CRO FORUM

The heat is on

Insurability and Resilience in a Changing Climate

Emerging Risk Initiative – Position Paper

Notes:
This paper frequently refers to insurers. When doing so this is intended to mean the insurance industry including reinsurers, insurers and distributors or brokers.

This paper relies heavily on the Intergovernmental Panel on Climate Change (IPCC) for data and charts, drawn from SR15 and AR5 working papers.

Foreword

Global warming is underway, yet there are a wide range of potential outcomes relating to the timing and extent of future warming. Furthermore, there are potentially huge consequences under scenarios at the upper end of the range. Conversely, to achieve the Paris targets and restrict the extent of warming will require a massive and prolonged transition effort, unprecedented in scale and duration, which may be orderly or disorderly.

Therefore, climate change is a risk of an unusually broad and rich nature, and many regard it as the greatest risk currently facing humanity. Although it has been recognised as a key emerging risk for some time, the CRO Forum decided now was a good time to focus on it, given its increasing urgency, complexity, wide range of scenarios and the pervasiveness of its impacts.

The intention of this position paper is to provide insurance sector CROs and their colleagues, and wider stakeholders, with a clear understanding of what climate change implies for the insurance industry, both from an underwriting and investment perspective, and to equip them to challenge their businesses and clients in their responses to climate change.

Existing research on climate change is broad and extensive. This paper does not aim to replicate this research, but to navigate the main issues, and provide a clear and up-to-date view of the climate change challenge, centred on the potential impacts on the insurance sector. This covers implications for:

- underwriting of climate change related risks (and the important question of insurability);
- investment activities; and
- reporting and disclosure.

The paper also considers the social role of the insurance industry and its responsibility to support the wider societal effort to transition to a lower carbon world, and to influence civic and infrastructure planning decisions now to help avoid an insurability gap in the decades ahead.

During our research we have been struck by the precarious situation, with the world currently on a path towards ‘too little, too late’. On the other hand, we are encouraged that the Paris target is technically achievable as recently set out by the IPCC, IEA, EDC and others. It will, however, require a determined and wide-ranging set of transition policies and programmes (sustained at several times the pace of current transition activity).

We have approached the topic as risk managers, so we give due attention to the downside risks as well as the central projections gathered from existing research and publications. We consider assumptions and mitigation plans with a critical eye, bearing in mind the context and any empirical evidence of their relevance and effectiveness. At times we have not shied away from expressing our opinion.

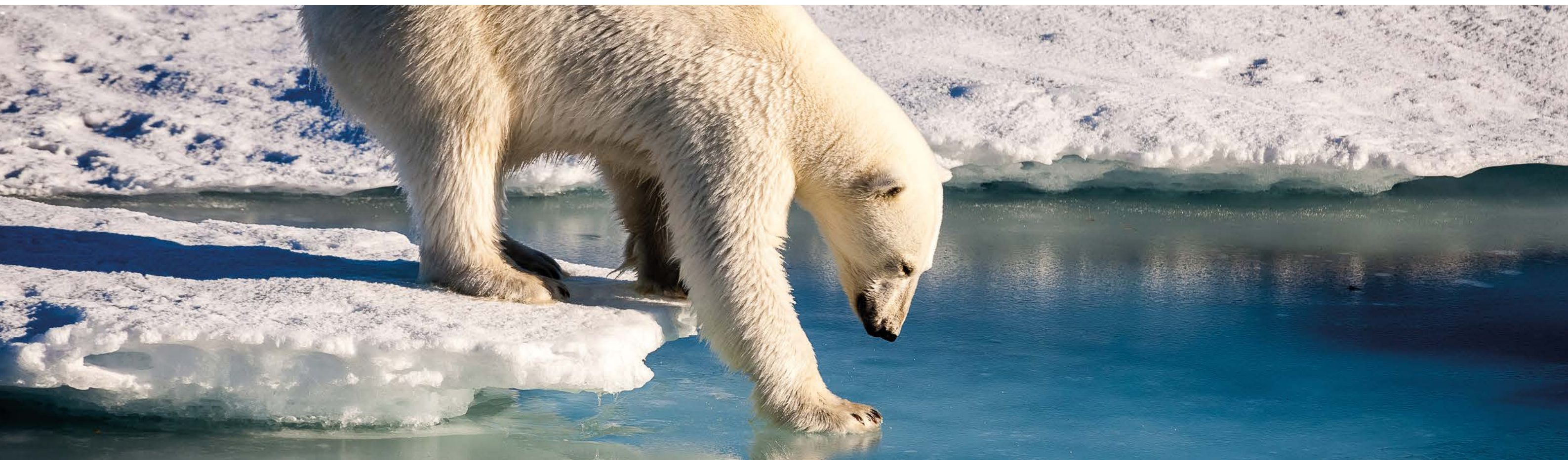
I would like to thank our external reviewers, Professor Joanna Haigh, Professor Peter Höppe, Dr Maryam Golnaghi of the Geneva Association and Professor Sonia Seneviratne, for giving up their time and for their insightful comments. Any errors are ours, not theirs.

And I would like to express my gratitude and respect for my colleagues on this CRO Forum working group, from Allianz, AXA, Generali, Hannover Re, Munich Re, NN Group, Prudential, Swiss Re, SCOR, Uniqa and Zurich Insurance Group, for their energy, insight and active participation in the production of this paper, and in particular to Luke Watts from RSA for organising and facilitating the entire project and for careful editing. It is the collaborative efforts of all that result in what we hope you will find a balanced and thought-provoking summary of the climate change issues facing insurance.

William McDonnell

Group Chief Risk Officer, RSA Insurance

January 2019



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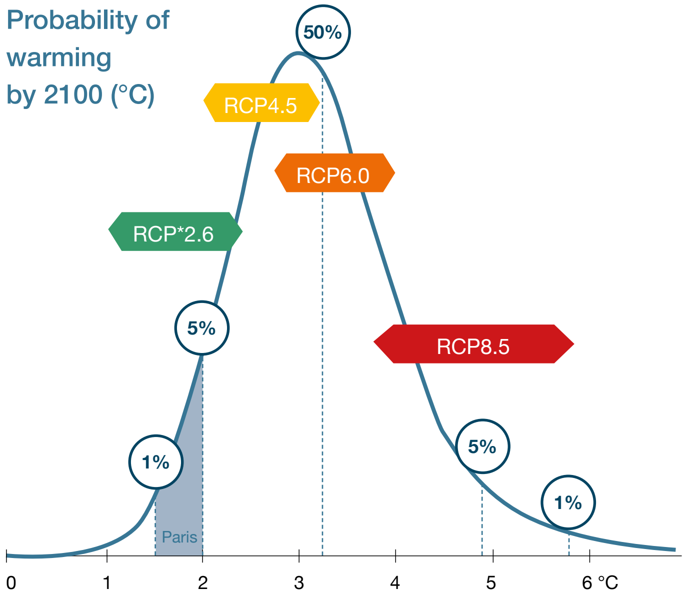
The Paris target (1.5-2°C) to limit dangerous physical effects of climate change is vital but tough to meet. Research indicates that 3-4°C warming is most likely. There is a risk of >5°C which would be catastrophic.

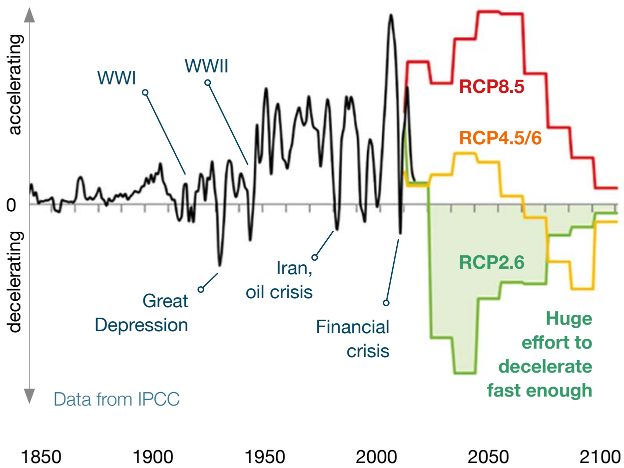
To hit the Paris targets will require a long, profound transition. This means major changes to energy, industry, freight, heating etc, sustained and extended to deliver large new emissions cuts every year, decelerating fast throughout 2020 to 2070.

Probability of warming by 2100 (°C)



* See page 48 for a description of RCP

Rate of acceleration of CO_2 emissions over time



Warming by 2100

Physical impacts

	<2 °C		3 °C	5 °C
	1.5 °C	2 °C		
Sea-Level Rise (cm)	0.3-0.6 m	0.4-0.8 m	0.4-0.9 m	0.5-1.7 m
Coastal assets to defend ($tn)	$10.2tn	$11.7tn	$14.6tn	$27.5tn
Chance of ice-free Arctic summer	1 in 30	1 in 6	4 in 6 (63%)	6 in 6 (100%)
Tropical cyclones: Fewer (#cat 1-5)	-1%	-6%	-16%	Unknown
Stronger (# cat 4-5)	+24%*	+16%	+28%	+55%
Wetter (total rain)	+6%	+12%	+18%	+35%
Frequency of extreme rainfall	+17%	+36%	+70%	+150%
Increase in wildfire extent	x1.4	x1.6	x2.0	x2.6
People facing extreme heatwaves	x22	x27	x80	x300
Land area hospitable to malaria	+12%	+18%	+29%	+46%

Economic impacts

	<2 °C		3 °C	5 °C
	1.5 °C	2 °C		
Global GDP impact (2018: $80tn)	-10%	-13%	-23%	-45%
Stranded assets	Transition: fossil fuel assets (supply, power, transport, industry)		Mixed: some fossil fuel assets mothballed, some physical stranding	Physical: uninhabitable zones, agriculture, water-intense industry, lost tourism etc
Food supply	Changing diets, some yield loss in tropics		24% yield loss	60% yield loss, 60% demand increase
Insurance opportunities	New low-carbon assets and infrastructure investment (e.g. CCS)		Increasing demand to manage growing risks	Minimal: recession, tensions, high and unpredictable risks

The data used in this infographic is sourced from IPCC data and other sources as listed in the Bibliography (incl Raftery et al, Schlosser et al, Jevrejeva et al, Knuston et al, Turco et al, Huang et al, Pretis et al, and Burke, Hsiang & Miguel)

* The total number of hurricane category 1-5 tropical cyclones is predicted to decline with rising temperatures, the proportion of those that are category 4-5 will increase. The interaction of these two effects is non-linear in the models, per Knuston et al, NOAA 2015.

Executive summary

Despite growing concern, 2018 again set new records in global consumption and greenhouse gas emissions. The carbon budget (i.e. the maximum cumulative emissions) consistent with the <2°C Paris target is being used up fast. It is clear warming cannot be kept below this level without radical and sustained economic and societal change.

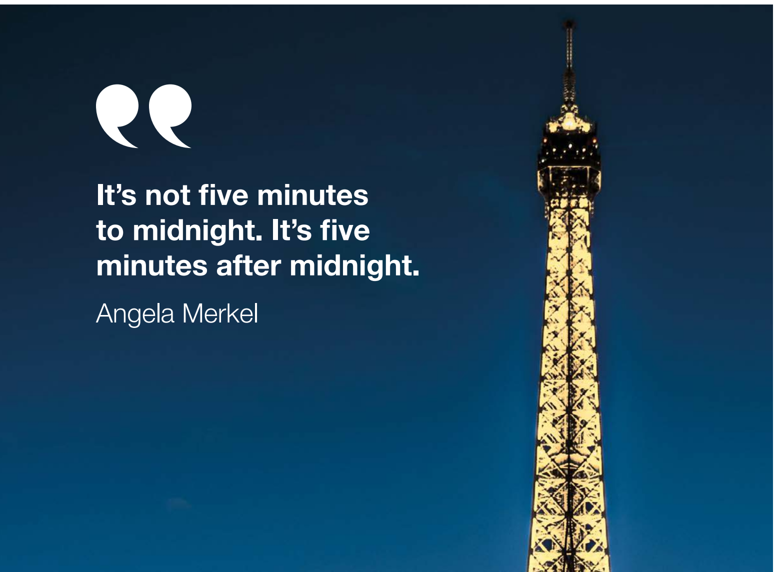
The risks to insurers and their customers from unchecked global warming are profound:

- The **'physical' risks** (where climate change affects property, industry, infrastructure and health) could be very severe, especially if warming exceeds 3°C. These risks are amplified by trends of urbanisation, value concentration, non-resilient land use planning and infrastructure vulnerabilities.
- To meet the Paris targets and avoid the worst physical risks requires fundamental economic and social changes, driven by public policy, political will and societal attitudes. It is important these actions are taken soon, and in an orderly and coherent way so the associated **'transition' risks** can be mitigated through careful and co-ordinated planning. By contrast, a disorderly transition scenario could involve abrupt political shifts and headlong economic disruption.

In terms of **timescale**, the physical climate change effects are similar for all scenarios in the short term, due to lag effects, and we are likely to reach 1.5°C by 2030-2040. The wide variation in physical outcomes arises after that, dependent on actions taken. However, the period 2020 - 2030 is critical for taking action to meet or exceed Paris targets as there is a wide range of possible policy paths, which alter how extensive and orderly transition activity is.

The scale of the challenge

There is no easy middle road. As Angela Merkel said, it's not five minutes to midnight; it's five after.



It's not five minutes to midnight. It's five minutes after midnight.

Angela Merkel

Research suggests probable warming of 1-6°C above pre-industrial levels by the end of the century, depending on the success of mitigating actions. Such increases may not sound large, but the upper half of this range implies catastrophic risks, far worse than is widely realised. To put this in context, it is broadly the same again as the warming from the depths of the last Ice-Age to the modern era, and in 1/100th of the time. This will, inevitably, overwhelm the ability of the world's natural systems to absorb and adapt. Disturbingly, many impacts are irreversible within centuries and the risks grow of passing 'tipping points' that trigger runaway effects. Some irreversible changes already occur above 1.5°C warming.

The IPCC (Intergovernmental Panel on Climate Change) published its Special Report (SR15) in October 2018 on 1.5°C global warming. It concludes that global warming can technically be limited to 1.5°C (the Paris goal), but an unprecedented breadth and scale of transition is required, which may well be inhibited by economic, institutional and socio-cultural barriers. National pledges agreed in Paris would not be enough to reach this goal. To achieve 1.5°C total emissions need to be cut by 33-50% in the next 12 years, potentially requiring investment of over $2 trillion per year, and net-zero CO_2 emissions needs to be achieved by 2050.

IPCC notes that all pathways to 1.5°C rely on removal of 100-1000 billion tons of CO_2 from the air this century. We are sceptical this is achievable given scant progress so far; carbon extraction techniques are uneconomic and largely unproven on the scale needed. There is significant moral hazard in assuming we can emit today and someone will clean it up tomorrow.

Efforts of a generation have not yet 'moved the dial' and global emissions are higher than ever. Widespread realisation of what a +3-5°C world would be like could further catalyse public opinion, helping overcome **socio-economic tipping-points** and create a political mandate for tougher action, in order to treble the current rate of transition.

Encouragingly, major institutions have collaborated to lay out clear and orderly policies and actions to achieve the Paris targets (e.g. NCE, 2018 or EDC, 2018) through adaptive technologies and incremental solutions, even in challenging sectors such as transport and heavy industry. Also, a range of institutions and public bodies are showing leadership, e.g. California aims to generate electricity fully fossil-free by 2045. This paper explores the physical and economic impacts under 2°C, 3°C and 5°C scenarios and the implications for insurers. It recognises more needs to be done by policymakers, businesses and individuals to change our outlook and to design and carry out the difficult steps. Society must work together globally with each of us taking responsibility for our emissions footprint and with policies to prevent ‘free-riding’.

Role of insurers

Insurers have a unique role in the global effort to mitigate and adapt to climate change, as both providers of risk protection and as major investors managing c.$30 trillion of assets. In line with our primary functions, insurers will continue to work with customers, industry and governments to:

- Protect customers from the impact of physical perils.
- Provide risk management advice, and support mitigation, resilience and adaptation solutions.
- Maintain insurability, sustaining the real economy by planning ahead with governments, industry and society.
- Remain resilient, to continue supporting our customers.
- Provide long-term investment, including existing efforts to support greener technologies and transition activities.
- Support understanding of the financial and strategic risks of climate change through research and disclosure.

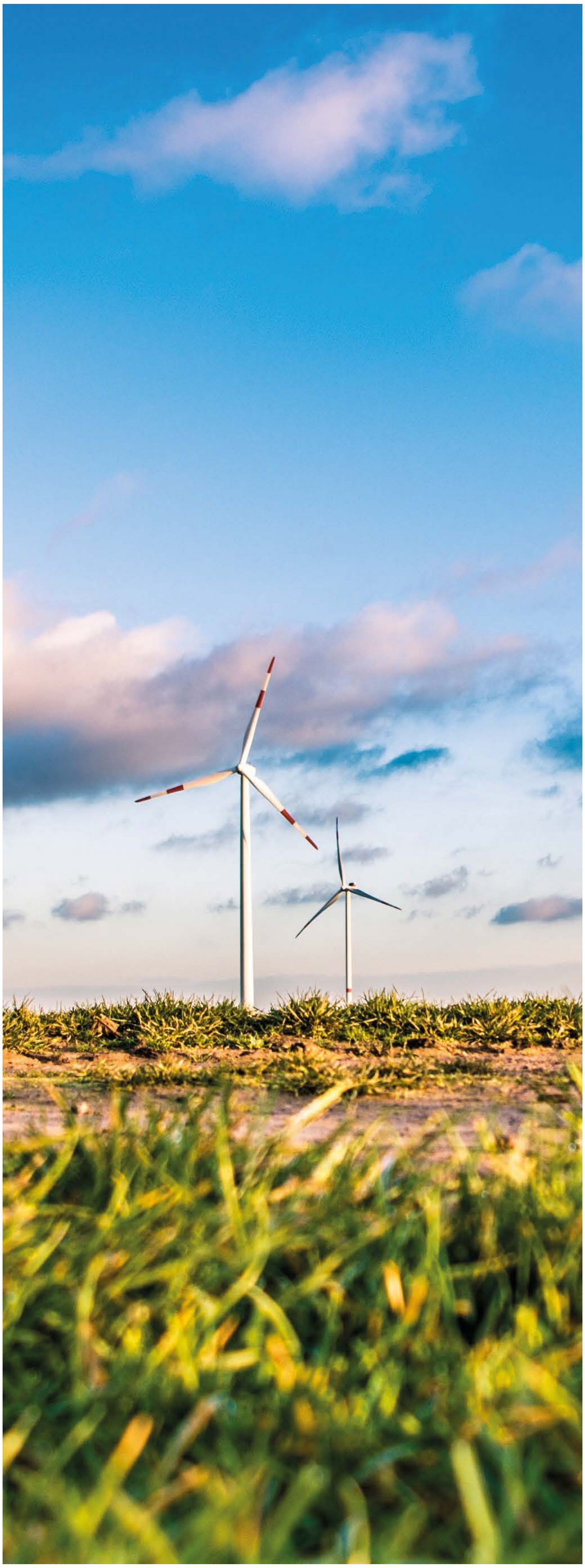
Insurability and resilience

Insurers can help fortify society’s resilience to climate change by continuing to invest in hazard models, promoting their use and advising on building codes and resilient engineering. This is urgent now to minimise a future insurability gap.

Such is the scale of the threat, however, that insurability and affordability are likely to become an increasing concern:

- As hazard modelling becomes ever more precise, certain local peak risks may exceed capacity or become unaffordable to insure. Certain coastal or forest-fringe properties in USA are already on the edge of insurability.
- Governments can overcome some of the issues through pooling mechanisms that share the peak risk across a wider pool of participants; however, unless these are designed very carefully, they can make the problem worse by incentivising unsustainable development.
- However, in the more extreme warming scenario of >5°C, severe damage and disruption could become so frequent later in the century that many risks may be uninsurable, with a profound impact on the economy and on society.

Ultimately the key to resilience for society, and also insurers, is to limit future warming by reducing emissions and adapting. Transition risk needs to be taken now to avoid physical risk in the future. The insurance sector is playing its part in current plans and is working on many fronts to do what it can to help the world achieve the vital goal of keeping warming to <2°C.



1 Introduction

> **Climate change is not some far off problem; it is happening here, it is happening now.**
>
> Barack Obama, former US President

1.1 The globe is warming

Introduction

The science behind global warming and the role of greenhouse gases is clear and generally accepted. While the physical effects of warming and climate change can be modelled, the full extent of impacts on living conditions or societies are complex to predict. However, enough is known to state that a failure to act now has significant implications for the citizens of today and generations of tomorrow.

Insurance has a key role to play not only in protecting society from the impacts of more extreme events, but also in helping others take action to reduce emissions or to adapt to climate effects. Transitioning at the pace required will require concerted effort from all in society.

The signs of climate change are already apparent. Examples include:

- New records for extreme weather (downpour, windstorm, drought, heatwave, wildfire) and more frequent events, as predicted by climate models.
- The extent and thickness of the Arctic polar ice-cap shrinking during the summer months.
- The rapid shrinkage of glaciers and snow-pack outside the polar regions.
- Global mean sea-level has risen by 0.19m between 1901 and 2010.
- 50% of coral reef area has sustained major bleaching damage.

However, this is just the start. There are many potential repercussions. For example, on the food chain even at 2°C warming, IPCC tells us the associated acidification will destroy vital marine ecosystems. The gravest for humanity, in the higher warming scenarios, may lead to widespread loss of livelihood and food shortages as repeated extreme water and heat stresses progressively impact farm production. Repeated extreme events may also strain

Figure 1 **Global temperature change relative to 1850-1900 (°C)**

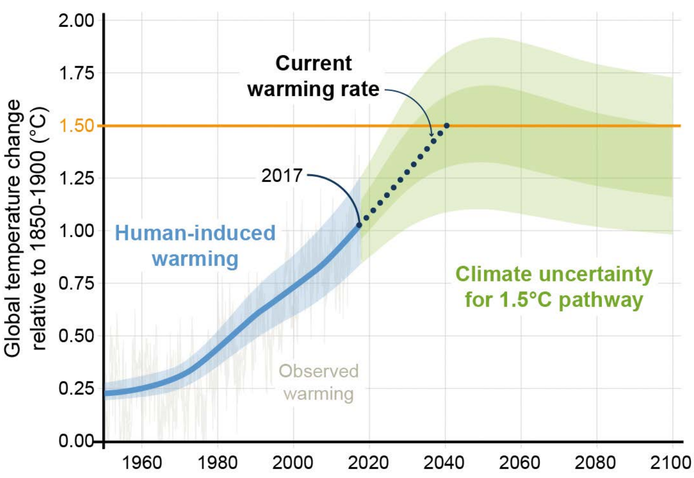
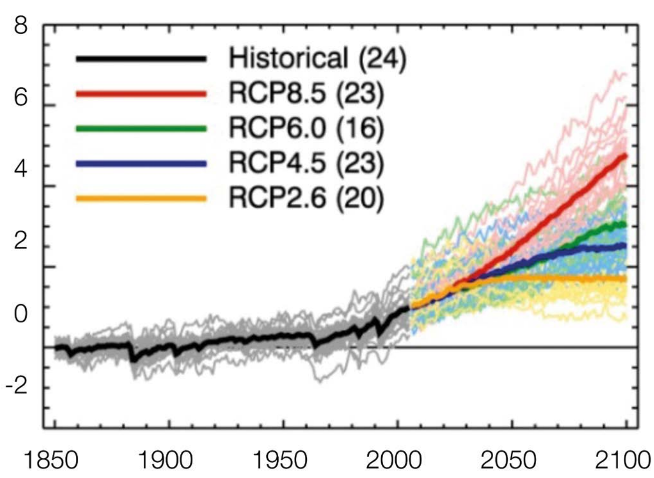


Figure 2 **Range of °C increase for each RCP**



IPCC SR15 FAQ1.2

Warming reached c.1°C above 1850-1900 in 2017 and is on course for 1.5°C around 2040.

and damage infrastructure. It is not unreasonable to assume such effects will be accompanied by socio-political upheaval, migration and conflict.

Physical and transition risks
Before reaching these extremes, people and organisations will face the physical risks of increasingly abnormal weather (heatwaves, droughts, flooding, wildfires, shifting storm patterns) and growing risk of coastal flooding. Zones of vulnerability will grow, affecting property values and making investment harder. Outbreaks of human and agricultural diseases and epidemics are likely to increase.

As physical impacts become more obvious and disasters more common, public opinion may shift, and with it **liability risks** may grow for those considered responsible.

Insurability concerns will also grow. For insurers to exist there must be an insurance need at an affordable price. Seeking to maintain insurability, where possible, to support adaptation and to build increased resilience will not only be vital for society but also to the long-term role for insurance within society. This may become an issue of public policy, where the question will be how far to spread or nationalise the risks so that insurance protection remains available to individuals and organisations. Linked with this is the need for long-term planning and adaptation.

As increasing efforts are made to mitigate emissions, these give rise to transition risks. The carbon budget to achieve <2°C warming means that the majority of proven fossil fuel reserves may need to "be stranded" – see section 1.4 below. Existing equipment and machinery may also need to be stranded, as their expected lifetime emissions would exhaust the carbon budget for <2°C warming. To highlight the magnitude of the challenge and the urgency of the problem, 2018 was set to see a record number of fossil fuel cars, trucks, aircraft, etc became operational.

1.2 Current assumptions on climate change

With recent experience of extreme weather conditions, climate change discussion has grown more prominent. Within the scientific community there exists very clear evidence as presented through the work of the IPCC, the international body for assessing the science related to climate change.

2018 has been a year with several extreme weather events. In the summer there was a global heatwave in the northern hemisphere, associated with deaths in Japan and Canada and fires in California, Canada, Sweden, Spain and Greece. In the autumn of 2017 there were US tropical cyclones with unusually intense rainfall. As noted by IPCC, the attribution of individual extreme weather events to warming is difficult. Recent and ongoing research is focusing on attribution science and how climate change affects the likelihood of extreme weather events occurring.

The IPCC provides policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. The key takeaways from its last full assessment report, AR5, in 2014 were:

- Human influence on the climate system is clear.
- The more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts.
- Any additional CO_2 emissions lead to increased global warming with the effect lasting for many millennia before natural processes remove it from the atmosphere, unless actively removed by other means, such as Carbon Capture and Storage (CCS) or re/afforestation.
- Humans have the means to limit climate change and build a more prosperous, sustainable future if we choose to.

The Special Report on 1.5°C (IPCC's SR15) further highlights the increased damage at 2°C vs 1.5°C and reflects recent research, as well as steps that can be taken in mitigation.

> **We appear to be embarked on a massive experiment where the consequences are hard to predict and the effects may be irreversible.**
>
> Professor Lord Nicholas Stern, Chair of the Grantham Institute, LSE

Alongside CO_2, increasing emissions of other greenhouse gases (GHGs) arise from changes in land use from deforestation and agriculture, primarily methane (CH_4) but also nitrous oxide (N_2O). Methane emissions are also rising due to leakage or releases from the oil and gas industry.

Scientists have observed various ongoing changes in the climate system, which intensify global warming:

- Temperature data of the combined land and ocean surface already shows a rise of over 1°C compared with the 'pre-industrial' average from 1850 to 1900, with a greater rise on land than over the ocean. There is already evidence that certain extreme events (e.g. heatwaves, drought) are more frequent, linked to climate change.
- The atmospheric water cycle is intensifying, with greater downpours and evaporation. Higher temperatures raise the saturation point of air (by c.7% per °C) and accelerate evaporation (by c.10% per °C). Also, as atmospheric layers warm and expand, so thunderclouds can grow in height and strength, leading to heavier rainfall. Warming is estimated to have boosted the intense rainfall of Hurricane Harvey in 2017 by at least 15%.
- Physical risks not only become more pronounced as temperatures increase but they also vary substantially by region, e.g. Bangladesh is projected to become even wetter but the Mediterranean and Southern Africa become significantly drier. Also, patterns may be affected, with extreme rainfall and droughts possibly

happening in succession. In turn, this could exacerbate extreme events like wildfires, as was the case in 2017 in California. An exceptionally wet season led to growth of vegetation that dried out in the following drought creating perfect conditions for wildfires. The Western US wildfire area has doubled due to these effects.
- A large part of the rising CO_2 emissions into the atmosphere is absorbed by the ocean. However this results in rising acidity levels. Ocean surface water pH is approaching the threshold when many marine organisms at the base of the food web struggle to form calcium-based shells or skeletons, and coral begins to dissolve. A compounding stress is the decrease of oxygen levels, particularly in coastal waters, observed since 1960 that is probably due to warming combined with fertiliser run-off.
- The Greenland and Antarctic ice sheets are more sensitive to warming than previously thought. The rate of ice mass loss contributes to a rise in sea levels and may have an impact on global ocean circulation. There is some evidence that the Atlantic circulation system that includes the Gulf Stream has slowed by c.30% since the late 1950s.
- The effect of Arctic ice loss on mid-latitude weather has also become a very active area of research, in particular into the slowdown and meandering of the jet stream which may contribute to more prolonged weather anomalies in economically productive regions including Canada, Northern USA and Europe.
- Between 1901 and 2010, global mean sea-level rose by 0.19m, rising at a faster rate since 1993. This makes a sea-level rise of up to 1m this century seem plausible.

Climate models make additional predictions of physical risk impacts relevant for insurers:
- Although average rainfall at a large scale increases at only c.2% per °C warming, the total water amount that clouds can release locally is growing at much faster rates at or above 10% per °C warming. Evaporation is rising at a similar rate. As a consequence, both flooding and large scale droughts are likely to be dominant loss factors; and due to increasing temperatures and dryness, wildfires are likely to become more common in many regions of the world.
- There is less certainty about the impact on windstorms, but direct physical consequences on large scale extra-tropical/tropical cyclones or winter storms seem less imminent. In fact the frequency in some areas could even become smaller. While the overall frequency of cyclones might not be significantly impacted, their potential maximum intensity is likely to increase (NOAA 2018) and storm paths may extend into higher latitudes than before. Due to the increased moisture it is also possible that cyclones could survive longer over land than currently and carry greater amounts of rain.

Tipping points are so dangerous because if you pass them, the climate is out of humanity's control: if an ice-sheet disintegrates and starts to slide into the ocean, there's nothing we can do about that.

Dr James Hansen, Climate Science, Awareness and Solutions Program, Earth Institute, Columbia University

1.3 Key physical tipping points

In the climate system, most of the feedback mechanisms are of a gradual nature while tipping points arise where a critical observable threshold is crossed indicating a change in state and that a specific point in the warming process has been crossed. In some cases tipping points trigger further warming or an acceleration, such as permafrost thawing. Therefore, monitoring tipping points is key to tracking climate risks and major step-changes.

Some feedback mechanisms are reversible (e.g. sea ice with warmer and cooler temperatures) on relatively short timeframes (50-100 years) whereas others are irreversible (e.g. carbon loss due to permafrost thawing). While in some cases, passing a tipping point could trigger abrupt, non-linear responses (e.g. Amazon rainforest changing to savanna or seasonally dry forest), others would lead to a more gradual response (e.g. large-scale loss of permafrost). There can be lags but also acceleration after passing a tipping point (e.g. ice sheet dynamics for Greenland or the Antarctica).

Sample physical tipping points

Examples of physical tipping points and their potential implications are as follows (Steffen, 2018 & WWF, 2009):

- **Reduction of northern hemisphere spring snow cover**, decreases the albedo effect and amplifies regional warming, as is already seen in higher latitudes
- **Arctic sea-ice loss**, linked to potential changes in thermohaline circulation (gulf stream and jet stream included) and rising sea levels
- **Greenland sea-ice loss**, linked to weather anomalies in North America and Europe with potential to change thermohaline circulation linked to the gulf stream
- **Ice sheet dynamics** (Greenland and West-Antarctica), raising sea levels over the long-term and potentially slowing down Atlantic thermohaline circulation
- **Permafrost thawing**, releasing CO_2 (under aerobic conditions) and/or methane (under anaerobic conditions). Note that IPCC have 'high confidence' permafrost will thaw and release carbon but 'low confidence' in how much will be emitted how soon
- **El Niño – Southern Oscillation (ENSO)** increasing and changing in amplitude, changing patterns of hurricanes, precipitation and drought
- **Collapsing marine ecosystems and dissolving coral reefs**, impacting fishing, biodiversity and coastal protection from storms or storm surges
- **Dying Boreal Forests and Amazon Rainforest** due to heat stress, reducing rainfall and wildfire, thereby reducing CO_2 uptake
- **Reduced West African Monsoon**, increased risk of drought and a greening of the Sahel
- **Interference in Indian Summer Monsoon**, increasing drought frequency
- **Prolonged S.W. North American droughts**, leading to desertification, as is already being experienced

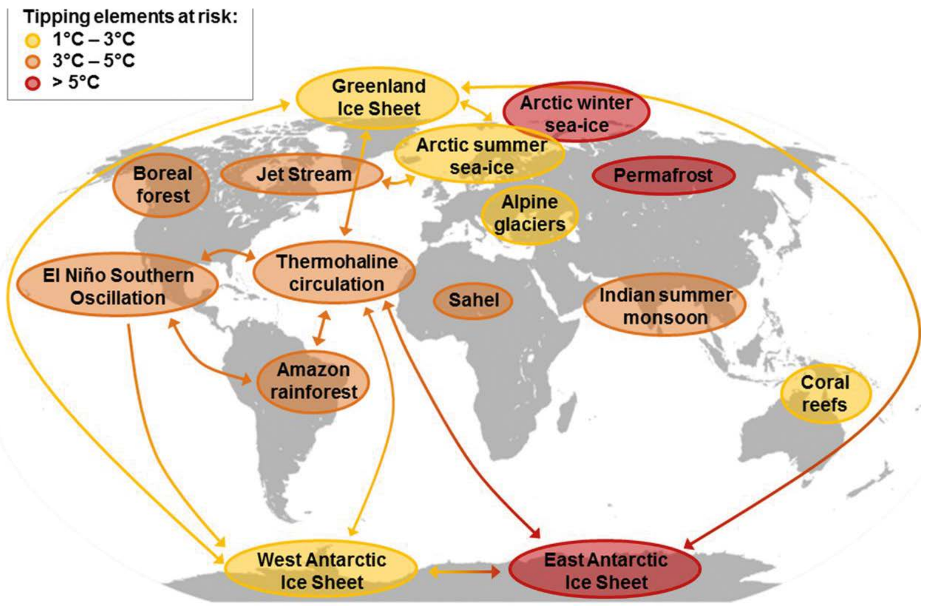


Figure 3 **Map of potential tipping points, colour-coded by global estimated mean temperature threshold, with arrows showing potential interaction cascades based on expert elicitation. NB: although the East Antarctic Ice Sheet risk is proposed at >5°C, some sectors may be vulnerable at lower temperatures (Steffen 2018).**

Methane hydrates not all about CO_2

Methane hydrate (or 'clathrate') consists of methane embedded in a crystal structure of water, with the water molecules completely surrounding the methane. In appearance it resembles wax or solid fuel tablets.

The methane is present in a highly compressed form. Under normal conditions, 1m³ of gas hydrate is equivalent to 164m³ of gas and 0.8m³ of water. Gas hydrate forms in cold water under pressure in sea-bed or lake-bed sediments. It is unstable at room temperature and the methane escapes. There are moves to try to extract the methane for use as a fuel.

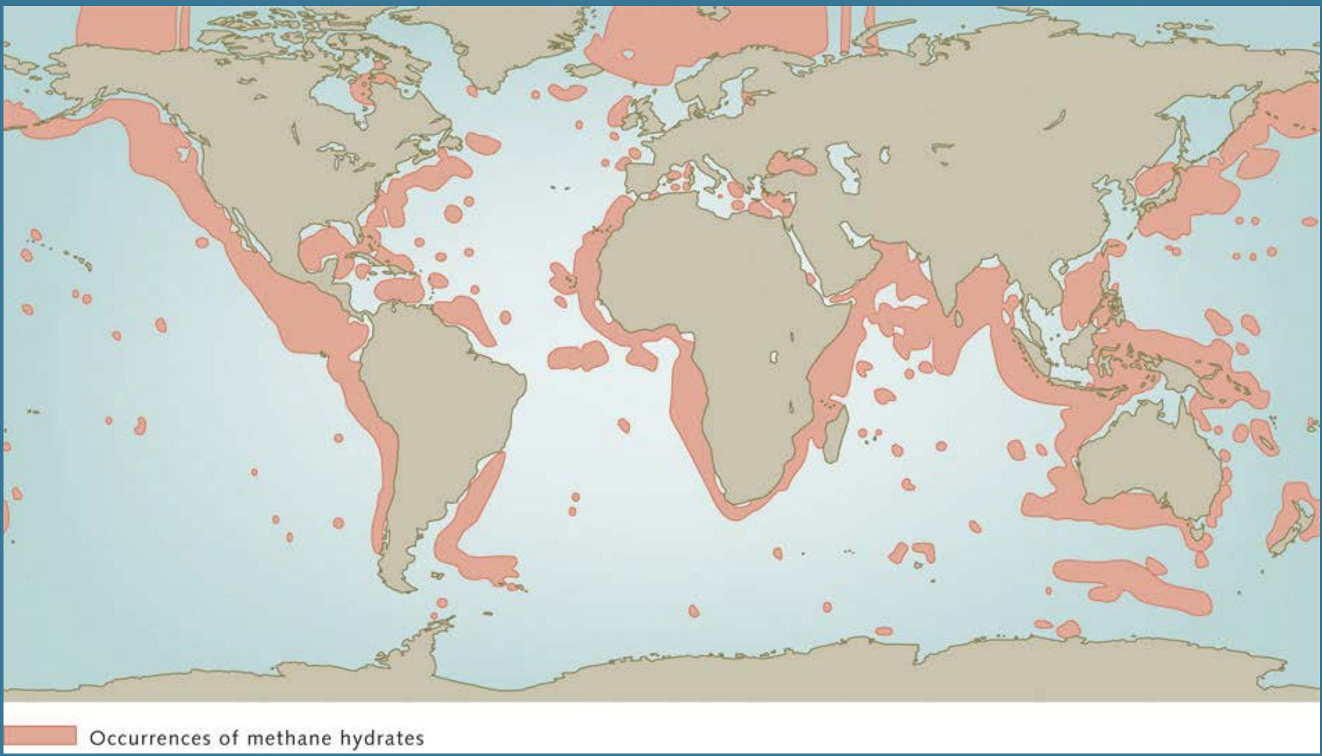
The environmental effects could be significant if methane is released during extraction, which given the technical complexities is possible. Methane is a greenhouse gas and about 60 times more dangerous than CO_2 per unit mass but it doesn't linger as long in the atmosphere. In 100 years following emission, methane has a warming effect 30 times greater than CO_2.

Over 60% of methane emissions are man-made through natural gas and petroleum industries, agriculture and human waste. Any increase in or appearance of new emission sources has significant ramifications.

By emitting just a little bit of methane, mankind is greatly accelerating the rate of climatic change.

Steve Hamburg, Environmental Defence Fund Chief Scientist

Figure 4 **Geographical distribution of methane hydrate deposits (World Ocean Review, 2017)**



1.4 Transition risk

Transition risk arises from attempting to avoid very significant and transformational long-term physical risks from climate change. Transition risk is likely to be a key source of near-term economic impacts, assuming enough action is taken to reduce emissions. However, there are also opportunities for insurers from transition risk through the need for new products and services, creating new or developing investment options.

The Bank of England defines transition risk as the risk of economic dislocation and financial loss associated with transitioning to a low carbon economy. This entails a wide range of policy, legal, technological and market changes intended to reduce emissions.

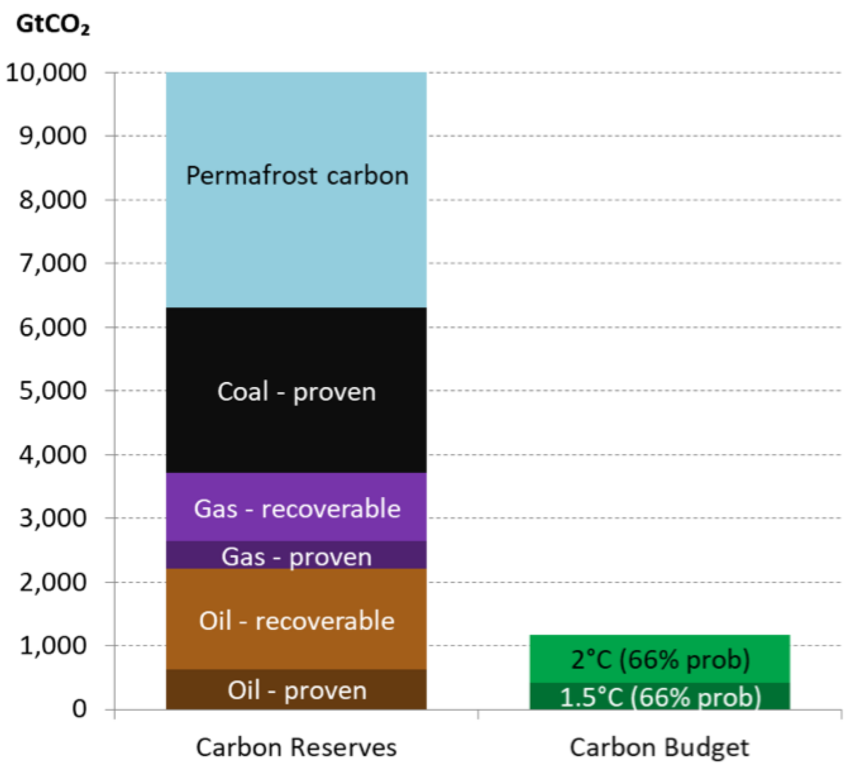
Impacts from transition risk could include:

- Fossil fuel businesses and infrastructure may lose value due to falling demand as a result of carbon pricing, or outright bans. Coal power plants in particular may be decommissioned early.
- Properties that are hard to insulate may lose value as regulations or expectations change.
- As social attitudes change, businesses may go into decline, e.g. carmakers that are slow to take a lead in electric vehicles, utility companies that fail to provide renewable fuel options or perhaps restaurant chains that are slow to introduce vegan alternatives.

The IPCC carbon budget for <2°C means 70-80% of proven fossil fuel reserves must be stranded – see figure 5 (unless expensive CCS is applied – see box on page 21). Worryingly, the IEA estimates that lifetime emissions from equipment already built and in use is alone expected to exceed the remaining carbon budget for <2°C, indicating that some of this equipment would need to be stranded early or modified to reduce its emissions, in order to meet the Paris targets.

Transition risk can best be managed by making the necessary policy changes in an open and coordinated way internationally, and by institutions making preparations in good time. The sectors and activities most exposed to transition risk are those that extract and produce fossil fuels and those that emit large volumes of GHGs.

Figure 5 **Carbon budget[1] vs carbon[2] reserves in the ground**



[1] Carbon budget as per SR15 including 100GtCO2 earth-system feedbacks and after c.50Gt emissions in 2018
[2] Proven carbon reserves per IEA. Probable reserves = proven x 3.5 (except assumed no new coal). Permafrost estimate per NSIDC.

1.5 Economic implications

Climate change directly and indirectly impacts economic outcomes, such as agricultural output, critical economic resources, manufacturing, energy production, transport and other services, as well as wider human welfare. These factors are likely to hamper economic development and contribute to inequality and poverty. Thus they are also likely to reduce ability to afford insurance, especially in developing countries, and negatively affect insurance penetration, to the detriment and lost opportunities for both customers and insurers.

Implications from physical risks

Moreover, recent research shows that the damage from higher warming scenarios will impact global GDP this century. Simply based on the observable data, global GDP could be 25-40% lower by 2100 in a >3°C scenario vs baseline.

However, when the risk associated with the compounding effects of large scale tipping points are included the NPV of damage rises eight fold. This being evaluated using a stochastic model containing a realistic range of policy decisions. The ultimate damage on the current trajectory towards 3.7°C is calculated as $550 trillion.[3]

Implications from transition risks

The benefit from acting now to minimise warming is to avoid the much greater cost that global warming brings in the long-term, as well as potentially saving lives and avoiding major hardship for many. However, that introduces risks associated with transition, although of a lower order of magnitude than physical risks.

One such implication is an economic drag on countries that are major fossil fuel extractors or major carbon emitters. However, there are also material opportunities for jobs and growth in many sectors as sustained investments are made into the low-carbon economy.

Rapid shift to a low-carbon economy is vital

The impacts of climate change have major economic repercussions. To date the overriding goal driving economic policy has been ongoing growth, which fuels consumption. But there is a feedback loop where that consumption, still based largely on fossil fuel, drives further climate change.

New or more nuanced economic principles will be necessary to achieve the sustainable global economy required. We do not believe we can rely heavily on negative emissions as a 'silver bullet', as outlined overleaf, and would caution against a human tendency towards optimism over realism.

One important economic question is how to design economic policies that are effective, and why actions successful at reducing emission from individual sources have not yet slowed emissions growth on an aggregate global scale. 'Balloon-squeezing', as this may be termed, is a complex matter. Counter-intuitively, efficiency gains appear to help drive growth and keep energy costs low, fuelling increasing consumption and therefore increasing emissions. This demonstrates the complexities ahead.

Any policy actions need to be appropriately calibrated and communicated. Without this, it could trigger a feeling of inequality or a sense of unfairness, leading to social unrest, nationalism/protectionism, climate litigation or even conflict.

[3] Some economic models show much more modest impacts from climate change, including those of 2018 Nobel laureate, William Nordhaus. Such results appear to be at odds with the IPCC and climate science, for reasons analysed by Nicholas Stern (Stern, 2013) and others. We have given more weight where these models have been adapted to take a broader view of risk such as allowing for damage from tipping points, extreme events and socio-political consequences of food crises, migration and conflict.

Negative emissions – "no silver bullet" (EASAC, 2018)

To meet the Paris targets, most IPCC scenarios[4] require not only major emissions cuts but also large-scale negative emissions, i.e. active removal of CO_2 from the atmosphere. Several technologies are proposed, which are mostly immature and face major drawbacks and challenges. The most cited are storage of CO_2 either from burning biomass for energy or captured directly from the air using chemical absorption machines.

To assume massive negative emissions is problematic as each technology has a drawback or limitation, although through continued research some may be overcome.

- The scale is vast, so requires huge capital investment, high running costs and competition with agriculture for land (except for direct air capture). This comes potentially when land value is at an increasing premium as climate change impacts food production and water security.
- The technology proposed is immature (apart from growing forest), so investment risk will be high until designs are refined and lifetime performance and costs are understood.
- Other complex factors arise: e.g. in the case of Bio-Energy CCS (BECCS) it is vulnerable to policy change, increasing water and energy costs, ecological risks, and the side-effects of warming, such as wildfires. Growing forest faces some of the same sustainability risks.

There is also significant risk associated with moral hazard, where the illusion of an easy way out clouds the urgency of emissions cuts.

The European Academies' Science Advisory Council published a report in 2018 which concludes negative emissions are not a credible option in the near term. "There are serious questions over whether any (separately or cumulatively) have the potential to deliver carbon removals at the gigatonne scale and rate of deployment envisaged as necessary in IPCC scenarios." They conclude that the first priorities should be to:

- reduce emissions;
- slow rapid deforestation; and
- develop CCS to be relevant and economically viable.

The 2018 Royal Society and Royal Academy of Engineering joint report reached a similar conclusion.

Comparison of Negative Emissions Technologies

	Maturity	Scale for 12Gt/yr CO_2 removal	Challenges
Growing forests	High	60% global arable land. Difficult on degraded land	Huge land use. Water needs. Vulnerable to logging, pests, fire, drought. Offset by reduced albedo, GHG emissions.
Manage land for CO_2 storage	Medium	N/a. Possibly 2Gt/yr for 10-20 years	Reach early saturation. Vulnerable to release from higher soil carbon respiration in warming climate.
BECCS (bio-energy + CCS)	Low	20-350% of global arable land	High cost. Huge land use, fertiliser. CO_2 'leakage' at various stages. Needs 'off the shelf' CCS. Up to 50% less efficient than fossil fuel energy + CCS.
Direct Air Capture (DACCS)	Low	Scalable subject to site availability and cost	Expensive. High energy and water needs. 1-10x more costly than point-source CCS of flue gas.
Chemical weathering	Speculative	3-10 billion tons/yr of powdered rock	Speculative. Major mining and logistics challenges. High costs. Ecological impacts.
Ocean iron fertilisation	Speculative	N/a. Max 3Gt/year	Huge ecological risks for small CO_2 removal potential.

[4] Among the AR5 models, 87% of sub-2°C scenarios include material negative emissions, and 100% of those that achieve 1.5°C.

2 Climate Change Scenarios

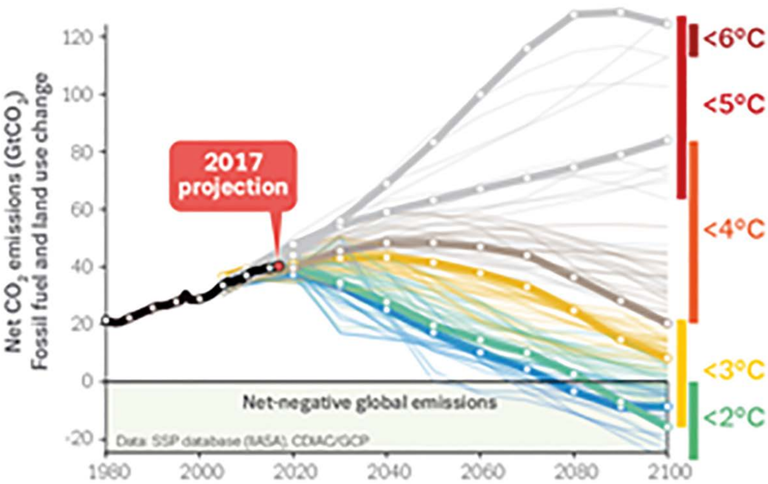
The use of models and scenarios is essential to understand future implications. Climate change progresses gradually and its effects may not be seen for decades. This chapter sets out the scenarios used to explore the range of possible outcomes in the rest of the paper. NB: these scenarios are not forecasts. As IPCC put it, “the goal of working with scenarios is not to predict the future, but to better understand uncertainties and alternative futures, in order to understand how robust different decisions or options may be”.

In order to project changes in global temperatures, the IPCC assessed different emission scenarios, called Representative Concentration Pathways (RCPs), which describe four sample paths for GHG emissions and atmospheric concentrations. They comprise an ambitious mitigation pathway (RCP2.6), limiting global warming to <2°C, two intermediate pathways (RCP4.5 and RCP6.0) and one very high emission ‘business as usual’ pathway (RCP8.5). These model pathways also include assumptions about the level of reforestation and further deforestation, and a steady decrease in aerosols due to action on smog. See appendix 1 for further details.

In the next 10-20 years, the physical effects are expected to be similar for all scenarios (see figure 2 above). This is because there are lags and inertia in the global system so short-term warming is largely driven by the increase in GHG concentrations that has already built up due to historical emissions. It is expected that extremes already being experienced, such as heat waves, droughts, increase in precipitations and their intensity, may become more pronounced and evident given emissions over the last decade or so. In the first 10-20 years, the main differences between these scenarios are policy choices and pace of transition.

In the longer term, i.e. from 2050 to 2100 and beyond, being on one emissions trajectory rather than another will produce quite different results in terms of physical risk. While this paper does not focus on longer-term developments in detail, it will consider the +5.2°C scenario to evaluate the scale of potential damage and to put the context around the actions needed today.

Figure 6 **CO_2 emissions ($GtCO_2$) – Fossil fuel & land use change**



Carbon Budget 2017 infographic, Global Carbon Project

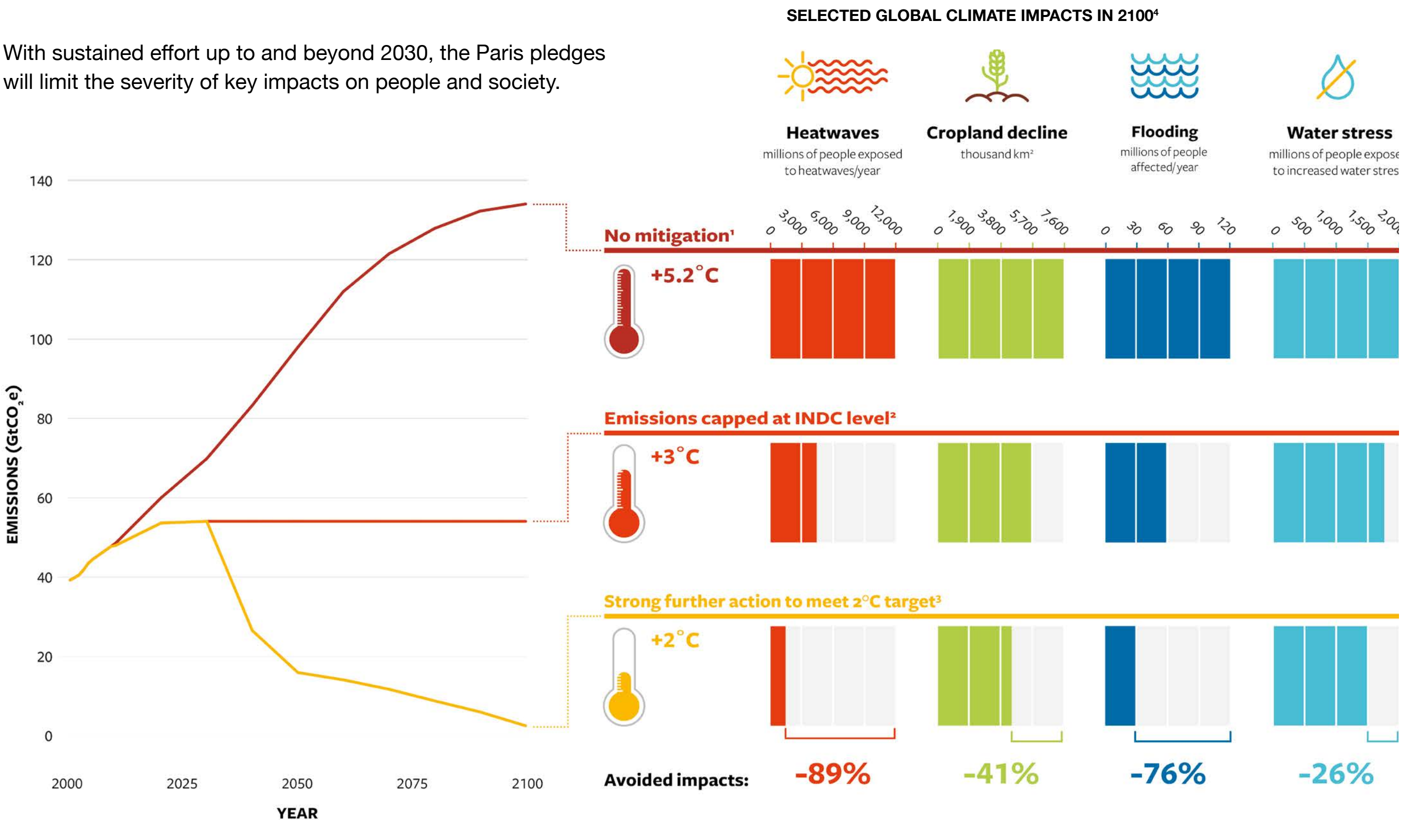
Selected scenarios

The paper will focus on **three broad scenarios**, based on temperature increase by 2100 relative to 1850-1900 baseline and linked to the IPCC's four RCPs. These are described in more detail in this chapter and are as follows. These are not forecasts but represent a reasonable synthesis of the science to provide guiding 'pathways'.

- The first corresponds to global warming of under +2°C, or 'Paris Targets Met – Steep Transition'
- The second assumes that global warming exceeds +3°C or 'More Severe Physical Impacts'
- The third corresponds to global warming reaching +5.2°C or 'Devastating Physical Impacts'.

The relative scale between the scenarios of some of the major human impacts is illustrated in Figure 7 below:

Figure 7 **Avoiding the impacts of dangerous climate change**



The scenarios used are:
1. No mitigation: RCP8.5
2. Emissions capped at INDC level: INDC pledgesto 2030 and no backtracking
3. Strong further action to meet 2°C target: INDC pledges to 2030, with further large reductions in greenhouse gas emissions to meet 2°C by 2100
4. Relative to a scenario with no climate change

The temperatures displayed here represent median values for each scenario. Water stress and cropland availability will also be affected by land use decisions e.g. concerning biofuels.

AVOID2 Can we avoid dangerous climate change?

2.1 Under 2°C scenario

(Paris targets met - steep transition)

This scenario can be associated with the IPCC's RCP2.6 that have following features or assumptions.

- In policy terms, it is closest to the Paris Agreement to contain warming to "well under 2°C" with the aim of achieving 1.5°C.
- Based on a rapid stabilisation and eventual reduction in the level of GHG's in the atmosphere after 2050.
- Median expected temperature increase by 2100 of 1.6°C, with a range of 1.0-2.8°C allowing for climate system uncertainties.
- Increase in sea level rise of 0.45m, with a range between 0.3m and 0.8m.

'Tipping points' that become likely by 2°C warming include:

- A profound impact on marine life and fisheries from rising ocean acidity, making it hard to form calcium-based shells or skeletons; total collapse of reef-building coral; very high risk to bivalves (mussels, clams, oysters etc.) and to fundamental food web species such as pteropods.
- The Greenland ice-cap enters gradual terminal decline (raising sea-level by 7m, over several centuries).

Physical risks

Physical risks arise within the scenario, which could lead to increased flooding, droughts, and severe convective storms. According to IPCC SR15:

- Heatwaves are likely to increase, particularly in mid-latitudes on land, with the increase in peak temperatures being 2-3 times higher than global average increase. The strongest change is found in Central and Eastern North America, Central and Southern Europe, the Mediterranean, Western and Central Asia, and Southern Africa. These regions all have a strong soil-moisture-temperature coupling leading to increased dryness.
- Climate change has substantially increased the probability of drought years in the Mediterranean (already seen) and in Southern Africa.
- Warming trends are likely to be partly offset in NW Europe by further 11% slowing of the Gulf Stream.
- Increased warming and drying are already linked to an almost doubling of the Western US wildfire area.
- Extreme downpours and fluvial flooding may increase in many areas. Robust increases in precipitation extremes can already be observed in mid-latitudes of the Northern Hemisphere. Hotspots for heavier downpours include high-latitude regions, as well as in Eastern Asia (including China and Japan) and in Eastern North America. At a European level, recent research models indicate that flood damage could increase in today's money from an average of €5 billion a year for 1976-2005 to €12 billion in a +2°C world.
- Tropical cyclones may be fewer overall, but the most powerful category 4-5 storms may be 16% more frequent.
- Heavy rainfall associated with tropical cyclones is likely to increase by 10-15% (already seen with Hurricane Harvey).
- Coastal flooding is likely to cost 0.3-5.0% of global GDP annually by 2100 with today's level of coastal protection.
- The Arctic Ocean is likely to be ice-free at least one summer in ten, opening it up for greater commercial use.

The effects on the global economy are likely to be significant. Some low lying and coastal communities would be impacted and require adaptation measures, particularly in developing nations, but widespread economic dislocation from physical impacts may be avoided. Nevertheless, a 13% net reduction in global GDP is forecast vs a no-increase scenario.

Figure 8 **Changes in annual daily maximum temperature relative to 1981–2010 at 2°C warming (Betts, 2018)**

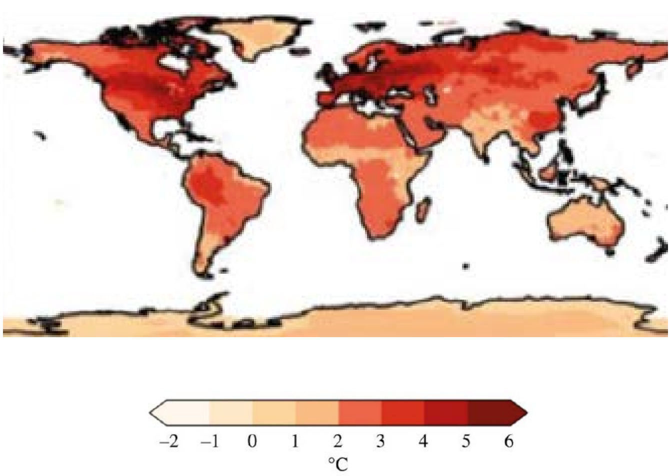
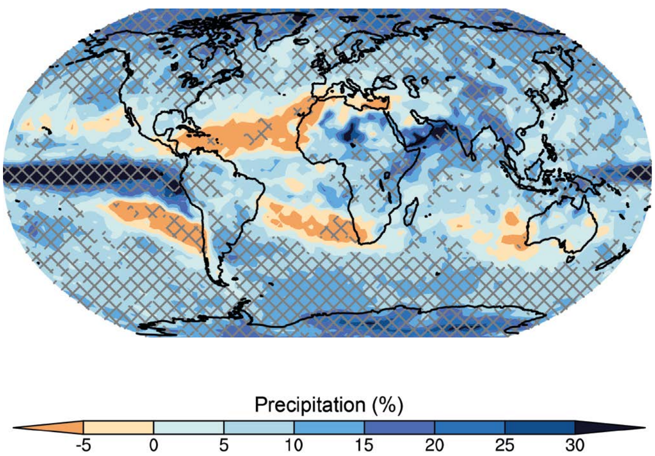


Figure 9 **Changes in extreme precipitation (Rx 5day) at 2°C GMST warming (IPCC SR15, 2018)**



Transition risks

To achieve the Paris targets, rapid action is vital to transform the world economy: over $1 trillion investment p.a. is needed (according to IPCC SR15) in order to transition to a low-carbon economy. This is comparable to aggregate global defence budgets (c.2% of GDP).

The unprecedented scale and duration compared with history can be appreciated from Figure 10 on the right.

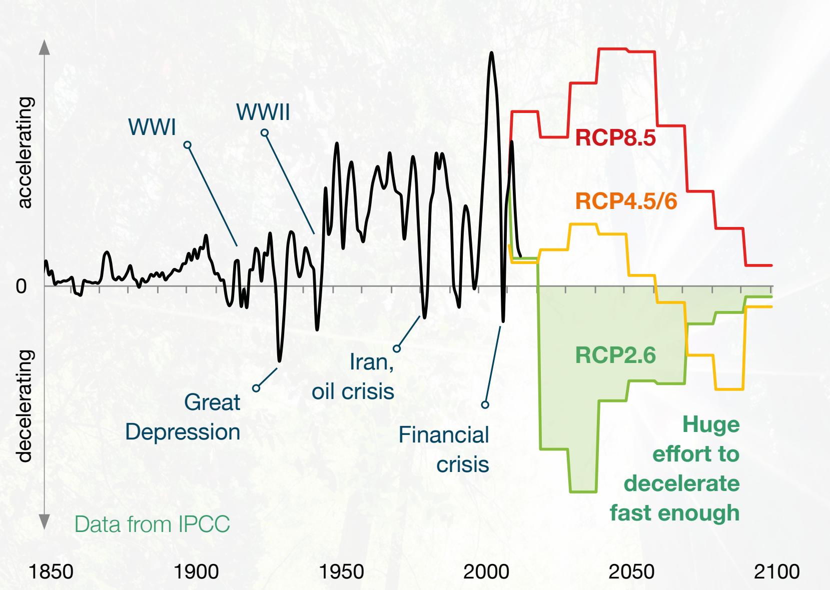
In RCP2.6 (the IPCC representative pathway to <2°C), steep reductions are forecast each year from 2021-2070, requiring an incremental effort to achieve further net reductions on top of those from the year before. Each annual reduction (initially c.1bn tonnes per year) is greater than occurred in any single year in the last 100 years including during the deepest recessions.

Encouragingly, transition at this pace is technically feasible. The policies and actions needed have been set out recently in detailed reports by leading economic thinktanks such as the Energy Transition Commission and New Climate Economy. These include how to tackle hard-to-abate sectors like heavy transport and industry.

If enough is done to curtail warming in line with this scenario then transition risk will arise due to the economic disruption likely due to the extent and pace of transition. To have a realistic expectation of achieving the under 2°C scenario, drastic policy measures are needed, such as:

- An agreed carbon price of up to $100 per tonne across all leading nations to incentivize rapid transition.
- A wide range of other policies, similar to those set out in the 2018 NCE report (see section 3.5).
- Stopping new fossil fuel development and redirecting subsidies to transition priorities.
- Rolling out CCS or forestation on a huge scale (see page 21).

Figure 10 **Annual change in CO_2 emissions over time**



The potential actions, as per the 2017 UN Emissions Gap Report, only account for around half the emissions reductions needed by 2030 to meet the Paris targets.

The speed and scale of reductions needed is visualised in Figures 11 and 12.

To close the gap, a range of tougher mitigation actions is set out in IPCC SR15 Chapter 4. Recently a similar list was set out in detail in the 2018 New Climate Economics report, including:

- Decarbonise electricity: growth of renewables, mothball coal and gas generators
- Decarbonise cars and heavy transport: electric buses, trucks, trains, ships
- Reduce air travel, promote car sharing or use of public transport
- Food: reduce waste at all stages promote concepts like 'farm to table', 'eat local', or vegan alternatives
- Heating: insulate buildings better and replace oil and gas boilers with renewable/electric
- Local / national planning for denser, car-less urban living
- Construction and industry: move to circular economy, re-use of materials, greener inputs
- Incentives including significant carbon pricing

Figure 11 **Annual global total greenhouse gas emissions ($GtCO_2e$)**

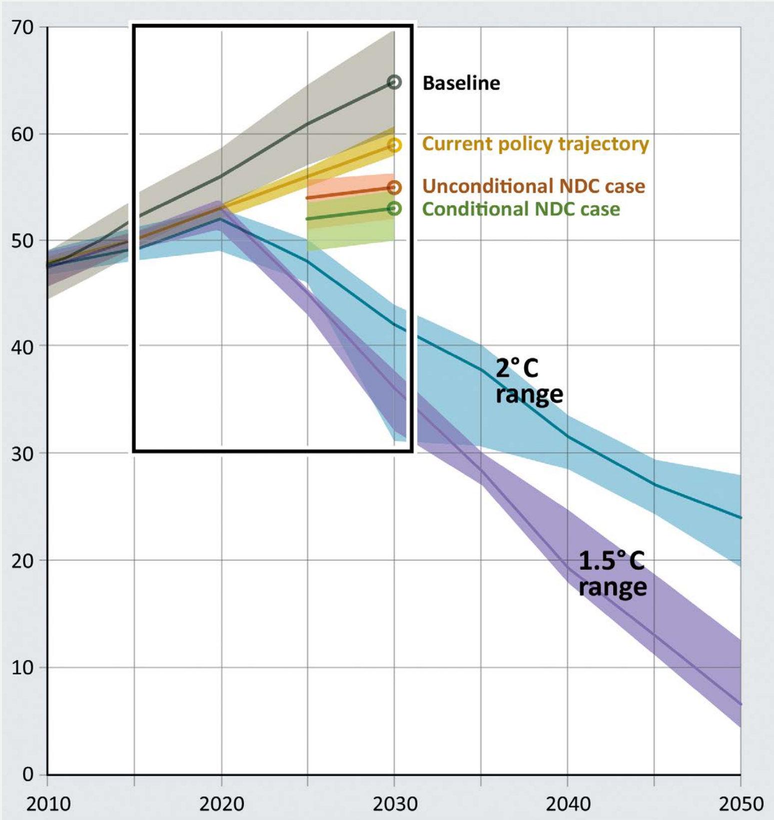
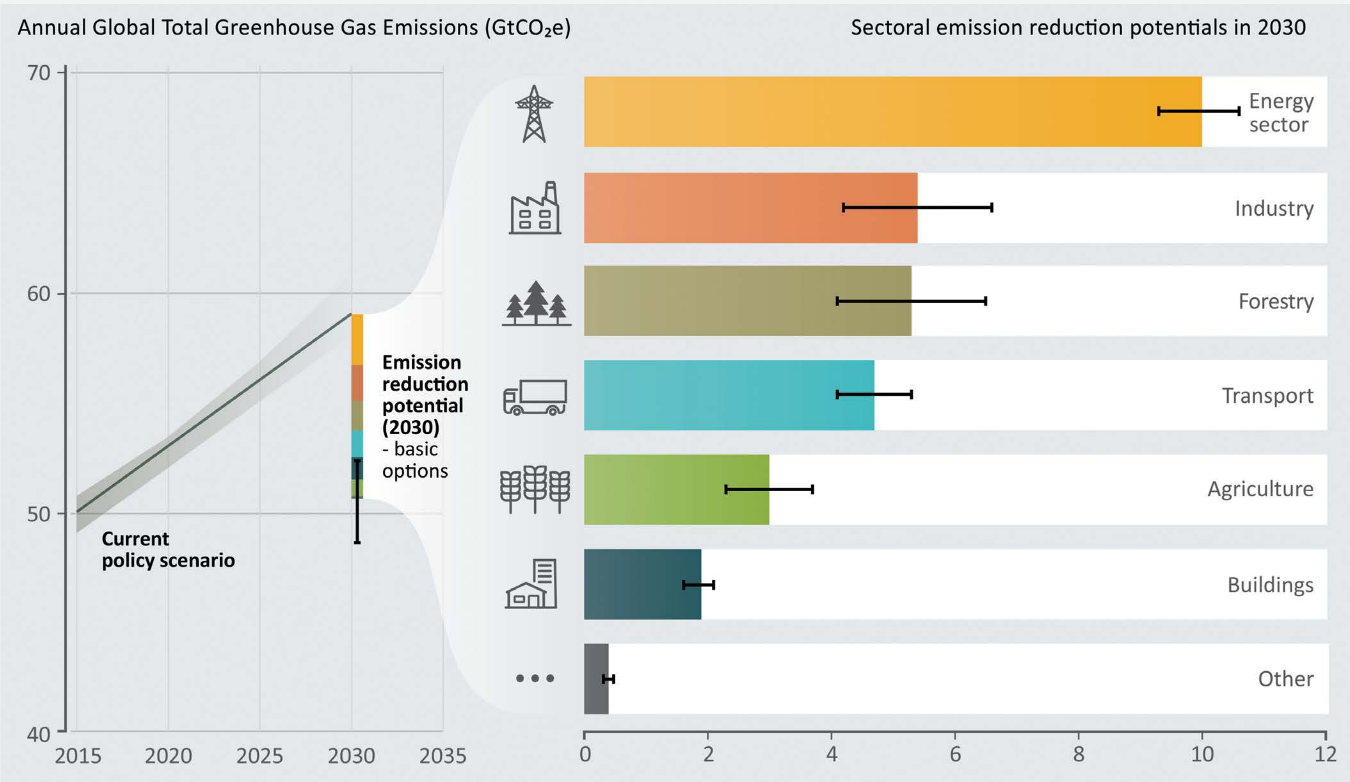


Figure 12 **Total emission reduction basic potentials compared to the current policy scenario in 2030**



Carbon capture & storage is the only hope for mankind.

Sir David King, Chief Scientist to UK Government

Carbon capture and storage (CCS) is a key technology but is developing far more slowly than expected. One example of an active project is Climeworks in Switzerland that have created a direct air capture system.

The main technical problems so far have been how to store the captured gas and the costs involved. In the case of reforestation and afforestation land use issues also arise.

In the absence of sound economics or incentives several CCS projects have been shelved, however the technology exists. Therefore, capturing carbon is a political and economic challenge not a technological one.

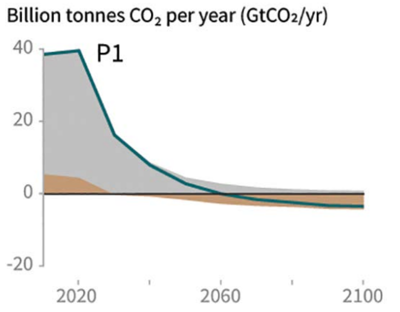
Most current projects capture CO_2 from natural gas fields rather than in flue gas from power plants. CCS is expensive to retrofit to existing plants, and 'cannibalises' up to 20% of output energy. Flue gas is typically c.10% CO_2. More efficient designs are proposed with CCS designed into new plants. Some burn fuel in pure oxygen, which improves efficiency and reduces the volume of flue-gas by around 75%. Once the water content is condensed out, it is mainly CO_2 which can be compressed and stored.

The scale of CCS required by 2050 to hit the Paris climate targets is equivalent to burying the total volume of liquid (oil, gas and water) handled today by the entire global oil industry. Total oil industry infrastructure is estimated at $30 trillion, so the order of magnitude of investment needed could be c.$1 trillion each year for the next 30 years. This is to install equipment for carbon capture, compression, pipelines to storage sites and underground injection.

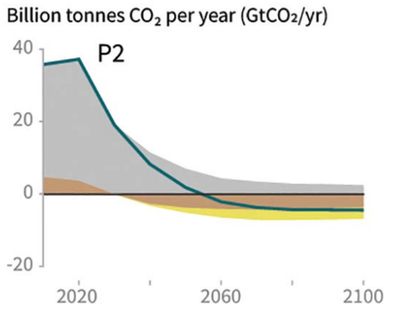
Alternatively, without CCS, countries with the highest emissions would need to cut them to zero within around 30 years, which is challenging.

Figure 13 **IPCC SR15 summary for policymakers**

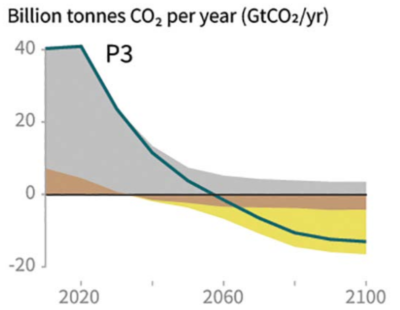
Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



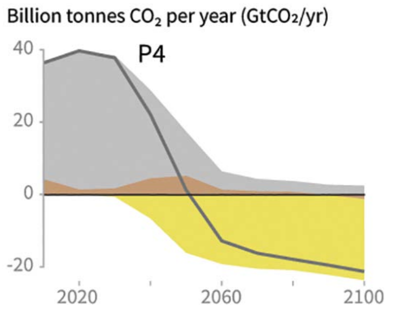
P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.



P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.



P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.



P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Fossil fuel and industry   AFOLU   BECCS

2.2 +3°C scenario

(More severe physical impacts)

This scenario corresponds to both IPCC's RCP 4.5 and RCP 6, as lower and higher bounds, and is close to the AVOID2, UK government funded research.

- It is marked by a stabilized flow of net emissions of GHGs into the atmosphere, resulting in a steady growth in GHG concentration levels.
- Median expected temperature increase by 2100 of 3.0, with a range of 1.5-5.8°C allowing for climate system uncertainties.
- Sea level rise, with a range between 0.4m and 0.9m.

It is roughly in line with current aspirations when considering country commitments to act, and appears increasingly as a base case. With it comes more severe physical damage and disruption than in the Low scenario. This scenario is broadly similar to the IEA WEO New Policies Scenario, at least until 2040, which assumes achieving and extending the latest policies as laid out in the Paris Agreement.

Physical risks

The physical risks are the same as for the 2°C scenario but with greater severity. For example, heatwaves could affect around three times as many people and farms as in the 2°C scenario, and flooding around twice as many. The 2°C tipping points become even more likely, and in addition above 3°C a number of models predict the loss of the Amazon rainforest (hotter and drier, not resilient to wildfires) and increasing desertification of the Mediterranean region. There is a growing risk at this point of accelerating warming, as a result of feedback effects from the release of natural carbon stores, either growing soil emissions or CO_2 and methane release from thawing permafrost. Passing this important 'tipping point' would have numerous consequences with direct impact on infrastructure in Alaska, Canada or Russia, plus landslides and rock fall in mountainous regions.

Extreme weather events (downpour, flood, windstorm, heatwave, drought, wildfire etc.) would lead to higher expenses tied to either the cost of damage and disruption, the reduction in value of exposed property, or the need to harden defences to reduce vulnerability to the events. Drought, heat stress and other weather extremes could degrade agricultural production in many regions. Some production may move together with its associated infrastructure. As well as price inflation, this could lead to food shortages with economic and political consequences arising from increased unrest, migration and conflict.

Sea level rise could lead to the eventual abandonment of low-lying coastal cities and economic regions. The most vulnerable include the Nile delta, Mekong delta, Bangladesh, parts of Florida as well as the well-known plight of certain small island states. For regions that can afford it, an alternative would be significantly increased costs in adaptation (e.g. building dykes, barriers and drainage solutions), with ever increasing maintenance costs given their critical dependency.

Diseases currently typical of tropical and equatorial areas may spread towards more temperate latitudes, requiring renewed research efforts and resulting in further strain to the national health systems. Agricultural diseases and pests may also migrate.

More severe physical impacts on investment performance may arise compared with the 2°C scenario. Emerging market assets (sovereign and corporate debt) are likely to be hardest hit. However, developed economies will not escape unscathed. The disruption to global trade and supply chains from climate change could erode corporate profits and physical damage from weather effects could weigh on economic performance. Public spending to restore and harden damaged infrastructure or to provide capital through pooling techniques could be a drag on government finances further restricting capacity for mitigation/adaptation projects.

Transition risks

Whilst the Physical Risks are greater the transition risks are reduced, although not avoided entirely. Some assets would still be stranded from the need to reduce emission and some carbon capture may be necessary. However, the major economic impact of substantially reducing consumption would not be as prominent. There will be some need to invest in adaptation and there is likely to be some social and political upheaval.

2.3 +5°C scenario

(Physically devastating)

This scenario may be linked to IPCC's RCP 8.5 and it is in line with current trends continuing. The scenario is close to the upper AVOID2 estimates.

- Continuous growth in GHG emissions throughout the century, accelerating further and then decelerating somewhat later in the century (see figure 10 above).
- Median expected temperature increase by 2100 of 4.5°C, with a range of 2.8-7.8°C allowing for climate system uncertainties.
- Sea level rise of a range between 0.5m and 1.7m.

The scenario is uncomfortably plausible, especially if the greatest contributors to GHG emission fail to respect their targets and no economic transformation were to occur. The current lack of clear climate policy continues to hamper the implementation of actions against climate change. It is important to factor in the role of 'growth' from growing populations, increasing consumption and increasing transportation/travel, which could all increase emissions despite significant efforts to reduce them, continuing the 'balloon squeezing' effect seen in recent decades.

Physical risks

In this scenario, the physical risks listed previously become more extreme, and natural protection and buffering e.g. by forests and wetlands will have been lost. In several regions, peak heatwaves are projected to be 10°C higher than current extremes.

It is estimated that 60% of global cropland may be degraded as soil moisture falls dramatically in many key regions (see figure 14), heat stress reduces yields from crops, and weather damage causes cumulative destruction. Widespread food and water shortages are likely (implied by many models), together with massive displacement of populations as large areas become uninhabitable due to flooding or drought.

The potential for reaching possible tipping points and runaway feedback effects would dramatically increase. Sea-level rise could accelerate to over 2 metres due to melting from destabilising areas of Arctic and Antarctic ice-caps or the occurrence of other tipping points. Eventual sea-level rise after many centuries may be 70 metres, transforming coast-lines and many land-masses.

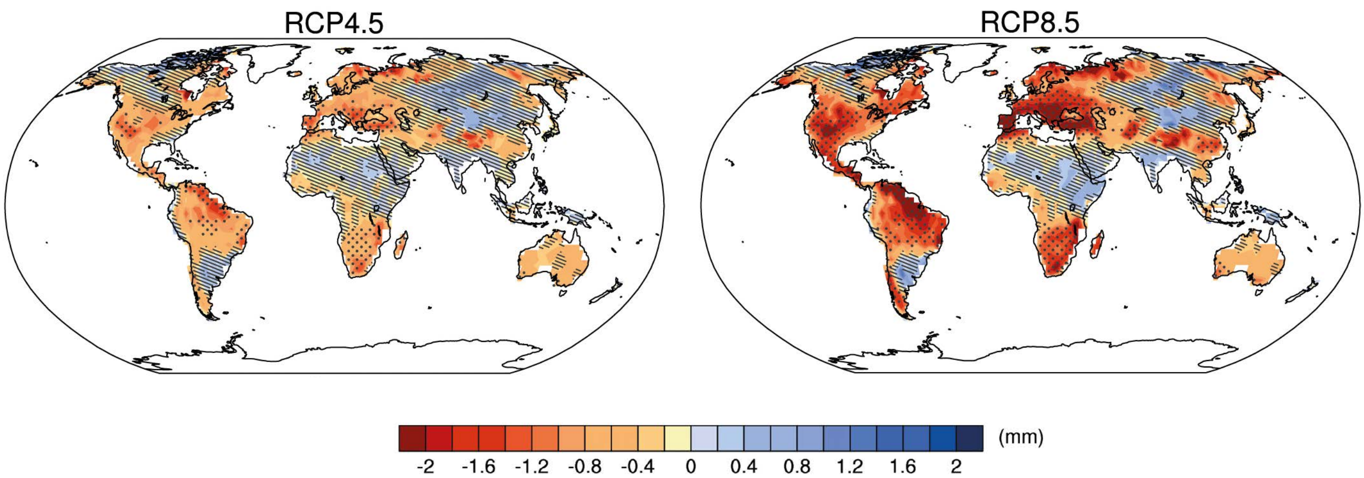
Social and political upheaval will be significant, as the global populations jostle for the shrinking habitable and productive lands. In this scenario, the consequences for investment performance are secondary to the potential collapse of sectors of the global economy and, conceivably, doubts over the ability of society to continue functioning.

Transition risks

Transition risk is largely avoided in this scenario in the medium term and investment will be focused on adapting to the changing planet. However, when the full effects of extreme climate change become obvious, stranding of assets may occur for the following reasons:

- Society may create a backlash against carbon emitting businesses resulting in assets being stranded even if too late to avoid the worst physical risks.
- In the longer term, human progress becomes unpredictable as the extremes of physical and social impacts play through.
- Stranded assets and disrupted business models would still arise in this scenario. As society struggles to adapt to climate change some areas, particularly those close to the equator, may be largely abandoned as environments become inhospitable.

Figure 14 **Annual near-surface soil moisture change 2081-2100 (IPCC AR5, 2014)**



3 Implications for Insurers and their Customers

> **Our sector will struggle to reduce this protection gap if our response is limited to avoiding, rather than managing, society's exposure to climate risk**
>
> Maurice Tulloch, Chairman of Global General Insurance at Aviva and previous Chair of ClimateWise

3.1 Insurability

Insurability is a key topic in a warming world with a chance of some risks or regions becoming uninsurable where premiums become unaffordable. Maintaining insurability could be challenged under the three different scenarios. Insurers' intention is to close the protection gap and good progress has been made in recent years. Schemes such as InsurResilience, initiated by G7, are designed to provide climate risk insurance to poorer countries, supported by the Insurance Development Forum. However, this may not be possible in the more extreme scenarios, which is likely to be led more by affordability than insurers' risk appetite.

Numerous factors will determine what is considered insurable so these must be understood in order to attempt to maintain continuation of cover in extreme circumstances or for high-risk areas. Government led pooling mechanisms may be key to locking in insurance for the high-risk areas or looking at other innovative ways of providing finance. However, the insurance industry needs to be cautious not to insure the truly uninsurable as this could impact resilience limiting the industry's ability to support the insurable.

Extreme weather risks have always been challenging for insurers and represent an accumulation risk that is a key driver of capital. This is particularly true for flood risk given that the majority of economic development has historically been in low-lying areas in flood-plains and on coasts where agriculture, infrastructure and trade is easier to develop and operate. Climate change, which is a global phenomenon, could have very different local consequences, and the way governments address these issues will significantly influence the context in which insurers operate and therefore insurability of the risks.

3.1.1 How is climate change challenging the insurability of risks?

For a risk to be insurable, the insurer must be able to meet the following conditions:

- Identify and quantify the frequency / severity of potential hazards and the resulting losses.
- Satisfy itself that the risks are unintended (no adverse selection) and unexpected (no moral hazard).
- Demonstrate it can pay potential losses while maintaining its solvency, partly by avoiding major risk accumulations.
- Offer a price that is acceptable to all stakeholders (insurers, reinsurers, policyholders, regulators).

Climate change is challenging many of these conditions:

Global trends and local uncertainties: The specific local impacts of current global warming trends are still hard to quantify. In extreme cases, this could challenge insurability as pricing depends on the assessment of risk. Existing climate models have limitations when it comes to assessing local trends (e.g. wildfire zones). Due to this and as a consequence of being unable to rely as much on historical data to predict future events, it will be key to invest in research that fosters innovation in data analytics and forward-looking models that identify trends in frequency and severity of extremes.

Affordability: In the context of changing climate, premiums may rise so high as to be uneconomic or unaffordable for the customer. Increased risk may translate into higher premiums or more restrictive terms and conditions, making an insurance product unattractive. A single event that changes the perception of a climate risk could disproportionately affect premium levels. Where there is an inability to properly model and price the risk, this can also mean that insurers decide to be more cautious, adding a risk margin to the premium (Silver 2014) or withdrawing capacity. The customer may underestimate the level of risk and consider the price to be excessive, rendering the risk uninsurable.

Threat to coverage availability: Mismatch of pricing expectations could prompt policymakers to limit the prices that can be charged to a level that is not sustainably profitable for insurers. They may exercise caution and refuse to underwrite risks in a given area. Examples have already been seen of weather-related risks becoming unaffordable or unavailable as follows.

- 2002 German floods (€9bn cost to public funds): risk reassessment by insurers led to an increase in premiums of up to 50%, and a reduction in areas where flood insurance was offered of 10-20%.

- 2005 Hurricane Katrina (insured loss >$100 billion): the availability of insurance fell following Katrina and other events in 2004-2005.

Imperfect information: Exposure to natural hazards is public information, but high-quality maps of changing perils, such as flash flood and wildfire, do not exist as yet or are proprietary. Additionally, some decision makers (e.g. real estate companies and local governments) continue knowingly to develop uninsurable areas for short term profit. It can be considered as a moral hazard, as they know homeowner insurance remains available under certain national regimes.

Risks of accumulation: The current global diversification of risks may be threatened if climate change increases the correlation between different physical risks. Accumulation could also occur in highly exposed regions and across Lines of Business. Physical risks of climate change will mostly have implications for property insurance, but liability risks could also arise, if there is growth in related litigation actions.

Solvency: Climate change may gradually change the risk profile for insurers and reinsurers, with stronger impacts and accumulations. This has potential solvency implications. Reinsurance is a key tool Property & Casualty (P&C) insurers use to manage their solvency. Currently, property insurance policies renew annually; this frequency of repricing is fundamental to the sustainability of the insurance market.

3.1.2 Insurability under different climate scenarios

The insurability challenges noted above will manifest differently for the various scenarios.

In the moderate warming scenario (2°C), the horizon of insurability may expand with the development of new industries with insurance needs (e.g. renewable energy, carbon capture and storage), and new types of operations becoming viable (e.g. drilling, shipping in the Arctic region). Insuring risks in some regions more affected by climate change may become difficult, and it will depend on the insurer's willingness to accept higher risks. Demand for insurance may grow in places as the increased uncertainty demonstrates the value of insurance. Regions most at threat are those already experiencing flooding, wildfires, and coastal surge threats. They are likely to get worse and the size of the area at risk is likely to grow. Low lying and coastal areas are considered most at risk.

Preventive and adaptive measures should be able to keep the overall risk at an affordable level for most perils in developed insurance markets. In regions with already high-risk levels, more risk participation of the insured might be required, either through investment in higher protection standards or by higher risk retentions.

The 3°C scenario creates real insurability challenges and could therefore challenge the sector. However, insurance will continue to be an important product. By actively monitoring developments caused by climate change and managing their risk portfolio, insurers will be able to adapt to new conditions. Some types of climate risks may become effectively uninsurable in highly exposed regions. Property insurance may become increasingly unaffordable in flood-prone areas and some regions may only be insurable with very high self-retentions on customer side due to high frequency of large loss events. Governments may get more involved, trying to find solutions in the private insurance sector or by resorting to self-insurance and mutualising risks.

In a +5°C degree world, insurance activity may remain in the regions where there continues to be economic activity. However, the intense warming and destruction of ecosystems, infrastructure and agriculture in some regions means economic activity may be significantly impaired.

3.1.3 Factors determining insurability

In practice insurability is not a fixed concept. For each risk, the boundary of insurability may not remain the same forever and may vary from one company to another. Some insurance companies may decide not to insure a risk that could be insurable, based on economic, strategic, reputational or ethical considerations.

The role of public administration is also critical and insurers should maintain dialogue, as per the following, helping to foster a culture of mitigation, adaptation and resilience.

- Governments' risk management strategies can positively impact insurability, e.g. building codes, land-use planning, flood-hazard zone regulations.
- The development of a "governmental backstop" for insurance claims related to climate change impacts, similar to the US Terrorism Risk Insurance Act, is another option and can improve loss sharing between the private and public sector.
- For some climate risks, such as flood, national governments can act as "last resort" insurers. However, this role could be challenged due to the growing uncertainty caused by climate change.

Pooling mechanisms: UK Flood Re vs other pooling approaches

Flood Re was established by UK insurers as part of a long-term deal with the UK government. It includes a number of features designed to incentivise disaster risk reduction (Mcaneney 2015):

- It applies only to homes built up to 2008 so as not to encourage new building in flood zones. It is available to cover the 2% of homes that are highest risk.
- The industry supported Flood Re in return for further government commitments to fund flood defences
- Flood Re was established with a finite 25-year life to allow market forces to encourage risk reduction as the scheme matures.
- On the other hand, there is little incentive to retrofit older properties to be resilient until the return of appropriate risk pricing when Flood Re is phased out.

One of the first multi-country risk pool mechanisms specifically for climate-related natural catastrophes such as tropical cyclones and excess rainfall is the Caribbean Catastrophe Risk Insurance Facility (CCRIF). It was set up in 2007 by 16 regional governments under the technical guidance of the World Bank and strongly supported by the insurance industry. Its objective is to provide governments quick access to emergency funding by using parametric policies that are automatically triggered according to the physical characteristics of an event. Such risk pools have proven to significantly increase the resilience of countries exposed to climate-related natural catastrophes.

In the Netherlands, the national government takes direct responsibility for the defences, including dykes.

In the US, the National Flood Insurance Program (NFIP) was set up in 1968 to cover river flood and storm surge. A range of state-based pools for hurricane, earthquake and other perils were also set up in the aftermath of other disasters to ensure ongoing availability of catastrophe cover when insurers have stated their intention to withdraw from these markets.

- Most of these schemes originally aimed simply to provide subsidised, affordable cover, with no risk pricing, which promoted construction in flood-prone areas.
- A number of these schemes have incentivised risk reduction in other ways, e.g. the TWIA in Texas has played a leading role in ensuring stronger building standards and a certification regime for weather-proofing that has now become standard.
- More recently, the NFIP aims at putting (Swiss Re 2018) the programme on a more sustainable financial path. Along with the establishment of a reserve fund, its strategy includes the creation of a reinsurance programme with partners from the private sector.

In France, bundled flood insurance is backed by the State through the Caisse Centrale de Réassurance. Cover is mandatory and included in property cover and flat rate additional premium is collected by direct insurers. A proportion of the premium is passed to the pool depending on the percentage of risk the direct insurer accepts or reinsures privately. However, there is no premium incentive for mitigation or disincentive for the construction of property at high risk, weakening sustainability.

3.2 P&C underwriting

For P&C, climate change will predominantly impact Property (including Specialty Lines) and Motor, and less prominently Liability (including tort or negligence claims and D&O).

The focus is often on catastrophic events. However, one of the most significant effects of a warmer atmosphere is likely to be an increased frequency of moderate to severe events that may constantly erode profitability if not adequately reflected in pricing. What we now call "normal" seasonal weather could happen less often as it will gradually be replaced by hot and dry seasons or extreme wet seasons.

This section explores how insurers should consider both physical and transition risks potentially by adjusting their underwriting under various scenarios and consider changing product needs.

3.2.1 How is P&C underwriting affected?

The most prominent impacts are likely to occur in Property, Specialty Lines and Motor, due to their direct physical exposure to weather. More indirect impacts will come via Liability, mainly due to likely shifts in legislation and legal norms as social attitudes gradually shift. New products or new lines of business might also develop to meet the needs created by climate change and the opportunities arising in mitigation or adaptation.

Historically, physical damage to property and related business interruption clearly dominated the claims costs in the P&C segment, especially from natural catastrophes. The high volatility caused by catastrophic events also led to significant capital requirements under the Solvency II regime with over 85% of natural catastrophe losses being weather related and therefore potentially exposed to a warming climate.

Forecasting future weather event distribution under global warming is not possible today with sufficient local accuracy. Climate models enable insurers to reproduce current weather phenomena but can only be used at a general level to model forthcoming events due to climate change (Golnaraghi, Nov 18).

Nevertheless, the P&C annual insurance renewal cycle allows for gradual adaptation of products, pricing and underwriting rules to reflect the changing realities. In parallel externally available or internally-developed models are continuously and pro-actively upgraded, which contributes to the understanding of climate change effects.

One consequence for insurers to be aware of is that changing social attitudes are a typical trigger for liability risks. A shift in the public mood around climate might encourage climate-related liability actions. Organisations may be accused of contributing to man-made climate change by failing to reduce emissions, to adapt to climate change, or to disclose risk insights transparently. Demonstrating direct attribution for climate change to the emitter and climate change to a particular weather loss will always be challenging. Although the science of attribution by changing likelihoods is developing fast.

3.2.2 How to prepare underwriting

Physical risks

Underwriting strategy focuses on the understanding of risk. When underwriting Natural Catastrophe cover, some elements are crucial to this understanding:

- Knowledge of risk location
- Nature of the risk (building, contents)
- Interconnection between risks through portfolio management (including interconnected risks and supply chains)

Understanding the local risk situation of any insured risk will become a precious asset and prudent underwriting will become ever more important.

In order to reduce the capital intensity of a property portfolio requires active management and steering of the portfolio to avoid high accumulations of risk in hazardous areas. Geographical diversification is also key to this. However, due to the changing risk landscape, opportunities to diversify might be limited in some local markets. Overall the insurance industry can react very flexibly to changing risk trends by risk-adjusted pricing. This will ensure sufficient insurance capacity as long as warming and loss trends are kept in a moderate range and are used to inform models.

Increasingly focus will need to be on loss prevention and adaptation in order to mitigate the physical impacts. Underwriters need to become more selective on the risk quality and actuaries will have to account for preventive measures more explicitly.

The more physical risks materialise, the more prevention will extend from large scale protection schemes (e.g. flood barriers and dams) to individual adaptation measures (adequate water proof materials, less vulnerable ways of construction). This could mean insurance companies requiring additional certifications and surveys carried out by engineers for smaller commercial risks than is performed today and maybe even for private households. Insurers will almost certainly leverage additional data, coming from new untapped sources, to better understand the risks.

In the agricultural insurance segment, similar risk management principles apply. Certain fruits and crops are vulnerable to diseases arising in the years of increased heat stress; mean while in years of flooding or prolonged wet weather, losses may arise due to direct damage and fungal diseases. Risk managers would have to identify disease resistant crops and focus on the farmers' risk management capabilities as industrial property underwriters do today.

As trends accelerate, in the more severe climate projections, pricing may need to rely on more forward-looking components alongside loss history and risk modelling.

Not only intensity and frequency of events might change but also the regions where they occur. Other perils might become relevant and others might have less relevance. This is why the annual renewal of contracts and permanently refined models are key to ensure limited mismatch between climate change effects and the way they are taken into consideration when underwriting.

Actuaries will have to consider that their claims data may not necessarily contain all trends. Catastrophe modellers and actuaries will have to continue collaborations to determine the "best estimate" view of future Natural Catastrophe events in order to build forward-looking pricing models.

Research and development

Insurance firms, therefore, need to continue to actively develop modelling for new perils stemming from climate change in different regions as well as economic factors such as value concentration due to urbanisation. They will need to refine existing models, and maintain solid, permanent research and development. This will allow better understanding of the changing risk landscape and related products. Firms will need to anticipate regulatory changes, monitor their business strategy for wanted and unwanted risks or segments, and do so in line with their risk appetite. The timing of technological development and deployment as well as related market prices will remain a key factor of uncertainty.

This also implies that organisations need to become more agile in their responses to a changing customer base, changing perceptions of risk and changes in regulatory framework.

Transition risks

Transition risks also impact underwriting in several ways. The changing social and regulatory environment could lead to a strategic risk due to the contraction of certain market sectors (especially for stranded assets) and thus shrinking demand for insurance or increased reputational risks when insuring these sectors. This mainly impacts segments with a high carbon footprint. Underwriting operations will have to expect pressure from NGOs and need to put prudent acceptance rules in place to enforce ESG criteria. This is a particular risk for mono-line and specialty insurers where their sectors shrink or disappear.

There will also be winners. New regulations or customer behaviours could lead to a boom in certain segments accompanied by rapidly growing exposures and demand. As an example new renewable energy production methods, battery production, rare earth mining, or new technologies, such as CCS facilities.

The technological transition to a low carbon economy can pose new risks for the insurance sector. The industry needs to adapt to insuring emerging technologies which by definition have no or very limited loss histories. An example could be hybrid electric ships, or large cargo ships fitted with auxiliary sails. Therefore, it might be initially challenging to price these emerging technologies accurately. Furthermore, while traditional technologies have an extensive loss history, they might be increasingly exposed to market shifts regarding supply and demand for certain commodities, products and services.

Another transition risk that could materialise is climate change litigation, which would impact liability insurance. This would require a clear scientific link attributing such events to climate pollutants and their emitters.

3.2.3 Impact of various scenarios

Scenario <2°C

To achieve this scenario either the entire energy production of the world would need to become carbon free within 30 years, or CO_2 needs to be actively taken out of the atmosphere and sequestered in the oceans or underground storage. It requires rapid implementation of new technologies to achieve either option.

Therefore transition risk is the dominant risk insurers face in this scenario.

Necessary actions ultimately lead to fast devaluation of carbon intensive assets. On the other side there will also be many winning enterprises, such as alternative energy companies, fuel cell producers, insulation suppliers and fitters etc., as well as their supply chains.

The negative impacts are likely to be relatively manageable for the insurance industry as a whole. However, a study by Federation Francaise de l'Assurance suggests claims costs in France could double by 2040 with climate change accounting for a third of the increase (l'Assurance 2016). So whilst the physical risk should be manageable within these timescales, firms still need to actively monitor and manage developments. It may even create opportunities for those firms who are most effective at doing so and best able to cope with increased loss frequency and severities.

Contrary to long term business, most property lines are annually renewed and re-priced. This allows insurers to cope with the expected loss trends and keep sufficient insurance capacity. For active risk managers there would even be opportunities driven by increased risk awareness and subsequent higher demands. The risk-return profile may differ among markets depending on their maturity and regulatory frameworks.

Preventive and adaptive measures should be able to keep the overall risk at an affordable level in all developed insurance markets. In regions with already high risk levels, more risk participation of the insured might be required, either through investment in higher protection standards or by higher risk retentions.

As more and more governments suffer from more frequent large loss events, impacting economic growth and state budgets, they will also see the benefits of a functioning global insurance market. We expect more insurance markets being created or opened for international business. This creates new opportunities to diversify geographically.
Where insurers are not actively providing enough cover to serve the increased needs of established markets, governments may decide to take action like imposing mandatory insurance schemes or creating local risk pools.

One way to cope with a moderate warming scenario will be to accept higher overall risk levels and volatility and actively strive to increase insurance penetration for natural perils in all markets. This helps to generate premium income streams from additional regions and perils in order to better diversify risks and make it easier to absorb losses.

This will increase demand for risk data and analytics so insurers would need to prepare themselves for a fight for talent for skilled loss control engineers, geospatial data analytics and portfolio managers, natural scientists, modellers and actuaries.

It may require new products that better serve the customers' requirements, although these may change as different perils dominate in different markets.

Overall, customers' needs for the insurance sector could grow and the risks would be manageable (as long as no tipping points are activated). Continually refined modelling, prudent underwriting and active portfolio management will be required to secure solvency and enable affordable premium. Globally diversified insurers may have an advantage, however, reinsurance capacity should be sufficient to absorb local shock events and keep local insurers in business. Carbon intensive businesses may struggle to get insurance cover or vanish entirely (in a scenario when transition risk is in any case very high), whilst transition risk will create new opportunities.

Scenario +3°C
Within the first 10 or 20 years there will be no significant difference compared to the moderate 2°C warming scenario. There should, however, be less pressure to change economies from a governmental and regulatory point of view, thus reducing transition risks in the earlier part of the path.

However, in the second half of the pathway towards 3°C, the full extent of the physical risks described in the proceeding sections will start to materialise. Insurance may become unaffordable or at least unattractive for highly exposed regions. Some regions may only be insurable with very high self-retentions on the customer side due to high frequency of large loss events. As a consequence of these developments market reaction and government responses are likely to be more dramatic in part forced by the recognition of historical inactions. Carbon intensive industries may experience litigation and this could have an impact on liability insurance.

As climatic events become more severe they may move outside "normal" volatility compared to pre-industrial levels and even today´s climate. Policy makers, and potentially individuals, may seek someone to blame and additional sources of capital to fund responses resulting in legislative or regulatory actions. Such a scenario would be more likely in developed economies.

For countries in tropical and subtropical latitudes the frequency of catastrophic events may become too high for a functioning and efficient insurance market to cover flood, drought and wildfire. These governments may see no other way than to mutualise risks and create state-run schemes for such perils. As more and more local insurance companies struggle with capital shortage and high losses, there could be moves to consolidate or pool risks with heavy cross subsidisation of high-risk portions of the population. The trend towards risk pools will need capital that may boost traditional and alternative reinsurance markets. In addition, companies could offer risk prevention services.

In all developed insurance markets the demand for insurance is likely to grow to unprecedented levels driven by frequent large scale loss events. This demand, however, may mean the industry suffers substantial losses and reaches the limits of risk appetite in certain perils and locations. Smaller local players might be overwhelmed by catastrophe events and face a capital shortage.

Retrofitting and resilient construction may become a dominant risk factor in building insurance and could even be a precondition to obtain cover in high risk areas.

Scenario +5°C
As many regions in the tropical and subtropical zone become uninhabitable, either due to extreme high temperatures, water stress and/or agricultural failure, or insurability issues will give way to basic considerations of survival.

If the world reaches +5°C, this may lead to widespread famine due to crop failures and potentially mass migration to higher latitude countries where climate allows survival. Agricultural food production could be severely reduced and shortage of fresh water supply will impact industry and populations alike.

The social and political consequences could significantly deplete the economic strength of societies globally so, for many, insurance may become a thing of the past. Governments may struggle financially impacting their ability to support catastrophe pools or other insurance type activity, or to fund catastrophe responses. This could lead to mutualisaiton of P&C insurance lines so as to gain access to capital reserves, or result in closure of pooling schemes. This would put greater pressure on the insurance industry.

That said, there would likely remain a space for private insurance solutions. As new territories become inhabitable, new insurance markets will be created. Nordic countries, Greenland, Alaska, Siberia and parts of Canada and Antarctica may become the sites for new developments. Currently only 1% of Antarctica is free of ice, this share will grow when warming reaches +5°C.

Insurance will survive as an industry. As discussed above the Northern countries may require insurance. However, in the developed insurance markets of the mid-latitude countries, such as Europe, US, Australia and large parts of Asia, property insurance may become a less attractive line of business. Weather events such as the pan-European hydrological event of 1342 may become relatively "normal" extreme event, interrupted by droughts that can last for several years (like in California from 2011-2017) As a result, the required impact on pricing may make insurance an expensive commodity available only to the wealthier in society and levels or type of cover may become reduced. Pricing could also be impacted by the reduced diversification options due to a reduced number of active markets and insurance classes.

It is not just in the interest of insurance to avoid such excessive warming. It is of fundamental interest to all.

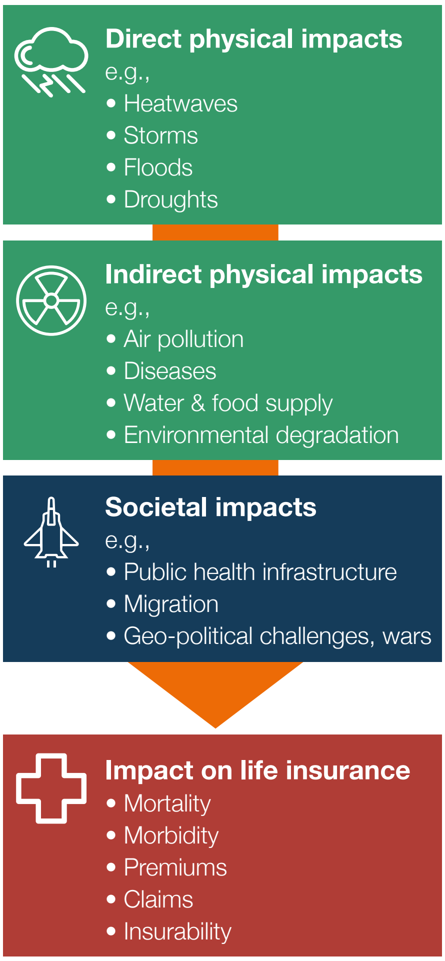
3.3 Life underwriting

3.3.1 How life insurers are exposed to climate change

Life insurance companies are exposed to climate change both in their in-force as well as in their new business. Climate change-related increases in mortality or morbidity rates could lead to adverse claims experience. Also climate change-related deterioration of macroeconomic conditions could hamper sales of life and health insurance.

In addition, life insurance companies invest in long-term assets, matching their investments to the maturity of their policies, e.g. to cover future pension claims. This makes them especially exposed to climate change on the asset side (Covington 2014). The exposure regarding investments by life insurance companies is discussed further in section 4.1.

Figure 15 **Life insurance exposure to climate change**



3.3.2 Impact on mortality and morbidity

There are obvious direct effects of climate change, such as heatwaves, which have a quantifiable, albeit difficult to predict impact on mortality and morbidity. This could impact mental health, including a rise in suicides as some predict, and an overall shift in the main causes of death. Heat and cold related mortality in the US are already a larger driver of deaths than natural catastrophe events.

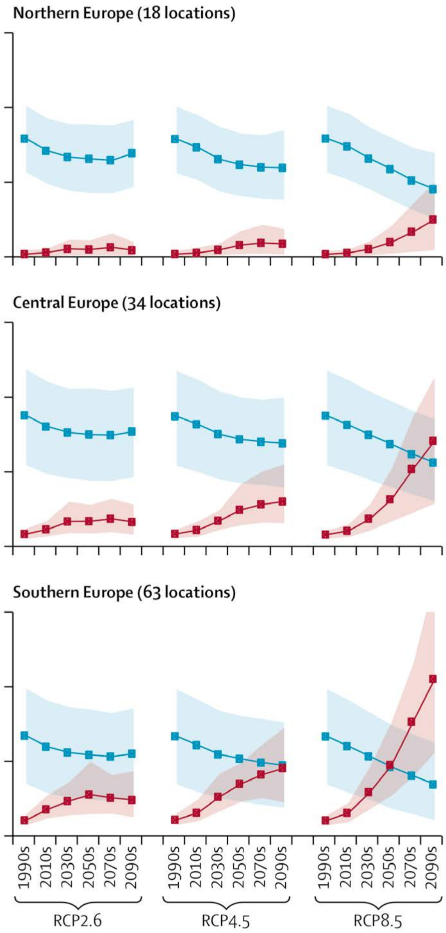
In addition, there are indirect threats such as poor air and water quality, irresponsible land use and extreme ecological changes including loss of biodiversity (Smith 2011), food insecurity and undernutrition, the spread of disease vectors, displacement and migration. These direct and indirect factors ultimately put an increasing strain on public health systems, social capital and infrastructure, which could conceivably lead to social unrest and political conflict.

Various studies show that health and prosperity are strongly correlated. The level of vulnerability of a specific region or country and population can in fact be defined by the four main indicators, namely population density, population age, GDP per capita and level of education (Kennedy 1997, Kawachi 2000). The lack of a well-functioning health care systems, or low purchasing power in general, may amplify the impacts of climate change.

Some early studies have made links between climate change and mortality, as articulated in the Countdown publications of the Lancet, who state, “by undermining the social and environmental determinants that underpin good health, climate change exacerbates social, economic, and demographic inequalities, with the impacts eventually felt by all populations.” (Gasparrini 2017) The charts given show excess mortality in the various IPCC scenarios.

In terms of extreme catastrophe events, the occurrence of pandemics as well as

Figure 16 **Excess mortality by decade attributed to heat and cold, under 3 climate change scenarios (Gasparrini 2017)**



epidemics could be strongly influenced by global warming. There is already a trend of increasing interactions between humans and pathogen-carrying wildlife, which drives the risk of new infectious diseases spreading (Carpenter 2018).

In general, the extent to which the life insurance sector could be affected by climate change related risk depends on the type of insurance products across different regions. Insurance portfolios that pay out if the insured person is alive (such as annuities and pension) and in the event of death (for example, term and whole life) are exposed to longevity and mortality risks respectively, with corresponding levels of impact from climate change scenarios. Income and health insurance portfolios are generally short-term products which are exposed to morbidity risks. Most health and disability covers are annually renewed, so are closer to P&C lines from a pricing perspective, and therefore less susceptible to mortality and morbidity changes. Depending on the portfolio of a specific insurance company, losses due to increasing mortality may be offset by mirroring developments in longevity products.

Purchasing power and life insurance penetration

In addition to the size and speed of global warming, there are several other factors that determine the extent of impact. Business and portfolio specific features like location, product types and pricing structure, market penetration, and risk mitigation measures will also have effects on the outlook for life insurers.

Adaptability to changing circumstances is inherently higher in wealthier areas or populations, which also enjoy higher life insurance penetration levels. Such portfolios are therefore less likely to be impacted immediately by global warming. However, this shielding effect may fade over time.

Under the 2 °C scenario, impacts on morbidity and mortality would arise from heat effects and social factors such as income, wealth and migration. In general, the impact in low income countries will likely be higher, often due to their geographical location and lower wealth resulting in lower adaptability levels. This could affect new business growth and market penetration in these regions. The transition risks in society and economy might re-route money and priority from life insurance cover to more immediate concerns, limiting growth. As well as customers reprioritising, life companies will need to monitor their investments carefully as transition risk changes the investment values and opportunities so as to avoid stranded assets and declining sectors. Asset Liability Management may become a more dynamic and rapidly changing skill.

For the second scenario, which assumes that global warming exceeds 3°C, within the first 10 or 20 years there will be no large difference compared to the moderate 2°C warming scenario, but morbidity and mortality deterioration should be more evident. However, over the longer term the impacts on mortality and morbidity may diverge from the 2°C scenario, which coupled with the economic implications could create significant challenges for insurers.

Under a +5°C scenario, the direct impact is likely to be further amplified and accelerated. In addition, in the longer term, a larger indirect impact is expected from geo-political instability as more regions of the world are expected to become uninhabitable. An increasing proportion of the world's population may struggle with extreme temperatures, lack of access to clean water, and famine that could give rise to large scale migration. Depending on how well populations adapt, morbidity and mortality may soar and new business may be heavily impacted.

Figure 17 **Probability distribution functions by shifting weather (SREX 2012)**

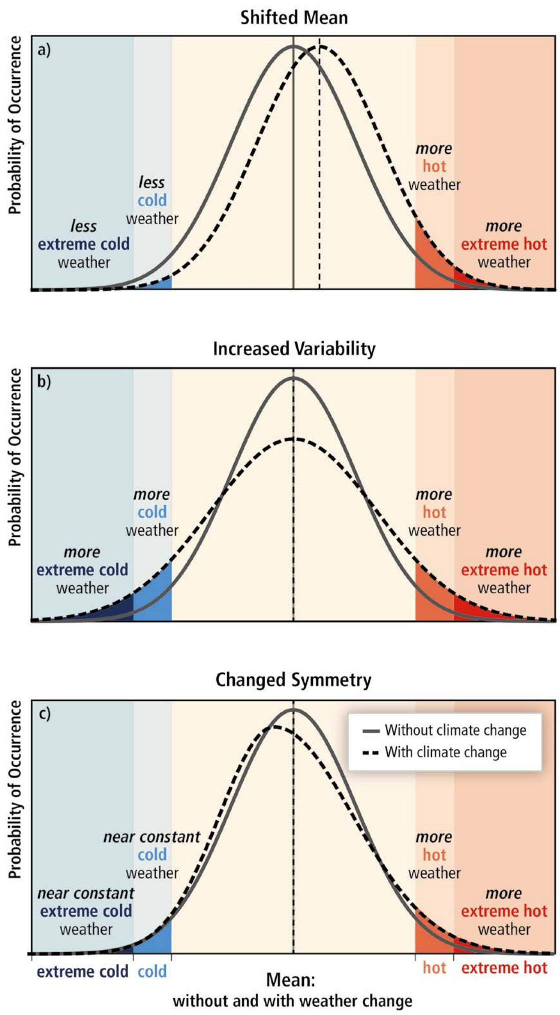
In a constant climate, weather should fit a bell curve with average temperatures most likely and extremes of hot or cold are rare.

If there is a simple shift in the weather then the entire distribution moves, as per a). The probability of more extreme hot weather increases slightly but cold extremes decline.

In b) the weather variability increases but there is no shift in the mean, which can also have the effect of increasing extremes but at both ends of the distribution.

In c) the distribution itself changes and in this example the chance of extreme heat increases with minimal change in cold extremes.

In theory all three things could happen. An increase in temperature, an increasing variability and a changing distribution. This could be worse as it increases the probability of extreme heat, yet extreme cold could still occur.



3.4 Investment implications and stranded assets

The investment implications of climate change for insurers are equally as diverse as the insurance implications. In the shorter term transition risk is likely to be the biggest area of influence on asset values, in part influenced by forward looking projections as we become more certain of the science of global warming. In the medium to longer term the physical effects are likely to be the driving factors influencing asset values and economic performance. In the worst scenarios, in the latter half of the century the financial markets may become completely disrupted as today's economy breaks down, further stranding assets and breaking business models.

Transition risk

The exposure of an institutional investor, such as an insurance company, to transition risk through its investment portfolio will be a function of three contingent factors (Thomä 2016).

- The level of transition in the "real economy" or, in other words, the extent to which the profile of a company's operations change and/or sectors become vulnerable to transition induced changes in demand and pricing.
- The reaction of financial markets to a company or sector's transition exposure.
- Changes in transition trends, due to a step-change in public mood and political will, leading to significant changes in carbon pricing and other policy initiatives. There could be a public backlash if warming accelerates leading to a rapid shift towards more dramatic transition responses.

Investors should be mindful of the various dimensions of transition risk when modelling their portfolio exposures, with the complication that the relationships may not be readily apparent. Depending upon matters such as the level of climate disclosures or the future path of governmental climate change policies, financial markets may either;

a) underreact to the change in the issuer's financial position (for example, if markets had already correctly anticipated and priced in the risk before it has materialized); or
b) overreact (for example, if markets were to adopt overly optimistic/ pessimistic market expectations about future trends or missing insights on risk mitigation measures of companies).

Stranded assets during transition

A manifestation of transition risk is the creation of the so-called "Stranded Assets" (although stranding could also arise from physical risks). This occurs where an asset is no longer able to earn an economic return, prior to the end of its usual economic life. These assets therefore suffer from unanticipated or premature write-downs, devaluations or conversion to liabilities. Assets are particularly vulnerable to stranding where the level of emissions associated with extracting and processing a resource would exceed the available carbon budget (see section 1.4).

Similarly, equipment can be 'stranded' if it will need to be decommissioned or expensively modified well before the end of its useful economic life. E.g. coal power or heating plants, or carbon fuelled transportation. Global equipment currently in use has already locked in more lifetime emissions than the remaining carbon budget to meet the 2°C target, and so some may need to be taken offline early. To meet the target, we need either to decommission $ trillions of equipment in the next few years or to implement a high carbon price or direct legislation to stimulate vast-scale carbon sequestration.

Energy reserves (coal, oil and natural gas) are particularly vulnerable to stranding. This could lead to a drop in the value of the company and even threaten its viability, depending on the value of reserves in relation to its balance sheet. For example the worlds largest private sector coal company, Peabody Coal, went bankrupt partly due to environmental considerations as well as falling price of coal.

The risk of stranding increases with the degree of ambition of the transition scenarios: the more ambitious the transition scenario, the greater risk that assets will be stranded. Indeed, Mark Carney, the FSB chair has stated that a carbon budget consistent with a 2°C target would render the vast majority of reserves 'stranded'.

Physical risks

Over the longer term (the mid part of the century and beyond), the physical impacts of climate change are likely to become more pronounced and have a greater bearing on investment performance than transition effects. The scale of the impact will depend on the actions taken and eventual outturn for global warming. The greater the level of warming, the more severe the weather and climate effects will be, and the greater the damage and disruption to the global economy. While it is not possible to precisely determine the implications for investment performance, broad impacts can be sketched out for each of the three global warming scenarios.

Stranding would still happen if there is no transition risk, as physical risks would alter economic priorities and change the viable industries and economic outputs of individual countries, especially in developing nations.

3.5 Transition risk and socio-economic factors

Transition risk can best be managed by making the necessary policy changes in an open and coordinated way internationally, and by institutions making preparations in good time. The sectors and activities most exposed to transition risk are those that extract and produce fossil fuels and those that emit large volumes of GHGs.

The characteristics of global warming make it fundamentally difficult for human psychology to act on. Long latency and the massive scale and global nature of the problem make it hard to comprehend. Moreover, differing stages of national development, and rising protectionism and cynicism about 'free-riding' can fuel counter-productive local behaviour.

This is the profound challenge of our times, which Mark Carney poignantly referred to as the 'tragedy of the commons' and the 'tragedy of horizon' (Carney 2015).

Despite the profound risk to humanity from a "too little, too late" response, most governments are a long way from having enough support from the public to make the necessary changes to be on track for the Paris targets. A key trigger to change goals and take radical action would be a deep and sustained rise in public concern (see graphic below).

Meanwhile, insurers have the opportunity to play a key social role, including contributing to business and public awareness of this profound and fundamental game-changer, whilst influencing some of the practical responses and policy implications. The most important responses will be to continue to make sustainable insurance protection widely available and with tailored products, to allow individuals to thrive in certainty and businesses to focus on their core purpose rather than consuming entrepreneurial energy and capital in climate risk management. Also, as insurers continue to invest in natural hazard models and update them to incorporate climate trends and any step-changes, they can make those models available for broader long-term risk assessment in infrastructure and adaptation planning.

The clear and present danger of climate change means we cannot burn our way to prosperity… We need a clean industrial revolution.

Ban Ki Moon, UN Secretary-General

Socio-economic tipping points

As noted above, deep and extensive social, behavioural and economic change is needed to meet the Paris target. This requires a major social shift.

It is hard to imagine such change in mind-set happening smoothly. Such a dramatic change in public mood carries the risk of social and legal shocks. These could cause sudden impacts to insurers' business areas or asset portfolios, even though in the long run it is desirable to mitigate climate change.

The graphic below briefly considers so-called socio-economic tipping-points, although this is a relatively new area of study (Kopp 2016).

Examples of possible triggers for a rapid shift in climate change attitudes include:

- Weather catastrophes cause shocking human tragedy and are solidly attributable to climate change
- Increasingly the public vote for political leaders who champion climate action, and social wellbeing over other matters, such as GDP growth
- Religious leaders galvanise a strong sense of moral duty for urgent climate action
- An international media 'hit', such as a TV series, that convincingly portrays the horrors of a 4°C world
- Emergence of eco-activism, and widespread public sympathy for their actions

Such triggers could be a catalyst for socio-economic or behavioural tipping points, reducing consumption and increasing sustainability:

- Widespread shifts of diet and social rejection of food waste and acceptance of lower carbon emitting options
- Take-off of circular economy, as social conscience about consumption and waste promotes reuse/recycling
- Falling costs of renewable technology accelerate roll-out, competition and R&D in a virtuous cycle
- Public support to implement meaningful carbon pricing which will then accelerate transition
- Subsidies for decentralised renewable energy production
- Increasing awareness of resilience following extreme events, e.g. abandoning low-lying areas that flood frequently, or changing crops / agricultural practices or climate migration

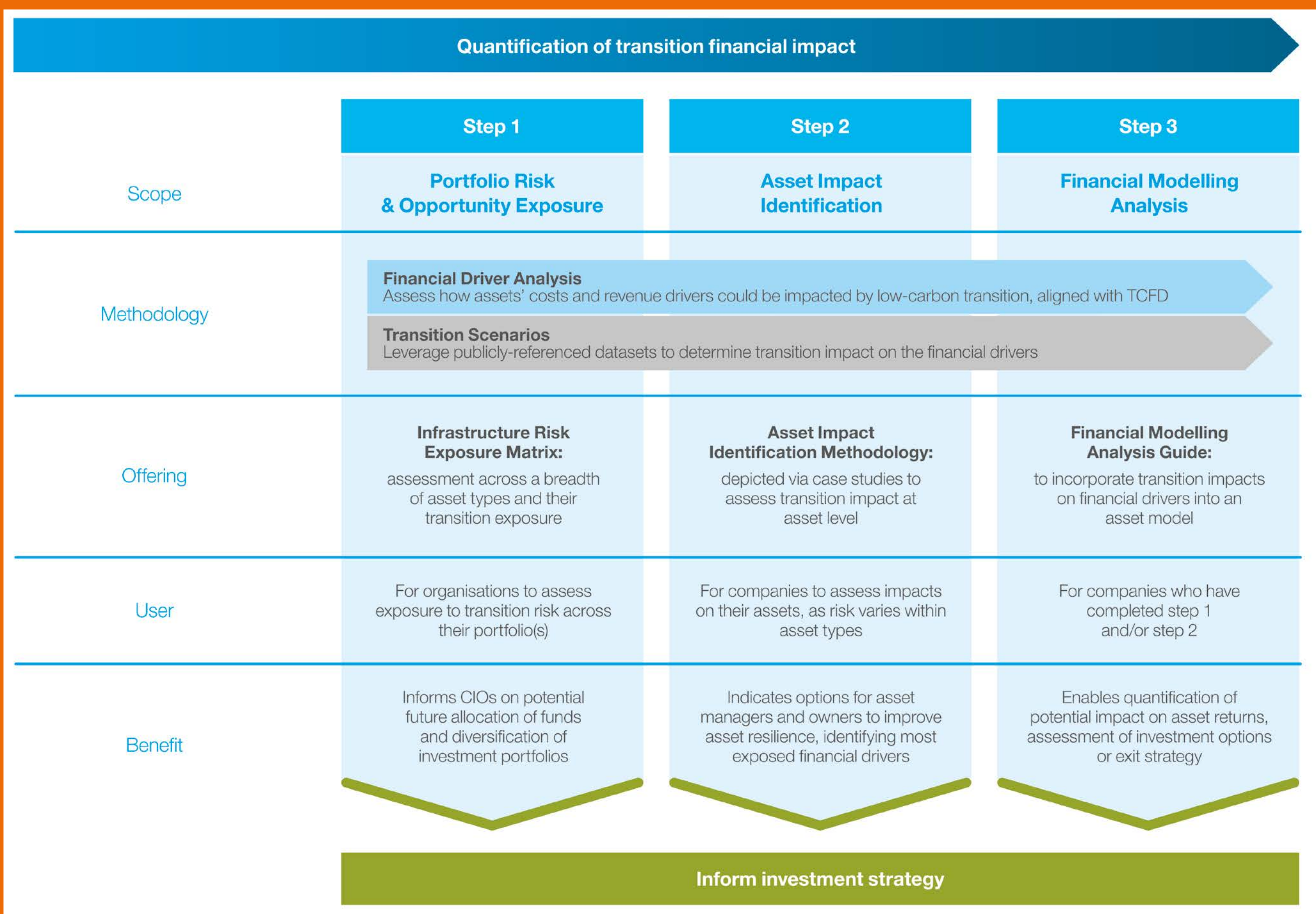
Modelling transition risk

To help institutional investors quantify and, where appropriate, reduce their exposure to transition risk in investment portfolios, various software tools have been developed by climate change advocacy groups, think-tanks and private sector vendors. Two examples, both open source tools, are frameworks developed by 2°C Investing Initiative (2II) - a global think-tank developing climate risk metrics and related policy options in financial markets; and by ClimateWise Insurance Advisory Council ("Climate Wise"), a network of leading insurance organisations that aims to align with, and support the principles of the Task Force on Climate-related Financial Disclosures (TCFD).

2II are in the process of rolling out their SEI Metrics project, which provides a portfolio test for listed equity portfolios. The model compares the exposure of a portfolio of stocks to a 2°C scenarios, mapped to specific asset classes and geographies, and with geography and stock market specific calculation outputs. Since its launch, some 2,000 portfolios have been tested for over 200 institutional investors, including asset managers, pension funds, insurance companies, banks, and sovereign wealth funds.

The ClimateWise modelling framework aims to assess the materiality of transition risk for infrastructure investment portfolios and can be used by asset managers on top of their own risk modelling. Infrastructure investments were chosen as a focus for this project, as these are particularly vulnerable to transition risk from both a revenue and cost perspective. ClimateWise have developed a three step framework (see below) that aims to, firstly, identify the range of asset types exposed to transition risk and opportunity; secondly, to define the potential impact of transition risk at asset level (this will indicate investment options for asset owners and regulators to help improve the resilience of their investment portfolios); and, thirdly, to incorporate the impacts of transition into in-house asset financial models.

Figure 18 **ClimateWise Transition Risk Framework**



4 Insurance Industry Responses

4.1 Resilience, mitigation and adaptation

We have highlighted earlier in the paper that climate change, among other major trends, is a major threat to the global economy and society as a whole. Therefore, our response should reflect the risk. This may require meaningful and potentially radical transformation to our way of life and our approach to economic activity (to render both sustainable) if the worst consequences of climate change are to be avoided. As providers of protection products, as well as major investors in the economy, insurers have a vested interest in supporting efforts aimed at curbing global warming and bolstering resilience. There is also a reputational incentive. As good corporate citizens we want to be seen to be playing our part in assisting with this critical issue. As is currently happening on a range of key topics, including climate change.

Mitigation and adaptations are key concepts informing climate change issues. Whilst governments' primary task must be to curb greenhouse gas emissions, insurers will work with policymakers to support adaptation and transition both through providing insurance protection and investing. Regardless of the success of efforts to contain emissions in future, both approaches will be needed to deal with the global changes that have already been set in motion.

- Mitigation refers to measures that can minimise or slow the rate of long term climate change and will centre on effort to curb emissions as the principal cause of global warming.
- Adaptation, on the other hand, refers to measures that can strengthen the resilience of economies and societies to the physical effects of climate change (in temperature, storm frequency, flooding and other factors).

Figure 19 **Insured vs uninsured weather-related catastrophe losses, per region**

Options available to mitigate climate change include phasing out fossil fuels by urgently switching to low-carbon energy sources, such as renewable energy, and protecting and expanding forests and other “sinks” to remove greater amounts of carbon dioxide from the atmosphere. Energy efficiency will also play a role, for example, through improving the insulation of buildings and encouraging people to accept a wider variances in temperature so reducing heating and cooling needs. Insurers can support these mitigation efforts through their underwriting activities and also through their investment activities.

As major institutional investors, insurers have significant influence over companies and can encourage them to switch to less carbon intensive operations (for example, through involvement in organisations like the Climate Action100+ initiative), and improve transparency through improved disclosure. Insurers can take more direct steps to curb global warming by disinvesting from sectors and/or businesses that are seen as heavily polluting. A number of prominent insurers have made public commitments to limit support and investment in carbon intensive industries.

As noted, adaptation measures can reduce vulnerability to climate change and can be as simple as moving location or as complex as investing in adaptive techniques/technologies.

Lowering sensitivity is one approach, such as building road surfaces that withstand higher temperatures, building in heat resistance or building defences to protect against sea-level rise. Alternatively, it is possible to build adaptive capacity, such as raised living quarters or building on stilts. Behavioural shifts such as individuals using less water and farmers planting different crops is an important part of adaptation. It is also possible to take advantage of opportunities arising from climatic changes, such as growing new crops in areas that were previously unsuitable.

The insurance industry helps through its mutualisation and shock absorbing capabilities for major risks, its abundant data information and abilities to analyse such data. The power in this data is achieved by raising awareness with the public, governments and corporations. Influence is also possible through the way insurance and reinsurance products are designed and in the way claims are fulfilled. For example, seeking suppliers who reduce delivery miles, or giving the customer options to move to lower emitting replacement goods. Developing public/private partnerships and building pooling options would also assist. It is important, however, to note that there are limits to the capacity of private sector insurers to absorb losses and climate change could strain this capacity.

It is also worth noting that these risks may have financial implications for the insurers’ own operations (including impacts on own premises, operations, supply chain, and employee safety) as well as for its own insurance portfolio.

Economics of climate adaptation

Major climate-related natural catastrophes such as storms, floods, droughts and other extreme weather events can threaten cities, regions and entire nations. Losses from natural catastrophes are rising, as wealth accumulates in the world’s most exposed regions and the climate continues to change.

The ECA outlines a framework for decision-making that identifies significant potential for cost-effective adaptation measures (ECA, 2009). They present a practical framework that national and local officials can use to quantify the risk that climate change poses to their economies, and to minimise the cost of adapting to that risk.

The good news is that up to 65% of climate risks can be averted. However, this needs quick and joint action by both the public and private sector. Only by combining risk prevention, risk mitigation and risk transfer measures as part of a comprehensive adaptation strategy, will communities become more resilient to the impacts of climate change.

The insurance industry is at the forefront to support such climate adaptation measures. As an example, the private sector advisory group for the Green Climate Fund has proposed to involve the private sector in climate adaptation. This includes focusing on risk transfer instruments, which includes insurance as a financing modality. Such instruments will be aimed at addressing ‘residual climate-induced risk’, where physical adaptation measures may not be feasible and/or make financial sense.

> **Insurers are therefore amongst those with the greatest incentives to understand and tackle climate change... And your response is at the cutting edge of the understanding and management of risks arising... Your genius has been to recognize that past is not prologue and that the catastrophic norms of the future can be seen in the tail risks of today.**
>
> Mark Carney, 2015

4.2 Supporting societal change – a social role for the insurance industry

Reinsurers, insurers and brokers have been influencing public policy, public perceptions and consumer behaviour since the first recorded modern style insurance sale in Edward Lloyd's Coffee House in 1688 London. In part this has been through policy wordings with the use of exclusions and open pricing improvements, but also through direct influence on customer actions. One notable example being in California in 2004 where Insurance Institute for Business & Home Safety issued leaflets to high risk homes encouraging the undertaking of protective measures against wildfires. Further examples include widespread use of risk surveys and risk advice in Commercial lines, the introduction of a no claims discount, reduced pricing for homes with window locks fitted for security purposes, or reduced life insurance premiums for non-smokers. In some cases, influence has been simply achieved by sharing claims data held by the insurance industry, in part to shift public perceptions. As already mentioned being an active institutional investor or considering how funds are invested can also influence or assist in driving change.

The insurance industry is in the position to choose whether to take an active position in mitigating global warming not only for the industry, but also to support society as a whole. Utilising the full range of mechanisms available to insurers in order to do so. As mentioned elsewhere in the paper, this includes taking appropriate pricing actions, managing policy wording, influencing claims spend such as making greener alternatives available, managing assets and investments, and utilising data and experience to inform public opinion.

There is also the obvious steps of managing our own operations to be as low in carbon impact as possible.

Interaction with government and other public bodies has been effective in the past in influencing regulation and legislation, and working in partnership to find solutions to complex problems. For instance, the UK government has engaged with the insurance industry on investment in flood protection measures and in joint ventures, such as pooling, to provide protection for high risk properties. Public health is another area where the insurance industry has striven to have its voice heard through the provision of policy suggestions backed by claims data.

While the insurance sector can be an important agent for change, firms need to be careful to manage the external reputation and communications so as not to be misunderstood or

Why not whiten the sky (geo-engineering)?

A seductive alternative to weaning the global economy off fossil fuels is to offset the warming by deliberate cooling. One idea is to spray a thin veil of sulphate particles into the upper atmosphere (above where most clouds form). This is technologically feasible and relatively affordable. However it carries major perils and moral hazards:

'Two wrongs don't make a right'

- It may cause drying of tropical / sub-tropical regions, as happened after massive eruptions (the 'Pinatubo Effect').
- It may act as a catalyst to destroy the ozone layer faster.
- There is no 'control' planet, so we cannot test for unintended health, ecology or weather risks.
- The approach doesn't stop CO_2 acidifying the oceans, potentially catastrophic for marine life and fisheries.
- The sulphates would only stay in the atmosphere for approximately a year before returning to earth so this is not a one-off action but a regular activity.

'You can't put the genie back in the bottle'

- High dependency and termination risk: with high CO_2 levels, the world will warm very fast if the aerosols are not maintained, creating a 'sword of Damocles' for millennia.
- It appears to buy time, but in reality it subverts any impetus to act on emissions.
- To be effective a globally coordinated activity would be required and it is doubtful there will be the political will given the risks.
- Even if outlawed, 'rogue' states may go ahead, with global consequences.

misconstrued. It is important when taking a public stance on a high-profile topic to consider all the reputational angles and how a message may be interpreted, especially if it proves to be out of step with public opinion or if the message is misrepresented to look like self-interest rather than for society as intended. Also the industry cannot be seen to be in conflict with consumer autonomy or to impact on the fair treatment of customers.

A key area where insurers can drive change is through claims fulfilment. Replacing insured goods with more energy efficient solutions is one potential option. Another is to allow customers to part fund replacement, for instance to choose a more energy efficient vehicle rather than direct replacement or to add energy efficient solutions into property rebuilds. The cost to insurers would be the same, but a more climate friendly solution would be achieved.

Overall the most important social role of insurers is providing protection to their customers. Sustaining financial stability and providing protection products to the insurable remains the key objective of all insurers. It is key insurers manage the challenges ahead, on behalf of all.

4.3 Tackling climate risks through investments

4.3.1 Introduction

Insurers must hold assets not just to cover expected claims, but also unexpected larger claims, and be able to absorb adverse results from any asset-liability mismatch (where investment portfolios do not closely match insurance liabilities). This additionally necessitates that, when insurers hold more risky investments, they must have more capital to protect policyholders in the event that the riskier investments lose value. Investment Management must determine the best combination of risk factors and assets to maximise risk-adjusted return and to ensure assets match liabilities.

In responding to climate change, insurers not only need to consider how best to support their customers in the protections it provides but also how to invest its assets to maintain financial stability. Evaluating the right investments, using carbon impact as one of the measures, will be essential to helping direct change and support investment in mitigating activities. ESG integration is one aspect of responsible investing that specifically lends itself to climate change. This is where environmental, social and governance factors are integrated into investment decisions.

Impact investing enables an investor to pro-actively influence climate mitigations in the real economy through investing in sustainability-themed investments.

As explained in chapter 2.4, investors also need to reactively consider the impact of underlying risks from climate change on their portfolios.

Pricing climate change risks

Climate change risks are currently not always correctly priced by the markets due to asymmetric information, short termism and unclear regulation, which bears not only investment risks but also opportunities. For example, carbon is priced in 39 countries and in 23 jurisdictions across the world. These prices are the basis for carbon taxation and emissions trading systems (the first one started in the EU in 2005). Alas, carbon prices currently cover a very broad range, from US\$1/tCO_2 in Mexico (carbon tax) to US\$140/tCO_2 in Sweden (carbon tax), making it difficult to apply a global standard, let alone calculate with a consistent shadow price. This is exacerbated by the fact that accurate data for physical risk is not yet very prevalent and hence underrepresented in financial analysis (World Bank 2016).

4.3.2 Investment considerations

In the investment process it is essential to define a clear strategy incorporating expected climate change factors, as well as short-term and long-term targets that the insurance company wants to achieve.

Insurers' needs in relation to investing are not purely driven by the need for investment return. Matching capital and maintaining low risk to give confidence in the matching of assets to liabilities is critical so is often the biggest driver of investment strategies. Fixed Income instruments are a natural match for the long-term liabilities of an insurer and it is unsurprising that this asset class makes up approximately 80% of the average insurers' asset allocation. At the other end of the spectrum, venture capital is often too risky and is therefore rarely included in the asset allocation of an insurance company.

However, there are strategies that an insurer can explore to mitigate climate risks whilst profiting from the opportunities of a low carbon and resilient economy. Mitigating the effects of climate change on a given portfolio can mainly be achieved through proactive climate/ESG integration. Investing proactively to play a role in mitigating climate change on a global level can mainly be achieved through impact investing.

Additional data and tools are currently required to raise awareness among investment professionals. With time, a growing set of accurate and material data will help investors to identify both risks and opportunities created by the transition and phyical aspects of climate change. Appropriate training of investment analysts and portofolio managers will help to price those risks and opportunites appropriately and to support integration of these factors into investment strategies. Revaluing assets to their proper ESG integrated risk-adjusted values provides an holistic base for asset selection considerations and will be reflected in decisions to buy/sell, or overweight/underweight a certain security or asset.

In order to support investors in their climate change risk integration journey, the sustainable investment community is diligently developing new data sets, literature and measures. Prominent examples are UN Principles for Responsible Investments, Cambridge Institute for Sustainability Leadership and 2degree Investing Initiative. Reporting climate change risk exposures through the voluntary TCFD framework, is expected to improve the data set available for ESG rating companies to support these developments.

4.3.3 Impact investments

Impact investments can be defined as investment opportunities that allow an organisation to target a specific positive social or environmental impact. It allows companies to measure the social or environmental impact alongside profitability, so achieving dual objectives.

As mentioned previously, mitigation is cheaper than adaption; therefore an insurers' mitigation focus should be primarily on transition risk and after that on physical risk. An insurer can actively pursue direct mitigation strategies in line with the industry opportunities and restraints with impact investments.

Insurance companies may consider impact investments to help increase energy efficiency, generate renewable energy or mitigate climate change and/or protect the environment in other ways. Through impact investments, positive outcomes may be targeted in two main ways.

- Mitigating environmental risks by supporting a low-carbon economy and encouraging environmentally-friendly technologies.
- Increasing community resilience by helping to build 'community capital' and addressing the needs of populations that lack traditional means to achieve such goals (the 'under-served populations').

Impact investment opportunities exist across various asset classes and across a spectrum of investments. Although this should always be in accordance with an insurer's own Strategic Asset Allocation (SAA) strategy.

The mitigating activities mentioned in this chapter are non-exhaustive options and examples. Every insurance company needs to assess and implement measures within their own parameters (e.g. overall company values and strategies, georgraphic focus areas and customer base, or other sustainablity targets) and according to their SAA.

The potential direct investment opportunities that support climate change mitigation are as follows.

4.3.3.1 Summary by asset class

Fixed income

Green bonds (Climate bonds): The unique characteristic of green bonds, over conventional bonds, is the pre-defined link to investments in specific 'green' projects that allow the bond issuer to report a clearly defined result or impact. The Green Bond Principles, an industry code produced by the International Capital Markets Association (ICMA), specify standards and criteria for Green Bond designation. The ICMA have set voluntary process guidelines for transparency and disclosure, which promote integrity in the development of the Green Bond market.

Private debt

Private Debt, whether investments in green technologies for fighting climate change (ie avoiding GHG emissions through upgrades in housing, transport, agriculture etc.) or investments in Green and/or energy saving infrastructure, can support efforts to reduce greenhouse gas emissions, support adaptation and mitigate climate change.

Real estate

Improvements in real estate can also be implemented in an investor's direct real estate portfolios, through investment, but especially refurbishment and development activities.

Private equity

In many ways, private equity as an asset class is particularly suited to impact investing: the companies receiving capital from private equity investors usually tend to be small and agile, and engage in a more limited number of activities that can be easily evaluated against impact objectives. A closer relationship between investor and investee also makes it easier to use innovative approaches, such as impact reporting. Particularly in emerging and high-growth economies, private equity is often the only capital available to fund growth.

Blended finance

High capital requirements for climate change mitigation require innovative solutions. In recent years, so called "Blended Finance" has attracted increasing interest. This approach allows an investor to blend small amounts of public concessional funds with private sector commercial funds to finance first-of-a-kind projects that provide high development impact and strong potential, but are yet to establish a commercial track record. In this way private sector money, and hence insurance capital, can help to close the investment gaps for low-carbon energy, transportation, and agriculture projects. This is particularly valuable for the developing world so they can achieve the characteristic instituationally investors need to be able to invest.

5 Climate Related Financial Disclosures

> **Increasing transparency makes markets more efficient, and economies more stable and resilient.**
>
> Michael R. Bloomberg, Chair FSB TCFD

5.1 Towards better climate disclosure

The insurance sector has been tackling climate change risks and opportunities for several decades and has developed related products, while continuously updating and monitoring its risk understanding and modelling capabilities.

Stakeholders, including investors and regulators, want to know companies understand their exposure and are taking steps to manage them. In this way climate change is just another risk that needs to be managed, alongside all other risks. Disclosure is one vehicle used to give investors and regulators the comfort they require. Going forward, stakeholders are likely to expect a higher granularity of disclosure regarding climate-related risks and opportunities on both insurance liabilities and assets.

In order to make disclosures meaningful investors require more insightful information that is more clearly presented than today. To drive this, the G20's Financial Stability Board (FSB) formed a Task Force on Climate-related Financial Disclosures (TCFD) with the brief to draft a voluntary framework for companies to develop more effective climate-related financial disclosures through their existing reporting processes.

This had the aim of tying together existing, disparate disclosure approaches. The work and framework of the TCFD had tremendous impact on the debate. As a consequence, climate disclosure expectations have started to trickle into investee engagement

Figure 20 **Recommendations and supporting recommended disclosures (FSB TCFD, 2017)**

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

(e.g. ClimateAction100+) as well as into regional debate and frameworks (e.g. EU Action Plan for Sustainable Finance).

It is clear that there are a variety of challenges associated with measuring and disclosing information on risks and opportunities related to climate change. However, reporting climate-related issues in mainstream financial filings and reports allows practices, techniques and third-party providers to evolve gradually and more rapidly. The TCFD framework has already reenergised a number of high-profile sector working groups.

Improved transparency helps inform efficient capital-allocation decisions, better pricing of risks, and stringent and efficient regulatory supervision and policy-making. In June 2017 the Task Force emphasized the importance of transparency in pricing risk, including risk related to climate change, to support informed and efficient capital-allocation decisions. The TCFD recommendations identify climate-related physical risks as being one of the two main types of risks that corporates should disclose. They distinguish between acute (event-driven) and chronic risks (those due to longer-term shifts in climate patterns), recognising that physical risks may affect all and any part of a company's financials, including expenditures, revenues, assets and liabilities, capital and financing.

Insurance related transition risks referenced by TCFD include climate-related litigation risks, shifts in technology and market shifts, and opportunity risk due to emerging insurance products arising from new technologies. Transition risks also arise from structural shift leading to stranded assets.

5.2 Accountability and measurement

The TCFD framework foresees disclosure along four pillars, which shed light on how a company identifies, assesses and manages the risks and opportunities arising from climate change, as per Figure 20.

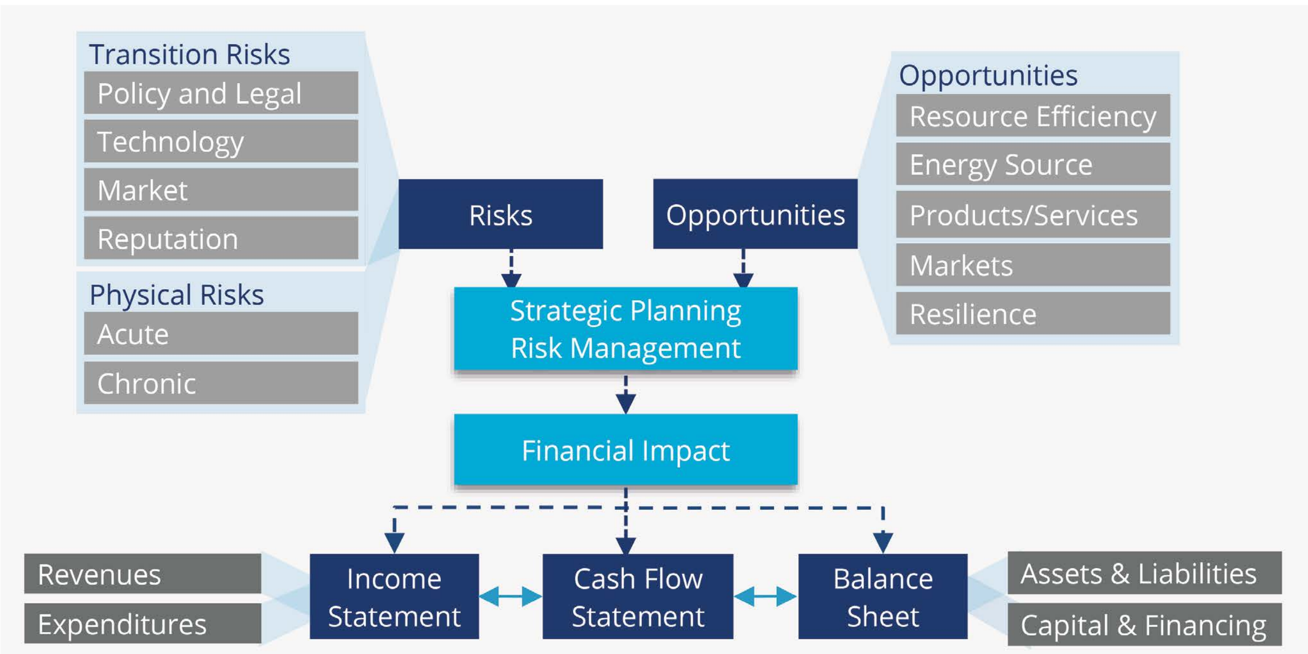
- How does the Board and Management govern climate change?
- What are actual and potential impacts of climate change on the company's strategy and financial planning?
- How does the company manage the risks and opportunities?
- What metrics are used to assess and manage it and what targets are in place?

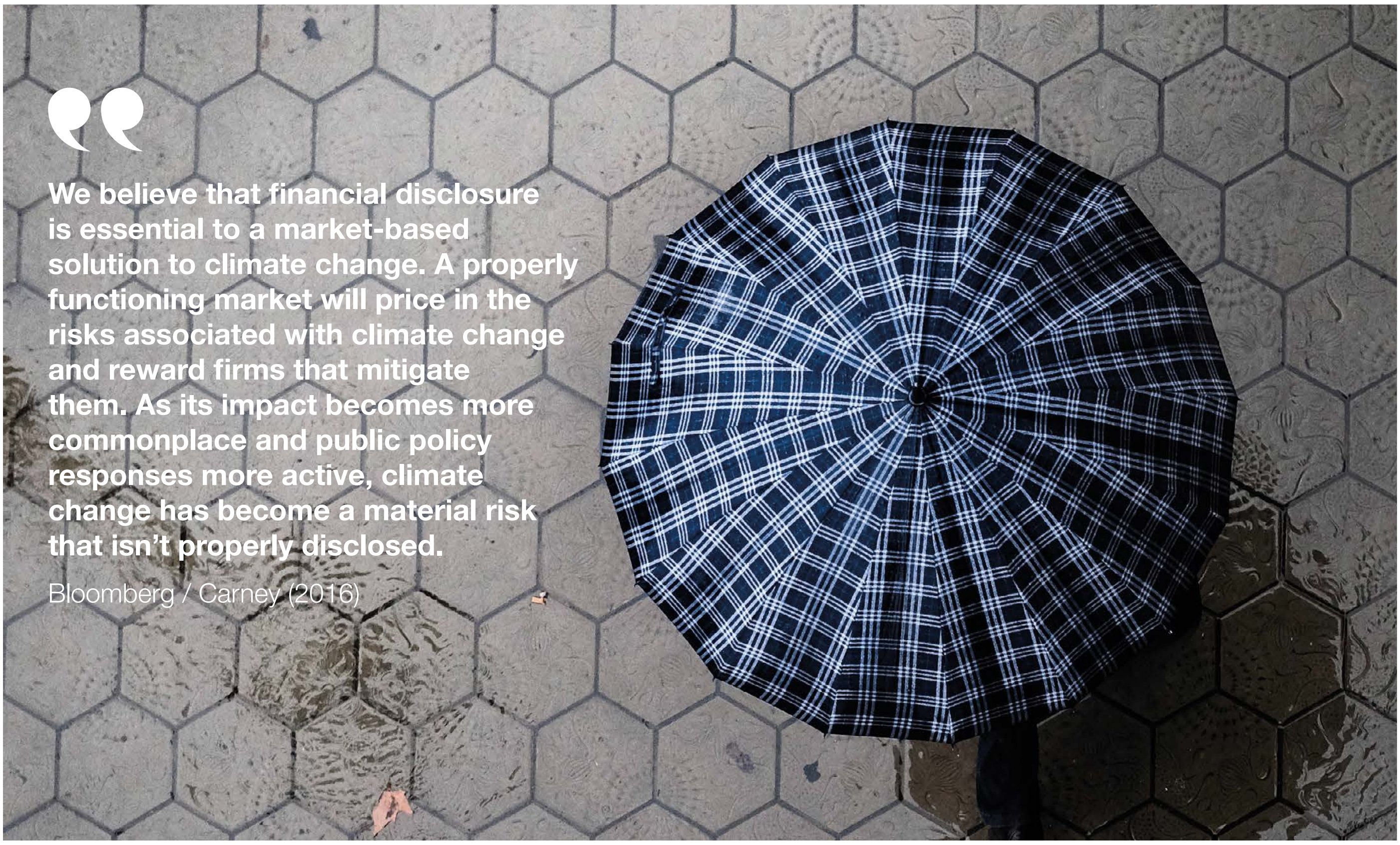
'The risks and opportunities in scope are described in Figure 21 with supporting recommended disclosures. This outlines TCFD recommendations for how companies should structure reporting against the risks and opportunities from climate change (TCFD, June 2017).

In their status report from September 2018, the TCFD reviewed disclosures in different industries to get a picture of most recent reporting practices. The report shows that the majority of companies assessed already disclose information that is aligned with certain elements of the four pillars of the TCFD recommendations. To date, much of the information provided has a qualitative nature, only few companies disclose the potential financial impact of climate change on the company. In the insurance sector a small number of companies have started to report details on the TCFD recommendation.

This paper recognises the power of disclosure and sees the TCFD principles as a positive step in increasing transparency and understanding.

Figure 21 **Climate-related risks, opportunities and financial impact (FSB TCFD, 2017)**





5.3 Challenges and ways ahead

The aspects of climate change described in the sections above are areas where disclosure will be reasonable but particularly challenging. Understanding the risk profile of a company due to climate change is a real challenge and one that goes beyond modelling. This will need to be an area of focus if disclosure is to be meaningful.

Physical risks and related business opportunities

Currently, disclosure on physical risks is mostly constrained to describing modelling procedures, known top risks, and measures of next-year's expected natural catastrophe losses. Opportunities are mostly articulated via case studies on new business segments. Quantified information on risk impacts, businesses operational risks or information on topics like affordability and insurability of insurance are not part of mainstream disclosure. With emerging taxonomies[5] and tools[6] disclosure becomes easier.

Climate-related opportunities need more consideration in disclosure as products develop. Natural catastrophe and other specialised weather-related protection products (including parametric products) can be considered part of climate action. As can any advisory services on climate resilience, including assessment of climate risks and related risk mitigation considerations.

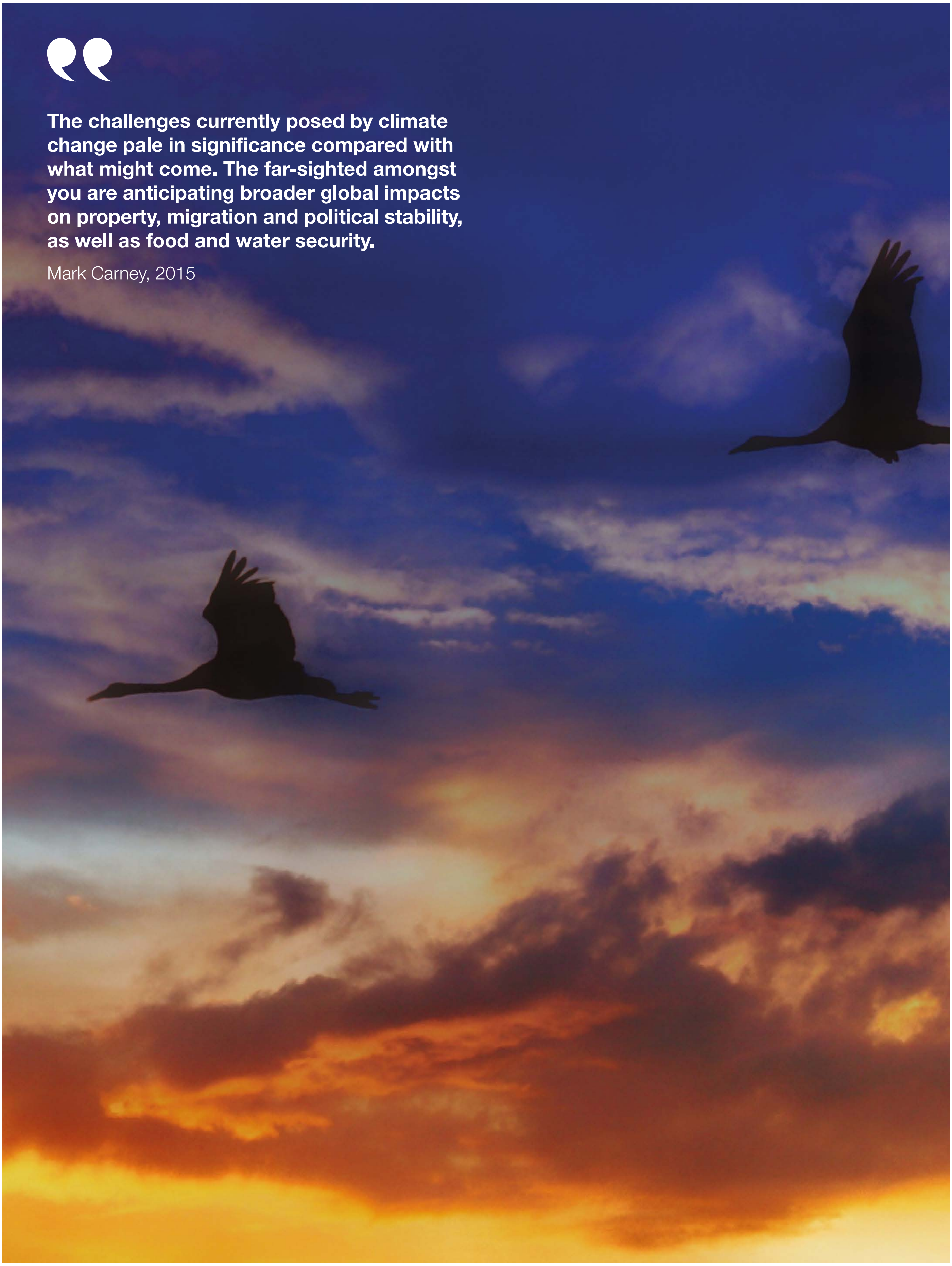
Transition risks and related business opportunities

To date, disclosure on transition aspects is mostly restricted to narrow view, such as green energy and coal, but a more coherent picture on transition risks and opportunities is needed. This can reflect wider aspects of technological and market shifts. Like the shift away from established (high-carbon) technologies with well-known loss patterns to emerging technologies with new loss patterns. This does not restrict itself to the energy sector as the transition has many implications for all major sectors. As an example, the electrification of sectors, e.g. in the transportation industry together with autonomous vehicles and maybe falling figures for car ownership towards public transport/ sharing will impact motor business and induce a shift of lines of business, with new business opportunities but also the loss of prior business.

Abrupt shifts in market sentiment could also pose impacts in the shorter term triggered by new regulation or by the occurrence of landmark physical risk events.

The disclosure on the investment side has seen more quantified approaches already, with methodologies and tools being published, like the ones from the EU-funded Energy Transition Risk project or Sustainable Energy Investment Metrics project.

5 Such as the EBRD-hosted industry working group on a taxonomy of physical climate risks, refer to https://www.physicalclimaterisk.com/
6 Such as asset-level data bases, refer to https://assetleveldata.org/



> **The challenges currently posed by climate change pale in significance compared with what might come. The far-sighted amongst you are anticipating broader global impacts on property, migration and political stability, as well as food and water security.**
>
> Mark Carney, 2015

Conclusion

In preparing this paper, we have been struck by the strength of evidence of the pace and effects of climate change and the precarious situation the globe finds itself in. It no longer appears to be a question of whether global warming will have material impact this century, but how much irreversible damage will have been done before sufficient action is taken. A massive and globally coordinated response is required to mitigate these risks, as highlighted in IPCC SR15, enabled by radical economic and socio-cultural change. Insurers have their role to play, not only in the interests of society but also in the strength and resilience of our sector.

The biggest threats arise from physical risks affecting both the Life and P&C sectors and will worsen as temperatures rise. The primary threat is weather catastrophes of flooding, heatwaves, drought and wildfire, but also threats arise through the risks of pandemic, water borne diseases and general human wellbeing. The human toll is likely to be greatest in developing nations, while major economic impacts are likely to be felt in due course in leading economies such as those in Europe and North America.

The tough changes needed will create transition risks, assuming public concern rises to such a level so as to support radical action to curtail emissions and strive for a sub-2°C scenario. If tough transition action is not taken, the ultimate economic and human impacts from the physical impacts will be far more severe. The transition risks will be manageable for institutions that are well prepared, and alongside the risks, transition opportunities should arise from changes in society and technology used to support low emissions and carbon capture.

People and corporations have always faced uncertain futures and they will continue to take business risks and invest. Insurers have over the past 300 years supported people and corporations to take risks, helping them undertake large and challenging projects. The investors retain the risks around business success; the risk of volatility from external causes is the territory of insurance. Insurance has an excellent track record from its early days enabling marine shipping, or more recently building renewable energy plants and the construction of more environmentally sustainable structures such as the Freedom tower. Insurance is well equipped with its tools, risk management practices and cost-efficient capital to cope with uncertainty and risks of adverse outcomes. It’s not modelling or risk awareness, but true risk transfer which have made and will continue to make the difference.

As this indicates, insurers are in a unique position not only to protect society and the real economy against the many risks associated with climate change but also to support society in transitioning and adapting. This includes support for existing products, innovating new products (such as for the sharing economy or supporting timber construction) and managing investment portfolios in a way that protects the assets underlying the business but also in providing capital for mitigation and adaptation.

To utilise this unique standing that insurers have will require working with customers, industry and governments. With customers our risk management knowledge can be used to inform and direct behaviours in ways that support societal change. With industry and governments we can apply insight and capital to building low carbon-intensity infrastructure to help mitigation/adaptation. We can influence government policy in key areas and provide innovative financial solutions, such as risk pooling.

As investors we can look to influence the organisations we invest in and work with (such as suppliers) to drive better behaviour and disclosure of climate related risks. As an industry, insurers can take a lead in disclosing such risks by following the framework provided by the FSB through the TCFD. Whilst this disclosure is voluntary it is only through disclosure that greater understanding of the economic risks and transparency will arise.

The heat is on. The time for action is upon us. The climate is changing and we have a clearer view of how bad the impacts could be and what needs to be done. Failure to act now will have repercussions for the whole of society including future generations. Insurers want to play their part, preparing themselves and working with society to help everyone ready themselves for the physical and transition risks ahead.

Appendix

Concentration pathways and scenario definitions

Over the years the scientific community has been devising the best possible instruments to help understand and estimate the possible future consequences of climate change.

Among the main actors involved in this process is the Intergovernmental Panel on Climate Change (IPCC), a scientific body set up by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP). Since its foundation, it was entrusted to coordinate, collate and elaborate the corpus of scientific knowledge on the subject, providing the most current scientific views, the possible associated impacts, and the available mitigation and adaptation strategies.

To achieve agreed targets, one of the main challenges faced by IPCC was to create a framework that allowed the scientific community to produce research in a consistent and comparable way. At first, the path chosen involved the creation of representative scenarios (IS92, then SRES), which required researchers to follow a lengthy sequential approach to introduce new findings. This approach is now being superseded by the introduction of "Representative Concentration Pathways" (RCPs), to illustrate how GHG concentration could develop in the future, irrespective of the social and economic circumstances driving them. A further step, involving "Shared Socioeconomic Pathways" (SSPs) completes the picture by introducing the impact of social and economic drivers, and should be ready for the next round of IPCC analyses. SSPs will explore if and how the paths indicated by the RCPs can be achieved by society. Together, RCPs and SSPs should allow for a parallel approach in incorporating research, and thus enabling a quicker integration of the latest science in the reports being produced.

Representative concentration pathways explained

Regarding RCPs, these are intended for the scientific community and not for the general public, hence the difficulty in conveying in simple terms what they stand for.

Each RCP is represented by a large database containing the figures related to different GHG emission levels, with details on geographical distribution and on how these variables change in time. These are the input values that should be used by researchers to conduct their analyses, so that they are comparable to what other teams are doing.
Since a specific RCP only describes a pathway in emission development, it is not necessarily tied to a single individual socio-economic scenario, since different mixes could all lead to the same pathway. Those selected were considered the most representative among all those possible to investigate the effects of GHG concentration levels until the end of the century.

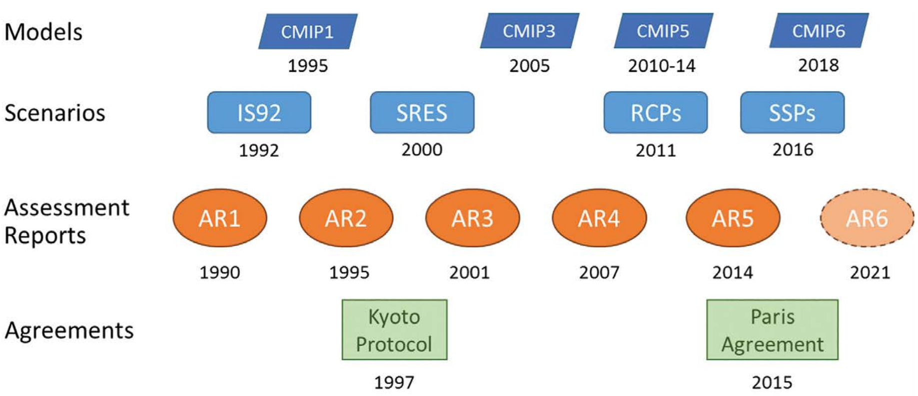
RCPs are classified in terms of radiative forcing, which in IPCC AR4 was defined as: "a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism". In this report radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter. So, RCP 2.6 refers to the increase in energy absorption in the Earth's atmosphere that would be associated with this scenario by 2100.

Models and scenarios

While modelling outcomes based on RCPs can be in the thousands (in AR5 the IPCC ended up considering approximately 1200 scenarios overall), the RCPs themselves constitute a good synthesis of the main paths that could be followed, and thus a good basis for effectively identifying the major underlying trends in a simplified way.

Regarding models and scenarios, a number of different approaches are possible. One of the main ones is constituted by the climate, social and economic models and scenarios coordinated by the IPCC. A second group uses energy system models and scenarios, such as the World Energy Outlook (WEO) devised by the International Energy Agency (IEA) or Bloomberg's New Energy Finance (NEF) Energy Outlook, which provide estimations of future emissions by considering current and projected energy production sources. Further models and scenarios are developed by commercial firms or business organisations (e.g. the World Business Council for Sustainable Development, WBCSD).

Figure 22 **Timeline of climate change assessment reports and models**



Glossary

Albedo
Albedo is a measure of how much of the incoming solar radiation is radiated back (diffuse reflection). A bright surface (such as snow) has an albedo approaching 1, while a dark surface (such as open ocean or forest) has a lower albedo absorbing more heat.

Aerobic / anaerobic
Aerobic means respiration in the presence of oxygen. Anaerobic is the reverse without the presence of oxygen.

AVOID2
UK government funded climate change research programme involving a multi-disciplinary consortium of UK research organisations. The programme ran from February 2014 to March 2016. The research undertaken provides scientifically-robust, policy-relevant answers to questions directly related to the Ultimate Objective of the UN Framework Convention on Climate Change (UNFCCC), which is to 'prevent dangerous anthropogenic interference with the climate system'.

AR5
The Fifth Assessment Report (AR5) published in 2014 by the IPCC is the fifth in a series of such reports providing the science of climate change, emphasizing new results since the publication of the IPCC Fourth Assessment Report (AR4) in 2007.

BECCS
Bio-energy with carbon capture and storage (BECCS) combines bioenergy use with carbon capture and storage. This technique uses trees and crops, which extract carbon dioxide from the atmosphere, as biomass in processing industries or power plants, which then uses carbon capture and storage techniques to stop the associated emissions going back into the atmosphere.

CCC
Committee on Climate Change provides independent advice to UK government on building a low-carbon economy and preparing for climate change.

CCS
Carbon capture and storage (CCS) is the capture of CO_2 from a point source, such as flue gas from a power plant or cement or steel works, compressing it to a liquid and storing it underground in geological reservoirs, typically a saline aquifer or depleted oil or gas field, so as to avoid adding to greenhouse gas emissions that drive global warming.

DACCS
Direct Air Capture with Carbon Storage (DACCS) is a technology that uses chemical processes to capture CO_2 directly from ambient air. The CO_2 is then separated from the chemicals and is subject to CCS. The chemicals are then reused to capture more CO_2.

GHG
A greenhouse gas is a gas that absorbs and emits radiant energy within the thermal infrared range causing the greenhouse effect. The primary greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide and ozone. Without greenhouse gases, the average temperature of Earth's surface would be about −18 °C (0 °F), rather than the present average of 15 °C (59 °F).

GMST
Global Mean Surface Temperature is the mean of the temperature measurements made over land and water across the globe, which are used as a standard reference to monitor temperature changes over time.

Greening
This is where increasing CO_2 levels a warming planet are driving growth in plants across the globe. This has the effect of offsetting part of the increase of CO_2 levels in the atmosphere. Despite significant greening, this has not abated rising CO_2.

IEA
The International Energy Agency is an autonomous organisation under the OECD framework. It advises on energy policy, provides research and data, and works to ensure reliable, affordable and clean energy for its 30 member countries and beyond.

InsurResilience
Global Partnership for Climate and Disaster Risk Finance and Insurance Solutions was launched at the 2017 UN Climate Conference with the aim of strengthening the resilience of developing countries and protecting the lives and livelihoods of poor and vulnerable people against the impact of disasters.

IPCC
The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. The IPCC was established in 1988 by the World Meteorological Organisation and the United Nations Environment Programme to assess scientific, technical and socio-economic information concerning climate change, its potential effects and options for adaptation and mitigation.

RCP
A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for AR5 in 2014. Four pathways have been selected for climate modelling and research, which describe different climate futures, all of which are considered possible depending on how much GHGs are emitted in the years to come. The four RCPs are labelled after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2).

SEI Metrics project
European Commission funded Sustainable Energy Investments (SEI) project focusing on metrics, benchmarks and assessment tools for the financial sector. The objective of the project is to measure the investment portfolios with climate related energy transition goals and seek to shift capital towards sustainable energy and energy efficiency investments.

SR15
An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels compared with 2°C. It was commissioned in 2015 at the time of the Paris agreement, and published in October 2018.

Thermocline
A thermocline is the transition layer between warmer water at the ocean's surface and the cooler deep water below.

TWIA
Texas Windstorm Insurance Association provides wind and hail insurance to 14 Texas gulf coast counties a portion of Harris county.

WEO
The annual World Energy Outlook is the IEA's flagship publication, widely recognised as the most authoritative source for global energy projections and analysis. It represents the leading source for medium to long-term energy market projections, extensive statistics, analysis and advice for both governments and the energy business. It is produced by the Office of the Chief Economist.

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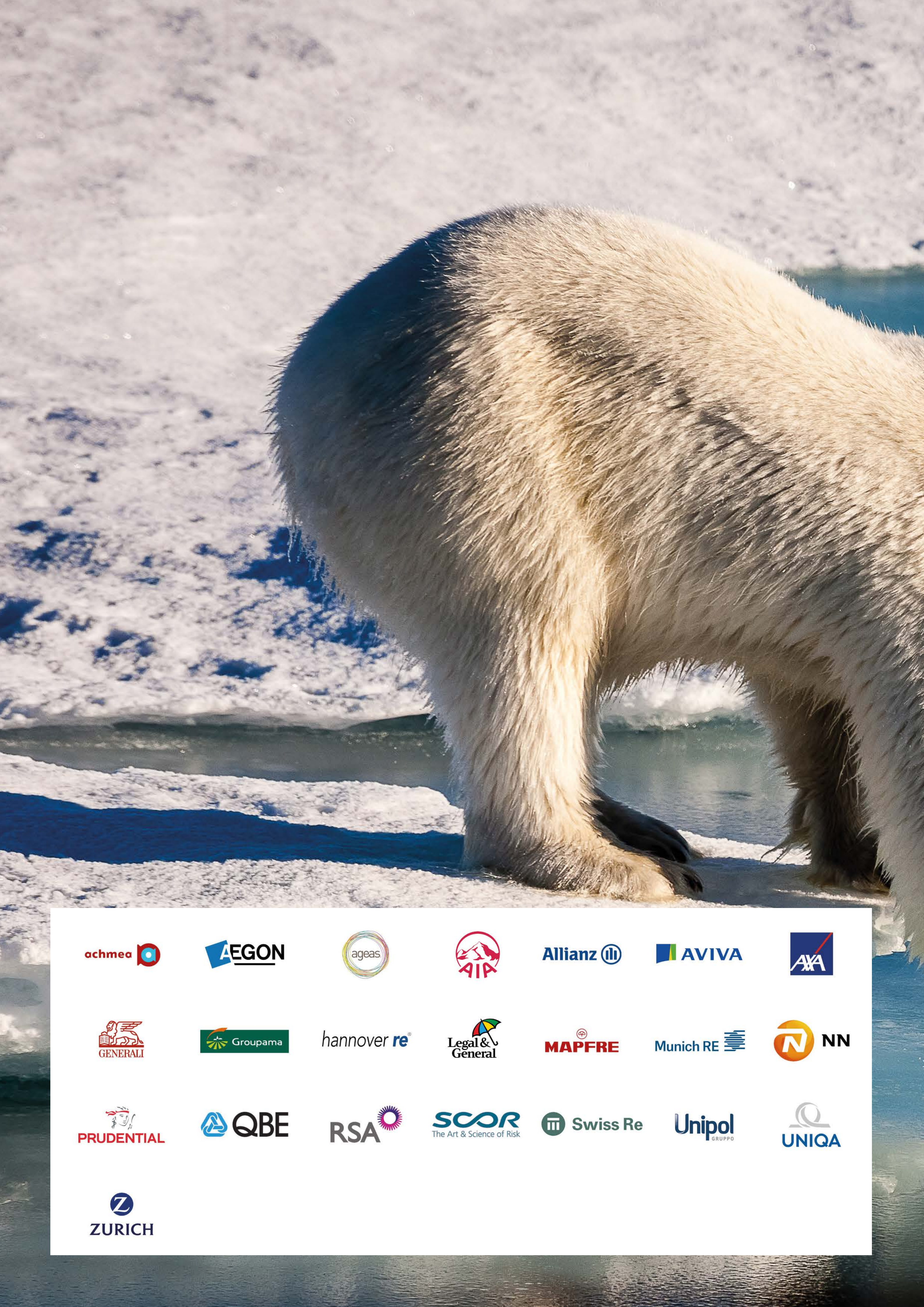

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