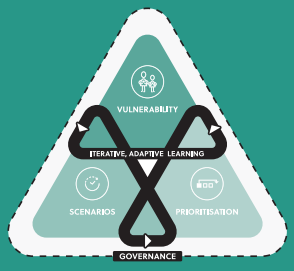
04

Climate and disaster risks:

What they are, why they matter and how to consider them in decision making

Guidance on Scenarios



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Disclaimer

The information within the guidance provided, and upon which it is based, has been obtained from engagement with a diverse range of stakeholders and sources that the authors believe to be reliable and accurate. The information in the guidance is solely intended to provide a general understanding of the subject matter and not intended to be complete or comprehensive in terms of content or resources. The guidance documents are a first iteration and have not been fully tried and tested. The guidance should be seen as credible and instructive but not authoritative.

The information contained may not be representative of all audiences and appropriate to all situations. The concepts and knowledge contained in the guidance will improve as the ability to engage more comprehensively with audiences such as the Aboriginal and Torres Strait Islander populations matures and as knowledge about the underlying drivers of climate and disaster risk broadens across society. No liability is accepted for any loss or damage arising from connection with the use of information in all guidance documents.

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Foreword

The risk landscape is changing quickly, and the stability of natural, social and economic systems can no longer be taken for granted. The scale and seriousness of the momentum of change requires genuine national collaboration, a broad range of knowledge and strategic guidance on navigating growing uncertainty.

Choices made at multiple levels by a wide range of decision makers in both government and industry interact to affect our vulnerability and resilience. Better decision making, guided by new forms of systemic risk governance, assessment and management are key to preventing and reducing climate and disaster risk.

Led by the National Resilience Taskforce and released in April 2019, the co-developed *National Disaster Risk Reduction Framework* (Framework) sets a common agenda for collective action. This new Framework is in part informed by the report *Profiling Australia's Vulnerability* that reflects a fuller understanding of systemic disaster risk and values, choices and trade-offs.

Profiling Australia's Vulnerability brings into sharp focus the reality that hazards lead to disaster where there is exposure of a vulnerable society and where the consequences exceed people's capacity to cope. The report also finds that what we value, and the choices that we make between these values, are different during periods of stability compared with disruption. Understanding this can help reframe how we approach climate and disaster risk reduction efforts into a whole-of-society approach.

The Framework sets a foundation for action for decision makers across all sectors of the Australian economy. It seeks to raise awareness of the causes and effects of climate and disaster risks and to enable decision makers to proactively take steps within their spheres of influence and control to reduce these.

To support its implementation and encourage new conversations about climate and disaster risk, a set of interconnected guidance documents has been developed.

This Guidance is foundational and is a first iteration. It is designed to help decision makers in the non-trivial task of contextualising the systemic physical impacts of a changing climate. In particular, it provides direction on how to call upon knowledge, capabilities and processes to apply climate and disaster risk to governance, strategic planning and investment decisions.

As you *Turn the Page*, you will be contributing to the journey from where we are now, to where we need to be.

Mark Crosweller AFSM
Head of National Resilience Taskforce
Department of Home Affairs

Turning the Page

Reducing Systemic Climate and Disaster Risk for a Resilient and Prosperous Australia

Momentum is Building

The risk landscape is changing quickly and we need to break from business as usual.

- Natural hazards are more frequent and intense
- Demand is growing to address financial impacts of a changing climate
- People, livelihoods and assets are more exposed and vulnerable
- Essential services are increasingly hyper-connected
- Disaster impacts are long-term and complex
- Costs of disasters are growing
- Stability of natural, social and economic systems can no longer be taken for granted

Where we need to be

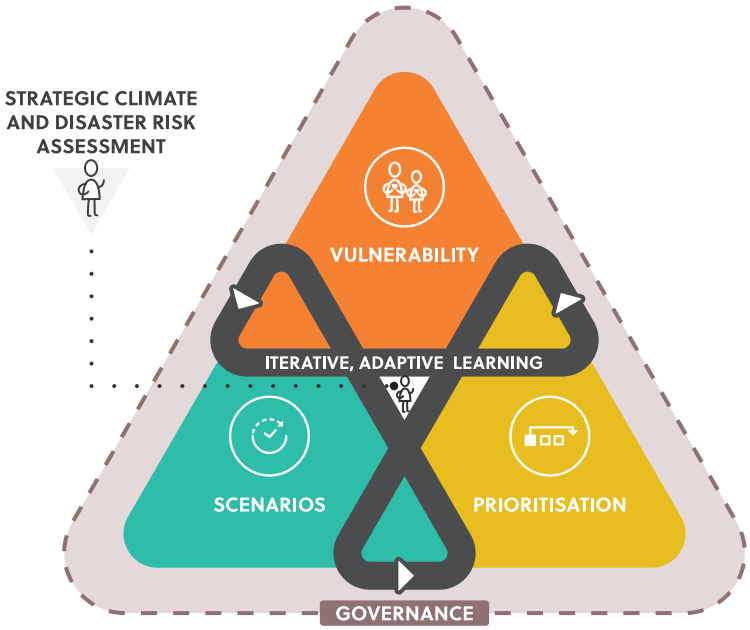
We are Aspiring Towards

A systems and values-based mindset reduces climate and disaster risks.

- Risk-informed sustainable development
- Substantial reduction in loss and harm
- Successfully living with natural hazards and a changing climate
- Reduced intergenerational vulnerability
- Wellbeing, trust and confidence

Guidance on Scenarios

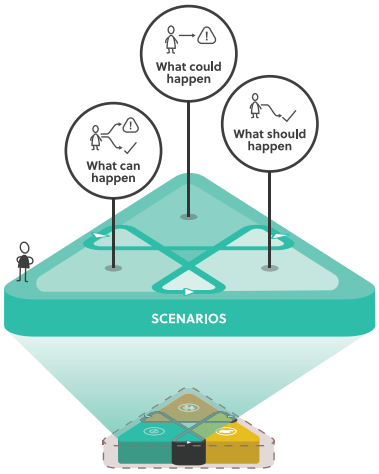
This document is one of a set of interconnected Guidance documents on *governance, vulnerability, scenarios* and *prioritisation* for enabling strategic climate and disaster risk reduction.



The set of Guidance documents has been developed to help you:

- more holistically understand the systemic nature of climate and disaster risk, particularly the causes and effects of societal vulnerability, using a systems- and values-based approach to assessment and collaboration;
- explicitly revisit the vision, goals, objectives and decision criteria of relevant stakeholders in the context of changing climate and disaster risk;
- recognise which aspects of uncertainty matter when making strategic long-term decisions and how to apply techniques to make robust decisions in lieu of complete knowledge; and
- understand what types of knowledge and information are important for different stages of strategic plans or risk assessments.

The Guidance on Scenarios can be read and applied in parts, independently or as an integrated set with the Guidance on Governance, the Guidance on Vulnerability and the Guidance on Prioritisation. It should be read in conjunction with the Introduction and the supporting Terms and Concepts.



The Guidance on Scenarios:

- provides detail about how to develop and apply different kinds of scenarios for different purposes;
- explains how scenarios can be used to explore the potential implications of highly uncertain changes in hazards, exposure and vulnerability under a changing climate;
- helps navigate high-stake strategic and operational decisions;
- emphasises using scenarios to develop aspirational futures (visions) that inform goals and decision criteria to guide collective and adaptive actions; and
- emphasises how important scenarios are for enabling robust, low-regrets decisions in the context of high uncertainty. Several questions sequentially guide the user through this guidance (i.e. what could happen, what should happen and what can happen).

Technical sections have been included for researchers, practitioners and decision makers seeking to leverage or evolve their existing use of scenarios to better support more robust decision making and adaptive learning.

Contents

Approach to developing the guidance

The National Resilience Taskforce led the co-development of this Guidance on Scenarios. It has been constructed by building on and drawing from existing capabilities, resources, decision processes and initiatives to complement and improve existing practices and enable the implementation of the National Disaster Risk Reduction Framework.

1. Introduction

Scenarios help visualise different ways the future could unfold. Scenarios can stretch people's thinking to imagine and explore plausible futures that could be radically different from the present.

The changing nature of climate and disaster risk is leading to new correlated and coincident risks emerging in ways that cannot be anticipated. This requires scenarios that characterise a range of potential future states of the world outside of lived experience or historical records and measurements.

For times of deep uncertainty and when information is inexact or absent, scenarios can be an effective technique to support decision making. Scenarios can enhance and enrich understanding of the broader context in which problems need to be solved, strategic objectives developed or modified or common visions identified.

Scenarios also serve as a powerful basis for learning and action. They can help overcome behavioural, cultural and psychological barriers. In this way scenarios can help to analyse and test assumptions and inform or enable proactive, strategic interventions. They can help people better understand what it is they need to respond to and how best to do this. Including how to think about interventions which target the systemic causes of climate and disaster risk.

There are many different types of scenarios and different ways to apply scenarios to climate and disaster risks.

The Guidance explains:

- the challenges in making decisions in the context of uncertainty;
- different types of scenarios;
- different applications of scenarios;
- different entry points for applying scenarios;
- the benefits that can be derived from using scenarios; and
- how to incorporate the acquired thinking and learning into decision making.

1 Foundational references are: Schwartz, P. 1991. *The art of the long view: Planning for the future in an uncertain world*: Bantam DoubleDay Dell Publishing. New York; and Ramírez, R., and A. Wilkinson. 2016. *Strategic Reframing: The Oxford Scenario Planning Approach*: Oxford University Press. Oxford, United Kingdom.

2. Decisions and Uncertainty

There is growing urgency for current and potential future climate and disaster risks to be considered in a range of decision-making processes.

Considering these risks is particularly challenging because of a number of complications[2]:

- the potential for changes to be substantial and unprecedented in magnitude;
- rapid rates of change in climate, environment, technology, socio-economic development and population that raise the urgency for action;
- uncertainty and ambiguity about how quickly and how much climate, hazards, exposure, vulnerability and the environment could change;
- many existing societal objectives (i.e. values), rules or knowledge may no longer be appropriate or compatible with the growing scale, rate or uncertainty of global change;
- the increasing difficulty of measuring and comparing the performance of particular policies, as these are likely to perform differently under different plausible futures[3]; and
- the relatively low levels of relevant skills, capabilities, data and information needed to navigate the complexities in decisions associated with climate and disaster risk.

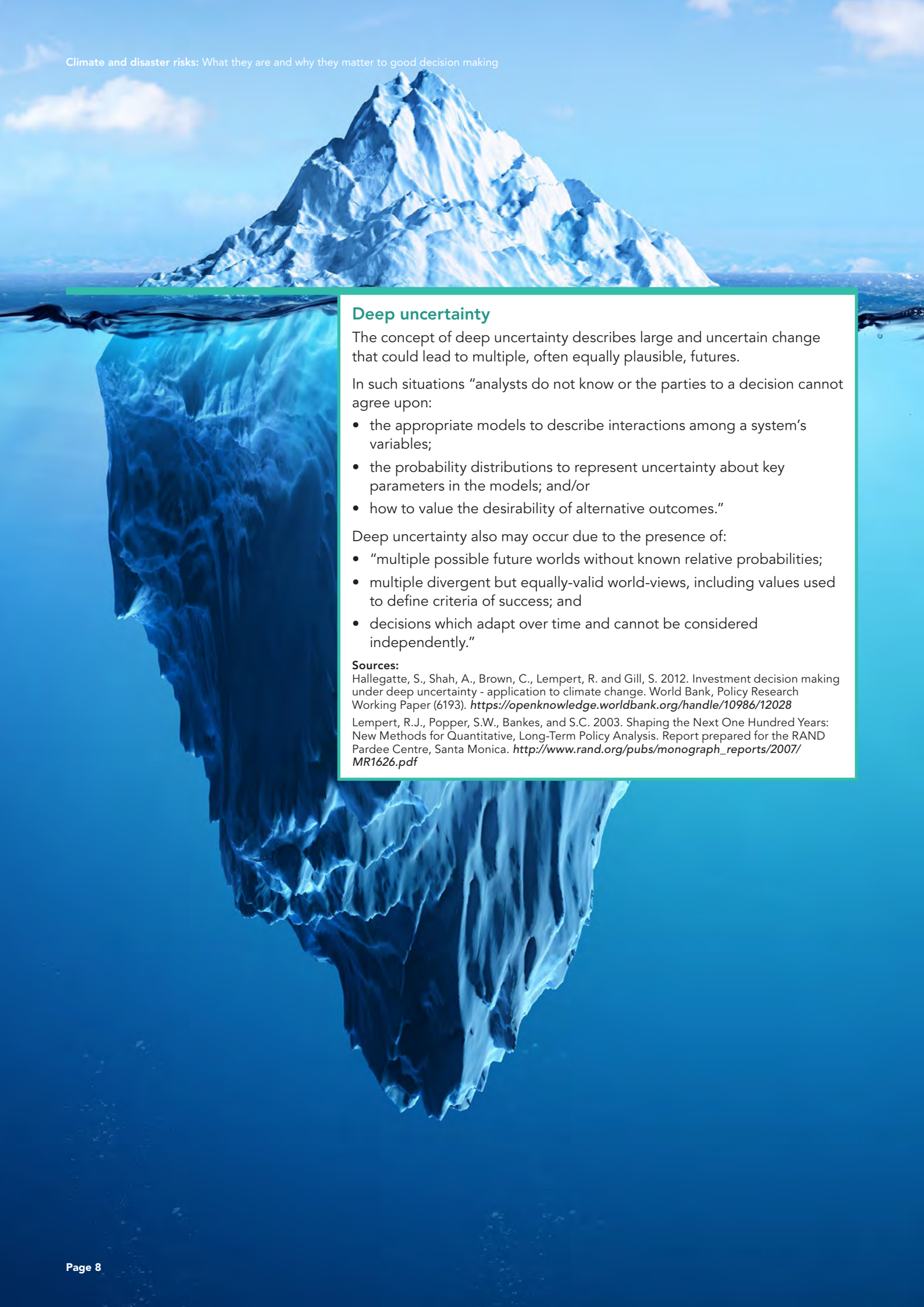
These complications create what is described as deep uncertainty. Many prevailing methods or approaches adopted to guide decision making do not consider deep uncertainty. Often well-established risk assessment or/and costbenefit-analysis methods understate the relevance of uncertainties (such as low probability, high consequence events) and the ambiguities these create. They often assume the system is understood and controllable, and that optimal decisions can be made based on narrowly defined goals and a single prediction of a 'best estimate' future.

The complications of deep uncertainty are most relevant to long-lived and high stakes decisions such as conservation planning, land-use zoning, and large-scale investments in infrastructure. These decisions have consequences that play out over decades (or lifetimes) and large areas. They are difficult or costly to reverse, and could result in 'high regrets' if the future unfolds in unexpected, unplanned or undesirable ways.

Increasingly, these challenges are also becoming relevant to operational decisions about whether to continue to manage an asset in a location or to let it rapidly depreciate and rebuild in a safer location.

2 Wise, R. M. 2018. *Key Capabilities for Long-Term Development Strategies in the Face of Unprecedented and Uncertain Large-Scale Global Change, Expert Perspectives on long-term climate strategies* World Resources Institute (WRI). Accessed 27 June, 2019: ***https://www.wri.org/climate/expert-perspective/key-capabilities-transformational-long-term-development-strategies***

3 McPhail, C., Maier, H. R., Kwakkel, J. H., Giuliani, M., Castelletti, A. and Westra, S. 2018. Robustness Metrics: How Are They Calculated, When Should They Be Used and Why Do They Give Different Results? *Earth's Future* 6 (2):169-191. doi: 10.1002/2017ef000649.



Deep uncertainty

The concept of deep uncertainty describes large and uncertain change that could lead to multiple, often equally plausible, futures.

In such situations "analysts do not know or the parties to a decision cannot agree upon:

- the appropriate models to describe interactions among a system's variables;
- the probability distributions to represent uncertainty about key parameters in the models; and/or
- how to value the desirability of alternative outcomes."

Deep uncertainty also may occur due to the presence of:

- "multiple possible future worlds without known relative probabilities;
- multiple divergent but equally-valid world-views, including values used to define criteria of success; and
- decisions which adapt over time and cannot be considered independently."

Sources:

Hallegatte, S., Shah, A., Brown, C., Lempert, R. and Gill, S. 2012. Investment decision making under deep uncertainty - application to climate change. World Bank, Policy Research Working Paper (6193). ***https://openknowledge.worldbank.org/handle/10986/12028***

Lempert, R.J., Popper, S.W., Bankes, and S.C. 2003. Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis. Report prepared for the RAND Pardee Centre, Santa Monica. ***http://www.rand.org/pubs/monograph_reports/2007/MR1626.pdf***

Decision makers need to recognise and possibly reframe their understanding of the scale, nature and opportunities that rapidly changing environments present. They will need to revisit values, objectives, assumptions and approaches underpinning strategy development, planning, risk management and economic assessment to be compatible with large-scale change and high uncertainty.

Numerous approaches can be adopted to navigate complexity and different levels of certainty, and to build the capacity to contemplate various futures. The suitability of each approach depends on:

- the level of awareness and understanding of climate and disaster risk;
- the complexity of the issues;
- the capacity of stakeholders; and
- the value and lifetime of the options and decisions being considered.

The types of decisions that are made in the context of climate and disaster risk are illustrated in Figure 1. Scenarios are required for decisions with lifetimes extending to decades and centuries with inevitably larger uncertainties.

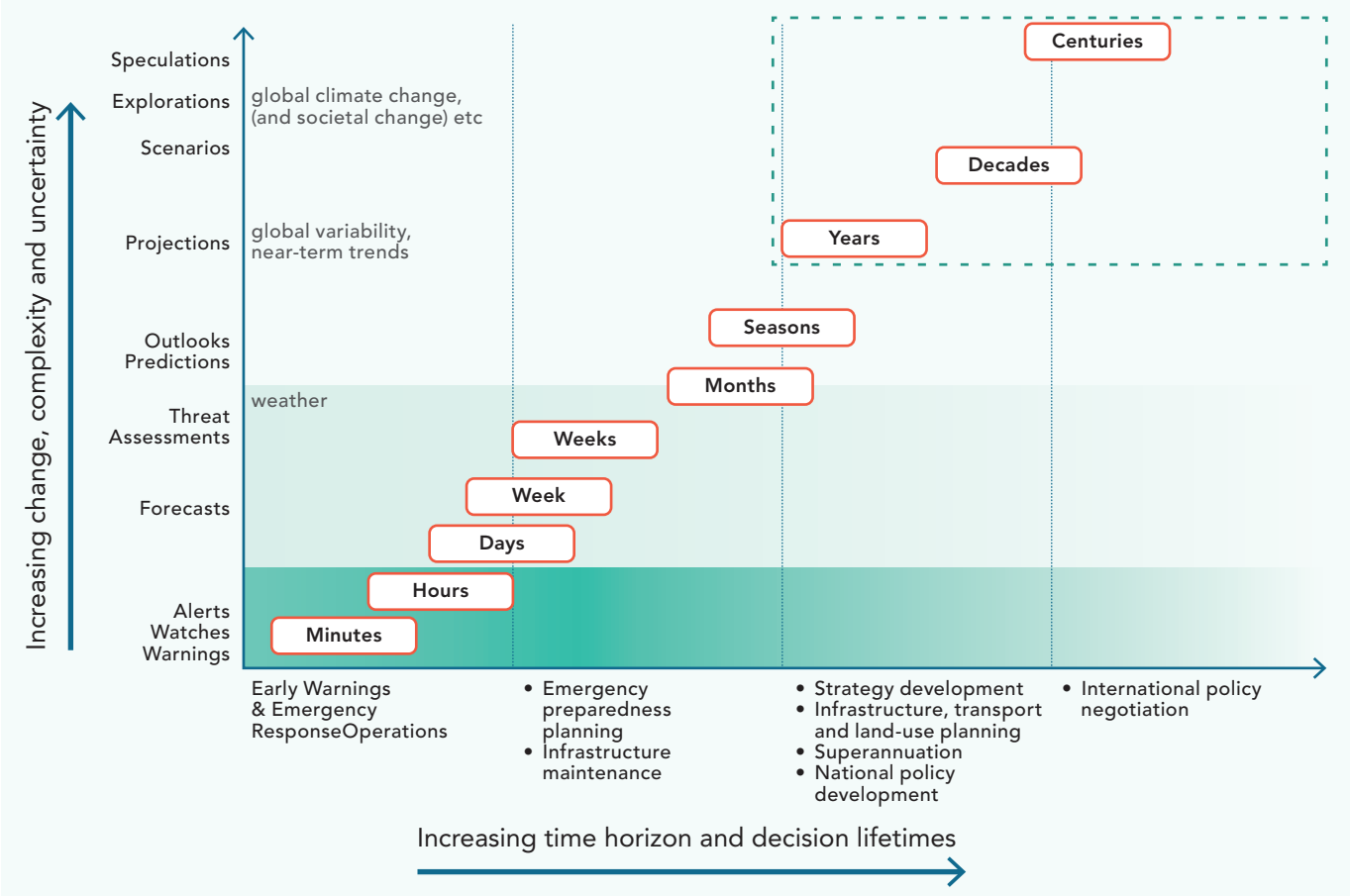


Figure 1: Illustrates different contexts when considering uncertainties about the future based on decision lifetimes (horizontal axis) and levels of complexity and uncertainty (vertical axis) for various risk management applications. The dashed green rectangle indicates scenarios required for decisions with large uncertainties and lifetimes extending to decades and centuries.
Source: adapted from the World Meteorological Organisation's Disaster Risk Reduction Programme Strategic Plan 2012-2015.

Large-scale effects of climate change have already been observed and measured. These include the warming of oceans, increases in extreme heatwaves and the shifting of agricultural zones and ecosystems into new states.

The viability of most long-term decisions about where and how to live, invest or build need to explicitly consider these large-scale effects of climate change, which are projected to worsen[4].

Scenarios can be used to predict, project, explore and speculate about the spectrum of preferred, probable, plausible, possible and even preposterous futures (Figure 2)[5].

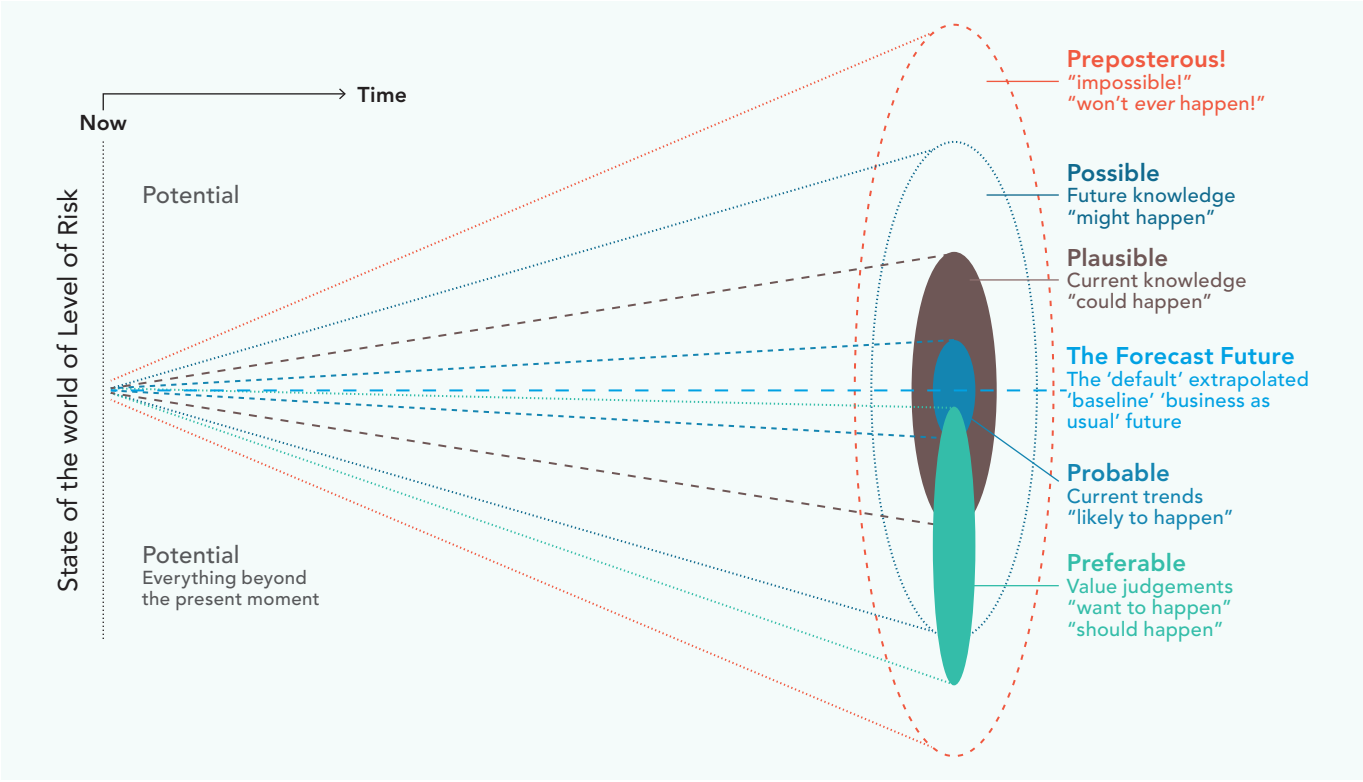
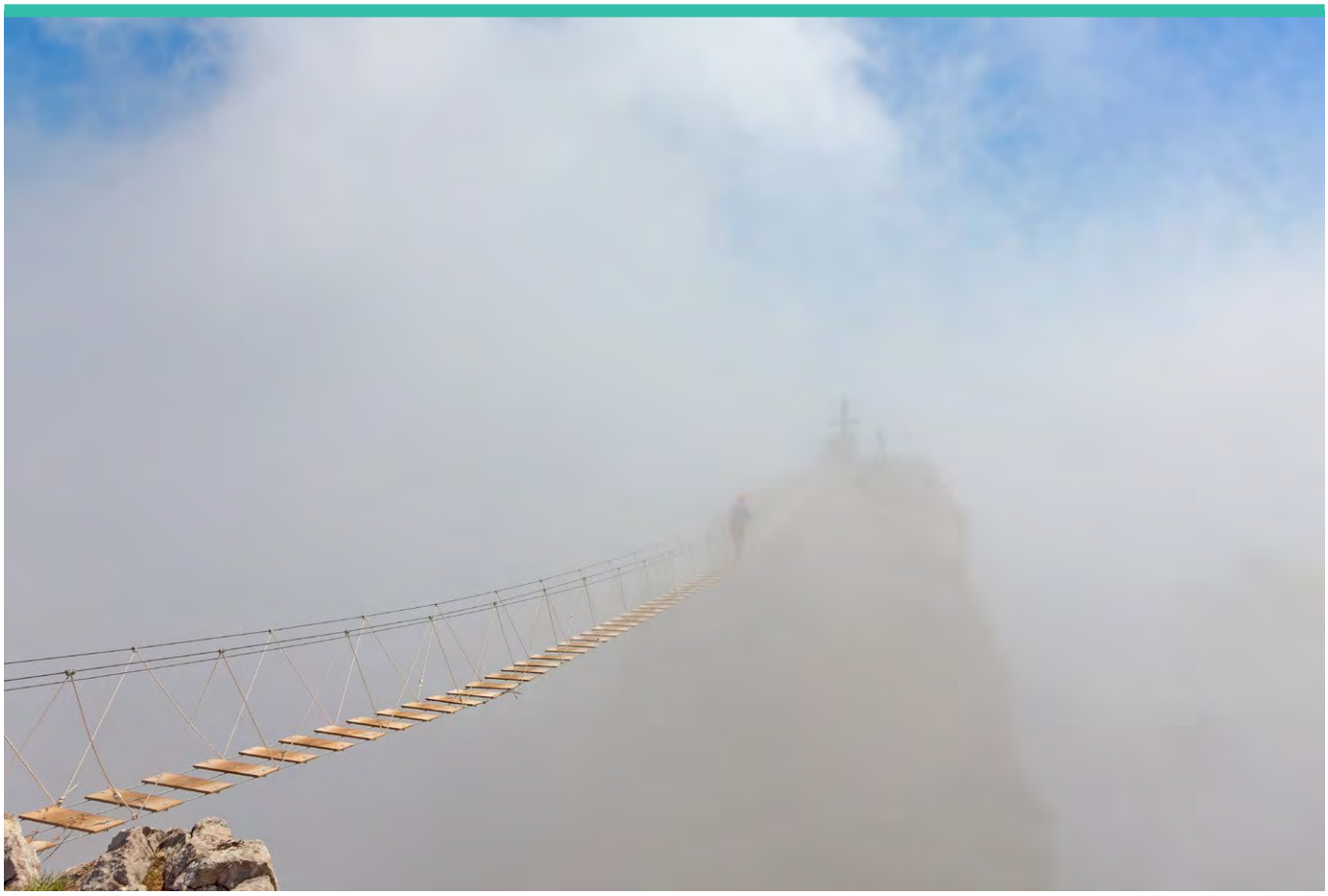


Figure 2: The Futures Cone – illustrating the spectrum of potential futures[6].

4. IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Report, The Intergovernmental Panel on Climate Change (IPCC). Accessed 27 June, 2019 at: ***https://www.ipcc.ch/report/ar5/wg2/***; and CSIRO and BOM. 2018. State of the Climate Report. Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BOM). Accessed 27 June 2019 at: ***http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2018.pdf***.
5. Iversen, J.S. 2006. Futures thinking methodologies: Options relevant for 'schooling for tomorrow'. Organisation for Economic Cooperation and Development (OECD). Accessed 27 June, 2019 at: ***http://www.oecd.org/education/ceri/35393902.pdf*** ; and Maier, H. R., J. H. A. Guillaume, H. van Delden, G. A. Riddell, M. Haasnoot, and J. H. Kwakkel. 2016. "An uncertain future, deep uncertainty, scenarios, robustness and adaptation: How do they fit together?" *Environmental Modelling & Software* 81:154-164. Accessed 27 June 2019 at ***https://agwaguide.org/docs/Maier_et_al_2016.pdf***.
6. Adapted from Voros, J. 2003. "A generic foresight process framework'." *Foresight* 5 (3):pp. 10-21. doi:10.1108/14636680310698379. Accessed 27 June, 2019 at: ***https://researchbank.swinburne.edu.au/items/48369bff-dc46-4648-9f03-871981d01a89/1/***



Navigating gaps in knowledge arising from uncertainty

The nature and scale of climate and disaster risk has changed so much that it challenges and increasingly calls into question established risk assessment approaches. Many elements of current approaches to risk measurement and management are inadequate in accounting for the dynamic and systemic implications of climate and disaster risks. Discrete risk matrices or static probability based approaches are not appropriate or suited to situations where:

1) the consequences are catastrophic but the likelihood is rare (i.e. extreme events)
2) the likelihood of known outcomes are not known or cannot be predicted (i.e. uncertainty)
3) the probabilities may be known, but not the characterisation of outcomes (i.e. ambiguity) or,
4) neither the likelihood or the consequences are known or knowable (i.e. ignorance).

Extreme events, uncertainty, ambiguity and ignorance describe situations under climate change that are becoming more prevalent and pervasive.

Decision makers need approaches to navigate and assess complex situations characterised with uncertainty and ambiguity and explore what is not known and unknowable or unpredictable.

Figure 3 illustrates two charts. Each chart has four common quadrants that describe different combinations of knowledge about likelihoods and outcomes (i.e. risk, ambiguity, uncertainty and ignorance). Chart A on the left explains contrasting states of incomplete knowledge. Chart B on the right describes some methods for responding to the different forms of knowledge deficits. The purpose of Figure 3 is to highlight benefits that can be derived from broad-based precautionary and participatory approaches to resolving knowledge gaps.

This Guidance emphasises that approaches to dealing with uncertainty, ambiguity and ignorance (i.e. Chart B) are urgently needed to support decision making to reduce climate and disaster risks. In particular approaches are needed that are capable of:

1) accounting for unprecedented and continually changing profiles of probability distributions (especially extreme events);
2) mapping and accommodating different framings of complex problems;
3) avoiding marginalising important perspectives;
4) reducing or entirely avoiding compounding exposure to surprise; and
5) 'opening up' greater accountability for the implicit normative judgements in decision making on risks.

'We must apply what we know and acknowledge the gaps in our knowledge, prioritising ways to understand what we do not know yet'.

Source: 2019 Global Assessment Report on Disaster Risk Reduction

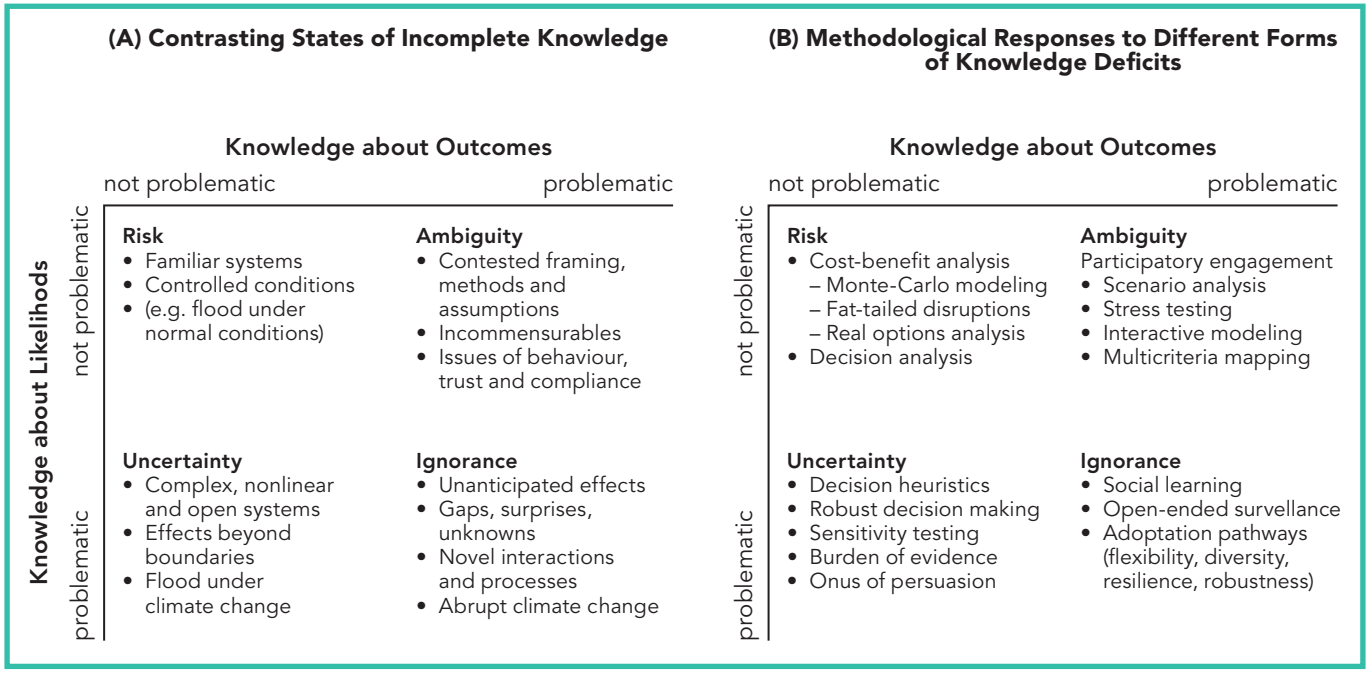


Figure 3: Different types of incomplete knowledge are presented with examples of methods that can kelp bridge knowledge gaps. Source: adapted from Stirling and Scoones, 2009[7].

7 Stirling, A. C. and Scoones, I. 2009. "From risk assessment to knowledge mapping: science, precaution and participation in disease ecology." *Ecology and Society* 14 (2):14. [freely available online] URL: ***http://www.ecologyandsociety.org/vol14/iss2/art14/***

3. Different Types of Scenarios

Different scenarios are often used to satisfy different purposes.

There are four types or classifications of scenario approaches that can be called upon at different times to satisfy different purposes: predictive, exploratory, aspirational and normative (Figure 4).

The four types correlate to four questions that can be used to prompt thinking about problems or decisions related to climate and disaster risk.

- ***What will, or is likely to, happen?*** – based on the simple assumption of existing trends and current thinking / practices continuing unchanged into the future (i.e. predictive scenarios)
- ***What could happen?*** – under combinations of potential, uncertain and largely uncontrollable drivers of change (i.e. exploratory scenarios)
- ***What should happen?*** – based on what the desired future is or a vision that then provides or defines the goals to guide interventions (i.e. aspirational scenarios)
- ***What can happen?*** – based on what happens with proactive interventions to change things (i.e. normative scenarios)

'We must provide decision-friendly scenarios and options to support people better understand the nature of their own risk and how to deal with it'.

Source: 2019 Global Assessment Report for Disaster Risk Reduction

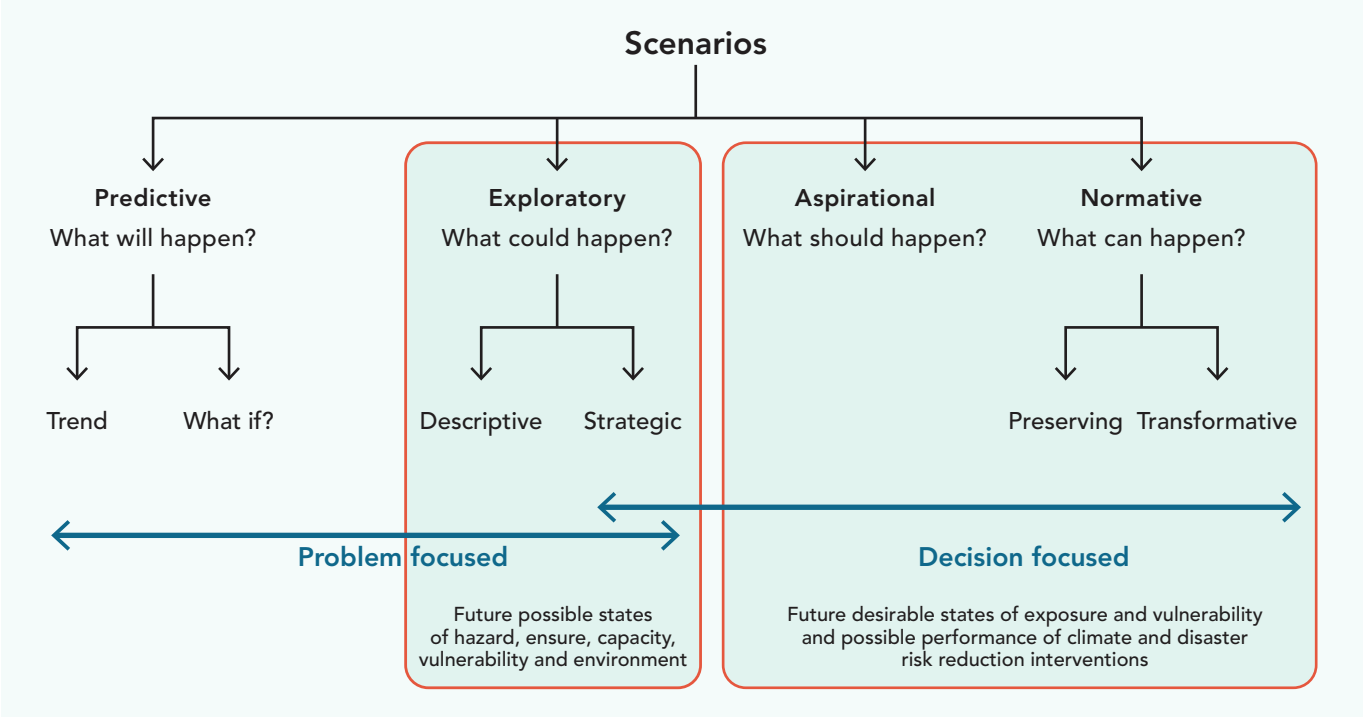


Figure 4: Four classifications of scenarios, each with a supporting question that prompts thinking, and illustration of which ones are appropriate for informing decision about climate and disaster risk[8]

8 Adaptated from Maier, H. R., Guillaume, J. H. A., van Delden, H., Riddell, G.A., Haasnoot, M. and Kwakkel, J.H. 2016. An uncertain future, deep uncertainty, scenarios, robustness and adaptation: How do they fit together? *Environmental Modelling & Software* 81:154-164. Accessed 27 June 2019 at ***https://agwaguide.org/docs/Maier_et_al_2016.pdf***

We need scenario approaches that explicitly engage with the dynamics and uncertainty of climate and disaster risks. Aspirational, exploratory and normative scenario approaches are the most appropriate for considering circumstances with deep uncertainty.

Predictive Scenarios

Predictive scenarios tend to be well applied and well tested. Examples include monthly and seasonal weather, economic predictions and forecasts. They are used to inform tactical, operational and short-term decisions, including investment decisions. Predictive scenarios have greatest utility and credibility in the very near-term future, in relatively stable situations and for tractable problems. Predictive scenarios are not described further in this guidance.

Aspirational Scenarios

Aspirational scenarios are used to help stakeholders create or identify shared goals based on a common understanding of the problem and shared values, desires and aspirations. These are important for informing the development of shared approaches to overcoming challenges and exploiting opportunities in pursuit of the goals (see Collective Impact Initiatives in Guidance on Governance).

Exploratory scenarios

Exploratory scenarios allow people to explore future possibilities. Future possibilities can be explored in two ways:

1. exploring possible problem definitions *without* consideration of any particular decision or decision maker (i.e. descriptive exploratory scenarios). With such scenarios, the purpose is to explore future possibilities as a result of external drivers of change outside of the control of any one particular decision maker (i.e. to provide the broader set of possible conditions of the context or operating space);
2. exploring possible problem definitions *with* a particular decision or decision maker in mind (i.e. strategic exploratory scenarios). With such scenarios, exploration of future possibilities is more focussed on drivers of change and aspects of the system that decision makers have some influence or control over. The purpose is to highlight key controlling drivers or variables and potential leverage points for decision makers to explore.

Normative scenarios

Normative scenarios are possible future trajectories of actions or interventions to shift the system on more desirable paths or away from undesirable paths. These scenarios also allow people to explore future possibilities, but are focused on interventions to 'solve' problems instead of framing problems. Generally speaking normative scenarios can involve interventions where the intent is to:

1. inform or enable decision makers to meet existing goals using existing practices (i.e. preserving normative scenarios); or
2. identify options to transform current systems and practices to realise different goals and objectives (i.e. transformative normative scenarios).

4. Applying Scenarios to Climate and Disaster Risk

The application of different types of scenarios to inform systemic climate and disaster risk reduction is relatively new and underdeveloped.

This Guidance provides information about selecting and applying scenarios for learning about the complex causes and effects of climate and disaster risk. It provides direction on how scenario approaches can be used to create qualitative and quantitative descriptions or narratives of distinctly different potential futures. These are used to develop long-term strategies that create benefits and perform satisfactorily (i.e. low regret) across all or most future possibilities.

'Climate and disaster risk' refers to the potential damage that could occur to social, economic, natural or infrastructural assets, services, or communities from natural hazards, climate change, exposure, vulnerability and environmental health[9].

Climate and disaster risks are systemic in nature as they encompass the deep-rooted often self-reinforcing socio-economic processes and drivers of exposure and vulnerability to natural hazards and disasters such as population growth, urbanisation, interconnectedness and resource development and use.

Generally speaking, we are most familiar with using a hazards-oriented approach to developing scenarios and subsequently undertaking hazards-based risk assessments. These have advanced understanding of exposure and vulnerability of physical infrastructural assets to natural hazards in particular. However, the breadth and dimensions of social vulnerability to natural hazards and climatic and environmental change is profoundly under developed and inadequate to meet the challenges of proactive climate and disaster risk reduction.

Recognising these limitations, this Guidance explains how new forms of learning and knowledge can be used to generate more holistic scenarios and assessments of climate and disaster risk. It encourages the development of low-regret scenarios of climate and disaster risk reduction in the context of high uncertainty.

Figure 5 illustrates five steps of an iterative, adaptive 'decision and learning' approach. This approach to decision making and learning is essential in situations where change is uncertain and particularly where the stability of systems can no longer be taken for granted. This Guidance explains how aspirational, exploratory and normative scenarios can be used to support the first four steps of this decision making and learning process to assess and manage climate and disaster risks.

Web links to examples of the different types of scenarios are provided in Further Reading.

9 UNDRR. 2017. Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. United Nations Office for Disaster Risk Reduction (UNDRR). Accessed 27 June, 2019 at: *https://www.preventionweb.net/files/50683_oiewgreportenglish.pdf*.

Aspirational, exploratory and normative scenarios can be applied to support strategic climate and disaster risk assessment. They can be used to explore drivers of change, desired and undesired future states and to explore options for risk reduction (Figure 5).

Specifically, the types of scenarios that can be used to support the assessment and management of climate and disaster risks includes:

1. Scenarios of aspirational futures as the basis for identifying the vision, goals and decision criteria (Step 2);
2. Scenarios to explore natural hazards under climate change to raise awareness and improve understanding of their changing dynamics today and into the future (Steps 1 and 3);
3. Scenarios of future exposure to explore possible future changes in exposure of the built environment (Steps 1 and 3);
4. Scenarios of future vulnerability of infrastructural assets to explore possible future changes in vulnerability of the built environment (Steps 1 and 3);
5. Scenarios of societal vulnerability to explore possible future changes in social systems (Steps 1 and 3); and
6. Scenarios of climate and disaster risk reduction to develop options and pathways under different possible climate and disaster risk futures, to inform prioritisation of investments (Steps 4 and 5).

Figure 5: Schematic of the five steps involved in adaptive decision making and learning to assess and manage climate and disaster risks

The importance of robust, 'low regrets' approaches to decision making

The most significant uncertainties associated with climate and disaster risk reduction relate to our limited ability to predict the magnitudes of change. These particularly relate to complex adaptive systems such as climate, socio-economic development, ecosystem functioning and societal vulnerability. There is little evidence to suggest these uncertainties are resolvable in the short to medium term.

Anticipatory decisions in highly uncertain situations could lead to substantial over- or under-investment in climate and disaster risk reduction.

Under-investments leads to additional costs being incurred through large residual climate change impacts or through failure to seize new opportunities. Over-investment leads to waste of these investments if changes are not as severe as projected.

Traditional decision-making processes such as Cost Benefit Analysis are limited for informing decisions in the presence of deep uncertainty (see Guidance on Prioritisation). So-called 'robust approaches' are increasingly being called upon to inform low regrets decision making. Low regrets or robust approaches are suited for deep uncertainty. They select options that perform satisfactorily across a variety of possible futures (as opposed to options that perform best under the central or expected scenario), or create benefits no matter what the future.

Robust approaches to decision making do this by testing possible interventions against integrated variations of climate and socio-economic (i.e. vulnerability) scenarios to:

- find the best performing intervention option across scenarios;
- identify intervention options that can be flexibly applied and adjusted if needed (i.e. real options analysis); or
- diversify the number or nature of adaptation options to reduce overall risk (i.e. portfolio risk).

Robust strategies are attractive for risk-averse decision makers as they help to reduce the range of uncertainty in an investment decision or across a range of policy measures. They help to reach consensus on actions. This is because different future scenarios and diverging viewpoints are better considered in the context of reducing the risk of over- and under-investment.

Limitations or challenges to robust decision making approaches are: they can demand high levels of capability and data, they are often costly and time-consuming, and they sometimes need to be based on unrealistic simplified assumptions. Increasingly, principles-based applications of low regrets or robust approaches are being used to inform strategic approaches to informing climate and disaster risk management.

Source:

Dittrich, R., Wreford, A. and Moran, D. 2016. A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward? *Ecological Economics* 122:79-89. doi: ***http://dx.doi.org/10.1016/j.ecolecon.2015.12.006***

Marchau, V.A.W.J., Walker, W. E., Bloemen, P.J.T.M. and Popper, S.W. eds. 2019. *Decision Making under Deep Uncertainty: From Theory to Practice*: Springer, Switzerland. Accessed 27 June, 2019 at: ***https://link.springer.com/content/pdf/10.1007%2F978-3-030-05252-2.pdf***

4.1 Scenarios of aspirational futures (visions)

Scenarios of aspirational futures describe the desirable vision for a region, sector or organisation.

Typically, a vision will encompass descriptions and stories of what things would need to look like for individuals and communities to be successfully living with natural hazards under a changing climate. They are used to answer the question ***'What should living successfully with natural hazards look like?'***

Describing desirable futures (i.e. aspirational scenarios)or visions provides opportunities for people to reflect on their values and objectives. In the development of shared visions, people should consider their values in the context of what others value, as well as an understanding of the large-scale changes that are likely to occur around them (see Values Analysis in the Guidance on Vulnerability).

Things that are of value to people include affordable and accessible essential services and associated critical infrastructure, healthy natural environments and well-functioning, just and fair governance arrangements and decision making processes.

How to use these

Scenarios of aspirational futures are typically captured in the form of pictures and emotive inspiring stories or narratives.

Aspirational scenarios stimulate positive emotions and a willingness to collaborate. They create shared goals and a sense of hope, belonging and stewardship among stakeholders. They develop mutually reinforcing options and actions for shifting the current reality towards the vision.

They also highlight the contrasts between what people want the world to be like and what the world is like or could become under a business as usual scenario. These contrasts create the necessary discomfort required for people to reflect on their assumptions and mental models. They generate a sense of urgency to take action to reduce the gap between the desired future and their current situation.

To be seen as credible, legitimate and to effectively realise their purpose, visions need to be developed with inclusive processes. There needs to be a rigorous acknowledgement of the diversity of perspectives, values and interests of the individuals and groups within the community, region or organisation of interest.

Evidence has shown that getting stakeholders to draw their visions together is an effective way of ensuring these diverse perspectives and values are included. It builds stakeholder support and buy-in to the shared vision that materialises.

The activity of drawing promotes both convergent and divergent thinking. It legitimises and allows for scientific, experiential and traditional knowledge. It acknowledges both emotional and rational perspectives.

Additionally, the inclusiveness of the process, along with the fact that visions are aspirational and forward looking, allows for any power imbalances and vested interests that may be present between individuals to be neutralised or minimised. In this way the integrity of the outcome is maintained.

Visions can be developed as stand-alone activities and products (such as the "Australia 2050 Living Scenarios" and the A24 Australia Remade vision). They can also be developed as part of a series of activities such as developing a strategy, an implementation plan for a region or organisation or as part of a problem-framing and narrative building exercise (i.e. *Profiling Australia's Vulnerability*). It is important to develop the vision before embarking on sessions that draw out the constraints and problems. These can be overwhelming and limit people from considering futures beyond their current realities. When undertaken within broader and extended decision processes, vision(s) are most useful and effective at fulfilling their purpose if they are accessible and revisited throughout the decision process.

Aspirational scenarios stimulate positive emotions and a willingness to collaborate. They create shared goals and a sense of hope, belonging and stewardship amongst stakeholders.

4.2. Scenarios to explore natural hazards under climate change

Exploratory scenarios are used to answer the question ***'What could happen to natural hazards under climate change?'***

The potentialities of natural hazards under climate change generally encompass changes in averages and extremes of hazards such as temperature, rainfall, wind, tropical cyclones, floods, coastal inundation, heatwaves, storm surge and bushfire. They also encompass new hazards emerging from a changing climate, that will increasingly stress environments and potentially shock the ways society and economies function.

Exploratory scenarios are needed because the behaviours of hazards will change in uncertain ways as climate, vegetation and land-uses change. The ways in which such changes might affect human activities or highly interconnected socio-infrastructural systems and services are hard to foresee.

Our ability to understand, model and project physical dimensions of hazards is constantly improving. However, it is likely that uncertainties will remain scientifically irreducible for many hazards[10], particularly those indirectly affected by climate change such as bushfires, flooding and coastal inundation.

Exploratory scenarios of how natural hazards may behave in the future are generally problem-focused. However, they can also be decision focused and strategic (Figure 4)**.**

Natural hazards under climate change

Climate-induced changes to the natural environment are creating widespread chronic stresses and potential insidious and unpredictable shocks – when they cross thresholds – to the socio-economic systems that depend on them. These changes to the natural environment are having, and increasingly will have, impacts on communities, societies and economies in the same way that natural hazards do.

For example, the economy and wellbeing of many communities at local through to national scales depend on activities related to agriculture, fisheries or tourism. These activities require the presence of healthy and safe ecosystems to sustain a productive natural resource base. However, these ecosystems are beginning to show signs of rapid, fundamental or irreversible changes as the climates they depend on alter. These changes compromise their ability to sustain the social and economic activities that depend on them (e.g. tourism, agriculture, fisheries). Another example relates to the dependence of human and societal wellbeing on relatively stable and benign environments, which are being increasingly compromised by the growing risks or threats of novel and emerging pests and diseases (see Introduction to Guidance).

10. Dessai, S., Hulme, M., Lempert, R. and Pielke, R. Jr. 2009. Do we need better predictions to adapt to a changing climate? *EOS* 90 (13):111-112. Accessed 27 June, 2019 at ***https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2009EO130003***

Exploratory scenarios of natural hazards under climate change could include:

- ***'Death by a thousand cuts'*** – when well-known, seasonal events gradually become more frequent, widespread, longer-lasting or intense under climate change
- ***'Extreme to catastrophic events' or 'inevitable surprises'*** – when single or multiple high-consequence events converge with a range of trends and extremes, simultaneously or sequentially (e.g. Tasmania's 2016 Summer of fires and floods[11]) or where multiple events arise at the same time across different regions
- ***'Insidious chronic stresses leading to future shocks'*** – when thresholds are crossed or decisions reach tipping points (e.g. widespread coastal inundation, extended extreme droughts and degrading and transforming ecosystems and biophysical processes under climate change which create chronic stresses and catastrophic shocks to the ongoing viability of human activities that depend on them).

For these types of situations, exploratory scenarios can:

- help reframe and build understanding of the unprecedented changes in natural hazards under climate change and recognition that these could become increasingly unpredictable and unmanageable;
- broaden the applicability of probability-based approaches, by integrating them within a wider range of possibilities that accommodate radical shifts in the environment;
- integrate with scenarios of changing socio-economic, infrastructural, technological and population futures to explore possible future exposure and vulnerability (see 6.3 to 6.5); and
- progressively build new forms of knowledge and ways of explicitly considering uncertainty across a broad range of decision-making needs, including the use of 'low regrets' approaches to hazard assessment and management.

11 *http://theconversation.com/was-tasmanias-summer-of-fires-and-floods-a-glimpse-of-its-climate-future-58055*

Benefits in applying exploratory scenarios to natural hazards under climate change include that they:

- help reframe and build understanding of changes in natural hazards under climate change and recognition that these could become increasingly unpredictable and unmanageable;
- broaden the applicability of probability-based approaches recognition by integrating them within a wider range of possibilities that accommodate radical shifts in the environment;
- can inform exploratory scenarios of exposure and vulnerability (see 4.3 – 4.5); and
- progressively build new forms of knowledge and ways of explicitly accounting for deep uncertainty across a range of decision making needs (i.e. 'low regrets' approaches to hazard assessment and management).

Exploratory scenarios of natural hazards in a changing climate can be developed a number of ways. They can involve numerical-based approaches, descriptive story telling approaches or a combination of both (i.e. quantitative, qualitative or mixed-method).

Quantitative approaches

Quantitative scenarios of natural hazards in a changing climate include:

1. *Global and downscaled climate model projections*
These are either process, statistical or mathematical models, useful for high-level assessments of changing trends of weather-related hazards.

An authoritative set of climate change scenarios for Australia, with standardised guidance on how to consistently apply these across scales, has not yet been developed to serve as a foundational point of reference. This is a critical challenge to developing exploratory scenarios of natural hazards under a changing climate in Australia.

A consistent suite of scenarios and associated guidance would provide coherence and consistency in the consideration of future potential threats and impacts in organisational, sectoral or jurisdictional assessments of climate and disaster risks. In the absence of these, there are several recommendations for climate scenario modelling:

- Current leading practice (e.g. Climate Compass: a climate risk management framework for Commonwealth agencies) suggests stress testing using the greatest plausible change based on a climate change scenario with Representative Concentration Pathway (RCP) of 8.5 to assess physical risk[12]. For long term decisions (beyond 2050) use of more than one scenario should be considered.

12 van Vuuren, D.P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J-F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J. and Rose, S.K. 2011. The representative concentration pathways: an overview. Climatic Change 109 (1):5. Accessed 27 June, 2019 at: ***https://link.springer.com/article/10.1007/s10584-011-0148-z***)

- The Task Force on Climate-related Financial Disclosures (TCFD) in their technical supplement on the use of scenario analysis recommends using a 2°C warming (between RCP 2.6 and RCP 4.5) scenario when assessing 'transition risks' and using both the RCP 4.5 and RCP 8.5 when assessing exposure and vulnerability to the physical impacts of climate change. This is to ensure robust responses to the range of potential futures are identified and considered in long-term strategies and plans.

2. Numerical simulation models
Natural hazard simulation models are more complicated process, statistical or mathematical models and consider a combination of physical processes to inform more detailed local planning and infrastructure investment decisions. Modelling tsunami, tropical cyclone, flooding, landslide or bushfire often require some datasets on the characteristics of the landscape (i.e. topography, geology and bathymetry), the atmosphere and the antecedent conditions (i.e. temperature, rainfall, shaking, tides, wind speed, soil moisture). Useful guidance for developing and using hazard models for probabilistic hazard risk assessments are in the "Words in Action Guidelines" of the United Nations Office for Disaster Risk Reduction (UNDRR).

Examples of some national or publicly funded natural hazard modelling tools and data sources are provided in Further Reading. Some of these tools factor in climate change although many do not.

Some methods target short term hazard modelling and are based on historical analysis. The decision context must be clearly understood in order to select the appropriate approach to consider natural hazards under climate change. Systemic risks are emergent and not necessarily obvious when using hazard based approaches.

Most models have been based on historical data and observations, assuming that the past is a reasonable guide to the present and the future. That assumption has been rendered obsolete on almost every frontier.

Source: 2019 Global Assessment Report on Disaster Risk Reduction

Quantitative or mixed-methods approaches

Mixed-methods approaches to developing exploratory scenarios of natural hazards under climate change involve storylines of plausible, extreme or worst case situations. These could include unprecedented and surprising combinations of multiple hazards or extreme values of hazards that exceed highest recorded values in historical records.

For example, they can be used for contextualising the State of the Climate Report for Australia (i.e. problem focussed and developed top down). They can also be used to reveal potential limitations or thresholds in existing practices or infrastructure at a more local scale (i.e. decision focused and developed bottom up).

Some exploratory scenarios of potential natural hazards will be outside the lived experiences of those involved. The scenarios will benefit from drawing upon diverse forms of knowledge including but not limited to science, expert judgement and relevant experiential and traditional knowledge.

Experiential and traditional forms of knowledge are particularly critical for scenarios exploring unprecedented extremes. It is well documented that people have difficulty imagining circumstances or events that they have not previously experienced, even when there may be reliable data on these risks.

Experiential and traditional forms of knowledge are particularly critical for scenarios exploring unprecedented extremes.

Examples of exploratory storylines of natural hazards under climate change

- An application of the climate analogues approach[13] in Nepal which was used to help farmers visualise their future climate and associated vegetation/environment in order to 'experience' the change and begin to exchange knowledge with people currently living in those climates and environments[14].
- Scenarios developed for *Profiling Australia's Vulnerability* drew upon the experiences of historical extreme events, expert judgement and emotional narratives of what could happen if such events eventuated. The storylines of plausible extreme to catastrophic scenarios were used to stretch the imagination of stakeholders to a point of considering the almost preposterous events, stress-test limitations of existing systems to prepare or cope and to identify the systemic causes of vulnerability that lead to disaster.
- The Queensland Reconstruction Authority's recent efforts in coordinating a place-based participatory approach to developing the Burnett Catchment Flood Resilience Strategy, which drew upon local indigenous history which speaks of 'big floods' of higher magnitude than those in the official records since 1875[15].

13. *https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/*
14. Jones, E., D. Arango, J. Ramírez Villegas, O. Bonilla-Findji, M. Bailey, A. Chaudhury, C. Sova, J. Thorn, A.E.S. Helfgott, and A. Jarvis. 2014. Farms of the future guidelines. CGIAR Research Program on Climate Change, Agriculture and Food Security and International Center for Tropical Agriculture (CIAT). *https://ccafs.cgiar.org/publications/farms-future-guidelines#.XRQkaLmP6tQ* and *https://ccafs.cgiar.org/farms-future#.XOXj1DoUmUl*
15. QRA. 2018. A connected catchment: Burnett Catchment Flood Resilience Strategy - an overview. The State of Queensland (Queensland Reconstruction Authority, QRA). Accessed 27 June, 2019 at: *https://www.qra.qld.gov.au/burnett*

How to use these

Broadly speaking, the purpose of exploratory hazard scenarios is to explore probable, plausible, possible and even preposterous hazard futures (Figure 2). They raise awareness, stretch current thinking, stress-test current practices and catalyse actions to reduce the possibility of 'inevitable surprises.'

Both numerically based hazard scenarios and descriptive storylines can usefully inform rapid high-level scans of natural hazards. They can also be a starting point, from which to develop other types of scenarios explained in this guidance.

The decision context can help determine whether exploratory scenarios are useful, and whether a quantitative or qualitative approach is best-suited. Regulatory requirements and the availability of time, money, capacity, models and data can often determine whether a numerical model-based approach is used or whether a descriptive storyline approach is more suitable.

Climate risk reporting of signatories to the Task Force on Climate-Related Financial Disclosure (TCFDs), the legal implications of the Hutley legal opinion[16] and the elevation of baseline expectations of investors and regulators around corporate disclosure of climate-related financial risks[17] have had significant impact on the need for scenarios.

Leaders of private corporations are frequently required to provide robust qualitative and quantitative estimates of their exposures and vulnerabilities to climate risks. They are also required to demonstrate how they are actively managing them.

Quantitative projections can be extremely resource intensive. They are generally used when the stakes are high and required by regulation and legislation. For example:

- large investments in critical infrastructure;
- emergency management preparedness planning; and
- specific locations or organisations where long-term viability depends on specific information (i.e. engineering, financial, insurance and investment decisions).

In these situations, sufficient expertise and resources are generally made available for investing in the development of the quantitative modelling capabilities and generating the exploratory scenarios.

The products generated from these modelled projections include static or interactive maps (often available online) showing the extent and magnitude of the hazard under different scenarios of change and at different points in time. These hazard projections under different climate scenarios can then be added to other data layers (e.g. population distribution, infrastructure and agricultural regions). These can then reveal future exposures of locations to these changing hazards under climate change (see 4.3).

Embedding quantitative scenarios within qualitative strategies is an effective way of engaging people's hearts and emotions. This is necessary for catalysing shifts in thinking and action by building, agency and hope.

16. CPD. 2019. Updated Hutley opinion on directors' duties and climate risk. Supplementary Memorandum of Opinion. Report prepared by the Centre for Policy Development (CPD). Accessed 27 June, 2019 at: ***https://cpd.org.au/2019/03/directors-duties-2019/***
17. Barker, S. 2019. New developments impact climate change related risks. Minter Ellison. Accessed 27 June, 2019 at: ***https://www.minterellison.com/articles/new-developments-impact-climate-change-related-risks***

4.3. Scenarios of future exposure

Scenarios of future exposure are mostly problem-focused scenarios. They can be either descriptive or strategic and can be developed with a particular decision maker or decision context in mind.

The purpose of these scenarios is to answer the question ***'What could happen to the exposure of locations, people, services and assets across landscapes over time?'***

Exposure scenarios are generated by combining exploratory scenarios of natural hazards under climate change (see 4.2) with scenarios of potential changes to the spatial distributions of population, infrastructure and essential services. In these scenarios, places and settings that could be adversely affected are considered and different policy, technology and socio-economic environments are tested.

These scenarios are 'driven' by different assumptions about the possible effects of variables such as:

- policies and decisions on population demographics and distribution; and
- the effects of land-use zoning and technological developments.

Overlaying the spatial distributions of these variables under different scenarios provides indications of which policies and decisions will lead to more or less exposure over time under each scenario.

Initial assessments of the changing exposure of people, services and assets against shifting hazards is usually undertaken as rapid high-level scans in the early stages of decision making. This raises awareness of the issues and helps identify priority areas (i.e. 'hot spots') for further analysis.

These are also often combined with rough measures of potential damage or economic cost based on simplified assumptions about what percentages of exposed areas are damaged. Note, there is usually no consideration of the actual physical vulnerability of a given asset to a given natural hazard in these scenarios. The application of these are explained in 4.4.

Scenarios of exposure are useful because they are not particularly data intensive. The data are more readily available and quantifiable (e.g. population distributions and projections, trends in land-use, construction and economic activity) than the data required for generating exploratory scenarios of societal vulnerability (see 4.5) or normative scenarios of disaster risk reduction (see 4.6).

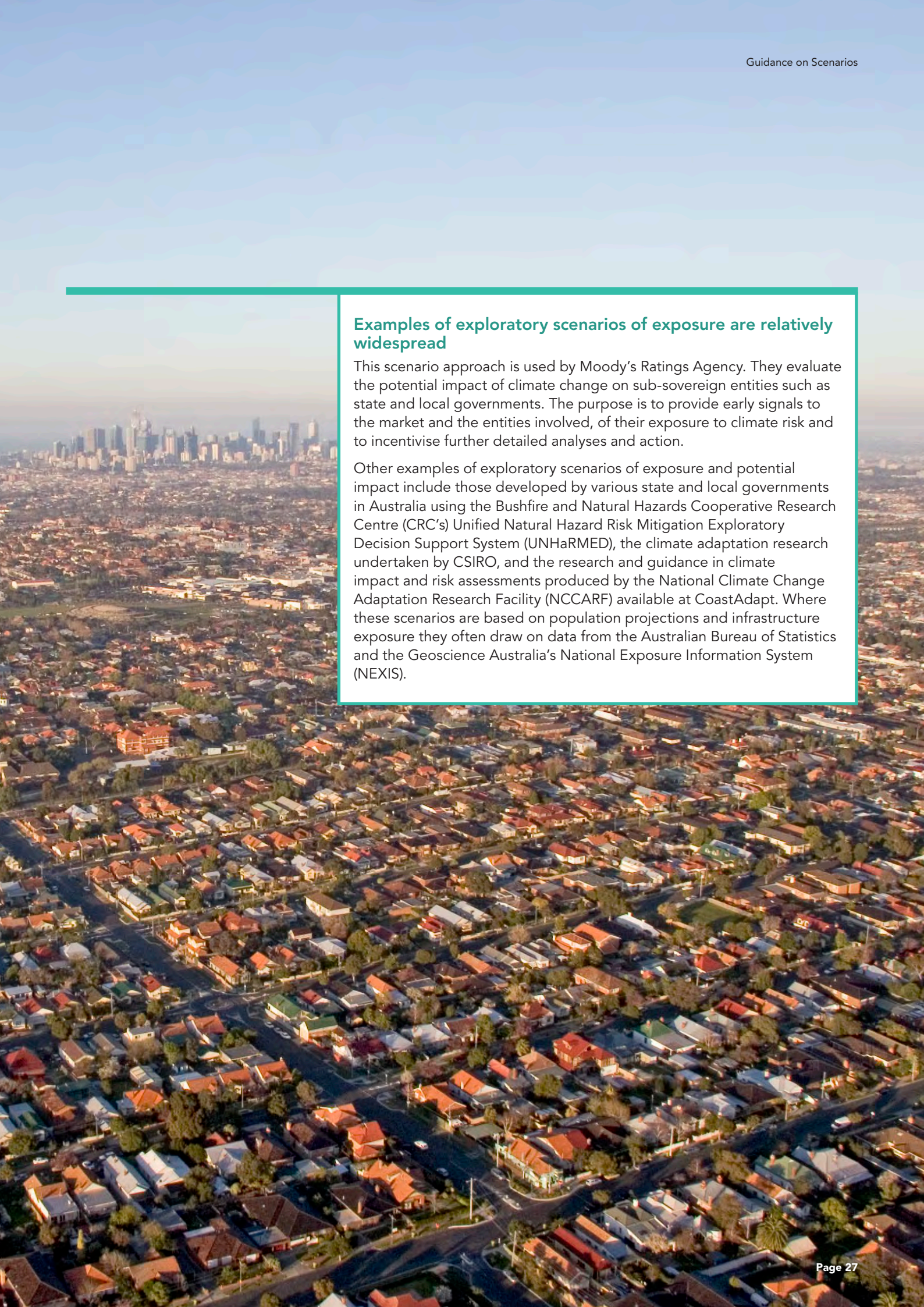
Exposure scenarios should not be used in isolation to prioritise interventions because they are generally poor proxy indicators of potential impact and loss. A more holistic and people-centred approach to interventions for climate and disaster risk reduction needs to be supported (see 4.5 and 4.6). A people-centred approach to inform intervention priorities requires the inclusion of information on:

- the causes of the exposure;
- the multidimensional aspects of vulnerability; and
- the potential cascading impacts of disruption from disaster.

Did you know?

An over-reliance on using asset losses to potentially explain risk or vulnerability obscures the relationship between underlying drivers of disaster and climate and disaster risk. By definition wealthy individuals have more assets to lose; therefore, their interests may dominate in exposure assessments that are limited to asset losses.

Source: 2019 Global Assessment Report on Disaster Risk Reduction



Examples of exploratory scenarios of exposure are relatively widespread

This scenario approach is used by Moody's Ratings Agency. They evaluate the potential impact of climate change on sub-sovereign entities such as state and local governments. The purpose is to provide early signals to the market and the entities involved, of their exposure to climate risk and to incentivise further detailed analyses and action.

Other examples of exploratory scenarios of exposure and potential impact include those developed by various state and local governments in Australia using the Bushfire and Natural Hazards Cooperative Research Centre (CRC's) Unified Natural Hazard Risk Mitigation Exploratory Decision Support System (UNHaRMED), the climate adaptation research undertaken by CSIRO, and the research and guidance in climate impact and risk assessments produced by the National Climate Change Adaptation Research Facility (NCCARF) available at CoastAdapt. Where these scenarios are based on population projections and infrastructure exposure they often draw on data from the Australian Bureau of Statistics and the Geoscience Australia's National Exposure Information System (NEXIS).

4.4. Scenarios of future vulnerability of infrastructural assets

These exploratory scenarios of the vulnerability of infrastructure and the built environment draw upon scenarios of hazards and exposure.

The purpose of these scenarios is to answer the question ***'What could happen to vulnerable infrastructural assets in the future?'***

They introduce measures of fragility and vulnerability of different infrastructure types and the potential damage/cost if they are impacted. Their purpose is to raise awareness (descriptive) and inform decisions (strategic) of the potential for the built environment to be exposed to, or damaged by, the forces of natural hazards in the future.

They can be targeted at:

a) a specific exposed asset (i.e. such as critical infrastructure); or

b) many infrastructural assets over large geographical areas including networked infrastructure.

Specific asset scenarios tend to consider factors that affect the fragility of infrastructure and its susceptibility to damage as constant over time. They draw upon existing probability-based damage functions for specific buildings and hazard types. Other drivers, such as the type of hazards or exposure are then varied as the basis of these scenarios.

Scenarios that consider many infrastructure assets and are broader geographically also tend to assume a constant susceptibility or vulnerability to harm. However, examples are emerging of strategic scenarios of infrastructure vulnerability which explore the influences of stricter building standards, design requirements or land-use zoning under different (i.e. implicit or explicit) policy and regulatory environments (e.g. UNHaRMED). These might be more aptly classified as a subset of normative scenarios of possible interventions to reduce infrastructural disaster risk.

These examples currently do not consider the increasingly unprecedented and transforming nature of natural hazard behaviours under climate change. However, they can be expanded to do so using qualitative storylines[18] or introducing sets of 'stochastic-events' using computer modelling[19].

Generally speaking, both approaches to these scenarios have the advantage of accessible quantitative data such as building locations, building functions, damage functions, economic costs and land-use zones, making quantitative exploratory scenarios possible.

Recently developed tools and applications of some of these tools to explore scenarios of physical vulnerabilities of infrastructure and built environments are provided in Further Reading.

18 Shepherd TG, Boyd E, Calel RA et al. Storylines: an alternative approach to representing uncertainty in physical aspects of climate change. Climatic Change 2018; 151: 555-571.

19 An example of this is Robust Decision Making. See Marchau, V.A.W.J., Walker, W. E., Bloemen, P.J.T.M. and Popper, S.W. eds. 2019. *Decision Making under Deep Uncertainty: From Theory to Practice*: Springer, Switzerland. Accessed 27 June, 2019 at: ***https://link.springer.com/content/pdf/10.1007%2F978-3-030-05252-2.pdf***

How to use these

Scenarios of future infrastructure vulnerability to inform project-level investments in resilience tend to be based on highly specialised and quantitative modelling approaches. They are generally developed by experts in partnership with the relevant owners and managers of the infrastructure asset(s).

Scenarios of future vulnerabilities of the built environment for high-level strategic scans or policy and portfolio assessments tend to be more high-level and top-down. They are based on available macro-level indicators and trends of governance, population, land-use, climate change, infrastructure location and socio-economic development. In these cases, technical expertise is not required for developing the scenarios. The resources and guidance provided here and in Climate Compass: A climate risk management framework for Commonwealth agencies are ideal for these purposes.

Due to the widespread and highly interconnected nature of climate and disaster risks, infrastructure-focused scenarios will increasingly need to be informed by exploratory scenarios of future natural hazards or future societal wellbeing or vulnerability at larger and smaller scales. The decision to defend, accommodate or retreat an infrastructure asset, for example, needs to consider more complex cross-scale scenarios of future hazards, societal vulnerabilities and adaptive pathways as responses.

Vulnerability-based approaches that reveal potential escalation points are emerging, which orient the nature of cascading effects in relation to society's feedback loops, rather than merely being an effect of natural triggers on a single infrastructure asset or network[20].

20 Pescaroli, G. Alexander D. 2016. Critical infrastructure, panarchies and the vulnerability paths of cascading disasters. *Natural Hazards*. 82:175-192

4.5. Scenarios of societal vulnerability

These exploratory scenarios focus on understanding the causes and effects of societal vulnerability. They answer the question ***'What could happen to the vulnerability of people (communities) over time in the context of changing natural hazards and climate?'***

Vulnerability describes the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community or systems to the adverse effects of hazards and climate change.

Vulnerability is therefore inherently dynamic, across temporal and spatial scales. However, the IPCC (2014) and UNDRR (2017) have emphasised that despite vulnerability being dynamic, most assessments of vulnerability only use present-day measures which are not projected into the future. There are growing calls for more empirical, methodological and conceptual development of these issues especially at the regional or local level.

Suggestions by the IPCC and UNDRR for how to reflect vulnerability dynamics in scenarios include using socio-economic scenarios to develop trends and pathways and using demographic projections (e.g. aging population, gender and poverty trends).

Vulnerability is currently the least understood dimension of disaster risk. Scenarios of future vulnerability that consider the dynamics and complexity of vulnerability are limited and are urgently needed. There are two focus points for scenarios of future vulnerability:

- Descriptive – entirely oriented towards general top-down diagnoses and descriptions of societal vulnerabilities at a high-level, and largely independent of specific decisions or decision makers. These are used to raise awareness, help (re-) frame problems or provide the boundary conditions to inform the development of detailed local-scale (bottom-up) vulnerability scenarios; and
- Strategic – targeted to specific decisions or decision makers. They emphasise the causes and effects of vulnerability. These reveal the leverage points a target decision maker has influence or control over and the potential consequences of acting on these leverage points.

There may be limited ability at local scales to address the deeper political, social and economic forces contributing to the systemic vulnerability that puts people at risk in the first place. Disaster risk reduction interventions may become fragmented and focus on a series of small-scale initiatives, artificially separating from the surrounding vulnerability context[21].

Indicator-based approach

The indicator-based approach to developing exploratory scenarios of future societal vulnerability uses indicators of adaptive capacity or vulnerability. Present-day socio-economic data is used to describe and visually represent and rank regions or countries in terms of their vulnerability. Indicators are derived using existing social and economic variables included in official economic and governance reports or census data and measures of wellbeing losses[22] or resilience[23].

21 Twigg, J. 2015. Good practice review on Disaster Risk Reduction at *https://goodpracticereview.org/9/*

22 Twigg, J. 2015. Good practice review on Disaster Risk Reduction. Report prepared for the Humanitarian Practice Network. Accessed 27 June, 2019 at: *https://goodpracticereview.org/9/*

23. GFDRR. 2016. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Report prepared by the Global Facility on Disaster Reduction and Recovery (GFDRR) and the World Bank. Accessed 27 June, 2019 at: *https://www.gfdrr.org/en/publication/unbreakable-building-resilience-poor-face-natural-disasters*

These provide aggregated proxy measures of vulnerability or the adaptive capacity of entities today, which are then projected into the future based on assumptions about how the trends and forecasts of these socio-economic and population variables might change over time. These can be applied at a high level, as top-down (i.e. macro-level) descriptive scenarios to raise awareness and help frame issues for high-level policy processes. They can also be applied at a local scale as bottom-up strategic scenarios to reveal critical drivers and trends that decision makers will need to better understand and manage.

These approaches tend to be spatially explicit and therefore can be mapped with other spatial data layers to reveal overlaps and potential hotspots of vulnerability over space and time (e.g. scenarios of future natural hazards and exposure; such as UNHaRMED). In doing so, these approaches reveal the priority and most uncertain proximate causes of vulnerability, based on aggregate and quantifiable measures of impact.

However, these approaches do not reveal the complex and dynamic contextual dimensions of the root causes and effects of vulnerability. A strong argument can be made for more explicitly 'topping and tailing' these indicator-based approaches with systemic vulnerability assessments, such as provided in the Guidance on Vulnerability.

Systems and values-based approach

The systems and values-based approach to developing exploratory scenarios of societal vulnerability starts with the recognition that societal vulnerability is a "complex, constantly evolving and changing phenomenon that needs to be situated within interactions between biophysical and socio-economic elements"[24].

The approach seeks to understand the root causes and effects of vulnerability to identify the key controlling variables and the factors that affect these. They involve qualitative and empirical studies of the context.

From a baseline understanding of the current state, qualitative or quantitative scenario approaches are then developed to generate scenarios of future vulnerability under different assumptions about how the drivers and variables might interact over time.

These future scenarios of societal vulnerability can be created in a number of ways. They can adopt qualitative, quantitative or mixed-methods approaches and are often incorporated into scenario planning processes such as the Oxford Scenario Planning approach.

Frequently used approaches to developing social vulnerability scenarios

A scenario planning approach, such as the Oxford Scenario Planning Approach, provides a minimum of **four scenarios** or **four alternative** futures based on explorations of the interactions between the most important and uncertain drivers of change.

The value in having four scenarios that articulate the range of possible futures is that it forces stakeholders to be exposed to multiple often contested interests, values and assumptions about what could and should happen to the world. These then form the basis for the often difficult deliberations and negotiations about how best to intervene given the uncertainties, the potential for large-scale change and the need to revisit values, goals and objectives.

In general, the most effective way for making progress in developing scenarios and strategies of 'what can be' in such uncertain and contested situations is to base these on principles and approaches of robustness and adaptability (see 4.6).

Readily accessible guidance on applying a scenario planning approach include:

- Futures Thinking Methodologies and Options: *www.oecd.org/education/ceri/35393902.pdf*
- Strategic thinking using scenario planning: *http://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mtkx/~edisp/dd_191840.pdf*
- Scenarios planning to inform adaptation pathways: *https://www.sciencedirect.com/science/article/pii/S2212096315000376*

24 Jurgilevich, A., Räsänen, A., Groundstroem, F. and Juhola, S. 2017. A systematic review of dynamics in climate risk and vulnerability assessments. *Environmental Research Letters* 12 (1):013002. Accessed 27 June, 2019 at: *https://iopscience.iop.org/article/10.1088/1748-9326/aa5508/pdf*

Some of the modelling tools for supporting the development of these scenarios planning approaches to exploring potential future vulnerabilities include: soft-systems modelling, agent-based simulation modelling, process simulation modelling (e.g. simulation of thresholds such as mortality thresholds with heat temperatures, or inundation tipping points, or identifying levels after which citizens are not able to cope with or adapt to climate change impacts) and war gaming (see Further Reading).

There are few examples of systems- and values-based exploratory scenario approaches to developing scenarios of future societal vulnerability to natural hazards under climate change. Two examples include:

- The narrative scenarios and storylines used to develop *Profiling Australia's Vulnerability* (see Deconstructing Disaster in the Guidance on Vulnerability); and
- Futures Greater Adelaide 2050[25]: An exploration of disaster risk and the future.

How to use these

The ***indicator-based approach*** to exploratory scenarios of social vulnerability can be developed and used in much the same way as infrastructure vulnerability scenarios. However, since in this case the focus is on people there are many more variables to consider in the vulnerability criteria. There are also many more potential drivers that directly or indirectly influence vulnerability.

This opens up the scenario space and requires the capacity to estimate and project changes in the vulnerability criterion (criteria) under changes in the drivers over time. The outputs from these scenarios are spatially mapped aggregate measures of social vulnerability. These are useful as initial high-level scans revealing relative priority areas (i.e. hotspots on vulnerability heat maps).

Because the criteria are aggregations of proxy measures, they hide the contextual variation within regions and cannot provide information about the systemic causes. To partially overcome these limitations, it is recommended this approach be topped and tailed with a more systemic- and values-based assessment of vulnerability.

Demonstrating how and why things could quickly become better or worse increases preparedness for the range of possibilities the future may hold, and willingness to engage in conversations about the systemic causes of vulnerability.

The ***systems and values-based*** approach to generating exploratory scenarios needs to be participatory to draw on diverse knowledge types including scientific, experiential and traditional knowledge. Vulnerability manifests in variations within communities in levels of social disadvantage, political sentiment, social cohesion, and capacities to cope and adapt. A broad range of perspectives can help to disentangle the complex and interconnected nature of the causes and effects of vulnerability.

A participatory and adaptive learning approach (see Guidance on Vulnerability) also contributes to the joint creation of new and shared knowledge. As mental models and world views are shared they support novel reframing of problems and opportunities. To encourage broader and more reflective deeper thinking it is helpful to introduce a suite of extreme hazard or disaster scenarios that catalyse a shift away from thinking the future will be similar to today or that change will only occur gradually.

Demonstrating how and why things could quickly become better or worse increases preparedness for the range of possibilities the future may hold, and willingness to engage in conversations about the systemic causes of vulnerability.

Guidance on how to develop and use scenarios of societal vulnerability is provided in the Guidance on Vulnerability.

25. Riddell, G. A., van Delden, H., Dandy, G., Maier, H., Zecchin, A., Newman, J. and Newland, C. 2017. Futures Greater Adelaide 2050: An exploration of disaster risk and the future. Bushfire and Natural Hazards CRC, Melbourne. Accessed 27 June, 2019 at: ***http://www.bnhcrc.com.au/publications/biblio/bnh-3355***

4.6. Scenarios of climate and disaster risk reduction

These are normative scenarios for developing answers to the question ***'What can happen?'***

Normative scenarios are possible future trajectories of actions or interventions to shift the system onto more desirable paths or away from undesirable paths. These scenarios allow people to explore future possibilities focused on the performance of climate and disaster risk reduction strategies or pathways over time.

Comparisons across these scenarios reveal which options perform satisfactorily across most futures (i.e. low regret or robust solutions) and which perform optimally under a subset of scenarios, usually the expected or preferred possible future (i.e. the optimal solution). These scenarios are also referred to as pathways (e.g. adaptation pathways, climate resilience development pathways, transition pathways) and as transition scenarios.

In the context of unprecedented change, normative scenarios are needed to help decision makers evaluate and make choices between options or strategies that:

a. maintain or preserve the status quo; or
b. transform existing practices and norms towards alternative visions or goals considered to be more compatible with very different and highly uncertain futures.

Two conceptually different approaches are available to develop scenarios of climate and disaster risk reduction to support these decisions.

The first approach is a static approach. A single fixed strategy – comprising one or many actions implemented over the planning horizon – is identified by back-casting from (or forecasting to) a static desirable future goal or endpoint. This is done through assessing the performance of the strategy at achieving the goal under different scenarios of 'what could happen'. Performance is assessed based on agreed upon criteria such as robustness, low regrets, or optimality.

This first approach conforms to an 'agree-on-assumptions-first' basis. It is most suited to familiar or controlled situations or conditions where uncertainties are relatively tractable and agreement can be reached on the future behaviour of the system (e.g. highly controlled and regulated environments such as the reliable provision of critical energy and water services to large populations).

The second approach is an adaptive approach. Multiple flexible strategies are developed that are tailored to different future conditions. Included, is the option to switch between them over the length of the planning period in response to increased knowledge about the state of the world. The adaptability of these multiple strategies essentially provides multiple pathways or scenarios for responding to different plausible futures.

This second approach conforms to an '*agree-on-decisions-first*' basis. It defers agreement on assumptions about how the world works or might unfold until decisions or options have been analysed under many alternative sets of assumptions, expectations, values and goals. This involves a process of 'scenario discovery' which is illustrated in Figure 6. The process of scenario discovery also aligns to Steps 1 to 4 of the adaptive risk assessment and management learning approach.

The iterative process of 'Scenario Discovery'

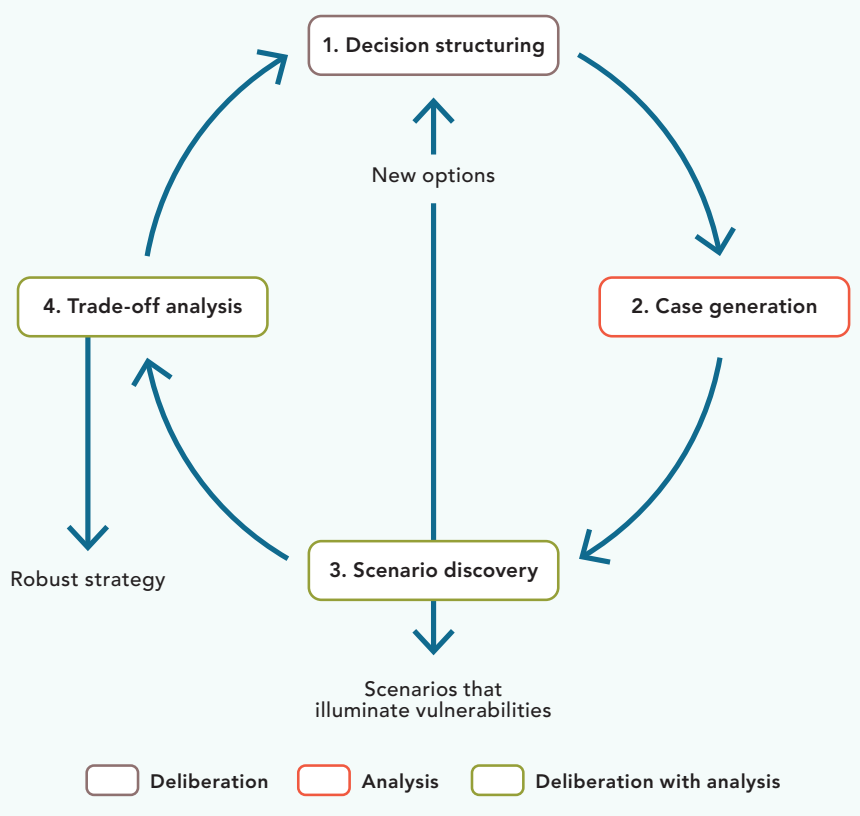


Figure 6: Schematic of the steps involved in iteratively discovering vulnerability scenarios and robust mitigation

The iterative process of scenario discovery begins with a decision-structuring exercise. In this exercise, decision makers define the goals, values, uncertainties and choices that need to be considered. This exercise will identify one or more policies that will be the focus of the initial iterations of the analysis.

This is followed by stakeholders generating multiple scenarios of the performance of the proposed policy under plausible futures. This considers the possible combinations of the initial set of goals, values, uncertainties and choices. This can be done qualitatively or quantitatively.

The latter would involve analysts using computer models to generate a large database of scenario 'runs', where each run represents the performance of a proposed policy.

The iterative process of 'scenario discovery' continues where decision makers identify and cluster future situations that illuminate vulnerabilities of the policies (this could be aided by computer visualisation and statistics where quantitative data exist). These scenarios help decision makers identify potential new ways to address those vulnerabilities. The potential new ways to can be evaluated through trade-off analysis to determine which are worth adopting.

This process continues until decision makers settle on strategies or pathways that most closely meet their decision criteria, which in the case of high uncertainty is generally one of robustness.

Importantly, the scenarios do not need to be assigned a likelihood or probability. However, where data are available or there is confidence and agreement in stakeholders' subjective estimates of the likelihood of different scenarios, then these can be applied in the process.

Source: Lempert, R. 2014. Embedding (some) benefit-cost concepts into decision support processes with deep uncertainty. Journal of Benefit-Cost Analysis. 5:3 pp.487-514

How to use these

These scenarios are used as the basis for developing strategies and plans to adapt to climate change, reduce exposure and vulnerability to hazards and build resilience.

They can be developed and applied for use in assessments of one-off interventions at a single scale or across scales, and for assessing multiple sequenced options that are either preserving of the status quo or transformational in their intent.

The assessment approaches described typically inform or feed into disaster risk strategy development and planning and climate adaptation planning.

There are numerous approaches available to develop normative scenarios of future vulnerability and interventions scenarios or adaptive pathways. Five are provided:

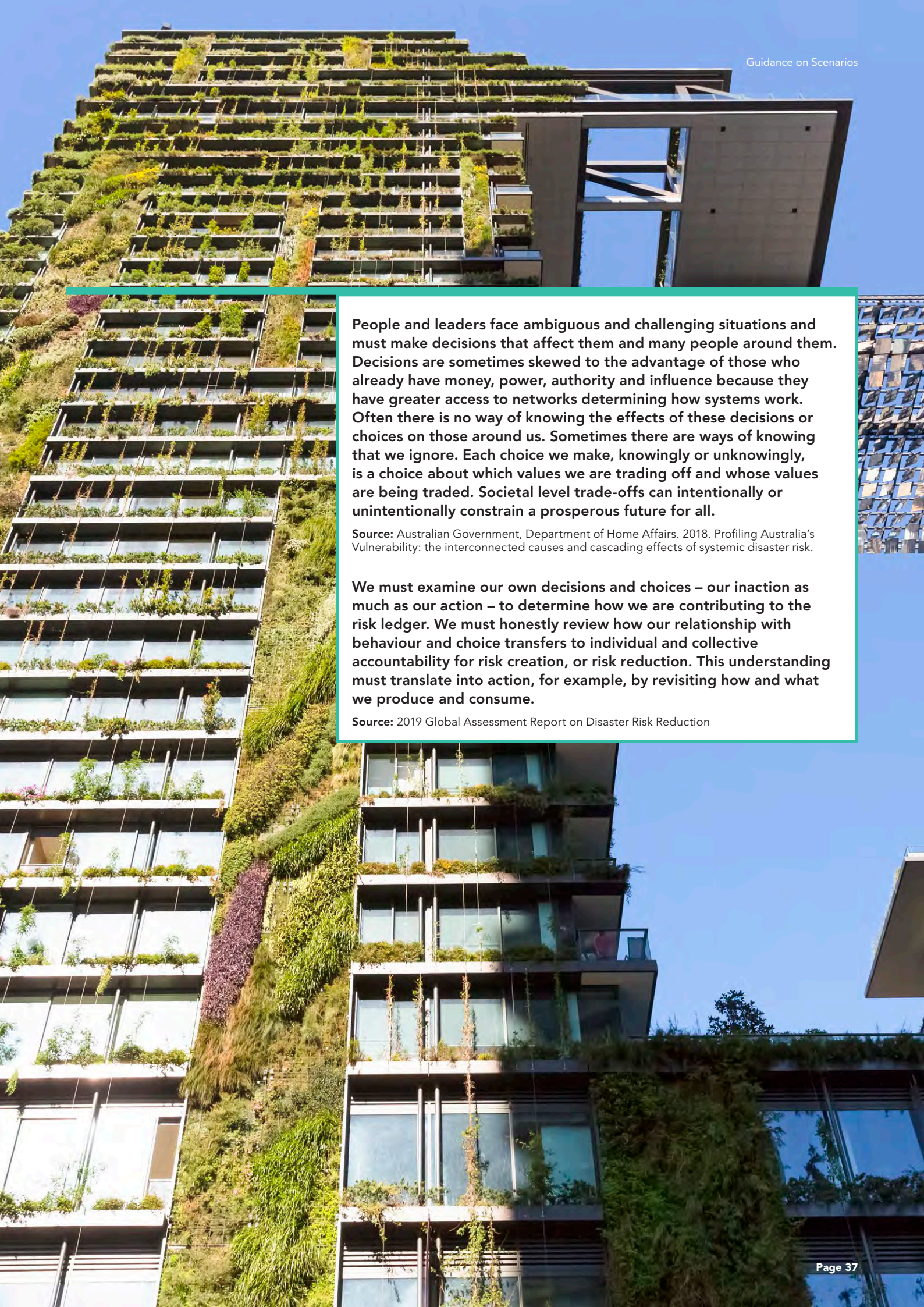
- **The Robust Decision Making approach:**
  https://www.rand.org/topics/robust-decision-making.html
  https://link.springer.com/chapter/10.1007%2F978-3-030-05252-2_2
- **The Dynamic Adaptive Policy Pathways approach:**
  https://www.deltares.nl/en/adaptive-pathways/
  https://www.sciencedirect.com/science/article/pii/S095937801200146X
- **The Real Options for Adaptive Decisions approach:**
  https://www.researchgate.net/project/ROADs-2020-Real-Options-for-Adaptive-Decisions
- **The Transformational Adaptation Pathways approach:**
  https://research.csiro.au/tara/core-concepts/
- **The Resilience Adaptation Pathways and Transformation approach:**
  https://research.csiro.au/eap/what-is-rapta/
  http://www.stapgef.org/rapta-guidelines

The suitability of each of these approaches depends on the levels of capability and data, uncertainty in knowledge, distribution of power, and ambiguity in the goals.

The first three approaches are most effectively or appropriately used where data and computer modelling capabilities are high. These can also be applied qualitatively to structure a process of problem framing and exploration of high-level options. The latter two approaches can be applied entirely qualitatively or as mixed-methods approaches if quantitative modelling capabilities are available to support and inform the processes.

Since the first three approaches are primarily quantitative they tend to be more suited to situations where there is a clear decision maker with the agency and mandate to make and act on decisions (i.e. the distribution of power is low) and where the goals are unambiguous. The latter two approaches, have been developed and are well equipped to deal with high ambiguity (i.e. the distribution of power is high).

All approaches need to be participatory and require capacity and commitment to undertake the necessary (often extensive and extended) stakeholder engagement.



People and leaders face ambiguous and challenging situations and must make decisions that affect them and many people around them. Decisions are sometimes skewed to the advantage of those who already have money, power, authority and influence because they have greater access to networks determining how systems work. Often there is no way of knowing the effects of these decisions or choices on those around us. Sometimes there are ways of knowing that we ignore. Each choice we make, knowingly or unknowingly, is a choice about which values we are trading off and whose values are being traded. Societal level trade-offs can intentionally or unintentionally constrain a prosperous future for all.

Source: Australian Government, Department of Home Affairs. 2018. Profiling Australia's Vulnerability: the interconnected causes and cascading effects of systemic disaster risk.

We must examine our own decisions and choices – our inaction as much as our action – to determine how we are contributing to the risk ledger. We must honestly review how our relationship with behaviour and choice transfers to individual and collective accountability for risk creation, or risk reduction. This understanding must translate into action, for example, by revisiting how and what we produce and consume.

Source: 2019 Global Assessment Report on Disaster Risk Reduction

5. Further reading

Complementary guidance documents

The UNDRR's "Words in Action Guidelines" which provide a series of guidance documents to assist in the assessment and prioritisation of climate and disaster risks such as:

- guidance for undertaking national disaster risk assessments, including using hazard models for probabilistic hazard risk assessments are in *https://www.unisdr.org/we/inform/publications/52828*
- guidance for developing national disaster risk reduction strategies *https://www.unisdr.org/we/inform/publications/65095*

The Task Force on Climate-related Financial Disclosures (TCFD) technical supplement on the use of scenario analysis:

- *https://www.fsb-tcfd.org/publications/final-technical-supplement/*

Climate Compass: A climate risk management framework for Commonwealth agencies is designed to help Australian public servants manage the risks from the changing climate to policies, programs and asset which includes step by step instructions, guidance and information to develop an understanding of climate change risks:

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

Aspirational scenarios or visions of the future

Exemplary examples of aspirational scenarios in Australia include:

- The A24 Australia Remade vision *https://www.australiaremade.org/*
- The Academy of Science's "Australia 2050 Living Scenarios" *https://www.science.org.au/support/analysis/reports/australia-2050-conversations-about-our-future*
- The visions for successfully living with natural hazards developed by stakeholders involved in the *Profiling Australia's Vulnerability* *https://knowledge.aidr.org.au/collections/profiling-australias-vulnerability/*

Exploratory scenarios of natural hazards under climate change

Projections of future behaviours (averages and extremes) of climate-related hazards such as temperatures, heatwaves, rainfall and cyclones under a changing climate are available at:

- *http://www.bom.gov.au/state-of-the-climate/*
- *https://www.climatechangeinaustralia.gov.au/en/climate-campus/climate-extremes*
- *https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/map-explorer/*

Climate change is compromising the abilities of agricultural and natural systems to sustain social and economic activities that depend on them (e.g. tourism, agriculture, fisheries):

- *https://www.rff.org/publications/issue-briefs/ecosystem-services-and-climate-adaptation/*
- *https://www.researchgate.net/profile/Kiva_Oken/publication/331434984_Impacts_of_historical_warming_on_marine_fisheries_production/links/5c7d76d5299bf1268d390c4f/Impacts-of-historical-warming-on-marine-fisheries-production.pdf?origin=publication_detail*

Climate change is shifting and enhancing the distribution, occurrence and severity of pests and diseases:

- *https://www.panna.org/sites/default/files/CC%20insects&pests.pdf* and
- *https://www.sciencedirect.com/science/article/pii/S2210909910000056*

Natural hazard modelling tools

The table below describes some national or publicly funded natural hazard modelling tools and data sources that can be applied in quantitative or qualitative natural hazard assessments. Some of these tools factor in climate change, although many do not. Some methods target short term hazard modelling and are based on historical analysis. The decision context must be clearly understood in order to select the appropriate approach to consider natural hazards under climate change.

Natural hazard type	Sources
Bushfire	**Phoenix Rapidfire**: *http://www.bushfirecrc.com/resources/poster/phoenix-rapidfire-%25E2%2580%2593-bushfire-simulator-and-risk-assessment-decision-support-tool* **Aurora:** *https://aurora.landgate.wa.gov.au/home.php* **Spark:** *https://research.csiro.au/spark/*
Floods	**CSIRO flood modelling capabilities:** *https://www.csiro.au/en/Research/Environment/Extreme-Events/Floods* **Bureau of Meteorology flood advisory resource:** *http://www.bom.gov.au/australia/flood/flashfloodadvisoryresource/* **Australian Rainfall and Runoff Guidelines:** *http://arr.ga.gov.au/arr-guideline*
Tropical Cyclones	**Geoscience Australia tropical cyclone hazard assessment:** *www.ga.gov.au/tcha*
Drought	**Australia National Drought Map:** *https://map.drought.gov.au/*
Tsunami	**Geoscience Australia probabilistic tsunami hazard assessment:** *http://www.ga.gov.au/ptha*
Sea level rise	**CoastAdapt:** *https://coastadapt.com.au/tools/coastadapt-datasets#future-datasets* *http://www.qcoast2100.com.au/*
Seismic	**Geoscience Australia national seismic hazard assessments:** *http://www.ga.gov.au/nsha*
Severe wind	**Geoscience Australia severe wind impact assessment:** *http://www.ga.gov.au/about/projects/safety/severe-wind-wa* and *http://www.ga.gov.au/about/projects/safety/severe-wind-qld*
Extreme temperature and rainfall	*http://www.bom.gov.au/state-of-the-climate/* *https://www.climatechangeinaustralia.gov.au/en/climate-campus/climate-extremes/*
Landslides	*https://landsliderisk.org/resources/guidelines*

Exploratory scenarios of exposure

Moody's exposure and impact assessments in the US:

– *http://southeastfloridaclimatecompact.org/wp-content/uploads/2017/12/Evaluating-the-impact-of-climate-change-on-US-state-and-local-issuers-11-28-17.pdf*

The many and diverse climate impact and risk assessment projects funded by the National Climate Change Adaptation Research Facility (NCCARF) and available at the CoastAdapt website:

– *https://coastadapt.com.au/assess-risks-and-impacts*;

The Climate change and adaptation research by CSIRO available at:

– *https://research.csiro.au/climate/*;
– *https://research.csiro.au/climate/themes/disaster-resilience/*

The application of the University of Adelaide's Unified Natural Hazard Risk Mitigation Exploratory Decision Support System (UnHaRMED) to a range of contexts in Australia:

– *https://figshare.com/s/041a239479300ef902a1*

The use and development of Geoscience Australia's National Exposure Information System (NEXIS). NEXIS provides comprehensive and nationally consistent exposure information. The Australian Exposure Information Platform (AEIP) is a front end to some of the NEXIS capability. The platform provides open access on buildings, businesses and people, covering public facilities and infrastructure assets, agricultural commodities, and environmental holdings within Australia. More information about NEXIS and access to the AEIP is available at:

– *https://www.ga.gov.au/scientific-topics/community-safety/risk-and-impact/nexis*.
– *https://www.info.aeip.ga.gov.au/*

Exploratory scenarios of vulnerability

The Cross-dependency Initiative (XDI) quantifies risks from flooding, coastal inundation, wildfires, droughts and windstorms on individual buildings, inter-dependent critical infrastructure assets, or the economy under scenarios of climate change. A recent application of XDI explored the insurance costs and property market implications of the physical impacts of climate change:

– *https://xdi.systems/wp-content/uploads/2019/05/CC_MVSA0195-Report-Costs-of-Climate-Change_V4-FA_Low-Res_Single-Pages.pdf*

The foreSIGHT (Systems Insights from Generation of Hydroclimatic Timeseries) tool allows users to model exposure and vulnerability of infrastructure assets using computer-generated scenarios of future hydro-meteorological conditions under changed climate conditions in order to inform the need for infrastructural design changes or even planning and regulatory changes to mitigate these risks. The free software and documentation is available at:

– *https://CRAN.R-project.org/package=foreSIGHT*

Various models developed by Geoscience Australia in collaboration with governments and industry partners provide information on present-day and future community and infrastructure risks and how these risks can be mitigated through retrofit investments. Some illustrative examples of the use of these models to generate scenarios and risk assessments include:

– *http://www.ga.gov.au/about/projects/safety/severe-wind-qld*
– *http://www.ga.gov.au/about/projects/safety/severe-wind-wa*

An exploration of future disaster risk in Greater Adelaide:

– *http://www.bnhcrc.com.au/publications/biblio/bnh-3355*

Modelling approaches to developing exploratory and normative scenarios

The Collaborative conceptual modelling approach to co-develop conceptual models of systems:

– *https://openresearch-repository.anu.edu.au/bitstream/1885/9386/6/Newell%20&%20Proust%20Introduction%20to%20collaborative%202012.pdf*

An agent-based modelling approach for assessing vulnerability futures is described at:

– *https://www.researchgate.net/publication/271847453_An_agent-based_framework_for_assessing_vulnerability_futures*

A review of vulnerability assessments and scenarios is available at:

– *https://iopscience.iop.org/article/10.1088/1748-9326/aa5508/pdf*

A structured war-gaming framework for managing extreme risks is available through request at:

– *https://www.researchgate.net/publication/278161779_A_structured_war-gaming_framework_for_managing_extreme_risks*