Welcome, thank you for joining us.
The webinar will begin shortly.

Scenarios, carbon budgets and temperature projections in the new IPCC WG1 AR6 report
Malte Meinshausen & Zebedee Nicholls, Australian-German Climate & Energy College
10th August 2021

CARBON BUDGETS AND TEMPERATURE PROJECTIONS IN THE NEW IPCC WG1 AR6 REPORT

Malte Meinshausen, Zebedee Nicholls
Climate & Energy College, University of Melbourne

#ClimateReport  #IPCC
Outline

1. Broad context
2. Historical warming
3. Scenarios
4. Projected warming
5. Remaining carbon budgets
6. CO₂ vs. other climate drivers
7. COVID
8. Global warming levels
9. Key takeaways
This report is more certain about the role fossil fuels play in climate change than ever before

- Unequivocal statement that fossil fuel burning is the key driver of climate change
- Clarity that climate change is already here
- Beacon of hope: the future is still in our hands, if we make rapid cuts to emissions then we can still keep warming to around 1.5°C
BY THE NUMBERS

**Author Team**

- 234 authors from 65 countries
- 28% women, 72% men
- 30% new to the IPCC

**Review Process**

- 14,000 scientific publications assessed
- 78,000+ review comments
- 46 countries commented on Final Government Distribution
Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.
Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be beyond reach.
It is indisputable that human activities are causing climate change, making extreme climate events, including heat waves, heavy rainfall, and droughts, more frequent and severe.
Climate change is already affecting every region on Earth, in multiple ways.

The changes we experience will increase with further warming.
There’s no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.
To limit global warming, strong, rapid, and sustained reductions in CO2, methane, and other greenhouse gases are necessary.

This would not only reduce the consequences of climate change but also improve air quality.
Historical warming
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Figure SPM.1

- Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)

- Warming is unprecedented in more than 2000 years

- Warmest multi-century period in more than 100,000 years

- Observed

- Reconstructed

- 1850

- 2020
Comparison to the classical
“Hockey stick”
Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

b) Change in global surface temperature (annual average) as observed and simulated using human & natural and only natural factors (both 1850-2020)
Historical warming - AR6 vs. AR5

- AR5: 1986-2005 was 0.61°C warmer than 1850-1900
- AR6: 1986-2005 was 0.69°C warmer than 1850-1900
  - Dataset innovations: improved coverage of poles
  - Methodological improvements: change between periods rather than linear trend (linear trend is increasingly poor estimate)
- GSAT vs. GMST
  - conflicting lines of evidence mean that GSAT assessed to be +/- 10%, with best-estimate that GSAT = GMST
Historical warming - today

- AR6: 2011-2020 was 1.09°C warmer than 1850-1900
**Historical warming - AR6 vs. SR1.5**

The warming underlying the carbon budget calculations in SR1.5.

- SR1.5 GSAT: 2006-2015 was 0.97°C warmer than 1850-1900
- AR6: 2006-2015 was 0.94°C warmer than 1850-1900
  - Increase due to dataset innovations and method discussed on previous slide
  - Decrease as AR6 assessed GSAT = GMST whereas SR1.5 assessed GSAT = GMST + 0.1
Historical warming - today

- AR6: 2011-2020 was 1.09°C warmer than 1850-1900
Scenarios
**Scenarios**

The philosophy Behind SSPs:

- AR5 used the RCPs
- AR6 has the SSPs

*SSPs stands for two things: either just the socio-economic narrative, or a particular SSPX-Y scenarios, such as SSP1-1.9.
# Shared socio-economic pathways

<table>
<thead>
<tr>
<th>Indicator for warming</th>
<th>SSP1: Sustainability</th>
<th>SSP2: Middle of the Road</th>
<th>SSP3: Regional Rivalry</th>
<th>SSP4: Inequality</th>
<th>SSP5: Fossil-fueled development</th>
<th>RCPs Previous Scenarios</th>
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<tbody>
<tr>
<td>Approximate 2100 radiative forcing label (W/m²)</td>
<td>8.5</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>SSP5-8.5</td>
<td>RCP8.5</td>
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<tr>
<td></td>
<td>7.0</td>
<td>n/a</td>
<td>SSP3-7.0</td>
<td>SSP3-7.0, lowNTCF</td>
<td>n/a</td>
<td>RCP6.0</td>
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<tr>
<td></td>
<td>6.0</td>
<td>SSP2-4.5</td>
<td>SSP4-6.0</td>
<td>n/a</td>
<td>SSP5-3.4, OS</td>
<td>RCP4.5</td>
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<tr>
<td></td>
<td>4.5</td>
<td>n/a</td>
<td>SSP4-3.4</td>
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<td>RCP2.6</td>
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<td>3.4</td>
<td>SSP1-2.6</td>
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<td>n/a</td>
<td>n/a</td>
<td>RCP2.6</td>
</tr>
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<td>n/a</td>
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<tr>
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<td>1.9</td>
<td>SSP1-1.9</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>RCP2.6</td>
</tr>
</tbody>
</table>

**Figure CCB1.4, Fig.1**

- No additional climate policy reference scenario
- Mitigation scenarios
- Five main SSP scenarios investigated in WG1
- SSPX-Y: Additional SSP scenarios
- RCPY: Previous RCP scenarios
Emissions variations amongst scenarios

Figure SPM.4

a) Future annual emissions of CO₂ (left) and of a subset of key non-CO₂ drivers (right), across five illustrative scenarios

Selected contributors to non-CO₂ GHGs

- Methane (MtCH₄/yr)
- Nitrous oxide (MtN₂O/yr)
- One air pollutant and contributor to aerosols
  - Sulfur dioxide (MtSO₂/yr)
Future emissions cause future additional warming, with total warming dominated by past and future CO$_2$ emissions
Future emissions cause future additional warming, with total warming dominated by past and future CO₂ emissions
Future emissions cause future additional warming, with total warming dominated by past and future CO$_2$ emissions.
Future emissions cause future additional warming, with total warming dominated by past and future CO₂ emissions

Sulfur dioxide (MtSO₂/yr)
Scenarios

The large Earth System Models crunched them all for the CMIP6 intercomparison. → New IPCC approach to distill future temperatures based on multiple lines of evidence.
Projected warming
# Warming projections

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Best estimate (°C)</td>
<td>Very likely range (°C)</td>
<td>Best estimate (°C)</td>
</tr>
<tr>
<td>SSP1-1.9</td>
<td>1.5</td>
<td>1.2 to 1.7</td>
<td>1.6</td>
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<tr>
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<tr>
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<td>1.5</td>
<td>1.2 to 1.8</td>
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</tr>
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<td>1.6</td>
<td>1.3 to 1.9</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Table SPM.1. See more in Table 4.5 and Fig 4.11
Warming projections

SSP1-1.9 (very low emissions): Peak at 1.6C, 1.4C by end of century

<table>
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The very low considered scenario (SSP1-1.9) results in temperatures around 1.5C at its peak (with limited overshoot up to +0.1C) and returns to below 1.5C warming by the end of the century.

This very low scenario implies global net-zero CO2 emissions around 2050.

Is it realistic?
- Around 60 countries around the world, representing more than 50% of global emissions, already have net-zero targets.
- If such targets are implemented on a global level, then yes, limiting warming to around 1.5C can become a reality.
Warming projections “like current NDCs”

SSP2-4.5 (middle of the road): 2.0C by mid-century, 2.7C by end of century (and still warming)

### Table SPM.1

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Warming projections
Warming projections

Assessed warming uses multiple lines of evidence:

1. Earth system model (CMIP6) runs
2. Observations (used to constrain CMIP6)
3. Assessed climate sensitivity (translated via an emulator, see also Cross-Chapter Box 7.1)

Great methodological advance on AR5
World to hit temperature tipping point 10 years faster than forecast

1.5°C global temperature rise set to hit ten years early

A "devastating" climate report is to warn that global warming will breach a significant threshold by 2040 without swift action.

RealClimate
Climate science from climate scientists...

We are not reaching 1.5°C earlier than previously thought

3 AUG 2021 BY GROUP — 9 COMMENTS

Guest commentary by Morteza Mehran, Zereideh Nichols, and Piets Forster

Of all the troubling headlines emerging from the release of the Intergovernmental Panel on Climate Change (IPCC) WG3 report, one warning will surely dominate headlines: The next days and weeks. Earth is likely to reach the crucial 1.5°C warming limit in the early 2020s.

In 2018, the IPCC Special Report on 1.5°C warming stated in its summary for policy makers that the world can only be saved from the 1.5°C threshold between now and 2030 at current

Remaining carbon budgets
The proportion of CO$_2$ emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO$_2$ emissions.

Total cumulative CO$_2$ emissions *taken up by land and oceans* (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100.

For scenarios with higher cumulative CO$_2$ emissions...

...the amount of CO$_2$ emissions taken up by land and ocean carbon sinks is larger, but more of the emitted CO$_2$ emissions remains in the atmosphere...

...meaning that the proportion of CO$_2$ emissions taken up by land and ocean carbon sinks from the atmosphere is smaller in scenarios with higher CO$_2$ emissions.
Every tonne of CO$_2$ emissions adds to global warming

The near linear relationship between the cumulative CO$_2$ emissions and global warming for five illustrative scenarios until year 2050.

Future cumulative CO$_2$ emissions differ across scenarios, and determine how much warming we will experience.
Every tonne of CO₂ emissions adds to global warming

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO₂ emissions (GtCO₂)

The near linear relationship between the cumulative CO₂ emissions and global warming for five illustrative scenarios until year 2050

Historical global warming

Cumulative CO₂ emissions since 1850

GtCO₂
Every tonne of CO₂ emissions adds to global warming

**Figure SPM.10**

Future cumulative CO₂ emissions differ across scenarios, and determine how much warming we will experience.
# Remaining carbon budgets

<table>
<thead>
<tr>
<th>Approximate global warming relative to 1850–1900 until temperature limit (°C) <em>(1)</em></th>
<th>Additional global warming relative to 2010–2019 until temperature limit (°C)</th>
<th>Estimated remaining carbon budgets from the beginning of 2020 (GtCO₂)</th>
<th>Variations in reductions in non-CO₂ emissions*(3)*</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td>Likelihood of limiting global warming to temperature limit*(2)*</td>
<td>17%</td>
</tr>
<tr>
<td>1.5</td>
<td>0.43</td>
<td>900</td>
<td>650</td>
</tr>
<tr>
<td>1.7</td>
<td>0.63</td>
<td>1450</td>
<td>1050</td>
</tr>
<tr>
<td>2.0</td>
<td>0.93</td>
<td>2300</td>
<td>1700</td>
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</tbody>
</table>

Higher or lower reductions in accompanying non-CO₂ emissions can increase or decrease the values on the left by 220 GtCO₂ or more.
## Remaining carbon budgets

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<th>Approximate global warming relative to 1850–1900 until temperature limit (°C)*1</th>
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<td>900</td>
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</tbody>
</table>

For a 50:50 chance of 1.5: net zero by 2045 (assuming linear decline in emissions)
## Remaining carbon budgets

<table>
<thead>
<tr>
<th>Approximate global warming relative to 1850–1900 until temperature limit (°C)*(^{(1)})</th>
<th>Additional global warming relative to 2010–2019 until temperature limit (°C)</th>
<th>Estimated remaining carbon budgets from the beginning of 2020 (GtCO(_2))</th>
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<tbody>
<tr>
<td>1.5</td>
<td>0.43</td>
<td>900 650 500 400 300</td>
</tr>
</tbody>
</table>

\(\textit{Likelihood of limiting global warming to temperature limit} \^{\textit{(2)}}\)

<table>
<thead>
<tr>
<th>17%</th>
<th>33%</th>
<th>50%</th>
<th>67%</th>
<th>83%</th>
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</thead>
</table>

### Variations in reductions in non-CO\(_2\) emissions*\(^{(3)}\)

- Higher or lower reductions in accompanying non-CO\(_2\) emissions

**For a 67% chance: net zero by 2040**

(assuming linear decline in emissions)
Remaining carbon budgets - AR6 vs. SR1.5

AR6 and SR1.5 estimates for a 50:50 chance are remarkably similar (more on that in the next seminar)
Remaining carbon budgets - AR6 vs. SR1.5

AR6 remaining carbon budget for a 67% chance is slightly higher than SR1.5 because we are more certain about the TCRE.
\( \text{CO}_2 \) vs. other climate drivers
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

Figure SPM.2
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling.
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling.

A slightly more granular view

- Different to the previous slide, here are CONCENTRATION-induced warmings.
- Climate uncertainty is a large driver of uncertainty in attribution.
Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling.

CO$_2$'s contribution is growing rapidly compared to all other climate drivers.
Future emissions cause future additional warming, with total warming dominated by past and future CO₂ emissions.

Figure SPM.4
Future emissions cause future additional warming, with total warming dominated by past and future CO$_2$ emissions

Change in global surface temperature in 2081-2100 relative to 1850-1900 ($^\circ$C)
Scenarios

Future warming dominated by CO2.

And carbon budgets can also be used to figure out GHG budgets over the short timeframe until 2050 (like Victoria does).
COVID
COVID

- No discernable signal on temperature above natural variability
COVID

- No discernable signal on temperature above natural variability
- Air quality improvements clear
  - Even greater air quality improvements could be achieved with targeted policies
COVID

- No discernable signal on temperature above natural variability
- Air quality improvements clear
  - Even greater air quality improvements could be achieved with targeted policies
- Gives us a sense of the challenge
  - COVID had emissions reductions of CO$_2$ of ~7% (5.8-13%)
  - For 2040 (2050) net zero, we need to reduce emissions by ~5% (~3.5%) of today’s levels every year to 2050
- Key question for climate: what happens post-COVID?
Global warming levels
With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture.

a) Annual mean temperature change (°C) at 1 °C global warming

Warming at 1 °C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

b) Annual mean temperature change (°C) relative to 1850-1900

Across warming levels, land areas warm more than oceans, and the Arctic and Antarctica warm more than the tropics.
With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture.

Figure SPM.5

**c) Annual mean precipitation change (%) relative to 1850-1900**

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.

Simulated change at 1.5 °C global warming

Simulated change at 2 °C global warming

Simulated change at 4 °C global warming

Relatively small absolute changes may appear as large % changes in regions with dry baseline conditions.
Interactive

OUR POSSIBLE CLIMATE FUTURES

+1.5°C
+2°C
+3°C
+4°C

Temperature
Precipitation

https://interactive-atlas.ipcc.ch/

#IPCCData #IPCCAtlas
Key takeaways
Key takeaways

- A problem we have created
- What happens next is up to us
- Greater certainty that if we get to net zero CO\textsubscript{2}, CO\textsubscript{2}-induced warming stops
- Since first IPCC report in 1990, we burnt through 2/3rds of our remaining carbon budget for 1.5C.
- Decisions made this decade determine what our climate future looks like
Thank you.

More Information:

IPCC: www.ipcc.ch
IPCC Secretariat: ipcc-sec@wmo.int
IPCC Press Office: ipcc-media@wmo.int

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#ClimateReport #IPCC
Upcoming seminars:

Tuesday 24 August, 4.30 PM (AEST)

A detailed look at future warming and remaining carbon budgets in the IPCC WG1 AR6 report
Zebedee Nicholls, Malte Meinshausen (Australian-German Climate & Energy College)
Register here: https://unimelb.zoom.us/webinar/register/WN_iGcZtHkHSyk3cEaaXBkbQ

For more details and to register, please visit: climatecollege.unimelb.edu.au/seminars