

[Jump to content](#)

☐ Main menu

Main menu

move to sidebar

hide

Navigation

- [Main page](#)
- [Contents](#)
- [Current events](#)
- [Random article](#)
- [About Wikipedia](#)
- [Contact us](#)
- [Donate](#)

Contribute

- [Help](#)
- [Learn to edit](#)
- [Community portal](#)
- [Recent changes](#)
- [Upload file](#)

?

?

[Search](#)

Search Wikipedia

Search

☐ Appearance

- [Create account](#)
- [Log in](#)

☐ Personal tools

- [Create account](#)
- [Log in](#)

Pages for logged out editors [learn more](#)

- [Contributions](#)
- [Talk](#)

## Contents

move to sidebar

hide

- [\(Top\)](#)
- [1 Terminology](#)
- [2 Global temperature rise](#)

Toggle Global temperature rise subsection

- [2.1 Temperature records prior to global warming](#)
- [2.2 Warming since the Industrial Revolution](#)
  - [2.2.1 Differences by region](#)
- [2.3 Future global temperatures](#)

- [3 Causes of recent global temperature rise](#)

Toggle Causes of recent global temperature rise subsection

- [3.1 Greenhouse gases](#)
- [3.2 Land surface changes](#)
- [3.3 Other factors](#)
  - [3.3.1 Aerosols and clouds](#)
  - [3.3.2 Solar and volcanic activity](#)
  - [3.3.3 Climate change feedbacks](#)

- [4 Modelling](#)
- [5 Impacts](#)

Toggle Impacts subsection

- [5.1 Environmental effects](#)
- [5.2 Tipping points and long-term impacts](#)

- [5.3 Nature and wildlife](#)
- [5.4 Humans](#)
  - [5.4.1 Food and health](#)
  - [5.4.2 Livelihoods and inequality](#)
  - [5.4.3 Climate migration](#)
- [6 Reducing and recapturing emissions](#)

Toggle Reducing and recapturing emissions subsection

  - [6.1 Clean energy](#)
  - [6.2 Energy conservation](#)
  - [6.3 Agriculture and industry](#)
  - [6.4 Carbon sequestration](#)
- [7 Adaptation](#)
- [8 Policies and politics](#)

Toggle Policies and politics subsection

  - [8.1 Policy options](#)
    - [8.1.1 Climate justice](#)
  - [8.2 International climate agreements](#)
  - [8.3 National responses](#)
- [9 Society](#)

Toggle Society subsection

  - [9.1 Denial and misinformation](#)
  - [9.2 Public awareness and opinion](#)
    - [9.2.1 Climate movement](#)
- [10 History](#)

Toggle History subsection

  - [10.1 Early discoveries](#)
  - [10.2 Development of a scientific consensus](#)
- [11 See also](#)
- [12 References](#)

Toggle References subsection

  - [12.1 Sources](#)
    - [12.1.1 IPCC reports](#)
    - [12.1.2 Other peer-reviewed sources](#)
    - [12.1.3 Books, reports and legal documents](#)
    - [12.1.4 Non-technical sources](#)
- [13 External links](#)

☐ Toggle the table of contents

# Climate change

☐ 154 languages

- [Afrikaans](#)
- [Alemannisch](#)
- [áŠ á^>á^áŠ>](#)
- [àꝛ...àꝛ,àꝛ—àꝛ¿àꝛ•àꝛ¾](#)
- [Āṯnglisc](#)
- [Ø\\$Ŭ,Ø¹Ø±Ø¨ÙŠØ©](#)
- [AragonĀ@s](#)
- [à!...à! ,à!@à\\$€à!`à!¼à!¾](#)
- [Asturianu](#)
- [AvaĀ±e'áº½](#)
- [AzĚ™rbaycanca](#)
- [ØªŬ†Ø±Ŭ©Ø¬Ŭ±](#)
- [à!¬à!¾à! ,à!²à!¾](#)
- [é-©â—èªž / BĀčn-lĀčm-gĀº](#)
- [Đ'Đ°Ñ^Ŏ;Đ¾Ñ€Ñ.ÑĐ°](#)
- [Đ'ĐµĐ»Đ°Ñ€ÑŦÑĐºĐ°Ñ](#)
- [Đ'ĐµĐ»Đ°Ñ€ÑŦÑĐºĐ°Ñ \(Ñ,Đ°Ñ€Đ°Ñ^ĐºĐµĐ²Ñ-Ñ†Đ°\)](#)
- [àꝛàŸ<àꝛœàꝛªàŸàꝛ°àŸ€](#)
- [Bikol Central](#)
- [Đ'ÑŠĐ»Đ³Đ°Ñ€ÑŦĐºĐ.](#)
- [Boarisch](#)
- [Bosanski](#)
- [Brezhoneg](#)
- [Đ'ÑŦÑ€ÑĐ°Đ´](#)
- [CatalĀ](#)
- [ĐŚÓ'Đ²Đ°Ñ^Đ»Đ°](#)

- [Cebuano](#)
- [ÄŒeÄjtina](#)
- [Cymraeg](#)
- [Dansk](#)
- [Ø\\$Û„Ø`Ø\\$Ø±Ø¬Ø©](#)
- [DavvisÄjmegiella](#)
- [Deutsch](#)
- [Eesti](#)
- [Î•Î»Î»Î·Î½Î¹ÎºÎ¬](#)
- [EspaÄ±ol](#)
- [Esperanto](#)
- [Euskara](#)
- [ÛØ\\$Ø±Ø³ÛŒ](#)
- [Fiji Hindi](#)
- [FÄ\\_royskt](#)
- [FranÄšais](#)
- [Furlan](#)
- [Gaeilge](#)
- [Gaelg](#)
- [GÄ\\_idhlig](#)
- [Galego](#)
- [àª—à«àªœàª°àª³¼àª¤à«€](#)
- [í•œêµì¬´](#)
- [Hausa](#)
- [Ô€Ô;ÔµÔ¥Ô€Ô¥Ô¶](#)
- [à¤¹à¤¿à¤¨à¥¨à¥à¥à¥€](#)
- [Hrvatski](#)
- [Ido](#)
- [Igbo](#)
- [Ilokano](#)
- [Bahasa Indonesia](#)
- [Interlingua](#)
- [IsiZulu](#)
- [Äslenska](#)
- [Italiano](#)
- [×ç×´×¨×™×ª](#)
- [Jawa](#)
- [à²•à²¨à³à²¨à²¿](#)
- [Kapampangan](#)
- [áfŸáfáf áf—áf£áfšáf¨](#)
- [ŒšĐ°Đ·Đ°Œ·Ÿ`Đ°](#)
- [Kernowek](#)
- [Ikinyarwanda](#)
- [Kiswahili](#)
- [KreyÄ²l ayisyen](#)
- [KriyÄ²l gwiyanen](#)
- [KurdÄ®](#)
- [ĐšŸ·Ÿ€Đ³Ÿ·Đ·Ÿ‡Đ°](#)
- [Ladin](#)
- [àºŸàº²àº§](#)
- [Latina](#)
- [LatvieÄju](#)
- [LÄ«tzebuergesch](#)
- [Đ·ĐµĐ·Đ³Đ¬](#)
- [LietuviÄ³](#)
- [Limburgs](#)
- [Lingua Franca Nova](#)
- [Luganda](#)
- [Lombard](#)
- [Magyar](#)
- [ĐœĐ°ĐºĐµĐ´Đ³¼Đ¹½ŸĐºĐ¬](#)
- [Malagasy](#)
- [à´@à´²à´¨à´³¼à´³à´¬](#)
- [à¤@à¤°à¤³¼à¤¨ à¥€](#)
- [Û...ØµØ±Û‰](#)
- [Bahasa Melayu](#)
- [ĐœĐ³¼Đ¹½Đ³Đ³¼Đ»](#)
- [á€™ á€¼á€¨á€°á€á€™ á€¬á€¨á€¬á€žá€¬¬](#)
- [Nederlands](#)
- [à¤¨à¥‡à¤ªà¤³¼à¤²à¥€](#)
- [à¤¨à¥‡à¤ªà¤³¼à¤² à¤à¤³¼à¤¤·à¤³¼](#)
- [æ—Ÿæœ¬èªž](#)
- [ĐĐ³¼Ÿ...Ÿ‡Đ¬Đ¹Đ¹½](#)
- [Nordfriisk](#)
- [Norsk bokmÄŸl](#)

- [Norsk nynorsk](#)
- [Occitan](#)
- [à¬“à¬¸à¬¼à¬¿à¬†](#)
- [Oromoo](#)
- [àˆˆàˆ©ˆˆàˆœàˆˆ³⁄⁄àˆˆ¬àˆ©€](#)
- [Û¼Û†Ø¬Ø\\$ØˆÛ€](#)
- [Û¼Û\\$ØªÛˆ](#)
- [Patois](#)
- [PlattdǺ¼Ǻ¼tsch](#)
- [Polski](#)
- [PortuguÃas](#)
- [RomÃ¢nÃf](#)
- [Rumantsch](#)
- [Đ ĦfÑĐ Ċ½ÑĈÑĐ°ÑĸĐ¹](#)
- [Đ ĦfÑÑĐ°Đ Ċ¹](#)
- [ĐĵĐ°Ñ...Đ° Ħ,ÑĸĐ»Đ°](#)
- [Sardu](#)
- [Seeltersk](#)
- [Shqip](#)
- [Sicilianu](#)
- [à·fà·’à¶,à·,à¶½](#)
- [Simple English](#)
- [Ø³Û†Û€Û\\$](#)
- [SlovenĀina](#)
- [SlovenĀĳĀina](#)
- [Ú©ÛˆØ±ØˆÛ€](#)
- [ĐĵÑ€ĐĴÑĐ°Đ Ą / srpski](#)
- [Srpskohrvatski / ĦÑ€ĐĴÑĐ°Đ³⁄⁄Ñ...Ñ€Đ²Đ°Ñ,ÑĐ°Đ](#)
- [Sunda](#)
- [Suomi](#)
- [Svenska](#)
- [Tagalog](#)
- [à®ªà®®à®¿à®´àˆ](#)
- [Taqbaylit](#)
- [ĐĉĐ°Ñ,Đ°Ñ€ÑĦĐ° / tatarĀša](#)
- [à°ªà±†à°²à±à°—à±](#)
- [à¹,à,—à,ĉ](#)
- [ĐĉĐ³⁄⁄Ō·Đ Ċ°Ō€](#)
- [TǺ¼rkĀše](#)
- [Đ€Đ°Ñ€Đ°Ñ—Đ½ÑÑĈ€Đ°Đ°](#)
- [Ø\\$Ø±ØˆÛˆ](#)
- [VepsĀrn kelâ€™™](#)
- [Tiá°¿ng Viá»tt](#)
- [VĀuro](#)
- [Walon](#)
- [æ-†èˆ€](#)
- [Winaray](#)
- [Ǻ´èˆ](#)
- [×™×™Ö´×“×™×©](#)
- [ĉ²µèªž](#)
- [Zazaki](#)
- [Ǻ½emaitĀ—Ǻĵka](#)
- [Ǻ,æ-†](#)

[Edit links](#)

- [Article](#)
- [Talk](#)

☐ English

- [Read](#)
- [View source](#)
- [View history](#)

☐ Tools

Tools

move to sidebar

hide

Actions

- [Read](#)
- [View source](#)
- [View history](#)

General

- [What links here](#)
- [Related changes](#)
- [Upload file](#)
- [Special pages](#)
- [Permanent link](#)
- [Page information](#)
- [Cite this page](#)
- [Get shortened URL](#)
- [Download QR code](#)
- [Wikidata item](#)

Print/export

- [Download as PDF](#)
- [Printable version](#)

In other projects

- [Wikimedia Commons](#)
- [Wikinews](#)
- [Wikiquote](#)
- [Wikisource](#)
- [Wikiversity](#)

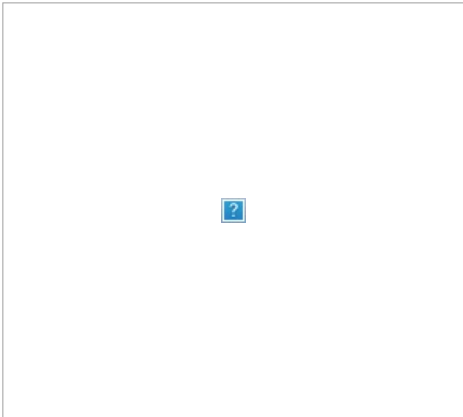
Appearance

move to sidebar

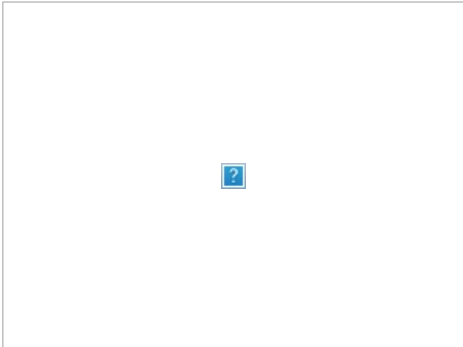
hide



From Wikipedia, the free encyclopedia



Changes in [surface air temperature](#) over the past 50 years.<sup>[1]</sup> The [Arctic](#) has warmed the most, and temperatures on land have generally increased more than [sea surface temperatures](#).



Earth's average surface air temperature has increased almost 1.5 °C (about 2.5 °F) since the [Industrial Revolution](#). Natural forces cause some variability, but the 20-year average shows the progressive influence of human activity.<sup>[2]</sup>

In common usage, **climate change** describes **global warming**—the ongoing increase in global average temperature—and its effects on Earth's [climate system](#). [Climate change in a broader sense](#) also includes previous long-term changes to Earth's climate. The [current rise in global average temperature](#) is [primarily caused by humans](#) burning [fossil fuels](#) since the [Industrial Revolution](#).<sup>[3][4]</sup> [Fossil fuel use](#), [deforestation](#), and some [agricultural](#) and [industrial](#) practices add to [greenhouse gases](#).<sup>[5]</sup> These gases [absorb some of the heat](#) that the Earth [radiates](#) after it warms from [sunlight](#), warming the [lower atmosphere](#). [Carbon dioxide](#), the primary greenhouse gas driving global warming, [has grown by about 50%](#) and is at levels unseen for millions of years.<sup>[6]</sup>

Climate change has an increasingly large [impact on the environment](#). [Deserts are expanding](#), while [heat waves](#) and [wildfires](#) are becoming more common.<sup>[7][8]</sup> [Amplified warming in the Arctic](#) has contributed to thawing [permafrost](#),

[retreat of glaciers](#) and [sea ice decline](#).<sup>[9]</sup> Higher temperatures are also causing [more intense storms](#), droughts, and other [weather extremes](#).<sup>[10]</sup> Rapid environmental change in [mountains](#), [coral reefs](#), and [the Arctic](#) is forcing many species to relocate or [become extinct](#).<sup>[11]</sup> Even if efforts to minimize future warming are successful, some effects will continue for centuries. These include [ocean heating](#), [ocean acidification](#) and [sea level rise](#).<sup>[12]</sup>

Climate change [threatens people](#) with increased [flooding](#), extreme heat, increased [food](#) and [water](#) scarcity, more disease, and [economic loss](#). [Human migration](#) and conflict can also be a result.<sup>[13]</sup> The [World Health Organization](#) (WHO) calls climate change one of the biggest threats to [global health](#) in the 21st century.<sup>[14]</sup> Societies and ecosystems will experience more severe risks without [action to limit warming](#).<sup>[15]</sup> [Adapting to climate change](#) through efforts like [flood control](#) measures or [drought-resistant crops](#) partially reduces climate change risks, although some limits to [adaptation](#) have already been reached.<sup>[16][17]</sup> Poorer communities are responsible for [a small share of global emissions](#), yet have the least ability to adapt and are most [vulnerable to climate change](#).<sup>[18][19]</sup>



Examples of some [effects of climate change](#): [Wildfire](#) intensified by heat and drought, [bleaching of corals](#) occurring more often due to [marine heatwaves](#), and worsening [droughts](#) compromising water supplies.

Many climate change impacts have been felt in recent years, with 2023 the warmest on record at +1.48Â°Â°C (2.66Â°Â°F) since regular tracking began in 1850.<sup>[21][22]</sup> Additional warming will increase these impacts and can trigger [tipping points](#), such as melting all of the [Greenland ice sheet](#).<sup>[23]</sup> Under the 2015 [Paris Agreement](#), nations collectively agreed to keep warming "well under 2Â°Â°C". However, with pledges made under the Agreement, global warming would still reach about 2.7Â°Â°C (4.9Â°Â°F) by the end of the century.<sup>[24]</sup> Limiting warming to 1.5Â°Â°C would require halving emissions by 2030 and achieving [net-zero](#) emissions by 2050.<sup>[25][26][27][28]</sup>

[Fossil fuel use can be phased out](#) by [conserving energy](#) and switching to energy sources that do not produce significant carbon pollution. These energy sources include [wind](#), [solar](#), [hydro](#), and [nuclear power](#).<sup>[29][30]</sup> Cleanly generated electricity can replace fossil fuels for [powering transportation](#), [heating buildings](#), and running industrial processes.<sup>[31]</sup> Carbon can also be [removed from the atmosphere](#), for instance by [increasing forest cover](#) and farming with methods that [capture carbon in soil](#).<sup>[32][33]</sup>

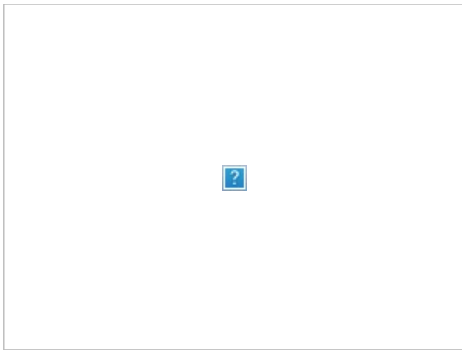
## Terminology

Before the 1980s it was unclear whether the warming effect of [increased greenhouse gases](#) was stronger than the [cooling effect of airborne particulates](#) in [air pollution](#). Scientists used the term *inadvertent climate modification* to refer to human impacts on the climate at this time.<sup>[34]</sup> In the 1980s, the terms *global warming* and *climate change* became more common, often being used interchangeably.<sup>[35][36][37]</sup> Scientifically, *global warming* refers only to increased surface warming, while *climate change* describes both global warming and its effects on Earth's [climate system](#), such as precipitation changes.<sup>[34]</sup>

*Climate change* can also be used more broadly to include [changes to the climate](#) that have happened throughout Earth's history.<sup>[38]</sup> *Global warming*â€”used as early as 1975<sup>[39]</sup>â€”became the more popular term after [NASA](#) climate scientist [James Hansen](#) used it in his 1988 testimony in the [U.S. Senate](#).<sup>[40]</sup> Since the 2000s, *climate change* has increased usage.<sup>[41]</sup> Various scientists, politicians and media may use the terms [climate crisis](#) or [climate emergency](#) to talk about climate change, and may use the term *global heating* instead of *global warming*.<sup>[42][43]</sup>

## Global temperature rise

### Temperature records prior to global warming



[Global surface temperature](#) reconstruction over the last 2000 years using proxy data from tree rings, corals, and ice cores in blue.<sup>[44]</sup> Directly observed data is in red.<sup>[45]</sup>

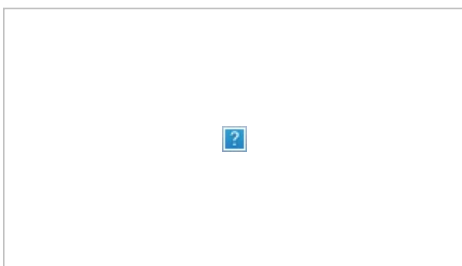
Over the last few million years [human beings evolved](#) in a climate that cycled through [ice ages](#), with global average temperature ranging between 1Â° C warmer and 5â€“6Â° C colder than current levels.<sup>[46][47]</sup> One of the hotter periods was the [Last Interglacial](#) between 115,000 and 130,000 years ago, when sea levels were 6 to 9 metres higher than today.<sup>[48]</sup> The most [recent glacial maximum](#) 20,000 years ago had sea levels that were about 125 metres (410Â ft) lower than today.<sup>[49]</sup>

Temperatures stabilized in the current interglacial period beginning [11,700 years ago](#).<sup>[50]</sup> Historical patterns of warming and cooling, like the [Medieval Warm Period](#) and the [Little Ice Age](#), did not occur at the same time across different regions. Temperatures may have reached as high as those of the late 20th century in a limited set of regions.<sup>[51][52]</sup> Climate information for that period comes from [climate proxies](#), such as trees and [ice cores](#).<sup>[53][54]</sup>

## Warming since the Industrial Revolution



In recent decades, new high temperature records have substantially outpaced new low temperature records on a growing portion of Earth's surface.<sup>[55]</sup>



There has been an increase in [ocean heat content](#) during recent decades as the oceans absorb over 90% of the [heat from global warming](#).<sup>[56]</sup>

Around 1850 [thermometer](#) records began to provide global coverage.<sup>[57]</sup> Between the 18th century and 1970 there was little net warming, as the warming impact of greenhouse gas emissions was offset by cooling from [sulfur dioxide](#) emissions. Sulfur dioxide causes [acid rain](#), but it also produces [sulfate](#) aerosols in the atmosphere, which reflect sunlight and cause so-called [global dimming](#). After 1970, the increasing accumulation of greenhouse gases and controls on sulfur pollution led to a marked increase in temperature.<sup>[58][59][60]</sup>

Ongoing changes in climate have had no precedent for several thousand years.<sup>[61]</sup> Multiple independent datasets all show worldwide increases in surface temperature,<sup>[62]</sup> at a rate of around 0.2Â° C per decade.<sup>[63]</sup> The 2013â€“2022 decade warmed to an average 1.15Â° C [1.00â€“1.25Â° C] compared to the pre-industrial baseline (1850â€“1900).<sup>[64]</sup> Not every single year was warmer than the last: internal [climate variability](#) processes can make any year 0.2Â° C warmer or colder than the average.<sup>[65]</sup> From 1998 to 2013, negative phases of two such processes, [Pacific Decadal Oscillation \(PDO\)](#)<sup>[66]</sup> and [Atlantic Multidecadal Oscillation \(AMO\)](#)<sup>[67]</sup> caused a so-called "[global warming hiatus](#)".<sup>[68]</sup> After the hiatus, the opposite occurred, with years like 2023 exhibiting temperatures well above even the recent average.<sup>[69]</sup> This is why the temperature change is defined in terms of a 20-year average, which reduces the noise of hot and cold years and decadal climate patterns, and detects the long-term signal.<sup>[70]:â€šâ€š[71]</sup>

A wide range of other observations reinforce the evidence of warming.<sup>[72][73]</sup> The upper atmosphere is cooling, because [greenhouse gases](#) are trapping heat near the Earth's surface, and so less heat is radiating into space.<sup>[74]</sup> Warming

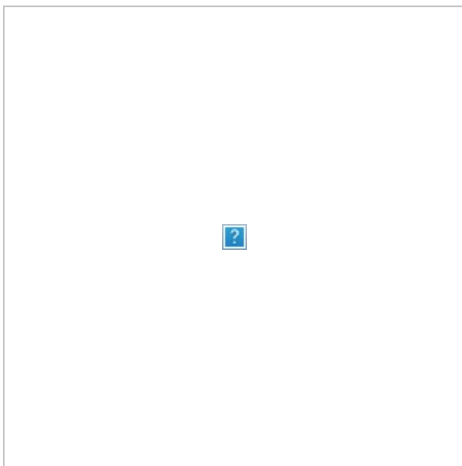
reduces average snow cover and [forces the retreat of glaciers](#). At the same time, warming also causes [greater evaporation from the oceans](#), leading to more [atmospheric humidity](#), more and heavier [precipitation](#).<sup>[75][76]</sup> Plants are [flowering](#) earlier in spring, and thousands of animal species have been permanently moving to cooler areas.<sup>[77]</sup>

## Differences by region

Different regions of the world [warm at different rates](#). The pattern is independent of where greenhouse gases are emitted, because the gases persist long enough to diffuse across the planet. Since the pre-industrial period, the average surface temperature over land regions has increased almost twice as fast as the global average surface temperature.<sup>[78]</sup> This is because oceans lose more heat by [evaporation](#) and [oceans can store a lot of heat](#).<sup>[79]</sup> The thermal energy in the global climate system has grown with only brief pauses since at least 1970, and over 90% of this extra energy has been [stored in the ocean](#).<sup>[80][81]</sup> The rest has heated the [atmosphere](#), melted ice, and warmed the continents.<sup>[82]</sup>

The [Northern Hemisphere](#) and the [North Pole](#) have warmed much faster than the [South Pole](#) and [Southern Hemisphere](#). The Northern Hemisphere not only has much more land, but also more seasonal snow cover and [sea ice](#). As these surfaces flip from reflecting a lot of light to being dark after the ice has melted, they start [absorbing more heat](#).<sup>[83]</sup> Local [black carbon](#) deposits on snow and ice also contribute to Arctic warming.<sup>[84]</sup> Arctic surface temperatures are increasing [between three and four times faster](#) than in the rest of the world.<sup>[85][86][87]</sup> Melting of [ice sheets](#) near the poles weakens both the [Atlantic](#) and the [Antarctic](#) limb of [thermohaline circulation](#), which further changes the distribution of heat and [precipitation](#) around the globe.<sup>[88][89][90][91]</sup>

## Future global temperatures



CMIP6 multi-model projections of [global surface temperature](#) changes for the year 2090 relative to the 1850–1900 average. The current trajectory for warming by the end of the century is roughly halfway between these two extremes.<sup>[24][92][93]</sup>

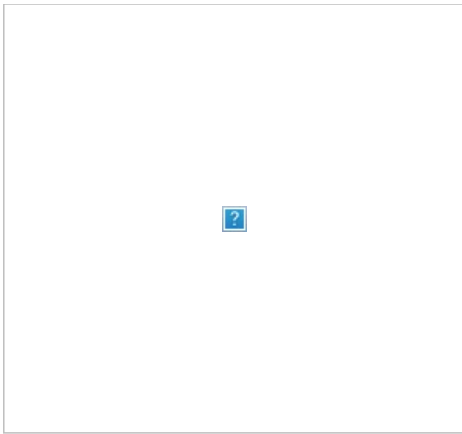
The [World Meteorological Organization](#) estimates a 66% chance of global temperatures exceeding 1.5 Å Å°C warming from the preindustrial baseline for at least one year between 2023 and 2027.<sup>[94][95]</sup> Because the IPCC uses a 20-year average to define global temperature changes, a single year exceeding 1.5 Å Å°C does not break the limit.

The IPCC expects the 20-year average global temperature to exceed +1.5 Å Å°C in the early 2030s.<sup>[96]</sup> The [IPCC Sixth Assessment Report](#) (2023) included projections that by 2100 global warming is very likely to reach 1.0-1.8 Å Å°C under a [scenario with very low emissions of greenhouse gases](#), 2.1-3.5 Å Å°C under an [intermediate emissions scenario](#), or 3.3-5.7 Å Å°C under [a very high emissions scenario](#).<sup>[97]</sup> The warming will continue past 2100 in the intermediate and high emission scenarios,<sup>[98][99]</sup> with future projections of global surface temperatures by year 2300 being similar to millions of years ago.<sup>[100]</sup>

The remaining [carbon budget](#) for staying beneath certain temperature increases is determined by modelling the carbon cycle and [climate sensitivity](#) to greenhouse gases.<sup>[101]</sup> According to the IPCC, global warming can be kept below 1.5 Å Å°C with a two-thirds chance if emissions after 2018 do not exceed 420 or 570 gigatonnes of CO<sub>2</sub>. This corresponds to 10 to 13 years of current emissions. There are high uncertainties about the budget. For instance, it may be 100 gigatonnes of CO<sub>2</sub> equivalent smaller due to CO<sub>2</sub> and [methane](#) release from [permafrost](#) and [wetlands](#).<sup>[102]</sup> However, it is clear that fossil fuel resources need to be proactively kept in the ground to prevent substantial warming. Otherwise, their shortages would not occur until the emissions have already locked in significant long-term impacts.<sup>[103]</sup>

## Causes of recent global temperature rise



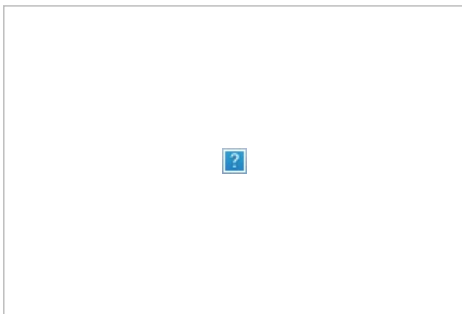


[Physical drivers](#) of global warming that has happened so far. Future [global warming potential](#) for long lived drivers like carbon dioxide emissions is not represented. Whiskers on each bar show the possible [error range](#).

The climate system experiences various cycles on its own which can last for years, decades or even centuries. For example, [El Niño](#) events cause short-term spikes in surface temperature while [La Niña](#) events cause short term cooling.<sup>[104]</sup> Their relative frequency can affect global temperature trends on a decadal timescale.<sup>[105]</sup> Other changes are caused by an [imbalance of energy](#) from [external forcings](#).<sup>[106]</sup> Examples of these include changes in the concentrations of [greenhouse gases](#), [solar luminosity](#), [volcanic](#) eruptions, and [variations in the Earth's orbit](#) around the Sun.<sup>[107]</sup>

To determine the human contribution to climate change, unique "fingerprints" for all potential causes are developed and compared with both observed patterns and known internal [climate variability](#).<sup>[108]</sup> For example, solar forcing“whose fingerprint involves warming the entire atmosphere”is ruled out because only the lower atmosphere has warmed.<sup>[109]</sup> Atmospheric aerosols produce a smaller, cooling effect. Other drivers, such as changes in [albedo](#), are less impactful.<sup>[110]</sup>

## Greenhouse gases

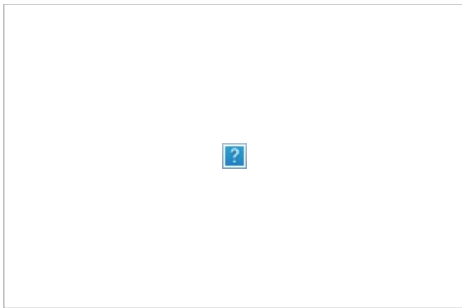


CO<sub>2</sub> concentrations over the last 800,000 years as measured from ice cores<sup>[111][112][113][114]</sup> (blue/green) and directly<sup>[115]</sup> (black)

Greenhouse gases are transparent to [sunlight](#), and thus allow it to pass through the atmosphere to heat the Earth's surface. The Earth [radiates it as heat](#), and greenhouse gases absorb a portion of it. This absorption slows the rate at which heat escapes into space, trapping heat near the Earth's surface and warming it over time.<sup>[116]</sup>

While [water vapour](#) (≈50%) and clouds (≈25%) are the biggest contributors to the greenhouse effect, they primarily change as a function of temperature and are therefore mostly considered to be [feedbacks](#) that change [climate sensitivity](#). On the other hand, concentrations of gases such as CO<sub>2</sub> (≈20%), [tropospheric ozone](#),<sup>[117]</sup> [CFCs](#) and [nitrous oxide](#) are added or removed independently from temperature, and are therefore considered to be [external forcings](#) that change global temperatures.<sup>[118]</sup>

Before the [Industrial Revolution](#), naturally-occurring amounts of greenhouse gases caused the air near the surface to be about 33 Å °C warmer than it would have been in their absence.<sup>[119][120]</sup> Human activity since the Industrial Revolution, mainly extracting and burning fossil fuels ([coal](#), [oil](#), and [natural gas](#)),<sup>[121]</sup> has increased the amount of greenhouse gases in the atmosphere, resulting in a [radiative imbalance](#). In 2019, the [concentrations of CO<sub>2</sub>](#) and methane had increased by about 48% and 160%, respectively, since 1750.<sup>[122]</sup> These CO<sub>2</sub> levels are higher than they have been at any time during the last 2 million years. [Concentrations of methane](#) are far higher than they were over the last 800,000 years.<sup>[123]</sup>

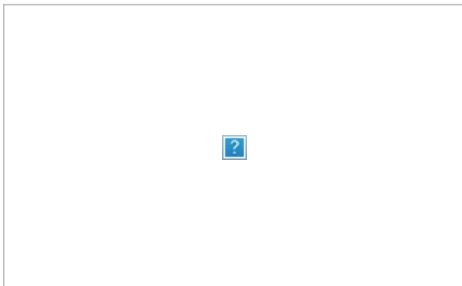


The [Global Carbon Project](#) shows how additions to CO<sub>2</sub> since 1880 have been caused by different sources ramping up one after another.

Global anthropogenic greenhouse gas emissions in 2019 were [equivalent to](#) 59 billion tonnes of CO<sub>2</sub>. Of these emissions, 75% was CO<sub>2</sub>, 18% was [methane](#), 4% was nitrous oxide, and 2% was [fluorinated gases](#).<sup>[124]</sup> CO<sub>2</sub> emissions primarily come from burning fossil fuels to provide energy for [transport](#), manufacturing, [heating](#), and electricity.<sup>[5]</sup> Additional CO<sub>2</sub> emissions come from [deforestation](#) and [industrial processes](#), which include the CO<sub>2</sub> released by the chemical reactions for [making cement](#), [steel](#), [aluminum](#), and [fertilizer](#).<sup>[125][126][127][128]</sup> Methane emissions [come from](#) [livestock](#), manure, [rice cultivation](#), landfills, wastewater, and [coal mining](#), as well as [oil and gas extraction](#).<sup>[129][130]</sup> Nitrous oxide emissions largely come from the microbial decomposition of [fertilizer](#).<sup>[131][132]</sup>

While methane only lasts in the atmosphere for an average of 12 years,<sup>[133]</sup> CO<sub>2</sub> lasts much longer. The Earth's surface absorbs CO<sub>2</sub> as part of the [carbon cycle](#). While plants on land and in the ocean absorb most excess emissions of CO<sub>2</sub> every year, that CO<sub>2</sub> is returned to the atmosphere when biological matter is digested, burns, or decays.<sup>[134]</sup> Land-surface [carbon sink](#) processes, such as [carbon fixation](#) in the soil and photosynthesis, remove about 29% of annual global CO<sub>2</sub> emissions.<sup>[135]</sup> The ocean has absorbed 20 to 30% of emitted CO<sub>2</sub> over the last 2 decades.<sup>[136]</sup> CO<sub>2</sub> is only removed from the atmosphere for the long term when it is stored in the Earth's crust, which is a process that can take millions of years to complete.<sup>[134]</sup>

## Land surface changes



The rate of global tree cover loss has approximately doubled since 2001, to an annual loss approaching an area the size of Italy.<sup>[137]</sup>

According to [Food and Agriculture Organization](#), around 30% of Earth's land area is largely unusable for humans ([glaciers](#), [deserts](#), etc.), 26% is [forests](#), 10% is [shrubland](#) and 34% is [agricultural land](#).<sup>[138]</sup> [Deforestation](#) is the main [land use change](#) contributor to global warming,<sup>[139]</sup> as the destroyed trees release CO<sub>2</sub>, and are not replaced by new trees, removing that [carbon sink](#).<sup>[32]</sup> Between 2001 and 2018, 27% of deforestation was from permanent clearing to enable [agricultural expansion](#) for crops and livestock. Another 24% has been lost to temporary clearing under the [shifting cultivation](#) agricultural systems. 26% was due to [logging](#) for wood and derived products, and [wildfires](#) have accounted for the remaining 23%.<sup>[140]</sup> Some forests have not been fully cleared, but were already degraded by these impacts. Restoring these forests also recovers their potential as a carbon sink.<sup>[141]</sup>

Local vegetation cover impacts how much of the sunlight gets reflected back into space ([albedo](#)), and how much [heat is lost by evaporation](#). For instance, the change from a dark [forest](#) to grassland makes the surface lighter, causing it to reflect more sunlight. Deforestation can also modify the release of chemical compounds that influence clouds, and by changing wind patterns.<sup>[142]</sup> In tropic and temperate areas the net effect is to produce significant warming, and forest restoration can make local temperatures cooler.<sup>[141]</sup> At latitudes closer to the poles, there is a cooling effect as forest is replaced by snow-covered (and more reflective) plains.<sup>[142]</sup> Globally, these increases in surface albedo have been the dominant direct influence on temperature from land use change. Thus, land use change to date is estimated to have a slight cooling effect.<sup>[143]</sup>

## Other factors

### Aerosols and clouds

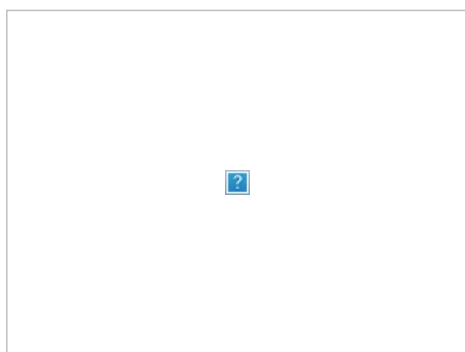
Air pollution, in the form of [aerosols](#), [affects the climate](#) on a large scale.<sup>[144]</sup> Aerosols scatter and absorb solar radiation. From 1961 to 1990, a gradual reduction in the amount of [sunlight reaching the Earth's surface](#) was observed.

This phenomenon is popularly known as [global dimming](#),<sup>[145]</sup> and is primarily attributed to [sulfate](#) aerosols produced by the combustion of fossil fuels with heavy sulfur concentrations like [coal](#) and [bunker fuel](#).<sup>[60]</sup> Smaller contributions come from [black carbon](#), organic carbon from combustion of fossil fuels and biofuels, and from anthropogenic dust.<sup>[146][59][147][148][149]</sup> Globally, aerosols have been declining since 1990 due to pollution controls, meaning that they no longer mask greenhouse gas warming as much.<sup>[150][60]</sup>

Aerosols also have indirect effects on the [Earth's energy budget](#). Sulfate aerosols act as [cloud condensation nuclei](#) and lead to clouds that have more and smaller cloud droplets. These clouds reflect solar radiation more efficiently than clouds with fewer and larger droplets.<sup>[151]</sup> They also reduce the [growth of raindrops](#), which makes clouds more reflective to incoming sunlight.<sup>[152]</sup> Indirect effects of aerosols are the largest uncertainty in [radiative forcing](#).<sup>[153]</sup>

While aerosols typically limit global warming by reflecting sunlight, [black carbon](#) in [soot](#) that falls on snow or ice can contribute to global warming. Not only does this increase the absorption of sunlight, it also increases melting and sea-level rise.<sup>[154]</sup> Limiting new black carbon deposits in the Arctic could reduce global warming by 0.2Â Â°C by 2050.<sup>[155]</sup> The effect of decreasing sulfur content of fuel oil for ships since 2020<sup>[156]</sup> is estimated to cause an additional 0.05Â Â°C increase in global mean temperature by 2050.<sup>[157]</sup>

## Solar and volcanic activity



The [Fourth National Climate Assessment](#) ("NCA4", USGCRP, 2017) includes charts illustrating that neither solar nor volcanic activity can explain the observed warming.<sup>[158][159]</sup>

As the Sun is the Earth's primary energy source, changes in incoming sunlight directly affect the [climate system](#).<sup>[153]</sup> [Solar irradiance](#) has been measured directly by [satellites](#),<sup>[160]</sup> and indirect measurements are available from the early 1600s onwards.<sup>[153]</sup> Since 1880, there has been no upward trend in the amount of the Sun's energy reaching the Earth, in contrast to the warming of the lower atmosphere (the [troposphere](#)).<sup>[161]</sup> The upper atmosphere (the [stratosphere](#)) would also be warming if the Sun was sending more energy to Earth, but instead, it has been cooling.<sup>[109]</sup> This is consistent with greenhouse gases preventing heat from leaving the Earth's atmosphere.<sup>[162]</sup>

[Explosive volcanic eruptions](#) can release gases, dust and ash that partially block sunlight and reduce temperatures, or they can send water vapour into the atmosphere, which adds to greenhouse gases and increases temperatures.<sup>[163]</sup> These impacts on temperature only last for several years, because both water vapour and volcanic material have low persistence in the atmosphere.<sup>[164]</sup> [volcanic CO<sub>2</sub> emissions](#) are more persistent, but they are equivalent to less than 1% of current human-caused CO<sub>2</sub> emissions.<sup>[165]</sup> Volcanic activity still represents the single largest natural impact (forcing) on temperature in the industrial era. Yet, like the other natural forcings, it has had negligible impacts on global temperature trends since the Industrial Revolution.<sup>[164]</sup>

## Climate change feedbacks



Sea ice reflects 50% to 70% of incoming sunlight, while the ocean, being darker, reflects only 6%. As an area of sea ice melts and exposes more ocean, more heat is absorbed by the ocean, raising temperatures that melt still more ice. This is a positive feedback [process](#).<sup>[166]</sup>

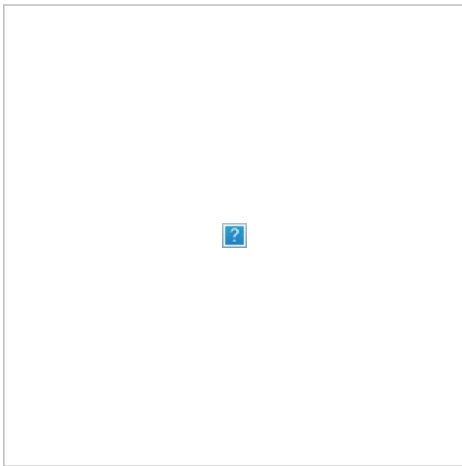
The response of the climate system to an initial forcing is modified by feedbacks: increased by ["self-reinforcing" or "positive" feedbacks](#) and reduced by ["balancing" or "negative" feedbacks](#).<sup>[167]</sup> The main reinforcing feedbacks are the [water-vapour feedback](#), the [iceâ€"albedo feedback](#), and the net effect of clouds.<sup>[168][169]</sup> The primary balancing mechanism is [radiative cooling](#), as Earth's surface gives off more [heat](#) to space in response to rising temperature.<sup>[170]</sup>

In addition to temperature feedbacks, there are feedbacks in the carbon cycle, such as the fertilizing effect of CO<sub>2</sub> on plant growth.<sup>[171]</sup> Feedbacks are expected to trend in a positive direction as greenhouse gas emissions continue, raising climate sensitivity.<sup>[172]</sup>

Radiative feedbacks are physical processes that influence the rate of global warming in response to warming. For instance, warmer air [can hold more moisture](#), and water vapour itself is a potent greenhouse gas.<sup>[168]</sup> Warmer air can also result in clouds becoming higher and thinner, where they act as an insulator and warm the planet.<sup>[173]</sup> Another major feedback is the reduction of snow cover and sea ice in the Arctic, reducing the reflectivity of the Earth's surface there and contributing to [amplification of Arctic temperature changes](#).<sup>[174][175]</sup> Arctic amplification is also thawing [permafrost](#), which releases methane and CO<sub>2</sub> into the atmosphere.<sup>[176]</sup>

Around half of human-caused CO<sub>2</sub> emissions have been absorbed by land plants and by the oceans.<sup>[177]</sup> This fraction is not static and if future CO<sub>2</sub> emissions decrease, the Earth will be able to absorb up to around 70%. If they increase substantially, it'll still absorb more carbon than now, but the overall fraction will decrease to below 40%.<sup>[178]</sup> This is because climate change increases droughts and heat waves that eventually inhibit plant growth on land, and soils will release more carbon from dead plants [when they are warmer](#).<sup>[179][180]</sup> The rate at which oceans absorb atmospheric carbon will be lowered as they become more acidic and experience changes in [thermohaline circulation](#) and [phytoplankton](#) distribution.<sup>[181][182][89]</sup> Uncertainty over feedbacks, particularly cloud cover,<sup>[183]</sup> is the major reason why different climate models project different magnitudes of warming for a given amount of emissions.<sup>[184]</sup>

## Modelling



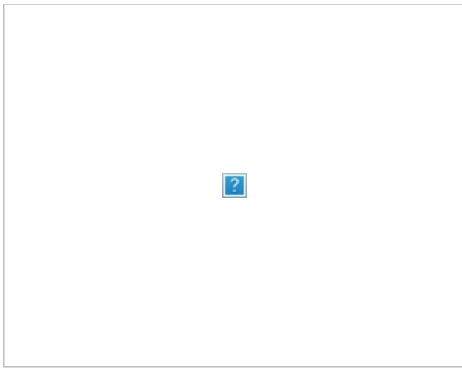
Energy flows between space, the atmosphere, and Earth's surface. Most sunlight passes through the atmosphere to heat the Earth's surface, then greenhouse gases absorb most of the heat the Earth radiates in response. Adding to greenhouse gases increases this insulating effect, causing an [energy imbalance](#) that heats the planet up.

A [climate model](#) is a representation of the physical, chemical and biological processes that affect the climate system.<sup>[185]</sup> Models include natural processes like changes in the Earth's orbit, historical changes in the Sun's activity, and volcanic forcing.<sup>[186]</sup> Models are used to estimate the degree of warming future emissions will cause when accounting for the [strength of climate feedbacks](#).<sup>[187][188]</sup> Models also predict the circulation of the oceans, the annual cycle of the seasons, and the flows of carbon between the land surface and the atmosphere.<sup>[189]</sup>

The physical realism of models is tested by examining their ability to simulate current or past climates.<sup>[190]</sup> Past models have underestimated the rate of [Arctic shrinkage](#)<sup>[191]</sup> and underestimated the rate of precipitation increase.<sup>[192]</sup> Sea level rise since 1990 was underestimated in older models, but more recent models agree well with observations.<sup>[193]</sup> The 2017 United States-published [National Climate Assessment](#) notes that "climate models may still be underestimating or missing relevant feedback processes".<sup>[194]</sup> Additionally, climate models may be unable to adequately predict short-term regional climatic shifts.<sup>[195]</sup>

A [subset of climate models](#) add societal factors to a physical climate model. These models simulate how population, [economic growth](#), and energy use affect—and interact with—the physical climate. With this information, these models can produce scenarios of future greenhouse gas emissions. This is then used as input for physical climate models and carbon cycle models to predict how atmospheric concentrations of greenhouse gases might change.<sup>[196][197]</sup> Depending on the [socioeconomic scenario](#) and the mitigation scenario, models produce atmospheric CO<sub>2</sub> concentrations that range widely between 380 and 1400 ppm.<sup>[198]</sup>

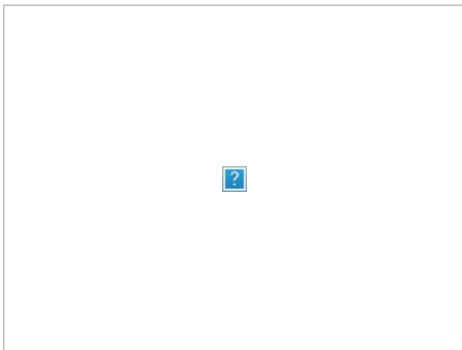
## Impacts



The sixth IPCC Assessment Report projects changes in average soil moisture at 2.0°C of warming, as measured in [standard deviations](#) from the 1850 to 1900 baseline.

## Environmental effects

The environmental effects of climate change are broad and far-reaching, [affecting oceans](#), ice, and weather. Changes may occur gradually or rapidly. Evidence for these effects comes from studying climate change in the past, from modelling, and from modern observations.<sup>[199]</sup> Since the 1950s, [droughts](#) and heat waves have appeared simultaneously with increasing frequency.<sup>[200]</sup> Extremely wet or dry events within the [monsoon](#) period have increased in India and East Asia.<sup>[201]</sup> Monsoonal precipitation over the Northern Hemisphere has increased since 1980.<sup>[202]</sup> The rainfall rate and intensity of [hurricanes and typhoons is likely increasing](#),<sup>[203]</sup> and the geographic range likely expanding poleward in response to climate warming.<sup>[204]</sup> Frequency of tropical cyclones has not increased as a result of climate change.<sup>[205]</sup>



Historical sea level reconstruction and projections up to 2100 published in 2017 by the U.S. Global Change Research Program<sup>[206]</sup>

Global sea level is rising as a consequence of [thermal expansion](#) and [the melting of glaciers](#) and [ice sheets](#). Between 1993 and 2020, the rise increased over time, averaging 3.3 ± 0.3 mm per year.<sup>[207]</sup> Over the 21st century, the IPCC projects 32–62 cm of sea level rise under a low emission scenario, 44–76 cm under an intermediate one and 65–101 cm under a very high emission scenario.<sup>[208]</sup> [Marine ice sheet instability](#) processes in Antarctica may add substantially to these values,<sup>[209]</sup> including the possibility of a 2-meter sea level rise by 2100 under high emissions.<sup>[210]</sup>

Climate change has led to decades of [shrinking and thinning of the Arctic sea ice](#).<sup>[211]</sup> While ice-free summers are expected to be rare at 1.5°C degrees of warming, they are set to occur once every three to ten years at a warming level of 2°C.<sup>[212]</sup> Higher atmospheric CO<sub>2</sub> concentrations cause more CO<sub>2</sub> to dissolve in the oceans, which is [making them more acidic](#).<sup>[213]</sup> Because oxygen is less soluble in warmer water,<sup>[214]</sup> its concentrations in the ocean [are decreasing](#), and [dead zones](#) are expanding.<sup>[215]</sup>

## Tipping points and long-term impacts



Different levels of global warming may cause different parts of Earth's climate system to reach tipping points that cause transitions to different states.<sup>[216][217]</sup>

Greater degrees of global warming increase the risk of passing through 'tipping points'—thresholds beyond which certain major impacts can no longer be avoided even if temperatures return to their previous state.<sup>[218][219]</sup> For instance, the [Greenland ice sheet](#) is already melting, but if global warming reaches levels between 1°C and

2.3Â °C, its melting will continue until it fully disappears. If the warming is later reduced to 1.5Â °C or less, it will still lose a lot more ice than if the warming was never allowed to reach the threshold in the first place.<sup>[220]</sup> While the ice sheets would melt over millennia, other tipping points would occur faster and give societies less time to respond. The collapse of major [ocean currents](#) like the [Atlantic meridional overturning circulation](#) (AMOC), and irreversible damage to key ecosystems like the [Amazon rainforest](#) and [coral reefs](#) can unfold in a matter of decades.<sup>[217]</sup>

The long-term [effects of climate change on oceans](#) include further ice melt, [ocean warming](#), sea level rise, ocean acidification and ocean deoxygenation.<sup>[221]</sup> The timescale of long-term impacts are centuries to millennia due to CO<sub>2</sub>'s long atmospheric lifetime.<sup>[222]</sup> When net emissions stabilize surface air temperatures will also stabilize, but oceans and ice caps will continue to absorb excess heat from the atmosphere. The result is an estimated total sea level rise of 2.3 metres per degree Celsius (4.2Â ft/Â°F) after 2000 years.<sup>[223]</sup> Oceanic CO<sub>2</sub> uptake is slow enough that ocean acidification will also continue for hundreds to thousands of years.<sup>[224]</sup> Deep oceans (below 2,000 metres (6,600Â ft)) are also already committed to losing over 10% of their dissolved oxygen by the warming which occurred to date.<sup>[225]</sup> Further, the [West Antarctic ice sheet](#) appears committed to practically irreversible melting, which would increase the sea levels by at least 3.3Â m (10Â ft 10Â in) over approximately 2000 years.<sup>[217][226][227]</sup>

## Nature and wildlife

Recent warming has driven many terrestrial and freshwater species poleward and towards higher [altitudes](#).<sup>[228]</sup> For instance, the range of hundreds of North American [birds](#) has shifted northward at an average rate of 1.5Â km/year over the past 55 years.<sup>[229]</sup> Higher atmospheric CO<sub>2</sub> levels and an extended growing season have resulted in global greening. However, heatwaves and drought have reduced [ecosystem](#) productivity in some regions. The future balance of these opposing effects is unclear.<sup>[230]</sup> A related phenomenon driven by climate change is [woody plant encroachment](#), affecting up to 500 million hectares globally.<sup>[231]</sup> Climate change has contributed to the expansion of drier climate zones, such as the [expansion of deserts](#) in the [subtropics](#).<sup>[232]</sup> The size and speed of global warming is making [abrupt changes in ecosystems](#) more likely.<sup>[233]</sup> Overall, it is expected that climate change will result in the [extinction](#) of many species.<sup>[234]</sup>

The oceans have heated more slowly than the land, but plants and animals in the ocean have migrated towards the colder poles faster than species on land.<sup>[235]</sup> Just as on land, [heat waves in the ocean](#) occur more frequently due to climate change, harming a wide range of organisms such as corals, [kelp](#), and [seabirds](#).<sup>[236]</sup> Ocean acidification makes it harder for [marine calcifying organisms](#) such as [mussels](#), [barnacles](#) and corals to [produce shells and skeletons](#); and heatwaves have [bleached coral reefs](#).<sup>[237]</sup> [Harmful algal blooms](#) enhanced by climate change and [eutrophication](#) lower oxygen levels, disrupt [food webs](#) and cause great loss of marine life.<sup>[238]</sup> Coastal ecosystems are under particular stress. Almost half of global wetlands have disappeared due to climate change and other human impacts.<sup>[239]</sup> Plants have come under increased stress from damage by insects.<sup>[240]</sup>

## Climate change impacts on the environment



- [Ecological collapse](#). [Coral bleaching](#) from [thermal stress](#) has damaged the [Great Barrier Reef](#) and threatens [coral reefs](#) worldwide.<sup>[241]</sup>



- [Extreme weather](#). Drought and high temperatures worsened the [2020 bushfires in Australia](#).<sup>[242]</sup>



- [Arctic warming.](#)  
[Permafrost thaws](#)  
undermine  
infrastructure and  
[release methane](#), a  
greenhouse gas. <sup>[176]</sup>



- [Habitat destruction.](#)  
Many arctic animals  
rely on sea ice, which  
has been disappearing  
in a warming Arctic.  
<sup>[243]</sup>



- [Pest propagation.](#)  
Mild winters allow  
more [pine beetles](#)  
to survive to kill  
large swaths of  
forest. <sup>[244]</sup>

## Humans



Extreme weather will be progressively more common as the Earth warms. <sup>[245]</sup>

The effects of climate change are impacting humans everywhere in the world. <sup>[246]</sup> Impacts can be observed on all continents and ocean regions, <sup>[247]</sup> with low-latitude, [less developed areas](#) facing the greatest risk. <sup>[248]</sup> Continued warming has potentially "severe, pervasive and irreversible impacts" for people and ecosystems. <sup>[249]</sup> The risks are unevenly distributed, but are generally greater for disadvantaged people in developing and developed countries. <sup>[250]</sup>

## Food and health

The World Health Organization (WHO) calls climate change the greatest threat to global health in the 21st century. <sup>[251]</sup> Extreme weather leads to injury and loss of life. <sup>[252]</sup> Various [infectious diseases](#) are more easily transmitted in a warmer climate, such as [dengue fever](#) and [malaria](#). <sup>[253]</sup> [Crop failures](#) can lead to food shortages and [malnutrition](#), particularly effecting [children](#). <sup>[254]</sup> Both children and older people are vulnerable to extreme heat. <sup>[255]</sup> The WHO has estimated that between 2030 and 2050, climate change would cause around 250,000 additional deaths per year. They assessed deaths from heat exposure in elderly people, increases in [diarrhoea](#), malaria, dengue, [coastal flooding](#), and childhood malnutrition. <sup>[256]</sup> By 2100, 50% to 75% of the global population may face climate conditions that are life-threatening due to combined effects of extreme heat and humidity. <sup>[257]</sup>

Climate change is affecting [food security](#). It has caused reduction in global yields of maize, wheat, and soybeans between 1981 and 2010. <sup>[258]</sup> Future warming could further reduce global yields of major crops. <sup>[259]</sup> [Crop production](#) will probably be negatively affected in low-latitude countries, while effects at northern latitudes may be positive or



negative.<sup>[260]</sup> Up to an additional 183 million people worldwide, particularly those with lower incomes, are at risk of [hunger](#) as a consequence of these impacts.<sup>[261]</sup> Climate change also impacts fish populations. Globally, less will be available to be fished.<sup>[262]</sup> Regions dependent on glacier water, regions that are already dry, and small islands have a higher risk of water stress due to climate change.<sup>[263]</sup>

## Livelihoods and inequality

Economic damages due to climate change may be severe and there is a chance of disastrous consequences.<sup>[264]</sup> Severe impacts are expected in South-East Asia and [sub-Saharan Africa](#), where most of the local inhabitants are dependent upon natural and agricultural resources.<sup>[265][266]</sup> [Heat stress](#) can prevent outdoor labourers from working. If warming reaches 4Â Â°C then labour capacity in those regions could be reduced by 30 to 50%.<sup>[267]</sup> The [World Bank](#) estimates that between 2016 and 2030, climate change could drive over 120 million people into extreme poverty without adaptation.<sup>[268]</sup>

Inequalities based on wealth and social status have worsened due to climate change.<sup>[269]</sup> Major difficulties in mitigating, adapting to, and recovering from climate shocks are faced by marginalized people who have less control over resources.<sup>[270][265]</sup> [Indigenous people](#), who are subsistent on their land and ecosystems, will face endangerment to their wellness and lifestyles due to climate change.<sup>[271]</sup> An expert elicitation concluded that the role of climate change in [armed conflict](#) has been small compared to factors such as socio-economic inequality and state capabilities.<sup>[272]</sup>

While women are not inherently more at risk from climate change and shocks, limits on women's resources and discriminatory gender norms constrain their adaptive capacity and resilience.<sup>[273]</sup> For example, women's work burdens, including hours worked in agriculture, tend to decline less than men's during climate shocks such as heat stress.<sup>[273]</sup>

## Climate migration

Low-lying islands and coastal communities are threatened by sea level rise, which makes [urban flooding](#) more common. Sometimes, land is permanently lost to the sea.<sup>[274]</sup> This could lead to [statelessness](#) for people in island nations, such as the [Maldives](#) and [Tuvalu](#).<sup>[275]</sup> In some regions, the rise in temperature and humidity may be too severe for humans to adapt to.<sup>[276]</sup> With worst-case climate change, models project that almost one-third of humanity might live in Sahara-like uninhabitable and extremely hot climates.<sup>[277]</sup>

These factors can drive [climate](#) or [environmental migration](#), within and between countries.<sup>[13]</sup> More people are expected to be displaced because of sea level rise, extreme weather and conflict from increased competition over natural resources. Climate change may also increase vulnerability, leading to "trapped populations" who are not able to move due to a lack of resources.<sup>[278]</sup>

### Climate change impacts on people



- Environmental migration. Sparser rainfall leads to [desertification](#) that harms agriculture and can displace populations. Shown: Telly, Mali (2008).<sup>[279]</sup>



- [Agricultural changes](#). Droughts, rising temperatures, and extreme weather negatively impact agriculture. Shown: Texas, US (2013).<sup>[280]</sup>





- [Tidal flooding](#). Sea-level rise increases flooding in low-lying coastal regions. Shown: [Venice, Italy](#) (2004).<sup>[281]</sup>

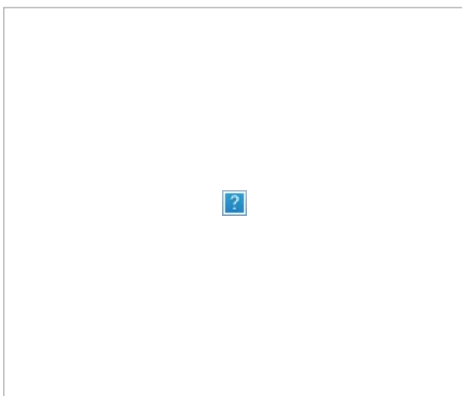


- [Storm intensification](#). Bangladesh after [Cyclone Sidr](#) (2007) is an example of catastrophic flooding from increased rainfall.<sup>[282]</sup>



- Heat wave intensification. Events like the [2022 Southern Cone heat wave](#) are becoming more common.<sup>[283]</sup>

## Reducing and recapturing emissions



Global greenhouse gas emission scenarios, based on policies and pledges as of November 2021

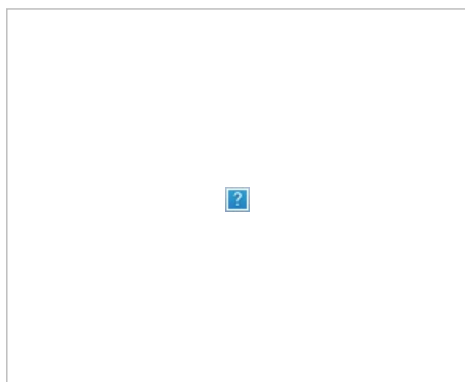
Climate change can be mitigated by reducing the rate at which greenhouse gases are emitted into the atmosphere, and by increasing the rate at which carbon dioxide is removed from the atmosphere.<sup>[284]</sup> In order to limit global warming to less than 1.5°C global greenhouse gas emissions needs to be [net-zero](#) by 2050, or by 2070 with a 2°C target.<sup>[102]</sup> This requires far-reaching, systemic changes on an unprecedented scale in energy, land, cities, transport, buildings, and industry.<sup>[285]</sup>

The [United Nations Environment Programme](#) estimates that countries need to triple their [pledges under the Paris Agreement](#) within the next decade to limit global warming to 2°C. An even greater level of reduction is required to meet the 1.5°C goal.<sup>[286]</sup> With pledges made under the Paris Agreement as of October 2021, global warming would still have a 66% chance of reaching about 2.7°C (range: 2.2–3.2°C) by the end of the century.<sup>[24]</sup> Globally, limiting warming to 2°C may result in higher economic benefits than economic costs.<sup>[287]</sup>

Although there is no single pathway to limit global warming to 1.5 or 2 °C,<sup>[288]</sup> most scenarios and strategies see a major increase in the use of renewable energy in combination with increased energy efficiency measures to generate the needed greenhouse gas reductions.<sup>[289]</sup> To reduce pressures on ecosystems and enhance their carbon sequestration capabilities, changes would also be necessary in agriculture and forestry,<sup>[290]</sup> such as preventing [deforestation](#) and restoring natural ecosystems by [reforestation](#).<sup>[291]</sup>

Other approaches to mitigating climate change have a higher level of risk. Scenarios that limit global warming to 1.5 °C typically project the large-scale use of [carbon dioxide removal methods](#) over the 21st century.<sup>[292]</sup> There are concerns, though, about over-reliance on these technologies, and environmental impacts.<sup>[293]</sup> [Solar radiation modification](#) (SRM) is also a possible supplement to deep reductions in emissions. However, SRM raises significant ethical and legal concerns, and the risks are imperfectly understood.<sup>[294]</sup>

## Clean energy



Coal, oil, and natural gas remain the primary [global energy](#) sources even as [renewables](#) have begun rapidly increasing.<sup>[295]</sup>



Wind and solar power, Germany

Renewable energy is key to limiting climate change.<sup>[296]</sup> For decades, fossil fuels have accounted for roughly 80% of the world's energy use.<sup>[297]</sup> The remaining share has been split between nuclear power and renewables (including [hydropower](#), [bioenergy](#), wind and solar power and [geothermal energy](#)).<sup>[298]</sup> Fossil fuel use is expected to peak in absolute terms prior to 2030 and then to decline, with coal use experiencing the sharpest reductions.<sup>[299]</sup> Renewables represented 75% of all new electricity generation installed in 2019, nearly all solar and wind.<sup>[300]</sup> Other forms of clean energy, such as nuclear and hydropower, currently have a larger share of the energy supply. However, their future growth forecasts appear limited in comparison.<sup>[301]</sup>

While [solar panels](#) and onshore wind are now among the cheapest forms of adding new power generation capacity in many locations,<sup>[302]</sup> green energy policies are needed to achieve a rapid transition from fossil fuels to renewables.<sup>[303]</sup> To achieve carbon neutrality by 2050, renewable energy would become the dominant form of electricity generation, rising to 85% or more by 2050 in some scenarios. Investment in coal would be eliminated and coal use nearly phased out by 2050.<sup>[304][305]</sup>

Electricity generated from renewable sources would also need to become the main energy source for heating and transport.<sup>[306]</sup> Transport can switch away from [internal combustion engine](#) vehicles and towards [electric vehicles](#), public transit, and [active transport](#) (cycling and walking).<sup>[307][308]</sup> For shipping and flying, low-carbon fuels would reduce emissions.<sup>[307]</sup> Heating could be increasingly decarbonized with technologies like [heat pumps](#).<sup>[309]</sup>

There are obstacles to the continued rapid growth of clean energy, including renewables. For wind and solar, there are environmental and land use concerns for new projects.<sup>[310]</sup> Wind and solar also produce energy [intermittently and with seasonal variability](#). Traditionally, [hydro dams with reservoirs](#) and conventional power plants have been used when variable energy production is low. Going forward, [battery storage](#) can be expanded, [energy demand and supply](#) can be matched, and long-distance [transmission](#) can smooth variability of renewable outputs.<sup>[296]</sup> Bioenergy is often not carbon-neutral and may have negative consequences for food security.<sup>[311]</sup> The growth of nuclear power is constrained by controversy around [radioactive waste](#), [nuclear weapon proliferation](#), and [accidents](#).<sup>[312][313]</sup> Hydropower growth is limited by the fact that the best sites have been developed, and new projects are confronting increased social and

environmental concerns.<sup>[314]</sup>

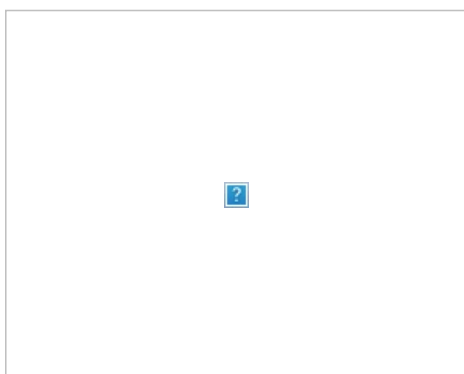
[Low-carbon energy](#) improves human health by minimizing climate change as well as reducing air pollution deaths,<sup>[315]</sup> which were estimated at 7 million annually in 2016.<sup>[316]</sup> Meeting the Paris Agreement goals that limit warming to a 2Å Å°C increase could save about a million of those lives per year by 2050, whereas limiting global warming to 1.5Å Å°C could save millions and simultaneously increase [energy security](#) and reduce poverty.<sup>[317]</sup> Improving air quality also has economic benefits which may be larger than mitigation costs.<sup>[318]</sup>

## Energy conservation

Reducing energy demand is another major aspect of reducing emissions.<sup>[319]</sup> If less energy is needed, there is more flexibility for clean energy development. It also makes it easier to manage the electricity grid, and minimizes [carbon-intensive](#) infrastructure development.<sup>[320]</sup> Major increases in energy efficiency investment will be required to achieve climate goals, comparable to the level of investment in renewable energy.<sup>[321]</sup> Several [COVID-19](#) related changes in energy use patterns, energy efficiency investments, and funding have made forecasts for this decade more difficult and uncertain.<sup>[322]</sup>

Strategies to reduce energy demand vary by sector. In the transport sector, passengers and freight can switch to more efficient travel modes, such as buses and trains, or use electric vehicles.<sup>[323]</sup> Industrial strategies to reduce energy demand include improving heating systems and motors, designing less energy-intensive products, and increasing product lifetimes.<sup>[324]</sup> In the building sector the focus is on better design of new buildings, and higher levels of energy efficiency in retrofiting.<sup>[325]</sup> The use of technologies like heat pumps can also increase building energy efficiency.<sup>[326]</sup>

## Agriculture and industry



Taking into account direct and indirect emissions, industry is the sector with the highest share of global emissions. Data as of 2019 from the IPCC.

Agriculture and forestry face a triple challenge of limiting greenhouse gas emissions, preventing the further conversion of forests to agricultural land, and meeting increases in world food demand.<sup>[327]</sup> A set of actions could reduce agriculture and forestry-based emissions by two thirds from 2010 levels. These include reducing growth in demand for food and other agricultural products, increasing land productivity, protecting and restoring forests, and reducing greenhouse gas emissions from agricultural production.<sup>[328]</sup>

On the demand side, a key component of reducing emissions is shifting people towards [plant-based diets](#).<sup>[329]</sup> Eliminating the production of livestock for [meat and dairy](#) would eliminate about 3/4ths of all emissions from agriculture and other land use.<sup>[330]</sup> Livestock also occupy 37% of ice-free land area on Earth and consume feed from the 12% of land area used for crops, driving deforestation and land degradation.<sup>[331]</sup>

Steel and cement production are responsible for about 13% of industrial CO<sub>2</sub> emissions. In these industries, carbon-intensive materials such as coke and lime play an integral role in the production, so that reducing CO<sub>2</sub> emissions requires research into alternative chemistries.<sup>[332]</sup>

## Carbon sequestration



Most CO<sub>2</sub> emissions have been absorbed by [carbon sinks](#), including plant growth, soil uptake, and ocean

uptake ([2020 Global Carbon Budget](#)).

Natural carbon sinks can be enhanced to sequester significantly larger amounts of CO<sub>2</sub> beyond naturally occurring levels.<sup>[333]</sup> Reforestation and [afforestation](#) (planting forests where there were none before) are among the most mature sequestration techniques, although the latter raises food security concerns.<sup>[334]</sup> Farmers can promote sequestration of [carbon in soils](#) through practices such as use of winter [cover crops](#), reducing the intensity and frequency of [tillage](#), and using compost and manure as soil amendments.<sup>[335]</sup> Forest and landscape restoration yields many benefits for the climate, including greenhouse gas emissions sequestration and reduction.<sup>[141]</sup> Restoration/recreation of coastal wetlands, [prairie plots](#) and [seagrass meadows](#) increases the uptake of carbon into organic matter.<sup>[336][337]</sup> When carbon is sequestered in soils and in organic matter such as trees, there is a risk of the carbon being re-released into the atmosphere later through changes in land use, fire, or other changes in ecosystems.<sup>[338]</sup>

Where energy production or CO<sub>2</sub>-intensive [heavy industries](#) continue to produce waste CO<sub>2</sub>, the gas can be captured and stored instead of released to the atmosphere. Although its current use is limited in scale and expensive,<sup>[339]</sup> [carbon capture and storage](#) (CCS) may be able to play a significant role in limiting CO<sub>2</sub> emissions by mid-century.<sup>[340]</sup> This technique, in combination with bioenergy ([BECCS](#)) can result in net negative emissions as CO<sub>2</sub> is drawn from the atmosphere.<sup>[341]</sup> It remains highly uncertain whether carbon dioxide removal techniques will be able to play a large role in limiting warming to 1.5°C. Policy decisions that rely on carbon dioxide removal increase the risk of global warming rising beyond international goals.<sup>[342]</sup>

## Adaptation

Adaptation is "the process of adjustment to current or expected changes in climate and its effects".<sup>[343]</sup> Without additional mitigation, adaptation cannot avert the risk of "severe, widespread and irreversible" impacts.<sup>[344]</sup> More severe climate change requires more transformative adaptation, which can be prohibitively expensive.<sup>[345]</sup> The [capacity and potential for humans to adapt](#) is unevenly distributed across different regions and populations, and developing countries generally have less.<sup>[346]</sup> The first two decades of the 21st century saw an increase in adaptive capacity in most low- and middle-income countries with improved access to basic [sanitation](#) and electricity, but progress is slow. Many countries have implemented adaptation policies. However, there is a considerable gap between necessary and available finance.<sup>[347]</sup>

Adaptation to sea level rise consists of avoiding at-risk areas, learning to live with increased flooding, and building [flood controls](#). If that fails, [managed retreat](#) may be needed.<sup>[348]</sup> There are economic barriers for tackling dangerous heat impact. Avoiding strenuous work or having [air conditioning](#) is not possible for everybody.<sup>[349]</sup> In agriculture, adaptation options include a switch to more sustainable diets, diversification, erosion control, and genetic improvements for increased tolerance to a changing climate.<sup>[350]</sup> Insurance allows for risk-sharing, but is often difficult to get for people on lower incomes.<sup>[351]</sup> Education, migration and [early warning systems](#) can reduce climate vulnerability.<sup>[352]</sup> Planting mangroves or encouraging other coastal vegetation can buffer storms.<sup>[353][354]</sup>

Ecosystems adapt to climate change, a process that can be supported by human intervention. By increasing connectivity between ecosystems, species can migrate to more favourable climate conditions. Species can also be [introduced to areas acquiring a favourable climate](#). Protection and restoration of natural and semi-natural areas helps build resilience, making it easier for ecosystems to adapt. Many of the actions that promote adaptation in ecosystems, also help humans adapt via [ecosystem-based adaptation](#). For instance, restoration of [natural fire regimes](#) makes catastrophic fires less likely, and reduces human exposure. Giving rivers more space allows for more water storage in the natural system, reducing flood risk. Restored forest acts as a carbon sink, but planting trees in unsuitable regions can exacerbate climate impacts.<sup>[355]</sup>

There are [synergies](#) but also trade-offs between adaptation and mitigation.<sup>[356]</sup> An example for synergy is increased food productivity, which has large benefits for both adaptation and mitigation.<sup>[357]</sup> An example of a trade-off is that increased use of air conditioning allows people to better cope with heat, but increases energy demand. Another trade-off example is that more compact [urban development](#) may reduce emissions from transport and construction, but may also increase the [urban heat island](#) effect, exposing people to heat-related health risks.<sup>[358]</sup>

### Examples of adaptation methods



- [Mangrove](#) planting and other [habitat conservation](#) can reduce [coastal flooding](#).



- [Seawalls](#) to protect against [storm surge](#) worsened by [sea level rise](#)



- [Green roofs](#) to provide cooling in cities





- [Selective breeding](#) for [drought-resistant crops](#)

## Policies and politics



The [Climate Change Performance Index](#) ranks countries by greenhouse gas emissions (40% of score), renewable energy (20%), energy use (20%), and climate policy (20%).

 A High

 A Medium

 A Low

 A Very low

Countries that are most [vulnerable to climate change](#) have typically been responsible for a small share of global emissions. This raises questions about justice and fairness.<sup>[359]</sup> Limiting global warming makes it much easier to achieve the UN's [Sustainable Development Goals](#), such as eradicating poverty and reducing inequalities. The connection is recognized in [Sustainable Development Goal 13](#) which is to "take urgent action to combat climate change and its impacts".<sup>[360]</sup> The goals on food, clean water and ecosystem protection have synergies with climate mitigation.<sup>[361]</sup>

The [geopolitics](#) of climate change is complex. It has often been framed as a [free-rider problem](#), in which all countries benefit from mitigation done by other countries, but individual countries would lose from switching to a [low-carbon economy](#) themselves. Sometimes mitigation also has localized benefits though. For instance, the benefits of a [coal phase-out](#) to public health and local environments exceed the costs in almost all regions.<sup>[362]</sup> Furthermore, net importers of fossil fuels win economically from switching to clean energy, causing net exporters to face [stranded assets](#): fossil fuels they cannot sell.<sup>[363]</sup>

## Policy options

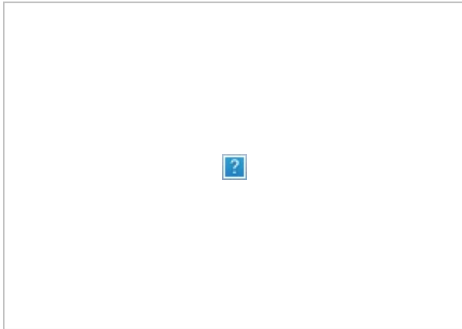
A wide range of [policies](#), [regulations](#), and [laws](#) are being used to reduce emissions. As of 2019, [carbon pricing](#) covers about 20% of global greenhouse gas emissions.<sup>[364]</sup> Carbon can be priced with [carbon taxes](#) and [emissions trading systems](#).<sup>[365]</sup> Direct global [fossil fuel subsidies](#) reached \$319 billion in 2017, and \$5.2 trillion when indirect costs such as air pollution are priced in.<sup>[366]</sup> Ending these can cause a 28% reduction in global carbon emissions and a 46% reduction in air pollution deaths.<sup>[367]</sup> Money saved on fossil subsidies could be used to support the [transition to clean energy](#) instead.<sup>[368]</sup> More direct methods to reduce greenhouse gases include vehicle efficiency standards, renewable fuel standards, and air pollution regulations on heavy industry.<sup>[369]</sup> Several countries [require utilities to increase the share of renewables in power production](#).<sup>[370]</sup>

## Climate justice

Policy designed through the lens of [climate justice](#) tries to address [human rights](#) issues and social inequality. According to proponents of climate justice, the costs of climate adaptation should be paid by those most responsible for climate change, while the beneficiaries of payments should be those suffering impacts. One way this can be addressed in practice is to have wealthy nations pay poorer countries to adapt.<sup>[371]</sup>

Oxfam found that in 2023 the wealthiest 10% of people were responsible for 50% of global emissions, while the bottom 50% were responsible for just 8%.<sup>[372]</sup> Production of emissions is another way to look at responsibility: under that approach, the top 21 fossil fuel companies would owe cumulative [climate reparations](#) of \$5.4 trillion over the period 2025–2050.<sup>[373]</sup> To achieve a [just transition](#), people working in the fossil fuel sector would also need other jobs, and their communities would need investments.<sup>[374]</sup>

## International climate agreements



Since 2000, rising CO<sub>2</sub> emissions in China and the rest of world have surpassed the output of the United States and Europe.<sup>[375]</sup>



Per person, the United States generates CO<sub>2</sub> at a far faster rate than other primary regions.<sup>[375]</sup>

Nearly all countries in the world are parties to the 1994 [United Nations Framework Convention on Climate Change](#) (UNFCCC).<sup>[376]</sup> The goal of the UNFCCC is to prevent dangerous human interference with the climate system.<sup>[377]</sup> As stated in the convention, this requires that greenhouse gas concentrations are stabilized in the atmosphere at a level where ecosystems can adapt naturally to climate change, food production is not threatened, and [economic development](#) can be sustained.<sup>[378]</sup> The UNFCCC does not itself restrict emissions but rather provides a framework for protocols that do. Global emissions have risen since the UNFCCC was signed.<sup>[379]</sup> [Its yearly conferences](#) are the stage of global negotiations.<sup>[380]</sup>

The 1997 [Kyoto Protocol](#) extended the UNFCCC and included legally binding commitments for most developed countries to limit their emissions.<sup>[381]</sup> During the negotiations, the [G77](#) (representing [developing countries](#)) pushed for a mandate requiring [developed countries](#) to "[take] the lead" in reducing their emissions,<sup>[382]</sup> since developed countries contributed most to the [accumulation of greenhouse gases](#) in the atmosphere. Per-capita emissions were also still relatively low in developing countries and developing countries would need to emit more to meet their development needs.<sup>[383]</sup>

The 2009 [Copenhagen Accord](#) has been widely portrayed as disappointing because of its low goals, and was rejected by poorer nations including the [G77](#).<sup>[384]</sup> Associated parties aimed to limit the global temperature rise to below 2° C.<sup>[385]</sup> The Accord set the goal of sending \$100 billion per year to developing countries for mitigation and adaptation by 2020, and proposed the founding of the [Green Climate Fund](#).<sup>[386]</sup> As of 2020, only 83.3 billion were delivered. Only in 2023 the target is expected to be achieved.<sup>[387]</sup>

In 2015 all UN countries negotiated the [Paris Agreement](#), which aims to keep global warming well below 2.0° C and contains an aspirational goal of keeping warming under 1.5° C.<sup>[388]</sup> The agreement replaced the Kyoto Protocol. Unlike Kyoto, no binding emission targets were set in the Paris Agreement. Instead, a set of procedures was made binding. Countries have to regularly set ever more ambitious goals and reevaluate these goals every five years.<sup>[389]</sup> The Paris Agreement restated that developing countries must be financially supported.<sup>[390]</sup> As of October 2021, 194 states and the [European Union](#) have signed the treaty and 191 states and the EU have [ratified](#) or acceded to the agreement.<sup>[391]</sup>

The 1987 [Montreal Protocol](#), an international agreement to stop emitting ozone-depleting gases, may have been more

effective at curbing greenhouse gas emissions than the Kyoto Protocol specifically designed to do so.<sup>[392]</sup> The 2016 [Kigali Amendment](#) to the Montreal Protocol aims to reduce the emissions of [hydrofluorocarbons](#), a group of powerful greenhouse gases which served as a replacement for banned ozone-depleting gases. This made the Montreal Protocol a stronger agreement against climate change.<sup>[393]</sup>

## National responses

In 2019, the [United Kingdom parliament](#) became the first national government to declare a climate emergency.<sup>[394]</sup> Other countries and [jurisdictions](#) followed suit.<sup>[395]</sup> That same year, the [European Parliament](#) declared a "climate and environmental emergency".<sup>[396]</sup> The [European Commission](#) presented its [European Green Deal](#) with the goal of making the EU carbon-neutral by 2050.<sup>[397]</sup> In 2021, the European Commission released its "[Fit for 55](#)" legislation package, which contains guidelines for the [car industry](#); all new cars on the European market must be [zero-emission vehicles](#) from 2035.<sup>[398]</sup>

Major countries in Asia have made similar pledges: South Korea and Japan have committed to become carbon-neutral by 2050, and China by 2060.<sup>[399]</sup> While India has strong incentives for renewables, it also plans a significant expansion of coal in the country.<sup>[400]</sup> Vietnam is among very few coal-dependent, fast-developing countries that pledged to phase out unabated coal power by the 2040s or as soon as possible thereafter.<sup>[401]</sup>

As of 2021, based on information from 48 [national climate plans](#), which represent 40% of the parties to the Paris Agreement, estimated total greenhouse gas emissions will be 0.5% lower compared to 2010 levels, below the 45% or 25% reduction goals to limit global warming to 1.5°C or 2°C, respectively.<sup>[402]</sup>

## Society

### Denial and misinformation



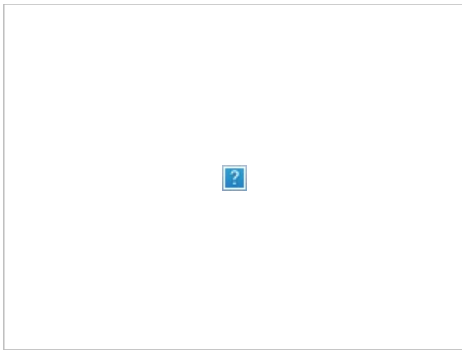
Data has been [cherry picked](#) from short periods to falsely assert that global temperatures are not rising. Blue trendlines show short periods that mask longer-term warming trends (red trendlines). Blue rectangle with blue dots shows the so-called [global warming hiatus](#).<sup>[403]</sup>

Public debate about climate change has been strongly affected by climate change denial and [misinformation](#), which originated in the United States and has since spread to other countries, particularly Canada and Australia. Climate change denial has originated from fossil fuel companies, industry groups, [conservative](#) think tanks, and [contrarian](#) scientists.<sup>[404]</sup> [Like the tobacco industry](#), the main strategy of these groups has been to manufacture doubt about climate-change related scientific data and results.<sup>[405]</sup> People who hold unwarranted doubt about climate change are called climate change "skeptics", although "contrarians" or "deniers" are more appropriate terms.<sup>[406]</sup>

There are different variants of climate denial: some deny that warming takes place at all, some acknowledge warming but attribute it to natural influences, and some minimize the negative impacts of climate change.<sup>[407]</sup> Manufacturing uncertainty about the science later developed into a [manufactured controversy](#): creating the belief that there is significant uncertainty about climate change within the scientific community in order to delay policy changes.<sup>[408]</sup> Strategies to promote these ideas include criticism of scientific institutions,<sup>[409]</sup> and questioning the motives of individual scientists.<sup>[407]</sup> An [echo chamber](#) of climate-denying [blogs](#) and media has further fomented misunderstanding of climate change.<sup>[410]</sup>

### Public awareness and opinion





The public substantially underestimates the degree of scientific consensus that humans are causing climate change.<sup>[411]</sup> Studies from 2019 to 2021<sup>[412][413]</sup> found scientific consensus to range from 98.7 to 100%.

Climate change came to international public attention in the late 1980s.<sup>[414]</sup> Due to media coverage in the early 1990s, people often confused climate change with other environmental issues like ozone depletion.<sup>[415]</sup> In popular culture, the climate fiction movie *The Day After Tomorrow* (2004) and the Al Gore documentary *An Inconvenient Truth* (2006) focused on climate change.<sup>[414]</sup>

Significant regional, gender, age and political differences exist in both public concern for, and understanding of, climate change. More highly educated people, and in some countries, women and younger people, were more likely to see climate change as a serious threat.<sup>[416]</sup> Partisan gaps also exist in many countries,<sup>[417]</sup> and countries with high CO<sub>2</sub> emissions tend to be less concerned.<sup>[418]</sup> Views on causes of climate change vary widely between countries.<sup>[419]</sup> Concern has increased over time,<sup>[417]</sup> to the point where in 2021 a majority of citizens in many countries express a high level of worry about climate change, or view it as a global emergency.<sup>[420]</sup> Higher levels of worry are associated with stronger public support for policies that address climate change.<sup>[421]</sup>

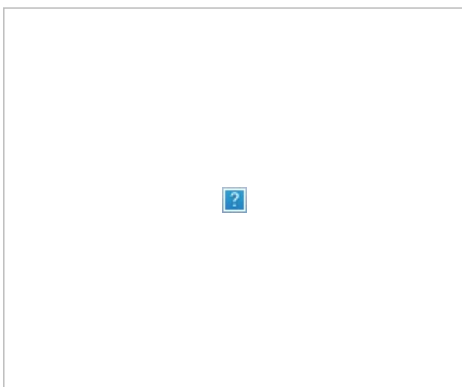
### Climate movement

Climate protests demand that political leaders take action to prevent climate change. They can take the form of public demonstrations, fossil fuel divestment, lawsuits and other activities.<sup>[422]</sup> Prominent demonstrations include the *School Strike for Climate*. In this initiative, young people across the globe have been protesting since 2018 by skipping school on Fridays, inspired by Swedish teenager Greta Thunberg.<sup>[423]</sup> Mass civil disobedience actions by groups like *Extinction Rebellion* have protested by disrupting roads and public transport.<sup>[424]</sup>

*Litigation* is increasingly used as a tool to strengthen climate action from public institutions and companies. Activists also initiate lawsuits which target governments and demand that they take ambitious action or enforce existing laws on climate change.<sup>[425]</sup> Lawsuits against fossil-fuel companies generally seek compensation for loss and damage.<sup>[426]</sup>

## History

### Early discoveries

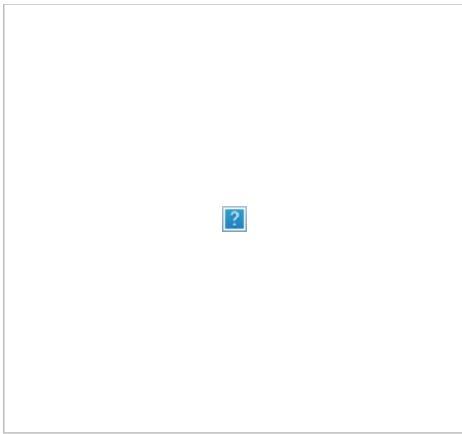


This 1912 article succinctly describes the greenhouse effect, how burning coal creates carbon dioxide to cause global warming and climate change.<sup>[427]</sup>

Scientists in the 19th century such as Alexander von Humboldt began to foresee the effects of climate change.<sup>[428][429][430][431]</sup> In the 1820s, Joseph Fourier proposed the greenhouse effect to explain why Earth's temperature was higher than the Sun's energy alone could explain. Earth's atmosphere is transparent to sunlight, so sunlight reaches the surface where it is converted to heat. However, the atmosphere is not transparent to heat radiating from the surface, and captures some of that heat, which in turn warms the planet.<sup>[432]</sup>

In 1856 Eunice Newton Foote demonstrated that the warming effect of the Sun is greater for air with water vapour than for dry air, and that the effect is even greater with carbon dioxide (CO<sub>2</sub>). She concluded that "An atmosphere of that gas would give to our earth a high temperature..."<sup>[433][434]</sup>



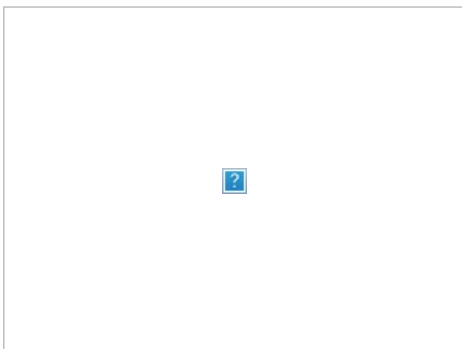


Studying what would become known as the greenhouse effect, Tyndall's pre-1861 [ratio spectrophotometer](#) measured how much various gases in a tube absorb and emit infrared radiation—which humans experience as heat.

Starting in 1859, <sup>[435]</sup> [John Tyndall](#) established that nitrogen and oxygen—together totalling 99% of dry air—are transparent to radiated heat. However, water vapour and gases such as methane and carbon dioxide absorb radiated heat and re-radiate that heat into the atmosphere. Tyndall proposed that changes in the concentrations of these gases may have caused climatic changes in the past, including [ice ages](#).<sup>[436]</sup>

[Svante Arrhenius](#) noted that water vapour in air continuously varied, but the CO<sub>2</sub> concentration in air was influenced by long-term geological processes. Warming from increased CO<sub>2</sub> levels would increase the amount of water vapour, amplifying warming in a positive feedback loop. In 1896, he published the first [climate model](#) of its kind, projecting that halving CO<sub>2</sub> levels could have produced a drop in temperature initiating an ice age. Arrhenius calculated the temperature increase expected from doubling CO<sub>2</sub> to be around 5–6 °C.<sup>[437]</sup> Other scientists were initially sceptical and believed that the greenhouse effect was saturated so that adding more CO<sub>2</sub> would make no difference, and that the climate would be self-regulating.<sup>[438]</sup> Beginning in 1938, [Guy Stewart Callendar](#) published evidence that climate was warming and CO<sub>2</sub> levels were rising,<sup>[439]</sup> but his calculations met the same objections.<sup>[438]</sup>

## Development of a scientific consensus




*Scientific consensus on causation:* Academic studies of scientific agreement on human-caused global warming among climate experts (2010–2015) reflect that the level of consensus correlates with expertise in climate science.<sup>[440]</sup> A 2019 study found scientific consensus to be at 100%,<sup>[441]</sup> and a 2021 study concluded that consensus exceeded 99%.<sup>[442]</sup> Another 2021 study found that 98.7% of climate experts indicated that the Earth is getting warmer mostly because of human activity.<sup>[443]</sup>

In the 1950s, [Gilbert Plass](#) created a detailed computer model that included different atmospheric layers and the infrared spectrum. This model predicted that increasing CO<sub>2</sub> levels would cause warming. Around the same time, [Hans Suess](#) found evidence that CO<sub>2</sub> levels had been rising, and [Roger Revelle](#) showed that the oceans would not absorb the increase. The two scientists subsequently helped [Charles Keeling](#) to begin a record of continued increase, which has been termed the "[Keeling Curve](#)".<sup>[438]</sup> Scientists alerted the public,<sup>[444]</sup> and the dangers were highlighted at James Hansen's 1988 Congressional testimony.<sup>[40]</sup> The [Intergovernmental Panel on Climate Change](#) (IPCC), set up in 1988 to provide formal advice to the world's governments, spurred [interdisciplinary research](#).<sup>[445]</sup> As part of the [IPCC reports](#), scientists assess the scientific discussion that takes place in [peer-reviewed journal](#) articles.<sup>[446]</sup>

There is a near-complete scientific consensus that the climate is warming and that this is caused by human activities. As of 2019, agreement in recent literature reached over 99%.<sup>[441][442]</sup> No scientific body of national or international standing [disagrees with this view](#).<sup>[447]</sup> Consensus has further developed that some form of action should be taken to protect people against the impacts of climate change. National science academies have called on world leaders to cut global emissions.<sup>[448]</sup> The 2021 IPCC Assessment Report stated that it is "unequivocal" that climate change is caused by humans.<sup>[442]</sup>

## See also

-  [Climate change portal](#)
- [Anthropocene](#) – proposed geological time interval in which humans are having significant geological impact
- [List of climate scientists](#)

## References

1. ["GISS Surface Temperature Analysis \(v4\)". NASA. Retrieved 12 January 2024.](#)
2. ["IPCC AR6 WG1 2021, SPM-7"](#)
3. ["IPCC SR15 Ch1 2018, p. 54: "These global-level rates of human-driven change far exceed the rates of change driven by geophysical or biosphere forces that have altered the Earth System trajectory in the past \(e.g., Summerhayes, 2015; Foster et al., 2017\); even abrupt geophysical events do not approach current rates of human-driven change."](#)
4. [^ a b Lynas, Mark; Houlton, Benjamin Z.; Perry, Simon \(19 October 2021\). "Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature". \*Environmental Research Letters\*. \*\*16\*\* \(11\): 114005. Bibcode:2021ERL....16k4005L. doi:10.1088/1748-9326/ac2966 . ISSN 1748-9326. S2CID 239032360.](#)
5. [^ a b Our World in Data, 18 September 2020](#)
6. ["IPCC AR6 WG1 Technical Summary 2021, p. 67: "Concentrations of CO<sub>2</sub>, methane \(CH<sub>4</sub>\), and nitrous oxide \(N<sub>2</sub>O\) have increased to levels unprecedented in at least 800,000 years, and there is high confidence that current CO<sub>2</sub> concentrations have not been experienced for at least 2 million years."](#)
7. ["IPCC SRCCL 2019, p. 7: "Since the pre-industrial period, the land surface air temperature has risen nearly twice as much as the global average temperature \(high confidence\). Climate change... contributed to desertification and land degradation in many regions \(high confidence\)."](#)
8. ["IPCC SRCCL 2019, p. 45: "Climate change is playing an increasing role in determining wildfire regimes alongside human activity \(medium confidence\), with future climate variability expected to enhance the risk and severity of wildfires in many biomes such as tropical rainforests \(high confidence\)."](#)
9. ["IPCC SROCC 2019, p. 16: "Over the last decades, global warming has led to widespread shrinking of the cryosphere, with mass loss from ice sheets and glaciers \(very high confidence\), reductions in snow cover \(high confidence\) and Arctic sea ice extent and thickness \(very high confidence\), and increased permafrost temperature \(very high confidence\)."](#)
10. ["IPCC AR6 WG1 Ch11 2021, p. 1517"](#)
11. ["EPA \(19 January 2017\). "Climate Impacts on Ecosystems". Archived from the original on 27 January 2018. Retrieved 5 February 2019. "Mountain and arctic ecosystems and species are particularly sensitive to climate change... As ocean temperatures warm and the acidity of the ocean increases, bleaching and coral die-offs are likely to become more frequent."](#)
12. ["IPCC SR15 Ch1 2018, p. 64: "Sustained net zero anthropogenic emissions of CO<sub>2</sub> and declining net anthropogenic non-CO<sub>2</sub> radiative forcing over a multi-decade period would halt anthropogenic global warming over that period, although it would not halt sea level rise or many other aspects of climate system adjustment."](#)
13. [^ a b Cattaneo et al. 2019; IPCC AR6 WG2 2022, pp. 15, 53](#)
14. ["We must fight one of the world's biggest health threats - climate change".](#)
15. ["IPCC AR6 WG2 2022, p. 19"](#)
16. ["IPCC AR6 WG2 2022, pp. 21–26, 2504"](#)
17. ["IPCC AR6 SYR SPM 2023, pp. 8–9: "Effectiveness<sup>15</sup> of adaptation in reducing climate risks<sup>16</sup> is documented for specific contexts, sectors and regions \(high confidence\)...Soft limits to adaptation are currently being experienced by small-scale farmers and households along some low-lying coastal areas \(medium confidence\) resulting from financial, governance, institutional and policy constraints \(high confidence\). Some tropical, coastal, polar and mountain ecosystems have reached hard adaptation limits \(high confidence\). Adaptation does not prevent all losses and damages, even with effective adaptation and before reaching soft and hard limits \(high confidence\)."](#)
18. ["Tietjen, Bethany \(2 November 2022\). "Loss and damage: Who is responsible when climate change harms the world's poorest countries?". \*The Conversation\*. Retrieved 30 August 2023.](#)
19. ["Climate Change 2022: Impacts, Adaptation and Vulnerability". IPCC. 27 February 2022. Retrieved 30 August 2023.](#)
20. ["Ivanova, Irina \(2 June 2022\). "California is rationing water amid its worst drought in 1,200 years". \*CBS News\*.](#)
21. ["Poynting, Mark; Rivault, Erwan \(10 January 2024\). "2023 confirmed as world's hottest year on record". \*BBC\*. Retrieved 13 January 2024.](#)
22. ["Human, economic, environmental toll of climate change on the rise: WMO | UN News". \*news.un.org\*. 21 April 2023. Retrieved 11 April 2024.](#)
23. ["IPCC AR6 WG1 Technical Summary 2021, p. 71"](#)
24. [^ a b c United Nations Environment Programme 2021, p. 36: "A continuation of the effort implied by the latest unconditional NDCs and announced pledges is at present estimated to result in warming of about 2.7 °C \(range: 2.2–3.2 °C\) with a 66 per cent chance."](#)
25. ["IPCC SR15 Ch2 2018, pp. 95–96: "In model pathways with no or limited overshoot of 1.5 °C, global net anthropogenic CO<sub>2</sub> emissions decline by about 45% from 2010 levels by 2030 \(40–60% interquartile range\), reaching net zero around 2050 \(2045–2055 interquartile range\)"](#)
26. ["IPCC SR15 2018, p. 17, SPM C.3: "All pathways that limit global warming to 1.5 °C with limited or no overshoot project the use of carbon dioxide removal \(CDR\) on the order of 100–1000 GtCO<sub>2</sub> over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5 °C following a peak \(high confidence\). CDR deployment of several hundreds of GtCO<sub>2</sub> is subject to multiple feasibility and sustainability constraints \(high confidence\)."](#)
27. ["Rogeli et al. 2015"](#)

28. [Hilaire et al. 2019](#)
29. [IPCC AR5 WG3 Annex III 2014](#), p.Â 1335
30. [IPCC AR6 WG3 2022](#), pp.Â 24â€“25, 89
31. [IPCC AR6 WG3 2022](#), p.Â 84: "Stringent emissions reductions at the level required for 2Â°C or 1.5Â°C are achieved through the increased electrification of buildings, transport, and industry, consequently all pathways entail increased electricity generation (high confidence)."
32. [a b IPCC SRCCL Summary for Policymakers 2019](#), p.Â 18
33. [IPCC AR6 WG3 2022](#), pp.Â 24â€“25, 114
34. [a b NASA. 5 December 2008.](#)
35. [NASA. 7 July 2020](#)
36. [Shaftel 2016](#): "â€œ'Climate change' and 'global warming' are often used interchangeably but have distinct meanings.Â ... Global warming refers to the upward temperature trend across the entire Earth since the early 20th centuryÂ ... Climate change refers to a broad range of global phenomenaÂ ...[which] include the increased temperature trends described by global warming."
37. [Associated Press. 22 September 2015](#): "The terms global warming and climate change can be used interchangeably. Climate change is more accurate scientifically to describe the various effects of greenhouse gases on the world because it includes extreme weather, storms and changes in rainfall patterns, ocean acidification and sea level."
38. [IPCC AR5 SYR Glossary 2014](#), p.Â 120: "Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use."
39. [Broeker, Wallace S. \(8 August 1975\). "Climatic Change: Are We on the Brink of a Pronounced Global Warming?". \*Science\*. \*\*189\*\* \(4201\): 460â€“463. Bibcode:1975Sci...189..460B. doi:10.1126/science.189.4201.460. JSTORÂ 1740491. PMIDÂ 17781884. S2CIDÂ 16702835.](#)
40. [a b Weart "The Public and Climate Change: The Summer of 1988", "News reporters gave only a little attentionÂ ...".](#)
41. [Joo et al. 2015.](#)
42. [Hodder & Martin 2009](#)
43. [BBC Science Focus Magazine. 3 February 2020](#)
44. [Neukom et al. 2019b.](#)
45. ["Global Annual Mean Surface Air Temperature Change". NASA. Retrieved 23 February 2020.](#)
46. [Thomas, Zoâ€« A.; Jones, Richard T.; Turney, Chris S.M.; Golledge, Nicholas; Fogwill, Christopher; Bradshaw, Corey J.A.; Menviel, Laurie; McKay, Nicholas P.; Bird, Michael; Palmer, Jonathan; Kershaw, Peter; Wilmshurst, Janet; Muscheler, Raimund \(April 2020\). "Tipping elements and amplified polar warming during the Last Interglacial". \*Quaternary Science Reviews\*. \*\*233\*\*: 106222. Bibcode:2020QSRv..23306222T. doi:10.1016/j.quascirev.2020.106222. S2CIDÂ 216288524.](#)
47. [Michon, Scott. "What's the coldest the Earth's ever been?". SMITHSONIAN INSTITUTION. Retrieved 6 August 2023.](#)
48. [Barlow, Natasha L. M.; McClymont, Erin L.; Whitehouse, Pippa L.; Stokes, Chris R.; Jamieson, Stewart S. R.; Woodroffe, Sarah A.; Bentley, Michael J.; Callard, S. Louise; Cofaigh, Colm Â; Evans, David J. A.; Horrocks, Jennifer R.; Lloyd, Jerry M.; Long, Antony J.; Margold, Martin; Roberts, David H. \(September 2018\). "Lack of evidence for a substantial sea-level fluctuation within the Last Interglacial". \*Nature Geoscience\*. \*\*11\*\* \(9\): 627â€“634. Bibcode:2018NatGe..11..627B. doi:10.1038/s41561-018-0195-4. ISSNÂ 1752-0894. S2CIDÂ 135048938.](#)
49. [Richard Z. Poore, Richard S. Williams, Jr., and Christopher Tracey. "Sea Level and Climate". United States Geological Survey.](#)
50. [Marcott, S. A.; Shakun, J. D.; Clark, P. U.; Mix, A. C. \(2013\). "A reconstruction of regional and global temperature for the past 11,300 years". \*Science\*. \*\*339\*\* \(6124\): 1198â€“1201. Bibcode:2013Sci...339.1198M. doi:10.1126/science.1228026. PMIDÂ 23471405.](#)
51. [IPCC AR5 WG1 Ch5 2013](#), p.Â 386
52. [Neukom et al. 2019a](#)
53. [IPCC SR15 Ch1 2018](#), p.Â 57: "This report adopts the 51-year reference period, 1850â€“1900 inclusive, assessed as an approximation of pre-industrial levels in AR5Â ... Temperatures rose by 0.0Â Â°Câ€“0.2Â Â°C from 1720â€“1800 to 1850â€“1900"
54. [Hawkins et al. 2017](#), p.Â 1844
55. ["Mean Monthly Temperature Records Across the Globe / Timeseries of Global Land and Ocean Areas at Record Levels for September from 1951-2023". NCEI.NOAA.gov. National Centers for Environmental Information \(NCEI\) of the National Oceanic and Atmospheric Administration \(NOAA\). September 2023. Archived from the original on 14 October 2023. \(change "202309" in URL to see years other than 2023, and months other than 09=September\)](#)
56. [Top 700 meters: Lindsey, Rebecca; Dahlman, Luann \(6 September 2023\). "Climate Change: Ocean Heat Content". climate.gov. National Oceanic and Atmospheric Administration \(NOAA\). Archived from the original on 29 October 2023. â€“ Top 2000 meters: "Ocean Warming / Latest Measurement: December 2022 / 345 \(Â± 2\) zettajoules since 1955". NASA.gov. National Aeronautics and Space Administration. Archived from the original on 20 October 2023.](#)
57. [IPCC AR5 WG1 Summary for Policymakers 2013](#), pp.Â 4â€“5: "Global-scale observations from the instrumental era began in the mid-19th century for temperature and other variablesÂ ... the period 1880 to 2012Â ... multiple independently produced datasets exist."
58. [Mooney, Chris; Osaka, Shannon \(26 December 2023\). "Is climate change speeding up? Here's what the science says". \*The Washington Post\*. Retrieved 18 January 2024.](#)
59. [a b "Global 'Sunscreen' Has Likely Thinned, Report NASA Scientists". NASA. 15 March 2007.](#)

60. [^ a b c](#) Quaas, Johannes; Jia, Hailing; Smith, Chris; Albright, Anna Lea; Aas, Wenche; Bellouin, Nicolas; Boucher, Olivier; Doutriaux-Boucher, Marie; Forster, Piers M.; Grosvenor, Daniel; Jenkins, Stuart; Klimont, Zbigniew; Loeb, Norman G.; Ma, Xiaoyan; Naik, Vaishali; Paulot, Fabien; Stier, Philip; Wild, Martin; Myhre, Gunnar; Schulz, Michael (21 September 2022). ["Robust evidence for reversal of the trend in aerosol effective climate forcing". \*Atmospheric Chemistry and Physics\*. \*\*22\*\* \(18\): 12221â€“12239. Bibcode:2022ACP....2212221Q. doi:10.5194/acp-22-12221-2022 . hdl:20.500.11850/572791 . S2CIDÂ 252446168.](#)
61. [^ IPCC AR6 WG1 2021](#), p.Â 43
62. [^ EPA 2016](#): "The U.S. Global Change Research Program, the National Academy of Sciences, and the Intergovernmental Panel on Climate Change (IPCC) have each independently concluded that warming of the climate system in recent decades is "unequivocal". This conclusion is not drawn from any one source of data but is based on multiple lines of evidence, including three worldwide temperature datasets showing nearly identical warming trends as well as numerous other independent indicators of global warming (e.g. rising sea levels, shrinking Arctic sea ice)."
63. [^ IPCC SR15 Ch1 2018](#), p.Â 81.
64. [^ Earth System Science Data 2023](#), p.Â 2306
65. [^ Samset, B. H.; Fuglestad, J. S.; Lund, M. T. \(7 July 2020\). "Delayed emergence of a global temperature response after emission mitigation". \*Nature Communications\*. \*\*11\*\* \(1\): 3261. Bibcode:2020NatCo..11.3261S. doi:10.1038/s41467-020-17001-1. hdl:11250/2771093 . PMCÂ 7341748 . PMIDÂ 32636367.](#) "At the time of writing, that translated into 2035â€“2045, where the delay was mostly due to the impacts of the around 0.2â€°C of natural, interannual variability of global mean surface air temperature"
66. [^ Seip, Knut L.; Gr n,  .; Wang, H. \(31 August 2023\). "Global lead-lag changes between climate variability series coincide with major phase shifts in the Pacific decadal oscillation". \*Theoretical and Applied Climatology\*. \*\*154\*\* \(3â€“4\): 1137â€“1149. Bibcode:2023ThApC.154.1137S. doi:10.1007/s00704-023-04617-8 . hdl:11250/3088837 . ISSNÂ 0177-798X. S2CIDÂ 261438532.](#)
67. [^ Yao, Shuai-Lei; Huang, Gang; Wu, Ren-Guang; Qu, Xia \(January 2016\). "The global warming hiatusâ€“a natural product of interactions of a secular warming trend and a multi-decadal oscillation". \*Theoretical and Applied Climatology\*. \*\*123\*\* \(1â€“2\): 349â€“360. Bibcode:2016ThApC.123..349Y. doi:10.1007/s00704-014-1358-x. ISSNÂ 0177-798X. S2CIDÂ 123602825.](#) Retrieved 20 September 2023.
68. [^ Xie, Shang-Ping; Kosaka, Yu \(June 2017\). "What Caused the Global Surface Warming Hiatus of 1998â€“2013?". \*Current Climate Change Reports\*. \*\*3\*\* \(2\): 128â€“140. Bibcode:2017CCCR....3..128X. doi:10.1007/s40641-017-0063-0. ISSNÂ 2198-6061. S2CIDÂ 133522627.](#) Retrieved 20 September 2023.
69. [^ "Global temperature exceeds 2  C above pre-industrial average on 17 November". \*Copernicus\*. 21 November 2023. Retrieved 31 January 2024.](#) "While exceeding the 2  C threshold for a number of days does not mean that we have breached the Paris Agreement targets, the more often that we exceed this threshold, the more serious the cumulative effects of these breaches will become."
70. [^ IPCC, 2021: \*Summary for Policymakers\*. In: \*Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change\* \[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. P  an, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelek  i, R. Yu, and B. Zhou \(eds.\)\]. Cambridge University Press, Cambridge, United Kingdom and New York, New York, US, pp. 3  32, doi:10.1017/9781009157896.001.](#)
71. [^ McGrath, Matt \(17 May 2023\). "Global warming set to break key 1.5C limit for first time". \*BBC News\*.](#) Retrieved 31 January 2024. "The researchers stress that temperatures would have to stay at or above 1.5C for 20 years to be able to say the Paris agreement threshold had been passed."
72. [^ Kennedy et al. 2010](#), p.Â S26. Figure 2.5.
73. [^ Loeb et al. 2021](#).
74. [^ "Global Warming". \*NASA JPL\*. 3 June 2010. Retrieved 11 September 2020.](#) "Satellite measurements show warming in the troposphere but cooling in the stratosphere. This vertical pattern is consistent with global warming due to increasing greenhouse gases but inconsistent with warming from natural causes."
75. [^ Kennedy et al. 2010](#), pp.Â S26, S59â€“S60
76. [^ USGCRP Chapter 1 2017](#), p.Â 35
77. [^ IPCC AR6 WG2 2022](#), pp.Â 257â€“260
78. [^ IPCC SRCCL Summary for Policymakers 2019](#), p.Â 7
79. [^ Sutton, Dong & Gregory 2007](#).
80. [^ "Climate Change: Ocean Heat Content". \*Noaa Climate.gov\*. NOAA. 2018. Archived from the original on 12 February 2019. Retrieved 20 February 2019.](#)
81. [^ IPCC AR5 WG1 Ch3 2013](#), p.Â 257: "Ocean warming dominates the global energy change inventory. Warming of the ocean accounts for about 93% of the increase in the Earth's energy inventory between 1971 and 2010 (high confidence), with warming of the upper (0 to 700 m) ocean accounting for about 64% of the total.
82. [^ von Schuckman, K.; Cheng, L.; Palmer, M. D.; Hansen, J.; et   al. \(7 September 2020\). "Heat stored in the Earth system: where does the energy go?". \*Earth System Science Data\*. \*\*12\*\* \(3\): 2013â€“2041. Bibcode:2020ESSD...12.2013V. doi:10.5194/essd-12-2013-2020 . hdl:20.500.11850/443809 .](#)
83. [^ NOAA, 10 July 2011](#).
84. [^ United States Environmental Protection Agency 2016](#), p.Â 5: "Black carbon that is deposited on snow and ice darkens those surfaces and decreases their reflectivity (albedo). This is known as the snow/ice albedo effect. This effect results in the increased absorption of radiation that accelerates melting."
85. [^ "Arctic warming three times faster than the planet, report warns". \*Phys.org\*. 20 May 2021. Retrieved 6 October 2022.](#)
86. [^ Rantanen, Mika; Karpechko, Alexey Yu; Lipponen, Antti; Nordling, Kalle; Hyv  rinen, Otto; Ruosteenoja, Kimmo; Vihma, Timo; Laaksonen, Ari \(11 August 2022\). "The Arctic has warmed nearly four times faster than the globe since 1979". \*Communications Earth & Environment\*. \*\*3\*\* \(1\): 168. Bibcode:2022ComEE...3..168R. doi:10.1038/s43247-022-00498-3 . hdl:11250/3115996 . ISSNÂ 2662-4435. S2CIDÂ 251498876.](#)
87. [^ "The Arctic is warming four times faster than the rest of the world". 14 December 2021. Retrieved 6 October 2022.](#)



88. [^ Liu, Wei; Fedorov, Alexey V.; Xie, Shang-Ping; Hu, Shineng \(26 June 2020\). "Climate impacts of a weakened Atlantic Meridional Overturning Circulation in a warming climate". \*Science Advances\*. \*\*6\*\* \(26\): eaaz4876. Bibcode:2020SciA....6.4876L. doi:10.1126/sciadv.aaz4876. PMCÂ 7319730 . PMIDÂ 32637596.](#)
89. [^ <sup>a</sup> <sup>b</sup> Pearce, Fred \(18 April 2023\). "New Research Sparks Concerns That Ocean Circulation Will Collapse". Retrieved 3 February 2024.](#)
90. [^ Lee, Sang-Ki; Lumpkin, Rick; Gomez, Fabian; Yeager, Stephen; Lopez, Hosmay; Takglis, Filippos; Dong, Shenfu; Aguiar, Wilton; Kim, Dongmin; Baringer, Molly \(13 March 2023\). "Human-induced changes in the global meridional overturning circulation are emerging from the Southern Ocean". \*Communications Earth & Environment\*. \*\*4\*\* \(1\): 69. Bibcode:2023ComEE...4...69L. doi:10.1038/s43247-023-00727-3 .](#)
91. [^ "NOAA Scientists Detect a Reshaping of the Meridional Overturning Circulation in the Southern Ocean". NOAA. 29 March 2023.](#)
92. [^ Schuur, Edward A.G.; Abbott, Benjamin W.; Commane, Roisin; Ernakovich, Jessica; Euskirchen, Eugenie; Hugelius, Gustaf; Grosse, Guido; Jones, Miriam; Koven, Charlie; Leshyk, Victor; Lawrence, David; Lorant, Michael M.; Mauritz, Marguerite; Olefeldt, David; Natali, Susan; Rodenhizer, Heidi; Salmon, Verity; SchÄdel, Christina; Strauss, Jens; Treat, Claire; Turetsky, Merritt \(2022\). "Permafrost and Climate Change: Carbon Cycle Feedbacks From the Warming Arctic". \*Annual Review of Environment and Resources\*. \*\*47\*\*: 343â€“371. Bibcode:2022ARER...47..343S. doi:10.1146/annurev-environ-012220-011847 . "Medium-range estimates of Arctic carbon emissions could result from moderate climate emission mitigation policies that keep global warming below 3Â° C \(e.g., RCP4.5\). This global warming level most closely matches country emissions reduction pledges made for the Paris Climate Agreement..."](#)
93. [^ Phiddian, Ellen \(5 April 2022\). "Explainer: IPCC Scenarios". \*Cosmos\*. Retrieved 30 September 2023. "The IPCC doesn't make projections about which of these scenarios is more likely, but other researchers and modellers can. The Australian Academy of Science, for instance, released a report last year stating that our current emissions trajectory had us headed for a 3Â° C warmer world, roughly in line with the middle scenario. Climate Action Tracker predicts 2.5 to 2.9Â° C of warming based on current policies and action, with pledges and government agreements taking this to 2.1Â° C."](#)
94. [^ McGrath, Matt \(17 May 2023\). "Global warming set to break key 1.5C limit for first time". BBC. Retrieved 17 May 2023.](#)
95. [^ Harvey, Fiona \(17 May 2023\). "World likely to breach 1.5C climate threshold by 2027, scientists warn". The Guardian. Retrieved 17 May 2023.](#)
96. [^ "Climate Change 2021 - The Physical Science Basis" \(PDF\). Intergovernmental Panel on Climate Change. 7 August 2021. IPCC AR6 WGI. Archived \(PDF\) from the original on 5 April 2024.](#)
97. [^ IPCC AR6 WG1 Summary for Policymakers 2021](#), p.Â SPM-17
98. [^ Meinshausen, Malte; Smith, S. J.; Calvin, K.; Daniel, J. S.; Kainuma, M. L. T.; Lamarque, J-F.; Matsumoto, K.; Montzka, S. A.; Raper, S. C. B.; Riahi, K.; Thomson, A.; Velders, G. J. M.; van Vuuren, D.P. P. \(2011\). "The RCP greenhouse gas concentrations and their extensions from 1765 to 2300". \*Climatic Change\*. \*\*109\*\* \(1â€“2\): 213â€“241. Bibcode:2011ClCh..109..213M. doi:10.1007/s10584-011-0156-z . ISSNÂ 0165-0009.](#)
99. [^ Lyon, Christopher; Saupe, Erin E.; Smith, Christopher J.; Hill, Daniel J.; Beckerman, Andrew P.; Stringer, Lindsay C.; Marchant, Robert; McKay, James; Burke, Ariane; O'Higgins, Paul; Dunhill, Alexander M.; Allen, Bethany J.; Riel-Salvatore, Julien; Aze, Tracy \(2021\). "Climate change research and action must look beyond 2100". \*Global Change Biology\*. \*\*28\*\* \(2\): 349â€“361. doi:10.1111/gcb.15871 . hdl:20.500.11850/521222 . ISSNÂ 1365-2486. PMIDÂ 34558764. S2CIDÂ 237616583.](#)
100. [^ IPCC AR6 WG1 2021](#), pp.Â 43â€“44
101. [^ Rogelj et al. 2019](#)
102. [^ <sup>a</sup> <sup>b</sup> IPCC SR15 Summary for Policymakers 2018](#), p.Â 12
103. [^ IPCC AR5 WG3 Ch5 2014](#), pp.Â 379â€“380.
104. [^ Brown, Patrick T.; Li, Wenhong; Xie, Shang-Ping \(27 January 2015\). "Regions of significant influence on unforced global mean surface air temperature variability in climate models: Origin of global temperature variability". \*Journal of Geophysical Research: Atmospheres\*. \*\*120\*\* \(2\): 480â€“494. doi:10.1002/2014JD022576 . hdl:10161/9564 .](#)
105. [^ Trenberth, Kevin E.; Fasullo, John T. \(December 2013\). "An apparent hiatus in global warming?". \*Earth's Future\*. \*\*1\*\* \(1\): 19â€“32. Bibcode:2013EaFut...1...19T. doi:10.1002/2013EF000165 .](#)
106. [^ National Research Council 2012](#), p.Â 9
107. [^ IPCC AR5 WG1 Ch10 2013](#), p.Â 916.
108. [^ Knutson 2017](#), p.Â 443; [IPCC AR5 WG1 Ch10 2013](#), pp.Â 875â€“876
109. [^ <sup>a</sup> <sup>b</sup> USGCRP 2009](#), p.Â 20.
110. [^ IPCC AR6 WG1 Summary for Policymakers 2021](#), p.Â 7
111. [^ LÄthi, Dieter; Le Floch, Martine; Bereiter, Bernhard; Blunier, Thomas; Barnola, Jean-Marc; Siegenthaler, Urs; Raynaud, Dominique; Jouzel, Jean; Fischer, Hubertus; Kawamura, Kenji; Stocker, Thomas F. \(May 2005\). "High-resolution carbon dioxide concentration record 650,000â€“800,000 years before present". \*Nature\*. \*\*433\*\* \(7193\): 379â€“382. Bibcode:2008Natur.453..379L. doi:10.1038/nature06949 . ISSNÂ 0028-0836. PMIDÂ 18480821. S2CIDÂ 1382081.](#)
112. [^ Fischer, Hubertus; Wahlen, Martin; Smith, Jesse; Mastroianni, Derek; Deck, Bruce \(12 March 1999\). "Ice Core Records of Atmospheric CO<sub>2</sub> Around the Last Three Glacial Terminations". \*Science\*. \*\*283\*\* \(5408\): 1712â€“1714. Bibcode:1999Sci...283.1712F. doi:10.1126/science.283.5408.1712. ISSNÂ 0036-8075. PMIDÂ 10073931.](#)
113. [^ IndermÄhle, Andreas; Monnin, Eric; Stauffer, Bernhard; Stocker, Thomas F.; Wahlen, Martin \(1 March 2000\). "Atmospheric CO<sub>2</sub> concentration from 60 to 20 kyr BP from the Taylor Dome Ice Core, Antarctica". \*Geophysical Research Letters\*. \*\*27\*\* \(5\): 735â€“738. Bibcode:2000GeoRL..27..735I. doi:10.1029/1999GL010960. S2CIDÂ 18942742.](#)
114. [^ Etheridge, D.; Steele, L.; Langenfelds, R.; Francey, R.; Barnola, J.-M.; Morgan, V. \(1998\). "Historical CO<sub>2</sub> Records from the Law Dome DE08, DE08-2, and DSS Ice Cores". Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory. U.S. Department of Energy. Retrieved 20 November 2022.](#)

115. <sup>^</sup> [Keeling, C.](#); Whorf, T. (2004). "[Atmospheric CO2 Records from Sites in the SIO Air Sampling Network](#)". *Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory*. U.S. Department of Energy. Retrieved 20 November 2022.
116. <sup>^</sup> NASA. "[The Causes of Climate Change](#)". *Climate Change: Vital Signs of the Planet*. [Archived](#) from the original on 8 May 2019. Retrieved 8 May 2019.
117. <sup>^</sup> Ozone acts as a greenhouse gas in the lowest layer of the atmosphere, the [troposphere](#) (as opposed to the stratospheric [ozone layer](#)). [Wang, Shugart & Lerdau 2017](#)
118. <sup>^</sup> [Schmidt et al. 2010](#); [USGCRP Climate Science Supplement 2014](#), p. 742
119. <sup>^</sup> [IPCC AR4 WG1 Ch1 2007](#), FAQ1.1: "To emit  $240 \text{ W m}^{-2}$ , a surface would have to have a temperature of around  $19^\circ\text{C}$ . This is much colder than the conditions that actually exist at the Earth's surface (the global mean surface temperature is about  $14^\circ\text{C}$ ).
120. <sup>^</sup> [ACS](#). "[What Is the Greenhouse Effect?](#)". [Archived](#) from the original on 26 May 2019. Retrieved 26 May 2019.
121. <sup>^</sup> [The Guardian](#), 19 February 2020.
122. <sup>^</sup> [WMO 2021](#), p. 8.
123. <sup>^</sup> [IPCC AR6 WG1 Technical Summary 2021](#), p. TS-35.
124. <sup>^</sup> [IPCC AR6 WG3 Summary for Policymakers 2022](#), Figure SPM.1.
125. <sup>^</sup> [Olivier & Peters 2019](#), p. 17
126. <sup>^</sup> [Our World in Data](#), 18 September 2020; [EPA 2020](#): "Greenhouse gas emissions from industry primarily come from burning fossil fuels for energy, as well as greenhouse gas emissions from certain chemical reactions necessary to produce goods from raw materials."
127. <sup>^</sup> "[Redox, extraction of iron and transition metals](#)". "Hot air (oxygen) reacts with the coke (carbon) to produce carbon dioxide and heat energy to heat up the furnace. Removing impurities: The calcium carbonate in the limestone thermally decomposes to form calcium oxide. calcium carbonate  $\rightarrow$  calcium oxide + carbon dioxide"
128. <sup>^</sup> [Kvande 2014](#): "Carbon dioxide gas is formed at the anode, as the carbon anode is consumed upon reaction of carbon with the oxygen ions from the alumina ( $\text{Al}_2\text{O}_3$ ). Formation of carbon dioxide is unavoidable as long as carbon anodes are used, and it is of great concern because  $\text{CO}_2$  is a greenhouse gas."
129. <sup>^</sup> [EPA 2020](#)
130. <sup>^</sup> [Global Methane Initiative 2020](#): "Estimated Global Anthropogenic Methane Emissions by Source, 2020: [Enteric fermentation](#) (27%), [Manure Management](#) (3%), [Coal Mining](#) (9%), [Municipal Solid Waste](#) (11%), [Oil & Gas](#) (24%), [Wastewater](#) (7%), [Rice Cultivation](#) (7%)."
131. <sup>^</sup> [EPA 2019](#): "Agricultural activities, such as fertilizer use, are the primary source of  $\text{N}_2\text{O}$  emissions."
132. <sup>^</sup> [Davidson 2009](#): "2.0% of manure nitrogen and 2.5% of fertilizer nitrogen was converted to nitrous oxide between 1860 and 2005; these percentage contributions explain the entire pattern of increasing nitrous oxide concentrations over this period."
133. <sup>^</sup> "[Understanding methane emissions](#)". International Energy Agency.
134. <sup>^</sup> [a b](#) Riebeek, Holli (16 June 2011). "[The Carbon Cycle](#)". *Earth Observatory*. NASA. [Archived](#) from the original on 5 March 2016. Retrieved 5 April 2018.
135. <sup>^</sup> [IPCC SRCCL Summary for Policymakers 2019](#), p. 10
136. <sup>^</sup> [IPCC SROCC Ch5 2019](#), p. 450.
137. <sup>^</sup> "[Indicators of Forest Extent / Forest Loss](#)". World Resources Institute. 4 April 2024. [Archived](#) from the original on 27 May 2024. Chart in section titled "Annual rates of global tree cover loss have risen since 2000".
138. <sup>^</sup> [Ritchie & Roser 2018](#)
139. <sup>^</sup> [The Sustainability Consortium](#), 13 September 2018; [UN FAO 2016](#), p. 18.
140. <sup>^</sup> [Curtis et al. 2018](#)
141. <sup>^</sup> [a b c](#) Garrett, L.; Lavie, H.; Besacier, C.; Alekseeva, N.; Duchelle, M. (2022). *The key role of forest and landscape restoration in climate action*. Rome: FAO. doi:10.4060/cc2510en. ISBN 978-92-5-137044-5.
142. <sup>^</sup> [a b](#) World Resources Institute, 8 December 2019
143. <sup>^</sup> [IPCC SRCCL Ch2 2019](#), p. 172: "The global biophysical cooling alone has been estimated by a larger range of climate models and is  $-0.10 \pm 0.14^\circ\text{C}$ ; it ranges from  $-0.57^\circ\text{C}$  to  $+0.06^\circ\text{C}$  ... This cooling is essentially dominated by increases in surface albedo: historical land cover changes have generally led to a dominant brightening of land."
144. <sup>^</sup> [Haywood 2016](#), p. 456; [McNeill 2017](#); [Samset et al. 2018](#).
145. <sup>^</sup> [IPCC AR5 WG1 Ch2 2013](#), p. 183.
146. <sup>^</sup> [He et al. 2018](#); [Storelvmo et al. 2016](#)
147. <sup>^</sup> "[Aerosol pollution has caused decades of global dimming](#)". *American Geophysical Union*. 18 February 2021. Archived from [the original](#) on 27 March 2023. Retrieved 18 December 2023.
148. <sup>^</sup> Xia, Wenwen; Wang, Yong; Chen, Siyu; Huang, Jianping; Wang, Bin; Zhang, Guang J.; Zhang, Yue; Liu, Xiaohong; Ma, Jianmin; Gong, Peng; Jiang, Yiquan; Wu, Mingxuan; Xue, Jinkai; Wei, Linyi; Zhang, Tinghan (2022). "[Double Trouble of Air Pollution by Anthropogenic Dust](#)". *Environmental Science & Technology*. **56** (2): 761–769. Bibcode:2022EnST...56..761X. doi:10.1021/acs.est.1c04779 . hdl:10138/341962. PMID 34941248. S2CID 245445736.
149. <sup>^</sup> "[Global Dimming Dilemma](#)". 4 June 2020.
150. <sup>^</sup> [Wild et al. 2005](#); [Storelvmo et al. 2016](#); [Samset et al. 2018](#).
151. <sup>^</sup> [Twomey 1977](#).
152. <sup>^</sup> [Albrecht 1989](#).
153. <sup>^</sup> [a b c](#) [USGCRP Chapter 2 2017](#), p. 78.
154. <sup>^</sup> [Ramanathan & Carmichael 2008](#); [RIVM 2016](#).
155. <sup>^</sup> [Sand et al. 2015](#)
156. <sup>^</sup> "[IMO 2020 – cutting sulphur oxide emissions](#)". [www.imo.org](#).
157. <sup>^</sup> Staff, Carbon Brief (3 July 2023). "[Analysis: How low-sulphur shipping rules are affecting global warming](#)". *Carbon Brief*.
158. <sup>^</sup> "[Climate Change: The Science](#)". *Carbon Brief*.

158. ["Climate Science Special Report: Fourth National Climate Assessment, Volume 1 - Chapter 3: Detection and Attribution of Climate Change". science2017.globalchange.gov. U.S. Global Change Research Program \(USGCRP\): 1â€“470. 2017. Archived from the original on 23 September 2019. Adapted directly from Fig. 3.3.](#)
159. [Wuebbles, D.J.; Fahey, D.W.; Hibbard, K.A.; Deangelo, B.; Doherty, S.; Hayhoe, K.; Horton, R.; Kossin, J.P.; Taylor, P.C.; Waple, A.M.; Yohe, C.P. \(23 November 2018\). "Climate Science Special Report / Fourth National Climate Assessment \(NCA4\). Volume I / Executive Summary / Highlights of the Findings of the U.S. Global Change Research Program Climate Science Special Report". globalchange.gov. U.S. Global Change Research Program: 1â€“470. doi:10.7930/J0DJ5CTG . Archived from the original on 14 June 2019.](#)
160. [National Academies 2008](#), p. 6
161. ["Is the Sun causing global warming?". Climate Change: Vital Signs of the Planet. Archived from the original on 5 May 2019. Retrieved 10 May 2019.](#)
162. [IPCC AR4 WG1 Ch9 2007](#), pp. 702â€“703; [Randel et al. 2009](#).
163. [Greicius, Tony \(2 August 2022\). "Tonga eruption blasted unprecedented amount of water into stratosphere". NASA Global Climate Change. Retrieved 18 January 2024. "Massive volcanic eruptions like Krakatoa and Mount Pinatubo typically cool Earth's surface by ejecting gases, dust, and ash that reflect sunlight back into space. In contrast, the Tonga volcano didn't inject large amounts of aerosols into the stratosphere, and the huge amounts of water vapor from the eruption may have a small, temporary warming effect, since water vapor traps heat. The effect would dissipate when the extra water vapor cycles out of the stratosphere and would not be enough to noticeably exacerbate climate change effects."](#)
164. [a b USGCRP Chapter 2 2017](#), p. 79
165. [Fischer & Aiuppa 2020](#).
166. ["Thermodynamics: Albedo". NSIDC. Archived from the original on 11 October 2017. Retrieved 10 October 2017.](#)
167. ["The study of Earth as an integrated system". Vital Signs of the Planet. Earth Science Communications Team at NASA's Jet Propulsion Laboratory / California Institute of Technology. 2013. Archived from the original on 26 February 2019.](#)
168. [a b USGCRP Chapter 2 2017](#), pp. 89â€“91.
169. [IPCC AR6 WG1 Technical Summary 2021](#), p. 58: "The net effect of changes in clouds in response to global warming is to amplify human-induced warming, that is, the net cloud feedback is positive (high confidence)"
170. [USGCRP Chapter 2 2017](#), pp. 89â€“90.
171. [IPCC AR5 WG1 2013](#), p. 14
172. [IPCC AR6 WG1 Technical Summary 2021](#), p. 93: "Feedback processes are expected to become more positive overall (more amplifying of global surface temperature changes) on multi-decadal time scales as the spatial pattern of surface warming evolves and global surface temperature increases."
173. [Williams, Ceppi & Katavouta 2020](#).
174. [NASA, 28 May 2013](#).
175. [Cohen et al. 2014](#).
176. [a b Turetsky et al. 2019](#)
177. [Climate.gov, 23 June 2022](#): "Carbon cycle experts estimate that natural "sinks"â€“processes that remove carbon from the atmosphereâ€“on land and in the ocean absorbed the equivalent of about half of the carbon dioxide we emitted each year in the 2011â€“2020 decade."
178. [IPCC AR6 WG1 Technical Summary 2021](#), p. TS-122, Box TS.5, Figure 1
179. [Melillo et al. 2017](#): Our first-order estimate of a warming-induced loss of 190 Pg of soil carbon over the 21st century is equivalent to the past two decades of carbon emissions from fossil fuel burning.
180. [IPCC SRCCL Ch2 2019](#), pp. 133, 144.
181. [USGCRP Chapter 2 2017](#), pp. 93â€“95.
182. [Liu, Y.; Moore, J. K.; Primeau, F.; Wang, W. L. \(22 December 2022\). "Reduced CO2 uptake and growing nutrient sequestration from slowing overturning circulation". Nature Climate Change. 13: 83â€“90. doi:10.1038/s41558-022-01555-7. OSTI 2242376. S2CID 255028552.](#)
183. [IPCC AR6 WG1 Technical Summary 2021](#), pp. 58, 59: "Clouds remain the largest contribution to overall uncertainty in climate feedbacks."
184. [Wolff et al. 2015](#): "the nature and magnitude of these feedbacks are the principal cause of uncertainty in the response of Earth's climate (over multi-decadal and longer periods) to a particular emissions scenario or greenhouse gas concentration pathway."
185. [IPCC AR5 SYR Glossary 2014](#), p. 120.
186. [Carbon Brief, 15 January 2018, "What are the different types of climate models?"](#)
187. [Wolff et al. 2015](#)
188. [Carbon Brief, 15 January 2018, "Who does climate modelling around the world?"](#)
189. [Carbon Brief, 15 January 2018, "What is a climate model?"](#)
190. [IPCC AR4 WG1 Ch8 2007](#), FAQ 8.1.
191. [Stroeve et al. 2007; National Geographic, 13 August 2019](#)
192. [Liepert & Previdi 2009](#).
193. [Rahmstorf et al. 2007; Mitchum et al. 2018](#)
194. [USGCRP Chapter 15 2017](#).
195. [HÃ©bert, R.; Herzschuh, U.; Laepple, T. \(31 October 2022\). "Millennial-scale climate variability over land overprinted by ocean temperature fluctuations". Nature Geoscience. 15 \(1\): 899â€“905. Bibcode:2022NatGe...15..899H. doi:10.1038/s41561-022-01056-4. PMC 7614181 . PMID 36817575.](#)
196. [Carbon Brief, 15 January 2018, "What are the inputs and outputs for a climate model?"](#)
197. [Matthews et al. 2009](#)
198. [Carbon Brief, 19 April 2018; Meinshausen 2019](#), p. 462.
199. [Hansen et al. 2016; Smithsonian, 26 June 2016](#).
200. [USGCRP Chapter 15 2017](#), p. 415.
201. [Scientific American, 29 April 2014; Burke & Stott 2017](#).
202. [Liu, Eui-Woong, Bin, Qiyang, Xu, Wang, Hui, Qiao, Shaochen, Chen, Guozhen, Deng, Wenjie \(10 April 2022\)](#)



202. [Liu, Fei; Wang, Bin; Ouyang, Yu; Wang, Hui; Qiao, Shaobo; Chen, Guosen; Dong, Wenjie \(19 April 2022\). "Intraseasonal variability of global land monsoon precipitation and its recent trend". \*npj Climate and Atmospheric Science\*. 5 \(1\): 30. Bibcode:2022npCAS...5...30L. doi:10.1038/s41612-022-00253-7 . ISSNÂ 2397-3722.](#)
203. [USGCRP Chapter 9 2017](#), p.Â 260.
204. [Studholme, Joshua; Fedorov, Alexey V.; Gulev, Sergey K.; Emanuel, Kerry; Hodges, Kevin \(29 December 2021\). "Poleward expansion of tropical cyclone latitudes in warming climates". \*Nature Geoscience\*. 15: 14â€“28. doi:10.1038/s41561-021-00859-1. S2CIDÂ 245540084.](#)
205. ["Hurricanes and Climate Change". \*Center for Climate and Energy Solutions\*. 10 July 2020.](#)
206. [NOAA 2017](#).
207. [WMO 2021](#), p.Â 12.
208. [IPCC AR6 WG2 2022](#), p.Â 1302
209. [DeConto & Pollard 2016](#)
210. [Bamber et al. 2019](#).
211. [Zhang et al. 2008](#)
212. [IPCC SROCC Summary for Policymakers 2019](#), p.Â 18
213. [Doney et al. 2009](#).
214. [Deutsch et al. 2011](#)
215. [IPCC SROCC Ch5 2019](#), p.Â 510; ["Climate Change and Harmful Algal Blooms". EPA. 5 September 2013. Retrieved 11 September 2020.](#)
216. ["Tipping Elements â€“ big risks in the Earth System". \*Potsdam Institute for Climate Impact Research\*. Retrieved 31 January 2024.](#)
217. [a b c Armstrong McKay, David I.; Staal, Arie; Abrams, Jesse F.; Winkelmann, Ricarda; Sakschewski, Boris; Loriani, Sina; Fetzer, Ingo; Cornell, Sarah E.; Rockström, Johan; Lenton, Timothy M. \(9 September 2022\). "Exceeding 1.5Â °C global warming could trigger multiple climate tipping points". \*Science\*. 377 \(6611\): eabn7950. doi:10.1126/science.abn7950. hdl:10871/131584 . ISSNÂ 0036-8075. PMIDÂ 36074831. S2CIDÂ 252161375.](#)
218. [IPCC SR15 Ch3 2018](#), p.Â 283.
219. [Pearce, Rosamund; Prater, Tom \(10 February 2020\). "Nine Tipping Points That Could Be Triggered by Climate Change". \*CarbonBrief\*. Retrieved 27 May 2022.](#)
220. [Bochow, Nils; Poltronieri, Anna; Robinson, Alexander; Montoya, Marisa; Rypdal, Martin; Boers, Niklas \(18 October 2023\). "Overshooting the critical threshold for the Greenland ice sheet". \*Nature\*. 622 \(7983\): 528â€“536. Bibcode:2023Natur.622..528B. doi:10.1038/s41586-023-06503-9. PMCÂ 10584691 . PMIDÂ 37853149.](#)
221. [IPCC AR6 WG1 Summary for Policymakers 2021](#), p.Â 21
222. [IPCC AR5 WG1 Ch12 2013](#), pp.Â 88â€“89, FAQ 12.3
223. [Smith et al. 2009; Levermann et al. 2013](#)
224. [IPCC AR5 WG1 Ch12 2013](#), p.Â 1112.
225. [Oschlies, Andreas \(16 April 2021\). "A committed fourfold increase in ocean oxygen loss". \*Nature Communications\*. 12 \(1\): 2307. Bibcode:2021NatCo..12.2307O. doi:10.1038/s41467-021-22584-4. PMCÂ 8052459 . PMIDÂ 33863893.](#)
226. [Lau, Sally C. Y.; Wilson, Nerida G.; Golledge, Nicholas R.; Naish, Tim R.; Watts, Phillip C.; Silva, Catarina N. S.; Cooke, Ira R.; Allcock, A. Louise; Mark, Felix C.; Linse, Katrin \(21 December 2023\). "Genomic evidence for West Antarctic Ice Sheet collapse during the Last Interglacial" \(PDF\). \*Science\*. 382 \(6677\): 1384â€“1389. Bibcode:2023Sci...382.1384L. doi:10.1126/science.ade0664. PMIDÂ 38127761. S2CIDÂ 266436146.](#)
227. [A. Naughten, Kaitlin; R. Holland, Paul; De Rydt, Jan \(23 October 2023\). "Unavoidable future increase in West Antarctic ice-shelf melting over the twenty-first century". \*Nature Climate Change\*. 13 \(11\): 1222â€“1228. Bibcode:2023NatCC..13.1222N. doi:10.1038/s41558-023-01818-x . S2CIDÂ 264476246.](#)
228. [IPCC SR15 Ch3 2018](#), p.Â 218.
229. [Martins, Paulo Mateus; Anderson, Marti J.; Sweatman, Winston L.; Punnett, Andrew J. \(9 April 2024\). "Significant shifts in latitudinal optima of North American birds". \*Proceedings of the National Academy of Sciences of the United States of America\*. 121 \(15\): e2307525121. Bibcode:2024PNAS..12107525M. doi:10.1073/pnas.2307525121. ISSNÂ 0027-8424. PMCÂ 11009622. PMIDÂ 38557189.](#)
230. [IPCC SRCCL Ch2 2019](#), p.Â 133.
231. [Deng, Yuanhong; Li, Xiaoyan; Shi, Fangzhong; Hu, Xia \(December 2021\). "Woody plant encroachment enhanced global vegetation greening and ecosystem water-use efficiency". \*Global Ecology and Biogeography\*. 30 \(12\): 2337â€“2353. Bibcode:2021GloEB..30.2337D. doi:10.1111/geb.13386. ISSNÂ 1466-822X. Retrieved 10 June 2024 â€“ via Wiley Online Library.](#)
232. [IPCC SRCCL Summary for Policymakers 2019](#), p.Â 7; [Zeng & Yoon 2009](#).
233. [Turner et al. 2020](#), p.Â 1.
234. [Urban 2015](#).
235. [Poloczanska et al. 2013; Lenoir et al. 2020](#)
236. [Smale et al. 2019](#)
237. [IPCC SROCC Summary for Policymakers 2019](#), p.Â 13.
238. [IPCC SROCC Ch5 2019](#), p.Â 510
239. [IPCC SROCC Ch5 2019](#), p.Â 451.
240. [Azevedo-Schmidt, Lauren; Meineke, Emily K.; Currano, Ellen D. \(18 October 2022\). "Insect herbivory within modern forests is greater than fossil localities". \*Proceedings of the National Academy of Sciences of the United States of America\*. 119 \(42\): e2202852119. Bibcode:2022PNAS..11902852A. doi:10.1073/pnas.2202852119 . ISSNÂ 0027-8424. PMCÂ 9586316 . PMIDÂ 36215482.](#)
241. ["Coral Reef Risk Outlook". \*National Oceanic and Atmospheric Administration\*. 2 January 2012. Retrieved 4 April 2020. "At present, local human activities, coupled with past thermal stress, threaten an estimated 75 percent of the world's reefs. By 2030, estimates predict more than 90% of the world's reefs will be threatened by local human activities, warming, and acidification, with nearly 60% facing high, very high, or critical threat levels."](#)
242. [Carbon Brief. 7 January 2020.](#)



243. [IPCC AR5 WG2 Ch28 2014](#), p. 1596: "Within 50 to 70 years, loss of hunting habitats may lead to elimination of polar bears from seasonally ice-covered areas, where two-thirds of their world population currently live."
244. ["What a changing climate means for Rocky Mountain National Park". National Park Service](#). Retrieved 9 April 2020.
245. [IPCC AR6 WG1 Summary for Policymakers 2021](#), p. SPM-23, Fig. SPM.6
246. [Lenton, Timothy M.; Xu, Chi; Abrams, Jesse F.; Ghadiali, Ashish; Loriani, Sina; Sakschewski, Boris; Zimm, Caroline; Ebi, Kristie L.; Dunn, Robert R.; Svenning, Jens-Christian; Scheffer, Marten \(2023\). "Quantifying the human cost of global warming". \*Nature Sustainability\*. \*\*6\*\* \(10\): 1237–1247. Bibcode:2023NatSu...6.1237L. doi:10.1038/s41893-023-01132-6 . hdl:10871/132650 .](#)
247. [IPCC AR5 WG2 Ch18 2014](#), pp. 983, 1008
248. [IPCC AR5 WG2 Ch19 2014](#), p. 1077.
249. [IPCC AR5 SYR Summary for Policymakers 2014](#), p. 8, SPM 2
250. [IPCC AR5 SYR Summary for Policymakers 2014](#), p. 13, SPM 2.3
251. [WHO, Nov 2015](#)
252. [IPCC AR5 WG2 Ch11 2014](#), pp. 720–723
253. [Watts et al. 2019](#), pp. 1836, 1848.
254. [Costello et al. 2009; Watts et al. 2015; IPCC AR5 WG2 Ch11 2014](#), p. 713
255. [Watts et al. 2019](#), pp. 1841, 1847.
256. [WHO 2014](#): "Under a base case socioeconomic scenario, we estimate approximately 250 000 additional deaths due to climate change per year between 2030 and 2050. These numbers do not represent a prediction of the overall impacts of climate change on health, since we could not quantify several important causal pathways."
257. [IPCC AR6 WG2 2022](#), p. 988
258. [IPCC SRCCL Ch5 2019](#), p. 451.
259. [Zhao et al. 2017; IPCC SRCCL Ch5 2019](#), p. 439
260. [IPCC AR5 WG2 Ch7 2014](#), p. 488
261. [IPCC SRCCL Ch5 2019](#), p. 462
262. [IPCC SROCC Ch5 2019](#), p. 503.
263. [Holding et al. 2016; IPCC AR5 WG2 Ch3 2014](#), pp. 232–233.
264. [DeFries et al. 2019](#), p. 3; [Krogstrup & Oman 2019](#), p. 10.
265. [a b Women's leadership and gender equality in climate action and disaster risk reduction in Africa – A call for action](#). Accra: [FAO & The African Risk Capacity \(ARC\) Group](#). 2021. doi:10.4060/cb7431en. ISBN 978-92-5-135234-2. S2CID 243488592.
266. [IPCC AR5 WG2 Ch13 2014](#), pp. 796–797
267. [IPCC AR6 WG2 2022](#), p. 725
268. [Hallegatte et al. 2016](#), p. 12.
269. [IPCC AR5 WG2 Ch13 2014](#), p. 796.
270. [Grabe, Grose and Dutt, 2014; FAO, 2011; FAO, 2021a; Fisher and Carr, 2015; IPCC, 2014; Resurrección et al., 2019; UNDRR, 2019; Yeboah et al., 2019.](#)
271. ["Climate Change | United Nations For Indigenous Peoples". United Nations Department of Economic and Social Affairs](#). Retrieved 29 April 2022.
272. [Mach et al. 2019](#).
273. [a b The status of women in agrifood systems - Overview](#). Rome: [FAO](#). 2023. doi:10.4060/cc5060en. S2CID 258145984.
274. [IPCC SROCC Ch4 2019](#), p. 328.
275. [UNHCR 2011](#), p. 3.
276. [Matthews 2018](#), p. 399.
277. [Balsari, Dresser & Leaning 2020](#)
278. [Flavell 2014](#), p. 38; [Kaczan & Orgill-Meyer 2020](#)
279. [Serdeczny et al. 2016](#).
280. [IPCC SRCCL Ch5 2019](#), pp. 439, 464.
281. [National Oceanic and Atmospheric Administration](#). "What is nuisance flooding?". Retrieved 8 April 2020.
282. [Kabir et al. 2016](#).
283. [Van Oldenborgh et al. 2019](#).
284. [IPCC AR5 SYR Glossary 2014](#), p. 125.
285. [IPCC SR15 Summary for Policymakers 2018](#), p. 15
286. [United Nations Environment Programme 2019](#), p. XX
287. [IPCC AR6 WG3 2022](#), p. 300: "The global benefits of pathways limiting warming to 2 °C (>67%) outweigh global mitigation costs over the 21st century, if aggregated economic impacts of climate change are at the moderate to high end of the assessed range, and a weight consistent with economic theory is given to economic impacts over the long term. This holds true even without accounting for benefits in other sustainable development dimensions or nonmarket damages from climate change (medium confidence)."
288. [IPCC SR15 Ch2 2018](#), p. 109.
289. [Teske, ed. 2019](#), p. xxiii.
290. [World Resources Institute. 8 August 2019](#)
291. [IPCC SR15 Ch3 2018](#), p. 266: "Where reforestation is the restoration of natural ecosystems, it benefits both carbon sequestration and conservation of biodiversity and ecosystem services."
292. [Bui et al. 2018](#), p. 1068; [IPCC SR15 Summary for Policymakers 2018](#), p. 17
293. [IPCC SR15 2018](#), p. 34; [IPCC SR15 Summary for Policymakers 2018](#), p. 17
294. [IPCC SR15 Ch4 2018](#), pp. 347–352
295. [Friedlingstein et al. 2019](#)
296. [a b United Nations Environment Programme 2019](#), p. 46; [Vox, 20 September 2019](#); Sepulveda, Nestor A.; Leising, Jesse D.; De Sistemes, Fernando J.; Lenton, Richard K. (2019). "The Role of Fossil-Fuel Carbon Electricity

- Jenkins, Jesse D.; De Sisternes, Fernando J.; Lester, Richard K. (2018). ["The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation"](#). *Joule*. 2 (11): 2403â€“2420. Bibcode:2018Joule...2.2403S. doi:10.1016/j.joule.2018.08.006 .
297. [IEA World Energy Outlook 2023](#), pp.Â 18
  298. [REN21 2020](#), p.Â 32, Fig.1.
  299. [IEA World Energy Outlook 2023](#), pp.Â 18, 26
  300. [The Guardian, 6 April 2020](#).
  301. [IEA 2021](#), p.Â 57, Fig 2.5; [Teske et al. 2019](#), p.Â 180, Table 8.1
  302. [Our World in Data-Why did renewables become so cheap so fast?](#); [IEA â€“ Projected Costs of Generating Electricity 2020](#)
  303. ["IPCC Working Group III report: Mitigation of Climate Change"](#). Intergovernmental Panel on Climate Change. 4 April 2022. Retrieved 19 January 2024.
  304. [IPCC SR15 Ch2 2018](#), p.Â 131, Figure 2.15
  305. [Teske 2019](#), pp.Â 409â€“410.
  306. [United Nations Environment Programme 2019](#), p.Â XXIII, Table ES.3; [Teske, ed. 2019](#), p.Â xxvii, Fig.5.
  307. [a b IPCC SR15 Ch2 2018](#), pp.Â 142â€“144; [United Nations Environment Programme 2019](#), Table ES.3 & p. 49
  308. ["Transport emissions"](#). *Climate action*. [European Commission](#). 2016. [Archived](#) from the original on 10 October 2021. Retrieved 2 January 2022.
  309. [IPCC AR5 WG3 Ch9 2014](#), p.Â 697; [NREL 2017](#), pp.Â vi, 12
  310. [Berrill et al. 2016](#).
  311. [IPCC SR15 Ch4 2018](#), pp.Â 324â€“325.
  312. Gill, Matthew; Livens, Francis; Peakman, Aiden. "Nuclear Fission". In [Letcher \(2020\)](#), pp.Â 147â€“149.
  313. Horvath, Akos; Rachlew, Elisabeth (January 2016). ["Nuclear power in the 21st century: Challenges and possibilities"](#). *Ambio*. 45 (Suppl 1): S38â€“49. Bibcode:2016Ambio..45S..38H. doi:10.1007/s13280-015-0732-y. ISSNÂ 1654-7209. PMCÂ 4678124 . PMIDÂ 26667059.
  314. ["Hydropower"](#). *iea.org*. [International Energy Agency](#). Retrieved 12 October 2020. "Hydropower generation is estimated to have increased by over 2% in 2019 owing to continued recovery from drought in Latin America as well as strong capacity expansion and good water availability in China (...) capacity expansion has been losing speed. This downward trend is expected to continue, due mainly to less large-project development in China and Brazil, where concerns over social and environmental impacts have restricted projects."
  315. [Watts et al. 2019](#), p.Â 1854; [WHO 2018](#), p.Â 27
  316. [Watts et al. 2019](#), p.Â 1837; [WHO 2016](#)
  317. [WHO 2018](#), p.Â 27; [Vandyck et al. 2018](#); [IPCC SR15 2018](#), p.Â 97: "Limiting warming to 1.5Â Â°C can be achieved synergistically with poverty alleviation and improved energy security and can provide large public health benefits through improved air quality, preventing millions of premature deaths. However, specific mitigation measures, such as bioenergy, may result in trade-offs that require consideration."
  318. [IPCC AR6 WG3 2022](#), p.Â 300
  319. [IPCC SR15 Ch2 2018](#), p.Â 97
  320. [IPCC AR5 SYR Summary for Policymakers 2014](#), p.Â 29; [IEA 2020b](#)
  321. [IPCC SR15 Ch2 2018](#), p.Â 155, Fig. 2.27
  322. [IEA 2020b](#)
  323. [IPCC SR15 Ch2 2018](#), p.Â 142
  324. [IPCC SR15 Ch2 2018](#), pp.Â 138â€“140
  325. [IPCC SR15 Ch2 2018](#), pp.Â 141â€“142
  326. [IPCC AR5 WG3 Ch9 2014](#), pp.Â 686â€“694.
  327. [World Resources Institute, December 2019](#), p.Â 1
  328. [World Resources Institute, December 2019](#), pp.Â 1, 3
  329. [IPCC SRCCL 2019](#), p.Â 22, B.6.2
  330. [IPCC SRCCL Ch5 2019](#), pp.Â 487, 488, FIGURE 5.12 Humans on a vegan exclusive diet would save about 7.9 GtCO<sub>2</sub> equivalent per year by 2050 [IPCC AR6 WG1 Technical Summary 2021](#), p.Â 51 Agriculture, Forestry and Other Land Use used an average of 12 GtCO<sub>2</sub> per year between 2007 and 2016 (23% of total anthropogenic emissions).
  331. [IPCC SRCCL Ch5 2019](#), pp.Â 82, 162, FIGURE 1.1
  332. ["Low and zero emissions in the steel and cement industries"](#) (PDF). pp.Â 11, 19â€“22.
  333. [World Resources Institute, 8 August 2019: IPCC SRCCL Ch2 2019](#), pp.Â 189â€“193.
  334. [Kreidenweis et al. 2016](#)
  335. [National Academies of Sciences, Engineering, and Medicine 2019](#), pp.Â 95â€“102
  336. [National Academies of Sciences, Engineering, and Medicine 2019](#), pp.Â 45â€“54
  337. Nelson, J. D. J.; Schoenau, J. J.; Malhi, S. S. (1 October 2008). ["Soil organic carbon changes and distribution in cultivated and restored grassland soils in Saskatchewan"](#). *Nutrient Cycling in Agroecosystems*. 82 (2): 137â€“148. Bibcode:2008NCyAg..82..137N. doi:10.1007/s10705-008-9175-1. ISSNÂ 1573-0867. S2CIDÂ 24021984.
  338. [Ruseva et al. 2020](#)
  339. [IPCC SR15 Ch4 2018](#), pp.Â 326â€“327; [Bednar, Obersteiner & Wagner 2019](#); [European Commission, 28 November 2018](#), p.Â 188
  340. [Bui et al. 2018](#), p.Â 1068.
  341. [IPCC AR5 SYR 2014](#), p.Â 125; [Bednar, Obersteiner & Wagner 2019](#).
  342. [IPCC SR15 2018](#), p.Â 34
  343. [IPCC, 2022: Summary for Policymakers](#) [H.-O. PÃ¶rtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. AlegrÃ­a, M. Craig, S. Langsdorf, S. LÃ¶schke, V. MÃ¶ller, A. Okem (eds.)]. In: [Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change](#) [H.-O. PÃ¶rtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. AlegrÃ­a, M. Craig, S. Langsdorf, S. LÃ¶schke, V. MÃ¶ller, A. Okem, B. Rama (eds.)]. Cambridge

- University Press, Cambridge and New York, pp. 33–33, doi:10.1017/9781009325844.001.
344. [IPCC AR5 SYR 2014](#), p. 17.
  345. [IPCC SR15 Ch4 2018](#), pp. 396–397.
  346. [IPCC AR4 WG2 Ch19 2007](#), p. 796.
  347. [UNEP 2018](#), pp. xii–xiii.
  348. [Stephens, Scott A.; Bell, Robert G.; Lawrence, Judy \(2018\). "Developing signals to trigger adaptation to sea-level rise". \*Environmental Research Letters\*. 13 \(10\). 104004. Bibcode:2018ERL....13j4004S. doi:10.1088/1748-9326/aadf96 . ISSN 1748-9326.](#)
  349. [Matthews 2018](#), p. 402.
  350. [IPCC SRCCL Ch5 2019](#), p. 439.
  351. [Surminski, Swenja; Bouwer, Laurens M.; Linnerooth-Bayer, Joanne \(2016\). "How insurance can support climate resilience". \*Nature Climate Change\*. 6 \(4\): 333–334. Bibcode:2016NatCC...6..333S. doi:10.1038/nclimate2979. ISSN 1758-6798.](#)
  352. [IPCC SR15 Ch4 2018](#), pp. 336–337.
  353. ["Mangroves against the storm". \*Shorthand\*. Retrieved 20 January 2023.](#)
  354. ["How marsh grass could help protect us from climate change". \*World Economic Forum\*. 24 October 2021. Retrieved 20 January 2023.](#)
  355. [Morecroft, Michael D.; Duffield, Simon; Harley, Mike; Pearce-Higgins, James W.; et al. \(2019\). "Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems". \*Science\*. 366 \(6471\): eaaw9256. doi:10.1126/science.aaw9256 . ISSN 0036-8075. PMID 31831643. S2CID 209339286.](#)
  356. [Berry, Pam M.; Brown, Sally; Chen, Minpeng; Kontogianni, Areti; et al. \(2015\). "Cross-sectoral interactions of adaptation and mitigation measures". \*Climate Change\*. 128 \(3\): 381–393. Bibcode:2015ClCh..128..381B. doi:10.1007/s10584-014-1214-0. hdl:10.1007/s10584-014-1214-0 . ISSN 1573-1480. S2CID 153904466.](#)
  357. [IPCC AR5 SYR 2014](#), p. 54.
  358. [Sharifi, Ayyoob \(2020\). "Trade-offs and conflicts between urban climate change mitigation and adaptation measures: A literature review". \*Journal of Cleaner Production\*. 276: 122813. Bibcode:2020JCPro.27622813S. doi:10.1016/j.jclepro.2020.122813. ISSN 0959-6526. S2CID 225638176.](#)
  359. [IPCC AR5 SYR Summary for Policymakers 2014](#), p. 17, Section 3
  360. [IPCC SR15 Ch5 2018](#), p. 447; United Nations (2017) Resolution adopted by the General Assembly on 6 July 2017, [Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development \(A/RES/71/313\)](#)
  361. [IPCC SR15 Ch5 2018](#), p. 477.
  362. [Rauner et al. 2020](#)
  363. [Mercure et al. 2018](#)
  364. [World Bank, June 2019](#), p. 12, Box 1
  365. [Union of Concerned Scientists, 8 January 2017; Hagmann, Ho & Loewenstein 2019.](#)
  366. [Watts et al. 2019](#), p. 1866
  367. [UN Human Development Report 2020](#), p. 10
  368. [International Institute for Sustainable Development 2019](#), p. iv
  369. [ICCT 2019](#), p. iv; [Natural Resources Defense Council, 29 September 2017](#)
  370. [National Conference of State Legislators, 17 April 2020; European Parliament, February 2020](#)
  371. [Gabbatiss, Josh; Tandon, Ayesha \(4 October 2021\). "In-depth Q&A: What is 'climate justice'". \*Carbon Brief\*. Retrieved 16 October 2021.](#)
  372. [Khalfan, Ashfaq; Lewis, Astrid Nilsson; Aguilar, Carlos; Persson, Jacqueline; Lawson, Max; Dab, Nafkote; Jayoussi, Safa; Acharya, Sunil \(November 2023\). "Climate Equality: A planet for the 99%" \(PDF\). \*Oxfam Digital Repository\*. Oxfam GB. doi:10.21201/2023.000001. Retrieved 18 December 2023.](#)
  373. [Grasso, Marco; Heede, Richard \(19 May 2023\). "Time to pay the piper: Fossil fuel companies' reparations for climate damages". \*One Earth\*. 6 \(5\): 459–463. Bibcode:2023OEart...6..459G . doi:10.1016/j.oneear.2023.04.012 . hdl:10281/416137 . S2CID 258809532 .](#)
  374. [Carbon Brief, 4 Jan 2017.](#)
  375. [a b Friedlingstein et al. 2019](#), Table 7.
  376. [UNFCCC. "What is the United Nations Framework Convention on Climate Change?"](#)
  377. [UNFCCC 1992](#), Article 2.
  378. [IPCC AR4 WG3 Ch1 2007](#), p. 97.
  379. [EPA 2019.](#)
  380. [UNFCCC. "What are United Nations Climate Change Conferences?"](#)
  381. [Kyoto Protocol 1997; Liverman 2009](#), p. 290.
  382. [Dessai 2001](#), p. 4; [Grubb 2003.](#)
  383. [Liverman 2009](#), p. 290.
  384. [Müller 2010; The New York Times, 25 May 2015; UNFCCC: Copenhagen 2009; EUobserver, 20 December 2009.](#)
  385. [UNFCCC: Copenhagen 2009.](#)
  386. [Conference of the Parties to the Framework Convention on Climate Change. Copenhagen. 7–18 December 2009. un document= FCCC/CP/2009/L.7. Archived from the original on 18 October 2010. Retrieved 24 October 2010.](#)
  387. [Bennett, Paige \(2 May 2023\). "High-Income Nations Are on Track Now to Meet \\$100 Billion Climate Pledges, but They're Late". \*Ecowatch\*. Retrieved 10 May 2023.](#)
  388. [Paris Agreement 2015.](#)
  389. [Climate Focus 2015](#), p. 3; [Carbon Brief, 8 October 2018.](#)
  390. [Climate Focus 2015](#), p. 5.
  391. ["Status of Treaties, United Nations Framework Convention on Climate Change". \*United Nations Treaty Collection\*. Retrieved 13 October 2021.; \[Salon, 25 September 2019.\]\(#\)](#)



392. [Goyal et al. 2019](#)
393. [Yeo, Sophie \(10 October 2016\). "Explainer: Why a UN climate deal on HFCs matters". Carbon Brief. Retrieved 10 January 2021.](#)
394. [BBC, 1 May 2019; Vice, 2 May 2019.](#)
395. [The Verge, 27 December 2019.](#)
396. [The Guardian, 28 November 2019](#)
397. [Politico, 11 December 2019.](#)
398. ["European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions". European Commission. 14 July 2021.](#)
399. [The Guardian, 28 October 2020](#)
400. ["India". Climate Action Tracker. 15 September 2021. Retrieved 3 October 2021.](#)
401. [Do, Thang Nam; Burke, Paul J. \(2023\). "Phasing out coal power in a developing country context: Insights from Vietnam". Energy Policy. 176 \(May 2023 113512\): 113512. Bibcode:2023EnPol.17613512D. doi:10.1016/j.enpol.2023.113512. hdl:1885/286612 . S2CID 257356936.](#)
402. [UN NDC Synthesis Report 2021](#), pp. 4–5; UNFCCC Press Office (26 February 2021). ["Greater Climate Ambition Urged as Initial NDC Synthesis Report Is Published"](#). Retrieved 21 April 2021.
403. [Stover 2014.](#)
404. [Dunlap & McCright 2011](#), pp. 144, 155; [Björnsberg et al. 2017](#)
405. [Oreskes & Conway 2010; Björnsberg et al. 2017](#)
406. [O'Neill & Boykoff 2010; Björnsberg et al. 2017](#)
407. [a b Björnsberg et al. 2017](#)
408. [Dunlap & McCright 2015](#), p. 308.
409. [Dunlap & McCright 2011](#), p. 146.
410. [Harvey et al. 2018](#)
411. ["Public perceptions on climate change" \(PDF\). PERITIA Trust EU – The Policy Institute of King's College London. June 2022. p. 4. Archived \(PDF\) from the original on 15 July 2022.](#)
412. [Powell, James \(20 November 2019\). "Scientists Reach 100% Consensus on Anthropogenic Global Warming". Bulletin of Science, Technology & Society. 37 \(4\): 183–184. doi:10.1177/0270467619886266. S2CID 213454806.](#)
413. [Myers, Krista F.; Doran, Peter T.; Cook, John; Kotcher, John E.; Myers, Teresa A. \(20 October 2021\). "Consensus revisited: quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later". Environmental Research Letters. 16 \(10\): 104030. Bibcode:2021ERL....16j4030M. doi:10.1088/1748-9326/ac2774 . S2CID 239047650.](#)
414. [a b Weart "The Public and Climate Change \(since 1980\)"](#)
415. [Newell 2006](#), p. 80; [Yale Climate Connections, 2 November 2010](#)
416. [Pew 2015](#), p. 10.
417. [a b Pew 2020.](#)
418. [Pew 2015](#), p. 15.
419. [Yale 2021](#), p. 7.
420. [Yale 2021](#), p. 9; [UNDP 2021](#), p. 15.
421. [Smith & Leiserowitz 2013](#), p. 943.
422. [Gunningham 2018.](#)
423. [The Guardian, 19 March 2019; Boulianne, Lalancette & Ilkiw 2020.](#)
424. [Deutsche Welle, 22 June 2019.](#)
425. [Connolly, Kate \(29 April 2021\). "'Historic' German ruling says climate goals not tough enough". The Guardian. Retrieved 1 May 2021.](#)
426. [Setzer & Byrnes 2019.](#)
427. ["Coal Consumption Affecting Climate". Rodney and Otamatea Times, Waitemata and Kaipara Gazette. Warkworth, New Zealand. 14 August 1912. p. 7. Text was earlier published in Popular Mechanics, March 1912, p. 341.](#)
428. [Nord, D.C. \(2020\). Nordic Perspectives on the Responsible Development of the Arctic: Pathways to Action. Springer Polar Sciences. Springer International Publishing. p. 51. ISBN 978-3-030-52324-4. Retrieved 11 March 2023.](#)
429. [Mukherjee, A.; Scanlon, B.R.; Aureli, A.; Langan, S.; Guo, H.; McKenzie, A.A. \(2020\). Global Groundwater: Source, Scarcity, Sustainability, Security, and Solutions. Elsevier Science. p. 331. ISBN 978-0-12-818173-7. Retrieved 11 March 2023.](#)
430. [von Humboldt, A.; Wulf, A. \(2018\). Selected Writings of Alexander von Humboldt: Edited and Introduced by Andrea Wulf. Everyman's Library Classics Series. Knopf Doubleday Publishing Group. p. 10. ISBN 978-1-101-90807-5. Retrieved 11 March 2023.](#)
431. [Erdkamp, P.; Manning, J.G.; Verboven, K. \(2021\). Climate Change and Ancient Societies in Europe and the Near East: Diversity in Collapse and Resilience. Palgrave Studies in Ancient Economies. Springer International Publishing. p. 6. ISBN 978-3-030-81103-7. Retrieved 11 March 2023.](#)
432. [Archer & Pierrehumbert 2013](#), pp. 10–14
433. [Foote, Eunice \(November 1856\). "Circumstances affecting the Heat of the Sun's Rays". The American Journal of Science and Arts. 22: 382–383. Retrieved 31 January 2016 – via Google Books.](#)
434. [Huddleston 2019](#)
435. [Tyndall 1861.](#)
436. [Archer & Pierrehumbert 2013](#), pp. 39–42; [Fleming 2008](#), [Tyndall](#)
437. [Lapenis 1998.](#)
438. [a b c Weart "The Carbon Dioxide Greenhouse Effect"; Fleming 2008, Arrhenius](#)
439. [Callendar 1938; Fleming 2007.](#)
440. [Cook, John; Oreskes, Naomi; Doran, Peter T.; Anderegg, William R. L.; et al. \(2016\). "Consensus on consensus:](#)

- a synthesis of consensus estimates on human-caused global warming". *Environmental Research Letters*. **11** (4): 048002. [Bibcode:2016ERL....11d8002C](#). [doi:10.1088/1748-9326/11/4/048002](#) . [hdl:1983/34949783-dac1-4ce7-ad95-5dc0798930a6](#) .
441. ^ [a b](#) Powell, James (20 November 2019). "Scientists Reach 100% Consensus on Anthropogenic Global Warming". *Bulletin of Science, Technology & Society*. **37** (4): 183â€“184. [doi:10.1177/0270467619886266](#). [S2CIDÂ 213454806](#). Retrieved 15 November 2020.
442. ^ [a b c](#) Lynas, Mark; Houlton, Benjamin Z; Perry, Simon (2021). "Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature". *Environmental Research Letters*. **16** (11): 114005. [Bibcode:2021ERL....16k4005L](#). [doi:10.1088/1748-9326/ac2966](#) . [ISSNÂ 1748-9326](#). [S2CIDÂ 239032360](#).
443. ^ Myers, Krista F.; Doran, Peter T.; Cook, John; Kotcher, John E.; Myers, Teresa A. (20 October 2021). "Consensus revisited: quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later". *Environmental Research Letters*. **16** (10): 104030. [Bibcode:2021ERL....16j4030M](#). [doi:10.1088/1748-9326/ac2774](#) . [S2CIDÂ 239047650](#).
444. ^ Weart "Suspensions of a Human-Caused Greenhouse (1956â€“1969)"
445. ^ Weart 2013, p.Â 3567.
446. ^ Royal Society 2005.
447. ^ National Academies 2008, p.Â 2; Oreskes 2007, p.Â 68; Gleick, 7 January 2017
448. ^ Joint statement of the [G8+5 Academies \(2009\)](#); Gleick, 7 January 2017.

## Sources

ð This article incorporates text from a [free content](#) work. Licensed under CC BY-SA 3.0. Text taken from *The status of women in agrifood systems â€“ Overview*, FAO, FAO.

## IPCC reports

### Fourth Assessment Report

- [IPCC](#) (2007). Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; etÂ al. (eds.). *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the [Fourth Assessment Report](#) of the Intergovernmental Panel on Climate Change. [Cambridge University Press](#). [ISBNÂ 978-0-521-88009-1](#).
  - Le Treut, H.; Somerville, R.; Cubasch, U.; Ding, Y.; etÂ al. (2007). "Chapter 1: Historical Overview of Climate Change Science" (PDF). *IPCC AR4 WG1 2007*. pp.Â 93â€“127.
  - Randall, D. A.; Wood, R. A.; Bony, S.; Colman, R.; etÂ al. (2007). "Chapter 8: Climate Models and their Evaluation" (PDF). *IPCC AR4 WG1 2007*. pp.Â 589â€“662.
  - Hegerl, G. C.; Zwiers, F. W.; Braconnot, P.; Gillett, N. P.; etÂ al. (2007). "Chapter 9: Understanding and Attributing Climate Change" (PDF). *IPCC AR4 WG1 2007*. pp.Â 663â€“745.
- [IPCC](#) (2007). Parry, M. L.; Canziani, O. F.; Palutikof, J. P.; van der Linden, P. J.; etÂ al. (eds.). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the [Fourth Assessment Report](#) of the Intergovernmental Panel on Climate Change. [Cambridge University Press](#). [ISBNÂ 978-0-521-88010-7](#).
  - Schneider, S. H.; Semenov, S.; Patwardhan, A.; Burton, I.; etÂ al. (2007). "Chapter 19: Assessing key vulnerabilities and the risk from climate change" (PDF). *IPCC AR4 WG2 2007*. pp.Â 779â€“810.
- [IPCC](#) (2007). Metz, B.; Davidson, O. R.; Bosch, P. R.; Dave, R.; etÂ al. (eds.). *Climate Change 2007: Mitigation of Climate Change*. Contribution of Working Group III to the [Fourth Assessment Report](#) of the Intergovernmental Panel on Climate Change. [Cambridge University Press](#). [ISBNÂ 978-0-521-88011-4](#).
  - Rogner, H.-H.; Zhou, D.; Bradley, R.; CrabbÂ©, P.; etÂ al. (2007). "Chapter 1: Introduction" (PDF). *IPCC AR4 WG3 2007*. pp.Â 95â€“116.

### Fifth Assessment report

- [IPCC](#) (2013). Stocker, T. F.; Qin, D.; Plattner, G.-K.; Tignor, M.; etÂ al. (eds.). *Climate Change 2013: The Physical Science Basis* (PDF). Contribution of Working Group I to the [Fifth Assessment Report](#) of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York: [Cambridge University Press](#). [ISBNÂ 978-1-107-05799-9](#).. [AR5 Climate Change 2013: The Physical Science Basis â€“ IPCC](#)
  - [IPCC](#) (2013). "Summary for Policymakers" (PDF). *IPCC AR5 WG1 2013*.
  - Hartmann, D. L.; Klein Tank, A. M. G.; Rusticucci, M.; Alexander, L. V.; etÂ al. (2013). "Chapter 2: Observations: Atmosphere and Surface" (PDF). *IPCC AR5 WG1 2013*. pp.Â 159â€“254.
  - Rhein, M.; Rintoul, S. R.; Aoki, S.; Campos, E.; etÂ al. (2013). "Chapter 3: Observations: Ocean" (PDF). *IPCC AR5 WG1 2013*. pp.Â 255â€“315.
  - Masson-Delmotte, V.; Schulz, M.; Abe-Ouchi, A.; Beer, J.; etÂ al. (2013). "Chapter 5: Information from Paleoclimate Archives" (PDF). *IPCC AR5 WG1 2013*. pp.Â 383â€“464.
  - Bindoff, N. L.; Stott, P. A.; AchutaRao, K. M.; Allen, M. R.; etÂ al. (2013). "Chapter 10: Detection and Attribution of Climate Change: from Global to Regional" (PDF). *IPCC AR5 WG1 2013*. pp.Â 867â€“952.
  - Collins, M.; Knutti, R.; Arblaster, J. M.; Dufresne, J.-L.; etÂ al. (2013). "Chapter 12: Long-term Climate Change: Projections, Commitments and Irreversibility" (PDF). *IPCC AR5 WG1 2013*. pp.Â 1029â€“1136.
- [IPCC](#) (2014). Field, C. B.; Barros, V. R.; Dokken, D. J.; Mach, K. J.; etÂ al. (eds.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Contribution of Working Group II to the [Fifth Assessment Report](#) of the Intergovernmental Panel on Climate Change. [Cambridge University Press](#). [ISBNÂ 978-1-107-05807-1](#).. Chapters 1â€“20, SPM, and Technical Summary.
  - JimÂ©nez Cisneros, B. E.; Oki, T.; Arnell, N. W.; Benito, G.; etÂ al. (2014). "Chapter 3: Freshwater Resources" (PDF). *IPCC AR5 WG2 A 2014*. pp.Â 229â€“269.

- Porter, J. R.; Xie, L.; Challinor, A. J.; Cochrane, K.; et al. (2014). "[Chapter 7: Food Security and Food Production Systems](#)" (PDF). *IPCC AR5 WG2 A 2014*. pp. 485–533.
- Smith, K. R.; Woodward, A.; Campbell-Lendrum, D.; Chadee, D. D.; et al. (2014). "[Chapter 11: Human Health: Impacts, Adaptation, and Co-Benefits](#)" (PDF). In *IPCC AR5 WG2 A 2014*. pp. 709–754.
- Olsson, L.; Opondo, M.; Tschakert, P.; Agrawal, A.; et al. (2014). "[Chapter 13: Livelihoods and Poverty](#)" (PDF). *IPCC AR5 WG2 A 2014*. pp. 793–832.
- Cramer, W.; Yohe, G. W.; Auffhammer, M.; Huggel, C.; et al. (2014). "[Chapter 18: Detection and Attribution of Observed Impacts](#)" (PDF). *IPCC AR5 WG2 A 2014*. pp. 979–1037.
- Oppenheimer, M.; Campos, M.; Warren, R.; Birkmann, J.; et al. (2014). "[Chapter 19: Emergent Risks and Key Vulnerabilities](#)" (PDF). *IPCC AR5 WG2 A 2014*. pp. 1039–1099.
- IPCC (2014). Barros, V. R.; Field, C. B.; Dokken, D. J.; Mach, K. J.; et al. (eds.). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects* (PDF). Contribution of Working Group II to the [Fifth Assessment Report](#) of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York: [Cambridge University Press](#). ISBN 978-1-107-05816-3. Chapters 21–30, Annexes, and Index.
  - Larsen, J. N.; Anisimov, O. A.; Constable, A.; Hollowed, A. B.; et al. (2014). "[Chapter 28: Polar Regions](#)" (PDF). *IPCC AR5 WG2 B 2014*. pp. 1567–1612.
- IPCC (2014). Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Farahani, E.; et al. (eds.). *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the [Fifth Assessment Report](#) of the Intergovernmental Panel on Climate Change. Cambridge, UK & New York, NY: [Cambridge University Press](#). ISBN 978-1-107-05821-7.
  - Blanco, G.; Gerlagh, R.; Suh, S.; Barrett, J.; et al. (2014). "[Chapter 5: Drivers, Trends and Mitigation](#)" (PDF). *IPCC AR5 WG3 2014*. pp. 351–411.
  - Lucon, O.; Åerge-Vorsatz, D.; Ahmed, A.; Akbari, H.; et al. (2014). "[Chapter 9: Buildings](#)" (PDF). *IPCC AR5 WG3 2014*.
  - Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Farahani, E.; et al. (2014). "[Annex III: Technology-specific Cost and Performance Parameters](#)" (PDF). *IPCC AR5 WG3 2014*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- IPCC AR5 SYR (2014). The Core Writing Team; Pachauri, R. K.; Meyer, L. A. (eds.). *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the [Fifth Assessment Report](#) of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.
  - IPCC (2014). "[Summary for Policymakers](#)" (PDF). *IPCC AR5 SYR 2014*.
  - IPCC (2014). "[Annex II: Glossary](#)" (PDF). *IPCC AR5 SYR 2014*.

## Special Report: Global Warming of 1.5 °C

- IPCC (2018). Masson-Delmotte, V.; Zhai, P.; Pörtner, H.-O.; Roberts, D.; et al. (eds.). *Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (PDF). Intergovernmental Panel on Climate Change. [Global Warming of 1.5 °C](#).
  - IPCC (2018). "[Summary for Policymakers](#)" (PDF). *IPCC SR15 2018*. pp. 3–24.
  - Allen, M. R.; Dube, O. P.; Solecki, W.; Arag n-Durand, F.; et al. (2018). "[Chapter 1: Framing and Context](#)" (PDF). *IPCC SR15 2018*. pp. 49–91.
  - Rogelj, J.; Shindell, D.; Jiang, K.; Fita, S.; et al. (2018). "[Chapter 2: Mitigation Pathways Compatible with 1.5 °C in the Context of Sustainable Development](#)" (PDF). *IPCC SR15 2018*. pp. 93–174.
  - Hoegh-Guldberg, O.; Jacob, D.; Taylor, M.; Bindi, M.; et al. (2018). "[Chapter 3: Impacts of 1.5 °C Global Warming on Natural and Human Systems](#)" (PDF). *IPCC SR15 2018*. pp. 175–311.
  - de Coninck, H.; Revi, A.; Babiker, M.; Bertoldi, P.; et al. (2018). "[Chapter 4: Strengthening and Implementing the Global Response](#)" (PDF). *IPCC SR15 2018*. pp. 313–443.
  - Roy, J.; Tschakert, P.; Waisman, H.; Abdul Halim, S.; et al. (2018). "[Chapter 5: Sustainable Development, Poverty Eradication and Reducing Inequalities](#)" (PDF). *IPCC SR15 2018*. pp. 445–538.

## Special Report: Climate change and Land

- IPCC (2019). Shukla, P. R.; Skea, J.; Calvo Buendia, E.; Masson-Delmotte, V.; et al. (eds.). *IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems* (PDF). In press.
  - IPCC (2019). "[Summary for Policymakers](#)" (PDF). *IPCC SRCCL 2019*. pp. 3–34.
  - Jia, G.; Shevliakova, E.; Artaxo, P. E.; De Noblet-Ducoudr , N.; et al. (2019). "[Chapter 2: Land-Climate Interactions](#)" (PDF). *IPCC SRCCL 2019*. pp. 131–247.
  - Mbow, C.; Rosenzweig, C.; Barioni, L. G.; Benton, T.; et al. (2019). "[Chapter 5: Food Security](#)" (PDF). *IPCC SRCCL 2019*. pp. 437–550.

## Special Report: The Ocean and Cryosphere in a Changing Climate

- IPCC (2019). P rtner, H.-O.; Roberts, D. C.; Masson-Delmotte, V.; Zhai, P.; et al. (eds.). *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (PDF). In press.
  - IPCC (2019). "[Summary for Policymakers](#)" (PDF). *IPCC SROCC 2019*. pp. 3–35.
  - Oppenheimer, M.; Glavovic, B.; Hinkel, J.; van de Wal, R.; et al. (2019). "[Chapter 4: Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities](#)" (PDF). *IPCC SROCC 2019*. pp. 321–445.
  - Bindoff, N. L.; Cheung, W. W. L.; Kairo, J. G.; Ar stegui, J.; et al. (2019). "[Chapter 5: Changing Ocean, Marine Ecosystems, and Dependent Communities](#)" (PDF). *IPCC SROCC 2019*. pp. 447–587.

## Sixth Assessment Report



- IPCC (2021). Masson-Delmotte, V.; Zhai, P.; Pirani, A.; Connors, S. L.; etÅ al. (eds.). [Climate Change 2021: The Physical Science Basis](#) (PDF). Contribution of Working Group I to the [Sixth Assessment Report](#) of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, US: [Cambridge University Press](#) (In Press).
  - IPCC (2021). ["Summary for Policymakers"](#) (PDF). [IPCC AR6 WG1 2021](#).
  - Arias, Paola A.; Bellouin, Nicolas; Coppola, Erika; Jones, Richard G.; etÅ al. (2021). ["Technical Summary"](#) (PDF). [IPCC AR6 WG1 2021](#).
  - Seneviratne, Sonia I.; Zhang, Xuebin; Adnan, M.; Badi, W.; etÅ al. (2021). ["Chapter 11: Weather and climate extreme events in a changing climate"](#) (PDF). [IPCC AR6 WG1 2021](#).
- IPCC (2022). PÄ¶rtner, H.-O.; Roberts, D.C.; Tignor, M.; Poloczanska, E.S.; Mintenbeck, K.; AlegrÄa, A.; Craig, M.; Langsdorf, S.; LÄ¶schke, S.; MÄ¶ller, V.; Okem, A.; Rama, B.; etÅ al. (eds.). [Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change](#). Cambridge University Press.
- IPCC (2022). Shukla, P.R.; Skea, J.; Slade, R.; Al Khourdajie, A.; etÅ al. (eds.). [Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change](#). Cambridge, UK and New York, NY, USA: [Cambridge University Press](#). doi:10.1017/9781009157926. ISBNÄ 978-1-009-15792-6.
  - IPCC (2022). ["Summary for Policymakers"](#) (PDF). [IPCC AR6 WG3 2022](#).
- IPCC (2023). Core Writing Team; Lee, H.; Romero, J.; etÅ al. (eds.). [IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change \[Core Writing Team, H. Lee and J. Romero \(Eds.\)\]. IPCC, Geneva, Switzerland](#) (PDF). Geneva, Switzerland: IPCC. doi:10.59327/IPCC/AR6-9789291691647. hdl:1885/299630. ISBNÄ 978-92-9169-164-7. S2CIDÄ 260074696.
  - IPCC (2023). ["Summary for Policymakers"](#) (PDF). [IPCC AR6 SYR 2023](#).

## Other peer-reviewed sources

- Albrecht, Bruce A. (1989). "Aerosols, Cloud Microphysics, and Fractional Cloudiness". [Science](#). **245** (4923): 1227â€"1239. Bibcode:1989Sci...245.1227A. doi:10.1126/science.245.4923.1227. PMIDÄ 17747885. S2CIDÄ 46152332.
- Balsari, S.; Dresser, C.; Leaning, J. (2020). ["Climate Change, Migration, and Civil Strife"](#). *Curr Environ Health Rep*. **7** (4): 404â€"414. Bibcode:2020CEHR....7..404B. doi:10.1007/s40572-020-00291-4. PMCÄ 7550406 . PMIDÄ 33048318.
- Bamber, Jonathan L.; Oppenheimer, Michael; Kopp, Robert E.; Aspinall, Willy P.; Cooke, Roger M. (2019). ["Ice sheet contributions to future sea-level rise from structured expert judgment"](#). *Proceedings of the National Academy of Sciences*. **116** (23): 11195â€"11200. Bibcode:2019PNAS..11611195B. doi:10.1073/pnas.1817205116 . ISSNÄ 0027-8424. PMCÄ 6561295 . PMIDÄ 31110015.
- Bednar, Johannes; Obersteiner, Michael; Wagner, Fabian (2019). ["On the financial viability of negative emissions"](#). *Nature Communications*. **10** (1): 1783. Bibcode:2019NatCo..10.1783B. doi:10.1038/s41467-019-09782-x. ISSNÄ 2041-1723. PMCÄ 6467865 . PMIDÄ 30992434.
- Berrill, P.; Arvesen, A.; Scholz, Y.; Gils, H. C.; etÅ al. (2016). ["Environmental impacts of high penetration renewable energy scenarios for Europe"](#). *Environmental Research Letters*. **11** (1): 014012. Bibcode:2016ERL....11a4012B. doi:10.1088/1748-9326/11/1/014012 . hdl:11250/2465014 .
- BjÄ¶rnberg, Karin Edvardsson; Karlsson, Mikael; Gilek, Michael; Hansson, Sven Ove (2017). ["Climate and environmental science denial: A review of the scientific literature published in 1990â€"2015"](#). *Journal of Cleaner Production*. **167**: 229â€"241. Bibcode:2017JCP...167..229B. doi:10.1016/j.jclepro.2017.08.066 . ISSNÄ 0959-6526.
- Boulianne, Shelley; Lalancette, Mireille; Ilkiw, David (2020). ["School Strike 4 Climate": Social Media and the International Youth Protest on Climate Change"](#). *Media and Communication*. **8** (2): 208â€"218. doi:10.17645/mac.v8i2.2768 . ISSNÄ 2183-2439.
- Bui, M.; Adjiman, C.; Bardow, A.; Anthony, Edward J.; etÅ al. (2018). ["Carbon capture and storage \(CCS\): the way forward"](#). *Energy & Environmental Science*. **11** (5): 1062â€"1176. doi:10.1039/c7ee02342a . hdl:10044/1/55714 .
- Burke, Claire; Stott, Peter (2017). "Impact of Anthropogenic Climate Change on the East Asian Summer Monsoon". *Journal of Climate*. **30** (14): 5205â€"5220. arXiv:1704.00563 . Bibcode:2017JCLI...30.5205B. doi:10.1175/JCLI-D-16-0892.1. ISSNÄ 0894-8755. S2CIDÄ 59509210.
- Callendar, G. S. (1938). "The artificial production of carbon dioxide and its influence on temperature". *Quarterly Journal of the Royal Meteorological Society*. **64** (275): 223â€"240. Bibcode:1938QJRMS..64..223C. doi:10.1002/qj.49706427503.
- Cattaneo, Cristina; Beine, Michel; FrÄ¶hlich, Christiane J.; Kniveton, Dominic; etÅ al. (2019). ["Human Migration in the Era of Climate Change"](#). *Review of Environmental Economics and Policy*. **13** (2): 189â€"206. doi:10.1093/reep/rez008. hdl:10.1093/reep/rez008 . ISSNÄ 1750-6816. S2CIDÄ 198660593.
- Cohen, Judah; Screen, James; Furtado, Jason C.; Barlow, Mathew; etÅ al. (2014). ["Recent Arctic amplification and extreme mid-latitude weather"](#) (PDF). *Nature Geoscience*. **7** (9): 627â€"637. Bibcode:2014NatGe...7..627C. doi:10.1038/ngeo2234. ISSNÄ 1752-0908.
- Costello, Anthony; Abbas, Mustafa; Allen, Adriana; Ball, Sarah; etÅ al. (2009). ["Managing the health effects of climate change"](#). *The Lancet*. **373** (9676): 1693â€"1733. doi:10.1016/S0140-6736(09)60935-1. PMIDÄ 19447250. S2CIDÄ 205954939. Archived from the original on 13 August 2017.
- Curtis, P.; Slay, C.; Harris, N.; Tyukavina, A.; etÅ al. (2018). ["Classifying drivers of global forest loss"](#). *Science*. **361** (6407): 1108â€"1111. Bibcode:2018Sci...361.1108C. doi:10.1126/science.aau3445 . PMIDÄ 30213911. S2CIDÄ 52273353.
- Davidson, Eric (2009). ["The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860"](#). *Nature Geoscience*. **2**: 659â€"662. doi:10.1016/j.chemer.2016.04.002 .
- DeConto, Robert M.; Pollard, David (2016). "Contribution of Antarctica to past and future sea-level rise". *Nature*. **531** (7596): 591â€"597. Bibcode:2016Natur.531..591D. doi:10.1038/nature17145. ISSNÄ 1476-4687.

- PMID<sup>Â</sup> 27029274. S2CID<sup>Â</sup> 205247890.
- Dean, Joshua F.; Middelburg, Jack J.; R<sup>Â</sup>ckmann, Thomas; Aerts, Rien; et<sup>Â</sup> al. (2018). "[Methane Feedbacks to the Global Climate System in a Warmer World](#)". *Reviews of Geophysics*. **56** (1): 207â€“250. [Bibcode:2018RvGeo...56..207D](#). [doi:10.1002/2017RG000559](#) . [hdl:2066/195183](#) . ISSN<sup>Â</sup> 1944-9208.
  - Deutsch, Curtis; Brix, Holger; Ito, Taka; Frenzel, Hartmut; et<sup>Â</sup> al. (2011). "[Climate-Forced Variability of Ocean Hypoxia](#)" (PDF). *Science*. **333** (6040): 336â€“339. [Bibcode:2011Sci...333..336D](#). [doi:10.1126/science.1202422](#). PMID<sup>Â</sup> 21659566. S2CID<sup>Â</sup> 11752699. [Archived](#) (PDF) from the original on 9 May 2016.
  - Doney, Scott C.; Fabry, Victoria J.; Feely, Richard A.; Kleypas, Joan A. (2009). "Ocean Acidification: The Other CO<sub>2</sub> Problem". *Annual Review of Marine Science*. **1** (1): 169â€“192. [Bibcode:2009ARMS....1..169D](#). [doi:10.1146/annurev.marine.010908.163834](#). PMID<sup>Â</sup> 21141034. S2CID<sup>Â</sup> 402398.
  - Fahey, D. W.; Doherty, S. J.; Hibbard, K. A.; Romanou, A.; Taylor, P. C. (2017). "[Chapter 2: Physical Drivers of Climate Change](#)" (PDF). In *USGCRP2017*.
  - Fischer, Tobias P.; Aiuppa, Alessandro (2020). "[AGU Centennial Grand Challenge: Volcanoes and Deep Carbon Global CO<sub>2</sub> Emissions From Subaerial Volcanism](#)"â€“ Recent Progress and Future Challenges". *Geochemistry, Geophysics, Geosystems*. **21** (3): e08690. [Bibcode:2020GGG....2108690F](#). [doi:10.1029/2019GC008690](#) . [hdl:10447/498846](#) . ISSN<sup>Â</sup> 1525-2027.
  - Friedlingstein, Pierre; Jones, Matthew W.; O'Sullivan, Michael; Andrew, Robbie M.; et<sup>Â</sup> al. (2019). "[Global Carbon Budget 2019](#)". *Earth System Science Data*. **11** (4): 1783â€“1838. [Bibcode:2019ESSD...11.1783F](#). [doi:10.5194/essd-11-1783-2019](#) . [hdl:10871/39943](#) . ISSN<sup>Â</sup> 1866-3508.
  - Goyal, Rishav; England, Matthew H; Sen Gupta, Alex; Jucker, Martin (2019). "[Reduction in surface climate change achieved by the 1987 Montreal Protocol](#)". *Environmental Research Letters*. **14** (12): 124041. [Bibcode:2019ERL....14l041G](#). [doi:10.1088/1748-9326/ab4874](#) . [hdl:1959.4/unsworks\\_66865](#) . ISSN<sup>Â</sup> 1748-9326.
  - Grubb, M. (2003). "[The Economics of the Kyoto Protocol](#)" (PDF). *World Economics*. **4** (3): 144â€“145. Archived from [the original](#) (PDF) on 4 September 2012.
  - Gunningham, Neil (2018). "[Mobilising civil society: can the climate movement achieve transformational social change?](#)" (PDF). *Interface: A Journal for and About Social Movements*. **10**. [Archived](#) (PDF) from the original on 12 April 2019. Retrieved 12 April 2019.
  - Hagmann, David; Ho, Emily H.; Loewenstein, George (2019). "Nudging out support for a carbon tax". *Nature Climate Change*. **9** (6): 484â€“489. [Bibcode:2019NatCC...9..484H](#). [doi:10.1038/s41558-019-0474-0](#). S2CID<sup>Â</sup> 182663891.
  - Hansen, James; Sato, Makiko; Hearty, Paul; Ruedy, Reto; et<sup>Â</sup> al. (2016). "[Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 Â°C global warming could be dangerous](#)". *Atmospheric Chemistry and Physics*. **16** (6): 3761â€“3812. [arXiv:1602.01393](#) . [Bibcode:2016ACP....16.3761H](#). [doi:10.5194/acp-16-3761-2016](#) . ISSN<sup>Â</sup> 1680-7316. S2CID<sup>Â</sup> 9410444.
  - Harvey, Jeffrey A.; Van den Berg, Daphne; Eilers, Jacintha; Kampen, Remko; et<sup>Â</sup> al. (2018). "[Internet Blogs, Polar Bears, and Climate-Change Denial by Proxy](#)". *BioScience*. **68** (4): 281â€“287. [doi:10.1093/biosci/bix133](#). ISSN<sup>Â</sup> 0006-3568. PMC<sup>Â</sup> 5894087 . PMID<sup>Â</sup> 29662248. (Erratum:Â [doi:10.1093/biosci/biy033](#), PMID<sup>Â</sup> 29608770, Â [Retraction Watch](#). If the [erratum](#) has been checked and does not affect the cited material, please replace {{[erratum](#)|...}} with {{[erratum](#)|...|checked=yes}}.)
  - Hawkins, Ed; Ortega, Pablo; Suckling, Emma; Schurer, Andrew; et<sup>Â</sup> al. (2017). "[Estimating Changes in Global Temperature since the Preindustrial Period](#)". *Bulletin of the American Meteorological Society*. **98** (9): 1841â€“1856. [Bibcode:2017BAMS...98.1841H](#). [doi:10.1175/bams-d-16-0007.1](#) . [hdl:20.500.11820/f0ba8a1c-a259-4689-9fc3-77ec82fff5ab](#) . ISSN<sup>Â</sup> 0003-0007.
  - He, Yanyi; Wang, Kaicun; Zhou, Chunl<sup>Â</sup>ae; Wild, Martin (2018). "[A Revisit of Global Dimming and Brightening Based on the Sunshine Duration](#)". *Geophysical Research Letters*. **45** (9): 4281â€“4289. [Bibcode:2018GeoRL..45.4281H](#). [doi:10.1029/2018GL077424](#) . [hdl:20.500.11850/268470](#) . ISSN<sup>Â</sup> 1944-8007.
  - Hilaire, J<sup>Â</sup>me; Minx, Jan C.; Callaghan, Max W.; Edmonds, Jae; Luderer, Gunnar; Nemet, Gregory F.; Rogelj, Joeri; Zamora, Maria Mar (17 October 2019). "[Negative emissions and international climate goals](#)"â€“ learning from and about mitigation scenarios". *Climatic Change*. **157** (2): 189â€“219. [Bibcode:2019ClCh..157..189H](#). [doi:10.1007/s10584-019-02516-4](#) . [hdl:10044/1/74820](#) .
  - Hodder, Patrick; Martin, Brian (2009). "Climate Crisis? The Politics of Emergency Framing". *Economic and Political Weekly*. **44** (36): 53â€“60. ISSN<sup>Â</sup> 0012-9976. JSTOR<sup>Â</sup> 25663518.
  - Holding, S.; Allen, D. M.; Foster, S.; Hsieh, A.; et<sup>Â</sup> al. (2016). "Groundwater vulnerability on small islands". *Nature Climate Change*. **6** (12): 1100â€“1103. [Bibcode:2016NatCC...6.1100H](#). [doi:10.1038/nclimate3128](#). ISSN<sup>Â</sup> 1758-6798.
  - Joo, Gea-Jae; Kim, Ji Yoon; Do, Yuno; Lineman, Maurice (2015). "[Talking about Climate Change and Global Warming](#)". *PLOS ONE*. **10** (9): e0138996. [Bibcode:2015PLoSO..1038996L](#). [doi:10.1371/journal.pone.0138996](#) . ISSN<sup>Â</sup> 1932-6203. PMC<sup>Â</sup> 4587979 . PMID<sup>Â</sup> 26418127.
  - Kabir, Russell; Khan, Hafiz T. A.; Ball, Emma; Caldwell, Khan (2016). "[Climate Change Impact: The Experience of the Coastal Areas of Bangladesh Affected by Cyclones Sidr and Aila](#)". *Journal of Environmental and Public Health*. **2016**: 9654753. [doi:10.1155/2016/9654753](#) . PMC<sup>Â</sup> 5102735 . PMID<sup>Â</sup> 27867400.
  - Kaczan, David J.; Orgill-Meyer, Jennifer (2020). "[The impact of climate change on migration: a synthesis of recent empirical insights](#)". *Climatic Change*. **158** (3): 281â€“300. [Bibcode:2020ClCh..158..281K](#). [doi:10.1007/s10584-019-02560-0](#). S2CID<sup>Â</sup> 207988694. Retrieved 9 February 2021.
  - Kennedy, J. J.; Thorne, W. P.; Peterson, T. C.; Ruedy, R. A.; et<sup>Â</sup> al. (2010). Arndt, D. S.; Baringer, M. O.; Johnson, M. R. (eds.). "How do we know the world has warmed?". Special supplement: State of the Climate in 2009. *Bulletin of the American Meteorological Society*. **91** (7). S26-S27. [doi:10.1175/BAMS-91-7-StateoftheClimate](#).
  - Kopp, R. E.; Hayhoe, K.; Easterling, D. R.; Hall, T.; et<sup>Â</sup> al. (2017). "[Chapter 15: Potential Surprises: Compound Extremes and Tipping Elements](#)". In *USGCRP 2017*. pp.Â 1â€“470. [Archived](#) from the original on 20 August 2018.
  - Kossin, J. P.; Hall, T.; Knutson, T.; Kunkel, K. E.; Trapp, R. J.; Walizer, D. E.; Wehner, M. F. (2017). "[Chapter 9: Extreme Storms](#)". In *USGCRP2017*. pp.Â 1â€“470.
  - Knutson, T. (2017). "[Appendix C: Detection and attribution methodologies overview](#)". In *USGCRP2017*. pp.Â 1â€“470.
  - Kreidenweis, Ulrich; Humpen<sup>Â</sup>lder, Florian; Stevanovi<sup>Â</sup> Miodrag; Bodirskv, Benjamin Leon; et<sup>Â</sup> al. (July 2016).



- ["Afforestation to mitigate climate change: impacts on food prices under consideration of albedo effects". \*Environmental Research Letters\*. \*\*11\*\* \(8\): 085001. Bibcode:2016ERL....11h5001K. doi:10.1088/1748-9326/11/8/085001 . ISSNÂ 1748-9326. S2CIDÂ 8779827.](#)
- Kvande, H. (2014). ["The Aluminum Smelting Process". \*Journal of Occupational and Environmental Medicine\*. \*\*56\*\* \(5 Suppl\): S2â€"S4. doi:10.1097/JOM.0000000000000154. PMCÂ 4131936 . PMIDÂ 24806722.](#)
  - Lapenis, Andrei G. (1998). "Arrhenius and the Intergovernmental Panel on Climate Change". *Eos*. **79** (23): 271. [Bibcode:1998EOSTr..79..271L. doi:10.1029/98EO00206.](#)
  - Levermann, Anders; Clark, Peter U.; Marzeion, Ben; Milne, Glenn A.; etÂ al. (2013). ["The multimillennial sea-level commitment of global warming". \*Proceedings of the National Academy of Sciences\*. \*\*110\*\* \(34\): 13745â€"13750. Bibcode:2013PNAS..11013745L. doi:10.1073/pnas.1219414110 . ISSNÂ 0027-8424. PMCÂ 3752235 . PMIDÂ 23858443.](#)
  - Lenoir, Jonathan; Bertrand, Romain; Comte, Lise; Bourgeaud, Luana; etÂ al. (2020). ["Species better track climate warming in the oceans than on land". \*Nature Ecology & Evolution\*. \*\*4\*\* \(8\): 1044â€"1059. Bibcode:2020NatEE...4.1044L. doi:10.1038/s41559-020-1198-2. ISSNÂ 2397-334X. PMIDÂ 32451428. S2CIDÂ 218879068.](#)
  - Liepert, Beate G.; Previdi, Michael (2009). ["Do Models and Observations Disagree on the Rainfall Response to Global Warming?". \*Journal of Climate\*. \*\*22\*\* \(11\): 3156â€"3166. Bibcode:2009JCLI...22.3156L. doi:10.1175/2008JCLI2472.1 .](#)
  - Liverman, Diana M. (2009). "Conventions of climate change: constructions of danger and the dispossession of the atmosphere". *Journal of Historical Geography*. **35** (2): 279â€"296. [doi:10.1016/j.jhg.2008.08.008.](#)
  - Loeb, Norman G.; Johnson, Gregory C.; Thorsen, Tyler J.; Lyman, John M.; Rose, Fred G.; Kato, Seiji (2021). ["Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate". \*Geophysical Research Letters\*. \*\*48\*\* \(13\). American Geophysical Union \(AGU\). e2021GL093047. Bibcode:2021GeoRL..4893047L. doi:10.1029/2021gl093047 . ISSNÂ 0094-8276. S2CIDÂ 236233508.](#)
  - Mach, Katharine J.; Kraan, Caroline M.; Adger, W. Neil; Buhaug, Halvard; etÂ al. (2019). ["Climate as a risk factor for armed conflict". \*Nature\*. \*\*571\*\* \(7764\): 193â€"197. Bibcode:2019Natur.571..193M. doi:10.1038/s41586-019-1300-6. hdl:10871/37969 . ISSNÂ 1476-4687. PMIDÂ 31189956. S2CIDÂ 186207310.](#)
  - Matthews, H. Damon; Gillett, Nathan P.; Stott, Peter A.; Zickfeld, Kirsten (2009). "The proportionality of global warming to cumulative carbon emissions". *Nature*. **459** (7248): 829â€"832. [Bibcode:2009Natur.459..829M. doi:10.1038/nature08047. ISSNÂ 1476-4687. PMIDÂ 19516338. S2CIDÂ 4423773.](#)
  - Matthews, Tom (2018). ["Humid heat and climate change". \*Progress in Physical Geography: Earth and Environment\*. \*\*42\*\* \(3\): 391â€"405. Bibcode:2018PrPG...42..391M. doi:10.1177/0309133318776490. S2CIDÂ 134820599.](#)
  - McNeill, V. Faye (2017). ["Atmospheric Aerosols: Clouds, Chemistry, and Climate". \*Annual Review of Chemical and Biomolecular Engineering\*. \*\*8\*\* \(1\): 427â€"444. doi:10.1146/annurev-chembioeng-060816-101538 . ISSNÂ 1947-5438. PMIDÂ 28415861.](#)
  - Melillo, J. M.; Frey, S. D.; [DeAngelis, K. M.](#); Werner, W. J.; etÂ al. (2017). ["Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world". \*Science\*. \*\*358\*\* \(6359\): 101â€"105. Bibcode:2017Sci...358..101M. doi:10.1126/science.aan2874 . hdl:1912/9383 . PMIDÂ 28983050.](#)
  - Mercure, J.-F.; Pollitt, H.; ViÃ±uales, J. E.; Edwards, N. R.; etÂ al. (2018). ["Macroeconomic impact of stranded fossil fuel assets" \(PDF\). \*Nature Climate Change\*. \*\*8\*\* \(7\): 588â€"593. Bibcode:2018NatCC...8..588M. doi:10.1038/s41558-018-0182-1. hdl:10871/37807. ISSNÂ 1758-6798. S2CIDÂ 89799744.](#)
  - Mitchum, G. T.; Masters, D.; Hamlington, B. D.; Fasullo, J. T.; etÂ al. (2018). ["Climate-changeâ€"driven accelerated sea-level rise detected in the altimeter era". \*Proceedings of the National Academy of Sciences\*. \*\*115\*\* \(9\): 2022â€"2025. Bibcode:2018PNAS..115.2022N. doi:10.1073/pnas.1717312115 . ISSNÂ 0027-8424. PMCÂ 5834701 . PMIDÂ 29440401.](#)
  - National Academies of Sciences, Engineering, and Medicine (2019). ["Negative Emissions Technologies and Reliable Sequestration: A Research Agenda" \(Report\). Washington, D.C.: The National Academies Press. doi:10.17226/25259. ISBNÂ 978-0-309-48455-8.](#)
  - National Research Council (2011). ["Causes and Consequences of Climate Change". \*America's Climate Choices\*. Washington, D.C.: The National Academies Press. doi:10.17226/12781. ISBNÂ 978-0-309-14585-5. Archived from the original on 21 July 2015. Retrieved 28 January 2019.](#)
  - Neukom, Raphael; Steiger, Nathan; GÃ³mez-Navarro, Juan JosÃ©; Wang, Jianghao; etÂ al. (2019a). ["No evidence for globally coherent warm and cold periods over the preindustrial Common Era" \(PDF\). \*Nature\*. \*\*571\*\* \(7766\): 550â€"554. Bibcode:2019Natur.571..550N. doi:10.1038/s41586-019-1401-2. ISSNÂ 1476-4687. PMIDÂ 31341300. S2CIDÂ 198494930.](#)
  - Neukom, Raphael; Barboza, Luis A.; Erb, Michael P.; Shi, Feng; etÂ al. (2019b). ["Consistent multidecadal variability in global temperature reconstructions and simulations over the Common Era". \*Nature Geoscience\*. \*\*12\*\* \(8\): 643â€"649. Bibcode:2019NatGe..12..643P. doi:10.1038/s41561-019-0400-0. ISSNÂ 1752-0908. PMCÂ 6675609 . PMIDÂ 31372180.](#)
  - O'Neill, Saffron J.; Boykoff, Max (2010). ["Climate denial, skeptic, or contrarian?". \*Proceedings of the National Academy of Sciences of the United States of America\*. \*\*107\*\* \(39\): E151. Bibcode:2010PNAS..107E.151O. doi:10.1073/pnas.1010507107 . ISSNÂ 0027-8424. PMCÂ 2947866 . PMIDÂ 20807754.](#)
  - Poloczanska, Elvira S.; Brown, Christopher J.; Sydeman, William J.; Kiessling, Wolfgang; etÂ al. (2013). ["Global imprint of climate change on marine life" \(PDF\). \*Nature Climate Change\*. \*\*3\*\* \(10\): 919â€"925. Bibcode:2013NatCC...3..919P. doi:10.1038/nclimate1958. hdl:2160/34111. ISSNÂ 1758-6798.](#)
  - [Rahmstorf, Stefan](#); [Cazenave, Anny](#); [Church, John A.](#); Hansen, James E.; etÂ al. (2007). ["Recent Climate Observations Compared to Projections" \(PDF\). \*Science\*. \*\*316\*\* \(5825\): 709. Bibcode:2007Sci...316..709R. doi:10.1126/science.1136843. PMIDÂ 17272686. S2CIDÂ 34008905. Archived \(PDF\) from the original on 6 September 2018.](#)
  - Ramanathan, V.; Carmichael, G. (2008). ["Global and Regional Climate Changes due to Black Carbon". \*Nature Geoscience\*. \*\*1\*\* \(4\): 221â€"227. Bibcode:2008NatGe...1..221R. doi:10.1038/ngeo156.](#)
  - Randel, William J.; [Shine, Keith P.](#); Austin, John; Barnett, John; etÂ al. (2009). ["An update of observed stratospheric temperature trends". \*Journal of Geophysical Research\*. \*\*114\*\* \(D2\). D02107. Bibcode:2009JGRD..114.2107R](#)

- [temperature trends - Journal of Geophysical Research](#). **115** (D2): D2107. [Bibcode:2008JGRD.115.2107A](#). [doi:10.1029/2008JD010421](#) . [HALÂ hal-00355600](#).
- Rauner, Sebastian; Bauer, Nico; Dirnaichner, Alois; Van Dingenen, Rita; Mutel, Chris; Luderer, Gunnar (2020). ["Coal-exit health and environmental damage reductions outweigh economic impacts"](#). *Nature Climate Change*. **10** (4): 308â€“312. [Bibcode:2020NatCC...10..308R](#). [doi:10.1038/s41558-020-0728-x](#). [ISSNÂ 1758-6798](#). [S2CIDÂ 214619069](#).
  - Rogelj, Joeri; Forster, Piers M.; Kriegler, Elmar; Smith, Christopher J.; etÂ al. (2019). ["Estimating and tracking the remaining carbon budget for stringent climate targets"](#). *Nature*. **571** (7765): 335â€“342. [Bibcode:2019Natur.571..335R](#). [doi:10.1038/s41586-019-1368-z](#) . [hdl:10044/1/78011](#) . [ISSNÂ 1476-4687](#). [PMIDÂ 31316194](#). [S2CIDÂ 197542084](#).
  - Rogelj, Joeri; Meinshausen, Malte; Schaeffer, Michiel; Knutti, Reto; Riahi, Keywan (2015). ["Impact of short-lived non-CO2 mitigation on carbon budgets for stabilizing global warming"](#). *Environmental Research Letters*. **10** (7): 1â€“10. [Bibcode:2015ERL....10g5001R](#). [doi:10.1088/1748-9326/10/7/075001](#) . [hdl:20.500.11850/103371](#) .
  - Ruseva, Tatyana; Hedrick, Jamie; Marland, Gregg; Tovar, Henning; etÂ al. (2020). ["Rethinking standards of permanence for terrestrial and coastal carbon: implications for governance and sustainability"](#). *Current Opinion in Environmental Sustainability*. **45**: 69â€“77. [Bibcode:2020COES...45...69R](#). [doi:10.1016/j.cosust.2020.09.009](#). [ISSNÂ 1877-3435](#). [S2CIDÂ 229069907](#).
  - Samset, B. H.; Sand, M.; Smith, C. J.; Bauer, S. E.; etÂ al. (2018). ["Climate Impacts From a Removal of Anthropogenic Aerosol Emissions"](#) (PDF). *Geophysical Research Letters*. **45** (2): 1020â€“1029. [Bibcode:2018GeoRL..45.1020S](#). [doi:10.1002/2017GL076079](#). [ISSNÂ 1944-8007](#). [PMCÂ 7427631](#) . [PMIDÂ 32801404](#).
  - Sand, M.; Berntsen, T. K.; von Salzen, K.; Flanner, M. G.; etÂ al. (2015). "Response of Arctic temperature to changes in emissions of short-lived climate forcers". *Nature*. **6** (3): 286â€“289. [Bibcode:2016NatCC...6..286S](#). [doi:10.1038/nclimate2880](#).
  - Schmidt, Gavin A.; Ruedy, Reto A.; Miller, Ron L.; Lacis, Andy A. (2010). ["Attribution of the present-day total greenhouse effect"](#). *Journal of Geophysical Research: Atmospheres*. **115** (D20): D20106. [Bibcode:2010JGRD..11520106S](#). [doi:10.1029/2010JD014287](#) . [ISSNÂ 2156-2202](#). [S2CIDÂ 28195537](#).
  - Serdeczny, Olivia; Adams, Sophie; Baarsch, Florent; Coumou, Dim; etÂ al. (2016). ["Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions"](#) (PDF). *Regional Environmental Change*. **17** (6): 1585â€“1600. [doi:10.1007/s10113-015-0910-2](#). [hdl:1871.1/c8dfb143-d9e1-4eef-9bbe-67b3c338d07f](#). [ISSNÂ 1436-378X](#). [S2CIDÂ 3900505](#).
  - Sutton, Rowan T.; Dong, Buwen; Gregory, Jonathan M. (2007). ["Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations"](#). *Geophysical Research Letters*. **34** (2): L02701. [Bibcode:2007GeoRL..34.2701S](#). [doi:10.1029/2006GL028164](#) .
  - Smale, Dan A.; Wernberg, Thomas; Oliver, Eric C. J.; Thomsen, Mads; Harvey, Ben P. (2019). ["Marine heatwaves threaten global biodiversity and the provision of ecosystem services"](#) (PDF). *Nature Climate Change*. **9** (4): 306â€“312. [Bibcode:2019NatCC...9..306S](#). [doi:10.1038/s41558-019-0412-1](#). [ISSNÂ 1758-6798](#). [S2CIDÂ 91471054](#).
  - Smith, Joel B.; Schneider, Stephen H.; Oppenheimer, Michael; Yohe, Gary W.; etÂ al. (2009). ["Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change \(IPCC\) 'reasons for concern' "](#). *Proceedings of the National Academy of Sciences*. **106** (11): 4133â€“4137. [Bibcode:2009PNAS..106.4133S](#). [doi:10.1073/pnas.0812355106](#) . [PMCÂ 2648893](#) . [PMIDÂ 19251662](#).
  - Smith, N.; Leiserowitz, A. (2013). ["The role of emotion in global warming policy support and opposition"](#). *Risk Analysis*. **34** (5): 937â€“948. [doi:10.1111/risa.12140](#). [PMCÂ 4298023](#) . [PMIDÂ 24219420](#).
  - Stroeve, J.; Holland, Marika M.; Meier, Walt; Scambos, Ted; etÂ al. (2007). ["Arctic sea ice decline: Faster than forecast"](#). *Geophysical Research Letters*. **34** (9): L09501. [Bibcode:2007GeoRL..34.9501S](#). [doi:10.1029/2007GL029703](#) .
  - Storelvmo, T.; Phillips, P. C. B.; Lohmann, U.; Leirvik, T.; Wild, M. (2016). ["Disentangling greenhouse warming and aerosol cooling to reveal Earth's climate sensitivity"](#) (PDF). *Nature Geoscience*. **9** (4): 286â€“289. [Bibcode:2016NatGe...9..286S](#). [doi:10.1038/ngeo2670](#). [ISSNÂ 1752-0908](#).
  - Turetsky, Merritt R.; Abbott, Benjamin W.; Jones, Miriam C.; Anthony, Katey Walter; etÂ al. (2019). ["Permafrost collapse is accelerating carbon release"](#). *Nature*. **569** (7754): 32â€“34. [Bibcode:2019Natur.569...32T](#). [doi:10.1038/d41586-019-01313-4](#) . [PMIDÂ 31040419](#).
  - Turner, Monica G.; Calder, W. John; Cumming, Graeme S.; Hughes, Terry P.; etÂ al. (2020). ["Climate change, ecosystems and abrupt change: science priorities"](#). *Philosophical Transactions of the Royal Society B*. **375** (1794). [doi:10.1098/rstb.2019.0105](#). [PMCÂ 7017767](#) . [PMIDÂ 31983326](#).
  - Twomey, S. (1977). ["The Influence of Pollution on the Shortwave Albedo of Clouds"](#). *J. Atmos. Sci.* **34** (7): 1149â€“1152. [Bibcode:1977JAtS...34.1149T](#). [doi:10.1175/1520-0469\(1977\)034<1149:TIOPOT>2.0.CO;2](#) . [ISSNÂ 1520-0469](#).
  - Tyndall, John (1861). ["On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connection of Radiation, Absorption, and Conduction"](#). *Philosophical Magazine*. **4**. **22**: 169â€“194, 273â€“285. [Archived](#) from the original on 26 March 2016.
  - Urban, Mark C. (2015). ["Accelerating extinction risk from climate change"](#). *Science*. **348** (6234): 571â€“573. [Bibcode:2015Sci...348..571U](#). [doi:10.1126/science.aaa4984](#) . [ISSNÂ 0036-8075](#). [PMIDÂ 25931559](#).
  - USGCRP (2009). Karl, T. R.; Melillo, J.; Peterson, T.; Hassol, S. J. (eds.). *Global Climate Change Impacts in the United States*. Cambridge University Press. [ISBNÂ 978-0-521-14407-0](#). [Archived](#) from the original on 6 April 2010. Retrieved 19 January 2024.
  - USGCRP (2017). Wuebbles, D. J.; Fahey, D. W.; Hibbard, K. A.; Dokken, D. J.; etÂ al. (eds.). *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Washington, D.C.: U.S. Global Change Research Program. [doi:10.7930/J0J964J6](#).
  - Vandyck, T.; Keramidas, K.; Kitous, A.; Spadaro, J.; etÂ al. (2018). ["Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges"](#). *Nature Communications*. **9** (4939): 4939. [Bibcode:2018NatCo...9.4939V](#). [doi:10.1038/s41467-018-06885-9](#). [PMCÂ 6250710](#) . [PMIDÂ 30467311](#).
  - Wuebbles, D. J.; Easterling, D. R.; Hayhoe, K.; Knutson, T.; etÂ al. (2017). ["Chapter 1: Our Globally Changing Climate"](#) (PDF). In *USGCRP2017*.
  - Walsh, John; Wuebbles, Donald; Hayhoe, Katherine; Kossin, Kossin; etÂ al. (2014). ["Appendix 3: Climate Science](#)



- Wulsh, John; Wuebbles, Donald; Rayner, Katherine; Rosh, Ross; et al. (2017). [Appendix 3. Climate Science Supplement](#) (PDF). *Climate Change Impacts in the United States: The Third National Climate Assessment*. US National Climate Assessment.
- Wang, Bin; Shugart, Herman H.; Lerdau, Manuel T. (2017). ["Sensitivity of global greenhouse gas budgets to tropospheric ozone pollution mediated by the biosphere"](#). *Environmental Research Letters*. **12** (8): 084001. [Bibcode:2017ERL....12h4001W](#). [doi:10.1088/1748-9326/aa7885](#) . [ISSNÂ 1748-9326](#).
- Watts, Nick; Adger, W Neil; Agnolucci, Paolo; Blackstock, Jason; et al. (2015). ["Health and climate change: policy responses to protect public health"](#). *The Lancet*. **386** (10006): 1861â€“1914. [doi:10.1016/S0140-6736\(15\)60854-6](#). [hdl:10871/20783](#) . [PMIDÂ 26111439](#). [S2CIDÂ 205979317](#). [Archived](#) from the original on 7 April 2017.
- Watts, Nick; Amann, Markus; Arnell, Nigel; Ayeb-Karlsson, Sonja; et al. (2019). ["The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate"](#). *The Lancet*. **394** (10211): 1836â€“1878. [Bibcode:2019Lanc..394.1836W](#). [doi:10.1016/S0140-6736\(19\)32596-6](#). [hdl:10871/40583](#) . [ISSNÂ 0140-6736](#). [PMIDÂ 31733928](#). [S2CIDÂ 207976337](#).
- Weart, Spencer (2013). ["Rise of interdisciplinary research on climate"](#). *Proceedings of the National Academy of Sciences*. **110** (Supplement 1): 3657â€“3664. [doi:10.1073/pnas.1107482109](#) . [PMCA 3586608](#) . [PMIDÂ 22778431](#).
- Wild, M.; Gilgen, Hans; Roesch, Andreas; Ohmura, Atsumu; et al. (2005). "From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface". *Science*. **308** (5723): 847â€“850. [Bibcode:2005Sci...308..847W](#). [doi:10.1126/science.1103215](#). [PMIDÂ 15879214](#). [S2CIDÂ 13124021](#).
- Williams, Richard G; Ceppi, Paulo; Katavouta, Anna (2020). ["Controls of the transient climate response to emissions by physical feedbacks, heat uptake and carbon cycling"](#). *Environmental Research Letters*. **15** (9): 0940c1. [Bibcode:2020ERL....15i40c1W](#). [doi:10.1088/1748-9326/ab97c9](#) . [hdl:10044/1/80154](#) .
- Wolff, Eric W.; Shepherd, John G.; Shuckburgh, Emily; Watson, Andrew J. (2015). ["Feedbacks on climate in the Earth system: introduction"](#). *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. **373** (2054): 20140428. [Bibcode:2015RSPTA.37340428W](#). [doi:10.1098/rsta.2014.0428](#). [PMCA 4608041](#) . [PMIDÂ 26438277](#).
- Zeng, Ning; Yoon, Jinho (2009). ["Expansion of the world's deserts due to vegetation-albedo feedback under global warming"](#). *Geophysical Research Letters*. **36** (17): L17401. [Bibcode:2009GeoRL..3617401Z](#). [doi:10.1029/2009GL039699](#) . [ISSNÂ 1944-8007](#). [S2CIDÂ 1708267](#).
- Zhang, Jinlun; Lindsay, Ron; Steele, Mike; Schweiger, Axel (2008). ["What drove the dramatic arctic sea ice retreat during summer 2007?"](#). *Geophysical Research Letters*. **35** (11): 1â€“5. [Bibcode:2008GeoRL..3511505Z](#). [doi:10.1029/2008gl034005](#) . [S2CIDÂ 9387303](#).
- Zhao, C.; Liu, B.; et al. (2017). ["Temperature increase reduces global yields of major crops in four independent estimates"](#). *Proceedings of the National Academy of Sciences*. **114** (35): 9326â€“9331. [Bibcode:2017PNAS..114.9326Z](#). [doi:10.1073/pnas.1701762114](#) . [PMCA 5584412](#) . [PMIDÂ 28811375](#).

## Books, reports and legal documents

- Academia Brasileira de CiÃ©ncias (Brazil); Royal Society of Canada; Chinese Academy of Sciences; AcadÃ©mie des Sciences (France); Deutsche Akademie der Naturforscher Leopoldina (Germany); Indian National Science Academy; Accademia Nazionale dei Lincei (Italy); Science Council of Japan, Academia Mexicana de Ciencias; Academia Mexicana de Ciencias (Mexico); Russian Academy of Sciences; Academy of Science of South Africa; Royal Society (United Kingdom); National Academy of Sciences (United States of America) (May 2009). ["G8+5 Academies' joint statement: Climate change and the transformation of energy technologies for a low carbon future"](#) (PDF). The National Academies of Sciences, Engineering, and Medicine. Archived from [the original](#) (PDF) on 15 February 2010. Retrieved 5 May 2010.
- [Archer, David; Pierrehumbert, Raymond](#) (2013). *The Warming Papers: The Scientific Foundation for the Climate Change Forecast*. John Wiley & Sons. [ISBNÂ 978-1-118-68733-8](#).
- Bridle, Richard; Sharma, Shruti; Mostafa, Mostafa; Geddes, Anna (June 2019). [Fossil Fuel to Clean Energy Subsidy Swaps](#) (PDF) (Report).
- Climate Focus (December 2015). ["The Paris Agreement: Summary. Climate Focus Client Brief on the Paris Agreement III"](#) (PDF). [Archived](#) (PDF) from the original on 5 October 2018. Retrieved 12 April 2019.
- ConceiÃ§Ã£o; et al. (2020). [Human Development Report 2020 The Next Frontier: Human Development and the Anthropocene](#) (PDF) (Report). [United Nations Development Programme](#). Retrieved 9 January 2021.
- [DeFries, Ruth](#); Edenhofer, Ottmar; Halliday, Alex; Heal, Geoffrey; et al. (September 2019). [The missing economic risks in assessments of climate change impacts](#) (PDF) (Report). Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.
- Dessler, Andrew E. and Edward A. Parson, eds. *The science and politics of global climate change: A guide to the debate* (Cambridge University Press, 2019).
- Dessai, Suraje (2001). ["The climate regime from The Hague to Marrakech: Saving or sinking the Kyoto Protocol?"](#) (PDF). *Tyndall Centre Working Paper 12*. Tyndall Centre. Archived from [the original](#) (PDF) on 10 June 2012. Retrieved 5 May 2010.
- Dunlap, Riley E.; McCright, Aaron M. (2011). "Chapter 10: Organized climate change denial". In Dryzek, John S.; Norgaard, Richard B.; Schlosberg, David (eds.). *The Oxford Handbook of Climate Change and Society*. Oxford University Press. pp.Â 144â€“160. [ISBNÂ 978-0-19-956660-0](#).
- Dunlap, Riley E.; McCright, Aaron M. (2015). "Chapter 10: Challenging Climate Change: The Denial Countermovement". In Dunlap, Riley E.; Brulle, Robert J. (eds.). *Climate Change and Society: Sociological Perspectives*. Oxford University Press. pp.Â 300â€“332. [ISBNÂ 978-0-19-935611-9](#).
- European Commission (28 November 2018). [In-depth analysis accompanying the Commission Communication COM\(2018\) 773: A Clean Planet for all â€” A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy](#) (PDF) (Report). Brussels. p.Â 188.
- Flavell, Alex (2014). [IOM outlook on migration, environment and climate change](#) (PDF) (Report). Geneva, Switzerland: [International Organization for Migration](#) (IOM). [ISBNÂ 978-92-9068-703-0](#). [OCLCÂ 913058074](#).
- Fleming, James Rodger (2007). *The Callendar Effect: the life and work of Guy Stewart Callendar (1898â€“1964)*.

- Boston: American Meteorological Society. [ISBNÂ 978-1-878220-76-9](#).
- Flynn, C.; Yamasumi, E.; Fisher, S.; Snow, D.; etÂ al. (January 2021). [Peoples' Climate Vote](#) (PDF) (Report). UNDP and University of Oxford. Retrieved 5 August 2021.
  - Forster, P. M.; Smith, C. J.; Walsh, T.; Lamb, W.F.; etÂ al. (June 2023). ["Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence"](#) (PDF). *Earth System Science Data*. **15** (6): 2295â€“2327. [Bibcode:2023ESSD...15.2295F](#). [doi:10.5194/essd-15-2295-2023](#) . Retrieved 25 October 2023.
  - Global Methane Initiative (2020). [Global Methane Emissions and Mitigation Opportunities](#) (PDF) (Report). Global Methane Initiative.
  - Hallegatte, Stephane; Bangalore, Mook; Bonzanigo, Laura; Fay, Marianne; etÂ al. (2016). [Shock WavesÂ : Managing the Impacts of Climate Change on Poverty. Climate Change and Development](#) (PDF). Washington, D.C.: World Bank. [doi:10.1596/978-1-4648-0673-5](#). [hdl:10986/22787](#). [ISBNÂ 978-1-4648-0674-2](#).
  - Haywood, Jim (2016). "Chapter 27 â€” Atmospheric Aerosols and Their Role in Climate Change". In Letcher, Trevor M. (ed.). *Climate Change: Observed Impacts on Planet Earth*. Elsevier. [ISBNÂ 978-0-444-63524-2](#).
  - IEA (December 2020). ["COVID-19 and energy efficiency"](#). Energy Efficiency 2020 (Report). Paris, France. Retrieved 6 April 2021.
  - IEA (October 2021). [Net Zero By 2050: A Roadmap for the Global Energy Sector](#) (PDF) (Report). Paris, France. Retrieved 4 April 2022.
  - IEA (October 2023). [World Energy Outlook 2023](#) (PDF) (Report). Paris, France. Retrieved 25 October 2021.
  - Krogstrup, Signe; Oman, William (4 September 2019). [Macroeconomic and Financial Policies for Climate Change Mitigation: A Review of the Literature](#) (PDF). IMF working papers. Vol.Â 19. [doi:10.5089/9781513511955.001](#). [ISBNÂ 978-1-5135-1195-5](#). [ISSNÂ 1018-5941](#). [S2CIDÂ 203245445](#).
  - Leiserowitz, A.; Carman, J.; Buttermore, N.; Wang, X.; etÂ al. (2021). [International Public Opinion on Climate Change](#) (PDF) (Report). New Haven, CT: Yale Program on Climate Change Communication and Facebook Data for Good. Retrieved 5 August 2021.
  - Letcher, Trevor M., ed. (2020). *Future Energy: Improved, Sustainable and Clean Options for our Planet* (ThirdÂ ed.). Elsevier. [ISBNÂ 978-0-08-102886-5](#).
  - Meinshausen, Malte (2019). "Implications of the Developed Scenarios for Climate Change". In Teske, Sven (ed.). [Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5Â Â°C and +2Â Â°C](#). Springer International Publishing. pp.Â 459â€“469. [doi:10.1007/978-3-030-05843-2\\_12](#) . [ISBNÂ 978-3-030-05843-2](#). [S2CIDÂ 133868222](#).
  - Miller, J.; Du, L.; Kodjak, D. (2017). [Impacts of World-Class Vehicle Efficiency and Emissions Regulations in Select G20 Countries](#) (PDF) (Report). Washington, D.C.: The International Council on Clean Transportation.
  - MÅller, Benito (February 2010). [Copenhagen 2009: Failure or final wake-up call for our leaders? EV 49](#) (PDF). [Oxford Institute for Energy Studies](#). p.Â i. [ISBNÂ 978-1-907555-04-6](#). [Archived](#) (PDF) from the original on 10 July 2017. Retrieved 18 May 2010.
  - National Academies (2008). [Understanding and responding to climate change: Highlights of National Academies Reports, 2008 edition](#) (PDF) (Report). National Academy of Sciences. Archived from [the original](#) (PDF) on 11 October 2017. Retrieved 9 November 2010.
  - National Research Council (2012). [Climate Change: Evidence, Impacts, and Choices](#) (Report). Washington, D.C.: National Academy of Sciences. Retrieved 21 November 2023.
  - Newell, Peter (14 December 2006). [Climate for Change: Non-State Actors and the Global Politics of the Greenhouse](#). Cambridge University Press. [ISBNÂ 978-0-521-02123-4](#). Retrieved 30 July 2018.
  - NOAA. ["January 2017 analysis from NOAA: Global and Regional Sea Level Rise Scenarios for the United States"](#) (PDF). [Archived](#) (PDF) from the original on 18 December 2017. Retrieved 7 February 2019.
  - Olivier, J. G. J.; Peters, J. A. H. W. (2019). [Trends in global CO2 and total greenhouse gas emissions](#) (PDF). The Hague: PBL Netherlands Environmental Assessment Agency.
  - Oreskes, Naomi (2007). "The scientific consensus on climate change: How do we know we're not wrong?". In DiMento, Joseph F. C.; Doughman, Pamela M. (eds.). *Climate Change: What It Means for Us, Our Children, and Our Grandchildren*. The MIT Press. [ISBNÂ 978-0-262-54193-0](#).
  - Oreskes, Naomi; Conway, Erik (2010). *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (firstÂ ed.). Bloomsbury Press. [ISBNÂ 978-1-59691-610-4](#).
  - Pew Research Center (November 2015). [Global Concern about Climate Change, Broad Support for Limiting Emissions](#) (PDF) (Report). Retrieved 5 August 2021.
  - REN21 (2020). [Renewables 2020 Global Status Report](#) (PDF). Paris: REN21 Secretariat. [ISBNÂ 978-3-948393-00-7](#).
  - Royal Society (13 April 2005). [Economic Affairs â€” Written Evidence](#). The Economics of Climate Change, the Second Report of the 2005â€“2006 session, produced by the UK Parliament House of Lords Economics Affairs Select Committee. UK Parliament. [Archived](#) from the original on 13 November 2011. Retrieved 9 July 2011.
  - Setzer, Joana; Byrnes, Rebecca (July 2019). [Global trends in climate change litigation: 2019 snapshot](#) (PDF). London: the Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy.
  - Steinberg, D.; Bielen, D.; etÂ al. (July 2017). [Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios with Widespread Electrification and Power Sector Decarbonization](#) (PDF) (Report). Golden, Colorado: National Renewable Energy Laboratory.
  - Teske, Sven, ed. (2019). ["Executive Summary"](#) (PDF). [Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5Â Â°C and +2Â Â°C](#). Springer International Publishing. pp.Â xiiiâ€“xxxv. [doi:10.1007/978-3-030-05843-2](#) . [ISBNÂ 978-3-030-05843-2](#). [S2CIDÂ 198078901](#).
  - Teske, Sven; Pregger, Thomas; Naegler, Tobias; Simon, Sonja; etÂ al. (2019). "Energy Scenario Results". In Teske, Sven (ed.). [Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5Â Â°C and +2Â Â°C](#). Springer International Publishing. pp.Â 175â€“402. [doi:10.1007/978-3-030-05843-2\\_8](#) . [ISBNÂ 978-3-030-05843-2](#).
  - Teske, Sven (2019). "Trajectories for a Just Transition of the Fossil Fuel Industry". In Teske, Sven (ed.). [Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5Â Â°C and +2Â Â°C](#). Springer International Publishing. pp.Â 403â€“411. [doi:10.1007/978-3-030-](#)



[05843-2\\_9](#) . ISBNÂ 978-3-030-05843-2. S2CIDÂ 133961910.

- UN FAO (2016). [Global Forest Resources Assessment 2015. How are the world's forests changing?](#) (PDF) (Report). Food and Agriculture Organization of the United Nations. ISBNÂ 978-92-5-109283-5. Retrieved 1 December 2019.
- [Emissions Gap Report 2019](#) (PDF). Nairobi: United Nations Environment Programme. 2019. ISBNÂ 978-92-807-3766-0.
- [Emissions Gap Report 2021](#) (PDF). Nairobi: United Nations Environment Programme. 2021. ISBNÂ 978-92-807-3890-2.
- UNEP (2018). [The Adaptation Gap Report 2018](#). Nairobi, Kenya: United Nations Environment Programme (UNEP). ISBNÂ 978-92-807-3728-8.
- UNFCCC (1992). [United Nations Framework Convention on Climate Change](#) (PDF).
- UNFCCC (1997). ["Kyoto Protocol to the United Nations Framework Convention on Climate Change"](#). United Nations.
- UNFCCC (30 March 2010). ["Decision 2/CP.15: Copenhagen Accord"](#). *Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19Â DecemberÂ 2009*. United Nations Framework Convention on Climate Change. FCCC/CP/2009/11/Add.1. [Archived](#) from the original on 30 April 2010. Retrieved 17 May 2010.
- UNFCCC (2015). ["Paris Agreement"](#) (PDF). United Nations Framework Convention on Climate Change.
- UNFCCC (26 February 2021). [Nationally determined contributions under the Paris Agreement Synthesis report by the secretariat](#) (PDF) (Report). [United Nations Framework Convention on Climate Change](#).
- Park, Susin (May 2011). ["Climate Change and the Risk of Statelessness: The Situation of Low-lying Island States"](#) (PDF). United Nations High Commissioner for Refugees. [Archived](#) (PDF) from the original on 2 May 2013. Retrieved 13 April 2012.
- United States Environmental Protection Agency (2016). [Methane and Black Carbon Impacts on the Arctic: Communicating the Science](#) (Report). [Archived](#) from the original on 6 September 2017. Retrieved 27 February 2019.
- Van Oldenborgh, Geert-Jan; Philip, Sjoukje; Kew, Sarah; Vautard, Robert; etÂ al. (2019). "Human contribution to the record-breaking June 2019 heat wave in France". *Semantic Scholar*. S2CIDÂ 199454488.
- Weart, Spencer (October 2008). [The Discovery of Global Warming](#) (2ndÂ ed.). Cambridge, MA: Harvard University Press. ISBNÂ 978-0-674-03189-0. [Archived](#) from the original on 18 November 2016. Retrieved 16 June 2020.
- [Weart, Spencer](#) (February 2019). [The Discovery of Global Warming](#) (onlineÂ ed.). [Archived](#) from the original on 18 June 2020. Retrieved 19 June 2020.
  - Weart, Spencer (January 2020). ["The Carbon Dioxide Greenhouse Effect"](#). *The Discovery of Global Warming*. American Institute of Physics. [Archived](#) from the original on 11 November 2016. Retrieved 19 June 2020.
  - Weart, Spencer (January 2020). ["The Public and Climate Change"](#). *The Discovery of Global Warming*. American Institute of Physics. [Archived](#) from the original on 11 November 2016. Retrieved 19 June 2020.
    - Weart, Spencer (January 2020). ["The Public and Climate Change: Suspicions of a Human-Caused Greenhouse \(1956â€"1969\)"](#). *The Discovery of Global Warming*. American Institute of Physics. [Archived](#) from the original on 11 November 2016. Retrieved 19 June 2020.
  - Weart, Spencer (January 2020). ["The Public and Climate Change \(cont.Â â€" since 1980\)"](#). *The Discovery of Global warming*. American Institute of Physics. [Archived](#) from the original on 11 November 2016. Retrieved 19 June 2020.
    - Weart, Spencer (January 2020). ["The Public and Climate Change: The Summer of 1988"](#). *The Discovery of Global Warming*. American Institute of Physics. [Archived](#) from the original on 11 November 2016. Retrieved 19 June 2020.
- [State and Trends of Carbon Pricing 2019](#) (PDF) (Report). Washington, D.C.: World Bank. June 2019. doi:10.1596/978-1-4648-1435-8. hdl:10986/29687 . ISBNÂ 978-1-4648-1435-8.
- World Health Organization (2014). [Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s](#) (PDF) (Report). Geneva, Switzerland. ISBNÂ 978-92-4-150769-1.
- World Health Organization (2016). [Ambient air pollution: a global assessment of exposure and burden of disease](#) (Report). Geneva, Switzerland. ISBNÂ 978-92-4-151135-3.
- [COP24 Special Report Health and Climate Change](#) (PDF). Geneva: World Health Organization. 2018. ISBNÂ 978-92-4-151497-2.
- [WMO Statement on the State of the Global Climate in 2020](#). WMO-No. 1264. Geneva: [World Meteorological Organization](#). 2021. ISBNÂ 978-92-63-11264-4.
- [Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050](#) (PDF). Washington, D.C.: World Resources Institute. December 2019. ISBNÂ 978-1-56973-953-2.

## Non-technical sources

- [Associated Press](#)
  - Colford, Paul (22 September 2015). ["An addition to AP Stylebook entry on global warming"](#). *AP Style Blog*. Retrieved 6 November 2019.
- [BBC](#)
  - ["UK Parliament declares climate change emergency"](#). BBC. 1 May 2019. Retrieved 30 June 2019.
  - Rigby, Sara (3 February 2020). ["Climate change: should we change the terminology?"](#). *BBC Science Focus Magazine*. Retrieved 24 March 2020.
- [Bulletin of the Atomic Scientists](#)
  - Stover, Dawn (23 September 2014). ["The global warming 'hiatus' "](#). *Bulletin of the Atomic Scientists*. [Archived](#) from the original on 11 July 2020.
- [Carbon Brief](#)
  - Yeo, Sophie (4 January 2017). ["Clean energy: The challenge of achieving a 'just transition' for workers"](#). *Carbon Brief*. Retrieved 18 May 2020.
  - McSweeney, Robert M.; Hausfather, Zeke (15 January 2018). ["Q&A: How do climate models work?"](#). *Carbon Brief*. [Archived](#) from the original on 5 March 2019. Retrieved 2 March 2019.
  - Hausfather, Zeke (19 April 2018). ["Explainer: How 'Shared Socioeconomic Pathways' explore future climate](#)

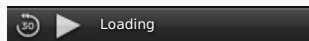


- [change](#)". *Carbon Brief*. Retrieved 20 July 2019.
- Hausfather, Zeke (8 October 2018). "[Analysis: Why the IPCC 1.5C report expanded the carbon budget](#)". *Carbon Brief*. Retrieved 28 July 2020.
- Dunne, Daisy; Gabbatiss, Josh; Mcsweeney, Robert (7 January 2020). "[Media reaction: Australia's bushfires and climate change](#)". *Carbon Brief*. Retrieved 11 January 2020.
- [Climate.gov](#)
  - Lindsey, Rebecca (23 June 2022). "[Climate Change: Atmospheric Carbon Dioxide](#)". *Climate.gov*. Retrieved 7 May 2023.
- [Deutsche Welle](#)
  - Ruiz, Irene Banos (22 June 2019). "[Climate Action: Can We Change the Climate From the Grassroots Up?](#)". Ecowatch. Deutsche Welle. [Archived](#) from the original on 23 June 2019. Retrieved 23 June 2019.
- [EPA](#)
  - "[Myths vs. Facts: Denial of Petitions for Reconsideration of the Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202\(a\) of the Clean Air Act](#)". U.S. Environmental Protection Agency. 25 August 2016. Retrieved 7 August 2017.
  - US EPA (13 September 2019). "[Global Greenhouse Gas Emissions Data](#)". [Archived](#) from the original on 18 February 2020. Retrieved 8 August 2020.
  - US EPA (15 September 2020). "[Overview of Greenhouse Gases](#)". Retrieved 15 September 2020.
- [EUobserver](#)
  - "[Copenhagen failure 'disappointing', 'shameful'](#)". *euobserver.com*. 20 December 2009. [Archived](#) from the original on 12 April 2019. Retrieved 12 April 2019.
- [European Parliament](#)
  - Ciucci, M. (February 2020). "[Renewable Energy](#)". *European Parliament*. Retrieved 3 June 2020.
- [The Guardian](#)
  - Carrington, Damian (19 March 2019). "[School climate strikes: 1.4 million people took part, say campaigners](#)". *The Guardian*. [Archived](#) from the original on 20 March 2019. Retrieved 12 April 2019.
  - Rankin, Jennifer (28 November 2019). "['Our house is on fire': EU parliament declares climate emergency](#)". *The Guardian*. ISSNÂ 0261-3077. Retrieved 28 November 2019.
  - Watts, Jonathan (19 February 2020). "[Oil and gas firms 'have had far worse climate impact than thought'](#)". *The Guardian*.
  - Carrington, Damian (6 April 2020). "[New renewable energy capacity hit record levels in 2019](#)". *The Guardian*. Retrieved 25 May 2020.
  - McCurry, Justin (28 October 2020). "[South Korea vows to go carbon neutral by 2050 to fight climate emergency](#)". *The Guardian*. Retrieved 6 December 2020.
- [International Energy Agency](#)
  - "[Projected Costs of Generating Electricity 2020](#)". IEA. 9 December 2020. Retrieved 4 April 2022.
- [NASA](#)
  - "[Arctic amplification](#)". NASA. 2013. [Archived](#) from the original on 31 July 2018.
  - Conway, Erik M. (5 December 2008). "[What's in a Name? Global Warming vs. Climate Change](#)". NASA. [Archived](#) from [the original](#) on 9 August 2010.
  - Shaftel, Holly (January 2016). "[What's in a name? Weather, global warming and climate change](#)". NASA *Climate Change: Vital Signs of the Planet*. [Archived](#) from [the original](#) on 28 September 2018. Retrieved 12 October 2018.
  - Shaftel, Holly; Jackson, Randal; Callery, Susan; Bailey, Daniel, eds. (7 July 2020). "[Overview: Weather, Global Warming and Climate Change](#)". *Climate Change: Vital Signs of the Planet*. Retrieved 14 July 2020.
- [National Conference of State Legislators](#)
  - "[State Renewable Portfolio Standards and Goals](#)". *National Conference of State Legislators*. 17 April 2020. Retrieved 3 June 2020.
- [National Geographic](#)
  - Welch, Craig (13 August 2019). "[Arctic permafrost is thawing fast. That affects us all](#)". *National Geographic*. [Archived](#) from [the original](#) on 14 August 2019. Retrieved 25 August 2019.
- [National Science Digital Library](#)
  - Fleming, James R. (17 March 2008). "[Climate Change and Anthropogenic Greenhouse Warming: A Selection of Key Articles, 1824â€1995, with Interpretive Essays](#)". *National Science Digital Library Project Archive PALE:ClassicArticles*. Retrieved 7 October 2019.
- [Natural Resources Defense Council](#)
  - "[What Is the Clean Power Plan?](#)". *Natural Resources Defense Council*. 29 September 2017. Retrieved 3 August 2020.
- [The New York Times](#)
  - Rudd, Kevin (25 May 2015). "[Paris Can't Be Another Copenhagen](#)". *The New York Times*. [Archived](#) from the original on 3 February 2018. Retrieved 26 May 2015.
- [NOAA](#)
  - NOAA (10 July 2011). "[Polar Opposites: the Arctic and Antarctic](#)". [Archived](#) from the original on 22 February 2019. Retrieved 20 February 2019.
  - Huddleston, Amara (17 July 2019). "[Happy 200th birthday to Eunice Foote, hidden climate science pioneer](#)". NOAA *Climate.gov*. Retrieved 8 October 2019.
- [Our World in Data](#)
  - Ritchie, Hannah; Roser, Max (15 January 2018). "[Land Use](#)". *Our World in Data*. Retrieved 1 December 2019.
  - Ritchie, Hannah (18 September 2020). "[Sector by sector: where do global greenhouse gas emissions come from?](#)". *Our World in Data*. Retrieved 28 October 2020.
  - Roser, Max (2022). "[Why did renewables become so cheap so fast?](#)". *Our World in Data*. Retrieved 4 April 2022.
- [Pew Research Center](#)
  - Pew Research Center (16 October 2020). "[Many globally are as concerned about climate change as about the spread of infectious diseases](#)". Retrieved 19 August 2021.

- [Politico](#)
  - Tamma, Paola; Schaart, Eline; Gurzu, Anca (11 December 2019). ["Europe's Green Deal plan unveiled"](#). *Politico*. Retrieved 29 December 2019.
- [RIVM](#)
  - [Documentary Sea Blind](#) (Dutch Television) (in Dutch). RIVM: Netherlands National Institute for Public Health and the Environment. 11 October 2016. [Archived](#) from the original on 17 August 2018. Retrieved 26 February 2019.
- [Salon](#)
  - Leopold, Evelyn (25 September 2019). ["How leaders planned to avert climate catastrophe at the UN \(while Trump hung out in the basement\)"](#). *Salon*. Retrieved 20 November 2019.
- [ScienceBlogs](#)
  - Gleick, Peter (7 January 2017). ["Statements on Climate Change from Major Scientific Academies, Societies, and Associations \(January 2017 update\)"](#). *ScienceBlogs*. Retrieved 2 April 2020.
- [Scientific American](#)
  - Ogburn, Stephanie Paige (29 April 2014). ["Indian Monsoons Are Becoming More Extreme"](#). *Scientific American*. [Archived](#) from the original on 22 June 2018.
- [Smithsonian](#)
  - Wing, Scott L. (29 June 2016). ["Studying the Climate of the Past Is Essential for Preparing for Today's Rapidly Changing Climate"](#). *Smithsonian*. Retrieved 8 November 2019.
- [The Sustainability Consortium](#)
  - ["One-Fourth of Global Forest Loss Permanent: Deforestation Is Not Slowing Down"](#). *The Sustainability Consortium*. 13 September 2018. Retrieved 1 December 2019.
- [UNFCCC](#)
  - ["What are United Nations Climate Change Conferences?"](#). *UNFCCC*. [Archived](#) from the original on 12 May 2019. Retrieved 12 May 2019.
  - ["What is the United Nations Framework Convention on Climate Change?"](#). *UNFCCC*.
- [Union of Concerned Scientists](#)
  - ["Carbon Pricing 101"](#). *Union of Concerned Scientists*. 8 January 2017. Retrieved 15 May 2020.
- [Vice](#)
  - Segalov, Michael (2 May 2019). ["The UK Has Declared a Climate Emergency: What Now?"](#). *Vice*. Retrieved 30 June 2019.
- [The Verge](#)
  - Calma, Justine (27 December 2019). ["2019 was the year of 'climate emergency' declarations"](#). *The Verge*. Retrieved 28 March 2020.
- [Vox](#)
  - Roberts, D. (20 September 2019). ["Getting to 100% renewables requires cheap energy storage. But how cheap?"](#). *Vox*. Retrieved 28 May 2020.
- [World Health Organization](#)
  - ["WHO calls for urgent action to protect health from climate change – Sign the call"](#). *World Health Organization*. November 2015. Archived from [the original](#) on 3 January 2021. Retrieved 2 September 2020.
- [World Resources Institute](#)
  - Butler, Rhett A. (31 March 2021). ["Global forest loss increases in 2020"](#). *Mongabay*. [Archived](#) from the original on 1 April 2021. – Mongabay graphing WRI data from ["Forest Loss / How much tree cover is lost globally each year?"](#). *research.WRI.org*. World Resources Institute – Global Forest Review. January 2021. [Archived](#) from the original on 2 August 2023.
  - Levin, Kelly (8 August 2019). ["How Effective Is Land At Removing Carbon Pollution? The IPCC Weighs In"](#). *World Resources institute*. Retrieved 15 May 2020.
  - Seymour, Frances; Gibbs, David (8 December 2019). ["Forests in the IPCC Special Report on Land Use: 7 Things to Know"](#). *World Resources Institute*.
- [Yale Climate Connections](#)
  - Peach, Sara (2 November 2010). ["Yale Researcher Anthony Leiserowitz on Studying, Communicating with American Public"](#). *Yale Climate Connections*. [Archived](#) from the original on 7 February 2019. Retrieved 30 July 2018.

## External links

**Listen to this article** (1 hour and 16 minutes)



[This audio file](#) was created from a revision of this article dated 30 October 2021, and does not reflect subsequent edits.

([Audio help](#) – [More spoken articles](#))



[Scholia](#) has a profile for **climate change (Q7942)**.

[Library resources](#) about  
**Climate change**

[Resources in your library](#)  
[Resources in other libraries](#)

- [Intergovernmental Panel on Climate Change: IPCC \(IPCC\)](#)
- [UN: Climate Change \(UN\)](#)
- [Met Office: Climate Guide \(Met Office\)](#)
- [National Oceanic and Atmospheric Administration: Climate \(NOAA\)](#)

Retrieved from "[https://en.wikipedia.org/w/index.php?title=Climate\\_change&oldid=1245899355](https://en.wikipedia.org/w/index.php?title=Climate_change&oldid=1245899355)"

Categories:

- [Climate change](#)
- [Anthropocene](#)
- [History of climate variability and change](#)
- [Global environmental issues](#)
- [Human impact on the environment](#)

Hidden categories:

- [Articles with short description](#)
- [Short description is different from Wikidata](#)
- [Featured articles](#)
- [Wikipedia indefinitely move-protected pages](#)
- [Wikipedia indefinitely semi-protected pages](#)
- [Use Oxford spelling from August 2024](#)
- [Use dmy dates from August 2024](#)
- [Pages using multiple image with auto scaled images](#)
- [Articles containing potentially dated statements from 2020](#)
- [All articles containing potentially dated statements](#)
- [Articles containing potentially dated statements from October 2021](#)
- [Free-content attribution](#)
- [Free content from FAO](#)
- [CS1 maint: numeric names: authors list](#)
- [Articles citing publications with errata](#)
- [CS1 Dutch-language sources \(nl\)](#)
- [Articles with hAudio microformats](#)
- [Spoken articles](#)
- [Pages using Sister project links with wikidata namespace mismatch](#)
- [Pages using Sister project links with wikidata mismatch](#)
- [Pages using Sister project links with hidden wikidata](#)
- [Articles containing video clips](#)

- This page was last edited on 15 September 2024, at 19:42Â (UTC).
- Text is available under the [Creative Commons Attribution-ShareAlike License 4.0](#); additional terms may apply. By using this site, you agree to the [Terms of Use](#) and [Privacy Policy](#). WikipediaÂ® is a registered trademark of the [Wikimedia Foundation, Inc.](#), a non-profit organization.

- [Privacy policy](#)
- [About Wikipedia](#)
- [Disclaimers](#)
- [Contact Wikipedia](#)
- [Code of Conduct](#)
- [Developers](#)
- [Statistics](#)
- [Cookie statement](#)
- [Mobile view](#)

- 
- 