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# Climate-Related Scenarios Applied to Insurers and Other Financial Institutions

Climate Risk Task Force

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# IAA Paper

# Climate-Related Scenarios Applied to Insurers and Other Financial Institutions

This paper was prepared by the Climate Risk Task Force of the International Actuarial Association (IAA).

The IAA is the worldwide association of professional actuarial associations, with several special interest sections and working groups for individual actuaries. The IAA exists to encourage the development of a global profession, acknowledged as technically competent and professionally reliable, which will ensure that the public interest is served.

The role of the Climate Risk Task Force is to deliver on the Statement of Intent for IAA Activities on Climate-Related Risks (SOI) as adopted by Council on 7 May 2020.

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This paper has been approved for IAA publication by the Climate Risk Task Force in accordance with the IAA's Communications Policy.

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*This paper was written prior to the release of the Sixth Assessment Report (AR6) produced by the Intergovernmental Panel on Climate Change (IPCC). AR6 adds to AR5 and updates it. The reader is advised to consult AR6 for updated information.*

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## Executive Summary

Scenario analysis is a core component of climate-related risk assessment and disclosure. This topic is of increasing importance to businesses, governments, standard-setters, and supervisors as they seek to understand the future impact of climate-related risks.

The actuarial profession has considerable experience and expertise with the construction and use of scenarios in risk management processes used by insurers and other financial institutions. With the increasing importance of climate-related risk, the actuarial profession recognizes the need to outline practical approaches in applying climate scenarios to firms.

This paper builds on an earlier IAA paper, "Introduction to Climate-Related Scenarios".[1] It examines the challenges faced by actuaries in implementing scenario analysis for climate-related risks and outlines a range of possible approaches.

The scope and information provided cover a wide variety of situations faced by actuaries working in different contexts. In addition to considering scenario development, the paper examines the guidance provided by several actuarial organizations to their members regarding climate risk assessment. An understanding of the various aspects of actuarial work which can be affected by climate risk is the foundation for the profession's role in scenario analysis.

The application of climate scenarios in firms is subject to a number of practical challenges different from those encountered with other more traditional categories of risk. For example, the climate scenarios provided by globally recognized agencies such as the United Nations Intergovernmental Panel on Climate Change lack the specificity needed by actuaries and firms to model their risks. This paper provides suggestions for incorporating the necessary specifics, using Australia for illustration. Another area requiring care in the preparation of climate scenarios relates to the time horizons over which climate-related risk may emerge. On the one hand, climate-related physical risks are frequently considered to develop over many years, while the timing and impact of climate-related transition and legal and reputational risks may be highly uncertain. This paper provides practical suggestions for incorporating these risks into climate scenarios.

The impact of the above guidance is illustrated for various businesses, namely investment and pension firms and general, life, and health insurers. Climate scenario developments from a number of other jurisdictions are provided so that readers can gain an appreciation of the range of activity on this topic.

Three simplified case studies are included to illustrate the concepts developed in this paper. These case studies have been chosen to stimulate broad thinking rather than to focus on an approach taken by a specific financial institution or for specific blocks of business.

It is hoped this paper can assist actuaries and others to understand the building blocks of climate-related scenarios and how they can be used to inform many critical risk management functions surrounding climate-related risks. Doing so will enable firms to better understand the risks involved and meet emerging disclosure and reporting recommendations or requirements.

While these scenarios should reflect a firm's own situation, it is hoped that in due course they will become sufficiently standardized to facilitate comparisons of disclosures across firms, industries, and countries.

Just as importantly, firms will identify ways to take advantage of the opportunities which will arise from a transition to a more sustainable world.

## Introduction

This paper is the third in a series of papers that the IAA Climate Risk Task Force has committed to develop over the coming years. The first paper was entitled "The Importance of Climate-Related Risks for Actuaries"[2] and was an introduction to the series. The second was an "Introduction to Climate-Related Scenarios".[3]

This paper continues the discussion in "Introduction to Climate-Related Scenarios", bringing the process of using scenarios to the level of an individual insurer or other financial institution ("firm") operating in a national jurisdiction. Many firms operate globally, but first it is useful to consider the problem from the perspective of a single country. Certain risks relating to transition are largely a function of the laws and policies at a country level, so starting there and then expanding the focus provides a practical and useful approach.

This paper does not cover the scientific basis of climate change beyond what is necessary for understanding its impacts. It is assumed that basic scientific information, such as the climate-related effects of various scenarios related to greenhouse gas (GHG) emissions, is known or available from sources such as the Intergovernmental Panel on Climate Change (IPCC). It is also assumed that key policies in countries in which a firm operates or is exposed, and which will impact transition risk, can be identified; examples include those involving carbon taxes or electric vehicles.

This paper covers a wide range of users (insurers, banks, pension schemes, and enterprises in various sectors) in different countries around the world but individual users may wish to only consider the subset of requirements that are relevant to the specific circumstances and purposes of the scenario at hand.

This paper was written in the first half of 2021. The state of the art and details of how various scenarios are constructed and used are evolving rapidly. Readers should anticipate that some of the contemporary examples used will be superseded by others before the IAA refreshes this paper. Illustrations in this paper are thus focused on the conceptual framework for scenario application using available examples, the details of which may not be appropriate for applications in the future.

This paper is organized into six sections:

- Section 1 discusses sources of information that may be used to support the development of specific estimates of changing weather from general climate scenarios, as well as general considerations for reporting financial effects to external stakeholders. An example of a set of standardized assumptions being developed for physical risk events in Australia is presented (the Climate Measurement Standards Initiative, or CMSI), followed by an outline of the general components of scenarios for transition. Legal and reputational risks (LRRs) are also discussed. The section concludes with a summary of scenario-analysis initiatives from several global regulators, including the European Insurance and Occupational Pensions Authority (EIOPA), French Prudential Supervision and Resolution Authority (ACPR), and Bank of England.
- Section 2 discusses actuarial considerations in climate-related risk analysis. It draws on an Information Note from the Actuaries Institute Australia which provides guidance on climate-related risks to Appointed Actuaries in preparing Financial Condition Reports (FCRs), and other global sources of actuarial practice guidance.
- Section 3 presents the concepts of systems thinking and systems dynamic modelling, to illustrate the importance of considering the broad environment in which a firm operates. This includes interactions between the political structure, prevalent economic

theories, resource usage, self-sufficiency, social cohesion, and other socioeconomic factors.

- Section 4 reviews how scenarios can be updated over time and outlines considerations for integrating scenarios within enterprise risk management (ERM) frameworks.
- Section 5 contains three simplified case studies illustrating specific scenarios. The first illustrates impacts on agriculture and food supply, as well as agricultural insurance, from an insurer's perspective. The second illustrates transition risks in a region dependent on fossil fuels from the perspective of an insurer (underwriter) or pension fund (investor). The third provides historical examples of how complex systems have been affected by extreme weather events and fragility.
- Section 6 reviews next steps.

Accompanying this paper is a separate glossary[4] of terms used, which the IAA will update as further papers on climate-related risks are developed.

# 1. Sources of Information and Considerations for Reporting Financial Effects

A significant challenge with setting boundaries for scenarios involves the lack of specificity in the guidance provided by the bodies defining standards or frameworks, including the Task Force on Climate-Related Financial Disclosures (TCFD). This is understandable given the early stage of development of techniques in this area, but nevertheless can lead to disclosures which are not comparable between firms. For example, there is considerable latitude around which Representative Concentration Pathways (RCPs) should be used, what time horizons are appropriate, and which models translating general climate conditions into specific weather event scenarios should be considered. The selection of key parameters such as these can make a significant difference in the measurement of the risks which could affect a firm's operations.

This section reviews the CMSI, an Australian framework for developing such specificity for physical risks. It also presents a structure for considering transition risks for firms in general, followed by a discussion of LRRs.

## 1.1 General Components of Scenarios

Before exploring some specific examples of scenario development, it is helpful to review the components of a scenario. While there is no attempt here to develop a comprehensive list of every aspect of possible scenarios, the following basic elements should be considered:

- *RCPs*: The IPCC 5th Assessment Report (AR5) identified four key temperature pathways for future GHG emissions. These represent a reasonable range of possible future states:[5]
  - RCP 2.6, which is consistent with an ambitious reduction in emissions aiming to limit global warming to below 2 degrees Celsius (2°C) above pre-industrial levels, the goal of the Paris Agreement. Its emissions were to peak around 2020.
  - RCP 4.5, which is an intermediate emissions scenario. Emissions would increase modestly until 2040 before declining. It is likely to produce warming of about 2.4°C.
  - RCP 6.0, a high-intermediate scenario, where emissions peak around 2060 and decline thereafter. It is likely to produce warming of about 2.8°C.

  - RCP 8.5, a scenario assuming little action to reduce emissions. It is likely to produce warming of about 4.3°C. While extreme, it is not intended to represent a worst-case scenario.

- *Time horizons*: Physical and transition risks will emerge over time (and at different times depending on mitigation actions taken), so future time frames should be specified when specific risks are evaluated.

- *Specific localized impacts*: Physical risks arise when climate change results in extreme weather patterns at the local level or changes to land cover, crops, and other environmental parameters. RCPs must be translated into changes in the frequency of weather events at specific locations, such as an increase in dry days leading to drought or fire risk in an area, additional extreme rainfall leading to flooding in a catchment, heat stress changing the type of crops which can be grown, etc.

- *Specific local economic and technological changes*: Governments around the world will enact and enforce changes in policy differently using a range of technologies to achieve national objectives. Although available technologies may be common, due to resources and differences in local conditions these technologies may be applied differently. Many factors can affect such policies; for example:

  - Commitments to overall objectives, such as “net zero by 2050”;
  - Local economic conditions, including the country’s ability to afford investments in renewable energy and its infrastructure;
  - Local renewable energy capabilities, such as access to hydropower, the amount of sun for solar power generation, wind patterns for wind power, etc.; and
  - The availability of “bridge” power supplies, such as nuclear, hydrogen, or gas, to replace thermal coal.

- *A view of the prospective political situation*: The ability to implement and sustain the potentially disruptive economic transformations required to achieve a reduction in GHG emissions is a function of the country’s political system and policies. Scenario construction should consider such factors as the likelihood of policy reversals, etc.

- *Technological assessment*: Possible new technologies, such as hydrogen-powered transport or smart electric grids, should be studied with appropriate cost–benefit analysis.

- *Nature of economic changes*: A transition to a low-emissions economy can be either gradual or abrupt. Scenarios should consider the nature of change, particularly regarding transition risk, and the underlying uncertainty of future assumptions.

- *Level of resilience*: Resilience of the local population, consumer behavior, the building stock, the agricultural system, etc., and the strategic or other importance of that place or people to other countries should be considered. The level of resilience affects the type and severity of impacts.

Several of the socioeconomic points above have been formulated into unique scenario narratives described as the Shared Socioeconomic Pathways (SSPs).[6] These narratives lead to assumptions relating to factors such as population, economic growth, and technology, to produce a global climate outcome aligned with the RCPs.

Globally, strong action to reduce physical risk will generate significant transition impacts. For example, achieving RCP 2.6 will involve quickly making major changes to power generation that will create transition risk. Conversely, failure to transition to low emissions will increase physical risk by making the RCP 6.0 and RCP 8.5 scenarios more likely. The level of transition risk is affected by the speed of transition and whether there are policy changes or reversals.

The time horizon over which risks emerge should also be considered. Physical risk generally emerges gradually (though there can be acute emergence of physical risk in some cases), while transition risk and LRRs can develop quickly because of changes in government policy or litigation against firms. Further, even with aggressive mitigation efforts to reduce GHG emissions, there will continue to be significant physical risk in the medium term as changes in weather patterns and sea levels reflect emissions over past decades and are already "locked in". Thus, scenarios should consider that there may be significant physical and transition risks, plus LRRs. This difference in time horizons explains some of the inertia involved with enacting decarbonization strategies.

A further general consideration involves the global nature of emissions policy. Effectively mitigating emissions and reducing physical risk require global action, which is the rationale behind the Paris Agreement and subsequent negotiations. Transition risk and LRRs, however, generally reflect policies at the national level. Thus, a firm could face a scenario wherein its national government enacts extremely tough emissions reductions, creating significant transition risk, while due to the inaction of other countries, emissions overall continue on an RCP 6.0 to 8.5 trajectory, leading to extreme physical risk. While value judgements about the appropriateness of "right" and "wrong" actions is outside the scope of this paper, various countries and supranational organizations will face significant pressures from a range of interest groups. An understanding of this is essential for a proper assessment of the risks and inherent uncertainty in scenarios developed to inform a firm's decision making. A lack of timely feedback between those responsible for emissions and those experiencing the adverse impacts has been one of the largest barriers to action.

As mentioned above, physical and transition risks may be poorly correlated across both space and time. LRRs are similar to, and in some cases characterized as, transition risks, since they can be expected to arise from entities' failure to enact certain policy changes, adopt low-emission technologies, or make appropriate disclosures.

The following table illustrates some general characteristics of physical and transition risks at a macro level that underlie the later discussion. Here "physical risk" refers to the emergence of real-world effects; some risks may emerge earlier if markets "price in" future events. This table is deliberately simplified to illustrate characteristics; actual risk characteristics are more complex.

**Table 1 – General Characteristics of Physical and Transition Risks**

| Topic | Physical Risk | Transition Risk |
|---|---|---|
| **Timing of risk emergence** | Gradual, long-term view essential<br>Risks may emerge rapidly if tipping points are reached | Possibly sudden or quick, but long-term view is challenging due to high level of political and social uncertainty |
| **Ability to change risk in the near term** | Low | High at the macro level |
| **Uncertainty in forecasts** | Near term: low to moderate<br>Medium to long term: moderate to high | High over all time horizons as to the precise nature of changes due to political, technological, and social uncertainty |
| **Nature of expert opinion** | Largely scientific and climate-focused, involving both weather and its effect on the ecosystem and physical assets | Varies, involving complex analysis of technology, macroeconomics, political situations, litigation environment, etc. |
| **Scale of action** | Global, based on coordinated local activities; physical risks will be influenced by local action | Local, with national policy dominating sources of risk; transition risks will be influenced by global action |
| **Measurement tools** | Objective measures in weather and climate data, supplemented by financial consequences of natural events (e.g., insurance losses from disasters) | Social, economic, and political data, supplemented by financial analysis of various mitigation and adaptation strategies |

## 1.2 Physical Risk Scenarios: The Climate Measurement Standards Initiative, Australia

The CMSI provides a roadmap of how a set of physical risk scenarios can be developed. According to the CMSI Summary for Executives[7] (page 4):

> In its first phase, the CMSI has recommended financial disclosure guidelines and developed scientific scenario specifications for the purpose of disclosure of scenario analyses for climate-related physical damage to buildings and infrastructure. It considers a wide range of chronic and acute risks for the general insurance, banking and asset owner sectors. These guidelines and specifications are open-source and voluntary.

To build a scenario, the CMSI first considers local effects of two scenarios: RCP 2.6 (low case) and RCP 8.5 (high case). It then selects timeframes of five years in the future, 2030, 2050, and 2090. It uses two SSPs: SSP1, reflecting a "sustainable" pathway; and SSP5, reflecting continued reliance on fossil fuels. It should be noted that there are significant uncertainties in long-term projections such as those to 2090.

It identifies the following general attributes of the scenarios as shown in the table below:

### Table 2 – Attributes of Low and High GHG Emission Scenarios

| Sector | Carbon dioxide emissions | Likely global SSP* | Global warming relative to 1850-1900** | Transition risk | Physical risk |
|---|---|---|---|---|---|
| Low case | Net zero by around 2070 (RCP2.6) | Sustainability (SSP1) | 1.3–2.2°C by 2050<br>0.9–2.4°C by 2090 | Higher challenges | Lower challenges |
| High case | High and accelerating (RCP8.5) | Fossil fueled development (SSP5) | 1.8–3.0°C by 2050<br>3.2–5.4°C by 2090 | Lower challenges | Higher challenges |

* There is an emerging system of SSPs that can be related to different RCPs.

** CMIP5 (Coupled Model Intercomparison Project Phase 5) models reported in IPCC (2013), but new-generation climate modelling suggests that even greater warming late in the century than cited here cannot be ruled out (see Grose et al. 2020).

*Source:* CMSI Summary for Executives[8] (page 6)

The CMSI's climate science report identifies two categories of climate hazard that can cause property damage:

- *Acute*: Extreme weather events like tropical cyclones or hailstorms; and
- *Chronic*: Gradually emerging issues like rising sea levels or increasing temperatures.

The CMSI then identifies specific expected weather effects for Australia. In Table 3 below, TS1 shows projected effects for acute hazards, while TS2 shows chronic hazards.

This is the type of specific information required to adjust models used to price property insurance policies or evaluate catastrophe reinsurance programs for future climate conditions. Modelling experts can take this information and estimate how metrics like average annual loss or probable maximum loss are likely to change in the future at specific locations. This information can inform physical risk assessment for various purposes, including insurance risk evaluation or public policy decisions such as the degree to which building codes need to be adjusted to "future proof" them against climate-related risks.

## Table 3 –Projected Effects for Acute Hazards, and Projected Changes Relative to 1966-2005 Chronic Hazards

**Table TS1:** Observed and projected changes in climate variables that influence physical risks for buildings and critical infrastructure in Australia. For each variable, the average in the IPCC baseline period (1986-2005) is given, along with the observed change averaged over recent decades (from 1986 onwards). Green text show projections for a low emissions scenario (RCP2.6 based on global warming of less than 2°C by 2090 while red boxes show projections for a high emissions scenario (RCP8.5 based on global warming of 3-5°C by 2090). Projections have a central estimate and a range of plausible change (based on 10th-90th percentile estimates considering multiple lines of evidence - for details see Section 3.2). These are broad estimates for Australia as a whole, or large regions of Australia. Spatial variation within Australia exists for all quantities and can be examined in the model projection data, with values above or below these also being possible and noting a wide range of uncertainties as discussed from literature examples in Section 3.2. Confidence ratings, using the IPCC guidance, provide an assessment of confidence that the range of change is a reliable and complete description (continued overleaf).

| Extreme or hazard | Average in 1986-2005 | Observed change and attribution | 2030 | 2050 | 2090 | Confidence rating |
|---|---|---|---|---|---|---|
| Tropical cyclone (TC) frequency in Australian region | 10-11 per year | -10%, weak | East -4% [-8% to 1%]; West -6% [-10% to -2%] | East -4% [-8% to 1%]; West -6% [-10% to -2%]<br>East -8% [-15% to 2%]; West -12% [-20% to -4%] | East -4% [-8% to 1%]; West -6% [-10% to -2%]<br>East -15% [-25% to 5%]; West -20% [-30% to -10%] | Medium |
| Cat 4-5 TC frequency, noting relevance for damaging winds | 2-3 per year | Little change (noting large variability), none | Little change or small increase | Little change or small increase<br>Little change or increase | Little change or small increase<br>Little change or increase | Low-Medium (for examples of numbers published in previous studies see Section 3.2) |
| TC location (latitude) with changes noted for southern extent | 10-20°S common (30°S less common) | Little change or small poleward expansion, none | Little change or small poleward expansion | Little change or small poleward expansion<br>Little change or poleward expansion | Little change or small poleward expansion<br>Little change or poleward expansion | Low (for examples of numbers published in previous studies see Section 3.2) |
| East coast low (ECL) frequency | 20 per year, with 2-3 Intense ECLs per year impacting on land | -10% (but with large variability), weak | -10% [-15% to -5%] | -10% [-15% to -5%]<br>-20% [-30% to -10%] | -10% [-15% to -5%]<br>-35% [-50% to -20%] | Medium (Low for summer and High for winter) |

| Extreme or hazard | Average in 1986-2005 | Observed change and attribution | 2030 | 2050 | 2090 | Confidence rating |
|---|---|---|---|---|---|---|
| Extreme rainfall intensity (considering 20-year return period) | Spatially variable intensity | +10% hourly and +7% daily (but with large variability), weak | +10% [+5% to +15%] hourly; +7% [+4% to +10%] daily | +10% [+5% to +15%] hourly; +7% [+4% to +10%] daily<br>+20% [+10% to +30%] hourly; +15% [+8% to +20%] daily | +10% [5% to 15%] hourly; +7% [4% to 10%] daily<br>+35% [+15% to +55%] hourly; +25% [+15% to +35%] daily | High for direction of change and Medium for magnitude of change |
| Extreme sea level events | Spatially variable | Mainly driven by mean sea level rise: 3 mm/year, strong | 1-in-100-year event becomes an annual event by the end of the present century under RCP 2.6 and by mid-century under RCP 8.5 | | | High |
| Floods | Spatially variable and dependent on flood type | No clear signal | Increase more likely than a decrease for most types of floods; Increases very likely for coastal flooding (based on the rate of sea level rise) and small-scale flash floods (based on extreme rainfall increases). | | | Low for large catchments and large floods in general (including river and surface water); High for coastal and flash floods |
| Large Hail (>2.5 cm diameter) frequency in city-scale regions | About 5-10 per year in eastern regions and 0-5 per year elsewhere | No information | Little change, but potential increase in east and poleward shift in features | As for 2030<br>As for 2030 | As for 2030<br>As for 2030 | Low |
| Extreme fire weather days (exceeding 95th percentile) | About 18 days per year to once every few years | 15%, medium-high | +20% [+5% to +35%]; East +15% [+0% to +30%] | +20% [+5% to +35%]; East +15% [+0% to +30%]<br>+40% [+10% to +70%]; East +30% [+0% to +60%] | +20% [+5% to +35%]; East +15% [+0% to +30%]<br>+75% [+20% to +130%]; East +55% [+0% to +110%] | High; Medium in East. Low confidence for lightning ignition and fuel load (as key risk factors particularly in north and central Aust) |

**Table TS2:** Observed and projected changes relative to 1986-2005 in chronic climate hazards that influence physical risks for buildings and infrastructure in Australia. Table details as for Table TS1. These are broad estimates for Australia as a whole, or large regions of Australia. Spatial variation within Australia exists for all quantities and can be examined in the model projection data. More detailed projections for four regions are provided in Section 3.

| Climate variable | Observed change and attribution | 2030 | 2050 | 2090 | Confidence rating |
|---|---|---|---|---|---|
| Annual average temperature | Around +1.4 °C since 1910 (strong) | +0.6 to 1.4 °C | +0.5 to 1.5 °C<br>+1.5 to 2.5 °C | +0.5 to 1.5 °C<br>+2.5 to 5.0 °C | Very High |
| Average sea level | Increased by 3.1 mm/year during 1993-2009 (strong) | +0.07 to 0.2 m | +0.1 to 0.3 m<br>+0.1 to 0.3 m | +0.2 to 0.6 m<br>+0.4 to 1 m | Very high |
| Average annual rainfall | Decreased 11% in the southeast during April to October for 1999 to 2018 relative to 1900 to 1998, and decreased 20% in the southwest during May to July since 1970 relative to 1900 to 1969 (strong), with an increase of 10mm/decade from 1900-2019 in the north (weak) | East: -13 to +5%<br>North: -9 to +4%<br>South: -9 to +2 %<br>Rangelands: -10 to +6 % | Drier in the south and east, uncertain in the north (see Tables 3.1-3.4)<br>Drier in the south and east, uncertain in the north (see Tables 3.1-3.4) | | High in southern Australia, Low elsewhere |
| Time in Drought* | Insignificant (weak) | Increase in many regions (see Table 3.6 and 3.7) | No data<br>Significant increase in many regions (see Table 3.6, 3.7) | | High in southern Australia, Low elsewhere |
| Annual days >35 °C# | Increase (strong) | Increases (see Table 3.8) | Increases (see Table 3.8)<br>Large increases (see Table 3.8) | | High |

*Source:* CMSI Scenario Analysis of Climate-Related Physical Risk for Buildings and Infrastructure: Climate Science Guidance[9]

The CMSI goes on to offer seven recommendations for developing scenarios to support reporting under the TCFD framework, which are summarized below. This paper does not endorse the validity of these recommendations but presents them to illustrate the types of practical considerations needed to construct physical risk scenarios.

- *Recommendation 1*: Disclosures should be made under a 2°C-or-lower scenario, RCP 2.6, and a greater-than-2°C scenario, RCP 8.5.
- *Recommendation 2*: Disclosures should be made for five years from the date of the disclosure, and then for 2030, 2050, and 2090.
- *Recommendation 3*: Disclosures should include a static scenario for both cases outlined in Recommendations 1 and 2. This refers to holding the portfolio of assets constant over time in order to measure the effects of changing climate-related risks without the complication of other changes in demographics, adaptation, etc.
- *Recommendation 4*: As well as in aggregate, disclosures should also consider the following sectoral splits where they are material to the business (Table 4):
    - By portfolio (for example, home loans, commercial loans, commercial insurance, personal insurance);
    - By hazard (for example, tropical cyclones, floods, convective storms and hail, coastal inundation, bushfire, soil contraction); and
    - By geographic region.
- *Recommendation 5*: Material impacts for these items at the specified timeframes (from Recommendation 2) should be disclosed.

**Table 4 – Accounting Items**

| | Banks | General Insurers | Asset Owners |
|---|---|---|---|
| **Balance sheet** | Loans to firms and households<br>Provisions for loan impairment | Outstanding claims<br>Reinsurance recoveries on outstanding claims | Total value of investments<br>Values of investments in physical infrastructure and/or other real estate |
| **Income statement** | Loan impairment charges | Gross incurred claims<br>Reinsurance recoveries on incurred claims<br>Gross premium income<br>Reinsurance expenses | Adjustments to the value of income from investment in physical infrastructure and/or other real estate |
| **Other metrics** | Impact on probability of default<br>Impact on loss given default | Portfolio Annual Average Losses for weather-related events<br>Portfolio Annual Exceedance Probabilities for 1 in 100-year events<br>Portfolio gross and net of reinsurance Probable Maximum Losses for 1 in 200-year weather related events | Overall % of value of investments subject to material physical risk |

*Source:* CMSI Summary for Executives (page 14)

- *Recommendation 6*: Disclosures should describe both the confidence and uncertainty in the critical assumptions made regarding the impact of climate change on hazards driving physical risk losses under each scenario.
- *Recommendation 7*: Without giving precise direction on how resilience should be disclosed, the CMSI provides commentary on some factors that could be used in assessing the resilience of different strategies. These factors include high-risk assets and liabilities, portfolio concentration, risk management, capital and other expenditure associated with resilience plans, impact on customers, GHG mitigation, and adaptation and resilience measures.

The CMSI provides a useful framework to illustrate the type of factors which underlie reporting under TCFD. Specific guidance is provided on the following:

- RCP scenarios;
- Timeframes;
- Specific weather effects by location, time, and peril;
- Composition of the asset portfolio being examined (static);
- How disclosures should be organized;
- What accounting items should be forecast;
- Confidence and uncertainty; and
- Adaptation and resilience.

## 1.3 Transition Risk (and Opportunity)

Although risk practitioners and actuaries usually consider the term "risk" to include both upside and downside variability, common usage and some practitioners may use the term to refer solely to downside impacts. In that context, it is inaccurate to describe climate effects solely in terms of "risk", since changes in climate will create a range of possible outcomes. Many of these will pose downside risks, such as losses to properties, declines in asset values, and loss of customers and/or market share. However, climate effects can also create opportunities, such as higher food production in certain high-latitude regions, new "green" investment vehicles, and growing customer demand for services.

The 2017 TCFD Report[10] specifically refers to "Climate-Related Risks, Opportunities, and Financial Impacts" and has separate sections on "risks" and "opportunities". This paper follows the lexicon used by most actuaries and takes "risk" to include both downside and upside effects. Many have argued that a transition to a decarbonized world will lead to a net overall increase in metrics like employment, wealth, and well-being. If correct, transition would create significant opportunities for firms which anticipate and capitalize on transition effects.

As discussed in Section 1.1, transition risks are characterized by greater uncertainty as to their nature and timing than are physical risks, at least in the short to medium term. Despite this, transition scenarios can be constructed using similar thinking as that used by the CMSI.

A process to build a scenario for transition might follow this illustrative process:

- Identify potential actions by governments, regulators, shareholders, and other stakeholders which would affect the macroeconomic environment in which a firm operates.
- Designate timeframes over which the actions may materialize.

- Describe specific national policies, such as:
  - Net zero carbon emissions is targeted by 2050;
  - Thermal coal is phased out for power generation by 2040;
  - Electric vehicles are x% of fleet by 2040; and
  - Carbon taxes are levied on air travel beginning in 2030.
- Identify demographic and macroeconomic shifts, such as:
  - Areas likely to gain or lose population (with rough quantification);
  - Areas and sectors likely to experience higher/lower economic activity (e.g., mining down, services up); and
  - Specific industry examples relevant to the firm – for example, international tourism falling by 20% due to carbon taxes on air travel while domestic tourism increases by 15% would be relevant if the firm were a travel insurer.
- Translate these overall goals into specific actions for the insurance sector and/or firm, such as (note that this list is intended to be illustrative and does not reflect any endorsement of these actions by the authors):
  - Divest thermal coal investments in line with sector decline, towards a stated target date.
  - Withdraw from underwriting solid fossil-fuel extraction beyond a stated target date.
  - Develop new insurance products for wind farms.
  - Develop new insurance products for electric vehicles.
  - Develop affordable and robust insurance for net-zero-carbon-emitting enterprises.
  - Engage in initiatives which fill protection gaps, and review the future business mix.
  - Retool travel insurance to focus on evolving travel patterns.
- Identify risks and opportunities for the firm, such as (note that this list is illustrative and not intended to be exhaustive):
  - The risk of increased morbidity or mortality from heat stress, particularly for vulnerable populations, which could lead to higher claim costs;
  - The risk to supply chains, loans, and leasing finance as businesses transition;
  - New products for "green" reconstruction; and
  - New markets for services, such as "green" superannuation fund offerings.

Once these topics are reviewed and categorized, scenarios can be constructed, risks/opportunities assessed, and disclosures made. Projections of key metrics, such as renewal of contracts or future business mix, can be made. Multiple scenarios should be constructed to illustrate the range of plausible future states. Importantly, transition effects carry an inherently high level of uncertainty which should be reflected in strategic planning, considering differences in the degree of effects and their timing. This implies that plans should stress agility and be subject to periodic review, as outlined in Section 4.

## 1.4 Legal and Reputational Risks

LRRs have characteristics similar to those of transition risks, in that they may emerge rapidly, reflect the local legal environment, and have a high level of uncertainty. Of the types of risks discussed in this section, these are likely to be more manageable for many firms in sectors like insurance, in the sense that they fall largely under the control of the firm, through the choices it makes, and the risk controls it employs. However, the severity of these risks may be material for certain firms if they fail to manage exposure to climate-related risks in a manner deemed appropriate by regulators, shareholders, members (in the case of mutual companies), beneficiaries, the public, or other stakeholders.

### 1.4.1 Legal Risk

Climate change brings challenges which may give rise to litigation against companies.

Grounds for legal action may exist if a firm fails to adapt its strategy, actions, and/or external reporting to properly recognize and address the risks arising from climate change. This legal exposure may extend to its advisers. In some cases, legal risks can be very high, particularly for financial services firms which have significant business relationships with producers of GHG emissions through loans, investments, financial services, or provision of insurance coverage.

Liabilities may arise not only to shareholders and creditors, but in some cases to trading partners and customers. The need for adequate disclosure is critical, and the definition of what is adequate is evolving. There may be sudden shifts in what is considered acceptable corporate behavior in terms of a firm's contribution to mitigating or exacerbating climate change.

Financial services firms face risks particular to that sector. Insurance coverage of another entity's liabilities has proven especially susceptible to risks that litigation may expand the previously accepted interpretations of contractual rights or liabilities for damages. It is now quite common for this to be influenced by government agencies, as was well illustrated during the COVID-19 pandemic – when, for example, the definitions of what constitutes "business interruption" were subject to strong challenges.

General insurance firms which underwrite Directors & Officers or product liability coverages may be exposed to latent liability for policies issued in the past which covered entities that engaged in fossil fuel extraction and production, much in the same way asbestos became a major issue in some countries in previous decades. There are growing numbers of lawsuits claiming damages for GHG emissions from a wide range of companies. Judgements in favor of plaintiffs in these cases could lead to exposure for insurers covering the companies by a variety of policy types.

Directors' duties around custodianship, market conduct, or product disclosure may also be interpreted more broadly. Investment selection and product labelling may be subject to a trend towards the broadening of custodial duties and heightened expectations of risk management. Each of these risks reflects growing community and government concerns over climate change and transition impacts.

### 1.4.2 Reputation Risk

Many of the legal risks mentioned in Section 1.4.1 may also give rise to strong customer reactions that may be damaging to a firm's financial performance, market share, and recruitment/retention of suitable staff.

The reasons for such actions are typically similar or related to legal risks, and might be expected to occur in parallel, and given the capabilities of modern communications systems and social media, large adverse consequences may occur suddenly.

A failure to anticipate or accommodate possible consumer reaction may also give rise to greater legal risks, since it may be seen as a failure of strategy.

As noted previously, the term "risk" should be understood to include both downside and upside outcomes. Reputation can be enhanced by taking actions which are viewed positively by stakeholders. For example, a firm which develops more sustainable products or practices may be rewarded with higher sales and customer satisfaction.

## 1.5 Other Sources of Information

The EIOPA published an Opinion[11] on the supervision of the use of climate change risk scenarios in the Own Risk and Solvency Assessment (ORSA). ORSA is an internal process undertaken by an insurer to assess the adequacy of its risk management and current and prospective solvency positions under normal and severe stress scenarios.

The Opinion showed the results of the information request conducted by EIOPA on the use of climate change scenarios in the ORSA. The body of the EIOPA Opinion is about mandating climate risk scenario analysis (or at least materiality assessment of the exposure), recommending the use of a 1.5–2°C scenario and a second, greater-than-2°C scenario. Then there are various appendices that are intended to help with how to perform such analyses in practice.

The quantitative analyses for physical risk found in the ORSA reports can be largely divided into four types:

- Physical risk with technical approaches that are not dissimilar to regular natural catastrophe scenarios. For example:
  - An increase in the loss ratio of 5% per year in non-life business affected by climate change, offset by loss-absorbency from any national insurance compensation arrangements; and
  - A widespread increase in windstorms that leads to an increase in claims in multi-risk lines of business, with a 30% increase in the loss ratio in the first year and 10% in the second year of the projection horizon.
- Physical risk linked to specific climate scenarios. For example:
  - Scenarios based on the Royal Netherlands Meteorological Institute climate change projection of increasingly intense hailstorms and periods of drought; and
  - Scenarios consistent with the IPCC's RCP 8.5.
- Physical risk on investment assets, considering a scenario over a three- to five-year period with prolonged droughts that negatively impact the value of residential property and hence the mortgage portfolio.
- Physical risk in combination with other risk factors:
  - A scenario with a severe weather event, which causes a significant increase in claims, followed by (unrelated) failure/default of a reinsurer; and
  - A scenario with a longer period of low interest rates combined with increases in the frequency and intensity of natural disasters due to climate change.

The quantitative transition risk analyses ranged from simple ones with generic parameters without tailoring to any climate-related investments to more sophisticated ones, such as:

- Assessment of the impact on investments of 1.5°C, 2°C, and 3°C climate scenarios from 2018–2033. Modelling is based on the United Nations Environment Programme Finance Initiative for stocks and bonds plus an in-house model for the property portfolio.
- Scenario analysis of the impact of an election resulting in a new government introducing swift legislation to ban diesel engines in major cities. The new government won the elections and is committed to mitigating climate change after significant storms and floods caused extensive damage.

The Opinion also details a mapping of climate change risks to prudential risks for non-life and life insurance in Annex 3 on pages 18–21, and Annex 4 on pages 22–25.

The EIOPA published the Second Discussion Paper on Methodological Principles of Insurance Stress Testing[12] in June 2020 in the process of enhancing its bottom-up stress-test framework. The paper proposes an approach that starts from the assessment of insurers' vulnerability using their current exposure (micro-dimension), followed by a forward-looking assessment of potential changes in business models and the implications on policyholders and any spillover to the other markets (macro-dimension).

In addition, the discussion paper covers guidelines on multi-period approaches to stress testing using an iterative calculation/validation process, focusing on how to treat future business and reactive management actions over the periods of the stress test. However, multi-period approaches incur high costs, so a cost–benefit analysis should be performed before starting such an exercise.

The ACPR published a provisional hypothesis of the climate change pilot exercise in May 2020,[13] which contained several scenarios that have been tested by nine banking groups and 15 insurance groups. The pilot exercise included a macroeconomic projection of the Eurosystem, which has the impact of the COVID-19 pandemic as a starting point, plus the transition scenarios published by the Network for Greening the Financial System. The main assumptions and parameters of the reference and adverse scenarios can be found in Section 3 of the ACPR paper.

The Bank of England was planning to conduct its Climate Biennial Exploratory Scenario (CBES) for banks and insurers in June 2021. The CBES would explore transition, physical, and litigation risks, with three climate scenarios: early policy action, late policy action, and no policy action. Scenario specifications can be found in Section 4 of the Bank's discussion paper.

The Bank of England released a report[14] that set out a six-stage framework that general insurers can use to manage and report exposure to physical climate risks related to extreme weather events. The six stages are: identify business decisions, define materiality, conduct background research, assess available tools, calculate impact, and reporting and action.

## 2. Actuarial Considerations

The previous sections have introduced the basic concepts of climate-related risks and constructing scenarios, and provided illustrative considerations in assessing transition risk. This section discusses the issue of how climate-related risks can affect actuarial work, using the process of Appointed Actuaries preparing FCRs as a guide.

Actuaries are frequently involved in many aspects of a financial institution's operations, including risk management, valuation, pricing, reinsurance, preparation of financial reports, etc. The Actuaries Institute Australia Information Note[15] on climate-related risks for Appointed Actuaries preparing FCRs provides a comprehensive example of the various things an actuary might consider when assessing a firm's exposure to climate-related risks. Some of the key issues identified in the Australian Information Note are highlighted below. While this material is specific to Australian actuaries, its principles are applicable globally. Some additional relevant guidance materials from other jurisdictions are summarized in Section 2.2.

These examples are offered for illustrative purposes to provide readers with a framework to understand the range of what various global actuarial organizations are identifying as best practice in their jurisdictions or for their members at the time of writing. The IAA makes no assertion that such practices are applicable outside of this context.

## 2.1 Actuaries Institute Australia Information Note for Appointed Actuaries

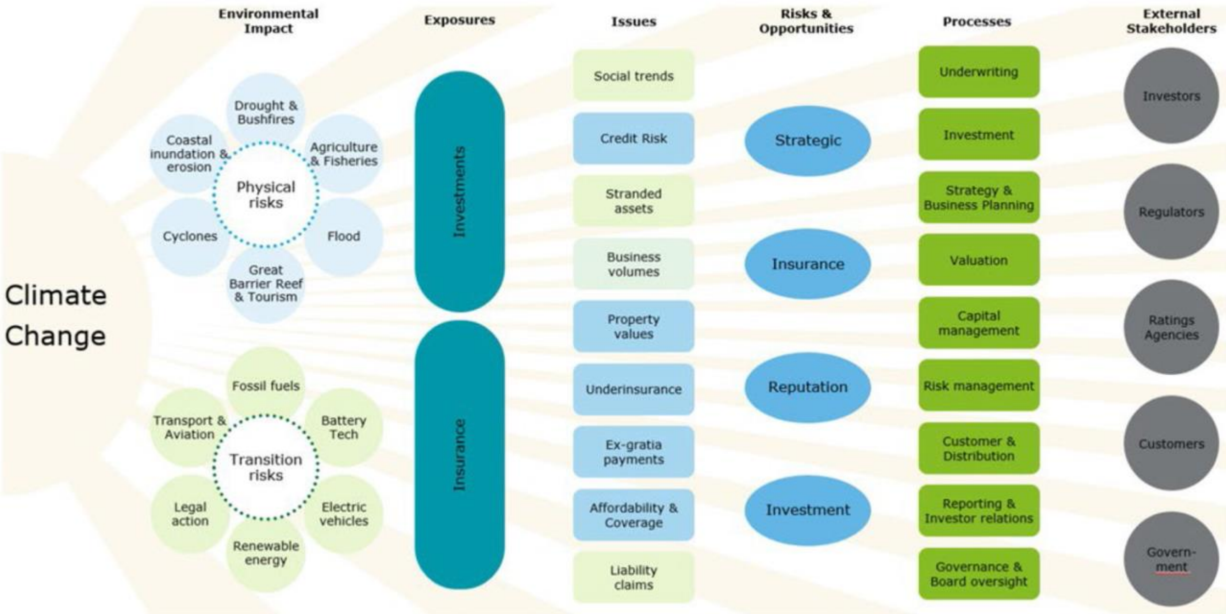
As noted above, all references in Section 2.1 to actuarial practices reflect what the Australian Institute recommends for its members and as such is illustrative of good actuarial practices. Not many jurisdictions have adopted climate-related actuarial guidance to date, but it is expected that many more will do so in the future.

Consideration of climate-related risks is increasingly a part of the management of risk for any financial institution. A comprehensive ERM framework should therefore include climate-related risks and other accelerating risks such as cyber and technology. The Australian Information Note identifies four ways an actuary can assess a firm in the context of its ERM framework. Does the institution and its management team:

- Have appropriate governance and leadership to address climate-related risks?
- Understand the financial and strategic risk associated with climate change?
- Have an effective plan or strategy to assess and address climate-related risks?
- Have a process to evaluate customer considerations and reputation risk?

The Note discusses the issues that actuaries should consider in the assessment of climate-related risks. The diagram below shows how climate-related risks affect various insurance processes for financial firms. The remainder of this section summarizes relevant content from the Note.

**Figure 1 – Climate-Related Risks and Insurance Processes**[16]



A key aspect of an Appointed Actuary's review involves an assessment of the firm's approach to capital management, especially its ability to continue attracting capital. Appointed Actuaries should consider allowing for uncertainties associated with climate change within the stress margins for insurance risk and target capital.

Stress tests and scenario analysis are important tools for assessing capital adequacy. Appointed Actuaries should comment on the appropriateness of these tests in relation to climate-related risks, considering, but not being limited to, the following:

- Time horizon of stress tests should be longer than that of a general stress test, which in the Australian case is three years – the time horizon could be longer for physical risks and shorter for market, transition, and legal and reputational risks as these emerge more quickly;
- The ability of existing natural hazard models to forecast potential climate change impacts (presented separately) may be especially challenging, as historical data is limited to the past or existing climate and less volatile weather;
- Whether recent historical claims costs reflect potential physical climate-related risks;
- Whether the nature of the hazards insured, or premium written, by an insurer is materially impacted by expected technological or regulatory changes driven by responses to climate-related risks;
- How climate change issues are likely to affect the value of, or returns from, investments, over both the short and long terms;
- Shifts in geographic distribution of natural hazard and health risks due to climate change; and
- Whether management actions identified are precautionary measures or responses to the scenario if it were to occur.

### 2.1.1 Reinsurers

The existence and types of ceded reinsurance used are other important considerations, as climate-related risks can affect the availability and price for reinsurance over the medium to long term. Insurers and reinsurers should also consider credit-rating targets, as major rating agencies are increasingly including climate-related risks in their credit-rating determinations. Reductions in ratings could impact the amount of capital a firm is required to hold for maintaining reinsurance balances.

### 2.1.2 Investment Management

Insurers and pension funds have the fiduciary duty to address financial and strategic risks, including climate change. This is particularly relevant as both insurers and pension plans have long-term investments. Accordingly, company directors need to carefully consider climate-related risks and make appropriate disclosures to reduce the climate change liability risk.

Actuaries also should assess the appropriateness of a firm's investment strategy, considering the company's liabilities. Climate change and decarbonization will impact the value of investment portfolios, creating positive and negative outcomes for different classes of investment. Directors and senior management may also be liable for how climate-related risks and other Environmental, Social, and Governance (ESG) issues are considered in long-term investment strategies.

There are several investment challenges involved in incorporating climate change in an assessment of an investment portfolio in terms of:

- How the timing and impact of climate change effects are affected by politics and response paths;
- The quality and extent of climate risk information on companies and securities;
- The capability of models to appropriately consider possible extreme events and climate tipping points – for example, sudden changes to physical risks, legislation, or sentiment;
- The suitability of current macroeconomic assumptions about growth, interest rates, and inflation due to the systemic nature of climate tipping points; and
- The impact of climate-related risk and decarbonization on supply chains.

In terms of measuring risk and returns, traditional risk/return indicators are complicated because returns are not only driven by GHG intensity but also industry structures, product constraints, the adaptability to alternative policy environments, and consumer sentiment. Calculating appropriate risk-adjusted returns requires consideration because there is a difference between integrating climate-related risk ratings into the investment process compared with actively screening out individual securities. In addition, there is a need for actuaries to become more familiar with non-financial information to integrate it into the risk assessment.

It is important for firms with long-duration assets or liabilities to perform stress testing using alternative and multiple climate change scenarios and government responses. Scientific literature such as the IPCC’s 1.5 Degree Report[17] can provide guidance to actuaries regarding the expected timing of policy responses and technological and behavioral change. Under the IPCC’s 1.5 Degree scenario, achieving net zero emissions will take decades, so actuarial considerations should include transition risks viewed over a longer time horizon:

- Heightened risks of stranded assets associated with certain infrastructure and capital-intensive industries; and
- Meeting customer expectations, as transition risks can particularly impact their pension balances during the accumulation and payout phases of their policies.

In addition to stress tests, Appointed Actuaries should consider:

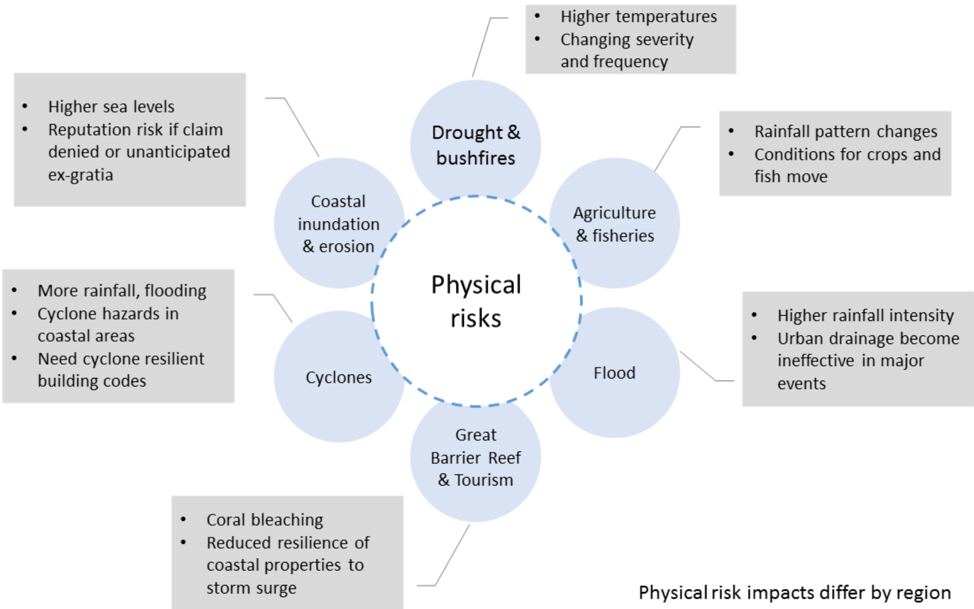
- Portfolio exposure to potentially stranded assets and those assets that can benefit from transition policy;
- Portfolio risks changing over time – that is, not being static;
- Possible climate tipping points for longer-term investment horizons;
- Including a “shadow” carbon price to reflect transition costs due to changes in technology, behavior, and policy responses;
- Keeping the assessment of climate change impact on the investment portfolio consistent with that on the business and its customers;
- Establishing a decision-making framework to reposition the portfolio in response to different policy outcomes and physical shocks;
- Establishing criteria for fund manager selection with respect to management of climate change risks; and
- The impact of climate change on liability duration, volatility, and uncertainty.

The Note then goes on to discuss some specific issues actuaries may face in general, life, and health insurance. Overall, Appointed Actuaries in Australia are required to comment on the adequacy of premiums, product design, and reserving. The next few subsections go through the specific considerations for general, life, and health insurers.

### 2.1.3 General Insurers

General insurers are exposed to physical risk through claims on insured events and through investment values on their asset portfolios and the assessment of credit risk. The diagram below shows examples of physical risk impacts for general insurers.

**Figure 2 – Physical Risks**




Physical risk is also relevant to workers' compensation claims because climate can affect mortality and morbidity risks at work. An example is heat stress from working outdoors during heat waves, or sickness from working outdoors during high-pollution days, without appropriate protection being provided.

Transitioning to a low-carbon economy involves policy, legal, technological, and market changes. Actuarial considerations for general insurers include:

- New technologies, such as battery-operated cars and autonomous vehicles, and how these will present insurance-pricing and product-design issues;
- Shifts in types of industries that may require changes in products or coverages underwritten; and
- Growth and contraction of economic sectors that can affect the insurer's premium revenue.

Some general insurers also write Directors & Officers and Professional Indemnity insurance contracts. Liability risks can arise from these contracts due to a firm's failure to address financial and strategic risks via mitigation, adaptation, or disclosures.

Australian Appointed Actuaries are required to include an assessment of pricing, including the adequacy of premiums, which incorporates climate change risk. A similar requirement exists under Solvency II regarding the actuarial function, which must express an opinion on the appropriateness of the overall underwriting policy. Since general insurance products are mostly annually renewable contracts, they have two means to mitigate excess losses: first, the insurer's risk is limited as they can reprice or refuse to renew their policies annually, and second, natural hazard prices and product design can be reviewed and recalibrated frequently using the latest science and experience. However, affordability and/or availability pressures can emerge as risk shifts, so Appointed Actuaries need to consider regulatory and reputational risks when premiums increase or coverage is limited.

The Information Note also indicates Appointed Actuaries should be aware of and should comment on:

- Leading indicators[18] that prompt pricing to reflect climate change risks;
- Regulatory and legal changes that can emerge rapidly over short timeframes; and
- New products and product designs that are being developed, and other industry developments.

For reserving, many physical risks will be known at the time of loss; for example, a hailstorm. Under some long-tailed lines like workers' compensation, claims will take longer to develop, and new sources of risk can emerge. Reserving methods may be affected by changes in claim payment patterns, which can be difficult to detect from historical data.

Natural hazard catastrophe modelling needs to be adjusted to expand beyond replicating historical weather patterns. Actuaries should consider:

- Capturing the current climate-related risks as much as possible in underlying assumptions, noting that it is challenging if long-term averages are used to estimate the frequency and size of infrequent events;
- Segregating climate change effects by geographical areas;
- Updating exposures in the models used to the current state – for example, building updates and regulations;
- Allowing for factors other than direct damage, such as demand surge and business interruption;
- Considering non-linearity or step changes that impact climate-related risks;
- Developing scenarios and estimating metrics for transition and liability risks; and
- Analyzing different time horizons for different applications, as illustrated in the table below.

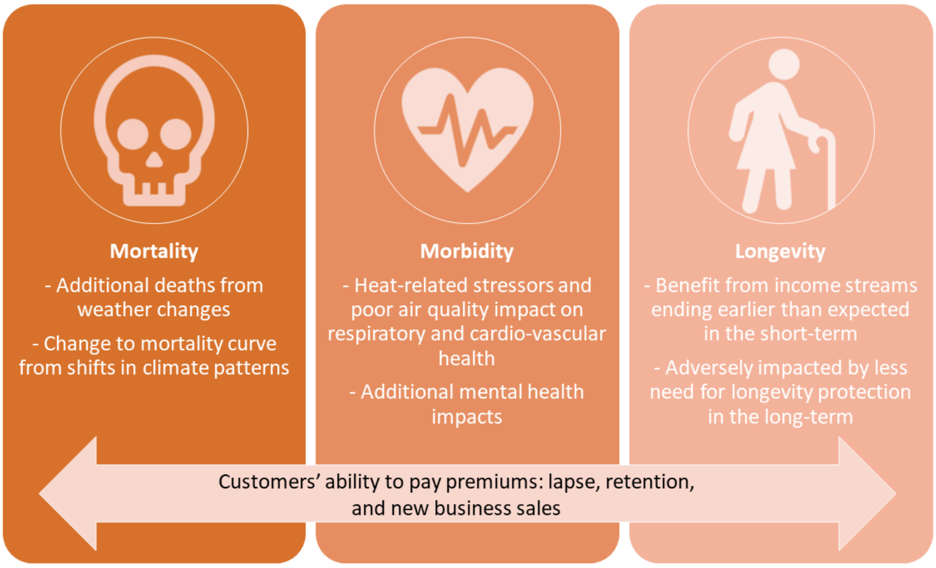
**Table 5 – Analyzing Different Time Horizons for Different Applications**

| Time horizon | Applications | How to adjust natural hazard catastrophe model |
|---|---|---|
| Short term | Annual pricing and valuation | Use current climate-related risks with small annual increments |
| Medium term | Portfolio steering | Sensitivity testing with trend or step change in parameters |
| Long term | Capital position<br>Rebalancing business | Sensitivity testing under different climate scenarios |

### 2.1.4 Life Insurers

Physical risks impact claims arising from mortality, morbidity, and longevity risks. The diagram below shows examples of how life insurers may be impacted in these areas.

**Figure 3 – Impact on Mortality, Morbidity, and Longevity Risks**




While the diagram offers examples of how risk can increase, of course examples could be constructed where risk decreases, such as milder winters making exposure to seasonal flu or frostbite less likely. Further, there are many other possible effects, such as vector-borne diseases (e.g., malaria or Zika) or stress on healthcare delivery systems.

Transition risk will be triggered by (among other things) the shift towards a lower-carbon economy, which in turn may drive widespread changes, particularly in sectors highly reliant on fossil fuels. These changes may lead to impacts on claims costs, risk exposure, and asset values. For example:

- A disorderly transition may cause disruptions to job stability in some sectors and could result in claims arising from mental health. There is much evidence that becoming unemployed has an adverse impact on mental health.
- Consumer preferences shifting away from carbon-intensive products and processes may exacerbate changes in industry and unemployment rates.
- New technologies could lead to growth in other industries involved in renewable or sustainable products, bringing about potential offsetting impacts to shrinking industries and short-term uncertainty to current occupation ratings.
- Due to the significant investment management function of life insurers, transition risk due to climate change will impact investment portfolios as decarbonization proceeds, creating positive and negative outcomes (e.g., stranded assets) for various classes of investment.

Given the long-term nature of many life insurance products (due to their guaranteed renewability), and the sensitivity of mortality and morbidity rates to unemployment and mental health, transition risk may have more material impacts on a life insurer's risk profile than physical risks in the short term.

Consequently, actuaries should consider identifying and quantifying climate-related risks, changes to underwriting, and regulatory changes in their pricing and product design. Actuaries should also consider data availability, accessibility, and model improvements to enhance and support pricing. Although life insurers may be able to reprice as a risk-mitigation strategy, there are challenges associated with repricing that actuaries should consider:

- Climate impacts for people already receiving claim payments, especially long-term benefits;
- The affordability of revised premiums and policyholder dividends, if applicable; and
- Shock lapses and anti-selection.

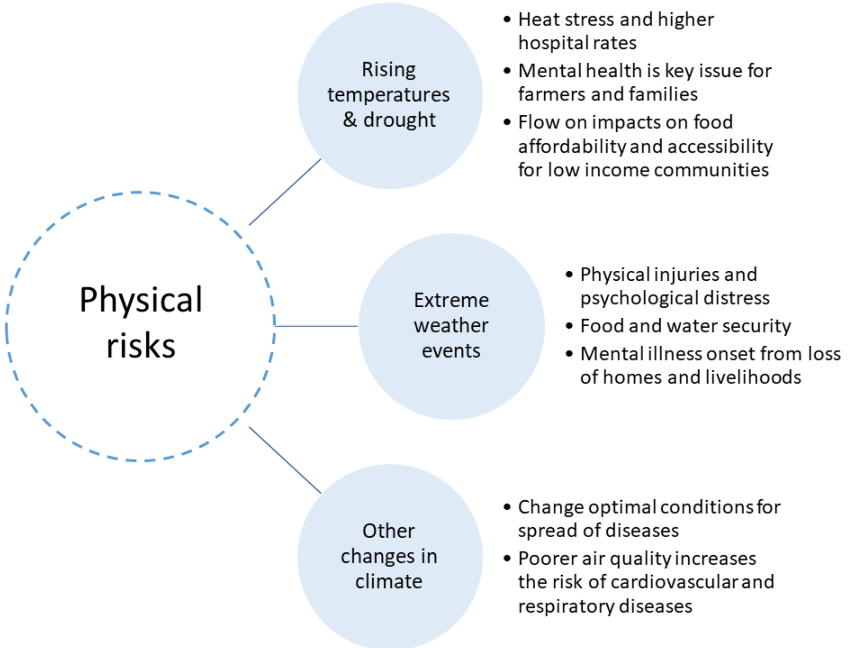
Setting best-estimate assumptions with climate change risks is difficult due to the uncertainty around the long-term nature and severity of climate change impacts. Appointed Actuaries could adjust industry tables due to specific characteristics of their insured lives, or adjust best-estimate and risk-margin assumptions due to the existence of a new risk factor.

### 2.1.5 Health Insurers

Appointed Actuaries should also communicate to the board how climate change is an additional source of uncertainty in future assumptions (e.g., mortality, morbidity, and investment). Stress testing and scenario analysis (also recommended by the TCFD) can help with this communication.

Physical risks of climate change can have direct impacts on the healthcare system and place indirect costs on a health insurer. The diagram below shows the links between physical risks and health outcomes.

**Figure 4 – Physical Risks and Health Outcomes**




When changes in population health outpace the adaptations made to health systems, upward pressure on costs to the healthcare system and increased insurance premiums may occur over the long term. Health insurers should therefore consider how the health insurance system will transition, so that their product offerings continue to meet changing health needs. A significant transition risk can be disruptions to job stability (unemployment), which can increase physical and mental health claims incidence.

In many countries, health insurance is community-rated (at least to some extent). It is also periodically renewable/repriced. Actuaries should consider the potential for both adverse and beneficial trends and how long these trends are expected to evolve. For example, potential considerations include both the spread of diseases enabled by hotter conditions and fewer pollution-related diseases due to energy transition. Actuaries should also consider the risk of extreme events and be wary that past data may underestimate the severity or frequency of future extreme events. It may be appropriate to consider adjusting for this bias in pricing.

Given the interaction of health insurance and the broader society, actuaries need to consider certain macro issues, such as:

- Government policy actions, such as heatwave- and flood-mitigation plans that can reduce the level of vulnerability to these climate-related hazards;
- The impact of climate change on public health and emergency response services – for example, how more frequent extreme weather events or emerging chronic conditions might impact the healthcare system; and
- The potential impact of migration or changing population locations on healthcare systems.

## 2.2 Other Actuarial Associations

The Institute and Faculty of Actuaries has published a number of useful guides on climate change for actuaries, including "Climate Change for Actuaries: An Introduction", "A Practical Guide to Climate Change for Life Actuaries",[19] and similarly titled documents for defined benefit pension actuaries and general insurance practitioners, all published or updated in 2019.

It is beyond the scope of this paper to summarize the many aspects of these guides. However, some highlights from two of them are relevant to the objectives of this paper.

For example, the general insurance practitioners' guide provides additional useful material on the nature of physical, transition, and liability risk as seen from the UK perspective. Further, it discusses the need for, and considerations involved in, modelling these risks for the short, medium, and longer term. The life actuaries' guide similarly provides information to support those integrating climate change considerations into their work. Most of the principles from the life guide are relevant to all actuaries.

The life guide refers to the implications of climate change as far-reaching, non-linear, correlated, and irreversible. As pointed out in the Australian Information Note in Section 2.1, the timing of these financial risks can arise over a very long period and is quite uncertain, often outside current business or governmental planning horizons. While the outcomes are highly uncertain, many types of climate change risks are foreseeable. That is, there is a high degree of certainty that financial impacts from a combination of physical and transition risks will occur, although their severity, specific location, and timing are uncertain. Further, impacts can occur in many metrics, including best estimates, trends, and volatility.

Some practical steps that actuaries should consider in addition to the ones from Section 2.1 are:

- Recognizing the high level of correlation between climate change risks;
- Developing disclosure of approaches to climate change risk so that this is integrated into the insurer's risk and business planning;
- Raising awareness and risk identification – for example, logging climate-related risks on the risk register;
- Analyzing qualitative aspects of scenarios with alternative potential future paths for climate change and societal response, possibly inspired by narratives from the CRO Forum[20] or the TCFD Knowledge Hub;[21]

- Formalizing strategic actions and the insurer's ability to respond to potential future outcomes in risk assessments; and
- Monitoring best practice and techniques in the quantification of the insurer's exposure to climate-related risks and opportunities.

The TCFD framework, as discussed in Section 1, is relevant to actuaries who support the disclosures made by the organization they work for. Actuaries also need to understand the disclosures of other companies that the firm might invest in or have a counterparty exposure to. Therefore, actuaries should not only be familiar with their organization's Corporate Social Responsibility and sustainability initiatives, but also understand the climate-related risk management framework of their organization, clients, suppliers, and other stakeholders.

Actuaries should include climate-related risks within the firm's ERM process, proportionate to the nature, scale, and complexity of the insurer and its risks. A risk identification grid may be helpful to assess the potential climate change risks to which the insurer is subject. It is important to distinguish between shock (or "acute") and trend (or "chronic") impacts. The life guide shows an example of how to lay out such a grid on its page 16:

**Table 6 – Example of a Risk Identification Grid**[22]

| Risk Class | Physical | Transition | Liability |
|---|---|---|---|
| **Market** | Yes | Yes | Yes |
| **Longevity** | Yes | Less material | No |
| **Mortality/Morbidity** | Yes | Less material | No |
| **Lapse** | Less material | Yes | No |
| **Counterparty** | Yes | Yes | Yes |
| **Operational** | Less material | Yes | No |
| **Strategic** | Yes | Yes | Yes |
| **Reputational** | n/a | Yes | Yes |

This table adds operational risk to those risks discussed in the Australian Information Note. The nature and effects of extreme weather events (physical risk) can vary by geography, so an insurer's exposure is linked to its geographical presence. Insurers with a global presence or with significant outsourcing may be more prone to business interruptions (operational risk) in countries that do not have appropriate infrastructure in place.

The UK Financial Reporting Council noted that actuaries should be aware of systemic risks and the risk of groupthink, which may discourage the widespread use of a small range of models and parameters where there is actuarial collaboration. This risk can be mitigated by collaborating with other professionals and getting multiple views from, for example, consulting firms or reinsurance companies, to encourage robust independent challenge and reviews.[23]

The Canadian Institute of Actuaries published a research paper in 2015, "Climate Change and Resource Sustainability: An Overview for Actuaries".[24] This paper noted that climate change can also provide insurance opportunities that actuaries can get involved in and so should be considered for scenario applications. It has been updated through a subsequent paper published in September 2019 entitled "Time to Act: Facing the Risks of a Changing Climate".[25]

The Society of Actuaries published the "Climate, Weather, and Environmental Sources for Actuaries"[26] report in 2017, which contains data, analysis, and discussion sources pertaining to climate change, environmental risks, and weather. The report also contains case studies and surveys on what the insurance industry is doing and disclosing. For each of the sources/analyses/discussions presented, the report highlights potential applications for actuaries in each source, which makes this report a very useful resource for actuaries wanting to know how to manage climate-related risks. The Society of Actuaries has also published a series of educational notes regarding various aspects of climate change that might provide useful insight into the issues involved.[27]

Actuarial organizations around the world are rapidly developing important guidance and relevant information for practitioners. Other groups, such as the regulatory bodies noted in Section 1.5, are also producing useful guidance. There will likely be additional resources available between the time this paper is published and when it is refreshed by the IAA. Readers are encouraged to investigate contemporary sources for updated material of the type outlined above.

## 3. Considering Interactions and Systematic Issues

When actuaries consider scenarios or how firms may be affected by various types of climate-related risks, they should also consider the broader social, economic, political, and technological environment in which the firm operates. A useful tool to accomplish this is known as "systems thinking".

In the TCFD's October 2020 "Guidance on Scenario Analysis for Non-Financial Companies",[28] two types of scenarios are described:

- Exploratory scenarios, which are intended to be used to explore a range of alternative plausible futures. They are considered useful for testing strategies for resilience, as they provide a diverse set of plausible future states. Stress tests could fall into this category, where only the "tail risk" scenarios developed and analyzed are the stressed ones; and
- Normative scenarios, where future outcomes are set from which the pathways that are likely to lead to them are plotted. These types of scenarios are often used with assessment of targets and implementation plans. Reverse stress testing, where the scenarios and circumstances which make a business model unviable are identified, is a variant of this approach.

For climate-related risk scenario analysis involving chronic and acute events, it can be tempting to refer to the IPCC reports and try to map outcomes such as sea-level rise, hurricanes, and droughts onto:

- Liabilities
  - In the case of an insurer, exposures of its lines of business in the respective region; and
  - In the case of a pension fund, mortality and morbidity rates plus longevity and disability assumptions.
- Assets
  - In the case of an insurer or pension fund, how respective financial markets or the valuation of instruments are expected to behave.

However, following this approach may miss several crucial aspects of risk, including the:

- Implicit assumptions that, for example, financial markets, healthcare systems, supply chains, and communication links will be functioning at the level required in those scenarios;
- Inherent assumptions in the modelling approach taken which are used to estimate the value of assets and liabilities, and on which the scenario will be overlaid;
- Importance of the sequencing, correlation, and cascading of effects;

- Path and impacts of climate-related risk on critical infrastructure that led to the outcome – this is especially important in determining the resilience and costs of the impacts;
- Extent of correlation of the value of assets with liabilities (climate-related risk is a key asset/liability matching issue); and
- The possibility that actions by one firm to address its climate-related risk may create risk for another.

An example of the last point above could involve the interaction of insurers and mortgage lenders in response to more frequent extreme events. Property insurers could mitigate their financial risk by raising prices, but that might have an adverse effect on mortgage lenders in terms of the ability of their borrowers to replay loans. Mortgage lenders might react by reducing loan offerings in high-risk areas, affecting the pool of customers for the property insurer.

The TCFD's October 2020 Guidance document provides a framework for addressing the two types of scenario analysis. What is needed for both is a broader view of the entire system in which the firm operates. This can be referred to as systems thinking or systems dynamic modelling, and provides important information to enrich the scenario narrative.

Following this approach can assist the firm with thinking about the interconnectedness inherent in complex systems like a modern economy, such as political fragility, the economic and legal landscape, the state and quantity of natural resources, mitigation and adaptation efforts underway, and the environment. It can also assist in deriving values for the variables needed for estimation of impacts of these scenarios. For example, systems thinking would help both types of firms described above anticipate how the system might react to their actions.

However, caution and rigorous thinking will be needed when utilizing these variables in models or other calculations, as they inherently include implicit assumptions, at least some of which might be inconsistent and even incompatible with the scenario outcome, pathway, or analysis.

If such an inconsistency arises, it is necessary for actuaries to, at a minimum:

- Be familiar with the limitations as well as inherent assumptions used in applying these and other modelling techniques; and
- Be aware of alternate forms of modelling which do not have these limitations, and be prepared to consider their suitability, given the question being asked and the purpose to which it is being put (a discussion of which is beyond the scope of this paper).

The TCFD October 2020's Guidance describes scenario storylines:

> Scenario storylines link historical and present events with hypothetical futures by presenting a seamless and integrated narrative describing the causal train of events (pathways) and underlying drivers, assumptions and affected systems.[29]

Systems thinking can be helpful in both types of scenarios cited at the beginning of this section. From the viewpoint of exploratory scenarios, this includes resilience testing. From the viewpoint of normative scenarios, this includes plotting the pathways that could have led to that scenario outcome.

This approach is consistent with that of many well-respected experts, including Nassim Nicholas Taleb, the author of *The Black Swan*. He and others have advanced the theory of fragility, which refers to the observation that systems which are occasionally stressed become resilient, while systems that suppress volatility become fragile. Thinking of climate-related risks in terms of resilience or fragility of a system can provide valuable insights into the risk of major disruptions.

Considering complex systems and the broader socioeconomic environment is also an important reminder that developing and applying scenarios requires actuaries to operate in multi-disciplinary teams that contain expertise in diverse fields such as macroeconomics, history, and social science. This supplements more traditional areas of non-actuarial expertise in climate-related risk work, such as natural perils and climate science.

## 4. Updating Scenarios and Integration with ERM Frameworks

Scenarios may involve macro-level views of future conditions which may not materialize for decades. Whenever one uses such long-range forecasts, it is important to include short- to medium-term "signposts" so that it will be clear if prerequisite steps are being completed for a scenario to be viable. For example, if a scenario is developed for a country that intends to reach net zero by 2050, the following signpost questions could be appropriate (these are examples only):

- At what point will the vehicle fleet be required to be electric, or hydrogen-powered?
- What is the target for the number of suitable charging/refueling stations? By when?
- Will related infrastructure keep pace and how is this measured?
- Will legislation be passed to raise the minimum energy-efficiency requirements of buildings or force the implementation of effective land-use practices? If so, when?
- What are the annual targets for renewable power in the electric grid? Are there any grid constraints that could limit the uptake of renewable power? If so, when will these be overcome?
- What targets exist for conversion of electric grids and installation of smart grid devices?
- Will carbon taxes be implemented? If so, when? How will they be implemented, and will there be social justice offsets?
- Will some subsidized biofuels (e.g., ethanol) or fossil fuels (e.g., diesel) be phased out? If so, when?
- What recycling targets and circular economy initiatives exist and how will they be executed and monitored?
- What changes in agricultural practices can be achieved on what timeline? How will agricultural land compete with land-based carbon offsets?
- Does the scenario rely on Carbon Capture and Storage technologies that impact the risks and uncertainties?

A list of questions like these can inform a host of management decisions affecting a financial institution. For example, if an entity's investment policy calls for targets for low-carbon investments, responses to questions like these can help identify whether such investments are likely to encounter difficulty and should form a basis for one or more scenarios.

If short- and medium-term targets derived from questions of the type noted above are consistently missed (or exceeded), then scenarios can be adjusted periodically to reflect new information. Breaking down long-term forecasts into smaller steps with measurable outcomes can assist with the integration of scenario analysis into a firm's overall ERM framework.

In addition to building a framework to monitor and adjust scenarios periodically, firms will also need to integrate scenario analysis more broadly into ERM frameworks. This will include blending stochastic financial modelling and scenario analysis into a coherent set of tools to facilitate risk management in a firm.

Firms can also apply a bottom-up method to implement the scenarios:

- Consider every aspect of the scenarios for each process of the firm, such as policy management, accounting, claims management, and so on;
- Consider the impact the scenarios could have on each process; and
- Test the ERM framework to evaluate whether processes are sufficient.

A broader process to capture emerging and developing risks may be needed. Since there will always be uncertainty regarding the future, no future scenario has a 100% probability of materializing, just as no one specific financial forecast in a financial analysis can capture the variability in possible outcomes. Thus, a process to assess the probability or likelihood of various future states outlined in scenarios and to understand how they affect a firm's decision metrics should be developed and followed.

All models have some limitations on what they do and do not allow for. It is critical to understand such limitations and adjust for them where practical. For example, a model used to forecast the change in flooding potential under a high-emissions scenario may have to consider not only the current flood-control infrastructure but also what may or should be planned. Further, the possibility that things like human error (e.g., not maintaining levees) may affect the assumptions underlying a hydrological model should be thought through. Issues of this type require that practitioners understand the assumptions and limitations of any models used and how external factors may affect the assumptions and resulting risk.

Finally, whether a scenario assumes a static or dynamic set of actions by a firm can be important. While it is likely a firm will adjust its business strategy to react to its evolving environment, it can also be useful to consider a base scenario where it does not react (a static case) in order to understand its exposure to risk and how its actions change it.

## 5. Case Studies

These three simplified case studies are intended to be illustrative and not comprehensive examples of complete scenarios, which would be beyond the scope of this paper. The focus in the case studies is on the thought process involved in identifying relevant information and assembling it in a way that would allow a firm to assess the risks and opportunities it faces. Readers should not focus on whether the details of the case studies (e.g., agriculture insurance) are applicable to their operations, but instead on how an issue can be examined and data organized.

### 5.1 Crop Insurance in an Emerging Country

This example considers the impact of climate change on agriculture insurance in India over the period 2025–2030 from the perspective of an insurer. Based on observed temperature trends and those projected from global climate model simulations, a mean global temperature increase of between 0.95°C and 1.2°C was estimated for the projection period 2025–2030, relative to pre-industrial times (1850–1900). This is equivalent to an average scenario of +1.075°C vs pre-industrial levels, so this scenario applies a chronic, instead of acute, climate hazard identified in Section 1.2.

In a future warmer environment, not only temperature but also other meteorological variables affecting agriculture (notably precipitation) may be different than today. In addition, climate change-induced biodiversity loss (e.g., bees, fish stocks) will also affect agricultural sectors such as fruit-growing and fisheries.

### 5.1.1 Climate Change Impact on Key Agriculture Perils

There is compelling evidence that temperatures in India have been increasing and that the observed and projected temperature increases can be largely attributed to anthropogenic forcing.[30] Temperature increase has a negative impact on yields of various important crops such as rice, wheat, soy, and maize.[31,32,33,34] This impact is the result of various biological processes described below:

- Heat stress (>35°C) affects flooded rice crops. Exposure to high temperatures for a few hours can greatly reduce pollen viability and, eventually, lead to yield loss.[35] For rice, every 1°C increase in temperature will reduce global rice yield by an average of 3.2% (± 3.7%).[36]
- Wheat is also affected by heat stress in various ways. Increasing temperature to 45°C for two hours seven days after germination in 10 diverse wheat genotypes led to reduced length and dry mass of shoot and root as well as decreased chlorophyll and a lower membrane stability index.[37]
- Soybean exhibits some sensitivity to high temperatures from the seed germination stage.[38] For example, raising day/night temperature from 29/20°C to 34/20°C during seed fill decreased soybean seed yield.[39]
- In a global study by Zhao et al.,[40] it was found that the largest loss in yield is observed for maize; every 1°C increase in the global mean temperature leads to a yield decrease of 7.4% (± 4.5%).

### 5.1.2 Climate Change Adaptation in Agriculture

Future crop yields will not only depend on climate change but also on the ability of global agricultural practice to adapt. Historically, agriculture has usually adapted quickly to changing environmental conditions; for instance, by planting different crops or varieties. Climate adaptation generally includes several elements: availability and adoption of new technology, application of improved farming methods, shifting cropping patterns, and improvements in public infrastructure. However, past benefits from improvements in agriculture technology and infrastructure do not guarantee that crop yields will continue to offset adverse effects of climate change in the future.

### 5.1.3 Methods and Data

The pricing approach for agriculture insurance in India is based on the recent history (10 years) of yield data, which is available for approximately one million location-crop combinations. The Indian government-sponsored crop insurance scheme (Pradhan Mantri Fasal Bima Yojana, or PMFBY) guidelines are applied to yield data to estimate loss costs on an annual basis. According to the PMFBY guidelines, a payout is made when yields are below a certain threshold. The threshold yield is calculated by taking the average of the best five of the last seven annual yields, multiplied by an indemnity level, which is location-crop-specific and can have values such as 70%, 80%, or 90%.

Before applying PMFBY guidelines to calculate annual loss costs, a detrending procedure is applied.[41] This means that the original yield data can be transformed to reflect current "as-if" yields, considering the possible presence of a yield trend.

### 5.1.4 Climate Change-Driven Trends of Major Crop Yields

The climate trends for various important crops in India are obtained in two articles.[42,43] The trend estimates found in the original articles have been scaled accordingly so that they correspond to the temperature increase scenarios described in the Introduction (low, medium, and high trends; see the table below). These trends refer to near-term yield projections and relate to major producing areas in India for the respective crops.

**Table 7 – Country-Wide Annual Yield Trends (in %) Used for the Climate Change Scenarios**

| season | crop | low | medium | high | comment |
|---|---|---|---|---|---|
| Kharif | Paddy | -0.183 | -0.202 | -0.221 | |
| Kharif | Soy | -0.180 | -0.270 | -0.310 | Mall et al, 2004 |
| Kharif | Other | -0.128 | -0.142 | -0.157 | average of maize, sorghum, pigeonpea and groundnut |
| Rabi | Wheat | -0.187 | -0.212 | -0.237 | |
| Rabi | Other | -0.089 | -0.102 | -0.115 | average of barley, chickpea and mustard |

Based on the above trends adapted to our specific scenario, the climate change impact is illustrated in the calculation sheet below for one crop-location:

**Table 8 – Illustration for One Crop-Location**

| Current India Payout Estimation | | | | Current India Payout Estimation Under Climate Change Assumption | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Yield | Threshold | Payout | Years until 2025 | Yield change for 2025 (perc) | Yield projection for 2025 | Threshold | Payout |
| 2009 | 300 | 528 | 43% | 16 | -4.621 | 286 | 512 | 44% |
| 2010 | 500 | 528 | 5% | 15 | -4.332 | 478 | 512 | 7% |
| 2011 | 400 | 528 | 24% | 14 | -4.043 | 384 | 512 | 25% |
| 2012 | 600 | 528 | 0% | 13 | -3.755 | 577 | 512 | 0% |
| 2013 | 700 | 528 | 0% | 12 | -3.466 | 676 | 512 | 0% |
| 2014 | 800 | 528 | 0% | 11 | -3.177 | 775 | 512 | 0% |
| 2015 | 200 | 528 | 62% | 10 | -2.888 | 194 | 512 | 62% |
| 2016 | 550 | 528 | 0% | 9 | -2.599 | 536 | 512 | 0% |
| 2017 | 450 | 528 | 15% | 8 | -2.310 | 440 | 512 | 14% |
| 2018 | 650 | 528 | 0% | 7 | -2.022 | 637 | 512 | 0% |
| mean | 515 | | **15.0%** | | mean | 498 | | **15.2%** |
| CoV | 0.358 | | | | CoV | 0.360 | | |
| mean 5 | 660 | | | | mean 5 | 640 | | |
| indem | 0.8 | | | | indem | 0.8 | | |
| threshold | 528 | | | | threshold | 512 | | |

*Notes:*

- "Mean 5" is calculated as the mean of the five best years over the last seven years.
- "Indem": According to the PMFBY guidelines, an 80% indemnity level is chosen for this example.
- "Threshold" is the indemnity level multiplied by the "Mean 5".
- "Payout" equals $1 - \frac{yield}{threshold}$
- For the climate change assumption, a 0.289% reduction of yield per year is assumed. With this assumption, reduced yield due to climate change can be estimated on an "as-if" basis.

In conclusion, under the yield-reduction assumption, the average payout for this crop-location will increase from 15.0% to 15.2%, which represents a negligible 1.3% increase. However, this increase relates to a projection for the period 2025–2030. Over this time horizon, adaptation and risk mitigation are likely to offset the climate change impacts. But looking in a more distant future, the conclusions could be quite different.

## 5.2 Investing or Underwriting in a Region Dependent on Fossil Fuels: A Transition Example

To illustrate some of the concepts discussed in Section 1 regarding transition risk, here is an example of investments in assets or underwriting of insurance risk supporting a country heavily dependent on fossil fuels. The scenario is designed to facilitate risk management by a pension fund that invests, but is not itself based, in Qatar, or an insurance company underwriting assets (e.g., buildings, aircraft, ships, ports) based in or which operate in the country.

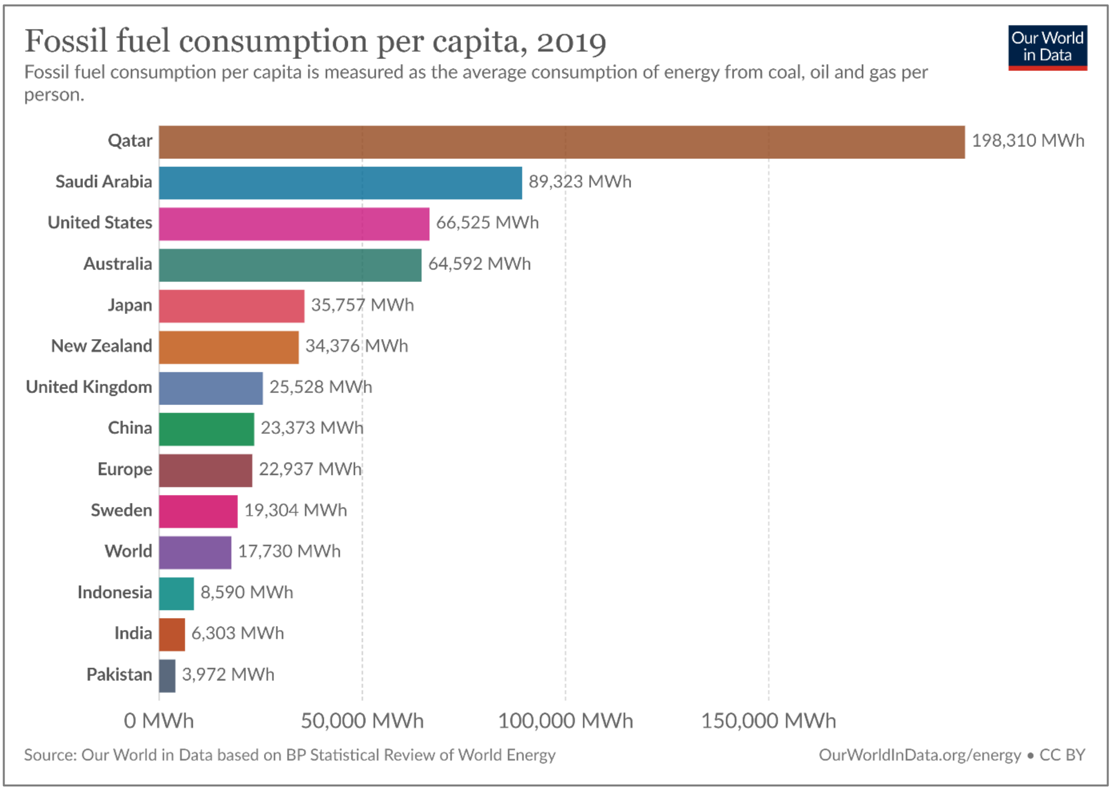
Section 3 introduced the concept of systems thinking. For purposes of brevity of illustration, not all aspects of systems thinking could be incorporated in this example. For example, in a fully developed scenario, it would also be important to consider additional aspects of population and workforce dynamics as well as the risks to political stability both regionally and domestically.

### 5.2.1 A Country Heavily Dependent on Fossil Fuels

What is the impact of transition risks that Qatar is expected to face because of transitioning to a low-carbon economy during the period 2025–2035, and what are the challenges this may pose for firms which have business interests there?

Qatar is a major producer and exporter of natural gas and oil, and its domestic oil and gas production entirely covers the country's energy needs. In 2019, Qatar's fossil fuel consumption per capita was the highest in the world, at almost 200MWh per person.[44]

**Figure 5 – Qatar's Fossil Fuel Consumption Per Capita, 2019**



Qatar's economic prosperity comes from the extraction and export of oil and natural gas. Exports from the oil and natural gas industries accounted for 38% of Qatar's GDP in 2019.[45] The next largest sector is the services industry.

Qatar has diversified into manufacturing such as flour milling. The manufacturing plants, however, rely on Qatar's own oil and gas resources.

Qatar has also promoted itself as a media centre through Al-Jazeera and a transportation hub through Qatar Airways. Qatar Airways has been active in promoting its environmental awareness, achieving a high-level certification from the International Air Travel Association's Environmental Assessment Program; is fully compliant with the European Union's Emissions Trading System; and participates in carbon offset programs.[46] By citing these activities, there is no judgement on Qatari actions, but simply a note that government and businesses in Qatar are attempting to address their environmental footprint despite the clear challenge that presents.

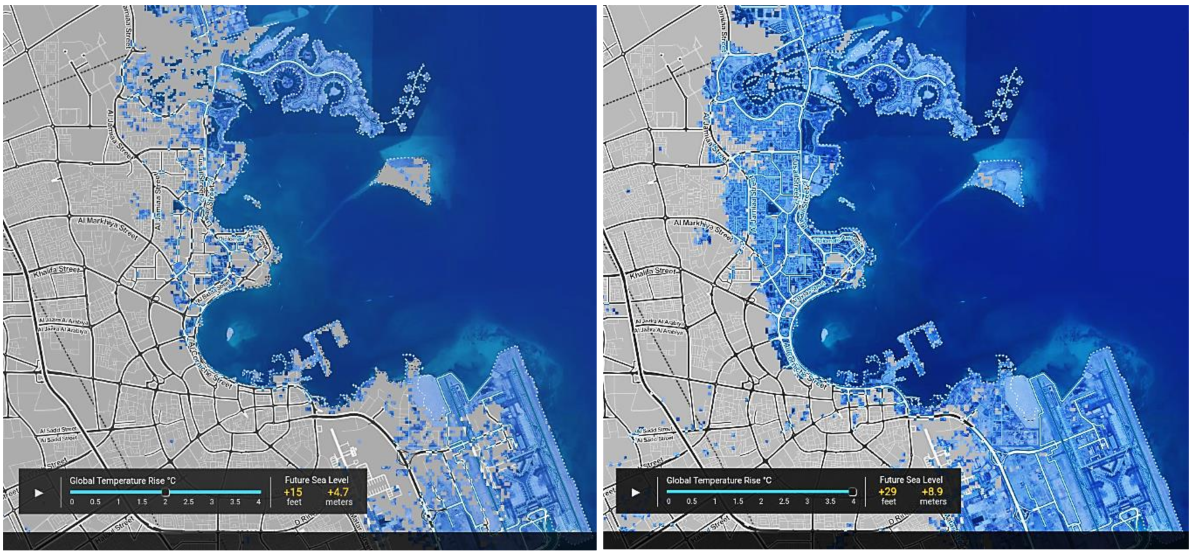
The scarcity of fertile land and water limits Qatar's ability to diversify into such sectors as agriculture. Fortunately, technology has helped Qatar overcome some of its land limitations; for example, by using treated sewage and desalinated water for irrigation. Qatar now produces and exports some fruit, meat, milk, cereal, and grains.[47]

### 5.2.2 Climate Change's Impact on Qatar's Economy

Qatar is in the Gulf region, which is characterized by an extreme climate, so a majority (80%) of its energy production is used for cooling services.[48] Around 92% of its population lives in the capital, Doha, a coastal city.

Due to Qatar's geographical location, the long-term climate change threat to Qatar's population is the impact on the sustainability of its economy, built environment, energy consumption, and energy systems.[49] Both images below show the Hamad International Airport and the Pearl-Qatar completely submerged underwater when projected long-term sea levels rise due to global temperatures increasing by 2°C and 4°C.[50]

**Figure 6 – Hamad International Airport and the Pearl-Qatar when Projected Long-Term Sea Levels Rise Due to Global Temperatures Increasing by 2°C and 4°C**




Climate change also poses an economic transition risk to Qatar as the country is heavily reliant on the exports of fossil fuels, which will be undergoing fundamental change. The International Monetary Fund's research team[51] projected that global demand for oil and natural gas will reduce due to:

- Slower population growth globally (1.1% in 2018 to 0.6% in 2046);
- Slower global GDP growth per capita (3.2% to 1.8% over the next decade) as emerging markets mature; and
- Accelerating improvements in energy efficiency and adoption of renewable energy sources.

The Qatari government recognizes these trends and has laid out a blueprint to diversify its economy to make it more self-sufficient and less reliant on gas and other natural resources.[52] The Qatar National Vision consists of four pillars, one of which is Environmental Development, which commits the country to invest in technologies which protect and conserve the environment. Despite these efforts, it will be extremely difficult for Qatar to achieve GHG emissions levels which will allow many investors and underwriters to continue activity in Qatar under their ESG guidelines. This may force such firms to re-evaluate their exposure to Qatar.

The next section discusses how a transition scenario can be constructed around the changes coming from national policies.

### 5.2.3 Scenario Construction

Table 1 in Section 1.1 illustrates that transition risk forecasts are highly uncertain and that actual outcomes will differ depending on technological, macroeconomic, and political conditions. Transition risks are influenced by the extent of global action, but acted upon locally through national policy, which contributes to the majority of transition risk. A relevant example is the developments in taxonomy for sustainable finance,[53] which could potentially allow Qatar to recognize its gas production as partially sustainable fuel for the EU. Such developments would affect Qatar's transition pathway to diversifying its economy to be less reliant on gas.

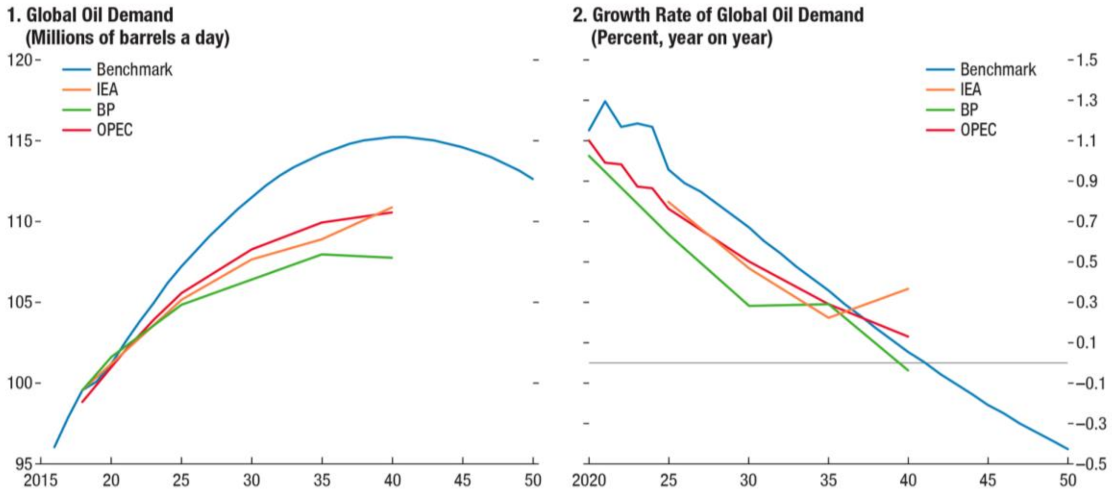
Measuring the impact of transition risks involves financial analysis of adaptation strategies using social and economic data. Methodologies used may be similar to current practice, although the scale of some changes may make the outcomes less reliable.

As outlined in Section 1.3, a transition risk scenario typically requires input such as appropriate transition pathways, designated timeframes, national policies, and demographic shifts. The end goal of the scenario analysis is to identify risks and opportunities and to set up or adapt a risk management framework to adequately accommodate the transition.

### 5.2.4 Designated Timeframe

In Qatar's case, the designated timeframe of the scenario is closely linked to the demand for oil and natural gas because its economy is currently highly reliant on these, both for exports and for domestic production and services. Energy institutions can provide guidance as to when the peak in demand for oil and natural gas is likely to occur. For example, the diagram below shows the different projections from British Petroleum (BP), the International Energy Agency (IEA), and the Organization of Petroleum Exporting Countries (OPEC), who envisaged a peak in oil demand around the year 2040.[54]

Figure 7 – Benchmark Projection and Forecasts by other Energy Institutions




Sources: BP (2019); International Energy Agency (2018); Organization of the Petroleum Exporting Countries (2019); IMF staff calculations.

The COVID-19 pandemic reduced fossil fuel consumption and may have brought forward the peak to be as early as 2028.[55] The IEA, in its October 2020 World Energy Outlook report, predicts that the demand for natural gas will first increase, as easy gains from coal-to-gas switching are largely exhausted by the mid-2020s. Prospects for gas start to deteriorate after that due to environmental considerations, competition from renewables, efficiency gains, and improvements in alternative low-carbon gases; for example, hydrogen[56] or ammonia.

### 5.2.5 National Policies, Transition Scenarios, and Macroeconomics

The table below summarizes the key national policies (Sustainable Development Goals, or SDGs) mentioned in the Qatar National Vision 2030 (QNV2030) that would be considered in developing a baseline transition (Planned Transition) scenario. The effects of such policies need to be quantified using economic and social data.

Table 9 – Key National Policies (SDGs) in QNV2030

| SDG | National policy | Consideration for scenario |
|---|---|---|
| 7 Affordable and clean energy | Increasing renewable energy; for example, through establishment of Qatar solar technologies | Increases revenue to offset loss from lower fossil-fuel exports |
| | Promoting energy and gas efficiency via National Renewable Energy Committee | Lowers expenditure on energy needs |
| | Improving rate of electricity and water per capita consumption | Reduces energy usage |
| 11 Sustainable Cities and Communities | Building of smart cities; for example, the Pearl and Lusail cities | Mitigates environmental impacts |

The concept of considering multiple scenarios was outlined in Sections 1.3 and 1.5 through the examples of scenario-development frameworks by various international bodies. In this case, it is useful to also consider an alternative scenario that takes into account the delay in implementing and achieving the QNV2030 and other national policies that help economic transition. This scenario is referred to the Delayed Transition scenario.

Macroeconomic trends are a key input to building a transition scenario for investments in Qatar as they have a direct impact on the value of its assets and indirectly on risks (sovereign, currency, political, economic structure, and banking sector risks).

The Economist Intelligence Unit published a long-term economic forecast for Qatar in 2019[57] assuming bursts of high growth with gas projects in the 2020s followed by diversification and expansion of the services sector. The population increases to 3.9 million by 2050, so growth in real GDP per capita slows down.

**Table 10 – Growth and Productivity (% Change; Annual Average)**

| **Growth and productivity (% change; annual average)** | **2020–30** | **2031–50** | **2020–50** |
|---|---|---|---|
| Growth of real GDP per capita | 1 | 1.8 | 1.5 |
| Growth of real GDP | 2.5 | 2.6 | 2.5 |
| Labor productivity growth | 1.1 | 2 | 1.7 |

### 5.2.6 Social and Technology Issues

Two scenarios are developed: a base scenario aligned with that of the Economist Intelligence Unit, and one featuring a delayed transition. The scenarios consider the following metrics:

- Population growth: Current population growth is at 2% p.a., of which 80% are immigrants – in the Delayed Transition scenario, immigration would decline by 50%;
- Renewables for energy needs: Qatar plans to generate 20% of its energy from renewables by 2024[58] – in the delayed scenario, there is late adoption from 2025, peaking at 20% at 2030;
- Adoption of low-carbon technology – for example, electric vehicles;
- Potential energy-efficiency measures; and
- More effective use of water resources, including “grey water”.

The impact of the diversion of national income and resources towards large-scale energy investment and debt servicing may reduce the availability of funding for state services (e.g., healthcare, subsidies). This may have impacts on society at large. Mitigation of this risk and “easing the transition” will be subject to the effectiveness of government policy decisions and their implementation. The provision of jobs in the newly created sustainable industry sectors, and the re-training of labor, will be a key issue.

**Table 11 – Summary of Key Scenario Assumptions**

| Inputs into scenario | Baseline (Planned Transition scenario) | Delayed Transition scenario |
|---|---|---|
| GDP growth (%) | 2.5% | 2.5% from 2025 to 2028<br>1.0% from 2029 to 2035 |
| Risk rating (sovereign risk) | BB[59] | BBB |
| Per capita electricity consumption | -6% by 2022[60] | -6% by 2025 |
| Per capita water consumption | -10% by 2022[61] | -10% by 2025 |
| Renewables as % of energy need | 20% by 2024 | 20% by 2030 |
| Population growth (%) | 2% | 1% |
| Labor productivity growth | 1.1% | 0.5% |
| Unemployment rate (%) | 0.10% | 0.5% |

In making these assessments, it must be recognized that Qatar's transition is dependent not only on its own progress, but also on the progress of its geographic neighbors, trading partners, and competitors, and other countries with which it might have cultural or other ties. Demand for products is important and will be driven by the pace of decarbonization globally. Also important is how Qatar's gas exports are classified by entities like the European Union. Given these dependencies, it would also be important to consider the risks to political stability both regionally and domestically.

### 5.2.7 Investment Considerations

If a pension fund or financial institution were exposed to investments or insurance underwriting in Qatar, consideration of the above types of issues would be required. There are several factors, in addition to political risk, that should be part of the analysis. For example:

- Does the investor have internal constraints on investments which include fossil-fuel production, and, if yes, will divestment be required and over what time horizon?
- Regardless of the investor's internal ESG policies, how will any investments exposed to Qatar be affected by a global push towards decarbonization?
- Regardless of the investor's internal ESG policies, how will any investments exposed to Qatar be affected by potential divestment actions by other investors? It should be noted that this effect may occur independently or on a different time horizon than changes prompted by decarbonization, and could have either positive or negative impacts on the value of such investments.
- Would investments in economic diversification in Qatar qualify under an investor's ESG policies?
- Has the financial institution adequately protected its policyholders, shareholders, or members from losses due to divestment or stranded assets? Is the firm exposed to legal or reputational risk by its involvement with Qatar?
- What is the timeframe of the investment in the context of the expected emergence of transition risk?

The answers to these questions would then feed into the investor's own assessment of transition risk from the entirety of its investment portfolio.

## 5.3 Climate-Related Risks, Crop Failures, Food Prices, Supply Chains, and Fragility

In the final case study, three brief historical examples are offered to illustrate the concepts discussed in Section 3 regarding systems thinking and fragility. While incorporating specific analysis of this type will lie beyond the scope of many practical applications in firms, practitioners developing scenarios should consider how the components of their scenarios can be affected by such large-scale effects, particularly given how dependent our society has become on complex global supply chains. Sternberg refers to this effect as "hazard globalization".[62]

### 5.3.1 Food Price Crisis

In 2010, extreme weather patterns caused a large decline in wheat production. An "omega block" high-pressure system over western Russia and Ukraine led to heat, drought, and bushfires in wheat-producing regions, with production falling by 32.7% in Russia and 19.3% in Ukraine.

Meanwhile, excessive rain in Canada and Australia dropped wheat production by 13.7% and 8.7% respectively.[63] At the same time, China increased wheat purchases following a once-in-a-century drought.

These events had a predictable effect on wheat prices, which skyrocketed to almost US$9 a bushel in February 2011 vs US$4 a bushel in June 2010.[64] Other grains were also affected, with the United States Department of Agriculture four-crop index (wheat, rice, corn, soybean) rising by 70% between June 2010 and March 2011.[65] At the time, countries in the Middle East and North Africa imported a large proportion of their wheat supply, with the top nine wheat importers per capita all being in this region.

People in many of these countries spent a large proportion of their income on food (in 2010 Libya 37.2%, Algeria 43.7%, Tunisia 35.6%, and Egypt 38.8%),[66] percentages which are far higher than those in most developed countries. The grain price increases in 2010–2011 led to large rises in the price of bread, placing great stress on significant parts of the population and countries' political systems.

This example demonstrates the complex relationship between weather, economics, and food security. That is why it is important to consider not only the local elements of a scenario as in Section 5.1, but also regional and global dependencies, such as the supply chain for food.

### 5.3.2 Floods and Global Automobile Parts Shortages

Also in 2010, abnormally late monsoon effects from the Bay of Bengal followed by tropical systems stalling over the country led to widespread flooding in Thailand. The event spanned several months and resulted in loss of life and property destruction across large parts of the country.

At that time Japanese and American automakers had production and assembly facilities in Thailand which supplied vehicles and parts to markets across the world. In addition to global manufacturers, scores of local suppliers provided parts. The floods affected automobile production and parts supplies in many countries.

The event caught many sophisticated manufacturers and insurers off guard. Some manufacturers were not fully aware of how dependent their supply chains were on diverse sources of components, which was also shown in the Tohoku Japan earthquake and the COVID-19 pandemic. Further, at the time, Thailand flood was not well covered by commercially available catastrophe models relied upon by insurers and reinsurers to assess risk. Thus, some failed to take the full potential for Thailand flooding into account when managing or pricing for risk.

The Thailand floods illustrated two important aspects of scenario analysis:

- Complex supply chains and an interdependent global economy can transform local climate events into global economic challenges.
- Just because a risk is not modelled does not mean it does not exist; those using simulation models need to understand not only what they do, but also what they do not do.

#### 5.3.3 Fragility

Taleb and Blyth[67] illustrate fragility from the conditions which existed before the 2008 Global Financial Crisis (GFC). They cite a series of government actions, particularly in the United States, which were designed to mitigate economic risk individually but, taken together, led to the financial system becoming fragile, which was a major contributor to the GFC. These included:

- Several large bailouts of major banks starting in 1983, with some financial institutions becoming "too big to fail";
- Suppressing volatility in the economy by using interest rate reductions at the slightest sign of downward trends in economic data; and
- Managing short-term risk without properly allowing for long-term consequences.

Taleb and Blyth argue: "Those who seek to prevent volatility on the grounds that any and all bumps in the road must be avoided paradoxically increase the probability that a tail risk will cause a major explosion."[68]

This example offers another important lesson in scenario construction: that the resilience or fragility of a given system should be considered when assessing how it may react to a stressor.

## 6. Next Steps

This paper is the third in a series of papers that the IAA Climate Risk Task Force has committed to develop over the coming years. The first paper was entitled "The Importance of Climate-Related Risks for Actuaries" and was an introductory paper to the series. The second was an "Introduction to Climate-Related Scenarios". To address the needs of actuaries, more are scheduled to be released over the following years, such as papers on:

- The application of climate-related risk scenarios to asset portfolios with an important subsidiary goal of encouraging consistency between assets and liability modelling;
- Climate-related risk management and addressing emerging third-party regulatory/reporting/disclosure requirements;
- The potential effects of transition and adaptation steps; and
- The link between climate-related risk scenarios and social security.

A review of existing IAA publications is also planned to identify and address any gaps related to climate-related risks. The IAA also plans to refresh the papers in this series periodically, given the rapid pace of change in the climate-related risk space.

The IAA Climate Risk Task Force welcomes and encourages input and involvement in these activities.

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