IPCC Explainer: The Science of Climate Change

Do you want to understand the latest IPCC report minus the report?

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It's a picture is worth a thousand words, a 750,000 word IPCC report is logically worth 750 pictures.

AN INDEPENDENT PRESENTATION OF
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)
CONCLUSIONS BY JOHN LANG

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 expert summaries are endorsed by all 195 member nations before publication

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

SIXTH ASSESSMENT REPORT (AR6)
2021 – 2022

WHAT IT IS
The IPCC provides objective info/expert advice: climate change & governments
A continuous evolving science and analysis

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

14,000 CITATIONS
234 AUTHORS

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

OUR OPTIONS
Options for mitigating reducing emissions and removing GHGs from the atmosphere

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

IPCC "WORKING GROUPS"
Accountant Reports are prepared by three IPCC Working Groups. Each publishes a report:
I · II · III

SYNTHESIS
Summary of the three reports – any "Special Reports" that fall in this reporting cycle
SYR

Special Reports are interdisciplinary assessments of specific issues:
SR1.5 GLOBAL WARMING OF 1.5°C
CLIMATE CHANGE AND LAND
OCEAN AND CRYOSPHERE

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
(PROBABILITY)

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

CONFIDENCE
(SCIENTIFIC)

Assessing the level of confidence involves considering two dimensions:

IPCC FIFTH CYCLE
2013
2014
2015
FIRST ASSESSMENT REPORT
SECOND ASSESSMENT REPORT
THIRD ASSESSMENT REPORT
FOURTH ASSESSMENT REPORT
FIFTH ASSESSMENT REPORT
SIXTH ASSESSMENT REPORT
THE IPCC WORK FOR MORE, MUCH MORE
GLOBAL CLIMATE POLICY CHANGED BY THE REPORTS
SIXTH ASSESSMENT REPORT CYCLE
2018
2019
2020
2021
2022
SPECIAL REPORTS
SYNTHESIS REPORT
WORKING GROUP I
WORKING GROUP II
WORKING GROUP III

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'

1a Humans emit about 40 billion tonnes of CO_2 into the atmosphere every year.

1b Since 1750, we've emitted over 2,500 billion tonnes of CO_2.

1c In 2021, the (and + ocean absorbed about 54% of human CO_2 emissions, but this proportion will decrease the more CO_2 we emit into the atmosphere.

1d But — about 46% of all the CO_2 we emit today will still be in the atmosphere in 100 years.

1e Because CO_2 is stubborn and accumulates in the atmosphere, in order to stabilize Earth's temperature at any level, we have to take human CO_2 emissions to net zero.

OTHER GHGs

Greenhouse gasses 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 PAINFULLY POSSIBLE)

02 Match any remaining inflow with an equal outflow using CO_2 REMOVALS
(ABSENCE OF CO2)

'UNPREDECENTED' 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 about the hottest in **125,000 YEARS**
(with little human influence, only natural forcings such as orbital variations, volcanoes & solar output had consequential influence)

THE HUMAN-ENHANCED GREENHOUSE EFFECT

We're heating at a rate unprecedented in at least **2,000 YEARS**

CHANGE IN GLOBAL SURFACE TEMPERATURE
PALEOCLIMATE ARCHIVES VS OBSERVED AND MODELED TIME SERIES

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

HOT EXTREMES
Virtually certain that "the frequency and intensity of hot extremes have increased"
HAVE HAD MORE DAMAGE THAN ANYTHING ELSE, "MORTALITY" DATA ON THEM

HEAVY RAINFALL
Likely increased since 1950 and has been increasing faster since the 1980s
AFFECTS PRECIPITATION AND EVAPORATION
ONE EXTRA DEGREE OF WARMING = A HUNDRED LITRES PER TONNE

TROPICAL CYCLONES
Likely that "anthropogenic forcing has increased over the last four decades", as well as heavier associated precipitation
HAS DONE ITS HIGHEST & MOST DIRECT DAMAGE TO HUMANS
ITS TRACK MAYBE SHIFTING

DROUGHTS
Decreases in water availability due to increased evapotranspiration

TEMPERATURE OVER LAND
Since 1850 it's warmed **1.5°C** over land, much more than over the ocean (1.0°C)
HAVE HAD MORE DAMAGE THAN ANYTHING ELSE, "MORTALITY" DATA ON THEM

CLIMATE ZONES
Climate zones have shifted poleward, in both hemispheres. Species are on the move.

> "HUMAN-INDUCED CLIMATE CHANGE IS ALREADY AFFECTING MANY WEATHER AND CLIMATE EXTREMES IN EVERY REGION ACROSS THE GLOBE"
> IPCC, 2021

The volume of ice land every day from the Greenland and Antarctic ice sheets is **300,000** OLYMPIC SWIMMING POOLS

The rate of ice sheet loss has increased **400%** in just 20 years

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

Sea levels are rising due to:
- Thermal expansion: 50%
- Glacier ice loss: 22%
- Ice sheet loss: 20%
- Other: 8%

MORE COASTAL FLOODING AT LEAST 10X

Land surface is 10% warmer than ocean surface

Land surface warms twice as fast as the ocean

The ocean has absorbed about **25%** of humanity's CO_2 emissions to date

The ocean has warmed faster over the past century than at any time in the last **11,000 YEARS**

The ocean has absorbed about **90%** of the excess heat caused by humans

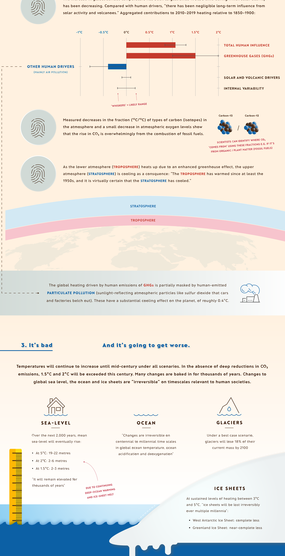
THE OCEAN BECOMES 10% MORE ACIDIC IN THE PAST 100 YEARS

GLOBAL OCEAN HEAT CONTENT
Zettajoules (ZJ) Total Ocean

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 lowest since 1880, a time during which solar activity



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:

- 4ft 5°C (9-22 metres)
- 6ft 2°C (6 metres)
- 4ft 1.5°C (2-3 metres)

"It will remain elevated for thousands of years"

DUE TO EXPANSION WHEN OCEAN WARMED (AND ICE CAPS MELT)

OCEAN

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

GLACIERS

Under a best-case scenario, glaciers will lose 90% of their current mass by 2100

ICE SHEETS

At sustained levels of heating between 2°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 2050. What happens after that depends on choices we make now.

	VERY LOW	LOW	INTERMEDIATE	HIGH	VERY HIGH
PROJECTIONS (TWO ENVELOPES)	SSP1-1.9	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
YEAR WE MAXIMIZE CO_2 EMISSIONS (A LEVEL OF EMISSIONS CLOSER TO ZERO MEANS EMISSIONS ARE FLAT)	2025	2050	2067	WE DON'T	NO WAY 2050!
YEAR WE PASS 1.5°C GLOBAL	2025	2032	2050	2030	2027
YEAR WE PASS 2°C GLOBAL	EXTREMELY UNLIKELY TO BE EXCEEDED	EXTREMELY UNLIKELY TO BE EXCEEDED	EXTREMELY UNLIKELY TO BE EXCEEDED (~20%)	WOULD BE EXCEEDED (~100%)	WOULD BE EXCEEDED (~100%)
TEMP. INCREASE BY 2050	1.6°C (WAS THERE IT ...)	1.7°C	2.0°C	2.2°C	2.4°C
TEMP. INCREASE BY 2100	1.4°C (MEDIAN PEAK WELL BEFORE 2100 IN SOME GROUP, "OVERSHOOT")	1.8°C	2.7°C	3.6°C	4.4°C
TEMP. INCREASE BY 2300	–	–	2.3 - 2.4°C (DROP TO BEFOREHAND) (REDUCE TEMP. BACK TO 1.5°C)	–	6.6 - 10.1°C (DROP TO BEFOREHAND) (REDUCE TEMP. BACK TO ~10°C)
CO_2 EMISSIONS 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 - 1.86m (RISE CONTINUES FOR AT LEAST ANOTHER 2000 YEARS)

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.

SEA-LEVEL RISE BY 2150	0.98 - 1.86m

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 decrease 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.

DESTABILISING FEEDBACKS

"Positive feedbacks" that amplify human-caused global heating

STABILISING FEEDBACKS

"Negative feedbacks" that dampen human-caused global heating

A THAWING PERMAFROST

Will release 3-4 billion tonnes of carbon per 0°C of heating by 2100

THE PERMAFROST ALTERNATES ITS CARBON BETWEEN 1,500 BILLION TONNES OF CO_2 TRAPPED THERE, THAT'S THE AMOUNT HUMANS HAVE EMITTED SINCE 1750

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)", as amplifies human-induced warming

"CLOUDS REMAIN THE LARGEST CONTRIBUTION TO OVERALL UNCERTAINTY ACROSS ASSESSMENTS"

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.

CLOUD FEEDBACKS ARE ONE OF THE MAIN REASONS DIFFERENT MODEL PROJECTIONS VARY MUCH MORE ON SHORT OFF

4. We can fix it

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

SCIENTIFICALLY SIMPLE

Q1 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 (the methane CH_4)

Q2 If we then implement ways to draw carbon down from the atmosphere at scale using carbon dioxide removal (CDR), temperatures could be reversed.

- CO_2 — CDR CAPACITY OF BIOMASS AT SCALE, THIS CAPACITY IS USED TO BURN A 1,000 BILLION TONNES OF COAL, THAT'S THE AMOUNT THAT WOULD BE EQUAL OF TODAY'S GLOBAL ANTHROPOGENIC SECTOR "DO NOT DO THIS UNLESS YOU HAVE ALREADY DEAR CARBON"

OUR SHRINKING 'CARBON BUDGET'

- CO_2 — Global heating is proportionate to the total cumulative CO_2 emitted
- We've emitted about 1,000 BILLION TONNES of CO_2 since 1850
- We were about 60 BILLION TONNES of CO_2 per year
- EQUIVALENT TO THE WEIGHT OF OVER 400,000 TOWER
- CO_2 — We have to go from 40,000,000,000 to 0 to stop the planet heating up more
- 1.5°C (50% CHANCE)
- 2°C (50% CHANCE)
- 420 BILLION
- REMAINING CO_2 BUDGET (CHANCE)
- 1,170 BILLION
- 11 YEARS
- THE LAST 11 YEARS AT CURRENT EMISSIONS RATES
- 33 YEARS

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

CO2 EMITS WITH THE POWER TO CHANGE THE 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

EnergyClimate · NET ZERO CARBON ALLIANCE

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PLEASE USE AND SHARE!

LATEST ACTIVITY(UPDATED)

This is the first of four infographic explainers. John is creating on the IPCC's Sixth Assessment Report (AR6) so as they can become accessible in a broader audience.

If you fancy using one of the above explainers or assets for yourself in your classroom, drop him a note over email or Twitter. He can provide them in various formats.

IPCC WG1 Report

- Climate Change 2021: The Physical Science Basis, IPCC

Other references:

- Climate at a glance: Global Temperatures (NI Record High in about Island)
- Frankenstein et al. Global Carbon Project Update

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CLIMATE SCIENCE INTERNATIONAL & COP

Special Report on the Ocean and Cryosphere

CLIMATE SCIENCE INTERNATIONAL & COP

Special Report on 1.5˚C

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2

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⚡ Winter Power Tracker update 14 Feb ⚡

#Renewables have generated 42TWh of