THE UNIVERSITY OF ADELAIDE
AUSTRALIA

SUB CRUCE LUMEN

The Environment Institute
University of Adelaide

Strengthening Basin Communities Program
Planning Component Consultancy SBC033A.1/2

Adaptation and emerging opportunities for the SA Murray-Darling region

MILESTONE 2 REPORT

28 August 2011

CONTENTS

Cite this report as:

Kellett, B., Summers, D., Barnett, K., Siebentritt, M., Meyer, W., Spoehr, J. (2010). Adaptation and emerging opportunities for the SA Murray-Darling region. Milestone 2 Report. A report prepared by SARDI Climate applications for the Environment Institute, The University of Adelaide, as part of the Strengthening Basin Communities Program Planning Component Consultancy SBC033A.1/2.

EXECUTIVE SUMMARY

The South Australian Murray-Darling Basin is one of the state's most productive regional areas, sustaining major irrigation and dryland farming areas as well as industries like tourism and manufacturing. However, recent years have seen some of the lowest water availability on record for businesses and communities reliant on the Murray. This has combined with low rainfall years in surrounding dryland farming areas and caused major impacts on the wellbeing of people living in the region and impacts on the environment and economy.

These conditions may be a pre-cursor of what is to come. Climate change forecasts suggest that the region will trend toward hotter and drier conditions on average over the next 20-60 years and inflows to the state from the River Murray will be reduced. Recognition of the impact of low rainfall and hotter temperatures over the past decade on the SA MDB means that the time is right to consider how to adapt to the forecast impacts of climate change.

This consideration should not be delayed by the assumption that climate change is declining as drought pressure eases such as in the coming season. It will be important therefore to develop user friendly information that differentiates between climate change scenarios and short term drought.

Eleven Councils within the SA Murray-Darling Basin Natural Resources Management Region established two consortia and attracted Federal funding through the Strengthening Basin Communities (SBC) Program – Planning Component to deliver a series of plans to assess the impact anticipated climate change will have on communities, their local water dependant industries, urban water resources management, development plan policy and other strategic planning documents for local government. These plans will identify opportunities to adapt to the anticipated climate, and in particular, living with less water. The "Impact Assessment, Adaptation and Emerging Opportunities" Project is the overarching parent project for both consortia.

The Environment Institute at the University of Adelaide and its team was appointed to undertake the overarching project and has four deliverables:

- Climate change scenarios - Make recommendations on the scenario(s) and associated projected climatic conditions to be applied to the parent and broader projects.

- Climate Change Impact Assessment Report - The report will assess the impact of recently experienced (i.e. the extended drought) and predicted climate conditions on each Council, their communities, community assets and services.

- Adaptation and Emerging Opportunities Plan - Opportunities will be identified for each partner Council and their community to address the predicted impacts of climate change.

- Horticultural/Rural Lands Review – This will identify and describe the horticultural/rural land affected by the current drought that may be affected by forecast climate change impacts and then develop potential model statutory planning policy.

This report is a requirement of Milestone 2 of the parent project and presents the Opportunities Discussion Paper.

The key messages arising from each of the three Milestone 2 reports are as follows:

1. Climate Change Scenarios :
    a. The study region like the rest of Southern Australia is expected to be warmer (high confidence) and drier (lower confidence). By 2030 the region shows a warming of between 0.5 to 1.3 degrees C with the mid range model showing 0.8 degrees. At 2030 the range in warming is due to different models and is not very sensitive to the emission scenarios. By 2070 there is a greater influence of emission scenarios (whether greenhouse gases are greatly increased or stabilised). Under medium emission scenarios the projected warming is 1.8 degrees with a range or 1.3 to 2.8 degrees.
    b. The most likely future is a drier future, but there is considerable uncertainty between models and considerable debate within the scientific community on the appropriate level of confidence to place on projected drying compared to the projected warming.

2. Outcomes of Stakeholder Engagement:
    - There is widespread awareness about the general concept of climate change, which is understood as a phenomenon that will drive warmer temperatures and lower rainfall across the SA MDB.
    - There is recognition that extreme weather events are the most difficult to plan for and therefore provide the most difficult and most costly

management challenges. This will be a key consideration of planning for climate change.

- There is a consistent view that irrigation and dryland farming will be the industries impacted the most by warmer and drier conditions under future climate change. This will have flow on impacts to the community and Councils.
- There is a widespread need for communities and industries to engage in planning and implementing an integrated approach to climate change across the whole region.
- Adaptation can best be achieved by a leadership model with capacity to foster connections between all levels of Government and the ability to evaluate a wide range of existing and alternative industries.
- Leadership elements will include a long term commitment and presence in the region, development of credible information resources and support to enable industries and communities to make decisions with confidence.

3. Opportunities Discussion Paper:
    - There is evidence that adaptation to climate change and seasonal variability is already happening in South Australian Murray-Darling Basin. Selecting new crop varieties and changes to road maintenance are two examples.
    - One avenue for adaptation is to move toward a low carbon economy. There are some drivers to consider with respect to low carbon economies including that carbon pollution is increasingly taxed or traded across the world and that fossil resources for agriculture and energy production, which are primary sources of carbon pollution, are becoming more scarce.
    - In developing strategy and actions for adapting to the effects of climate change, local government can consider vulnerability and risk management frameworks, community perspectives and existing climate change adaptation initiatives including the Local Government Association Mutual Liability Scheme (LGAMLS).

KEY FINDINGS

There is significant evidence that adaptation to climate change is already happening in South Australian Murray-Darling Basin. Selecting new crop varieties and changes to road maintenance are two examples.

Adaptation is a choice and we give four different future scenarios, all of which are plausible. We highlight some costs and benefits of each scenario. Scenarios include aimless wanderer, isolated centre, bigger is better and resilient town and region. Scenarios can aid as a structured basis for discussion and development of a desirable community vision.

One avenue for adaptation is to move toward a low carbon economy. We provide some information on the low carbon economy concept for you to consider if you take this route:

- Carbon pollution is increasingly taxed or traded across the world, including in the European Union and New Zealand.
- Fossil resources for agriculture and energy production, which are primary sources of carbon pollution, are becoming more scarce.
- Peak production of phosphorus is projected for 2040-2050, peak oil for between now and 2015, peak coal for between now and 2048, and peak natural gas for 2030.
- Beyond peak production, competition will drive resource prices higher until alternatives become feasible.
- Some experts argue that not all of the gap created by declining fossil resources can be filled by alternatives.

In developing strategy and actions for adapting to the effects of climate change, local government can consider vulnerability and risk management frameworks, community perspectives and existing climate change adaptation initiatives including the Local Government Association Mutual Liability Scheme (LGAMLS). Further information on each of these elements is presented in the report.

1 CONTEXT FOR THIS REPORT

The *Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region* project is the umbrella project in a suite of 21 projects being undertaking as part of the Strengthening Basin Communities program funded by the Australian Government. The funding was provided to the following eleven councils within the South Australian Murray-Darling Basin Natural Resources Management Region to undertake this work:

- Berri Barmera Council
- Regional Council of Goyder
- District Council of Karoonda East Murray
- District Council of Loxton Waikerie
- Renmark Paringa Council
- Southern Mallee District Council
- Alexandrina Council
- The Coorong District Council
- Mid Murray Council
- District Council of Mount Barker
- Rural City of Murray Bridge

Findings from the project will assist the region to plan for a climate change driven future with less water through addressing risk and implications and identifying options for adaptation (including emerging industries and associated socio demographic patterns).

The key deliverables for the project are:

1) Climate Change Scenarios;
2) Climate Change Impact Assessment Report;
3) Adaptation and Emerging Opportunities Plan; and
4) Horticultural/Rural Lands Review.

This paper addresses one of the three deliverables for the second milestone of the project, which is the development of an Adaptation and Opportunities Discussion Paper, which is a precursor to the final report on the Adaptation and Emerging Opportunities Plan.

2 INTRODUCTION

In the Milestone 1 report we presented data that supports a warmer and dryer climate and rising sea levels in the future. Authoritative climate scenarios and their use for decision-making were emphasised. Impacts were also discussed, ranging from council infrastructure, agricultural production, ecosystem health and economies. A large number of specific measures for councils to adapt to climate change were proposed based on previous studies. This report gives further detail on climate change adaptation and emerging opportunities.

Section 3 deals with adapting to the effects of climate change with an account of a range of climate adaptation initiatives. Results from interviews are given in a section that discusses local governments developing strategy for climate change adaptation. We emphasise selecting adaptation actions through council strategies and planning procedures.

To inspire proactive planning we set out four alternative management scenarios for the future in section 4. These scenarios integrate different adaptation actions and economic principles for local governments to consider when making decisions that will shape the future of their communities.

Section 5 explains adaptation from the perspective of economic performance and structuring economies to suit future circumstances. We present the case for the development of low carbon economies. This move has the potential to bolster business activity and revenue, conserve the health of ecosystems, improve lifestyles, and save money that would otherwise be lost to carbon taxes or increasingly expensive energy derived from fossil fuels. Importantly, a low carbon economy provides the financial capability to allow climate change adaptation.

While reading this report you may wish to consider these questions. Your responses will help to shape the Adaptation and Emerging Opportunities Plan:

- Do you think Council needs a climate change strategy?
- How should your council prioritise climate change adaptation actions?
- How should your council pay for climate change adaptation and mitigation programs?
- Is a climate change and energy strategy a good idea for your area?
- What issues would you have with a carbon tax or a carbon pollution reduction scheme?
- Does the region need to take action in its own right or leave this for State and Federal Governments?

- Does it matter if the types of primary production in the region change and economic output from agriculture reduces?
- Do you think making a transition to a low carbon economy would help your community?

3 ADAPTING TO THE EFFECTS OF CLIMATE CHANGE

3.1 DEVELOPING STRATEGY FOR COUNCILS

A range of impacts on agriculture and rural enterprises, and on local government were identified in the Milestone 1 report, as were a range of adaptation and emerging opportunities. With regard to local government adaptive responses, a number of recent Australian reports and resources (such as the ICLEI toolkit (ICLEI 2008)) were overviewed. The report noted (Section 4.2.8) that a similar adaptation focused report was being prepared by the Local Government Association of South Australia (Local Government Association of South Australia 2010). This section updates the literature review by summarising the findings of that report.

The Local Government Association Mutual Liability Scheme (LGAMLS) **Climate Adaptation Program** (CAP) is the first coordinated assessment of climate change risks affecting a government sector in Australia. It is designed to provide South Australian Councils with *'… a framework to translate climate impacts into identified risks to their business operations, whilst developing realistic adaptation measures over short and long term planning horizons.*' The program also aims to build and maintain the resilience of local communities, and is based on local level assessment which has then been consolidated into an industry wide position. Using climate change variables developed by the Australian Government's *Climate Change in Australia Technical Report 2007* and endorsed by the Bureau of Meteorology and region specific CSIRO scientific data, a number of scenarios have been developed to inform decision making about future risks and potential adaptive responses (CSIRO and BoM 2007). Furthermore, the CAP is designed to integrate adaptation measures into strategic planning and management by using an existing risk management framework based on the *Australian Standard Risk Management* (AS/NZ ISO 31000).

The Interim Report found that this common risk assessment framework could be applied across 29 councils with diverse locations, and that this framework supports the identification of key risks on individual councils as well as a sector wide basis.

Risks were assessed using a four step method involving –

1) Rating the level of impact of a risk event on a community, in a range from Insignificant ⇨Minor ⇨Moderate⇨Major⇨Catastrophic.
2) Exploring the consequences of those impacts on a community's resilience
3) Rating the likelihood of a risk event occurring (in a range from Rare to Almost Certain)
4) Assigning risk management priorities.

The report assessed five climate change variables against their potential impacts, and the assessment of risk was applied to each, with extreme temperature having the highest risk.

Table 1. Level of risk associated with climate change variables

Climate change variable	Level of assessed risk
Extreme temperature	39%
Reduced average rainfall	18%
Extreme bushfire weather	17%
Sea level rise	15%
Extreme rainfall	11%

The following five steps were found to be critical to Councils implementing a '*comprehensive climate-resilient strategy'* at local or state wide level -

- Create an inclusive local community effort.
- Recognise the different roles for each stakeholder, including all tiers of government, community, business and individuals.
- Define current and target priorities for adaptation measures.
- Address existing obstacles to implementing adaptation measures, such as, policy, organisational capabilities and legislative barriers.
- Encourage sufficient funding from State and/or Federal governments.

These are broad interventions, with the Interim Report detail focusing more on assessing and identifying risks than on specific adaptive strategies to those risks, with the exception of the following which are relevant to rurally located Councils.

3.2 LOCAL GOVERNMENT AND COMMUNITY ADAPTATION PERSPECTIVES

Interviews with local government officials and community members identified that they are strongly interested in being better informed about climate change. Interviewees provided some evidence of climate change, which is presented in ***Box 1***. Using energy and water resources efficiently, using appropriate technology and the economic effects of reduced agricultural production were significant concerns. These and other points are summarised below. Interviewees identified potential responses that local government could take and these are listed in Box 2. A more comprehensive list of adaptation options available to local government are given in Table .

1. **Understanding climate change** – at least 50% rely on personal observation for evidence of climate change. This includes local older people with years of experience in observing changing climate patterns as well as Aboriginal elders who bring to bear generations of experience in understanding landscape and climate change. Few scientific organisations are regarded as credible sources of information, but a notable exception is the Bureau of Meteorology (BOM). Different forms of evidence of climate change are given in ***Box 1***.

2. **Enabling informed understanding and decision making** - In order to inform and educate people about climate change, it is essential that they trust and view as credible the sources of information provision. Apart from the BOM, industry peak bodies, different levels of government and the media were identified as credible. There is the likely need to raise the profile of the Intergovernmental Panel on Climate Change (IPCC) so that this it understood more widely and seen as another credible source of information on climate change.

3. **Providing complete information about employment impacts and changes** – Many people have concerns about loss of jobs and industries from reducing agricultural footprint, resulting in loss of local population and reduced economic viability. However, there will be some new jobs emerging including those that involve expertise in managing the impacts of climate change.

Box 1. Evidence of climate change identified by interviewees.

- Higher temperatures
- Lower rainfall
- Most see a combination of natural variation with climate change
  Increased exposure, as seen in bleached bones in burial sites
- Trees and other vegetation dying or suffering heat stress

Box 2. Potential responses of local government to climate change identified by during interviews with the Consultation Reference Group.

- Maintain flexibility in land use planning and legislation to allow adaptive responses (e.g. tree plantings)
- Give effective leadership on adapting to climate change
- Provide accurate and trusted information, including through fact sheets that bring together research & scientific evidence in a user friendly way
- Educate and raise community awareness, such as energy efficient resources and behaviours
- Increase collaboration to increase project efficiency
- Educate and train staff and councillors
- Employ climate change coordinators
- Create more favourable business conditions
- Encourage new industry development (eg lower rates, incentives)
- Coordinate across councils for funding submissions for sustainability initiatives
- Introduce new services relevant to climate change (eg service to growers to mulch prunings)
- Build energy efficient buildings
- Develop water efficient parks

Table 2. Climate change adaptation measures for councils (Adapted from (SMEC 2009)).

ASSETS/SERVICE DELIVERY	POSSIBLE CLIMATE CHANGE IMPACTS	IMPACT AND POSSIBLE ADAPTION ACTIONS
Infrastructure and property services		
Infrastructure and property impacted by changing temperatures, rainfall intensity and greater bushfire risk	• Changes in building heating/cooling costs (can be either negative or positive). • Increased risk of damage from bushfires. • Changes in frequency of wind, rain, hail, flood, storm events and damage, potentially resulting in destruction. • Higher rates of building deterioration and associated maintenance costs.	<u>All climate change impacts:</u> • Showcase best practice in climate sensitive building design in public buildings. <u>Temperature increases:</u> • Design council buildings to allow for ease of future adaptation, e.g. have the ability for significant amounts of shade to be added or removed from a facade. <u>Increased temperatures – increased risk of bushfires:</u> • Risk assessment to ensure new infrastructure is not placed in fire-prone areas. • For those where location is not flexible, investigate standards of construction that reduce their sensitivity to bushfire. <u>Increased temperatures/hot spells – increased demand for comfort cooling in buildings, affecting energy consumption:</u> • Increase use of insulation in new buildings. • Retrofitting existing buildings with addition of insulation materials and effective and efficient cooling systems. • Reduce lighting and equipment loads to reduce overheating.

ASSETS/SERVICE DELIVERY	POSSIBLE CLIMATE CHANGE IMPACTS	IMPACT AND POSSIBLE ADAPTION ACTIONS
Recreational facilities		
Provision and use of recreational facilities impacted by increased temperatures and decreased overall rainfall and resulting water scarcity	• Reduced water quality and quantity resulting in less watering/irrigation of open space and sports grounds and closure of ovals. • Limited water for swimming pools, etc.	<u>Increased temperatures - heat stress:</u> • Review/prepare design guidelines for street furniture, shelters and awnings, and infrastructure to provide protection, e.g. development of a shade and sun protection policy. • Conduct shade audits to determine the adequacy of existing shade, whether there is a need for more, if appropriately located and of appropriate size. • Include provision of shade structures in design of new council recreational facilities. <u>Decreased overall rainfall – impacts on watering requirements for turf sports ovals, open spaces, golf courses etc:</u> • Train staff on irrigation system auditing and scheduling. • Develop an irrigation plan to identify and reduce existing irrigation levels where possible. • Water controls and management be tailored for specific council areas.
Healthy services		
Community/workplace health impacted by increasing temperature and extreme weather events	• Milder winters improving communities' comfort levels. • Increase in geographical range and seasonality of vector-borne diseases and the possibility for an expansion of receptive zones. • High temperatures increasing incidence of food and water-borne diseases. • Risk of increased cryptosporidium infections during open water	<u>All climate change related health impacts:</u> • Utilise demographic profile and social analysis of council area to assess health vulnerability. • Identify affected communities and needs. • Develop a Public Health Plan that looks at the current health and wellbeing of the communities within the

ASSETS/SERVICE DELIVERY	POSSIBLE CLIMATE CHANGE IMPACTS	IMPACT AND POSSIBLE ADAPTION ACTIONS
	swimming in summer. • Health impacts due to exposure to extreme weather, e.g. heatwaves. • Extreme rainfall events transporting contaminants into waterways and drinking water supplies. • Increased pressure on drinking water supplies.	council area and develop • Wellbeing Indicators so that the program can be assessed over future years. <u>Increased temperatures – possibility for increased sunburn/rise in heat stress:</u> • Shade audits/provision of more shade in public recreational areas. • Reduce the impact of thermal stress via advice on how to stay cool including the use of portable fans, improved ventilation of homes, public buildings, and other residential institutions and workplaces. • Development of community heat emergency management plans. <u>Extreme weather events:</u> • Review local disaster management plans. • Evaluate bushfire risks. • Improve community disaster preparedness and response systems.
Planning and Development Approval		
Planning policy and developments impacted by increased temperatures and reduced rainfall , which influence land use demands	• Inappropriate location of urban expansion areas. • Increased uncertainty in long-term land-use planning and infrastructure design, i.e. location of future developments, suitability of infrastructure designs to cope with changing climate, etc. • Cost of retrofitting of systems. • Loss of private property and community assets. • Increase in insurance costs. • Increased pressure on disaster management and response	<u>Increased temperatures – increased risk of bushfire:</u> • Identify which areas will be more vulnerable to bushfire. • Encourage new developments, or changes to existing developments, to include improved protection and adaptations to increased bushfire risk (bushfire management strategies are largely available).

ASSETS/SERVICE DELIVERY	POSSIBLE CLIMATE CHANGE IMPACTS	IMPACT AND POSSIBLE ADAPTION ACTIONS
	resources. • Early retirement of capital infrastructure.	<u>Increased temperatures and reduced rainfall – water a more valuable resource:</u> • Incorporate polices which ensure that the water resource implications of new developments are assessed. • Promote water sensitive urban design at the plan making and development assessment stages of the planning process.
Natural Resource Management		
Biodiversity impacted by changed climatic conditions in general	• Shifts in distributions of plant and animal species. • Increased risk of population and species extinctions. • Reduced ecosystem resilience to stress. • Increased ecosystem and species heat stress. • Increases in ecological disturbances.	<u>Changed climatic conditions in general – adversely affecting ecological succession:</u> • Develop a Local Biodiversity Plan as a component of the Local Planning Strategy and Town Planning Scheme. • Implement conservation management plans for local reserves and other local government lands. • Encourage private land conservation, e.g. through incentives. <u>Increased risk of bushfires:</u> • Take into account the areas at increased risk of bushfire from climate change in the use of prescribed fire as a tool for managing fuel accumulation (recognising that inappropriate fire regimes can potentially threaten the conservation of

ASSETS/SERVICE DELIVERY	POSSIBLE CLIMATE CHANGE IMPACTS	IMPACT AND POSSIBLE ADAPTION ACTIONS
		biodiversity). • Use of fire adapted vegetation (much of Australian vegetation is fire adapted). • Ensure that 'fire management zones' have been identified.
Water and sewerage services		
Water supply/provision and water conservation activities impacted by increased temperatures and reduced rainfall making water a more valuable resource.	• Changes in mean and peak stream and river flows. • Uncertain water availability. • Insufficient water supply in some areas. • Increased potential for water contamination. • Salination of surface and groundwater supplies. • Changes in availability of groundwater available for irrigation.	<u>Increased temperatures and reduced rainfall – water a more valuable resource:</u> • Develop water strategies that incorporate greywater reuse. • Supplement existing supplies with recycled water where possible. • Community education on water efficient garden planting and watering. <u>Increased temperatures and reduced rainfall – water a more valuable resource:</u> • Promotion of use of Sustainable Urban Design Systems (SUDS) and water efficient installations into new developments. • Identification of opportunities to include Sustainable Urban Design Systems in existing developments/infrastructure.

3.3 THE AGRICULTURAL SECTOR

This section presents information collected from interviews with farmers as well as an account of alternative crops for climate adaptation identified in the literature. **Box 3.** *is a summary of how farmers are currently adapting to climate change and variability, and covers altering production methods and systems as well as seeking off-farm employment. Anticipated future responses, which are presented in Box 4, include sourcing alternative feed for livestock and farm amalgamation.*

Box 3. Farmers current adaptive responses to climate change

- Methods that maintain soil moisture, such as no till
- Move to production that is less reliant on water, such as changing from dairy to beef cattle
- Methods that limit heat and water stress
- Finding new sources of off-farm income generation
- Diversification of on-farm revenue generation

Box 4. Farmers anticipated future responses to climate change

- Moving away from feeding cattle with irrigated pasture grass to locally sourced wheat distributed in a feed lot system
- Strategic planting to limit heat and water stress
- Amalgamating farms to increase viability
- Collaborative farming to reduce input costs
- Barn dairies involving hand feeding, exercise yards, collection of stormwater runoff and reuse of waste water

There has been substantial research into the viability of different crops under future climatic conditions. Much of this research examines the viability of different crops based on their ability to grow under projected future climate conditions. However, much is also focused on the development of markets and competing interests such as energy and food production. Many food crops, for example date palms (*Phoenix dactylifera*) and pomegranates (*Punica granatum*), are seen as very suitable to the hot and dry conditions that are projected for future climate change (Cullen, Thorburn et al. 2010); (DAFWA 2008). However, these industries would need to compete with international markets and potentially develop local markets to sustain

themselves. There are also native crops, which are extremely well suited to local growing conditions, for example the desert lime (*Citrus glauca*) and the quandong (*Santalum acuminatum*) (Cullen, Thorburn et al. 2010). However, while there may be few limits on growing these crops the current markets are limited, and, though they may be growing quickly they are starting from a very small base (Lethbridge 2004); (Macintosh 2004). A further complication for land use under climate change is the potential for energy crops to become more economically viable (as discussed in Section 5.8 Agriculture for energy production).

A recent report by the Rural Industries Research and Development Corporation (RIRDC) (Cullen, Thorburn et al. 2010) conducted a study into new potential industries for rural communities under climate change. As a part of this they examined new rural industry opportunities in the Murray-Darling Basin for both irrigated and dryland farming systems and suggested alternative crops for this region. The general selection criteria for these alternative crops is that they have high water use efficiency, heat and drought tolerance, frost tolerance and lower chilling requirements (vernalisation) (Cullen, Thorburn et al. 2010).

For irrigated systems under future climate change they identified two main strategies; farming high value irrigated crops and farming resilient irrigated crops (Cullen, Thorburn et al. 2010). High value irrigated crops, while more dependent on a secure supply of good quality water, are also able to pay a higher price for water during shortages and thus exploit what water is available (Mallawaarachchi and Foster 2009). Whereas more resilient irrigated crops are able to exploit water of varying quality but survive shortages when required. Thus, new and alternative crops that are able to exploit this niche of resilience and adaptability are going to become increasingly important.

For dryland systems the same report identified three strategies that could make a contribution to the resilience and adaptation of farming systems in a warming and drying climate. These were; alternative crops in cereal systems, industrial crops (i.e. crops to produce goods for the production sector such as fibre, gums and resins) for arid environments and options for retired cereal country (Cullen, Thorburn et al. 2010). Typically, cereal crops are less resilient than industrial crops and if the land is no longer suitable for either there are still options although they are less profitable. Examples of alternative cereal crops include mustard (*Brassica juncea* and *B. carinata*), crambe (*Crambe abyssinica*), quinoa (*Chenopodium quinoa*) and tepary bean (*Phaseolus acutifolius*) and potential industrial crops include guayule (*Parthenium argentatum*) and lesquerella (*Lesquerella fendleri*) (Cullen, Thorburn et al. 2010). Options for retired cereal country include such things as animal industries and less traditional crops such as native vegetation for essential oils and other by

products (Cullen, Thorburn et al. 2010). Furthermore, this land may be suited to biomass for energy production or forests for carbon sequestration as discussed in section 5.8 Agriculture for energy production.

3.3.1 ALTERNATIVE CROPS

3.3.1.1 Dryland crops

Alternative oil seed crops include mustard (*Brassica juncea* and *B. carinata*) and crambe (*Crambe abyssinica*) (Francis and Campbell 2004). These are suited to the dryland cropping conditions of southern Australia with some advantages over the traditional oilseed crop canola (*B. napus*). Mustard has higher yields under low rainfall conditions and is better able to tolerate water stress, pests and disease. Crambe, which is used as an industrial oil crop, is generally able to out compete weeds better than canola. The market for mustard seed is extensive in south east Asia although somewhat limited in Australia. While there are many industrial uses for crambe unreliable production has limited its uptake (Francis and Campbell 2004).

Quinoa (*Chenopodium quinoa*) is a pseudocereal that is adapted to low rainfall (250-380 mm). It has a short growing season and can tolerate drought, frost and salinity. The plant produces a gluten free grain with high fibre and protein contents (Cullen, Thorburn et al. 2010). The market for gluten free grain is generally limited to coeliacs (those allergic to gluten) although as a good source of protein it also appeals to vegetarians and those seeking healthy diet alternatives (Vinning and McMahon 2006).

Tepary bean (*Phaseolus acutifolius*) is a drought and heat tolerant food crop that can reach maturity on single sufficient rainfall or irrigation events (Debouck 1994). While it is native to southwest USA and Mexico, it has not been extensively exploited there because access to cheap irrigation water has favoured other crops. However, its short growing season and drought tolerance makes it well suited to dryer conditions. One limitation is the small seed size which makes harvesting difficult and expensive (Cullen, Thorburn et al. 2010).

Guayule (*Parthenium argentatum*) is a small perennial shrub that produces a natural rubber (Thompson 1990); (Cullen, Thorburn et al. 2010). Unlike other natural rubbers the latex product does not cause allergies. The plant is well suited to semi-arid conditions, although it does require 325 mm of water. It does not cope well with water logging but can tolerate long periods of drought (George, Gupta et al. 2005).

Lesquerella (*Lesquerella fendleri*) is a perennial plant native to southwest USA and Mexico that produces vegetable oil well suited to lubricants and cosmetics (Dierig

1995); (Cullen, Thorburn et al. 2010). It is also a potential source of biofuel (Kish 2008) although research regarding this is ongoing. The plant is well suited to temperate arid regions with 250-400 mm rainfall on well drained soils and can be grown in an annual or perennial system. The United States Department of Agriculture is currently developing salt tolerant varieties (Kish 2008).

3.3.1.2 Irrigated crops

Date palms (*Phoenix dactylifera*) have a high tolerance to salinity and can survive long periods of drought but they require high levels of irrigation for production. Thus they are suited to areas where there is ample water of reduced quality or recycled water. The date palm is suited to a wide range of soils but prefers to be free draining and can tolerate very hot temperatures (Cullen, Thorburn et al. 2010). There is a wide range in the quality of date varieties from lowly cooking dates to high end table dates. In Australia, the domestic production is almost exclusively cooking dates with the vast majority of table dates imported (Reilly, Reilly et al. 2010).

Olives (*Olea europaea*) are well suited to production in Australia with a suitable climate, physical resources, infrastructure and expertise to support the industry (Sweeney and Davies 2004). Irrigation may be required for suitable yields but the plants are able to survive relatively low rainfall (Cullen, Thorburn et al. 2010). There is an extensive market for olives world-wide but also extensive production in many countries in the northern and southern hemispheres (Sweeney and Davies 2004).

Jojoba (*Simmondsia chinensis*) is a drought tolerant perennial shrub from the Sonoran desert regions of North America (Cullen, Thorburn et al. 2010). It produces a liquid wax that is used in cosmetics and industrial applications. While it is suited to desert conditions, higher yields are achieved with at least 450 mm of rain or supplemental irrigation (Milthorpe 2004). It is seen as a relatively good crop for diversification of production systems because, relative to fruit and other crop types, as the timing of the timing management operations is not critical (Milthorpe 2004).

Pomegranates (*Punica granatum*) are a perennial fruit bearing tree that is suitable for Mediterranean climates. It does require chilling to break dormancy, so minimum temperatures are important. However, it can tolerate hot summers, water logging and frost (DAFWA 2007); (Cullen, Thorburn et al. 2010). The fruit can be stored for up to 7 months and the juice can be easily extracted with modified grape crushing equipment (DAFWA 2008).

Capers (*Capparis spinosa*) are a perennial plant that can be harvested for its edible flower buds, berries and leaves. It is native to the Mediterranean and tolerant of drought, salinity and high temperatures, although it is sensitive to frost during its

growing season (Trewartha and Trewartha 2004); (Cullen, Thorburn et al. 2010). Capers are almost exclusively imported into Australia with most production taking place in Morocco, Turkey, Spain and Italy (Trewartha and Trewartha 2005). There is the opportunity to develop a local niche industry here however harvesting is done by hand making it very labour intensive (Trewartha and Trewartha 2004).

The quandong (*Santalum acuminatum*) is a native Australian perennial fruit producing plant. The plant is highly drought and salinity tolerant and requires full sun and a dry humidity (Cullen, Thorburn et al. 2010). The plant is semi-parasitic, requiring a host plant whose roots it colonises, for best production. Commercial production of fruit is in its infancy with wild harvested fruit making up approximately two thirds of production. Processed fruit (dried and frozen) dominates the market and is used for a variety of culinary applications (Lethbridge 2004).

Bush tomato (*Solanum centrale*) is a fruit producing perennial native to central Australia. They are very well adapted to growing dry and hot conditions with variable rainfall (Cullen, Thorburn et al. 2010). They are susceptible to frost damage and some irrigation may be required for higher levels of production. Bush tomatoes are generally harvested dry and are used as a spice additive in food. There is an increasing market both domestically and internationally as a boutique ingredient for both restaurant and home cooking (Robins and Ryder 2004).

Desert lime (*Citrus glauca*) is native to the semi-arid regions of eastern Australia and is extremely tolerant of drought, heat and frost. It is well suited to heavy soils and responds well to irrigation and fertiliser (Cullen, Thorburn et al. 2010). The fruit, which is described as having a refreshing tangy taste is generally sold fresh or frozen. There are also a wide range of other native citrus that are less well distributed and suited to dry growing conditions (Macintosh 2004). The market for native citrus is in its infancy although desert lime is among the most well known within the native food industry. Market development will require increased production along with marketing and product development (Macintosh 2004).

3.4 Adaptation initiatives

There is a range of climate adaptation initiatives operating nationally and within South Australia. Many of these, such as the South Australian Local Government Climate Adaptation Program, encompass a wide range of social, infrastructure and environmental issues. As such they are necessarily broad and provide little information specific to individual industries or production systems. There are also a range of State Government programs. These include vulnerability and adaptation assessments such as the Vulnerability assessment of Northern and York NRM region

and the Climate Change and Communities Program looking at vulnerability in the Eyre Peninsula and South Australian Murray Darling Basin NRM regions. There are also sustainability initiatives aimed specifically at climate change to improve adoption of improved land management practices. These include programs such as the Developing Landholder Capability to Adapt program and the Sustainable Dryland Agriculture Initiative. Furthermore, there are a series of programs to monitor land and environmental condition in the face of climate change such as the Climate Change and Land Capability program which aims to reduce the potential risk of wind erosion.

There are also a series of National programs. The CSIRO Climate Adaptation Flagship is a major National research initiative by CSIRO aimed to equip Australia with practical and effective adaptation option across a range of sectors including agriculture, natural ecosystems and urban and coastal environments. There is also the National Climate Change Adaptation Research Facility (NCCARF) which is a national interdisciplinary effort to coordinate research and information for decision makers and communities. Within NCCARF there is the Primary Industries Adaptation Research Network (PIARN) which aims to improve the coordination, development and accessibility of climate change adaptation research for primary industries. A list of the various programs at all levels of government is provided in Appendices Section 6.3 Climate change adaptation initiatives.

Aside from participating in government programs and initiatives, organisations interested in learning how to adapt to climate change can use a variety of tools and methods. These include climate change tailored risk management and action planning processes through to application of environmental management system tools like EMAS (Community Eco-management and Audit Scheme), certification under standards like ISO 14001 or use of life-cycle assessment tools like cradle to cradle design.

4 MANAGEMENT SCENARIOS FOR THE FUTURE

Dealing with rising temperatures and sea levels is really only one part of the conundrum of managing climate change at the local level. Updating procedures and engineering specifications for constructing roads and drainage are critical considerations, but they represent a narrow view on their own. Looking outwards, there is benefit in reviewing emerging policies and actions that are revolutionising communities and landscapes around the world. These revolutions at local, regional, national and international levels are giving priority to low carbon economies.

In this section we encourage you to contemplate different hypothetical routes into the future, even if you think they are not plausible. The value of your considering these four future scenarios is to inspire a response on how to best navigate decisions into the future. We have organised these scenarios along two dimensions. "Connections with global community" refers to working with others, for example participating in international trade and working with other levels of government to achieve community objectives. "Adaptations to limited fossil resources" refers to using alternative technologies and practices, including solar energy, soil conservation and rainwater harvesting.

4.1 AIMLESS WANDERER

The local government and community have no formal strategy for the future. Major decisions rest with a few key people and local government decisions often prompt fierce community debate. Some community members recognise that climate change is an issue, but most are ambivalent or sceptical. You have no emergency response plans and assume that the State or Federal government will come to your aid in crisis. Business leaders and developers strongly influence local government decisions, which often contribute to environmental degradation. The local economy experiences spurts of growth and periods of stagnation. Blame for carbon taxes, rising energy costs and degrading roads and parks is passed to other levels of government and organisations outside of the region.

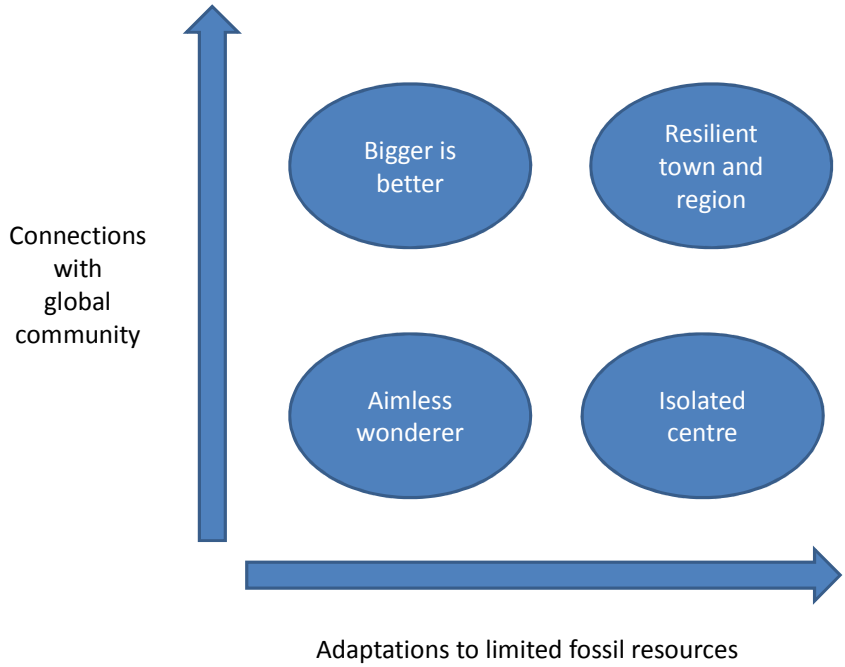

Figure 1. Management scenarios for the future can be organised according to the dimensions of "connections with global community" and "adaptations to limited fossil resources"

4.2 ISOLATED CENTRE

Fear about climate change and impending resource crises spark a local community movement, headed by newly elected councillors, to become more independent and self-reliant. Farmers are encouraged to produce food for local people and local markets over national and international markets in the belief that the world economic system is going to collapse. Along these lines, local government provides incentives to produce energy locally including solar and wind as well as energy from crops. A new system of recycling all waste in the local area is implemented, new waste businesses are established and new jobs are created for local people. There are limited public transport connections with the outside world and few tourists are attracted to the region. New technologies are slow to be adopted. Wages decline in the slowing economy before reaching a steady state as there is little money brought into the region. Community members are content in their isolation, even though roads and infrastructure are in a poor state. Rising energy costs are not a significant problem as many people generate their own electricity and because local farmers produce biofuel for the region.

4.3 BIGGER IS BETTER

Big business, developers and all levels of government work together to make the region a powerhouse of economic activity. Chemical processing facilities, a new industrial estate and a nuclear waste disposal site are all under construction. Primary production is mostly corporatized and based on large holdings that serve international markets as commodity prices increase with world population. There are fewer farmers in the region and much of the agricultural returns are exported out of the region. You are a big energy importer with a huge carbon footprint. Much of the local community live on the coast part-time and fly in for work. Large chain stores dominate the urban area and local businesses close down one by one. Housing prices have skyrocketed and long time local residents struggle to make ends meet. Residential development is prioritised over conservation and amenity and the town becomes an ugly expanse of identical homes. There is strong public denial over climate change and high disposable incomes enable residents to cope with rising electricity and fuel costs.

4.4 RESILIENT TOWN AND REGION

Your community is well aware of its strengths and weaknesses and are actively involved in strategic planning. A diversified economy has helped businesses and residents to manage a changing climate and national and international markets. Local businesses easily accommodated a new carbon tax introduced by the federal government. Local government has a strategic plan that sets aside land for habitat conservation, urban development, industrial development and agriculture. A local climate change and energy strategy was developed and a range of measures have been implemented to culminate in the region being a net carbon sink and an exporter of electricity. Federal government support was attracted for the development of an innovative solar and wind farm project where local community members became co-owners in the venture and make money from the sale of electricity. Public transport is fast and connects the community with other regional centres. The town is friendly and people walk and ride from place to place. There is a mix of small and large farms with food processing facilities that provide work for local people. Farmers supply local, national and international markets and they use diversity in markets, varieties and production systems to cope with fluctuating commodity prices.

4.5 WHERE TO FROM HERE?

Community actions are tied to reasoning and world view. How we perceive what is happening now with respect to climate change and our role in responding to it is critical and will guide the next steps the community takes. The scenarios presented above explore how different starting conditions on two dimensions can shape quite different futures for a community.

One view is that climate is not changing and current management is working fine. A second view recognises that there are changes in climate and we can successfully adapt our practices to cope. Another recognises that Australia contributes less than 2% of global carbon emissions and that any effort to cut emissions in my local area is not going to make any difference to climate change. A fourth view is that local people and businesses see themselves as part of a global community and are motivated to cultivate hope and showcase efforts to adapt with due recognition of the dangers of climate change and limited fossil resources.

Future planning to position the region to adapt to climate change and take advantage of emerging opportunities might ask:

- Where on this continuum does your community sit?
- Where on this continuum would you like your community to be?

5 ECONOMIC ADAPTATION AND OPPORTUNITIES

5.1 PLANETARY LIMITS AND RESOURCE CONSTRAINTS FOR DEVELOPMENT

Society today operates from a mindset which was conditioned by resource abundance. The recently discovered energy bonanza of coal, oil and natural gas fuelled the creation of modern industrial societies and a population explosion. The ability to do more work has pushed three of nine critical measures, including climate change, biodiversity loss and the nitrogen cycle beyond safe limits for humankind (see Figure 2). Other measures are fast approaching the danger zone. In the coming decades we will experience a decline in the following parameters:

- Population
- Grain production (total and per capita)
- Uranium production
- Climate stability
- Freshwater availability per capita
- Arable land in agricultural production
- Wild fish harvests
- Yearly extraction of some metals and minerals (including copper, platinum, silver, gold and zinc) (Heinberg 2007).

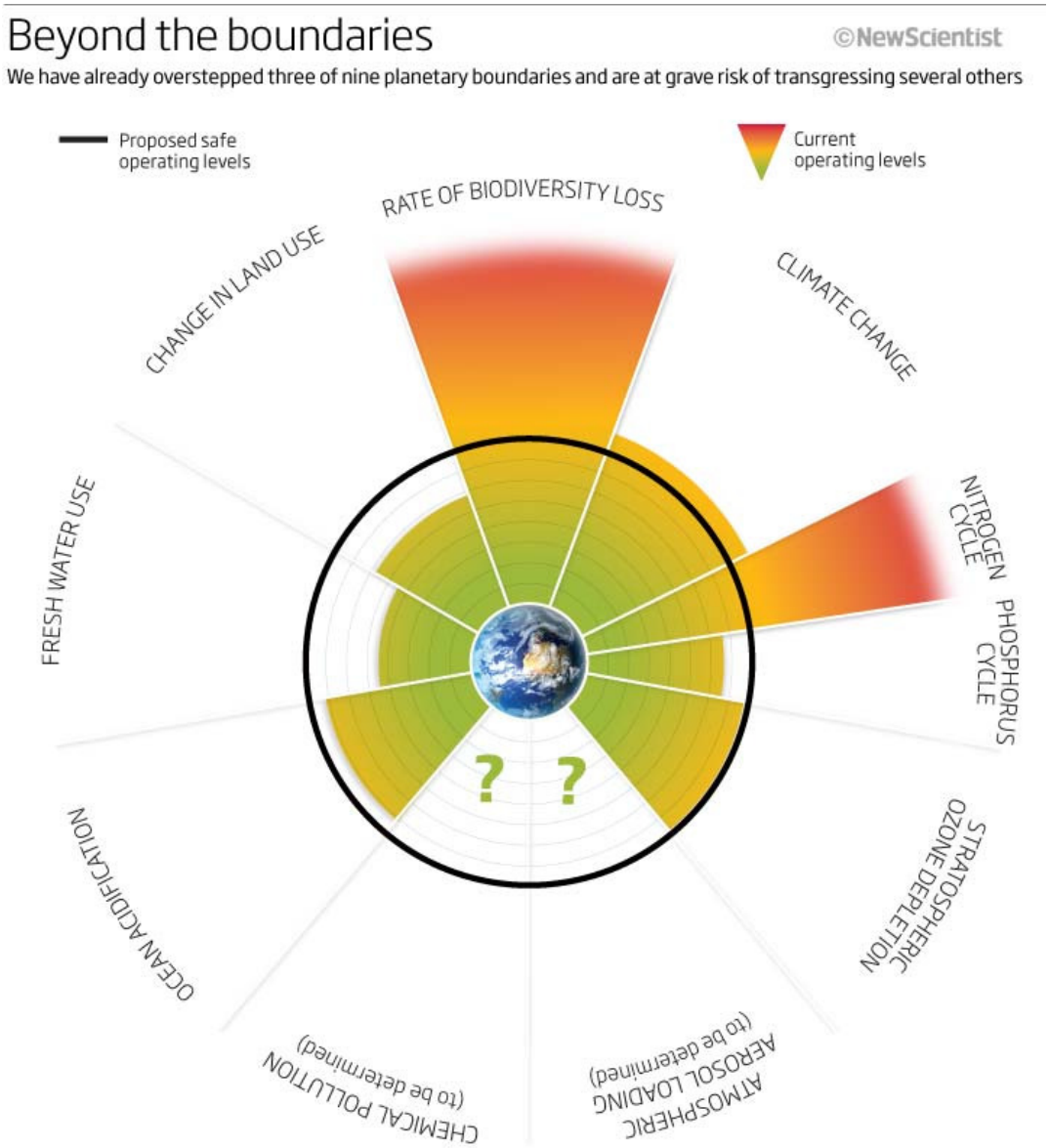

Figure 2 Planetary boundaries that define a safe operating space for humanity

Source: (Pearce 2010) & (Rockstrom, Steffen et al. 2009).

Price crunches and global peak levels of production for a number of critical resources are looming:

- Phosphorus (used for fertilizer) – high prices have already been experienced and demand is projected to outstrip supply within 30-40 years (Clabby 2010).
- Oil – global production to peak between 2010-2015 (Nashawi, Malallah et al. 2010), see Figure 3.
- Coal – global production to peak between now and 2048 (Mohr and Evans 2009).

- Natural gas (used for energy and nitrogen fertilizer) – global production to peak around 2030 (Zhang, Sun et al. 2010).

These last three of these resources are the source of most of the world's carbon pollution. Beyond peak production of these resources it is reasonable to expect that competition will push prices higher until alternatives become economically feasible. The issue with alternatives is that the transition can take a long time and be very costly. For example, replacing oil will be a huge challenge, because it is used to produce petrol, diesel, jet fuel, heating oil, LPG for taxis and fleets, asphalt, chemicals, plastics, rubber, clothing and pharmaceuticals. Further, the transition to alternatives not only means replacing the resources themselves, but in many cases the equipment and systems used to make, distribute and use the resources.

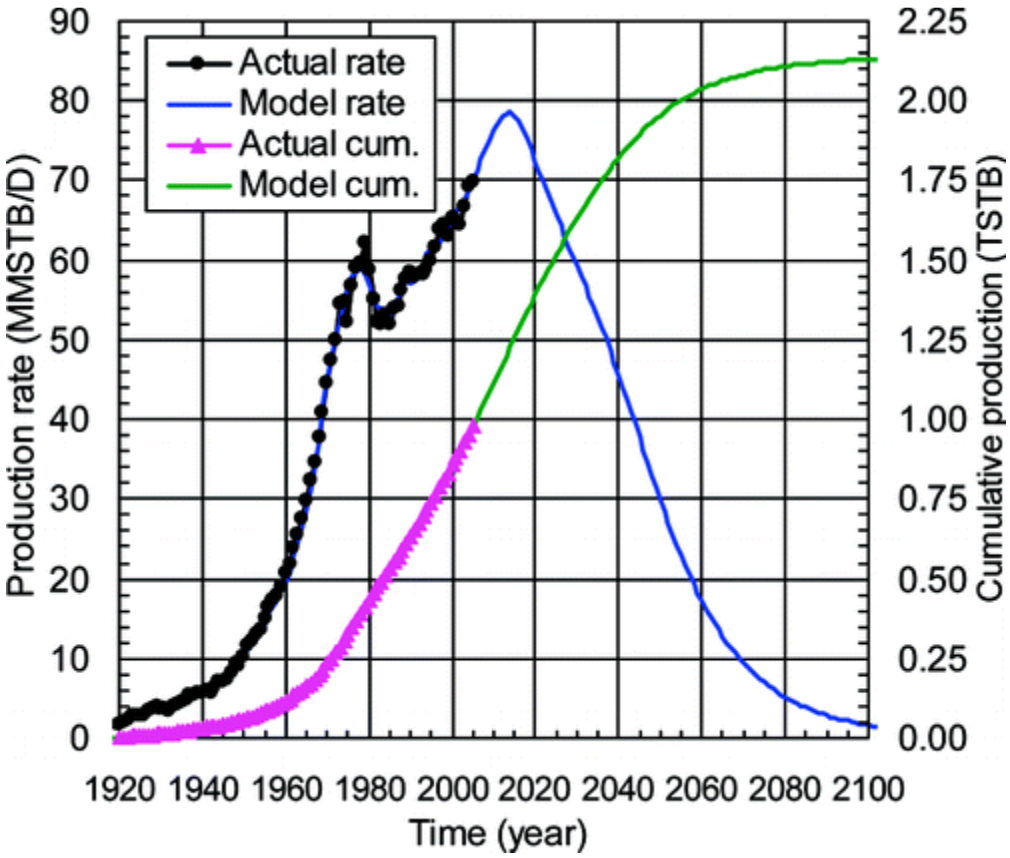

Figure 3 Actual and modelled world production of crude oil indicating a peak in production of crude oil between 2010-2015 (Source: (Nashawi, Malallah et al. 2010))

Stabilising climate at 445-535ppm CO_2e will require cutting carbon emissions from a projected 85 to 20 gigatons per year by 2050 (Beinhocker, Oppenheim et al. 2008); (Stern 2007); (IPCC 2007). Meeting this target implies cutting current fossil fuel use by 1.73% per year and no technology is available and ready to fill all of the energy gap created (Newman, Beatley et al. 2009). While economists argue that economic

growth must continue (Beinhocker, Oppenheim et al. 2008), others reason that transport, distribution, production and economic activity will inevitably decline (Heinberg 2007).

Dealing with these trends and impending limits will require all of our resourcefulness. In this 6th wave of innovation (Hargroves and Smith 2005), transformation of society will involve renewable technologies and approaches to reduce distribution costs and take advantage of local water, energy and waste resources (Newman, Beatley et al. 2009). Adopting a low carbon economy will be either encouraged through carbon policy at the national level (e.g. carbon tax) or forced through eventual escalating prices of fossil fuels as scarcity increases. Most likely it will be a combination of both, which presents a number of risks, but also opportunities for the future.

5.2 INTEGRATING ECONOMIC TRANSFORMATION AND ADAPTATION TO EFFECTS OF CLIMATE CHANGE

A strong local economy underpins the ability to adapt to higher temperatures, declining water availability and rising sea levels. High profits, diverse economic activity and low unemployment give businesses, local governments and families the finances to adjust management. Coastal structures to prevent damage from storm surges and more frequent paving of roads are costly. So too is replacing a nectarine orchard with a variety that can cope with longer heat spells. The rising cost of running a home air-conditioner can be managed with a decent salary. Finding the money to cover a departure from current conditions will be harder if economies degenerate. If done carefully, a transition towards a low carbon economy can create sustainable businesses and boost employment (McEvoy, Gibbs et al. 2000). Local governments can help communities adapt to climate change by re-focusing and broadening activities around a "low carbon economy".

Snapshot - Climate change adaptation Vs mitigation
Climate change adaptation is acting to tolerate the effects of global warming. Mitigating climate change instead focuses on the causes of climate change, by reducing greenhouse gas emissions or by increasing sinks.

Scientists tend to distinguish climate change adaptation and mitigation – see Snapshot above. While the distinction is useful for scientific communication, isolating or prioritising one over the other for local management is short-sighted. In this report we wish to emphasise the importance of building strong economic foundations that will allow us to modify management to "tolerate the effects of global warming". By ignoring the energy policy of the European Union, that New

Zealand already has national carbon trading and pressures within Australia to price carbon, we are blind to the local conditions needed for future prosperity.

Some economists argue that any successful program on climate change must stabilise greenhouse gases and maintain economic growth (Beinhocker, Oppenheim et al. 2008). Economic growth does not understand planetary limits, human well-being and nature. And "prosperity" appears to be a better policy cornerstone for this age as the costs of consumerism-driven growth weigh down on ecosystem health and lifestyles (Jackson 2009). Meeting the twin objectives of prosperity and stabilising greenhouse gases, a low carbon economy can strengthen resilience to future change as shown in Figure 4. Resilience has three elements including the ability to buffer change, the capacity to learn and adapt as well as the capacity for self organisation in response to outside influence (Carpenter, Walker et al. 2001). The flipside of resilience is vulnerability. This means farmers are vulnerable, for example, if they have too little money in the bank to cover increasing water costs. Urban residents are vulnerable if they do not plan for rising electricity costs. And businesses are vulnerable if supplier contracts or government regulations prevent them from easily changing management to suit new circumstances. In recent times, the Riverland of South Australia was shown to be vulnerable to changes to international commodity prices and a drought that extended far across the Murray Darling Basin. Farmers had little influence over decisions and market interactions, partly because they were precipitated outside of the region.

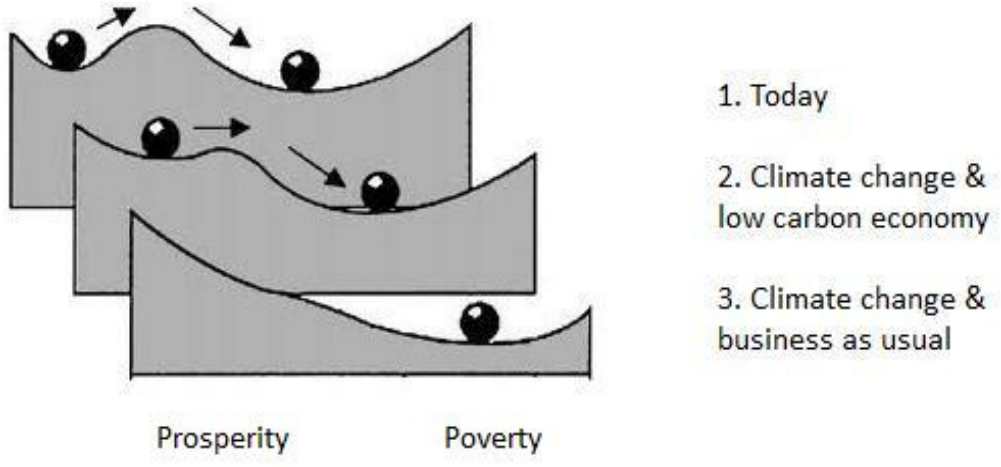

Figure 4 In these images, the left basin depicts community prosperity and the right basin depicts poverty. A community may more easily "roll" into a state of decline as the management "landscape" alters over time due to climate, business conditions and policies. The size of the "hill" that divides the two basins depicts resilience.

Recognising the climate change risks of a business as usual approach, we can enhance resilience to community poverty by developing a low carbon economy.

5.3 Defining a low carbon economy

Snapshot
A low carbon economy has a minimal output of greenhouse gases to the atmosphere.

A low carbon economy is a blueprint for the future. It is based on reducing carbon inputs, increasing carbon recycling, decreasing carbon emissions and increasing carbon storage. It recognises that climate change policies around the world are increasingly penalising carbon pollution. It makes use of the increasing cost of energy derived from fossil fuels to promote renewable energy and improve lifestyles by redesigning urban areas and improving public transport services. Low carbon is reducing waste first, reusing second and recycling third. Low carbon is recycling locally, where different waste streams become inputs to an array of new businesses that generate local wealth. A consumer demanding low food miles is low carbon. Biomass for electricity and biodiesel for transport fuel are low carbon opportunities. High organic matter in productive agricultural soils and mosaics of protected native vegetation are low carbon. It is securing food production and protecting productive farmland as well as ensuring houses are designed and built to reduce energy demand. These and other elements of a low carbon economy are summarised in

5 below.

Box 5. Elements of a low carbon economy

- All waste minimised by (1) reducing, (2) reusing, (3) recycling
- Energy produced using renewable sources
- Natural resources used with a conservation ethic
- Local needs are met through local production where practical, including food, materials and energy
- Industry, governments and individuals are environmentally and socially responsible

Source: Adapted from (The Low Carbon Economy Limited 2010)

5.4 Measuring a low carbon economy

A low carbon economy requires a new kind of literacy. In the past policy makers have focussed on productivity per unit of labor and capital. With increasing water prices, decision-makers developed a new appreciation for productivity per unit of water. With the dawn of a carbon economy now upon us, decisions will increasingly be based on productivity per unit of carbon emitted. At the global scale, carbon productivity was about US$740 per ton of CO_2e in 2008. Sustaining global economic growth at 3.1% and reducing emissions to 20 gigatons per year, which is the reduction required to stablilise emissions at between 445-535 ppm CO_2e recommended by the International Panel on Climate Change (IPCC 2007), will require a carbon productivity increase of ten times (5.6% per year until 2050), to US$7,300 per ton of CO_2e by 2050 (Beinhocker, Oppenheim et al. 2008). Even if we do not agree with across-the-board economic "growth" as the solution, it does highlight the magnitude of the challenge ahead.

Snapshot – Carbon budget
In a business as usual scenario (current global economic growth & current policies for carbon pollution control), to avoid severe consequences of climate change you will have to choose between a 40 kilometre car ride, a day of air conditioning, buy two new T-shirts (without driving to the shop), or eating two meals.

5.5 Prioritising actions for a low carbon transition

The calculations above leave governments and communities with the difficult decision of prioritising actions to control carbon emissions. Some actions such as insulating homes and installing energy efficient lighting actually save money. Globally, we can save 7 giga-tons of emissions per year and save money at the same time (Beinhocker, Oppenheim et al. 2008). Cutting emissions further will cost money. And costs increase from generating nuclear energy, reforesting land, substituting industrial feedstocks, constructing carbon capture and storage plants, producing biodiesel to avoiding deforestation. Making use of the full suite of options to avoid severe consequences of climate change (IPCC 2007), would incur a total annual cost to society of 800-1,750AUD billion or 0.6-1.4% of world GDP in 2030 (Beinhocker, Oppenheim et al. 2008). This demonstrates that development of a low carbon economy is affordable, can save us money in the short run and does not depend on new technology.

Case studies of local governments acting to develop low carbon economies are presented below. The first involves local governments in the UK and Australia working with energy providers to greatly increase energy efficiency, while the second shows how a local government can work on large integrative community, housing and industry projects to reduce carbon emissions and sequester carbon.

CASE STUDY 1: Trigeneration – From Woking UK to Sydney & Melbourne Australia

Woking is a large town of about 60,000 in southern England. Recognising that 69% of energy generated from coal is lost in transmission networks, the local government formed a partnership with energy companies to come up with a solution. The development of a trigeneration power system began in 1990. It burns gas to deliver heating, cooling and electricity achieving an efficiency of 85%. The electricity grid is no longer used, as gas burning units are installed in public and private buildings that make use of existing gas networks. With impressive carbon emission cuts of 80% in Woking, both Sydney and Melbourne are implementing trigeneration power in an effort to achieve low carbon economies. Sydney city recognises that they are at significant risk from the effects of climate change and are pursuing low carbon energy as a key adaptation measure. For further information see 2030 Sustainable Sydney - http://www.cityofsydney.nsw.gov.au/2030/default.asp.

CASE STUDY 2: The Masdar initiative in the United Arab Emirates (UAE)

The Masdar initiative began in 2006, when the UAE decided to pursue a workable economic response to global warming and international pressure for a global carbon price. The aim of the initiative is to demonstrate world leadership in developing a low carbon economy. It includes Masdar city, which is to be a carbon-neutral, zero waste urban community in the centre of Abu Dhabi and a world scale carbon capture and storage project.

Masdar city will be completely powered by renewable energy and cover an area of seven square kilometres. The city will house 40,000 residents and provide space for businesses and institutions with employment for 50,000 people focussed on renewable energy research and development. Passive building design, reusing and recycling materials, water recycling and composting are some of the features.

The carbon capture and storage project, claiming to be the largest in the world, will involve injecting CO_2 into oil reservoirs. The aim is to reduce Abu Dhabi's carbon footprint by one third.

The UAE is a member of the Organisation for Petroleum Exporting Countries (OPEC) with the seventh largest reserve of oil in the world by country.

Source: (Nader 2009)

5.6 CARBON POLLUTION REDUCTION SCHEME

The Carbon Pollution Reduction Scheme (CPRS) Bill 2009 emerged from a review on energy policy of Australia, the Garnaut Climate Change Review. The Bill, introduced to the Senate in May 2009, aimed to contribute to stabilising greenhouse gas emissions at 5% of 2000 levels by 2050, with the provision to aim for a 25% or 60% reduction depending on agreements around the world. The Bill failed to gain enough support and was rejected twice by the Parliament before then Prime Minister, Kevin Rudd, announced the delay of the implementation of the CPRS citing lack of bipartisan support and slow international progress on climate change action. While it seems that the CPRS will no longer be introduced in Australia as it was, there is still considerable support for some form of price on carbon to be introduced. This may be in the form of a straight tax or it may be through some form of emissions trading scheme, such as a cap and trade, a baseline and credit, a project based scheme or some form of hybrid (Parliamentary Library of Australia 2010).

Under the original CPRS there were many exemptions for various industries and sectors. These included the rural sector, landfill sites closed before 30 June 2008, forestry and deforestation (although they could opt in if they chose), or emissions from the combustion of biofuels or biomass that was used for energy combustion (Parliamentary Library of Australia 2010). There was much criticism of the scheme for these many exemptions. Given the exemptions and the complication of the scheme it is difficult to understand the impact for rural local governments as many of them are exposed to different industries. For example, the exclusion of forestry or the rural sector may benefit some industries within the community because they are not exposed to a price on carbon while others will be disadvantaged because they cannot make money from the price on carbon. It is not clear what any future scheme will or will not include and the potential impacts are uncertain. Nonetheless, any Commonwealth policy on carbon pollution will only strengthen the case for the transition to a low carbon economy.

5.7 Low carbon approaches to investment opportunities identified by Regional Development Australia Murraylands & Riverland Incorporated

Regional Development Australia Murraylands and Riverland Incorporated (RDA MR) aims to facilitate business development and works to identify and analyse development opportunities, whether associated with new industry or value adding to existing industry (Murraylands and Riverland Incorporated 2010). The RDA MR has identified numerous opportunities for investment and development for the region. Table 3 identifies these opportunities and then presents some low carbon approaches to these opportunities.

Table 3. Low carbon approaches to investment opportunities identified by Regional Development Australia Murraylands & Riverland Incorporated.

Investment opportunity	Low carbon approaches
Alternative energy	Biofuels, biomass, solar and wind are all renewable forms of energy and low carbon options. Install decentralised energy generation to reduce transmission loses.
Education	Train local government staff in low carbon concepts and applications. Include low carbon solutions in environmental science courses in schools, TAFE and universities. Offer certification courses in low carbon technology (e.g. solar installation) at technical colleges. Educate the public about low carbon benefits and methods.
Housing & building	Promote solar passive and energy efficient design to reduce energy demand. Use locally sourced building materials. Refurbish existing structures to increase energy efficiency. Design and construct buildings to last for 100s not 10s of years. Install solar panels or wind turbines & solar water heaters. Use energy efficient appliances. Install devices inside houses so that people can easily monitor electricity use.
Intensive animal production, aquaculture, horticulture and viticulture	Use locally produced inputs and supply local markets to reduce transportation. Maintain and continually update irrigation equipment. Construct energy efficient buildings. Use renewable energy. Capture methane from animals for local energy production. Use animal wastes as fertiliser and for compost. Integrate animal production with crop production using permaculture principles to recycle nutrients, reduce inputs and save energy. Compost rather than burn waste material. Adopt no till, low till, rotation cropping and companion plantings.
Food processing	Give preference to locally produced foods. Use food processing waste for energy production or compost or inputs to other industry. Use packaging that can be reused or recycled. Use renewable energy.
Manufacturing & mining	Halt flaring and venting of natural gas. Give preference to locally produced input materials. Modify or add to imported products to increase value.

Investment opportunity	Low carbon approaches
	Avoid fly-in-fly-out mining operations and employ local people where possible. Use renewable energy.
Retail	Sell and promote locally produced goods. Use renewable energy.
Recreation and retirement	Provide local facilities for recreation activities. Provide plenty of open space in urban areas for recreation. In public parks reduce lawn and plant native species to reduce water use and fuel use for water pumping and mowing.
Transport & logistics	Continually improve combustion engines to reduce emissions, noise and fuel consumption and move to electric engines where possible. Work towards a transit system that is faster than traffic for all major routes. Use renewable transportation fuels. Use rail transport where possible. Phase out freeways and phase in congestion taxes to fund sustainable transport. Encourage transit oriented development in urban areas that are compact and walkable and serviced by public transport. Give priority to pedestrians and cyclists in town centres. Provide services and connectivity to guarantee frequent day and night access. Provide bicycle paths in urban areas.
Tourism	Promote nature-based and low impact tourism. Target tourists from surrounding regions. Transition to low carbon fuels. See Housing & building and Transport & logistics
Water use and reuse	Install rainwater tanks. Recycle grey water on site. Capture and use stormwater at the community scale. Scale urban water prices to water availability.

Sources: (Booz & Company 2009); (Newman, Beatley et al. 2009)

5.8 AGRICULTURE FOR ENERGY PRODUCTION

Biofuels, biomass and planting trees for carbon benefits are all potential alternative land uses that may become increasingly viable under climate change. Biofuels is the production of liquid fuels such as biodiesel, often produced from canola and other oil seed crops, and ethanol, produced from wheat and corn. Whereas biomass production is growing trees which are used as a fuel source for the production of electricity and, in some cases, includes the production of secondary products such as oils and activated carbon (Bryan, Ward et al. 2008). The introduction of a carbon market would also see carbon abatement through the planting trees become increasingly viable.

In a recent study (Bryan, King et al. In Press), the cost benefits and tradeoffs of biofuels were found to be equivocal. While biofuels present some opportunity for increased profitability and a source of renewable transport fuel, this would be at the cost of food and fibre production. Furthermore, crops such as canola and cereals are equally susceptible to the effects of climate change whether produced for biofuels or for food. The adoption of biofuel production may provide some greenhouse gas abatement by sourcing transport fuels from a renewable source. However, it is not clear that this would be significant and food security and environmental concerns may outweigh the potential benefits (Bryan, King et al. In Press).

Woody biomass production from oil Mallee Eucalyptus species has been shown to have significant potential for both economic and environmental benefits. Biomass production has the potential to be more resilient than traditional agriculture to climatic warming and drying because tree species are better suited to warmer and dryer conditions (Bryan, King et al. 2010). Furthermore, there are other environmental benefits from biomass production such as the mitigation of salinity and wind erosion and biodiversity benefits (Bryan, King et al. 2010). Planting trees for carbon sequestration, without harvesting the biomass for electricity generation, may also have additional benefits such as biodiversity conservation and salinity and wind erosion prevention. However, these carbon sequestration forests are likely to be much less profitable than biofuels and will not provide additional energy or co-product benefits (Bryan, King et al. 2010). Several authors have also found that biomass for the production of renewable electricity is more efficient than biofuel production (Campbell, Lobell et al. 2009); (Ohlrogge, Allen et al. 2009).

Figure 5 and Figure 6 indicate the economically viable areas of the lower Murray under biofuels and biomass production respectively, with different climate and carbon price scenarios. To create these figures, the spatial distribution of productivity of agricultural crops and pasture, biofuels and biomass were modelled. These different land use

options were all modelled under the historical mean climate (S0) and three climate change scenarios (S1 – mild warming and drying, S2 – moderate warming and drying and S3 – severe warming and drying). The average annual economic returns at full equity for each of these land uses were calculated with farm gate commodity prices and varying prices on carbon. For biofuels (Figure 5) modelled carbon prices were $\$0/tCO_2^{-e}$, $\$10/tCO_2^{-e}$, $\$20/tCO_2^{-e}$, $\$30/tCO_2^{-e}$ and for biomass (Figure 6) the carbon prices were $30/tonne, $40/tonne and $50/tonne. Figure 5 shows that climate is the biggest driver of economic viability for biomass production. Increasing warming and drying will decrease the viability of biofuel production and higher carbon prices will have little effect. Alternatively, Figure 6 shows that increased warming and drying will have little effect on the economic viability of biomass production which is instead driven by carbon price. As discussed above, the deep rooted perennials used in biomass production (e.g. oil mallee) are less susceptible to warming and drying than the shallow rooted species used in biofuels production (e.g. canola and wheat). This demonstrates that biomass production is more resilient to changes in climate than biofuels production.

Figure 5. Economically viable areas (dark shade) for biofuels agriculture (i.e. where profitability of biofuels agriculture > profitability of food agriculture) under different climate (S0, S1, S2 and S3) and carbon price ($0 $t^{-1}CO_2^{-e}$, $10 $t^{-1}CO_2^{-e}$, $20 $t^{-1}CO_2^{-e}$ and $30 $t^{-1}CO_2^{-e}$) scenarios (Bryan, King et al. 2010). $t^{-1}CO_2^{-e}$ is tonnes of CO_2 equivalents, S0 is the current climate, S1 is 1 ^oC increase in temperature and 5% decrease in precipitation, S2 is 2 ^oC increase in temperature and 15% decrease in precipitation, S1 is 4 ^oC increase in temperature and 25% decrease in precipitation.

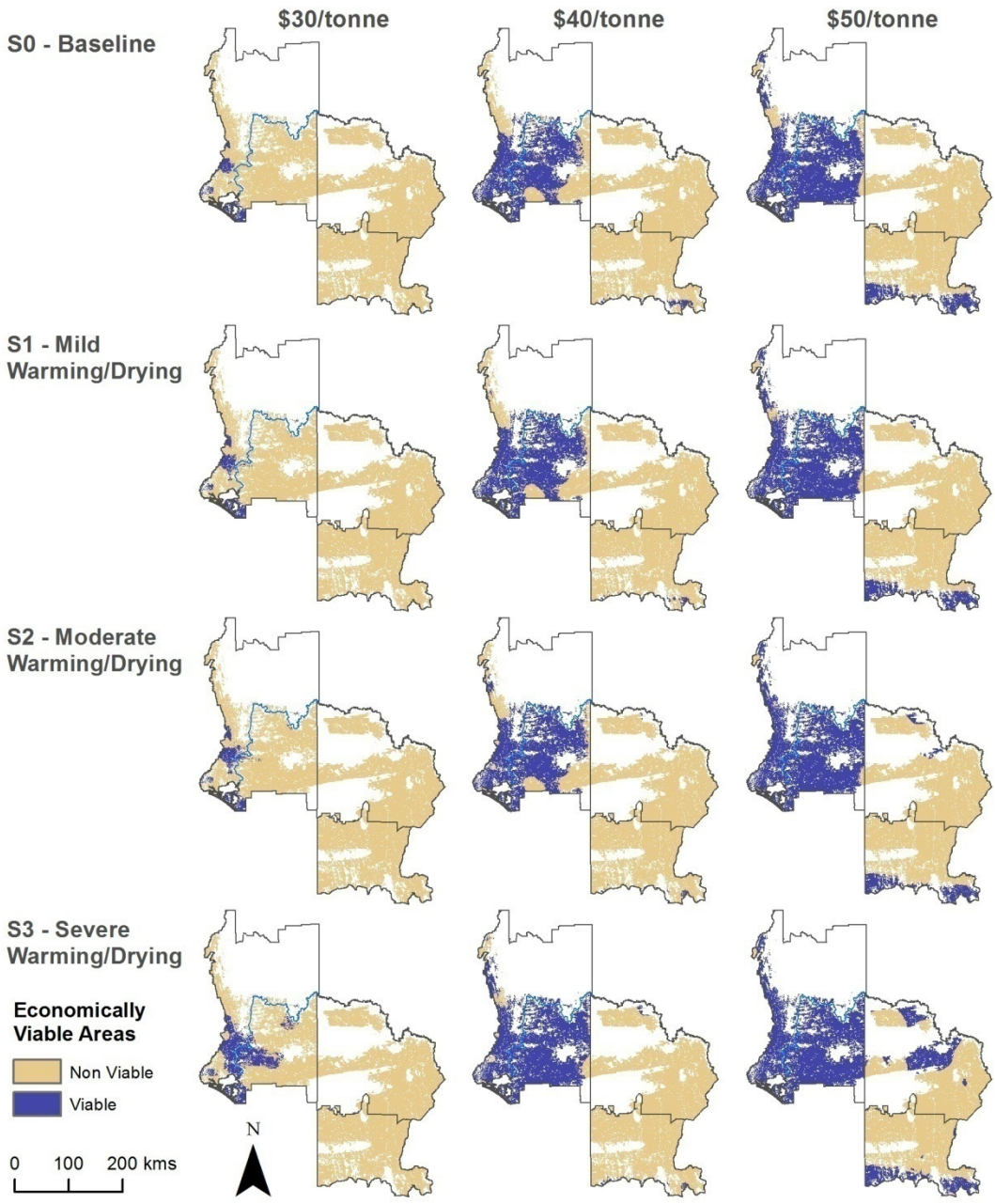

Figure 6. Economically viable areas (dark shade) of biomass production under climate change and carbon price scenarios ($ per tonne) (Bryan, King et al. 2010).

6 APPENDICES

6.1 ACRONYMS

DWLBC – Department for Water, Land and Biodiversity Conservation

IPCC – The Intergovernmental Panel on Climate Change

PIRSA – Primary Industries and Resources of South Australia

SARDI – South Australian Research and Development Institute

6.2 DEFINITIONS

Adaptive Capacity
The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC: 2011)[1]

Resilience
The capacity of a system, community or society potentially exposed to hazards to adapt in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures (IPCC: 2011)

Risk
A function of the probability and consequences (ie magnitude and severity) of an adverse event or hazard (IPCC: 2011)

Hazard
A field of certain threats or impacts, which exist regardless of the availability of object or element exposed to the impact (IPCC: 2011)

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC: 2011)

Climate scenarios
A technical tool to identify the specific adaptation needs of a local community. These present plausible future climate conditions and are designed to investigate potential climate change impacts and communicate some of the potential consequences. (Mehdi B 2006, Adapting to climate change: an introduction for Canadian municipalities, Canadian Climate lmpacts and Adaptation. Research network (C-CIARN) www.c-ciarn.ca)

[1] Intergovernmental Panel on Climate Change

6.3 CLIMATE CHANGE ADAPTATION INITIATIVES

6.3.1 LOCAL GOVERNMENT

Title: South Australian Local Government Climate Adaptation Program:
Contact: Adam Gray, Local Government Association
Summary: Aims to help identify risks to council business operations and develop realistic adaptation measures over short and long-term planning horizons

The LGA Climate Change Strategy includes the completion of a sector based Climate Change Risk Management Assessment and Adaptation Program over 2 years during 2009-10. As of May 2010 the LGA Mutual Liability Scheme has successfully delivered the program to approximately half of the 68 South Australian Councils.

The aim of this Climate Adaptation Project (CAP) is to capture relevant risk /opportunity related data based on predicted climate variables that will support Local Government in South Australia to develop individual/regional based climate adaptation modelling and adaptation plans. Further, the framework of the CAP has enabled the development of a sector profile relevant to climate change adaptation risks and opportunities that are recognised as a priority for South Australia.

A draft interim report and brochure on the CAP findings to date can be found below. For further information relating to this project please contact Adam Gray, Senior Policy Officer Sustainability at the LGA on 8224 2055 or at adam.gray@lga.sa.gov.au

6.3.2 SOUTH AUSTRALIA

Title: Developing Landholder Capacity to Adapt to Climate Risks and Variable Resource Availability in the Murtho, Pike, Bookpurnong and Pyap to Kingston on Murray Regions of the Riverland South Australia
Contact: Bart Kellett, University of Adelaide
Summary: This project aims to work with farmers and natural resource managers to explore options to deal with climate and resource variability. Commodity prices, climate scenarios, water allocations and local policy options are being considered at district and farm scales.

Title: Climate Change and Land Capability – Advancing NRM Plan 2.2.4
Contact: Susan Sweeney DENR/DWLBC
Summary: This project has developed criteria and models to help assess the impacts of climate change on the potential for soil (wind) erosion

Title: Impact and adaptation to climate change in low rainfall cropping zones of SA: Linking production and land management outcomes
Contact: Susan Sweeney DENR/DWLBC
Summary: This project investigated the potential impact of climate change on land management strategies in the mid to low rainfall dryland agricultural regions of SA as a result of changes in land use from climate change

Title: Vulnerability assessment of Northern and York NRM region
Contact: Susan Sweeney DENR/DWLBC
Summary: An initial climate change vulnerability assessment conducted for the Northern and York NRM region. This will involve assessing the available scientific evidence of climate change risks to NRM systems in the Northern and York region, using the upper-end of projections from Suppiah et al (2006) and CSIRO, with input from key stakeholders.

Title: Sustainable Dryland Agriculture Initiative
Contact: Tim Herrmann DENR/DWLBC
Summary: This program will increase the adoption of improved land management practices across the dryland agricultural areas of South Australia. Individual projects cover various aspects of sustainable land management and include:

Increased protection of soils from erosion through the adoption of no-till and stubble retention crop establishment techniques and improved grazing management of pastures and stubbles.

Development of a decision support system to deal with climate variability including best use of land no longer viable for cropping.

Modification of soil profiles to improve resilience to climate variability and soil protection.

Title: Implementing SASP T3.3
Contact: Tim Herrmann DENR/DWLBC
Summary: DWLBC leads and implements a collaborative effort with industry, NRM and agency partners to achieve the SASP Target 3.3. The project involves working with NRM Boards and industry partners to raise awareness and improve the capacity of land managers to protect land from erosion and to define and promote best practice. Quantitative soil

erosion protection targets have been included in regional comprehensive NRM plans and projects developed to promote best practice land management. The project addresses existing risks of soil erosion as well as those posed by climate change.

Title: Land Condition Monitoring
Contact: Giles Forward
Summary: Monitor, assess and report on the condition and management of agricultural lands in the face of climate change. Includes monitoring progress towards the SASP Target T3.3, "Soil Protection".

Title: Building knowledge of soil carbon, impacts of climate change and opportunities for carbon storage in SA soils.
Contact: Tim Herrmann DENR/DWLBC
Summary: This project will audit and benchmark soil carbon in agricultural soils in SA and update our soil landscape database with essential soil carbon information. This will enable future spatial analysis and modelling of the impacts of climate change on soil carbon, the potential for sequestering carbon in SA soils, options for storing carbon, and the relationships between carbon and soil health. The project will provide information on the opportunities to improve soil carbon levels and risks involved. The project will also investigate approaches to monitoring long-term changes in soil carbon and soil pH.

Title: Climate Change, Communities and Environment:
Contact: Wayne Meyer - University of Adelaide
Summary: Building research capability to identify climate change vulnerability and adaptation options for South Australian landscapes The State Government, through the Premier's Science Research Fund, has funded a collaborative project to develop new modelling, mapping and decision tools to identify those combinations of environment, land use, social and economic factors that give the best opportunity for regions, to adapt. A key element of this work is the development of alternative landscape futures that facilitate robust environments, incomes and communities under a warmer, drier climate.

Title: Planning for a transformed future: Modelling synergistic climate change and land use impacts on biodiversity
Contact: Barry Brook – University of Adelaide
Summary: To achieve biological resilience under global change, innovative new approaches are required which explicitly couple ecological and climatic-

geophysical processes. We will determine the mechanisms of synergistic feedbacks between climate change and non-climatic factors on species extinction risk. Our approach is powerful because it will integrate multidisciplinary evidence (ecological, demographic, geospatial, climatic) using Bayesian statistical analyses and population-habitat-climate models. This research will deliver the computational tools required to anticipate biological reactions to climate change in the context of other human-driven threatening processes, and so guide proactive management responses.

Title: Landscape Analysis – Investigation and review of perennial and sustainable land use options in dryland agricultural regions at risk from climate change.

Contact: Trevor Hobbs DENR/DWLBC

Summary: This project will scientifically analyse and review the development potential of sustainable perennial vegetation systems with optimum resilience and capacity to adapt to climate change for dryland agricultural regions of SA; including likely impacts of any proposed land use changes on farm economics, industries and natural resources. This will inform land managers, communities, industries and policy makers of opportunities and constraints relating to the development of sustainable landuse options that include woody biomass crops and carbon sequestration activities in the dryland agriculture regions of SA. This work is closely linked to DWLBC's role in the Future Farm Industries CRC.

6.3.3 NATIONAL

Title: CSIRO Climate Adaptation Flagship

Contact: Liese Coulter

Summary: The CSIRO Climate Adaptation Flagship aims to equip Australia with practical and effective adaptation options to climate change and climate variability.
http://intranet.csiro.au/intranet/multi/flagships/CAF.htm

There are various themes within the Flagship, these are listed below:

Pathways to adaptation – Aims to build biophysical, social and institutional dimensions
of adaptive capacity to position Australian sectors, regions and communities to deal more effectively with climate change.

Sustainable cities and coasts – Aims to revitalise Australian cities and coasts in the face of climate change through planning, design, infrastructure, management and governance solutions.

Managing species and natural ecosystems – Aims to develop and deliver adaptation options to protect Australia's marine and terrestrial species, ecosystems and the services they provide from the impacts of climate change.

Adaptive primary industries, enterprises and communities – Aims to provide economic benefits and improved livelihoods for Australian primary industries, enterprises and communities through developing and delivering adaptation options in response to climate change.

Title: National Climate Change Adaptation Research Facility (NCCARF)
Contact: nccarf@griffith.edu.au
Summary: NCCARF is a national interdisciplinary effort to coordinate and generate the information needed by decision makers at all levels, from government to vulnerable sectors and communities, to manage the risks of climate change. http://www.nccarf.edu.au/home

Title: Primary Industries Adaptation Research Network (PIARN)
Contact: piarn-info@unimelb.edu.au
Summary: PIARN is a program operating within NCCARF that was established to provide a access to climate change adaptation research for primary industries. Its aim is to improve the coordination, development and accessibility of climate change adaptation research in the sector. http://piarn.org.au/

Title: Future Farm Industries CRC
Contact: Anna Dutkiewicz DENR/DWLBC
Summary: The FFI CRC research program is developing more sustainable farming systems based on perennial plants that contribute to drought and climate change adaptation strategies in dryland farming areas throughout Australia. The outcomes of this CRC will be new technologies and land management options for a variety of farming systems and community groups, focussed on the establishment of profitable perennials across the landscape for biodiversity, soil protection and salinity benefits.
http://www.futurefarmcrc.com.au/index.html

7 REFERENCES

Beinhocker, E., J. Oppenheim, et al. (2008). The carbon productivity challenge: Curbing climate change and sustaining economic growth, McKinsey Gobal Institute.

Booz & Company (2009). Towards a Low Carbon Travel and Tourism Sector. T. Chiesa and A. Gautam, World Economic Forum.

Bryan, B., D. King, et al. (2010). "Biofuels agriculture: Landscape-scale trade-offs between food, energy, carbon, and regional development." Global Change Biology Bioenergy.

Bryan, B., D. King, et al. (In Press). "Biofuels agriculture: Landscape-scale trade-offs between food, energy, carbon, and regional development." Global Change Biology Bioenergy.

Bryan, B. A., D. King, et al. (2010). "Potential of woody biomass production for motivating widespread natural resource management under climate change." Land Use Policy **27**(3): 713-725.

Bryan, B. A., J. Ward, et al. (2008). "An assessment of the economic and environmental potential of biomass production in an agricultural region." Land Use Policy **25**(4): 533-549.

Campbell, J. E., D. B. Lobell, et al. (2009). "Greater Transportation Energy and GHG Offsets from Bioelectricity Than Ethanol." Science **324**(5930): 1055-1057.

Carpenter, S., B. Walker, et al. (2001). "From metaphor to measurement: Resilience of what to what?" Ecosystems **4**(8): 765-781.

Clabby, C. (2010). "Does Peak Phosphorus Loom? Scientists make the case that easily accessible supplies of an essential element are being depleted." American Scientist **98**(4): 291-292.

CSIRO and BoM (2007). Climate Change in Australia Technical Report 2007.

Cullen, B., P. Thorburn, et al. (2010). New Rural Industries for Future Climates. Canberra, Rural Industries Research and Development Corporation.

DAFWA (2007). Growing pomegranates in Western Australia. Perth, Department of Agriculture and Food.

DAFWA (2008). Pomegranates: New woolbelt opportunities. Perth, Department of Agriculture and Food.

Debouck, D. (1994). Beans: Phaseolus spp. Neglected Crops: 1492 From a Different Perspective. J. Hernándo and J. León. Rome, Food and Agriculture Organisation of the United Nations.

Dierig, D. (1995) "New Crop Factsheet: Lesquerella."

Francis, C. and M. Campbell (2004). Alternative oilseeds for Australia. New Crop Industries Handbook. S. Salvin, M. Bourke and T. Byrne. Canberra, Rural Industries Research and Development Corporation**:** 270-279.

George, D., M. Gupta, et al. (2005). Evaluating new guayule varieties for low-allergenic rubber production No. 05/147, Rural Industries Research and Development Corporation.

Hargroves, K. and M. Smith (2005). The natural advantage of nations: Business opportunities, innovation and governance in the 21st Century. London, Earthscan.

Heinberg, R. (2007). Peak everything: Waking up to the century of declines. Gabriola Island, New Society Publishers.
ICLEI (2008). Local Government Climate Change Adaptation Toolkit, Cities for Climate Protection Australia Adaptation Initiative, Local Governments for Sustainability.
IPCC (2007). Summary for policy makers, 4th assessment report IPCC working group III.
IPCC (2007). Summary for policymakers. Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. B. Metz, O. Davidson, R. Bosch, R. Dave and L. Meyer. Cambridge.
Jackson, T. (2009). Prosperity without growth: Economics for a finite planet. London, Earthscan.
Kish, S. (2008) "Lasquerella: The Next Source of Biofuel ".
Lethbridge, B. (2004). Quandong. The New Crop Industries Handbook. Canberra, Rural Industries Research Development Corporation**:** 373-376.
Local Government Association of South Australia (2010). Local Government Climate Adaptation Program, Interim Report, July 2010, Local Government Association of South Australia and the Local Government Association Mutual Liability Scheme.
Macintosh, H. (2004). Native citrus. The New Crop Industries Handbook. Canberra, Rural Industries Research and Development Corporation**:** 358-367.
Mallawaarachchi, T. and A. Foster (2009). Dealing with irrigation drought: The role of water trading in adapting to water shortages in 2007-08 in the southern Murray-Darling Basin, Australian Bureau of Agricultural and Resource Economics.
McEvoy, D., D. C. Gibbs, et al. (2000). "The employment implications of a low-carbon economy." Sustainable Development **8**(1): 27-38.
Mohr, S. H. and G. M. Evans (2009). "Forecasting coal production until 2100." Fuel **88**(11): 2059-2067.
Murraylands and Riverland Incorporated. (2010). "About Us." Regional Development Australia Murraylands and Riverland South Australia Retrieved 19 November 2010, from http://www.rdamurraylands.org.au/about_us.html.
Nader, S. (2009). "Paths to a low-carbon economy - the Masdar example." Greenhouse Gas Control Technologies 9 **1**(1): 3951-3958
4984.
Nashawi, I. S., A. Malallah, et al. (2010). "Forecasting World Crude Oil Production Using Multicyclic Hubbert Model." Energy & Fuels **24**: 1788-1800.
Newman, P., T. Beatley, et al. (2009). Resilient cities: Responding to peak oil and climate change. Washington, D.C., Island Press.
Ohlrogge, J., D. Allen, et al. (2009). "Driving on Biomass." Science **324**(5930): 1019-1020.
Parliamentary Library of Australia (2010) "Carbon Pollution Reduction Scheme."
Parliamentary Library of Australia (2010) "Emissions Trading."
Pearce, F. (2010). "From ocean to ozone: Earth's nine life-support systems." Retrieved 3 November, 2010, from

http://www.newscientist.com/special/ocean-to-ozone-earths-nine-life-support-systems.

Reilly, D., A. Reilly, et al. (2010). Towards an Australian Date Industry: An Overwiew of the Australian Domestic and International Date Industries. Canberra, Rural Industries Research and Development Corporation.

Rockstrom, J., W. Steffen, et al. (2009). "A safe operating space for humanity." Nature **461**(7263): 472-475.

SMEC (2009). Climate change adaptation actions for local government. Canberra, Department of Climate Change**:** 67.

Stern, N. (2007). The economics of climate change: The Stern review. Cambridge, Cambridge Univeristy Press.

Sweeney, S. and G. Davies (2004). Olive oil. New Crop Industries Handbook. S. Salvin, M. Bourke and T. Byrne. Canberra, Rural Industries Research and Development Corporation**:** 295-301.

The Low Carbon Economy Limited. (2010). "About a low carbon economy." Retrieved 19 October, 2010, from http://www.lowcarboneconomy.com/LCE/AboutALowCarbonEconomy.

Thompson, A. (1990). Arid-land Industrial Crops. Advances in New Crops. J. Janick and J. Simon. Portland, Timber Press**:** 232-241.

Vinning, G. and G. McMahon (2006). Gluten Free Grains. A Demaind and Supply Analysis of Prospects for the Australian Health Grains Industry, Rural Industries Research and Development Corporation.

Zhang, J., Z. D. Sun, et al. (2010). "Risk-opportunity analyses and production peak forecasting on world conventional oil and gas perspectives." Petroleum Science **7**(1): 136-146.