CLIMATE HORIZONS

DISCUSSION PAPER

Next steps for scenario analysis in Australia

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You can read more about the Sustainable Economy Program here.

EXECUTIVE SUMMARY

This discussion paper is about the use of scenario analysis by companies and other financial actors to manage, disclose, and regulate climate-related risks and opportunities in Australia. It suggests how Australian practice can be consistent with our international climate commitments under the Paris Agreement and with the leading international framework for robust climate disclosures, the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD). Its intent is to accelerate discussion between policymakers, business, investors, and regulators so that practices and capabilities for scenario analysis are fit for purpose.

It is abundantly clear that Australian companies and investors must now disclose the financial and economic risks that climate change poses to their business. This is not just a market expectation, but a legal requirement. To discharge it, businesses need to develop tools and expertise required to assess, report and respond to climate risks in a robust way. This is especially important in Australia, where climate risks are profound.

Scenario-based analysis of climate-related risks and opportunities is a key tool at a crucial time. Scenario planning considers how risks and opportunities might evolve under different climate and policy trajectories, and the implications for financial performance and strategy. The TCFD – a business-led group chaired by Michael Bloomberg and charged with providing a global roadmap for better information on climate risks – said systematic use of scenario analysis in climate risk planning and disclosure should be a key priority for firms and investors. But such analysis is complex. Achieving consistent, robust scenario analysis will be particularly challenging while standards and capabilities are still developing and different stakeholder expectations are emerging.

There is a danger that inconsistent or flawed approaches to scenario analysis will obscure more than they reveal. The TCFD raised awareness and expectations but did not set out a standard approach. The most readily available and global scenarios have key shortcomings. Many tools for judging local and sectoral impacts on climate risks are promising but incomplete. Building the full suite of standards and capabilities for robust scenario analysis will take time. But we cannot make perfection the enemy of the good. A disjointed approach, where stakeholders cannot agree on the right standards and scenarios, or where corporate spin masks low-quality analysis, will make a pressing challenge much harder.

To work towards greater consistency, stakeholders should focus on fundamental principles that are hallmarks of robust scenario analysis. These principles can guide those designing and assessing scenario analysis and ensure that early efforts set a high bar for broader take-up. This will be especially important in Australia because our climate-specific corporate disclosures requirements are relatively weak and the physical and transition risks we face are profound.

This paper puts forward five core propositions as a basis for further discussion as Australian responses to the TCFD recommendations gather pace. Scenario analysis efforts should:

- Include a scenario that is genuinely consistent with Paris targets. This means a scenario that incorporates a high probability of limiting warming to below 2°C, and towards 1.5°C.
- Include the physical impacts of climate change, not just transition risks. In Australia, physical risks (such as from droughts, floods and other exceptional weather events) will be significant even if warming is kept below 2°C, and will be extreme under business-as-usual settings.
- Engage with the most robust and relevant sectoral or regional scenarios and resources, and consider incorporating challenging sector-specific scenarios for technological, policy and other changes.

- Be transparent about assumptions and parameters used to develop the scenarios, in line with the TCFD disclosure framework.
- Show evidence of responses to scenario analysis results through changes to strategy, governance, and risk management processes.

Businesses and investors need to take the lead on scenario analysis – but there is a key role for regulators and policymakers too. The Australian Prudential Regulation Authority (APRA) and others have highlighted the relevance of climate-related risks at a company and systemic level. Australian regulators can take further steps to promote a consistent, robust approach by:

- Providing unambiguous support for the widespread adoption of the TCFD recommendations in Australia, including on scenario analysis.
- Updating their guidance, supervision, and internal capabilities in order to better understand the systemic implications of climate risk. This should include scope for system-wide stress testing around tail risks, as well as proactive oversight of how companies and investors are mapping and managing their own climate-related risks.
- Considering more stringent climate-related financial disclosure requirements, including in light of how effectively Australian institutions respond to the TCFD.
- Improving co-ordination and information sharing on climate-related risks between key regulators. Several key organisations are likely to face common goals in identifying and understanding the financial implications of climate change. Better co-ordination could be overseen by Australia's Council of Financial Regulators, which is an established forum for considering matters that overlap the respective mandates and roles of APRA, the Australian Securities and Investments Commission, the Reserve Bank, and Treasury. Involvement of the financial reporting authorities (the Financial Reporting Council, Australian Accounting Standards Board, and the Auditing and Assurance Standards Board) may also be warranted.

This paper draws on early examples of climate-related scenario analysis that are already available (see Appendix). It is informed by conversations with a variety of stakeholders and experts in Australia and overseas, plus several forums held under the Chatham House Rule during the past 12 months.[1]

Our primary aim is to identify and tease out key areas of interest and debate. The TCFD notes that the use of scenario analysis for financial climate risk is at an early stage, and that various actors (including industry groups, NGOs, and official bodies) have a role to help develop better scenarios and drive better practice.[2] Our intent here is to provoke a bigger conversation around scenario analysis and to provide a jumping-off point for further consultation and research into both stakeholder needs and empirical information.

CPD will hold a series of high-level consultations on these issues in the first quarter of 2018, which will inform an updated major report that responds to many of the issues and questions highlighted in this discussion paper.

[1] Including the Commonwealth Climate Law Initiative forum with reporting and other financial authorities in July 2017; roundtable discussions with Dr Paul Fisher of the Bank of England and Cambridge University in October 2016 and October 2017, and engagement with other stakeholders, experts and authorities during this period.
[2] TCFD, 2017, *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*, June 2017, p.11.

Introduction: Raising the bar at home and abroad

Global awareness of how climate change can impact the reputation, profitability, and strategy of corporations and investors has been building for some time. Until recently this has been framed largely in terms of 'divestment' from fossil fuel intensive industries and companies for primarily ethical or environmental reasons.

Two major international developments have now put a much wider set of climate-related risks and opportunities, particularly their economic and financial implications, in the spotlight. The first was the entry into force of the Paris Climate Agreement in November 2016, which secured a credible global commitment to deliver the major emissions reductions needed to keep global warming below 2°C. The second was the report of the TCFD, which established a business-led framework for how firms and investors should manage and disclose the financial impacts of climate change.

In turn, major developments in Australia have highlighted how influential these global developments will be in raising the bar for boards, companies and investors domestically.

In February 2017, APRA executive member Geoff Summerhayes delivered the first major statement by a leading Australian regulator on the financial impacts of climate change, highlighting the Paris Agreement and TCFD. He described some climate risks as "distinctly financial in nature" and "foreseeable, material and actionable right now". Australia's prudential regulator is now on the record endorsing the TCFD framework and expecting higher standards from regulated entities in understanding and managing climate risks.[3] The companies regulator, ASIC, said in September 2017 that proactive climate risk reporting should be a key part of annual report disclosures on the financial impact of sustainability-related risks.[4] Policymakers are considering the case for a stronger legislative and regulatory response: a 2017 Senate committee report into carbon risk disclosure, which is currently awaiting a formal government response, recommended the government commit to implementing the TCFD framework and nominate a single entity to co-ordinate the government's response.[5]

Box 1 – Physical and transition climate risks

Physical risks stem from the physical impacts of climate change, including from more volatile and variable weather events and from longer-term changes in climate patterns. ***Transition risks*** flow from the major policy, legal, technological and market changes associated with attempts to mitigate climate change or adapt to its impacts. It is the financial impact of these risks, and also climate-related opportunities, that are the focus of the TCFD.

Examples: Transition and physical risks

TRANSITION	PHYSICAL
Collapse in demand for products due to policy shifts	Direct damage to assets
Stranding of assets due to market shifts	Resources or supply chains being permanently damaged by climate change
Reputational damage from limited response to mitigation needs	Input prices permanently changed by climate change
Business model fails to accommodate changing technology	Markets affected (e.g. demand falls due to climate change-related losses)
Liability due to failure to foresee and mitigate losses from any of the above	Liability due to failure to foresee and mitigate losses from any of the above

[3] Geoff Summerhayes, *Australia's new horizon: climate change challenges and prudential risk*, February 2017,
[4] ASIC, *Regulation of Corporate Finance: January to June 2017*, August 2017, p.42.
[5] Senate Economic References Committee, *Carbon risk: A burning issue*, April 2017

As well as risking the ire of regulators, companies and investors that fail to properly consider how climate change might impact financial performance open themselves up to major legal risks. An important legal opinion by Noel Hutley SC and Sebastian Hartford-Davis, commissioned by CPD and the Future Business Council and instructed by MinterEllison Lawyers, recently found that company directors who fail to properly consider these issues could be held personally liable for breaching their directors' duties. The opinion also highlighted disclosure requirements under ASX listing rules.[6] Subsequent analysis has shown that directors of superannuation funds are also obliged to consider how climate change impacts the financial interests of beneficiaries.[7]

Australia's largest companies and investors have a long way to go to meet the higher standards that are being set out by regulators, shareholders, and beneficiaries. There is some evidence that general sustainability-related strategy and reporting has been improving. For example, Australian Council of Superannuation Investors research shows that the share of ASX200 companies with leading or detailed sustainability disclosures doubled to just under 50 per cent in the last 5 years (Figure 1). However, climate-specific disclosures and capabilities – especially forward-looking analysis on targets and strategy that go beyond legislated requirements on carbon footprint disclosures – continue to lag. ACSI found that while 58 per cent of companies reported on greenhouse gas emissions in 2017, less than half had developed a climate change policy or targets (Figure 2).

Figure 1: ASX 200 sustainability reporting trends

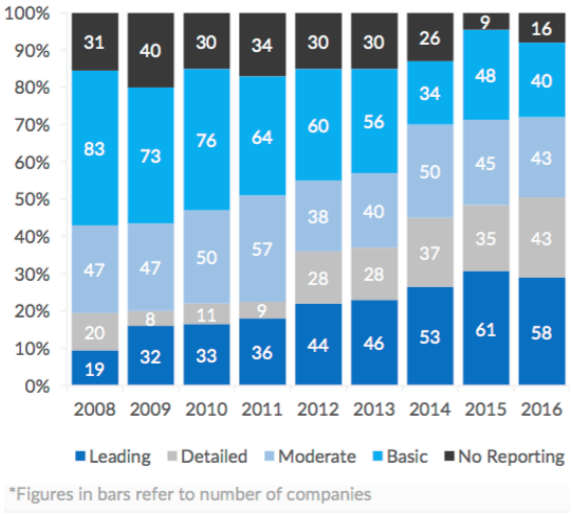
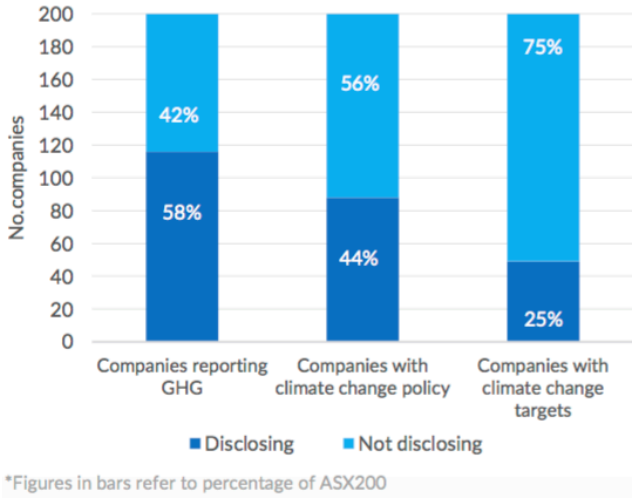


Figure 2: ASX reporting of climate-related indicators



Source: ACSI 2017

The threshold questions – are climate risks financial in nature, and must companies and investors consider and disclosure them – have been answered emphatically. The focus now is on what types of climate-related analysis and disclosure are required, and on the tools and capabilities that companies, investors, and the regulators that oversee them need to make sure these standards are met. The remainder of this paper considers one tool that is likely to be a focal point: the use of scenario-based climate-risk analysis.

[6] Noel Hutley SC and Sebastian Hartford-Davis, *Climate change and directors' duties*, October 2016.
[7] Noel Hutley SC and James Mack, *Superannuation trustee duties and climate change risk*, September 2017.

1. From static to strategic: scenario analysis and disclosure

Assessing the probable and possible financial implications of climate change is a uniquely challenging task. While we know the direct physical impacts of climate change will be profound, their precise timing and magnitude are difficult to predict. Similarly, while we understand there will be far-reaching social, policy and technological changes as part of a transition to a zero-emissions world, there is a great deal of uncertainty about how these impacts will interact and play out. Putting together the fullest possible picture requires overlapping scientific, technological and economic expertise – and a framework for anticipating how politics will influence national and global policies.

Companies and investors need to be able to grapple with this uncertainty to anticipate how climate change might impact their business. They need tools to and strategies to identify and manage trends, risks and opportunities as they emerge, or to change tack if they do not. They also need the ability to communicate climate-related policies and narratives to shareholders and stakeholders, and to disclose material information to markets.

Scenario analysis is a way to grapple with an uncertain future by considering, and preparing for, different possible trajectories and situations (Box 2). It is likely to be particularly valuable and useful in identifying climate-related risks and opportunities. For this reason it was a critical part of the TCFD's recommendations for improving overall climate-related risk management and disclosure:

> *"One of the Task Force's key recommended disclosures focuses on the resilience of an organization's strategy, taking into consideration different climate-related scenarios, including a 2° Celsius or lower scenario. An organization's disclosure of how its strategies might change to address potential climate-related risks and opportunities is a key step to better understanding the potential implications of climate change on the organization."* [8]

This recommendation was among the strongest and most novel elements of the TCFD framework. The TCFD goes on to acknowledge that climate-related risks are likely to manifest in a variety of ways, and that climate change poses a unique set of challenges for all financial market participants.

In Australia, APRA has also emphasised that climate analysis should go beyond more narrow measures of climate-related exposures, such as carbon emissions footprints:

> *"Practice and expectations are moving beyond mere documentation of static metrics. Robust, scenario-based thinking about risks should be the new standard for risk management. Markets and investors expect to see evidence of more sophisticated analysis to identify risks and strategy for managing them. The questions investors (and regulators) will want answered are not just about "what" but "how". How do you model and identify relevant trends, opportunities and risks? How robust are your strategies given different scenarios and contingencies?"*[9]

Answering these questions will be challenging. Within both the transition and physical categories (Box 1 above), there are a multitude of factors which companies, investors and regulators may need to understand and respond to. They range from physical sciences to technological disruption, legal liability, politics, policy, international diplomacy and more.

[8] Financial Stability Board, Taskforce on Climate-related Financial Disclosures, Recommendations Report, p.V.
[9] Geoff Summerhayes, 'Australia's new horizon: Climate change challenges and prudential risks", February 2017'.

However, in meeting these new expectations, businesses, investors and regulators – particularly large and sophisticated organisations – also have ready-made strengths. Scenario analysis is an established tool that is used in a range of other business and investment contexts, and climate-specific analysis can draw on a wide range of models and resources that have been developed to understand the impacts of climate change at a global and regional level.

However, while established scenarios and approaches offer a reasonable starting point for these efforts, many have important caveats or limitations that must be addressed and overcome to suit the needs of different users. These limitations are discussed in the next section. The balance of this paper considers some of the most pressing priorities, taking the TCFD recommendations as a starting point.

Box 2: Scenario analysis in the TCFD

The TCFD defines scenario analysis as a means of evaluating "a range of hypothetical outcomes by considering a variety of alternative plausible future states (scenarios) under a given set of assumptions and constraints". Its purpose, in the case of climate change, is to help an organisation "explore and develop and understanding of how the physical and transition risks and opportunities of climate change might plausibly impact the business over time."

Scenarios are not forecasts or predictions that seek to provide a full description of the future, but hypothetical constructs to "highlight central elements of a possible future and draw attention to key factors that will drive future developments." The TCFD notes that scenarios used for this kind of analysis can be qualitative (relying on descriptive narratives), quantitative (relying on numerical modelling), or a combination of both.

Most entities will face both transition and physical implications (see Box 1) of climate change. The TCFD notes that while the impact and importance of transition and physical risks will vary across different organisations, "both transition and physical risks are complimentary when assessing climate-related impacts and both are required to understand the full impacts of climate change and the resilience of organisations to those implications."

The TCFD states that scenarios should have the following characteristics:

1. "Plausible. The events in the scenario should be possible and the narrative credible (i.e., the descriptions of what happened, and why and how it happened, should be believable).
2. Distinctive. Each scenario should focus on a different combination of the key factors. Scenarios should be clearly differentiated in structure and in message, not variations on a single theme. Multiple scenarios should be used to explore how different permutations and/or temporal developments of the same key factors can yield very different outcomes.
3. Consistent. Each scenario should have strong internal logic. The goal of scenario analysis is to explore the way that factors interact, and each action should have a reaction. Neither actors nor external factors should completely overturn the evidence of current trends and positions unless logical explanations for those changes are a central part of the scenario.
4. Relevant. Each scenario, and the set of scenarios taken as a whole, should contribute specific insights into the future that relate to strategic and/or financial implications of climate- related risks and opportunities.
5. Challenging. Scenarios should challenge conventional wisdom and simplistic assumptions about the future. When thinking about the major sources of uncertainty, scenarios should try to explore alternatives that will significantly alter the basis for business-as-usual assumptions."

Source: TCFD Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities.

2. The starting point for climate scenario work

Limitations of existing scenarios

There are two related barriers to widespread, co-ordinated use of scenario analysis along the lines identified by the TCFD, APRA and many others. These are the shortcomings and limitations of existing models and reference scenarios for conducting this analysis, and the different needs and capabilities of actors in different markets, industries, regions and regulatory contexts. A third barrier can be added: a lack of clear consensus on what defines a robust scenario analysis exercise.

The TCFD refers to reference scenarios produced by the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) as authoritative starting points. However, these are also subject to important caveats and limitations. Some of the limitations are technical; many of stem from the purposes for which the leading scenarios were created. As the TCFD highlights, most scenarios have been developed to allow global assessments of climate impacts to inform policy, rather than to provide the transparency, functionality and range of outcomes to facilitate their use by business or investors.[10] This is changing rapidly as the need for business-ready tools and scenarios becomes more apparent. But in general, neither the global reference scenarios, nor the promising attempts to provide more granular models for analysing transition or physical risks at a sectoral or national level (see Box 5), offer a single ready-made resource for consistent scenario analysis.

In brief, while existing reference scenarios offer an important starting point, major gaps and limitations include the following:

- A lack of transition reference scenarios that extend beyond energy systems.
- A lack of longer-term transition scenarios that extend to 2050 and beyond.
- A lack of consistency around the definition of a 2°C budget and trajectory.
- A lack of challenging assumptions around technological disruption, behavioural change and material substitution and efficiency.
- Mitigation pathway scenarios included in the latest IPCC report pre-date the Paris Agreement, making it difficult to identify a Paris-consistent scenario.
- Mitigation pathway scenarios found in the IPCC database can be difficult to access and collate.
- Climate impact modelling has historically lacked granularity and a focus on outcomes that may be relevant to businesses, although this is changing rapidly.

What does the TCFD propose?

The TCFD establishes an important starting point: that a 2°C scenario should be among those analysed by organisations seeking to adopt its disclosure recommendations. This in significant, because it establishes a clear expectation that a Paris-consistent scenario should feature in all scenario planning exercises.

Crucially, however, the TCFD does not endorse or provide any one particular scenario or approach. This decision reflects a desire to balance standardisation and setting of robust minimum requirements on one hand, with the need to preserve flexibility and minimise onerousness of scenario analysis – and therefore maximise TCFD adoption – on the other. It also recognises the limitations of the scenarios that are currently available.

While the TCFD's rationale is difficult to fault, many stakeholders have identified the lack of prescriptiveness in the TCFD framework as a key challenge for widespread adoption of scenario analysis. Several submissions in response to the TCFD's draft 2016 recommendations called for the final TCFD report to recommend a

[10] TCFD, Technical Supplement on Scenario Analysis, 2017.

standardised transition scenario. For example, Carbon Tracker Initiative (CTI) proposed that the TCFD choose the IEA450 scenario, arguing that its widely-documented shortcomings would be outweighed by the benefits of having clear and consistent assumptions to base disclosures around. After the final TCFD report was released, the governance advisory group Regnan said that the lack of specificity "risks the potential value of the recommendation in creating comparable, decision useful information. It also creates additional work for disclosers."[11] Standard & Poor's (S&P) points out that "a wide margin for variation in the assumptions that underpin any given two degree scenario exists", adding that while flexibility is important in early stages of adoption, "it is likely to lead to inconsistencies and gaps in disclosure which will make it harder to use the information for peer analysis."[12]

Box 3: Important caveats for key global scenarios

While there are a range of resources available to organisations conducting scenario analysis, they are subject to important caveats and methodological limitations. The TCFD identifies two major sets of shortcomings:

> *"First, most scenarios have been developed for global and macro assessments of potential climate-related impacts that can inform policy makers. These climate-related scenarios do not always provide the ideal level of transparency, range of data outputs, and functionality of tools that would facilitate their use in a business or investment context."*
>
> *"Second, the availability and granularity of data can be a challenge for organizations attempting to assess various energy and technology pathways or carbon constraints in different jurisdictions and geographic locations."*
>
> Source: TCFD Technical Supplement on Scenario Analysis

Many widely-used scenarios also have specific drawbacks which must be kept in mind when using them as resources for climate risk analysis. Transition scenarios developed by the IEA are a prime example. The IEA has produced a range of scenarios, ranging from those based on current policies (implying warming of as much as 6°C) through to two major scenarios (450 and 2DS) that are commonly regarded as consistent the 2°C Paris target.

Both 450 and more recently, 2DS, have been used as a reference for expectations between investors, disclosers, and NGOs. However the IEA acknowledges that both scenarios are not consistent with the Paris Agreement, in part because they do not limit warming to "well below 2°C", but rather are pathways for a 50 per cent chance of limiting warming to 2°C. Other shortcomings of IEA reference scenarios to date include:

- Only energy sector transitions are modelled.
- Nation-level granularity is limited for countries including Australia.
- They do not extend beyond 2040, when the decade to follow will be a critical and challenging time for accelerating emissions reductions to meet the Paris goals.
- They have a track record of significantly underestimating the growth rate of renewables.

A more recent scenario developed by the IEA and the International Renewable Energy Agency (IRENA) examines a 66 per cent chance of limiting warming to 2°C, and work is planned for scenarios more consistent with the objectives of "well below 2°C" and 1.5°C by 2100.

Comparisons between the IEA's new 66 per cent scenario and its 450 scenarios can be found on pages 70 to 73 of the IEA's "Perspectives for the Energy Transition", 2017.

[11] Alison George, "The key to achieving the TCFD's aims for climate disclosure", Regnan, February 2017.
[12] Michael Wilkins, "How the recommendations of the TCFD may figure into our ratings," S&P Global, August 2017.

The TCFD will operate until September 2018 to support adoption of its recommendations, and is continuing its work on scenario analysis.[13] However, given the current approach, it is unlikely that near-term scenario-related analysis and disclosures will have the level of detail, transparency, and standardisation to enable the kind of peer analysis referred to by S&P and others. Without careful co-ordination, a significant gap could open between the expectations and capabilities of disclosers and their various stakeholders, which would undermine the credibility and value of scenario analysis at this critical early stage.[14]

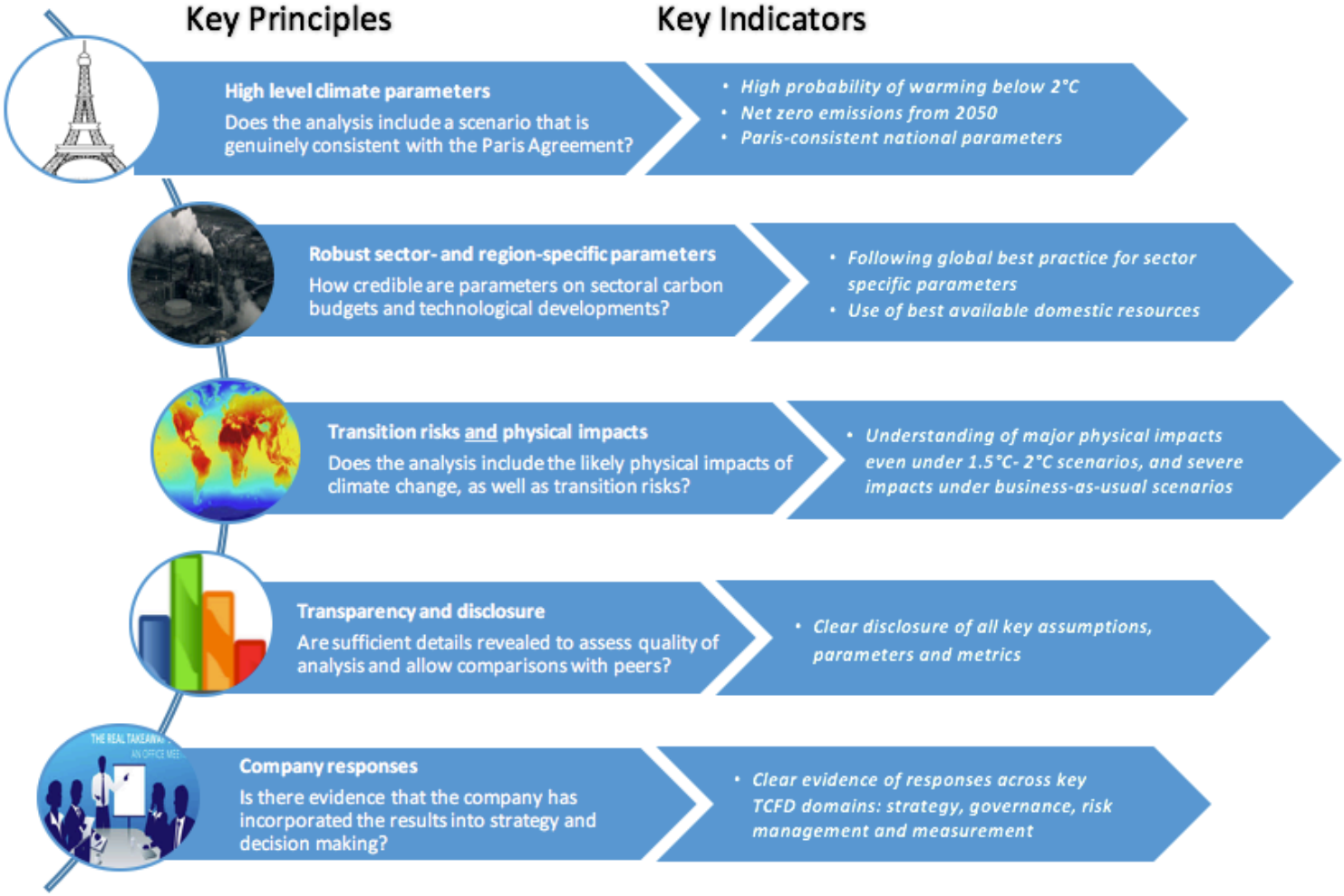
[13] Scenario analysis which was the topic of a two-day seminar hosted by the FSB and Bloomberg in November 2017. Further information on these discussions is available here: https://www.fsb-tcfd.org/event/tcfd-boe-conference-climate-scenarios-financial-risk-strategic-planning/

[14] An early example of this can be seen in recent reports by ShareAction, a UK investment focused NGO. In 2015 ShareAction together with ClientEarth, proposed shareholder resolutions asking BP and Royal Dutch Shell to disclose, among other things, their "asset portfolio resilience to the IEA's scenarios". The resolutions gained board support and were passed with 98.28 per cent and 98.91 per cent of the respective votes. While much of ShareAction's criticisms focus on the company's response to the scenario analysis in its business strategy, the robustness and detail of the analysis itself, including the lack of pathways beyond 2035, were specifically critiqued.

3. The way forward - some suggestions

Australian actors do not have time to wait for a perfect global framework. In fact, they can lead the way in developing a robust approach to scenario analysis that is consistent with the TCFD framework, builds on common ground between disclosers, users and regulators, and lays foundations for a more sophisticated approach over time. Australia has strong scientific expertise on climate change and is the developed country perhaps most exposed to its impacts – we have the capability and the imperative to be a leader on scenario analysis.

There are common starting points that can underpin a rigorous and credible approach to scenario analysis right now, despite the complexities involved. Based on our review of existing scenario disclosures (see Appendix), available reference scenario resources, and preliminary conversations with a variety of stakeholders, we suggest five principles that offer a simple, practical framework for developing and assessing approaches to scenario analysis and disclosure. These are:



Each of these principles specifically relate to climate change risks and opportunities, have been identified by stakeholders as areas of importance and concern, and are emerging as key areas of focus or differentiation in early examples of scenario analysis and disclosure. We now consider them in turn.

1. High level transition scenario parameters: hallmarks of Paris-consistent scenarios

The Paris objective is to limit global warming to *well below* 2°C above pre-industrial levels, and to pursue efforts to limit warming to 1.5 °C (Box 4). This is the starting point for robust scenario analysis of transition risks.

As discussed above, one of the challenges for potential users of scenario analysis is that most available scenarios are not robustly consistent with Paris targets. This is true even of several of the most widely known and used 2°C scenarios. This means that even when disclosers are using their best efforts and some of the best available scenarios, there is a risk they may misstate or underestimate risks and opportunities and the scale of transition required to meet Paris obligations.

Identifying Paris-consistent analysis is relatively straightforward if details of an underlying carbon budget and emissions trajectory have been disclosed. There are a number of key factors that underpin the calculation of a carbon budget used in scenario analysis – that is, the total amount of GFG emissions that can be added to the atmosphere to achieve a particular warming target. The most important are the temperature **target** or limit itself, the specified **probability** of achieving the target, and the **timeframe** for achieving the target. (Other important factors include whether greenhouse gases other than CO_2 are included, and the extent to which net negative emissions are assumed to have a role in meeting the carbon budget. Determining the carbon budget for an individual country requires several more decisions about whether to allocate emissions on the basis of current emissions per capita, relative wealth of the country, ability to reduce emissions, and historical emissions.)

***Probability*: scenarios should be based around a high probability of meeting the <2°C target**

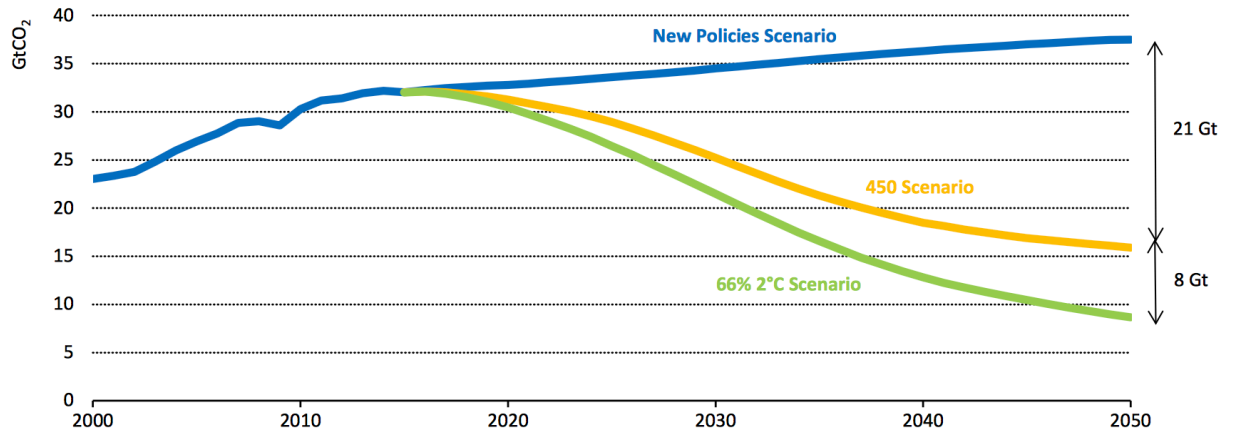
Robust, Paris-consistent scenario analysis should utilise carbon budgets and scenarios that incorporate a high probability of keeping global warming below 2°C.

The precise extent of global warming generated under any carbon budget is uncertain. For this reason, most budgets and the scenarios derived from them assign a probability, or a range of probabilities, for hitting the desired target. This means that the choice of the acceptable probability of hitting a particular warming target is very important, as well as the selection of the target itself. Policymakers and international regulators generally emphasise carbon budgets and scenarios that are consistent with a 66 per cent chance of keeping warming below the 2°C degree level. This is consistent with international agreement that 2°C of warming is an upper limit that should be stringently defended, while preserving the best prospect of keeping warming well below this level. However, in the corporate and investor context, much lower probabilities are often used. Many important and widely used reference scenarios – including the IEA's 450 and 2DS scenarios – are based around a 50 per cent probability of keeping warming below 2 degrees.

This difference is not academic. A 66 per cent chance of keeping warming below 2 degrees requires cutting emissions much faster than a 50 per cent probability. The IEA's own recent work on a 66 per cent scenario finds energy sector emissions would need to be almost halved by 2050, relative to its 450 Scenario.[15] The implications of this difference are stark. For example, the IEA's 66 per cent scenario involves almost half of all trucks being electric by 2050, while the 450 Scenario requires no truck electrification. Figure 3 shows the difference in emissions trajectories between IEA scenarios and Paris-consistent targets.

[15] International Energy Agency and International Renewable Energy Agency, *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System*, 2017

Figure 3: Divergence between IEA 450 scenario and 66 per cent 2°C scenarios



Source: International Energy Agency and International Renewable Energy Agency, 2017

Widespread use of ostensibly 2°C-consistent scenarios that only provide an even chance of keeping warming below agreed global limits will not provide an adequate, accurate basis for assessing the climate-related risks and transitions. Organisations aiming for credible, high-quality disclosures, and investors, shareholders and regulators insisting on scenario analysis that is robustly consistent with Paris targets, should ensure that central Paris consistent scenarios imply a high probability of keeping warming well below this level.

Box 4: Key requirements in the Paris Agreement

Article 2.1 *This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:*

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;

(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate- resilient development.

Article 4.1 *In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.*

***Timeframe:* scenarios should include a pathway to net zero emissions by 2050, including major near-term reductions in global emissions**

The Paris Agreement calls for rapid reductions in greenhouse gas emissions "in accordance with the best available science" to achieve balance between anthropogenic emissions and greenhouse gas sinks "in the second half of this century". This is sometimes misinterpreted as meaning that this "balance" can occur anywhere between 2050 and 2100. However, the "best available science" – including research on the physics of the carbon cycle, and the available emissions mitigation scenarios – indicates that to avert the most dangerous changes associated with global warming exceeding 2°C, global CO_2 emissions must reach net zero by around 2050, and all greenhouse gas emissions (including methane and HFCs) must reach net zero by 2060 to 2080.[16]

The timing of major emissions reductions efforts is also a critical factor. Several key scenarios such as the energy-oriented IEA suite only extend out until 2040, and imply accelerated transitions and adjustments from 2040 onwards to reach a net zero emissions target 2050. However, rapid and sustained declines in global emissions are needed in the near-term to avoid exhausting a Paris-consistent carbon budget within the next 10 or 15 years. Feasible Paris-consistent scenarios must therefore include both early emissions reductions and steep and sustained decarbonisation rates.[17]

***National targets:* domestic carbon budgets must be credible and consistent with the Paris framework**

The regional or national carbon budgets used in scenario analysis must be consistent with global agreements and targets if they are to be a useful guide to likely climate-related risks. In the lead-up to the 2015 Paris climate meeting, countries put forward intended nationally-determined commitments (INDCs) on emissions reductions. For most countries, these commitments were tied to 2025 or 2030. However under the "ratchet mechanism" agreed in Paris, countries will submit increasingly ambitious targets every few years. Countries have until 2020 at the latest[18] to put forward their longer-term targets, which is generally viewed as being a 2050 target. The Paris Agreement does not prescribe a methodology for determining each country's contribution to emissions reduction, although it sets out a process by which each country's iterative Nationally Determined Contribution (NDC) will be judged by its peers.

NDC's are a useful starting point for domestic scenarios – but their relatively near-term horizon, the Paris ratchet mechanism, and the fact that collectively the NDCs are not sufficient to deliver the Paris goals mean that adjustments are likely to be more ambitious and demanding than the NDCs suggest. In Australia, most companies conducting climate-related scenario analysis to date have acknowledged that the current policy target of a 26 to 28 per cent reduction on 2005 levels by 2030 is effectively an interim measure that does not represent the full "Paris Agreement commitment" (See Appendix).

High-level parameters – key questions for further discussion:

- *Are the expectations of information users around high level parameters beginning to converge?*
- *Is an IEA 450-based scenario acceptable for certain types of information preparers?*
- *Should a 1.5°C scenario be included?*

[16] Methodologies are explained in: Joeri Rogelj, Michiel Schaeffer and Bill Hare, 'Timetables for Zero emissions and 2050 emissions reductions: State of the Science for the ADP Agreement', Climate Analytics, February 2015.
[17] Climate Change Authority, *Reducing Australia's Greenhouse Gas Emissions – Targets and Progress Review,* 2014, p.3.1. http://climatechangeauthority.gov.au/chapter-3-global-emissions-budget-2-degrees-or-less
[18] Conference of the Parties, Decision 1/CP21, Paragraph 35, United Nations Framework Convention on Climate Change.

2. Robust sector- and region-specific parameters

Detailed scenario analysis of the type recommended in the TCFD and elsewhere also requires more granular resources to understand how climate and emissions reductions pathways will impact different industries, sectors, assets and business models. This requires selecting and applying region- or sector- specific resources, parameters and assumptions that are most relevant for different firms, asset owners and asset managers.

This is a demanding task and in many cases this will require developing new expertise and capabilities. The TCFD framework provides the flexibility for different users to develop more detailed approaches over time, depending on their own circumstances and needs. However, the TCFD framework and emerging global best practice suggest that well-resourced organisations with complex exposures will be expected to develop high-calibre scenario analysis.

In this context, key focal points for designing and assessing scenario analysis are:

- what sector-specific parameters and assumptions are most relevant and useful?
- how robust are judgements about sectoral carbon budgets and technological developments given international best practice and the best available domestic, sector specific analysis?

Sectoral granularity

Many of the detailed reference scenarios that are widely available for third party use are limited to the energy sector. Organisations primarily focused on energy resource extraction and production are therefore the best-served for scenario analysis, both in terms of reference scenario material, and the nature of the businesses' exposure to transition scenarios. Oil and gas producers already disclose estimated recoverable reserves, and their break-even price point on these reserves, in their financial filings. This allows third parties to form their own estimate of a company's exposure to various climate transition risks; resulting shifts in demand can be layered over a company's production cost curve. Carbon Tracker Initiative has performed this type of analysis on many oil and gas companies in some detail. Similarly, pathways for the electricity sector have been examined in detail. The electricity generation sector is often contained within national boundaries, and its role is relatively clear in Australia, with the Climate Change Authority noting the sector must be virtually decarbonised by 2050.[19]

Applying a mitigation scenario to other sectors – even closely related, energy-intensive sectors - requires further work. The initial emphasis on energy is warranted, given the energy system is where the earliest and fastest transitions need to be made under the majority of <2°C scenarios.[20] However, major emissions reductions are also required in other sectors under Paris-consistent pathways.

Additional efforts are underway to develop usable parameters for major energy-intensive sectors, in order to enable wider adoption of scenario analysis in line with the TCFD recommendations. For example, recent research by the 2° Investing Initiative and The CO-Firm specify a range of key parameters for six major energy-intensive sectors: power, automotive, steel, cement, aviation, and shipping (see Figure 4 below).[21] These build down from major global scenarios, mapping credible assumptions about production and technology, market pricing of key inputs and outputs, and policy costs and incentives (e.g., anticipated fuel efficiency standards), available at global levels and/or for key economies. This is one of the first such attempts to publicly map out climate transition scenarios for these sectors in detail, using a global trajectory with a mixed degree of granularity at regional or national level. Another recent sectoral study, by the FERI Cognitive Finance Institute and ISS-Ethix

[19] Climate Change Authority, *Policy Options for Australia's Electricity Sector: Special Review Research Report*, August 2016.
[20] Rogelj, J., Gunnar Lederer, Robert C. Pietzker, Elmar Kriegler, Michiel Schaeffer, Volker Krey and Keywan Riahi, 2015, 'Energy system transformations for limiting end-of-century warming to below 1.5°C', Nature Climate Change, 5, 519-527 doi: 10:1038/nclimate2572
[21] See 2° Investing Initiative, *Transition Risk Toolbox: Scenarios, Data and Models*, 2016

Climate Solutions,[22] looks at sectors including agriculture, buildings, and various transport sub-sectors. It finds that all except for electric vehicles are either "needing more work" or "not on track" for compliance with a 2°C scenario. While these resources do not currently include Australia, the parameters, assumptions, and methodology are highly relevant in the Australian context as a guide for companies, investors and information users.

Regional and national granularity

Country-scale resources and analysis, including on physical impacts and transition dynamics in key sectors, is also a key input into effective scenario analysis. The lack of detailed regional and country-level transition scenario material is particularly important for some sectors, companies, and activities. While some commodities, particularly oil, are fungible and broadly subject to global price benchmarks, most other business activities have a degree of regional specificity.

As noted in Box 3, IEA scenarios only have limited geographical granularity, as do the models used to generate IPCC scenarios, which seek to describe a relationship between emissions and temperature outcomes. This relationship is global in nature and makes them difficult to apply to more granular geographies,[23] although some downscaling of those scenarios has been conducted recently.[24]

The Deep Decarbonisation Pathways Project (DDPP) developed a series of 16 detailed **country-level scenarios** for a transition to net zero emissions by 2050. The DDPP work for Australia, conducted by ClimateWorks and the Australian National University, provides a detailed illustrative pathway for achieving decarbonisation consistent with a 2°C global target.[25] As well as energy systems, it models industry, transport, agriculture, the built environment and land use. DDPP-type approaches build a nuanced 'bottom up' picture of national decarbonisation pathways complementing global mitigation scenarios used in IPCC reports; although they share the shortcoming (for financial purposes) of being focused primarily on policy pathways rather than financial impacts.[26] Some important and emerging resources on transition pathways and physical impacts are included in Box 5 below.

Incorporating challenging assumptions

Scenario analysis should challenge an organisation's business as usual approach. Below are several key areas for incorporating challenging assumptions, and examples of recent work exploring each area:

- **Innovation and disruption:** The failure of prominent energy scenarios, such as those of the IEA, to foresee rapid growth in renewables suggests other plausible and relevant disruptions may also emerge. Carbon Tracker's *Expect the Unexpected* explores how to model challenging technological developments.[27] A 2014 paper from researchers in the climate mitigation modelling community outlines how technological assumptions affect mitigation pathways; for instance, technology for CCS and bioenergy tends to be an important factor in low emissions scenarios due to their ability when combined (as "BECCS") to produce negative emissions.[28]

[22] FERI Cognitive Finance Institute and ISS-Ethix Climate Solutions, 'Transition to a low-carbon economy: How it impacts investors and the sectors they invest in', 2017.
[23] Steve Pye and Chris Bataille, ' Improving deep decarbonisation modelling capacity for developed and developing country contexts', *Climate Policy*, 27-46. 2016.
[24] For example, see: Climate Analytics, 'Implications of the Paris Agreement for coal use in the power sector,' November 2016.
[25] ClimateWorks and Australian National University, *Pathways to deep decarbonisation in 2050: How Australia can prosper in a low carbon world*, Initial Project Report, 2014.
[26] See Henri Waisman and Chris Bataille, "Methodological Insights for Builiding Scenarios in the Post-Paris Context,' IDDRI, July 2016.
[27] Carbon Tracker Initiative, *Expect the Unexpected: The Disruptive Power of Low-carbon Technology*, 2017.
[28] Elmar Kriegler,, John P. Weyant, Geoffrey J. Blanford, Volker Krey, Leon Clarke, Jae Edmonds ,Allen Fawcett, Gunnar Luderer, Keywan Riahi & Richard Richels & Steven K. Rose & Massimo Tavoni & Detlef P. van Vuuren, "The role of technology for achieving climate policy

- **Material efficiencies and material substitution:** this is particularly relevant in energy-intensive sectors. In the steel sector, for example, energy efficiency has been pursued and, to a lesser extent, emissions reduction. However efficiency of input materials, and more efficient end use of steel could result in significantly reduced demand in uses such as office space and cars.[29] There is also scope for much broader use of secondary steel.[30]

- **Behavioural changes** can be difficult to model, particularly in CGE and bottom-up approaches. Cambridge CISL's *Unhedgeable Risks* paper, looks at three "sentiment scenarios" in which markets behave in a way consistent with each of three different scenarios unfolding: 2 degrees, no mitigation, and baseline.[31]

Sensitive parameters – key questions for further discussion:

- *Should standardised, sector-based reference scenarios be used?*
- *Should standardised nation-based reference scenarios be used?*
- *How can information preparers who lack resources identify credible sector-specific parameters?*
- *How can challenging elements such as technological and behavioural change and material substitution be incorporated?*

objectives: overview of the EMF 27 study on global technology and climate policy strategies", *Climatic Change*, 2014, DOI 10.1007/s10584-013-0953-7.

[29] Manfred Fischedick, Joyashree Roy et al, '2014: Industry', in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambrdige University Press.

[30] Johannes Morfeldt, Wouter Nijs, Semida de Campos Silveria , 'The impact of climate targets on future steel production: an analysis based on a global energy system model', *Journal of Cleaner Production* (103), 469-482, 2014.

[31] The University of Cambridge Institute for Sustainability Leadership, *Unhedgeable risk: How climate change sentiment impacts investment*, 2015.

Box 5: Key tools and resources for challenging assumptions

Mitigation: Australia

Deep decarbonisation pathways project: Australia

The Deep Decarbonisation Pathways Project for Australia was developed by Climateworks, ANU with CSIRO and Victoria University. It details a scenario for Australia to reach net zero emissions by 2050, using existing technologies. While the DDPP initiative was focused on policymakers, it has useful sectoral and regional detail.
https://www.climateworksaustralia.org/project/national-projects/pathways-deep-decarbonisation-2050-how-australia-can-prosper-low-carbon

Mitigation: Sectoral

Energy Transition Risk initiative

An early version of this reference scenario for sector-based transition has been released, under an EU-funded project. It features some geographical granularity, but does not include Australia. However its assumptions look at the impact on projected demand in key export sectors for Australia, such as steel. http://et-risk.eu/toolbox/scenarios/

Impact: Australian

Climate Change in Australia (CSIRO, Bureau of Meteorology, Australian Government)

CCIA is a significant public resource which includes several web-based tools, ranging from easy to advanced, and a rich selection of accompanying information and guidance. A particularly useful page with links to each of the tools and key related information can be found here:
https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/about-data/

NARCliM and AdaptNSW (NSW government, ACT government,University of NSW)

NARCliM covers much of eastern Australia (NSW, ACT, Victoria and South-East Queensland) at grid scales of 10km. It uses CMIP3 global climate models, and there are plans to upgrade using the newer CMIP5 models. Climate impact data can be explored for numerous impacts at time intervals and drawing on three emissions pathways. NARCliM data can be downloaded in ASCII or GIS file formats.
http://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW

Coastalrisk.com.au (CRC for Spatial Information (CRC-SI) and WA company, GIS.)

This is a very easy-to-use satellite-map tool for exploring basic sea level rise impacts. Users can calibrate the level of sea level rise with a simple slider tool.

Impact: global resources focused on financial risks

Deutsche Bank Asset Management / Four Twenty Seven white paper

This paper details regional climate risks, particularly east and southeast Asia. It also provides a rough breakdown of physical risk by sector:
http://427mt.com/wp-content/uploads/2017/11/Physical_Climate_Risk_FourTwentySeven_November2017.pdf

WRI's Aqueduct tool

The World Resources Institute, a US-based not-for-profit, has developed a tool that maps geospatial water risk exposure with projections to 2020, 2030 and 2040 using multiple emissions pathways. It is available on the Bloomberg terminal.

Global impacts: IPCC scenario database (various research institutions)

The database of mitigation scenarios used in the IPCC 5th Assessment Report (AR5) can be accessed using a "guest" login or free registration at the IIASA website. While the interface is designed for researchers, it is fairly easy to explore key characteristics of models, model runs and the resulting mitigation pathways:
https://secure.iiasa.ac.at/webapps/ene/AR5DB/

Figure 4: 2° Investing Initiative – example parameters from key sectoral scenarios

Sector	Type	Indicator	Page	Geography	Main Sources
Cross-sector	Market Pricing	Crude oil price (USD/bbl)	22	World	IEA ETP
		Natural gas price (USD/MBtu)	23	US, EU	IEA ETP
		Coal prices (USD/ton)	24	World	IEA ETP
		Electricity prices (2015 EUR/MWh)	25	BR, MX, USA, FR, DE, IT	IEA WEO, Third-party source
	Policies costs and incentives	Carbon prices (2015 USD / T-Coeq)	26	US, EU, BR	IEA WEO
Power Utilities	Production & Technology	Electricity generation (TWh)	29	World, BR, MX, USA, FR, DE, IT	IEA ETP, EC Trends 2050
		Electricity capacity (GW)	31	World, BR, MX, USA, FR, DE, IT	IEA ETP, EC Trends 2050
	Market Pricing	Levelised costs of electricity (€/MWh)	32	World, BR, MX, USA, FR, DE, IT	NREL
	Policies costs and incentives	Subsidies (€/Mwh)	34	US	NREL
		Effective carbon rates ($/tCO2)	35	BR, MX, USA, FR, DE, IT	IEA WEO
Automotive	Production & technology	Sales by drivetrain (%)	38	World	IEA
	Market Pricing	Carbon fibre (USD/pound)	39	World	NREL
		Battery costs (USD/kWh)	40	World	Third-party source, BNEF
	Policy costs and incentives	Fuel efficiency standards (%)	41	BR, MX, USA, EU	ICCT
		Effective carbon rates(EUR/tCO2)	42	World, BR, MX, USA, FR, DE, IT	OECD, Third-party source
Steel	Production & technology	Crude Steel production (Mt)	45	World, BR, MX, USA, FR, DE, IT	IEA ETP, EC
		Share of primary/secondary steel(%)	46	World, BR, MX, USA, FR, DE, IT	IEA ETP, EC
		Energy Intensity (GJ / t crude steel)	47	World, BR, MX, USA, FR, DE, IT	IEA ETP
		Carbon Intensity (t CO2 / t crude steel)	48	World, BR, MX, USA, FR, DE, IT	IEA ETP
	Market Pricing	Crude Steel Price (USD / ton)	49	World	Third-party source
		Raw Materials Prices (USD / ton)	50	World	Third-party source
	Policy costs and incentives	Allowances of free CO2 allowances(% of total CO2 direct emissions)	51	BR, EU, MX, USA	Third-party source
Cement	Production & technology	Cement production (Mt)	54	World, BR, MX, USA, FR, DE, IT	IEA ETP, EC Trends 2050
		Clinker to cement ratio (%)	55	World, BR, MX, USA, FR, DE, IT	IEA ETP
		Energy intensity for clinker production (GJ / t clinker)	56	World, BR, MX, USA, FR, DE, IT	IEA ETP
		Share of alternative fuel use (%)	57	World, BR, MX, USA, FR, DE, IT	IEA ETP
		CCS deployment (%)	58	World, BR, MX, USA, FR, DE, IT	IEA ETP
		CO2 Intensity (t CO2 / t cement)	59	World, BR, MX, USA, FR, DE, IT	IEA ETP
	Market Pricing	Secondary Fuels (USD/ton)	60	World	Third-party source
	Policy costs and incentives	Allowances of free CO2 allowances(% of total direct emissions)	61	BR, EU, MX, USA	IEA ETP and Third-party source
Aviation	Production & technology	Demand (passenger-km)	64	World, BR, MX, USA, EU	IEA ETP and Third-party source
		Fuel efficiency (g fuel burned /revenue passenger-km)	65	World	ICCT
		Biofuel penetration (%)	66	BR, MX, USA, FR, DE, IT	ICAO IEA ETP and Third-party source
	Market pricing	Jet fuel prices (USD / gallon)	67	World	IEA ETP
	Policy costs and incentives	Carbon credit mandates (USD/tCO2)	68	World	ICCT, ENVI
		Fuel efficiency standards (kg/km)	69	World	ICCT
Shipping	Production & technology	Shipping Transport Demand (G ton km / year)	72	World	IMO
		Fuel efficiency (kJ/tonne-km)	73	World	Third-party source
		Alternative fuels penetration (%)	74	World	Third-party source
	Market Pricing	Marine Fuel prices (fraction to 2010 HFO price) and (USD/GJ)	75	World	Third-party source
	Policies costs and incentives	Efficiency Design Regulations	76	World	Third-party source
		Emission/Fuel standard	77	World	Rightship

Source: 2° Investing Initiative 2017.

3. Considering transition risks and physical risks as part of scenario analysis

Transition and physical risks are both likely to be crucial for most organisations. A nuanced view of how they interact is crucial for effective scenario analysis.

Many regulators and organisations, including APRA in Australia, have heavily emphasised the importance of transition risks, particularly following the entry into force of the Paris Agreement. The Agreement implies major policy transitions which are likely to accelerate technological, market and socioeconomic changes that drive different transition risks.

However, while it is true that physical risks will be most severe under business-as-usual scenarios, major physical climate impacts and risks will occur even under optimistic, Paris-consistent emissions trajectories. The absence of these risks in much of the existing climate scenario analysis to date is a striking gap. The TCFD technical supplement itself includes a stylised chart of the relationship between "transition" and "impact" risks at different temperature outcomes (Figure 5). This illustration, while only conceptual, creates the impression that a low emissions scenario has negligible impact risks:

Figure 5: Transition and physical risks schematic graph from TCFD technical supplement

Source: TCFD Technical Supplement on Scenario Analysis 2017.

This assumption is widespread, but incorrect, and dangerous. Underplaying the importance of physical impacts within low emissions scenarios could lead to companies and investors overlooking crucial key near- and long-term drivers of financial risk and performance.

The <2°C Paris target is frequently described as a "safe" level of warming, and international agreement that global warming should be limited to 2°C was the main outcome of the Copenhagen COP in 2009. However, the identification of the 2°C threshold, which dates back to the 1980s, was rooted in perceived pragmatism, rather than science. In 1990, the precursor to the IPCC noted that warming of 1°C "may elicit rapid, unpredictable and non-linear responses that could lead to extensive ecosystem damage" while 2°C was "*limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly.*"[32]

Scientific research is increasingly illustrating that physical climate impacts are likely to be profound under any feasible scenario, even the most optimistic scenarios for averting global warming. Figures 6 and 7 are

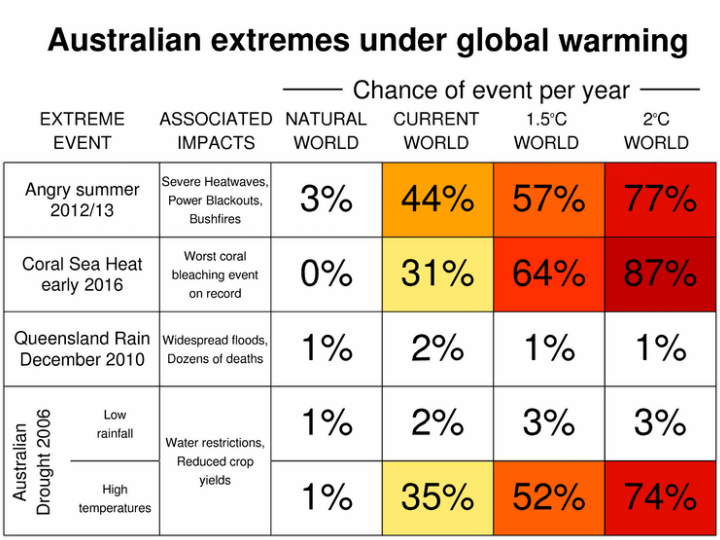
[32] FR Rijsberman, and RJ Swart (eds) "Targets and indicators of climatic change", The Stockholm Environment Institute, 1990.

illustrations from just two recent scientific analyses (one global and one focused on impacts in Australia) highlighting the potential for dangerous physical impacts under 1.5°C and 2°C scenarios, and more concerted research efforts are under way around the world.[33] Even under these emissions trajectories, physical impacts are likely to have major implications for businesses and investors, as well as in other areas like defence and national security.[34]

Figures 6 and 7: Illustrative global and Australian physical impacts under under 1.5-2°C scenarios

	1.5°C	2°
Heat wave duration (months)	1.1	1.5
Reduction in fresh water availability (Mediterranean)	9%	7%
Coral reefs at risk of annual bleaching (global)	90%	98%
Maize yield (tropics)	-3%	-6%
Increase in warm spell duration (southern part of Australia)	12.7 days	19.8 days
Increase in warm spell duration (northern part of Australia)	36.5 days	52.3 days

Source: Schleussner et al 2016, Hare et al 2016



Source: King, Henley, Karoly, 2017

Physical impacts – key questions for further discussion:

- *How can information preparers begin disclosing useful information about the physical impacts of climate change?*
- *What tools, resources and capabilities might be needed?*
- *How can extremes, variance and increased uncertainty be incorporated, rather than averages and threshold exceedance?*
- *How can the available resources for estimating physical impacts be translated into financial impacts?*

4. Ensuring transparency about assumptions, challenges and implications

The need for transparency is at the core of the push for better climate risk analysis and disclosure. At the highest level, the TCFD framework is an attempt to help markets better price risk and support more informed and efficiently capital allocation decisions, by focusing on a subset of financial risks – those that are climate related – that have typically been misunderstood and mispriced. Scenario analysis is meant to provide rigorous, actionable information to both firms and markets about how these risks and exposures might evolve under different assumptions regarding an uncertain future.

To state the obvious, scenario analysis can only fulfil this purpose if it generates comparable, useful information that is consistently disclosed. Particularly in the absence of a formal or de facto "standard" scenario,

[33] For example, the HELIX project (High End Climate Impacts and Extremes) is an EU-funded partnership between more than a dozen research institutions examining impacts under a 1.5°C, 2°C, 4°C and 6°C of warming.
[34] See Robert Sturrock, Submission to Australian Senate Foreign Affairs, Defence and Trade References Committee inquiry into implications of climate change for Australia's national security , July 2017, Centre for Policy Development.

transparency at least ensures that what is analysed and disclosed can provide useful insight into the discloser's understanding of climate-related risks, and whether and how that factors into its strategy, risk management, and other key decisions.

This has proved challenging so far. As our comparison of scenario analyses exercises to date illustrates (see Appendix), many have failed to include even rudimentary information that would allow anything more than superficial analysis and comparison of the results.

Stakeholders recognise that the capabilities and experience to conduct and disclose high-quality scenario analysis will take time to develop. However, without clear disclosure of the parameters and assumptions behind scenario analysis, corporate attempts to conduct and disclose these exercises may fail to generate credibility and goodwill from investors and other stakeholders.

On scenario analysis specifically, the TCFD says organisations with significant climate-related exposures should strive to disclose the following:

(1) The scenarios used, including the 2°C or lower scenario
(2) Critical input parameters, assumptions and analytical choices for the scenarios used, including:
    a) assumptions about possible technology responses and timing
    b) assumptions about potential differences in input parameters across countries, regions, asset locations and markets
    c) approximate sensitivities to key assumptions
(3) Time frames used for scenarios, including short, medium and long-term milestones
(4) Information about the resiliency of the organisations strategy, including
    a) strategic performance implications under the various scenarios
    b) potential qualitative or directional implications for the value chain, capital allocation decisions, and R&D focus
    c) potential material financial implications for operating results and/or financial position.[35]

We suggest two additional hallmarks of appropriate transparency around scenario disclosures.

First, disclosures should make genuine attempts to **incorporate and recognise difficult scenarios and assumptions**. Publicly-available climate scenario exercises to date invariably demonstrate that the discloser can prosper in any scenario. If the potentially challenging implications of some scenarios are overlooked or not disclosed this will undermine the credibility of disclosures and the ability of markets to utilise this information.

Second, disclosures should **openly recognise capability gaps, methodological challenges and areas that require further work** – especially in the early stages as familiarity with and adoption of scenario analysis grows. Recognising that scenario analysis at an early stage does not mean lowering expectations or standards – indeed, there is a clear expectation that sophisticated organisations with large potential exposures should be conducting high-quality scenario analysis. However it is natural to expect that early approaches will face challenges, including due to limitations in reference scenarios and other resources documented above.

Transparency – key questions for further discussion:

- *How can the qualitative and quantitative elements of scenario analysis be disclosed in a clear way?*

[35] TCFD, Technical Supplement on Scenario Analysis, 2017.

5. Disclosures should show that organisations are responding to scenario analysis

A core question in assessing disclosures is whether the information provided identifies whether and how the company is responding to scenario analysis through its strategy, governance and risk management processes. As the TCFD and statements by leading regulators make clear, the core purpose of conducting scenario analysis is to help organisations and information users assess possible climate-related risks and opportunities over time, and design or predict appropriate responses. The TCFD framework explicitly requires disclosure not just of metrics and targets to assess risk, but comprehensive information about (1) organisational governance around climate-related risks and opportunities (2) their actual and potential impacts on businesses, strategy and financial planning (3) the risk management processes used to identify, assess and manage them.

The requirement to demonstrate steps taken to address risk is consistent with existing Australian guidelines and expectations. The ASX Listing Rules and associated guidance recommend that as part of existing reporting requirements, a listed entity should "disclose whether it has any material exposure to economic, environmental and social sustainability risks and, if it does, how it manages or intends to manage those risks."[36]

Disclosing climate risks without also setting out prudent responses merely raises additional risks – including negative reactions from shareholders, markets, regulators or the courts. Regulators and major investors who are increasingly attuned to emerging climate and other sustainability-related risks will want to see evidence that these are being addressed through risk management processes and good governance. In some cases, failing to respond to identified risks could raise the prospect of legal liability for the consequences. The Hutley SC opinion on climate risk concluded that in some cases, directors' duties of due care and diligence require directors "to go further than merely to consider these risks…[s]ome further action may be required." From a legal standpoint, this requires weighing up the foreseeable harm associated with certain risks with potential benefits from addressing (or not addressing) them, including factors such as the magnitude of the risk, the probability it will occur, and the expense, difficulty and inconvenience of taking alleviating action.[37]

Clearly identifying a "base case" scenario, and the rationale for choosing it, is an important way to link the discloser's understanding of climate risks and opportunities to its governance and its decisions on strategy and risk management.

Early scenario analysis exercises in Australia provide only limited evidence of company responses, although there are some examples of scenario analysis exercises being cited as key driver of updated long-term climate-related strategy and targets (see Appendix). The TCFD recommendations raise the bar. As the Hutley opinion concludes, "internal processes and cultures for assessing, disclosing and responding to climate and other sustainability risks are still in an early stage of development However, there are prominent examples…of what

Company responses – key questions for further discussion:

- *How should the information preparer's response to its own scenario analysis be reflected in specific sections of the TCFD disclosures, particularly around risk and strategy?*
- *Should this go beyond simply identifying a base-case scenario?*
- *If a high-emissions scenario is identified as the base case, can this be balanced with appropriate physical impact scenario analysis?*

[36] See ASX Listing Rules, Rule 4.10.3.
[37] Noel Hutley SC 2016, p.38.

level of reporting is possible, which might serve as benchmarks for what is desirable (or even legally necessary) in the future."[38]

4. Implications for policymakers and regulators

This paper has focused primarily on steps that business, investors and market participants can take to develop and assess scenario based analysis and disclosures. But regulators and policymakers also have a key role to play too – both by guiding early efforts and standards for robust scenario analysis, and by developing analytical capability and expertise of their own. In simple terms, they need to know the right questions to ask when it comes to climate-related risks and scenario analysis, and to know when they are getting good answers.

By setting out clear guidance and expectations, regulators and other authorities can make a very important contribution to the broader task of building a consistent, robust approach to scenario analysis by companies, investors and key stakeholders. APRA has already played a crucial role in Australia by bringing increased attention to the relevance of climate risks in the financial sector and emphasising the importance of strategic, scenario-based assessments of climate risk. An important next step is to encourage Australian approaches that are consistent with emerging international standards and best practice, as exemplified by the TCFD. Early this year, a Senate Economic References Committee inquiry into carbon risk disclosure recommended that the Government commit to implementing the TCFD framework, and that a single authority should be nominated to lead the Government's response.[39] A key part of this task is continuing to build awareness of the TCFD recommendations, and setting out clear expectations that local investors and companies work towards a Australia-specific approach that builds on the high-level guidance offered by the TCFD report.

Regulators and policymakers also need to develop climate-specific expertise and capabilities themselves – including in the area of scenario analysis. Without these capabilities, key agencies will not be able to assess the accuracy and rigour of climate-related disclosures by the firms and institutions they oversee. They also need to be able to conduct stress-testing and scenario exercises of their own, in order to pre-empt and respond to emerging systemic risks, and to update their own strategy and supervision accordingly. For example, to assess how effectively regulated entities are identifying and managing possible climate-related risks, APRA supervisors will need to have well-developed frameworks for understanding how different transition and physical risks might manifest and impact across different financial institutions and markets. Similarly, to incorporate climate-related shocks into system-wide stress testing, APRA will require greater expertise on how important tail risks in physical impact and transition scenarios should be selected and modelled.

In addition to investing in this internal capability, we suggest three clear priorities for Australian regulators and policymakers:

- **Unambiguously support widespread adoption of the TCFD recommendations, including on scenario analysis.** APRA's February 2017 statement emphasised the TCFD's key themes, including on scenario analysis, and said that APRA expected this framework to be influential. While awaiting a formal government response to the Senate Committee report, APRA and other regulators should take the lead by formally endorsing the TCFD, and making it clear that they expect regulated entities to work towards emerging international best practice as embodied in the report.

- **Consider more stringent climate-related disclosure requirements, including in light of how well Australian institutions respond to emerging voluntary standards.** The Senate Committee report

[38] Noel Hutley SC 2016 p. 49.
[39] *Carbon risk: A burning issue*, Senate Economics References Committee, April 2017.

on carbon risk considered international models for regulating the disclosure of carbon risks, and recommended the government review the adequacy of mandatory financial disclosures under the *Corporations Act 2001 (Cth)*. The Government has still not responded formally to this and other recommendations, although ASIC has clarified that climate-related risks should be proactively considered and reported by companies and their boards, pursuant to *Corporations Act* requirements on financial disclosures. Policymakers should continue to consider options for more stringent, or mandatory, disclosure requirements for climate-related risks – particularly in light of whether there is adequate take up of voluntary guidelines and standards that are now well known and readily usable.

- **Improve co-ordination and information sharing on climate-related risks between key regulators and authorities, including APRA, ASIC, the RBA and Treasury.** Regulation of Australia's financial system is premised on careful co-ordination and information sharing between relevant regulators and agencies to identify financial system risks and promote financial system stability. Climate-related risks are clearly an area of significant focus and emerging concern. This warrants a co-ordinated response to share information and expertise, to clarify roles and responsibilities across different agencies and, if necessary, co-ordinate responses to potential financial stability threats. This process could be overseen by the Council of Financial Regulators, which provides an established forum for considering matters that overlap the respective mandates and roles of APRA, ASIC, the RBA and Treasury. Involvement of the financial reporting authorities (the AASB, AUASB, and Financial Reporting Council) may also be warranted. The UK and the European Union have already convened multi-authority panels and taskforces.

Appendix: Examples of company scenario analysis

This table provides a high-level overview of example scenarios for illustrative purposes only. For full details please refer to the links provided.

	HIGH LEVEL PARAMETERS		SENSITIVE PARAMETERS	TRANSPARENCY	PHYSICAL RISK	EFFECT ON DECISIONS	
Organisation	**Net zero emissions by 2050?**	**Horizon of analysis**	**Key transition parameters**	**Level of transparency/disclosure**	**Physical impacts included?**	**Impact on decisions?**	**Identifies base case?**
AGL[40]	Yes	2030, aligned with 2050 decarbonisation	Budgeted response, using the Climate Change Authority's (CCA) 10.1Gt budget for 2030 – 2050. The National Electricity Market (NEM) budget is 3,026Mt (derived from national budget). PLEXOS modelling for NEM reduction pathways (three pathways: 1. no carbon reduction; 2. 26-28% reduction from 2005 levels by 2030; and 3. 2°C budget based on CCA analysis). Discusses marginal abatement cost of carbon at AUD$40/t for a new coal power plant, and >AUD$100/t for an existing coal plant.	• Discloses carbon budget • Discloses trajectory • Discloses own sectoral budget allocation • Includes 2030 and 2050 horizon	No	Unclear, but company has supported net zero emissions for electricity generation by 2050.	Not explicitly, but indicates "significant emissions reductions" are a reasonable assumption.
Origin Energy[41]	Yes	2030, aligned with 2050 decarbonisation	Budgeted response applied to the wholesale generation portfolio, using the Climate Change Authority's (CCA) 10.1Gt budget for 2013 – 2050. PLEXOS modelling for NEM reduction based on three pathways: (1) Business as usual which assumes no more measures once LRET and VRET are met. (2) A GHG reduction of -27% from 2005 levels by 2030; and (3). A 2°C budget based on CCA analysis with -45% GHG by 2030.	• Discloses carbon budget • Discloses trajectory • Discloses own sectoral budget allocation • Includes 2030 and 2050 horizon • Limited to wholesale generation business	No	Unclear, but company has supported net zero emissions for electricity generation by 2050.	Unclear, but states that wholesale generation is better off under 2°C scenario than either BAU or NDC.

[40] AGL, http://agl2016.sustainability-report.com.au/files/carbon_constrained_future.pdf
[41] Origin Energy - https://www.originenergy.com.au/content/dam/origin/about/investors-media/AGM%202017/Scenario%20Analysis%20FY2017.pdf

	HIGH LEVEL PARAMETERS		SENSITIVE PARAMETERS	TRANSPARENCY	PHYSICAL RISK	EFFECT ON DECISIONS	
Organisation	**Net zero emissions by 2050?**	**Horizon of analysis**	**Key transition parameters**	**Level of transparency/disclosure**	**Physical impacts included?**	**Impact on decisions?**	**Identifies base case?**
South32[42]	Yes	2050	Global emissions peak 2025 Net zero emissions in 2050 Global carbon market by 2030 Solar + wind make up 41% of "energy mix" by 2040. Limited CCS deployment. Commodity recycling "to its technical limits"	• Discloses emissions peak and end-point • Discloses reference scenarios • Discloses renewables level in 2040 • Discloses CCS assumptions • Carbon price assumptions • Carbon market assumptions	Yes, although detail is limited.	Says decision on no greenfield coal developments linked to 2°C scenario. Lays out plan for five-yearly emissions reductions plans towards zero in 2050; but for Scope 1 only.	Unclear
BHP Billiton[43]	No	2030	Four scenarios, plus 'signals' which show that the world is moving towards or away from each scenario. In the 'Global accord' 2°C scenario, a carbon price of US$50 in 2030 is identified.	• Discloses assumptions on government emissions targets to 2030 by region (or peak emissions date where applicable) • Does not disclose global budget or trajectory; states "in line with levels indicated by the IPCC" after 2030 (in case of the Global accord) and by 2030 (in case of the shock event) • Discloses carbon prices • Does not disclose 2050 point	Yes, although detail is extremely limited.	BHP states scenario analysis informs its approach to portfolio management; "all commodities in existing portfolio, including oil, gas and thermal, have strong future margins."	Central case is informed by NDCs, equivalent to warming of 3°C

[42] South32: https://www.south32.net/docs/default-source/all-financial-results/2017-annual-reporting-suite/our-approach-to-climate-change.pdf?sfvrsn=87ac4576_9
[43] BHP http://www.bhp.com/-/media/bhp/documents/investors/reports/2015/bhpbillitonclimatechangeporfolioanalysis2015.pdf?la=en and http://www.bhp.com/-/media/bhp/documents/investors/reports/2016/bhpbillitonclimatechangeporfolioanalysis2016.pdf?la=en

Organisation	HIGH LEVEL PARAMETERS		SENSITIVE PARAMETERS	TRANSPARENCY	PHYSICAL RISK	EFFECT ON DECISIONS	
	Net zero emissions by 2050?	Horizon of analysis	Key transition parameters	Level of transparency/disclosure	Physical impacts included?	Impact on decisions?	Identifies base case?
BP[44]	No	2035	"Base case" of fossil fuels accounting for 78% of total energy supplies in 2035. Energy demand rises 30% from 2015 levels. 'Faster transition' case requires $100/t price on carbon by 2035 and strict emission policy. "Faster Transition" is -12% CO2 emissions by 2035 from 2015 "Even faster transition" is -32% CO2 emissions by 2035 from 2015; is aligned with IEA 450 Scenario.	• Draws on BP's Energy Outlook, a detailed set of historical data and projections.	States that adaptation is incorporated into planning of all new projects, gives examples; refers to global climate models supported by scientists at Princeton University and Imperial College London	Shifting to gas and "advantaged oil", while "moving away from projects that don't fit our strategy, like the Great Australian Bight".	Yes: emissions increase by 13% to 2035
Royal Dutch Shell[45]	No	2100; detailed disclosures of energy production and consumption at decadal intervals to 2060.	Two independent scenarios and International Energy Agency's 450 Scenario, all scenarios out to 2100; expectation of net zero emissions in 2100. "Mountains" incorporates high CSS deployment, with 30% of CO_2 from energy by 2050 and 70% by around 2075. Liquid fuels eliminated by 2080 from passenger road vehicles. "Oceans" has slower CCS deployment (unspecified); 60% improvement in residential energy efficiency by 2060; 80% increase in	• Discloses CCS assumptions • Discloses detailed quantitative demand assumptions • Discloses long-term changes in substitution, liquid fuels, efficiency	Food and water stress are referenced; but little detail.	Shell states that decisions are based on scenarios but no specifics are provided.	

[44] BP: https://www.bp.com/content/dam/bp/en/corporate/pdf/sustainability-report/group-reports/bp-sustainability-report-2016.pdf
[45] Royal Dutch Shell: http://www.shell.com/energy-and-innovation/the-energy-future/scenarios/new-lenses-on-the-future/_jcr_content/par/relatedtopics.stream/1448477051486/08032d761ef7d81a4d3b1b6df8620c1e9a64e564a9548e1f2db02e575b00b765/scenarios-newdoc-english.pdf and http://www.shell.com/energy-and-innovation/the-energy-future/scenarios/a-better-life-with-a-healthy-

Organisation	HIGH LEVEL PARAMETERS		SENSITIVE PARAMETERS	TRANSPARENCY	PHYSICAL RISK	EFFECT ON DECISIONS	
	Net zero emissions by 2050?	Horizon of analysis	Key transition parameters	Level of transparency/disclosure	Physical impacts included?	Impact on decisions?	Identifies base case?
			industry energy efficiency by 2100; 33% of chemical feedstocks from recycling by 2100.				
Westpac[46]	Yes	2050	Three 2°C scenarios which all achieve net zero emissions by 2050: • Strong national action where countries act on their own and there is rapid domestic action on climate change; • Combined global action where coordinated global action results in a smooth transition to a low carbon economy; and • Delayed action where initial delays in action lead to a rapid mitigation post-2030. Although implied, there is no explicit mention of the level of a carbon price in any scenario.	• Discloses net zero endpoint by 2050 for Australia; a necessary achievement for <2°C • Doesn't disclose budget or midpoint/trajectory • Discloses broad assumptions around existence or lack of a global coordinated carbon market across different scenarios	No	Westpac says it has set targets, including energy generation financing, coal mining financing, and lending to climate change solutions, "to remain on a credible pathway" to net zero emissions by 2050.	No; but all three scenarios are <2°C

planet/_jcr_content/par/textimage_494361683.stream/1475857466913/a1aa5660d50ab79942f7e4a629fcb37ab93d021afb308b92c1b77696ce6b2ba6/scenarios-nze-brochure-interactive-afwv9-interactive.pdf

[46] Westpac: Scenario: https://2016annualreport.westpacgroup.com.au/assets/Westpac_Sustainability_Report_2016.pdf Response https://www.westpac.com.au/content/dam/public/wbc/documents/pdf/aw/sustainability/WestpacCCEActionPlan.pdf

Organisation	HIGH LEVEL PARAMETERS		SENSITIVE PARAMETERS	TRANSPARENCY	PHYSICAL RISK	EFFECT ON DECISIONS	
	Net zero emissions by 2050?	Horizon of analysis	Key transition parameters	Level of transparency/disclosure	Physical impacts included?	Impact on decisions?	Identifies base case?
Glencore Xstrata[47]	No	2040	Three scenarios: • "Delayed Action" is a weak and uncoordinated implementation of current NDCs and carbon prices of $US10-40 by 2040; • "Committed Action" based on the IEA's New Policies Scenario (full implementation of current NDC and carbon prices of $US20-50 by 2040; and • "Ambitious Action" based on IEA 450 scenario with carbon prices of $US125-140 by 2040.	No. ("Ambitious Action" based on IEA 450 Scenario).	Lists many climate impacts including rainfall changes, drought, storm surge. Briefly describes a process of surveying assets and amending risk register.		Yes; "Delayed Action", based on weak implementation of current NDCs, is central scenario.

[47] Glencore http://www.glencore.com/assets/sustainability/doc/sd_reports/2017-Climate-change-considerations-for-our-business.pdf

Glossary of terms and acronyms

APRA	Australian Prudential Regulation Authority
ASIC	Australian Securities and Investments Commission
IEA	International Energy Agency
IEA 2DS Scenario	An IEA *Energy Technology Perspectives* scenario that lays out an energy system deployment pathway and an emissions trajectory consistent with at least a 50 per cent chance of limiting the average global temperature increase to 2°C.
IEA 450 Scenario	A IEA *World Energy Outlook* decarbonisation scenario built around an objective of limiting the average global temperature increase in 2100 to 2°C. above pre-industrial levels. The scenario was created when climate targets were typically expressed in terms of the concentration of greenhouse gases in the atmosphere (in this case, 450 parts per million of CO_2 equivalent). The scenario is now expressed as realising a 50 per cent chance of limiting warming to 2°C by 2100.
IPCC	Intergovernmental Panel on Climate Change

References

2° Investing Initiative and The CO Firm, 'The transition risk-o-meter: Reference scenarios for financial analysis', 2017. http://et-risk.eu/wp-content/uploads/2017/11/2ii_TransitionRiskScenarios_v0.pdf

Alison George, "The key to achieving the TCFD's aims for climate disclosure", Regnan, February 2017, http://regnan.com/the-key-to-achieving-the-tcfds-aims-for-climate-disclosure

Andrew King, Ben Henley and David Karoly, 'Why 2℃ of global warming is much worse for Australia than 1.5℃',*The Conversation,* 16 May 2017. https://theconversation.com/why-2-of-global-warming-is-much-worse-for-australia-than-1-5-77548

Australian Council of Superannuation Investors, *Corporate Sustainability Reporting in Australia: An Analysis of ASX200 Disclosure, Featuring Climate-related risk,* July 2017 *https://acsi.org.au/images/stories/ACSIDocuments/generalresearchpublic/2017-Sustainability-Report-FINAL.pdf*

Australian Government, Climate Change Authority, *Policy Options for Australia's Electricity Sector: Special Review Research Report*, August 2016., http://climatechangeauthority.gov.au/sites/prod.climatechangeauthority.gov.au/files/files/SR%20Electricity%20research%20report/Electricity%20research%20report%20-%20for%20publication.pdf

Australian Government, Climate Change Authority, *Reducing Australia's Greenhouse Gas Emissions – Targets and Progress Review*, Final Report, February 2014 http://www.climatechangeauthority.gov.au/files/files/Target-Progress-Review/Targets%20and%20Progress%20Review%20Final%20Report.pdf

Australian Securities and Investments Commission, *Regulation of Corporate Finance: January to June 2017*, August 2017, http://www.asic.gov.au/media/4425125/rep539-published-28-august-2017-1.pdf

Australian Senate Economics References Committee, *Carbon risk: a burning issue*, April 2017

Bill Hare, Niklas Roming, Michiel Schaeffer and Carl-Friedrich Schleussner, 'Implications of the limit in the Paris Agreement for climate policy and decarbonisation', *Climate Analytics*, August 2016. http://climateanalytics.org/files/1p5_australia_report_ci.pdf

Carbon Tracker Initiative, *Expect the Unexpected: The Disruptive Power of Low-carbon Technology*, 2017. http://www.carbontracker.org/wp-content/uploads/2017/02/Expect-the-Unexpected_CTI_Imperial.pdf

Carl-Friedrich Schleussner, Tabea K. Lissner, Erich M. Fischer, Jan Wohland, Mahé Perrette, Antonius Golly,, Joeri Rogelj, Katelin Childers, Jacob Schewe, Katja Frieler, Matthias Mengel, William Hare, and Michiel Schaeffer, 'Differential climate impacts for policy-relevant limits to global warming: the case of 1.5 ◦C and 2 ◦C', *Earth System Dynamics*, 7, 327-351, 2016.

Climate Analytics, 'Implications of the Paris Agreement for coal use in the power sector,' November 2016 http://climateanalytics.org/files/climateanalytics-coalreport_nov2016_1.pdf

ClimateWorks and Australian National University, *Pathways to deep decarbonisation in 2050: How Australia can prosper in a low carbon world*, Initial Project Report, 2014 https://www.climateworksaustralia.org/sites/default/files/documents/publications/climateworks_pdd2050_initialreport_20140923.pdf

Conference of the Parties, Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015, United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf#page=2

Elmar Kriegler,, John P. Weyant, Geoffrey J. Blanford, Volker Krey, Leon Clarke, Jae Edmonds,m ,Allen Fawcett, Gunnar Luderer, Keywan Riahi & Richard Richels & Steven K. Rose & Massimo Tavoni & Detlef P. van Vuuren, "The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies", *Climatic Change*, 2014, DOI 10.1007/s10584-013-0953-7.

FERI Cognitive Finance Institute and ISS-Ethix Climate Solutions, 'Transition to a low-carbon economy: How it impacts investors and the sectors they invest in', 2017 https://www.feri-institut.de/media/1606/fcfi_iss_ethix-201711.pdf

Financial Stability Board Task Force on Climate-related Financial Disclosures, *Final Report*, June 2017 http://www.fsb.org/wp-content/uploads/P290617-5.pdf

Financial Stability Board Task Force on Climate-related Financial Disclosures, *Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*, June 2017 https://www.fsb-tcfd.org/publications/final-technical-supplement/

Fischedick M., J. Roy, A. Abdel-Aziz, A. Acquaye, J. M. Allwood, J.-P. Ceron, Y. Geng, H. Kheshgi, A. Lanza, D. Perczyk, L. Price, E. Santalla, C. Sheinbaum, and K. Tanaka, 2014: Industry. In: *Climate Change 2014: Mitigation of Climate Change. Contri- bution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S.

Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter10.pdf

FR Rijsberman, and RJ Swart (eds) "Targets and indicators of climatic change", The Stockholm Environment Institute, 1990. https://www.sei-international.org/mediamanager/documents/Publications/SEI-Report-TargetsAndIndicatorsOfClimaticChange-1990.pdf

Geoff Summerhayes, 'Australia's new horizon: climate change challenges and prudential risk', Australian Prudential Regulation Authority, February 2017 http://www.apra.gov.au/Speeches/Pages/Australias-new-horizon.aspx

Henri Waisman and Chris Bataille, "Methodological Insights for Builiding Scenarios in the Post-Paris Context,' IDDRI, July 2016. http://blog.iddri.org/en/2016/07/04/methodological-insights-for-building-scenarios-in-the-post-paris-context/

International Energy Agency and International Renewable Energy Agency, *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System*, 2017 https://www.energiewende2017.com/wp-content/uploads/2017/03/Perspectives-for-the-Energy-Transition_WEB.pdf

Joeri Rogelj, Michiel Schaeffer and Bill Hare, 'Timetables for Zero emissions and 2050 emissions reductions: State of the Science for the ADP Agreement', Climate Analytics, February 2015. http://climateanalytics.org/files/ca_briefing_timetables_for_zero_emissions_and_2050_emissions_reductions.pdf

Joeri Rogelj,, Gunnar Lederer, Robert C. Pietzker, Elmar Kriegler, Michiel Schaeffer, Volker Krey and Keywan Riahi, 'Energy system transformations for limiting end-of-century warming to below 1.5°C', *Nature Climate Change*, 5, 519-527, 2015 DOI: 10:1038/nclimate2572

Johannes Morfeldt, Wouter Nijs, Semida de Campos Silveria , 'The impact of climate targets on future steel production: an analysis based on a global energy system model', *Journal of Cleaner Production* (103), 469-482, 2014. https://www.researchgate.net/publication/262811886_The_impact_of_climate_targets_on_future_steel_production_-_An_analysis_based_on_a_global_energy_system_model

Michael Wilkins, "How the recommendations of the TCFD may figure into our ratings," *S&P Global*, August 2017, https://www.spglobal.com/our-insights/How-The-Recommendations-Of-The-Task-Force-On-Climate-Related-Financial-Disclosures-May-Figure-Into-Our-Ratings.html

Noel Hutley SC and James Mack Superannuation trustee duties and climate change risk, Market Forces/Environmental Justice Australia, September 2016, http://superswitch.org.au/wp-content/uploads/2017/07/170615-Market-Forces-Memorandum-Superannuation-Trustee-Duties-and-Climate-Change-Risk-Hutley-Mack-.pdf

Noel Hutley SC and Sebastian Hartford-Davis, *Climate change and directors' duties*, CPD and the Future Business Council/MinterEllison Lawyers, October 2016,, https://cpd.org.au/wp-content/uploads/2016/10/Legal-Opinion-on-Climate-Change-and-Directors-Duties.pdf

Robert Sturrock, Submission to Australian Senate Foreign Affairs, Defence and Trade References Committee Inquiry into Implications of Climate Change for Australia's National Security , July 2017, Centre for Policy Development https://cpd.org.au/wp-content/uploads/2017/07/Sub-24_Centre-for-Policy-Development.pdf

Steve Pye and Chris Bataille, ' Improving deep decarbonisation modelling capacity for developed and developing country contexts', *Climate Policy*, 27-46. 2016.

TCFD and Bank of England, Conference on Climate Scenarios, Financial Risk and Strategic Planning, 31 October and 1 November 2017, London.

The University of Cambridge Institute for Sustainability Leadership, *Unhedgeable risk: How climate change sentiment impacts investment*, 2015. https://www.cisl.cam.ac.uk/publications/publication-pdfs/unhedgeable-risk.pdf

United Nations Framework Convention on Climate Change, *Paris Agreement*, 2015 http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf