Comparing climate impacts at 1.5°C, 2°C, 3°C and 4°C
Projected levels of temperature rise[1]

Climate change has already caused global temperatures to rise about 1.2°C above pre-industrial levels. On a high emissions pathway, temperatures would rise 1.5°C by around 2026, 2°C by around 2039, 3°C by around 2060 and 4°C by around 2078.

The 2015 Paris climate agreement saw world leaders commit to limit temperature rise to well below 2°C above pre-industrial levels and to aim to limit the increase to no more than 1.5°C by the end of the century. Governments also produced a set of pledges detailing how they intend to reduce emissions. If countries meet all these pledges, global warming is likely to reach 2.4°C by the end of the century, but possibly as high as 3.3°C. If all mid-century net-zero targets that have been announced are met, it would take the world to about 2°C with a range up to 2.8°C. Policies that are currently in place take us to around 2.6°C, but possibly as high as 3.5°C.

In the past, it has taken thousands of years for temperature to rise by a few degrees, and dramatic changes are already occurring as a result of a 1.2°C increase. The climate system may have many unpleasant surprises in store for us, and scientists are calling for climate change to be limited as much as possible to avoid triggering cascading and compounding 'tipping points' that could limit our ability to contain global heating.

How climate will change the planet

Most of the projections in this briefing are based on Intergovernmental Panel on Climate Change (IPCC) scenarios. The IPCC's Representative Concentration Pathways (RCPs) and Special Report on Emissions Scenarios (SRES) model different scenarios for how temperatures might change over the course of the 21st Century.[2] The IPCC also considers a set of societal scenarios - the Shared Socioeconomic Pathways (SSPs) - which map how these projections are changed by different social and economic factors, including whether the world becomes more equitable, or less so, levels of conflict, and gender issues.

Climate change will cause hot extremes to become even hotter, and will change rainfall patterns, for example causing heavier rainfall in South and South-East Asia and longer droughts in southern Africa. Extreme rainfall and

[1] This review is based on materials prepared by Leo Barasi from Global Strategic Communications Council (collaborative network of communications professionals on climate, energy and nature) www.gsccnetwork.org

[2] RCP1.9 models pathways roughly consistent with a 1.5°C temperature rise by the end of the century; RCP2.6 models those consistent with a 2°C temperature rise and RCP4.5 models those consistent with a 3°C by the end of the century. A 4°C temperature rise by the end of the century lies between the projections for RCP4.5 and those for RCP8.5. See Table SPM.1, p.13. http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf

floods are likely to increase everywhere, but there will also be increased evaporation caused by hotter temperatures, leading to more frequent and severe droughts in places. Tropical countries are likely to experience the most severe impacts of climate change, partly because this is where temperatures are already the greatest, but also because most tropical countries have less capacity to adapt. Temperatures will change at different rates across the world. Temperatures across Africa, for example, are projected to increase faster than the global average.

Temperature rise of 1.5°C: how likely is it, and what does it mean?

On current trends, global average temperature will rise 1.5°C above pre-industrial levels by the end of this decade. Limiting temperature rise to 1.5°C by 2100 means immediate and radical cuts in global emissions on a scale never seen before. It will also almost certainly require using some combination of measures to suck carbon dioxide out of the atmosphere. If this happens, temperatures will probably exceed the 1.5°C target at some point during this century, and then fall again by 2100. Whatever happens, it is very unlikely that the world can avoid the impacts detailed below at some point this century.

Rising heat and humidity: The world is already experiencing the effects of a 1.2°C temperature rise. Under hot conditions, if humidity is also high, humans can no longer cool themselves by sweating. Extreme heat-humidity combinations are increasing globally. Heat and humidity combinations lethal within hours even to fit acclimatized humans resting in the shade never occurred before 1980, and are still very rare. Even at 1.5°C around 30,000 people will die of heat annually in Europe, up from 2,750 today.

Changes to rainfall and water shortages: Climate change is already impacting water supplies, for example in the western US where climate change accounts for half the magnitude of a recent drought that was the worst in 500 years. The amount of freshwater available in rivers and lakes could decrease 9% in the Mediterranean region, 10% in Australia, and 7% in north-east Brazil as a result of a 1.5°C temperature rise. Around 350 million more people living in urban areas will be exposed to water scarcity from severe droughts at 1.5°C warming. 800 million people are at least partly dependent on meltwater from glaciers in the high mountains of Asia; around a third of the ice stored in these glaciers would be lost if temperatures are limited to 1.5°C. The area covered by glaciers in Peru has already shrunk by a third, and further Andean glacier loss could affect the water supply of 4 million people in major cities along with hydropower energy generation.

Nearly all coral reefs lost: The equator is already becoming too hot for some ocean life, with many marine species already moving to higher latitudes. Between 2014 and 2017, 21 of the 29 reefs listed as World Heritage Sites suffered from heat stress as a result of rising ocean temperatures. The Great

Barrier Reef has, in 2021, been listed as an endangered World Heritage Site. If temperatures rise 1.5 °C, 9 out of 10 coral reefs are at risk from severe degradation. Nearly 9 in 10 marine heatwaves, which can devastate marine ecosystems, are currently attributable to human-induced warming - the number of marine heatwave days will increase 16-fold with 1.5 °C warming.

Species moving, Amazon drying, fires increase. 40% of the Amazon rainforest is already so dry it could exist as savanna, a trend which would increase with further heating. Climate change has already increased the length of the fire season in one-quarter of land area, increased average fire season length by one-fifth and doubled the global burnable area that was affected by a severe fire season. In Mediterranean Europe, burned area would increase by 40-50% at 1.5 °C. Almost half of species studied have become locally extinct at the warmest points of their distribution. At 1.5°C, 6% insects, 8% plants, and 4% vertebrates could lose half or more of their range.

Food production suffers: Rising temperatures, drought and unstable weather patterns have serious implications for global food production. Every degree of global temperature rise reduces global yields of wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1%. Some regions are more affected than others - for example in West Africa wheat yields could fall up to 25% if temperatures rise 1.5°C. The global food production system will also become more vulnerable as the planet warms. Food productivity is already 20% lower than it would have been without climate change and the risk will continue to increase with warming. The cost of adaptation plus residual change for global crops at 1.5ºC has been estimated at $63 billion a year. The risks of simultaneous failure in maize production would increase from 6% to 40% at 1.5°C-warming. International food production failures that currently have a risk of happening once every 100 years could become as frequent as 1-in-30 years or more by 2040.

Rising sea levels displace people: Climate change causes sea level rise for two reasons: because water expands as it warms, and because melting ice sheets add water to the seas. Under a very low emissions scenario, global mean sea-level rise could rise 0.28–0.55m by 2100, compared with recent levels. 46 million people[3] currently live in areas that are at risk of permanent inundation from the sea if temperatures rise 1.5°C, equivalent to about 70% of the number of people currently displaced from their homes globally by war, instability or human rights violations. About half of this at-risk population is in China, Vietnam or Japan.

[3] These are median estimates. The ranges are 31.87–68.83 for 1.5°C and 31.99–78.38 for 2C. The estimates are based on the 2010 population.

Economic impacts: At "well below" 2℃, global heating will reduce global GDP by 4.2% annually, according to analysis by reinsurance company Swiss Re.

Temperature rise of 2°C: how likely is it, and what does it mean?

On current trends, global average temperature will rise 2°C above pre-industrial levels before 2050. Limiting temperature rise to 2°C means sharp reductions in global emissions and the rapid reversal of economic and population growth trends observed the last 50 years. If all mid-century net-zero targets that have been announced are met, it would take the world to about 2°C (though with a range of possible warming up to 2.8°C)). Nearly all scenarios that limit temperature rise to 2°C by the end of the century also require measures to remove carbon dioxide from the atmosphere.

Lethal heat and humidity: 2.3 billion people would be exposed to deadly combinations of heat and humidity at least annually, over double the population that would have experienced these conditions before global warming. Before global warming, nowhere on Earth was exposed to lethal heat-humidity combinations. Today, 9 million people worldwide are exposed at least once a decade, rising to 210 million people with 2°C of heating. In South Asia, nearly three times as many people would be exposed to combinations of heat and humidity that would kill even a healthy person within hours, even assuming the population remains the same.

Changes to rainfall and water shortages: In a world where temperatures rise 2°C, the amount of rain falling in central and northern Europe in winter could increase 20%, leading to increased flooding. A reduction in rain in southern and eastern Europe and increased evaporation is likely to increase drought in Europe, with the number of droughts more than doubling, a 30% increase in drought duration and a 15% increase in drought area. Globally, 411 million more people living in urban areas will be exposed to water scarcity from severe droughts at 2°C warming. With low population growth, the population exposed to water stress would increase 50% by 2050 compared to today.

All coral reefs disappear: If temperatures rise 2°C, virtually all the world's tropical coral reefs are at risk of severe degradation and collapse. Coral reefs provide food, income and protection from storms for millions of people along coastal areas. About 25% of fish in the oceans depend on coral reefs. Seagrass meadows and kelp forests will face moderate to high risk above 1.5°C, and very high risks above 2.2°C. Their loss would cause drastic shifts in productive and carbon-rich marine ecosystems.

Animals go extinct: With 2°C warming, 25% of the 80,000 plant and animal species in the world's most naturally rich areas, such as the Amazon and the Galapagos, could face local extinction by the end of the century. Warming temperatures may affect the behavior of insects and animals, causing a cascade effect that affects entire ecosystems. 18% of insects, 16% of plants, and 8% of vertebrates could lose 50% or more of their range. Mangroves, and polar species like penguins, seals and bears, will be under threat, while the likelihood of severe drought will quadruple in important habitats in Brazil.

Arctic sea ice melt: The Arctic is warming at twice the rate of the rest of the world, and its sea ice has rapidly declined over the last decade. If global temperatures rise 2°C, Arctic sea ice is likely to melt completely - possibly for several months of the year, for several years in a row. This could in turn speed up warming by decreasing the amount of sunlight that is reflected away from the planet.

Food supplies at risk: Worldwide, agricultural yields will fall rapidly as global temperatures rise from 1°C to 3°C. This will leave an additional 8-80 million people at risk of hunger by 2050. The risks of simultaneous multiple failure in maize production would increase from 6% to 54% at 2°C-warming. The cost of adaptation and residual damage to global crops at 2ºC has been estimated at $80 billion a year. Beyond 2ºC, adaptation measures won't be enough to prevent impacts on food production.

Multiple risks affect Africa and Asia: In a scenario where temperatures rise to 2°C by the end of the century, 29% of the global population face intolerable risks in at least two out of the three main sectors - water, energy and food, and environment. The overwhelming majority of the exposed and vulnerable people are in Africa and Asia, with about half in south Asia alone.

Abrupt change is possible: There are a number of potential tipping points at which abrupt change may occur. The Arctic could become ice-free even in winter, the Amazon rainforest could die off, or the Tibetan Plateau could see the total disappearance of snow and ice cover. It is extremely difficult to know if and when such sudden events will occur - so scientists can only assess changing levels of risk. But in a recent study, half of the potential tipping points identified could be triggered by a global temperature rise of 2°C or less.

Economic damage: If the world warms 2°C, it could lose 11% of total GDP - including about 7% of GDP in North America, and about 8% in Europe. Global labour capacity could fall from 80% to around 70% due to heat and humidity alone.

3°C temperature rise - how likely is it, and what does it mean?

Based on current policies, global average temperature will reach around 2.6°C (but as high as 3.5°C) by 2100. If governments deliver on the pledges made to reduce emissions as a part of the Paris climate change agreement, but *go no further, temperatures will climb at a slower rate and may stabilize at about 2.4°C but as high as 3.3°C. Achieving the pledges means a shift to more renewable power, the use of carbon capture and storage technology to limit emissions from fossil fuels, and an increase in global forest area by the end of the century.*

Lethal heat and humidity: Without population growth, 3.25 billion people would be exposed to deadly heat humidity-conditions at least annually. Currently, lethal heat-humidity combinations occur in just a few parts of South Asia for a day a decade or more. At 3°C these conditions would expand and affect 711 million people globally at least once a decade. Around 96,000 people in Europe will die annually from heat.

Changes to rainfall and water shortages: A 3°C temperature rise would likely reduce groundwater (water stored underground). Groundwater supplies about a third of US drinking water, the majority of public water supply in England and about two-thirds of public water supply in western Australia. A 3°C temperature rise would very likely reduce groundwater recharge to half of 1990 levels by 2050 in some parts of Australia. 43% of Himalayan high mountain glaciers - which currently provide water for 800 million people - would be lost, along with 85% of glaciers in the US and western Canada. Half of the Mediterranean area would suffer drought, with the drought duration would increase from 2.1 months per year before global warming to 5.6 months. Globally, the population exposed to water stress would double.

Marine ecosystems may collapse: 3°C of temperature rise poses substantial risks to marine ecosystems. Simultaneous threats - like ocean warming, oxygen depletion, and ocean acidification - may interact, increasing the impacts on species and ecosystems and making them hard to predict. Oxygen could decline 8% in the subsurface ocean, while pH would fall from 8.2 before global warming to 7.9 - a large increase in acidity. At 3.5°C, the number of marine heatwaves days increases by a factor of 41, spreading over an area on average 21 times larger than in preindustrial times, lasting an average of 112 days, and being on average 2.5°C hotter than surrounding waters.

Extinctions of plants and animals: A third of endemic species (those unique to a particular area) that live on land, and about half of endemic species living in the sea, face extinction with 3°C of warming. On mountains, 84% of endemic animals and plants would face extinction at 3°C, while all endemic island-living species are likely to go extinct. 49% insects, 44% plants, and 26% vertebrates could lose 50% or more of their range, which will likely drive some extinct. Species whose sex-ratio is dependent on temperature, such as loggerhead turtles, would probably go extinct.

Potential for catastrophic sea level rise: At some point rising temperatures will trigger the near-complete melting of the Greenland ice sheet. The whole process could take 2,000 years, but it would ultimately lead to a sea level rise of several meters. The temperature threshold triggering this level of melt is somewhere between 1°C and 4°C above pre-industrial levels. The West Greenland ice sheet is already melting at the fastest rate in centuries, and some scientists suggest it will melt faster than projected. Under climate scenarios with moderate emissions, sea-level rise will rise an average of 0.44–0.76m by 2100 compared with early 21st century levels. Without adaptation measures, 35–50% of the world's sandy beaches could be lost by 2100.

High risk of hitting tipping points: A 3°C temperature rise increases the possibility that fragile natural systems like the Arctic or Amazon experience "abrupt and irreversible changes" by melting entirely, or drying out, for example. The risks of these 'tipping points' are moderate from 0 to 1°C temperature rise, but "increase disproportionately" as temperature increases from 1–2°C, becoming "high" above 3°C, according to the IPCC.

Rapid fall in food production: Globally, agricultural yields fall rapidly between 1°C and 3°C of warming. Once local temperatures reach 3°C above pre-industrial levels, nearly all crops are negatively affected, wherever they are in the world - including in temperate regions. The cost of adaptation plus residual damages to global crops hits $128 billions a year. Fish species go locally extinct, with serious impacts on ecosystems and the people who depend on them.

Economic damage: If the world warms 3.2°C by 2050, it could lose 18% of total GDP - including about 10.5% of GDP in both North America and Europe.

4°C temperature rise - how likely is it, and what does it mean?

Until 2015, global carbon emissions were tracking above the highest emission scenario produced by the Intergovernmental Panel on Climate Change (IPCC), exceeding 4°C by 2100. Policies in place would put temperatures on track for around 2.6°C, but possibly as high as 3.5°C by 2100. But 4°C warming this century remains possible, if policies are not delivered or if temperature rise is greater than scientists expect, possibly because certain climate 'tipping points' could lead to faster heating.

Lethal heat and humidity: At around 4.5°C, 4.7 billion people would experience potentially lethal heat. A million people live in places that could experience heat-humidity conditions lethal within hours for at least once a year. There would be 750 million-person days of heat-humidity conditions considered too dangerous to work.

Changes to rainfall and water shortages: Low latitude glaciers such as those in the Tropical Andes will lose 93-100% of their volume, with the average glacier mass globally declining by 37-57%. The timing of India's monsoon is already becoming harder to predict; for every degree Celsius of warming, monsoon rainfalls will increase by about 5%, so 4°C would cause a 20% increase. The whole European continent, with the exception of Iceland, will be affected by more frequent and severe extreme droughts. At the same time, heavy winter precipitation could increase 15-25% over most of Europe, and 25-35% in much of Eastern Europe.

Food disaster: A temperature rise of 4°C or above means significant parts of the world could experience medium to high levels of food insecurity by the 2080s, reversing the whole development path of those regions. The probability that the four major maize-exporting countries have simultaneous production losses of more than tenth of their output in any given year, which is currently virtually zero, will be 86% after 4ºC warming.

Hundreds of millions at risk from sea level rise: A 4°C temperature rise is projected to lead to eventual sea level rise of between 6-19 meters over several hundred years as it triggers melting of the Antarctic and Greenland ice sheets. This level of sea level rise would inundate all the world's coastal city locations. 470 to 760 million people currently live in at-risk areas, including 145 million people in China. India, Bangladesh, Vietnam, Indonesia, Japan, the US, Philippines, Egypt, Brazil, Thailand, Myanmar and the Netherlands all have more than 10 million people living in areas at risk. Some scientists argue the melt could happen much quicker than projected, adding several meters to sea level over the next 50-150 years, but this argument is controversial amongst the scientific community.

Struggling oceans: The most recent time when global warming, ocean acidification, and oxygen depletion converged in a way similar to values projected for 4-4.5°C heating was 56 million years ago, during a global warming event known as the Paleocene-Eocene Thermal Maximum. This caused the extinction of 35-50% of some groups of deep sea species. Oxygen could decline 13% in the subsurface ocean, while pH would plummet to 7.7 - a 216% increase in acidity.

Half of all plant animal species in valuable areas at risk: Half of plant and animal species in the world's most naturally rich areas could face local extinction. 25-35%[4] of vertebrate species would be at risk of extinction due to climate change and land use change. In the Amazon 4°C of heating, combined with high deforestation, could double the area of high fire probability, increase burned area by 5 to 29 times the current levels, and increase fire intensity 90%. Up to half of the Amazon could shift to savanna through drought and fire and a further 25-33% through reduced evapotranspiration, vastly reducing rainfall across most of South America, as the Amazon rainforest creates its own weather systems.

[4] Figure 1b

Economic damage: It's hard to predict economic impacts from this level of warming with accuracy due to the potential triggering of tipping points and conflicts. Just the heat impacts of unmitigated global warming could reduce global average incomes by 23% by 2100, compared to what they would have been.

Adaptation to 4°C may not be possible: A 4°C world is likely to create a set of interacting pressures, making it hard to project what will happen as a result. Models, for example, often don't take into account what might happen if reduced water availability, new diseases, and heat extremes happen at the same time. In its 2012 report on the impacts of a 4°C temperature rise, the World Bank concluded: "there is no certainty that adaptation to a 4°C world is possible … the projected 4°C warming simply must not be allowed to occur."

Examples of impacts in selected regions, which have now clear damages and dramatic future losses

Middle East and North Africa: More than 500 million people currently live in the Middle East and North Africa. This part of the world is likely to warm faster than the global average. If global temperatures rise by 2°C, summer temperatures in this region could more than double. With 4 C of heating, daytime temperatures could rise to 60°C on the hottest days. Heat and humidity combinations could make parts of the region uninhabitable. Rising temperatures are also likely to lead to water shortages. The Al-Wehda dam between Jordan and Syria for example is designed to provide Jordan with water for both human consumption and agriculture. At 3°C temperature rise, the amount of water available from the dam is likely to halve. Changes of this magnitude are likely to contribute to instability in the region. It is possible this has already happened. The Syrian conflict followed the longest and the most intense drought in the region in the last 900 years. While a complicated series of social and economic factors triggered the crisis in Syria, research suggests a drought played a role.

Small Island Developing States (SIDS): Small islands are extremely vulnerable to the impacts of climate change. People living on small islands are very exposed to the weather, often live on the coast, are dependent on fisheries based on corals, and only have limited resources and options for employment available. One extreme weather event can have a significant effect. More than 4,600 people died on the island of Puerto Rico for example as a result of a hurricane in November 2017, which has also triggered a healthcare and humanitarian crisis.

As sea levels rise, large waves are also likely to inundate the low lying islands more and more often, contaminating groundwater supplies of drinking water with salt. In a high emissions scenario where temperatures rise by more than 4°C by the end of the century, this could make these islands uninhabitable by around 2030-40, according to one study. In a scenario where temperature rise is limited to 3°C, they could be uninhabitable by 2055-65. Previous studies are more optimistic, suggesting they could be uninhabitable by the end of the century.

The difference between a 1.5°C to 2°C temperature rise are important for small island states. For several SIDS, particularly across the Caribbean, about a quarter of the overall freshwater stress projected under a 2°C temperature rise can be avoided if temperatures only rise by 1.5°C.

Mediterranean Basin: Southern Europe is particularly vulnerable to climate change, and likely to be more affected than other parts of Europe. A 2°C temperature rise could lead to summer rain decreasing by 20%. Water availability in the region could decrease by 9% if temperatures rise by 1.5°C, and 17% if they rise by 2°C. As temperatures rise, droughts are likely to become increasingly frequent and severe. Multiple sectors - tourism, agriculture, infrastructure, energy and health - could be affected. If temperatures rise by more than 4°C, much of southern Spain could become a desert by the end of the century.

Almost half of the plants and animals and more than half of the habitats protected by the EU Habitats Directive occur in the Mediterranean region. If temperatures rise by 1.5°C, Mediterranean ecosystems may survive, but if temperatures rise by 2°C or more, they will change more dramatically than at any point in human history.