc.ch/)

Raw Reality of Climate Change

https://www.rediff.com/news/report/pix-devastating-images-capture-raw-reality-of-climate-change-ciwem-photographer-of-the-year/20191004.htm

Timeline For Earth's Sixth Mass Extinction

https://www.sciencealert.com/study-links-bigger-temperature-changes-with-larger-extinction-events#

https://www.rediff.com/news/report/pix-devastating-images-capture-raw-reality-of-climate-change-ciwem-photographer-of-the-year/20191004.htm

Cont…

https://interestingengineering.com/science/when-will-the-sixth-mass-extinction-happen-a-japanese-scientist-may-have-an-answer

The next mass extinction

- When Kunio Kaiho, the Japanese climate scientist, tried to map the stability of the Earth's average surface temperature to that of its biodiversity.
- He found almost a linear relation between them.
- When the temperature change is greater, the extent of extinctions is also large.
- However, when the Earth is warming up, the greatest mass extinctions happen when temperatures have increased by 9^{o}C.
- But warnings by climate scientists have said that at the current rate of emissions, the Earth would warm up by as much as 4.4^{o}C by the end of the century, and current efforts are focused on not letting that happen.
- This is because the extent of the damage may not be massive as in previous events, but the damage is happening faster.
- This may put species at greater risk. This is further because it may not give species sufficient time to adapt.
- Do we have more time on our hands to slow down our emissions?

Kaiho, K. (2022). Relationship between extinction magnitude and climate change during major marine/terrestrial animal crises. *Biogeosciences Discussions*, 1-15.

https://bg.copernicus.org/articles/19/3369/2022/

Need & Importance of Environmental Economics

- However, it is an important subject, not only for emerging countries undergoing transition, but also developed and developing countries emerging from financial crisis, armed conflicts, and natural disaster.

- The bundling of economic and environmental benefits- a sort of double dividend-has two implications:

- Pollution reductions are achieved at higher economic growth, but improved environmental quality increases well-being of the people.

- The double dividend may or may not be obtained in highly distorted economies if they lack right environmental education both at macro and micro levels.

- Ignoring effective environmental education may undermine the provision of public goods (e.g. air quality, water quality) that may also intensify public health risks.

- The parts of the world that are still developing are also the parts of the world where important choices will be made on preserving this balance. This makes the field very relevant.

- However, I beg the question of whether environmental quality is increased with income and education levels.

- It is hoped that the analysis and understanding of this subject hold some lessons for students, policymakers and government in developing countries.

Prosperity Lost

- ✓ It is all about things going well for us.
- ✓ It speaks of the elimination of hunger, homelessness,, an end to poverty and injustice, hopes for a secure and peaceful world.
- ✓ In a world of nearly 6.7 billion people, 4 billion people still live without basic entitlements.
- ✓ By the end of this century, when the population is expected to rise to over 9 billion, if the distribution of wealth on the finite planet remains skewed, many more people will be impoverished.
- ✓ Individual prosperity is curtailed in the presence of social calamity and material wants. Morality is itself threatened.
- ✓ Our technologies, our economy and our social aspirations are all mis-aligned with any meaningful expression of shared prosperity.
- ✓ What does island of prosperity mean in a world of 9 billion people living in world of finite resources, oceans of poverty and under the threat of climate change and resources scarcity?

✓The concept of prosperity is a modern construction.

✓In pursuit of good life today, we are not only developing ‘’shopping generation’’ but also systematically eroding the basis for well-being tomorrow.

✓The age of consumerism adds more to material comfort against the ecological limits of a finite planet.

✓For example, people in poor countries value more to their social and economic status. Unproductive status competition among people in poor countries drives their spending on commodities it’s because they value them.

✓The continued increasing consumption is essential for economic growth. The poor countries will suffer if economic growth is less.

✓If economic growth or material consumption rises, it creates ecological overshoot which is not good for the sustainability of natural environment in long-run.

✓It can also widen the gap between rich and poor living in poor countries.

✓Such social disparities and environmental injustice are unacceptable for developmental and environmental economists.

✓Alleviating poverty and preserving a balance between the human sphere and the natural environment are the major issues of our world.

✓Therefore we stand in real danger of losing any prospect of a shared and lasting prosperity for poor economies.

The Economics of the Environment

- ✓ There is a small tribe of economists, known as resources/environmental economists (I happen to belong to this tribe), who tend to view the natural environment through the lens of population ecology.
- ✓ Population ecology: The focus in population ecology is the dynamics of interacting population of different species. How people are related to each other with their living and non-living environment?
- ✓ The healthier our ecosystems are, the healthier the planet - and its people.
- ✓ Our activities are dependent ultimately on resources found in nature.
- ✓ Whether it is consumption or production, or whether it is exchange, the commodities which are involved are made of constituents by nature……………the production of commodities by means of resources.
- ✓ Each of the manufactured product, labour time, skills and resources found in nature.
- ✓ This implies that the manufactured product with which we began our economic activities is a combination of labour time and skills, and resources found in nature.

- ✓ The resources that sustain our life are found from the nature.
- ✓ For example, the multitude of nutrients we consume, the air we breathe, and the water we drink.
- ✓ All above commodities are traceable to natural resources.
- ✓ In many instances, natural resources are of direct value to us as needs or as consumption goods (breathable air, drinkable water, and fisheries).
- ✓ They are of indirect value (e.g. plankton which serves food as food for fish, which we, in turn, consume).
- ✓ Sometimes they are both (e.g. drinking and irrigation water).
- ✓ The value I am indicating to may be utilitarian (e.g. resources may be a source of food, or a key stone species in an ecosystem).

- ✓ Resource stocks are very important as they provide direct and indirect values to humans and other species.
- ✓ Depending on the context, the flow of value we derive from a resource stock could be dependent on the rate at which it is harvested, or on the size of the stock.
- ✓ In many cases, it would be dependent on both.
- ✓ For example, annual commercial profits from a fishery depend not only on the rate at which it is harvested, but also on the stock of the fishery.
- ✓ Because unit harvesting costs are costs that are typically low when stocks are large and high when stocks are low.
- ✓ The valuation of resources and the rates at which populations are in different institutional settings are among the resource economist’s objects of enquiry (Clark, 1976; Dasgupta and Heal, 1979; Dasgupta, 1982; 1996).

Emissions Gap Report 2014

- It focuses on examining the gap in 2020 between emission levels consistent with the 2 °C limit, and levels expected if country pledges/commitments are met.

Emissions Gap Report 2015

- It compares the 2030 emission levels that would result from these commitments with what science tells us would keep average temperature increases on track to stay below 2°C by the end of the century.

Emissions Gap Report 2016

- This report estimates we are actually on track for global warming of up to 3.4 degrees Celcius. Current commitments will reduce emissions by no more than a third of the levels required by 2030 to avert disaster.

Source: https://www.unep.org/emissions-gap-report-2020

Emissions Gap Report 2017

- ❖ Phasing out coal gradually.

- ❖ This also examines the options and barriers for a gradual coal phase-out.

Emissions Gap Report 2018

- ❖ It calls for efforts to limit the temperature increase even further to 1.5 degrees Celsius.

Emissions Gap Report 2019

- ❖ The report presents the latest data on the expected gap in 2030 for the 1.5°C and 2°C temperature targets of the Paris Agreement.

- ❖ This year, the report looks at the potential of the energy transition – particularly in the power, transport and buildings sectors – and efficiency in the use of materials such as iron steel and cement.

Source: https://www.unep.org/emissions-gap-report-2020

Emissions Gap Report 2020

- Is Climate Change Getting Better?

- The report finds that, despite a brief dip in carbon dioxide emissions caused by the COVID-19 pandemic, the world is still heading for a temperature rise in excess of 3°C this century.

- This is far beyond the Paris Agreement goals of limiting global warming to well below 2°C and pursuing 1.5°C.

Source: https://www.unep.org/emissions-gap-report-2020

- ✓ This Year’s lockdowns have caused emissions to fall dramatically.
- ✓ But emissions are already rising again, in places surpassing pre-COVID levels.
- ✓ Carbon dioxide emissions were reduced about 7% in 2020 due to COVID-19.
- ✓ But the Pandemic offers only a short term reduction in global emissions.
- ✓ Long-term, this dip means only a 0.01°C reduction of global warming by 2050.
- ✓ The richest 1% produce more than twice the emissions of the poorest 50% of the global population.
- ✓ G20 members alone account for close to 80% of global greenhouse gas emissions.

- ✓ Unless low carbon recovery measures are put in place, the recent reduction will have no significance.
- ✓ Countries must strengthen their contributions to meet the 1.5°C Paris Agreement.
- ✓ Even if current country targets are achieved, global warming will only be limited to around 3.2°C by 2100.
- ✓ Ecosystems are collapsing. Our life support systems are being destroyed.
- ✓ Larger parts of the planet will be uninhabitable. But there is hope.
- ✓ A low carbon pandemic recovery could cut 25% off the emissions we expect to see in 2030.
- ✓ Building a better future means supporting zero-emissions technology, reducing fossil fuel subsidy, and no new coal plants.
- ✓ Also restoring landscapes, reforestation and working with nature for a better tomorrow.

What is environmental economics?

- It is the study of understanding natural environment
- Specifically, ecological economics an important field of environmental economics
- Ecology is the study of nature’s housekeeping
- Economics is the study of human housekeeping
- How two sets of housekeeping are related to one another [Boulding, 1966]

Boulding, K. E. (1966). The economics of the coming spaceship earth. *New York*, 1-17.

Emergence of environmental economics

❖ The role of classical economics to the development of environmental economics

❑ **Adam Smith [1776]**-''An Enquiry into the Nature and Causes of the Wealth of Nations''

- Natural resources key to wealth & growth [i.e. Land use]

❑ **Thomas Malthus [1798]**-''Essay on the Principle of Population''

- Population can grow through biological reproduction [i.e. renewable]
- Uncultivated land into productive use for subsistence living of mass people

❑ **David Ricardo [1817]**-''Principles of Political Economy and Taxation''

- Taxation on fossil fuels if harvested too long

❑ **John Start Mill [1857]**-''Growth of knowledge and technical progress''

- Innovation increases agricultural productivity

Fundamental environmental issues

- ✓ Property rights and government intervention
- ✓ Valuation techniques
- ✓ Irreversibility

Origins of Sustainability Problem

- ❑ Population Growth
- ❑ Poverty
- ❑ Low economic growth
- ❑ Poor income distribution
- ❑ Humanity’s ecological footprint
- ❑ Economic growth at the cost of environment

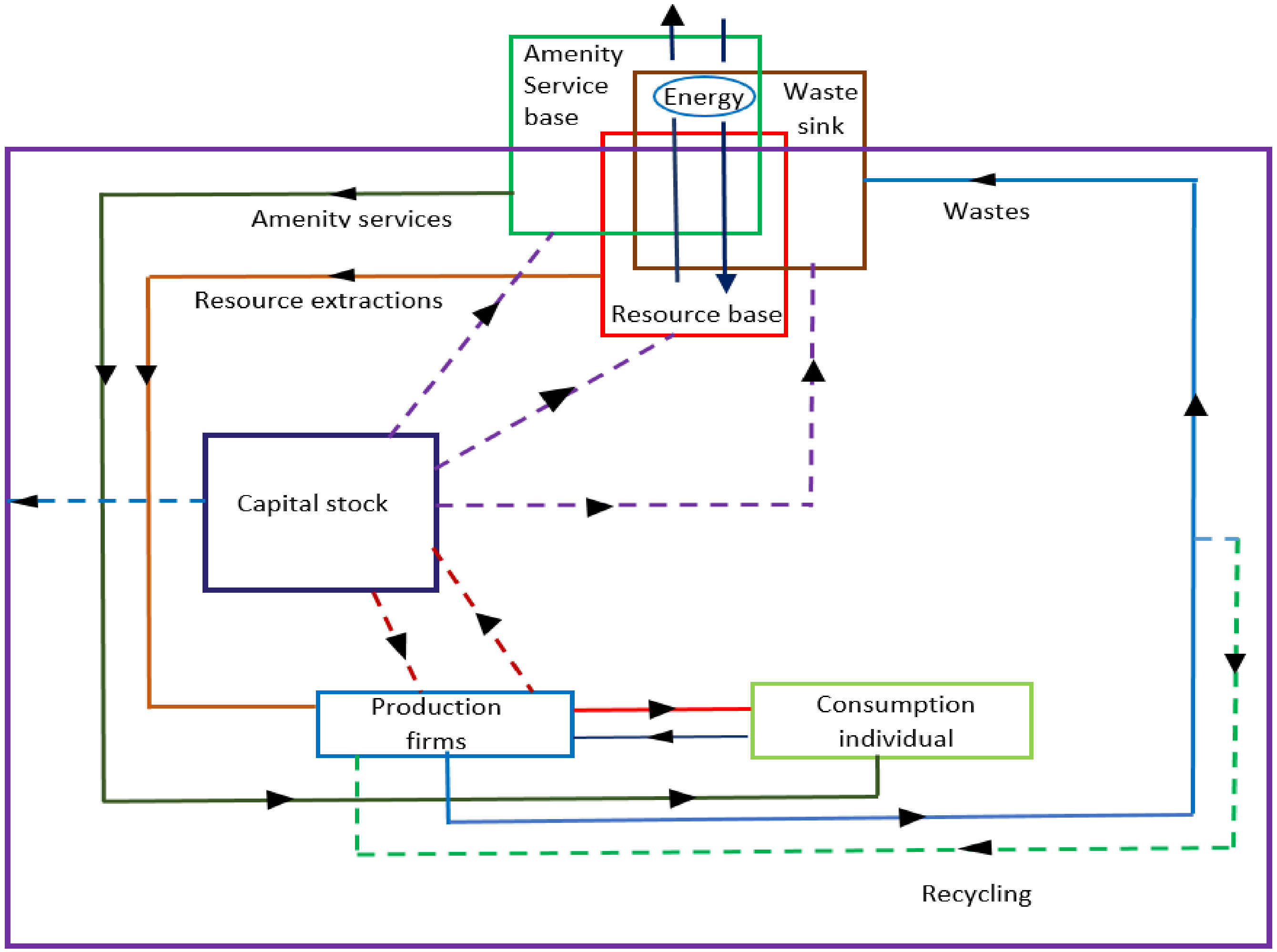
- ❖ Above issues we call the ‘‘sustainability problem’’

- ✓ How to alleviate poverty?

- Ensuring economic prospects
- Enhancing environmental health

Economy-environment relations

- Environment performs in relation to economic activity
- Economic activity performs in relation to environment



Source: Common, M., Common, M. S., & Michael, C. (1995). *Sustainability and policy: limits to economics*. Cambridge University Press

Economy-environment interdependence

- The services that environment provides
- Substituting for environmental services
- Some environmental science

Common, M., Common, M. S., & Michael, C. (1995). *Sustainability and policy: limits to economics*. Cambridge University Press

❑ The services that environment provides

- Flow resources
- Stock resources

✓ Flow resources: no link between current use and future availability

- Solar radiation-if a roof has a solar water heater on it, amount of water heating today

- Same water heating can be done tomorrow

- Renewable resources-biotic, plant & animal populations

- Capacity to grow over time via biological reproduction

✓ Stock resources: current use does affect future availability

- stocks of minerals-coal, oil [non-renewable-abiotic]
- Don’t have capacity to grow over time
- No positive constant rate of use
- Exhaustible or depletable resources
- Resources are exhaustible if harvested too long exceeding their generation capacities
- If harvest exceeds natural growth, unsustainable resources or declining stock size
- No natural reproduction except geological timescales

Renewable & exhaustible resources

- How they are managed?
- How they should be managed?

Renewable resource:

- It regenerates itself
- Examples-fish and trees
- Fishery-catch a number of fish and leave the rest to grow naturally
- Fish stock does not die with reproduction

Exhaustible resource [Gray, 1914; Hotelling, 1931]:

- It is fixed in overall quantity
- Usage in a given time is less available for other time
- Does not have regenerating capability
- Examples-coal and oil [fossil fuels] & minerals

Management Issue:

- Fish & trees are exhaustible if not managed in a sustainable way.

The tragedy of the commons

- ✓ Commons refer to common property
- ✓ Resources owned by a community
- ✓ Tragedy of the commons-unfortunate phrase
- ✓ Risk associated with the open access
- ✓ Tragedy of open access-no one owns the resource
- ✓ Open access causes resources to be extinct

❖ **Key argument**

- Free entry to fisheries should not be permitted.

Property rights and the management of renewable resources

❖ Problems

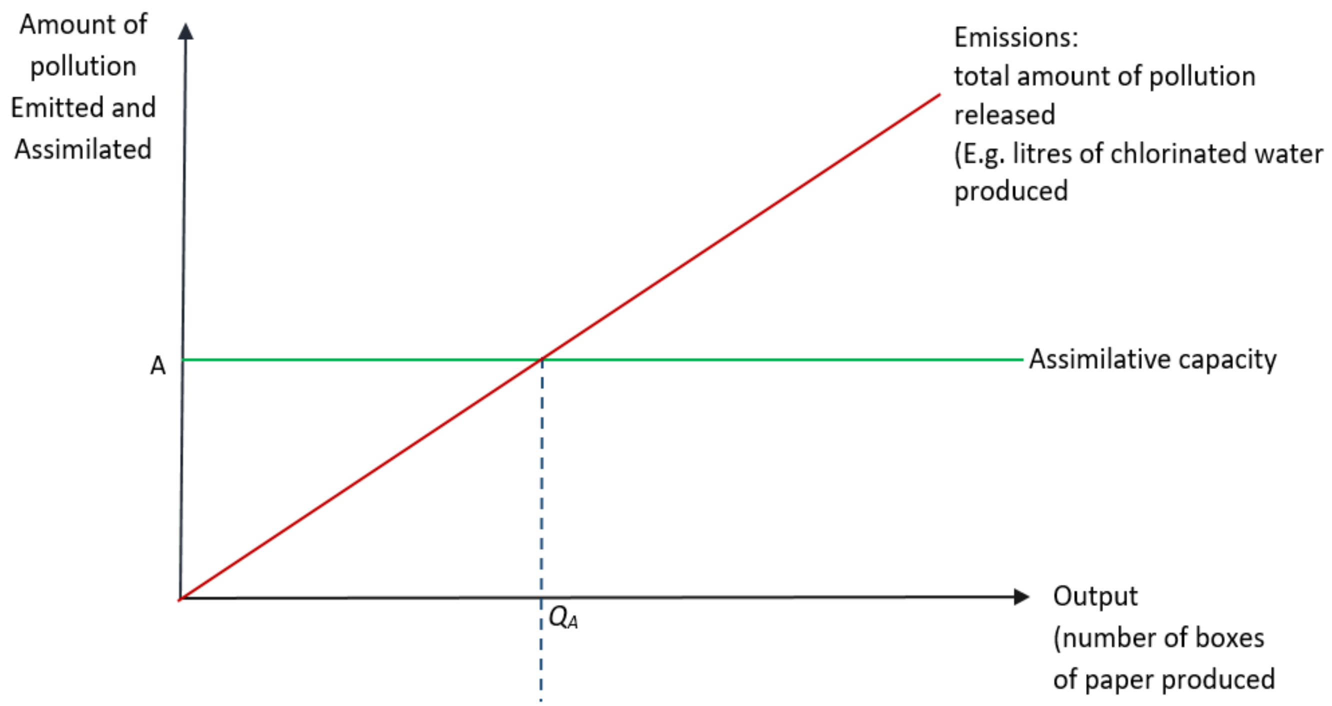
- Communal management of natural resources will break down
- Due to incentive to free ride
- Lack of property right
- Open access
- Renewable resources are under threat

❖ Way out

- Communal management
- State ownership
- Privatization

Pollution Possibilities

- No pollution if wastes or residual flows < assimilative capacity
- Pollution exists if wastes or residual flows > assimilative capacity



Threat from Pollution

- ✓ Pollution interfere with reproductive capacity of marine species
- ✓ Closure of the fishery
- ✓ Reduces recreational activity-swimming & boating
- ✓ Biological extinction
- ✓ Climate change & global warming

Advantages of Renewable and Non-renewable Energies

Renewable Energy	Non-Renewable Energy
✓ Operating cost is low.	✓ It is affordable and easily available.
✓ Environmental Friendly.	✓ Easy to use and more reliable in the short-run.
✓ Clean energy and more can be produced in the long-run.	✓ More can be produced in the short-run.
✓ Produces Low carbon emissions and stimulates green economy.	✓ known for its quick exploration.
✓ Infinite (stock)	✓ Expandable in response to human effort (flow)

Dis-advantages of Renewable and Non-renewable Energies

Renewable Energy	Non-Renewable Energy
✓ Expensive in the short-run, and less reliable and becomes affordable in the long-run.	✓ Eventually run out, becomes scarce and also becomes expensive.
✓ Not effective of producing energy in massive scale, particularly in the short-run.	✓ Threatening to the natural environment.
✓ It can be noisy and requires more space.	✓ Dirty Energy.
✓ Finite at a given time (flow)	✓ Finite (stock)

❑ Substituting for environmental services

- ✓ Reducing waste resources
- ✓ Recycling waste resources
- ✓ Reusing resources
- ❖ Once recycled materials substituted, extractions decline.
- ❖ Once reduced and reused, sustainability emerges.
- ❖ Natural capital is protected.
- ❖ Example-sewage treatment plant, control system, fuel-saving for waste sink

Managing waste [3 crore living population in India's capital city]

- ✓ 80% of water supplied to households
- ✓ Ends up as wastewater
- ✓ Threatening health and well-being of residents
- ❖ **Solution for sustainable water management**
- ✓ Wastewater treatment plant supports recycling
- ✓ Preventing pollution
- ✓ Supporting water security
- ✓ Non-potable uses like toilet flushing, car washing

The pollution levels in Yamuna have often triggered concern among environmentalists

https://www.unep.org/news-and-stories/story/how-reduce-pollution-delhis-waterways-study

Production with exhaustible resources

- Microeconomics: $Qi=fi(Li, Ki)$ (1)
- Resources Economics: $Qi=fi(Li, Ki, Ri)$ (2)
- Environmental Economics: $Qi=fi(Li, Ki, Mi)$ (3)
- Alternatively: Dirty Firms: $Qi=fi(Li, Ki, Mi, A[SumMi])$ (4)

Where

- Q is output of ith firms
- Li & Ki: labour and capital of ith firm's activity
- Ri: natural resources of ith firm's activity
- Mi: flow of resources arising from the ith firm's activity
- A: concentration level of some pollution derived from waste emissions across all firms

Rational use of exhaustible resources

- ✓ With renewable resource, easy to define ‘sustainability’
  - Resources used year after year
- ✓ With non-renewable resource, far away from ‘sustainability’
  - Resources are exhaustible

- ✓ **If no rational use, big problems arise**
  - Nature imposes limits on fish harvesting by killing the fish.
  - Imposes limits on our waste dumping by killing us.

The economics of exhaustible resources

- Minerals and forests disappear due to extraction
  - The feeling that these assets are too cheap
  - Selfishly exploited at a rapid rate
- Conservation movement on irreplaceable resources
  - Calls for regulation-carbon tax imposition
  - Prohibitions against oil and mineral development-optimal restrictions

Hotelling, H. (1931). The economics of exhaustible resources. *Journal of political Economy*, *39*(2), 137-175.

The problem of survival

- The problem of survival: A closed economy
- The problem of survival: An open economy
- On the development of a substitute for an exhaustible resources
- Green growth as a solution-production can be rearranged

❑ Some Environmental Science

❖ **Thermodynamics**

- **First law of thermodynamics**

✓ "Energy can neither be created nor destroyed but only transformed"

✓ Less conversion-more energy conservation

- **Second law of thermodynamics**

✓ "The entropy law"

✓ Measure of unavailable energy

✓ Energy conversion increases entropy

✓ Matters matter

✓ Complete recycling possible if energy available

The material balance principle

- Conservation of mass
- Economic activity involves transferring material extracted from the environment
- It is valuable to humans
- Materials extracted from the environment returned to.

- Identity principle states

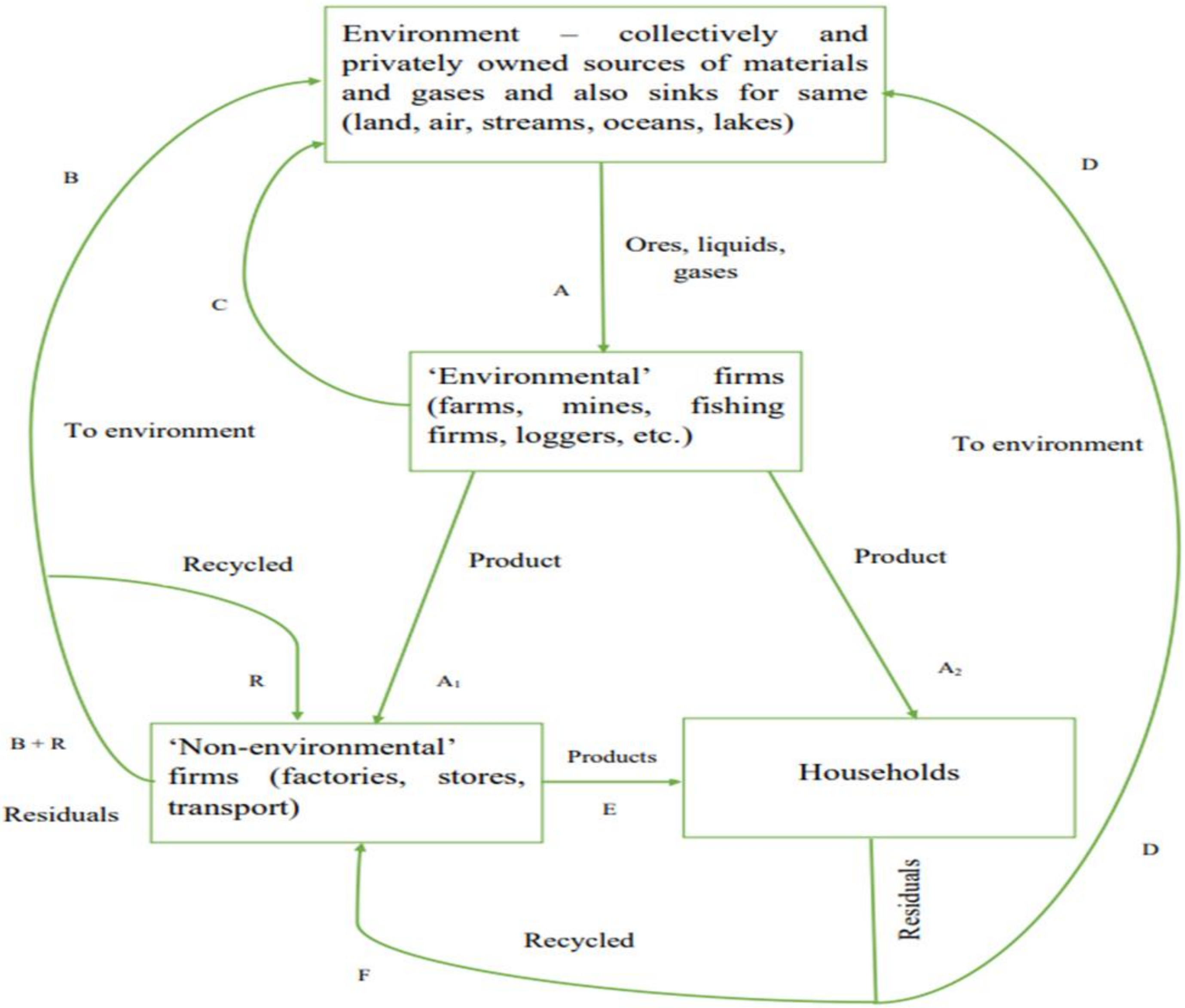
The environment: **A=B+C+D** **(1)**

Where

A: mass of materials flow from the environment

B+C+D: mass of residual material discharge flows to the environment

The Material Balance Principle



Source: Adapted from Herfindahl & Kneese (1974)

Environmental Firms [farms, fishing firms, mines]: **$A=A1+A2+C$** (2)

Non-Environmental Firms [factories, stores, transport]: **$B+R+E=R+A1+F$** (3)

Households: **$A2+E=D+F$** (4)

❑ Economic and environmental Implications

- Mass of residuals into the environment [B+C+D]=mass of fuels, food and raw materials extracted from the environment
- Treatment of residuals from economic activity does not reduce their mass
- Rather it alters their form
- Extent of recycling is important
- Residual recycling increases, extraction of resources decreases
- Increasing efficiency of materials utilization through recycling process

Ecology

❑ Ecology

✓ Abundance of plants and animals

❑ Ecosystem

✓ Interaction between plants and animals

❑ Elements of ecosystem

✓ Abiotic-non-living [wind, water, sunlight, soil, atmosphere, temperature]
✓ Biotic-living [plants, animals, bacteria]

❑ Biodiversity loss

- Variability of all living organisms in terrestrial and marine ecosystems [animals die]
- Loss of forest and minerals

Drivers of ecological collapse

❑ Causes of ecological collapse

- Humanity's ecological footprint
- Harvesting timber
- Grazing domesticated animals
- Growing crops
- Fishing
- Construction of housing, road and factories

❑ Loss of biodiversity and human impact

- Over the past 200 years, humans have changed ecosystems more rapidly.
- Resulted in irreversible loss and degradation of many ecosystems.
- These problems unless addressed, will diminish benefits that future generations obtain from ecosystems.

Insurance against ecological collapse

- **Human science**
  - Walking
  - Cycling
- **Physical science**
  - Electric vehicles
- **Natural science**
  - Planting trees
  - Resilience

The drivers of environmental impact

- ❑ Environmental impact of economic activity

  - ✓ Extractions from the environment

  - ✓ Insertions into the environment

- ❑ The IPAT Identity=population, affluence and technology

I=PxAxT (1), tonnes= n x $/n x tonnes/$ (2)

Where

I: Impact (measured in volume i.e. tonnes)

P: population (in size [n])

A: Influence (in per capita i.e. GDP/population [$])

T: Technology (resource use [tonnes] per unit of production i.e. Resource use/GDP)

Class Test 1 on 8/09/2022

- **Answer any *two* of the following questions** **Marks: 2x5=10**

1. Explain the effective reasons for choosing an alternative energy
2. Describe the key driving factors of ecological collapse
3. Explain green growth as a solution for effective pollution reduction

The Role of Energy in Economic Development

❑ Role of Energy

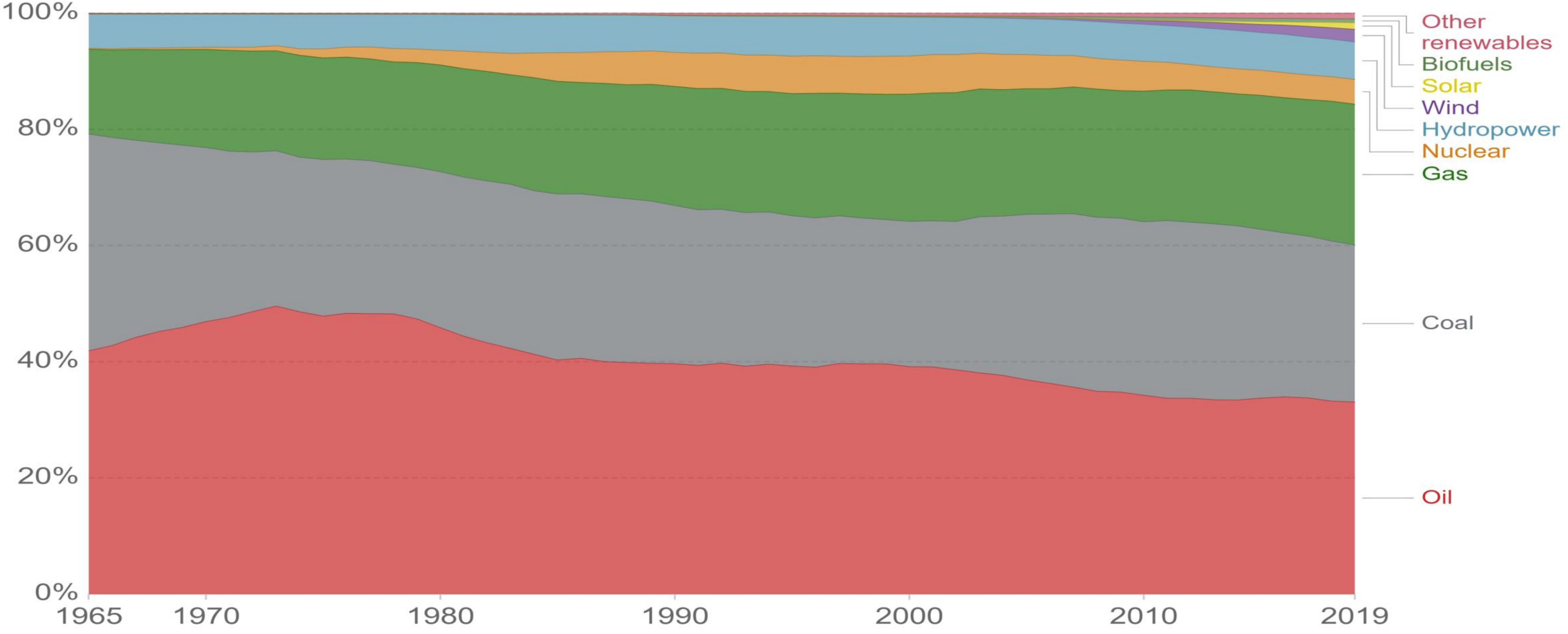
- Energy is an input in economic activities.
- Energy consumption matters for households, firms and governments.

❑ Environmental Consequences

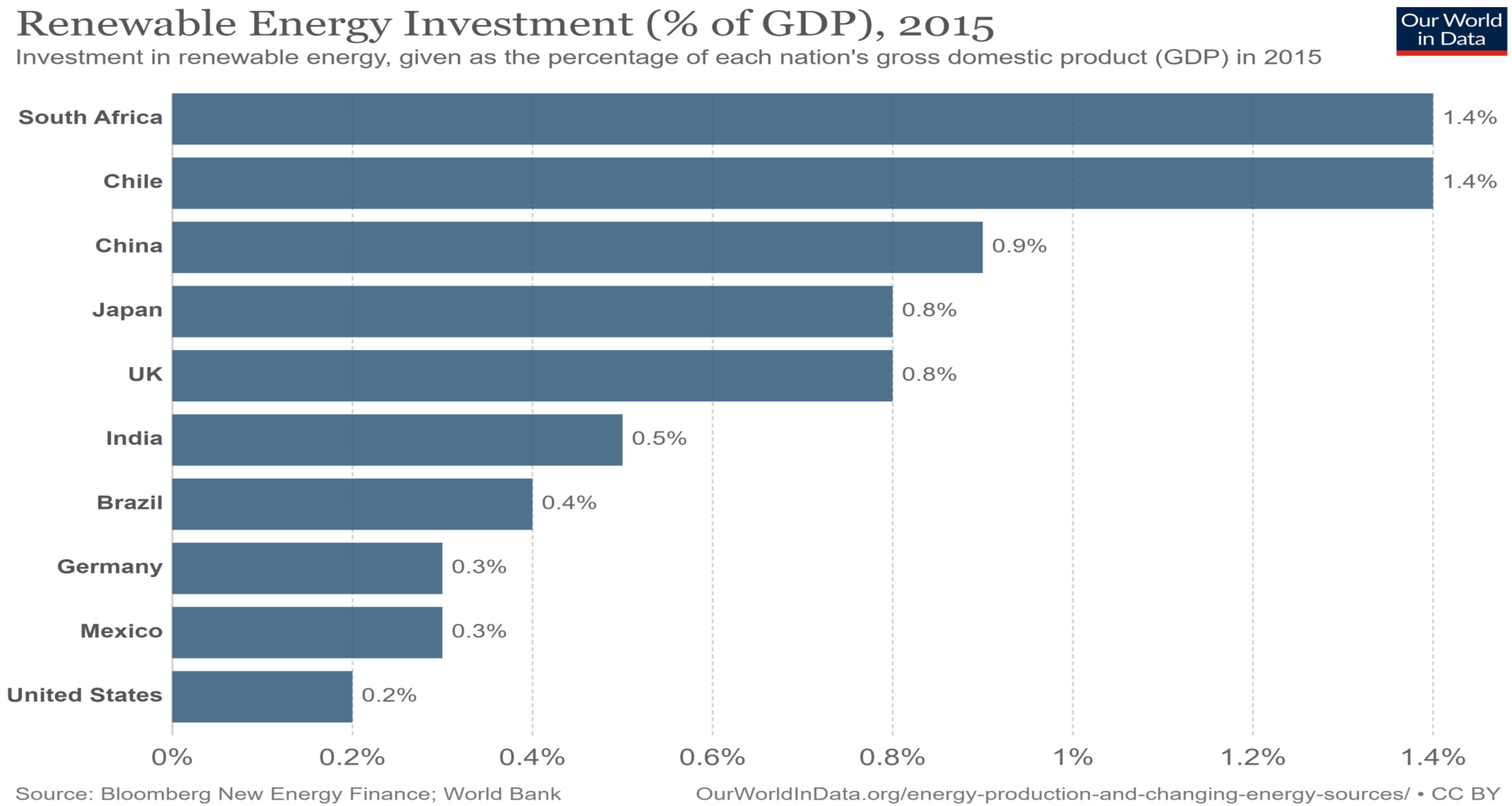
- Planet is becoming hotter because of fossil fuels extraction and usage.
- Excessive energy usage creates ‘‘anthropogenic carbon emissions’’.
- Pollution level in the atmosphere is increasing due to ‘‘human activities’’.

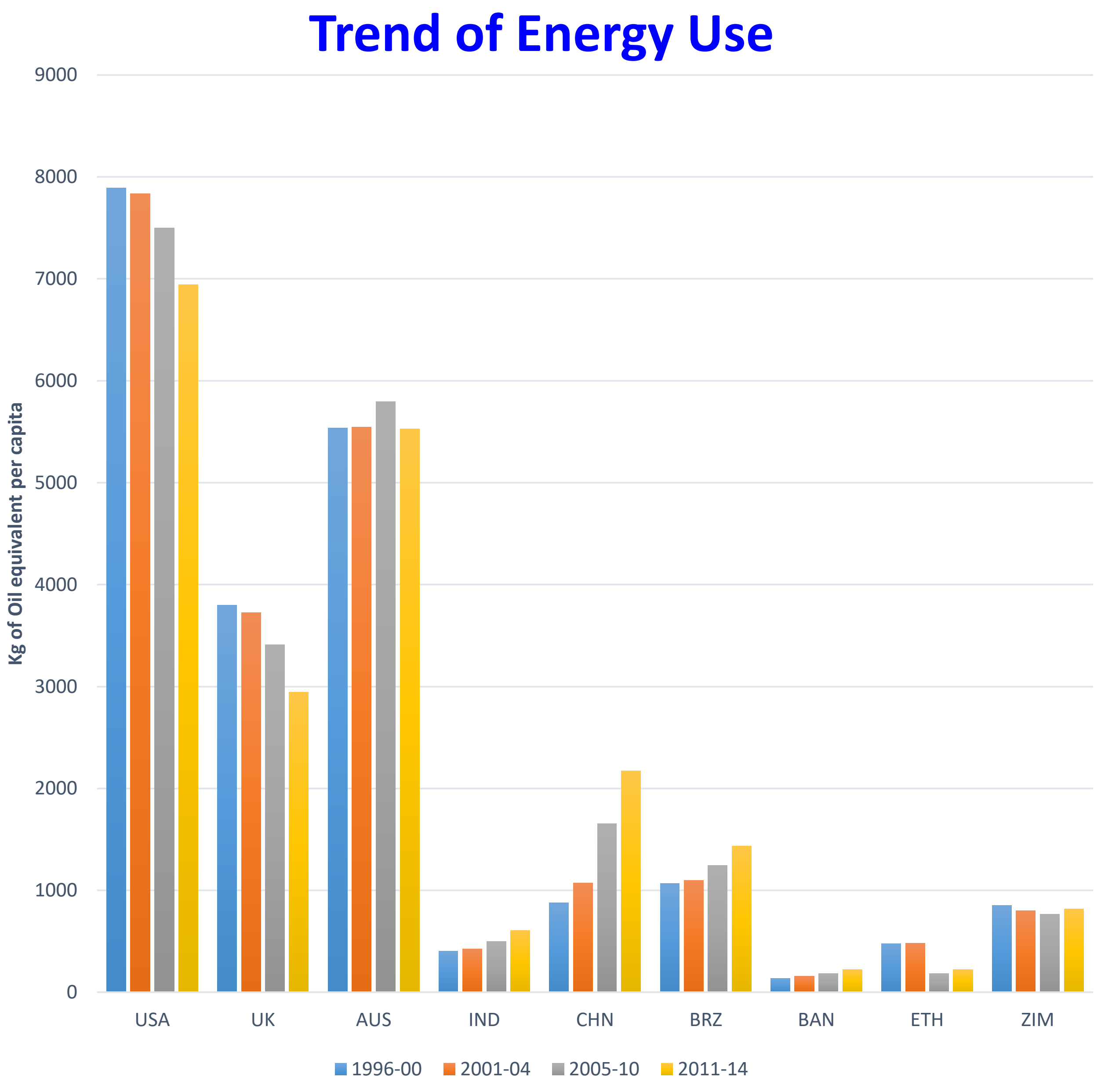
Energy consumption by source, World

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.

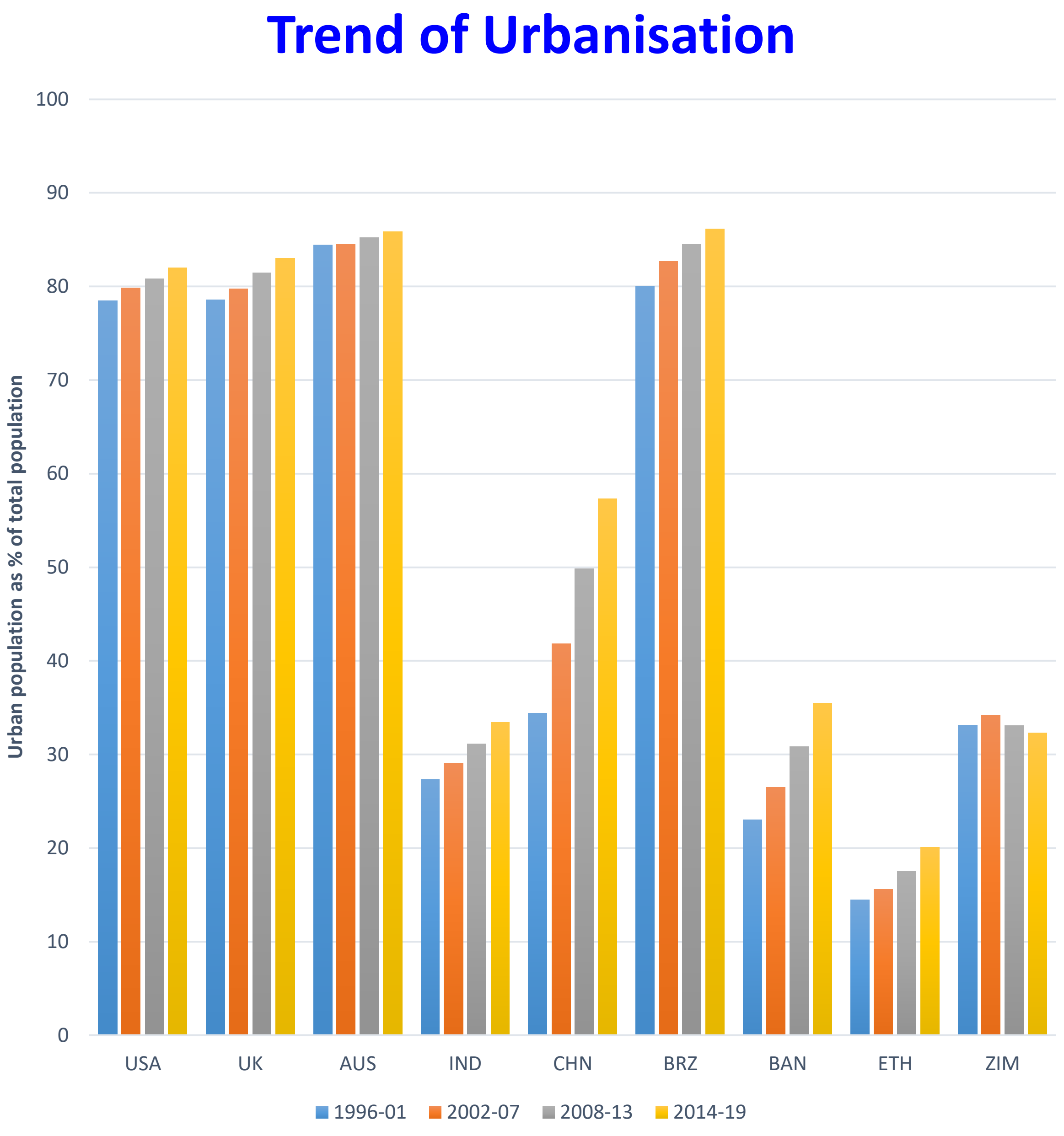


Source: BP Statistical Review of World Energy
Note: 'Other renewables' includes geothermal, biomass and waste energy.


Renewable Energy Investment (% of GDP), 2015
Investment in renewable energy, given as the percentage of each nation's gross domestic product (GDP) in 2015
Our World in Data
South Africa
1.4%
Chile
1.4%
China
0.9%
Japan
0.8%
UK
0.8%
India
0.5%
Brazil
0.4%
Germany
0.3%
Mexico
0.3%
United States
0.2%
0%
0.2%
0.4%
0.6%
0.8%
1%
1.2%
1.4%
Source: Bloomberg New Energy Finance; World Bank
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY



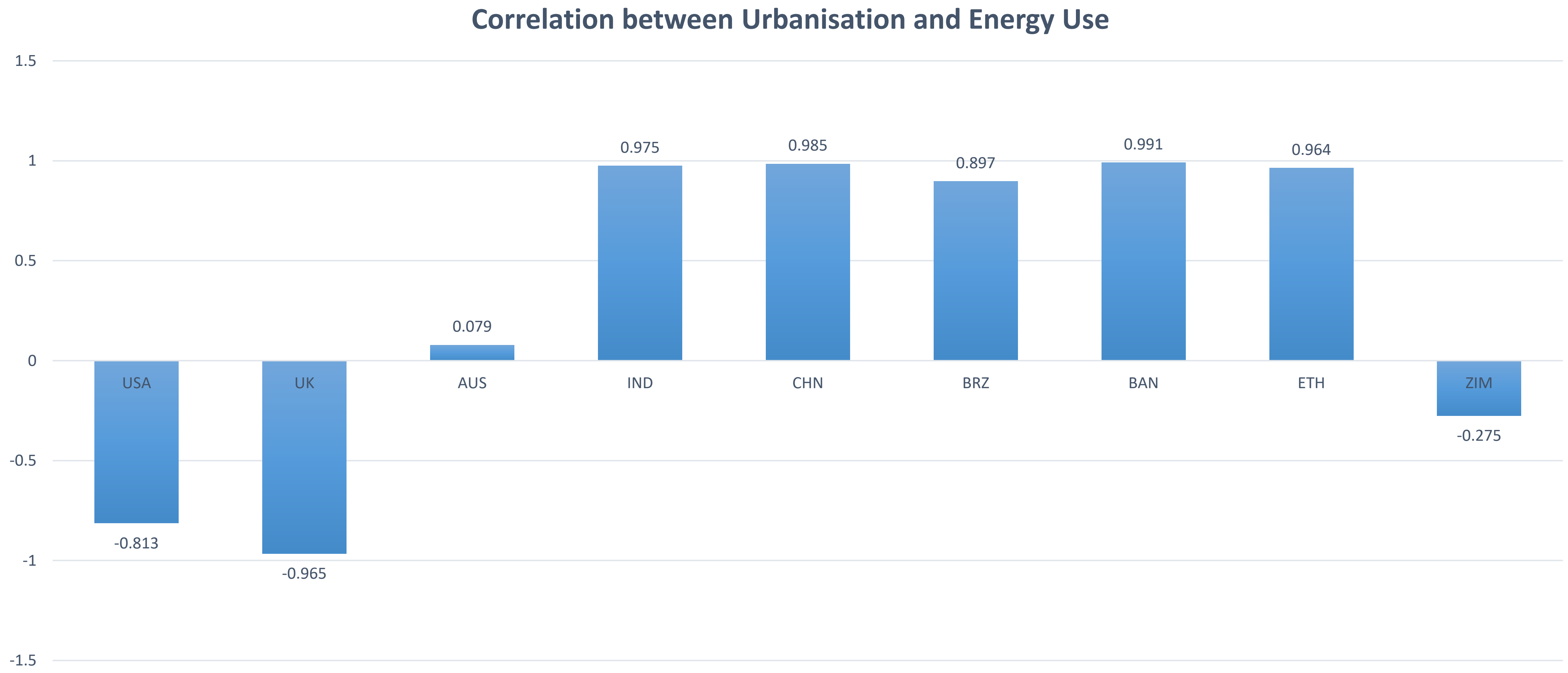
Trend of Energy Use
Kg of Oil equivalent per capita
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
USA
UK
AUS
IND
CHN
BRZ
BAN
ETH
ZIM
1996-00
2001-04
2005-10
2011-14

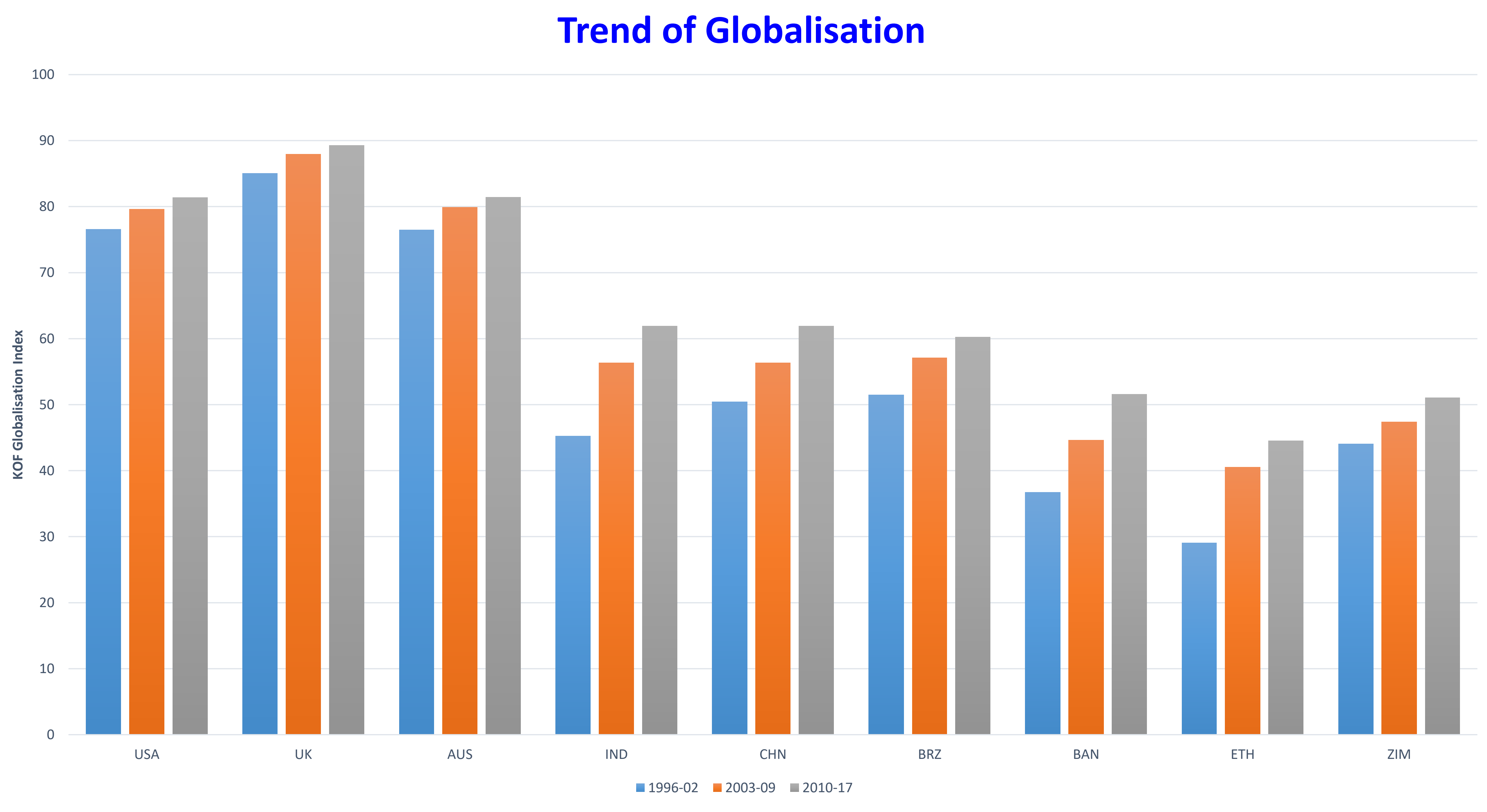


Trend of Urbanisation
Urban population as % of total population
100
90
80
70
60
50
40
30
20
10
0
USA
UK
AUS
IND
CHN
BRZ
BAN
ETH
ZIM
1996-01
2002-07
2008-13
2014-19

Correlation between Urbanisation and Energy use

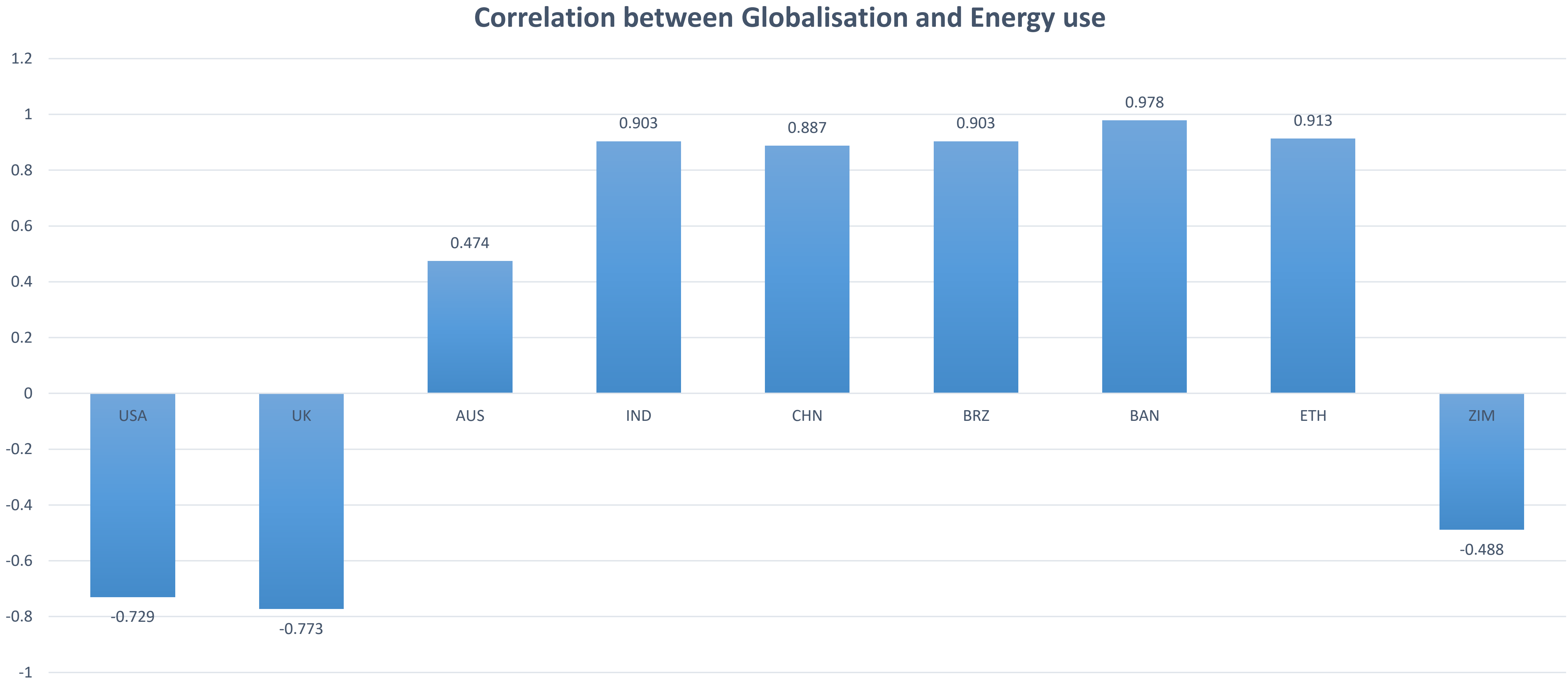
USA	UK	AUS	IND	CHN	BRZ	BAN	ETH	ZIM
-0.8137	-0.9652	0.079104	0.975913	0.985266	0.897754	0.991837	0.964068	-0.276

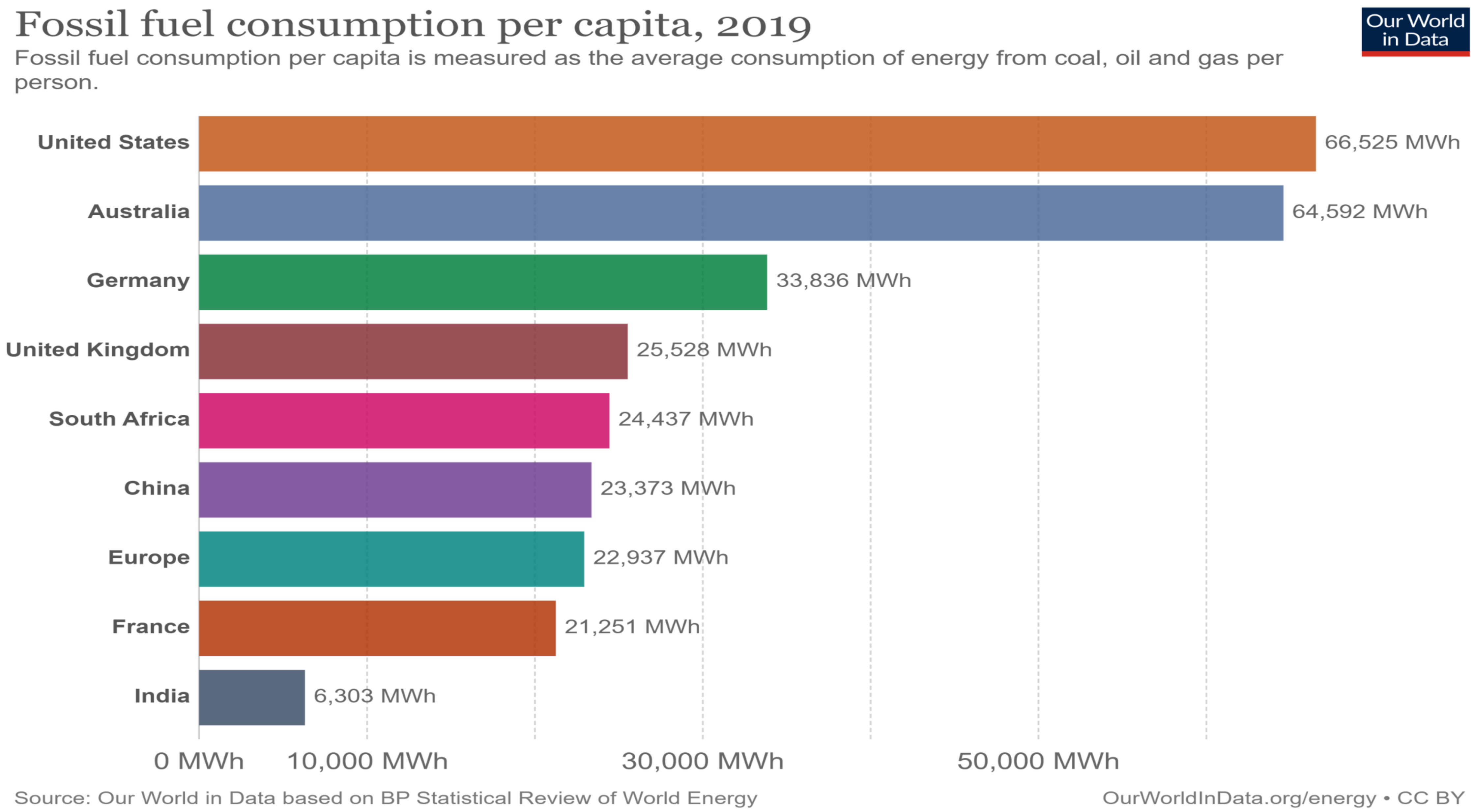


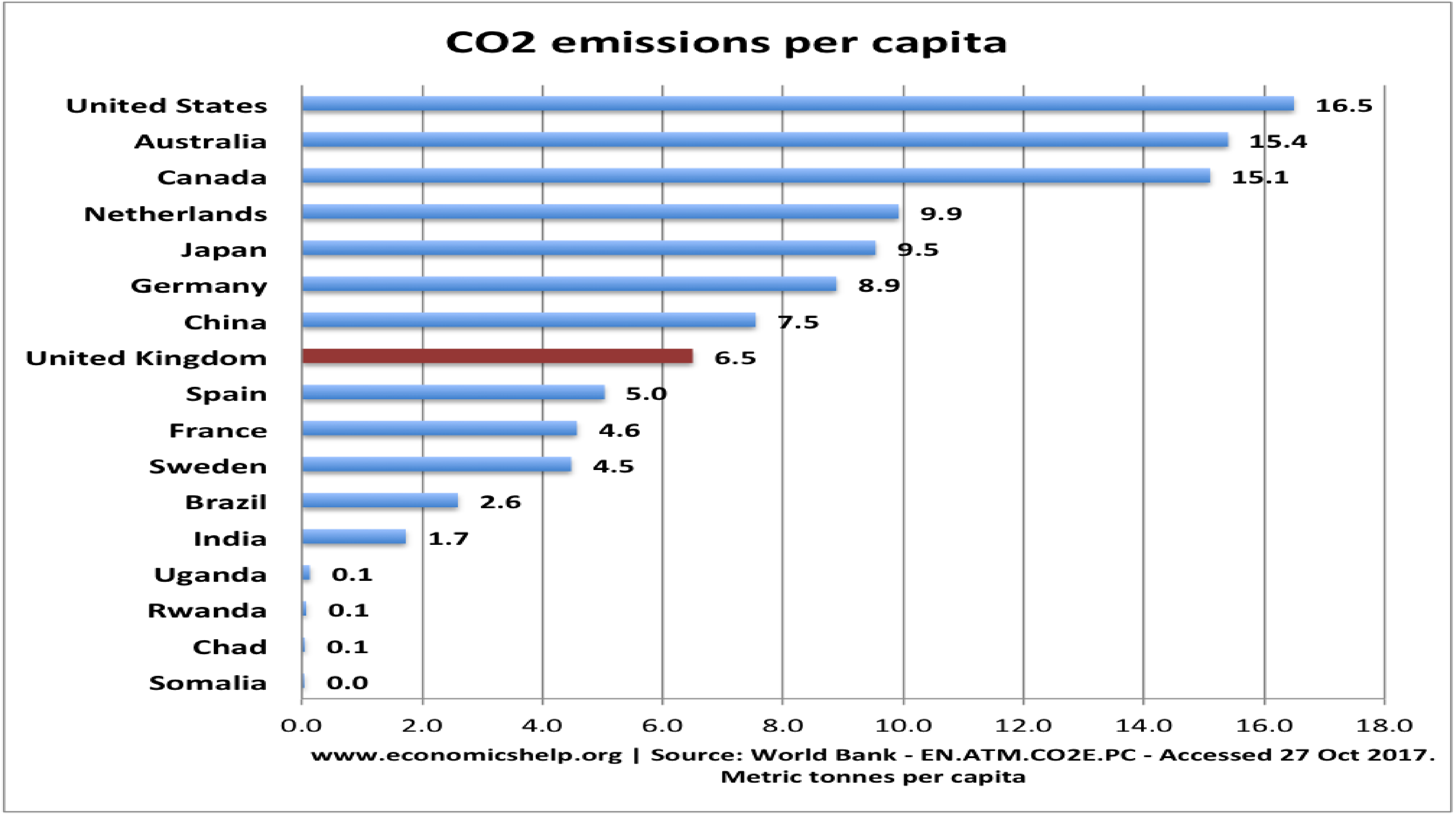

Trend of Globalisation
KOF Globalisation Index
100
90
80
70
60
50
40
30
20
10
0
USA
UK
AUS
IND
CHN
BRZ
BAN
ETH
ZIM
1996-02
2003-09
2010-17

Correlation between Globalisation and Energy Use

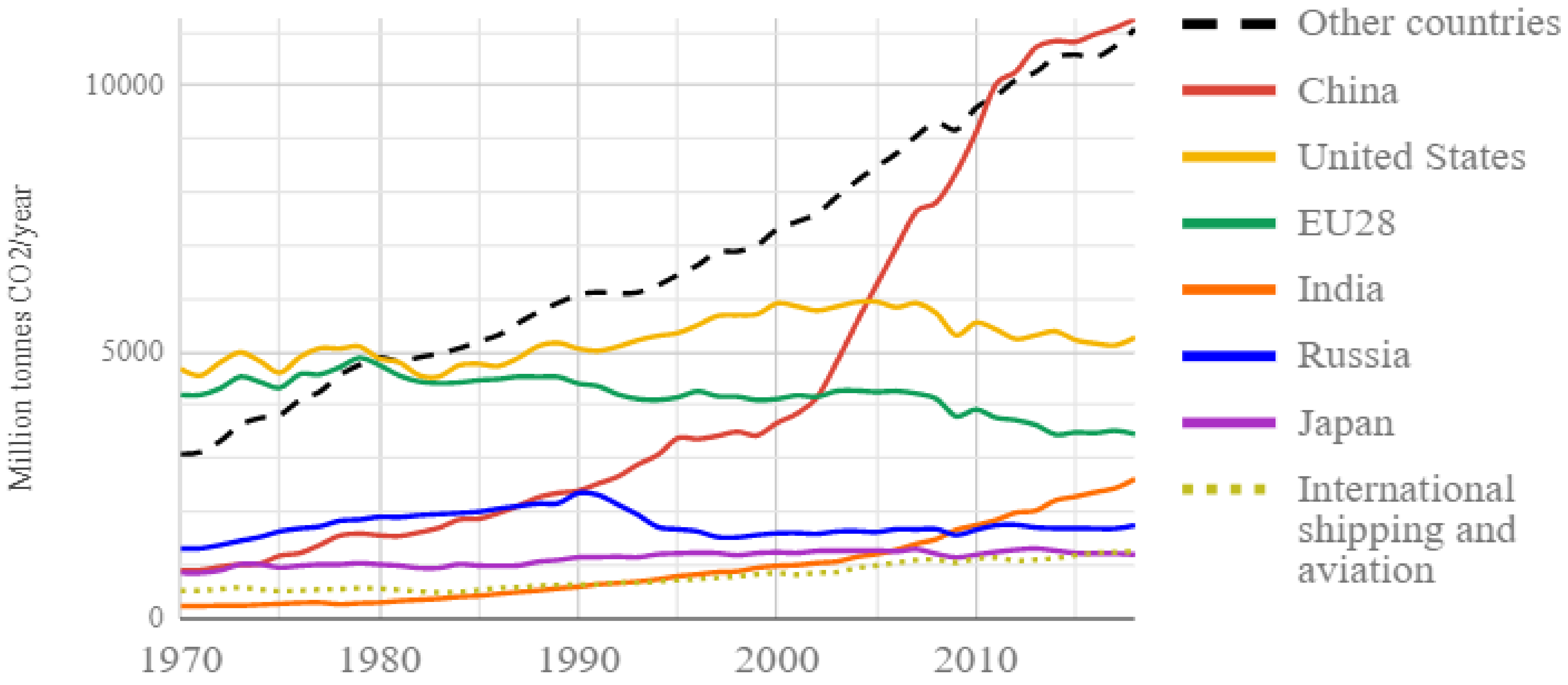
USA	UK	AUS	IND	CHN	BRZ	BAN	ETH	ZIM
-0.729	-0.773	0.474	0.903	0.887	0.903	0.978	0.913	-0.488



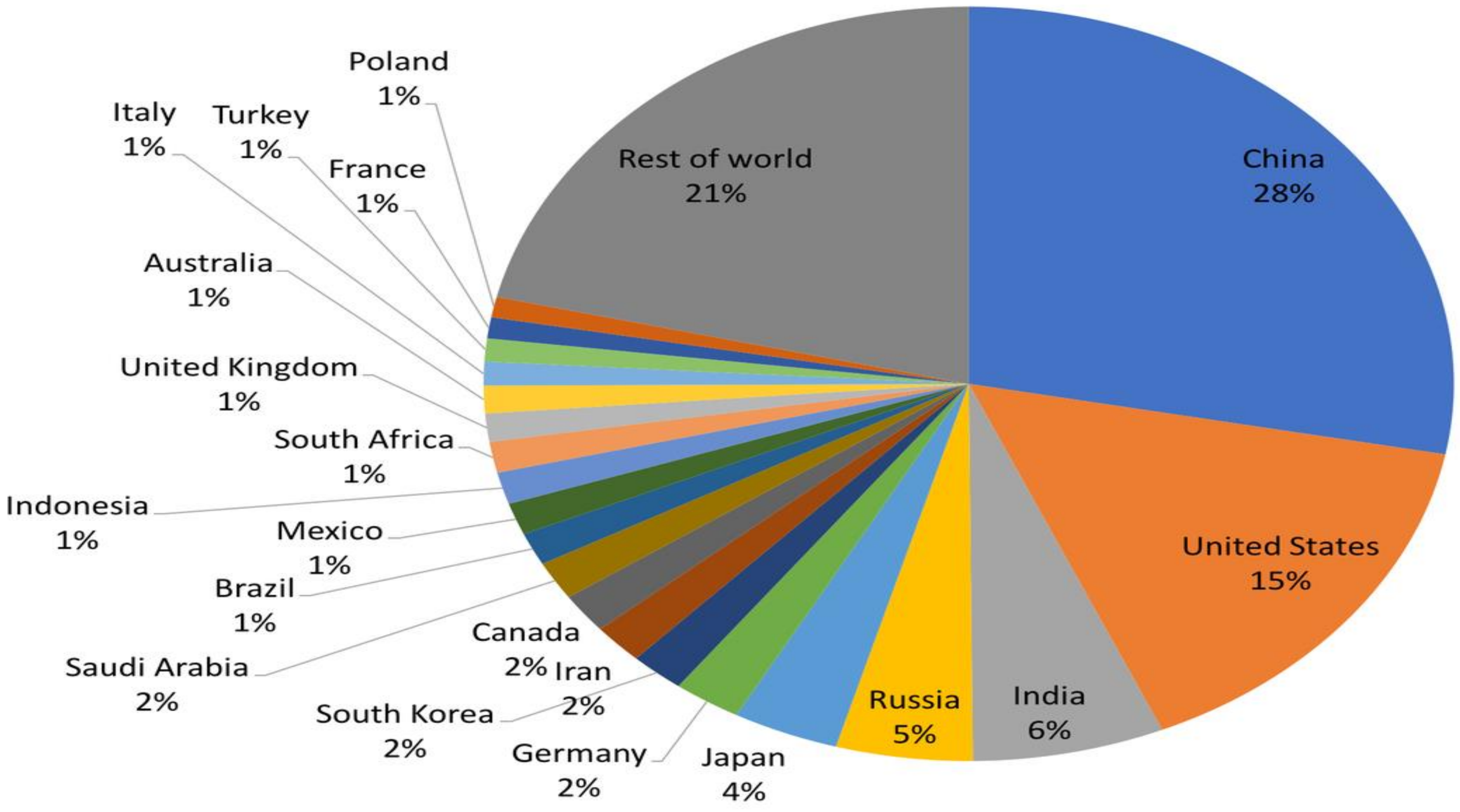

Fossil fuel consumption per capita, 2019
Fossil fuel consumption per capita is measured as the average consumption of energy from coal, oil and gas per person.
Our World in Data
United States
66,525 MWh
Australia
64,592 MWh
Germany
33,836 MWh
United Kingdom
25,528 MWh
South Africa
24,437 MWh
China
23,373 MWh
Europe
22,937 MWh
France
21,251 MWh
India
6,303 MWh
0 MWh
10,000 MWh
30,000 MWh
50,000 MWh
Source: Our World in Data based on BP Statistical Review of World Energy
OurWorldInData.org/energy • CC BY


CO2 emissions per capita
United States
16.5
Australia
15.4
Canada
15.1
Netherlands
9.9
Japan
9.5
Germany
8.9
China
7.5
United Kingdom
6.5
Spain
5.0
France
4.6
Sweden
4.5
Brazil
2.6
India
1.7
Uganda
0.1
Rwanda
0.1
Chad
0.1
Somalia
0.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
www.economicshelp.org | Source: World Bank - EN.ATM.CO2E.PC - Accessed 27 Oct 2017.
Metric tonnes per capita

World fossil carbon dioxide emission 1970-2018

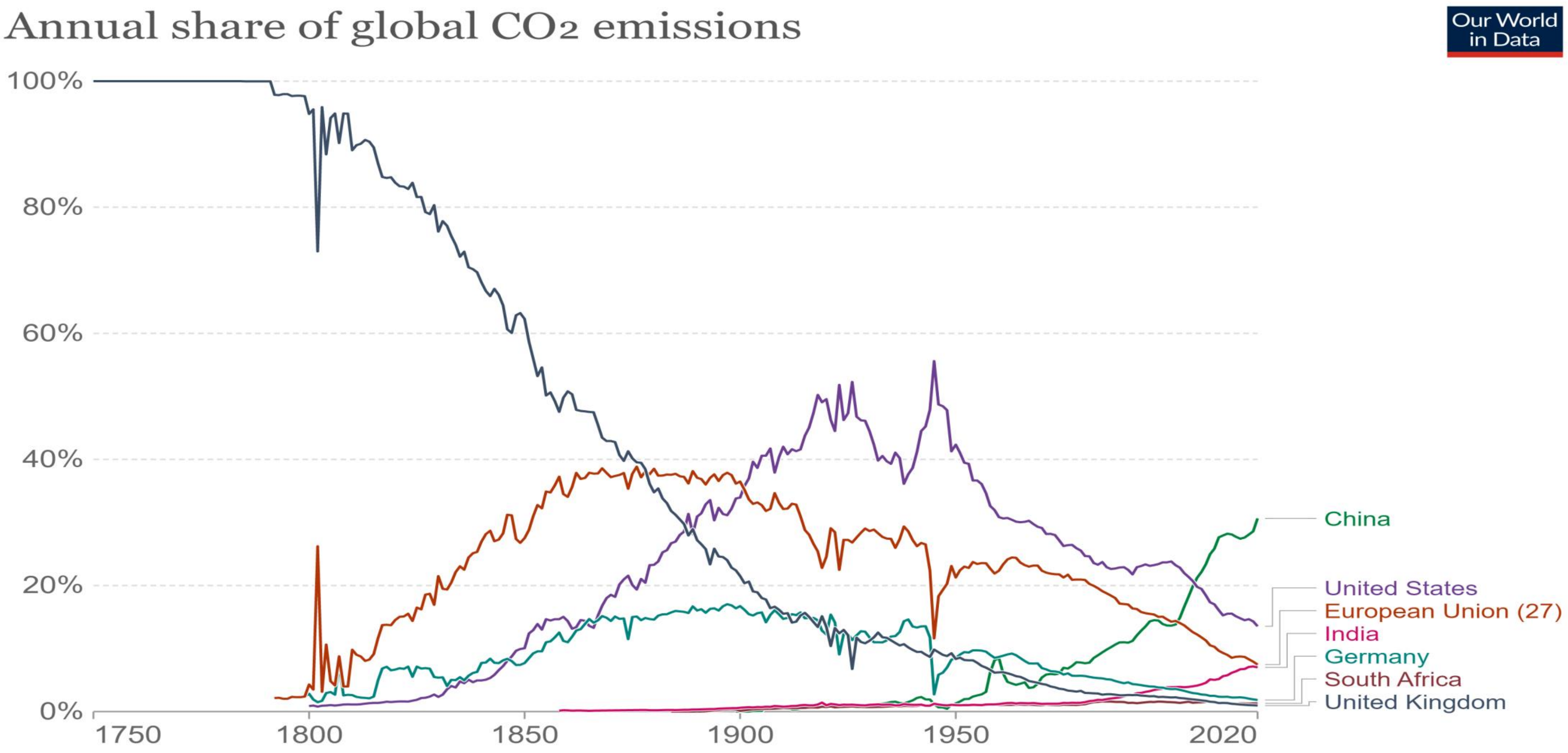


Share of global carbon dioxide emissions from fuel combustion (2015)



Data: IEA
Image: Union of Concerned Scientists

Annual share of global CO_2 emissions

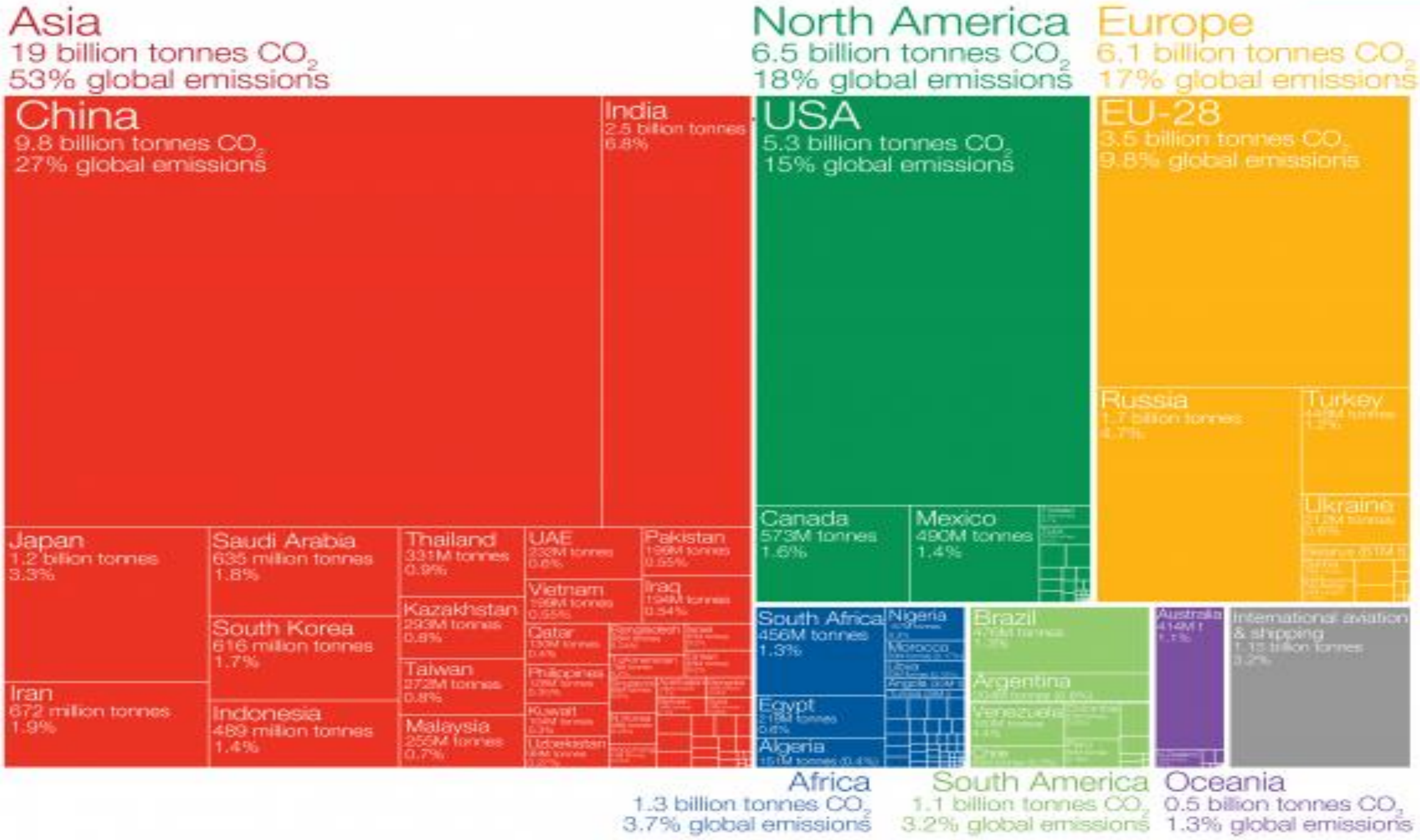


Source: Our World in Data based on the Global Carbon Project OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY
Note: This is measured as each country's emissions divided by the sum of all countries' emissions in a given year plus international aviation and shipping (known as 'bunkers') and 'statistical differences' in carbon accounts.

Who emits the most CO_2?

Global carbon dioxide (CO_2) emissions were 36.2 billion tonnes in 2017.

Our World in Data



Shown are national production-based emissions in 2017. Production-based emissions measure CO_2 produced domestically from fossil fuel combustion and cement, and do not adjust for emissions embedded in trade (i.e. consumption-based).

Figures for the 28 countries in the European Union have been grouped as the 'EU-28' since international targets and negotiations are typically set as a collaborative target between EU countries. Values may not sum to 100% due to rounding.

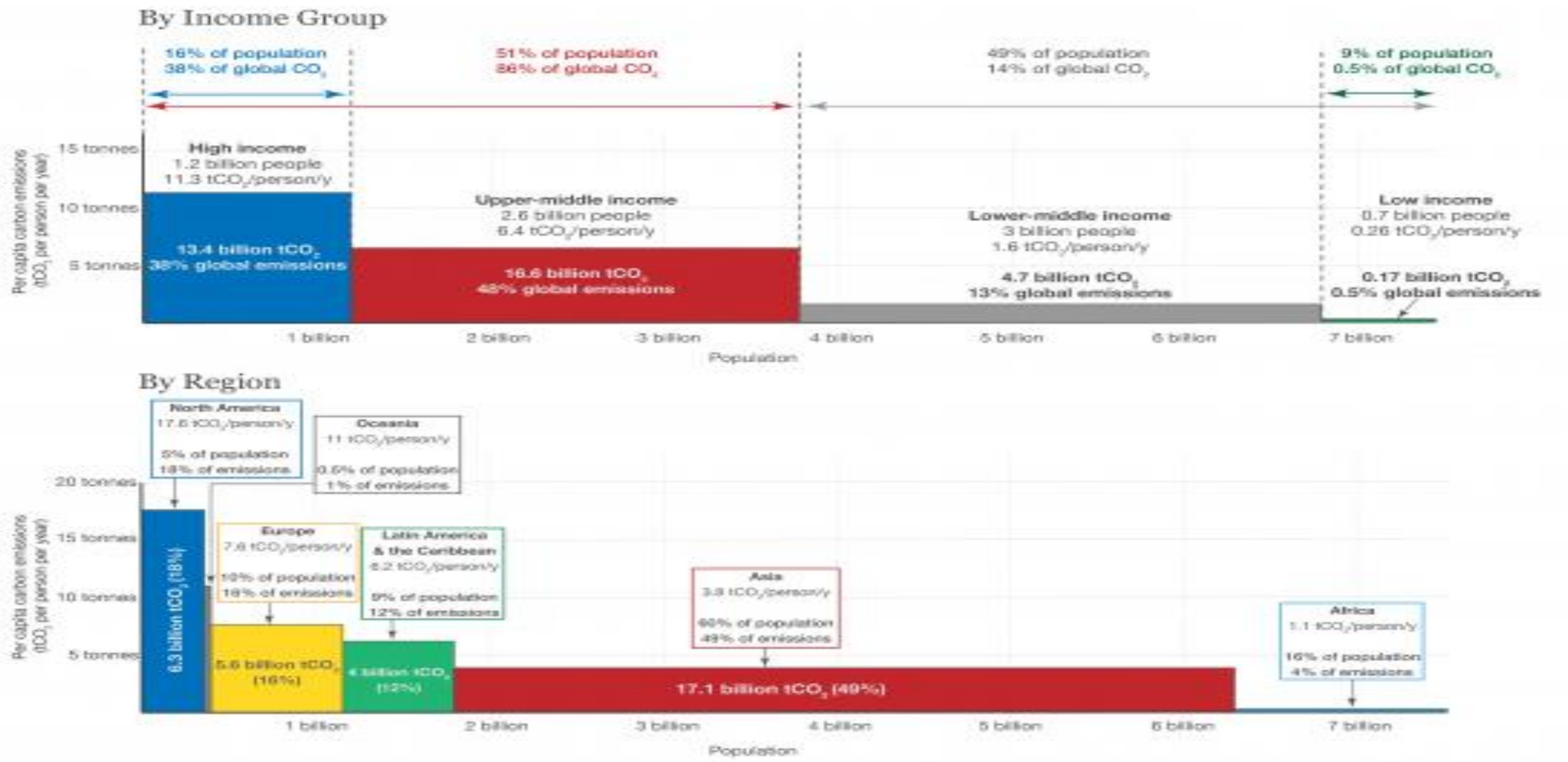
Data source: Global Carbon Project (GCP).

This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.

Global CO_2 emissions by income and region

Breakdown of global carbon dioxide (CO_2) emissions in 2016 by World Bank income group (top) and world region (bottom). This is shown based on average per capita emissions (y-axis) and population size (x-axis), with the area of the box representing total annual emissions in 2016.

- Emissions represent domestic production (not accounting for embeddded emissions in traded products), and do not include cross-boundary emissions such as international aviation & shipping.
- Aggregation by income is based on the total emissions of countries within each of the World Bank's income groupings. It reflects average national incomes rather than the distribution of incomes within countries. E.g. 'Low income' reflects the total emissions of all countries defined as low income, rather than the emissions of global individuals defined as low income. If defined on the basis of individuals (without country contexts), the global inequality would be even larger.



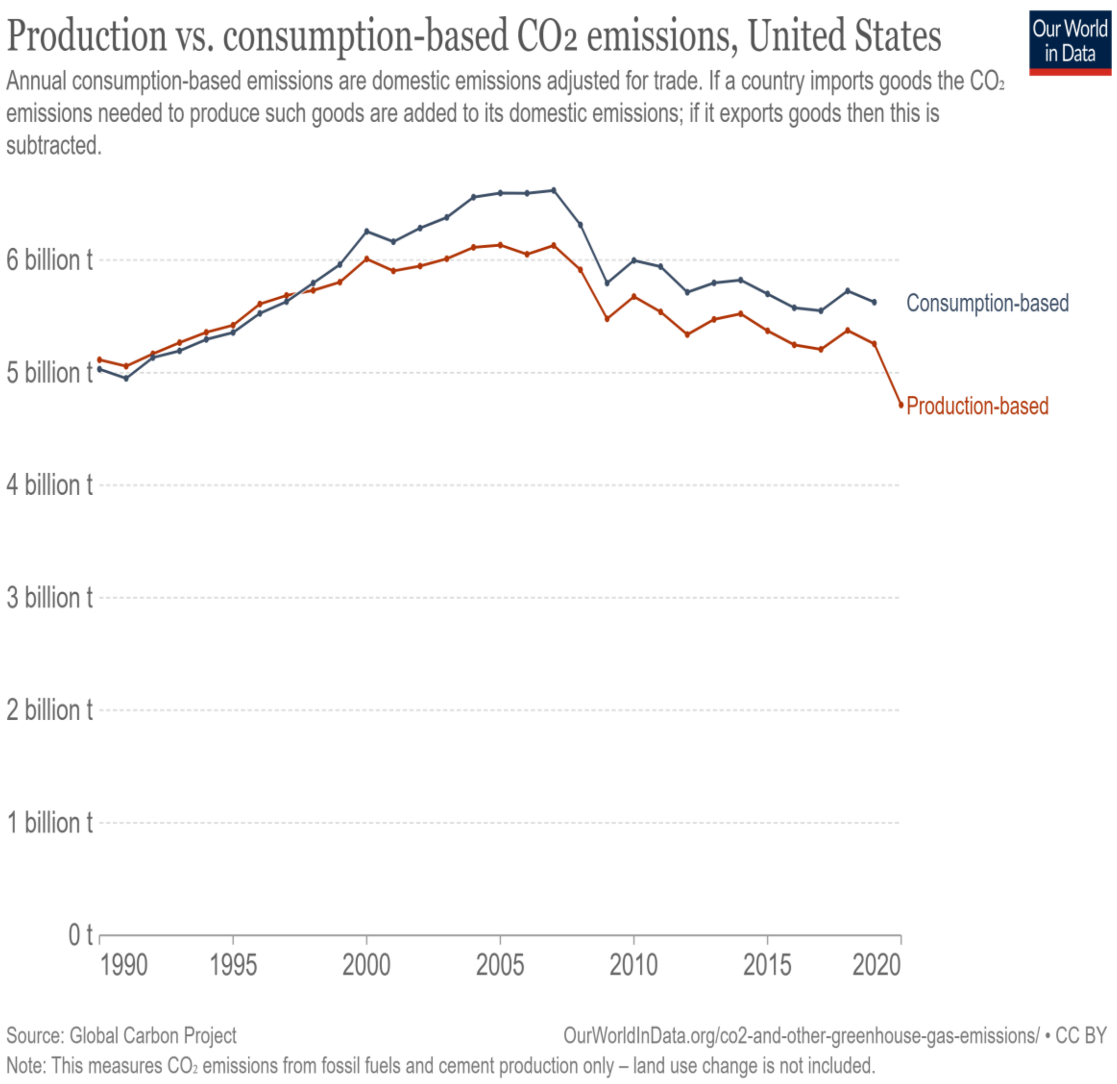
Source: Our World in Data based on data from the Global Carbon Project, UN Population Division (2016) & World Bank income groups.
This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing.

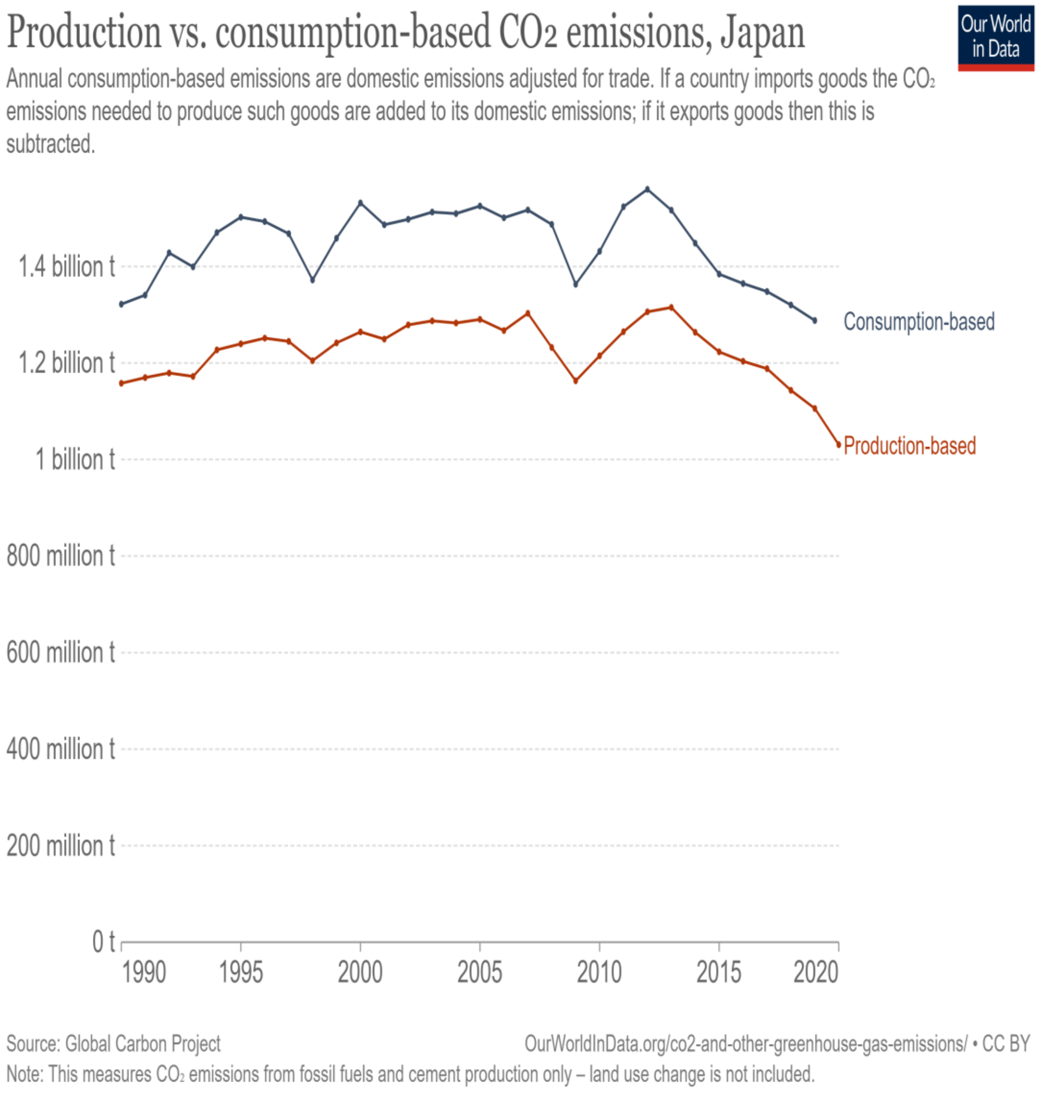
Global Pollution Inequalities

Income or regional group	Share of population (%)	Share of production-based CO_2 emissions (%)	Share of consumption-based CO_2 emissions (%)
High income **[83 countries]**	16%	39%	**46%**
Upper-middle income **[56 countries]**	35%	**48%**	41%
Lower-middle income **[50 countries]**	40%	13%	13%
Low income **[28 countries]**	9%	0.4%	0.4%
North America [40 countries]	5%	17%	**19%**
Europe [50 countries]	10%	16%	**18%**
Latin America & the Caribbean [33 countries]	9%	6%	6%
Asia [50 countries]	60%	**56%**	52%
Africa [57 countries]	16%	**4%**	3%
Oceania [23 countries]	0.5%	1.3%	1.3%

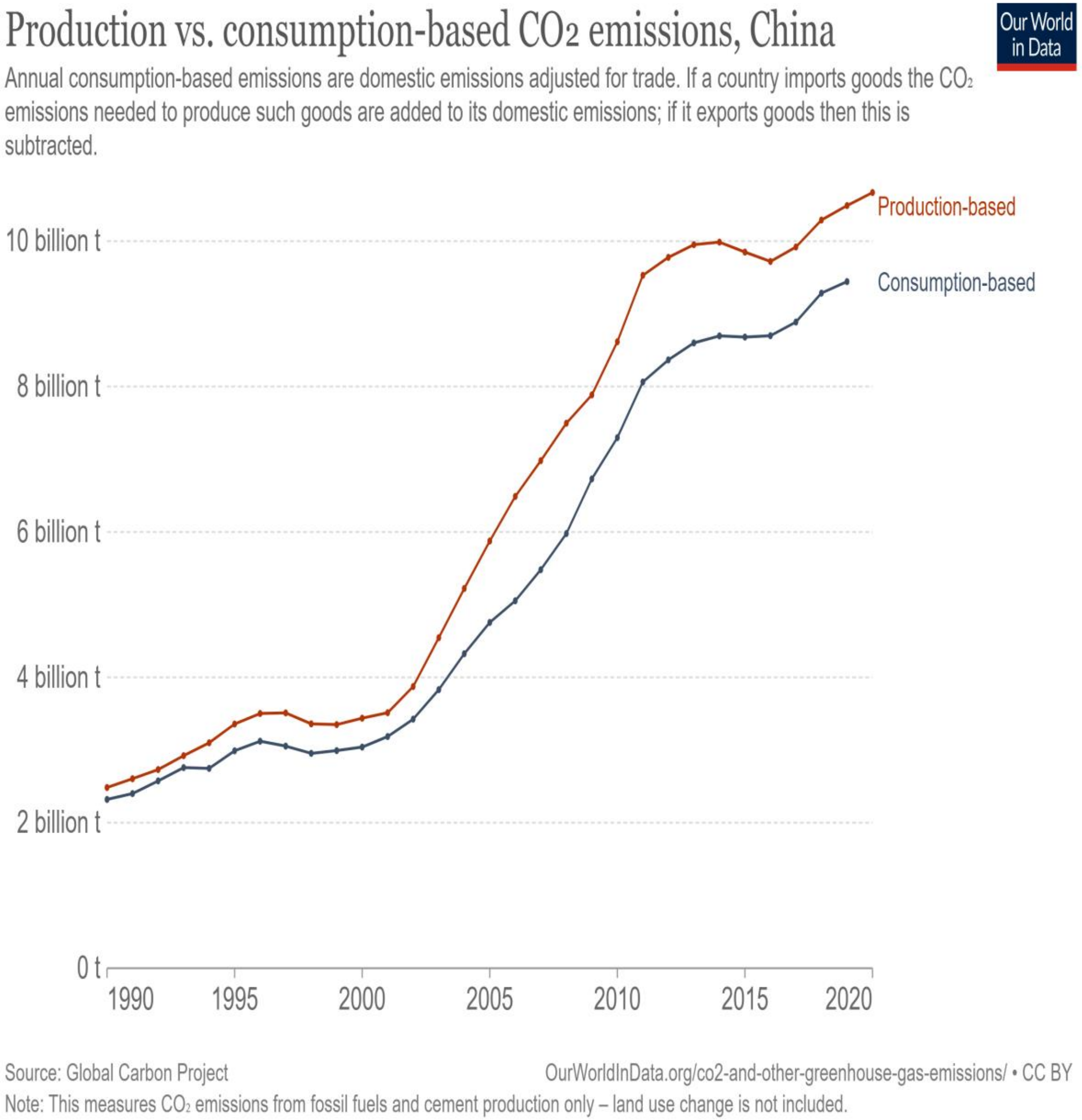
https://ourworldindata.org/co2-emissions

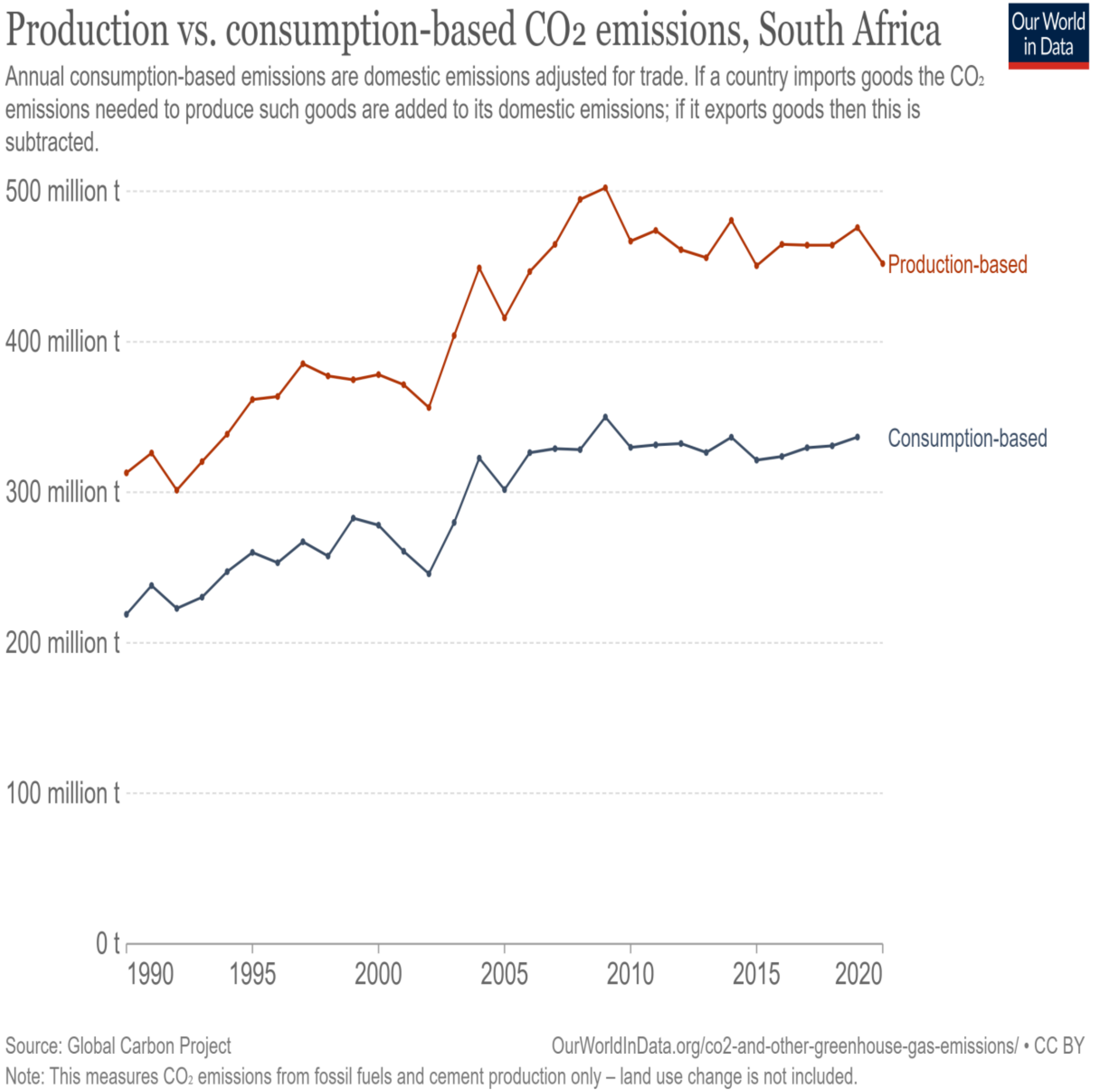
High Income Countries





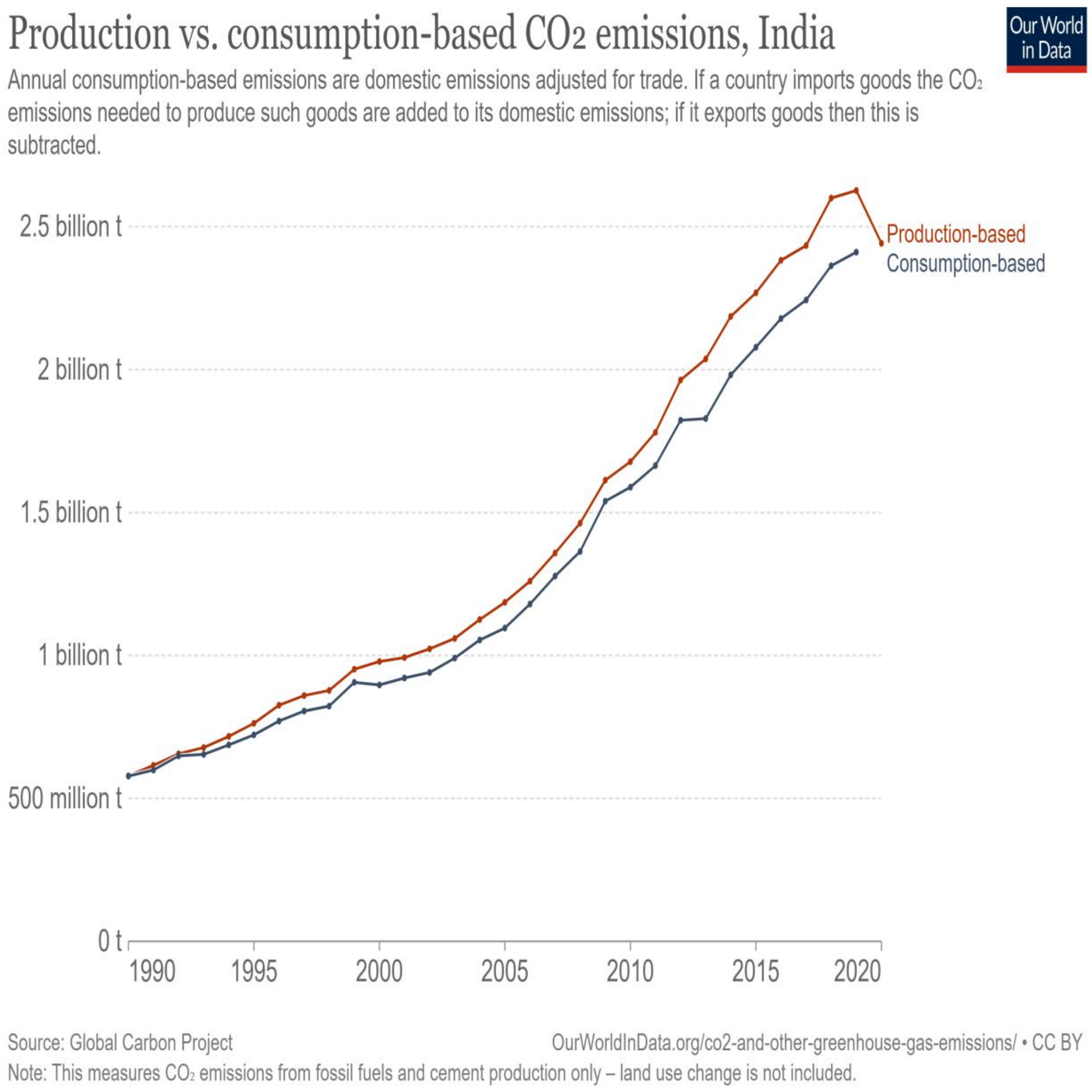
Upper-Middle Income Countries

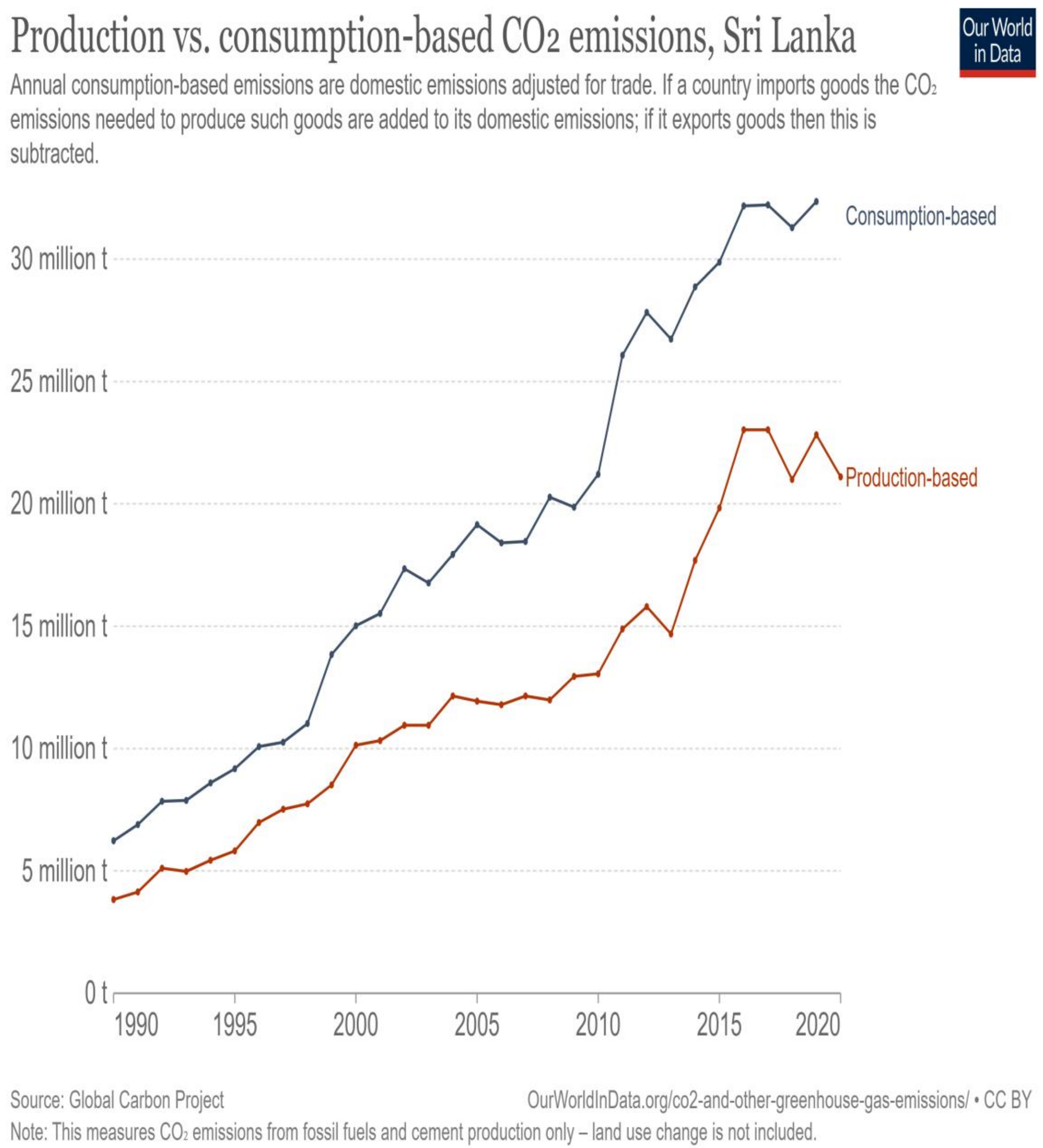




https://ourworldindata.org/grapher/production-vs-consumption-co2-emissions?country=~ZAF

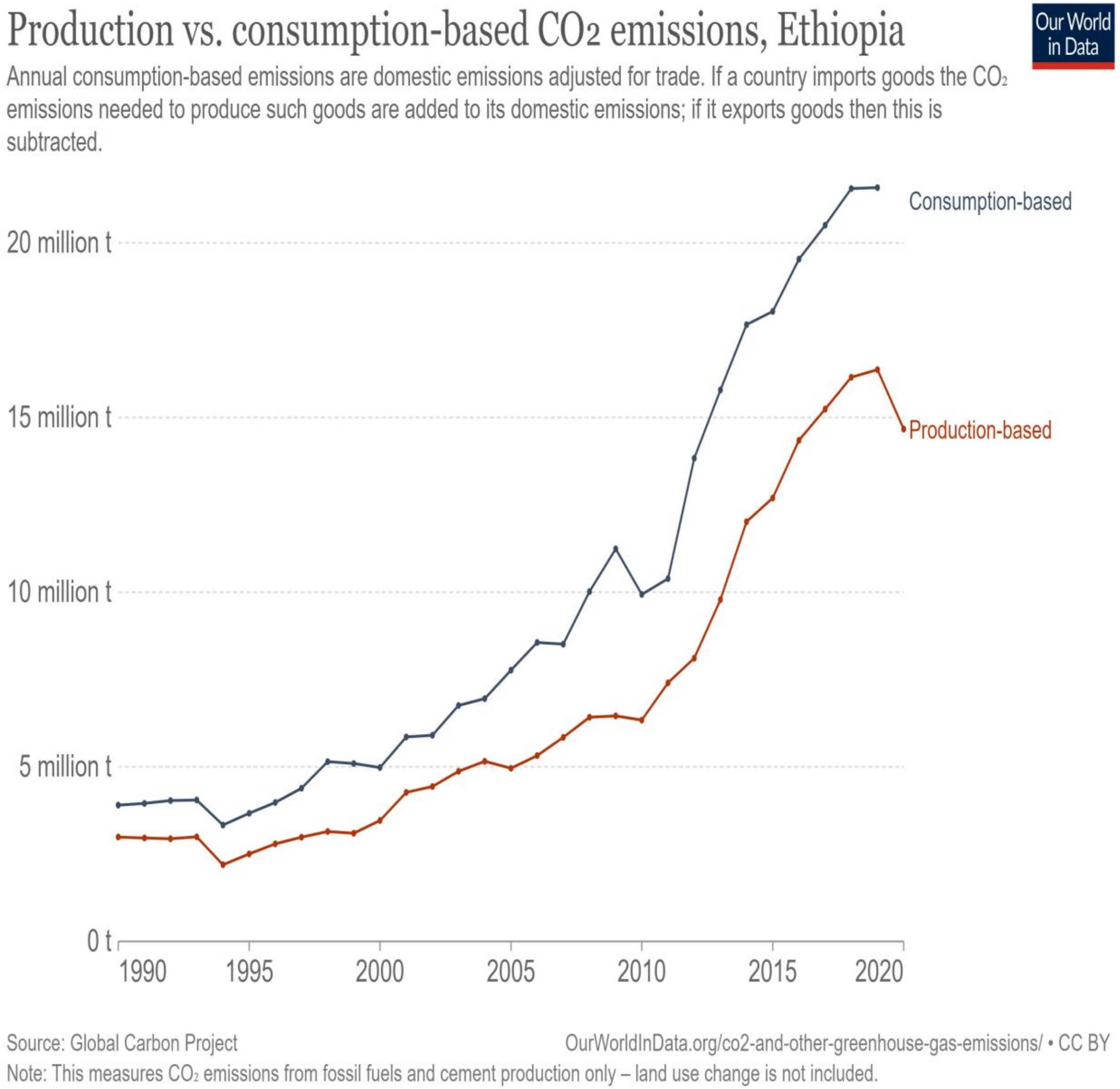
Lower-Middle Income Countries

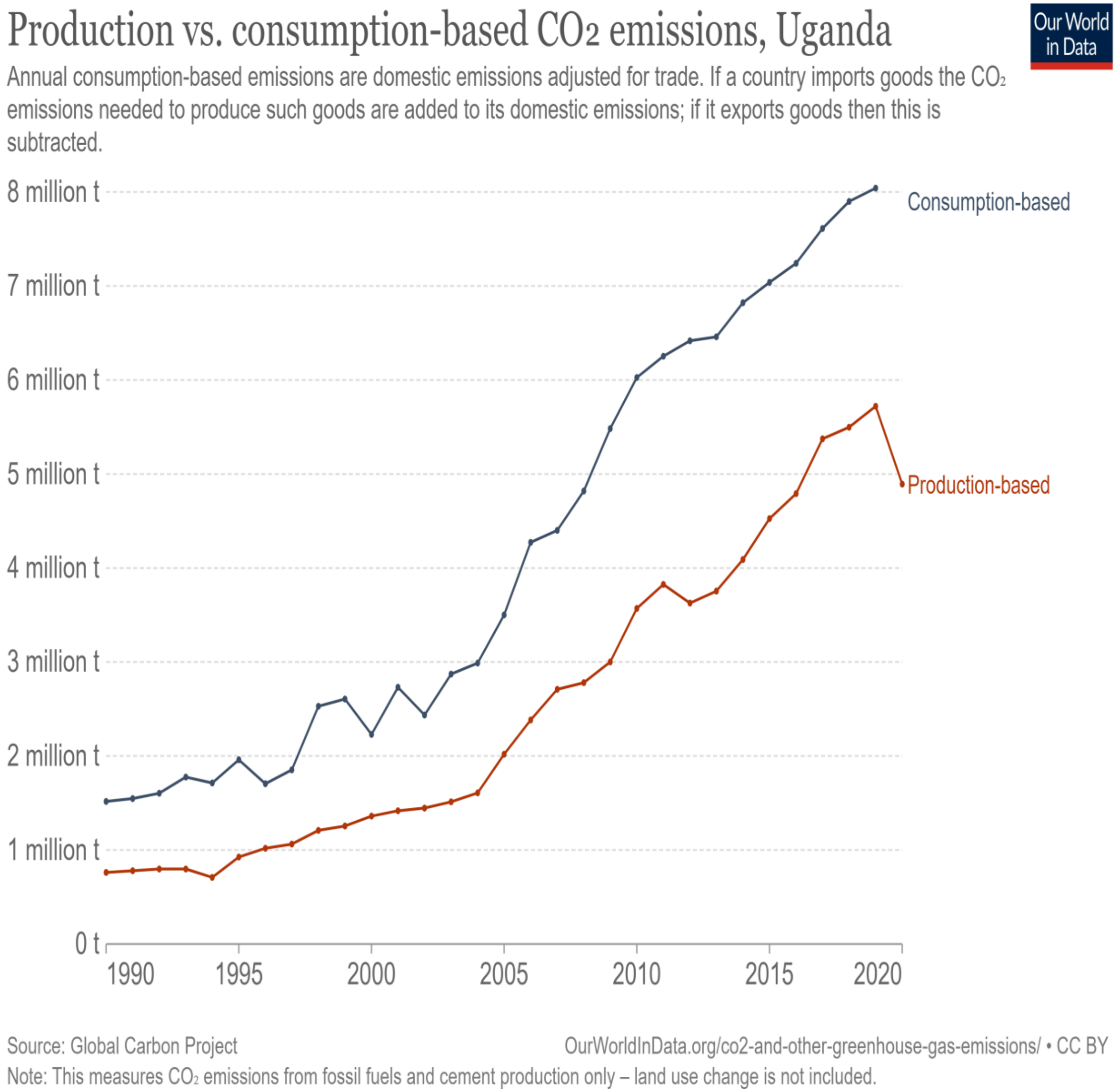




https://ourworldindata.org/grapher/production-vs-consumption-co2-emissions?country=~IND

Low Income Countries



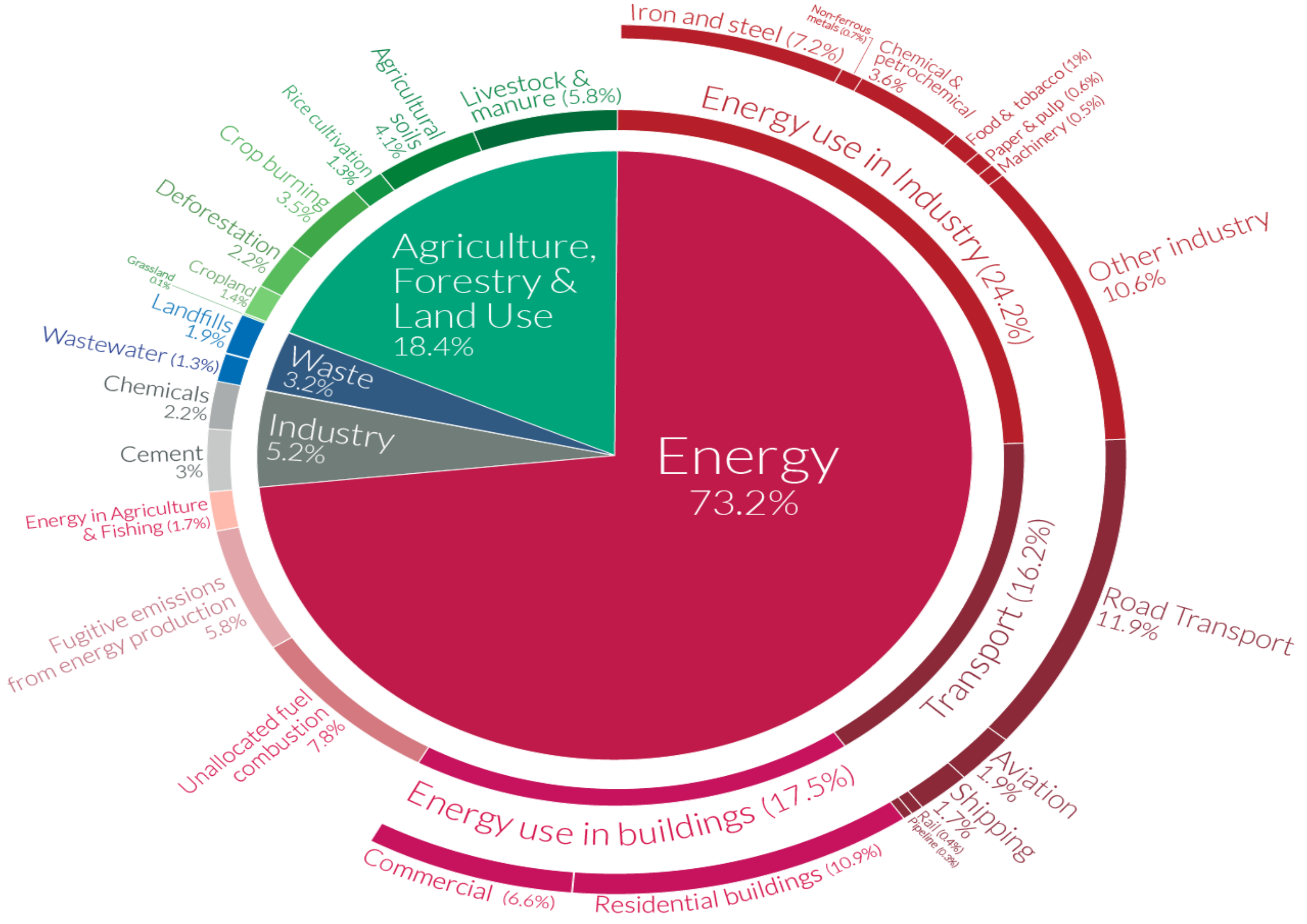


https://ourworldindata.org/grapher/production-vs-consumption-co2-emissions?country=~UGA

Global greenhouse gas emissions by sector

Our World in Data

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.



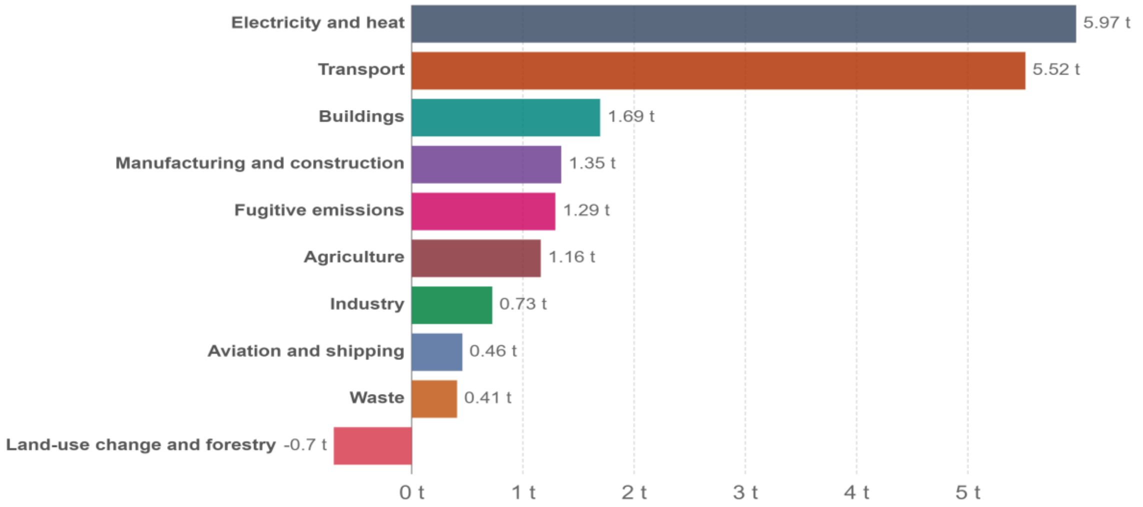
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Source: Climate Watch, the World Resources Institute (2020).

https://ourworldindata.org/emissions-by-sector

Per capita greenhouse gas emissions by sector, United States, 2019

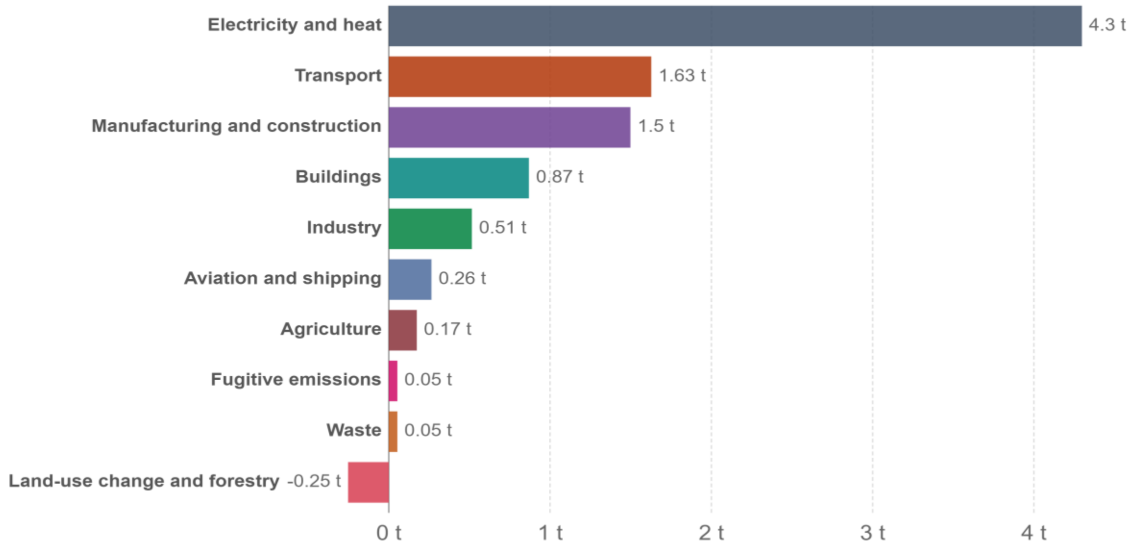
Per capita greenhouse gas emissions are measured in tonnes of carbon-dioxide equivalents (CO_2e) per person per year. This metric converts all greenhouse gases to CO_2e based on their global warming potential value over a 100-year timescale.



Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Per capita greenhouse gas emissions by sector, Japan, 2019

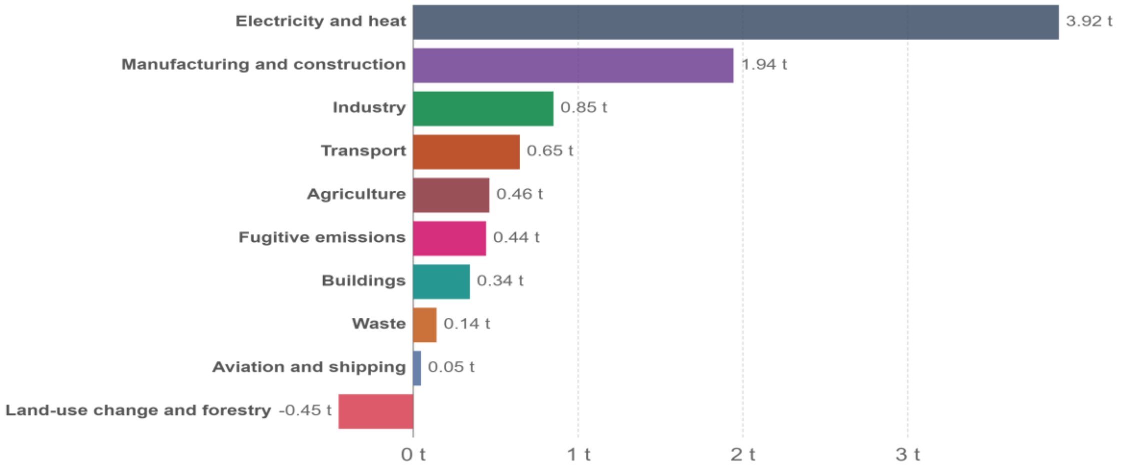
Per capita greenhouse gas emissions are measured in tonnes of carbon-dioxide equivalents (CO_2e) per person per year. This metric converts all greenhouse gases to CO_2e based on their global warming potential value over a 100-year timescale.



Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Per capita greenhouse gas emissions by sector, China, 2019

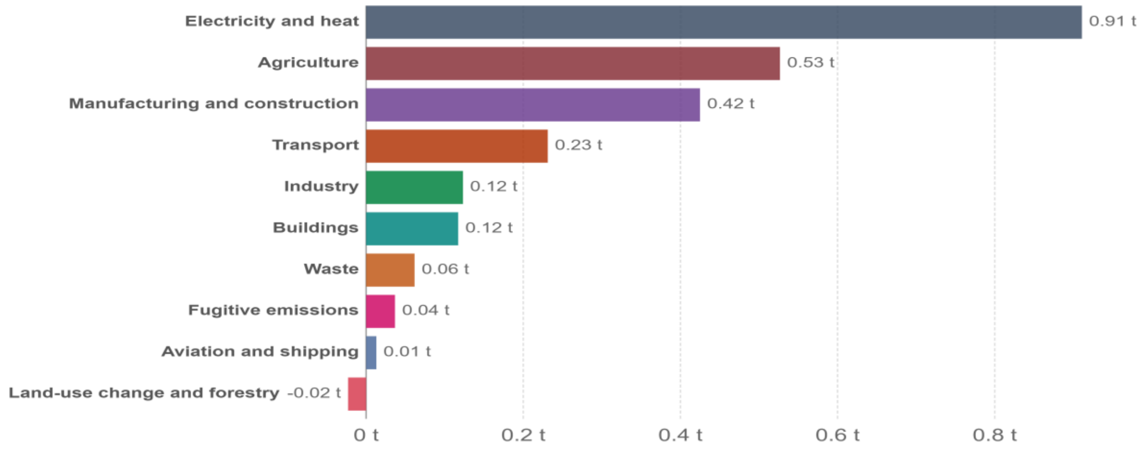
Per capita greenhouse gas emissions are measured in tonnes of carbon-dioxide equivalents (CO_2e) per person per year. This metric converts all greenhouse gases to CO_2e based on their global warming potential value over a 100-year timescale.



Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

Per capita greenhouse gas emissions by sector, India, 2019

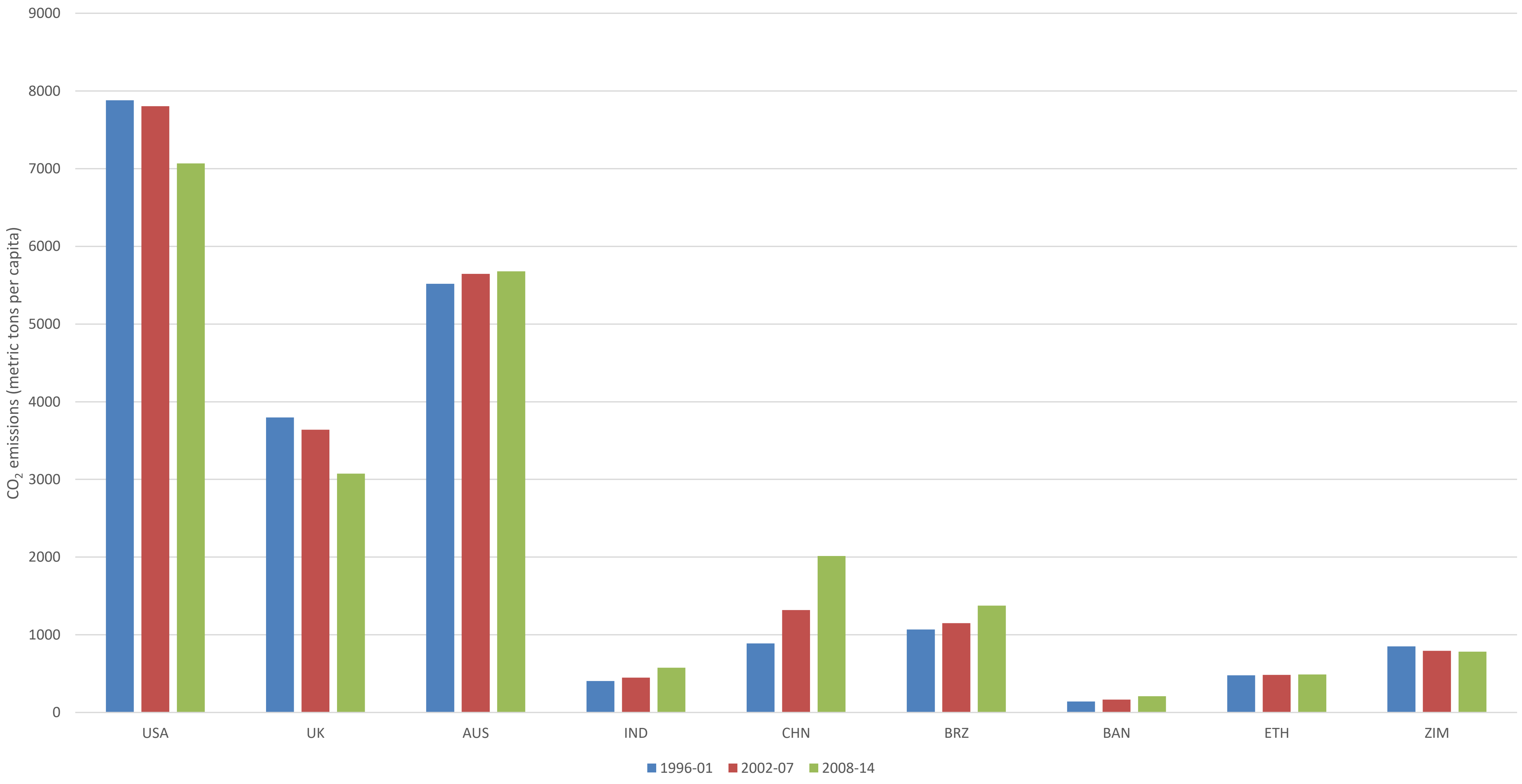
Per capita greenhouse gas emissions are measured in tonnes of carbon-dioxide equivalents (CO_2e) per person per year. This metric converts all greenhouse gases to CO_2e based on their global warming potential value over a 100-year timescale.



Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

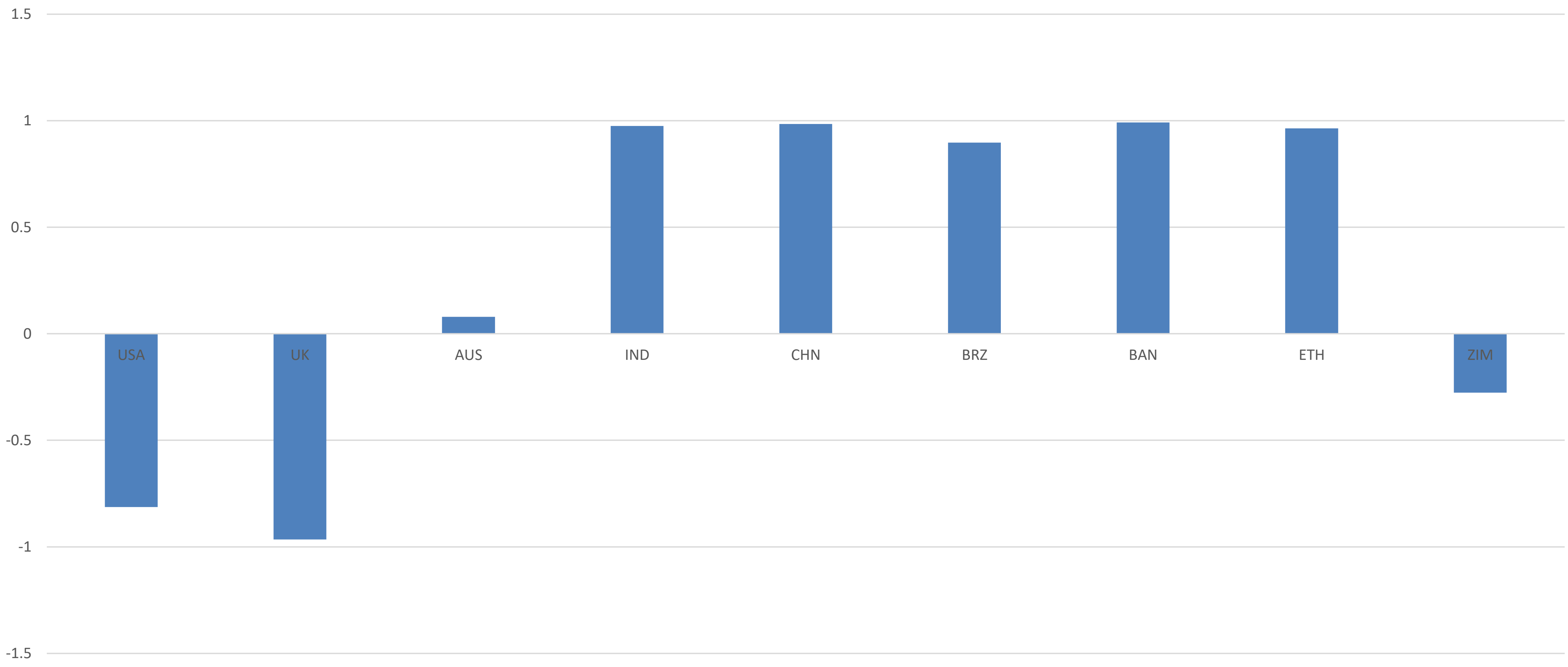
https://ourworldindata.org/emissions-by-sector

Trend of Carbon Emissions



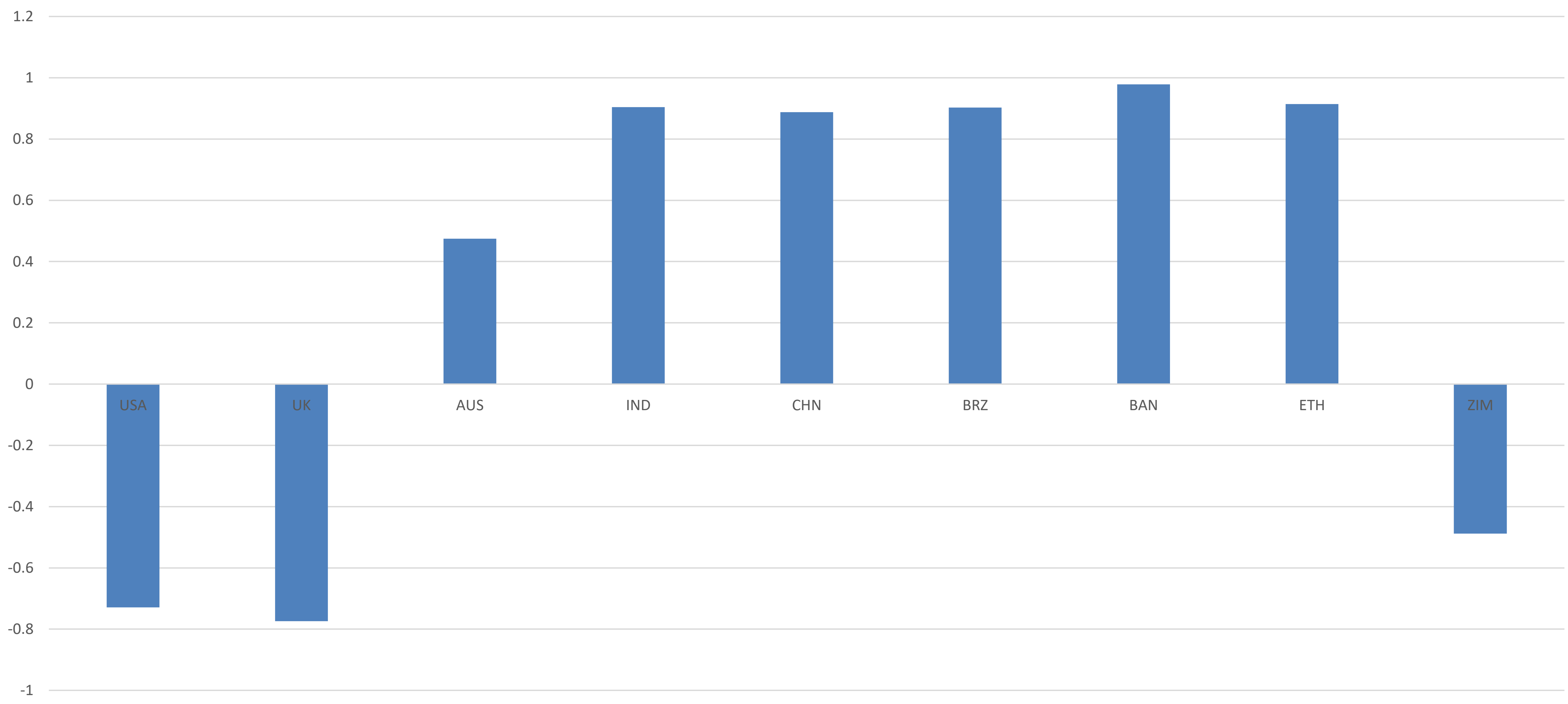
Correlation between Carbon emissions and Urbanisation

USA	UK	AUS	IND	CHN	BRZ	BAN	ETH	ZIM
-0.813	-0.965	0.0791	0.9759	0.985	0.8977	0.9918	0.964	-0.2759



Correlation between Carbon emissions and Globalisation

USA	UK	AUS	IND	CHN	BRZ	BAN	ETH	ZIM
-0.729	**-0.7737**	0.4749	**0.9039**	**0.8877**	0.903	0.9783	0.9139	-0.4881



On the relationship between energy consumption and GDP

- ✓ Energy-led growth hypothesis.
- ✓ Efficient utilisation of energy resources.
- ✓ Higher economic growth.
- ✓ Decouple Hypothesis.

The nexus between energy use (EC) and economic growth (GDP)

Four Hypothesis (Kraft and Kraft, 1978)

a) Conservation Hypothesis (GD $\rightarrow$ PEC)

b) Growth Hypothesis (EC $\rightarrow$ GDP)

c) Feedback Hypothesis (EC $\leftrightarrow$ GDP)

d) Neutrality Hypothesis (EC — GDP)