Institute and Faculty of Actuaries

CCAG
Climate Crisis Advisory Group

Climate Emergency – tipping the odds in our favour

A climate-change policy briefing for COP27

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Pathways to Sustainability

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Foreword

Sir David King, Climate Crisis Advisory Group founder and Chair

Human-caused climate change has run down the clock and soon there will be no time left to meet the goals set under the 2015 Paris Agreement. The action we take in the next five to ten years will determine the future of humanity for the next millennium. While daunting, we have great agency here. It is still technically possible to reduce emissions and stabilise the climate.

We must reduce emissions urgently, deeply and rapidly, while ensuring an orderly, just transition. To help restore climate stability, the emission of CO_2 and other greenhouse gases (GHG) – such as methane – into the Earth's atmosphere must be drastically reduced from the current level of more than 40Gt CO_2 equivalent per year (Gtpa) – consistent with an ordered and rapid withdrawal from fossil fuels globally.

We must remove CO_2 from the atmosphere in vast quantities– tens of Gtpa. Additional efforts to test and deploy GHG removal solutions must also start today. And the target must be set at limiting temperature rise to 1.5°C – only reducing from there.

We must repair broken parts of the climate system, starting with the Arctic, in an attempt to reverse local changes and stop the cascade effects of said changes through global climate systems.

As damage done to the Arctic, by rapid climate change, is causing weather patterns to shift all over the world (see The Case for Arctic repair, **page 20**), it is now the most urgent area to be addressed and repaired.

The actuarial approach to risk analysis is different from that followed by most in the scientific community. Scientists are geared toward making predictions that are as accurate as possible. In contrast, actuaries are often concerned with predicting low-probability – high-impact events. A caricature of this is:

- **Science** – we should not typically say that there is an iceberg until we are fully confident there is one present
- **Risk** – there could be an iceberg, so we should typically steer well clear of it

Often complementing science, actuaries, alongside risk-analysis experts, have a direct and important contribution to make to the management of climate risks going forward.

Introduction

The IFoA Presidential Team

Matt Saker
President, Institute and Faculty of Actuaries

Louise Pryor
Immediate Past President

Kalpana Shah
President-elect

Climate change, driven by human activity, is happening more quickly than expected, with impacts already being felt by millions. This damage will become more severe as the climate continues to warm. The impacts of climate change are global and systemic. There are significant risks – and beyond risk, uncertainty – for the biosphere and the functioning of our societal, economic and financial structures. Climate change is a risk-management problem on a global scale.

Our analysis shows that although we have the solutions needed to mitigate climate change, we are not currently taking action fast enough to avoid the catastrophic impacts that would be experienced if we allow global temperatures to continue rising. Tipping points mean these impacts are closer than we previously thought. Thus climate change is a material risk to the UN's Sustainable Development Goals objective of *'all people enjoying peace and prosperity'*.

Climate change is a risk-management problem on a global scale

Actuaries have spent more than two centuries developing techniques for managing risk and uncertainty over long timescales. The purpose of this paper is to inform the policy debate on how these risk-management techniques can be applied to the climate-change problem, including what action to take to mitigate the tail risks of climate breakdown. These tail risks are complex, poorly understood, and too often side lined in policy formulation. Actuaries have always had a public interest duty, and we are keen to contribute our professional skills and insight to this debate, not just now but in the years to come.

Actuaries help society to price and manage long-term risks by considering data around what has happened in the past and how this might change in the future. We also identify adverse or worst-case scenarios, and how these might be driven by unlikely risk events, sometimes referred to as tail risks. Risk management includes taking action to mitigate risks or adapt to the adverse outcomes. The likelihood of achieving a desired objective is therefore increased.

We are delighted to partner with CCAG to bring cutting-edge climate science into climate-change risk management. Our goal is to accelerate the action required, by policymakers and many others, to limit the effects of climate change. We also urge society, citizens, governments and all economic actors to realise the transformational opportunities that climate action offers, and prepare for the less desirable, but unavoidable, outcomes.

We support the 3Rs of CCAG. We need to Reduce emissions, Remove GHGs from the atmosphere and Repair the Earth's natural carbon cycles. Climate action needs to recognise nature as an important ally, embed justice and equity as central objectives, and ensure we adapt to the changing climate we already face.

In this paper we explore how to apply risk-management techniques to climate change. We also explore reasons for hope. We are neither climate doom-mongers nor climate appeasers. As a profession, we are long-term probabilistic thinkers and advisers who see it as part of our public duty to help humanity avoid the risk-management failure that climate breakdown would represent.

Key findings

Climate change is a risk-management problem on a global scale. We need to accelerate climate action to avoid catastrophic climate impacts on society.

1. We have underestimated climate change. It is progressing faster than expected, driving severe impacts which we need to adapt to as further warming occurs.

Climate change is happening more quickly than anticipated, with severe impacts already being felt by millions globally at current levels of warming. For example, the Arctic has warmed by 3˚C, driving extreme weather, and the sea level is rising faster than anticipated with low-lying areas potentially inundated by 2050.

Greenhouse gas (GHG) levels continue to increase and current pledges are inadequate to meet the 1.5°C target. We need to plan for further warming and climate impacts through adaptation. As warming increases beyond the 1.2C level we are at today, so will the impacts we feel.

2. Multiple climate change tipping points, which may be irreversible, are likely to be triggered at 1.5°C.

Warming of 1.5˚C is extremely risky, with a high chance of triggering multiple climate tipping points, including the collapse of ice sheets in Greenland, West Antarctica and the Himalayas, permafrost melt, Amazon die back and halting major ocean current circulation.

These tipping points may interact, triggering each other and cascading like dominoes. Once triggered they may be irreversible and would act to accelerate global warming (by increasing GHG levels) and increase the severity of impacts (eg accelerating multi-metre sea level rise). Some of these climate elements have already started to tip.

3. Net-zero carbon budgets only give a 50% chance or less of limiting warming to 1.5°C, which represents an unreasonable risk of not meeting our objectives.

The Glasgow Climate Pact target of 1.5°C should be seen as similar to a ruin limit for our global society. While severe outcomes are already emerging, risks increase the closer to (and further beyond) 1.5°C we get. The increased likelihood of these risks and severity of impacts above 1.5 reinforce the need to reduce our emissions to net zero as rapidly as possible. Current pledges are inadequate to meet even the 1.5°C target

Carbon budgets are uncertain. Widely discussed carbon budgets only give a 50% or less chance of limiting global warming to 1.5°C and assume 'no surprises', which is unrealistic. Assuming 'no surprises' means budgets may be much smaller than planned and may already be zero for 1.5°C. IPCC emissions pathways that are in line with the Paris Agreement have a high probability of overshooting 1.5°C.

4. In addition to rapid reduction, delivering a stable climate will require removing GHGs from the atmosphere. It will be economically and socially positive to mitigate climate change.

Climate scenarios are roadmaps that show us how the future might evolve and ways in which we could reach net zero. However, some have implausible assumptions. Many now show it is overwhelmingly economically positive to limit warming to 1.5˚C compared with the scale of damages we would experience at higher levels of warming.

Given the large scale impacts of even 1.5°C of warming we will need to go beyond net zero and use both technological and natural solutions to remove greenhouse gases from the atmosphere. Indigenous and local community members must be drivers and partners in any removal or repair programme.

> We need to plan for further warming and climate impacts through adaptation.

5. **Tipping points mean there is even more uncertainty which we need to plan for by exploring tail risks and introducing prudence.**

   Climate impacts are simultaneously uncertain yet completely foreseeable. We cannot predict precisely when they will happen or in what combination, but we know they will occur. This uncertainty cannot be eliminated but it can be managed.

   Incorporating uncertainty into our approach to climate change would lead to a downward revision in available carbon budgets, an acceleration towards decarbonisation sooner than the current 2050 timeline, and a move to better understand and invest in options for adaptation.

   This represents prudence that would increase the likelihood of limiting warming to 1.5°C and reduce impacts of adverse outcomes through adaptation, where possible.

We have agency, powerful allies and solutions – policymakers must act decisively to accelerate the transition and it is overwhelmingly in our economic interest to do so.

1. **We have agency; we can choose to drive the planet responsibly**

   Human activity has become the driving force of climate change on the planet. It is in our gift to change course, accelerate solutions and improve the odds of success.

2. **We have solutions that are now scaling, and positive tipping points around food, transport, energy and financial systems**

   Many now see the technological disruption of the food, energy and transport sectors as inevitable. Capital is beginning to flow into these sectors, driving system-level change. Supportive policies are needed to supercharge the rate of adoption and deliver the acceleration required.

3. **We have a powerful ally in nature, which we must help to repair**

   Nature has played a critical role in mitigating climate change, absorbing around half of the carbon emitted since the industrial revolution, while the ocean has absorbed a staggering 90% of the excess heat. Repairing natural carbon sinks is essential in order to rapidly remove material amounts of greenhouse gases from the atmosphere.

4. **Societal tipping points are also being reached on climate action**

   More people than ever before believe that we must take action, at unprecedented pace and scale, to limit global warming. We can accelerate this societal shift by educating stakeholders to be carbon and climate literate. We must change the story from one of cost to one of opportunity. This is perhaps our most important task.

5. **We must enable a just transition**

   We need to work together as a global community to achieve net zero. This must include rebuilding trust between the Global North and the Global South, addressing the challenge of providing capital to developing countries, and including vulnerable and forgotten communities in order to build the trust and faith we need in each other for global collaboration. A just transition must be led by government policy, though finance and support must follow quickly.

I: Assessing our climate approach

Actuaries have well-established processes to help pension funds and organisations, such as insurance companies, manage risk and uncertainty over long time horizons. In this section we lay out what these processes are to illustrate how they can be applied to the climate-change challenge.

We introduce the concept of a tipping point, a non-linear change in a system that may be difficult or impossible to reverse.

The actuarial approach to managing risk and uncertainty

Risk is often characterised by referring to events that might occur and the impact these events would have on an objective. Risks may be categorised by likelihood (the chance that a risk event may occur) and severity (the impact of an event should it occur). 'Tail risks' is a term often used to describe low-likelihood but high-severity risks; actuaries would say that these sit at the extreme end of the risk distribution. On the other hand, uncertainty cannot be easily quantified or modelled. The outcomes themselves may be unknown or we may not be able to assign a probability to their occurrence.

Risk management is the set of coordinated activities used to direct and guide an organisation regarding risk. Actuaries work with long-term financial institutions of societal importance, such as pension funds and insurance companies. They support these institutions to take decisions today to ensure that over time they can meet their future commitments – their liabilities – with a sufficiently high level of probability. The risk-management control cycle ensures that action is taken to safeguard desired outcomes and ensure payments can be made even if the future develops in an adverse way for the organisation.

> Our starting point is 'What do we want to avoid?'

The control cycle has five main components:

- **Risk identification** involves recognising all the risks that might threaten the objectives of an organisation. Part of this process is determining to what extent the organisation is willing to have their objectives exposed to these risks – in other words, its risk tolerance.
- **Risk measurement** involves estimating the probability of a risk occurring and its severity. This involves deriving assumptions and forming a view about what is likely to happen in the future.
- **Risk control** means taking actions to reduce the probability of a risk happening, or limiting the severity of the potential outcome.
- **Risk financing** determines the likely cost of the risk and the financial resources required to cover it, combined with the level of likelihood.
- **Risk monitoring** is the regular assessment of all risks, incorporating experience as it emerges, reviewing whether assumptions remain valid or should be adjusted, and identifying any new or previously omitted risks. Where risks approach or breach pre-agreed limits, actions are taken to mitigate worsening and return a risk to within tolerance.

Actuarial approaches take uncertainty into account, asking not just 'What is likely?' but 'What is possible?' This includes considering extremely bad scenarios, often driven by tail risks or a combination of risks, that could 'break' an organisation. Our starting point is 'What do we want to avoid?' This includes considering activities such as the exploration of adverse future scenarios to ensure we are comfortable with those we advise that we can withstand them. A process known as reverse stress testing identifies scenarios that could cause failure.

A critical part of this process is ensuring consistency between the assumptions that underpin scenarios and their plausibility.

In summary, risk management identifies when action is required to mitigate risks that are outside tolerance and might drive adverse outcomes if they occurred. Action is then taken to try to ensure that even if tail risks do happen, the organisation will be able to mitigate these adverse outcomes, even if they are unlikely.

For example, insurance companies hold capital to meet the liabilities they expect to meet in the future, as well as to cover adverse events so they can avoid becoming insolvent. In Europe the amount of capital insurers are required to hold is set at a level designed to withstand an extreme loss scenario that would occur only once in 200 years. Put another way, the amount of capital held is calculated to give a 0.5% chance that an insurance company would fail in any one year. Nuclear facilities have an even higher threshold for failure, designed to cope with hazards on a 1 in 10,000 basis.

Applying an actuarial approach to climate change

We can replace the solvency of an insurance company with our shared objectives, those of the Paris Agreement to limit global warming and the United Nation's Sustainable Development Goals, which have the overarching objective of *'all people enjoying peace and prosperity'*. Climate change is a clear risk to these goals. Viewed through this lens, we can assess the activities we are undertaking to manage climate-change risk and form a view as to whether these are adequate when compared to established risk-management standards.

A risk-management approach, although informed by science and data, is different to a scientific approach. In science, a hypothesis is proposed, data is gathered to test this hypothesis, and then conclusions are drawn about the validity of the hypothesis. In the case of climate change, where data is scarce or risks are hard to model, the scientific community has arguably been biased towards erring on the side of least drama. This has led to under-prediction on key attributes of global warming.[1] A risk-management approach instead requires that, even where evidence is not available, we should explore plausible outcomes and take steps to manage the risk, especially if the outcomes have the potential to be severe. We apply expert judgement to estimate the likelihood and severity while ensuring that we revise our estimates as more evidence becomes available.

For risk management to be effective, decision makers must understand the business model and the risks. Financial regulators[2, 3] ensure that senior individuals with influential decision-making and risk-taking responsibilities are fit and proper. This includes assessing the honesty, integrity, competence and capability of these senior individuals.

Given the societal importance of climate change, the same principles apply to governments and non-financial regulators, as well as business. It is important for decision makers in all areas, but especially policymakers, to ensure they have the climate and risk literacy to make complex decisions under uncertainty. They need to be open and honest in their dealings and be capable of engaging with the public in good faith. Importantly, they need to be accountable for their decisions.

The following section takes four of the five elements of the risk-management control cycle and applies them to the problem of climate change.

Information Box: Climate Tipping Points

The term 'Tipping Point' is used to describe a critical threshold that, when crossed, leads to sudden and often irreversible changes in the climate system.

Tipping points are driven by positive (or amplifying) feedback loops where the effects caused by an initial change serve to cause more of that initial change to occur – they are self-perpetuating. For example, the ice-albedo effect whereby increasing temperatures melts sea ice which in turn reflects less solar radiation, raising temperatures further and causing more sea ice loss.

Tipping points are described as non-linear or abrupt because a small change in the initial driver leads to a significantly larger change in the state of the system. This is because the small initial change has pushed the system beyond a critical threshold which is then self-perpetuating until a new state is reached. Once the threshold has been exceeded it is harder to get back to the original state even if the initial drivers are removed; most tipping points are thus irreversible.

II: Risky business

Climate change is a risk-management problem. Even 1.5°C of global warming is extremely risky, with the chance of triggering multiple climate tipping points (such as Greenland ice sheet collapse or Amazon die back) and multi-metre sea level rise, which may be irreversible.

The severe physical impacts of higher levels of warming mean that it is overwhelmingly economically positive to limit global warming to 1.5˚C.

Greenhouse gas levels are continuing to rise, meaning we need to plan for further warming and climate impacts through adaptation. We need to prepare for these uncertain but foreseeable impacts, including considering adverse outcomes and building resilience into our systems.

Carbon budgets are uncertain and, in our view, offer an unacceptably low probability of success. Widely discussed carbon budgets give only a 50% chance or less of limiting global warming to 1.5°C, meaning there is a high likelihood of overshooting. Further, they predominantly include the unrealistic assumption of ‘no surprises’.

Delivering a stable climate for future generations will require removing historic emissions. This will require going beyond net zero to remove greenhouse gases from the atmosphere, using both technological and natural solutions.

A. The emergence of climate tipping points (risk identification)

Warming of 1.5˚C is extremely risky, with a high chance of triggering multiple climate tipping points such as the collapse of ice sheets in Greenland, West Antarctica and the Himalayas, permafrost melt, Amazon die back and halting major ocean current circulation.

These tipping points may cascade, triggering each other. Collectively, tipping points act to accelerate global warming (by increasing GHG levels) and the impacts (eg accelerating multi-metre sea level rise).

Recent research[4] on climate tipping points identified 16 tipping elements[5] that could be triggered beyond a certain level of warming. While the report considered these tipping points independently, there are multiple interactions between tipping points that risk triggering ‘cascades’ – where tipping points trigger one another like dominoes. The collective effect of these interactions is to lower the temperature threshold at which a tipping point is triggered.

> Widely discussed carbon budgets give only a 50% chance or less of limiting global warming to 1.5°C, meaning there is a high likelihood of overshooting.

Figure 1: The likelihood of tipping points being triggered for different global warming temperatures

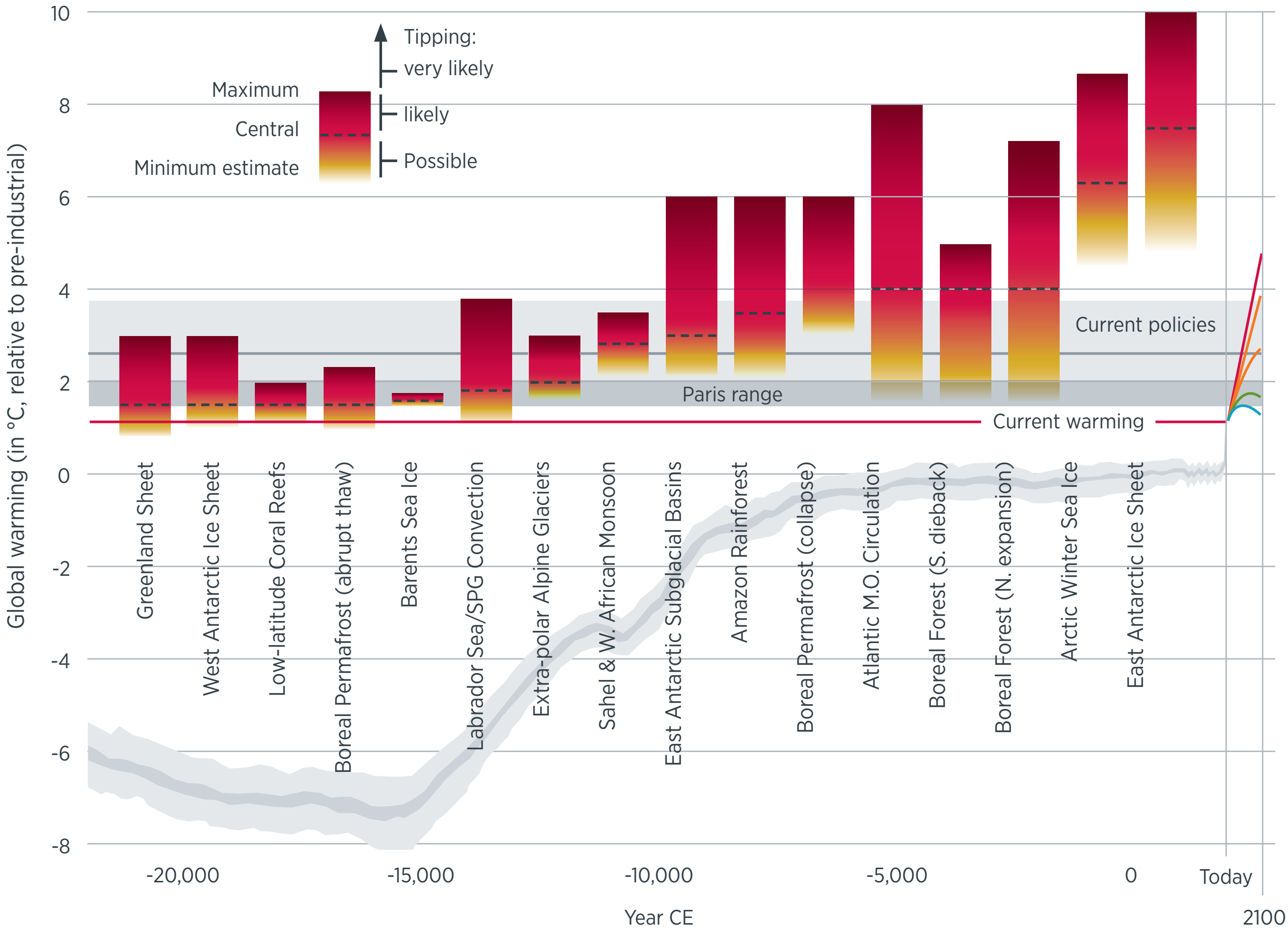


Figure 1, taken from the *Exceeding 1.5°C global warming could trigger multiple climate tipping points* report, shows that within the Paris Agreement range (1.5˚C to 2°C), six of the 16 tipping points are likely to be triggered. The melting of the Greenland and West Antarctic ice sheets has the potential to increase sea level by 7m and 3m respectively.[6] For coral reefs, there is an expected 70–90% loss at 1.5°C, with a near total loss by 2°C. Permafrost melt would release GHGs, further increasing greenhouse gas emissions, and Barents Sea ice loss would accelerate Arctic warming, with consequences for global weather.

The implications of this include an impact on carbon budgets (that are likely to be smaller than currently assumed if we are to avoid tipping points) and accelerated, or more severe, climate impacts emerging at lower temperatures than previously thought. The latest science on tipping points strengthens the case for pursuing aggressive mitigation and increases the likelihood of decarbonisation scenarios that feature temporary overshoot (ie allowing the temperature to increase beyond 1.5˚C before reducing it again) being significantly more risky. Tipping points must be included if scenarios are to be realistic.

They are no longer high-impact, low-likelihood events but are now high impact, high likelihood, and we need to mitigate and plan for them. Ignoring them in scenarios and modelling may significantly understate risk.

B. Progressing faster than expected, with more severe impacts (risk monitoring)

Climate change is happening more quickly than anticipated, with severe impacts already being felt by millions globally. A consistent pattern of corrections over time is observed, in the direction of worse than we anticipated, leading to downward revisions of 'safe' temperature levels towards 1.5˚C.

In IPCC reports, Arctic warming, sea-level rises and extreme weather events provide examples of climate impacts that are progressing faster than expected. It is important to note that the IPCC reports process lags emerging experience and are softened by consensus, which may be a factor.

This reinforces the case for rapid decarbonisation and adaptation, ensuring that we plan for future climate impacts and build resilience into man-made systems.

Climate change impacts are emerging at lower temperatures and more quickly than expected; over the last three years (2020–2022) we have witnessed record-breaking floods, fires, droughts, storms, temperature extremes and ice loss across the globe. As CCAG states: 'These are all outlier events that exceed what one would expect if it were 'only' a 1.2°C warming impact. It is likely that there are additional interactions between the climate system and tipping elements (in this case the Arctic and the Jet Stream) occurring simultaneously.'[7]

In 2018, as part of the fifth assessment cycle, the IPCC published a special report: *Global Warming of 1.5°C.* This report cemented evidence for limiting warming to 1.5°C by demonstrating the negative physical impacts associated with higher warming of 2°C; just one example of how emerging scientific evidence has led to downward revisions around 'safe' temperature thresholds over time.

The Reasons for Concern (RFC) framework was introduced in the IPCC's *Third Assessment Report* and categorises risks from temperature rises into several categories (unique and threatened systems, extreme climate events, distribution of impacts, aggregate impacts, and large-scale discontinuities). The burning embers diagram (see *Figure 2*), shows how the level of each risk changes with different levels of warming.

Zommers et al. evaluated changes in these risks across the various IPCC reports. Figure 2, taken from this report shows how estimates of the temperature at which severe climate impacts will occur have consistently reduced over time.[8] Put another way, the level of risk at a given temperature has increased with each subsequent assessment. In particular, the temperature at which large-scale singular events become high risk fell from around 5.5°C above pre-industrial in the third assessment report to <2°C in the IPCC's special report *Global Warming of 1.5°C*.

Arctic warming – three times faster than the global average

A further example are the changes happening in the Arctic. Temperature changes do not occur uniformly, with greater warming in high latitudes than low latitudes. The greatest increase in temperature is experienced in the Arctic, known as Arctic amplification, where we are already seeing Arctic temperatures around 3°C above pre-industrial levels. Changes in the Arctic are occurring faster than expected;[7] permafrost is thawing 70 years sooner than model projections, resulting in 12 times more nitrous oxide release than previously thought.

Figure 2: The risks associated with temperature rise in successive climate models

It is important for policymakers to understand that the political negotiation around the final wording of IPCC reports invariably softens the risk message

The Arctic is also home to potential tipping points and feedbacks, which once set in train would lead to changes irreversible on human timescales. Additionally, there is some evidence that these may be triggered with as little as 1.5–2°C of warming (see earlier).

Sea level rise – faster than expected, risk of inundating low-lying areas by 2050

Sea levels are now 0.2m above their 1901 level and even if emissions ceased today, sea levels would likely rise an additional 0.7–1.1m by 2300.[9] By 2100 the IPCC forecasts rises between 0.3m (in low-emissions scenarios) and 1m (in high-emissions scenarios), but they are unable to rule out rises of 2m by 2100 in this scenario, due to deep uncertainty in ice sheet processes.[10]

Over time, sea level rise has been tracking near the upper IPCC limits, with ice loss both from Greenland and Antarctica in line with the upper range of IPCC projections. Further evidence[11] suggests that the IPCC levels presented for high-emissions scenarios represent the low end of possible outcomes.[12] Using a different methodology, a recent paper estimates sea-level rises are likely to be triple IPCC estimates.[13] If correct, this would put Vietnam and other low-lying regions under water at high tide by 2050,[14] presumably driving involuntary mass migration.

It is important for policymakers to understand that the political negotiation around the final wording of IPCC reports invariably softens the risk message, so there is concern that even the scientific message paints an over-optimistic picture, which may be a factor in these observations.

C. Challenging to predict likely and possible outcomes (risk measurement)

Climate scenarios are roadmaps that show us how the future might evolve and ways in which we could reach net zero. However, some have implausible assumptions. Many now show it is overwhelmingly economically positive to achieve 1.5˚C compared with the scale of damages we would experience at higher levels of warming.

IPCC scenarios

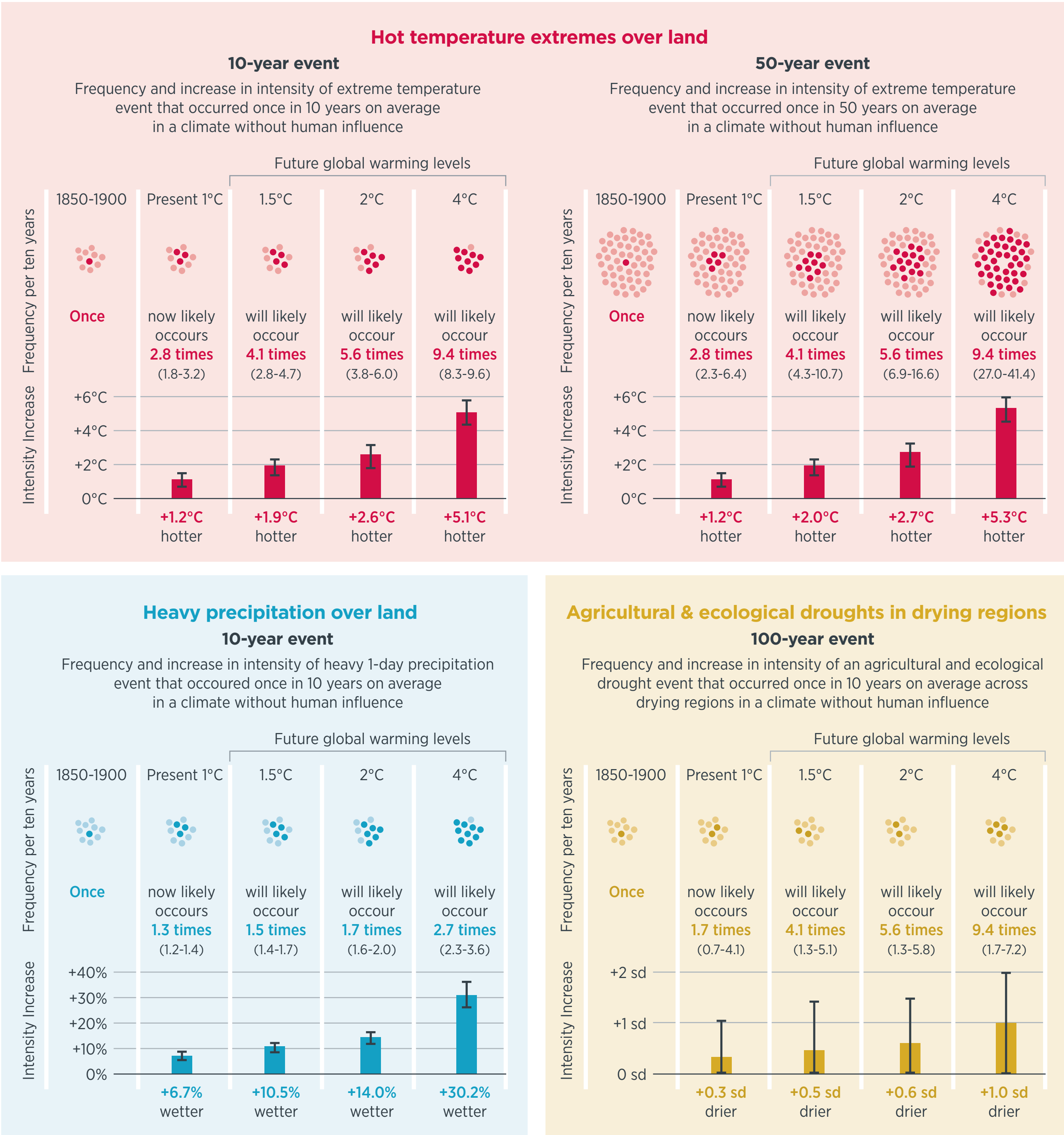
The IPCC's *Sixth Assessment Report* explores future scenarios known as the shared socioeconomic pathways (SSPs). Key aspects of the scenarios and changes in extreme events (IPCC)[10] under different levels of warming are shown in *Table 1* below and *Figure 3* on the next page.

Table 1: A summary of temperature rise statistics from IPCC reports

Scenario	Temp rise 2100 (°C) (50th (5th-95th) percentile values)	Peak temp rise (°C) (50th (5th-95th) percentile values)	Likelihood of staying below (%)			2000 year sea level rise
			<1.5°C	<2°C	<3°C	
SSP1-1.9 (very low)	1.3 (0.8-1.5)	1.6 (1.3-1.6)	38	90	100	2-3m for 1.5°C
SSP1-2.6 (low)	1.6 (1.1-1.8)	1.7 (1.4-1.8)	20	76	99	
SSP2-4.5 (intermediate)	2.7 (2-2.9)	2.7 (2-2.9)	0	8	71	4-10m for 3°C
SSP3-7.0 (high)	3.5 (2.5-3.9)	3.5 (2.5-3.9)	0	0	22	12-16m for 4°C
SSP5-8.5 (very high)	4.2 (3.3-5)	4.2 (3.3-5)	0	0	4	19-22m for 5°C

Temperature rise and likelihoods are taken from Table SPM.2 of the AR6 WG3 Summary for Policymakers[15] and are relative to 1850-1900 baseline. Sea-level rise taken from Table 9.10 of the AR6 WG1 Full report[16] with the sea-level rise for a given temperature matched to the nearest scenario.

Figure 3: Projected changes in the frequency and intensity of extreme events relative to an 1850-1900 base under different levels of warming[10]



Source: IPCC, 2021: Summary for Policymakers, Figure SPM.6. in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. © IPCC, reproduced with permission.

These scenarios highlight the following:

- All pathways modelled by the IPCC that meet the Paris Agreement depend on negative emissions and GHG removal in the future[17]
- Even low-emissions pathways (in line with the Paris Agreement commitments) lead to long-term sea-level rise that presents huge challenges for adaptation
- Low-emissions pathways (SSP1-1.9 and SSP1–2.6) give a low probability (38% and 20% chance respectively) of limiting global warming to less than 1.5˚C.

Consistency of assumptions in scenarios

IPCC high-emissions pathways present overly optimistic economic outcomes when compared to the latest scientific evidence, comparison scenarios and the weaknesses of integrated assessment models (IAM).[18]

SSP5 is a scenario that foresees fossil-fuel development and high levels of global warming reaching 4˚C by 2100, using solutions such as geo-engineering, if required. The physical frequency and severity of impacts from a high-emissions pathway can be seen in Figure 3 and include increases in heat stress, extreme weather, including heavy precipitation, more frequent droughts, higher sea level rise and a high chance of triggering further climate tipping points.

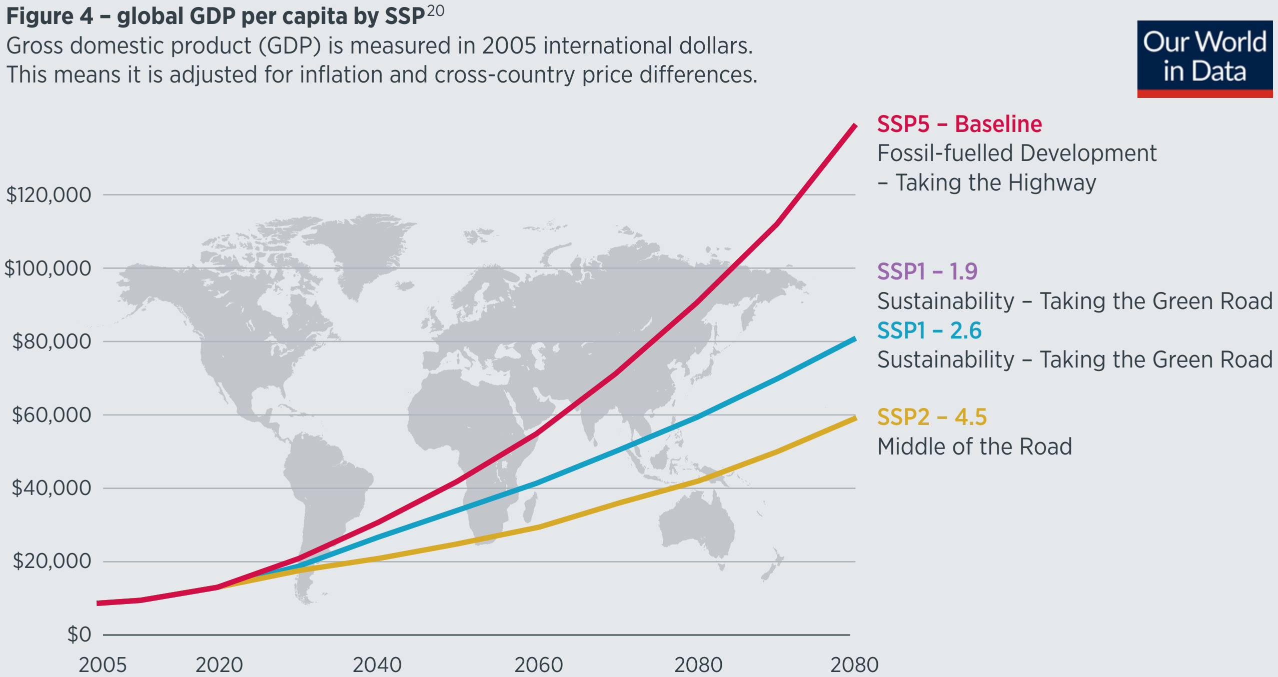
However, as shown in *Figure 4*, this scenario predicts the highest global GDP, which is counterintuitive, given the physical impacts anticipated.

A comparison with other scenario-modelling results shows inconsistencies, with some providers showing the most severe negative GDP impacts in the highest-warming scenarios. The Network for Greening the Financial System (NGFS) states that 'for all scenarios and time scales, physical risks outweigh transition risks.'[19] In a current policies scenario (3.2˚C of warming), NGFS estimates a reduction in global GDP of 18% by 2100 but caution that this does not include 'impacts related to extreme weather, sea-level rise or wider societal impacts from migration or conflict,' all of which would act to further reduce global GDP. Adaptation costs are likewise excluded. Other limitations of the IAMs underlying NGFS scenarios include reliance on carbon prices as the exclusive policy lever which fails to capture the full impacts of policy tools, and not accounting for the role of the financial sector (including feedback between finance and real economy transition) in mitigation pathways.[21]

In a joint paper with the IFoA, Ortec Finance provide a more severe estimate of impacts, citing a negative GDP impact of 73% in the event of a failed transition.[22] Cambridge Econometrica,[23] whose model Ortec Finance use, estimates that a 4˚C temperature rise would result in a 65% negative impact to global GDP by 2100. Again, the authors advise that this is likely to be an understatement as it does not account for tipping points or other unprecedented changes in the climate system. The International Monetary Fund's World Economic Outlook October 2022 reinforces this message, urging policymakers to establish credible and irreversible climate policies and stating that the costs of transitioning would be *'dwarfed by the innumerable long-term costs of inaction'*.[24]

There is a need for users to consider carefully the plausibility and consistency of assumptions underlying climate scenarios. We also conclude that, from a GDP perspective, there is increasing evidence to show it will be overwhelmingly positive to mitigate climate change.

Figure 4 – global GDP per capita by SSP[20]
Gross domestic product (GDP) is measured in 2005 international dollars.
This means it is adjusted for inflation and cross-country price differences.



Source: Riahi et al, **The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: an overview,** licensed under **CC BY 4.0**.

D: Limited consideration of tail risks and adverse scenarios (risk measurement)

Climate impacts are simultaneously uncertain yet completely foreseeable. We cannot predict precisely when they will happen or in what combination, but we know they will occur. This uncertainty cannot be eliminated but it can be managed.

Examining tail risks that drive adverse outcomes, even where they cannot be precisely quantified, is critical for decision making under uncertainty but is currently under-utilised.

From a risk-management perspective, understanding extreme outcomes is key, 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.[25] From a climate-change perspective, this would involve exploring the worst outcomes, even if their probability is low, and asking 'How bad can it get'?[25] It is these extremes that would drive policy decisions – what is society willing to accept? And what actions can we take to mitigate those outcomes that we find unacceptable?

Despite the importance of examining worst-case scenarios, a recent paper[26] found that while there is evidence that climate change outcomes could be catastrophic, even with modest levels of warming, the extreme impacts are under-examined, with very few quantitative estimates of extreme impacts from above 3°C warming. The paper found that the focus of the IPCC reports had drifted towards lower temperatures over time – in part due to the Paris commitment to limit warming to well below 2°C, even though this may be premature considering current commitments do not yet put us on this pathway.

The authors also found that studies of how climate change impacts could cascade or drive larger crises were sparse. Interactions between risks is particularly important due to the characteristics of both the natural earth and economic systems, which are complex adaptive systems. Understanding how climate-change risks exacerbate existing weaknesses in our societies, act as multipliers to other risks, and contribute to system-wide failures is essential for robust climate-change risk management.

E. We should view 1.5˚C similar to a ruin scenario (risk control and identification)

1.5˚C should be viewed similar to a ruin scenario for society – a level we must not exceed. While severe outcomes are already emerging, risks increase the closer to (and further beyond) 1.5°C we get. The increased likelihood of these risks and severity of impacts above 1.5°C reinforce the need to reduce our emissions to net zero as rapidly as possible. Widespread impacts, even at this level of warming, mean we will eventually need to go beyond net zero with a net removal greenhouse of gases from the atmosphere.

Carbon budgets are uncertain, and the budgets currently discussed give an unacceptably low chance of success. Assuming 'no surprises' means they may be much smaller than planned and may already be zero for 1.5°C.

IPCC emissions pathways that are in line with the Paris Agreement have a high probability of overshooting 1.5°C. However, there is a lack of coordinated planning for the impacts we will face. We need to plan for these impacts through adaptation and by building resilience[27] into our human systems.

What constitutes acceptable outcomes involves a value judgement. When managing for the extremes, we need to determine what level of uncertainty we are willing to accept for a given risk. This must be a shared view across all nations, not simply a Western view or developed world view, recognising the unequal global distribution of past and future impacts. For example, those countries with populations who live in low-lying areas will be far more affected by sea-level rise than others. It is our collective responsibility to ensure that their voices are heard with equal weight to our own. An essential element of any risk-management exercise is the discussion and debate of what outcomes we are, and are not, willing to accept. Only then can decision makers assess the degree of risk by understanding the full range of scenarios – particularly worst-case scenarios – in order to fully understand the implications of action or inaction.[25]

The current status of the loss and damage conversation illuminates the problem. Despite the Warsaw International Mechanism for Loss and Damage, the Santiago Network and the Glasgow Dialogue, progress in this area has been pitifully slow.

> Given the extreme impacts already emerging, one can reasonably argue that exceeding 1.5°C is similar to a 'ruin' scenario for our planet.

Society has recognised the danger and developed a shared goal of limiting man-made climate change to 1.5°C. However, even this level of warming presents significant tail risks which need to be explored and then managed. Given the extreme impacts already emerging, one can reasonably argue that exceeding 1.5°C is similar to a 'ruin' scenario for our planet. A risk-management approach would accept that not all risks can be reduced to zero and would ensure the worst outcomes and those identified as unacceptable by society remain below appropriate levels of likelihood and severity.

Revisiting the shared socioeconomic pathways (SSPs) from the IPCC's *Sixth Assessment Report* (see ***Table 1***), the five scenarios, based on different socioeconomic assumptions, each result in a different level of GHG emissions by 2100. SSP1–1.9 and SSP1–2.6, the very low and low-emissions scenarios, are the two scenarios considered as meeting the 1.5°C limit. The probability of success in these scenarios is 38% and 20% respectively. According to Carbon Tracker's analysis,[28] our existing carbon budgets give us around a 50% chance of limiting global warming to 1.5°C. We would be unlikely to trust our pensions or savings to an insurer with a 50% chance of ruin, yet by basing our actions on the lowest risk pathway (SSP1) we are implicitly accepting this level of risk when it comes to climate change.

Carbon budgets also have large margins for error. For example, the carbon budgets in IPCC SR15 for achieving 1.5˚C are 420Gt (67% chance) and 570Gt (50% chance) with error margins of +/-650GtCO_2, meaning we may already have exceeded those carbon budgets with the cumulative emissions to date. Additionally, carbon budgets assume strong action on non-CO_2 emissions, no big shift in the Atlantic Meridional Overturning Circulation (AMOC), and that we do not cross any unexpected tipping points, in other words 'no surprises'. Other sources[29] suggest that we have already exceeded the greenhouse gas concentrations to keep within the 1.5 ˚C limit, meaning that there is a possibility that the remaining carbon budget for limiting warming to 1.5°C is already zero.

Greenhouse gas levels continue to increase and current pledges are inadequate to meet the 1.5°C target.

F. Insufficient action to manage the risks we are facing (risk control)

Greenhouse gas levels continue to increase and current pledges are inadequate to meet the 1.5°C target. We need to plan for further warming and climate impacts through adaptation. As warming increases beyond the 1.2°C level we are at today, so will the impacts we feel.

Significant reductions in GHG emissions are required to reach a point where removal is able to mitigate residual emissions. Given the importance of removal across all emissions scenarios, solutions must be researched, invested in and rapidly scaled.

Mitigation and avoidance of climate risks can be undertaken by many different stakeholders, such as individuals, companies, NGOs, regulators and governments. Each has a different set of tools available with which they can impact the likelihood and severity of the wide number of risks associated with climate change. One of the largest impacts will come from the range of net-zero targets committed to by companies in all sectors and industries. These wide-reaching goals will require companies to rethink supply chains, energy use and even business strategies. With the support of governments and NGOs, and growing enthusiasm and understanding from individuals and customers, there is clear momentum towards taking meaningful action. The question we need to answer is whether these actions are enough to reduce risks to an acceptable level.

The UNEP's Emissions Gap Report 2021 tells us that the latest climate pledges and other mitigation measures in place put us on track for an expected 2.7˚C rise by the end of this century – well above the 1.5°C that we are aiming for. Current levels of CO_2 in the atmosphere have risen to around 420 ppm, an increase of 50% from the pre-industrial level of 280 ppm and the largest driver of climate change. In 2021 power-sector emissions set a new height at 13.6 GtCO_2, with countries continuing to complete constructions of new coal plants.[30] Emissions from deforestation, primarily for agriculture, were estimated to be equivalent to the emissions of India, over 5% of global emissions, at 2.5GtCO_2.[31] While it is harder to track exactly where methane comes from, a significant amount is driven by agriculture, particularly emissions from ruminants. In 2021 atmospheric methane hit record levels.[32] If we continue at this trajectory, scientists estimate we could experience a Pliocene climate, with sea levels 17m higher and 2˚C to 3˚C of warming.[33]

Global emissions are on track to reduce by 7.5% by 2030, but to limit warming to 1.5°C they need to drop by 55%. The World Meteorological Organization predicts a 50/50 chance of exceeding the 1.5˚C target by 2026.[34] This strongly suggests more urgent action is needed.

Carbon capture and storage schemes are in place worldwide to bring about some of these negative emissions, although with mixed success. Most have captured less CO_2 than expected, with some only capturing half as much as planned, and two projects have failed.[35] However, two projects in Norway have been successful, which gives hope for the future of this industry and its ability to mitigate the risk that reducing emissions is insufficient to avoid climate ruin.

G: A need to incorporate uncertainty by introducing prudence (risk control)

Incorporating uncertainty into our approach to climate change would lead to a downward revision in available carbon budgets, an acceleration towards decarbonisation sooner than the current 2050 timeline, and a move to better understand and invest in options for adaptation.

This represents prudence that would increase the likelihood of limiting warming to 1.5°C and reduce impacts of adverse outcomes through adaptation, where possible.

How can we incorporate uncertainty into our approach, to allow for factors such as weaknesses in the assumptions underlying carbon budgets, or to plan for worse outcomes than the models are predicting, at the same time as taking action to try to meet our existing targets?

Risk management deals with uncertainty in a number of ways:

1. **Understand the source of uncertainty** – we can aim to identify the limits to our knowledge, models, assumptions, data and problem framing. Once we have done this, we can explore the sensitivity of outcomes to changes in these factors to understand the 'what-ifs'. We may decide to introduce prudence into assumptions, particularly those where outcomes are material and detrimental. Prudence here means erring on the side of caution in relation to impacts, regardless of the causality. Rather than take the view that "We shouldn't say there is an iceberg until we are confident there is one" we should instead say "There may be an iceberg, we should steer well clear or reduce our speed".
2. **Adaptability, resilience, and optionality** – we can try to understand what we can control and what might go wrong. For those things that cannot be controlled, we need to think about building resilience and the corrective options available to respond. Resilience means the ability to bounce back after a disturbance, the capacity to maintain essential function and the potential for transformation. Optionality – understanding when decisions taken might close off alternative options – is important for transformation and adaptability.
3. **Drive awareness and management of adverse outcomes** – we can explore unquantifiable scenarios, even if the underlying causes are too complex, and plan for a range of possible outcomes.

III: Solutions for a stable climate

At one level climate action is simple – reduce the level of GHGs in the atmosphere. In practice, this means reducing our emissions today as rapidly as possible, removing GHGs from the atmosphere and repairing natural carbon sinks to enable a stable climate.

Critical enablers include enhanced governance, social justice and carbon literacy for decision makers and stakeholders.

Government policies will drive emissions reductions, as supportive policies can supercharge the rate of uptake of climate solutions. The financial system will be an important enabler of successful adaptation and mitigation, with an important role for actuaries.

The 3Rs: Reduce, Remove, Repair – a strategy to ensure a manageable future

If a manageable and equitable future is to be achieved, simultaneous action is required along three axes. We must pursue the 3Rs for mitigation of climate change: Reducing our GHG emissions, Removing GHGs from the atmosphere and Repairing elements of the climate system where we can.

Given the importance of backing away from tipping points, and recognising the underlying logic of a remaining carbon budget, removal of GHGs from the atmosphere, at scale, is urgent. Net-zero emissions by 2050 is crucial, but after that the world must get onto a 'beyond net zero' pathway to ensure that GHG concentrations are systematically reduced year on year until a safe level (CCAG suggest c.350 ppm CO_2 at most) is restored.

Preparing for the expected – resilience and adaptation

Even with concerted efforts to reduce, remove and repair, human societies and ecosystems will need to adapt and build resilience to the inevitable impacts of a changing climate. Pursuing climate resilient development[36] involves working with communities and employing the best scientific evidence to live well in a warmer world.

Adaptation measures for resilience should be developed to be fair and inclusive of all citizens, local and indigenous communities, and groups who are the most vulnerable. Climate resilient development takes place in close connection with the 3Rs for mitigation. Scientific evidence and long-held indigenous knowledge point to ways for adapting to rapidly changing weather patterns. CCAG commits to gathering and disseminating evidence-based insights to the public and decision-makers to support and accelerate systematic climate resilient development across the world.

Reduce

To help restore climate stability, the emission of CO_2 and other GHGs (such as methane) into the earth's atmosphere must be drastically reduced from the current level of more than 40Gt per year, consistent with an ordered, rapid withdrawal from fossil fuels globally.

Reducing the concentration of CO_2 in the atmosphere requires an immediate reduction in the dangerous volume of CO_2 being produced by human activities across the world. If the 1.5°C target is to have a realistic prospect of being achieved, we must reach net-zero emissions in the next 25 years. This rapid and radical reduction of emissions must also be fair.

A concerted effort to reduce emissions to net zero across the world by 2050 may still not be enough to secure a manageable future for humanity. This has led to a set of assumptions that are captured in the idea of a carbon budget covered earlier. The analysis here shows that humanity is already on track to 'borrow' emissions from the future, and therefore must take steps now to begin to 'repay'. Those steps involve CO_2 removal and climate repair.

Removal of GHGs at scale is essential for the world and its future stability.

Remove

Additional efforts to test and deploy GHG removal solutions must start today, and the target must be to limit temperature rise to 1.5°C – and to reduce from there.

Significant carbon removal will be required to meet 1.5°C pathways and to deliver a stable climate by reducing CO_2 levels and temperatures back to pre-industrial levels, to mitigate multi-metre sea level rise and reduce the risk of triggering tipping points.

Including the cost of removal in emissions scenarios is likely to make rapid decarbonisation more favourable from a cost perspective.

Removal of GHGs at scale is essential for the world and its future stability.

Achieving GHG removal at scale will give a clear chance of a manageable future, with reason to hope that new tipping points will be avoided – such as the loss of the Atlantic Meridional Overturning Circulation (AMOC), the total loss of Himalayan glaciers, degradation of the Amazon, sea-level rise for many coastal cities, island nations and much of South East Asia.

Options for carbon removal will depend on regional context and available resources. Some options will fit into industrial processes, such as carbon-neutral or carbon-negative building materials. Others belong in rural or less-developed areas, such as soil management for CO_2 capture,[37] or reinstatement of wetlands, tropical forests and mangrove forests to reduce methane emissions and recapture GHGs. In places such as Africa, where the carbon footprint is low, nature-based solutions will feature prominently. The location of removal schemes is an important consideration, including the impact on biodiversity and local communities.

There is a very clear prospect that the oceans can permanently capture tens of billions of tons more CO_2 than currently, regenerating fish and mammal stocks in the process. In this way ocean biodiversity and climate change are tackled simultaneously.[37]

Duration of carbon storage is important. Many carbon off-set schemes, implemented by airlines, for example, make assumptions about the future health and maintenance of forests that are difficult to judge, especially in the absence of any consistent and transparent, globally agreed accountability mechanisms. Climate change itself threatens forests and their efficiency as natural sinks. At worst, off-set schemes may be no more than greenwash. Action is needed to close off opportunities for industries to 'go through the motions', whether for reasons of conscience or profit, rather than to seriously curb emissions.

Carbon removal that is inherently reversible must be considered temporary and regulated and transparently managed to stay out of the global atmosphere. In parallel, permanent storage options must be expanded. They may not add to other aspects of environmental gain, but they provide storage certainty and opportunities for certification of removal. This may assist the development of global carbon-pricing schemes and regulations.

If removal fails, then repair (see below) will take longer, the benefits of reduce may be lost, and we will be forced to rely more heavily on building resilience: a potentially catastrophic scenario.

Repair

As damage done to the Arctic by rapid climate change is causing weather patterns to shift all over the world[38] it is the most urgent area for repair.

Damage to the global commons has been caused by wealthy nations over many years.[39] These nations owe it to everyone to fix things. But they must approach their duty with humility, care and a commitment to creating safe and effective governance, building trust as they go.

Indigenous and local community members must be drivers and partners in any repair programme. Their willingness to engage will be a litmus test for the whole process. Building these new partnerships is the foundation of new governance structures.

There are large gaps in existing international regulatory frameworks. Some existing frameworks fail to support climate-preserving actions.[40] New approaches are needed. Building new frameworks is urgent and essential.

Small-scale studies will be the first step in repairing the Arctic. Biomimicry may well emerge as the safest first approach. Early studies of climate repair should be incrementally scalable – so they can be paused or reversed at any point. Transparency and good governance will consolidate trust in the process.

Case study: Arctic repair

The speed of change in the Arctic, the risk that a tipping point has been passed, and the breadth of the consequences across the globe, makes the Arctic the first urgent focus for climate repair.

Adopting CCAG's preference for biomimicry, there is a strong argument for small-scale experimentation with marine-cloud brightening. This approach proposes a fine mist of sea water being sprayed upwards throughout the Arctic summer. The spray will take fine salt crystals into the overhead clouds, creating brighter, whiter clouds that reflect the energy of the sun away from the surface of the ocean, allowing new ice to remain through the summer and to thicken the following winter.

The biomimicry approach has many advantages: it brings no new materials into the environment; it imitates processes that occur naturally (if intermittently); it is intuitively scalable; the infrastructure required is small and non-intrusive and can be augmented piece by piece; it can be driven by wave power, meaning the process is carbon neutral.

However, even such a benign model should be carefully tested before being deployed at scale. It requires sensible ground-rules, and clear stages and objectives. An entirely new governance model will be required, recognising both the deeply 'local' nature of the proposal, and the massively 'global commons' nature of the desired outcomes.

The local aspect demands that governance structures include the most local participation. Below national level, the focus should be on indigenous and local community presence in the design process. The participation at the most local level will secure the benefit of deep local knowledge of how the local climate works, and how to operate in harmony with nature to ensure that benefits are achieved – and that nothing is made worse by the climate-repair intervention.

At the global level, all categories of national representation will be important: wealthy countries and poorer countries must be heard. This is how the idea of a 'global commons' interest in the Arctic will be made real. Ultimately, the wealthy countries will have to pay the cost of the experimentation, the governance processes and, perhaps, the eventual roll-out at scale. Compared with the costs of the damage being done (and the damage that will be avoided if the repair programme is successful) the costs will be very modest.

Critical enablers – governance, just transition, education and financial system

Governance

Across the 3Rs, participation and consent from the outset by local and indigenous communities is fundamental, especially if actions take place in their home areas or have an impact upon them. If financial benefits flow from investment in marine biodiversity and GHG removal, for example, those benefits (such as improved fish-stocks, enhanced biodiversity supporting tourism, and so on) must be shared locally and equitably. Governance structures must secure direct benefits for communities without reliance on distribution by supra-national bodies or by the mechanics of national economic policy.[41] Small-scale studies must be transparent, carefully regulated and monitored; they must also be positively accommodated in new regulatory arrangements.

A new governance system must include:

- Local representation, at community level, from the outset
- Recognition that responsibility for damage is linked to responsibility for the costs of repair
- Development of appropriate fiscal and regulatory policies to accelerate mitigation
- Participation of all key stakeholders, including the financial sector.

The just transition

Trust between the Global North and the Global South must be restored

It will not be possible to reach net zero by 2050 without international cooperation between all countries, and this will not be possible without the restoration of trust, especially between the historically wealthy Global North and the nations of the rest of the world.

Rich countries have benefitted from the last 200 years of emissions, but they have been slow and unreliable in reducing their emissions. Against this troubled historical background, recent unmet pledges of climate finance and the deeply concerning situation in Ukraine, trust in the Global North is low. This has been compounded by the refusal of wealthy countries to contribute sufficiently to addressing and adapting to the consequences of climate change in the poorest areas, as well as continued under-investment in technologies to reduce or remove GHGs. In effect there is a double debt: the debt of insufficient investment and roll-out in technological solutions; and the debt of failing to commit finance, thus delegating the financial burden of adaptation to poorer nations already bearing the brunt of climate externalities.

Significant development is therefore required in developing markets. For example, a number of African countries urgently require capital both for climate change mitigation and adaptation. However, structural barriers prevent Western capital flowing freely. While this will not change overnight, it is heartening to see announcements around the intent of Western asset owners to address this, such as this announcement from 12 UK asset owners.[42]

Absence of trust, exclusion of vulnerable or forgotten communities, and under-valuing of local knowledge or citizens' perspectives, are difficult legacies that must be addressed if future global action is to have an impact.

This will be a key topic at COP27, where the largely unresolved issue of loss and damages will be prominent. It is important that recent unmet climate finance pledges by the Global North are addressed, to rebuild trust so that international cooperation can take place.

> We must recognise that we wield great influence through the decisions we make.

Education

Climate change is complex, nuanced and the context is moving quickly. Education is required to ensure leaders and decision makers across the spectrum of human activity understand the context and why the making of wise decisions needs to accelerate. Richer carbon literacy is needed around the drivers of climate change, the solutions and why accelerated climate action is required.

Financial system and policy environment

The financial system makes a big contribution to shaping the world we live in and plays a significant part in determining what we do as a society. This is because *'the financial system wields great power, in that it directly influences which activities are financed and insured, the price at which such activities are economically viable, and the extent to which legacy activities are able to continue.'*[43]

However, the financial system operates in a broader regulatory economic construct, governed by the laws of relevant jurisdictions. The policy framework acts to both incentivise and disincentivise activities through taxes, subsidies and regulation. Governments set the rules and cannot, and should not, delegate their responsibilities for driving economic outcomes to finance. Given the scale of change and speed required, we need policymakers to take this role seriously, now more than ever. The financial system reacts extremely quickly to policy signals, and policy signals have driven rapid uptake for some climate solutions, such as the growth of offshore wind in the UK, or the uptake of EVs in Norway.

The financial system has made significant commitments to support net zero. However, the financial system also continues to finance high-carbon activities, which will make it more challenging to reach net zero. This is a complex and nuanced area. Support is required for the high-carbon industries of today to transition. Some large companies have the scale and capability to decarbonise but will require transition finance to do so. Conversely, continuing to finance businesses that are unwilling or unable to credibly plan for transition will make it much harder to achieve net zero.

Actuaries work extensively in the fields of pensions and insurance, and increasingly in banking. The decisions we take about how to advise our clients can make a profound difference. We will need to adapt our actuarial toolkit to embrace climate risks and uncertainty and net zero. We will also need to nourish our sense of responsibility. We must recognise that we wield great influence through the decisions we make, and help others to make, in the global financial system. We must use that influence wisely to play our part in securing a sustainable future for the citizens of the world.

IV: Accelerating action

There are compelling reasons to believe climate action can be accelerated linked to the positive tipping points that are starting to emerge in our global society. These include changing beliefs on climate action, the rate of technological innovation on climate solutions, having nature as a powerful ally and perhaps, above all, the recognition that as a species we have agency here. It is within our collective capabilities to steer our future back onto a safe course.

Humans are in the driving seat – which gives us agency to choose our future

Humans are now so dominant that, for the first time in planetary history, the activities of a single species are driving planetary outcomes, rather than geological and natural processes. Scientists have started to refer to this as the Anthropocene, coining the phrase for a new geological epoch in which the activities of humans have become the driving force of change on the planet.

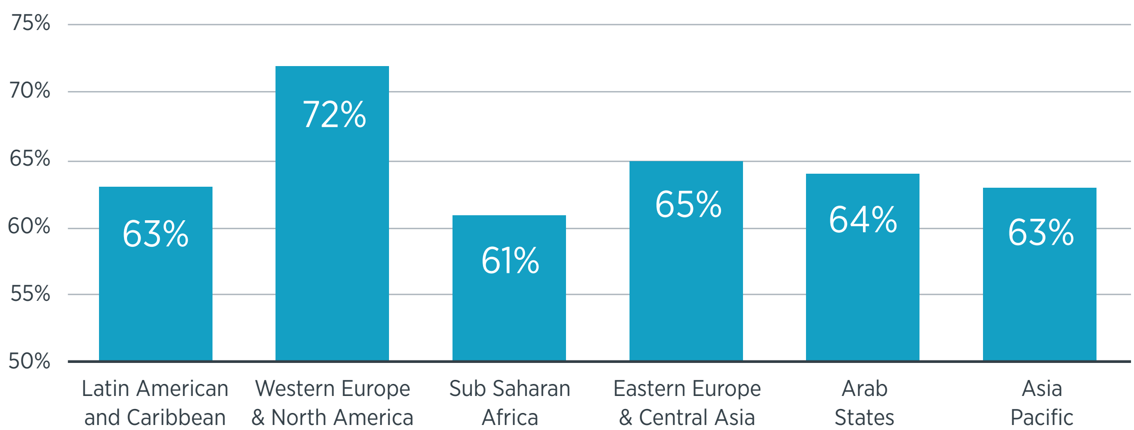
This gives us agency. Now that we have recognised we are driving planetary outcomes, we have both the responsibility and the ability to change course, to drive responsibly, to veer away from climate breakdown, and to deliver a good Anthropocene, underpinned by a stable climate.[44]

However, this will require fundamental changes to our human operating system. We need to re-imagine the way we do things and change our beliefs about what is best for us. Human beliefs can change but only if we want them to and believe the story about why we are changing.

Mindset shift – changing the story on climate action and opportunity

More people than ever before are aware of the climate crisis. The Peoples' Climate Vote[45] found that nearly two-thirds (64%) of people in 50 countries believe that climate change is a global emergency, with 59% of people wanting their country to do 'everything necessary, urgently'. Net-zero commitments now span hundreds of governments and thousands of companies, cities, states and universities.[46] More people than ever before believe that we must take action at unprecedented pace and scale to decarbonise our economy and so limit global warming. Climate change solutions are scaling rapidly and reducing in cost. The increasingly attractive economics of renewables and other climate solutions are reflected in the wider economy, with increasing amounts of capital now being allocated towards decarbonisation initiatives.

Figure 5: Proportion of people seeing climate change as an emergency[47]



Source: United Nations Development Programme, The Peoples' Climate Vote (2021). © UNDP, reproduced with permission.

Public sentiment driven by physical risk events and economics helps to drive policy decisions, with some calling the policy response to climate change as inevitable.[48] Indeed, in 2022 alone we have seen shifts in policy from national actors, such as the passing of the Inflation Reduction Act by the US Congress and new commitments from Australia to cut emissions.

There is also further recognition of the opportunity that climate action presents, whether in relation to energy security needs driven by the war in Ukraine, the lower costs of renewable energy, the need to build resilience and lower costs in our food system, or simply viewing the energy transition as a massive job creation opportunity. In turn, this is driving increasing recognition that climate action is an investment in the future not a cost. This is a significant change in mindset.

With renewable energy, extensive cheap energy resources are becoming available. Wind and solar give the potential for us to enter a new era where we unlock renewable energy reserves greater than our current demand, creating new possibilities for cheaper energy and more local jobs in a more equitable world with far less environmental stress.[49] Solar is now the cheapest form of generation and can be expected to become even cheaper as volumes increase further, with some forecasts predicting a cost reduction of 57% by 2025 compared to 2015 costs.[50] Renewables provided over 10% of global power generation for the first time in 2021.[51]

Poor countries could be the greatest beneficiaries. They have the largest ratio of solar and wind potential to energy demand and stand to unlock huge domestic benefits. The continent of Africa could be a renewables superpower, with 39% of global potential. For many countries, a small percentage (<0.1%) of land area is required to meet current energy demand.

New research on the economics of the energy transition[52] reinforces the opportunity, estimating that *'a rapid green energy transition will likely result in trillions of net savings.'*

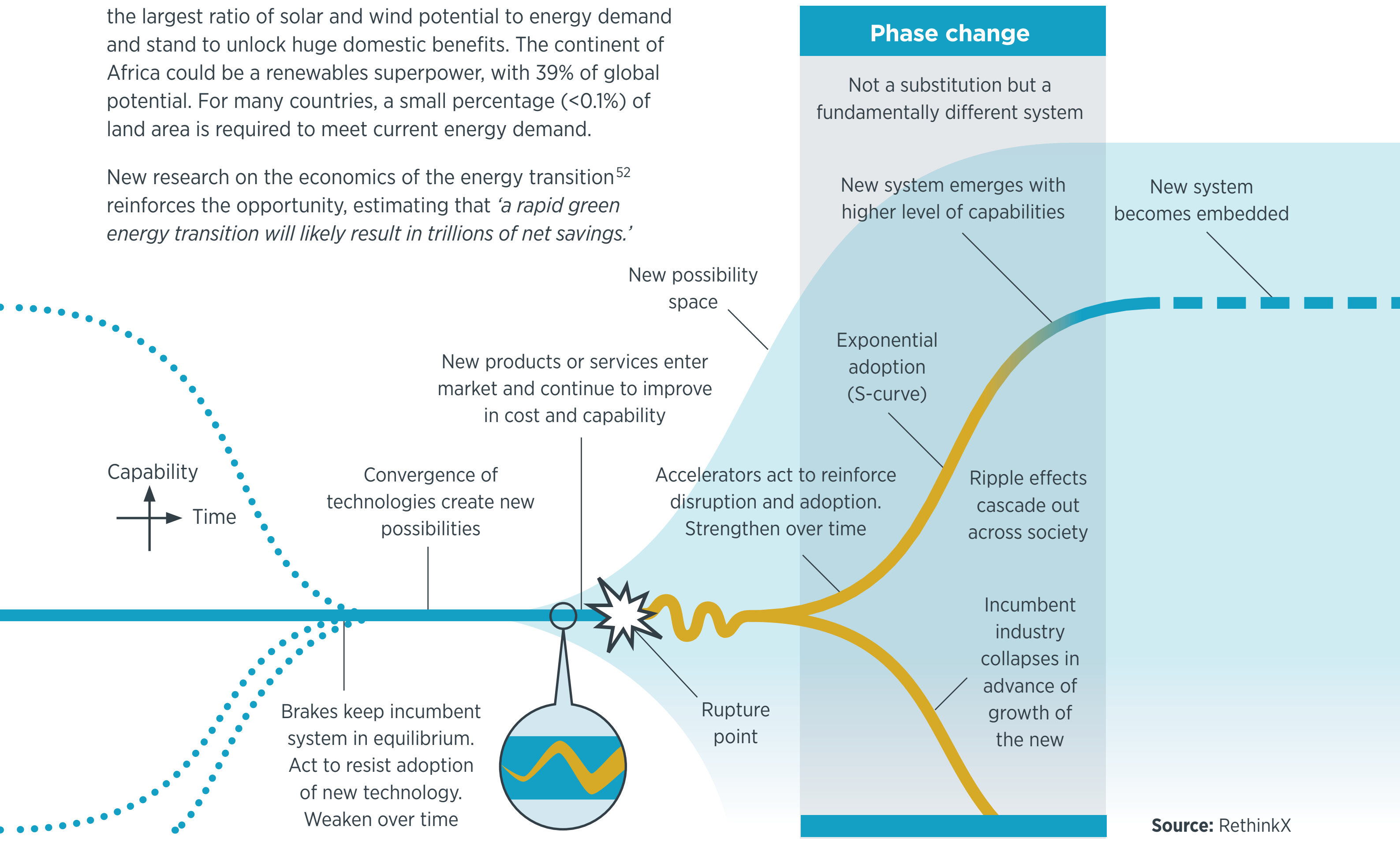
We can accelerate the change in food, transport, energy and other systems

In the energy transition and GHG removal challenges, investment needs to step up. Over the period to 2030, investment in clean energy technologies needs to be three times larger than annual levels in recent years to set the world on course for net-zero emissions by 2050.

But 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.

Analysis carried out by RethinkX[53] shows this change is non-linear. The classic S-curve of disruption applies, observed in various shifts from the introduction of mass-produced cars to the introduction of smartphones 100 years later. Incumbents often struggle to see and react to the change that is coming. Society can be surprised too, but once the cost and convenience become clear, public interest and political support follow quickly. Supportive policies can supercharge rates of adoption.

Figure 6: Disruption Framework[54]



Source: RethinkX

In their publication *Rethinking Climate Change,*[56] Rethink X put forward a scenario whereby humanity chooses to reduce emissions by 90% by 2035 through the disruption of energy, transportation and food systems.

- **Energy** – disruption of fossil fuels by renewables and battery technology
- **Transportation** – a move to electrification and transportation as a service
- **Nutrition** – disruption of animal products by precision fermentation and cellular agriculture.

This scenario relies on the disruption of animal farming and 2.7 billion hectares of land being freed up for passive reforestation.

However, while RethinkX sees these disruptions as inevitable given the decreasing cost curves of the technologies, they caution that *'it will be up to us to decide whether or not we deploy these technologies worldwide rapidly enough to avoid dangerous climate change'.*

While the specifics of these scenarios may be viewed as optimistic, it is clear that disruption is highly non-linear and that the societal choices we make have the potential to significantly increase the rate of technology adoption and change in the system, with supportive policy environments being an important enabler.

Working with nature, already a formidable ally in mitigating climate change

Nature has played an essential role in mitigating climate change, absorbing to date around 1/2 of the 550 giga-tonnes of carbon we have emitted since the industrial revolution. The ocean absorbs around 25% of global carbon emissions today and has absorbed over 90% of the additional heat from global warming. Land-based ecosystems such as forests, wetland and grasslands absorb around 30% of our emissions.[55] Nature also holds a huge amount of carbon in land-based carbon sinks and in the ocean.

Working with nature to regenerate land and ocean-based carbon sinks will be crucial to successfully mitigating climate change, including reducing our negative impact on carbon sinks, for example by reducing deforestation. There is significant overlap here with food system changes. If plant and lab-based protein disrupts animal agriculture, this in turn will free up significant land for regeneration. As with other system changes, supportive policies will be critically important. The outcomes of COP15 on Biodiversity are likely to be significant, as well as initiatives like the Taskforce on Nature-related Financial Disclosures (TNFD).

An example is given of the carbon sequestration potential of marine biomass regeneration.

Case study: Marine biomass regeneration

Marine biomass regeneration is an example of biomimicry in climate repair and CO_2 removal. The aim is to recreate the deep-ocean conditions in which whales used to thrive before their mass eradication by humans. Whales are now understood to be drivers of very healthy marine ecosystems, as well as indicators of biodiversity in their own right. Small-scale regeneration of ecosystems to bring whales and other marine species back to areas that are currently marine deserts will increase biodiversity, enhance fishing grounds and create new CO_2 sinks.

Marine biomass regeneration offers the possibility of incremental scaling. If the effects are not positive, it will be easy to stop the processes. If successful, there is a chance of restoring marine populations in all its biodiversity alongside CO_2 removal equivalent to tens of Gt – a chance that should not be missed.[57]

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37. See **page 24** for details about Marine Biomass Regeneration

38. See **CCAG: A Critical Pathway for a manageable future for humanity**

39. We use the term 'Global Commons' to denote a part of the world's ecosystem that is –and should be – regarded as belonging in common to all of the planet earth, including all of humanity. Nobel Laureate Elinor Ostrom was passionate about the potential for identifying and managing 'the commons' at all levels of human society. See for example her book 'Governing the Commons' (2015) **https://www.cambridge.org/core/books/governing-the-ommons/A8BB63BC4A1433A50A3FB92EDBBB97D5**

40. International regulations, such as the London Protocol have the potential to impede legitimate studies for regenerating ocean biomass, for example. See the National Academies of Science, Engineering and Medicine (2021) page 39 for a discussion **https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration**

41. Indigenous Peoples and Local Communities are directly managing around 17% of the carbon stored in forests. They rarely receive direct funding, and there is a clear, massive funding gap for securing of customary land rights. There is good evidence that land-right security enhances forest management by IPLCs. This is explained in the CCAG report 'Aftermath' following COP26, page 13. **https://www.ccag.earth/s/CCAG_Reflecting-on-COP26.pdf**

42. **12 leading UK pension funds to collaborate in support of climate transition in emerging markets | The Church of England**

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45. **The Peoples' Climate Vote | United Nations Development Programme (undp.org)**

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57. It is difficult to calculate exactly the full potential impact of marine biomass regeneration, based on the current available data. However, the American Academies of Science (2021), in their plan for a research strategy, show that several Gt of CO2 per year from phytoplankton can be sequestered to deep ocean - with estimates in relevant model studies ranging from 1 to 5 Gt per year via addition of limiting nutrients. These estimates are likely to be an underestimate of the potential for carbon sequestration since they exclude carbon from regenerated fish and whale populations as well as other elements of a healthy oceanecosystem. **https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration**

    See Pershing et al (2010) and Savoca et al (2021) for insights into the role of whales in sequestering carbon.
    https://journals.plos.org/plosone/article?id=10.1371/journal/pone.0012444 and https://www.nature.com/articles/s41586-021-03991-5

About CCAG and the IFOA

CCAG and the IFoA brings climate scientists, who are comfortable speaking the difficult truth, together with a profession that has a public interest duty based on risk, uncertainty and financial skills – a powerful combination to help address the existential risk of climate change.

CCAG is an independent group of experts reflecting a wide range of academic disciplines and indigenous knowledge, comprising 16 experts from 11 nations. CCAG members include leading authorities in climate science, carbon emissions, energy, environment and natural resources.

CCAG aims to deliver cutting-edge science at breakneck speed. By putting expertise directly into the public domain, its aim is to reach the public and civil society, as well as the financial sector and policymakers' decision processes. Rather than just saying 'this is the state of the global climate', CCAG points to necessary and achievable options for the global response from governments, companies and the public.

CCAG launched in June 2021 and has published seven reports to date, available on the **CCAG website**. CCAG's approach is framed around the 3Rs:

Remove – GHG removal at scale

Repair – collaborative action to manage parts of the climate system that are beyond tipping points

Reduce – rapid emissions reductions

The Institute and Faculty of Actuaries (IFoA) is the chartered professional body for actuaries in the United Kingdom. It represents and regulates over 32,000 members worldwide and oversees their education at all stages of qualification and development throughout their careers. Under its Royal Charter it has a duty to put the public interest first.

This includes speaking out on issues where the IFoA can contribute, raising public awareness of the work of actuaries and the value they add to society, while working with government and others who shape policy.

The **IFoA policy statement on climate change** recognises that the climate is changing globally at an unprecedented rate as a result of human activity. This change presents ecological, social, economic and financial risks. The potential impacts of climate change are global and systemic. As well as highly disruptive physical changes, there are significant implications for the entire financial system.

The actuarial profession specialises in risk management, and climate change is one of the greatest risks facing our world today. Mitigating this risk is urgent. Future outcomes are uncertain, but the best value insurance premium that society can pay is to reduce our emissions today in order to avoid the irreversible consequences of unmitigated climate change tomorrow.

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