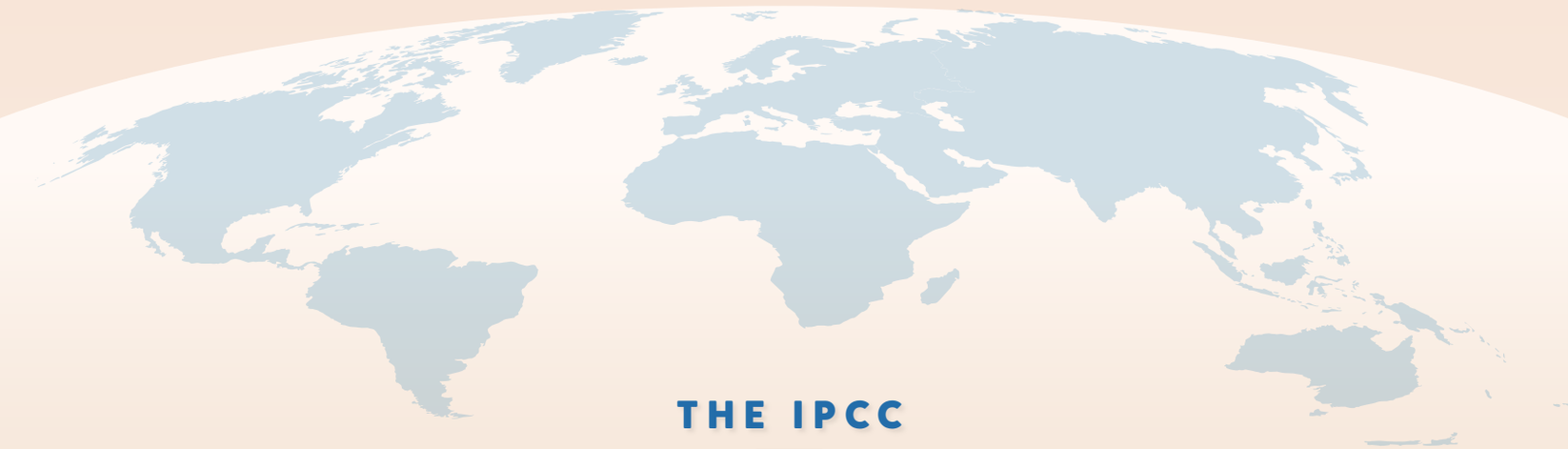
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

THE SCIENCE OF CLIMATE CHANGE

SIXTH ASSESSMENT REPORT (AR6)

I → II → III → SYR



THE IPCC

A UN body of government representatives that commissions expert reports on the state of the climate.

ASSESSMENT REPORTS

Massive systematic reviews of all the world's climate knowledge, every seven years or so

INTERGOVERNMENTAL

IPCC report summaries are endorsed by all 195 member nations before publication

MEANING GOVERNMENTS CANNOT IGNORE THE FINDINGS THEY HAVE THEMSELVES ENDORSED

VOLUNTEER EXPERTS

Hundreds of scientists (and other experts) contribute thousands of hours to IPCC reports

SIXTH ASSESSMENT REPORT (AR6)

2021 - 2022

THE IPCC SELECTED 721 EXPERTS FROM 90 NATIONS TO PARTICIPATE

THE SCIENCE

Assesses the scientific basis of the climate system and how we are changing it

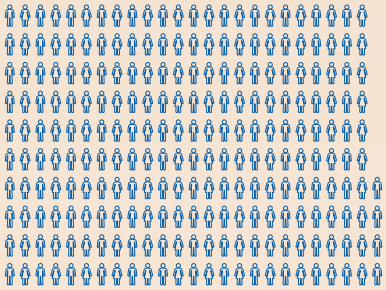
WHAT IT IS

The IPCC provides objective information about climate change to governments

It synthesises existing science and analysis

14,000
CITATIONS

234
EXPERTS



I

THE IMPACTS

Assesses the vulnerability of human and natural systems, and options for adapting

II

OUR OPTIONS

Options for mitigation, reducing emissions and removing GHGs from the atmosphere

III

SYNTHESIS

Summary of the three reports + any 'Special Reports' that fell in this reporting cycle

SYR

'ADOPTED' WORD-BY-WORD BY GOVERNMENTS IN CONSULTATION WITH THE REPORT AUTHORS

IPCC 'WORKING GROUPS'

Assessment Reports are prepared by three IPCC Working Groups. Each publishes a report:

I II III

WHAT IT'S NOT

The IPCC is neutral on policy — it does not tell world leaders what to do

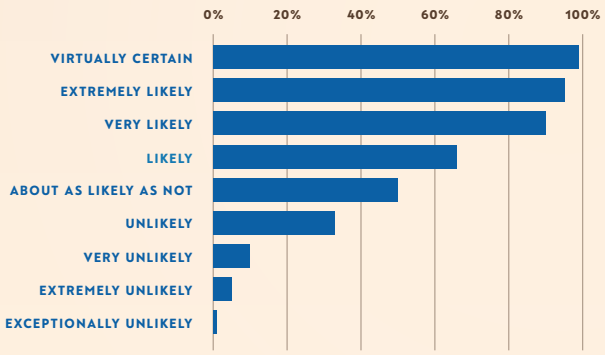
It does not publish its own original research

COMMUNICATING UNCERTAINTY

For all findings, IPCC working groups use 'calibrated language' to convey the likelihood ('very likely') or level of confidence ('very high') in their synthesis conclusions.

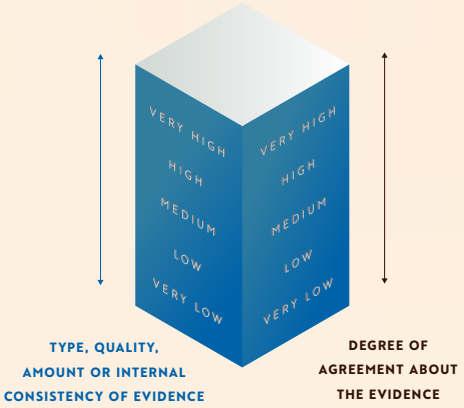
LIKELIHOOD
(PROBABILISTIC)

A quantitative measure of certainty in a finding based on statistical observations, model results, expert surveys etc.



CONFIDENCE
(QUALITATIVE)

Asessing the level of confidence involves considering two dimensions

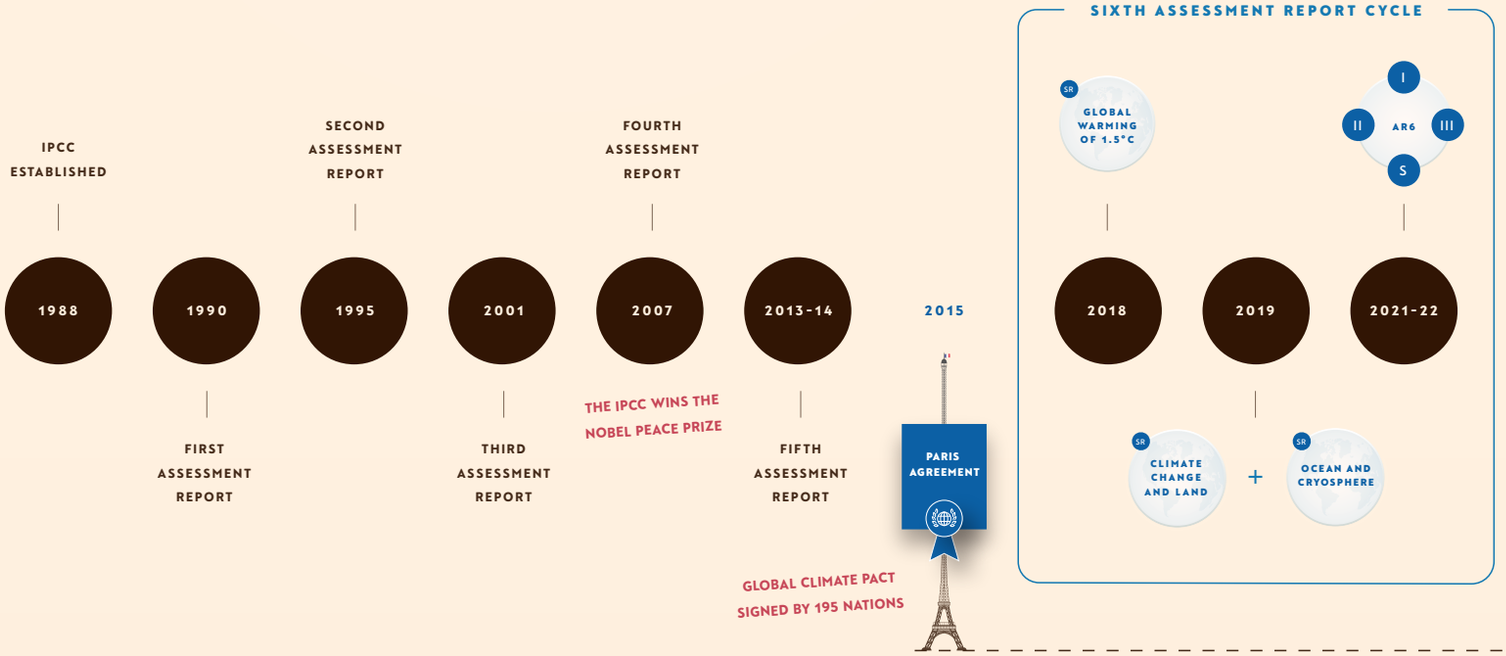


Special Reports are interdisciplinary assessments of specific issues:

SR GLOBAL WARMING OF 1.5°C

SR CLIMATE CHANGE AND LAND

SR OCEAN AND CRYOSPHERE



WHAT THE SCIENCE TELLS US

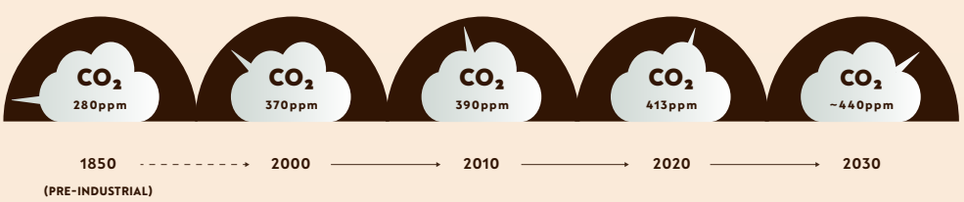
The world is heating up because carbon dioxide (CO_2) and other greenhouse gases (GHGs) are accumulating in the atmosphere, meaning less heat can escape to space. The growing thickness of this extra planetary blanket has caused widespread and rapid changes in the atmosphere, biosphere, cryosphere and ocean.

Climate change is **real**, it's **caused by us** and it's **bad**. But — it **can be fixed**.

1. It's real

CO_2: 'I'M CUMULATIVE'

ATMOSPHERIC LEVELS OF CO_2 ARE ALREADY HIGHER THAN AT ANY TIME IN AT LEAST 2 MILLION YEARS

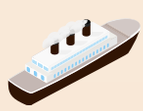


01 Humans emit about 40 billion tonnes of CO_2 into the atmosphere every year.

EQUIVALENT TO THE WEIGHT OF ABOUT 863,000 TITANICS

02 Since 1750, we've emitted over 2,500 billion tonnes of CO_2.

53 MILLION TITANICS



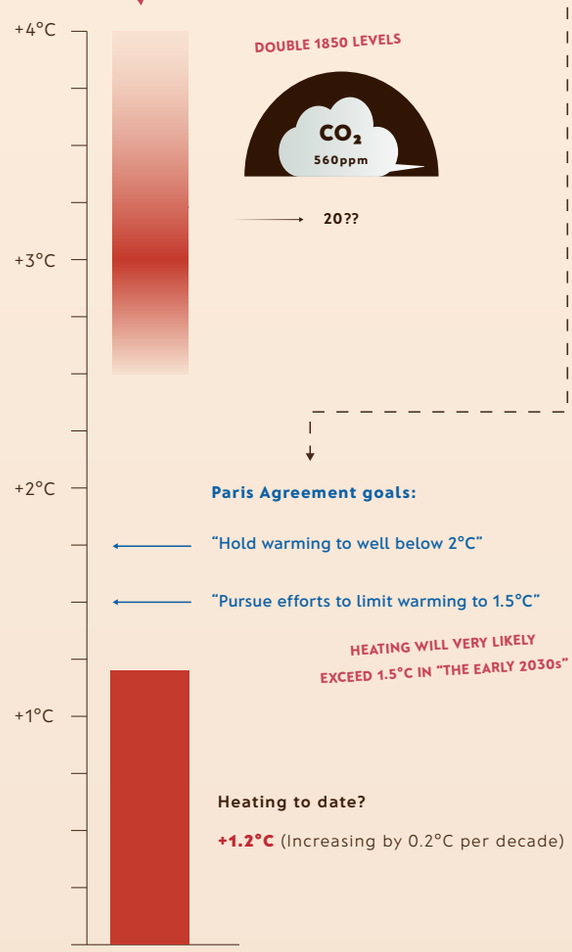
03 In 2021, the land + ocean absorbed about 56% of human CO_2 emissions, but this proportion will decrease the more CO_2 we emit into the atmosphere.

04 But — about 40% of the CO_2 we emit today will still be in the atmosphere in 100 years.

AND ABOUT 20% WILL STILL BE UP THERE IN 10,000 YEARS!

05 Because CO_2 is stubborn and accumulates in the atmosphere, in order to stabilise Earth's temperature at any level, we have to take human CO_2 emissions to net zero.

IF CO_2 LEVELS DOUBLE FROM 1850, THE BEST ESTIMATE IS WE'LL EVENTUALLY HEAT UP BY ABOUT 3°C. IF WE GET UNLUCKY, IT COULD BE MUCH HIGHER



OTHER GHGs

Greenhouse gases like methane (CH_4) and nitrous oxide (N_2O) need "strong, rapid and sustained" reductions, too

NET ZERO CO_2

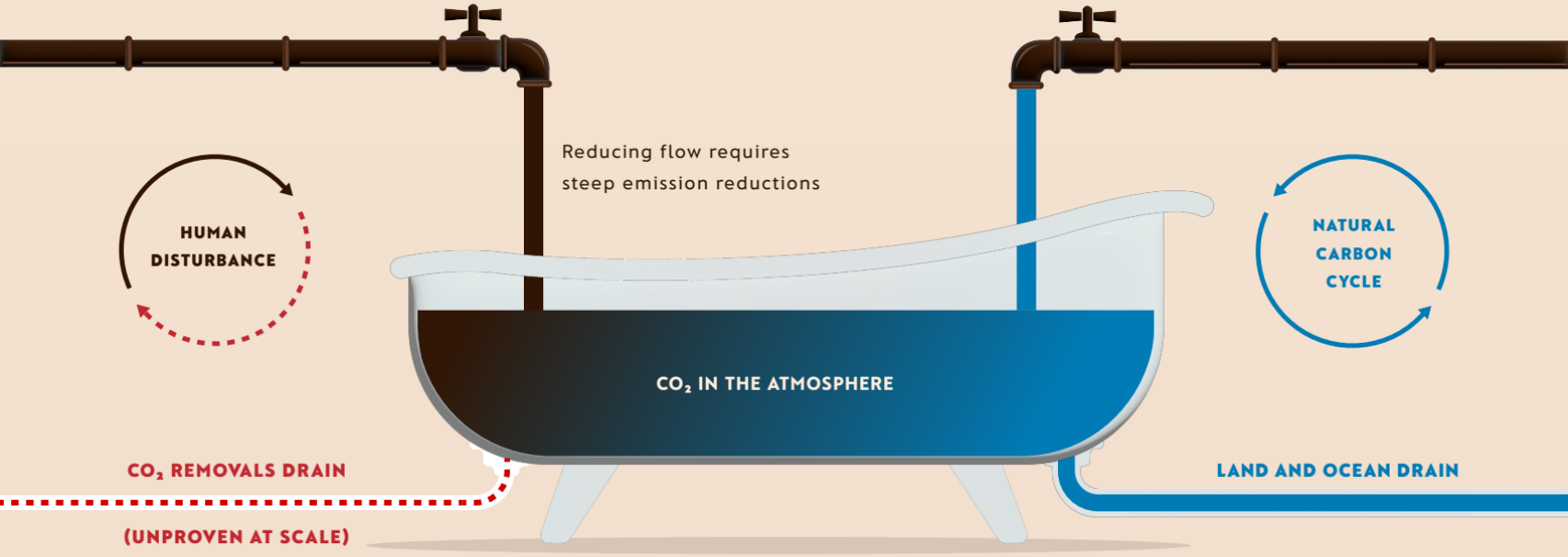
Where the sum of human-caused CO_2 emissions and removals is zero. To get to net zero, we need to:

01 Urgently turn down the **HUMAN CO_2 EMISSIONS TAP**

AS FAR AS HUMANLY POSSIBLE

02 Match any remaining inflow with an equal outflow using **CO_2 REMOVALS**

UNPROVEN AT SCALE



'UNPRECEDENTED' CHANGES

Global heating is leading to unprecedented and irreversible changes. As a 1.5°C-hotter world approaches, it's the temperature extremes that will affect people and nature most. A 1.5°C world is more different than it sounds.

The last decade was likely the hottest in

125,000

YEARS

BACK THEN, HOTTER TEMPERATURES WERE CAUSED BY SLOW MULTI-MILLENNIAL VARIATIONS IN EARTHS'S ORBIT (MILANKOVITCH CYCLES)

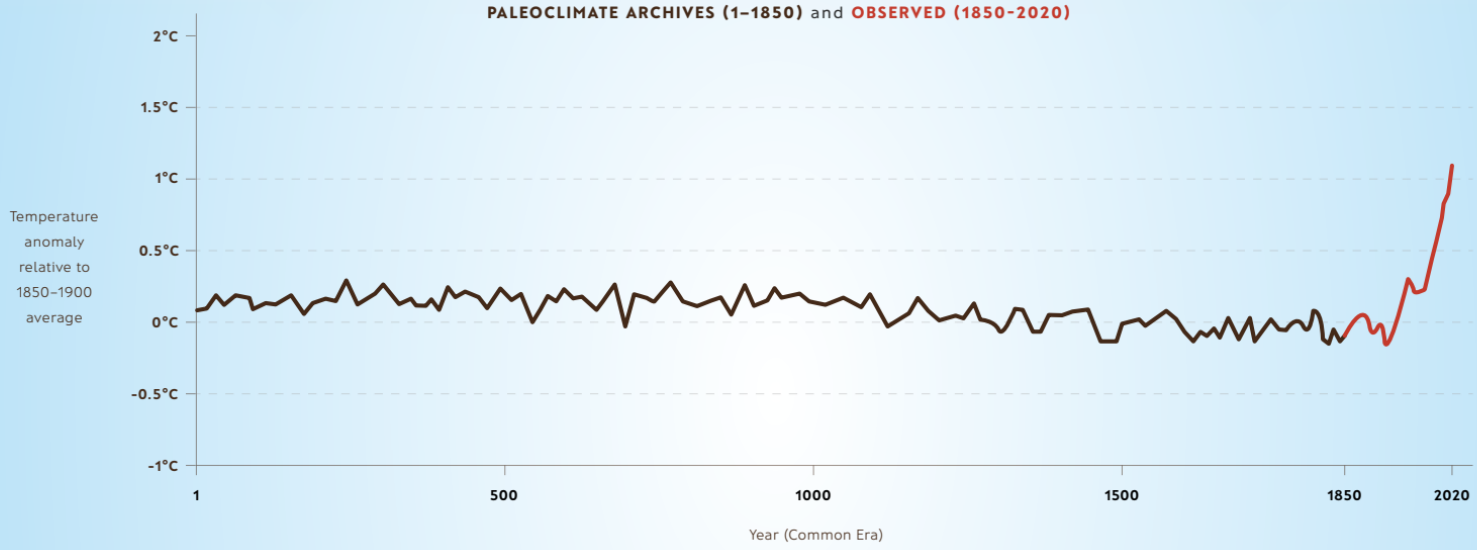
THE HUMAN-ENHANCED GREENHOUSE EFFECT

We're heating at a rate unprecedented in at least

2,000

YEARS

CHANGE IN GLOBAL SURFACE TEMPERATURE



The link between human-caused heating and increasingly severe extreme weather is now "an established fact".

HOT EXTREMES

Virtually certain that "the frequency and intensity of hot extremes have increased"

MARINE HEATWAVES HAVE "APPROXIMATELY DOUBLED IN FREQUENCY" SINCE THE 1980s

HEAVY RAINFALL

Likely increased since 1950 and has been increasing faster since the 1980s

AVERAGE PRECIPITATION AND EVAPORATION ARE INCREASING, VERY LIKELY WITH A RANGE OF 1-3% PER 1°C

TROPICAL CYCLONES

Likely that "occurrence has increased over the last four decades", as well as heavier associated precipitation

FOR EVERY 1°C HOTTER IT GETS, THE ATMOSPHERE CAN HOLD ABOUT 7% MORE WATER VAPOUR

DROUGHTS

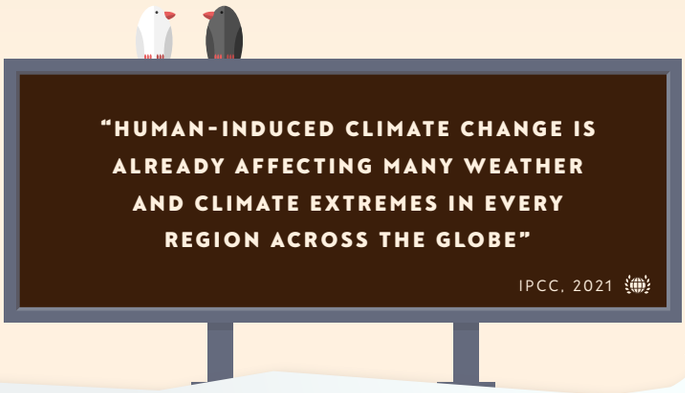
Decreases in water availability due to increased evapotranspiration

TEMPERATURE OVER LAND

Since 1850 it's warmed **1.59°C** over land, much more than over the ocean (0.88°C)

CLIMATE ZONES

Climate zones have shifted polewards in both hemispheres. Species are on the move...



NO ONE LIVES IN THE GLOBAL AVERAGE... MANY HIGH LATITUDE REGIONS HAVE ALREADY WARMED MORE THAN 2°C

The volume of ice lost every day from the Greenland and Antarctic ice sheets could fill

300,000

OLYMPIC SWIMMING POOLS

The rate of ice sheet loss has increased

400%

in just 20 years

MASSIVE WHITE SPACES LIKE ARCTIC SEA ICE PERFORM A VITAL SERVICE BY REFLECTING SUNLIGHT BACK TO SPACE BEFORE IT'S CONVERTED INTO HEAT. ANY LOSS OF ICE ACCELERATES CLIMATE CHANGE

Late summer Arctic sea ice area is smaller than at any time in at least the past

1,000

YEARS

Sea-level has increased by 0.20 metres in the last 120 years, and it's accelerating... fast.

Sea levels are rising due to:

- Thermal expansion: 50%
- Glacier ice loss: 22%
- Ice sheet loss: 20%
- Other: 8%

WATER EXPANDS AS IT HEATS UP

The ocean has absorbed about

25%

of humanity's CO_2 emissions to date

THE OCEAN ACIDIFIES AS IT TAKES UP MORE CO_2, ADVERSELY AFFECTING MARINE CREATURES LIKE CORAL REEFS

The ocean has warmed faster over the past century than at any time in the last

11,000

YEARS

WARMING RATES ARE HIGHEST IN THE UPPER 700m OF THE OCEAN

The ocean has absorbed about

90%

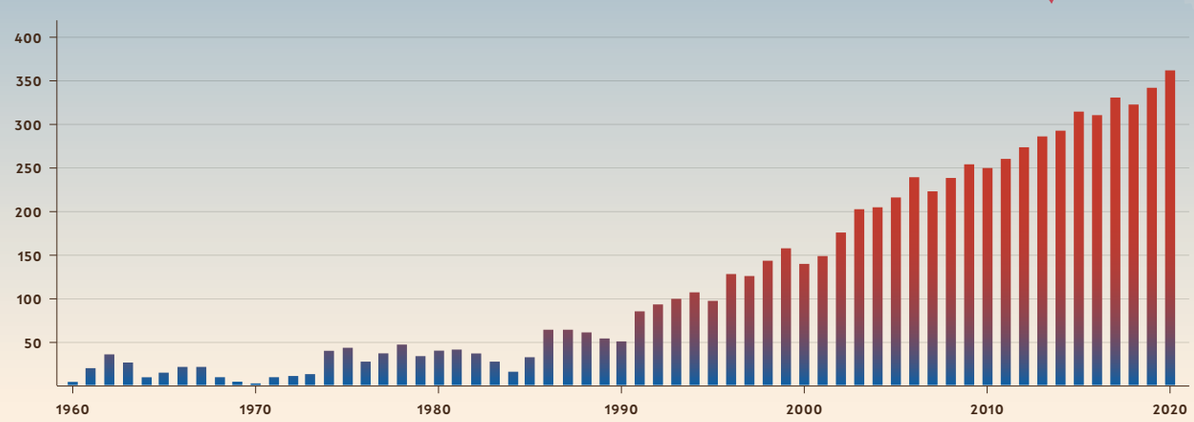
of the excess heat caused by humans

"IT'S HOT IN HERE"

"A LOT"

GLOBAL OCEAN HEAT CONTENT

(Relative to 1958-1960 average)



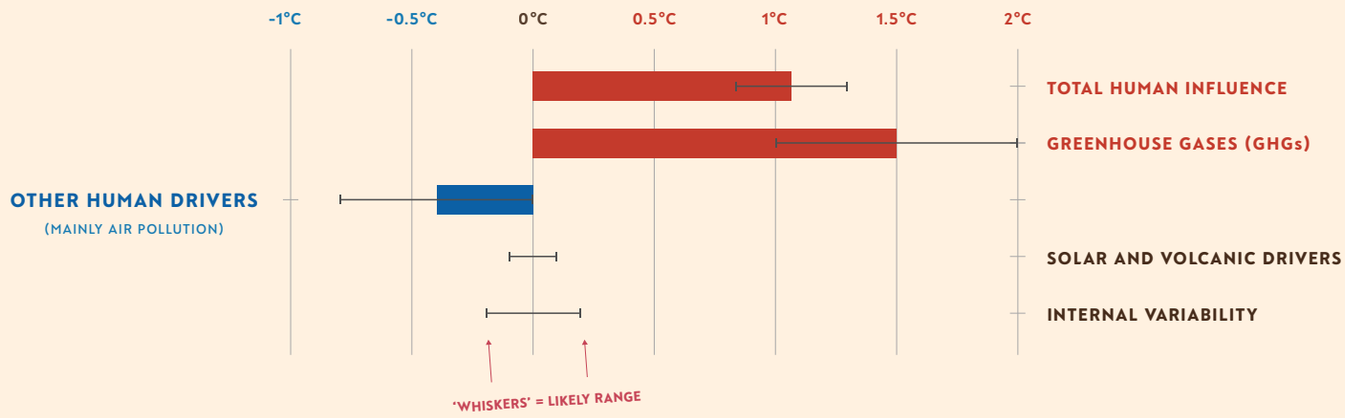
Year

EVEN IF WE STABILISE HEATING, THE OCEAN WILL KEEP ABSORBING HEAT FOR A MILLENIUM

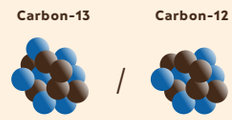
2. It's us

"It is unequivocal that human influence has warmed the atmosphere, ocean and land." The best estimate of the human contribution to modern heating is around 100%. Humans have their fingerprints all over climate change.

The increase in global surface temperature has been largest since 1980, a time during which solar activity has been decreasing. Compared with human drivers, "there has been negligible long-term influence from solar activity and volcanoes." Aggregated contributions to 2010–2019 heating relative to 1850–1900:

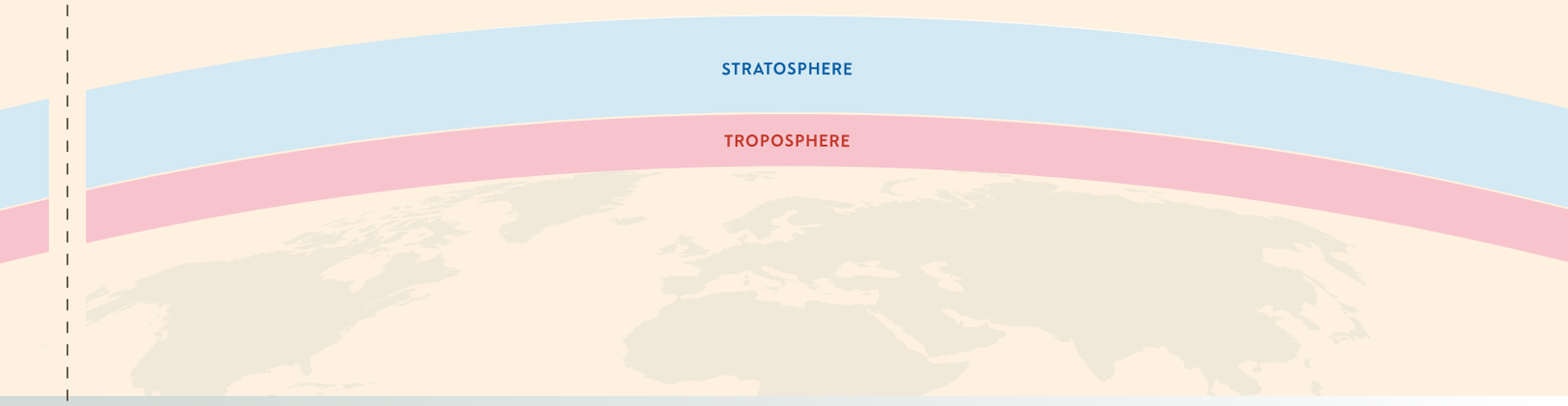


Measured decreases in the fraction ($^{13}C/^{12}C$) of types of carbon (isotopes) in the atmosphere and a small decrease in atmospheric oxygen levels show that the rise in CO_2 is overwhelmingly from the combustion of fossil fuels.



SCIENTISTS CAN IDENTIFY WHERE CO_2 'COMES FROM' USING THESE FRACTIONS E.G. IF IT'S FROM ORGANIC / PLANT MATTER (FOSSIL FUELS)

As the lower atmosphere (**TROPOSPHERE**) heats up due to an enhanced greenhouse effect, the upper atmosphere (**STRATOSPHERE**) is cooling as a consquence: "The **TROPOSPHERE** has warmed since at least the 1950s, and it is virtually certain that the **STRATOSPHERE** has cooled."



The global heating driven by human emissions of **GHGs** is partially masked by human-emitted **PARTICULATE POLLUTION** (sunlight-reflecting atmospheric particles like sulfur dioxide that cars and factories belch out). These have a substantial cooling effect on the planet, of roughly 0.4°C.

3. It's bad

And it's going to get worse.

Temperatures will continue to increase until mid-century under all scenarios. In the absence of deep reductions in CO_2 emissions, 1.5°C and 2°C will be exceeded this century. Many changes are baked in for thousands of years. Changes to global sea level, the ocean and ice sheets are "irreversible" on timescales relevant to human societies.

SEA-LEVEL

Over the next 2,000 years, mean sea-level will eventually rise:

- At 5°C: 19-22 metres
- At 2°C: 2-6 metres
- At 1.5°C: 2-3 metres

"It will remain elevated for thousands of years"

DUE TO CONTINUING DEEP-OCEAN WARMING AND ICE-SHEET MELT

OCEAN

"Changes are irreversible on centennial to millennial time scales in global ocean temperature, ocean acidification and deoxygenation"

GLACIERS

Under a best case scenario, glaciers will lose 18% of their current mass by 2100

ICE SHEETS

At sustained levels of heating between 3°C and 5°C, "ice sheets will be lost irreversibly over multiple millennia":

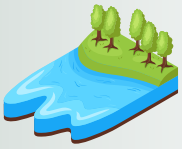
- West Antarctic Ice Sheet: complete loss
- Greenland Ice Sheet: near-complete loss

WORLDS APART: POSSIBLE FUTURES

The IPCC used five illustrative scenarios – **'Shared Socioeconomic Pathways' or SSPs** – to investigate how emissions and heating may increase. In all of them, CO_2 increases out to about 2040. What happens after that depends on choices we make now.

PROJECTIONS (GHG EMISSIONS)	VERY LOW	LOW	INTERMEDIATE	HIGH	VERY HIGH
	A BEST CASE SCENARIO: NET ZERO CO_2 BY 2055		ROUGHLY IN LINE WITH CURRENT NATIONAL PLEDGES UNDER THE PARIS AGREEMENT		REVERSAL OF CLIMATE POLICIES
SSPs:	SSP 1-1.9	SSP 2-2.6	SSP 2-4.5	SSP 3-7.0	SSP 5-8.5
YEAR WE HALVE CO_2 EMISSIONS TO ABOUT 20 BILLION TONNES PER YEAR	2035	2050	2087	WE DON'T	NO WAY JOSÉ
YEAR WE PASS 1.5°C GOAL	2035	2032	2030	2030	2027
YEAR WE PASS 2°C GOAL	EXTREMELY UNLIKELY TO BE EXCEEDED	EXTREMELY UNLIKELY TO BE EXCEEDED	EXTREMELY LIKELY TO BE EXCEEDED (~2052)	WOULD BE EXCEEDED (~2046)	WOULD BE EXCEEDED (~2041)

TEMP. INCREASE BY 2050	1.6°C WAIT FOR IT ...	1.7°C	2.0°C	2.1°C	2.4°C
TEMP. INCREASE BY 2100	1.4°C ... DROPS BACK BELOW 1.5°C AFTER SMALL 'OVERSHOOT'	1.8°C	2.7°C	3.6°C	4.4°C
TEMP. INCREASE BY 2300	–	–	2.3 - 4.6°C SIMILAR TO TEMPERATURES 3 MILLION YEARS AGO (2.5 - 4°C)	–	6.6 - 14.1°C SIMILAR TO TEMPERATURES 50 MILLION YEARS AGO (10 - 18°C)
CO_2 EMISSSIONS TAKEN UP BY LAND + OCEAN SINKS	70%	65%	54%	44%	38%
SEA-LEVEL RISE BY 2150	37 - 86cm	46 - 99cm	0.66 - 1.33m	–	0.98 - 1.88m SEA LEVEL RISE OF 5 METRES BY 2150 "CANNOT BE RULED OUT"

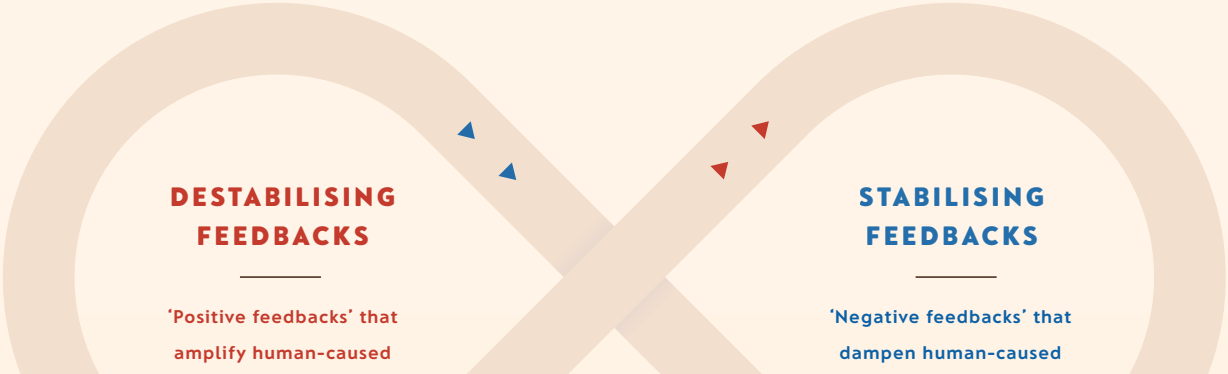


Overall, the carbon cycle is expected to *weaken* as a result of increasing temperatures, leading to more CO_2 emissions remaining in the atmosphere and less being absorbed by the land and ocean. That's not good news because without the land and ocean doing its thing (generously absorbing about half of the CO_2 we emit today) climate change would already be around twice as bad as it is now.

While the VERY HIGH scenario is unlikely as the rate of annual CO_2 emissions slows down — as we transition away from fossil fuels and decouple emissions from economic growth — the CO_2 levels it contains "cannot be ruled out". This is because as we heat up, there's an increasing risk we open a Pandora's Box of climate feedbacks...

CLIMATE FEEDBACKS

Earth's energy balance is not only affected by 'climate drivers' such as CO_2 emissions. Climate feedbacks (or 'carbon-cycle feedbacks') are self-reinforcing changes to the Earth's temperature from a secondary factor.



global heating

global heating

IN OTHER WORDS, NOT THAT POSITIVE...

E.G.

E.G.

CO_2 'FERTILISATION EFFECTS' CAN LEAD TO PLANTS SEQUESTERING MORE CARBON

A THAWING PERMAFROST

Will release 3-41 billion tonnes of carbon per 1°C of heating by 2100

THE PERMAFROST IS ESTIMATED TO CONTAIN 5,500 BILLION TONNES OF CO_2, TWICE THE TOTAL THAT'S IN THE ATMOSPHERE TODAY

SHIFTS IN FOREST ECOSYSTEMS

"The probability of crossing uncertain regional thresholds increases with future warming (high confidence)"

E.G. AMAZON FOREST DIEBACK

CLOUDS

The "net cloud feedback is positive (high confidence)", so amplifies human-induced warming

"CLOUDS REMAIN THE LARGEST CONTRIBUTION TO OVERALL UNCERTAINTY IN CLIMATE FEEDBACKS"

It's "virtually certain" that the combined effects of all feedbacks is to **amplify** the heating caused by emissions, and these are expected to become more powerful over time, further amplifying heating.

CLIMATE FEEDBACKS ARE ONE OF THE MAJOR SOURCES OF UNCERTAINTY WHEN MODELLING HOW MUCH HOTTER WE MIGHT GET

4. We can fix it

The door is still open to a VERY LOW scenario and avoiding the worst impacts and risks of a hotter planet – keeping 1.5°C alive is geophysically and technically feasible. But it depends on political leadership.

SCIENTIFICALLY SIMPLE

01 By 2050, if we bring our **CO_2 emissions down to net zero** and **reduce other GHGs** heating can be stabilised at 1.5°C.

CO_2

Halve annual CO_2 emissions by 2030

+

CO_2

Achieve net zero CO_2 emissions by 2050

+

GHGs

Strong reductions in other greenhouse gas emissions like methane (CH_4)

02 If we then implement ways to draw carbon down from the atmosphere at scale using carbon dioxide removal (CDR), temperature increase could be reversed.

CO_2

CDR IS DEEPLY UNCERTAIN AT SCALE. THIS CENTURY WE'D NEED TO BUILD A CDR INDUSTRY THAT RIVALS THE SCALE OF TODAY'S GLOBAL AUTOMOBILE SECTOR TO PUT US ON TRACK TO ACHIEVE THE PARIS AGREEMENT TEMPERATURE GOALS

OUR SHRINKING 'CARBON BUDGET'

CO_2

Global heating is proportionate to the total cumulative CO_2 emitted

CO_2

We've emitted about 2,500 BILLION TONNES of CO_2 since 1850

CO_2

We emit about 40 BILLION TONNES of CO_2 per year

EQUIVALENT TO THE WEIGHT OF OVER 860,000 TITANICS

CO_2

We have to go from 40,000,000,000 to 0 to stop the planet heating up more

THE BRUTAL MATHS OF CLIMATE CHANGE

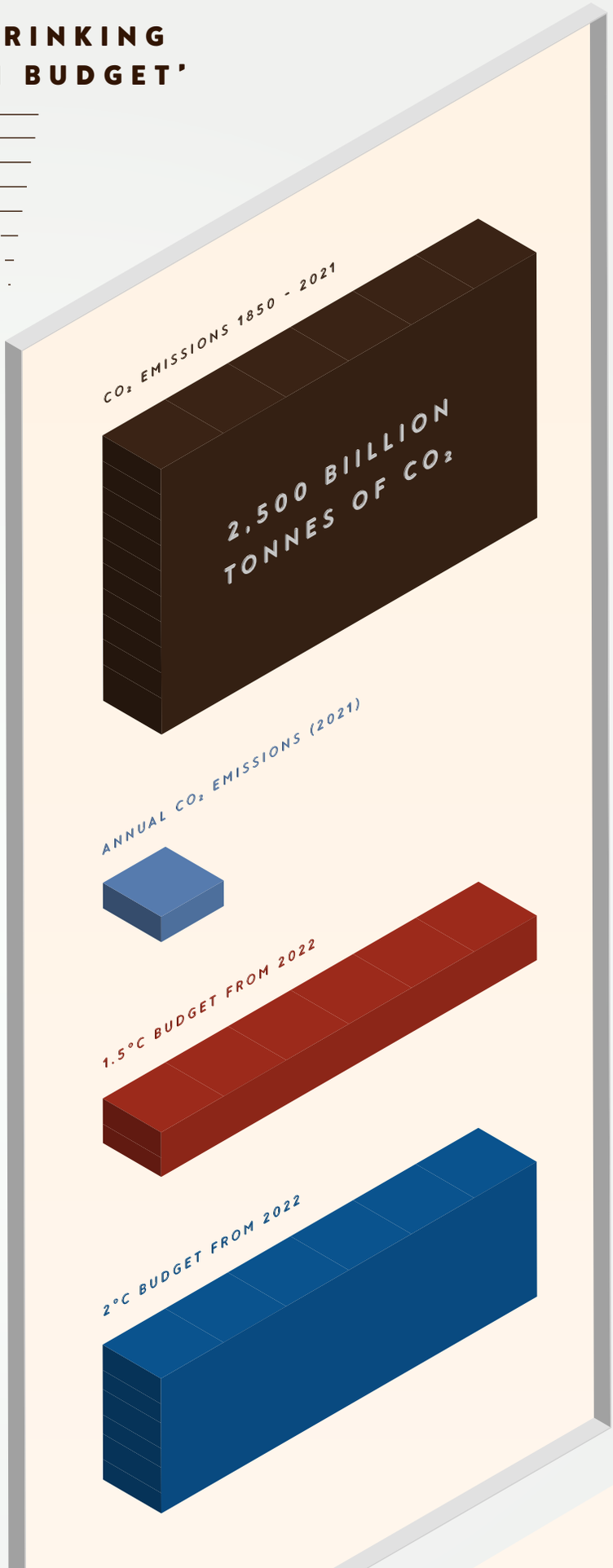
1.5°C (50% CHANCE)

2°C (50% CHANCE)

REMAINING CO_2 BUDGET (TONNES)

420 BILLION

1,270 BILLION



TIME LEFT IF ANNUAL EMISSIONS DON'T BUDGE

A MINEFIELD

Climate change isn't a cliff we go off at 1.5°C or 2°C. It's more a minefield we're stepping into. The farther we step in — the more we heat the planet — the more likely it is we set off devastating tipping point-like changes.

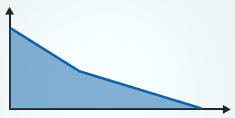
HOW QUICKLY MIGHT HEATING STOP?

Once CO_2 emissions reach **NET ZERO**, heating is likely to stabilise very quickly i.e. after a few years

THIS MEANS WE HAVE THE POWER TO CHOOSE OUR FUTURE

THE PATHWAY TO NET ZERO MATTERS

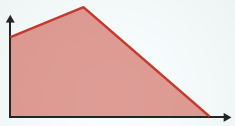
The path we take will determine the total amount of CO_2 we emit.



LESS CUMULATIVE EMISSIONS

The earlier the action, the lower the cumulative emissions.

THE LOWER THE CUMULATIVE EMISSIONS, THE LOWER THE TEMPERATURE OUTCOME



MORE CUMULATIVE EMISSIONS

The later the action, the higher the cumulative emissions.

Every tonne of CO_2 we emit adds to global heating and reduces the remaining carbon budget.

By John Lang

Energy&Climate INTELLIGENCE UNIT

NET ZERO LAWYERS ALLIANCE

Creative Commons

PLEASE USE AND SHARE!