CLIMATE COUNCIL

EXPLAINER

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Climate Change 2021: The Physical Science Basis

Understanding the Working Group I Contribution to the IPCC's Sixth Assessment Report: What it tells us, why it matters, and what it means for Australia

Key messages

- The most important climate science update for almost a decade shows there is a narrow path to avoiding climate catastrophe, but only through immediate, deep and sustained emissions reductions. This may be our final warning.
- Climate change is already wreaking havoc around the world, with worse to come. Our decisions this decade will be the difference between a liveable future for today's young people, and a future that is incompatible with well-functioning human societies.
- Every choice and every fraction of a degree of avoided warming matters. The right choices will be measured in lives, livelihoods, species and ecosystems saved. The benefits of stronger action will be realized well within our lifetimes, and even more so for our children and grandchildren.

Introduction

The report from Working Group I of the IPCC, covering the physical science of climate change, is the first contribution to the IPCC's Sixth Assessment Report, and the only part that will be published before COP26 in Glasgow. Its release is a key moment in what has become the most important year for international cooperation on climate change since at least 2015 and the negotiation of the Paris Agreement. It is an essential input to international negotiations culminating at COP26, ensuring that governments have the latest and most authoritative science to inform their commitments and actions.

The report is years in the making and draws from a new generation of highly advanced climate models and scenarios. It is the work of literally hundreds of scientists from around the world and is put through an extraordinarily rigorous process of review. The Summary for Policymakers is approved line-by-line by governments.

In the eight years since the Working Group I contribution to the IPCCs Fifth Assessment Report in 2013, global emissions have continued to rise, temperatures have skyrocketed, and the world has witnessed a terrifying run of extreme weather disasters, from Australia's 2019-20 summer to the extraordinary heatwaves, fires and floods that have shaken the northern hemisphere this year. In that time our understanding of climate change, and in particular its link to extreme weather, has improved considerably, as has our picture of likely future changes. The need for deep and rapid cuts to emissions is even clearer than before.

Based on the latest science, and taking into account Australia's national circumstances, the Climate Council has concluded that Australia should reduce its emissions by 75% below 2005 levels by 2030, and achieve net zero emissions by 2035.

While extraordinarily sophisticated, the models underpinning the Sixth Assessment Report still have their limitations. They do not fully incorporate all of the ways in which the Earth System may respond to warming. Climate science is advancing all the time, and findings published since January of this year will not have been incorporated into the Sixth Assessment Report. These limitations, coupled with the fact the report represents a consensus position, mean that IPCC reports are considered by some scientists to be somewhat conservative. In other words, the reports are more likely to understate than overstate the risks. That said, no policymaker reading this landmark assessment will be able to claim they were unaware of the profound threat that the world now faces and the need to immediately ramp up our response. Immediate, deep and sustained emissions reductions are fundamental to protecting communities and ecosystems in Australia, the Pacific and worldwide.

Box: About the Intergovernmental Panel on Climate Change (IPCC) and the Sixth Assessment cycle

The Intergovernmental Panel on Climate Change was established in 1988 and is an essential component of the world's response to climate change. It's Assessment Reports – published every five to eight years – have been a driving force for action, heavily influencing international agreements.

Like its earlier iterations, the Sixth Assessment Report is divided into three main parts, which are the contributions from the IPCC's three working groups.

Working Group I assesses the physical scientific basis of climate change. Among other things it covers humans' influence on the climate system, extreme weather, and the current and future state of our climate.
Working Group II assesses the vulnerability of societies and ecosystems to climate change and options for adapting to its impacts.
Working Group III focuses on climate change mitigation. That is, how we reduce greenhouse gases emissions, remove greenhouse gases from the atmosphere, and the scale and pace of action required.

The contributions from Working Groups II and III will be published in 2022, followed by a synthesis report combining the three parts.

The Working Group I contribution to the IPCC's Sixth Assessment Report has the following components:

- A Summary for Policymakers (around 30 pages, approved by governments)
- A Technical Summary
- Regional factsheets
- An interactive atlas, allowing detailed exploration of how global climate change will affect different regions
- The full report (several hundred pages)

The reports can be found on the IPCC website: www.ipcc.ch

Observations, scenarios and models
The report uses a set of five illustrative emissions scenarios known as Shared Socio-economic Pathways (SSPs) that include factors such as technology development, economic growth and population change. These range from the very low greenhouse gas emissions scenario (SSP1-1.9) that would see global emissions declining to net zero around 2050 and then further efforts to draw carbon dioxide down from the atmosphere, to the very high greenhouse gas emissions scenario (SSP5-8.5) that would see greenhouse gas emissions roughly double from current levels. This set of scenarios informs climate model projections.

Teams of climate modellers coordinate their updates around the IPCC assessment cycle, releasing a set of results ahead of each assessment report. Climate models are constantly improving, incorporating higher resolutions and new elements of the Earth System. This report assesses results from phase 6 of the Coupled Model Intercomparison Project (CMIP6), carried out by the World Climate Research Programme (WCRP).

The Sixth Assessment Report also includes new real-time observations of our changing climate, new information on past climates, and new ways of combining evidence.

Likelihoods and confidence levels
The report uses the following scale to describe the probability of an event or outcome.

Virtually certain:	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely or not	33-66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

In addition, scientists ascribe a confidence level to their finding. For example, if there is substantial and consistent evidence for a finding it will be given "high confidence". If there is less or more variable evidence then the confidence rating will be lower.

Key take-outs

The following points do not cover everything in the report, but are among the conclusions we feel represent the most significant changes since the IPCC's Fifth Assessment Report in 2013 or which we feel are particularly important in the Australian context. The references refer to the relevant paragraph in the Summary for Policymakers. Unless otherwise stated, the observations and projections apply at the global level.

The scale and pace at which humans are altering the climate system has almost no precedent

Current atmospheric concentrations of carbon dioxide (CO_2) are higher than at any time in the last two million years (A.2.1). It is "unequivocal" that this human interference has warmed the atmosphere, ocean and land (A.1). Global surface temperature was 1.09°C higher over the last decade (2011-2020) than the 1850-1900 average (A.1.2), with larger increases over land (1.59°C). Almost all of that increase can be attributed to humans (A.1.3).

Human influence has warmed the climate at a rate that is unprecedented in at least the last two thousand years (A.2.2, Figure SPM.1). While there may have been periods during the current and previous interglacial periods that were close to today's temperature, the warming in those cases occurred over centuries or millennia.

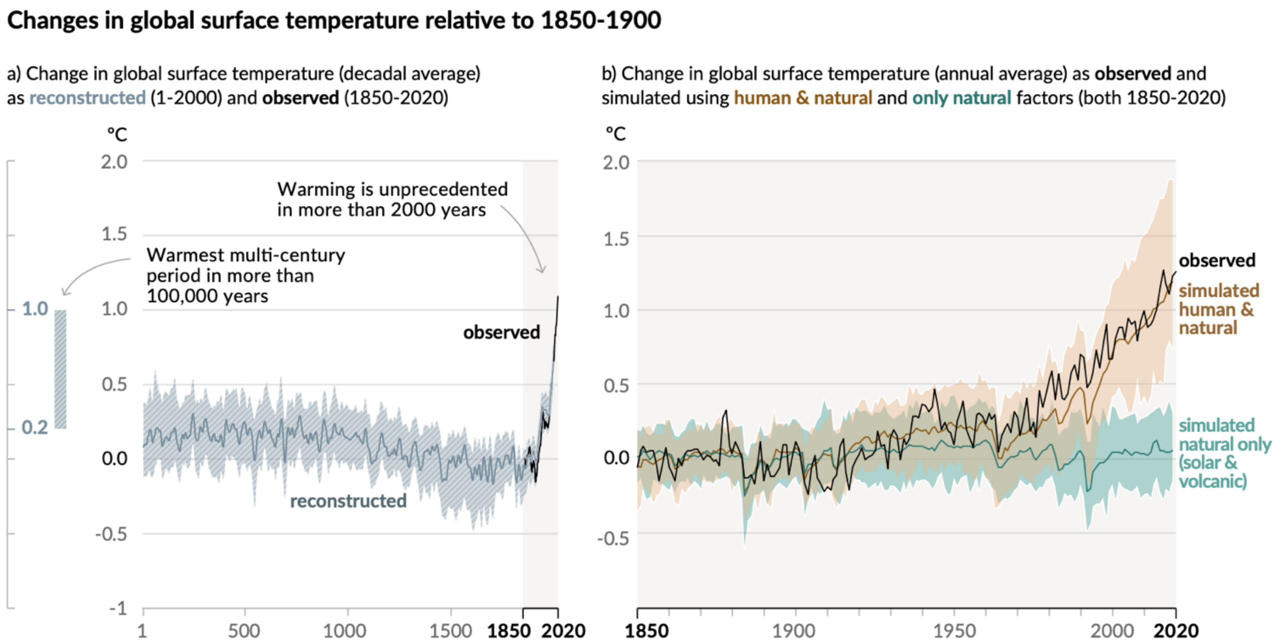

Figure 1 from the Summary for Policymakers: History of global temperature change and causes of reent warming.

Climate change and its impacts are accelerating

We all know by now that temperatures and sea levels are rising, rainfall patterns are changing, and extreme weather events are becoming more intense and destructive, with deadly consequences. Having ignored the decades of warnings, we are now seeing these alarming changes unfold at a faster and faster rate. In other words, our climate is not merely changing, the rate of change is now accelerating.

One example of this is sea level rise. Between 2006 and 2018, the rate of sea level rise was around twice as fast as between 1971 and 2006: 3.7 mm yr^{-1} compared to 1.9 mm yr^{-1} (A.1.7). Another example is the rate of ice sheet loss, which increased by a factor of four between 1992-1999 and 2010-2019 (A.4.3).

Heatwaves, droughts, floods, heavy downpours and other extreme events are getting worse, driven by the burning of coal, oil and gas

The eight years since the Fifth Assessment Report (AR5) have seen major advances in our understanding of how climate change is affecting the severity and/or frequency of extreme weather events, from heatwaves and droughts to floods and storms. Across almost all types of extreme weather events, the degree of likelihood ascribed to existing and future trends has been increased, as has scientists' level of confidence in their conclusions. Attribution science, through which scientists are able to say the likelihood that a given event could have occurred in the absence of human-induced climate change, is far more advanced than at the time of AR5.

Heatwaves

It is virtually certain that heatwaves have become more frequent and more intense since 1950, with human-induced climate change the dominant driver. (A.3.1. Compared to AR5, this has increased from "likely" to "virtually certain".) Some recent hot extremes would have been "extremely unlikely" to occur without human influence (A.3.1).

Marine heatwaves

Marine heatwaves have become more frequent since the 20th century. Recent marine heatwaves (such as those that have proved catastrophic for our Great Barrier Reef) were very likely driven by human-induced climate change (A.3.1).

Fire weather

In many parts of Australia the frequency of extreme fire weather days has already increased, and the fire season has become longer. The intensity, frequency and duration of fire weather are projected to increase throughout Australia (Regional factsheet – Australasia).

Heavy rainfall

There is high confidence that the frequency and intensity of heavy rainfall events has increased since the 1950s, with human-induced climate change likely the main driver (A.3.2. An increase from "more likely than not" in AR5.) The report projects an increase in heavy rainfall and river flooding in the northern, central, and eastern parts of Australia (Regional factsheet – Australasia).

Droughts

Compared to AR5, there is greater confidence that human-induced climate change has contributed to increases in droughts in some regions (A.3.2). The report warns of further increases in droughts in the southern and eastern parts of Australia, and particularly in the southwest (Regional factsheet – Australasia).

Cyclones
It is likely that the proportion of cyclones that become extremely destructive (reaching category 3-5 strength) has increased. Human-induced climate change has also increased the amount of rainfall associated with cyclones (A.3.4).

The risk of compound extreme events is also increasing

As the frequency and/or intensity of extreme events has increased, so has the likelihood of extreme events occurring concurrently in a given place, compounding one another to create an even greater disaster. This includes increases in the frequency of concurrent heatwaves, droughts, and fire weather (A.3.5). There is high confidence that the probability of these compound events will increase with further warming (C.2.7).

Every fraction of a degree matters!

"With every additional increment of global warming, changes in extremes continue to become larger" (B.2.2). Even at 1.5°C, there will be an increasing occurrence of extreme weather events that have no precedent in our observational record (B.2.2).

Every additional 0.5°C of warming causes clearly discernible increases in the intensity and frequency of heatwaves, damaging rainfall, and droughts (B.2.2).

For warming of 2°C compared to 1.5°C, the greater impacts (depending on the specific region) would include further intensification of storms and/or cyclones, increases in river floods, reductions in overall rainfall and increases in aridity, and increases in fire weather (C.2.4).

More impacts from climate change are on the way

While immediate action is necessary to avoid truly devastating impacts in future, and we will start to see the benefits of this action in two decades or so, our past inaction and the inertia in the climate system means that some impacts will continue to escalate over longer timeframes. Responding to climate change means doing everything possible to reduce emissions and address the problem at its source, while also adapting to the impacts that can no longer be avoided. As a wealthy developed country, Australia has a responsibility to support the world's most vulnerable countries, in particular Pacific Island Countries, with adapting to climate change and addressing the loss and damage they experience.

Sea levels will continue to rise over this century. The projected increases are now slightly higher than AR5, at 0.28-0.55m for the very low greenhouse gas emissions scenario, up to 0.63-1.01m for the very high greenhouse gas emissions scenario (B.5.3). At more than half of locations, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually by the end of this century (C.2.5). Sea levels around Australia have been rising at a faster rate than the global average in recent decades and sandy shorelines have already retreated in many locations (Regional factsheet – Australasia). As sea levels continue to rise, we must prepare for increased coastal flooding and shoreline retreat.

Around Australia and worldwide, there will be a further increase in marine heatwaves and ocean acidity (Regional factsheet – Australasia), posing severe challenges for our precious marine ecosystems including the Great Barrier Reef.

The water cycle will become both more intense and more erratic, bringing greater dangers from floods and droughts (B.2.4). Extreme rainfall events will intensify and become more frequent in most regions (B.3.1). Overall, rainfall and river flows will become more variable. More regions will be affected by drought. Of particular note for Australia, rainfall patterns related to the El Niño Southern Oscillation will be amplified by the second half of the century (B.3.2). Sand storms and dust storms are also projected to increase throughout Australia (Regional factsheet – Australasia).

Glaciers will continue to melt for several decades or more (B.5.2).

Catastrophic turns of events cannot be ruled out, and should be part of our risk assessments

The possibility of abrupt changes with the potential to massively disrupt human societies, such as ice sheet collapse, sudden changes in ocean circulation, or much higher levels of warming than expected, should compel us to take far stronger action today. While many of these events are considered low likelihood in the near term, should they occur they would be catastrophic (C.3).

For example, the Atlantic Meridional Overturning Circulation (AMOC) - a key component of the Earth's climate system - is very likely to weaken over the 21st century. However, at present it is hard to know how quickly that will occur. A sudden collapse would very likely cause abrupt shifts in weather patterns, including weakening of the African and Asian monsoons upon which hundreds of millions of people depend for their survival. Scientists have medium confidence that the decline of the AMOC will not involve an abrupt collapse before 2100 (C.3.4). Though should one occur, it would be catastrophic.

Similarly, the possibility of much greater sea level rise within the relatively near term - up to about 5m by 2150 under a scenario of high greenhouse gas emissions - cannot be excluded (B.5.3).

The decisions we make today will resonate for centuries or millennia

Changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in ocean temperature and sea level (B.5). Some impacts can no longer be avoided, but strong action today can make things far better than they would otherwise be.

Sea level will continue to rise for centuries or millennia. AR6 provides important new estimates for this long-term sea level rise. If warming is limited to 2°C then global mean sea level is projected to rise by about 2m to 6m over 2,000 years. If the world warms by 5°C then global sea level is projected to rise by 19m to 22m over the next 2,000 years, and will continue to rise over subsequent millennia (B.5.4).

Past greenhouse gas emissions have also committed us to significant further warming of the ocean. For the rest of this century, a low greenhouse gas emissions scenario would likely drive ocean warming of two to four times the 1971-2018 change, and a very high greenhouse gas emissions scenario would likely drive ocean warming of four to eight times that change (B.5.1)

We are perilously close to exceeding even more dangerous temperature limits

All five scenarios used in the report suggest the temperature rise will reach 1.5°C in the near term (Table SPM.1). However, the report shows that limiting warming to 1.5°C in the long-term (by the end of the century), while extremely challenging, is possible with only a small and temporary overshoot (B.1.3).[1] However, this demands immediate, deep and sustained emissions reductions. All but the very lowest scenario for greenhouse gas emissions, which was designed to create a pathway to limiting warming to 1.5°C, are inconsistent with limiting warming to 1.5°C.

The message is simple: every fraction of a degree matters, and we must do everything possible to limit warming to as close to 1.5°C as possible.

Beware of far off, vague 'net zero' targets, and relying on removing large amounts of CO_2 from the atmosphere. We must reduce emissions as far and as fast as possible!

All paths to avoiding truly devastating climate change involve removing CO_2 from the atmosphere. However, these cannot be a substitute for efforts to first reduce emissions to as close to zero as possible.

Carbon Dioxide Removal (CDR) technologies can involve dangerous side effects and trade-offs. For example, they often require large areas of land and may affect food production, water availability and biodiversity (D.1.4).

Furthermore, the effect of one tonne of CO_2 removed does not equal that of one tonne emitted. The atmospheric CO_2 decrease from CDR could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions (D.1.5).

Importantly, it is not only the date at which we achieve net zero emissions that matters. It is the cumulative amount of emissions produced along the way (D.1.1). A commitment to net zero emissions that not does not also include very strong early reductions is incompatible with avoiding catastrophic climate change.

It's time to get off gas

Avoiding catastrophic warming requires sharp reductions in both CO_2 and other greenhouse gases including methane (CH_4) (D.1). In fact, CH_4 emissions currently account for 0.5°C of warming, compared to about 0.75°C for CO_2 (Figure SPM.2). The increase in CO_2 emissions from Australia's gas industry have been a major factor behind Australia's

[1] Note that today's climate models, as sophisticated as they are, don't include feedbacks such as forest dieback and permafrost thaw. At a 1.5°C forcing, these feedbacks could add 0.1°C or 0.2°C to the overshoot, creating greater impacts upon communities and ecosystems, and creating an even greater challenge when it comes to removing enough CO_2 from the atmosphere to return temperatures to a lower level. These additional risks were explored in our report *Aim High, Go Fast* earlier this year.

failure to substantially reduce its overall CO_2 emissions. The gas industry is also responsible for fugitive emissions of CH_4. While shorter lived in the atmosphere, CH_4 has far greater potency as a greenhouse gas than CO_2. Limiting future warming depends on deep, rapid and sustained reductions in CH_4 emissions (D.1).

There is no room for new gas if we're to avoid catastrophic warming.

The benefits of stronger action will be realized well within our lifetimes

AR6 is more precise than AR5 on when we would start to see major benefits from our efforts today to reduce emissions. In terms of the actual positive impact on temperature trends and a variety of harmful effects from climate change, the benefits of rapid and sustained reductions in greenhouse gas emissions will begin to show in about 20 years, at around the time a child born today might be entering university (D.2). Beyond 2040, we would start to see significant improvements, such as fewer deadly heatwaves compared to a scenario in which the world fails to rapidly reduce emissions. By the end of the century, well within the lifespan of many young people alive today, ambitious action through the 2020s will have strongly limited the impacts that would otherwise occur (D.2.4). In other words, the positive and negative impacts of today's decisions will have an enormous impact on younger people, not to mention future generations.

About the Climate Council

The Climate Council is an independent non-profit organisation funded by donations by the public. Our mission is to provide authoritative, expert advice to the Australian public on climate change.

To find out more about the Climate Council's work, visit www.climatecouncil.org.au.