CO_2 and other Greenhouse Gas Emissions

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This article was first published in May 2017; however, its contents are frequently updated with the latest data and research.

Introduction

Carbon dioxide (CO_2) is known as a greenhouse gas (GHG)—a gas that absorbs and emits thermal radiation, creating the 'greenhouse effect'. Along with other greenhouse gases, such as nitrous oxide and methane, CO_2 is important in sustaining a habitable temperature for the planet: if there were absolutely no GHGs, our planet would simply be too cold. It has been estimated that without these gases, the average surface temperature of the Earth would be about -18 degrees celsius.[1]

Since the Industrial Revolution, however, energy-driven consumption of fossil fuels has led to a rapid increase in CO_2 emissions, disrupting the global carbon cycle and leading to a planetary warming impact. Global warming and a changing climate have a range of potential ecological, physical and health impacts, including extreme weather events (such as floods, droughts, storms, and heatwaves); sea-level rise; altered crop growth; and disrupted water systems. The most extensive source of analysis on the potential impacts of climatic change can be found in the 5th Intergovernmental Panel on Climate Change (IPCC) report; this presents full coverage of all impacts in its chapter on Impacts, Adaptation, and Vulnerability.[2] In light of this evidence, UN member parties have set a target of limiting average warming to 2 degrees celsius above pre-industrial temperatures.

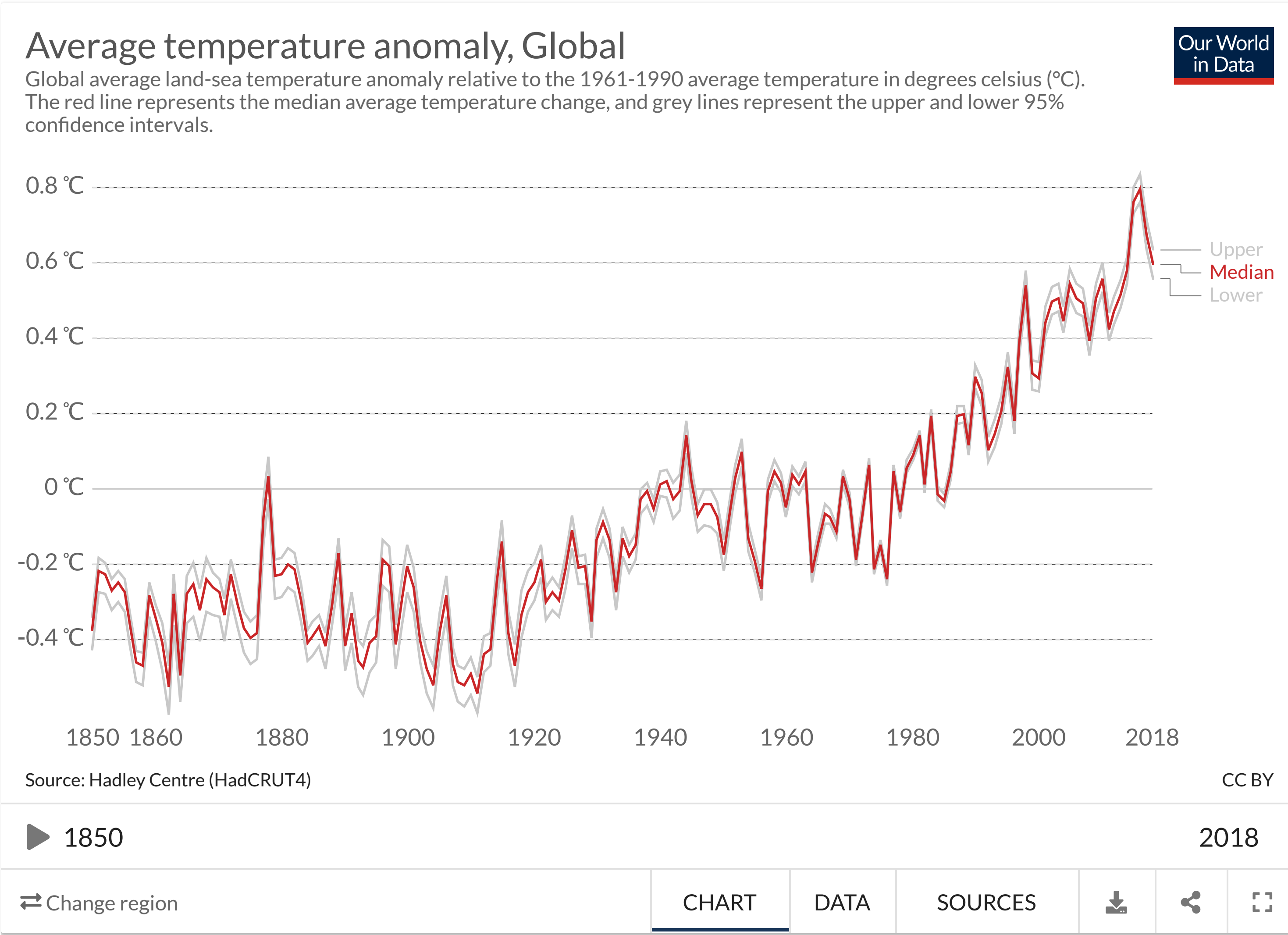
This entry provides a historical to present day perspective of how CO_2 emissions have evolved, how emissions are distributed, and the key factors that both drive these trends and hold the key to mitigating climate change.

To set the scene, let's briefly look at how the planet has warmed — particularly since the Industrial Revolution. In the chart below the x-axis shows the time spanning 1850 to 2018. On the y-axis, we see the global average temperature rise above or below the 1961-1990 baseline temperature. This means that we use the average temperature over the 1961-1990 period as a baseline against which yearly changes in temperature are measured.

The red line represents the average annual temperature trend through time, with upper and lower confidence intervals (the possible upper and lower range) shown in light grey. We see that over the last few decades, temperatures have risen sharply at the global level — to approximately 0.8 degrees celsius higher than our 1961-1990 baseline. When extended back to 1850, we see that temperatures then were a further 0.4 degrees colder than they were in our 1961-1990 baseline. Overall, if we look at the total temperature increase since pre-industrial times, this therefore amounts to approximately 1.2 degrees celsius. We have now surpassed the one-degree mark, an important marker as it brings us more than halfway to the global limit of keeping warming below two degrees celsius.

In the interactive chart below you can also view these trends by hemisphere (North and South), as well as the tropics (defined as 30 degrees above and below the equator). Here we see that the median temperature increase in the North

Hemisphere is higher, at closer to 1.4 degrees celsius since 1850, and less in the Southern Hemisphere (closer to 0.8 degrees celsius). Evidence suggests that this distribution is strongly related to ocean circulation patterns (notably the North Atlantic Oscillation) which has resulted in greater warming in the northern hemisphere.[3]



Empirical View

The long-run history: Cumulative CO_2

If we extend our timeline back to 1750 and total up how much CO_2 each country has emitted to date, we calculate each nation's 'cumulative emissions'.

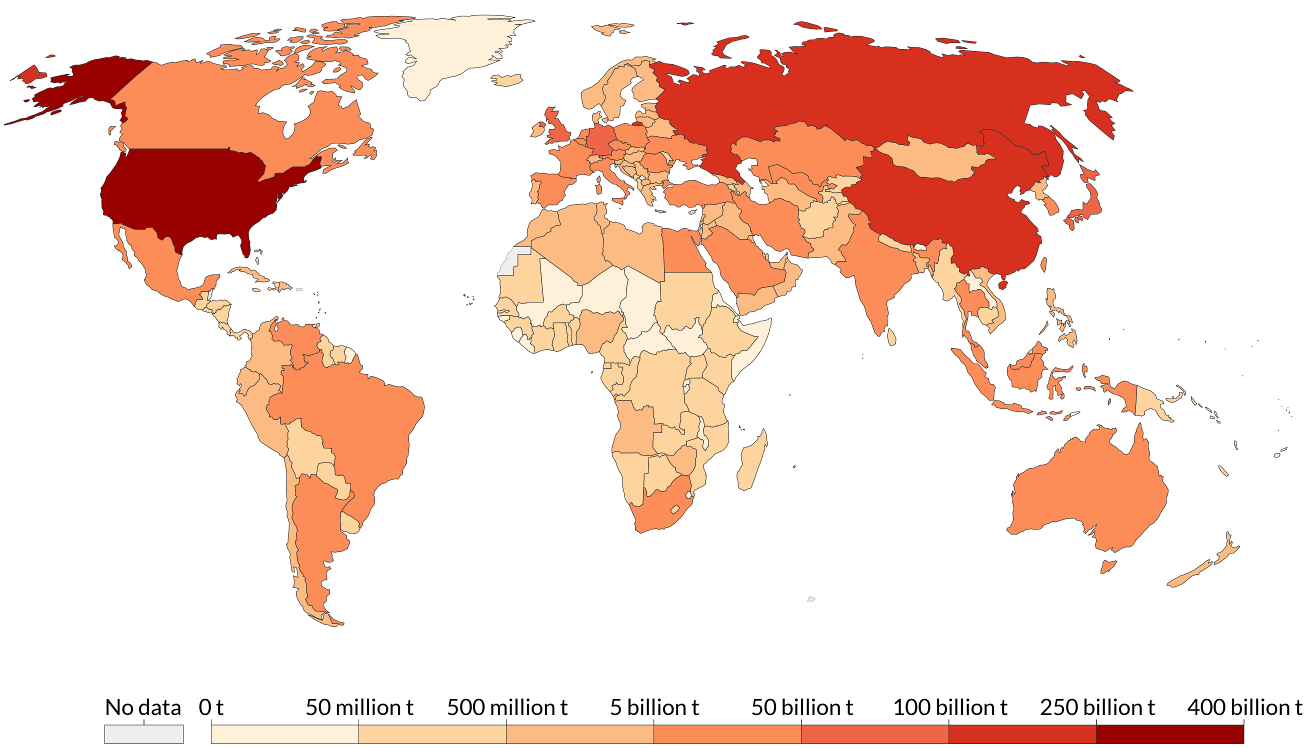
In the chart below, we have plotted the cumulative emissions of each nation through time from the industrial revolution in 1750 to 2016. The UK was the world's first industrial-scale CO_2 emitter. Emissions in other European countries and North America shortly followed and produced CO_2 over the majority of this time period. Other regions—Latin America, Asia and Africa—started contributing to global CO_2 emissions much later, largely contained to the 20th and 21st centuries.

If we fast-forward to the accumulated totals we see today, the US and Europe dominate in terms of cumulative emissions. China's rapid growth in emissions over the last few decades now makes it the world's second largest cumulative emitter, although it still comes in at less than 50% of the US total.

Cumulative CO_2 emissions, 2017

Cumulative carbon dioxide (CO_2) emissions represents the total sum of CO_2 emissions produced from fossil fuels and cement since 1751, and is measured in tonnes.

Our World in Data



Source: Global Carbon Project (GCP); Carbon Dioxide Information Analysis Centre (CDIAC)

1751 2017 CHART MAP DATA SOURCES

Share of global cumulative CO_2

In the chart below we see this measure of cumulative CO_2 emissions given as the share of the global total. Here we see even more clearly, the significant transitions and shifts in global emissions which have occurred. For most of the 19th century, global cumulative emissions were dominated by Europe: firstly in the United Kingdom, then to other countries in the (now) European Union.

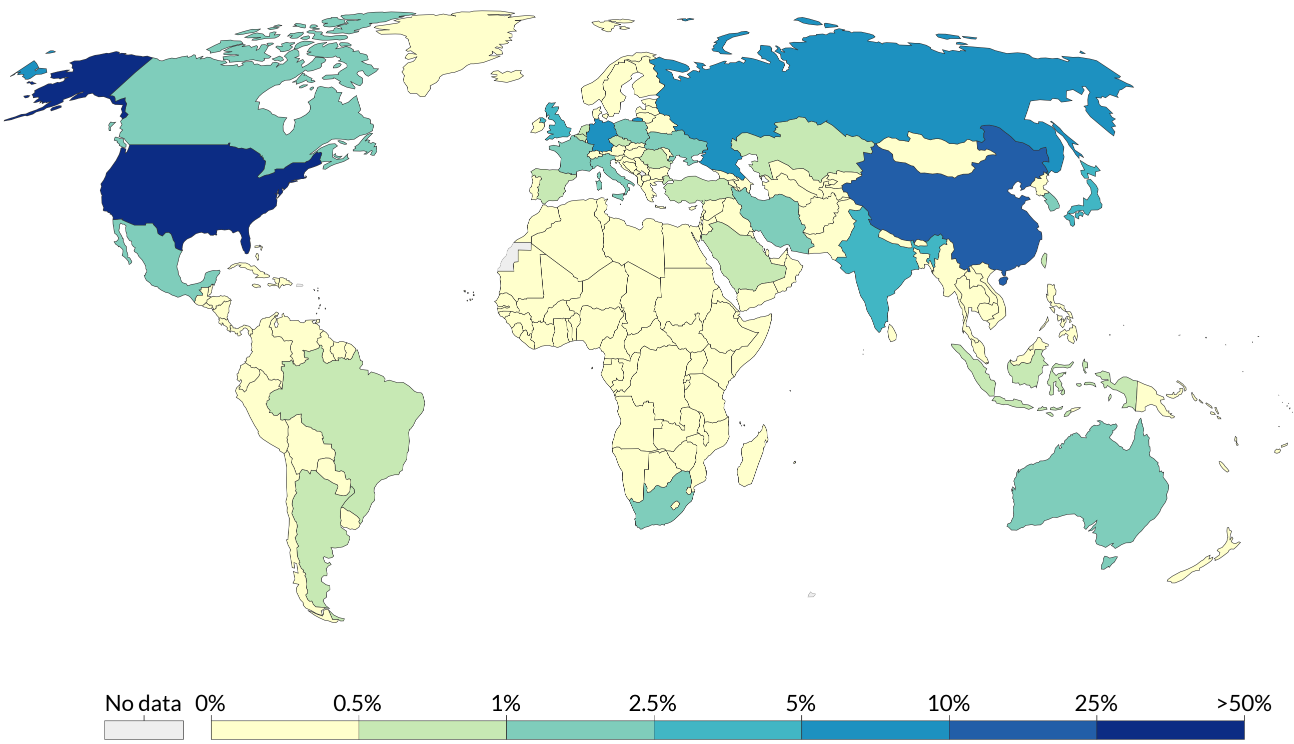
The cumulative contribution of the United States began to rise in the second half of the 19th century into the 20th. By 1950 its contribution peaked at 40 percent; since then it has declined to approximately 26 percent, but remains the largest in the world.

By 2015, China accounted for 12 percent of total cumulative emissions, and India for 3 percent.

Share of global cumulative CO_2 emissions, 2017

Each country or region's share of cumulative global carbon dioxide (CO_2) emissions. Cumulative emissions are calculated as the sum of annuals emissions from 1751 to a given year.

Our World in Data



Source: OWID based on CDIAC & Global Carbon Project (GCP)

1751 2017 CHART MAP DATA SOURCES

Annual CO_2 emissions

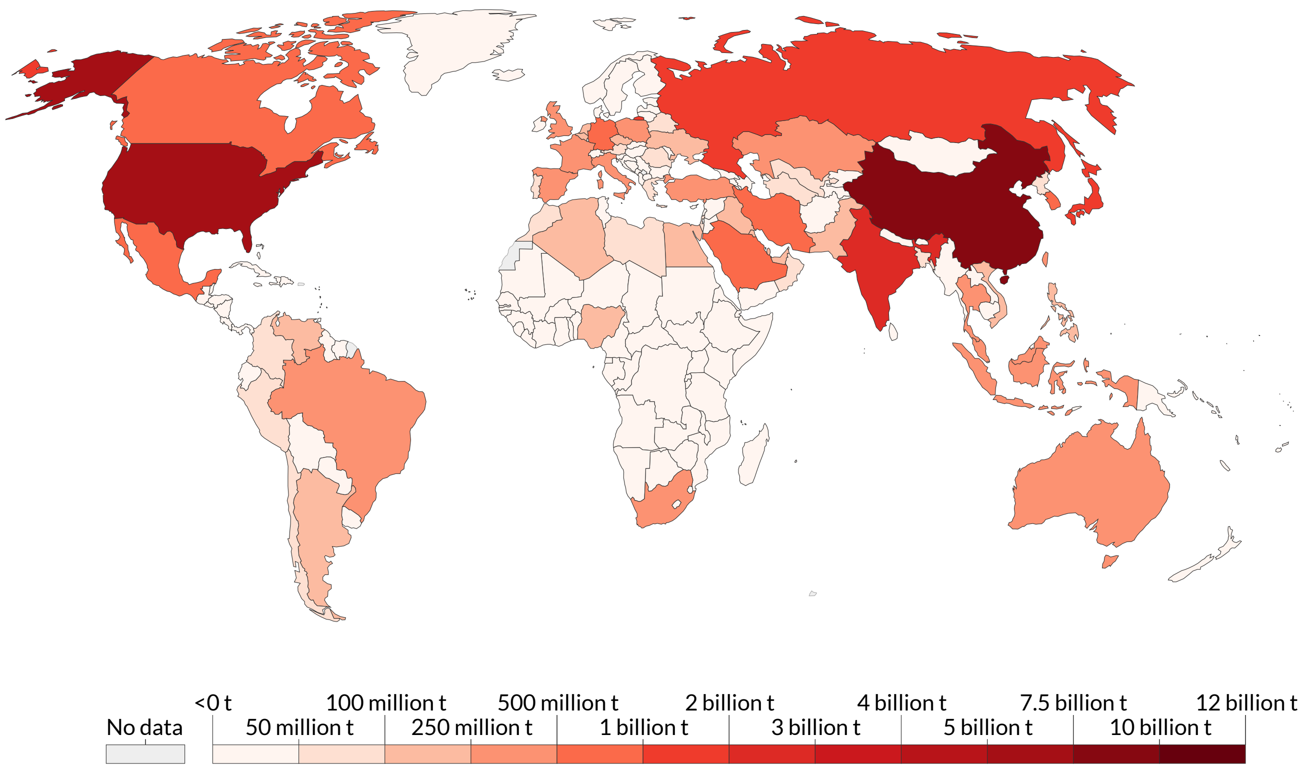
If we forget the cumulative time dimension and focus only on annual emissions, how do more recent annual emission trends compare? In the chart below, we can view annual CO_2 emissions by country. You can select a range of countries to compare through time in the "chart" tab, or alternatively click on a country on the "map" tab to see its time series. In support of the cumulative chart we explored above, we can see that the annual trends of European and North American nations have grown much earlier than in other regions.

Emissions from a number of growing economies have been increasing rapidly over the last few decades. Fast-forwarding to annual emissions in 2014, we can see that a number of low to middle income nations are now within the top global emitters. In fact, China is now the largest emitter, followed by (in order) the US, EU-28, India, Russia, Indonesia, Brazil, Japan, Canada and Mexico. Note that a number of nations that are already top emitters are likely to continue to increase emissions as they undergo development.

In contrast to CO_2 emissions growth in low to middle income economies, trends across many high income nations have stabilized, and in several cases decreased in recent decades. Despite this downward trend across some nations, emissions growth in transitioning economies dominates the global trend—as such, global annual emissions have continued to increase over this period.

Annual CO_2 emissions, 2016

Annual carbon dioxide (CO_2) emissions, measured in tonnes per year.



Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)

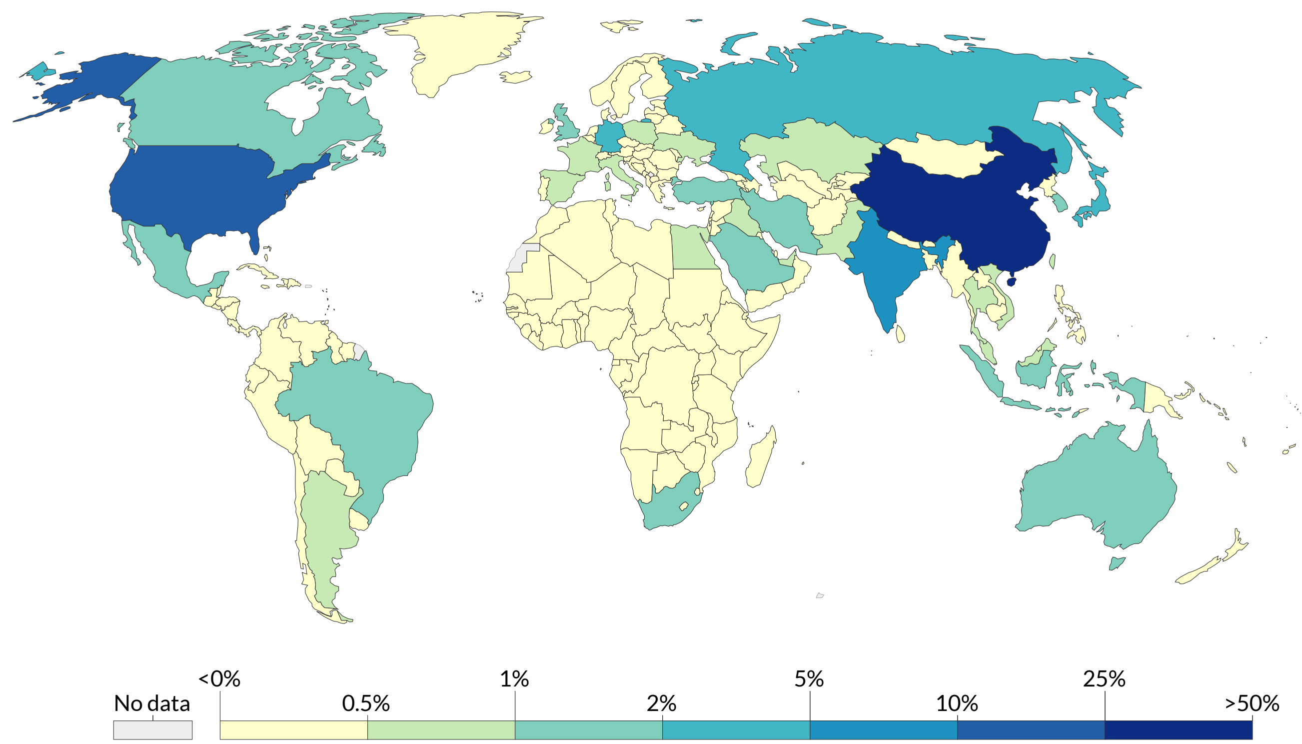
1751 2017 CHART MAP DATA SOURCES

Share of annual CO_2 emissions

In the chart below we see each country's share of global CO_2 emissions from 1751 through to 2016. This is calculated by dividing each country's emissions divided by the sum of all countries' emissions in a given year. This doesn't include emissions from international aviation and shipping (so-called 'bunkers') and 'statistical differences'.

Annual share of global CO₂ emissions, 2017

Each country's share of global carbon dioxide (CO₂) emissions. 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.



Source: Our World in Data based on Global Carbon Project (2018)

1751 2017 CHART MAP DATA SOURCES

Per capita CO_2 emissions

The key drawback of measuring the total national emissions is that it takes no account of the nation's population size. China is currently the world's largest emitter, but since it also has the largest population, all being equal we would expect this to be the case. To make a fair comparison of contributions, we have to therefore compare emissions in terms of CO_2 emitted per person.

In the map below we compare CO_2 emissions per capita through time since 1950. Again, if we cycle through time by moving the slider below the map, we see that per capita emissions in most countries have continued to increase in line with development. However, if we look at the distribution of per capita emissions in 2014, large global inequalities remain.

Note that carbon dioxide is not the only greenhouse gas which contributes to climate change—nitrous oxide and methane are also greenhouse gases, but are not included here. Food production, especially intensive livestock-rearing for meat and dairy, is a major contributor to both of these non-CO_2 GHGs. Since capita meat intake is strongly linked to GDP levels, per capita emissions of nitrous oxide and methane tend to be much larger in high-income nations. Therefore, if these gases *were* included alongside CO_2, the global inequalities would be even higher.

With a few exceptions, there is an important north-south divide in terms of per capita emissions. Most nations across sub-Saharan Africa, South America and South Asia have per capita emissions below five tonnes per year (many have less than

1-2 tonnes). This contrasts with the global north where emissions are typically above five tonnes per person (with North America above 15 tonnes). The monthly emissions per capita in rich countries are mostly higher than the yearly emissions per capita in poorer countries. The largest emitter, Qatar, has per capita emissions of 50 tonnes per year (1243 times that of Chad, the lowest emitter).

1800 2017 CHART MAP DATA SOURCES

CO_2 emissions by fuel source

Carbon dioxide emissions associated with energy and industrial production can come from a range of fuel types. The contribution of each of these sources has changed significantly through time, and still shows large differences by region. In the chart below we see the absolute and relative contribution of CO_2 emissions by source, differentiated between gas, liquid (i.e. oil), solid (coal and biomass), flaring, and cement production.

At a global level we see that early industrialisation was dominated by the use of solid fuel—this is best observed by switching to the 'relative' view in the chart. Coal-fired power at an industrial-scale was the first to emerge in Europe and North America during the 1700s. It wasn't until the late 1800s that we begin to see a growth in emissions from oil and gas production. Another century passed before emissions from flaring and cement production began. In the present day, solid and liquid fuel dominate, although contributions from gas production are also notable. Cement and flaring at the global level remain comparably small.

You can also view these trends across global regions in the chart below, by clicking on 'change region'. The trends vary significantly by region. Overall patterns across Europe and North America are similar: early industrialisation began through solid fuel consumption, however, through time this energy mix has diversified. Today, CO_2 emissions are spread fairly equally between coal, oil and gas. In contrast, Latin America and the Caribbean's emissions have historically been and remain a product of liquid fuel—even in the early stages of development coal consumption was small.[4] Asia's energy remains dominant in solid fuel consumption, and has notably higher cement contributions relative to other regions.[5] Africa also has more notable emissions from cement and flaring; however, its key sources of emissions are a diverse mix between solid, liquid and gas.

Change country/region Relative CHART DATA SOURCES

CO_2 emissions by sector

Which is the largest contributor to carbon dioxide emissions — transport or electricity, residential or manufacturing? In the chart below we see the share of CO_2 emissions from fuel combustion derived from each sector.

Globally around half of global emissions were the result of electricity and heat production in 2014. Transport and manufacturing industries both contributed approximately 20 percent; residential, commercial and public services around 9 percent and other sectors contributing 1 to 2 percent.

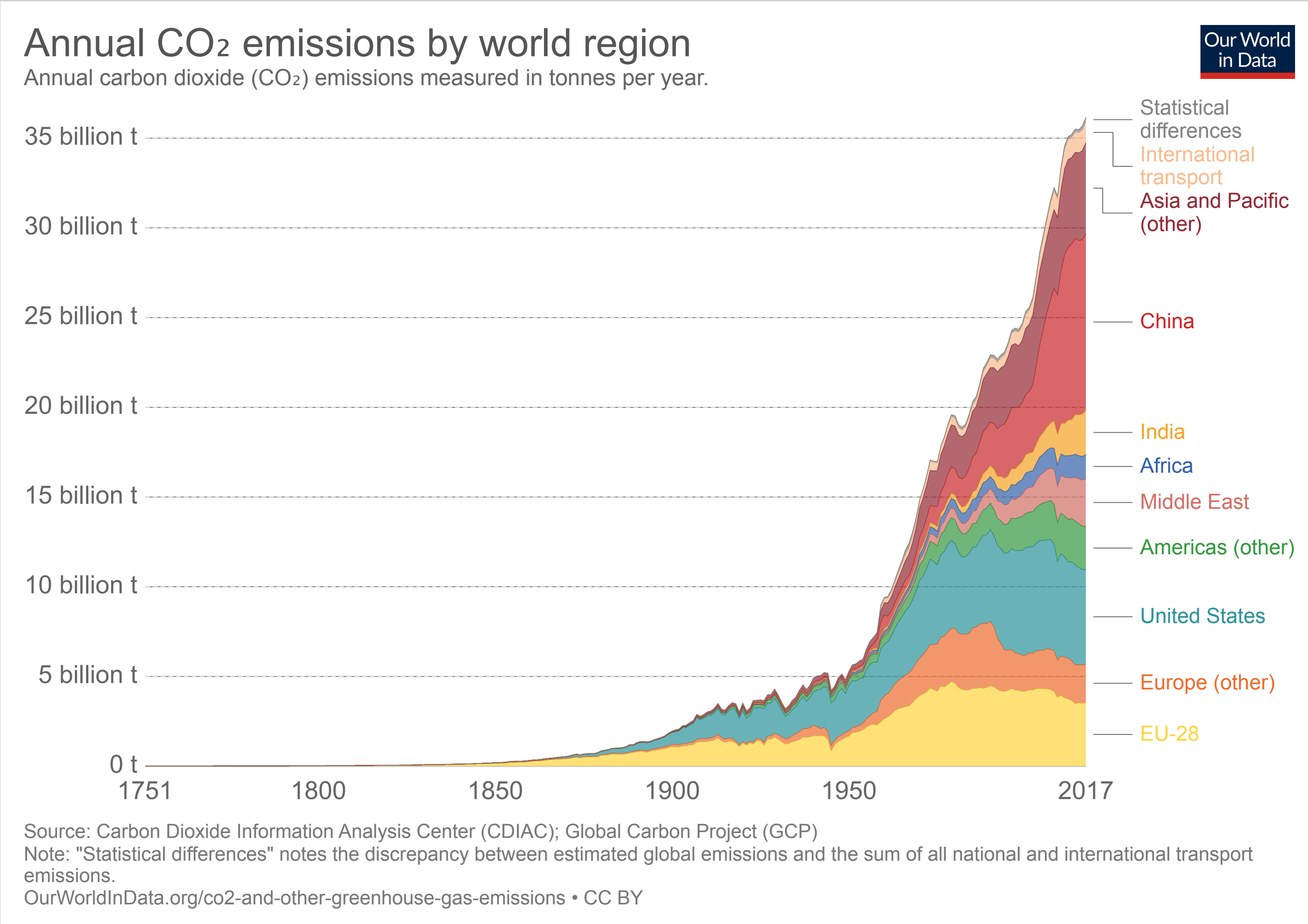
Change country or region CHART DATA SOURCES

CO$_2$ emissions—global and regional trends

The visualisation below presents the long-run perspective on global CO_2 emissions. Global emissions increased from 2 billion tonnes of carbon dioxide in 1900 to over 36 billion tonnes 115 years later.

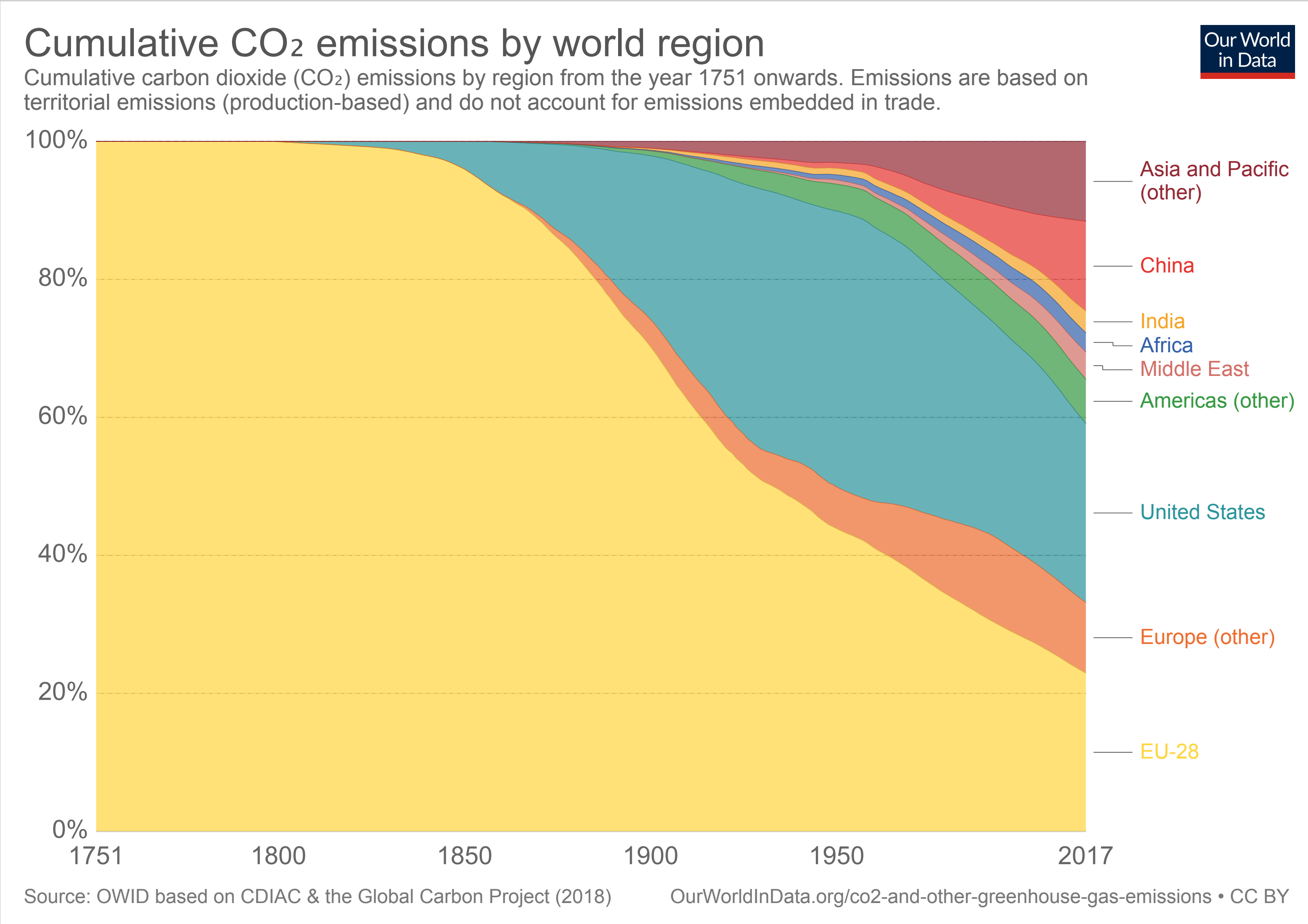
What do our most recent trends in emissions and concentrations look like? Are we making any progress in reduction?

Whilst data from 2014 to 2017 suggested global annual emissions of CO_2 had approximately stabilized, the most recent (preliminary) data from the Global Carbon Project reported a 2.7 percent increase in 2018.



Cumulative CO_2 emissions by region

The chart below shows cumulative emissions of CO_2 by region. This is given as the cumulative emissions since 1751, and is based on territorial (production-based) accounting, meaning it does not account for emissions embedded in trade.



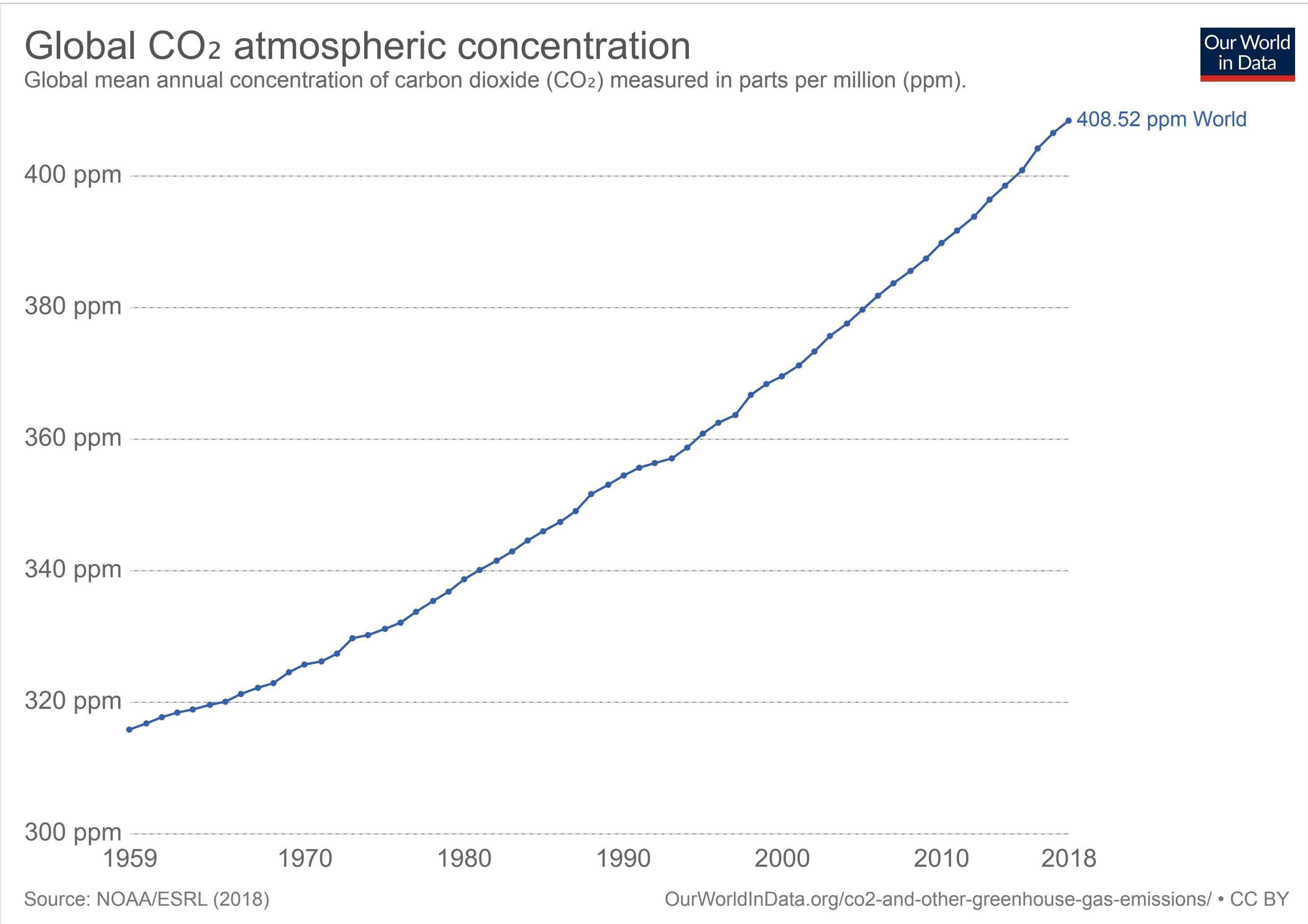
Atmospheric CO_2 concentrations

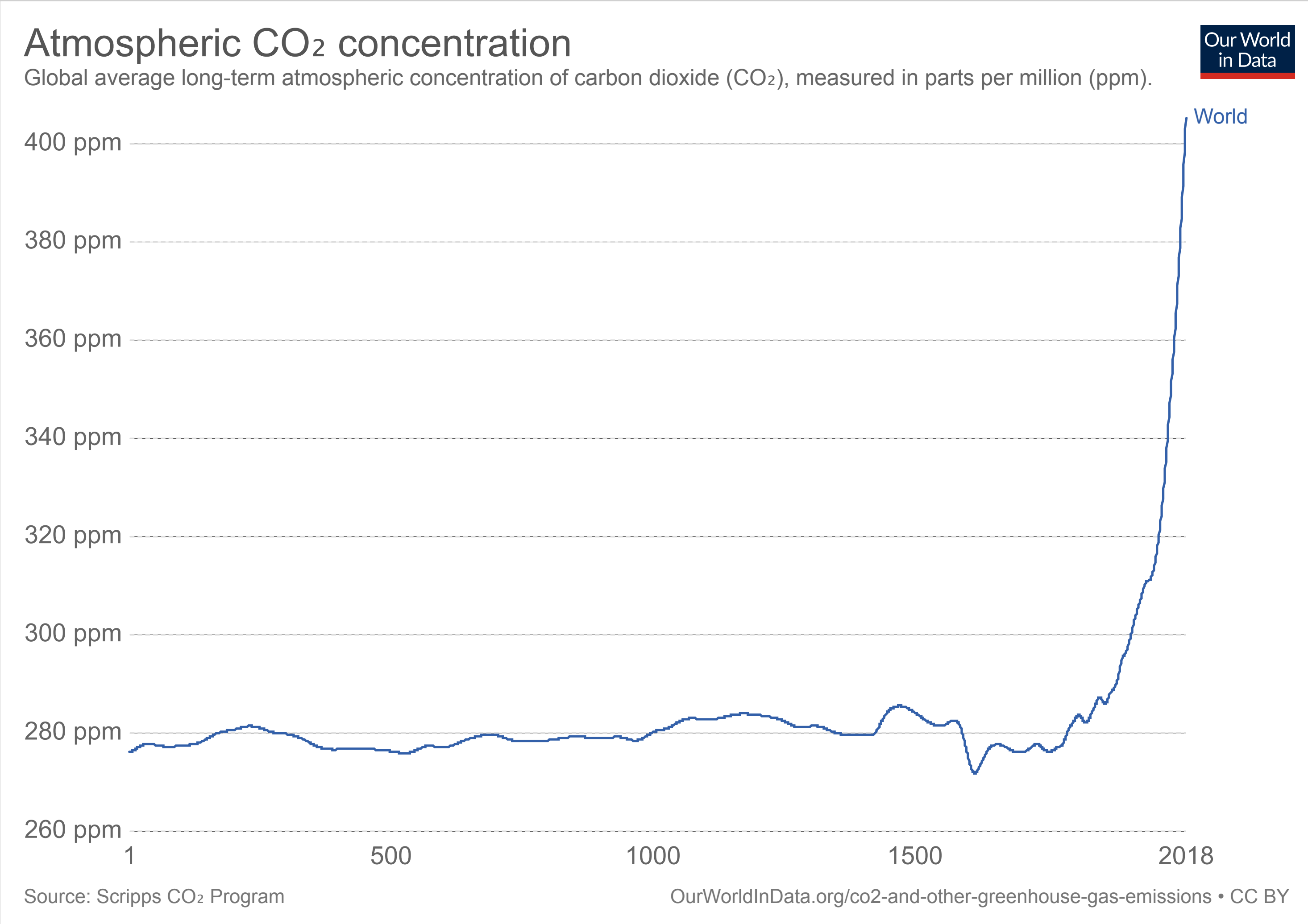
The large growth in global CO_2 emissions has had a significant impact on the concentrations of CO_2 in Earth's atmosphere. If we look at atmospheric concentrations over the past 2000 years (see the Data Quality and Measurement section in this entry for explanation on how we estimate historical emissions), we see that levels were fairly stable at 270-285 parts per million (ppm) until the 18th century. Since the Industrial Revolution, global CO_2 concentrations have been increasing rapidly.

However, CO_2 is not the only GHG we're concerned about—emissions of nitrous oxide (N_2O) and methane (CH_4) have also been increasing rapidly through agricultural, energy, and industrial sources. Like CO_2, the atmospheric concentration of both of these gases has also been rising rapidly.

Has a global stabilization of CO_2 emissions over the last few years had an impact on global atmospheric concentrations? While it appears progress is being made on global emissions, atmospheric concentrations continue to rise, as shown below. Atmospheric concentrations have now broken the 400ppm threshold—considered its highest level in the last three million years. To begin to stabilise—or even reduce—atmospheric CO_2 concentrations, our emissions need to not only stabilise but also decrease significantly.

Why would a stabilization in CO_2 emissions not directly translate into the same for atmospheric concentrations? This is because CO_2 accumulates in the atmosphere based on what we call a 'residence time'. Residence time is the time required for emitted CO_2 to be removed from the atmosphere through natural processes in Earth's carbon cycle. The length of this time can vary—some CO_2 is removed in less than 5 years through fast cycling processes, meanwhile other processes, such as absorption through land vegetation, soils and cycling into the deep ocean can take hundreds to thousands of years. If we stopped emitting CO_2 today, it would take several hundred years before the majority of human emissions were removed from the atmosphere.[6]





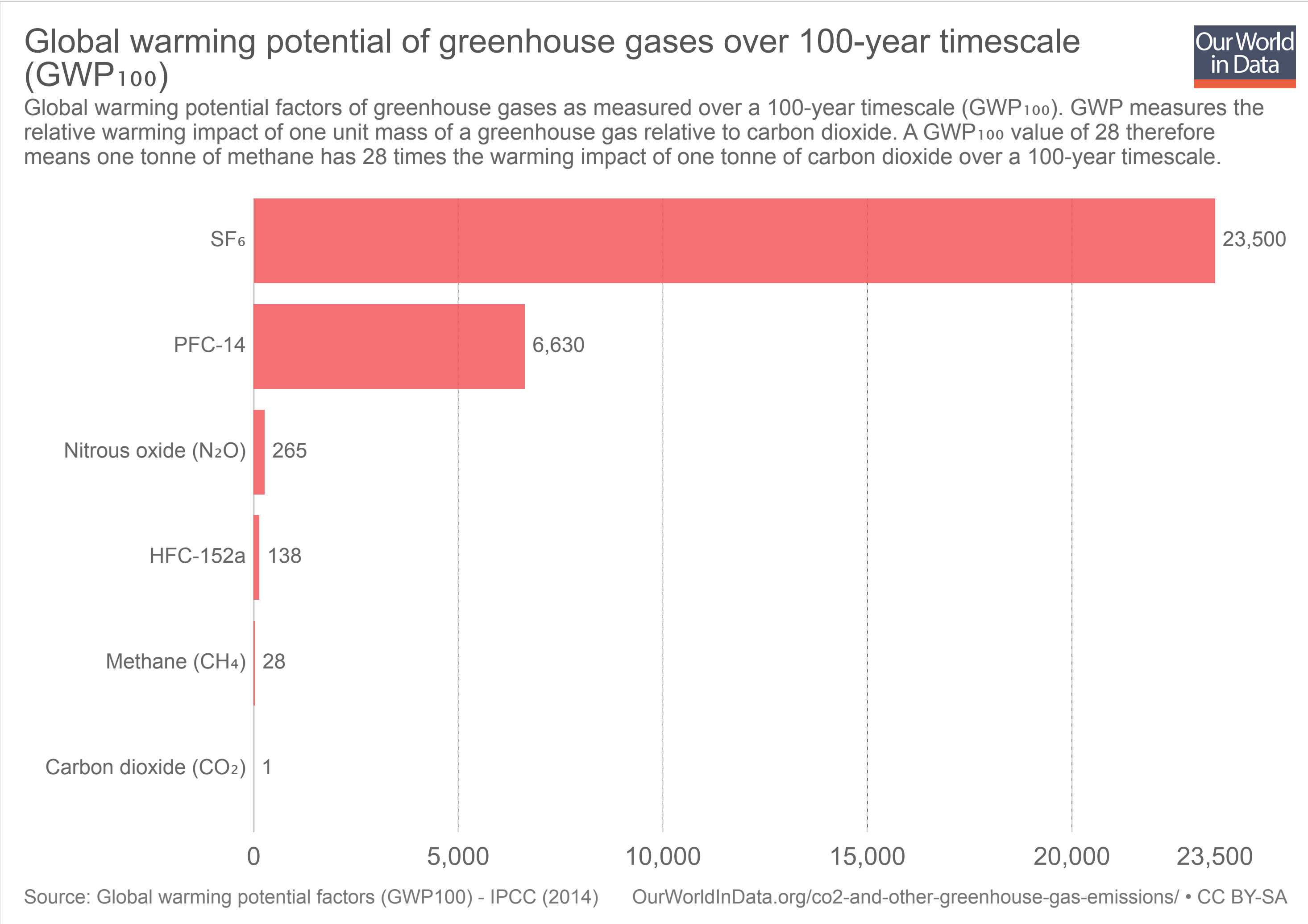
Greenhouse gas emission sources

Global warming potential of greenhouse gases

Carbon dioxide is not the only greenhouse gas of concern for global warming and climatic change. There are a range of greenhouse gases, which include methane, nitrous oxide, and a range of smaller concentration trace gases such as the so-called group of 'F-gases'.

Greenhouse gases vary in their relative contributions to global warming; i.e. one tonne of methane does not have the same impact on warming as one tonne of carbon dioxide. We define these differences using a metric called 'Global Warming Potential' (GWP). GWP can be defined on a range of time-periods, however the most commonly used (and that adopted by the IPCC) is the 100-year timescale (GWP_{100}).[7]

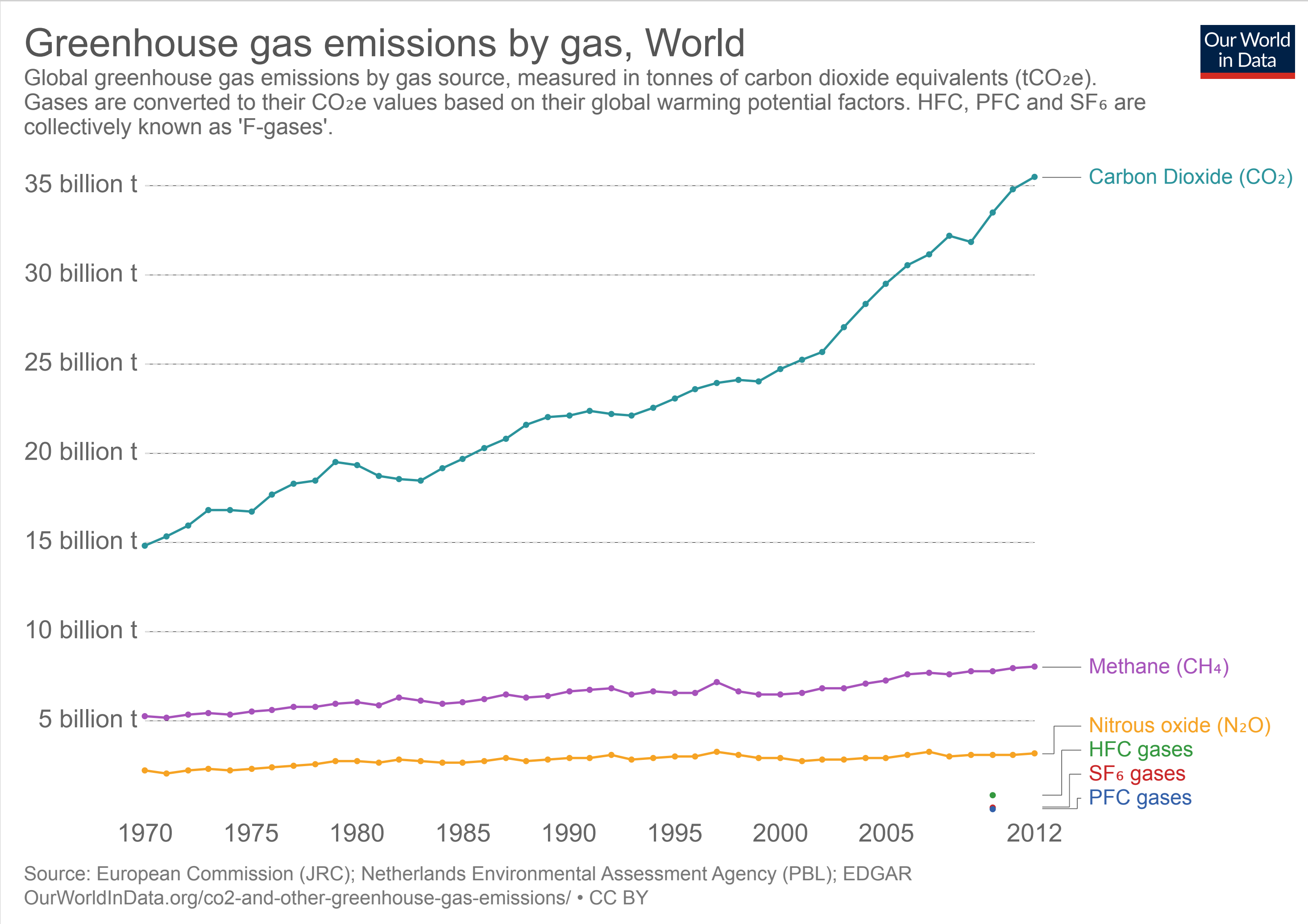
In the chart below we see the GWP_{100} value of key greenhouse gases relative to carbon dioxide. The GWP_{100} metric measures the relative warming impact one molecule or unit mass of a greenhouse gas relative to carbon dioxide over a 100-year timescale. For example, one tonne of methane would have 28 times the warming impact of tonne of carbon dioxide over a 100-year period. GWP_{100} values are used to combine greenhouse gases into a single metric of emissions called carbon dioxide equivalents (CO_2e). CO_2e is derived by multiplying the mass of emissions of a specific greenhouse gas by its equivalent GWP_{100} factor. The sum of all gases in their CO_2e form provide a measure of total greenhouse gas emissions.



Greenhouse gas emissions by gas source

In the chart below, we see the contribution of different gases to total greenhouse gas emissions. These are measured based on their carbon-dioxide equivalent values (as explained in the section above). Overall we see that carbon dioxide accounts for around three-quarters of total greenhouse gas emissions. However, both methane and nitrous oxide are also important sources, accounting for around 17 and 7 percent of emissions, respectively.

Collectively, HFC, PFC and SF_6 are known as the 'F-gases'. Despite having a very strong warming impact per unit mass (i.e. a high global warming potential), these gases are emitted in very small quantities; they therefore make only a small contribution to total warming.



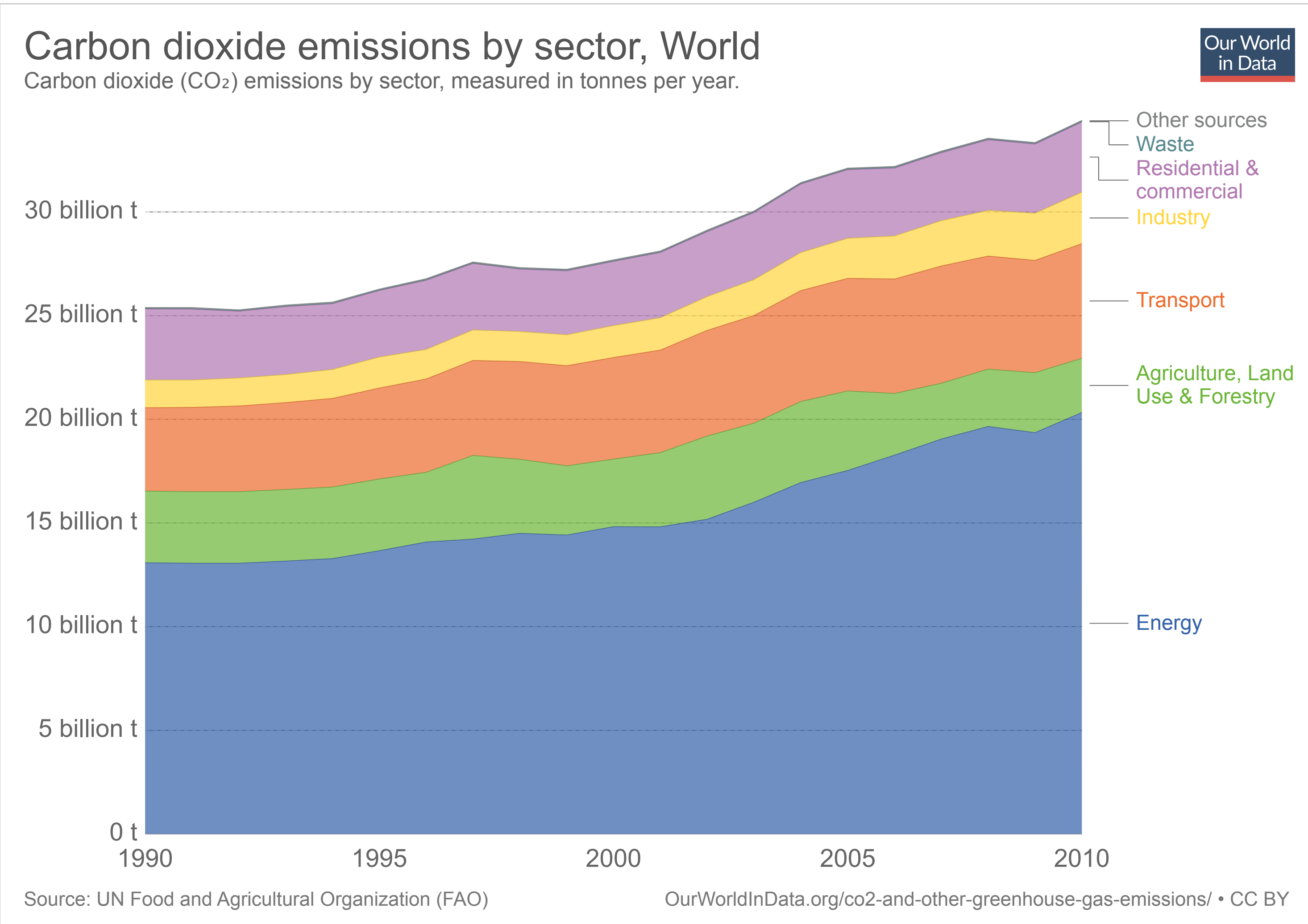
Emissions by sector

Global greenhouse gas emissions are broken down by sectoral sources in the sections which follow (showing carbon dioxide, methane and nitrous oxide individually, as well as collectively as total greenhouse gas terms). The data below is based on UN reported figures, sourced from the EDGAR database. Sources define sectoral emissions groupings in the following way[8]:

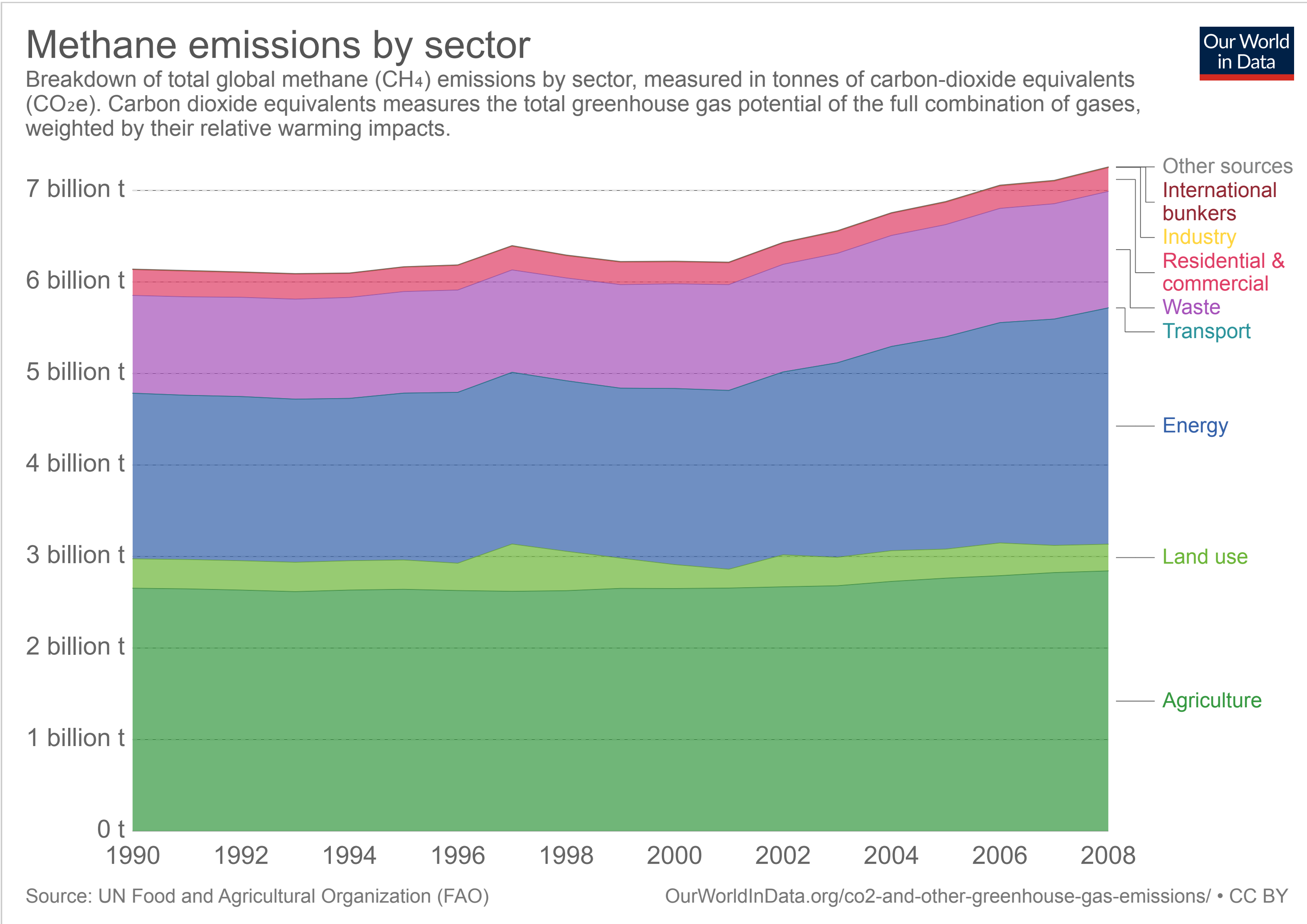
- **Energy** (energy, manufacturing and construction industries and fugitive emissions): emissions are inclusive of public heat and electricity production; other energy industries; fugitive emissions from solid fuels, oil and gas, manufacturing industries and construction.
- **Transport**: domestic aviation, road transportation, rail transportation, domestic navigation, other transportation.
- **International bunkers**: international aviation; international navigation/shipping.
- **Residential, commercial, institutional and AFF**: Residential and other sectors.
- **Industry** (industrial processes and product use): production of minerals, chemicals, metals, pulp/paper/food/drink, halocarbons, refrigeration and air conditioning; aerosols and solvents; semicondutor/electronics manufacture; electrical equipment.
- **Waste**: solid waste disposal; wastewater handling; waste incineration; other waste handling.

- **Agriculture**: methane and nitrous oxide emissions from enteric fermentation; manure management; rice cultivation; synthetic fertilizers; manure applied to soils; manure left on pasture; crop residues; burning crop residues, savanna and cultivation of organic soils.
- **Land use**: emissions from the net conversion of forest; cropland; grassland and burning biomass for agriculture or other uses.
- **Other sources**: fossil fuel fires; indirect nitrous oxide from non-agricultural NOx and ammonia; other anthropogenic sources.

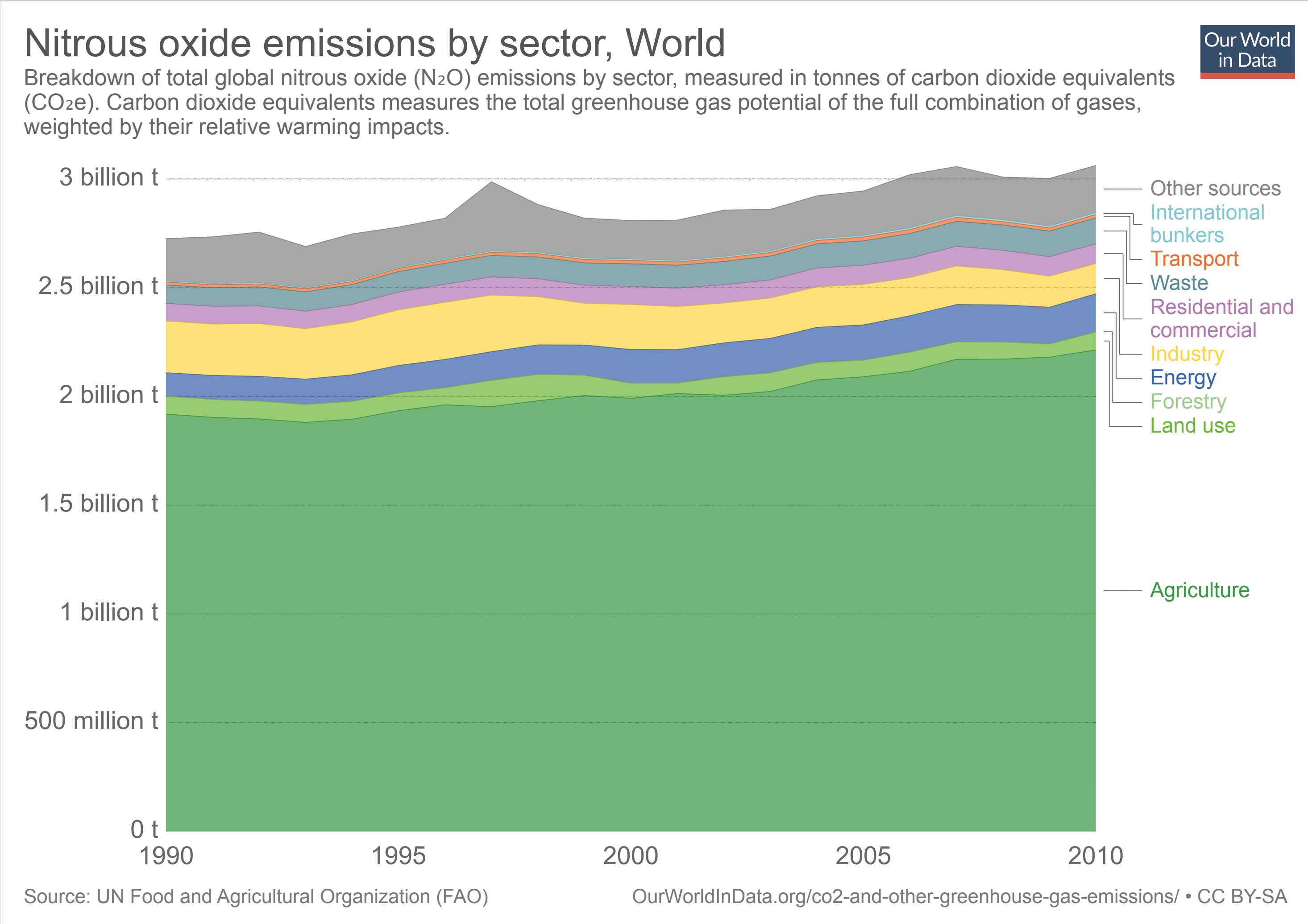
Carbon dioxide (CO_2) emissions by sector



Methane (CH_4) emissions by sector



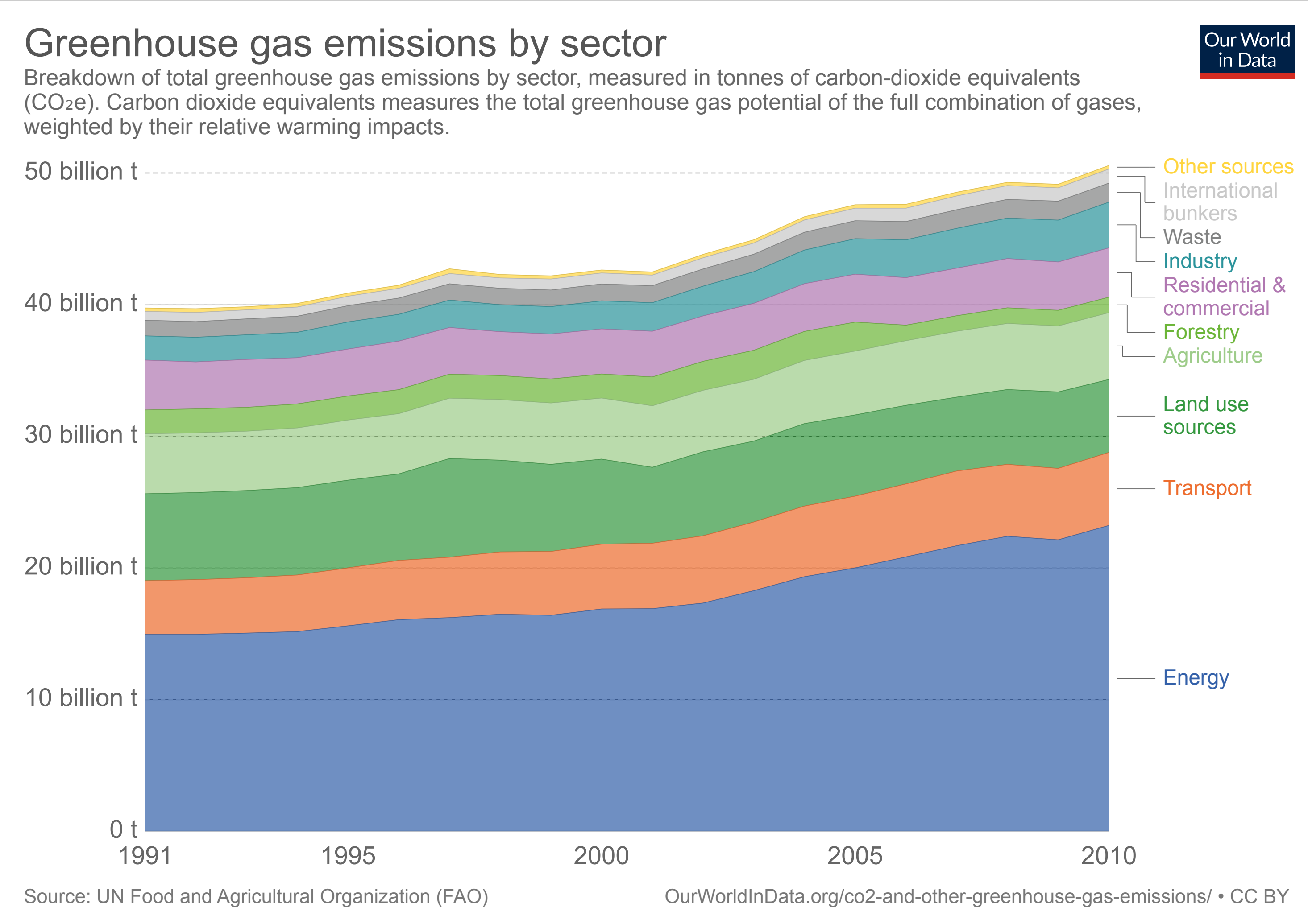
Nitrous oxide (N_2O) emissions by sector



Emissions from agriculture and land use

Although many people typically attribute CO_2 emissions to energy production, there are other important contributing activities, such as transportation and agriculture. The most recent Intergovernmental Panel on Climate Change (IPCC) reported that the agriculture, forestry, and land use (AFOLU) sector was responsible for about one-quarter of global greenhouse gas emissions.[9] [10]

Total greenhouse gas emissions (measured in their carbon-dioxide equivalent values) by sector are shown in the chart below. The combined figures for agriculture, forestry and land use yield a similar result to that of the IPCC: collectively these emissions account for approximately one-quarter of global emissions.



Why have emissions from agriculture been increasing with time? There are two key contributors to increasing emissions. Firstly, a growing global population requires an overall higher food production. This increased requirement for food has led to both expansion of agricultural land and an intensification of farming practices.[11]

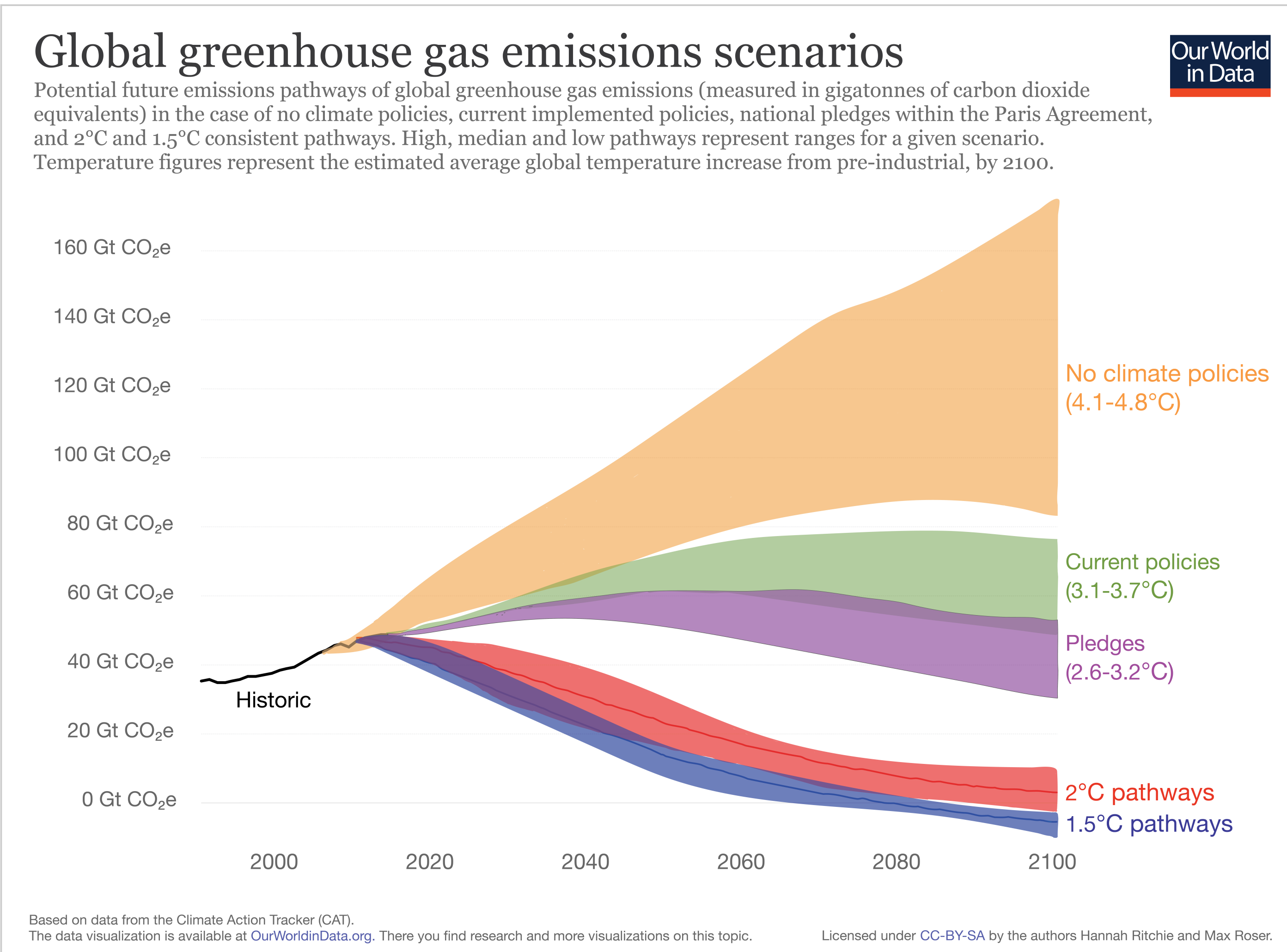
Agricultural land often expands into previously forested areas, and this process of deforestation releases CO_2 stored in trees and soils. These emissions are included in the accounting related to agriculture, forestry and land use (ALOFU), and it is estimated that up to 80 percent of deforestation is the result of agricultural expansion.

Secondly, global economic growth has not only resulted in an increase in food demand (richer people tend to eat more), but also in changes in dietary composition; that is, changes in what we eat. Economic growth is typically related to an increase in meat consumption.[12] Livestock are an important source of greenhouse gas emissions, with variations between animal products (lamb and beef are usually the most carbon-intensive and chicken the least).[13] A growing global middle class has led to significant increases in global meat consumption in recent decades—trends in meat consumption can be found at our entry on Meat and Seafood Production & Consumption.

Future emission scenarios

What does the future of our carbon dioxide and greenhouse gas emissions look like. In the chart below we show a range of potential future scenarios of global greenhouse gas emissions (measured in gigatonnes of carbon dioxide equivalents), based on data from Climate Action Tracker. Interactive data of these pathways can be found here. Here, five scenarios are shown:

- **No climate policies**: projected future emissions if no climate policies were implemented; this would result in an estimated 4.1-4.8°C warming by 2100 (relative to pre-industrial temperatures)
- **Current climate policies**: projected warming of 3.1-3.7°C by 2100 based on current implemented climate policies
- **National pledges**: if all countries achieve their current targets/pledges set within the Paris climate agreement, it's estimated average warming by 2100 will be 2.6-3.2°C. This will go well beyond the overall target of the Paris Agreement to keep warming "well below 2°C".
- **2°C consistent**: there are a range of emissions pathways that would be compatible with limiting average warming to 2°C by 2100. This would require a significant increase in ambition of the current pledges within the Paris Agreement.
- **1.5°C consistent**: there are a range of emissions pathways that would be compatible with limiting average warming to 1.5°C by 2100. However, all would require a very urgent and rapid reduction in global greenhouse gas emissions.

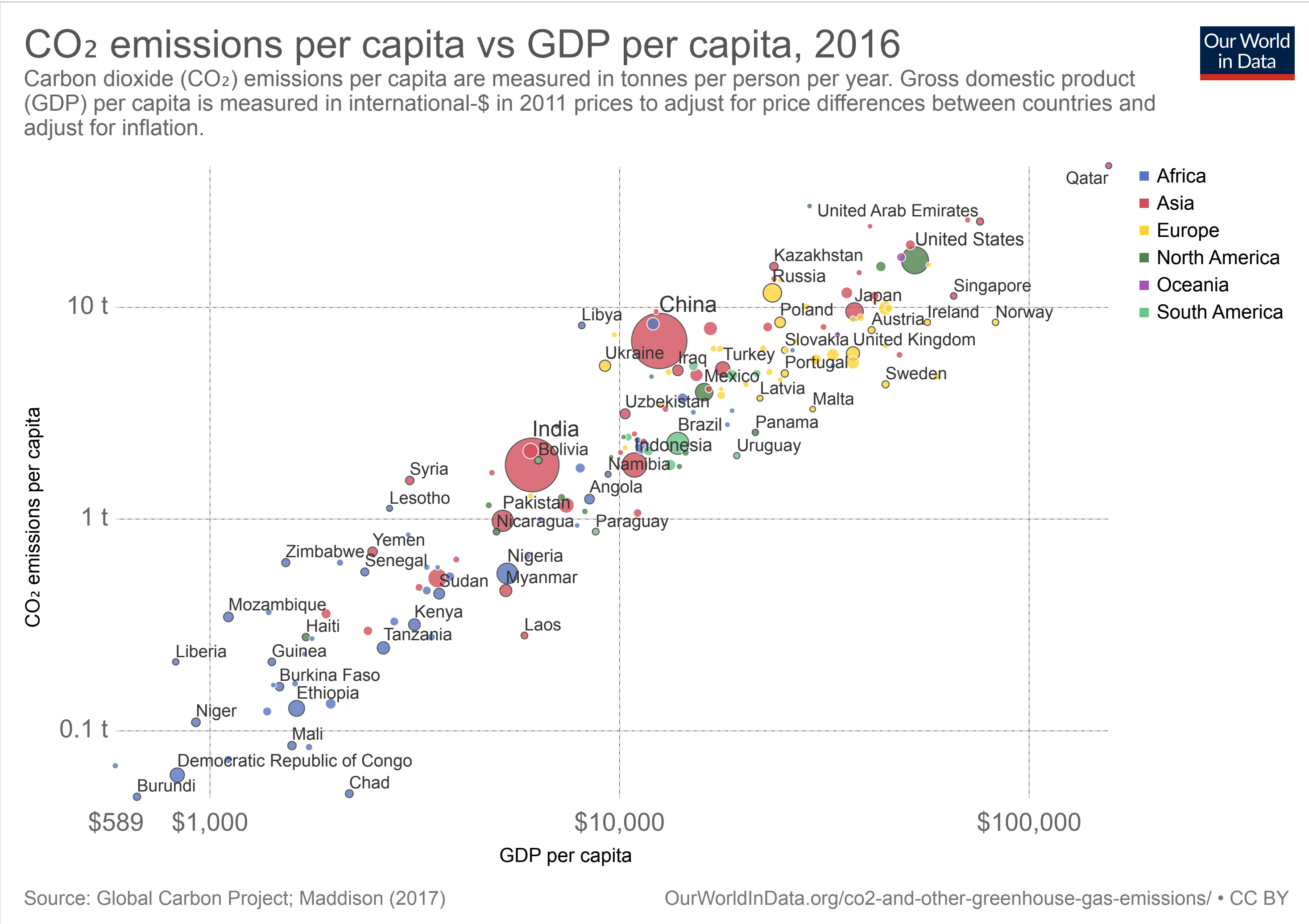


Correlates, Determinants & Consequences

CO_2 emissions and prosperity

Historically, CO_2 emissions have been primarily driven by increasing fuel consumption. This energy driver has been, and continues to be, a fundamental pillar of economic growth and poverty alleviation. As a result, we see in the visualization below that there is a strong correlation between per capita CO_2 emissions and GDP per capita.

This correlation is also present over time: Countries begin in the bottom-left of the chart at low CO_2 and low GDP, and move upwards and to the right. Historically, where fossil fuels are the dominant form of energy, we therefore see increased CO_2 emissions as an unintended consequence of development and economic prosperity.



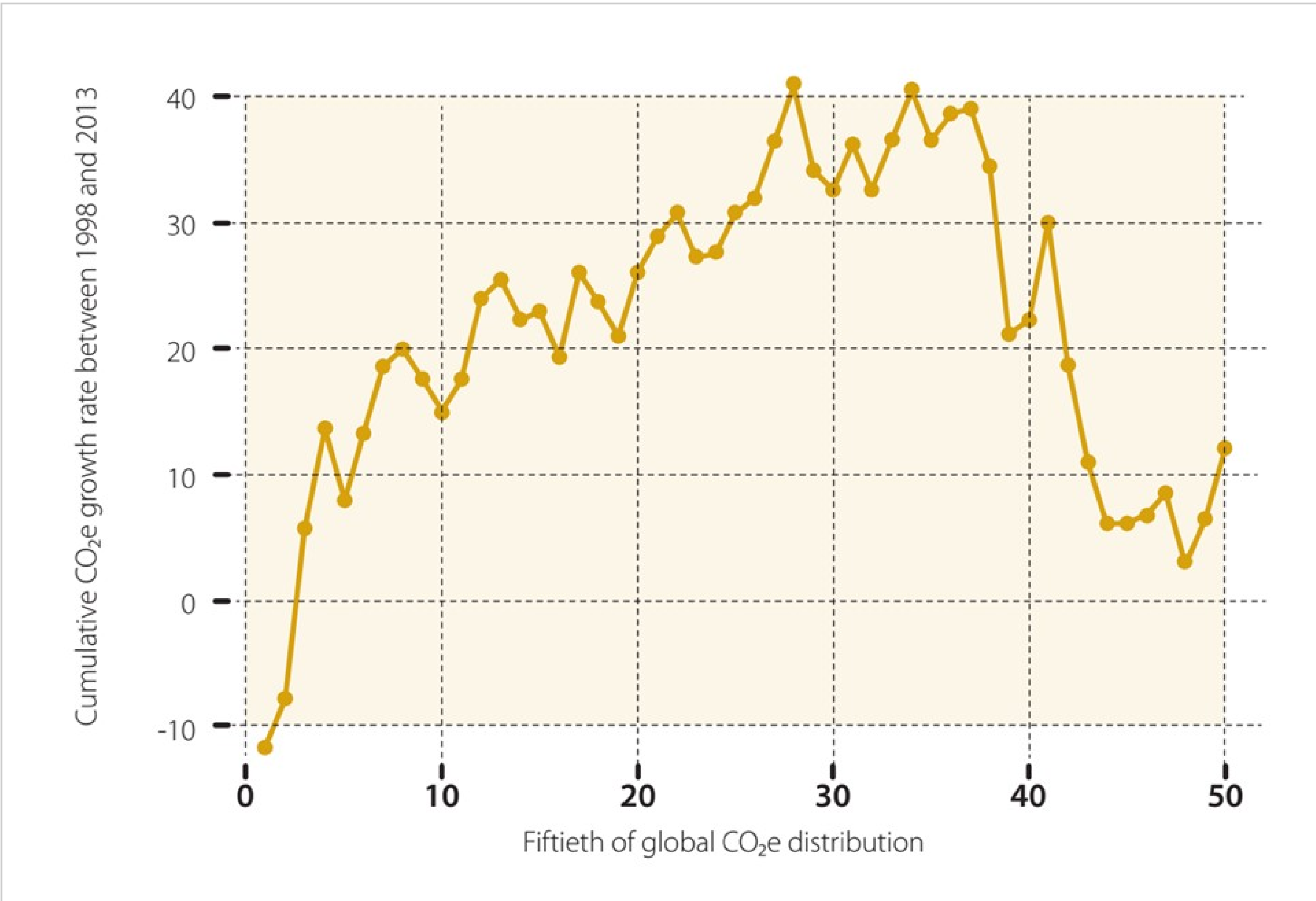
While we see this general relationship between CO_2 and GDP, there are outliers in this correlation, and important differences exist in the rate with which per capita emissions have been growing.

These differences are exemplified in global inequalities in energy provision, CO_2 emissions, and economic disparities. In the chart below we see the change in CO_2 emissions (i.e. the growth rates) over the last few decades (1998-2013) across the global spectrum of emitters.

On the x-axis we have the spectrum of global emitters (where those at the far left have very low per capita emissions, and those at the far right have the world's highest per capita emissions). On the y-axis we have the growth (in %) in CO_2 emissions that each segment of emitters has undergone from 1998-2013. We see that the middle of the spectrum—typically those near the middle of the global income spectrum—have experienced a large growth in CO_2 emissions over the last few decades (most between 25-40%). Insofar as emissions are a correlate of development, this is good news and reflects the fact that a global middle class is developing, but it does present important challenges in terms of global CO_2 emissions.

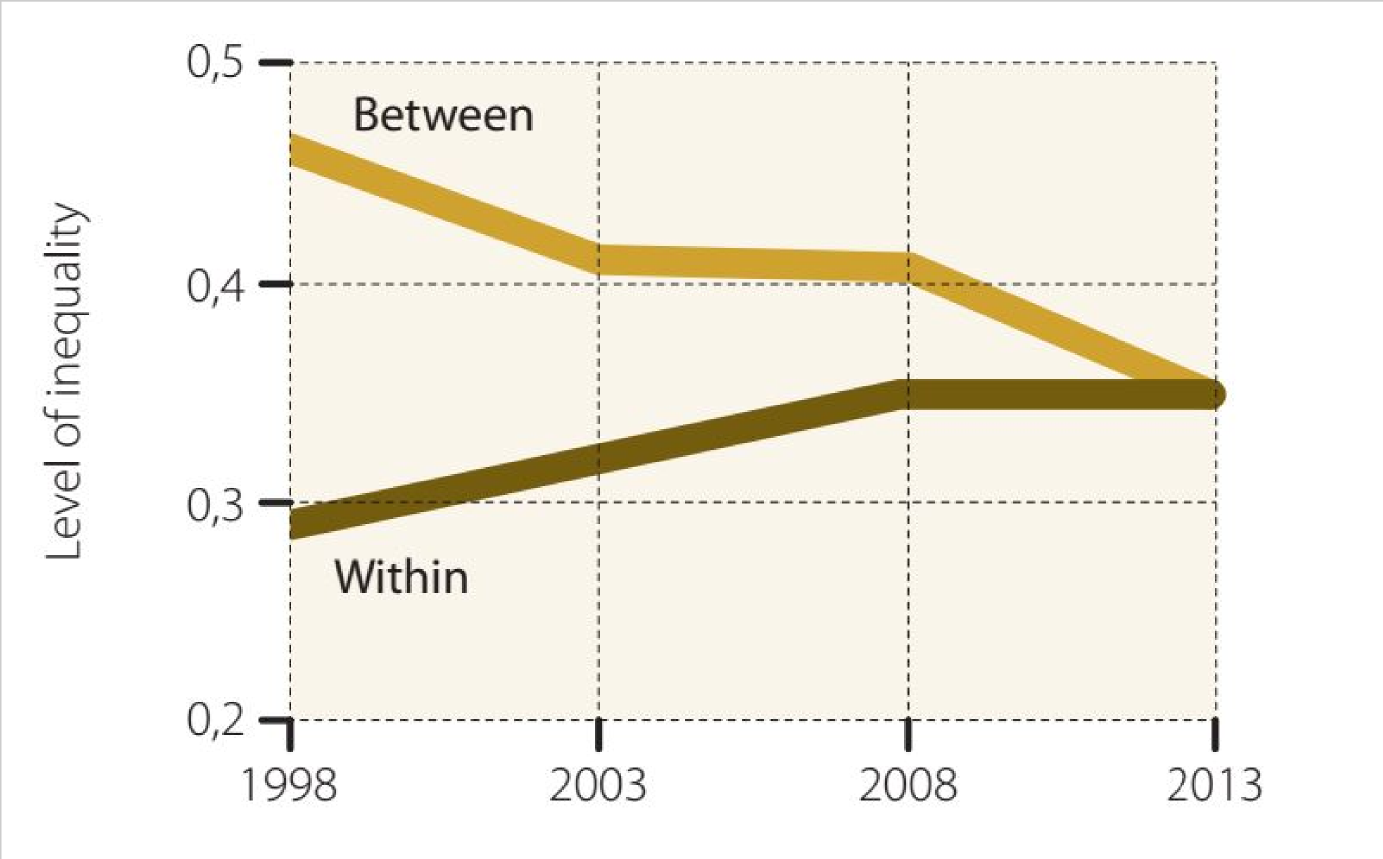
It is therefore concerning that at the bottom of the spectrum (the group of people of whom many are part of the world's poorer population) have seen a 12% *decline* in CO_2 emissions over this same period. While a decline in emissions is necessary and possible for individuals with high per capita emissions, for the poorest, this potentially suggests stagnation or decline in living conditions.

Growth rate in CO_2 emissions (from 1998-2013) across the spectrum of global emitters[14]



Not only cross-country inequalities in CO_2 emissions are important—there are also noticeable within-country inequalities. In fact, as the global inequalities in CO_2 emissions between countries begin to converge, within-country inequalities become more important. As the chart below shows, in 1998 two-thirds of inequality in CO_2 emissions were due to between-country differences. Within-country differences then became more important, and by 2013, within and between-country differences were responsible for roughly the same share of total inequalities.

Levels of CO_2 inequality between and within countries[15]



CO_2 growth and poverty alleviation

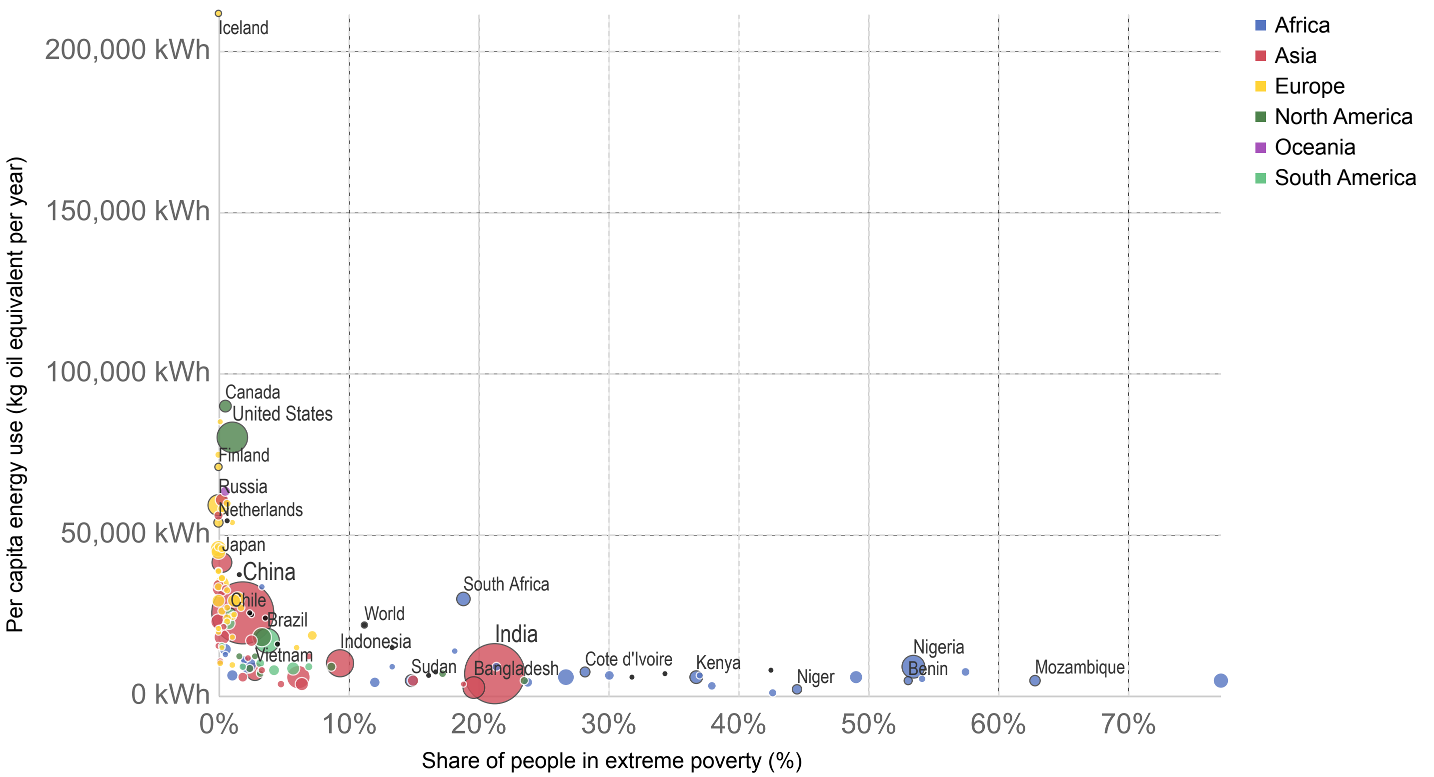
The link between economic growth and CO_2 described above raises an important question: do we actually want the emissions of low-income countries to *grow* despite trying to reduce global emissions? In our historical and current energy system (which has been primarily built on fossil fuels), CO_2 emissions have been an almost unavoidable consequence of the energy access necessary for development and poverty alleviation.

In the two charts below, we see per capita CO_2 emissions, and energy use per capita (both on the y-axes), plotted against the share of the population living in extreme poverty (%) on the x-axis. In general, we see a very similar correlation in both CO_2 and energy: higher emissions and energy access are correlated to lower levels of extreme poverty. Energy access is therefore an essential component in improved living standards and poverty alleviation.[16]

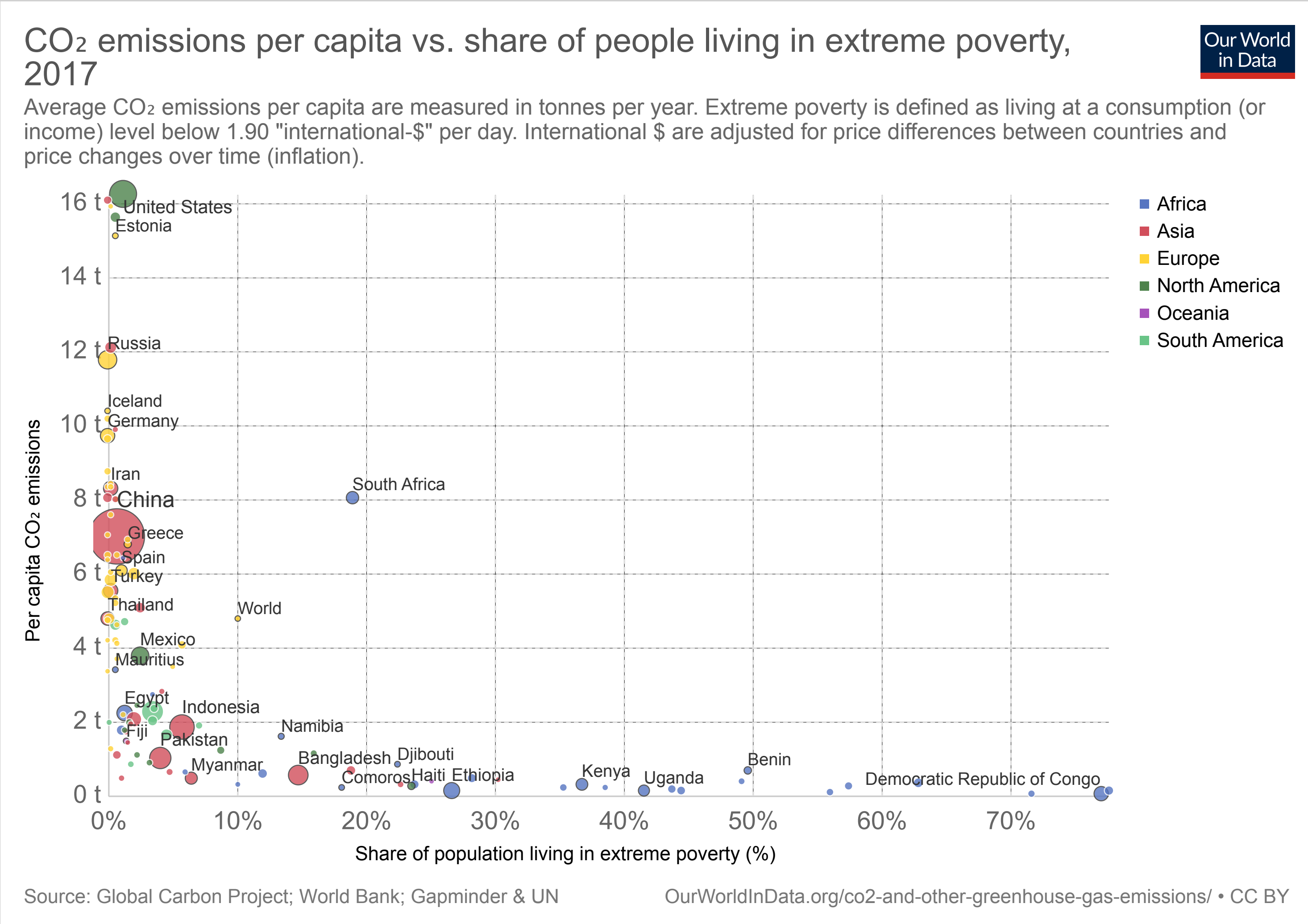
In an ideal world, this energy could be provided through 100% renewable energy: in such a world, CO_2 emissions could be an avoidable consequence of development. However, currently we would expect that some of this energy access will have to come from fossil fuel consumption (although potentially with a higher mix of renewables than older industrial economies). Therefore, although the global challenge is to reduce emissions, some growth in per capita emissions from the world's poorest countries remains a sign of progress in terms of changing living conditions and poverty alleviation.

Energy use per capita vs. share of population in extreme poverty, 2013

Per capita energy use measured in kilowatt-hours (kWh) per year. Extreme poverty is defined as living at a consumption (or income) level below 1.90 "international-$" per day. International $ are adjusted for price differences between countries and price changes over time (inflation).



Source: International Energy Agency (IEA) via The World Bank
OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY-SA



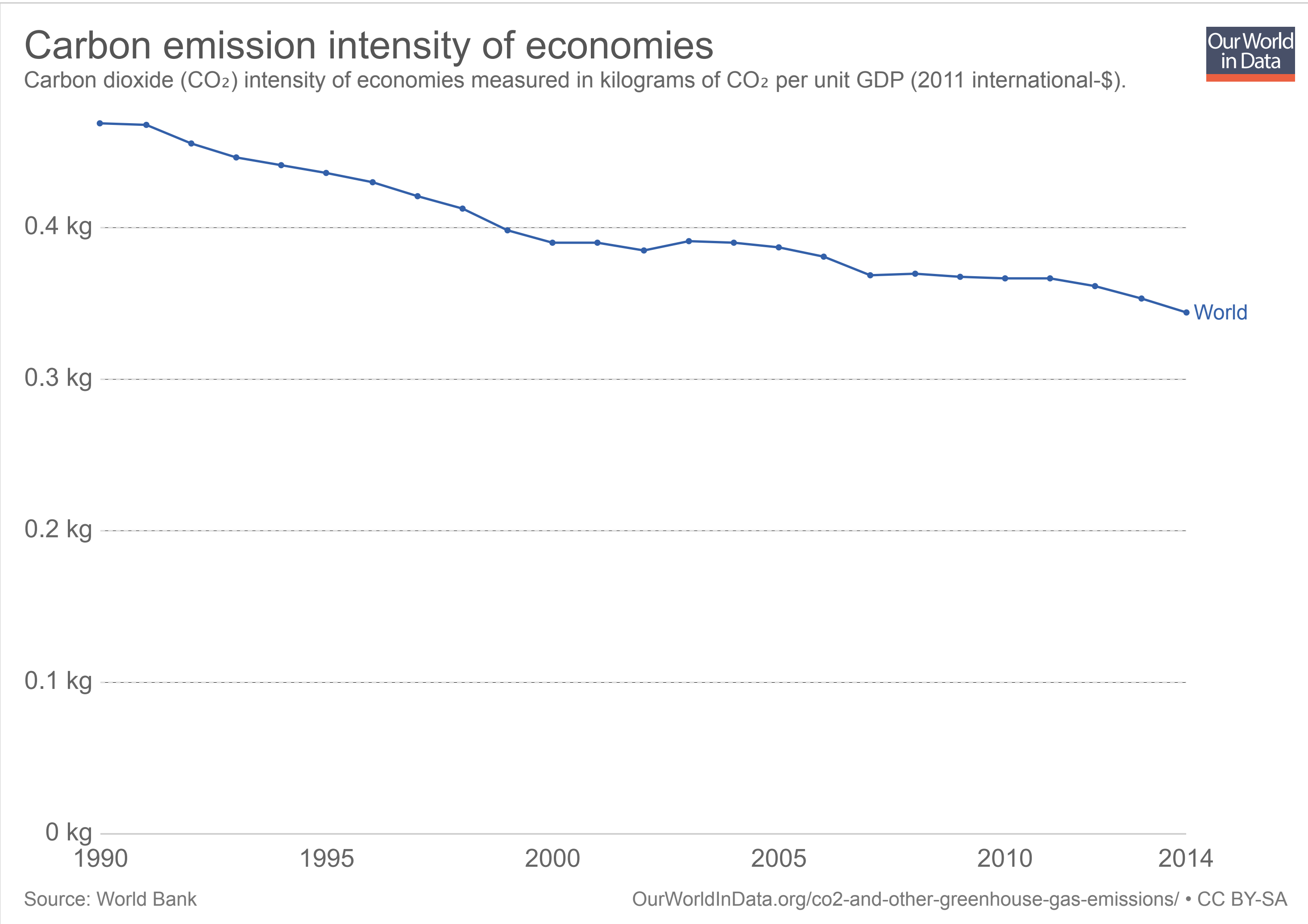
CO_2 intensity of economies

If economic growth is historically linked to growing CO_2 emissions, why do countries have differing levels of per capita CO_2 emissions despite having similar GDP per capita levels? These differences are captured by the differences in the *CO_2 intensity* of economies; CO_2 intensity measures the amount of CO_2 emitted per unit of GDP (kgCO_2 per int-$). There are two key variables which can affect the CO_2 intensity of an economy:

- Energy efficiency: the amount of energy needed for one unit of GDP output. This is often related to productivity and technology efficiency, but can also be related to the type of economic activity underpinning output. If a country's economy transitions from manufacturing to service-based output, less energy is needed in production, therefore less energy is used per unit of GDP.
- Carbon efficiency: the amount of CO_2 emitted per unit energy (grams of CO_2 emitted per kilowatt-hour). This is largely related to a country's energy mix. An economy powered by coal-fired energy will produce higher CO_2 emissions per unit of energy versus an energy system with a high percentage of renewable energy. As economies increase their share of renewable capacity, efficiency improves and the amount of CO_2 emitted per unit energy falls.

In the chart below, we see that the global CO_2 intensity has been steadily falling since 1990.[17] This is likely thanks to both improved energy and technology efficiency, and increases in the capacity of renewables.[18] The carbon intensity of nearly all national economies has also fallen in recent decades. Today, we see the highest intensities in Asia, Eastern Europe, and South Africa. This is likely to be a compounded effect of coal-dominated energy systems and heavily industrialized economies. The shift in industrial production from high-income to transitioning economies, and its impact on CO_2 emissions, is discussed in the next section.

Although carbon intensities have generally shown a steady, gradual decline in recent decades, dramatic short-term fluctuations in intensity can occur and are typically the result of significant short-term political or economic change. The most dramatic example of this was seen in China during its 'Great Leap Forward' campaign in the 1950s-60s, which we have explored in detail on our blog here.

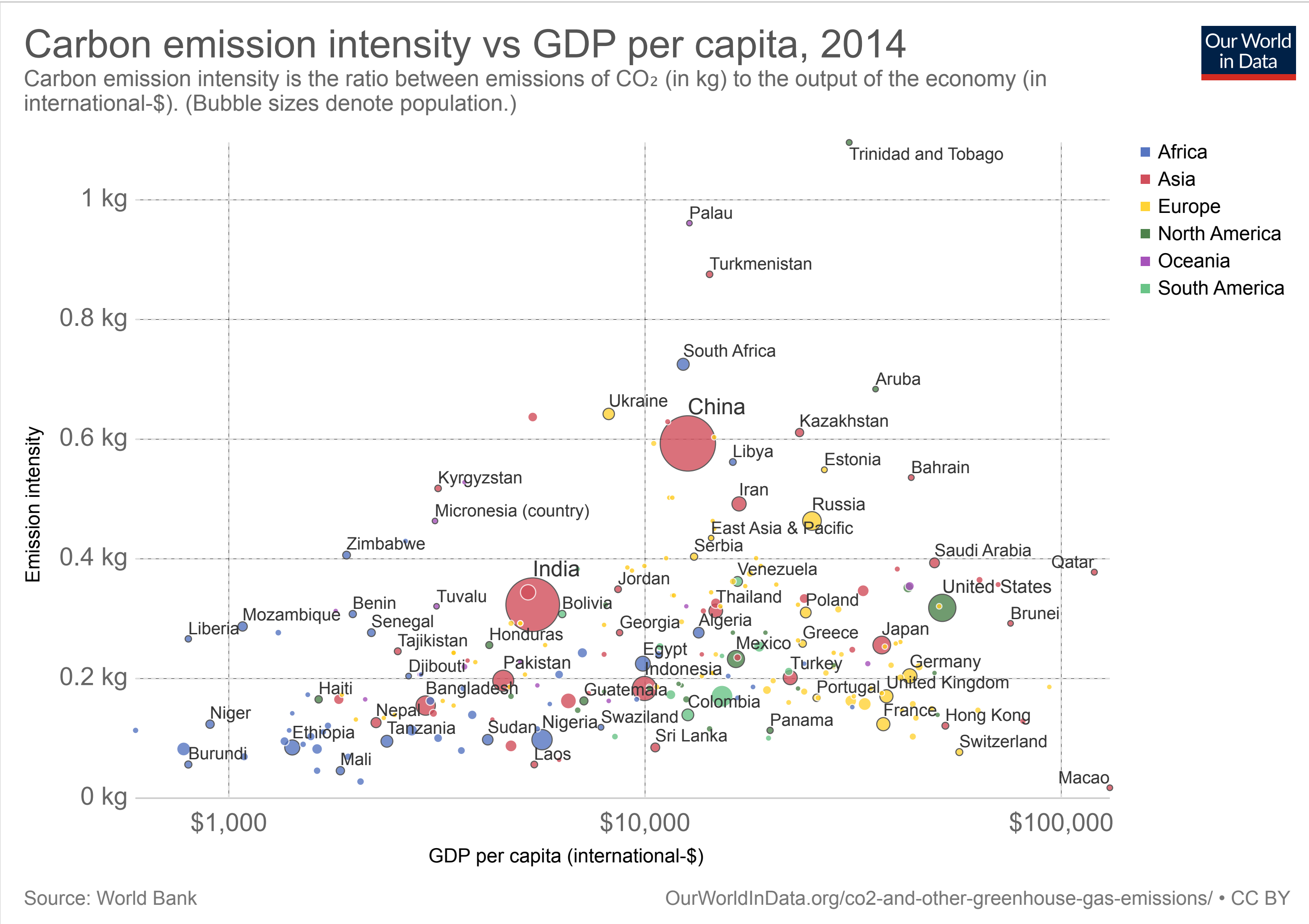


CO_2 intensity and prosperity

As seen in the section above, the general trend in carbon intensity at the global and national level is a downward trend over time. But how do levels of CO_2 intensity change across different levels of prosperity?

In the chart below we have plotted average carbon intensities by country (y-axis) against gross domestic product (GDP) per capita (x-axis, log scale). As a cross-section across countries in any given year, we see an overall shape akin to an inverted-U. On average, we see low carbon intensities at low incomes; carbon intensity rises as countries transition from low-to-middle incomes, especially in rapidly growing industrial economies; and as countries move towards higher incomes, carbon intensity falls again.

This trend is approximately true as a cross-section across countries. However, such trends differ for individual countries over time. If we view these trends over the timeline from 1990 onwards we see that there are large variations in the evolution of carbon intensities, even for countries with similar income levels.



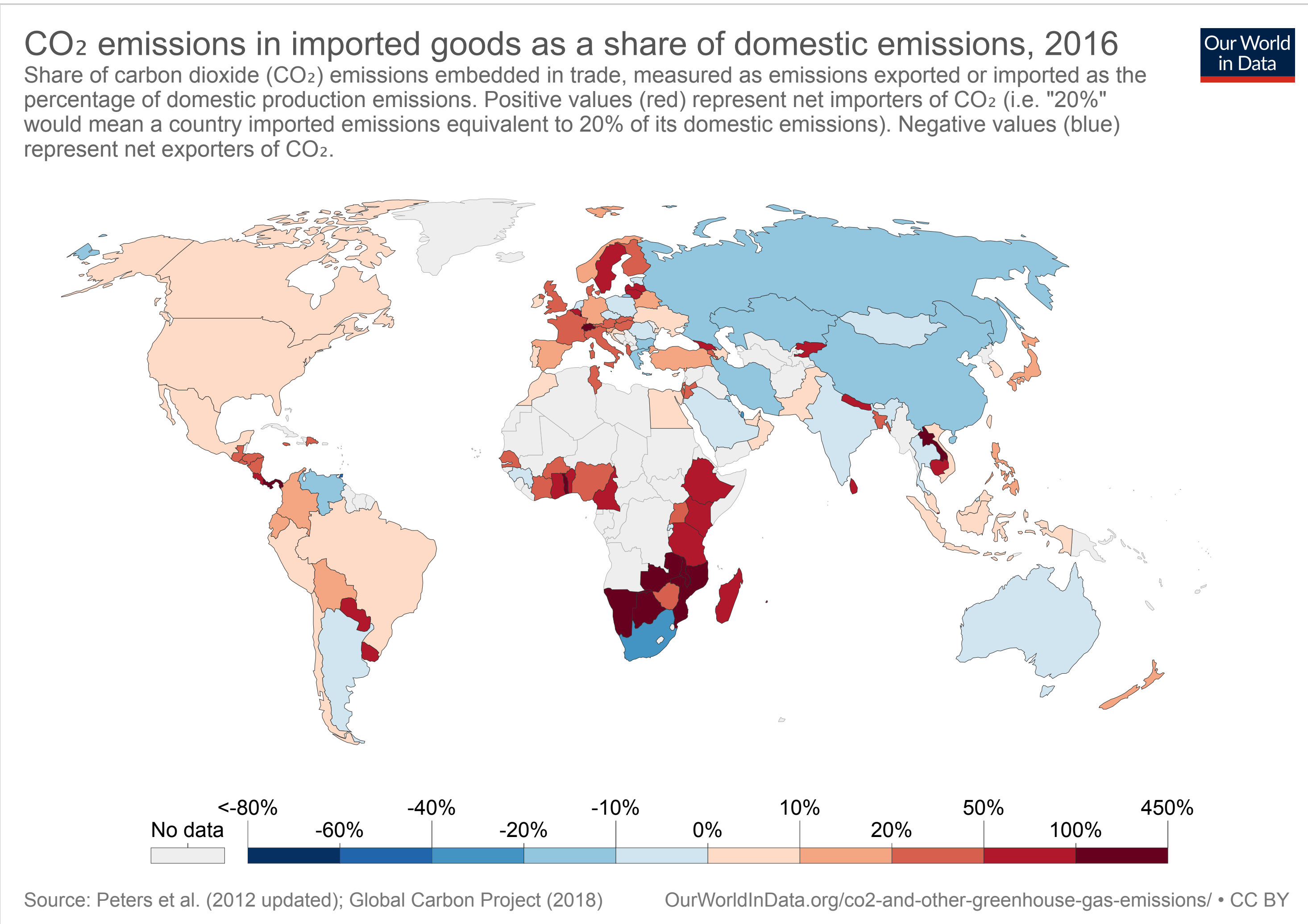
CO_2 embedded in trade

CO_2 emissions are most typically measured and reported in terms of CO_2 "production". This accounting method is also sometimes referred to as "territorial-based" emissions because it reports emissions as those emitted within a country's given geographical boundaries. As a result, this method takes no account of emissions which may be imported or exported in the form of traded goods.[19] "Consumption-based" accounting adjusts CO_2 emissions for this trade of emissions and more accurately reflects the emissions necessary to support a given country's way of living.

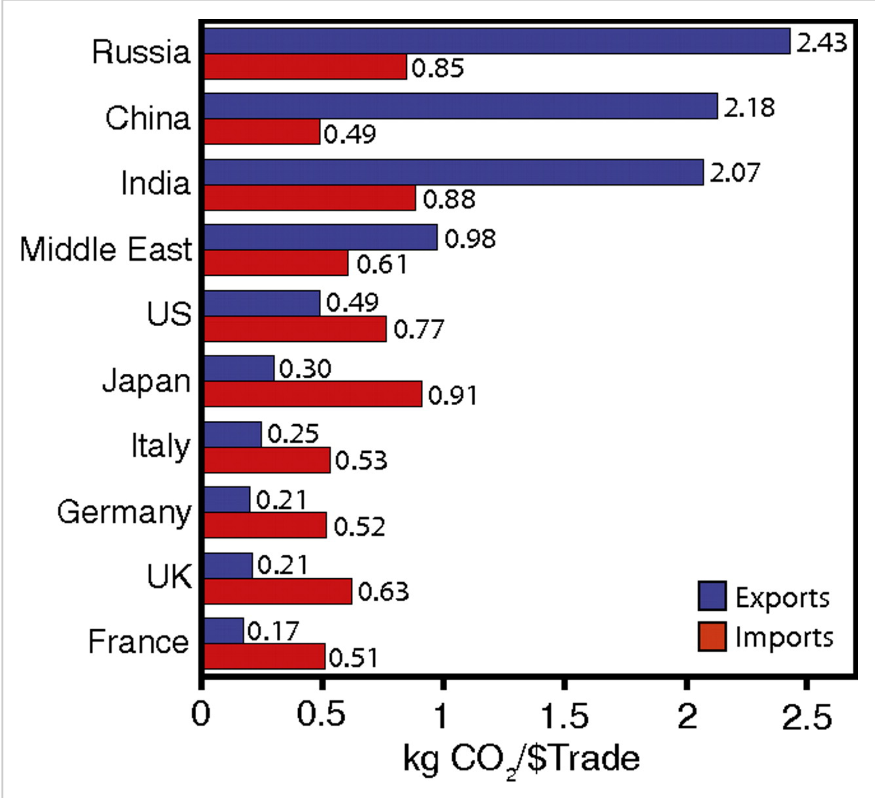
What does a global map of traded CO_2 emissions look like? In the map below we see the net emissions transferred between countries as a percentage of their domestic production emissions [you can also view these trends in absolute terms here]. The net emissions transfers here is the CO_2 embedded in imported goods minus the CO_2 embedded in exported goods. This tells us whether a country is a net exporter or importer of emissions. In our chart, positive values (red) indicate a country is a net importer of emissions, and negative values (blue) represent net exporters. Here we see an important East-to-West relation, with large exports from Asia and Eastern Europe into Western Europe and North America.

In other words: some of the CO_2 produced (and reported) in emission records of Asian and Eastern European countries is for the production of goods consumed in Western Europe and North America. Based on the updated data gathered by Peters et al. (2012) and the Global Carbon Project[20], if we switched to a consumption-based reporting system (which corrects for this trade), in 2014 the annual CO_2 emissions of many European economies would increase by more than 30% (the UK by 38%; Sweden by 66%; and Belgium's emissions would nearly double); and the USA's emissions would increase by 7%. On the other hand, China's emissions would decrease by 13%; India's by 9%; Russia's by 14% and South Africa by 29%.

The composition of this trade is also important in terms of carbon intensity. In the second figure below we see the carbon intensity (kgCO_2 per $ of trade) for imports and exports across several countries. The goods exported from Russia, China, India, and the Middle East typically have a high carbon intensity, reflecting the fact that their exports are often manufactured goods. In contrast, we see that exports from the UK, France, Germany and Italy are low; this is likely to be the higher share of export of service-based exports relative to those produced from heavy industry.

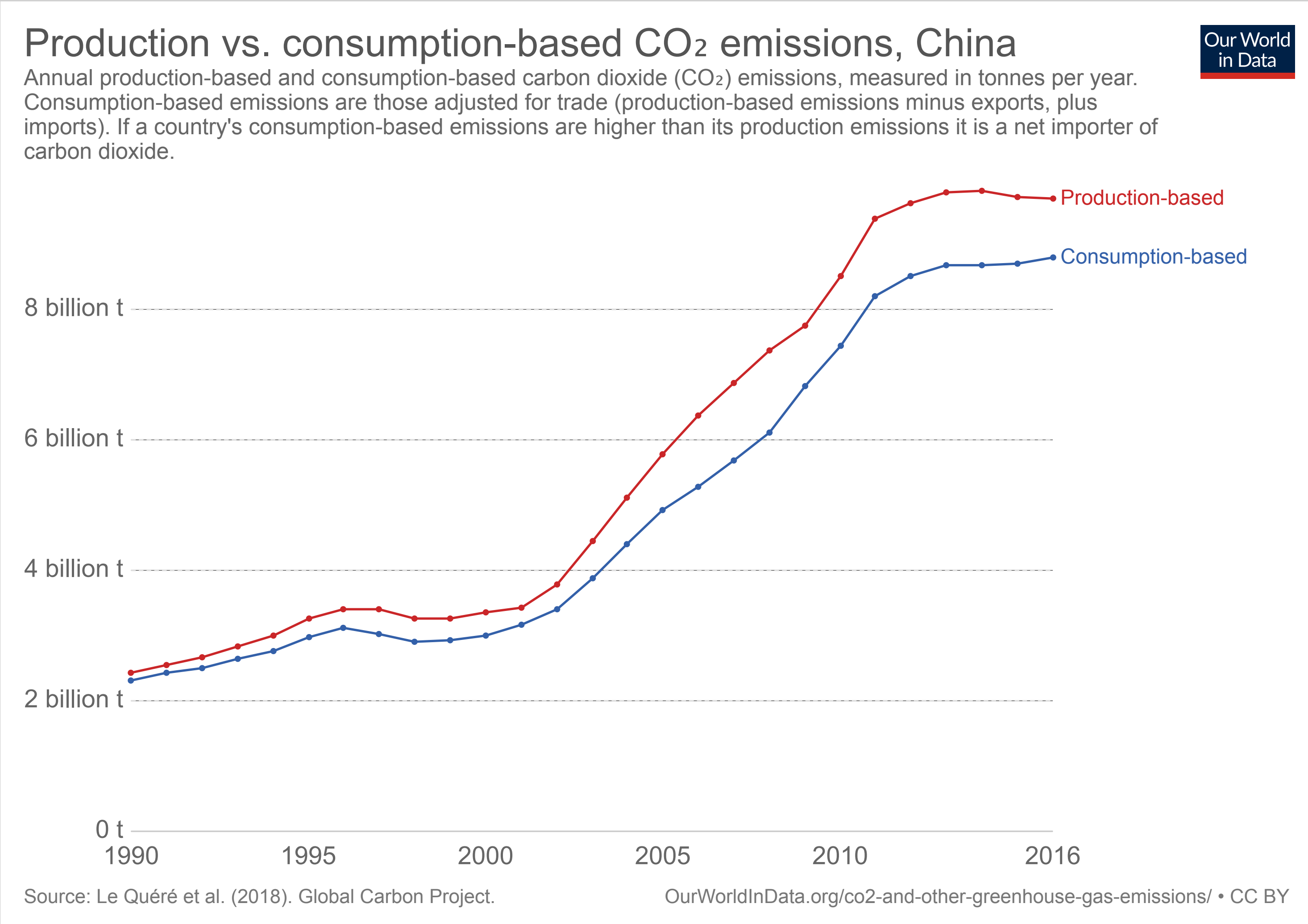


CO_2 intensity of goods imported and exported by country[21]



Production vs consumption-based emissions over time

The chart below shows how production and consumption-based emissions have changed since 1990 across regions and countries. If a country's consumption-based emissions are higher than its production-based emissions then it is a net importer of CO_2. If production-based emissions are higher, it is a net exporter.



The cost of global CO_2 mitigation

With an understanding of the link between CO_2 and global temperatures, as well as knowledge of the sources of emissions, an obvious question arises: How much could we reduce our emissions by, and how much would it cost? The possible cost-benefit of taking global and regional action on climate change is often a major influencing factor on the effectiveness of mitigation agreements and measures. How we work out the potential costs of global climate change mitigation has been covered in an explainer post here.

Data Quality, Definitions and Measurement

How do we reconstruct long-term CO_2 concentrations?

In more recent years, global concentrations of CO_2 can be measured directly in the atmosphere using instrumentation sensor technology. The longest and most well-known records from direct CO_2 measurement comes from the Mauna Loa Observatory (MLO) in Hawaii. The MLO has been measuring atmospheric composition since the 1950s, providing the clearest record of CO_2 concentrations across the 20th and 21st century.

To reconstruct long-term CO_2 concentrations, we have to rely on a number of geological and chemical analogues which record changes in atmospheric composition through time. The process of ice-coring allows for the longest extension of historical CO_2 records, extending back 800,000 years. The most famous ice core used for historical reconstructions is the Vostok Ice Core in Antarctica. This core extends back 420,000 years and covers four glacial-interglacial periods.

Ice cores provide a preserved record of atmospheric compositions—with each layer representing a date further back in time. These can extend as deep at 3km. Ice cores preserve tiny bubbles of air which provide a snapshot of the atmospheric composition of a given period. Using chemical dating techniques (such as isotopic dating) researchers relate time periods to depths through an ice core. If Looking at the Vostok Ice Core, researchers can say that the section of core 500m deep was formed approximately 30,000 years ago. CO_2 concentration sensors can then be used to measure the concentration in air bubbles at 500m depth—this was approximately 190 parts per million. Combining these two methods, researchers estimate that 30,000 years ago, the CO_2 concentration was 190ppm. Repeating this process across a range of depths, the change through time in these concentrations can be reconstructed.

How do we measure or estimate CO_2 emissions?

Historical fossil fuel CO_2 emissions can be reconstructed back to 1751 based on energy statistics. These reconstructions detail the production quantities of various forms of fossil fuels (coal, brown coal, peat and crude oil), which when combined with trade data on imports and exports, allow for national-level reconstructions of fossil fuel production and resultant CO_2 emissions. More recent energy statistics are sourced from the UN Statistical Office, which compiles data from official national statistical publications and annual questionnaires. Data on cement production and gas flaring can also be sourced from UN data, supplemented by data from the US Department of Interior Geological Survey (USGS) and US Department of Energy Information Administration. A full description of data acquisition and original sources can be found at the Carbon Dioxide Information Analysis Center (CDIAC).

As an example: how do we estimate Canada's CO_2 emissions in 1900? Let's look at the steps involved in this estimation.

- **Step 1**: we gather industrial data on how much coal, brown coal, peat and crude oil Canada extracted in 1900. This tells us how much energy it could produce if it used all of this domestically.
- **Step 2:** we cannot assume that Canada only used fuels produced domestically—it might have imported some fuel, or exported it elsewhere. To find out how much Canada *actually* burned domestically, we therefore have to correct for this trade. If we take its domestic production (account for any fuel it stores as stocks), add any fuel it imported, and subtract any fuel it exported, we have an estimate of its net consumption in 1900. In other words, if we calculate: Coal extraction − Coal exported + Coal imported − Coal stored as stocks, we can estimate the amount of coal Canada burned in 1900.
- **Step 3:** converting energy produced to CO_2 emissions. we know, based on the quality of coal, its carbon content and how much CO_2 would be emitted for every kilogram burned (i.e. its emission factor). Multiplying the quantity of coal burned by its emission factor, we can estimate Canada's CO_2 emissions from coal in 1900.
- **Step 4:** doing this calculation for all fuel types, we can calculate Canada's total emissions in 1900.

Providing good estimates of CO_2 emissions requires reliable and extensive coverage on domestic and traded energy—the international framework and monitoring of this reporting has significantly improved through time. For this reason, our understanding of emissions in the late 20th and 21st centuries is more reliable than our long-term reconstructions. The Intergovernmental Panel on Climate Change (IPCC) provide clear guidelines on methodologies and best practice for measuring and monitoring CO_2 estimates at the national level.[22]

There are two key ways uncertainties can be introduced: the reporting of energy consumption, and the assumption of emissions factors (i.e. the carbon content) used for fuel burning. Since energy consumption is strongly related to economic and trade figures (which are typically monitored closely), uncertainties are typically low for energy reporting. Uncertainty can be introduced in the assumptions nations make on the correct CO_2 emission factor for certain fuel types.

Country size and the level of uncertainty in these calculations have a significant influence on the inaccuracy of our global emissions figures. In the most extreme example to date, Lui et al. (2015) revealed that China overestimated its annual emissions in 2013 by using global average emission factors, rather than specific figures for the carbon content of its domestic coal supply.[23] As the world's largest CO_2 emitter, this inaccuracy had a significant impact on global emissions estimates, resulting in a 10% overestimation. More typically, uncertainty in global CO_2 emissions ranges between 2-5%.[24]

Data Sources

Carbon Dioxide Information Analysis Center

- **Data:** CO2 emissions (also by fuel type), and data on trace gas emissions, aerosols, the carbon cycle, the Full Global Carbon Budget (1959-2013), land use and more.
- **Geographical coverage:** Global, regional, national, subnational (for some) and globally gridded (1°x1°; since 1751).
- **Time span:** Since 1751
- **Available at:** Online here.
- *CDIAC is the climate-change data and information analysis center of the U.S. Department of Energy (DOE).*

- *The Historical Carbon Dioxide Record from the Vostok Ice Core is available here - it covers the period 417,160 - 2,342 years BP.*
- *The Atmospheric Carbon Dioxide Record from Mauna Loa is available here - it goes back to 1958.*
- *The **Clio Infra Project** is also using CDIAC data. The data is available for download here.*

T.A. Boden, G. Marland, and R.J. Andres. 2017. Global, Regional, and National Fossil-Fuel CO2 Emissions

- **Data**: CO2 emissions by source
- **Geographical coverage:** Global- by region

- **Time span:** 1751-2013
- **Available at:** http://cdiac.ornl.gov/trends/emis/overview

National Oceanic and Atmospheric Administration (NOAA)

- **Data**: Global CO2 concentrations
- **Geographical coverage:** Global
- **Time span:** 1980-2016
- **Available at:** www.esrl.noaa.gov/gmd/ccgg/trends/

Met Office Hadley Centre for Climate Science and Services

- **Data**: Atmospheric and marine global temperatures and pressure data
- **Geographical coverage:** UK-based and global
- **Time span:** 1850-2017
- **Available at:** http://www.metoffice.gov.uk/hadobs/

Climate Tracker

- **Data**: National, regional and global level analysis on progress on greenhouse gas mitigation and targets
- **Geographical coverage:** Global, regional and national
- **Time span:** 1990-2100 (projections)
- **Available at:** http://climateactiontracker.org/global.html

World Resources Institute (WRI)

- **Data**: National and global level GHG emissions, global temperature trends and climate change impacts
- **Geographical coverage:** Global, regional and national
- **Time span:** 1860-2015
- **Available at:** http://www.wri.org/blog/2017/04/climate-science-explained-10-graphics

Intergovernmental Panel on Climate Change (IPCC)

IPCC reports are produced periodically, and provide the most complete and comprehensive aggregation of our knowledge and understanding of climatic change, including emissions, temperature correlation, mitigation and adaptation potential. This analysis provides a long-term historical outlook and covers data at both a national, regional and global level. IPCC publications and datasets are available at: https://www.ipcc.ch/

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   [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp. Available online.

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10. Note that these figures are for total greenhouse gases (not just CO_2), so nitrous oxide and methane production also play an important role.

11. The application of agricultural inputs, such as nitrogen fertilizer, is a key contributor to nitrous oxide emissions (a potent greenhouse gas).

    Jonathan A. Foley, Navin Ramankutty, Kate A. Brauman, Emily S. Cassidy, James S. Gerber, Matt Johnston, Nathaniel D. Mueller, Christine O'Connell, Deepak K. Ray, Paul C. West, Christian Balzer, Elena M. Bennett, Stephen R. Carpenter, Jason Hill, Chad Monfreda, Stephen Polasky, Johan Rockström, John Sheehan, Stefan Siebert, David Tilman & David P. M. Zaks. (2011) Solutions for a cultivated planet. Available online.

12. Meat production is generally a resource-intensive process, requiring large land, water and feed ressources.

Jonathan A. Foley, Navin Ramankutty, Kate A. Brauman, Emily S. Cassidy, James S. Gerber, Matt Johnston, Nathaniel D. Mueller, Christine O'Connell, Deepak K. Ray, Paul C. West, Christian Balzer, Elena M. Bennett, Stephen R. Carpenter, Jason Hill, Chad Monfreda, Stephen Polasky, Johan Rockström, John Sheehan, Stefan Siebert, David Tilman & David P. M. Zaks. (2011) Solutions for a cultivated planet. Nature. Available online

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17. Note that data of intensity based on collective global/national figures works out the same as when normalised to per capita intensities. This is because in the calculation of per capita figures, both CO_2 emissions and GDP are divided by population size. This means they effectively cancel each other out, giving the same result.

18. Du, K., Lin, B., & Xie, C. (2017). Exploring Change in China's Carbon Intensity: A Decomposition Approach. *Sustainability*, *9*(2), 296. Available online

19. Note that there is an important distinction here between traded *goods* and traded *fuels*. Fuels which are traded, then ultimately burned (with CO_2 emissions as a result) within a country's boundaries *are* included in production-based accounts. In fact, this trade data on fuel imports and exports is an essential component in reconstructing historical emissions. Production-based accounts, however, do not account for non-fuel traded goods or products. In this case, we assume that the energy necessary to produce these products was consumed within the exporting country's boundaries, and therefore recorded in its reported CO_2 emissions. For example, if the UK imports coal from China then burns it for energy production, the CO_2 from combustion will have been emitted within the UK's boundaries and it will therefore be accounted as emissions of the UK. If the UK imports aluminium from China, the energy and emissions necessary to mine this aluminium would have already been emitted within China's boundaries; in this case the emissions are attributed to China.

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Hannah Ritchie and Max Roser (2019) - "CO₂ and other Greenhouse Gas Emissions". Published online at OurWorldInData.org.
Retrieved from: 'https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions' [Online Resource]
```

BibTeX citation

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    title = {CO₂ and other Greenhouse Gas Emissions},
    journal = {Our World in Data},
    year = {2019},
    note = {https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions}
}
```
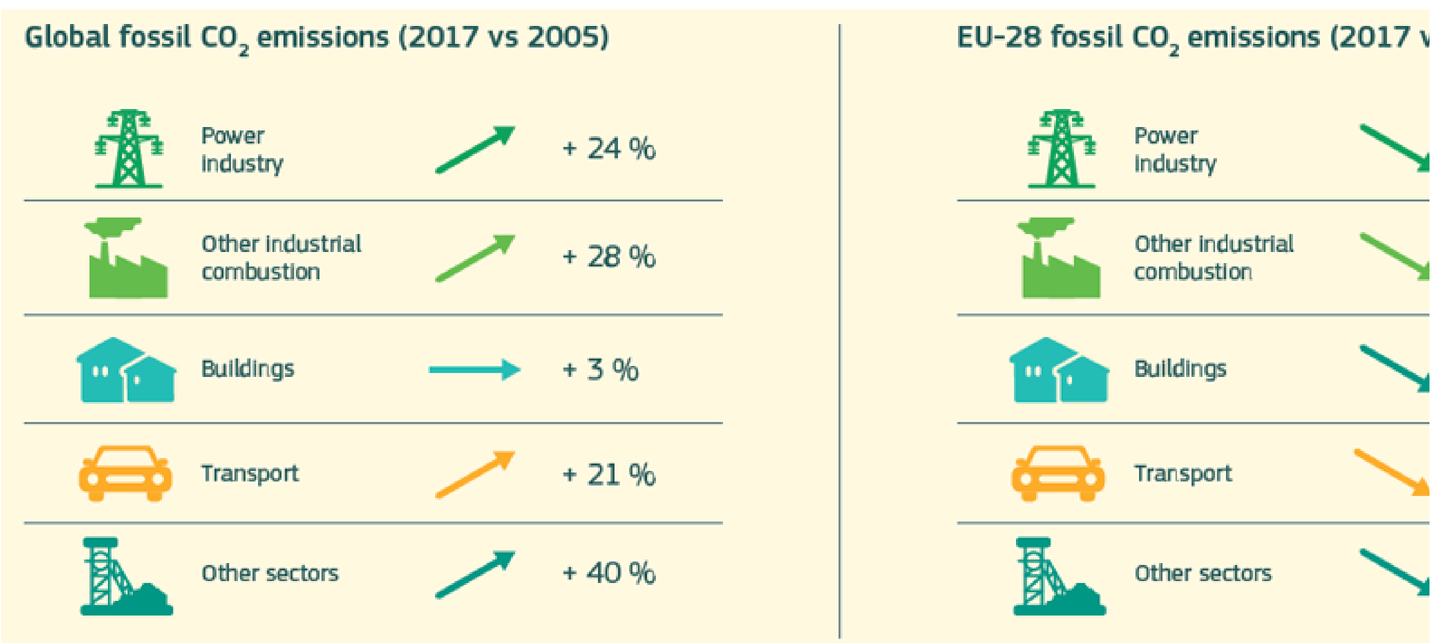

European Commission
Title of the site

Overview Emissions Data and Maps Other Activities

Fossil CO2 emissions of all world countries, 2018 report

The global GHG emissions trend has increased since the beginning of the 21st century in comparison to the three previous decades, mainly due to the increase in CO2 emissions from China and the other emerging economies. As a result, the atmospheric concentrations of greenhouse gases substantially increased enhancing the natural greenhouse effect, which may negatively affect the life on the Earth. These issues are internationally addressed in the framework of UNFCCC; countries are developing national emissions inventories and propose/implement actions to mitigate GHG emissions. CO2 emissions, which are the main responsible for global warming are still increasing at world level despite climate change mitigation agreements. However, CO2 emissions within the EU28 have decreased in the last two decades. Human related activities largely influence the total CO2 emissions – particularly, power generation and road transport but also emissions from combustion in the residential and commercial sectors play a key role. Despite decreasing trends for total EU28 CO2 emissions, CO2 emissions per capita within the EU28 are still higher than the world average value.



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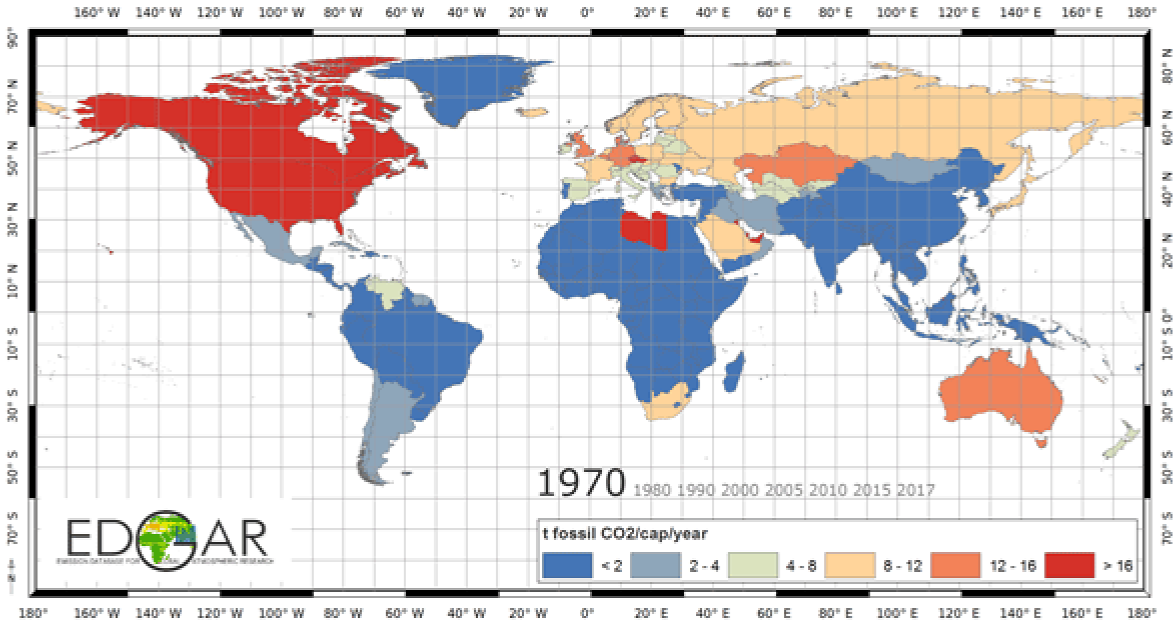
Data download

edgar_fossil_CO2_booklet2018



Fossil CO2 emissions by country

The data are presented in the table below for key years, to allow easy comparison of different countries.
"Country names are consistent with the Interinstitutional Style Guide of the European Commission available at http://publications.europa.eu/code/en/en-370100.htm; the "Short name" definition listed in the "List of countries, territo table at http://publications.europa.eu/code/en/en-5000500.htm has been used (as of 18/09/2018).

CO2 total emissions - CO2 per capita emissions - CO2 per GDP emissi

2012 emissions

Country unit	1990 kton	2000 kton	2005 kton	2010 kton	2012 kton	2015 kton	2016 kton
EU28	4409339.00	4121754.00	4249995.00	3918289.00	3725681.00	3510993.00	35104
GLOBAL TOTAL	22674089.00	25697193.00	30049770.00	33924230.00	35451841.00	36515871.00	36652
Afghanistan	2545.60	1091.58	1063.10	5641.92	9657.81	9788.62	10747
Albania	6583.27	3263.27	4196.45	4592.99	4543.51	4691.68	4943.5
Algeria	65677.48	83692.60	98196.90	116408.54	137141.91	160369.72	15992
Angola	5851.41	16613.19	15975.45	23810.68	23717.62	30817.36	32114
Anguilla	6.11	15.53	13.66	24.00	26.02	28.00	27.62
Antigua and Barbuda	223.43	243.76	282.77	356.46	615.46	624.15	624.14
Argentina	112434.08	150585.17	165429.42	191336.87	205402.69	212405.87	21229
Armenia	20699.07	3661.39	4541.81	4455.99	5866.97	5006.27	5084.8
Aruba	297.32	451.19	470.13	498.46	799.73	959.44	959.43
Australia	275407.56	353814.40	391589.92	412842.63	409894.56	403255.06	40246
Austria	62917.96	68091.25	80993.88	75307.85	70742.63	69558.87	69802
Azerbaijan	58076.92	28066.51	30484.79	24745.26	30809.43	32891.74	34097
Bahamas	1523.81	1632.77	2068.03	1746.62	3013.42	2997.00	2996.9
Bahrain	11988.31	17760.54	23388.23	28798.75	29578.81	33549.47	35383
Bangladesh	13868.26	26705.30	38834.46	58538.76	66085.52	80013.89	81603
Barbados	776.35	1649.89	2161.73	2336.70	2829.80	3169.58	3168.6
Belarus	109068.56	57782.28	61395.69	66812.91	65000.25	60552.25	61026
Belgium	115902.87	124873.03	118707.92	115748.98	103790.78	104096.88	10431

Belize	187.54	314.53	440.27	251.94	432.79	440.10	440.0
Benin	414.66	1571.64	2838.54	5105.71	4756.11	5983.32	6364.
Bermuda	335.44	279.24	283.65	357.28	616.27	428.59	428.5
Bhutan	208.29	452.57	514.52	1319.26	1955.57	1237.78	1353.
Bolivia	6286.67	8298.09	9998.14	14832.51	17923.58	19574.43	20130
Bosnia and Herzegovina	24558.83	14329.20	16890.07	22185.84	23234.18	23925.64	25036
Botswana	2817.98	4175.92	4465.34	3468.99	5064.79	7128.03	7124.
Brazil	228602.96	361435.67	380765.42	445246.57	501340.24	530826.72	49192
British Virgin Islands	26.35	29.30	31.61	71.29	123.08	148.71	148.7
Brunei	3396.76	4887.99	5174.31	7336.66	7475.99	6517.39	6475.
Bulgaria	82270.77	47740.21	52031.83	48638.86	48977.43	49281.59	45841
Burkina Faso	379.54	902.91	1037.97	1873.55	2252.80	3114.10	3199.
Burundi	210.01	278.86	307.01	225.91	295.32	270.46	275.6
Cambodia	406.99	1998.38	2685.65	5011.08	5500.16	8639.58	9940.
Cameroon	7096.76	5773.89	5519.79	7630.99	7255.38	9167.55	9799.
Canada	455826.85	558590.74	581267.38	567139.04	576608.47	587032.85	60123
Cape Verde	48.83	155.60	227.26	332.33	407.53	876.17	897.2
Cayman Islands	148.47	173.64	188.18	284.55	491.75	493.24	493.2
Central African Republic	158.60	275.87	245.78	351.56	426.39	447.57	457.7
Chad	268.32	195.98	382.95	416.90	623.62	901.80	952.1
Chile	32653.69	53848.08	59746.73	74162.60	83291.83	87233.47	92175
China	2397048.05	3671621.88	6263064.35	9124808.25	10256379.35	10808380.42	10777
Colombia	51918.86	61454.00	60609.66	66509.37	72579.43	79751.67	79723
Comoros	49.17	53.22	114.95	134.53	164.56	188.77	193.2
Congo	902.19	4541.66	4359.02	5326.19	4509.37	5317.09	5468.
Cook Islands	42.85	43.51	58.48	58.62	105.98	39.39	43.72
Costa Rica	2912.98	5085.36	6305.63	7242.52	7505.75	7661.35	7998.
Côte d'Ivoire	3019.53	6946.49	6391.63	7387.62	9226.28	11397.28	11617
Croatia	25163.85	19597.75	23634.26	21444.74	19262.02	18342.42	18548
Cuba	37109.46	28929.97	26165.15	33774.87	31740.54	31026.74	31493
Curaçao	5473.84	5390.70	4774.24	6202.54	7352.48	7377.31	7520.
Cyprus	4539.96	7021.46	7882.54	7978.98	7159.78	6324.80	6951.
Czechia	162835.21	130686.33	127157.47	120691.45	113906.29	109037.62	10894
Democratic Republic of the Congo	3441.32	1969.35	2589.50	3053.00	3108.76	3550.25	3549.
Denmark	53705.10	54061.91	51484.58	48994.27	38740.56	33942.60	36200
Djibouti	1100.93	1287.18	1469.13	1126.00	1381.82	930.98	952.7
Dominica	32.54	38.03	35.15	71.65	123.44	121.92	121.9
Dominican Republic	8024.28	19722.52	19409.25	21382.73	22209.60	23515.21	23794
Ecuador	16119.31	21820.90	28319.85	37814.32	38746.00	42538.32	40552
Egypt	90782.91	125916.60	176329.06	211649.61	232914.75	240023.56	25134
El Salvador	2633.43	5806.61	6904.75	6706.01	7074.55	7372.94	7676.
Equatorial Guinea	97.40	2534.65	3371.07	4362.13	3979.29	2848.29	2660.
Eritrea	213.54	678.91	688.34	471.43	602.45	657.48	704.8
Estonia	38467.03	16960.56	19642.58	22097.29	20376.06	19891.08	15846

Ethiopia	2389.89	3704.44	5327.22	6856.97	8933.25	13453.40	14311
Falkland Islands	13.03	13.72	16.47	23.35	40.38	37.73	37.73
Faroes	1.49	1.66	1.83	1.89	1.91	1.94	1.95
Fiji	1028.47	1143.78	2174.08	1203.96	2093.66	1225.66	1356.1
Finland	57242.49	57961.85	58360.21	65319.77	52026.19	45431.06	49000
former Yugoslav Republic of Macedonia, the	11188.91	9029.84	9694.36	9156.44	9595.20	7920.79	7852.0
France and Monaco	386213.86	402048.66	408157.88	378391.15	349349.07	327725.36	332034
French Guiana	370.65	516.66	491.25	529.74	712.11	716.53	717.43
French Polynesia	838.98	551.08	785.14	887.29	1597.57	539.84	598.25
Gabon	4857.19	6606.27	6394.36	5951.39	5889.68	6419.75	6627.4
Georgia	34744.53	5374.66	4978.62	6228.41	8183.57	10146.34	10531
Germany	1018097.10	871124.85	837283.83	815945.35	803978.52	789892.52	79858
Ghana	3194.94	6123.99	7328.63	11416.83	14694.91	15899.84	16575
Gibraltar	143.78	341.18	406.26	474.82	468.59	574.67	616.12
Greece	79201.41	97079.21	104834.79	89996.02	82446.08	70617.25	68179
Greenland	3.06	3.29	630.89	665.99	563.46	517.70	517.71
Grenada	74.61	69.80	125.45	142.43	246.02	279.80	279.78
Guadeloupe	874.75	996.76	1034.80	1188.45	2025.12	2255.39	2253.5
Guatemala	3873.88	9583.10	11674.25	11647.63	12057.07	16919.89	17998
Guinea	1073.62	1091.94	1118.97	1392.65	1703.16	2514.33	2571.6
Guinea-Bissau	195.84	263.30	289.35	404.69	494.84	375.44	384.25
Guyana	337.32	800.26	725.38	785.73	1412.96	1666.04	1776.3
Haiti	1146.51	1610.08	2234.26	2358.25	2300.31	3449.93	3510.7
Honduras	2350.77	5024.26	7806.14	8007.61	9052.28	9904.78	10361
Hong Kong	34182.40	41141.74	41916.41	42691.54	45810.45	44624.09	45155
Hungary	71929.44	58305.06	59758.30	51680.60	47074.10	46868.98	48039
Iceland	2346.49	2866.75	3170.15	3672.07	3632.83	3826.77	3981.1
India	605968.42	986578.00	1210754.48	1751894.06	1988738.27	2290068.98	23710
Indonesia	161999.51	294805.59	359988.61	418160.11	441777.79	491456.33	48839
International Aviation	258941.24	355816.87	422776.64	457664.56	480052.55	529686.63	53755
International Shipping	371803.52	498583.92	572169.18	663227.28	605091.27	657324.00	668394
Iran	206780.49	351664.96	467904.60	569466.47	586811.89	621019.21	63541
Iraq	69261.62	86521.83	89103.12	125602.66	156780.15	169800.33	18953
Ireland	32852.07	44227.15	47276.75	41270.61	37762.13	37838.96	39433
Israel and Palestine, State of	35291.05	59371.40	62149.22	72186.83	77833.39	66650.56	65666
Italy, San Marino and the Holy See	430761.89	460188.30	498204.59	427369.70	396793.32	354355.17	35646
Jamaica	7525.07	10220.93	10630.91	7452.93	7249.00	7397.93	7558.2
Japan	1149399.80	1241516.86	1276862.86	1197379.50	1289286.26	1336499.70	13198
Jordan	10207.99	15427.96	19754.58	20610.85	24492.04	25822.44	24700
Kazakhstan	250381.61	131160.42	182369.35	242955.50	256988.53	252243.12	25423
Kenya	6467.24	8582.93	8787.42	13007.91	12461.10	16902.30	17819
Kiribati	20.12	19.54	32.58	51.56	92.97	30.24	30.21
Kuwait	31414.38	54849.11	75218.25	86252.82	85647.73	94980.27	96690

Kyrgyzstan	23695.73	4861.93	5475.10	6555.59	10243.51	10702.16	10645
Laos	211.29	644.60	1038.01	1706.88	2417.17	2486.11	2673.8
Latvia	20141.45	7561.98	8242.32	8909.40	7986.31	7774.27	8090.6
Lebanon	5977.27	15232.43	16504.92	20561.78	23348.24	25134.33	23293
Lesotho	100.24	159.48	174.54	534.42	248.53	691.61	708.11
Liberia	415.52	331.36	472.85	573.76	710.69	1060.25	1063.6
Libya	37142.59	49923.72	56700.45	61575.72	59369.03	53893.18	52241
Lithuania	35313.90	11792.52	14075.36	13818.05	14369.25	13437.45	15170
Luxembourg	11750.37	8836.13	12155.74	11242.50	10904.37	9329.70	9205.7
Macao	982.43	1204.75	1623.63	1183.95	2589.08	1105.05	1208.2
Madagascar	700.31	1418.70	2220.48	2201.90	3327.21	3817.09	3909.0
Malawi	457.47	793.85	1436.65	1469.26	1386.37	1441.22	1484.3
Malaysia	59225.41	132410.98	182502.88	217362.30	221683.53	250714.05	25594
Maldives	64.74	381.63	479.34	880.27	1590.76	816.81	906.40
Mali	383.12	492.19	543.05	574.27	557.30	887.63	905.06
Malta	2351.64	2162.24	2769.42	2633.65	2771.22	1719.44	1842.3
Martinique	943.86	1060.04	1120.23	1340.34	2271.94	2371.56	2370.5
Mauritania	683.72	2580.25	2910.52	2056.02	2535.99	2728.33	2826.3
Mauritius	1190.64	2446.44	2976.78	3679.60	3757.10	3995.99	3809.7
Mexico	290354.63	397026.74	448170.66	478558.67	507754.87	493610.09	52179
Moldova	31957.05	6792.86	8138.58	8361.68	8248.68	8236.42	8522.0
Mongolia	13150.91	9049.51	11082.87	14367.13	17226.22	17415.69	24314
Morocco	22385.77	33435.22	44367.74	51979.56	58471.76	61495.24	59782
Mozambique	1182.76	1600.66	2702.56	3683.27	4108.41	6594.99	7409.6
Myanmar/Burma	4401.20	9914.40	11145.98	8490.26	12286.53	25667.72	27069
Namibia	1541.83	1911.11	2503.74	3089.18	3440.76	4130.33	4227.4
Nepal	1066.19	3384.14	3298.03	4792.99	6181.30	6533.13	7760.6
Netherlands	161446.99	176533.61	181432.81	185515.53	172171.79	175602.10	17679
New Caledonia	1622.87	1877.25	2453.37	4949.30	6512.35	5029.51	5563.3
New Zealand	24006.49	33313.52	36745.84	34121.71	35298.44	35563.55	35227
Nicaragua	1944.85	3762.69	4311.57	4626.77	4789.85	5524.78	5768.3
Niger	874.89	696.34	796.11	1431.28	2038.84	2146.86	2275.7
Nigeria	68581.33	99947.87	100196.44	90284.65	90431.32	89025.70	88305
North Korea	131365.34	73739.98	79568.44	52781.59	39257.49	25833.02	35748
Norway	36462.90	42837.85	44190.92	46720.77	44653.07	44758.08	42665
Oman	11883.74	25293.51	32963.82	52480.48	66507.25	76993.05	78196
Pakistan	66270.14	107820.26	130354.13	150490.00	153219.10	167557.48	18450
Palau	2154.96	2121.44	1734.09	2110.13	3603.41	1194.24	1325.5
Panama	2735.35	5207.00	7204.39	9436.54	10660.37	11531.07	12100
Papua New Guinea	2307.23	2262.05	4379.16	3077.85	4971.94	3767.70	4237.0
Paraguay	2262.91	3757.04	3933.86	5179.91	5614.12	6348.84	6446.1
Peru	21039.35	28870.29	31692.44	45152.99	48710.57	53858.53	57488
Philippines	43623.06	76384.00	81261.24	87052.89	91836.72	118350.44	12823
Poland	371139.39	312190.90	316255.68	327832.57	317177.45	302961.93	31509
Portugal	43671.80	64507.88	68077.26	53506.58	50471.67	52270.49	52132
Puerto Rico	2064.20	2191.27	2272.38	2125.08	2132.75	2163.54	2159.9
Qatar	16291.48	31739.86	43434.51	69780.65	81890.73	90607.75	90879
Réunion	1010.40	2024.01	2367.01	2960.77	3622.06	2677.43	2741.0

Romania	187141.88	97077.73	104712.80	82665.73	86774.94	77748.50	76420
Russia	2378920.94	1675397.32	1733949.89	1731455.61	1799085.42	1730126.18	17455
Rwanda	525.06	618.85	748.26	791.76	957.88	951.69	1045.6
Saint Helena, Ascension and Tristan da Cunha	9.53	11.22	9.70	11.49	12.19	14.96	14.95
Saint Kitts and Nevis	34.47	35.18	63.03	142.84	246.10	237.88	237.87
Saint Lucia	75.89	174.87	158.11	214.32	369.88	363.81	363.79
Saint Pierre and Miquelon	147.83	34.56	31.21	35.45	61.35	75.13	75.13
Saint Vincent and the Grenadines	38.12	70.32	94.82	108.05	185.40	179.20	179.19
Samoa	129.24	109.92	120.77	118.43	213.14	125.02	138.62
São Tomé and Príncipe	46.68	52.03	57.11	133.02	163.10	144.15	147.61
Saudi Arabia	166172.31	264166.85	339440.73	478050.93	530890.32	620695.16	62945
Senegal	2397.25	4033.06	5800.34	7034.18	7421.87	8374.84	8840.6
Serbia and Montenegro	66388.39	50814.93	61497.22	59853.49	57801.79	57617.53	60458
Seychelles	287.56	412.18	678.16	926.91	1137.61	888.03	909.45
Sierra Leone	741.10	731.82	493.41	734.53	878.49	1209.00	1234.6
Singapore	31622.60	45343.41	42998.25	51070.74	53241.60	52202.27	53672
Slovakia	60536.60	42367.01	42193.72	39657.03	36430.47	35103.38	35558
Slovenia	16622.83	15665.89	18300.26	17887.72	16295.21	14366.23	15350
Solomon Islands	133.33	169.96	187.11	184.16	326.21	125.31	138.14
Somalia	694.80	540.66	764.75	827.85	1007.19	853.47	872.82
South Africa	312463.47	345194.03	433169.72	464862.35	461354.62	477277.55	47662
South Korea	270055.94	481823.49	514946.07	596454.57	628583.97	646110.30	65076
Spain and Andorra	229966.33	311868.97	368948.02	288033.23	284970.91	271171.09	26390
Sri Lanka	4187.01	11344.53	14421.29	13677.35	17614.27	21399.45	22778
Sudan and South Sudan	5536.12	6014.80	10773.49	16666.42	17271.14	19090.48	20226
Suriname	908.00	1487.01	1685.62	1719.79	2054.36	2122.52	2210.4
Swaziland	601.82	1674.27	1541.15	2047.91	1762.79	1142.59	1170.9
Sweden	58117.12	58379.27	55876.90	53344.41	45976.60	49554.10	51222
Switzerland and Liechtenstein	44955.15	44901.55	47160.91	46468.05	43655.10	40036.47	38919
Syria	33876.41	45672.85	58581.85	61596.62	44605.22	29209.96	27212
Taiwan	124383.41	229591.82	269098.52	271033.94	262504.64	266713.55	27108
Tajikistan	12266.59	2804.93	3263.46	3130.66	3767.04	5394.08	5469.6
Tanzania	2096.14	3094.10	5780.15	7140.88	11009.41	12884.18	13988
Thailand	93008.72	171543.77	225612.82	245373.99	262366.86	270290.97	27444
The Gambia	148.71	213.45	234.72	472.58	496.33	508.41	520.41
Timor-Leste	130.20	337.15	271.78	252.48	631.45	402.42	399.58
Togo	765.35	1266.46	1327.45	2539.67	2222.60	2431.24	2570.1
Tonga	64.49	109.20	120.01	176.26	318.35	115.09	127.67
Trinidad and Tobago	14894.79	19018.12	34449.66	41041.76	38452.66	40226.70	37945
Tunisia	14704.76	21143.67	23354.95	27608.54	28008.49	30423.34	30331

Turkey	149893.02	227379.59	246169.11	308520.94	346214.98	365593.79	38690
Turkmenistan	45627.99	39346.88	52850.59	61491.93	70931.64	75183.67	76330
Turks and Caicos Islands	6.99	13.53	5.46	106.25	183.95	165.13	165.1
Uganda	644.39	1164.34	1663.65	3714.44	4477.05	4613.12	4767.8
Ukraine	783210.15	358117.34	354428.81	308833.75	317513.21	214641.49	22712
United Arab Emirates	56922.36	88382.03	122394.72	171855.30	185719.36	202156.60	20193
United Kingdom	589037.69	552842.74	561543.48	502367.01	486995.49	416748.70	39147
United States	5085896.78	5942427.76	5971571.22	5580707.80	5273584.60	5247226.36	51463
Uruguay	3892.58	5449.24	5483.01	6363.16	8666.09	6731.08	6840.4
Uzbekistan	123105.60	121179.43	116386.27	107453.40	118546.55	105752.72	94458
Vanuatu	130.20	56.95	62.61	120.21	214.93	77.60	85.78
Venezuela	109267.54	132574.95	152464.34	188991.14	198861.56	168266.02	15739
Vietnam	20182.30	55529.79	99230.91	154655.30	154033.60	203240.32	21769
Western Sahara	144.00	206.48	226.64	265.54	325.71	253.51	259.60
Yemen	6887.22	15498.87	21768.18	26096.92	21078.72	14039.25	12443
Zambia	2954.91	1949.37	2456.67	2235.80	3566.34	4382.81	4759.2
Zimbabwe	17178.48	14488.89	11388.09	9995.11	12481.94	12772.41	11502

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