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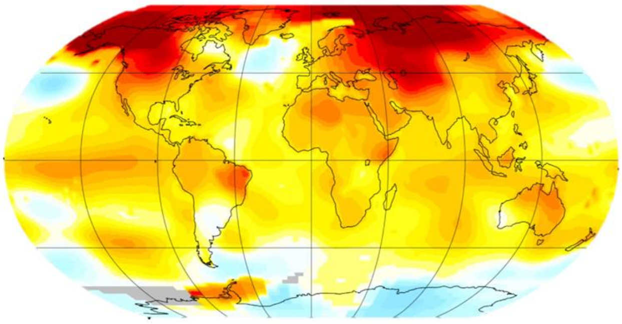
Limiting Global Warming to 1.5°C



A 2018 UN Special Report examined how peak global warming can be limited to 1.5°C and the implications of doing so. The UK has a statutory long-term target for reducing greenhouse gas emissions, which is expected to tighten in future. This POSTnote outlines key features of the Special Report and UK responses to climate change.

Overview

- The Paris Agreement aims to limit average global warming to well below 2°C, and towards 1.5°C, above pre-industrial levels. There has been 1°C of warming to date.
- A 2018 UN assessment examined the implications of limiting warming to 1.5°C.
- Global warming of 1.5°C would result in risks to natural and human systems, but many of these risks would be greater at 2°C.
- Different options for keeping warming below this level exist. Global net CO_2 emissions would likely need to halve by around 2030 and reach zero around 2050. This entails substantial technological and social change. CO_2 would likely need to be removed from the atmosphere at unprecedented levels.

Background

The Paris Agreement on climate change (Box 1) was agreed in 2015. Its main goal is to limit average global warming to well below 2°C above pre-industrial temperatures, and to 'pursue efforts' to limit warming to 1.5°C.[1,2] This is more ambitious than a prior goal of below 2°C.[3] In 2018, scientists working with the UN Intergovernmental Panel on Climate Change (IPCC) reviewed the evidence base on the impacts and implications of a 1.5°C limit. Its resulting Special Report was published in October 2018 (Box 2).[7–12] This POSTnote summarises the key messages of the Special Report on approaches to meeting the target and impacts of 1.5°C global warming. It also examines UK approaches to climate change mitigation and adaptation, and potential changes to emissions targets.

Box 1: UN COPs and the 2015 Paris Agreement

The UN Framework Convention on Climate Change (UNFCCC) was established in 1992 with the objective of preventing dangerous climate change,[4] via international negotiations at annual Conferences of the Parties (COPs). The 2015 Paris Agreement, agreed at COP21, was the first legally binding global climate deal. It was negotiated and agreed by 196 parties in December 2015, and 184 had ratified in December 2018. The Agreement has three specific goals:[1]

- Hold global temperature rise at 'well below' 2°C above pre-industrial levels and pursue efforts to limit this rise to 1.5°C
- Increase the ability to adapt to adverse climate change impacts without threatening food production
- Use international finance for these aims (Box 4).

Paris signatories are required to submit a 'Nationally Determined Contribution' (NDC) plan for reducing greenhouse gas emissions which takes effect in 2020.[5] Current NDCs would result in warming of around 3°C or more,[6] though the Agreement's 'ambition mechanism' reviews and seeks to increase NDC ambitions every 5 years.

Increasing Global Temperature

Global warming is the increasing trend in global average surface temperature which is a key driver of climate change. Greenhouse gas (GHG) from human activity have caused global warming of 1°C since pre-industrial times, and global temperature is currently increasing by 0.2°C per decade.[8] This is measured as an average across long timeframes (30 years) and across temperatures over land and ocean.[8] Warming has been greater over land than over oceans, and has been greatest in Arctic regions.[8] The level of warming to date is almost entirely caused by human emissions of different types:[8,13]

- **Carbon dioxide (CO_2)** is the GHG emitted in greatest quantity by human activity. It is the most dominant GHG over long time periods,[14] as it is chemically stable and can remain in the atmosphere for many thousands of years. Although natural CO_2 emissions from plants, soils and oceans are much greater than human emissions, these natural emissions are in equilibrium with removal of CO_2 by natural 'sinks' (such as oceans and plants).
- **Non-CO_2 GHGs** include methane, nitrous oxide and hydrofluorocarbons (HFCs), among others. Nitrous oxide

Box 2: IPCC Special Report on Global Warming of 1.5°C
Scientific experts emphasise that no specific temperature target should be seen as a safe limit,[15] and that "efforts should be made to push the defence line as low as possible".[16,17] Climate negotiations before COP21 focused on a limit of below 2°C above pre-industrial levels.[3,18] Interest in a 1.5°C limit increased from 2008, driven by small island states' concerns around risks from sea level rise at 2°C.[19] In 2015 the UNFCCC invited the IPCC to assess the evidence base on the implications of limiting warming to 1.5°C relative to 2°C. The IPCC assessed over 6000 research papers to produce a 2018 Special Report on Global Warming of 1.5°C.[7–12]

and some HFCs persist for centuries.[20] Others, such as methane and black carbon, are 'short-lived climate pollutants' (SLCPs) (POSTnote 480), which generally break down in the atmosphere within decades. SLCPs cause greater warming in the short term.[21,22]

- **Aerosols** are particles emitted from human and natural sources (many industrial and transport pollutants are aerosols). They reflect or absorb sunlight and affect cloud growth, and are short-lived (persisting for weeks at most). They have an overall cooling effect.[23]

Long-term temperature rise is primarily dependent on the cumulative amount of CO_2 emitted by human activity since pre-industrial times (as well as some long-lived non-CO_2 GHGs such as nitrous oxide).[20,24,25] High annual SLCP emissions increase the rate of warming in coming decades, which makes limiting warming to 1.5°C more challenging.[26]

Reducing Emissions for a 1.5°C Limit

All GHG emissions must be substantially reduced for temperature increase to peak at, or close to, 1.5°C. Temperature will peak when CO_2 emissions are net zero and SLCP emissions are constant or declining. Different approaches to meeting these aims exist. Slower emissions reductions over the next decade require greater use of unproven greenhouse gas removal (GGR) in later decades, and increase the likelihood that temperature rise temporarily 'overshoots' 1.5°C.

Emissions Reduction Pathways

Scenarios resulting from 'integrated assessment models', which describe the global economy, energy and land use are used to illustrate pathways of how emissions and temperature could develop in the 21st century.[9]

CO_2 Pathways
Annual human CO_2 emissions are increasing; 2018 global emissions were estimated to be 2.7% higher than in 2017.[27] Most 1.5°C pathways suggest that global CO_2 emissions would need to peak in the near future, be halved around 2030, and reach net zero around 2050.[24,25,28] Net zero occurs when human CO_2 emissions are equal to the amount removed from the atmosphere by GGR. The 'remaining carbon budget' (Box 3) for a 1.5°C limit is estimated to be equivalent to 10-15 years of CO_2 emissions at 2018 levels.[9]

Non-CO_2 Pathways
Pathways for 1.5°C generally require deep reductions in non-CO_2 emissions (nitrous oxide, SLCPs and aerosols), but not that net zero is reached for these. For SLCP

Box 3: Remaining Carbon Budgets
Estimates of the amount of the 'remaining' CO_2 that can be emitted in the future, before reaching a given level of warming, are known as 'remaining carbon budgets'. They are given in quantities of CO_2. The IPCC estimates a remaining global carbon budget (from the beginning of 2018) for limiting to 1.5°C of 420–580 billion tonnes (Gt) of CO_2.[9] This is equivalent to 10-15yr of global CO_2 emissions at 2018 levels.[27] This estimate was revised upwards from a 2014 IPCC estimate of 120Gt,[20] due to a better scientific understanding of levels of historical warming and the amount of warming caused by additional CO_2 and non-CO_2 emissions.[9] There are large uncertainties around these factors. Complex 'feedbacks' (such as methane release from melting permafrost) (POSTnote 454) could reduce the remaining budget.

emissions such as methane, black carbon and HFCs, a constant or declining annual level of emissions is required at the time of peak temperature.[8,9,26] Reductions in aerosol emissions would occur naturally along with many GHG emissions reductions measures (for example, closing coal power plants reduces CO_2 and aerosol emissions).[9] Decreasing aerosol concentrations would act to increase temperature, but these would be offset by GHG reductions.[9]

Reducing Emissions to Meet Pathways

Reducing global emissions in line with 1.5°C pathways would require social and technological changes to:[8,9]

- **Energy systems**, including growth in renewables and less power and fuel production from fossil fuel sources
- **Transport and buildings,** reducing energy demand and increasing the proportion of energy from electricity
- **Lifestyle and behaviour**, reducing demand for high-CO_2 transport, meat or GHG-intensive consumer goods
- **'Difficult-to-decarbonise' sectors** in which technical solutions are challenging, e.g., aviation and agriculture.

A 1.5°C target can be met using a combination of the above and GGR. Pathways involving greater lifestyle change rely less on GGR.[8] IPCC experts suggest that in any case the emissions reductions required imply "rapid, far-reaching changes on an unprecedented scale".[29] Current NDC pledges for the Paris Agreement (Box 1) could result in around 3°C of warming.[6,9,30]

Greenhouse Gas Removal and Overshoot

GGR (POSTnote 549) encompasses a range of processes that remove CO_2 from the atmosphere (there are no proven ways of removing non-CO_2 GHGs). These include three broad categories of GGR:

- **Land-based removals** enhance natural systems' ability to absorb CO_2 from the atmosphere. This includes growth, restoration or better management of forest, wetlands and soils, among other processes.[31,32]
- **Bioenergy with carbon capture and storage (BECCS)** converts plant-based fuel (biomass) into other energy carriers (such as electricity or hydrogen). It stores the waste CO_2 using carbon capture and storage (CCS).
- **Direct Air Capture with CCS (DACCS)** captures CO_2 directly from the atmosphere, and stores it using CCS.[33]

All 1.5°C and most 2°C pathways require some level of GGR. In many scenarios, temperature rise temporarily overshoots and then returns, to 1.5°C, by using GGR to make global net CO_2 emissions negative.[9]

Most forms of emissions reduction are expected to be less costly and more technologically feasible than most forms of GGR.[34,35] It is unclear how feasible it would be to increase GGR at the scales generally required by 1.5°C pathways, because of significant technological, economic and social challenges.[9,11,36,37] All GGR techniques (except increasing forest cover) are at early stages of development and all result in competition for resources (land, water or energy).[36] Land-based approaches can only provide a finite amount of GGR.[11] BECCS needs large inputs of biomass using land and water, which could impact biodiversity and food production.[36–38] DACCS is currently costly and requires a high energy input.[34]

GGR will be necessary to offset emissions in 2050 and beyond from difficult-to-decarbonise sectors.[39] Experts highlight the risks of relying on future developments in GGR techniques which could prove less effective than hoped;[40] the Royal Society and Royal Academy of Engineering suggest pursuing a range of GGR approaches to avoid this.[34] To develop GGR at lowest risk, they and other groups recommend focusing on developing CCS technology and infrastructure, improving natural carbon sinks (e.g. forestation and soils), and increasing R&D.[34,35] An £8.6m UK research programme examining the feasibility of GGR processes launched in 2017.[41] In 2018 a pilot BECCS project began operating at Drax Power Station in Selby.[42]

Global Impacts of Climate Change at 1.5°C

There is strong evidence that human-induced climate change to date has impacted natural ecosystems, human systems and human well-being globally.[10] Future risks to these are expected to be lower at 1.5°C than at 2°C, but impacts vary widely across regions.[43,44] A larger and longer overshoot increases these risks, as some impacts at higher temperature, such as ecosystem loss, may be irreversible.[10] Adaptation (the process of addressing climate change risks to lower their impact) will be required at any temperature increase, but costs of doing so will be lower at 1.5°C.[12]

Research on UK climate change impacts at 1.5°C of warming relative to 2°C is limited. Met Office UK Climate Projections 2018 (UKCP18) provide information on potential temperature, rainfall and sea level rise under different future emissions scenarios.[45]

Changes to Natural Systems

Extreme Weather

Extreme weather refers to individual extreme events, such as temperature (e.g. heatwaves) and rainfall. Extreme events amplify the risks of increasing temperature within a specific region.[46] More frequent and intense extreme weather is expected to occur at 2°C average warming than at 1.5°C.[10,47] Limiting warming to 1.5°C may lead to extreme heat being less intense (the hottest days being less hot) than at 2°C, particularly in the mid-latitudes, further from the equator.[10] Around 500m fewer people would be frequently exposed to extreme heatwaves at 1.5°C than at 2°C,[48] and around a fifth of excess heat-related deaths in cities such as London may be avoided.[49] Limiting to 1.5°C would reduce risks from heavy precipitation events, and substantially reduce the probability of extreme drought and other water availability risks in certain regions.[10] Sub-Saharan Africa is projected to be at particular risk of extreme heat and drought.[50]

Sea Level Rise

Global warming of 1.5°C is projected to cause sea level rise (SLR) (POSTnote 555) of 26-77cm by 2100 – on average 10cm less than projected for 2°C. SLR at 2°C would affect up to 10.4m more people. Regardless of peak temperature, SLR will continue well past 2100 and could increase by a number of metres after then if polar ice-sheet ‘tipping points’ are reached and the Greenland or West Antarctic Ice Sheet collapse. There is uncertainty around the temperature at which this could happen, but the risk will increase substantially as temperature rise increases past 1.5°C.[10,51]

Impacts on Marine and Arctic Ecosystems

Warming of 2°C and above makes the Arctic Ocean substantially more likely to be ice-free in summer than at 1.5°C.[52] This would make animals such as polar bears, whales and seals that depend on Arctic ice, as well as Arctic communities, more at risk.[10] Oceans have absorbed about 30% of human-emitted CO_2 to date,[20] resulting in ocean acidification and changes to marine chemistry that are unprecedented in 65m years.[53,54] Upper ocean temperatures have increased and will continue to do so. Plankton and fish species are projected to move to higher latitudes, whereas less mobile species are more at risk. Global warming of 1.5°C is projected to cause a 70-90% decline in warm water coral reefs, whereas at 2°C more than 99% are expected to disappear.[10,55,56]

Impacts on Terrestrial Ecosystems

Terrestrial ecosystems and organisms would be less at risk at 1.5°C than at 2°C.[10] The projected area of land affected by significant ecosystem change is reduced (from roughly 13% to 4% of global land area).[57] Severe geographic range reduction is approximately half under 1.5°C compared to 2°C for vertebrates and plants, and reduced by two thirds for insects.[58] Projected increases in wildfire frequency further threatens terrestrial ecosystems at 2°C.[10]

Risks to Human Systems

Climate-related risks to health, livelihoods, food security, water supply and human security make it more challenging to meet several UN Sustainable Development Goals (SDGs) (Box 4). These risks are greater at 2°C warming, though adaptation will be necessary at any level of warming. Small island states and economically disadvantaged nations are at greater risk as they have less capacity to adapt.

Food and Water Security

Climate change affects food availability, quality, access and distribution. Although moderately warmer conditions and greater atmospheric CO_2 concentrations can, in theory, act to increase crop yield,[59] these effects are complex and do not occur for every crop or region. The combination of wider climate change effects (extreme weather, increasing precipitation and temperature) will have negative effects on crop yields.[10] Climate change to date has resulted in more yield reductions than increases.[60] Limiting warming to 1.5°C

Box 4: Equity in Meeting Climate Change Targets

Differentiated Responsibility and Climate Funding

Developing countries are, in general, less responsible for historical climate change and less able to pay for adaptation and mitigation. These and other 'equity' issues result in disagreement over how much responsibility individual countries should have for the remaining global carbon budget,[61–64] and international climate finance. The Paris Agreement contains a commitment to mobilise $100bn annually by 2020 from a range of public and private sources in developed countries to financially assist developing countries for mitigation and adaptation measures.[1,18] $57bn of public finance was raised in 2017.[65] The UK is the second-largest donor to multilateral UN climate funds.[66]

Sustainable Development

Limiting warming to 1.5°C rather than 2°C would make it easier to achieve a number of SDGs.[12] Adaptation measures for 1.5°C would have benefits for sustainable development, poverty and inequality reduction goals. Pathways for 1.5°C would help achieve SDGs 3 (health), 7 (clean energy) and 11 (cities and communities) among others. Some mitigation pathways, if not managed carefully, could make it more difficult to achieve SDGs 1 (poverty), SDG 2 (hunger), 6 (water) and 7 (energy access). Pathways that reduce energy demand would decrease these trade-offs.[7,12]

is projected to lead to smaller reductions of maize, rice and wheat yield, particularly in West and Central Africa, Southeast Asia, and Central and South America.[10] Greater use of GGR increases potential risks to food security.[12] At less than 2°C of warming, changes in population have a stronger effect on water security than climate change.[10] However, limiting to 1.5°C rather than 2°C could lead to up to half the number of additional people (compared to now) at risk of water scarcity.[10]

Human Health and Wellbeing

Climate-related negative health outcomes have been observed and will increase with future warming.[10,20] Increased transmission of infectious diseases (such as malaria or dengue fever), exposure to heatwaves and fires, undernutrition and reduced labour productivity in vulnerable populations are likely to lead to greater risks of injuries, disease and death. Overall, 2°C poses greater risks to human health than 1.5°C, with regional differences. Adaptation could reduce the magnitude of these impacts.[10]

UK Climate Change Policy

The UK Climate Change Act 2008 (CCA) provides the framework for climate change mitigation and adaptation in the four UK nations.[67] The independent Committee on Climate Change (CCC), set up under the CCA, advises the UK and devolved governments on these issues.

Reducing UK Emissions

Current UK Emissions and Targets

Territorial UK CO_2 emissions (those produced in the UK) are 43% lower than in 1990, mainly because most coal power (which is highly CO_2 emitting) has been replaced by natural gas and renewable generation.[68] There has been much less of a decline in national 'consumption-based emissions'. These include emissions from manufacturing goods and services that are imported into the UK.[69,70] They are not counted towards carbon budgets.

Box 5: UK Carbon Budgets

Statutory UK carbon budgets (which differ from remaining carbon budget estimates (Box 3)) are interim GHG emissions targets for five-yearly periods from 2008 onwards. Budgets decrease in each successive period. They are set by the UK Government 12 years in advance following advice from the CCC, and cover territorial GHG emissions from all sectors except international shipping and aviation.[71]

The CCA sets an overall UK GHG emissions reduction target of at least 80% by 2050 (compared to 1990), as well as interim 'carbon budget' targets (Box 5).[67] The CCC annually reports on UK progress on carbon budgets.[72] The first and second budgets (2008–2018) have been met. However, the CCC has raised concerns that current policies for reducing emissions from heating (in buildings and industry) and transport will be insufficient to meet the fourth (2023–2027) and fifth (2028–2032) budgets.[71,72]

Future Changes to Targets

The UK's long-term target was designed to contribute to a 2°C global warming target.[39] Because of the raised ambition of the Paris Agreement (Box 2), many commentators have suggested that current UK targets should be amended.[73,74] Different equity assumptions (Box 4) lead to a UK allocation of between 0.8% and 1.5% of the remaining global budget.[75]

The UK Government has indicated that it will legislate for a net zero emissions target.[76,77] In October 2018 it requested that the CCC provide advice on the timing and level of UK GHG emissions that would contribute to limiting warming to well below 2°C, and to 1.5°C.[78] The UK Government has indicated it does not currently seek to change the level of the fourth and fifth carbon budgets,[78] though the CCC is still able to advise greater action before 2032 as the least-cost pathway.[72,79] It plans to publish its advice in spring 2019.[78]

Adapting to Climate Change in the UK

Defra assesses potential future impacts in the Climate Change Risk Assessment (CCRA) (Box 6) every five years.[80] The UK Government sets out the responding adaptation framework for England in the National Adaptation Programme (NAP).[82] The CCC will present a formal assessment of the NAP in 2019.[83,84] Adaptation is also addressed under the Scottish Climate Change Adaptation Programme,[85,86] the Welsh Government National Adaptation Strategy and Northern Ireland Adaptation Programme.[87,88]

Box 6: The Climate Change Risk Assessment (CCRA)

The second CCRA, published in 2017, focused on potential climate impacts at 2°C and 4°C.[80] Greatest risks identified include:[80,81]

- Flood risk to communities, businesses and infrastructure
- Exposure to high temperature and heatwaves
- Water shortage risk for the public, agriculture and industry
- Risks to natural ecosystems and UK wildlife
- Risks to UK and international food production and trade
- New and emerging pests and diseases.

It suggests that more action is needed to address these issues, and that emerging pests should be a research priority. The CCRA also highlights some opportunities for the UK arising from moderate levels of climate change, such as prolonged agricultural growing seasons.[80]

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