MANAGING CLIMATE VARIABILITY
R & D PROGRAM

REPORT

Analysis of the benefits of improved seasonal climate forecasting

For sectors outside agriculture

Prepared for
Managing Climate Variability Program

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THE CENTRE FOR INTERNATIONAL ECONOMICS
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CANBERRA

Centre for International Economics
Ground Floor, 11 Lancaster Place
Majura Park
Canberra ACT 2609

GPO Box 2203
Canberra ACT Australia 2601

Telephone +61 2 6245 7800
Facsimile +61 2 6245 7888
Email cie@TheCIE.com.au

Website www.TheCIE.com.au

SYDNEY

Centre for International Economics
Suite 1, Level 16, 1 York Street
Sydney NSW 2000

GPO Box 397
Sydney NSW Australia 2001

Telephone +61 2 9250 0800
Facsimile +61 2 9250 0888
Email ciesyd@TheCIE.com.au

Website www.TheCIE.com.au

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Abbreviations

ACT	Australian Capital Territory
AEMO	Australian Energy Market Operator
AWEFS	Australian Wind Energy Forecasting System
BOM	Bureau of Meteorology
CDD	cooling degree days
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ESOO	Electricity Statement of Opportunities
GDP	gross national product
GSL	Guaranteed Service Level
GSP	gross state product
GVA	gross value added
GW	gigawatt
HDD	heating degree days
kWh	kilowatt hours
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MCVP	Managing Climate Variability Program
MT PASA	Medium Term Projected Assessments of System Adequacy
NASA	National Aeronautics and Space Administration
NEM	National Electricity Market
NSW	New South Wales
NT	Northern Territory
PJ	petajoules
POAMA	Predictive Ocean Atmosphere Model for Australia
PV	photovoltaic
R&D	research and development
RDC	Research and Development Corporation
ST PASA	Short Term Projected Assessments of System Adequacy
TWh	terawatt hours
US	United States
WA	Western Australia

Summary

This report

This report discusses and analyses the value of improved seasonal climate forecasts to various sectors of the Australian economy.

- **There are very few studies in the literature that have estimated the value of seasonal climate forecasts for sectors other than agriculture.**

The analysis covers 11 sectors. The climate sensitivity of each sector is considered in detail and in some cases we have been able to quantify the potential benefits of improved seasonal forecasts.

- **This quantification should be seen as indicative rather than a precise forecast**
- **The report indicates a number of factors that contribute to the value of improved seasonal forecasts**
- **A companion report – 'Analysis of the benefits of improved seasonal climate forecasting for agriculture' discusses the value of improved seasonal climate forecasts for the agriculture sector.**

Our quantification takes as a reference point work from the United States (Lazo et al 2011) on understanding the climate sensitivity of different sectors of the economy (see box 1).

- **This work is chosen as a point of comparison to help understand the possible relationship between climate sensitivity and the value of improved seasonal forecasts**
- **Of course, some care must be taken when making comparisons with the US. Our quantification of potential benefits for Australia is independent of the US work.**

Climate variability and economic performance

It is clear that climate variability and extreme weather events can affect the economic performance of a range of sectors. However, the extent that these impacts can be cost-effectively mitigated through the use of improved seasonal climate forecasts is less clear.

- **Despite some uncertainties, this report finds the estimated value of improved seasonal forecasts to be positive and significant for a number of sectors.**

The ability of businesses and industries to make use of seasonal climate forecasts are influenced by the characteristics of that industry or business. Some of the relevant characteristics include:

- capital and infrastructure intensity;
- approaches to, and expertise in, risk management;
- the type of weather conditions the activities are sensitive to; and
- the extent that management systems have already adapted to expected ranges of climate variability.

Table 4 below summarises information on the usefulness of forecasts for each sector.

Quantification of benefits

This report uses relatively simple probabilistic methodology to estimate the value of improved seasonal forecasts. The methodology is flexible enough to be used on a range of different sectors. Key benefits of the chosen methodology are that:

- it relies on information about the value of two easy-to-consider scenarios (existing forecasts and perfect forecasts);
- it considers the extent that losses can be mitigated (rather than total climate related losses);
- it incorporates the costs associated with mitigation activities; and
- it includes the cost of uncertainty and incorrect forecasts.

The methodology is used to estimate the value of improved seasonal climate forecasts for the coal mining, construction, electricity and offshore oil and gas sectors.

- Estimates of the value of the forecasts are set out in the last column of table 2.
- Table 2 also summarises:
  - … the gross value added of each sector (this is effectively the sectors output that contributes to the nation's gross domestic product);
  - … the sector's share of GDP;
  - … the sector's climate sensitivity as based on the US estimates; and
  - … the implied dollar value of this sensitivity;

The potential value of improved forecasts ranges from $192 million per year for construction to $2 million per year for electricity.

- Importantly, this value is much lower than the value of sensitivity to climate. The estimates of the value of improved seasonal climate forecasts ranged from 0.2 per cent of climate sensitivity for the electricity sector to 4.9 per cent for the construction sector.
- This reflects the fact that not all climate effects can be mitigated through the use of forecasts.

1 Climate sensitivity and the value of forecasts

Lazo et al. (2011) estimated the climate sensitivity of different economic sectors in the US using historical climate and economic activity data. They defined the climate sensitivity of a sector as the inter-annual variation in economic activity attributable to climate variability.

In table 2, the per cent measure of climate sensitivity of the US sectors has been applied to the equivalent Australian sectors to provide an indication of the possible value of economic activity that is susceptible to climate variation in Australia. A number of key points need to be considered, however, when examining these figures.

- The methodology used by Lazo et al. does not account for the economic interactions between sectors. Some of the sensitivity of a sector to climate may be a consequence of its interactions with other sectors that are themselves sensitive to climate. Thus, we would expect the climate sensitivity of a particular sector to be a sum of its own direct climate sensitivity and indirect sensitivity through its interactions with other sectors. This is likely to be the case for sectors such as retail trade and insurance services.
- The sensitivity values may not be directly transferable from the US context to Australia. The climate conditions experienced in the US and Australia are quite different. For example, significant proportions of the US experience very cold, icy and snowy conditions through winter months not experienced in Australia.

Finally, it is important to highlight that the value of climate sensitivity cannot be used as an indicator of the value of climate forecasts to the various sectors. The climate sensitivity measure is an indicator of the extent that the value of output of a sector is affected by climate. The value of a climate forecast is the extent that he impact of weather events can be avoided or reduced using the additional information in the forecast.

Further discussion on the value of climate sensitivity and the value of climate forecasts is presented in chapter 3 of the report.

2 Climate sensitivity and the value of improved forecasts

Sector	Average GVA 2002-03 to 2011-12	Contribution to GDP (average 2002-03 to 2011-12)	Equivalent U.S. sectoral 70-year climate sensitivity	Average GVA 2002-03 to 2011-12	Estimated annual value of improved seasonal forecasts (per cent of the climate sensitivity)
	$m	%	%	$m	$m
Agriculture	21 429	1.88	12.1	21 429	1567 (45%)
Health care (and social assistance)	61 879	5.43	3.3	61 879	--
Construction	79 851	7.00	4.7	79 851	192 (4.6%)
Electricity	16 556	1.45	7.0	16 556	2.3 (0.2%)
Coal mining	20 852	1.83	14.4	20 852	68 (2.0%)
Offshore oil and gas (90% of oil and gas extraction)	20 363	1.79	14.4	20 363	93 (2.8%)
Retail trade	50 696	4.44	2.3	50 696	--
Transport (road and air)	22 824	2.00	3.5	22 824	5 (0.5%)
Water (water supply and waste services)	10 550	0.92	7.0	10 550	28 (3.3%)
Emergency services (public administration and safety)	55 920	4.90	3.3	55 920	--
Financial and insurance services	104 079	9.13	8.1	104 079	--
Tourism [a]	23 761	1.91	3.3	23 761	--

[a] Tourism figures are from the Tourism Satellite Account and are based on a 10 year average of 2001-02 to 2010-11

Note: The sensitivity of US sectors to climate has been used here as an initial indicator of the degree of climate sensitivity, however, the climate sensitivity of US and Australian sectors are likely to differ due to the climate conditions faced and the nature of the sectors. These figures should be interpreted considering these caveats. See chapter 3 for further discussion.

GVA = gross value added, the sectoral equivalent of gross domestic product (GDP); All values are given in Australian dollars at 2012 prices.

Source: ABS 2012a; ABS 2011; Lazo *et al*. 2011

Total value over time

The total annual value of benefits quantified in table 2 is $388 million

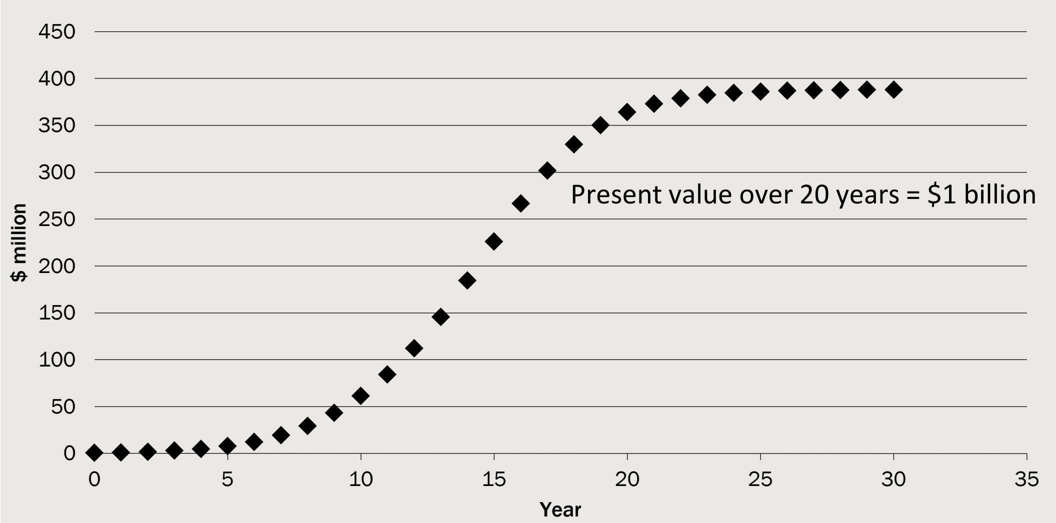
This annual values is unlikely to be realised immediately. It is more likely that the benefits will evolve over time.

Chart 1 illustrates the potential steady growth in benefits over time.

- **It is based on the assumption that benefits gradually emerge to the maximum value over 20 years for electricity, coal mining and transport and over 30 years for construction, offshore oil and gas and water. Emergence of** benefits follows an S-curve with half the maximum at the 10 or 15 year period

– The present value of all benefits to 2020 is $1 billion (assuming a discount rate of 5 per cent).

3 Potential profile of benefits



Data source: CIE estimates

Priorities for sector engagement

In addition to the quantitative analysis summarised in table 2, we have also provide a summary, qualitative ranking of sectors in terms of priority for engagement.

- This ranking recognises that there are a number of hard to quantify factors that influence the ability of sectors to use improved seasonal forecasts.
- The highest ranked sectors include coal mining, electricity and construction, with low ranked sectors including tourism and retail trade.
- Within this ranking, we view the insurance sector as a special case because of the nature of the relationship between forecasts and insurance as a risk management tool.

Other recommendations

Based on the analysis undertaken for this report as well as stakeholder discussions, we make the following broad recommendations for future investigation.

- Develop a clear product statement for how the seasonal forecasts will be improved, the technology underlying them and the ways in which they will intersect with existing risk management tools.
- Work with priority sectors to develop a number of case studies (possibly based around historical events) that can both demonstrate and research how

improved seasonal forecasts will practically work in these sectors. This is likely to generate important information both for agents in the sector as well as for the forecasting research itself.

- **Engage with the insurance sector to improve understanding of seasonal forecasting in the context of a range of implications for risk management. As a sector with major investment in risk quantification and the contractual sharing of risk, it is likely to provide valuable insights for the forecasting research.**
- **Develop awareness of the 'human' side of improved seasonal forecasts: particularly the ways in which they will affect attitudes to risk and attitudes to production and insurance contracts. The cases studies noted above will be a major contribution to this.**

4 Summary: impacts of climate on sector activities and usefulness of forecasts

Sector	Impact of climate	Responses and use of forecasts	Lead time
Agriculture	Temperatures have physical impacts on crop and livestock systems affecting productivity; water shortages can limit production; flooding can damage crops and livestock.	Optimise the timing of planting, harvesting, irrigation and fertiliser application; manage water supply requirements.	Decisions are made on a spectrum of time scales from days to months.
Health	Increased demand for services through spread of disease and injuries; extreme events may affect service delivery.	Public awareness campaigns; planning for increased demand and contingencies for affected delivery.	Normal planning horizon 5 years; some shorter term measures may be taken.
Construction	Long term climatic conditions can affect choice of building materials, design, and construction methods; immediate weather can affect worker comfort and site work. Extreme temperatures, rainfall, storms and wind affect activities.	Proper preparation, adjustment, and reaction to local weather will influence the success of a construction project and the completed building; large companies may benefit from improvements to planning and scheduling.	Long term design decisions made over decades; scheduling and costing is conducted prior to commencement of a project – months to years ahead of construction; short term operational decisions made daily.
Electricity	Temperatures affect demand for electricity; production of electricity from renewables can depend on temperature, sunlight, wind speed, water availability; distribution infrastructure can be affected by extreme events.	Forecasts can be inputs into demand forecasts; inputs into reliability forecasts to ensure adequate supply; targeted maintenance of distribution infrastructure.	Electricity forecasting is conducted on scales from minutes to years with different responses available at different scales.
Coal mining	Flooding can fill mines and damage equipment; droughts limit water availability and affect production; wind, temperature and rainfall can affect management of dust, noise, blast timing and transport, higher energy prices observed during droughts.	Moving equipment, planning operations and use of resources; forecasts need to be localised.	Weeks to move equipment, longer for securing water resources; annual planning cycles are used.
Offshore oil and gas	Cyclones, winds, waves and strong currents can halt petroleum production, drilling or rig construction.	Shut down production or operations; evacuate crews.	Annual planning estimates production volumes; shut down and evacuation decisions made on scale of days.

Retail	Climate affects demand for certain products and general store foot traffic.	Forecasts may be used to help with inventory management through improved demand forecasts, marketing strategies or staff management.	Time horizons vary between months and days (depending on the length of the supply chain or the reason for using of the forecast).
Emergency services	Weather related emergencies are a direct driver of demand for emergency services. These emergencies may include cyclones, storms, storm surges, floods, bushfires, and heatwaves.	Forecasts may help in targeted mitigation of impacts, reducing the demand for emergency services, and improving planning of emergency services to enhance delivery of services.	Any
Insurance	Climate affects insurance payouts and management of staffing and financial resources. The insurance sector is also affected by the impacts on all other sectors.	Forecasts could be used to predict payouts and price insurance accurately; may also be used by the public affecting decisions to purchase insurance; and can be used by reinsurers to adjust pricing.	Over a year, shorter for customer reactions.
Tourism	Affects demand for services in different ways, also affects delivery/maintenance of some services.	Forecasts are likely to be beneficial to tourists but limited by their ability to interpret probabilistic forecasts. Operators with the relevant expertise may benefit from improved demand forecasts and more efficient service delivery. However, there are significant risks associated with unfavourable forecasts for tourism operators.	Ranges from several months to very short term.
Transport	Severe storms, flooding, and heat causes damage to road, rail and port infrastructure, increased infrastructure maintenance requirements, increased operational costs for road, rail, sea and air and time delays across all modes of transport.	Responses are limited. Over long timeframes infrastructure may be improved. Some improvements in scheduling may be possible in the air and sea transport.	Ranges from long term (for infrastructure development), to immediate (for managing flight delays).
Water services	Rainfall in the catchment areas is the primary determinant of water supply levels. Rainfall and temperatures can affect the level of demand for water.	Responses prior to rainfall events are limited. Over long timeframes infrastructure may be built. On shorter time scales decisions can be made about water restrictions, pumping between storages and use of desalination plants.	Most decisions made with a long term view. Some limited actions are taken in the short term.

Note: Agriculture is not discussed in this report but in the companion report – 'Analysis of the benefits of improved seasonal climate forecasting for agriculture'.

1 Introduction

The Managing Climate Variability Program (MCVP), and its predecessor the Climate Variability in Agriculture Program, has been investing in improving the knowledge and information available on climate and climate variability. The focus of the program has been on products that help primary industries and natural resource managers manage the risks and opportunities presented by Australia's variable climate.

Despite the focus on primary industries and natural resources, the results of the investments have, and are expected to continue to have, positive spill-overs for other industries from improved climate forecasts. The MCVP is interested in understanding the possible benefit of further improvements in seasonal climate forecasting for other sectors within the Australian economy.

This report seeks to identify how different sectors of the economy are affected by the climate, how seasonal forecasts could be used within the sector and the potential value that seasonal forecasts may generate for the various sectors. The potential benefits of improved seasonal climate forecasts for the agriculture sector and rural communities is discussed in the companion report – 'Analysis of the benefits of improved seasonal climate forecasting for agriculture' – also prepared by the CIE for MCVP. Unless otherwise stated, all values given in the report are in Australian dollars at 2012 prices.

2 Context

Managing Climate Variability Program

The Managing Climate Variability Program is a collaborative rural research and development (R&D) program that aims to help primary industries and natural resource managers manage the risks and exploit the opportunities afforded by Australia's variable and changing climate. The MCVP continues the work of the Climate Variability in Agriculture Program which started in 1992.

The Managing Climate Variability Program is funded by the Grains, Rural Industries and Sugar Research and Development Corporations (RDCs), and Meat and Livestock Australia, with possible future support from other rural RDCs. The program invests in projects undertaken by research organisations including the Bureau of Meteorology (BOM) and Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Over the past two phases of the program (2007/08 to 2013/14), MCVP has invested in 28 projects including research, communication and management/administration. A significant part of the work program is being undertaken by BOM aimed at more rapid development of a range of forecasts based on the Predictive Ocean Atmosphere Model for Australia (POAMA), a coupled ocean-atmosphere model. Development of POAMA has been a priority in recent years due to its potential for forming dynamical seasonal forecasts. Statistical forecasts are expected to become less reliable as a result of climate change.

The impact assessment of MCVP phases II and III (2007 to 2013) found that the MCVP investments led to a more rapid uptake of the POAMA products than would have been the case without MCVP investment. The benefit to farm production would be the same regardless of MCVP investment, however the benefits would be realised faster and earlier. It was assumed that the increase in profit for farm establishments would be 2 per cent and would be realised by 25 per cent of farms. The net benefit of the MCVP was estimated to be $80m over 30 years, with a benefit cost ratio of 6.15. The quantified benefits, however, did not include the benefits that accrued to sectors other than the agricultural sector.

In the next phase of the MCVP, investments will likely be focused on:

- climate forecasting research: such as improving the accuracy of seasonal climate forecasting (on the 2-8 week and 3-6 month timescales) and improving the ease of use of forecasts. The focus will be on investment in POAMA, recognising the benefits of dynamical forecasting
- providing climate forecasting services to help users benefit from forecasts
- developing climate risk management tools and decision support using improved forecasts.

This report

The MCVP seeks to understand the potential value that may be realised through further investment in improving seasonal forecasting. Consequently, in this report the value of improved seasonal climate forecasting to a number of different sectors of the economy is estimated. There have been limited previous studies that estimate the value of seasonal, or any, climate forecasts to the economy outside the agriculture and water management sectors.

The limited previous attempts at valuing seasonal climate forecasting services may be attributed to the following facts.

- There has been very limited use of seasonal climate forecasts by industries other than agriculture.
- Valuation of forecasts generally requires:
  - a model of how users incorporate forecasts into the decision making process
  - a model of how economic outcomes are determined by decisions and the realised state of nature.
- These requirements demonstrate that the value of improved seasonal forecasting is not a simple calculation. It is, in many ways, highly particular and highly contextual.

This report documents the process undertaken to make these estimates, the methodology adopted and the challenges faced. For this project, eleven sectors were selected that were initially assessed as likely to face costs associated with climate variation.

In the remainder of this chapter, some definitional issues relevant to the rest of the report are discussed. In the next chapter, the climate sensitivity of the economy is discussed along with some key areas of consideration in understanding the use and value of climate forecasts. Chapter 4 provides a summary of the literature on the value of climate forecasts. Chapter 5 describes the methodology that was adopted to estimate the value of improved seasonal forecasting for this project. Chapters 6 to 16 each focus on one of the selected sectors and discuss:

- how the businesses in the sector are affected by climate variation
- the options available to respond to the variation
- the role that forecasts play, or could play, in decision making
- costs associated with weather events and responses
- application of the chosen valuation approach to the sector

Finally, chapter 17 summarises the sectoral results and provides a ranking of the sectors most likely to find improved seasonal forecasts of value.

Climate and weather

The main difference between weather and climate is related to the time period that is being considered. Weather refers to atmospheric conditions observed or expected over a short time frame whereas climate refers to atmospheric conditions, patterns and behaviour over a longer time period. The time frame at which atmospheric conditions are referred to as climate may differ between people, industries and organisations. For example, the US National Aeronautics and Space Administration (NASA) defines weather as short term changes in the atmosphere of periods of between minutes to seasons (Gutro 2005). Climate is defined as average weather conditions observed over longer time periods of up to 30 years. BOM defines climate as the atmospheric conditions over a long period of time and climate generally refers to the normal or mean course of weather (BOM n.d.). It may include the future expectation of weather in the order of weeks, months or years ahead.

MCVP defines weather as atmospheric conditions for up to 3 days and climate as the conditions for any time period longer than 7 days. Of particular interest to the program for this project is seasonal climate over the time frame of between 2-8 weeks and 3-6 months.

From discussions with various industry leaders, it appears as though most people outside the weather/climate science field, interpret the term climate as being of very long time frames, greater than a year. The term weather is used to describe conditions for periods of up to a year. This differing definition may be the source of some confusion when the climate forecasting products are marketed to different industries.

Climate variability and climate change

The MCVP goals are specifically targeted at issues associated with climate variability rather than climate change. Climate variability refers to short term variations in climate. This may cover periods of seasons, years, or several years. El Niño/La Niña events are also part of climate variability. Climate change refers to the longer term trend of changes in climatic averages, but also incorporates climatic extremes. Despite the focus on climate variability, climate change is important in the context of the MCVP for two main reasons.

- Climate change is expected to lead to an increase in climatic extremes. Therefore the role of the MCVP is likely to increase as the climate becomes more variable.
- Because climate change leads to changes in long term climate averages, statistical forecasting, that has been relied on in the past (based on historical climate observations and averages), is expected to be less reliable in the future. Dynamical forecasts however, are based on physical climate systems and interactions. Dynamical forecasts are expected to have better skill compared to statistical models under climate change, and these forecasts are the focus of the MCVP climate research investments.

3 Understanding the value and use of forecasts

Sensitivity of the economy to climate

Many sectors of the economy are exposed to impacts resulting from weather or climate conditions, either directly or indirectly. The agriculture sector is clearly an example of a sector whose production is directly impacted by climate. Other sectors face changes to the cost of production or demand for their products because of climatic conditions.

Lazo et al. (2011) estimated climate sensitivity of different economic sectors by examining the extent of inter-annual variation in economic activity in the United States attributable to climate variability. The sensitivity was estimated using 24 years of state level economic data for 11 sectors and 70 years of historical weather observations. The data were used to estimate models of economic output as a function of economic inputs and climate variability and then the effects of climate were isolated by controlling for the effects of the economic inputs.

The study estimated the climate elasticity of gross state product (GSP) (the percentage change in GSP due to a 1 per cent change in a climate variable). These elasticities are reproduced in table 3.1 below (for those values that were significantly different from zero). The elasticities provide an indication of whether the output of a sector increases or decreases with the alternative climate variables, and which sectors are more sensitive to changes in climate.

For example, output of the mining sector decreases with an increase in total precipitation, whereas the output of the manufacturing sector increases. Furthermore, the retail trade and services sectors are less sensitive to an increase in heating degree days (cooler weather) compared to the manufacturing sector. Lazo et al. estimated the proportion of GSP for each sector that is sensitive to variation in climate. This sensitivity ranged from 14.4 per cent for the mining sector to 2.2 per cent for the wholesale trade sector. Lazo et al. noted that the elasticities, and accordingly the final percentage value of sensitivity, for the mining sector are large and anomalous. They suggest further research before drawing strong conclusions from the results.

3.1 Elasticity of gross state product with respect to climate variables (United States)

Sector	Heating degree days (HDD)	Cooling degree days (CDD)	Total precipitation	Precipitation standard deviation
Agriculture		-0.19***	0.28*	-0.12***
Communications	0.13***	0.06***		0.17***
Construction		0.06***		0.26***
Finance, insurance and real estate	0.15***	0.06***	0.54***	-0.08***
Manufacturing	0.18*		0.49**	-0.22***
Mining	0.25**		-3.52***	1.10***
Retail trade	0.04*	0.03***		0.13***
Services	0.04**		0.33***	-0.05***
Transportation				0.15***
Utilities		0.08*		-0.28***
Wholesale trade	0.10***	0.02*	-0.19*	0.02***

Note: The sectors analysed by Lazo et al. (2011) do not correspond directly with the sectors analysed in this report

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

Source: Lazo et al. 2011

We have applied the percentage sensitivities estimated by Lazo et al. (2011) to selected sectors of the Australian economy as an initial indication of the value of output that may be sensitive to variation in climate (table 3.2). These estimates, however, should not be interpreted as the value that forecasts may have on the various sectors.

Furthermore, these values may not be directly transferable from the US context to Australia. The climate conditions experienced in the US and Australia are quite different. For example, significant proportions of the US experience very cold, icy and snowy conditions through winter months not experienced in Australia. Other areas of the US are prone to hurricanes whereas much of Australia has drier conditions than large areas of the US. Given these differences, the application of the Lazo et al. estimates of climate sensitivity to Australia should be interpreted with caution.

A rule of thumb for the value of information has been estimated to be in the order of 1 per cent of the associated value of output. This applies to information such as forecasts and research. As a starting point, this 1 per cent rule applied to the initial estimate of the value of output sensitive to variation in climate to provides a first (and very rough) cut of the value climate forecasts may create.

3.2 Climate sensitivity of economic sectors

Sector	Average GVA 2002-03 to 2011-12	Contribution to GDP (average 2002-03 to 2011-12)	Equivalent U.S. sectoral 70-year climate sensitivity	Sensitivity to climate
	$m	%	%	$m
Agriculture	21 429	1.88	12.1	2593
Health care (and social assistance)	61 879	5.43	3.3	2042
Construction	79 851	7.00	4.7	3753
Electricity	16 556	1.45	7.0	1159
Coal mining	20 852	1.83	14.4	3003
Offshore oil and gas (90% of oil and gas extraction)	20 363	1.79	14.4	2932
Retail trade	50 696	4.44	2.3	1166
Transport (road and air)	22 824	2.00	3.5	799
Water (water supply and waste services)	10 550	0.92	7.0	739
Emergency services (public administration and safety)	55 920	4.90	3.3	1845
Financial and insurance services	104 079	9.13	8.1	8430
Tourism [a]	23 761	1.91	3.3	784

[a] Tourism figures are from the Tourism Satellite Account and are based on a 10 year average of 2001-02 to 2010-11

Note: The sensitivity of US sectors to climate has been used here as an initial indicator of the degree of climate sensitivity, however, the climate sensitivity of US and Australian sectors are likely to differ due to the climate conditions faced and the nature of the sectors. These figures should be interpreted considering these caveats.

GVA = gross value added, the sectoral equivalent of gross domestic product (GDP); All values are given in Australian dollars at 2012 prices.

Source: ABS 2012a; ABS 2011; Lazo *et al*. 2011

Interaction between sectors

It is important to note that the Lazo et al. results do not account for the economic interactions between sectors. For example, some of the sensitivity of a sector to climate may be a consequence of its interactions with other sectors that are themselves sensitive to climate. Thus, we would expect the climate sensitivity of a particular sector to be a sum of its own direct climate sensitivity and indirect sensitivity through its interactions with other sectors.

This is likely to be particularly important for sectors such as retail trade and insurance services. Retail trade will be influenced indirectly through the effect of reduced incomes in other sectors. For example, reduced output in mining through climate effects will have economywide effects on income, some of which will be felt in the retail sector. Similarly, the insurance sector sells products to other sectors (particularly construction) so changes in construction activity will have direct consequences for insurance.

To test these interaction effects, we undertook some simulations with the CIE's in-house economywide model. By imposing a simulated 'climate' shock[1] on agriculture, mining, construction, electricity and water supply, we can observe the change in output in the retail and insurance sectors. We then calibrate these effects according to the climate sensitivity results in table 3.2. We find that the climate sensitivity in each of these sectors, when combined, would be expected to reduce retail trade output by 8 per cent and insurance output by 7 per cent. Looking at the sensitivities for these sectors in table 3.2 shows that these indirect effects could easily explain most of the climate variation for these sectors.

Climate sensitivity and the value of forecasts

While the value of climate sensitivity estimated in the table above places a maximum bound on the value of climate forecasts, it cannot be used as an indicator of the value of climate forecasts to the various sectors. The climate sensitivity measure is an indicator of the extent that the value of output of a sector is affected by climate. The value of a climate forecast is the extent that the impact of weather events can be avoided or reduced using the additional information in the forecast. The value of a climate forecast is less than climate sensitivity due to the following factors.

- Not all impacts of weather on sectoral output can be eliminated with a climate forecast, no matter how skilful. For most industries, there will be some impacts that cannot be eliminated through any degree of investment or preparation to mitigate weather impacts.
- Any mitigation actions that are adopted must be cost effective. There are likely to be some actions that could be taken to protect an industry from the impacts of weather events, however they will only be adopted if they are cost effective. The cost of taking the action should be outweighed by the expected losses avoided by taking such action. This will depend in part on the probability that a particular weather event will occur and the accuracy of the forecasts that are used.
- Mitigation actions are not costless and therefore the value of a climate forecast is diminished by the cost of acting on it.
- Climate forecasts are not perfectly accurate and there are costs associated with incorrect forecasts, both in terms of damage due to missed events and the cost of taking unnecessary mitigation action for false alarms.

Climate forecasts and industry use

Climate forecasts provide indications of the weather conditions that are expected to prevail in the future. Forecasts may provide indications of the expected level or range of temperatures, precipitation, wind, humidity and sunshine. This information may be useful to industries that are exposed to direct or indirect impacts of weather events.

The risk associated with a weather event is a combination of the probability of occurrence of that event and the consequences of the event. Forecasts may enable

1 We assume a productivity loss in each of these sectors.

businesses to reduce the risk of a weather event by reducing the negative consequences of the event. Forecasts, however are imperfect and inherent uncertainties in forecasts result in false alarms (forecasts that indicate an event will occur but doesn't eventuate) and missed events (where the forecast does not predict an event that occurs). This uncertainty decreases the potential reduction in risks that forecasts could bring.

Mitigating the impacts of weather events

Risk of a weather event can be managed or reduced through a range of measures. These may be long term structural or infrastructure-based measures, or they may be shorter term, operational responses. Long term measures may include:

- construction of additional electricity generation facilities
- construction of additional water storage dams and levees on mine sites
- development of alternative construction techniques that are less vulnerable to rain, heat or cold
- design of offshore oil and gas facilities that can withstand high seas and storms
- construction of water catchment and storage dams to hold greater volumes of water in the water services sector.

These long term measures are planned for and constructed over time periods of years in response to shifting long term climates. Planning for these developments may incorporate long term climate forecasts associated with climate change.

Non-structural or short term measures are those that can be adopted in a shorter time frame and are incorporated into operational costs rather than capital expenditure. These measures would involve increased use of labour and materials to prepare for expected weather events. Measures may include:

- additional planning efforts
- increasing awareness and information provisions
- weather proofing of equipment and site
- implementation of forecast, warning and risk management systems
- temporary redistribution of resources to activities not affected by weather events.

Industry characteristics

The ability of an industry or business to respond to forecasts depends on the economic characteristics of the industry and the nature of the climate sensitivity of the activities they undertake. Some of the characteristics that have been considered in assessing industries' ability to use seasonal forecasts, and the value the forecasts might bring to the industries, are listed here:

- Seasonal activities where production occurs on a seasonal basis
  - These are clearly the most climate sensitive activities. According to White (2000) 'The underlying source of climate variability affecting the Australian economy is the occasional substantial fluctuations in agricultural production due to rainfall variability, notably major droughts'.

- Infrastructure intensive activities have limited ability to respond to short term seasonal forecasts
- 'Downstream effects' exposed activities where the seasonal effects depend not necessarily on the location of production, but on watershed effects of rainfall, potentially taking place some distance from the location of production.
  - This is the case, for example, in coal mining but is also the case in some water management activities (yield for a water utility does not necessarily depend on rainfall within a particular location, but potentially dispersed. Yield also does not necessarily depend on a single event, but on the sequence of events and the full hydrological characteristics)
- Intense or extreme event-exposed activities
- Climate exposed activities which are only partially seasonal and which are optimised across long term climate expectations
- Activities with a great emphasis on 'weather proofing'
- Activities where risk management is currently a major focus of business activity and planning
- Activities where risk management is not traditional and where the value of forecasts is unlikely to emerge quickly
- Industries where production is concentrated in a number of large firms
- Industries where activities are undertaken by a large number of small firms with relatively little formal coordination between them

The value of improved seasonal forecasting is not a simple calculation. As illustrated by the range of characteristics listed above, the use of seasonal climate forecasts is highly particular and highly contextual. Optimising the use of seasonal climate forecasts cannot be done independently of establishing a range of pre-conditions. It requires changes in business practices and conceptions of how to undertake risk management (even cognitive understandings of probabilistic forecasts).

There is also a taxonomy on the sorts of economic benefits that can be realised with improved seasonal forecasts, these are associated with the categories above.

- capital savings
- operation cost savings
  - materials
  - labour
- sectoral gains from revenue balancing (financing gains)
- avoided export revenue loss
- avoided costs to consumers

The distribution of these economic benefits is complex; the incidence of the forecast savings may distributed between various actors in complex ways. For example, the cost of a weather-related delay to production of coal may be borne by the coal miner, rail and ship transport companies, buyers, insurance companies and government revenues. The benefits associated with a reduction in the risk of weather-events may be realised by a combination of these parties.

Infrastructure intensive industries – climate proofing

Climate sensitive activities in Australia currently have a range of means of dealing with risks associated with seasonal variability. In many cases these have evolved without expecting prospective seasonal (probabilistic) forecasts.

Not all climate sensitive activities are able to respond within the time frame of seasonal forecasts — this ability depends crucially on the capital and infrastructure intensity of these activities. On the one hand, capital intensive activities are unable to respond in short time frames. And on the other, they often arrange their activities in ways that do not necessarily require good seasonal forecasts. Indeed, much of the trend of modern infrastructure management is concerned with 'weather proofing' — finding means of organising daily activities that are optimised across a very long view of climate outcomes rather than finding means of quickly responding to the latest seasonal forecast. (Even this point, of course, is highly contextual and depends on the activity concerned.)

4 The value of seasonal climate forecasts: literature review

While seasonal climate forecasts have been generated for some time, Kumar (2010) notes that there are limited studies on the value of these seasonal forecasts. Most of those studies that have been done focus on the agriculture sector. Kumar also notes that:

"for a seasonal forecast system to have a value... its use should lead to subsequent changes in key management decisions, thereby altering outcomes that are different than those based on business as usual scenarios that have evolved from the use of climatological information".

Key issues

For forecasts to lead to changes in management decisions they need to be relevant and accessible to decision makers. The difference between the potential value that forecast information may have in different sectors differs from the actual effective use of that information was highlighted by Goddard et al. (2009). Some of the reasons for this gap were listed as a lack of spatial, temporal and element specificity, and the way in which information is communicated such as timing, content, phrasing or language. Kumar (2010) also drew attention to the reasons that seasonal forecasting has not been adopted by many potential users and implied that the limited uptake of seasonal forecast information may inhibit the ability to determine the economic value of the seasonal forecasting system.

The value of forecasts is different from the economic impact of climate conditions as the value of forecasts is only realised through deliberate decision making by the user rather than a natural outcome. Two broad categories for the use of seasonal forecasts were mentioned in the literature: micro- and macro-scale use. Micro use refers to individual users that are interested in detailed forecasts that are location specific. This type of information may be useful for maximising agricultural output and reservoir management. Detailed weather and climate information is incorporated into comprehensive decision support systems.

Other potential uses of seasonal forecasts are more likely to be based on broader shifts in the probability density functions of seasonal means. These uses may include inventory management, use in economic markets (eg agricultural commodity futures and insurance), and resource allocation for droughts, disease outbreaks, and wildfires. These applications are likely to rely on heuristic rules rather than detailed decision models. For example, when cyclones are expected customers tend to stock up on food supplies and so retailers will endeavour to have sufficient supplies.

To date, it appears that most studies into the use of seasonal forecasts, and their value, have been for the micro-scale applications – water and agricultural management. One reason for this may be a lack of uptake by the other potential users. Kumar states that so far, the macro-scale forecasts have not produced results that are significantly different to historical climatology information and therefore users may be unlikely to make use of seasonal forecasts. Furthermore, information on the costs of these sorts of actions is not readily available making analysis of the benefits of forecasts difficult.

These are not the only challenges in estimating the value of climate forecasts. Even for the more studied micro-scale applications there are plenty of difficulties to overcome. The application and decision support models that determine outcomes for decision makers from a given set of state of weather and action pairing are complex, data intensive and often site-specific. There are many exogenous factors that are outside the scope of this type of model but still may have significant impacts on results such as plant disease outbreaks, second round impacts on prices and financial market fluctuations. The usual approach to assessing the value of the forecasts assumes a set of actions are taken at the beginning of the season. In reality however, decisions may be continually updated based on evolving conditions and exogenous factors. These adjustments are not incorporated into the decision making framework. Finally, there are difficulties in up-scaling from individual user level to sector level.

Approaches

A summary of four broad approaches to valuing meteorological services and forecasts was provided by Freebairn and Zillman (2002). Key points from their summary are provided here:

- **Market prices** have been used in circumstances where meteorological services have a private good aspect, such as specialised forecasts or value added processing or interpretation, and have been sold in the market. The applicability of this approach is limited by the public good properties of meteorological information and is not suitable for ex-ante analysis where the demand for services is not known.
- **Normative or prescriptive decision making models** are the most common approach used. These models are based on simplified optimising decision models solved under circumstances of imperfect information about weather or climate conditions. Most applications of this approach examine the decisions of an individual (or business) and do not incorporate second or third round impacts (for example changes in prices or countering responses of consumers or suppliers). These types of models are also used for analysis of the value of information or the benefits of R&D.
- **Descriptive behavioural response studies** aim to estimate the value of meteorological services by observing behaviour of actors (individuals, businesses, and government), by using surveys, experiments and regression methods. This approach enables researchers to determine how decisions are made and how meteorological information is used to inform these decisions. Regression models can be used where there is data available on the use of meteorological services, economic performance, and activity levels of enterprises, to determine the impact of meteorological services on economic performance. Behavioural models can be used to complement prescriptive studies as actual behaviour may differ from rational, theoretically modelled behaviour. Most applications of descriptive models have examined the use, rather than value, of forecasts.

- **Contingent valuation methods** seek to reveal the willingness to pay of individuals or businesses for a particular level of public good by using surveys that set up hypothetical market situations. Results of the surveys are aggregated to generate society values.

Kite-Powell and Solow (1994) describe a Bayesian approach (one example of a normative or prescriptive model described above) to estimating the economic benefits of improved forecasts. They highlight the benefits of a Bayesian approach that takes into account how users utilise forecast information compared to benefit estimates that are simply based on mitigated impacts. The Bayesian approach is set up by considering a decision maker who chooses from a set of actions and the consequences of those actions depend on the state of nature. The state of nature is a random variable with a probability density function. The net benefit or consequence of the action to the decision maker depends on both the action taken, and the state of nature realised. The optimal action is that which produces the maximum expected net benefit for the decision maker. Knowledge obtained through a forecast enables the decision maker to up-date the probability distribution function of the state of nature which leads to a new optimal action and expected net benefit. The value of the forecast is given by the difference between the expected net benefit with and without the forecast. Estimating the value of a forecasts requires three key elements:

- information about the quality of forecasts and the baseline conditions;
- a model of how users incorporate forecasts into the decision making process (ie how is the expected net benefit determined); and
- a model of how economic outcomes are determined by decisions and the state of nature.

Katz and Ehrendorfer (2006) also examine the Bayesian approach for estimating the value of weather forecasts obtained from ensemble-based weather forecasts. The aim of the paper is to take account of the uncertainty attributable to the forecast probability being estimated from a limited ensemble size. They do this by using an estimator for the actual forecast probability.

Teisberg et al. (2005) also used a prescriptive decision model. They estimated the cost savings attributable to temperature forecasts used by the US electricity generation industry in planning electricity production with a lead time of up to 24 hours. They argued that accurate temperature forecasts could improve the accuracy of demand forecasts and as a result can lower the cost of electricity production by allowing the best mix of generating units available as required. They used results from Hobbs et al. (1999) for the relationship between demand forecast errors and economic costs associated with the error. With a forecast error of 5 per cent (compared to a perfect forecast) the associated costs were estimated to be 0.35 to 0.85 per cent depending on the generating system specifications and the utility system. They used data on actual electric loads and corresponding location specific temperature observations and forecasts for six sites in the US to develop a load forecasting model. The accuracy of the load forecasting model was tested using three different sets of temperature forecasts – persistence (or today's temperature as a forecast for tomorrow), perfect forecast and national weather service forecasts. Finally, the cost savings associated with improved weather forecasts were determined using these two models. The results show that, for the US, cost reductions obtained by using the national weather service forecasts compared with persistence range from 0.013 to 0.592 per cent depending on the state and generation system.

Cost-loss model

Most of the studies that estimate the value of climate or weather forecasts used the normative or prescriptive model approach and focused on the agriculture sector (Freebairn and Zillman 2002). The cost-loss model used in many of these prescriptive studies is an application of Bayesian decision theory. It sets out the expected net return of an activity with and without taking action and whether a weather-related event occurs or not. The framework is illustrated in the decision tree (chart 4.1) below. A weather or climate forecast will provide a user with the probability of an adverse weather event occurring on each occasion. Based on this probability the user will decide whether to take action based on their expected returns. That is they will take action if the expected value of taking action is greater than the expected value of not taking action. Using information on the net return from the four possible outcomes (*A,B,C* and *D* in equation 1 and chart 4.1), this decision can be shown to depend on the probability of the event occurring relative to the net returns as shown below:

$$EV_{action} \geq EV_{no\ action}$$

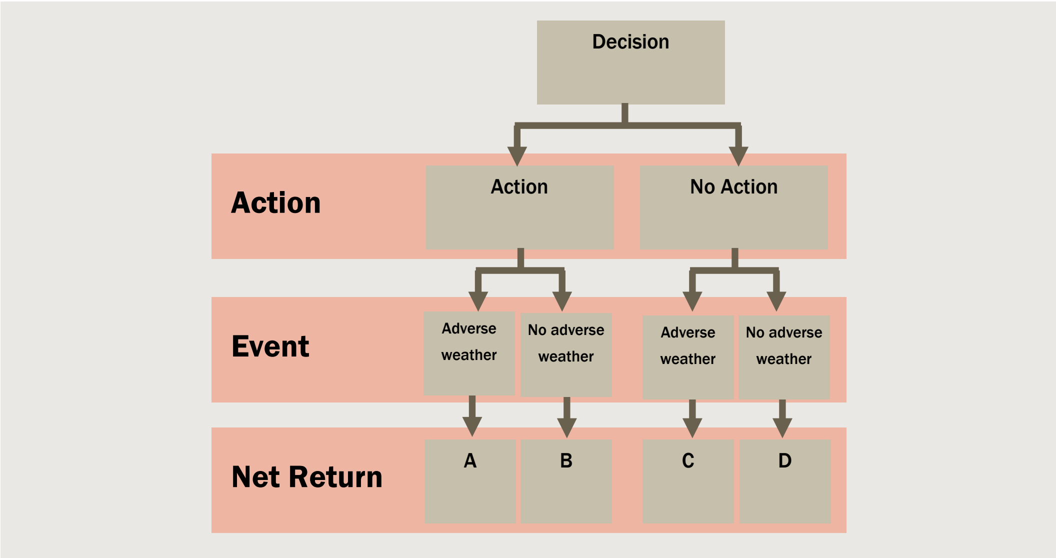
$$pA + (1 - p)B \geq pC + (1 - p)D$$

$$p \geq \frac{(D-B)}{(D-B)+(A-C)} \qquad (1)$$

Where:

- EV is the expected value or return from taking action or not
- p is the probability of an event occurring
- *A, B, C, D* are the net returns of 4 different possible event/action combinations as shown in chart 4.1.

4.1 Cost-loss framework



Over repeated actions, there will be a total expected return achieved by the user. Comparing this total return with the return that would have been achieved with an alternative forecast yields a measure of the value of forecasts.

The cost-loss framework provides a helpful starting point to considering the value of forecasts, however, it requires detailed information on:

- which weather events will impact on the activity
- what effect those weather events have on the activity
- the cost of weather impacts on the activity
- the actions that can be taken to mitigate the impacts
- the cost of undertaking these actions
- the residual cost of the weather impacts after the mitigating actions.

The cost-loss framework is also a simplification of the decision scenarios most users would face as it examines a binary choice of 'take action' or 'don't take action' and looks at the occurrence of only one weather event. In reality, users of weather and climate forecasts may be interested in a range of different variables and time scales.

The benefit of the Bayesian approach, compared to an approach that estimates the impacts that can be mitigated by the use of forecasts, is that the Bayesian approach incorporates the costs associated with an incorrect forecast. For some industries this cost may be significant.

The cost-loss framework, nonetheless, has limitations. Marzban (2012) argued that the cost-loss framework is not always appropriate as both the value and quality of forecasts are multifaceted, attributes which are not captured in the cost-loss framework. Additionally, as noted previously, returns from forecasts will depend heavily on how forecasts are used.

Despite the drawbacks of the cost loss framework, the approach to estimating the value of seasonal climate forecasts that has been adopted for this project, outlined in the next chapter, is based on the basic cost-loss model. This is because of the limited availability of alternatives, the ease of understanding and the ability to apply the methodology to multiple sectors.

5 *Estimating the value of seasonal climate forecasts in Australia: a methodology*

The decision to use forecasts

Climate forecasts are beneficial because they may allow decision makers to gain an understanding of the likelihood that an otherwise random event might occur. By having greater information about the probability of an event occurring the decision maker is better placed to take action to reduce the costs associated with that event.

However, climate forecasts are not perfect and incorrect forecasts may be costly for decision makers that rely on forecasts.

- If a particular weather event is forecast but does not occur (a false alarm) then the forecast user will unnecessarily bear the costs associated with taking mitigating actions.
- Alternatively, if the event is not forecast but does occur (miss) then the full extent of the losses are incurred.

Deciding whether or not to use a forecast will require an assessment of the overall benefits and expected costs. That is the benefits associated with the times when the forecast is accurate compared to the costs incurred when it is incorrect. That will depend on the accuracy of the available forecasts and the relative costs of taking mitigating action and the cost that the weather event may incur. A forecast is more likely to be used if:

- if the forecast has demonstrated skill in the past
- the cost of taking action is low
- the losses from the weather event are expected to be high.

The approach used to value forecasts should incorporate all of these aspects of the decision making process. That is, the framework should include:

- a model of how users incorporate forecasts into decision making (how is the net benefit determined)
- a model of how economic outcomes are determined by the decisions taken and the realised state of nature.

As was highlighted in chapter 3, valuing improved seasonal forecasting is not a simple calculation and is highly particular to an industry or business and also highly contextual. Ideally, specific models of the decision making process and the economic outcomes would be developed for the particular industry, business and location of interest to account for the particular circumstances facing that industry. However, construction of these individual models is beyond the scope of this project. Therefore, a more general framework has been adopted which incorporates the uncertainty aspects of using imperfect forecasts. The approach relies on other sources of information about the losses associated with weather events and the cost of mitigating these losses.

Methodology

The methodology used here to estimate the value of improved seasonal forecasts to different sectors is based on Verkade and Werner (2011) and incorporates the trade-offs described above. Verkade and Werner used the concept of relative economic value to determine the benefits of an imperfect forecast (or in this case the improved seasonal forecast) relative to the benefits associated with no forecasts (currently available forecasts) and perfect forecasts. The approach incorporates the reduction in losses due to a weather event, the costs of taking mitigating action and the costs associated with forecast uncertainty.

The methodology can be summarised by equations (2) and (3).

$$B_{seasonal\ forecast} = V\left(EAD_{perfect} - EAD_{current}\right) \quad (2)$$

$$V = \frac{p-(h+f)r-m}{p(1-r)} \quad (3)$$

Where:

- *B* is the benefit or value of the improved seasonal forecasts
- *EAD* is the estimated expected annual damage from the weather event under the currently available forecasts and perfect forecasts
- *V* is the relative economic value
- *h* is the probability that the forecast correctly forecasts the event (hit, or true positive)
- *f* is the probability that the event is forecast but does not eventuate (false alarm, or false positive)
- *m* is the probability that the event occurs but is not forecast (miss, or false negative)
- *p* is the probability that the weather event occurs ($p=h+m$)
- *r* is the cost-loss ratio, that is the ratio of the cost of mitigation action to the losses that could be avoided by that action under a perfect forecast.

Within this framework, the values of the various probabilities (*p*, *h*, *f* and *m*) are all related as they come from the same possible event chain. Also, they are each constrained by the assumed value of accuracy of the forecasts (*a*).

The relationships between the values can be summarised in table 5.1 — essentially a matrix setting out the relationships between possible outcomes (event occurs or does not occur) and possible forecasts (correct versus incorrect). The values of *h*, *f*, *m* and *q* (probability of a true negative occurring) must all sum to 1. By definition, *h* and *m* sum to *p*, and *q* and *f* must sum to (1-p).

To implement the model we assume that the overall accuracy the forecast applies equally to circumstances where the event occurs or does not, so the sum of *h* and *q* is *a*.

5.1 The relationships between *h*, *m*, *f*, and *p*

	Correct forecast	Incorrect forecast	Row sum
Event occurs	*h* (hit)	*m* (miss)	*p* (probability of event)
Event does not occur	*q* (true negative)	*f* (false alarm)	*(1-q)* (probability of no event)
Column sum	*a* (accuracy or probability of correct forecast)	*(1-a)* (probability of incorrect forecast)	1

Source: CIE

Benefits of using this method are that:

- it relies on information about the value of two easy-to-consider scenarios (no forecast and perfect forecasts)
- it considers the extent that losses can be mitigated (rather than total climate related losses)
- it incorporates the costs associated with mitigation activities
- it includes the cost of uncertainty and incorrect forecasts.

Some considerations however:

- This approach assumes one decision maker for one type of event; to look at a sector as a whole the results need to be aggregated. The impacts and available methods of mitigating impacts are likely to vary across different areas of the country and for different companies within the sector. These differences should be considered before the results are aggregated to the sector wide level.
- For some sectors the value of forecasts may be achieved through a greater ability to take advantage of favourable weather conditions. In this case, the avoided losses may be substituted for the value of potential gains from optimal reaction to the weather conditions.
- For those sectors that are not directly affected by the weather but rather affected by consumer responses to the weather (for example demand for electricity, health, water and tourism services) there is an added layer of uncertainty associated with understanding consumer responses.
- This method does not consider second or third round effects which may be observed through market adjustments.

Placing bounds on the parameters

The approach described above is useful as it requires consideration of two clear and relatively easy to assess scenarios – the current situation and a perfect, ideal situation.

Understanding the methodology and the logic behind it can be aided by considering the bounds within which the parameters are within.

- The parameters p and r must be between 0 and 1.
  - The probability of a weather event occurring (p) is, by definition, between 0 and 1.

  - Logic dictates that the cost-loss ratio (*r*) should be between 0 and 1. A value of r greater than one would indicate the costs associated with mitigating the losses were greater than the expected losses and therefore would not be worth undertaking.
- The value of *p* must be greater than that of *r* (*p*>*r*).
  - The logic around this condition is explained by the optimal forecast rule below.
- The value of seasonal forecasts will be positive if V is between 0 and 1.
  - For a perfect forecast, *V* has a value of 1 (*m=f=0,h=p*)
  - For the currently available forecast, *V* has a value of 0.
  - A value of *V* less than 0 suggests that the forecast was less useful than the current forecast and therefore would not be used.

Optimal forecast rule

For any given situation, where a weather event is forecast to occur, a decision maker is faced with the choice to either take mitigation actions, at a cost of C, to avoid some of the expected damage or losses associated with the weather event. Of the total expected losses from a weather event, some (L_u) will be unavoidable but some of the losses (L_a) could be avoided by taking the mitigation action.

A forecast will only be acted upon if the total expected costs from acting are less than the expected costs from not acting. That is:

$$C + pL_u < p(L_a + L_u)$$

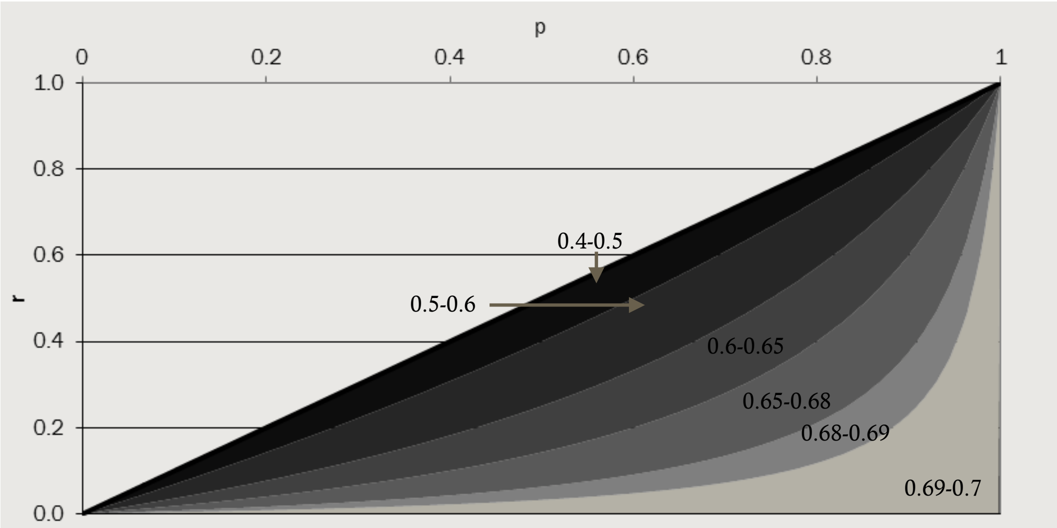
$$p > \frac{C}{L_a} = r \quad (4)$$

This inequality shows that for the forecast to be useful, the cost loss ratio must be less than the probability of the given weather event occurring.

The shaded area in chart 5.2 shows the range of combinations of *r* and *p* that yield positive values of *V*, and satisfy the optimal forecast rule. The different shading shows combinations of *p* and *r* that provide similar relative economic values (*V*). For an accuracy of 70 per cent[2], the combinations of *r* and *p* in the darkest area towards the centre of the chart return a value of *V* between 0.4 and 0.5. For the lightest area to the bottom right of the chart, the value of *V* is between 0.69 and 0.7.

2 Accuracy of 70% can be interpreted as proportion of true forecasts in total forecasts (that is the sum of true positives and true negatives to total forecasts). It was assumed that this proportion was also the proportion of true positives in the total number of positives and the proportion of true negatives in total number of negatives.

5.2 Combinations of p and r that satisfy the optimal forecast rule



Data source: The CIE

High probability events

There are two clear scenarios in which a forecast is not of value but which not captured in the proposed model illustrated above. These are the specific situations where the cost loss ratio is 0 or where the probability of an event occurring is 1. In each of these situations, basic reasoning shows that mitigation actions should be taken regardless of the forecast. This is because either the mitigation action is costless (*r=0*) or the event is certain to take place (*p=1*).

The idea can be extended to cases where *r* is very low and *p* is high. In these circumstances, taking mitigation regardless of the forecast could be justified to avoid the costs associated with a missed forecast. In the case of high probability events, this logic is demonstrated by the actions of industry. As explained in chapter 3, for events that can be reasonably expected to occur, industries endeavour to 'climate proof' their activities so that they do not necessarily need to adjust their activities in the short term.

6 Electricity

The electricity sector and climate

Sector introduction

In 2010-11, 909PJ (or 252TWh) of electricity were consumed in Australia (ABS 2012b) and the electricity supply sector generated total income of $67 714 million (m) and value added of $22 455m (ABS 2012c). Total principle electricity generation capacity was 54GW in 2009-10, capacity utilisation was 49 per cent and the system reliability index (SAIDI) was 247 (BREE 2012).

The Australian electricity market is separated into 3 geographically distinct power grids, the National Electricity Market (NEM), the WA grid, and the NT grid. The largest market is the NEM which covers Queensland, South Australia, Victoria, NSW, ACT and Tasmania, accounting for around 200TWh of generation per year supplying 19 million residents (AEMO 2010).

The electricity sector can be separated into different parts – generation, transmission, distribution and retailing. The share of value added between the industry segments is 35, 11, 47 and 7 per cent respectively for generation, transmission, distribution and retail (Productivity Commission 2012).

The NEM is managed by the Australian Electricity Market Operator (AEMO). AEMO acts as an intermediary to ensure the required demand is met by generators. AEMO balances the demand and supply of electricity by dispatching the generation necessary to meet demand.

Meeting demand

The AEMO forecasts electricity demand 5 minutes ahead, and orders electricity to meet the demand from generators. Generators nominate their available capacity and minimum price. Based on generator offers, the AEMO dispatches generators to produce the required volume of electricity.

The NEM standards state that unserved energy (that is electricity that is demanded but not met) must not exceed 0.002 per cent of total energy consumed per year for each region. In order to meet this standard, a certain level of reserve must be maintained. Each quarter the AEMO produces an Energy Adequacy Assessment Projection which seeks to estimate the regional level of unserved energy at an hourly resolution for a 24 month study period. This study aims to identify and address potential times when the unserved energy standard might not be met. The assessment is based on information about generation capacity from scheduled generators under alternative rainfall scenarios, and demand forecasts. The alternative rainfall scenarios used are defined in terms of historical rainfall levels (eg low rainfall as observed in 2006-07, rainfall of the past 10 years and average rainfall of the past 50 years).

Climate may impact on the ability of the electricity sector to meet demand in three ways:

- Impacts on the demand for electricity (in recent years this has been driven primarily by the use of domestic air conditioners on hot days);
- Impacts on the ability of generators to maintain production (through for example limited water availability for steam generation, water, wind and solar radiation levels for renewable energy generators, or extreme heat leading to shut down of thermal generators); and
- Impacts on the transmission and distribution network (storm, natural disasters or extreme heat damage to wires).

There may be little opportunity to directly address, or protect against, these impacts, even with accurate climate forecasts. Some options may be to conduct marketing campaigns to attempt to reduce peak demand, to improve the management of water resources to ensure a sufficient supply is available, or upgrade network infrastructure to limit damage from extreme weather events. However, seasonal climate forecasts may improve planning and scheduling of generation to reduce costs and improve system reliability.

Use of seasonal climate forecasts

There are a few different opportunities in the management of electricity supply in which climate forecasts may be incorporated. These include:

- demand forecasting on a range of time scales, for average and peak demand
- Energy Adequacy Assessment Projections
- Australian Wind Energy Forecasting System
- rooftop PV forecasts
- network revenue determinations.

Demand forecasting

Demand forecasts are prepared by AEMO for operational purposes, for the calculation of marginal loss factors, and as a key input into AEMO's national transmission planning role.

Demand forecasts produced by AEMO for its own use and as market information include:

- 5 minute dispatch forecasts
- pre-dispatch forecasts produced one day ahead
- 7 day forecasts for the Short Term Projected Assessments of System Adequacy (ST PASA)
- 2 year forecasts for the Medium Term Projected Assessments of System Adequacy (MT PASA) which has a daily resolution

- 10 year forecasts for the Electricity Statement of Opportunities (ESOO) (yearly resolution).

The purpose of each of the forecasts is slightly different. Seasonal climate forecasting will probably be of most use for the 2 year forecasts in the MT PASA. The MT PASA provides information on the supply / demand balance for the coming two years based on the generation capacity that can be met by scheduled and semi scheduled (>30MW) generation. It is updated weekly and includes information on projected demand (from the ESOO) and maintenance outages and short term variations in generation provided by generators. The assessment is used to determine reserve levels at daily peak demand and points of low reserve conditions. It also highlights any opportunities for market responses and possible interventions through the Reliability and Emergency Reserve Trader process.

Currently the MT PASA demand forecasts are based on the demand forecasting conducted for the ESOO process. These forecasts include some weather variables in determining demand. These climate variables include heating degree days (HDD) and cooling degree days (CDD) at indicator sites in each state. The temperatures used in the forecasts are based on historical observations rather than any climate forecasts. Furthermore, the temperature variables are assumed to be the same across each state, not allowing for diversity in temperatures which may have impacts on overall peak demand state-wide. A climate change factor has been included to increase the average temperature over time, however it does not account for any changes in temperature variation.

Energy Adequacy Assessment Projections

The EAAP focuses on the potential impact of water availability on generation capacity and the resulting impact on the level of unserved energy. As mentioned previously, these projections are based on three scenarios of varying water availability. The scenarios are defined using historical rainfall levels, rather than any rainfall forecasts.

Australian Wind Energy Forecasting System

Electricity generation through wind powered power plants is fully dependent on the immediate wind conditions at a particular location. Because of this dependence on the wind, wind generation is intermittent and cannot respond to demand. This makes incorporating wind power into the scheduling of generation difficult. The Australian Wind Energy Forecasting System (AWEFS) was developed to produce forecasts of wind generation of large scale wind farms on timescales ranging from 5 minutes ahead to 2 years. This information is incorporated into the AEMO forecasting and scheduling activities. The AWEFS wind generation forecasts use data for wind speed, direction and temperature from historical data, real time observations and three different weather forecasts (from Australian, European and US Weather Bureaus).

Rooftop PV forecasts

Electricity generated through rooftop PV systems act to offset electricity demanded from the grid, therefore forecast generation from rooftop PV systems are an important element in determining net electricity demand for the NEM. Rooftop PV forecasts are developed based on historical install rooftop PV capacity and historical growth in capacity, historical solar intensity data, and previous observations of rooftop PV contributions to meeting maximum demand.

Network revenue determinations

The AER forecasts the expenditure requirements of network operators to determine the revenue requirements and set the ceiling on prices or revenue that a network can earn for a five year period. The determination of the revenue cap includes consideration of operational and maintenance expenditure, a return on capital, asset depreciation costs and tax liabilities. Network expansion has been a key driver of increasing capital expenditure, under pinned by growth in demand (RBA 2011) (which is potentially weather dependent as discussed earlier). Weather events are a significant driver of expenditure as preventative or reactive activities may be required to maintain safe and reliable network services. However, it is not apparent that any climate forecasts are used in forecasting operating expenditures.

Indications of the cost of weather events and responses

As many of the opportunities associated with using seasonal climate forecasts are indirect, it is difficult to estimate the potential value these forecasts may have to the sector. Much of the use of forecasts is in the incorporation of forecasts into the planning process, and possibly reducing the uncertainty associated with future electricity demand, supply and network maintenance. Presumably, because the demand and supply forecasts are developed, there must be some value in them, but quantifying this value is another matter.

Two studies have been conducted into the value of customer reliability, one for Victoria and another for NSW. The value of customer reliability was found to be $94.99/kWh in NSW and $57.88/kWh in Victoria (Oakley-Greenwood 2012).

- An indication of the cost of weather events on the distribution system can be garnered from observations of the South Australian network in 2010-11. In South Australia in 2010-11 a number of extreme weather events led to significant interruptions in electricity supply. Seven severe weather events were recorded, including three particularly severe storm events. These storm events resulted in wires down and disrupted services. ETSA Utilities, the company that owns and maintains the SA distribution system, made Guaranteed Service Level (GSL) payments of $7.1m in 2010-11 as compensation to customers that received services worse than the predetermined guarantee level (The Essential Services Commission of South Australia 2011). These compensatory payments are based on estimates of the value of customer reliability. The GSL payment was $1.6m in 2009-10 and the average payment over the past 6 years was $2.1m. The payments made depend on the duration of interruptions, frequency of interruptions, street light repairs needed and the cost of new connections.

As discussed in this chapter, there are a range of impacts that climate may have on different aspects of electricity production and delivery. As a starting point, electricity supply disruptions due to high winds will be the focus of the analysis in the following section.

Estimating the value of seasonal climate forecasts

Inputs

The focus of this exercise was on the disruption of electricity supply due to high winds in the major Australian cities. The probability of high winds occurring in a major city across Australia in a year was assumed to be 4 per cent. The accuracy of the improved seasonal forecast was assumed to be 70 per cent (and therefore probability that a high wind event is correctly forecast was assumed to be 2.9 per cent, the probability that the event is forecast but does not eventuate 29 per cent, probability of the event occurring but not being forecast 1.2 per cent).

The cost-loss ratio (the ratio of the cost of mitigation action to the losses that could be avoided by that action) was assumed to be 0.06 (that is, for every $10,000 spent on preventative maintenance, $175,000 in costs could be avoided).

Finally, the expected annual damage associated with high winds under the current forecasts and perfect forecasts was required. Due to the high degree of uncertainty associated with these inputs, and the significant impact these inputs can have on the final result, three different assumptions were tested (scenarios 1, 2 and 3). The magnitude of the chosen figure for scenario 1is broadly based on the observed costs from the recent power outages in Adelaide (scenarios 2 and 3 represent higher and lower estimates). The assumptions also incorporate the idea that a significant proportion of the damage, or losses, cannot be avoided with perfect forecasts. The assumptions are summarised in table 6.1 below.

6.1 Expected annual damage assumptions

Scenario	1 (based on observed costs of power outages)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Current forecasts	33.04	49.6	16.5
Perfect forecasts	24.78	31	15

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

Results

Table 6.2 shows the value of improved seasonal forecasts (compared to the currently available forecasts) for the three different input assumptions that were outlined in table 6.1 and assuming a forecast accuracy of 70 per cent. The minimum accuracy required of the improved forecast, for the assumed values of r and p, that would yield a positive value is 59 per cent.

6.2 Annual value of improved seasonal forecasts to the coal mining industry, assuming forecast accuracy of 70%

Scenario	1 (based on observed costs of power outages)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Value of improved forecasts	2.28	5.12	0.42

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

7 Health

Weather, climate and health

While there are a number of gaps in knowledge about some of the linkages between climate and health costs, a number of factors suggest there is a substantive link.

- On the one hand, the Australia Medical Association (2013) have pointed out that a systematic analysis of the health costs associated with increased weather events is yet to be undertaken and that there is also limited understanding about the risks to health from extreme weather.
- On the other hand, a number of studies and observations, as discussed below, have established a link.

General health impacts of weather events

Table 7.1 summarises some of the main impacts weather conditions may have on human health, and therefore demand for health services.

7.1 Examples of health impacts of weather events

Heat related impacts	Extreme weather effects	Air quality impacts	Disease impacts
Heat stroke Dehydration Aggravation of chronic diseases (cardiovascular, respiratory disease)	Physical injuries (fractures, lacerations etc) Increased number of car accidents Mental health impacts Drowning Aggravation of chronic disease through disruptions to the healthcare services Contamination of freshwater supplies Smoke and burn injuries from bushfires	Lung injury from increased concentration of ground level ozone, and increasing the severity of respiratory diseases such as asthma and chronic obstructive pulmonary disease Increase in fossil fuel use and therefore increased airborne particulates indirectly leading to respiratory disease Pollen production worsening allergic reactions and respiratory disease Respiratory disease from bushfire smoke	Food borne disease Water borne parasites Spread of vector borne diseases

Source: EPA, and; CDC 2010

In Australia in 2011, 68 deaths were attributed to ‘forces of nature’, 11 of these due to excessive heat, 26 due to excessive cold, 26 due to flood, and 3 due to storms (ABS 2013).

The health effects of extreme weather are expected to increase over time as the Australian population ages and chronic disease burdens increase. Observations from the 2011 Queensland floods and the 2009 Victorian bushfires indicate that deaths and injuries were more likely in isolated areas that lack ready access to emergency services support, centralised planning and risk management services (Australian Medical Association 2013). This would seem to indicate that advanced warning of events provided by seasonal forecasts could enable targeted planning to address this.

Excessive heat

There are a variety of lines of evidence pointing to the costs of excessive heat.

- According to some studies, extreme heat events have killed more people than any other natural hazard experienced in Australia over the past 200 years (Coates 1996).
- Health impacts of heat events can range from heat related illnesses (such as heat cramps and heat stroke), exacerbation of existing co-morbidities, to unexpected deaths. There have also been observations of increased rates of violent crime during heat events. The health impacts of heat events can be influenced by city size and structure, urban density, micro-climates, demography and public awareness.
- A recent study by the Australian Institute of Health and Welfare (AIHW 2011) noted that:
  - mortality typically increases rapidly after passing a certain high temperature threshold (which varies between cities). For example, mortality is lowest in Sydney when the maximum temperature is 23–24°C;
  - there is a 0.9% increase in mortality for every 1°C increase in maximum temperature in Sydney with mortality 7.8% higher than expected when the maximum temperature reaches 32°C;
  - there is a a 4.5–12.1% increase in mortality for every 10°C increase in maximum temperature in Sydney;
  - hot weather is also associated with an increase in morbidity. Elevated temperatures can cause heat cramps, fainting, exhaustion, heat stroke and dehydration.
  - a study in Melbourne noted that acute myocardial infarction admissions increased by 10% on days over 30°C, while in Brisbane an increase in temperature is significantly associated with hospital admissions for stroke.
  - the risk of heat-related problems may increase for those living in urban areas and for those without air conditioning. Elderly persons are particularly at risk for health reasons as well as socioeconomic reasons.
  - a number of studies have also associated increased mortality and morbidity with heat waves. Some of this may be due to frail elderly people dying slightly earlier than otherwise due to the heat wave.
- PricewaterhouseCoopers estimates that there are approximately 80 excess deaths each year associated with heat events across the major capital cities of Adelaide, Brisbane, Melbourne, Perth and Sydney, and the ACT and Tasmania (PricewaterhouseCoopers 2011). With changes in population size and demographic composition this may increase to 120-130 by 2030 and 170-200 by 2050.

Recent extreme heat events have prompted the development of response and planning arrangements. Each of the 5 states have a plan in place for dealing with heat waves. These plans are the responsibility of either health or emergency services agencies. The relevant forecast periods for the plans range from a matter of hours to 6 days.

During periods of high temperatures there is increased demand for general practice, ambulance and hospital emergency services and as heatwaves continues the capacity to meet high demand for these services can be seriously compromised. Staff providing the services may experience adverse health effects and organisations need to ensure they have sufficient occupational health and safety procedures.

Maintaining a register of at-risk individuals and 'checking-up' on them during heat events has proven to be effective at mitigating adverse impacts of heat events. PricewaterhouseCoopers suggested other measures that could be taken to manage the impacts of heat events. These measures included:

- education campaigns aimed at improving public understanding of how to avoid heat-related illness and to service providers for at risk individuals; and
- maintaining responder capacity, by for example, rostering more staff and rotating staff during high temperatures to minimise staff exposure.

Excessive cold

The AIHW (2011) also noted that excessive cold can be a cause of morbidity and mortality.

- Exposure to cold may increase blood pressure and heart rate and lead to thrombosis and hypothermia. Breathing cold air may also exacerbate existing respiratory conditions.
- A number of studies have found increases in mortality (amongst the elderly and others) as a consequence of cold weather.

As noted above, in 2011, mortality attributed to excessive cold was around twice that attributed to excessive heat.

Bushfires

An indirect consequence of extreme weather may be resulting bushfires (noting that bushfires have many complex causes). Bushfire can lead directly to death and injury and can also have serious consequences for respiratory disorders and traumatic stress and depression.

Drought

This most common of Australian phenomena can have a variety of direct and indirect health consequences. Many of these are related to mental health effects, particularly among rural communities.

Storms and floods

Aside from direct mortality, storms and floods are associated with a variety of health effects including:

- contamination of water supplies leading to gastroenteritis;
- interruption of electrical supplies leading to food spoilage;
- increased infections of various kinds in cases where pathogens are present in floodwaters;
- the consequences of long term water damage including mould and damp.

Limiting health delivery

As well as affecting demand for health services, weather may impact the supply of health services. For example, staff may experience heat stress and required an increased number of breaks; natural disasters may damage infrastructure or inhibit staff access; and there may be flow on effects of electricity supply disruptions.

Health service delivery costs

Weather or climate conditions affect costs to the health sector through few avenues:

- meeting increased demand for services may require additional resources;
- damage to facilities requires repairs and management of patients. During the Victorian floods of January 2011 Rochester Hospital in northern Victoria was required to evacuate 65 patients and Charlton Hospital was flooded and required $22.7m in repairs; and
- a loss of services in a given area imposes additional costs on the community as they incur costs to travel to receive care.

Planning in the health sector

Authorities undertake a range of planning activities for different services and timeframes within the health sector. For example, the NSW Ministry of Health uses a number of sophisticated planning tools to assess the state of health infrastructure capacity and assess unmet demand. These tools include FlowInfo, aIM (acute inpatient modelling), SiAM (subacute inpatient activity modelling), Operating Room Modelling, and MHCCP (Mental Health – Clinical Care and Prevention Model) (Meleady 2011). These models primarily appear to rely on historical data, combined with forecast population and demographic changes, to estimate the demand for particular services. The planning time scale appears to be 5-10 years.

There is evidence that early warning systems can reduce the morbidity and mortality associated with extreme weather events (Australian Medical Association 2013). Managing and minimising health impacts require accurate and timely alert systems. For example, emergency departments in hospitals could better manage increased admissions and community and service providers could take action and preventative measures.

The Australian Medical Association identified a lack of relevant and accessible information on climate trends and likely impacts to inform future planning and strategic allocation of resources as factors that can compromise the preparedness of the health sector.

Coordination between emergency services and health professionals, medical centres, clinics, hospitals and other health care facilities is critical to manage an increase in demand, and the infrastructure disruptions that may accompany major emergencies (Australian Medical Association 2013).

Making use of seasonal forecasts

As noted, the potential incremental value of seasonal forecasts relates to targeting of particular preventative intervention measures. For example, the value of seasonal forecasts may be realised through:

- effective targeting of education campaigns when and where extreme heat events are expected to occur
- improved planning for events by improving staffing and resource management well in advance of an event.

There may currently be some institution limitations to realising this value.

- According to the AMA (2013), infrastructure, capacity, and limitations in knowledge and awareness inhibit the Australian health system from dealing with extreme weather events.

8 Tourism

Total tourism consumption in 2011 amounted to $95,653, of which 25 per cent was international tourism, 11 per cent business and government domestic tourism and 64 per cent domestic household tourism (ABS 2011). The most significant components of the tourism industry are accommodation, air, water and other transport, retail trade, and cafes, restaurants and takeaway food services.

Climate conditions have the potential to influence the tourism sector through:

- changes in demand for tourism related goods and services; and
- impacts on the management and supply of tourism services.

While improved climate forecasting is likely to be useful for many aspects of the tourism sector there is also a significant downside. Many of the current tourist destinations and facilities rely on the positive climatic conditions that the destination exhibits. Without accurate long term forecasts tourists rely on long term climatic conditions for their decision making. Developing seasonal climate forecasting may have a negative impact on tourism operations if unfavourable conditions are forecast, whether accurate or not. Highly accurate and detailed spatial resolution in forecasts may lead to positive effects for the tourism sector.

Tourism services demand

Impacts of climate

Climate can be both a push and pull factor for tourists. Attractive weather at a destination can pull tourists and poor weather at home or other locations can push tourists to take holidays. For example, extremely hot conditions in southern Spain in 2003 led to an increase in tourists in cooler inland areas of Spain.

The impact of poor weather conditions can have very long lived effects on the tourism sector. Experience shows that tourist numbers can remain low in the year after poor environmental conditions. For example, the impacts from Hurricane Katrina in the US are expected to remain on the convention and gambling sectors for years and decades in New Orleans and Mississippi. It has been observed that the demand for tours to sunshine locations by Norwegians is influenced by the conditions that were observed in the previous summer.

Use of forecasts by tourists

Tourists use climate information and forecasts both before booking travel and before travelling. The time frame for forecasts used by tourists depend on the activities. For example, international tourists booking flights and accommodation may be interested in the climate several months ahead. Shorter domestic trips, however, may be planned in much shorter times. Shorter term forecasts are also likely to be used by tourists to prepare for travel. The value that tourists may gain from improved probabilistic forecasts is unclear as probabilistic forecasts can be difficult to interpret and understand.

Forecasts of poor conditions can have significant impacts on tourist numbers. There have been several examples in Queensland, Britain and Belgium in which tourism operators have complained of low customer numbers due to unfavourable forecasts. High resolution forecasts would be of use to combat this problem as often tourist destinations have unique and better microclimates which attract tourists but are not featured in climate forecasts.

Use of forecasts by operators

Climate forecasts can be used by tourism operators to forecast demand for services, market destinations or activities, and provide additional information and services to customers. With additional information operators may be able to improve management of resources to meet demand, and optimise investment decisions. Marketing campaign can be targeted at locations likely to have poor weather, or can use climate forecasts as an incentive for travel.

Supply of tourism services

Impacts of climate

In addition to impacting the demand for tourism services, the weather can impact on the delivery of some services. Some examples of services that may be affected by weather include:

- golf courses
- ski fields
- airline or cruise ship routes
- outdoor or water based activities (outdoor events, hiking, snorkelling, scuba diving, sailing etc)

Use of forecasts

Forecasts may be used by operators to optimise service delivery. For example, forecasts may help decision making regarding snow making requirements in ski fields, or may help in re-routing and scheduling flights if severe weather is expected. The lead time required for decision making varies from immediate for guest information or running snow making machines, to short term for transport routing and outdoor activity planning, and long term for investment decisions (such as purchasing snow making equipment) or job creation. Improvements in forecasting skills may enable some activities to be undertaken earlier, or it may reduce the uncertainty associated with planning.

Value of seasonal forecasts for tourism

The value of seasonal forecasts for the tourism sector is limited by the ability of the sector to understand, interpret and employ the probabilistic forecasts. Such a diverse and dispersed sector is characterised by many small operators and limited degree of coordination to make the most of improved seasonal forecasts.

There is a great risk that forecasts not well understood by tourists, or forecasts that are incorrect or of low spatial resolution, will result in tourists making unjustified decisions not to visit some destinations or attractions at the cost of tourism operators. With most tourist destinations generally having favourable climates, the change to demand likely to arise from availability of new forecasting products would be negative for tourism operators.

Optimisation of the management of tourism services that has taken place historically will limit the gains that can be made through the use of improved seasonal forecasts.

Overall, a lack of available information on the costs of weather events on the tourism industry and the constraints outlined have led to the conclusion that the value of improved seasonal forecasts to the tourism sector are likely to be limited, and therefore the model for valuing the improved forecasts has not been applied to the sector.

9 Retail

Impact of climate on retail activities

Weather and climate can affect the retail sector through changes in demand and/or changes in costs. A weather event may change in store foot-traffic, the cost of obtaining stock, and demand for certain products such as fresh fruit, seasonal clothing, heaters and cooling equipment.

General trends in demand for many products follow seasonal patterns, however the timing and extent of demand may vary year to year. For example, demand for winter clothes may start earlier in years with cold autumns and demand for air conditioners may be higher in very hot summers. Star-McCluer (2000) found that unusual weather is a significant determinant of monthly fluctuations in retail sales.

Measures to mitigate climate impacts

An initial look at the activities of the retail sector may indicate some scope for the use of climate forecasts. Climate forecasts may potentially be helpful with inventory management, marketing and staffing. If certain climatic conditions that are associated with increased or decreased demand for a product are forecast, a retail outlet may be able to adjust orders for those products to ensure they can meet demand. The time horizon over which the forecasts would be useful depend on the length of the supply chain. For seasonal products, the start or peak of sales may vary by a few weeks. The risk to retail operators are that sales are missed at the beginning of the season by failing to have sufficient products in stores or overstocking if the season turns out to be short (RTT 2011). To accurately adjust stock to expected weather conditions, retailers not only need to understand the expected weather but also the responsiveness of demand to changes in weather, and how this response is also affected by other factors.

Climate forecasts may also be used as a tool in marketing campaigns. For example, where particularly hot temperatures are expected a retail outlet may increase their marketing of air conditioners to ensure they capture the demand the hot weather leads to increased sales.

Staffing decisions may also be affected by climate forecasts. In periods where increased or decreased demand for products are expected, retail managers may increase or decrease staffing levels to ensure they can meet customer demand efficiently.

Value of improved seasonal forecasts to the retail sector

Despite the potential opportunities for the use of forecasts, a number of factors may limit the value of improved seasonal forecasts to the retail sector. Retail is a diverse and highly dispersed sector with little coordination between firms. There are almost 140 000 retail businesses in Australia, accounting for 4.1 per cent of GDP and 10.7 per cent of employment (Productivity Commission 2011a). Compared with mining which contributes over 9 per cent of GDP (ABS 2012a) but by just 8438 businesses (ABS 2013).

The variation in sales due to climate variability all but washout at the annual and sector-wide level. Observations of sales data demonstrate a substitution effect, with sales in one segment of the sector increasing as sales in another decrease. Overall retail sales are relatively unaffected (RTT 2011). Additionally, over the course of the year, the effects of climate on retail sales often cancel out as planned consumer spending is usually only shifted by a couple of days (RTT 2011).

The Retail Think Tank argues that retailers that are flexible, plan well, and anticipate and manage risk, will cope better with weather variations (RTT 2011). However, the majority of firms don't have these risk management systems and flexible processes. An increase in non-weather related volatility has not led to this majority of retail operators to invest in risk management systems. If firms have not adopted sophisticated risk management systems they are unlikely to have the expertise to make use of probabilistic, seasonal climate forecasts. The sector is dispersed and diverse with little coordination and therefore no obvious body that could take responsibility for interpreting and disseminating the forecast information.

Furthermore, given some degree of climate variability is always present, management systems should be responsive to changes in climate and very few weather events would have an unexpected impact on demand or costs (RTT 2011).

For these reasons, along with a lack of data on the costs of climate to the retail sector, the value of improved seasonal forecasting for the retail sector has not been estimated.

10 Coal mining

Background

The coal mining industry provides an excellent example of the complexities of using seasonal climate forecasts in a strongly climate affected industry outside of the agricultural sector.

Coal mining (and the mining sector in general) has a complex relationship with water — both ground and surface water. The mining sector is a large water user, although this use is quite different to other sectors. Mining is a large in stream user of water (rather than a net consumer). For some operations the mining sector is a producer of water either through dewatering of underground activities or through stream diversion of surface activities.

Managing mine flooding is currently (and has always been) a major risk management activity within the industry. The focus of the discussion below will be on how seasonal forecasts may help the industry deal with unwanted (and unexpected) water flows.

Features of the sector

A number of economic features of coal mining are relevant to the question of value of seasonal forecasts.

- While simple in principle, mining operations are economically and technically complex. The mining sector has one of the highest R&D expenditures in the economy and has training expenditure (as a share of its wage bill) around 2 times higher than the national average.
- Mining is a capital and logistical intensive activity with long lead times before formal production (for new mines) and with a more or less predictable mine life (which could be 20 to 60 years).
- Risk management is a central feature of mining operations. On the one hand, safety is a major concern for any mining operation. At the same time, operations manage many other sorts of economic risks including the high variability of commodity prices, the complexity of contract negotiations and sometime unpredictable government regulations.
- These points combined suggest that the use of highly technical information (including probabilistic forecasts) is already a feature of mining operations. Given its risk management characteristics the sector has the capacity to engage in the kind of background development that may be required to use new seasonal forecasts.

Climate impacts on coal mining activities

Managers of mining sites need to consider weather conditions for managing day-to-day activities such as dust and noise control, timing of blasts, refinery operations, transport planning and other site operations. Prevailing wind, temperature and rainfall conditions may affect these activities.

Too much water

Extreme weather events, such as cyclones, heavy rainfall and floods have significant and disruptive impacts on mine activities. These impacts were very clear during the high rainfall events and associated flooding in Queensland in 2008 and 2010-11.

- Flooding limits revenue generation because flooded pits can't be mined and road and rail damage limits the supply of products to ports.
- Additional costs are also incurred to hire pumping equipment and labour for the dewatering of pits, for equipment repairs, and to ensure the safety of the workforce.

It is important to note in this context that 'weather events' that create a risk for a mine may be unique to the specific geography and geomorphology — especially the surrounding landforms and their influence on rainfall and hydrology — associated with the mine.

Too little water

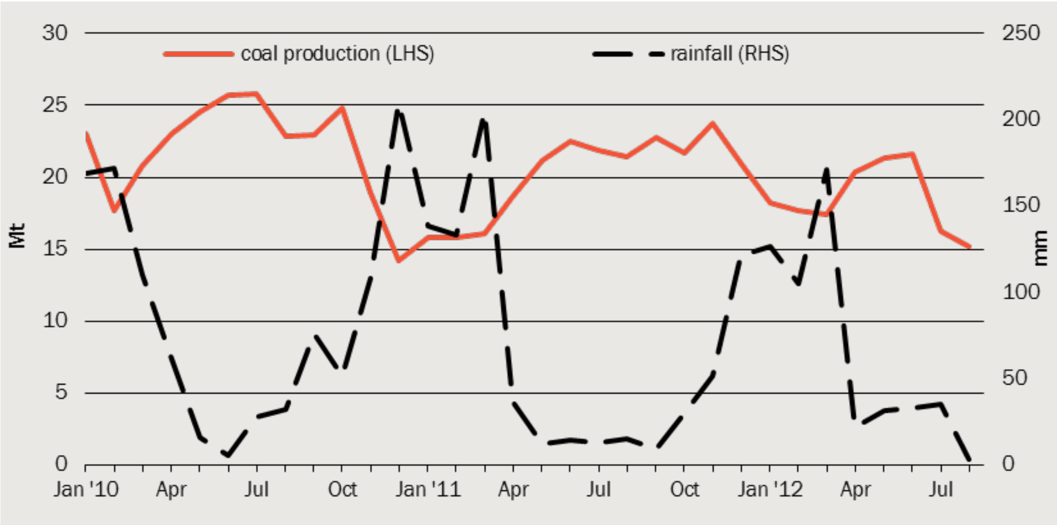
Water scarcity can also reduce production volumes, inhibit mine rehabilitation efforts and competition for water may have negative impacts on the industry's relationships with other sectors of the community. Drought may also lead to increased uncertainty around the supply of water and increased costs associated with securing water supplies. Dry and dusty conditions may damage infrastructure. Indirectly, drought can lead to increased electricity costs for the industry.

Historical relationships

Figure 10.1 plots coal production in Queensland from January 2010 to August 2012 alongside state-wide average rainfall. There is a clear correlation between high rainfall (observed in the summer months) and lower coal production. The Queensland floods of 2010-11 resulted in $5b loss to Queensland GSP from reduced revenues and royalties. Export earnings were reduced by $2b (Sharma et al. 2013).

During the 2008 Queensland floods one example mine incurred costs of $270-300 million due to lost time in production (but not including the lost revenue), clean-up costs and loss of infrastructure and equipment (Sharma et al. 2013). This mine was not able to move a dragline to safety before it was inundated which resulted in repairs to the value of $100m. Production at this mine was affected for some time with operations returning to 50 per cent capacity 6 months after the flood and full capacity after a year.

10.1 Queensland coal production and state-wide average rainfall



Data source: BOM, 2012; Queensland Government Department of Natural Resources and Mines, 2012

Current climate management methods

The sector has initiated some long-term responses to drought and flood conditions such as introducing water efficiency measures, and making greater investments in gaining access to water. Reassessment is also underway for measures to manage excess water, the structural design parameters for water storage dams, maintaining supply of dewatering equipment, and strengthening internal management and preparedness. In response to recently flooding in Queensland, some mines have built (or increased the height of) levee banks on rivers.

Examples of immediate responses to floods that may be taken in response to seasonal climate forecasts include moving of equipment to safety, movement of staff via helicopters, and securing dewatering equipment.

Operators in the mining industry have indicated that reliable, localised climate information with longer lead times than currently available would enable the mines to focus planning and manage climate related risks more effectively.

Following the 2008 floods, mines invested in projection devices (mostly levies) to withstand 1 in 1000 year events (previously the standard was 1 in 100 year events).

Likely interactions with seasonal forecasts

As noted above, the sector has the technical capacity to make use of probabilistic seasonal forecasts. There remain, however, a number of challenges in using these forecasts.

Watershed effects

Floods for many mines are created not just by rainfall and conditions at the mine site but through stream and related flooding that may be the consequence of distant rainfall events.

There is no single linear relationship between rainfall and flooding as this depends on a range of hydrological conditions including factors such a soil moisture and other stream flow effects.

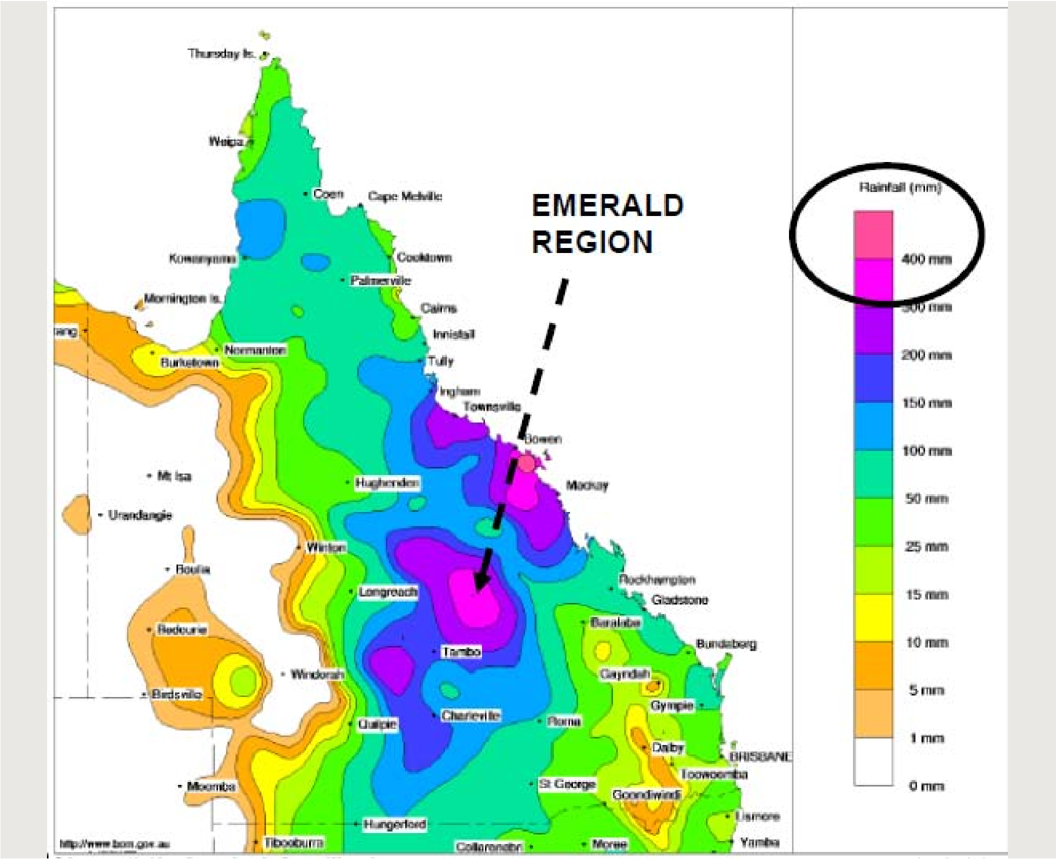
For seasonal climate forecasts to be useful, they must be combined with considerable hydrological information. One of the major issues in the recent Queensland floods was not just related to climate forecasts, but to general uncertainty around these hydrological issues.

The 2008 flooding of the Ensham mine in Queensland provides an interesting example of this.

- For this mine, it was not the localised rainfall which was of concern but the huge water volumes which were generated by a multiple storm cells (ie not singular cells albeit they were part of a large system) in the catchments 100 kilometres away.
- The issue here was not so much forecasts, but lack of adequate real-time information and inadequate hardware for real-time monitoring by radar and stream gauges of discrete separate storm cells. During this event, the cells moved all over the 20,000 square kilometres of catchment with one confluence – the Nogoa River near Emerald (which flows eventually through the Ensham mine and into the Mackenzie River and then Fitzroy River and on to Rockhampton).

Chart 10.2 presents an extract from a flood forum presentation which illustrates the incredibly wide spread of these events.

10.2 Widespread intense rainfall events before flooding of the Ensham mine



Source: Ensham Resources, 2008.

Timeframes

Seasonal climate forecasts are too short a timeframe to allow for major capital works in response to expected floods. Essentially, the protective structure of the mine needs to be established at mine development or at major intervals in the mine life.

This limits the extent to which costs of unexpected events, or events outside the risk envelope of the mine, can be limited through the use of seasonal forecasts.

Estimating the value of seasonal forecasts

A major weather event that impacts on the coal mining sector is heavy rainfall and associated flooding, and it is this weather event that has been chosen to as the basis estimate the potential value of improved seasonal forecasts.

Inputs

The focus of this exercise is on flooding of coal mines, mostly located around the Bowen Basin in Queensland. The probability that a mine would experience a flood was assumed to be 2.5 per cent, which is the observed frequency of monthly rainfall greater than

200mm at one site (Comet) in Queensland. The accuracy of the improved seasonal forecast was assumed to be 70 per cent (and therefore probability that a flood event is correctly forecast was assumed to be 1.7 per cent, the probability that the event is forecast but does not eventuate 30 per cent, probability of a flood occurring but not being forecast 0.7 per cent).

The cost-loss ratio (the ratio of the cost of mitigation action to the losses that could be avoided by that action) was assumed to be 0.001. This is broadly based on estimated costs of moving equipment and obtaining additional pumping equipment for dewatering and the costs observed in the example mine described above associated with a damaged drag line and lost production time.

Finally, the expected annual damage associated with floods under the current forecasts and perfect forecasts was required. Due to the high degree of uncertainty associated with these inputs, and the significant impact these inputs can have on the final result, three different assumptions were tested. The magnitude of the chosen figures are broadly based on the observed damage from the recent Queensland floods, assuming this extent of damage is observed once in a decade. They also incorporate the idea that a significant proportion of the damage, or losses, cannot be avoided with perfect forecasts. The assumptions are summarised in table 10.3 below.

10.3 Expected annual damage assumptions

Scenario	1 (based on observed costs of floods)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Current forecasts	200	100	50
Perfect forecasts	100	75	45

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

Results

Table 10.4 shows the value of improved seasonal forecasts (compared to the currently available forecasts) for the three different input assumptions that were outlined in table 10.3 and assuming a forecast accuracy of 70 per cent. For the assumed values of r and p, a forecast with any level of accuracy greater than the currently available forecasts would result in a positive value for the improved seasonal forecast.

10.4 Annual value of improved seasonal forecasts to the coal mining industry, assuming forecast accuracy of 70%

Scenario	1 (based on observed costs of floods)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Value of improved forecasts	68	17	3

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

11 Construction

Nature of the sector

Basic structure

The construction industry is comprised of a number of different activities including:

- residential building construction
- non-residential building construction
- heavy and civil engineering construction and
- construction services

Activity is evenly distributed between the first three of these, with construction services being considerably larger. It represents the wide range of activities that sell products (including contracting) to other construction activities. Construction services are around a fifth of the costs of the other construction sectors.

For the construction sector as a whole, labour costs are just under 20 per cent of total industry costs.

The sector is divided into small, medium and large firms. Small firms are responsible for 60 per cent of total employment but only 35 per cent of the total wage bill. Small firms are responsible for just under 50 per cent of total industry value added.

In contrast, large firms are responsible for 15 per cent of employment, 35 per cent of wage costs and around a quarter of total industry value added.

Core activities

Construction, especially at the larger scale, is a logistic and planning intensive activity. Long term and large construction activities involve considerable use of program management software, some of which is already integrated with climate forecasting software. Within the sector, considerable effort goes into minimising costs through careful logistics, with varying degrees of success.

Intersection with climate

Activities in the construction sector can be affected by climate at two broad scales: long term climate and short term weather. Long term climatic conditions can affect the appropriate choice of building materials, construction methods and building design. These choices are driven by historical climatic observations. Climate change may lead to changes in the optimal choices over time. However, these changes are likely to occur in a timeframe longer than the seasonal scale being considered here.

Construction activities are also affected by immediate weather conditions. Hot, cold, wet and windy conditions can affect the ability to undertake certain tasks. For example, Crissinger (2005) notes that:

- hot and dry conditions can create dust that needs to be controlled or can damage equipment, concrete, mortar or paint can dry too fast
- large temperature variations can cause materials to expand and move; heat can be uncomfortable for workers (or may require cessation of work)
- similarly, cold conditions can affect mortars, paint, equipment, and workers
- wet weather can cause delays and increased costs by creating muddy conditions, affecting equipment, and inhibiting paving and laying of foundations
- high water tables can require dewatering
- thunderstorms can threaten worker safety; and wind and hail can damage materials and structures.

A number of construction activities require careful planning, and climate outcomes may have an impact on these including:

- general project planning and scheduling
- timing of critical activities such as concrete pouring
- planning of crane use (on large construction sites where cranes can be influenced by high winds)
- preparation before storms and extreme events (including lightning)

11.1 Construction and weather

Weather event	Impacts
Rainfall and flooding	Delaying construction - Contraction in the construction sector due to high rainfall associated with La Nina was observed in 2010 to 2012, and also brought higher construction costs
Cyclones	Delays to construction and risks to meeting completion targets Damage to cranes, or cost of taking cranes down, or more secure grounding Costs associated with flood mitigation measures and pumping equipment Increased insurance costs
High temperatures	Productivity loss from heat related fatigue and higher risk of accidents
Low water availability	Inadequate water to service developments Increased water prices Water restrictions impact on landscaping Higher electricity costs

Source: Smith 2013

These weather conditions can result in additional costs and time delays in completing construction projects. Advance information about the likelihood of experiencing these conditions can help in the scheduling and pricing of a project before it commences.

Delays to the delivery due to weather conditions are usually not penalised because they are beyond the control of the construction company. However, when conditions are not suitable to continue work, staff are still required to be paid thus increasing the cost of construction. Planning at the commencement of a project can incorporate allowances for inclement weather, with the availability of seasonal forecasts these allowances can be more accurate thus reducing the risk of under estimating cost and time allowances.

Climate and planning activities

A number of points are relevant to the use of improved seasonal climate forecasts.

- Scheduling is a major concern of large construction activities. Forecasts need to interface with existing scheduling systems.
- Constructing activities often use historical climate data to plan a calendar of activities. This may include simulation techniques to understand risks to activities at particular times.
- Internationally, there are a large number of commercial service providers who sell customised products that work with specific sites and specific projects.
- Software is available to incorporate real time weather information into project management schedules.

Estimating the value of forecasts

The weather event that causes the greatest delays for construction is rain. This weather event that has been chosen to as the basis estimate the potential value of improved seasonal forecasts.

Inputs

The focus of this exercise was on rainfall in the major cities of Australia. The probability of rainfall (greater than 10 mm) was assumed to be 7 per cent, which is the weighted average number of rain days annually in the five major capital cities (weighted by the value of construction activity in past five years). The accuracy of the improved seasonal forecast was assumed to be 70 per cent (and therefore probability that a rain day is correctly forecast was assumed to be 4.8 per cent, the probability that the event is forecast but does not eventuate 28 per cent, probability of the event occurring but not being forecast 2.1 per cent).

The cost-loss ratio (the ratio of the cost of mitigation action to the losses that could be avoided by that action) was assumed to be 0.04 (that is, for mitigation expenditure of $1 million, avoided costs of $22 million could be realised).

Finally, the expected annual damage or loss associated with rain days under current forecasts and perfect forecasts was required. An initial estimate of current losses due to weather was based on an estimate of 5 per cent of labour costs and 1 per cent of materials costs for the large construction firms only. Due to the high degree of uncertainty associated with these inputs, and the significant impact these inputs can have on the final result, three different assumptions were tested. They incorporate the idea that a significant proportion of the damage, or losses, cannot be avoided with perfect forecasts. The assumptions are summarised in table 11.2 below.

11.2 Expected annual damage assumptions

Scenario	1 (based on estimated cost of delays)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Current forecasts	1,500	3,150	790
Perfect forecasts	1,125	2,362	593

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

Results

Table 11.3 shows the value of improved seasonal forecasts (compared to the currently available forecasts) for the three different input assumptions that were outlined in table 11.2 and assuming a forecast accuracy of 70 per cent. For the assumed values of r and p, a forecast with any level of accuracy greater than the currently available forecasts would result in a positive value for the improved seasonal forecast.

11.3 Annual value of improved seasonal forecasts to the construction industry, assuming forecast accuracy of 70%

Scenario	1 (based on estimated cost of delays)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Value of improved forecasts	192	403	101

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

12 Offshore oil and gas

Nature of the industry

Australia's petroleum and gas sector accounts for about 1.8 per cent of GDP (ABS 2012a), and around 90 per cent of production is in the offshore sector (Department of Resources, Energy and Tourism 2011). During 2009, Australia produced 559,000 barrels per day of crude oil representing 0.6 per cent of the world's crude oil production (Department of Resources, Energy and Tourism 2011). There are two main areas of offshore petroleum extraction:

- the Carnarvon Basin in the northwest coastal areas of Australia accounts for most of Australia's offshore petroleum production; and
- the Gippsland Basin of the Victorian coast contributes a smaller yet still significant amount of petroleum production.

Other areas include the Otway and Bonaparte Basins but their contribution to national petroleum production is relatively minor.

The gas produced is piped to the mainland, however, the production of a floating LNG processing facility is currently underway for use on the Northwest Shelf.

The companies that are involved in offshore operations in Australia include: BHP Billiton, Woodside, Santos, Origin, ExxonMobil, Chevron, Apache, BP, Shell, ConocoPhillips, BG Group, MIMI, INPEX, ENI, and China National Offshore Oil Corporation (Department of Resources, Energy and Tourism 2011).

Table 12.1 provides information on the daily production volumes of some facilities:

12.1 Average daily production Q2 2012, Woodside petroleum fields

Field	Pipeline gas	LNG	Condensate	Oil	LPG
	Terajoules	tonnes	barrels	barrels	tonnes
Northwest Shelf	517	39401	86469	27759	2008
Pluto		9517	8123		
Laminaria-Corallina				6237	
Mutineer-Exeter				5203	
Enfield				11215	
Stybarrow				13774	
Vincent				36725	

Source: Woodside, 2012

The oil and gas industry is highly capital intensive: indeed according to the ABS input-output tables it is the most capital intensive activity in the Australian economy (with a capital share of 73 per cent compared with the economywide average of 22 per cent.

Climate impacts and cost examples

Epps (1997) provides a summary of some of the impacts climate can have on offshore petroleum production:

- Tropical cyclones are the major threat, causing deferral of production, lost revenue and royalties, cost of transporting crews to safety, damage assessments and facility repairs.
- After a cyclone a fixed facility may be operational in 48-72 hours, a floating facility in up to a week.
- Transport of crews is usually conducted every 14 days and unscheduled evacuations could add up to $10,000 per production facility and $50,000 per rig.
- Fog can prevent the use of helicopters, requiring the use of boats instead.
- Ocean currents exceeding 3 knots in the upper 1000m of water produce unsafe loads on risers during drilling. Over the period 1989-1995 in the Gulf of Mexico there were 126 days of delays due to currents, costing BP over $6.5m.
- Drilling on fixed platforms is unsafe in 3m waves and winds over 25knots. In 1996 one rig had 10 days of delays which cost $300,000.
- Poor weather can also affect and delay construction and installation of facilities.

In 2011, 7 weeks of weather delays to the construction of Woodside's Pluto LNG plant added an extra $955m to construction costs (Offshore 2011). By itself this is around 2 per cent of the whole industry's net capital expenditure in 2010-11.

The annual average damage incurred by hurricanes throughout the US has been estimated at $5.1b (Kaiser and Pulsipher 2004). Reducing the length of coastline under hurricane warnings has been estimated to save on average $640,000 per coastal mile in evacuation cost and preparedness action (Kaiser and Pulsipher 2004).

The costs associated with tropical cyclones for offshore petroleum and gas production range from long term investments, such as well-designed production facilities to withstand the strong forces associated with tropical cyclones, to short term costs such as interruptions to drilling. McBride (2012) investigated the costs associated with tropical cyclones in WA and found:

- total insured losses to WA due to direct damage from tropical cyclones averaged $28 million per year
- exploration drilling disruptions can occur around four times a year, for about four days at a time and can cost around $800,000 per day
- disruptions to fixed platforms (through evacuation of the facility) only occur once every two or three years but delays in production can cost companies in the order of $20-30 million. There are at least four of these platforms in operation
- floating production systems are disrupted by tropical cyclones about twice a year for about five days at a time. There are about seven of these systems operating off the north west coast of WA producing around 25,000bbl[2] each day

- onshore and offshore construction activities delayed at a cost of $1million per day
- other disruptions may include halted ship loading of LNG by an approaching cyclone (which subsequently may require production to stop) and closing of ports (which can cost around $100,000 per day) for 2-3 days

Use of forecasts

Even with improved seasonal climate forecasts many of the cost associated with delayed production and construction will not be able to be avoided. However, forecasts may enable companies to undertake improved planning and reduce the extent of the costs associated with extreme weather, in particular evacuation and downtime costs, without compromising safety. For drilling and development operations, if weather is expected to be a problem, then more reliable but more expensive equipment can be used (Kaiser and Pulsipher 2004).

Currently about 5-7 days of weather related losses each year are incorporated into business plans (Epps 1997). Epps estimates that improved forecasts (of some unknown description) could avoid 3 days of lost production each year. Assuming an after tax margin of $5/barrel, the cost of deferred production in the Gulf of Mexico could be up to $15m per day (Epps 1997).

Kaiser estimates that around 1-3 per cent of drilling costs are associated with waiting for weather and improved weather observation systems could mitigate 1 per cent of the waiting costs. Overall, improving the forecast path of a hurricane in the Gulf of Mexico by 10-20 per cent could result in benefits in the order of $85-126m.

Estimating the value of forecasts

Most of the production of the petroleum and gas sector in Australia is offshore, and a major weather event that impacts on the sector is cyclones and associated winds and high seas. This weather event that has been chosen to as the basis estimate the potential value of improved seasonal forecasts.

Inputs

The focus of this exercise was on cyclones in the northwest coastal areas of Australia where most of Australia’s petroleum and gas production takes place. The probability that a cyclone would occur in this area was assumed to be 21 per cent, which was calculated based on the assumption that cyclones are a week-long event and an average of 5 cyclones occur of the coast of WA per 6 month season. The accuracy of the improved seasonal forecast was assumed to be 70 per cent (and therefore probability that a cyclone event is correctly forecast was assumed to be 15 per cent, the probability that the event is forecast but does not eventuate 24 per cent, probability of an event occurring but not being forecast 6 per cent).

The cost-loss ratio (the ratio of the cost of mitigation action to the losses that could be avoided by that action) was assumed to be 0.004. This is broadly based on the estimated costs of cyclones from McBride (2012) and an assumption that, with improved forecasts and planning, around 10 per cent of the costs could be avoided. With very limited information about examples of mitigation actions it was assumed that increased planning efforts would cost around $100,000.

Finally, the expected annual damage associated with cyclones under the current forecasts and perfect forecasts was required. Due to the high degree of uncertainty associated with these inputs, and the significant impact these inputs can have on the final result, three different assumptions were tested. The magnitude of the chosen figures are broadly based on cost estimates provided by McBride (2012). They also incorporate the idea that a significant proportion of the damage, or losses, cannot be avoided with perfect forecasts. The assumptions are summarised in table 12.2 below.

12.2 Expected annual damage assumptions

Scenario	1 (based on estimated cost of cyclones)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Current forecasts	269	403	134
Perfect forecasts	134	168	101

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

Results

Table 12.3 shows the value of improved seasonal forecasts (compared to the currently available forecasts) for the three different input assumptions that were outlined in table 12.2 and assuming a forecast accuracy of 70 per cent. For the assumed values of r and p, a forecast with any level of accuracy greater than the currently available forecasts would result in a positive value for the improved seasonal forecast.

12.3 Annual value of improved seasonal forecasts to the offshore gas and petroleum industry, assuming forecast accuracy of 70%

Scenario	1 (based on estimated cost of cyclones)	2 (high cost estimate)	3 (low cost estimate)
	$ million	$ million	$ million
Value of improved forecasts	93	163	23

Note: Scenarios 1, 2 and 3 represent middle, high and low estimates of the expected annual damage and are provided due to the uncertainty around the true figure.

13 Insurance

Insurance and climate

The private sector insurance industry generates gross premium revenue of $36.9 billion per annum (2012) in Australia and has assets of $101.7 billion. The general insurance industry on average pays out $87 million in claims to policyholders each working day (Insurance Council of Australia 2013a). The average annual insured losses in Australia due to natural perils have been estimated at $1b (Insurance Australia Group 2013). In 2012 there were 110 direct insurers operating in Australia and 12 reinsurers (Insurance Australia Group 2013).

According to the Insurance Australia Group (2013), managing weather and climate are core business for the insurance industry. The primary impact weather and climate conditions have on the insurance sector is on the demand for insurance pay outs as a result of weather-related damage. Extreme weather events such as cyclones, storms, high winds, hail, floods and bushfires would all impact on the insurance sector. In the case of cyclones, variables such as intensity of the storm, central pressure, eye size, radius of storm force winds and storm surges are of interest for insurance purposes (Insurance Australia Group 2013).

In addition to the cost of pay outs, insurance companies need to consider the impact of weather on:

- the number of claims (and therefore the staffing and other resources needed to process claims);
- pricing decisions in the reinsurance sector; and
- the actions of the insured entities, including public and a range of companies and enterprises.

The key decisions taken by insurers include:

- pricing of premiums;
- extent of reinsurance used;
- management of company operations; and
- investment of the float.

Use of forecasts

Insurance premiums reflect the risks to, and the value of, insured assets. Understanding the extent of risks to certain assets is therefore essential in insurance pricing and in profitable insurance operations.

Typically, insurers use detailed historical data (including historical weather sequences) to make pricing and reinsurance decisions. Accurate and comprehensive data allows insurers to be confident in risks and therefore make appropriate pricing decisions (Insurance Australia Group 2013). Modification of historical data in the light of recent experience is a major adjustment mechanism within the insurance industry. Recent changes in premiums due to flood events is an example of this, but such pricing changes are also seen, for example, in motor vehicle insurance policies where effective pricing following an accident may change substantially.

The general practice of using forecasting information within pricing and other decisions seems to be varied within the insurance industry. For some underwriters, forecasts of various kinds are integrated into decision making, while this is not the case for others.

Potential value of seasonal forecasts

The availability of improved seasonal forecasts has the potential to provide valuable information and to change practices within the insurance industry. Assessing the ultimate impacts of this, however, is difficult as there are a wide variety of factors that will determine industry outcomes. These can be summarised as following.

Timing and writing of contracts.

Seasonal forecasts would only be useful in contract pricing if they are available with enough lead time to be incorporated into pricing decisions.

Insurance contracts are generally written for a year, with starting dates ranging from January to July. Seasonal climate forecasts would need to be available ahead of the contract period with time to allow for preparation. Effectively this means a forecast lead time of 4-12 months for the seasonal forecast to be able to influence contract pricing.

Targeting of forecast

To be valuable, the forecast needs to be accurately targeted at the relevant risk for the insurer. This may involve combining the seasonal forecast with other relevant information systems such as hydrological systems in the case of floods.

Confidence and accuracy

The value of forecasts will depend crucially on their perceived accuracy within the industry. Different perceptions of accuracy may create opportunities for trade within insurance markets.

Reinsurance

A large portion of the insurance industry's gross property claims arising from natural disaster events in 2011 were recovered from global reinsurers. Reinsurers also react to demand and risks in a similar manner to direct insurers. APRA confirms that the increase in claims on reinsurance resulted in a general hardening of global reinsurance premiums when insurers sought to renew their reinsurance arrangements (Insurance Council of Australia 2013a).

Emanuel et al. (2012) found that information generated by seasonal hurricane forecasts could be used to increase the profits of property insurance companies. Insurance companies were assumed to be able to adjust the extent that reinsurance was used based on the number of hurricanes expected in the season. However, the study did not consider the response that may be taken by reinsurers in reaction to changes in demand and information from the forecasts. Nor did the study consider actions of the insured public in response to the hurricane forecasts.

Response of customers

Presumably, seasonal climate information would also be available to customers, potentially at the time of contract negotiation. This could lead to a variety of potential responses. As a minimum, customers would expect some of the advantages of better pricing to be passed on to them, potentially reducing some of the gains to the insurance sector itself.

Insurance versus forecasts?

There is also a complex relationship between the behaviour of those insured and their response to forthcoming risk in the presence of insurance.

Both insurance and forecasts are risk management tools. The availability of insurance may mean that users pay less attention to forecasts. On the other hand, the availability of forecasts may change user behaviour in the presence of insurance.

At one extreme, users may be able to exploit seasonal forecasts within their insurance contract period if these contracts are unable to respond to expected seasonal outcomes.

Pricing transparency

Dramatic changes in premiums due to the use of seasonal forecasts may be resisted by some customers, leading to a need for more transparency in pricing decisions.

Public responses

Forecasts are also likely to be used by the public to respond to climate related risks, and to make decisions about the most appropriate level of insurance cover to purchase. The use of forecasts to prepare for, and minimise the risk of, weather events is likely to be beneficial to insurers as the extent of claims would be reduced.

However, if the public have access to information about the probability of extreme weather events they may increase or decrease insurance cover accordingly. This is likely to lead to increased exposure to insurance companies and difficulties in planning and pricing decisions.

Value captured in other sectors

To an extent, some of the value of seasonal forecasts to the insurance sector may have already been captured in the discussion of other sectors. To the extent that the forecasts reduce risk, some of this value will be captured by the insurance industry, but a great deal of it is likely to be passed on to customers (where insurance markets are competitive).

Overall

The complexities of the relationship between insurance and seasonal forecasts mean it is extremely difficult to place a single value on these forecasts for the insurance industry.

Further, the interactions between insurance and seasonal forecasts as risk management tools means that it is difficult to consider insurance independently of other sectors. In many ways, the value of seasonal forecasts to climate exposed sectors will be, in part, a function of the response of the insurance sector. At the same time, usefulness and value to insurance will depend on the responses of customers.

Seasonal forecasts that are perceived by both sides of the transaction to be accurate have the potential to change the relationship between customers and insurers, as well as to change the nature of competition within the insurance industry.

14 Emergency services

Emergency management is defined in the Productivity Commission's Report on Government Services (Productivity Commission 2013) as the practice of managing the impact from emergency events to individuals, communities and the environment. Natural disaster events such as bushfires, floods, storms, cyclones, storm surges, and tornados and other natural events such as drought, frost, heatwaves and epidemics are all weather driven and make up a significant proportion of emergency management tasks.

Emergency service organisations include fire service organisations, State/Territory emergency service organisations, ambulance service organisations, marine rescue and coast guard organisations, and life saving organisations (Productivity Commission 2013). Excluding life saving and marine services, expenditure on emergency service organisations in 2011-12 ranged from $3008 million in Victoria to $116 million in the Northern Territory (Productivity Commission 2013). Nationally, over 34000 FTE people were employed by emergency service organisations and 240 844 volunteers were registered in 2011-12.

Usefulness of forecasts

The key functions of emergency service organisations are classified by the Productivity Commission (2013) as:

- prevention/mitigation
- preparedness
- response
- recovery (community)
- recovery (emergency service organisations).

Forecasts would be valuable to the prevention/mitigation and preparedness functions. Providing information to agencies and the community to take measures to eliminate or reduce the incidence or severity of emergencies and ensuring communities will reduce the overall demand for emergency services. And, improving the planning by emergency service organisations can help in the delivery of services.

Longer lead times on preparing for emergencies would be of value to ensure communities know how to react to emergencies before imminent emergency warnings are issued.

Preparedness for extreme weather events requires an understanding of the likelihood and consequence of those events, and how they will affect the community, based on robust evidence, data and research (Australasian Fire and Emergency Service Authorities Council 2013). The Australasian Fire and Emergency Service Authorities Council noted that additional efforts in climate prediction would be beneficial. Actions that may be taken to prepare of emergencies include:

- implementing arrangements for sharing resources between emergency service organisations and across state and territory boundaries
- prescribed burning
- floodplain management strategies such as the construction of levees

In its submission to the Senate Standing Committee on Environment and Communications Inquiry into 'Recent trends in and preparedness for extreme weather events', the Australasian Fire and Emergency Service Authorities Council noted that in a well-prepared riverine flood environment, up to 80 per cent of direct flood damage losses can be prevented by timely and accurate warnings. It also noted that the rate of return on expenditure on disaster mitigation has been conservatively estimated at 15 per cent, and in analysis of over 67 projects every dollar invested in flood mitigation saved more than $2.10.

Estimating the value of forecasts

Of the different types of natural disasters in Australia flooding has resulted in the greatest costs in recent years (Insurance Council of Australia 2013b). The most recent, and well documented, examples of extreme flooding occurred in south west Queensland. Therefore, this is the focus of this example for estimating the value of climate forecasts for emergency services.

The focus of this exercise was on flooding in south west Queensland. The probability that a flood would occur in this area was assumed to be 2.5 per cent, which is the observed frequency of monthly rainfall greater than 200mm at one site (Comet) in Queensland. The accuracy of the improved seasonal forecast was assumed to be 70 per cent (and therefore probability of a flood event is correctly forecast was assumed to be 1.7 per cent, the probability that the event is forecast but does not eventuate 30 per cent, probability of a flood occurring but not being forecast 0.7 per cent).

For an event that has a probability of occurring of 2.5 per cent, the cost loss ratio would need to be between 0.0015 and 0.07 in order for the seasonal forecast with accuracy of 70 per cent to be of value. For a cost loss ratio greater than 0.07 the forecast is not valuable. This is because the costs that would be incurred by taking mitigation action for the false alarms would outweigh the benefits that would be realised for an accurate forecast.

The cost loss ratios provided (indirectly) in the literature summarised above are in the range of 0.5 to 0.8. Therefore, according to the analysis framework adopted here, seasonal forecasts with an accuracy of 70 per cent are not likely to be of value to the emergency services in responding to flooding events.

15 Water services sector

The sector

The water services sector comprises both water supply as well as sewerage and waste collection. Overall, the sector is capital intensive with high fixed costs. Operations are largely based around lumpy investments — dams and other large pieces of infrastructure. Energy is a significant component of operational costs of the sector (for pumping) as are construction services (for maintenance and so on).

Traditionally, the water supply component of the sector relies on climate dependent sources of water — around 80 per cent of water supply is from surface water, with groundwater around 10 per cent, desalination around 3 per cent and recycled water around 4 per cent (Productivity Commission 2011b).

Recent years have seen major challenges to inflows, with lower rainfall and falling storage levels leading to quantitative restrictions on consumption in recent years. Indeed, a number of jurisdictions faced perilously low storage levels.

These recent challenges have led to large investments in new supply augmentation. This includes increased storages — new dams or new pipelines allowing the connection of disparate catchments — as well as investments in climate independent supply sources including desalination plants and major water recycling schemes.

Water services sector and climate

Rainfall largely determines supply

In this sector, the various service providers are responsible for constructing the infrastructure necessary to capture, store and deliver water to users. They also manage water storages and alternative sources of water.

The ability of a water service provider to serve their customers clearly depends on the available water supply and the level of demand for water, both of which are determined, in part, by the climate. The service provider may control, to some extent, the volume of water available by moving water between storages, controlling the volume of water released from dams, or investing in water recycling or desalination facilities.

Rainfall in water storage catchment areas, however, is the primary determinant of the volume of water available.

Demand for water is also affected by the weather, with hot and dry weather generally increasing demand for water. Water service providers may introduce water restriction programs in urban areas with the aim of curbing demand and saving water in times of drought and generally low water availability.

Optimising operations

Most utilities in Australia have sophisticated, stochastic, hydrological models which they use to manage their operations. Typically, these models incorporate historical inflow data (which consists of both rainfall and catchment characteristics) which are used to simulated a variety of potential outcomes. In some cases, long term climate change in explicitly incorporated into these models.

In general, the utility models are used to optimise the basic operational rules for the relevant supply jurisdiction. This includes rules about when to pump water between storages and so on. These rules are optimised over the full stochastic range of inflow outcomes. Day to day management refers to these rules in making average decisions.

This same basic approach is also used to derive operating rules for climate independent sources such as desalination plants. Given that these are costly to operate, in times of high inflows, desalination plants are 'switched off' to make use of lower marginal cost inflows into catchments. The operating rules for the desalination plants (derived from stochastic simulations) dictate, for example, the dam levels at which the plant should be switched on or off.

The Australian situation is similar elsewhere in the world. A study conducted by Case et al. (2012) found that in the US, over 60 per cent of water managers used some form of weather or climate forecasts and 37 per cent used seasonal forecasts. Those using forecasts are more likely to have recently experienced extreme events. Seasonal climate forecasts were found to have been used mostly to manage demand through demand side management policies. Other studies found that water managers rely on experience and past weather observations to manage systems. Water systems are generally constructed to handle extreme occurrences (droughts and floods) and therefore new information is not in demand (Case et al. 2012).

Use of seasonal forecasts

Water utilities are, not surprisingly, intensive users of a range of weather and climate information. Given that many operations are optimised using long periods of data, seasonal forecasts — particularly the very short term ones — are likely to have limited impacts in utility operations. The capital intensity and lumpy nature of investments means that short term forecasts are unlikely to have any impact on major augmentation investments or other long term responses.

There may, however, be some limited implications for the operational aspects of utility operations. In particular, seasonal forecasts may assist with:

- planning the implementation of quantitative water restrictions; and
- balancing demand and supply in the short term, leading to lower pumping costs.

Potential value of seasonal forecasts

Water restrictions

As noted, quantitative water restrictions have been a common feature of operations in most jurisdictions recently. Water restrictions are costly (to households and to the community in various ways), so any measures which can avoid or delay restrictions have the potential to be valuable.

Seasonal forecasts, while unable to affect the ultimate requirement for restrictions — which is determined by actual inflows — may allow utilities to modify the timing of restrictions, by delaying their implementation, for example.

The benefits of this, however, are likely to be quite small.

- The Productivity Commission estimates that the 10 year cost of water restrictions in Melbourne and Perth is $765 million and $39 million, respectively.
- Converting this to an annual cost, and scaling this up (according to water use) across all of Australia implies and annual expected cost of restrictions of $286 million.
- Assuming this accrues over the 4 hottest months of the year implies a monthly cost of $72 million.
- If the use of seasonal forecasts is able to delay the introduction of restrictions by one month (but not avoid them altogether), the value of this saving is around $0.3 million.

Improved operational efficiencies

Improved seasonal forecasts may allow better demand management and balancing of supply, effectively leading to lower operational costs.

To estimate the magnitude of this, using the cost loss framework, we assume that the improved seasonal forecasts lead to a one month saving in pumping and related costs. Australia-wide, this is a saving of around $40 million per year.

Assuming a 70 per cent forecast accuracy, and a 6.5 per cent underlying probability of weather (rainfall)[3] that allows the cost saving implies and expected benefit of $28 million per year.

3 Derived by weighting capital city rainfall by water usage.

16 Transport

The sector

The transport sector operates to transport freight or passengers (either public or private) and is broadly composed of activities across four modes of transport:

- Road
- Rail
- Air
- Sea

In 2011-12 road transport accounted for 57 per cent of the total GVA of the transport sector. Air transport accounted for 17 per cent, rail 17 per cent and water transport 3.4 per cent. The majority of businesses in the sector are small and medium enterprises. The activities of the transport sector are closely linked to the activities of other sectors of the economy. Road transport in Australia is used by the wholesale and retail trade, manufacturing and construction sectors, as well as public and private passenger transport. Rail is closely linked with the mining sector, sea freight is used for the transport of agricultural and resource commodities. Most air transport in Australia is passenger transport.

Impact of climate

Various climatic conditions affect the different modes of transport in different ways. The impacts of weather events can be categorised as:

- Infrastructure costs – infrastructure damage, impacts on the maintenance of infrastructure, cleaning and clearing
- Operational costs – vehicle fleet damage, impact on the costs of service provision
- Costs of delays to passenger and freight transport and safety aspects.

Table 16.1 provides a matrix outlining the main types of impact climate has on the different modes of transport under these categories.

16.1 Types of climate impacts on transport activities

Mode	Infrastructure damage	Operational costs	Time delays and safety
Road	▪ damage to roads from heavy rainfall, storms, flooding and landslides ▪ softening and cracking of pavements in heat ▪ removal of debris after floods and storms	▪ hail storm damage to vehicles ▪ increase in accidents in rain conditions ▪ increased fuel costs with stop-go traffic and road closures/detours ▪ heat can lead to vehicles overheating and tire deterioration	▪ road congestion causes delays in wet weather and strong winds ▪ increased travel time associated with road closures and detours
Rail	▪ high temperatures lead to buckling of tracks ▪ costs associated with track maintenance after storms and floods	▪ cost of freight detours and replacement bus services for passenger transport when tracks are closed ▪ lost revenue from cancelled services	▪ rail delays due to track maintenance and infrastructure closure
Air		▪ reduced airport capacity for acceptances and departures in thunderstorms ▪ heavy weather and lightning can hinder ground operations ▪ rerouting and diversions of flights in storms and wind ▪ lightning and hail damage to aircraft	▪ poor visibility and strong winds at destination airports cause delays ▪ any delays flow through the network affecting other flights and airports
Sea	▪ strong storms can cause damage to port infrastructure	▪ storms, heavy rains, high winds may damage ships ▪ delay port loading/unloading activities in storms and high winds ▪ rescues of vessels/people in trouble in storms and high winds ▪ loss of revenue when not operating ▪ rerouting of vessels to avoid storms and high winds	▪ delays to freight delivery ▪ cancelled or delayed passenger ships due to extreme weather either on route or at port

Source: based on Enei et al. 2011

Much of the literature on the impacts of weather on the transport sector focuses on Europe and North America where there are significant costs associated with the cold winters experienced in these areas with winter snow storms and extreme cold temperatures affecting transport infrastructure, operational costs and causing delays. Australia does not experience this cold weather and therefore the sensitivity of the Australian transport sector would be expected to be much lower than the American or European sectors.

Responses to climate impacts

There are limited options available to mitigate the weather impacts on the transport sector through the use of seasonal climate forecasts. Infrastructure is constructed to be able to withstand general weather conditions. Extreme events such as floods can inundate roads and rails but there is little response that can be taken to mitigate this. Long term development of construction methods endeavour to improve the construction of roads, rail and ports to be more resistant to the damage caused by weather, but this is a long term activity that cannot be undertaken in response to seasonal climate forecasts.

Many of the operational and time delay costs associated with weather events are due to the inability to operate in certain conditions, often associated with damage to infrastructure or safety concerns. Climate forecasts may be of use in avoiding damage to vehicles associated with hail storms – although a very short term forecast (rather than a seasonal forecast) is likely to be sufficient to achieve this.

The greatest use of seasonal forecasts may be in scheduling and routing of shipping and airline services.

Airlines

Bad weather reduces airport capacity leading to airlines cancelling or delaying some flights. Airlines have to reschedule crew and aircrafts and re-accommodate passengers and passengers are usually not satisfied. Weather is just one element that can affect airline scheduling. Other factors include passenger demand, available gate space, air traffic control conditions and equipment failures. Weather conditions, however, have been found to be the most significant factors that influence the arrival delay due to the destination airport[4] (Bai 2006). Many airlines employ computer software to develop schedules considering a range of complicated restrictions. This software is used to continually update the scheduling requirements as new information about weather or unexpected delays arise.

Airlines use short term weather forecasts and observations to help determine routes and altitudes for flights, primarily to allow flights to avoid thunderstorms. Flight schedules are already developed to take into account the weather patterns that have been observed historically, and incorporate some leeway to account for unexpected delays. Changes to the established schedules require accurate (in both time and location) information about expected conditions.

The lead time required to redirect flights and passengers varies with the departure and destination and with the length of the flight. As an example, a change to a Chicago–Tokyo flight due to upper wind forecasts that indicate the aircraft must have additional fuel could require the number of passengers to be reduced. To cater for these passengers on another flight to the same destination, they have to be re-routed to a different departure airport. The passengers therefore need to be notified in time to get them from their initial location to the new departure point. In order for such a scenario to be

4 This study was conducted in the United States where significant delays are experience associated with winter conditions not experienced in Australia.

successful, planning must begin at least eighteen hours prior to the start of the Chicago–Tokyo flight (Qualley 1997).

Cost of airline delays

Ball et al. (2010) estimated the cost to airlines of all flight delays to be around $6700 per delayed flight. Applying the same figure to the number of delayed flights in Australia gives a total cost of delayed flights to airlines of around $747 million annually. These costs include fuel, labour, and materials that are increased with flight delays. The extent that these costs could be reduced through the use of seasonal forecasts is expected to be very limited:

- Many of the delays would not be due to weather conditions
- Of the delays caused by weather, scheduling using improved seasonal forecasts is likely to have only a marginal benefit.

Using the value of forecasts methodology, the benefit that could be realised from the use of improved forecasts is estimated to be in the order of $5 million. This assumes that 10 per cent of the flight delays were caused by weather and costs could be reduced by 1 per cent through the uptake of improved seasonal forecasts to enhance flight scheduling.

17 Conclusions and recommendations

Summary assessment

The discussion and estimates presented in this report indicate that there is considerable potential for improved seasonal forecasts to generate value in a variety of sectors. Table 17.1 summarises the potential annual benefits for the sectors where quantification was possible.

17.1 Summary of quantified values for improved seasonal forecasting

Sector	Annual value of improved seasonal forecasts	Annual value as a share of industry value added
	$ million	%
Construction	192	0.20
Offshore oil and gas	93	0.46
Coal mining	68	0.33
Water	28	0.27
Transport	5	0.02
Electricity	2	0.01
Total	**388**	
Potential present value over 20 years	*1 000*	

[a] Assumes benefits gradually emerge to the maximum value over 20 years for electricity, coal mining and transport and over 30 years for construction, offshore oil and gas and water. Emergence of benefits follows an S-curve with half the maximum at the 10 or 15 year period. Present value calculations assume a real discount rate of 5 per cent.

Source: CIE estimates

A number of points need to be made about these estimates. First, they should be interpreted as indicative rather than precise projections or forecasts. Of interest is the broad order of magnitude, and in particular the value of estimates as a proportion of total industry value added — this is less than 0.5 per cent and in some cases less than 005 per cent.

Second, these values are not an automatic or inevitable consequence of improved forecasts and will not necessarily immediately emerge from the development of improved seasonal forecasting products. In particular, it is important to recognise that:

- the needs of different sectors vary considerably and are often quite different to those for agriculture
- in most cases, value from improved seasonal forecasts requires not just the forecasts themselves, but a range of complementary technologies and in some cases institutional developments

It follows from this that further developments will require some priority focus between potential using sectors.

Priorities for sector focus

While table 17.1 indicates a broad ranking of sectors in terms of the estimated value of benefits (using the methodology outlined in this report) there are some other important factors — much harder to quantify — that also need to be considered.

In particular, the suitability of improved seasonal forecasts for a particular sector depends on:

- the availability of short term adjustment options that would enable the sector to avoid the impacts that weather events have on the sector
- the ability of agents in the sector to interpret probabilistic forecasts and to optimise activities in response to improved forecasts
- the cost effectiveness of the available short term responses to the information contained in seasonal forecasts.

Table 17.2 provides a broad scoring for each of these factors in each of the sectors considered in this report. This is a broad qualitative assessment based on the information compiled in the previous chapters. The final column of the table provides an overall qualitative ranking of the various sectors.

Table 17.2 suggests a broad set of priorities for working with particular sectors in developing a case for the use of seasonal forecasting products.

- Coal mining ranks highly because it is part of a sector that is already familiar with risk management technologies. While it does not necessarily have the most cost effective adjustment options available (particularly over a seasonal time frame), the ability to absorb and use probabilistic information is crucial if forecasts are to be of value.
- At the other extreme, sector such as retail trade and tourism, while having some costs effective adjustment options are institutionally not in the same position with regards to effective use of probabilistic forecasts.

Insurance

There are some reasons why the insurance sector should be treated as a special case when considering the value of improved seasonal forecasts.

First, insurance and forecasts represent two different forms of risk management — to some degree, there is scope for substitution between them from a user perspective. At the same time, seasonal forecasts will potential influence the insurance pricing decision (particularly if the forecasts fall within the pricing cycle).

Second, the existence of improved seasonal forecasts may change the nature of the contractual relationships between parties — both with the insurance contracts and with other related arrangements. The existence of a good seasonal forecast may imply something new about due diligence, for example.

17.2 Ranking of the value of improved seasonal forecasts to economic sectors

Sector	Short term adjustment options	Appropriate systems in place to manage probabilistic forecasts	Cost effective responses available	Ranking of likely usefulness of seasonal forecasts
Coal mining	☆☆☆☆	☆☆☆☆☆	☆☆	☆☆☆☆
Electricity	☆☆	☆☆☆☆☆	☆☆☆	☆☆☆
Construction	☆☆	☆☆☆	☆☆☆☆	☆☆☆
Offshore oil and gas (90% of oil and gas extraction)	☆☆	☆☆☆☆	☆☆	☆☆☆
Financial and insurance services	☆☆	☆☆☆☆	☆☆☆	☆☆☆
Transport (road and air)	☆☆	☆☆☆	☆☆☆	☆☆☆
Health care (and social assistance)	☆	☆☆☆	☆	☆☆
Water (water supply and waste services)	☆	☆☆☆☆	☆☆☆	☆☆
Emergency services (public administration and safety)	☆☆☆	☆☆	☆☆	☆☆
Retail trade	☆☆	☆	☆☆☆	☆
Tourism	☆☆	☆	☆	☆

The need for a clear 'product statement'

One interesting qualitative result to emerge from discussion in the course of developing material for this report is a general scepticism about the ability to provide more accurate seasonal climate forecasts. There are probably a number of elements to this view, ranging from a scepticism about forecasts in general to scepticism about the ability to provide forecasts that are specific enough to the circumstances of the sector.

- For example, using forecasts for flood management or catchment management requires targeted information about precisely *where* the rain will fall — small changes in geographic outcomes can have significant impacts for some sectors.

This implies a particular communication issue for the promotion of improved seasonal forecasting. It will be important to set out a clear case for the nature and implementation of improve forecasts as well as the ways in which they could intersect with existing risk management technologies.

Recommendations

Analysis of the potential benefits of improved seasonal forecasting suggests a number of approaches to further developing these forecasts that could be valuable, particularly when dealing with a range of sectors. These are as follows.

- ***Develop a clear product statement*** for how the seasonal forecasts will be improved, the technology underlying them and the ways in which they will intersect with existing risk management tools.
- ***Work with priority sectors*** to develop a number of case studies (possibly based around historical events) that can both demonstrate and research how improved seasonal forecasts will practically work in these sectors. This is likely to generate important information both for agents in the sector as well as for the forecasting research itself.
- ***Engage with the insurance sector*** to improve understanding of seasonal forecasting in the context of a range of implications for risk management. As a sector with major investment in risk quantification and the contractual sharing of risk, it is likely to provide valuable insights for the forecasting research.
- ***Develop awareness of the 'human' side of improved seasonal forecasts***: particularly the ways in which they will affect attitudes to risk and attitudes to production and insurance contracts. The cases studies noted above will be a major contribution to this.

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