Institute and Faculty of Actuaries

University of Exeter

Collaborative insights in the public interest

January 2026

Parasol Lost: Recovery plan needed

Global risk management for human prosperity

A Planetary Solvency supplementary risk report

Contents

Technical Appendix on Climate Sensitivity is published seperately to complement this report

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Acknowledgements

The authors wish to thank the members of the Advisory and Review Group for their time, scrutiny, and expert contributions to this report:

Doug Baird, Georgina Bedenham, Neil Cantle, Professor Colm Connaughton (London Mathematical Laboratory), Paul Dickinson (CDP), Professor Molly Jahn (University of Wisconsin-Madison), Dr. Luke Kemp (University of Cambridge), Laurie Laybourn-Langton (Strategic Climate Risks Initiative), Dr. Trevor Maynard (Cambridge Centre for Risk Studies), Professor Michael Obersteiner (University of Oxford), Jo Paisley (GARP Risk Institute), Richard Percy and Dr. Pete Sudbury.

Foreword

Sir David King
Founder and Chair of the global Climate Crisis Advisory Group, CCAG

Unmitigated climate change risks Planetary Insolvency, defined as 'significant societal disruption driven by climate and nature risks'. Without immediate policy action to change course, catastrophic impacts are eminently plausible. These include fires, floods, heat and droughts. This is a national security issue as food, water, heat stresses and rising sea levels will impact populations. If unchecked then mass mortality, involuntary mass migration events and severe GDP contraction are likely.

In recent years climate impacts have been sooner than expected and worse than expected. This highlights the risk of basing policy decisions on the central estimates of climate change, when actual climate impacts may emerge towards the top end of estimated ranges.

In this report, we explore several lines of evidence about the sensitivity of our climate to greenhouse gases. That evidence is consistent with the range for climate sensitivity estimated by the Intergovernmental Panel on Climate Change (IPCC), but it points to a risk that the actual sensitivity of our climate might be towards the top end of that range. If climate sensitivity is higher than expected we have underestimated the rate of future warming, with catastrophic warming levels of over 2°C before 2050 now likely, unless we change course. These findings show that net zero carbon budgets will not limit temperatures to 1.5°C.

This is a classic model risk situation, with strong parallels to the global financial crisis, where financial models could not see the interconnected nature of the global financial system, leading to complacency and a failure to mitigate systemic risk. Emergency action was required to stabilise the system, which would have been unimaginable without the crisis. Following this, significant work took place to enhance financial services risk management practices.

We have arrived at a similar 'break glass' moment for climate change. Emergency action is required to stabilise the climate system, and to implement equivalent risk management practices to those that protect financial stability. Governments and other stakeholders need to execute a Planetary Solvency recovery plan, congruent with CCAG's 4R planet strategy, identifying quick wins, emergency brakes and options to change our trajectory away from the high-risk zone[1]. Action is required to: radically accelerate societal adaptation to a changing climate, supercharge the pace of the energy transition to reduce fossil fuel use and emissions, and remove excess greenhouse gases already in the atmosphere. It will be overwhelmingly positive economically to do so.

The key message is that we still have agency here and the ability to change course. To avoid Planetary Insolvency, policymakers must urgently implement a fundamental, policy-led change of direction, informed by up-to-date information on what is happening, what is likely, the risks associated with ongoing global warming and a willingness to address the root causes of the problems we face.

This is a classic model risk situation, with strong parallels to the global financial crisis.

The urgent need for a Planetary Solvency recovery plan

There are large numbers of potentially effective structural interventions that could be made to change the trajectory of global warming, by working with nature, changing consumption patterns and using technological ‘emergency brakes’.

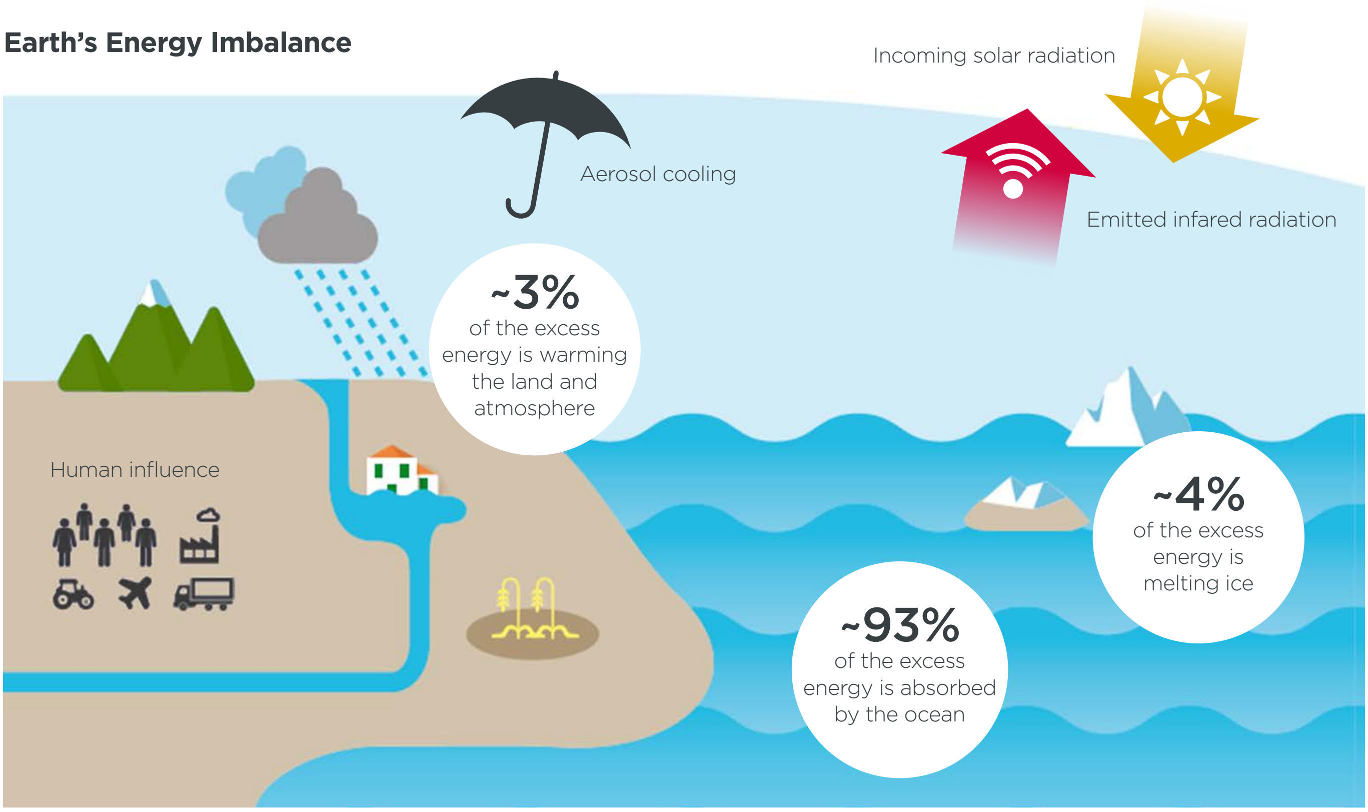
Figure 1: Planetary Solvency recovery plan

By focusing primarily on the energy transition, we are operating with one hand tied behind our backs. Learning to work with nature offers the potential for material climate interventions.

An important consideration is the cooling effect of aerosols, which are produced as a side-effect of pollution from fossil fuel burning. Without aerosol cooling the global temperature would be around 0.5°C higher than the 1.4°C increase above pre-industrial temperature that we have today[2].

It is critically important to recognise that, as air pollution is cleaned up, this may ironically lead to a short-term increase in warming through the loss of aerosol cooling. The question must be asked, can we afford to lose this cooling and if not, should this be replaced by working with nature, using technology or both?

Figure 2: Earth's Energy Imbalance (EEI) – the driver of climate change



Source: World Climate Research Programme - "The Earth's Energy Imbalance and its implications"

It is absolutely imperative that technological methods are not presented as an alternative to accelerating the transition to net zero carbon energy, transport and food systems to reduce emissions. While not the focus of this report, changes to consumption patterns and our dominant economic model will also be required.

The Planetary Solvency recovery plan is designed to rapidly reduce Earth's energy imbalance, recognising that the high sensitivity finding means achieving net zero is no longer enough to avoid catastrophic levels of warming. As with a financial solvency recovery plan, there must be a laser-like focus on what is effective in moving the needle, while avoiding unproven distractions being pushed by incumbents.

‘

Learning to work with nature offers the potential for material climate interventions.

Key findings

High emissions and accelerating warming past 1.5°C

1. **Emissions, warming and the energy imbalance – a runaway trend**

   The decadal running average is already at 1.4°C of warming, with recent temperatures above the 1.5°C temperature goal of the Paris Agreement. Emissions, the energy imbalance and the rate of warming are all increasing, making catastrophic warming of greater than 2°C before 2050 likely unless action is taken to change course.

2. **Aerosol cooling – the hidden sunshade and the termination shock**

   Particulates in the atmosphere from pollution have acted like a sunshade, reflecting sunlight and fostering cloud formation, so reducing the energy imbalance. This 'aerosol cooling' has offset warming by around 0.5°C in an inadvertent form of Planetary Solvency management. Recent efforts to remove sulphur from the emissions from coal and oil burning improved air quality, but had the side effect of reducing aerosol cooling, contributing to an acceleration of warming in recent years. This can be termed as unmasking; others have referred to it as a 'termination shock.'

3. **Satellite data reveals the size of the termination shock and high sensitivity**

   New satellite measurements suggest that the impact of reduced aerosols may be larger than estimated in models and a significant contributor to recent accelerated warming. If the aerosol cooling effect has been larger than previously believed, then more warming has been masked, and the Earth's climate could be more sensitive to greenhouse gases than the central estimate. Even without any more emissions, we may be on course for much more warming than expected.

Global catastrophic risks, including economic shocks, are proximate

4. **Risks include climate-driven inflation, migration and economic shocks**

   Climate impacts are accelerating, including heat spikes, floods, fires and storms, which can cause significant disruption to food, water, health, energy and transport systems. Economic growth is threatened and insurance withdrawal is occurring in some regions. We have underestimated the severity and proximity of these risks, which are now impacting global and UK society.

5. **Accelerated adaptation is needed to reduce impacts and avoid derailment**

   Societal preparation and response can significantly reduce the impact of accelerated climate hazards. An immediate step up in pace and preparedness is needed to build resilience. Simultaneously, safeguards must be put in place to avoid derailment risk – i.e. society being too distracted by escalating crises to address the root causes of climate change by reducing emissions.

6. **Climate tipping points mean there is a point of no return**

   Above 1.5°C, we enter the danger zone where multiple climate tipping points may be triggered, such as the collapse of ice sheets in Greenland and Antarctica, permafrost melt, Amazon dieback and changes in ocean circulation. Some tipping points accelerate climate change and worsen impacts, meaning there is a point of no return, after which it may be impossible to stabilise the climate close to conditions that we are able to adapt to.

A Planetary Solvency recovery plan is urgently needed

7. **Becoming planetary stewards and working with nature**

   We are intertwined with and dependent on the Earth system, which we have been shaping since prehistoric times. Beyond greenhouse gas emissions and aerosol cooling, human impacts include deforestation, bottom trawling, extermination of megafauna, wetland drainage and urbanisation. We need to recognise the agency we have and intentionally manage our interactions with our biggest ally: nature.

8. **Delivering quick wins and researching emergency brakes**

   Rapid movement on methane emissions and other short lived climate forcers could be one of the most significant quick wins we have, alongside halting deforestation. Simultaneously, we must protect land-based carbon sinks, restore ocean carbon sinks and explore technological solutions to ensure we aren't tripped up by the loss of aerosol cooling.

9. **Accelerate the transition to deliver huge economic upside**

   It will be overwhelmingly positive economically to minimise climate risks by reducing emissions deeply and rapidly, and removing excess GHGs already in the atmosphere. In this way we could avoid short term economic shocks and long term economic decline. There are also significant economic upsides from investing in the future, including improved food and energy security, lower energy costs, investment and job creation, economic growth and reduced climate-driven migration.

> **It will be overwhelmingly positive economically to minimise climate risks by reducing emissions, avoiding short term economic shocks and long-term economic decline.**

1. Developing planetary stability standards as a priority

In this section we argue that planetary stability standards should be equivalent to global financial stability practices, with financial services risk management processes adopted to help manage climate change and other planetary risks.

The global financial crisis (GFC) of 2007-08 originated in the United States housing market and quickly spread to financial systems and economies around the world, becoming the deepest downturn since the Great Depression.

One of the striking aspects of the crisis was that very few people saw it coming. Even once issues started to occur, we saw high levels of complacency and low levels of risk understanding. For example, Ben Bernanke, the Federal Reserve Chair, repeatedly stated that housing challenges would not derail growth. In March 2006, he said, *"Strong fundamentals support a relatively soft landing in housing. I think we are unlikely to see growth being derailed by the housing market."*[3] He also predicted that no major banks would face insolvency, saying in late 2007, *"I do not expect insolvency or near-insolvency among major financial institutions."*[4]

Bernanke was far from alone in failing to understand the fragility of the global financial system, with a range of contributory factors leading to widespread institutional and systemic risk management failures. Perhaps chief amongst these was excessive risk taking by banks and investors, with a failure to fully understand the complex nature of some financial instruments and the true level of risk in mortgage-backed securities in particular. The global interconnectedness of the financial system, which helped to transmit risks rapidly across borders, was also underappreciated.

Chastened, the financial sector initiated multiple projects to understand what had happened and why risks had been missed, and to develop recommendations for improvements to avoid similar issues in the future. For example, the Institute of International Finance produced a comprehensive report[5] with a suite of recommendations to improve and standardise risk management practices in the global banking community, later taken forward by the Basel Committee on Banking Supervision.

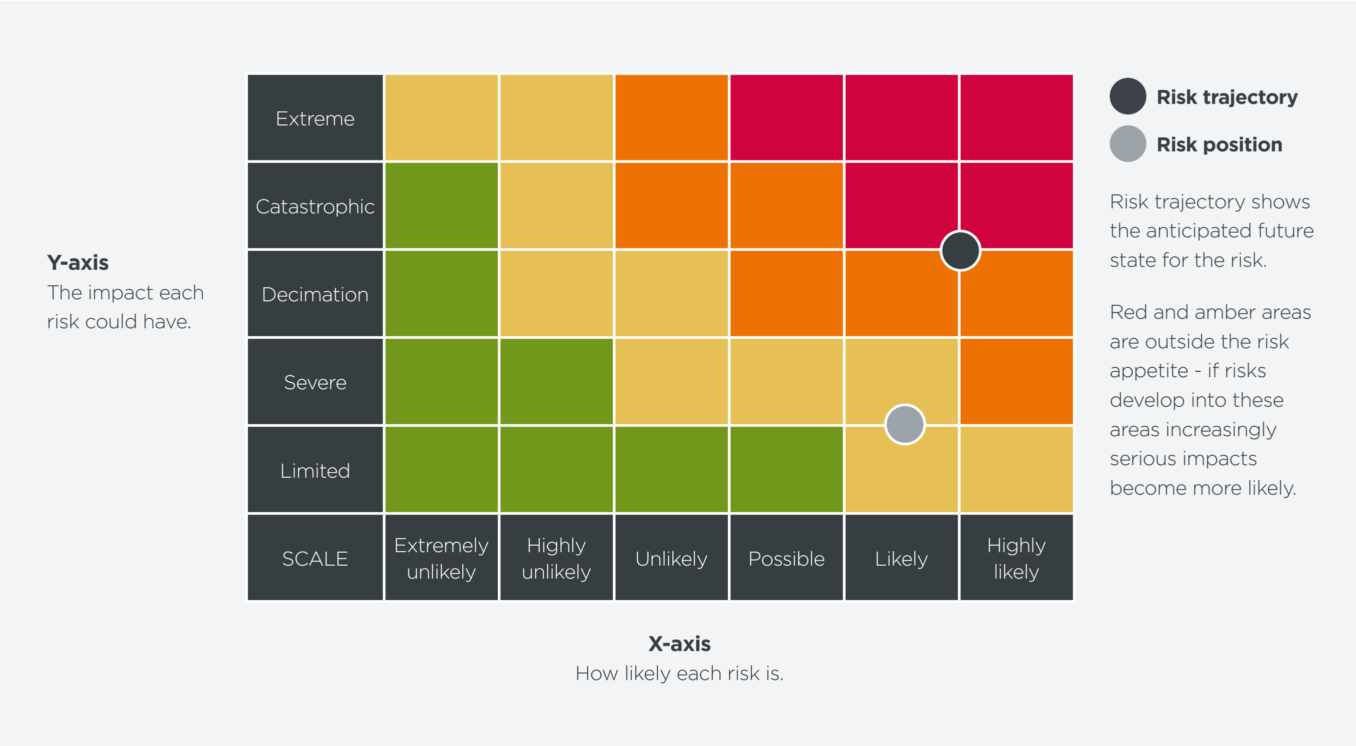
In *Planetary Solvency – finding our balance with nature*[6], we simply argue that we should apply these well-developed financial services risk management practices to our global challenges on climate change and nature.

To support decision-makers, we created a digital Planetary Solvency risk dashboard[7], clearly illustrating risk position and trajectory and highlighting not only the level of risk but also the action required to mitigate it.

We developed a Planetary Solvency risk appetite, suggesting this should be set to a low appetite for the climate, nature and societal risks that undermine the ecosystem services upon which our prosperity and well-being ultimately depends.

One of the striking aspects of the crisis was that very few people saw it coming.

Figure 3: Planetary Solvency risk dashboard template



In particular, we suggested the following set of events should be well outside risk appetite for our species:

- Crossing Earth system tipping points and triggering tipping cascades
- Habitat loss and species extinctions
- Breakdown of critical ecosystem services
- Climate change above 1.5°C
- Climate- and nature-driven forced displacement, conflict and mass mortality events
- Derailment risk, where society is too distracted by escalating crises to address root causes.

However, analysis shows that we are effectively seeking all these risks on our current trajectory, i.e. they are all likely as we move beyond 1.5°C and towards 2°C, rather than setting a course that seeks to avoid them.

To support the communication of this more effectively to policymakers, we developed a one-page document, *Planetary Solvency – Risks & Recommendations*[8], which warned that:

"There is an increasing risk of Planetary Insolvency unless we act decisively. Without immediate policy action to change course, catastrophic or extreme impacts are eminently plausible, which could threaten future prosperity."

Our economic analysis shows the potential for GDP damages to increase significantly as temperatures increase, leading to a 50% drop in GDP later in the century. A recent paper published by the UK's Climate Financial Risk Forum[9] suggests a specific and plausible but severe climate-nature scenario could result in a significant (15% to 20%) global GDP contraction over a five-year period.

These outputs illustrate how to lift and drop well-researched and developed financial services risk and solvency management techniques into the climate change and nature space, moving from globally systemically important banks to globally systemically important natural systems[10].

Our strong recommendation is that our management of planetary systems should leverage well-established financial services risk management protocols. We suggest creating a Planetary Stability Board to leverage existing Earth System scientific outputs, enabling risk-informed policy decisions to mitigate a systemic planetary shock—analogous in scale and oversight to a global financial crisis, yet encompassing the foundational stability of our food, water, and political systems.

2. An actuarial review of climate sensitivity

In this section we summarise the latest science which points towards higher estimates for climate sensitivity, focusing on satellite data, recent temperature trends and paleoclimate studies.

We discuss the implications for global warming and carbon budgets. Achieving net zero by 2050 will not limit warming to 1.5°C. Without action to change course, catastrophic warming levels of above 2°C by 2050 are likely, threatening Planetary Solvency.

Global warming is driven by concentrations of greenhouse gases (GHGs) in the atmosphere, which are increasing due to human activity. The greenhouse effect traps heat in the atmosphere. When greenhouse gas concentrations increase, more outgoing radiation is trapped, creating an energy imbalance where more energy comes in (absorbed sunlight) than goes out (heat radiated to space). This is referred to as Earth's energy imbalance (EEI)[11].

The question of how sensitive our planet is to GHGs, and how much the Earth will warm for a given emissions pathway, has been researched for decades[12]. Even if we reduced emissions to zero today, GHGs already in the atmosphere commit us to additional warming until Earth returns to thermal equilibrium, where incoming solar energy equals outgoing heat[13].

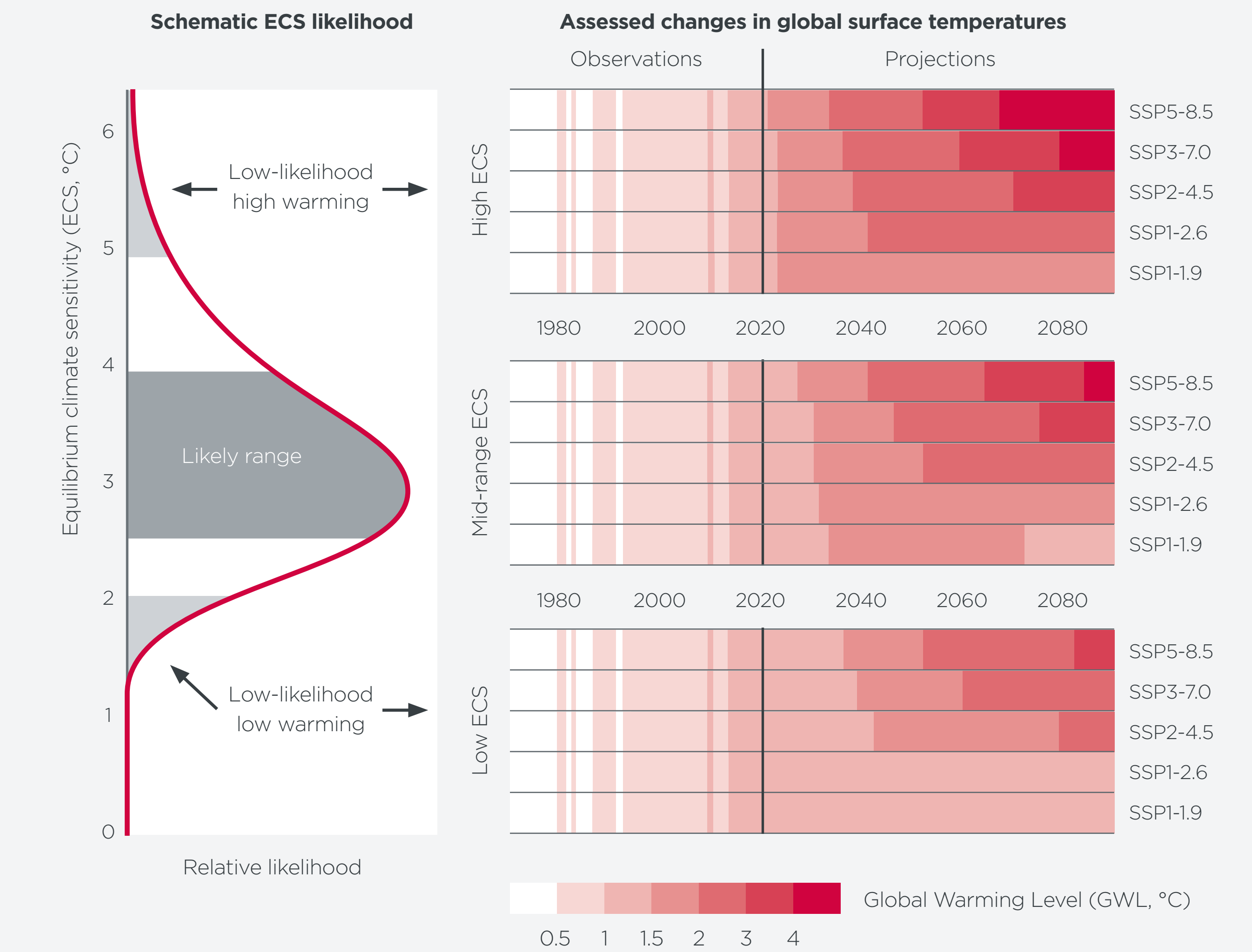
Equilibrium climate sensitivity (ECS) gauges the eventual global temperature increase after the Earth system has stabilised following a doubling of atmospheric CO_2. The latest IPCC consensus estimated a range for ECS of 2°C to 5°C, with 90% probability that the true value of ECS falls within this range and a 5% probability that it falls either below or above the range. The central estimate is 3°C, as shown on the left-hand side of *Figure 4* on the following page.

A higher ECS or high sensitivity implies more warming for a certain amount of GHGs, a low ECS implies less warming. *Figure 4* shows a range for ECS likelihood and how this impacts changes in global temperature over time and different emissions scenarios.

A technical appendix on climate sensitivity is published seperately to complement this section[14].

The question of how sensitive our planet is to GHGs, and how much the Earth will warm for a given emissions pathway, has been researched for decades[12].

Figure 4: Climate sensitivity distribution and impact on estimated warming [15]



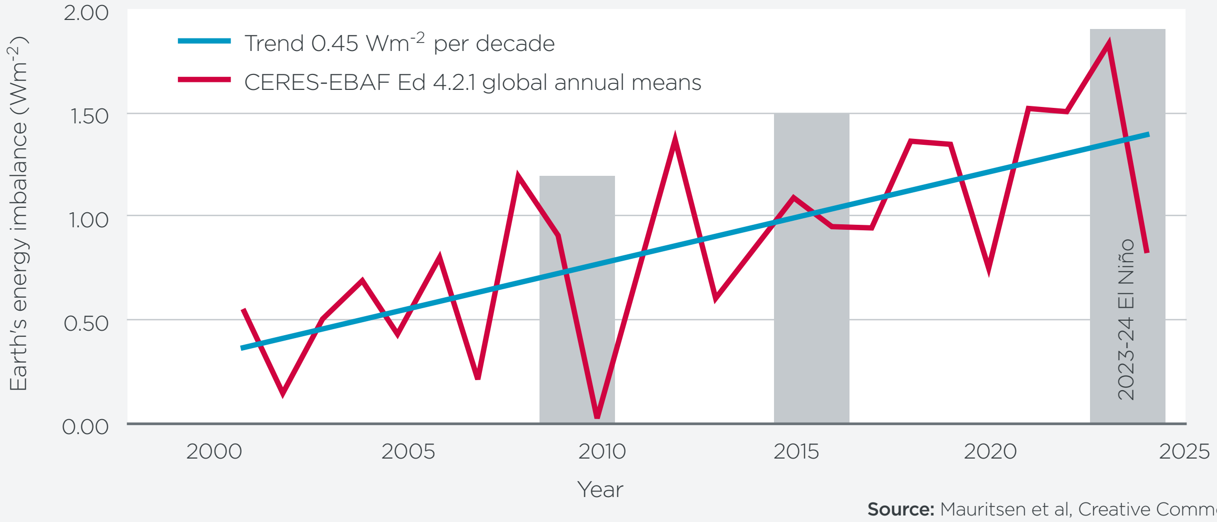
Source: IPCC

The SSPs in *Figure 4* refer to different emissions scenarios. SSP5-8.5 is a high emissions scenario, SSP1-1.9 a low emissions scenario. A high ECS of 5°C, shown in the top right, implies higher and faster warming for each scenario, with all but the very low emissions scenario breaching 2°C before 2040.

This rate of warming is consistent with our findings in *Planetary Solvency – finding our balance with nature*. If current warming rates persist, warming could exceed 2°C before mid-century, though significant uncertainty remains about whether recent acceleration represents a sustained shift or includes temporary factors.

Recent observational and modelling studies suggest ECS is higher than the central estimate. Three lines of evidence have emerged since the last IPCC report that point to ECS being towards the top of the IPCC's range: satellite measurements of Earth's energy imbalance, paleoclimate records and analysis of recent warming trends against climate model output. We summarise these findings below.

Figure 5: Earth's energy imbalance[17]



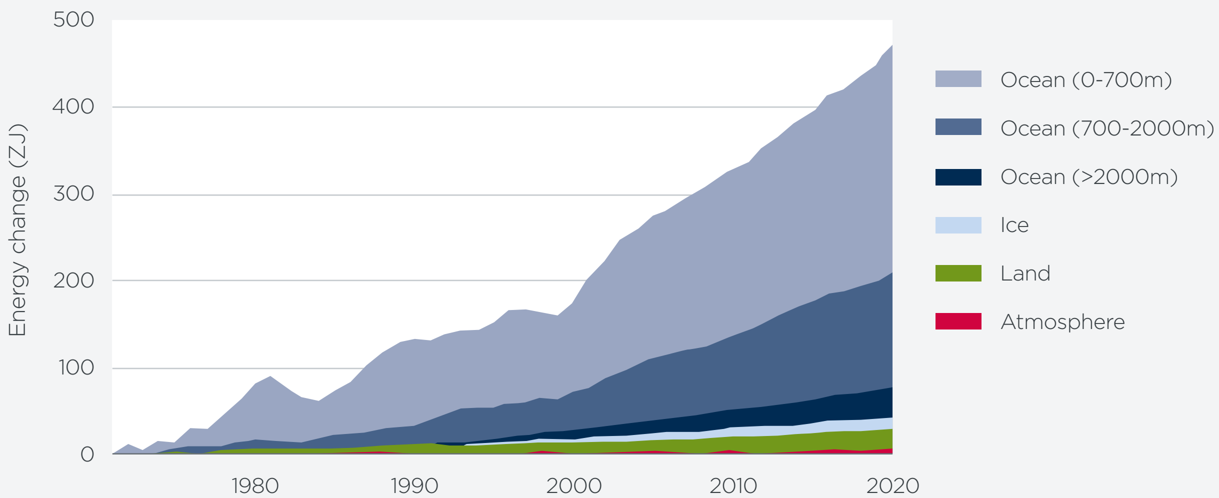
Source: Mauritsen et al, Creative Commons

I: Satellite measurements of Earth's energy imbalance

Satellite data this century shows EEI has doubled in recent decades and has reached a level significantly higher than that predicted by climate models. In early 2023 the rate of absorption of solar energy was equivalent to every person alive continuously boiling 60 kettles[16].

Figure 5 shows the upward trend in EEI over time this century. This sharp, sustained upward trend exceeds the range simulated by most models, even those accounting for recent increases in greenhouse gas emissions and changes in aerosols. The root cause appears to be a drop in Earth's solar reflectivity (albedo) and possibly poorly modelled sea surface temperatures and aerosol interactions. An important finding is that models with low climate sensitivity do not predict this level of EEI[18].

Figure 6: Earth's heat inventory



Source: Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence, Creative Commons

Over the period 1971 to 2020, the excess heat absorbed by the planet is estimated to be over 400 zettajoules (ZJ)[19]. To get a sense of scale, in 2024 the world's total primary energy consumption was 0.67 ZJ[20], meaning the Earth system has accumulated more than 500 times as much energy in the 50 years since 1971 than our total energy use in 2024. The excess heat that is retained by the planet has been largely absorbed by the ocean as illustrated in the diagram above, with around 4% of energy used to melt ice and the remaining 3% warming the land and atmosphere.

The 2025 Planetary Health Check explains that the ocean is, in a very real way, "the unsung guardian of planetary health"[21], taking up over 90% of the excess energy from EEI and a significant portion of carbon. The report goes on to outline the ocean's vital and foundational role in supporting Earth system stability, resilience and habitability.

Another area of concern relates to recent evidence that ocean and land-based natural carbon sinks may be degrading[22] (e.g. through deforestation, overfishing and pollution) and losing their capability to continue absorbing carbon at the rate they have been[23], though this remains an active area of research with evolving evidence. Should this trend continue, this will again lead to more warming than expected, as these factors are not typically included in models.

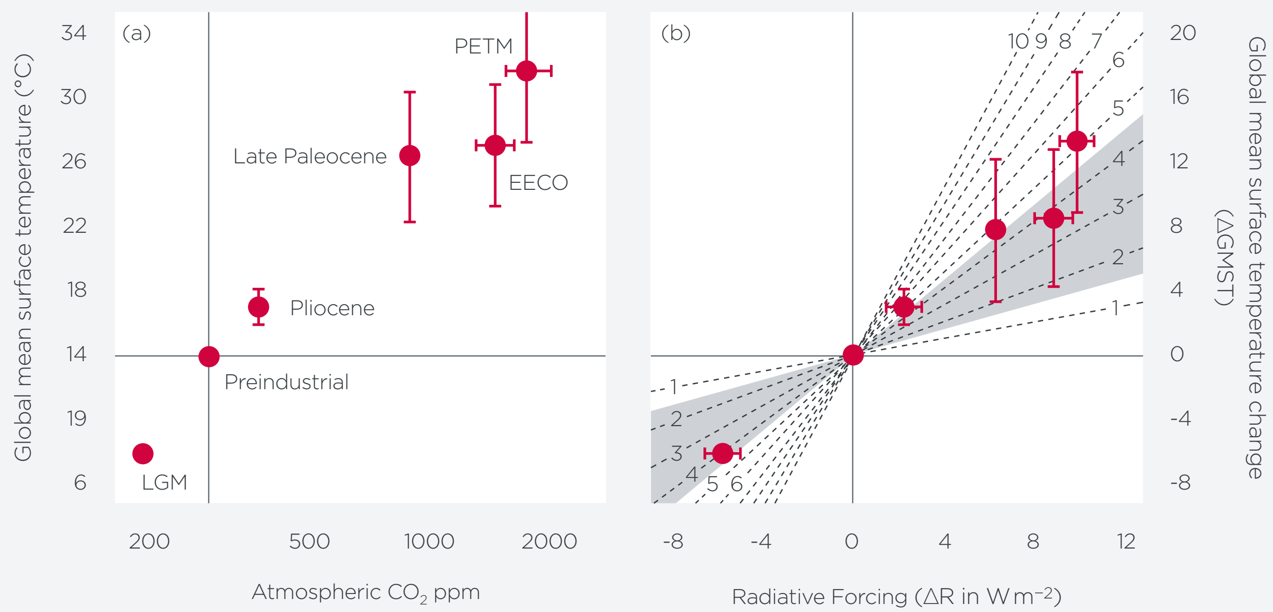
II: Paleoclimate records

Paleoclimate analysis, using evidence from millions of years of climate evolution, shows that large swings in past CO_2 were accompanied by temperature responses in line with higher sensitivity values.

Figure 7 (from Lear et al, 2020[24]) shows how five different eras from the geological record have been used to estimate ECS by mapping expected radiative forcing from different CO_2 concentration. The diagonal lines in (b) show the estimated likely range for the value of ECS from IPCC AR5 (2014) of 1.5°C to 4.5°C in blue. Some paleoclimate analyses suggest ECS toward the high end of the range, though estimates vary depending on how slow feedbacks are accounted for.

Figure 7 also shows the estimated temperature difference between various thermal states. Strikingly, the three maximum temperatures shown are more than 10°C higher than the pre-industrial temperature of 14°C.

Figure 7: Analysis of temperature and atmospheric CO_2 concentrations



(a) The relationship between atmospheric CO_2 concentration and global mean surface temperature (GMST) for five time intervals where both variables have been recently well constrained by geological data (Anagnostou et al. 2020; de la Vega et al. 2020; Inglis et al. 2020; Sherwood et al. 2020; Tierney et al. 2020). Error bars reflect 68% confidence intervals and in some cases are smaller than the symbol. LGM, Last Glacial Maximum; EECO, Early Eocene Climatic Optimum; PETM, Paleocene–Eocene Thermal Maximum. (b) The relationship between radiative forcing (ΔR in W m^{-2}) and global mean surface temperature (ΔGMST) relative to pre-industrial values. Contours show equilibrium climate sensitivity from 1 to 10°C per CO_2 doubling, and the blue band shows the canonical IPCC range of Equilibrium Climate Sensitivity of 1.5 to 4.5°C per CO_2 doubling. Note that data in panel (b) are corrected for slow feedbacks (see text) following the methods detailed in Tierney et al. (2020) and Inglis et al. (2020).

III: Analysis of recent warming trends against climate model output

The level of global warming increased significantly in 2023, with every internationally produced global temperature dataset showing 2024 to be the hottest year since records began in 1850. 2025 temperatures are slightly lower than 2024, although it is still likely to be the second or third hottest year on record.

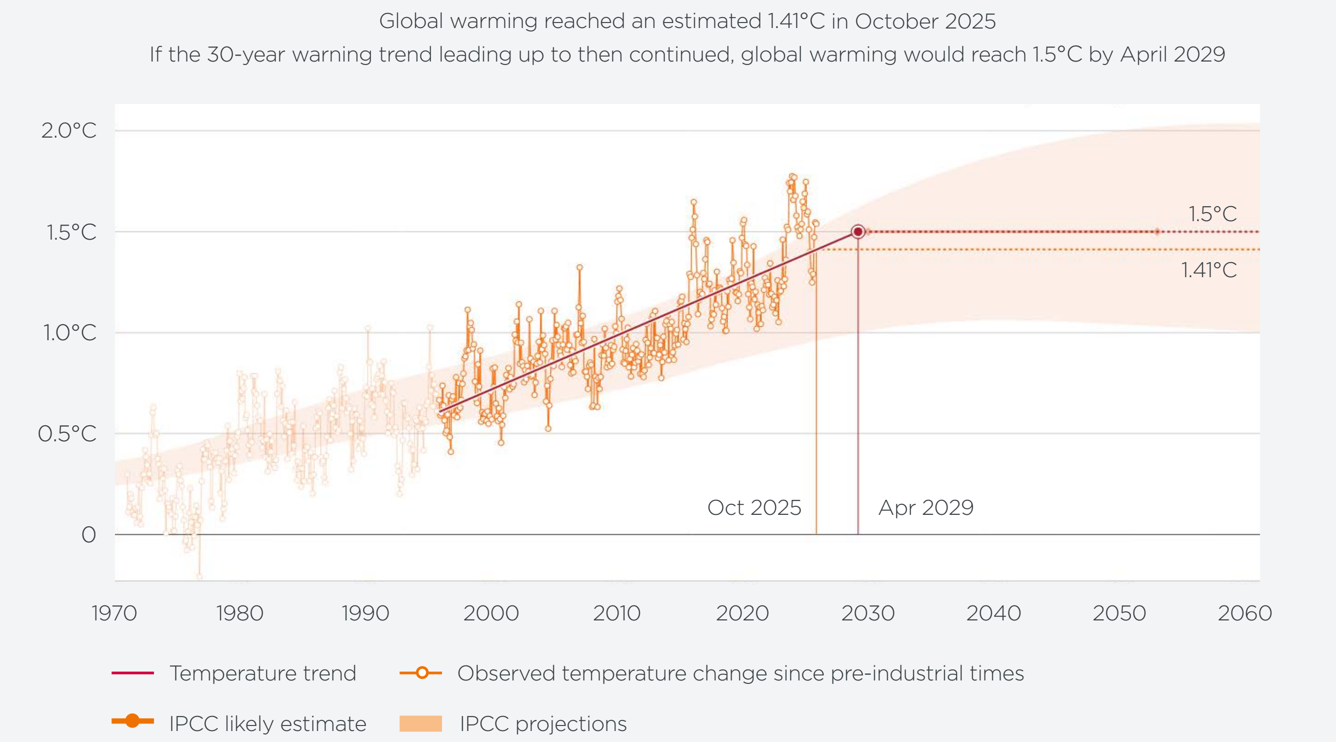
The rate of global warming has been steady since the 1970s, at around 0.18°C per decade. This has accelerated significantly in the last ten years to 0.27°C per decade[25], with some analyses suggesting rates as high as 0.4°C per decade when natural variability is removed, though these estimates carry uncertainty[26]. This is important – the global temperature is not only increasing, the rate of warming is also accelerating.

The chart below was recreated from the Copernicus dataset. It shows the global average temperature expressed as the change versus the pre-industrial temperature. It also shows the IPCC projections and the temperature trend, with a linear best-fit trend line which can be used for extrapolation to show what the temperature will be in the near future, if the current rate of warming continues. The linear best-fit trend line from the last 30 years shows the temperature reaching 1.5°C above pre-industrial before 2030. This linear projection does not account for natural variability cycles and should be interpreted as illustrative of recent trends rather than a formal forecast.

These recent observed warming trends, including the record temperatures of 2023-25, show an acceleration unaccounted for by low-sensitivity climate models. Some factors that could be acting to increase warming include reduction in aerosol cooling (which may be partially due to cleaner shipping fuel standards[27]), ice melt reducing reflectivity, reduced albedo, and cloud feedbacks[28].

These three findings point in the same direction: to the risk that the real climate response to emissions is towards the high end of previously accepted ranges.

Figure 8: Global warming temperatures and trends (Copernicus)



Source: Copernicus

Implications of high sensitivity for future warming

Even assuming no further acceleration in the rate of global warming, this reinforces the finding from Planetary Solvency that catastrophic warming (>2°C by 2050) is likely[29] unless action is taken to change course. Should further acceleration occur, extreme warming (>3°C by 2050) becomes possible, though this remains a low-probability scenario requiring both high sensitivity and sustained acceleration of warming beyond current rates.

Although CO_2 levels are the largest driver of warming, with methane the second largest contributor, there are more greenhouse gases. One way of tracking overall GHG levels is to convert the warming impact of other greenhouse gases into 'CO_2 equivalent' warming: CO_{2e}.

Analysis provided by NOAA[30] calculates that, at year end 2023, CO_{2e} was 534ppm, compared to a pre-industrial baseline of 275ppm CO_{2e} in 1750. With an annual rate of increase of 4ppm CO_{2e}, concentrations of 550ppm CO_{2e} may be reached before the end of this decade. We are already almost at double the level in the pre-industrial period.

There is uncertainty around how quickly we will warm. While equilibrium climate sensitivity describes the eventual warming after many centuries, about two-thirds of this warming may manifest within a century, with the remainder emerging over longer timescales as the deep ocean equilibrates.

This has significant implications for carbon budgets and climate projections, as higher sensitivity means more warming for any given level of emissions, and faster approach to dangerous temperature thresholds. In particular, these findings show that net zero carbon budgets will not be even close to limiting the temperature to 1.5°C.

The key policy implication is that relying on optimistic (low sensitivity) scenarios is not congruent with up-to-date climate analysis based on physical reality. Using these assumptions for climate planning will systematically underestimate both the speed and magnitude of future climate change, potentially leaving societies underprepared for the scale of adaptation and mitigation required.

... higher sensitivity means more warming for any given level of emissions, and faster approach to dangerous temperature thresholds.

3. Climate change is a risk to Planetary Solvency

In this section we discuss the risks and implications of higher levels of warming and why unmitigated climate change is a risk to Planetary Solvency. This section is structured in three parts, as follows:

A. Risks of higher warming, including climate tipping points

- The risks associated with additional global warming, including the withdrawal of insurance.
- We emphasise that tipping point risk increases beyond 1.5°C alongside the risk of passing a point of no return.

B. Mitigating climate change is critical to support future growth

- Why higher sensitivity reduces the carbon budget and increases the proximity of catastrophic risks, including economic contraction, making risk underestimation a major concern.

C. Climate change as a risk to Planetary Solvency

- Climate change is a risk to Planetary Solvency, due to its effects on vital ecosystem services that support human society, the economy and global biodiversity.
- Climate change is an unprecedented risk management problem on a global scale.

A Risks of higher warming, including climate tipping points

In this section we highlight the risks associated with additional global warming, including the withdrawal of insurance. We emphasise that tipping point risk increases beyond 1.5°C and the risk of passing a point of no return.

Additional levels of global warming will drive increasingly severe events – fires, floods, heat, storms and droughts, together with rising sea levels which are increasingly impacting critical human systems including food, water, transportation and health. As infrastructure systems are tuned for efficiency, not resilience, and with crisis events multiplying, cascading failure becomes increasingly plausible[31].

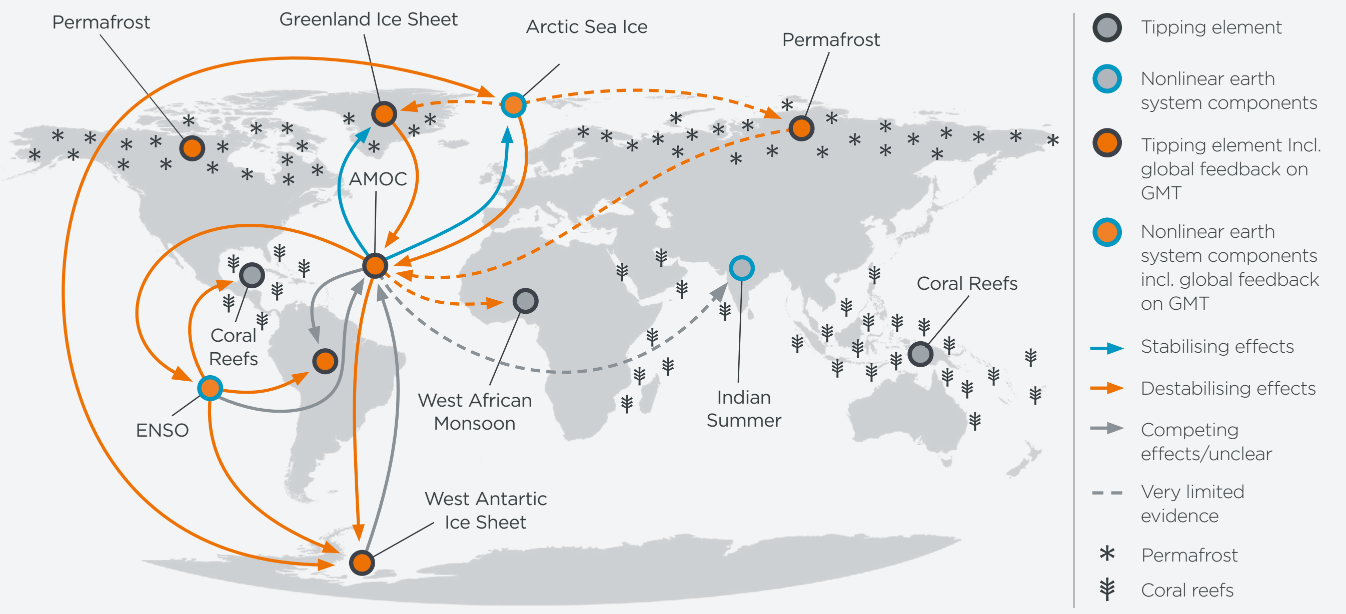
Entering the danger zone for tipping points

Higher climate sensitivity significantly increases both the likelihood and proximity of tipping points in the Earth system, critical thresholds beyond which changes become self-reinforcing and potentially irreversible. Crossing these points risks significant global consequences: collapsing ice sheets in Greenland and Antarctica, permafrost thaw releasing massive methane bursts, the dieback of the Amazon, and slowing or shutdowns of major ocean currents such as the Atlantic Meridional Overturning Circulation (AMOC).

The second global tipping point report[32] warns that the "danger zone" for tipping points begins as global average warming passes 1.5°C, a threshold already reached or exceeded in recent years. Each fraction of a degree beyond this point multiplies the risk that one or more tipping elements will cross a critical line, generating feedback loops that accelerate further warming and compound impacts.

Like the global financial crisis, tipping points may interact to form tipping cascades, meaning one tipping element destabilises another, amplifying both warming and impacts, as illustrated in the diagram[33] on the following page. In such cascades, there may be thresholds beyond which climate stabilisation becomes infeasible within human timescales[34].

Figure 9: Interactions between tipping elements on a world map



Source: Wunderling et al, Climate tipping point interactions and cascades: a review https://esd.copernicus.org/articles/15/41/2024/

Impacts could be catastrophic, including significant loss of capacity to grow major staple crops and multi-metre sea level rise. Some tipping points act to accelerate climate change through release of greenhouse gases, loss of carbon sinks or further loss of reflectivity. Others, such as AMOC collapse, might change patterns of rainfall globally, leading to significantly reduced capability to grow wheat and maize.

Could climate change outpace insurance solutions?

Insurance is the invisible lubricant of the economy. Insurance facilitates risk taking and innovation, enabling economic growth and stability. It allows individuals and businesses to take on calculated risks, knowing they are protected against potential financial losses, thus supporting economic activity.

The consequences of accelerated global warming and increasing climate hazards may result in increasing claims, premiums and uninsurability, with the potential withdrawal of insurance from some areas.

In the decade since the Paris Agreement, insured losses from natural catastrophes have nearly doubled. They have jumped from $77 billion (adjusted to 2024 price terms) in 2015 to $145 billion in 2024. Part of the increase is due to increases in exposure values and the proportion of losses that is insured, but also there has been a large increase in aggregate losses from extreme weather events which are increasingly affected by climate change. The increase in the so-called "non-peak perils" such as flooding, severe thunderstorms and wildfires has been particularly marked, with aggregate losses attributable to these natural hazards more than tripling since the early 2000s, while insured losses increased nearly sixfold.

The current annual rate of increase of overall insurance losses from natural catastrophes of 5 to 7% is equivalent to a doubling every 10 to 15 years. If this rate doesn't increase further, average annual losses could amount to $250 billion by 2035. The findings in this report indicate that this trend is almost certain to continue and likely to accelerate, with significant consequences for the insurance business model and society.

It is important to note that a significant proportion of humanity do not have access to insurance.

References: Swiss Re Institute: sigma 1/2025: Natural catastrophes: insured losses on trend to USD 145 billion in 2025, Munich Re - Severe thunderstorms, wildfires, and flooding – losses from "non-peak perils" are on the rise" and Sandy Trust - Planetary insolvency: could climate change outpace insurance solutions?

The need to avoid a hothouse Earth trajectory

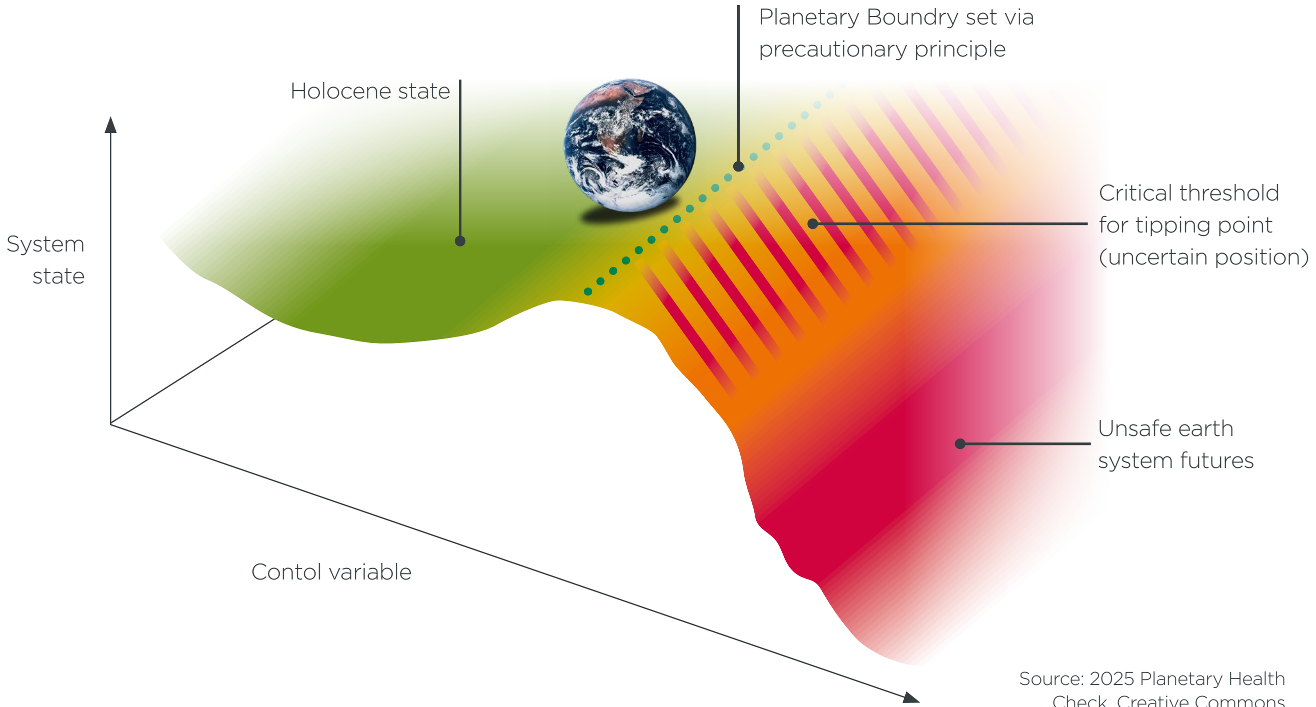
A worst-case outcome is a transition toward a hothouse Earth state[35]. In this scenario, Earth crosses a planetary threshold where self-reinforcing feedbacks, including ice loss, permafrost carbon release, weakening land and ocean carbon sinks, and changes in ocean circulation take control of the trajectory, overwhelming our mitigation efforts.

The 2025 Planetary Health Check report warns that Earth may be leaving the safe operating space for humanity, defined as "the range of environmental conditions in which humanity can safely live, grow, and prosper long-term. Staying within this space ensures Earth's systems remain stable and supportive of life. Going outside it is very different from anything humans have experienced in approximately the last 12,000 years, a stable period called the Holocene Epoch". Some scientists suggest that the Earth system has reached a fork in the road as to what the pathway of the new proposed epoch, the Anthropocene, will look like. This concept was introduced in the Planetary Solvency paper, with the fork being represented as a solvent or insolvent system[36].

The key message is loss of agency. Beyond certain thresholds, even large-scale interventions such as solar radiation modification may only partially offset the consequences. Avoiding this scenario requires action before critical thresholds are passed. After that point, the system's inertia and feedbacks dominate.

The potential severity of a hothouse Earth world, which would include multiple climate tipping points and catastrophic or extreme global risks, should be seen as well outside risk appetite. Realistic risk assessment in line with the Planetary Solvency RESILIENCE principles is required, that accounts for these tail risks, highlights the inadequacy of relying solely on central projections, and underlines that delayed action dramatically raises the probability of systemic, irreversible change.

Figure 10: Stylised stability landscape of the Earth system



Source: 2025 Planetary Health Check, Creative Commons

A worst-case outcome is a transition toward a hothouse Earth state.

B Mitigating climate change is critical to support future growth

Why higher sensitivity reduces the carbon budget and increases the proximity of catastrophic risks, making risk underestimation a major concern and missing the goals of the Paris agreement more likely.

Climate sensitivity – the expected warming following a doubling of atmospheric CO_2 – sets the effective "leverage" between emissions and global temperatures. New measurements and analysis, explored in the previous section, suggest we are closer to the upper end of the Intergovernmental Panel on Climate Change (IPCC) estimate (approaching or even exceeding 4°C per doubling of CO_2), rather than towards the central value of 3°C previously used for most scenario development.

A serious corollary to this is that the risk profile of climate change is substantially worse than many current models imply. Carbon budgets considered "appropriate" are likely to be significantly overestimated, and pathways that were once considered viable to limit warming to 2°C or 1.5°C targets do not deliver under higher sensitivity assumptions. The time lag between emissions and realised warming increases the risk of overshooting critical thresholds or triggering abrupt, irreversible changes in the Earth system.

If we have underestimated how much the climate will warm for a given level of emissions (real climate sensitivity is on the high side), then we have also underestimated the damages, as illustrated in *Figure 11* below. This in turn impacts decision making. If climate is incorrectly perceived as a distant or immaterial threat, taking action to mitigate climate change may be seen as lower priority.

Many first-generation climate risk analyses produced overly benign economic impact assessments, due to model limitations in the damage function which are not always well understood by model users[37]. Many mainstream methodologies simply exclude many of the risks now anticipated, such as tipping points, nature degradation or human health impacts[38]. One early methodology (Nordhaus) excluded nearly 90% of the economy from analysis, assuming that those who work indoors would not be impacted by climate[39]. These methodologies are still widely cited as rationale for delaying climate action, including by the current US Energy Secretary[40].

An alternative methodology, developed by Professor Steve Keen[41], and previously presented in *'The Emperor's New Climate Scenarios'*, leverages an established financial services risk management technique: reverse stress testing. In reverse stress testing, insurance companies ask themselves the question, "What would ruin us?" and work backwards from insolvency to construct a set of events that may lead to it.

This approach does not explicitly model the impact of the various risks that may be faced. Rather, it takes the approach that we will be unable to adapt beyond a certain level of warming, recognising the challenges of accurately modelling the unknown impact of tipping points and other factors. This approach also provides an explicit link between an environmental factor (GHG levels) and current economic metrics (GDP).

Figure 11: A simplified climate risk assessment process

I: Emissions

The first step is to estimate how GHG emissions will change in the future, as this will determine the levels of atmospheric GHGs, which in turn will drive warming. This is a key specification of any climate scenario.

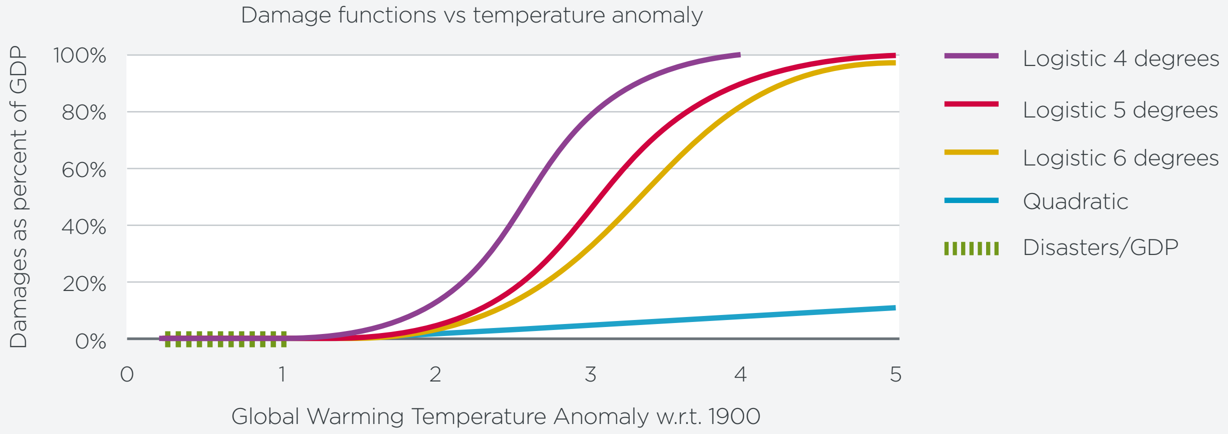
II: Warming

Following this, a key question is how much warming will be driven by a certain level of GHGs and how quickly this warming will happen, as this will drive the frequency and severity of the acute and chronic physical risks we expect to be impacted by. This is driven by climate models, which are parameterised to past climate-system changes.

III: Damages

Finally, we seek to estimate how much damage these physical risks will inflict – what the impact could be on individual assets, companies, countries and the global economy.

Figure 12 Climate damage functions - % GDP loss vs temperature



Source: Carbon Tracker (forthcoming), Keen et al, IFoA analysis.
Reproduced with permission Loading the DICE against pension funds https://carbontracker.org/reports/loading-the-dice-against-pensions/

The red and orange lines in *Figure 12* show an approximation of GDP losses up to 100% at 4°C and 5°C of warming. This is a global average and different countries would be impacted at different rates. An alternative would be to calibrate to 90% or 80% GDP loss, assuming some adaptation that permits survival of a much-reduced human population with associated residual economic activity.

This graph shows climate damages increasing rapidly above 1.5°C of warming and overwhelming the global GDP growth rate of 3% per annum, between that temperature and 2°C of warming. Put another way, unmitigated climate change and the disruption that extreme events drive, could force a structural decline in GDP and welfare.

A particular danger in risk management is anchoring to outdated or conservative risk estimates, as well as over-reliance on model outputs, without full understanding of the limitations and assumptions of models (see Technical Appendix for further details). Financial models have famously failed to capture real world characteristics of the global economy, and climate models have also struggled to fully explain recent accelerations in warming. Historic underestimation of risk in early climate change economic damage models persists in policy guidance, despite increasing observation of real-world impacts arriving sooner and being more severe than early projections. As a result, policymakers and other actors may not have understood either the proximity or severity of climate risk, seeing a distant speed bump rather than a child running into the road.

Risk management practices are clear here: advice on risk mitigation must be clear on the limitations and assumptions of models, as well as understanding plausible worst-case scenarios, especially when we are operating under conditions of high uncertainty.

A risk-based approach aims to limit the probability of very bad outcomes to an acceptably small value. From a climate change perspective, this would involve exploring the worst outcomes, even if their probability is low or cannot be accurately quantified due to a lack of reliable data. It means asking the question: “How bad can it get?”

It is these extremes that should drive policy decisions. What is society willing to accept? And what actions can we take to mitigate those outcomes that we find unacceptable? These are value judgements, and it will be important to be transparent about who makes them, as well as the implications of decisions.

A risk-based approach aims to limit the probability of very bad outcomes to an acceptably small value.

C Unmitigated climate change is a risk to Planetary Solvency

Climate change is a risk to Planetary Solvency, due to its effects on vital ecosystem services that support human society and economy. This is a risk management problem on a global scale.

Human prosperity is deeply interconnected with the health of the Earth system[42]. The Earth system provides the essentials that underpin all our activity: food, water, species, energy, raw materials, climate regulation and more. Many of these critical support functions, or ecosystem services, are not substitutable. If Earth system processes are disrupted so that they can no longer sustain the functioning of society and the economy, there is a risk of Planetary Insolvency.

The scale of human activity is now so significant that we are impacting outcomes at a planetary scale, rather than these being determined by geological and natural processes. Scientists label this the *Anthropocene*, a new geological epoch in which the activities of humans have become the driving force of change on the planet[43].

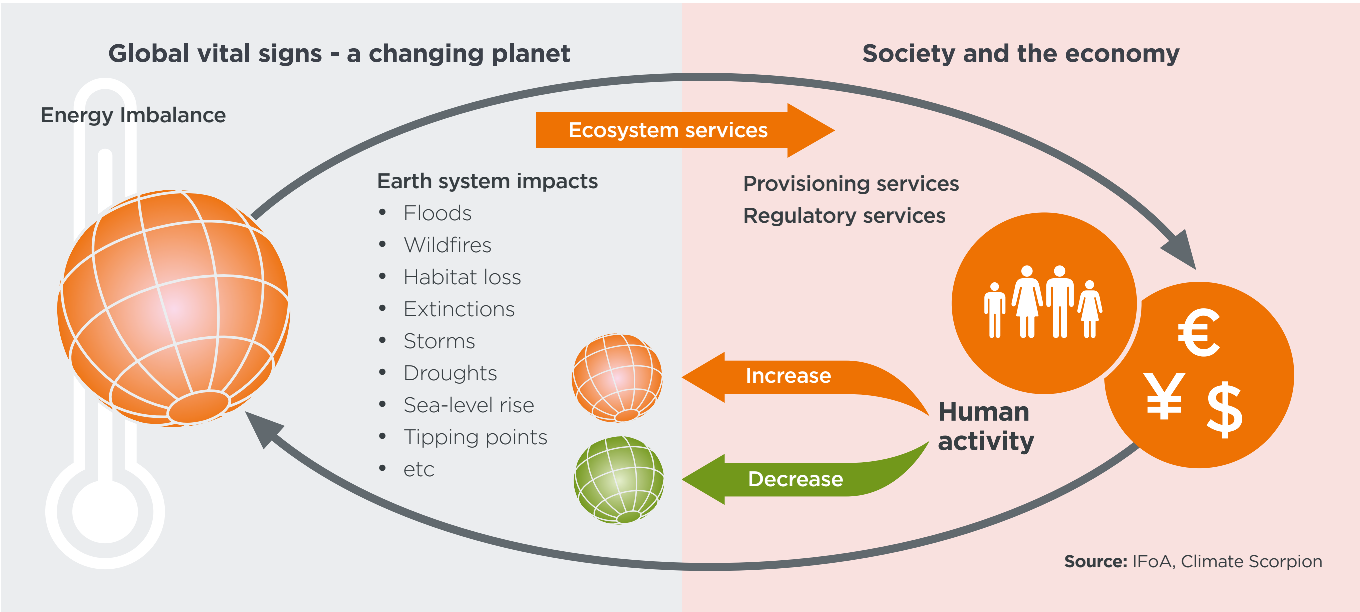
However, while we might be driving planetary outcomes, these have been largely unintentional to date, a by-product of human progress[44]. Our intention has not been to pollute the biosphere, drive species extinction, cross planetary boundaries or cause climate change. Nevertheless, our activities have largely acted to accelerate the degradation of nature and so risk destabilising the ecosystem services that we rely on. We are at risk of leaving "the safe operating space" for the Earth system, one that "allows humanity to develop and thrive for generations to come"[45].

Although this is daunting, it means we have agency – we can choose to manage human activity to minimise the risk of societal disruption from the loss of critical support services from nature. We have the ability to *intentionally* manage our activities to reduce the Earth's energy imbalance, as shown in *Figure 13*, choosing activities that will rapidly decrease the imbalance rather than unintentionally increasing it.

The analysis in the previous sections shows that global warming has accelerated and is likely to accelerate further, driving increasingly severe impacts and disruptions to health, food and water systems. In particular, each fraction of a degree of extra warming brings us closer to triggering tipping points, which may destabilise the critical Earth system processes on which we rely[46], possibly beyond a point of no return. Global society could face cascading system failures and global catastrophic risks, defined as severe, unprecedented, and irreversible catastrophes that could happen in the space of decades[47]. Unmitigated climate change is therefore a clear risk to Planetary Solvency.

In financial services, if risks are identified which threaten solvency, then management must decide what action to take, informed by the proximity and severity of the risk and any solvency recovery plan that has been developed. *In extremis,* if the risk is so severe that it would exhaust the balance sheet of the firm, then the firm may be closed to new business, or shut down. The urgency of the action is dictated by the proximity and severity of the risk.

Figure 13: Intentionally managing human activity to reduce the Energy Imbalance



4. Developing a Planetary Solvency recovery plan

In this section we lay out recommendations for developing a risk-based, coordinated Planetary Solvency recovery plan and indicative components of a plan.

What is a Planetary Solvency recovery plan?

After the global financial crisis, new rules from regulators required financial firms to develop solvency recovery plans, should circumstances threaten the viability of the firm. Firms are urged to consider broad and radical options in these plans, like fundamentally changing the structure and business model of the firm. Part of the rationale for recovery plans is that they should address the risk of management focusing disproportionately on growth opportunities at the expense of managing downside risk.

This is analogous to the situation human society finds itself in today with respect to Planetary Solvency. A narrow focus on GDP growth has failed to consider the risks that the extractive economy produces, with economic activities driving further global warming and nature degradation. We are using up the Earth's resources at a faster rate than they can be replenished, breaching planetary boundaries on multiple dimensions. We would need 1.7 Earths to meet our current rate of consumption on an ongoing, sustainable basis[48]. Policymakers are unwilling or unable to take the action required to mitigate the global catastrophic risks which are now becoming more likely.

This report evaluates strong evidence that the true value of climate sensitivity is actually close to the high end of the range provided by the IPCC. Since carbon budgets have been set using the IPCC's central estimate, this means our carbon budgets are smaller than we thought and may be negative. This is analogous to a financial firm finding it has overstated its reserves. There is an urgent restatement of the solvency position, and rapid action is required from management.

Planetary Solvency is threatened and a recovery plan is needed: a fundamental, policy-led change of direction, informed by realistic risk assessments that recognise our current market-led approach is failing, accompanied by an action plan that considers broad, radical and effective options.

Principles for developing a Planetary Solvency recovery plan

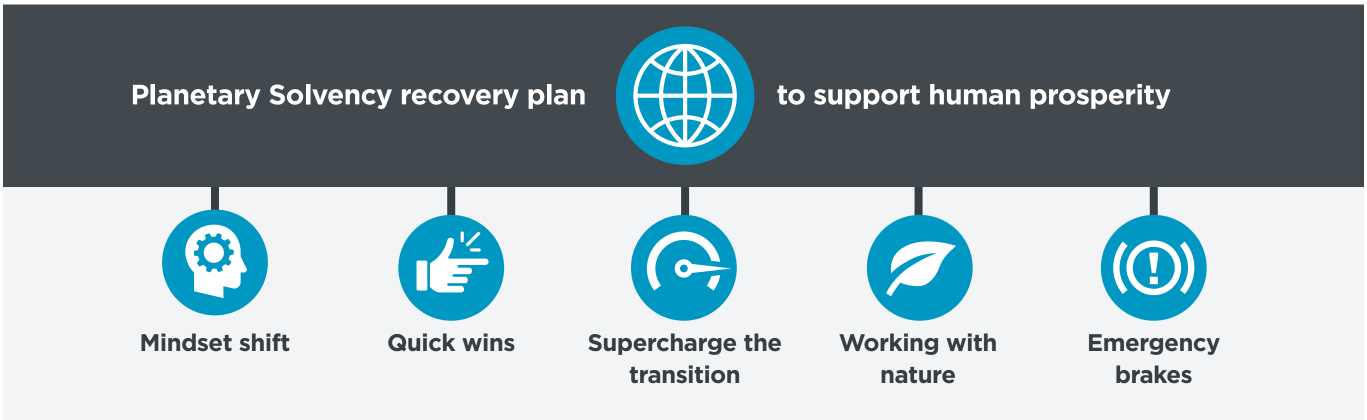
A Planetary Solvency recovery plan, modelled on principles from financial services recovery planning regulation, should establish a robust, forward-looking framework to restore and protect the planet's ability to sustain human society and the economy. The objectives of the plan are:

- To avoid Planetary Insolvency, or the risk of societal and economic collapse from loss of nature's critical support systems.
- To take action to minimise global catastrophic risks, ensuring the continuity of vital ecosystem services and restoration of natural capital.

The plan should be informed by realistic risk assessments in line with the Planetary Solvency RESILIENCE principles[49] and should consider broad, radical options. The plan and risk assessments should be reported directly to heads of government, the cabinet and national security councils. In practical terms this would need to be taken forward by a coalition of willing countries.

This plan is consistent with Climate Crisis Advisory Group's 4R campaign[50], a holistic climate action framework centered on Reduction of emissions, Removal of GHGs, Repair of damaged climate systems, and comprehensive action to build Resilience to climate impacts.

Figure 14: Planetary Solvency recovery plan



An indicative five-point Planetary Solvency recovery plan

Despite the severity of the risks faced and the current climate trajectory outlined in this analysis, a number of viable options are available to change course and avoid catastrophic or extreme impacts. The purpose of this section is not to provide a comprehensive plan, rather it is to illustrate the potential for such a plan and lay out several ideas that could be taken forward.

Whilst they may all be technically viable, it is important to recognise these are not 'out of the box' solutions and will require a range of enabling conditions including policy support, international collaboration, innovative financing structures and – perhaps greatest of all – a mindset shift that recognises our fundamental reliance on the Earth system and the need to manage our activity to avoid destabilising the foundation our society and economy rest on.

> **The good news is that there are already numerous global initiatives that exist to support various aspects of planetary management.**

I. Rapidly develop a Planetary Solvency manager mindset

This challenge demands a shift in perspective, recognising that humanity is not separate from nature but embedded in it, reliant on it and, furthermore, now required to actively steward the Earth system.

To maintain Planetary Solvency, we need to put in place mechanisms to ensure our social, economic, and political systems respect the planet's biophysical limits, thus preserving or restoring sufficient natural capital for future generations to continue receiving ecosystem services.

The good news is that there are already numerous global initiatives that exist to support various aspects of planetary management, including the Paris Agreement, the Kunming-Montreal biodiversity agreement, the newly ratified High Seas treaty and ongoing discussions on a global plastics treaty. However, the frameworks are often fragmented and issue-specific, rather than grounded in a systems-based approach. Success will require more coherent policy integration, stronger coordination across levels of governance, and cross-sectoral collaboration[51].

In addition to developing and enforcing appropriate frameworks, the root causes of global catastrophic risks will need to be addressed and must be at the forefront of any plans. The prevailing economic system is a risk driver and requires reform, as economic dependency on nature is unrecognised in dominant economic theory which incorrectly assumes that natural capital is substitutable by manufactured capital[52]. A particular barrier to climate action has been lobbying from incumbents and misinformation which has contributed to slower than required policy implementation.

II. Quick wins

A key component of solvency management plans is identifying material factors and quick wins. Three areas of high opportunity are: action on methane, deforestation.

a. Action on methane and other short-lived climate forcers

Methane is a potent greenhouse gas, with over 80 times the warming effect of carbon dioxide in its first 20 years in the atmosphere. Methane accounts for approximately 30-45% of the current rate of global warming from human activity, and reductions translate into immediate climate benefits by rapidly slowing temperature rise. Satellite data shows how significant methane emissions are (see ClimateTrace[53]), as well as being able to pinpoint the source of emissions, driven by agriculture, fossil fuels and waste[54]. Delivering on the Global Methane Pledge's goal of a 30% reduction by 2030 would significantly help reduce Earth's energy imbalance quickly.

Action on other short lived climate forcers including black carbon, ozone, hydrofluorocarbons and other aerosols, would support further rapid reductions in EEI.

b. Halting global deforestation

Halting global deforestation has been identified as an "emergency brake" solution that could reduce global emissions by up to 4 gigatonnes annually[55], close to the annual emissions of the United States. Global deforestation in 2024 contributed to the loss of 30 million hectares of natural forest, with wildfire a significant contributory factor[56].

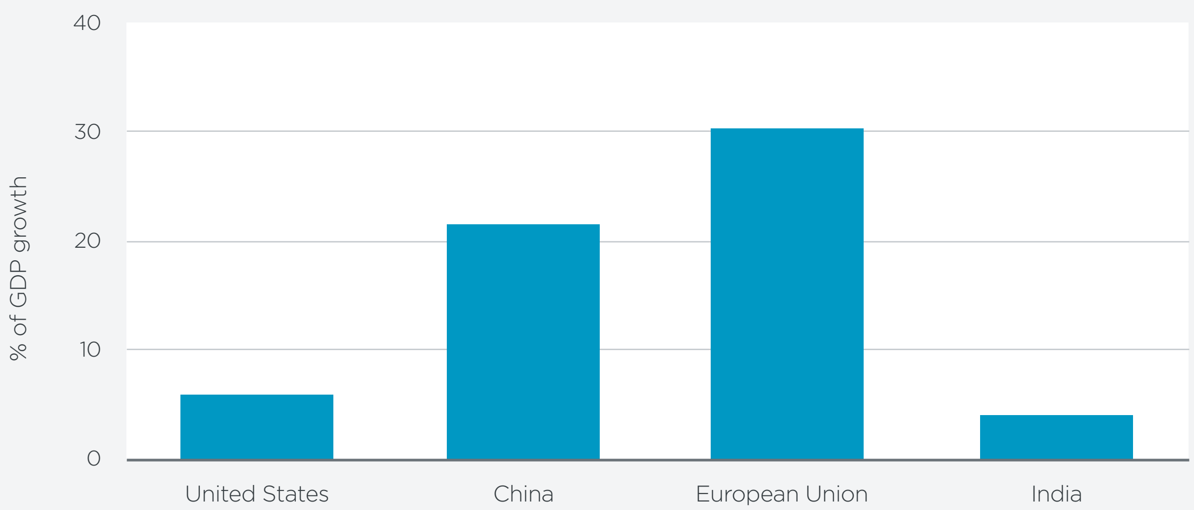
III. Supercharge the energy transition, a classic tech disruption story

The energy transition is simply a classic human development story featuring novel technologies that disrupt incumbents. History shows that change can happen surprisingly quickly when new technologies emerge, particularly if those new technologies offer both cost and convenience advantages. The Ford Model T was launched in 1908. 99 years later Apple launched the iPhone. Both technologies completely disrupted existing transport (horses) and communication (mobile phones and landlines) markets in around a decade, as well as fundamentally changing the way society operated[57].

Transition success stories show that a mix of policy support and technological development are critical to supporting these shifts. The decarbonisation of the UK grid[58], electric vehicle adoption in Norway[59] and the stunning pace of renewable deployment in China[60] have all been enabled by government policies. Phasing out of government subsidies for fossil fuels, which have been estimated at between $1.5 and $7 trillion[61], will help in this transition.

What is now increasingly recognised is that this is an economic opportunity, as illustrated in *Figure 15*. As well as offering huge investment and manufacturing opportunities, the transition also offers the potential for cheap, abundant and secure energy in many locations – a crucial enabler to economic development and competitiveness.

Figure 15: Contribution of cleantech to GDP Growth, 2023



Source: Ember, The Electrotech Revolution

IV. Work with nature on a global scale

It is difficult to envisage a viable Planetary Solvency recovery plan that does not include an intentional, structured and strategic approach to protecting and restoring natural carbon sinks. Nature should be recognised as a strategic investment opportunity[62], and critically important for climate given the materiality of carbon sinks associated with tipping points. For example: "The Amazon rainforest, tropical peatlands and mangroves currently store around 220 gigatons of carbon – the equivalent of around 20 years of global CO_2 emissions[63]."

On land, the temperature of adjacent areas can differ by over 20°C depending on whether the surface is concrete, grass or forest. As well as having different reflective properties, trees "influence local and global temperatures and the flow of heat. At the local scale, forests can remain much cooler during daytime due to shade and the role of evaporation and transpiration in reducing sensible heat.[64]"

In addition to the cooling potential of trees and forests, there is evidence that human activity might have had a material impact on the climate since well before the industrial revolution. Possible examples include:

a. Holocene climate stability and aerosol cooling from human wood burning: 'we know of no other persuasive explanation for absence of global warming in the last half of the Holocene[65]

b. Huge population reductions in South America may have led to large scale vegetation re-growth and the Little Ice Age[66]

c. The Late Pleistocene Megafauna extinction contributing to 0.5°C temperature drop due to reduction in methane and increase in vegetation[67]

While the exact magnitudes remain debated, these examples may show the scale of humanity's accidental impact on the climate even before fossil fuels, and the potential for working with nature to restore natural carbon sinks.

As detailed previously, the ocean absorbs huge amounts of heat and carbon. Protecting and restoring marine carbon sinks, including the restoration of marine biomass, offers significant carbon sequestration potential. Action on over-fishing and bottom trawling, including implementation of marine protected areas, are an urgent priority.

V. Research and deploy emergency brakes

A range of potential technological solutions exist to rapidly reduce Earth's energy imbalance, reduce warming and mitigate the risk of tipping points. There are valid concerns about the implications and potential unintended consequences of some of these methodologies; more research is urgently needed to more fully understand these. However, emergency brakes are useless if deployed too late and, given the level of risk now faced, our option pathway to a prosperous future has narrowed – we face a break glass moment.

The focus of this short report is on the evidence for climate sensitivity. But a risk report on climate sensitivity would not be complete without discussing the full range of mitigating actions. We urgently need more open, honest, respectful debate among people and groups that are dedicated to getting us through this predicament. Many diverse forms of expertise and viewpoints are needed – no one person or group has all the answers.

Geoengineering is the term often used to refer to deliberate, large-scale intervention in the Earth's climate system to counteract the effects of anthropogenic climate change and potentially to reverse global temperature increases. These interventions are also known as climate interventions. Such interventions, in contrast to weather modification techniques such as inducing rainfall by cloud seeding, operate at planetary scale and aim to address long-term climate objectives.

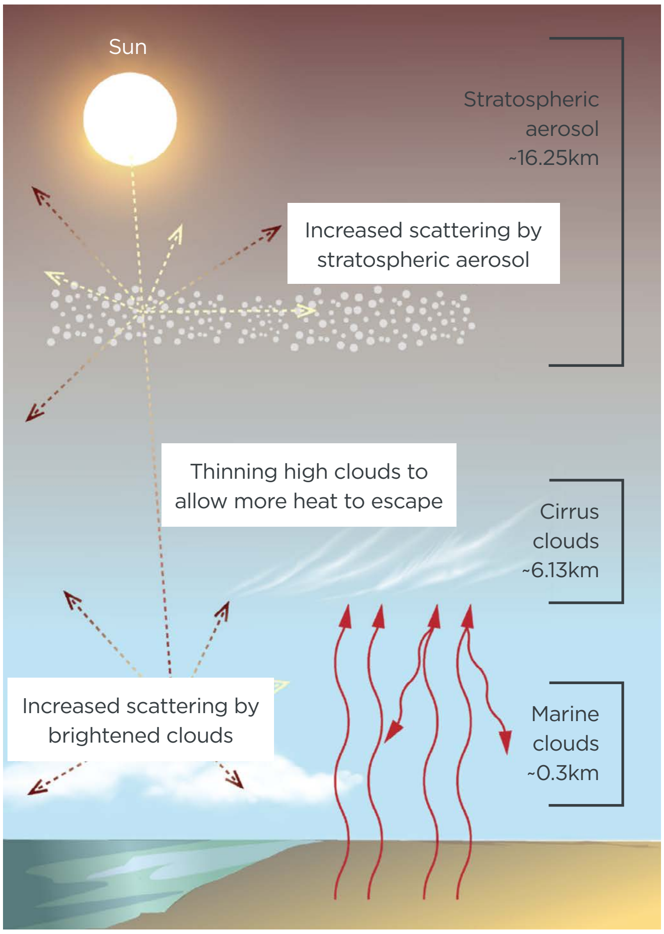
The two main techniques of geoengineering are:

a. Solar Radiation Modification (SRM) – reflecting sunlight to reduce its warming effect. This could be localised as with Marine Cloud Brightening or global as with aerosol dispersement at large scale into the stratosphere.

b. Carbon Dioxide Removal (CDR) – extracting carbon dioxide from the air or the ocean.

CDR will be necessary to reduce the atmospheric concentration of GHGs, which is an urgent issue. We are entering a period of 1.5°C overshoot, but the risks are such that his period needs to be as short as possible. Removal of GHGs must take place with urgency on a large scale. There is huge potential to draw down CO_2 from the atmosphere by restoring nature[68], as well as from technological solutions. Some have argued that what is needed for a manageable future for humanity is to reduce atmospheric CO2e to below 350ppm[69], and global temperature to be reduced to below 1°C above pre-industrial[70].

Figure 16: Solar Radiation Modification techniques [71]



Earth's energy imbalance might be altered by Marine Cloud Brightening

A technique that has been trialled at a small scale in Australia by the Reef Restoration and Adaptation Program is Marine Cloud Brightening (MCB). This makes low-lying ocean clouds reflect more sunlight by spraying small sea salt particles, made from seawater, into the clouds. This process, called atomisation, increases the clouds' albedo, or their ability to reflect sunlight.

While this small-scale trial of MCB is primarily designed to mitigate the risk of coral bleaching, Chen et al estimate carrying out MCB over 5% of the ocean could reduce global temperatures by 1°C, although further research and development is needed to make the technology energy efficient enough to scale up to a global scale.

Global Solar Radiation Modification (SRM) has the potential to reduce EEI relatively quickly after it is deployed, but there are risks which are discussed later in this section. More research and development is needed before it could be deployed, and issues of international governance should be carefully considered.

The main techniques include:

- **Stratospheric Aerosol Injection (SAI):** Injecting sulphate or other aerosols into the Earth's stratosphere, mimicking volcanic eruptions in blocking a small proportion of incoming solar radiation.
- **Marine Cloud Brightening (MCB):** Increasing the reflectivity of low-lying marine clouds by spraying fine droplets of seawater into the atmosphere, enhancing cloud brightness and coverage.
- **Cirrus Cloud Thinning (CCT):** Thinning out high-altitude ice clouds to increase the amount of terrestrial radiation escaping into space.
- **Space-based methods:** A more speculative approach, this involves placing mirrors or shields in orbit to deflect sunlight before it reaches Earth.
- **Surface albedo enhancements:** Brightening land surfaces to reflect more sunlight, for example by painting rooftops white or modifying crops. Although useful locally, the global impact of these techniques is limited.
- **Glacial geoengineering:** Targeted cooling in polar regions to slow ice melt, for instance by shading glaciers or modifying local albedo.

There are a range of views on SRM. Some argue that solar geoengineering poses unacceptable risks [72], others call for further research [73], and some argue that the risk of unmitigated climate change is so high it should be deployed as soon as possible [74]. We also note one group of experts are calling for actions that would reduce the global temperature to well below 1°C above the pre-industrial level in the coming decades [75].

SRM's supporters stress that it is not a substitute for climate mitigation efforts, which include decarbonisation and GHG emission cuts. It is a complement, not a replacement, potentially buying time while mitigation and adaptation scales up. Although SRM can reduce surface temperatures, it does not address the fundamental cause of warming itself – rising levels of atmospheric GHGs.

However, there are many concerns about the use of SRM. These include:

- **Termination shock:** If global SRM were deployed and then suddenly stopped, the result could be a rapid and severe temperature increase, which would be more difficult to adapt to due to the speed of increase (as with the termination shock we are already experiencing from reduction in the aerosol cooling from sulphate pollution).
- **Uncertain secondary effects:** Global SRM's potential side effects include acid rain, potential ozone layer depletion and disruption of regional weather patterns, e.g. monsoon cycles. Scientific reports, for example, for the UN[76] and the EU Commission[77], cite the need for a precautionary approach, high uncertainty about unintended consequences and ongoing research.
- **Climate justice and equity:** Global SRM may not affect all regions equally. Some areas could experience reduced rainfall, altered monsoon patterns, or other unintended consequences, raising concerns about climate justice and equity.
- **Governance challenges:** There is currently no international framework to regulate SRM research or deployment. Questions remain about who would control such technologies, how decisions would be made, and how risks would be shared. Effective governance frameworks would need to address not only technical deployment questions but also issues of consent, liability, and equitable distribution of both benefits and risks across different populations and regions. These questions are particularly important if those making the decisions on SRM are not those likely to be most affected, either from unmitigated climate change or from side effects of SRM, an issue that the Degrees Initiative[78] seeks to address.
- **Moral hazard:** The availability of SRM could reduce the perceived urgency of cutting emissions. However, a recent, well-controlled study provided evidence of the absence of a significant effect from awareness of geoengineering on public support for mitigation policies in either direction[79]. Given the importance of this topic, further data-based enquiries should be carried out.

We urgently need more open, democratic debate, informed by the latest science and by expert risk assessments. We welcome the UK government's funding of research into climate cooling methods via ARIA[80] and agree with their assessment that *"Ethical and governable interventions to prevent tipping points, or adaptations to adjust to a post tipping point climate, could be possible, but an enormous amount of research is needed to determine how such approaches could work and what their regional and global effects might be".*

We urgently need more open, democratic debate, informed by the latest science and by expert risk assessments.

Risk assessments must assess the risk of actions against the risk from unmitigated climate change, sometimes called a risk-risk assessment, rather than a hypothetical world without climate change.

Several risk-risk assessments have been done[81], but this is not yet the norm. Without such holistic analysis, discussions risk bias toward the status quo, underestimating the dangers of inaction. By systematically comparing the magnitude, likelihood, and reversibility of harms from both deploying and not deploying geoengineering, policymakers can make more balanced, evidence-based decisions and avoid crisis-driven, poorly informed interventions.

We must include all relevant information, including the fact that, by any reasonable understanding, SRM is already deployed accidentally on a global scale via sulphate from fossil fuel burning which, as explained in this report, cools the Earth by around 0.5°C. Also, MCB has been implemented locally to protect the Great Barrier Reef[82].

The Royal Society's Solar Radiation Modification Policy Briefing[83], published in October 2025, is a very useful summary of scientific research, with over 500 references[84]. It covers all the main SRM techniques but focuses on SAI and MCB, with a review of what is known about the efficacy, risks, benefits, cost and feasibility of these technologies. We recommend that any risk assessment of SRM should take full advantage of this resource.

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Global risk management for human prosperity

January 2026

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