The Economics of Climate Change

June 2014

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About this publication
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ISBN: 0 85801 294 4

Design: Robyn Zwar Graphic Design

Photography:
Page 29: Flooding in regional Australia, Emerald, Queensland, Jodie Richter/Newspix, January 2011.
All other images: iStock Photo Library.

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We achieve this through a rigorous and evidence-based research agenda, and forums and events that deliver lively debate and critical perspectives.

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Foreword

Climate change, and the world's response, has recently again been thrust on to the Federal Government's agenda, notwithstanding a current focus on economic management.

Internationally the United States has flagged a sharp policy response to carbon emissions while domestically the Australian Government faces a fractious Senate as it seeks to eliminate most aspects of the former government's approach to this issue.

However, as detailed in *The Economics of Climate Change*, CEDA's latest report, regardless of arguments about the how and why, if Australia does not respond with a scientific, evidence-based, appropriately funded policy, the economic consequences may be devastating.

Two examples illustrate this succinctly.

The first relates to the consequences of increasing extreme weather events and the economic and social impact that these events have on Australia's production capacity.

Roma in Queensland has endured several significant floods in recent years. If a levee to protect the town had been built in 2005, it would have cost $20 million. However, since 2008 $100 million has been paid out in insurance claims and since 2005 a repair bill of over $500 million has been incurred by the public and private sectors.

This is but one example, and statistics highlighted in this publication show that the number of catastrophic weather events is increasing. The economic losses associated with these events are also trending up.

These statistics clearly indicate that introducing risk assessment and mitigation strategies is a sensible, practical and cost-effective approach to management. It is argued for these reasons the Federal Government should introduce a national risk register that includes strategies to manage risks of adverse climate events both in the public and private sector.

The second example of not recognising the economic consequences of climate change and appropriate responses relates to capital investment in Australian industries. Australia is reliant on accessing foreign capital for major projects. However, changes in policy may mean changes to international capital flow and investment decision making which could have consequences for nationally significant industries in Australia and associated asset values.

Applying climate related risk assessments when considering investment and financing decisions is an emerging trend globally. Concerns about environmental and economic risks associated with carbon intensive investments have already directly influenced the strategies of major international lending institutions.

Australia needs to ensure it keeps in step with international developments on this front and importantly has the options available to move to less carbon intensive industries and energy sources.

What energy sources will be the cheapest and cleanest in the future will be dependent on supply and the technological breakthroughs that are aimed at a cleaner but economically sustainable future. This is why Australia should develop robust regulatory regimes for all energy sources, including nuclear, along with ensuring they have a social licence to operate.

It naturally follows that we must also be investing in research and development to drive these technological breakthroughs to occur.

Australia cannot avert climate change in isolation but it has both a responsibility as a developed nation and an economic imperative to respond with the rest of the world. A prudent government and industry more generally would be wise to recognise this.

I would like to thank the contributing authors and CEDA advisory group for their work in making this publication possible and hope you find it any insightful resource.

Professor the Hon. Stephen Martin
Chief Executive
CEDA

Executive summary

The politics of climate change are highly contested in Australia at this point in time. In *The Economics of Climate Change* CEDA explores the economic issues of climate change examining the international context, how to minimise Australia's exposure to climate change risks and how best to expend its natural resources. In the international context, the report examines both the emerging policy responses and their economic consequences for Australia.

Adjusting to the impacts of climate change and mitigating its effects will be a task for both this and future generations. As a relatively small industrialised nation, Australia must be open and responsive to global developments in both the economic and the policy environment. Many of the implications of climate change can be ameliorated through effective policy responses, whereas poor public policy will exacerbate the challenges. These issues were explored in CEDA's recent publications on population, *A Greater Australia: Population, policies and governance*; water, *The Australian Water Project*; and energy, *Australia's Energy Options*. This policy perspective suggests that there is considerable scope to improve Australia's policy response to climate change.

CEDA has also extensively examined the policy settings surrounding climate change in the 2009 report *Climate change: Getting it right*, the 2010 report, *A taxing debate: Climate policy beyond Copenhagen* and the 2012 policy perspective *A taxing debate: The forgotten issues of climate policy.*

The contributions to this policy perspective accept the science of climate change but acknowledges that there are uncertainties about its ramifications both at the global and, particularly, the local level. They also appreciate Australia's inability to avert global climate change in isolation while appreciating the nation's economic need to respond in conjunction with the rest of the world, particularly the developed world. It also appreciates that climate change is a source of economic and social challenge but also of opportunity.

Contributions and acknowledgements

This report includes three contributions on the economics of climate change and makes a series of recommendations for how Australia should respond.

In *The global economic environment and climate change*, Martijn Wilder AM outlines how Australia's response to climate change fits within the global context and identifies potential challenges for the nation's economic activity. He also identifies how emerging trends in capital flows have the potential to significantly influence the value of assets owned by Australian industry. These trends have the potential to fundamentally reshape a number of nationally significant industries and the nation needs an appropriate policy response to encourage economic diversity.

In *Climate risks: Probabilities, consequences and actions*, Professors Quentin Grafton and Rodney J Keenan describe how Australia is already suffering from climate events, chiefly weather related at this point. These events have been increasing over time. They also explain how a probability-consequence risk framework provides a useful way to describe climate risk and indicates how to respond domestically. In particular, these frameworks are valuable for minimising the social and economic consequences of climate change.

In *Effective action: Identifying Australia's best options to mitigate climate change*, Nathan Taylor elaborates on past CEDA research to articulate a methodology for assessing Australia's potential climate mitigation options. This approach explicitly deals with the uncertainties involved in responding to climate change, particularly the technical uncertainty and the social cost of responding.

CEDA wishes to acknowledge the input and expert advice from this project's advisory group in developing the final reform recommendations endorsed by CEDA. The CEDA Advisory Group consisted of:

- Professor Warwick McKibbin, Chair in Public Policy and Australian National University Public Policy Fellow; and
- Professor Ross Garnaut, AO, University of Melbourne.

These experts provided guidance and input into the final recommendations of the report. However, the final report is entirely the responsibility of the individual authors.

The global economic environment and climate change

Irrespective of a failure to develop a global consensus response to climate change, it would be inappropriate for Australian businesses to assume that the international response will have no influence over their activities. In addition to the physical reality of climate change, increasingly onerous regulatory regimes across many counties are attempting to limit greenhouse gas emissions. Meanwhile changes in international capital flows and investment decision making, the emergence of disruptive technologies and the inter-relationship of all those factors means that no business is immune from the economic impacts of climate change. This is particularly so for those Australian businesses in the emissions intensive or fossil fuel sectors and those competing internationally.

Governments around the world are developing law and policy to directly address climate change. This includes laws to require emitters of greenhouse gas emissions to cap, reduce or eliminate those emissions or introducing policies to encourage renewable energy or energy efficiency measures that will change business-as-usual behaviour. The emerging global network of regulatory limits to control and regulate emissions now covers most major emitters. The consequence for Australian businesses of international policy developments include:

> "Concerns with environmental and economic risks associated with carbon intensive investments have already directly influenced the strategies of major international lending institutions. There is an emerging trend to apply climate change related risk assessments when considering important investment and financing decisions."

- Changes in demand by our traditional customers for Australian fossil fuels and commodities;
- A direct impact on asset values and certain assets becoming stranded;
- Overseas investments becoming regulated; and
- The emergence in other countries of disruptive technologies which may drive greater competiveness in our trading partners.

The world is now seeing national governments directly implement a suite of domestic measures to regulate global greenhouse emissions. While the full introduction of these measures will take time there is already a focus on how such national and regional schemes can be globally integrated outside of an international global agreement. Investors and the owners of businesses have to consider the rate at which this will occur and emissions will become a permanent cost of production. This includes consideration of various carbon price scenarios that may result in stranded assets – those that would become unprofitable under certain carbon regulatory scenarios resulting in considerable reductions in the long-term value of particular companies.

These issues are being considered by investors. Concerns with environmental and economic risks associated with carbon intensive investments have already directly influenced the strategies of major international lending institutions. There

is an emerging trend to apply climate change related risk assessments when considering important investment and financing decisions. A disinvestment and shift from financing is not simply based on a philosophical opposition to carbon intensive activities, but is often based on a hard analysis that the demand in markets for such industries or their commodities is diminishing and at risk.

Notwithstanding the challenges, climate change can present new opportunities to industry and business. These include relocating farming systems to more desirable locations as a result of warming, such as viticulture in Tasmania, and also innovation in new technologies and systems, such as renewable energy and storage, that respond to changing social, environmental and commercial conditions. Australian industry needs to be open to these opportunities. Furthermore, Australia has considerable experience in dealing with climatic vagaries. This experience can be a source of benefit to the nation and the world: CEDA's *The Australian Water Project* found that:

> *Australia's water management policies enabled it to do something that no other country could conceivably have managed…a 70 per cent reduction in water availability had very little aggregate economic impact. This represents an achievement of global significance as human communities across the world respond to a changing climate.*[1]

While not all of these impacts may occur immediately, disruptions are already evident and the trends are clear. Australia's carbon intensive industries need to plan for a very different future economic environment and Australian industry as a whole must be open to emerging international efforts aimed at addressing climate change.

Managing domestic risks

Climate change poses a number of substantive physical risks for the world. Possible adverse consequences include threats to unique and threatened ecosystems and cultures, extreme weather events such as heat waves and coastal flooding, and large-scale singular events such as large and irreversible sea level rises in response to increases in global mean temperature. The consequences of these changes are likely to be unevenly distributed.

In Australia, the key projected consequences of climate change include: temperature increases with more hot days and fewer cool days; a rise in extreme fire-weather days in southern Australia; an increase in the incidence of droughts in southern Australia and an increase in the intensity of tropical cyclones among others. According to data compiled on weather related losses for insurers over the past few decades:

- The number of catastrophic weather events is getting larger; and
- The economic losses associated with weather related events is trending upwards over time.

Australia is already suffering from the influence of adverse climate events.

Australia requires a framework for assessing climate risks and considering possible actions that may lower them. Adaptive actions are inevitably geographically specific, focused at local to regional scales and require actions by individuals, communities, businesses and government.

An assessment of climate risks and vulnerabilities requires planning that connects the probabilities of future climate events to the abilities of people and places impacted by the event to recover. It should also examine what actions could be undertaken to reduce the consequences of events if they should occur. Governments by themselves cannot, and should not, undertake all the actions adaptation to climate change requires. However, they are key to leveraging resources across the private sector and to developing the social networks that underpin resilience to extreme climatic events.

"Appreciating the nature of the risks facing regions can help reduce the consequences of climate risks. For instance, had a levee to protect the town of Roma in Queensland from flooding been built in 2005, it would have cost $20 million. Since the levee was not built, $100 million has been paid out in insurance claims since 2008 and a repair bill of over $500 million incurred by the public and private sector since 2005."

Appreciating the nature of the risks facing regions can help reduce the consequences of climate risks. For instance, had a levee to protect the town of Roma in Queensland from flooding been built in 2005, it would have cost $20 million. Since the levee was not built, $100 million has been paid out in insurance claims since 2008 and a repair bill of over $500 million incurred by the public and private sector since 2005.

To address and assist in minimising climate change risks:

- The existing overview of climate risks facing Australia should be expanded to include a national risk register in a similar fashion to the United Kingdom's National Security Risk Assessment; and
- The national risk register should also examine strategies, for both the public and private sectors, to manage risks that account for both the probability and consequence of adverse climate events.

Effective action

The changes necessary to avert climate change will be difficult and expensive, but particularly so for Australia which is a relatively unusual industrialised energy exporter. If Australia is to make the necessary adjustments, and preserve the wellbeing of its citizens, it needs to spend its national resources effectively. Yet Australia's overall policy response to climate change has not been suitable for the challenge. What has been absent from the policy debate has been a contextualisation of individual policy approaches within a wider framework that allows for comparison of policy efficacy.

One approach that specifically deals with the uncertainty involved, and that provides an objective basis for comparing different policies, is to consider that Australia has a portfolio of possible responses to climate change. These potential responses represent the ability, but not the obligation, to undertake singly or in combination any of a range of actions currently and in the future if the conditions emerge that makes them appropriate. These possible actions are in substance options – real options.

Adopting a real options investment approach to Australia's response to climate change would provide a transparent and objective basis for comparing the costs and benefits of different policy approaches and enable the nation to maximise the net benefits (gross benefits less costs) of its actions.

To implement this approach to addressing climate change, the Federal Government should:

- Regularly update the Australian Energy Technology Assessment (AETA);
- Assign probabilities to these forecasts and identify the technological breakthroughs that would underpin reduced future levelised costs of energy assessments;
- Forecast the future costs over time for greenhouse gas emissions to determine the net present value (NPV) of alternative low greenhouse gas emissions technologies; and
- Use a real options investment approach to maximise the potential greenhouse gas emissions that Australia can efficiently mitigate.

To maximise the value of Australia's option portfolio, the Emissions Reduction Fund should focus on energy efficiency improvements, given their relative cost to deliver emission reductions, to meet Australia's greenhouse gas emissions reduction targets while also using the insights of the options analysis to spend funds on means to maximise emissions reductions over the longer term.

"To maximise the value of Australia's option portfolio, the Emissions Reduction Fund should focus on energy efficiency improvements, given their relative cost to deliver emission reductions, to meet Australia's greenhouse gas emissions reduction targets…"

Key examples of ways in which the potential for low greenhouse gas emissions could be encouraged include:

- Focusing research and development on enabling specific technology breakthroughs, such as those identified as necessary for geothermal power to reduce its parasitic load (energy required internally to run a plant);
- Developing robust regulatory regimes for all energy sources prior to their deployment, including nuclear power;
- Working to ensure a social licence to operate exists for all energy sources, including nuclear power and wind generation;
- Integrating low greenhouse gas emissions energy sources with the transmission and distribution system; and
- Developing domestic skills in implementing the initial investments in emerging technologies.

This approach would not be technologically neutral. Instead it would focus on trying to capture as much of the potential positive NPV of each low greenhouse gas emission technology. While this may result in greenhouse gas emissions being marginally higher in the short term, Australia would be spending funds to maximise their long-term reduction.

Endnotes

1 Briscoe, J., 2011, *The Australian Water Project, Crisis and opportunity: Lessons of Australian water reform*, Volume 1, page 12.

1. The global economic environment and climate change

Martijn Wilder AM

This chapter examines what is happening globally with climate change policy in both the public and private sectors and how this may change financing and investment decisions both internationally and here in Australia.

Martijn Wilder is head of Baker and McKenzie's Global Environmental Markets practice. He is also Chairman of Low Carbon Australia, a Board Member of the Clean Energy Finance Corporation, Chair of the NSW Climate Change Council, on the governing board of the Renewable Energy and Energy Efficiency Partnership (REEEP), a Committee Member of the Australian Initiative for Sustainable Aviation Fuels and a Director of WWF and the Climate Council. He holds academic positions as a Professor of Climate Change Law at the Australian National University and an Affiliate, Cambridge Centre for Climate Change Mitigation Research, Department of Land Economy, University of Cambridge.

Introduction

Since 1992, the United Nations Framework Convention on Climate Change (the UNFCCC) has been the basis upon which countries have sought to cooperate to pursue international political and legal commitments to reduce rising levels of global greenhouse gas emissions. However, it is also a process that is politically complex and as a result has been unable as yet to deliver a long-term global agreement to implement binding limits on greenhouse emissions, with countries refusing to adopt real measures in the absence of other countries doing the same. It is clearly perceived by many governments and the business interests within those economies that limiting emissions growth will directly limit economic growth and place them at a competitive disadvantage.

In the Australian context, this has long been the view with industry ensuring adequate protection under the *Clean Energy Act 2012* through free permits and compensation payments and more recently as demonstrated by the growing business support for repeal of the *Clean Energy Act* with no alternative regulatory cap to limit greenhouse gas emissions from industry.

However, for any Australian business to consider that the failure to date of the UNFCCC to deliver a binding global agreement on climate change or the removal of any domestic regulation to restrict greenhouse gas emissions, allows them to operate in a business as usual scenario, is naive.

The physical reality of climate change impacts, the increasing introduction of regulatory regimes across many countries to limit greenhouse gas emissions, changes in international capital flows and investment decision-making, the emergence of disruptive technologies and the inter-relationship of all those factors means that no business is immune from the economic impacts of climate change and investors that consider climate change risk. This is particularly so for Australian business in the emissions intensive or fossil fuel sectors and those which compete internationally.

The direct impacts of climate change on business

In October 2006, Sir Nicholas Stern made clear that climate change will have a major economic impact, equivalent to losing at least "five per cent of global gross domestic product (GDP) each year, now and forever" in a business as usual emissions scenario.[1] The Stern Review describes how climate change creates the risk of "major disruption to economic and social activity, on a scale similar to those associated with the great wars" and how "it will be difficult or impossible to reverse these changes".[2]

The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) released in September last year reinforced the cause of such damage, stating that the warming of the climate system is "unequivocal" and "adaptation and mitigation choices in the near-term will affect the risks of climate change throughout the 21st century". It identified in specific detail the more localised impacts of climate change on many areas around the world, building on and complementing the significant research that is already taking place.[3] Such analysis also builds upon the actual impacts that have for some time been witnessed over the last few years in terms of the physical impacts that climate change is already causing. For investors and owners of business this provides a clear basis for making investment decisions.

The physical effects of climate change are far-reaching and include sea-level rise, ocean acidification, change in rainfall patterns and increased disaster risk as weather events (including storms and droughts) increase in frequency and intensity.[4] Further, extreme weather events caused by climate change, may lead to additional bushfires,[5] while heavy rainfall and cyclones may lead to flooding.[6] Such events have far-reaching flow-on effects for Australian and international business.

For example, the 2011 floods in Queensland not only had an impact on insurance earnings,[7] but also reduced production for some miners[8] and forced up global coal prices, which had flow-on effects for companies relying on cheap coal for profitability.[9] The insurance and mining industries factor in big climate events such as flooding in their respective decision-making processes. While it is not necessarily suggested that these particular floods occurred as a result of climate change, science indicates that due to climate change, events like these

will become more frequent and so, climate events are likely to have a greater effect on these industries. Other examples include changing rainfall patterns altering agriculture yields and the ability of hydroelectric power stations to generate electricity, which again has flow-on effects for certain asset classes.

This may directly affect investments by impacting on the value of assets. The Mercer Report on the implications of climate change on investments[10] predicts that the cumulative economic cost of climate change impacts (with respect to the physical environment, health and food security) may be up to $3.7 trillion to 2030.[11] In particular, health impacts and population migration risks are said to be underrated, as there is presently not sufficient evidence to draw sound conclusions on these impacts.[12]

In recent years, the high cost of increasingly frequent and severe weather events has made global headlines. In October 2012, Hurricane Sandy caused widespread damage in New York City, crippling electricity infrastructure and leaving downtown Manhattan without power for four days. It is estimated that the record 14 foot storm surge alone cost the utility Con Edison $500 million and New York businesses $6 billion.[13] In 2011, widespread floods struck Thailand, closing down an important auto parts supply chain and reducing car production by hundreds of thousands of vehicles, costing Toyota alone $1.5 billion in lost earnings.[14] More recently, the United Kingdom has seen devastating floods for the third time since 2007 with British Prime Minister David Cameron attributing this increased frequency of "abnormal weather events" to climate change.[15]

The impact of climate change on the infrastructure underpinning developed economies is particularly significant. A report by the Climate Institute found that most infrastructure owners were focused on maintaining their assets to standards based on historic, not future climate.[16] In Australia alone, there are 35,000 km of coastal road and rail worth $60 billion at risk of sea level rise and storm surges as the result of climate change.[17] A report published by the Victorian Government has found that "[t]he water, power, telecommunications, transport and building sectors are all at significant risk from climate change impacts" by 2030 (in the worst case scenario) or 2070 (in the best case scenario).[18]

"The impact of climate change on the infrastructure underpinning developed economies is particularly significant…

"A failure of major public infrastructure has follow-on costs for the broader economy, affecting supply chains and the ability to get products to market. The insurance industry and governments must also fund the cost of reconstruction, with associated increases in premiums and taxes."

A failure of major public infrastructure has follow-on costs for the broader economy, affecting supply chains and the ability to get products to market. The insurance industry and governments must also fund the cost of reconstruction, with associated increases in premiums and taxes.

Increasingly we see the experience of the physical climate change impacts and predictions of future scenarios resulting in:

- A re-evaluation of existing business practices and business risks by both businesses themselves and investors; and
- The adoption of business practices that make them more completive in the short to medium term (for example energy and water efficiency or alternative supply chains) and more likely to exist as viable investment in the longer term.

This changing behaviour has been seen across a variety of industries and countries. In the United States, Apple is protecting itself from future energy price shocks with data centres and new manufacturing facilities that run on 100 per cent renewable energy.[19] Nike has adapted its processes in light of increasing water scarcity by building a manufacturing facility that eliminates the use of water and process chemicals in fabric dyeing. While in Europe, British Telecom is planning its infrastructure spending on the basis of flooding scenarios 50 to 100 years in the future.[20]

In comparison to much of the rest of the world, Australia is a long way behind. According to the Climate Institute, "the proportion of organisations reporting that they had carried out a vulnerability assessment for climate impacts fell from a majority (nearly 60 per cent) in 2008 to less than half (47 per cent) two years later, and those that had taken action or made plans for adaptation in response to the findings of the vulnerability assessments were even fewer – just over a third."[21] Sectors of the Australian economy found to be "underprepared" included electricity, road and rail, and financial services.[22]

"The investment required to reduce greenhouse gas emissions and prepare for the impacts of climate change is often capital intensive and requires appropriate policy certainty and incentives. The lack of bipartisan approach to climate change mitigation and the fragmented approach to adapting to its impacts is not conducive to the economic transformation required to bring Australia back up to pace with the rest of the world."

The fragmented and inconsistent political response to climate change is likely a contributing factor to the inaction and attitude of Australian businesses. Since 2007, the Australian Government has put forward three different legislative regimes to reduce greenhouse gas emissions, and the current intention is to remove any cap on industry emissions altogether. Moreover, there remains no central agency responsible for adaptation, with management of climate change risk primarily left to local councils. Major policy reviews intending to map out Australia's economic development, including the Energy White Paper, Agricultural Competiveness White Paper and the more recent Productivity Commission inquiry into Public Infrastructure, make no mention of climate change or its associated risks.

The investment required to reduce greenhouse gas emissions and prepare for the impacts of climate change is often capital intensive and requires appropriate policy certainty and incentives. The lack of bipartisan approach to climate change mitigation and the fragmented approach to adapting to its impacts is not conducive to the economic transformation required to bring Australia back up to pace with the rest of the world.

The emerging global regulatory and policy framework

In Australia there is now a clear intent at the political and business level to ensure that any regulation of greenhouse gas emissions by Australian industry be removed. The Business Council of Australia, the Australian Industry Group and the Minerals Council of Australia have all been vocal proponents of the immediate repeal of the *Clean Energy Act*.[23] The Australian Petroleum Production & Exploration Association has gone further and called for the "removal of any greenhouse gas abatement requirements that may be imposed as part of environmental approval processes".[24]

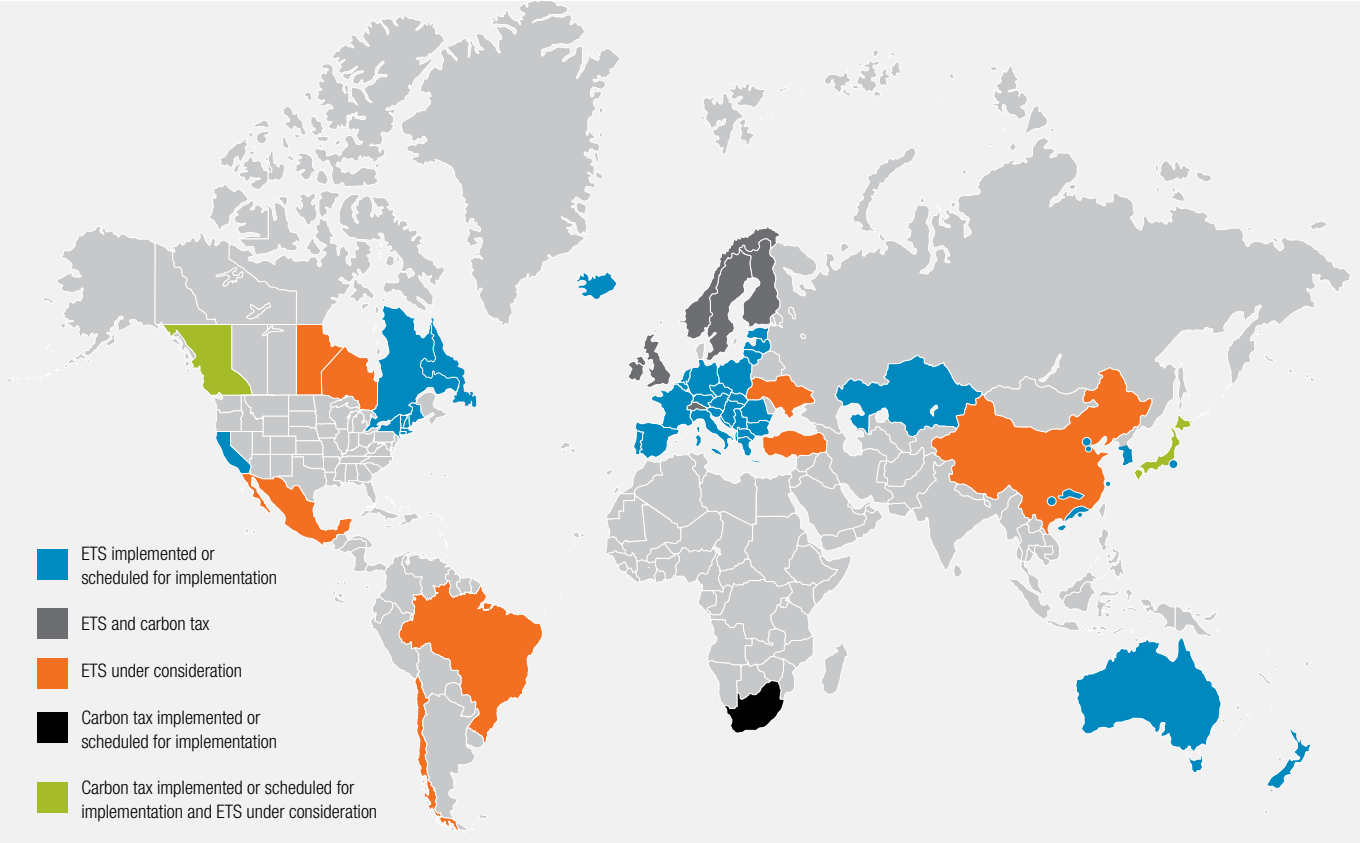
The current government has for some considerable time, both now and while in opposition, argued that Australia should not adopt any emissions regulation while other countries fail to do the same. The argument as it goes, is that Australia's Emissions Trading Scheme (ETS) under the *Clean Energy Act* places it well ahead of other countries and as such places Australian industry at a clear competitive disadvantage. The European Union (EU) ETS is constantly criticised as a failed framework and China is brushed aside as a scheme that will never take real effect. It is a view that has been supported by many business leaders but ignores the reality and carries with it real risks.[25]

Such thinking is out of step with current global developments and is based on the falsehood that Australia has been acting alone. To the contrary, with growing concern over rising levels of greenhouse gases around the world, governments are developing law and policy to directly address climate change. This includes laws to require emitters of greenhouse gas emissions to cap, reduce or eliminate those emissions (for example putting a price on carbon emissions) or introducing subsidies, measures or policies in areas, such as renewable energy or energy efficiency, which will change business-as-usual behaviour. The emerging global network of regulatory limits to control and regulate emissions now covers most major emitters. Figure 1 below shows the current stage of development of carbon pricing regimes around the world.

For any business or investor, law and policy developments represent major risks for Australian business due to:

- Changes in demand by our traditional customers for Australian fossil fuels and commodities;
- Linked direct impacts on asset values and certain assets becoming stranded;
- Overseas investments becoming regulated through a cost on carbon (which the Mercer Report estimates could increase by up to $8 trillion from 2010 to 2030 depending upon the policy approach taken); and
- The emergence in other countries of disruptive technologies and an accelerated uptake in alternative technologies, as is being seen with renewable energy and energy efficiency, all of which drive greater competiveness in our trading partners.

FIGURE 1
COUNTRIES WITH CARBON PRICING MECHANISMS (IMPLEMENTED AND SCHEDULED)



Source: Ecofys, presentation on International Carbon Markets, Carbon Expo Barcelona, 2013

For Australian companies operating overseas this again has a direct cost to their businesses that must be factored in. It is made all the more complex where law and policy developments are in a state of flux. Key Australian industries such as coal mining and oil and gas cannot escape the effect that these regulatory regimes have on demand and regulation of fossil fuels in major export consumers.

While Europe has had an ETS in place since 2005, China and the US are now progressing quickly. In addition, our other trading partners are also developing long-term climate policies. For example the world's eighth largest emitter, the Republic of Korea has passed laws to implement an economy wide emissions trading scheme in 2015. The scheme is part of the broader Korean National Strategy for Low Carbon, Green Growth which has the stated aim of transitioning the Korean economy from a carbon intensive industrial base towards green technology and investment. As part of the current five year plan, implemented in 2009, Korea committed two per cent of GDP to create a knowledge and technological foundation to sustain a green growth economy.[26]

The world's largest emitter China is pursuing an aggressive approach to investment in and support for renewable energy and the implementation of provincial and regional emissions trading schemes, driven by a genuine and immediate desire to manage increasing levels of pollution and their severe and detrimental health impacts, the need to manage energy prices and to ultimately maintain political stability.

The six (and soon to be seven) provincial and regional emissions trading schemes now cover an estimated one billion metric tons of carbon dioxide, making the evolving market second only to the EU ETS in size.[27] In its next five year plan, to be released in 2015, China is expected to lay out plans for a national ETS, which would create the world's largest carbon market.

A key objective in China's climate change policy is to become a world leader in renewable energy. Renewable energy targets in the latest five year plan called for 160 GW of new installed wind capacity by 2020. In 2012, the initial 5 GW solar target was revised upwards twice, with a new target of 40 GW by 2020 set by the Chinese government.[28] In 2013, wind power generation increased more than coal generation and passed nuclear power output for the first time.[29] These ambitious policy settings have resulted in China becoming the world's largest renewable energy manufacturer and single largest investment destination in less than a decade.[30]

The government has previously announced its commitment to spending approximately $15 billion over the next decade to boost electric car development.[31] This follows a 2010 commitment to boosting the number of electric-powered vehicles by 20 million by 2020. China's influential National Development and Reform Commission has said that it is looking to subsidise the cost of at least four million electric-powered vehicles and that the government is already trialling their use in the country's main cities, including Beijing and Shanghai.

These measures will have wide-ranging impacts, changing global demand for fossils fuels and driving the emergence of new and disruptive technologies. The point is made clear by Jim O'Neil in his book *The Growth Map*:

> *"Western critics may point to China's polluted cities and rivers and call the country's growth unsustainable, but China's leaders see exactly the same problems, feel them even more acutely that these distant critics, and are busily seeking solutions.*
>
> *By 2020, China plans to have reduced its carbon intensity by between 40 per cent and 45 per cent compared with 2005 levels. Writing in the* Financial Times *in November 2009, Sir Gordon Conway, co-chair of the China Council for International Cooperation on Environment and Development (CCICED), described China's plan for a low-carbon economy. 'The Chinese leaders are moved by a sense of urgency,' he wrote. 'Following the traditional economic model is not an option: resource, social and environmental constraints make it impossible. They are also aware of the danger that rapid growth will lock China into industrial and urban structures that will become a liability in a low-carbon world.' …*
>
> *The key to cutting emissions, wrote Conway, was 'decoupling growth from greenhouse gas emissions'. This would mean reducing energy consumption per unit of GDP by 75–85 per cent by 2050, through a comprehensive efficiency scheme, involving everything from low-carbon cities and transport systems to revamped factories. Fossil fuels would be used more efficiently, use of renewables and nuclear energy would expand, and carbon-heavy emissions would be captured before they polluted the environment. Not only do the Chinese see this plan as a means to cleaner air and water, and less dependence on fluctuating fossil fuel prices, but they*

also see it as a way for China to develop a competitive advantage in a low-carbon world. The ambition and detail of this policy far outstrip anything we have seen from the United States.

Applying the impact of China's low-carbon measures to predictions for China's oil consumption in 2050 is fascinating. If China were to succeed in supplying 50 per cent of its new energy needs with renewable resources by 2030, and 100 per cent by 2050, as the CCICED reports it hopes to, then this would have a dramatic effect on our projections for global oil demand. In 2004 we predicted that the world would be using 75.2 million barrels of oil per day by 2050. Assuming the Chinese do what they intend, then that estimate is 20 per cent too high. The world in 2050 will be using just 60 million barrels of oil per day. If India were to commit to similar targets, that would slash a further 20 million barrels per day from our 2004 projection for oil consumption by 2050."

More recently, more direct measures have been taken to tackle emissions, including measures to limit coal to 65 per cent of primary domestic energy consumption by 2015 and banning new coal generation in Beijing, Shanghai and Guangzhou.[32] These measures all directly impact demand from the largest importer of Australian coal and therefore the value of major mining and export infrastructure assets across Australia.

"More recently, more direct measures have been taken to tackle emissions (in China), including measures to limit coal to 65 per cent of primary domestic energy consumption by 2015 and banning new coal generation in Beijing, Shanghai and Guangzhou. These measures all directly impact demand from the largest importer of Australian coal and therefore the value of major mining and export infrastructure assets across Australia."

Finally, the world's second largest emitter, the US, has again been identified by many Australian politicians and businesses as supportive of an Australian approach of taking little action. The reality is at the federal level, President Barack Obama is using his powers under the *Clean Air Act* and through the Environmental Protection Authority (EPA) to circumvent a hostile Congress to implement emissions standards on new coal fired power stations, which will effectively prevent the construction of new coal power stations without carbon capture storage technology.[33] In addition, the EPA has implemented national emission standards on coal power stations that require them to reduce emissions of mercury and other hazardous air pollutants. The effect of these regulations and other air pollution measures introduced by the Obama administration is projected to lead to 60 GW of coal-fired generation being retired by 2020.[34]

The US also has a number of state based and regional emission trading schemes currently in operation. The Californian ETS commenced operation in 2013 and follows the Regional Greenhouse Gas Initiative launched among north-eastern states in 2009 and in 2007 the Western Climate Initiative among a number of US states and Canadian provinces. Just this month, the Governor of Washington State unveiled a carbon reduction plan that would include a cap-and-trade scheme.[35]

The world is now seeing national governments directly implement a suite of domestic measures to regulate global greenhouse emissions. While the full introduction of these measures will take time there is already a focus on how such national and regional schemes can be globally integrated outside of an international global agreement. Investors and owners of businesses have to consider the rate at which this will occur and emissions will become a permanent cost of production. This includes consideration of various carbon price scenarios that may result in stranded assets – those that would become unprofitable under certain carbon regulatory scenarios resulting in considerable reductions in the long-term value of particular companies.

International capital flows

While the physical effects of climate change as well as increased regulation will have a clear impact on Australian investments, the third critical factor at play is the rapidly changing landscape with respect to international capital flows.

Traditionally, investors and financiers simply have not taken climate change risk into account in their decision-making. There are a number of reasons for this. Climate change occurs over decades and many investors have much shorter investment timeframes. In addition, the lack of climate change related reporting by companies has made it difficult for investors to evaluate risk. Finally, political uncertainty and the lack of a stable carbon market also make it difficult for investors to price in a regulatory carbon price.[36]

However, there is increasing momentum to more carefully assess investments in carbon intensive industries or divest altogether and in last 12 months there have been some significant developments.

The Secretary-General of the Organisation for Economic Co-operation and Development (OECD), Angel Gurría has called for the "complete elimination of emissions to the atmosphere from the combustion of fossil fuels in the second half of the century". In supporting the need for drastic action, Mr Gurría made reference to the immense cost associated with extreme weather events such as Hurricane Sandy (0.5 per cent of US GDP in 2011) and made the point that unlike the financial crises, we do not have "a climate bailout option".[37]

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"However, there is increasing momentum to more carefully assess investments in carbon intensive industries or divest altogether and in last 12 months there have been some significant developments."

Recently, the head of the International Monetary Fund, Christine Lagarde, in response to what she termed "the merciless march of climate change", called on governments to phase out energy subsidies and spur investment in low-carbon technologies of the future.[38] At the World Economic Forum in Davos, Ms Lagarde called for a new kind of economic growth that included putting a price on carbon.[39]

Concerns with environmental and economic risks associated with carbon intensive investments have directly influenced the strategies of major international lending institutions. At this year's World Economic Forum, the President of the World Bank, Jim Yong Kim, publically supported divestment from carbon intensive assets and put pressure on pension funds "to recognise their fiduciary responsibility to future pension holders who will be affected by decisions made today".[40] The World Bank has modified its energy lending strategy to limit financing of coal-fired power plants to "rare circumstances" and only in countries that have "no feasible alternative".[41]

"Even in institutions that continue to fund fossil fuel projects, closer scrutiny of environmental effects and risks are being imposed…

"Such activity is not limited to international institutions. Increasingly international pension funds are also heading in this direction. Pension funds, with more than US$30 trillion under management, have the ability to significantly change investment flows, especially as they can afford to take a long term view."

The world's largest public financial institution, the European Investment Bank, has also implemented restrictions on financing for new fossil fuel projects, including applying an Emissions Performance Standard to all new funding proposals.[42] At the end of last year, the US Export-Import Bank approved similar investment guidelines for coal power projects and coal mines. This is backed by revised "coal guidelines" released by the US Treasury, which require the US to use its votes in international lending institutions such as the World Bank and the Asian Development Bank (ADB) to block funding for coal projects that aren't fitted with carbon capture storage technology.[43]

Even in institutions that continue to fund fossil fuel projects, closer scrutiny of environmental effects and risks are being imposed. The ADB safeguard principles require that project proposals take into account environmental impacts including transboundary emissions. The ADB itself is under increasing pressure to change its financing of coal plants.

Such activity is not limited to international institutions. Increasingly international pension funds are also heading in this direction. Pension funds, with more than US$30 trillion under management, have the ability to significantly change investment flows, especially as they can afford to take a long term view. In response to the recent attempts by Ian Dunlop to raise attention on BHP's approach to managing climate risk by running for a position on the BHP Board, the California Public Employees' Retirement System (CalPERS) stated: "We want the industry to take action, and this is an opportunity to have that agenda taken into the heart of the debate in the boardroom by someone who understands the severity and potential impacts of this risk."[44]

The Norwegian Sovereign Wealth Fund, which grew by $200 billion in 2013 alone and owns about one per cent of all global stocks, exited its investments in 27 gold and coal mines in 2013 and cut its stakes in others.[45] The wider sector review potentially heralds one of the biggest changes since it was set up as a sovereign wealth fund in 1998. It is also examining whether the fund should quit oil, gas and coal firms over their environmental impact.

Interestingly, some Australian superfunds are starting to follow suit. The Asset Owners Disclosure Project (AODP) rates the world's biggest funds on their management of climate risk. Currently, Australian funds make up six of the top 10 highest rating funds.[46] In April this year, UniSuper announced that it plans to exclude fossil fuel companies from its socially responsible investment options.[47] At the same time, the Chief Executive Officer of QSuper, Rosemary Vilgan, has recognised that discussions around stranded assets are "getting traction in the investment community".[48] Colonial First State Global Asset Management, which is owned by the Commonwealth Bank, has established a task group to examine how it should respond to the prospect of stranded assets as a result of climate risk.[49] Finally, AMP has just announced that its responsible funds would have limited scope to invest in mining and energy companies. This fund represents about $3 billion and about two per cent of all funds under management by AMP.

"Divestment from carbon intensive investments is being seen across all sectors of the investment community. Early this year, 17 of the world's largest philanthropic foundations announced commitments to withdraw funds from investments in fossil fuel companies and reinvest in the clean energy sector."

Divestment from carbon intensive investments is being seen across all sectors of the investment community. Early this year, 17 of the world's largest philanthropic foundations announced commitments to withdraw funds from investments in fossil fuel companies and reinvest in the clean energy sector.[50] The Divest-Invest coalition includes almost 20 funds which manage a total of approximately $2 billion. In addition, a number of the major US university endowment funds are following suit.

There is significant pressure being placed on international and Australian funds in this regard. Groups such as the Investor Group on Climate Change, the AODP and the Carbon Tracker Initiative, are publicising the enormous potential declines in the valuations of fossil fuel companies that will occur once capital markets recognise the staggering investment risks associated with climate change. Carbon Tracker has calculated that, if we are to keep temperature increases to no more than two degrees Celsius above pre-industrial levels as the world's governments have agreed, then most of the world's remaining fossil fuel reserves cannot be extracted. This will force a major downward market correction in the value of, for example, Xstrata (coal), Exxon (oil and gas), and British Gas (gas) – and in the total funds under management by pension funds who hold these shares. Even in the absence today of a single country with a robust carbon price in place, the market is doing its job and beginning to take notice of these enormous risks.[51]

Not all companies agree with the Carbon Tracker and stranded asset argument. Exxon Mobil Corporation in early April acknowledged that climate change poses a risk to the company's bottom line, but it made clear it would not chart a future without fossil fuels. In a recent letter to its shareholders[52], Shell, while acknowledging that risks from climate change will "continue to rise up the public and political agenda", expressed confidence that none of its current reserves will become stranded. Rather, the company said: "The world will continue to need oil

and gas for many decades to come, supporting both demand and oil and gas prices." Moreover, Shell said, the notion of oil and gas companies risking billions of dollars in potential stranded assets due to climate regulation has "significant gaps", including its failure to acknowledge the significant projected growth in energy demand; the role of carbon capture and storage technologies; and the rise of natural gas, bioenergy and energy efficiency measures. It stated that: "Energy demand growth, in our view, will lead to fossil fuels continuing to play a major role in the energy system – accounting for 40-60 per cent of energy supply in 2050 and beyond." However, Shell did acknowledge the increasing risk from regulatory regimes and the need for a fundamental transition in the energy system.

Changes are also increasingly occurring in the financing sector. As investment banks and retail banks sign up to international principles such as Principles for Responsible Investing[53] they are increasingly held to account against such principles by community advocates and non-government organisations (NGOs). As a result, they are increasingly moving away from financing certain carbon intensive activities or activities with adverse environmental or community outcomes. In this regard, Deutsche Bank's recent refusal to finance the expansion of the Abbot Point Coal Facility is indicative of the pressure being placed on such institutions. For Australian business this ultimately makes obtaining financing not only more difficult but more expensive resulting in delays and cost overruns for projects.

It is important to also recognise that such disinvestment and shift from financing is not simply based on an increasing philosophical opposition to carbon intensive activities, but is often based on a hard analysis that the demand in markets for such industries or their commodities is diminishing and at risk.

We are also witnessing a significant growth in investment alternatives. For example, the Mercer Report predicts that additional cumulative investment in energy improvements, renewable energy, biofuels, nuclear energy and carbon capture and storage could expand by more than $5 trillion to 2030.[54]

The global bond market with a total valuation of US$90 trillion is witnessing significant movement into climate smart investments. A recent report produced by the Climate Bonds Initiative and commissioned by HSBC estimates that this new asset class has approximately US$350 billion in the pipeline.[55] The size of the issuances range from US$100 million to US$2.5 billion and are almost all highly oversubscribed by investors. Interestingly, this emerging green bond asset class is not being driven by a sudden interest in managing the enormous risks of climate change nor any other environmental constraint.[56] It is strictly the result of pure market forces where demand for risk-adjusted returns is no longer being met by the traditional asset classes. As Molitor notes, what might happen when the growth of this market-driven new asset class intersects with the capital market's recognition of the staggering climate change risks as put forward by the Carbon Tracker Initiative?[57] A tipping point is now clearly visible.

Fossil fuels and renewables

It is now clear that the trends around regulating emissions and international capital flows, combined with the more general regulation of the environmental impacts of fossil fuels, will have and is having a direct impact on the cost competitiveness of fossil fuels. Leading European broking house Kepler Chereux has predicted that the global fossil fuel industry faces a $30 trillion loss in revenues over the next two decades if the world takes action to address climate change and decarbonise the global energy system.[58] For example, lower demand profiles for coal in the US, Europe and China has resulted in a steady stream of downgrades to long-term coal price forecasts.[59] As described above, major drivers in this lower demand profile are pollution reduction measures and a rapid uptake of renewable energy among the world's largest coal consumers.

"…the global bond market with a total valuation of US$90 trillion is witnessing significant movement into climate smart investments. A recent report produced by the Climate Bonds Initiative and commissioned by HSBC estimates that this new asset class has approximately US$350 billion in the pipeline."

As noted above it is clear that renewables are now reaching a point of disruption and will in many parts of the world displace coal and gas power stations. Global investment banking giant Citigroup has called this the start of the "age of renewables", claiming that renewable energy is becoming increasingly cost competitive with natural gas peaking and baseload plants.[61] The key metric used in the Citi report is the levalised cost of energy, which looks at the average cost of producing a unit of electricity over the lifetime of the generating source. The Citi report is based on modelling a long-term gas price forecast of $5.50 in the US. With long-term gas prices predicted to be double that in Australia, the cost competitiveness of renewables increases significantly.[60] Unlike natural gas and coal, the input for renewable energy is not subject to the volatility of global energy markets and with renewable costs continuing to decline, renewable generation represents a safer long-term investment.

When combined, the increasing regulatory limits on carbon intensive industries and incentives for renewables, these investment trends and capital flows will increasingly assist renewable energy and other disruptive technologies to become more cost competitive and displace some key carbon intensive industries or at least impact on their role within the global economy. For example renewable energy combined with future long-term battery storage will directly challenge the commercial viability of the traditional power station and the transmission/distribution network business model. It is interesting to note that over the past few years, *The Economist* recently reported that electric power companies in Europe have lost €500 billion in market value both because of declining renewable energy costs and their over-investment in fossil fuel generation assets.[62]

How quickly, and to what extent, fossil fuels are affected remains to be seen. While there is no suggestion that fossil fuels will not continue to be the major source of global energy in the short term, over the medium and longer term the changes to the fossil fuel sector will be dramatic.

Conclusion

Australian business and Australian investors operate in a global business environment. While our current political and business leaders pursue an approach of not regulating the greenhouse emissions of Australian industry, the global economy is rapidly moving in the opposite direction. The physical reality of climate change impacts, the increasing introduction of regulatory regimes across many counties to limit greenhouse gas emissions, changes in international capital flows and investment decision-making, the emergence of disruptive technologies and the inter-relationship of all these factors means that no business is immune from the economic impacts driven by climate change. While not all of these impacts may occur immediately, disruptions are already evident and the trends are clear. Australia's carbon intensive industries need to plan for a very different future economic environment.

Endnotes

1 Stern, N 2006, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, p. xv.

2 ibid, pg. xv

3 Folger, T 2013, Rising Seas, accessed at http://ngm.nationalgeographic.com/2013/09/rising-seas/folger-text, 2 May 2014

4 United Nations Environmental Program, Division of Early Warning and Assessment 2010, *UNEP Year Book 2010: New Science and Developments in our Changing Environment*, p. 44.

5 For example see: http://adl.brs.gov.au/forestsaustralia/facts/fire.html

6 For example, see: http://www.aph.gov.au/library/pubs/climatechange/theclimate/moreextreme.html

7 Citigroup Global Markets, Equity Research 2011, "Climate Change Risks and Opportunities: Learning from flood impacts on a wide range of Companies and Sectors," p. 4.

8 Citigroup Global Markets, Equity Research 2011, "Climate Change Risks and Opportunities: Learning from flood impacts on a wide range of Companies and Sectors," p. 9.

9 Citigroup Global Markets, Equity Research 2011, "Climate Change Risks and Opportunities: Learning from flood impacts on a wide range of Companies and Sectors," p. 3.

10 Mercer LLC Carbon Trust and International Finance Corporation, 2011, Climate Change Scenarios – Implications for Strategic Asset Allocation Public Report (*Mercer Report*).

11 Mercer Report p. 31.

12 Mercer Report p. 18.

13 Winston, A 2014, *Resilience in a Hotter World* Harvard Business Review, April 2014.

14 ibid

15 Atkins, A 2014, 'Floods: David Cameron must face down climate scepticism in his own party", *The Guardian*, 13 February.

16 The Climate Institute, 2012, *Coming Read or Not: Managing climate risks to Australia's infrastructure*, Sydney, 2012, p. 5.

17 ibid, p. 39.

18 Victorian Government, 2010 "Climate Change and Infrastructure: Planning Ahead".

19 Apple, 2014, *Environmental Responsibility*, accessed at http://apple.apple.com/au/environment/, 1 May 2014.

20 E. Lowitt, 2014, *How to Survive Climate Change and Still Run a Thriving Business* Harvard Business Review, April 2014.

21 The Climate Institute, 2012, Coming Read or Not: Managing climate risks to Australia's infrastructure, Sydney, 2012, p. 30.

22 ibid, p. 30.

23 Minerals Council of Australia, 2013, *Industry Groups United: Carbon Tax Must Go*, accessed at http://www.minerals.org.au/news/industry_groups_united_carbon_tax_must_go, 3 May 2013.

24 Carbon + Environment Daily, 2014, *Direct Action sparks new carbon deregulation campaign*, Carbon + Environment Daily, 28 April 2014.

25 Graham Bradley, former head of the Business Council of Australia on Q&A 11 November 2013, transcript available here: http://www.abc.net.au/tv/qanda/txt/s3873461.htm

26 World Bank, 2012, *Korea's Global Commitment to Green Growth*, accessed at: http://www.worldbank.org/en/news/feature/2012/05/09/Korea-s-Global-Commitment-to-Green-Growth, May 3 2014

27 Bifera, L 2014, *Carbon Trading in China: short-Term Experience, Long-Term Wisdom* access at: https://theenergycollective.com/lucas-bifera/366391/carbon-trading-china-short-term-experience-long-term-wisdom, 2 May 2014.

28 CleanTechnica, 2013, *China's New Solar Target: 40 GW by 2015 (8 Times More Than Its Initial 5 GW Target*, accessed at: http://cleantechnica.com/2012/12/13/chinas-new-solar-target-40-gw-by-2015-8-times-more-than-its-initial-5-gw-target/, 2 May 2014.

29 REN 21, 2013, *Renewables 2013, Global Status Report*, Paris, REN21 Secretariat, p. 13.

30 ibid, p. 13.

31 O'Neil, J 2011, *The Growth Map, Economic Opportunity in the BRICs and beyond*, Penguin Group, London.

32 Bloomberg News, 2014 *China to Cut Dependence on Coal Energy as Smoke Chokes Cities*, Bloomberg, 24 January 2014. Parkinson, G 2013, *China, US say no to new coal plants*, RenewEconomy, 16 September 2013.

33 Parkinson, G 2013, China, *US say no to new coal plants*, RenewEconomy, 16 September 2013.

34 Harder, A & Kendall, B 2014, Appeals Court Upholds EPA Rule on Power-Plant Emissions, The Wall Street Journal, 15 April 2014.

35 Thomson Reuters, 2014, *Washington State Governor Unveils Carbon Reduction Plan*, Point Carbon, 30 April 2014.

36 Peltz, M 2014, *Climate Change and the Years of Investing Dangerously*, Institutional Investor, 7 April 2014.

37 Gurria, A 2013, 'The Climate Challenge: Achieving zero emissions', Lecture by the OECD Secretary-General, London, 9 October 2013

38 Lagarde, C 2014, 'A New Multilateralism for the 21st Century' the Richard Dimbleby Lecture, London, 3 February 2014.

39 Romm, J 2013, 'IMF Chief: 'Unless We Take Action on Climate Change, Future Generations Will be Roasted, Toasted, Fried and Grilled' accessed at: http://thinkprogress.org/climate/2013/02/05/1546471/imf-chief-unless-we-take-action-on-climate-change-future-generations-will-be-roasted-toasted-fried-and-grilled/, 4 May 2014.

40 Yong Kim, J 2014, 'World Bank group President Jim Yong Kim remarks at Davos Press Conference' the World Economic Forum, Davos, 23 January 2014.

41 Yujhananov, A & Volcovici, V 2013, *World Bank to Limit Financing of Coal-Fired Plants*, Reuters, 16 July 2013.

42 EurActiv, 2013 *EIB restricts lending for fossil fuel projects, with exceptions*, accessed at: http://www.euractiv.com/energy/fundraising-europe-fossil-fuel-p-news-529565, 4 May 2014

43 US Department of Treasury, 2013, 'Guidance for U.S. Positions on Multilateral Development Banks Engaging with Developing Countries on Coal-fired Power Generation' accessed at: http://www.treasury.gov/resource-center/international/development-banks/Pages/guidance.aspx, 4 May 2014.

44 Hoyle, R 2013, *BHP fights Board Seat for Climate-Change Activist*, Reuters, 20 November 2013.

45 Knudsen, C & Fouche, G 2014, *Norway's sovereign fund halves coal exposure*, Reuters, 28 January 2014.

46 Asset Owners Disclosure Project, 2014, 'AODP Global Climate Index', accessed at: http://aodproject.net/climate-ratings/aodp-global-climate-index/list/2.html, 4 May 2014

47 Carbon + Environment Daily, 2014, *Coal, oil and gas not socially responsible, UniSuper says*, Carbon + Environment Daily, 1 April 2014.

48 Sinclair, K 2014, *QSuper CEO says climate risk an emerging issue for super industry*, The Courier-Mail, 30 April 2014.

49 Carbon + Environment Daily, 2014, *Colonial First State rethinks its investment strategy on stranded assets*, Carbon + Environment Daily, 15 April 2014.

50 Divest Invest, 2014, 'Philanthropy' accessed at: http://divestinvest.org/, 5 May 2014.

51 M. Molitor *De-carbonising for growth: why everyone is wrong about the costs of addressing climate change* Public lecture, University of New South Wales, 20 April 2014

52 http://s02.static-shell.com/content/dam/shell-new/local/corporate/corporate/downloads/pdf/investor/presentations/2014/sri-web-response-climate-change-may14.pdf

53 PRI, 2014, 'Signatories to the Principles for Responsible Investment' accessed at: http://www.unpri.org/signatories/signatories/ , 5 May 2014.

54 Mercer Report, p. 30.

55 Climate Bonds Initiative 2014, 'Bonds and Climate Change: the State of the Market in 2013' accessed at: http://www.climatebonds.net/files/Bonds_Climate_Change_2013_A3.pdf, 6 May 2014, p. 4.

56 ibid, p. 4.

57 M. Molitor *De-carbonising for growth: why everyone is wrong about the costs of addressing climate change* Public lecture, University of New South Wales, 20 April 2014

58 Parkinson, G 2014, *Fossil fuels face $30 trillion losses from climate, renewables*, RenewEconomy, 28 April 2014.

59 IEEFA, 2014, 'IEEFA Briefing Note – Thermal Coal Outlook February 2014' accessed at: http://www.ieefa.org/wp-content/uploads/2014/02/Thermal-Coal-Outlook-February-2014-Observations-IEEFA.pdf, 1 May 2014

60 Parkinson, G 2014, *Citigroup says the 'Age of renewables' has begun*, RenewEconomy, 27 March 2014.

61 Chambers, M 2014, *LNG demand to force spike in gas prices*, The Australian, 7 March 2014.

62 The Economist 2013, 'How to lose half a trillion euros' accessed at: http://www.economist.com/news/briefing/21587782-europes-electricity-providers-face-existential-threat-how-lose-half-trillion-euros, 5 May 2014.

2. Climate risks: Probabilities, consequences and actions

Professor Quentin Grafton
Professor Rodney J Keenan

This chapter presents a framework for assessing climate risks and considering possible actions that may lower climate risks.

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Professor Rodney Keenan is Director of the Victorian Centre for Climate Change Adaptation Research, a research partnership between Victorian universities funded by the Victorian Government. He has worked for the Federal Government, in a number of Australian states and in Canada, Japan and Papua New Guinea.

"Almost all regions of the world have suffered extreme weather events in recent years…Despite protection measures, vulnerability has not been reduced in general. Climatic changes are discernible in most areas and already certain in some. Hence, the consequences of weather events are on the rise throughout the world, and the risks associated with them are changing faster and faster."[1]

Introduction

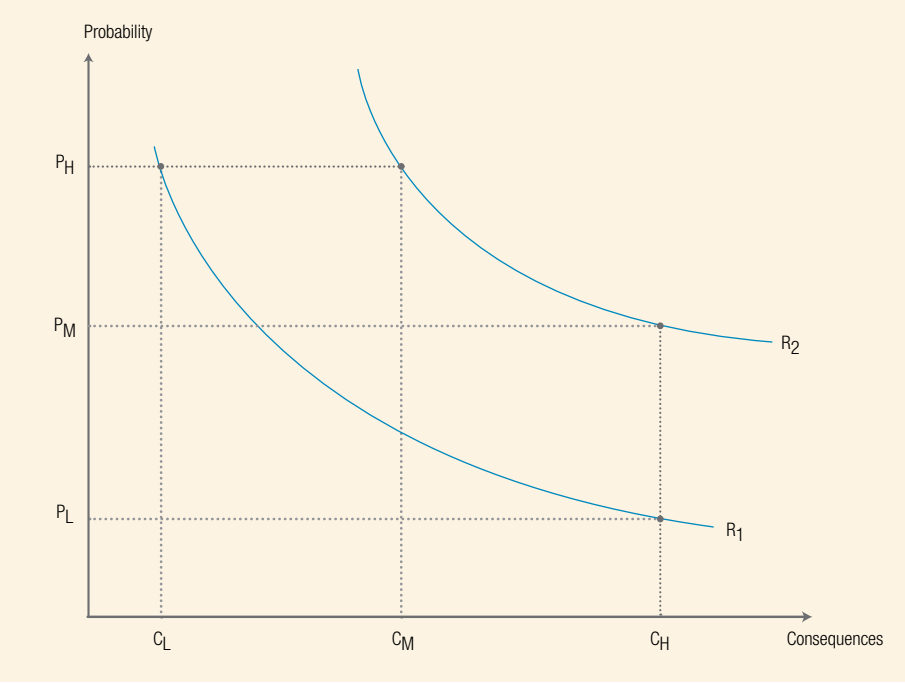
Climate risks are bio-physical, chiefly weather related, events that occur as part of the current climate, have a probability or a likelihood of occurrence, and impose a negative cost or adverse consequences on current and/or future generations. These risks have always been with us, with the frequency, intensity and impact of climate related events varying with natural variation in the climate system. Climate risks are being magnified by changes in climate change due to emissions of greenhouse gases from burning of fossil fuels, deforestation and industrial processes.

At a global scale the possible adverse consequences of climate change include threats to unique and threatened ecosystems and cultures, extreme weather events (such as heat waves, extreme precipitation and coastal flooding) and large-scale singular events (such as large and irreversible sea-level rise) in response to increases in global mean temperature.[2] These projected effects are likely to be unevenly distributed with larger impacts for the disadvantaged, to have global impacts on the world economy, and to contribute to extensive biodiversity loss. In Australia, the key projected consequences of climate change include: temperature increases with more hot days and fewer cool days; a rise in extreme fire-weather days in southern Australia; an increase in the incidence of droughts in southern Australia; sea-level rise; an increase in the intensity of tropical cyclones; and a greater intensity and frequency of extreme daily rainfall.[3]

Risk is commonly defined as the probability of an adverse event 'multiplied' by the consequence, or the expected value of the adverse event. A common risk assessment framework assumes there can be a trade-off between the probability of an event and its consequence. This implies that a high probability event that has a low consequence (P_H–C_L) is commensurable with a low probability event with a high consequence (P_L–C_H), as shown in Figure 1. The slope of the risk curve represents the hypothetical willingness to trade-off a lower probability with a higher consequence where the steeper the slope, the smaller the willingness to trade-off a decline in probability for a higher consequence.

Using the climate risk framework identified in Figure 1, climate change can be visualised as a shift outwards in the risk trade-off curve from R_1 to R_2 such that for a given probability of an adverse event the consequence is greater, or

FIGURE 1
PROBABILITY AND CONSEQUENCES OF CLIMATE RISKS



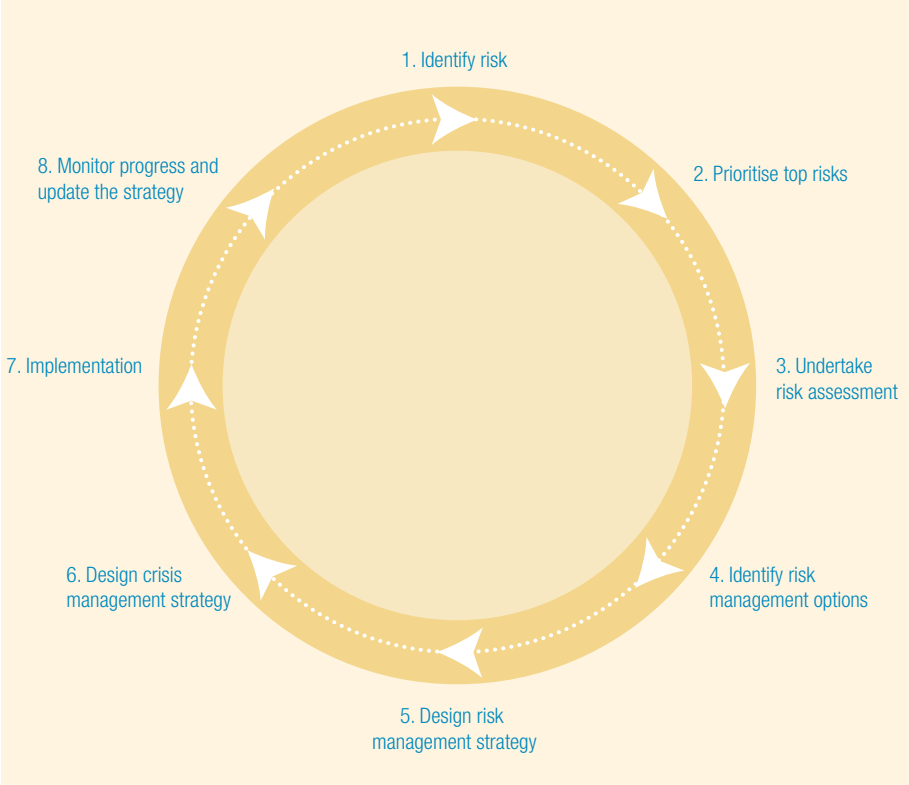
Source: Grafton, RQ 2010, Adaptation to climate change in marine capture fisheries', *Marine Policy,* vol. 34, p. 607.

for a given adverse consequence, the probability of the event is greater. As the impacts of climate change are projected to increase with higher average global mean temperatures, it is possible the shape of the risk trade-off will change as the willingness to substitute between probability and consequence may decline the higher the global mean temperature.

Risk identification, as presented in Figure 1, presents the first step in a risk assessment and management framework. Figure 2 illustrates the seven other steps in a circular process undertaken by most of the more than 100 of the Standard and Poor's 500 firms interviewed by the Wharton School in relation to catastrophic risks.[4] The risk analysis and management steps include:

- Risk identification;
- Prioritisation of risks;
- A risk assessment;
- Identification of risk management options;
- Design of a risk management strategy;
- Design of a crisis management strategy;
- Implementation; and
- Monitoring of progress and updates to the strategy.

FIGURE 2
CIRCULAR RISK ANALYSIS AND MANAGEMENT PROCESS



Source: Kunreuther, H, Michel-Kerjan, E and Useem, M 2013, Corporate Strategies for Managing Catastrophic Risks in the S&P 500: Linking Initiative and Deliberative Thinking, Wharton School, University of Pennsylvania, accessed at http://opim.wharton.upenn.edu/risk/library/CorpStrategiesForManagingCatRisksInP500_WhartonRiskCtr_2013Nov.pdf, 28 April 2014. p. 7

The vast majority of firms undertake assessments of catastrophic risk on an annual or more frequent basis, and more than 75 per cent of interviewed firms noted the importance of risk identification and prioritisation to their businesses.

We present a framework for assessing climate risks and considering possible actions that may lower climate risks. Our focus is on actions to reduce the consequences of climate change or what is commonly referred to as climate adaptation. Adaptation does not substitute for mitigation (reduced probability of climate change). Both sets of actions may reduce climate risks with mitigation reducing the potential future magnitude of climate change and adaptation reducing the adverse effects of that change. While mitigation measures are best handled through national policies, adaptation is context and geographically specific, necessarily focused at local to regional scales that involve actions by individuals, communities, businesses and government.

"Uncertainty poses a dilemma as to what actions should be undertaken today in the absence of certainty about the future consequences of climate change. However, uncertainty does not imply that possible actions to reduce the consequences of climate change should be postponed until the certainty is resolved."

Uncertainty and climate probabilities

Uncertainty poses a dilemma as to what actions should be undertaken today in the absence of certainty about the future consequences of climate change. However, uncertainty does not imply that possible actions to reduce the consequences of climate change should be postponed until the certainty is resolved. Indeed, the greater the uncertainty, all else equal, the more important it becomes to:

- Create options and flexible pathways in the future should the consequences of climate change prove to be large and negative; and
- Avoid 'lock in' in terms of climate action or irreversible investments as actions are, typically, sequential and may need to change as additional information comes available.

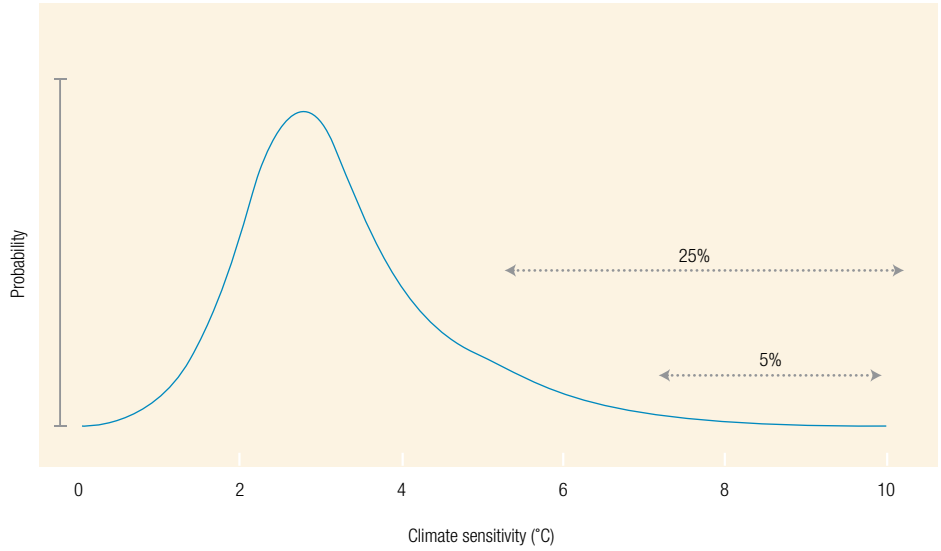
Two key features of climate change uncertainty are:

1: The probability and consequence of the events are uncertain; and

2: The probability of extreme warming and also the probability of extreme consequences of extreme warming are both subject to 'fat-tailed distributions'[5].

Fat-tailed probability distributions share the characteristic that both the mean and median have a higher value than the mode, as illustrated in Figure 3. A key implication with a fat-tailed distribution is that the probability of an extreme or a high impact event can be much higher than with a normal distribution with the same modal value. For instance, fat-tailed distributions mean that the probability of an increase in global mean temperature in excess of seven degrees Celsius

FIGURE 3
HYPOTHETICAL FAT-TAILED PROBABILITY DISTRIBUTION



Source: Adapted from Calel, R, Stainsforth, DA and Dietz, S 2013, Tall tales and fat tails: the science and economics of extreme warming, *Climatic Change* DOI 10.1007/s10584-013-0911-4. Figure2(b)

is as high as five per cent[6] based on multiple probability distributions of climate sensitivity (increase in global mean temperature from a doubling in pre-industrial levels of carbon dioxide). Fat tails may also arise from positive feedbacks with climate change such as methane emissions from peat land in northern latitudes.[7]

The implication of fat-tailed probability distributions for both climate sensitivity and positive feedbacks with climate change is that they can greatly alter the economic calculus of possible damage, and the benefits versus the costs of mitigation. For example, assuming a higher damage function whereby damages are much greater at higher temperatures, and using fat-tailed rather than a thin-tailed distribution for climate sensitivity, can increase the projected consumption losses due to climate change by a factor of more than 100[8].

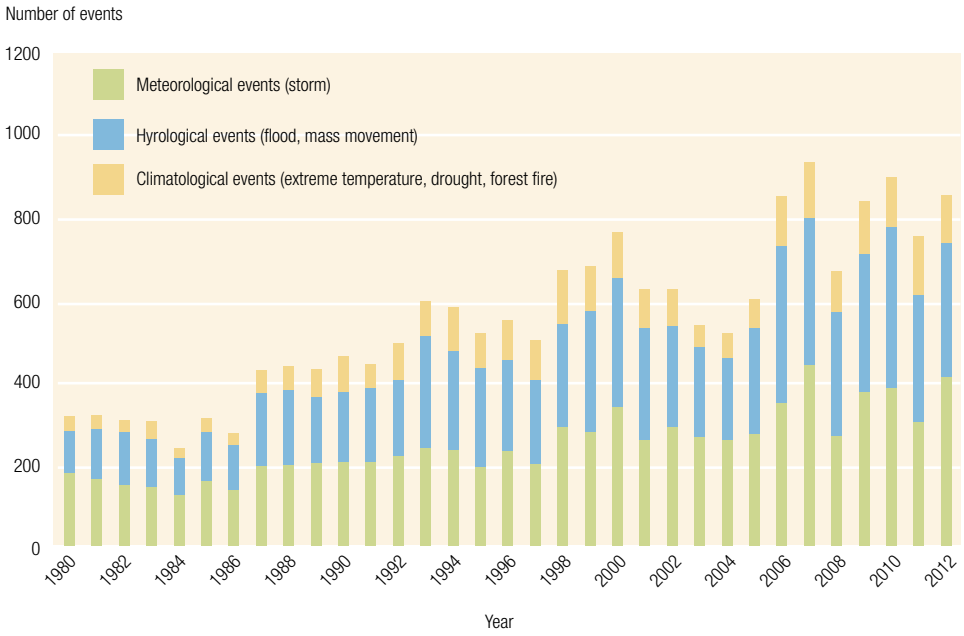
Climate consequences

Debates about an appropriate climate damage function and the probability distributions of climate sensitivity mask the fact there are already some quantitative data about the adverse consequences of current weather events with the present climate. Two outstanding features of the data compiled to date on weather related losses for insurers over the past few decades are:

- The number of catastrophic weather events is getting larger; and
- The economic losses associated with weather related events is trending upwards over time, and for some events such as severe thunderstorm events, this loss increase occurs even after accounting for the rise in destructible values over time.[9]

FIGURE 4A

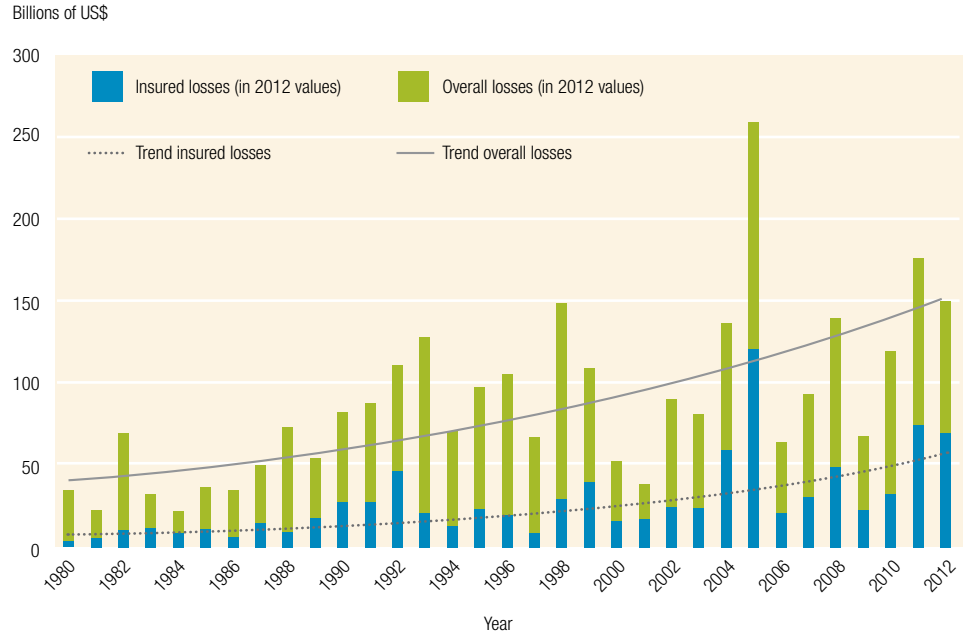
NUMBER OF GLOBAL WEATHER RELATED CATASTROPHES 1980–2012



Sourced from data at Muchener Ruckversicherungs-Gesellschaft, Geo Risk Research, NatCatSERVICE, January 2013.

FIGURE 4B

GLOBAL WEATHER RELATED CATASTROPHES ECONOMIC LOSSES ($US BILLION) 1980–2012



Sourced from data at Muchener Ruckversicherungs-Gesellschaft, Geo Risk Research, NatCatSERVICE, January 2013.

Figures 4a shows the global number of weather related catastrophes from 1980-2012 while Figure 4b shows the total losses (insured and uninsured) from these events. Both of these figures, sourced from data compiled by the world's largest reinsurer, Munich RE[10], show an increasing trend and that the rate of change (slope) is increasing over time. A trend of an increasing number of weather related

catastrophes is true for Australia[11] and is consistent with climate change model projections[12]. An increasing trend in weather related catastrophes also exists for countries in East Asia[13] that includes some of Australia's nearest neighbours.

A review of data on weather catastrophes reveals that:

- Not all the events are storm or precipitation related events; and
- Property damages are not necessarily required to cause fatalities.

For instance, in 2013, the third largest global weather related event recorded in terms of fatalities was the July heatwave in the United Kingdom. This was estimated to have caused 760 fatalities, but resulted in no recorded property losses.[14] The point is that actions intended to reduce the consequences of climate risks should include responses to immediate and regional/local events (such as a cyclone) as well as events that may occur at a national level and over a protracted period of time (such as a widespread drought).

Climate risks and vulnerabilities

The probability and the consequences of climate change events determine climate risks. To what extent climate risks are realised depends on multiple factors that include: exposure to climate events, sensitivity of bio-physical and socio-economic systems to these exposures, and human actions.

Exposure is determined by the climate system and the location of assets or communities in relation to climate events. It is influenced by greenhouse gases (GHG) concentrations in the atmosphere along with other climate drivers. There are three ways to reduce future climate risk exposure:

1: Reduce current and future GHG concentrations by limiting emissions and/or by undertaking GHG sequestration;

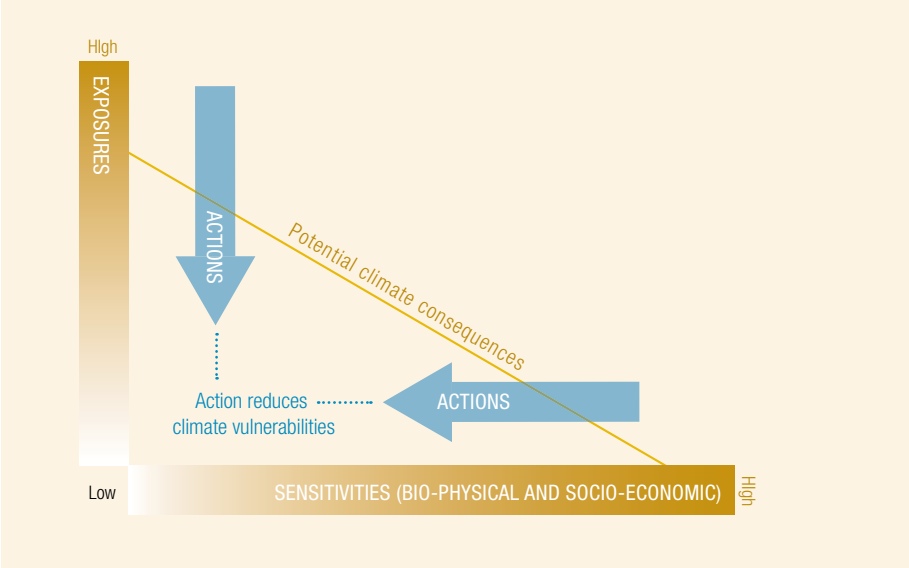
2: Relocate people and assets from relatively more exposed to less exposed locations; or

3: Undertake geo-engineering such as enhancing the earth's albedo effect.[15]

Sensitivity is the responsiveness of the community, industry or physical or natural assets to different climate related events for a given level of exposure. This includes the capacity to resist the impacts of climate events and the resilience of bio-physical and socio-economic systems to 'bounce back' or recover from a given level of exposure. Sensitivity can be reduced by investments and actions that make systems more resilient.

Climate risk exposure and sensitivity combined determine the *potential* consequences of climate events. What ultimately are the consequences of future climate related events is determined by actions to reduce exposure (such as through relocation) and/or sensitivity (such as through increased climate resilience). These inter-relationships are illustrated in Figure 5 whereby both exposure

FIGURE 5
CLIMATE CONSEQUENCES AND VULNERABILITIES: EXPOSURES, SENSITIVITIES AND ACTIONS



and sensitivity determine potential climate consequences. Actions that diminish sensitivities and exposure may reduce the actual consequences or climate vulnerabilities. The action arrows in Figure 5 illustrate the multiple pathways to reduce the potential climate consequences for a given global mean temperature. The residual exposure and sensitivity after actions have been implemented determine climate vulnerability.

An assessment of climate risks and vulnerabilities requires planning processes that connect the probabilities of future climate events to the abilities of bio-physical/socio-economic systems to recover, and to the possible actions or pathways to reduce the consequences of the events should they occur. This involves multiple processes and evaluations. A valuable first step is the establishment of national or state risk registers that provide a quantitative index of relative consequences and relative probability in both the short and long run. This allows a comparative assessment of all risks (such as earthquakes and terrorist attacks), not just climate related risks, in a transparent process to inform decision-makers about how to allocate scarce resources to reduce exposure and/or sensitivities at a national and regional scale.

The United Kingdom (UK) National Security Risk Assessment[16] is an example of risk identification process undertaken at a national level. Its risk assessment is on a biennial cycle and a 20 year planning horizon that is intended to identify national security risks and support a National Security Strategy. While far short of a national risk register, the Australian government has prepared an overview of both current and future climate risks facing Australia denominated by water, agriculture, infrastructure, natural ecosystems, human health, and coasts[17].

Climate adaptation actions

Actions to reduce sensitivities and exposure are commonly referred to as climate adaptation. They can be responsive – implemented after an adverse climate event to reduce impact or assist recovery – or anticipatory – undertaken before an event occurs to prepare for or avoid impacts.[18] Whether ex-ante or ex-post, adaptation to climate change should be dynamic and respond, when necessary, to updates in evidence and understanding.

Actions can be incremental in that they aim to maintain an existing piece of infrastructure, an industry or a community by 'adding on' to actions already in place to manage climate risks. Alternatively, anticipated climate events with a high consequences and/or at a widespread spatial scale may require collectively and explicitly planned transformational actions that result in new types of industries, infrastructure or communities in new locations.[19]

A debate exists about the need for investment of public funds for adaptation. Some[20] have argued that there is only a limited requirement for public investment beyond the need to provide and disseminate information on possible consequences and advice on appropriate actions. In this view, the role of government in adaptation is primarily to promote a diverse and resilient economy and well-functioning markets for risk management tools, such as insurance.

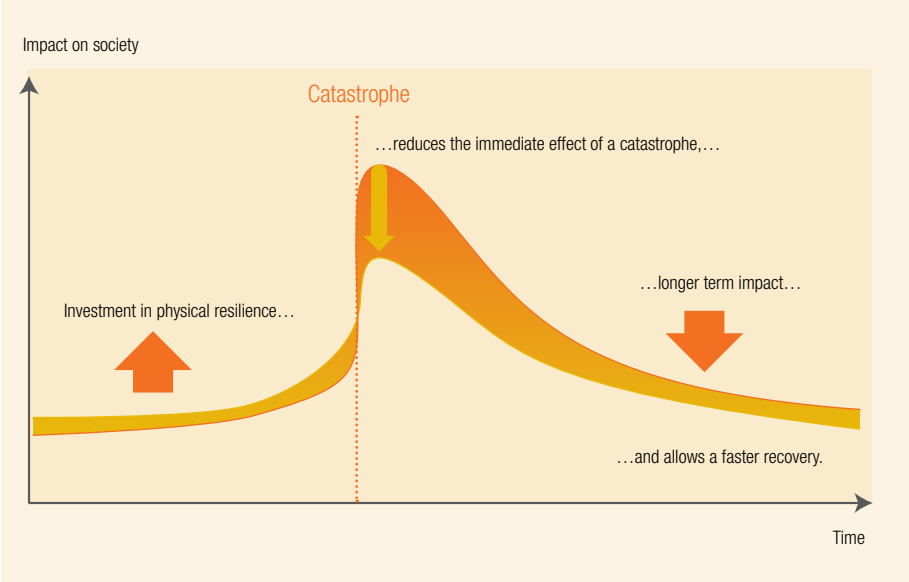
An alternative perspective is that adaptation requires the establishment of incentives, standards and regulations that promote appropriate individual and community actions to climate risks, such as building standards or land zoning rules; institutional changes, such as development of effective planning, national strategic assessments and increased emergency preparedness and responses to climate change events. Actions may also include public assistance to help the private sector manage large-scale catastrophes, improved public investment decisions in relation to public infrastructure, and the provision of public goods provided or regulated by governments, such as roads and natural or cultural heritage areas.[21]

> "Governments by themselves cannot, and should not, undertake all transformation adaptation actions, but are key to leveraging resources across the private sector and civil society and are fundamental to the development of across society networks and the development of public-private-civil society partnerships to improve resilience."

Assessing the costs and benefits of public adaptation actions can be approached by a comprehensive framework for assessment of 'total climate risk'[22] based on:

- An assessment of the expected annual losses to the economy from existing climate patterns;
- Projection of the extent to which future economic growth will put greater value at risk;
- An assessment of the incremental loss that could occur over a 20 year period under a range of climate change scenarios based on the latest scientific knowledge; and

FIGURE 6
THE CASE FOR INVESTING IN RESILIENCE AND ADAPTATION



Source: WEF 2011. A vision for managing natural disaster risk: proposals for public-private stakeholder solutions. World Economic Forum, Geneva. Accessed at http://www.weforum.org/reports/vision-managing-natural-disaster-risk 23 April 2014. p. 57

- An evaluation using risk-based cost-benefit analysis of a selection of feasible and applicable measures to adapt to the expected risk – spanning infrastructural, technological, behavioural and financial solutions and including environmental and non-market values[23].

Such assessments are required to avoid public actions that contribute to maladaptation that make bio-physical/socio-economic systems less resilient to climate events.

Anticipating and managing the effects of climate related events as part of public actions can reduce the overall costs to government, industry and the community in the long run (see Figure 6) by both speeding up the recovery time and lowering the consequences of climate related events[24]. Governments by themselves cannot, and should not, undertake all transformation adaptation actions, but are key to leveraging resources across the private sector and civil society and are fundamental to the development of across society networks and the development of public-private-civil society partnerships to improve resilience[25]. While lowering future costs is desirable, in general, it is not efficient to reduce future climate related losses to zero. This is because when determining what actions should be undertaken, private or public, the marginal costs of adaptation actions must be considered against the expected benefits from these actions[26].

Assessment of the costs of climate related events

Key challenges when assessing the case for investment in adaptation is to understand what are the costs of climate related events, and how these might increase under a changing climate. Important data sources of climate risks are weather related disaster cost estimates. In many countries, including Australia, these are largely drawn from insurance data.[27] While valuable, insurance payout-based assessments only account for insured losses, and these represent only a fraction of the total cost of a weather related disaster. For instance, they do not include many indirect costs, the loss of life, or intangibles such as damage to ecosystem services or cultural sites and are, typically, limited to those hazards and assets that are actually subject to insurance.

To assess the full economic effects of climate change is challenging and resource intensive. Three broad approaches to assess impacts, according to Keating and Handmer[28], include:

- General equilibrium analysis;
- Partial equilibrium analysis; and
- Integrated assessments.

General equilibrium analysis provides a top down approach to economy-wide impacts using computer models based on multiple-sectors of the economy. This approach is useful to assess complex flow-on or indirect impacts to an economy and provides insights into impacts on multiple markets or sectors. *Partial equilibrium analysis* has the benefit of utilising various and flexible valuation methodologies that can be applied to a variety of impacts, sectors or markets and is well suited to exploring the impacts of extreme events. *Integrated assessments* include analysis of specific sectoral circumstances as well as the flow-on and feedback effects within the economy as a whole. Socio-economic projections and qualitative decision-support tools can also be incorporated within integrated assessments.

Key issues associated with the economic assessment of climate change impacts include:

- The valuation of impacts on intangibles (such as the environment or amenity values);
- The selection of an appropriate discount rate;
- The inclusion of uncertainty;
- The analysis of low probability but high impact events; and
- Assessment of distributional impacts between different parts of the community.

Assessment of adaptation actions

Adaptation actions can take a variety of forms, including 'hard' options such as investment in infrastructure or technology or 'soft' actions that involve changes in policy settings, and support for behavioural change or financial solutions.

Infrastructure or technology investments

To manage climate risks for hard infrastructure or technology investments the timing of investment, and the payoffs or costs from delaying these projects, are important. Waiting to invest in a project means planners can improve their ability to learn about likely payoffs in a situation where these payoffs are initially imperfectly known. Delaying investments may also have a positive value where investments are irreversible and there is a positive option value from improved information in the future[29].

There is an inherent trade-off between the enhanced flexibility from delaying a large project and the potential benefits from early implementation. For instance, society is generally risk-averse when it comes to basic needs, such as water security. Consequently, it may be desirable when meeting basic needs to undertake early implementation to protect these needs regardless of the irreversibility of investments. Pre-planning or modular design options may also improve outcomes where there is risk and irreversibility, because they can reduce the costs of waiting and speed up implementation time when the decision is made to invest. Modular design options, for instance, allow for smaller initial infrastructure investments to be built and then be scaled up, as required, depending on updates in information and understanding.

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An example of good practice in the assessment of the costs and benefits of adaptation is the Port Phillip Bay Coastal Adaptation Pathways Project in Victoria. This project developed an applied research framework to identify adaptation pathways, summarised in Table 1, to support coastal adaptation planning in urbanised areas in response to changing inundation risks under climate change due to a combination of increasing sea level and catchment flooding[30]. This framework was used to assess economically feasible adaptation pathways to help manage inundation risk over time. The planning process combined forecasts of inundation hazards, economic analysis and community involvement. Action options were then compared based on net present value while Monte Carlo analysis was used to consider uncertainty in inputs (i.e. distributions between upper and lower estimates of future inundation).

TABLE 1
POTENTIAL ADAPTATION OPTIONS TO MANAGE INCREASED FLOOD RISK

Policy	Physical/engineered	Research	Behavioural
New or extended flood overlays to inform land use planning	Upgrade of local drainage assets	Develop climate resilient design standards for developments and assets in flood prone areas	Increased training to enhance organisational capacity to prepare for and respond to flood events
New or extended special building overlays	Increase height or extent of current flood levees	Undertake erosion assessments	Community awareness and education campaigns to increase resilience to flood events
Update state and municipal emergency management plans	Upstream retarding basins to improve flood storage capacity	Detailed risk assessments to determine risk of flood protection failure	Targeted information resources for flood protection measures for builders and renovators
Incorporate changing inundation risks into corporate risk registers	Floodgates for creeks and rivers	Technical feasibility studies for proposed flood protection measures	Increased maintenance of key assets such as stormwater drains
Rezoning of land subject to inundation	Modify stormwater diversions and storages		Review insurance arrangements
Mandatory disclosure of flood risk at time of purchase and leasing	Restore natural floodplains and swamps		Clarify roles and responsibilities for flood mitigation, response and recovery
Update drainage asset management plans	Elevate critical assets above the flood level		
Incorporate consideration of inundation issues in relevant planning checklists	Relocate critical assets		
Review heritage policies to minimise potential barriers to flood protection measures			

Source: AECOM/MAV 2012. Adapting to Inundation in Urbanised Areas: Supporting Decision Makers in a Changing Climate. Accessed at http://www.abm.org.au/adaptationproject/about.html on 23 April 201

Role of the business sector

Industry

Adaptation has not been a priority for business and industry with the exception of a few sectors more exposed or sensitive to climate change, such as tourism and primary industries[31]. Nevertheless, an awareness of how climate change may affect businesses is growing. For instance, the World Economic Forum has identified the failure to adapt to climate change as a key global risk.[32] Many large companies and those investing in assets with a long service life also consider future climate risks and their actions include responses to events that directly affect their operations. However, what is lacking is a need to consider wider system implications and to develop a more anticipatory approach to investment in adaptation.

"Ultimately, investment in adaptation measures is a business decision and industries require frameworks to assess the business case for investment based on tangible (monetary) and intangible (non-monetary) benefits and costs."

Notwithstanding the costs, climate change can present new opportunities to industry and business. These include relocating farming systems to more desirable locations as a result of warming, such as viticulture in Tasmania, and also innovation in new technologies and systems, such as renewable energy and storage, that respond to changing social, environmental and commercial conditions.

Climate risks to industry include the effects of increasing maximum daily temperatures on productivity.[33] For example, in Victoria the annual total days of extreme heat have increased faster than expected. Since 1996, the total days above 35°C have been at the level previously estimated for 2030. The difficulty is that heat stress in employees poses a significant risk to those businesses with workers outdoors, such as construction, heavy industry and defence. Extreme heat can also increase the rate of equipment failure and maintenance costs on essential infrastructure such as electricity (brownouts, reduced conductivity), communications (infrastructure failure) and rail (buckling tracks) and can have negative health impacts for employees and employers.

Identified needs for adaptation in industry include accessible and sector-specific adaptation information and networks that enable knowledge exchange within and between organisations; planning support to enable better preparedness and recovery from climate events; and appropriate finance-related products to support businesses to prepare and recover from climate related events.[34] Ultimately, investment in adaptation measures is a business decision and industries require frameworks to assess the business case for investment based on tangible (monetary) and intangible (non-monetary) benefits and costs.

Finance

The quality and availability of information is essential to the creation of an adequate risk management strategy and in assisting the decision making process of governments, financial sector participants, businesses and individuals. Collaboration between 'content creators', information distributors and end users of information is necessary to improve the usability, granularity and accessibility of climate risk information.

The financial sector currently plays an important role in providing information on the short-term risks associated with investment decisions through the price signals embedded in bank loans and insurance premiums.[35] Nevertheless, these contracts are generally relatively short-term in nature and, therefore, fail to provide information on the potential long-term effects associated with climate change. An expanded role for the funds management and superannuation sectors is possible with the provision of additional information on long-term climate risks and also through their investment decisions based on environmental, governance and sustainability (ESG) factors.

Sole reliance on the insurance sector to assume climate risks is becoming increasingly inadequate. While the cost of insurance sends a very important price signal for risk to the community or businesses, a holistic risk management strategy that identifies potential risks and puts in place mitigation measures or deters risk taking behaviour is required to reduce the potential total cost associated with extreme events. For example, a levee to protect the town of Roma in Queensland from flooding would cost $20 million, compared with $100 million paid out in insurance claims since 2008 and a repair bill of over $500 million incurred by the public and private sector since 2005.[36]

"…a levee to protect the town of Roma in Queensland from flooding would cost $20 million, compared with $100 million paid out in insurance claims since 2008 and a repair bill of over $500 million incurred by the public and private sector since 2005."

In some cases there is a market failure or missing market that requires government intervention. These interventions may include the establishment of the 'rules of the game' that promote the development of new financial instruments, for example climate derivatives[37], or national catastrophic insurance, such as in New Zealand with its Earthquake Commission, or supplementation of the private reinsurance market such as the Japanese Reinsurance Company. Such government interventions must be carefully designed to ensure that market price signals and indicators of risk are not skewed in ways that promote moral hazard or maladaptation. For instance, public actions that compensate asset owners for risky behaviour, such as building on regularly flooded locations, may create perverse incentives for individuals to assume excessive risk.

Conclusions

Climate risks have always existed, but with climate change and a growing global population expected to exceed more than 9 billion by 2050, the adverse consequences of climate related events are projected to increase. While the consequences of some climate risks may not occur for decades, the number and the economic costs of weather related catastrophes are currently growing at an increasing rate globally, and in Australia.

Responding to climate risks requires a risk assessment and management framework that registers the key risks and includes planning and strategies to manage these risks that account for both the probability and consequence of adverse climate events. Such a framework promotes the efficient allocation of scarce resources such that, for a given level of climate exposure, the adverse effects of climate change events can be reduced via actions (private and public) that diminish climate sensitivity. These adaptation actions include investments in both 'hard' infrastructure and also 'soft' approaches that alter policy settings and improve how institutions and systems respond to change.

Adaptation actions, especially those that are required at a widespread spatial scale and for events with high negative consequences, require collective action and planning and public-private-civil society partnerships. In particular, high risk events demand effective and appropriate government action to correct for market failures or missing markets and to set the 'rules of the game'. These interventions should encourage individuals, firms and communities to develop actions that can allow for win-win risk transfers, the correct pricing of risk, and also pathways for decision-makers to flexibly respond to updates in information, evidence and analysis.

Endnotes

1 Munich Re, 2014a, Topics Geo, 2014 issue, accessed at https://www.munichre.com/touch/site/touchnaturalhazards/get/documents_E435413367/mr/assetpool.shared/Documents/0_Corporate%20Website/_Publications/302-08121_en.pdf, 18 April 2014. p.5

2 (IPCC 2013, P. 13) only 2014 reference in original list: IPCC WGII AR5, 2014, Climate Change 2014: Impacts, Adaptation, and Vulnerability Summary for Policy Makers, accessed at http://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf, 17 April 2014. p.13.

3 CSIRO 2014, State of the Climate 2014, accessed at http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2014.aspx, 21 April 2014. p.15.

4 Kunreuther, H, Michel-Kerjan, E and Useem, M 2013, Corporate Strategies for Managing Catastrophic Risks in the S&P 500: Linking Initiative and Deliberative Thinking, Wharton School, University of Pennsylvania, Accessed at http://opim.wharton.upenn.edu/risk/library/CorpStrategiesForManagingCatRisksInP500_WhartonRiskCtr_2013Nov.pdf, 28 April 2014.

5 Calel, R, Stainsforth, DA and Dietz, S 2013, Tall tales and fat tails: the science and economics of extreme warming, *Climatic Change* DOI 10.1007/s10584-013-0911-4.

6 Dietz, S 2011, 'High impact, low probability? An empirical analysis of risk in the economics of climate change', *Climatic Change* DOI 10.1007/s10584-010-9993-4.pp.521–522

7 Schur, EAG, Bockheim, J, Canadell, JG, Euskirchen, E, Field, CB, Goryachkin, SV, Hagermann, S, Kuhry, P, Lafleur, PM, Lee, H, Mazhitova, G, Nelson, FE, Rinke, A, Romanovsky, VE, Shiklomanov, N, Tarnocai, C, Venevsky, S, Vogel, JG, Zimov, SA 2008, Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle, *Bioscience* vol. 58, no. 8, pp. 701–714.

8 Calel, R, Stainsforth, DA and Dietz, S 2013, Op. cit.

9 Sander et al. 2013, 'Rising variability in thunderstorm-related US losses as a reflection of changes in large-scale thunderstorm forcing', *Weather, Climate and Society*, vol. 5, pp. 317–331.

10 Munich RE, 2014b, Natural Catastrophes Worldwide, accessed at https://www.munichre.com/touch/site/touchnaturalhazards/get/documents_E-2127666060/mr/assetpool.shared/Documents/0_Corporate%20Website/_NatCatService/Focus_Analyses/1980_2012_paket_welt_fokus_analysen_touch_en.pdf, 18 April 2014.

11 Schuster, S, 2011, Managing the unavoidable: Natural Catastrophes, data, trends analyses accessed at http://www.greenhouse2011.com/UserFiles/Presentation/presentationUrl_23.pdf, 18 April 2014.

12 CSIRO 2014, State of the Climate 2014, accessed at http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2014.aspx, 21 April 2014.

13 Munich RE, 2013, Severe weather in Eastern Asia Perils, Risks and Insurance, accessed at https://www.munichre.com/touch/site/touchpublications/get/documents_E-2085678205/mr/assetpool.shared/Documents/0_Corporate%20Website/_Downloads/severe-weather-in-eastern-asia-executive-summary-en.pdf, 18 April 2014.

14 (Munich RE 2014, pp. 56-57) – no just Munich RE 2014 is author referring to a?

15 University of Oxford Martin School 2014, What is Geoengineering? accessed at http://www.geoengineering.ox.ac.uk/what-is-geoengineering/what-is-geoengineering/, 21 April 2014.

16 United Kingdom Cabinet Office, 2013, National Risk Register of Civil Emergencies, accessed at https://www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2013-edition, 21 April 2013.

17 Commonwealth of Australia: Australian Department of Industry, Innovation, Climate Change. Science, Research and Tertiary Education 2013, *Climate Adaptation Outlook: A Proposed National Adaptation Assessment Framework*, Canberra. pp.87-103

18 Smit, B, Burton, I, Klein, R, and Wandel, J 2000, An anatomy of adaptation to climate change and variability, *Climatic Change* vol. 45, no. 1, pp. 223-251.

19 Kates, RW, Travis, W and Wilbanks, TJ 2012, Transformational adaptation when incremental adaptations to climate change are insufficient, *Proceedings of the National Academy of Sciences*, vol. 109, no. 19, pp. 7156-7161.

20 Garnaut, R. 2008 The Garnaut Climate Change Review. Cambridge University Press, Cambridge, UK; Productivity Commission 2012. Barriers to Effective Climate Change Adaptation. Report number 59, Final Inquiry Report, Canberra.

21 Hallegatte, S, Lecocq F, de Perthuis, C 2011, Designing Climate Change Adaptation Policies: An Economic Framework, World Bank Sustainable Development Network Policy Research Working Paper 5568, accessed at http://elibrary.worldbank.org/doi/book/10.1596/1813-9450-5568, 21 April 2014.

22 ECA Working Group 2011. Shaping Climate Resilient Development: A Framework for Decision Making. Economics of Climate Adaptation Working Group. Accessed at http://mckinseyonsociety.com/shaping-climate-resilient-development/ on 23 April 2014.

23 Akter, S and Grafton RQ, 2010, Confronting Uncertainty and Missing Values in Environmental Value Transfer as Applied to Science Conservation. *Conservation Biology* doi 10.1111/j.1523-1739.2010.01489.x, 2010.

24 WEF 2011. A vision for managing natural disaster risk: proposals for public-private stakeholder solutions. World Economic Forum, Geneva. Accessed at http://www.weforum.org/reports/vision-managing-natural-disaster-risk 23 April 2014.

25 WEF. 2014. Global Risks 2014: 9th Edition. World Economic Forum, Geneva. Accessed at http://www.weforum.org/issues/global-risks 28 April 2014.

26 Grimes, A, 2012, Optimal Infrastructure Adaptation to Climate Change, MOTU Note #11, accessed at http://www.motu.org.nz/publications/detail/motu_note_11_optimal_infrastructure_adaptation_to_climate_change, 21 April 2014.

27 Keating, A. and Handmer, J. 2011. The cost of disasters to Australia and Victoria – no straightforward answers. VCCCAR Framing Project Working Paper 3. Accessed http://www.vcccar.org.au/publication/working-paper/cost-disasters-to-australia-and-victoria-%E2%80%93-no-straightforward-answers Accessed 28 May 2014.

28 Keating, A and Handmer J. 2011a. Options for assessing the cost of climate change for adaptation policy in Victoria. VCCCAR Framing Project Working Paper 2. Accessed at http://www.vcccar.org.au/sites/default/files/publications/Framing_project_workingpaper2_240511_0_0.pdf, 23 April 2014.

29 Clarke H., Freebairn, J., Jayanath, A. and Le Roux, A. 2012. Enhancing water infrastructure provision with climate change uncertainty. VCCCAR Project Report. Accessed at http://www.vcccar.org.au/sites/default/files/publications/Water%20provision%20report%20090414.pdf on 23 April 2014.

30 AECOM/MAV 2012. Adapting to Inundation in Urbanised Areas: Supporting Decision Makers in a Changing Climate. Accessed at http://www.abm.org.au/adaptationproject/about.html on 23 April 2014

31 Young, C. and Jones R. 2013. Building Bridges: Supporting Adaptation in Industry. VCCCAR Think Tank Context Paper. Accessed at http://www.vcccar.org.au/sites/default/files/publications/VCCCAR%20Industry%20Think%20Tank%20Context%20Paper%2019%209%2013.pdf, 23 April 2014.

32 WEF. 2013. Global Risks 2013: 8th Edition. World Economic Forum, Geneva. Accessed at http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2013.pdf 23 April 2014.

33 Young, C. and Jones R. 2013. Building Bridges: Supporting Adaptation in Industry. VCCCAR Think Tank Context Paper. Accessed at http://www.vcccar.org.au/sites/default/files/publications/VCCCAR%20Industry%20Think%20Tank%20Context%20Paper%2019%209%2013.pdf, 23 April 2014.

34 Ibid

35 Davis, K. and Jenkinson, M. 2013. Risk Management and Climate Change: The Role of the Financial Services Sector. VCCCAR Think Tank Report. Accessed at http://www.vcccar.org.au/sites/default/files/publications/VCCCAR%20Think%20tank%20Risk%20management%20version%20050713.pdf on 23 April 2014.

36 Ben Honan, Suncorp General Insurance Ltd, presentation to VCCCAR 2014 Annual Forum

37 Bloch D, Annan, J and Bols, J 2010, Cracking the climate conundrum with derivatives, *Wilmott Magazine* Vol , pp. 271-287.

3. Effective action: Identifying Australia's best options to mitigate climate change

Nathan Taylor

This chapter examines current climate change mitigation policies and options for how Australia can strategically respond to climate change.

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Adjusting to the impacts of climate change and mitigating its effects will be a task for both this and future generations. As a relatively small industrialised nation, Australia must be open and responsive to global developments in both the economic and the policy environment. This paper sets out a framework for how Australia can strategically approach its response to climate change.

The industrial revolution fundamentally altered the human condition. The average person living in a developed country now has more wealth, health and material wellbeing than all but an elite few from previous generations. But the planet too has been transformed. Geologists now refer to the past 200 hundred years as the Anthropocene, a period now indelibly marked into the record of the earth.[1] Unfortunately, the greenhouse gases emitted as a consequence of the Industrial Revolution are directly contributing to climate change that, if not checked and ultimately reversed, will have very adverse consequences for the quality of life of all living beings on earth. The challenge is to avert the worst consequences of climate change while maintaining the benefits of the material wealth that economic development has generated.

To prevent climate change becoming dramatic, and to limit the global risks associated with it, will require major adjustments in human activity. These changes will be difficult and expensive, but particularly so for Australia which is relatively unusual in being both an industrialised country and a significant energy exporter.

If Australia is to make the necessary adjustments, and protect the wellbeing of its citizens, it needs to spend its national resources effectively. Yet Australia has not reached a wide consensus on what should be the overall policy framework to respond to climate change. It remains a fiercely contested area of policy. It need not be.

Australia's Emissions Trading Scheme was a mechanism for engaging market forces in minimising the cost of adjusting to climate change while coordinating efforts with those of other countries. It also would have made explicit a market price associated with the costs to human society of greenhouse gas emissions. However, as implemented, it was insufficient to initiate the necessary transformation within Australia's economy required to optimise the balance between the benefits and costs of tackling climate change.[2] Significant market failures on the technology front inhibited the development of low greenhouse gas emission technologies, while structural aspects of the energy market discouraged their deployment. Additional policy responses would still have been necessary to achieve scenarios where climate change was kept to no more than two per cent Celsius of preindustrial levels.

The alternative policy, the Emissions Reduction Fund, is an attempt to meet the current Federal Government's commitment to a five per cent reduction in Australia's greenhouse gas emissions of 2000 levels by 2020. The proposed methodology, of purchasing greenhouse gas emission reductions via an auction process, has the potential to be costly while having limited effects. It need not be so. Properly executed, the Emissions Reduction Fund, in conjunction with supplementary policies, could make a valuable contribution to Australia's efforts at climate change mitigation.

"The proposed methodology, of purchasing greenhouse gas emission reductions via an auction process, has the potential to be costly while having limited effects. It need not be so. Properly executed, the Emissions Reduction Fund, in conjunction with supplementary policies, could make a valuable contribution to Australia's efforts at climate change mitigation."

Policy uncertainty will hinder the changes that Australia undoubtedly needs to make, since it increases perceived risk attached to actions that individuals or organisations may take, and so increases the cost of change and reduces the amount of change achieved. The Intergovernmental Panel on Climate Change (IPCC) has stated that scenarios restricting global warming to two degrees Celsius relative to pre-industrial levels are:

> *"… characterised by more rapid improvements of energy efficiency, a tripling to nearly quadrupling of the share of zero- and low-carbon energy supply from renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy by the year 2050."*[3]

The energy supply mix identified by the IPCC is very different to what currently exists or is likely to exist without substantial investment in the energy sector. For instance, the scenarios whereby very adverse levels of climate change are avoided identify a major expansion in nuclear energy and widespread use of CCS

but the current trend is for nuclear energy to contribute a declining share of the energy mix while CCS power stations are not currently commercially viable. It is strategically important for Australia that CCS technology be adopted, given the nation's significant coal reserves.

In addition to changes in the energy supply mix, there are widespread transformations required in transportation and land use patterns, building design and industrial and social use of energy more broadly. The costs of action are substantial even if they are less than the costs of inaction.[4]

What has been absent from the policy debate has been a contextualisation of individual policy approaches within a wider framework that allows for comparison of policy efficacy. Good public policy is not necessarily about getting the one right answer but it is about setting up a clearly defined framework with explicit goals and an explicit set of policy instruments, and a process within which policy interventions can be adjusted over time as conditions change and more information and experience accumulate. The Australian policy response to climate change is yet to fit this mould.

One approach that specifically deals with the uncertainty involved, and that provides an objective basis for comparing different policies, is to consider that Australia has a portfolio of possible responses to climate change. These potential responses represent the ability, but not the obligation, to undertake singly or in combination, any of a range of actions currently and in the future if the conditions emerge that make them appropriate. These possible actions are in substance options – real options. Adopting a real options investment approach to Australia's response to climate change would provide a transparent and objective basis for comparing the costs and benefits of different policy approaches and enable the nation to maximise the net benefits (gross benefits less costs) of its actions.

This paper accepts the science of climate change but acknowledges that there are uncertainties about its ramifications both at the global and, particularly, the local level. It also appreciates Australia's inability to avert global climate change in isolation and the fact that it is, in general, a technology taker. However, as a rich industrialised energy exporting country Australia has both an economic imperative and an obligation as a good global citizen to play its part in responding to climate change. Australia, as a major producer and exporter of fossil fuels, has benefited substantially from the causes of climate change.

Economically, Australia faces threats as the rest of the world responds. That requires Australia to respond also, and to recognise that Australia has expertise that can be leveraged, so that the nation 'punches above its weight' in responding to climate change. For instance, CEDA's *The Australian Water Project* found that:

> *Australia's water management policies enabled it to do something that no other country could conceivable have managed … a 70 per cent reduction in water availability had very little aggregate economic impact. This represents an achievement of global significance as human communities across the world respond to a changing climate.*[5]

A portfolio of potential responses

The basis of quantifying the uncertainty involved with adjusting to climate change involves viewing low greenhouse gas emission technologies and mitigation alternatives as representing call options for Australia. Owning a call option gives someone the right, but not the obligation, to purchase something in the future. Complex financial modelling methods have been developed to value options and a key factor in their pricing is the underlying uncertainty around whether it will be exercised. This makes them highly relevant when considering how to respond to climate change. The process of internalising the social cost of greenhouse gas emissions has yet to be settled at the national or global level while significant technological advances are required to enable competitive energy supply to be deployed. All these factors compound the uncertainty about the best policy response to climate change.

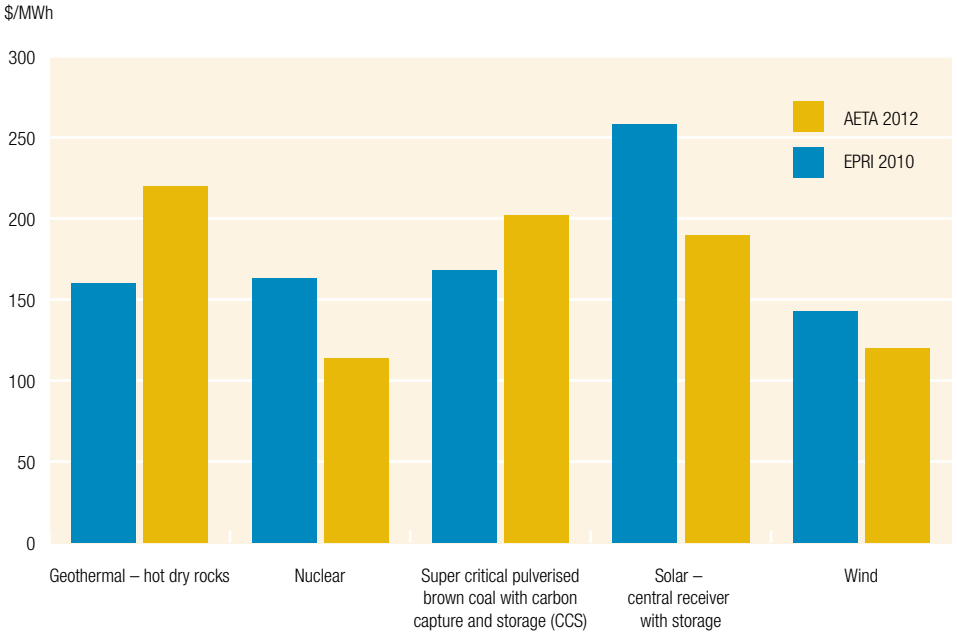
Australia has the right to deploy more low greenhouse gas emission technology in the future if the levelised cost of such technology is less than a similar assessment of existing technology when the cost to human society of greenhouse gas emissions is internalised. Quantifying the value of this portfolio of options is valuable when there are different strategies that can be developed to encourage their deployment. This approach helps address the question of whether the nation should effectively expend its limited resources. The value of Australia's portfolio of low greenhouse gas emission technologies was exhaustively developed by the Australian Academy of Technological Sciences and Engineering (ATSE) and elaborated on by Dr John Burgess in CEDA's *Renewables and efficiency* policy perspective.[6]

Conceptualising Australia's response to climate change as optimising a portfolio of call options allows the application of a financial technique to a 'real', as distinct from a purely financial, investment, such as a project to commercially develop a piece of technology. A real option value can also be determined for the value of a choice to make a business or investment decision. It is a particularly useful technique to unlock the potential value involved in choices among options when there is considerable uncertainty around future conditions. It is designed to capture the value of any progressive resolution of future uncertainties as a project progresses and information accumulates, and of the associated flexibility of being able to wait, abandon, or expand on an investment opportunity as more knowledge of actual conditions is accumulated. A real options investment approach helps maximise the value of a portfolio of options.

The value of Australia's portfolio of low greenhouse gas emissions technologies can be estimated by:

- Examining the estimate of the future cost of energy from different technologies; and
- Assigning probabilities to these forecasts.

FIGURE 1
LEVELISED COST OF ENERGY IN 2030



Source: Estimates of the average LCOE are based on data from BREE (2012) and EPRI (2010)

When combined with a projection of the cost to human society of greenhouse gas emissions, this approach allows the value of various technologies to be quantified under different scenarios for technological progress. While these projections are complicated, the Australian Energy Technology Assessment (AETA) represents the best available current cost estimates for a number of energy generation technologies to 2050 and highlights how rapidly expected costs can change. Comparing the AETA projections with an earlier forecast of energy expectations conducted by the Electric Power Research Institute (EPRI) highlights how estimates of the levelised cost of energy (LCOE) generated by different technologies can change rapidly due to global innovation or to the technical challenges associated with accessing the various forms of energy.

Policies designed under current circumstances, but not taking into account the changing technological and operating environment, can be significantly wrong footed. Take for instance, policies designed to encourage photovoltaic panel (PV) installation in Australia. The budgetary costs of setting feed-in-tariffs designed to subsidise PV deployment blew out, and they were subsequently cut out or cut back in most jurisdictions as the global price fell dramatically.

A better approach for the environment and for Australia as a whole, would have been to address any market failures that would prevent PV deployment when and where it does become commercially viable, and spend exactly the same amount as was spent in inefficiently subsidising outdated PV panels on research and development (R&D) activity instead. This approach assumes that Australia is too small a market to influence the global manufacturing supply of PV panels but acknowledges it can make a valuable contribution via R&D. Australia should do better at capitalising on its R&D, as CEDA has previously suggested.[7]

Assigning probabilities to the process of innovation and the technological breakthroughs necessary to reduce the costs of low greenhouse gas emission technologies is the next stage of quantifying its future value. While any forecast is limited in its accuracy, making assumptions explicit ensures a common basis for comparison between anticipated technological advances and provides an ability to compare public policy options.

The ATSE study used a Monte Carlo method to create a distribution of investment profiles for Australia's portfolio of low greenhouse gas emission technologies based on the EPRI technology cost estimates.[8] Consider the case of solar thermal central towers which, it has been forecast, will see the LCOE shift significantly from approximately $200-$250/MWh to $80/MWh by 2020, if a range of technological breakthroughs occur.[9] The technological advances required to achieve those cost reductions include:

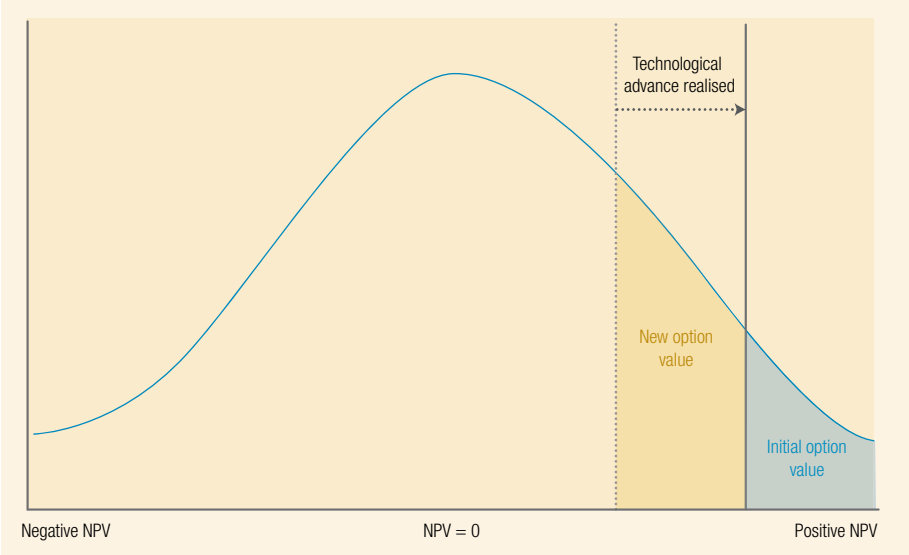
- Improving high temperature molten salt storage;
- Reducing the parasitic power load; and
- Reducing capital expenditure and operations and maintenance costs among others.

The technological advances identified in the roadmap essentially shift the anticipated probability distribution from that described in the initial ATSE report to another more attractive one – meaning that the technology is more likely to make a viable contribution to Australia's efforts to mitigate climate change. If or when the required technological advances occur, the overall value of that technological option increases until such a time as it represents a positive investment for the nation.

A more nuanced assessment of the probability of technological progress would attribute probability estimates to the different technological breakthroughs necessary to make each low greenhouse gas emissions technology viable. Doing so would enable Australia to play a more strategic role in contributing to global climate change mitigation as it would allow for research and development funding that focused on the specific critical breakthroughs needed to make the technology viable. The nation's abundance of renewable energy resources, wealth, and highly skilled workforce should enable Australia to make a disproportionate contribution to the commercial viability of low greenhouse gas emission technologies. That contribution will not occur by trying to encourage their deployment at this point in time via large subsidies, but by focusing resources on achieving the breakthroughs that will make them commercially viable in the foreseeable future. It also makes economic sense to then export that expertise to the rest of the world.

The merit of adopting the ATSE approach is that if the net present value (NPV) of the distribution of future outcomes is positive at any stage there is the potential it will create wealth in the future and so can justify taking action now to capture that wealth. For example, action may take the form of reserving land for future generation capacity, as this initial action can be undertaken with less expense than the widespread (subsidised) deployment of the technology now. This may create value by making the technology available in the future on a commercial basis.

FIGURE 2
STYLISTIC PROBABILITY DISTRIBUTION OF NET PRESENT VALUE (NPV) FOR A TECHNOLOGY



Source: This represents key concepts contributed by Dr John Burgess in CEDA's *Australia's Energy Options: Renewables and efficiency* policy perspective.

Australia's wealth should be spent less on mitigating greenhouse gas emissions now and more on maximising the capacity to mitigate greenhouse gas emissions in the future. This approach would involve spending the nation's resources predominantly on capturing the positive NPV component of the probability distribution of future outcomes. Such an approach would ensure that the nation's financial resources are wasted in an attempt to address climate change by costly means with limited effectiveness but instead to make sure that they are effectively deployed to make a real difference over time.

Establishing the social licence to operate

According to the IPCC, global scenarios that avoid temperature increases greater than two degrees Celsius above preindustrial levels have much higher levels of all low greenhouse gas emission technologies than is currently the case. Unfortunately, in addition to technological challenges, significant social barriers also exist to the deployment of a range of effective technologies, particularly nuclear power. ATSE's study found that nuclear power had one of the highest NPVs of all technologies.

The Federal Government's Energy White Paper noted:

> *Australia's range of abundant low-cost energy resources has shaped our energy generation base around coal and gas. While other countries have adopted nuclear power as a way of diversifying their energy mix, Australia has not deployed the technology because it has never been economically competitive with fossil fuel technologies and because a community consensus on deployment is lacking.*[10]

However, the Energy White Paper noted that in "future circumstances" it may become viable, but that considerable social opposition exists. For this and other reasons, there would be lead times of 10 to 15 years prior to its potential deployment. Removing a viable option from the portfolio available to Australia is not in the nation's interest. CEDA's research has indicated that while nuclear power may not be commercially viable for Australia at this point, technological innovations that are being explored, particularly small modular reactors, have the potential to change that significantly.[11] Only hydropower displaces more carbon emissions than nuclear energy, and Australia is already utilising nearly all of its practically available hydropower resources.

Behavioural economics indicates that a human desire to eliminate extreme risks, particularly those with vividly memorable outcomes and negative emotional consequences, can result in decisions that accept more moderate risk but which has higher probability.[12] While rejecting nuclear energy may eliminate an extreme form of risk, that can be kept to a very low probability of occurrence, for example the risk of a significant radiation leak, the decision means achieving less mitigation and so accepting a lower probability of avoiding extreme climate change.

Creating a social licence, either for nuclear power or other forms of low greenhouse gas emissions technologies, represents a direct action that would improve the ability of the nation to meet its climate mitigation objectives without unnecessary costs.

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Australia should 'purchase' a call option on the ability to deploy nuclear power by developing a suitable regulatory framework and beginning to develop relevant domestic skills now. These relatively cheap actions would help position Australia to take advantage of all technological developments. It would also help Australia to develop more value adding activity in the nuclear energy space, potentially the most significant contribution Australia can make to mitigating global climate change.

Taking effective action

The Emissions Reduction Fund, as currently configured, is likely to continue the trend of using Australia's resources wastefully while achieving limited mitigation of climate change. It need not. Properly configured, the Emissions Reduction Fund could make an effective contribution by enhancing the value of Australia's portfolio of options and seeking to capture the NPV associated with low greenhouse gas emission technologies.

An important way of enhancing the value of a portfolio of options is to extend their expiry date, other things being equal. In the context of Australia's portfolio of options, if the nation can meet its greenhouse gas emission reduction

targets relative to 2000 levels without the need to deploy relatively expensive low greenhouse gas emission technologies, it is effectively extending the expiry date associated with those technological options. This gives time for further technological breakthroughs to occur and reduces the overall subsidy necessary to make it competitive. The marginal abatement cost curve modelling conducted by Climate Works suggests that energy efficiency improvements would both save money while reducing greenhouse gas emissions and may contribute significantly to Australia's greenhouse gas emissions targets.[13]

Extending the expiry of Australia's portfolio of call options would be a positive act in itself. However, investing funds focused on the technological developments that would enhance the value of low greenhouse gas emissions technology, particularly in areas such as CCS that are strategically important to Australia, would also significantly enhance the portfolio of options.

To optimise Australia's portfolio of responses to climate change and to take effective action requires the following process:

- Regularly update the Australian Energy Technology Assessment;
- Assign probabilities to these forecasts and identify the technological breakthroughs that would underpin reduced future levelised costs of energy assessments;
- Forecast the future costs over time for greenhouse gas emissions (proxied by global carbon prices) to determine the NPV of alternative low greenhouse gas emissions technologies; and
- Use a real options investment approach to maximise the potential greenhouse gas emissions that Australia can efficiently mitigate.

This approach would focus on maximising the potential to mitigate greenhouse gas emissions rather than focusing on directly mitigating greenhouse gas emissions now with inadequate technologies. Considering the pace of technological change for low greenhouse gas emissions technologies, both experienced and anticipated, this would make a substantial difference to the amount of greenhouse gas emissions that could be mitigated for a given level of funding. For the Emissions Reduction Fund this would involve encouraging energy efficiency improvements to meet Australia's greenhouse gas emissions reduction targets while also using the insights of the options analysis to spend funds on means to maximise emissions reductions over the longer term.

Adopting a real options investment analysis to mitigating climate change would provide a great deal more certainty for decision-makers. It would focus the political debate on exactly what Australia is 'buying' with its efforts to mitigate climate change and point the way towards a constructive discussion on the value of various approaches to minimising climate change. Having explicit assumptions underpinning Australia's greenhouse gas emission reduction actions would allow for greater contestability, and eventually greater cohesiveness in terms of policy direction.

Key examples of ways in which the potential for low greenhouse gas emissions could be encouraged include:

- Focusing R&D on enabling specific technology breakthroughs, such as those identified as necessary for geothermal power to become commercially viable;
- Developing robust regulatory regimes for all energy sources prior to their deployment, including nuclear power;
- Working to ensure a social licence to operate exists for all energy sources, including nuclear power and wind generation;
- Integrating low greenhouse gas emissions energy sources with the transmission and distribution system; and
- Developing domestic skills in implementing the initial investments in emerging technologies.

This would not be technologically neutral. Instead it would focus on trying to capture as much of the potential positive NPV of each low greenhouse gas emission technology. While this may result in greenhouse gas emissions being marginally higher in the short term, Australia would be spending funds to maximise their long-term reduction.

Endnotes

1 Steffen, W., Crutzen, P. J., and McNeill, J., R., *The Anthropocene: Are humans now overwhelming the great forces of nature?*, Ambio, Vol 36, Number 8, December 2007, pp. 614-621.

2 Australian Academy of Technological Sciences and Engineering, December 2008, *Energy technology for climate change: Accelerating the technology response.*

3 IPCC WGIII AR5, Summary for policymakers, page 15 http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

4 IPCC WGIII AR5, Summary for policymakers, page 17 http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

5 Briscoe, J., 2011, *The Australian Water Project, Crisis and opportunity: Lessons of Australian water reform*, Volume 1, page 12.

6 Australian Academy of Technological Sciences and Engineering, November 2010, *Low carbon energy: Evaluation of new energy technology choices for electric power generation in Australia* and, Burgess, J., May 2012 Financial uncertainty of technological change, CEDA.

7 CEDA, April 2013, *Healthcare: Reform or ration.*

8 Burgess, J., *Financial uncertainty of technology change*, Renewables and efficiency, CEDA Policy Perspective, 2011.

9 Klob G J, Ho C K, Mancini T R, Gary J A, Power Tower Technology Roadmap and Cost Reduction Plan, 2011, Sandia National Laboratories, USA Department of Energy, SAND2011-2419, April.

10 Department of Resources, Energy and Tourism, Energy White paper 2012: Australia's energy transformation, page 98, http://www.aip.com.au/pdf/Energy_%20White_Paper_2012.pdf

11 Irwin, T., *Small Modular Reactors*, Australia's Nuclear Options, CEDA Policy Perspective, 2011.

12 De Martino, B, Kumaran, D, Seymour, B, and Dolan R J, 2006, Frames, biases and rational decision making in the human brain, Science 313, 684 687

13 Climate Works Australia, Marginal abatement cost curve, accessible from here: http://www.climateworksaustralia.org/

Acknowledgements

CEDA would like to acknowledge the following members and individuals who have contributed to CEDA's general research fund between 30 May 2013 and 30 May 2014.

CEDA undertakes research with the objective of delivering independent, evidence-based policy to address critical economic issues and drive public debate and discussion. It could not complete its research agenda without the support of these contributions.

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