United In Science

High-level synthesis report of latest climate science information convened by the Science Advisory Group of the UN Climate Action Summit 2019

This report has been compiled by the World Meteorological Organization under the auspices of the Science Advisory Group of the UN Climate Action Summit 2019, to bring together the latest climate science related updates from a group of key global partner organizations - The World Meteorological Organization (WMO), UN Environment (UNEP), Intergovernmental Panel on Climate Change (IPCC), Global Carbon Project, Future Earth, Earth League and the Global Framework for Climate Services (GFCS). The content of each chapter of this report is attributable to published information from the respective organizations. Overall content compilation of this material has been carried out by the World Meteorological Organization.

This report is available electronically, together with more extended background reports and additional supporting material at:
public.wmo.int/en/resources/united_in_science

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Foreword by António Guterres, United Nations Secretary-General

Climate change is the defining challenge of our time.

This important document by the United Nations and global partner organizations, prepared under the auspices of the Science Advisory Group of the Climate Action Summit, features the latest critical data and scientific findings on the climate crisis. It shows how our climate is already changing, and highlights the far-reaching and dangerous impacts that will unfold for generations to come.

Science informs governments in their decision-making and commitments. I urge leaders to heed these facts, unite behind the science and take ambitious, urgent action to halt global heating and set a path towards a safer, more sustainable future for all.

Statement by the Science Advisory Group

Co-Chairs Prof Petteri Taalas (WMO) and Dr Leena Srivastava (IIASA)[1]

The UN Climate Action Summit 2019 Science Advisory Group called for this High Level Synthesis Report, to assemble the key scientific findings of recent work undertaken by major partner organizations in the domain of global climate change research, including the World Meteorological Organization, UN Environment, Global Carbon Project, the Intergovernmental Panel on Climate Change, Future Earth, Earth League and the Global Framework for Climate Services. The Report provides a unified assessment of the state of our Earth system under the increasing influence of anthropogenic climate change, of humanity's response thus far and of the far-reaching changes that science projects for our global climate in the future. The scientific data and findings presented in the report represent the very latest authoritative information on these topics. It is provided as a scientific contribution to the UN Climate Action Summit 2019, and highlights the urgent need for the development of concrete actions that halt the worst effects of climate change.

The Synthesis Report is an example of the international scientific community's commitment to strategic collaboration in order to advance the use of scientific evidence in global policy, discourse and action. The Science Advisory Group will remain committed to providing its expertise to support the global community in tackling climate change on the road to COP 25 in Santiago and beyond.

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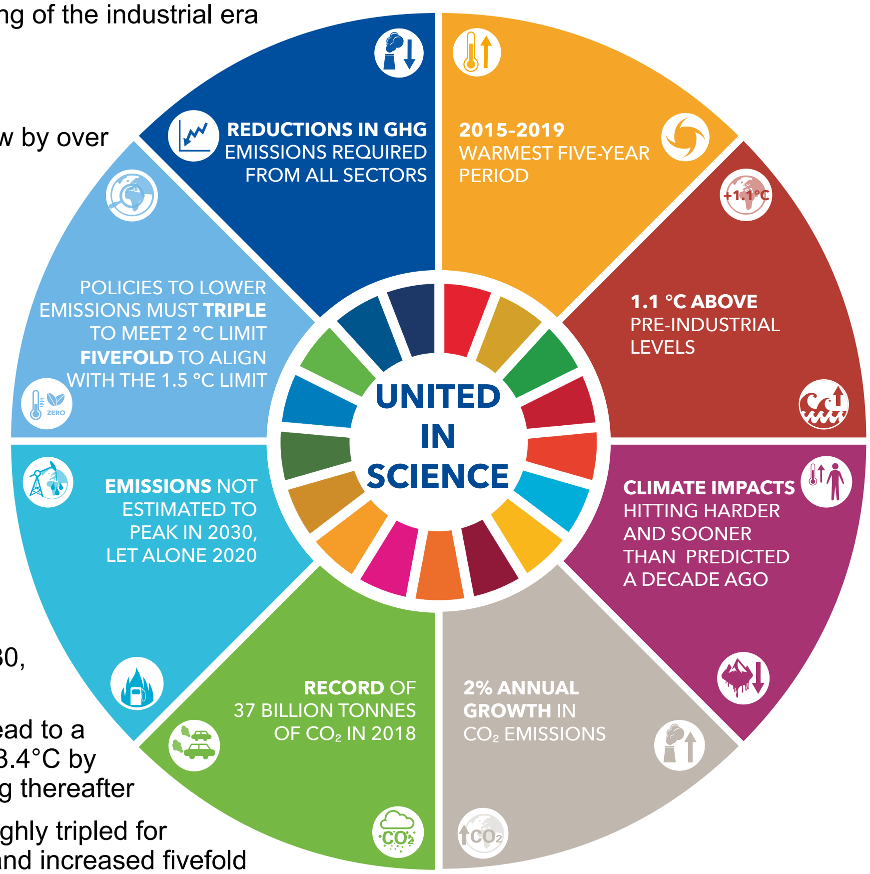
Key Messages

The Global Climate in 2015 - 2019

- Average global temperature for 2015-2019 is on track to be the warmest of any equivalent period on record. It is currently estimated to be 1.1°C above pre-industrial (1850-1900) times and 0.2°C warmer than 2011-2015
- Observations show that global mean sea level rise is accelerating and an overall increase of 26% in ocean acidity since the beginning of the industrial era



Global Fossil CO_2 Emissions

- CO_2 emissions from fossil fuel use continue to grow by over 1% annually and 2% in 2018 reaching a new high
- Growth of coal emissions resumed in 2017
- Despite extraordinary growth in renewable energy, fossil fuels still dominate the global energy system

Greenhouse Gas Concentrations

- Increases in CO_2 concentrations continue to accelerate
- Current levels of CO_2, CH_4 and N_2O represent 146%, 257% and 122% respectively of pre-industrial levels (pre-1750)

Emissions Gap

- Global emissions are not estimated to peak by 2030, let alone by 2020
- Implementing current unconditional NDCs would lead to a global mean temperature rise between 2.9°C and 3.4°C by 2100 relative to pre-industrial levels, and continuing thereafter
- The current level of NDC ambition needs to be roughly tripled for emission reduction to be in line with the 2°C goal and increased fivefold for the 1.5°C goal. Technically it is still possible to bridge the gap

Intergovernmental Panel on Climate Change 2018 & 2019 Special Reports

- Limiting temperature to 1.5°C above pre-industrial levels would go hand-in-hand with reaching other world goals such as achieving sustainable development and eradicating poverty
- Climate change puts additional pressure on land and its ability to support and supply food, water, health and wellbeing. At the same time, agriculture, food production, and deforestation are major drivers of climate change

Climate Insights

- Growing climate impacts increase the risk of crossing critical tipping points
- There is a growing recognition that climate impacts are hitting harder and sooner than climate assessments indicated even a decade ago
- Meeting the Paris Agreement requires immediate and all-inclusive action encompassing deep decarbonisation complemented by ambitious policy measures, protection and enhancement of carbon sinks and biodiversity, and effort to remove CO2 from the atmosphere

Global Framework for Climate Services

- Climate and early warning information services should underpin decision-making on climate action for adaptation
- The capacities of countries to deliver climate and early warning information services varies across regions

The Global Climate in 2015–2019

Warmest five-year period on record

The average global temperature for 2015–2019 is on track to be the warmest of any equivalent period on record. It is currently estimated to be 1.1°Celsius (± 0.1 °C) above pre-industrial (1850–1900) times and 0.20 ±0.08 °C warmer than the global average temperature for 2011–2015.

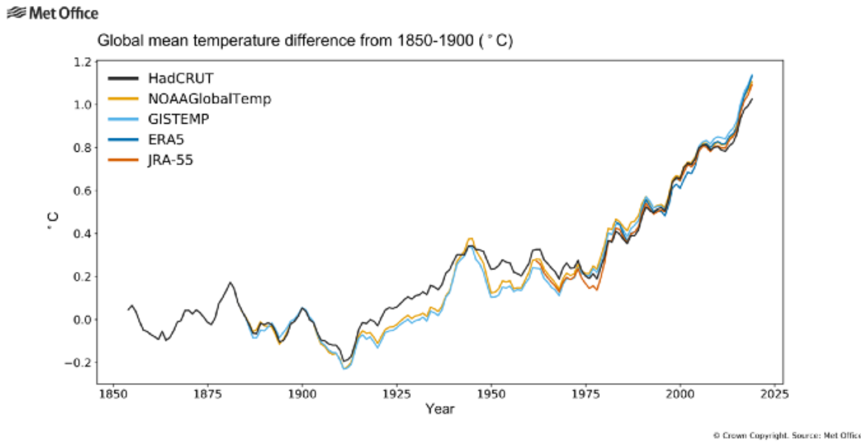
The 2015-2019 five-year average temperatures were the highest on record for large areas of the United States, including Alaska, eastern parts of South America, most of Europe and the Middle East, northern Eurasia, Australia, and areas of Africa south of the Sahara. July 2019 was the hottest month on record globally.

Sea-level rise is accelerating, sea water is becoming more acidic

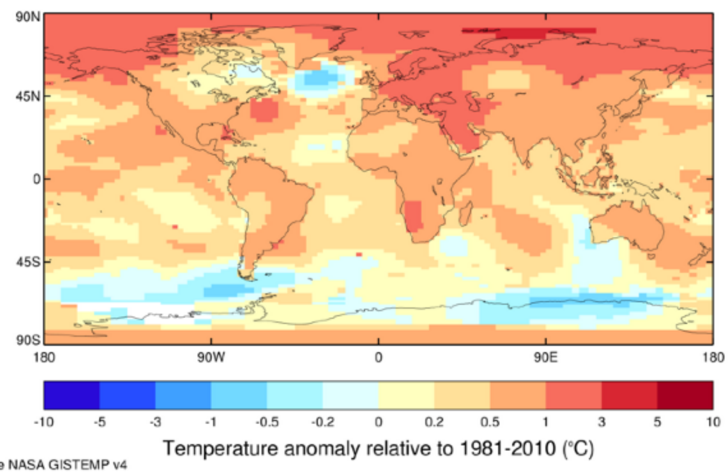
The observed rate of global mean sea-level rise increased from 3.04 millimeters per year (mm/yr) during the period 1997–2006 to approximately 4 mm/yr during the period 2007–2016. The accelerated rate in sea level rise as shown by altimeter satellites is attributed to the increased rate of ocean warming and land ice melt from the Greenland and West Antarctica ice sheets.

The ocean absorbs nearly 25% of the annual emissions of anthropogenic CO_2 thereby helping to alleviate the impacts of climate change on the planet. The absorbed CO_2 reacts with seawater and increases the acidity of the ocean.

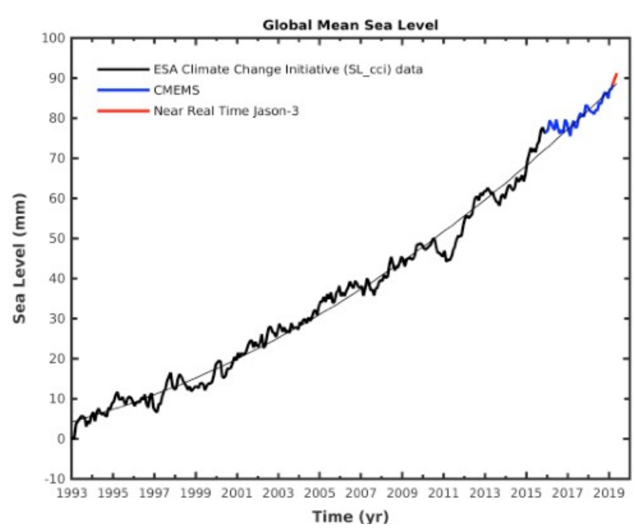
Figure opposite: Time series of altimetry-based global mean sea level from January 1993–May 2019. The thin black line is a quadratic function showing the mean sea-level rise acceleration. Data source: European Space Agency (ESA) Climate Change Initiative (CCI) sea-level data until December 2015, extended by data from the Copernicus Marine Service (CMEMS) as of January 2016 and near real-time Jason-3 as of April 2019



Five-year running average of global temperature anomalies (relative to pre-industrial) from 1854 to 2019 for five data sets: HadCRUT.4.6.0.0, NOAAGlobalTemp v5, GISTEMP v4, ERA5, and JRA-55. Data for 2019 to June



2015-2019 five-year average temperature anomalies relative to the 1981-2010 average. Data are from NASA GISTEMP v4. Data for 2019 to June.



Observations show an overall increase of 26% in ocean acidity since the beginning of the industrial era. The ecological cost to the ocean, however, is high, as the changes in acidity are linked to shifts in other carbonate chemistry parameters, such as the saturation state of aragonite. This process, detrimental to marine life and ocean services, needs to be constantly monitored through sustained ocean observations.

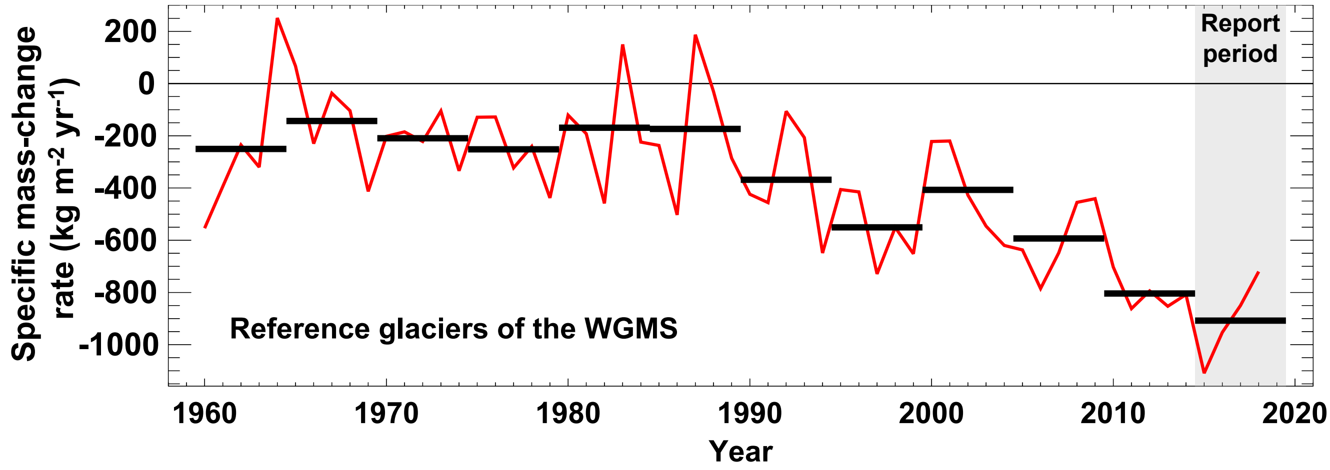
Continued decrease of sea ice and ice mass

The long-term trend over the 1979-2018 period indicates that Arctic summer sea-ice extent has declined at a rate of approximately 12% per decade. In every year from 2015 to 2019, the Arctic average summer minimum and winter maximum sea-ice extent were well below the 1981–2010 average. The four lowest values for winter sea-ice extent occurred in these five years.

Summer sea ice in Antarctica reached its lowest and second lowest extent on record in 2017 and 2018, respectively. The second lowest winter extent ever recorded was also experienced in 2017. Most remarkably sea ice extent values for the February minimum (summer) and September maximum (winter) in the period from 2015-2019 have been well below the 1981-2010 average since 2016. This is a sharp contrast with the 2011-2015 period and the long term 1979-2018 values that exhibited increasing trends in both seasons.

Overall, the amount of ice lost annually from the Antarctic ice sheet increased at least six-fold between 1979 and 2017. The total mass loss from the ice sheet increased from 40 Gigatons (Gt) average per year in 1979–1990 to 252 Gt per year in 2009–2017**.**

Sea level rise contribution from Antarctica averaged 3.6 ± 0.5 mm per decade with a cumulative 14.0 ± 2.0 mm since 1979. Most of the ice loss takes place by melting the ice shelves from below, due to incursions of relatively warm ocean water, especially in West Antarctica and to a lesser extent along the Peninsula and in East Antarctica.



Time series of average of observed annual specific mass-change rate of all WGMS reference glaciers, including five-year averages (data source: WGMS)

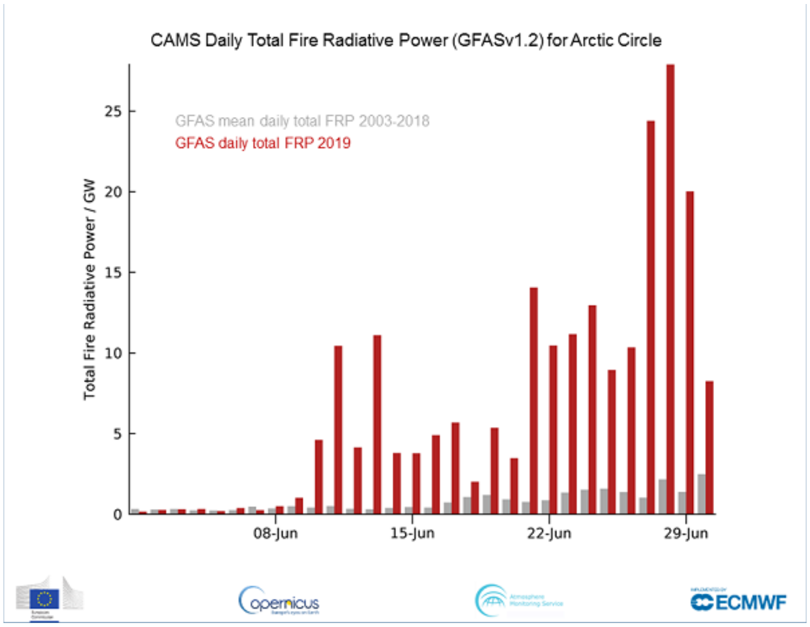
Analysis of long-term variations in glacier mass often relies on a set of global reference glaciers, defined as sites with continuous high-quality in situ observations of more than 30 years. Results from these time series are, however, only partly representative for glacier mass changes at the global scale as they are biased to well-accessible regions such as the European Alps, Scandinavia and the Rocky Mountains. Nevertheless, they provide direct information on the year-to-year variability in glacier mass balance in these regions. For the period 2015–2018, data from the World Glacier Monitoring Service (WGMS) reference glaciers indicate an average specific mass change of −908 mm water equivalent per year. This depicts a greater mass loss than in all other five-year periods since 1950, including the 2011-2015 period. Warm air from a heatwave in Europe in July 2019 reached Greenland, sending temperature and surface melting to record levels.

The Global Climate in 2015–2019

Intense heatwaves and wild fires

Heatwaves were the deadliest meteorological hazard in the 2015–2019 period, affecting all continents and setting many new national temperature records. Summer 2019 saw unprecedented wildfires in the Arctic region. In June alone, these fires emitted 50 megatons (Mt) of carbon dioxide into the atmosphere. This is more than was released by Arctic fires in the same month from 2010 to 2018 put together.

There were multiple fires in the Amazon rainforest in 2019, in particular in August.



The Fire Radiative Power (Gigawats)– a measure of heat output from wildfires shown in June for 2019 (red) and the 2003–2018 average (grey) (Source: Copernicus Atmospheric Monitoring Services (CAMS)).

Costly tropical cyclones

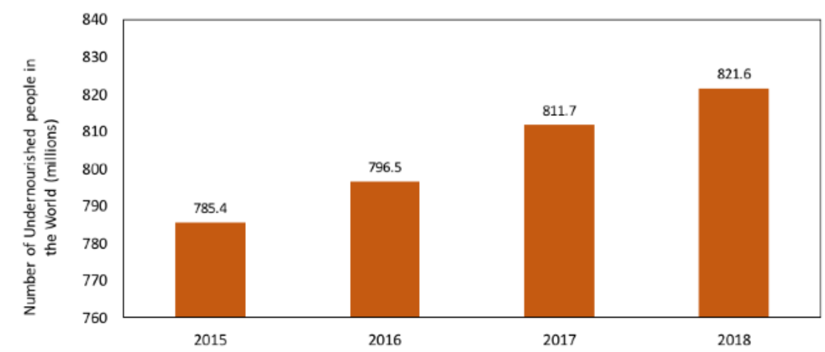
Overall, the largest economic losses were associated with tropical cyclones.

The 2018 season was especially active, with the largest number of tropical cyclones of any year in the twenty-first century. All Northern Hemisphere basins experienced above-average activity – the Northeast Pacific recorded its largest Accumulated Cyclone Energy (ACE) value ever.

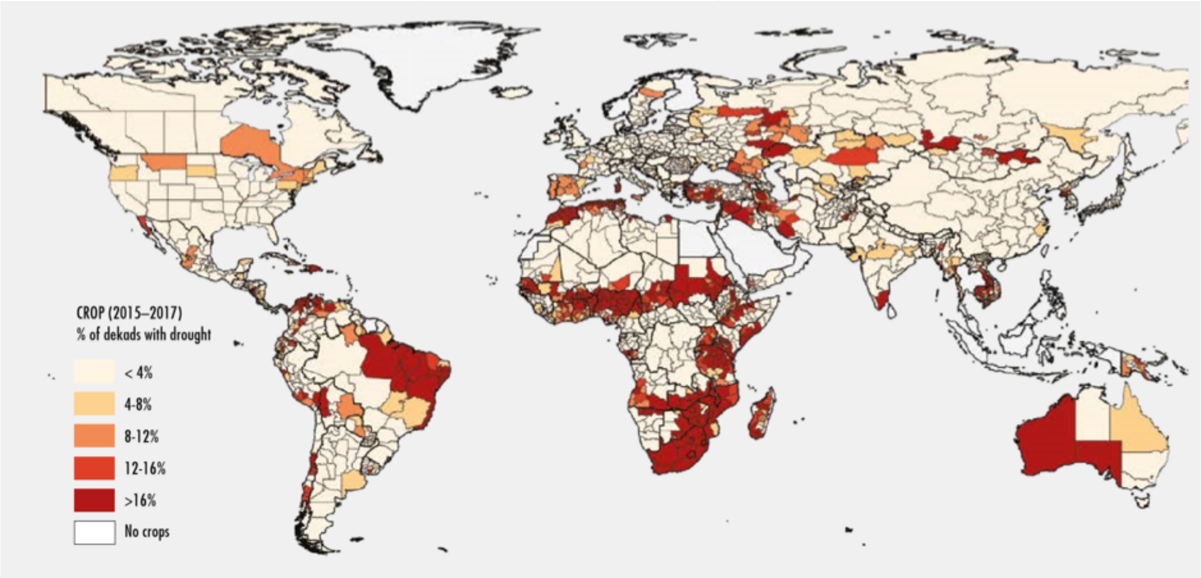
The 2017 Atlantic hurricane season was one of the most devastating on record with more than US$ 125 billion in losses associated with Hurricane Harvey alone. Unprecedented back-to-back Indian Ocean tropical cyclones hit Mozambique in March and April 2019.

Food insecurity increasing

According to the Food and Agriculture Organization of the United Nations (FAO) report on the State of Food Security and Nutrition in the World, climate variability and extremes are among the key drivers behind the recent rises in global hunger after a prolonged decline and one of the leading contributors to severe food crises. Climate variability and extremes are negatively affecting all dimensions of food security – food availability, access, utilization and stability. The frequency of drought conditions from 2015–2017 show the impact of the 2015–2016 El Niño on agricultural vegetation. The following map shows that large areas in Africa, parts of central America, Brazil and the Caribbean, as well as Australia and parts of the Near East, experienced a large increase in frequency of drought conditions in 2015–2017 compared to the 14-year average.



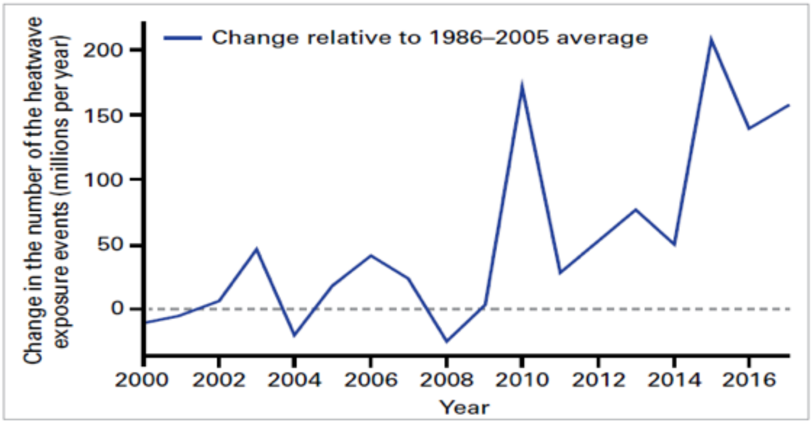
Number of undernourished people in the world, 2015–2018 (FAO, IFAD, UNICEF and WHO, 2019).



Percentage of time (dekad is a 10-day period) with active vegetation when the Anomaly Hot Spots of Agricultural Production (ASAP) was signaling possible agricultural production anomalies according to NDVI (Normalized Difference Vegetation Index) for more than 25% of the crop areas in 2015–2017 (FAO, IFAD, UNICEF, WFP and WHO, 2018)

Overall risk of climate-related illness or death increasing

Based on data and analysis from the World Health Organisation (WHO), between 2000 and 2016, the number of people exposed to heatwaves was estimated to have increased by around 125 million. The average length of individual heatwave events was 0.37 days longer, compared to the period between 1986 and 2008, contributing to an increased risk of heat-related illness or death.



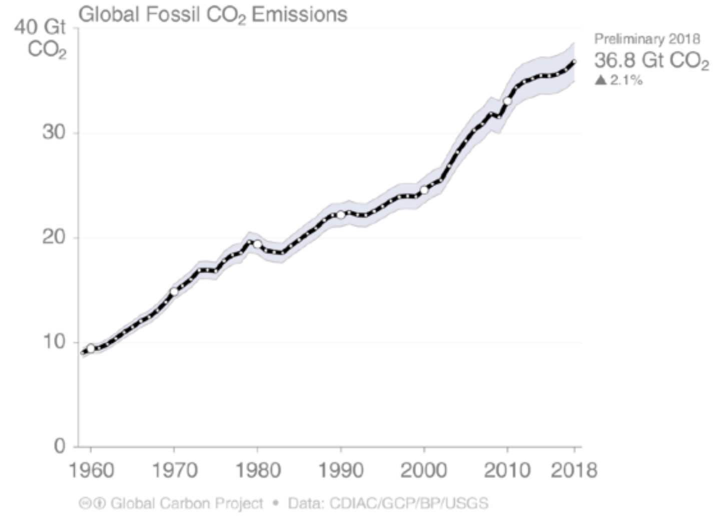
The change in the number of people exposed to heatwaves in millions per year from 2000 to 2017, relative to the 1986–2005 average. Source: Watts et al., 2018.

Gross domestic product is falling in developing countries due to increasing temperatures

The International Monetary Fund found that for a medium and low-income developing country with an annual average temperature of 25 °C, the effect of a 1 °C increase in temperature is a fall in growth by 1.2%. Countries whose economies are projected to be hard hit by an increase in temperature accounted for only about 20% of global Gross Domestic Product (GDP) in 2016. But they are home to nearly 60% of the global population, and this is expected to rise to more than 75% by the end of the century.

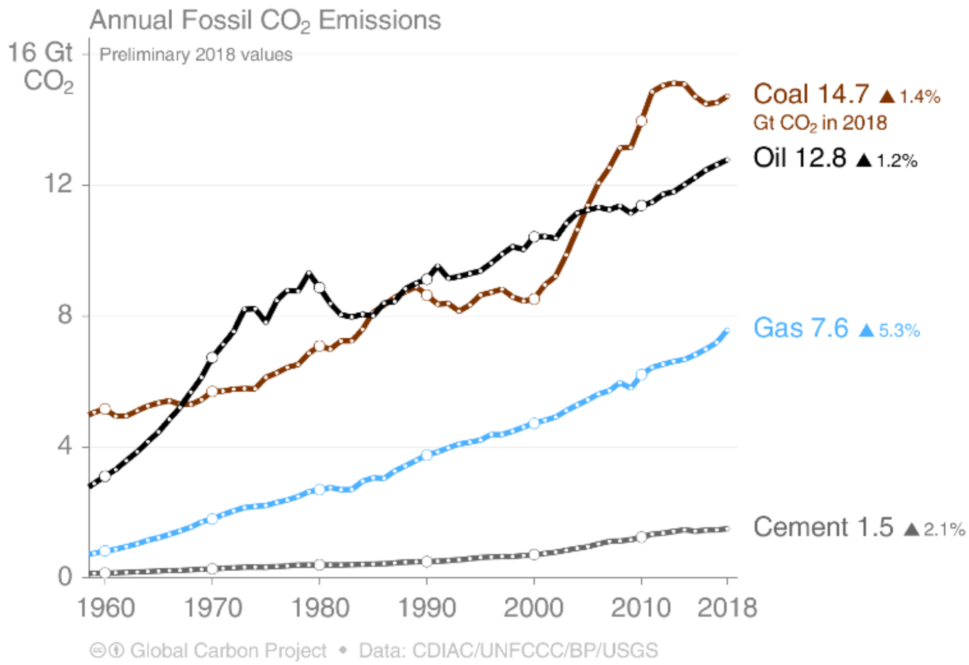
Global Fossil CO_2 Emissions

Fossil fuel combustion and cement production release about 90% of all carbon dioxide (CO_2) emissions and about 70% of all greenhouse gas emissions from human activities. Fossil CO_2 emissions continue to grow by over 1% annually and grew by 2% in 2018, reaching a record high of 37 billion tonnes of CO_2. Although emissions are growing slower than growth in the global economy, showing continued progress in reducing the carbon intensity of economic activity, there is still no sign of a peak in global emissions.



Current economic and energy trends suggest that emissions will be at least as high in 2019 as in 2018. Global GDP is expected to grow at 3.2% in 2019, and if the global economy decarbonized at the same rate as in the last 10 years, that would still lead to an increase in global emissions. However the outlook for Chinese emissions is quite uncertain in 2019; there are risks associated with a potential US-China trade-war; the carbon price in the European Union Emissions Trading system is higher than the last few years; and there is uncertainty over Brexit – all suggest that the global economy could grow slower than expected. Thus, while global emissions are expected to grow in 2019, the size of the growth remains uncertain.

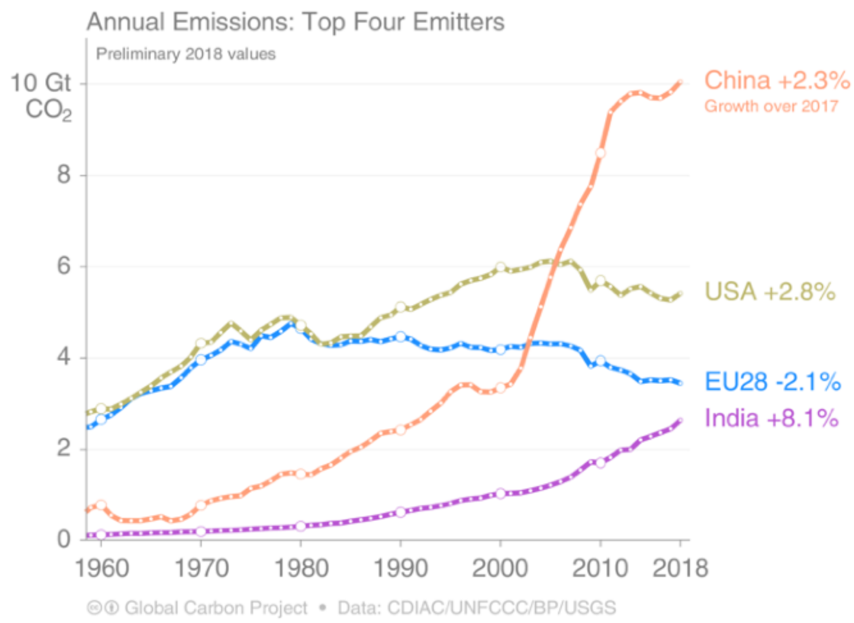
Emissions from the combustion of coal were thought to have peaked in 2013 and were responsible for a slowdown in the growth rate of global emissions, but growth of coal emissions resumed in 2017. Emissions from oil and gas continue to grow rapidly.



Global Fossil CO_2 Emissions

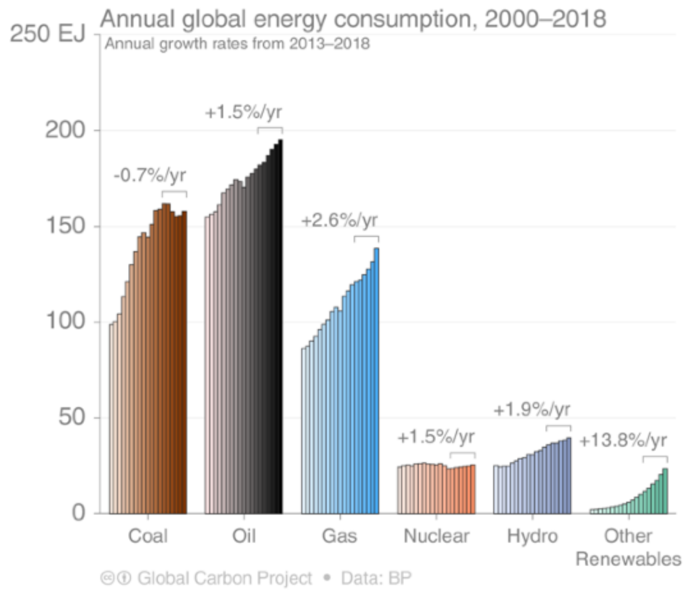
Despite the global upward trend, emissions from the USA and the European Union have declined over the past decade, and growth in China's emissions has slowed significantly compared to the 2000s. Indian emissions are the fourth highest, and are growing strongly at annual rates in excess of 5%, albeit starting from a much lower base of per capita emissions. More than a hundred other countries, mainly developing, are responsible for the remaining 40% of emissions which also continue to grow strongly on aggregate.

The highest per capita emissions are found in the USA, Australia and top oil-producers such as Saudi Arabia. Increases in energy efficiency and renewable energy production have led to declines in per capita emissions in most developed economies. Per capita emissions are rapidly growing in India and in other developing economies.

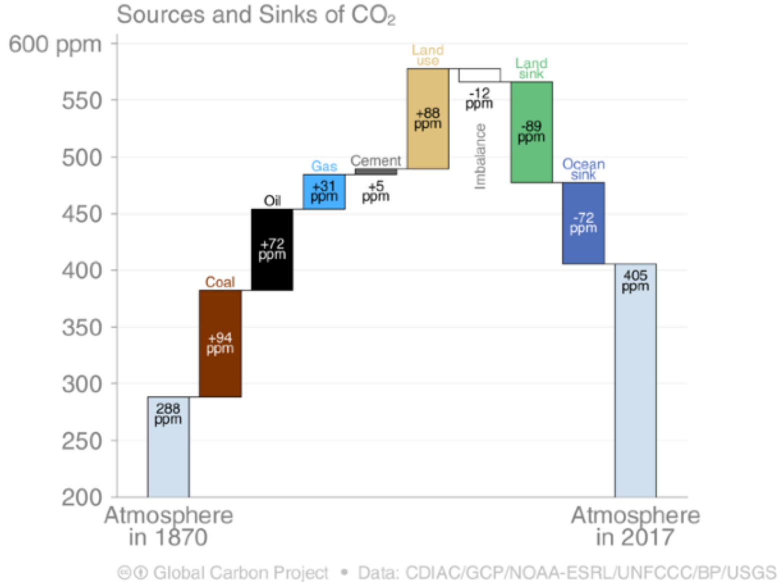


Despite extraordinary growth in renewable energy over the past decade, the global energy system is still dominated by fossil fuel sources. The annual increase in global energy use is greater than the increase in renewable energy, meaning fossil fuel use and CO_2 emissions continue to grow. The net-zero emissions needed to stabilize the climate requires both an acceleration in the deployment of non-carbon fuels and a rapid decline in the global share of fossil fuels in the energy mix (or of their emissions if technologies such as carbon capture and storage are deployed). This dual requirement to stabilize the climate system illustrates the scale of the challenge.

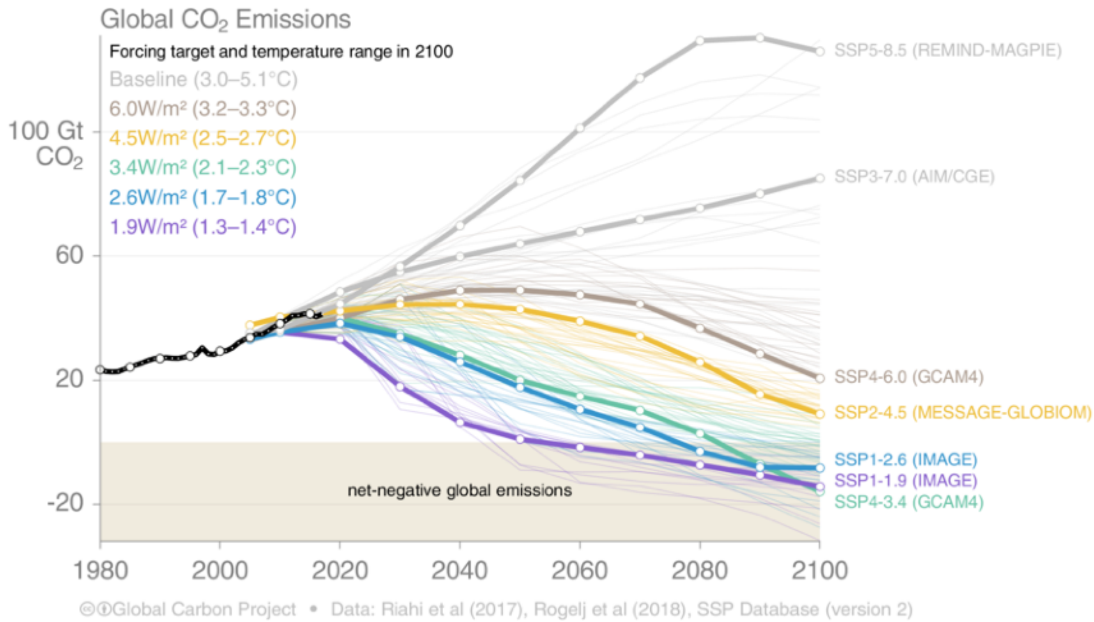
Natural gas use is growing strongly at over 2% per year since 2013. Natural gas, despite being the cleanest of the fossil fuels, is still a major contributor to global growth in CO_2 emissions and leaks contribute to growth in methane emissions.



Global Fossil CO_2 Emissions



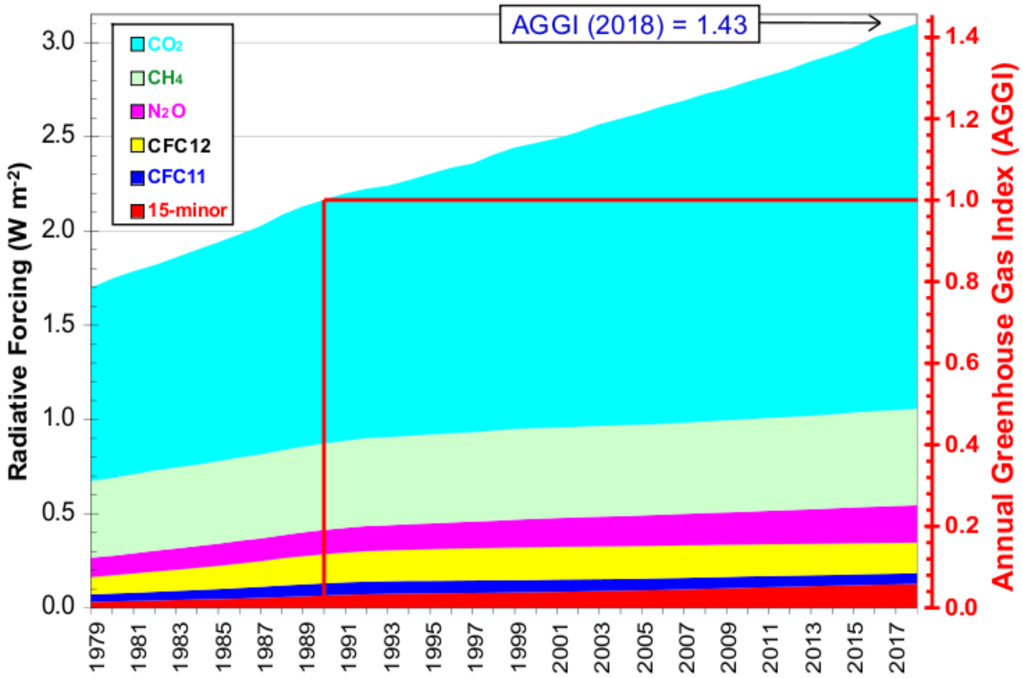
The "waterfall" plot shows the historical contribution of CO_2 emissions from different sources to the concentration of atmospheric CO_2 (measured in parts per million; ppm). Natural CO_2 sinks, such as vegetation and oceans, remove about half of all emissions from human activities. This important benefit underscores the need to reduce deforestation and expand natural CO_2 sinks, particularly those in forests and soils that can be improved by better management and habitat restoration.



Overall, if current trends in CO_2 and other greenhouse gas emissions continue over the coming decade (see figure above), the Earth's mean global temperature is likely to warm well above the climate targets of the Paris Agreement. Immediate and sustained action is needed to slash fossil fuel emissions.

CO_2 and other greenhouse gas (GHG) concentrations continue their upward trend

Levels of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have reached new highs. In 2018, global CO_2 concentration was 407.8 parts per million (ppm), 2.2 ppm higher than 2017. Preliminary data from a subset of GHG monitoring sites for 2019 indicate that CO_2 concentrations are on track to reach or even exceed 410 ppm by the end of 2019.



Annual Greenhouse Gas Index from 1990 to 2018 showing radiative forcing by long-lived greenhouse gases (GHGs) which increased by 43%, with CO_2 accounting for about 80% of this increase (Source NOAA).

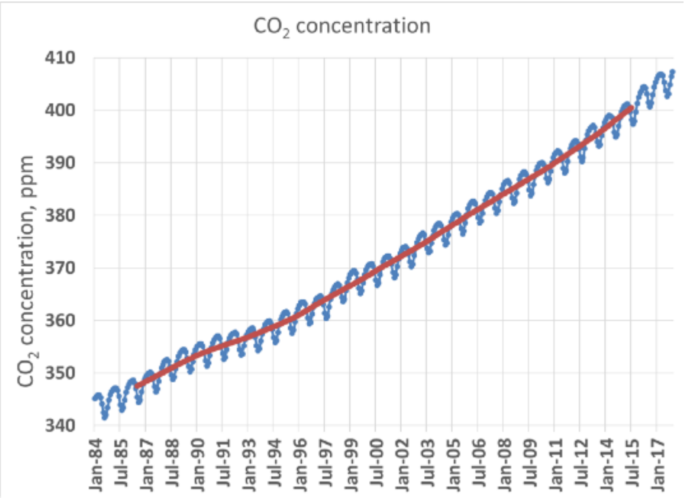
A full analysis for 2017 for the three main GHG shows that globally averaged atmospheric concentrations of CO_2 were 405.6 ±0.1 ppm, CH_4 at 1859 ±2 parts per billion (ppb) and N_2O at 329.9 ±0.1 ppb. These values constitute, respectively, 146%, 257% and 122% of pre-industrial levels (pre-1750).

CO_2 is the single most important anthropogenic greenhouse gas in the atmosphere, contributing about 66% of the radiative forcing by long-lived greenhouse gases. It is responsible for about 82% of the increase in radiative forcing over the past decade and over the past five years. The atmospheric CO_2 concentration levels always represent a balance between emissions in the atmosphere and sinks in the oceans and the land biosphere.

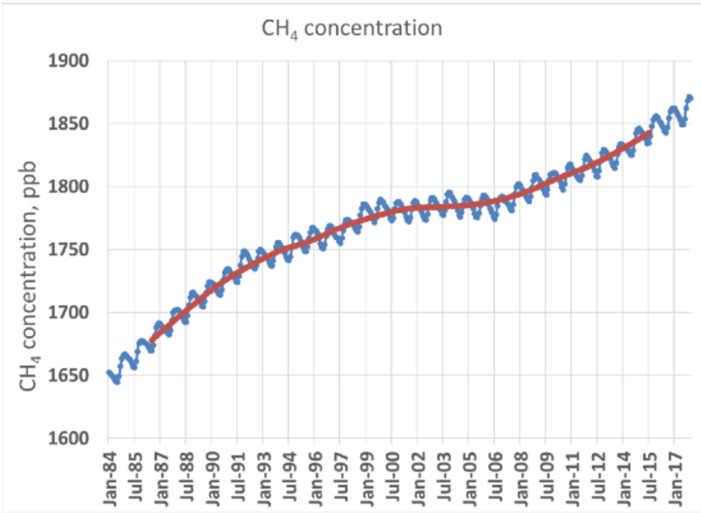
The growth rate of CO_2 averaged over three consecutive decades (1985–1995, 1995–2005 and 2005–2015) increased from 1.42 ppm/yr to 1.86 ppm/yr and to 2.06 ppm/yr with the highest annual growth rates observed during El Niño events. The globally averaged CO_2 mole fraction in 2017 was 2.2 ppm higher than the previous year.

Methane contributes ~17% of the radiative forcing by long-lived greenhouse gases. Approximately 40% of methane is emitted into the atmosphere by natural sources (for example, wetlands and termites), and about 60% comes from anthropogenic sources (for example, ruminants, rice agriculture, fossil fuel exploitation, landfills and biomass burning). Globally averaged CH_4 calculated from in-situ observations in 2017 was 7 ppb higher with respect to the previous year.

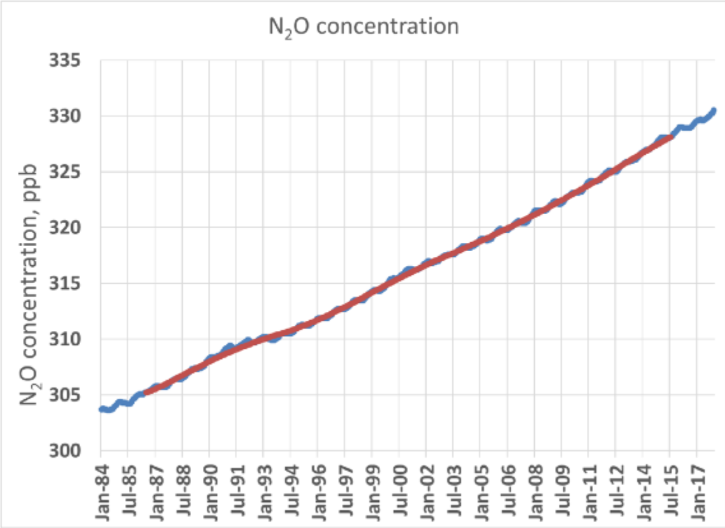
Greenhouse Gas Concentrations in the Atmosphere
Global Atmosphere Watch Programme (GAW)



Globally averaged CO_2 mole fraction (ppm) from 1984 to 2017. Observations from 129 stations have been used for this analysis, (Source:GAW)



Globally averaged CH_4 mole fraction (ppb) from 1984 to 2017. Observations from 126 stations have been used for this analysis (Source: GAW).



Globally averaged N_2O mole fraction (ppb) from 1984 to 2017. Observations from 96 stations have been used for this analysis (Source:GAW).

The mean annual increase of CH_4 decreased from ~12 ppb/yr during the late 1980s to near zero during 1999–2006. However, since 2007, atmospheric CH_4 has been increasing again.

Nitrous oxide contributes ~6% of the radiative forcing by long-lived GHGs. It is the third most important individual contributor to the combined forcing. N_2O is emitted into the atmosphere from both natural (about 60%) and anthropogenic sources (approximately 40%), including oceans, soils, biomass burning, fertilizer use, and various industrial processes. The globally averaged N_2O mole fraction in 2017 was 0.9 ppb above the previous year.

The Emissions Gap - Where we are and where we need to be

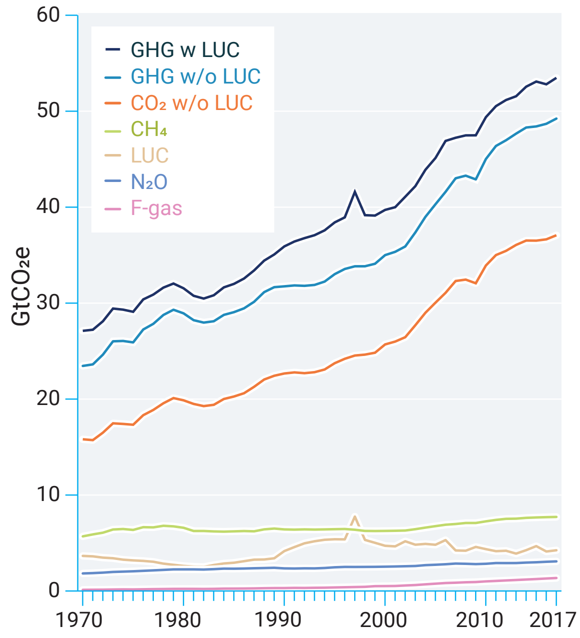
Global emissions show no sign of peaking

Global greenhouse gas emissions have grown at a rate of 1.6% per year from 2008 to 2017, reaching a record high of 53.5 Gigatons of CO_2 equivalent ($GtCO_2e$) in 2017, including emissions from land-use change. Preliminary findings from the Emission Gap Report 2019 indicate that emissions continued to rise in 2018. Global emissions are not estimated to peak by 2030, let alone by 2020, if current climate policies and ambition levels of the Nationally Determined Contributions (NDCs) are continued.

Collectively, G20 members are projected to achieve the Cancun pledges, which consist of economy-wide emission reduction targets, by 2020, but they are not yet on track to realize their NDCs for 2030.

Concerns about the current level of both ambition and action are amplified in the 2018 and forthcoming 2019 Emissions Gap Reports compared to previous reports.

Global greenhouse gas emissions per type of gas

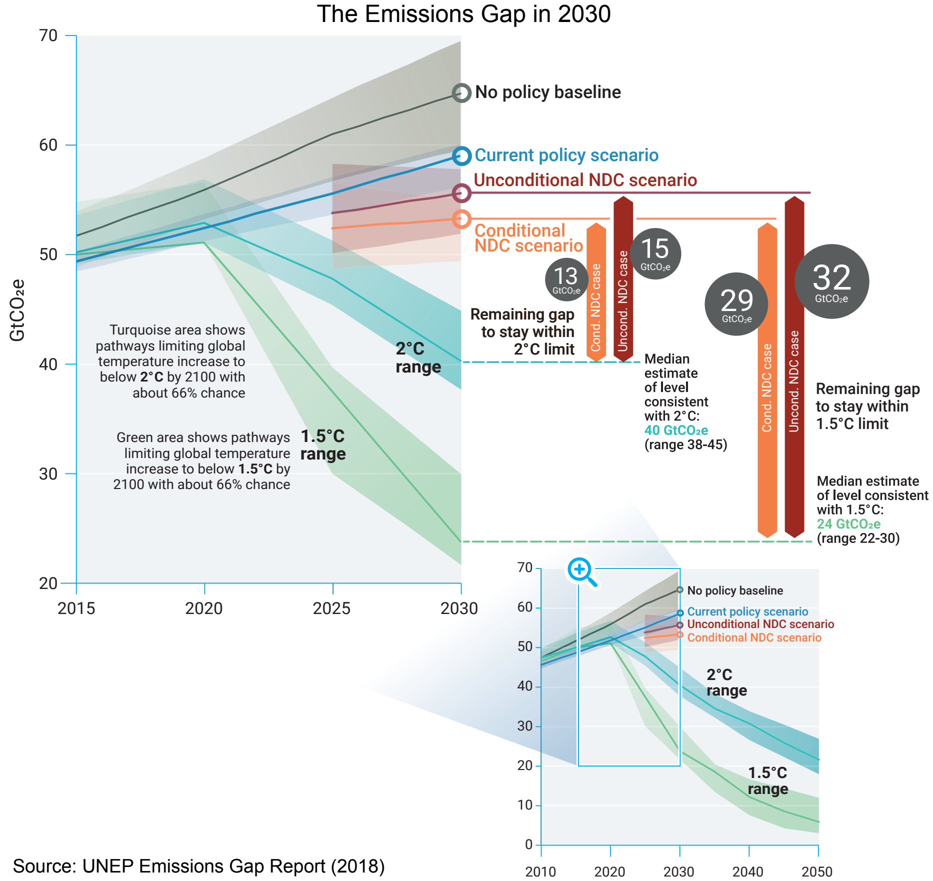


Source: UNEP Emissions Gap Report (2018)

The gap is larger than ever

The emissions gap in 2030 between emission levels under full implementation of conditional NDCs and levels consistent with least-cost pathways to the 2 °C target is 13 $GtCO_2e$. If only the unconditional NDCs are implemented, the gap increases to 15 $GtCO_2e$. The gap in the case of the 1.5 °C target is 29 $GtCO_2e$ and 32 $GtCO_2e$ respectively. The gap numbers increased in 2018 compared with 2017, mainly as a result of the more detailed and diverse literature on 1.5 °C and 2°C pathways prepared for the IPCC Special Report on 1.5 °C. Only minor changes to the gap numbers are expected in the 2019 report.

The Emissions Gap in 2030



Source: UNEP Emissions Gap Report (2018)

The Emissions Gap - Where we are and where we need to be

The current NDCs are estimated to lower global emissions in 2030 by up to 6 $GtCO_2e$ compared to a continuation of current policies. This level of ambition needs to be roughly tripled to be aligned with the 2 °C goal and increased around fivefold to align with the 1.5 °C goal.

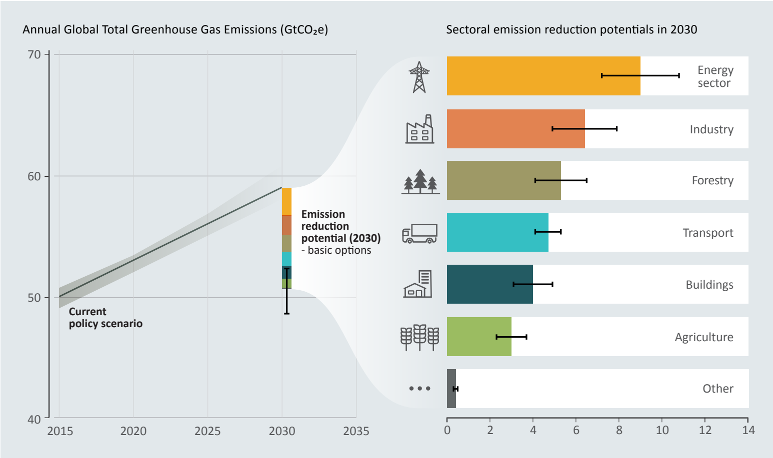
Implementing the unconditional NDCs, and assuming that climate action continues consistently throughout the twenty-first century, would lead to a global mean temperature rise between 2.9 °C and 3.4 °C by 2100 relative to pre-industrial levels, and continuing thereafter. Implementation of the conditional NDCs would reduce these estimates by 0.2 °C in 2100.

Technically, it is still possible to bridge the gap in 2030 to ensure global warming stays below 2 °C and 1.5 °C. The sectoral emission reduction potential in 2030 is estimated to be up to between 30 and 40 $GtCO_2e$.

However, if NDC ambitions are not increased urgently and backed up by immediate action, exceeding the 1.5 °C goal can no longer be avoided. If the emissions gap is not closed by 2030, it is very plausible that the goal of a well-below 2°C temperature increase is also out of reach.

A substantial part of the technical potential can be realized through scaling up and replicating existing, well-proven policies that simultaneously contribute to key sustainable development goals. Remarkably, the potential available in just six relatively well-developed areas as shown (below left) present a combined potential of up to 21 $GtCO_2e$ per year by 2030.

Total emission reduction basic potentials compared to the current policy scenario for 2030



Source: UNEP Emissions Gap Report (2017)

Six abatement measures could bring the world on track to bridge the emissions gap in 2030

Solar & wind energy

- Feed-in tariffs
- Auctions
- Competitive electricity costs

Energy efficient appliances & passenger cars

- MEPS
- Labels
- Fuel economy standards
- CO_2 emission standards

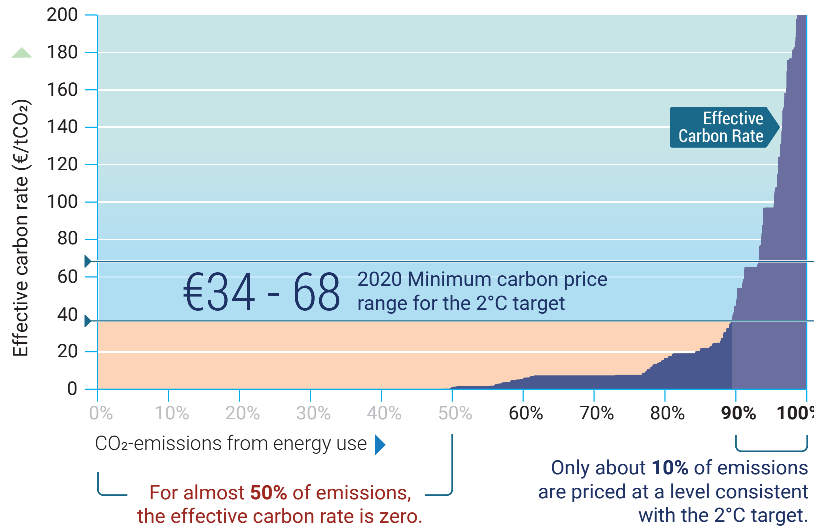
Reforestation & reducing deforestation

- Land use planning
- Sustainable production
- Monitoring and verification

The use of carbon pricing to reduce greenhouse gas emissions is still only emerging in many countries and is generally not applied at a sufficient level to facilitate a real shift towards low-carbon societies. Even when considering energy-specific taxes together with explicit carbon pricing policies, half of the emissions from fossil fuels are not priced at all, and only 10% of global emissions from fossil fuels are estimated to be priced at a level consistent with limiting global warming to 2 °C.

If all fossil fuel subsidies were phased out, it would lead to a reduction of global carbon emissions of up to about 10% by 2030.

Effective carbon rates on energy use across 42 OECD and G20 countries (estimate for 2018) and the minimum carbon price range needed in 2020 for the 2°C target

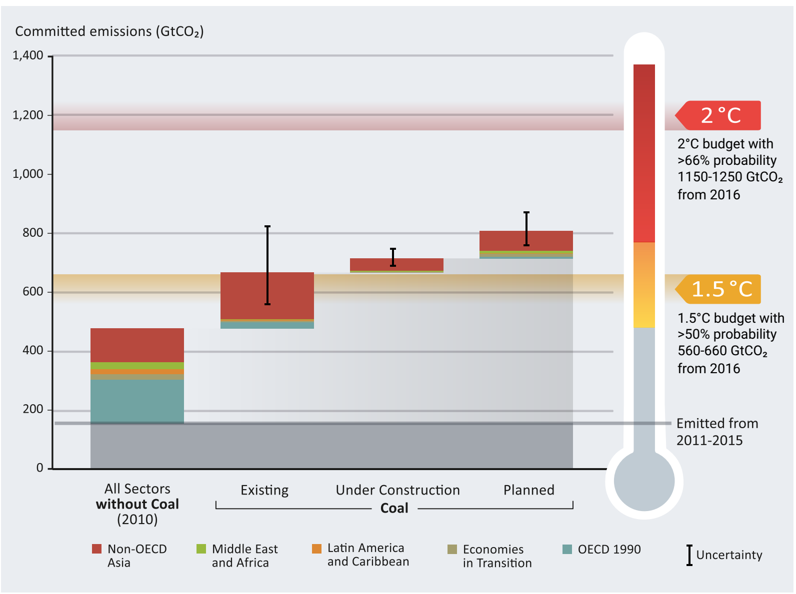


Source: UNEP Emissions Gap Report

At the global scale, the stock of coal-fired power plants is still increasing, as are emissions from coal. The existing stocks, in combination with what is currently planned and under construction (assuming standard lifetimes and usage rates), account for a significant share of the available carbon budget for a 2 °C target, and would make a 1.5 °C target infeasible.

Avoiding further lock-in and facilitating a balanced transition out of coal for power production will therefore be essential for the success of global mitigation efforts.

Emissions committed to the atmosphere from coal-fired power plants (existing, under construction and planned) and other economic sectors, by region



Source: UNEP Emissions Gap Report (2017)

Finally, non-state and subnational action plays an important role in delivering national pledges. Emission reduction potential from non-state and subnational action could ultimately be significant, allowing countries to raise ambition, but currently such impacts are extremely limited and poorly documented. Coordinated, comparable and transparent reporting and verification of actions by all actors is essential to clarify effects and possible overlaps.

Intergovernmental Panel on Climate Change (IPCC) 2018 and 2019 Special Reports

The Intergovernmental Panel on Climate Change (IPCC) assesses the state of knowledge about climate change. It is currently preparing its Sixth Assessment Report. The three Working Group contributions will be released in 2021, followed by the Synthesis Report in early 2022, in time for the Global Stocktake in 2023 when governments will review the Paris Agreement and their NDCs under the Agreement. In addition, three Special IPCC Reports released in 2018 and 2019 take a deeper dive into assessing complementary and specific aspects of climate change.

Limiting temperature to 1.5 ºC above pre-industrial levels would provide benefits and avoid significant risks

Global Warming of 1.5 ºC: *An IPCC Special Report on the impacts of global warming of 1.5 ºC above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* was released in October 2018 and transformed the public discussion around climate change. Key findings include:

- Climate change is already affecting people, ecosystems and livelihoods all around the world.
- Limiting warming to 1.5 ºC is not physically impossible but would require unprecedented transitions in all aspects of society.
- There are clear benefits to keeping warming to 1.5 ºC compared to 2 ºC or higher. Every bit of warming matters.
- Limiting warming to 1.5 ºC can go hand in hand with reaching other world goals such as achieving sustainable development and eradicating poverty.

Climate change exacerbates the effect of a growing human pressure on land, coordination on improved land use is needed

Climate Change and Land, an *IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* was released on 8 August 2019. Key findings include:

- Land is a critical resource – we rely on it for food, water, health and wellbeing – but it is already under growing human pressure. Climate change is adding to these pressures. Agriculture, food production, and deforestation are major drivers of climate change.
- Coordinated action to tackle climate change can simultaneously improve land, food security and nutrition, and help to end hunger.
- The way we produce our food matters; dietary choice can help reduce emissions and pressure on land.
- There are things we can do to both tackle land degradation and prevent or adapt to further climate change.
- The land that we are already using could feed the world in a changed climate and provide biomass for renewable energy, but it would require early, far-reaching action across several fronts.
- Better land management also supports biodiversity conservation.
- Tackling this challenge requires a coordinated response.
- Better land management can play its part in tackling climate change, but it cannot do it all.

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

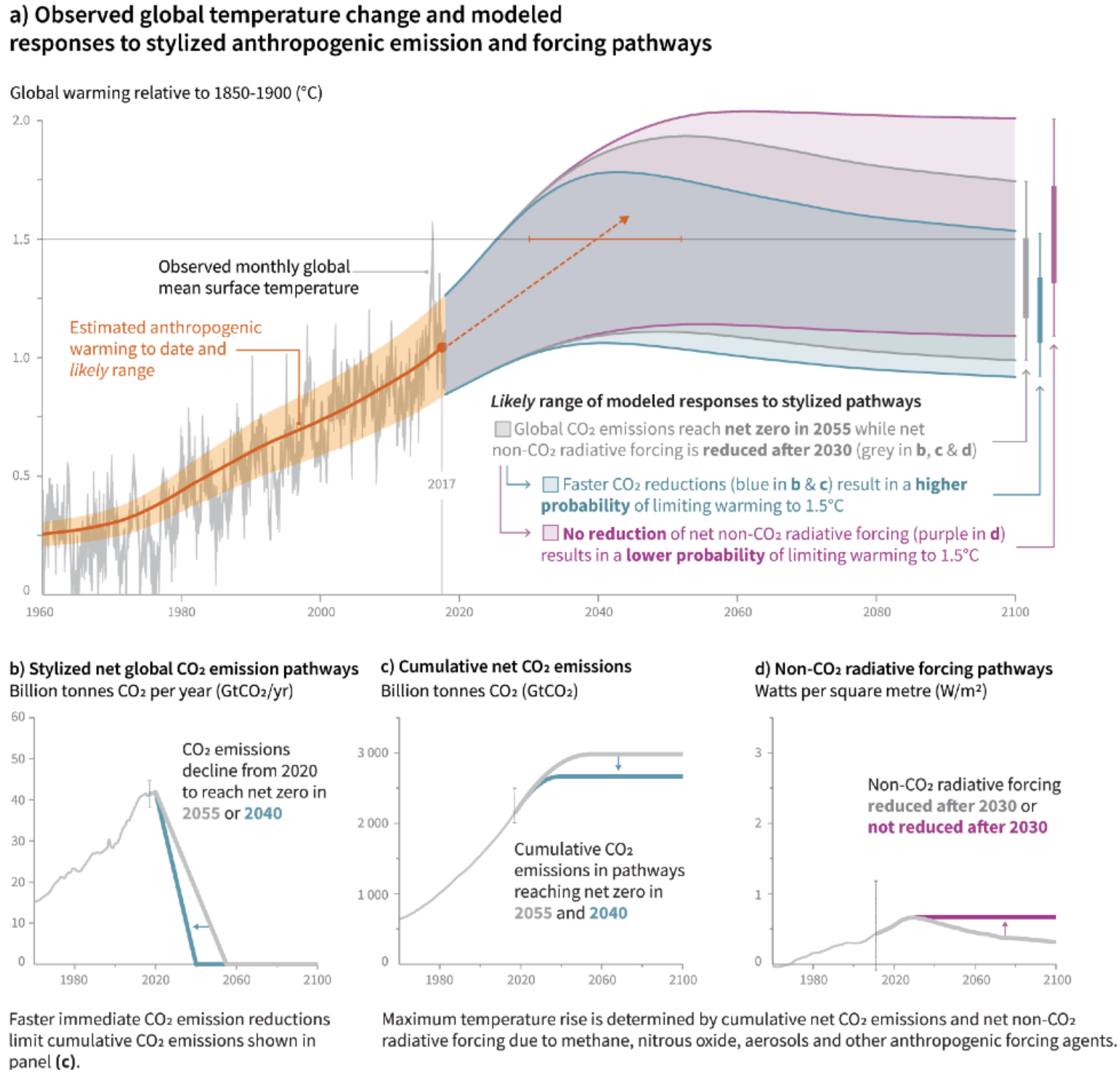
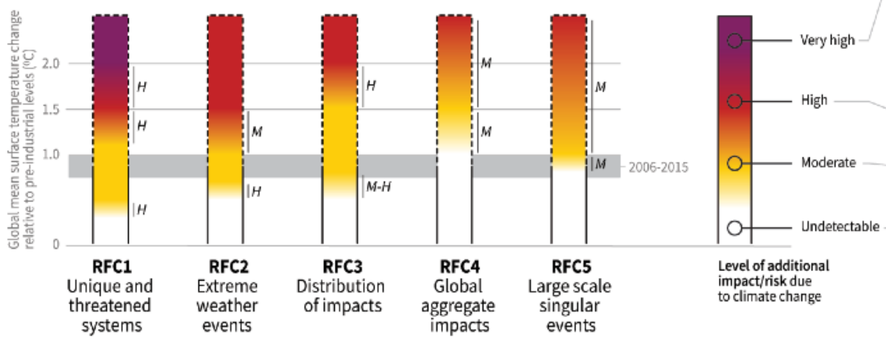


Figure (SPM.1) from the Summary for Policy Makers report of the IPCC special report on Global Warming of 1.5 °C Panel a: Observed monthly global mean surface temperature (GMST, grey line up to 2017, from the HadCRUT4, GISTEMP, Cowtan–Way, and NOAA datasets) change and estimated anthropogenic global warming (solid orange line up to 2017, with orange shading indicating assessed likely range). Orange dashed arrow and horizontal orange error bar show respectively the central estimate and likely range of the time at which 1.5°C is reached if the current rate of warming continues. The grey plume on the right of panel a shows the likely range of warming responses, computed with a simple climate model, to a stylized pathway (hypothetical future) in which net CO_2 emissions (grey line in panels b and c) decline in a straight line from 2020 to reach net zero in 2055 and net nonCO2 radiative forcing (grey line in panel d) increases to 2030 and then declines. The blue plume in panel a) shows the response to faster CO_2 emissions reductions (blue line in panel b), reaching net zero in 2040, reducing cumulative CO_2 emissions (panel c). The purple plume shows the response to net CO2 emissions declining to zero in 2055, with net non-CO_2 forcing remaining constant after 2030. The vertical error bars on right of panel a) show the likely ranges (thin lines) and central terciles (33rd – 66th percentiles, thick lines) of the estimated distribution of warming in 2100 under these three stylized pathways. Vertical dotted error bars in panels b, c and d show the likely range of historical annual and cumulative global net CO_2 emissions in 2017 (data from the Global Carbon Project) and of net non-CO_2 radiative forcing in 2011 from AR5, respectively. Vertical axes in panels c and d are scaled to represent approximately equal effects on GMST

How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems

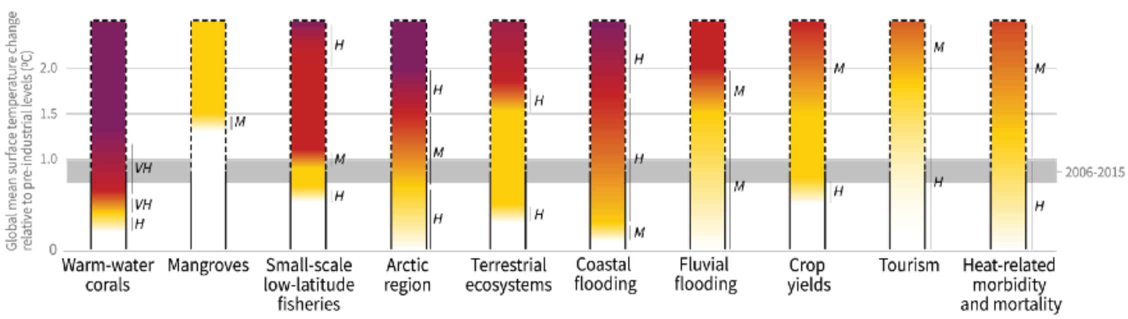
Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)



Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
Red indicates severe and widespread impacts/risks.
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.
White indicates that no impacts are detectable and attributable to climate change.

Impacts and risks for selected natural, managed and human systems



Confidence level for transition: *L*=Low, *M*=Medium, *H*=High and *VH*=Very high

On 25 September 2019, the IPCC is due to release a *Special Report on the Ocean and Cryosphere in a Changing Climate.* The cryosphere comprises the frozen components of the Earth system including snow, glaciers, ice sheets and ice shelves, icebergs and sea ice, ice on lakes and rivers and permafrost and seasonally frozen ground. The report will examine high mountain areas; polar regions; sea-level rise and implications for low-lying islands, coasts and communities; the changing ocean, marine ecosystems and dependent communities; and extremes, abrupt changes and managing risks.

Consolidated evidence (on climate, extreme weather, oceans and land) reinforces human influence as the dominant cause of changes to the Earth system, in a new geological epoch, the Anthropocene.

New research shows that the current CO_2 concentration in the atmosphere is unprecedented over the past three million years and that global temperature never exceeded the preindustrial value by more than 2 °C during that time. A combination of Earth's orbital cycles in constant interplay with biogeochemical processes, such as greenhouse gas regulation on land and in the ocean, accounted for the long-term stability during that time, and there is new understanding that these interactions are changing.

The effect of anthropogenic climate change on the increasing frequency and/or intensity of extreme events is becoming more compelling in a number of case studies. For example, science has improved our understanding of how interconnections among ocean currents, ice sheets, and heat exchange in the atmosphere and land play a major role in accelerating warming and extreme weather events. Recent examples include confirmation that a slow-down of the jet stream – fast moving winds in the upper atmosphere - was directly related to record-breaking heatwaves across North America, Europe and Asia in 2018 and 2019, and that a series of extreme rainfall events were connected, despite being thousands of kilometres apart, and were also linked to the jet-stream pattern.

Sea-level rise and ocean acidification are other important indicators of climate change, and both are accelerating with major consequences for coastal communities and habitats. The rate of sea-level rise has increased in the period 2007-2016 to approximately 4mm/yr, well above the long term trend of 3mm/yr. Ocean acidification is progressing an order of magnitude faster today than at any previous time.

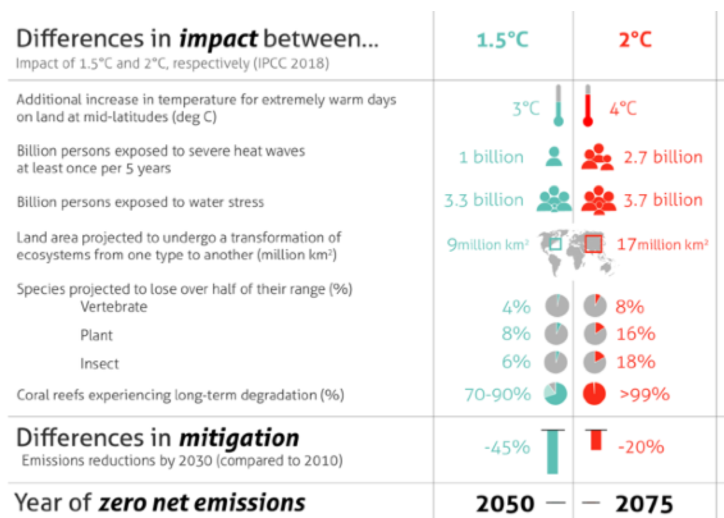
We now also know that human land use directly affects more than 70% of Earth's ice-free land surface and that an estimated 23% of total greenhouse gas emissions (2007-2016) originate from agriculture, forestry and other land use activities. Land use and land use change also impact systems beyond climate, causing loss of biodiversity and ecosystem services.

Growing climate impacts increase the risks of crossing critical tipping points.

Tipping points in the Earth System refer to thresholds that, if crossed, lead to far-reaching, in some cases abrupt and/or irreversible changes. With continued warming, systems can reach tipping points where they rapidly collapse or a major, largely unstoppable transformation is initiated. Scientists have studied plausible pathways to a "Hothouse Earth" scenario, where interacting tipping points could potentially lead to a cascading effect where Earth's temperature heats up to a catastrophic 4 °C – 5 °C. Another study estimates that unmitigated emissions could reverse a multimillion-year cooling trend in less than two centuries.

There are large differences in the magnitude and risks of climate change impacts between 1.5°C and 2°C of warming.

For example, limiting warming to 1.5°C relative to 2°C can avoid the inundation of lands currently home to about five million people, including 60,000 people currently residing in Small Island Developing States.



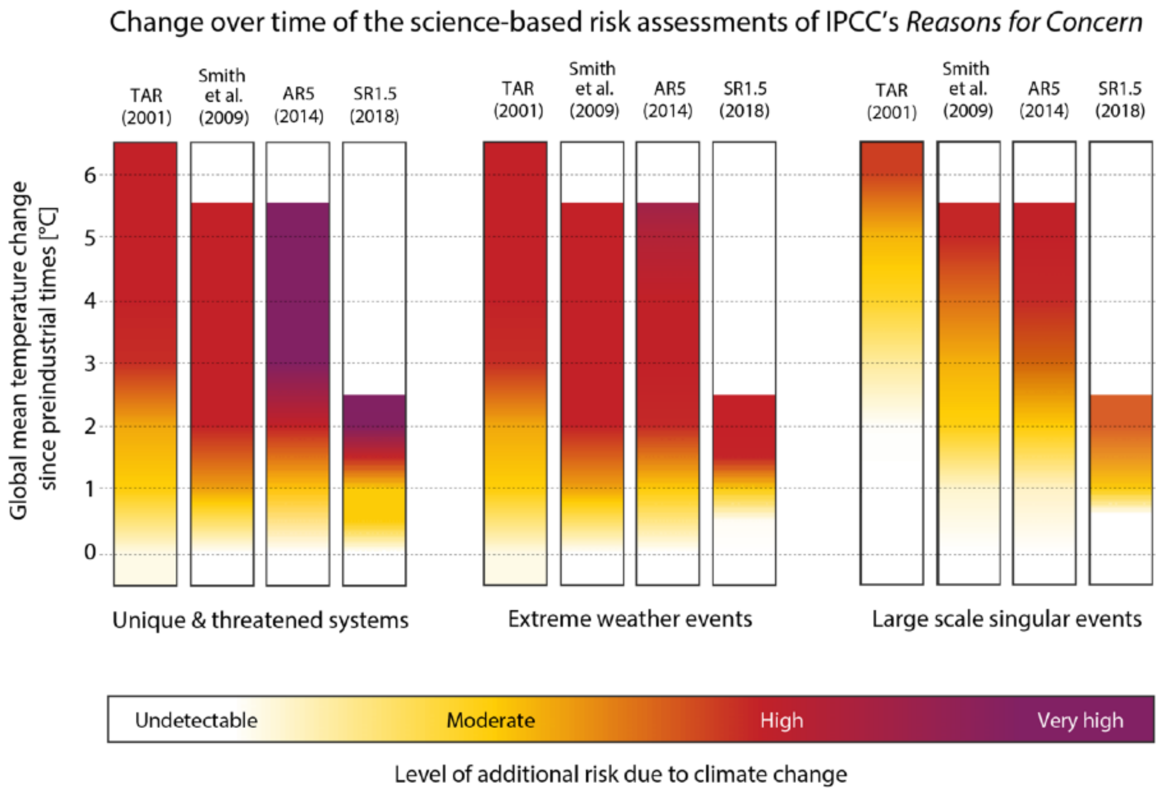
Half a degree of additional warming can also heighten risk in our social systems with impacts like large-scale migration and civil unrest. Extreme and changing weather can undermine livelihoods, threaten infrastructure increase food insecurity and compromise the ability of states to provide conditions for human security, especially where there is existing political instability.

Key processes that currently keep the climate stable are weakening, risking the establishment of feedback loops (e.g. loss of Arctic sea ice or forest dieback) that could hinder efforts to stabilize the climate, even as emissions are reduced. For example, the extreme case of a complete disappearance of Arctic sea ice during the sunlit part of the year, while unlikely in the short term, could accelerate warming by 25 years.

The stability of the Earth system is influenced by feedbacks between the climate system and carbon-regulating processes such as frozen soils in permafrost or carbon uptake by forests. There is a growing understanding of the critical role of these biosphere carbon feedbacks in stabilizing the climate system and that those processes are loosing strength, thereby increasing the risk that self-reinforcing mechanisms become relevant and counterplay efforts to mitigate further climate change. Examples include the reduced carbon sink and carbon retention capacity of land and soils in the tropics, or the release of CO_2 and methane from thawing permafrost soils.

There is a growing recognition that climate impacts are hitting harder and sooner than climate assessments indicated even a decade ago.

Since 2001, the IPCC has published a science-based risk assessment of several Reasons for Concern (RFC) to illustrate the impacts of different levels of warming for people, ecosystems and economies worldwide. A comparison of these from 2001 to 2018 (including an update in 2009) shows the evolution of the assessment - the level of risk has increased with each subsequent analysis.



As climate change intensifies, cities are particularly vulnerable to impacts such as heat stress and can play a key role in reducing emissions locally and globally.

Heatwaves now pose a recurring challenge on all inhabited continents and generate an increasing range of threats to human lives and well-being, particularly in cities where built environments magnify heat exposure. This matters because close to 70% of the world's population is expected to live in cities by 2050 and will be exposed to extreme heat if no actions are taken to modify urban environments. A study of the 1692 largest cities in the world found that about 60% of the urban population has already experienced warming twice as large as the world during the 1950-2015 period.

As cities consume about 78% of the world's energy and produce more than 60% of all CO_2 emissions their actions are central to minimizing the rise in global mean temperature. In particular, shifts towards cleaner energies will not only reduce greenhouse gas emissions, but will also reduce localized air pollution and heat island effects within cities.

The cities of the world are thus key players for stepping up climate action. Commitments have been made by more than 9,000 cities in 128 countries, home to 16 % of the global population.

Strategies for mitigation and for upscaling adaptive risk management are necessary going forward. Neither is adequate in isolation given the pace of climate change and magnitude of its impacts.

A mitigation-only strategy will not be effective because many changes are already underway and are now unavoidable. Similarly, an adaptation-only strategy will become more costly (the annual cost of adaptation is estimated in the range of US$ 140 - US$ 300 billion by 2030) as the magnitude of climate change increases. Currently only 40 developing countries have quantifiable adaptation targets in their current Nationally Determined Contributions and many existing targets are relatively short-term, not going beyond 2020. So, our resilience and adaptive capacities must still be strengthened to deal with committed climate impacts and to plan to manage residual risks that will remain in the long term despite mitigation actions.

Only immediate and all-inclusive action encompassing: deep decarbonization complemented by ambitious policy measures, protection and enhancement of carbon sinks and biodiversity, and efforts to remove CO_2 from the atmosphere, will enable us to meet the Paris Agreement.

Deep decarbonization

Pathways to limit warming to 1.5 °C require halving global emissions every decade from 2020 onward and respecting a global carbon budget – around 420–570 billion tons total net CO_2 emitted to the atmosphere. Such deep decarbonisation also requires major transformations in all of society's socio-technical systems starting with the energy and food sectors as pivotal first adopters.

In the energy sector, social and technological innovations coupled with strong efficiency standards can potentially reduce the energy demand without compromising global living standards, especially as readily-available technological substitutions already exist for more than 70% of today's emissions. The speed of the transformation will also be decided by the growing political, technological and economic momentum of renewable energy. Between 2006 and 2016, solar and wind power have gone from a combined 0.7% to 5% share of global electricity production, doubling their output every 3 years while dropping in price.

In the food sector, new research confirms that a global transformation to healthier diets (including reduced meat consumption) and a more sustainable food production system is critical to achieve the Paris Agreement and could avert up to 11 million deaths per year.

Ambitious policy measures

Stronger and more diverse policy measures for rapid decarbonization are essential elements of climate policy to achieve the Paris Agreement:

Fiscal reforms: Both tax reforms and emissions trading systems (ETS) can be elements of the necessary transformation towards a single, cross-sectoral carbon price, along with a phase out of fossil fuel subsidies. To achieve social acceptability, fiscal reforms should consider social balance and benefit low-income households.

Sector-specific policy instruments: New standards and practices, incentives, moratoriums in traffic, building and energy sectors can mediate market or policy failures and tilt development towards a sustainable path.

Protection and enhancement of carbon sinks and of biodiversity

Protecting existing carbon sinks and biodiversity, and expanding lands from source to sink, is possible via natural solutions that promote conservation of landscapes, restoration of degraded forested land at global scale, and improved land management actions. Such actions could provide over one-third of the climate mitigation needed between now and 2030 to stabilize warming to below 2 °C and can help reverse some of the adverse impacts of climate change on land degradation.

CO_2 removal

To achieve the 1.5°C target, approximately 100–1000 billion tons of CO_2 must be removed from the air during this century. To do so, a range of negative emissions technologies (NETs) have been proposed, from re- and afforestation to bioenergy with carbon capture and storage (BECCS) or direct air capture of CO_2. These differ widely in terms of maturity, potentials, costs, risks, co-benefits and trade-offs. NETs play an essential role in mitigation scenarios in accordance with the Paris Agreement – but to a scale much larger than currently tested and deployed. There is also a risk that they may be used to delay implementing emissions reduction policies. While NETs will be indispensable in combination with other mitigation efforts, especially to counterbalance emissions sources such as from aircraft or cattle, large-scale deployment options are limited with feasibility constraints and increasing sustainability trade-offs. Furthermore, new assessments indicate that few of these large-scale removal options could be available before 2050, thus such techniques cannot be relied on over the next several decades, which is the timescale relevant for achieving the Paris Agreement.

> *A global report on the State of Climate Services capacities will be released for the first time at COP 25 in December, in Chile. In addition to WMO, current contributors include the Adaptation Fund, CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS), Food and Agriculture Organization, the Green Climate Fund, the Global Environment Facility, the World Bank Group (WBG), the World Bank Global Facility for Disaster Reduction and Recovery and World Food Programme (WFP)*

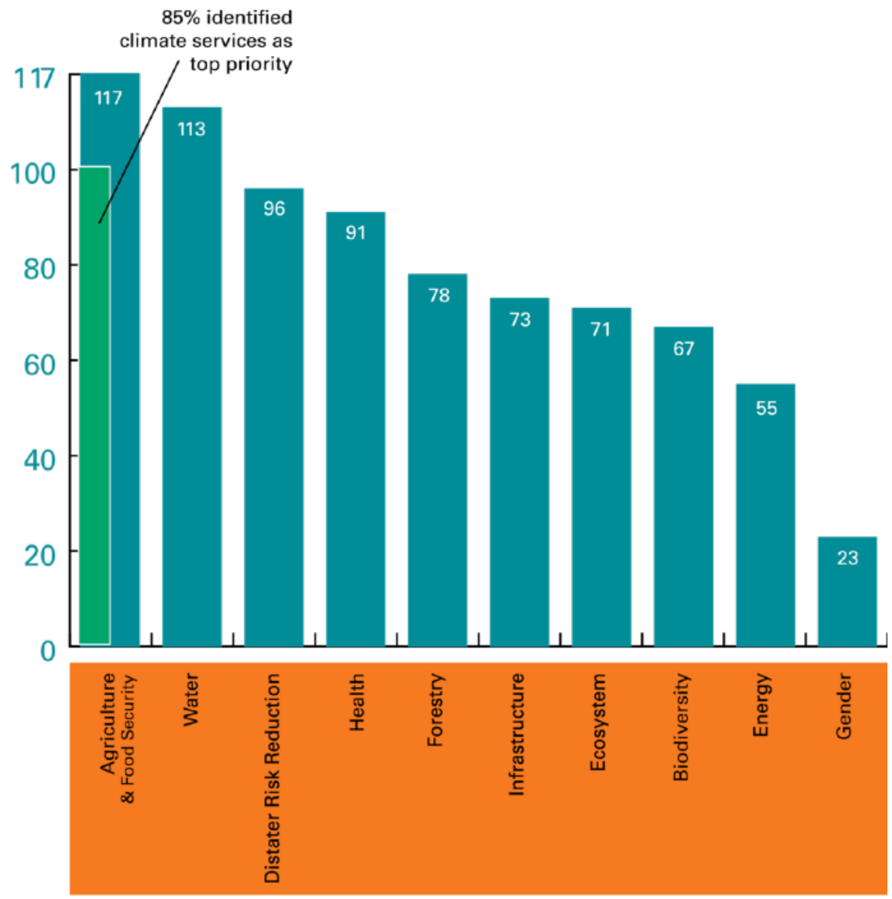
Climate and early warning information services should underpin decision-making on climate action for adaptation.

The Global Framework for Climate Services was established in 2009 with the vision to enable better management of the risks of climate variability and change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice addresses the critical elements for effective provision and uptake of seamless weather, water and climate services, namely: observations and monitoring; research; modelling and prediction; climate services information system; user interface platform; and capacity building.

With the appropriate capacities, countries will provide tailored, science-based information that helps people from policymakers to farmers make better decisions about how to adapt to the challenges of climate variability and change.

Availability of this information is essential in addressing the adaptation needs highlighted in NDCs.

The majority of countries' NDCs highlight agriculture, food security and water as the top priority sectors for climate change adaptation (WMO and FAO, 2019). In the area of agriculture and food security, 85% of countries (100/117) identified "climate services" as being a valuable part of planning and decision-making.

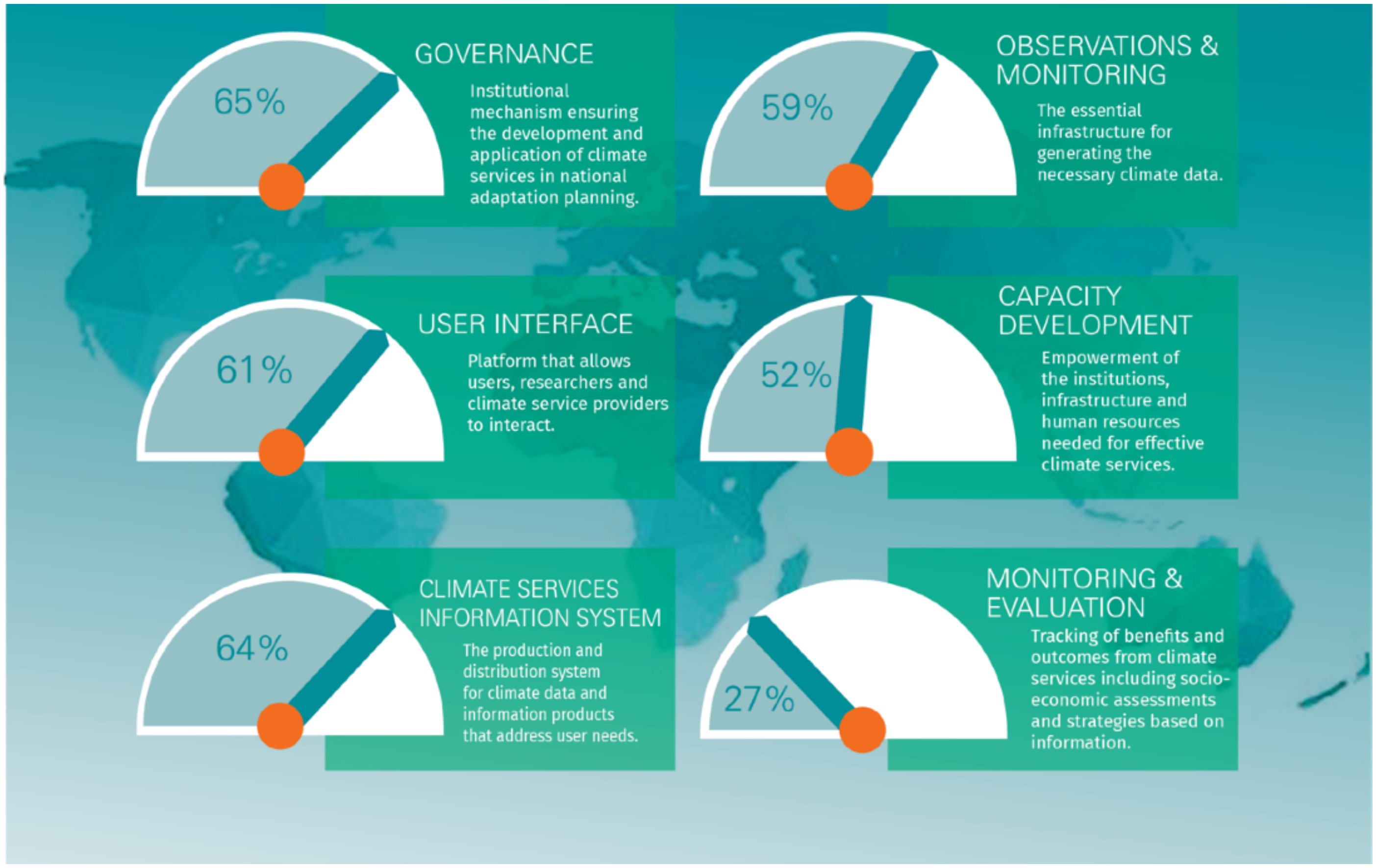


The capacities of countries to deliver climate and early warning information services varies across regions.

The capacity of countries to benefit from climate services depends on several factors. These range from the observations and monitoring of weather and climate events to the aggregation and combination of climate data with socio-economic data and effective delivery of services to end users.

As highlighted by the FAO and the WFP, the accessibility of these services, such as covering last mile delivery to farmers, is especially critical. Equally important, according to CCAFS, is the continual refining and improvement of raw data for climate information to ensure the information is both accurate and actionable.

The capacities of countries to deliver climate and early warning information services varies across regions. Overall, available data suggest that there has been progress on governance, implementation of basic hydro-meteorological systems and stakeholder engagement for the implementation of climate services but the set of functional capacities focused on monitoring and evaluation of the results and benefits of the use of climate services remains weak.



WMO Member capacities across selected hydro-meteorological system functions across 137 functional areas (Source: WMO)

For more information please visit:

public.wmo.int/en/resources/united_in_science