



Institute
and Faculty
of Actuaries

Resource and Environment Issues for Pensions Actuaries: Considerations for Setting Financial Assumptions

A working paper outlining climate change considerations for financial assumptions and practical examples of the role of scenario analysis to support them

by the Resource and Environment Issues for Pensions
Actuaries Working Party

Claire Jones (Chair); Jake Attfield; Evie Calcutt; Ruairi Campbell; Andrew Claringbold; Laura Duckering; Stuart Gray; Scott Harrison; Stephan Le Roes; Nick Spencer

15 October 2018

Contents

1. About this report.....	3
2. Why actuaries should consider climate risks	6
3. Previous climate/financial modelling studies	14
4. How pensions actuaries might reflect climate risks in financial assumptions.....	18
5. Illustrative impact on pension scheme funding.....	21
6. Considerations for actuaries wanting to use climate scenarios	25
7. Action points	27
Appendix 1: How actuaries might develop climate scenarios	29
Appendix 2: Resources for climate scenario analysis	35

sign up to receive updates from the IFoA by selecting “Resource and Environment” in their contact preferences on the IFoA website.

2. Why actuaries should consider climate risks

While there are many risks that actuaries need to consider, climate change is increasingly being highlighted as one that warrants special consideration due to its significant and systemic nature⁶.

There are three core reasons why actuaries should give specific consideration to climate risks, which we consider in the next three subsections:

1. **A material financial risk:** the market pricing typically used as a basis for financial assumptions may not fully reflect climate risks and the impact could be significant within the time horizon of pensions actuaries' work.
2. **Professional duty:** an IFoA risk alert highlights that actuaries are expected to consider climate risks and communicate their approach. Furthermore, some legal opinions suggest that actuaries have a professional obligation to explicitly consider climate risks and regulations increasingly make explicit reference to climate change.
3. **Widespread interest:** there is growing interest among regulators and policymakers in how financial institutions are considering climate risks. This in turn is prompting greater interest from pension scheme trustees, sponsors and members.

2.1 A material financial risk⁷

In his 2015 speech "Breaking the tragedy of the horizon"⁸, Mark Carney, Governor of the Bank of England, described three categories of risk arising from climate change: physical, transition and liability risks⁹. Each of these risk categories can impact the underlying assets in which pension funds are invested to achieve their return, as well as the broader macroeconomic environment.

2.1.1 Physical risks¹⁰: Physical risks arise from the effects of a changing climate itself. Such risks may arise in the short-term from damage to property and from business disruption due to a changing frequency and severity of extreme weather events such as hurricanes, droughts and flooding. In the longer-term, chronic impacts may dominate, such as rising temperatures and changes to rainfall patterns affecting use of land for agriculture and local workforce availability. Cities may face water shortfalls (for example, Cape Town has already required extreme conservation¹¹) and potentially be unable to supply households with

⁶ For example, the UN-backed Principles for Responsible Investment (PRI) recently described it as "the highest-priority environmental, social and governance (ESG) issue facing signatories today". See PRI (2018) *The Inevitable Policy Response to Climate Change* [online]. Available at <https://www.unpri.org/climate-change/the-inevitable-policy-response-to-climate-change/3578.article>

⁷ Some of the material in this section is repeated from IFoA (2018) *Climate Risk: A Practical Guide for Actuaries working in Defined Contribution Pensions*. Available at <https://www.actuaries.org.uk/documents/climate-risk-practical-guide-actuaries-working-defined-contribution-pensions>.

⁸ Carney, M (2015) *Breaking the tragedy of the horizon – climate change and financial stability*. Transcript available at <https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability>

⁹ For more information on the three types of risk, see PRA (2015) *The impact of climate change on the UK insurance sector: A Climate Change Adaptation Report by the Prudential Regulation Authority*. Available at <https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf>

¹⁰ For more information on physical risks, see European Bank for Reconstruction and Development and Global Centre of Excellence on Climate Adaptation (2018) *Advancing TCFD Guidance on Physical Climate Risks and Opportunities* <https://www.physicalclimaterisk.com/advancing-tcfid-guidance-physical-climate-risk>

¹¹ Welch, C (2018) *Why Cape Town Is Running Out of Water, and Who's Next*. National Geographic [online]. Available at <https://news.nationalgeographic.com/2018/02/cape-town-running-out-of-water-drought-taps-shutoff-other-cities/>

running water. This can impact long-term viability and attractiveness of the city to the workforce as well as constraining water use for industrial activity. Some areas will become less habitable, potentially causing large scale migrations that trigger social unrest and disrupt economic activity.

Rising sea levels represent another threat. Climate Central estimates that 275 million people worldwide live in areas that will eventually be flooded at 3°C of global warming¹². Cities that will be impacted include Miami, Shanghai, New York, Mumbai, Tokyo, Hong Kong, Rio de Janeiro, Alexandria, Lagos and Bangkok.

2.1.2 Transition risk: Transition risk is engendered by the shift to a low carbon economy, that is, an economy with significantly lower emissions of greenhouse gases (such as carbon dioxide) due to much lower fossil fuel use¹³. Depending on the nature and speed of policies and requirements by governments and regulators related to climate change, transition risks may pose varying levels of financial and reputational risk to insurers, pension funds and other institutional investors from the potentially rapid reduction in the market value of, or income generated by, assets.

For example, the risk referred to as “stranded assets” includes the inability of a company or industrial sector to generate revenue from its assets (eg plants, rights, land) due to restrictions placed on its activities or simply a collapse in demand. In effect, the assets become stranded, resulting in a decline in the company’s balance sheet value and share price, because the value or cash flows would no longer be able to materialise as expected. The collapse in the value of coal mining companies¹⁴ is often used as an example of stranded asset risk, with other fossil fuel-dependent companies and associated infrastructure considered to be at risk in future.

A broad array of companies and activities is likely to be impacted by transition risk, although opportunities are also emerging such as growth in low carbon renewable energy production and electric vehicles.

2.1.3 Liability risk: Liability risk relates to the potential costs arising where third parties seek compensation because they have suffered damage or losses from the effects of climate change¹⁵. A commonly cited example is the case of the Pacific Island nations, whose territory may disappear as sea levels rise, seeking recompense from industrial nations¹⁶.

From a pension scheme point of view, companies in which investments are held may face

¹² Climate Central (undated) *Surging Seas: Sea level rise analysis* [online]. Available at <http://sealevel.climatecentral.org/>. Holder, J, Kommenda, N and Watts, J (2017) *The three-degree world: the cities that will be drowned by global warming*. The Guardian [online]. Available at <https://www.theguardian.com/cities/ng-interactive/2017/nov/03/three-degree-world-cities-drowned-global-warming>

¹³ Or, possibly, extensive use of carbon capture and storage technologies

¹⁴ Goldenberg, S (2016) *The death of US coal: industry on a steep decline as cheap natural gas rises*. The Guardian [online]. Available at <https://www.theguardian.com/environment/2016/apr/08/us-coal-industry-decline-natural-gas>

¹⁵ For a summary of legal cases, see United Nations Environment Programme (2017) *The Status of Climate Change Litigation: A Global Review*. Available at <http://wedocs.unep.org/handle/20.500.11822/20767>

¹⁶ Sutton, M (2018) *Climate change litigation rising with the seas as victims revert to 'Plan B'*. ABC News [online]. Available at <http://www.abc.net.au/news/2018-04-10/climate-change-litigation-rising-with-the-seas-plan-b/9627870>

liability claims. For example, the Mayor of New York is suing oil and gas companies, seeking to recover the costs of measures to increase the city's resilience to climate change¹⁷ and ExxonMobil is facing a lawsuit for allegedly misleading investors by a historic failure to acknowledge climate risks to its business¹⁸. Whilst direct impacts may be unclear, such liability risks may become wrapped into other actions, taxes or sequestrations for specific companies.

There is also the possibility that pensions actuaries and their clients could face legal claims themselves if they fail to fulfil their professional duties – see section 2.2 below.

In his 2015 speech, Mark Carney contended that long term risks such as those arising from climate change were typically not priced properly by the market. This contention underpinned the formation of the Taskforce on Climate-related Financial Disclosures (TCFD) by the international Financial Stability Board¹⁹, in an attempt to improve transparency around climate risks and hence enable markets to price them more accurately. Although it is difficult, if not impossible, to test empirically the degree to which market prices reflect any given risk²⁰, the underpricing of climate risk is consistent with relatively low (albeit increasing) levels of climate knowledge and understanding among market participants. Further, whilst there is some evidence that markets have become more aware of potential climate risks since 2015, Mark Carney's general point of markets being poor at pricing of long-term risks remains²¹.

If markets are underestimating climate risks, that would likely mean there are additional risks relative to those reflected within market-based actuarial assumptions. In particular, markets may be underestimating the risk that:

- Lower economic growth leads to lower returns on equities, property and other assets
- Greater uncertainty in the economic outlook leads to lower asset values
- Costs of dealing with climate change (eg carbon taxes) lead to higher price inflation
- Lower economic growth due to climate impacts leads to lower price inflation
- Greater investment in climate adaptation and mitigation leads to higher interest rates
- Monetary policy measures to address lower economic growth lead to lower interest rates.

Clearly some factors act in opposite directions, so the net or predominant impact needs to be evaluated. We outline some studies into potential climate impacts on financial markets in section 3 and how scenarios to consider them may be developed in Appendix 1. However, it should be noted

¹⁷ Mooney, A and E Crooks (2018). *New York sues big oil companies over climate change*. Financial Times [online]. Available at <https://www.ft.com/content/4de8e4fc-f62b-11e7-88f7-5465a6ce1a00>

¹⁸ Stempel, J (2018). *U.S. judge dismisses Exxon lawsuit to stop climate change probes*. Reuters [online]. Available at <https://uk.reuters.com/article/us-exxon-mobil-lawsuit/u-s-judge-dismisses-exxon-lawsuit-to-stop-climate-change-probes-idUKKBN1H536R>

¹⁹ *Taskforce on Climate-related Financial Disclosures* [online] <https://www.fsb-tcf.org/>

²⁰ Some attempts have been made, eg Society of Actuaries (2018) *Managing Climate and Carbon Risk in Investment Portfolios*, available at <https://www.soa.org/research-reports/2018/managing-climate-carbon-risk/>

²¹ For more on market pricing of long-term risks, see 2nd Investing Initiative and The Generation Foundation (2018) *All Swans are Black in the Dark*, available at <http://tragedyofthehorizon.com/All-Swans-Are-Black-in-the-Dark.pdf>

that whilst the real world impacts of climate change may emerge over long time horizons, the impacts on financial markets could be sudden, “*a climate Minsky moment*” in Mark Carney’s words²². The CISL study outlined in section 3.2 illustrates an “*extreme yet plausible*”²³ scenario in which equity prices drop by around 50% as part of the market repricing climate risks. The Principles for Responsible Investment (PRI)’s Inevitable Policy Response research programme considers “*an inevitable, rapid and forceful climate policy response*” as likely in the 2020s²⁴.

2.2 Professional duty

An IFoA risk alert, dated May 2017, states that “*Actuaries should ensure that they understand, and are clear in communicating, the extent to which they have taken account of climate-related risks in any relevant decisions, calculations or advice*”²⁵. Risk alerts contain non-mandatory guidance which the IFoA publishes to protect the public interest.

UK DB pensions actuaries’ wider professional duties in this area have been highlighted in a report²⁶ by ClientEarth, an environmental law charity which is perhaps best known in the UK for winning three air pollution cases against the Government²⁷. It has already demonstrated its willingness to file reports with financial regulators when it considers pension schemes and companies are taking insufficient action on climate risks²⁸.

In ClientEarth’s view, actuaries’ duties include conducting their work with “reasonable” care and skill, using assumptions and models that are fit for purpose, communicating material risks and uncertainties to clients, and taking care that their advice is appropriate given the legal duties and other rules which may govern the matter. ClientEarth notes that “*actuaries who fail to consider and take into account climate risk in their work and advice now face increasing risks of legal liability and regulatory sanctions*”²⁹. More recently, ClientEarth has written to the trustees of 14 of the UK’s largest pension schemes, putting them on notice of possible legal challenge if they fail to take climate risk seriously³⁰. Whilst the exact nature and extent of actuaries’ and trustees’ duties in this area would be for the courts to decide, we imagine that individual actuaries and trustees would prefer to exercise caution and minimise the risk of becoming the subject of a test case.

²² Carney, M (2015) *op. cit.*

²³ CISL (2015) *Unhedgeable risk: How climate change sentiment impacts investment* (p50). Available at <http://www.cisl.cam.ac.uk/publications/sustainable-finance-publications/unhedgeable-risk>

²⁴ PRI (2018) *The Inevitable Policy Response to Climate Change* [online]. Available at <https://www.unpri.org/climate-change/the-inevitable-policy-response-to-climate-change/3578.article>

²⁵ IFoA (2017) *Risk Alert: Climate-Related Risks*. Available at <https://www.actuaries.org.uk/documents/risk-alert-climate-related-risks>

²⁶ ClientEarth (2017) *Risky business: Climate change and professional liability risks for DB pensions actuaries*. Available at <https://www.clientearth.org/new-reports-bring-light-climate-liability-risks-facing-pensions-advisers/>

²⁷ ClientEarth (2018) *UK Government loses third air pollution case as judge rules air pollution plans ‘unlawful’* [online]. Available at <https://www.clientearth.org/government-loses-third-air-pollution-case-judge-rules-air-pollution-plans-unlawful/>

²⁸ ClientEarth and ShareAction (2017) *Referral to the Pensions Regulator: Local Government Pension Scheme and Climate Risk*. Available at <https://www.documents.clientearth.org/wp-content/uploads/library/2017-02-10-clientearth-referral-to-the-pensions-regulator-igps-funds-coll-en.pdf>. ClientEarth and ShareAction (2018) *Contract-based pensions and climate risk: Report and recommendations to the Financial Conduct Authority*. Available at <https://www.documents.clientearth.org/wp-content/uploads/library/2017-02-01-contract-based-pensions-and-climate-risk-report-and-recommendations-to-the-financial-conduct-authority-coll-en.pdf>. ClientEarth (2018) *EasyJet among companies reported to regulator by ClientEarth* [online]. Available at <https://www.clientearth.org/easyjet-among-companies-reported-to-regulator-by-clientearth/>

²⁹ ClientEarth (2017) *op. cit.*, p12

³⁰ ClientEarth (2018) *Top UK pension funds put on notice over climate risk*. ClientEarth [online]. Available at <https://www.clientearth.org/top-uk-pension-funds-put-on-notice-over-climate-risk/>

There is an increasing number of explicit references to climate change in pensions law and regulation, including:

- The Pensions Regulator’s DB Investment guidance³¹
- The revised EU Directive for Institutions for Occupational Retirement Provision (IORPs)³²
- Recent changes to the 2005 Investment Regulations³³.

Whilst, strictly speaking, these requirements relate to investment rather than funding, climate risks to investments are clearly relevant to funding advice, particularly within an integrated risk management framework.

In addition, subject to materiality and proportionality, consideration of climate risks is arguably required to meet the Reliability Objective which underpins the UK Financial Reporting Council’s technical actuarial standards: “Users for whom actuarial information is created should be able to place a high degree of reliance on that information’s relevance, transparency of assumptions, completeness and comprehensibility, including the communication of any uncertainty inherent in the information”³⁴.

2.3 Widespread interest

There has been growing interest in climate risks across the financial sector and beyond. In addition to the regulatory developments listed in section 2.2:

- The Prudential Regulation Authority (PRA) published a report on climate change³⁵ in September 2015, alongside Mark Carney’s “tragedy of the horizon” speech (see section 2.1). Whilst predominately focused on the insurance sector, it highlighted the potential risks to financial stability across the whole market.
- Several organisations have co-ordinated letter writing campaigns by pension scheme members, citing concerns about climate risks and often requesting divestment from fossil fuels³⁶. In October 2018, a member threatened to complain to the UK Pensions Ombudsman because he was not satisfied with the responses provided by the Shell

³¹ The Pensions Regulator (2017) *DB investment*. Available at <http://www.thepensionsregulator.gov.uk/guidance/db-investment.aspx>

³² Official Journal of the European Union (2016) *Directive (EU) 2016/2341 of the European Parliament and of the Council of 14 December 2016 on the activities and supervision of institutions for occupational retirement provision (IORPs)*. Available at <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016L2341>

³³ Department for Work and Pensions (2018) *Pension trustees: clarifying and strengthening investment duties*. Available at <https://www.gov.uk/government/consultations/pension-trustees-clarifying-and-strengthening-investment-duties>

³⁴ Financial Reporting Council (2016) *Framework for FRC technical actuarial standards* (p2). Available at <https://www.frc.org.uk/actuaries/actuarial-policy/technical-actuarial-standards/technical-actuarial-standards-2017>

³⁵ PRA (2015) *The impact of climate change on the UK insurance sector: A Climate Change Adaptation Report by the Prudential Regulation Authority*. Available at <https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/publication/impact-of-climate-change-on-the-uk-insurance-sector.pdf>

³⁶ For example, Howard, E (2015) *How to divest your pension fund: steps to take and arguments to face*. The Guardian [online]. Available at <https://www.theguardian.com/environment/2015/jul/06/how-to-divest-pension-fund-steps-arguments-fossil-fuels>. Fossil Free UK (undated) *How to Run a Divestment Campaign* [online]. Available at <https://gofossilfree.org/uk/divestment-guide/>. Friends of the Earth (2018) *What is divestment? And is your council funding climate change?* [online]. Available at <https://friendsoftheearth.uk/climate-change/divestment>. UNISON (2018) *UNISON launches campaign to divest pensions from carbon* [online]. Available at <https://www.unison.org.uk/news/press-release/2018/01/unison-launches-campaign-divest-pensions-carbon/>

Contributory Pension Fund to his climate letters³⁷. In Australia, a member filed a legal case against his superannuation fund in July 2018 for failing to provide sufficient information about climate risks and any plans to address those risks to enable him to make informed decisions³⁸.

- In June 2017, the TCFD issued disclosure recommendations³⁹ for companies and other financial institutions relating to climate-related risks and opportunities. These voluntary recommendations have attracted widespread support, including from over 280 financial firms responsible for assets of nearly \$100 trillion⁴⁰. There is specific guidance for asset owners, with a number of UK pension schemes already publicly committed to reporting in line with the TCFD recommendations⁴¹.
- The European Commission has a “sustainable finance” programme, launched in 2016, with ambitious plans to build a financial system that supports sustainable growth. Supporting the transition to a low carbon economy is central to its proposals, which include clarifying institutional investors’ duties regarding sustainability⁴².
- In February 2018, the Environmental Audit Committee (a House of Commons select committee) asked the largest 25 UK pension schemes how they are addressing climate risk. It published the responses on 25 May 2018 and concluded that *“it is encouraging that a majority of the UK’s largest pension funds say they are taking steps to manage the risks that climate change poses to UK pension investments. But a minority of funds appear worryingly complacent. Pension funds should at least assess the exposure of their assets to the physical, transition and liability risks from climate change that will materialise during savers’ lifetimes.”*⁴³
- Following an appearance before the Environmental Audit Committee in February 2018, the Pensions Regulator highlighted in a blog that *“Climate risks impact broadly across business, the economy and markets and are not just an issue for scheme investments. Many schemes are also sponsored by employers whose financial positions and prospects for growth are dependent on current and future policies and developments in relation to climate change. ... many trustees seem to be behind the curve in assessing and managing climate risk to their schemes”*⁴⁴.

³⁷ Thompson, J (2018) *Shell pension fund challenged to disclose response to climate risk*. Financial Times [online]. Available at <https://www.ft.com/content/f4a43daa-511e-384e-b297-9193f90233a7>

³⁸ Grantham Research Institute on Climate Change and the Environment (2018) *McVeigh v. Retail Employees Superannuation Trust* [online]. Available at <http://www.lse.ac.uk/GranthamInstitute/litigation/mcveigh-v-retail-employees-superannuation-trust/>

³⁹ TCFD (2017) *Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures*. Available at <https://www.fsb-tcdf.org/publications/final-recommendations-report/>

⁴⁰ TCFD (2018) *TCFD Publishes First Status Report while Industry Support Continues to Grow*. Available at https://www.fsb-tcdf.org/wp-content/uploads/2018/09/Press-Release-TCFD-2018-Status-Report_092518_FINAL.pdf

⁴¹ *TCFD Supporters* [online] <https://www.fsb-tcdf.org/supporters-landing/>

⁴² European Commission (undated) *Sustainable Finance* [online]. Available at https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance_en

⁴³ Environmental Audit Committee (2018) *UK’s top 25 Pension funds show mixed response to climate change*. Available at <https://www.parliament.uk/business/committees/committees-a-z/commons-select/environmental-audit-committee/news-parliament-2017/top-25-pension-funds-letters-17-19/>

⁴⁴ Raymond, A (2018) *TPR at the Environmental Audit Committee*. The Pensions Regulator [online]. Available at <https://blog.thepensionsregulator.gov.uk/2018/02/20/tr-at-the-environmental-audit-committee/#more-835>

As a result of these developments and rising public and business awareness of climate change more generally, more pension trustees are discussing climate risks with their advisers. While most attention is currently focused on investment angles, there will likely be greater interest in the funding (and covenant) angles in future as trustees take a more holistic view of the impact of climate risks. The funding angle will be particularly important for those schemes seeking to implement the TCFD's recommendation to use scenario analysis to understand their exposure to climate-related risks and opportunities.

2.4 Why actuaries should consider climate risks: conclusion

As explained above, from a materiality and professional duty perspective, it is clear that pensions actuaries should consider climate risks and, where relevant, communicate their approach, regardless of whether their client explicitly requests them to do so. The UK Department of Work and Pensions recently introduced a specific reference to climate change in the policies to be set out in occupational pension schemes' Statements of Investment Principles due to its "systemic and cross-cutting nature"⁴⁵, having previously stated that "*there is a broad scientific and public policy consensus that climate change is such a [financially material] risk*"⁴⁶. When consulting on this change, it said that it expects the occasions where "*trustees conclude that there is no requirement for consideration of financially material risks, including those arising from ... climate change, to be limited and focused on very particular circumstances – for example imminent scheme wind-up*"⁴⁷.

In our view, pensions actuaries and their clients are currently much more likely to make implicit than explicit adjustments to allow for climate risks. When considering the implications of climate risks for their funding advice, pensions actuaries may wish to have regard to:

- The fact that climate risks are emerging risks so are likely to have had limited impact on the market return history which is typically used to calibrate return forecasts and expectations;
- The contention that markets do not typically price these risks well but focus on shorter time horizons (see section 2.1);
- The potential financial impact of risks shown by modelling studies (see sections 3.2 and 6);
- Potential interrelated effects, especially the impact of climate risks on investments and sponsor covenant strength within an integrated risk management framework;
- The time horizon of funding objectives, recovery periods and investment strategy, noting that climate risks may also affect annuity pricing from insurers if buy-out forms part of the scheme's targeted objective (see section 3.3);
- The degree to which climate risks and opportunities have been taken into account within the scheme's investment approach;
- The ability of the scheme to navigate emerging risks and opportunities (for example through

⁴⁵ Department of Work and Pensions (2018) *Clarifying and strengthening trustees' investment duties: Government response*. Available at <https://www.gov.uk/government/consultations/pension-trustees-clarifying-and-strengthening-investment-duties> (p17)

⁴⁶ Letter from Guy Opperman MP, Minister for Pensions, to Mary Creagh MP, Chair of the Environmental Audit Committee, dated 15 February 2018. Available at <https://www.parliament.uk/documents/commons-committees/environmental-audit/180215-Guy-Opperman-to-Chair-Green-Finance.pdf>

⁴⁷ Department of Work and Pensions (2018) *Consultation on clarifying and strengthening trustees' investment duties*. Available at <https://www.gov.uk/government/consultations/pension-trustees-clarifying-and-strengthening-investment-duties> (p11)

well-resourced and proactive investment committees);

- The desired level of overall prudence for the funding basis, mindful of the uncertainties arising from climate risks;
- Suitable scenarios and stress tests to communicate the potential impact of climate risks to their client;
- Appropriate caveats for their work, given the uncertainty and early stage of modelling work in this area.

3. Previous climate/financial modelling studies

3.1 Research on financial impact has been focused on climate change

As a working party, we investigated the previous research that had been undertaken on the financial impacts of R&E issues. We found that almost exclusively the work had focused on climate change, reflecting the fact that climate change is a very significant issue for the whole global economy and, as discussed in section 2.1, represents a material financial risk for pension schemes.

We found limited research on financial impacts of other R&E issues. There was some discussion of water availability, although this work is difficult to undertake as water impact is location-specific and overlaps with the physical impacts from climate change. Although this report focuses on climate change, actuaries should be aware of the potential impact of R&E issues more generally (and other emerging risks) on economic and financial conditions when advising on financial assumptions. The World Economic Forum's annual Global Risks Reports are good sources of information on emerging risks⁴⁸.

3.2 Limited number and suitability of studies that have quantified financial impacts

We have found limited published research that gives even tentative answers to the potential financial impact of climate change. Almost all studies into the macroeconomic effects of climate change have been confined to exploring the impact on GDP, which is only indirectly relevant for pension scheme funding⁴⁹. There are also challenges in differentiating between long term economic effects, what the markets are currently pricing, and the potential market shocks if and when the market reprices climate risks.

Such studies that exist have generally focused on asset risks, primarily for equities, with limited quantification of macroeconomic risks such as future interest rates and inflation expectations. The main studies we found that looked at risks to pension schemes' investment portfolios were:

3.2.1 Mercer – Investing in a time of climate change, 2015⁵⁰

This considers the impacts of four climate change scenarios on 14 industry sectors, 16 asset classes and an example portfolio. It uses an integrated assessment model (IAM) which combines climate and economic aspects. The investment impacts are modelled by considering the sensitivity of each asset class and industry sector to four climate risk factors – technology (T), resource availability (R), physical impact (I) and policy (P) – which play out differently under each scenario. It finds the sector-level impacts to be most meaningful over the period 2015-2050, ranging from +3.5% pa for renewable energy to -4.9% pa for coal under the most impactful scenario, with asset class and portfolio impacts more muted.

⁴⁸ The latest one is World Economic Forum (2018) *The Global Risks Report 2018*. Available at <https://www.weforum.org/reports/the-global-risks-report-2018>

⁴⁹ See Bank of England (2018) *Staff Working Paper No. 706: Climate change and the macro-economy: a critical review*. Available at <https://www.bankofengland.co.uk/working-paper/2018/climate-change-and-the-macro-economy-a-critical-review>

⁵⁰ Mercer (2015) *Investing in a time of climate change*. Available at <https://www.mercer.com/our-thinking/wealth/investing-in-a-time-of-climate-change.html>

This study investigates the impact on asset classes that are relevant for pension schemes, although its focus on average impacts over a 35 year period makes it less relevant for those with shortened time horizons. It does not present all the information needed to study the overall effect on the funding level, although we understand that Mercer will be releasing a report later in 2018 that addresses this gap. However, there are two more fundamental problems: IAMs have structural limitations which means they are likely to underestimate climate impacts⁵¹; and the modelling assumes that real world economic impacts are felt simultaneously in financial markets, whereas in practice markets can react much more quickly as they anticipate and price in future changes, thereby impacting asset prices sooner and more suddenly. Mercer recognised these challenges and adjusted the IAM to address the underestimation of physical damages to help address the first of them.

3.2.2 Cambridge Institute for Sustainability Leadership (CISL) – Unhedgeable risk: How climate sentiment impacts investment, 2015⁵²

This complements Mercer’s work by studying the potential impact of climate change on investment portfolios if the long-term real world effects are priced into markets in the short-term. It was not aimed specifically at UK pension schemes, but nonetheless provides useful insights for this audience.

The study uses the Oxford Economics Global Economic Model, a widely-used international macroeconomic model, and applies “sentiment” shocks to eight macroeconomic variables over the next 1-5 years corresponding to two scenarios (2 Degrees and No Mitigation). It then models the economic impacts over the period to 2050 if the subsequent real world changes mirror those assumed by the sentiment shocks (and there are no further sentiment changes). The impact, relative to a Baseline scenario, is calculated for four investment portfolios with differing allocations to equities, government and corporate bonds. All portfolios experience losses over the next five years in the No Mitigation scenario, the largest being a 45% loss for the portfolio with the highest equity allocation (60%). The authors conclude that it is not possible to hedge much more than half of this risk by reallocating assets to different sectors and regions, hence the report’s title.

Like the Mercer one, this study only considers the asset side of pension scheme’s balance sheets. It uses fewer asset classes than the Mercer study and ones that are less relevant for UK pension schemes (the bonds have a three month, two year or ten year term, and all of the portfolios studied have an international mix of government bonds), reflecting its different audience and purpose. The results are more extreme than those from Mercer, reflecting CISL’s deliberate consideration of possible but not probable scenarios, as well as a significantly different modelling approach. Whilst being a helpful illustration, it should be noted that a single sentiment shock which correctly anticipates all future real world impacts

⁵¹ Kolstad C., K. Urama, J. Broome, A. Bruvoll, M. Carino Olvera, D. Fullerton, C. Gollier, W. M. Hanemann, R. Hassan, F. Jotzo, M. R. Khan, L. Meyer, and L. Mundaca, 2014: Social, Economic and Ethical Concepts and Methods. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlomer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Available at http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter3.pdf. Robert S. Pindyck; The Use and Misuse of Models for Climate Policy, *Review of Environmental Economics and Policy*, Volume 11, Issue 1, 1 January 2017, Pages 100–114, <https://doi.org/10.1093/reep/rew012>

⁵² CISL (2015) *op.cit.*

would not happen in practice. Sentiment shocks tend not to occur at a single point in time but as information emerges – and then tend to overshoot before an equilibrium is found. Additionally, investment market shocks trigger actions with real world consequences and that interaction takes time to resolve.

3.2.3 Aon – Climate change challenges: Climate change scenarios and their impact on funding risk and asset allocation, 2018⁵³

This considers four scenarios and, like the CISL study, considers how asset prices may suddenly change to capitalise anticipated future changes in growth. In addition to equity returns (from various regions) and property returns, it considers the potential impact on gilt yields and corporate bond spreads thereby allowing pension scheme funding levels to be assessed. The impacts on key parameters are presented over the short-term (next three years), the intermediate-term (four to ten years) and long-term (eleven to twenty years). Under some scenarios the funding impact can be significant over the next 10 years, although the sooner that policy action is taken the less significant the impact is likely to be and the sooner the market recovers (because the policy changes are smaller and more gradual, hence less disruptive). Under the no mitigation scenario, the funding impact is not felt for ten years but is then very significant over the next five years (with the impact on equity returns being of similar magnitude to that experienced in the CISL no mitigation scenario). See section 5 for more details.

This is the most useful report published to date, from the perspective of a UK pensions actuary, because it considers the key funding parameters over relevant time horizons. It sidesteps some of the theoretical challenges encountered by Mercer and CISL by not explicitly using an economic model to estimate the climate impacts. Instead, the starting point for the derivation of the scenarios is a review of relevant studies such as those referred to in this section and Appendix 1. These studies (in particular the CISL study) together with expert opinion are used to inform the sensitivities. This is then combined with analysis of historic financial data and modelling work to understand the scale of shocks and interactions. Plausible narratives are presented for each scenario.

We hope this will be an increasing body of work over time.

3.3 No published research into implications for annuity pricing

An increasing proportion of UK DB pension schemes have funding objectives linked to the cost of buying out their liabilities with an insurer and/or are de-risking through a series of buy-in contracts. For such schemes, whether, when and how much climate risks affect annuity pricing is critical.

We had no success in identifying any published research into how annuity pricing is, or might be, impacted by R&E effects, other than some preliminary comments in the PRA's 2015 report about the impact of climate change on the UK insurance sector⁵⁴. Anecdotal evidence suggests that there has

⁵³ Aon (2018) *Climate Change Challenges: Climate change scenarios and their impact on funding risk and asset allocation*. Available at <http://www.aon.com/getmedia/8ddb2a56-c1a9-4689-81e6-f3b7c178e57c/Climate-Change-Challenges.aspx>. Aon (2018) *Climate Change Challenges: Some case studies*. Available at www.aon.com/getmedia/e8648ded-3146-4a81-9887-65a02d8f49fe/Climate-Change-Challenges-Case-Studies.aspx

⁵⁴ Prudential Regulation Authority (2015) *op. cit.*

been little, if any, impact on annuity pricing to date. However, this might change as the regulatory focus increases⁵⁵ and insurers' thinking on climate risks develops (perhaps as they start to implement the TCFD recommendations that many of them have shown support for). Moreover, an IFoA working party is developing a practical guide to climate change for life insurance actuaries⁵⁶ which might lead to research in this area. The ongoing interest from the regulators was highlighted in October 2018 when the PRA announced a consultation on a draft supervisory statement setting out its expectations regarding UK financial firms' approaches to managing the financial risks from climate change⁵⁷.

3.4 The uncertainty of uncertainty: scientific consensus but a range of unknowns

In addressing climate risks, the quantification of potential risks is made harder by the multiple levels of uncertainty. Not only is there uncertainty about the climate system itself and how it will respond to increasing atmospheric concentrations of greenhouse gas emissions, but there is much uncertainty about future levels of greenhouse gas emissions. These will depend on the responses of governments, regulators, businesses and individuals, both to climate change targets (particularly those set out in the 2015 Paris Agreement⁵⁸) and to technological and economic developments. Moreover, the risks will play out over many decades, with a lag in the physical impacts due to inertia in the climate system.

The uncertainty means a wide range of possible outcomes, and there are many different pathways that lead to similar climate outcomes yet have different economic impacts⁵⁹. For example, a long-term equilibrium rise in global average temperatures of (say) 3°C relative to pre-industrial times might arise from various different trajectories of energy consumption levels and mix of energy sources.

It will be important for actuaries to continually keep climate expectations, probabilities and impacts under review as more information emerges about policy initiatives, technological developments, climate modelling developments and business responses. The actual climate and financial impacts will almost certainly be different from current expectations. This should not be used as an excuse for not considering climate risks, but instead emphasises the need to consider a range of possible scenarios and the resilience of a pension scheme's funding position under these different scenarios.

⁵⁵ Bank of England (undated) *Climate Change* [online]. Available at <https://www.bankofengland.co.uk/climate-change>

⁵⁶ *A Practical Guide to Climate Change for Life Actuaries* [online]. Available at <https://www.actuaries.org.uk/practice-areas/resource-and-environment/research-working-parties/practical-guide-climate-change-life-actuaries>

⁵⁷ Prudential Regulation Authority (2018) *Consultation Paper 23/18: Enhancing banks' and insurers' approaches to managing the financial risks from climate change*. Available at <https://www.bankofengland.co.uk/prudential-regulation/publication/2018/enhancing-banks-and-insurers-approaches-to-managing-the-financial-risks-from-climate-change>

⁵⁸ United Nations Climate Change (undated) *The Paris Agreement* [online]. Available at <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>

⁵⁹ UNEP Finance Initiative (2018) *Extending our Horizons, Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations, PART 1: Transition-related risks & opportunities*. Available at <http://www.unepfi.org/publications/banking-publications/extending-our-horizons/>

4. How pensions actuaries might reflect climate risks in financial assumptions

As stated in section 3, there are few studies which are directly relevant to the potential impact of climate risks on financial assumptions, hence it is not possible to confidently assess the impact let alone adjust financial assumptions, particularly at this early stage of analysis. We recognise that there are perceived difficulties in allowing explicitly for climate risks within market-consistent financial assumptions. Actuaries are appropriately cautious within a market-consistent basis about incorporating factors that are not based on direct market observations. However, for the aspects of funding models that are calibrated using historic market data rather than current market prices, it is important for actuaries to consider how the future may differ from the past. This is particularly relevant for climate risks which are barely captured in historic data and will be much more significant in the future.

There is often subjectivity in the choice of assumptions for future investment returns as these typically include expected returns from growth assets which cannot be directly derived from market prices. It is possible that increased uncertainty, for example due to climate risks, may lead actuaries to conclude that a greater margin of prudence is required. However, in practice, we expect that actuaries will not be comfortable recommending explicit adjustments to financial assumptions to allow for climate risks. It is more likely that they would like to assess the risks to the funding position through scenario analysis. Of course, this may indirectly lead to actuaries recommending the adoption of a more prudent basis as it leads to a desire to get to “full funding” quicker. However, it should also be noted that this may be just one of several factors that would lead to trustees wanting to accelerate funding. In addition, consideration of climate risks might cause trustees to have less confidence in the strength of the employer covenant and conclude that this warrants a greater margin of prudence.

There is not a wide and openly-available body of research on the macroeconomic impacts of climate change, especially on inflation and interest rates. This makes it difficult to robustly incorporate these impacts, and their potential variability, into stochastic funding projections. Further there is a risk that such calculations generate a spurious level of confidence, with the limitations being overlooked by users even if they are very clearly communicated. Instead, given the uncertainty of macroeconomic impacts, narrative scenarios and stress tests can be more helpful tools. The limitations and assumptions of scenarios and stress tests are more visible to different audiences.

Scenario analysis gives the trustees or employer an understanding of plausible future paths. They can then take a view as to how important climate risks are to them and will be better able to identify the warning signs and key risks. Having a narrative description of the scenarios is key to developing users’ understanding of climate risks and supporting any parameterisation.

There has recently been an explosion of interest in climate scenario analysis due to its prominence in the TCFD recommendations: *“Organizations should describe how resilient their strategies are to climate-related risks and opportunities, taking into consideration a transition to a lower-carbon economy consistent with a 2°C or lower scenario and, where relevant to the organization, scenarios*

*consistent with increased physical climate-related risks.*⁶⁰ We expect to see considerable work in this area over the coming years, including some directly relevant to pension schemes, as organisations start to implement the recommendations and this is likely to provide useful material for actuaries⁶¹.

The focus of scenario analysis will differ between schemes. Ideally, scenarios would incorporate the impacts on covenant strength and demographic assumptions, as well as the impacts on asset values and financial assumptions. The analysis might be used to show the deficit and additional contributions that would be required if the scenario unfolds or whether climate risks could derail the chance or timing of meeting the long-term funding objective. The various stakeholders could then decide whether the scenario would be manageable and whether they should do anything differently, now or in the future.

If there is a narrative, the impact on the employer's covenant can also be considered in any particular scenario. This does not necessitate a numerical analysis, but should at least allow a subjective comparison as to whether the employer would still be able to manage the same level of funding in that scenario.

This fits with the Pensions Regulator's Integrated Risk Management framework⁶². If some of the scenarios would cause significant problems for the scheme, then the parties can consider:

- Whether any further action should be taken now;
- Identifying the key metrics that could be monitored to give advance warning of the scenario;
- What action could be taken quickly if the scenario does unfold.

Actions that can be taken include:

- Review the investment strategy to reduce its climate risk exposure and/or increase diversification away from the covenant risk;
- Aim to pay more or earlier contributions (either through strengthening of the Technical Provisions or shortening of the Recovery Plan) so that the funding has reached a sufficient level before the risks are expected to get too high;
- Seek to take less investment risk generally, to keep within the trustees' overall risk appetite;
- Ask the employer to consider further the risks to the business that could arise from the scenarios and provide assurance that it is managing climate risks appropriately.

Finally, for a scheme that is targeting buy-out, the impacts of climate risks on annuity pricing will also be relevant. Potential impacts may become clearer as a result of the anticipated developments outlined in section 3.3. It will be important for pensions actuaries to monitor these developments to inform allowances for possible future changes in annuity pricing in their advice.

⁶⁰ TCFD (2017) *Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures*. Available at <https://www.fsb-tcf.org/publications/final-recommendations-report/> (p21)

⁶¹ For some of the latest materials, visit the TCFD Knowledge Hub at <https://www.tcfhub.org/>

⁶² The Pensions Regulator (2015) *Integrated Risk Management*. Available at <http://www.thepensionsregulator.gov.uk/guidance/guidance-integrated-risk-management.aspx>

Section 5 illustrates the potential impacts of climate change on two real-life pension schemes under a set of scenarios. Section 6 then outlines why actuaries might need to develop climate scenarios themselves and sets out some challenges to consider when using scenarios. The appendices provide material to help actuaries develop their own climate scenarios.

5. Illustrative impact on pension scheme funding

Section 6 discusses the considerations for creating and using climate scenarios. However, before describing such considerations, we thought it would be helpful to provide an example of their use.

As outlined in section 3.2, Aon has published a set of climate scenarios to support trustees' decision making⁶³. The scenarios were based on expert opinion on the potential financial impacts of climate change together with historical analysis of the interactions between asset classes and were chosen to focus on the most relevant and thought-provoking scenarios for pension schemes.

Aon has also published a couple of real-life case studies which use these scenarios⁶⁴. We have summarised these case studies below to indicate the potential magnitude of climate impacts on pension scheme funding and give insights into how the results of the scenario analysis can be used.

Aon considers five scenarios:

- **Base Case** – future returns in line with what is priced into the market. This is assumed to mean that some progress is made to limit greenhouse gas emissions and the effects of climate change are not as bad as climate scientists predict.
- **Green Regulation** – immediate and coordinated action to tackle climate change using taxes and regulation.
- **Green Skies** – in addition to Green Regulation there is also rapid advancement of green technology and private innovation.
- **Forced Green** – little is done for 5 years but then sufficient scientific evidence emerges/social awareness increases (eg through increasing extreme weather events) such that governments then address greenhouse gas emissions.
- **No Mitigation** – little sustainable policy action is undertaken over the next 10 years but eventually market participants grasp the implications of climate change. There is then an expectation of a permanent future loss and the market reacts accordingly.

In these scenarios, it is assumed for simplicity that there is no impact on the demographic variables⁶⁵.

The two case studies involve companies that are already actively managing climate risks and have low residual exposure to the transitional risks from climate, so consideration of the covenant was not a significant part of the scenario analysis. Both schemes have a long-term objective to be significantly de-risked (at which point they would be invested in gilts and bonds and probably with

⁶³ Aon (2018) *Climate Change Challenges: Climate change scenarios and their impact on funding risk and asset allocation*. Available at <http://www.aon.com/getmedia/8ddb2a56-c1a9-4689-81e6-f3b7c178e57c/Climate-Change-Challenges.aspx>

⁶⁴ Aon (2018) *Climate Change Challenges: Some case studies*. Available at www.aon.com/getmedia/e8648ded-3146-4a81-9887-65a02d8f49fe/Climate-Change-Challenges-Case-Studies.aspx

⁶⁵ For a discussion of how climate change might affect UK mortality rates, see IFoA (2017) *Resource and Environment Issues for Pensions Actuaries: Implications for Setting Mortality Assumptions*. Available at <https://www.actuaries.org.uk/documents/environment-issues-pension-actuaries-implications-setting-mortality-assumptions> and International Actuarial Association (2017) *Climate Change and Mortality*. Available at https://www.actuaries.org/CTTEES_ENVIRO/Papers/REWG_CCandMortality_final_Nov2017.pdf

an eye on securing the benefits with an insurance company). In the first case, the scheme was expected to reach its long-term objective in around 5-6 years whereas in the second case, the time expected was around 10 years. Both schemes still had a reasonable exposure to growth assets. However, the first scheme had most of the liabilities hedged whereas the second scheme was largely unhedged.

These characteristics are summarised below (to make comparison easier, we have expressed both funding levels relative to the long-term target whereas the Aon case study shows the second case study relative to Technical Provisions):

Case Study	Sensitivity of covenant to climate change	Allocation to growth assets	Liability hedge	Starting Funding Level	Expected time to reach long-term objective
1	Low	50%	90%	87%	5-6 years
2	Low	65%	30%	80%	10 years

The projections of the funding levels under different time horizons under the No Mitigation, Green Regulation and Forced Green scenarios (relative to base case) are shown below. For the purpose of the modelling, the investment strategy was assumed to remain unchanged until the scheme reaches its long-term objective (at which time it would be de-risked and the funding level would remain at 100%):

Scenario	Change in Funding Level relative to Base Case					
	After 2 years		After 10 years		After 20 years	
	Case Study 1	Case Study 2	Case Study 1	Case Study 2	Case Study 1	Case Study 2
No Mitigation	0%	-5%	0%*	-10%	0%*	-40%
Green Regulation	-11%	-9%	0%*	0%*	0%*	0%*
Forced Green	-1%	-4%	-6%	-20%	0%*	-1%

* would have achieved the long-term objective and de-risked by this time

Under the No Mitigation scenario, the physical impacts of climate change would not seriously damage economic growth over the short term and markets would react very little to what damage there is (so the short-term returns are only marginally below the base case). However, inflation expectations would increase in this scenario. This would not have a significant impact on the funding in the first case study because inflation is largely hedged but it would increase the liabilities in the second case study (without a compensating increase in the value of the assets). In case study 1, the scheme would have de-risked by the time a significant impact is felt. However, in case study 2, the scheme would not have reached its long-term objective after 10 years and it would still be significantly exposed to climate change impacts on financial markets thereafter. Under case study 2 the impact on the relative funding level is huge, exacerbated by the maturity of the scheme at that time.

Under the Green Regulation scenario, the changes that are made to policy and regulation would create uncertainty and economic disruption, hampering economic growth and corporate profitability in the short term. This would lead to a reduction in the funding level over the first few years for both case studies. The impact is slightly lower in the second case study as a result of the scheme's liabilities being under-hedged and therefore it would benefit from higher gilt yields. In both cases, these short-term losses would be reversed over the next few years so that both schemes would be expected to reach their long-term objectives within 10 years.

Under the Forced Green scenario, delaying action would mean that the costs of tackling the problem were higher. In the first Case Study, the funding level would be 15% lower than the base case at the end of year 6 and the scheme would not be expected to reach its long-term objective within 10 years. Nevertheless, it would still be expected to reach its long-term objective within 20 years. The trustees felt that this was manageable albeit undesirable. The impact is worse in the second case study – partly because the scheme has a higher allocation to growth assets but also because it has less hedging and therefore the funding level under its long-term objective is negatively impacted by falling gilt yields. In this case study, the funding level would be 24% lower than the base case at the end of year 6. The scheme would still be expected to reach its long-term objective eventually, but it would now be expected to take around 20 years. While the trustees believe the covenant to be strong, they were a little nervous about relying on the covenant for that long.

At the time of writing this report, the trustees are considering the implications of these projections⁶⁶. Even in the first case study where the outcomes are considered more manageable, the trustees have decided that they wish to consider their investment strategy to mitigate some of this risk.

However, should they be doing anything else?

There is probably little that can be done with regards to the company covenant other than what the company is already doing. However, in the second case study, in particular, it has raised the following questions:

- Should the trustees be trying to get to full funding quicker to reduce the risk that they will be hit by a sudden and significant market correction in the medium- to long-term?
- What measures can the trustees put in place to try and receive advance warning that climate risks are crystallising, so they can react before it is too late?

Furthermore, issues still remain even when the scheme may be regarded as de-risked. Firstly, there is the general point that (unless liabilities are exactly matched by an insurance policy) hedging is imperfect due to uncertainties in the liability cashflows and hence some residual risk, including from climate change, is inevitable. Secondly, there may be additional risks from climate change, for example:

- Where the matching investments include corporate bonds, there could be increased default risk for many corporate bonds

⁶⁶ The conclusions outlined in the following paragraphs are repeated from Aon (2018) *Climate Change Challenges: Some case studies*. Available at www.aon.com/getmedia/e8648ded-3146-4a81-9887-65a02d8f49fe/Climate-Change-Challenges-Case-Studies.aspx

- Inflation may be affected which would have an impact on the projected liability cashflows, and so the structure of the hedging requires careful consideration.

In both these case studies, the companies have been very supportive and were already taking action themselves to mitigate the risks of climate change. For other schemes, the covenant risks may be more significant and warrant explicit inclusion in the scenarios. Some sponsoring companies will be less engaged with climate risks and scenario analysis could start a dialogue with the company as how they can manage the risks more effectively.

6. Considerations for actuaries wanting to use climate scenarios

Following publication of the TCFD recommendations in June 2017, there has been an increased focus on developing tools to assist with climate-related scenario analysis. Much of this work has been aimed at assisting individual companies, rather than financial institutions which need to consider economy-wide impacts. A few projects are helping financial institutions to apply scenario analysis to equity and corporate bond portfolios by aggregating impacts across individual holdings⁶⁷. However, we are not aware of any that are considering the interest rate and inflation parameters required by pension schemes to apply scenario analysis to their overall funding position, other than the proprietary approaches being developed by Aon and Mercer (see section 3.2) and Ortec Finance⁶⁸.

Other actuarial firms may wish to develop their own scenarios and some actuaries may need bespoke scenarios to assist individual clients (for example, to incorporate aspects of particular relevance to the sponsor covenant). In these situations, actuaries might leverage commonly used scenarios such as those published by the International Energy Agency (IEA) or the Intergovernmental Panel on Climate Change (IPCC), or they might develop their own from first principles. Appendix 1 provides some more detail that can assist with this⁶⁹.

The case studies in section 5 are illustrative of the work that can be undertaken with trustees. But it should be clear that this is an emerging area of practice with a number of issues that actuaries need to consider, both for themselves and for communicating clearly to their clients:

- Climate change scenarios are likely to be more subjective than other types of scenarios that pensions actuaries typically use (eg recession). This is because there is little (or no) past data with which to calibrate them. This makes them more dependent on the narratives with less certainty on both the risk levels and potential impact.
- The nature of climate risks is such that actuaries will probably want to consider scenarios over a longer range of durations than usual.
- The physical impacts of climate change are likely to emerge gradually and the full impacts will not be felt for decades. However, markets may anticipate the impacts and price them in more quickly (although discounting would reduce the effect of future impacts, particularly the longer-term ones).
- Transitional impacts are likely to emerge a lot sooner. Again, market pricing may anticipate the expected future impact of these transitional changes. As seen by the dot-com crash in 2000 and the credit crunch in 2008, when markets do react they can react very rapidly.
- It is hard to disentangle the physical and transitional impacts. As physical impacts emerge, and there is greater awareness of likely future physical impacts in the absence of mitigating actions, transitional measures are more likely to be implemented.

⁶⁷ For example, ET Risk (undated) *Models* [online], available at <http://et-risk.eu/toolbox/models/> and UNEP Finance Initiative (undated) *Pilot Project on Implementing the TCFD Recommendations for Banks* [online], available at <http://www.unepfi.org/banking/tcfd/>

⁶⁸ Ortec Finance (2018) *Climate-savvy scenarios sets for strategic investment decision-making* [online]. Available at <https://www.ortecfinance.com/en/insights/research/climate-savvy-scenarios-sets-for-strategic-investment-decision-making>

⁶⁹ Contrary to a statement in the July 2017 version of “Resource and Environment Issues: A Practical Guide for Pensions Actuaries”, the IFA does not currently have any plans to develop or commission its own climate scenarios. However, we welcome actuaries’ views on whether such work would be helpful.

- Scenarios are usually developed relative to a base case. Actuaries need to be clear about the climate assumptions underlying the base case and allow for them appropriately when estimating scenario impacts relative to the baseline. For example, in the Aon scenarios, the base case assumes future experience is in line with what is priced into the market. However, as discussed in section 2.1, it is likely that the market does not have climate risks fully priced in. Effectively, Aon has assumed that market prices are consistent with the combined effects of physical and transition impacts not being as bad as experts are warning.
- Key drivers of the present value of pension scheme liabilities are movements in gilt yields (nominal and real) and price inflation. The long-term objective for many trustees is to secure the liabilities with an insurance company or to run a very low risk investment strategy – in both cases, the biggest driver is likely to be the movement in gilt yields. However, it is very difficult to predict climate impacts on gilt yields as there are a number of competing drivers:
 - On one hand, nominal (and to a lesser extent, real) yields may be pushed higher in the short-term due to a substantial increase in borrowing by governments to finance transition measures (which necessitates a rise in yields to attract funds) and a rise in inflation due to higher production costs incurred by the shift away from fossil fuels (eg due to a carbon price or tax to incentivise the shift).
 - On the other, the forced reduction in emissions and a shift away from fossil fuels may lead to a drag on economic growth and lower yields.

Therefore, it is probably important to have different scenarios where each of these drivers dominate.

- Scenarios may be used to identify the magnitude of climate risks for high-level investment strategies, but they may not have sufficient granularity to design an investment strategy with lower climate risk. For example, Aon's initial scenarios only consider the main asset classes (ie equities, property, corporate bonds, fixed interest gilts and index-linked gilts) although they do consider the impacts separately by region.
- Given the considerable uncertainty around how and when climate impacts will emerge, and the challenges of allowing for them in actuarial work, it will be important for actuaries to communicate clearly the purpose and limitations of any scenario analysis.

The point of a scenario is to give some insight as to what may happen rather than trying to predict the future precisely. As in the case studies, these can inform judgements on how impactful risks can be and the value of investigating potential mitigating actions.

7. Action points

Climate modelling is a very active area of research and recent developments such as the TCFD recommendations are focusing attention on how to improve the modelling of economic and financial impacts. It is clear that much remains to be done, particularly in understanding how climate risks might affect the macroeconomic variables of greatest interest to pensions actuaries, and the interplay between real world economic impacts and financial market pricing impacts. It will be important for actuaries to stay abreast of developments, both of research which improves our understanding of climate risks, and of policy, regulatory and technological changes that change the likelihood of possible future scenarios.

We encourage actuaries to contribute to research in this area. So far, only a handful of quantitative scenarios for pension funding impacts are publicly available. There are many more scenarios that could be considered, for many more pension scheme contexts, with different judgements made regarding the design and parameterisation of models. Aspects that warrant greater attention include the potential impacts on gilt yields, inflation and annuity pricing, especially identifying the types of scenarios that could lead to an increase in these variables and the types that could lead to a decrease. Whilst uncertainty is inherent in this type of modelling, we hope that consensus will emerge over the direction and order of magnitude of the impacts.

We also hope that modelling approaches will be developed which enable more integrated consideration of the funding, investment and covenant impacts. Most investment modelling currently groups assets by asset class, but, as Mercer's work has shown (see section 3.2), climate impacts are expected to vary more by industry sector than by asset class. Moreover, the impacts are expected to vary considerably within industry sectors. In the future, more granular models may be able to help trustees explore the funding impacts of possible options to increase the climate resilience of investment portfolios.

In the short term, we suggest the following actions for actuaries who advise on the financial assumptions adopted by UK defined benefit pension schemes:

- Learn more about R&E risks, particularly climate risks, and discuss them with your clients. See the footnotes to this report for suggested reading and look at our working party's other reports;
- Encourage trustees to discuss R&E issues with their investment adviser, covenant adviser and the employer as well;
- Find out how your clients are addressing R&E risks in their investment processes, and their assessment of R&E risks to the covenant strength, and consider whether your funding advice is consistent with this information;
- Help trustees to adopt an integrated risk management approach that considers long term risks such as R&E risks;
- Use scenario analysis to explore the uncertainty in financial (and demographic) factors arising from climate risks;
- Offer to help your clients to apply the TCFD's recommendations in their reporting;

- Review whether your financial modelling adequately incorporates R&E risks and whether the documentation is adequate;
- Contribute to discussions about how actuaries might improve the allowance for R&E risks in their modelling, especially through the development of climate risk scenarios;
- When giving advice, communicate your approach to R&E risks and the associated uncertainty;
- Keep abreast of relevant developments in all areas (climate modelling, policy, regulation and technology), for example through selecting R&E in your IFoA communication preferences.

Appendix 1: How actuaries might develop climate scenarios

1. Approaches to developing scenarios

To enable an integrated risk management approach, actuaries would ideally use scenarios that incorporate impacts on all of the following:

- Asset values
- Covenant strength
- Financial parameters (gilt yields, inflation and investment returns)
- Demographic parameters, particularly mortality⁷⁰.

Various organisations have published climate scenarios, with varying focuses and varying levels of detail. However, none of them are likely to be suitable for actuaries to use “off the shelf” because they typically include few of the variables needed to study the impacts listed above. Instead, actuaries will probably need to extend existing scenarios by adding these variables or to develop their own scenarios from scratch.

An alternative approach that might be available to some actuaries is to collaborate with the sponsoring employer, particularly if the pension scheme is material to the company’s financial position. Climate scenario analysis is already used quite extensively by companies in the energy and resources sectors, increasing numbers of financial companies are now working on such analysis, and its use is likely to spread to other sectors as take-up of the TCFD recommendations increases⁷¹. If the company already has its own scenarios, and is willing to share them, the actuary might be able to use them as the starting point, which has the advantage of providing a relatively easy way of incorporating the covenant impacts and (if the company has done them well) indicate the most significant risks from a covenant perspective.

We outline some of the most commonly used published scenarios in section 3 of this appendix. Actuaries wishing to develop their own scenarios may wish to look at the Energy Transition Risks & Opportunities (ET Risk) research consortium’s toolkit⁷². It is designed to help stakeholders assess the financial risks and opportunities associated with the transition to a low-carbon economy⁷³. For other resources to help with the development of scenarios, see Appendix 2.

Once the starting point for developing the scenarios has been chosen, actuaries will need to select the number and type of scenarios to use.

⁷⁰ Club Vita has published three climate change longevity scenarios. See Club Vita (2018) *Hot and Bothered? How climate change might affect UK longevity*. Available at <https://www.clubvita.co.uk/collaborative-research/hot-and-bothered>

⁷¹ Centre for Policy Development (2018) *Climate horizons report: Scenarios and strategies for managing climate risk*. Available at <https://cpd.org.au/wp-content/uploads/2018/06/Climate-Horizons-report-2018.pdf>

⁷² ET Risk (2016) *Transition Risk Toolbox: Scenarios, Data, and Models*. Available at <http://et-risk.eu/transition-risk-toolbox/>

⁷³ ET Risk has also developed two scenarios for use by financial analysts and institutional investors, but they are not cross-sectorally consistent so are not suitable for portfolio-level analysis.

2. Selection of scenarios

The TCFD recommends that narrative scenarios should incorporate not just the outcomes of the scenario (eg temperature rise of 2°C by 2100⁷⁴), but also the pathways to achieving those outcomes (both the “how” and the “why”). The TCFD envisages that organisations will start with qualitative narratives and only later attempt to add quantitative information⁷⁵. We concur with this approach.

The TCFD has stated five desirable characteristics of scenarios: plausible, distinctive, consistent, relevant and challenging (to conventional wisdom)⁷⁶. In addition, scenarios should reflect the latest developments in climate science, policy and technology. Good sources of information on these topics include the IPCC and the United Nations Environment Programme⁷⁷.

Given the uncertainties associated with climate outcomes, it is likely to be appropriate for actuaries to consider more than one scenario, corresponding to different temperature outcomes and perhaps also different speeds of low carbon transition (eg smooth and early, late and sudden)⁷⁸. This might include:

- 1.5°C scenario, corresponding to the ambition within the Paris Agreement⁷⁹
- 2°C scenario, corresponding to the long-standing international policy target confirmed in the Paris Agreement
- 3°C scenario, corresponding to the national policy pledges⁸⁰ made to date in support of the Paris Agreement⁸¹
- 4-5°C scenario, corresponding to a failure to honour existing policy pledges and/or climate impacts being more severe than indicated by current models.

Note that there is a trade-off between long-run physical risks and short-run transition risks. Keeping to lower temperature rises will require more significant short-run transition impacts. The long-run physical risks become larger as the temperature rise becomes greater. However, short-run physical impacts are likely to be similar under all scenarios for the next 20-30 years due to inertia in the climate system which takes significant time to reach equilibrium following changes in greenhouse gas concentrations⁸². Temperatures will continue to rise over this period due to greenhouse gases that have already been emitted, almost regardless of the greenhouse gases that are emitted in future.

⁷⁴ Global average, relative to the pre-industrial period

⁷⁵ TCFD (2017) *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*. Available at <https://www.fsb-tcf.org/publications/final-technical-supplement/>

⁷⁶ TCFD (2017) *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*. Available at <https://www.fsb-tcf.org/publications/final-technical-supplement/>

⁷⁷ <http://www.ipcc.ch/> and <https://www.unenvironment.org/explore-topics/climate-change>

⁷⁸ TCFD and Bank of England (2017) *Conference on Climate Scenarios, Financial Risk and Strategic Planning – Summary of Day 2*. Available at <https://www.fsb-tcf.org/event/tcf-d-boe-conference-climate-scenarios-financial-risk-strategic-planning/>

⁷⁹ United Nations Climate Change (undated) *op. cit.*

⁸⁰ Known as Nationally Determined Contributions (NDCs). These are reviewed every five years and are due to increase under a ratchet mechanism.

⁸¹ United Nations Environment Programme (2017) *The Emissions Gap Report 2017*. Available at <https://www.unenvironment.org/resources/emissions-gap-report>

⁸² Centre for Policy Development (2018) *op. cit.*

Nonetheless, physical risks should be included within scenarios, as these can be material particularly for real assets and sectors such as agriculture. Furthermore, scenarios in which physical risks emerge earlier are likely to lead to earlier action to cut greenhouse gas emissions.

3. Commonly used scenarios

Some of the published scenarios describe the policy and technology pathways leading to a particular temperature outcome, whereas others are described in terms of greenhouse gas emission levels⁸³. The former are more suitable for investigating the economic and financial impacts of climate change. They are typically top-down macro scenarios that include variables such as:

- Energy demand
- Energy production, split by type of fossil fuel, renewable energy and nuclear
- Carbon pricing, fossil fuel subsidies and energy efficiency measures
- Deployment of solar power, electric vehicles and CCS (carbon capture and storage)
- GDP and population growth⁸⁴.

The most commonly used scenarios are those of the IEA, with the IPCC ones also widely cited. The main IEA and IPCC scenarios are outlined below. Figure 1 indicates the approximate global average temperature rise they correspond to, relative to pre-industrial times. The Paris Agreement commitment to pursue efforts to limit temperature rises to 1.5°C has catalysed additional research into 1.5°C scenarios, but these are not yet widely used⁸⁵.

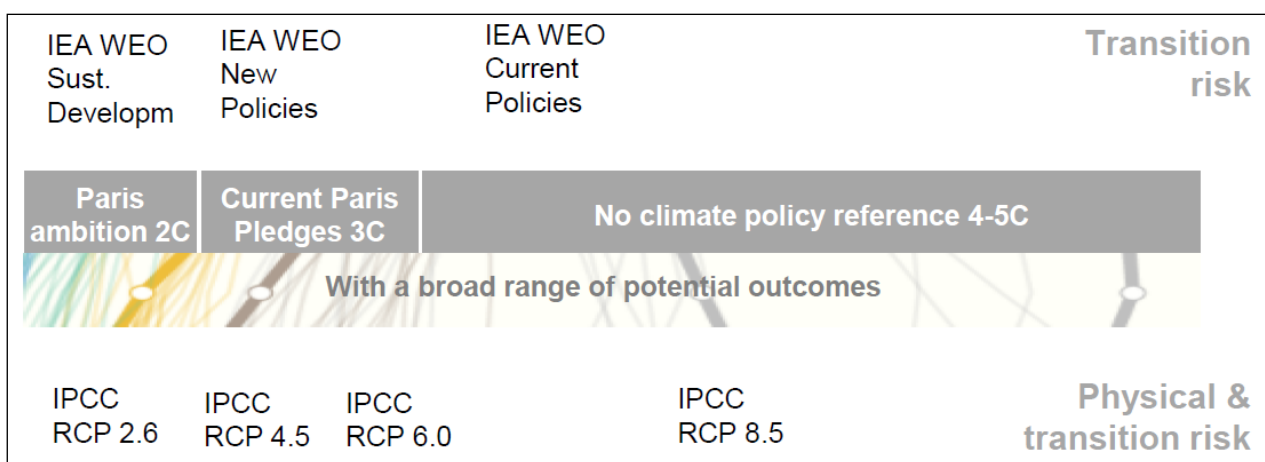


Figure 1 – Approximate temperature outcomes associated with commonly-used IEA and IPCC scenarios⁸⁶

⁸³ TCFD (2017) *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*. Available at <https://www.fsb-tcfd.org/publications/final-technical-supplement/>

⁸⁴ *ibid*

⁸⁵ For comprehensive information on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, see IPCC (2018) *Global Warming of 1.5°C*. Available at <http://ipcc.ch/report/sr15/>

⁸⁶ CICERO Climate Finance (2018) *Climate scenarios demystified. A climate scenario guide for investors*. Available at <http://www.cicero.oslo.no/en/publications/internal/2867>. Reproduced with permission.

The IEA used three main scenarios in its 2017 World Energy Outlook report⁸⁷. These describe policy and technology pathways that represent increasing levels of mitigation ambition:

- Current Policies – only policies that were firmly enacted by mid-2017
- New Policies – also includes aims, targets and policies that had been announced
- Sustainable Development – intended to keep long-term temperature rises below 2°C⁸⁸.

The IEA scenarios are relatively comprehensive, but have various limitations:

- Only extend to 2040
- Omit physical risks
- Focused on the energy sector, so less useful for other sectors⁸⁹
- High reliance on nuclear energy and CCS
- Historically misaligned with trends
- May overlook or underestimate important factors such as tipping points, unforeseen technological innovation and failure to deploy the most cost-efficient solutions
- Assume limited disruption over next five years since based on existing investment pipeline⁹⁰.

Nonetheless, they are widely used and are probably more amenable to adaptation by actuaries than the IPCC scenarios which are described in terms of greenhouse gas concentrations.

The main IPCC scenarios are a set of four Representative Concentration Pathways (RCP). They are named after their corresponding radiative forcing values in the year 2100 relative to pre-industrial times (ie 2.6, 4.5, 6.0, and 8.5 W/m²)⁹¹. The highest number corresponds to the highest temperature increase and greatest physical risks. As shown in Figure 2, this is a “business as usual” scenario in which heavy fossil fuel use continues and so transition risks are limited. Moving to the right across the diagram, the scenarios with lower numbers have lower physical risks but higher transition risks. On the right-hand side of Figure 2, the RCP 2.6 scenario corresponds to a good chance of global average temperature rises being limited to 2°C. It should be noted that there are still considerable physical risks in this scenario, albeit they are much smaller than in RCP 8.5.

On their own, the RCP scenarios are of limited use for assessing the economic and financial impacts of climate change. However, the IPCC has also developed a set of five Shared Socioeconomic Pathways (SSP) that describe possible social, demographic and economic changes up to 2100. The baseline SSP scenarios make no allowance for climate mitigation beyond those already in place⁹².

⁸⁷ IEA (2017) *World Energy Outlook 2017*. Available at <https://www.iea.org/weo2017/>

⁸⁸ TCFD and Bank of England (2017) *op. cit.*

⁸⁹ This may make it harder for actuaries to incorporate the covenant impact if the sponsoring employer is not in the energy sector.

⁹⁰ Centre for Policy Development (2018) *op. cit.* and ET Risk (2017) *The Transition Risk-o-Meter: Reference Scenarios for Financial Analysis*. Available at <http://et-risk.eu/the-transition-risk-o-meter/>

⁹¹ Radiative forcing is a measure of cumulative greenhouse gas emissions from human sources.

⁹² We understand that the current version of the SSP pre-date the 2015 Paris Agreement and so do not include the policies arising from the commitments made under that Agreement.

Mitigation measures can then be added to the SSPs and IAMs used to assess the climate impacts.

It seems that the economic models underlying the IEA and IPCC scenarios do not incorporate interest rates and inflation; certainly these variables are not included in any of the published outputs we have seen. Even if they were included, it is not clear whether they would be suitable for use by pension schemes:

- The scenarios are typically underpinned⁹³ by integrated assessment models (IAMs) that combine socioeconomic and climate models. As noted in section 3.2, IAMs have serious limitations which means they are likely to underestimate the financial impacts of climate change.
- The interest and inflation rates components of the model may not have been intended for use in this way and/or have received less scrutiny than the more commonly used components.
- The model's baseline economic scenario may not be consistent with the economic parameters used in the actuary's own base case (eg the funding basis to which climate impacts are being applied)⁹⁴.

As noted in the main body of the report, the TCFD's recommendation to use scenario analysis is catalysing considerable work in this area, so we are hopeful that more useful scenarios for actuaries will become available over the next few years. One initiative to watch is the PRI's Inevitable Policy Response research programme which will be looking in depth at scenarios involving "an inevitable, rapid and forceful climate policy response" including the implications for strategic asset allocation and how to increase the resilience of investment portfolios⁹⁵. Another is Ortec Finance's recently-announced "climate-savvy scenarios" which aim to help pension schemes and insurers explore the impact of climate risks on their asset-liability modelling⁹⁶.

⁹³ OECD and IEA (2012) *Macroeconomic analysis using the OECD ENV-Linkages model*. Available at <http://www.iea.org/media/weowebiste/2013/Methodologymacroeconomicimpacts.pdf> and Keywan Riahi, Detlef P. van Vuuren, Elmar Kriegler, Jae Edmonds, Brian C. O'Neill, Shinichiro Fujimori, Nico Bauer, Katherine Calvin, Rob Dellink, Oliver Fricko, Wolfgang Lutz, Alexander Popp, Jesus Crespo Cuaresma, Samir KC, Marian Leimbach, Leiwen Jiang, Tom Kram, Shilpa Rao, Johannes Emmerling, Kristie Ebi, Tomoko Hasegawa, Petr Havlik, Florian Humpenöder, Lara Aleluia Da Silva, Steve Smith, Elke Stehfest, Valentina Bosetti, Jiyong Eom, David Gernaat, Toshihiko Masui, Joeri Rogelj, Jessica Strefler, Laurent Drouet, Volker Krey, Gunnar Luderer, Mathijs Harmsen, Kiyoshi Takahashi, Lavinia Baumstark, Jonathan C. Doelman, Mikiko Kainuma, Zbigniew Klimont, Giacomo Marangoni, Hermann Lotze-Campen, Michael Obersteiner, Andrzej Tabeau, Massimo Tavoni (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, *Global Environmental Change*, Volume 42, 2017, Pages 153-168, <https://doi.org/10.1016/j.gloenvcha.2016.05.009>.

⁹⁴ The model's economic parameters may be static (or periodically recalibrated) rather than mark-to-market. In this case, it may be more appropriate to use the relative impacts from the model rather than the absolute ones. For example, the change in inflation between the base case and climate scenario, rather than the absolute inflation rate in the climate scenario. However, it will be important to consider carefully what climate outcomes are implied by the base case and whether this is consistent with the climate outcomes being priced by the markets (if the actuary is using a market-related basis). Note that market pricing may not correspond to a coherent climate scenario: it could simultaneously underestimate both physical and transition risks.

⁹⁵ PRI (2018) *The Inevitable Policy Response to Climate Change* [online]. Available at <https://www.unpri.org/climate-change/the-inevitable-policy-response-to-climate-change/3578.article>

⁹⁶ Ortec Finance (2018) *Climate-savvy scenarios sets for strategic investment decision-making* [online]. Available at <https://www.ortecfinance.com/en/insights/research/climate-savvy-scenarios-sets-for-strategic-investment-decision-making>

Carbon crossroads

The Intergovernmental Panel on Climate Change (IPCC) explores four potential futures depending what policies governments adopt to cut emissions

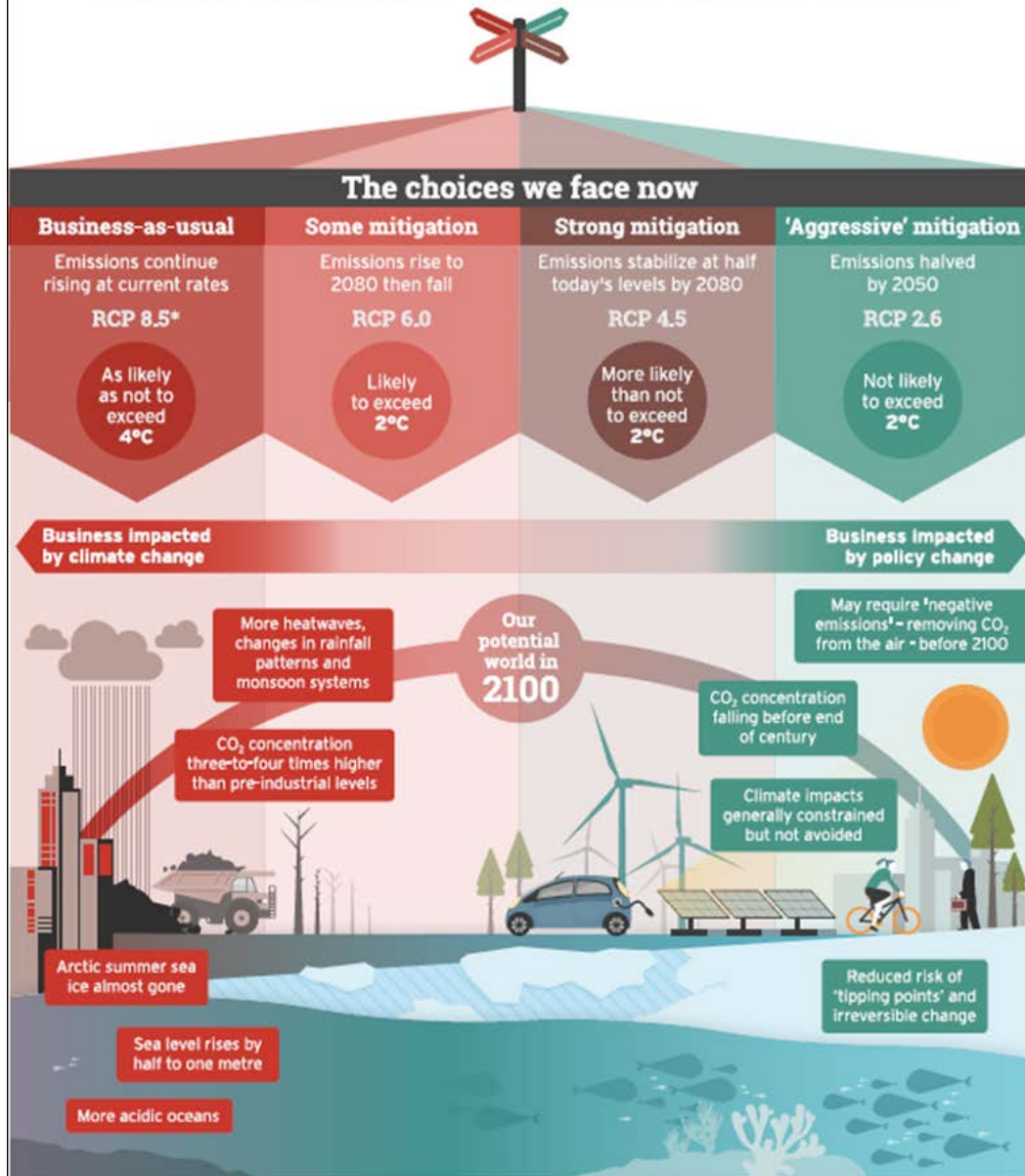


Figure 2 – The IPCC’s four scenarios illustrate the trade-off between physical risks resulting from climate change and transition risks resulting from mitigating actions⁹⁷

⁹⁷ European Climate Foundation (2013) *Climate change: Action, trends and implications for business - The IPCC's Fifth Assessment Report, Working Group 1*. Available at <http://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/climate-science>. Reproduced under a Creative Commons BY-NC-SA licence: <https://creativecommons.org/licenses/by-nc-sa/3.0/>

Appendix 2: Resources for climate scenario analysis

2° Investing Initiative and Paris Agreement Capital Transition Assessment (2017) *Out of the fog: Quantifying the alignment of Swiss pension funds and insurances with the Paris Agreement* <https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-and-financial-markets.html>

Acclimatise (2017) *Using scenarios in corporate disclosure of physical climate risk* http://www.acclimatise.uk.com/wp-content/uploads/2017/11/Acclimatise-Briefing_TCFD-Recommendations.pdf

Action on Climate Today (2017) *Calculating the impact of climate change on economic growth* http://www.actiononclimate.today/images/pdf/P1976_Working_Paper_130417_WEB.pdf

Aon (2018) *Climate change challenges: Climate change scenarios and their impact on funding risk and asset allocation* www.aon.com/getmedia/8ddb2a56-c1a9-4689-81e6-f3b7c178e57c/Climate-Change-Challenges.aspx

Aon (2018) *Climate change challenges: Some case studies* www.aon.com/getmedia/e8648ded-3146-4a81-9887-65a02d8f49fe/Climate-Change-Challenges-Case-Studies.aspx

Cambridge Institute for Sustainability Leadership (2015) *Unhedgeable risk: How climate sentiment impacts investment* <http://www.cisl.cam.ac.uk/publications/sustainable-finance-publications/unhedgeable-risk>

Carbon Brief (2018) *Explainer: How 'Shared Socioeconomic Pathways' explore future climate change* <https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change>

Centre for Policy Development (2018) *Climate Horizons Report: Scenarios and Strategies for Managing Climate Risk* <https://cpd.org.au/wp-content/uploads/2018/06/Climate-Horizons-report-2018.pdf>

CICERO Climate Finance (2018) *Climate Scenarios Demystified: A Climate Scenario Guide for Investors* <http://www.cicero.oslo.no/en/publications/internal/2867>

Club Vita (2018) *Hot and Bothered? How climate change might affect UK longevity* <https://www.clubvita.co.uk/collaborative-research/hot-and-bothered>

ET Risk (2016) *Transition Risk Toolbox: Scenarios, Data, and Models* <http://et-risk.eu/transition-risk-toolbox/>

European Bank for Reconstruction and Development and Global Centre of Excellence on Climate Adaptation (2018) *Advancing TCFD Guidance on Physical Climate Risks and Opportunities* <https://www.physicalclimaterisk.com/advancing-tcf-d-guidance-physical-climate-risk>

IEA *Future Scenarios for Climate Change* <https://www.iea.org/topics/climatechange/scenarios/>

Mercer (2015) *Investing in a Time of Climate Change* <http://www.mercer.com/content/dam/mercer/attachments/global/investments/mercer-climatechange-report-2015.pdf>

Riahi et al (2017) *The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview*, *Environmental Change* 42 (2017), 153–168 <https://www.sciencedirect.com/science/article/pii/S0959378016300681>

PRI (2018) *The Inevitable Policy Response to Climate Change* <https://www.unpri.org/climate-change/the-inevitable-policy-response-to-climate-change/3578.article>

TCFD (2017) *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities* <https://www.fsb-tcf.org/publications/final-technical-supplement/>

TCFD Knowledge Hub <https://www.tcfhub.org/>

TCFD and Bank of England (2017) *Conference on Climate Scenarios, Financial Risk and Strategic Planning*: <https://www.fsb-tcf.org/event/tcf-boe-conference-climate-scenarios-financial-risk-strategic-planning/>

van Vuuren et al (2011) *The Representative Concentration Pathways: An Overview* *Climatic Change* (2011) 109: 5 <https://link.springer.com/article/10.1007/s10584-011-0148-z>



Institute and Faculty of Actuaries

DISCLAIMER The views expressed in this publication are those of invited contributors and not necessarily those of the Institute and Faculty of Actuaries. The Institute and Faculty of Actuaries do not endorse any of the views stated, nor any claims or representations made in this publication and accept no responsibility or liability to any person for loss or damage suffered as a consequence of their placing reliance upon any view, claim or representation made in this publication. The information and expressions of opinion contained in this publication are not intended to be a comprehensive study, nor to provide actuarial advice or advice of any nature and should not be treated as a substitute for specific advice concerning individual situations. On no account may any part of this publication be reproduced without the written permission of the Institute and Faculty of Actuaries.

Beijing

14F China World Office 1 · 1 Jianwai Avenue · Beijing · China 100004
Tel: +86 (10) 6535 0248

Edinburgh

Level 2 · Exchange Crescent · 7 Conference Square · Edinburgh · EH3 8RA
Tel: +44 (0) 131 240 1300 · Fax: +44 (0) 131 240 1313

Hong Kong

1803 Tower One · Lippo Centre · 89 Queensway · Hong Kong
Tel: +852 2147 9418

London (registered office)

7th Floor · Holborn Gate · 326-330 High Holborn · London · WC1V 7PP
Tel: +44 (0) 20 7632 2100 · Fax: +44 (0) 20 7632 2111

Oxford

1st Floor · Park Central · 40/41 Park End Street · Oxford · OX1 1JD
Tel: +44 (0) 1865 268 200 · Fax: +44 (0) 1865 268 211

Singapore

163 Tras Street · #07-05 Lian Huat Building · Singapore 079024
Tel: +65 6717 2955

www.actuaries.org.uk

© 2018 Institute and Faculty of Actuaries