Climate Reality Check 2020

IMPACTS | RISKS | ACTIONS

20 critical understandings, observations & insights

BREAKTHROUGH
National Centre For Climate Restoration

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Climate Reality Check 2020 draws together current climate research from around the world to present 20 critical observations, insights and understandings to help inform and guide the stark choices that now stand before us.

Climate Reality Check 2020 is a resource designed to help climate practitioners, advocates, journalists, business leaders and policymakers better understand and address the alarming mismatch between the current climate risks and considerably inadequate level of climate action.

IMPACTS & RISKS

Analysis & assessment of threats

If we continue down the present path "there is a very big risk that we will just end our civilisation. The human species will survive somehow but we will destroy almost everything we have built up over the last two thousand years.

PROF. HANS JOACHIM SCHELLNHUBER
DIRECTOR EMERITUS OF THE POTSDAM INSTITUTE

CURRENT IMPACTS

Warming is approaching 1.2˚C and accelerating

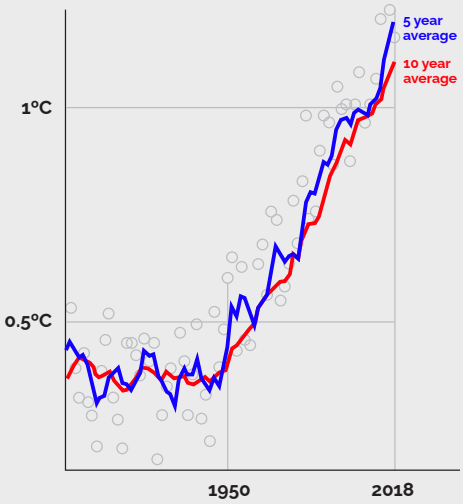
#1

The rate of global temperature increase is speeding up

- The 5-year global average temperature for 2015-2019 was 1.16˚C above a late 19th-century baseline.[1]
- Two of the last four years have been ≥ 1.2˚C.
- Hotter years are usually associated with El Nino conditions. It is ominous that 2020 could be ~1.2˚C during La Nina conditions.
- Warming has accelerated to ~0.25˚C for the most recent 2010-19 decade.[2] Average decadal rate of warming prior to 2010 was ≤ 0.2˚C.
- The next 25 years are projected to warm at a rate of 0.25–0.35˚C per decade.[3]

Chart 1

Rise in global average temperature above 1880–1899 baseline



Source: Berkeley Earth

CURRENT IMPACTS

1.5˚C warming is likely by 2030, even earlier

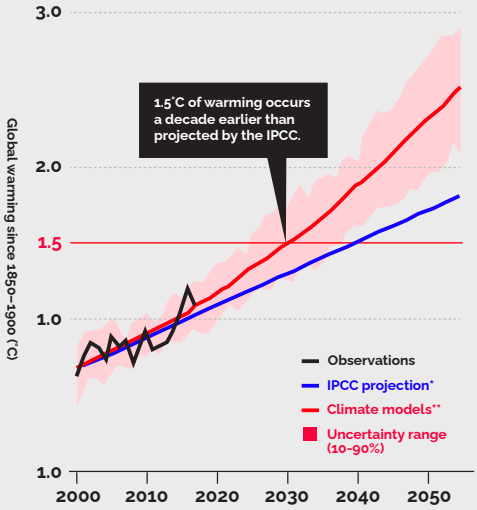
#2

Breaching 1.5˚C Paris Agreement boundary likely a decade ahead of IPCC projections

- Many research papers project warming to reach 1.5˚C around 2030, or sooner.[4]
- A comparison of results from the latest generation of climate models suggest 1.5˚C may be only five-to-seven years away (see Table 2).[5]
- Reaching 1.5˚C by 2030 would be a decade ahead of IPCC projections.[6]
- Rising emissions, declining aerosols (air pollution) and natural climate cycles will contribute to faster warming,[7] as will greater stratification of the ocean with a hotter layer of water on top contributing to faster warming.[8]

Chart 2

Rise in global average temperature above 1880–1899 baseline



Source: Nature 564:30-32

* Trend for 2001–15 extended with a constant rate of 0.2˚C per decade, as per IPCC special report.

** Ten-year average, 37 climate models for the RCP8.5 scenario (IPCC Fifth Assessment, 2014).

CURRENT IMPACTS

Reducing emissions alone will have no significant impact on warming trend over next two decades

#3

As fossil fuel use declines, so will aerosol emissions, which have been offsetting some warming

- A by-product of burning fossil fuels are sulfate aerosols, which have a strong cooling impact, but are short-lived in the atmosphere. Aerosols have been "masking" some of the warming so far.[9]
- Declining coal use and clean air policies reduce the aerosol impact. This is our "Faustian bargain":[10] as fossil fuel use declines so does the aerosol cooling, so that for the next two decades lower emissions will have little impact on the warming trend.
- A 5% annual reduction in emissions of a single greenhouse gas, from 2020 and based on a middle-road emissions path, has no statistically significant effect on warming for more than two decades, as compared to a no-mitigation pathway (see Table 1).[11]

Table 1

Emergence years with 5% annual emissions reductions from 2020*

Carbon dioxide	2044
Methane	2055
Nitrous oxide	2079
Black carbon	2048
Organic carbon	2064

Source: Nature Communications 112:3261, table 3

- Nevertheless, fast emission cuts are vital to flatten the warming curve.

* Year of emergence, after mitigation of one climate forcing component from 2020, defined as the year when half or more of the ensemble members are significantly different from the baseline (RCP4.5) according to a Student's t-test.

CURRENT IMPACTS

1.75–2.4˚C of warming for current greenhouse gas levels

#4

Higher temperatures will result from greenhouse gases already in the atmosphere

- Earth energy imbalance (EEI) is the radiative imbalance at the top of the atmosphere (between outgoing and incoming radiation), which is driving global warming.
- The current EEI is 0.6–0.75˚C.[12] Added to the 1.15–1.2˚C of warming so far, expected warming is 1.75–1.95˚C for the current level of greenhouse gases.
- The total theoretical warming, if the current level of greenhouse gases (~490 ppm CO_2e)[13] were maintained, is ~2.4˚C at equilibrium.[14]
- If a prudent risk-management approach is taken — with attention given to the high-damage, high-end possibilities rather than middle-of-the-road probabilities — there is no carbon budget for the 2˚C target.[15]

CURRENT IMPACTS

On current emissions path, 2°C warming well before 2050

#5

Upper Paris boundary of 2˚C likely to be breached before mid-century

- A comparison of current climate model projections show the median year in which warming thresholds of 1.5˚C, 2˚C, 3˚C, 4˚C and 5˚C are reached for three emissions trajectories: low, central and high (see Table 2).[16] Using the MAGIC model, timings of key temperatures of 1.5˚C, 2˚C, 2.5˚C and 3˚C are illustrated with dots for various emission paths (see Chart 3 overleaf).[17] [Warming so far is consistent with the RCP8.5 high-emissions path.]
- The emissions path has little impact on timing of the 1.5˚C threshold.
- 2˚C will be reached before 2050 for both the high and central emission scenarios.
- Under a high emissions scenario, 3˚C may be reached ~2060 and 5˚C before 2100.

Table 2

Warming scenarios	Low	Central	High
1.5˚C	2026	2027	2025
2˚C	2058	2044	2038
3˚C	n/a	2090	2059
4˚C	n/a	n/a	2076
5˚C	n/a	n/a	2094

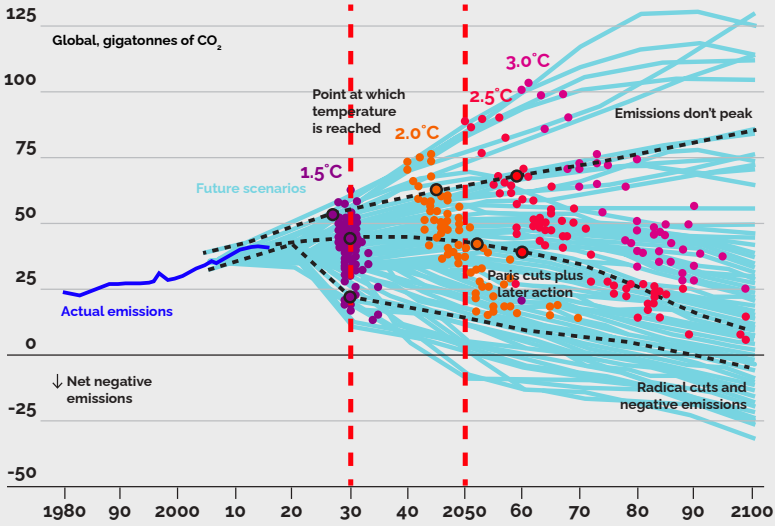
Source: Tebaldi et al. (2020) Earth System Dynamics 16 September, pre-print, table A7

The climate emergency is evolving faster than predicted. We must accelerate our response, with ambition and urgency. This is the battle for our lives.

ANTÓNIO GUTERRES
UN SECRETARY GENERAL

Chart 3

Scenarios for future CO2 emissions with three representative pathways picked out



Source: Glen Peters chart from GCP, CDIAC data

CURRENT IMPACTS

The picture painted by the IPCC is too conservative

#6

There is a serious underestimation of future climate impacts

- Until now, climate models used for projecting future warming and calculating carbon budgets in IPCC reports estimate a warming sensitivity of ~3˚C (for doubled CO_2).
- Including factors such as "slow" feedbacks (carbon stores, such as permafrost) and albedo changes (reflectivity), warming may be as high as 5–6˚C for a doubling of CO_2 for a range of climate states between glacial conditions and ice-free Antarctica.[18]
- Future warming is likely to be 15% higher (~0.5˚C) for high scenarios by 2100 compared to raw climate model projections reported so far by the IPCC.[19]
- Climate models do not account well for increased warming due to loss of Arctic sea-ice: "Losing the reflective power of Arctic sea ice will advance the 2°C threshold by 25 years."[20]

CURRENT IMPACTS

1.5˚C is not a safe target

7

Vital ecosystems including The Great Barrier Reef are facing devastation now

- The Great Barrier Reef is in a death spiral: at the current level of global warming, it will bleach on average once every three-to-four years,[21] whereas recovery takes a decade or more.
- West Antarctic Ice Sheet (WAIS) glaciers have passed a tipping point.[22] The *Paris Agreement* temperature target of 1.5˚C is sufficient to drive runaway retreat of WAIS.[23]
- Parts of East Antarctica might be similarly unstable.[24]
- Three-quarters by volume of summer Arctic sea-ice has already been lost.[25]
- One-quarter of the Himalayan & Tien Shan ice sheets have already been lost.[26]
- The forest systems are oscillating to non-forest ecosystems in eastern, southern & central Amazonia.[27]

CURRENT IMPACTS

2°C is very dangerous

With further tipping points close at hand, 2°C is a recipe for disaster

- Further tipping points could be triggered at low levels of global warming. A cluster of abrupt shifts could occur between 1.5°C and 2°C (#10).[28]
- These include the Greenland Ice Sheet, which is close to a tipping point,[29] previously estimated to be around 1.6°C;[30] and the Amazon rainforest.[31]
- It is a big mistake to think we can "park" the Earth System at any given temperature rise – say 2°C – and expect it to stay there.[32] 2°C may not be a point of system stability.
- Former NASA climate chief Prof. James Hansen said that it is "well understood by the scientific community" that goals to limit human-made warming to 2°C are "prescriptions for disaster".[33]

CURRENT IMPACTS

The world is on a 3–5°C warming path by 2100

#9

We are heading for levels of warming incompatible with an organised global community

- Global temperatures are on track for 3–5˚C of warming by 2100.[34]
- The temperature increase is still on the high-emissions RCP8.5 path, and RCP8.5 is also the best match to mid-century under current and stated policies.[35]
- Prof. Kevin Anderson says that "a 4˚C future is incompatible with an organised global community, is likely to be beyond 'adaptation', is devastating to the majority of ecosystems and has a high probability of not being stable".[36]
- Prof. Johan Rockström says that at 4˚C: "It's difficult to see how we could accommodate eight billion people or maybe even half of that."[37]

CURRENT IMPACTS

2˚C may trigger a “Hothouse Earth” scenario of self-reinforcing warming

#10

We are perilously close to dramatic climate change that could run out of our control

- The "Hothouse Earth" scenario is one in which climate system feedbacks and their mutual interaction drive the Earth System climate to a point of no return, whereby further warming would become self-sustaining (that is, without further human perturbations).[38]
- This planetary threshold could exist at a temperature rise as low as 2°C, possibly even in the 1.5°C–2°C range.[39]
- Similarly, Prof. James Hansen warned in 2007 that: "Recent greenhouse gas emissions place the Earth perilously close to dramatic climate change that could run out of our control."[40]
- The paper *Trajectories of the Earth System in the Anthropocene* (known as "Hothouse Earth" paper) was ranked as the most impactful climate research article of the year in 2018.[41]

CURRENT IMPACTS

3˚C of warming would be catastrophic

#11

Sea levels will eventually rise tens of metres for current level of greenhouse gases

- At 3˚C of warming, food production would be inadequate to feed the population due to a global average one-fifth decline in crop yields, a decline in nutrition content of crops, catastrophic decline in insect populations, desertification, monsoon failure and chronic water shortages.[42]
- 3˚C would be "catastrophic" for the livelihoods of the world's poorest three billion people, comprising mostly subsistence farmers, whose livelihood will be severely impacted, if not destroyed, with a one- to five-year megadrought, heat waves, or heavy floods.[43]
- Sea levels would eventually rise by tens of metres: "Even if we curb all CO_2 emissions today, and stabilise at the modern level, then our natural relationship suggests that sea level would continue to rise to about 25 metres."[44]

CLIMATE IMPACTS

Climate history previews our hot future

#12

The last time Earth had the current level of greenhouse gases, there were forests in Antarctica

- During the Pliocene, 3–5 million years ago, when the CO_2 level was similar to today, temperatures were 2–4˚C higher than pre-industrial and sea levels 20–25 metres higher.[45]
- "The indication is that there [was] no Greenland ice sheet any more, no West Antarctic ice sheet and big chunks of East Antarctic [ice sheet] taken."[46]
- During the Pliocene, there were trees at the South Pole. "I call them the last forests of Antarctica. They were growing at 400 ppm CO_2, so this may be where we are going back to with ice sheets melting at times, which may allow plants to colonise again," says Jane Francis, the Executive Director of the British Antarctic Survey.[47]

Chart 4

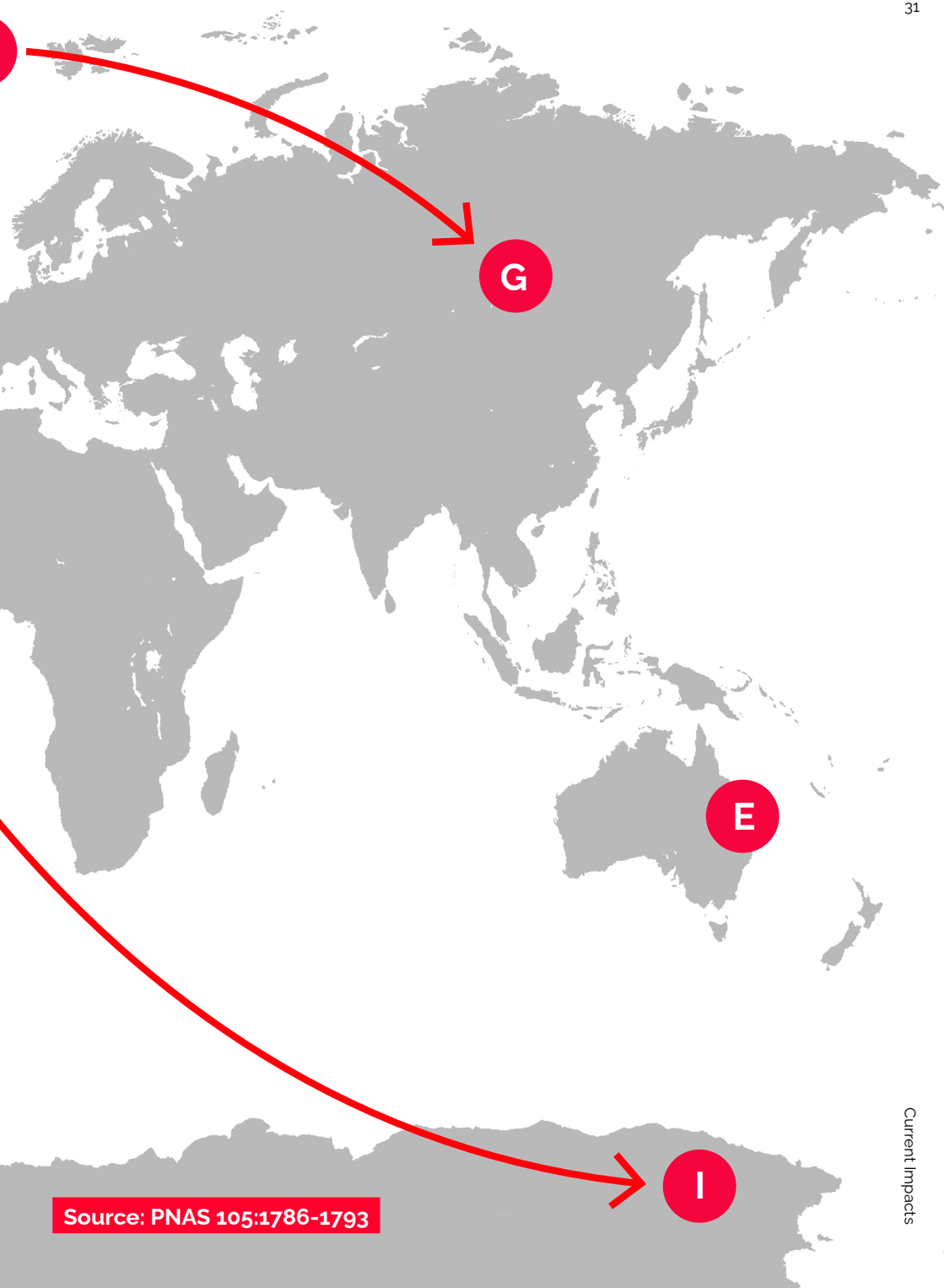
Raising the Alarm

Evidence that tipping points are underway in the past decade. Domino effects have also been proposed.

- **A** Amazon rainforest
  Frequent droughts
- **B** Arctic sea ice
  Reduction in area
- **C** Atlantic circulation
  In slowdown since 1950's
- **D** Boreal forest
  Fires & pests changing
- **E** Coral reefs
  Large-scale die-offs
- **F** Greenland ice sheet
  Ice loss accelerating
- **G** Permafrost
  Thawing
- **H** West Antarctic Ice sheetIce Loss accelerating
- **I** Wilkes Basin East Antarctica Ice loss accelerating

Tipping point

Connectivity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Source: PNAS 105:1786-1793

MAJOR RISKS

Understanding the urgency

Crisis prevention requires strategic coordination at the system level... Because of the non-linearity of the corona pandemic and climate change, the creation of capacities for adaptation to these crises does not suffice. Only if the unmanageable is avoided is there a chance to stabilize the system.

KIRA VINKE, SABINE GABRYSCH, EMANUELA PAOLETTI
JOHAN ROCKSTRÖM AND HANS JOACHIM SCHELLNHUBER
CORONA & THE CLIMATE: A COMPARISON OF TWO EMERGENCIES

MAJOR RISKS

The risks are existential

#13

We are in a state of planetary emergency: the risk and urgency are acute

- In 2019 scientists offered an emergency formula.[48] Generally, risk is considered to be the potential damage multiplied by the probability, but in this equation, another element is added, called urgency. This is the relationship between:
  - the reaction time "τ" (how long it takes to solve a problem); and
  - the intervention time "T" (the time you actually have, before it is "too late").
- Think of the Titanic: "If reaction time is longer than the intervention time left (τ / T > 1), we have lost control."[49]
- "The evidence from tipping points alone suggests that we are in a state of planetary emergency: both the risk and urgency of the situation are acute… If damaging tipping cascades can occur and a global tipping point cannot be ruled out, then this is an existential threat to civilization."[50]

Risk (R) is damage (D) multiplied by probability (p).

$$\text{Emergency } (E) = R \text{ (risk)} \times U \text{ (urgency)} = (p \times D) \times (\tau / T)$$

Urgency (U) in emergency situations is reaction time – the time required to solve the problem (τ) – divided by the intervention time actually available left to avoid a bad outcome (T).

MAJOR RISKS

The risks are existential for nature, too

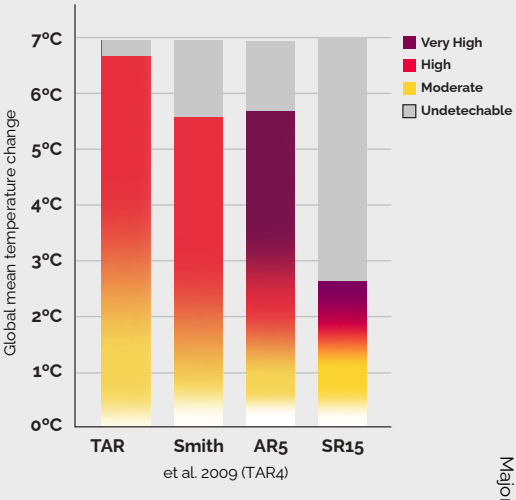
#14

We are now entering the sixth mass extinction inEarth's history

- The rate of change matters. Many ecosystems (e.g. Arctic, corals, dry subtropics) have not adapted to 1˚C change in a century (0.1˚C/decade).
- Warming for the 2010-2019 decade was >0.25˚C, and projected to be higher in next 2–3 decades (#2)
- We are now entering the sixth mass extinction in Earth's history.[52]
- At warming of 3.5˚C by 2100 (rate of 0.3˚C/decade), only 30% of all impacted ecosystems can adapt and only 17% of all impacted forests can adapt.[51] Common tree species cannot adapt naturally by poleward shifts to >2˚C per century.
- The "burning embers" diagram from the IPCC special report SR15 shows "very high risk" with limited ability for unique and threatened ecosystems to adapt to 2˚C of warming (Chart 6).

Chart 5

Unique & threatened ecosystems



IPCC Special Report 1.5˚C

MAJOR RISKS

Sensible risk-management requires special attention be given to high-end possibilities

#15

Precautionary action is necessary to prevent existential outcomes

- An emergency exists if the world is approaching a global cascade of tipping points that leads to a "hothouse" climate state: "Cascading effects might be common… examples are starting to be observed."[53]
- Climate change is an existential risk to human civilisation (contemporary society).[54]
- This requires special precautions beyond conventional risk management practice if the increased likelihood of "fat tail" (high end) risks are to be adequately dealt with.
- Calculating probabilities makes little sense in the most critical instances. Rather, we should identify and focus on the very large climate impact, "fat tail", possibilities.[55]
- And then take precautionary action to prevent them occurring.

Fundamental questions about the risk we need to ask:

How close are we to losing control? Is there a non-trivial probability that we "might already have lost control of whether tipping happens",[56] that the reaction time required to solve the problem (τ) is greater than the intervention time actually left to avoid a bad outcome (T)?

How large is that emergency/ existential risk?

Can the reaction time required to solve the problem and apply the solutions be reduced, for example from 2050 to 2030? How could this be done?

Can the intervention time available to avoid catastrophe be extended? How can the rate of warming be slowed and the Earth cooled?

CRITICAL ACTIONS

Key responses for protection

We are literally in a climate emergency, and... We are increasingly hearing that this is the fight of our lives.

PATRICIA ESPINOSA
UNFCCC EXECUTIVE SECRETARY

CRITICAL ACTIONS

Zero emissions at emergency speed: 2030 — not 2050 — is the crucial time frame

#16

Long-term targets are an excuse for procrastination

- It is already too hot (#6), and we are dangerously close to the "Hothouse Earth" scenario (#10), yet *current* greenhouse gas levels may be enough to cause 2–4˚C of warming in the longer term (#12).
- The primary task is to build capacity for emergency speed and scale emissions elimination, and to minimise the rate and magnitude of warming.
- Mobilising for zero emissions by 2030 is critical.
- A 2050 timeframe will not prevent catastrophic outcomes.
- Long-term targets are an excuse for procrastination. That has been the history of international climate policy-making.

CRITICAL ACTIONS

The Earth is already too hot: large-scale carbon drawdown is vital

#17

Removing carbon dioxide from the atmosphere can cool an overheated Earth

- Stabilisation (at current climate) would require carbon drawdown of 60 ppm (back to ~350 ppm) to stop further warming of ~0.7˚C. Lowering current warming would require more drawdown.[57]
- CO_2 may be drawn out of the atmosphere by natural cycles on land (by reforestation, for example) and in oceans, by rock weathering and by storage in soils.[58]
- These processes can be enhanced, and new technologies are being developed. Large-scale research and deployment is crucial.
- Drawdown is a slow process that will not provide active cooling until it is greater than level of emissions.
- We should be wary of relying on claims that in the distant future bioenergy with carbon capture and storage (BECCS) is a panacea.[59]

CRITICAL ACTIONS

A safe means of immediate cooling is critical to protect people & nature

#18

Damage is — and will become more —dangerous before long-term solutions are effective

- Warming is already dangerous, likely to reach 1.5˚C by 2030 (#2), 2˚C before 2050 (#5) and 3–5˚C by 2100 on the current path (#9), bringing unacceptable risks of a "Hothouse Earth" scenario (#10).
- Mitigation is vital but by itself will not have noticeable beneficial impact on temperature trajectory till mid-2040s (#3).
- This delay in mitigation effect may trigger further significant physical tipping points.
- Zero emissions, even in a decade, coupled with large-scale drawdown, is not sufficient to negate the existential risk (#13)

Can strong, immediate cooling be of net environmental and social benefit?

- We need options to cool the planet and/or protect vital climate systems, particularly in the polar regions. Options for polar cooling include enhancing the capacity of marine clouds to reflect incoming radiation.
- Solar radiation management (SRM), using cooling aerosols, can have a strong, immediate cooling effect.
- There is no current evidence that SRM would demonstrate a net environmental and social benefit, but if proven it may be useful whilst longer-acting solutions are deployed.[60]
- There are global SRM governance issues and risks to navigate in order to prevent unilateral deployment and misuse.[61]

CRITICAL ACTIONS

Adaptation actions should protect the most vulnerable

#19

Adaptation is vital, but no substitute for deep climate mitigation

- Adaptation should be seen as a parallel strategy to mitigation to deal with unavoidable impacts and risks.
- It is no substitute for deep climate mitigation and restoration because it is not possible for most people and nature to adapt to 3–5˚C of warming this century (#9 and #11).
- There is the danger of the "adaptation trap", where most effort is put into adaptation, and the lack of adequate mitigation delivers a "hothouse Earth".
- Adaptation should prioritise actions to protect the most vulnerable human populations and nature.
- We should strengthen the capacity and skills required by people to face climate disruption with honesty, courage and compassion.

CRITICAL ACTIONS

The collapse of civilisation is not inevitable, but emergency-level action right now is critical

#20

An emergency response would make climate the number one priority of politics and economics

- Many human and Earth systems are increasingly fragile.
- The end of civilisation due to climate disruption — the generalised collapse of contemporary societies — is not certain or inevitable.
- But it is likely unless dramatic global action is taken to make climate the number one priority of economics and politics in an emergency response.
- But large-scale disruption is inevitable, either by failing to act fast enough, or because the scale of action now required is far beyond a gradualist approach.
- The short term is crucial: what we do now and before 2030 matters, not aspirations about 2050.

SUMMARY

Key points

IMPACTS & RISKS

- 1.5˚C around or before 2030, irrespective of actions taken in the interim, and a decade ahead of IPCC projections.
- Even substantial emission reductions will have no significant impact on the warming trend over the next 20-25 years, due to the offsetting effect of aerosols.
- 2˚C is likely prior to 2050, even with actions better than the current *Paris Agreement* commitments, and 3˚C in the early-to-mid second half of the century on current emissions trajectory, with 5˚C possible by 2100.
- The current 1.2˚C of warming is already dangerous; 2˚C would be extremely dangerous; 3˚C catastrophic; and 4˚C unlivable for most people.
- A "Hothouse Earth", non-linear, irreversible, self-sustaining warming may be triggered between 1.5–2˚C. There is a risk that we have already lost control of the system.

RESPONSES & ACTIONS

Societies that are successfully overcoming the Covid pandemic threat are doing so by making it the highest priority of politics and economics, based upon acceptance of the best available science. Climate is a much bigger threat, that requires the same approach.

- Assess the real risks with brutal, rigorous honesty.
- Recognise that climate disruption requires an emergency, planned response.
- Act fast for zero emissions by 2030.
- Build capacity to draw down carbon.
- Understand what role solar radiation management may play.
- Making action on climate disruption the first priority of government is the key to protecting people, society and nature.

FOOTNOTES

Sources & references

1 NASA Global Land-ocean Temperature Index Dataset (1951-2020).

2 Based on 5-year average for second half of each decade, from NASA dataset: 2005-2009 (above 1880-1909) 0.89°C; 2015-2019 1.16°C.

3 Xu, Y, Ramanathan V & Victor, DG 2018, 'Global warming will happen faster than we think', *Nature*, vol. 564, pp. 30-32; Tebaldi, C et al, 2020, 'Climate model projections from the Scenario Model Intercomparison Project (ScenarioMIP) of CMIP6', *Earth System Dynamics*, 16 September, pre-print.

4 Jacob, D et al 2020, 'Climate impacts in Europe under +1.5°c global warming', Earth's Future, vol. 6, pp. 264-285; Xu, Y, Ramanathan V & Victor DG 2018, 'Global warming will happen faster than we think', Nature, 5 December; Henley, BJ & King, AD 2017, 'Trajectories toward the 1.5°C Paris target: Modulation by the Interdecadal Pacific Oscillation', Geophysical Research Letters, vol. 44, pp. 4256-4262.

5 Tebaldi, C et al, 2020, 'Climate model projections from the Scenario Model Intercomparison Project (ScenarioMIP) of CMIP6', *Earth System Dynamics*, 16 September, pre-print.

6 Xu, Y, Ramanathan V & Victor, DG 2018, 'Global warming will happen faster than we think', *Nature*, vol. 564, pp. 30-32.

7 Xu, Y, Ramanathan V & Victor, DG 2018, 'Global warming will happen faster than we think', *Nature*, vol. 564, pp. 30-32.

8 Berwyn, B 2020, 'New study shows a vicious circle of climate change building on thickening layers of warm ocean water', *Inside Climate News*, 28 September.

9 Samset, BH et al, 2018, 'Climate impacts from a removal of anthropogenic aerosol emissions', *Geophysical Research Letters*, vol. 45, pp. 1020-1029.

10 Hansen, J, Kharecha, P & Sato, M 2013, 'Climate forcing growth rates: Doubling down on our Faustian bargain', *Environmental Research Letters*, vol. 8, pp. 1-9.

11 Samset, BH, Fuglestvedt, JS & Lund, MT 2020, 'Delayed emergence of a global temperature response after emission mitigation', *Nature Communications*, vol. 11, pp. 3261.

12 von Schuckmann, K et al, 2020, 'Heat stored in the Earth system: where does the energy go?', *Earth System Science Data*, vol. 12, pp. 2013–2041.

13 CO_2e — or carbon dioxide equivalent — is an estimate of the effect of the well-mixed greenhouse gases, including methane and nitrous oxide, measured as a carbon dioxide equivalent, in parts per million (ppm).

14 Based on $\Delta T = ECS * \log(CO_2t/280)$ where ECS is climate sensitivity and CO_2t is total well-mixed greenhouse gases in parts per million.

15 Spratt, D 2015, 'Recount: It's time to do the math again', Breakthrough, Melbourne.

16 Tebaldi, C et al, 2020, 'Climate model projections from the Scenario Model Intercomparison Project (ScenarioMIP) of CMIP6', *Earth System Dynamics*, 16 September, pre-print.

17 Chart courtesy Glen Peters, based on data from GCP and CDIAC.

18 Hansen, J et al, 2008, 'Target atmospheric CO_2: Where should humanity aim?' Open Atmospheric Science Journal, vol. 2, pp. 217-231. Palaeosens Project Members 2012, 'Making sense of palaeoclimate sensitivity', *Nature*, vol. 491, pp. 683–691.

19 Brown, PT & Caldeira, K 2017, 'Greater future global warming inferred from Earth's recent energy budget', *Nature*, vol. 552, pp. 45–50.

20 Pistone, K, Eisenman, I & Ramanatham, V 2019, 'Radiative heating of an ice-free Arctic Ocean', *Geophysical Research Letters*, vol. 46, pp. 7474-7480. Monroe, R & IGSD 2019, 'Research Highlight: Loss Of Arctic's Reflective Sea Ice Will Advance Global Warming By 25 Years', Scripps Institution of Oceanography, San Diego.

21 King, AD, Karoly, DJ & Henley, DJ 2017, 'Australian climate extremes at 1.5 °C and 2 °C of global warming', *Nature Climate Change*, vol. 7, pp. 412–416.

22 Rignot, E 2014, 'Global warming: it's a point of no return in West Antarctica. What happens next?', *The Guardian*, 18 May.

23 Beltran, C et al, 2020, 'Southern Ocean temperature records and ice-sheet models demonstrate rapid Antarctic ice sheet retreat under low atmospheric CO_2 during Marine Isotope Stage 31', *Quaternary Science Reviews*, vol. 228, 15 January.

24 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

25 Jansen, Eet al, 2020, 'Past perspectives on the present era of abrupt Arctic climate change', *Nature Climate Change*, vol. 10, pp. 714-721.

26 Associated Press/2019, 'Cold War spy satellite images show Himalayan glaciers are melting fast', *ABC News*, 20 June. Naik, G 2015, 'Central Asia mountain range has lost a quarter of ice mass in 50 years, study says', *The Wall Street Journal*, 17 August.

27 Lovejoy, TE & Nobre C 2018, 'Amazon tipping point', *Science Advances*, vol. 4, eaat2340.

28 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

29 King, MD et al, 2020, 'Dynamic ice loss from the Greenland Ice Sheet driven by sustained glacier retreat', *Communications Earth & Environment*, vol. 1, 1.

30 Robinson, A, Calov, R & Ganopolski, A 2012, 'Multistability and critical thresholds of the Greenland ice sheet', *Nature Climate Change*, vol. 2, pp. 429-432.

31 Harvey, F 2020, 'Amazon near tipping point of switching from rainforest to savannah – study', *The Guardian*, 5 October.

32 Readfearn, G 2018, 'Earth's climate monsters could be unleashed as temperatures rise', *The Guardian*, 6 October.

33 Spratt, D 2011, 'Rethinking a "safe climate": have we already gone too far?', *Climate Code Red*, 23 January.

34 Reuters, 2018, 'Global temperatures on track for 3-5 degree rise by 2100: UN', *Reuters*, 29 November.

35 Schwalm, CR, Glendon, S & Duffy, PB 2020, 'RCP8.5 tracks cumulative CO_2 emissions', *Proc. Natl. Acad. Sci.*, vol. 117, pp. 19656-19657

36 Roberts, D 2011, 'The brutal logic of climate change', *Grist*, 6 December.

37 Vince, G 2019, 'The heat is on over the climate crisis. Only radical measures will work', T*he Guardian*, 19 May.

38 Steffen, W et al, 2018, 'Trajectories of the Earth System in the Anthropocene', *Proc. Natl. Acad. Sci.*, vol. 115, pp. 8252-8259.

39 Steffen, W et al, 2018, 'Trajectories of the Earth System in the Anthropocene', *Proc. Natl. Acad. Sci.*, vol. 115, pp. 8252-8259.

40 Hansen, J et al 2007, 'Climate change and trace gases', *Phil. Trans. R. Soc. A*, vol. 365, pp. 1925–1954.

41 Potsdam Institute for Climate Impact Research 2019, 'Ranking: the climate papers most featured in online media', *News*, 12 January.

42 Spratt, D & Dunlop, I 2019, 'The third degree: Evidence and implications for Australia of existential climate-related security risk', *Breakthrough*, Melbourne.

43 Xu, Y & Ramanathan, V 2017, 'Well below 2 °C: Mitigation strategies for avoiding dangerous to catastrophic climate changes', *Proc. Natl. Acad. Sci.*, vol. 114, pp. 10315-10323.

44 Rohling, E et al, 2009, 'Close relationship between past warming and sea-level rise', *Science Daily*, 7 July.

45 Burke, KD et al, 2018, 'Pliocene and Eocene provide best analogs for near-future climates', *Proc. Natl. Acad. Sci.* vol. 115, pp. 13288-13293. McClymont, EL et al, 2020, 'Lessons from a high-CO_2 world: an ocean view from ~3 million years ago', *Climate of the Past*, vol. 16, pp. 1599–1615.

46 Carrington, D 2019, 'Last time CO_2 levels were this high, there were trees at the South Pole', *The Guardian*, 3 April.

47 Carrington, D 2019, 'Last time CO_2 levels were this high, there were trees at the South Pole', *The Guardian*, 3 April.

48 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

49 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

50 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

51 Leemans, R & Eickhout, B 2004, 'Another reason for concern: regional and global impacts on ecosystems for different levels of climate change', *Global Environmental Change*, vol. 14, pp. 219-228.

52 Ceballos, G et al, 2015, 'Accelerated modern human–induced species losses: Entering the sixth mass extinction', Science Advances, vol. 1, 19 June. Román-Palacios, C & Wiens, JJ 2020, 'Recent responses to climate change reveal the drivers of species extinction and survival', *Proc. Natl. Acad. Sci.*, vol. 117, pp. 4211-4217.

53 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

54 Schellnhuber, HJ 2018, 'Foreword', in Spratt, D & Dunlop, I, in *What lies beneath: The understatement of existential climate risk*, Breakthrough, Melbourne.

55 Spratt, D & Dunlop, I 2018, '*What lies beneath: The understatement of existential climate risk*', Breakthrough, Melbourne.

56 Lenton, TM et al, 2020, 'Climate tipping points — too risky to bet against', *Nature*, vol. 575, pp. 592-595.

57 von Schuckmann, K et al, 2020, 'Heat stored in the Earth system: where does the energy go?', *Earth System Science Data*, vol. 12, pp. 2013–2041.

58 Caldeira, K, Bala, G & Cao, L 2013, 'The science of geoengineering', *Annual Review of Earth and Planetary Sciences*, vol . 41, pp. 231-256. Cowie, A et al, 2020, 'The Morrison government wants to suck CO_2 out of the atmosphere. Here are 7 ways to do it', *The Conversation*, 21 September.

59 Anderson, K & Peters, G 2016, 'The trouble with negative emissions', *Science*, vol. 354, pp. 182-183.

60 Boettcher, M & Schäfer, S 2017, 'Reflecting upon 10 years of geoengineering research: Introduction to the Crutzen + 10 special issue', *Earth's Future*, vol. 5, pp. 266-277.

61 Talberg, A et al, 2018, 'Geoengineering governance-by-default: an earth system governance perspective', *International Environmental Agreements: Politics, Law and Economics*, vol. 18, pp. 229–253

Quote references

Q1 Prof. Hans joachim schellnhuber Director emeritus of the potsdam institute. Breeze, N, 2019, 'It's nonlinearity – stupid!', The Ecologist, 3 January.

Q2 António Guterres UN Secretary General, 30 June 2019. United Nations, 2019, 'Secretary-General's remarks to Climate Summit Preparatory Meeting', United Nations, 30 June.

Q3 Vinke, K et al, 2020, 'Corona and the climate: a comparison of two emergencies', Global Sustainability 3, e25, 1–7.

Q3 Rowling, M, 2019, 'UN climate chief says 3C hotter world "just not possible"', Thomson Reuters News, 17 June.

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