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Climate change adaptation in industry and business: a framework for best practice in financial risk assessment, governance and disclosure

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CLIMATE CHANGE ADAPTATION IN INDUSTRY AND BUSINESS

A Framework for Best Practice in Financial Risk Assessment, Governance and Disclosure

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

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ABSTRACT

The Australian business community has long been aware of the risks and opportunities associated with greenhouse gas mitigation and climate change policies. Some businesses have taken initial steps to adapt to the expected effects of climate change; however, most enterprises are only vaguely aware of the breadth of adaptation that may be required. Associated with strategic adaptation are the principles of financial/operational risk management and governance, as well as financial impact disclosure to investors and regulators. We develop a consolidated framework in which boards and executive managers can develop a robust approach to climate change adaptation governance, climate change risk assessment and financial disclosure. The project outlines a matrix of disclosures required for investors to enable them to evaluate corporate exposure to climate change risk.

The project initially comprised a set of workshops with members of the Australian business community, industry representatives, regulatory authorities and academics with expertise in business risk and disclosure effects. Each workshop focused on a separate theme that built upon the work of previous workshops. A set of follow-up discussions was held with some of the key members who contributed to the project, including the Australian Stock Exchange (ASX) Investor Group on Climate Change (IGCC), the Australian Accounting Standards Board (AASB) and the Australian Institute of Company Directors. This discussion permitted each body to comment on the final report, advise on the mechanics of the costing, reporting and disclosure approaches of climate change adaptation, and lend their expertise to the formulation of an appropriate framework.

The scope of the research is constrained to firm behaviour and the requirements for investor disclosure and governance of adaptation activities. The project therefore focuses on financial analyses – including real options – undertaken by firms with regard to investing in climate change adaptation activities and projects. While the economic costs and benefits are important to organisational adaptation activities, they represent a secondary level of analysis that may need to be carried out on either an independent or cumulative scale by governments or other bodies to measure the wider effects.

As the degree of sophistication in climate change adaptation activities, modelling and cost estimation increases, along with the anticipated growth in interest of both company boards and managers, it is expected that accounting standards, ASX listing rules and disclosures required under the *Corporations Act* would need to explicitly reflect these corporate actions. The asset allocation of banks, mutual funds, superannuation funds and other investments is also likely to adapt as companies quantify their exposure to climate change. The makeup of assets in investment portfolios may therefore markedly shift, and thus indirectly adjust to the climate change adaptation activities of companies in the broader market.

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EXECUTIVE SUMMARY

Mitigation of the likely impacts of climate change is already a priority. The impacts of climate change are anticipated to be felt by businesses and governments around the world. It is becoming generally accepted that businesses and governments will need to adapt their plans and behaviours to respond to the challenges of climate change. While global-level adaptation dynamics are varied and complex, this study focuses specifically on climate change adaptation mechanisms for companies whose focus on adaptation has increased with the aim of protecting their business operations from climate change risk. In particular, the study covers climate change adaptation governance, risk assessment and financial disclosure of adaptation measures in the context of Australian business laws and practices.

Climate change and its impacts will vary by company. The extent to which assets and operations will need to adapt, and the form that this may take, will vary with the nature and level of risk. This study assesses the adequacy of the current regulatory framework for the reporting of climate change adaptation, addressing its relevance to both investors and regulators, and assesses the likely impacts on the sources and uses of company finances. The study finds that some of the current systems by which climate change adaptation is reported are inadequate for the needs of investors. To combat this deficiency, we define a matrix of disclosures for investors to enable them to evaluate investment exposure to climate change risk.

Adaptation strategies cover all aspects of policy and planning approaches to changes to asset and operation design, the modification, relocation or replacement of existing infrastructure and/or operations and the alteration of operations or maintenance regimes. The framework developed in this study avoids prescription and advocates an approach to adaptation planning and cost estimation based on fundamental and well-understood risk-management principles so that climate change impact mitigation is considered in terms of the risks involved and the asset or operation's sensitivity to such risks. The nature and extent of adaptation in each situation will depend on the costs and efforts involved, compared with the benefits of adopting different adaptation strategies to achieve the target level of resilience.

An informed market that values organisations with a clear charter for the management of climate change risk is a necessity if Australian business is to adapt. This project outlines a framework through which the provision of information to the market through improvements in the disclosure, corporate governance and risk management of climate change. This will allow businesses to optimise their exposure to the threats and opportunities of climate change.

The study revealed that climate change adaptation activities, cost estimates and modelling will be conducted by companies ahead of formal changes to ASX listing rules, changes to accounting standards and disclosures required under the *Corporations Act* to explicitly deal with the issue. But given the rudimentary approach by many firms with regard to adaptation measures, these frameworks can, at present, largely accommodate climate change adaptation activities and cost estimates without an explicit and separate governance and reporting structure. This is valid for companies needing to comply with such requirements as well as firms whose need to comply is limited. The framework developed from this analysis provides *additional guidance* on risk management, governance, cost estimates and investor disclosure for boards and company managers engaged in climate change adaptation activities. In many cases, voluntary disclosures, bespoke governance frameworks and risk-management practices will be necessary to provide investors with a more complete picture of undertakings and costs specifically associated with adaptation as a separate corporate activity.

For companies to successfully prosecute their response to climate change through adaptation, they require a framework for valuing, executing and managing risks associated with adaptation actions. The framework we describe in this study advocates that climate change risks and adaptation measures should be managed under an integrated framework that:

- articulates climate change adaptation policy
- demonstrates commitment
- allocates resources
- assigns responsibility, and
- advocates continuous improvement.

The framework is constructed to cater for company boards and executives, investors, regulators and other stakeholders such as community bodies, consumers and suppliers. The broad framework identifies four distinct activities where businesses will increasingly need to apply effort to successfully manage their adaptation activities:

- risk assessment
- vulnerability
- adaptation
- disclosure.

A crucial first step in climate change adaptation is for companies to assess the implications of climate change on their:

- systems and processes (e.g. productivity, resource supply, infrastructure damage, supply chain disruptions)
- workplace environment (e.g. worker health, long-term liabilities), and
- external effects (e.g. operational restrictions, government regulation)

to determine the extent to which climate change will pose a risk or offer beneficial opportunities.

When assessing more precise expected costs and benefits of adaptation options, companies either implicitly or explicitly use one or more of the following approaches, which have proven to be effective decision support tools: expected loss assessment (ELA); cost benefit analysis (CBA); cost effectiveness analysis (CEA); and multi-criteria analysis (MCA). The approach selected depends on the number of adaptation objectives required by the company’s business units and the measurability of the impacts. In many situations, several approaches are applied in a complementary fashion. Regardless of the assessment approach chosen, each should be:

- practical – appropriate for a given economic setting and take into account data constraints
- relevant – with results presented in a format compatible with existing decision-making systems
- robust – transparent and consistent within and across sectors, where appropriate using common underlying climatic and economic assumptions, and discount rates
- comprehensive – assess a wide range of options, including inaction, action outside sectoral boundaries and co-benefits, and
- proportional – motivated by the need for a decision rather than aiming to make the perfect decision.

Companies taking action to adapt to climate change must identify current and potential impacts on business, reduce vulnerability to them and take advantage of any potential opportunities they present. Companies increasingly and inevitably will address adaptation as aspects integral to their business strategy and risk management. Actions taken to minimise and respond to the effects of climate change should ultimately be reflected in financial statements, but there are other implications for continuous disclosure rules, reporting transparency for improving investor relations, auditing of financial statements around adaptive capacity, and board and executive governance of the adaptation and risk-management process.

The major issues of reporting on adaptation activities identified in the study include:

- initial accounting for adaptive (idle) capacity
- impairment and provisioning of adaptive capacity assets and insurance
- financing adaptive activities
- defining additional financing costs for adaptive capacity, and
- revaluation of assets with adaptive capacity through time.

Climate change activities will naturally impact important aspects of company reporting. Based on the potential financial impacts associated with climate change, there are several existing financial accounting standards that adequately address disclosure of climate change risk and adaptation activities. However, there are a number of elements that are of concern. Adaptation activities such as building adaptive capacity into assets and operations may incur detrimental accounting treatment if such investment occurs in the absence of tax relief under certain accounting standards and principles. While building adaptive capacity can be an alternative to insurance, insurance can be expensed but adaptive capacity in excess of an asset's 'fair' or book value cannot. This puts firms that adopt adaptive capacity activities (in other words, firms that self-insure) at a disadvantage relative to those that simply obtain insurance coverage from a third party.

Governance of disclosures relating to adaptation activities and adaptive capacity fall into three areas under the ASX Corporate Governance Principles: timely and balanced disclosures; the need to respect the rights of shareholders; and the need to recognise and manage risk. These ‘best practice’ principles apply equally to non-listed firms, and clearly require companies to keep shareholders informed of *any* relevant information that affects the value of their investment. The critical tests of relevance and materiality as per the accounting standards are useful guidelines for the disclosure of adaptation activities. Companies should disclose whether they have explicitly considered climate change adaptation and also adopt the ‘if not, why not’ approach to ensure that corporate governance actions around adaptation costs are adequately covered. The study revealed that companies should state the exposure period they face for specific climate change adaptation activities, and annually report both tangible and intangible costs of climate change adaptation activities. Where a listed company is not required to comply with sections 250RA and 300A of the *Corporations Act* or AASB 124 Related Party Disclosures, it should consider the range of means by which it might achieve the same ends. The company should include a statement in its annual report disclosing the extent to which it has achieved the aims of the relevant provisions during the reporting period and give reasons for not doing so. This is in line with ASX Principles and Recommendations endorsed by the ASX Corporate Governance Council.

Finally, the project proposes an investor disclosure matrix derived from adaptation options, cost estimates, vulnerability assessments, disclosures and governance principles. The matrix provides a summary of which accounting standard and governance principle applies under different adaptation objective and cost accuracy assessments. This is not an exhaustive outline of assessment options and disclosures, but provides a basic framework to define the minimum level of analysis and reporting of climate change adaptation activities.

1. OBJECTIVES OF THE RESEARCH

This study develops two primary outcomes in conjunction with the corporate sector, which address how companies can efficiently implement climate change adaptation plans. First, we develop a climate change adaptation framework that allows companies to define the relative costs and benefits of adaptation plans. Second, we develop a comprehensive set of governance, risk-management and disclosure principles that companies can use to guide corporate actions for climate change adaptation.

1.1 Climate Change Adaptation Corporate Response Framework

Climate change adaptation action in the corporate sector historically has been intermittent and has generally occurred without a robust agenda for a climate change response based on risk management objectives consistent with the full set of risks facing an organisation. Companies rely on various mechanisms to motivate the development of adaptation plans to mitigate climate change using traditional risk-assessment principles. These mechanisms can take a number of forms.

First, companies may seek to develop a significant piece of infrastructure, and a vital part of the cost-benefit analysis during the planning process would be to analyse the risk of long-term climate change effects impacting the availability of the infrastructure. Adaptation actions may need to be integrated into the construction of the asset over its expected life. Similarly, companies purchasing established infrastructure will analyse all aspects of potential harm to the investment, particularly if there is any suggestion that the vendor's motivation to sell may have been influenced by knowledge of the expected local effects of climate change. Infrastructure already owned by the company may require additional capital to help protect the asset over its life. A similar style of analysis can be conducted on corporate operations and assets.

A second mechanism is where a company is concerned about unforseen liabilities and risk associated with climate change but does not, or cannot, identify specific adaptation measures. The breadth of climate change risks facing corporate assets and operations would motivate companies to undertake some form of risk audit to assess exposure and options for reducing risk.

A final mechanism may be the requirement to undertake a risk assessment and develop suitable treatment through an adaptation plan (and subsequent necessary actions) prior to approval of a specific objective. This could emerge in the form of a direction from the firm's board, depending on the governance structure, that a climate change risk assessment is carried out before a new project is approved or simply as part of a company's corporate governance processes. Having decided on the need to undertake a risk assessment, the company can then decide how to approach the project.

For companies to successfully prosecute their response to climate change through adaptation, they require a framework for valuing, executing and managing risks associated with adaptation actions. The framework we describe in this study advocates that climate change risks and adaptation measures should be managed under an integrated framework that:

- articulates climate change adaptation policy
- demonstrates commitment
- allocates resources
- assigns responsibility, and
- advocates continuous improvement.

The framework is constructed to cater for company boards and executives, investors, regulators and other stakeholders such as community bodies, consumers and suppliers.

1.2 Governance, risk assessment and financial disclosure

Responding to change and managing risks are normal corporate activities. Adaptation to climate change can be thought of as a part of the continual process of risk management – identifying, evaluating and responding to changes in risks faced to minimise damage from harmful events and maximise gains from new opportunities with the ultimate aim of shareholder wealth maximisation. Generally speaking, corporations and other organisations are capable of managing climate variability and the risks they face because companies have an incentive to assess the costs and benefits of taking action to mitigate the impacts of climate change on their activities.

1.3 Research Outputs

There are three main research outputs from the project. The first is a comprehensive report that addresses the corporate issues that relate to climate change, including risk and vulnerability assessment, asset protection, financing, reporting and disclosure. This also includes techniques for adaptation policy development and cost estimation. The second key output is a summary statement that contains the main guiding principles and governance metrics, including the climate change adaptation framework structure. The third key output is a set of case studies for companies to use to adapting the guiding principles in their own business structures. These case studies will be designed to be broad enough to cater for a wide range of Australian industries.

The framework outcomes are aimed at principal end-users such as industry associations and sector representatives, company directors represented by the AICD, the Australian Stock Exchange Compliance Committee and the CPA Australia Advisory and Compliance committees. These bodies represent the primary point for implementing best practice advice on disclosures concerning climate change adaptation and risk-management frameworks. The study conducted a final plenary with representatives from the ASX, ASA, CPA Australia, the Australian Institute of Company Directors and the NCCARF to verify findings and validate the framework.

2. PRIMARY CONSIDERATIONS

While some businesses have taken initial steps to adapt to the expected effects of climate change, many enterprises – particularly small and medium-sized firms (SMEs) – may only be vaguely aware of the breadth of adaptation required. Associated with strategic adaptation are the principles of financial/operational risk management and governance, as well as financial impact disclosure to investors and regulators. Through a process of engagement with key industry groups in Australia representing important sectors of the economy, along with investor groups and other agencies, we have developed a consolidated framework within which boards and executive managers can develop a robust approach to climate change adaptation governance, climate change risk assessment and financial disclosure. Industry representative from sectors of the Australian economy participated in a series of workshops to explore the development of a consistent approach to climate change adaptation governance, climate change risk assessment and financial disclosure.

In particular, the project assessed the likely impacts on company finances and this report outlines a matrix of disclosures required by investors to enable them to evaluate corporate exposure to climate change risk. A major output of the project is the provision of a set of tangible mechanisms to integrate climate change impact risks into the overall risk-management framework of the business.

The primary output of this project is a high-level conceptual framework that aligns climate change adaptation policies to best practice financial risk assessment and governance mechanisms as well as external disclosure with a practical application for Australian businesses. These project outputs will directly benefit industry participants as well as the wider Australian business community. The study thus achieved the rigour required for scholarly research coupled with guidance and endorsement from industry participants.

2.1 Governance and Risk Management

To gain a better understanding of the breadth of climate change adaptation management, measurement and reporting issues facing companies, we conducted a series of workshops with key industry representatives to canvas barriers within, and solutions to, the following key issues:

- how to properly elevate climate change as a governance priority for board members and firm executives
- how to integrate risk management and governance principles within existing governance frameworks
- how to account for climate change adaptation cost disclosures incurred by companies not subject to the *Corporations Act*
- how to set company-wide energy efficiency goals and mandate energy efficiency evaluations as well as other activities such as intangible adaptation costs and long-term rehabilitation costs for all major capital investments
- how to expand programs to educate, empower and reward employees for climate-specific adaptation initiatives.

All investors should have equal and timely access to material information concerning climate change adaptation measures and costs, as well as performance and governance issues. Company announcements related to such material disclosures should be factual and presented clearly, and also must disclosure both positive and negative information (balanced reporting). Principle 5 of the ASX Corporate Governance Principles concerns the need for listed companies to make timely and balanced disclosures. The same practices should be adopted by unlisted firms. In particular, the principle states that companies should 'promote timely and balanced disclosure of all material matters concerning the company' by establishing written policies to ensure compliance with ASX Listing Rule disclosure requirements and to ensure accountability at a senior executive level. It also emphasises the need to adopt a robust continuous disclosure policy.

2.2 Public Disclosure

Public interest groups have been pressing for greater disclosure of the financial impacts of climate change, and the impact on business operations of regulations to limit greenhouse gas emissions, in the reports of public companies filed with the Australian Securities and Investments Commission (ASIC). Recent developments related to climate change now make it prudent for companies in certain sectors to evaluate whether and how to disclose climate risks in both their ASIC filings and disclosure to investors. The challenge for businesses considering climate risk disclosure is that there are no explicit rules or ASIC guidance as to the length, scope or substance of such disclosures. As a result, disclosures related to environmental issues – in particular, governance around adaptation – have attracted much interest but there is no robust consolidated approach to financial risk assessment of climate change or governance of approaches to adaptation. Private investment will only flow at the scale and pace necessary if it is supported by clear, credible and long-term policy frameworks that properly account for climate change risks and adaptation costs (Global Investor Statement on Climate Change 2011). As adaptation measures are developed and future risks valued, businesses will develop better mechanisms to govern such risks and disclose activities. However, without consensus and an aligned framework across industry, the response is likely to be confused and result in significant differences between industry sectors. This jeopardises investor confidence and access to finance. The project objective is to address this deficiency through engagement with investor relations groups and industry representatives, in order to develop a set of appropriate responses to fill this gap.

2.3 Guiding Research Principles

The project is constrained by the way in which companies are held to account. Some key principles were therefore derived to guide the research. These constraints are an operational, informational and legal reality of corporate activity. The principles used as a foundation for the analysis are as follows:

- The research outputs and associated framework must offer both a strategic vision of adaptation actions as well as tangible tools that firms can use to measure, cost, finance and govern.

- Where possible, the framework must be aligned with existing accounting standards, risk-management principles, board activities, public reporting requirements and company disclosure laws.
- The framework must seek to reconcile the interests of the main governing bodies such as compliance with the *Corporations Act 2001* through the Australian Securities and Investments Commission (ASIC), the listing rules governed by the Australian Stock Exchange (ASX), the reporting guidelines issued under Australian Accounting Standards Board (AASB), including compliance with International Financial Reporting Standards (IFRS), reporting requirements of the Australian Taxation Office (ATO) and governance principles advocated by the Australian Institute of Company Directors (AICD).
- The framework will be designed primarily for the Australian corporate context but must be easily adaptable to SMEs, not-for-profit companies and government bodies, as well as firms with international interests.

In order for business to take action on climate change adaptation, the first step is to define the problem in terms of its potential impact on the business. Whether extant risk-assessment techniques are valid depends on the availability of appropriate information. The issue of defining the risk for business was therefore a two-stage process:

- Provide an assessment tool to allow businesses to decide whether they have sufficient information to conduct effective risk assessment of climate change risk.
- Develop for those businesses that do not have sufficient information a method of understanding the risk that climate change represents, and to quantify it, if possible.

2.4 Financial vs Economic Analysis

It is important to recognise the features of financial and economic analysis. Both can estimate the net benefits of an investment based on the difference between the with-project and the without-project situation. However, the principle of financial net benefit is not the same as economic net benefit. While financial net benefit provides a measure of the commercial viability of an adaptation project on a firm, the economic net benefit indicates the real worth of a project to the region or country. Financial and economic analyses are complementary, in that for a project to be economically viable, it must be also financially sustainable.

Some research suggests that financial viability should not be a primary concern for climate change adaptation options because so long as a project is economically sound, it can be supported through government subsidy or other source of public funding. However, governments face severe budgetary constraints, and consequently the range of adaptation projects available to be financed will be greatly limited.

The basic difference between the financial and economic benefit-cost analyses of a project is that the former compares benefits and costs to a firm in constant financial prices, while the latter compares the benefits and costs to the wider economy measured in constant economic prices. Financial prices are market prices of goods and services that include the effects of government intervention and distortions in the market structure. Economic prices reflect the true cost and value to the economy of goods and services after adjustment for the effects of government intervention and distortions in the market structure through shadow pricing of the financial prices. In such analyses, depreciation charges, sunk costs and expected changes in the general price should not be included. While financial analysis taxes and subsidies included in the price of goods and services are integral to financial prices, they are treated differently in economic analysis. Financial and economic analyses also differ in their treatment of external effects (benefits and costs) as well as the effects on adaptation on health, community and welfare. Economic analysis attempts to value such externalities, health effects and non-technical losses, while financial analysis considers externalities only if they can be reasonably well monetised.

This project has focused on financial analyses undertaken by firms with regard to investing in climate change adaptation activities and projects. While the economic costs and benefits are important to organisational adaptation activities, they represent a secondary level of analysis that may need to be carried out on either an independent or cumulative scale by governments or other bodies to measure the wider effects. The scope of this research is therefore constrained to firm behaviour and the requirements for investor disclosure and governance of adaptation activities.

3. RESEARCH ACTIVITIES AND METHODS

The research program used a number of research methods to derive a climate change adaptation framework. First, a desktop survey of the literature reviewed the major contributions to climate change adaptation research over the past 30–40 years. The survey revealed a good number of research projects that examined the economic implications of climate change adaptation measures, but few studies that investigated the optimal climate change adaptation activities for firms and no studies that have examined firm behaviour around adaptation activities. A comprehensive report was produced, outlining the extent of studies done in climate change adaptation and the likely gaps that exist.

Second, several workshops were conducted with members of the Australian business community, industry representatives, regulatory authorities and academics. The report was provided to workshop participants as background. Each workshop focused on a separate theme that built upon the work of the previous workshop, with the final workshop being a culmination of the breadth of areas discussed through the project.

Finally, a set of follow-up discussions was conducted with some of the key members, including ASX, IGCC, AASB, AICD and BCA. This discussion permitted each body to advise on the mechanics of the costing, reporting and disclosure approaches of climate change adaptation, lend their expertise the formulation of an appropriate framework and comment on the final report.

3.1 Desktop Study and Survey

A desktop study of climate change adaptation programs and costs, as well as a survey, was initially conducted with each of the workshop participants. The study canvassed a range of research agencies and government bodies tasked with climate change adaptation forecasting and planning. The study revealed that a great deal of the current focus remains on climate change mitigation and abatement, with very little research being conducted into climate change adaptation. The lack of focus resonates not only within government agencies but also throughout private enterprise.

A substantial body of literature has been developed on adaptation and related concepts, such as sensitivity, vulnerability, resilience and adaptive capacity (Easterling et al. 1993; Burton 1997; Downing et al. 1996; Yohe et al. 1996; Glantz 1998; Tol et al. 1998; Schneider et al. 2000; McCarthy et al. 2001; Adger et al. 2001). However, progress towards developing theoretical understandings of adaptation has been slow (Kasperson et al. 1995; Kelly & Adger 2000; Folke et al. 2002). Existing accounts draw on frames, methods and taxonomies borrowed from a range of disciplines, including conservation ecology, welfare economics, and hazards and risk research. Although efforts have been made to develop common definitions and generic prescriptions, especially through the Intergovernmental Panel on Climate Change (IPCC) and in national assessment processes, these have not yet generated a coherent conceptual framework or a clear research agenda – particularly at the firm level.

Organisations are the primary social units within which processes of adaptation will take place, even if their vulnerability and adaptive capacity will be influenced profoundly by the market and regulatory contexts in which they operate. This analysis takes the perspective of the organisation, and views climatic stimuli as one among many drivers for change that the organisation will face. This contrasts with much climate-related literature on adaptation, which takes as its starting point climate stimuli (Burton 1997; Smit & Pilifosova 2001; Reilly & Schimmelpfennig 2000). We take a more organisation-centred view of adaptation that looks at processes of adaptation in the operations and assets of firms.

Previous research in the field of climate change adaptation appears to be designed as theory-generating rather than theory-testing in its goals. The objective has been to explore adaptive behaviour in firms and to interpret the empirical findings using concepts from behavioural approaches in organisational studies (Eisenhardt 1989). A multiple case study approach was used in Berkout et al. (2006) to examine two sectors: house-building and water utilities in the United Kingdom. They covered different types of companies whose activities span a range of geographic locations and markets. The initial research focused on the firms' current understanding and approach towards climate change, existing and potential sources of information and the perception of its likely impact on their businesses. They analysed the specific mechanisms through which climate change impacts would affect different activities and parts of the organisation. Finally, they explored how the company (and the various internal actors) might respond to impacts recognised as significant, and the factors that would determine their ability to respond. The research found that much of the knowledge needed to adopt adaptation measures already appeared to be held by the specialised communities at work in each of the organisations.

A brief survey instrument was sent to each of the proposed workshop participants to gauge the level of climate change adaptation work currently undertaken within their agencies and firms. This was not meant to highlight the low level of current work in adaptive thinking, but rather to set the scene for the workshops that were to follow. The surveys presented a relatively broad picture of the current level of development in climate change adaptation programs within the Australian business community.

A summary of the study and the survey were both provided to each of the workshop participants as part of the briefing pack prior to the first workshop.

3.2 Engaging Stakeholders

The project engaged the main peak industry groups representing the Australia's main industry sectors (such as the mining and minerals sector, the energy sector and the financial services sector). The workshops also included direct engagement by associated organisations with necessary expertise in the area of risk management (Australian Institute of Company Directors), governance (CPA Australia) and financial disclosure (ASX) Workshop participants included representatives from the following bodies:

- Minerals Council of Australia (MCA)
- Australian Institute of Petroleum (AIP)
- Energy Supply Association of Australia (ESAA)
- Investor Group on Climate Change (IGCC)

- Australian Business Council for Sustainable Energy (ABCSE)
- Financial Services Institute of Australia (FINSIA)
- Australian Bankers Association (ABA)
- Association of Superannuation Funds of Australia (ASFA)
- Australian Shareholders Association (ASA)
- Australian Securities Exchange (ASX)
- Australian Institute of Company Directors (AICD)
- CPA Australia.

Each of the above organisations agreed in principle to participate in a series of four workshops and follow-up consultations through the project.

3.3 Workshops

The success of the project relied heavily on a dedicated program of workshops. The workshops involved a four-stage process to:

- collate and review existing information
- develop a consolidated view of some of the likely impacts of climate change on financial performance
- develop a matrix of disclosures to regulators and investors concerning the risks of climate change and the cost of adaptation measures, and
- develop a suite of governance mechanisms for boards and senior management.

Each workshop focused on a specific element of the project and was structured to deliver tangible outcomes:

- *Workshop 1* – current approaches to adaptation, scenario development using quantitative techniques
- *Workshop 2* – climate change risks, financial performance impacts, case studies
- *Workshop 3* – cost of adaptation to climate change, investor disclosures
- *Workshop 4* – governance, risk, disclosure and best practice, scenario testing.

The first workshop defined target outcomes and action items, and presented existing governance frameworks and/or current approaches to adaptation disclosures. The second workshop defined the scenarios used for testing risk responses to adaptation alternatives and developed strategies to deal with scenario alternatives. The third workshop categorised strategy options to develop the high-level framework. The final workshop finalised and present the adaptation framework to obtain participant endorsement, and also employed stress-testing and sensitivity analysis to ensure the implications of the framework outcomes were well understood, which required detailed input from each participant.

3.4 Developing the Framework

Initial analysis of the problem indicated that current risk-management practices do not offer a complete solution for business to manage the impact, or potential impact, of climate change. A framework is needed to allow business to manage climate change risk and meet good governance and disclosure requirements. There is currently a perception that climate change adaptation is merely a sub-set of risk management, so the first step in developing the framework was to test this theory. Can current risk-management practices be used in dealing with climate change?

While general risk-management processes can be adopted for climate change risks, there are issues that are unique to climate change that make the process much more complex than for many other business risks. The major factor in climate change is the availability of quality data on which to base risk assessment, which requires quantification of the probability of events occurring. Climate change data is generally very broad in scale, and although the range of variables forecast to change and the amplitude of change are reasonably well quantified, an understanding of the rate and timescale for such changes to occur is much less well developed. This is in contrast to the very specific weather information that can drive operational decision-making.

To illustrate how this mismatch complicates risk management, suppose a business has a factory that cannot operate if the ambient air temperature is greater than 40ºC. Historically, the location of the factory has experienced an average of a certain number of days that reach this temperature, and this fact is factored into the business operating model. Climate change predictions suggest that the general area where the factory is located will experience an overall increase in average daily temperature of 0.6ºC over the next ten years, which may or may not impact the number of days on which the factory cannot operate. The increase may be due to an overall warming, or else more extreme volatility in daily temperatures; and the change may occur rapidly at the start, rapidly at the end or slowly over the time period. Quantifying the actual risk represented by climate change in this scenario is extremely difficult. It is even more difficult to meet disclosure obligations regarding risk.

Infrastructure projects represent a special case because the additional cost of engineering assets for potential climate change impacts occurs at the beginning of the asset life, while the impact may not be felt until closer to the end of that life. With the investment horizon for many investors significantly shorter than the life-cycle of many major infrastructure assets, the impact of the cost of capital for this additional engineering on current shareholders is a major consideration.

3.4.1 Defining Risk and Vulnerability

The approach was to use current risk-management principles to develop a Risk Assessment Matrix for the assessment of climate change risk. The premise is that if a business can use the matrix to assess its climate change risk, then there is sufficient information to do so. If not, the business has to adopt the alternate assessment tool of vulnerability assessment. In this study, we outline a process that allows businesses to determine the limits of their ability to adapt to climate change impacts. This capability is known as ‘adaptive capacity’. The aim of the framework design is to define a business’s exposure to climate change risk using these two processes.

The framework was developed in a sequential iterative process with all of the workshop participants through the initial stages of the project. First, the array of business risks was defined through an engagement process that highlighted the main forms of risk (market, credit, operational, catastrophic loss, liquidity, occupational health and safety, asset-liability management, etc.). These risks were then further cascaded by identifying the range of sub-risks within each category (for instance, under operational risk the main exposed elements are distribution, supply chain, working capital, inventory management and process management). Workshop participants then highlighted (by voting) the main forms of risk facing businesses with respect to climate change (for instance, under operational risks the main form of loss was disruption to the distribution network caused by extensive flooding). Likely loss impacts on each exposed element were then collated and ranked. This process led to the identification of assets, supply chains and operational processes as being the three key climate change risks facing the business community that can be addressed through adaptation.

The identification of the main risks contributing to firm vulnerability as well as ranking the risks permitted the workshop participants to then develop adaptation mechanisms, identify valuation principles, highlight potential impediments to funding and address the main forms of disclosure required.

3.4.2 Adaptation

Having defined the risk that climate change impacts represent, the business then has to decide what adaptation action – if any – to take. Appropriate responses to climate change impacts will be specific to circumstances. Generally, a centralised government lacks the agility to orchestrate a differentiated response with the necessary precision to address business needs. The requirements of government would be slow and costly, and it is unlikely that a directive approach to adaptation would be as effective as one motivated by individual business interests (Garnaut 2008). Maladaptation refers to adaptation actions that ultimately leave the organisation worse off – that is, the costs of maladaptive actions exceed their benefits.

The purpose of our analysis and the report was not to prescribe specific adaptation actions but rather to identify was in which possible adaptation actions can be evaluated. This is particularly important given the long investment horizons involved for such measures. Five distinct valuation approaches were developed as a summary of the best practice methods currently employed in both business and government to assess risk and properly value the liability of long-dated exposures. Each of the five methods discussed here represent the main ways in which investors and companies isolate long-dated exposures, depending on data quality and the complexity of the objective. A multitude of other approaches exist, such as real options and variants of these methods which can also be applied to assess adaptation opportunities. However, these methods were considered subordinate to the approaches discussed in this report by the business community due to poor data quality issues. Workshop participants agreed that these measures quantify the broad approach needed for assessing adaptation actions.

3.4.3 Adaptation Baseline

To estimate the costs of climate change, a baseline scenario (projections of a future without climate change) is often used. The baseline creates projections under a future where all other environmental and socio-economic conditions remain as they are today. It should be noted that most analyses of climate change impacts adopt a relatively static approach, which implies that they assess the impacts of a discrete change in climatic conditions on the 'current' system. While this type of analysis can provide a useful starting point, the climate as well as economic and other societal conditions will continue to change and dynamically interact (Tol 2002b). A dynamic baseline, however, accounts for projected changes in non-climate change conditions. While the use of a dynamic baseline increases the uncertainty inherent in a forecasting model, the uncertainty is increased by no more than in any existing economic forecasting approach (World Bank 2010).

We employed a static scenario though the workshop process. A static baseline scenario of 2012 was established for company valuation purposes (asset valuation and operational process forecasting), and future scenarios were developed with this in mind. We employ a few examples of how such a baseline and scenario testing can be effectively employed, and these are available in Appendix 13.

3.4.4 Disclosure and Governance

Adapting to climate change will lead to a range of both private and public opportunities and net benefits. Some examples include offsetting damages (e.g. reduced damage to privately built assets due to flooding or reduced disruption of infrastructure and public facility services), productivity gains from the more efficient use of scarce resources and increased revenues from new business opportunities (longer growing seasons for crops). Adaptation might also result in ancillary benefits, which should be recognised explicitly. Resilience against climate disruption is also likely to build resilience against other disruptions. Businesses are faced with uncertainty about the amount of disclosure that is necessary and prudent regarding climate change adaptation.

One of the more critical aspects of climate change adaptation for business is to understand disclosure requirements. With no specific climate change adaptation regulations in existence now, or expected in the short term, a survey of current regulations that may have impacts for disclosure of climate change adaptation was conducted. This survey included the ASX Governance Principles and Recommendations, and various Accounting Standards.

The main forms of investor disclosure and items critical to board governance were identified through the workshop process. The main forms of disclosure with regard to adaptation activities are defining materiality, valuing intangible assets, valuing impaired assets, assessing fair value and the implications of insurance versus self-insurance as a cost to the firm. At this point in the workshop process, the Australian Accounting Standards Board (AASB) was heavily involved in defining what would be best practice in accounting for such issues when engaging with investors. These outcomes were then debated and a final set of accounting actions were endorsed by workshop participants. The resulting principles presented in this report constitute best practice investor disclosure outcomes working within existing accounting standards and guidelines.

Governance principles were also identified and endorsed through the workshop process. The guiding principles matched the ASX Governance Principles, with the critical ones being to make timely and balanced disclosures, respect the rights of shareholders, and recognise and manage risk. These will be discussed in more detail through the report.

3.5 Defining Adaptation

Adaptation is not a new concept. Through human history, societies and ecosystems have adapted to different environments and conditions. The current challenge lies in keeping pace with the rapidly increasing need for adaptation measures as a consequence of climate change, ensuring that adaptation is considered in both political and economic decision-making and subsequently translated into action.

Adaptation is a response to climate change that seeks to reduce the vulnerability of natural and human systems to climate change effects. It means not only protecting against impacts, but also improving the ability to take advantage of potential benefits. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as 'any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. Alternatively, adaptation has been defined by Fankhauser et al. (1999) as 'projects or policy measures that are undertaken to ease expected and realised adverse impacts of climate change'. This latter definition is more of an institutional as opposed to a strictly economic definition of adaptation. An economic definition of climate change adaptation costs should be broader, and should quantify costs related to actions that both learn about climate change impacts and reallocate resources to adjust to the impacts.

Adaptive actions in response to climate change by communities and businesses are linked with mitigation measures. Some mitigation measures constrain adaptation, while others can increase adaptive capacity. The need to change behavioural patterns through both mitigation and adaptation actions is clear; however, the optimal route to achieve this is not.

There are significant analytical challenges associated with economic assessments of mitigation and adaptation. However, the boundaries of mitigation measures are more clearly defined, and research into the cost of mitigation is much more comprehensive. Furthermore, there is a clear metric (reduction in greenhouse gas emissions) for assessing the effectiveness of such measures. In contrast, what does and does not fall within the purview of adaptation is much more ambiguous, and there are no widely accepted metrics for assessing the effectiveness of adaptation policies and measures. Attempts to price adaptive responses are conducted in piecemeal fashion and adaptation measures typically are derived from first principles for each and every new project.

Adaptation relates not only to technical measures aimed at infrastructure, such as higher flood dams, levees and landslide barriers, but also to enabling capital activities and frameworks that enhance resilience to altered climatic conditions. Efforts by businesses in developed countries to devote capital for adaptation measures has increased in recent years; however, questions concerning the scale and time horizon of climate change impacts arise with respect to funding sources and costs.

The effects of climate change will vary across business structures. Geographic location, degree of exposure and the capacity to reduce vulnerability will influence the response strategy. The appropriate adaptation response will therefore depend on company specific circumstances rather than broad economy-wide actions. Unlike the mitigation effort, adaptation is best seen as a localised and fundamental (bottom-up) response. Businesses are best placed to make the decisions that preserve their livelihoods and help to maintain value.

For planning decisions with long lifetimes (infrastructure, power generation, etc.), it is clear that business must plan its adaptation strategies to cope with anticipated higher temperatures, changing rainfall patterns and other anticipated changes that may not occur for several decades. This includes ensuring that services, infrastructure, supply chains and transport links are robust against flooding, storm damage, heatwaves, subsidence and other threats. Because of the uncertainty inherent in projections of future climate, adaptation strategies designed now should be able to cope with a range of possible future changes, and be flexible enough to incorporate new knowledge and information as it becomes apparent. When adapting to climate change, in many cases there will be a number of different options available to an organisation. Maintaining flexibility in adaptation responses is essential for organisations, to develop organisational resilience and not become restricted to a single response.

Adaptation to changes in average climate and climate variability can take many forms. It can vary in terms of timing, scale and nature. Adaptation can occur in anticipation of impacts or as a reaction to existing impacts or vulnerabilities. It can be decentralised, occurring as a dispersed, uncoordinated and varied response at the local level by individual businesses, households and communities, or it can occur at the regional or national level as a centralised and coordinated strategy. Adaptation can occur as a behavioural change, as a restructuring of economic frameworks or policy, or as technological response. These reactions are not mutually exclusive, and it is likely that many overlapping initiatives may occur.

Faced with uncertainty about the impacts of climate change, it is impossible to prepare for every possible eventuality. However, companies can take actions that increase their ability to deal with impacts as they arise. Two concepts that relate to this idea are 'adaptive capacity' and 'resilience'. *Adaptive capacity* is the ability to adjust to new ways of doing things in the face of climate change (including moderating damages, taking advantage of opportunities and coping with consequences). *Resilience* is the ability to learn and recover from external impacts. The combination of both concepts defines the ability of a company to deal with uncertain future impacts.

3.6 Understanding the Context

One of the main reasons why climate change adaptation is problematic for business is the complexity of the issue. The role of business organisations is to increase shareholder value; however, in many cases, shareholder investment horizons differ – sometimes significantly – from the timelines for climate change effects to occur. A shareholder's investment horizon may be eight to ten years, corresponding with very short-term climate change impacts. Increasing shareholder value for today's shareholders potentially negatively impacts the value for shareholders beyond that horizon, and *vice versa*, particularly if long-term climate change effects fall into the low probability areas of current predictions. Infrastructure projects are particularly problematic, as their typical life is much longer than the investment horizon for current investors, and they may be significantly exposed to climate change effects. While share prices and credit spreads implicitly incorporate all future information, the long horizons of possible climate change impacts will dampen their effect when discounted to a present value.

Businesses operate in a complex environment, and are subject to pressures not only from investors and regulators, but other stakeholders such as local communities and suppliers who will feature heavily in climate change adaptation activities due to their proximity to firm behaviours. Figure 3.1 illustrates a simple overview of the regulatory and self-governance contexts within which businesses operate, and the impacts of interested parties that may either help or hinder firms engage in climate change activities.

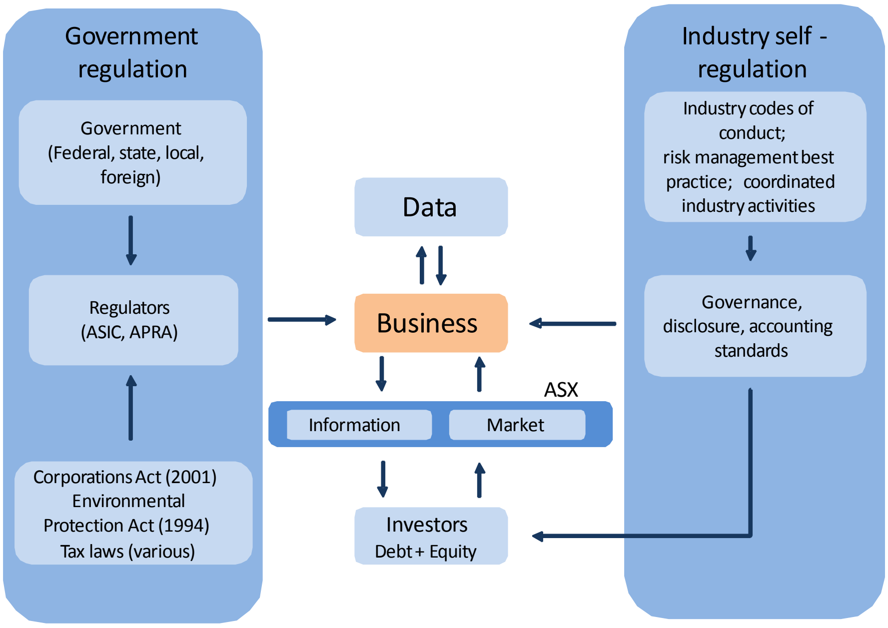

Figure 3.1: Both external regulation and internal self-regulation pressures drive firm behaviours

3.6.1 Government

The role of government in climate change adaptation is to provide clear, stable legislation in order for businesses to understand the potential impact of legislation, both now and in the future (Department of Climate Change and Energy Efficiency 2010). Governments that constantly change legislation increase risk to business and investors, and reduce the market's confidence. Multiple levels of government – each with its own legislation – all making changes can increase the effect.

Government also has a role to play in the promotion of climate change adaptation in order to ensure that businesses can endure climate change effects, remain productive and provide a range of benefits to the community. Government has the capacity to provide incentives – or at least no disincentives – to climate change adaptation through legislation, including tax law and corporate law.

3.6.2 Regulators

Regulators ensure that appropriate standards are maintained in order that both business and investors can have confidence that the market, or particular sectors of it, operate fairly. There may be some reluctance by regulators to provide prescriptive regulation regarding climate change adaptation cost accounting and disclosures. This could be considered to be an effective strategy because prescriptive measures often lead to ‘minimum reporting’, or add onerous reporting burdens to business that may not be justified. It also leaves businesses free to make appropriate decisions under existing regulations regarding the level of adaptation that will be undertaken and the disclosures made. The major concern regarding climate change is that there are many variables, each with its own probability distribution. This results in a high degree of uncertainty about climate change effects and the subsequent need for adaptation. Meeting continuous disclosure requirements in this environment can be extremely difficult. Additionally, investor groups are increasingly likely to take action when they feel that continuous disclosure has not been made. This means that decisions regarding what to disclose, and when, are becoming even more problematic for many businesses.

While regulators are more likely to engage business in decision-making, the process of regulation remains largely prescriptive, with regulators deciding the rules and business complying.

3.6.3 Data

Climate change modelling and research are driven largely by factors other than the needs of business, so data on which to base risk-management decisions may not be available. Large corporations are likely to be able to mitigate this through commissioning their own studies; however, the large number of SMEs have no such opportunity. Coupled with this is the lack of a ‘library’ where climate change predictions could be made available for use.

3.6.4 Investors

Both retail and wholesale investors receive information from companies as and when the company decides to make relevant information public. In regard to climate change adaptation, there is currently no *explicit* requirement that insists companies or non-public entities disclose the implementation of adaptation activities, aside from those actions that fall under existing disclosure provisions. This naturally results in some entities avoiding providing information specific to climate change adaptation to their investors. For instance, the largest 100 listed companies in Australia by market capitalisation all address their risk-management profile in their annual reports, but only 25 specifically address climate change adaptation. An additional 50 mention their sustainability activities and performance but whether this incorporates climate effects on company performance in unclear. Some firms also voluntarily report against the GRI Sustainability Framework; however, this framework does not require a specific focus on how the business is working to ensure it is able to adapt to climate change. Conversely, business receives regular and clear information from investors about its perceived performance, through the market.

The research conducted through the workshops suggested that an investor disclosure framework should strike an appropriate balance between:

- improving the quality of disclosure on investments that have complex characteristics and risks
- not unduly interfering with the operation and marketing of investments, and
- not impeding efficiency of capital markets.

When issuing financial products, firms must already comply with the disclosure principle model of disclosure. The disclosure principle model of disclosure addresses the following:

- It identifies the key characteristics and risks that investors should understand before making a decision to invest.
- It enables an issuer to apply the disclosure principles to those key characteristics and risks, where appropriate.
- It sets out ASIC requirements regarding disclosure in a PDS or prospectus and other disclosures material to comply with the *Corporations Act*.

The disclosure principles clarify the standards to which retail (and increasingly wholesale) investors are to be provided key information to assess financial products and investment schemes for which there are typically few readily comparable products.

4. RESULTS AND OUTPUTS

While global-level adaptation dynamics are varied and complex, this analysis focuses on climate change adaptation mechanisms for Australian businesses, whose interest in adaptation has increased with the aim of protecting their operations. In particular, the study covers climate change adaptation governance, climate change risk assessment and financial disclosure of adaptation measures in the context of Australian businesses. We assess the likely impacts on the sources and uses of company finances, and define a matrix of disclosures for investors to enable them to evaluate investment exposure to climate change risk.

The workshop outcomes, as well as current academic literature, have identified that investors generally seek four types of disclosure to analyse a company's business risks from climate change:

- emissions liability disclosure
- strategic analysis of climate risk and emissions management
- assessment of physical risks of climate change
- analysis of regulatory risks.

Investors also seek information about the opportunities created by climate change and regulation of greenhouse gases. Investors have a fiduciary responsibility that requires them to seek optimal risk-adjusted returns on their investments; however, in the absence of strong and stable policy frameworks, many low-carbon investment opportunities are missed. This chapter addresses the links between risk, vulnerability, adaptation and disclosure within a flexible framework that permits firms to better understand their exposures to climate change, identify adaptation actions, disclose cost-benefit outcomes and implement appropriate governance mechanisms.

4.1 Climate Change Adaptation Framework

The framework was developed through the workshop process described above. The broad framework, illustrated in Figure 4.1, identifies four activities where businesses should apply specific efforts to address climate change adaptation activities:

- risk assessment
- vulnerability
- adaptation
- disclosure

For ease of illustration, these are represented as equal-sized quadrants of a circle as each piece is equally necessary for a complete response. The process is also cyclic, with the central circular arrow representing the codependence of each activity and continual monitoring and assessment of the process. Supporting functional decision-making in each of the activities are a number of processes and assessment tools, outlined in the boxes behind each quadrant. Each aspect of the framework is addressed below.

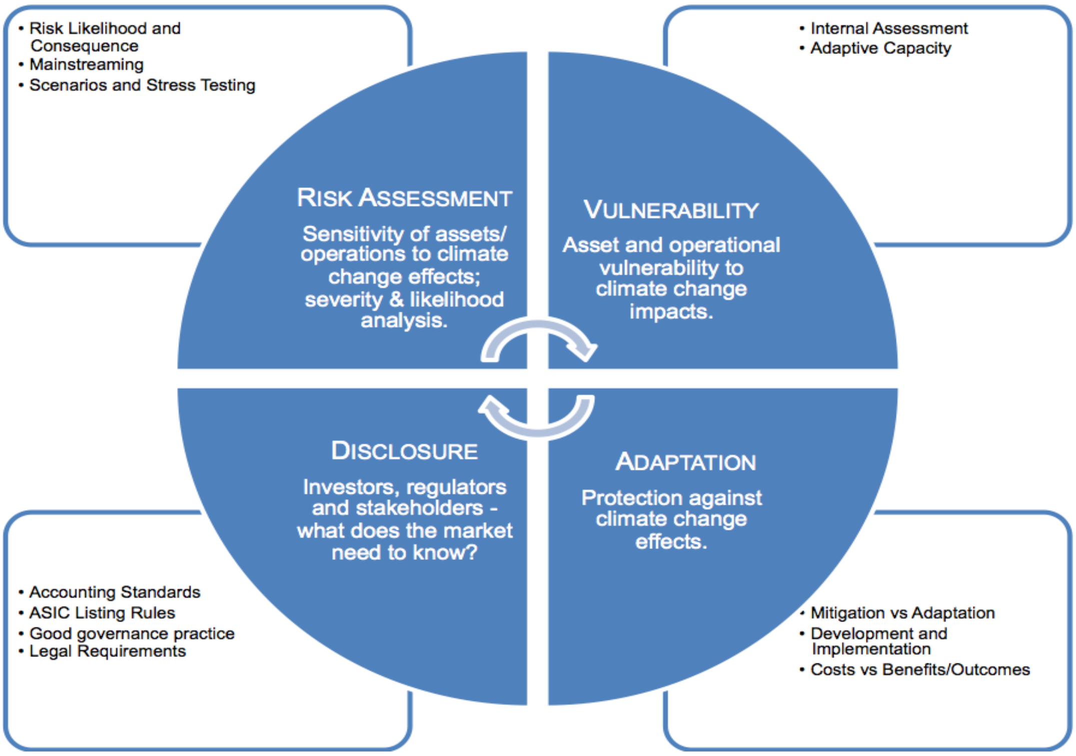

Figure 4.1: Introducing the climate change adaptation framework

4.2 Risk Assessment

Risk management involves exploring, making and acting on decisions under conditions of uncertainty. Here, we define risk management as the culture, processes and structures that are directed towards realising potential opportunities while managing adverse effects. We quantitatively assess risk as the combination of the probability of an event and its consequences; there may be more than one event, consequences can be both positive and negative, but likelihoods can be measured qualitatively or quantitatively. These definitions are also appropriate for assessing climate risks.

Risk-management frameworks are an essential tool used for climate change impact assessments. Assessment of climate change impacts, adaptation and vulnerability, and risk management have many elements in common, including the need to manage uncertainty, the linking of hazards and consequences, communication between technical experts and stakeholders, the reduction of risk by decreasing both the hazard and consequences of those hazards and formal processes to link all of these activities.

Risk management is generally an iterative process, with risk assessment as the foundation activity. Standard elements of a risk-management process that can be adapted to assess climate vulnerability, impacts and adaptation include:

- risk identification, including scenario development
- risk analysis, where the consequences and their likelihood are analysed

- risk evaluation, where adaptation and mitigation methods are prioritised (Schipper & Burton 2008).
- risk management or treatment, where selected adaptation and mitigation measures are applied (Schipper & Burton 2008)
- monitoring and review, where measures are assessed and the decision made to reinforce, re-evaluate or repeat the risk assessment process.

Further issues in risk-management practices are addressed in Appendix 12.

To calculate the overall risk level, companies need to assess the likelihood of the risk occurring and the magnitude of the consequences if the risk eventuates; taking into consideration controls that are already in place:

- *Risk likelihood* can be expressed in terms of probability of the risk event occurring, and normally is represented on a scale from rare (1) to almost certain (5). Likelihood should be considered within a defined period of time, but should encompass the firm's investment horizon.
- The *consequences* or severity can also be represented on a scale from insignificant (1) to critical/extreme (5). Consequences should be considered not just from a financial perspective but also take into account safety, environment, legal and reputational impacts.

Specific likelihood and consequence/severity criteria can be set for each division in the company individually. The matrix-formulation process below shows the relationship between likelihood and consequence/severity ratings, and various risk levels. Material business risks that fall in the sector coloured in blue usually represent risks that are possible or likely to occur, and if they do they will have a significant impact on the company. Existing options to mitigate risk for increasing investment horizons are identified in Figure 4.2.

Numerous methodologies aligned with Australian Standard AS 4360 Risk Management have been developed, and the standard can be interpreted in a variety of ways. Samples of risk management methodologies based on AS 4360 are provided in Appendix 12.

Companies do not necessarily need a dedicated risk manager to manage firm risk, including the risks associated with climate change adaptation. However, companies do need strong commitment to risk management and involvement by upper management, an organised process for risk analysis and response, assignment of specific risk responsibilities and performance accountability, and a workplace culture where every employee understands risk and their role in addressing it.

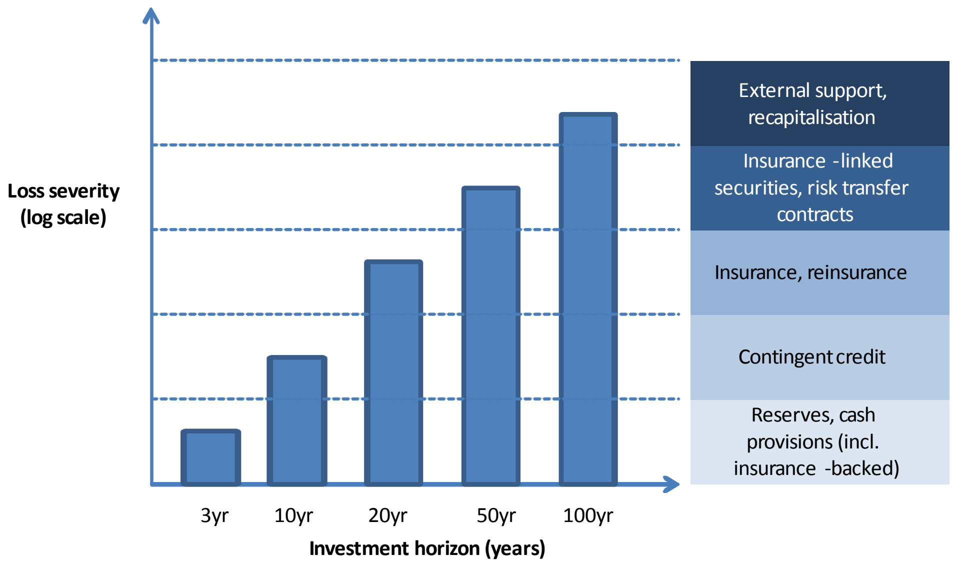

Figure 4.2: Risk transfer options for expected climate change-related events.

4.3 Vulnerability

In order to effectively conduct risk assessment, both the likelihood and the consequences of the risk must to some extent be quantified – for instance, how likely is the occurrence of impacts and how bad could the outcome be? However, for climate change assessments, these data are not reliably available. The five activities outlined below were defined through the workshops to enable businesses to prepare a vulnerability assessment that can serve as a stand-alone indication of current vulnerability, or can be expanded to consider climate change projections for an assessment of future climate vulnerability.

Vulnerability assessments are useful where data are scarce and a comprehensive understanding of climate change exposure is not well developed. We refer to a system here as a business group that is exposed to specific climate hazards.

It is important to note that risk assessment and vulnerability assessment are related but separate. Risk assessment identifies the main risks while vulnerability assessments 'operationalise' the risks. The general risk exposure is valued in the context of the firm through a vulnerability assessment. The term 'vulnerability' may have alternative meanings in various industries, but for the purpose of consistency and simplicity, the term is used in this analysis to refer to the financial manifestation of risk.

4.3.1 Structuring the Vulnerability Assessment

The process of developing a conceptual and analytical framework should clarify differences between disciplines, sectors and stakeholders, and focus on creating a working approach and practical steps to be taken, rather than a 'final' conceptual model. The output of this activity is a core framework for the vulnerability assessment.

The context of the adaptation framework and its objectives are both important for determining the set of questions that the assessment is intended to address. This has a bearing on the operational definition of vulnerability used in the analysis. For example, a vulnerability assessment could be used at two different points in the framework. An initial assessment of vulnerability may be used to identify more vulnerable sections of the firm. These might be treated to more intensive assessment. Another use of the vulnerability assessment might be to feed into the design and evaluation of adaptation policies, including indicators of vulnerability as criteria.

Table 4.1 illustrates the linkages between the objectives, the context and the set of assessment questions, using the example of adaptation to sea level rise. Identifying a core set of questions for the vulnerability assessment will also help designing the project.

Table 4.1: Objectives, context and analysis questions in vulnerability assessments

Objective	Context	Analysis questions
Gathering and organising data, identifying data and information needs	Preliminary assessment, often part of related environmental strategy documents	What are the trends in relative sea level? What are the geomorphological characteristics of the coastline? Is there a hazard map relating to our assets?
Providing estimates of abatement costs and climate damages	Input of local data to inform international estimates of the benefits of greenhouse gas stabilisation	What are the physical impacts of sea level rise? What are the market and non-market losses associated with sea level rise?
Formulating and evaluating adaptation options	Input to development planning and adaptation policy	What will be the reduction in losses due to a specific adaptation option (such as creating coastal barriers)? In what way and to what extent should the design of coastal infrastructure accommodate the possibility of sea level rise?
Determining how the value of reducing uncertainty through research will be designed	Input to research prioritisation	Which research and observation strategies will have the greatest benefit in reducing uncertainty? How should observation and monitoring programmes be established?
Allocating resources efficiently for adaptation	Input to policy prioritisation	Which coastal region is most vulnerable? Which region or sector can benefit the most from adaptation actions?

4.3.2 Identifying Vulnerable Areas

Having identified a working definition of vulnerability and a core set of questions for the assessment, the company needs to identify which of its current and future operations are vulnerable, to what, in what way and where. The characteristics of the system chosen for the assessment include sectors, stakeholders and institutions, geographical regions and scales and time periods.

A multi-dimensional baseline of vulnerability includes:

- targeting of vulnerable divisions or operations of the firm
- the firm's operational characteristics, and in particular those aspects that are sensitive to climate hazards, referred to as exposure
- natural resources and adaptive resource management
- the degree of (present and/or future) climatic risks that affect operations of the firm identified via appropriate hazard mapping
- institutional processes for planning adaptation strategies and options.

The exposure of companies to climate risk can be described using indicators. These may reflect different financial characteristics, including geographic concentration, composition of operational activity, infrastructure and so on. Indicators may describe stocks – for example, of natural and manufactured capital – or flows – for example, of economic goods and services, income and the supply chain. Developing and using indicators requires an awareness of technical issues, including their sensitivity to change, standardising indicators for comparison, the reliability of the data, mapping of indicators, collinearity among indicators, coverage of the relevant dimensions of vulnerability and so on (Downing and Patwardhan, 2002).

The output of this activity could be a set of vulnerability indicators and identification of vulnerable assets and operations that, together, form a vulnerability baseline of present conditions for the firm.

Indicators chosen to describe the baseline should be used during project monitoring and evaluation whenever possible. Desirable indicators fulfil three criteria: (1) they summarise or otherwise simplify relevant information; (2) they make the phenomena of interest visible or perceptible; and (3) they quantify, measure and communicate relevant information. They may be qualitative, quantitative or both. If quantitative scenarios of the future relevant to climate change vulnerability and adaptive capacity are desired, the process involves choosing indicators, collecting or locating appropriate data, and estimating future values for those proxies.

4.3.3 Assessing Sensitivity

Current vulnerability can be expressed as a conjunction of climatic hazards, financial conditions and the adaptation baseline. The first two items in the vulnerability assessment establish the present conditions of development. This task directly links climate hazards to key economic outcomes or impacts. In this activity, the firm develops an understanding of the process by which climate outcomes translate into risks and disasters. This may be done through a variety of approaches, ranging from simple, empirical relationships to more complex, process-based models.

Climate outcomes can be described through technical identifiers – for instance, hydrological and meteorological variables. Depending on the nature of the consequences and the nature of the impacts, these variables may be used directly; however, secondary variables may also be computed. For example, if a company is interested in the sensitivity of energy demand to climate change, a typical directly observed quantity might be daily maximum or minimum temperature, whereas heating or cooling degree-days are quantities that may be more relevant for capturing the relationship between climate and energy demand. Such quantities may need to be derived from historical and forecast primary climate data.

In many sectors there are already well-developed models and frameworks that describe system sensitivity. For example, there are a variety of crop models (physiology-based or empirical) that link crop yield and output to climate parameters. In many instances, detailed process models may be either unavailable, or too complex for inclusion in the assessment. In such cases, a variety of simpler techniques may be adopted, including empirical models based on analysis of historical data and events or models that look at simple climatic thresholds (e.g., the probability of drought). If it is difficult to implement even simple empirical approaches, an alternative might be to use expert opinion or examples from different, but related settings (e.g., similar firms) to develop understanding of the relationship between hazards, exposure and outcomes.

An important part of this activity is the identification of points of intervention, and options for response in the sequence leading from hazards to outcomes. Not only is this relevant for considering responses in the short-term, it is also important for the evaluation of future vulnerability. The evolution of vulnerability in the future depends quite critically on endogenous adaptation – planned or autonomous.

4.3.4 Assessing Future Vulnerability

The next activity in a vulnerability assessment is to develop a more qualitative understanding of the drivers of vulnerability, in order to better understand possible future vulnerability. This type of analysis aims to link the present with possible future pathways. Such pathways may lead to sustainable development or increased vulnerability through maladaptation (Downing and Patwardhan, 2002). This activity requires the firm to consider ways in which planned and autonomous adaptation may modify the manner and mechanisms by which climate is a source of risk. For example, the availability of flood insurance might alter the perceptions of firms regarding risk, leading to increased development in flood-prone areas, and therefore to increased damage from the cyclone. Intervention would lead to a change in the impacts associated with climate change.

Downing and Patwardhan (2002) suggest that specific techniques may be used for this purpose that is likely to be qualitative in the first instance. Interactive exercises (such as cognitive mapping) among experts and stakeholders can help refine the initial vulnerability assessment framework by linking the vulnerable operations and assets, government factors (e.g. regulation and governance), firm resources and financial activities, and the kinds of threats (and opportunities) resulting from climatic variations. Downing and

Patwardhan (2002) also suggest that thought experiments, case studies, in-depth semi-structured interviews, discourse analysis and close dialogue are approaches that can be used in understanding the dynamics of vulnerability. Other formal techniques are available which include cross-impact matrices, multi-attribute typologies and multi-agent social simulation.

Two technical issues need to be clarified when developing a vulnerability assessment (Downing and Patwardhan, 2002):

- Most indicators are snapshots of present conditions. However, vulnerability is dynamic, and indicators that foreshadow future vulnerability may be useful. For example, future port developments may be correlated with exports but only weakly correlated with present rates of firm growth.
- The common drivers of development need to be related to the firm. Industry and sectoral trends may not map directly on to the marginalisation, land use and markets that characterise vulnerability. Shocks and surprises have disproportionate effects for the vulnerable.

Researchers generally claim that scenarios of future vulnerability are best developed at the local or firm level (Downing and Patwardhan, 2002), while other reason that future financial conditions of vulnerability should be placed in an industry-wide context (Figge and Hahn, 2005). The vulnerability assessment may benefit from a comparison with vulnerability in an international context but as Downing and Patwardhan (2002) describe, it would be methodologically incorrect to develop local financial vulnerability estimates from global economic scenarios (theoretically, practically and empirically).

Outputs of this activity could be qualitative descriptions of the present structure of economic vulnerability, future vulnerabilities and a revised set of vulnerability indicators that include future scenarios.

4.3.5 Linking Vulnerability Assessment Outputs with Adaptation Policy

The workshops identified the outputs of a vulnerability assessment to include:

- a description and analysis of present vulnerability, including representative vulnerable operations of the firm
- descriptions of potential future vulnerabilities including scenarios analysis that relates the present to the future
- comparison of vulnerability under different economic conditions, climatic changes and adaptive responses
- identification of points and options for intervention, which can lead to formulation of adaptation responses (defined in Downing and Patwardhan, 2002).

The final task is to relate the range of outputs to stakeholder decision-making and firm-wide awareness. Therefore the primary concern is to present useful information that is analytically sound and robust to account for inherent uncertainties. One consideration to ask is whether stakeholders or decision-makers already have decision criteria they commonly apply to strategic and project analyses. For instance, if the firm is committed to the Millennium Development Goals (MDGs) within their development plan can the set of firm-wide vulnerability indicators be related to the MDGs? In the interests of efficiency and consistency most firms would prefer to relate climate change vulnerability assessments directly within existing frameworks. A simple (and common) approach has been to aggregate the individual indicators into an overall score.

Another aspect is to query whether stakeholders have a formal multi-criteria framework that defines the choice of aggregation procedures and weights. Formal multi-criteria approaches are rarely generic and can often be contentious and the same is true for composite vulnerability indices. As a result, caution has to be exercised in the use of such indices. A preferable device for communicating the vulnerability assessment is to use multi-attribute profiles (Downing and Patwardhan, 2002).

An alternative aggregation technique is to cluster vulnerable operations or asset classes according to certain key indicators using basic analysis or a more formal method such as principal components analysis (PCA). Indicators derived from the vulnerability assessment can be used to evaluate adaptive strategies and measures. They can also be used as the baseline for monitoring development status.

Representative operations and assets (and multiple scales of vulnerability) can form a baseline for adaptation strategy analysis. Downing and Patwardhan (2002) suggest that a multi-level assessment might include an inventory of infrastructure protection strategies and their effectiveness in different financial and climatic conditions. For instance, this might consider how port and rail facilities might be affected by substantial rain or to develop firm contingency planning for increased severity of cyclones. A consistent analysis across these scales would better inform the firm’s climate adaptation strategy and identify specific responsibilities for individual stakeholders. Vulnerability strategy development could even go as far a developing a qualitative understanding of storylines to use in scenarios that describe future representative conditions (Downing and Patwardhan, 2002).

4.4 Adaptation

Once general risks and specific firm vulnerabilities are recognised, the next phase is to identify actions that seek to address potential losses. The process of adaptation is therefore an active measure that seeks to minimise climate change losses identified by the firm. This step represents the tangible implementation of plans and policies to avoid the excesses of long-term climate change exposures.

4.4.1 Climate Change Mitigation vs Adaptation

Addressing climate change by reducing greenhouse gas (GHG) emissions alone is expected to be insufficient to overcome the environmental and social challenges of global warming. Both climate change mitigation and adaptation measures will be needed for businesses and communities to cope with climate change. Mitigation is distinct from adaptation. In this context, mitigation describes actions that decrease the intensity of the greenhouse effect caused by emissions to reduce the potential effects of climate change. In contrast, adaptation can be defined as actions taken to help businesses and communities cope with changing climate conditions. Mitigation involves actions that target the primary *causes* of climate change while adaptation involves actions aimed at enhancing tolerance to climate change *effects*.

4.4.2 General Features

In general terms, the following features are recognised as the critical components of an effective adaptation strategy:

- *Information flow.* In order to make informed and effective decisions about adaptive strategies, businesses need accurate estimates of climate change projections and the subsequent environmental and socio-economic effects. Interactive effects and the influences of mitigation and adaptation responses can also be estimated and can guide responses. Governments will need to ensure that appropriate information is available to allow businesses to develop initiatives that are tailored to specific risks. Reliable data are therefore a key issue.
- *Flexibility.* An effective adaptation response should build in the flexibility to respond to new information and changing circumstances. Risk-management approaches allow for such flexibility through regular reviews of effectiveness of adopted strategies and update of risks.
- *Anticipatory planning.* It has been argued that the not insignificant uncertainties in forecasts and projections of both climate change and subsequent economic conditions preclude formulation of a cost-effective adaptation strategy. However, general consensus is that, in many cases, delayed action will be much more costly than anticipatory action and investment in climate-proofing new assets is generally cheaper than retrofitting.
- *Mainstreaming.* Mainstreaming is the integration of climate change adaptation responses into broader sectors, such as water resource planning, disaster management, urban planning and coastal defence. Climate change adaptation measures should be consistent with other planning and development priorities.

Figure 4.3 outlines an example of an adaptation identification process used to identify adaptation gaps in existing facilities and the range of inputs required to develop an appropriate adaptation plan. Critically examining existing assets, exposures and constraints occurs early in the process so that gaps are readily identified so that technical alternatives can be evaluated. A set of independent financial and economic cost analyses can be performed to account for both internal costs and all externalities from adaptation actions. Finally a risk and sensitivity analysis draws the whole process together as a final audit of the adaptation activity.

This diagram is meant to illustrate that most adaptation actions will occur in conjunction with existing assets or developments. Few adaptation actions will be the result of brand new initiatives or ‘greenfield’ developments, since firms will be searching for ways to protect the assets they already have. Given the context of this study to focus on adaptation actions for existing companies to mitigate the risks of climate change, this approach is particularly relevant.

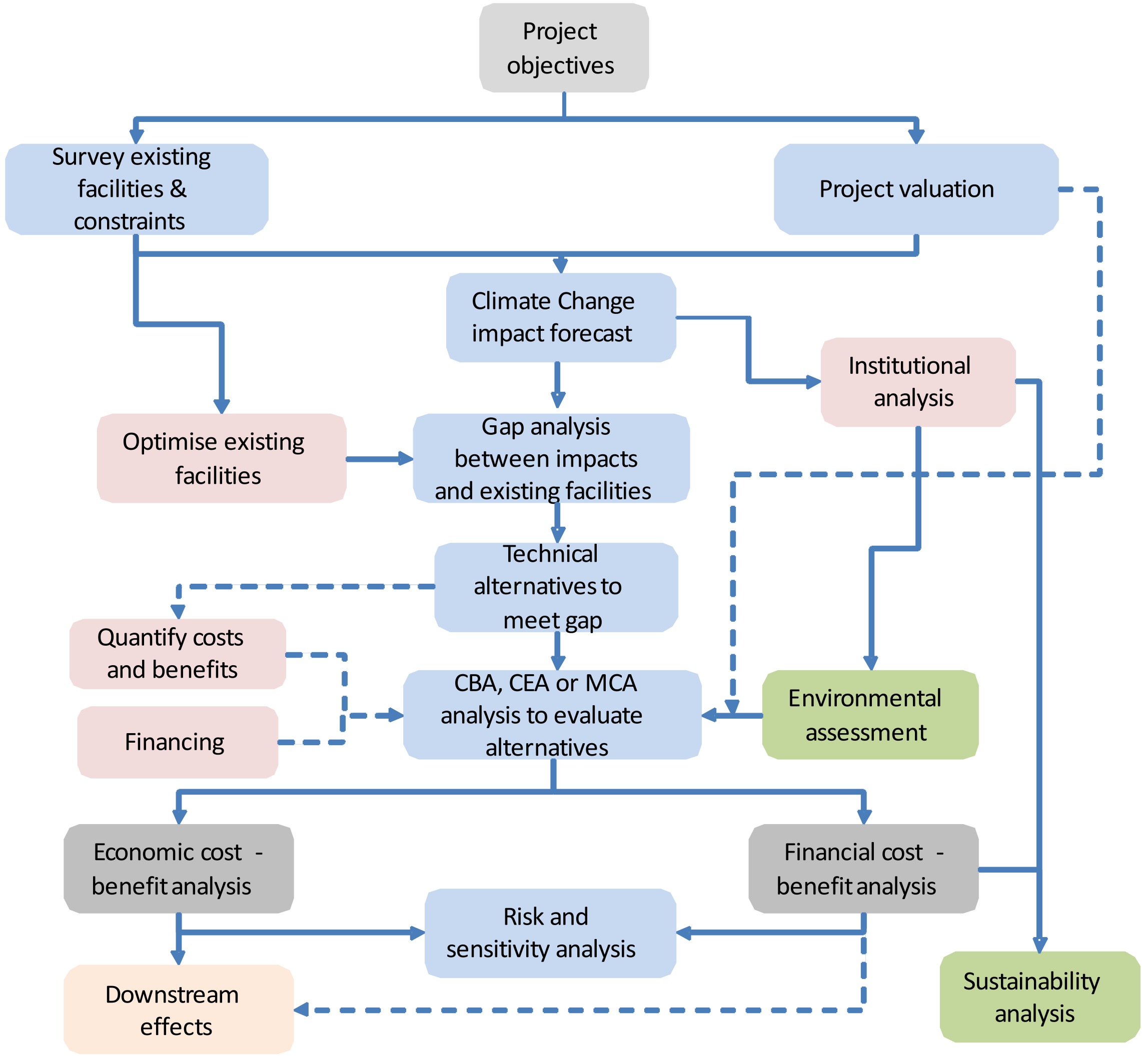

Figure 4.3: A sample project adaptation process

4.4.3 Broad Adaptation Measures

There are many examples of adaptation measures that have already been implemented where climate change has been factored into planning and development. Such measures include the installation and upgrade of levees as well as projections of sea level rise being factored into coastal infrastructure and land management/development policies, investment in climate-proofing of buildings and infrastructure, development of integrated risk assessment tools in the insurance industry and investment in drought-proofing measures.

In general, adaptation measures include the following:

- *Bear losses.* All adaptation measures can be compared with the baseline response of 'doing nothing' – that is, bearing or accepting the losses. In theory, bearing loss occurs when those companies affected have no capacity to respond in any other ways (e.g. poorly financed companies) or where the costs of adaptation measures are considered to be high in relation to the risk or the expected damage.

- *Share losses.* This type of adaptation response involves sharing the losses among the wider industry or business community. Losses can be shared through public relief, rehabilitation and reconstruction paid for from public funds as well as from insurance. However, the use of public funds for losses incurred by private entities that choose to ignore their exposure to climate change is likely to greatly diminish in the future. Insurance only mitigates the risk of those who choose to pay premiums as an expense while those who choose to partly insure or self-insure indirectly and substantially add to the wider social cost. It is important to note that governments should not be relied upon to subsidise premiums for business property insurance, whether directly or by underwriting risks, since it is likely to impose a significant barrier to effective adaptation to climate change.
- *Modify the threat.* For some risks, it is possible to exercise a degree of control over the environmental threat itself. When this is a 'natural' event, such as a flood or a drought, possible measures include flood-control works (dams, dykes, levees). This response is likely to be expensive and may require the use of cost-benefit analysis to arrive at an optimal solution.
- *Prevent effects.* A frequently used set of adaptation measures involves steps to prevent the effects of climate change and variability. In agriculture such measures include changes in crop management practices, such as increased irrigation water, additional fertiliser use and pest and disease control. In other industries, it may require a simple change in operating practices.
- *Change use.* Where the threat of climate change makes the continuation of an economic activity impossible or extremely risky, consideration can be given to changing the use. For example, the agricultural sector may choose to substitute a more drought-tolerant crop or switch to varieties with lower moisture.
- *Change location.* A more extreme response is to change the location of economic activities. This may be relatively easy for some operations, but for others such as mining or agriculture, relocation is almost impossible.
- *Research.* The process of adaptation can also be advanced by research into new technologies and new methods of adaptation.

In general, firms will deploy a varied range of these options as part of their climate change adaptation response. However, the optimal set of measures greatly depends on the costs of each response. This is a factor to which we now turn.

4.4.4 The Costs of Adaptation: Assessment Options

Adaptive capacity can be seen as a component of economic capital. Economic capital is the smallest amount that can be invested to insure the value of a firm's net assets against a loss in value relative to the risk-free investment of those net assets (Merton & Perold 1993). Economic capital is thus the amount of equity capital that a company can allocate to fund operations, to fund a portfolio of assets or indeed to fund the entire firm itself (typically applied to financial institutions). Economic capital provides a buffer against potential losses. It allows, at an acceptable degree of confidence, the firm to continue its operating activities and capital investment program. The cost of economic capital is the spread the firm pays in the form of insurance to cover its bankruptcy risk. The cost of economic capital depends on adverse selection, moral hazard and agency costs.

Whether the adaptive capacity is an asset such as a sea wall or levee, a desalination plant or the relocation of a plant, or be it a process such as changed irrigation practices and water rights management in agricultural activities, adaptive capacity is a vital component of economic capital that is rarely explicitly valued. A crucial first step in any climate change adaptation initiative is for companies to assess the implications of climate change on their systems and processes (e.g. productivity, resource supply, infrastructure damage, supply chain disruptions), workplace environment (e.g. worker health, long-term liabilities) and external effects (e.g. operational restrictions, government regulation) to determine whether, and the extent to which, climate change will have an impact, pose a risk or offer beneficial opportunities.

When assessing more precise expected costs and benefits of adaptation options, companies should use one or more of the following approaches, which have proven to be effective decision-support tools. The approach selected depends on the number of adaptation objectives required by the company's business units and the measurability of the impacts.

We surveyed the literature and engaged with a variety of firms to distil the primary methods used to estimate climate change adaptation costs. The method used generally varied with the quality and availability of data, the degree of climate change impacts, the complexity of the suite of objectives and the ability for firms to monetise costs and benefits of adaptive actions.

Figure 4.4 provides a general overview of which method is most applicable depending on objectives, impacts and measurability. For instance, for a single objective (protection from floods) with a high degree of measurability of likely costs and benefits and the likelihood and severity of climate change impacts, an expected loss or a cost benefit approach is appropriate. Alternatively, for a firm with many objectives (supply chain and distribution protection), as the ability to measure likely impacts decreases, the firm is likely to move towards a multi-criteria analysis approach (MCA) or even a more general risk-based assessment that acts on qualitative information more than it does on quantitative data.

Figure 4.5 illustrates the decision tree/flow diagram to use when considering what approach may be most appropriate given the number of adaptation objectives and whether costs and benefits can reliably be monetised. We derived this decision tree to help identify the appropriate approach for adaptation cost assessment.

The different decision criteria lead to the selection of an appropriate adaptation cost measurement methodology. For instance, if the firm faces a single adaptation objective (e.g. loss of construction days due to inclement weather and site flooding), and the impact is measurable and the potential loss quantifiable, either the expected loss assessment (ELA) or cost-benefit analysis (CBA) approach may be suitable.

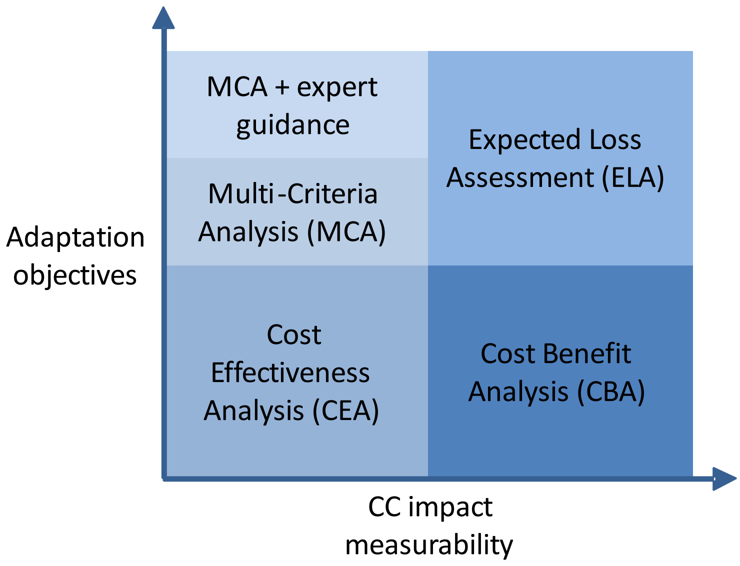

Figure 4.4: Tradeoff between the number of adaptation objectives and the measurability of the impact leads to the optimal cost method

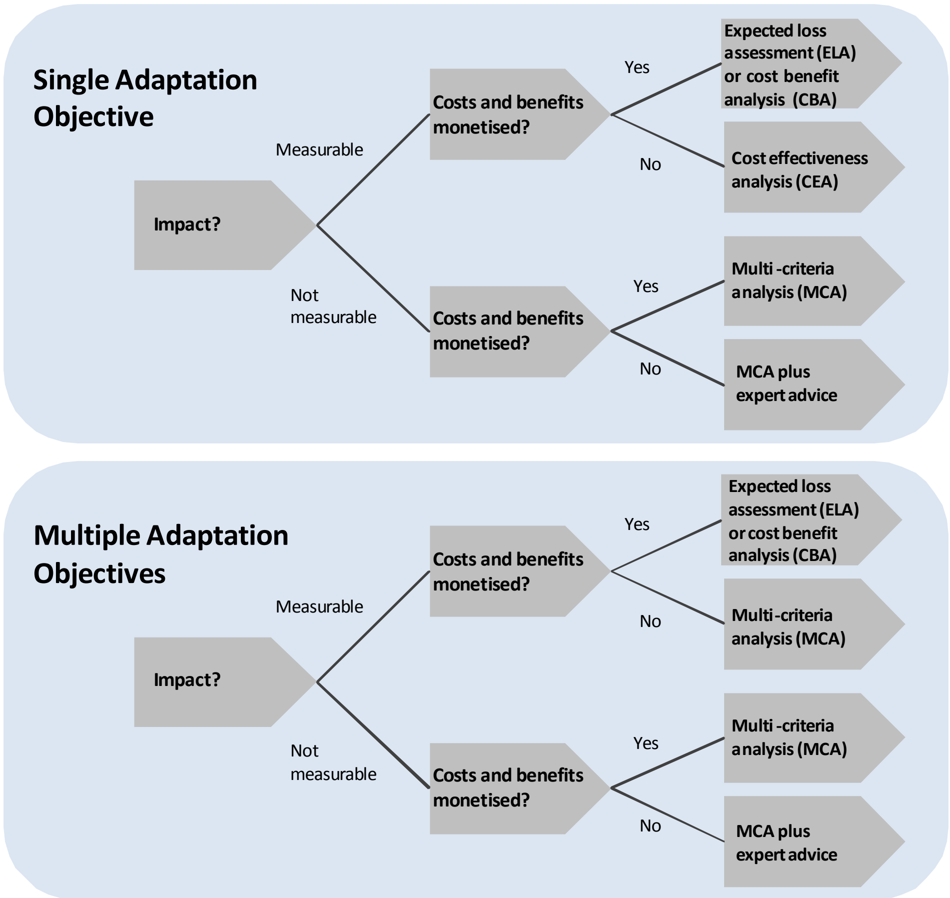

Figure 4.5: Decision tree/flow diagram of approaches for assessing the financial implications of an adaptation activity

For a firm facing multiple adaptation objectives (e.g. surface mining operation with exposures to pit activities, road, rail and port access and parallel development activities such as exploration and drilling), if the impact is not exactly measurable but the costs and benefits of a given action plan can be monetised, then a multi-criteria analysis (MCA) approach would be appropriate. It should be noted that real options are an alternative valuation approach, but have not gained much traction in industry circles, despite their popularity among researchers. While theoretically robust, in practice they are difficult to use in decision-making due to the inherent uncertainty of the assumptions used in the model (primarily the typical lack of an underlying, an assumed constant volatility and a long duration to option maturity). These assumptions significantly affect the option value, which is highly sensitive to such inputs. Given their limited use by industry and investors, they are not included in this analysis, although their popularity may increase in future years as better data become available. Each of these approaches is discussed in more detail in Appendix 13.

4.4.5 Adaptation Costing Best Practice

Firms should consider the strengths and weaknesses of the various approaches for assessing adaptation options. In some situations, a number of approaches could be applied in a complementary fashion. Regardless of which assessment approach the firm chooses, each should be:

- *Practical.* Approaches have to be appropriate for a given economic setting and take into account data constraints. For example if the benefits cannot be quantified monetarily it is not advisable to undertake a CBA.
- *Relevant.* Results should be presented in a timely manner and in a format that is compatible with existing decision making. For example, if adaptation options are assessed by an industry sector using CBA, a firm that assesses its adaptation options using CEA may not be aligned with common practice.
- *Robust.* Approaches should be transparent and consistent within and across sectors using, where appropriate, common underlying climatic and economic assumptions, and discount rates. Sensitivity analysis is critical.
- *Comprehensive.* Approaches should assess a wide range of options, including inaction, action outside sectoral boundaries and co-benefits.
- *Proportional.* The selected approach should be motivated by the need for a decision rather than aiming to make the perfect decision.

Assessing the costs and benefits of different policy options is not unique to adaptation actions. Governments, businesses and communities have applied assessment approaches such as CBA, CEA and MCA, along with other tools, to support their decision-making. Issues related to uncertainty, valuation and equity have often necessitated adjusting those approaches to the adaptation context.

4.5 Disclosure

Companies taking action to adapt to climate change are encouraged to identify current and potential impacts on business, reduce vulnerability to them and take advantage of any potential opportunities they present. Companies and other entities will increasingly and inevitably address adaptation as aspects integral to their business strategy and risk management. Actions taken to minimise and respond to the effects of climate change should ultimately be reflected in financial statements, but there are other implications for continuous disclosure rules, reporting transparency for improving investor relations, auditing of financial statements around adaptive capacity and board and executive governance of the adaptation and risk management process.

Listed companies are legally obliged to comprehensively report an extensive amount of information related to their corporate activities. Unlisted companies and other businesses are required to report only a sub-set of these activities, so many will not be relevant – particularly the requirement for continuous disclosure. We provide an overview of the disclosure and reporting rules, the impact of adaptive capacity on this information and derive a framework for the disclosure of costs, benefits, operations and the financing of adaptation measures.

It is important to note that the research outputs from the workshops relating to asset impairment, materiality, intangible assets and reporting disclosure are not a prescriptive set of requirements recommended by the project team. The following discussion merely points to the critical areas of concern around adaptation reporting and disclosure, as well as the alternatives available to firms *under current accounting rules*. The discussion emphasises the relevant accounting principles and the impact of adaptation activities on reporting and disclosure.

4.5.1 Accounting Principles

To date, the accounting profession's focus on climate change mitigation and adaptation have been confined to accounting for tradeable rights arising from emissions taxes and the reporting requirements under an emissions trading scheme. Less attention has been given to the broader question of the measurement and reporting framework required to assist investors, ratings agencies and lenders to link climate change adaptation costs with capital allocation decisions.

The major issues of accounting for adaptation are as follows:

- initial accounting for adaptive capacity
- impairment and provisioning of adaptive capacity assets
- financing adaptive activities
- defining additional financing costs for adaptive capacity, and
- revaluation of assets with adaptive capacity through time.

Based on the potential financial impacts associated with climate change, there are several existing financial accounting standards that arguably require disclosure with respect to climate change risk. Climate change activities will naturally impact important aspects of company reporting.

The relevant standards are discussed below in detail, with reference to Figure 4.6, which identifies the accounting treatment for each aspect of adaptive capacity for cost reporting and control.

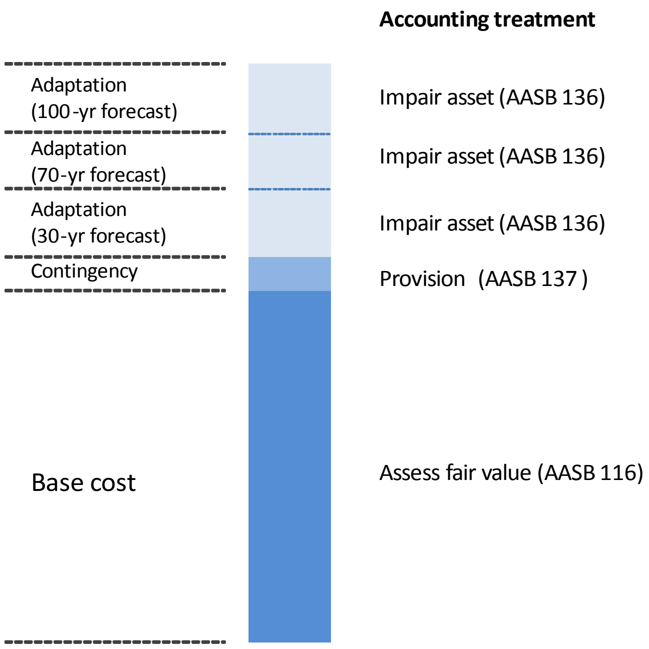

Figure 4.6: Asset valuation with adaptive capacity and the appropriate accounting treatment

4.5.2 Asset Impairment and Adaptive Capacity

The inclusion of adaptive capacity in various assets or processes may mean that, under accounting rules, companies may be forced to write down the value of assets. This raises fears that asset impairments could affect debt-to-asset ratios, which are key triggers for debt covenants, and are also relevant to ASIC-administered financial services licences.

A company that adopts adaptive capacity will encounter some critical issues. Building adaptive capacity has the potential to create 'idle assets', which over-compensate for expected impacts. To offset potential losses, the assets may be over-engineered. However in economic terms this capacity will be naturally offset by the avoidance of insurance associated with expected losses.

Building adaptive capacity directly impacts asset values, depreciation, insurance, expected losses and financing. For instance, adaptive capacity built into an infrastructure asset may increase the capital cost of the asset, or the asset's value may be partially written down upon construction. Subsequent accounting treatment is critical in recognising both the current and future value of the asset. So-called idle assets may not necessarily attract the same reporting treatment as over-engineered assets.

Australian accounting standard AASB 136 requires that assets on an entity's balance sheet are shown at no more than their recoverable amount. This is the higher of the amount obtainable from the sale of an individual asset or the present value of its anticipated cash flows. Where the recoverable amount of the asset is less than the amount that it is carried at in the balance sheet, the asset is said to be impaired and must be written down to its recoverable amount and the business must recognise an impairment loss. This may be of concern for companies who buy or build assets with contingencies to cope with expected climate change impacts. The recoverable amount of the asset is heavily dependent on the revaluation assessment used. At each reporting date, companies must assess whether there is any indication that an asset may be impaired so in addition to the 'base value' of an asset, any additional adaptive capacity must be assessed.

For impairment, the determination of fair value can be complex. Fair value can be defined as an asset's sale price in a transaction between willing parties. The best evidence of fair value is prices quoted in active markets and companies must use this amount to value assets if available. But because market prices are not available for many long-lived assets, fair value estimates must be based on the best information available, including prices for similar assets. While firms may use other valuation techniques, present value is often the best method for estimating fair value.

In Australia, there is no current tax relief for asset impairment. Companies could argue that an asset containing adaptive capacity be exempt from impairing losses; however, in return the asset is entitled to a lower depreciation claim because its effective life is increased. An entity can do this by re-estimating the effective life of its assets, but it can do this only if the asset was acquired after 21 September 1999.

Another key concern to companies is the fact that, while building adaptive capacity is an alternative to insurance, insurance can be expensed but adaptive capacity in excess of an asset's 'fair' or book value cannot. This puts firms that adopt adaptive capacity activities (that is, firms who self-insure) at a disadvantage relative to those who simply obtain insurance coverage from a third party.

The standard relating to property, plant and equipment, AASB 116, permits the reversal of previous impairment through higher revaluation of an asset's carrying amount to be credited to equity as a revaluation reserve. It must also be recognised as reversing a devaluation decrease of the same asset previously recognised in the profit or loss statement. Many assets are not stand-alone units but rather are integrated with a range of ancillary assets. When an asset group consists of long-lived assets with different remaining useful lives (i.e. different degrees of adaptive or other capacity), determining the group's life is critical to estimating cash flows. But the remaining useful life should be based on the life of the primary asset, which is defined as the most significant asset from which the group derives its cash flow generating capacity, notwithstanding the requirement of AASB 116 to componentise assets.

The impact of adaptive capacity can readily be assessed in accordance with the above guidelines.

4.5.3 Materiality

To determine materiality of value adjustments to an asset with in-built adaptive capacity, the firm must consider and evaluate the size and nature of the adjustment. An item in the income statement should be assessed with reference to the profit or loss and the appropriate income or expense amount for the current reporting period (or averaged over a number of reporting periods) as a base amount. An item from the statement of cash flows should be assessed with reference to net cash provided by or used in the operating, investing or financing activities for the current reporting period (or over a number of reporting periods) as a base amount.

The quantitative thresholds used to guide the materiality assessment are set as:

- material if equal to or greater than 10 per cent of the base amount, or
- immaterial if the amount is equal to or less than 5 per cent of the base amount.

These levels are clearly arbitrary, but they are useful as a guide. Materiality levels between 5 and 10 per cent require the professional judgement of the firm to balance the increased costs of monitoring and reporting against the disclosure demands of investors. Thus materiality of the impact of adaptive capacity is an important consideration when assessing when or if to include adaptation activity costs in the financial statements. Other standards such as AASB 107 Cash Flow Statements clarify the materiality issue for specific accounts however the materiality of adaptation activities and adaptive capacity relative to asset total levels can be assessed against the above thresholds.

4.5.4 Provisions, Contingent Liabilities and Contingent Assets

International accounting standard IAS 37, incorporated by the Australian Accounting Standards Board as AASB 137, ensures that appropriate recognition criteria and measurement bases are applied to provisions, contingent liabilities and contingent assets, and that sufficient information is disclosed in the notes to enable users to understand their nature, timing and amount.

Provisions are measured at the best estimate of the expenditure required to settle the present obligation at the end of the reporting period and must include considerations for risks and uncertainties, time value of money (if material), future events but must exclude gains from asset disposal and also exclude tax consequences.

Inconsistent reporting actions for asset values and insurance coverage will occur when assets with in-built adaptive capacity are also insured. While adaptive capacity is one measure of self-insurance firms may find it necessary (under debt arrangements for instance) to obtain insurance coverage. This type of action may generate inconsistent reporting measures. Assets that are ‘over-insured’ (policy coverage amount is greater than the book value of the asset) will naturally arise when adaptive capacity built-in to an asset is then provisioned while the asset itself is insured at its full construction value. To qualify as an expense, the level of ‘over-insurance’ will need to be justified over that portion of an asset that now features as a liability on the balance sheet. This relation is inconsistent and may need to be addressed through relief for assets with adaptive capacity

AASB 137 prohibits the recognition of contingent assets, since this may result in recognising income that may never be realised. Contingent assets usually arise from unplanned or other unexpected events that give rise to the possibility of an inflow of economic benefits to the firm (e.g. leasing of assets with adaptive capacity during loss periods).

With reference to both contingent assets and contingent liabilities, it is important to note that AASB 137 also requires certain disclosures that account for obligations, uncertainties and other contingencies using 'best estimates'.

4.5.5 Non-Financial Reporting

The non-financial reporting of costs associated directly with climate change adaptation should address material (relevant and significant) issues affecting stakeholders. Principles to be considered when reporting on climate change adaptation include:

- *Inclusivity*. This should outline the commitment to be accountable to those stakeholders that the organisation impacts and those stakeholders who have an impact on it. It should also include an account of the degree of collaboration and governance.
- *Materiality*. An issue is deemed 'material' if it will influence the decisions, actions and performance of a firm or its stakeholders.
- *Responsiveness*. This is defined as how a firm demonstrates its response and accountability to its stakeholders.
- *Stakeholder inclusiveness*. The firm should identify its stakeholders and explain how it has responded to their expectations and interests.
- *Completeness*. This is the coverage of the material topics, adaptation indicators and the definition of the reporting process.

These principles are reflected in the philosophy taken by national accounting standards boards as well as the IFRS.

4.5.6 Corporate Law Economic Reform Program Act

In the United States, the *Corporate Law Economic Reform Program Act* (CLERP 9) of 2004 was developed to reform corporate governance through improvements in transparency, accountability and the rights of shareholders. Australian firms trading on US stock exchanges via American Depositary Receipt (ADR) issues are also required to comply with the *Sarbanes-Oxley Act* (SOX).

The main changes associated with the *Corporate Law Economic Reform Program Act* (CLERP 9) related to continuous disclosure offence provisions and changes to financial reporting. The directors' report for listed entities must include a declaration from the directors that they have received a declaration from the CEO and CFO regarding the company's financial reports. This declaration must state that the financial records and annual financial statements are in compliance with the *Corporations Act* and accounting standards. It must also include a section stating that the financial statements give a true and fair view of the entity's financial affairs.

The *Sarbanes-Oxley Act* of 2002 established a system of increased responsibility and accountability for publicly traded companies. While it did not alter or amend existing SEC rules (e.g. item 101, 103 and 303), the implementation of the Act impacts the accounting and disclosure of environmental information and liabilities. Of particular relevance for environmental disclosure is section 404, which requires companies to establish an 'internal control program' to ensure that fraud and inaccuracies are avoided in the gathering, processing and disclosure of corporate financial information, including environmental liabilities. Section 302(a) requires that the CEO and CFO certify to the effectiveness of the company's financial controls, and that the financial statements fairly represent in all material respects the financial situation of the company with no material omissions; thereby increasing the legal accountability of CEOs and CFOs for financial statement preparation (Lee and Trabucci, 2008).

The main pertinent elements of existing accounting standards that are likely to impact on climate change adaptation cost disclosures are materiality, provisions and liabilities, and valuing intangible assets. As such, both the senior executives and company directors are tasked with the responsibility of ensuring that adaptation activities and assets with adaptive capacity are properly and fairly accounted.

4.5.7 ASX Corporate Governance Principles and Recommendations

While these guidelines are only prescriptive for businesses listed on the ASX, having been developed by the ASX Corporate Governance Council, they are widely recognised as 'best practice' corporate governance guidelines for all types of businesses.

Disclosures relating to adaptation activities and adaptive capacity fall into three areas under the ASX guidelines (2010 amendments released 30 June 10, came into effect 1 January 11):

- *ASX Corporate Governance Principle 5* – make timely and balanced disclosure
- *ASX Corporate Governance Principle 6* – respect the rights of shareholders
- ASX Corporate Governance Principle 7 – recognise and manage risk
    - Recommendation 7.1: Companies should establish policies for the oversight and management of material business risks and disclose a summary of those policies.
    - Recommendation 7.2: The board should require management to design and implement the risk management and internal control system to manage the company's material business risks and report to it on whether those risks are being managed effectively. The board should disclose that management has reported to it as to the effectiveness of the company's management of its material business risks.
    - Recommendation 7.3: The board should disclose whether it has received assurance from the chief executive officer (or equivalent) and the chief financial officer (or equivalent) that the declaration provided in accordance with section 295A of the *Corporations Act* is founded on a sound system of risk management and internal control and that the system is operating effectively in all material respects in relation to financial reporting risks.

These principles clearly require firms to keep shareholders informed of *any* relevant information that affects the value of their investment. The critical tests of relevance and materiality with regard to the accounting standards are useful guidelines for the disclosure of adaptation activities (ASX, 2007). Of these principles, the most pertinent for investors reviewing a firm's exposure to climate change and subsequent adaptation activities is the management and disclosure of risks under Principle 7.

Principle 7 requires the board to report whether it has received an assurance from management that management has identified and addressed the material business risks effectively. This assessment should occur at the individual material business risk level and support the focus on risk. A commonly used method for communicating the firm's material business risks to the board is to present them in the form of a risk register (see Appendix 10) that summarises the significance of each risk as well as actions taken by management to mitigate the risks since they were originally identified (ASX, 2007).

Companies should establish a sound system of risk oversight/management and internal control by establishing policies for the oversight and management of material business risks and disclose a summary of those policies. This requirement is mandatory for listed companies. Boards need to insist that executives design and implement a risk-management and internal control system to cater for the company's material business risks and report on whether those risks are being managed effectively. The board must also disclose whether it has received assurance from the chief executive officer (or equivalent) and the chief financial officer (or equivalent) that the declaration provided in accordance with section 295A of the *Corporations Act* is founded on a sound system of risk management and internal control, and that the system is operating effectively in all material respects in relation to financial reporting risks (ASX, 2007).

Climate change adaptation risk assessment is the responsibility of the board and the management team, and assurance is provided by internal and external auditors. The internal audit function conducts independent appraisal of the adequacy and effectiveness of the company's risk management and internal control system and, while not a statutory requirement, best practice suggest that companies should consider maintaining an internal audit function or some alternative mechanism depending on the company's size and complexity. The internal audit function should be independent of the external auditor. The internal audit function and the board audit committee should have direct access to each other, and should have all necessary access to company information and management.

In the presence of climate change, a firm's risk profile will evolve over time as risk priorities change, so risks of both a short and long term nature need to be continuously reported. To provide full assurance, risk management could serve as a standing item on the board's agenda. Risk reporting to a board should cover:

- risk description and outline of likely impacts of the risk
- current controls to mitigate the likelihood or impact of the risk
- assurance on the effectiveness of current risk controls
- risk-level based on the firm's risk governance policy or risk framework, and
- management actions required to better manage the risk.

Reporting under Principle 7 is to provide meaningful information to investors about the firm's risk-control policies and risk-management system. Increasingly, stakeholders will require firms to provide evidence of effective management of not only the financial risks but also other non-financial material business risks including those directly associated with climate change.

Principle 7 endorses open disclosure consistent with the 'if not, why not' philosophy. The principles do not prescribe content, format or style of public disclosures, and such disclosures should not be a simple 'boilerplate' statement but provide genuine insight into the risk-management processes and management of material business risks within the firm.

Commercially sensitive information, details of the firm's risk profile and details of the firm's material business risks are not required to be disclosed under Principle 7. However, when considering material business risks, firms must be aware of their obligations under ASX Listing Rule 3.1 to immediately make an announcement to the market in relation to some or all their material business risks and/or changes to those risks, where the risk or change is likely to have a material impact on the price or value of a company's securities (ASX, 2007). This requirement may arise if funding arrangements, the building of adaptive capacity or a significant change in firm strategy occurs as a direct action against climate change risks. The board will continue to exercise judgement when considering whether such detailed disclosure is required (Robinson, 2007).

4.6 Summary

This study has addressed the main elements of concern to firms related to valuing adaptation actions, disclosure and governance. To some degree, firms are already engaged in these activities as part of their usual business processes. However, it is clear that firms with significant future exposures to climate change need to make substantial adaptation decisions now.

4.6.1 Firm and Investor Disclosure Matrix

Table 4.2 outlines the firm and investor disclosure matrix derived using the above information concerning adaptation options, cost estimates, vulnerability assessments, disclosures and governance principles. This provides a summary overview of which accounting standard and governance principle applies under different adaptation objective and cost accuracy assessments. This is not an exhaustive outline of assessment options and disclosures but provides a basic framework to define the minimum level of analysis and reporting of climate change adaptation activities.

Table 4.2: Firm and investor disclosure matrix for climate change adaptation activities

Adaptation objectives	Adaptation costs	Cost estimate quality	Vulnerability assessment	Disclosure rules	Governance
Single	Monetised	Accurate forecast	ELA CBA	AASB116 AASB136	ASX Principles 5 & 7
		Uncertain forecast	CEA	AASB116 AASB137 AASB136	ASX Principles 5, 6 & 7
	Un-monetised	Uncertain forecast	MCA	AASB137 AASB136	ASX Principles 6 & 7
		Unknown costs	MCA plus expert advice	AASB137 AASB136	ASX Principles 6 & 7
Multiple	Monetised	Accurate forecast	ELA CBA	AASB116 AASB136	ASX Principles 5 & 7
		Uncertain forecast	MCA	AASB116 AASB137 AASB136	ASX Principles 5, 6 & 7
	Un-monetised	Uncertain forecast	MCA	AASB137 AASB136	ASX Principles 6 & 7
		Unknown costs	MCA plus expert advice	AASB137	ASX Principles 6 & 7

5. DISCUSSION

Having outlined the framework that we believe represents best practice in business responses to climate change, the discussion now focuses on the implementation of adaptation activities and adaptive capacity, impediments to business adopting this framework and suggestions for helping to overcome these barriers.

5.1 Risk Assessment

Risk assessment is a valuable mechanism for capturing business opportunities that might arise from climate change and to identify those that can be secured with relative ease. To some extent, adaptation is likely to occur autonomously; however, barriers may prevent companies – and indeed the environment itself – from adapting appropriately. It is therefore important that governments gather information to assess the extent to which such barriers exist and how they can be overcome.

Assessing the range of potential impacts of future weather events and climate effects is a fundamental element of adapting to the risks of climate change. The risk assessment should generate a suite of priority actions that will inform an adaptation plan. Implementing a flexible program of responses to climate effects is intended to reduce the aggregate risk of financial losses through time.

Climate impacts will vary in time, space, nature of onset, duration and persistence. The effect of the impact on organisations will obviously vary with organisational structure, function, dependencies, planning and investment timescales, exposure to liabilities and other factors. Consequently, organisational climate adaptation plans must differ enormously, with some companies with little exposure posting relatively minor elements in their risk register to a full strategic program for those firms facing major potential exposures. An added dimension for these differences is the variation in the state of recognition and planning for climate impacts. Priorities need to be established using a rigorous and analytical risk-based approach to ensure that impacts are dealt with in a prioritised and proportionate way.

Standardising the approach to climate change adaptation reporting should be informed by the business risk-management procedures that are used across industries. Where possible these should:

- be documented
- be evidenced
- be justified
- be repeatable
- analyse likelihood and severity both individually and in aggregate, and
- express where the accountability lies.

5.1.1 Using evidence and dealing with uncertainties

Every organisation should obviously use the best available evidence to inform its risk assessment, including currently available material (as well as so-called ‘sector resilience plans’). However it cannot be expected that all firms have the capacity to explore the scientific analysis of climate change impacts in depth. The approach should be proportionate to the size and nature of the organisation and the types of risk it faces. For example, organisations that face similar risks with an average temperature rise of 2ºC compared with, say, 5ºC can plan a strategy without conducting a detailed analysis of the probability of each. Organisations should only use detailed information where this reflects their sensitivity to different future climates.

The timescales involved in looking at the short and/or long term will depend on the context of the policy, program or project. Organisations need to take their own view on what timescales should be assessed (e.g. where infrastructure has a long asset life, a longer timescale must be considered when considering risks). Some organisations may need to consider some of the more extreme potential changes in climate due to the nature of their functions. Each organisation is well placed to consider its own particular circumstances (i.e. nature of impacts of climate change on its work – whether it is dealing, for example, with low-risk, but high-impact events or medium-risk, but low-impact events).

While the risk assessments will necessarily embody significant uncertainty, organisations should be encouraged to quantify the likelihood and consequences of impacts and opportunities wherever possible. This would assist with the prioritisation of risks and also help organisations consider the extent of climate change risks alongside other business risks they face.

It is important to note that while some analysis attempts to quantify uncertainty, the results are not absolute and do not include processes or changes that cannot currently be modelled. As such projections provide a rough (and probably conservative) estimate of the uncertainty in future climate, strategies to deal with the level of quantified risk should include flexibility to respond as knowledge improves and projections change in future. Organisations should develop a range of adaptation responses and retain an organisation's flexibility over which future course of action to follow.

5.1.2 Institutional Capacity for Risk Management

Adaptive capacity influences not only the ability of institutions to undertake risk assessments, but also to implement management responses to address identified risks (Smit & Wandel 2006). The specific capacities required to successfully carry out risk assessments and implement processes have a different relevance at successive stages of the process. The capacities required to carry out the early stages of an assessment are largely technical, while those required later on become dominated by institutional and governance issues.

If evidence regarding the accelerating pace of climate change increases along with firm awareness of potential consequences, the demand for risk assessment and adaptation will grow. During the workshops, it became clear that stakeholders still identify knowledge deficit as a major concern, often nominating research, risk assessment and other forms of capacity building high on the list of adaptation actions. This suggests that firms are still struggling to frame the adaptation challenges they are likely to experience, and are constrained in their attempts to address knowledge gaps. In response, governments need to increase support to institutions and firms to facilitate risk assessment and adaptation.

Evidence of anticipatory adaptation actions remains limited (Adger et al. 2001), which suggests that the emphasis on risk has been limited to the identification and assessment of climate change associated risk rather than risk management, or monitoring and evaluation. Much of the work on evaluating adaptation has been to support adaptation funding programs and projects by institutions such as the Global Environment Facility and World Bank, as well as traditional development assistance (UNDP 2007). Firms historically have focused on what can be described as substantive risk management, which emphasises the identification and quantification of risk and the identification of risk treatment options. However, without first defining system boundaries, selecting appropriate stakeholders and asking the appropriate questions in the initial stages, such assessments are prone to failure. The failure to articulate a process by which adaptation outcomes will be realised can result in viable plans sitting idle or being rejected by interest groups not involved in the risk-management process.

5.1.3 Adaptation Strategy Development

Although adaptation strategies will be contingent and varied, a case study outlined in Berkout et al. (2006) identified four factors that appeared to shape firm adaptation strategies:

- *Core competencies.* Companies can be expected to search for and adopt adaptation measures in areas that match their core competencies. The firms must internally develop adaptation measures to implement within the framework of the knowledge base of the organisation. Adaptation measures are generally framed in terms of current business practices and drivers.
- *Core business.* If a climate change is seen to have a significant physical impact on the core business, companies will tend to engage with the issue on a technical level. For instance, utility companies will be inclined to adopt engineering solutions to respond to an imbalance between supply and demand due to climate change. Where only a marginal activity is affected, risk-sharing or risk-shifting options such as insurance or out-sourcing often appear more appealing. The degree of exposure therefore influences the mode of adaptation.
- *Dynamic capabilities.* Whether a firm is an early or a late adapter will depend on its dynamic capabilities (i.e. the ability to modify and adapt organisational routines and behaviours in response to external drivers of change). For instance, this effect is likely to emerge in the construction sector, where a single firm that employs adaptation mechanisms is likely to lead on other industry issues (e.g. sustainable construction).
- *Organisational culture.* Culture is a key determinant of how a firm responds to new risks posed by climate change. Firms with a conservative business culture will respond more cautiously to potential climate impacts than others who operate in a dynamic and competitive market. In general terms, we would expect that adaptation measures affirm, rather than undermine a company's attitude and approach to risk management.

Taken together, these factors play into an organisation's adaptation strategy. Given the limits to experiential learning, the ambiguous link between adaptation and performance and the indirect nature of feedback, an adapting organisation needs to employ some ‘guiding principles’ in making choices between alternative approaches. Rather than assuming an optimal set of measures, as in Mendelsohn (2000), Berkout et al. (2006) claim that an organisation will choose from a range of measures available in its perceived adaptation space. The research identified four alternative strategies:

- *‘Wait and see’.* A strategy of deferral, based on scepticism or uncertainty about the possible impacts of climate change and about the benefits of adaptation.
- *Risk assessment and options appraisal.* A strategy of appraising options in preparation for adaptation of organisational routines.
- *Bearing and managing risks and opportunities:* A strategy of handling risks and opportunities arising from climate impacts employing organisational resources and capabilities.
- *Sharing and shifting risks.* A strategy of seeking to ‘externalise’ risks associated with climate impacts through processes of syndication and collaboration.

The ways in which firms respond to pressures from climate change are quite similar to conventional market, technological or regulatory adaptation. However, climate change adaptation has certain distinct features.

Interpreting climate change signals is a challenging process. Not only is evidence of change ambiguous (the problem of signal to noise), but the stimuli are often not experienced directly by the organisation. In addition, interpretation of signals frequently depends on the advice of external specialists who are not able to provide clear and definitive answers. Advice therefore does not usually come in a form that translates easily to the experience and routines of the organisation. Because of the weakness and ambiguity of climate change stimuli, trial-and-error experimentation around standard operating routines will play a significant role in all but extremely climate-sensitive organisations that operate with short decision and investment cycles. In most sectors, organisations are likely to engage in search and assessment processes, suggesting also that the process of adaptation will be managed by higher-level functions in the organisation (Berkout et al. 2006).

Average climatic conditions change only slowly compared with learning cycles typical in organisations, and because examples of more extreme events can usually not be related to climate change with any certainty. Even if such events do remove ambiguity about climate signals and precipitate action, they may not, by themselves, generate sufficient evidence with which to justify and calibrate adaptation measures. Much feedback is generated indirectly through appraisal processes such as risk assessments that deal with hypothetical, rather than measurable, performance.

Adaptive behaviour is patterned by specific internal resources and external conditions, and is therefore difficult to predict and subject to generalisations. While companies will often be afforded a wide adaptation space, adaptation measures do not always represent discrete and well-defined options. Most adaptations require chains of adjustment and innovation, and complex management processes drawing on external resources and conditions. When, and how, companies adapt will depend not only on costs and benefits, but also on the process of receiving and interpreting climate change signals. The long timescales and uncertainties inherent to climate change set it apart from more conventional drivers of change, such as competition, technological change or market demand. Many of the pressures to adapt are likely to be indirect, and many of the resources employed in carrying out processes of adaptation are likely to lie outside the boundary of the organisation.

5.2 Disclosure and Adaptation Reporting

To some degree, regulators have a duty to encourage adaptation measures that aim to assist companies to deliver adaptation actions. However, they must also play a guidance role. For instance, it is the AASB's role to encourage particular actions by reporting entities via accounting standards, as these standards are intended to help reporting entities consistently report the financial impacts of actions they have taken and events that have affected them for the purpose of providing useful information to users of general-purpose financial statements for economic decision-making.

There is some requirement for the development of an underlying framework to encourage adaptive actions.

- *Developing an appropriate framework for adaptation.* Firms make decisions within a regulatory and institutional framework, and therefore this framework should provide appropriate incentives for effective adaptation by permitting instruments that account for climate risk and adaptation. These could be regulations, standards, codes or regulatory guidance. Market-based instruments will become increasingly appropriate.
- *Encouraging information flow. It is important that firms are informed about the likely consequences of climate change, so they can assess the potential impacts and risks they face.* Education, information and training can communicate the effects of climate change while independent research can help improve knowledge of such effects.

Sustainable adaptation ensures that adaptation measures do not contribute to the causes or consequences of climate change, and that action plans implemented in one sector or location do not unreasonably limit the implementation of plans in another. Sustainable adaptation, coupled with sustainable development, allows organisations to minimise the threats posed by the impacts of climate change and to capitalise on potential opportunities presented by it.

The success of an adaptive measure depends upon assessing its impacts on the natural environment, society and the economy. Sustainable adaptation is underpinned by some general principles adopted by many Australian and foreign organisations and governments:

- using sound science responsibly
- living within environmental limits
- promoting good governance, and
- achieving sustainable business outcomes.

Obviously, for adaptation measures to be successful, they must gain broad acceptance among firms and their stakeholders. No stakeholder or interested party should be disproportionately affected. Adaptation options must consider the wider impact on the environment. Adaptation measures that avoid damage to the natural environment and rely on energy efficient and resource efficient technologies will be received more readily.

It has been shown that there can be significant cost advantages in adapting to possible changes in climate before they occur, rather than responding to changes as they occur (Stern 2007). The most effective method to implement sustainable adaptation programs will vary by firm and industry sector. The underlying principles on evaluating the costs and benefits of adaptation measures should be widely applicable; however, organisations are likely to have their own systems for appraising investments. Given the diversity of circumstances, it is not desirable to be more prescriptive than necessary.

An important question concerns how organisations implement their adaptation plan, embed adaptation into existing structures and monitor the effects so that such measures become business-as-usual. Organisations should acknowledge that adapting to climate change is a process. It therefore needs to be built in to normal planning and risk-management processes. Organisations can therefore make sustainable adaptation decisions at appropriate times to maximise benefits and minimise costs. For some organizations, the process of climate change adaptation may be a core function of the business and be built into an organisation's:

- business planning processes
- business risk management
- investment decisions, and
- gateway reviews and audit.

5.3 Principal Investment Areas

Infrastructure is the most visible area that may need to adapt to climate change impacts. Infrastructure assets most likely to be impacted include:

- commercial and residential property
- transport infrastructure, including roads, rail, bridges, airports and ports
- social infrastructure including prisons and hospitals, and
- energy-generation assets and network infrastructure.

Other sectors likely to be more indirectly affected by climate change impacts include:

- mining and minerals assets and infrastructure including ports and rail
- water and sewage utilities
- insurance and reinsurance, and
- agriculture.

In assessing adaptation investments in each of these markets, the following factors should be carefully considered by investors (IGCC 2011):

- design of the asset – new (design and development) or existing (refurbishment)

- type, quality, age and location of the asset
- confidence levels about the extent of local physical climate impacts
- regulatory constraints, now and in the future
- the effect of adaptive features in capital expenditure, operating costs and sales
- insurance options available to the asset in future
- the capacity to assess, price and manage the asset relative to physical risks, and
- taxation implications of alternative financing strategies.

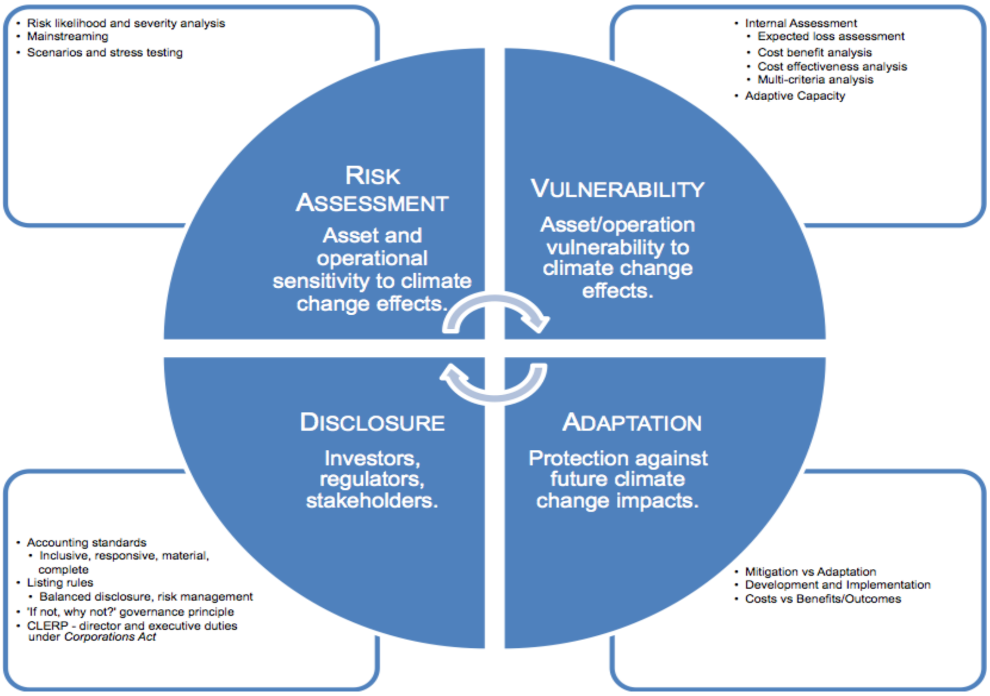

Figure 5.1: The investment disclosure framework for climate change adaptation activities

As investors account for each of these factors while also accounting for the investment horizon, an indication of the level of risk and potential return of the investment derives a tangible cost.

There are significant barriers to a comprehensive investment in climate change adaptation. Some of the primary barriers identified by investors are constraints on the efficient use of capital, inconsistencies in development regulations, limited availability of reliable data on climate change impacts, low liquidity in insurance markets to manage climate change risks and no agreed benchmark or reporting mechanism to describe asset resilience to investors (IGCC, 2011).

5.3.1 Infrastructure

Infrastructure generally represents a major investment of firms, and most firms recognise that it is prudent to build such assets to cope with future environmental conditions. Most infrastructure has been designed, built and maintained on the premise that the future climate will be similar to that experienced in the past. Recognition of the risks associated with climate change should lead to better planning of new infrastructure investments and mitigating potential damage to existing infrastructure. If a firm assesses its exposure to likely climate change impacts at a level that warrants action, the implementation of appropriate adaptation measures will be costly.

Inevitably, all infrastructure assets operate at or beyond design capacity at different locations and times. Notwithstanding the impacts of climate change, it has long been conventional practice to accommodate significant infrastructure investment to raise capacity. Very little infrastructure is designed to meet peak demand, with some demand management measures being applied. The likely impacts of climate change need to be recognised, and an adaptive management approach to designing and managing investment is essential. In the context of climate change, the principal focus is on 'hard' infrastructure, such as roads, rail and ports; however, the same principles apply to 'soft' forms of infrastructure such as agricultural processes and logistics support. Firms must have a sound understanding of the capacity of their infrastructure to continue operations under projected climate conditions, particularly during and after extreme climate events when demand may be greatest.

Climate conditions are expected to change considerably over the useful economic life of long-lived infrastructure, such as bridges (100+ years), ports (75 years) and rail tracks (60+ years). The capacity for such assets to incorporate adaptation measures and alterations to their maintenance regime will in part determine their resilience to accelerated degradation of materials and fatigue of structures if faced with increased intensity and frequency of extreme events (storms, wind, rainfall, bushfire). Assets that are periodically renewed, such as communication infrastructure – which can be renewed within a decade – or roads – with a life expectancy of less than 20 years – are likely to have a larger adaptive capacity than long-lived assets such as bridges. Although a road surface may be degraded more rapidly than a bridge from increases in temperature, solar radiation or flooding events, each periodic renewal of the road (four times in 100 years) can incorporate knowledge about then-current and anticipated climate conditions in its design, and new technologies and materials in its mix of materials. Adaptive capacity is directly related to the present condition of the infrastructure, life expectancy, service level expectancy, maintenance regime, levels of investment and lead times for planning, design and construction of adaptation options such as protection, reinforcing and elevation adjustments. Information that enables firms to avoid unwittingly damaging the infrastructure or rendering it ineffective during extreme events can also increase the adaptive capacity of the infrastructure system.

The long-term nature of climate change poses obvious challenges for companies to value adaptation costs, particularly defining inputs to the valuation process like discount rates. The higher the discount rate, the less value ascribed to impacts felt by future generations. The discount rate can also be interpreted as a reflection of one's treatment of intergenerational equity (Van den Bergh 2004). The fact that climate change impacts may be irreversible is an argument for a lower discount rate than the rate of return on capital. Climate change impacts expected to occur over a longer horizon support the case for using a lower discount rate when assessing impacts. When there are potential intergenerational issues, including those involving environmental impacts, it has been argued that society has a duty of care to future generations to avoid such adverse consequences, and therefore a low or zero discount rate is appropriate when considering climate change impacts to long-lived assets (Australian Greenhouse Office 2004). This approach is highly debatable, and has been considered in detail elsewhere (Downing et al. 1996; Fankhauser et al. 1999). The discount rate used also depends on the purpose of the evaluation. In a case where the analysis is trying to identify an option least affected by climate change impacts, and whether adaptation measures are worthwhile, a discount rate that represents the compensation required for a risk-free investment is perhaps more suitable.

Ultimately, financing activities that cater for climate change impacts requires an estimate of the true cost of capital that equity and debt investors are willing to bear. Ignoring time values, incorporating all possible intangible costs and deriving estimates of intergenerational equity is not how investors in the capital markets behave. Investors earn a monetary return for bearing risk. This reality must remain at the forefront of accounting for climate change adaptation activities.

When assessing more precise expected costs and benefits of adaptation options, companies should use one or more of the following approaches, which have proven to be effective decision-support tools. The approach selected depends on the number of adaptation objectives required by the company's business units and the measurability of the impacts.

5.3.2 Addressing the Distribution of Impacts

Firms generally perceive their vulnerability (risk) to asset impairment as a function of both risk exposure and sensitivity, and adaptive capacity. The relationship between these elements is outlined in Figure 5.2. For infrastructure, the most relevant consideration is the adequacy of the construction standards (e.g. built to withstand a 1 in 100 year flood). Analysis of whether the risk of such an event will increase due to climate change, and whether the consequence of such an event would be any greater than it currently is, are primary considerations.

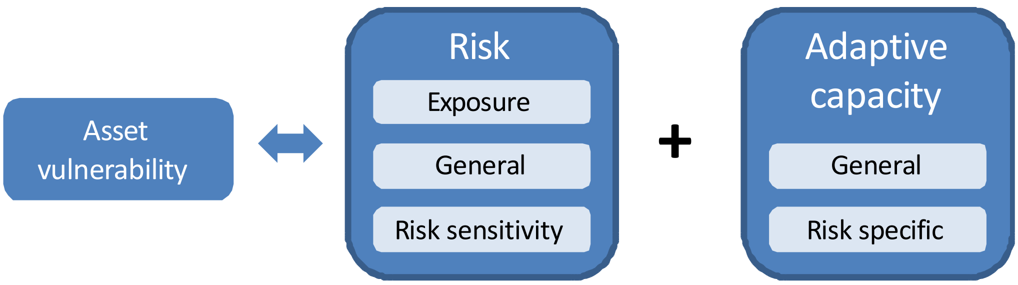

Figure 5.2: Perceived relationship between vulnerability, risk and adaptive capacity

Exposure is the nature and degree to which an asset is exposed to significant climatic variations. This aspect of vulnerability covers climate variables and biophysical elements strongly influenced by changes in the climate. Vulnerability refers to the degree to which a system is affected, either adversely or beneficially, by climate-related variables including means, extremes, gradual changes and variability. It is influenced by biophysical elements such as ground slope or aspects, infrastructure elements (e.g. drainage infrastructure) and operational elements (e.g. importance of this infrastructure service for the firm's continued operations). Some aspects of the vulnerability are generic across all risks, while others are specific to a particular risk or combination of risks. Adaptive capacity may be generic, that is common across all climate change risks, or risk specific at a local or firm level.

5.3.3 Low-Probability, High-Severity Events – Catastrophes

The risk of low-probability, high-severity climate catastrophes is claimed to be the primary driver for action to mitigate and adapt to climate change (Van den Bergh 2004; Jotzo 2010). Omitting low-probability, high-severity outcomes biases damage estimates downwards. However, consideration of these impacts is routinely absent from climate change impact analysis, particularly general equilibrium-based analyses due to modelling difficulties (Weitzman 2009). Weitzman argues that the treatment of catastrophes in most models is inadequate, and that it may not be possible to adequately address these issues due to deep structural uncertainty. Other research suggests that extreme impacts ought to be treated separately from mean impacts because they require different analytical treatments and ultimately different adaptation initiatives. This position is also reflected in IPCC reports, which treat disasters separately from slower onset impacts.

These low-probability, high-severity events have significant potential to damage business, and without being able to manage the potential outcomes adequately through adaptation plans, businesses remain vulnerable. Appendix 11 outlines alternative financial instruments that may be useful for businesses to offset their exposure to these events.

5.4 Financing Adaptation: Capital Costs and Other Concerns

Private sector financing of climate change adaptation measures immediately presents problems, especially when a significant proportion of asset value lays idle as stock adaptation. Investors seek risk-adjusted returns on capital with a time horizon that is much more limited than the horizon required for a range of adaptation measures.

5.4.1 The Role of Markets and Adaptation Policies

The objective of adaptation activities for companies is to facilitate their ability to respond effectively to the anticipated impacts of climate change. While markets provide an immediate and well-established avenue for addressing uncertainty, governments can facilitate adaptation by enhancing the flexibility of the markets while managing barriers to efficient exchange. Markets are well placed to transfer risk to those best placed to deal with it, and disperse concentrated risks across a wide base. This is achieved through the insurance and capital markets as well as through diversely connected domestic and international product markets. The smooth flows of goods, services and the factors of production are aimed at increasing the ability of an economy to absorb abrupt shocks and anticipated changes over the long term.

Broad and flexible markets allow scarce resources to flow to parts of the economy where the value is highest, and constantly updated information continually changes the understanding of economic value. At a regional level, resources that are stranded in areas of declining productivity will affect broader economic growth due to the magnifying effects of so-called idle capital. For instance, if agricultural yields decline in certain areas due to drought and higher average temperatures, capital, labour and water resources could produce better economic outcomes in absolute terms if they were freely redeployed to other more productive areas of the economy. A more specific example is capacity building (over-engineering) port facilities to cater for projected sea level rises, which implies a degree of so-called 'idle capital' that potentially could be funded at a similar cost to existing operational facilities in the capital markets for that portion of the project. Flexible and adaptable markets are essential for financing such adaptation activities.

The structure of project funding and activities that cater for adaptation will need to match expected investment returns, which in turn rely on the risk of the underlying investment. The structure of private sector financing will require innovative solutions. Potential avenues for private sector involvement in the financing of adaptation projects include project financing, public–private partnerships that cater for lower returns of idle capital assets using a portion of public funds, and strategic alliances between private firms seek diversification benefits from different sectors of the economy and superannuation funds. The efficient financing of infrastructure investment depends on selecting a financing vehicle that minimises the total cost of finance over the lifetime of the asset. Principal markets that require increased policy attention are those heavily involved with infrastructure, energy, insurance, agriculture, water, tourism and transport. The role of government in adaptation is likely to be crucial, given the potential convergence in the provision of goods and services using private and public assets. Businesses that seek to build capacity into new infrastructure as a form of adaptation will increasingly need to better identify the excess component to match the liability with a funding structure.

Private sector financing of adaptation in industries such as forestry, infrastructure and agriculture is still in its infancy, and there are few relevant examples of project opportunities. Nevertheless, there are a number of options for involving private sector investors in adaptation:

- *Public–private partnerships.* An option for increasing private sector involvement in adaptation activities is public–private partnerships (PPPs) that aim to harness private efficiency and resources to meet goals that benefit both the public and private sectors. The establishment of such partnerships may help to identify and use synergies to finance and implement adaptation projects that not only support the public good but also result in economic returns for private investors. An example would be the development of climate-resilient crops through a PPP aiming to combat desertification and help protect the biophysical foundations of agriculture, such as forests, soils and water.

- *Insurance.* Insurance is an area through which private sector companies can become involved in financing adaptation. Investors cannot explicitly purchase insurance to protect their investments from climate change risks since most policies are of an annual duration. In terms of climate effects, insurance companies mitigate concentration risk through reinsurance; however, the insurance sector faces considerable constraints to operating efficiency in certain areas and industries. Owing to the lack of climate change data and information on the damaging effects of climate change, risk analyses cannot be conducted with a high degree of confidence.

At present, the most readily identifiable adaptation measures reside almost exclusively within infrastructure and technological solutions. The development of adaptation measures focused on these areas alone may limit stakeholders into specific paths at the expense of potentially broader and more diverse adaptive responses. Allowance must therefore be made for potentially broader, deeper and more sustainable adaptation responses.

5.4.2 Cost of Capital

The total cost of finance is generally made up of

- a return paid to investors who provide capital for an investment
- contingent liabilities arising from financial claims associated with the investment, and
- transaction costs.

Transaction costs aside, in general the total cost of finance is minimised where the financing vehicle assigns project risks to those parties in the transaction that are best able to manage those risks.

Aggregate estimates generally do not take account of the distribution of impacts (Tol 2002a). This is a concern for climate change analysis because impacts and costs are unlikely to be borne uniformly between organisations, so conducting an analysis of the distribution of impacts and costs is critical. This can be achieved through a formal weighting of selected impacts or simply a disaggregation of where impacts and costs will be borne.

Formally accounting for the distribution in an impact assessment using arbitrary weights is not a simple task (Kiker et al. 2005). Analysis of distribution and equity has shown that such an approach to economic analysis should be a part of the decision-making process. The use of qualitative decision-support tools (MCA) can be utilised in an integrated assessment to inform decision-making (Bell et al. 2003). It has been suggested that the current decision-making context for adaptation limits stakeholder participation within the decide-and-defend paradigm that positions stakeholders as constraints to be tested rather than as the source of core values that should drive the decision-making process (Kiker et al. 2005).

Discounting converts future costs and benefits into present values. Discount rates reflect a preference for consumption today over consumption tomorrow equivalent to the risk-adjusted rate of return on capital investment. Small changes in the discount rate have enormous impacts on present value, particularly for long-dated investments. A decision is deemed efficient (cost-benefit ratio greater than 1 using a CBA approach) if the present value of the expected benefits exceeds the present value of the expected costs. An activity may be deemed to be economically efficient even though there are, for instance, potentially sizable rehabilitation costs that are discounted heavily as they represent a liability far into the future. Many costs are ignored due to the difficulties in agreeing upon a value. Economic efficiency does not necessarily account for sustainability or equity.

The selection of the discount rate is a contentious issue in climate change adaptation activities because it is the primary way in which costs and benefits to future generations are weighted against costs and benefits to the current generation (Farber et al. 2002). Discount rates can be determined in either a positive or normative way (Garnaut 2011). Positive approaches to economic analysis involve observation, description and explanation of economic phenomena, while a normative approach aims to consider values and ethics. A normative approach to determining the discount rate is derived from judgements about how to value the well-being of future generations compared with those of today. Reflecting Stern (2007), Garnaut (2008, 2011) and other researchers suggest that a normative approach is more appropriate for climate change where issues of equity and sustainability are important. However, financing adaptation activities – particularly for private projects – requires an objective assessment of actual funding costs based on the risk of the activity, which is assessed by investors. While the normative approach may appear to offer an all-embracing view of underlying impacts, investors traditionally rely on positive approaches, and it is difficult to reconcile the differences between the two.

The long-term nature of climate change offers significant challenges for companies to value adaptation costs. The higher the discount rate, the less value ascribed to impacts felt by future generations. The discount rate can also be interpreted as a reflection of one's treatment of intergenerational equity (Nunes & Ding 2009). Van den Bergh (2004) argues that since an economy or society – unlike an individual – does not have a finite life, the concept of a time preference is not applicable, and therefore discounting in the current context is irrelevant. The fact that climate change impacts may be irreversible is another argument for a lower discount rate than the rate of return on capital (AGO 2004). In a study of the impacts of climate change in five European sectors, Ciscar (2009) avoids the discounting problem by reporting non-discounted monetary effects. Others argue that the presentation of results under various discount rates (i.e. discount rate sensitivity analysis) within a range based on positive and normative approaches would be a useful for companies and regulators.

Ultimately, financing activities that cater for climate change impacts requires an estimate of the true cost of capital that equity and debt investors are willing to bear. Ignoring time values, incorporating all possible intangible costs and deriving estimates of intergenerational equity is not how investors in the capital markets behave. Investors earn a monetary return for bearing risk. This reality must remain at the forefront of accounting for climate change adaptation activities.

5.4.3 The Efficient Use of Capital

Preparing assets for climate change impacts requires assumptions about the extent of potential impacts throughout an asset's life. Building in resilience or redundancy for impacts that have been over-estimated allocates scarce capital resources to inefficient uses. There will be cases where future refurbishment or retrofitting to protect an asset for future climate change impacts may not be an option due to the scale, complexity and nature of particular assets (i.e. the height of a runway above expected storm surges or seas levels). Therefore, there is by definition a level of over-investment in the asset to provide for sufficient resilience, relative to the absence of the risks of climate change impacts during the initial operating period of the asset. The cost of carrying this additional capital investment in the asset is therefore high, relative to its short- to medium-term impact. These costs are most relevant in long-lived transport and social infrastructure projects, such as airports, ports and railways.

Investors who are aware of the physical risks of climate change are faced with a limited array of risk-modelling information and technological resources for investment decision-making. Embedded in this deficiency are a number of issues:

- The geographical scale of analysis is often too large for specific infrastructure or property corridors or development sites.
- Analysis that finds a wide range of possible environmental impacts usually opens a wide range of possible investment scenarios and implications, complicating scenario planning.
- Investors historically have been reluctant to interpret analysis of climate impacts and draw specific conclusions for investment decisions.
- Limited climate change data and assumptions exist concerning the extent, likelihood and severity of expected impacts, which is limiting the ability of investors to competently assess the risk and return of future investments, particularly in the infrastructure sector.
- Limited willingness of insurers to provide cover for asset impacts caused by climate change at a reasonable premium is expected to constrain the ability of businesses to properly manage risk. If insurance markets are not able to provide cover for physical impacts, then it is likely that some assets will become unviable since the risk profile will skew returns beyond a reasonable hurdle rate. Businesses will be forced to self-insure certain assets, which is a much less efficient approach to risk management. There may be options to turn to the capital markets by creating certain risk-sharing instruments – for instance, catastrophe bonds that insure against a specific event and a specific asset, but investors have been wary of engaging in such investments due to poor data quality.
- There is no commonly agreed guidance to assess and demonstrate consideration of climate change risks. Investors in turn find it difficult to assimilate and compare information from sources that are not consolidated.

All sectors of Australia's infrastructure operate at or beyond design capacity at different locations and times. Notwithstanding the impacts of climate change, it has long been conventional practice to accommodate significant infrastructure investment to raise capacity. However, very little infrastructure is designed to meet peak demand, with some demand-management measures being applied. The likely impacts of climate change need to be recognised, and an adaptive management approach to designing and managing investment is essential. It has also been recognised that infrastructure users must have a sound understanding of the capacity of infrastructure to deliver services under projected climate conditions – particularly during and after extreme climate events, when demand may be greatest.

The adaptive capacity of each of the infrastructure sectors as a whole is complex, and relates to a range of drivers of adaptation and barriers to adapting within each sector. Some of the key adaptation drivers include (Thom et al. 2010):

- the level of early climate change impact on a sector's key assets or service provision
- increase in capital and operational costs due to climate impacts, and
- regulatory, investment and liability pressures to increase the adaptive capacity of the network or new assets.

Some of the key adaptation barriers include (Thom et al. 2010):

- understanding the cost versus the benefit of incorporating adaptation capacity into new and existing assets
- knowledge gaps for infrastructure-specific climate information (such as extreme rainfall events) to inform decision-makers, and
- climate change adaptation not being specified in investment, design, operation and maintenance requirements.

For all infrastructure sectors, adaptive capacity is directly related to the present condition of the infrastructure, life expectancy, service level expectancy, maintenance regime, levels of investment and lead times for planning, design and construction of adaptation options such as protection, reinforcing and elevation adjustments. Information that enables users to unwittingly avoid damaging the infrastructure or rendering it ineffective during extreme events can also increase the adaptive capacity of the infrastructure system.

5.5 Governing Adaptation Programs

Governance is crucial, as climate change should be fully integrated into a company's processes to be managed effectively (Porter & Reinhardt 2007). From a climate change perspective, governance includes an overall company-wide climate management framework, related risk and data management processes, and intellectual capital to manage climate change, as well as disclosure, engagement and leadership. The generic elements of climate governance are similar to environmental management standards. Risk management has been added as a specific and important feature of company management systems. In this framework, risk management refers to the management of overall risk in the corporate portfolio (including natural or artificial hedging of climate change risks) as well as the management of climate change-related risks to the assets and operations of companies.

Figure 5.3 illustrates that the governance of climate change adaptation activities is easily integrated with existing management processes of a typical firm.

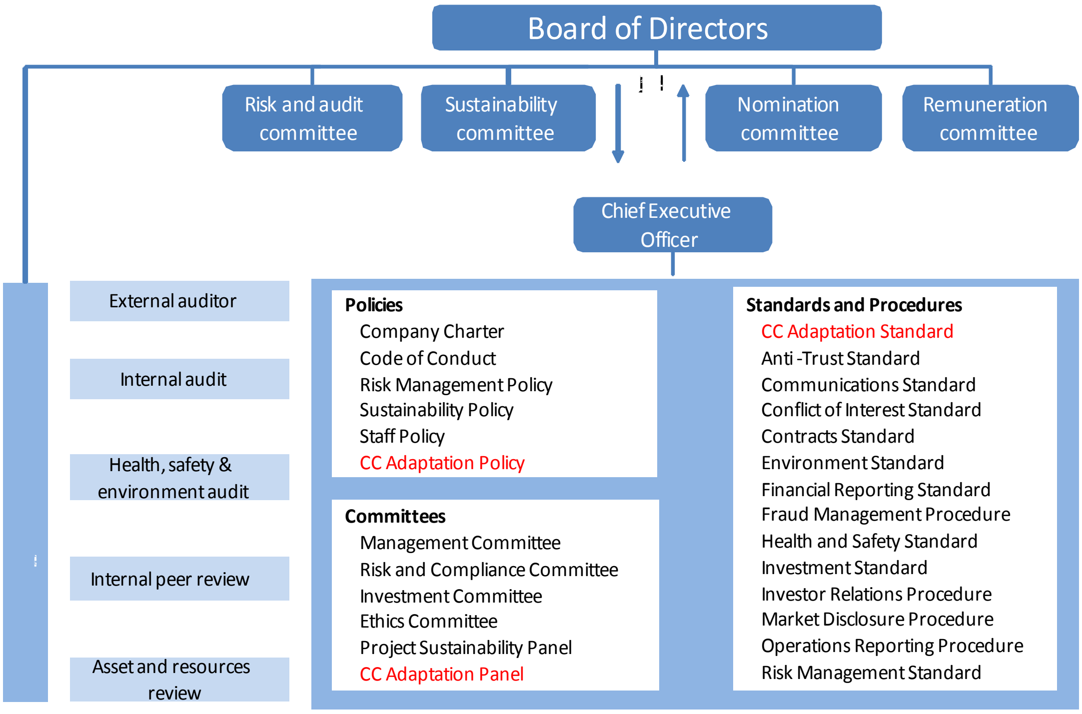

Figure 5.3: A typical governance structure with climate change adaptation activities integrated with the existing governance and management structures of the firm

Smaller firms that do not need to be arranged as comprehensively as the one shown in Figure 5.3 can adapt their own governance mechanisms so long as they are incremental and form part of the existing structure. They do not necessarily need to be a separate consideration unless the severity and/or likelihood of climate change exposures is extreme.

Three tiers of government with different regulatory instruments contain overlapping requirements for adaptation planning. This provides distinct challenges for developers, investors and insurers. Inconsistencies create uncertainty through the due diligence process, which is likely to increase the chance of implementing ineffective adaptation measures. The effect of the regulatory environment is that property investors and developers are faced with no clear understanding of the different approaches in, for instance, managing changing sea-level and erosion. Uncertainty concerning the status of existing property and infrastructure is also a key issue, particularly in relation to obligations of local government to protect existing assets.

5.6 Summary

The anticipated risks of climate change emphasises the importance of developing and deploying new technology, and redesigning infrastructure and other assets. The degree to which these new and emerging technologies successfully adapt to climate change impacts will influence how companies and investors value and account for climate impacts (and opportunities) on their financial statements. These valuations likely will influence investor perception and behaviour, as well as identify true climate leaders. This report has highlighted the various accounting and valuation frameworks that currently exist to address disclosure of environmental obligations, intangibles, and climate risks/opportunities. Lessons learned from the history and evolution of environmental disclosure requirements, coupled with recent advancements in the valuation and disclosure of intangible assets, can inform efforts to recognise and measure opportunities related to climate change, as well as the range of other socially responsible initiatives.

Without a clear, analytic framework to measure the beneficial impacts of these initiatives, it is unlikely that their true value will be recognised by the investment community. And without clearly defined methodologies for assessing both climate change risks and opportunities, the material financial impacts of climate change and associated adaptation initiatives will continue to go unreported and unmeasured. This has the potential to inhibit the ability of investors to appropriately weigh the 'true' value of corporate actors in key industries.

The work presented here represents the important next steps towards defining a broad and comprehensive climate change adaptation risk, disclosure and governance framework within which companies, SMEs, investors, boards and regulators can function.

5.7 Recommendations

As a result of this analysis and the workshops conducted with industry representatives, we offer the following recommendations:

1. The Australian government, in consultation with relevant sections of the business community, should undertake research into quantifying the costs and benefits of climate change adaptation activities in infrastructure, supply chains, operations and other processes of relevance to industry. This would require the development of a database and cost-benefit outcome model, similar to the now unsupported Dynamic Interactive Vulnerability Assessment model (DIVA), previously supported by the EU Global Climate Forum.
2. The Australian government via the Joint Environment Protection and Heritage Council and Ministerial Council on Energy Policy Working Group should seek to rationalise Australia's climate change exposure reporting requirements into a national framework.
3. Government and industry bodies (e.g. IGCC, CPAA) should liaise further on developing mechanisms for setting sectoral benchmarks for climate change adaptation costs and benefits.

4 Auditors could make recommendations to company boards and other entities they routinely cover on the adequacy of climate change adaptation disclosures to meet the evolving needs of shareholders, and the wider capital market in order to assess and value material non-financial performance, risk profile and risk-management strategies on an annual basis. This assumes a certain degree of knowledge by auditors on climate change risk metrics and activities, which may not be feasible.

5 The ASX Council should continue to consult with industry to determine areas where companies, investors and other stakeholders believe further guidance is necessary in relation to the non-financial disclosure requirements for climate change adaptation and reporting under the ASX Council's Principles of Good Corporate Governance and Best Practice Recommendations.

6 Investors, stakeholders and relevant business associations should encourage companies to include long-term corporate responsibility performance measures and climate change adaptation requirements as part of the remuneration packages of company directors, executive officers and managers.

7 Industry associations and peak bodies should actively promote analysis of climate change adaptation costs and benefits to their members.

8 The Australian government, in consultation with companies, institutional investors and rating agencies, should establish and operate a central web-based open-source tool for the dissemination of likely climate change effects, adaptation costs and benefits by geographical location. This could form an essential part of the *National Climate Change Database* to provide business (especially SMEs) and investors access to the most current and relevant information.

9 The development of a national climate change database will assist in identifying gaps in current knowledge, providing the opportunity to fill those gaps through future research. Decisions on the direction of future research as defined via the Australian Research Council (ARC) National Research Priorities list need to consider specific needs of business, as well as topics for the wider national interest.

10 A common database containing input assumptions will ease the burden for risk managers and investors to properly account for climate change impacts. It would provide: a single point information source for the current research into climate change risk impacts; information regarding current gaps in understanding; clear understanding of the assumptions underpinning current climate change risk research; and a baseline by which individual organisations could assess their internal climate change risk impact models.

11 In order to show leadership and to encourage more agencies to disclose climate change adaptation planning and activities, the Australian government should require all of its agencies to disclose their climate change adaptation activities and costs in their annual reports.

12 The Australian government, in consultation with the investment community, should develop educational material that covers the materiality of climate change adaptation costs and benefits for use by institutional investors and fund managers.

13 To facilitate greater uptake of climate change adaptation reporting, the Australian government should examine the feasibility of introducing inflated

write-off arrangements for the ‘year one’ costs of initiating climate change adaptation programs, to assist companies that commence adaptation reporting for the first time.

14 The Australian government should consider options for providing regulatory relief to corporations that voluntarily undertake climate change adaptation planning and other activities. Tax relief for firms that develop adaptive capacity within their assets as a form of self-insurance would equalise the cost burden compared with firms that choose to insure with third parties rather than adapt to climate change.

15 Consistency across all tiers of government is necessary for regulating climate change adaptation measures. A consistent national approach is needed, which recognises and allows for the different severities and likelihoods of climate risks in different regions, but which at a national level provides:

- clear protections for private property owners and insurers in order to provide greater investment certainty
- consistency in the overarching framework, definitions and procedural matters to reduce compliance costs and the risk of errors, and
- policy guidance based on the current scientific understanding of the risks, particularly as hazard maps and other forecasting tools become more sophisticated, so as to ensure that adequate adaptation policies are implemented.

16 Investment should be encouraged through incentives and providing greater regulatory consistency. This will provide the stimulus for individual organisations to better manage climate change adaptation. Investors have identified several initiatives for reducing investment risk and providing confidence in investment returns:

- market incentives (e.g. accelerated depreciation on building assets)
- co-investment in the form of direct funding via PPPs or low cost debt financing to reduce the cost of capital
- support for innovation in adaptive technologies (e.g. construction materials) to reduce capital expenditure needed for adaptation projects; informational support (e.g. research to promote understanding of risks and making specific development corridors and adaptation projects more transparent to investors), and
- learning from the experience of governments, for example in the form of shared technical information as a result of project due diligence.

17 The *Corporations Act 2001* permits directors to have regard for the interests of stakeholders and shareholders, and therefore amendment to the directors' duties and provisions within the *Corporations Act* with explicit regard to climate change adaptation is not required. Such regard for risk assessment is already required for *all* business risks.

6. GAPS AND FUTURE RESEARCH DIRECTIONS

Adaptive capacity influences not only the ability of institutions to undertake risk assessments, but also to implement management responses to address identified risks. The specific capacities required to successfully carry out risk assessments and implement management have different relevance at successive stages (e.g. to identify, evaluate, manage risk and monitor and review risks). The capacities required to carry out the early stages of an assessment are largely technical, while those required later on become dominated by institutional and governance issues.

If evidence regarding the accelerating pace of climate change increases along with stakeholder awareness of potential consequences, the demand for risk assessment and adaptation will develop further. Currently, the number of adaptation strategies and action plans is doubling approximately every two years (Preston & Westaway in press). Nevertheless, stakeholders still identify knowledge deficit as a major concern and assert that research, risk assessment and other forms of capacity building are critical for implementing adaptation actions. This suggests that firms are finding it difficult to frame the adaptation challenges they face while being constrained in their attempts to address knowledge gaps, particularly given the long horizons involved. In response, governments increasingly need to allocate support to firms, and especially SMEs, to facilitate risk assessment and adaptation activities.

Several large gaps still exist in firm knowledge and understanding of adaptation actions.

6.1 Financing Capital Programs

Although commercial banks are naturally highly skilled in risk management and credit loss estimates, this study has indicated that it is not yet clear where in these calculations the effects of climate change on loan targets and fixed interest yields should feature. Very few banks have actually developed tools to help quantify risk management implications associated with lending decisions (for example, industry and company benchmarking techniques), although the development of qualitative benchmarking schemes has been available for some time.

The adoption of universal principles may result in better general awareness of best practice, but in practice most banks will rely on their own proprietary methods for competitive reasons. Proprietary credit rating analyses are critical to banks and climate change-related initiatives are likely to be treated in the same way – and increasingly so as the loss exposure grows in magnitude.

Importantly, banks are uncomfortable providing loans in cases where insurers are unable or unwilling to provide insurance coverage for the underlying assets. Should climate effects impair the ability of companies to service debt and insurance is unavailable, then banks will lend only with a higher credit spread. Commercial banks are also strongly in favour of public–private partnerships to avoid major controversy or public incident over some of the effects of climate change, particularly the possibility of diminishing land values.

6.1.1 Adaptive Capacity or Idle Capital?

Firms must emphasise that adaptation is not an objective or process that is considered in isolation, but rather one part of broader decision-making, such as an integral part of sustainable development, resource planning, risk management and environmental sustainability. Investors understand that adaptation considered in isolation will miss important synergies and tradeoffs with other areas, however complex. Risks, opportunities, objectives and measures should be considered within the context of the broader goals and strategies of the firm.

Both the financing and reporting of built capacity are subject to the same prejudices in the capital markets as the practice of 'gold-plating' certain assets. Many investors currently view adaptive or built capacity as 'idle capital', usually infrastructure or insurance employed by a firm or government well in excess of what is deemed necessary. Relying solely on loss models to convince investors to finance capital projects to finance assets carrying adaptive capacity is unlikely to convince many capital investors (both bondholders and shareholders). To address this natural prejudice, firms need to disclose the cost-benefit tradeoff of adaptive capacity as an integral part of their risk-management structure. This practice will aid in convincing investors that the built capacity is a necessary feature for future asset development.

6.1.2 Organisational Learning

Organisational learning is critical when both irreversibility and uncertainty are present. When actions are irreversible and implications are uncertain, decision-making no longer involves a simple weighing up of fixed costs and benefits, since these are contingent on what the firm might learn in the future.

Three key factors influence firm decision-making for climate change adaptation. First, uncertainty over the future and firm learning will have a material effect on the extent of that uncertainty. Second, it should be possible for firms to delay implementation of adaptation options – or at least implement them in stages. Third, adaptation options being considered will be at least partially irreversible, which means that they constitute sunk costs that are not fully recoverable, or will be subject to adjustment costs if they are to be adapted for other uses. Examples of irreversible options include defensive infrastructure projects (no one will want to buy a levee that is never needed), whereas the decision to change the mix of crops planted may be quite reversible (assuming that the change occurs at negligible cost).

Firms increasingly will need to take account of the value of deciding based on new information received in the future, and then weigh this against the loss of benefits from not acting today. This requires an appreciation for contingent valuation techniques such as real options analysis (Dixit & Pindyck 1994) and other quasi-option approaches (Arrow & Fisher 1974; Henry 1974; Epstein 1980).

6.2 Is There a Need for Prescriptive Regulations for Reporting?

Company directors and executives of public companies undoubtedly face growing climate change-related exposures. A particular danger to publicly traded companies is not the fact that they face greater disclosure obligations but rather that, when they undertake greater disclosure commitments – either voluntarily or compulsorily – they may be exposed to allegations that they have engaged in ‘selective disclosure’ or ‘omission’ of unfavourable information. It may be inevitable that unintended disclosures transform into civil complaints. Prescriptive reporting requirements under the direction of the ATO, AASB or ASIC (and other relevant industry bodies) may alleviate the risk of relatively loose disclosure principles impacting on the actions of company boards and executives.

6.3 Data Availability and Prioritising Research to Assist Business

There is clearly a lack of quantitative and semi-quantitative analysis that demonstrates the relationship between climate change, expected losses and adaptation costs. A crucial element of engagement for financial institutions is the extent to which climate change adaptation and mitigation measures create or destroy value. For asset managers and shareholders used to dealing with risk and opportunity in quantitative financial terms, the development of models capable of linking expected losses from extreme value distributions with adaptation costs is almost a prerequisite to becoming more involved. An inability to calculate how expectations of future earnings might be affected by climate change and other regulations such as building design standards can confound investors’ abilities to factor such issues into their calculations. This lack of quality analysis on equity and debt risk is therefore a key concern to securities markets.

Duplication can be valuable in basic research but, because the size and complexity of the data-collection task, most nations including Australia can only afford one comprehensive, coordinated effort in their contribution towards the international climate modelling work. The relative size of Australia’s industry and economy reinforces the case for a single consolidated approach.

Correcting gaps in the understanding of adaptation requirements rests not just on the research effort, but also on the interpretation and presentation of scientific projections in a meaningful and relevant form that can be factored into local risk management and decision-making. Even when soundly researched information is widely communicated, it may be of limited utility if firms encounter problems comprehending it or using it in making their decisions. A single comprehensive database is necessary, containing not only the physical impacts of climate change but also some attempt at estimating costs of adaptation actions.

Decisions on the direction of future research as defined via the Australian Research Council (ARC) National Research Priorities list need to consider specific needs of business as well as topics for the wider national interest.

6.4 SME Adaptation Vulnerability and Capacity

Small and medium-sized enterprises (SMEs) are not prepared for the impacts of climate change, despite the fact that the smaller the business, the more vulnerable it is to climate shocks. Most SMEs expect the emergency services or government agencies to assist them in an extreme event like flooding, but post-event surveys show that their insurers provide the most help. Insurers and intermediaries can do more to help this sector deal effectively with climate change by providing appropriately tailored products and services.

6.5 The ‘Business Judgement Rule’ and Climate Change

The ‘Business Judgement Rule’ seeks to allow proper entrepreneurial activity by businesses by allowing that the duty of care and due diligence requirements of the *Corporations Act* have been met if directors and officers of the corporation:

- make judgement in good faith and for a proper purpose
- do not have a material personal interest in the subject matter of the judgement
- inform themselves about the subject-matter to an extent they reasonably believe to be appropriate, and
- rationally believe that the judgement is in the best interests of the corporation.

The decision must be actively made and not merely a passive stance of doing nothing: the directors and officers must actively apply effort to making a decision, even if the decision is to do nothing.

This rule has implications for climate change adaptation, as decisions made now may have impacts on the future of businesses, and thus the current directors and officers have a duty of care and due diligence obligations regarding climate change risk. For example, the decision to defer adaptation strategies may result in increased cost later as the issue becomes more urgent. The extent to which the climate change adaptation framework – particularly the adaptation approach assessment and selection criteria – proposed in this report allows directors and officers to meet their obligations of duty of care and due diligence under the Business Judgement Rule needs to be assessed.

6.6 Future Research

Future research needs to address the following issues:

- development and coherent integration of loss models for improved risk measurement and management
- capital market valuation of adaptation options
- development of public–private partnerships to better address the financing of adaptation options
- development of generalised models for SMEs to employ for their own risk assessments
- development of a National Climate Change Database that can be used by business in making adaptation decisions, and that will capture user information and inform researchers of the current gaps in climate data.

7. GLOSSARY

Adaptation: Actions undertaken to reduce the adverse future consequences of climate change as well as to harness any beneficial opportunities. A process by which strategies to moderate, cope with and take advantage of the consequences of climate events are enhanced, developed and implemented.

Adaptation baseline: A comprehensive description of adaptations that are in place to cope with the current climate. The baseline may be both qualitative and quantitative, but should be operationally defined with a limited set of parameters (indicators).

Adaptation benefits: The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.

Adaptation community: The network of stakeholders that takes shape over the course of an adaptation project and persists following the project's completion; its goals are to implement, support and improve adaptation strategies, policies and measures.

Adaptation costs: Costs of planning, preparing for, facilitating and implementing adaptation measures, including transition costs.

Adaptation project: A project for developing and implementing adaptation strategies, policies and measures, which may be designed and carried out using some or all of the concepts of the framework.

Adaptive capacity: The ability of a company or system to respond to climate change to moderate potential damages, to take advantage of opportunities or to cope with the consequences. Adaptive capacity can be an inherent property or it could have been developed as a result of previous policy, planning or design decisions. It reflects existing controls, including contingency plans and their effectiveness. The property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions. Different adaptations will have a variety of priorities and needs.

Asset(s): Items that have a distinct value to the company. This includes plant, machinery, property, buildings, ports, rail, access roads, vehicles, vessels, software code and other tangible and non-tangible items critical to the delivery of the function of the asset.

Climate scenario: Coherent, plausible description of a possible future state of the climate. A climate scenario should not be viewed as a projection of the future climate, but rather a means of understanding the potential impacts of climate change, and identifying potential threats and opportunities to a company created by uncertain future climate conditions.

Climate change scenario: Difference between a climate scenario and the current climate.

Co-benefit: An additional benefit from an action that is undertaken to achieve a particular purpose, with the benefit not directly related to that purpose.

Contingent capability: Supplementary resources provided specifically to enable a company to respond to events should they occur. It may be required to make a contingency plan viable.

Contingent valuation: A non-market-based approach used to provide an estimate of the economic value of non-traded goods, such as environmental effects, for which there is no direct market information. It estimates willingness to pay based on stated preferences of beneficiaries of adaptation measures.

Event: An occurrence or change of a particular set of circumstances. An event can be one or more occurrences, and can have several causes. An event can also consist of something not happening. Events are generally referred to as an 'incident' or 'accident', but an event without consequences can also be referred to as a 'near miss', 'incident', 'near hit' or 'close call'.

Extreme weather event: Extreme weather includes weather phenomena that are at the extremes of the historical distribution, including especially severe or unseasonal weather.

Internal rate of return (IRR): The rate of return used to determine and compare profitability of investments. While the NPV calculation finds the net present value using a predefined discount rate, the IRR estimated the discount rate that equates the NPV to zero. The higher the internal rate of return of an adaptation measure, the more desirable it is. The measure with the highest IRR that is higher than the discount rate would be considered the best, and would be undertaken first.

Net present value (NPV): The difference between the present value of the benefit flows and the present value of the cost flows for an adaptation measure. The net present value should be greater than zero for a measure to be economically acceptable.

No-regret: Adaptation measures that would be justified under all plausible future scenarios, including the absence of climate change impacts such as floods or droughts.

Opportunity cost: Cost of any activity compared with its best alternative use. Assessing opportunity costs is important to determine the real cost of an activity.

Residual risk: Risk remaining after risk treatment. Residual risk can contain unidentified risk and also be known as 'retained risk'.

Resilience: Adaptive capacity of a company in a complex and changing environment.

Risk assessment: Overall process of risk identification, risk analysis and risk evaluation.

Risk appetite: A company's approach to assessing and eventually deciding to pursue, retain, take or turn away from risk.

Risk evaluation: Process of comparing the results of risk analysis with risk criteria to determine whether the risks, or their magnitude, are acceptable or tolerable. Risk evaluation assists in the decision about risk treatment.

Risk identification: The process of finding, recognising and describing risks. Risk identification involves the identification of risk sources, events, their causes and their potential consequences. Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholders' needs.

Vulnerability: The degree to which assets and processes are susceptible to, or unable to cope with, adverse effects of climate change. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity.

Willingness to pay: The maximum amount a company is prepared to spend, sacrifice or exchange in order to consume a particular good or service or to avoid something undesired, such as environmental pollution.

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9. APPENDIX 1: CLIMATE CHANGE ASSUMPTIONS

[Adapted from CSIRO 2012]

Rising global temperatures are expected to cause changes in weather patterns and rising sea levels, and may increase the frequency and/or intensity of extreme weather across the globe. The earth has warmed, on average, by about 0.7ºC since 1910. Climate and weather agencies have observed an increase in heatwaves, fewer frosts and a warming of the lower atmosphere and upper ocean. Evidence suggests that much of the warming since 1950 is due to human activities that have increased the concentration greenhouse gases in the atmosphere, known as the enhanced greenhouse effect. Atmospheric carbon dioxide levels have increased by 35 per cent from pre-industrial times, and ice-core records indicate that this current level is higher than at any other time in the past 420 000 years.

In the Australian context, temperatures have increased by almost 0.9ºC over the last hundred years, slightly higher than the global average. Projections for Australia are for a hotter climate and potentially more frequent extreme events. The CSIRO estimates that there may be:

- warming of 0.4–2ºC by 2030 and 1– 6ºC by 2070 compared with 1990 (warming will not be the same everywhere but almost everywhere the climate will be different)
- more hot days over 35ºC (up to three times as many by 2070) and a reduction in the number of frost days
- an increase in the frequency and duration of extreme events such as heavy rains, cyclones, floods and droughts, and
- a rise in sea level rise of 9–88 cm by 2100 compared with 1990.

The effects of climate change can be observed, such as:

- the retreat of some glaciers and sea-ice
- a decline of 10–15 per cent of Arctic sea ice and up to a 40 per cent decrease in its average thickness
- a 40 per cent decline in the snow depth at the start of October in each year in the Australian Alps over the last 40 years
- an average sea level rise of 20 mm per decade over the last 50 years
- changes in mating and migration times of birds
- poleward and altitudinal shifts of plants and animals, particularly in the Alpine zone, and
- an increase in coral bleaching due to increased water temperature.

More broadly, the National Climate Change Adaptation Research Facility (NCCARF) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have identified a range of possible future impacts. The most widely anticipated impacts are:

- an increase in the risk of flooding, salinity and erosion
- greater pressure on drainage systems

- water supply shortages and increased water demand
- increased summer cooling demands
- significant changes in weather paths affecting consumption and transport
- international supply chain effects on impacts and exports
- loss of many important habitats for wildlife
- summer water shortages and low stream flows
- increased risk of subsidence (in areas where subsidence is already a problem)
- increased demand for summer cooling
- buildings becoming uncomfortably hot, and
- health issues.

Mitigation of the likely impacts of climate change is already a priority. It has been established that cutting greenhouse gas emissions now will have a delayed effect on the climate system, and we therefore already face some inevitable changes due to past emissions. Businesses have generally accepted that they will need to adapt plans and behaviours to respond to the challenges of climate change. The impacts of climate change are anticipated to be felt by businesses around the world.

10. APPENDIX 2: CLIMATE CHANGE PROJECTIONS

Australia's vulnerability to climate change – CSIRO projections

Australian average temperatures are projected to rise by 0.6–1.5ºC by 2030 and by 1–5ºC by 2070. The projected warming of 1–2.5ºC by 2070 is for a low-emission scenario (similar to a 500 parts per million CO_2-equivalent path). A high emission scenario (similar to the world's current emissions path) is projected to result in warming of 2.2–5.0ºC by 2070. Warming is projected to be lower near the coast and in Tasmania, and higher in central and north-western Australia. These changes will be felt through an increase in the number of hot days. In Canberra, for example, the present annual average of five days with maximum temperatures above 35ºC may rise to seven to ten days by 2030 and eight to 26 days by 2070.

Projections indicate that by 2030, southern Australia may receive up to 10 per cent less rainfall while northern areas see changes of –10 to +5 per cent. By 2050, southern areas may get up to 20 per cent less rainfall, with changes of –20 to +10 per cent in the north.

Water security problems are projected to intensify by 2030 in southern and eastern Australia as a result of reduced rainfall and higher evaporation. The frequency and extent of droughts are projected to increase over most of southern Australia; however, it is difficult to determine with certainty how much of the drying of the past decade is due to human activities.

The effects of climate change will be superimposed on natural climate variability, leading to changes in the frequency and intensity of extreme weather events. It is very likely that extreme fire weather will occur more often in southern Australia, with longer, more intense fire seasons. Days with heavy rainfall are projected to become more intense over most areas in summer and autumn, and in northern areas in winter and spring.

Tropical cyclone days are projected to increase in the north-east, but decrease in the north-west, with the strongest cyclones becoming more intense. The number of days with large hail is projected to increase along the east coast from Fraser Island to Tasmania and decrease along the southern coast of Australia.

Coastal settlements and infrastructure

By 2050, Australia's growing coastal towns and cities will face heightened risks from sea-level rise and more frequent storms and flooding. Sea-level rise on the east coast may be greater than the global average. In low-lying areas, a mean sea-level rise of 18–79 cm or more could lead to coastal inundation tens or even hundreds of metres inland, depending on local topography.

Risks to major infrastructure are expected to increase. These include failure of flood protection; urban drainage and sewerage; increased storm and fire damage; and power failures during heatwaves.

The natural environment

Significant loss of biodiversity is projected to occur as early as 2020 in some ecologically rich sites. For example, rising sea temperatures are almost certain to increase the frequency and intensity of mass coral bleaching on the Great Barrier Reef. Other sites at risk include the Queensland wet tropics, Kakadu wetlands, south-western Australia, sub-Antarctic islands and the Australian Alps.

Primary industries

Production from primary industries is projected to decline by 2030 over much of southern and eastern Australia due to increased drought, reduced water resources and higher temperatures. Changes in the distribution and abundance of commercial fish species may create new opportunities in some coastal regions, although some very significant risks remain for the fishing industry.

Human health

One of the major health impacts is likely to be an increase in heat-related deaths. Without preventative action, the number of heat-related deaths in people aged above 65 could rise from 1115 per year at present in the major capital cities to between 4300 and 6300 per year by 2050. Some mosquito-borne diseases, such as dengue fever, may move south.

11. APPENDIX 3: CLIMATE COST ESTIMATION

DERIVING A CLIMATE COST ESTIMATE USING DISTRIBUTION ASSUMPTIONS

Risks to infrastructure and other assets may be categorised in terms of:

- *frequency*: the number of loss events over a given period, and
- *severity*: the impact of events in terms of financial loss.

Risks with low frequency and high severity (in practice, the true frequency may be irrelevant), such as extreme weather events, can jeopardise the future of the asset and potentially the solvency of the asset's owner. These are the risks that lie in the upper tail of the loss distribution. Credit risk models are not really designed to account for these risks; however, such risks might be insurable. This avenue of mitigation will be discussed later.

Risks with high frequency and low severity can have a high *expected loss* coupled with a relatively low *unexpected loss*. The range of loss outcomes is therefore relatively narrow. If expected losses for high-frequency, low-severity risks can be absorbed by both engineering design and general provisions made by the business, the implication is that the aggregate credit risk exposure for these risks is relatively low. Unless the expected losses of high-frequency, low-severity risks are extremely high, the total risk is generally lower than that of medium-frequency, medium-severity risks, which generally constitute the focus for asset risks.

Figure 11.1 provides a representation of the relationship between the total loss distribution and its underlying frequency and severity distributions.

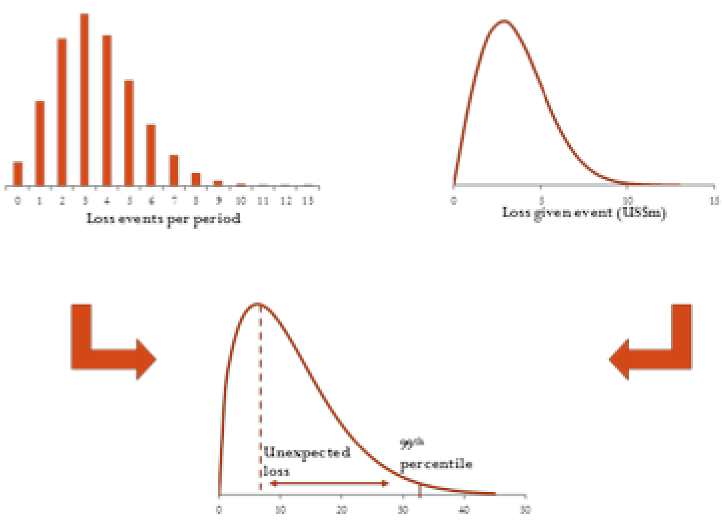

Figure 11.1: Representing a loss model for infrastructure vulnerability

If the basic time period for the frequency density period is one year, the total loss distribution is referred to as the *annual loss distribution*. The representation of the density function for the total loss distribution shows:

- *expected loss*: the mean of the distribution, and
- *unexpected loss (at a 99th percentile)*: unexpected loss at the αth percentile is the difference between the upper αth percentile and the mean of the annual loss distribution.

If the basic time period for the frequency density period is one year, the total loss distribution is referred to as the annual loss distribution. The representation of the density function for the total loss distribution shows expected loss: the mean of the distribution; and unexpected loss (at a 99th percentile): unexpected loss at the αth percentile is the difference between the upper αth percentile and the mean of the annual loss distribution.

Credit and insurable risk models account for all losses, other than highly exceptional losses, that are not already covered by the normal risks inherent in business activity. Defining the term 'highly exceptional' requires the identification of a percentile of the loss distribution above, and such losses are regarded as significantly rare. Scenario analysis and stochastic simulation functions are one way to control for these.

Frequency distribution

Total loss refers to a fixed time period over which the impacts of events on a given asset or set of assets can be observed. The time period is the risk horizon of the loss model. Horizons for credit and insurable risk modelling generally do not exceed a period of one to five years; however, for catastrophe modelling and other risk events – particularly those associated with sequential trends and very large cycles – the risk horizon should be significantly longer and generally match the life of the asset (over 100 years in some cases).

Having defined a risk horizon, the probability of a loss event, which has no time dimension, can be translated into the loss frequency – that is, the number of loss events occurring during the risk horizon. The expected loss frequency λ is the product of the expected total number of events *N* during the horizon and the expected loss probability *p*:

$$\lambda = Np.$$

It can be convenient to forecast λ directly when the total number of events N cannot be quantified and we can only observe loss events, but in most cases the models will be more robust if *N* and *p* are derived separately. If it is possible to specify *N* then a binomial distribution can be used to represent the density of loss frequency. If it is not possible to specify *N* and given that *p* is generally small, a binomial distribution can be approximated by a Poisson distribution which has the single parameter λ as the expected frequency also equal to the variance of the Poisson distribution. The density function is expressed as

$$(n) = \frac{\lambda^n \exp(-\lambda)}{n!} \text{ for } n = 0,1,2, \ldots$$

If the empirical frequency density is not well modelled by a Poisson distribution (e.g. the observed frequency λ does not match the sample variance) a more flexible approach can be to use the negative binomial distribution, whose density function is expressed as

$$h(n) = \binom{\alpha+n-1}{n}\left(\frac{1}{1+\beta}\right)^{\alpha}\left(\frac{\beta}{1+\beta}\right)^{n} \text{ for } n = 0,1,2, \ldots$$

This distribution has a mean of $\alpha\beta$ and a variance of $\alpha\beta^2$. The two parameters that define the negative binomial density function will naturally provide a 'better fit' than the one-parameter Poisson density function. However the choice of functional form should depend on the type and source of data and given the methods used to estimate loss events generally a Poisson distribution will be sufficient.

Severity distribution

Fitting a severity distribution requires some critical assumptions. A number of functional forms are available for replicating the notion of severity using continuous random variables. For instance, the density function of a lognormal distribution for loss severity *l* is expressed as

$$g(l) = \frac{1}{\sqrt{2\pi}\sigma l}\exp\left(-\frac{1}{2}\left(\frac{\ln l-\mu}{\sigma}\right)^2\right) \text{ for } (l > 0).$$

The logarithm of the severity (log severity) is normally distributed with mean μ and variance σ^2. High-frequency risks have severity distributions that can be well-described by lognormal distributions however low-frequency risks generally have distributions that are highly skewed and/or leptokurtic to be adequately described by a lognormal density function.

Another choice is therefore the gamma density which is expressed as

$$g(l) = \frac{l^{\alpha-1}\exp(-l/\beta)}{\beta^{\alpha}\Gamma(\alpha)} \text{ for } (l > 0)$$

where $\Gamma(.)$ denotes the gamma function. A second choice may be the two-parameter hyperbolic density which is expressed as

$$g(l) = \frac{\exp\left(-\alpha\sqrt{\beta^2+l^2}\right)}{2\beta B(\alpha\beta)} \text{ for } (l > 0)$$

where B(.) denotes the first-order Bessel function. Other functions that may be considered include the generalised hyperbolic distribution, Pareto distributions, lognormal mixtures and general mixture distributions. The selection of an appropriate distribution depends on the demands of parameter calibration, data, model parsimony and model homogeneity. Distributions with a greater number of parameters will always obtain a better fit than simpler parameterised distributions however data quality and source should drive selection of an appropriate distribution that parsimoniously caters for extreme values.

Capital at risk

To measure the capital at risk for a given asset one can estimate the expected annual loss, assuming a Poisson frequency distribution for loss frequency, as

$$\text{Capital at Risk} = \lambda \times L$$

where $\lambda = Np$ from above and L is the size of the loss given an event has occurred.

Example

High frequency risks: Assume historical loss events give the following data on the number of loss events per year over the last 24 years.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Loss events	20	13	24	26	25	21	17	13	21	30	16	24	31	20	19	21	14	14	15	18	16	21	22	19

The total number of loss events is 480 so the average number of loss events each year is 20. The yearly frequency distribution is estimated as a Poisson distribution with $\lambda = 20$.

Low frequency risks: Assume historical loss events give the following data on the number of loss events per year over the last 24 years.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Loss events	0	12	3	0	8	4	10	1	0	9	2	10	3	5	3	5	1	7	4	7	10	5	7	4

The total number of loss events is now 120 so the average number of loss events each year is 5. The yearly frequency distribution is therefore estimated as a Poisson distribution with $\lambda = 5$.

The frequency distribution for each function is shown in Figure 11.2.

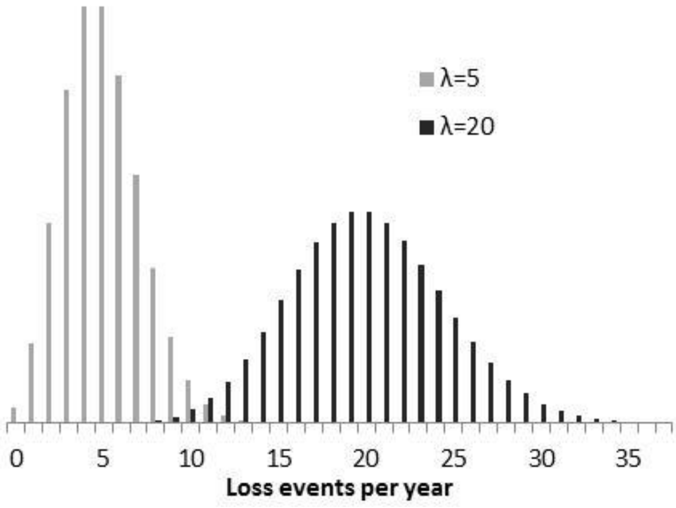

Figure 11.2: Poisson frequency densities for high-frequency and low-frequency risks

Lower frequency risks have a more skewed and leptokurtic frequencies than high density risks. Similar to the loss frequency distributions, we can apply similar calibration techniques to estimate and model the severity of losses.

To combine the likelihood and severity measures we can apply the following analysis. If $S = X_1 + X_2 + \cdots + X_N$ where $X \sim \mathrm{Gamma}(\alpha, \beta)$, $N \sim \mathrm{Poisson}(\lambda)$ where λ varies by *X*, then $S \sim \mathrm{NegBinomial}(r = \alpha, \beta = \theta)$. The combination of a Poisson and Gamma distribution forms a negative binomial distribution governed by parameters *r* and θ, which has a mass function as follows

$$f(k) = \int_0^\infty f_{Poisson(\lambda)}(k) f_{Gamma\left(r,\frac{p}{1-p}\right)}(\lambda) d\lambda,$$

$$= \int_0^\infty \frac{\lambda^k}{k!} e^{-\lambda} . \lambda^{r-1} \frac{e^{-\lambda(1-p)/p}}{(p/1-p)^r \Gamma(r)} d\lambda,$$

$$= \frac{\Gamma(r+k)}{k!\Gamma(r)} (1-p)^r p^k.$$

where the mixing distribution of the Poisson rate is a gamma distribution (a Poisson(λ) distribution, where λ is a random variable distributed according to Gamma(*r, p/(1 − p)*).

This can also be represented as

$$f(k) = \Pr(X = k) = \binom{k+r-1}{k}(1-p)^r p^k \text{ for } k=0,1,2\ldots$$

The negative binomial distribution is also known as the gamma–Poisson (mixture) distribution. Using the transformed parameters, the combined distribution resembles the form in Figure 11.3.

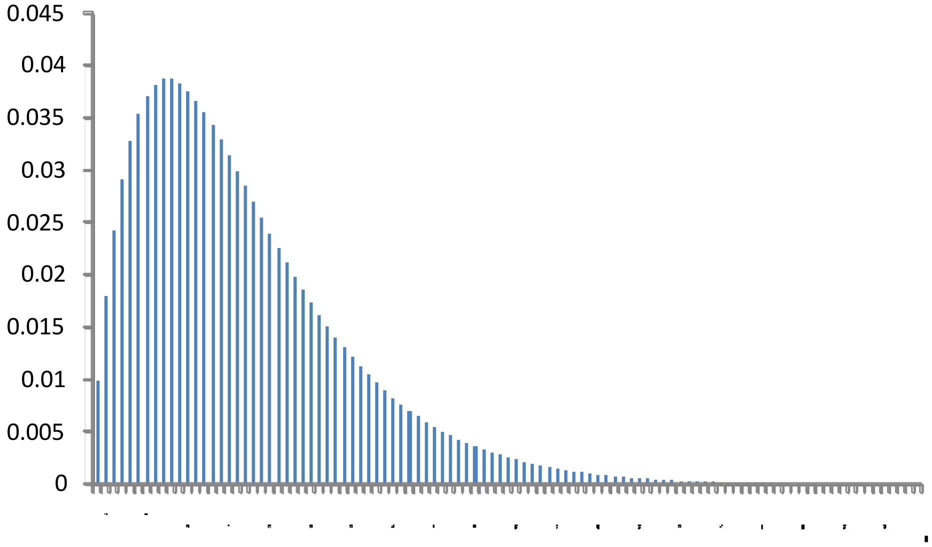

Figure 11.3: Negative binomial distribution

From the resulting distribution in we can obtain the expected loss, the unexpected loss at a given probability and an appreciation for the magnitude of the tail risk.

12. APPENDIX 4: CASE STUDY 1 – INSURANCE AVOIDED FINANCIAL ANALYSIS OF WIND-SPEED DAMAGE TO COASTAL ASSETS

Adapted from The World Bank Group (2010).

Consider a firm focused on the impact of and adaptation to changes in the distribution of tropical storms that strike the firm's coastal assets as a consequence of climate change. This modelling relies upon concepts such as the 'return period' of storms with different impacts.

This analysis serves as a very brief introduction to evaluating extreme events. It focuses on the probability distribution for cyclones and storms characterised by their peak wind speed sustained over land for a period of at least 10 minutes. This is referred to as peak wind speed. The peak wind speed is closely correlated with structural asset damage caused by high winds, storm surges, intense rainfall, and flooding.

Assets (buildings and other infrastructure) that can withstand storms with higher wind speeds typically cost more but the expected annual value of damage will be lower. Regulations in OECD countries generally require firms to use return periods of 50 to 100 years for setting infrastructure and building design standards. But the additional cost may not be warranted in some locations where assets are built with a shorter investment horizon. This example demonstrates the cost-benefit analysis that scales the design standard from a 10-year return period to a 50-year return period for a given asset.

A simple test can be used to consider whether the current design standards for the asset, based on a 10-year period (peak wind speed of around 108kph), are appropriate. This is based on comparing the reduction in the expected annual losses from storm or cyclone damage if a higher design standard were adopted, with the annualised value of the additional investment and operating costs required to construct and maintain assets to the higher standard. We wish to determine the expected annual value of losses from the new design standards based on protecting buildings and other infrastructure from storms with return periods up to 50 years (peak wind speed of 148kph). The model will indicate the expected annual benefit of adopting higher design standards as a percentage of the annualised cost of the capital stock.

Assume that the severity of a severe storm or cyclone is measured by its peak wind speed measured over a period of 10 minutes and that S_t^* denotes the peak wind speed for the worst storm in year *t*. This is closely correlated to the amount of wind damage caused by the storm and provides a reasonable proxy for storm damage caused by rain and flooding since.

Assume that in any year *t* a firm's asset is subject to a series of more or less severe storms $n = 1, \ldots, N_t$ with peak wind speed for each 'event' denoted by S_t^n. The maximum peak wind speed in year *t* is $S_t^* = \max(S_t^n)$. The distribution of S_t^* is characterised by observations over many years. In this example we apply a variant of the generalised extreme value (GEV) to describe the distribution of extreme wind speeds caused by severe storms and cyclones, but the analysis can apply to other natural events such as floods, storm surges and earthquakes. In this case the Gumbel distribution (a two-parameter version of the GEV distribution) will be used because of the limited data available. The two parameters are location α (distribution mode) and scale $\beta > 0.7$.

The probability of a storm with a peak wind speed of $S^* \geq S$ is

$$\mathrm{prob}(S^* \geq S) = 1 - \exp\left[-\exp\left(\frac{-(S-\alpha)}{\beta}\right)\right].$$

The return period of a storm with peak wind speed of *S* is the reciprocal of $\mathrm{prob}(S^* \geq S)$. Thus, the peak wind speed for a storm with a return period of *N* years is

$$S(N) = \alpha - \beta \ln[\ln(N) - \ln(N-1)].$$

An estimate for the financial damage caused by a storm with peak wind speed *S* can be represented by a power function of the positive difference between *S* and the wind speed that the asset is designed to resist without damage S_D

$$D = \gamma[\max(S - S_D, 0)]^{\lambda} \times A$$

where *A* is the asset value and the parameters γ and λ are chosen to represent historical empirical observations of damage caused by storms that have affected similar assets.

If design standards at a coastal location allow assets to resist storms with a 5-year return period $S_D \approx 108\,\mathrm{kph}$, which represents a storm with a 10-year return period. On this basis, the damage parameters are estimated as $\gamma = 1.5$ and $\lambda = 0.004$.

The expected value of the economic damage caused by storms in any year is

$$E(D) = \int_{S_D}^{S_M} p(S)D(S)dS$$

where $p(S)$ is the probability density function for peak wind speed *S*, *D(S)* is the damage function for *S*, and S_M is the maximum wind speed used for the calculation. To conduct the estimate a discrete approximation is used in place of the continuous integral with steps of 1kph. The value of S_M corresponds to the peak wind speed with a return period of 200 years since there is insufficient data to calibrate either the probability distribution or the damage function beyond this level. The impact of a shift in the probability distribution of storms on the expected value of storm damage can be largely offset by changing the design standards that are applied when building new assets.

To illustrate Figure 14 shows that the two forecast curves predict a fall in the return period if it is assumed that both the location and scale parameters of the storm distribution increase by either 10 per cent (climate forecast - low) or 25 per cent (climate forecast - high) due to climate change. These increases correspond to the range for the year 2100.[1] The changes have the effect of reducing the return period of a storm with a peak wind speed of 165kph from 100 years to 55 years for the low scenario and 26 years for the high scenario.

The figure shows the effect of increasing both the location parameter α and the scale parameter β by 15 per cent. It reduces the return period for a storm with a peak wind speed of 165kph from 100 years to 40 years. If there were no change in design standards, then the expected value of annual storm damage would increase from 4.8 per cent of asset value to 11.6 per cent using a base design standard of a one-in-ten-year storm, which corresponds to $S_D \approx 108$kph.

[1] It should be noted that NOAA's National Hurricane Centre in Miami expects increases to only be in the order a few meters a second for the most intense hurricanes.

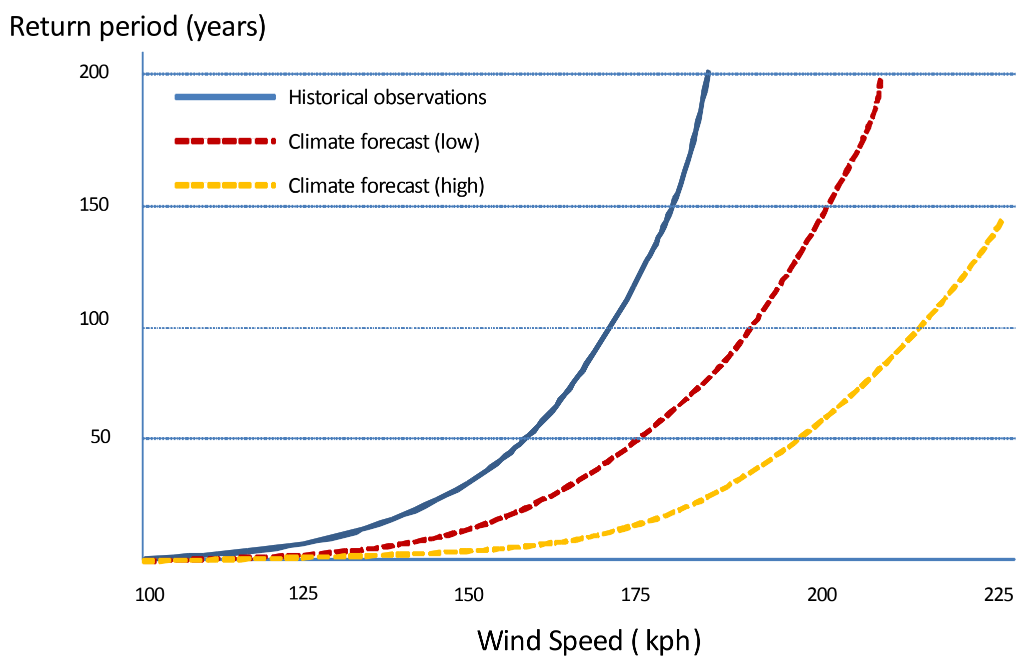

Figure 12.1: Cyclone and severe storm return periods by peak wind speed

If the design standard is adjusted to maintain the one in 10-year storm assumption S_D would increase to 125kph and the expected value of storm damage would be 5.4 per cent of asset value. The specification of the damage function means that the proportional adjustment in S_D required to hold expected damage constant is greater than the proportional change in the parameters of the probability distribution. In this case the design standard S_D would have to be around 128kph to restore the expected damage to 4.8 per cent of asset value.

To protect buildings and other assets from storms with return periods up to 50 years (peak wind speed of 148kph) the model indicates that the expected annual value of storm losses would fall from about 5.5 per cent of asset value to about 0.7 per cent of asset value, saving the asset from damages of around 4.8 per cent. In the long run, the cost of adopting higher design standards, calculated using the methods described above, will be 2–3 per cent of the annualised cost of the capital stock (assets).

There are some conditions attached to this analysis:

- There is an important constraint on any detailed examination of the impact of climate change or the costs of adaptation. A key feature of climate change is the possibility that the distribution of extreme weather events - not only severe storms and cyclones but also El Niño-Southern Oscillation (ENSO) droughts - will shift to more frequent or severe cyclones making landfall. Unfortunately the empirical evidence on how the distribution might shift over time for different climate scenarios is very limited (International Workshop on Tropical Cyclones (IWTC), 2006).
- These estimates only apply to damage that can be prevented by implementing appropriate adaptive capacity (design standards) to a particular asset. Potential

damage broader assets such as agricultural plantations may increase if peak wind speeds with a 10- or 50-year return period increase.

- Existing assets built to older design standards will suffer more damage than new assets. In some cases their remaining economic life may be relatively short so the increased risk of wind speed damage may be relatively small. These calculations assume that a trade-off exists between the options of accelerated depreciation (early replacement) of long-lived assets that do not meet the new design standards or incurring higher costs of maintenance and repairs as a consequence of higher peak wind speeds.
- In some cases buildings and infrastructure assets may actually be in well-protected locations and the assumptions are too crude to be relevant. In terms of adaptive capacity it is important to not only focus on resistance to peak wind damage but to also ensure that planning and development accounts for the impact of changes in future frequency and severity.

This is a relatively simple example adapted for a single asset. Many larger firms are likely to have a range of assets that are exposed to climate change which marginally complicates the analysis. Different distributions can be used to model different loss exposures. Nevertheless the basic principles remain and damage estimates can be obtained and compared with insurance costs and other forms of loss mitigation to yield the most cost effective outcome.

Disclosure, risk management and governance

As discussed above the asset construction cost will rise by 2–3 per cent on an annualised basis to improve the protection standard from a 10-year return period to a 50-year return period. Given that the 2–3 per cent annualised asset cost increase is derived with a relatively good level of accuracy, the cost increase may escape the materiality requirement under AASB 1013, since it does not exceed the 5 per cent threshold. If confidence of the 2–3 per cent estimate is low, it may be preferable to disclose and appropriately account for the additional cost on the firm's balance sheet.

If annual insurance premiums avoided decline by 2–3 per cent or more, it could be argued that the new design standard does not represent idle capital and thus the asset fair value be represented by its book value (cost of construction). If no partial relief is obtained from a commensurate insurance discount (because the insurer's pool of assets are dominated by older design standards), the balance sheet may need to annually provision the asset by 2–3 per cent and provide sufficient reasoning and value assessments in accordance with IAS 37.

The immediate effect will be a reduction in balance sheet equity which may have implications for debt covenants and other performance metrics and ratios. Professional judgement is clearly needed to define what to disclose and how it is reported in the balance sheet, income statement and equity statement. The above discussion serves as a guideline for the minimum requirements.

The risk likelihood and the impact rating under the risk assessment matrix should also be defined to classify the change in the severity and likelihood combination resulting from strengthening the design standards.

Likelihood / Impact	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Enhancing design standards from that equivalent to a 10-year return period to a 50-year return period may decrease the likelihood while simultaneously maintaining or even decreasing the impact level. The risk rating may therefore decline from a value of 20 (catastrophic – likely) to a value of 12 (major - possible) or a value of 9 (moderate – possible). This transforms the asset risk exposure from being 'catastrophic' to 'high risk' or even 'moderate risk' if the risk reduction is clearly articulated through comparative metrics.

Ongoing governance of this process is also critical to the management of the asset over its life. At a minimum, a listed firm needs to comply with ASX Corporate Governance Principle 5 to make timely and balanced disclosure statements concerning the new design standards being applied to its highly exposed assets not only through its annual report and investor updates, but also in accordance with the ASX continuous disclosure requirements. Also relevant to this issue, a listed firm must comply with ASX Corporate Governance Principle 7 to recognise and manage the risk, which has been briefly discussed above.

The 'if not, why not?' disclosure principle is important for this case study, especially if a 2–3 per cent annual increase in asset cost is deemed immaterial by executive management who choose not to report the cost differential but the Board deems it necessary to do so. If a listed entities chooses not to comply with the above 'recommendations' under the ASX Corporate Governance Guidelines, it is still necessary for the company disclose the reasons for non-compliance in the company's annual report. Other disclosures that can be considered here include appropriate ASX announcements and interim investor disclosure statements.

13. APPENDIX 5: CASE STUDY 2 – COST-BENEFIT ANALYSIS OF A ROAD UPGRADE, NEW SOUTH WALES

This case study has been adapted from an Options and Route Selection Study, Concept Development and Environmental Assessment (EA) for upgrading the Princes Highway between Gerringong and Bomaderry, developed by Maunsell AECOM for the New South Wales Roads and Traffic Authority (RTA) in December 2006.

Road infrastructure is designed with the expectation that the road will have a life of around 100 years. However, specific elements within the asset will have design lives that differ from the underlying asset's life. In Australia, the growth of urbanisation in coastal and regional areas naturally leads to the development of road infrastructure in zones that are potentially vulnerable to the effects of climate change. In particular, the utilisation of coastal zones has greatly increased, which may exacerbate the impacts of climate change felt by communities in these areas (Nichols et al. 2007).

Adaptation measures for new assets should involve planning to reduce vulnerability to climate change and associated consequences, taking into account the potential for effects such as increased frequency and duration of rainfall and storms, sea level rise, changes in water content of soils and changes in wind speed, among others. Augmenting climate change vulnerability is the risk posed by extreme weather events as well as the more gradual anticipated effects of climate change (Wilbanks et al. 2007). Low-lying areas will be exposed to increasing risks, including erosion over the coming decades due to climate change and sea level rise.

Nichols et al. (2007) recommend that adaptation measures should be indispensable for coastal roads in the medium and long term, since sea level rise is considered unavoidable on those time scales due to the significant inertia of the climatic systems. The vulnerability of communities and companies to climate change is generally greater in high-risk locations such as coastal and riverine areas (Wilbanks et al. 2007). It is expected that adaptation costs for vulnerable coasts will be less than the aggregate cost of inaction (Nichols et al. 2007), although the effects may be more diversified and intangible.

The approach adopted by Maunsell AECOM for the NSW RTA employed an aggregate cost measure estimated using scenario analysis. Seven options were devised for further evaluation using a structured value management study and technical assessment of the risks to the design features of a coastal road.

Most design cost assumptions are assumed to be more economically efficient when adaptive measures are incorporated at the time of construction or in research pre-construction, rather than as a post-construction solution. This has been demonstrated at a macro level, and this assumption must continue to be justified using project-level analysis.

Cost considerations

An economic appraisal of the route options for the study was conducted. Economic appraisals are designed to analyse the costs and benefits of road routes to compare viability and effectiveness of options. The economic appraisal must consider *all* costs and benefits resulting from the project, not just those that impact on the firm. To compare costs and benefits that occur in different years on equal basis, yearly cash flow values are discounted to a common year and the net present value is used as the main decision variable for choosing a given option. The economic appraisal measures the costs and benefits relative to a base case (often referenced as maintaining the asset in its current form).

The CBA uses financial techniques to quantify the impacts of climate change on infrastructure and to assess the value of adaptation measures. It necessarily features engineering project management and cost accounting. Various issues arise in adapting the standard engineering appraisal process to cater for climate change and include the following.

- *Incorporating risk and uncertainty.* There are various climate change scenarios that can be forecast, and such scenarios will contain many dynamic and interrelated mechanisms. Predicting both the scale and the timing of expected climate change impacts is challenging. To quantify the effect of uncertainty on cost estimates we assign probabilities to outcomes and calculate expected values for the impact of a specific event.
- *Selecting an appropriate timeframe.* Most appraisals cover a 30- to 50-year time horizon, but the present value of estimates beyond 50 years is negligible. This analysis uses a 100-year time horizon, which represents the design life of the upgrade, and corresponding adjustments to discount factors have been considered.
- *Selecting an appropriate discount rate.* Discounting is the textbook approach for comparing costs and benefits that occur at different times. For this project, a discount rate of 7 per cent was used while sensitivity analyses were conducted using rates of 4 and 10 per cent. This rate is assumed to reflect the funding costs and risk premium attached to road projects while catering for opportunity costs of alternative projects.
- *Factoring in non-quantifiable costs and benefits.* There are often significant costs and benefits that cannot be quantified which are then excluded from the appraisal. For example, an increase in extreme weather events is likely to have an impact on the number of vehicle accidents, however, little is known about the relationship between extreme weather events and accident rates. Allowing CBA to be more of an iterative process can cater for this improvement of knowledge.

Methodology

The general approach taken is to:

- quantify the costs
- update the financial model, and
- compare the costs of climate change with implementing adaptation measures.

The expected cost of the projected increase in the intensity of design rainfall events has been estimated using the following equation.

$$E[cost] = \sum_{t=0}^{100} \frac{TC \times Pr(event)_y}{(1+d)^t}$$

where TC is total cost caused by an event, $Pr(event)_y$ is the probability of an event in year y and d is the discount rate. The expected cost is therefore equivalent to the sum of the costs caused by climate change events over the lifetime of the infrastructure asset.

The expected cost in each year was calculated over a 100-year period and discounted to the present value. The financial model was estimated out to 2045. We assumed annual growth rate in traffic of 0.5 per cent beyond 2045. The financial assessment considers the effects of increased intensity of rainfall events limited to bridges, drainage infrastructure and pavement since other infrastructure elements and climate variables have insignificant or no impact on the cost differences between options. We assume that materials will be selected appropriately to cope with changed conditions and that the effects on footing stability will be avoided by standard engineering techniques. Increased extreme winds, average rainfall and average temperatures will not have impacts significant enough to result in material variations between options. The impacts to infrastructure identified above will also increase the frequency of road or lane closure. These areas were explicitly considered in the economic assessment.

Table 13.1: Special Report on Emission Scenarios (SRES)

<table>
<tr><th>SRES Scenario</th><th colspan="2">Scenario Description</th></tr>
<tr><td>A1F1</td><td rowspan="3">Rapid economic growth, a global population that peaks mid-twenty-first century and rapid introduction of new technologies</td><td>Intensive reliance on fossil fuel energy resources</td></tr>
<tr><td>A1T</td><td>Increased reliance on non-fossil fuel energy resources</td></tr>
<tr><td>A1B</td><td>Balanced across all energy sources</td></tr>
<tr><td>A2</td><td colspan="2">Very heterogeneous world with high population growth, slow economic development and slow technological change</td></tr>
<tr><td>B1</td><td colspan="2">Convergent world, same global population as A1 but with more rapid changes in economic structures toward a service and information economy</td></tr>
<tr><td>B2</td><td colspan="2">Intermediate population and economic growth, emphasis on development of solutions to economic, social and environmental sustainability</td></tr>
</table>

Source: Adapted from Nakićenović and Swart (2000).

Climate change scenarios

The study chooses two climate change scenarios developed by the IPCC (Nakićenović & Swart, 2000) to represent alternatives to the base case, both of which define parameter estimates of climate change impacts. The IPCC developed scenarios in 1990, 1992 and 2000, and released a Special Report on Emission Scenarios (SRES). The scenarios are divided into four families: A1, A2, B1 and B2. A description of each scenario is provided in Table 13.1 and the rainfall implications presented at Table 13.2.

The two scenarios used in this analysis are broad estimates and represent potential outcomes that consider both economic growth and population growth patterns. The A1 storyline describes a state of rapid economic growth in which the population peaks in 2050 and declines thereafter, with the rapid introduction of new and more efficient technologies. Scenario A1 has three subgroups: fossil fuel intensive (A1FI), non-fossil fuel using (A1T) and balanced across all energy sources (A1B).

The two scenarios used in this analysis are as follows:

- *Scenario 1:* Moderate climate change scenario using the so-called A1FI model from 2030 and the A1B model from 2070.
- *Scenario 2:* High climate change scenario using the A1FI model from both 2030 and 2070.

Table 13.2: Probabilities of a rainfall event of the present 100-year ARI intensity occurring per year

	2030		2070	
Scenario	**ARI**	**Prob**	**ARI**	**Prob**
Bridges				
Present climate	100-year	0.01	100-year	0.01
Scenario 1	90-year	0.011	40-year	0.025
Scenario 2	60-year	0.018	35-year	0.03
Drainage				
Present climate	50-year	0.02	50-year	0.02
Scenario 1	45-year	0.022	24-year	0.042
Scenario 2	40-year	0.03	18-year	0.055

Table 13.3 describes the parameter values for expected climate change impacts on road infrastructure under each scenario. The variables identified as being critical to the impact on road infrastructure were average annual rainfall and extreme daily rainfall, sea level rise, average maximum temperature and extreme daily temperatures, extreme wind-speed and high bushfire danger days.

Table 13.3: Climate change variables used for modelling climate change impact on road infrastructure

Year	2030	2070	2070	
IPCC Emissions Scenario	A1FI	A1B	A1FI	Source
Average annual rainfall	+3% or -8%	+6% or -18%	+8% or -25%	CAPSI Database, 24/01/2008
Intensity of design rainfall event (1/100 yr return interval)	+2%	+15%	–	Abbs et al, CSIRO 2006.
Global average sea level rise, including isostatic rebound	+0.16m	+0.23m	+0.27m	IPCC, 2007
Additional sea level rise on Australian east coast due to thermal expansion	+0.04m	+0.08m	+0.12m	McInnes et al., CSIRO 2007
Additional sea level rise due to increased polar ice sheet melting	0.0m	+0.1m	+0.1m	Macadam et al., CSIRO 2007
Total increase in sea level	+0.20m	+0.41m	+0.49m	Sources as above
Increase in 1/100 yr storm surge sea level height	0	+4%	+4%	Macadam et al., CSIRO 2007
Change in mean temperature	+1°C	+2°C	+3°C	CAPSI Database, 24/01/2008
Days over 35°C per year.	+5	+6	+10	CAPSI Database, 24/01/2008
Increase in annual solar radiation intensity	+/-1%	+/-1%	+/-1%	Holper et al., CSIRO 2007
Increase in velocity of 1/100 yr wind event (no. of days)	+5	+9	+9	Macadam et al., CSIRO 2007
Number of extreme forest fire danger days per year (FFDI > 50)	+2	+2	+6	Hennessy et al., CSIRO 2005

Source: Maunsell (2008).

A range of probability distributions are available to represent future states including linear, exponential and step changes. The study uses an exponential distribution coupled with sensitivity analysis, as well as linear and step change probability distributions to ensure consistency. The recurrent interval (ARI) was exponentially interpolated and then inversed to get annual probabilities of a design rainfall event occurring.

Rainfall

Climate change is projected to increase the intensity of extreme rainfall in the study area above the present design standards set out in Australian Rainfall and Runoff (Institution of Engineers, Australia, 1987), which does not allow for climate change because it is based on historical rainfall data. Consequently the probability of occurrence of the 50 and 100 year ARI design rainfall events that are used by the RTA for bridges and culverts respectively will increase.

The following climate change impacts are quantified:

- a requirement to upgrade bridges to meet current design standards under more intense rainfall events (Scenario 1)
- degradation of concrete caused by carbonation when poorly cured or when cover is insufficient
- a requirement to upgrade drainage infrastructure to prevent unacceptable build-up of flood water upstream of the road under more intense rainfall events (Scenario 1)
- damage to footings from changes in chemical composition of dryer soil, or movement due to more extremes in wet and dry conditions
- landslides or damage to natural or engineered slopes
- increased frequency of road or lane closure due to infrastructure damage and bushfires
- sea level rise – this will affect the project only through its compounding effect on flooding
- accelerated degradation of bituminous pavements and road formation (road substructure).

Different methodologies were used to assess the costs for each impact. The methodologies used are discussed below:

- *Upgrading bridges*. It was assumed that if the intensity of the 100-year ARI design rainfall event increases, bridges will not be significantly damaged but would be potentially submerged for a period of time and need cleaning up as well as minor repairs (e.g. repairs to abutments and scour protection). The study proposed a cost of $35 000 per bridge for this process.
- *Damage to pavement*. Costs of pavement maintenance and rehabilitation will increase by $700 (undiscounted) per road kilometre over a 20-year period. This equates to $761 per road kilometre over a 20-year period, which is the equivalent of an additional $38 per road kilometre per year.
- *Upgrading drainage infrastructure*. Design standards currently ensure that there is sufficient drainage infrastructure to prevent damage by flooding of surrounding property. The capacity of the drainage infrastructure systems is not sufficient for more intense 50-year ARI rainfall events projected under the climate change scenarios. The cost of upgrading drainage infrastructure under traffic was derived using a rate for working under traffic from the existing cost estimate for the project. The cost of adding drainage infrastructure for each option varied between $14.9 million and $19.1 million.

- *Road closure*. It was assumed that following an extreme rainfall event that exceeds the intensity of the current design standard the road would be closed for four days at the time of a flood. This four-day period includes the initial flooding period as well as time for emergency repairs. The daily costs of road closure are calculated by adding the costs of additional travel time and the additional vehicle operating costs. Estimates for the total cost of road closures were expected to be around $93 300 per day on the existing road and $125 100 per day on the upgraded road.
- *Lane closure*. It was assumed that if bridges and drainage infrastructure were required to be upgraded due to current design rainfall events becoming more intense due to climate change, it would be undertaken in a scheduled program of work that would not require full road closure to minimise disruption. The work would need to be managed through lane closures, reducing the four lanes of traffic to two. This would result in reduced speed limits along the route and it has been assumed that the resulting average speed would be 60 kilometres per hour. The methodology for calculating the cost of lane closures is similar to the methodology for calculating the cost of road closures. The difference is that for lane closure there is no alternative route, just a lower speed on the existing route, which increases the journey time and changes the vehicle operating costs. The estimated total travel time cost was $16 000 per day of lane closure in the base case and $38 400 per day of lane closure with the other options. The cost of lane closure is higher under the new road, as it is a faster road, where reduced speed limits have larger impacts. Vehicle operating costs were estimated using the same parameters for road closures. As the upgrade will be slower vehicle operating costs are slightly reduced. The total costs of lane closure due to adding drainage infrastructure were calculated by adding the costs of additional travel time and the vehicle operating costs. The total cost of road closure was estimated to be $14 000 per day on the existing road and $34 200 per day on the new road.
- *Road and lane closure for bridges*. The total cost of closure was obtained by multiplying the above results by the duration of the closure. It was assumed that all bridges would require clean-up works and some repair works (abutments and scour protection) after a flood event exceeding the current 100-year ARI flood. It is estimated that the road would be closed for four days at the time of a flood and, based on previous experience, clean-up and minor works as required at bridges would require up to six months (180 days) of lane closure.

The probability of a rainfall event occurring in a particular year was multiplied by the total cost caused by the event. The total cost is the upgrade cost plus road closure or lane closure costs. This gives an expected cost each year, over a 100-year timeframe, for the base case and the options. This was discounted by the cost of capital to give a present value of the cost of more intense design rainfall events occurring under each of the options.

Adaptation measures and costs

Using the expected cost of the impact of an increase in design rainfall event intensity on bridges and drainage infrastructure, the value for money of designing the highway upgrade for future more intense rainfall events can be compared with the value for money of designing the upgrade to meet the current rainfall events and upgrading the highway in the future when design rainfall events become more intense. Table 13.4 compares the cost of adaptation against the expected costs under the current climate and a moderate climate change scenario. When assessing if adaptation measures provide value for money, a lower discount rate representing the risk free rate can be more suitable. The adaptation cost is the additional construction cost of designing the infrastructure now to withstand the future impacts of climate change.

Table 13.4: Cost of adaptation against the expected costs under the current climate and moderate climate change scenarios for a single road route option

	Base case	Scenario 1	Scenario 2*	Remarks
Bridges	9	16	16	Number
Bridges	$315,000	$560,000	$760,000	Cost
Pavement	31.4	30.5	30.5	Km
Pavement incremental cost	$1,200	$1,160	$1,160	Per annum
Drainage costs	$14.9m	$15.6m	$15.6m	
Added travel time	$58,400	$80,800	$100,000	Road closures from rain
Added vehicle costs	$34,900	$44,300	$55,000	Road closures from rain
Lane closure	$16,000	$38,400	$48,400	Road closure (drainage)
Bridge and drain upgrades	$2.9m	$6.7m	$8.5m	Road closures
Pavement maintenance	$12,100	$11,800	$14,000	PV at 7%
Totals				
Pavements	$0.0m	$1.1m	$2.2m	PV at 7%
Bridges	$3.2m	$6.2m	$10.0m	PV at 7%
Drainage	$25.1m	$41.1m	$55.1m	PV at 7%

* These costs are assumed.

Using these results, we can quantify the financial impact of climate change on available road route options to assess whether climate change is a route differentiator and if adaptation measures at the design stage provides value for money.

The analysis highlighted the following:

- All road route options have a higher expected cost than the existing road, as the upgrade will be a faster road so any disruptions will have bigger impacts.
- The biggest impact from climate change is caused by the requirement to upgrade drainage infrastructure to prevent unacceptable build-up of floodwater upstream of the road under more intense rainfall events.
- The cost of climate change can change the economic ranking of route options.
- It is worthwhile adapting the design of drainage infrastructure for projected future, more intense-design rainfall events at the construction stage under all of the shortlisted options.

- Whether it is worthwhile adapting the design of bridges for projected future rainfall intensity at the construction stage depends on which of the road route options is preferred and which climate scenario is used.
- Expenditure required to adapt the pavement *does not* provide value for money and regular pavement maintenance is a more cost effective adaptation strategy.

Disclosure, risk management and governance

Asset construction cost will rise by $41–55 million to improve the protection standard for a road upgrade from increased rainfall and flooding. Assuming a total base-case project cost of $310 million, the additional cost represents a significant increase in expenditure to allow minimum road closures over the next 70–100 years. Given that the increase has been estimated with a relatively good level of accuracy, the cost increase is clearly material under AASB 1013 since it exceeds the 10 per cent threshold. If this adaptive capacity were implemented, it would be necessary to disclose and appropriately account for the additional cost on the firm's balance sheet.

From an accounting perspective, the asset 'value' is $310 million while its construction cost will be at least $355 million if the actions in Scenario 1 are selected for the upgrade. The new build standards represent idle capital, and thus the asset fair value represented by its book value will need to provision for the adaptive capacity (additional cost of construction) in accordance with AASB 137.

The immediate effect may be a significant reduction in balance sheet equity, which may have implications for debt covenants and other performance metrics and ratios. This may be critical when employing project financing or other debt-intensive mechanism to fund the upgrade.

The risk likelihood and the impact rating under the risk assessment matrix should also be defined to classify the change in the severity and likelihood combination resulting from strengthening the design standards.

Enhancing the design is aimed at decreasing the likelihood of impacts while simultaneously maintaining or even decreasing the impact level, as in the previous case study. In this example, the risk rating may decline from a value of 12 (major – possible) to a value of 6 (moderate – unlikely). This is not sufficient to transform the asset risk exposure from 'high risk', but it does reduce the exposure.

Likelihood / Impact	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Ongoing governance of this process is critical to the management of the asset over its 100-year lifespan. Compliance with ASX Corporate Governance Principle 5 to make timely and balanced disclosure statements concerning the new design standards being applied as well as ASX Corporate Governance Principle 7 to recognise and manage the risk are the key governance and disclosure items in this example.

An unlisted, government, private or other entity can choose their own governance and risk-management approach, but the methods used here represents best practice and are not overly complex or costly.

14. APPENDIX 6: CASE STUDY 3 – COST EQUIVALENT ANALYSIS (CEA) OF WATER SECURITY OPTIONS FOR AN AGRICULTURAL FIRM

Water resources are vital for operations in remote areas. For agricultural firm operations, the aim of an adaptation project is not usually to identify adaptation options that might yield higher adaptation benefits, but to identify options that ensure sustainable water quality and quantity in vulnerable locations.

An agricultural firm might identify the following adaptation options to secure water supply in a remote location:

- desalinisation systems
- upgrading existing mains systems
- rainwater harvesting
- using brackish or salt-contaminated water for appropriate irrigation systems
- watershed protection measures, including contour farming, planting trees on hillsides, planting fruit trees within crop plots to provide shade for the plants or reinforcing salt tolerant vegetation buffers
- improving sanitary conditions in remote communities by installing compost toilets that reduce water consumption.

A simple analysis of the choice of the three feasible water solutions to produce the most volume of uncontaminated water for irrigation in a semi-arid crop area is provided in Table 14.1.

Table 14.1: Choosing between three feasible water solutions to produce the most volume of uncontaminated water for an irrigation project

	Desalination	Rain harvest	System upgrade
1. Annualised cost	$300,000	$200,000	$160,000
2. Number of water tests p.a.	2,000	2,500	2,100
3. Volume free from contamination (water tests x 10 in kilo-litres H_2O)	20,000	25,000	21,000
4. Number of interventions p.a.	500	350	200
5. Volume free from contamination (intervention x 50 in kilo-litres H_2O)	25,000	17,500	10,000
6. Total volume free from contamination	45,000	42,500	31,000
7. Cost per kl of H_2O volume	$6.67	$4.71	$4.16

As shown, the most cost-effective solution is not necessarily the most effective. Rainwater harvesting is more cost effective than desalination, but desalination will produce a greater volume of water free of contamination. The annualised cost of desalination exceeds rainwater harvesting by $100 000 per annum and generates 2500 kl of uncontaminated water. The cost of the extra volume of uncontaminated water is therefore $40 per kilolitre. If rainwater harvesting can be expanded, then it will generate the most volume of uncontaminated water for a given budget. However, if there is a constraint on expanding one of the components in the rainwater harvesting process, or if reliable volumes are critical, then a decision should be taken as to whether the extra volume of uncontaminated water is worth the cost of achieving it.

Because of the uncertainty involved in forecasting demand and the complex relationships between output cost and price, CEA should be more of an iterative process. Any analysis should also account for the value of flexibility in adaptation options.

From the above CEA, a firm would select rainwater harvesting as its preferred adaptation option. It was deemed to be the most cost-effective option (i.e. yielding the desired quantity and quality of water at the least cost). In addition, rainwater harvesting may also turn out to be most practical, easily implemented and sustainable measure, so long as a reliable steady supply of water is not a critical need for the project.

Disclosure, risk management and governance

This project endorses the construction of a replacement asset to improve water security at low cost. Given that the asset cost increase is derived with some degree of confidence the cost increase is unlikely to escape the materiality threshold under AASB 1013. The replacement assets associated with rainwater harvesting must be recorded at book value on the balance sheet while the existing asset must be written down if decommissioned in situ in accordance with IAS 37 or treated as an asset sale under the usual provisions if sold. These are the minimum requirements.

The immediate effect may be a reduction in balance sheet equity that could have implications for debt covenants and other performance metrics and ratios.

The risk likelihood and the impact rating under the risk assessment matrix should also be defined to classify the change in the severity and likelihood combination resulting from replacing the asset.

Likelihood / Impact	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Switching to rainwater harvesting may increase the likelihood of supply shortages while simultaneously decreasing the impact level. The risk rating may therefore decline from a value of 12 (major – possible) to a value of 8 (minor – likely). Even though the likelihood has increased, the asset replacement transforms the risk exposure from being 'high risk' to 'moderate risk'. Professional judgement is required to manage this change.

Ongoing governance of this process is also critical to the management of the asset over its life. At a minimum, a listed firm needs to comply with the ASX Corporate Governance Principle 5 to make timely and balanced disclosure statements concerning the new asset not only through its annual report and investor updates, but also in accordance with the ASX continuous disclosure requirements. Also relevant to this issue, a listed firm must comply with ASX Corporate Governance Principle 6 to respect the rights of shareholders and Principle 7 to recognise and manage the risk, which has been discussed briefly above.

If a listed entity chooses not to comply with the above 'recommendations' under the ASX Corporate Governance Guidelines, it is still necessary for the company to disclose the reasons for non-compliance in the company's annual report (the 'if not, why not?' disclosure rule). Other disclosures that can be considered here include appropriate ASX announcements and interim investor disclosure statements. An unlisted government, private or other entity can choose their own governance and risk-management approach, but the methods used here represent best practice and are not overly complex or costly.

15. APPENDIX 7: CASE STUDY 4 – MULTI-CRITERIA ANALYSIS (MCA) OF A FIRM WITH DIVERSIFIED OPERATIONS FACING MULTIPLE THREATS

A firm assessed its vulnerability to climate change and possible adaptation options during the development of strategy and long-term planning. A task force consisting of representatives from the firm's divisions included agriculture, forestry, infrastructure, health and water resources identified and ranked possible priority adaptation projects using MCA. Initially, the firm identified the most likely and severe climate related hazards and detected high-risk groups:

- hazards, such as increased floods, landslides and flash-floods
- most vulnerable operations, such as agriculture and hydropower, and
- most vulnerable externally controlled supply chains.

A number of adaptation options were identified, based on the framework of climate-induced hazards. The firm adapted the following four criteria to create a short list of six priority adaptation options:

- convincing threats of climate and climate change/level or degree of adverse effects of climate change
- demonstrates fiscal responsibility (or cost effectiveness)
- level of risk (by not choosing to adapt)
- complements other firm goals, such as enhancing adaptive capacity and environmental standards.

The six options (see Table 15.1) were ranked based on the following four criteria (the first three constitute benefits and the last costs):

- arable land with associated water supply (for agriculture/livestock) and productive forest (for forestry/forest products collection) saved by the intervention
- essential infrastructure saved by the intervention such as existing and projected hydropower plants, communication systems and industrial complexes
- estimated project cost
- external supply chains that the firm relies on for continued operations.

Initially, the benefits of the different adaptation projects were scored to be able to rank them. Sub-teams were assigned and each consistently ranked the projects on a scale from 1 to 5 (5 represents the greatest achievable benefit). The rankings from the sub-teams were then used to identify mean scores. The scores were standardised on a scale from 0 to 1 to proceed with the analysis, and to allow costs to be included. The last step of the MCA was assigning weights to different benefits.

The firm then weighed the criteria differently according to its needs and the geographical scale of its operations (projects with national coverage were given greater weight than projects with local impact only).

Table 15.1 shows the standardised scores, the general and local weighing and the final ranks of the potential sources.

Table 15.1: Results of the ranking of prioritised adaptation options for MCA

Criteria	**Cost**	**Arable land & H_2O saved**	**Infra-structure saved**	**Supply chains saved**	**Weight summary**	**Initial rank**	**National (N) Regional (R) Local (L)**	**Adj. rank**
Weights / **Options**	0.20	0.33	0.27	0.2			N +15% R +/-0% L -15%	
1) Disaster control/ business continuity mgt	0.71	1.00	0.75	0.75	0.825	1	N 0.948	1
2) Landslide management	0.56	0.75	0.50	0.75	0.645	3	L 0.548	5
3) Rainwater harvesting	0.81	0.75	0.75	0.50	0.712	2	R 0.712	2
4) Weather and shipping forecasts	0.26	1.00	0.25	0.50	0.549	6	N 0.632	3
5) Forest fire mitigation	0.85	0.50	1.00	0.00	0.605	5	R 0.605	4
6) Flood protection	0.93	0.75	0.50	0.25	0.618	4	L 0.526	6

As shown, each adaptation option is initially ranked, which is then adjusted for the breadth of significance.

Disclosure, risk management and governance

Annualised asset cost increases are derived using broad estimates only with a poor degree of confidence. Hence cost increases may or may not escape the materiality requirement under AASB 1013. Since the confidence of the cost estimates is low, it may be preferable to disclose and appropriately account for the additional cost on the firm's balance sheet. Significant notes on assumptions used, the modelling approach adopted and any other factors are appropriate.

If annual insurance premiums avoided decline by an amount equal to the capital outlay for the adaptive measures, it could be argued that the new design standard does not represent idle capital, and thus the asset fair value be represented by its book value (cost of construction). If no partial relief is obtained from an insurance discount or other subsidy, the balance sheet may need to provision the asset by an appropriate amount and provide sufficient reasoning and value assessments in the notes to the financial report in accordance with IAS 37. Professional judgement is clearly needed to define what to disclose and how it is reported in the balance sheet, income statement and equity statement. The immediate effect will be a reduction in balance sheet equity which may have implications for debt covenants and other performance metrics and ratios.

The risk likelihood and the impact rating under the risk assessment matrix should also be defined to classify all potential adaptation options. Cost, land/water saved and protections around both infrastructure and supply chains all contribute to the selection of an adaptation action (or at least a ranking of the actions). It is likely that these activities will decrease both the likelihood and impact levels of climate change events. The risk ratings are therefore likely to decline but to properly employ the risk reduction matrix, the outcomes of each action need to be clearly articulated through comparative metrics.

Likelihood / Impact	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Ongoing governance of this process is also critical to the management of the selected actions over their lives. At a minimum, a listed firm needs to comply with the ASX Corporate Governance Principle 5 to make timely and balanced disclosure statements concerning the activities not only through its annual report and investor updates, but also in accordance with the ASX continuous disclosure requirements. Also relevant to this issue, a listed firm must comply with ASX Corporate Governance Principle 6 to respect the rights of shareholders and Principle 7 to recognise and manage the risk, which has been briefly discussed above.

If a listed entity chooses not to comply with the above 'recommendations' under the ASX Corporate Governance Guidelines, it is still necessary for the company to disclose the reasons for non-compliance in the company's annual report (the 'if not, why not?' disclosure rule). Other disclosures that can be considered here include appropriate ASX announcements and interim investor disclosure statements. An unlisted, government, private or other entity can choose their own governance and risk management approach but the methods used here represents best practice and are not overly complex or costly.

16. APPENDIX 8: ECONOMIC ASSESSMENT OF ADAPTATION

Estimating the costs of climate change impacts is an important first step in the economic evaluation of adaptation options for businesses. There is a need for organisations, investors, regulators and other stakeholders to analyse the specific costs and benefits of climate change impacts that can then be compared with the potential costs of adaptation. These are important for assessing potential risks and making the case for adaptation plans. Assessing the economic impacts of climate change is a challenging process. Nevertheless, companies are burdened with attributing both qualitative and quantitative estimates of costs associated with adaptation measures, and must therefore make allowance for managing these costs and reporting them as well as their expected efficacy to all relevant stakeholders, particularly shareholders and creditors.

The objectives for an economic assessment must ensure that the methodology matches these objectives and the strengths and limitations of the methodology are clearly articulated to end users. Three broad economy-wide approaches have been identified. These generally are used to assess the impacts of climate related events:

- general equilibrium analysis
- partial equilibrium analysis
- integrated assessments.

General equilibrium analysis is a top-down approach that looks at projected economy-wide impacts using dynamic models that account for the interaction between different sectors of the economy. It considers the impacts and interactions arising from the ‘shocks’ or economic shifts associated with climate-related events between two given points in time, and permits the reallocation of resources. This approach is useful when indirect impacts need to be assessed, and can also provide insights when multiple markets or sectors need to be analysed together.

Partial equilibrium analysis has the benefit of utilising various and flexible valuation methodologies that can be applied to a variety of impacts, sectors or markets. The disaggregated, bottom-up nature of partial equilibrium analysis does not require overly complex economic models, and is also well suited to exploring the impacts of extreme events. However, it is limited by the more static nature underlying the mechanics of the approach.

Integrated assessments capture the strengths of both forms of equilibrium analysis by including analysis of specific sectoral circumstances as well as the flow-on and feedback effects within the economy as a whole. Socio-economic projections and qualitative decision-support tools can also be incorporated. This approach is usually more resource intensive.

When conducting economic assessments of climate change impacts, the most common concerns include the valuation of impacts on intangibles, selecting an appropriate discount rate, evaluating uncertainty, analysing low-probability, high-severity events and evaluating the distribution of impacts between different parts of the economy. These challenges highlight the importance of transparency of assumptions, sensitivity analysis of the assumptions and integrating quantitative and qualitative data.

There are some alternatives to the traditional assessment options. For instance, the so-called 'hypothetical markets' approach to valuing intangible climate change impacts is one option available for analysis. This involves techniques such as 'stated preference methods' which use contingent valuation within structured surveys to estimate the willingness to pay for specified changes in the value of intangibles (Carson et al., 2003). Other methods such as hedonic pricing value a particular attribute that can be observed in a proxy markets (e.g. variations in residential property value, correcting for quality characteristics, etc.). These methods can be quite sophisticated and are widely used however their validity has been questioned since data generally sporadic and often not directly observed (Barkmann et al., 2008). The way in which companies handle these key issues can have profound impacts on analysis outcomes, and it is important that end-users fully understand the treatment of them in a given analysis.

An assessment of the costs of climate change would ideally include all things that are valued by the company doing the analysis. This could include the value of environmental amenity, ecosystems and their benefits to a firm as well as the value of avoiding operational disruptions. However, valuing intangibles for climate change impact assessments using economic modelling approaches is a challenge because it involves attributing a dollar value to an activity that can be largely qualitative and can sometimes deal with purely ideological concepts.

One concern related to valuing the impact of climate change on intangibles – particularly on ecosystems – is the notion of 'substitutability'. Even if impacts on natural systems can be valued and integrated into an economic analysis, some techniques such as cost-benefit analysis tend to assume that value is substitutable (e.g. trading ecosystem benefits/services for greater consumption). There are a variety of instances where human-produced capital is not an adequate substitute for natural capital (AGO 2004), and as the availability of natural capital declines, substituting will become increasingly difficult. Costanza et al. (1997) attempted to attach a value to the world's biosphere and were criticised for using marginal valuations to aggregate total value (Van den Bergh 2004). While these studies were conducted on a more global scale, the issues are particularly important at the local level where asset substitution is not always possible.

Despite these concerns, it is known that omitting intangible (non-market) impacts limits the insight provided the analysis. A lack of evaluation of intangibles may bias the analysis to consider only tangibles, and this omission will inevitably bias cost estimates down since the overall impact of climate change on natural systems is thought to be negative (Nunes & Ding 2009). Some adaptation options may successfully pass the cost-benefit criterion when intangibles are not included, as is the case with extreme events.

If it is impossible to assign a dollar value to an impact, it is still necessary for the impact to be included in the analysis discussion. The use of qualitative impact assessments that describe impacts on intangible assets under various scenarios is the main option used for dealing with uncosted intangible impacts (Kiker et al. 2005), which highlights the notion that economic analysis should be only one of many inputs to the decision-making process.

A broad economic assessment may be helpful for allowing companies to define potential impacts using scenario analysis, but it will ultimately be limited by the general nature of the approach. These assessments permit a broad understanding of wider impacts, but are rarely granular enough for an asset by asset assessment needed to define company specific exposures. Companies will therefore turn to one of or a combination of the following types of analyses to better understand expected exposures.

Macro-Level Methods of Attributing Costs to Adaptation

Adaptation modelling in businesses should differentiate between (1) adaptation that businesses would undertake on their own to avoid, or benefit from, the impacts of climate change in the absence of government regulation or programmes that encourage firms to adapt to climate change, and (2) actions that governments in their role as provider of social benefits (roads, rail, etc.) undertake to adapt to climate change. Such modelling must also account for measures that are structural in nature, like dams and levees, as well as any behavioural adaptation measures.

Fankhauser et al. (1999) employed a model identifying five types of costs that can be defined for different climate states, which we adapt for costs to business as follows:

- Adaptation costs (AC) are the costs of resources forgone by a company to undertake adaptation measures both in the baseline and future climates.
- Climate change damages (CD) are the value of the extra damages that occur exclusively because of climate change (zero in the baseline scenario).
- Ordinary climate damages (OD) include the adverse effects associated with the current climate, that is, all climate-related costs that would also occur in the absence of climate change.
- Other relevant costs (OC) are the indirect costs that result from taking an adaptation action.
- The imposed costs of climate change (ICCC) are defined as the difference in overall costs (AC+CD+OD+OC) between the climate change and reference scenario, taking economically optimal adaptation into account.

The framework is neat, but it reveals a number of problems. First, the model is not sufficiently general as it focuses only on adaptation measures aimed at counteracting the effects of climate change. Second, the cost definitions require a specific quantification of adaptation costs in both the reference scenario and the climate change scenario to estimate the delta. This may be appropriate for some expenditures such as levees, abandoning coastal regions and shifting harvest dates; however, it represents a broad approximation of other adaptation actions involving more general forms of input and output substitution. These activities might include evolving policy estimation of insurers that may already be occurring due to non-climate change factors. Finally, most firms would agree that it is not always feasible to isolate the partial components of cost changes due to climate change adaptation – particularly in both the reference and climate change scenarios – and that in any case such cost estimates generally ignore changes in behavioural actions.

One way to address the above deficiencies is to adopt an alternative structure that measures benefits and costs due to changes in climate instead of defining costs and benefits in each climate state. Using this approach, it has been shown that it is possible to separate the effects of climate change from those of adaptation actions (Calloway 2003).

The costs and benefits associated with this approach are defined as follows:

- Climate change costs (damages) are the net costs to the company from climate change if no adaptive measures are taken. These costs are equal to the sum of the net adaptation benefits and the imposed costs of climate change.
- Adaptation benefits are the value of climate change damages avoided by adaptation actions.
- Adaptation costs are the value of the real resources the company surrenders – opportunity costs – to create adaptation benefits.
- Net adaptation benefits are the value of adaptation benefits minus adaptation costs.
- The imposed costs of climate change (ICCC) are therefore the net costs to the company of climate change if adaptation actions are taken. These costs are the difference between climate change costs and net adaptation benefits.

This is a straightforward representation; however, it relies heavily on data as well as baseline and future assumptions. The core ideas in the conceptual framework developed by Fankhauser et al. (1999) and then by Callaway (2003) can be explained with the use of Table 16.1, which characterises four different, general adaptation cases. The columns indicate the climate, either C_0, the existing climate, or C_1, the altered climate, to which organisations adapt, while the rows indicate whether the company is adapted to the existing climate, A_0, or the altered climate, A_1. The idea is that individual and organisational behaviour is 'optimally' adapted to an existing climate regime (C_0) through behaviour that can be broadly characterised as A_0. When the climate changes from C_0 to C_1, there is associated with the new climate, a new behavioural optimum, characterised by A_1. This framework was originally developed in the context of a market economy.

Table 16.1: Alternative adaptation scenarios for estimating adaptation costs and benefits

Adaptation type	Existing climate (C0)	Altered climate (C1)
Adaptation to existing climate (A0)	Existing climate. Company adapts to existing climate: (C0, A0), or Base Case	Altered climate. Company adapts to existing climate: (C1, A0).
Adaptation to altered climate (A1)	Existing climate. Company adapts to altered climate: (C0, A1).	Altered climate. Company adapts to altered climate: (C1, A1).

Source: Callaway (2003).

The top left cell describes a situation in which a company is adapted to the existing climate, C_0, through adaptive behaviour A_0. This is the base case. The lower right cell represents a situation where a company is adapted to a change in climate from C_0 to C_1 that has changed over time through behaviour A_1. The top right cell describes a situation in which a company behaves as if the climate is not changing, and is adapted to the existing climate, but not the altered climate. The bottom left cell represents a case in which a company decides to behave as if the climate had changed, when in fact the climate has not changed. Note that if the null hypothesis is that the current climate does not change, H_0: $C_0=C_1$, then accepting the null hypothesis when it is false, and not adjusting to climate change that does occur (top right-hand cell), is associated with making a Type II error. Rejecting H_0 when it is true, by adjusting to climate change that does not occur (bottom left-hand cell), represents a Type I error.

The Calloway model can be interpreted as follows. If we let W(C, A) represent a function W(.) of net company 'welfare', however measured, then the imposed cost of climate change as discussed above, is calculated as the difference between net welfare in the lower right-hand scenario in Table 15.1, or $W(C_1, A_1)$, minus net welfare in the top left scenario, $W(C_0, A_0)$. However, it is clear that this is not the correct comparison to be used for measuring the costs and benefits of adaptation. To do this one must compare the costs and benefits of actions that are taken in the top right box with those in the bottom right box, or between the following two states: (i) when climate changes, but the company is not adapted to the new climate (C_1, A_0), and (ii) when climate changes and the company adapts to the altered climate (C_1, A_1). Thus we can estimate Climate Change Damages = $W(C_1, A_0) – W(C_0, A_0)$, the Imposed Cost of Climate Change = $W(C_1, A_1) – W(C_0, A_0)$, and the Net Benefits of Climate Change = $W(C_1, A_1) – W(C_1, A_0)$. This model is an early version of the cost-benefit analysis discussed in detail below.

An alternative estimate of adaptation costs covered in the research of Smith and Hitz (2002) focuses on the relationship between economic development and adaptation to climate change. This approach involves the relationship between 'no regrets' actions taken by companies. In the context of adaptation, a no regrets action is one that is taken for reasons other than avoiding climate change damages, but that nevertheless 'softens' the impacts of climate change as they occur. In their analysis, Smith and Hitz (2002) indicate that exogenous assumptions about economic development in a number of studies had a fairly substantial effect on most damage and benefit estimates. Economic development often reduces vulnerability to climate change naturally; however, they emphasise the importance of 'proactive' adaptation measures that can be taken today to reduce regional vulnerability to climate change. This point can be extended by saying that there are potentially many actions that can be taken today for reasons that are more directly related to a broad variety of other developmental goals (including reduced vulnerability to existing climate variability) that also are potentially effective in reducing the vulnerability of companies to climate change.

Flow and Stock Adaptation – Temporal Aspects

In integrated assessment modelling, it is important to distinguish between adaptation investments where both costs and benefits accrue in the same time period and those where initial investments offer benefits that extend beyond the time period when the costs were incurred (Agrawala et al. 2010). Generally, the former can be termed 'flow' adaptation and the latter 'stock' adaptation.

Flow adaptation generally is associated with reactive actions such as changes in agricultural practices, capital expenditures in energy production for heating and cooling and treatment of climate related diseases. Flow adaptation includes disaster relief and recovery for firms that experience weather-related losses. Flow adaptation can also include planned and proactive measures with benefits that persist but are generally not of sufficient duration to provide adaptive measures over the long term. In most cases it is likely that no cumulative build-up of investments occurs.

In contrast stock adaptation is characterised by an accumulation of investments in capital assets aimed at reducing climate change impacts. Investments in infrastructure such as sea walls, water storage and desalination facilities are examples of stock adaptation that require upfront investments, that then offer a stream of benefits over the long term.

Previous research on adaptation planning (for instance Agrawala et al., 2010) distinguishes between stock and flow adaptation for several reasons. From an economic perspective the time lag between costs and benefits will change the optimal time profile of adaptation and it will also affect the optimal mix of adaptation and mitigation. This optimal mix depends crucially on the discount rate, as the cost-to-benefit time lag of mitigation is larger than that of adaptation. The discount rate will thus influence what the optimal mix at any moment in time will be, and how this optimal mix changes over time. Agrawala et al. (2010) demonstrate that the discount rate will also affect the optimal mix of both forms of adaptation. For instance, high discount rates have a much stronger effect on stock adaptation than on flow adaptation, while lower rates improve the economics of stock adaptation activities.

Stock adaptation must include the investment of funds for the build-up of capital stock. This will inevitably be a significant constraint for potential investments. Flow adaptation in the private sector is likely to be more prevalent while proactive public adaptation may be limited, since many entities do not have ready access to funds to build up sufficient reserves. Distinguishing between these forms of adaptation can assist in understanding the severity of such adaptation limits.

Stock and flow adaptations are obviously closely related. All sectors are likely to have a combination of both flow and stock measures. For example, while changes in agricultural practices in response to climatic conditions are a flow adaptation, investments in irrigation or water storage represent stock adaptations. The efficacy of many flow adaptation activities depends at least in part on the adaptation stock available. Flow and stock adaptations can be substitutes for each other; however, the substitution will never be perfect.

Besides stock and flow, another relevant distinction is between investments in adaptation actions that directly help reduce the adverse consequences of climate change impacts (or help capitalise on beneficial opportunities) from investments in 'adaptive capacity'. Adaptive capacity is vital for effective adaptation responses. Investments in adaptive capacity and adaptive actions can substitute for each other to a certain extent. Understanding the linkages between investments in developing adaptive capacity and adaptation actions themselves is critical for an effective integrated assessment model.

Selecting an Approach

Four major approaches to devising a framework in the literature are outlined here:

- *Hazards-based approach*. A firm assesses current climate vulnerability or risk in the priority system, and uses climate scenarios to estimate changes in vulnerability or risk over time and space.
- *Vulnerability-based approach*. A firm focuses on the characterisation of a priority system's vulnerability and assesses how likely critical thresholds of vulnerability are to be exceeded under climate change. Current vulnerability is seen as a reflection of both development conditions and sensitivity to current climate. The vulnerability-based approach can be used to feed into a larger climate risk assessment.
- *Adaptive-capacity approach*: A firm assesses a system with respect to its current adaptive capacity, and proposes ways in which adaptive capacity can be increased so that the system is better able cope with climate change including variability.
- *Policy-based approach*: A firm tests a new policy being framed to see whether it is robust under climate change, or tests an existing policy to see whether it manages anticipated risk under climate change.

This is also applicable for governing bodies and other regulators that impact on firms' activities.

The two major pathways available for risk assessment are the natural hazards and the vulnerability-based approaches. The natural hazards approach is a climate scenario-driven approach. It constitutes climate scenarios, applies them to impact models and determines expected changes in vulnerability.

The vulnerability-based approach starts with possible future outcomes in the form of physical or economic criteria that represent a given state of vulnerability. It then determines how likely those criteria are to be met/exceeded under different future climates, again by applying a range of climate scenarios. Outcomes used as criteria for risk assessment can be desirable (e.g. total protection from flood risks) or undesirable (e.g. an important activity that may cease in flooding).

The natural hazards-based approach fixes a level of hazard (such as a peak wind speed of 10 m/s hurricane severity, or extreme temperature threshold of 35°C), and then assesses how changing that particular hazard, according to one or more climate scenarios, changes vulnerability. Limitations in climate modelling often mean that changing hazards cannot be represented specifically, but scenario-building methods are continually evolving. A broad formulation of the level of risk can be stated as:

Risk = probability of climate hazard x vulnerability

The vulnerability-based approach sets criteria based on the level of harm in the system being assessed, then links that to a specific frequency, magnitude and/or combination of climate events. For example, this could be loss of operational income linked to severe drought, of loss of property due to flooding or critical thresholds for the management of company operations. The level of vulnerability that provides this 'trigger' can be decided by firms based on past experience or defined according to policy guidelines. With this approach, risk is equated to the probability of exceeding one or more criteria of vulnerability.

The risk and adaptation costs using the IPCC definition of vulnerability are deliberately less strictly defined and is estimated as

Vulnerability = risk (predicted adverse climate impacts) – adaptation

Both the natural hazards approach and the IPCC method are complementary, but they also can be used separately. Table 16.2 provides a broad overview that helps define which technique may be most appropriate. If the ranges of uncertainty described by climate scenarios and/or the characterisation of a hazard under climate change are well-calibrated and if the drivers of change and the processes by which change can be represented are understood, then the natural hazard approach may be most appropriate. If climate hazards cannot easily be characterised under climate change scenarios, there are many drivers of change and many pathways along which change can take place, a vulnerability-based approach may be most appropriate. Another important distinction is that the natural hazard method is largely exploratory (McCarthy et al., 2001; Metz et al., 2001) while the vulnerability-based approach offers a normative perspective of exposure.

Table 16.2: Checklist to determine the efficacy of using the natural hazard- and vulnerability-based approaches in an assessment

Method	Natural hazard-based approach	Vulnerability-based approach
Hazard characterisation	Ranges of uncertainty described by climate scenarios and/or characterisation of hazard under climate change well-calibrated	Ranges of uncertainty described by climate scenarios and/or characterisation of hazard under climate change not well calibrated
Drivers of change	Main drivers known and understood	Many drivers with multiple uncertainties
Structure	Chain of consequences understood	Multiple pathways and feedbacks
Formulation of risk	Risk = P (Hazard) x Vulnerability	Risk = P (Vulnerability) e.g. critical threshold exceedance
Approach	Exploratory	Normative

If no information – or only insufficient information – on the costs and benefits is available, the Delphi method can be applied, whereby a structured iterative group communication is conducted to collect opinions and feedback from selected experts. First, the opinions of the different experts are collected by carrying out surveys using a questionnaire. The results of the survey will then be presented to the group and another questionnaire will be provided to the group building upon the results of the first survey. In this way, opinions can be exchanged equally, and results cannot be influenced by more vocal stakeholders as could be the case in face-to-face conversations. A Delphi survey can be undertaken via mail, online or face to face.

Strategic environmental assessments (SEA) are another planning tool. SEAs systematically assess environmental effects of strategic land use-related plans and programs, and are usually undertaken in transportation, waste management, regional planning, tourism and energy sectors. While SEAs are directed at strategic plans and programs, environmental impact assessments (EIAs) are aimed at the project level and analyse possible negative or positive impacts that a project might have on the environment. Here, natural, social and economic aspects are accounted for to ensure that decision-makers consider the environmental impacts before selecting an option. EIAs are usually undertaken in conjunction with other approaches such as CBA, MCA and various participatory tools.

The risk-assessment process is intended to generate a priority list of risks for which a range of possible adaptation responses can be developed. In some cases, only a few sensible options will exist, while in others, serious consideration will be required to assess the benefits of different adaptation responses. Adaptation measures should be aimed at adjusting an activity to account for the effects of climate change, or at addressing barriers to individuals and organisations adapting optimally within the institutional framework. The aim of the implemented adaptation measures is to reduce the residual risk posed by climate change to the organisation, so monitoring of the residual risk is required to ensure the measures are having the desired effect.

Some issues will require immediate practical adaptation responses while others will require more extended periods of investigation. These are likely to include research, cost-benefit appraisal and other types of capacity-building initiatives. An implementable action plan should be the primary outcome of this analysis. The program should look to ensure continuity of operations, supply chains and services across the organisation.

Obviously, it is difficult to define the success or otherwise of a particular adaptation measure given that such a measure may not be tested for many years. Cost-benefit analysis, where quantifiable, of the various potential responses to adaptation is necessary to implement the optimal measure.

Developing adaptation plans

Ideally, an adaptation plan should:

- monitor an implementation timetable
- monitor accountability for implementation
- outline responsibilities for the delivery and management of actions

- monitor and report on the delivery of the actions with reference to risk reduction, and
- establish a review schedule of the plan to assess the reaction to new information.

Where adaptation requires a long lead time, the company should highlight what monitoring actions are included in the forward work program. Uncertainty over the future impacts of climate change means the ability to use and value flexibility is critical. Techniques such as real options analysis and scenario testing can provide a framework to incorporate uncertainties and value decision-making flexibility

In developing an adaptation program, it may be prudent to use the principles of sustainable adaptation. This would include an assessment of social, economic and environmental sustainability of the overall plan.

Climate change adaptation and mitigation are not mutually exclusive. It is possible to combine measures to reduce emissions with those to build resilience to climate change. It is anticipated that companies will take the need to mitigate their emissions into account when developing an adaptation program. In some cases, it may be necessary to undertake measures that lead to increased emissions; however, this should obviously be a measure of near-last resort.

It is also necessary to consider and demonstrate how to build resilience into each process rather than adaptation being considered a one-off activity. In doing so, the plan should develop indicators to monitor such resilience.

Broadly, an adaptation plan can be process-based or outcome-based:

- *Process based.* Building adaptive capacity describes many of the adaptation responses that the company will undertake to plan for adaptation. Such processes will include new project management systems and data collection on climate change impacts. Perhaps additional research may be required on certain adaptation activities as well as training and staff development. These activities are aimed at building adaptive capacity.
- *Outcome based.* Practical adaptation actions generally are illustrated by physical examples (such as increasing the height of a flood defence levee), but they can also include non-physical actions (such as installing early warning systems on local flooding).

Monitoring and Evaluation

Evaluating adaptation measures will often be complex, with a range of factors that need to be explained. The long timeframes over which the effects of climate change are likely to occur mean that it will be difficult to assess the success of adaptation plan outcomes. Emphasis should be placed on monitoring and evaluating processes. This will be important for understanding the contextual factors and mechanisms that underlie an activity's success, and developing the evidence base for evaluating outcomes.

The aim of evaluation is to assess the extent to which an activity has been successful, in what circumstances and why. A framework for evaluation is to assess how a measure has performed against the principles of good adaptation including effectiveness (outcome achieved, unintended consequences, flexibility), efficiency (benefits vs costs) and equity (disproportionate costs on companies or on the natural environment).

Evaluation is a continuous process. It focuses on developments in knowledge and information on changes in climate and adaptation processes, and the implications of these for the functions of the organisation.

Factors that may influence points at which to evaluate progress include:

- the provision of new climate information (such as new climate projections), and
- the availability of new research (for instance resolving uncertainty about the effectiveness of an adaptation measure).

Adapting to climate change should involve making decisions that preferably are sustainable, maximise the benefits and opportunities and minimise the potential costs of a changing climate. In broad terms, adaptation must be built into planning and business risk management to increase resilience to ensure the continued growth of business activity while maintaining a commitment to sustainable social and environmental practices.

Assessing Adaptation Costs

There are several approaches to assessing and evaluating the value of a company. Improper disclosure and/or valuation of environmental liabilities can result in a company overstating its actual value. For example, if environmental liabilities are understated, then the company likely is overstating its actual value (or market) value compared with its book value. Likewise, understatement of intangible assets (e.g. emission allowances) may understate actual (market) value.

Market value of a firm takes into account additional factors not included on a company's balance sheet, such as the company's potential for future growth, industry conditions and intangible assets/liabilities. Intangible assets are becoming an increasingly important component of a company's market value, and include non-monetary assets, such as copyrights, patents, research and development, reputation, brand and even employees. More recently, climate risk has emerged as an intangible asset liability that potentially offsets a company's market value.

As we introduce key accounting standards, it is helpful to keep three concepts in mind:

- *Disclosure.* When are companies required to disclose information about their adaptation liabilities?
- *Accrual.* When are companies required to accrue (i.e. record) adaptation liabilities on their financial statements?
- *Estimation.* How do companies determine what amount to accrue for their adaptation liabilities?

We integrate the findings of various studies and workshops conducted to understand the impact of environmental disclosure standards on company behaviour.

Dealing with Model Uncertainty

Major uncertainty surrounds biophysical impacts from climate change, and the ways in which they subsequently impact the socio-economic status of companies. Obviously, long-term predictions are significantly more difficult than short-term ones. Most researchers argue that pressures from increasingly speculative assumptions about emissions pricing and climate change impacts in climate models mean that they become useless for analysis beyond 2030.

The relationship between emissions, temperature increases and other physical impacts result in feedback loops, and are probably not as linear as implied by many models. A probabilistic determination of the risk of catastrophic and/or irreversible impacts may not be possible. Nor may it be feasible to predict the economic impacts of such events (Jotzo 2010). Merely valuing impacts of an intermediate scenario (as the average of an extreme high and low scenario) neglects to account for extreme impacts, which is often the driving concern of climate change in the first place. All economic predictions are based on assumptions about future trends in economic growth, population, capital, investment, technology and wealth accumulation, among others. Parts of these assumptions inevitably are based on historical observations, which clearly have no merit in accurately forecasting future trends. With climate change potentially having profound effects on businesses and society in general, justifying the use of past trends in models becomes increasingly speculative. So long as this constraint is firmly acknowledged, a forecast may still have merit. Investigating the impact of climate change on the current situation allows for only one parameter (climate) to be varied, thereby reducing uncertainty. The results can still be a useful indicator of key impact sites and relative vulnerabilities (Tol 2002a).

Despite the inherent uncertainties, there are tools available for decision-makers to help account for uncertainty. If there is reasonable knowledge of the probability of an event or circumstance, the use of concepts such as expected monetary value, expected utility criterion and expected value-at-risk analysis offer an initial framework for understanding the severity and likelihood of a particular event. In situations where uncertainty is more significant, the use of sensitivity analysis, Monte Carlo simulation and interval analysis can add another layer of sophistication to the analysis, although the complexity can magnify quickly. Sensitivity testing can lend much to the quality of an analysis, particularly in relation to highlighting the profound impact of uncertainty of the major economic and climate assumptions.

Uncertainty is prevalent because forecasts of climate impacts and economic outcomes are based on models that use a complex set of input parameters. Despite this uncertainty, it is possible to create credible scenarios upon which to base decision-making on adaptation measures and costs. One approach for dealing with implicit uncertainty in assessing climate change impacts and adaptation initiatives is to favour initiatives that increase the flexibility of systems or enhance adaptive capacity (Fankhauser, Smith & Tol 1999). This means favouring 'soft' adaptation options that increase capacity to respond to a plethora of unexpected circumstances. Unfortunately, 'soft' adaptation options are more difficult to cost than 'hard' options such as changes in infrastructure (Parry et al. 2009).

17. APPENDIX 9: ASX LISTING RULES – A DISCUSSION

Listing rule 4.10.3 (adopted in 2003, amended in 2010) requires each entity admitted to the official list as an ASX listing to include in its annual report a

> statement disclosing the extent to which the entity has followed the recommendations set by the ASX Corporate Governance Council during the reporting period. If the entity has not followed all of the recommendations the entity must identify those recommendations that have not been followed and give reasons for not following them. If a recommendation had been followed for only part of the period the entity must state the period during which it had been followed.

The policy objectives of Listing Rule 4.10.3, as noted in ASX Guidance Note 9, states that '[a]part from the requirements in Listing rules 12.7 (audit committees) and 12.8 (remuneration committees) for certain entities to have audit and remuneration committees and in various other Listing Rules for certain matters to be submitted to security holders for approval, the Listing Rules do not seek to prescribe the corporate governance practices that a listed entity must adopt. This role is fundamentally one for the entity's board of directors, the body with the legal responsibility for managing its business with due care and diligence. It is the board of directors of an entity who must ensure that it has appropriate corporate governance practices in place and who must be prepared to explain and justify those practices to security holders and the broader investment community.'

The objective of Listing Rule 4.10.3 is to ensure that the market receives appropriate disclosures about the corporate governance practices of an entity so that security holders and other stakeholders can participate in 'meaningful dialogue with the board and management on corporate governance matters'.

The guidance note emphasises that it is not the role of this listing rule

> to pass judgement on the quality or effectiveness of the corporate governance policies and practices that a listed entity may have adopted … nor the reasons an entity may give for not adopting a particular Corporate Governance Council (CGC) recommendation. Those judgements are initially for the entity's board, and then ultimately for its security holders and the broader investment community to make. The role of the ASX under Listing Rule 4.10.3 is to ensure that a listed entity meets its disclosure obligations under that rule so that security holders and the broader investment community have the information they need to make those judgements.

Eight central principles are stated as being from the CGC Principles and Recommendations, two of which state the following:

- Listed entities should promote the timely and balanced disclosure of all material matters concerning the entity.
- Listed entities should establish a sound system of risk oversight and management and internal control.

ASX Guidance Note 10 provides general guidance to listed entities on the form and content of a Review of Operations and Financial Condition which supplements the financial statements. The aim is to establish guidelines for companies to explain past performance and provide information which will increase understanding of its future direction. The note prescribes that these aims can be achieved through

> a Review which provides a critical and objective analysis and explanation of a company's past and likely future performance and financial condition concentrating on the opportunities and risks associated with the past operations of the company and the opportunities and risks likely to impact on the future activities of the company.

The Review allows for both financial and non-financial information to be disclosed which allows 'analysts and others who regularly assess company performance against financial and non-financial industry-specific indicators'.

The Guidance Note provides an outline of the framework and presentation of such a Review. To meet the listing requirements 'the Review should:

- be comprehensive and include matters that are likely to be significant to users
- update material comments or disclosures made in previous reports where actual outcomes warrant such updating
- make clear how any financial or non-financial key performance indicators (both key business drivers and outcomes), ratios or other information relate to the financial statements
- include a discussion of initiatives, events and transactions which can, at the time of preparing the Review, be expected to affect future reporting periods rather than limiting the discussion to the next reporting period
- define and explain the financial and non-financial measures included in the Review, their sources and the relevant assumptions and adjustments, if any, made in respect of information also included in the financial report, and
- deal with broader dimensions of the company's performance, such as sustainability reporting, where that is relevant to users.

Review – Company Overview and Strategy

The guidance note also states that the focus of the Review is on 'explanations and analyses'.

In terms of the Company Overview and Strategy component of a Review, it should

> discuss the main factors and influences that may have a major effect on future results *whether or not they were significant in the period under review*. The principle opportunities, risks and threats in the main lines of business that pervade a company's competitive landscape, together with commentary on the approach to managing those opportunities and risks and, in qualitative terms, the nature of the potential impact on strategies and results, should be clearly communicated.

Review – Review of Operations

The Review should describe the business and identify and explain the 'main factors that affect the activities and performance of the company. Specific mention should be made of those factors that have varied in the past or are expected to change in the future. Discussion of past performance should be supplemented by known trends and factors that are likely to affect future performance.'

Review – Shareholder Returns

Among other things, the Review should discuss 'relevant indicators of returns to shareholders, such as movements in share prices or the results of shareholder and economic value analysis.'

Review – Investments for Future Performance

> Users of financial reports are interested in the extent to which the directors have sought to maintain and enhance the position of the company, including future profitability. The Review should also deal with activities and expenditures intended, wholly or partly, to enhance future profitability which, in the short term, can be varied over a relatively wide range at the discretion of management. The Review should facilitate the user's assessment of the future prospects of the company.

In addition to capital expenditure, many other activities and expenditures can be regarded as a form of investing in the future. By their very nature, the definition and timing of such items will vary from one company to another and from one industry to another.

Review – Risk Management

Shareholders and other users of financial reports are interested in the various risk exposures of the company and the way in which those risks are managed. The Review should contain a discussion of the company's risk profile and risk-management practices if these are not dealt with elsewhere in the Annual Report. The company is also subject to other risks which need to be discussed. Environmental issues are an important feature of the disclosures required in the Review.

18. APPENDIX 10: SAMPLE RISK REGISTER

The following sample risk register may be used by firms to capture all risk information, including climate change adaptation plans, discussed in this study.

Identify material business risks			**Prioritise risks**			**Manage risks**		**Report risks**
Risk description	Current controls	Quality of current controls	Likeli-hood	Impacts	Risk level	Management actions	Responsi-bility & timeframe	Status
1. Risk type, impacts history, etc.	Risk mitig-ation action	Effect-iveness of current controls	Expect-ed freq-uency or prob-ability of occur-ence	Finan-cial and phys-ical impacts	Overall risk level and change since last report	If risk level exceeds the firm's risk tolerance, document additional manage-ment action required to reduce the risk level	Allocate respons-ibility for each risk and specify timeframe	Track the status of risk-mitigation actions and report to the board; note if risk is climate change related
2.								
3.								

19. APPENDIX 11: RISK INSTRUMENTS

Insurance and Reinsurance

Insurance is the main form of risk management used to hedge against the risk of a contingent, uncertain loss. Insurance is defined as the equitable transfer of the risk of a loss, from one entity to another, in exchange for payment. Since insurance operates through pooling resources, the majority of insurance policies are provided for individual members of large classes, allowing insurers to benefit from the law of large numbers in which predicted losses are similar to actual losses. If the likelihood of an insured event is so high, or the cost of the event so large, that the resulting premium is large relative to the level of protection offered, it is unlikely that insurance will be purchased. Accounting standards formally recognise that the premium cannot be so large that there is not a reasonable chance of a significant loss to the insurer. If there is no such chance of loss, the transaction may have the form of insurance, but not the substance. Insurable losses are ideally independent and non-catastrophic. Insurers prefer to limit their exposure to a loss from a single event to some small portion of their capital base. Such exposures can be shared among several insurers or be insured by a single insurer who syndicates the risk into the reinsurance market.

Reinsurance is a second-order form of insurance purchased by an insurance company (cedent) from one or more other insurance companies (reinsurer) as a means of risk management. Many reinsurance placements are not placed with a single reinsurer, but are shared between several reinsurers. Alternatively, one reinsurer can accept the whole of the reinsurance and then retrocede it to other companies. Under proportional reinsurance, one or more reinsurers take a stated percentage share of each policy that an insurer writes, which means that the reinsurer will receive that stated percentage of premiums and will pay the same percentage of claims. Under non-proportional reinsurance, the reinsurer only pays out if the total claims suffered by an insurer exceed a pre-agreed amount. An insurer prepared to accept a total loss up to $300 million may purchase a layer of reinsurance of $500 million in excess of the $300 million. If a loss of $600 million were then to occur, the insurer would bear $300 million of the loss and would recover $300 million from its reinsurer. The insured would also retain any excess of loss over $800 million unless it has purchased a further excess layer of reinsurance.

Catastrophe Bonds

A catastrophe bond (also known as a CAT bond) is a high-yield debt instrument that can be used to raise money in anticipation of a catastrophe caused by climate change, but can also be non-climate related (earthquakes). These instruments transfer a set of risks from the sponsor to bond investors. They are generally a floating-rate corporate bond whose principal is either deferred or forgone if specified trigger conditions are met. For example, if an insurer has built up a portfolio of risks by insuring homes in south-east Queensland, they might wish to pass on some of the risk in case a severe flood occurs, to prevent against insolvency. They could choose to sponsor a CAT bond, which would pass the risk on to investors in the capital market. The insurer would issue the bond to investors with an expected return that exceeds a similar straight bond. In the absence of a flood event, the investors would earn an above-average yield on their investment; however, if a flood event (however defined) does occur, then it may trigger the CAT bond and a portion of the bond principal paid by investors may be used to pay the sponsor's claims.

Catastrophe bonds were developed in the mid-1990s to facilitate the direct transfer of catastrophe insurance risk from insurers, reinsurers and corporations (referred to as the CAT bonds' 'sponsors') to investors. They were designed to protect sponsoring companies from financial losses caused by large natural catastrophes (such as Hurricane Katrina in the United States) by providing an alternative or supplement to traditional reinsurance. The instruments usually target layers of risk with low annual loss probabilities – frequently less than 1 per cent per annum – although many transactions have been completed with significantly higher expected loss estimates.

From the sponsor's perspective, the fully collateralised nature of cat bonds provides an important measure at a time when many are focused on reinsurer market security. The ways in which catastrophe bonds are structured have evolved to the point where there is now a well-defined set of attributes that satisfy the competing demands and desires of investors, rating agencies, regulatory agencies and sponsors.

The way in which the trigger conditions are met, causing the principal to be deferred or completely forgiven, is specified by the sponsor and investment bank who structured the CAT bond. These bonds can be categorised into four trigger types: indemnity, modelled loss, indexed to industry loss and parametric.

- *Indemnity loss* bonds are triggered by the issuer's actual losses. For example, if the layer indicated in the CAT bond is $80 million in excess of $500 million, then the bond will be triggered if losses add up to more than $500 million.
- *Modelled loss* bonds are triggered if modelled losses are above a certain threshold. The modelled losses are calculated from an exposure portfolio that is made to work with catastrophe modelling techniques. When an event occurs, the event parameters are run against the exposure database in the CAT model.
- *Indexed to industry loss* bonds are less correlated to the insurer's actual losses and are triggered when the insurance industry loss reaches a certain threshold.
- *Parametric loss* bonds are indexed to the natural hazard cause by nature. The parameter from which data is collected could be flood heights or wind speed. If the data collected indicate flood levels or wind speeds greater than a specified amount, the CAT bond is triggered.

The desire to access greater risk-bearing capacity through the capital markets underscores the risk of catastrophic losses in insurance portfolios. Catastrophe bonds have also become popular because their return is highly uncorrelated with the return on traditional asset classes (equities, fixed interest, real estate, etc.), which assists investors to achieve requisite diversification.

From an investor's point of view, three-year CAT bonds – which are common – are not considered long term, given the market's relative illiquidity, yet it helps avoid reinvestment risk and the structuring effort associated with one-year bonds. Almost all

CAT bonds have a floating-rate component in their coupons (usually based on LIBOR) designed to mitigate interest rate risk during the risk period.

Weather Derivatives

The impact of weather on all forms of commercial activity is significant and varies both geographically and seasonally. Many businesses, including agriculture, insurance, energy and tourism, are either favourably or adversely affected by weather. For this reason, the financial markets have devised a class of instruments, typically called weather derivatives. Through these financial instruments, risk exposure to weather may be transferred or reduced. Commonly referenced weather indices include, but are not restricted to, heating degree days, cooling degree days, precipitation, snowfall and wind. The flexibility of defining a specific weather index allows innovative hedging structures to be developed using these instruments to manage an almost unlimited variety of weather-related risks. In addition, it is widely perceived that the correlation between weather indices and most established financial indices is negligible, and therefore weather derivatives may appeal to a rapidly increasing variety of investors.

A weather derivative is a contract that provides a payoff in response to an index level based on weather phenomena. Such a weather index is, for instance, taken as daily average or daily maximum temperature. Weather materially affects many industries where the risks related to weather of one industry may offset those of another. By swapping risks, two parties can safeguard their sales and profits from the particular set of weather conditions that usually would result in an uncertain profit and potentially a loss. The stability that arises from a weather derivative hedge is an attractive prospect for firms intent on securing earnings consistency. An important aspect of weather derivatives is that they are financially settled. Since the underlying is not a traded asset that attracts a market determined price, a dollar multiplier is used to convert the weather index into a dollar value. The multipliers are based on the average trading demands of the market. The use of weather derivative contracts is more popular relative to a formal weather insurance contract because the latter requires evidence of a definable and measurable event and loss. From this requirement emerges the need to consider adverse selection along with the moral hazard and basis risk issues associated with a formal insurance contract. Weather derivative products, however, alleviate the need for complicated contractual devices, and as long as a strong correlation exists between expected loss and the underlying weather index, the weather exposure can be reduced or wholly transferred.

20. APPENDIX 12: BASIC RISK MATRIX

The following table is an example of an AS 4360-compliant risk likelihood representation that indicates a basic quantitative measure of likelihood (i.e. the probability of a given event occurring). These tools can be modified to account for more exact probabilities to be established (for instance level 3 could represent a 50 per cent probability while level 5 represents certainty).

Rating		**Likelihood of occurrence**
Almost certain	**5**	The threat ***is expected to occur*** within the target period
Likely	**4**	The threat ***is likely*** to occur within the target period
Possible	**3**	The threat ***may occur*** within the target period
Unlikely	**2**	The threat ***could occur sometime*** in the target period
Rare	**1**	The threat ***may occur only in exceptional circumstances***

Table 20.1 indicates qualitative measures of impact – that is, the specific financial outcome of a given threat occurring.

Table 20.1: Qualitative measures of impact

If the consequences would	**Then an appropriate consequence rating is**
Threaten the survival of not only the asset or process but also the company	Catastrophic
Threaten the survival or continued effective function of the asset, process or company and require top level management or board intervention	Major
Not threaten the asset or process but would mean that the asset or process could be subject to significant review or changed ways of operating	Moderate
Threaten the efficiency or effectiveness of some aspect of the asset or process but would be dealt with internally	Minor
Negligible impact on the asset or process or the reputation of the company	Insignificant

By combining the risk likelihood and the impact rating, the following risk-assessment matrix can be defined. In this sample, the scores are represented by colours and numeric values. In variants of this matrix, scores can be represented as letters or some other form of classifier.

Likelihood / Impact	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

The legend for the risk-analysis matrix is as follows:

Risk	Required actions
Extreme risk	**Significant risk** – Immediate treatment required
High risk	**Significant risk** – Treatment required as high priority
Moderate risk	**Accepted risk** – Manage by specific monitoring or response procedures, with management responsibility specified and strategies implemented as part of day-to-day project management
Low risk	**Rejected risk** – Manage and monitor by routine internal procedures

Almost all firms use a form of this type of assessment matrix to represent and report risk, and many larger companies maintain very complex and comprehensive risk-assessment tools (banks and insurers for instance are subject to mandatory management and reporting standards under Basel II and APRA capital adequacy requirements). The matrix tool above serves as a very basic framework for businesses to start to quantify their risk exposure.

Risk-Management Practices

As a tool for coping with uncertainty in decision-making, risk management offers a number of distinct benefits over other approaches. Risk management also aims to manage uncertainty, but does so within a framework for weighing likelihood and consequence. As such, it is flexible; while capturing a broad array of future states or consequences, stakeholders can expand their options by tailoring strategies to best suit their particular circumstances. Under conditions of high uncertainty, decision-making around risk will require deliberation over values and preferences, which should be explicit attributes of the risk management process. This opens up the decision-making process to so-called ‘hedging in the face of uncertainty’, and the preferential weighting of different lines of evidence or values, such as tradeoffs between financial and environmental goals.

Top-down assessments focus on direct cause-and-effect relationships within systems of interest. Such relationships are convenient in that they represent the perceived critical linkages between changes and impacts, which are often amenable to direct quantitative analysis. However, they tend to neglect some areas of complexity associated with social and environmental systems. Many nodes within these systems may be poorly defined, unappreciated or even unrecognised, and some relationships between components can perhaps only be described qualitatively. For example, the determinants of a firm's vulnerability to climate change, and thus of many of its climate change risks, may be a function of social, cultural, political and institutional characteristics (Adger & Kelly 1999). Many of these issues only become apparent at regional-to-local scales of operation.

Recognition of the importance of more nuanced perspectives on adaptation has seen greater attention given to bottom-up approaches to risk assessment. This process begins at the local scale, assessing the current and emerging risks, financial and environmental factors that underpin risk and the capacity for risk management (Dessai & Hulme 2004). This permits change processes – including planning horizons and scenario generation – to be used to assess future adaptation needs. Integrating adaptation into this setting includes recognising adaptation as a social process within the firm rather than a set of adjustments, taking a more dynamic view of adaptation based on past and present experience of climate variability and change, and combining climate with other drivers of change. This has been referred to as 'mainstreaming' (Huq et al. 2003). How an assessment deals with time is also important, with approaches looking both forwards and backwards in time, influencing how likelihood is combined with hazard and consequence. They can be labelled as prescriptive or predictive approaches, and diagnostic approaches, and can be defined as follows:

- *Predictive* – event risk, natural hazard or prescriptive approach. Drivers are projected through a cause and effect analysis to determine vulnerability to each driver. The likelihood of occurrence of hazards such as sea-level rise, storm surge or extreme rainfall events is modelled and vulnerability is measured as the likelihood of an event multiplied by the cost. This method is generally identified with top-down methods of analysis.
- *Diagnostic* – also known as an inverse, outcome, goal-oriented or critical threshold approach. Risks are associated with a valued outcome of climate change loss of agricultural productivity, or days lost per annum due to flooding. Consequences are expressed as the risk of exceeding a predefined standard. This method is generally identified with bottom-up methods.

Tradeoffs between a top-down and a bottom-up approach represent benefits and limitations that arise from simplicity versus complexity. Top-down approaches, while limited in scope, generally are more amenable to a pragmatic approach to avoid over-complicating the analysis. Results can be more readily compared across region and time. However, simplicity can lead to risk being inappropriately framed. Although bottom-up approaches may better suit the context of the system in question, risk-management processes often need to be tailor-made for each context, so are less amenable to generalisation. Robust investigation of the dimensions associated with climate risk management can be labour-intensive and simple conclusions about causes and implications of risk may be difficult to achieve.

21. APPENDIX 13: VALUATION APPROACHES

Expected loss assessment (ELA)

In terms of either expected loss or actuarial valuation principles for assets, the costs of adaptation can be defined as the present value of expected losses or future insurance costs avoided. This approach is most useful for assessing impacts on identifiable assets, supply chains and measurable operational activities. As illustrated in the equation below, the costs of adaptation can be derived and compared against the total amount of insurance avoided, as such:

$$\text{PV(Insurance avoided)} = \text{Adaptation costs} = \sum_{t=1}^{n} \frac{A_t}{(1+r_t)^t} \approx \frac{A_0(1+g)}{r-g}$$

where A_t is the annual cost of insuring a given asset in year *t*, r_t is the discount rate during year *t*, *g* is an assumed fixed growth rate and *r* is an assumed fixed discount rate, assuming such an asset is insurable. The discount rate must equal the company's target weighted average cost of capital (WACC) in the absence of another appropriate proxy that fairly represents the discount rate.

This estimate relies heavily on the ability of the company to calculate expected losses and unexpected losses at a given significance level, or to actuarially compute an annual insurance cost and obtain accurate forecasts of the future cost of capital. An approximation for total adaptation costs can be obtained from the expression on the right hand side of the above equation assuming appropriate insurance cost growth rates and a suitable proxy for the cost of capital.

If the actual costs of adaptation exceed the estimated present value of insurance costs then the asset is being over-engineered above the required standard, while if actual costs are less than the estimated present value of insurance costs then the asset is potentially under-engineered with reference to the required standard. The excess in asset capacity is referred to as "built capacity" or "idle capacity" and can be readily identified using the above approach. An example of how to estimate expected and unexpected losses under the ELA approach is provided in Appendix 4.

Cost Benefit Analysis (CBA)

Cost-benefit analysis (CBA) is often used to assess adaptation options when efficiency is the only decision making criteria. CBA involves calculating and comparing all of the costs and benefits, which are expressed in monetary terms. The comparison of expected costs and benefits helps inform decision makers about the likely efficiency of an adaptation investment. CBA provides a basis for prioritising possible adaptation measures. The benefit of this approach is that it compares diverse impacts using a single metric. However, it is important to be explicit about how the costs and benefits are distributed, in addition to their aggregate values.

Implementing a Cost -Benefit Analysis

- *Agree on adaptation objective and identify adaptation options.* Adaptation objectives must be well defined and quantifiable in monetary terms. It can be defined in terms of reducing vulnerability, such as achieving a particular standard of protection from flood risks.
- *Establish a baseline.* It is essential to define a baseline (the situation without the adaptation intervention being carried out) and the project-line (the situation with successful implementation of the adaptation option) to determine the costs and benefits by comparing the two situations. For example, information on past disaster frequencies and associated damages can be obtained and recorded as part of the baseline vulnerability assessment. A baseline can also be derived using data and models to compare a 'with' and 'without' situation (not a 'before' and 'after' situation).
- *Quantify and aggregate the costs over a specific time period.* Costs include direct costs (e.g. investment and regulatory) and indirect costs (e.g. social welfare losses and transitional costs). Indirect costs will be more uncertain than direct costs.
- *Quantify and aggregate the benefits over a specific time period, preferably matched to the time period used to measure costs.* Benefits should include avoided damages and co-benefits, where relevant. Contingent evaluation may be needed to measure uncertain costs.
- *Compare the aggregated present value of costs and benefits.* The bottom line for choosing an adaptation option is the comparison of the monetised and costs and benefits.
- Three output measures can be used to obtain the most efficient adaptation decision:

  – Net present value (NPV). If greater than zero then the option is acceptable. NPVs can be used for capital rationing. NPV is structurally the most reliable metric.
  – The benefit-cost ratio (BCR): The ratio of the present value of the benefits to the present value of the costs is the BCR and indicates the overall value for money of a project (NPV expressed as a profitability index). Benefits and costs are discounted at an appropriate discount rate. If the ratio exceeds 1 the option is acceptable. The BCR can also be used for capital rationing.
  – The internal rate of return (IRR). The discount rate that makes the NPV equal to zero. The higher an option's IRR, the more efficient it is. The IRR must exceed the firm's cost of capital for the project to be value accretive.

If an adaptation investment costing C^N is undertaken in period 0, there is unmitigated damage of d_0^N in that period and partially mitigated damages of d_t^N in subsequent periods (*t*). Future benefits and costs are discounted at an appropriate rate *r*. Calculating the net present value (NPV) of the cost of the damage is

$$NPV\ D^N = C^N + d_0^N + \frac{d_1^N}{(1+r)} + \frac{d_2^N}{(1+r)^2} + \cdots + \frac{d_{2t}^N}{(1+r)^t}.$$

Postponing the adaptation investment for one period (making an investment of C^L) would lead to unmitigated damages in period 0 and in period 1. From that point the damages in each period would be d_t^L. The benefits of delay would exceed the costs if

$$C^N - \frac{C^L}{(1+r)} > (d_0^L - d_0^N) + \frac{(d_1^L - d_1^N)}{(1+r)} + \frac{(d_2^L - d_2^N)}{(1+r)^2} + \cdots + \frac{(d_t^L - d_t^N)}{(1+r)^t}.$$

This approach is most useful for assessing impacts on identifiable assets, supply chains and measurable operational activities. Whether the benefits of delaying the adaptation investment exceed the costs depends on the discount rate, the costs of making the investment in the current period or one period later, and the costs of mitigated damage compared to unmitigated damage (Fankhauser, Smith & Tol, 1999). This assessment is repeated as new information arises which will lead to a set of dynamic results through time. In practice, it will not always be feasible to quantify all of the impacts of reforms to address barriers to climate change adaptation. In these situations, a pragmatic approach is to consider qualitative evidence in any cost-benefit analysis of adaptation

Large projects, particularly ones that cater for adaptive capacity in the form of 'through-life' upgrade options, will face alternative measures during the life of the asset. If CBA is adopted for a project then *average incremental costs* can be computed through the life of that project. This will assist a firm identify the alternatives with the lowest per unit costs. The average incremental cost is calculated as the ratio of the present value of incremental investment and operation costs, with and without the project alternative, to the present value of the incremental output or benefits, with and without the project alternative. It can be estimated as follows:

$$\text{Average incremental costs} = \frac{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{O_t}{(1+r)^t}}$$

where C_t is the incremental and operation investment in year *t*, O_t is the incremental output in year *t*, r is the discount rate and *n* is the remaining life of the project.

CBA is appealing because it compares different categories of benefits or costs using a single value. One major limitation is that it requires all benefits to be measured and expressed in monetary terms and that there is a particular emphasis on efficiency. CBA does not address those equity considerations related to the distribution of the costs and benefits of adaptation options across stakeholder groups. The argument that adaptation options with the best BCR are socially desirable rests on the assumption that those who gain can in principle compensate those negatively impacted by an activity, and still be better off. CBA must also monetise categories of costs and benefits experienced at different times which require the need to discount costs and benefits incurred in the future to compute their present value, but doing so requires choosing a reliable discount rate. An example of how to estimate exposure using CBA is provided in Appendix 5.

Cost Effectiveness Analysis (CEA)

Cost-effectiveness analysis (CEA) can be used to find the least costly adaptation action that achieves a certain (usually physical) target. CEA is performed when some adaptation measures have been identified and the remaining task is to find the lowest-cost option for meeting these objectives. It does not evaluate whether the measure is justified by deriving a benefit-cost ratio or IRR. CEA is generally best applied in assessing adaptation options in areas where adaptation benefits are difficult to express in monetary terms but the costs can be readily identified (e.g. water resources, tonnes of topsoil). The aim of the assessment is not to necessarily identify alternative adaptation options that might yield higher adaptation benefits, but to identify those options that provide suitable activities in vulnerable areas.

Implementing Cost-Effectiveness Analysis

- Agree on the adaptation objective and identify adaptation options. The adaptation objective must be well-defined and measurable as either reducing vulnerability or achieving a certain level of adaptive capacity.
- Establish a baseline. The baseline can either be the status quo or a projected baseline which should be based on a ‘business as usual’ scenario. The firm must agree on a set of indicators for evaluating and tracking benefits in non-monetary terms over time against the baseline.
- Quantify and aggregate the various costs. All costs need to be quantified and aggregated, including direct and indirect costs over the life-cycle. Similar to CBA, all costs should be discounted to their present value.
- Determine the effectiveness. Effectiveness depends on the adaptation objective and the established baseline.
- Compare the cost effectiveness of the available options. Cost-effectiveness can either be compared overall or in incremental terms. An overall cost effective analysis compares the cost per unit of effectiveness for each adaptation option. An incremental cost effectiveness analysis considers the difference in costs divided by the difference in effectiveness that result from comparing one adaptation option to the next most effective policy measure (or baseline). The incremental cost effectiveness ratio is expressed as

$$\text{Incremental CR} = \frac{C_A - C_B}{E_A - E_B}$$

where *C* and *E* are the cost and effectiveness where *A* and *B* are the most effective and second most effective measures respectively. Using an overall CEA is appropriate in cases where only one adaptation option will be implemented, which would be the option with the lowest cost-effectiveness ratio (least cost per unit of effectiveness).

Where a single adaptation measure may not be sufficient such that a combination of different options will comprise the adaptive action, use of an incremental CEA is appropriate. The lowest incremental cost-effectiveness ratio indicates that one approach dominates in terms of cost-effectiveness. To maximise cost-effectiveness, firms should implement an approach until its marginal cost-effectiveness is dominated by that of another approach. Narrowly and naively choosing a single option will rarely be the most cost-effective action and the preferred option often will be a combination of activities.

CEA is an alternative to CBA when the benefits cannot be quantified monetarily to compare alternative adaptation options. CEA cannot be used as a standalone tool for comparing options because the benefits are defined in a single dimension (cost-effectiveness). Other dimensions such as equity, feasibility or co-benefits are not usually considered in the primary analysis. An example of how to estimate exposure using CEA is provided in Appendix 6.

Multi-Criteria Analysis (MCA)

Multi-criteria analysis (MCA) permits the assessment of different adaptation options against a set of criteria. Each criterion is given a weighting and, using the weights, an overall score for each adaptation activity is obtained. The adaptation option with the highest score is deemed the most optimal set of activities. MCA is an alternative when only partial data is available, when certain considerations are difficult to quantify and when the monetary benefit or effectiveness are only one of many criteria. MCA defines a framework to integrate different decision criteria via quantitative analysis without assigning monetary values to all factors. The robustness of MCA depends on the quality of the information used to derive the criteria and the relative weightings given to the criteria. Sensitivity analysis or other optimisation techniques (such as data envelopment analysis) can be used to check the robustness of the result for changes in scores and/or weights.

Implementing Multi-Criteria Analysis

- Identify adaptation options. In contrast to CBA and CEA, an MCA can be conducted in cases where multiple adaptation objectives and criteria exist. For example, adaptation actions may be needed to manage water resources while simultaneously accounting for other development priorities.
- Agree on the decision criteria. Each criterion needs to be described, including the unit and span of possible scores to ensure the assessment process is transparent and objective. A firm may assess adaptation options against their importance or their urgency, or even whether they represent no-regret options and have ancillary benefits and mitigation linkages.
- Score the performance of each action against the criteria. Standardisation is required when scores of the various criteria differ in units (monetary or qualitative values) or time horizons. Transformation of scores into similar units allows for effective comparison of the criteria. Standardisation is completed through a value function or standardisation procedure. The scores will be dimensionless.

- Assign a weight to criteria to reflect priorities. Weightings can be reassigned to appropriately account for firm priorities.
- Rank the options. A total score for each option is calculated by multiplying the standardised scores with their appropriate weight.

Weight-adjusted scores are then aggregated. The main output of an MCA is a rank order of adaptation options and an appreciation of the weaknesses and strengths of the attributes of each of the options. An MCA can be conducted in conjunction with other assessment approaches. MCA identifies various objectives and the criteria to measure those objectives in a transparent manner. MCA can accommodate quantitative as well as qualitative information to help communicate the strengths and weaknesses of each adaptation option.

MCA problems can be represented as

$\max q$

subject to

$q \in \mathbb{Q}$

where *q* is the vector of *k* criterion functions (objective functions) and $\mathbb{Q}$ is the feasible set, $\mathbb{Q} \subseteq R^k$. In most instances relating to adaptation options, $\mathbb{Q}$ is defined explicitly and mathematically the MCA is referred to as a *multiple criteria evaluation* problem.

The main weakness of MCA is the assigning of weights, especially if the number of criteria is large and the criteria are very different in character. Also, standardising scores leads to the loss of some information that could be valuable. The assignment of weights however need not be arbitrary. The use of DEA optimisation techniques, for instance, can avoid the need to reach agreement among stakeholders on criteria and their relative importance. An example of how to estimate exposure using MCA is provided in Appendix 7.

Expert Guidance and Multi-Criteria Analysis

In certain cases where there are unmeasurable impacts along with costs and benefits that cannot be readily monetised, the use of a hybrid between MCA and expert input is required. The objective outputs of MCA combined with the more subjective and intuitive outputs from an expert assessment derive an understanding of loss likelihood and severity which leads to an adaptive action. This approach is similar to risk assessments undertaken in many areas which contain a certain element of subjectivity. It is important to factor in the long horizon of climate change and the associated adaptation activity.

This approach can employ a Delphi method where structured group interaction considers opinions and feedbacks from experts to eventually converge on an agreed level of risk and an appropriate adaptation action. There are other approaches that use similar techniques. These approaches should be used with caution and only when impacts and costs / benefits are not known with certainty.

Other Assessment Approaches

Besides ELA, CBA, CEA and MCA, a number of other approaches can be used to support adaptation planning. These include environmental assessments, expert panels or risk-based approaches in which options that achieve an acceptable risk level can be deemed appropriate.

Risk assessments are appropriate for long-term planning because they can identify programmes and infrastructure most at risk. They combine the likelihood and severity components of climate-related impacts, and can assess risks for both current and anticipated impacts. Climate change risks are assessed alongside other non-climate related risks, ensuring that any identified action can be fully integrated into ongoing planning efforts. Risk assessments often lead to no-regrets, low regrets or win-win options. In many cases they can identify several complementary options that combine to achieve an agreed adaptation goal. Risk assessments should also consider the possibility of ‘knock-on’ impacts; that is, interconnected and interdependent consequences for the business and other stakeholders.

22. APPENDIX 14: RELEVANT ACCOUNTING STANDARDS

Asset Impairment and Adaptive Capacity

Australian Accounting Standard AASB 136 requires that assets on an entity's balance sheet are shown at no more than their recoverable amount. This is the higher of the amount obtainable from the sale of an individual asset or the present value of its anticipated cash flows. Where the recoverable amount of the asset is less than the amount that it is carried at in the balance sheet, the asset is said to be impaired and must be written down to its recoverable amount and the business must recognise an impairment loss. AASB 136 defines impairment loss as the amount by which the carrying value exceeds an asset's fair value and therefore an asset with adaptive capacity may be subject to impairment provisions.

This may be of concern for companies who buy or build assets with contingencies to cope with expected climate change impacts. The recoverable amount of the asset is heavily dependent on the revaluation assessment used. At each reporting date, companies must assess whether there is any indication that an asset may be impaired so in addition to the 'base value' of an asset, any additional adaptive capacity must be assessed.

The standard relating to property, plant and equipment, AASB 116, permits the reversal of previous impairment through higher revaluation of an asset's carrying amount to be credited to equity as a revaluation reserve. It must also be recognised as reversing a devaluation decrease of the same asset previously recognised in the profit or loss statement.

Firms must group long-lived assets with other assets and liabilities at the lowest level for which there are identifiable cash flows. Firms need not check every asset an entity owns in each reporting period. When circumstances change indicating a carrying amount may not be recoverable, firms should test the asset for impairment, and a test is required when *one or more* of the following occurs:

- significant decrease in the market price of a long-lived asset
- significant change in how a company uses a long-lived asset or in its physical condition
- significant change in legal factors or in the business climate that could affect an asset's value, including an adverse action or assessment by a regulator
- accumulation of cost significantly greater than the amount originally expected to acquire or construct a long-lived asset
- current-period operating or cash flow loss combined with a history of such losses or a forecast demonstrating continued losses associated with use of a long-lived asset
- expectation that the entity will sell or otherwise dispose of a long-lived asset significantly before the end of its previously estimated useful life.

The estimated cash flows needed to test for recoverability must include only future flows (cash inflows less cash outflows) directly associated with use and eventual disposal of a given asset. The company should exclude interest charges it will expense as incurred. Cash flow estimates are based on the entity's assumptions about employing the long-lived asset for its remaining useful life.

Many assets are not stand-alone units but rather are integrated with a range of ancillary assets. When an asset group consists of long-lived assets with different remaining useful lives (i.e. different degrees of adaptive or other capacity), determining the group's life is critical to estimating cash flows. But the remaining useful life should be based on the life of the primary asset, which is defined as the most significant asset from which the group derives its cash flow generating capacity, notwithstanding the requirement of AASB 116 to componentise assets. If the primary asset is tangible and depreciable, and contains adaptive capacity, the firm must also justify the following in relation to the primary (adaptive capacity) asset:

- whether the entity would have acquired other assets in a group without this asset
- the investment required to replace the asset, and
- the asset's remaining useful life relative to other assets in the group.

If the primary asset does not have the longest remaining life of the group, the cash flows from operating the group can still be based on that asset's estimated life, using the assumption the company will dispose of the entire group at the end of the primary asset's life. Companies must include an impairment loss in the income from continuing operations before income taxes on the income statement. A not-for-profit organisation would include the loss in income from continuing operations in the statement of activities. When a subtotal – such as income from operations – is present, firms should include the impairment loss in determining that amount.

Other required information companies must disclose in the notes to the financial statements includes:

- a description of the impaired long-lived asset and the facts and circumstances leading to its impairment
- the amount of the impairment loss and the caption in the income statement or the statement of activities that includes the loss
- the method or methods used to determine fair value.

Materiality

In the context of adaptation, materiality is a professional judgement that determines what to include, and how to present adaptive capacity and other activity cost information in financial statements. The fundamental principle behind the reporting of adaptation activities is that information shall (or shall not) be included if it is material (immaterial). The usefulness of information may obviously be undermined if this fundamental principle is not consistently met.

The Australian accounting standard AASB 1031:

- defines materiality

- explains its role in making judgements in the preparation and presentation of the financial statements, and
- requires the standards specified in other Australian Accounting Standards to be applied when the information resulting from their application is material.

The quantitative thresholds used to guide the materiality assessment are set as:

- *material* if equal to or greater than *10 per cent* of the base amount, or
- *immaterial* if the amount is equal to or less than *5 per cent* of the base amount.

These levels are clearly arbitrary, but they are useful as a guide. Materiality levels between 5 and 10 per cent require the professional judgement of the firm to balance the increased costs of monitoring and reporting against the disclosure demands of investors. Other standards, such as AASB 107 Cash Flow Statements, clarify the materiality issue for specific accounts. We note here that the AASB has recently decided to propose the withdrawal of AASB 1031 on the basis that the matters dealt with in that standard are adequately dealt with elsewhere in appropriate accounting principles and standards.

Provisions, Contingent Liabilities and Contingent Assets

International Accounting Standard IAS 37, incorporated by the Australian Accounting Standards Board as AASB 137, ensures that appropriate recognition criteria and measurement bases are applied to provisions, contingent liabilities and contingent assets and that sufficient information is disclosed in the notes to enable users to understand their nature, timing and amount.

Firms should apply AASB 137 in accounting for provisions, contingent liabilities and contingent assets, except in the cases where the provision is covered by another standard (e.g. financial instruments (including guarantees), construction contracts, employee benefits, insurance contracts) or results from executor contracts.

Provisions

Provisions are distinguished from other liabilities due to the uncertainty concerning the timing or amount of the future expenditure required in settlement. Generally, all provisions are contingent because they are uncertain in timing and/or amount. Within AASB 137, the term ‘contingent’ is used for liabilities and assets that are not recognised because their existence will be confirmed only by the occurrence or non-occurrence of one or more uncertain future events (out of the firm’s control). This is a simple overview of a complex set of principles which will not be explicitly addressed here.

AASB 137 requires a provision be recognised when all of the following apply:

- A firm has a present obligation (legal or constructive) as a result of a past event.
- it is likely that an outflow economic benefits will be required to settle the obligation.
- The amount of the obligation can be reliably estimated.

Provisions are measured at the best estimate of the expenditure required to settle the present obligation at the end of the reporting period, and must include considerations for risks and uncertainties, time value of money (if material), future events but must exclude gains from asset disposal and also exclude tax consequences.

Contingent Liabilities

AASB 137 prohibits the recognition of contingent liabilities, given that they are either:

- possible obligations (yet to be confirmed whether the firm has a present obligation that could lead to an outflow of resources that resemble economic benefits), or
- present obligations that do not meet the recognition criteria (either it is not probable that an outflow of resources resembling economic benefits will be required to settle the obligation, or a sufficiently reliable estimate of the amount of the obligation cannot be made).

Contingent Assets

AASB 137 prohibits the recognition of contingent assets, as this may result in recognising income that may never be realised. Contingent assets usually arise from unplanned or other unexpected events that give rise to the possibility of an inflow of economic benefits to the firm (e.g. leasing of assets with adaptive capacity during loss periods).

With reference to both contingent assets and contingent liabilities, it is important to note that AASB 137 also requires certain disclosures that account for obligations, uncertainties and other contingencies using 'best estimates'.

Intangible Assets

IAS 38, also incorporated by the Australian Accounting Standards Board under AASB 138, prescribes the recognition, measurement and disclosures applicable to intangible assets which are not dealt with specifically in another standard. AASB 138 applies to all intangible assets except those dealt with under another standard (e.g. goodwill), financial assets (AASB 132), exploration and evaluation assets, and assets related to the development and extraction of minerals, oil, natural gas and similar non-regenerative resources.

The recognition of an item as an intangible asset applies to costs incurred initially to acquire or internally generate an intangible asset and those incurred subsequently to add to, replace part of, or service it. To meet the definition of an intangible asset, *all* of the following elements must be present:

- identifiable (i.e. separable from the firm)
- control over a resource, and
- future economic benefits.

An intangible asset should be recognised if it is probable that the expected future economic benefits attributable to the asset will flow to the firm and the cost of the asset can be measured reliably.

A firm should assess the probability of expected future economic benefits using reasonable and supportable assumptions that represent management's best estimate of the set of economic conditions that will exist over the useful life of the asset. An intangible asset should be initially measured at cost.

Internally generated intangible assets

To assess whether an internally generated intangible asset meets the criteria for recognition, an entity classifies the generation of the asset into:

- a research phase, and
- a development phase.

An intangible asset arising from development (or from the development phase of an internal project) is to be recognised if all the conditions described below can be demonstrated:

- the technical feasibility of completing the intangible asset so that it will be available for use or sale
- its intention to complete the intangible asset and use or sell it
- its ability to use or sell the intangible asset
- how the intangible asset will generate probable future economic benefits
- the availability of adequate technical, financial and other resources to complete the development and to use or sell the intangible asset, and
- its ability to measure reliably the expenditure attributable to the intangible asset during its development.

Ongoing measurement of intangible assets

After initial recognition, either the cost model or revaluation model can be applied; however, the revaluation model can only be selected if fair values can be determined in an active market. AASB 138 notes that it is uncommon for an active market to exist for intangible assets. However, some jurisdictions may have an active market for freely transferable licences, which may provide a fair value for some intangible assets. An intangible asset is carried at its cost less any accumulated amortisation and any accumulated impairment losses.

Revaluation model

An intangible asset is carried at a revalued amount, being its fair value at the date of the revaluation less any subsequent accumulated amortisation and any subsequent accumulated impairment losses. Fair value is determined by reference to an active market, and revaluations are obtained to ensure the carrying amount of the intangible asset is not materially different from its carrying amount.

The AASB is working closely with the International Integrated Reporting Council (IIRC), which was convened to lead businesses and investors towards an 'integrated reporting' approach, which is aimed to make sustainability issues mainstream.

It is envisaged that climate change adaptation activities will, in due course, form part of integrated reporting alongside strategy, risk, performance and sustainability reporting elements, which are inseparable.

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