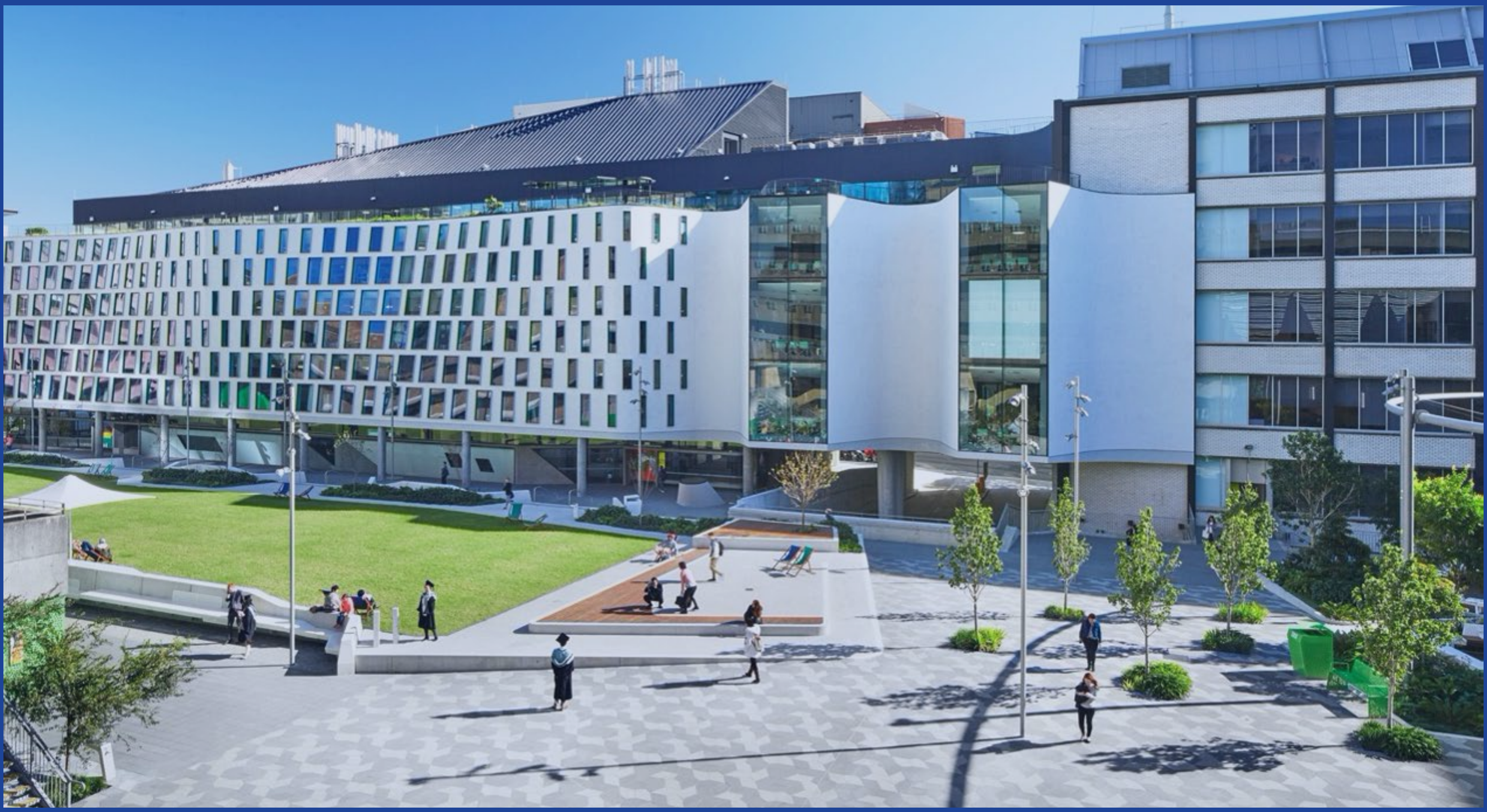
THE USE OF CLIMATE SCENARIOS IN AUSTRALIA

Prepared for Department of Agriculture Water and Environment

CLIMATE-KIC AUSTRALIA
& INSTITUTE FOR SUSTAINABLE FUTURES



RESEARCH TEAM

Scott Kelly
Research Director
scott.kelly@uts.edu.au

Katie Vines
Director of Operations
katie.vines@climate-kic.org

Karin Kobelentz
Senior Researcher
karin.kobelentz@uts.edu.au

Jay Rutovitz
Research Director
jay.rutovitz@uts.edu.au

Alison Atherton
Research Director
alison.atherton@uts.edu.au

Jack Herring
Research Assistant
jack.herring@uts.adu.au

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UTS Institute for Sustainable Futures

University of Technology Sydney
PO Box 123 Broadway, NSW 2007
www.isf.uts.edu.au

CLIMATE KIC AUSTRALIA

Climate-KIC Australia
Bldg 10, 235 Jones Street, Ultimo, NSW 2007
www.climate-kic.org.au

EXECUTIVE SUMMARY

Climate scenarios are increasingly being used by organisations to understand the risks and opportunities under different climate futures. Scenarios are a robust method for undertaking assessments of the future. They allow users to strengthen their awareness of the future by offering alternative possible futures and comparing responses based on those futures.

As yet, however, there is not a national set of climate scenarios for general use across Australia which is internally consistent in terms of the data, frameworks and tools that are being applied. This leads to increased costs and inconsistent outputs that can be difficult to compare.

Organisations that undertake climate scenario analysis have made important steps to understand climate-related risks and opportunities at an organisational level. However, there are still many barriers for organisations wishing to undertake climate scenario analysis.

There are high upfront costs in time, money and staff resources that are required to learn how to undertake climate scenario analysis. Users must source and interpret relevant data, and choose from a growing number of frameworks, tools and scenarios that are available. There are financial risks to the organisation if climate-related risks are not assessed and dealt with appropriately. There are also regulatory and litigation risks if disclosure is insufficient. Finally there are reputational risks if investors, customers or stakeholders take the view that climate change is not being taken seriously enough by the organisation.

More broadly, if climate risks are not adequately assessed and addressed there is a risk that unplanned responses to climate change impacts will produce negative outcomes for the economy, society and the environment.

There is now an opportunity to consolidate efforts at a national and sectoral level to produce a set of standard or reference climate scenarios for Australia with accompanying guidance and information on their application. This research recommends clearly articulating the purpose of any standard scenarios, as this will influence both their content and the stakeholders engaged in their development.

It then suggests the development of standard scenarios of the following three types:

1. **Generalised scenario analysis:** Scenarios that allow organisations to test their response to probable, and relatively high impact, physical climate risks, and/or transition risks arising from shifts to a low- or net-zero-carbon economy. Such scenarios could assume high emissions pathways to focus on physical risks, and low or net-zero emission pathways to assess transition risk, or combinations of the two. The scenario would include information on associated socio-economic trajectories, policy assumptions, market dynamics and fossil fuel divestment. These generalised scenario analyses seek to understand how external risk factors impact on the entity.

2. **Stress testing:** Scenarios designed to stress a system or an organisation. As such, they are low probability, high severity events and can incorporate both qualitative and quantitative information intended to stress a system or infrastructure. They can describe specific weather-related events (frequent or combination of events), and may also specify effects on infrastructure, buildings and the economy. Stress test scenarios can often be very specific providing a high-level of detail around particular events such as locations, timings and emergency response and recovery. It is this more detailed nuance of stress tests that distinguish them from generalised scenario analyses. Stress test scenarios can also describe a rapid transition scenario.

3 **Backcasting:** Scenarios that provide guidance and benchmarks across different sectors and assets that are aligned with a desired future state, such as a net-zero emissions pathway. Having clear benchmarks allows organisations and their stakeholders to assess whether their strategies are consistent with the desired future state. Where a generalised scenario analysis and stress testing explore the impact of external changes on an organisation, a backcasting scenario describes how a company will have to change to a be consistent with emissions or resilience targets.

Figure I below shows the main differences between these three scenarios.

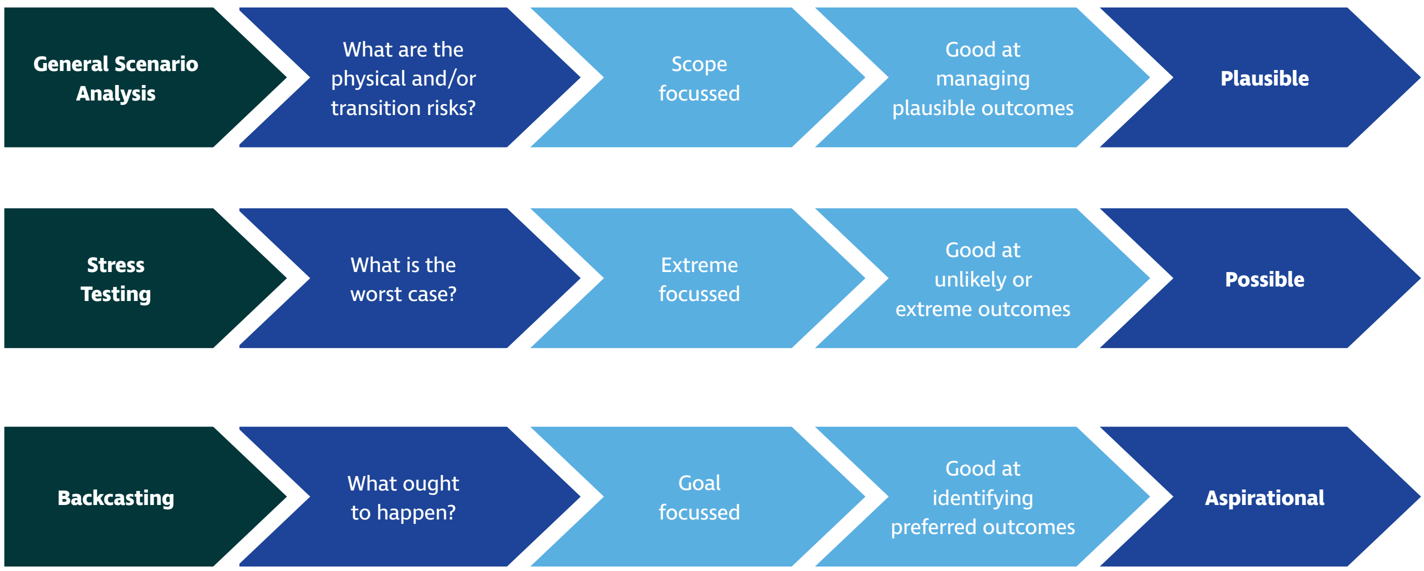


Figure I: Climate Scenario Archetypes

BACKGROUND AND MOTIVATION

The publication of the Task Force on Climate-related Financial Disclosure (TCFD, 2017a) was a watershed moment for climate risk analysis and disclosure. A key insight from the TCFD was acknowledging that mispricing climate-related risks can lead to mispricing of assets and misallocation of capital which could give rise to concerns about financial stability. Moreover, climate-related risks have a material financial impact on an organisation's income and balance sheet as well as potentially disrupting the business model of the organisation.

A key pillar of the TCFD was the recommendation to undertake climate scenario analysis to describe the resilience of an organisation's strategy. Over 1,440 organisations have now committed to reporting on the recommendations within the TCFD, representing a market capitalisation of more than US$12.6 trillion.

Even though the TCFD is voluntary, law-makers, regulators and standard setters are increasingly adopting the principles articulated within the TCFD and applying them to listed companies and regulated entities. In September 2020, New Zealand became the first country in the world to mandate the disclosure of climate-related risks for all banks, insurers and asset managers with more than NZ$1 billion of assets under management in line with the TCFD guidance.

Official institutions and regulators such as the ASX, APRA, ASIC, AASB and AUSAB have all made clear statements on the requirement to include material climate-related risks within official financial reporting, some referring directly to the TCFD for guidance. While the TCFD provides strong arguments for the use of climate scenarios in assessing climate-related risks, it falls short on providing the detailed guidance that is required to undertake robust, evidence-based climate scenario analysis across different organisations and geographies.

In order to fill this gap, governments in countries like New Zealand, Canada, United Kingdom, Switzerland and Sweden are starting to provide resources such as data, standards, frameworks and tools to assist organisations with the development and communication of different climate scenarios. Australia has to date adopted an industry-led approach. The Climate Measurement Standards Initiative (CMSI[1]) was formed to build on the recommendations of the TCFD by providing standards and guidance that companies in the financial sector can use when disclosing information about climate-related risks (CMSI, 2020a, 2020b, 2020c, 2020d).

The CMSI represents a world-first attempt at bringing together organisations from across the financial sector including banks, insurance and institutional investors along with reporting standards professionals, climate scientists, service providers and academics. The CMSI has now successfully developed and launched financial disclosure guidelines and scientific scenario specifications for the purpose of disclosing scenario analysis for climate-related physical damage to buildings and infrastructure. Future work of the CMSI may include the development of stress tests and transition risk scenarios.

In alignment with the recommendations of the TCFD and work of the CMSI, the Royal Commission into National Natural Disaster Arrangements has recommended that Australian, state and territory governments should support the implementation of the National Disaster Risk Information Services Capability and aligned climate adaptation initiatives, including developing integrated climate and disaster risk scenarios tailored to various needs of relevant industry sectors and end users. The Federal Government supports this recommendation in its response (Australian Government, 2020).

This research finds that the development and use of climate scenarios has been occurring for decades and was a key feature of the Intergovernmental Panel on Climate Change's (IPCC's) First Assessment Report (IPCC, 1991). While early definitions of the term 'climate scenario' were used specifically to refer to different climate emissions pathways, a broader definition is now commonplace. This contemporary and broader definition acknowledges interdependencies not just within the earth-climate system but also within the social, economic, technological and policy dimensions of pathways and particular future states. This broader definition is necessary when applying the TCFD, and when undertaking transition risk scenarios which are dependent on the market and policy impacts of a low carbon transition. This broader definition of climate scenario has been applied throughout this report.

Alongside the transition to a broader definition of climate scenarios is the need to shift from an adaptation to a resilience mindset. An adaptation mindset might be appropriate when considering

[1] The Climate Measurement Standards Initiative aims to establish open-source technical business and scientific standards for climate physical risk and projections of future repair and replacement costs for residential and commercial buildings and infrastructure in Australia https://www.cmsi.org.au/

physical climate but is not relevant when thinking about transition risks or the ability of organisations to build resilience into their balance sheets. Under the threat of extreme weather events, adaptation is an insufficient concept for dealing with transition risks or other indirect impacts that occur from physical climate-related risks (e.g. displacement, immigration and economic impacts etc.). Moreover, the concept of adaptation does not allow for the recovery of impacted buildings and infrastructure as it primarily addresses the ability to withstand climate-related impacts. An organisation that aims for resilience rather than adaptation, will not only be able to withstand future related physical impacts but will have the resources to bounce back faster and will have developed adaptive capacity to respond.

This report is produced in the context of helping organisations prepare for the future consequences of climate change that builds on the work of many others, including the recently released Royal Commission into National Natural Disaster Arrangements (Royal Commission, 2020).

METHOD

A review of academic and grey literature was carried out on the historical evolution of scenarios and how these techniques have been applied in the context of climate scenarios. A review of 21 climate scenario guidance documents published over the last two decades was reviewed. This also included a review of official and regulatory guidance on the disclosure of climate-related risks in Australia. Online tools and datasets that are relevant for an Australian context are also provided. A review of government-led, international, best practice on the provision and support of climate scenario development was also completed. In addition, ten leading case studies that represent a cross section of different sectors from within Australia and overseas were assessed and synthesised. In depth, semi-structured interviews were undertaken for each case study to enhance the depth of analysis.

KEY INSIGHTS

Key insights from the review of guidance documents show a clear shift from guidance being provided by climate scientists, development agencies and multilateral organisations to guidance being provided by the financial sector. This has coincided with a trend towards a broader and more holistic definition of what is meant by 'climate scenario'.

Climate scenario guidance is also increasingly being developed for specific sectors (e.g. institutional investors) or for specific types of risks (e.g. transition risks). Australia is also an international leader on the release of official and regulatory guidance for the disclosure of material climate-related risks.

The publication of the TCFD was clearly a watershed moment for undertaking climate-related risk analysis and there is an opportunity for future guidance to draw heavily on this resource as it has become the default standard across industry. The recently released CMSI guidance reports, particularly the science-based guidance, provides a promising resource for any future steps.

A synthesis of the case studies highlights that there are many differences in the way that climate scenarios are being developed, applied and disclosed. There are clear benefits for consistency of data use, clarity of assumptions, consistency of approach and consistency in disclosure.

Consistency of data is hindered because, although there are many publicly available datasets relevant for climate scenario analysis, these are difficult to find and are often incompatible with desired climate scenarios. There are also multiple different ways of constructing climate scenarios, so disclosure and clarity over different input assumptions is important for meaning to be derived from the outputs of the scenario analysis.

A core challenge for the development of a consistent approach driven by climate scenario guidance is the trade-off between utility for a given application and consistency between applications. In most situations the information required to inform decision-making is specific to the organisation. That is, different users require different spatial and temporal scales of information, different timeframes, varying climate information (e.g. extreme events), different emission scenarios and a variety of socio-economic drivers relevant to their organisation. The provision of future guidance, frameworks, data, tools and information would need to take these different user requirements into account.

Consistency is more useful in some situations than in others. For example, in financial disclosures, consistency can allow investors and regulators to compare the risk exposure of different companies or asset managers to inform investment decisions, or drive policy considerations. In this context, consistent scenarios are useful.

However, in the context of small and medium sized enterprises (SMEs) there is little need to compare amongst the businesses. The key driver for considering climate scenarios is to build the resilience of the business and allow identification of risks and opportunities. In the case of SMEs, the benefit of standardised scenarios isn't consistency but the ability to use a commonly adopted set of scenarios for assessing risks and opportunities.

Other benefits of a standardised consistent approach include sharing the burden, lowering barriers to entry and reducing costs. It is also important that scenarios do not become a tick-box exercise where organisations simply follow a template. The process of undertaking the climate scenario and systematically thinking through the risks and opportunities for the organisation is the most valuable part of the process. At the end of developing these climate risk scenarios, organisations may need to start considering their own decarbonisation strategies where appropriate. In order for these strategies to be aligned with net-zero outcomes, decarbonisation scenarios also need to be developed from which organisations can benchmark their performance against different sectors and asset classes.

Alongside the need to develop a national set of climate scenarios, is the need for sectoral coordination and guidance. The needs of every sector are unique and have differing capability and capacity for dealing with climate scenario analysis. Given these differences there might be a role for existing industry bodies to play a role in supporting and providing specific guidance on the use of climate scenarios within the sector (e.g. the CMSI was established to provide support for the financial sector in Australia).

FINAL RECOMMENDATIONS

› Provide standardised scenarios (and accompanying data, frameworks, guidance and tools)

There are many arguments for providing standardised scenario guidance, tools and frameworks. These range from regulating specific sectors, protecting consumers, guiding investor decision-making, reducing societal costs and improving the communication and management of climate-related risks and opportunities amongst others. Nonetheless due to trade-off between utility for a given application and consistency between applications of climate scenarios, the purpose of standardised scenarios needs to be clearly articulated. The scope of standardisation also needs to be carefully considered.

There are at least two climate emissions pathways that should be adopted from a risk and opportunity perspective, a low emissions pathway scenario for analysing transition risk and a high emissions pathway scenario for analysing physical risks. Recognising that earth-climate systems are interdependent with socio-economic drivers, climate scenarios should be holistic and describe internally consistent information on economic growth, population, changing demographics, climate policies and other drivers.

This holistic view of climate scenarios is consistent with the approach of the IPCC Sixth Assessment Report (AR6) and would allow development of socio-economic information and climate scenarios to proceed without needing to wait for AR6. These new socio-economic pathways will build on the Standardised Socio-economic Pathways (SSPs) that were reported alongside the release of the IPCC Fifth Assessment Report (AR5).

In order to understand the impacts of extreme scenarios (e.g. rapid decarbonisation pathways or the physical impacts of compounding extreme weather events) it is necessary to consider the development of stress test scenarios for use in certain contexts. Stress test scenarios are useful for understanding the impacts of low-probability but high-severity events that may occur in the tails of distributions. They can be useful for building strategic resilience to extreme shocks across both transition and physical risk scenarios.

› How to support use

Climate scenario analysis is complex. Even the most well-resourced organisations have difficulty finding the data and expertise required to undertake scenario analysis. In order to assist organisations, it is recommended that the Australian Government work with key information holders such as the Australian Bureau of Statistics, the Bureau of Meteorology, CSIRO, researchers and peak bodies to identify data gaps, issues and solutions for addressing data access and consistency issues.

We also recommend updating the Climate Change in Australia website to include guidance and information on climate scenarios. This could include communication of key messages, interactive scenario content, decision-making frameworks, comprehensive resource library, climate scenario helpline and external links to climate-related information and strategies.

Once these systems and tools have been established there needs to be ongoing support and maintenance to ensure that information and data remains up to date. Training and education for the end-users of these climate scenarios is also important.

GLOSSARY

AASB	Australian Accounting Standards Board
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AOGCM	Atmosphere-Ocean General Circulation Model
APRA	Australian Prudential Regulation Authority
AR6	IPCC Sixth Assessment Report
ASIC	Australian Securities and Investments Commission
ASX	Australian Stock Exchange
AUASB	Auditing and Assurance Standards Board
BES	Biennial Exploratory Scenarios
BNEF	Bloomberg New Energy Finance
BoE	Bank of England
CMSI	Climate Measurement Standards Initiative
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment
DDPP	Deep Decarbonisation Pathways Project
ESCI	Electricity Sector Climate Information
FSB	Financial Stability Board of the G20
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IAAF	Infrastructure Australia Assessment Framework
IASB	International Accounting Standards Board
IEA	International Energy Agency
IIRC	International Integrated Reporting Council
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
NarCliM	NSW and ACT Regional Climate Modelling
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NGO	Non-Governmental Organisation
OFR	Operating and Financial Review
PACTA	Paris Agreement Capital Transition Assessment
PRI	Principles for Responsible Investment
RCP	Representative Concentration Pathway
SME	Small and Medium sized Enterprise
SSPs	Shared Socio-economic Pathways
TCFD	Task Force on Climate-related Financial Disclosures
UK	United Kingdom
UNEPFI	United Nations Environment Programme Finance Initiative
XDI	Cross Dependency Initiative

CONTENTS

INTRODUCTION

PURPOSE

There is growing understanding of the importance of considering climate futures in decision-making and strategic planning and embedding resilience at an organisational level. As yet, there is no standard approach to the use of climate scenarios in these activities. This report provides foundational information on how to progress the development of climate change scenarios within an Australian context, which could underpin the development of national guidance on approaches to climate scenarios. The report was commissioned by the Australian Government Department of Agriculture, Water and the Environment (DAWE) and reviews current practice on the development of climate scenarios and their use in planning and reporting.

The primary audience for this report is DAWE as the recommendations from this report are aimed at informing next steps in the development of climate scenario guidance for Australia. The secondary audience for this report is other interested parties across Australia, and internationally who may wish to consider the insights and recommendations and adopt some of the lessons learned from other sectors when undertaking climate scenario analysis.

SCOPE OF THIS REPORT

The scope of this study was intentionally kept broad to include a range of sectors across the economy. Given the primary application of this study will be for use within an Australian context, Australian-based case studies were prioritised. However, given the richness, experience and quality of resources that are available internationally, this study also reviewed international best practice and case studies. Several of the case studies used in this report are from multinational organisations. The case studies were not selected to be comprehensively representative of the Australian economy, rather, case studies were chosen because of their level of maturity in climate scenario development and use. The following sectors were chosen for this study:

- Finance
- Critical Infrastructure
- Buildings
- Agriculture
- Resources and Mining

The primary focus of this report is on climate physical risk scenarios; however, many organisations consider physical climate scenarios alongside or simultaneously with transition risk scenarios. In addition, the socio-political context that might drive certain emissions, and hence, climate scenarios are often critical to effective decision-making. As a result, some discussion of transition risk and socio-economic scenarios is also included.

This report is not intended to provide information about climate change risk or vulnerability assessment, adaptation planning or resilience planning processes. It is important to note that these activities usually make use of climate change scenarios, so development of climate scenario guidance will need to also consider how these broader activities may also benefit from the development of climate scenario guidance.

METHODOLOGY

This study consisted of the following activities:

1. Review of the literature on: incorporating the history of scenario development and use; the use of climate scenarios for decision-making; and recent advances in the application and disclosure of climate-related risks when using scenarios.
2. Review of international best practice on the development and use of climate scenarios.
3. Review of climate scenario guidance, datasets, frameworks and tools published from multilateral organisations, peak bodies, regulators, consultancies, private sector companies and research institutes.
4. Deep dive into ten climate scenario case studies including a review of annual reports, online material and in-depth interviews with key individuals who were involved in the development and application of the climate scenarios in question.

STRUCTURE OF THIS REPORT

The report starts by defining climate scenarios and then presents a short history of scenario use and how the 'scenario' approach can be applied to a climate change context and then to a business application. The next section reviews international best practice in the development, application and provision of climate scenarios. The next section reviews 21 climate scenario guidance documents published over the last two decades followed by an up to date review of regulatory guidance within a climate risk context. This is then followed by high level insights from the ten case studies and half page summaries of each case study (a description of each case study can be found in Appendix 6). The final section provides a list of recommended next steps. Climate scenario guidance is included in the appendices.

WHAT IS CLIMATE SCENARIO ANALYSIS AND WHY IS IT SO IMPORTANT?

WHAT ARE SCENARIOS?

Scenarios are a robust method for undertaking assessments of the future. They allow users to strengthen their awareness of the future by offering alternative possible futures and comparing responses based on those futures. Within the academic literature, scenario analysis comes under the emerging discipline of futures studies.

Numerous definitions of scenarios exist for example:

“ ...a description of a possible set of events that might reasonably take place. The main purpose of developing scenarios is to stimulate thinking about possible occurrences, assumptions relating these occurrences, possible opportunities and risks, and courses of action.”

(Jarke et al., 1998)

“ ...a tool for ordering one’s perceptions about alternative future environments in which one’s decisions might be played out.”

(Porter, 1990)

“ ...a set of reasonably plausible, but structurally different futures.”

(Schwartz, 2012)

“ ...conjectures about what might happen in the future.”

(Heijden, 2011)

Scenarios can incorporate both quantitative and qualitative information and often incorporate a combination of both qualitative narrative and analytical modelling. It is a process of describing how a country, organisation, portfolio or asset may perform or be impacted by a potential future state. The process of undertaking scenario analysis allows users to understand key drivers and possible future outcomes.

Rubin and Kaivo (1999) characterise scenarios using the following questions: What will happen? What can happen? How can a specific future outcome be achieved? (Figure 1).

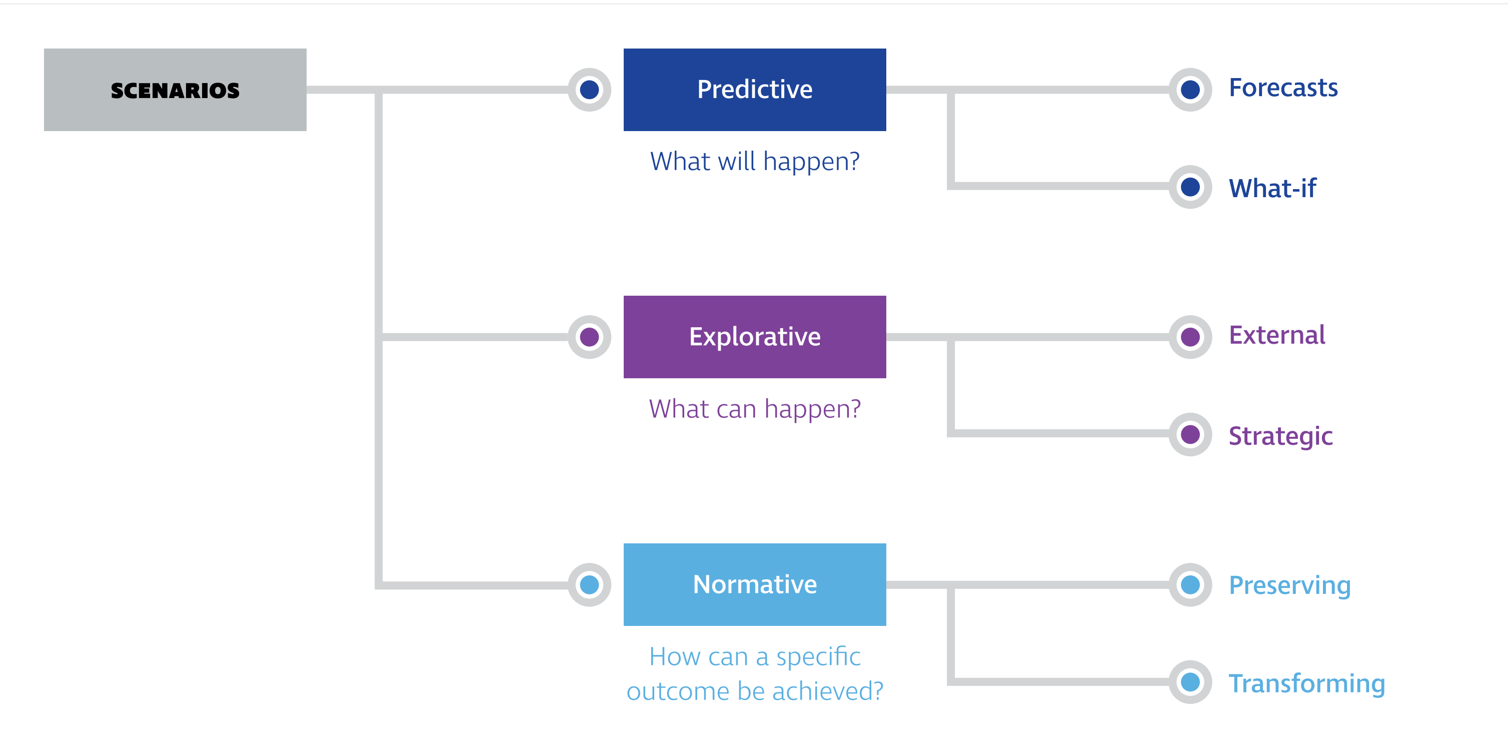
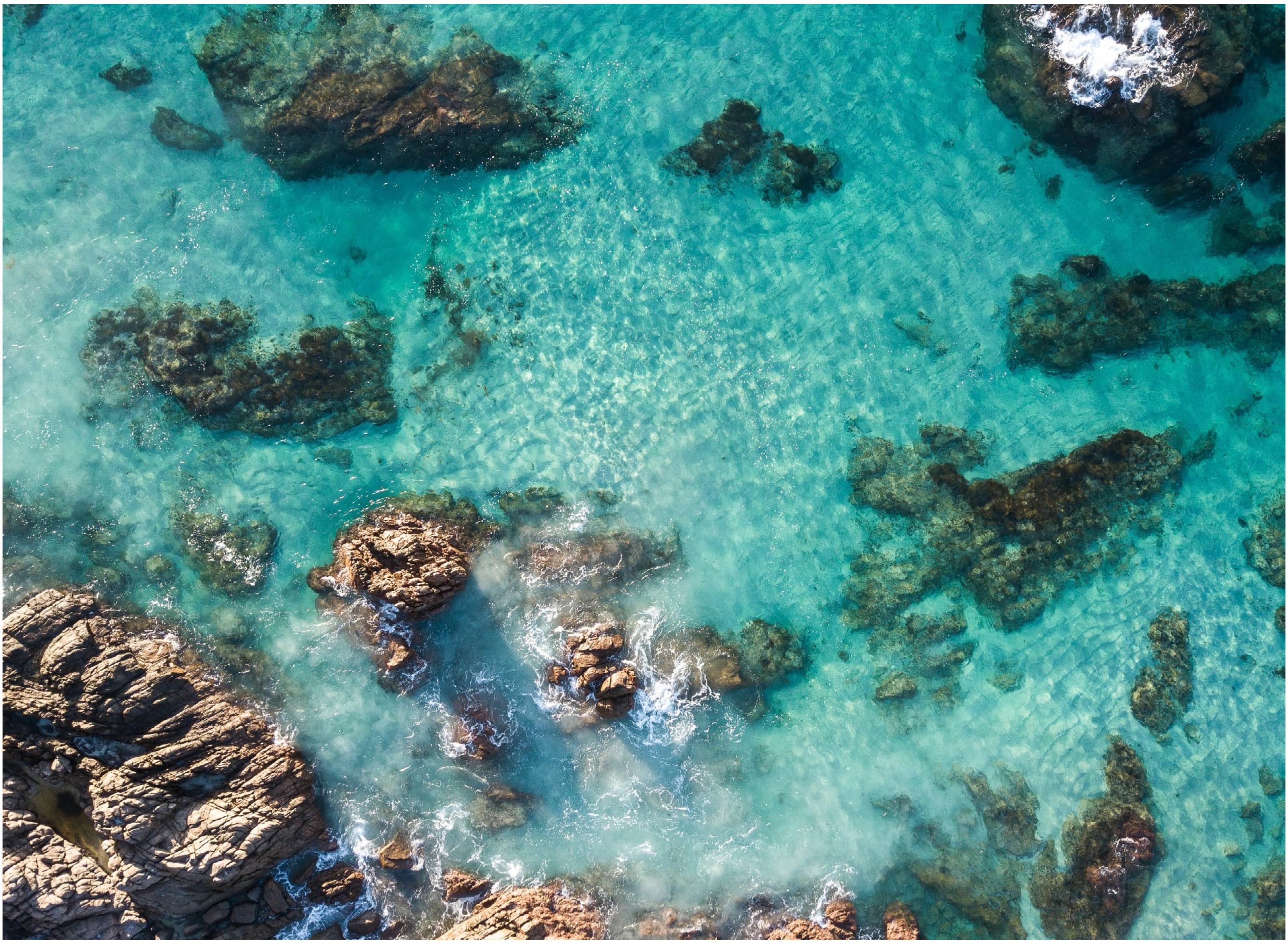


Figure 1: Scenario typologies. Source: (Börjeson et al., 2006)

The aim of predictive scenarios is to predict what is going to happen in the future. Predictive scenarios are not typically used for climate scenario development owing to the large uncertainty, long time-horizon and the inability of historical data to make forecasts about future climate change. Thus, climate scientists develop alternative scenarios based on different emissions pathways and their impact on the global climate.

The aim of explorative scenarios can be distinguished by external scenarios and strategic scenarios. External scenarios are focussed on the question of what can happen in the future owing to external factors, while strategic scenarios respond to the question of what can happen if we respond in a different way. It is this family of scenarios that are most often considered when carrying out climate scenarios and is important when considering the question of how to build resilience to the future consequences of climate-related risks.

The final group of normative scenarios has a focus of interest on a certain future situation or objective and how these can be realised. This category of scenarios use techniques like backcasting to understand what steps need to be taken to arrive at a desirable future state. For example, a target to achieve net-zero emissions in 2050 could apply either backcasting or optimisation to achieve the desired future state and are also a form of climate scenario analysis.



COMMON TERMS AND DEFINITIONS

There are many different terms used in the use, development and description of climate scenarios. Even terms like 'scenario analysis', 'sensitivity analysis', 'stress test', 'reverse stress test', 'forecasting' and 'backcasting' all have specific differences which are important to understand. The following definitions have been developed from several sources including: The IPCC, TCFD, and The International Actuarial Association.[5]

Scenario: A scenario describes a possible future state, describing either a single point in time or the process of change over time. One or more events or changes in circumstances may be forecast, often over multiple time periods. They are coherent, internally consistent and plausible descriptions of possible future states of the world (IPCC, 2001). Scenarios can also be complex, involving changes to, and interactions among many factors over time, perhaps generated by a set of cascading events. It can be helpful in scenario analysis to provide a narrative to support the scenario and put it into context. Scenarios can also reflect the range of uncertainty or the likelihood of a particular magnitude of warming given a particular emission concentration pathway.

Sensitivity analysis: The effect of a set of alternative assumptions regarding a future state, assessing the effect of a large move in one or two critical factors. For example, a scenario used for sensitivity testing usually alters the input assumptions to the scenario to understand how much final outputs deviate. Two different scenarios would typically represent much wider variation in model outputs than a sensitivity analysis completed on the same scenario.

Stress test: A projection of the condition of a business, asset or economy under a specific set of severely adverse conditions. This may be the result of several risk factors over multiple periods or time, or one risk factor that is short duration. A stress test is designed to represent a severe set of circumstances that will place the entity under stress. It is specifically used to understand how an entity would be impacted under a set of severe and extreme conditions. By understanding how an organisation responds under extreme (high severity, low probability) circumstances it is possible to identify strategies that may build resilience.

Reverse stress test: Similar to a stress test, a reverse stress is designed to test an entity under an extreme set of conditions. Unlike a stress test, a reverse stress test is a process of identifying the point at which an entity's business model becomes unviable and then identifying scenarios and circumstances that might cause this to occur. In other words, it is about identifying the point at which the entity fails. It therefore allows users to identify the weakest link.

Forecast/Prediction: Is a technique that uses historical information to make informed predictions of future outcomes. Forecasts are often quantitative and use analytical techniques to predict future states based on historical data and realistic assumptions about the future.

Projection: The term projection is used in two senses. First it describes a description of the future state and second, it can describe the pathway leading to it. More specifically, a "climate projection" is used by the IPCC when referring to model-derived estimates of future climate.

Hindcasting: Typically involves running a model or models with a known history to determine if the model can reproduce historical outputs accurately. These methods are typically used to test the accuracy of climate science models and for testing historical counterfactuals.

Backcasting: Working in the opposite direction to forecasting, backcasting picks a desirable state in the future then adjusts important variables and parameters back to the present day. It can be used to identify the required step-by-step changes across multiple objectives for meeting a future condition at a certain point in time.

Representative Concentration Pathway (RCP) describe possible future emissions and the concentration of greenhouse gases in the atmosphere. They describe a pathway or trajectory of concentrations over time to reach a particular radiative forcing at 2100. There are four pathways described in the IPCC Fifth Assessment Report (AR5)—RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The numbers in each RCP refer to the level of radiative forcing produced by greenhouse gases in 2100 (e.g. RCP 8.5 refers to 8.5 W/m^2).

Shared Socio-economic Pathways (SSPs) create a consistent set of assumptions of different socio-economic pathways to study climate-related scenario outcomes. The SSPs released alongside the IPCC Fifth Assessment Report explore five distinct narratives for exploring future climate change impacts.

[5] International Actuarial Association (2013). Available here.

WHAT ARE CLIMATE SCENARIOS?

Upon reviewing the literature, we have discovered two broad categories for how the term 'climate scenarios' is being used and interpreted. The traditional or narrow definition focuses on changes to the climate and how this influences the natural environment, society and the economy. This is the definition used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The contemporary or broader definition acknowledges that society and the economy are interdependent and thus a climate scenario must also include information about changes to society and the economy to ensure that a future climate scenario is both plausible and coherent. It is this later definition that is required for the consideration of transition risks (e.g. divestment away from fossil fuels) and therefore it is this broader definition that is used by the TCFD. The broader definition is also consistent with the theory behind the use of shared socio-economic pathways (SSPs) released alongside the IPCC AR5. The broader definition of a climate scenario will be fully adopted in the forthcoming IPCC Sixth Assessment Report (AR6) which will fully incorporate climate scenarios that are coherent across social, economic, technological and climate dimensions. It is the broader definition that is used in this report when referring to climate scenarios. When referring to the older narrower definition of climate scenario, the term 'climate science scenario' will be used.

Under the traditional narrow definition, a climate scenario is a plausible representation of a future climate that has been constructed for a specific use in investigating the potential consequences of human-induced climate change and natural climate variability (IPCC & Working Group I, 2001) . Climate science scenarios most often make use of climate projections (descriptions of the modelled response of the climate system to scenarios of greenhouse gas and aerosol concentrations) at both global and higher resolutions, in combination with other lines of evidence such as recent climate trends and their attribution, understanding of regional climate variability, physical climate theory, historical climate and emerging research.

Climate science scenarios can serve as valuable decision-support tools by enabling actors to explore how climate change might plausibly affect their activities over time. More specifically, climate science scenarios can assist businesses and governments in better understanding historical exposure, the strategic implications of climate-related risks and opportunities, and possible future developments that could exacerbate potential hazards (Palutikof et al., 2019). For example, investors may draw on climate scenarios to explore how the performance of particular assets, sectors or regions might change under different future states (Palutikof et al., 2019)

Climate science scenarios can exist at different scales. Coarse resolution scenarios—global, regional (global regions) and national—are readily available. However, these scales of scenarios are rarely useful for decision-making. Most policy, program and project decision-making require sub-national, or even local information, at fine time scales (hours or days), and include information on extreme climate events. Developing local or sub-national scale climate change projections usually includes:

- A prediction of global greenhouse gas and aerosol emissions most commonly for the this century (see description of Representative Concentration Pathways below)
- A global carbon cycle model to convert these emissions into changes in carbon dioxide concentrations (and similar models for calculating concentrations of other greenhouse gases and aerosols)
- A coupled atmosphere-ocean general circulation model (AOGCM) which uses the greenhouse gas and aerosol concentration information to predict climate variations forward in time.
- Downscaling of the AOGCM results through a procedure which takes account of the influence of topography on local climate. This can be done either statistically or dynamically with a high-resolution regional climate model.

Given the current knowledge and modelling technology, there are uncertainties in each of these steps. For example, emission predictions depend on the difficult tasks of predicting changes in population, economic growth, technology, energy availability and national and international policies, including predicting the results of international negotiations on constraining greenhouse gases (GHGs). Our understanding of the carbon cycle and of sources and sinks of non-carbon dioxide greenhouse gases is still incomplete. There are significant uncertainties in current global climate model predictions—particularly at regional levels.

The climate science scenario approach described above recognises these uncertainties. A climate scenario is a model-generated projection of one plausible future climate for a region consistent with assumptions about social, economic and technological developments. When carrying out climate scenario analysis, particularly at a more granular scale, it is recommended to use a range of climate scenarios. These can span credible estimates of future GHGs, and the uncertainty range in climate emission predictions.

Nonetheless, to ensure it is robust, climate information used to create climate scenarios needs to have three important ingredients, described by Cash et al. (2003):

- **Credibility**—information that is authoritative, believable and trusted. The scientific process supports this through practices such as peer review, and assessment and rebuttal of controversial claims. Credibility may also come from the use of international peer-reviewed literature and assessments from the IPCC and reputable scientific bodies such as universities, the CSIRO and the Bureau of Meteorology.
- **Salience**—the relevance of the information to decision makers and the public. This requires collaboration and co-production of knowledge between sector experts and climate scientists. Information needs to be fit-for-purpose, with appropriate descriptions of confidence and uncertainty.
- **Legitimacy**—the fairness of the consultation and information-producing process, and how it considers the values, concerns and perspectives of different actors. Legitimacy may be provided by appropriate governance structures, engagement, communication and review processes.

Making decisions regarding the most useful and scientifically defensible[2] estimates accounting for uncertainty ranges and identifying the most relevant climate data points requires participatory processes in order to capture both scientific inputs and stakeholder views (Palutikof et al., 2019). This allows for the development of consistent scenarios across multiple scales of interest, which are also decision-useful.

GREENHOUSE GAS EMISSION AND CONCENTRATION SCENARIOS

Climate change models use the IPCC's Representative Concentration Pathways (RCPs) as inputs to drive changes in radiative forcing, which in turn affect the climate. The RCPs specify the concentrations of greenhouse gases in the atmosphere over time. The climate modelling community has produced a set of RCPs to serve as a basis for near-term and long-term modelling experiments (Vuuren et al., 2011). In total, four pathways (8.5, 6, 4.5 and 2.6) were developed, with each RCP covering the period from 1850–2100 and describing possible time-series of changing greenhouse gas (GHG) emissions. The labels for the RCPs represent the net radiative forcing implied by each for the end of this century, expressed in watts per meter squared.

It is common for people to refer to the IPCC RCPs as 'climate scenarios', however while they are used as inputs to the climate projections that underpin climate scenarios, the RCPs are not climate scenarios in themselves. It is possible to model the future climate by only considering the greenhouse gas concentrations and assume static or constant; growth in population, economic output or portfolio growth. The RCPs provide only high-level context on socio-economic assumptions to describe the policy or economic context that might drive the RCPs. However, scenarios driven only by the RCPs would constitute a narrow definition of a climate scenario, in this report referred to as climate science scenario. The reality is that socio-economic pathways are intrinsically linked to different emissions pathways, and hence climate projections. SSPs were developed to provide complementary global scale scenarios of policy and economic activity that could align with the possible concentration and emission of GHGs outlined in the RCPs.

[2] Scientifically defensible means that the scientific scenario specifications have been prepared based on a review of current scientific literature and independent expert assessment on the expected change in behaviour of physical risks under the climate scenarios recommended in the financial disclosure guidelines (see Scientific Scenario Guidelines (CMSI, 2020b)

SHARED SOCIO-ECONOMIC PATHWAYS

In the most recent IPCC report (AR5) SSPs were developed to sit alongside the RCPs to articulate the feedbacks between climate change and socio-economic factors. The new SSPs are based on five narratives describing alternative socio-economic developments, including sustainable development, regional rivalry, inequality, fossil-fuelled development, and middle of the road development. The long-term demographic and economic projections of the SSPs allow for a wide range of outcomes consistent with the scenario literature.

For AR6 the radiative forcing pathways of the SSPs are being used as important inputs for the latest climate models. They are being used to explore how societal choices will affect GHGs and how climate goals of the Paris Agreement could be met. Five new SSPs describe scenarios of global warming in 2100 that range from a low of 3.1°C to a high of 5.1°C above pre-industrial levels.

The benefit of using SSPs is that each represents an internally consistent future that an organisation can use for building scenarios that incorporate both physical and socio-economic futures. This allows an organisation:

- to characterise the demographic, socio-economic and technological driving forces underlying anthropogenic GHGs which cause climate change; and
- to characterise the sensitivity, adaptive capacity and vulnerability of social and economic systems in relation to climate change (Carter et al., 2001).

PURPOSE OF UNDERTAKING CLIMATE SCENARIO ANALYSIS

Climate scenarios are generally developed to investigate the implications of long-term climatic, environmental, and anthropogenic futures in order to design robust policies, programs, strategies and even infrastructure in an environment of interacting-complex systems and uncertainty (Hall et al., 2016; Harrison et al., 2015; Kebede et al., 2018; Kelly, 2015)

Navigating the complexity of climate change impacts, interacting dynamically with government policy, the advancement of new technologies as well as changes to population, socio-demographics and economic growth is impossible with traditional forecasting models that rely on historical precedence to predict the future (Kelly et al., 2016). We are now in uncharted territory with significant uncertainty about future carbon trajectories and the resultant changes in climate impacts. Climate scenarios, guidance and tools aim to allow decision makers to work with these uncertain futures and make robust decisions about policy, programs, investments and strategy.

With this in mind, climate scenarios can provide input to:

- Adaptation planning: identifying the actions required to respond to the impacts of physical climate change (usually adaptation planning does not consider transition risk);
- Risk assessment and management: avoiding the negative impacts and identifying the opportunities from climate change (both physical and transition risk);
- Stress testing: assessing the impact of relevant extreme events and outcomes on an entity such as an organisation, portfolio or asset.
- Achieving carbon reductions: low carbon futures are selected, and the actions required to keep GHG emissions below that set level are identified;
- Assessing socio-economic or environmental impacts: Identifying how possible future climates will affect socio-economic or environmental systems.

In summary, climate scenario analysis allows decision makers to consider the full-range of possibilities allowing the identification and consideration of robust responses that may challenge prevailing mindsets. Importantly any given scenario describes one path of development that leads to a particular outcome. They are not forecasts of what will happen, nor do they try to represent the full description of the future. They are hypothetical constructs designed to challenge currently held views about the future. As discussed in the TCFD, scenarios should be plausible, distinctive, internally consistent, relevant and challenging.

USERS OF SCENARIOS

Both public and private sector organisations are increasingly applying climate scenario analysis to understand climate-related risks. However, climate scenarios are complex and remain an active field of development globally. Even over the last few years new guidance and approaches have emerged. There however remains large variation between different guidance methods and approaches. As a result, most of the users of climate scenarios to date have been professionals and scientists with high levels of technical capacity in the area. For effective management of climate change risks and opportunities into the future, more people and organisations will need to become proficient in using climate scenarios. This will require both increasing capacity across society to understand and use climate scenarios as well as approaches to make the use of climate scenarios more accessible.

LIMITS OF CLIMATE SCENARIOS

Climate scenarios are descriptions of possible futures. Even climate change projections that are based on rigorous science and sophisticated climate models contain profound uncertainty. These models don't predict what future GHG emissions will be, but rather they aim to model the future climate outcomes based on assumptions about different levels of GHG concentrations in the atmosphere. Given the scale, long time-horizons, embedded complexity and numerous earth-climate feedbacks that these models need to compute, even the smallest deviations or differences in assumptions between models will produce varying results. As with any model of the real-world, imperfections and idealisations need to be tolerated. This is known as model uncertainty. Despite these uncertainties, climate models remain robust and have consistently been validated using a range of scientific methods.[3]

Scenarios are an important tool for making decisions in the face of such uncertainty, but they often feed into decision-making processes that are not well equipped to acknowledge or manage uncertainty. As a result, there are some concerns and limitations about the use of scenarios in decision-making, understanding risk, or planning adaptation responses. Some of the issues in the use of scenarios include:

- **False sense of accuracy:** Some scenarios can be very specific and include detailed information. This information can be easily misunderstood as a specific prediction about the future or a statement about what will happen. This can give users a false sense of accuracy about any organisational impacts calculated based on this information. In fact, they are a statement of what may happen. Sometimes they have probability ratings, and in some cases (such as compound extreme events, or stress tests) have a low or zero probability of occurrence.
- **The decision-making processes they inform:** In many cases climate scenarios are used to feed into existing decision-making processes which may not be fit for purpose when dealing with uncertain futures.
- **Unknown unknowns:** Scenarios are not able to identify or easily allow consideration of unknown unknowns—processes or impacts outside the models' domains, physics or numerical representations. There may be future events, or attributes of the future that are not predicted in scenarios. There is a risk that organisations may be more at risk from unknown unknowns if they assume they have considered all possible future conditions.
- **Historical precedent:** many scenarios are driven by historical precedent, especially those considering extreme events. In the case of climate change, future events cannot be accurately predicted based only on historical precedent since climate change is likely to create conditions unprecedented on historical timescales.
- **Tipping points:** Although climate models are becoming increasingly sophisticated at modelling earth-climate system feedbacks they do not yet account for tipping points that could lead to long lasting, step changes in the climate. Model-based climate projections (even RCP 8.5) therefore need to be considered in the context that they may not represent the worst climate outcomes.
- **Physical and transition risks will occur simultaneously:** whilst most discussions around physical and transition risk scenarios keep these two types of scenarios mutually independent and distinct, in reality they are not. Any future climate scenario will likely incorporate features of both physical risk and transition risk. While it is convenient to separate these concepts as a mental exercise it is important to acknowledge that a transition risk scenario will still incur physical risks and a physical risk scenario will still incur transition risks.

[3] [1] Sawyer (1972)
[2] Broecker (1975)
[3] Hansen et al. (1981, 1988)
[4] Van Vuuren et al. (2011)

HISTORY OF SCENARIO USE

EARLY HISTORY OF SCENARIO USE

According to Fahey and Randall (1998, p. 17) the use of scenarios (or strategic foresight) to explore different possible futures goes back to the work of Herman Kahn (Kahn, 1971) at the RAND corporation in the 1950s. Kahn used scenario analysis to investigate different military strategies and communicated these scenarios through stories about the future. Kahn encouraged people to 'think the unthinkable' first about consequences and then about every manner of future condition (Bishop et al., 2007).

While the early use of scenarios predominantly had a military application, they soon made their way into the world of business, most famously via Royal Dutch Shell Plc in the 1960s. Pierre Wack, head of corporate planning for Royal Dutch Shell discovered the oil industry was making two very uncertain assumptions, firstly that oil would remain plentiful and secondly that oil prices would remain low. When the possibility of a different scenario was presented to senior management, it changed their perception and the need to plan for different possible futures. This led to a change in strategic planning and to rethink many of the initial assumptions about the future. When the major oil shock of 1973 came to pass, Shell was the only major Western oil company that was prepared. Within two years Shell moved from the eighth largest oil company to the second largest. By the 1980s Shell was leading the world in the use of scenario thinking to form strategic decisions.

HISTORY OF CLIMATE SCIENCE SCENARIOS

Over the past four decades, climate scenarios have been developed to provide plausible descriptions of how alternative futures may evolve including GHGs, energy use, land-use, economic growth, and technological change (Vuuren et al., 2011). Early examples of modern climate scenarios can be found in the works of John Sawyer (1972), Wally Broecker (1975) and James Hansen et al. (1988). Climate scenarios have since been developed and featured in the IPCC's First, Second (the IS92 scenarios), Third, (the SRES scenarios), Fourth and Fifth Assessment Reports. A notable feature of the IPCC's reports is the growth of the use of General Circulation Models (GCMs) for the construction of the scenarios.

HISTORY OF CLIMATE SCENARIOS IN BUSINESS DECISION-MAKING

Scenario analysis is now a well established method for informing strategic thinking and strategy formulation in a business context. The application of climate scenario analysis by governments, organisations and civil society, however, is a more recent phenomenon.

Up until very recently climate scenario use had been confined to a few large energy and mining companies. The upsurge in the use of scenarios across the financial sector is almost entirely due to the TCFD. The Bloomberg led taskforce recommended that companies produce multiple, plausible future scenarios as a way to analyse and disclose how different climate-related futures might affect them financially.

To date, the potential of climate scenarios to function as a practical tool in informing decision-making has been limited by the information gap between the data which climate scientists are able to provide and the information that decision-makers require to assess impacts for areas or sectors of interest (Wilby & Dessai, 2010). In recent years this gap has been closing, although there remain challenges, especially in considering extreme events. Beyond gaps in data there is also an issue in the communication of the available data to decision makers—they are often dispersed and hard to find if uninitiated. Further, there is lack of access to climate information in relevant and contextualised formats, that are tailored to different decision-maker groups.

Over the past decade a proliferation of tools and adaptation platforms have emerged to meet these information requirements. These resources bring together climate data with guidance and risk management frameworks to assist organisations and governments in incorporating climate scenarios into their decision-making processes (Palutikof et al., 2019).

GOVERNMENT LED INTERNATIONAL BEST PRACTICE IN CLIMATE SCENARIO ANALYSIS

Many countries provide information and guidance regarding climate scenarios. These range from high level guidance on suggested emission scenarios with resulting impacts of climate change relevant to the country, to detailed information including: climate scenarios with detailed future climate datasets, interactive online tools, how scenario analysis outcomes link to decision-making, as well as climate education, training and support tools.

A high-level desktop review was conducted to consider current best practice elements on the approach and presentation of country-specific climate scenarios. The following best practice elements were identified:

- **Clear and informative web-based communication:** Leading countries provide clear consistent communication on the impact of climate change on the country, and the importance of both adaptation and mitigation efforts. Information, data, tools, frameworks and customised climate scenarios are provided clearly on specially designed websites. Examples of some of the information provided include high level multimedia narratives as well as information on impacts to specific sectors, ecosystems, human health and economic activity.
- **Interactive climate scenario tools:** Several countries provide user-friendly online interactive tools such as a climate atlas or climate explorer, which allow users to run different climate scenarios. These tools often provide users with the options to explore specific locations/regions, emission scenarios (RCP level or low/high emissions), season, time horizon (to 2050, 2080, etc) and climate variable (such as temperature, precipitation, wind, etc). The best tools also provide clear outputs including (heat)maps, timeline graphs, datasets, and clear result descriptions. These tools can be useful for organisations to undertake an exploratory analysis of climate change to identify relevant risks and hazards under different scenarios.
- **The provision of decision-useful information:** The most advanced countries provided information on how climate scenarios can be translated into decision-useful information. These include descriptions of risks including extreme weather event impacts, rising sea levels and droughts as well as opportunities such as changes to the length of growing season and crop yields that are specific to the country or sectors.
- **Links to climate resilience and adaptation information:** Several countries have developed climate change adaptation and resilience initiatives, including online adaption and resilience toolkits and knowledge centres. These initiatives include information on what the changing climate might mean to businesses, organisations and communities, and include guidance and risk assessment information outlining steps for how to build resilience. As climate change adaptation and resilience are relevant to climate scenario outcomes, climate scenario websites often link to these initiatives.
- **Updated resource library:** Links to reliable external datasets, tools, frameworks, guidance and science reports relevant for both specific or general scenario analysis, including sector specific information. These can include information from international, federal, state, non-government organisations, academic and other resources and publications.
- **Training and Education:** Training and educational material range from information about the science of climate change, how to conduct scenario analysis right through to how to identify relevant climate-related risks and opportunities.
- **Support helpline:** A support desk hotline to assist in finding, understanding and using climate data to support users on climate change considerations in decision-making.
- **One stop source for countrywide climate information:** Climate scenario information is often provided within a country-specific climate change website (with relevant links from government websites), making these websites easy to use for individuals, SMEs, larger businesses, academics and technical experts.

The countries identified as having best practice elements are New Zealand, Canada, US, UK, Switzerland, Sweden and Japan. An overview of the main findings by country are outlined below:

- **New Zealand:** Provides a description of climate scenarios, key outcomes and an online interactive tool to explore climate projections (with map, graph and other outputs), as well as an overview of expected extreme weather impacts (temperature, rainfall, winds). A linked Climate Adaptation Toolbox includes information on what the changing climate might mean to businesses, organisations and communities, as well as an assessment tool to review current climate resilience. New Zealand is also the first country in the world that plans to make TCFD disclosure mandatory for publicly listed companies and large insurers, banks and investment managers.[4, 5]
- **Canada:** Provides an overview of climate scenarios and models, how the outcomes are translated into practice in decision-making (risks and opportunities), a library of climate resources (including links to over 300 datasets, tools, guidance and related resources), climate education as well as a support desk hotline to assist users to find, understand and use climate information. The Climate Atlas of Canada is an interactive tool that allows users to run climate scenarios based on various variables, with map, graphical and dataset outputs that can be used in decision-making.[6, 7]
- **US:** The US Climate Resilience Toolkit is an online support service to find information and digital tools to assist in understanding and addressing climate risks and includes the interactive online Climate Explorer scenario tool which provides graphs, maps and datasets of projected climate variables (such as flooding, temperature to 2100) for every county in the US. The Toolkit also provides case studies, adaptation planning, a "steps to resilience" framework and training courses to build knowledge to manage climate-related risks and opportunities.[8]
- **UK:** The UK Climate Projections provide an assessment of climate change in the UK to assist users with climate change risk assessments and adaptation plans. Information includes slide packs and factsheets with key findings of climate scenario outputs (including for land and marine projections), as well as technical data, science reports/supporting documents, an interactive climate scenario tool, and a description of the science that underpins the climate data and projections.[9]
- **Switzerland:** Provides an overview of key messages of the climate scenarios (and impact on Switzerland), detailed datasets and technical information, risks and opportunities by sector (i.e. agriculture, forestry, energy, tourism, urban planning, etc) as well as climate education on climate scenarios (how results can be interpreted) and climate adaptation measures that are being undertaken by various levels of Swiss government. An interactive climate Web Atlas allows users to run scenarios based on variables including region, time series, season, emission/RCP scenario and climate indicator (temperature, precipitation), with map, graphical and data outputs that can be used for decision-making.[10]
- **Sweden:** Climate scenarios can be run based on area/region, RCP, season and climate index (i.e., temperature, precipitation, etc), with outputs presented on maps, as diagrams and downloadable data as well as information explaining the results. The site also links to the Swedish Climate Change Adaptation Knowledge Centre and Swedish portal for climate change adaptation, including a film and case studies.[11]
- **Japan:** An overview of key observations and climate projections as well as climate impacts on key sectors (agriculture, water, etc) and on human health, economic activity and urban life are available in English in the "Climate Change in Japan and its Impacts" document.[12]

Some of these best practice elements are already available through the Climate Change in Australia website. Specific recommendations on how the Climate Change in Australia website (or similar site) can be improved to incorporate some of these best practice elements are included in the final recommendations of this report.

[4] Source [5] Source [6] Source
[7] Source [8] Source [9] Source
[10] Source [11] Source [12] Source

REVIEW OF CLIMATE SCENARIO GUIDANCE

INTRODUCTION

Informed by desktop research and primary data collection, key domestic and international examples of climate scenario guidance were reviewed. The review includes both national and international examples of climate scenario development and use for decision-making. The review includes both general and sector specific guidance from trusted, well regarded sources.

There is a large and growing resource of publications that provide climate scenario guidance, frameworks and analysis methodologies. Some focus on specific sectors (e.g. investment, insurance, resources) while others on the type of risk (physical risk, transition risk) and others on the method or process that is being applied. There is also a growing number of commercial providers and consultants who are contributing expertise to advance and improve climate scenario analysis. Many of the reviewed methods share common language, frameworks (e.g. TCFD), use similar methods and call on common datasets (IPCC RCPs). However, significant diversity still exists with some providers offering different (and complementary) methods for assessing risks and opportunities across different asset classes, scenarios and output formats.

The documents reviewed can be grouped into roughly three categories:

- Those that provide general guidance or frameworks for applying climate scenarios (e.g. The Network of Central Banks and Supervisors for Greening the Financial System (NGFS, TCFD)
- Those that provide specific guidance on a sector or type of climate scenario (e.g. CMSI)
- Those that provide information on the use of climate scenario projections and the risks associated with physical climate impacts (e.g. NSW and ACT Regional Climate Modelling (NARCliM), CSIRO etc.)

Another finding from this review was that a clear trend has emerged over time. From the mid 2000s guidance documents were mostly authored by national governments and multilateral organisations. These reports tended to focus on scientific climate projections and adaptation to climate risks. In the last few years there has been an increase in the release of new climate scenario guidance, but this has predominantly been developed by the financial sector and has a clearer focus on guidance, frameworks and methods that allow organisations to identify and disclose all climate-related risks (e.g. TCFD, CMSI etc.)

Two of the most significant guidance documents for Australia are the TCFD and the CMSI. These are both summarised below in more detail.

THE TASK FORCE FOR CLIMATE-RELATED DISCLOSURE

The Financial Stability Board's TCFD published its recommendations for the voluntary disclosure of climate-related risk and opportunities by financial institutions and other entities. Shortly after the release of the TCFD leading insurance supervisors and regulators announced their support for the adoption of the suggested climate risk disclosure framework. The TCFD guidance is now the default standard for large companies disclosing climate-related risks, with over 1,440 global organisations having committed to supporting the recommendations.

A key insight of the TCFD was that climate-related risks could have a material financial impact. In understanding this, organisations should consider different climate scenarios including a low emissions climate scenario for understanding impacts on the organisation. The TCFD also calls on organisations to develop a climate strategy, assign metrics for measuring progress and to build strategic resilience.

The TCFD introduced an innovative scenario-based framework that encourages forward-looking, long-term assessment of the financial implications of climate change. However, it provided very little specific detail on the data, models or tools to be used for carrying out this type of assessment.

The use of scenario analysis to identify climate risks was a key recommendation of the TCFD. The TCFD's 2017 Technical Supplement[13] provides the rationale and high-level advice on climate risk analysis. Scenario analysis is now an effective and important element of climate risk management as it helps decision-makers visualise:

- What future states, conditions or events are plausible or possible
- What the consequences of future events within this scenario might be
- How to respond, build resilience or benefit from the future conditions in the face of uncertainty.

The 2019 Status Report referred to the following challenges with using climate-related scenario analysis:

- The lack of appropriately granular, business relevant data and tools supporting scenario analysis
- Difficulty determining scenarios, particularly business-oriented scenarios, and connecting climate-related scenarios to business requirements
- Difficulties quantifying climate-related risks and opportunities in business operations and finances
- Challenges around how to characterise resiliency.

There is a growing library of resources and tools to assist organisations with the implementation of the TCFD analysis. Some of these include:

- Knowledge, Tools and Resources (TCFD Knowledge Hub).[14] This includes a range of resources relating to implementation of the TCFD including a scenario analysis page
- The World Business Council for Sustainable Development has convened preparers forums for different sectors and industries (e.g. oil and gas, electric utilities, chemicals, construction, automobiles, food, agriculture and forest products)[15]
- The UN Environment Programme Finance Initiative has worked with 16 major banks to pilot the TCFD Framework and develop a scenario-based approach for assessing the impact of climate change on banks' lending portfolios.[16]

[13] View source [14] View source [15] View source
[16] View source

THE CLIMATE MEASUREMENT STANDARDS INITIATIVE

The CMSI is an industry led collaboration between Australian Insurers, banks, scientists, reporting standards professionals, service providers and academics. The CMSI builds on the recommendations from the TCFD providing standards and guidance that companies can use when disclosing information about climate-related risks. Specifically, the CMSI aims to provide companies with:

- A consistent approach to disclosure under the TCFD, so that disclosure by each company adopting the standard is comparable.
- Increased confidence in disclosures, as the standards will be supported by science from Australia's leading climate experts.
- A potential framework that can be used should regulators decide to mandate disclosures
- A roadmap for future research and development aligned with disclosure requirements
- Guidance on issues relevant to specific industries
- Guidance that will allow smaller companies to disclose their climate change scenarios analysis
- Lower likelihood of unintentionally adopting nonstandard approaches
- Modelling requirements that support provision of transparent advice to industry.

During the first phase, the CMSI has developed **financial disclosure guidelines** and developed **scientific scenario specifications** for the purpose of disclosure of scenario analysis for climate-related physical damage to buildings and infrastructure. The scientific guidelines consider a wide range of chronic and acute risks for the insurance, banking and asset owner sectors. The standards are open source and voluntary.

The CMSI project identified several areas where further work is needed to support robust and consistent disclosure, including:

1. The inclusion of additional risks, hazards and impacts
2. Inclusion of socio-economic scenarios
3. Indirect impacts and other interdependencies
4. Expansion of industries and types of analysis for other purposes
5. Detailed models, tools and specific guidance on business planning and strategy
6. Stress testing and vulnerability testing
7. Modelling changes to exposure and vulnerability over time
8. Developing datasets
9. Providing guidance on the implementation of transition risks

AUSTRALIAN CLIMATE-RELATED RISK DISCLOSURE REQUIREMENTS

There are growing requirements for Australian businesses and entities to disclose climate-related risks.

AUSTRALIAN STOCK EXCHANGE (ASX) AND CORPORATE GOVERNANCE COUNCIL (CGC)

Recommendation 7.4 of the *Corporate Governance Council (CGC) Governance Principles and Recommendations*[17] requires an entity to disclose whether it has any material exposure to environmental or social risks, and if it does, how it manages or intends to manage those risks. The principles and recommendations can be made by cross-referring to an integrated report using the International Integrated Reporting Council (IIRC) framework, or sustainability report using the IIRC framework or in accordance with the Global Reporting Initiative, the Sustainability Accounting Standards Board sustainability standards or the Climate Disclosures Standards Board. If commentary to the Recommendation 7.4 indicates the entity has no material exposure to environmental risks, then careful consideration should be undertaken to benchmark against peers. It also specifies that physical and transition risks associated with climate change are not restricted to mining and fossil fuel intensive sectors. Entities are also encouraged to consider material exposure to climate change risk by reference to the TCFD recommendations and, if they do, to make the recommended disclosures.

AUSTRALIAN ACCOUNTING STANDARDS BOARD (AASB) AND THE AUDITING AND ASSURANCE STANDARDS BOARD (AUSAB)

In April 2019 the Australian Accounting Standards Board (AASB) and Auditing and Assurance Standards Board (AUASB) released joint guidance on the consideration of materiality and disclosure of climate-related risk in financial reporting. They noted the importance of climate-related risk disclosure for investment decisions and observed that present disclosure was more often than not only being disclosed outside of official financial statements. The joint guidance put forward new guidance that qualitative external factors, such as the industry in which an entity operates and investors' expectations may make climate-related risks material and therefore warrant disclosures in the preparation of financial statements, regardless of any numerical impact.

Under the AASB and AUASBs definition for materiality (see AASB Practice Statement 2 (APS 2))[18] entities can no longer treat climate-related risks as merely a matter of corporate social responsibility and should consider them also in the context of their financial statements. Even though the recommendations within the guidance are not mandatory it does represent the International Accounting Standard Board (IASB) best practice interpretation of materiality. Significantly, it shifts the reporting of climate risk assumptions from being outside financial and audit requirements to within the scope of external audit scrutiny. Although recommendations within the guidance are not mandatory the AASB and AUASB expect directors, preparers and auditors to consider APS 2 within future financial reporting.

[17] View source [18] View source

AUSTRALIAN SECURITIES AND INVESTMENTS COMMISSION (ASIC) AND AUSTRIAN PRUDENTIAL REGULATION AUTHORITY (APRA)

The Australian Prudential and Regulation Authority (APRA) has confirmed it is going to embed the assessment of climate-related risks into its ongoing supervisory activities. It has also said 'that although the time horizon for the risks is uncertain, this does not justify inaction.'[19] APRA have also confirmed their intention to increase the intensity of its supervisory activities to assess the effectiveness of risk identification, measurement and mitigation from banks, insurers and superannuation trustees.

The Australian Securities and Investments Commission's (ASIC's) position on climate-related risks is set out in Regulatory Guide 247.[20] Australian law requires that listed entities include a discussion within their operating and financial review (OFR) of environmental and other sustainability risks (including climate-related risks) where they could affect the achievement of financial performance or the outcomes disclosed. Later updates to Regulatory Guide 247 and Regulatory Guide 228 clarify the application of climate-related risks and opportunities with respect to the TCFD on the common risks that need to be disclosed, including climate scenarios. It highlights that climate change is a systemic risk that potentially impacts the entity's financial prospects for future years and therefore requires disclosure in the OFR. It also reinforces that disclosures outside the OFR (e.g. voluntary reporting against the TCFD) must be consistent with disclosures made in the OFR.

In a recently released report *Climate Risk Disclosure by Australia's Listed Companies* ASIC recommends that listed directors and officers adopt both a probative and proactive approach to climate risk as an emerging risk (ASIC 2018). The report also makes clear that 299(1)(c) of the Corporations Act requires disclosure of material business risks affecting future prospects in the OFR which may include climate-related risks.

[19] View source [20] View source

AUSTRALIAN DATA, TOOLS AND FRAMEWORKS

The most high profile examples of climate information available at the national level are outlined below. Australia does not have an authoritative, agreed set of climate change scenarios for the nation nor standardised guidance on how to interpret and use these scenarios consistently. Many of the tools and frameworks presented below look at shifts in arithmetic mean values over time, but what is more important from a scenario perspective is some assessment of how hazards are likely to occur at the extremes.

These national resources are complemented by state and territory resources, which are not reported here. State and territory climate initiatives have contributed much to the climate information available, with many of them articulating climate and weather hazard impacts.

However, these remain differentiated state-level datasets with limited interoperability for information end users e.g. business with operations across multiple jurisdictions.

To better support scenario analysis, existing climate projection ensembles need to be analysed for the projected changes in hazard characteristics. In particular, analysis across the range of hazards and their extremes is required. This was the gap being filled by the CMSI.

CLIMATE COMPASS

Is a climate risk management framework designed to assist Commonwealth agencies and Australian public servants in identifying and responding to the risks, challenges and opportunities a changing climate poses to current policies, programs and assets.[21] It includes step by step instructions, guidance and information to develop an understanding of climate change risks. It builds on the best climate change adaptation research and science over the past decade and reflects planning for long-term, uncertain, pervasive change.

https://www.environment.gov.au/climate-change/adaptation/publications/climate-compass-climate-risk-management-framework

[21] Australian Government, Department of Home Affairs (2019); Australian Government, Department of Environment and Energy (2018)

CLIMATE CHANGE IN AUSTRALIA

Climate Change in Australia is a website that provides access to data, tools and resources for a variety of different audiences. The website includes climate projection information which has been primarily developed to support the needs of Australia's natural resource management sector, and to provide information to assist climate adaptation processes. Information on the site covers the whole of Australia. Climate model data from the full set of current global climate models can be explored through different website dashboards. Registered users are able to download climate change projection data from the site. There are two types of data available: (i) Projected change data that is available in annual, seasonal and monthly timescales and is based on the 10-90th percentile change of the model range and (ii) application-ready data applied to a 30 year observational set between 1981 and 2010. These 'climate scenarios' are representative emissions projections and therefore only represent the natural and physical variability of the climate and do not include other factors such as socio-economic projections or mapping of impacts to exposures and vulnerabilities.

https://www.climatechangeinaustralia.gov.au/en/

COASTADAPT

CoastAdapt is a decision support framework designed by the National Climate Change Adaptation Research Facility (NCCARF) to support coastal managers and decision-makers, specifically local councils, take action to better understand plausible future climate risks and potential response options.[22] CoastAdapt contains climate datasets on coastal sensitivity to erosion; sea-level rise; historical flooding; inundation; and future climate extremes for each coastal council. A unifying risk management framework supports users in exploring system sensitivities to various climate scenarios and provides guidance on risk assessment, evaluation and monitoring.[23] The CoastAdapt resource includes access to data, case studies, infographics, information manuals, impact sheets, tools and how to pages for users.

https://www.nccarf.edu.au/content/coastal-tool-overview

THE CROSS-DEPENDENCY INITIATIVE (XDI)

XDI is an Australian commercial software platform that seeks to quantify the future risks of extreme weather events (wildfires, droughts, floods and coastal inundation) on buildings and other infrastructure assets under different climate scenarios.[24] Originally developed for the water sector in Australia, the tool was then expanded to include interdependencies between other infrastructure assets. A recent application of XDI assessed the physical risks and implications of climate change (including insurance costs) for the property sector.[25] The XDI vision is to make possible a systems analysis of how climate risk affects not just one organisation but all of its upstream and downstream interdependencies. The platform enables standard reporting to meet the needs of diverse users. The tool now covers eight sectors and ten different hazards.

https://xdi.systems/

22 Palutikof et al. (2019)
23 Palutikof et al. (2019)
24 Australian Government, Department of Home Affairs (2019))
25 Australian Government, Department of Home Affairs (2019); Steffen et al. (2019)

A number of other resources are available for specific sectors or regions providing hazard specific impacts data, adaptation, information on approaches, and decision-making under uncertainty. Some of these resources are included below.

- Australian Bureau of Agriculture and Resource Economics and Science (ABARES) provides climate information relevant to actors in the agricultural sector.
- AdaptNRM provides tools and resources for national-level adaptation. These are particularly useful for regional and natural resource management planning.
- AdaptNSW provides a range of climate change resources to assist with improving climate change adaptation in NSW.
- CSIRO's Strengthening Australia's Resilience to Climate Change provides access to noncommercial in confidence research being completed at CSIRO.
- Climate Data Online produced by the Bureau of Meteorology provides long range information and data on climate change across Australia.
- Climate Ready Victoria is a state-wide resource providing information on impacts and climate adaptation across Victoria.
- Coastal Risk Australia is an interactive map tool designed to communicate coastal inundation associated with sea level rise to the year 2100.
- Earth Systems Climate Change Hub is part of the National Environmental Science Program and is a partnership between Australia's leading earth system and climate change research institutions. Its aim is to ensure that Australia's policies and management decisions are effectively informed by earth systems and climate change science.
- Enterprise suitability toolkit—provides tools for mapping the climate impacts on different crops.
- Sea Level Rise is another CSIRO led initiative to understand the impacts of sea level rise.

CASE STUDIES

OVERVIEW

Nine case studies were undertaken on the use or production of climate scenario information and/ or guidance across four sectors, with summary information shown in Table 1. The case studies were varied, reflecting both the sector and the type of entity involved, with information taken from desktop research and interviews. Appendix 6 contains the case studies themselves, while this section summarises the insights gained and a brief description of each one.

Table 1: Overview of case studies

	Aim / Purpose	Industry or sector	Primary audience	Geographical scope	RCP projections	Socio-economic factors considered	What's provided	Extreme events	Physical risks	Transition risks	Time horizon	Spatial resolution
Australia's Wine Future: A Climate Atlas	Deliver future climate information at high resolution in an accessible format	Agriculture	Wine industry	Australia	Yes RCP 8.5	No	Atlas of detailed information on relevant climate indicators for past, present & projected period	Yes (heat)	Yes	No	1961–2100	Downscaled 5 km grid
Farmpredict (ABARES)	Simulate farm production, financial outcomes & stock changes using climate scenarios & commodity prices	Agriculture	Government	Australia	No	No	Farm performance predictions on a regional basis	No	Yes	No	2080–2020	Downscaled Point data to 5 km
Lendlease	Build strategic resilience to future climate-related risks & opportunities	Real Estate	Various	Global regions	Yes RCP 2.6, 4.5, 6, 8.5	Yes (SSPs)	Potential outcomes under four scenarios, including impact on a wide range of factors	Yes	Yes	Yes	2010–2100	Global regions
Electricity Sector Climate Information	Support improved long-term planning for electriciy infrastructure	Utilities	Electricity Sector	National Electricity Market	Yes RCP 2.6, 4.5, 8.5	No	Tailored, high-resolution climate datasets; guidance materials; climate impact information	Yes	Yes	No	1980–2099	Downscaled Point data to 50 km
XDI Cross Dependency Initiative	Support investment decisions with detailed, costed analysis of climate risk & adaptation options	Infrastructure	Infrastructure asset owners	Australia	Yes	No	Quantified climate risk to assets & financial & non-financial KPIs	Yes	Yes	No	1990–2100	Downscaled 5–30 m
National Australia Bank	Understand the impact of significant events on the portfolio to help the business & customers	Finance	Risk managers, underwriters, investors	Australia/NZ	Yes?	No	Physical risk data overlaid on company assets at a granular level across portfolio	Aim to	Yes	Aim to	2050+	Point data for some areas
QBE	Understand financial impact of different emissions scenarios on QBE's business	Finance	Investors	Australia/ Global	Yes	No	High-level summaries in published reports	Aim to	Yes	Aim to	2030 / 2050 / 2090	5 regions
Bank of England	Test the resilience of the financial system to physical & transition risks from climate change	Finance	Banks, Insurers	UK	No	Yes (modelled)	Stress test scenarios & process for undertaking risk assessment & disclosure	Yes	Yes	Yes	2050+	UK (specific to each user)
Rio Tinto	Build strategic resilience to future climate-related risks & opportunities	Resources	Various	Global regions	Yes RCP 8.5	Yes	Overview of impacts of climate change on Rio Tinto's business	Yes	Yes	Yes	18 months / 2030 / 2050+	Global regions

HIGH LEVEL INSIGHTS

When using climate change scenarios there is a trade-off in achieving utility for a given application and consistency between applications. In addition, there is a range of needs and considerations that should be taken into account when developing and using climate scenarios, when considering a consistent national approach and the role of government.

DRIVERS FOR CONSISTENCY

Reporting and disclosure of climate-related risks and opportunities needs to be comparable. Investors, regulators and consumer advocates or watchdogs want to be able to compare and assess the relative risks and opportunities across different organisations. This means that reporting and disclosure of climate-related risks and opportunities need to have some consistent elements, such as emissions pathways, input assumptions and disclosure requirements. Several interviewees recognised the importance of consistency of science, of approach, of data and of reporting. While the TCFD was often mentioned as being a critical driver in delivering consistency it remains very open to interpretation and does not provide guidance on specific datasets, methods, or disclosure requirements.

It is important to note, that the needs of investors, regulators and advocates may be different from those of the organisations themselves. As a result, the requirement for consistency will need to be balanced with flexibility to ensure organisations can also undertake different analyses where they are required to produce decision-useful information internally. Where deviations from standard practice are applied, these should be highlighted and disclosed.

Collaboration across the sector shares the burden. Organisations within the same sector face similar impacts and issues when undertaking climate scenario analysis. The benefits of collaboration were seen to reduce the costs to individual organisations but also as a way to accelerate group learning, avoid duplication and promote consistency.

Set, predefined scenarios can assist SMEs, consumer advocates, local governments and others. Climate scenario development and analysis is a costly and time consuming activity. It requires development or access to significant expertise both within the organisation and from consultants and external experts. The existence of standard scenarios, climate data and guidance on their use could support those organisations that do not have the internal resources or capacity to develop them for their specific use. While they may not provide the same level of detail as customised or specially developed scenarios, in many cases a less specific information is more than sufficient to inform decision-making and strategy.

Opportunity for collaborative adaptation. The XDI case study reveals the potential for climate risk tools to identify climate risk clusters (interdependency risks) and opportunities for collaborative adaptation measures. The ability to do this effectively is currently restricted by lack of coordination, lack of transparency on risk and issues around data sharing. The use of consistent climate change scenarios and analysis methods could help to smooth the way for future sharing of risk information, which could create the opportunity for collective adaptation.

DRIVERS FOR SPECIFIC UTILITY

Requirements of end users can be very specific. When scenarios are being produced for a sector or organisation, consultation is required to ensure the information produced addresses the needs of the intended users, in both content and format. In many instances, climate scenario information has to interface with organisations on internal systems, and the information may be needed for highly specific analysis. For example, the information required to make decisions on the size or type of electricity infrastructure in a highly regulated process, is likely to be different from that required for multinational corporations to consider acquisition or divestment decisions in the light of transition risk. As a result, it was also considered necessary that different sectors or organisations had the flexibility to apply or develop scenarios in a manner that was relevant to their organisation.

Outputs need to be decision useful. Climate scenario analysis is most often done in order to understand the potential impacts of climate-related risks and opportunities and inform strategic planning and decision-making on adaptation measures. Therefore, the framework, scenarios, and analysis processes need to be designed in a way that produce decision-useful outputs that will improve the future resilience and adaptation of the sector, organisation or assets (emphasising the need for user consultation).

The process is important when applying climate scenarios. The act of undertaking the scenario analysis is very valuable and this will be different for every company. This means the process should not be overspecified, as the organisation thinking through the impacts for themselves can be beneficial.

NEEDS / CONSIDERATIONS

Sectoral coordination and guidance. In order to balance the drivers for consistency and specificity it is necessary to engage with the end users of climate scenarios. Every sector is different in terms of the importance of climate-related risks and opportunities and how they will manifest over time. In addition, different sectors have varying capability and capacity to engage with climate scenario analysis. The CMSI was established with the purpose of producing climate scenario guidance for the financial sector in Australia. This group could provide a model for engagement with and within other sectors. Existing industry bodies also have an important role to play in the provision of information and guidance to their members and may be best able to address specific sectoral needs for building climate resilience.

Data inaccessibility and integration—many publicly available datasets exist but they can have limits on their use, be incompatible and/or kept in disparate locations and formats. Substantial effort is therefore required to find and connect up the multitude of datasets that cover climate change, extreme events and economic projections for different climate projections and assumptions. For example, flood risk data is often held by local government, whilst the CSIRO holds climate projection data and economic projections that are handled by the Australian Government.

Transparency of inputs, assumptions and methods used for scenarios analysis. There are multiple different ways to construct climate scenarios and undertake scenario analysis. The projections and assumptions associated with different climate and socio-economic pathways are significant and can yield very different risk outcomes based on different input conditions and assumptions. It is therefore open to abuse and greenwashing. Overcoming this issue requires transparency in the use and disclosure of inputs and methods that have been applied.

Establishing a decarbonisation strategy is key. Organisations that were more advanced in scenario analysis were actively pursuing decarbonisation strategies in line with the TCFD. Organisations that were committing to decarbonisation strategies were doing this alongside their disclosures to physical and transition risks. Decarbonisation strategies were therefore seen as part and parcel of a well developed climate change strategy.

Ongoing maintenance and support of climate scenario information: climate science is constantly improving and evolving so climate scenario information needs to be maintained and updated to reflect these changes. In addition, the use of climate scenarios and other climate data often requires support and guidance. Documents alone are not engaging, nor dynamic enough to support the variety of needs of climate scenario users so targeted support, training, capacity building and engagement are also required.

Internal and external communication is key. Communication throughout the scenario development process is essential, both internally within the organisation and externally to investors and other stakeholders. The broader public (including civil society) is also an audience that needs to be considered with regards to engagement and communication as the public are ultimately impacted by the effects of climate-related risks and will fund through taxes, the development of future climate scenarios as well as potentially the responses to these risks where public investment is required.

Involvement of external experts. The successful engagement of outside experts across multiple disciplines from science, academia, and independent consultancies was seen as essential for incorporating the latest knowledge and for building in-house capacity.

The following section provides a high-level summary for each of the case studies undertaken. Further detail on each case study can be viewed in Appendix 6. Note that the views contained in these case studies are the responsibility of the research team and do not reflect the opinion or position of the organisations represented.

AGRICULTURE

AUSTRALIA'S WINE FUTURE: A CLIMATE ATLAS

The objective of the Australia's Wine Future: A Climate Atlas, is to assist Australian wine industry and growers adapt to a variable and changing climate. This includes consolidating available high-resolution climate information in an accessible and useful form to the wine regions of Australia, identifying important weather risks within different wine regions, developing region-specific indices of "heatwave" and heat accumulation and assessing the variability and trends in these indices, assessing the impact of these changes across different stages of grapevines; identifying regionally relevant adaptation options in the short, medium and long term, and improving understanding and uptake of climate information. It aims to achieve this by delivering relevant climate information at high resolution to all members of the wine industry in an accessible format. Key insights from this case study include:

i Sectoral needs are very specific, and extensive consultation was needed to identify the specific indicators relevant for wine growing. The geographic scope was also very particular, with analysis and presentation of results required in 73 different wine regions.

ii The ongoing support and maintenance of the atlas is potentially problematic, as there is so far no plan beyond the initial webinar dissemination. Targeted sectoral presentation and discussion seem very important to engage people who are not already considering climate change impacts.

iii The physical format of the information is important, with each avenue presenting specific challenges (for example, many users do not have good internet connections, so an online tool was not favoured.

AUSTRALIAN BUREAU OF AGRICULTURE AND RESOURCE ECONOMICS AND SCIENCE FARMPREDICT

The objective of the farmpredict tool is to model the impact of climate conditions and climate change on farm productivity and profit. The tool, developed by ABARES, simulates production, financial outcomes and stock changes for individual farms using scenarios for climate conditions and commodity prices. Currently the model is used to assess the effects of recent and immediate short-term change in climate on farm profitability (over next several years) and to develop indicators of drought exposure and sensitivity which could help to inform government farm risk management and drought programs.

Key insights from this case study include:

i A key challenge for farmpredict is the labour intensiveness of cleaning data for use. Access to data and transfer of data from other agencies are also sometimes challenging and data confidentiality can be a constraint.

ii The farmpredict tool provides useful data for Government and the agricultural sector and with additional resources could be further developed for new uses and audiences. For example, upgrades to the front end of farmpredict could help to make its outputs more publicly accessible. It could be extended to assess farm lender exposure to climate change, and to inform the design of weather insurance products

iii To be useful to a sector, specific sectoral data is needed and needs to be integrated in specific ways with other data. Details of scale, resolution etc are very dependent on the need/use/application of the data.

BUILDINGS AND INFRASTRUCTURE

LENDLEASE

The objective of undertaking climate scenarios at Lendlease was to test strategic resilience to climate-related risks and to determine opportunities that inform business and strategic planning. Initially driven by the Board to commit to the TCFD, the scenarios now form a key part of Lendlease's commitment to sustainability and are integrated into its "placemaking" strategy. The scenarios were developed in-house to ensure they are relevant to the business and range from Transformation (rapid decarbonisation) and Paris Alignment to Polarisation (limited climate action) and Resignation (used to assess physical risks). The scenarios are outlined in detail on the Lendlease website and further information including risks and opportunities to the business are included in the Annual Report. They are targeted to both internal (including Board, strategy teams, business units and employees) and external stakeholders (including investors, customers, public and government).

Key insights from this case study include:

i Importance of using and presenting a range of climate scenarios and developing these in-house to ensure they are specific to the business.

ii Effective internal communication and engagement are critical to ensure adoption and use of climate scenarios for business planning purposes.

iii Strong disclosure and collaboration are important—across the real estate industry, customers, supply chains, investors and government. By sharing climate scenario information, Lendlease hope to assist other stakeholders in their processes contributing to better outcomes and encourage Government to work together with the private sector.

INFRASTRUCTURE AUSTRALIA

Infrastructure Australia is the key source of research and advice for governments, industry and the community on nationally significant infrastructure needs. The Infrastructure Australia Assessment Framework (IAAF) provides information about how infrastructure initiatives and projects are assessed, including specific guidance on considering and managing climate risk, which was included in the last update to the IAAF published in 2018. The IAAF encourages the use of scenario analysis to ensure that projects are robust to a range of plausible futures. None of the 30 projects submitted by proponents for evaluation have fully adopted the IAAF climate scenario guidance since it was included. In response to the lack of adoption of the climate scenario guidance, a current review of the IAAF is considering how to support proponent's consideration of climate risk, the clarity of existing guidance, and alignment with similar guidance provided by state and territory governments. The infrastructure bodies are working together to share information, including best practice definitions and datasets, new assessment guidance and decision-making tools.

Key insights from this case study include:

i A key barrier to wide scale use of scenario analysis in the infrastructure sector is the absence of an agreed set of climate futures and associated planning assumptions.

ii The sector is complex, with many infrastructure bodies and companies currently undertaking climate risk projects—it is important to avoid duplication.

iii The importance of identifying opportunities for collaboration and information sharing between the public and private sectors, and cross-sectoral and inter-jurisdictional projects

ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT

The objective of the Electricity Sector Climate Information (ESCI) project is to improve the reliability and resilience of the National Electricity Market to the risks from climate change and extreme weather by providing a framework and tailored climate information to enable climate-risk based decision-making and support improved long-term planning for electricity infrastructure. There are two specific aims: to improve long-term supply and demand forecasting, which is to a large extent temperature driven, and to provide underlying climate change information for investment planning for a more resilient grid. The important information for reliability is long term trends, including trends in specific extremes with quantifiable probability (for example, heatwaves). Resilience is primarily affected by the compound and/ or widespread extreme events, which are approached through case studies. There are two key outputs, the science output (datasets, climate scenarios, case studies), and detailed user guidance. The main format will be an online toolkit, which will be available on the Climate Change in Australia website, consisting of datasets, time series, and maps showing exceedance thresholds for different variables. This will be accompanied by guidance material on how to select and use the climate information, including guidance on understanding sources of uncertainty and assessments of confidence in climate trends, including a risk and adaptation framework with step-by-step problem orientated guidance.

Key insights from this case study include:

- **i** The type and format of information is extremely specific to the electricity sector, and to the level of user, varying from narrative overview to full data sets and input requirements of the models. Climate scenario information therefore needs to be tailored to the expected use following detailed consultation with subject matter experts.
- **ii** It would be desirable to provide standard scenarios to be used across the sector, with a single credible source, and which the regulator understands. This is particularly the case for regulated businesses, although it would also be helpful for the rest of the industry.
- **iii** Ongoing curation of the information, including support and updating, will be required.

CROSS DEPENDENCY INITIATIVE

The objective of the Cross Dependency Initiative (XDI) platform is to provide detailed, costed analysis of climate risk and adaptation options for property and infrastructure assets, to support investment decisions. It has evolved from a series of initiatives and projects with public and private sector partners and is now applied in projects with multiple State governments in Australia, private sector companies and overseas governments, companies and investors. The tool creates a bridge between high resolution climate models and decision-oriented metrics. It provides quantified climate change risk assessment metrics for infrastructure assets—likelihood of asset failure, costs of failure, productivity loss, human impacts. It tests and provides cost benefit analysis of adaptation options and has the potential to be used to identify areas of shared risk and opportunities for collaborative adaptation.

Key insights from this case study include:

- **i** A key challenge for XDI is data access, cost and consistency. Nationally consistent, accessible data sets would be highly beneficial, such as national flood layers, wind fields for cyclones and also consistent nationally downscaled climate data.
- **ii** There are opportunities to continue to extend the applications of XDI, particularly in relation to collaborative adaptation, economics and in standardised risk analysis and reporting.
- **iii** Identification of geographical climate risk clusters and potential collaborative adaptation measures is an area of opportunity in addressing climate risk. This would require greater data sharing and transparency

FINANCE

BANK OF ENGLAND

The Bank of England (BoE) has a mandate to maintain monetary and financial stability within the UK. The BoE recognises that climate-related risks can impact both the soundness of individual firms and the stability of the financial system. With the release of the proposed 2021 Biennial Exploratory Scenarios (BES) the bank is signalling the need for banks and insurers in the UK to carry out climate risk stress tests. To this end, the aim of these scenarios is to test the resilience of current business models of the largest banks and insurers and the financial system to both physical and transition risks from climate change. The exercise is expected to provide a comprehensive assessment of the UK financial system's exposure to climate-related risks. Each scenario is internally consistent and designed to test exposure to corporates, households and government. From this information the bank is hoping to publish aggregate information about the size of climate risks in the financial system and the capacity of firms to respond.

Key insights from this case study include:

- **i** recognition that there is a lot of data already available, but this data is not necessarily publicly available nor is the data connected or compatible.
- **ii** there is a lot of research activity, but this is predominantly being undertaken in disciplinary silos with a recognised need for more interdisciplinary and cross-cutting research.
- **iii** there is a growing need for greater coordination across different government departments on the development of climate scenarios for general and specific use cases.
- **iv** ultimately, organisations are going to want to undertake scenarios for their own circumstances, so the framework needs to incorporate a degree of flexibility to allow the scenarios to be extended and applied to different circumstances.

QBE

The objective of undertaking climate scenarios at QBE was to implement the recommendations from the TCFD and increase the awareness of climate-related risks and response for risk managers, underwriters and investors. QBE therefore aim to understand climate-related risks and opportunities for their business and to financially protect assets and people and to assist recovery from extreme weather events. Although QBE are only just starting to undertake scenario analysis themselves, they have shown financial sector leadership by founding and co-ordinating the CMSI. The CMSI has a remit to develop a consistent standardised set of climate scenarios that can be applied across the financial sector of Australia.

Key insights from this case study include:

- **i** ensuring scenarios are developed in a way that they are decision useful.
- **ii** to consider both climate risks and opportunities and to also consider opportunities for developing decarbonisation strategies.
- **iii** producing consistent scenarios but allowing the ability for specific sectors to adapt and apply the scenarios in a way that is relevant for them.

NATIONAL AUSTRALIA BANK

The objective of undertaking climate scenarios at National Australia Bank Limited ("NAB") is to implement the recommendations from the TCFD and to understand the impact of particularly significant climate-related events on its lending portfolio. This will ultimately help NAB to manage climate-related risk facing its business related to operations, the supply chain and customers. It will also help NAB understand the climate-related risks and challenges faced by customers—which means NAB will be better placed to support customers with finance as they manage climate-related risks and transition to the low carbon economy.

NAB has been reporting on climate-related information in line with TCFD recommendations within its annual financial reports since 2017 (when it publicly supported the TCFD recommendations—refer to the TCFD website). Since this time, NAB has undertaken work to grow its understanding of climate scenarios and how climate-related scenario analysis can be used in a banking context. It has learnt that having customer data in a geospatial format is important for analysis of the physical impacts of climate change as these impacts are local, specific and spatial granularity is important. NAB has ongoing engagement with external consultants and academics to build in-house capability to overlay climate-related data and information over its customer data to develop an understanding of potential physical climate risk on its lending portfolio. Importantly, NAB is already including disclosure of climate-related risks as part of the bank's annual financial reporting.

Within these reports, the bank acknowledges that climate-related risks may result in increased credit risk affecting property values or business operations (physical risks) as well as new laws and government policies designed to mitigate climate change (transition risk).

Key insights from this case study include:

- **i** collaboration across a sector is important to reduce costs and accelerate sector and individual bank learning.
- **ii** engaging experts across multiple disciplines is important to build in-house capability.
- **iii** expectations around climate-risk disclosure need to be adjusted based on the quality of data available and where the information is being published (e.g. financial reports, sustainability reports, standalone TCFD reports etc).

RESOURCES

RIO TINTO

Rio Tinto's main objective of undertaking climate scenarios is to support long term strategic planning to build strategic resilience to future climate-related risks and opportunities. Although Rio Tinto is a TCFD supporter, TCFD disclosure is not the main driver. Rio Tinto has used scenario planning and considered the impacts of climate change for many years and view the transition to a low carbon economy as critical to their long-term strategy and operations. They have recently moved away from using standalone climate scenarios to fully integrated climate change considerations into the scenarios that are used as part of the Group strategy process. Three strategic scenarios are developed in-house using various data sources and consider technological, social and geopolitical megatrends. These result in a range of climate change outcomes that are considered in strategic planning to identify risks and opportunities to the business, including to ensure that Rio Tinto have the right asset portfolio and product mix over the medium and long term. Further, Rio Tinto use an International Energy Agency (IEA) Sustainable Development Scenario (aligned with the Paris Agreement) to test implications of a low carbon transition to the resilience of the business and an RCP 8.5 scenario to test physical risks on real assets. Information on the scenarios is provided in Climate Change Reports and the Annual Report, which is targeted to both internal and external stakeholders.

Key insights from this case study include:

- **i** Moving away from stand-alone climate scenarios to fully integrated climate change considerations in the Group strategic planning process. Climate scenarios are further used to test the implications of transition and physical risks on the business.
- **ii** Importance of testing business resilience to ensure the right asset portfolio and product mix over the medium to long term, such as products that will be in demand in a low carbon transition.
- **iii** Rio Tinto would like to encourage the implementation of the TCFD recommendations to ensure more consistent and comparable approaches in scenario analysis, as well as more granular physical impact data sources and scenarios for the Australian regions to assess physical risks to its Australian assets.

FINAL RECOMMENDATIONS

LIMITATIONS OF RESEARCH

While this research is sufficient to provide an overview of the broad landscape of climate scenario use in Australia, a deeper dive on specific case studies and recommendations that outline options to consider are potential next steps. The recommendations below are based solely on this research and interviews undertaken and therefore have only received limited consultation. Prior to any recommendations being adopted, further in-depth research and consultation is recommended.

WHY STANDARDISE

There are several drivers for the standardisation of climate change scenarios for certain applications. These include:

- Comparison and clarity of risks and opportunities across different organisations for:
  - Management of regulated industries
  - Guiding investor decision-making
  - Assisting in providing oversight from consumer groups or advocates
- Supporting the use of climate scenarios in smaller organisations with less capacity or need to develop bespoke information
- Coordinating government research, action and investment
- Reducing costs to society so organisations don't have to create scenarios from scratch each time
- Improve the communication and management of climate-related risks
- Assessment of total risks and potential for resilience within and across whole sectors and the economy (e.g. financial stability)

The purpose of any standardised or reference climate scenarios needs to be clearly articulated as it will influence the content of those scenarios. The purpose will also inform the stakeholders that should be consulted in the development of the scenarios. Stakeholder consultation will be important to ensure that the scenarios are legitimate, salient and credible.

Articulate purpose
It is recommended the purpose of standard climate change scenarios and guidance be clearly articulated including engagement with the relevant stakeholders in the development process.

WHAT TO STANDARDISE

While the purpose will drive the content of any standard scenarios and guidance (as mentioned above) further insight is provided below on what could be standardised. These recommendations are consistent with the findings of the Royal Commission National Natural Disaster Arrangements. The Royal Commission recommends that Australian, state and territory governments should support the implementation of the National Disaster Risk Information Services Capability and aligned climate adaptation initiatives, including developing integrated climate and disaster risk scenarios tailored to various needs of relevant industry sectors and end users.

› Global warming scenarios consistent with the IPCC

This research has shown the most common IPCC emission scenario for assessing transition risk is RCP 2.6 and for physical risk is RCP 8.5, representing the bookends of the climate scenario extremes. We also note that an RCP 1.9 scenario was recently released defining a representative concentration pathway for a 1.5°C world. There is also scientific controversy on the plausibility of the RCP 8.5 scenario.

We do not recommend specifying RCPs as they will be updated in the forthcoming IPCC AR6. Instead, we recommend specifying a set level of warming that would drive the development of climate scenarios. This would mean the recommendation remained relevant without the need for the guidance to be updated each time the RCPs were updated. Although they could be translated, for ease of understanding to the current RCPs (or other system that may emerge over time).

Based on this report, it is suggested that at least two global warming scenarios be recommended, one with an emissions pathway where there was above 50% chance of warming staying below 2°C and one where there was an above 50% chance of warming above 4°C by the end of the century.

› Generalised climate physical risk scenarios applied to an Australian context

Based on the evidence in this report climate physical risk scenarios are the most tractable for standardisation. The CMSI project was able to produce recommended standardised climate physical risk scenarios for use in understanding the physical damage risks from climate change to buildings and infrastructure. This is the first time in Australia that climate scientists, industry decision makers and service providers have worked together to produce such recommendations.

The information that would be contained in any reference climate physical risk scenarios is currently available on the Climate Change in Australia website, in particular content from Climate Compass could form a basis for new reference scenarios by including explicit information on changes in climate averages and chronic hazards as well as extreme events (where possible) and providing ranges and confidence ratings for these (based on RCPs and IPCC and other scientific evidence) (similar to the CMSI climate science report approach).

Support would also be required to facilitate access to climate change projection data consistent with the scenarios, as well as to climate impact data (flood projections, biodiversity change, etc) that is consistent. See the recommendation on improving the consistency and accessibility of data for more information.

It is recommended work on scenarios and guidance occur in collaboration with the appropriate end users to develop physical risk scenarios that are consistent with the recommended GHG warming scenarios and provide climate information at scales and for climate factors most important to them.

› Generalised transition risk scenarios applied to an Australian context

Alongside climate physical risk, general transition scenarios are important for organisations to understand how future climate responses may impact their organisation. However, global practice on defining transition scenarios is still emerging. Transition scenarios require statements about possible future policy and changes in future markets and consumer preferences. Presently, there are no standard scenarios recommended for use, but several toolkits and frameworks are available.

For a transition risk scenario, it would also be necessary to specify variables like the change in market prices for fossil fuels, carbon prices, growth in new technology, impacts of future litigation and the impacts from human behaviour on consumer demand for carbon intensive products etc.

It is recommended that support be developed to guide organisations wishing to undertake transition scenario analysis. It is also suggested that a watching brief be maintained to follow the evolution of transition scenarios in Australia and overseas in order to identify developments that may prompt the development of local standard recommendations.

› Produce stress test scenarios for priority sectors and risks

Stress tests provide a unique way to test an entity against an extreme but plausible future scenario. They are complementary to a generalised climate physical or transition risk scenario analysis and provide unique insights. Stress test scenarios often combine specific details about extreme low probability events so the effects of the scenario can be used to test the resiliency of the entity. Stress tests have a low (or zero) probability of occurrence due to both the low likelihood of the scenario unfolding as it is designed to be extreme, but also because of the unique combination of parameters and variables that are specified for describing the scenario. For example, one stress test scenario could involve a sequence of compounding or cascading extreme events, combined with different assumptions about economic growth, population dynamics and technology assumptions.

The development of detailed numerically based, and scientifically robust stress tests can be time consuming and resource intensive. In addition, the information required in a stress test to assess the performance of an entity is likely to be very specific to that entity—an event that stresses the electricity sector, may not stress the transport sector.

A narrative based approach to stress testing is another option that has been used successfully and is less costly than a numerically based stress test as described above. Descriptive or qualitative stress tests also provide the opportunity for developing strategic resilience and for reorienting business models to mitigate potential risks and identify opportunities.

It is recommended a process be undertaken to identify those sectors, or regions where understanding the outcomes of a stress test would be most valuable, then work with stakeholders in the sector to develop appropriate tests.

› Supporting socio-economic information

This report highlights that climate change physical risk scenarios are of limited use without contextual information about the changes in population, Gross Domestic Product (GDP) and other socio-economic factors that are associated with particular climate futures. IPCC produces standard SSPs that broadly map to RCPs that drive climate change scenarios. In future IPCC reports these SSPs will be further integrated into the global warming scenarios. Thus, some guidance could be provided at a global scale.

However, for organisations that are predominantly operating in Australia more detailed socio-economic scenarios would be helpful. The Australian National Outlook core scenarios could be considered as a basis for developing socio-economic scenarios that would complement the climate physical risk scenarios and provide important context. Support would be needed to help users understand their use and apply these scenarios appropriately.

It is recommended to begin exploring precisely what work would be required to develop useful socio-economic scenarios based on the Australian National Outlook and be ready to make recommendations on scenarios to apply following the next round of RCP/SSPs from the IPCC.

› Decarbonisation scenarios

The need for well-defined decarbonisation scenarios is evident. Implementing a decarbonisation strategy requires information about the carbon intensity of assets and economic activities over time. Although many of these datasets are presently being developed in other parts of the world (e.g. European Union Taxonomy, Net Zero Asset Owner Alliance, Science Based Targets etc) there are as yet no proposals for the development of an Australian net zero emissions scenario from which organisations can benchmark progress to meeting net zero targets. Every country has a unique set of emissions intensities across assets and economic activities. This is a function of the GHGs that are released or imported within a country's national borders. For an organisation to be net zero aligned its activities would need to be aligned with a nationally approved decarbonisation scenario.

HOW TO SUPPORT USE

Climate scenario analysis is complex. Even the most well-resourced organisations have difficulty finding the data and expertise required to undertake scenario analysis. Our findings, informed by the case studies, echo the findings of the National Climate Science Advisory Committee, in their 2019 report on *Climate Science for Australia's Future* as they would apply specifically to climate scenario analysis.

› Develop climate scenario guidance

Building on the work of the Climate Compass, there is still a need for structured guidance that shows how organisations can undertake different types of climate scenarios analysis (e.g. physical risk, transition risk, stress tests and decarbonisation scenarios). This guidance would provide access to information and resources and describe the high-level process for what needs to be considered when undertaking different types of climate scenarios. It would clarify what decisions a user could make, and what decisions or factors are set. Importantly it would describe the methods used and the assumptions applied during the analysis (e.g. economic growth, inflation, discounting etc). What type of information should be disclosed publicly could also be provided within the templates.

› Improve consistency and accessibility of data

The research has identified issues with accessibility and consistency of climate data, such as the absence of nationally consistent, or centrally accessible downscaled climate data and the high cost of accessing some data types. This finding is consistent with the findings of the Royal Commission into National Natural Disaster Management Systems and its recommendation that Australian, state and territory governments should produce downscaled climate projections underpinned by an agreed common core set of climate trajectories and timelines, and subject to regular review. It is recommended next steps are taken with key information holders, researchers and peak bodies to identify data gaps, issues and solutions and invest in addressing the issues to improve data access and consistency.

› Provide ongoing support and maintain resources

It is recommended systems and resources are put in place to ensure that there is ongoing support for the use of climate scenarios and climate information and that the information is maintained. The development of climate scenarios, guidance, use cases, and any online material should not be considered a one-off project. It is important to recognise the evolving and rapidly changing nature of climate scenario analysis, and the changing requirements for use. New data is being updated and made available continuously. Risks are changing as the exposure and vulnerability of assets and organisations evolve, as do regulatory, business, or consumer requirements for risk analysis or disclosure. As different sectors start to apply these scenarios to different circumstances, new lessons will be learned, and information and guidance will need to be updated.

› Training and education are also important

Without prior experience or knowledge in the application of scenarios it can be difficult to know where to start. With access to data and tools being an important first step for the uninitiated user, the practice of creating and completing a scenario analysis to understand the impacts on an organisation still requires a high level of knowledge. Even in situations where consistency is not a priority, support to improve the application of climate scenarios will be important in driving their use and improving the overall quality of consideration of future climate risk in our economy, government and community.

Scenario analysis is not a tick-box exercise, it requires a deep understanding of both the effects of climate change and the potential effects across different parts of the business. Appropriate training and educational materials are therefore important to ensure climate scenario analysis is being applied appropriately. Training courses to build knowledge of climate-related risks and opportunities should also be considered. This training and education can build on the information already included in the "Climate Campus" section of the Climate Change in Australia website.

Providing a support helpline for users who would like to get one-on-one help should also be considered. This may also be used as a signposting service, recognising that users may well prefer to access information via the bodies relevant to their sectors.

› Refresh the Climate Change in Australia website

The following international best practice elements should be considered in refreshing the Climate Change in Australia website:

- Overview of key messages: provide a high-level overview of key messages of climate scenario analysis upfront on the website, including projected climate impacts that are relevant to Australia.
- Interactive online climate scenario tool: develop a web based user-friendly tool for users to access the recommended climate scenarios by location, selected climate variables, with outputs including (heat)maps, timeline graphs, and description of results. There should also be straight-forward navigation to the detailed climate projection data sets that are consistent with these scenarios. The current Climate Futures Tool could be updated or a new Australian Climate Atlas developed.
- Decision-making framework: provide a description of how climate scenario information informs decision-making, including risks and opportunities by sector.
- Link to climate change resilience and adaptation information: provide links to climate resilience and adaptation strategies (the creation of an Australian Climate Adaptation Toolbox should also be considered), including state-based information.
- Extensive resource library: expand the existing library to include links to reliable external datasets, tools, frameworks and guidance relevant for both specific or general scenario analysis (including international, state and sector-specific resources and publications).

› Show leadership by working in partnership

There is a role for federal government to lead and support sectoral co-ordination and to work with sectors to understand their climate science needs, capacity and capability. This can then allow the provision of targeted and effective support to ensure that Australia is resilient to future climate change and associated socio-economic disruptions. It is recommended a gap analysis be undertaken to understand which sectors are ahead and which sectors are behind, as well as which are most exposed to climate change, and prioritise engagement.

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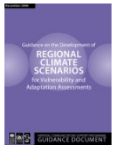
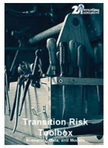
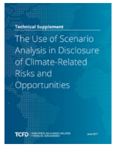
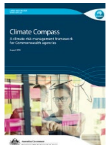
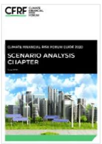
APPENDICES

Appendix 1:
REVIEW OF GUIDANCE DOCUMENTS

ID	Report	Report Title	Author	Audience	Type	Spatial Resolution	Purpose	Reference	Year
1		Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management	CSIRO	Scientists	Scientific guidance	Australia	Provide regional climate scenarios for an initial assessment of risk	(CSIRO, 2006)	2006
2		Guidance on the Development of Regional Climate Scenarios for Application in Climate Change Vulnerability and Adaptation Assessments	UNFCC	Practioners	General Guidance	Global	Guide scenario development for adaptation purposes	(Xianfu, 2006)	2006
3		General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2	IPCC	Technical / Scientific	Scientific guidance	Global / National	General guidance for the use of data in climate impact assessment	(IPCC, 2007)	2007
4		Formulating Climate Change Scenarios to Inform Climate-Resilient Development Strategies	UNDP	Development Practioners	General Guidance	Global	Acquaint users with a variety of methodologies appropriate for low emissions climate resilient development	(Puma & Gold, 2011)	2011
5		Climate Change in Australia Technical Report	CSIRO	Technical / Scientific	General Guidance	Australia	Provides an assessment of the observed climate change in Australia and projected future changes over the 21st Century	(Pearce et al., 2007)	2015
6		A Framework for 2 Degrees Scenario Analysis: A Guide for Oil and Gas Companies and Investors for Navigating the Energy Transition	CERES	Oil & Gas Sector	Sector specific guidance and use	Global	Guidance for development of transition scenario for oil and gas sector	(Jaffe, 2016)	2016

ID	Report	Report Title	Author	Audience	Type	Spatial Resolution	Purpose	Reference	Year
7		Transition Risk Toolbox	2° Investing Initiative	Financial sector and corporates	Transition guidance	Global	Designed as a guide for relevant stakeholders seeking to use tools, scenarios, data and models required for transition risk assessment	(2Degrees Investing Initiative, 2016)	2016
8		The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities	TCFD	Financial Sector	General Guidance	Global	General guidance for reporting climate-related risks	(TCFD, 2017b)	2017
9		Navigating Climate Scenario Analysis	IIGCC	Investment Community	Sector Specific Guidance	Global	Guidance for development of climate scenarios using TCFD for investors	(IGCC, 2018)	2017
10		Climate Compass	Department of Environment and Energy	Government Agencies	Scenario Guidance	Australia	Help public servants identify and take action to manage the risks and opportunities of climate change across government	(CSIRO, 2018)	2018
11		Recommendations of the Task Force on Climate-Related Financial Disclosures – Review of Local Relevance. Australia	Baker McKenzi	General	General Guidance	Australia	Providing arguments for why TCFD reporting is relevant in an Australian context.	(Baker McKenzie & PRI, 2018)	2018
12		Guidance on the Use of NARCliM Models. Climate and Disaster Risks	CSIRO	Scientists	Scientific Guidance	Australia / Regional	Provide guidance and data on the use of climate model simulations from NARCliM Models	(CSIRO, 2019)	2019
13		Climate and Disaster Risk: What They Are, Why They Matter and How to Consider Them in Decision-making. Chapter 4.	National Resilience Taskforce (Australian Government)	General	General Guidance	General	Provide interconnected guidance on governance, vulnerability, scenarios and prioritisation of enabling strategic climate and disaster risk reduction	(Commonwealth Government, 2019)	2019

ID	Report	Report Title	Author	Audience	Type	Spatial Resolution	Purpose	Reference	Year
14		Electricity Sector Climate Information (ESCI) Project	ESCI	Electricity Sector	General Guidance	National / Regional	Improve reliability and resilience of National Electricity Markets from extreme weather events.	(ESCI, 2020)	2019
15		Climate-related Financial Disclosures: Examples of Leading Practices in TCFD Reporting by Financial Firms	Institute for International Finance	Financial Sector	Financial Guidance	Global	Provide additional guidance for how the financial services industry can report against the TCFD recommendations	(Institute for International Finance, 2019)	2019
16		Changing course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD	UNEP Finance Initiative	Financial Sector	Financial Guidance	Global	This report details the results of the UNEP FI Investor Pilot on TCFD Adoption, a collaborative effort of 20 institutional investors to develop methodologies for forward-looking, scenario-based, assessments of climate-related risks and opportunities faced by their portfolios.	(UNEP Finance Initiative, 2019)	2019
17		Network for Greening the Financial System Scenarios – Climate Scenarios	NGFS	Central Banks (finance sector)	Financial Guidance	Global	Explore the impacts of climate change and climate policy for central banks and supervisors.	(NGFS, 2020)	2020
18		Climate Financial Risk Forum Guide	CFRF	Financial Sector (UK)	Financial Guidance	UK	Industry led forum to develop climate-related guidance to the financial sector.	(Climate Financial Risk Forum Guide 2020—Scenario Analysis Chapter, 2020)	2020
19		Climate Change Risk Disclosure	Governance Institute of Australia	Australian Publicly Listed Companies	Financial Guidance	Australia	Provide practical assistance for ASX-listed entities and others to report against Recommendation 7.4 (material exposure to environmental or social risks) with a focus on climate risks	(Governance Institute, 2020)	2019
20		Climate and Disaster Resilience	CSIRO	General	General Guidance	Australia	Provide recommendations to the Australian Federal Government on better equipping Australia to build resilience through scenario planning, risk and vulnerability assessment	(CSIRO, 2020)	2020

ID	Report	Report Title	Author	Audience	Type	Spatial Resolution	Purpose	Reference	Year
21		Full Disclosure	IGCC & Energetics	Investors	General Guidance	Australia	For the first time, the view of multiple major Australian and New Zealand investors have been brought together to define investor priorities for climate-related reporting.	(IGCC, 2020)	2020
22		Scenario Analysis of Climate Related Physical Risk for Building and Infrastructure: Financial Disclosure Guidelines	Climate Measurement Standards Initiative	Financial Sector	General Guidance	Australia	Provide financial disclosure guidelines for the purpose of disclosure of scenario analyses for climate-related physical damage to buildings and infrastructure.	(CMSI, 2020a)	2020
23		Scenario Analysis of Climate-related Physical Risk for Buildings and Infrastructure: Climate Science Guidance	Climate Measurement Standards Initiative	Financial Sector	Science Guidance	Australia	Provide financial disclosure guidelines whilst considering the scientific basis for climate change scenarios with physical risks.	(CMSI, 2020b)	2020
24		Task Force on Climate-related Financial Disclosures: Guidance on Scenario Analysis for Non-Financial Companies	TCFD	Non Financial Companies	General Guidance	Global	The TCFD Strategy recommendations calls on companies to disclose the strategic and financial implications of their material climate-related risks and opportunities. This report is aimed at non-financial companies completing scenario analysis.	(TCFD, 2020)	2020

Appendix 2: COMMON GUIDANCE FOR USING SCENARIOS

THE PURPOSE OF SCENARIOS

The following section will provide high-level guidance for how organisations may start applying climate-related scenarios and assess performance under different climate futures. The development of scenarios allows organisations to explore and develop an understanding for how physical and transition risks and opportunities may play out over time. This research recommends the implementation of a range of scenarios to illuminate future exposure to both transition and physical climate-related risks and opportunities. More advanced users can also explore the implementation of stress test scenarios and strategic scenarios that are aligned with a net-zero future. The following guidance applies to the development of physical and transition risk scenarios.

WHAT TO CONSIDER

Following the TCFD guidance, there are several characteristics that are important to keep in mind when using and developing climate scenarios, these are:

1. **Plausible:** The events described in the scenario should be plausible and the narrative credible. The descriptions of what happened and why it happened should be believable.
2. **Distinctive:** When constructing more than one scenario it is important that each scenario focuses on a different combination of important factors. One way to think of this is to consider scenarios as exploring the envelope of potential futures.
3. **Consistent:** Each scenario should have strong internal logic that ensures the timeline and cause and effect relationships are maintained.
4. **Relevant:** Scenarios should explore futures that are relevant to the organisation so as to generate specific insights that relate to strategic or financial implications for the organisation arising from climate-related risks and opportunities.
5. **Challenging:** Scenarios need to challenge conventional wisdom and typical assumptions about the future. When major sources of uncertainty exist, the scenarios should try to explore alternatives that will significantly alter the basis for business-as-usual assumptions.

DIFFERENT TYPES OF USERS

Just starting out: Organisations who are just starting scenario analysis may choose to start with qualitative scenario analysis to explore the potential range of narratives or storylines that could help explore the range of climate implications for the organisation. Scenario narratives should remain consistent with external best practice where possible. Organisations that are likely to be significantly impacted by either physical or transition risk are recommended to consider some form of quantitative scenario analysis.

Intermediate experience: Once an organisation develops experience and confidence with the use and application of scenarios, quantitative information can be incorporated to illustrate potential pathways and different outcomes. External scenarios and existing models should be incorporated where possible.

Sophisticated user: Organisations with significant experience can then move onto the use of large datasets and the use and development of sophisticated models that may include probabilistic information, sensitivity analysis and other emerging techniques. For those developing their own internal models and datasets, it may be necessary to engage external experts and specialists in climate change, economics, and data science.

THE FIVE-PHASE CLIMATE SCENARIO PROCESS

The following five-step approach for undertaking climate scenario analysis is designed for a general audience engaging with climate scenarios for the first time. After reading this guidance users will have a very strong foundation for diving deeper into and to start applying climate scenarios to their own situation. The following flow chart (Figure 2) provides a high-level view of the different steps involved in this process.

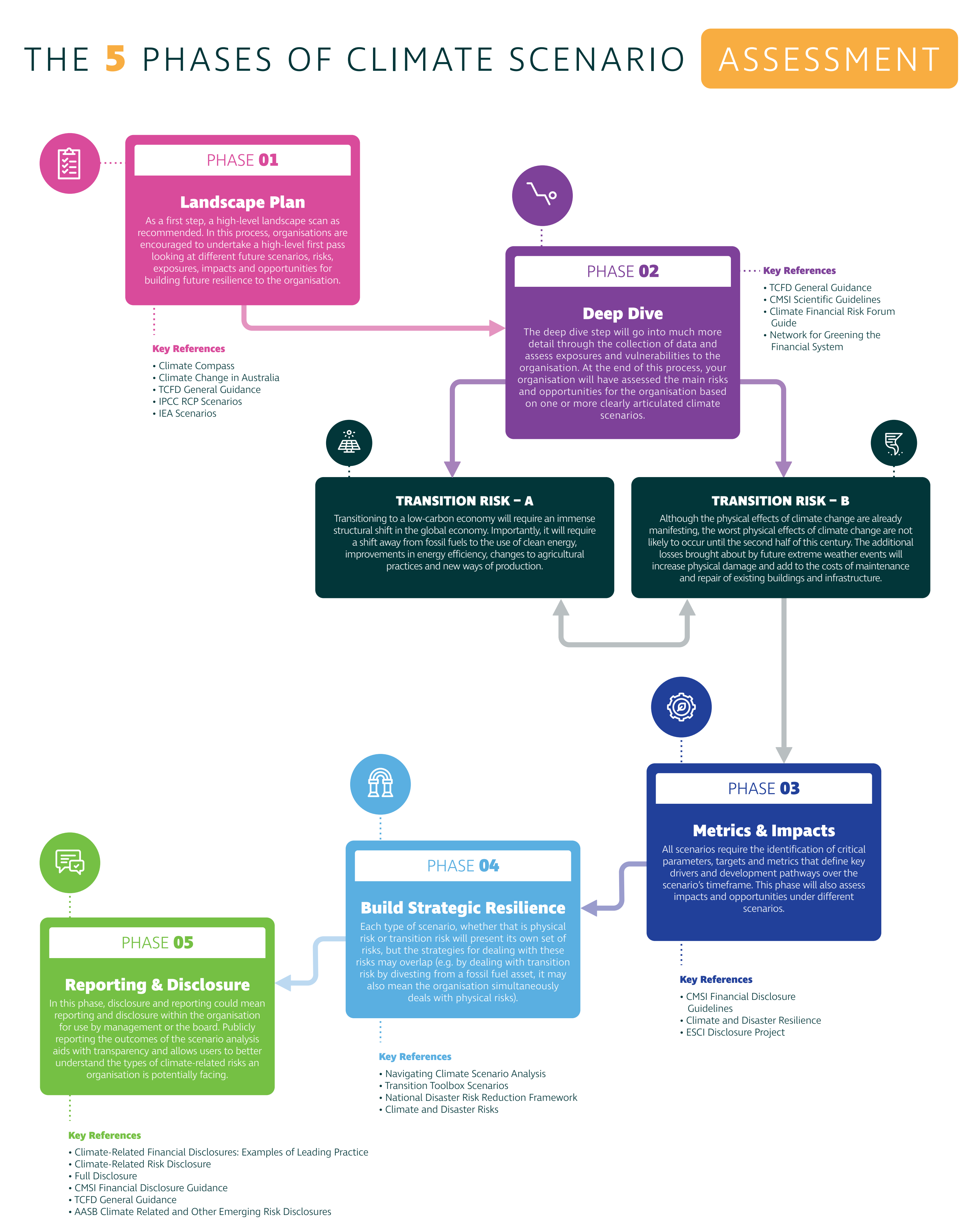


Figure 2: The 5 Phases of Climate Scenario Assessment

PHASE 1
High level landscape scan and narrative development

As a first step a high-level landscape scan is recommended. In this process, organisations are encouraged to undertake a high-level first pass looking at different future scenarios, risks, exposures, impacts and opportunities for building future resilience to the organisation. This exercise should be completed across each of the scenarios that are being considered. The most common pitfalls of the landscape scan are spending too much time going into too much detail. This exercise could be completed over a single day or in a single workshop.

This step consists of the following elements:

1. **Set the scope by answering the following questions:**
   a. Why are you developing climate scenarios? Is there a genuine need to understand impacts? Is climate change already impacting your organisation? Is this being driven by external stakeholders? Are there commercial opportunities? Is it a regulatory requirement?
   b. What is in scope for these scenarios? What policies, programs, assets, geographies, timelines, objectives should be included?
   c. Who should be involved? Climate change and adaptation specialists? Internal risk management? Business continuity? Senior executives? Futures thinking expertise?
2. **Develop a narrative describing the high-level scenario**
   a. Develop a narrative that describes how climate risks will affect the world and as a consequence your organisation. The aim with the development of this scenario is to envision a scenario with the greatest plausible change to test the resilience of your organisation to a range of associated risks.
   b. Start by envisioning a picture of what this world might be like. Questions to consider include: What types of change could you expect? How much change do you expect to occur over the decision lifetime?
   c. This will include shifts in temperature, rainfall, extreme weather events and indirect climate change impacts. You can use the Climate Analogues Explorer on Climate Change in Australia to get a sense of what this might mean.
3. **Identify and list important risks and opportunities**
   a. Brainstorm climate risks and potential opportunities should the future described above come to pass.
   b. Examples include: damage to assets, loss in revenue, reputation, governance, strategic direction, financial stability, revenue, people and community, sustainability etc.
   c. If undertaking a transition risk scenario be sure to consider regulatory risks, technological risks, market risks, litigation risks and reputational risks.
4. **Prioritise risks and decide which risks to focus on**
   a. Traditional risk management processes assign likelihood and consequence scales to determine overall risk ratings. This is not the best process for understanding climate-related risks as it often excludes or misplaces risks that are uncertain. It also doesn't consider the fact that risks are dynamic.
   b. One approach is to rank risks based on consequence alone or the risk appetite of the organisation.
   c. The likelihood of occurrence for climate-related risks are difficult to assess. Therefore, it is possible to add a third rating that includes 'uncertainty' and risks that have high uncertainty are elevated.
5. **Risk mitigation planning**
   a. For each priority risk develop a short plan or mitigation strategy to manage the risk
   b. Who is responsible? Is coordination across different risks required? Are there any barriers?
   c. Sequence efforts to address the risks, what can be done now and what can be done later?
   d. Understand the approval process, intended reporting and possible actions that are within scope.

Other questions that can be addressed at this stage include:

What are the main objectives of the climate scenario? There are many drivers that may initiate a company completing a physical climate risk scenario and may include requests from clients and regulators, internal risk management and opportunity or horizon scanning. What prompted the creation of the scenario may determine what the final objectives will be. Clearly articulating the end objectives of undertaking the scenario will help to refine the scope.

What resources are needed and available? Even if off the shelf scenarios and data are being implemented to the fullest extent possible, scenario analysis is not a tick-box exercise and the process of undertaking the scenario is perhaps more valuable than the end result. This will require setting aside dedicated resources from the organisation and may require establishing special working groups and access to external subject matter experts.

What is the scope and scale of options potentially available to the organisation? The type and sector of an organisation will determine the scope and scale of the transition risk scenario that will be undertaken. A government department or infrastructure owner for example may not be able to divest from carbon intensive assets to build resilience, however a privately listed company or an institutional investor may have the option to divest completely from high carbon assets. Key questions for consideration include:

- Is divestment an option?
- Is adaptation an option?
- Is improving the management of existing assets an option?
- Is better management or changing suppliers and counterparties an option?
- Is working with stakeholders, partners and customers an option?

PHASE 2
Deep dive into climate scenario risks and opportunities

After the scan cycle has been completed and you have a high-level overview of the main risks and opportunities as well as a rough plan for how to proceed it is time to delve into more detail. The deep dive step will go into much more detail through the collection of data and assess exposures and vulnerabilities to the organisation. At the end of this process, your organisation will have developed one or more clearly articulated climate scenarios and assessed the main risks and opportunities for the organisation. The deep dive will go through a process collecting relevant physical and transition climate information and data from reputable evidence based sources. Where possible try to use existing guidance and pre-published scenarios (e.g. CMSI Scientific Guidance, NARCliM, IEA projections, IPCC Scenarios etc.). The scenarios developed by these organisations have long been used by scientists and policy analysts to assess future vulnerability to climate change.

1. Search for existing scenarios, data and information to build your own scenarios. Using the landscape scan as a starting point review published scenarios and guidance to decide on the types of impacts that will be considered.
2. Collect organisation level data that will be used in the scenario. e.g. location and value of physical assets and infrastructure, investments, balance sheet and cashflow information, supply chain risks, counterparty risks, customers, business plans and future strategy.
3. Flesh out the narrative of the external scenario including a specification of key risks and opportunities to the organisation for how the climate scenarios will have an impact on the organisation.
4. The data and information that is being collected for these scenarios should focus on the geographic and temporal scales that are meaningful for the scenario being analysed. For physical risk, the time horizons should at least go out to 2050, while transition risk can adequately be represented on shorter time horizons.
5. Parameters used to define the scenario (e.g.

discount rates, GDP growth, demographic variables)

6 Clearly state the assumptions and analytical choices made about the scenarios such as time-horizons, supporting data, external models etc.

Key outputs during this phase include:

- Clearly defined scenarios (and narratives) that describe a plausible climate future that will have a material impact on the organisation
- An assessment of materiality and the identification of key organisational exposures to climate-related risks and opportunities for each of the scenarios
- An assessment of key vulnerabilities of climate-related risks and opportunities to the organisation over temporal and spatial geographies that are material to the organisation.

For more detail on the deep dive phase for undertaking either physical risk or transition risk scenarios please refer to the physical and transition risk guidance documents below.

The main questions that need to be addressed during this phase include:

What type of scenarios need to be considered?
Is the objective to assess probable and expected outcomes as the economy transitions to a low carbon future (e.g. plausible and expected impacts)? Alternatively, is the objective to consider low probability but highly material unexpected outcomes (e.g. stress tests related to unexpected scenarios)?

While these two scenarios are related, they require different modelling approaches and will achieve different results. A future that haphazardly and chaotically moves towards decarbonisation without any policy certainty might have a lower probability of occurrence and much higher impacts. Alternatively, a world that is steadily moving towards decarbonisation with global policy certainty will lead to lower transition risk impacts.

What is the time horizon and temporal resolution of the scenario?
The effects of transition risk are likely to occur in the short to medium term depending on the transition scenario selected. The time horizon could therefore be as short as 10 years or as long as 30 years. The temporal resolution should be selected to align with the business model of the organisation but could be annual, five-yearly or decadal.

What is the geographic scope and spatial resolution?
There are two things to consider when considering geographic scope and spatial resolution. First, the geographic scope should at least include the footprint of the organisation. Secondly, if the scope of the analysis was to include second order impacts then the organisation should consider both its suppliers and customers in the assessment of climate risk. This would include the supply of goods and services from overseas, transportation logistics and the impacts on the location of final customers being serviced.

Will socio-economic projections be incorporated in the scenario?
A decision on the extent for the inclusion of socio-economic factors needs to be made (e.g. economic growth, new policies, population and demographics and technological factors). There are many alternative methods for creating a transition scenario that range from keeping socio-economic factors static (e.g. population and economic growth are static) to specifying specific growth rates that are consistent with different policy and technology pathways. A decision therefore needs to be made if and how social, political, economic, market and technological factors are considered within the scenario.

What data and models will be used?
As the risks from a transition scenario are likely to come from policy, litigation and changes to market prices using a coherent, internally consistent transition risk scenario is important. Where possible, standardised reliable datasets from well-established data providers should be used.

PHASE 3

Understand business impacts: the identification of key metrics and targets for measuring climate-related risks and the evaluation of impacts against these metrics.

All scenarios require the identification of critical parameters, targets and metrics that define key drivers and development pathways over the scenario's timeframe. There are three important steps for this scenario:

1. Identification of key metrics for assessing climate risks against the organisation. For example, in the CMSI different indicators were identified for different parts of the financial sector (e.g. for insurance indicators such as portfolio annual average loss, portfolio annual exceedance for 1 in 100 year events). See Appendix 8 for more examples of recommended indicators.
2. Collection of organisational information:
   - **a** Assessment of the geographic location of the organisation's assets and nature of operations
   - **b** Assessment of value chain (both up-stream and down-stream)
   - **c** The structure and dynamics of the organisation's supply and demand markets
   - **d** Assessment of the organisation's stakeholders and customers.
3. Evaluation of business impacts against the metrics chosen across the organisation's assets, value chain, customers for different geographic locations and time-periods.
4. An assessment of the financial and strategic position of the organisation for each scenario.

As a final step, organisations could also undertake sensitivity analysis across different variables used in the scenarios. A sophisticated user could also employ stochastic methods to assess the full impact across the known range of variables within the scenario.

Other questions that need to be addressed during this phase include:

What are the exposures to specific climate-related risks? Organisations should conduct an analysis to understand their exposure in order to identify scenarios that are relevant and proportionate to the business. It is important to focus efforts where it matters. A high level first pass analysis can provide some initial guidance on key exposures across sectors and geographies to both direct and indirect climate-related risks.

PHASE 4

Build strategic resilience and develop strategies to mitigate risks, meet targets and decarbonise

After the scenarios have been defined (Phase 2) and the impacts on the organisation are understood (Phase 3) it is then necessary to develop strategies to mitigate future risks. Each type of scenario, whether that is physical risk or transition risk will present its own set of risks, but the strategies for dealing with these risks may overlap (e.g. by dealing with transition risk by divesting from a fossil fuel asset, it may also mean the organisation simultaneously deals with physical risks).

This phase is about developing strategic resilience to climate risks. To better understand the relative impacts of different risks it might be necessary to rank and rate risks through a risk heat map, impact ranking or some other method. For each type of transition risk one or more resilience strategies should be identified with the aim of ameliorating the risks. Once all risks have a resilience strategy applied solutions should be critiqued, costed and then prioritised.

Different organisations will choose to implement strategic resilience in different ways. For example, organisations could choose to divest or sell risky assets, they could choose to build adaptation measures into existing assets, reconfigure supply chains, purchase insurance or develop new markets. There are many options available to an organisation wishing to build strategic resilience, and this will depend on the unique combination of different climate-related risks that are impacting an organisation.

Once resilience strategies have been applied to the organisation, the climate scenario can be re-run against the organisation to assess how impacts have changed. The difference between the original scenario (prior to resilience strategies being applied) and the resilient scenario represents the adaptive and resilient capacity for the organisation to withstand climate-related risks.

PHASE 5

Reporting and disclosure

The final step involves reporting and disclosure. There are several reasons why this final step is critical when undertaking climate scenario analysis. These include:

- Documenting the scenario process and assumptions for future reference and development
- Building a coherent evidence base for future decision-making
- The production of reports and recommendations for management and executive
- Inclusion in company public reporting documents
- For inclusion in company financial reports
- To ensure an audit trail exists for potential future litigation
- For meeting other laws and regulations that will likely come into force in the future.

In this phase disclosure and reporting could mean reporting and disclosure within the organisation for use by management or the board. In addition, and preferably the outcomes of the scenario assessment exercise should be prepared for public release either as separate independent reports or within official company reports. Publicly reporting the outcomes of the scenario analysis aids with transparency and allows investors, customers, policymakers, auditors and other stakeholders better understand the types of climate-related risks that an organisation is potentially facing. It also allows the users of these scenarios to compare climate-related risks across different organisations and assess how an organisation is proposing to respond to these risks over time and for the development of strategic resilience.

It is also becoming apparent that regulators as well as accounting and auditing bodies are increasingly expecting entities to report against 'material' climate-related risks. It is thus crucial that appropriate documentary evidence is kept for future auditing purposes. In Australia accounting and auditing bodies have provided detailed guidance on how the materiality of climate-related risks should be disclosed in financial accounts (AASB AUASB, 2019). Many organisations are already starting to report climate-related risks outside official financial reporting, such as the voluntary TCFD reporting. As a first step organisations should, at a minimum, be reporting against the TCFD as there is an expectation that climate risk reporting will increase over time.

A primary aim of climate risk disclosure is to ensure that there is transparency in the application and use of scenarios. If common datasets, frameworks and methods are applied then there is also consistency for comparison across other entities who apply the same datasets, frameworks and methods. If a bespoke approach is adopted then it is necessary for the entity to be as transparent as possible with the assumptions, data and methods that are being applied so that users of the outputs can make informed, evidence based judgements on the materiality of climate-related risks.

Reporting may include the following elements:

- The scenarios, datasets and models that were applied to assess climate-related risks
- An overview of organisational practices and exposures to climate-related risks including assets, business processes, value chains, markets, customers, stakeholder and future organisational strategy
- The primary metrics, targets and parameters for which the impact of climate-related risks will be assessed by the organisation
- Disclosure of how the organisation will build strategic resilience to climate-related risks
- The impact of climate-related risks on the organisation after strategic resilience has been taken into account.

If unique or custom datasets, methods and models are being created and applied then additional information should be disclosed alongside the main conclusions and results from the scenario. The following information is recommended in disclosure.

- Describe the source and type of climate emissions projections used
- Describe the source of other input data including economic projections (GDP etc.), energy use, demographic changes and any assumptions about policy and technology
- Describe any assumptions about markets, prices and capital valuations that are pertinent to the analysis
- Describe the boundaries of climate scenario analysis (e.g. are indirect climate risks being considered, such as risks to supply chains,

counterparties or sovereign risks)

- Describe the level of granularity in both geospatial and temporal terms
- Describe the process for how the modelling was completed and where to find more information
- Describe the level of impacts across each of the transition risk factors (policy, legal, market, reputational)
- A causal analysis for how climate-related risks lead to an impact on the organisation
- Description of the steps that will be taken to build strategic resilience and associated assumptions
- Description of revised climate-related impacts after strategic resilience has been implemented.

Appendix 3: PHYSICAL RISK SCENARIO GUIDANCE

This process is a subset of Phase 2: Scenario Deep Dive of the general scenario guidance described earlier. It is assumed that the general guidance is being followed and this guidance is a branch of the general guidance.

WHAT IS IT?

Although the physical effects of climate change are already manifesting (e.g. Australian 2019/20 and Californian 2020 wildfires) the worst physical effects of climate change are not likely to occur until after the middle of this century. The additional losses brought about by future extreme weather events will increase physical damage and add to the costs of maintenance and repair in order to make buildings and infrastructure more resilient.

Damaged infrastructure can lead to a write-down in the valuation of the asset and induce additional costs for repair. Although the physical consequences of climate change such as extreme weather events can cause devastation to buildings and infrastructure, the economic disruption brought about by critical infrastructure failure can be more costly. Direct damage and business interruption are often what people consider first when they think about the effects of climate change. This can have direct risks for the financial markets in the form of market valuations, higher and more volatile losses for the insurance industry and possible operational risks such as the closure of business.

Indirect climate risks such as disruption to shipping lanes and ports could disrupt global supply chains. This can lead to loss in business activity and loss in revenues. There are also indirect risks for the financial market, increasing insurance costs, uninsured losses and may cause losses in the value of companies leading to a greater default risk of loans. This would have knock-on effects in the real economy feeding through to unexpected depreciation, higher default risk of loans and potentially the downgrading of the creditworthiness for companies and nation states that are worst affected by climate change. In some cases, governments will respond with aid programs, but this in turn would put pressure on public finances. Downgrading the creditworthiness of those countries which are the worst impacted by climate change could lead to capital outflows and poorer credit ratings.

WHAT CLIMATE SCENARIOS ARE CONSIDERED?

From the review of guidance material, international best practice and case studies, physical risk scenarios incorporate high GHG emissions pathways. When considering physical risks, the TCFD recommends that organisations should undertake a scenario that leads to warming of over 2°C. Organisations have therefore tended to adopt scenarios that use models driven by the higher range RCPs available—the most common of these being RCP 8.5 and RCP 6.0. However, within these climate emission pathways it is also important to consider the impact of extreme weather events.

WHAT FACTORS NEED TO BE CONSIDERED?

Because physical climate risks occur over such long time frames it is important to take a long-term view when considering a physical climate risk scenario. Given these long timeframes and the truism that uncertainty increases over longer time horizons, the role and use of climate scenarios to define these future states (and pathways) is evident. Figure 2 shows the historical mean annual surface warming for Australia over different future emissions pathways. RCP 8.5 shows the high emissions scenario and RCP 2.6 shows the low emissions pathway. As clearly shown, the uncertainty range increases over time. It is also clear from this chart how emissions pathways diverge markedly from 2030 onwards. The purple line represents a simulation from Australia's community climate model (ACCESS) showing what a future time series might look like for high emissions including year-to-year variability in the change of annual mean temperature.

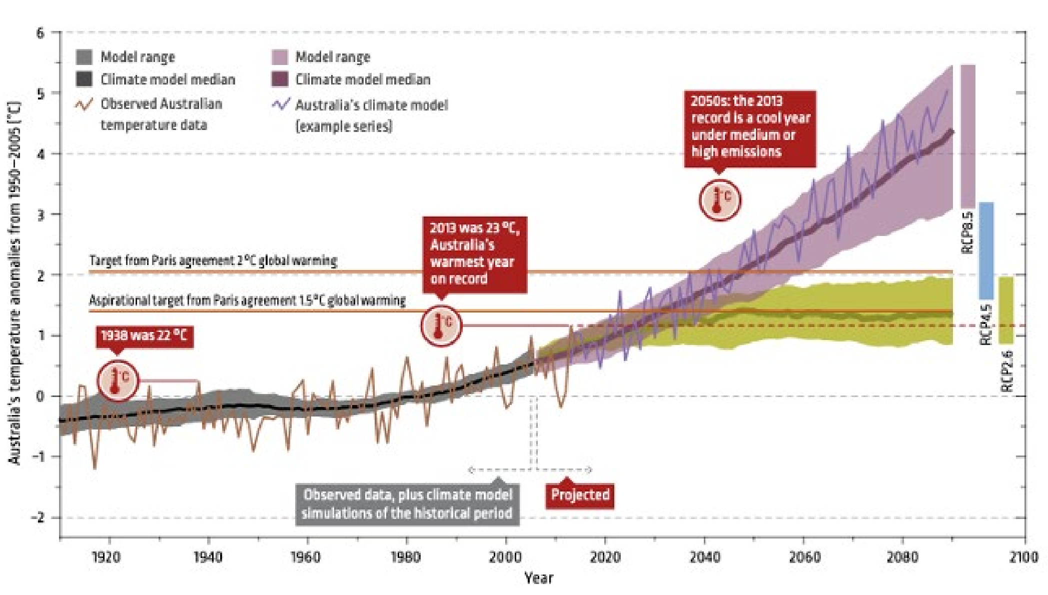


Figure 3: Australian representative concentration pathways and temperature change under different scenarios. Source: Climate Compass.

An important factor when considering physical risks is the distinction between chronic and acute risks. Chronic physical risks refer to the longer-term shifts in climate patterns (e.g. sustained higher temperatures) that may cause sea levels to rise or the occurrence of chronic heat waves and shifts in the duration and location of different weather patterns (e.g. La Niña and El Niño). Acute risks refer to the risks that are even-driven and include increased severity of extreme weather events, such as cyclones, floods, hailstorms. It is appropriate when defining a physical risk scenario to consider both acute and chronic risks.

While Figure 3 shows how the expected annual mean temperature changes over time, it does not show the impact of extremes. Figure 4 below shows how climate change not only changes the mean of the distribution, but can also affect both the variance and shape of the distribution. By only considering changes to the mean (e.g. change in annual global mean temperatures) the frequency and severity of extreme events that occur in the tail of the distribution cannot appropriately be captured. While monitoring and reporting the change in mean temperatures provides an indication for the direction (e.g. the world is getting warmer), it alone cannot give an indication for how the change in extreme events may change. The frequency and severity of extreme events can only be estimated by knowing the shape of the distribution and how the shape of the distribution is changing over time. Climate models are getting better at these types of estimations, but uncertainty necessarily increases the further into the tail of the distribution that you go, thus making it particularly difficult to know how extreme events may evolve over time. These caveats need to be kept in mind when applying extreme event scenarios.

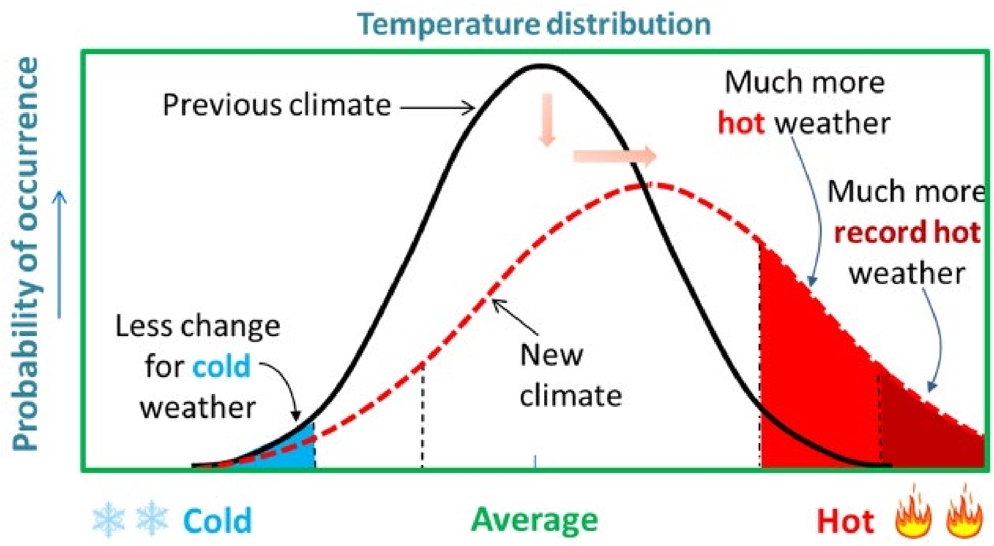


Figure 4: Probability distribution of temperature showing a shift in the mean and variance of temperature under climate change.

When considering what physical risks need to be considered it is important to look at the greatest plausible change and include all potential hazards that may represent a risk to the organisation. This helps to ensure that the full scope of risks are considered and nothing is missed. The scope of hazards chosen (i.e. which extreme events) and the magnitude in the severity of hazard (i.e. how much worse/less will they get) will have an impact on the risks that are being considered for the scenario. Importantly the level of detail should only match the level that is required for making and informing the objective of carrying out the scenario. Only use granular, high resolution data if there is a need to understand impacts at a granular level. If regional information at coarser levels of granularity will enable evidence-based decision-making then the need for more granular data can be avoided.

WHAT ARE THE MAIN STEPS REQUIRED?

This process assumes these steps are being followed as a subset of the general guidance provided earlier. Before attempting these steps it is recommended that a landscape scan is first completed to gain high level understanding of the risks and opportunities facing an organisation. Therefore before proceeding with the steps below, an organisation should already have a good understanding of the types of scenarios that should be applied, main organisational exposures across different assets and practices and a high level expectation for the most important risks.

Step 1: Identify objectives, material risks and stakeholders

- **(i)** Clearly articulate objectives for undertaking the scenario;
- **(ii)** Identify the physical risk factors that will be used to drive the scenario;
- **(iii)** Decide on key parameters and metrics that the organisation will use to shock/impact the business (e.g. value of damage to property, loss in revenue, loss in market share, etc.);
- **(iv)** Identify key stakeholders (suppliers, counterparties, customers, public).

Step 2: Choose and/or design the external physical risk scenario to be used

- **(i)** Decide on the timeframe of analysis - typical time-horizons include 2030, 2050 and 2090 (available on the Climate Change in Australia website);
- **(ii)** Determine the geographic regions and spatial resolutions that are being considered;
- **(iii)** Define the chronic changes in climate that will occur over time consistent with the climate projection selected;
- **(iv)** Define the acute weather-related risks and hazards that will occur that are consistent with the climate emissions projection and chronic risks;
- **(v)** Define other relevant scenario parameters;
- **(vi)** Select socio-economic conditions and parameters that are consistent with the scenario (if one is being used);
- **(vii)** After broad scope of the analysis has been decided including, time frames, spatial resolution, hazards etc it is then possible to determine which RCP emissions pathway could be applied.

Step 3: Collect internal asset, financial and business process information

- **(i)** Complete an internal audit of physical assets owned and / or operated by the organisation;
- **(ii)** Complete an internal audit of financial assets on the balance sheet including investments in equities, bonds and property;
- **(iii)** Identify important or at risk stakeholders;
- **(iv)** Complete an audit of transport supply lines, imports, exports and the movement of goods and people critical for the business.

Step 4: Apply physical risk model to organisation

- **(i)** Decide on the metrics and parameter choices for the objectives of the scenario
  - **a** Decide on the geographical scope and spatial resolution
  - **b** Decide on the time horizon and temporal resolution
  - **c** Decide on the extent which second order (supply chain) and third order (broader socio-economic) impacts will be incorporated in the model
  - **d** Clearly define assumptions and system boundaries (e.g. adaptive capacity etc).
  - **e** Calculate impacts and output results;
- **(ii)** Identify how changes in chronic risks (e.g. sea level rise, drought, warmer temperatures etc.) will impact different areas of the business
  - **a** This needs to be completed for each chronic risk factor identified;
- **(iii)** Identify how important changes in acute risks (extreme weather-related events) will impact different areas of the business
  - **a** This needs to be completed for each acute risk (e.g. cyclones, floods, hailstorms etc);
- **(iv)** Evaluate the impacts of different risks across the organisation
  - **a** Undertake sensitivity analysis on modelled results
  - **b** Identify and rank assets and parts of the business at most risk
  - **c** Estimate total impacts on the organisation.

WHAT DATASETS AND MODELS ARE AVAILABLE?

Freely available:

- CLIMADA uses state of the art probabilistic modelling to estimate the expected economic damage as a result of climate change. The economics of climate adaptation methodology as implemented in CLIMADA provides decision makers with a fact base to understand the impact of weather and climate on the economy. It includes cost/benefit perspectives on specific risk reduction measures. It is an economic Integrated Assessment Model (IAM) that is well suited to provide an open and independent view on physical risk in line with TCFD disclosure
- The World in 2050 (TWI2050, 2018) has been led by the International Institute for Applied Systems Analysis (IIASA). The TWI2050 aims to provide fact-based knowledge to support the policy process and implementation of the SDGs. It is a first attempt to explore transformational pathways that take a comprehensive people and planet approach to attaining the SDGs.

Commercial:

- XDI is an Australian commercial software platform that seeks to quantify the future risks of extreme weather events (wildfires, droughts, flooding and coastal inundation) on buildings and other infrastructure assets under different climate scenarios.[26] The platform enables standard reporting to meet the needs of diverse users. The tool now covers eight infrastructure sectors and ten different hazards.
- ERM has a suite of internal proprietary tools which are used to analyse financial opportunities and risks. These tools are applied to the client's portfolio and aligned with the recommendations of the TCFD. The analysis could include identification of asset-specific financial drivers and creation of scenarios for asset financial models to understand financial impact. A dashboard is used to monitor and signpost market indicators within a sector that indicate an inflection point or movement, enabling quick responses and exposure adjustments. It includes detailed asset-specific consideration of vulnerability and resilience to physical climate hazards, including development of adaptation plans.
- FourTwentySeven have a bottom-up climate risk model for global equities, fixed income, sovereigns and real assets. It provides the identification of assets, sectors and geographies most vulnerable to physical impacts of climate change. It enables a risk mitigation strategy and resilience plan based on a granular assessment. It can perform due diligence for new asset acquisition. Scores measure exposure and sensitivity to climate impacts (storms, droughts, floods, heat waves, wildfires, sea level rises) at the facility-level for publicly-listed companies and real asset portfolios. Focusses on exposure to tail risks and change from current conditions against a 2020–2040 timeframe. Available: physical risk in Equities and U.S. Munis.
- ISS-Climate offers impact and risk-oriented scenario analysis at the company, total portfolio and sector level, and is available for different asset classes. To date, eight scenario approaches are available. The tool analyses potential impacts and highest risks within the portfolio to support the development of appropriate strategies and plans for action.
- Mercer Top-down, asset allocation climate scenario tool that examines risk/return impacts at total portfolio, asset class and sector level. The model identifies priority risks and opportunities and the potential relative impacts under different climate scenarios to support strategic decision-making on asset allocation and portfolio construction.
- South Pole's tool Arctica covers physical and transition risks (with primary focus on policy risks). provide a forward-looking, scenario-based analysis at portfolio, sector and holding level with global sectoral and geographical coverage. Using IPCC, OECD and ND-GAIN data, it models all major physical risks. Transition risks are calculated by integrating OECD and IEA data assessing the risk for a 2°C scenario based on IEA and SSP scenarios. Risks are defined by hazard, vulnerability and exposure.
- Vivid Economics Climate Risk Toolkit assesses the transition and physical climate risk exposure of listed equities, corporate bonds, real estate and sovereign bonds using a scenario-driven approach. The toolkit covers over 20,000 listed companies, and associated corporate bonds, as well as real estate and sovereign bonds for major economies. Asset price value impairment based on the Climate Risk Toolkit's modelling of cost, price, and quantity impacts under climate scenarios. These impacts can further be broken down into different impact channels, including transition-related demand destruction, demand creation, direct physical impacts, carbon taxes, abatement opportunities, adaptations to physical risk, and cost-pass through. Vivid also provides carbon intensity and temperature alignment analysis.

[26] Australian Government, Department of Home Affairs (2019)

Appendix 4: TRANSITION RISK SCENARIO GUIDANCE

This process is a subset of Phase 2: Scenario Deep Dive of the general scenario guidance described earlier. It is assumed that the general guidance is being followed and this guidance is a branch of the general guidance.

WHAT IS IT?

Transitioning to a low-carbon economy will require an immense structural shift in the global economy. Importantly it will require a shift away from fossil fuels to the use of clean energy, improvements in energy efficiency, changes to agricultural practices and new ways of production. This shift will be monumental and require extensive policy, legal, new technology and changes to the financial markets to meet the mitigation and adaptation challenges to avoid the worst impacts of future climate change.

WHAT CLIMATE SCENARIOS ARE CONSIDERED?

From the review of guidance material and international best practice, transition scenarios incorporate low carbon development pathways. The TCFD recommends that organisations consider a set of scenarios, including a 2°C or lower scenario for assessing transition risks. Organisations therefore tend to adopt the lowest range IPCC RCP scenarios, the most common of these being RCP 2.6 which aligns with 2°C of warming over this century. In 2019 the IPCC launched another low carbon scenario, RCP 1.9, which aligns with 1.5°C of warming by the end of this century.

WHAT FACTORS NEED TO BE CONSIDERED?

Many uncertainties remain as to the form a low-carbon transition scenario might take. A review of the transition risk literature has highlighted that there are two broad types of transition scenario outcomes. The first is characterised by a gradual, smooth ambitious scenario that takes meaningful concerted steps towards achieving future decarbonisation goals. The second scenario is late, disorderly and sudden. The concept of a disorderly transition is used as one of the Bank of England's BES scenarios and describes a do nothing approach with a sudden transition to zero carbon (Bank of England, 2020). The major elements that should be considered as part of a transition scenario are included below:

- **Policy risk and opportunities**
  - **Policy actions** from government that aim at reducing greenhouse gas consumption
  - **Supply side policies** such as restrictions on fossil fuel exploration, regulating land-use and regulating energy efficiency standards
  - **Demand side policies** such as putting a price on carbon, increasing the cost of carbon intensive industry
- **Legal risks and opportunities**
  - **Litigation or legal risks** are increasingly important to business but also to governments who contravene or disregard their own commitments and targets.
  - **Litigation claims** have been brought before the courts by property owners, municipalities, states, insurers, shareholders and other public interest organisations.
  - **Climate-related litigation** cases are rising globally. As at January 2020 the total number of climate-related legal cases reached 1,444 globally.[27]
  - **Claimants are increasingly** relying on constitutional and human rights laws in attempts to hold governments and companies accountable for addressing climate change.
  - **Organisations that fail to mitigate** the impacts of climate change, adapt to climate change or insufficiently disclose material financial risks are increasingly being targeted.
  - **As climate risks grow** the risks of litigation also grow.
- **Market risk and opportunities**
  - **Market based risks** are varied and complex and could result in trillions of dollars of capital reallocation over the next two decades.

[27] View source

- **Investor expectations** about future markets could drive carbon intensive sectors such as the fossil fuel and heavy industry sectors to new lows.
- **Market sentiment shifts** could accelerate the shift away from carbon intensive sectors towards green alternatives very rapidly.
- **Stranded assets** are assets for which the value of the asset has collapsed because the market no longer considers it of any value. It is estimated that some US$900 billion of oil and gas reserves will become stranded (lost) if Paris Climate goals are achieved.[28]
- **The impairment** of assets is regulated from a financial perspective where accountants are required to ensure that an entity's assets are not carried at more than their recoverable value (e.g. IAS 16)[29]

• **Reputational risk and opportunities**

- **Consumer demand** is a powerful force that can mean the success or failure of a commercial business.
- **Democratic elections** are increasingly being driven by policies seeking to address climate change risks.
- **Surveys after survey** are showing that the public are increasingly 'very concerned' about the effects of climate change.[30]
- **Climate change** is increasingly seen by the public and particularly younger generations as the most important issue of their generation.

• **Technological risks and opportunities**

- **A shift to low carbon technologies** could mean old technologies become a stranded asset (e.g. fossil fuel assets). However, at the same time, businesses that shift to use new and emerging technologies could benefit from increased efficiency, lower costs and increased reliability.
- **Demand for new energy materials and resources** will stimulate demand in different regions of the world taking demand away from regions that previously depended on fossil fuels.
- **Companies and countries that lead the development of sustainable energy technology** will be the new establishment in a low carbon economy.
- **There will be winners and losers** that emerge from the 'Schumpeterian' creative destructive process. There remains significant uncertainty over the timing of technology development and deployment (e.g. hydrogen).

WHAT ARE THE STEPS FOR CARRYING OUT A TRANSITION RISK SCENARIO?

Step 1: Choose and define the external transition risk scenario

(i) Define the scenario parameters and transition risk elements that will be considered;

(ii) Choose the climate trajectory and socio-economic pathway;

(iii) Choose the speed of transition and orderliness of the scenario;

(iv) Identify what transition factors will be included (policy, technology, market, legal).

Step 2: Identify objectives, material risks and relevant stakeholders

(i) Clearly articulate objectives for undertaking the scenario;

(ii) Identify the transition risk factors that will be used in the scenario;

(iii) Decide on key parameters and metrics that the organisation will be assessed against;

(iv) Identify key stakeholders.

Step 3: Collect internal asset, financial and business process information

(i) Complete an internal audit of physical assets owned and / or operated by the organisation;

(ii) Complete an internal audit of financial assets on the balance sheet including investments in equities, bonds and property;

(iii) Identify stakeholders including suppliers customers and broader groups and identify any other inputs that are required for the organisation;

(iv) Complete an audit of transport supply lines, imports, exports and the movement of goods and people critical for the business.

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Step 4: Apply transition risk assessment to organisation

(i) Decide on the financial models that best suit the need of the risk assessment. E.g. traditional discounted cash flow model, credit risk model or economic asset impairment.

(ii) Assign macro impacts to micro-actors. The macro trends need to be mapped using one of the following methods:

- **a** Fair share approach where a 'fair share' allocation rule is used to allocate sector-level production and capacity trends proportionally based on company market share.
- **b** Cost approach uses sector-level variables such as demand and price as a constraint that interacts with production costs of companies where the 'marginal product' is produced at the lowest cost.
- **c** Bottom-up company analysis positions the company relative to macro trends in a bottom-up manner, tracking assets, pricing power, market positioning, and other parameters. From both a financial and economic risk perspective this method can be applied most generally and is considered most appropriate. The challenge is cost of application and availability of data.

(iii) Decide on the metrics and parameter choices for the objectives of the scenario.

- **a** Decide on the geographical scope and spatial resolution
- **b** Decide on the time horizon and temporal resolution
- **c** Decide on the extent which second order (supply chain) and third order (broader socio-economic) impacts will be incorporated in the model
- **d** Clearly define assumptions and system boundaries (e.g. adaptive capacity etc).
- **e** Calculate impacts and output results

(iv) Evaluate the impacts of different risks across the organisation

- **a** Undertake sensitivity analysis on modelled results
- **b** Identify and rank assets and parts of the business at most risk
- **c** Estimate total impacts on the organisation

WHAT DATASETS AND MODELS ARE AVAILABLE?

Freely available:

- The Paris Agreement Capital Transition Assessment (PACTA) tool, supported by the PRI is a free tool based on the analysis by the 2°C investing initiative. The tool covers both equity and bond issuers and is based on companies' investment plans for both high and low carbon activities. These are then compared with a technology and energy mix which would be consistent with a trajectory towards a 2°C scenario.
- Transition Pathway Initiative[31] is a global initiative led by asset owners and supported by asset managers. It is aimed at investors to assess company's preparedness for the transition to a low-carbon economy.
- CISL Transition Risk Framework is a framework set out in three steps, which can be used to independently explore transition risks and opportunities. Aimed at investors it can be used to test infrastructure portfolios or investments.

Commercially available:

- Carbon Delta uses country level emissions targets to allocate carbon constraints at a sectoral, company and individual facility level. Emission reduction costs are then forecast to calculate the cost of cutting emissions to meet those constraints. Positive revenue opportunities are also estimated.
- ET Risk Project / CO-Firm implements two transition scenarios, one limited transition and one ambitious scenario. The model incorporates asset level information covering 30 countries and 200,000 factories and products in order to model risks. The model operates on a sectoral basis aiming to estimate potential impacts on financial metrics including cashflows and capital expenditure.
- Bloomberg / Carbon Tracker Initiative is available to Bloomberg subscribers. The model uses proprietary oil and gas industry data from Rystad Energy, combined with Bloomberg market data to provide company level modelling of transition risk for the oil and gas sector. It is based on previous analysis from the Carbon Tracker Initiative which was developed to produce project-level cost information on different companies.

31 https://transitionpathwayinitiative.org

Appendix 5:
COMMONLY USED REFERENCE CLIMATE SCENARIOS

Provider	Scenario Name	Characteristic	Peak	Net-zero	Reference
Emissions, energy and technology scenarios					
IEA	Beyond 2 Degrees Scenario	Limits warming to 1.75°C by 2100. Starts in 2014.	2017	2060	2 Degrees of Separation, PACTA, TPI, TCFD technical annex
IEA	Energy Technology Pers-pectives 2 Degrees scenario	ETA 2°C scenario. From 2014–2100	2020	2060 for power	TPI
IEA	Sustainable Development Scenario	Combines climate and social targets for limiting global warming to 2°C. Starts in 2016 until 2040.	2020 for energy and industry	Not modelled (beyond 2040)	PACTA
IEA	New Policy Scenario	Pathway if all new policy, set out in countries' NDCs, are effectively implement. From 2016–2040	2029 (China peak energy only)	Not modelled (beyond 2040)	2DS, PACTA, TPI, TCFD technical annex
IEA	Current Policy Scenario (CPS)	Business-as-usual without new climate policies. From 2016–2040	No peak	No net zero	PACTA, TCFD technical annex
IRENA	RE Map	Doubles renewable energy share of world's energy mix by 2030. From 2010–2030			PACTA, TCFD technical annex
Greenpeace	Advanced Energy [R] evolution	Pathway for a fully decarbonised energy system by 2050			PACTA, TCFD technical annex
Institute for Sustainable Development	Deep Decarbonization Pathway Project (DDPP)	Country level pathways for reducing emissions consistent with 2°C. From 2010–2050			TCFD technical annex
Bloomberg	BNEF reference scenario	Power sector pathway scenario			PACTA, TCFD technical annex
Emissions concentration pathways					
IPCC	RCP 8.5	High emission scenario, 4–5°C, consistent with no policy changes to reduce emissions	No peak	No net zero	TCFD technical annex
IPCC	RPC 6	High-to-immediate climate emissions scenario, 2~3.7°C.	2080	No net zero	TCFD technical annex
IPCC	RCP 4.5	Immediate climate emission scenario. Global emissions peaking in 2040 and falling rapidly thereafter until 2080	2040	No net zero	TCFD technical annex
IPCC	RCP 2.6	Limits warming to the Paris Agreement's target of 2°C by 2100	2020	2070	TCFD technical annex
Shared socio-economic pathways					
IPCC	SSP1	Sustainability (Taking the Green Road)			
IPCC	SSP2	Middle of the road			
IPCC	SSP3	Regional Rivalry			
IPCC	SSP4	Inequality			

Appendix 6:
CASE STUDIES

Any information and views contained in these case studies are solely the responsibility of the research team and do not reflect in any way the opinion or position of the organisations represented.

Case Study:
AUSTRALIA'S WINE FUTURE: A CLIMATE ATLAS

Title	Australia's Wine Future: A Climate Atlas
Type of case study	Scenario development.
Aim	Assist Australian wine industry adapt to a variable and changing climate by: • identifying important weather risks within different wine regions • developing region-specific indices specifically tailored to the wine sector, for example "heatwave" and heat accumulation • assessing the variability and trends in these indices between regions • assessing the impact of these changes during the grapevine growing season • assessing historical and future changes in large scale climate drivers that drive drought and extreme heat in Australia • consolidating available high-resolution climate information in an accessible and useful form to the wine regions of Australia • identifying regionally relevant adaptation options in the short, medium and long-term • improving understanding and uptake of climate information to empower grape growers to plan for the coming season, future years and decades.
Purpose of climate scenarios	To deliver future climate information at high resolution to all members of the wine industry in an accessible format.
Organisation(s) involved	Australian Wine Research Institute, CSIRO, the University of Tasmania, South Australian Agricultural Research Development Institute, and the Tasmanian Institute of Agriculture.
Support for scenario development	Developed in house by University of Tasmania and CSIRO.
Sector and target audience	Agriculture Wine industry (including grape growers, winemakers, viticulturists, consultants, and investors).
Geographical scope	Wine growing regions of Australia, grouped by state.
Type of information provided	Detailed information on relevant climate indicators for past, present, and projected period, plus details of observed change between two 20-year periods.
Time period for development	2016–2019.

The scenarios	Type	Quantitative (based on RCP 8.5) overlayed with associated global temperature change expectations e.g. >2°C).
	Time horizon	2100, plus comparison of present period (1997 to 2017) to previous (1961 to 1990).
	Time resolution	Annual, Monthly and Seasonal (nb indicators include days).
	Geographical resolution	Information produced for wine growing regions of Australia, via downscaling to a 5 km grid.
	Climate data included	**Temperature** • Growing Season Temperature (GST) • Growing Degree Days (GDD). **Rainfall and evaporative demand** • Annual, Monthly and Seasonal, and Growing Season rainfall; • Number of rainy days during harvest • Annual, Monthly and Seasonal aridity • Number of dry spells before harvest. *NB. some of these indicators were developed and/ or adapted specifically for the project.*
	Extreme events	**Heat extremes** • Extreme heat factor (EHF) • Heatwave duration and intensity • Days per year exceeding thresholds (30°C, 35°C, 40°C, 45°C) • Frequency of days with high human heat stress (above both 30°C & 60% humidity). **Cold extremes** • Number of days at risk of frost during the growing season; • Daily minimum temperature; • Annual chilling degree days; • Days per year below thresholds (<2°C, <0°C, <-2°C).
	Range of scenarios	Business as usual or worst case emissions scenario (RCP 8.5) is the only one presented for future climate
	Main data source for scenarios	Six Global Climate Models (GCMs) from the Coupled Model Intercomparison Project 5 (CMIP5) were used to produce high resolution projections for the atlas, These were CSIRO-BOM-ACCESS1-0, CNRM-CERFACS-CNRM-CM5, NOAA-GFDLGFDL- ESM2M, MOHC-HadGEM2-CC, MIROC-MIROC5 and NCC-NorESM1-M.
Sources	Harris, R. M. B., Remenyi, T. A., Hayman, P., Thomas, D., Risbey, J., Petrie, P., Thatcher, M., Bindoff N. L. (2019) Australia's Wine Future: Adapting to short-term climate variability and long-term climate change. Final report to Wine Australia, Antarctic Climate and Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Tasmania. Remenyi, T.A., Rollins, D.A., Love, P.T., Earl, N.O., Bindo, N.L., Harris, R.M.B. (2019) Australia's Wine Future. A Climate Atlas, University of Tasmania, Hobart, Tasmania.	
Contact details for further information	Tom Remenyi (University of Tasmania) Tom.Remenyi@utas.edu.au Sharon Harvey (Wine Australia) Sharon.Harvey@wineaustralia.com	

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

Only one emissions scenario was used as the basis of the climate information, described as *the business as usual or worst case scenario* corresponding to emissions continuing on their current path. However, timeseries were also overlayed with 'global temperature change' so users could think about impacts based on either time (following an RCP 8.5, or as a change in temperature (for example a >2°C world). In this way one RCP was presented, but covered off on four separate future warming scenarios. It is also noted that the climate divergence between the emission scenarios is not all that great prior to 2050. Continuous data was presented from 1961–2100.

Time series data was also presented as averages over 20-year blocks in order to eliminate some of the noise of annual variation while still giving meaningful results.

Data resource and requirements for the scenario development or use

- IPCC RCP datasets (Source)
- Six Global Climate Models (GCMs) from the Coupled Model Intercomparison Project 5 (CMIP5): ACCESS 1-0, CNRM-CM5, GFDL-ESM2M, HadGEM2-CC, MIROC5, NorESM1-M (Source)
- High resolution regional climate model simulations, downscaled from the above 6 GCMs using the CSIRO Cubic Conformal Atmospheric Model (CCAM):
  The full archives is not yet easily publicly available (portal to be completed soon—an unfunded activity so is taking some time). CCAM simulations are best described here.
- Observational data sets: Australian Gridded Climate Data (AGCD) (Source); QLD Government SILO data. (Source)
- List of operational weather and climate metrics used by the wine industry:
  Consolidated and developed during the project, no consolidated list or database for any industry exists across Australia.

Implementation and use

At time of writing, the project outputs had only been available for three months, but it is expected that the Atlas will be used right across the industry, from small grower/makers to large investors to inform decisions about investment, planting, equipment, and operations. The atlas is expected to assist grape growers and winemakers make short- and long-term decisions about how to manage their vines. For example, a multinational investor may use the Atlas in their selection of region or wine style, while a small grower may choose a different climate adapted clone or variety when replanting a vineyard, or may decide to adopt an adaptation strategy, such as a mulching system they were considering. Comparison between regions allows producers to ask the question, "Which region will my region resemble in the future?", allowing growers and wineries to look to their peers and viticultural experts on how to adapt.

Publication and reporting

The wine atlas is published as an A2 PDF available for download in its entirety as an overall document for Australia, by state, or by wine region. It is a national document, but the detail lies at a regional level. Each of the 71 regions contains a summary infographic of the main indicators (mean growing season temperature and rainfall, extreme heat and cold, aridity) for three 20-year time periods (1997–2017, 2041–60, and 2081–2100), followed by more detailed climate indicators for the entire period from 1960–2100 both as continuous data and as various summary statistics for 20-year time periods. The final report for the project is available for download from the Wine Australia website, as well as the Atlas itself. Wine Australia has also been running a series of eleven webinars, with each covering a cluster of regions (these were intended to be a roadshow, but have gone virtual because of Covid-19, resulting in the benefit of each being a recording that can be, and already have been, reused later).

Challenges and Limitations

The challenges in producing the atlas were firstly that there was no model available of the phenology of grapes, to test the response to climate. The number of wine regions in Australia is large (more than 70), and there was a need to consult widely on what climate indicators are important. The use and definition of indices varied between regions, with some indices only relevant in particular areas (hail, for example), and so were not included, and some indices are more relevant for particular grapevine varieties than for others. Some of the larger regions contain wide variation in climate within them, which is not necessarily captured in the resolution used or in the use of averages. There was also insufficient data linking pests and diseases to climate indicators to include anything meaningful without a great deal of additional primary research.

The atlas is focussed on the technical information. It is accompanied with an extensive background and methodology chapters that explicitly describe how to interpret the information presented. However, it is a technical document, aimed at supporting the technical users in the industry, and some of it is hard to understand unless you have a science background. The associated final report to Wine Australia includes much of the ‘how to use’ or ‘what it might mean’ information the industry may require, although this is limited as the project was intended as the underpinning first step along an adaptation journey for the industry, rather than the producer of solutions. Given its online format, Wine Australia intends the Atlas to be a dynamic document which could be added to as more information becomes available. It could also be redesigned into an interactive online tool, but there is a caveat that many users are in areas without good internet access, so a downloadable format has advantages.

Future improvements / opportunities / next steps

The inclusion of additional indicators (such as bushfire risk, flooding, or hail) and climatic impact on pest and disease pressure would be beneficial, as would creating a dynamic interface—provided there was also the option of downloading relevant information. Updating the Atlas (for example incorporating new higher quality climate information as it becomes available) is made possible by its online format (see above). Carrying out an analysis of overseas wine regions would place the findings of the Atlas in an International context and be beneficial for both marketing and for identifying regions which currently manage the climate conditions of our future. There is also need for guidance to regions in how to use the Atlas to drive decision-making, and potentially the ability to provide on-going extension and adoption support. Development of a grapevine variety selection tool could match varieties to climate scenarios and allow growers to plant vineyards now for sustainability in 5, 10 or 20 years.

Conclusions

Sectoral needs are very specific, and extensive consultation was undertaken to identify the specific indicators that are relevant and impactful for growing wine grapes. The geographic scope was also very specific, with analysis and presentation of results required in multiple (71) climate regions which vary greatly in their climatic conditions.

The ongoing support and maintenance of the Atlas is potentially problematic, as there is no plan or provision of additional funding for updates and additions of new data. Extension and adoption by the wine sector will be supported through existing mechanisms at Wine Australia, but there is so far no plan beyond the initial webinar dissemination.

The physical format of the information is important, with each option presenting specific issues, challenges and opportunities.

Case Study:
ABARES, FARMPREDICT

Title	farmpredict
Type of case study	Tool that uses climate data and in future will use scenarios.
Aim	• Simulate production, financial outcomes and stock changes for individual farms using scenarios for climate conditions and commodity prices. • Currently the model is used to assess the effects of recent and future potential changes in climate on farm profitability and to develop indicators of drought exposure and sensitivity which could help to inform government farm risk management and drought programs. • Future potential applications: assessing farm lender exposure to climate change, and designing and testing weather insurance products.
Purpose of climate scenarios	Study identified that climate change has a significant impact on farm productivity and profit—farmpredict was developed to model these impacts and to extend the study from cropping to livestock
Organisation(s) involved	Used by ABARES, DAWE, Drought Recovery Taskforce
Support for scenario development	Developed in-house by ABARES
Sector and target audience	Agriculture Target audience (current): government and government agencies Target audience (future): farmers, financial sector
Geographical scope	Australia
Type of information provided	Financial year farm financial performance predictions on a regional basis
Time period for development	Financial year scenarios

The scenarios	Type	Currently scenarios for future climate are not provided.
	Time horizon	30 years of historical farm and climate data.
	Time resolution	Results can be updated monthly but are provided on a financial year basis.
	Geographical resolution	Approximately 5 km grid—farms at the point scale level, not farm boundaries. Data is published at the level of 32 farm survey regions.
	Climate data included	• Historical climate data is used rather than scenarios and short-term BoM forecasts • Rainfall volume • Rainfall volatility • Exposure to hail storms • Average maximum and minimum temperature • Root zone soil moisture • Exposure to frost (days below 2°C) and high temperatures • Heat accumulation (growing degree days).
	Extreme events	The tool is not useful for extreme weather analysis.
	Range of scenarios	N/A
	Main data source for scenarios	• Monthly rainfall and temperature data are sourced from the Australian Water Availability Project (AWAP) • Soil moisture data are obtained from the BoM Australian Water Resources Assessment Landscape model (AWRA-L) • Daily rainfall and temperature data for Australian weather stations are obtained from the Scientific Information for Land Owners (SILO) database • Farm information from the Australian Agricultural and Grazing Industry Survey (AAGIS) • Hail data from BoM • Satellite water observation data from Geoscience Australia. • Plan to do climate projections using subset of global climate models provided by CSIRO (application ready climate projection data), downscaled using the Delta method—weather station and daily time-set data. Will use RCP 4.5 and 8.5.
Contact details for further information	Neal Hughes, Director at ABARES, Neal.Hughes@agriculture.gov.au	

ADDITIONAL INFORMATION

Summary

The Farmpredict model was developed in response to a study on farm productivity over 20 years that identified climate change as a key factor impacting productivity. The model uses historical climate data (observations) rather than scenarios, combined with farm survey data to provide predictions of the impacts of climate on farm profits and productivity. It is currently the only such model that provides national coverage and financial outcomes data. It is hoped that the tool will be used to provide financial projections using CSIRO climate projection data. It is also hoped to incorporate climate scenarios to provide longer-term climate projections.

Data resource and requirements for the tool

Farmpredict is based on data from the Australian Agricultural and Grazing Industry Survey (AAGIS) a long running national survey of Australian broadacre farms covering the major cropping, livestock (beef and sheep) and mixed farming industries, along with a range of climate data sources as detailed in the table above. The input data is not publicly available.

Implementation and use

The outputs are primarily used by ABARES and Government, for example as inputs to the Drought Recovery Taskforce by the National Drought and North Queensland Flood Response and Recovery Agency. The model can provide analysis of the impact of climate on farm productivity and profits both historically and forecast for a financial year. In 2019 ABARES produced a report covering the impacts of climate change including policy advice.

Publication and reporting

ABARES plans to publish outputs in aggregate but to date outputs have not been made publicly available other than through government reports/papers that have been published.

Challenges and Limitations

A key limitation is that it is a statistical (structural simulation) model i.e. it is only as good as the historical data and it is not possible to extrapolate outside the range e.g. to consider extreme drought. It does not capture impacts that are difficult to capture statistically e.g. CO_2 concentration impacts on plants.

A major challenge is the labour intensiveness of cleaning data for use. Access to data and transfer of data from other agencies are also sometimes challenging and data confidentiality can be a constraint—data is accessible only to ABARES and ABS staff and therefore cannot be provided to universities for analysis, for example. It is difficult to bring the tool to its full potential without additional resources particularly people and computing power.

Future improvements / opportunities / next steps

This year ABARES aims to develop 2050 climate projections, publish a drought analysis update, provide regular updates of drought indicators and expand the tool to the dairy sector.

Additional potential future developments and uses of the tool include:

- Simulating long-term climate projections to indicate farm performance under future climate conditions.
- Informing development of insurance products, particularly drought insurance, by modelling exposure to climate risk. The outputs are potentially useful to farmers, bankers and insurers.
- Assessing the performance of the Future Drought Fund or assessing eligibility for drought relief programs.
- Upgrading the front end of farmpredict to make it accessible to business and financial services clients—for example a website that would provide climate change farm data.
- Developing a hybrid between a structural simulation model and a data driven model.

There is also potential from the following related projects:

- A collaboration with Australian Bureau of Statistics (ABS) on a Data Integration Partnership for Australia (DIPA) project 'Effect of drought on Australian farms'. This project uses ABS data from the agriculture census rather than ABARES data. The ABS data has bigger samples but it is not in an appropriate state to be used in the farmpredict model. The project aims to link with ATO financial data to cover all farm businesses and to build another level of farm models that could be used in development of insurance products and that could do similar things to farmpredict, but on a much bigger scale and with much higher resolution.
- Another project between BoM and Data 61 is trying to increase weather data by bringing in private farm weather station data. This would help to make rainfall insurance more viable.

Conclusions

The farmpredict tool provides useful data for Government and the agricultural sector and with additional resources could be further developed for new uses and audiences. It is worth considering further investment to realise the full potential of existing tools as well as consideration of new guidance and tools.

Case Study:
LENDLEASE

Title	Lendlease FY2020 Annual Report TCFD disclosure
Type of case study	Scenario development and use (corporate user case study)
Aim	Scenario planning for building strategic resilience to future climate-related risks and opportunities .
Purpose of climate scenarios	• To test strategic resilience and to incorporate into overall strategic planning • TCFD disclosure (initially—2018—Board driven) • Consider climate-related impacts on and risks and opportunities for individual business units (development, construction, investment).
Organisation(s) involved	Many different technology and other scenarios and roadmaps reviewed to develop in-house climate scenarios bespoke to the business (references include IPCC, IEA, BOM).
Support for scenario development	Developed scenarios in-house using various sources—to ensure aligned with Lendlease business (useful for the business units to test strategic resilience).
Sector and target audience	Sector: Real estate/property, construction and investment. Target audience: • Internal: Board, strategy team, business units, employees • External: investors, customers, public, government, other stakeholders.
Geographical scope	Australia, Europe/UK, Asia, US (locations of development projects and investments)—including key gateway cities for "placemaking" strategy.
Type of information provided	Four scenarios developed (Resignation, Polarisation, Paris Alignment and Transformation), with detailed information/assumptions provided on how the scenarios were developed (Indicators of Change), including: • Reference points: temperature change, RCPs, energy pathways, energy technology perspectives, SSPs, etc • Socio-cultural: global carbon peak, net zero year, EV in 2040 • Technological: residential/commercial building efficiency improvements, % electricity used for heating/cooling, reduction carbon intensity cement/steel, proportion of energy from renewables, etc • Economic: carbon price, reduction in labour capacity • Environment: sea level rise, people displaced, frequency of extreme rainfall, increase in drought length • Political: world population, intergroup conflict, malaria transmission. Potential outcomes under various scenarios outlined, including impact on cost of disasters, supply chains, air quality, GDP decline, conflict, food bowl, outdoor work impacts, privatised resources, geoengineering, corporate climate action, etc.

	Further impact of various climate scenarios on key factors possible in 2100, including drought length, sea level rise, GDP growth/decline, land suitable for growing coffee.	
Time period for development	2010–2100	
The scenarios	Type	Narrative (qualitative)/ Quantitative/ Socio-economic (SSPs) / Transition pathways (all of the above)
	Time horizon	2010, 2020, 2030, 2040, 2050, 2100 (decadal)
	Time resolution	Yearly, seasonal, monthly, daily, hourly? Not that granular. Annual for Resignation scenario to test physical risk
	Geographical resolution	Looked at on global basis to ensure consistency—regional level with regional business leaders
	Climate data included	Aspects considered in scenario development: temperature range, extreme rainfall, drought severity, sea level rise
	Extreme events	Not granular for strategic business planning, but look at physical (acute and chronic) risks at asset/project level
	Range of scenarios	Four scenarios developed and used: 1. Resignation (RCP 8.5, 4°C+, SSP4 & 5) 2. Polarisation (RCP 6.0, 3-4°C, SSP3) 3. Paris Alignment (RCP 4.5, 2-3°C, SSP2) 4. Transformation (RCP 2.6, <2°C, SSP1)
	Main data source for scenarios	IPCC, IEA, BOM, specific climate models—reviewing use of SIMClim for physical asset testing
Contact details for further information	Simon Wild (Group Head of Transformation) Simon.Wild@lendlease.com Cate Harris (Group Head of Sustainability) Cate.Harris@lendlease.com	

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

As an Australian-based, global real estate company with a strong commitment to sustainability, Lendlease have developed four scenarios specific to the company:

- **Scenario 1: Resignation (RCP 8.5, 4°C+, SSP4 & 5):** represents giving up on climate action, with apathy towards positive action resulting in conflict and collapse. Beyond 2050 outcomes are the worst for humanity, leading to multiple ecosystem collapse, failed harvests and the planet unable to sustain life for current population size. *This scenario is currently used to assess the inherent physical risks and not for strategic business resilience.*
- **Scenario 2: Polarisation (RCP 6.0, 3-4°C, SSP3):** imagines the world falters on serious climate action, with a resultant national self interest taking precedence over multilateral cooperation. This scenario sees higher levels of economic protectionism with significant impacts on global supply chains.
- **Scenario 3: Paris Alignment (RCP 4.5, 2-3°C, SSP2):** sees a market led transition to a lower carbon future through global government commitment to the Paris Agreement. Relies heavily on negative emissions technologies, such as CCS, as a stress test of a situation in which the economy is decarbonised without any significant structural change occurring.
- **Scenario 4: Transformation (RCP 2.6, <2°C, SSP1):** sees a societally driven, controlled and rapid decarbonisation pathway, where global emissions peak in 2020 and are close to zero in 2040. Instead of relying on technological fixes, this scenario sees a substantial reduction in emissions through lifestyle changes and a reprioritisation of capital to community level investment.

The scenarios test both transition and physical risks over time. The Resignation and Polarisation scenarios are viewed as similar, in that the likely government, society and private sector response would be similar. Lendlease received feedback from investors that testing RCP 8.5 (Resignation) to a business strategy is not relevant, given the outcome under that scenario; therefore, it is used for physical risk stress testing (looking at both chronic and acute physical risks). Given its focus on sustainability, Lendlease are working towards the Transformation scenario, but recognise the importance of strategic resiliency to other scenarios.

Data resource and requirements for the scenario development or use

Various metrics provided for "Indicators of Change", including reference points, socio-cultural, technological, economic, environmental and political factors, as noted above. These include:

- Carbon emission (RCP) pathways (IPCC Assessment Report 5, 2014)
- Energy pathways and energy technology perspectives (IEA scenarios, 2017 & 2018)
- Social and economic pathways (IPCC shared socio-economic pathways—SSPs)
- Other: cement and steel transition risks and CICERO climate scenarios.

A qualitative approach is primarily used for longer term strategy/business planning, and quantitative approach for the operational level (with a shorter-term outlook). As Lendlease's vision is to create the best places for communities, including shared socio-economic pathways (SSPs) is considered important to test strategic resiliency, also in terms of looking at how society (and governments) may respond to social issues. Further narratives have been developed for the potential outcomes of the four scenarios. Sources are outlined in Scenario References in the website.

Implementation and use

Quote (Lendlease):

"*We made the very conscious decision to do [climate scenario planning] in-house... we've created a level of engagement and been able to use this... to be a catalyst around changing the conversation in the organisation around climate... it allowed us to really elevate that conversation and fully engage our senior leadership... looking at the risks and opportunities to the organisation through the lens of our future climate scenarios.*"
Cate Harris, Group Head of Sustainability, Lendlease

Initially driven by the Board's commitment to the TCFD, Lendlease has developed four climate scenarios, which are used to:

(i) establish climate-related impacts that test strategic resilience and inform overall corporate strategy;

(ii) consider climate-related risks and opportunities of business units (i.e., development, construction, investment); and

(iii) assess the inherent climate-related physical risks on assets (Resignation scenario).

The scenarios were developed in-house to ensure that they were bespoke and relevant to the Lendlease business. Lendlease has found the process of undertaking climate scenario analysis very valuable to the organisation. It has changed the conversation internally and has been a catalyst to educate within the organisation. The climate scenarios were presented internally through workshops with over 200 senior leaders globally, engaging them to consider both climate-related risks and opportunities to the business. Lendlease developed short in-house videos for the various scenarios, which were powerful in engaging senior leaders in the workshops and were later also used to engage business teams. The outcome of the workshops was that under various scenarios, there were both risks and opportunities available to the business.

Lendlease is further integrating climate-related risks and opportunities into its Risk Appetite Framework, as well as continuing to develop physical and transitional risk assessments. Lendlease have focussed on eight key physical impact areas for the Resignation scenario (RCP 8.5), which will continue to be refined in FY21 and will form the starting point for physical risk assessment for financial disclosure. Lendlease have set a shadow carbon price within investment assessments for transitional risk assessment.

Lendlease have been very open to sharing the information of their climate scenario work, including for other real estate industry participants, businesses in the Lendlease supply chain, and clients/customers. Lendlease have taken the view that greater openness to information around climate scenarios will help to contribute to a better outcome around climate change. The climate scenarios have also been useful for investors, at both a project and company level. Lendlease worked with ESG equity analysts to ensure that the scenarios would be useful to investors.

Publication and reporting

The outputs are reported in the Lendlease Annual Report and on the website. Information provided in the Annual Report includes details on climate-related impacts and associated risks and opportunities under the various climate scenarios for the Lendlease business units. Further information on how climate-related risks and opportunities are integrated into Lendlease's risk management process, as well as an outline of the TCFD disclosure process, progress and next steps, is also provided.

The Lendlease website includes information regarding the four scenarios (2050 Future Scenarios for TCFD) developed as part of Lendlease's commitment under the TCFD (Lendlease became a supporter in 2018). Detailed narratives of the scenarios are provided (including past and possible future outcomes), as well as a table of Indicators of Change (reference points, socio-cultural, technological, economic, environment, political) and references.

Challenges and Limitations

The greatest challenge was the awareness of climate change within the organisation. Key aspects to overcoming this challenge:

- to inform and present what future plausible climate scenarios look like, using a scientific basis;
- ensuring the scenarios were relevant to the Lendlease business; and
- organisational engagement, including ensuring senior business leaders were supportive through exploring climate-related risks and opportunities to the business under the various scenarios.

Future improvements / opportunities / next steps

Lendlease is further integrating climate-related risks and opportunities into its Risk Appetite Framework, as well as further developing physical and transitional risk assessments. Lendlease have focussed on eight key physical impact areas for the Resignation scenario (RCP 8.5), which will continue to be refined in FY21 and will form the starting point for physical risk assessment for financial disclosure. Lendlease are also developing their approach to how to account for more specific acute and chronic physical risks as well as transitional risks on an individual project/asset level. Further, Lendlease have set a shadow carbon price within investment assessments for transitional risk assessment.

As a leader in TCFD disclosure, Lendlease have been asked to take part in key TCFD forums and advisory groups, including the TCFD Construction Preparers Forum and the TCFD Secretariat Scenario Advisory Group. Next steps in TCFD disclosure are ongoing, and include:

- Strategy—further assessing the climate-related impacts on the business, strategy and financial planning
- Risk Management—climate-related risk assessments integrated into investment committee decision-making process
- Metrics and Targets—further establishing metrics and targets for managing climate-related risks and opportunities, continued disclosure of scope 1 and 2 emissions, and establish methodologies for and disclose scope 3 emissions

A key challenge from a TCFD disclosure perspective, is that there is focus on wanting to ensure scenario consistency across companies. Lendlease consider scenario consistency across companies less important than tailoring scenarios to individual companies to test strategic resilience.

Conclusions

Lendlease has developed a range of four climate scenarios in-house to test strategic resilience to physical and transitional climate risks and to determine opportunities that inform business and strategic planning. Originally driven by the Lendlease Board to commit to the TCFD, the scenarios were developed with a focus on building strategic resiliency to climate change into the Lendlease business. The scenarios form a key part of Lendlease's commitment to sustainability and are integrated into its "placemaking" strategy.

The scenarios range from Transformation (rapid decarbonisation pathway) and Paris Alignment to Polarisation (limited climate action) and Resignation. They were developed in-house to ensure that they are specific and relevant to the business, and use various climate and technology scenarios, roadmaps and sources, including the IPCC RCPs, SSPs, IEA and climate data such as temperature ranges, extreme rainfall, drought severity and sea level rises. They are both qualitative (narrative) and quantitative in nature and consider socio-economic and transition pathways, and present potential outcomes including impact on cost of disasters, supply chains, GDP and other factors. While the first three scenarios are used in strategic business planning, the Resignation scenario is used primarily to assess and stress test climate-related physical risks on Lendlease assets.

Effective internal communication and engagement were critical to ensure adoption and use of the climate scenarios as part of business planning across the company. The senior leadership team was engaged to consider climate-related risks and opportunities within their business units under the various climate scenarios. As a company committed to strong sustainability, Lendlease is working towards the Transformation scenario, but recognise the importance of strategic resiliency to the other scenarios.

Strong disclosure and collaboration are also considered important, for the real estate industry, customers, supply chains as well as investors. By sharing climate scenario information through for example TCFD forums and advisory groups, Lendlease hope to assist other stakeholders in their processes contributing to better outcomes. Although the private sector is driving much of the climate scenario and disclosure process through the TCFD, Lendlease encourage Government to undertake the same process to explore climate scenarios and climate-related risks and opportunities through their own lens, and further consider how the private and public sectors can work together.

Case Study: INFRASTRUCTURE AUSTRALIA

CLIMATE RISK GUIDANCE IN THE INFRASTRUCTURE SECTOR – INFRASTRUCTURE AUSTRALIA

Infrastructure Australia is exploring opportunities to update their climate change risk guidance

Infrastructure Australia is an independent statutory body that is the key source of research and advice for governments, industry and the community on nationally significant infrastructure needs. Infrastructure Australia has responsibility to strategically audit Australia's nationally significant infrastructure, and develop 15-year rolling infrastructure plans that specify national and state level priorities.

The Infrastructure Australia Assessment Framework (IAAF) provides information about how infrastructure initiatives and projects are assessed, including specific guidance on considering and managing climate risk, which was first included in the last update to the IAAF published in 2018. The IAAF encourages the use of scenario analysis to ensure that projects are robust to a range of plausible futures. None of the 30 projects submitted by proponents to Infrastructure Australia for evaluation have fully adopted the IAAF's climate scenario guidance since it was included. In response to the lack of adoption of the climate scenario guidance, a current review of the IAAF is considering how to support proponents' consideration of climate risk, the clarity of the existing guidance, and alignment with similar guidance provided by state and territory governments.

A key barrier to wide scale use of scenario analysis in the infrastructure sector is the absence of an agreed set of climate futures and associated common planning assumptions. A nationally consistent set of climate scenarios would support greater consideration of climate risk in infrastructure planning, assessment, design and investment decision-making. Climate scenarios could be developed by and sit externally with a third party, to ensure harmonisation and consistency.

Once sufficiently robust climate scenarios exist, any future review of the IAAF could include the development of more detailed supporting guidance including the practical consideration of associated key hazards, impact pathways, exposure and climate risks. This will support national, local and place-based risk assessments of infrastructure options.

Recognising the breadth of activities supporting the development of climate scenarios, in June 2020, Infrastructure Australia, Infrastructure NSW and Building Queensland hosted an online, collaborative workshop to map climate risk research associated with infrastructure planning and decision-making, and identify overlap and gaps in climate scenario research. The 19 organisations who participated identified more than 70 relevant projects. The workshop highlighted that:

- There is substantial effort underway by public and private organisations, however ongoing communication across and within government is critical to avoid project overlap and duplication
- Most projects are focussed on physical risks but very few projects were working on the transition risks
- Opportunities exist across government to embed project findings into national and/or state decision-making frameworks
- There are opportunities to democratise access to private and public sector information, create local data standards (especially flood information and hazard layers), and promote interoperability so that information can be shared and built upon.

The infrastructure bodies are working together to share information, including best practice definitions and data sets, and new assessment guidance and decision-making tools. They are also working to identify opportunities for collaboration and information sharing between the public and private sector, and cross sectoral and inter-jurisdictional projects. This work is ongoing, and led in collaboration between IA, Infrastructure NSW and Building Queensland.

Case Study:
ELECTRICITY SECTOR CLIMATE INFORMATION (ESCI) PROJECT

Title	Electricity Sector Climate Information (ESCI) Project
Type of case study	Scenario and guidance development (including filling gaps in climate data).
Aim	The project is designed to improve the reliability and resilience of the National Electricity Market to the risks from climate change and extreme weather by providing a framework and tailored climate information to enable climate-risk based decision-making.
Purpose of climate scenarios	Climate scenarios are required to support improved long-term planning for electricity infrastructure, with two specific aims: • to improve long-term supply and demand forecasting, which are to a large extent temperature driven • to provide underlying climate change information for investment planning for a more resilient grid. The important information for reliability is long term trends, including trends in specific extremes with quantifiable probability (for example, heatwaves). Resilience is primarily affected by the compound and/ or widespread extreme events, which can be approached through case studies. Most of the detailed scenario work in the project is aimed at reliability.
Organisation(s) involved	Bureau of Meteorology (BOM), CSIRO, Australian Energy Market Operator (AEMO), Department of Industry, Science, Energy and Resources (DISER).
Support for scenario development	Mostly in house as both BOM and CSIRO were project partners. Additional experts were contracted for specific project areas, including the National Hydrological Projections project in BOM, a NARCliM expert from UNSW and a user experience/ user design data expert from Data61.
Sector and target audience	The electricity sector, with two distinct audiences: • The regulated elements (the market operator, AEMO, and all the network planners and operators), who will use the climate scenarios for improved long term planning and supply and demand forecasting • The unregulated generation sector, including developers, operators, and investors, who are likely to use scenario data for investment and development decisions.
Geographical scope	National Electricity Market (most of Southern and Eastern Australia and Tasmania)
Type of information provided	1) **Tailored climate data to be included on the Climate Change in Australia** CCiA web portal; users will be able to explore specific parameters and variables, including: • Global climate model projections of selected climate variables • High-resolution projections of selected climate variables • Probability information on selected extreme events • Maps of temperature threshold exceedance • Maps of threshold data • Case studies of compound extreme events.

	2) **Guidance material for target audiences, including:** • Best practice climate risk analysis methodology and risk assessment framework • Communication products for target audiences with a range of expertise, from non-technical overviews to detailed technical guidance on selecting and using the data outputs. • Use-case studies of climate impacts on electricity sector infrastructure, such as the effects of bushfires on transmission lines, or of heatwaves on variable renewable energy output.	
Time period for development	2015–2021 (although the specific scenario development element was 18 months from 2020–2021).	
The scenarios	Type	Quantitative.
	Time horizon	2020–2090 and 1980–2090 (1950–2100 for some data), with specifics chosen by the user. 2030 is a focus date.
	Time resolution	Yearly, seasonal, monthly, daily, hourly.
	Geographical resolution	Point data for some locations, and regional average data for National Resource Management clusters Gridded national datasets: • ESCI simulation data at 12 km resolution for RCP 4.5 and RCP 8.5 emission scenarios • BARPA and QME provided on a 5 km resolution • Delta scaling temperature projections at a 5 km resolution. • NARCliM data for NSW, VIC, southern QLD and eastern SA at 10 km resolution.
	Climate data included	• Bushfire weather (Forest Fire Danger Index) • Wind (average and gust) (TBC) • Maps of temperature exceedance probabilities over the NEM • Temperature 10th, 50th and 90th percentiles • Standard climate variables include: 2m air temperature (dry bulb), 2 m dew point temperature, 2m relative humidity, Precipitation, Surface pressure, Global Horizontal Irradiance (GHI), 10 m wind speed and direction, Direct Normal Irradiance (DNI), 150 m & 250 m wind speed and direction.
	Extreme events	Additional case studies for co-incident and compound extreme events (for example, temperature, bushfires, and high wind events). Two case studies have been developed that are fully characterised with weather data for the time period before the event. Specific events have been simulated using climate model projections.
	Range of scenarios	The focus has been two IPCC Representative Concentration Pathways (RCPs), from lower (RCP 4.5) to Very High (RCP 8.5), although some datasets have used RCP 2.6.

	Main data source for scenarios	• Conformal Cubic Atmospheric Model (CCAM) • Quantile Matching for Extremes (QME) • Bureau of Meteorology Atmospheric Regional Projections for Australia (BARPA) • Delta scaling using selected CMIP5 Global Climate models • NSW and ACT Regional Climate Modelling (NARCliM) v1.5 regional climate modelling (NSW DPIE).
Contact details for further information	Project coordinator: Dr Judith Landsberg, Bureau of Meteorology Judith.Landsberg@bom.gov.au Project Owner: Jasna Mitic, Department of Industry, Science, Energy and Resources Jasna.Mitic@industry.gov.au	

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

Projections are given using the Very High Emission (RCP 8.5) and the Intermediate Emission (RCP 4.5) pathways, with climate data provided for all variables. Information from the ESCI project based on these pathways have been used in the AEMO 2020 Integrated System Plan (Australian Energy Market Operator, 2020).

Data resource and requirements for the scenario development or use

- ESCI Project case studies and data (Source)
- Bureau of Meteorology Atmospheric Regional Projections for Australia (BARPA). (Publication in preparation.)
- Conformal Cubic Atmospheric Model (CCAM) (Source)
- NSW and ACT Regional Climate Modelling (NARCliM v1.5) regional climate modelling (NSW DPIE) (Source)
- Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (Source)
- IPCC RCP datasets (Source 1; Source 2)
- CMIP5 climate modelling drawn from eight selected models. (Source 1; Source 2)

Implementation and use

The project will be finished in June 2021. The data sets and case studies from the project are currently being tested and validated and the climate information is being co-designed with users and reviewed by the Australian Energy Regulator. At that point monitoring and evaluation will be put into place to assess how widely the climate information is being used and how it informs decision-making.

Initial scenario data was used in the 2020 Integrated System Plan (Australian Energy Market Operator, 2020), to inform supply and demand modelling in the alternative scenarios. It is expected that AEMO and the network businesses will use the trend data from the climate projections for demand and supply projections, to test and inform network operations and management and for some stress testing for resilience, and will use the extreme and compound event case studies for operational resilience testing, and for investment planning.

Renewable generation developers, operators, investors and insurers will use the climate projection datasets to predict how an asset will perform over its lifetime.

Publication and reporting

There are two key outputs, the science output (datasets, scenarios, case studies), and detailed user guidance. The project also provides webinars (live and recorded) and peer review and publication of the contributing science in scientific journals.

The main format for the guidance and information will be an online toolkit on the Climate Change in Australia website, consisting of datasets, time series, and maps showing exceedance thresholds for different variables (for example, frequency of going over various temperature thresholds). This will be accompanied by guidance material on how to select and use the climate information, including guidance on understanding sources of uncertainty and assessments of confidence in climate trends. The guidance will include a climate risk assessment framework with step by step problem orientated guidance.

Different information formats and types are needed for different groups within our audience, with at least three types of data needed:

- Narrative, aimed at, boards or strategic planners, and energy consumers
- Synthesised data and guidance on understanding and using it, aimed at risk assessment (for example, maps, trend lines, case studies)
- Raw datasets with guidance on understanding and using them, aimed at planners and engineers, consultants, who want the data to feed into their own models, so the specific format is important.

Challenges and Limitations

Providing rigorous climate science understanding, in particular for rarer climate extremes, is a challenging undertaking. The project needed to balance the need for rigour with resourcing , which limited the number of extreme compound weather case studies. Work done may have value well beyond the electricity sector, and so the intention was to validate and demonstrate an approach that could produce further rigorous case studies. An additional challenge is that for certain climate projections, the combined evidence and expert judgement indicates that quantitative information cannot be supplied with confidence, and so qualitative descriptions of likely trends were provided.

Climate projections
One challenge was that normal practice in both network planning and operation, and investment decisions by generators and network businesses, is to use climate data from the past, rather than incorporate future projections; AEMO, for example, uses data from "nine standard years" in their supply and demand modelling, and are therefore accustomed to information in this form. In addition, the electricity sector is used to data supplied by observation stations (point source). Climate projections are supplied as low- or high-resolution grids, but this form doesn't map directly to sector risk models. To align with the sector modelling, climate projections have to be in exactly the same temporal format, so wherever possible the project derives synthetic time series data at the temporal and spatial resolution used by the sector.

Stress testing—scenarios for extreme events
The original scope did not include quantitative stress scenarios for compound extreme events, although it rapidly became apparent that quantitative data is needed. The sector's decision-making processes, particularly for the regulated part of the industry, are designed for events that have a known probability. Current climate science, while rigorous, can't necessarily include probability information for future compound events, which, while potentially very high impact, are also rare, and therefore using these case studies in current decision-making frameworks is challenging.

Future improvements / opportunities / next steps

The next steps in the project are to finalise the underlying climate data products, produce detailed guidance appropriate for the different levels of users, and establish the toolkit on the Climate Change in Australia website. The project will provide guidance on how the industry could produce a set of fully characterised case studies of compound extreme events, noting that identifying the number and range of case studies needed for a 'standard set' remains to be agreed by the sector and the regulator.

In the future, it would be highly desirable to provide standard scenarios to be used across the sector, with a single credible source, and which the regulator understands. This is particularly the case for regulated businesses, although it would also be helpful if used by the rest of the industry. It would also be useful to undertake work on terminology, as standardisation of what is meant by scenarios, or transition risk, case studies, or risk mitigation is inconsistent in different sectors, sometimes making it challenging to 'translate' between sectors.

There is a gap in developing climate information to assess bushfire risk. The project has developed fire weather projections, but bushfire risk is also affected by fuel loads (which may in turn be affected by climate trends), land management practices and sources of ignition. An integrated, rigorous assessment, combining all the contributors to future bushfire risk, would be of value well beyond the electricity sector.

Datasets will require ongoing maintenance, contextualising and updating, and it would be useful to curate a single standardised dataset, ensuring it captures the range of plausible projections, for use across the sector.

Conclusions

The provision of highly user- and sector-specific data is crucial for climate projection information and data to be used within the electricity industry, and extensive detailed consultation was needed to determine the required format and type of data, and the type of data and scenarios directly applicable to the issues the sector faces. Users have a very sophisticated understanding of probabilities and integrating non-quantitative information into decision-making processes is challenging. However, adapting to climate change is challenging, and high quality, defensible information about future climate change is a first step.

Case Study:
QBE

Title	QBE
Type of case study	Scenario development and use (finance sector).
Aim	Understand financial impact of different emissions scenarios on QBE's business, identify risks and opportunities, develop strategy to manage risks and seize opportunities.
Purpose of climate scenarios	Develop and test strategies to manage climate-related risks and opportunities.
Organisation(s) involved	QBE.
Support for scenario development	Used in house expertise and was guided by the TCFD. The scenarios will be implemented by our catastrophe modelling teams using support from external catastrophe modelling firms.
Sector and target audience	Internal use for risk managers, underwriters and investors. External reporting for shareholders and regulators.
Geographical scope	Australia, global.
Type of information provided	QBE undertake the development of scenarios in house and provide high level summaries in published reports.

The scenarios	Risks	Physical risk (most important) / transition risk / liability risk Focus on acute risks and extreme weather events (e.g. hurricanes)
	SSPs	CMSI excludes impact of SSPs in physical risk scenarios
	Time horizon	2030 / 2050
	Time resolution	Just disclosure at 2030 and 2050
	Geographical resolution	By divisions (Australia & Pacific, Europe, North America, Asia)
	Climate data included	Varied significantly depending on the geography and hazard
	Extreme events / Hazards	Acute Climate Risks • Tropical cyclone frequency, latitude, Cat 4-5 • Convective storms • Coastal surge • Floods • Large hail • Bushfire
	Range of scenarios	Two scenarios predominantly used (from CMSI): RCP 2.6 and RCP 8.5 Both are physical risk scenarios. Transition scenarios under development, but likely to be aligned to NGFS Paris Aligned scenarios.
	Main data source for scenarios	IPCC, CSIRO, BOM, specific climate models. CMSI Science Report Provides uncertainty ranges and confidence levels for extreme events.
Contact details for further information	Sharanjit Paddam (Head of ESG) Sharanjit.Paddam@qbe.com	

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

The primary purpose for developing these scenarios is to meet QBE's commitment to disclosing under the TCFD recommendations. It is also important that the scenarios have rigour, this means they need to be based on science. Regulators have also expressed concern about the impact of climate change on the industry. That is why there needs to be consistency across the scenarios for what the industry is doing. This is particularly important when it comes to disclosure. The scenarios are focussed in terms of their financial outcomes, and that is the level of detail the investors are interested in seeing in terms of the sustainability and resilience of the business.

"The primary purpose is providing assurance to our investors that we have resilient strategies to deal with climate change."

QBE are therefore implementing and aligning scenarios with those that have been developed by the Climate Measurement Standards Initiative.

At the time of publication only physical risk scenarios have been completed as part of the CMSI. There are two physical risk scenarios representing RCP 2.6 and RCP 8.5. The CMSI is an industry-led collaboration between insurers, banks, scientists, regulators, reporting standard professionals, service providers and supporting parties. Climate scientists from the Earth Systems Climate Change Hub were the authors of the climate science report drawing on their own expertise and latest literature. The scenarios were developed to be internally consistent and based on an updated review of current scientific consensus on the expected change in behaviour of physical risks. The scenarios are designed to support organisations within the financial sector on the development of climate scenarios that are consistent with the TCFD recommendations.

The Science committee has focussed on the change in behaviour of extreme events as these are what are important for considering damage to buildings and infrastructure. As shown in the following table only direct physical damage to buildings and infrastructure is within the scope for these scenarios.

	In scope	Likely future scope
Purpose	• Disclosure of TCFD scenario analyses	• Stress testing and vulnerability testing • Other types of analysis
Analysis	• Scenario specification	• Stress testing including compound events • Sensitivity analysis • Modelling exposure changes • Modelling vulnerability changes • Developing data sets
Climate-related risks	**Physical risk**	**Transition risk**
Hazards	**Acute physical risks:** • Tropical cyclones • East coast lows • Extreme rainfall and riverine floods • Extreme sea level events • Large hail • Extreme bushfire events **Chronic physical risks:** • Average temperature and extreme heat events • Average rainfall • Sea level rise • Drought	**Acute physical risks:** • Storm surge and coastal flooding **Transition risks:** • Technology • Policy and legal • Market • Reputation
Impacts	• Damage to property (buildings and infrastructure)	**Physical risks:** • Loss of use of asset • Loss due to cross-dependency on other assets • Health and human impacts • Agriculture and other sectors Macroeconomic impacts from both physical and transition risks

Data resource and requirements for scenario development and use

The CMSI project did not endeavour to create new climate science datasets, extreme event sets or asset level risk data. The science guidance document provides several tables which include likely ranges and uncertainty for a comprehensive list of extreme events for both RCP 2.6 and RCP 8.5. Both acute and chronic physical climate hazards are included for 2030, 2050 and 2090. The following table is a summary of the extreme events included in the CMSI reports.

Acute climate hazards to buildings and critical infrastructure

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%] East -8% [-15% to 2%]; West -12% [-20% to -4%]	East -4% [-8% to 1%]; West -6% [-10% to -2%] 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 Little change or increase	Little change or small increase 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 Little change or poleward expansion	Little change or small poleward expansion 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%] -20% [-30% to -10%]	-10% [-15% to -5%] -35% [-50% to -20%]	Medium (Low for summer and High for winter)
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 +20% [+10% to +30%] hourly; +15% [+8% to +20%] daily	+10% [5% to 15%] hourly; +7% [4% to 10%] daily +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 As for 2030	As for 2030 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%] +40% [+10% to +70%]; East +30% [+0% to +60%]	+20% [+5% to +35%]; East +15% [+0% to +30%] +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)

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Chronic climate hazards

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	+0.5 to 1.5 °C	Very High
			+1.5 to 2.5 °C	+2.5 to 5.0 °C	
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	+0.2 to 0.6 m	Very high
			+0.1 to 0.3 m	+0.4 to 1 m	
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% North: -9 to +4% South: -9 to +2 % Rangelands: -10 to +6 %	Drier in the south and east, uncertain in the north (see Tables 3.1-3.4)		High in southern Australia, Low elsewhere
			Drier in the south and east, uncertain in the north (see Tables 3.1-3.4)		
Time in Drought·	Insignificant (weak)	Increase in many regions (see Table 3.6 and 3.7)	No data		High in southern Australia, Low elsewhere
			Significant increase in many regions (see Table 3.6, 3.7)		
Annual days >35 °C#	Increase (strong)	Increases (see Table 3.8)	Increases (see Table 3.8)		High
			Large increases (see Table 3.8)		

Implementation and use

These CMSI scenarios have just been published and QBE have not applied them in house yet.

Publication and reporting

Climate risk disclosure will be published as part of QBE's annual reporting. Climate-related risk disclosures were published for the first time in February 2019, but scenario analysis will be included for the first time in February 2021. The aim is to adopt best market practice, aligned with peer reporting. Each year QBE will also need to consider advancements being made in the science and consider if there are material differences from previous years. Primarily the reporting deals with the strategies that the companies are employing to deal with climate change. It will likely be updated at some point within a five-year timeframe. The frequency of reporting will also need to consider the pace of change as things are moving quickly, particularly in the area of transition risk.

Investors are looking for well-articulated strategy and they are looking for rigour in how the strategy has been developed and how effective those strategies are. This does not necessarily require a large volume of disclosure. The disclosure needs to fit into a section of the annual financial reports. This typically equates to somewhere between six to eight pages—this year it might be 12. If it is for regulatory purposes regulators may require more detail to test assumptions and get more assurance, particularly if they are thinking about the stability of the financial system. The average investor will not want that level of detail and that may actually prove counterproductive.

Challenges and Limitations

First, there is a lot of technical complexity to doing climate scenario analysis well. In order to get that rigour, the disclosures that are being made need to be science-based. Second, there is a lot of information that's available but the frameworks that have been designed doesn't necessarily lead to effective decision-making. How decisions are made at an organisational level needs to be embedded within the framework. What is needed is decision useful framework, not necessarily more research, but to understand the levers that need to be pulled that will lead to better decision-making, both from customers (e.g. what insurance they buy and at what price) but also from the internal decision-making structures within the organisation.

Designing scenarios around temperature outcomes makes a lot of sense. For example, the TCFD recommends designing scenarios of less than 2°C and one that is more than 2°C, the envelope of possibilities. In a broad sense the high level factors for each climate change scenario can be applied across the economy, across all sectors. What the decision levers are and how they can be applied in each industry is unique. Each industry sector will have different drivers and different levers so the challenge is to identify those drivers for different sectors and build the framework around that for the industry.

Future improvements / opportunities / next steps

What New Zealand government has recently done in their risk assessment is very useful. They have prioritised climate risk assessment for the whole country in terms of impact, likelihood and urgency. It allows the scenarios to be developed around the most important risks. While trying to do everything is laudable it won't drive outcomes. There isn't yet an analysis identifying the biggest risks in Australia, like what New Zealand has done.

Another important next step is the strategy perspective, and this is how do we start decarbonising the economy. The first is a risk assessment for Australia, the second is a decarbonisation strategy for companies across Australia. These need to be drafted from the perspective of the organisation to drive change in decision-making processes.

Companies need to start taking climate change seriously. The industry is now in the collaboration phase, sharing information, tools and helping one another. This is different to a competitive phase where companies are competing on their resilience to climate change. The industry is not at competitive phase yet. At this stage, collaboration has got to be the model. Government certainly has a role in this coordination and I think that because each industry response is different, each sector needs to establish its own representative body. The CMSI is that organisation for the financial sector, there needs to be one for government, agriculture etc. For this to work effectively each sector needs to be operating under the same the strategic framework.

Conclusions

Although QBE are only just starting to undertake scenario analysis themselves in-house, they have shown industry wide leadership through the co-ordination and creation of the CMSI with a remit to develop a consistent standardised set of scenarios that can be applied across the financial sector. Up to now, only guidance on physical risk scenarios has been released by the CMSI, but there are plans to expand the work of this body. The physical risk guidance produced by the CMSI is set to be the new standard for the assessment and disclosure of physical climate risks within the Australian financial sector. The contribution and novelty of the approach applied by the CMSI is that it is an industry led initiative that includes representation from across the financial sector including, banks, investors, insurers, regulators, peak bodies and academia.

Case Study:
NATIONAL AUSTRALIA BANK

Title	National Australia Bank
Type of case study	Scenario development for own use.
Aim	Risk management and implementing the TCFD recommendations.
Purpose of climate scenarios	To understand the impact of physical climate risk events on the lending portfolio and operations, to understand transition risk, and help the business respond and to support customers.
Organisation(s) involved	Climate-KIC and IAG. Oliver Wyman. Acclimatise. The University of Melbourne Energy Transitions Hub. UNEP FI TCFD pilot.
Support for scenario development	Climate Measurement Standards Initiative. Energetics. Melbourne University. ClimateWorks Australia. CSIRO. Methodologies developed by Paris Agreement Capital Transition Assessment (PACTA)—A tool developed by the 2° Investing Initiative with backing from UN Principles for Responsible Investment, and the Partnership for Carbon Accounting Financials (PCAF)—A tool developed by an industry-led partnership to facilitate transparency and accountability of the financial industry to the Paris Agreement.
Sector and target audience	Financial Sector—Banking specifically.
Geographical scope	Australia and New Zealand.
Type of information provided	Physical risk data overlaid on lending portfolio at a granular level (individual customer asset location) to understand physical climate impacts across portfolio.
Decarbonisation plan	Yes, NAB have committed to meeting a science-based operational greenhouse gas reduction target to 2025. Committed to exit coal by 2035, apart from residual performance guarantees to rehabilitate existing coal assets (NAB now expects its thermal coal mining exposure to reduce by 50% by 2026, and to be effectively zero by 2030).

The scenarios	Type	Quantitative/ Socio-economic.
	Time horizon	Through to 2060.
	Time resolution	Reporting occurs each year.
	Geographical resolution	For physical risk: High spatial resolution—address level overlay on physical climate risks.
	Climate data included	Physical risk data / Geospatial asset data / cyclone tracks under four different warming levels (1.2°C, 1.5°C, 2°C and 3°C above pre-industrial levels) were selected and analysed by the Climate and Energy College (Melbourne University) in collaboration with the Potsdam Institute for Climate Impact Research For transition risk: 4°C, 2°C and 1.5°C scenarios in the REMIND model, an integrated assessment model (IAM) developed by the Potsdam Institute for Climate Impact Research (PIK).
	Extreme events	Starting analysis with cyclone data—methodology still being fine-tuned. Planning to examine impacts of extreme temperature next.
	Range of scenarios	Scenarios consistent with 1.2°C, 1.5°C,2°C, and 3°C above pre-industrial levels are selected for analysis.
	Main data source for scenarios	Melbourne University Energy Transitions Hub, Potsdam Institute (PIK), Energetics, Oliver Wyman.

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

To date, NAB like most banks, has considered only first order impacts from physical risk and transition risk, while the bank is developing an understanding of the data and methodologies available for use. The analytical complexity required to examine second or third order impacts from disruptions to supply chains or economic impacts—is a consideration for possible future work. The scenario outputs have been used to inform risk appetite and credit risk policy settings such as exclusions policies, to set Paris Agreement portfolio alignment trajectories and in the development of a low-carbon strategy, The first phase of modelling undertaken by NAB used a heat mapping exercise in a semi-quantitative way applying the Bank of England's framework which included physical risk, transition risk and liability risk. The bank considered it important to understand liability risk, because it is changing rapidly in the current business environment. NAB's work with the Climate and Energy College (Melbourne University) in collaboration with the Potsdam Institute for Climate Impact Research (PIK) has involved overlaying physical climate risk data on the bank's exposures across residential properties for which the bank holds mortgages. The next step is overlay this information over the bank's agribusiness portfolio. Transition risk work as part of the UNEP FI TCFD pilot has considered the impacts of four key risk factors—direct and indirect emissions cost, low carbon 'capex' and revenue of customers' business and the corresponding parts of the bank's lending portfolio.

Data resource and requirements for the scenario development or use

For transition risk analysis, as part of the UNEP FI pilot, NAB used scenarios produced using the REMIIND Integrated Assessment Model developed by PIK. NAB has also used the International Energy Agency's New Policy and Sustainable Development Scenarios and a 1.5°C scenario developed by the IPCC/Global Energy Monitor to look at decarbonisation pathways for thermal coal-related sectors which led to the announcement of two portfolio transition commitments:

- Supporting current coal-fired power generation customers implementing transition pathways aligned with Paris Agreement goals of 45% reduction in emissions by 2030 and net zero emissions by 2050.
- Capping thermal coal mining exposures at 2019 levels and reducing thermal coal mining financing by 50% by 2028, intended to be effectively zero by 2035, apart from residual performance guarantees to rehabilitate existing coal assets.

For physical climate risk-related scenario analysis, the bank had no in-house access to, or experience using geospatial climate data as an overlay on its lending portfolio, so the bank worked closely with the Energy Transitions Hub and Climate and Energy College at the University of Melbourne in collaboration with the Potsdam Institute for Climate Impact Research (PIK) to develop a process for geocoding lending portfolio data so it could be geospatially overlaid with physical climate data. This collaborative research project shows promise and the work is ongoing. The bank is open to collaboration with other institutions to develop methodologies and share data where possible. The bank has recognised the need to work with others to gain the knowledge and to use and develop relevant knowledge and analytical skills across multiple disciplinary areas. Climate risk scenario analysis is an interdisciplinary field and there is a need for subject matter experts with different skills coming together to facilitate this analysis.

Implementation and use

NAB, like other banks, has drawn extensively on the help of climate scientists, external consultants and data providers, as well as colleagues from across a range of internal teams, for their scenario analysis to date. As a member of the UNEP FI TCFD pilot banking group, NAB has used tools that were developed specially by Oliver Wyman (transition risk scenario tool) and Acclimatise (physical risk scenario tool) for use by the UNEP FI TCFD pilot banks, in addition to tools that have been developed by others including PACTA and PCAF. Additionally, to these tools, and using the knowledge gained from its experience in phase 1 of the UNEP FI TCFD pilot, NAB also worked with the Energy Transitions Hub and Climate and Energy College at the University of Melbourne in collaboration with PIK to geocode its loan portfolio data and consider the impact of extreme events—cyclones being the first hazard type being tested using this new method. Using a range of approaches to scenario analysis has been important in developing the bank's understanding of potential climate-related impacts on its customers and scenarios. This work, particularly the collaboration as part of the UNEP FI TCFD phase 1 and 2 work programs has demonstrated that a range of scenario tools and approaches are required to analyse the transition and physical climate risk impacts on different sectors. The scenario work conducted by the bank to date has informed the bank's decision making related to credit risk ESG policy settings and risk appetite and portfolio limits for certain sectors.

Publication and reporting

NAB seeks to provide climate-related information which helps stakeholders, including investors, to understand how it is managing climate risk. Where this may have a material impact on sectors within NAB's lending portfolio and NAB provides relevant information to support investors and others making informed decisions. For example, the impacts of drought are included in forward provisions where relevant from time to time. A key element of NAB's climate change strategy is to learn by doing and to share that knowledge with relevant stakeholders. NAB considers climate-related information should be integrated, as much as possible into existing disclosures, making note of key assumptions and key impacts. It's important to disclose the things that matter. For example, in NAB's 2019 Annual Financial Report it reported that "Initial analysis suggests that an increased geographic proportion of the Group's Australian retail mortgage portfolio is likely to experience cyclones under higher warming scenarios" as cyclones shift southward. NAB did not disclose quantitative results from this analysis as the bank indicated there is still further work to refine the methodology. Few banks have tried to quantify changes in the probability of default or credit rating. It's important to note, that the outputs of scenario analysis, do not provide an exact answer, but information on possible climate impacts and outcomes. The outputs of scenario analysis are useful for decision making as they generate outcomes that may be experienced in a range of possible futures and can inform risk management to build resilience to climate change—both in bank loan portfolios and customers' operations. To date disclosures from banks have ranged from qualitative, to semi-quantitative and quantitative.

Information on scenario analysis presented in an Annual Report is usually a brief to inform stakeholders about work being completed and the key results. For most banks it is not the place to provide detailed information about outcomes. This is often reported in a standalone report with more detailed information about methodologies. At the conclusion of phase 1 and 2 of the UNEP FI TCFD project, project reports were published by UNEP FI, Oliver Wyman and Acclimatise, featuring bank case studies to share the learnings with other banks and stakeholders. NAB and a range of other financial institutions have joined and supported the Climate Measurement Standards Initiative (CMSI) in 2020. The CMSI aims to provide consistent scientific and technical guidance on how to assess the physical risk of climate-related damage to homes, buildings and other critical infrastructure arising from extreme weather events—such as tropical cyclones, bushfires and floods. The CMSI focussed on supporting implementation of the TCFD recommendations. Initiatives like the UNEP FI pilot, CMSI, PACTA and PCAF are useful as they are helping to develop standardised methodologies for analysing climate-related scenarios.

Challenges and Limitations

At this stage of development in the use of climate scenarios in banks, methodologies need to be open source to be the most useful. Banks need to be able to 'lift the bonnet' on methodologies so they can see and understand how the various climate scenarios and modelling methodologies work. The challenge, then, is how to integrate this information into bank systems and processes so it can be used for analysis of risk and ultimately for decision making. NAB considers at this stage, it is important to experiment with a range of models to understand how they work so that it can work out how, when and where they are best applied. Different models and approaches are emerging for undertaking different types of scenario analysis on different sectors. Therefore, collaborations like the CMSI and the UNEP FI pilot are very important—they can speed up the process of collaboration and create standardisation, reduce costs and increase the speed of learning.

Future improvements / opportunities / next steps

A benefit of the CMSI and UNEP FI projects is that they have h independent secretariats separate from industry and government and regulators. This is good because they provide an independent forum in which to help support industry collaboration and learning. Another advantage of an independent Secretariat/initiative is that many organisations can come together and share the costs of developing new approaches to climate-related scenario analysis. The CMSI and UNEP FI both offer valuable platforms for ongoing collaboration.

Conclusions

The objective of undertaking climate scenarios at NAB was to implement the recommendations from the TCFD and to understand the impact of particularly significant climate-related events on the portfolio. This will ultimately help NAB manage climate-related risk facing the business related to operations, the supply chain and customers. It will also help NAB understand the climate-related risks and challenges faced by customers—which means NAB will be better placed to support customers with finance as they manage climate-related risks and transition to the low carbon economy. NAB has been reporting on climate-related information in line with TCFD recommendations within its annual financial accounts since 2017 (when it publicly supported the TCFD recommendations—refer to TCFD website). Since this time, NAB has undertaken work to grow its understanding of climate scenarios and how climate-related scenario analysis can be used in a banking context. It has learnt that having customer data in a geospatial format is important for analysis of the physical impacts of climate change as these impacts are local specific and spatial granularity is important. Importantly, climate-related risks are already being included as part of the bank's annual financial reporting. Within these reports the bank acknowledges that climate-related risks may result in increased credit risk affecting property values or business operations (physical risks) as well as new laws and government policies designed to mitigate climate change (transition risk). The bank has not publicly quantified the size of any potential losses or opportunities that arise from different climate scenarios, except where provisions are made in its accounts for the impacts of drought and bushfire.

Case Study:
BANK OF ENGLAND

Title	Bank of England
Type of case study	Proposed stress test
Aim	Test the resilience of current business models of the largest banks, insurers and the financial system to the physical and transition risks from climate change.
Purpose of climate scenarios	There are three objectives to the banks proposed climate stress test scenarios: (1) Understand the size of risks in the UK financial system; (2) Understand how firms are likely to respond to the risks; (3) Enhance risk management within firms.
Organisation(s) involved	Bank of England. The stress test builds on climate scenarios by the NGFS, which were produced with assistance from: Potsdam Institute for Climate Impact Research, IIASA, University of Maryland, Climate Analytics and ETH Zurich.
Scenario development	Based on the scenarios developed by the NGFS, but with increased focus on risks that are relevant to the UK.
Sector and target audience	Largest banks and insurers regulated by the Bank of England.
Geographical scope	The stress test will be conducted for banks and insurers in the UK. The scenarios are global in scope to reflect the global exposures of these firms, but will likely be more detailed for the UK.
Type of information provided	Discussion paper on the Bank's proposed approach to the 2021 Biennial Exploratory Scenario (stress test)

The scenarios	Type	Physical risk, transition risk, quantitative, qualitative, macroeconomic and financial
	Time horizon	30 years (2050)
	Time resolution	Every five years.
	Geographical resolution	Analysis is reported at a country level (e.g. UK). Some exposures would be reported at a more granular level (e.g. household exposures to physical risk at a four-digit postcode level, large corporate exposures at counterparty level).
	Climate data included	BoE will include physical and transition variables on a global and regional level that will build on the NGFS scenarios. The NGFS scenarios are available on the NGFS website. This includes outputs from: GCAM (University of Maryland), REMIND MAgPIE (Potsdam) and MESSAGE-GLOBIOM (IIASA). Physical risk datasets are available from CLIMADA (ETH Zurich).
	Macro-economic effects included	Macroeconomic and some aggregate financial market variables would be included as part of the scenarios.
	Extreme events	This scenario tests financial firms' resilience to both chronic changes in weather (e.g. rising sea levels), as well as more frequent and extreme weather events (e.g. flash floods).
	Range of scenarios	Three scenarios provided: Early policy action scenario—where the transition to carbon-neutral economy starts in 2020 and the global mean temperature increases stays below 2°C, in line with the Paris climate targets. Late policy action scenario—where the Paris climate targets are met but the transition is delayed to 2030 and must be more severe to compensate for the late start. No additional policy action scenario—where no policy action beyond which has already been announced is delivered. Therefore the transition is insufficient to meet the Paris climate targets.
	Main data source for scenarios	Various Integrated Assessment Models (IAMs)
Contact details for further information	Ryan Barrett Ryan.Barrett@bankofengland.co.uk	

ADDITIONAL INFORMATION

Please note that the information in sections 1–4 below is based on the 2019 Discussion Paper on the Bank's proposed approach to the 2021 Biennial Exploratory Scenario (BES), where the term "2021 BES" refers to the climate stress test. The final specification of the exercise may differ from the information provided below and as such, this information should be treated as provisional.

High level description/narrative of the climate scenarios

The objective of these scenarios is to determine the vulnerability and resilience within the UK financial system to climate-related risks. The BoE has proposed that large UK banks and insurers participate in the stress-testing exercise. The first part of the exercise is to size the risks, where participants would quantify the change in impairment rates (for credit exposures) and in the value of their assets and liabilities at different points in time. The nominal size and composition of balance sheets does not change. The results would need to account for both direct and indirect impacts of climate-related financial risks. The second part of the exercise is for firms to consider the vulnerability of their business models, and to indicate what management actions they might take to mitigate that vulnerability.

In the no additional policy scenario some physical risks would start to crystallise in the period up to 2050, but more material impacts would occur later in the century. In order to capture the most severe risks but avoid lengthening the modelling period, the Bank calibrates the model to a 30-year time horizon out to 2050, but assumes that any material physical risks anticipated in the period from 2050–2080 occur by 2050.

The Bank proposes three scenarios that would be based on the scenarios developed by the Network for Greening the Financial System. See Figure below.

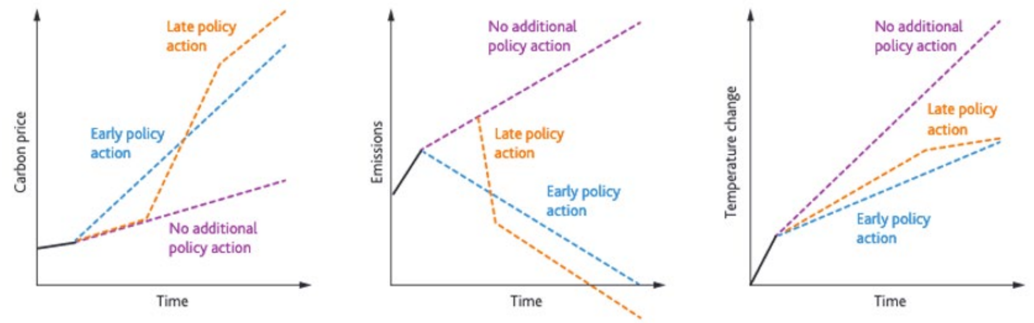

Figure 5: Illustrative variable pathways (source: Bank of England, Biennial exploratory scenarios, 2020)

The following table describes the indicative variables proposed for undertaking the stress test.

Climate risk variables		Macrofinancial variables	
Physical variables	**Transition variables**	**Macrofinancial variables**	**Financial market variables**
• Global and regional temperature pathways • Frequency and severity of specific climate-related perils in regions with material exposure (including UK flood, subsidence and freeze). • Longevity. • Agricultural productivity.	• Carbon price pathways. • Emissions pathways (aggregate, and decomposed into world regions and sectors). • Commodity and energy prices (including renewables), by fuel type. • Energy mix.	• Real GDP (aggregate and decomposed by sector). • Unemployment. • Inflation. • Central bank rates. • Corporate profits (aggregate and decomposed by sector). • Household income. • Residential and commercial property prices.	• Government bond yields for major economies. • Corporate bond yields for major economies (investment grade and high yield.) • Equity indices. • Exchange rates. • Bank rate.

Figure 6: Illustrative variable pathways (source: Bank of England, Biennial exploratory scenarios, 2020)

The 2021 BES would provide data for the underlying physical and transition risks for each scenario and then map these risks onto some macroeconomic and financial variables. These variables would reflect the macroeconomic and financial impact of the combination of climate-related risks in each scenario; they would not layer on an additional macroeconomic shock that is unrelated to climate change. They are not intended to be substitutes for individual counterparty analysis, but rather are designed to provide common background assumptions for participants' modelling (e.g. imposing common discount rates). The 2021 BES would not explicitly incorporate social and political feedback effects from the climate scenarios, such as migration or political upheaval, in its specification or calibration.

The 2021 BES will provide pathways for physical and transition variables to represent risks and opportunities at the global and regional level. For example, physical variables could include things like sea level increases and changes in flood patterns. Transition variables could include pathways for emissions or a carbon price. Macroeconomic and financial variables would be calibrated at the global level, and at the level of key countries, regions, and sectors. Not all data that participants need to perform the scenario will be provided. Firms would need to undertake scenario expansion to extrapolate additional scenario variables needed to estimate impacts on counterparties.

The scenarios for the 2021 BES would draw on the NGFS scenarios. There are three categories of scenarios in the NGFS and eight individual scenarios across those categories. Each of these are being modelled in a number of different integrated assessment models. Looking across a range of different models gives a sense of the range of model uncertainty.

The three IAMs that are used by the NGFS are the GCAM model from the University of Maryland, the REMIND MAgPIE model used by Potsdam Institute and the MESSAGE-GLOBIOM model which is used by IIASA. The outputs of these models are now contained in the NGFS scenarios database. The geospatial resolution is different for each model but there are around 500 variables in the database.

Implementation and use

Participants would be required to model the impact on their assets according to their corporate exposure, household exposure and government exposure.

Corporate exposures (e.g. loans, equities, bonds, commercial real estate) would including modelling cashflows and collateral values and should reflect judgements about how companies would be positioned in light of both their underlying risk and uncertainty.

Household exposure (e.g. mortgages, unsecured lending) would include country-specific economic impacts such as changes in household income and property prices. Physical risk exposure is undertaken at regional granularity of no less than four digit postcode.

Government exposure (e.g. sovereign and municipal securities) would specify bond yields for major countries.

In addition, insurers would model the impact from climate risks on their liabilities.

Publication and reporting

The BoE will ask members to submit templates reporting impacts for each five-year interval in the 30-year time horizon. The exercise is exploratory in nature and will focus on sizing the risks rather than setting capital requirements. Published results will set out system-level metrics detailing the financial sector's exposure to climate change, including the main sources of loss by sector and geography. The Bank does not intend to disclose the results of individual firms. This reflects the exploratory nature of the exercise.

Key metrics for banks include:

Banking book: the high-level results metric would be the impairment charge. For each reporting period firms would submit the impairment charges in the first year of the scenario and cumulative five-year impairment charges. Impairment charges would then be compared to those in the baseline scenario of the BoE's 2020 Annual Cyclical Scenario (ACS) stress test.

Trading book: the high-level results metrics would be the change in fair value of the assets. So the 2021 BES would measure the impact of climate-related risks above those already priced in by firms.

Key metrics for insurers include:

Liabilities: the high level results metrics for non-life insurers would be the annual average loss and 1:100 year return period aggregate exceedance probability (AEP). Life insurers would show best estimate liabilities, risk margin, transitional measures on technical provisions (TMTP) and other liabilities.

Assets: key metrics would include change in the market value of investments/total investment returns, surplus change and change in eligible own funds.

Other: insurers would also need to quantify the approximate effects on Matching Adjustment Portfolios (MAPs), with profits funds (WPFs) and Solvency II transitionals such as TMTP. These results would need to consider equity risk, commercial property risk and longevity risk where relevant.

Challenges and Limitations

There are a number of challenges and limitations to the financial sector undertaking scenario analysis. These are set out in the NGFS Guide to Scenario Analysis that was published in June 2020.

The first relates to using Integrated Assessment Models. These models have primarily been developed for academic research and/or advice for policymakers. However, while broad in scope, they also have a number of limitations. At the less complex end, only a simple growth model is used or the costs (associated with mitigation policies and/or climate damages) are estimated in non-economic terms. While more complex models have now also been developed, they still tend to focus on a limited number of transmission channels and produce a narrow scope of macroeconomic indicators. The NGFS Scenarios are working to address some of these challenges. In the interim it is likely that central banks will have to deploy a combination of approaches to understand the macroeconomic impacts. For example, climate-economy models can be used to develop coherent scenarios, and traditional macro models can be used to expand the number of economic variables for assessing risks.

A second issue pertains to aligning impacts between physical and transition risks. Physical and transition risk scenarios are often modelled separately. If the scenario is intended to assess the macro-financial impacts of both risks, the models should be as coherent as possible. At a high level the scenario narratives should be aligned to the same emissions pathway and temperature outcome as far as possible. The scenario models should also use consistent input assumptions (e.g. on policy, technology and the socio-economic context). A full integration would require simultaneously considering physical impacts and transition policies in the scenario development. At the moment the scenario modelling tends to be roughly aligned (e.g. the NDC emissions pathway for an IAM is similar but exactly equal to RCP 6.0 used in physical impact modelling).

A third challenge pertains to calibration. Central banks and supervisors may approach scenario analysis with different questions in mind, and should calibrate the scenarios accordingly. For example, they may be interested in mapping out a required adjustment path for the financial sector under plausible climate change scenarios, or they may be interested in exploring potential losses under worst-case scenarios. At a high level, the scenario calibration can be conducted in at least two ways. First, one can select climate scenarios that are more or less severe in terms of physical and transition risks. Second, for variables for which a probability distribution is available (e.g. probability of reaching a particular climate outcome, probability of a physical hazard occurring), one can decide to focus more on mean or median ranges, or on tail risk

A fourth challenge pertains to stakeholder engagement. Central banks and supervisors should consider how their stakeholders will be involved in the scenario analysis. These stakeholders could be included explicitly, as part of the exercise (e.g. in a firm-based stress test); and/or as part of the target audience for the results (refer to Chapter 6 for more details on communication). Key stakeholders include financial institutions, financial standard setters, the general public, governments and international bodies and the academic community.

Future improvements / opportunities / next steps

There is a need for stronger interdisciplinary research to link climate science to impacts on the economy and financial sector. Scenario modelling in a consistent co-ordinated approach can bring together diverse research communities and improve the quality and alignment of research for central banks.

There are a lot of data available or being made available to help assess climate risks. There is a need for this data to be brought together in a more systematic way, in formats that can be readily consumed by economists and the financial sector. There may be a strategic role for central banks, international bodies, and governments in this.

Climate risk analysis is still relatively new for central banks and the financial industry more broadly. There is a need for capacity building to enable these risks to be fully assessed.

Increasing standardisation in scenario narratives can be helpful to improve the comparability of results. However, at the same time, scenario analysis should be bespoke enough that it can help individual institutions assess the risks they face. There is a need for some flexibility in the framework.

Conclusions

The Bank of England has a mandate to maintain monetary and financial stability and climate change creates risks for both the soundness of individual firms and the stability of the financial system. The objective of the 2021 BES is to test the resilience of the current business models of the largest banks, insurers and the financial system to the physical and transition risks from climate change. The exercise is expected to provide a comprehensive assessment of the UK financial system’s exposure and business model responses to climate-related risks.

The BoE has developed three climate scenarios, these include a high and low emissions scenario as well as a disorderly transition scenario. Each scenario is accompanied by a set of variables that are used to stress test a firms’ balance sheets. Each scenario is internally consistent and designed to enable financial firms to identify their climate-related exposures to corporates, households and government. From this information the bank is hoping to publish aggregate information about the size of climate risks in the financial system and the capacity of firms to respond.

The main opportunities for improvement relate to the need for stronger interdisciplinary research, data availability and increasing standardisation while preserving some flexibility in scenario analyses frameworks.

Case Study:
RIO TINTO

Title	Rio Tinto (RT) 2018 & 2019 Climate Change Reports 2019 Annual Report
Type of case study	Scenario development and use (corporate user case study)
Aim	Scenario planning for building strategic resilience to future climate-related risks and opportunities
Purpose of climate scenarios	Purpose of climate scenarios • Incorporation of climate change considerations into long term strategic planning, including to consider portfolio and asset base (corporate development) strategy • To determine implications of low carbon transition to the RT business • To test physical risk and how to build resilience into RT assets and wider business to physical impacts of climate change
Organisation(s) involved	Developed strategic scenarios in-house using various sources—IPCC, IEA and other data
Support for scenario development or use	Developed the strategic scenarios in-house, also use IEA SDS and IPCC RCP 8.5 scenarios
Sector and target audience	Sector: Mining & resources Target audience: • Internal: board, strategy team, business units, employees • External: investors, customers, public, government, other stakeholders (including bondholders, lenders, ratings agencies)
Geographical scope	Regions where RT has operations and projects (fully owned and operated, as well as JVs)—primarily iron ore, aluminium, copper and minerals: • Asia-Pacific (Australia, New Zealand) • North America (USA, Canada, Iceland) • Africa (South Africa, Madagascar, Mozambique, Guinea) • Latin America (Chile, Brazil) • Middle East (Oman) & Europe (Serbia)
Type of information provided	RT provide information relating to climate scenarios in their Climate Change Reports ("Our Approach to Climate Change" – 2018 and 2019). Note that RT have moved away from using standalone climate scenarios to fully integrated climate change considerations in the scenarios used as part of the Group strategy process—more information on the strategic scenarios is included in the Rio Tinto Annual Report.

	Information provided includes an overview of the impacts of climate change on RT's business, including: • Group strategy scenario framework: Various geopolitical, technological and societal (including sustainability/climate change) factors considered in the Group strategy scenario framework, with resulting climate change outcomes which are included in business planning (with outcomes ranging from keeping global warming below 2°C to global warming reaching over 3°C by 2100). • IEA Sustainable Development Scenario (IEA SDS): used to test the resilience of the business against a less than 2°C transition pathway aligned with the Paris Agreement. A portfolio resilience analysis under this scenario is presented, including impacts on the key RT commodities and businesses (i.e., iron ore, aluminium, copper and minerals) • IPCC RCP 8.5 scenario: used to assess physical risks to RT real assets, including the probability and potential impact of future extreme weather events. Both acute and chronic physical risks are considered over the life of the assets, from project design, operations to closure and beyond.	
Time period for development	Short term—18 months for cashflows / Medium term—2030 Long term—2030 to 2050 and beyond	
The scenarios	Type	Narrative (qualitative)/ Quantitative/ Socio economic (not sure about use of SSPs) / Transition pathways
	Time horizon	Beyond 10 years for scenario planning (i.e., 2050)
	Time resolution	Annual for quantitative
	Geographical resolution	IPCC RCP 8.5 scenario looked at on regional basis (assume regions share similar climactic changes), i.e., Australasia, North America, etc IEA SDS on individual assets
	Climate data included	IPCC RCP 8.5 scenario consider four climate variables: • Temperature (including averages and extremes, heat stress) • Rainfall/water cycle (rainfall averages and extremes, water stress) • Sea level rise (including storm surge) • Extreme climatic events (including cyclones and floods)
	Extreme events	Considered in assessing physical climate (acute and chronic) risks and RCP 8.5 scenario on physical assets
	Range of scenarios	• Climate change integrated into Group strategy scenario framework (as above) • IEA SDS to test strength of RT portfolio in low-carbon transition • IPCC RCP 8.5 to assess physical risk exposure
	Main data source for scenarios	IPCC, IEA and other sources
Contact details for further information	Jonathan Grant (Principal Advisor, Climate Change) Jonathan.Grant@riotinto.com	

ADDITIONAL INFORMATION

High level description/narrative of the climate scenarios

As a global mining company, RT have recently moved away from using standalone climate change scenarios to fully integrated climate change considerations into the scenarios they use as part of the Group strategy process. RT use three global megatrends to develop their Group strategy scenario framework—geopolitics, technology and society—which result in a range of possible climate change outcomes that are considered in strategic planning. These scenarios have been developed in-house and are bespoke to the RT business.

The current Group strategy scenario framework considers the following scenarios:

- Political, economic and technological fragmentation (including nationalism and populism); changing nature of US-China relationship; lack of global and regional coordination; leading to >3°C by 2100.
- Strong domestic, regional and global collaboration; coordinated carbon policies; rapidly rising and converging carbon prices; global warming stays below 2°C.
- Fast technology development and execution (fourth industrial revolution); low cost, low carbon solutions (with resulting opportunities); slower adoption due to lack of strong GHG emissions policies; leading to >2°C by 2100.

RT also refer to the *IEA Sustainable Development Scenario (IEA SDS) to test the resilience of the business* against an independent pathway to a less than 2°C transition aligned with the Paris Agreement. This scenario combines societal and technological dimensions to drive early adoption of clean energy solutions in the transition to a low carbon economy.

RT also use the *IPCC RCP 8.5 scenario to assess physical risks to real assets*, including the probability and potential impact of future extreme weather events. Both acute and chronic physical risks are considered over the life of the assets, from project design, operations to closure and beyond.

Data resource and requirements for the scenario development or use

RT use a range of data sources in their Group strategic scenario planning. The IPCC RCP 8.5 scenario considers four climate variables, including temperature, rainfall/water cycle, sea level rise and extreme climatic events. The IEA SDS scenario uses data from the IEA and assumes a carbon price and other data related to energy transition.

Implementation and use

RT has used scenario planning and considered the impacts of climate change for many years. Scenario development and use has been an iterative process in part driven by RT investors. Although RT is a supporter of the TCFD, TCFD disclosure is not the main driver of scenario planning. RT currently uses climate scenarios for the following key purposes:

(i) To develop Group strategy and business planning, taking into account potential geopolitical, technological and societal impacts on possible climate change outcomes (RT Group strategy scenario framework);

(i) To test business portfolio resilience in the low carbon transition (IEA SDS scenario); and

(iii) To assess the inherent climate change physical risks on assets (IPCC RCP 8.5 scenario).

The main priority of scenario use is to support long term strategic planning, including that RT has the appropriate portfolio and product mix to ensure the company is well-placed to consider climate-related risks and opportunities. For example, several years ago RT sold its thermal coal assets, and is currently focussed on minerals and metals such as copper that will be in demand in the low carbon transition.

The IEA SDS scenario is used to test the resilience of the RT business portfolio in the transition as climate change policies are implemented, including the commodity and business impacts and overall trends on RT's key products of iron ore, aluminium, copper and minerals. The IPCC RCP 8.5 scenario is used to assess business resilience to physical climate risks, which are considered over the life of RT operations. These include acute and chronic physical impacts such as extreme weather events and warming temperature trends that may impact the overall RT business, assets and value chains.

Climate change mitigation planning and physical risk management is well integrated into existing business processes from a governance perspective.

Publication and reporting

Outputs are reported in annual Climate Change Reports ("Our Approach to Climate Change"), which can be downloaded from the RT website (i.e., publicly available online). Further information on the Group strategy scenarios, including climate change and sustainability challenges to society, are included in the RT Annual Report.

Challenges and Limitations

In terms of scenario planning for physical risks, RT has found getting reasonable granularity in terms of heat maps on specific assets that is good enough to inform decision-making a challenge. For example, more detailed information is needed to inform investment decisions in enhancing the resilience of specific infrastructure such as a pier, a bridge or power assets.

In terms of transition risks, the key challenge in scenario analysis is the current focus on detailed data requirements by external parties to be used for comparability purposes. As every business in different, the focus should instead be on using scenario analysis to test individual business resilience, as well as adequately managing assets and value chains to physical risks. As there are many complications and uncertainties inherent to climate scenarios, it is also important to ensure financial resiliency (i.e. strong balance sheets).

Future improvements / opportunities / next steps

RT would like to have a set of physical impact scenarios that are granular and focussed on Australia, that could support decision-making around resilience of RT's assets in Eastern Australia and the Pilbara. As the IPCC RCP 8.5 is a meta-analysis, it would be preferable to have reference scenarios for physical risks specific to Australia at a granular level.

Conclusions

As a global mining company, RT view the transition to a low carbon economy as critical to their long-term strategy and operations. RT have recently moved away from using standalone climate change scenarios to fully integrated climate change considerations into the scenarios they use as part of the Group strategy process. RT use global technology, social and geopolitical megatrends to develop their Group strategy scenario framework, which result in a range of possible climate change outcomes that are considered in planning.

The three strategic scenarios are developed in-house using various data sources and range from political and economic fragmentation (with resulting negative climate change outcomes) to strong global coordination (with resulting positive climate change outcomes). They are used in strategic planning to identify risks and opportunities to the business, including ensuring that RT have the right asset portfolio and product mix over the medium and long term, such as products that will be in demand in a low carbon transition.

The IEA SDS (Paris Agreement) scenario is used to test implications of the low carbon transition to the resilience of the business. The IPCC RCP 8.5 scenario is used to test physical risks to real assets and build resilience through the business to the physical impacts of climate change.

RT would like to encourage the implementation of the TCFD recommendations to ensure more consistent and comparable approaches to scenario analysis. Further, more granular physical impact data sources and scenarios for the Australian regions would be useful for RT to assess physical risks to its assets in Australia.

Appendix 7:
TABLE OF CONSULTATION UNDERTAKEN

In addition to the case studies in the report, the following stakeholder consultation was undertaken:

Organisation	Name	Position
BoM	Judith Landsberg	Project Coordinator, ESCI
Cross-Dependency Initiative (XDI)	Dr Karl Mallon	Director of Science and Technology
CSIRO	John Clarke	Team Leader Regional Projections
	Dr Michael Grose	Climate Projections Scientist
	Russ Wise	Senior Sustainability Economist
Energetics	Dr Nick Wood	Associate
Infrastructure NSW	Hala Hubraq	Policy Principal
NSW DPIE	Nerida Buckley	Senior Team Leader Climate Preparedness
	Christopher Weston	Senior Project Officer, Climate Preparedness
Vic DELWP	Rhynah Subrun	Manager, Climate Change
	Tom Wilson	Senior Policy Officer, Climate Change
	Zabrina Batterham	Senior Communications and Stakeholder Engagement Officer, Climate Change

Appendix 8:
EXAMPLE INDICATORS FOR THE FINANCIAL SECTOR

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

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