Long-Term Climate Mitigation Perspectives and the 2°C Objective

based on Chapter 14 of *Climate Science Special Report (CSSR)*

Benjamin DeAngelo, Deputy Director
Climate Program Office
Oceanic and Atmospheric Research, NOAA

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Presentation overview

Important concepts for any mitigation trajectory: long-term nature of CO$_2$ climate effect and short-term nature of some non-CO$_2$ species

Carbon budgets: how much can we still emit globally if the goal is to prevent X amount of warming?

2°C objective: some history and are we on a path to achieve this?

Geoengineering questions and concerns
Mitigation chapter: Key finding #1

Reducing net emissions of CO$_2$ is necessary to limit long-term warming. Other greenhouse gases (for example, methane) and black carbon aerosols exert stronger warming effects than CO$_2$ on a per ton basis, but they do not persist as long in the atmosphere; therefore, mitigation of non-CO$_2$ species contributes substantially to near-term cooling benefits but cannot be relied upon for ultimate stabilization goals. (Very high confidence)
Long-term warming influence dominated by cumulative CO$_2$ emissions

IPCC estimated that 15% to 40% of CO$_2$ emitted until 2100 will remain in the atmosphere longer than 1,000 years.

Persistence of warming is longer than the atmospheric lifetime of CO$_2$ (and other GHGs), owing in large part to the thermal inertia of the ocean.

Large reductions in emissions of the long-lived GHGs are estimated to have modest temperature effects in the near term (e.g., over one to two decades).

Long-term projections of global surface temperature (after mid-century), on the other hand, show that the choice of global emissions pathway, and thus the long-term mitigation pathway the world chooses, is the dominant source of future uncertainty in climate outcomes.
Radiative Forcing of Climate Between 1750 and 2011

Forcing agent

- Well Mixed Greenhouse Gases
  - CO₂
  - Other WMGHG
    - CH₄
    - N₂O
  - Halocarbons

- Ozone
  - Stratospheric
  - Tropospheric

- Stratospheric water vapour from CH₄

- Surface Albedo

- Land Use
  - Black carbon on snow
  - Contrail induced cirrus

- Contrails

- Aerosol-Radiation Interac.

- Aerosol-Cloud Interac.

- Total anthropogenic

- Solar irradiance

Radiative Forcing (W/m²)
Mitigation chapter: Key finding #2

Stabilizing global mean temperature to less than 3.6°F (2°C) requires substantial reductions in net CO₂ emissions prior to 2040 and likely requires net emissions to become zero or negative later in the century.

Cumulative CO₂ emissions must stay below about 800 GtC in order to provide a two-thirds likelihood of preventing 3.6°F (2°C). Given estimated emissions since 1870, no more than approximately 230 GtC may be emitted in the future to remain under this. Assuming emissions equal to or greater than RCP4.5, this cumulative carbon threshold would be exceeded in approximately two decades. (High confidence)
Nearly linear relationship between cumulative CO$_2$ emissions and global mean temperature increases

Source: IPCC 2013
Dates by when cumulative carbon emissions (GtC) since 1870 reach amount commensurate with 3.6°F (2°C), when accounting for non-CO₂ forcings:

<table>
<thead>
<tr>
<th></th>
<th>66% = 790 GtC</th>
<th>50% = 820 GtC</th>
<th>33% = 900 GtC</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP4.5</td>
<td>2037</td>
<td>2040</td>
<td>2047</td>
</tr>
<tr>
<td>RCP8.5</td>
<td>2033</td>
<td>2035</td>
<td>2040</td>
</tr>
</tbody>
</table>

Dates by when cumulative carbon emissions (GtC) since 1870 reach amount commensurate with 2.7°F (1.5°C), when accounting for non-CO₂ forcings:

<table>
<thead>
<tr>
<th></th>
<th>66% = 593 GtC</th>
<th>50% = 615 GtC</th>
<th>33% = 675 GtC</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP4.5</td>
<td>2019</td>
<td>2021</td>
<td>2027</td>
</tr>
<tr>
<td>RCP8.5</td>
<td>2019</td>
<td>2021</td>
<td>2025</td>
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</tbody>
</table>
Remaining carbon budget for a 66% chance of less than 1.5C warming

Source: Carbon Brief, https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c
Some history and background on 2°C (3.6°F)

The idea of a 3.6°F (2°C) goal can be found in the scientific literature as early as 1975.

Nordhaus justified it by simply stating, “If there were global temperatures more than 2 or 3°C above the current average temperature, this would take the climate outside of the range of observations which have been made over the last several hundred thousand years.”

The Stockholm Environment Institute published a report in 1990 stating that 3.6°F (2°C) “can be viewed as an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly.”

In 2007, the IPCC Fourth Assessment Report stated, among other things: “Confidence has increased that a 1 to 2°C increase in global mean temperature above 1990 levels (about 1.5 to 2.5°C above pre-industrial) poses significant risks to many unique and threatened systems including many biodiversity hotspots.”
Mitigation chapter: Key finding #3

Achieving reductions before 2030 consistent with actions announced by governments in the lead up to Paris would hold open the possibility of meeting the long-term temperature goal of limiting warming to 3.6°F (2°C) above preindustrial levels, whereas there would be virtually no chance if net emissions followed a pathway well above those implied by country announcements. Actions in the announcements are, by themselves, insufficient to meet a 3.6°F (2°C) goal; the likelihood of achieving that goal depends strongly on reductions after 2030. (High confidence)
Source: Fawcett et al. 2015
Mitigation chapter: Key finding #4

Further assessments of the technical feasibilities, costs, risks, co-benefits, and governance challenges of climate intervention or geoengineering strategies, which are as yet unproven at scale, are a necessary step before judgments about the benefits and risks of these approaches can be made with high confidence. (High confidence)