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VCCCAR Project: Framing Adaptation in the Victorian Context

**Future potential losses from extremes under climate change: the case of Victoria, Australia**

Working Paper

Adriana Keating and John Handmer

Centre for Risk and Community Safety

RMIT University

ISBN: 978 0 7340 4866 0

August 2013

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**Preface**

This report is a product of the research project “Framing multi-level and multi-actor adaptation responses in the Victorian context.” Previous working papers in this component analysed the variety of estimates of both the aggregate costs of disasters and the cost of specific climate-related events in Victoria (Keating and Handmer, 2011b), methodologies for assessing the costs of climate change (Keating and Handmer 2011a) and the current cost of climate anomalies to key vulnerable sectors in Victoria (Keating, Handmer & Whittaker, forthcoming). This report extends this work by extrapolating these estimates into the future under various climate scenarios, and highlighting issues pertinent to a full cost-benefit analysis of climate change adaptation in Victoria.

**Authorship**

This report was prepared by Adriana Keating and John Handmer, Centre for Risk and Community Safety, School of Mathematics and Geospatial Science, at RMIT University.

Additional reviewers’ input included:

## Summary

Victorian policy-makers have identified that their greatest challenge is identifying priorities and making well-informed decisions in the face of a confounding variety of information on the possible impacts of climate change (climatically, socially, economically), all with significant uncertainties. (Wiseman et al 2011). This report sits within the wider Victorian Centre for Climate Change Adaptation Research (VCCCAR) project entitled “Framing multi-level and multi-actor adaptation responses in the Victorian context.” This project includes a work package investigating a “preliminary economic analysis of climate change impacts.” This report extends this work by exploring how the current costs of bushfire to the Victorian agricultural and timber industries, and heatwave mortality in Melbourne, may change in the future under various climate scenarios, and provides an overview of some key issues in climate adaptation economics in Victoria.

Orthodox economic thinking on climate change adaptation is centred around the optimality criterion, where investment and action on adaptation should maximise benefit to society. Osberghaus et al (2010, pg. 837) state “the sum of all marginal benefits from public adaptation should equal the marginal costs of public investment.” A key aspect of optimality criteria is that in some instances adapting to impacts may not be deemed to be efficient, because the marginal benefits of adapting do not outweigh the marginal costs of the corresponding adaption investment. In these instances the damages would be endured rather than addressed (Osberghaus et al 2010). While private or autonomous adaptation will play a major role in climate change adaptation in Victoria, there exists sites where government intervention is justified. Government intervention is required when autonomous adaptation will not achieve the social optimum due to market failures or information asymmetries (Osberghaus et al 2010) which lead to inefficiency in autonomous adaptation.

Cost-benefit analysis is the standard economic approach to decision-making of this type. Ackerman & Stanton (2011, pg. 6) state in their assessment of the current state of the art of climate economics that “climate economics has often been hampered by its uncritical adoption of a traditional cost-benefit framework, minimizing or overlooking the deep theoretical problems posed by uncertainty, intergenerational impacts, and long-term technological change”. Here we highlight the issues of transformation, intergenerational equity, hard and soft adaptation, data limitations, uncertainty, catastrophes, security of supply and intangibles. We also explore the issue of maladaptation. Moench et al (2007, pg. 16) argue that “[t]he primary value of CBA…lies in the analytical process itself and the manner in which that can be used to force project proponents to clarify the logic relating proposed courses of action”.

The estimates for bushfire costs associated with damage to the Victorian agricultural and timber industries are developed from Lucas et al ‘s (2007) models of predicted increases in bushfire weather under climate change scenarios. We present the results of the cost estimates for two discount rates – 5% and 0.1%, and under two climate change scenarios: CSIRO MK2 and MK3 (CSIRO 2012).

Bushfire and the Victorian agricultural industry:

Total bushfire damage cost from damage to the Victorian agricultural industry under baseline and climate change scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Change in number of days where FFDI>50** | **2020 No climate change** | **2020 low mk2 – 11%** | **2020 high mk3 – 40%** | **2050 No climate change** | **2050 low mk2 – 19%** | **2050 high mk3 – 138%** |
| **Present Value (discount rate = 5%)** | $895.3 | $943.7 | $1059.1 | $2385.7 | $2720.0 | $3761.7 |
| **Present Value (discount rate = 0.1)** | $1136.4 | $1211.9 | $1398.0 | $6156.8 | $7281.2 | $12165.9 |

***With no adaptation, by 2050 increases in bushfire due to climate change will have cost the Victorian agricultural industry an additional $1.4 billion (or $46.6 million per annum by 2050) over and above the no climate change scenario. (High mk3 climate change scenario, 5% discount rate).***

Bushfire and the Victorian timber industry:

Total bushfire damage cost from damage to the Victorian timber industry by 2020 and 2050 under baseline and climate scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Increase based on % change in FFDI>50 days per year | **2020 Exposure only** | **2020 low mk2** | **2020 high mk3** | **2050 Exposure only** | **2050 low mk2** | **2050 high mk3** |
| **i=5%** | $1797.0 | $1894.0 | $2125.6 | $4788.3 | $5459.1 | %7549.8 |
| **i=0.1%** | $2280.7 | $2432.4 | $2805.8 | $12357.0 | $14613.7 | $24417.2 |

***With no adaptation, by 2050 increases in bushfire due to climate change will have cost the Victorian timber industry an additional $2.8 billion (or $93.4 million per annum by 2050) over and above the no climate change scenario. (High mk3 climate change scenario, 5% discount rate).***

Extreme heat mortality in Melbourne:

We note that there is no standard definition of heatwave and estimates vary widely because of this. Developing a standard definition for use throughout Victoria (and potentially Australia) would be beneficial for researchers and policy-makers. The estimates presented here are developed from McMichael’s (2003) estimate of current heatwave mortality in Melbourne. Cost estimates are based on statistical value of life discounted at 5% and 0.1%.

Total number of deaths by 2020 and 2050 due to heatwaves under baseline and climate change scenarios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| 4288 | 4436 | 4522 | 23222 | 27161 | 29436 |

**Total cost of heatwave mortality by 2020 and 2050 under baseline and climate change scenarios, $million 2010AUD**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Total cost low/high by 2020 and 2050, $million 2010AUD** | | | | | | |
|  | **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| **Discount = 5%** | $12779.5 | $13172.9 | $13399.7 | $34036.5 | $38055.9 | $40397.0 |
| **Discount = 0.1%** | $16291.7 | $16854.3 | $17178.7 | $86704.2 | $101319.1 | $109764.2 |

***With no adaptation, by 2050 increases in heatwaves due to climate change will have caused an additional 6214 deaths (or 402 deaths annually by 2050) over and above the no climate change scenario. These figures translate to an additional $6.4 billion (or $218 million per annum by 2050) loss over and above the no climate change scenario. (CSIRO3.5 climate model, 5% discount rate).***

The estimates presented here should be taken as first pass order-of-magnitude assessments. The current damage estimates used are limited in themselves due to data availability, however it is unlikely that they overestimate current costs. Climate change cost estimates are based on a simple, linear extrapolation that assumes a one-to-one relationship between damage and increases in extreme heat days. We judge that the figures presented above are an underestimation of the true cost of extreme heat to these industries, and mortality.

Hallegatte et al (2011) find that it would be ineffective to relegate adaptation decision-making and budgetary commitment to one single government body. Instead they argue that integrating adaptation into all government policies is essential.

Previous work for this project (Keating & Handmer 2011a) outline a starting point for determining estimates of the potential costs of climate change to Victoria. The approach recommended involves a general equilibrium analysis for high-level information on economy-wide impacts including which sectors are vulnerable. This could be complimented by a series of partial equilibrium analyses of key vulnerable sectors. It is in these sectoral analyses that cost-benefit analysis would be a key decision-support tool. This recommendation foreshadows the Productivity Commission’s finding (Productivity Commission 2012) that top-down modelling of adaptation is limited in its usefulness for specific adaptation decision-making because the models tend to be highly aggregated.

In an ideal world a full cost-benefit analysis of all options, with thorough treatment of issues such as uncertainty and intangibles, could be undertaken to inform decision-making. The Productivity Commission (2012) considers that this would be too onerous for their assessment at the national level and it is likely that a similar situation applies to state-level decision-making in Victoria. The costliness of cost-benefit analysis, coupled with criticisms of the methodology outlined here, and other political considerations mean that it is highly likely that cost-benefit analysis will not be the sole determinant of climate change adaptation decision-making in Victoria. If this is the case we strongly urge decision-makers to utilise cost-benefit analysis, potentially including willingness-to-pay considerations as an input into a systematic decision-making framework (UNFCCC 2009).

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## List of Acronyms

ABS: Australian Bureau of Statistics

AUD: Australian Dollars

CBA: Cost-benefit analysis

CFA: Country Fire Authority

CSIRO: Commonwealth Scientific and Industrial Research Organisaiton

DRR: Disaster risk reduction

EIA: Environmental Impact Assessment

FFDI: Forest Fire Danger Index

IPCC: Intergovernmental Panel on Climate Change

OPBR: Office of Best Practice Regulation

VCCCAR: Victorian Centre for Climate Change Adaptation Research

WTP: Willingness-to-pay

# 1. Introduction

To date there is no global agreement on climate change mitigation and very few countries have made individual commitments to reducing their greenhouse gas emissions. Unfortunately the likelihood of a substantial global agreement is considered to be low (Osberghaus et al 2010). Impacts from climate change are already being felt and will continue in the future regardless of any global agreement on mitigation (Ackerman & Stanton 2011). Climate change adaptation is about “reducing vulnerability to these damages and enhancing resilience towards changing climatic conditions” (Ackerman & Stanton 2011, pg. 16).

Victorian policy-makers have identified that their greatest challenge is identifying priorities and making well-informed decisions in the face of a confounding variety of information on the possible impacts of climate change (climatically, socially, economically), all with significant uncertainties. (Wiseman et al 2011). Similarly Batterbury’s (2010) ‘think-tank’ with Victorian local policy and decision-makers found that there “is a need to go beyond case studies to generate comparative studies of the costs and benefits of climate change adaptation options using a rigorous and consistent assessment framework” (Batterbury 2010, pg. 1).

This report sits within the wider Victorian Centre for Climate Change Adaptation Research (VCCCAR) project entitled “Framing multi-level and multi-actor adaptation responses in the Victorian context.” This project includes a work package investigating a “preliminary economic analysis of climate change impacts.” Previous working papers in this series have explored the confounding variety of estimates of both the aggregate costs of disasters and the cost of specific events in Victoria (Keating and Handmer, 2011b), the methodologies for assessing the costs of climate change in Victoria (Keating and Handmer 2011a) and the current costs of climate anomalies to key vulnerable sectors in Victoria (Keating et al *forthcoming*). This report extends this work by exploring how current costs may change in the future under various climate scenarios, and provides an overview of some key issues in climate adaptation economics in Victoria.

This work package responds to the demand from Victorian policy-makers for research on the economic impact of climate change and climate change adaptation options. This is because economics has a vital role to play in adaptation policy because it sheds light on a) the conditions that foster autonomous or private adaptation, and b) the relative costs and benefits of investment in adaptation (Heuson et al 2012). Climate change adaptation economics helps answer the questions of “to what extent, in what areas and at what point of time should a society perform adaptation to climate change?” (Heuson et al 2012, pg. 15).

There are significant challenges associated with the economics of climate change adaptation. While adaptation is now recognised as an essential part of the Australian policy landscape, Hallegatte et al (2011, pg. 3) point out that it remains, for many policy makers “very far from being an operational concept.” This can be attributed to the fact that ‘adaptation to climate change’ will be as all encompassing as climate change itself. Adaptation will occur privately and will require government intervention, it is required in a huge variety of sectors and regions, at a range of scales both geographical and temporal. It will require a suite of responses including investment decisions, tax measures and regulatory adjustments (Hallegatte, 2011).

Our knowledge about the potential economic costs of climate change and adaptation investments, and the potential economic benefits of adaptation is scarce (Aaheim & Aasen 2008). There is significant uncertainty associated with adaptation (discussed below), there is no single measure of adaptation and impacts are highly localized and contextual; all this make climate change adaptation extremely difficult to analyse economically (Ackerman & Stanton 2011). Ackerman & Stanton (2011) lament the fact that climate economics often lags behind the physical sciences, and uses oversimplified representations of the physical science that are often severely out-dated.

Decisions made today will have profound impact on the climate impacts felt in the future, so decisions must be made despite uncertainties. The Economics of Climate Adaptation Working Group’s (ECA, 2009) rapid assessment of the economics of climate change adaptation in eight test cases including cities in the UK and the US came to three key conclusions pertinent to Victoria (ECA 2009, pg. 11): 1) Despite uncertainty it is possible to “build plausible scenarios on which to base decision-making” ; 2) there is “significant economic value…at risk”, and; 3) “between 40-68 percent of the loss expected to 2030…could be averted through adaptation measures whose economic benefits outweigh their costs”.

## 1.1 Defining ‘adaptation’

Before we outline some of the definitions and conceptualisations of climate change adaptation economics, it is first important to distinguish between climate change adaptation and climate change mitigation. Climate change mitigation and climate change adaptation, while connected, have fundamental differences in economic terms. The key difference from an economics perspective is that mitigation is a global public good whereas adaptation is often a private good (discussed below). Similarly the value of mitigation in reducing the impacts of global climate change is relatively certain when compared to local adaptation measures which are uncertain regarding future local climatic and socioeconomic conditions. Mitigation schemes are designed on the principle of ‘polluter pays’ whereas adaptation measures are generally paid for by those who will benefit from them (Heuson et al 2012). Some key differences are outlined in the table below.

Table 1: Aspects of mitigation and adaptation

  
Heuson et al (2012, pg. 12)

There are numerous global studies that use an integrated climate-economy model to interrogate mitigation and adaptation scenarios. While these may have benefits at the international level (for example in the debate about international adaptation assistance to developing nations) their usefulness at the national or sub-national level is limited because confidence in their estimates is low (Handmer et al 2012; Osberghaus et al 2010). The Productivity Commission (Productivity Commission 2012) specifically differentiates adaptation from mitigation as well as from adaptation to mitigation initiatives (ie adapting to the carbon tax). Victoria’s adaptation policy can be viewed as independent from mitigation because mitigation outcomes are determined at the international level.

It is precisely because the benefits of adaptation are local (and the benefits of mitigation are global) that adaptation is increasingly becoming the focus for Victoria in the climate change arena. Furthermore, there are considerable co-benefits to adaptation that can be realised locally, such as reduced risk to disasters. Responding to these potential co-benefits is a key part of optimal adaptation (Productivity Commission 2012). Finally, the benefits of adaptation in many cases have a much shorter time frame than the benefits of mitigation which are multi-generational (Heuson et al 2012). Considering that these benefits are at the scale pertinent to Victorian state policy, it is essential that Victoria turns its attention to adaptation despite the difficult and complex decision-making involved. Furthermore, key theorists in the field of climate change economics argue that the differences between mitigation and adaptation policy outlined above (impact, scale, actors etc) mean that evaluating them separately is preferred (Heuson et al 2012).

Considering adaptation specifically the IPCC (2012, pg. 3) defines adaptation:

*In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.[[1]](#footnote-1)*

Anticipatory and reactive adaptation is one distinction used within the adaptation literature. Anticipatory adaptation consists of actions taken to prevent or ameliorate expected impacts in the future. Reactive adaptation on the other hand refers to actions taken in response to a climate change impact, after it has occurred. The distinction however is not always clear (Hallegatte et al, 2011). For example, actions taken following the Black Saturday bushfires in Victoria may be considered reactionary, however they could also be classed as anticipatory adaptation to similar events in the future, which are expected under climate change.

Aaheim & Aasen (2008) distinguish between ‘autonomous direct’ and ‘autonomous indirect’ adaptation, the former being the direct producer or consumer response to climate change impacts, and the latter being the resulting market adjustments and whole of economy effects. Since this paper focuses on the case for adaptation by Victorian state and local governments this issue will not be further explored here.

Adaptation occurs at different levels or scales, and within discreet or overlapping systems (Heuson et al 2012). For example adaptation may happen at the level of the farm in regards to crop selection in response to drought, right through to the whole of Victoria in the form of health initiatives in response to increased heatwaves. Adaptations can also be distinguished by the system that is impacted, be it the political, economic or ecological system, or some combination (Heuson et al 2012).

Before Victoria looks to the future and considers the possible impacts of climate change on the status quo, it is essential that we first take a step back and consider whether we are currently adapted to the prevailing climatic conditions. This is because adaptation policy can be very different depending on whether its starting point is the current situation or the optimal situation. The current level of risk has not been determined in any systematic way, instead it is the result of historical circumstances. Adaptation that maintains the current risk level may not lead to optimal climate adaptation. Adaptation actions must first look at whether the current risk level is optimal, and may include actions to correct this in the present (Hallegatte et al 2011). Hallegatte et al (2011, pg. 33) define the different definitions of adaptation in Figure 1 below as:

* “The passage from square 1 to square 2 is the reduction of the “adaptation gap”, i.e., the passage from a sub-optimal situation to a situation that would be optimal in the absence of climate change.
* The passage from square 2 to square 4 is adaptation in the strict sense, i.e. the investment necessary because of climate change alone, to go from an optimal state without climate change to a new optimal state with climate change. This type of adaptation can be qualified as " adaptation *stricto sensu*" and corresponds to actions that would not be desirable without climate change and that only become desirable because there is a change in climate.
* The direct passage from square 1 to square 4 is the trajectory that should be followed in practice, i.e., passage from the current sub-optimal situation without climate change to an optimal situation with climate change. This adaptation can be qualified as "optimal adaptation".
* Finally, the passage from square 1 to square 3, i.e., maintaining the risk at its initial level, can be qualified as "constant level adaptation". This type of constant level adaptation is often that which is analyzed in the scientific literature when authors begin with the premise that the current situation is optimal.”

Figure 1: Different definitions of adaptation cost

  
*Source: Hallegatte et al, 2011, pg. 33.*

The estimates presented later in this report could be characterised as assuming adaptation in Victoria would follow the path from square 1 to square 3, which makes no comment on the current level of adaptation to climate anomalies.

Adaptation is not a static goal state. The climate will change constantly for centuries to come, and adaptation is about adjusting to that constant change (Hallegatte et al 2011). The goal of adaptation planning in Victoria is not to go from the current status quo to a new, stable state where we are “adapted to climate change”. Adapting to future climate means making decisions with a recognition that the climate is in a state of dynamic flux.

# 2. Climate change adaptation economics for Victoria

The growing field of climate change adaptation economics applies orthodox and alternative economic theory to the adaptation question at the local, national and international levels. This section outlines some of the issues pertinent to climate change adaptation economics for Victorian public policy decision-making. The optimality criterion, upon which orthodox adaptation economics is founded, is considered first. Next economic theory has much to say on the appropriate sphere for government intervention in adaptation, this section also introduces the issue of equity. Section 2.3 looks at the mechanics of valuing adaptation costs and benefits, with key theoretical and methodological issues. Unfortunately little is known about the costs of adaptation, as shown in the section on the status of global studies. Finally cost-benefit analysis is explored, along with key challenges and limitations and alternative methods.

## 2.1 The optimality criterion

Orthodox economic thinking on climate change adaptation is centred around the optimality criterion, where investment and action on adaptation should maximise benefit to society. Osberghaus et al (2010, pg. 837) state “the sum of all marginal benefits from public adaptation should equal the marginal costs of public investment.” Heuson et al (2012) provides Figure 2 below which is helpful for understanding the dimensions of optimal adaptation through from the micro to the macro level.

Figure 2: Optimal Adaptation

  
*Heuson et al (2012, pg. 17)*

At the bottom of the inverted triangle, the micro level, we have the requirement that a single adaptation measure only be undertaken if its benefit outweighs its cost, and ideally the net benefit is maximised. At the next level several measures addressing one problem, such as the threat of bushfire, are assessed and the measure (or group of measures) that provide the greatest net benefit is selected. Moving upwards the challenge becomes to select the group of measures that provide the greatest net benefit across multiple problems (Heuson et al 2012). This level and the ones below is probably the level at which Victorian Governments are realistically working. The next level up looks at the whole system and then incorporates mitigation; while these levels provide important context for Victoria they incorporate national and global policy and outcomes.

A key aspect of optimality criteria is that in some instances adapting to impacts may not be deemed to be efficient, because the marginal benefits of adapting do not outweigh the marginal costs of the corresponding adaption investment. In these instances the damages would be endured rather than addressed (Osberghaus et al 2010).

A further aspect of optimal adaptation is timing. In sectors that are able to respond quickly and have relatively low capital-intensity, timing of adaptation is less important. However when adaptation will take time and requires many years of transition, selecting the optimal time for adaptation becomes important. Optimal timing of adaptation attempts to optimise over three factors: 1) change in adaptation cost over time, 2) any immediate or short-term co-benefits of adaptation, and 3) long-term irreversibility of the adaptation measure (Heuson et al 2012).

Economic theory states that the goal of climate change adaptation is to maximise the net benefit to society by selecting the type, degree and timing of adaptation measures (Heuson et al 2012). Individual economic actors are in a prime position to respond to climate change (autonomous adaptation) because they will always strive to optimise their position. However there are instances where achieving the social optimum requires government intervention.

While it is a relatively straightforward matter to theoretically conceptualise the costs and benefits of optimal adaptation, it may in practice be very difficult, or even impossible, to determine specific climate adaptation costs. This is partially because many adaptation initiatives are taken within the context of wider social, economic and environmental conditions which may be more influential than the climate change component. Hence separating out the climate adaptation aspect of a decision is not straightforward (OECD, 2008). Furthermore, the theory of optimal adaptation assumes to some degree that a “comprehensive catalogue of potential damages and adaptive measures” (Ackerman & Stanton 2011, pg. 16) can be utilised for decision-making, and this is simply not the case.

## 2.2 The case for government intervention

Mitigation of climate change via reduction in greenhouse gas emissions reduces the overall climate change risk. This reduction in risk is freely available to everybody on the planet, and as such mitigation produces a ‘public good’. Economic theory purports that public goods are market failures (Aaheim & Aasen 2008) and are produced at below-optimal quantities because individuals can benefit from the actions of others without having to take action themselves. As such the economic case for government intervention in the case of mitigation is well established. Adaptation on the other hand often produces private goods because adaptation actions generally reduce risk to a certain group. In the case of private goods economic theory suggests that private goods (adaptation) will be produced by the people who benefit from them and as such the case for government intervention is theoretically less clear (Productivity Commisson 2012; OECD 2008; Hallegatte et al 2011). This is in stark contrast to the unquestioned proliferation of government interest in adaptation in an effort to identify where public funds would be most beneficial.

While private or autonomous adaptation will play a major role in climate change adaptation in Victoria, there exists sites where government intervention is justified. Government intervention is required when autonomous adaptation will not achieve the social optimum due to market failures or information asymmetries (Osberghaus et al 2010) which lead to inefficiency in autonomous adaptation. Aaheim & Aasen (2008) identify three broad categories where government intervention is warranted:

* Public goods: adaptations that produce benefits for multiple economic actors in a non-exclusionary way are likely to be under-pursued privately.
* Large transaction costs: required adjustments may be so expensive for autonomous actors that they will only occur with government intervention.
* Immobility: the factors of production are not always mobile, and may be located in climate-sensitive areas. Example fisheries and tourism.

The Productivity Commission (PC2012) has identified local and State/territory governments are the primary bearers of responsibility for implementing adaptation reform, because climate change impacts are ‘local’ (sub-State). Local governments are tasked with providing locally-specific information on climate change to support private adaptation, as well as incorporating climate change into land use planning. The Victorian State government is tasked with supporting local governments by clarifying their “roles, responsibilities and legal liability” (Productivity Commission 2012, pg. 18) and ensuring they have adequate resources for the task. Here we see that government intervention is not isolated to ‘climate proofing’ major, publically funded infrastructure projects. In fact Hallegatte et al (2011) argue that in many instances action can effectively be achieved at very little cost. Potential government actions include:

* Information dissemination because fundamental research is a public good, also where technical innovation will be beneficial but will not be pursued privately (Hallegatte et al 2011; Productivity Commission 2012; Heuson et al 2012; Osberghaus et al 2010).
* Disaster-mitigation infrastructure because benefits to the community outweigh costs and there are barriers to collective action at the local level (Productivity Commission 2012; Osberghaus et al 2010; Hallegatte et al 2011; Aaheim & Aasen 2008).
* Land use planning to ensure that private decisions take long term and intergenerational consequences into account (Hallegatte et al 2011; Ackerman & Stanton 2011; Aaheim & Aasen 2008)
* Externalities, such as the fact that it is profitable for a developer to build on a flood plain but this is not optimal for the community at large (Hallegatte et al 2011). Environmental externalities such as water usage (OECD 2008) can be incentivised by incorporation into economic systems by creating markets for these.
* Climate risks associated with government activities (Productivity Commission 2012) including major infrastructure networks, including public-private partnerships (OECD 2008; Hallegatte et al 2011)
* Standards and regulations, in terms of building codes etc, to ensure that they allow individuals and companies to respond to signals to adapt, and to mainstream adaptation considerations into all government procedures. (Productivity Commission 2012; OECD 2008; Hallegatte et al 2011)
* Taxation and levies such as on general insurance and property transfers (Productivity Commission 2012).
* In cases where a community is heavily dependent on a climate-sensitive industry (immobility) (Aaheim & Aasen 2008).
* Equity issues (Productivity Commission 2012; Hallegatte et al 2011). Productivity Commission (2012) argues that standard social security and tax-based mechanisms are the best way to address distributional impacts from climate change and climate change adaptation initiatives.

Equity is a key concern for all policy-makers and is a central theme in the climate change adaptation field. The neoclassical economics view is that equity issues in climate adaptation ought to be dealt with via the welfare and taxation system (Dobes & Bennett 2009; Productivity Commission 2012). This way relative prices are not distorted and there is transparency in government support (Osbergaus et al 2010). This approach is favoured by the Productivity Commission’s draft report on barriers to climate adaptation (Productivity Commission 2012). However this approach is not always possible and/or adequate. Osbergaus (2010) describes the use of heat wave shelters for the homeless which are increasingly being used in the United States. This example shows the importance of specifically considering equity in all decisions, rather than just relegating it to the social welfare and taxation sphere – clearly social welfare and taxation would not be a sufficient approach for homeless people in the event of a heatwave. Economics cannot determine for policy-makers how equity should be treated in climate change adaptation policy because this is a political question (Osbergaus et al 2010). However economic analyses can include analysis on how costs and benefits will be distributed between different groups in society.

The Victorian economy is never in a static state, it is constantly changing and adapting. Climate change may hasten and increase structural changes and this is a key challenge for government (Aaheim & Aasen 2008). Fostering a strong and flexible economy through education and a facilitative business environment is an important step in allowing the economy to autonomously adapt to climate change (Productivity Commission 2012; Dobes 2012; Aaheim & Aasen 2008). However, it is also a key responsibility on government to monitor and respond to issues of social upheaval and exclusion and the possibility of unemployment (Aaheim & Aasen 2008).

### 2.2.1 Moral hazard

Several authors highlight the potential for moral hazard in climate change adaptation, where a planned adaptation is a substitute for an autonomous one. When there is an expectation that government will bear some or all of the costs associated with a climate change impact, individuals and businesses lack appropriate incentives to engage in autonomous adaptation (Aaheim & Aasen 2008; Heuson et al 2012; OECD 2008). A common example relates to government recovery payments following a natural disaster, which creates an expectation that government will cover costs following future disasters, which in turn dulls the incentive of individuals and businesses to protect themselves through hazard reduction and/or full insurance coverage (Aaheim & Aasen 2008; Productivity Commission 2012; OECD 2008). Another example refers to a planned coastal protection initiative that reduces incentive for autonomous protection (Heuson et al 2012). Examples like this highlight the need for a thorough analysis of potential investments.

How the above theory plays out in Victoria is unclear. The Productivity Commission (2012) has argued that cash transfers for farmers suffering drought and flood or bushfire disaster victims create a disincentive to adapt to climate change. This assumption is questionable when one considers whether a cash transfer of a few thousand dollars even begins to compensate people for the loss of loved ones and livelihoods.

While substitutive adaptations as the ones described above highlight potentially sub-optimal planned adaptation, there also exist instances where a planned adaptation can be a complement to autonomous adaptation. In these cases the planned adaptation increases the benefits from autonomous adaptation, for example by reducing transaction costs associated with an autonomous adaptation (Heuson et al 2012). For example, a government may create a favourable taxation environment (planned adaptation) to encourage people to take up a particular vulnerability reduction practise (autonomous adaptation). OECD (2008) cautions against government subsidies for systemic risks as discussed above, however they do point out that government intervention may be required to reduce risk levels when catastrophic risk is creating an imperfection in the insurance market. They alternatively suggest that government subsidises insurance against low probability high impact events.

## 2.3 Valuing the costs and benefits of adaptation

The consensus in economics is that an adaptation initiative ought to be pursued if its expected marginal cost (to the Government) equals the expected marginal benefit (to society). Hallegatte et al (2011, pg. 7) state that the “cost of adapting to climate change is the sum of investment costs and operating costs linked to the establishment of adaptation strategies.” They point out that climate change adaptation will not totally ameliorate the impacts of climate change, but that the goal is to optimize climate change adaptation investment over time to minimize undesirable climate change impacts (Hallegatte et al 2011). UNFCCC (2009, pg. 3) defines the costs of adaptation as “the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs” and the benefits of adaptation as “the avoided damage costs of the accrued benefits following the implementation of adaptation measure”. In this context the costs and benefits are not only financial but consider wider societal impacts.

Many theorists (World Bank 2010) measure the benefit of adaptation in terms of climate change damages avoided. So the benefit of adaptation is calculated by estimating the total damage costs of climate change without the adaptation, then deducting the estimated damage cost avoided by the adaptation (because it is unlikely that the total damage costs of climate change will be avoided). Co-benefits that flow from adaptation measures are also ideally estimated and included as benefits. Estimating the benefit of adaptation is complicated by the difficulty in assigning a dollar value to intangible assets such as ecosystem services.

Dobes (2012) argues that the damage-cost avoided approach to benefit estimation is fundamentally problematic because it is at best “a very poor proxy for the conceptually correct measure of ‘willingness to pay’ (WTP) for adaptation measures, or the converse of ‘willingness to accept’ any negative aspects associated with climate change” (Dobes 2012, pg. 6). He proposes a series of choice modelling studies to estimate willingness to pay to address climate disaster damages in different regions. While this critique identifies important issues, WTP estimates are themselves highly contentious (Venkatachalam 2004).

Heuson et al (2012) outline the two general approaches to empirically determining the costs and benefits of adaptation – via a bottom-up or a top-down approach. Top-down approaches utilise downscaled estimates from global Integrated Assessment Models (which model the global climate-economy system) in a process called ‘dynamic downscaling’. The bottom-up approach first utilises local or regional climate projections and impact estimates; then with the input of local decision-makers and stakeholders potential adaptation options are determined and evaluated economically. While the top-down approach is beneficial in the fact that these studies can utilise available global models, they have been criticised for the fact that the investment flow focus leads them to omit relevant costs. Bottom-up studies on the other hand are more able to capture important local and regional conditions relevant to decision-making at that level (Heuson et al 2012). Considering the relative strengths and weaknesses of these approaches we suggest that a bottom-up approach is best for Victoria, with a top-down study potentially providing contextual backing.

### 2.3.1 Global studies

There have been a few key global studies on climate change economics that have drawn attention to the significance of potential economic impacts. Unfortunately, as OECD (2008) and Handmer et al (2012) suggest serious limitations inherent in global, multi-sector studies mean that their usefulness for national or sub-national decision-making is limited.

Global studies draw much of their estimate by assessing the cost of ‘climate proofing’ investments. These estimates are based on assumptions about the exposure of investments and costs associated with climate proofing them; there is little empirical support for the assumptions regarding these parameters. Furthermore they rarely include the benefits of adaptation (OECD 2008). Many global adaptation studies are scaled up from a limited number of local studies. They have the problem of double-counting and are not directly attributable to specific investments in adaptation (OECD 2008; Haneman 2008). Haneman (2008) identify several key problems with global studies such as compounding uncertainties, lack of data and overestimation of benefits. UNFCCC (2009) add to this list problems with non-monetary benefits, cross-sectoral and wider economic effects and the limits of adaptation.

Ackerman & Stanton (2011) review recent estimates of global adaptation costs for near-term adaptation and fine a range of annual estimates from as little as $4 billion to $166 billion. They conclude that this range indicates that it is not currently feasible to draw conclusions about even the order of magnitude of costs. Haneman (2008) similarly concludes that significant issues with global studies coupled with their aggregate level, mean that scaling down for local estimates should be avoided. Handmer et al (2012) also find little confidence in the global estimates.

Despite significant problems identified with global studies UNFCCC (2009) find much promise in sub-national and local analyses. They conclude that these studies are more able to effectively address issues of hard/soft options, co-benefits and real option values (discussed below).

### 2.3.2 Cost-benefit analysis and real options

Many economists (see for example Dobes 2012) suggest that cost-benefit analysis is the most appropriate evaluative procedure on which to make specific adaptation decisions. The merits and limitations of the cost-benefit analysis methodology for climate change adaptation is a hotly debated topic. The most significant challenge relates to how we measure expected costs and benefits with compounding uncertainty in climate change impact estimates. Another key issue relates to how ‘benefit’ is defined and estimated. These issues are addressed below.

Cost-benefit analysis is a tool that is used to systematically “organize, appraise and present the costs and benefits, and inherent tradeoffs of projects taken by the public sector authorities” (Moench et al 2007). Cost-benefit analysis calculates expected net values by summing the probability weighted set of all contingencies according to :

Equation 1: Expected net benefit in cost-benefit analysis  
E[NB] = p1(B1 – C1) + … + pi(Bi – Ci) + … + pn(Bn – Cn) (Dobes 2012, pg. 6)

Where E[NB] is the expected net benefit, p is the probability of the contingency occurring, B is benefit and C is cost.

As this equation demonstrates, traditional cost-benefit analysis assumes that the probability of each occurrence is known. In order to address this uncertainty an increasingly popular extension of cost-benefit analysis is cost-benefit analysis including ‘real options’. As discussed above optimal adaptation includes selecting not only the optimal adaptation measures but their optimal timing. Adaptation costs change over time, and immediate benefits must be weighed against irreversibility (Heuson et al 2012). Dobes (2012) argues that the significant uncertainties mean that the potential for irreversible maladaptation should play a significant part in the decision-making process. Dobes and others (Productivity Commission 2012; see Heuson et al 2012) suggest that option value theory is an applicable model for addressing uncertainty in climate change adaptation decision-making.

Dobes (2012) describes the real options approach for situations where the probability of an occurrence is uncertain to the point where traditional cost-benefit analysis is inappropriate. The benefit of real options is that they retain flexibility, they maintain the option to make a more appropriate decision once more information becomes available. Dobes compares the standard cost-benefit approach with a cost-benefit with real options approach in relation to a dike proposal. In the standard cost-benefit approach costs of acquiring and preparing land plus building the dike today are weighed against future benefits. In the real options approach action taken today only involves acquiring and preparing land – the option to build the dike in the future is there, once when more information is known. In this case the ‘option value’ is the strategic flexibility, and the premium is the cost of acquiring and preparing land. Dobes states that the “greater the degree of uncertainity, and the longer the period during which the option can be exercise, the greater is the value of the flexibility afforded by the option” (Dobes 2012, pg. 8).

The real options approach applies when people can reasonably expect that their knowledge will increase in the future. In these instances there is a benefit to delaying action, particularly when action taken now could be costly if it turns out to be inappropriate (Productivity Commission 2012). In these instances the real options approach suggests favouring options that contribute to addressing the current scenario and maintain flexibility for future actions (Productivity Commission 2012). As Dobes (2012) points out, public policy decision-makers are not experienced at making decisions under uncertainty and formally justifying the value of maintaining flexibility.

### 2.3.3 Key challenges for cost-benefit analysis

As Dobes & Bennett (2009) assert, cost-benefit analysis can theoretically incorporate all costs and benefits to society, including social ones. Moench et al (2007) claim that while this is theoretically the case, in reality most cost-benefit analyses fail to fully include costs and benefits that are not easily quantifiable.

The key benefit of cost-benefit analysis is that because all items are assessed in dollar terms, comparisons between projects and goals are clear (Heuson et al 2012). However there are significant challenges for cost-benefit analysis in terms of valuing intangible assets such as ecosystem services, as described in earlier work on this project (Keating and Handmer 2011b).

Ackerman & Stanton (2011, pg. 6) state in their assessment of the current state of the art of climate economics that “climate economics has often been hampered by its uncritical adoption of a traditional cost-benefit framework, minimizing or overlooking the deep theoretical problems posed by uncertainty, intergenerational impacts, and long-term technological change”.

Moench et al (2007, pg. 16) argue that “[t]he primary value of CBA…lies in the analytical process itself and the manner in which that can be used to force project proponents to clarify the logic relating proposed courses of action”.

*Transformation*  
The modelling and valuation methods described above are largely suited to assessing economic changes at the margins of current systems. It may be the case that some places and/or sectors in Victoria may have to undergo significant transformation[[2]](#footnote-2) or bifurcation in light of climate change impacts. Examples include the moving of an entire population due to unacceptable risk of natural disasters or the shifting of an entire industry due to the present geographical region becoming unsuitable for production (Aaheim & Aasen 2008). These changes are not marginal and as such the economic techniques described here would have difficulty assessing them. It is important that transformations are not ignored simply because they cannot be easily assessed by dominant assessment methodologies such as cost-benefit analysis (Hallegatte et al 2011).

*Intergenerational equity and the discount rate*

Discounting in economics is used to determine the present value of future costs (and benefits). Discount rates are usually positive because they reflect a preference for consumption today over consumption tomorrow – a dollar today is worth more than a dollar tomorrow. The size of the discount rate determines how much the future is discounted *vis a vis* the present[[3]](#footnote-3). The debate most pertinent to the issue of discount rates is that of intergenerational equity. Because decisions made today will have significant impacts for generations to come, the treatment of the discount rate is crucial (Ackerman & Stanton 2011). Batterbury (2010) found that the treatment of the discount rate was a “critical factor” for Victorian local policy and decision makers.

Ackerman & Stanton (2011) argue that all analyses should include a statement explaining the choice of discount rate. They further suggest that when the case of a particular choice of discount rate is weak the discount rate should be varied and multiple results reported.

*Hard vs soft adaptation*

The literature on climate change adaptation distinguishes between ‘hard’ and ‘soft’ adaptation options. Hard adaptation is adaptation via specific investments in physical assets, for example a sea wall. Soft adaptation on the other hand relates to information, regulation and institutional factors. It is generally considered more difficult to assess the economic impact of soft initiatives compared to hard ones (OECD 2008; Hallegatte et al 2011). It has been suspected that this is leading to a bias in adaptation cost estimates that may be favouring hard measures and leading to an overestimation of adaptation costs (OECD 2008). It is imperative that soft adaptations are not ignored due to estimation difficulties because a) they may be the most effective course of action, b) they are thought to often be more cost effective (OECD 2008; Hallegatte et al 2011), and c) they may retain more flexibility in the future. It may be the case that soft initiatives are not in direct competition with hard one, but that they are necessary complements. In this case it is also important that they are not ignored due to estimation complexity, because they can generate considerable benefits within the overall adaptation policy; an adaptation policy that ignores institutional issues for example, is unlikely to meet its objectives (Hallegatte et a 2011; IPCC 2012).

*Data limitations*

The data requirements of cost-benefit analysis specifically and adaptation estimates in general are not always easy to meet. Handmer et al (2012) find that estimates to date are still partial and preliminary, and subject to compounding uncertainty in estimates and assumptions. As Keating & Handmer (2011b) show, even assessing the cost of current climate anomalies in Victoria is a significant challenge.

*Uncertainty*There are various sites of uncertainty pertinent to climate change adaptation economics in Victoria:

* Uncertainty about the extent of future emissions. This depends on future scenarios of global mitigation agreements, global population growth and technological advances (Productivity Commission 2012).
* Uncertainty about the effect of emissions on mean climate variables. Climate models can project some of these variables better than others (IPCC 2012; Agrawala et al 2012). Agrawala et al (2012) report that temperature increase is more easily estimated than is sea level rise and changes in rainfall, which are again more easily estimated than changes in wind intensity.
* Uncertainty about the effect of emissions on extremes. Projecting this is more difficult than for mean changes, while it is changes in extremes that are arguably more important for adaptation decision-making (Jotzo 2012).
* Uncertainty is higher for local level predictions than global predictions. This may even be exacerbated by local variability (Hallegatte et al 2011). This is unfortunate since this is the scale at which many adaptation decisions are felt (Agrawala et al 2012).
* Uncertainty about future socio-demographic conditions and future vulnerabilities (Handmer et al 2012)
* Uncertainty increases with time (Ackerman & Stanton 2011). Many decisions such as infrastructure standards and settlement patterns have key implications far into the future.

When these long time spans are coupled with the uncertainty regarding the impacts of climate change there is a very real risk of maladaptation (Hallegatte et al 2011). Traditional economic theory has a difficult time calculating net present value when the probabilities of outcomes in the future are not know (Ackerman & Stanton 2011). How Victoria makes these decisions in light of what we know, and what we do not know, about climate change is a key question for policy makers.

Taking action in the face of uncertainty is essential, and the best outcomes will be achieved if decision-makers are given the best possible information available, and are able to make decisions that maintain flexibility in response as new information becomes available in the future (Hallegatte et al 2011).

*Low-probability, high impact events*

Low-probability high impact events are a challenge for climate economics. Catastrophic disasters are one such possibility, which are relatively easy to imagine. However the most recent climate science also warns of the possibility of various catastrophic risks where a climatic tipping point is reached which shifts the entire climate system with catastrophic outcomes for human welfare. These types of events are inherently uncertain and will remain so; learning by doing or a wait and see approach are not an option here (Ackerman & Stanton 2011).

A key criticism of CBA is that the significant impacts of catastrophic events are given little importance because of the low-probability of these events (Hallegatte et al 2011). The costs associated with catastrophes can be underestimated because traditional cost assessments typically ignore (potentially non-marginal) indirect and intangible impacts which may be profound in the case of catastrophe. As Jotzo (2010) points out, it is these events that are arguably the main driver behind climate change mitigation and adaptation action.

*Security of supply*

The CBA methodology does not consider the value placed on security of supply of energy, food, water etc. For example, a CBA analysis might determine that the presence of relatively inexpensive food imports mean that it is not cost effective to adapt the Victorian food industry to climate change impacts. While this may be correct economically, it does not speak to the issue of security of supply. Victorian policy-makers may wish to maintain a local agricultural industry to ensure against disruptions in global food markets, or even to maintain the history and culture of rural Victoria. It is theoretically possible to include these issues within the CBA framework by undertaking a WTP analysis to determine the value of security of supply and rural cultural heritage, however this is currently uncharted waters as far as we are aware.

*Intangibles*The valuation of intangible impacts of climate change is a key issue in climate change adaptation. Intangible effects are those that pertain to ‘assets’ for which there is no market and as such are not immediately measurable in monetary terms (Markantonis et al 2012). Frequently cited categories of intangibles include mortality and morbidity, environmental amenity, ecosystem services, cultural heritage and community cohesiveness.

Including loss of life in a cost-benefit analysis is a relatively straightforward procedure for economists. The Australian Office of Best Practice Regulation provides guidance on valuing lives in regulation appraisal for example; they put the statistical value of life at $3.5 million (AUD2007) (OBPR 2008). While this is widely accepted by economists it is conceptually contentious in many other arenas (Moench et al 2007).

In regards to valuing effects on intangibles such as environmental assets or cultural heritage, orthodox economics proposes the use of contingent valuation methods. While it is theoretically possible to valuate intangibles using these methods, it is rarely done due because it is resource intensive, conceptually challenging and theoretically contentious (Barkann et al 2008). The valuation of intangibles is plagued by two significant ideological debates. Firstly, ecological economists argue that the possibility of trade-offs (substitutability) implied by aggregating methods such as cost-benefit analysis is invalid because there comes a point where we can no longer trade consumption for clean air (Neumayer 2007). Secondly, at a deeper level many non-economists are uncomfortable with the prospect of attributing a monetary value to assets that they consider to be priceless (Farber et al 2002; Bell et al 2003).

The valuing of intangibles in the disasters field highlights two significant ideological debates in disasters research and climate change adaptation alike. Firstly in relation to valuations of the environment such as ecosystem services the question of substitutability is a key debate. Orthodox economics approaches such as cost-benefit analysis reduce all costs and benefits to their dollar value and thereby assume that their values are substitutable. Ecological economists argue that in some cases this trade-off is invalid because human-produced capital (ie consumption) cannot be an adequate substitute for natural capital (for example an ecosystem) (Neumayer 2007). Eventually, as environmental quality declines, substitution will become impossible. Secondly, an even deeper ideological rift exists – and is often highlighted in discussions with non-economists – whereby some feel that it is invalid to even attempt to ascribe a monetary value to the environment or human lives, which are seen as priceless (Farber et al 2002; Bell et al 2003).

### 2.3.4 Maladaptation

Maladaptation, or adaptation gone awry, is a serious threat to the success of adaptation initiatives (Hallegatte et al 2011). While definitions of maladaptation vary, Barnett & O’Neill’s (2010) paper synthesises and extends various definitions and defines it as:

*Action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups (Barnett & O’Neill 2010).*

Barnett & O’Neill (2010) identify five types of maladaptation. They state that actions, relative to alternatives, are maladaptive if they:

* Increase emissions of greenhouse gases
* Disproportionately burden the most vulnerable
* Have high opportunity costs
* Reduce incentives to adapt
* Set paths that limit the choices available to future generations

Research within the natural hazards field sheds light on how the practice of cost-benefit analysis can engender a maladaptive threat via the problems of low probability/high impact events (described above), the levee effect and socioeconomic inequality contributing to vulnerability. The levee effect occurs when a levee is built and people assume that it will provide protection against floods and as such build on the lands “protected” by the levee, thereby increasing future damages (Travis 2010). When the levee effect is not anticipated and factored into the analysis results are more likely to favour a path that is ultimately maladaptive. Similarly when analyses disregard the impact of adaptation actions on vulnerability, for example by exclusively focussing on aggregate outcomes, they can be maladaptive.

### 2.3.5 Alternatives to cost-benefit analysis

*Low-regrets*  
One starting point for adapting to climate change under uncertainty is to initially focus on low-regrets measures. These initiatives are ones that have benefits regardless of future climate scenarios, or in the near future under more certain climatic conditions (Ackerman & Stanton 2011; IPCC 2012). The prime example of a low-regrets adaptation is improved disaster risk reduction because it has considerable benefits in the present (Aasheim & Aasen 2008) and addresses the climate change impacts expected in the next 100 years. Other examples include improvements in water or energy efficiency (Ackerman & Stanton 2011). Low-regrets policies are also ones that “aim to reduce exposure and vulnerability and to increase resilience and preparedness for risks that cannot be entirely eliminated” (IPCC 2012, pg. 16). Heuson et al (2012) suggest that the presence of uncertainty dictates that measures to enhance adaptive capacity, rather than ‘hard’ adaptation measures, allow more flexibility and hence are preferred. Dobes’ (2012) proposal for the use of the ‘real options’ framework described above is one way to formally quantify and incorporate a low-regrets criteria into more traditional methods.

*Precautionary cost-effectiveness analysis*

As Jotzo (2010) points out, it may in fact be the case that catastrophic risks are the ones driving the need for climate change adaptation, especially significant public investments. Cost-benefit analysis has been criticised (see below) for its treatment of low probability, high impact events. An alternative decision-making framework in light of this issue is based on the ‘precautionary principle’. These standards-based approaches are sometimes referred to as “safe minimum standards” or “tolerable windows” (Ackerman & Stanton 2011). This type of decision-making framework leads to a cost-effectiveness analysis where the least-cost option for achieving the standard is considered optimal. Cost-effectiveness analysis is a special type of cost-benefit analysis and many of the methodological approaches and issues carry over. With cost-effectiveness analysis only the costs of adaptation need to be estimated, not the damages avoided; this reduces some of the uncertainty inherent in estimating future scenarios.

*Multicriteria analysis*

Hallegatte et al (2011) argue that multicriteria analysis is useful because it allows for the consideration of impacts and projects that are not easily assessed using cost-benefit analysis. Dobes & Bennett (2009) vehemently disagrees with this assessment, describing multi-critieria analysis as being “founded in conceptual quicksand” (Dobes & Bennett 2009, pg. 8). They argue that the use of experts, interest groups and self-selecting focus groups to determine the weights applied to specific impacts introduces intolerable bias to the exercise, as compared to cost-benefit analysis which they argue takes the view of all of society.

However Hallegatte et al (2011) also suggest that regardless of choice of assessment method, cost-benefit analysis should always be included.

# 3. What we know about future losses in Victoria

The current body of evidence on the economic costs and benefits of adaptation is unfortunately very limited; this has been demonstrated by a review of the literature for this project and is reported by others (Aaheim & Aasen 2008; Handmer et al 2012). Despite this there is sufficient evidence to provide a starting point for establishing areas of urgency for climate adaptation in Victoria.

Work on this project utilises what we know about the current costs of climate extremes to begin to explore the potential costs of adaptation. International experts are in “high agreement” (IPCC 2012, pg. 9) that there are key synergies between disaster risk management and climate change adaptation. Quality disaster risk management in the present sets the foundations for climate change adaptation in general and adaptation to increasing frequency and severity of extreme events in particular. IPCC (2012, pg. 9) argue that “[s]trategies and policy are more effective when they acknowledge multiple stressors, different prioritized values, and competing policy goals.”

There is strong evidence to suggest that post-disaster recovery and reconstruction provide a valuable opportunity for adapting to climate-related disaster risk, and to improve adaptive capacity. It is paramount that response and rebuilding efforts are situated within a long term planning policy in order to take advantage of these opportunities (IPCC, 2012). Assessing the costs of current and future disaster losses in Victoria is an important input into this sort of policy.

Hennessy et al. (2007) identify a number of Australian sectors as being particularly vulnerable under climate change: agriculture, health, and tourism and recreation. The *Victorian Climate Change Adaptation Plan* (DSE 2013) does not assess or compare the vulnerabilities of key sectors however the adaptation priorities identified in the Plan highlight in particular the vulnerability of the agriculture, emergency services and health sectors to extreme events.

The estimates presented here look at the potential future costs of the extreme heat via bushfires to the Victorian agricultural and timber industry, and heatwave mortality in Melbourne. IPCC (2012, pg. 3) defines ‘climate extreme (extreme weather or climate event’ as:

*The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events an extreme climate vents are referred to collectively as ‘climate extremes.’*

The following estimates are built upon estimates derived in previous work for this project (Keating et al *forthcoming*) that estimates current costs of bushfires to the Victorian agricultural and timber industries, and heatwave mortality in Melbourne. Details of how our estimates are derived are outlined below, it should be noted that they are first-pass, order of magnitude assessments and should be read cautiously.

The IPCC (2012, pg. 14) states that “[i]n many regions, the main drivers of future increases in economic losses due to some climate extremes will be socioeconomic in nature (medium confidence, based on medium agreement, limited evidence)”. Handmer et al 2012 argue that a key challenge for assessing the costs of climate change impacts of extreme events is to extrapolate with consideration of future demographic conditions rather than current ones. The estimates presented here have are based on certain assumptions about future industry and population conditions.

Global studies predict that modest adaptations in agriculture could have a significant impact on ameliorating predicted negative impacts from climate change on crop yield (OECD 2008). Of course this varies by region and type of agricultural production so we cannot directly make this claim for Victoria.

## 3.1 Methodology

The estimates for bushfire costs associated with damage to the Victorian agricultural and timber industries are developed from Lucas et al (2007) models of predicted increases in bushfire weather under climate change scenarios. The models predict changes in bushfire weather across Australia, as represented by the forest fire danger index (FFDI). The FFDI is a composite index that considers weather factors influencing the likelihood and severity of fire in a particular location on a given day. Forecast FFDIs form the basis for fire weather warnings. The FFDI scale and warnings are:

Table 2: Forest Fire Danger Index ranges

|  |  |
| --- | --- |
| Fire Danger Rating | FFDI Range |
| Low | 0-5 |
| Moderate | 5-12 |
| High | 12-25 |
| Very high | 25-50 |
| Extreme | 50-100 |
| Catastrophic (Code Red) | 100+ |

*Source: Bureau of Meteorology 2012,* [*http://www.bom.gov.au*](http://www.bom.gov.au)

Lucas et al (2007) generate their estimates using two CSIRO climate simulations – CCAM (Mark2) and CCAM (Mark 3), and a ‘low’ and ‘high’ climate change scenario within each model. Results presented here estimate costs under the lowest and highest climate scenarios, delineated as ‘low mk2’ and ‘high mk3’.

below shows Lucas et al’s (2007) Victorian estimates, under the different climate scenarios, the average number of days per year where FFDI is at least 50 (“extreme” or greater) and the percentage change from current conditions.

Table 3: Change in average number of days per year where FFDI is at least 50 (“extreme” or greater”)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Site** | **Now** | **2020 low mk2** | **2020 high mk3** | **2050 low mk2** | **2050 high mk3** |
| Bendigo | 1.2 | 1.5 | 2.0 | 1.6 | 4.0 |
| % change |  | 23% | 65% | 35% | 230% |
| Melbourne AP | 2.5 | 2.8 | 3.4 | 3.0 | 5.8 |
| % change |  | 12% | 38% | 20% | 136% |
| Mildura | 7.3 | 8.0 | 10.0 | 8.6 | 15.9 |
| % change |  | 10% | 38% | 18% | 120% |
| Sale | 0.6 | 0.6 | 0.9 | 0.6 | 1.9 |
| % change |  | 5% | 45% | 5% | 215% |
| **AVERAGE** | **2.9** | **3.2** | **4.1** | **3.5** | **6.9** |
| **% change** |  | **11.2%** | **40.5%** | **19.0%** | **137.9%** |

*Adapted from Lucas et al (2007)*

Lucas et al (2007) present data for estimates of changes in annual cumulative FFDI as well as change in the average number of days where FFDI exceeds 25. The analysis presented here is based on change in average number of days per year where FFDI exceeds 50. This is justified because, as seen in Table 4 below, the majority of the fires upon which the original estimates were based occurred on days where FFDI was greater than 50.

Table 4: FFDI for Victorian fires used in Keating et al’s (*forthcoming*) analysis of the current cost of bushfires to Victorian and agricultural industries

|  |  |
| --- | --- |
| **Fire** | **FFDI (source for FFDI)** |
| 1983 Ash Wednesday - Victoria only | 110 (Blanchi et al 2010) |
| 1985 Central Victoria and Alpine fires | 91 (Blanchi et al 2010) |
| 1990 Strathbogie | 48 (Blanchi et al 2010) |
| 2000 Dadswell Bridge | Unknown |
| 2003 Alpine fires - Victoria only | 63 (Tolhurst 2009) |
| 2005/06 Grampians | 60 (Blanchi et al 2010) |
| 2006/07 Great Divide Complex - Cooma, Melbourne | 100+ (Comrie 2010) |
| 2009 Black Saturday - Cooma, Mount Gambier, Warrnambool, Wilsons Promontory, Melbourne | 134 (Blanchi et al 2010) |

We present the results of the cost estimates for two discount rates – 5% and 0.1%. A 5% discount rate is low for many analyses but more standard considering the lifespan of adaptation decision-making. A discount rate of 0.1% (close to zero) is contentious in the economics field but promoted by some theorists as the only one that is ethical from the standpoint of intergenerational equity (see section 2.3.3 for further discussion). Both results are presented here as a type of sensitivity analysis and to show the impact discount rates can have on outcomes. These estimates are meant only to shed light on the types of costs associated with climate change in Victoria, rather than to be specific inputs into an adaptation cost assessment. For in-depth adaptation cost assessment the choice of discount rate(s) depends on various factors.

The estimates presented here should be taken as first pass order-of-magnitude assessments. The current damage estimates used are limited in themselves due to data availability, however it is unlikely that they overestimate current costs. Climate change cost estimates are based on a simple, linear extrapolation that assumes a one-to-one relationship between damage and increases in extreme heat days. We judge that the figures presented above are an underestimation of the true cost of extreme heat, for three key reasons:

1. Due to lack of data availability many bushfires were not included in the ‘current cost’ estimates upon which these estimates are based (see Keating et al *forthcoming*).
2. For the fires included in the ‘current cost’ estimates, data only covers a portion of total costs (see Keating et al *forthcoming*).
3. We have extrapolated costs linearly, assuming a one-to-one relationship between increase in FFDI and bushfire damage costs. This assumption is analytically convenient but theoretically improbable. It is widely held that fires ignited on days of catastrophic FFDI aptly result in catastrophic damage costs. Theoretically the relationship between FFDI is more likely to be closer to exponential or a stepped/staged relationship with certain thresholds or tipping points.

Despite the simplistic nature of these estimates some effort has been taken to highlight how the treatment of uncertainty and intergenerational equity can impact an analysis. The tables presented here show results for two climate change scenarios which demonstrates how different assumptions about the physical impacts can lead to differing results. We also report results using two different discount rates (5% and 0.1%) to show how the treatment of intergenerational equity has a profound impact on results.

## 3.2 Bushfire and the Victorian agricultural industry

We estimate future costs due to damage to the agricultural industry by bushfires. We utilise the following figures in our analysis:

* The current total cost to the Victorian economy due to bushfire damage to the agricultural industry is estimated to be $92 million per annum (Keating et al *forthcoming*); this is likely an underestimation.
* The Australian agricultural industry has had a long term growth trend of 2.4% per annum (Productivity Commission 2005).

Table 5 below shows average annual bushfire damage costs in 2020 and 2050. First we consider the baseline scenario with no climate change, in this case losses due to bushfires increase with exposure, at the same rate as long term growth. Next we consider the impact of climate change may have on these expected damage costs, under two scenarios. Shown in above, Lucas et al (2007) estimate that climate change will increase the frequency of days where FFDI exceeds 50. We assume that these increases will correlate with a direct increase in damage costs. Note this is predicated on the assumption that the current ratio of ‘days where FFDI exceeds 50 and does not result in a fire’ to ‘days where FFDI exceeds 50 and does results in a fire’ remains constant in the future. Hence we have assumed that the current level of disaster risk reduction is maintained. First row reports figures calculated using a discount rate of 5%, second row a discount rate of 0.1%.

Table 5: Annual bushfire damage cost from damage to the Victorian agricultural industry under baseline and climate change scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Change in number of days where FFDI>50** | **2020 no climate change** | **2020 low mk2 – 11%** | **2020 high mk3 – 40%** | **2050 no climate change** | **2050 low mk2 – 19%** | **2050 high mk3 – 138%** |
| **Present value (discount rate = 5%** | $71.6 | $79.6 | $100.6 | $33.7 | $40.1 | $80.3 |
| **Present value (discount rate = 0.1%** | $115.4 | $128.4 | $162.2 | $228.2 | $271.5 | $543.0 |

Table 6 shows the estimated total damage costs by 2020 and 2050 for the baseline and climate change scenarios.

Table 6: Total bushfire damage cost from damage to the Victorian agricultural industry under baseline and climate change scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Change in number of days where FFDI>50** | **2020 No climate change** | **2020 low mk2 – 11%** | **2020 high mk3 – 40%** | **2050 No climate change** | **2050 low mk2 – 19%** | **2050 high mk3 – 138%** |
| **Present Value (discount rate = 5%)** | $895.3 | $943.7 | $1059.1 | $2385.7 | $2720.0 | $3761.7 |
| **Present Value (discount rate = 0.1)** | $1136.4 | $1211.9 | $1398.0 | $6156.8 | $7281.2 | $12165.9 |

## 3.3 Bushfire and the Victorian timber industry

We estimate future costs due to damage to the timber industry by bushfires. We utilise the following figures in our analysis:

* The current total cost to the Victorian economy due to bushfire damage to the timber industry is estimated to be $185 million per annum (Keating et al *forthcoming*); this is likely an underestimation.
* The Victorian timber industry has had a long term growth trend of 2.4% (TACG 2006).

Long term industry growth of 2.4% (TACG 2006) is reflective of past long term growth. In the future several factors may influence long term growth. The structure of the timber industry is changing – some plantation types are declining, others are increasing. Likewise demand for timber products is shifting. It is possible that the industry may in the future be able to take advantage of carbon sequestration services under a carbon emissions trading scheme. Climatic changes from climate change will also impact the industry in the future; bushfires as described here will reduce growth, however other changes may foster growth in some areas. A thorough analysis of the dynamics other timber industry in the future is beyond the scope of this paper however we recommend that this work be undertaken because it would be beneficial for industry, policy-makers and researchers.

Using the same procedure as for the agricultural industry, we estimate the annual and total costs from bushfire damage to the Victorian timber industry in 2020 and 2050:

Table 7: Annual bushfire damage cost from damage to the Vic timber industry in 2020 and 2050 under baseline and climate scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Increase based on % change in FFDI>50 days per year | **2020 Exposure only** | **2020 low mk2** | **2020 high mk3** | **2050 Exposure only** | **2050 low mk2** | **2050 high mk3** |
| **i=5%** | $143.7 | $159.8 | $201.9 | $67.7 | $80.6 | $161.1 |
| **i=0.1%** | $231.7 | $257.6 | $325.6 | $458.0 | $544.9 | $1089.7 |

Table 8: Total bushfire damage cost from damage to the Victorian timber industry by 2020 and 2050 under baseline and climate scenarios, $millions AUD2010

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Increase based on % change in FFDI>50 days per year | **2020 Exposure only** | **2020 low mk2** | **2020 high mk3** | **2050 Exposure only** | **2050 low mk2** | **2050 high mk3** |
| **i=5%** | $1797.0 | $1894.0 | $2125.6 | $4788.3 | $5459.1 | %7549.8 |
| **i=0.1%** | $2280.7 | $2432.4 | $2805.8 | $12357.0 | $14613.7 | $24417.2 |

## 3.4 Heatwave mortality in Victoria

We estimate future costs due to heatwave mortality in Melbourne. We start with the estimate that current heatwave mortality in Melbourne results in 330 deaths and costs Victoria approximately $1.26 billion annually. Estimates for increased exposure (population increases) are based on increases in the population of persons over 65 (DPCD 2009; ABS 2008) because we assume that the majority of deaths from heatwaves occur in people over the age of 65. Climate change scenario estimates are based on predicted increases in the number of days over 35 degrees. Figures for the current and projected days over 35 degrees are an average from 12 sites across Victoria (see Table 9).

Table 9: Current and projected annual number of days over 35 degrees in Victoria

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Days 35+ per year:** | | | | |
| **Present** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| 22.79 | 24.65 | 25.69 | 29.88 | 33.97 |

*Adapted from Climate Change in Australia (2012)*

The estimates presented below contain two significant assumptions. Firstly we assume that the increase in heatwave deaths is directly proportional to the increase in number of days above 35 degrees as presented in Table 9 above. In actuality a heatwave is usually classified as a run of days above a certain temperature, or a run of nights where the temperature does not drop below a certain point, because it is the lack of reprieve from heat that impacts human physiology. Unfortunately modelling for increased heatwaves, as defined as a run of hot days/nights is not available. In the absence of more specific heatwave estimates we have used the above data as a proxy for increased heat. Secondly, all estimates assume that the current level of adaptation to heatwaves remains constant. This includes an assumption of constant physiological response to heat over time, however it may actually be the case that the Victorian population becomes acclimatised to higher temperatures over time.

Table 10 and Table 11 show the predicted annual and total mortality rate in/by 2020 and 2050 under baseline and climate change scenarios. Table 12 and Table 13 show these figures converted into dollars via a statistical value of life calculation (OBPR 2008), and presented with two discount rates.

Table 10: Annual mortality rate in 2020 and 2050 due to heatwaves under baseline (no climate change) and climate change scenarios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| 457.4 | 494.7 | 515.6 | 820.0 | 1075.2 | 1222.1 |

Table 11: Total number of deaths by 2020 and 2050 due to heatwaves under baseline and climate change scenarios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| 4287.6 | 4436.0 | 4521.6 | 23222.1 | 27160.73 | 29436.3 |

Table 12: Annual cost of heatwave mortality in 2020 and 2050 under baseline and climate change scenarios, $million 2010AUD

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Annual cost in 2020 and 2050, $million 2010AUD** | | | | | | |
|  | **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| **Discount rate = 5%** | $1072.77 | $1160.1 | $1209.2 | $445.0 | $583.4 | $663.1 |
| **Discount rate = 0.1%** | 1730.05 | $1871.0 | $1950.1 | $3009.7 | $3946.4 | $4485.4 |

Table 13: Total cost of heatwave mortality by 2020 and 2050 under baseline and climate change scenarios, $million 2010AUD

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Total cost by 2020 and 2050, $million 2010AUD** | | | | | | |
|  | **2020 baseline** | **2020 Miroc3.2** | **2020 Csiro3.5** | **2050 baseline** | **2050 Miroc3.2** | **2050 Csiro3.5** |
| **Discount = 5%** | $12779.5 | $13172.9 | $13399.7 | $34036.5 | $38055.9 | $40397.0 |
| **Discount = 0.1%** | $16291.7 | $16854.3 | $17178.7 | $86704.2 | $101319.1 | $109764.2 |

As previously stated, the estimates presented here should be considered to be a first-pass, lower-bound estimate of true costs. They represent only a tiny fraction of the true cost of climate change to Victoria. More, and more sophisticated, estimates of the costs of climate change to Victoria would be a useful input into climate change adaptation decision-making. Previous work in this project has outlined a paucity of data on the current costs of climate anomalies and massive inconsistency within what is available (Keating & Handmer 2011b). Furthermore, it is noted that there is no standard definition of heatwave. Developing a standard definition for use throughout Victoria (and potentially Australia) would be beneficial for researchers and policy-makers.

# 4. Foundations for more detailed cost benefit analysis of adaptation

Hallegatte et al (2011) find that it would be ineffective to relegate adaptation decision-making and budgetary commitment to one single government body. Instead they argue that integrating adaptation into all government policies is essential.

Previous work for this project (Keating & Handmer 2011a) outline a starting point for determining estimates of the potential costs of climate change to Victoria. The approach recommended involves a general equilibrium analysis for high-level information on economy-wide impacts including which sectors are vulnerable. This could be complimented by a series of partial equilibrium analyses of key vulnerable sectors. It is in these sectoral analyses that cost-benefit analysis would be a key decision-support tool. This recommendation foreshadows the Productivity Commission’s finding (Productivity Commission 2012) that top-down modelling of adaptation is limited in its usefulness for specific adaptation decision-making because the models tend to be highly aggregated.

***Step 1 – Current risk assessment***

As discussed above, it may be the case that the current level of climate risk is not optimal and ideally this would be assessed before predictions about future conditions and risks are made.

***Step 2 – Identify scenarios and possible adaptation measures***

Following Hallegatte et al (2011) the next step in a CBA of adaptation for Victoria would be to determine the climatic and economic scenarios upon which Victoria will base its analysis. Where the probability of occurrence of impacts is relatively certain these can be used directly in the analysis. Where the probability of occurrence is relatively uncertain a subjective assessment needs to be made. As described above, several scenarios both optimistic and pessimistic should be evaluated. The suite of possible adaptation measures need to also be identified.

Selection of adaptation measures must consider their urgency and choose the more urgent measures first. IPCC (2012) advocate for ‘no-regrets’ measures, particularly in relation to disaster risk reduction, to be pursued first because these have immediate benefits regardless of the eventual climate change scenario. Hallegatte et al (2011) suggest that measures should be selected as follows:

1. Adaptations to impacts that are already being observed or will occur in the near future should be addressed first.
2. Adaptations to longer term or extreme warming impacts that are relatively certain, and that require long term adaptation action.
3. Adaptations to longer term or extreme warming impacts that are severe even if they are uncertain, and require long term adaptation action.

In relation to point 1 above, IPCC (2012) labels these measures as ‘low-regrets’ and includes the following initiatives as examples pertaining to disaster risk reduction:

* + Early warning systems
  + Risk communication between decision-makers and local citizens
  + Sustainable land management including land use planning
  + Ecosystem management and restoration
  + Health surveillance
  + Water supply
  + Climate proofing of infrastructure
  + Development and enforcement of building codes
  + Better education and awareness

(IPCC 1212, pg. 14-15).

Mechler et al (2010) lend further support for disaster risk reduction (DRR) in their assessment of adaptation to environmental conditions in the European agricultural sector. They find that farmers exhibit more capacity for autonomous adaptation to gradual climate changes over extreme weather events.

These types of adaptations are also ones that increase overall adaptive capacity, which Heuson et al (2012) suggest is the starting point for adaptation under uncertainty. Productivity Commission (2012) echoes this recommendation and suggests first pursuing policies that have positive net benefits under a range of climate scenarios.

In relation to point 2 above, Aaheim & Aasen (2008) highlight the potential for devastating impacts from climate change in communities that are dependent on a climate-sensitive industry. Climate change has the potential to create significant upheavals, both positive and negative, and these need to be anticipated and planned for well in advance for the wellbeing of Victorians.

The Productivity Commission’s report Barriers to Effective Adaptation takes a national view of the adaptation issue, with particular reference to how Australian governments can provide an optimal environment for autonomous adaptation. The report identifies the high priority areas for State Governments based on the fact that they relate to current climate risks and have a high degree of certainty. They are:

* Clarify the roles, responsibilities and legal liability of local governments
* Better align building and planning regulation
* Phase out inefficient taxes (such as taxes on insurance and property transfers)

(Productivity Commission 2012, pg. 11)

The high priority area for local governments identified as “Improve communication of hazard information to residents” (Productivity Commission 2012, pg 11). It should be noted that the Victorian State Government, in response to the February 2009 bushfires, has taken on a significant role in improving hazard information through the use of the internet and text messaging systems.

***Step 3 – Establish boundaries and factors of the analysis***

*Temporal and geographic scale*The temporal and geographical scales associated with an adaptation assessment can have considerable impact on the outcome and as such must be considered carefully. IPCC (2012) uses the example of a maladaptive dike system that provides flood protection in the short term but in the long term encourages settlement patterns that increase risk.

Incorporating local knowledge and working in collaboration with local communities is an essential part of climate change adaptation. Local people often have the clearest picture of their own risks, preferences and options for adaptation (IPCC 2012). ECA (2009) find that impacts vary considerably between cities and regions, and even within them. This point is important to consider so as not to inappropriately scale up estimates from one location and assume they apply in another.

*Choose discount rate*As discussed above, the choice of discount rate is contentious. It is likely that the appropriate discount rate will depend on the type of adaptation under consideration and the lifespan of decision impacts. Numerous discount rates could be reported (as is the case here) and/or sensitivity analysis using statistical methods can be carried out.

*Dealing with uncertainty*When dealing with uncertainty Hallegatte et al (2011, pg. 30) argue that it is preferable to conduct a CBA using subjective judgements on likely occurrence probabilities with “at least two ‘optimistic’ and ‘pessimistic’ scenarios”, and to conduct careful sensitivity analysis. In particular catastrophic scenarios should be considered because while their probability is very low their impacts would be immense. Stanton & Ackerman (2011) echo this sentiment when they caution against using CBA to determine a definite result. They also call for a range of estimates and a significant focus on uncertainties and the risks of catastrophic losses.

***Step 4 – Calculate net present value(s) and conduct sensitivity analysis***

Once the options being considered and the approach of the analysis have been established, net present value of each option can be calculated as discussed in section 2.3 above. Also discussed above is the standard practice of defining the benefits of adaptation as the damage cost avoided has been criticised by Dobes (2009; 2012). He proposes an Australia wide study or studies to assess the relative priorities and preferences of all Australian residents and utilise stated preference techniques to determine Australians’’ willingness-to-pay for damages avoided via adaptation. The Victorian Government might consider a study in a similar vain as a key input into adaptation cost-benefit analysis.

*Sensitivity analysis*

A variety of methods are available for conducting sensitivity analysis in a CBA. The simplest method is to vary a parameter (such as the discount rate) holding all others constant and explore then report the impact this has on outcomes. More complex methods include Monte Carlo analysis (Hallegatte et al 2011).

Hallegatte et al (2011) argue that when uncertainty is high CBA is only able to shed light on the assumptions used in the modelling exercise and to provide a suite of possible outcomes. It is not able to clearly identify ‘The Best’ adaptation option. Decision-makers can use the outcomes of CBA to inform their decision-making but they need to be aware that it is not a crystal ball into our uncertain future. Monech et al (2007) highlight that when a high quality CBA study can be very instructive in identifying where benefits clearly outweigh costs, as opposed to when net benefits depend on a narrow set of assumptions about future climatic and socioeconomic conditions.

***Step 5 – Monitoring and evaluation***

Monitoring and evaluation for climate change adaptation is a field that is in its infancy. Ideally all government investment incorporates performance indicators that accurately assess progress and allow for new information to be incorporated. The Victorian Government needs to carefully consider how it will monitor adaptation (Hallegatte et al 2011). IPCC (2012, pg. 15) suggest that “[a]n iterative process of monitoring, research, evaluation, learning, and innovation can reduce disaster risk and promote adaptive management in the context of climate extremes (high agreement, robust evidence).” They go on to argue that it is this iterative process of constant evaluation and adjustment that allows for the reduction of uncertainty as new external knowledge and internal learnings become available.

# 5. Conclusion

“Progress toward resilient and sustainable development in the context of changing climate extremes can benefit from questioning assumptions and paradigms and stimulating innovation to encourage new patterns of response (medium agreement, robust evidence)“ (IPCC 2012, pg. 18). Responding to the challenge of climate change adaptation requires Victorian policy-makers and researchers to think in innovative and new ways. While CBA is not a new concept, a thorough application thereof could potentially yield challenging results. Utilising a ‘real options’ approach would also be a significant paradigm shift for Victorian State and Local Governments, and is one that ought to be considered because of its focus on flexibility and low-regrets investment.

Numerous studies have identified that the key impediment to climate change adaptation at the local and regional level is “institutional capacities and in the insufficient coordination and cooperation between national and local government bodies” (Heuson et al 2012, pg. 44). Political leadership and cross-government coordination is essential for Victoria if benefits are to be maximised and losses minimized, because climate change impacts and solutions are rarely confined to one sector or area.

In an ideal world a full cost-benefit analysis of all adapation options, with thorough treatment of issues such as uncertainty and intangibles, could be undertaken to inform decision-making. The Productivity Commission (2012) considers that this would be too onerous for their assessment at the national level and it is likely that a similar situation applies to state-level decision-making in Victoria. The costliness of cost-benefit analysis, coupled with criticisms of the methodology outlined here, and other political considerations mean that it is highly likely that cost-benefit analysis will not be the sole determinant of climate change adaptation decision-making in Victoria. If this is the case we strongly urge decision-makers to utilise cost-benefit analysis, potentially including willingness-to-pay considerations as an input into a systematic decision-making framework (UNFCCC 2009). Agrwala et al (2012) suggest that an alternative approach may be to incorporate climate change impact and adaptation analysis into existing decision-making structures such as Environmental Impact Assessment (EIA).

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1. Following from the majority of literature on climate change adaptation this paper does not consider ‘climate engineering’, which is the field of technical interventions into the Earth’s climate system to reduce the impact of greenhouse gases (Heuson et al 2012). While this could be considered an ‘adaptation’ it is not currently at a scale that warrants consideration for the state of Victoria. [↑](#footnote-ref-1)
2. IPCC (2012, pg. 3) defines ‘transformation’ as “The altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems).” [↑](#footnote-ref-2)
3. For a full discussion of discount rates generally and as they pertain to Victorian climate change adaptation, see earlier work form this project Keating & Handmer (2011a). [↑](#footnote-ref-3)