



CONSTRAIN

ZERO IN
ON

THE CRITICAL DECADE
INSIGHTS FROM THE LATEST IPCC
REPORTS ON THE PARIS AGREEMENT,
1.5°C, AND CLIMATE IMPACTS

THE ZERO IN REPORT SERIES

The annual ZERO IN reports by the CONSTRAIN project provide information on scientific topics that are central to the Paris Agreement, as well as background and context on new developments at the climate science-policy interface.

This includes new insights into the complex processes represented in climate models and what they mean for temperature change and other climate impacts over the coming decades. This fourth and final ZERO IN report looks at how cutting emissions this decade can limit temperature rise and other climate impacts in the near-term. In doing so, it provides supporting information on the latest Intergovernmental Panel on Climate Change (IPCC) report on the mitigation of climate change. It also looks back to what was set out by governments in the Glasgow Climate Pact¹, which:

■ Stresses the urgency of enhancing ambition and action in relation to mitigation, adaptation and finance **in this critical decade** to address the gaps in the implementation of the goals of the Paris Agreement.

and unpacks what “enhanced mitigation ambition in this critical decade” must look like, based on the latest IPCC science.

THE CONSTRAIN PROJECT

The EU-funded CONSTRAIN project is a consortium of 14 European partners tasked with developing a better understanding of global and regional climate projections for the next 20-50 years. CONSTRAIN brings together world-leading scientists from leading European academic institutions, including Climate Analytics, who bring expertise in disseminating this information to policy makers and practitioners.

CONSTRAIN also contributed to all three Working Group reports in the latest IPCC assessment cycle, with several scientists participating in author teams and dozens of papers cited. CONSTRAIN launches its ZERO IN reports each year around the UNFCCC Conference of the Parties (COP), providing a platform to discuss new developments in climate science and their policy implications.

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¹ unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26

EXECUTIVE SUMMARY

WHAT KIND OF EMISSIONS PATHWAYS ARE CONSISTENT WITH PARIS AGREEMENT GOALS?

The IPCC's Working Group III report assessed more than a thousand greenhouse gas emissions pathways and what they mean for future temperature rise. These pathways have certain characteristics, for example, how likely they are to hold temperatures to certain limits, and when greenhouse gas emissions are likely to peak and reach net zero.

These characteristics can be used to identify which pathways meet the three main Paris Agreement criteria of a) limiting warming to 1.5°C; b) limiting warming to well below 2°C; and c) achieving net zero greenhouse gas emissions in the second half of the 21st century.

The most ambitious pathways fall into a category labelled C1. C1 pathways have a 50% or higher chance of limiting warming to 1.5°C (with no or limited overshoot), as well as around a 90% chance of limiting warming to 2°C, and so meet the Paris Agreement goals on limiting temperature rise.

There is also a subcategory C1a in which emissions of greenhouse gases reach net zero by 2070-2075, balancing sources and sinks in the second half of this century and fulfilling the third criteria above.

The C1a pathways therefore set benchmarks for how we can fully achieve the Paris Agreement goals, in terms of both limiting global warming and reaching net zero greenhouse gas emissions.



EXECUTIVE SUMMARY



WHAT DIFFERENCE CAN STRONG MITIGATION MAKE IN THE COMING DECADES?

The IPCC Working Group III report's “illustrative pathways” demonstrate how different societal choices translate into emissions and temperature change, showcasing alternative futures.

The most ambitious of these pathways, which include immediate and rapid energy system transformations and emissions cuts, would slow down the rate of global warming between now and 2050, potentially halving it over the next twenty years.

Such strong and immediate mitigation measures could halt warming by 2050. Delaying strong action to mid-century would also mean a delay in slowing down warming, while following current climate pledges would mean warming essentially continuing at its current and very high rate.

The differences in total warming by 2050 also have significant implications for climate impacts. For example, global warming of 1.8°C in 2050, compared to 1.5°C, could see the area of land annually exposed to river floods more than triple in COP27 host country Egypt, highlighting how every fraction of a degree of warming matters.

EXECUTIVE SUMMARY

UPDATE ON THE REMAINING CARBON BUDGET

The remaining global carbon budget estimates the amount of CO₂ the world can emit to have a given likelihood of staying below a given temperature limit.

Forthcoming CONSTRAIN research shows how updates to the methodology used to calculate the remaining carbon budget confirm the scientific understanding that the budget for limiting warming to 1.5°C is very small. Small absolute changes can therefore appear very large in relative terms.

Following the latest science, the remaining global carbon budget for a 50% chance of staying within 1.5°C is diminished to 300 Gt CO₂ from the beginning of 2022. This will be further reduced by ongoing emissions since the start of 2022.

The various uncertainties affecting remaining carbon budget estimates never change the fact that the remaining carbon budget for 1.5°C is small and further emphasise the need for strong and immediate emissions cuts.



WHY IS THIS THE CRITICAL DECADE FOR CLIMATE?

A 50% chance of keeping global warming to 1.5°C this century, in line with the Paris Agreement, is still technically achievable. Yet without increased ambition and action this decade, our ability to keep temperature rise below 1.5°C will be lost: current climate policies and targets will not get us there.

The **IPCC Working Group I report**² states this with unprecedented certainty:

- *It is unequivocal that human influence has warmed the atmosphere, ocean and land.*
(IPCC AR6 WGI SPM A.1)
- *Global warming of 1.5°C [...] will be exceeded during the 21st century unless deep reductions in carbon dioxide and other greenhouse gas emissions occur in the coming decades.*
(IPCC AR6 WGI SPM B.1)

The Working Group I report, which assessed the physical science basis of climate change, was instrumental in informing COP26, the last UN climate change conference held in Glasgow in November 2021. The report was one of several factors that helped to bring science to the forefront of the COP26 negotiations, with its findings reflected throughout the final outcome of COP26, the **Glasgow Climate Pact** - a commitment by all countries to pursue efforts to limit the temperature increase to 1.5°C.

In particular, the Pact:

- *Notes with serious concern the findings from the contribution of Working Group I [...], including that climate and weather extremes and their adverse impacts on people and nature will continue to increase with every additional increment of rising temperatures.*

and

- *Recognises that the impacts of climate change will be much lower at the temperature increase of 1.5°C compared with 2°C.*

It highlights that 1.5°C is not just a number: it reflects a science-based policy choice that reflects in turn how adverse impacts will increase with every fraction of a degree of temperature rise. By limiting warming to 1.5°C we can avoid the worst of them.

The latest science confirms that limiting warming to 1.5°C is still technically feasible – albeit increasingly difficult, with deep, rapid, and immediate emissions reductions needed across all sectors. Achieving this is a matter of political will, and the choices made between now and 2030 will be critical.

² The IPCC is now in its Sixth Assessment Report (AR6) cycle, which includes contributions from its three Working Groups and a Synthesis Report, three Special Reports, and a refinement to its latest Methodology Report. The Synthesis Report will be the last of the AR6 products and is scheduled to be released in early 2023.



The **IPCC Working Group II report**, which focuses on the impacts of climate change, makes this clear:

- *Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all.*

(IPCC AR6 WGII SPM B.3)

It also stresses that despite progress being made on adaptation across all sectors and regions:

- *[with] increasing global warming, losses and damages will increase and additional human and natural systems will reach adaptation limits.*

(IPCC AR6 WGII SPM C.3)

The **IPCC Working Group III report** on the mitigation of climate change acknowledges that limiting warming to 1.5°C means global greenhouse gas (GHG) emissions must peak immediately, and approximately halve by 2030:

- *Global GHG emissions are projected to peak between 2020 and at the latest before 2025 in global modelled pathways that limit warming to 1.5°C [...] rapid and deep GHG emissions reductions follow throughout 2030, 2040 and 2050.*

(IPCC AR6 WGIII SPM C.1)

Specifically, this means:

- *[...] reductions of 43% [34–60%] by 2030 [...] in pathways that limit warming to 1.5°C (>50%) with no or limited overshoot.*

(IPCC AR6 WGIII SPM C.1.1)

The report goes on to assess more than a thousand possible emissions pathways, some of which meet these criteria and illustrate potential ways in which the world can meet the Paris Agreement (SECTION 1).

Reducing emissions now, in line with the Paris Agreement, can not only slow down warming in the near future, but also reduce future climate impacts across the world, and therefore the scale of action needed to cope with them (SECTION 2).

Our ability to keep temperature rise to below 1.5°C is dependent on governments' collective action in the very near term. By 2023 we are already well into 'the critical decade', and by delaying action we are not only increasing the scale and immediacy of the emissions cuts needed to prevent the worst impacts of climate change, but also the severity of the impacts we do experience. The IPCC is incredibly clear on this - we need to target larger emissions cuts, and achieve them by 2030. The diminishing remaining global carbon budget serves as a potent reminder in this regard (SECTION 3).

Whatever happens, the Glasgow Climate Pact, and the latest IPCC reports, must continue to be front and centre of negotiations at COP27 and beyond (SECTION 4).

KEY MESSAGES FROM THE FIRST THREE ZERO IN REPORTS

The Paris Agreement Long-Term Temperature Goal is aimed at:

■ *holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels.*

The Paris Agreement also refers to global, human-made temperature change, excluding short-term natural variability in the climate system. To smooth out the effects of non-human influences on the climate, the Long-Term Temperature Goal is based on global mean temperature change over multiple (i.e., two to three) decades. As a result, a 1.5°C temperature increase in one individual year or a particular location does not mean that the Long-Term Temperature Goal has been reached or exceeded.

Even with very strong emissions cuts, where emissions rapidly decline to net zero around 2050 and become net negative in the second half of this century, the IPCC assesses that we have a 50% probability or higher of reaching **1.5°C global warming** in the near future, with the best estimate being the mid-2030s.

However, best estimates of warming from very low emissions scenarios see 1.5°C only temporarily reached, or exceeded by no more than 0.1°C, before temperatures return to below 1.5°C (known as “overshoot”).

Regardless of emissions cuts, CO₂-driven warming will continue until CO₂ emissions reach net zero. Additional future warming caused by declining aerosol emissions could be offset by rapid declines in non-CO₂ greenhouse gases, especially methane, highlighting the importance of cutting methane emissions in particular in the short-term.

The rate of warming we experience will largely depend on emissions cuts: higher emissions will mean faster warming and less time available for effective adaptation, particularly for those most vulnerable to climate impacts. Conversely, strong emissions cuts could reduce the rate of human-induced warming in the near-term by up to half, allowing more time and space to adapt to the impacts that higher temperatures will inevitably bring.

Finally, the emissions pathway that we follow as a global society remains the largest influence on the speed and scale of warming that we can expect to see.

Although the temperature projections made by climate models are still subject to uncertainties, and different approaches to climate modelling also affect temperature projections, we can still make robust projections of medium-term changes.





ZERO IN ON: WHAT DOES THE LATEST IPCC REPORT TELL US ABOUT MEETING THE PARIS AGREEMENT?

WHAT DOES THE LATEST IPCC REPORT TELL US ABOUT MEETING THE PARIS AGREEMENT?

WHAT KIND OF EMISSIONS PATHWAYS ARE CONSISTENT WITH PARIS AGREEMENT GOALS?

As part of the IPCC's Sixth Assessment Report (AR6) cycle, the IPCC's Working Group III report on the mitigation of climate change assessed more than a thousand greenhouse gas emissions pathways³, representing an extensive exploration of our potential climate futures.

Each of these pathways has different implications for whether, when, and how we will meet the Paris Agreement and can be categorised according to a range of characteristics such as how likely they are to hold temperatures to certain limits, and when greenhouse gas emissions are likely to peak and reach net zero (see Table 1, Scientific Background I).

Probabilities and Likelihoods

The Paris Agreement's Long-Term Temperature Goal of **"well below 2°C"** represents a strengthening of the previous temperature goal of holding warming **"below 2°C"** agreed at Cancun's 2010 COP16 climate summit. **"Below 2°C"** was commonly considered as a *likely* chance (i.e., >67% in IPCC calibrated language⁴) of limiting warming to 2°C.

Given that **"well below 2°C"** is a strengthening of that goal, it follows that this translates into the next IPCC category of a *very likely* (i.e., >90%) chance of limiting warming to 2°C⁵.

The most ambitious pathways in the IPCC Working Group III report are grouped into category C1. These pathways "limit warming to 1.5°C (>50%) with no or limited overshoot" and have a simultaneous likelihood of limiting warming to 2°C of around 90% – i.e. **"well below 2°C"**. The C1 emissions pathways therefore meet the Long-Term Temperature Goal requirement on limiting warming - no other category does.

Peaks, Sources and Sinks, and Net Zero

The Paris Agreement also states that:

■ *Parties aim to reach global peaking of greenhouse gas emissions as soon as possible [...] so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.*

This "balance" is commonly understood as achieving net zero greenhouse gas emissions.

Peak emissions for category C1 pathways occur by 2020-2025⁶, which the Working Group III report clarifies as being "as soon as possible between 2020 and at latest before 2025". Pathways in the C1 subcategory C1a⁷ also achieve net zero greenhouse gases by 2070-2075 – or balancing sources and sinks "in the second half of this century".

³ The IPCC WGIII SPM states: "In the literature, the terms 'pathways' and 'scenarios' are used interchangeably, with the former more frequently used in relation to climate goals."

⁴ See the IPCC's uncertainty guidance note for more information: www.ipcc.ch/site/assets/uploads/2018/05/uncertainty-guidance-note.pdf

⁵ www.nature.com/articles/s43247-022-00467-w

⁶ Emissions milestones are given in five-year intervals because the underlying models operate in five-year time-steps.

⁷ See Scientific Background I for further details on the characteristics of C1a pathways.

In summary, only category C1a pathways fulfil the three main Paris Agreement criteria to:



The C1a pathways therefore set standards for how we can fully achieve the Paris Agreement goals – both limiting global warming and achieving net zero greenhouse gas emissions – and deliver on the Glasgow Climate Pact in a way that guides global efforts over the coming decades to avoid the most dangerous climate change.





2.

**ZERO IN ON:
WHAT DIFFERENCE CAN STRONG MITIGATION
MAKE IN THE COMING DECADES?**

WHAT DIFFERENCE CAN STRONG MITIGATION MAKE IN THE COMING DECADES?

Strong mitigation could lead to us halting warming by 2050 while delivering multiple benefits in terms of for example biodiversity; ecosystem services; health and livelihoods; and limiting extreme events; alongside the economic benefits from avoided damages and reduced adaptation costs.

Many different choices, and combinations of choices, could get us there, and different modelled pathways can provide insights into what future emissions could mean for temperature rise and the Paris Agreement goals.

The IPCC Working Group III report uses seven illustrative pathways (Page 14) to look at how different mitigation choices across major economic sectors translate into future emissions and temperatures. These pathways can also be used to assess climate impacts, for example annual damages from tropical cyclones.



IPCC ILLUSTRATIVE PATHWAYS

To illustrate a future with relatively high emissions, two **reference pathways** highlight what happens to emissions and temperatures in a future where we follow policies implemented in 2020 (*CurPol*); and in a future where, by 2030, countries meet the Nationally Determined Contributions (NDCs) they set out in 2020, but only moderate further action is taken (*ModAct*).

Five **illustrative pathways with mitigation action** show how transformations in key sectors such as energy, industry, and land use affect greenhouse gas emissions. They consider worlds in which there is a gradual strengthening of current policies (*GS*); extensive use of net negative emissions (*Neg*); heavy reliance on renewable energy (*Ren*); low energy demand (*LD*); and a broader shift towards sustainable development (*SP*). Only *Ren*, *LD*, and *SP* limit warming to 1.5°C with no or limited overshoot, corresponding to pathway category C1.

These three 1.5°C-compatible pathways all include a phase-out of fossil fuels. Energy supply is primarily met with renewables, as well as biomass (non-traditional), with very little or next-to-no nuclear energy.

All achieve net zero CO₂ emissions around mid-century, with net land-use change and bioenergy with carbon capture and storage acting as sinks to balance out residual non-CO₂ emissions such as methane. However, only the pathways with a focus on sustainable development (*SP*) and low energy demand (*LD*) also achieve net zero greenhouse gas as well as net zero CO₂ emissions, meaning they would also lead to a decline in temperatures. A pathway focusing on sustainable development also reflects policies aimed at, for example, poverty reduction and broader environmental protection, while a low energy demand pathway would capture a successful international climate policy regime⁸.

None of the illustrative mitigation pathways explicitly assess the effects of **solar radiation modification** (SRM), a deliberate large-scale climate intervention involving, for example, injecting aerosols into the stratosphere in order to reflect more sunlight back to space and reduce warming.

While SRM may reduce warming, there would still be a substantial need for emissions reductions even with SRM in place. SRM would also not return the climate to a previous state, as the climate system would respond differently to SRM than it would to greenhouse gases.

The effects of SRM would also only last for as long as it is deployed, requiring for example yearly aerosol injection, whereas greenhouse gases have atmospheric lifetimes of decades to centuries.

The latest IPCC reports⁹ also conclude that SRM would still lead to substantial residual climate change, and that there are large uncertainties around how aerosols, clouds, and radiation interact. In addition, as SRM would not stop CO₂ from increasing in the atmosphere, ocean acidification and risks to marine life would continue, while abrupt water cycle changes are likely if SRM is introduced rapidly. Overall, SRM would "mask" the problem rather than attempting to address the root cause of climate change: continuing greenhouse gas emissions. The IPCC reports also point to the significant non-geophysical uncertainties attached to SRM (including financial), the technological and geopolitical challenges, and the potential risks it presents to ecosystems, crop yields, human health, and economies.

⁸ See this analysis of what the IPCC WGIII report says about how to limit warming: www.carbonbrief.org/analysis-what-the-new-ipcc-report-says-about-how-to-limit-warming-to-1-5c-or-2c

⁹ See, for example, Cross-Working Group Box 4 of IPCC WGIII Chapter 14.

The immediate and rapid energy system transformations and emissions cuts represented by the *Ren*, *SP*, and *LD* illustrative pathways would slow down the rate of global warming between now and 2050 (Figure 1). In fact, the current warming rate of around 0.2°C per decade could well halve in the 2030s, and warming could be halted or even begin to reverse by the middle of the century.

In contrast, if rapid emissions reductions are delayed until mid-century (*GS*), warming would only start noticeably slowing down in the 2040s. And if countries do not raise ambition but continue to follow their NDCs (*ModAct*), warming would essentially continue at its current very high rate.

These relatively small differences in warming rates over the coming decades, and in absolute warming by 2050, still have significant implications for climate impacts¹⁰.

The IPCC's Working Group II report states with *very high confidence* (at least a 9 out of 10 chance) that:

■ [...] projected adverse impacts and related losses and damages escalate with every increment of global warming.
(IPCC AR6 WGII SPM B.4)

In other words, every fraction of avoided warming matters. This is especially true at the regional scale with some countries more strongly affected, or less able to respond, than others. For instance, if temperatures increased by 1.7°C rather than 1.5°C by 2050, the additional warming of 0.2°C could increase the number of people exposed to heatwaves by around one third in a number of different countries across the world (Figure 2).

NEAR-TERM GLOBAL WARMING RATES

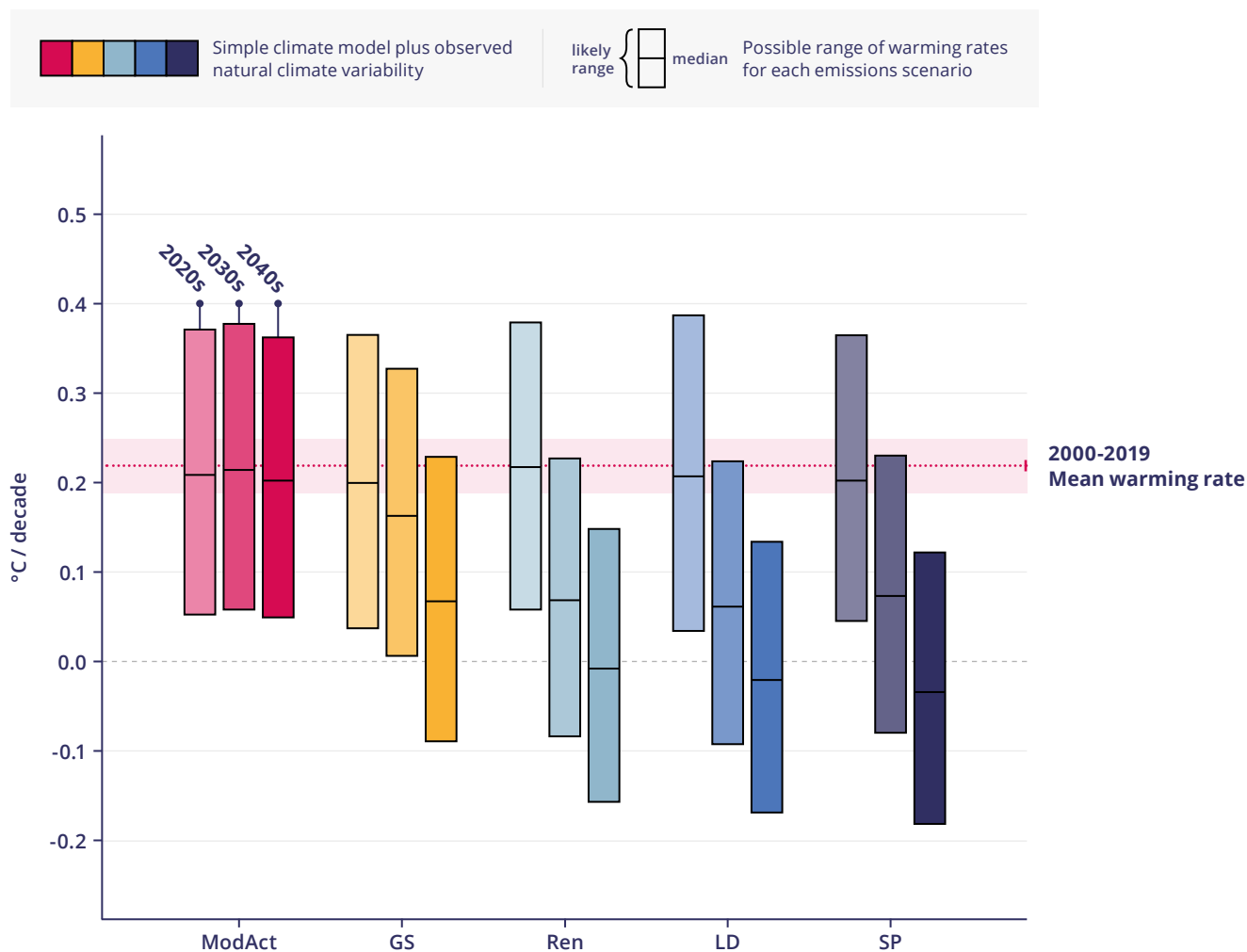


FIGURE 1: Warming per decade up to 2050 of selected illustrative pathways (sustainable development – SP; low energy demand – LD; renewable energy – Ren; gradual strengthening of current policies – GS; and the reference pathway for moderate action – ModAct), based on projections from FaIR. FaIR is a simple climate model or climate model “emulator”. For further information on emulators see ZERO IN 3, Scientific Background II¹¹.

¹⁰ See Scientific Background II for details of how the 2050 warming outcomes of the illustrative pathways have been translated into climate impacts, using data from the Climate Action Tracker.

¹¹ constrain-eu.org/wp-content/uploads/2021/11/Constrain-Zero-In-3-final.pdf

ILLUSTRATIVE 2050 CLIMATE IMPACTS

1.5°C of 2050 global warming | 1.7°C of 2050 global warming | 1.8°C of 2050 global warming

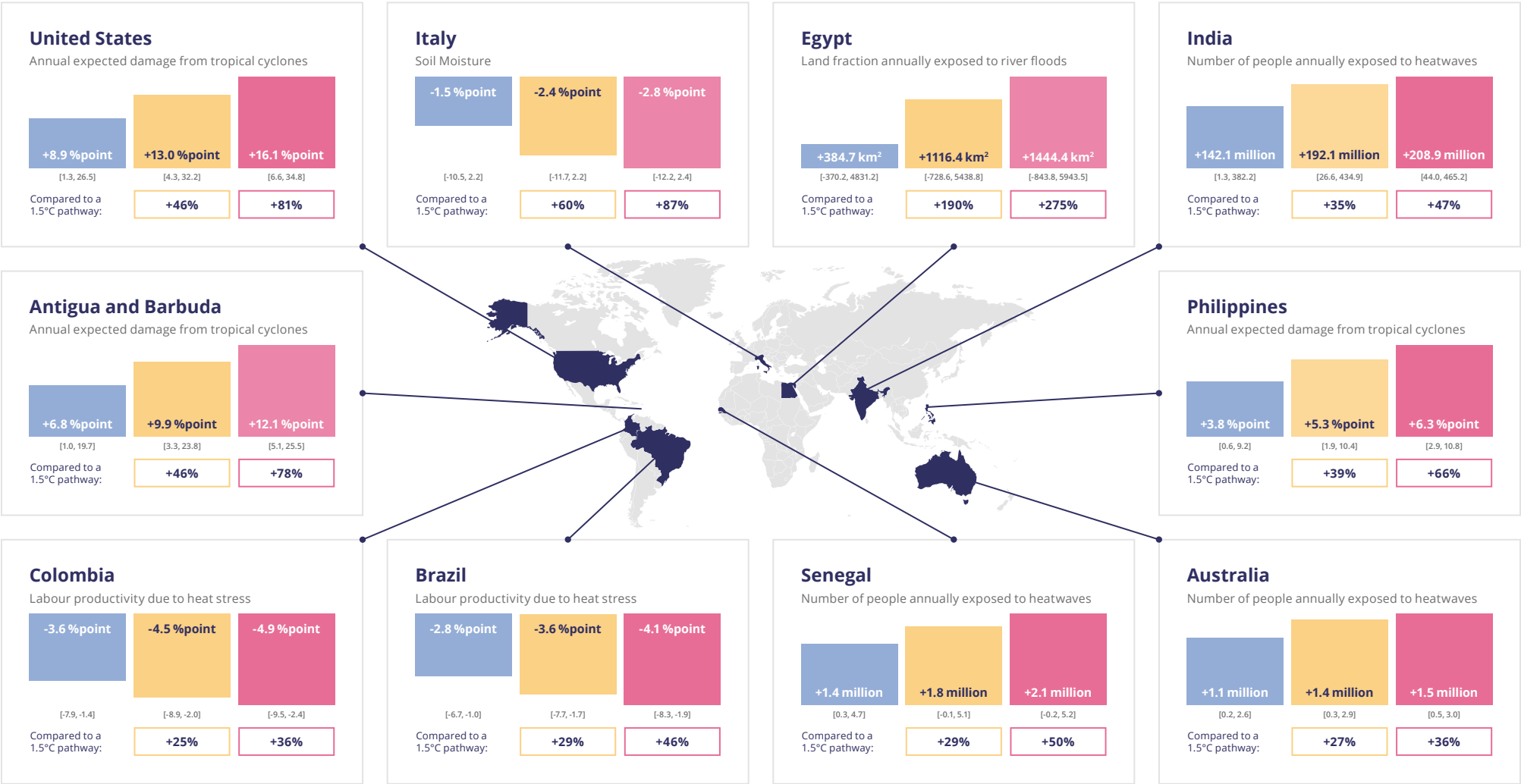


FIGURE 2: Examples of climate impacts in 2050 as a result of three different global warming levels (blue: 1.5°C; orange: 1.7°C; magenta: 1.8°C) in different countries. Results are presented in either absolute terms or changes in percentage points relative to the 1986-2005 reference period (median; 90% uncertainty range in square brackets). Relative differences in 2050 impacts compared to the 1.5°C scenario are based on data from the Climate Impact Explorer¹².

¹² climate-impact-explorer.climateanalytics.org

If warming reached 1.8°C in 2050, the additional 0.1°C temperature rise could mean these numbers increase by a further 10% or more¹³.

Global warming of 1.8°C in 2050, compared to 1.5°C, could see the area of land annually exposed to river floods more than triple in COP27 host country Egypt. This relatively small difference in global warming of 0.3°C also matters across different regions and types of impacts: for example, labour productivity in Colombia could fall by over a third as a result of heat stress with 2050 global warming of 1.8°C rather than 1.5°C, while in the Philippines, the annual damage from tropical cyclones could be two thirds higher under warming of 1.8°C than under 1.5°C.

These results clearly show that every fraction of a degree of global warming makes a difference, with every bit of avoided warming potentially preventing more severe climate impacts for people around the world.

¹³ climateanalytics.org/publications/2022/no-time-for-complacency-without-closing-the-2030-gap-net-zero-targets-cannot-prevent-severe-climate-impacts





3.

**ZERO IN ON:
UPDATES ON THE REMAINING
CARBON BUDGET**

UPDATES ON THE REMAINING CARBON BUDGET

As in previous years, this ZERO IN report provides an update on the remaining global carbon budget, which estimates the amount of CO₂ the world can emit to have a given likelihood of staying below a given temperature limit.

Because of a lack of global action on reducing CO₂ emissions, the central estimate of the remaining carbon budget becomes increasingly small compared to the uncertainties and variations that surround it. This means that secondary factors such as the level of non-CO₂ emissions or uncertainties regarding their effect on climate will play an increasingly important part in determining if staying within the remaining carbon budget will effectively halt warming below the intended limit. Such factors also play a role when comparing different remaining carbon budgets.

The IPCC's AR6 Working Group I estimated how much CO₂ we can emit in order to have a 50% chance of staying within 1.5°C of warming. It concluded that the remaining carbon budget was around 500 Gt CO₂ from the start of 2020.



This is larger than the corresponding first CONSTRAIN ZERO IN estimate of 400 Gt CO₂ which was based on the IPCC Special Report on 1.5°C of global warming (Figure 3).

We now know that total emissions in 2020 and 2021 amounted to 70-80 Gt CO₂¹⁴, rebounding in 2021 to near pre-COVID19 levels and reducing these remaining carbon budget estimates considerably as we look beyond 2020.

Forthcoming CONSTRAIN research by Lamboll et al. (2022)¹⁵ shows how updates to the methodology used to calculate the budget not only confirm the scientific understanding that the remaining carbon budget for limiting warming to 1.5°C actually is very small, but also highlight the sensitivity of the remaining carbon budget to those updates. Small absolute changes can therefore appear very large in relative terms.

For a 50% chance of keeping warming to 1.5°C from the start of 2022, Lamboll et al. estimate that the remaining carbon budget from the start of 2022 is around 300 Gt CO₂. In absolute terms, this estimate is thus again closer to estimates of the first ZERO IN report. The remaining carbon budget will be further reduced by ongoing emissions from the start of 2022.

For comparison, the IPCC assessed that from 2018, future cumulative CO₂ emissions from existing and planned fossil fuel infrastructure alone, to the end of its lifetime, amount to 850 Gt CO₂¹⁶. Accounting for actual fossil CO₂ emissions since 2018¹⁷, this would change to around 780 Gt CO₂ from 2020 (Figure 3).

Updates to the methodology since publication of the WGI report include the incorporation of more recent emissions; use of an updated version of MAGICC, the climate model emulator used to estimate how much warming to expect from non-CO₂ emissions, plus incorporation of results from the FaIR climate model emulator; updates to the scenario database used in the calculations; and new approaches to deriving non-CO₂ trends and their warming contribution.

The various uncertainties affecting remaining carbon budget estimates, such as the role of non-CO₂ emissions and the potential warming occurring after emissions reach net zero (see ZERO IN 3) further highlight the need for strong emissions cuts that reach net zero by mid-century. Ultimately, the remaining carbon budget is very small, and every tonne of CO₂ we emit is eating into that budget.

REMAINING CARBON BUDGET

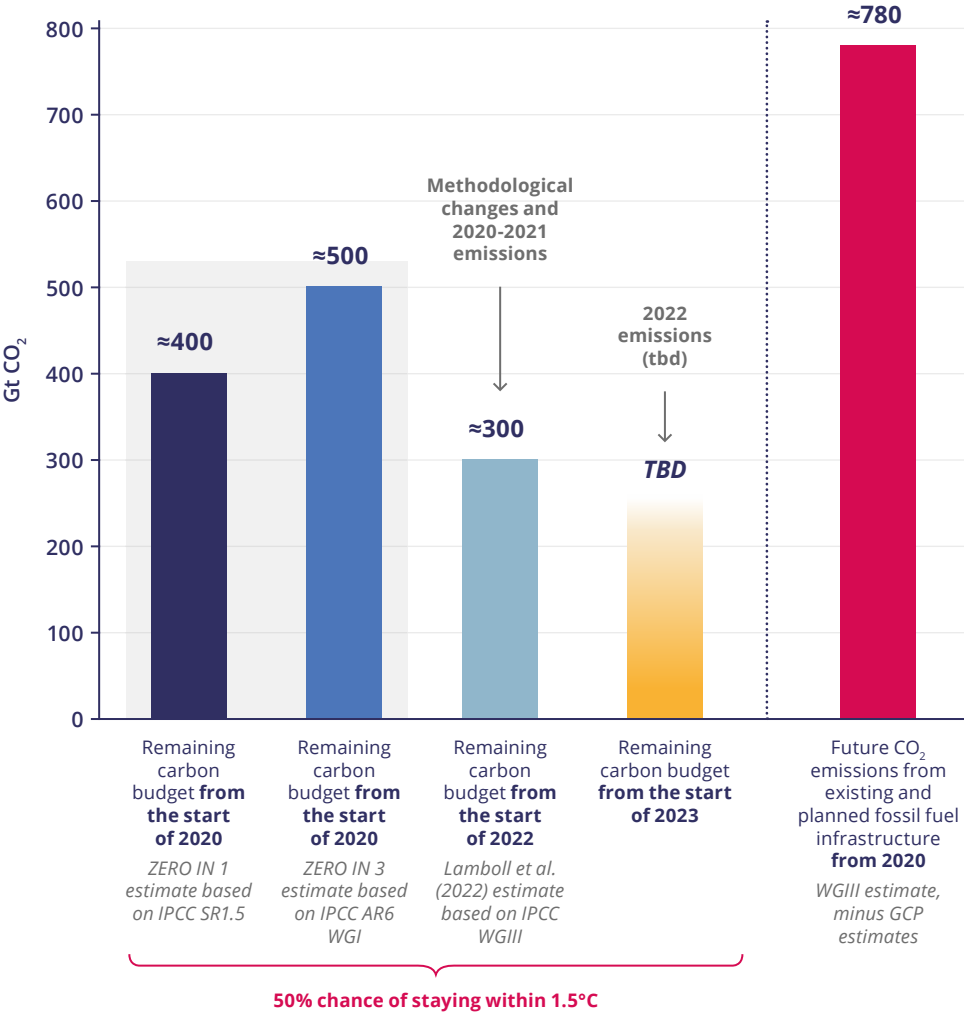


FIGURE 3: Central remaining carbon budget estimates for a 50% chance of staying within 1.5°C warming, based on different methodologies, compared to future emissions from planned and existing fossil fuel infrastructure from 2020 (far right, based on IPCC AR6 WGIII and Global Carbon Project [GCP] estimates).

¹⁴ www.globalcarbonproject.org/carbonbudget

¹⁵ www.researchsquare.com/article/rs-1934427/v1

¹⁶ www.ipcc.ch/report/ar6/wg3/SPM.B.7.1

¹⁷ Based on information from the Global Carbon Project (GCP): zenodo.org/record/5569235#.Yz6jcC0Rr3R



**ZERO IN ON:
HOW CAN CONSTRAIN INFORM
THE UNFCCC GLOBAL STOCKTAKE
AND FUTURE IPCC ASSESSMENTS?**

HOW CAN CONSTRAIN INFORM THE UNFCCC GLOBAL STOCKTAKE AND FUTURE IPCC ASSESSMENTS?

Many aspects of the UN climate negotiations rely on the latest science to inform effective international climate policy. In particular, the UNFCCC Global Stocktake¹⁸ is a key means of scientific input to the UNFCCC process.

The Global Stocktake aims to assess the world's collective progress towards the Paris Agreement and its long-term goals. In doing so, it considers progress in three areas: mitigation, adaptation, and finance.

The first GST kicked off in 2021 and runs to 2023, and a second will run from 2026 to 2028. CONSTRAIN has made contributing to the Global Stocktake a priority, with a focus on clarifying the state of the current and future climate system and supporting the flow of the latest climate science into policy- and decision-making.

CONSTRAIN's initial submission to the Global Stocktake¹⁹ outlines how the first three ZERO IN reports and associated material can support understanding of where we currently are in terms of the Paris Agreement Long-Term Temperature Goal, what we might expect in terms of future near-term warming, and our estimate of the remaining global carbon budget.

The submission also highlights some of the key sources of uncertainty in climate projections, including future societal choices and related greenhouse gas emissions; how the climate system responds to these emissions; and natural variations in the climate due to, for example, volcanic eruptions. Addressing these scientific knowledge gaps will help to improve near-term climate projections, and also improve the evidence base available to inform timely policy decisions on adaptation and mitigation.

A summary of CONSTRAIN's input to the Global Stocktake will be published on our website in February 2023.

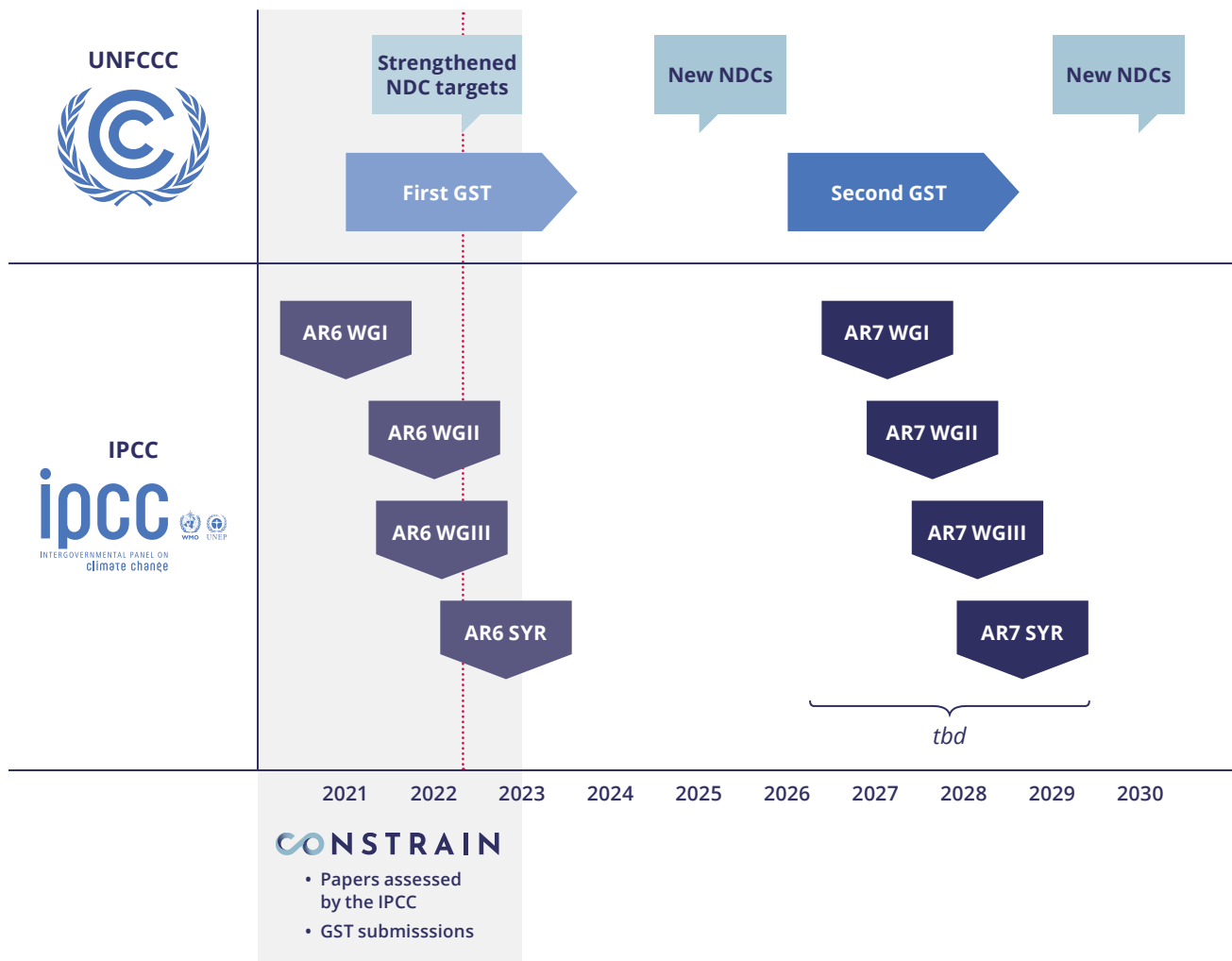
The IPCC also plans to align its future assessment cycles with the Global Stocktake (Figure 4), as well as take into account its scientific and stakeholder needs.



¹⁸ unfccc.int/topics/global-stocktake/global-stocktake

¹⁹ www4.unfccc.int/sites/SubmissionsStaging/Documents/202204200919---CONSTRAIN_The%20First%20GST.pdf

TIMELINE OF KEY SCIENCE AND POLICY PROCESSES



CONSTRAIN will continue to build its record of peer-reviewed research publications²⁰ as well as open source tools and data²¹ until June 2023 with a view to making important contributions to both the Global Stocktake and the IPCC's AR7.

Looking beyond CONSTRAIN, several project partners will continue to be engaged in related research, for example through the Horizon 2020 ESM2025²² and PROVIDE²³ projects.

FIGURE 4: Timeline of key science and policy processes. Upper panel: processes under the UNFCCC relating to the Global Stocktake (GST) and NDCs; lower panel: IPCC Working Group I (WGI), II (WGII), and III (WGIII) as well as Synthesis Report (SYR) releases of the AR6 cycle and potential release dates of the main reports of the upcoming IPCC Seventh Assessment (AR7) cycle (yet to be determined).

²⁰ constrain-eu.org/publications/type/academic

²¹ constrain-eu.org/tools-data

²² www.esm2025.eu

²³ climateanalytics.org/projects/provide



SCIENTIFIC BACKGROUND I

INTRODUCTION TO IPCC

SCENARIOS AND PATHWAYS

INTRODUCTION TO IPCC SCENARIOS AND PATHWAYS

Rather than predicting exactly how the world will evolve, climate scientists aim to better understand alternative climate futures and their related uncertainties. In doing so they develop various scenarios by modelling different greenhouse gas emission trajectories as well as capturing different socio-economic storylines.

The IPCC now draws its scenarios directly from the research modelling community, coordinated by the International Committee on New Integrated Climate Change Assessment Scenarios (ICONICS)²⁴.

WHY DO THE IPCC WORKING GROUPS USE DIFFERENT SCENARIOS?

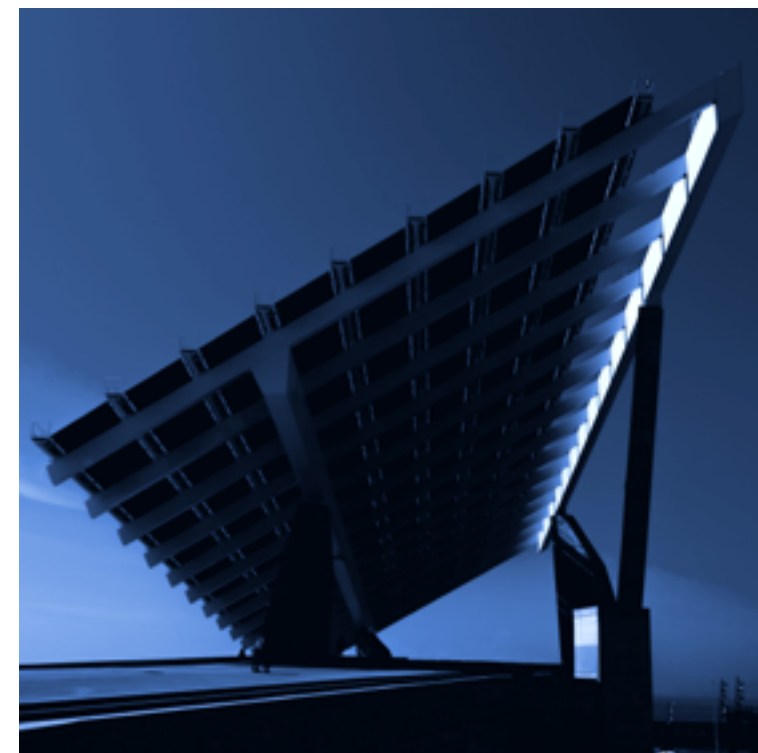
The IPCC Working Groups focus on sets of scenarios that best suit their respective topics. For AR6, Working Group I (physical science) and Working Group II (impacts, adaptation and vulnerability) mainly used the Shared Socioeconomic Pathway (SSP) scenarios. These range from SSP1-1.9 (very low emissions) to SSP5-8.5 (very high emissions)²⁵.

The scenario base for Working Group III (mitigation) is much larger. Over 1,200 scenarios were assessed and grouped into eight categories according to their global warming outcomes in 2100. All categories have distinct emissions and temperature characteristics over the 21st century, e.g., limiting warming to 2°C or 3°C (see Table 1 for details) but category C1 (97 pathways that limit warming to 1.5°C [with a >50% probability] with no or limited overshoot) captures the most ambitious mitigation efforts assessed.

Working Group III also identified several illustrative pathways providing examples of the climate outcomes of future mitigation efforts (Page 14).

Although the scenarios are labelled differently across the Working Groups, they were developed using consistent methods: they are the results of the same overall scenario generation process, using the same group of Integrated Assessment Models (IAMs), climate models, and processing steps.

The impact assessment carried out by Working Group II was additionally informed by the previous generation of Representative Concentration Pathways (RCP).



²⁴ depts.washington.edu/iconics

²⁵ For more information on SSPs see ZERO IN 2: A new generation of climate models, COVID-19 and the Paris Agreement - constrain-eu.org/wp-content/uploads/2020/12/Constrain-Report-2020-Final.pdf

Pathways		GHG emissions reductions in 2030 from 2019, %	Net zero GHG timing, median 5-year intervals	Pathways that reach net zero GHGs, %	Peak warming, °C	2100 warming, °C	Likelihood of peak warming staying below..., %	
(Sub-) Category	Illustrative Pathway						1.5°C	2°C
C1a	SP, LD	41 [31 – 59]	2070-2075	100%	1.6 [1.4 – 1.6]	1.2 [1.1 – 1.4]	38 [34 – 60]	90 [85 – 98]
C1b	Ren	48 [35 – 61]	No net zero	0%	1.6 [1.5 – 1.6]	1.4 [1.3 – 1.5]	37 [33 – 56]	89 [87 – 96]
C2	Neg	23 [0 – 44]	2070-2075	87%	1.7 [1.5 – 1.8]	1.4 [1.2 – 1.5]	24 [15 – 42]	82 [71 – 93]
C3b	GS	5 [0 – 14]	*	41%	1.8 [1.6 – 1.8]	1.6 [1.5 – 1.7]	17 [12 – 35]	73 [67 – 87]
C6	ModAct	2 [-10 – 11]	No net zero		No peak by 2100	2.7 [2.4 – 2.9]	0 [0 – 0]	8 [2 – 18]
C7	CurPol	-11 [-18 – 3]				3.5 [2.8 – 3.9]	0 [0 – 0]	0 [0 – 2]

TABLE 1: Key emissions and temperature characteristics of selected emissions pathway categories and corresponding illustrative pathways. The kind of pathways that are in line with the Paris Agreement's Long-Term Temperature Goal and the mitigation goal are highlighted in blue; pathways illustrative of relatively high emissions are highlighted in red.

- **C1a:** limit warming to 1.5°C (>50%) with no or limited overshoot, with net zero GHGs – corresponding to illustrative pathways shifting pathways (SP) and low demand (LD)
- **C1b:** limit warming to 1.5°C (>50%) with no or limited overshoot, without net zero GHGs – illustrative pathway renewables (Ren)
- **C2:** return warming to 1.5°C (>50%) after a high overshoot – illustrative pathway net negative emissions (Neg)
- **C3b:** limit warming to 2°C (>67%), NDCs until 2030, followed by accelerated emissions reductions – illustrative pathway gradual strengthening of current policies (GS)
- **C6:** limit warming to 3°C (>50%) – illustrative pathway moderate action (ModAct): NDCs with some further strengthening
- **C7:** limit warming to 4°C (>50%) – illustrative pathway current policies (CurPol): current policies with only a gradual strengthening

Where numbers in square brackets are given, they indicate the very likely range of estimates (5th-95th percentile), next to the best estimate (median). For GHG emissions reductions, negative numbers indicate an emissions increase compared to 2019. For net zero GHG timings, the asterisk (*) indicates that the upper range lies beyond 2100 so that no 5-year interval can be calculated. Adapted from IPCC AR6 WGIII SPM Table SPM.2.



SCIENTIFIC BACKGROUND II
FROM ILLUSTRATIVE PATHWAYS
TO CLIMATE IMPACTS

FROM ILLUSTRATIVE PATHWAYS TO CLIMATE IMPACTS

To investigate how the IPCC's illustrative pathways relate to climate policy choices, and how their future warming outcomes translate into climate impacts, we have compared them with three scenarios used by the Climate Action Tracker (CAT)²⁶, a tool for tracking government climate action and measuring it against the Paris Agreement temperature goals.

Figure 5 shows the projected temperature increase in 2050 for both the illustrative pathways shown in Figure 1 and the selected CAT scenarios. Colours for the illustrative pathways have been changed to facilitate comparison between the two different scenario groups.

The CAT scenario that meets all Paris Agreement criteria and limits global warming to 1.5°C with a 50% chance is labelled *1.5°C*. This scenario is comparable – in terms of 2050 temperature increase – to the 1.5°C-consistent illustrative pathways *SP*, *LD*, and *Ren*.

The CAT scenario that assumes climate mitigation measures as of COP26²⁷ to 2030, and also captures all net zero emission targets adopted or discussed in more than 140 countries, is labelled *NDC₂₀₂₁+NetZero* here. Finally, the CAT scenario which captures all existing international emission reduction pledges to 2030 as of COP26, called *NDC₂₀₂₁* here, is similar to the *ModAct* pathway in terms of mitigation assumptions.

These relatively small differences in absolute warming by 2050 lead to the significant implications for climate impacts set out in Figure 2.

GLOBAL TEMPERATURE INCREASE BY 2050

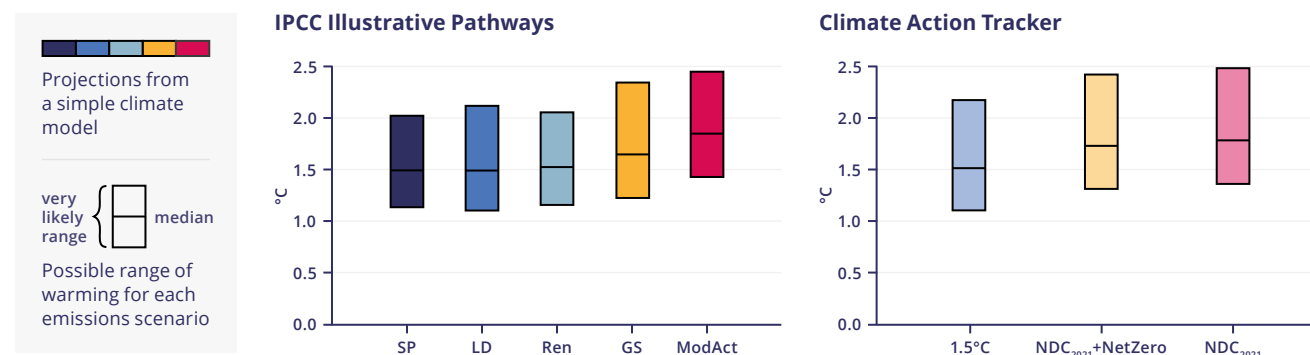


FIGURE 5: Global temperature increase in 2050 compared to pre-industrial levels (1850-1900) of selected illustrative pathways (left panel) and CAT scenarios (right panel). The boxes show the very likely (90%) range, the horizontal lines show the median – or best estimate – warming outcome. Note that this only allows for comparison between the 2050 temperature increase of the illustrative pathways and the CAT scenarios as shown here, and not necessarily between the underlying assumptions of the two, such as their emissions profiles.

²⁶ climateactiontracker.org

²⁷ For the latest analysis of national climate pledges and targets see climateactiontracker.org



SCIENTIFIC BACKGROUND III

KEY REMAINING UNCERTAINTIES FOR EMISSIONS PATHWAYS AND TARGETS

KEY REMAINING UNCERTAINTIES FOR EMISSIONS PATHWAYS AND TARGETS

Key sources of uncertainty in climate simulations stem from future societal choices and related emissions from human activities, the response of the climate system to emissions, and natural variations in the climate.

Emissions of greenhouse gases, especially CO₂, are still rising, driving up rates of warming, but emissions from human activities also include compounds that form particulates – or aerosols – in the air. Some of these aerosols, such as sulphur dioxide, also cause a cooling effect by reflecting incoming solar radiation. As we clean up aerosol pollution, this cooling effect, although still uncertain, is reducing.

Numerous aspects of the climate system, such as biogeochemical cycles and ocean circulation, are meanwhile not only affected by warming, but affect warming in return. Clouds are particularly important in the near term, and how clouds respond to a warming climate is expected to intensify any human-caused warming. However, interactions between the atmosphere and the pattern of sea-surface temperature change are believed to have limited the warming influence of clouds in some places.

Finally, in any given year, natural variations can cause the climate to depart from the long-term average. External natural influences on the climate include volcanic eruptions (where volcanic aerosols reflect sunlight) and variations in the sun's output; while internal influences tend to arise from interactions between the atmosphere and ocean (for a broader discussion on natural variability in the climate system and implications for the Paris Agreement see ZERO IN 2).

Uncertainties in emissions levels can be explored and quantified by looking at the effects on climate of following different emissions pathways, while uncertainties in the climate system can be explored using different climate models or model setups (see ZERO IN 3).

The IPCC Working Group III assessment provides estimates for both types of uncertainty. For instance, pathway category C1 *very likely* leads to end-of-century warming between 1.1°C and 1.5°C, taking scenario uncertainty into account. When considering climate and scenario uncertainties together, the *very likely* range expands to 0.8°C to 2.2°C, although the central estimate for end-of-century warming remains 1.3°C in both cases.

This means that even for the most ambitious pathway category, although there is a good chance of limiting warming to 1.5°C, warming above 2°C cannot be ruled out, further highlighting the need for stringent mitigation.

²⁸ climateactiontracker.org

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